BUSINESS CLASS M2 WORKSHOP MANUAL

Models: M2 100
M2 106
M2 106V
M2 112
M2 112V

STI-457, S18 (9/10P)

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Daimler Trucks North America LLC
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Foreword

The purpose of this manual is to assist the service technician when the vehicle is serviced. Major drivetrain component service information is not included in this manual, but is located in each manufacturer's service manual.

Instructions and procedures are those recommended by Freightliner Trucks or the component manufacturer.

Maintenance schedules and additional service information are included in the **Business Class® M2 Maintenance Manual**.

IMPORTANT: Descriptions and specifications in this manual were in effect at the time of printing. Freightliner Trucks reserves the right to discontinue models, and to change specifications or design at any time without notice and without incurring obligation. Descriptions and specifications contained in this publication provide no warranty, expressed or implied, and are subject to revision and editions without notice.

Refer to **www.Daimler-TrucksNorthAmerica.com** and **www.FreightlinerTrucks.com** for more information, or contact Daimler Trucks North America LLC at the address below.

Environmental Concerns and Recommendations

Whenever you see instructions in this manual to discard materials, you should attempt to reclaim and recycle them. To preserve our environment, follow appropriate environmental rules and regulations when disposing of materials.

NOTICE: Parts Replacement Considerations

Do not replace suspension, axle, or steering parts (such as springs, wheels, hubs, and steering gears) with used parts. Used parts may have been subjected to collisions or improper use and have undetected structural damage.

Daimler Trucks North America LLC
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Descriptions of Service Publications

Daimler Trucks North America LLC distributes the following major service publications in paper and electronic (via ServicePro®) formats.

Workshop/Service Manual

Workshop/service manuals contain service and repair information for all vehicle systems and components, except for major components such as engines, transmissions, and rear axles. Each workshop/service manual section is divided into subjects that can include general information, principles of operation, removal, disassembly, assembly, installation, specifications, and troubleshooting.

Maintenance Manual

Maintenance manuals contain routine maintenance procedures and intervals for vehicle components and systems. They have information such as lubrication procedures and tables, fluid replacement procedures, fluid capacities, specifications, and procedures for adjustments and for checking the tightness of fasteners. Maintenance manuals do not contain detailed repair or service information.

Driver's/Operator's Manual

Driver's/operator's manuals contain information needed to enhance the driver's understanding of how to operate and care for the vehicle and its components. Each manual contains a chapter that covers pretrip and post-trip inspections, and daily, weekly, and monthly maintenance of vehicle components. Driver's/operator's manuals do not contain detailed repair or service information.

Service Bulletins

Service bulletins provide the latest service tips, field repairs, product improvements, and related information. Some service bulletins are updates to information in the workshop/service manual. These bulletins take precedence over workshop/service manual information, until the latter is updated; at that time, the bulletin is usually canceled. The service bulletins manual is available only to dealers. When doing service work on a vehicle system or part, check for a valid service bulletin for the latest information on the subject.

IMPORTANT: Before using a particular service bulletin, check the current service bulletin validity list to be sure the bulletin is valid.

Parts Technical Bulletins

Parts technical bulletins provide information on parts. These bulletins contain lists of parts and BOMs needed to do replacement and upgrade procedures.

Web-based repair, service, and parts documentation can be accessed using the following applications on the AccessFreightliner.com website.

ServicePro

ServicePro® provides Web-based access to the most up-to-date versions of the publications listed above. In addition, the Service Solutions feature provides diagnostic assistance with Symptoms Search, by connecting to a large knowledge base gathered from technicians and service personnel. Search results for both documents and service solutions can be narrowed by initially entering vehicle identification data.

PartsPro

PartsPro® is an electronic parts catalog system, showing the specified vehicle's build record.

EZWiring

EZWiring™ makes Freightliner, Sterling, Western Star, Thomas Built Buses, and Freightliner Custom Chassis Corporation products' wiring drawings and floating pin lists available online for viewing and printing. EZWiring can also be accessed from within PartsPro.

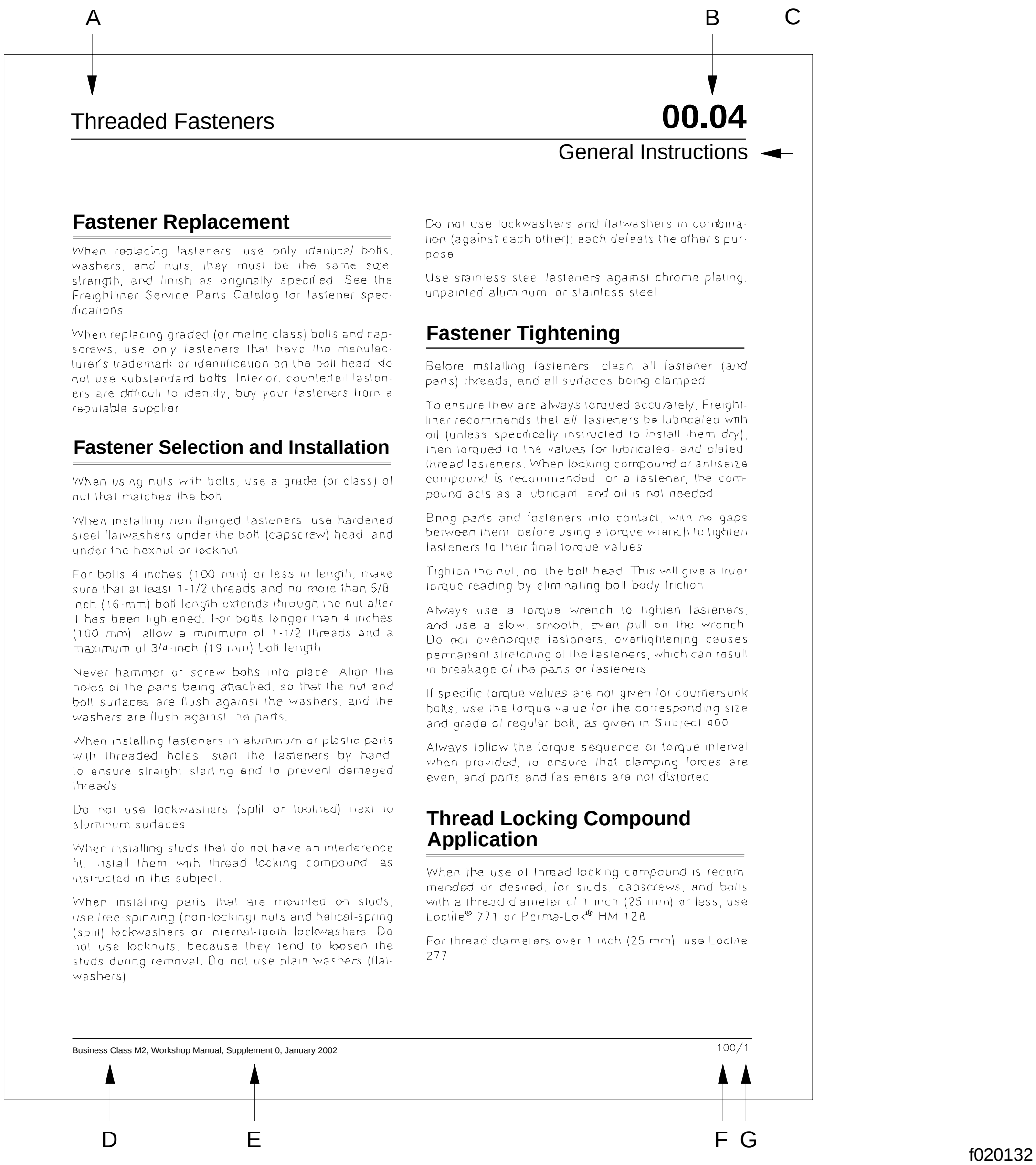
Descriptions of Service Publications

Warranty-related service information available on the AccessFreightliner.com website includes the following documentation.

Recall Campaigns	Recall campaigns cover situations that involve service work or replacement of parts in connection with a recall notice. These campaigns pertain to matters of vehicle safety. All recall campaigns are distributed to dealers; customers receive notices that apply to their vehicles.
Field Service Campaigns	Field service campaigns are concerned with non-safety-related service work or replacement of parts. All field service campaigns are distributed to dealers; customers receive notices that apply to their vehicles.

Page Description

For an example of a *Business Class M2 Workshop Manual* page, see **Fig. 1**.



A. Section Title
B. Section Number (made up of the Group Number—first two digits, followed by a sequence number—last two digits)
C. Subject Title
D. Manual Title
E. Release (Supplement) Date
F. Subject Number
G. Subject Page Number

Fig. 1, Example of a Business Class M2 Workshop Manual Page

Workshop Manual Contents

List of Abbreviations

The following is a list of definitions for abbreviations and symbols used in Freightliner publications.

A .... amperes
AAVA ...... auxiliary air valve assembly
ABS .... antilock braking system
ABS .... acrylonitrile-butadiene-styrene
A/C .... air conditioner
AC .... alternating current
acc .... accessories
ACM .... aftertreatment control module
ACPU ..... air conditioning protection unit
ADLO ..... auto-disengagement lockout
AGM .... absorbed glass mat
AGS .... automated gear shift
AG2 .... Aluminum Generation 2
a.m. .... *ante meridiem* (midnight to noon)
AM .... amplitude modulation
amp(s) .... ampere(s)
AMT .... automated mechanical transmission
AMU .... air management unit
ANSI ...... American National Standards Institute
API .... American Petroleum Institute
API .... application programming interface
ARI .... Air Conditioning and Refrigeration Institute
ASA .... American Standards Association
ASF .... American Steel Foundries
ASR .... automatic spin regulator
assy. ...... assembly
ASTM ..... American Society for Testing and Materials
ATC .... automatic temperature control
ATC .... automatic traction control
ATC .... automatic transmission control
ATD .... aftertreatment device
ATF .... automatic transmission fluid
ATS .... aftertreatment system
attn .... attention
aux. .... auxiliary
av .... *avoirdupois* (British weight system)
AWD .... all-wheel drive
AWG ...... American wire gauge
AWS .... American Welding Society
BAT .... battery
BBC .... bumper-to-back-of-cab
BHM .... bulkhead module
BOC .... back-of-cab
BOM .... bill of material
BTDC ...... before top dead center
Btu(s) ..... British thermal unit(s)
C .... common (terminal)
CAC .... charge air cooler
CAN .... controller area network
CARB ..... California Air Resources Board
CAT .... Caterpillar
CB .... circuit breaker
CB .... citizens' band
CBE .... cab behind engine
CCA .... cold cranking amperes
CD-ROM .. compact-disc/read-only memory
CDTC ...... constant discharge temperature control
CEL .... check-engine light
CFC .... chlorofluorocarbons (refrigerant-12)
cfm .... cubic feet per minute
CFR .... Code of Federal Regulations
CGI .... clean gas induction
CGW ...... central gateway
CHM .... chassis module
CIP .... cold inflation pressure
CLS .... coolant level sensor
cm .... centimeters
cm^3 .... cubic centimeters
CMVSS .... Canadian Motor Vehicle Safety Standard
Co. .... company
COE .... cab over engine
Corp. ...... corporation
CPC .... common powertrain controller
CPU .... central processing unit
CRT .... cathode ray tube
cSt .... centistokes (unit of measurement for describing the viscosity of general liquids)
cu ft .... cubic feet
cu in ...... cubic inches
CUM .... Cummins
CVSA ...... Commercial Vehicle Safety Alliance
CWS .... collision warning system
DC .... direct current
DCDL ...... driver-controlled differential lock
DDA .... Detroit Diesel Allison (obs)
DDC .... Detroit Diesel Corporation
DDDL ...... Detroit Diesel Diagnostic Link
DDE .... Detroit Diesel Engines
DDEC ..... Detroit Diesel Electronic (engine) Control
DDR .... diagnostic data reader
DDU .... driver display unit
def .... defrost
DEF .... diesel exhaust fluid
DFI .... direct fuel injection
DGPS ..... differential global positioning system
dia. .... diameter
DIAG ...... diagnosis
DIP .... dual inline package (switch)
DIU .... driver interface unit
DLA .... datalink adaptor
DLM .... datalink monitor
DLU .... data logging unit
DMM ...... digital multimeter
DOC .... diesel oxidation catalyst
DOT .... Department of Transportation
DPF .... diesel particulate filter
DRL .... daytime running lights
DRM .... dryer reservoir module
DSM .... district service manager
DTC .... diagnostic trouble code
DTC .... discharge temperature control
DTNA ...... Daimler Trucks North America
DVOM ..... digital volt/ohm meter
ea. .... each
EBS .... electronic braking system
ECA .... electric clutch actuator
ECAP ...... electronic control analyzer programmer
ECAS ...... electronically controlled air suspension
ECI .... electronically controlled injection
ECL .... engine coolant level
ECM .... electronic control module
ECT .... engine coolant temperature
ECU .... electronic control unit

List of Abbreviations

EDM .... electronic data monitor
EEPROM .. electrically erasable programmable read-only memory
EFG .... electric fuel gauge
EFPA ...... electronic foot pedal assembly
EGR .... exhaust gas recirculation
ELC .... extended-life coolant
EMC .... electromagnetic compatibility
EMI .... electromagnetic interference
EOA .... electric over air
EP .... extreme pressure (describes an antiwear agent added to some lubricants)
EPA .... Environmental Protection Agency
EPS .... engine position sensor
ESC .... electronic stability control
ESC .... enhanced stability control
ESD .... electrostatic discharge
ESS .... engine syncro shift (transmission)
etc. .... *et cetera* (and so forth)
ETEC ...... electronic truck engine control
EUI .... electronic unit (fuel) injectors
EVA .... electronic vibration analyzer
EXM .... (chassis) expansion module
E85 .... 85% ethanol fuel
FAS .... Freightliner air suspension
FCCC ...... Freightliner Custom Chassis Corporation
FET .... field effect transistor
Fig. .... figure
fl oz .... fluid ounces
FLA .... post-1984 advancements Freightliner COE
FLB .... enhanced Freightliner FLA COE
FLC .... steel-cab Freightliner 112 Conventional
FLD .... post-1984 advancements Freightliner 112/120 aluminum-cab Conventional
FLR .... forward-looking radar
FM .... frequency modulation
FMCSA .... Federal Motor Carrier Safety Administration
FMEA ..... failure mode effects analysis
FMI .... failure mode indicator
FMSI ...... Friction Materials Standards Institute
FMVSS .... Federal Motor Vehicle Safety Standard
FRP .... fiberglass reinforced plastic
FSA .... field service authorization
FSM .... fleet service manager
ft .... feet
ft^3 .... cubic feet
ft^3/min ..... cubic feet per minute
FTL .... Freightliner
F.U.E.L. .... fuel usage efficiency level
g .... grams
gal .... gallons
GAWR ..... gross axle weight rating
GHG .... greenhouse gas
GL .... gear lubricant
GND .... ground
gpm .... gallons per minute
GPS .... global positioning system
GVWR ..... gross vehicle weight rating
HBED ..... hard-braking event data
HCM .... hybrid control module
HCOE ..... high cab over engine
HCU .... hydraulic control unit
HD .... heavy-duty
HDU .... hybrid drive unit
HEPA ...... high-efficiency particulate air (filter)
HEST ...... high exhaust system temperature
HEV .... hybrid electric vehicle
HFC .... hydrogenated fluorocarbons (refrigerant-134a)
hp .... horsepower
hp .... high pressure
HRC .... Rockwell "C" hardness
hr(s) .... hour(s)
HSA .... hill start aid
HSD .... high-side driver
htr. .... heater
HVAC ...... heating, ventilating, and air conditioning
HVLP ...... high velocity, low pressure
H/W .... hardware
Hz .... hertz
IAD .... interaxle differential
ICS .... integrated child seat
ICU .... instrumentation control unit
i.d. .... inside diameter
ID .... identification
IFI .... Industrial Fasteners Institute
IFS .... independent front suspension
IGN .... ignition
ILB .... intelligent lightbar
ILO .... *in lieu of* (in the place of)
in .... inches
in^3 .... cubic inches
Inc. .... incorporated
inH_2O ..... inches of water
inHg .... inches of mercury
I/O .... input/output
IP .... instrument panel
ISO .... International Organization for Standardization
IVS .... idle validation switch
k .... kilo (1000)
kg .... kilograms
km .... kilometers
km/h .... kilometers per hour
kPa .... kilopascals
kW .... kilowatts
L .... liters
lb .... pounds
LBCU ...... lightbar control unit
lbf·ft .... pounds force feet
lbf·in ...... pounds force inches
LCD .... liquid crystal display
LCOE ...... low cab over engine
LED .... light-emitting diode
LH .... left-hand
LH DR ..... left-hand drive
LHK .... liters per hundred kilometers
LHS .... low-hydrogen steel
LIN .... Local Interconnect Network
LLC .... limited liability company
L/min ...... liters per minute
LNG .... liquefied natural gas
LPG .... liquefied petroleum gas
LPR .... low pressure reservoir
LSD .... low-side driver
LVD .... low-voltage disconnect
m .... meters
max. .... maximum
M-B .... Mercedes-Benz
MCM ...... motor control module
MESA ..... Mining Enforcement Safety Act
mfr. .... manufacturer
mi .... miles

List of Abbreviations

MID .... message identifier
MIL .... malfunction indicator lamp (light)
MIL .... military specification
min. .... minutes
min. .... minimum
misc. ...... miscellaneous
mL .... milliliters
mm .... millimeters
mod. ...... module
mpg .... miles per gallon
mph .... miles per hour
MSF .... modular switch field
MMT .... methylcyclopentadienyl manganese tricarbonyl
MSHA ..... Mining Safety and Health Administration
MVDA ..... Motor Vehicle Dealers Association
n .... negative (front axle wheel alignment specification)
N .... nitrogen
N/A .... not applicable
N·cm ...... Newton-centimeters
NC .... normally closed (terminal or switch)
NHTSA .... National Highway Traffic Safety Administration
NIOSH ..... National Institute for Occupational Safety and Health
NLGI ...... National Lubricating Grease Institute
N·m .... Newton-meters
NO .... normally open (terminal or switch)
NOAT ...... Nitrited Organic Acid Technology
NOx .... nitrogen oxides
no. .... number
NPT .... national pipe thread
NPTF ...... national pipe thread fitting
NT .... nylon tube or nylon tubing
NTSB ...... National Transportation Safety Board
OAT .... Organic Acid Technology
OBD(s) .... on-board diagnostic(s)
obs .... obsolete
OC .... open circuit
OCV .... open circuit voltage
o.d. .... outside diameter
O.D. .... overdrive
OEM .... original equipment manufacturer
OSHA ..... Occupational Safety and Health Administration
oz .... ounces
ozf·in ...... ounces force inches
p .... positive (front axle wheel alignment specification)
PACE ...... programmable electronically controlled engine
PAG .... polyalkylene glycol (oil)
parm ...... parameter
PAS .... passenger advisory system
PC .... personal computer
PCB .... printed circuit board
PDC(s) .... parts distribution center(s)
PDM .... power distribution module
PEC .... power electronics carrier
PEEC ...... programmable electronic engine control
PID .... parameter identifier
PLC .... power line carrier
PLD .... *Pumpe-Linie-Düse* (pump-line-nozzle)
PNDB ..... power-net distribution box
PM .... particulate matter
p.m. .... *post meridiem* (noon to midnight)
p/n .... part number
PO .... purchase order
PRD .... product requirements document
PSA .... pressure-sensitive adhesive
PSG .... pressure sensor governor
psi .... pounds per square inch
psia .... pounds per square inch, atmosphere
psig .... pounds per square inch, gauge
pt .... pints
PTCM ..... pressure time control module
PTO .... power takeoff
PTP .... powertrain protection
pvc .... polyvinyl chloride
PWM ...... pulse width modulation
pwr .... power
qt .... quarts
qty. .... quantity
R & O ..... rust inhibitors and oxidants
R–12 ...... refrigerant-12 (CFC)
R–134a .... refrigerant-134a (HFC)
RAM .... random access memory
RC .... reserve capacity
recirc. ..... recirculation
Ref(s). ..... reference(s)
regen ...... regeneration
RELS ...... reduced engine load at stop
RFI .... radio frequency interference
RH .... right-hand
RH DR ..... right-hand drive
R/I .... removal and installation
RMA .... return material authorization
ROM .... read-only memory
rpm .... revolutions per minute
R/R .... removal and replacement
RSA .... roll-stability advisor
RSG .... road speed governor
RSM .... regional service manager
RTS .... ready-to-spray
RTV .... room temperature vulcanizing
RV .... recreational vehicle
SA .... source address
S-ABA ..... self-setting automatic brake adjusters
SAE .... Society of Automotive Engineers
SB .... service bulletin
SBT .... seat back thickness
SCA(s) .... Supplemental Coolant Additive(s)
SCR .... selective catalytic reduction
SCU .... system control unit (speedometer)
SD .... severe-duty
SDU .... step deployment unit
SEL .... shutdown engine light
SEM .... switch expansion module
SEO .... stop engine override
SHM .... switch hub module
SI .... service information
SI .... *Système International*
SID .... subsystem identifier
SM .... system malfunction
SMC .... sheet molded compound
S/N .... serial number
SOC .... state-of-charge
SPACE .... seat pretensioner activation for crash survival enhancement
SPG .... special purpose grease

List of Abbreviations

- **SPN** .... suspect parameter number
- **sq in** ...... square inches
- **SRP** .... seating reference point
- **SRS** .... supplemental restraint system
- **SRS** .... synchronous reference sensor
- **SRT** .... standard repair time
- **SSD** .... side sensor display
- **SSID** .... smart switch identification
- **SST** .... stainless steel
- **std.** .... standard
- **S/W** .... software
- **SW** .... switch
- **TAM** .... thermocouple amplifier module
- **TBB** .... Thomas Built Buses
- **TBS** .... turbo boost sensor
- **TCM** .... transmission control module
- **TCU** .... transmission control unit
- **TDC** .... top dead center
- **TDR** .... technician diagnostic routine
- **TEM** .... truck equipment manufacturer
- **temp** ...... temperature
- **TIG** .... tungsten inert gas
- **TIR** .... total indicator reading
- **TPMS** ...... tire pressure monitoring system
- **TPS** .... thermal protection switch
- **TPS** .... throttle position sensor
- **TRS** .... timing reference sensor
- **TSO** .... truck specification order
- **TSU** .... transmission shift unit
- **U.D.** .... underdrive
- **ULSD** ...... ultralow-sulfur diesel
- **UNC** .... unified national coarse
- **UNF** .... unified national fine
- **U.S.** .... United States
- **U.S.A.** ..... United States of America
- **USC** .... United States customary (measures)
- **V** .... volts
- **VCU** .... vehicle control unit
- **VDC** .... vehicle data computer
- **Vdc** .... volts, direct current
- **VIMS** ...... vehicle information management system
- **VIN** .... vehicle identification number
- **VIP** .... vehicle instrumentation and protection (Kysor)
- **VIW** .... vehicle interface wiring (connector)
- **VOC** .... volatile organic compounds
- **VOM** .... volt-ohmmeter
- **VRS** .... variable resistance sensor
- **VSG** .... variable speed governor
- **VSS** .... vehicle speed sensor
- **VSU** .... vehicle security unit
- **WB** .... wire braid
- **WI** .... work instructions
- **WIF** .... water-in-fuel
- **WOT** .... wide open throttle
- **–** .... minus or negative
- **+** .... plus or positive
- **±** .... plus-or-minus
- **>** .... greater than
- **<** .... less than
- **x** .... by (used in fastener size descriptions)
- **"** .... inches
- **°** .... degrees (of an angle)
- **°C** .... degrees Celsius (centigrade)
- **°F** .... degrees Fahrenheit
- **#** .... number
- **%** .... percent
- **&** .... and
- **©** .... copyright
- **™** .... trademark
- **®** .... registered trademark

General Information

U.S. Customary to Metric			Metric to U.S. Customary		
When You Know	**Multiply By**	**To Get**	**When You Know**	**Multiply By**	**To Get**
Length					
inches (in)	25.4	millimeters (mm)		0.03937	inches (in)
inches (in)	2.54	centimeters (cm)		0.3937	inches (in)
feet (ft)	0.3048	meters (m)		3.281	feet (ft)
yards (yd)	0.9144	meters (m)		1.094	yards (yd)
miles (mi)	1.609	kilometers (km)		0.6215	miles (mi)
Area					
square inches (in^2)	645.16	square millimeters (mm^2)		0.00155	square inches (in^2)
square inches (in^2)	6.452	square centimeters (cm^2)		0.15	square inches (in^2)
square feet (ft^2)	0.0929	square meters (m^2)		10.764	square feet (ft^2)
Volume					
cubic inches (in^3)	16387.0	cubic millimeters (mm^3)		0.000061	cubic inches (in^3)
cubic inches (in^3)	16.387	cubic centimeters (cm^3)		0.06102	cubic inches (in^3)
cubic inches (in^3)	0.01639	liters (L)		61.024	cubic inches (in^3)
fluid ounces (fl oz)	29.54	milliliters (mL)		0.03381	fluid ounces (fl oz)
pints (pt)	0.47318	liters (L)		2.1134	pints (pt)
quarts (qt)	0.94635	liters (L)		1.0567	quarts (qt)
gallons (gal)	3.7854	liters (L)		0.2642	gallons (gal)
cubic feet (ft^3)	28.317	liters (L)		0.03531	cubic feet (ft^3)
cubic feet (ft^3)	0.02832	cubic meters (m^3)		35.315	cubic feet (ft^3)
Weight/Force					
ounces (av) (oz)	28.35	grams (g)		0.03527	ounces (av) (oz)
pounds (av) (lb)	0.454	kilograms (kg)		2.205	pounds (av) (lb)
U.S. tons (t)	907.18	kilograms (kg)		0.001102	U.S. tons (t)
U.S. tons (t)	0.90718	metric tons (t)		1.1023	U.S. tons (t)
Torque/Work Force					
inch-pounds (lbf·in)	11.298	Newton-centimeters (N·cm)		0.08851	inch-pounds (lbf·in)
foot-pounds (lbf·ft)	1.3558	Newton-meters (N·m)		0.7376	foot-pounds (lbf·ft)
Pressure/Vacuum					
inches of mercury (inHg)	3.37685	kilo Pascals (kPa)		0.29613	inches of mercury (inHg)
pounds per square inch (psi)	6.895	kilo Pascals (kPa)		0.14503	pounds per square inch (psi)

When You Know	Subtract	Then Divide By	To Get	When You Know	Multiply By	Then Add	To Get
degrees Fahrenheit (°F)	32	1.8	degrees Celsius (°C)		1.8	32	degrees Fahrenheit (°F)

General Information

Vehicle Receipt

Prior to signing for vehicle delivery from a transporter company, the dealer is responsible for checking for transporter-related shortages or damages, and noting these discrepancies on the transporter's delivery receipt.

The dealer is also responsible for ensuring that the vehicle was built according to the Truck Sales Order/ Invoice.

Refer to Section 3 of the Freightliner LLC *Warranty Manual* for details.

Vehicle Storage

There may be times when a vehicle is stored for long periods before customer delivery. To protect all vehicles from deterioration and weather, they must be properly maintained. Adequate protection and storage of new vehicles is the responsibility of the dealer.

Claims arising from loss and damage to improperly stored vehicles will not be reimbursed.

See Section 3 of the Freightliner LLC *Warranty Manual* for instructions on storage of new vehicles.

Pre-Delivery Information

All pre-delivery inspections and services must be performed at an authorized Freightliner LLC facility, assigned to fully qualified service personnel and recorded on the "New Vehicle Pre-Delivery Inspection" form.

Refer to Section 3 of the Freightliner LLC *Warranty Manual* for details.

It is recommended the pre-delivery inspection be performed within 30 days of vehicle receipt.

Threaded Fastener Types

The majority of threaded fasteners used throughout the vehicle have U.S. customary threads (diameter and pitch are measured in inches). See **Fig. 1**. However, the engine and some items attached to the cab use metric fasteners (diameter and pitch are measured in millimeters).

Most threaded fasteners used on the vehicle that are 1/2-inch diameter or larger are plain hex-type fasteners (non-flanged); *all* metric fasteners are non-flanged. Special hardened flatwashers are used under the bolt head, and between the part being attached and the hexnut, to distribute the load, and to prevent localized overstressing of the parts. The washers are cadmium- or zinc-plated, and have a hardness rating of 38 to 45 HRC.

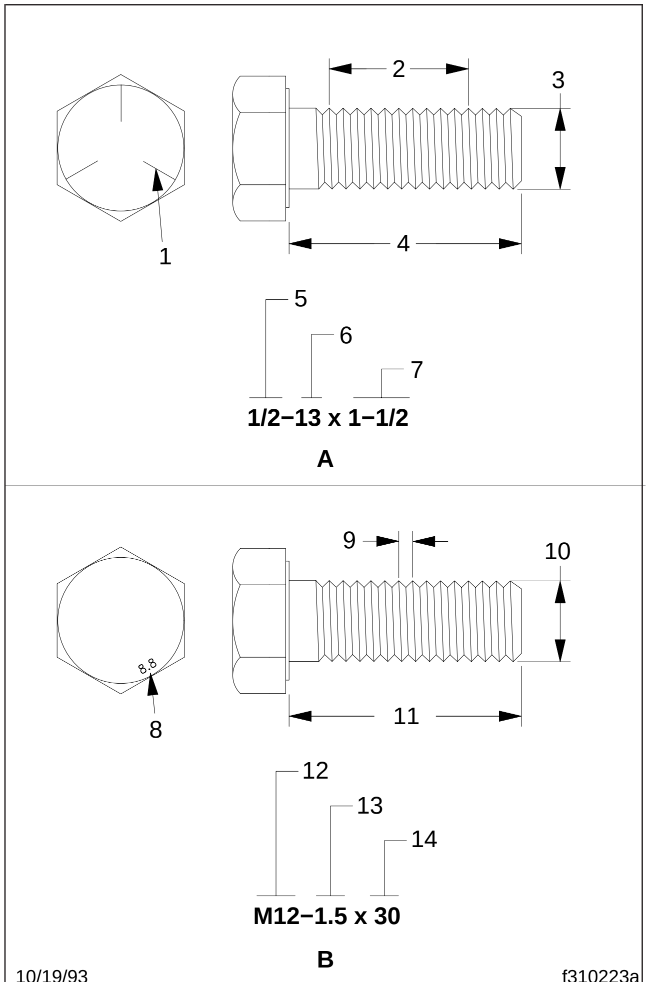
Some fasteners smaller than 1/2-inch diameter are flanged fasteners, which have integral flanges that fit against the parts being fastened. The flanges eliminate the need for washers.

NOTE: The standard fasteners used to assemble the vehicle frame and to attach components to the vehicle frame are threaded lockbolts (Spin Hucks). These fasteners are covered in **Section 31.00**.

Fastener Grades and Classes

Fasteners with U.S. customary threads are divided into grades established by the Society of Automotive Engineers (S.A.E.) or the International Fastener Institute (I.F.I.). The fastener grades indicate the relative strength of the fastener; the higher the number (or letter), the stronger the fastener. Bolt (capscrew) grades can be identified by the number and pattern of radial lines forged on the bolt head. See **Fig. 2**. Hexnut (and locknut) grades can be identified by the number and pattern of lines and dots on various surfaces of the nut. See **Fig. 3**. Nearly all of the bolts used on the vehicle are grades 5, 8, and 8.2. Matching grades of hexnuts are always used: grade 5 or grade B hexnuts are used with grade 5 bolts; grade 8, grade C, or grade G (flanged) hexnuts are used with grade 8 or 8.2 bolts.

Fasteners with metric threads are divided into classes adopted by the American National Standards Institute (ANSI). The higher the class number, the stronger the fastener. Bolt classes can be identified by the numbers forged on the head of the bolt. See **Fig. 4**. Hexnut (and locknut) classes can be identified by the marks or numbers on various surfaces of the

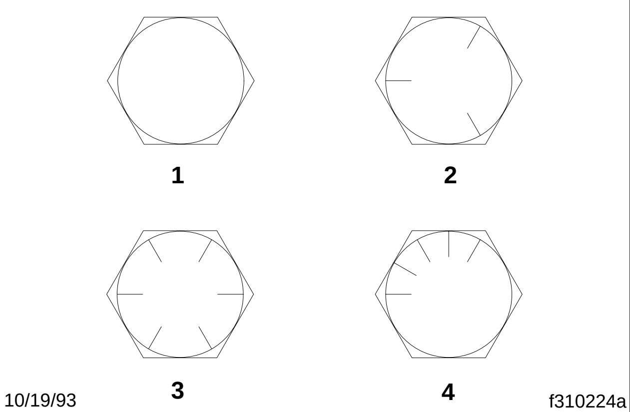


A. Bolt with U.S. Customary Threads
B. Bolt with Metric Threads

1. S.A.E. Grade Marking
2. Thread Pitch
3. Nominal Diameter
4. Bolt Length
5. Nominal Diameter in Inches
6. Thread Pitch in Threads per Inch
7. Bolt Length in Inches
8. Metric Class Marking
9. Thread Pitch
10. Nominal Diameter
11. Bolt Length
12. Nominal Diameter in Millimeters
13. Thread Pitch (thread width from crest to crest in millimeters)
14. Bolt Length in Millimeters

Fig. 1, Fastener Size and Thread Identification

nut. See **Fig. 5**. Class 8 hexnuts are always used with class 8.8 bolts; class 10 hexnuts with class 10.9 bolts.



NOTE: Grade 2 bolts have no grade marking; grade 2 bolts are rarely used by Freightliner.These grade markings are used on plain hex-type and flanged bolts (capscrews). In addition to the grade markings, the bolt head must also carry the manufacturer’s trademark or identification.

1. Grade 2
2. Grade 5
3. Grade 8
4. Grade 8.2

Fig. 2, Bolt Grades

Frame Fasteners

The standard fasteners used to assemble the vehicle frame and to attach most components to the vehicle frame are threaded lockbolts (Spin Hucks). These fasteners are covered in **Section 31.00**.

For some other components attached to the frame, grade 8 and 8.2 phosphate-and oil-coated hexhead bolts and grade C cadmium-plated and wax-coated prevailing torque locknuts are used. The prevailing torque locknuts have distorted sections of threads to provide torque retention. For attachments where clearance is minimal, low-profile hexhead bolts and grade C prevailing torque locknuts are used. See **Fig. 6**.

Tightening Fasteners

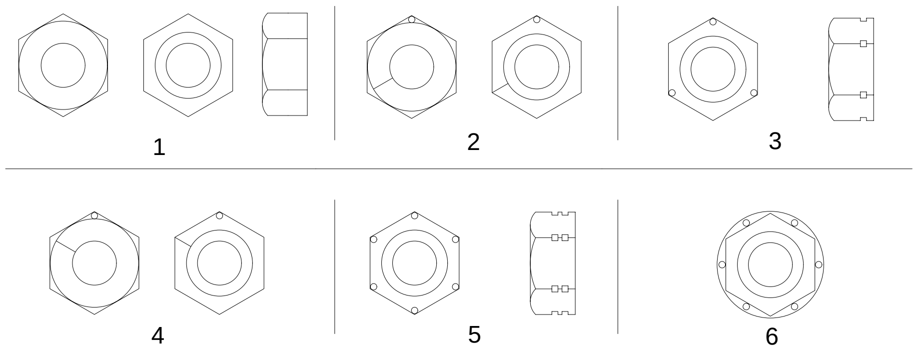
When a capscrew is tightened to its torque value in a threaded hole, or a nut is tightened to its torque value on a bolt, the shank of the capscrew or bolt is stretched slightly. This stretching (tensioning) results in a preload that reduces fatigue of the fasteners. The torque values given in the tables in **Specifications, 400** have been calculated to provide enough clamping force on the parts being fastened, and the correct tensioning of the bolt to maintain the clamping force.

Use of a torque wrench to tighten fasteners will help prevent overtensioning them. Overtensioning causes permanent stretching of the fasteners, which can result in breakage of the parts or fasteners.

When torquing a fastener, typically 80 to 90 percent of the turning force is used to overcome friction; only 10 to 20 percent is used to stretch the capscrew or bolt. About 40 to 50 percent of the turning force is needed to overcome the friction between the underside of the capscrew head or nut and the washer. Another 30 to 40 percent is needed to overcome the friction between the threads of the capscrew and the threaded hole, or the friction between the threads of the nut and bolt.

The amount of torque required to tighten a fastener is reduced when the amount of friction is reduced. If a fastener is dry (unlubricated) and plain (unplated), the amount of friction is high. If a fastener is wax-coated or oiled, or has a zinc phosphate coating or cadmium plating, the amount of friction is reduced. Each of these coatings and combinations of coatings has a different effect. Using zinc-plated hardened flatwashers under the bolt (capscrew) head and nut reduces the amount of friction. Dirt or other foreign material on the threads or clamping surfaces of the fastener or clamped part also changes the amount of friction.

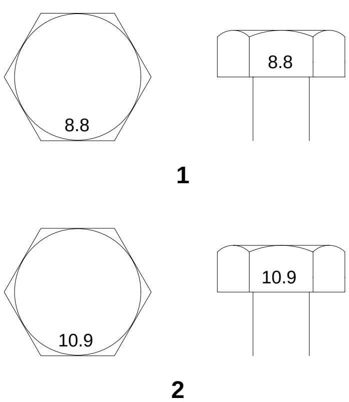
Even though each different condition affects the amount of friction, a different torque value cannot be given for each different condition. To ensure they are always torqued accurately, Freightliner recommends that all fasteners be lubricated with oil (unless specifically instructed to install them dry), then torqued to the values for lubricated- and plated-thread fasteners. When locking compound or anti-seize compound is recommended for a fastener, the compound acts as a lubricant, and oil is not needed.



NOTE: Grade 2 (S.A.E.) and grade A (I.F.I.) nuts have no identification marks or notches; they are rarely used by Freightliner. Grade B (I.F.I.) nuts have three identification marks at 120 degrees, or 6 notches. Grade C (I.F.I.) nuts have three identification marks at 60 degrees, or 12 notches. Grade G (I.F.I.) flanged nuts have six identification marks as shown; each identification mark may be a dot, line, pair of dots or lines, or any other symbol at the manufacturer's option.

1. S.A.E. Grade 2 or I.F.I. Grade A Nut (strength compatible with grade 2 bolt.)
2. S.A.E. Grade 5 Nut (strength compatible with grade 5 bolt.)
3. I.F.I. Grade B Nut (strength compatible with grade 5 bolt.)
4. S.A.E. Grade 8 Nut (strength compatible with grade 8 or grade 8.2 bolt.)
5. I.F.I. Grade C Nut (strength compatible with grade 8 or grade 8.2 bolt.)
6. I.F.I. Grade G Nut (flanged locknut; strength compatible with grade 8 or grade 8.2 bolt.)

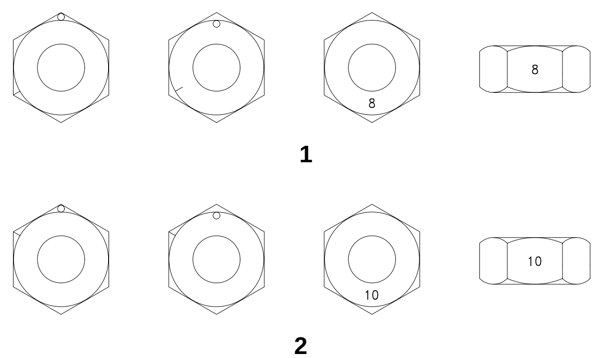
Fig. 3, Nut Grades



NOTE: In addition to the class markings, the bolt head must also carry the manufacturer's trademark or identification.

1. Class 8.8
2. Class 10.9

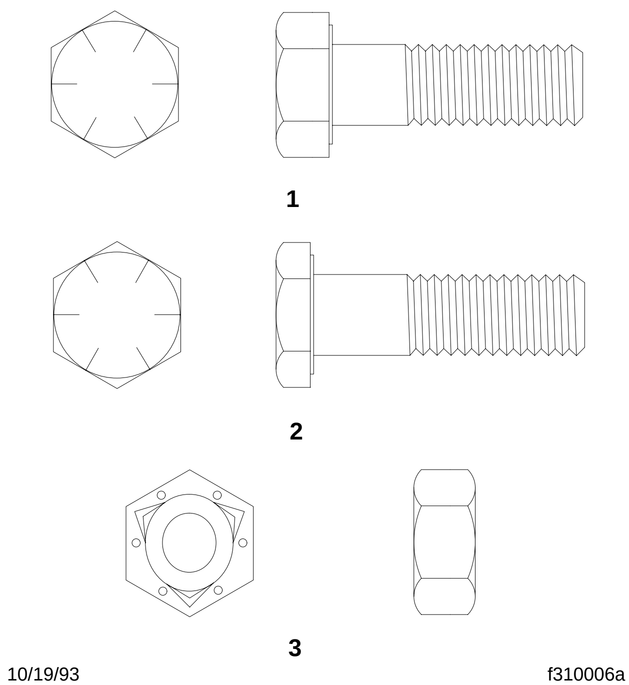
Fig. 4, Bolt Classes



1. Class 8 Nut
2. Class 10 Nut

Fig. 5, Nut Classes

General Information



1. Grade 8 Hexhead Bolt
2. Grade 8 Low-Profile Hexhead Bolt
3. Grade C Prevailing Torque Locknut

Fig. 6, Frame Fastener Identification

Fastener Replacement

When replacing fasteners, use only identical bolts, washers, and nuts; they must be the same size, strength, and finish as originally specified. See the Freightliner Service Parts Catalog for fastener specifications.

When replacing graded (or metric class) bolts and capscrews, use only fasteners that have the manufacturer's trademark or identification on the bolt head; do not use substandard bolts. Inferior, counterfeit fasteners are difficult to identify; buy your fasteners from a reputable supplier.

Fastener Selection and Installation

When using nuts with bolts, use a grade (or class) of nut that matches the bolt.

When installing non-flanged fasteners, use hardened steel flatwashers under the bolt (capscrew) head, and under the hexnut or locknut.

For bolts 4 inches (100 mm) or less in length, make sure that at least 1-1/2 threads and no more than 5/8-inch (16-mm) bolt length extends through the nut after it has been tightened. For bolts longer than 4 inches (100 mm), allow a minimum of 1-1/2 threads and a maximum of 3/4-inch (19-mm) bolt length.

Never hammer or screw bolts into place. Align the holes of the parts being attached, so that the nut and bolt surfaces are flush against the washers, and the washers are flush against the parts.

When installing fasteners in aluminum or plastic parts with threaded holes, start the fasteners by hand, to ensure straight starting and to prevent damaged threads.

Do not use lockwashers (split or toothed) next to aluminum surfaces.

When installing studs that do not have an interference fit, install them with thread locking compound, as instructed in this subject.

When installing parts that are mounted on studs, use free-spinning (non-locking) nuts and helical-spring (split) lockwashers or internal-tooth lockwashers. Do not use locknuts, because they tend to loosen the studs during removal. Do not use plain washers (flatwashers).

Do not use lockwashers and flatwashers in combination (against each other); each defeats the other's purpose.

Use stainless steel fasteners against chrome plating, unpainted aluminum, or stainless steel.

Fastener Tightening

Before installing fasteners, clean all fastener (and parts) threads, and all surfaces being clamped.

To ensure they are always torqued accurately, Freightliner recommends that *all* fasteners be lubricated with oil (unless specifically instructed to install them dry), then torqued to the values for lubricated- and plated-thread fasteners. When locking compound or antiseize compound is recommended for a fastener, the compound acts as a lubricant, and oil is not needed.

Bring parts and fasteners into contact, with no gaps between them, before using a torque wrench to tighten fasteners to their final torque values.

Tighten the nut, not the bolt head. This will give a truer torque reading by eliminating bolt body friction.

Always use a torque wrench to tighten fasteners, and use a slow, smooth, even pull on the wrench. Do not overtorque fasteners; overtightening causes permanent stretching of the fasteners, which can result in breakage of the parts or fasteners.

If specific torque values are not given for countersunk bolts, use the torque value for the corresponding size and grade of regular bolt, as given in **Specifications, 400**.

Always follow the torque sequence or torque interval when provided, to ensure that clamping forces are even, and parts and fasteners are not distorted.

Thread Locking Compound Application

When the use of thread locking compound is recommended or desired, for studs, capscrews, and bolts with a thread diameter of 1 inch (25 mm) or less, use Loctite® 271 or Perma-Lok® HM-128.

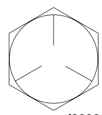
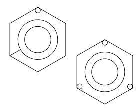
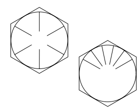
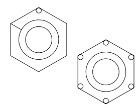
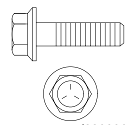
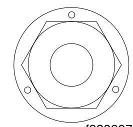
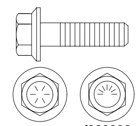
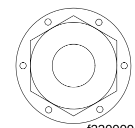
For thread diameters over 1 inch (25 mm), use Loctite 277.

General Instructions

NOTE: Follow the safety precautions given on the locking compound container.

1. Clean the male and female threads of the fasteners, removing all dirt, oil, and other foreign material. If parts are contaminated, use Stoddard solvent for cleaning; then allow the fasteners to air dry for 10 minutes. Be sure solvent is completely gone before applying adhesive.
2. Transfer a small amount of the locking compound from the container to a paper cup or small non-metal dish.
3. Using a plastic brush (a metal brush will contaminate the compound), apply a small amount of compound to the entire circumference of three or four of the male threads that will be covered by the nut after it has been tightened. Be sure enough compound is applied to fill the inside of the nut threads, with a slight excess.
4. Install and torque the nut. Readjustment of the nut position is not possible after installation is complete, without destroying the locking effect.

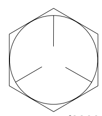
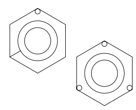
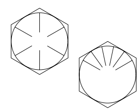
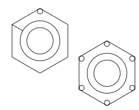
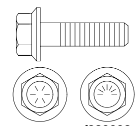
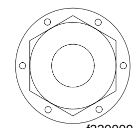
NOTE: To disassemble the fasteners, heat the bond line to 400°F (200°C) before removing the nut. Every time the fasteners are disassembled, replace them. If any parts are damaged by overheating, replace the parts.

TORQUE VALUES FOR U.S. CUSTOMARY THREAD FASTENERS WITH LUBRICATED * OR PLATED THREADS †								
Thread Diameter–Pitch	Regular Hex				Flanged			
	 f230002	 f230003	 f230004	 f230005	 f230006	 f230007	 f230008	 f230009
	Grade 5 Bolt	Grade 5 or B Nut	Grade 8 or 8.2 Bolt	Grade 8 or C Nut	Grade 5 Bolt	Grade B Nut	Grade 8 or 8.2 Bolt	Grade G Nut
	Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)	
1/4–20	7 (9)		8 (11)		6 (8)		10 (14)	
1/4–28	8 (11)		9 (12)		7 (9)		12 (16)	
5/16–18	15 (20)		16 (22)		13 (18)		21 (28)	
5/16–24	16 (22)		17 (23)		14 (19)		23 (31)	
3/8–16	26 (35)		28 (38)		23 (31)		37 (50)	
3/8–24	30 (41)		32 (43)		25 (34)		42 (57)	
7/16–14	42 (57)		45 (61)		35 (47)		60 (81)	
7/16–20	47 (64)		50 (68)		40 (54)		66 (89)	
1/2–13	64 (87)		68 (92)		55 (75)		91 (123)	
1/2–20	72 (98)		77 (104)		65 (88)		102 (138)	
9/16–12	92 (125)		98 (133)		80 (108)		130 (176)	
9/16–18	103 (140)		110 (149)		90 (122)		146 (198)	
5/8–11	128 (173)		136 (184)		110 (149)		180 (244)	
5/8–18	145 (197)		154 (209)		130 (176)		204 (277)	
3/4–10	226 (306)		241 (327)		200 (271)		320 (434)	
3/4–16	253 (343)		269 (365)		220 (298)		357 (484)	
7/8–9	365 (495)		388 (526)		320 (434)		515 (698)	
7/8–14	402 (545)		427 (579)		350 (475)		568 (770)	
1–8	—		582 (789)		—		—	
1–12	—		637 (863)		—		—	
1–14	—		652 (884)		—		—	

* Freightliner recommends that all plated and unplated fasteners be coated with oil before installation.
† Use these torque values if either the bolt or nut is lubricated or plated (zinc-phosphate conversion-coated, cadmium-plated, or waxed).

Table 1, Torque Values for U.S. Customary Thread Fasteners with Lubricated or Plated Threads

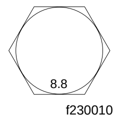
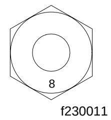
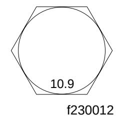
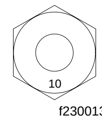
Specifications

TORQUE VALUES FOR U.S. CUSTOMARY THREAD FASTENERS WITH DRY (UNLUBRICATED) * PLAIN (UNPLATED) THREADS †						
Thread Diameter–Pitch	Regular Hex				Flanged	
	 f230002	 f230003	 f230004	 f230005	 f230008	 f230009
	Grade 5 Bolt	Grade 5 or B Nut	Grade 8 or 8.2 Bolt	Grade 8 or C Nut	Grade 8 or 8.2 Bolt	Grade G Nut
	Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)	
1/4–20	8 (11)		10 (14)		—	
1/4–28	9 (12)		12 (16)		—	
5/16–18	15 (20)		22 (30)		22 (30)	
5/16–24	17 (23)		25 (34)		—	
3/8–16	28 (38)		40 (54)		40 (54)	
3/8–24	31 (42)		45 (61)		—	
7/16–14	45 (61)		65 (88)		65 (88)	
7/16–20	50 (68)		70 (95)		—	
1/2–13	70 (95)		95 (129)		95 (129)	
1/2–20	75 (102)		110 (149)		—	
9/16–12	100 (136)		140 (190)		140 (190)	
9/16–18	110 (149)		155 (210)		—	
5/8–11	135 (183)		190 (258)		190 (258)	
5/8–18	155 (210)		215 (292)		—	
3/4–10	240 (325)		340 (461)		340 (461)	
3/4–16	270 (366)		380 (515)		—	
7/8–9	385 (522)		540 (732)		—	
7/8–14	425 (576)		600 (813)		—	
1–8	580 (786)		820 (1112)		—	
1–12	635 (861)		900 (1220)		—	
1–14	650 (881)		915 (1241)		—	

* Threads may have residual oil, but will be dry to the touch.
† Male and female threads (bolt and nut) must both be unlubricated and unplated; if either is plated or lubricated, use Table 1. Freightliner recommends that all plated and unplated fasteners be coated with oil before installation.

Table 2, Torque Values for U.S. Customary Thread Fasteners with Dry (Unlubricated) Plain (Unplated) Threads

TORQUE VALUES FOR METRIC THREAD FASTENERS WITH LUBRICATED * OR PLATED THREADS †

Thread Diameter–Pitch	 Class 8.8 Bolt	 Class 8 Nut	 Class 10.9 Bolt	 Class 10 Nut
	Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)	
M6	5 (7)		7 (9)	
M8	12 (16)		17 (23)	
M8 x 1	13 (18)		18 (24)	
M10	24 (33)		34 (46)	
M10 x 1.25	27 (37)		38 (52)	
M12	42 (57)		60 (81)	
M12 x 1.5	43 (58)		62 (84)	
M14	66 (89)		95 (129)	
M14 x 1.5	72 (98)		103 (140)	
M16	103 (140)		148 (201)	
M16 x 1.5	110 (149)		157 (213)	
M18	147 (199)		203 (275)	
M18 x 1.5	165 (224)		229 (310)	
M20	208 (282)		288 (390)	
M20 x 1.5	231 (313)		320 (434)	
M22	283 (384)		392 (531)	
M22 x 1.5	315 (427)		431 (584)	
M24	360 (488)		498 (675)	
M24 x 2	392 (531)		542 (735)	
M27	527 (715)		729 (988)	
M27 x 2	569 (771)		788 (1068)	
M30	715 (969)		990 (1342)	
M30 x 2	792 (1074)		1096 (1486)	

* Freightliner recommends that all plated and unplated fasteners be coated with oil before installation.
† Use these torque values if either the bolt or nut is lubricated or plated (zinc-phosphate conversion-coated, cadmium-plated, or waxed).

Table 3, Torque Values for Metric Thread Fasteners With Lubricated Or Plated Threads

VIN Information

Code of Federal Regulations Title 49, Part 565 specifies that all vehicles sold in the U.S. be assigned a 17-character Vehicle Identification Number (VIN). Using a combination of letters and numerals, the VIN defines the manufacturer, model, and major characteristics of the vehicle. See **Table 1** for the character positions of a typical Freightliner VIN, 1FUPABAV11PA12345.

The VIN can be found on the Vehicle Specification Decal (see the driver's manual for decal location) and stamped on the left frame rail over the front axle about 2 inches (50 mm) from the top of the web or on the top flange of the left frame rail at frame station 30.

For all vehicles, a check digit (9th character) is determined by assignment of weighted values to the other 16 characters. These weighted values are processed through a series of equations designed to check validity of the VIN and to detect VIN alteration.

NOTE: Always specify the VIN when ordering parts.

Seventeen-Character Vehicle Identification Number (VIN)								
Typical VIN	**1 F U**	**P**	**AB**	**AV**	**1**	**1**	**P**	**A 1 2 3 4 5**
Character Position	1, 2, 3	4	5, 6	7, 8	9	10	11	12–17
Code Description	World Manufacturer Identification	Chassis Configuration	Model, Cab, GVWR	Engine, Brakes	Check Digit Calculation	Model Year	Build Location	Production Serial Number
Decoding Table*	Table 2	Table 3	Table 4	Table 5	—	Table 6	Table 7	—

* For corresponding decoding information, see the applicable tables in this subject.

Table 1, Seventeen-Character Vehicle Identification Number (VIN)

VIN Positions 1, 2, and 3 (World Manufacturer Identification)			
Code	**Vehicle Manufacturer**	**Vehicle Make**	**Vehicle Type**
1FU	Freightliner, U.S.A.	Freightliner	Truck-Tractor
1FV	Freightliner, U.S.A.	Freightliner	Incomplete Vehicle
3AK	Daimler AG, Mexico	Freightliner	Truck-Tractor
3AL	Daimler AG, Mexico	Freightliner	Incomplete Vehicle
RSA	NAI, Saudi Arabia	Freightliner	Incomplete Vehicle
RSB	NAI, Saudi Arabia	Freightliner	Truck-Tractor

Table 2, VIN Positions 1, 2, and 3 (World Manufacturer Identification)

VIN Position 4 (Chassis Configuration)	
Code	**Chassis**
A	4 x 2 Truck
B	4 x 2 Truck-Tractor
C	8 x 8 Truck
D	4 x 4 Truck
E	4 x 4 Truck-Tractor
F	6 x 2 Truck
G	6 x 2 Truck-Tractor
H	6 x 4 Truck

VIN Position 4 (Chassis Configuration)	
Code	**Chassis**
J	6 x 4 Truck-Tractor
K	6 x 6 Truck
L	6 x 6 Truck-Tractor
M	8 x 4 Truck
N	8 x 4 Truck-Tractor
P	8 x 6 Truck
R	8 x 6 Truck-Tractor
S	10 x 4 Truck

VIN Information

VIN Position 4 (Chassis Configuration)	
Code	**Chassis**
T	10 x 4 Truck-Tractor
U	10 x 6 Truck
V	10 x 6 Truck-Tractor
W	12 x 4 Truck
X	Glider
Y	8 x 2 Truck
Z	14 x 4 Truck
1	12 x 6 Truck

Table 3, VIN Position 4 (Chassis Configuration)

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**GVWR**
AA	FLB Glider	COE	Glider
AB	FLD112	Conventional	Class 7
AC	FLD112	Conventional	Class 8
AD	FLD112 Glider	Conventional	Glider
AE	FLD112 SD	Conventional	Class 8
AF	FLD112 SD Glider	Conventional	Glider
AG	FLD120	Conventional	Class 7
AH	FLD120	Conventional	Class 8
AJ	FLD120 Glider	Conventional	Glider
AK	FLD120 SD	Conventional	Class 7
AL	FLD120 SD	Conventional	Class 8
AM	FLD120 SD Glider	Conventional	Glider
AN	FLD132 XL Classic	Conventional	Class 7
AP	FLD132 XL Classic	Conventional	Class 8
AR	FLD132 XL Glider	Conventional	Glider
AS	FLD120 Military	Conventional	Class 7
AT	FLD120 Military	Conventional	Class 8
AU	FLD120 Military Glider	Conventional	Glider
AV	Argosy	COE	Class 7
AW	Argosy	COE	Class 8
AX	Argosy Glider	COE	Glider
AY	C112	Conventional	Class 7
AZ	C112	Conventional	Class 8
A1	C112 Glider	Conventional	Glider
A2	C120	Conventional	Class 7
A3	C120	Conventional	Class 8
A4	C120 Glider	Conventional	Glider
A5	Columbia 120	Conventional	Class 7

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**GVWR**
A6	Columbia 120	Conventional	Class 8
A7	Columbia 120 Glider	Conventional	Glider
A8	CST112	Conventional	Class 7
A9	CST112	Conventional	Class 8
A0	CST112 Glider	Conventional	Glider
BA	CST120	Conventional	Class 7
BB	CST120	Conventional	Class 8
BC	CST120 Glider	Conventional	Glider
BD	FLD120 Classic Legacy	Conventional	Class 8
BE	FLS112 Legacy	Conventional	Class 8
BF	FL112	Conventional	Class 7
BG	FL112	Conventional	Class 8
BH	FL112 Glider	Conventional	Glider
BJ	FL50	Conventional	Class 4
BK	FL50	Conventional	Class 5
BL	FL50	Conventional	Class 6
BM	FL50	Conventional	Class 7
BN	FL60	Conventional	Class 5
BP	FL60	Conventional	Class 6
BR	FL60	Conventional	Class 7
BS	FL70	Conventional	Class 6
BT	FL70	Conventional	Class 7
BU	FL70	Conventional	Class 8
BV	FL80	Conventional	Class 6
BW	FL80	Conventional	Class 7
BX	FL80	Conventional	Class 8
BY	FL106	Conventional	Class 6
BZ	FL106	Conventional	Class 7
B1	FL106	Conventional	Class 8
B2	FC70 Cargo	COE	Class 6
B3	FC70 Cargo	COE	Class 7
B4	FC70 Cargo	COE	Class 8
B5	FC80 Cargo	COE	Class 6
B6	FC80 Cargo	COE	Class 7
B7	FC80 Cargo	COE	Class 8
B8	RIV	None	Class 8

VIN Information

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	Model	Cab	GVWR
B9	Sport Chassis	Conventional	Class 6
B0	Sport Chassis	Conventional	Class 7
CA	FL106 Glider	Conventional	Glider
CB	FL60 Glider	Conventional	Glider
CC	FL70 Glider	Conventional	Glider
CD	FL80 Glider	Conventional	Glider
CE	Condor	COE	Class 7
CF	Condor	COE	Class 8
CG	FLD120/84" Sleeper MY2001	Conventional	Class 7
CH	FLD120/84" Sleeper MY2001	Conventional	Class 8
CJ	FLD120 Glider/84" Sleeper MY2001	Conventional	Glider
CK	FLD132 XL Classic/84" Sleeper MY2001	Conventional	Class 7
CL	FLD132 XL Classic/84" Sleeper MY2001	Conventional	Class 8
CM	FLD 132 XL Glider/84" Sleeper	Conventional	Glider
CN	FL112	Conventional	Class 6
CP	FLD120 Military Reman	Conventional	Class 8
CR	Coronado CC132	Conventional	Class 8
CS	M2 100	Conventional	Class 4
CT	M2 100	Conventional	Class 5
CU	M2 100	Conventional	Class 6
CV	M2 106 Medium Duty	Conventional	Class 5
CW	M2 106 Medium Duty	Conventional	Class 6
CX	M2 106 Medium Duty	Conventional	Class 7
CY	M2 106 Medium Duty	Conventional	Class 8
CZ	M2 106V Heavy Duty	Conventional	Class 5
C1	M2 106V Heavy Duty	Conventional	Class 6
C2	M2 106V Heavy Duty	Conventional	Class 7
C3	M2 106V Heavy Duty	Conventional	Class 8
C4	M2 112 Medium Duty	Conventional	Class 7
C5	M2 112 Medium Duty	Conventional	Class 8
C6	M2 112V Heavy Duty	Conventional	Class 7
C7	M2 112V Heavy Duty	Conventional	Class 8
C8	M2 106 Medium Duty	Conventional	Class 4
C9	Sport Chassis	Conventional	Class 5
F1	Sport Chassis 112	Conventional	Class 6
F2	FLB High COE	COE	Class 8

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**GVWR**
F3	Sport Chassis 112	Conventional	Class 7
F4	Coronado CC132	Conventional	Class 7
F5	Classic 120	Conventional	Class 7
F6	Classic 120	Conventional	Class 8
F7	Condor Glider	Conventional	Glider
F8	M2 106 Medium Glider	Conventional	Glider
F9	Columbia 112	Conventional	Class 7
F0	Columbia 112	Conventional	Class 8
FA	Columbia 112	Conventional	Glider
FB	Coronado CC132 Glider	Conventional	Glider
FC	M2 106 Sport Chassis	Conventional	Class 5
FD	M2 106 Sport Chassis	Conventional	Class 6
FE	M2 106 Sport Chassis	Conventional	Class 7
FF	M2 112 Sport Chassis	Conventional	Class 5
FG	M2 112 Sport Chassis	Conventional	Class 6
FH	M2 112 Sport Chassis	Conventional	Class 7
FJ	Classic 120	Conventional	Glider
GA	Cascadia 113 Day Cab	Conventional	Class 7
GB	Cascadia 113 Day Cab	Conventional	Class 8
GC	Cascadia 113 Sleeper Cab	Conventional	Glider
GD	Cascadia 125 Day Cab	Conventional	Class 7
GE	Cascadia 125 Day Cab	Conventional	Class 8
GF	Cascadia 125 Sleeper Cab	Conventional	Glider
GG	Cascadia 113 Sleeper Cab	Conventional	Class 7
GH	Cascadia 113 Sleeper Cab	Conventional	Class 8
GJ	Cascadia 132	Conventional	Glider
GK	Cascadia 125 Sleeper Cab	Conventional	Class 7
GL	Cascadia 125 Sleeper Cab	Conventional	Class 8
GM	Coronado 132	Conventional	Class 8
GN	Coronado SD 122	Conventional	Class 8
GP	Coronado 122	Conventional	Class 8
GR	Coronado 122	Conventional	Glider
GS	Coronado SD 122 Glider	Conventional	Glider
GT	Coronado 132	Conventional	Glider
GU	M2 106V Glider	Conventional	Glider
GV	Coronado 122 RHD	Conventional	Class 8

VIN Information

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	Model	Cab	GVWR
GW	Coronado 122 RHD Glider	Conventional	Glider
GX	Coronado 132	Conventional	Class 7
GY	Coronado SD 122	Conventional	Class 7
GZ	Coronado 122	Conventional	Class 7
G1	M2 112 Glider	Conventional	Glider
G2	MD109 Military	Conventional	Class 8
G3	114SD	Conventional	Class 8
G4	114SD	Conventional	Glider
G5	108SD	Conventional	Class 8
G6	108SD	Conventional	Glider
G7	Coronado 114 RHD	Conventional	Class 8
G8	Coronado 114 RHD	Conventional	Glider
G9	114SD	Conventional	Class 7
G0	108SD	Conventional	Class 7
HA	Cascadia 113 Day Cab	Conventional	Glider
HB	Cascadia 125 Day Cab	Conventional	Glider
HC	108SD	Conventional	Class 6
HD	M2 100	Conventional	Class 7

Table 4, VIN Positions 5 and 6 (Model, Cab, Class/GVWR)

VIN Positions 7 and 8 (Engine, Brakes)					
Code	Engine	Fuel	Displacement	Configuration	Brakes
AA	Caterpillar 3176	Diesel	10.3 Liter	I-6	Air
AB	Caterpillar 3176	Diesel	10.3 Liter	I-6	Hydraulic
AC	Caterpillar 3176	Diesel	10.3 Liter	I-6	Air/Hydraulic
AD	Caterpillar 3406	Diesel	14.6 Liter	I-6	Air
AE	Caterpillar 3406	Diesel	14.6 Liter	I-6	Hydraulic
AF	Caterpillar 3406	Diesel	14.6 Liter	I-6	Air/Hydraulic
AG	Caterpillar 3406 E	Diesel	15.8 Liter	I-6	Air
AH	Caterpillar 3406 E	Diesel	15.8 Liter	I-6	Hydraulic
AJ	Caterpillar 3406 E	Diesel	15.8 Liter	I-6	Air/Hydraulic
AK	Caterpillar 3126/CFE	Diesel	7.2 Liter	I-6	Air
AL	Caterpillar 3126/CFE	Diesel	7.2 Liter	I-6	Hydraulic
AM	Caterpillar 3126/CFE	Diesel	7.2 Liter	I-6	Air/Hydraulic
AN	Caterpillar C10	Diesel	10.3 Liter	I-6	Air
AP	Caterpillar C10	Diesel	10.3 Liter	I-6	Hydraulic

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement**	**Configuration**	**Brakes**
AR	Caterpillar C10	Diesel	10.3 Liter	I-6	Air/Hydraulic
AS	Caterpillar C12	Diesel	12.0 Liter	I-6	Air
AT	Caterpillar C12	Diesel	12.0 Liter	I-6	Hydraulic
AU	Caterpillar C12	Diesel	12.0 Liter	I-6	Air/Hydraulic
AV	Caterpillar C15	Diesel	14.6 Liter pre 2008/15.2 Liter	I-6	Air
AW	Caterpillar C15	Diesel	14.6 Liter pre 2008/15.2 Liter	I-6	Hydraulic
AX	Caterpillar C15	Diesel	14.6 Liter pre 2008/15.2 Liter	I-6	Air/Hydraulic
AY	Caterpillar C16	Diesel	15.8 Liter	I-6	Air
AZ	Caterpillar C16	Diesel	15.8 Liter	I-6	Hydraulic
A1	Caterpillar C16	Diesel	15.8 Liter	I-6	Air/Hydraulic
A2	Cummins L10	Diesel	10.8 Liter	I-6	Air
A3	Cummins L10	Diesel	10.8 Liter	I-6	Hydraulic
A4	Cummins L10	Diesel	10.8 Liter	I-6	Air/Hydraulic
A5	Cummins M11	Diesel	10.8 Liter	I-6	Air
A6	Cummins M11	Diesel	10.8 Liter	I-6	Hydraulic
A7	Cummins M11	Diesel	10.8 Liter	I-6	Air/Hydraulic
A8	Cummins ISM	Diesel	10.8 Liter	I-6	Air
A9	Cummins ISM	Diesel	10.8 Liter	I-6	Hydraulic
A0	Cummins ISM	Diesel	10.8 Liter	I-6	Air/Hydraulic
BA	Cummins NTC	Diesel	14 Liter	I-6	Air
BB	Cummins NTC	Diesel	14 Liter	I-6	Hydraulic
BC	Cummins NTC	Diesel	14 Liter	I-6	Air/Hydraulic
BD	Cummins N14	Diesel	14 Liter	I-6	Air
BE	Cummins N14	Diesel	14 Liter	I-6	Hydraulic
BF	Cummins N14	Diesel	14 Liter	I-6	Air/Hydraulic
BG	Cummins ISX	Diesel	14.9 Liter	I-6	Air
BH	Cummins ISX	Diesel	14.9 Liter	I-6	Hydraulic
BJ	Cummins ISX	Diesel	14.9 Liter	I-6	Air/Hydraulic
BK	Cummins C 8.3	Diesel	8.3 Liter	I-6	Air
BL	Cummins C 8.3	Diesel	8.3 Liter	I-6	Hydraulic
BM	Cummins C 8.3	Diesel	8.3 Liter	I-6	Air/Hydraulic
BN	Cummins B5.9	Diesel	5.9 Liter	I-6	Air
BP	Cummins B5.9	Diesel	5.9 Liter	I-6	Hydraulic
BR	Cummins B5.9	Diesel	5.9 Liter	I-6	Air/Hydraulic

VIN Information

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement**	**Configuration**	**Brakes**
BS	Cummins ISC	Diesel	8.3 Liter	I-6	Air
BT	Cummins ISC	Diesel	8.3 Liter	I-6	Hydraulic
BU	Cummins ISC	Diesel	8.3 Liter	I-6	Air/Hydraulic
BV	Cummins ISB	Diesel	5.9 Liter	I-6	Air
BW	Cummins ISB	Diesel	5.9 Liter	I-6	Hydraulic
BX	Cummins ISB	Diesel	5.9 Liter	I-6	Air/Hydraulic
BY	Cummins B5.9	Propane	5.9 Liter	I-6	Air
BZ	Cummins B5.9	Propane	5.9 Liter	I-6	Hydraulic
B1	Cummins B5.9	Propane	5.9 Liter	I-6	Air/Hydraulic
B2	Cummins B5.9	Natural Gas	5.9 Liter	I-6	Air
B3	Cummins B5.9	Natural Gas	5.9 Liter	I-6	Hydraulic
B4	Cummins B5.9	Natural Gas	5.9 Liter	I-6	Air/Hydraulic
B5	Cummins C8.3	Natural Gas	8.3 liter	I-6	Air
B6	Cummins C8.3	Natural Gas	8.3 liter	I-6	Hydraulic
B7	Cummins C8.3	Natural Gas	8.3 liter	I-6	Air/Hydraulic
B8	Detroit Series 50	Diesel	8.5 liter	I-4	Air
B9	Detroit Series 50	Diesel	8.5 liter	I-4	Hydraulic
B0	Detroit Series 50	Diesel	8.5 liter	I-4	Air/Hydraulic
CA	Detroit Series 55	Diesel	12.Liter	I-6	Air
CB	Detroit Series 55	Diesel	12.Liter	I-6	Hydraulic
CC	Detroit Series 55	Diesel	12.Liter	I-6	Air/Hydraulic
CD	Detroit Series 60	Diesel	11.1 Liter	I-6	Air
CE	Detroit Series 60	Diesel	11.1 Liter	I-6	Hydraulic
CF	Detroit Series 60	Diesel	11.1 Liter	I-6	Air/Hydraulic
CG	Detroit Series 60	Diesel	12.7 Liter	I-6	Air
CH	Detroit Series 60	Diesel	12.7 Liter	I-6	Hydraulic
CJ	Detroit Series 60	Diesel	12.7 Liter	I-6	Air/Hydraulic
CK	Detroit Series 60	Diesel	14.0 Liter	I-6	Air
CL	Detroit Series 60	Diesel	14.0 Liter	I-6	Hydraulic
CN	Mercedes-Benz MBE-900	Diesel	4.3 liter	I-4	Air
CP	Mercedes-Benz MBE-900	Diesel	4.3 liter	I-4	Hydraulic
CR	Mercedes-Benz MBE-900	Diesel	4.3 liter	I-4	Air/Hydraulic
CS	Mercedes-Benz MBE-900	Diesel	6.4 liter	I-6	Air
CT	Mercedes-Benz MBE-900	Diesel	6.4 liter	I-6	Hydraulic
CU	Mercedes-Benz MBE-900	Diesel	6.4 liter	I-6	Air/Hydraulic
CV	Mercedes-Benz MBE4000	Diesel	12.8 Liter	I-6	Air

VIN Information

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement**	**Configuration**	**Brakes**
CW	Mercedes-Benz MBE4000	Diesel	12.8 Liter	I-6	Hydraulic
CX	Mercedes-Benz MBE4000	Diesel	12.8 Liter	I-6	Air/Hydraulic
CY	Cummins ISL	Diesel	8.9 Liter	I-6	Air
CZ	Cummins ISL	Diesel	8.9 Liter	I-6	Hydraulic
C1	Cummins ISL	Diesel	8.9 Liter	I-6	Air/Hydraulic
C2	Cummins B 3.9	Diesel	3.9 Liter	I-4	Air
C3	Cummins B 3.9	Diesel	3.9 Liter	I-4	Hydraulic
C4	Cummins B 3.9	Diesel	3.9 Liter	I-4	Air/Hydraulic
C5	Cummins ISB 3.9	Diesel	3.9 Liter	I-4	Air
C6	Cummins ISB 3.9	Diesel	3.9 Liter	I-4	Hydraulic
C7	Cummins ISB 3.9	Diesel	3.9 Liter	I-4	Air/Hydraulic
C8	John Deere 6081H	CNG	8.1 Liter	I-6	Air
C9	John Deere 6081H	CNG	8.1 Liter	I-6	Hydraulic
DA	Caterpillar C9	Diesel	8.8 Liter	I-6	Air
DB	Caterpillar C9	Diesel	8.8 Liter	I-6	Hydraulic
DC	Caterpillar C7	Diesel	7.2 Liter	I-6	Air
DD	Caterpillar C7	Diesel	7.2 Liter	I-6	Hydraulic
DE	Caterpillar C13	Diesel	12.5 Liter	I-6	Air
DF	Caterpillar C13	Diesel	12.5 Liter	I-6	Hydraulic
DG	Mercedes-Benz MBE-900	Diesel	4.8 Liter	I-4	Air
DH	Mercedes-Benz MBE-900	Diesel	4.8 Liter	I-4	Hydraulic
DJ	Mercedes-Benz MBE-900	Diesel	7.2 Liter	I-6	Air
DK	Mercedes-Benz MBE-900	Diesel	7.2 Liter	I-6	Hydraulic
DL	Caterpillar C11	Diesel	11.1 Liter	I-6	Air
DM	Caterpillar C11	Diesel	11.1 Liter	I-6	Hydraulic
DN	Cummins L Gas Plus	Natural Gas	8.9 Liter	I-6	Air
DP	Cummins L Gas Plus	Natural Gas	8.9 Liter	I-6	Hydraulic
DR	Detroit DD15	Diesel	14.8 Liter	I-6	Air
DS	Detroit DD15	Diesel	14.8 Liter	I-6	Hydraulic
DT	Cummins ISB	Diesel	6.7 Liter	I-6	Air
DU	Cummins ISB	Diesel	6.7 Liter	I-6	Hydraulic
DV	Detroit DD13	Diesel	12.8 Liter	I-6	Air
DW	Detroit DD13	Diesel	12.8 Liter	I-6	Hydraulic
DX	Cummins ISL G	Natural Gas	8.9 Liter	I-6	Air
DY	Cummins ISL G	Natural Gas	8.9 Liter	I-6	Hydraulic
D1	Detroit DD16	Diesel	15.6 Liter	I-6	Air

VIN Information

VIN Positions 7 and 8 (Engine, Brakes)					
Code	Engine	Fuel	Displacement	Configuration	Brakes
D2	MDEG 7.7	Diesel	7.7 Liter	I-6	Air
D3	MDEG 7.7	Diesel	7.7 Liter	I-6	Hydraulic
D4	Cummins ISX12	Diesel	11.9 Liter	I-6	Air
D5	Detroit DD15 EV	Diesel	14.8 Liter	I-6	Air
D6	Detroit DD15 STD	Diesel	14.8 Liter	I-6	Air
D7	Detroit DD15 EV	Diesel	14.8 Liter	I-6	Hydraulic
D8	Detroit DD15 STD	Diesel	14.8 Liter	I-6	Hydraulic
D9	Cummins ISX12	Natural Gas	11.9 Liter	I-6	Air
00	NO ENGINE				

Table 5, VIN Positions 7 and 8 (Engine and Brakes)

VIN Position 10 (Model Year)	
Code	Model Year
Y	2000
1	2001
2	2002
3	2003
4	2004
5	2005
6	2006
7	2007
8	2008
9	2009
A	2010
B	2011
C	2012
D	2013

Table 6, VIN Position 10 (Model Year)

VIN Position 11 (Build Location)	
Code	Plant of Manufacture
L	Cleveland, North Carolina
P	Portland, Oregon
D	Daimler AG, Santiago, Mexico
S	Daimler AG, Saltillo, Coahuila Mexico
H	Mt. Holly, North Carolina

Table 7, VIN Position 11 (Build Location)

General Information

General Description

Three mounts support the engine and transmission, holding a total of almost 1800 lb (816 kg). Two of the engine mounts support the rear of the engine and transmission assembly. The third supports the front of the engine/transmission assembly.

Each of the rear engine mounts is bolted to the inside of the frame rail near the flywheel housing. These mounts support legs which are bolted to the flywheel housing. Caterpillar engines use a rear engine leg that rests flat on the mount.

The front engine mount is an underslung crossmember under the front of the engine. It supports a bracket that is bolted to the front of the engine.

To isolate the engine and transmission from road shock, and to isolate the vehicle frame from engine vibration, the engine mounts are sandwiched between rubber isolator cushions (sometimes called restriction pads). Steel snubbers protect the cushions from wearing on the engine support brackets, and a single bolt runs through the mount, cushions, and snubbers to hold the assembly together and hold the engine on the mount.

Rear Engine Mount Replacement

Replacement

1. Apply the parking brakes, chock the tires, and (if applicable) drain the air brake system.

WARNING

The jack used to lift the engine must be capable of safely lifting and supporting two metric tons. Once the engine mount is disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death, and component damage.

2. Disconnect the right rear engine mount from the right rear frame mount.

   2.1 Place a jack under the rear of the engine and raise the jack until it's braced against the engine.

   2.2 Remove the bolt from the right rear engine mount. Save the fasteners, rubber isolator cushions, and snubbers.

   2.3 Lift the engine slightly to take its weight off the right rear engine mount. Place engine stands under the engine to keep it off the engine mount.

3. Remove the bolts that secure the mount to the frame rail. Remove the mount from the frame rail.

   If necessary, remove the four bolts that secure the right engine leg to the flywheel housing, and remove the engine leg.

4. Place a new engine mount against the inside of the frame rail, and secure it with bolts, washers, and nuts. Tighten the nuts 45 lbf·ft (61 N·m).

5. If removed, install the engine leg on the right side of the flywheel housing. Apply thread lock compound to the bracket mounting bolts and tighten the bolts as follows:

   For Caterpillar 3126 and C-7 engines: tighten the bolts 100 lbf·ft (136 N·m).

   For Caterpillar C-9, C-10 and C-12 engines: tighten the bolts 190 lbf·ft (258 N·m).

   For MBE900 engines: tighten the bolts 92 lbf·ft (125 N·m).

   For MBE4000 engines: tighten the bolts 175 lbf·ft (237 N·m).

6. Inspect the engine mount rubber isolators for wear or damage and replace them if necessary.

CAUTION

Do not lubricate the components with oil, grease, or silicone lubricants; they will deteriorate the rubber isolators.

7. Install the upper isolator in the engine mount. If applicable, place the snubber on the isolator.

WARNING

The jack used to lower the engine must be capable of safely lifting and supporting two metric tons. Once the engine is removed from the engine stands, do not get under the engine until it is securely installed on the engine mount. An unsecured engine may fall, causing personal injury or death, and component damage.

8. Secure the engine to the frame mount.

   8.1 If not in place, set a jack under the rear of the engine and raise the jack until it is braced against the engine.

   8.2 Lift the engine slightly to remove the engine stands. Remove the stands, and carefully lower the engine onto the engine mount.

   8.3 Holding the lower isolator and snubber in place, install the bolt in the right rear engine mount, and secure it with the nut and hardened washer. Tighten the nut 241 lbf·ft (327 N·m).

WARNING

The jack used to lift the engine must be capable of safely lifting and supporting two metric tons. Once the engine mount is disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death, and component damage.

9. Disconnect the left rear engine mount from the left rear frame mount.

Rear Engine Mount Replacement

9.1 Place a jack under the rear of the engine, and raise the jack until it's braced against the engine.

9.2 Remove the bolt from the left rear engine mount. Save the fasteners, rubber isolator cushions, and snubbers.

9.3 Lift the engine slightly to take its weight off the left rear engine mount. Place engine stands under the engine to keep it off the engine mount.

10. Remove the capscrews that secure the mount to the frame rail. Remove the mount from the frame rail.

    If necessary, remove the four capscrews that secure the left engine leg to the flywheel housing, and remove the bracket from the engine.

11. Place a new engine mount against the inside of the frame rail, and secure it with bolts, washers, and nuts. Tighten the nuts 45 lbf·ft (61 N·m).

12. If removed, install the engine leg on the left side of the flywheel housing. Apply thread lock compound to the bracket mounting bolts and tighten them as follows:

    For Caterpillar 3126 and C-7 engines: tighten the bolts 100 lbf·ft (136 N·m).

    For Caterpillar C-9, C-10 and C-12 engines: tighten the bolts 190 lbf·ft (258 N·m).

    For MBE900 engines: tighten the bolts 92 lbf·ft (125 N·m).

    For MBE4000 engines: tighten the bolts 175 lbf·ft (237 N·m).

13. Inspect the engine mount rubber isolators for wear or damage and replace them if necessary.

CAUTION

Do not lubricate the components with oil, grease, or silicone lubricants; they will deteriorate the rubber isolators.

14. Install the upper isolator in the engine mount. If applicable, place the snubber on the isolator.

WARNING

The jack used to lower the engine must be capable of safely lifting and supporting two metric tons. Once the engine is removed from the engine stands, do not get under the engine until it is securely installed on the engine mount. An unsecured engine may fall, causing personal injury or death, and component damage.

15. Secure the engine mount to the frame mount.

    15.1 If not in place, set a jack under the rear of the engine and raise the jack until it is braced against the engine.

    15.2 Lift the engine slightly to remove the engine stands. Remove the stands, and carefully lower the engine onto the engine mount.

    15.3 Holding the lower isolator in place, install the bolt in the left rear engine mount, and secure it with the nut and hardened washer. Tighten the nut 241 lbf·ft (327 N·m).

16. Remove the jack from under the engine, and remove the chocks from the tires.

Replacement

1. Apply the parking brakes, chock the tires, and (if applicable) drain the air brake system.

WARNING

The lifting device and chain used to lift the engine must be capable of safely lifting and supporting two metric tons. Once the engine mount is disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death, and component damage.

2. Disconnect the front engine mount from the frame crossmember.
   - 2.1 Attach a chain to the front engine lifting hook(s), and position a lifting device to lift the engine. Attach the chain to the lifting device, and raise the chain to remove any slack.
   - 2.2 Remove the bolt(s) from the front engine mount. Save the fasteners, rubber isolator cushions, and snubber(s).

   NOTE: In order to raise the front of the engine, you may have to loosen the bolts that run through the rear engine mounts.

   - 2.3 Lift the engine slightly to take its weight off the front engine mount. Place engine stands under the engine to keep it off the engine mount.
3. If necessary, remove the bolts which secure the engine support bracket to the front of the engine. Remove the bracket from the engine.
4. If necessary, install a new engine support bracket on the front of the engine. Secure per manufacturer specifications.
5. Inspect the engine mount rubber isolators for wear or damage and replace them if necessary.

CAUTION

Do not lubricate the components with oil, grease, or silicone lubricants; they will deteriorate the rubber isolators.

6. Install the upper isolator(s) in the engine mount. If applicable, place the snubber(s) on the isolator(s).

WARNING

The lifting device and chain used to lower the engine must be capable of safely lifting and supporting two metric tons. Once the engine is removed from the engine stands, do not get under the engine until it is securely installed on the engine mount. An unsecured engine may fall, causing personal injury or death, and component damage.

7. Secure the front engine mount to the frame crossmember.
   - 7.1 Attach a chain to the front engine lifting hook(s). Attach the chain to a lifting device and remove any slack.
   - 7.2 Lift the engine slightly to remove the engine stands. Remove the stands, and carefully lower the engine onto the engine mount.
   - 7.3 Holding the lower isolator(s) and tube(s) in place, install the bolt(s) in the front engine mount and secure it with the nut(s) and washer(s). Tighten the nuts 136 lbf·ft (184 N·m).

   NOTE: If you loosened the bolts that run through the rear engine mounts, tighten those bolts 241 lbf·ft (327 N·m) for all engines.

   - 7.4 Remove the lifting chain from the engine lifting hooks.
8. Remove the chocks from the tires.

Replacement

1. Apply the parking brakes, chock the tires, and (if applicable) drain the air brake system.

WARNING

The jack used to lift the engine must be capable of safely lifting and supporting two metric tons. Once the engine mount is disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death, and component damage.

2. Disconnect the right rear engine mount from the right rear frame mount.
   - 2.1 Place a jack under the rear of the engine, and raise the jack until it's braced against the engine.
   - 2.2 Remove the bolt from the right rear engine mount. Save the fasteners and snubbers. Discard the rubber isolators.
   - 2.3 Lift the engine slightly to take its weight off the right rear engine mount. Place engine stands under the engine to keep it off the engine mount.
3. Inspect the new engine mount rubber isolators for wear or damage and replace them if necessary.

CAUTION

Do not lubricate the new components with oil, grease, or silicone lubricants; they will deteriorate the rubber isolators.

4. Install the new upper isolator in the engine mount. If applicable, place the snubber on the isolator.

WARNING

The jack used to lower the engine must be capable of safely lifting and supporting two metric tons. Once the engine is removed from the engine stands, do not get under the engine until it is securely installed on the engine mount. An unsecured engine may fall, causing personal injury or death, and component damage.

5. Disconnect the engine from the right rear engine mount.
   - 5.1 If not in place, set a jack under the rear of the engine and raise the jack until it is braced against the engine.
   - 5.2 Lift the engine slightly to remove the engine stands. Remove the stands, and carefully lower the engine onto the engine mount.
   - 5.3 Holding the lower isolator in place, install the bolt in the right rear engine mount, and secure it with the nut and hardened washer. Tighten the nut 241 lbf·ft (327 N·m).

WARNING

The jack used to lift the engine must be capable of safely lifting and supporting two metric tons. Once the engine mount is disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death, and component damage.

6. Disconnect the left rear engine mount from the left rear frame mount.
   - 6.1 Place a jack under the rear of the engine, and raise the jack until it's braced against the engine.
   - 6.2 Remove the bolt from the left rear engine mount. Save the fasteners and snubbers. Discard the rubber isolators.
   - 6.3 Lift the engine slightly to take its weight off the left rear engine mount. Place engine stands under the engine to keep it off the engine mount.
7. Inspect the new engine mount rubber isolators for wear or damage and replace them if necessary.

CAUTION

Do not lubricate the new components with oil, grease, or silicone lubricants; they will deteriorate the rubber isolators.

Rear Engine Mount Isolator Replacement

8. Install the new upper isolator in the engine mount. If applicable, place the snubber on the isolator.

WARNING

The jack used to lower the engine must be capable of safely lifting and supporting two metric tons. Once the engine is removed from the engine stands, do not get under the engine until it is securely installed on the engine mount. An unsecured engine may fall, causing personal injury or death, and component damage.

9. Secure the engine to the engine mount.
   - 9.1 If not in place, set a jack under the rear of the engine and raise the jack until it is braced against the engine.
   - 9.2 Lift the engine slightly to remove the engine stands. Remove the stands, and carefully lower the engine onto the engine mount.
   - 9.3 Holding the lower isolator in place, install the bolt in the left rear engine mount, and secure it with the nut and hardened washer. Tighten the nut 241 lbf·ft (327 N·m).
10. Remove the jack from under the engine, and remove the chocks from the tires.

Front Engine Mount Isolator Replacement

Replacement

1. Apply the parking brakes, chock the tires, and (if applicable) drain the air brake system.

WARNING

The lifting device and chain used to lift the engine must be capable of safely lifting and supporting two metric tons. Once the engine mount is disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death, and component damage.

2. Disconnect the front engine mount from the frame crossmember.
   - 2.1 Attach a chain to the front engine lifting hook(s), and position a lifting device to lift the engine. Attach the chain to the lifting device and remove any slack.
   - 2.2 Remove the bolt(s) from the front engine mount. Save the fasteners, tube(s), and snubber(s). Discard the rubber isolator cushions.

   NOTE: In order to raise the front of the engine, you may have to loosen the bolts that run through the rear engine mounts.

   - 2.3 Lift the engine slightly to take its weight off the front engine mount. Place engine stands under the engine to keep it off the engine mount.
3. Inspect the new front engine mount rubber isolators for wear or damage and replace them if necessary.

CAUTION

Do not lubricate the new components with oil, grease, or silicone lubricants; they will deteriorate the rubber isolators.

4. Install the upper isolator(s) in the engine mount.

WARNING

The lifting device and chain used to lower the engine must be capable of safely lifting and supporting two metric tons. Once the engine is removed from the engine stands, do not get under the engine until it is securely installed on the engine mount. An unsecured engine may fall, causing personal injury or death, and component damage.

5. Secure the front engine mount to the frame crossmember.
   - 5.1 Attach a chain to the front engine lifting hook(s). Attach the chain to a lifting device and.remove any slack.
   - 5.2 Lift the engine slightly to remove the engine stands. Remove the stands, and carefully lower the engine onto the engine mount.
   - 5.3 Holding the lower isolator(s) and tube(s) in place, install the bolt(s) in the front engine mount and secure it with the nut(s) and washer(s). Tighten the bolts 136 lbf·ft (184 N·m).

   NOTE: If you loosened the bolts that run through the rear engine mounts, tighten those bolts 241 lbf·ft (327 N·m).

   - 5.4 Remove the lifting chain from the engine lifting hook(s).
6. Remove the chocks from the tires.

Replacement

NOTE: The rear engine mounts for EPA07 engines are designed to last for the life of the vehicle, and should not normally need replacing. The isolators are bonded to the brackets and cannot be replaced separately.

If the rear engine mounts need replacing due to damage, or if you are removing and installing the engine, use this procedure.

In the past, substituting softer isolators from the MBE4000 engine was a way to sometimes remedy engine vibration problems with other engines. This will not work with the EPA07 engines, because all the engine isolators now have the same durometer hardness.

1. Shut down the engine, set the parking brake, and chock the tires.
2. Drain the air tanks.
3. Disconnect all the cables from the batteries. Cover them, using dry rags and tie straps.
4. Remove the battery MEGA Fuse Block from the left-side frame rail, underneath the cab. The mounting nuts are inboard of the frame rail.
5. Open the hood.
6. If present, remove the two tow hooks from the right frame rail.
7. Remove the rain tray.
   - 7.1 Mark, then remove the wiper arms.
   - 7.2 Disconnect any hoses or drains from the bottom of the rain tray.
   - 7.3 Remove the fasteners that hold the rain tray to the frontwall.
   - 7.4 Remove the rain tray from the vehicle.
8. Remove the right and left quarter fenders and the inner splash shields.
9. Remove the air intake canister assembly.
10. Remove the mounting bracket for the air intake canister.
11. Remove the turbocharger heat shield.
12. Disconnect the air lines from the primary air tank, then remove the tank from the vehicle.

DANGER

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine has been shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

13. Make sure the aftertreatment device (ATD) is cool, then remove it from the vehicle.

CAUTION

The ATD assembly weighs from 125 to 150 pounds (57 to 68 kg) and must be protected from impact or sharp jolts. Dropping the ATD, or subjecting it to jarring impact can crack the diesel particulate filter (DPF) inside, which is built on a ceramic substrate. If that happens, the DPF is ruined and must be replaced.

A secure support is necessary to remove and install the ATD safely. The ATD must be held securely to protect it from falling, or hitting hard against something else.

The horizontal ATD lifting device (TLZ00785) is designed for the job on a horizontal ATD. Vertical ATDs require a shop hoist secured to the lifting ears on top.

   - 13.1 Put a transmission jack (or equivalent) under the ATD, and strap the ATD to the jack.
   - 13.2 Disconnect the five sensors from the ATD.

WARNING

Wear adequate eye protection, such as safety goggles or a face shield, when working with the ATD mounting bands. The mounting bands are

Rear Engine Mount Replacement, EPA07 Engines

under spring tension, and can cause eye injury or other personal harm if they spring out of control.

13.3 Remove the Marmon clamps from each end of the ATD.

13.4 Disconnect the ATD from the exhaust tubing, and remove it from the vehicle. Keep the ATD strapped to the jack, and make sure it is placed away from any combustible materials.

14. Remove the cab skirts from both sides of the vehicle.
15. Disconnect and remove the exhaust tubing from the turbocharger.
16. As applicable, remove the steps, air fairings, fuel tank(s), and/or the battery box.

    For instructions on removing the fuel tank(s), refer to **Group 47**.
17. Remove the fasteners that hold the driveline midship-bearing bracket to the frame crossmember.
18. Using suitable straps, secure the driveline and the midship bearing to the frame crossmember. Make sure the driveshaft is supported loosely enough so that the slip joint aft of the midship bearing will be able to extend when the engine is raised.
19. Remove the overslung crossmember from the transmission housing.

    19.1 If present, remove the standoff bracket for the A/C refrigerant line from the top of the overslung crossmember. Leave the line attached to the bracket.

    19.2 Remove the fasteners that hold the overslung crossmember to the transmission housing, then remove it.
20. Disconnect both ends of the clutch linkage and remove it from the vehicle.
21. Remove the shifter and shifter boot from the transmission.
22. Raise the front of the vehicle so the tires are off the ground, and support it with safety stands. Put the safety stands behind the rear spring hangers for the front suspension.

WARNING

Never work around or under a vehicle that is supported only by a jack. Always support the vehicle with safety stands. Jacks can slip, allowing the vehicle to fall, which could result in serious injury or death.

23. From underneath the vehicle, install a suitable lifting bracket or stand, such as an engine shipping stand (for Detroit Diesel Series 60 engines) on the rear of the engine. See **Fig. 1**.

    If using the Detroit Diesel engine shipping stand, there should be two holes on each side of the engine block, just forward of the bell housing. These should match up with the holes in the engine shipping stand. When any stand or bracket is installed correctly, it should not be touching the floor, and should be wide enough and strong enough to support a jack to raise the engine.

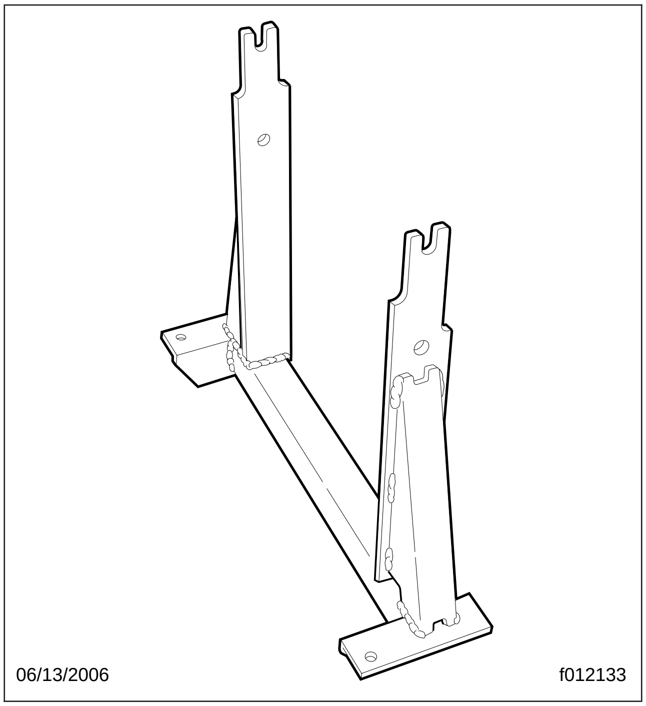
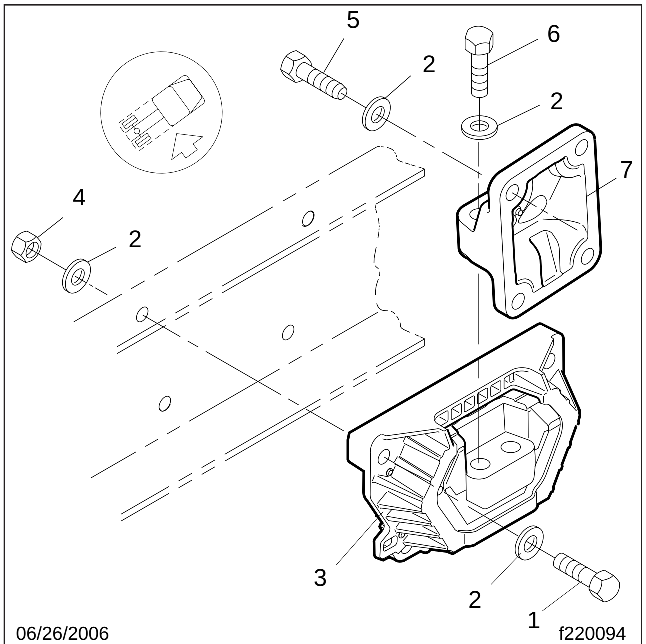


Fig. 1, Engine Shipping Stand, Detroit Diesel Series 60 Engine

24. If present, remove the starting aid bottle from the left-side frame rail.
25. On one side of the vehicle, remove the two mounting capscrews that hold the engine leg to

Rear Engine Mount Replacement, EPA07 Engines

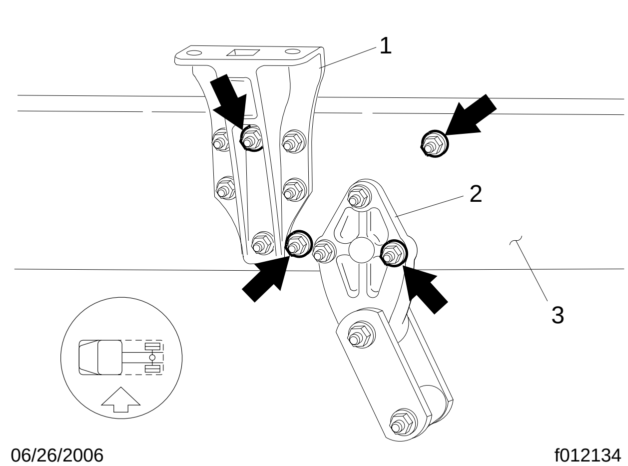
the frame-rail engine mount. See **Fig. 2**. If needed, repeat the procedure on the other side of the vehicle.



1. Hexbolt, 5/8–11
2. Hardened Washer
3. Rear Engine Mount Assembly
4. Hexnut, 5/8–11
5. Capscrew, 5/8–11
6. Capscrew, 3/4–10
7. Engine Leg

Fig. 2, Rear Engine Mount and Engine Leg

26. Place a jack under the engine shipping stand (or other suitable stand/bracket) attached to the rear of the engine, and gradually raise that side of the engine until the bottom of the engine leg is above the top of the frame rail.
27. Remove the four fasteners that hold the rear engine mount to the frame rail. See **Fig. 3**.
28. Remove the rear engine mount from the vehicle.
29. If needed, remove the four bolts that hold the engine leg to the transmission housing. Remove the engine leg.
30. If applicable, install the engine leg on the bell housing. Apply Loctite® 271 (or equivalent) to the threads of the capscrews, and tighten to 320 lbf·ft (434 N·m).



NOTE: The engine mount is not visible in this view.

1. Cab Mounting Bracket
2. Front Spring-Shackle Hanger
3. Frame Rail

Fig. 3, Engine Mount-to-Frame Rail Fasteners

31. With the engine supported, install the rear engine mount on the frame rail. Install the four 5/8–11 hexbolts with the bolt heads inboard. Tighten the hexnuts 136 lbf·ft (184 N·m).
32. If applicable, repeat the above procedure on the other side of the vehicle.
33. Lower the engine onto the rear engine mount.
34. Apply Loctite 271 to the threads of the two 3/4–10 capscrews. Install them and the hardened washers in the holes of the engine leg and the rear engine mount and tighten to 320 lbf·ft (434 N·m).
35. Remove the fasteners that hold the engine shipping stand to the side of the transmission, and remove the stand.
36. Install the clutch linkage.
37. Install the overslung crossmember.
38. Install the shifter and shifter boot on the transmission.
39. Install the standoff bracket for the A/C refrigerant line, then attach the line to the bracket.
40. If it was removed, install the starting aid bottle to the left-side frame rail.
41. Attach the driveline midship bearing and its bracket to the frame crossmember.

Rear Engine Mount Replacement, EPA07 Engines

42. Connect the exhaust tubing to the turbocharger.
43. Install the cab skirts to the bottom of the cab.
44. Install the ATD to the exhaust tubing. As previously marked, connect the wiring to the sensors on the ATD.
45. Install the primary air tank and connect the air lines to it.
46. In the engine compartment, install the turbocharger heat shield.
47. Install the mounting bracket for the air-intake canister.
48. Install the air-intake canister to the mounting bracket.
49. Install the right and left inner splash shields.
50. Install the right and left quarter fenders.
51. As applicable, install the steps, air fairings, fuel tank(s), and/or the battery box.

    For instructions on installing the fuel tank(s), refer to **Group 47**.
52. Using the previously removed fasteners, install the rain tray on the frontwall.
53. Connect the hoses and drains to the bottom of the rain tray.
54. As previously marked, install the wiper arms.
55. If they were removed, install the two tow hooks on the side of the right frame rail.
56. Close the hood.
57. Install the battery MEGA Fuse Block on the left-side frame rail, underneath the cab.
58. Connect the battery cables.
59. Remove the chocks.

Specifications

Engine Mount Torque Values, Pre-EPA07 Engines			
Description	**Grade/Class**	**Size**	**Torque: lbf·ft (N·m)**
Rear Engine-Mount to Support-Bracket:			
All Engines	8	3/4–10	241 (327)
Rear Engine-Mount to Frame Rail Bolts:			
Caterpillar Engines	8	1/2–13	45 (61)
Engine Leg-to-Flywheel Bolts:			
Caterpillar 3126 and C-7 Engines	10.9	M14 x 2 x 45	100 (136)
Caterpillar C-9 Engines	8	3/4–10 x 2	190 (258)
MBE900 Engines	10.9	M16 x 2 x 55	92 (125)
MBE4000 Engines	10.9	M16 x 1.5 x 50 (upper) M16 x 1.5 x 40 (lower)	175 (237)
Front Engine-Mount Bolt:			
Caterpillar Engines	8	5/8–11	136 (184)

Table 1, Engine Mount Torque Values, Pre-EPA07 Engines

Engine Mount Torque Values, EPA07 Engines			
Description	**Fastener Size**	**Grade/Class**	**Torque: lbf·ft (N·m)**
Engine Mount-to-Frame Rail Capscrew	5/8–11	8	120–152 (163–206)
Engine Leg-to-Flywheel Housing Bolts:			
Detroit Diesel Series 60 Engines	5/8–11 x 2-1/4	8	136 (184)
MBE4000 Engines	M16 x 1.5 x 60 (upper) M16 x 1.5 x 50 (lower)	10.9	175 (237)
Caterpillar Engines (C13 & C15)	3/4–10 x 2-3/4	8	170–210 (230–285)
Engine Leg-to-Engine Mount Capscrew	3/4–10	8	300 (407)
Front Engine Bracket-to-Front Engine Mount Capscrew	3/4–10	8	213–269 (289–365)

Table 2, Engine Mount Torque Values, EPA07 Engines

Principles of Operation

EPA 2007

The Environmental Protection Agency (EPA) mandated that all engines built after December 31, 2006 meet lower exhaust emissions levels:

- 1.1 grams per brake horsepower hour (g/bhp-hr) of nitrogen oxides (NOx)
- 0.01 g/bhp-hr of particulate matter (PM)

To meet the EPA07 requirements, most engine manufacturers developed an aftertreatment system (ATS). The ATS varies according to engine and vehicle configuration, but instead of a muffler, an ATS has an aftertreatment device (ATD) that outwardly resembles a muffler.

Inside the ATD on Cummins, Detroit Diesel, and Mercedes-Benz engines, the exhaust first passes over the diesel oxidation catalyst (DOC), which uses a chemical process to break down pollutants into less harmful components. The exhaust then passes through the diesel particulate filter (DPF), which traps soot particles. See **Fig. 1**.

The DPF core in all ATDs is comprised of ceramic channels that are blocked off at alternate ends to force the exhaust through the porous walls.

As soot accumulates in the DPF, it periodically needs to be converted to its basic parts: carbon dioxide, water, and ash. The conversion takes place through an event in the ATD referred to as regeneration (regen). If the exhaust temperature is high enough, the trapped soot is reduced to ash in a process called passive regen, which occurs as the vehicle is driven normally.

Passive regen, however, cannot always keep the DPF clean, so the ATD must also periodically undergo active regen. During active regen, extra fuel is injected into the exhaust stream to superheat and reduce the soot trapped in the DPF to ash. Active regen happens only when the vehicle is moving above a certain speed, as determined by the engine manufacturer.

Both active and passive regen happen automatically, without driver input. When operating conditions do not allow for active or passive regen, the vehicle may require a driver-activated parked regen, which takes 20 to 60 minutes, depending on ambient conditions.

Over time, ash collects in the ATS and needs to be removed through cleaning at specific intervals. For ATS maintenance and repair information, see the engine manufacturer's service literature.

EPA 2010

The Environmental Protection Agency (EPA) mandated that all engines built after December 31, 2009 must reduce the level of emissions exhausted by the engine to 0.2 grams per brake horsepower hour (g/bhp-hr) of nitrogen oxides (NOx).

To meet the EPA10 requirements, Daimler Trucks North America is using technology known as Selective Catalytic Reduction (SCR) in the exhaust aftertreatment system (ATS). The ATS will rely on existing EPA07 technology, which includes an aftertreatment device (ATD), with the addition of SCR. See **Fig. 2**. The SCR process requires the introduction of diesel exhaust fluid (DEF) into the exhaust stream.

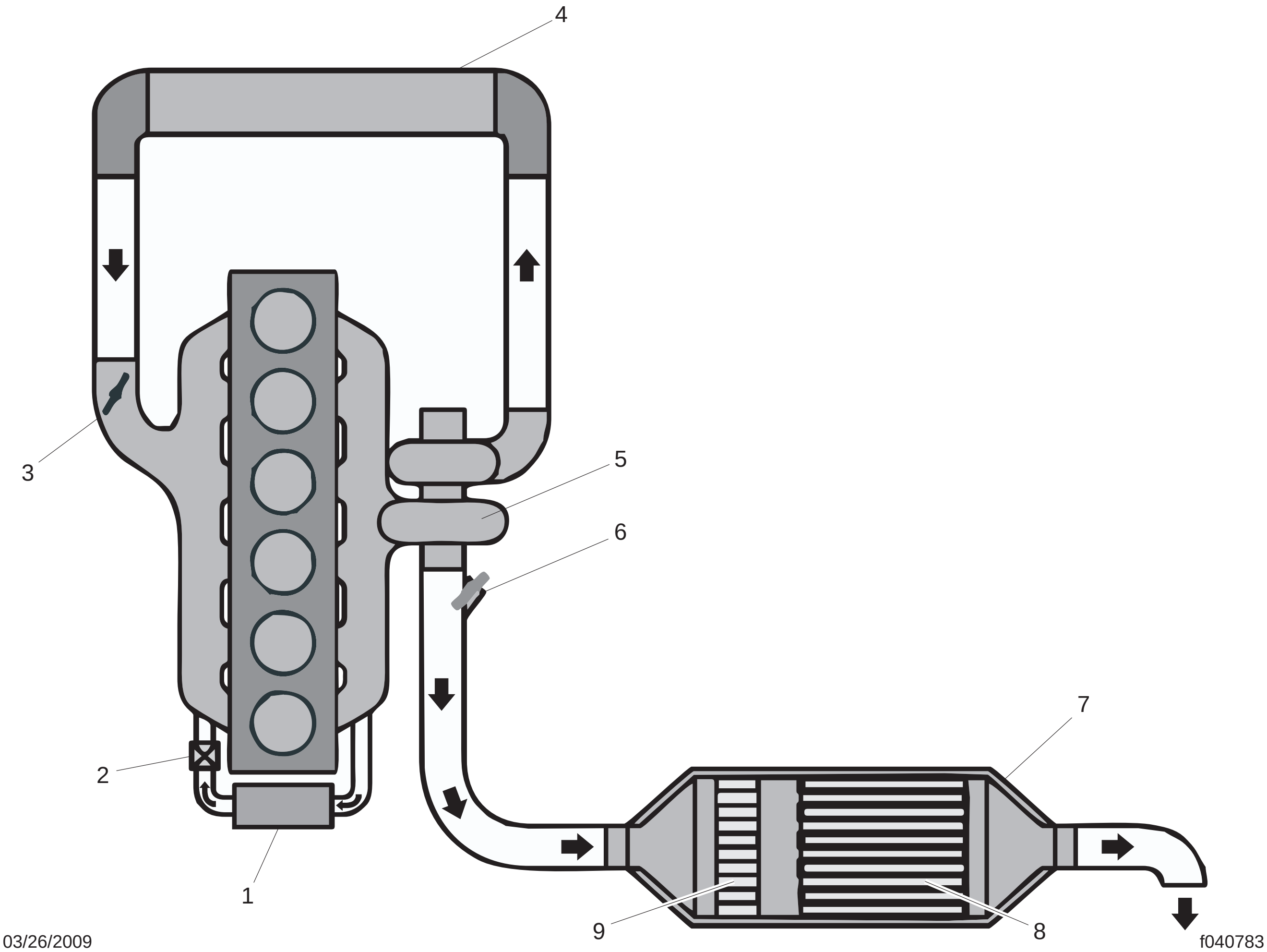
The ATS is always chassis-mounted, with several different installation options available to fit various vehicle configurations. ATS exhaust piping is made of stainless steel. The ATS includes all piping and equipment between the turbocharger outlet and the end of the exhaust pipe, including the aftertreatment device (ATD), SCR catalyst, DEF tank, DEF tank header unit, DEF pump, DEF metering unit, and the DEF, coolant, and air lines that run between each component.

All EPA10-compliant DTNA vehicles require the use of ultra-low sulfur diesel (ULSD) fuel with a sulfur content of 15 parts per million (ppm) for low emissions and long life of the diesel particulate filter (DPF) in the ATD. In addition, DTNA vehicles require the use of CJ-4 engine oils with less than 1% ash.

Inside the ATD, the exhaust first passes over the diesel oxidation catalyst (DOC), where combustion gases are chemically broken down into water and carbon dioxide. The exhaust then passes through the DPF, a honeycomb-like filter that traps solid soot particles. The soot particles trapped in the DPF are reduced to ash during regeneration (regen).

If the exhaust temperature is high enough, a process called passive regen occurs as the vehicle is driven normally. Passive regen, however, cannot always keep the DPF clean, so the ATD must also periodically undergo active regen. During active regen, extra fuel is injected into the exhaust stream to superheat and reduce the soot trapped in the DPF to

General Information



1. Exhaust Gas Recirculation (EGR) Cooler
2. EGR Valve
3. Intake Throttle Valve
4. Charge Air Cooler (CAC)
5. Turbocharger
6. Hydrocarbon Doser
7. Aftertreatment Device (ATD)
8. Diesel Particulate Filter (DPF)
9. Diesel Oxidation Catalyst (DOC)

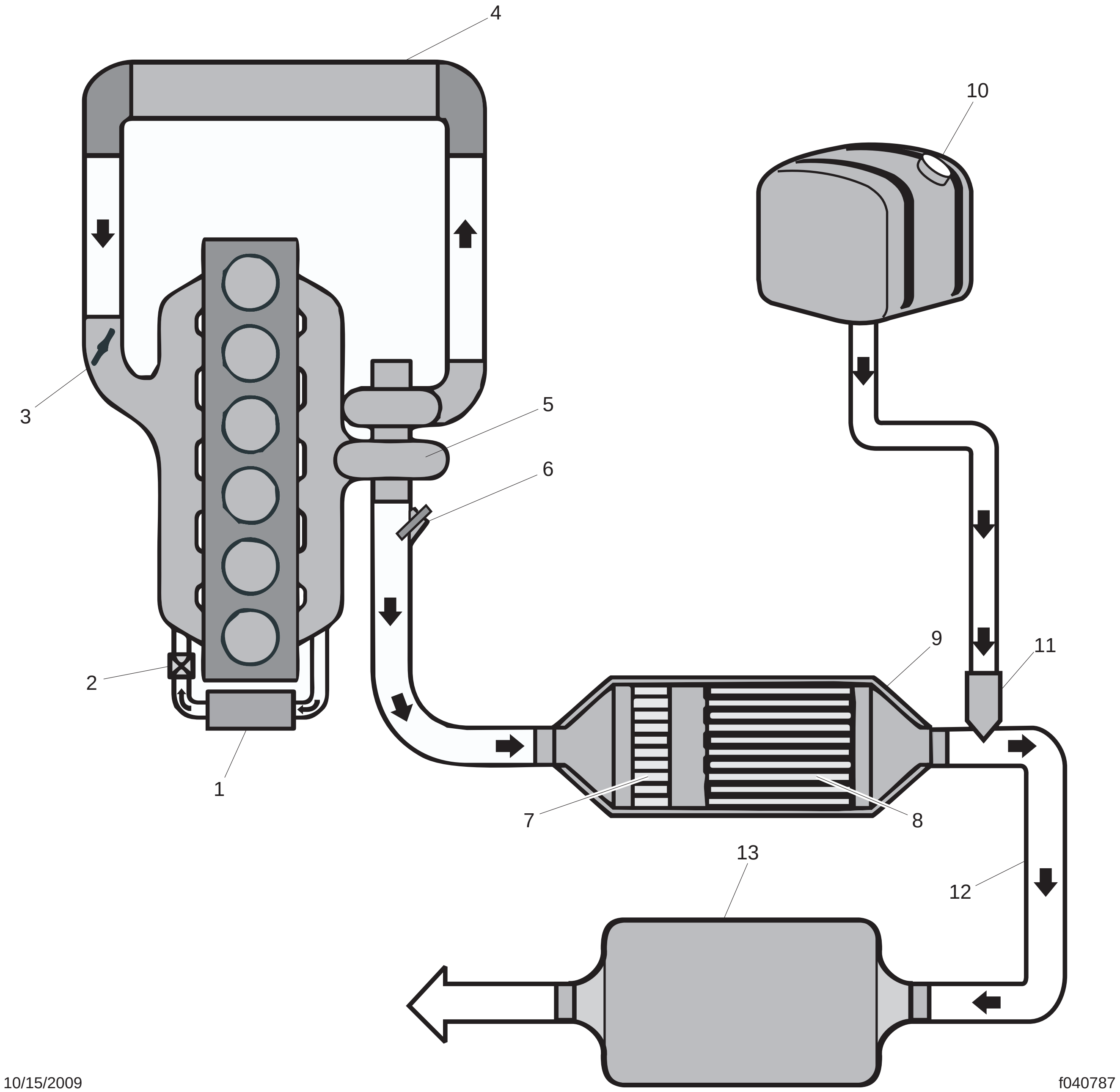
Fig. 1, EPA07 ATS (Detroit Diesel engine shown)

ash. Active regen happens only when the vehicle is moving above a certain speed, as determined by the engine manufacturer.

Both active and passive regen happen automatically, without driver input. When operating conditions do not allow for active or passive regen, the vehicle may require a driver-activated parked regen, which takes 20 to 60 minutes, depending on ambient conditions.

Despite the regen process, ash collects in the DPF over time and needs to be removed through cleaning at specific intervals. For DPF maintenance intervals and repair information, see the engine manufacturer's service literature.

After exhaust gases leave the ATD, a controlled quantity of diesel exhaust fluid (DEF) is injected into the exhaust stream. In the presence of heat, DEF is converted to ammonia gas, which reacts with NOx in the selective catalyst chamber to yield nitrogen and water vapor, which exit through the tailpipe.



1. Exhaust Gas Recirculation (EGR) Cooler
2. EGR Valve
3. Intake Throttle Valve
4. Charge Air Cooler (CAC)
5. Turbocharger
6. Hydrocarbon Doser
7. Diesel Oxidation Catalyst (DOC)
8. Diesel Particulate Filter (DPF)
9. Aftertreatment Device (ATD)
10. DEF Tank
11. DEF Injector
12. Mixing Tube
13. SCR Catalyst Chamber

Fig. 2, EPA10 ATS (Detroit Diesel engine shown)

General Information

EPA10-compliant DTNA vehicles are equipped with an additional tank to carry the DEF necessary for the SCR process. DEF is colorless, non-toxic, and biodegradable. DEF consumption will vary depending on ambient conditions and vehicle application.

Service Literature Coverage

Engine service procedures in this manual are limited to components installed by Daimler Trucks North America. See the following sections for information on EPA07/10-compliant parts and systems installed by Daimler Trucks North America:

- **Section 01.01**, Engine Mounts
- **Section 30.00**, Electronic Throttle Control
- **Section 49.01**, Aftertreatment System, EPA07
- **Section 49.02**, Aftertreatment System, EPA10
- **Section 49.03**, Diesel Exhaust Fluid System, EPA10
- **Section 83.00**, Cab Heater and Air Conditioner, Valeo
- **Section 88.00**, Hood

Complete engine coverage including engine adjustment, preventive maintenance, and engine repair are covered in each engine manufacturer's service literature:

- Cummins: **www.cummins.com**
- Detroit Diesel: **www.detroitdiesel.com**
- Mercedes-Benz: **www.detroitdiesel.com**

Periodic inspection of the ATS is required. For instructions, see the *Business Class M2 Maintenance Manual*.

For driver pre- and post-trip inspection information, see the *Business Class M2 Driver's Manual*.

Definition of Terms

Refer to the following terms for a better understanding of EPA07/10 engines.

Ash Unburnable solids that remain after regeneration in the ATD.

Aftertreatment Device (ATD) A device that removes pollutants from exhaust gas after the gas leaves the combustion chamber.

Aftertreatment System (ATS) The entire exhaust system from the turbocharger to the exhaust stack or tail pipe.

Diesel Exhaust Fluid (DEF) A colorless, non-toxic, and biodegradable fluid used in the SCR process.

Diesel Oxidation Catalyst (DOC) A flow-through device that enhances the oxidation of hydrocarbons in the ATD on Cummins, Detroit Diesel, and Mercedes-Benz engines.

Diesel Particulate Filter (DPF) A component in the ATD that captures particulate matter from the exhaust gas, preventing discharge from the tailpipe.

Exhaust Gas Recirculation (EGR) A process whereby exhaust is recirculated into the air intake system, creating lower cylinder temperatures.

Nitrogen Oxides (NOx) Air pollutants composed of nitrogen and oxygen in various forms that contribute to the formation of smog.

Particulate Matter (PM) Soot particles formed by incomplete combustion of fuel that contribute to atmospheric pollution.

Regeneration (Regen) A process that occurs inside the ATD whereby accumulated soot is superheated and burned to ash, carbon dioxide, and water.

Selective Catalytic Reduction (SCR) A vehicle emissions control technology to reduce diesel engine emissions for passenger cars, and light and heavy-duty trucks.

ULSD (Ultra-Low Sulfur Diesel) Fuel A clean burning diesel fuel containing a maximum of 15-ppm sulfur. To meet EPA requirements, all highway diesel fuel sold in the U.S. must be ULSD.

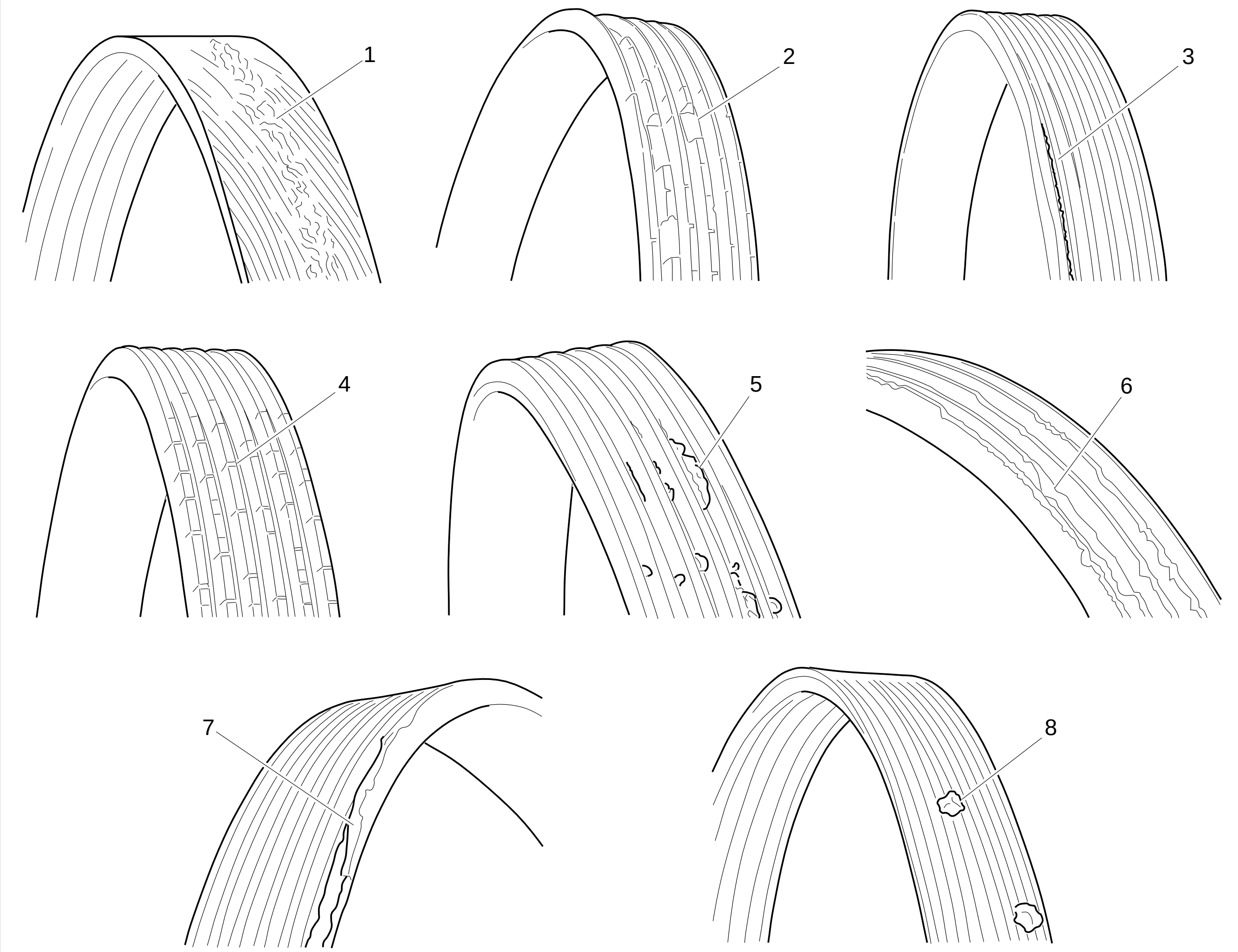
Drive Belt Inspection

NOTE: For diagnostic procedures and engine component replacement, refer to the engine manufacturer’s service literature. See **Detroit Diesel** **www.detroitdiesel.com** or **Cummins Engine** **www.cummins.com**.

Inspection

1. Inspect the belt contact surfaces for chips, flaking, cracks, discoloration, and other damage. See **Fig. 1**.
2. Inspect the bearings in the idler pulleys, and accessories, by rotating the pulleys to look for bearing slop, or choppy feeling bearings.
3. Inspect the springs on the belt tensioner. If the springs are damaged, change the belt tensioner following the engine manufacturer’s instructions.
4. Inspect the pulleys for damage. If the pulleys are damaged, change both the damaged pulley and the belt following the engine manufacturer’s instructions. See **Fig. 2**.
5. Check the belt allignment on all idler pulleys. If the alignment is incorrect as shown in **Fig. 3**, and pulley wear is visible, replace the pulley and bracket following the engine manufacturer’s instructions.

Drive Belt Inspection



1. Abrasion
2. Chunk-out
3. Improper Install
4. Cracking
5. Pilling
6. Uneven Rib Wear
7. Misalignment
8. Gravel Penetration

Fig. 1, Damaged Belts

Drive Belt Inspection

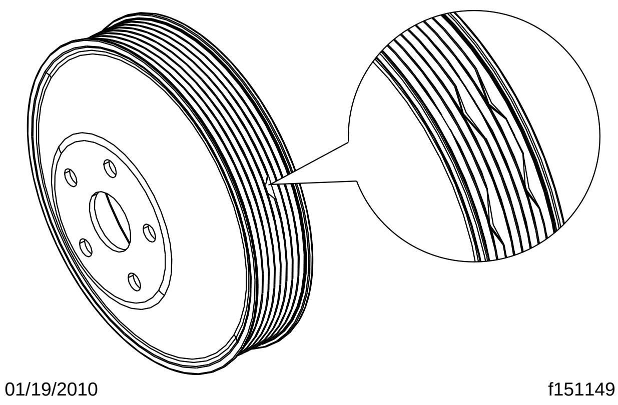
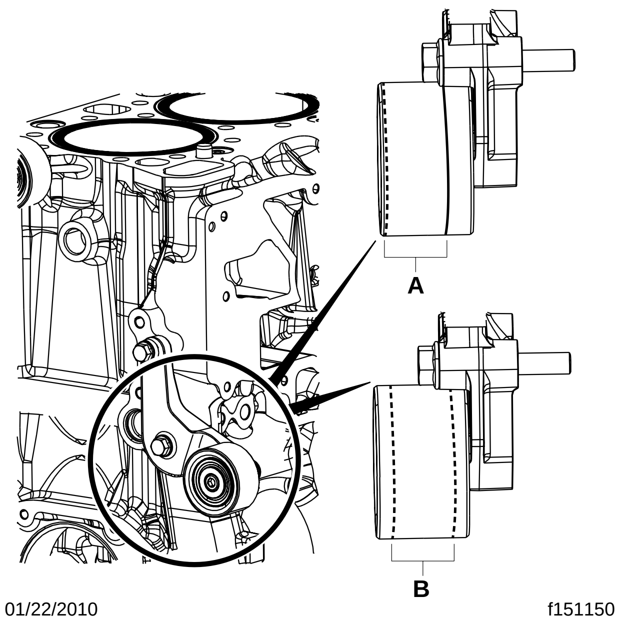


Fig. 2, Damaged Pulley



A. Incorrect Belt-Alignment Area
B. Correct Belt-Alignment Area

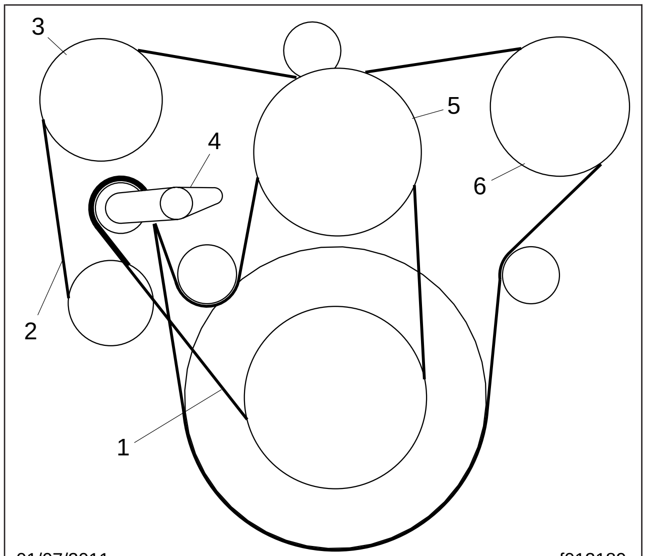
Fig. 3, Idler-Pulley Belt Alignment

Drive Belt Replacement, Detroit Diesel Engines

Detroit Diesel engines are equipped with two serpentine poly-V drive belts. The rear belt (closest to the engine block surface) drives the alternator, the A/C compressor, and the water pump. The front belt drives the engine fan. See **Fig. 1**. Both drive belts are kept at the correct tension with pulleys and a dual automatic belt-tensioner assembly.

NOTICE

When replacing the drive belts for the DD engine, it is crucial to follow the correct procedure for releasing and locking the belt tensioners. The belt tensioners must be released and locked separately, and in the correct sequence, or the assembly may be damaged.

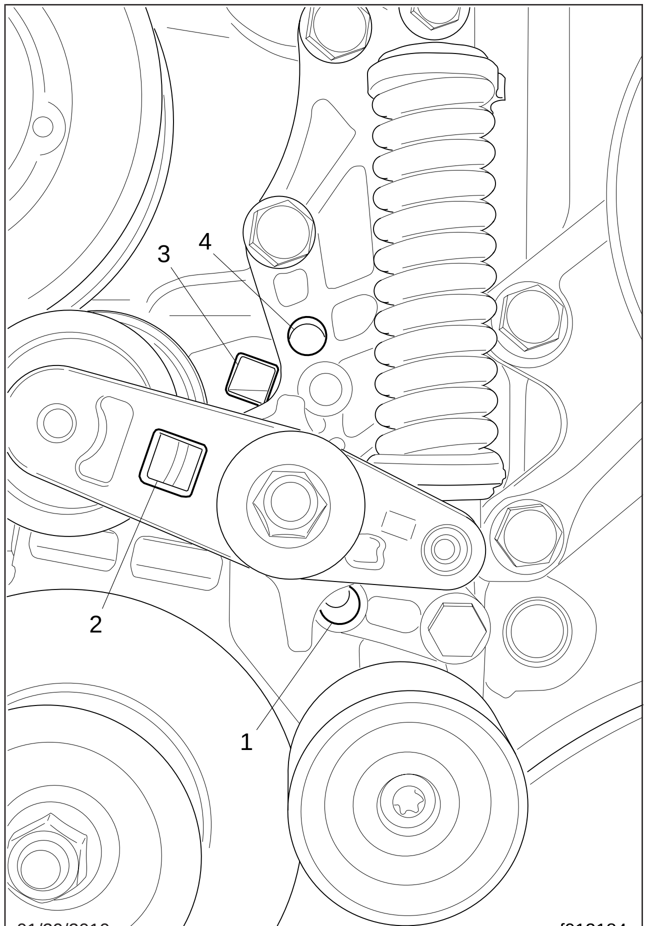


1. Front Drive Belt
2. Rear Drive Belt
3. AC Compressor
4. Spring Loaded Tensioner
5. Fan Clutch
6. Water Pump

Fig. 1, DD13/15/16 Drive Belt Routing

Replacement

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Disconnect the batteries at the negative terminals.
3. Raise the hood.
4. Locate the automatic belt tensioner assembly, on the left (passenger) side of the engine, as you are facing it. Note the location of the square 1/2-inch drive holes, and the round holes for the locking bolts. See **Fig. 2**.



1. Front Round Hole for 10-mm Locking Bolt
2. Front Square1/2-inch Drive Hole
3. Rear Square 1/2-inch Drive Hole
4. Rear Round Hole for 10-mm Locking Bolt

Fig. 2, Belt Tensioners

NOTICE

To prevent damage to the belt tensioners, always rotate them counterclockwise. Never rotate the automatic belt tensioners clockwise, to do so may damage them, and require replacement of

Drive Belt Replacement, Detroit Diesel Engines

the entire assembly. Never use more force than 66 to 73 lbf (90 to 100 N).

IMPORTANT: Always release the front tensioner and belt (fan drive) first, then the rear tensioner and belt (alternator, A/C compressor, and water pump). When removing the locking bolts reverse the procedure by unlocking the rear belt tensioner first, then the front one.

5. Insert a 1/2-inch breaker bar, or 1/2-inch ratchet into the square hole in the idler arm of the front belt tensioner (grooved pulley), then smoothly rotate it downward (counterclockwise) until you feel resistance. See **Fig. 3**.

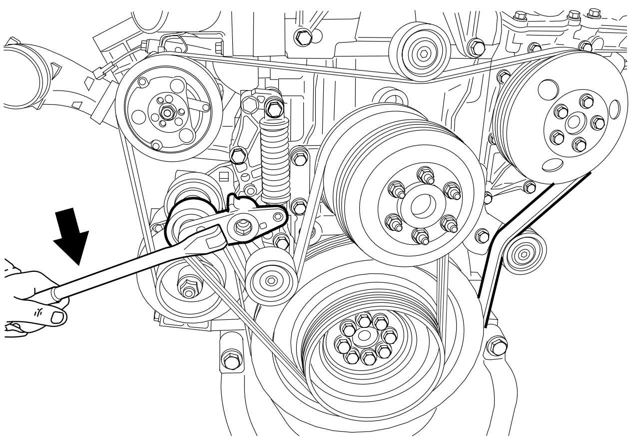


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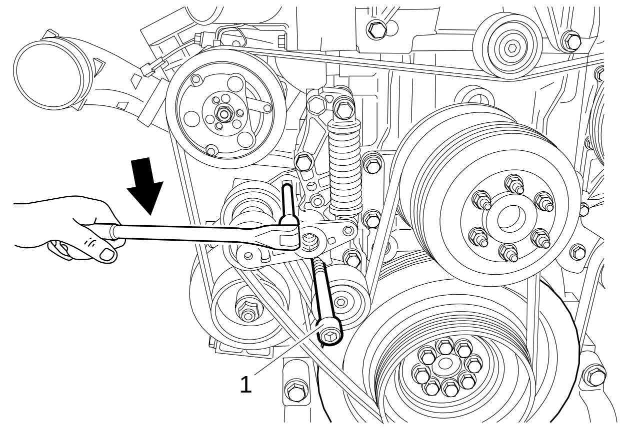
Fig. 3, Releasing the Front Tensioner

6. Insert a 10-mm diameter x 80 mm long bolt into the round hole on the idler arm of the tensioner as shown in **Fig. 4**, then push it all the way in to lock the tensioner in the released position. Remove the socket wrench from the square hole.
7. Insert a 1/2-inch breaker bar, or 1/2-inch ratchet, into the square hole in the idler arm of the rear belt tensioner (smooth pulley), then smoothly rotate it downward (counterclockwise) until you feel resistance. See **Fig. 4**.
8. Insert a second 10-mm diameter x 80 mm long bolt into the round hole on the idler arm of the rear tensioner as shown in **Fig. 5**, then push it all the way in to lock the tensioner in the released position. Remove the wrench from the square hole.



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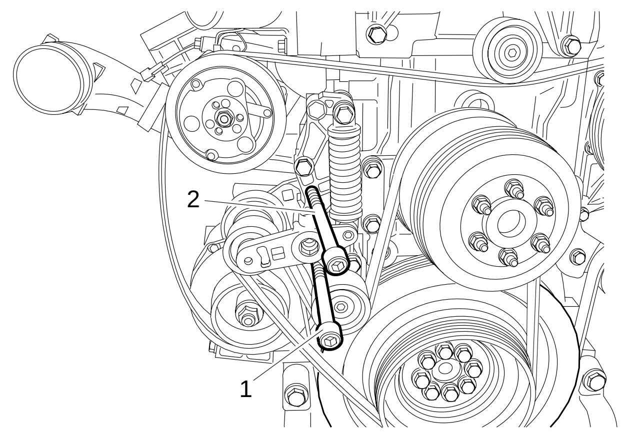
Note: For clarity, the locking bolt is shown in position but not pushed all the way in.

1. Front Belt Tensioner Locking Bolt Position

Fig. 4, Releasing the Rear Tensioner (smooth pulley)



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Note: For clarity, the locking bolts are shown in position but not pushed all the way in.

1. Locking Bolt for Front Belt Tensioner
2. Locking Bolt for Rear Belt Tensioner

Fig. 5, Belt Tensioner Locking Bolts in Position

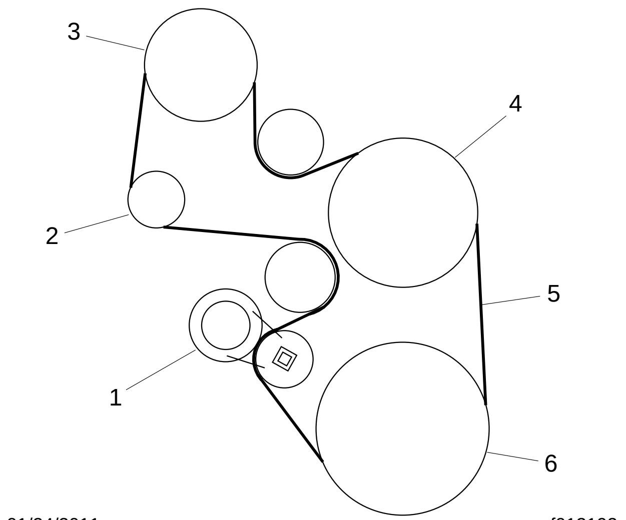
9. Replace the drive belts, making sure the new belts are correctly installed on all the pulleys.
10. Using the 1/2-inch breaker bar, or 1/2-inch ratchet, rotate the idler arm on the rear (smooth pulley) tensioner downward (counterclockwise), until you can remove the locking bolt. Smoothly release the idler arm all the way up, being careful not to jerk it.

Drive Belt Replacement, Detroit Diesel Engines

11. In the same manner as the previous step, remove the locking bolt from the front tensioner.
12. Do a final check to make sure both drive belts are configured correctly, and correctly installed on all the pulleys.
13. Close the hood, connect the batteries, then remove the chocks.

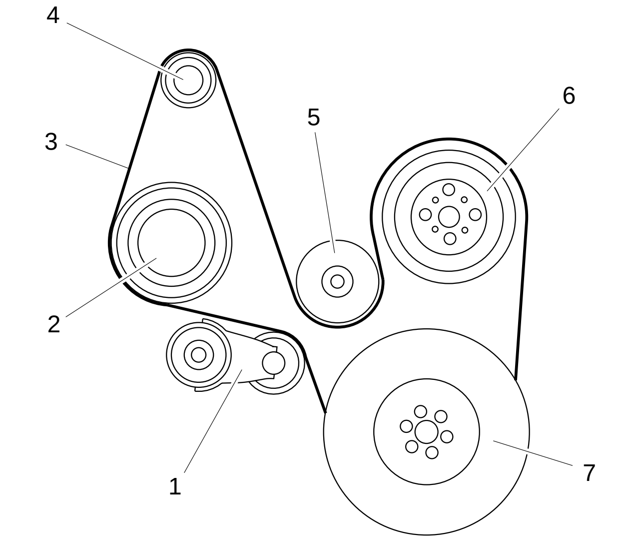
Drive Belt Replacement, Cummins Engines

Cummins ISC/ISL and ISB engines are equipped with one poly-V drive belt. The drive belt is kept at the correct tension by a system of pulleys and an automatic belt tensioner. See **Fig. 1** and **Fig. 2**.



1. Spring Loaded Tensioner
2. Alternator Pulley
3. AC Compressor
4. Fan Clutch
5. Drive Belt
6. Crank Shaft Pulley

Fig. 1, Cummins ISC/ISL Drive Belt Routing



1. Spring Loaded Tensioner
2. AC Compressor
3. Drive Belt
4. Alternator Pulley
5. Water Pump
6. Fan Clutch
7. Crank Shaft Pulley

Fig. 2, Cummins ISB Drive Belt Routing

Replacement

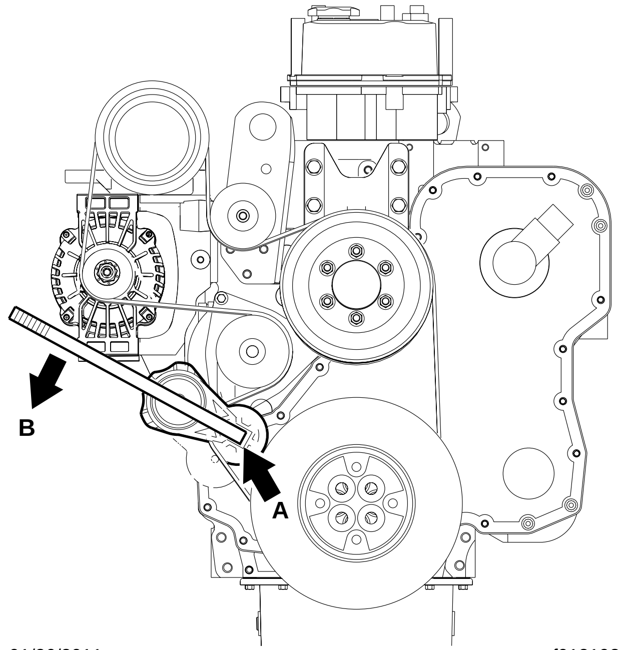
1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Disconnect the batteries at the negative terminals.
3. Raise the hood.
4. Locate the drive-belt-tensioner assembly on the left (passenger) side of the engine, as you are facing it. Insert a 1/2-inch-drive ratchet or 1/2-inch breaker bar into the pivot point on the small end of the tensioner. See **Fig. 3**. Push downward on the breaker bar, rotating the tensioner counter-clockwise until you feel resistance.
5. Holding the tensioner released, remove the drive belt.
6. Install a new drive belt, ensuring it is routed correctly, and centered on all the pulleys.
7. Smoothly release the pressure from the breaker bar.

NOTICE

Never allow the tensioner to slam back against the stop, or damage may occur.

8. Start the engine, standing clear of the belt and accessories. Check the belt tracking on all pulleys to ensure correct belt operation.
9. Close the hood and connect the batteries.

Drive Belt Replacement, Cummins Engines



A. Pivot Point for Belt Tensioner
B. Push Downward

Fig. 3, Releasing the Tensioner

Removal

NOTE: This procedure involves removing and installing the engine and the transmission as a single unit.

1. Apply the parking brakes, chock the tires, and drain the air system.
2. Disconnect the batteries.
   - 2.1 Disconnect the battery ground cable from the frame rail.
   - 2.2 Disconnect the positive battery cable from the batteries.
3. Drain the air tanks.
4. Remove the hood and bumper. For instructions, refer to **Group 88** and **Group 31** of this workshop manual.
5. Remove the air-intake filter housing.

WARNING

Drain the coolant only when the coolant and engine are cool. Draining it when these are hot could cause severe personal injury due to scalding.

6. Drain the radiator.
   - 6.1 Place a suitable container under the left side of the radiator.
   - 6.2 Remove the surge tank cap.
   - 6.3 Loosen the draincock at the bottom of the radiator.

     After the coolant has drained, tighten the draincock firmly.
7. If so equipped, disconnect the transmission oil cooler from the bottom of the radiator.

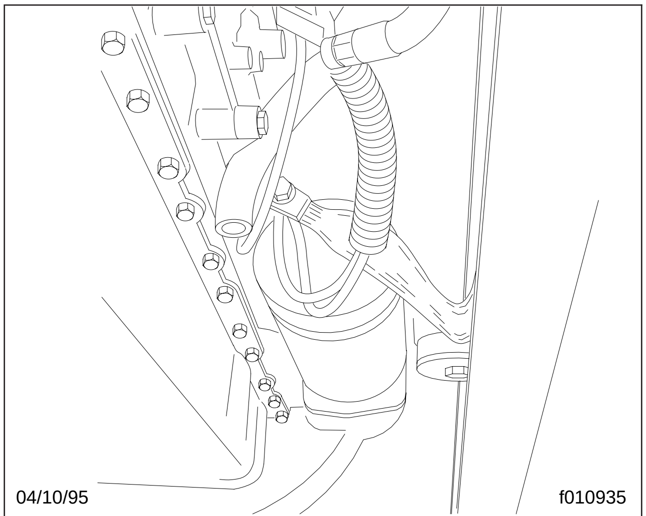
   If the transmission oil cooler is separate from the radiator: place a suitable container under it, then disconnect the hoses. Cover the hoses to keep out dirt. Remove the fasteners holding the transmission oil cooler to the bottom of the radiator. Remove the transmission oil cooler.

   If the transmission oil cooler is integral with the radiator: place a suitable container under the hose connections at the bottom of the radiator. Disconnect the hoses, drain them, then cover the hose ends to keep out dirt.
8. Mark, disconnect and remove the charge air cooler hoses.
9. If so equipped, remove the air conditioning condenser from the front of the radiator.
   - 9.1 Remove the fasteners holding the condenser to the front of the radiator.
   - 9.2 Keeping the refrigerant lines connected, move the condenser aside.
   - 9.3 Using cardboard or other suitable material, wrap the condenser to protect it from damage.
   - 9.4 Using tie straps, secure the condenser to a suitable bracket.
10. Remove the radiator.
    - 10.1 Disconnect the upper and lower radiator hoses at both ends.
    - 10.2 Mark and disconnect the hoses between the radiator and the top of the surge tank.
    - 10.3 Mark and disconnect the hose leading from the bottom of the surge tank to the engine block.
    - 10.4 Disconnect the left and right radiator struts from the radiator side channels
    - 10.5 Remove the fasteners holding the fan shroud to the radiator, and move the shroud back against the engine.
    - 10.6 Remove the lower radiator mounting nuts.
    - 10.7 Attach a lifting chain to the top of the radiator, and using a suitable lifting device, remove the radiator and charge air cooler from the vehicle.
    - 10.8 Remove the fan shroud.
11. Disconnect and remove the left-side radiator struts from the front wall.
12. Disconnect and remove the right-side radiator strut from the air filter housing bracket.
13. Disconnect the hose between the air filter housing and the engine, then remove the air filter housing from its bracket.

Engine Removal and Installation

14. Using a suitable breaker bar in the belt tensioner, rotate the tensioner counterclockwise. Remove the serpentine drive belt from the engine.
15. Mark and disconnect the wiring from the refrigerant compressor.
16. Free the refrigerant lines from all routing clamps and stand-off brackets as needed. Leaving the refrigerant lines connected, remove the refrigerant compressor from its bracket, and move it aside. Secure the compressor with tie straps.
17. Disconnect the heater hoses.
    - 17.1 Disconnect the heater return hose from the water pump inlet tube, and move the hose aside.
    - 17.2 Disconnect the heater supply hose from the rear of the engine block and move the hose aside.
18. Mark and disconnect the wiring from the alternator. Remove the alternator from the engine.
19. If so equipped, mark and disconnect the wiring from the block heater.
20. Remove the V-clamp holding the exhaust pipe to the turbocharger.
21. Mark and disconnect the air lines from the air compressor.
22. If so equipped, disconnect the air line from the fan clutch.
23. Leaving the hoses connected, remove the power steering pump from the engine. Using tie straps, secure it to a suitable place on the frame rail.
24. Mark and disconnect the wiring from the starter. See **Fig. 1**. Remove the starter from the engine.
25. Mark and disconnect all the wiring from the engine and the ECM.
26. At the fuel/water separator, disconnect the fuel delivery line that runs to the engine, then disconnect the fuel return line from the engine.
27. If equipped with an automatic transmission, mark and disconnect the wiring harness from the transmission.

    If equipped with a standard transmission, remove the shift tower. For instructions, refer to **Group 26** of this manual.



NOTE: Not all the wiring is shown.

Fig. 1, Starter Wiring Connections

28. If so equipped, disconnect the forward end of the clutch rod and tie-strap the rod to the engine.
29. Remove the forward midship bearing from the frame rail. See **Group 41** for instructions.
30. Disconnect the driveline from the transmission U-joint. See **Group 41** for instructions.
31. From under the cab, disconnect the exhaust pipe from the saddle clamp mounted on the transmission housing.

WARNING

The crane and lifting chains used to remove the engine must be capable of safely lifting and supporting 2 metric tons. Once the engine mounts are disconnected, do not crawl under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing severe personal injury or death, and component damage.

32. Remove the engine and transmission from the vehicle.
    - 32.1 Attach the chain to the lifting eyes at the front and the rear of the engine. See **Fig. 2**.
    - 32.2 Using a suitable jack, support the transmission. If they are present, remove the transmission mounting fasteners.

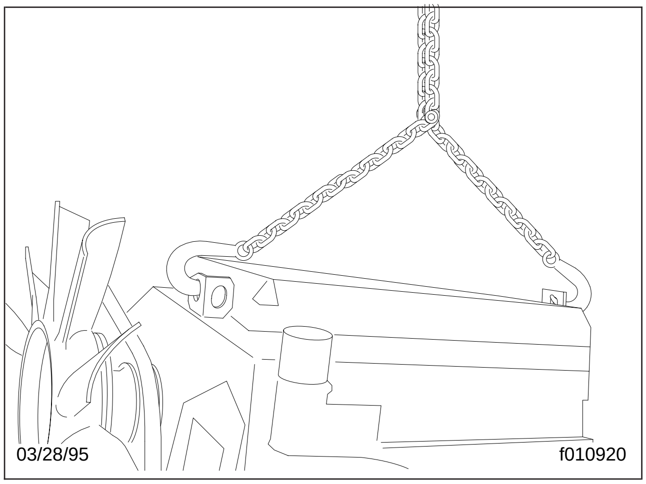


Fig. 2, Lifting Chain Installed

32.3 With the engine lifting eyes connected by chain to the crane, raise the crane enough to tighten the chains, but not enough to lift the front of the vehicle.

32.4 With the engine securely supported by the crane and lifting chains, disconnect the rear engine legs from the engine mounts on the frame rails.

On each engine leg, remove the nut from the bolt that runs down through the engine leg, rubber isolators, and engine mount. Save the fasteners and isolators.

32.5 Remove the nuts from the bolts that fasten the front engine support bracket to the underslung crossmember. See **Fig. 3**.

32.6 Using the crane and a transmission jack, lift the engine and pull it forward.

32.7 Once the engine and transmission are clear of the vehicle, place the engine on an engine stand.

33. Remove the transmission from the engine. See **Group 26** for instructions.

Installation

1. Install the transmission onto the engine. See **Group 26** for instructions.

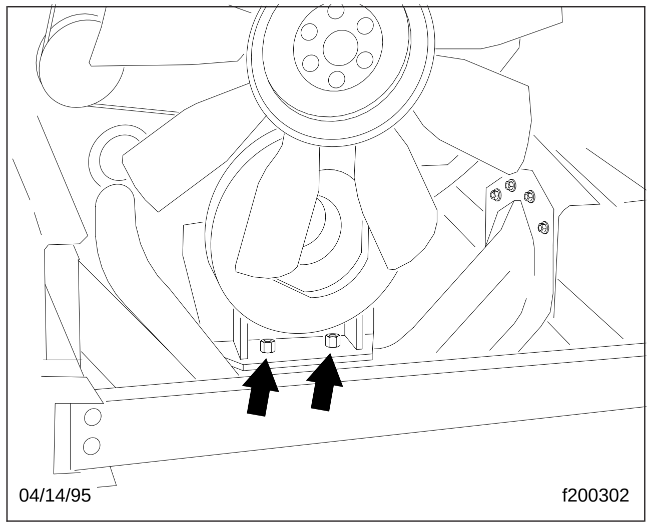


Fig. 3, Front Engine Mount Fasteners

WARNING

The crane and lifting chains used to install the engine must be capable of safely lifting and supporting 2 metric tons. Once the engine is removed from the engine stands, do not get under the engine until it is securely supported on the engine mounts. An unsecured engine may fall, causing personal injury or death, and component damage.

2. Install the engine and the transmission in the vehicle.

2.1 Attach the chain to the existing lifting eyes at the front and the rear of the engine.

2.2 With the two engine lifting eyes connected by chain to the crane, and supporting the transmission with a jack, lift the engine and transmission and position them in the vehicle.

2.3 Connect the engine to the rear engine mounts, and tighten each bolt that runs down through the engine leg, rubber isolators, and engine mount 241 lbf·ft (327 N·m).

2.4 Place the lower isolators under the underslung crossmember and the front engine support bracket, and secure the front en-

Engine Removal and Installation

gine mount with nuts and washers. Tighten the nuts 136 lbf·ft (184 N·m).

2.5 Once the engine and transmission are securely installed in the vehicle, remove the lifting chains.

3. If applicable, install the transmission mounting fasteners. Tighten 136 lbf·ft (184 N·m).
4. If equipped with an automatic transmission, connect the wiring harness to it.

   If equipped with a standard transmission, install the shift tower. For instructions, see **Group 26**.
5. Connect the driveline.

   5.1 Connect the driveline to the transmission. For instructions, refer to **Group 41**.

   5.2 Connect the driveline midship bearing bracket. For instructions, refer to **Group 41**.
6. If so equipped, connect the forward end of the clutch rod, and remove any tie straps that hold the rod to the engine.
7. Install the exhaust pipe.

   7.1 Under the engine, connect the exhaust pipe to the saddle clamp mounted on the transmission.

   7.2 Install the forward end of the exhaust pipe to the rear of the turbocharger. Tighten the V-band clamp 85 lbf·in (940 N·cm).
8. If so equipped, connect the air line to the fan clutch.
9. Connect the fuel delivery line.
10. Install the power steering pump onto the engine.
11. As previously marked, connect all the engine and ECM wiring.
12. Connect the heater hoses.

    12.1 Connect the heater return hose to the water pump

    12.2 Connect the heater supply hose to the rear of the engine block.
13. Install the refrigerant compressor onto the engine. For instructions, refer to **Group 83**.
14. Install the serpentine drive belt onto the engine.
15. Install the radiator.

    15.1 Set the radiator shroud back against the engine.

    15.2 Attach a lifting chain to the top of the radiator, then attach the chain to a lifting crane.

    15.3 Lift the radiator/charge air cooler assembly, and position it on the radiator mounts.

    15.4 Install the radiator/charge air cooler onto the frame crossmember mounts. For instructions, refer to **Group 20**.

    15.5 Install the fan shroud onto the radiator.

    15.6 Connect the upper and lower radiator hoses.

    15.7 As previously marked, connect the two hoses to the top of the surge tank.

    15.8 Connect the hose at the bottom of the surge tank to the engine block.

    15.9 Install the condenser onto the front of the radiator and charge air cooler.

    15.10 Install the two left-side and one right-side radiator struts.
16. Route the refrigerant lines between the compressor and the condenser, and secure the lines with clamps and stand-off brackets.
17. Install the air-intake filter housing onto its bracket. For instructions, see **Group 09**.
18. If not already done, connect the hose between the air-intake filter housing and the engine.
19. Install the charge air cooler hoses.
20. If so equipped, install the transmission oil cooler.

    If the transmission oil cooler is separate from the radiator: install the fasteners holding the transmission oil cooler to the bottom of the radiator. Connect the hoses.

    If the transmission oil cooler is integral with the radiator: connect the hoses to the bottom of the radiator.
21. Fill the radiator with coolant. Use a 50/50 antifreeze-water mixture.

Engine Removal and Installation

22. If equipped with a transmission oil cooler, check the fluid level in the transmission and add automatic transmission fluid as needed. Refer to Group 26 of the *Business Class M2 Maintenance Manual* for approved automatic transmission fluids.
23. Install the hood and bumper. For instructions, refer to **Group 88** of this manual.
24. Connect the batteries.
25. Remove the chocks from the tires.
26. Start the engine, and check for leaks. Repair any leaks found.
27. Test drive the vehicle.

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Open the hood.

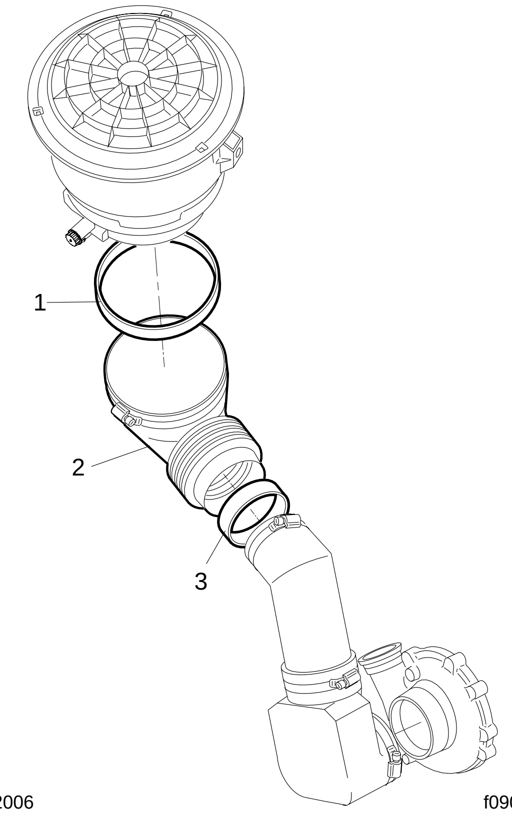
WARNING

Do not operate the engine with any component of the air intake system removed. Serious physical injury can occur if the turbocharger impeller is touched when it is rotating.

NOTICE

All air intake components and connections must be air- and water-tight. Dirt or dust entering the engine can cause internal engine damage. Most of the dirt and dust particles are silicates, which fuse into abrasive glass-like particles when exposed to engine combustion. These particles can grind piston rings, pistons, and cylinder liners.

3. Remove the hose clamps that attach the air intake duct assembly to the air cleaner and the turbocharger. If the duct assembly consists of more than one piece, remove the clamps that secure the elbows. See **Fig. 1** and **Fig. 2**.
4. Remove the air intake duct assembly.
5. Determine which new air intake duct assembly to install. Use PartsPro® to determine specific part numbers.
   - Vehicles built before November 26, 2003 with MBE900 or C7 engines require the installation of smaller clamps and rubber seals on the plastic duct connections.
   - Vehicles built between November 26, 2003 and November 1, 2004 with MBE900 or C7 engines require the installation of rubber seals only.
   - Vehicles built after November 1, 2004 have the correct clamps and seals already installed.
6. Inspect the new air intake duct assembly for debris that may have collected during shipping. Remove any debris or dirt before installation.
7. Install the new air intake duct assembly between the air cleaner and turbocharger.



1. Air Cleaner-to-Elbow Seal
2. Elbow
3. Elbow-to-Duct Seal

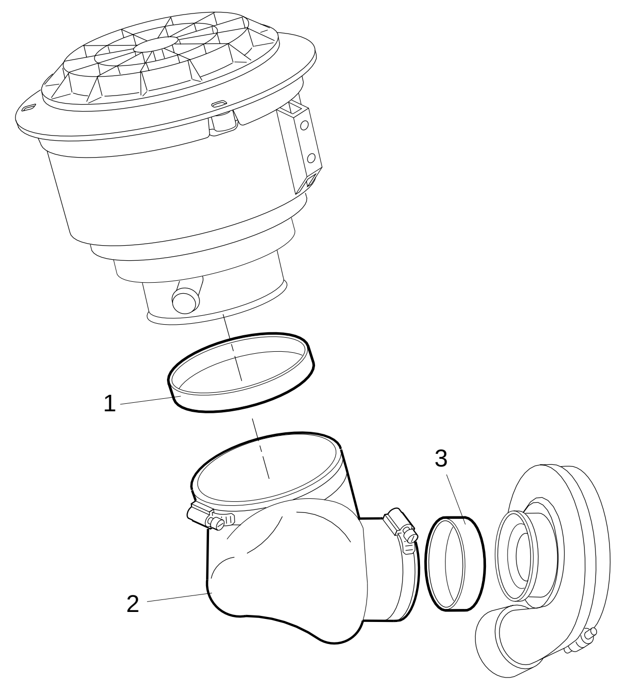
Fig. 1, Typical Elbow-to-Duct Configuration (MBE906 engine shown)

7.1 Apply P-80® Rubber Lubricant Emulsion to the overlapping areas of all seals, elbows, and tubes, and the air cleaner housing outlet and turbocharger inlet.

NOTE: P-80 Emulsion eases installation of tight-fitting rubber and plastic parts by reducing the force needed for assembly. Once assembly is complete, P-80 Emulsion dries and the part returns to its original condition. Use P-80 Emulsion when a thin film of lubricant is desired.

7.2 Install all parts so that each connection overlaps at least 1.18 inch (30 mm). The rubber seal, duct, and clamp of each connection should be fitted as shown in **Fig. 3**.

Air Intake Ducting Replacement



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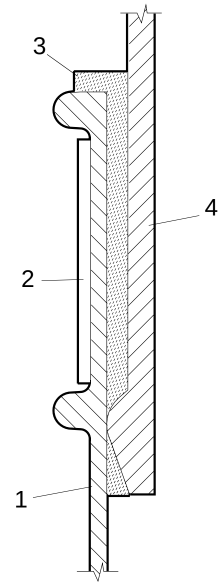
1. Air Cleaner-to-Elbow Seal
2. Elbow
3. Elbow-to-Turbocharger Seal

Fig. 2, Typical Elbow-to-Turbocharger Configuration (CAT C7 engine shown)

7.3 Check the installed assembly for any interference or contact with adjacent components. Loosen and adjust as necessary to avoid chafing.

NOTE: Be sure all hose connections are square and have proper overlap before tightening the hose clamps.

8. Tighten the clamps on the air intake duct assembly 40 lbf·in (452 N·cm).
9. Lower the hood.



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1. Duct
2. Clamp
3. Seal
4. Air Cleaner Housing

Fig. 3, Cross-Section of Air Intake Ducting

Replacement

IMPORTANT: Do not modify, or use modified air cleaners or duct components.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake.
2. Chock the tires and open the hood.

NOTICE

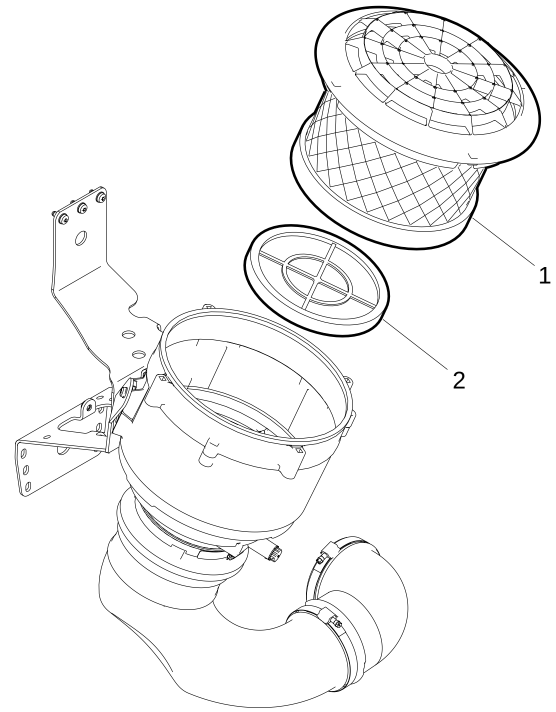
All air intake components and connections must be air- and water-tight. Dirt or dust entering the engine can cause internal engine damage. Most of the dirt and dust particles are silicates, which fuse into abrasive glass-like particles when exposed to engine combustion. These particles can grind piston rings, pistons, and cylinder liners. Do not operate the engine with the air cleaner element or any air intake component removed.

3. Check the air cleaner housing for damage, and check all ducts and connections for leakage. Adjust or replace parts as necessary.
4. Remove the capscrews that secure the primary air cleaner element in the air cleaner housing.

   Remove the primary air cleaner element. See **Fig. 1**.

NOTE: The vehicle is equipped with either a stainless steel safety screen or a safety air cleaner element. Replace the safety screen or the safety element with every third primary air cleaner element replacement.

5. Remove the safety screen or element from the air cleaner and wipe the inside of the air cleaner with a clean, damp cloth. Check the housing and sealing surfaces for damage, dust, or foreign matter that could cause sealing problems. Clean surfaces or replace parts as necessary.
6. Inspect the safety screen or element for damage. Replace if necessary, or according to the recommended maintenance interval (see the NOTE before step 5).
7. Install the safety screen or element in the air cleaner housing.
8. Inspect the new primary air cleaner element for damage or holes.



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1. Primary Air Cleaner Element
2. Stainless Steel Safety Screen or Safety Air Cleaner Element

Fig. 1, Air Cleaner Elements

9. Using capscrews, install the air cleaner element in the air cleaner housing. Tighten the capscrews 25 to 35 lbf·in (280 to 400 N·cm).
10. Check all connections for tightness.

Removal

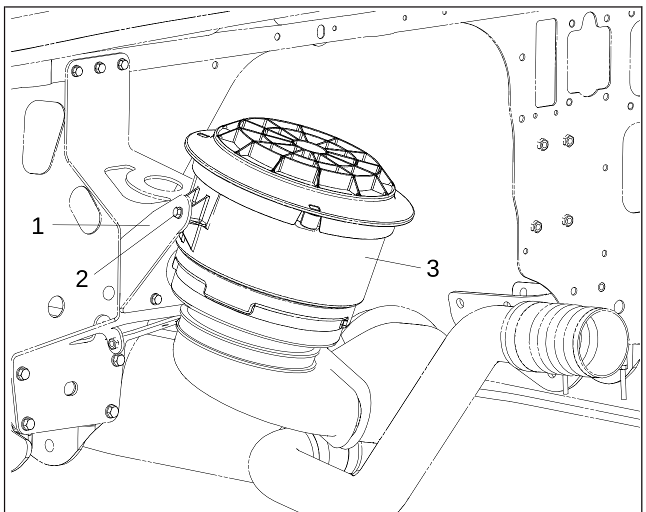
IMPORTANT: Do not modify, or use modified air cleaners or duct components.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake.
2. Chock the tires and open the hood.

NOTICE

All air intake components and connections must be air- and water-tight. Dirt or dust entering the engine can cause internal engine damage. Most of the dirt and dust particles are silicates, which fuse into abrasive glass-like particles when exposed to engine combustion. These particles can grind piston rings, pistons, and cylinder liners. Do not operate the engine with the air cleaner element or any air intake component removed.

3. Remove the air restriction indicator or sensor, if equipped.
4. Loosen the hose clamp that attaches the air intake duct to the air cleaner outlet port, then pull the duct off the port. See **Fig. 1**.



1. Mounting Bracket
2. Capscrew
3. Air Cleaner

Fig. 1, Air Cleaner Installation

5. Remove the three capscrews that attach the air cleaner to the air cleaner mounting bracket.

Installation

1. Check the air cleaner housing for damage, and check all ducts and connections for leakage. Adjust or replace parts as necessary.
2. Using three capscrews, install the air cleaner housing on the mounting bracket.
3. Install the air intake duct on the air cleaner outlet port so that it overlaps by at least 1 inch (25 mm). P80® Rubber Lubricant Emulsion, or equivalent rubber lubricant, can be used to ease assembly.

NOTE: To locate your local International Products Corporation distributor, call 1-609-386-877 or visit **www.ipcol.com**.

4. Check the duct for any interference or contact with adjacent components. Loosen and adust as necessary.
5. Tighten the hose clamp at the air cleaner outlet 40 lbf·in (450 N·cm).
6. Install the air restriction indicator on the air cleaner, if equipped.

Restriction Checking

Restriction of air flow through the air cleaner element is measured at the tap in the air cleaner outlet. Check the restriction indicator at the air cleaner or in the cab if the vehicle is equipped with a dash-mounted restriction gauge.

Vehicles may be equipped with either a manual-reset restriction indicator with graduations (**Fig. 1**), or a go/no-go restriction indicator without graduations (**Fig. 2**).

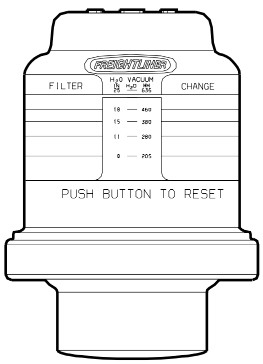


Fig. 1, Manual-Reset Air Restriction Indicator, Graduated

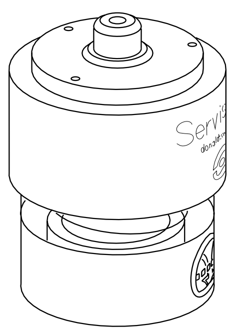


Fig. 2, Manual-Reset Air Restriction Indicator, Go/No-Go

1. For vehicles equipped with a manual-reset indicator with graduations, check the indicator with the engine off to see if air restriction equals or exceeds the value shown in **Table 1** for maximum air restriction.

   For vehicles equipped with a go/no-go restriction indicator without graduations, check the indicator with the engine off to see if the colored bar shows through the clear window.

Air Cleaner Element Maximum Restriction		
Engine	**Pre-EPA07 Engines**	**EPA07/EPA10 Engines**
Caterpillar	25 inH_2O	—
Cummins	25 inH_2O	25 inH_2O
Detroit Diesel	20 inH_2O	22 inH_2O
Mercedes-Benz	22 inH_2O	22 inH_2O

Table 1, Air Cleaner Element Maximum Restriction

2. If air restriction is below the maximum, no further work is necessary.

   If air restriction is at or above the maximum, push the reset button on the indicator.
3. Operate the engine to see if air restriction exceeds recommended values again. This can be done by running the vehicle on a dynamometer at **full-load and rated rpm**, or by driving the vehicle for one day in the vehicle's typical operating environment while not exceeding the rated rpm. See the engine manufacturer's service literature for information on rated rpm for your engine.
4. Check the indicator again. If air restriction continues to equal or exceed the maximum air restriction value in **Table 1** on an indicator with graduations, or if the colored bar shows through the clear window on a go/no-go indicator, replace the air cleaner element, then reset the indicator.

   For air cleaner element replacement instructions, see **Subject 100** for instructions.

General Information

The charge air cooler (CAC) is attached to the front of the radiator. The function of the CAC is to cool the hot, compressed air that exits the turbocharger. The CAC reduces the temperature of this air to the engine manufacturers’ specified air intake temperature before the air reaches the engine intake manifold. The lower temperature reduces exhaust emissions, improves fuel economy, and increases horsepower.

CAC Removal and Installation

Removal

NOTE: This procedure covers vehicles that have the charge air cooler (CAC) mounted above the condenser.

1. Apply the parking brakes and chock the tires.
2. Disconnect the batteries.
3. Remove the four Torx® fasteners that attach the grille to the hood.
4. Loosen the constant tension hose clamps at both ends of the flex tubes that attach the inlet and outlet air piping to the CAC. Remove the flex tubes and the CAC pipes from the CAC.
5. Standing in the grille opening of the hood, remove the nuts that attach the CAC to the mounting brackets. Remove the CAC.
6. For a CAC that is mounted on a 1350-square-inch radiator that has aluminum CAC baffles attached to the radiator support channels, remove the six Torx fasteners that secure the baffles to the radiator. Discard the aluminum CAC baffles.

Installation

1. Using nuts, attach the right side of the CAC to the mounting bracket, then attach the left side of the CAC to the mounting bracket. After all four nuts are installed, tighten them 25 to 31 lbf·ft (34 to 42 N·m).
2. Install the flex tubes between the CAC and the CAC inlet and outlet air pipes. Place the constant tension hose clamps over the flex tubes.
3. Turn the constant tension hose clamps so their tightening screws are under the hoses or facing inboard. Tighten the clamps 45 lbf·in (500 N·cm).

IMPORTANT: Vehicles built on or after February 26, 2007, have modified constant tension clamps that adjust to changes in diameter at the hose connection. When installing a new clamp or reinstalling a modified clamp, tighten the fastener 98 lbf·in (1100 N·cm). Do not retighten the clamp unless the measured torque drops below 50 lbf·in (560 N·cm), at which time it should be tightened again 98 lbf·in (1100 N·cm).

4. Using four Torx fasteners, attach the grille to the hood.
5. Connect the batteries.

Inspection

1. Apply the parking brakes and chock the tires.
2. Check the charge air cooler (CAC) flex tubes and the inlet and outlet piping for holes or other damage. Also check for loose or damaged constant tension hose clamps. Replace damaged parts. If hose clamps are loose, turn them so their tightening screws are under the hoses or facing inboard. Tighten the screws 45 lbf·in (500 N·cm).

IMPORTANT: Vehicles built on or after February 26, 2007, have modified constant tension clamps that adjust to changes in diameter at the hose connection. When installing a new clamp or reinstalling a modified clamp, tighten the fastener 98 lbf·in (1100 N·cm). Do not retighten the clamp unless the measured torque drops below 50 lbf·in (560 N·cm), at which time it should be tightened again 98 lbf·in (1100 N·cm).

3. Check the CAC core fins. If the fins are bent, use a small pair of needlenose pliers or a small screwdriver to straighten them.
4. Check the CAC core for clogged fins. Use compressed air or water to dislodge any material restricting airflow through the core.
5. Perform the "CAC Core Leakage Test."

CAC Core Leakage Test

Charge air coolers are designed in such a way that they may leak an insignificant amount of air. The allowable leakage mentioned in **Table 1** represents a loss of less than 0.1 percent of charge airflow. Based on this rate, there should be no measurable loss of performance.

Leakage Rate Specifications		
Engine	**Pressure Drop in 15 Seconds: psi (kPa)**	**Start Pressure: psi (kPa)**
Caterpillar	5 (34)	30 (207)
Cummins	7 (48)	30 (207)
Mercedes-Benz	5 (34)	30 (207)

Table 1, Leakage Rate Specifications

The CAC core leakage test should be performed using a CAC test kit, part number 5039, which can be purchased from SPX Kent-Moore at 1-800-328-6657.

1. Apply the parking brakes and chock the tires.
2. Connect the test equipment to the CAC core, as follows. See **Fig. 1**.
   - 2.1 Remove the inlet and outlet air piping from the flex tubes that attach them to the CAC air inlet and air outlet.
   - 2.2 Slip a safety ring with thumbscrew over each flex tube and onto the CAC air inlet and air outlet. Turn the rings so the thumbscrews are facing outboard and the safety chains are inboard. Tighten the thumbscrews securely.
   - 2.3 Install an additional constant tension hose clamp on each flex tube.
   - 2.4 Install the test plug without an adapter in the CAC air inlet and turn the plug so the safety chain is inboard. Tighten each constant tension hose clamp 72 lbf·in (810 N·cm).
   - 2.5 Install the test plug with adapter in the CAC air outlet and turn the plug so the safety chain is inboard. Tighten each constant tension hose clamp 72 lbf·in (810 N·cm).

WARNING

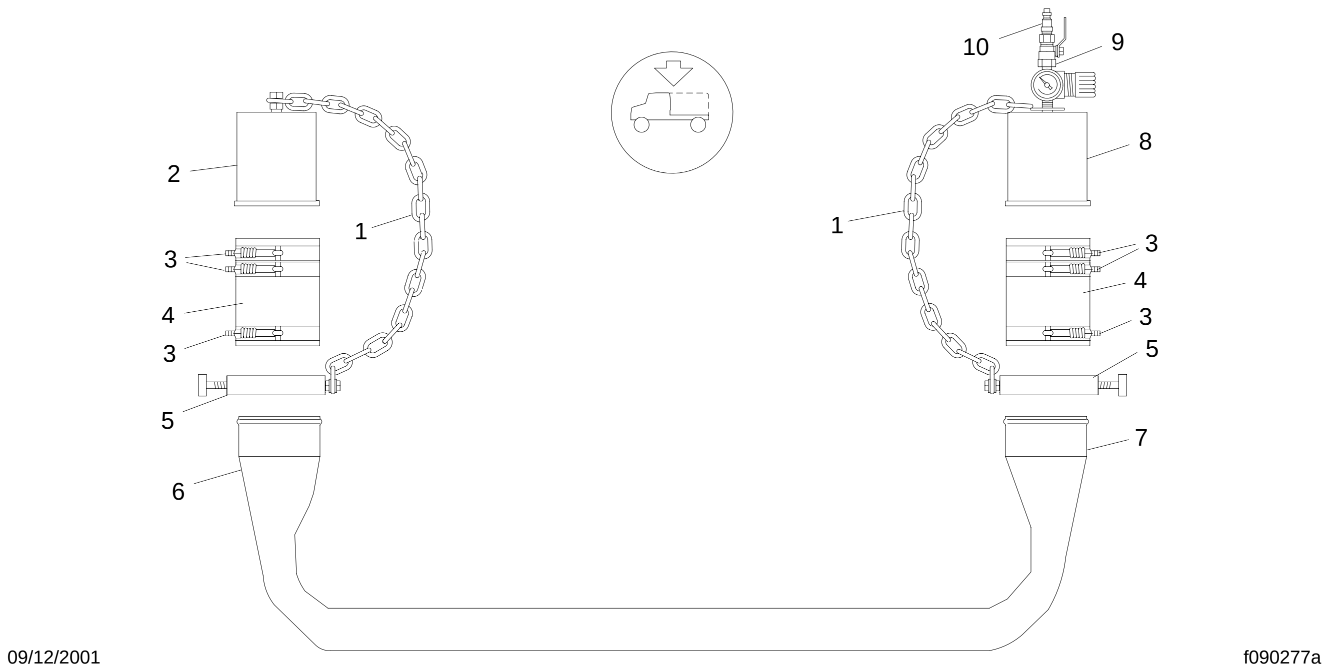
Always secure the test plugs with the safety rings. Test pressures could blow out an unsecured test plug at high speed, possibly causing eye injury or other serious personal injury.

   - 2.6 If not already installed, install a test valve/gauge assembly and air chuck in the test plug with adapter.
   - 2.7 Attach a pressurized air line to the air chuck on the pressure regulator valve.
3. Test the CAC core as follows.

WARNING

Always wear safety glasses when doing this procedure. Do not stand in front of the test plugs while the core is pressurized. A plug could sud-

CAC Inspection and Leakage Test



1. Safety Chain
2. Test Plug
3. Constant Tension Hose Clamp
4. Flex Tube
5. Safety Ring
6. CAC Air Inlet
7. CAC Air Outlet
8. Test Plug with Adapter
9. Test Valve/Gauge Assembly
10. Air Chuck

Fig. 1, CAC Core Testing

denly release debris at high speed, possibly resulting in eye injury or other serious personal injury.

3.1 Open the test valve, then slowly open the pressure regulator valve and allow the CAC to gradually fill with air to the start pressure. See **Table 1**.

3.2 Close the test valve and watch the gauge for 15 seconds. If there is more than the specified drop in the CAC pressure in 15 seconds, replace the CAC. See **Table 1**.

IMPORTANT: Do not attempt to repair the CAC.

3.3 When testing is completed, reduce the pressure on the pressure regulator valve to bleed air from the CAC.

4. Remove the test equipment (and the additional constant tension hose clamps) from the flex tubes.
5. Pull the flex tubes and constant tension hose clamps rearward until the hoses cover about 1-1/2 inches (38 mm) of the CAC air inlet and air outlet piping.
6. Turn the clamps so their tightening screws are under the hoses or facing inboard. Tighten the screws 45 lbf·in (500 N·cm).

IMPORTANT: Vehicles built on or after February 26, 2007, have modified constant tension clamps that adjust to changes in diameter at the hose connection. When installing a new clamp or reinstalling a modified clamp, tighten the fastener 98 lbf·in (1100 N·cm). Do not retighten the clamp unless the measured torque drops below 50 lbf·in (560 N·cm), at which time it should be tightened again 98 lbf·in (1100 N·cm).

Flushing

If the charge air cooler (CAC) is suspected of being contaminated, flush the CAC.

1. Apply the brakes and chock the tires.
2. Remove the CAC. For instructions, see **Subject 100**.
3. Set the CAC in a horizontal position with the inlet and outlet ports facing up.

IMPORTANT: Use only naphtha or mineral spirits to clean the charge air cooler. Do not use caustic solutions such as those that are commonly used in radiator shops. Do not use steam or high-temperature cleaning operations. Caustic solutions, steam, and high-temperature cleaning operations will damage the RTV that seals the charge air cooler tubes to the headers, which may result in leaking.

4. Pour a filtered naphtha or mineral spirits solution into the CAC until it is 40 percent full.
5. Cap the inlet and outlet ports on the CAC.
6. Rock the CAC back and forth so that the solvent travels from one tank, through the tubes, to the other tank and back. Repeat this process ten times.

NOTE: Do not leave the solvent in the CAC for more than 10 minutes.

7. Remove the caps from the inlet and outlet ports.
8. Drain the CAC and properly dispose of the solvent.
9. Leave the caps off and allow the residual solvent to evaporate.
10. Install the CAC. For instructions, see **Subject 100**.

Restriction Test

After flushing the charge air cooler (CAC) because of turbocharger or engine damage, test the pressure drop across the CAC and air piping as follows:

1. Remove the pipe plug from the tapped hole in the turbocharger air outlet elbow.

   Remove the pipe plug or the nylon tube and atomizer for the ether start system if so equipped, or the air line to the turbocharger air-pressure gauge if so equipped from the tapped hole in the rear-left side of the intake manifold.

   Install an air pressure gauge in each tapped hole.
2. Operate the engine at rated speed and horsepower. There is no need to operate the engine at its peak torque rating. While operating the engine, read both air pressure gauges.

   Because of air turbulence at the turbocharger outlet, subtract 0.3 inHg (1 kPa) from the pressure measurement taken at this point to make it a true reading.

   From that reading, subtract the reading taken at the intake manifold. This is the pressure drop of the CAC.

   If the pressure drop is more than 4 inHg (14 kPa), flush or replace the CAC as needed.

General Information

The Tu-Flo 550 and 750 air compressors are two-cylinder, single stage, reciprocating compressors. The Tu-Flo 550 air compressor has a rated displacement of 13.2 cubic feet (4 cubic meters) per minute at 1250 rpm. The Tu-Flo 750 air compressor has a rated displacement of 16.5 cubic feet (5 cubic meters) per minute at 1250 rpm.

The compressor consists of two major subassemblies, the cylinder head and the crankcase.

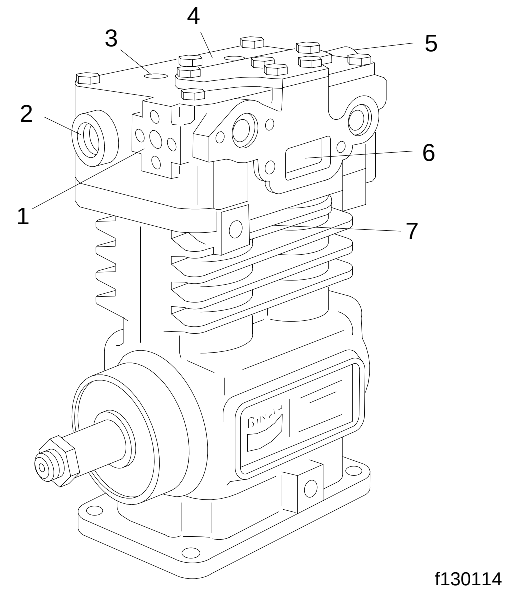
The cylinder head is an iron casting that houses the inlet, discharge, and unloader valving. The cylinder head contains the air inlet port and has both top and side air discharge ports. There are three water coolant ports on the cylinder head. Governor mounting surfaces are provided at both the front and rear of the cylinder head. The cylinder head is mounted on the crankcase and is secured by six capscrews.

The crankcase houses the cylinder bores, pistons, crankshaft and main bearings, and provides the flange or base mounting surface. See **Fig. 1** and **Fig. 2**.

Operation

The compressor is driven by the vehicle engine and is operating continuously while the engine is running. Actual compression of air is controlled by the compressor unloading mechanism and the governor. The governor, which is generally mounted on the air compressor, maintains the brake system air pressure between a preset maximum and minimum pressure level.

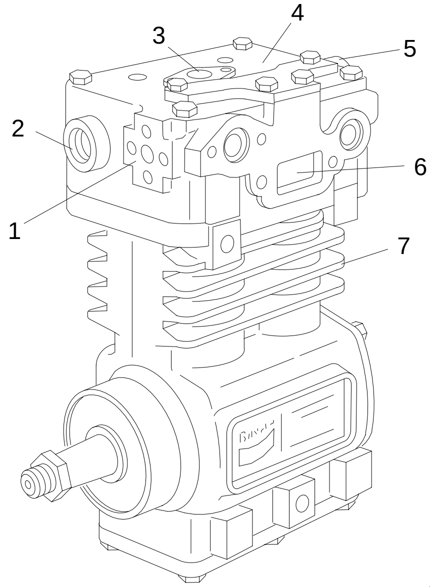
See **Fig. 3** for a section view of the Tu-Flo 550 and 750 air compressors.



1. Governor Mounting Pad
2. Water Inlet Port
3. Air Discharge
4. Cylinder Head
5. Water Outlet Port
6. Air Inlet
7. Crankcase

Fig. 1, Tu-Flo 550 Air Compressor

General Information



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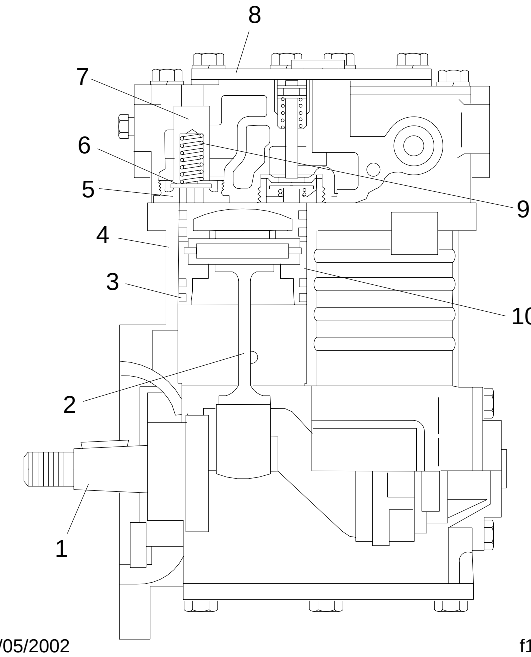
1. Governor Mounting Pad
2. Water Inlet Port
3. Air Discharge
4. Cylinder Head
5. Water Outlet Port
6. Air Inlet
7. Crankcase

Fig. 2, Tu-Flo 750 Air Compressor



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1. Crankshaft
2. Connecting Rod
3. Piston Ring
4. Crankcase
5. Discharge Valve Seat
6. Discharge Valve
7. Discharge Valve Stop
8. Unloader Cover
9. Discharge Valve Spring
10. Piston

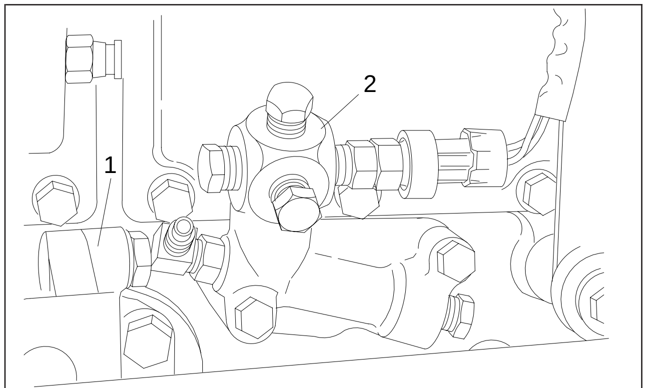
Fig. 3, Tu-Flo 550 and 750 Air Compressor

Replacement

1. Apply the parking brakes, chock the tires, and open the hood.
2. Drain the air system.
3. Clean all the fittings and hose connections on the air compressor, power steering pump, and the supply and pressure lines on the power steering gear until they are free of dirt.
4. Drain the radiator coolant. For instructions, see **Section 20.01**, Subject 100.
5. Loosen the constant torque hose clamps at both ends of the charge air cooler outlet air piping. Remove the piping to access the air compressor.
6. Remove the pressure line on the power steering gear.
7. Remove the radiator support rods to access the air compressor.

NOTE: On vehicles with combined air dryers and air reservoir modules, the air governor is mounted on the air reservoir module not the air compressor.

8. If the air governor is mounted on the compressor, remove it and the air governor gasket. Discard the gasket.
9. Remove the pressure line on the power steering pump and allow the power steering fluid to drain. After the fluid has drained, disconnect the other end of the pressure line and remove it. Plug the line and fittings to keep out dirt.
10. Remove the supply line from the power steering pump and plug the line and fitting.
11. Remove the capscrews that attach the power steering pump to the air compressor and remove the steering pump. Remove and discard the steering pump gasket.
12. Remove the cushion clamp from the air compressor.
13. Marking their locations and positions, disconnect all air, coolant, and oil lines attached to the air compressor. Plug the lines and fittings.
14. Remove the oil manifold that is attached to the engine. See **Fig. 1**.



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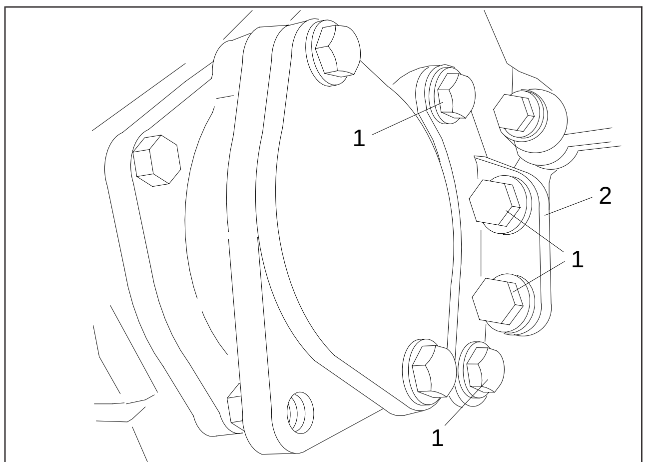
1. Air Compressor 2. Oil Manifold

Fig. 1, Oil Manifold

15. Remove the two capscrews that attach the air compressor to the mounting bracket at the aft end of the air compressor. Remove the two capscrews that attach the mounting bracket to the engine and remove the mounting bracket. See **Fig. 2**.



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1. Capscrew 2. Mounting Bracket

Fig. 2, Air Compressor Mounting Bracket

16. Support the air compressor and remove the two capscrews that attach the air compressor to the engine. Remove the air compressor and the gasket.
17. Inspect the condition of the air compressor gasket and replace the gasket if necessary.

Air Compressor Replacement

NOTE: On Caterpillar engines, apply thread lock compound 9S-3263 to the mounting capscrews.

18. Attach the air compressor to the front of the engine. Be sure that the drive gear engages correctly with the gear in the front of the engine. Install the capscrews on the air compressor and tighten 60 to 90 lbf·ft (80 to 100 N·m).
19. Install the oil manifold on the engine.
20. Using a capscrew, attach the cushion clamp to the air compressor and tighten 16 to 27 lbf·ft (21 to 35 N·m).
21. Install a new gasket on the power steering pump. Using capscrews, attach the power steering pump to the air compressor and tighten the capscrews 32 to 37 lbf·ft (43 to 50 N·m).
22. Unplug the air, coolant, and oil lines and attach them to the air compressor.
23. If the air governor is mounted on the compressor, install a new gasket on the air governor and attach the air governor to the compressor.
24. Attach the supply line and pressure line to the power steering pump.
25. Attach the pressure line to the power steering gear.
26. Using bolts and nuts, attach the radiator support rods to the mounting brackets.
27. Using constant torque hose clamps, install the charge air cooler outlet air piping. Tighten the hose clamps 45 lbf·in (500 N·cm).
28. Fill the power steering reservoir to between the MAX HOT and MIN COLD lines. For approved power steering fluids, see **Section 46.06**, Subject 400.
29. Fill the cooling system. For instructions, see **Section 20.01**, Subject 100.
30. Start the engine and turn the steering wheel from full right to full left two or three times to remove air from the lines.
31. Check the power steering reservoir again and add fluid if needed.
32. Check the hydraulic lines for leaks.
33. Remove the chocks from the tires and close the hood.

Troubleshooting Tables

Problem—Excessive Oil Passage

Problem—Excessive Oil Passage	
Possible Cause	**Remedy**
Restricted air intake.	Check engine or compressor air cleaner and replace if necessary. Check compressor air inlet for kinks, excessive bends, and be certain inlet lines have the minimum specified inside diameter. Recommended minimum inlet line inside diameter is 5/8 inch (16 mm). Recommended maximum air inlet restriction is 25 inches of water.
Restricted oil return to engine.	Oil return to the engine should not be restricted in any way. Check for excessive bends, kinks, and restrictions in the oil return line. Minimum recommended oil return line size is 5/8-inch (16 mm) outside diameter or equivalent inside diameter of 1/2 inch (13 mm). The return line **must constantly descend** from the compressor to the engine crankcase. Make certain oil drain passages in the compressor and mating engine surfaces are unobstructed and aligned. Special care must be taken when sealants are used with, or instead of, gaskets.
Poorly filtered air inlet.	Check for a damaged or dirty air filter on the engine or compressor. Check for leaking or damaged compressor air intake components such as induction line, fittings, gaskets, and filter bodies. The compressor intake should not be connected to any part of the exhaust gas recirculation (E.G.R.) system on the engine.
Insufficient compressor cooling (compressor runs hot).	For air-cooled portions of the compressor: • Remove accumulated grease and dirt from the cooling fins. Replace components found damaged. • Check for damaged cooling fins. Replace compressor if found damaged. For a water-cooled compressor or water-cooled portions of the compressor: • Check for proper coolant line sizes. Minimum recommended line outside diameter is 1/2 inch (13 mm). • Check the coolant flow through the compressor. Minimum allowable flow is 2.5 gallons per minute at engine governed speed. If low coolant flow is detected, inspect the coolant lines and fittings for accumulated rust scale, kinks, and restrictions. • Water temperature should not exceed 200°F (93°C). • Optimum cooling is achieved when engine coolant flows as shown in **Fig. 1**.
Contaminants not being regularly drained from system reservoirs.	Check reservoir drain valves to insure that they are functioning properly. It is recommended that the vehicle be equipped with functioning automatic drain valves or have all reservoirs drained to zero psi daily, or optimally, to be equipped with a desiccant-type air dryer prior to the reservoir system.
Compressor runs loaded an excessive amount of time.	Vehicle system leakage should not exceed 1 psi (7 kPa) pressure drop per minute without brakes applied and 3 psi (21 kPa) pressure drop per minute with brakes applied. If leakage is excessive, check for system leaks and repair.

Troubleshooting

Problem—Excessive Oil Passage	
Possible Cause	**Remedy**
Excessive engine crankcase pressure.	Test for excessive engine crankcase pressure and repair or replace ventilation components as necessary. NOTE: An indication of crankcase pressure is a loose or partially lifted dipstick.
Excessive engine oil pressure.	Check the engine oil pressure with a test gauge and compare the reading to the engine specifications. Bendix does not recommend restricting the compressor oil supply line because of the possibility of plugging the restriction with oil contaminants. Minimum oil supply line size is 3/16-inch (5 mm) inside diameter.
Malfunctioning compressor.	Replace or repair the compressor only after making certain none of the preceding conditions exist.

Problem—Noisy Compressor Operation

Problem—Noisy Compressor Operation	
Possible Cause	**Remedy**
Loose drive gear or components.	Inspect the fit of the drive gear on the compressor crankshaft. The pulley or gear must be completely seated and the crankshaft nut must be tight. If the compressor crankshaft surface or keyway is damaged, it is an indication of loose drive components. If damage to the compressor crankshaft is detected, replace the compressor. When installing the pulley or drive gear, torque the crankshaft nut to the appropriate torque specifications. Do not back off the crankshaft nut once it is tightened to the proper torque. Do not use impact wrenches to install the crankshaft nut.
Excessively worn drive couplings or gears.	Inspect drive gear, couplings, and engine for excessive wear. Replace as necessary. NOTE: Nonmetallic gears should be replaced when the compressor is changed.
Compressor cylinder head or discharge line restrictions.	Inspect the compressor discharge port and discharge line for carbon buildup. If carbon is detected, check for proper compressor cooling. See the remedy for insufficient compressor cooling in the previous table. Inspect the discharge line for kinks and restrictions. Replace the discharge line as necessary.
Worn or burned out bearings.	Check for proper oil pressure in the compressor. Minimum required oil pressure is 15 psi (103 kPa) when engine is idling and 15 psi (103 kPa) maximum governed engine rpm. Check for excessive oil temperature; oil temperature should not exceed 240°F (115°C).
Malfunctioning compressor.	Repair or replace the compressor after making certain none of the preceding conditions exist.

Problem—Excessive Buildup and Recovery Time

Problem—Excessive Buildup and Recovery Time*	
Possible Cause	**Remedy**
Dirty induction air filter.	Inspect engine or compressor air filter and replace if necessary.

Problem—Excessive Buildup and Recovery Time*	
Possible Cause	**Remedy**
Restricted induction line.	Inspect the compressor air induction line for kinks and restrictions and replace as necessary.
Restricted discharge line or compressor discharge cavity.	Inspect the compressor discharge port and line for restrictions and carbon buildup. If carbon buildup is found, check for proper compressor cooling. Replace faulty sections of the discharge line.
Slipping drive components.	Check for faulty drive gears and couplings and replace as necessary. Check the condition of drive belts and replace or tighten, whichever is appropriate.
Excessive air system leakage.	Test for excessive system leakage and repair as necessary. Use the following as a guide: Build system pressure to governor cutout and allow the pressure to stabilize for one minute. Using a test gauge, note the system pressure drop after two minutes. The pressure drops should not exceed: • 2 psi (14 kPa) in each reservoir for a single vehicle; • 6 psi (41 kPa) in each reservoir for a tractor and trailer; • 8 psi (55 kPa) in each reservoir for a tractor and two trailers.
Sticking unloader pistons.	Check the operation of the unloading mechanism. Check for proper operation of the compressor air governor. If the governor is operating properly, replace the unloader mechanism. Inspect for bent, kinked, or blocked tubing leading to or from the governor.
Malfunctioning compressor.	Repair or replace the compressor after making certain none of the preceding conditions exist.

* Compressor should be capable of building air system pressure from 85 to 100 psi (552 kPa to 689 kPa) in 40 seconds with engine at full governed rpm. Minimum compressor performance is certified to meet Federal requirements by the vehicle manufacturer. Do not downsize the original compressor.

Problem—Compressor Does Not Unload

Problem—Compressor Does Not Unload	
Possible Cause	**Remedy**
Malfunctioning governor or improper governor installation.	Test the governor for proper operation and inspect air lines to and from the governor for kinks or restrictions. Repair or replace the governor or connecting air lines.
Malfunctioning or worn unloader pistons or bores.	Inspect for worn, dirty, or corroded unloader pistons and their bores. Replace as necessary.

Problem—Compressor Leaks Oil

Problem—Compressor Leaks Oil	
Possible Cause	**Remedy**
Damaged mounting gasket.	Check the compressor mounting bolt torque. If the mounting bolt torque is low, replace the compressor mounting gasket before retorqueing the mounting bolts.
Cracked crankcase or end cover.	Visually inspect the compressor exterior for cracked or broken components. Cracked or broken crankcases or mounting flanges can be caused by loose mounting bolts. The end cover can be cracked by overtorquing fittings or plugs installed in the end cover. Repair or replace the compressor as necessary.

Troubleshooting

Problem—Compressor Leaks Oil	
Possible Cause	**Remedy**
Loose end cover.	Check the capscrew torques and tighten as necessary. Replace gaskets or O-rings.
Loose oil supply or return line fittings.	Check the torque of external oil line fittings and tighten as necessary.
Porous compressor casting.	Replace the compressor if porosity is found.
Mounting flange or end cover, O-ring or gasket missing, cut, or damaged.	Replace as necessary.

Problem—Compressor Constantly Cycles; Compressor Remains Unloaded for a Very Short Time

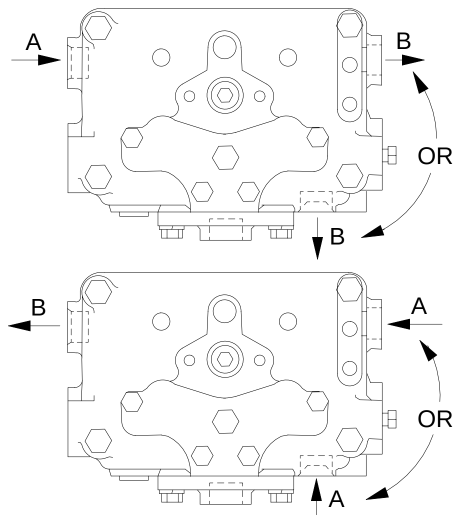
Problem—Compressor Constantly Cycles; Compressor Remains Unloaded for a Very Short Time	
Possible Cause	**Remedy**
Leaking compressor unloader pistons.	Remove the compressor inlet strainer or fitting. With the compressor unloaded (not compressing air), check for air leakage. Replace as necessary.
Malfunctioning governor.	Test the governor for proper operation and repair or replace as necessary.
Excessive air system leakage.	Test for excessive system leakage and repair as necessary. Use the following as a guide: Build system pressure to governor cutout and allow the pressure to stabilize for one minute. Using a test gauge, note the system pressure drop after two minutes. The pressure drops should not exceed: • 2 psi (14 kPa) in each reservoir for a single vehicle; • 6 psi (41 kPa) in each reservoir for a tractor and trailer; • 8 psi (55 kPa) in each reservoir for a tractor and two trailers.
Excessive reservoir contaminants.	Drain reservoirs.

Problem—Compressor Leaks Coolant

Problem—Compressor Leaks Coolant	
Possible Cause	**Remedy**
Improperly installed plugs and coolant line fittings.	Check torque of fittings and plugs and tighten as necessary. Overtorqued fittings and plugs can crack the head or block casting.
Freeze cracks due to improper antifreeze strength.	Test antifreeze and strengthen as necessary. Check coolant flow through compressor to assure the proper antifreeze mixture reaches the compressor.
Malfunctioning compressor due to porous castings.	If casting porosity is detected, replace the compressor.

Problem—Compressor Head Gasket Malfunction

Problem—Compressor Head Gasket Malfunction	
Possible Cause	**Remedy**
Restricted discharge line.	Clear restriction or replace line.
Loose cylinder head capscrews.	Tighten evenly to a torque of 25 to 30 lbf·ft (34 to 41 N·m).
Malfunctioning compressor or head gasket.	Check for rough or poorly machined head or block surfaces. Replace compressor as necessary.



A. Coolant In
B. Coolant Out

Fig. 1, Coolant Flow Options

Specifications

Tu-Flo 550 and 750 Specifications

- Displacement at 1250 rpm:
  - Tu-Flo 550: 13.2 cfm
  - Tu-Flo 750: 16.5 cfm
- Maximum recommended rpm:
  - Tu-Flo 550: 3000 rpm
  - Tu-Flo 750: 2400 rpm
- Minimum oil pressure required at engine idle speed: 15 psig (103 kPa)
- Maximum inlet air temperature: 250°F (121°C)
- Minimum Coolant Flow (water cooled) at:
  - Maximum rpm: 2.5 gpm (9.5 L/min)
  - Minimum rpm: 5 gpm (19 L/min)
- Maximum discharge air temperature: 400°F (204°C)
- Minimum oil pressure required at maximum governed engine speed: 15 psig (103 kPa)
- Number of cylinders: 2
- Weight: 50 pounds (23 kilograms)

Fastener Torque Values	
Description	**Torque**
Cylinder Head Capscrews	440 to 500 lbf·in (4970 to 5650 N·cm)
End Cover Capscrews	175 to 225 lbf·in (1980 to 2540 N·cm)
Bottom Cover Capscrews	175 to 225 lbf·in (1980 to 2540 N·cm)
Unloader Cover Plate	175 to 225 lbf·in (1980 to 2540 N·cm)
Crankshaft Nut: Marsden or Castle	100 to 120 lbf·ft (136 to 163 N·m)
Discharge Valve Seat	70 to 90 lbf·ft (95 to 122 N·m)
Inlet Valve Stop	70 to 90 lbf·ft (95 to 122 N·m)

Table 1, Fastener Torque Values

Air Compressor Removal, Inspection, and Installation

Special Tools

A special tool is needed to replace the drive gear on the WABCO 15.5 cfm and 28.1 cfm air compressors. See **Table 1**.

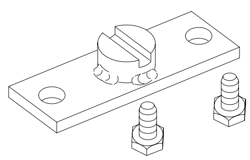
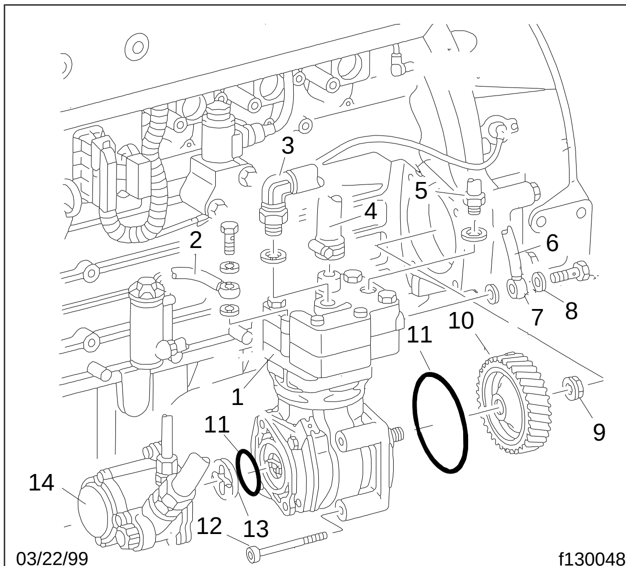
Special Tool			
Tool	**Description**	**Manufacturer**	**Part Number**
	Air Compressor Locking Device	SPX Kent-Moore	KM 904 589 03 63 00

Table 1, Special Tool

Removal

1. Shut off the engine, apply the parking brakes, and chock the tires.
2. Drain the air tanks.
3. Open the hood and clean all the fittings and hose connections on the air compressor and power steering pump until they are free of dirt.
4. Drain the radiator coolant. For instructions, see **Section 20.01**, Subject 100.
5. Remove the engine trim panel.
6. Disconnect the discharge line from the air compressor and move it away from the compressor. See **Fig. 1**.
7. Remove the air governor unloader line from the compressor.
8. Remove the capscrew that attaches the air governor to the engine and move the governor away from the air compressor.
9. Disconnect the air inlet line from the air compressor and plug the hole on the compressor.
10. Remove the tie straps on the wiring harnesses as needed to access the coolant line. Disconnect the rear coolant line from the cylinder head.
11. Disconnect the front coolant line at the compressor.



1. Air Compressor
2. Front Coolant Line
3. Discharge Line
4. Air Inlet Line
5. Unloader Air Line
6. Rear Coolant Line
7. Banjo Fitting
8. Washer
9. Drive Nut
10. Drive Gear
11. O-Ring
12. Capscrew
13. Cross Plate
14. Power Steering Pump

Fig. 1, Air Compressor Installation

12. Remove the capscrews that attach the power steering pump to the air compressor and move the steering pump away from the compressor.

Air Compressor Removal, Inspection, and Installation

IMPORTANT: Do not remove the power steering lines. Secure the lines and the pump so they are out of the way.

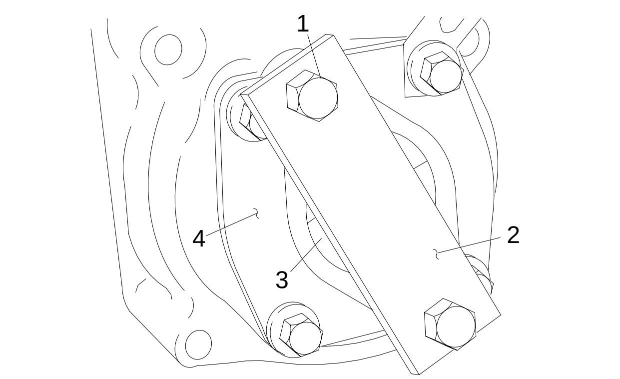
13. Remove the cross plate between the compressor and the power steering pump. See **Fig. 1**.

NOTE: On vehicles with automatic transmissions, it may be necessary to remove the brackets that attach the automatic transmission cooler lines to the engine to obtain enough room to remove the compressor.

14. Use a drain pan to catch any oil or water when the compressor is removed. Remove the capscrews that attach the air compressor to the engine and remove the compressor.

Inspection

1. Attach the fittings to the replacement compressor and replace damaged O-rings and fittings as needed. Note the position of the rear coolant line on the back of the compressor for reference during installation.
2. Replace the O-ring between the power steering pump and the air compressor.
3. Inspect the drive gear for worn or broken teeth, or spalling. If necessary, replace the drive gear. If replacing the drive gear, use the instructions in the following substeps; otherwise proceed to the next step.
   - 3.1 Using two capscrews, install the SPX Kent-Moore locking device (PN KM 904 589 03 63 00) on the air compressor where the power steering pump connects to the air compressor. Tighten the capscrews until the air compressor drive is locked. See **Fig. 2**.
   - 3.2 Place the air compressor securely in a vise.
   - 3.3 Using an impact wrench, remove the drive nut from the drive gear.
   - 3.4 Remove the drive gear from the air compressor. If necessary, use a gear puller to remove the drive gear.
   - 3.5 Install a new drive gear and nut on the drive shaft. Torque the nut 200 lbf·ft (270 N·m).



1. Capscrew
2. Locking Device
3. End of Drive Shaft
4. Air Compressor

Fig. 2, Locking Device Installation

   - 3.6 Remove the locking device from the air compressor.

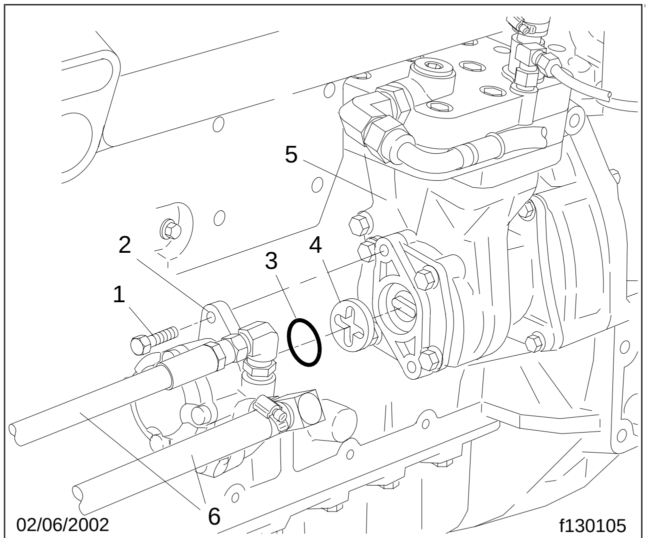
Installation

1. Using four capscrews, attach the air compressor to the engine. Torque the capscrews 30 lbf·ft (40 N·m).

IMPORTANT: Before installing the power steering pump, make sure the cross plate is installed on the air compressor. See **Fig. 3**.

2. Using two capscrews, attach the power steering pump to the air compressor. Torque the capscrews 30 lbf·ft (40 N·m).
3. Install the two coolant lines. Tighten the banjo fittings 30 lbf·ft (40 N·m). Use tie straps to secure the crank angle position sensor wires to the coolant line as needed.
4. If the brackets that attach the automatic transmission cooler lines to the engine were removed, use capscrews to install the brackets.
5. Install the air inlet line.
6. Using a capscrew, install the air governor on the engine.
7. Attach the unloader line to the air compressor.
8. Attach the discharge line to the air compressor.
9. Install the engine trim panel.

Air Compressor Removal, Inspection, and Installation



1. Capscrew
2. Power Steering Pump
3. O-Ring, Power Steering Pump
4. Cross Plate
5. Air Compressor
6. Hydraulic Lines

Fig. 3, Power Steering Pump Installation

10. Fill the cooling system. For instructions, see **Section 20.01**, Subject 100.
11. Remove the chocks from the tires and close the hood.

General Information

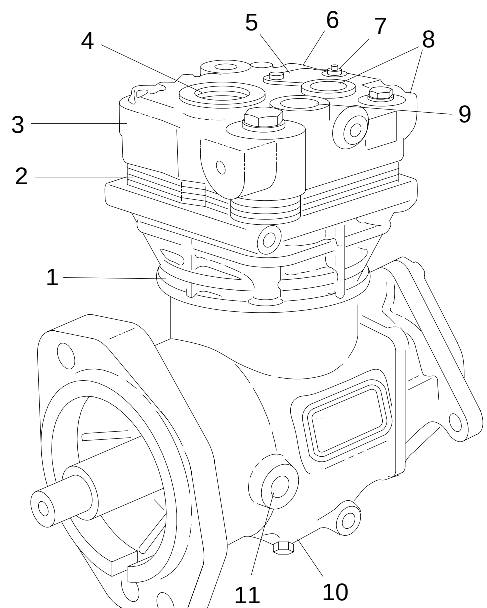
The BA-921 air compressor is a single-cylinder reciprocating compressor with a rated displacement of 15.8 cubic feet per minute at 1250 rpm. The compressor consists of a water-cooled cylinder head, a valve plate assembly, and an air-cooled integral crankcase and cylinder block. See **Fig. 1**. The cylinder head is an aluminum casting that contains the required air and water ports as well as an unloader piston. The valve plate assembly consists of laminated and brazed steel plates that incorporate various valve openings and channels for conducting air and engine coolant in to and out of the cylinder head.

The discharge valves are part of the valve plate assembly. The cylinder head and the valve plate comprise a complete cylinder head assembly. The cast iron crankcase and cylinder block assembly houses the piston, connecting rod, crankshaft, and related bearings.

The BA-921 crankcase cover is stamped with information identifying the compressor model, customer piece number, Bendix piece number, and serial number. See **Fig. 2**.

Principles of Operation

The compressor is driven by the vehicle engine and functions continuously while the engine is in operation. Actual compression of air is controlled by the compressor unloading mechanism operating in conjunction with a governor.



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1. Crankcase
2. Valve Plate Assembly
3. Cylinder Head
4. Air Inlet Port
5. Unloader Cover
6. Water Port
7. Governor Connection
8. Discharge Port
9. Water Port
10. Crankcase Cover
11. Oil Port

Fig. 1, BA-921 Air Compressor

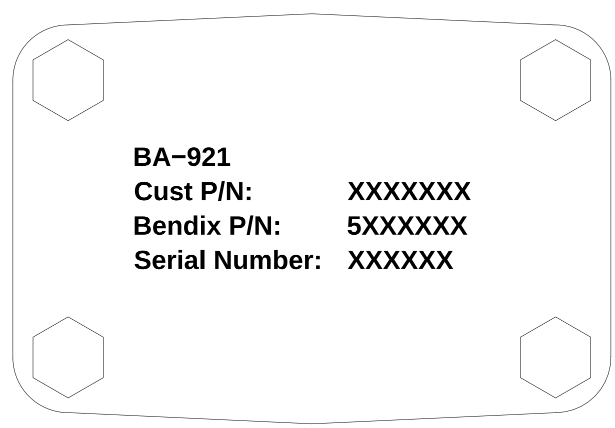

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Fig. 2, BA-921 Crankcase Cover

Replacement

1. Shut down the engine, apply the parking brakes, chock the tires, and open the hood.
2. Drain the air system.

WARNING

Wear goggles when using compressed air to clean or dry parts, as permanent eye injury could result from flying debris.

3. Using a cleaning solvent, remove road dirt and grease from the outside of the air compressor. Then dry the compressor with compressed air.
4. Drain the radiator coolant. For instructions, see **Group 20**.
5. Identify and disconnect all air, water, and oil lines attached to the air compressor.
6. Remove the air governor and the air governor mounting gasket.
7. Remove any components attached to the air compressor, such as a fuel pump or power steering pump.
8. Support the air compressor and remove the capscrews that attach the compressor to the gear case. Remove the air compressor.
9. Discard all gaskets.

IMPORTANT: Be sure the new gaskets are clean and not damaged.

10. Install a new air compressor gasket on the compressor.
11. Using capscrews, attach the air compressor to the gear case. For torque specifications, see the engine manufacturer’s service manual.
12. Install any components that were removed from the air compressor, such as a fuel pump or power steering pump.
13. Install a new gasket on the air governor. Then install the air governor on the engine.
14. Identify and connect the air, coolant, and oil lines to the air compressor.
15. Fill the engine cooling system. For instructions, see **Group 20**.
16. Turn on the engine and check for leaks.
17. Remove the chocks from the tires and lower the hood.

Troubleshooting Tables

Problem—Noisy Compressor Operation

Problem—Noisy Compressor Operation	
Possible Cause	**Remedy**
Loose drive gear or components.	Inspect the fit of the drive gear on the compressor crankshaft. The gear or coupling must be completely seated and the crankshaft nut must be tight. If the compressor crankshaft surface is damaged, it is an indication of loose drive components. If damage to the compressor crankshaft is detected, replace the compressor. When installing the drive gear or pulley, torque the crankshaft nut to the appropriate torque specifications and use care when pressing drive components on to the crankshaft. Do not back off the crankshaft nut once it is tightened to the proper torque. Do not use impact wrenches to install the crankshaft nut.
Excessively worn drive couplings or gears.	Inspect drive gear, couplings, and engine for excessive wear. Replace as necessary. NOTE: Nonmetallic gears should be replaced when the compressor is changed.
Compressor cylinder head or discharge line restrictions.	Inspect the compressor discharge port and discharge line for carbon buildup. If carbon is detected, check for proper cooling to the compressor. See the remedy for insufficient compressor cooling in the table titled Problem—Excessive Oil Passage. Inspect the discharge line for kinks and restrictions. Replace the discharge line as necessary.
Worn or burned out bearings.	Check for proper oil pressure in the compressor. Minimum required oil pressure is 15 psi (103 kPa) when engine is idling and 15 psi (103 kPa) maximum at governed engine rpm. Check for excessive oil temperature; oil temperature should not exceed 240°F (115°C).
Malfunctioning compressor.	Repair or replace the compressor after making certain none of the preceding conditions exist.

Problem—Compressor Does Not Unload

Problem—Compressor Does Not Unload	
Possible Cause	**Remedy**
Malfunctioning governor or installation.	Test the governor for proper operation and inspect air lines to and from it for kinks or restrictions. Repair or replace the governor or connecting air lines.
Malfunctioning or worn unloader pistons or bores.	Inspect for worn, dirty, or corroded unloader piston and bore. Replace as necessary.

Problem—Compressor Leaks Oil

Problem—Compressor Leaks Oil	
Possible Cause	**Remedy**
Damaged mounting gasket.	Check the compressor mounting capscrew torque. If the mounting capscrew torque is low, replace the compressor mounting gasket before retorquing the mounting capscrews.

Troubleshooting

Problem—Compressor Leaks Oil	
Possible Cause	**Remedy**
Cracked crankcase or end cover.	Inspect the compressor exterior for cracked or broken components. Cracked or broken crankcases or mounting flanges can be caused by loose mounting bolts. The end cover can be cracked by overtorquing fittings or plugs installed in the end cover. Repair or replace the compressor as necessary.
Loose crankcase end cover or bottom cover.	Check the capscrew torques and tighten as necessary. Replace gaskets or O-ring.
Loose oil supply or return line fittings.	Check the torque of external oil line fittings and tighten as necessary.
Porous compressor casting.	Replace the compressor if porosity is found.
Mounting flange or end cover, O-ring or gasket missing, cut, or damaged.	Replace as necessary.

Problem—Compressor Constantly Cycles; Compressor Remains Unloaded for a Very Short Time

Problem—Compressor Constantly Cycles; Compressor Remains Unloaded for a Very Short Time	
Possible Cause	**Remedy**
Leaking compressor unloader pistons.	Repair or replace as necessary. Remove the compressor inlet air strainer or fitting. With the compressor unloaded (not compressing air), listen for air escaping.
Malfunctioning governor and installation.	Test the governor for proper operation and inspect air lines for kinks or restrictions. Repair or replace the governor or connecting air lines as required.
Excessive system leakage.	Test for excessive system leakage and repair as necessary. Use the following as a guide. Build system pressure to governor cutout and allow the pressure to stabilize for one minute. Using a test gauge, note the system pressure and the pressure drop after two minutes. The pressure drops should not exceed: • 2 psi (14 kPa) in each reservoir for a single vehicle; • 6 psi (41 kPa) in each reservoir for a tractor and trailer; • 8 psi (55 kPa) in each reservoir for a tractor and two trailers.
Excessive reservoir contaminants.	Drain reservoirs.

Problem—Compressor Leaks Coolant

Problem—Compressor Leaks Coolant	
Possible Cause	**Remedy**
Improperly installed plugs and coolant line fittings.	Check torque of fittings and plugs and tighten as necessary. Overtorqued fittings and plugs can crack the head or block casting.
Freeze cracks due to improper antifreeze strength.	Test antifreeze and strengthen as necessary. Check coolant flow through compressor to assure the proper antifreeze mixture reaches the compressor.
Malfunctioning compressor due to porous castings.	If casting porosity is detected, replace the compressor.

Troubleshooting

Problem—Compressor Head Gasket Malfunction

Problem—Compressor Head Gasket Malfunction	
Possible Cause	**Remedy**
Restricted discharge line.	Clear restriction or replace line.
Loose cylinder head capscrews.	Tighten evenly to a torque of 265 to 292 lbf·in (2990 to 3300 N·cm).
Malfunctioning compressor or head gasket.	Check for rough or poorly machined head or block surfaces. Replace compressor as necessary.

Problem—Excessive Oil Passage

Problem—Excessive Oil Passage*	
Possible Cause	**Remedy**
Restricted air intake.	Check engine air cleaner and replace if necessary. Check compressor air inlet for kinks and excessive bends, and be certain inlet lines have the minimum specified inside diameter. Recommended maximum air inlet restriction is 25 inches of water.
Restricted oil return to engine.	Oil return to the engine should not be in any way restricted. Make certain oil drain passages in the compressor and mating engine surfaces are unobstructed and aligned. Correct gaskets must be used. Special care must be taken when sealants are used with, or instead of, gaskets.
Poorly filtered air inlet.	Check for a damaged or dirty air filter on the engine or compressor. Check for leaking or damaged compressor air intake components such as induction line, fittings, gaskets, and filter bodies. The compressor intake should not be connected to any part of the exhaust gas recirculation (E.G.R.) system on the engine.
Insufficient compressor cooling (compressor runs hot).	For air-cooled portions of the compressor: • Remove accumulated grease and dirt from the cooling fins. Replace damaged components. • Check for damaged cooling fins. Replace compressor if damaged. For water-cooled portions of the compressor: • Check for proper coolant line sizes. Minimum recommended line i.d. is 3/8 inch (10 mm). • Check the coolant flow through the compressor. Minimum allowable flow is 2.5 gallons (9 L) per minute at engine governed speed. If low coolant flow is detected, inspect the coolant lines and fittings for accumulated rust scale, kinks, and restrictions. • Water temperature should not exceed 200°F (93°C). • Optimum cooling is achieved when engine coolant flows as shown in **Fig. 1**.
Contaminants not being regularly drained from system reservoirs.	Check reservoir drain valves to insure that they are functioning properly. It is recommended that the vehicle be equipped with functioning automatic drain valves or have all reservoirs drained to zero psi daily, or optimally, to be equipped with a desiccant-type air dryer prior to the reservoir system.

Troubleshooting

Problem—Excessive Oil Passage*	
Possible Cause	**Remedy**
Compressor runs loaded an excessive amount of time.	Vehicle system leakage should not exceed 1 psi (7 kPa) pressure drop per minute without brakes applied and 3 psi (21 kPa) pressure drop per minute with brakes applied. If leakage is excessive, check for system leaks and repair any leaks.
Excessive engine crankcase pressure.	Test for excessive engine crankcase pressure and repair or replace ventilation components as necessary. NOTE: An indication of crankcase pressure is a loose or partially lifted dipstick.
Excessive engine oil pressure.	Check the engine oil pressure with a test gauge and compare the reading to the engine specifications. Bendix does not recommend restricting the compressor oil supply line because of the possibility of plugging the restriction with oil contaminants. Minimum oil supply line size is 3/16-inch (5-mm) i.d. tubing.
Malfunctioning compressor.	Replace or repair the compressor only after making certain none of the preceding conditions exist.

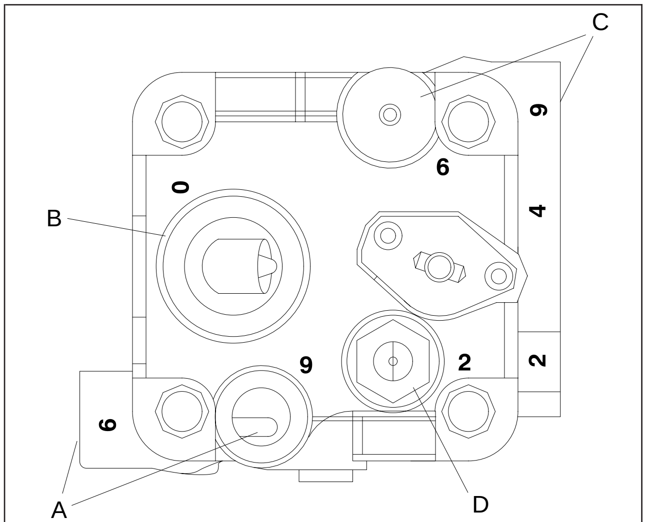
* Compressor passes excessive oil as evidenced by presence of oil at the exhaust ports of valving.

Problem—Excessive Buildup and Recover Time

Problem—Excessive Buildup and Recover Time*	
Possible Cause	**Remedy**
Dirty induction air filter.	Inspect engine or compressor air filter and replace if necessary.
Restricted induction line.	Inspect the compressor air induction line for kinks and restrictions and replace as necessary.
Restricted discharge line or compressor discharge cavity.	Inspect the compressor discharge port and line for restrictions and carbon buildup. If carbon buildup is found, check for proper compressor cooling. Replace faulty sections of the discharge line.
Slipping drive components.	Check for faulty drive gears and couplings and replace as necessary. Check the condition of drive belts and replace or tighten, whichever is appropriate.
Excessive air system leakage.	Test for excessive system leakage and repair as necessary. Use the following as a guide. Build system pressure to governor cutout and allow the pressure to stabilize for one minute. Using a test gauge, note the system pressure and the pressure drop after two minutes. The pressure drops should not exceed: • 2 psi (14 kPa) in each reservoir for a single vehicle; • 6 psi (41 kPa) in each reservoir for a tractor and trailer; • 8 psi (55 kPa) in each reservoir for a tractor and two trailers.
Sticking unloader pistons.	Check the operation of the unloading mechanism. Check for proper operation of the compressor air governor. Make certain the air connections between the governor and compressor are correct. See **Fig. 2**. If the governor is operating properly, replace the unloader mechanism. Inspect for bent, kinked, or blocked tubing leading to or from the governor.

Problem—Excessive Buildup and Recover Time*	
Possible Cause	**Remedy**
Malfunctioning compressor.	Repair or replace the compressor after determining none of the preceding conditions exist.

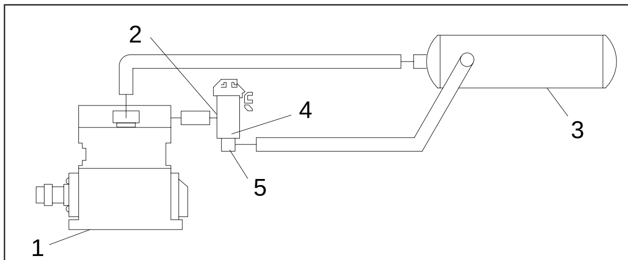
* Compressor should be capable of building air system pressure from 85 to 100 psi (586 to 689 kPa) in 40 seconds with engine at full governed rpm. Minimum compressor performance is certified to meet Federal requirements by the vehicle manufacturer. Do not downsize the original equipment compressor.



NOTE: The cylinder head connection ports are identified with the following numbers which are cast into the compressor: 0–Air In; 2–Compressed Air Out; 9–Coolant In or Out; 4–Governor Control.

A. Coolant In or Out (One of the two ports is plugged.)
B. Inlet Port
C. Coolant In or Out (One of the two ports is plugged.)
D. Discharge Safety Valve

Fig. 1, Cylinder Head Port Identification



1. Compressor
2. Governor Unloader Port
3. Supply Reservoir
4. Governor
5. Reservoir Port

Fig. 2, Plumbing Diagram

Specifications

BA-921 Specifications:

- Flow capacity at 1800 rpm and 120 psi (827 kPa): 11.8 cfm
- Flow capacity at 3000 rpm and 120 psi (827 kPa): 16.5 cfm
- Approximate horsepower required:
  - loaded 1800 rpm at 120 psig (827 kPa): 4.5 hp
  - unloaded 1800 rpm: 1.3 hp
- Minimum governor cutout pressure: 130 psi (896 kPa)
- Maximum inlet air temperature: 250°F (121°C)
- Maximum discharge air temperature: 400°F (204°C)
- Minimum oil pressure required at engine idle speed: 15 psi (103 kPa)
- Minimum oil pressure required at maximum governed engine speed: 15 psi (103 kPa)
- Number of cylinders: 1
- Weight: 28 pounds (13 kilograms)

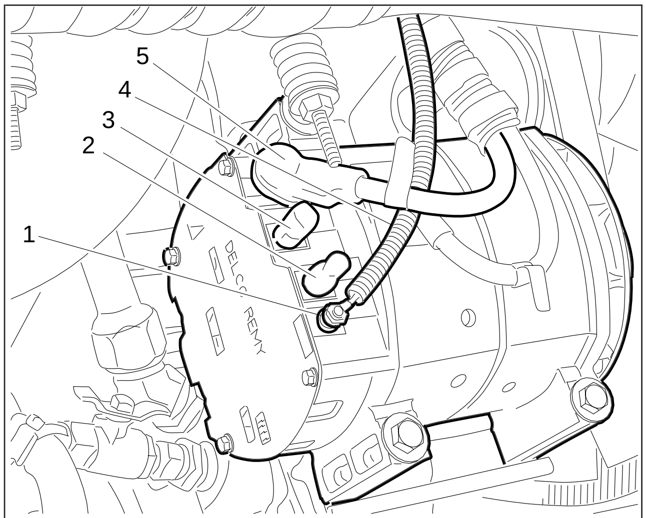
Fastener Torque Values	
Description	**Torque lbf·in (N·cm)**
Cylinder Head Capscrews	265 to 292 (2990 to 3300)
Unloader Cover Capscrew	62 to 71 (700 to 800)
Rear End Cover Capscrews	195 to 213 (2200 to 2400)
Governor Adapter	300 to 325 (3390 to 3672)
Crankcase Cover Capscrew	62 to 71 (700 to 800)
Crankshaft Nut	220 to 254 lbf·ft (298 to 344 N·m)

Table 1, Fastener Torque Values

General Information

Both Leece-Neville and Delco Remy alternators are available as original equipment on Freightliner vehicles. Installation and removal are the same for all alternators on a given engine design.

Many alternators are equipped with a remote-sense terminal that connects to the batteries, and adjusts the alternator output to keep the system at full charge. See **Fig. 1** for a Delco Remy alternator with remote sense. See **Fig. 2** for a Leece-Neville alternator with remote sense.



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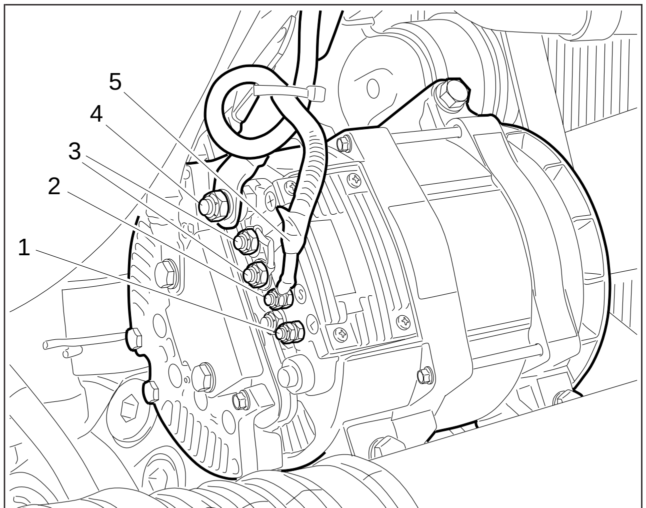
1. Remote-Sense Terminal
2. Indicator Terminal (lamp)
3. Relay Terminal 'R'
4. Remote Sense Circuit 123E
5. Positive Terminal (Battery)

Fig. 1, Delco Remy Alternator with Remote Sense



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1. Lamp Terminal 'L'
2. Remote-Sense Terminal 'S'
3. A.C. Terminals
4. Positive Terminal (Battery)
5. Remote Sense Circuit 123E

Fig. 2, Leece-Neville Alternator with Remote Sense

Removal

1. Apply the parking brake, shut down the engine, and chock the rear tires. Open the hood.
2. Disconnect the batteries.

NOTICE

Some vehicles are equipped with a cab load disconnect switch (CLDS). The CLDS does not disconnect power to the alternator and starter, so a short-circuit hazard still exists when working on the vehicle. The batteries must be disconnected to remove the short-circuit hazard when working on the charging system.

3. Remove the alternator drive belt, following the instructions in **Section 01.01** of this manual.

NOTE: Be sure the belt is working correctly before replacing the alternator. Many charging system problems originate in the drive belt. Inspect the belt for glazing, wear (frayed edges), damage (breaks or cracks), or oil contamination. Replace the belt if any of these conditions are present.

4. Note the wire connections on the terminals, then disconnect the wiring harness. Refer to **Subject 050** in this section for wiring connections.
5. Remove the alternator-mounting capscrews. Remove the alternator.
6. Remove the pulley for use on the new alternator. If the alternator is a Delco Remy, remove the pulley as follows:

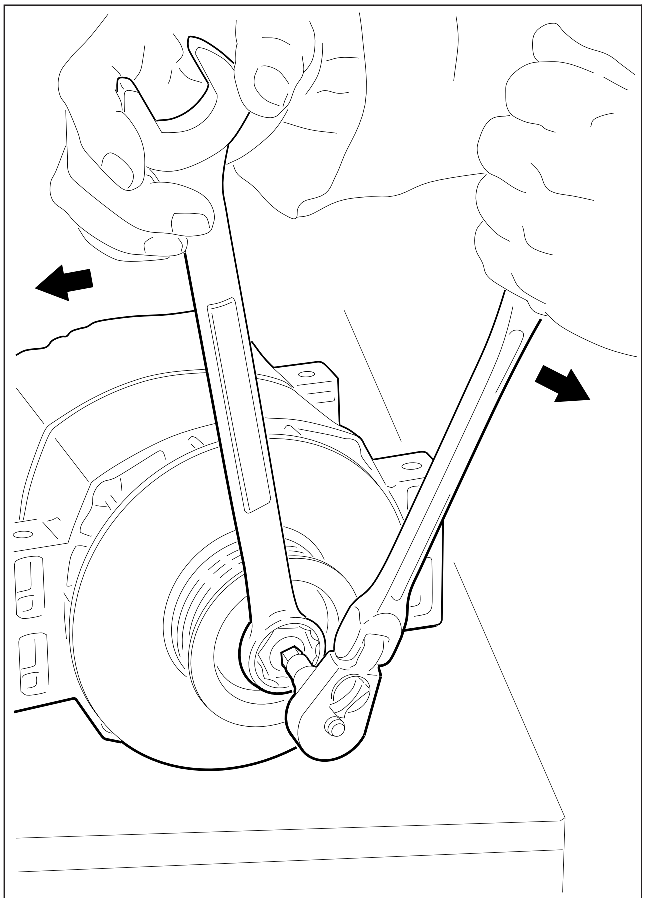
WARNING

Do not attempt to keep the pulley from turning with your hand, and do not jam a screwdriver into the cooling fins to keep it from turning, as you attempt to loosen the pulley nut. Using pulley nut removal and installation methods other than the one described below may cause personal injury, or damage the alternator and void the warranty.

6.1 Hold the alternator pulley retaining nut with a box-end wrench.

6.2 Insert a 5/16-inch Allen wrench into the Allen fitting in the rotor shaft.

6.3 Hold the rotor shaft with the Allen wrench, and turn the pulley nut counterclockwise to remove it. See **Fig. 1**. Remove the nut, washer, and pulley.



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Hold the rotor shaft with the Allen wrench, and turn the pulley nut counterclockwise to remove it. Remove the nut, washer, and the pulley.

Fig. 1, Loosening a Delco Remy Alternator Pulley Nut

Installation

1. For a Delco Remy alternator, install the pulley on the new alternator.

1.1 Hold the alternator pulley retaining nut with a box-end wrench.

1.2 Insert a 5/16-inch Allen wrench into the Allen fitting in the rotor shaft.

Removal and Installation

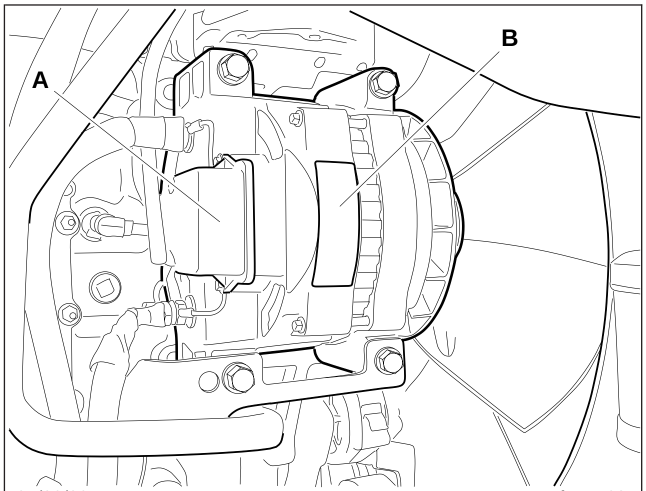
1.3 Hold the rotor shaft with the Allen wrench, and turn the pulley nut clockwise to tighten.

1.4 Tighten the pulley nut 75 lbf·ft (101 N·m).

2. Install the alternator.

2.1 Position the alternator on the engine. and start the mounting capscrews.

On Leece Neville pad-mounted alternators, belt alignment is obtained by the two mounting bolt holes closest to the alternators pulley. These holes are precision drilled so the alternator is positioned correctly on the engine bracket for proper belt alignment. When mounting a Leece-Neville alternator, it is important that the label or regulator face away from the engine block. If this is not adhered to then the belt alignment will not be correct. See **Fig. 2**.



A. Regulator must face away from the engine block.
B. Label must face away from the engine block.

Fig. 2, Leece-Neville Pad-Mounted Alternator Installation

2.2 Tighten the mounting capscrews 35 lbf·ft (48 N·m).

2.3 Install the drive belt following the instructions in **Section 01.01** of this manual.

3. As noted during removal, connect the wiring harness to the alternator terminals. Tighten the output-terminal hexnut 100 lbf·in (1140 N·cm). Tighten the ground-terminal hexnut 65 lbf·in (730 N·cm). Tighten the other terminal hexnuts 20 lbf·in (225 N·cm).

4. Protect any exposed terminal connectors with dielectric red enamel.

5. Connect the batteries.

6. Close and latch the hood, and remove the tire chocks.

Troubleshooting

IMPORTANT: Before testing, make sure:

- All belts are tensioned and are not cracked, worn, or glazed;
- The wiring and terminals are free of corrosion, properly torqued, and protected with dielectric enamel.

Pre-Test Checks

1. Shut down the engine, apply the parking brake, and chock the tires. Raise the hood.
2. If the vehicle is equipped with a remote-sense circuit, inspect as follows:

   2.1 Verify that the remote-sense wire (circuit # 123E) is connected to the remote sense terminal.

   2.2 Verify the fuse for the remote-sense circuit is not open. This fuse is located in the PTPDM on pre EPA 10 vehicles and is in the PNDB on EPA 10 vehicles. The remote sense terminal on the alternator will measure approximately 1/2 volt below battery voltage when the remote sense circuit (123E) fuse is open.
3. Check all connections between the battery, starter and alternator for tightness and signs of corrosion. Tighten, clean, and protect as necessary.

Using the Intelli-Check 2 Systems Analyzer

NOTE: The Intelli-Check 2 tester is recommended for alternator testing. It is capable of testing alternators with an output that is greater than the limit of the Intelli-Check (original) tester limit of 145 amps.

IMPORTANT: The batteries should be charged to at least 12.6 volts before performing the following tests. Remove the surface charge from freshly charged batteries by turning the headlights and blower fan on high for several minutes.

1. Using the Intelli-Check 2, perform a voltage drop test on the alternator cables. See **Fig. 1**.

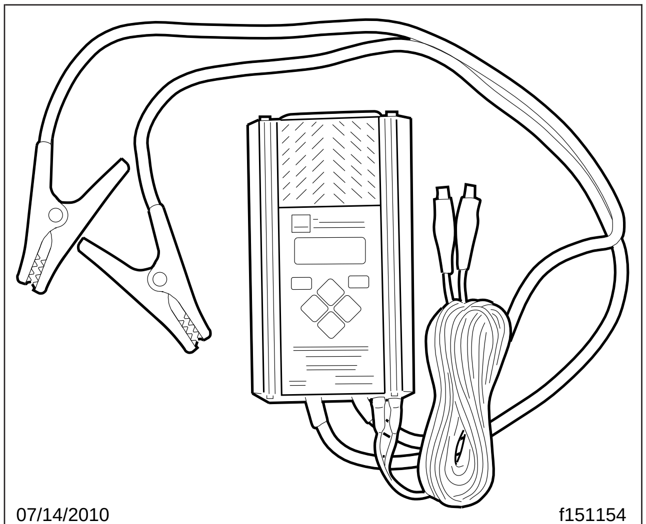


Fig. 1, Intelli-Check 2 Alternator Analyzer

   1.1 With the vehicle shut down, begin by turning the tester on. Select “Voltage Drop” Test and press Enter. Press ESC to bypass the vehicle ID screen.

   1.2 Select “Charging Cables” and press Enter. Enter the rated alternator output from the label on the alternator and press Enter.

   1.3 Connect the large leads to the alternator output terminal and ground and press Enter.

   NOTE: Disregard the tester summary of pass/fail. A voltage drop of 1/2 volt or less is acceptable.

   1.4 Connect the small leads to the battery. Press Enter to run the test. Use caution as the tester becomes warm during the test. If there is ½ volt or less voltage drop measured on each cable, the cables and connections are acceptable. If there is voltage drop in excess of ½ volt, locate and repair the cause before continuing with further testing.
2. Test the alternator using the Intelli-Check 2.

   2.1 With the vehicle shut down, begin by turning the tester on. Select “Alternator Test” and press Enter. Press ESC to bypass the vehicle ID screen.

2.2 Remove the small leads from the battery, leaving the large leads connected as they were in the voltage drop test and press Enter. The alternator rated output will ‘stick’ from the value used in the voltage drop test. Press Enter.

2.3 Start the engine. The amount of time it takes to walk back to the tester should have given the system enough time for the voltage to stabilize. Press Enter to begin the test.

2.4 When prompted, accelerate the engine to governed speed for 10 seconds.

2.5 Turn the engine off. The results will be displayed on the Intelli-Check 2.

Using the Intelli-Check (Original) Systems Analyzer

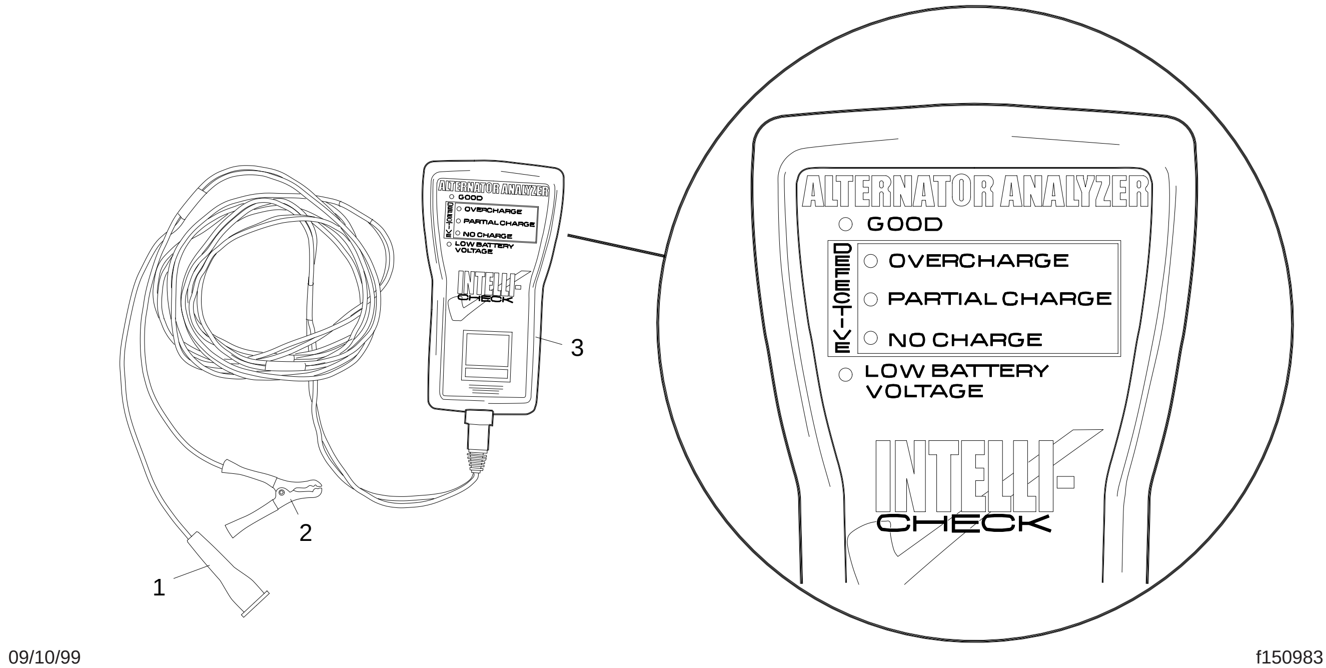
See **Fig. 2**.

1. With the engine off, connect the red alligator clip to the output terminal of the alternator. Connect the black alligator clip to the alternator ground. An optional ground connection is to the body of the alternator. The tester LEDs will illuminate and then go off as it performs a self-test.
2. After 4 seconds the tester will activate. The following LEDs may illuminate depending on the condition of the batteries:

   2.1 **GOOD** (green) LED indicates the battery voltage is above 12.8 and has a surface charge. The surface charge must be removed before proceeding with the alternator test. To remove the surface charge, turn on the headlights and blower fan for 2 minutes without restarting the engine. Reset the tester by disconnecting, then reconnecting the tester alligator clips. The analyzer will again perform its self-test.

   2.2 **NO CHARGE** (red) LED indicates the battery voltage is below 12.8. This LED should illuminate for most tests. Proceed with the alternator test.

   2.3 **LOW BATTERY VOLTAGE** (blue) LED indicates the battery voltage is below 12.35. If the batteries will start the vehicle, proceed with the alternator test.
3. Start the engine using onboard batteries only. If the batteries will not start the engine, they must be charged. Start the test again after charging the batteries and removing the surface charge.
4. Verify the engine is at idle and all electrical loads are off.
5. Depress the accelerator to governed speed, hold for 10 seconds, then return to idle.
   - If the **GOOD** (green) LED illuminates, proceed to the next step.
   - If any LEDs illuminate indicating overcharge, partial charge or no charge (the three red lights in the **DEFECTIVE** section), replace the alternator.
6. With the engine running, turn on all electrical loads.
7. Depress the accelerator to governed speed, hold for 10 seconds, then return to idle.
8. If the **GOOD** (green) LED illuminates, the alternator is OK and the test is complete.
9. If any LEDs illuminate indicating overcharge, partial charge or no charge (the three red lights in the **DEFECTIVE** section), replace the alternator.



1. Red Alligator Clip
2. Black Alligator Clip
3. Hand-Held Alternator Analyzer

Fig. 2, Intelli-Check Alternator Analyzer (original)

Specifications

Delco Remy Alternator, Terminal Fastener Torque		
Description	**Size**	**Torque: lbf·in (N·cm)**
Output ("BAT") Terminal Hexnut	5/16–18	100 (1140)
Ground ("GND") Terminal Hexnut	1/4–20	50 to 60 (565 to 675)
	5/16–18	60 to 90 (675 to 1016)
Terminal Hexnuts	10–24	20 (220)

Table 1, Delco Remy Alternator, Terminal Fastener Torque

Leece Neville Alternator, Terminal Fastener Torque		
Description	**Size**	**Torque: lbf·in (N·cm)**
Output ("BAT") Terminal Hexnut	5/16–24	100 (1140)
Ground ("GND") Terminal Hexnut	1/4–28	75 to 80 (850 to 900)
Remote Sense Terminal or Lamp Driver	M5 x 0.8	25 to 30 (280 to 330)

Table 2, Leece Neville Alternator, Terminal Fastener Torque

Pulley and Mounting Fastener Torque		
Description	**Size**	**Torque: lbf·ft (N·m)**
Pulley Nut Delco Remy	1/2–20	75 (102)
Pulley Nut Leece Neville	5/8–18	75 (102)
Mounting Capscrew	M10 X 1.5	35 (48)

Table 3, Pulley and Mounting Fastener Torque

General Information

The starter is mounted on the forward face of the flywheel housing. Under normal operating conditions, no maintenance will be required between engine overhaul periods. The starter has sealed bearings with lifetime lubrication. At the time of engine overhaul, replace the starter with one that has been remanufactured.

When the starter is engaged, the pinion gear extends outward to mesh with the ring gear on the engine flywheel. An overrunning clutch reduces the likelihood of the engine over driving the starter. Even with this protective feature, always release the keyswitch as soon as the engine starts to avoid overheating the overrunning clutch.

The starter is capable of drawing over 2000 amps and will quickly build up heat that could possibly cause damage. Never crank the starter continuously for more than 30 seconds, and always wait at least 2-minutes between cranking attempts. To prevent the starter from overheating, a thermal management model is incorporated in the starter control electronics. Starting is interrupted and disallowed when the software calculates the starter is too hot. If the starter does not engage after a previous crank attempt, or if cranking is only allowed for a few seconds, wait several minutes for the starter to cool down.

Principles of Operation

When battery power is applied to the magnetic switch activate terminal, cranking will begin. The magnetic switch sends power to the starter solenoid. The solenoid moves a lever which causes the pinion gear to engage with the ring gear on the flywheel. As the gears engage, battery power spins the starter motor.

When diagnosing starting problems, always begin with fully charged batteries, and perform a voltage drop test on the battery cables and magnetic-switch circuit. Once the engine is running, check that the alternator is properly charging the batteries.

A starter that cranks slowly, or just clicks when the keyswitch is turned, typically indicates a problem with supplying adequate power to the starter. Corrosion and loose connections in the battery cables will cause significant voltage drop and may prevent the starter from cranking the engine.

The bulkhead module monitors engine RPM, calculates the starter temperature, and analyzes the specific neutral conditions for the type of transmission. Cranking is not allowed if the engine is running, the transmission is engaged, or if the starter is too hot.

When the keyswitch is in the crank position, it supplies battery power to connector B6, pin A5 of the bulkhead module. This signals the bulkhead module to check for the required starter protection conditions. If these conditions pass, the BHM activates the starter output on connector B4, pin B. See **Fig. 1** for a mechanization diagram of the starter control circuitry on vehicles with an integrated magnetic switch. See **Fig. 2** for vehicles with a remote mounted magnetic switch.

NOTE: **Figure 2** is a combination diagram that shows the different starting interlock circuits that may be possible. No vehicle will have all of the circuits shown.

General Information

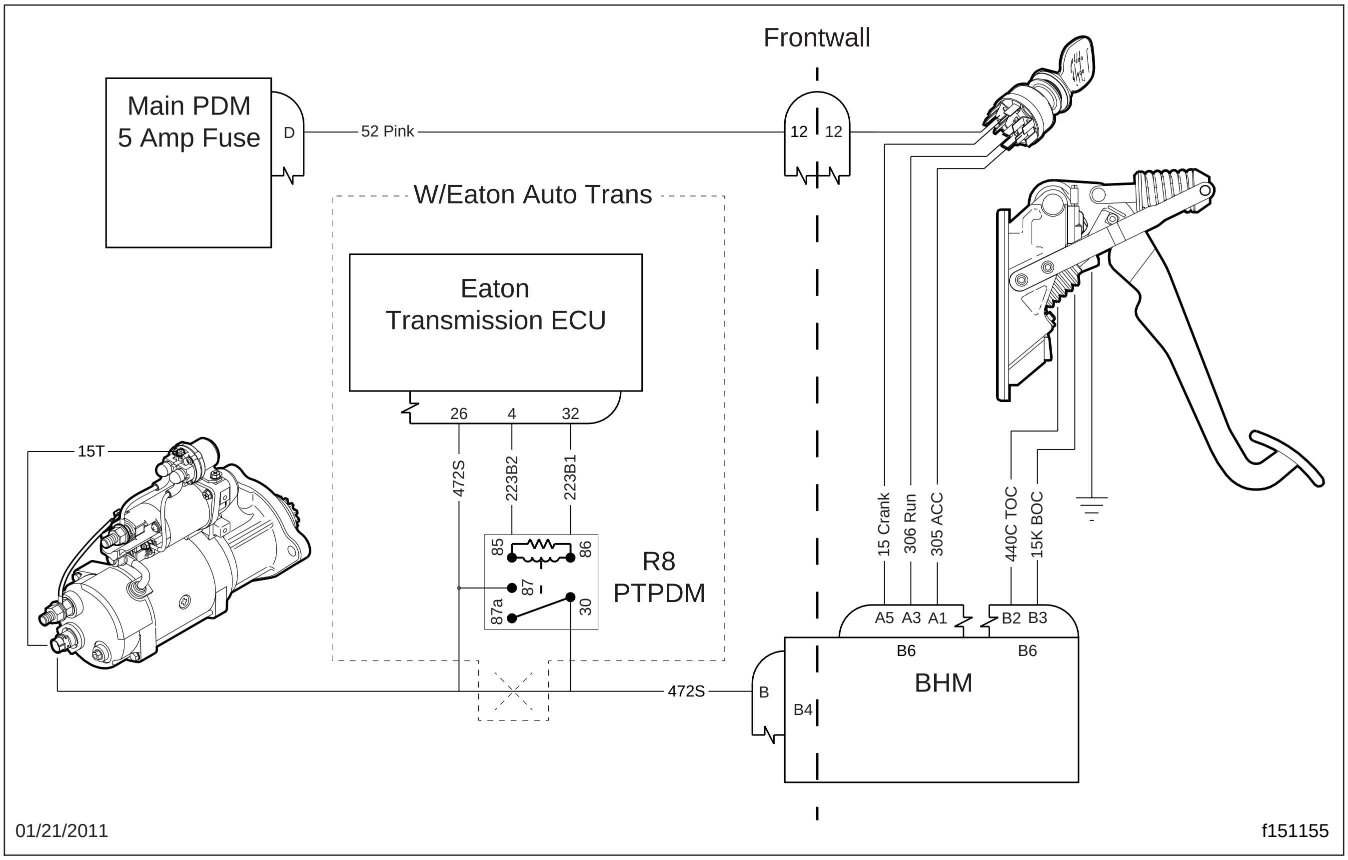


Fig. 1, Starter Control Circuitry with Integrated Magnetic Switch

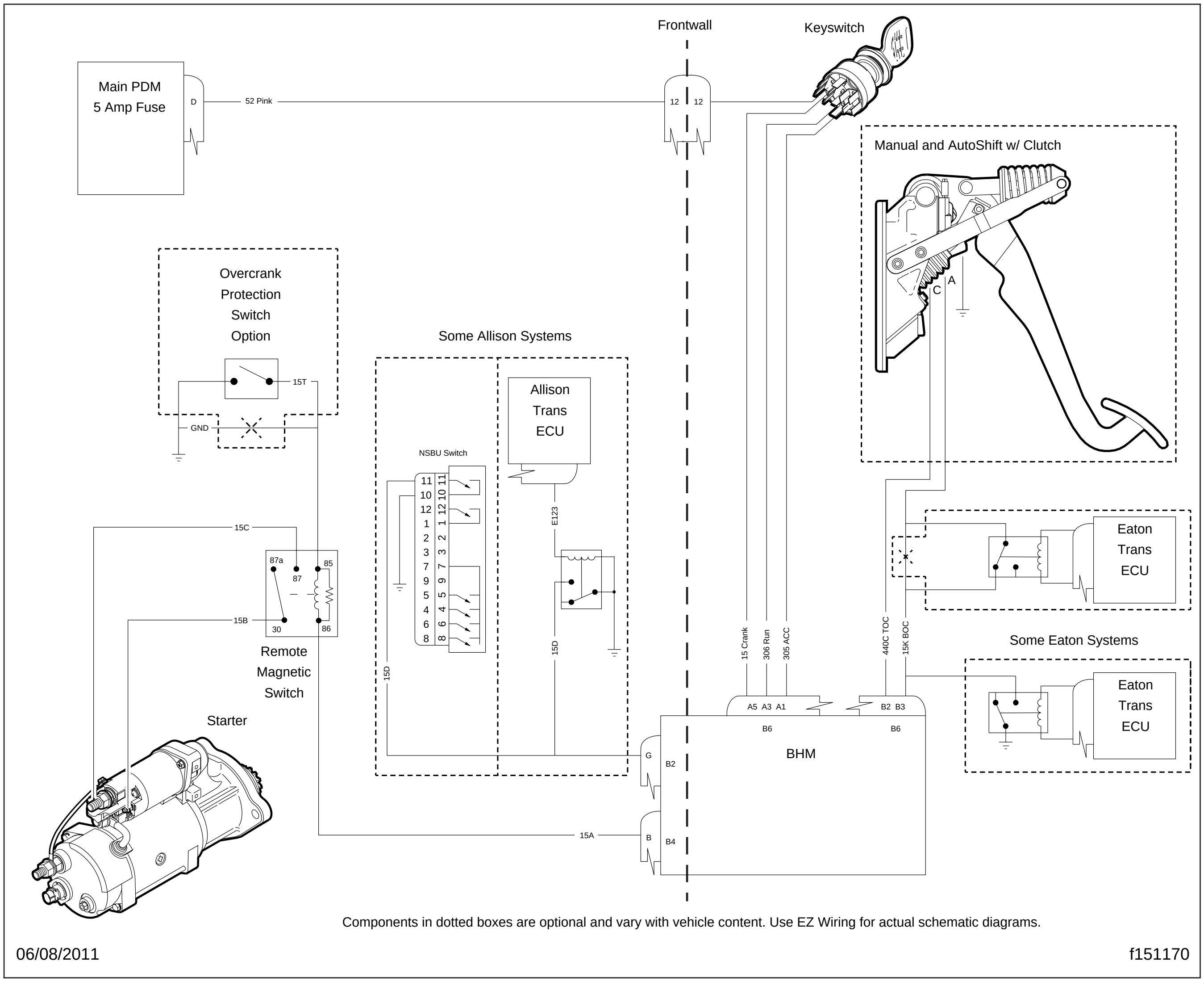


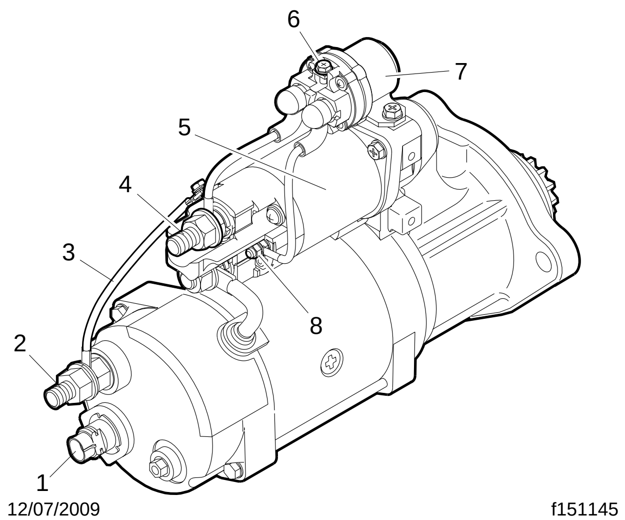
Fig. 2, Starter Control Circuitry with Remote Mounted Magnetic Switch

Starter Removal and Installation

Removal

Before replacing the starter, perform the checks in **Troubleshooting 300**.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Disconnect the negative battery cables at the batteries. Open the hood.
3. Disconnect and label the wiring that connects to the starter. See **Fig. 1**.



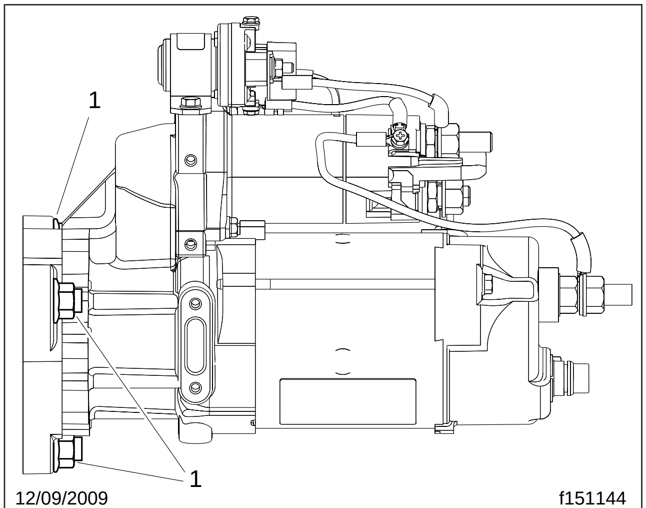
1. Over-Crank Protection Switch Terminal
2. Battery Ground Terminal
3. Ground Circuit to Starter Solenoid
4. Battery Positive Terminal
5. Solenoid
6. Magnetic Switch Activate Terminal
7. Magnetic Switch
8. Solenoid Activate Terminal

Fig. 1, Starter with Integrated Magnetic Switch (IMS)

4. Support the starter, then remove the bolts that mount it to the flywheel housing. See **Fig. 2**.

Installation

1. Place the starter into the mounting hole in the flywheel housing.
2. Hand start the three mounting bolts, then hand tighten them until snug. Using a torque wrench, tighten them to the values shown in **Specifications 400**.



1. Mounting Bolts

Fig. 2, Starter Mounting

3. Connect the wiring to the solenoid and starter as previously marked. Tighten the terminals to the torque values shown in **Specifications 400**.
4. Protect all exposed terminal connectors with dielectric red enamel.
5. Connect the batteries.

Starter System Troubleshooting

Use troubleshooting tables 1 through 5 for system diagnosis to reduce the likelihood of replacing a starter that is not defective, and to insure the complete starting system is tested.

Check for fault codes from Source Address 33 (BHM) and the transmission. Perform the recommended action in **Table 1** if fault codes from the BHM are shown. Use the applicable transmission manufacturers troubleshooting material if fault codes from the transmission control system are shown.

Vehicles with automated manual or automatic transmissions may have electrical hardware to interrupt or enable starting. Newer designs use serial data messaging to broadcast neutral status. Use EZ-Wiring to access the schematics for the vehicle and ServiceLink to analyze which neutral and starter interlock conditions are being broadcast by the transmission controller.

If the vehicle has an Allison transmission and a NSBU, the shift lever must be in the N, PB, or P position to close the switch between pins 10 and 11. The NSBU is located on the drivers side of the transmission case. If the NSBU requires adjustment, use the procedure in the Allison service manual.

If the vehicle is equipped with an automated or automatic transmission, also check for any fault codes with gear position selection and control. If the transmission is not confirmed to be in neutral, the transmission controller will not allow the engine to be started.

See **Table 2** for troubleshooting related to the starter cranking slowly, or making repeated clicking sounds.

See **Table 3** for troubleshooting problems relating to the starter doing nothing, or making only a single click for vehicles with an integrated magnetic switch.

See **Table 4** for troubleshooting problems relating to the starter doing nothing, or making only a single click for vehicles with an remote mounted magnetic switch.

See **Table 5** for troubleshooting relating to the starter making spinning or grinding sounds.

Starting System Faults from SA 33					
SPN	**FMI**	**Conn/Pin**	**Description**	**Behavior**	**Action**
598	7	B6, pins B2 & B3	Clutch switch fault	The bottom of clutch switch and the top of clutch switch are both closed at the same time.	Check the clutch switch for an open or short in circuits 15K and 440C, between the BHM and the clutch switch.
6983	6	B4, pin B	Starter relay output circuit	Current too high when cranking is attempted.	Check for a short to ground on circuits 472S and 15T, between the BHM and the magnetic switch on the starter.
6986	7	B6, pins A1, A3, & A5	Ignition switch inputs fault	The ignition switch input circuits are in a combination of states that is not expected. E.G: • Pin A5 is at battery voltage but pin A3 is not. • Pin A3 is at battery voltage but pin A1 is not. • Pin A5 and A1 are at battery voltage.	Check for open circuit or short in circuits 305, 306, and 15, between the ignition switch and the BHM. Also check the ignition switch.

Table 1, Starting System Faults from SA 33

Troubleshooting

Slow Cranking or Repeated Clicking Sound but the Engine Does Not Start			
This symptom often indicates low voltage at the starter, or worn and binding starter components.			
Step	**Test Procedure**	**Test Result**	**Action**
1.	Check the ambient temperature. Is the temperature extremely cold?	Yes	Slow cranking due to extreme cold is a normal condition. Do not mistake slow cranking due to cold for slow cranking due to equipment malfunction. Go to step 2.
		No	Go to step 2.
2.	With the keyswitch in the ON position, and the engine not running, measure the voltage at the batteries. Is the voltage below 12 volts?	Yes	Charge the batteries then go to step 3. Perform an alternator test when the vehicle is able to start.
		No	Go to step 3.
3.	Test the batteries individually with the Midtronics battery tester. Are any batteries defective?	Yes	Replace any batteries that tested defective.
		No	Go to step 4.
4.	Use the Midtronics EXP HD1000TA tester to perform a voltage drop test on the starter cables. Is excessive voltage drop present?	Excessive voltage drop	Inspect for corroded and loose connections. Clean, tighten and repair all connections, then protect all exposed terminal connectors with dielectric red enamel.
		Ok	Go to step 5.
5.	Turning the keyswitch to START (cranking), measure the voltage at the magnetic switch activate terminal. Is battery voltage present?	No voltage, or intermittent voltage	Use the troubleshooting procedures in the table titled Starter Does Nothing, or Makes Only a Single Click.
		Yes	Replace the starter.

Table 2, Slow Cranking or Repeated Clicking Sound but the Engine Does Not Start

Starter Does Nothing or Makes Only a Single Click—Vehicles with an Integrated Magnetic Switch			
This symptom often indicates a problem with the magnetic switch or starter solenoid circuit. Worn components in the starter or engine can also create binding and result in this symptom.			
Step	**Test Procedure**	**Test Result**	**Action**
1.	With the keyswitch in the START (crank) position, measure the voltage at the magnetic switch activate terminal. Is battery voltage present?	Yes	Go to step 2.
		No	Go to step 3.
2.	Use the Midtronics EXP HD1000TA tester to perform a voltage drop test on the starter cables. Is excessive voltage drop present?	Excessive voltage drop	Inspect for corroded and loose connections. Clean, tighten and repair all connections, then protect all exposed terminal connectors with dielectric red enamel.
		No	Replace the starter.
3.	With the keyswitch in the START (crank) position, measure the voltage on connector 6, pin A5 of the bulkhead module Is battery voltage present?	Yes	Go to step 5.
		No	Go to step 4.

Starter Does Nothing or Makes Only a Single Click—Vehicles with an Integrated Magnetic Switch			
This symptom often indicates a problem with the magnetic switch or starter solenoid circuit. Worn components in the starter or engine can also create binding and result in this symptom.			
Step	**Test Procedure**	**Test Result**	**Action**
4.	Measure the voltage on circuit 52 at the keyswitch. Is battery voltage present?	Yes	Troubleshoot for an open in circuit 15 between the keyswitch and the BHM, and for an open keyswitch.
		No	Check for an open 5 amp fuse (F5) in the main PDM. Test for a wiring fault in circuit 52 between the PDM and the keyswitch and in circuits 15, 305, and 306 between the keyswitch and the BHM.
5.	With the keyswitch in the START (crank) position, measure the voltage on connector 4, pin B of the bulkhead module. Is battery voltage present?	Yes	Go to step 6.
		No	Allow time for the starter protection temperature model to calculate that the starter has cooled off. Troubleshoot for a wiring fault in the bottom of the clutch switch circuit on connector 6, pin B3. If the vehicle has an automated transmission, troubleshoot for faults with gear position and control circuits, otherwise replace the bulkhead module.
6.	Does the vehicle have an Eaton automated transmission?	Yes	Ensure the transmission is in neutral. Test for a wiring fault in circuit 472S between the bulkhead module and relay R8 in the PTPDM. Test for a fault with the transmission control of R8 and repair if necessary. If R8 testing passes, test circuit 472S to the overcrank protection switch in the starter, and circuit 15T to the magnetic switch.
		No	Test for a wiring fault in circuit 472S between the bulkhead module and the starter. If the starter uses the internal overcrank protection switch, test circuit 15T from the overcrank protection switch to the magnetic switch.

Table 3, Starter Does Nothing or Makes Only a Single Click—Vehicles with an Integrated Magnetic Switch

Starter Does Nothing or Makes Only a Single Click—Vehicles with a Remote Mounted Magnetic Switch			
This symptom often indicates a problem with the magnetic switch or starter solenoid circuit. Worn components in the starter or engine can also create binding and result in this symptom.			
Step	**Test Procedure**	**Test Result**	**Action**
1.	With the keyswitch in the START (crank) position, measure the voltage at the starter solenoid (circuit 15C) activate terminal. Is battery voltage present?	Yes	Go to step 2.
		No	Go to step 3.

Troubleshooting

Starter Does Nothing or Makes Only a Single Click—Vehicles with a Remote Mounted Magnetic Switch			
This symptom often indicates a problem with the magnetic switch or starter solenoid circuit. Worn components in the starter or engine can also create binding and result in this symptom.			
Step	**Test Procedure**	**Test Result**	**Action**
2.	Use the Midtronics EXP HD1000TA tester to perform a voltage drop test on the starter cables. Is excessive voltage drop present?	Excessive voltage drop	Inspect for corroded and loose connections. Clean, tighten and repair all connections, then protect all exposed terminal connectors with dielectric red enamel.
		No	Replace the starter.
3.	With the keyswitch in the START (crank) position, measure the voltage on connector 6, pin A5 of the bulkhead module Is battery voltage present?	Yes	Go to step 5.
		No	Go to step 4.
4.	Measure the voltage on circuit 52 at the keyswitch. Is battery voltage present?	Yes	Troubleshoot for an open in circuit 15 between the keyswitch and the BHM, and for an open keyswitch.
		No	Check for an open 5 amp fuse (F5) in the main PDM. Test for a wiring fault in circuit 52 between the PDM and the keyswitch and in circuits 15, 305, and 306 between the keyswitch and the BHM.
5.	With the keyswitch in the START (crank) position, measure the voltage on connector 4, pin B of the bulkhead module. Is battery voltage present?	Yes	Go to step 6.
		No	Allow time for the starter protection temperature model to calculate that the starter has cooled off. Use EZ wiring to access the vehicle wiring schematic and determine if the vehicle uses the clutch switch input on BHM connector B6, pin 3 or the neutral input on connector B2 pin G. If none of these hardwire inputs are used, connect ServiceLink to determine if the transmission controller is detecting neutral gear. If either of these hardwire neutral/ clutch inputs are used, use the vehicle schematic to determine where the ground signal is interrupted. This circuit must be at ground to enable starting. If the circuit is at ground replace the bulkhead module.
6.	Allow time for the starter protection model to calculate that the starter has cooled. Then with the keyswitch in the START position, measure for battery voltage across the 15A circuit and the ground circuit at the magnetic switch on the two small terminals. Is battery voltage present?	Yes	Troubleshoot and repair for an open magnetic switch or a wiring fault in circuit 15B or 15C between the starter and the magnetic switch.
		No	Troubleshoot and repair for an open magnetic switch, an open overcrank protection switch, or for a wiring fault in circuit 15A between the BHM and the magnetic switch or for an open ground circuit at magnetic switch or overcrank protection switch.

Table 4, Starter Does Nothing or Makes Only a Single Click—Vehicles with a Remote Mounted Magnetic Switch

Starter Makes Spinning or Grinding Sounds but the Engine Does Not Crank.			
This symptom often indicates a mechanical problem with the starter or the ring gear.			
Step	**Test Procedure**	**Test Result**	**Action**
1.	With the keyswitch in the START (crank) position, test the voltage at the starter battery cable connections. Is battery voltage present?	Low or No	Go to step 2.
		Yes	Go to step 3.
2.	Use the Midtronics EXP HD1000TA tester to perform a voltage drop test on the starter cables. Is excessive voltage drop present?	No	Go to step 3.
		Excessive voltage drop	Inspect for corroded and loose connections. Clean, tighten and repair all connections, then protect all exposed terminal connectors with dielectric red enamel
3.	Remove the starter and inspect the starter pinion gear for milling. Attempt to spin the pinion gear in both directions. The overrunning clutch will allow the gear to be turned in the clockwise direction, but it should be extremely difficult or impossible to turn in the counter clockwise direction.	Ok	Go to step 4.
		Defective	Replace the starter.
4.	Bar the engine over to inspect the 3 positions on the ring gear where the starter engages.	Damaged	Replace the ring gear.

Table 5, Starter Makes Spinning or Grinding Sounds but the Engine Does Not Crank

Specifications

Torque Values, Starter-Motor to Flywheel-Housing Bolts		
Fastener Description	**Size**	**Torque Value: lbf·ft (N·m)**
MBE 400, DD 13/15/16	M10 x 1.5	38±5 (51±7)
Cummins ISB	M10 x 1.5	38±5 (51±7)
Cummins ISC/ISL	M12 x 1.5	58±5 (78±7)
CAT 3176, 3406, 10/12, Cummins ISX	5/8–11	100±48/-0 (+65)

Table 1, Torque Values, Starter-Motor to Flywheel-Housing Bolts

Torque Values, Starter Connections		
Magnetic Switch (+)	**Solenoid Battery (+)**	**Starter Ground (–)**
18 to 21 lbf·in (200 to 250 N·cm)	18 to 20 lbf·ft (24 to 28 N·m)	18 to 20 lbf·ft (24 to 28 N·m)

Table 2, Torque Values, Starter Connections

General Information

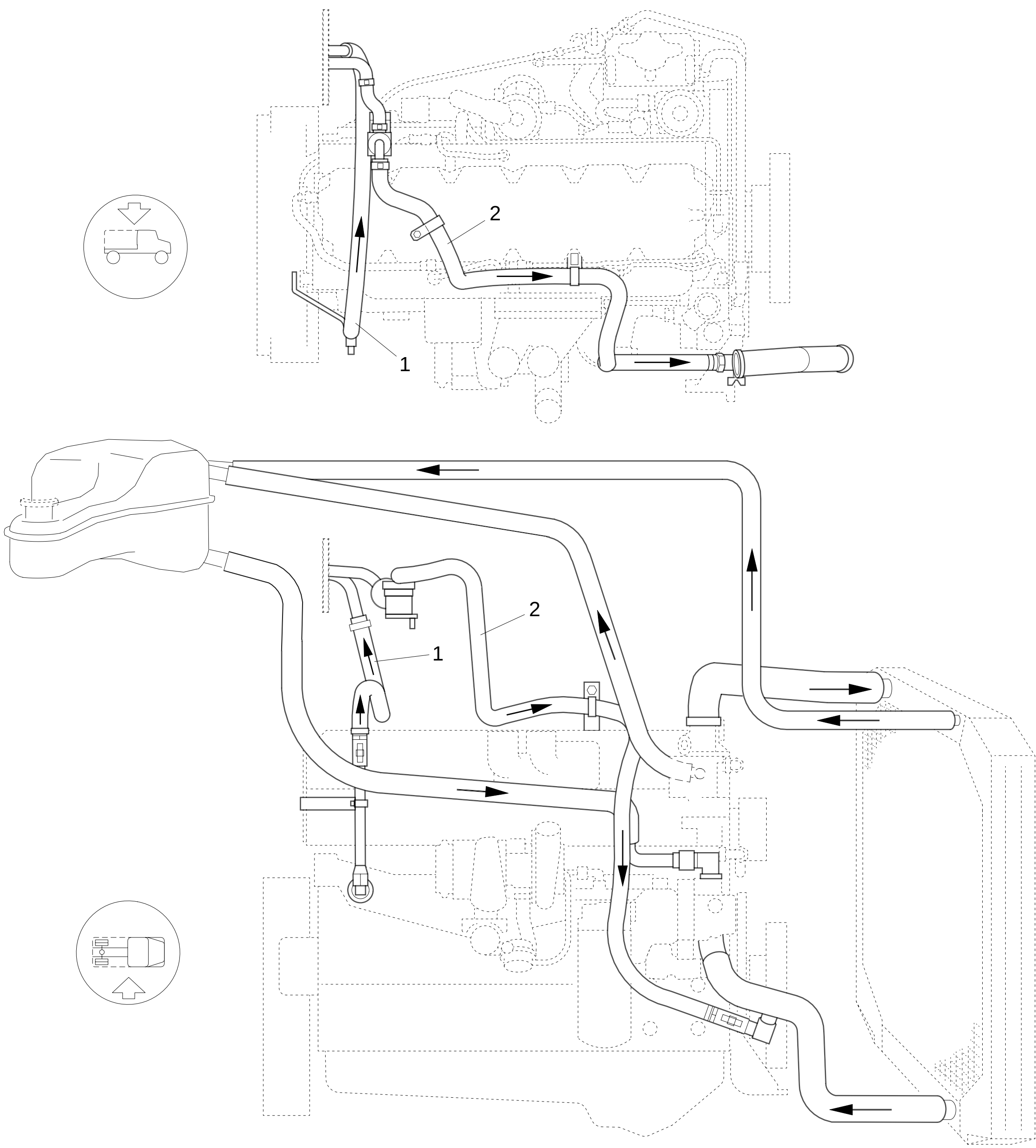
The main function of a cooling system is to keep the engine at its optimum operating temperature. This results in the most efficient use of fuel and allows the engine oil to provide a good lubricating film. For the typical coolant plumbing, see **Fig. 1**.

The cooling system is a high-flow design, where most of the coolant in a warm engine moves relatively quickly across the radiator in a single pass.

Coolant flows from the radiator to the water pump, which forces the coolant into the engine block. Inside the block, the coolant flows around and between the cylinders, and then up into the cylinder head. From the head, it flows to the temperature regulator (thermostat) housing. If the engine is cool, the thermostat directs the coolant back to the water pump, and the water pump forces the coolant back into the engine. As the engine warms, the thermostat directs the coolant to the radiator. The thermostat keeps the engine temperature in the optimum range by controlling the two flows.

To prevent air and vapor from being trapped in the radiator or engine, vent lines rise from the high points where air and vapor would collect in those components. The vent lines carry any collected air to the surge tank.

General Information



1. Heater Supply Hose
2. Heater Return Hose

Fig. 1, Coolant Plumbing (typical)

Troubleshooting

Possible causes of abnormally high or low coolant temperatures are listed below. For repairs, see other sections of this manual or the engine and component manufacturer's service publications.

Problem—Coolant Temperature Above Normal

Problem—Coolant Temperature Above Normal	
Possible Cause	**Remedy**
Coolant leakage (see possible sources below) is causing a low coolant level. External Leakage: hoses and hose connections radiator seams, core, petcock and cap block core and drain plugs water pump thermostat housing surge tank heater hoses and core temperature sending unit(s) cylinder head(s) mating (gasket) surfaces coolant filter oil cooler Internal Leakage: cylinder head gasket warped head or block surfaces cracked cylinder head or block cylinder head capscrews loose, missing, or tightened unevenly oil cooler aftercooler.	Do the repairs necessary to stop the leaks. Fill to the surge tank sight glass with the correct mixture of antifreeze and water. See Group 20 of the *Business Class M2 Maintenance Manual* for coolant specifications.
Inoperative temperature gauge	Check the gauge wiring, circuit breaker, and sending unit. If the gauge circuit is okay, replace the temperature gauge. If the gauge circuit is broken, repair it and then check the temperature gauge operation.
Clogged radiator, aftercooler, or condenser fins	Clean the outside of the core and the condenser with compressed air directed from the fan side, or with water and a mild laundry soap. Straighten bent fins.
Collapsed or plugged radiator hose	Replace the hose(s).
Loose fan belt or water pump belt	Adjust belt tension.
Damaged cooling fan shroud	Repair or replace the shroud.
Incorrect or malfunctioning radiator cap	Make sure the correct radiator cap is installed. If the cap does not hold the correct pressure, replace it.
Viscous fan drive not operating to specifications	Check for unobstructed airflow through the radiator core, aftercooler, and condenser to the fan clutch sensor. Check that the radiator core is getting hot in front of the fan clutch (core is not internally clogged in that area) so that the sensor is getting a correct reading. If no radiator problems exist, refer to the viscous fan clutch section in this group for fan clutch inspection procedures and operation tests.
Incorrect engine oil level	Fill to the high (H) mark on the dipstick.
Too much antifreeze in system	Clean and flush the cooling system. Refill the system with the correct mixture of antifreeze and water.
Incorrect or inoperative thermostat	Make sure the correct thermostat is installed in the temperature regulator housing. Test the thermostat according to the engine manufacturer's instructions. Replace it if it does not operate correctly.
Malfunctioning water pump	Repair or replace the water pump.

Troubleshooting

Problem—Coolant Temperature Above Normal	
Possible Cause	**Remedy**
Internally plugged or damaged radiator core	To check for blockages, warm the engine to normal operating temperature. Turn off the engine, and run your hand over the finned surface of the radiator. If there is a blockage in the radiator, it should cause an obvious temperature difference from one area of the core to another. An obvious difference between inlet and outlet temperatures is normal. If blockage is suspected, clean and flush the cooling system. Repair or replace a damaged core.
Air or combustion gases entering cooling system	Check the cylinder heads, head gaskets, cylinder liners, and aftercooler for leaks. Repair or replace parts, as necessary.
Internally plugged or damaged aftercooler	Repair or replace the aftercooler.
Internally plugged or damaged oil cooler	Repair or replace the oil cooler.
Engine receiving too much fuel	Refer to the engine manufacturer's fuel delivery system adjustment procedures.
Wrong replacement fan installed	Install the correct fan.
Exhaust blockage	Remove the blockage.
Frozen coolant in radiator due to subfreezing temperatures	Use the proper antifreeze-to-water ratio needed for winter temperatures.

Problem—Coolant Temperature Below Normal

Problem—Coolant Temperature Below Normal	
Possible Cause	**Remedy**
Inoperative temperature gauge	Check the gauge circuit wires, circuit breaker, and sending unit. If the gauge circuit is okay, replace the temperature gauge. If the gauge circuit is broken, repair it and then check the temperature gauge operation.
Viscous fan drive operates continuously	See **Section 20.02** of this manual for fan clutch inspection procedures and operation tests. Replace the fan drive if necessary.
Incorrect or inoperative thermostat	Make sure the correct thermostat is installed. Test the thermostat according to the engine manufacturer's instructions. Replace it if it does not operate correctly.

General Information

The main function of a cooling system is to keep the engine at its optimum operating temperature. This results in the most efficient use of fuel and allows the engine oil to provide a good lubricating film.

The central component of the cooling system, the radiator assembly, includes the surge tank (remote mounted on the firewall), the radiator, and the surge tank pressure relief cap.

The surge tank provides storage space for reserve coolant, expansion space for heated coolant, and deaeration space. When coolant in the radiator runs low, reserve coolant stored in the surge tank flows from the tank through the fill hose to the water pump. As the coolant heats and expands beyond radiator capacity, excess coolant travels back through the fill hose from the water pump to the surge tank. Any air trapped in the engine block or radiator rises to the top of the engine or radiator and escapes through the vent hoses to the surge tank.

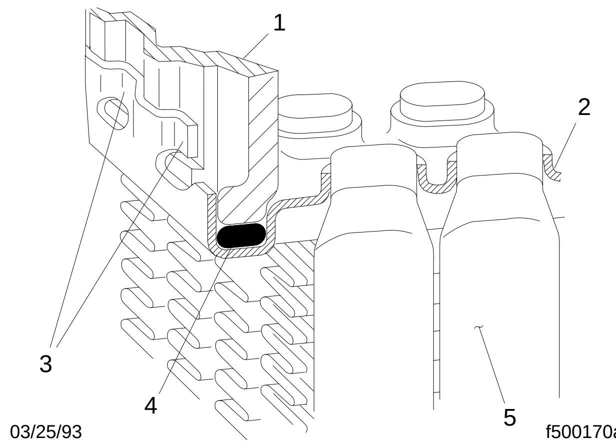
The low coolant level sensor in the surge tank warns the driver when coolant is running low. The surge tank is translucent polypropylene so you can see the coolant level and compare it to the maximum and minimum levels marked on the tank.

These vehicles use full-flow (or high-flow) radiators. With full-flow radiators, the coolant flows into the radiator at the top of the left side tank and flows out of the radiator at the bottom of the right side tank. Most of the engine coolant is routed through the radiator, and it moves relatively quickly in a single pass.

There are three sizes of two-row radiators in use:

- 805-square-inch area
- 870-square-inch area
- 1000-square-inch area

The radiators use glass-filled nylon side tanks. The edges of the radiator core header are compressed in a "dimple wave lock" crimp (see **Fig. 1**) that holds the tanks on the radiator core, and the tanks and core are held in steel channels that mount on the front closing crossmember. The radiator is also secured by struts that run between the top of the radiator and the firewall. The fins of the radiator core are reinforced along their forward edge to resist damage from road debris and pressure washing.



1. Nylon Tank
2. Radiator Header
3. Dimple Wave Lock Crimp
4. Sealing Gasket
5. Radiator Core

Fig. 1, Radiator Core and Header (cutaway view)

Because crimping holds the nylon side tanks tanks in place, the radiators can be disassembled and assembled.

The surge tank cap limits system pressure to about 11 to 12 psi (76 to 83 kPa), which raises the boiling point of the coolant. If the cooling system overheats, excess coolant is released through the overflow tube.

For more general information about the radiator and surge tank, and for cooling system troubleshooting procedures, refer to **Section 20.00**.

Radiator Removal and Installation

Removal

The 870-square-inch radiator is held in place by a support bracket that is attached to the front of the radiator, and to the closing crossmember. An isolator assembly is installed between the L-shaped radiator support bracket and the front closing crossmember. Four strut rods, attached to the sides of the radiator and the frontwall, stabilize the radiator. See **Fig. 1** for the installation drawing.

The 805-square-inch radiator mounts with brackets attached to the sides of the radiator that attach to isolators mounted on the frame rails. Two strut rods attach to the sides of the radiator and to brackets on the frame rail. See **Fig. 2** for the installation drawing.

The 1000-square-inch radiator is a cross flow configuration. It is attached to a mounting bracket on the closing crossmember by two studs with isolators. Three strut rods, attached to the top of the radiator and to brackets on the frontwall, stabilize the radiator. See **Fig. 3** for the installation drawing.

NOTE: The M2 112 may be equipped with a 1350-square-inch radiator, which mounts on a module support bracket under the charge air cooler.

1. Park the vehicle on a level surface, shut down the engine, set the parking brake. Chock the tires.
2. Open the hood.
3. Disconnect the hood damper from the bracket on the bumper by pulling the end of the cylinder out of the nylon clip.

WARNING

Drain the coolant only when the coolant and engine are cool. Draining it when these are hot could cause severe personal injury due to scalding.

4. Drain the coolant.
   - 4.1 Remove the cap from the surge tank.
   - 4.2 Place a clean container under the radiator.
   - 4.3 Open the draincock at the bottom of the radiator.
5. If equipped, disconnect the transmission oil cooler hoses.
   - 5.1 Place a clean container under the hose connections.
   - 5.2 Disconnect the transmission oil cooler hoses from the radiator, or the transmission oil cooler, mounted below the radiator.

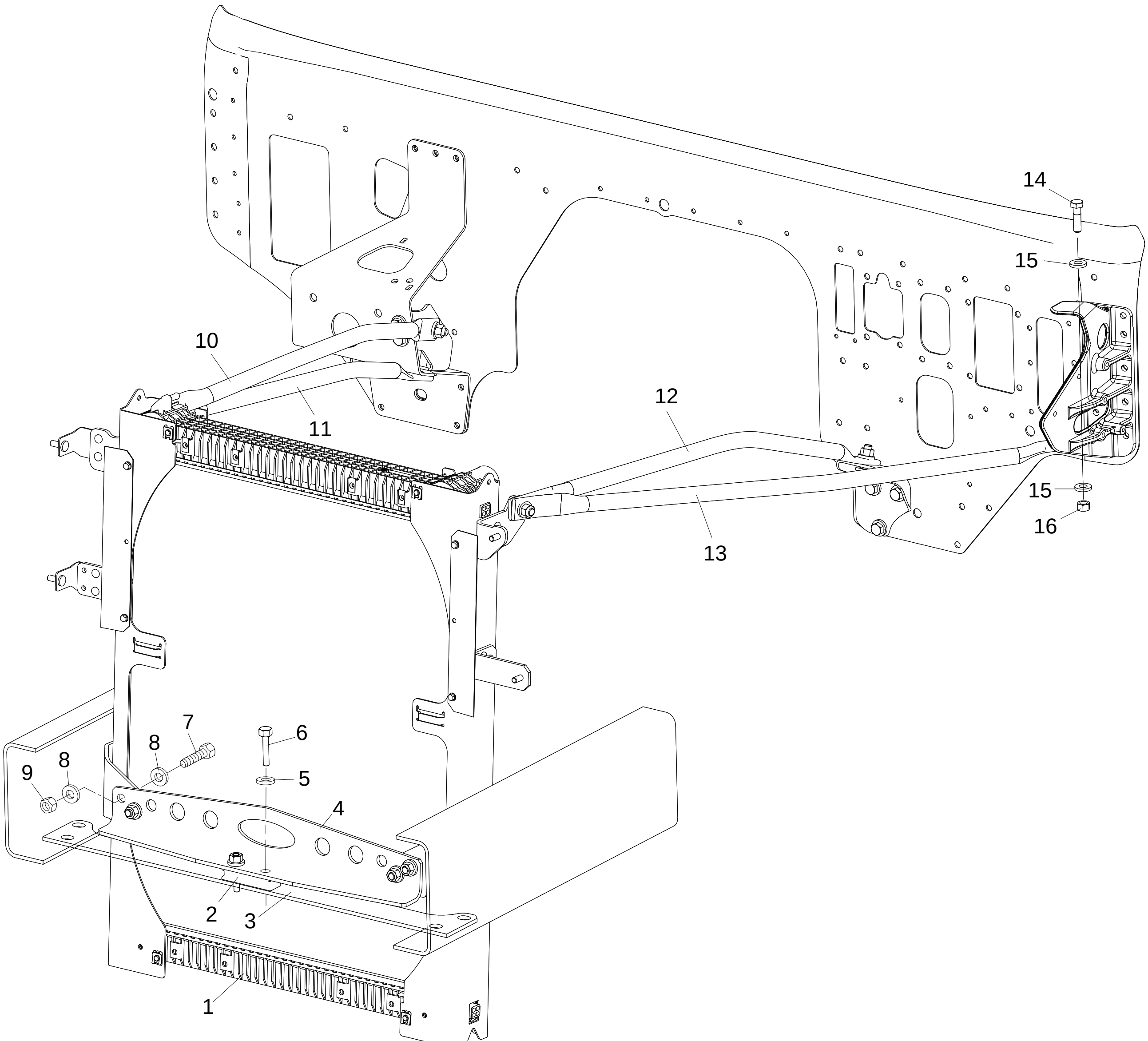
     After the hoses have drained, cover them to keep out dirt. Secure the hoses to the side, above the level of the automatic transmission.
6. Disconnect the upper and lower radiator hoses.
7. Disconnect the upper left surge tank hose from the radiator.
8. Disconnect the charge air cooler hoses from the charge air cooler.
9. With an assistant supporting the hood, disconnect the hood-stop cables from the top of the radiator and support the hood on a padded table.
10. Disconnect the radiator struts from the radiator. Swing them out of the way.
11. If equipped with a viscous fan clutch, remove the fan and clutch from the fan hub. See **Section 20.04**, Subject 110 for the procedure.
12. Remove the fasteners holding the fan shroud to the radiator, then remove the fan shroud.

NOTE: Do not disconnect the refrigerant lines.

13. Move the A/C condenser aside.
    - 13.1 Free up the refrigerant lines from any stand-off brackets near the radiator.
    - 13.2 Swing the condenser out of the way and wrap it with cardboard. Secure it with tie-straps.
14. Position a hoist over the radiator.
15. Connect straps or chains to the radiator.
16. Remove the nuts from the studs holding the radiator to the radiator support bracket.

    On the M2 112 with the 1350-square-inch radiator, remove the radiator mounting nuts from the module support bracket, underneath the charge air cooler.
17. Carefully move the radiator back toward the frontwall. If necessary, pry the lower bracket studs from the holes in the radiator support bracket.

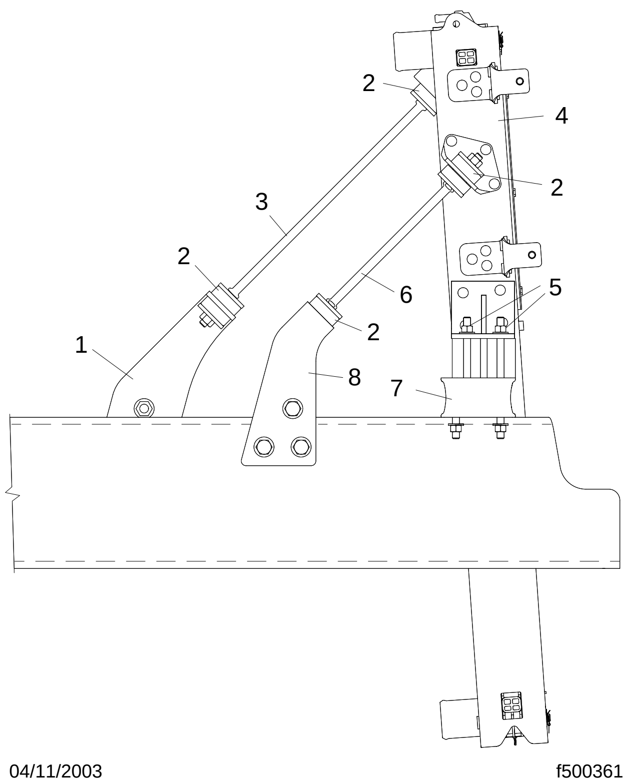
Radiator Removal and Installation



1. Radiator
2. Isolator
3. Front Crossmember
4. Support Bracket
5. Lockwasher
6. Hexbolt
7. Hexbolt
8. Flatwasher
9. Hexnut
10. Right Upper Strut Rod
11. Right Lower Strut Rod
12. Left Inner Strut Rod
13. Left Outer Strut Rod
14. Hexbolt
15. Washer
16. Hexnut

Fig. 1, 870-Square-Inch Radiator

18. Lift the radiator assembly from the vehicle.
19. If necessary, remove the charge air cooler from the radiator. For instructions, see **Group 09**.



1. Left Strut Rod Bracket
2. Strut Rod Bushing
3. Left Strut Rod
4. Radiator
5. Hexnuts
6. Right Strut Rod
7. Isolator
8. Right Strut Rod Bracket

Fig. 2, 805-Square-Inch Radiator

20. If the vehicle has a transmission oil cooler, remove it from the radiator. For instructions, see **Group 26**.

Installation

1. If there is a transmission oil cooler, install it on the radiator.
2. If it was removed, install the charge air cooler on the radiator. For instructions, see **Group 09**.
3. Using a suitable hoist, align the studs of the radiator lower brackets with the holes in the radiator support bracket, and lower the radiator into place.
4. For 870- and 1000-square-inch radiators, install the 1/2–13 hexnuts and washers onto the studs on the radiator lower brackets. Tighten 68 lbf·ft (92 N·m).

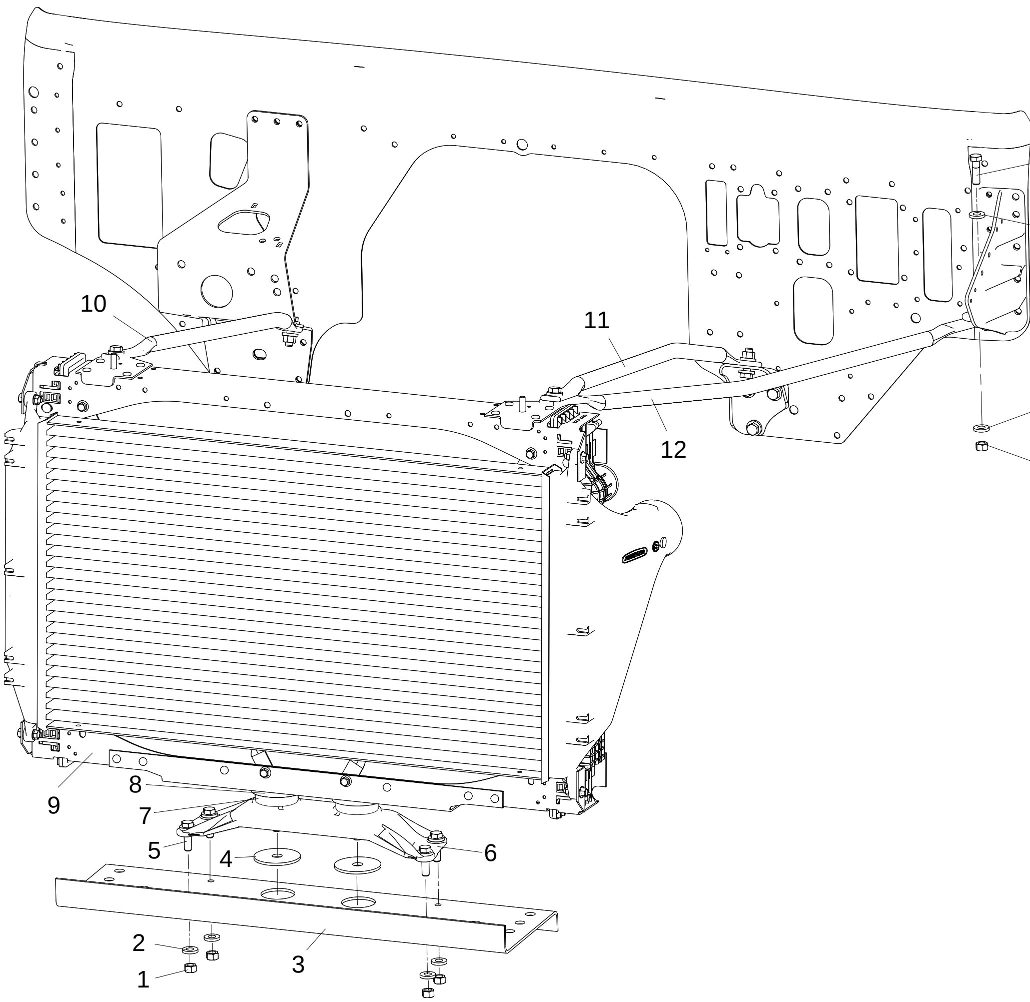
   For 805-square-inch radiators, install the nuts and washers on the studs on the isolators at the sides of the radiator.
5. Remove the chains or straps from the radiator.
6. Attach the radiator strut rods to the radiator. Tighten the 1/2–13 hexnuts 68 lbf·ft (92 N·m).
7. Install the air conditioner condenser on the front of the radiator. Tighten the fasteners firmly.
8. Install any standoff brackets that were removed from the refrigerant lines.
9. Install the fan shroud onto the radiator.
10. Install the fan and the viscous fan clutch on the fan hub. See **Section 20.04**, Subject 110, for the procedure.
11. Connect the upper surge tank hose to the radiator.
12. Connect the upper and lower radiator hoses.

    Remove the seals from the coolant hose ends, connect the hoses to the radiator, and tighten the hose clamps. See **Table 1** for proper torque values.

NOTE: Your hose clamps can be either T-bolt clamps (see **Fig. 4**), Breeze Constant-Torque clamps (see **Fig. 5**), or ABA clamps (see **Fig. 6**).

NOTE: All hose clamp adjusters lose torque after installation, due to cold-flow of the hose material from under the clamp. Breeze Constant Torque clamps typically show a 30 percent loss of torque shortly after installation; a 50 percent loss after heat-cycling, and up to 80 percent loss after time and repeated heat cycles. However, when correctly installed, Breeze Constant-Torque clamps adjust automatically, holding enough torque to keep consistent sealing pressure. During vehicle operation and shutdown, the screw tip may adjust in and out, according to temperature and pressure changes. The torque may need to be adjusted for individual applications.

Radiator Removal and Installation



1. Hexnut
2. Washer
3. Closing Crossmember
4. Washer
5. Hexbolt
6. Radiator Support Bracket
7. Isolator
8. Washer
9. Radiator
10. Right Strut Rod
11. Left Inner Strut Rod
12. Left Outer Strut Rod
13. Hexbolt
14. Washer
15. Hexnut

Fig. 3, 1000-Square-Inch Radiator

ABA Radial worm-drive hose clamps may lose 30 percent of their torque at the screw adjuster, shortly after being correctly tightened. This is due to cold-flow of the hose material, not an actual loosening of the clamp. This is the way they are designed to work, they should not be tightened further. To check the torque of an ABA clamp, it must be loosened completely, then torqued to the proper value listed in **Table 1**.

Over-tightening an ABA Radial worm-drive hose clamp can result in coolant leaks.

13. Connect the charge air cooler hoses. Tighten the constant torque hose clamps 60 lbf·in (680 N·cm).

14. If applicable, connect the transmission oil cooler hoses.

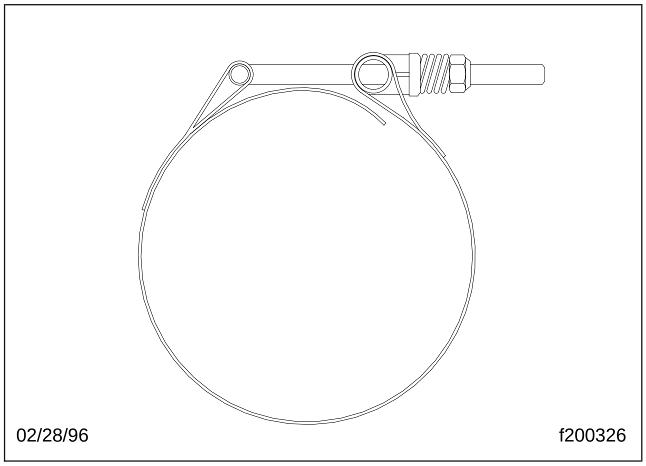


Fig. 4, T-Bolt Type Hose Clamp

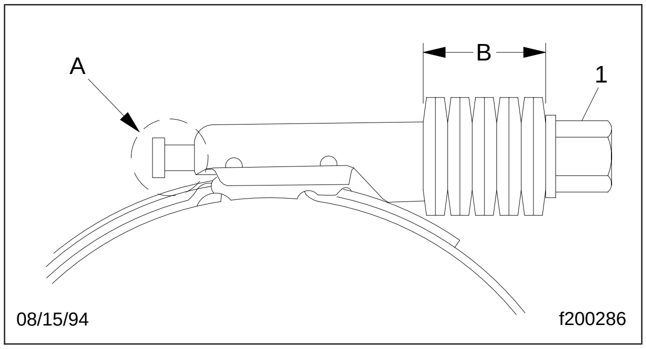


Fig. 5, Breeze Constant-Torque Hose Clamp Installation

15. Attach the hood-stop cables to the top of the radiator.
16. Connect the hood damper to the bracket on the bumper.
17. Fill the radiator with coolant. Refer to Group 20 of the *Business Class M2® Maintenance Manual* for approved coolants and system capacities.
    17.1 Add approved coolant to the radiator.
    17.2 Idle the engine with the heater circulation valve open for 15 to 20 minutes.
    17.3 Add coolant as necessary to fill the system to capacity.
18. While the engine is idling, check for leaks. Tighten fittings and connections to specified torque.
19. Remove the chocks from the tires.

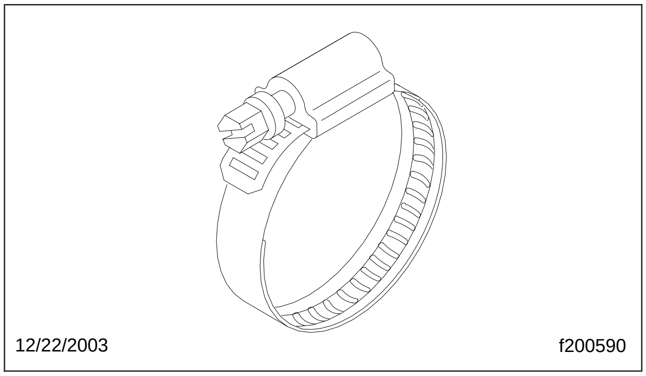


Fig. 6, ABA Radial Worm-Drive Hose Clamp (typical)

Radiator Removal and Installation

Hose Clamp Torque Values		
Clamp Type	**Size**	**Torque: lbf·in (N·cm)**
T-Bolt	All	55 (620)
Breeze Constant-Torque	5/16-inch tightening screw hex	90 (1020)
	3/8-inch tightening screw hex	90 (1020)
ABA	1.26-inch Diameter	31 (360)
	1.50-inch Diameter	35 (400)
	1.73-inch Diameter	35 (400)
	1.97-inch Diameter	35 (400)
	2.28-inch Diameter	35 (400)
	2.68-inch Diameter	40 (460)
	3.03-inch Diameter	40 (460)

Table 1, Hose Clamp Torque Values

Pressure Testing

1. Remove the radiator from the vehicle. For instructions, refer to **Subject 100**.
2. Pressure-test the radiator.
   2.1 Plug the inlet, outlet, and all other ports on the radiator assembly.

CAUTION

Don’t apply a higher amount of air pressure than specified below; too much pressure will damage the radiator core.

   2.2 Remove the radiator cap, and install a pressure regulator and gauge. Using a hand pump, apply 20 psi (140 kPa) air pressure through the filler neck.
   2.3 Submerge the radiator in a tank of water and check it for leaks. Remove the radiator from the water.
   2.4 Remove the plugs and the testing gauge, and install the radiator cap. Repair the radiator, if necessary.
3. Install the radiator in the vehicle. For instructions, refer to **Subject 100**.

Radiator Disassembly and Assembly

IMPORTANT: Disassembling and assembling radiators with nylon tanks requires the special tools listed in **Table 1**.

Dissassembly Tools	
Description	**Quantity**
Plastech II® Tanking Machine With Five 2-Inch Cylinders	1
T-Bar	1
Hooked-End Bar	1
Wave Form Bar	1

Table 1, Disassembly Tools

Order these tools from:

RAD PAL
2364 17 St.
Detroit, MI 48216
313-963-3194

Disassembly

Before disassembling the radiator, pressure flush it and check the surge tank, following the instructions in Group 20 of the *Business Class M2 Maintenance Manual*. Clean and check the exterior of the radiator, following the instructions in the *Business Class M2 Driver's Manual*.

1. Remove the radiator from the vehicle; for instructions, refer to **Subject 100**. See **Fig. 1**.

CAUTION

Use care when handling or supporting the nylon tanks. Failure to do so could damage the tanks.

2. Remove the side channels from the radiator assembly.
   - 2.1 Remove the four spring clips that hold the side channel mounting pins in position. See **Fig. 2**. Insert a screwdriver blade in the open end of each clip, and pry the clip open until it clears the edge of the mounting pin. Then, slip the clip off the pin.
   - 2.2 Use a rubber mallet and a punch to tap out the four mounting pins. See **Fig. 3**.
   - 2.3 Slip the side channels off the radiator core and tank assembly. See **Fig. 4**.
3. Leak test the radiator core and tank assembly.
   - 3.1 Securely plug all tank ports.

CAUTION

Don't apply a higher amount of pressure than specified below; too much pressure will damage the radiator core.

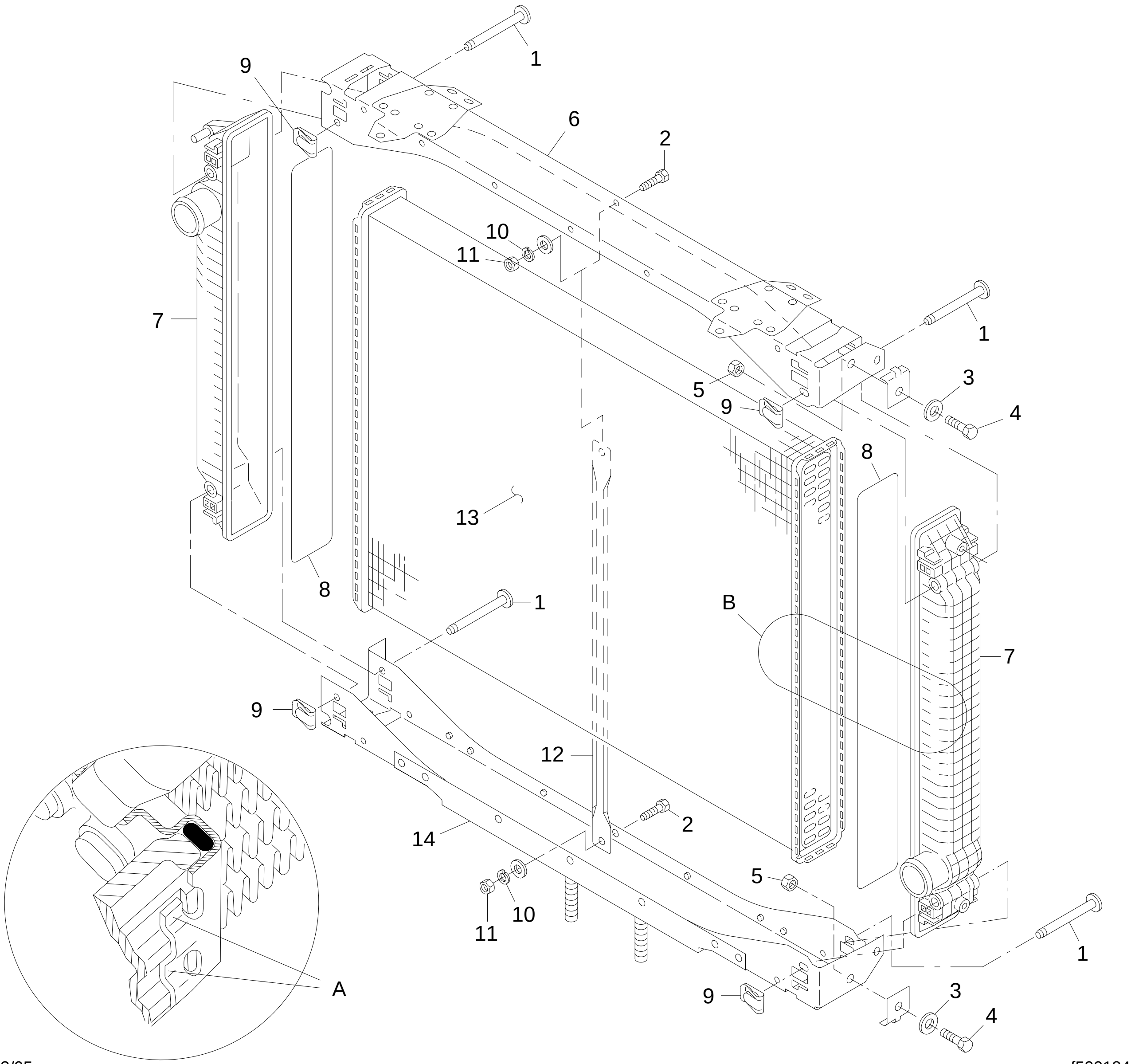
   - 3.2 At one tank port, install a pressure regulator and gauge. Using a hand pump, apply 20 psi (138 kPa) air pressure through the port.
   - 3.3 Submerge the radiator in a tank of water and check it for leaks. Mark any leaks for repair. If a leak is between the radiator core header and a tank, remove the tank and inspect the tank flange, the header sealing surface, and the sealing gasket. If the leak is in the core, but within 3 inches (7.5 cm) of the tank, remove the tank before repairing the leak. If the leak is in the tank, replace the tank.
4. Remove the tanks.
   - 4.1 Place the radiator core and tank assembly in the disassembly/assembly fixture, and clamp the assembly securely in place. See **Fig. 5**.
   - 4.2 Position the tank clamping cylinders evenly across the top of the tank. Make sure the cylinders' rubber plungers will not press against breakable fittings, such as vent tube ports.

CAUTION

Apply only enough pressure to compress the sealing gasket. Too much pressure will crack the nylon tank.

   - 4.3 Apply pressure evenly across the top of the tank until the tank-to-core sealing gasket is compressed enough to show a small gap between the bottom of the dimple wave lock crimp and the tank sealing flange.

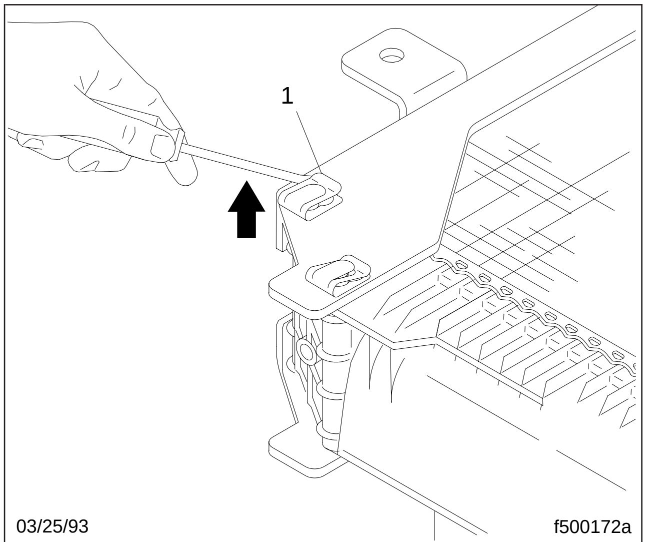
Radiator Disassembly and Assembly



A. Dimple Wave Lock Crimp
B. See Detail

1. Channel Mounting Pin
2. Bolt
3. 3/8-Inch Flatwasher
4. 3/8-16 Bolt
5. 3/8-16 Nut
6. Side Channel (top)
7. End Tank
8. End Tank Gasket
9. Spring Clip
10. Lockwasher
11. Nut
12. Radiator Brace Rod
13. Radiator Core
14. Side Channel (bottom)

Fig. 1, Radiator With Plastic End Tanks



1. Spring Clip

Fig. 2, Remove the Spring Clip

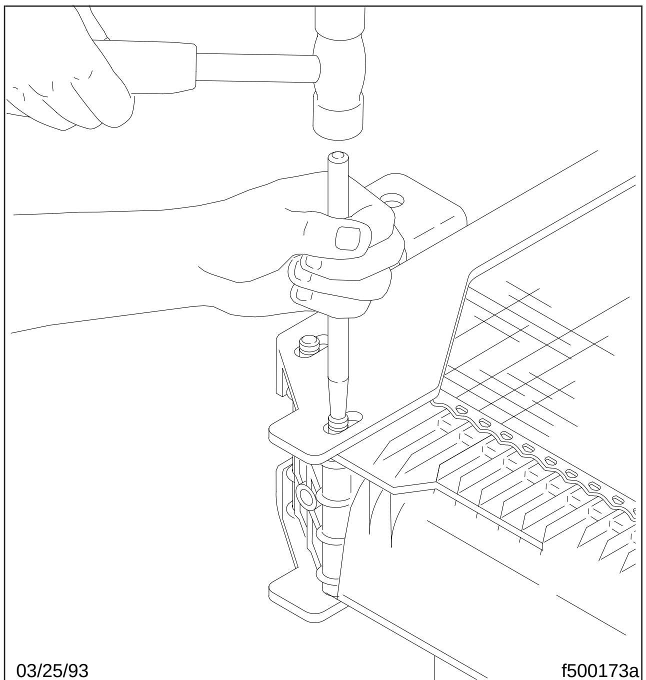
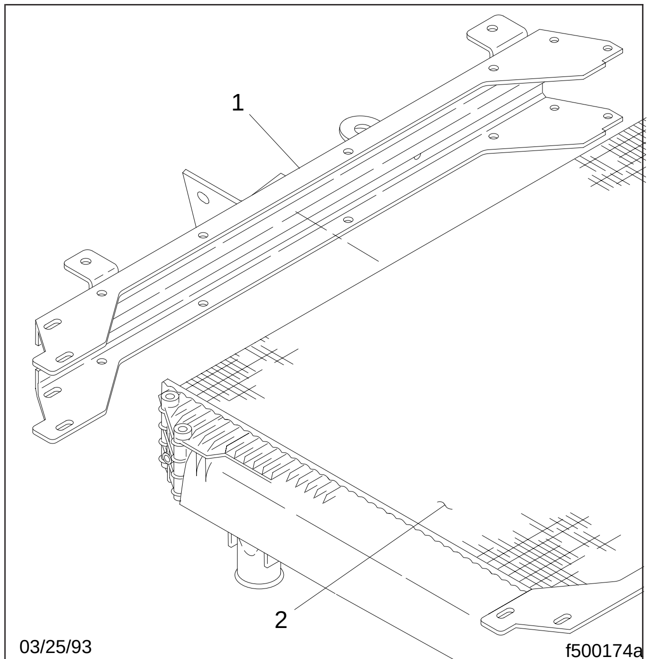


Fig. 3, Tap Out the Mounting Pins

CAUTION

In some places, especially around the tank ports, the wave lock crimps may have to be unlocked



1. Side Channel
2. Radiator Core

Fig. 4, Remove the Side Channels

with a screwdriver. When using a screwdriver, use care not to crack or gouge the nylon tank.

4.4 Place the T-bar into the T-bar groove in the disassembly/assembly fixture. See Fig. 6.

4.5 Slide the hooked-end bar over the T-bar. Place the hook over the top of the wave crimp and pull the T-bar back to unlock the crimp. See Fig. 6.

4.6 Slide the hooked-end bar and the T-bar down the T-bar groove to the next wave crimp, and repeat the previous step until all the wave crimps are unlocked.

5. Once the wave crimps are unlocked, remove the tank.

5.1 Release the pressure from the tank, and move the clamping cylinders off the radiator core and tank assembly.

Radiator Disassembly and Assembly

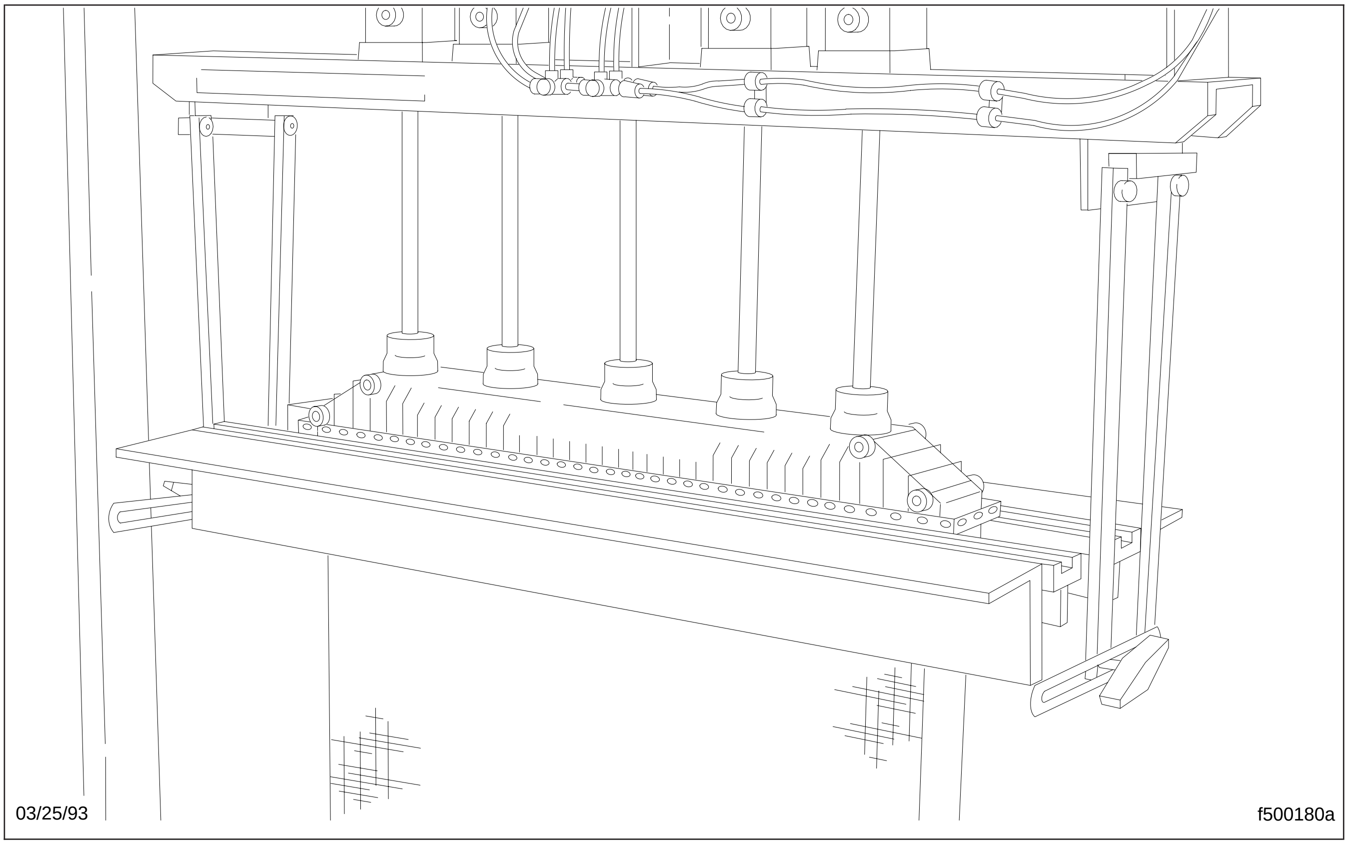


Fig. 5, Clamp the Radiator in the Disassembly/Assembly Fixture

CAUTION

If needed, use a rubber mallet or the heel of your hand and tap the side of the tank to loosen it. Do not use a screwdriver against the tank sealing flange. A screwdriver blade may damage the flange and prevent a good seal after the tank is installed.

5.2 Lift the tank from the forward side, the side opposite the tank ports. Remove the nylon tank from the radiator core. See **Fig. 7**.

5.3 Remove the sealing gasket from the sealing surface of the radiator core header. See **Fig. 8**.

5.4 Clean the sealing surface of the radiator core header.

5.5 Repair any leaks marked during leak testing.

5.6 Repeat the preceding steps to remove the opposite tank.

IMPORTANT: Check the tubes of the radiator core for scale deposits. If the radiator has been pressure-flushed, and the tubes are still clogged, the radiator should be rodded or boiled out with acid by an experienced radiator shop. Otherwise, replace the core.

Assembly

1. Install the nylon tanks on the radiator core.

   1.1 With the radiator securely clamped in the disassembly/assembly fixture, header sealing surface up, make sure the bottom of the radiator core and tank assembly is completely supported, and that the

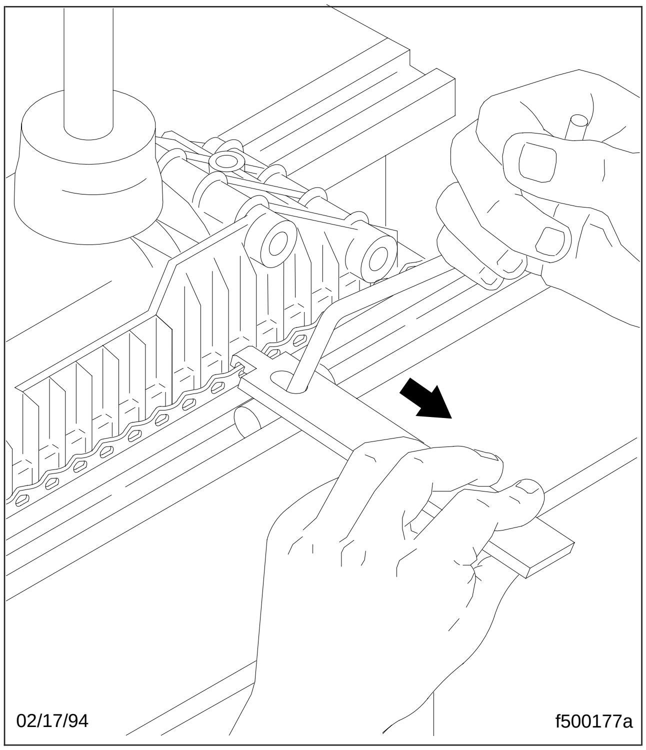


Fig. 6, Place the T-Bar

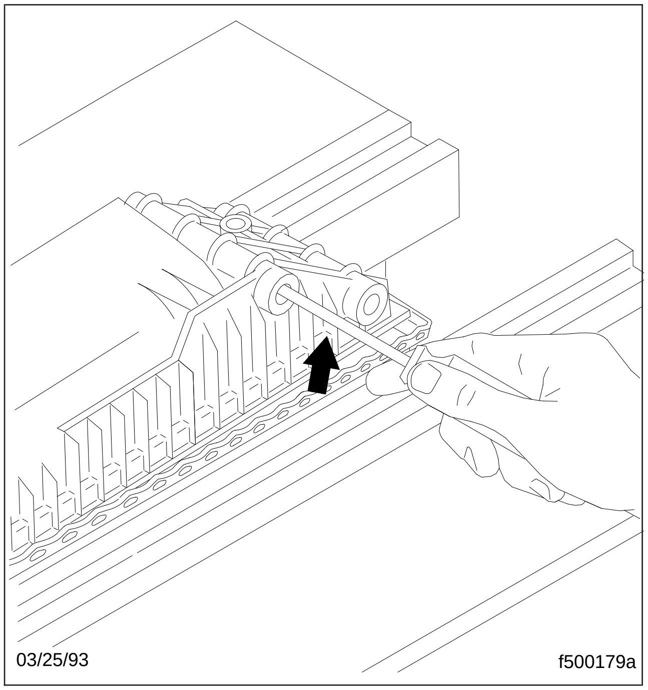
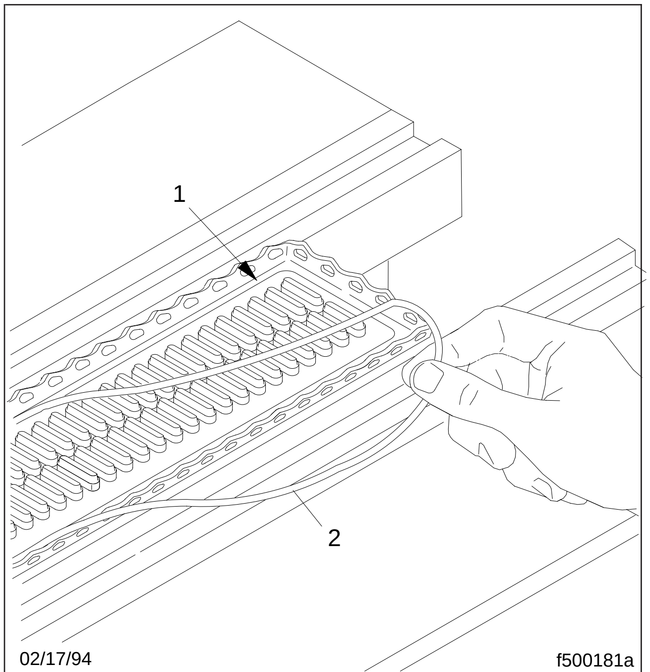


Fig. 7, Lift the Tank



1. Sealing Surface
2. Gasket

Fig. 8, Remove the Gasket

header sealing surface is free of any dents, tool marks, or foreign particles.

1.2 Lubricate a new sealing gasket with a soap and water solution, and position the gasket on the header sealing surface. See Fig. 8. To make sure the gasket is not twisted, run a finger along the gasket as it lies on the sealing surface. The mold lines of the gasket should be on the outside and inside diameters of the gasket; if you can feel a mold line cross over the top of the gasket, the gasket is twisted.

1.3 Inspect the tank sealing flange. The flange must be clean and free of defects. If the sealing flange is damaged, replace the tank.

1.4 Place the tank on the gasket, and tap the tank with a rubber mallet or the heel of your hand to seat the tank. Make sure the tank ports are facing the correct direction.

1.5 Position the tank clamping cylinders evenly across the top of the tank. Make sure the cylinders' rubber plungers will

Radiator Disassembly and Assembly

not press against breakable fittings, such as vent tube ports. See **Fig. 5**.

CAUTION

Apply only enough pressure to compress the sealing gasket. Too much pressure will crack the nylon tank.

1.6 Apply pressure evenly across the top of the tank until the tank-to-core sealing gasket is compressed enough to show a small gap between the bottom of the dimple wave lock crimp and the tank sealing flange.

1.7 Place the T-bar into the T-bar groove in the disassembly/assembly fixture.

1.8 Slide the wave form bar over the T-bar, and center the bar in front of the wave crimp slot.

CAUTION

Do not push the wave crimp until it touches the side of the nylon tank, or the tank may crack.

1.9 Push the T-bar forward to crimp the header's edge until it almost touches the tank's side. See **Fig. 9**.

1.10 Slide the tools down the T-bar groove to the next wave crimp slot, and repeat the previous steps until all the wave crimps are crimped.

CAUTION

In some places, especially around the tank ports, the wave crimps may have to be crimped with a screwdriver. When using a screwdriver, use care not to crack or gouge the nylon tank.

1.11 Release the pressure from the tank, and move the clamping cylinders off the radiator core and tank assembly.

1.12 Repeat the first step in this procedure to install the opposite tank.

2. Leak test the radiator core and tank assembly. For instructions, refer to "Disassembly."

3. Install the radiator side channels.

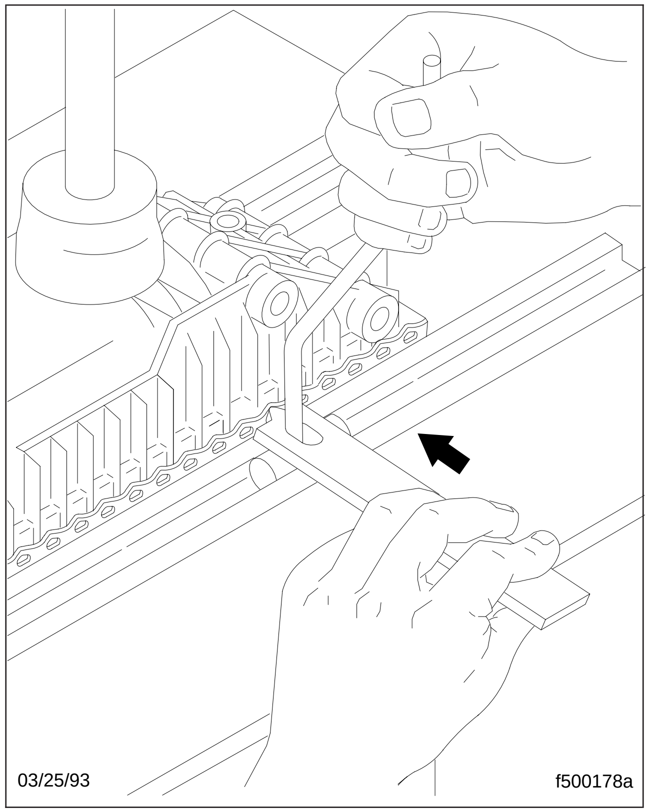


Fig. 9, Crimp the Header

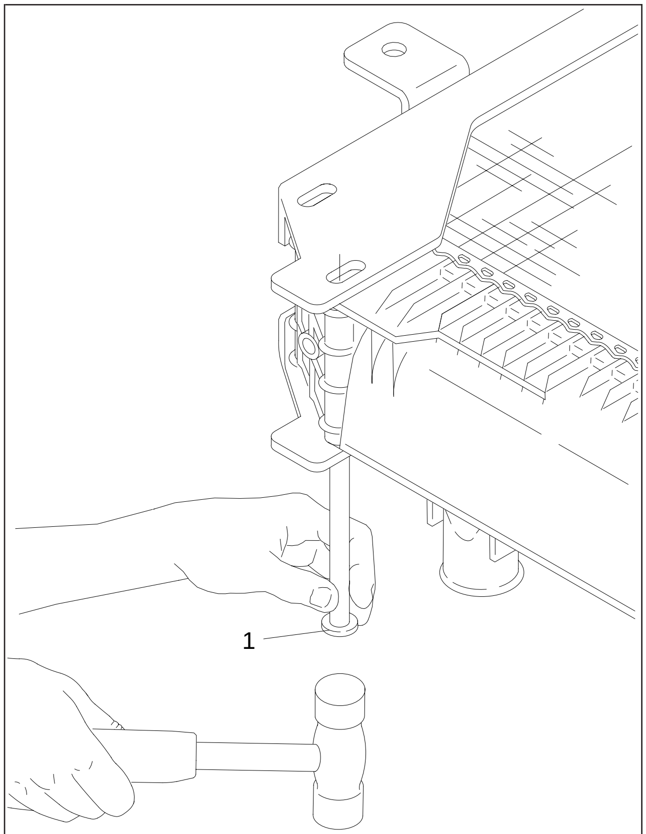
3.1 Slide the side channels onto the radiator core and tank assembly.

3.2 Using a rubber mallet and a punch, install the four mounting pins through the side channel holes and tank bosses. See **Fig. 10**.

3.3 Install the four spring clips to secure the mounting pins in position. See **Fig. 11**. To install each clip, place the clip over the end of the mounting pin, and slide the clip until it engages the groove in the pin and the open end of the clips snaps over the edge of the pin. If necessary, use a clamp to compress the side channel while installing the clips.

4. Install the radiator in the vehicle. For instructions, refer to **Subject 100**.

Radiator Disassembly and Assembly



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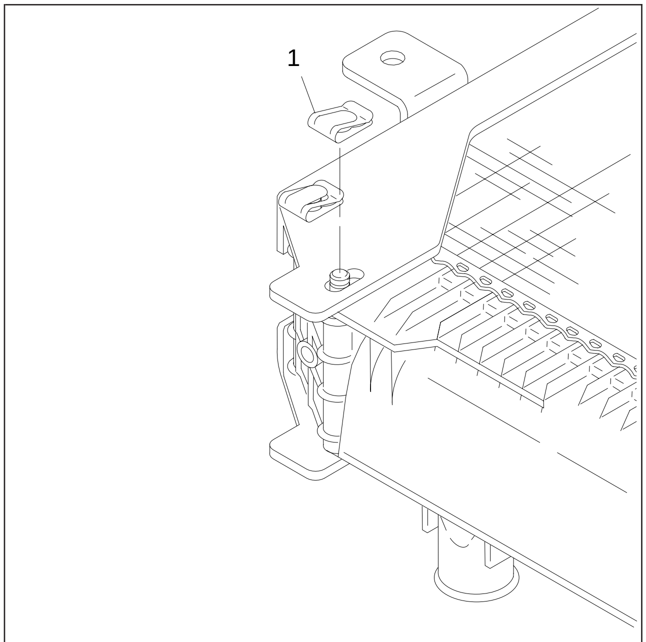
1. Pin

Fig. 10, Install the Mounting Pins



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1. Spring Clip

Fig. 11, Install the Spring Clips

Surge Tank Removal and Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Tilt the hood.

WARNING

Drain the coolant only when the coolant and engine are cool. Draining it when these are hot could cause severe personal injury due to scalding.

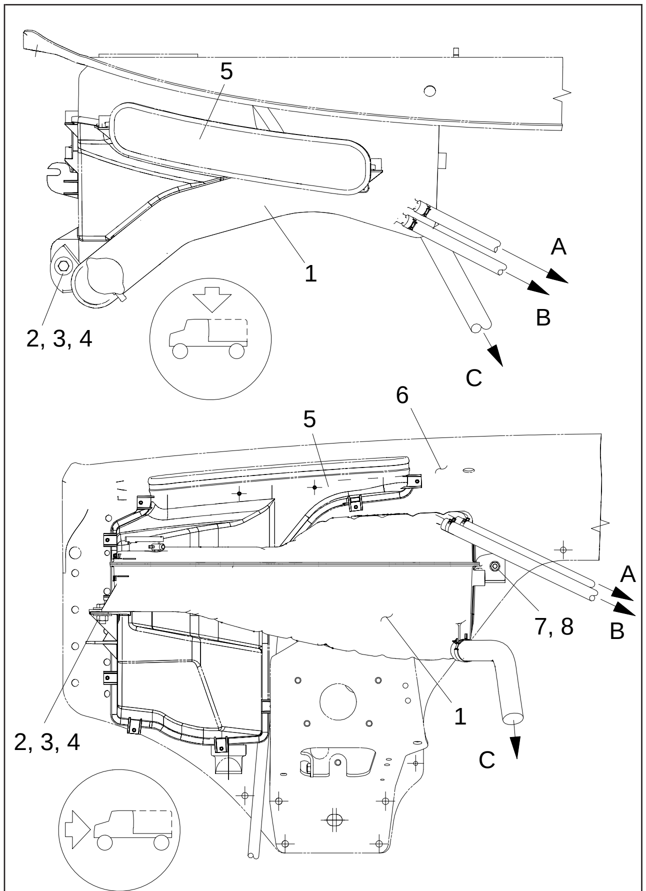
3. Drain the radiator.
   - 3.1 Remove the surge tank cap.
   - 3.2 Open the draincock on the bottom of the radiator to drain the engine coolant. Drain only enough coolant to empty the surge tank.
4. Remove the surge tank.
   - 4.1 Mark and disconnect the engine and radiator vent hoses from the front of the surge tank. There are three hoses. See **Fig. 1**.

   NOTE: Cap all the disconnected hoses to prevent the remaining coolant from spilling.

   - 4.2 Remove the fasteners holding the right side of the surge tank to the air cleaner bracket. See **Fig. 1**.
   - 4.3 Remove the fasteners holding the left side of the surge tank to the frontwall and the HVAC air plenum.
   - 4.4 Remove the surge tank from the vehicle.
5. If replacing the surge tank, remove the overflow hose from the bottom.

Installation

1. If it was removed, install the overflow hose to the bottom of the surge tank.
2. Position the surge tank onto the air cleaner bracket, then install the M8 fasteners. See **Fig. 1**. Tighten just enough to hold the surge tank in place.



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A. To Radiator
B. To Engine Vent Port
C. To Engine Shunt Port
1. Surge Tank
2. Capscrew, M8
3. Washers (2 qty.)
4. Flanged Nut, M8
5. HVAC Air Plenum
6. Frontwall

Fig. 1, Surge Tank Installation (top and front views)

3. Using the fasteners previously removed, attach the surge tank to the HVAC air plenum and the frontwall.
4. Tighten all the fasteners 18 lbf·ft (24 N·m).
5. As previously marked, connect the engine and radiator hoses to the surge tank.
6. Fill the coolant system through the surge tank.
7. Install the surge tank cap.
8. Start the engine and check for coolant leaks. Repair any leaks.

Surge Tank Removal and Installation

9. Lower the hood and remove the chocks from the tires.

Specifications

Fastener Torques				
Description	Grade	Size	Torque	
			lbf·ft (N·m)	lbf·in (N·cm)
Radiator Lower-Bracket Stud Hexnuts	8	1/2–13	68 (92)	—
Fan Shroud Mounting Screws	—	1/4–20 x 3/4 Inch	—	108 (1220)
Radiator Strut Nuts	8	1/2–13	68 (92)	—

Table 1, Fastener Torques

General Information

An engine block heater keeps the engine coolant about 80°F (27°C) warmer than the ambient air temperature. In cold weather, the heater helps engine starting and reduces wear on the piston walls.

When starting the engine, the diesel normally ignites on the compression stroke of each piston, when the compressed air within the cylinder reaches about 725°F (385°C). However, during cold weather starts, the heat of the compressed air dissipates into the surrounding engine block so the diesel may never reach the temperature it needs to ignite. Using the engine block heater, the engine block is already warm, so heat is held in the cylinder to ignite the diesel. To reduce engine wear, the block heater warms the oil film on the piston walls and reduces piston drag caused by cold oil film.

The Phillips 1000W heater consists of an element that screws into the side of the engine water jacket. See **Fig. 1**. A cord plugs into the outside end of the element, and the cord runs to a plug below the front bumper.

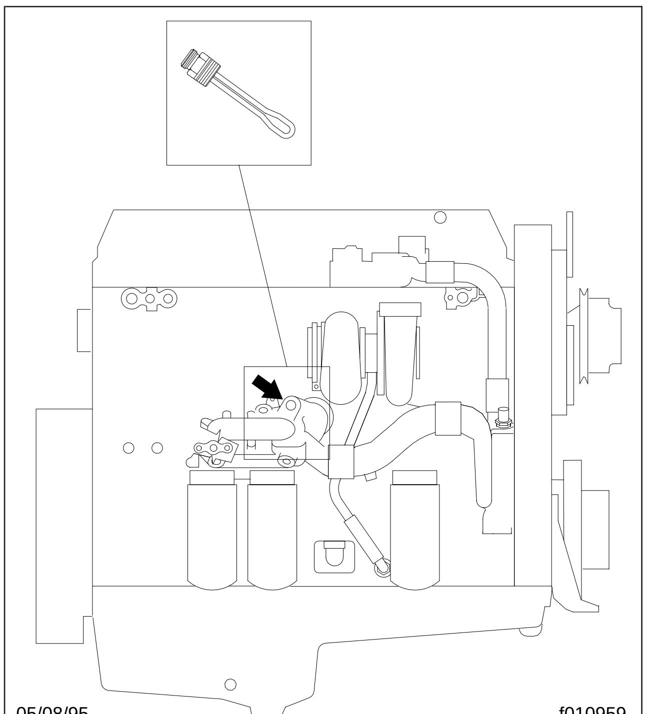


Fig. 1, Block Heater Element Installation (typical)

To turn on the heater, connect the heater cord to a power source. The element has no thermostat. Heat dissipating from the engine block prevents coolant overheating.

Block Heater Element Replacement

Removal

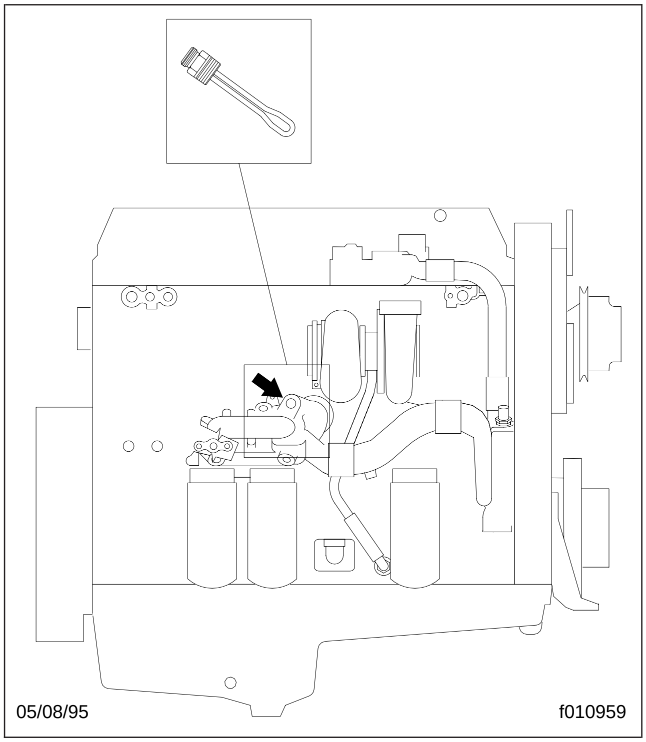


Fig. 1, Block Heater Element Installation (typical)

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Tilt the hood.

WARNING

Drain the coolant only when the coolant and engine are cool. Draining it when these are hot could cause severe personal injury due to scalding.

3. Drain the radiator. For instructions, refer to **Section 20.01**.
4. If applicable, unscrew the threaded cover that secures the cord to the element. See **Fig. 1**.
5. Pull the cord from the element.
6. Remove the element from the engine block by loosening the jam nut (if applicable) and unscrewing the element from the engine block.

Installation

1. Position the heater element in the engine block.

   Coat the threads of the element with a small amount of sealant. For the approved sealants, refer to **Specifications, 400**.
2. Secure the heater element in the engine block by screwing the element into the engine block hand tight, then use a wrench to turn the element 1-1/2 turns more.
3. Plug the cord into the element and (if applicable) secure it by screwing the threaded cord cover in place.
4. Fill the cooling system. For instructions, refer to **Section 20.01**.
5. Start the engine and check for leaks. Repair any leaks as necessary. Run the engine for half an hour to purge any air from the coolant system.
6. To test the heater, plug a wattmeter into a power source, and connect the heater cord to the meter. A reading on the meter will indicate the heater is working.

Troubleshooting

Use the following procedures to check for the most common engine block heater problems.

Wiring Problems

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Tilt the hood.
3. Unscrew the threaded cover that secures the cord to the element. Pull the cord off the element.
4. Using an ohmmeter, check the continuity between the two poles of the element. The resistance should be very low, typically between 9 and 10 ohms. If there is no reading, the element has burned out, and if the reading is very high, the element is about to burn out.
5. If the element is good, check the cord. Plug the cord into the element and secure it by screwing the threaded cover in place.
6. Using an ohmmeter at the receptacle, check the continuity between the two power terminals. The resistance should be low, typically between 9 and 10 ohms. If there is no reading or a very high reading, the cord is damaged. Replace the cord.
7. Check the continuity between each power terminal and the ground terminal. There should be no ohmmeter reading. If there is a reading, replace the cord.
8. Check the ohmmeter reading between the ground terminal and a good vehicle ground. The reading should be zero. If not, replace the cord.

Fouled Element

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Tilt the hood.

WARNING

Drain the coolant only when the coolant and engine are cool. Draining it when these are hot could cause severe personal injury due to scalding.

3. Drain the radiator. For instructions, refer to **Section 20.01**.
4. Unscrew the threaded cover that secures the cord to the element. Pull the cord off the element.
5. Remove the element from the engine block. For instructions, refer to **Subject 100** in this section.
6. Inspect the element for residue deposits, discoloration, or damage.

   Coolant dye residue indicates the coolant solution contains too much antifreeze. Replace the element, and refer to Group 20 of the *Business Class M2 Maintenance Manual* for the recommended antifreeze/water ratio.

   Gray or black residue indicates anti-leak coolant additives have been added to the system. Replace the element, and refer to Group 20 of the *Business Class M2 Maintenance Manual* for the recommended coolant additives.

   Blue or black discoloration on the element indicates the coolant system needs more coolant. Replace the element, and fill the coolant system until coolant is visible in the surge tank sight glass.

   Holes in the element indicate the coolant solution contains too little antifreeze. The weak solution is boiling inside the engine block and causing pitting of the element and block. Replace the element, and refer to Group 20 of the *Business Class M2 Maintenance Manual* for the recommended antifreeze-to-water concentrations.

   For element installation instructions, refer to **Subject 100**.

Specifications

APPROVED SEALANTS

- Loctite 567
- Henkel 790 Pipegrip
- Perma-Loc LH-150

General Information

The fan clutch senses the air temperature behind the radiator core, and engages or disengages the fan depending on that temperature. It spins the fan when more cooling airflow is needed, and disengages it when the radiator is sufficiently cooled.

The Eaton 690 viscous fan clutch drive consists of two basic parts: the input plate and shaft, and the output plate. See **Fig. 1**. The input shaft is mounted to the fan hub, so they turn together as the engine runs. The output plate is attached to the fan, but engages with the input plate only when extra engine cooling is needed.

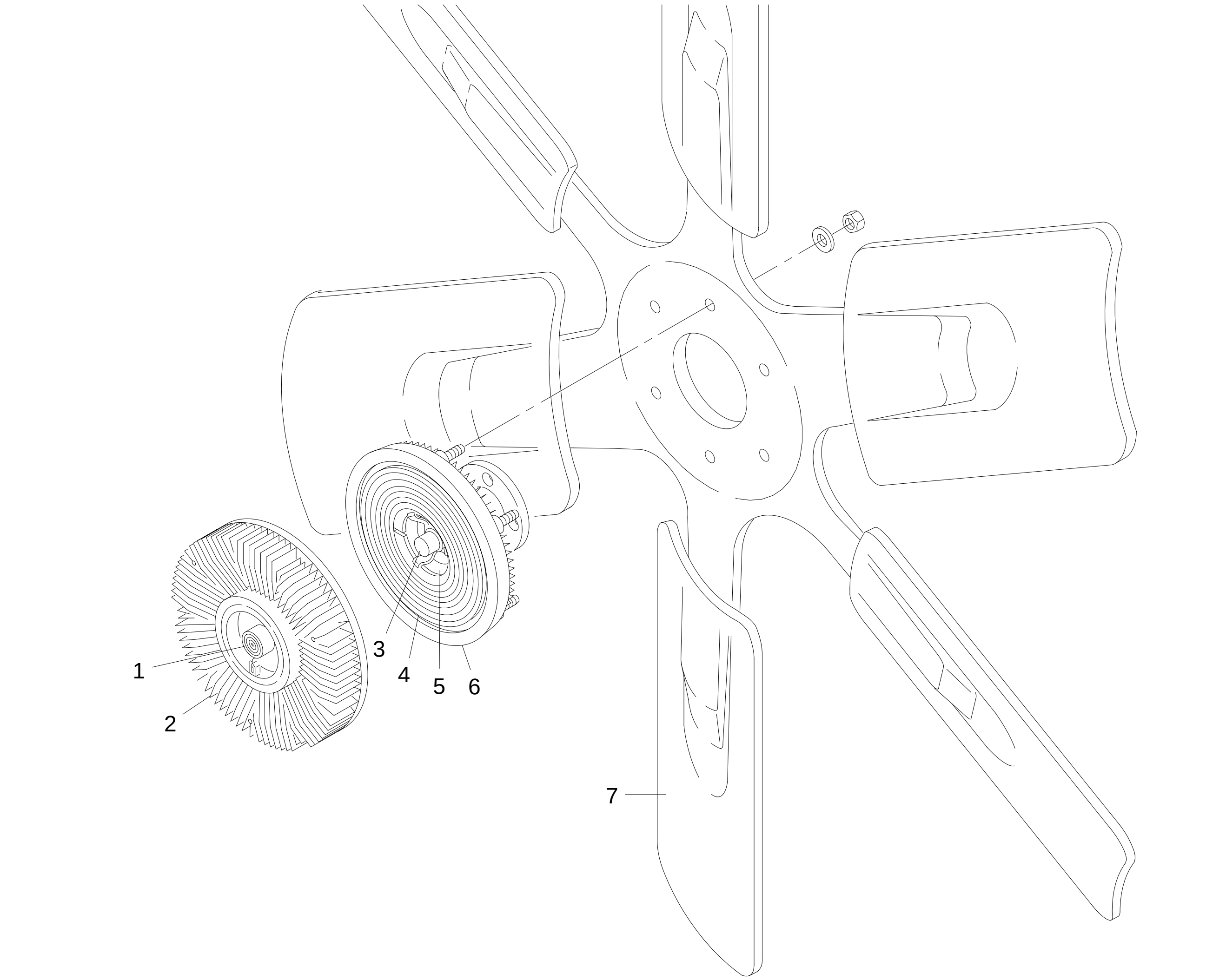
To spin the fan, the heat sensor on the front of the clutch opens a valve in the clutch drive chamber. The centrifugal force of the turning input plate forces the thick silicone fluid, stored in the drive chamber, to flow out through tightly meshing grooves between the input and output plates. this creates friction between them. As that friction increases, it causes the output plate and fan to turn with the input plate. The fluid continues to spread out between more grooves, increasing the friction between the plates until they spin at about the same speed.

When air passing through the radiator is cool enough, the heat sensor disengages the fan clutch. It does this by closing the valve in the drive chamber. That stops the flow of silicone fluid to the input and output plates. For the fluid already between the plates, centrifugal force continues to push it outward until it has moved beyond the grooves. There, at the outer edge of the clutch, it returns through a passage in the input plate to the drive chamber.

With only a small amount of fluid to create friction between the two plates, the fan turns much slower than the input plate and the input shaft.

When the fan is disengaged, a single bearing allows the output plate and fan to free-wheel in relation to the input shaft and plate.

General Information



1. Heat Sensor
2. Input Plate
3. Input Shaft
4. Concentric Grooves
5. Drive Chamber
6. Output Plate
7. Fan

Fig. 1, Eaton 690 Viscous Fan Clutch

Inspection and Operation Check

Inspection

CAUTION

If the fan drive assembly is damaged, replace the unit as soon as possible. Operating a vehicle with a seized or otherwise damaged clutch reduces fuel economy, and could cause serious engine damage.

The fan clutch is only one part of the cooling system and will function well only if all other parts of the system are working correctly. All parts of the system should be checked if there is a cooling problem. Do each of the checks in the cooling system troubleshooting section in this group, and pay special attention to the fuel flow rate and exhaust temperature. Over-fueling can cause engine overheating and high exhaust temperatures.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. With the engine off, rotate the fan at least one full turn by hand. It should have a smooth, steady drag. If it does not, replace the fan clutch.
3. Check for physical damage to the fan or fan shroud.
4. Inspect the fan clutch mounting.
   - 4.1 Check the torque of the nuts holding the fan input shaft to the fan hub. They should be tightened 28 lbf·ft (38 N·m).
   - 4.2 Check for wear of the fan clutch bearings. There should be no side-to-side or in-and-out movement of the fan clutch.
5. Remove the chocks from the tires.

Operation Check

Use the following procedure to check for correct engagement and disengagement of the fan clutch:

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Coolant temperature in the radiator should be below 140°F (60°C) before the start of the test; the outside temperature should be above 50°F (10°C). Ideally, a temperature probe placed about 1/2 inch (13 mm) from the fan clutch sensor is needed to see if the fan clutch engages at the right temperature.
3. Disconnect any hydraulic pumps (such as the power steering pump) to prevent oil overheating.
4. Use a piece of cardboard large enough to block the entire front of the radiator. Cut a round 7-inch (18-centimeter) hole in the cardboard; locate the hole so that it lines up with the fan clutch. Do not put the cardboard in front of the radiator yet.

WARNING

Before starting the engine, make sure your hands and all other objects are away from the fan blades. Do not try to restrict the fan blade rotation when the engine is on. It is extremely dangerous to get too close to the fan blades when the engine is on, because the fan could start operating without warning. This could result in serious personal injury.

5. Turn off the air conditioner, if so equipped. Start the engine and let it idle until the oil pressure is normal.
6. As soon as there is normal oil pressure, bring the engine up to high idle (about 80 percent of governed engine speed) and lock the throttle at this speed.

   If the engine has been idle for more than 8 hours, the fan clutch may engage as soon as the engine is started. If this happens, the usual noise from the fan will be heard; the noise will stop after 5 minutes or less, when the fan clutch disengages.
7. After the fan clutch disengages, put the cardboard in front of the radiator.
8. Look at the temperature gauge and note at what point the engine thermostat opens. As the engine warms up, the coolant temperature will rise steadily and then seem to level off after the thermostat opens. It will then start rising again, before the fan clutch engages.
9. Keep watching the coolant temperature and, if possible, the temperature of the air in front of the fan clutch, until the clutch engages. Note the temperature(s) at which the clutch engages. The

Inspection and Operation Check

fan should be fully engaged when the air at the fan clutch sensor rises to about 155 to 165°F (68 to 74°C).

With the clutch engaged, the coolant temperature will keep rising, at a slower rate, as long as the radiator is blocked with cardboard.

10. Remove the cardboard. Keep watching the coolant temperature while the clutch is engaged; you should notice a decrease after the cardboard is removed.
11. The fan should disengage when the air temperature at the fan clutch sensor drops to about 120 to 130°F (49 to 54°C).

    If the coolant temperature keeps rising, even though the fan is engaged and the cardboard has been removed, the fan clutch may be working properly; the problem is probably in another part of the cooling system.

IMPORTANT: If the air temperature in front of the clutch is being tested, and it does not rise as the coolant temperature rises, the problem could be a clogged radiator or a stuck engine thermostat.

If the engine still overheats during operation, even though everything described above checks out properly, use a stroboscope to check peak fan speed. The fan speed should be at least 93 percent of the fan pulley speed when the clutch is fully engaged.

Example: 2160 = fan pulley speed x .93 = 2009 = 93 percent of fan pulley speed.

Fan speed must be at least 2009 rpm when the fan clutch is fully engaged.

12. Remove the chocks from the tires.

Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries or, if the vehicle is equipped with a battery shutoff switch, turn off the switch.

   Disconnect the battery ground cable at the vehicle frame.
3. Tilt the hood.
4. Disconnect the radiator struts from the radiator side-channels.
5. If so equipped, disconnect the left-side charge air cooler hose from the charge air cooler.
6. Disconnect the fan clutch from the fan hub. See **Fig. 1**.

   6.1 Holding the fan to keep it from turning, remove the four locknuts or four capscrews holding the fan clutch to the fan hub.

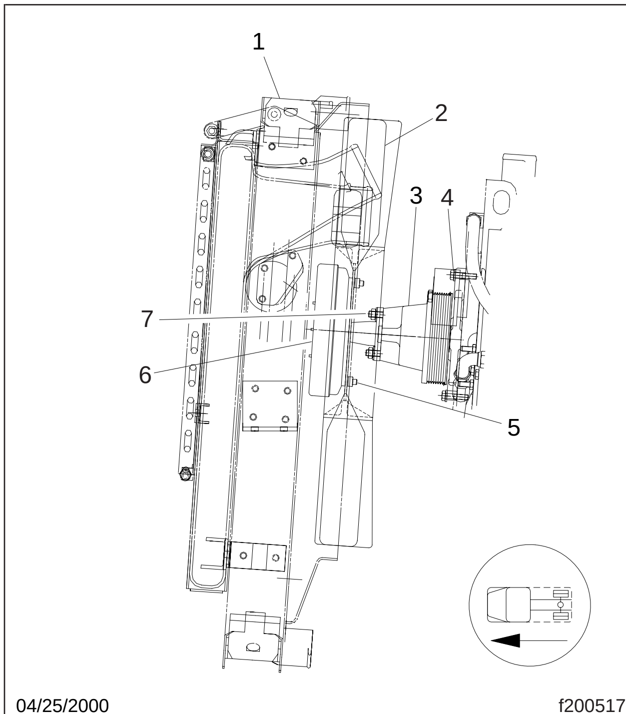
   6.2 Remove the fan (with the fan clutch attached to it) from the fan hub, and push them forward into the fan shroud.
7. Remove the serpentine drive belt.

   7.1 Using a 1/2-inch breaker bar, move the belt tensioner clockwise

   7.2 Remove the belt from the various engine and component pulleys.
8. Remove the fan hub from the engine.

   8.1 Remove the top two bolts holding the fan hub to the engine block. Then loosen the bottom two bolts. It is not necessary to remove them.

   8.2 Remove the fan hub from the engine block.
9. Remove the fan and the attached fan clutch from the vehicle.
10. Remove the locknuts and washers that hold the fan clutch to the fan. Remove the clutch.



1. Radiator
2. Fan
3. Fan Hub
4. Hexbolt, M8
5. Locknut, 5/16–18
6. Fan Clutch Assembly
7. Locknut, 3/8–16

Fig. 1, Viscous Fan Clutch Mounting, Caterpillar 3126 Engine

Installation

1. Install the fan clutch onto the fan. Tighten the 5/16–18 locknuts 15 lbf·ft (20 N·m).

NOTE: Use only approved fans. Never go over the maximum input speeds, and do not make changes to the engine that will raise the operating speed of the fan.

2. Install the fan hub onto the engine. See **Fig. 1**.

   2.1 Put the hub in place on the engine so the lower mounting ears fit over the lower two bolts on the engine block.

   2.2 Install the two upper hexbolts and washers. Tighten all the hexbolts 15 lbf·ft (20 N·m).

Removal and Installation

3. Install the fan clutch assembly onto the fan hub. Tighten the 3/8–16 locknuts 28 lbf·ft (38 N·m).
4. Install the serpentine drive belt.
5. Connect the left-side charge air cooler hose to the charge air cooler.
6. Connect the radiator struts to the radiator side-channels. Tighten the fasteners firmly.
7. Lower the hood and connect the batteries.
8. Remove the chocks from the tires.

Specifications

Fastener Torques			
Description	Grade	Size	Torque: lbf·ft (N·m)
Fan Clutch-to-Fan Hub Locknuts	8	3/8—16	28 (38)
Fan Hub-to-Engine Hexbolts	10.9	M8	15 (20)
Fan Clutch-to-Fan Locknuts	G	5/16—18	21 (28)

Table 1, Fastener Torques

General Information

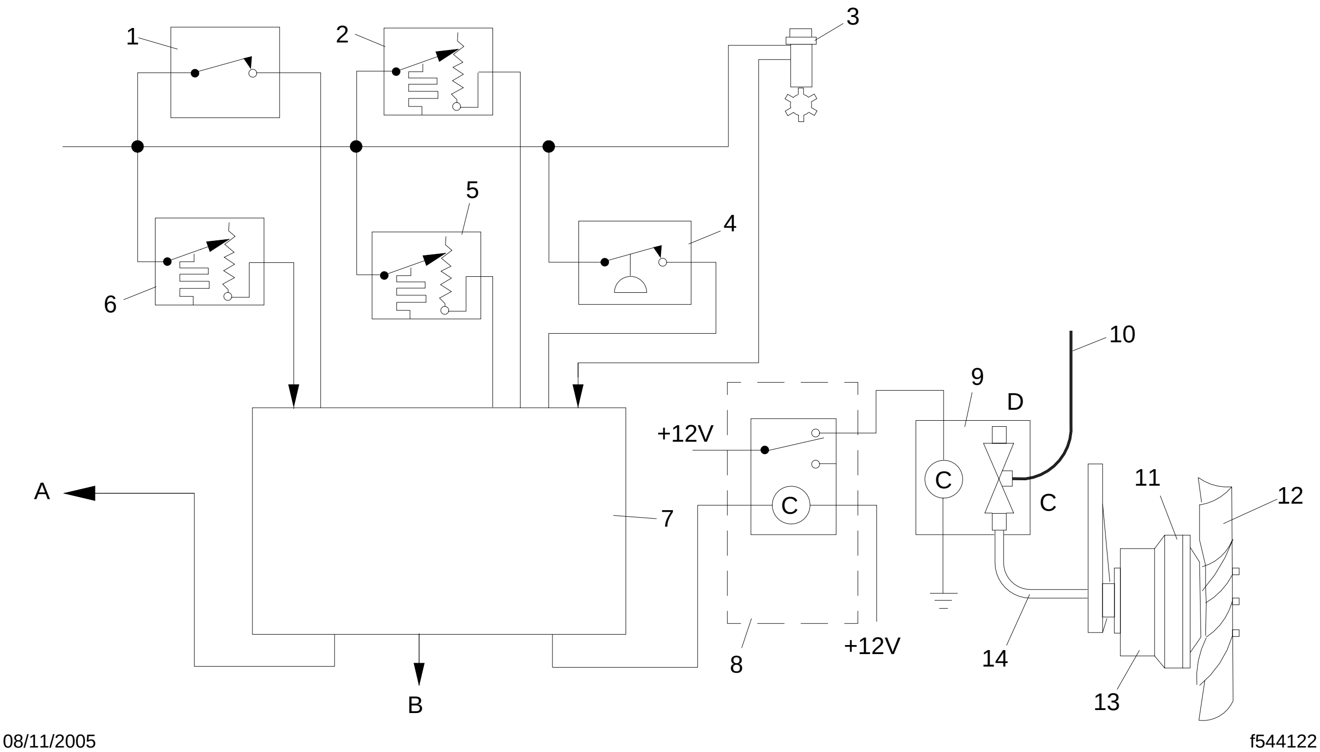
The Horton DriveMaster® fan clutch is a temperature-controlled, air-operated clutch for the engine cooling fan. It is spring engaged, and controls the engine temperature by engaging or disengaging the fan.

When the coolant temperature is below a specified range, air pressure keeps the fan disengaged to save engine power. When the coolant temperature rises above the specified range, air pressure to the fan clutch is cut off and internal spring pressure engages the fan.

Air pressure to the fan clutch is controlled by a solenoid valve; the solenoid valve is controlled by a temperature switch installed in the thermostat housing. The temperature switch is connected to the engine ECM, which controls the solenoid valve. See **Fig. 1**. When you start a cold engine, the solenoid valve allows air pressure to the fan clutch and the clutch remains disengaged. When the coolant temperature rises to the temperature switch setting, the switch provides power to the solenoid valve and the valve cuts off compressed air to engage the fan.

On vehicles with air conditioning, the fan clutch solenoid valve is connected to a fan cycling switch at the receiver-dryer. If the refrigerant pressure exceeds the setting of the fan cycling switch, the switch supplies power to the solenoid valve, which cuts off air to the fan clutch, engaging the fan.

General Information



A. To Indicators and Gauges
B. To Electronic Injectors and Other Actuators
C. Normally Closed
D. Normally Open

1. Fan Override Switch
2. Air Temperature Sensor
3. Engine Speed Sensor
4. A/C Pressure Switch
5. Coolant Temperature Sensor
6. Foot Throttle
7. Engine ECM
8. Fan Relay (not present in all systems)
9. Solenoid Valve
10. Air Supply from Reservoir
11. Fan Clutch
12. Air Supply to Fan Clutch

Fig. 1, Fan Clutch Schematic (engine ECM controlled)

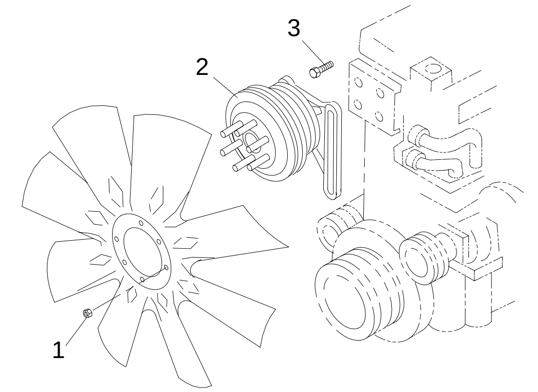
Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brakes, and chock the tires.

WARNING

Wear safety goggles when draining the air system or disconnecting an air line because dirt and sludge could fly out at high speeds. Don't direct the airstreams at anyone. Don't disconnected pressurized air lines, as they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

2. Drain the air tanks.
3. Tilt the hood.
4. Disconnect the left-side hose from the charge air cooler.
5. Remove the drive belts from the engine.
6. Disconnect the air line from the fan hub.
7. Remove the fan.
8. Remove the fan clutch assembly from the engine. See **Fig. 1**.



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1. Hexnut
2. Fan Clutch Assembly
3. Hexbolt,

Fig. 1, Fan Clutch Removal (typical)

8.1 If equipped with a metal fan ring, remove the two top fasteners holding the upper mounting bracket for the fan ring.

8.2 Remove the fasteners holding the fan clutch mounting bracket to the front of the engine.

WARNING

The fan clutch assembly may weigh up to 55 lbs. (25 kg). Be careful when lifting it. Use a helper or a hoist, if necessary. Failure to use care when lifting the fan clutch could cause the assembly to fall, which could result in injury or component damage.

8.3 Remove the fan clutch assembly from the vehicle. If equipped with a metal fan ring, carefully push the ring forward to allow removal of the fan clutch assembly.

Installation

1. Using either a helper or a hoist, position the fan clutch assembly in place on the front of the engine, aligning the holes in the mounting bracket with those in the front of the engine.
2. Install the fasteners.

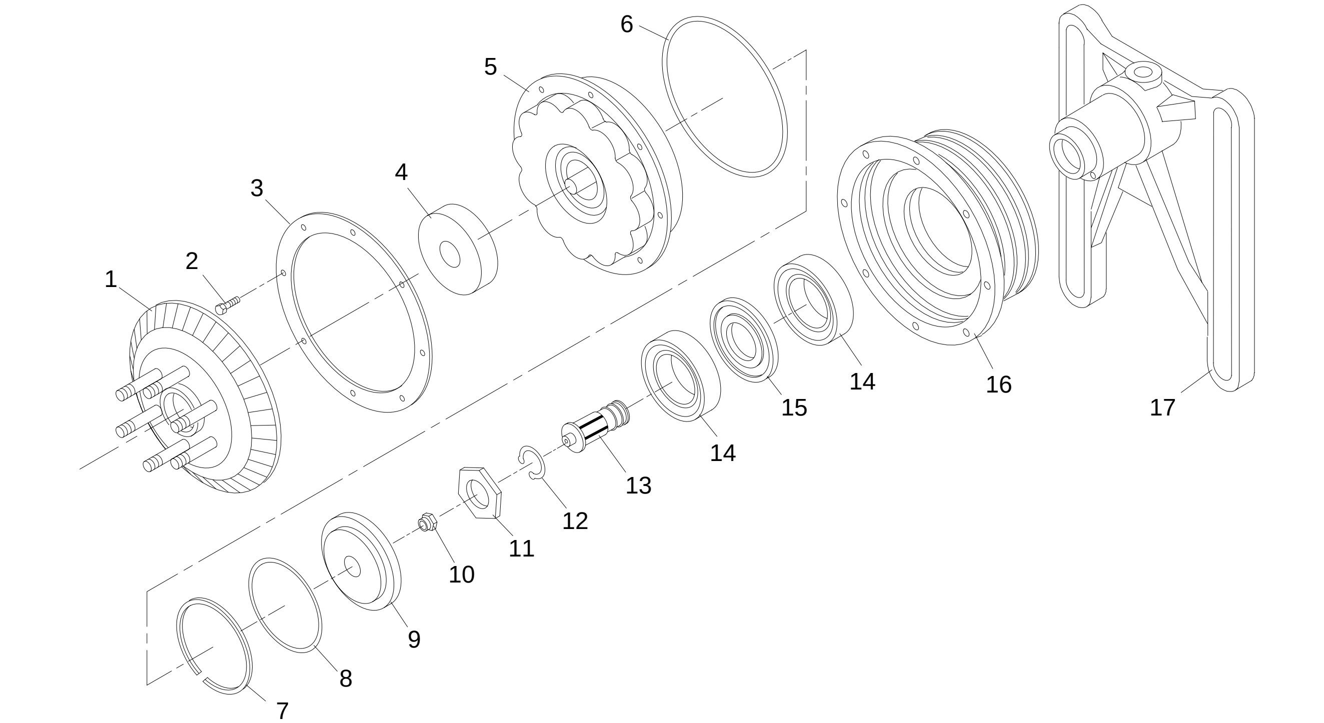
   If equipped with a metal fan ring, don't tighten the upper fan clutch fasteners completely.
3. Install the drive belts.
4. Connect the air line to the fan clutch.
5. Install the fan. Tighten the fan mounting nuts firmly.
6. Tighten the M8 fan-clutch mounting fasteners 15 lbf·ft (20 N·m).
7. Connect the left-side hose to the charge air cooler.
8. Lower the hood.
9. Remove the chocks from the tires.

Fan Clutch Major Rebuild

Disassembly

NOTE: This procedure involves a major rebuild of the Horton DriveMaster® fan clutch, using parts from the manufacturer's Super Kit. If you are replacing just the seals or the air cartridge, see **Subject 120** for the minor rebuild procedure.

Refer to **Fig. 1** for this procedure.



1. Fan Mounting Disc
2. Torx®-Head Screw (8 qty.)
3. Friction Lining
4. Cage Nut (supplied with repair kit)
5. Spring Housing/Piston Assembly
6. Air Chamber Seal
7. Air Chamber Cap Retaining Ring
8. O-Ring
9. Air Chamber Cap
10. Face Seal
11. Bearing Nut
12. Air Cartridge Retaining Ring
13. Air Cartridge Assembly
14. Sheave Bearings
15. Bearing Spacer
16. Sheave
17. Journal Bracket

Fig. 1, Horton DriveMaster Fan Clutch

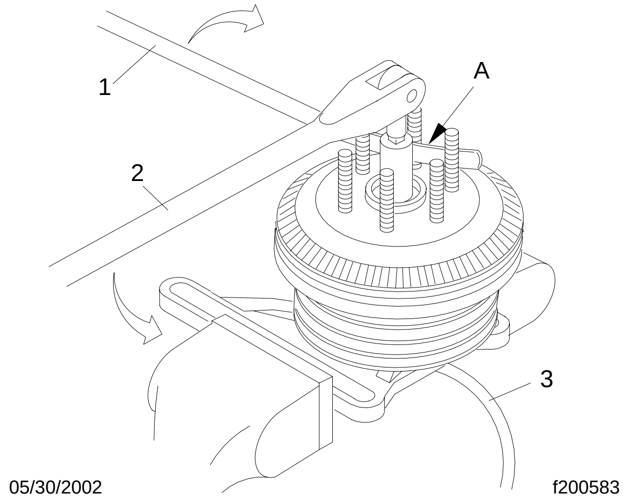
1. Remove the fan clutch assembly from the vehicle. For instructions, see **Subject 100**.
2. Put the fan clutch assembly in a vise.
3. Connect a shop air hose to the fan clutch air inlet.
4. Apply 80 to 120 psi (552 to 827 kPa) to the fan clutch to lift the fan mounting disc off the spring housing/piston assembly.

CAUTION

Use care when placing the pry bar onto the fan mounting disc. Make sure it is secure and flat on the surface. Failure to do so make cause the pry bar to slip, which could result in damage to studs or the fan mounting disc.

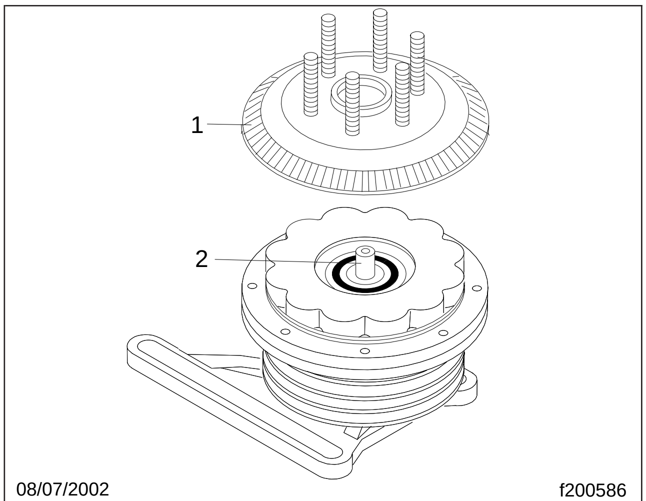
5. Using a pry bar, wrench, and a T55 Torx® bit, loosen the jack bolt (left-hand thread) by turning it counterclockwise. See **Fig. 2**.
6. Unscrew the fan mounting disc from the jack bolt. See **Fig. 3**

Fan Clutch Major Rebuild



A. Place the pry bar here.
1. Pry Bar (push clockwise)
2. Torx Bit and Wrench (turn counterclockwise)
3. Shop Air Hose (connected to the inlet port)

Fig. 2, Loosening the Jack Bolt



1. Fan Mounting Disc
2. Jack Bolt (left-hand thread)

Fig. 3, Fan Mounting Disc Removal and Installation

7. Inspect the fan mounting disc for wear or damage.

WARNING

Do not disassemble the spring housing from the piston. The interior springs are very strong, and if released could eject the housing with considerable force, possibly resulting in serious injury. Always use the cage nut to hold the spring housing and the piston together.

8. Using a wrench and a T55 Torx bit to hold the jack bolt, install the cage nut from the kit onto the jack bolt (left-hand thread). Hand tighten it onto the spring housing.

   The cage nut will keep the spring housing and piston together as an assembly. It will also maintain pressure on the internal springs after the Torx-head screws holding the friction lining in place are removed.

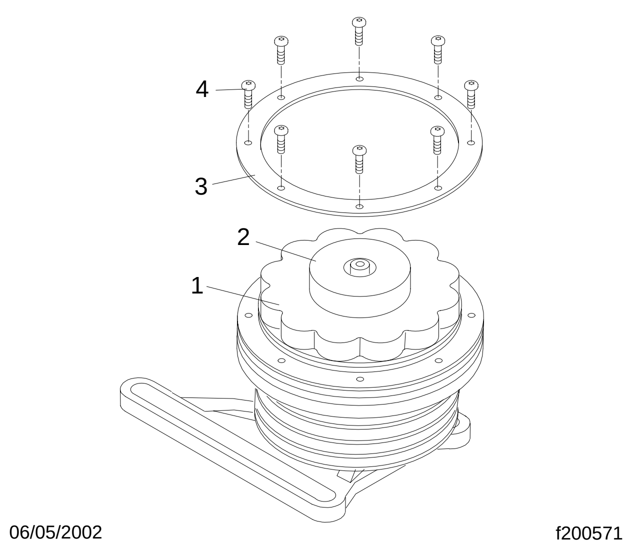
9. Release the air pressure from the fan clutch.

WARNING

Release the air pressure from the fan clutch before removing the friction lining Torx-head screws. Failure to release the air pressure could result in the spring housing/piston assembly being ejected with force, which could result in personal injury.

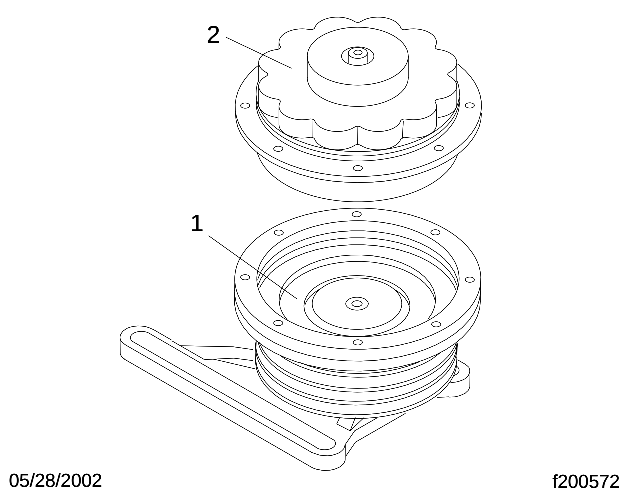
10. Using a T27 Torx bit, remove the eight Torx-head screws holding the friction lining in place.
11. Remove the friction lining. See **Fig. 4**.
12. *Keeping the cage nut installed and tightened,* remove the spring housing/piston assembly. See **Fig. 5**.
13. Remove the air chamber seal. See **Fig. 6**.
14. Examine the inside of the air chamber for signs of moisture and/or contaminants.
15. Remove the air chamber cap retaining ring. See **Fig. 6**.
16. Using two small screwdrivers placed 180 degrees apart, gently and evenly pry the air chamber cap out of the sheave.
17. Remove the O-ring seal from the air chamber cap. See **Fig. 6**.
18. Remove the face seal. See **Fig. 6**.

Fan Clutch Major Rebuild



1. Spring Housing/Piston Assembly
2. Cage Nut
3. Friction Lining
4. Torx-Head Screws

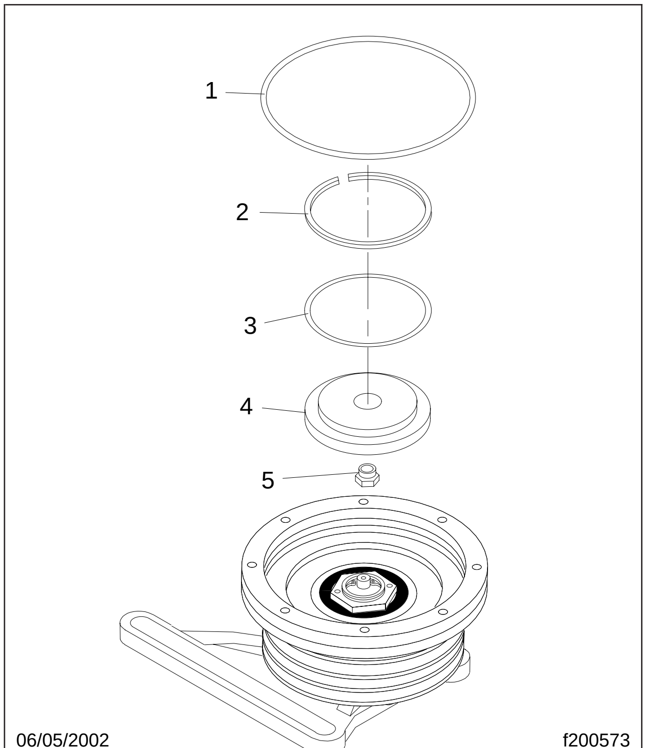
Fig. 4, Friction Lining Removal and Installation



1. Air Chamber
2. Spring Housing/Piston Assembly (with cage nut installed)

Fig. 5, Spring Housing/Piston Assembly Removal and Installation

19. Inspect the face seal for signs of wear. Wear indicates that dirt may exist in the air system.



1. Air Chamber Seal
2. Retaining Ring
3. O-Ring Seal
4. Air Chamber Cap
5. Face Seal

Fig. 6, Air Chamber Seal Removal and Installation

20. Remove the bearing nut from the mounting bracket. See **Fig. 7**.
21. Remove the sheave from the mounting bracket. See **Fig. 8**.
22. If replacing the bearings, support the sheave and press them out.
23. Clean and remove any dirt, debris, or corrosion that may be present.
24. Remove the air cartridge.

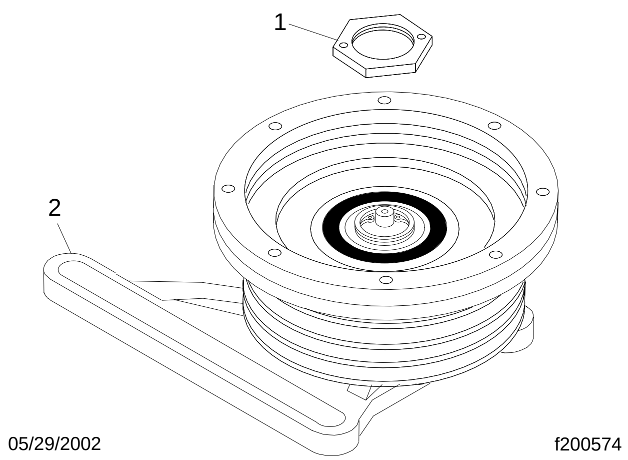
    24.1 Remove the retaining ring. See **Fig. 9**.

    24.2 Remove the air cartridge assembly. See **Fig. 10**.

Assembly

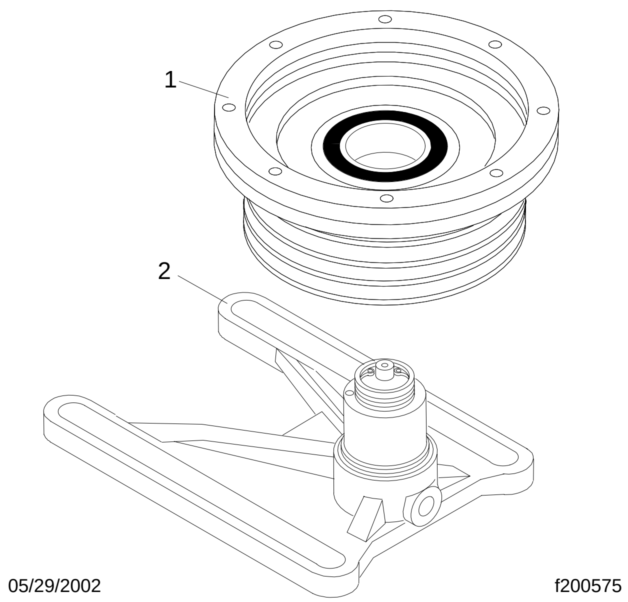
1. If necessary, clean the air cartridge bore in the mounting bracket.

Fan Clutch Major Rebuild



1. Bearing Nut
2. Mounting Bracket

Fig. 7, Bearing Nut Removal and Installation



1. Sheave
2. Mounting Bracket

Fig. 8, Removing the Sheave

NOTE: The sheave bearings do not require lubrication.

2. If replacing the sheave bearings, do the following:

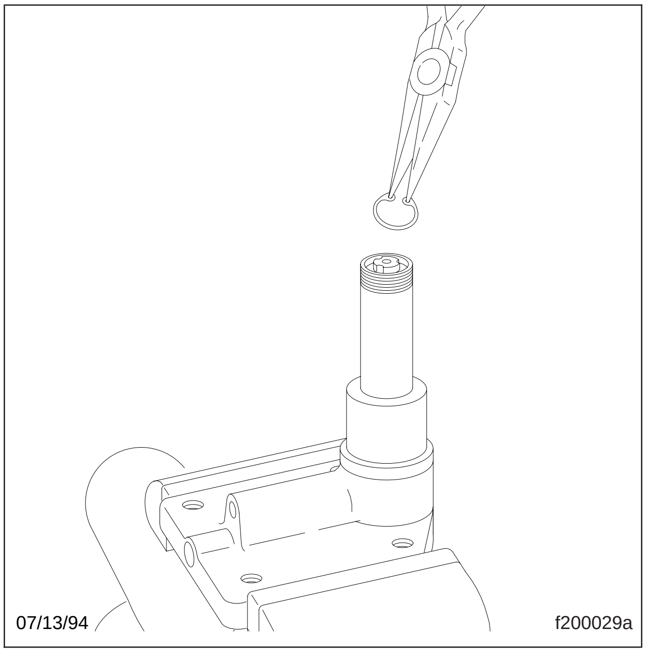
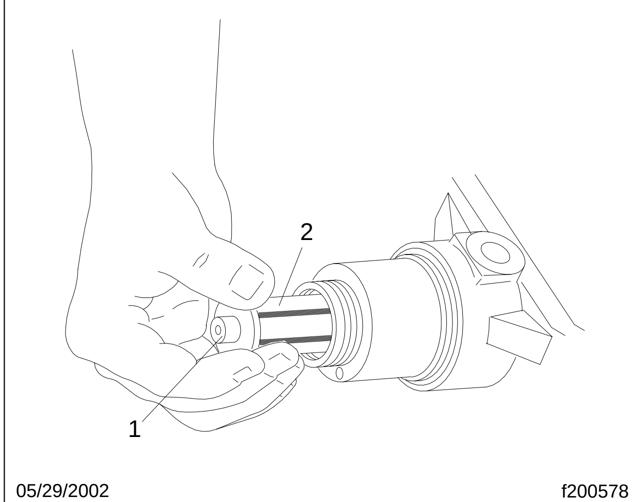


Fig. 9, Retaining Ring Removal and Installation



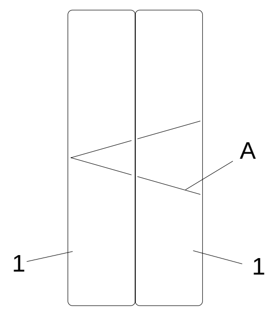
1. Float Seal Tip
2. Air Cartridge

Fig. 10, Removing the Air Cartridge

2.1 If equipped with two bearings, assemble the bearings so the markings on their edges line up to form an arrow. See

Fan Clutch Major Rebuild

Fig. 11. It doesn't matter which way the arrow faces when the bearings are installed.



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A. Align the markings to form an arrow.
1. Sheave Bearing

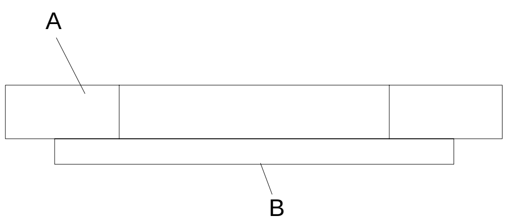
Fig. 11, Aligning the Bearings

IMPORTANT: If the fan clutch uses spacers, be sure to install them between the bearings.

2.2 Supporting the sheave, press the new sheave bearings — and spacers, if applicable — into place. Note the position of the lip inside the sheave.

2.3 Slide the sheave onto the mounting bracket. See Fig. 8.

2.4 Making sure that the bearing nut hex is facing up, install the bearing nut. See Fig. 12. Tighten 130 lbf·ft (176 N·m). See Fig. 7.



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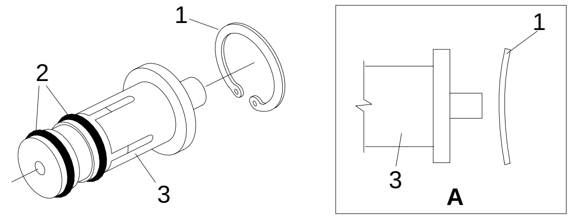
A. Hex faces up.
B. Relief faces toward mounting bracket and bearings.

Fig. 12, Correct Bearing Nut Orientation

3. Apply O-ring lubricant from the kit to the outside O-rings of the new air cartridge assembly. See Fig. 13.



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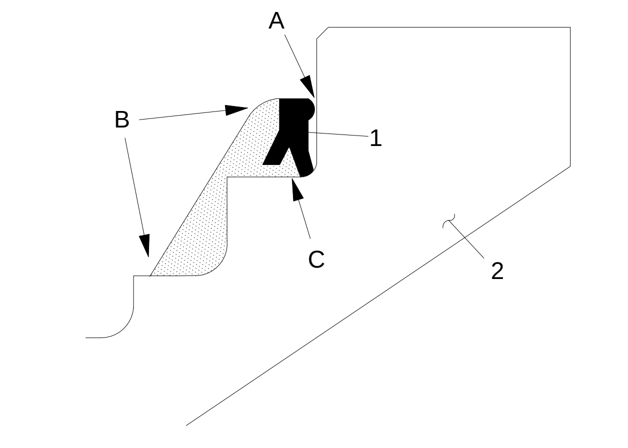
A. Convex surface of the retaining ring goes toward the air cartridge.
1. Retaining Ring
2. O-Rings
3. Air Cartridge

Fig. 13, Installing the Air Cartridge Retaining Ring

4. Install the new air cartridge assembly into the mounting bracket.
5. Install the retaining ring, making sure the convex surface of the ring is toward the air cartridge. See Fig. 13.
6. Using a clean, dry cloth, clean both the float seal tip of the air cartridge and the face seal of the air chamber cap.
7. Assemble the air chamber cap and face seal. See Fig. 6.

   Tighten the face seal 75 to 100 lbf·in (850 to 1130 N·cm).
8. Lubricate the O-ring seal with the fresh lubricant from the kit.
9. Install the O-ring seal on the air chamber cap. See Fig. 6.
10. Carefully set the air chamber cap into the sheave. See Fig. 6.
11. Install the retaining ring. See Fig. 6.
12. Install the air chamber seal into the sheave. Be sure the seal is evenly seated against the side and bottom of the groove surfaces, and the "V" of the seal is facing down. See Fig. 14.
13. Lubricate contact surfaces with the fresh lubricant from the kit.

Fan Clutch Major Rebuild



A. Seal is seated evenly against side and bottom of groove.
B. Apply grease only between these areas.
C. "V" of Seal Facing Down

1. Air Chamber Seal
2. Sheave

Fig. 14, Correct Installation of Air Chamber Seal (cross-section view)

⚠ WARNING

The new spring housing/piston assembly from the kit has a cage nut installed on it. Do not remove the cage nut. This will cause the spring housing to be forcibly ejected from the piston assembly, which could result in serious injury.

14. Carefully set the new spring housing/piston assembly into position. See **Fig. 6**. Note that the new assembly has a cage nut installed on it.
15. Rotate the new spring housing/piston assembly to align the mounting holes with those of the sheave.

IMPORTANT: Handle the new friction liner by the edges to avoid contamination.

16. Set the new friction liner from the kit into place, being careful to touch only the edges.
17. Using a T27 Torx bit, install the eight Torx-head screws. See **Fig. 4**. Tighten alternately 80 lbf·in (900 N·m).
18. Apply a minimum of 80 psi (552 kPa) of clean air to the air inlet.
19. Remove the cage nut from the spring housing/piston assembly.
20. Install the new fan mounting disc from kit.

⚠ CAUTION

Use care when placing the pry bar onto the fan mounting disc. Make sure it is secure and flat on the surface. Failure to do so make cause the pry bar to slip, which could result in damage to studs or the fan mounting disc.

21. Using a suitable wrench, a T55 Torx bit, and a pry bar, tighten the jack bolt (left-hand thread) 100 lbf·ft (136 N·m). Turn the wrench clockwise and push the pry bar counterclockwise.
22. Using shop air, actuate the fan clutch and check for correct engagement and disengagement of the fan mounting disc. If there is a problem, it must be corrected before installing the fan clutch onto the engine.
23. Check for air leaks at the bleed hole and around the spring housing/piston assembly.
24. Install the fan clutch assembly onto the engine. See **Subject 100** for instructions.

Fan Clutch Minor Rebuild

Disassembly

NOTE: This procedure involves a minor rebuild of the Horton DriveMaster® fan clutch, using parts from the manufacturer's Seal Kit. If a major rebuild of the fan clutch is needed, see **Subject 110**.

1. Remove the fan clutch assembly from the vehicle. For instructions, see **Subject 100**.
2. Put the fan clutch assembly in a vise.
3. Connect a shop air hose to the fan clutch air inlet.
4. Apply 80 to 120 psi (552 to 827 kPa) to the fan clutch to lift the fan mounting disc off the spring housing/piston assembly.

CAUTION

Use care when placing the pry bar onto the fan mounting disc. Make sure it is secure and flat on the surface. Failure to do so make cause the pry bar to slip, which could result in damage to studs or the fan mounting disc.

5. Using a pry bar, wrench, and a T55 Torx® bit, loosen the jack bolt (left-hand thread) by turning it counterclockwise. See **Fig. 1**.
6. Unscrew the fan mounting disc from the jack bolt. See **Fig. 2**.
7. Inspect the fan mounting disc for wear or damage.

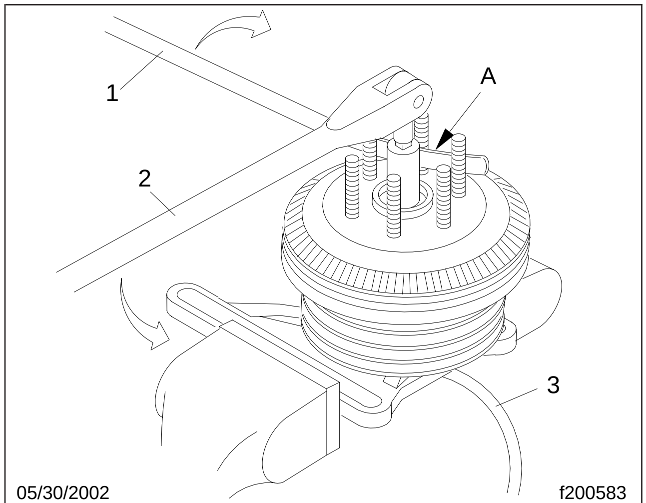
WARNING

Do not disassemble the spring housing from the piston. The interior springs are very strong, and if released could eject the housing with considerable force, possibly resulting in serious injury. Always use the cage nut to hold the spring housing and the piston together.

8. Using a wrench and T55 Torx bit to hold the jack bolt, install the cage nut from the kit onto the jack bolt (left-hand thread). Hand tighten it onto the spring housing.

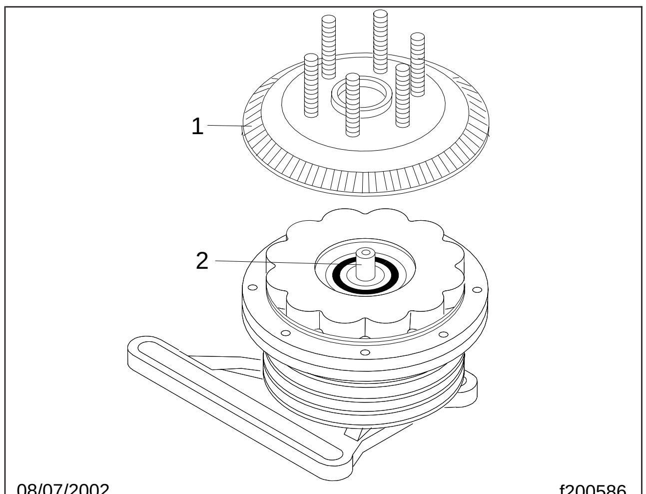
   The cage nut will keep the spring housing and piston together as an assembly. It will also maintain pressure on the internal springs after the Torx-head screws holding the friction lining in place are removed.

9. Release the air pressure from the fan clutch.



A. Place the pry bar here.
1. Pry Bar (push clockwise)
2. Torx Bit and Wrench (turn counterclockwise)
3. Shop Air Hose (connected to the inlet port)

Fig. 1, Loosening the Jack Bolt



1. Fan Mounting Disc
2. Jack Bolt (left-hand thread)

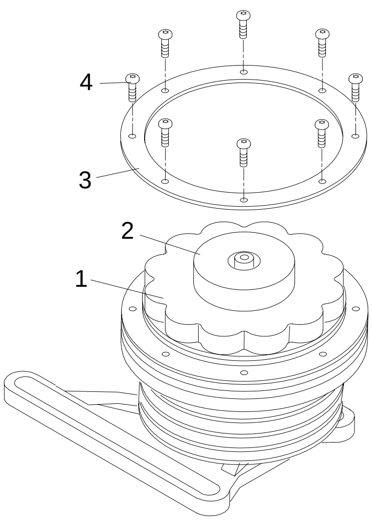
Fig. 2, Fan Mounting Disc Removal and Installation

Fan Clutch Minor Rebuild

WARNING

Release the air pressure from the fan clutch before removing the friction lining Torx-head screws. Failure to release the air pressure could result in the spring housing/piston assembly being ejected with force, which could result in personal injury.

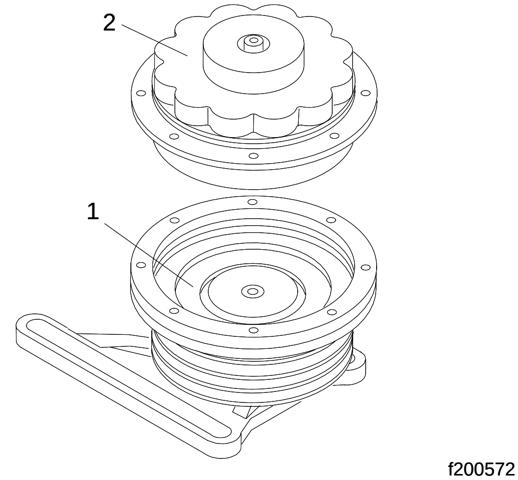
10. Using a T27 Torx bit, remove the eight Torx-head screws holding the friction lining in place.
11. Remove the friction lining. See **Fig. 3**.



1. Spring Housing/Piston Assembly
2. Cage Nut
3. Friction Lining
4. Torx-Head Screws

Fig. 3, Friction Lining Removal and Installation

12. *Keeping the cage nut installed and tightened,* remove the spring housing/piston assembly. See **Fig. 4**.
13. Remove the air chamber seal. See **Fig. 5**.
14. Examine the inside of the air chamber for signs of moisture and/or contaminants.
15. Remove the air chamber cap retaining ring. See **Fig. 5**.
16. Using two small screwdrivers placed 180 degrees apart, gently and evenly pry the air chamber cap out of the sheave.



1. Air Chamber
2. Spring Housing/Piston Assembly (with cage nut installed)

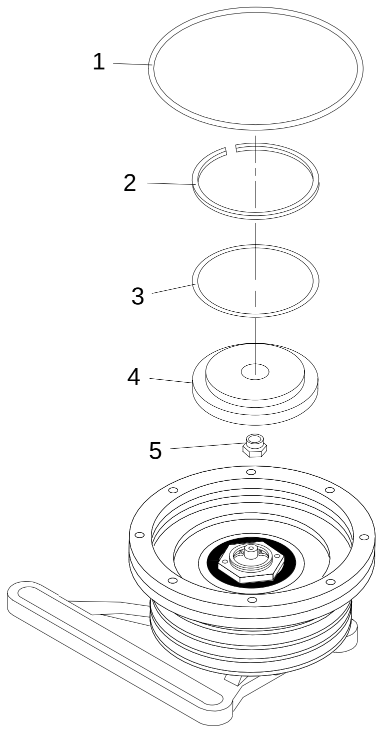
Fig. 4, Spring Housing/Piston Assembly Removal and Installation

17. Remove the O-ring seal from the air chamber cap. See **Fig. 5**.
18. Remove the face seal. See **Fig. 5**.
19. Inspect the face seal for signs of wear. Wear indicates that dirt may exist in the air system.
20. Remove the air cartridge.
    20.1 Remove the retaining ring. See **Fig. 6**.
    20.2 Remove the air cartridge assembly. See **Fig. 7**.

Assembly

1. Clean the mounting bracket bore if necessary.
2. Apply O-ring lubricant from the kit to the outside O-rings of the new air cartridge assembly. See **Fig. 8**.
3. Install the new air cartridge assembly into the mounting bracket.
4. Install the retaining ring, making sure the convex surface of the ring is toward the air cartridge. See **Fig. 8**.

Fan Clutch Minor Rebuild



1. Air Chamber Seal
2. Retaining Ring
3. O-Ring Seal
4. Air Chamber Cap
5. Face Seal

Fig. 5, Air Chamber Seal Removal and Installation

5. Using a clean, dry cloth, clean both the float seal tip of the air cartridge and the face seal of the air chamber cap.
6. Assemble the air chamber cap and face seal. See **Fig. 5**.

   Tighten the face seal 75 to 100 lbf·in (850 to 1130 N·cm).
7. Lubricate the O-ring seal with the fresh lubricant from the kit.
8. Install the O-ring seal on the air chamber cap. See **Fig. 5**.
9. Carefully set the air chamber cap into the sheave. See **Fig. 5**.
10. Install the retaining ring. See **Fig. 5**.
11. Install the air chamber seal into the sheave. Be sure the seal is evenly seated against the side

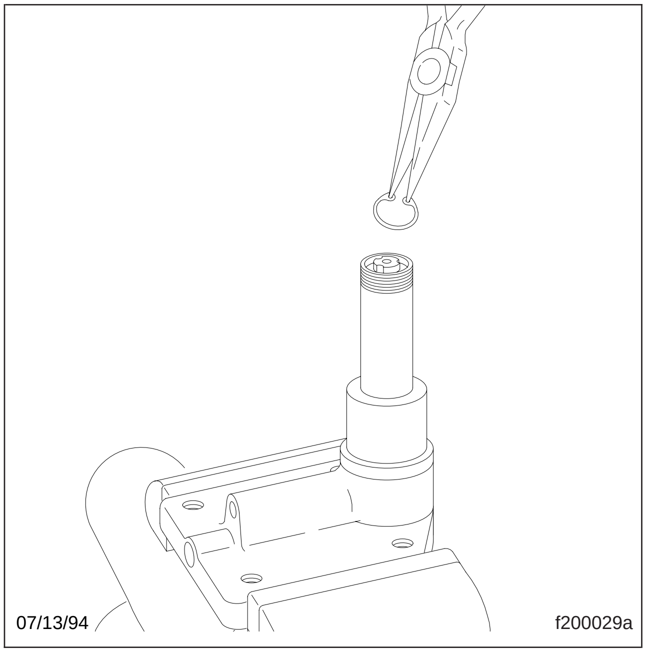
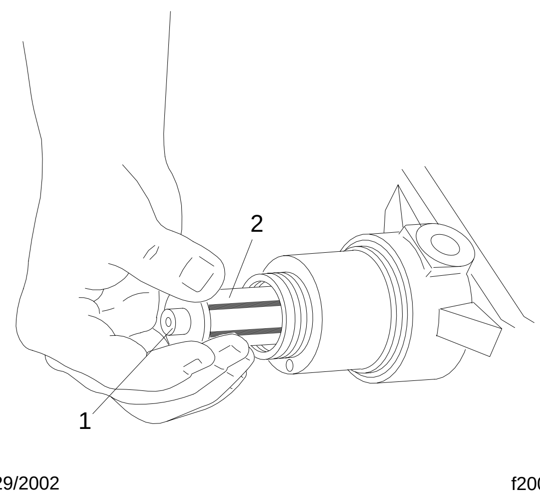


Fig. 6, Retaining Ring Removal and Installation (sheave not shown)



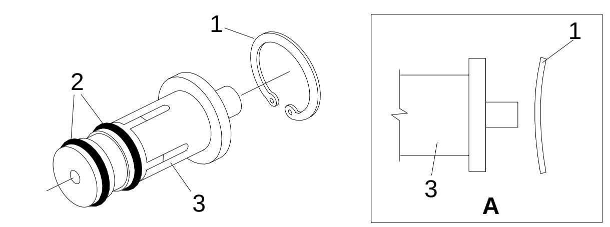
1. Float Seal Tip
2. Air Cartridge

Fig. 7, Removing the Air Cartridge (sheave not shown)

and bottom of the groove surfaces, and the "V" of the seal is facing down. See **Fig. 9**.

12. Lubricate contact surfaces with the fresh lubricant from the kit.

Fan Clutch Minor Rebuild



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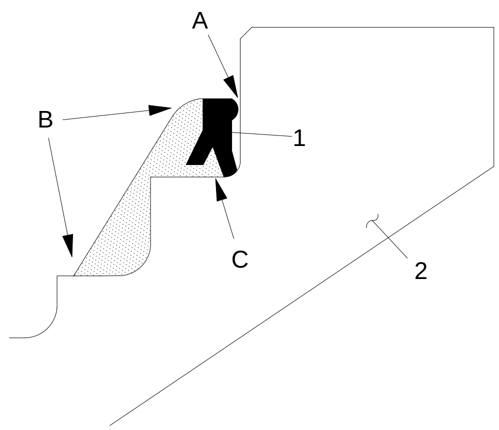
A. Convex surface of the retaining ring goes toward the air cartridge.
1. Retaining Ring
2. O-Rings
3. Air Cartridge

Fig. 8, Installing the Air Cartridge Retaining Ring



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A. Seal is seated evenly against side and bottom of groove.
B. Apply grease only between these areas.
C. "V" of Seal Facing Down
1. Air Chamber Seal
2. Sheave

Fig. 9, Correct Installation of Air Chamber Seal (cross-section view)

WARNING

The new spring housing/piston assembly from the kit has a cage nut installed on it. Do not remove the cage nut. This will cause the spring housing to be forcibly ejected from the piston assembly, which could result in serious injury.

13. Carefully set the new spring housing/piston assembly into position. See Fig. 4. Note that the new assembly has a cage nut installed on it.
14. Rotate the new spring housing/piston assembly to align the mounting holes with those of the sheave.
15. Set the friction liner from the kit into place, being careful to touch only the edges.
16. Using a T27 Torx bit, install the eight Torx-head screws. See Fig. 3. Tighten alternately 80 lbf·in (900 N·cm).
17. Apply a minimum of 80 psi (552 kPa) of clean air to the air inlet.
18. Remove the cage nut from the spring housing/piston assembly.

CAUTION

Use care when placing the pry bar onto the fan mounting disc. Make sure it is secure and flat on the surface. Failure to do so make cause the pry bar to slip, which could result in damage to studs or the fan mounting disc.

19. Using a suitable wrench, a T55 Torx bit, and a pry bar, tighten the jack bolt (left-hand thread) 100 lbf·ft (136 N·m). Turn the wrench clockwise and the pry bar counterclockwise.
20. Using shop air, actuate the fan clutch and check for correct engagement and disengagement of the fan mounting disc. If there is a problem, it must be corrected before installing the fan clutch onto the engine.
21. Check for air leaks at the bleed hole and around the spring housing/piston assembly.
22. Install the fan clutch assembly onto the engine. See Subject 100 for instructions.

Troubleshooting Tables

Problem—Air Is Leaking from the Fan Clutch

Problem—Air Is Leaking from the Fan Clutch	
Possible Cause	**Remedy**
The face seal or air cartridge is damaged or worn.	Install a new seal kit.
The O-ring seals are damaged or worn.	Install a new seal kit.

Problem—The Fan Clutch Fails to Engage

Problem—The Fan Clutch Fails to Engage	
Possible Cause	**Remedy**
There’s no power to the fan clutch control circuit.	Check all electrical connections, and repair or replace wiring as needed. Check the circuit breaker for the engine fan and repair or replace as needed.
The engine temperature switch is damaged or an incorrect sensor has been installed.	Make sure the switch is normally open, not normally closed. Replace the switch if it is damaged or if the switch is the wrong type.
The solenoid valve is malfunctioning.	Replace the solenoid valve.
The solenoid is not exhausting.	Make sure the solenoid exhaust port is not plugged.

Problem—The Fan Clutch Does Not Disengage

Problem—The Fan Clutch Does Not Disengage	
Possible Cause	**Remedy**
The engine temperature switch is damaged or an incorrect sensor has been installed.	Make sure the switch is normally open, not normally closed. Replace the switch if it is damaged or if the switch is the wrong type.
A restricted air line doesn’t allow air supply to the clutch.	Make sure the air lines are not pinched or plugged. Repair the air lines as needed.
The fan clutch is leaking.	Install a new seal kit.
The air supply to the fan clutch is restricted.	Make sure the fan clutch air lines are not leaking or pinched. Repair the lines as needed.
The piston is seized due to contamination or dry seals.	Clean the air supply. Do a major rebuild.

Problem—The Fan Clutch Cycles Frequently

Problem—The Fan Clutch Cycles Frequently	
Possible Cause	**Remedy**
The fan clutch control circuit has a loose connection or is poorly grounded.	Check all wiring connections, and repair the circuit as needed. Check the circuit breaker for the engine fan and repair or replace as needed.
The temperature control settings are incorrect.	Check the fan clutch control setting of the temperature switch, according to the engine installed in the vehicle. Repair or replace the temperature switch as needed.

Troubleshooting

Problem—The Fan Clutch Cycles Frequently	
Possible Cause	**Remedy**
The fan cycling switch at the receiver-dryer is set too low.	Check the switch at the receiver-dryer, and if needed, replace the switch with a switch with a higher setting. Check the ACPU switch and unit.
There is an air restriction in front of the fan clutch.	Check for incorrect radiator shutter operation, winterfronts, or any other air restrictions.
The engine temperature is too high.	Check the programmable engine control parameters, and reprogram as needed.
The temperature switch is malfunctioning.	Replace the temperature switch.

Problem—The Fan Clutch Engages, But the Engine Still Overheats

Problem—The Fan Clutch Engages, But the Engine Still Overheats	
Possible Cause	**Remedy**
There is an air restriction in front of the fan clutch.	Check for incorrect radiator shutter operation, winterfronts, or any other air restrictions.
There is a problem somewhere else in the cooling system.	Refer to the cooling system troubleshooting section, **Section 20.00**.

Specifications

Horton DriveMaster® Repair Kits		
Kit Description *	**Part Number**	**When Used**
Super Kit	HOR994347	Fan Clutch Major Rebuild
Seal Kit	HOR994346	Replacing Seals and Air Cartridge
Friction Disc Kit	HOR994348	Replacing Fan Mounting Disc and Friction Lining
Friction Liner Kit	HOR994349	Replacing Friction Lining Only

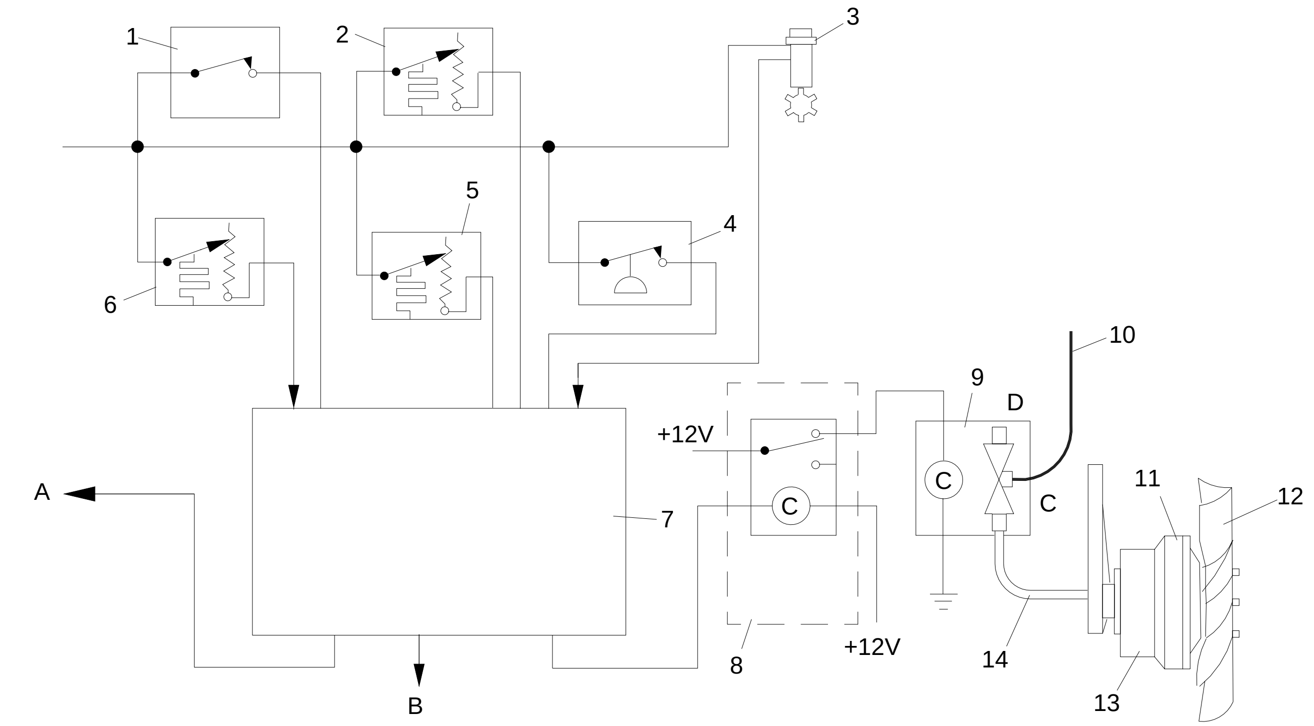
* All kits are available from the PDCs.

Table 1, Horton DriveMaster Repair Kits

Description	Torque	
	lbf·in (N·cm)	**lbf·ft (N·m)**
Friction Lining Screws	80 (900)	—
Face Seal	75 to 100 (850 to 1130)	—
Bearing Nut	—	130 (176)
Jack Bolt	—	100 (136)

Table 2, Torque Values

Specifications



A. To Indicators and Gauges
B. To Electronic Injectors and Other Actuators
C. Normally Closed
D. Normally Open

1. Fan Override Switch
2. Air Temperature Sensor
3. Engine Speed Sensor
4. A/C Pressure Switch
5. Coolant Temperature Sensor
6. Foot Throttle
7. Engine ECM
8. Fan Relay (not present in all systems)
9. Solenoid Valve
10. Air Supply from Reservoir
11. Fan Clutch
12. Air Supply to Fan Clutch

Fig. 1, Fan Clutch Schematic (engine ECM controlled)

General Information

The fan clutch is a temperature-controlled, air-operated clutch for the engine cooling fan. It is spring engaged, and controls the engine temperature by engaging or disengaging the fan.

When the coolant temperature is below a specified range, air pressure keeps the fan disengaged to save engine power. When the coolant temperature rises above the specified range, air pressure to the fan clutch is cut off and internal spring pressure engages the fan.

Air pressure to the fan clutch is controlled by a solenoid valve; the solenoid valve is controlled by a temperature switch installed in the thermostat housing. The temperature switch is connected to the engine MCM, which controls the solenoid valve. When you start a cold engine, the solenoid valve allows air pressure to the fan clutch and the clutch remains disengaged. When the coolant temperature rises to the temperature switch setting, the switch provides power to the solenoid valve and the valve cuts off compressed air to engage the fan.

On vehicles with air conditioning, the fan clutch solenoid valve is connected to a fan cycling switch at the receiver-drier. If the refrigerant pressure exceeds the setting of the fan cycling switch, the switch supplies power to the solenoid valve, which cuts off air to the fan clutch, engaging the fan.

Fan Clutch Removal and Installation

Removal

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Tilt the hood.

WARNING

Wear safety goggles when draining the air system or disconnecting an air line because dirt and sludge could fly out at high speeds. Don't direct the airstreams at anyone. Do not disconnect pressurized air lines, as they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

3. Drain the air tanks.
4. Disconnect the air line from the fan clutch.
5. Remove the upper fan shroud as follows.
   - 5.1 Place alignment marks on the upper and lower fan shrouds, and mark the shroud-to-channel positions, so the shroud can be installed in the same position on the radiator.
   - 5.2 Remove the four fasteners that connect the upper and lower fan shrouds.
   - 5.3 Remove the fasteners that hold the upper fan shrouds to the radiator.
   - 5.4 Remove the upper fan shroud from the vehicle.
6. Remove the fasteners that hold the fan to the fan clutch, then remove the fan.

WARNING

If the fan clutch engages during the next step, it could cause personal injury. Keep the fan clutch disengaged throughout this procedure by maintaining between 90 and 120 psi (620 and 827 kPa) of air pressure.

7. Align the access holes in the fan clutch with the allen screws on the fan hub. See **Fig. 1**.
   - 7.1 Using shop air and a suitable nozzle attachment, apply between 90 and 120 psi (620 and 827 kPa) of air pressure to the fan clutch to disengage the clutch.
   - 7.2 Line up the access holes.

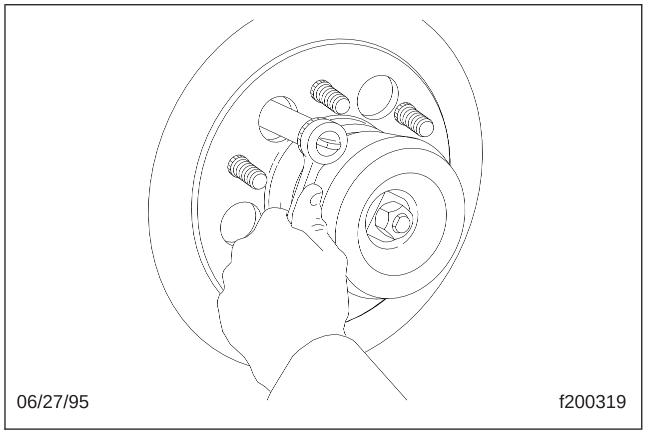


Fig. 1, Line Up the Access Holes

8. Remove the air pressure from the fan clutch, and allow the fan to engage.
9. Remove the allen screws holding the fan clutch to the fan hub.
10. Remove the fan clutch from the fan clutch hub. It may be necessary to gently pry the clutch from the hub.

Installation

IMPORTANT: A new coupler must be used when installing the clutch onto the hub.

1. Install the fan clutch onto the fan clutch hub.
   - 1.1 Install a new coupler onto the fan hub.
   - 1.2 Position the fan clutch onto the fan hub, then push it toward the rear of the vehicle and rotate the clutch until the flats of the coupler engage the fan clutch.
   - 1.3 Line up the access holes in the clutch with the holes for the allen screws in the clutch hub.
   - 1.4 Install the allen screws, and tighten them 45 lbf·ft (61 N·m).
2. Install the fan.
3. Connect the air line to the fan clutch.
4. Position the upper fan shroud on the radiator; align the marks, then install the fasteners that hold it to the radiator and the lower fan shroud.

Fan Clutch Removal and Installation

5. Connect the left-side hose to the charge air cooler.

Fan Clutch Minor Rebuild

Special Tools

IMPORTANT: Special tools are are recommended, but not required for this procedure. See **Table 1** for the special tool set.

Special Tools		
Description	**Part Number**	**Order From**
Support and Compressor (see **Fig. 1**)	1090-00000-02	Wright Brothers Enterprises 8171 Hibma Marion, MI 49665 Telephone: 231-825-2939

Table 1, Special Tools

Rebuild

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Remove the fan clutch from the vehicle. For instructions, refer to **Subject 100**.

NOTICE

When caging and compressing the engagement spring of the fan clutch, depress the clutch shaft only enough to relieve the pressure on the retaining plates (about 1/16-inch, or 1.5 mm). Applying additional force after the clutch shaft bottoms in the housing will damage the housing and render it unserviceable.

NOTE: There are two methods of caging the engagement spring. One uses the special tools and a press. The other uses carriage bolts, washers, and wingnuts. Either method is effective.

3. Cage the engagement spring.

   If using the special support and compressor tools, place the fan clutch in a press to cage the engagement spring. See **Fig. 2**.

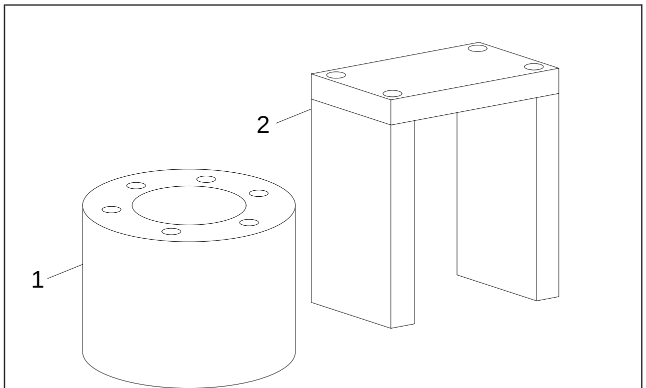
   If using the optional method of caging the engagement spring, do the following:

   3.1 With the access holes in the housing assembly aligned with those in the shaft assembly, install two 3-1/2-inch (89-mm) long carriage bolts and suitable washers on opposite sides of the clutch assembly.

   3.2 On the shaft assembly side, install about a 1/2-inch (13-mm) thickness of washers onto each carriage bolt.

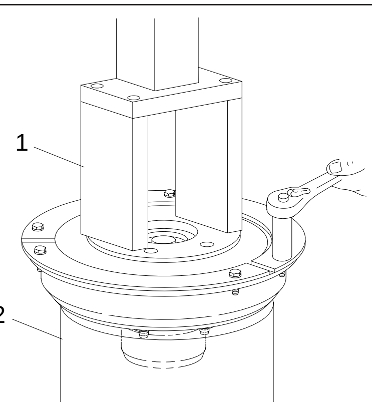
   3.3 Install a wingnut on the end of each carriage bolt and tighten the wingnuts evenly until the engagement spring is caged.

4. Remove the lining retaining plates and the lining. See **Fig. 2** and **Fig. 3**.



1. Support 2. Compressor

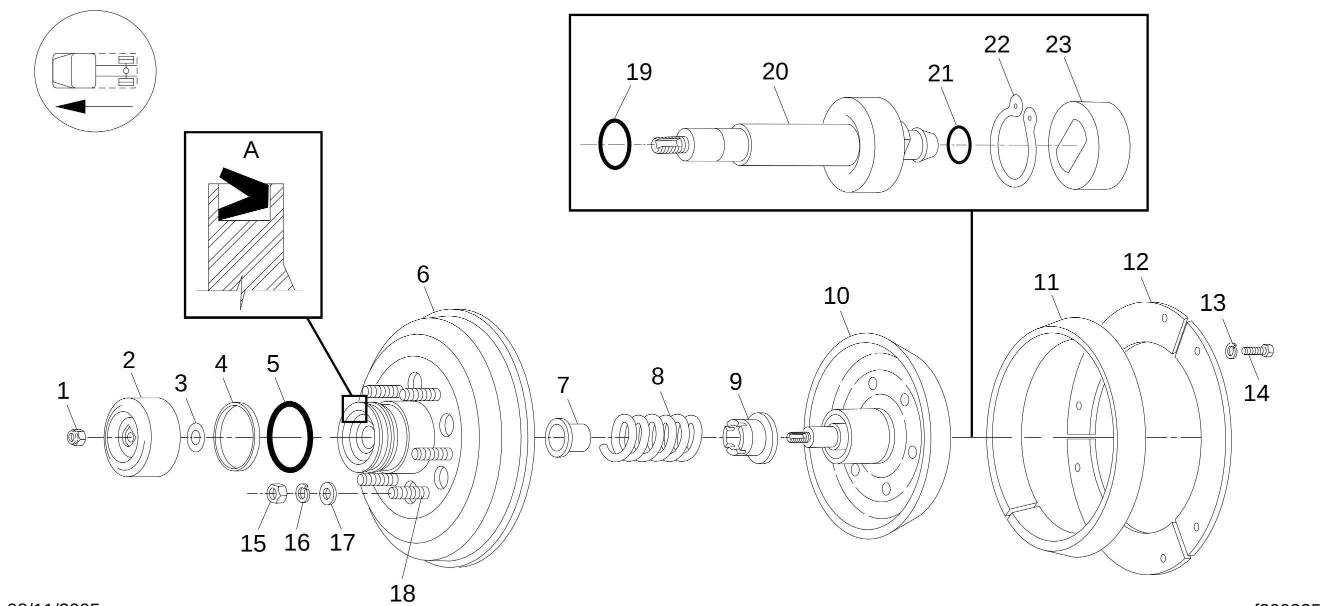
Fig. 1, Special Tools



1. Compressor Tool 2. Support Tool

Fig. 2, Caging the Engagement Spring and Removing the Lining Retaining Plates

Fan Clutch Minor Rebuild



A. If a lip seal is used, install it so that it faces away from the fan studs.

1. Cylinder Nut
2. Cylinder Assembly
3. Piston Rod Seal Washer
4. Lip Seal (may be O-Ring)
5. Dust Seal
6. Housing Assembly
7. Engagement Spring End Cap
8. Engagement Spring
9. Engagement Spring Carrier
10. Shaft Assembly
11. Lining
12. Lining Retaining Plates
13. Lockwasher
14. Screw
15. Fan Nut
16. Lockwasher
17. Flatwasher
18. Fan Stud
19. O-Ring
20. Piston Rod Assembly
21. O-Ring
22. Snap Ring
23. Coupling

Fig. 3, Kysor K26RA Fan Clutch (exploded view)

NOTICE

Do not press on the cylinder during this step, or the cylinder will be damaged. Use a 5/8-inch wrench as shown in Fig. 4 on the piston rod flats.

5. If applicable, turn the clutch over in the press, and use the special compressor tool to cage the engagement spring while removing the cylinder nut and cylinder. See Fig. 4.
6. Inspect the fan clutch. See Fig. 3

    6.1 Inspect the two surfaces where the lining rides.

    6.2 Inspect the needle bearing race on the shaft.

    6.3 Inspect the needle bearings inside the clutch housing.

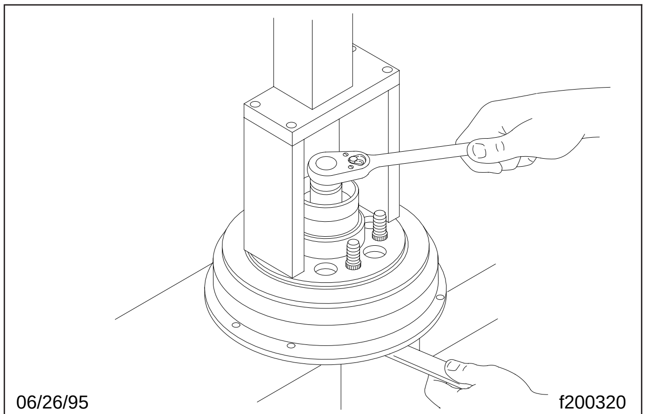


Fig. 4, Removing the Cylinder Nut and Cylinder

    6.4 Inspect the piston bearing by rotating the piston.

Fan Clutch Minor Rebuild

7. If you find cracking or scoring on any surface, or if the bearings are rough, loose, or missing, replace the fan clutch.

NOTE: If you find metal particles in the existing grease, replace the fan clutch or contact Kysor for the training needed to perform a major fan clutch rebuild. Kysor will not provide parts for a major rebuild until the technician has completed rebuild training provided by Kysor.

IMPORTANT: Do not wash the clutch parts in solvent.

8. Using **Fig. 3** as a reference, lubricate the following rebuild parts with lubricant supplied with the rebuild kit (if the lubricant is unavailable, use one of the approved lubricants listed in **Specifications, 400)** :
   - The piston seal (pack the seal groove also)
   - The dust seal (pack the seal groove also)
   - The needle bearings inside the housing
   - The inside of the engagement spring
   - The outside of the piston rod assembly
   - The inside of the piston rod assembly
   - The inside of the cylinder assembly
   - Pack the lip of the grease seal

NOTICE

When caging and compressing the engagement spring of the fan clutch, depress the clutch shaft only enough to relieve the pressure on the retaining plates (about 1/16-inch, or 1.5 mm). Applying additional force after the clutch shaft bottoms in the housing will damage the housing and render it unserviceable.

IMPORTANT: When caging the engagment spring, compress the clutch shaft only 1/16-inch (1.5 mm).

9. Assemble the fan clutch parts according to **Fig. 3**. Using either the special tools and a press, or carriage bolts, washers, and wingnuts, cage the engagement spring when installing the cylinder and lining. Be careful to depress the clutch shaft only 1/16-inch (1.5 mm).

   The piston rod seal washer is the last item to install before the cylinder goes on. See **Fig. 5**.

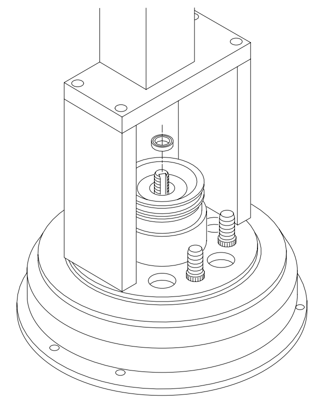


Fig. 5, Installing the Piston Rod Seal Washer

10. Tighten the cylinder nut 84 lbf·in (940 N·cm).
11. Tighten the lining screws 30 lbf·in (340 N·cm).
12. As applicable, remove the fan clutch from the press or remove the carriage bolts, washers, and wing nuts.
13. Check the front-to-rear travel of the fan clutch. For instructions, refer to **Group 20** in the *108SD and 114SD Maintenance Manual*.
14. Install the fan clutch on the engine. For instructions, refer to **Subject 100**.

Relining

IMPORTANT: Premature wearing of the fan clutch lining is due to either insufficient air pressure necessary to fully disengage the clutch (allowing the clutch to remain partially engaged, thus increasing wear), or a problem in the control circuit for the fan. Before putting the fan clutch back in service, check the fan control and air supply systems and make any necessary repairs.

1. Park the vehicle on a level surface, apply the parking brake, and shut down the engine. Chock the tires.

WARNING

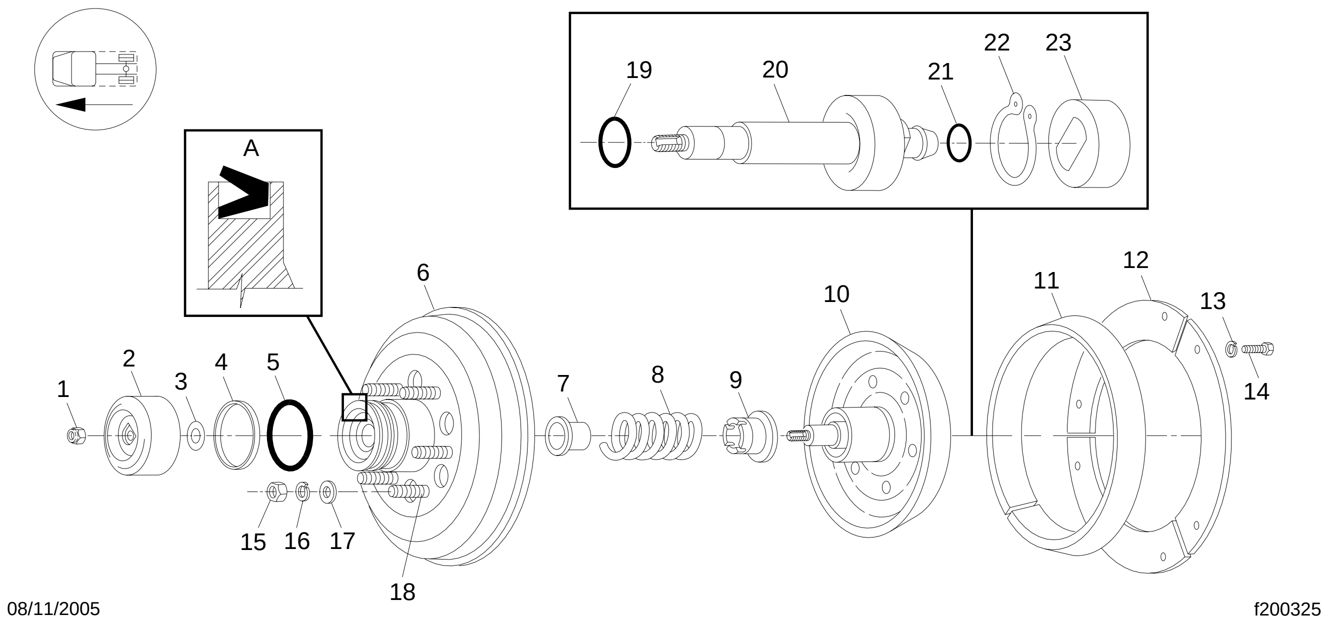
If the fan clutch engages during the next step, it could cause personal injury. Keep the fan clutch disengaged throughout this procedure by maintaining between 90 and 120 psi (620 and 827 kPa) of air pressure.

2. Bleed all the air from the primary and secondary tanks.
3. Disconnect the air line from the fan drive, and apply 90 to 110 psi (620 to 760 kPa) shop air pressure to the fan drive.
4. Remove the six lining plate screws, and remove the three lining plates. See **Fig. 1**.
5. Remove the old lining. If the lining sticks, use a hammer and a screwdriver to free it by tapping on the dividing cut in the lining.
6. Inspect the clutch shaft. If lining residue is present, or if the surface appears glazed over (non-metallic), temporarily release the air pressure from the clutch to allow shaft to protrude, and use a ScotchBrite to break the glaze.

NOTE: Some applications may be too tight to spread the lining and slip it over the pulley. If necessary, the lining can be cut in half with a hacksaw for installation.

7. Apply air pressure to the clutch again, and install the new lining. See **Fig. 2**.
8. Install the new lining plates. Tighten the screws 30 lbf·in (340 N·cm).
9. Remove the air pressure from the fan clutch, and allow the fan to engage.
10. Disconnect the shop air, and connect the air line to the fan drive.

Fan Clutch Relining



A. If a lip seal is used, install it so that it faces away from the fan studs.

1. Cylinder Nut
2. Cylinder Assembly
3. Piston Rod Seal Washer
4. Lip Seal (may be O-Ring)
5. Dust Seal
6. Housing Assembly
7. Engagement Spring End Cap
8. Engagement Spring
9. Engagement Spring Carrier
10. Shaft Assembly
11. Lining
12. Lining Retaining Plates
13. Lockwasher
14. Screw
15. Fan Nut
16. Lockwasher
17. Flatwasher
18. Fan Stud
19. O-Ring
20. Piston Rod Assembly
21. O-Ring
22. Snap Ring
23. Coupling

Fig. 1, Kysor K26RA Fan Clutch (exploded view)

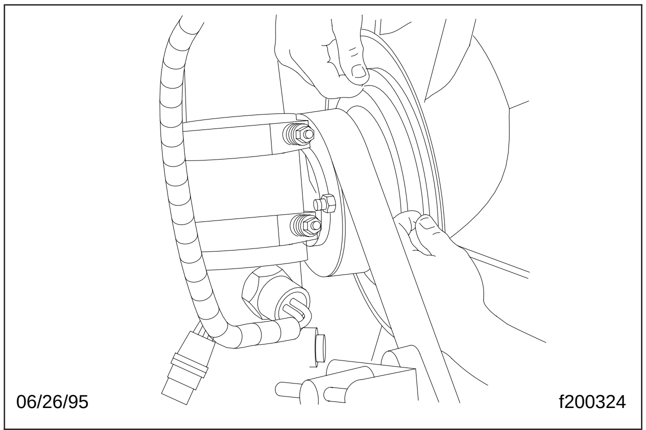


Fig. 2, Removing the Lining Plates

Specifications

If the lubricant that comes with the rebuild kit for the Kysor K26RA fan clutch is unavailable, use one of the following approved lubricants:

- Aeroshell 5
- Shell Alvania R3
- Chevron SR12
- Amoco Rykon Premium #2EP
- Texaco RB Premium

Kysor K26RA Fan Clutch Torques		
Description	Torque	
	lbf·ft (N·m)	lbf·in (N·cm)
Clutch-to-Hub Fasteners	45 (61)	—
Fan-to-Clutch Fasteners	26 (35)	—
Front Piston Nut	—	84 (950)
Lining Plate Screws	—	30 (340)

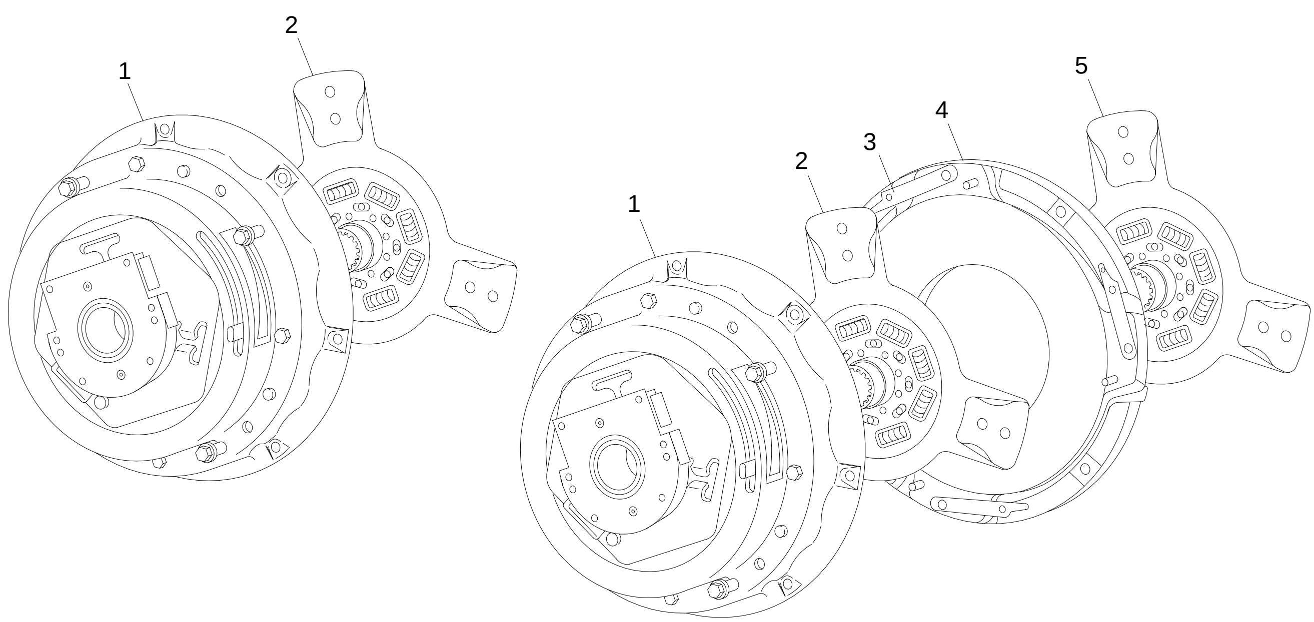
Table 1, Kysor K26RA Fan Clutch Torques

General Description

Eaton Fuller Solo™ clutches are 14-inch (350-mm) single- or dual-disc assemblies used in medium-duty applications and 15.5-inch (394-mm) dual-disc assemblies used in heavy-duty applications. See **Fig. 1** and **Fig. 2**. Both versions are mounted to a flat flywheel.

Solo clutches are adjustment-free: as the clutch wears, its wear-adjusting technology monitors clutch components and makes necessary adjustments. The wear-adjusting technology comes from two sliding cams, which rotate to maintain the proper adjustment. Atop the upper cam, a wear indicating tab mirrors the cam movement to let you know when it's time to replace the clutch. See **Fig. 3**. The wear indicating tab cannot be used as a mechanism for adjusting the clutch.

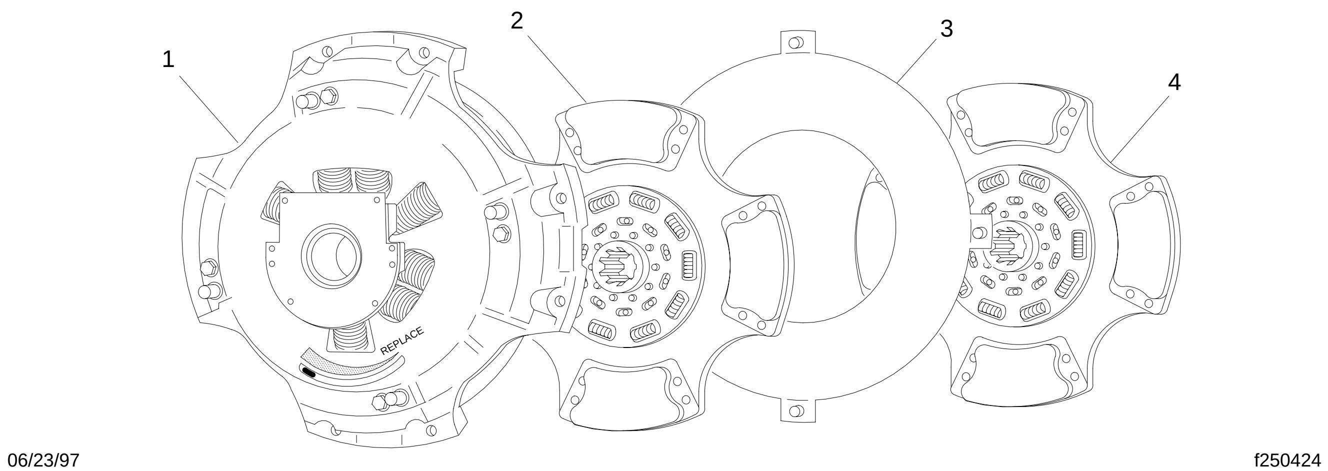
In the dual-disc versions of these clutches, the intermediate plate separating the driven discs is mounted directly to the flywheel. Four separator pins ensure an equal gap on all sides of the intermediate plate and increase the life of the clutch.



1. Cover Assembly
2. Front Disc
3. Drivestrap
4. Intermediate Plate
5. Rear Disc

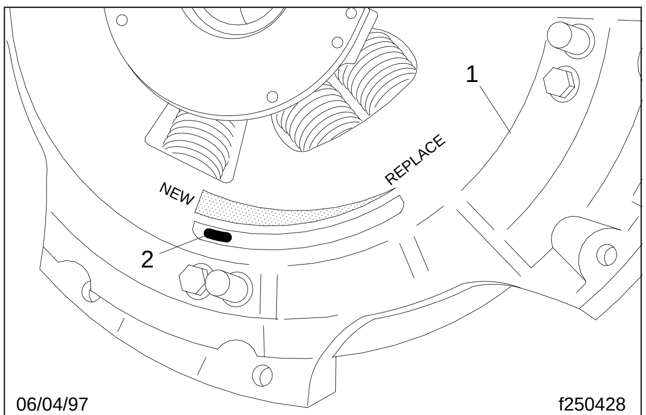
Fig. 1, Solo Medium-Duty Clutches

General Information



1. Clutch Cover
2. Rear Driven Disc
3. Intermediate Plate
4. Front Driven Disc

Fig. 2, Solo Heavy Duty Clutches



1. Clutch Cover
2. Wear Indicating Tab

Fig. 3, Wear Indicator

Clutch Removal

Use the following procedure if you need to temporarily remove and then reinstall an Eaton Fuller Solo clutch. Failure to follow these steps could cause the Solo clutch to drag or not release upon installation.

IMPORTANT: Check the position of the wear indicating tab on the clutch cover. If the wear indicating tab is near the REPLACE position on the indicator, it is time to replace the clutch.

Removal

NOTICE

For proper reinstallation of the Solo clutch, the wear indicating tab must be reset. Failure to reset this tab will prevent clutch release and result in possible clutch damage.

NOTE: This step requires two persons: one under the vehicle with access to the wear indicating tab, and the other in the vehicle to press the clutch pedal.

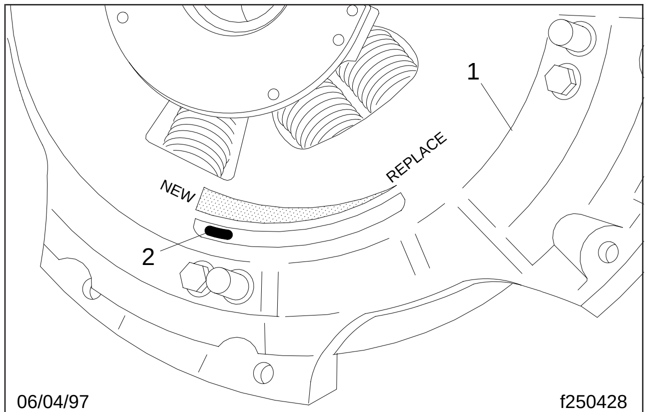
1. Reset the wear indicating tab with the clutch in the vehicle, as follows.
   1.1 From inside the cab, press the clutch pedal all the way down. Hold the clutch pedal down until the wear indicating tab is reset.
   1.2 Through the clutch inspection cover, slide the wear indicating tab until it is at the NEW position on the indicator. See Fig. 1.
   1.3 From inside the cab, release the clutch pedal. Check to be sure the wear indicating tab stays at the NEW position on the indicator.

NOTICE

When removing the transmission from a vehicle equipped with a hydraulic clutch control system, disconnect the clutch grease tube to avoid component damage.

NOTE: Before pulling the transmission from the bell housing, disconnect the external clutch linkage and rotate the release yoke so the yoke will clear the release bearing when it is removed.

2. Remove the transmission. See Section 26.00.



With the clutch pedal down, set the tab to the NEW position on the indicator.

1. Clutch Cover
2. Wear Indicating Tab

Fig. 1, Resetting the Wear Indicating Tab

NOTICE

Do not let the rear of the transmission drop, and do not let the transmission hang unsupported in the splined hubs of the clutch discs. Taking these precautions will prevent bending and distortion of the clutch discs.

3. Remove the clutch brake from the transmission input shaft. See Fig. 2.

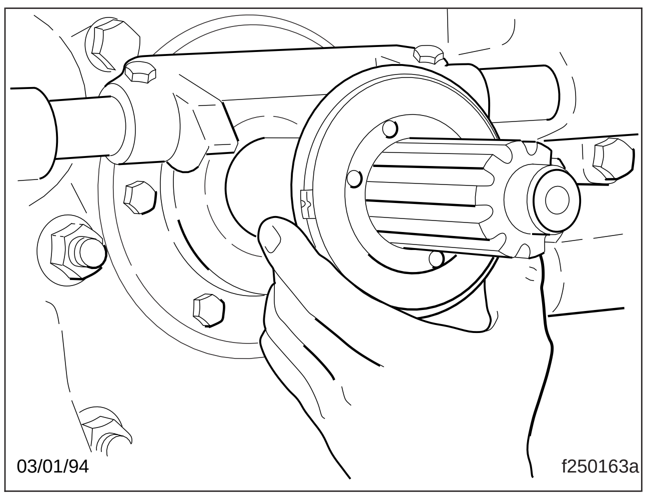


Fig. 2, Clutch Brake Removal

4. Install a spline aligning tool into the release bearing assembly, and through the driven discs. See

Clutch Removal

Fig. 3. An old transmission input shaft may be used for this purpose.

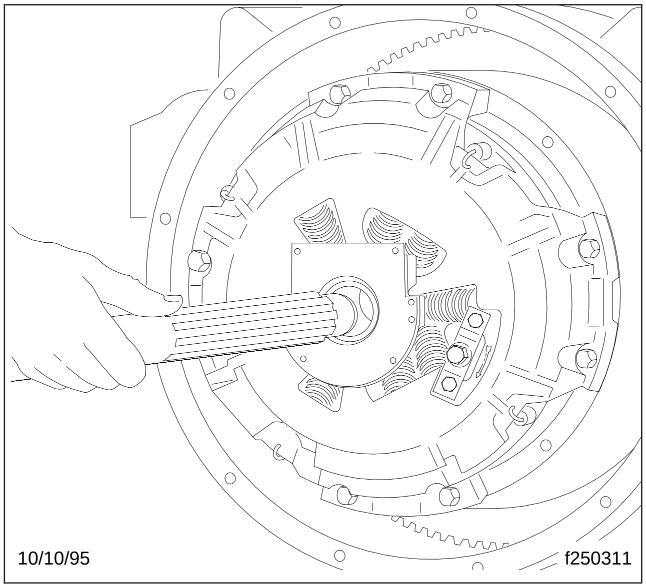


Fig. 3, Installing a Spline Aligning Tool

NOTE: Shipping bolts are installed on the clutch cover prior to removal to prevent the clutch adjustment mechanism from unloading.

5. Cage the pressure plate, as follows.

   For a 14-inch clutch, install four 3/8–16 x 1-1/4 shipping bolts (if available) or hexhead machine screws into the four clutch cover holes, and tighten them finger-tight plus one full turn.

   For a 15.5-inch clutch, install four 7/16–14 x 1-3/4 shipping bolts (if available) or hexhead machine screws into the four clutch cover holes, and tighten them finger-tight plus one full turn.

   These bolts will cage the pressure plate, preventing the four plate spacers from moving out of position when the clutch is removed from the flywheel. See **Fig. 4**.

6. Progressively loosen each of the mounting capscrews in the pattern shown in **Fig. 5**. This will prevent warping or bending within the clutch, and will ease removal of the clutch mounting capscrews.

7. Remove the two top mounting capscrews from the cover assembly, and install two guide studs in the open holes to help support the clutch assembly during removal. See **Fig. 6**. *For a 14-inch clutch*, use 3/8–16 x 3 guide studs. *For a 15.5-inch clutch*, use 7/16–14 x 5 guide studs.

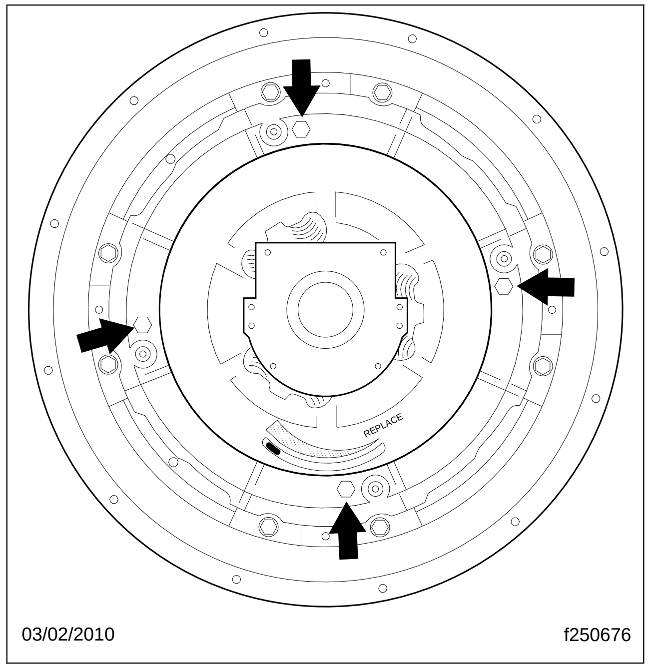


Fig. 4, Installed Shipping Bolts

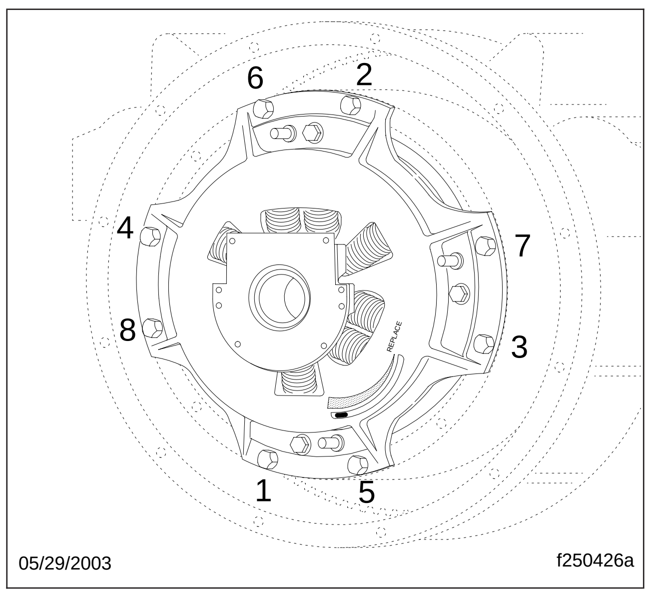


Fig. 5, Loosening Sequence

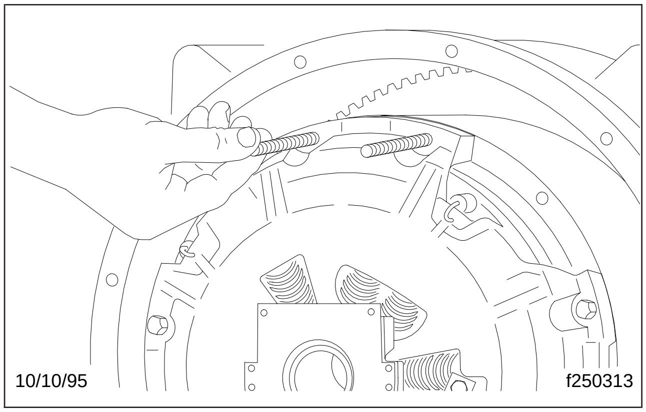


Fig. 6, Installing Guide Studs

NOTE: Mark the positions of the clutch components so they can be properly oriented during installation.

WARNING

The clutch assembly is heavy. It should be removed and installed only with a lifting device. If the assembly is lifted incorrectly or dropped, it could cause serious personal injury.

8. Remove the mounting capscrews, and carefully remove the clutch assembly together with the spline aligning tool.
9. Reset the pressure plate, as follows. See **Fig. 7**.

   9.1 Progressively tighten the four shipping bolts in a crisscross pattern.

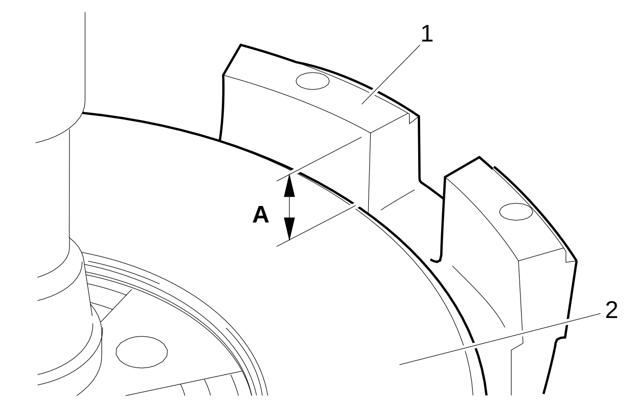
   9.2 Measure the depth of the pressure plate, as follows.

   For a 14-inch clutch, the pressure plate is reset when the face of the pressure plate is 0.50 inch (12.7 mm) below the mounting surface of the clutch cover.

   For a 15.5-inch clutch, the pressure plate is reset when the face of the pressure plate is 1.75 to 1.78 inches (44.4 to 45.2 mm) below the mounting surface of the clutch cover.

NOTE: Resetting the pressure plate will allow the clutch to release after installation.

10. Use an appropriate puller to remove the pilot bearing. Inspect the old pilot bearing for any unusual wear or damage. Discard the pilot bearing.



NOTE: *For a 14-inch clutch*, the pressure plate will be reset when it is 0.50 inch (12.7 mm) below the mounting surface of the clutch cover. *For a 15.5-inch clutch*, the pressure plate will be reset when it is 1.75 to 1.78 inches (44.4 to 45.2 mm) below the mounting surface of the clutch cover.

A. 0.50 inch (12.7 mm) for 14-inch clutches; 1.75 to 1.78 inches (44.4 to 45.2 mm) for 15.5-inch clutches

1. Mounting Surface
2. Pressure Plate

Fig. 7, Reset Pressure Plate

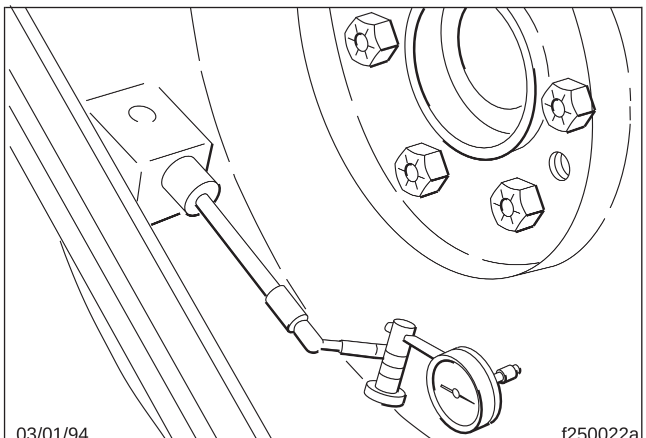
Inspection

NOTICE

Misalignment of any parts described in these procedures will cause premature wear of drivetrain components.

IMPORTANT: When taking the following readings, rotate the engine by hand; do not crank the engine with the starter. The engine may be rotated by the pulley nut at the front of the crankshaft, the flywheel mounting bolts, or the starter ring-gear on the flywheel.

1. Clean the surfaces being measured to ensure accurate measurements.
2. Measure the runout of the flywheel face (friction surface), as follows. See **Fig. 1** for the correct setup.



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Secure the dial indicator to the flywheel housing, with the gauge finger against the flywheel face, and near the outer edge.

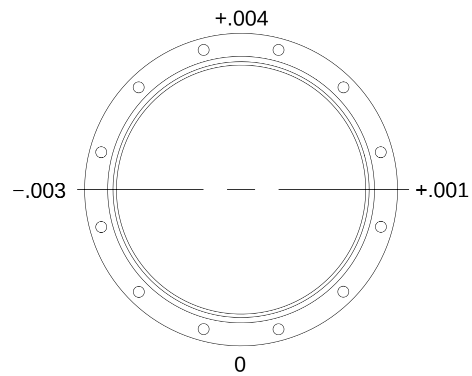
Fig. 1, Measuring the Flywheel Face

2.1 Secure the dial indicator to the flywheel housing, with the gauge finger against the face of the flywheel near the outer edge.

2.2 Turn the flywheel through one complete revolution. With chalk or soapstone, mark the high and low points on the flywheel face.

2.3 The total runout will be the difference between the highest plus and lowest minus readings. To calculate the runout, see **Fig. 2**.

Example: The highest reading is +0.004 at 12 o'clock. The lowest reading is –0.003 at 9 o'clock. Therefore the total runout is 0.007 inch.



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Take four readings, starting with zero at the 6 o'clock position, and going on to 9, 12, and 3 o'clock. Make sure the dial returns to zero at the original start position.

Fig. 2, Calculating the Runout

2.4 The SAE maximum total runout for the flywheel face is 0.008 inch (0.20 mm). If the readings are higher, see the engine manufacturer's manual for instructions.

3. Measure the runout of the pilot-bearing bore in the flywheel, as follows. See **Fig. 3** for the correct setup.

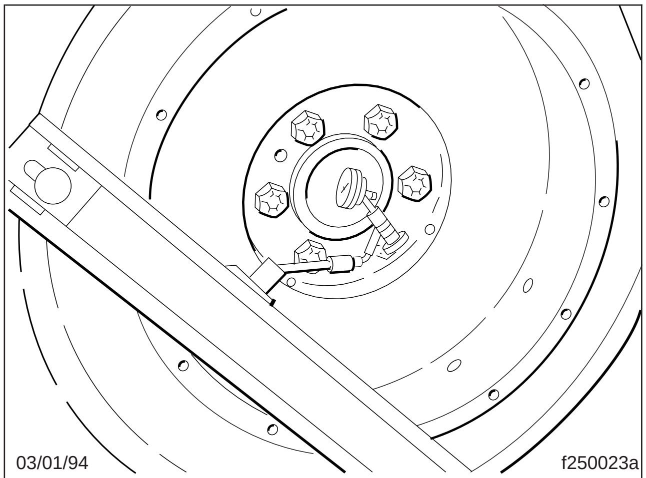
3.1 With the indicator still secured to the flywheel housing, move the gauge finger to contact the surface of the pilot-bearing bore.

3.2 Turn the flywheel through one complete revolution. With chalk or soapstone, mark the high and low points on the bore of the pilot bearing.

3.3 Calculate the runout as before.

3.4 The SAE maximum total runout for the pilot-bearing bore is 0.005 inch (0.13 mm). If the readings are higher, see the engine manufacturer's manual for instructions.

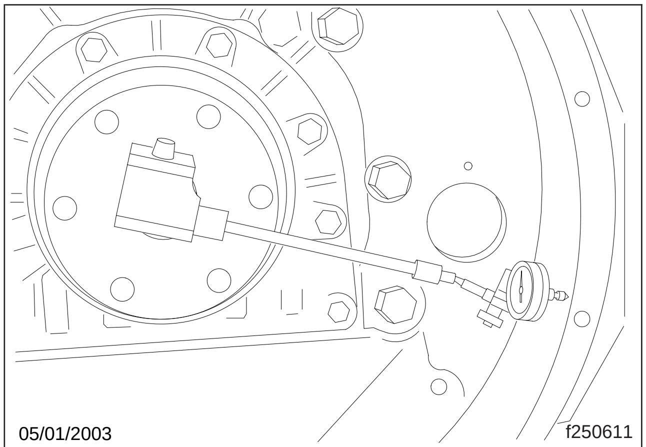
Clutch Inspection and Pre-Installation Procedures



Secure the dial indicator to the flywheel housing, with the gauge finger on the surface of the pilot-bearing bore.

Fig. 3, Measuring the Pilot-Bearing Bore

4. Measure the runout of the flywheel housing bore, as follows. See **Fig. 4** for the correct setup.



Secure the dial indicator to the crankshaft, with the gauge finger against the side of the flywheel housing.

Fig. 4, Measuring the Flywheel Housing Bore

4.1 Secure the dial indicator to the crankshaft, with the gauge finger against the side of the flywheel housing.

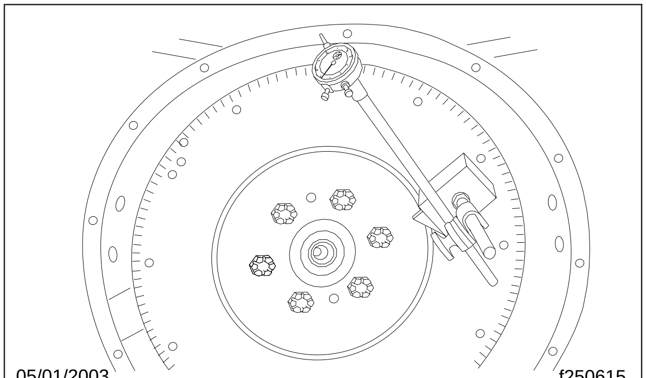
4.2 Turn the flywheel through one complete revolution. With chalk or soapstone, mark the high and low points on the side of the flywheel housing.

4.3 Calculate the runout as before.

NOTE: Only if you have to reposition the flywheel housing is it necessary to mark the high and low runout readings in clock positions.

4.4 The SAE maximum total runout for the flywheel-housing bore is 0.008 inch (0.20 mm). If readings are higher, replace the flywheel housing. For instructions, see the engine manufacturer's manual.

5. Measure the runout of the face of the flywheel housing, as follows. See **Fig. 5** for the correct setup.



Secure the dial indicator to the outer diameter of the flywheel, with the gauge finger against the face of the flywheel housing.

Fig. 5, Measuring the Flywheel Housing Face

5.1 With the dial indicator secured to the outer diameter of the flywheel, move the gauge finger to contact the face of the flywheel housing.

5.2 Turn the flywheel through one complete revolution. With chalk or soapstone, mark the high and low points on the face of the flywheel housing.

5.3 Calculate the runout as before.

NOTE: Only if you have to reposition the flywheel housing is it necessary to mark the high and low runout readings in clock positions.

5.4 The SAE maximum total runout for the flywheel-housing face is 0.007 inch (0.18 mm) for a 14-inch clutch, and 0.008 inch

(0.20 mm) for a 15.5-inch clutch. If the readings are higher, replace the housing. For instructions, see the engine manufacturer's manual.

NOTE: Use a case-bore plug and shaft set to measure the bell-housing face and pilot. Case-bore plugs are tapped into the front and rear bores of the transmission case, and have very close tolerances. The shaft runs through the center of the plugs, and extends to the front far enough to secure a dial indicator and obtain a reading on the bell housing.

6. Measure the runout of the bell housing face and pilot, as follows.

   6.1 Secure the dial indicator to the case-bore shaft, with the gauge finger against the face of the bell housing.

   6.2 Turn the case-bore shaft through one complete revolution. With chalk or soapstone, mark the high and low points on the face of the bell housing.

   6.3 Calculate the runout as before.

   6.4 The SAE maximum total runout for the bell-housing face is 0.008 inch (0.20 mm). If the readings are higher, replace the bell housing. See the transmission manufacturer's service manual for instructions.

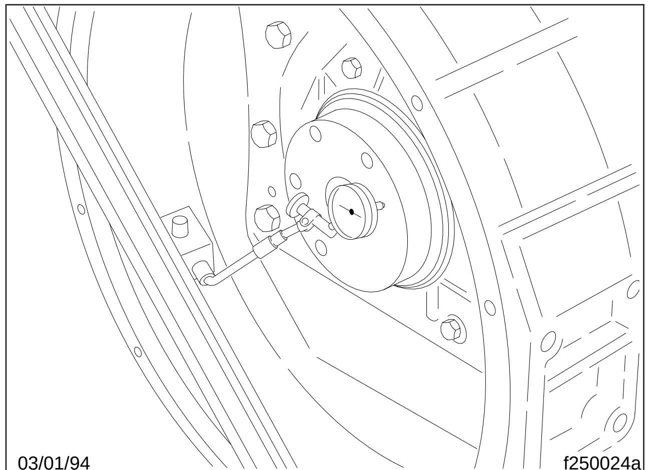
7. Remove the flywheel (see the engine manufacturer's manual), and measure the runout of the flywheel crankshaft face. See **Fig. 6**.

   7.1 Secure the dial indicator to the flywheel housing, with the gauge finger against the crankshaft face, and near the outer edge.

   7.2 Turn the crankshaft through one complete revolution. With chalk or soapstone, mark the high and low points on the face of the crankshaft.

   7.3 Calculate the runout as before.

   7.4 See the engine manufacturer's manual for maximum runout, corrective measures, and flywheel installation instructions.



Secure the dial indicator to the flywheel housing, with the gauge finger against the crankshaft face, and near the outer edge.

Fig. 6, Measuring the Crankshaft Face Runout

Resetting (clutch out of vehicle)

NOTICE

Use this procedure if the clutch was removed without caging the pressure plate. Resetting the pressure plate allows the clutch to release after installation and prevents possible clutch damage.

1. Remove the four shipping bolts if they have been installed. See **Fig. 7**.
2. Support the clutch cover in an arbor press with the release bearing facing down. When setting up the arbor press, allow at least 1 inch (25 mm) clearance for both movement of the release bearing and access to install shipping bolts. See **Fig. 8**.
3. Center the ram and press downward on the retainer until it comes to a stop. Lock the ram in position.
4. Slide the wear indicating tab to the left until it is at the NEW position of the indicator (**Fig. 9**) and hold it in position with a magnet.

NOTE: Shipping bolts are installed on the clutch cover prior to installation to prevent the clutch adjustment mechanism from unloading. See **Fig. 7**.

Clutch Inspection and Pre-Installation Procedures

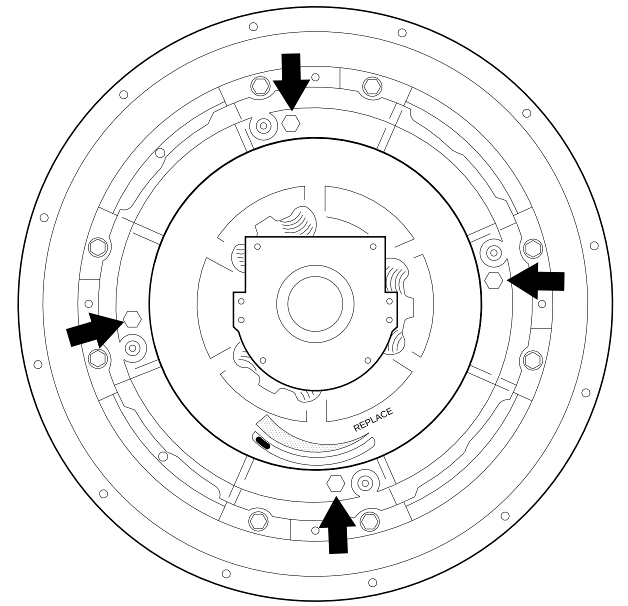


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Fig. 7, Installed Shipping Bolts

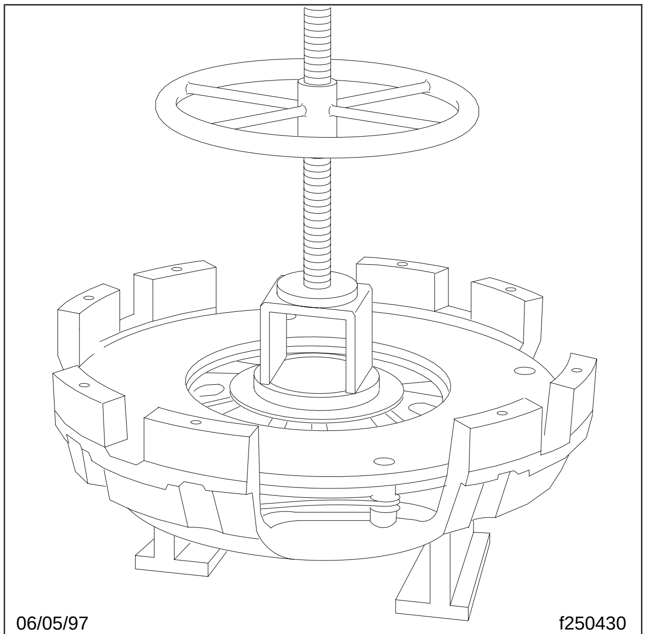

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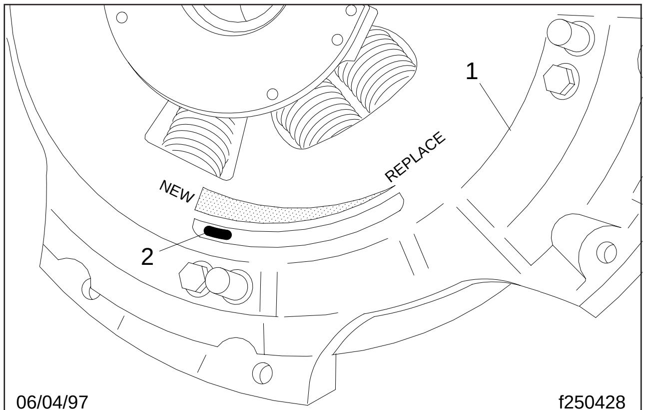
Fig. 8, Arbor Press Setup

5. *For 14-inch clutches*, install four 3/8–16 x 1-1/4 shipping bolts (if available) or hexhead machine screws into the four clutch cover holes, and tighten them finger-tight plus one full turn.

   For 15.5-inch clutches, install four 7/16–14 x 1-3/4 shipping bolts (if available) or hexhead machine screws into the four clutch cover holes, and tighten them finger-tight plus one full turn.



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1. Clutch Cover 2. Wear Indicating Tab

Fig. 9, Resetting the Wear Indicating Tab

NOTE: You may need to temporarily install slightly longer bolts to allow access of the shipping bolts.

6. Reset the pressure plate, as follows.

   6.1 Progressively tighten the four shipping bolts in a crisscross pattern.

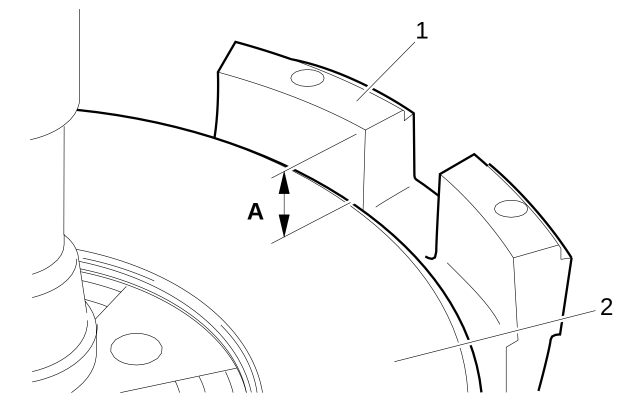
   6.2 Measure the depth of the pressure plate. See **Fig. 10**.

   For 14-inch clutches, the pressure plate is reset when the face of the pressure plate is 0.50 inch (12.7 mm) below the mounting surface of the clutch cover.

   For 15.5-inch clutches, the pressure plate is reset when the face of the pressure plate is 1.75 to 1.78 inches (44.4 to 45.2 mm) below the mounting surface of the clutch cover.

Pre-Installation Procedures

Before installing a new, rebuilt, or used clutch, do the following procedures:



A. 0.50 inch (12.7 mm) for 14-inch clutches; 1.75 to 1.78 inches (44.4 to 45.2 mm) for 15.5-inch clutches

1. Mounting Surface
2. Pressure Plate

Fig. 10, Reset Pressure Plate

1. Install a new pilot bearing. Be sure that the pilot bearing has a press-fit in the flywheel.

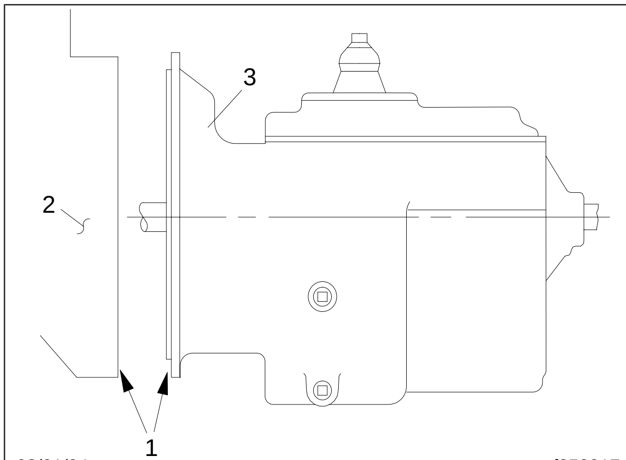
NOTICE

Tap on the outer race only. Tapping on the inner race could damage the pilot bearing.

NOTE: To discourage warranty claims for drag or clutch noise, use a premium grade C3/C4 pilot bearing. Due to increased operating temperatures and longer clutch life, the standard pilot bearings and grease are no longer acceptable.

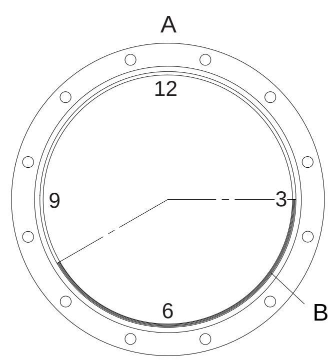
2. Check for wear on the mating surfaces of the flywheel housing and the transmission bell housing. Any noticeable wear on either part causes misalignment. If worn, replace the part. See **Fig. 11**.
3. Check the flywheel housing for wear caused by the bell housing pilot (projecting lip of the bell housing). The correct dimension is 1/8-inch (3.2-mm). Wear is most likely to appear between the 3 o'clock and 8 o'clock positions. See **Fig. 12**.

NOTE: The pilot (lip) of the bell housing can wear into the flywheel housing. This can be caused by the transmission loosening up, or by road and engine vibration after high mileage.



1. Mating Surfaces
2. Engine Flywheel Housing
3. Transmission Bell Housing

Fig. 11, Inspecting the Mating Surfaces

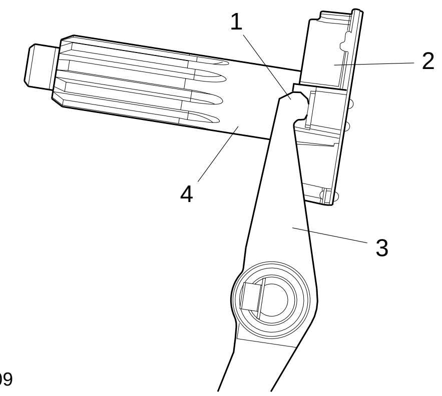


A. Top
B. The most common areas of wear are between the 3 o'clock and 8 o'clock positions.

Fig. 12, Checking the Flywheel Housing for Wear

4. Inspect the flywheel, as follows. Replace or repair the flywheel if the wear is extreme.
   - 4.1 Visually inspect the friction surface of the flywheel for heat checks and scoring.
   - 4.2 Measure the friction surface wear with a straightedge and feeler gauge. For instructions, see the engine manufacturer's manual.
5. Inspect the input shaft, both the splined and the smooth area, as follows. See **Fig. 13**.

Clutch Inspection and Pre-Installation Procedures



1. Release Fork Finger
2. Release Bearing
3. Release Fork
4. Input Shaft

Fig. 13, Input Shaft, Release Bearing, and Release Fork

5.1 Check the fit of the splined hubs of the driven discs by sliding them along the splines of the input shaft. The hubs must slide freely so the clutch will release cleanly. If necessary, use a hand stone to dull the sharp edges of the splines.

5.2 If the input shaft splines are worn or notched, or if the hubs still do not slide freely, replace the input shaft. For instructions, see the transmission manufacturer's service manual.

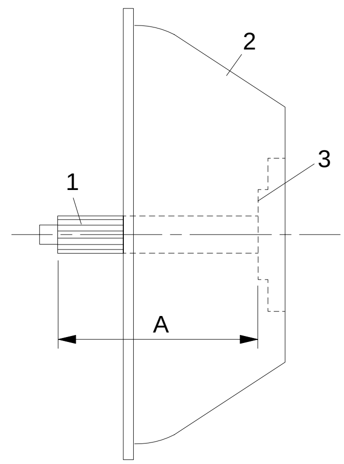
5.3 Inspect the smooth area of the input shaft for wear and/or rough spots. Replace the input shaft if necessary.

6. Check for excessive wear at the fingers of the release fork. See **Fig. 13**.
7. To prevent clutch brake wear, check the input-shaft bearing cap, as follows, and measure it as shown in **Fig. 14**.

7.1 Visually check the bearing cap for excessive wear.

7.2 Measure the distance between the splined end of the input shaft and the bearing cap (dimension A). If dimension A is greater than 8.71 inches (221.5 mm), replace the bearing cap.

NOTE: A torque-limiting clutch brake has facings on both sides. When installing it, orient the shallow side toward the transmission, and the deep



A. Length of Input Shaft, from the Splined End to the Bearing Cap

1. Input Shaft
2. Bell Housing
3. Bearing Cap

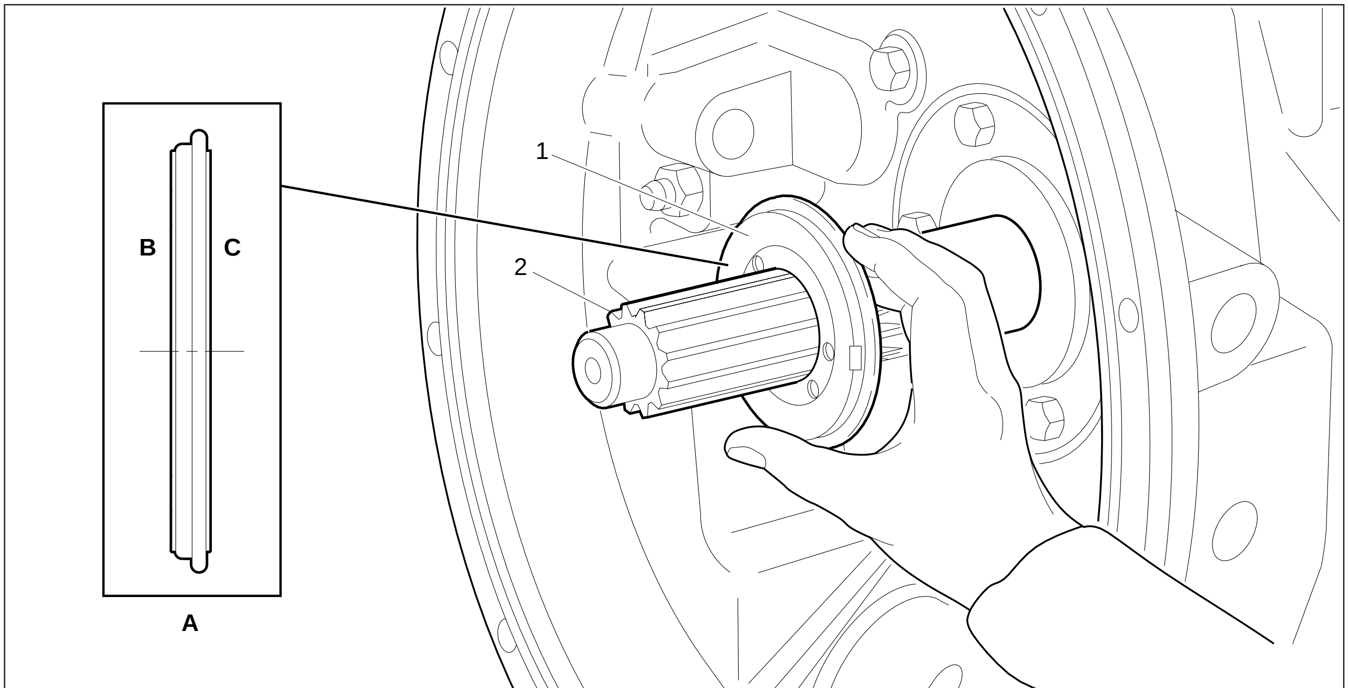
Fig. 14, Measuring the Input Shaft

side toward the engine to allow clearance for the release bearing.

8. On unsynchronized transmissions, install a new clutch brake on the transmission input shaft, as shown in **Fig. 15**. Slide it tight against the input-shaft bearing cap.
9. Measure the diameter of the flywheel bore opening (this is the recessed area for the flywheel bolt circle). See **Table 1** for minimum flywheel bore diameters for each disc type.

Minimum Flywheel Bores	
Disc Type	**Flywheel Bore in inch (mm)**
10-Spring	8.562 (217.48)
9-Spring	9.750 (247.65)
8-Spring	7.250 (184.15)
7-Spring	9.750 (247.65)
6-Spring	9.750 (247.65)

Table 1, Minimum Flywheel Bores



A. Cross section of clutch brake
B. Install deep side toward release bearing
C. Install shallow side toward the transmission
1. Clutch Brake
2. Input Shaft

Fig. 15, Installing the Clutch Brake

Installation

1. Do the clutch pre-installation procedures in **Subject 110**.
2. If not already in place, install two 3/8–16 x 3 guide studs in the two upper mounting holes of the flywheel. See **Fig. 1**.

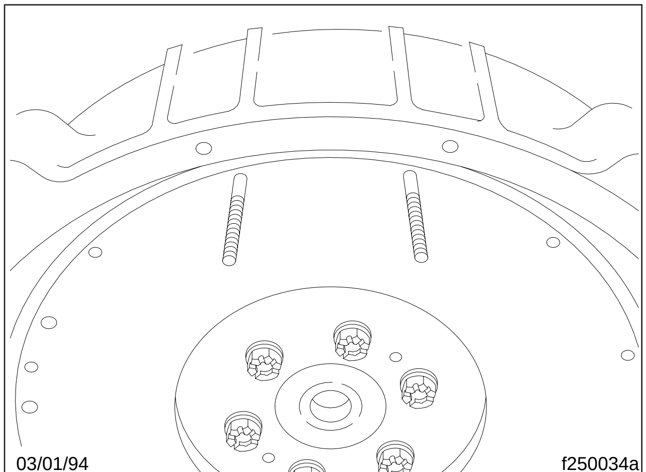


Fig. 1, Guide Studs, Installed

3. If the clutch is new, remove any protective coating applied to the pressure plate and the intermediate plate.
4. Insert an aligning tool through the splines of the front disc and, with the side marked *FLYWHEEL SIDE* facing the flywheel, install the front driven disc on the flywheel.

IMPORTANT: The drivestraps of the intermediate plate must face the pressure plate.

5. Install the intermediate plate assembly over the two guide studs and slide it forward until it touches the flywheel. Make sure the side marked PRESSURE PLATE SIDE faces the pressure plate. See **Fig. 2**.
6. Make sure the separator pins protrude toward the flywheel side. The pins should be flush on the pressure-plate side.
7. Remove the aligning tool.
8. Insert the aligning tool through the splines of the rear driven disc and, with the side of the rear disc marked *PRESSURE PLATE SIDE* facing the pressure plate, install the rear driven disc. See **Fig. 3**.

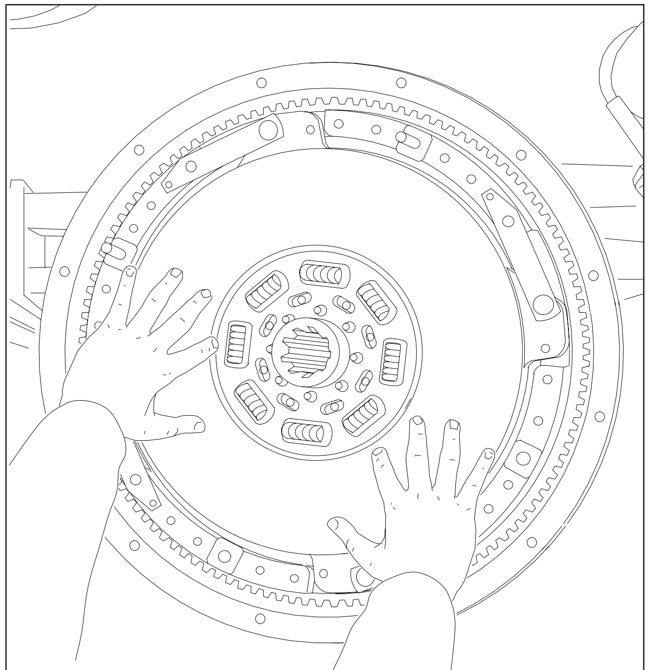


Fig. 2, Install the Intermediate Plate

9. Make sure that the ceramic buttons on each disc are as closely aligned as possible. See **Fig. 4**.

NOTE: Aligning the discs aids the function of the separator pins.

10. With the aligning tool still in place, slide the cover assembly over the aligning tool and the two guide studs until it rests against the intermediate plate assembly.
11. Install the clutch mounting capscrews, as follows. See **Fig. 5** for the tightening sequence.

NOTICE

If the capscrews are not tightened in sequence, it may cause permanent damage to the clutch cover and create an out-of-balance condition.

11.1 Start six 3/8–16 (grade 5 or better) mounting capscrews with lockwashers, and tighten them finger-tight.

14-Inch Dual Disc Clutch Installation

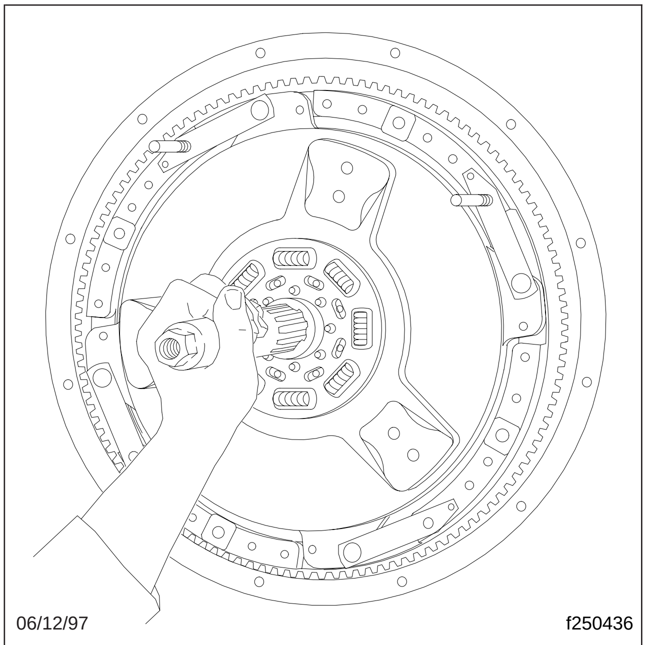
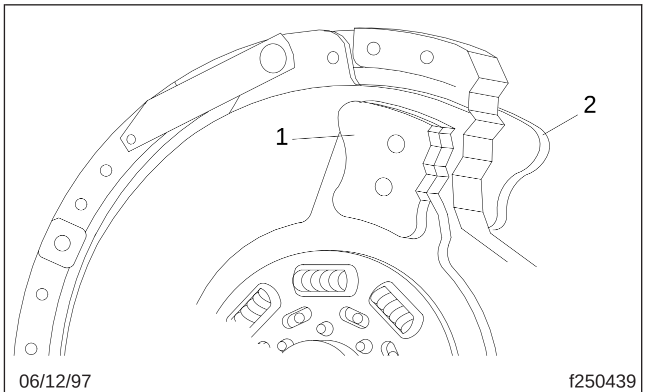


Fig. 3, Position the Rear Disc, Solo



1. Front Ceramic Button
2. Rear Ceramic Button

Fig. 4, Driven Disc Alignment

11.2 Remove the guide studs and replace them with the two remaining mounting capscrews, as above.

11.3 Tighten the eight capscrews progressively. The final torque is 30 to 35 lbf·ft (40 to 47 N·m).

12. Remove the aligning tool.

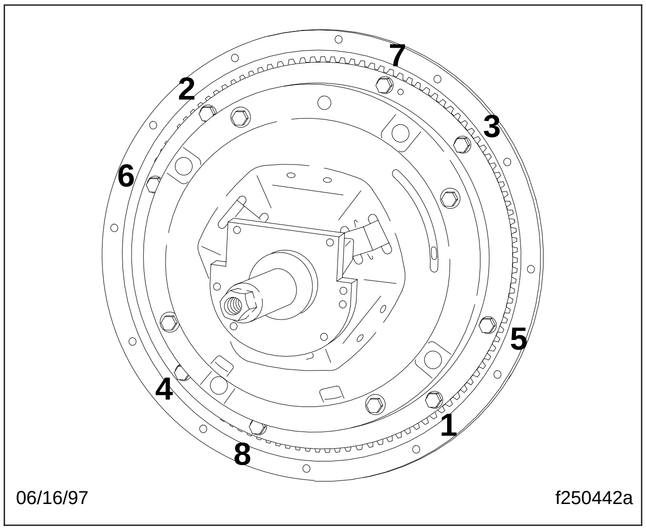


Fig. 5, Tightening Sequence

13. Follow a crisscross pattern to remove the four shipping bolts from the clutch cover. See **Fig. 6**.

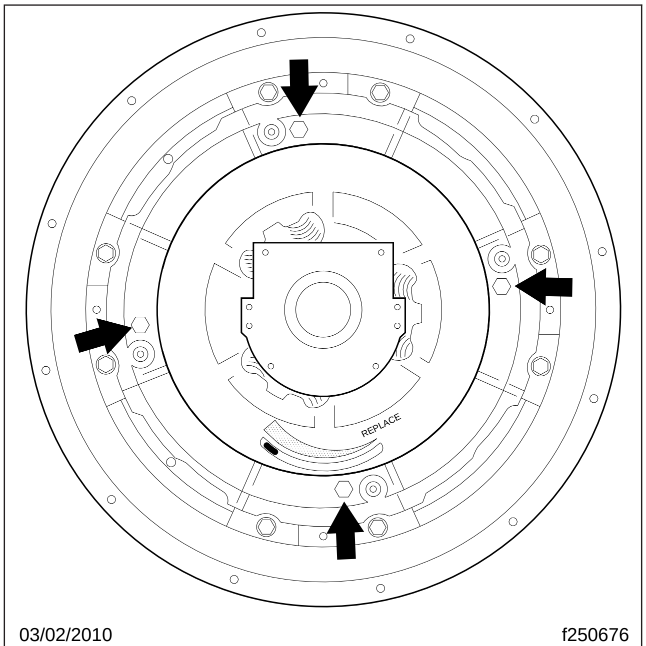


Fig. 6, Installed Shipping Bolts

NOTE: Retain the four shipping bolts. These bolts will be needed in the future to secure the clutch assembly during removal and installation.

WARNING

Wear safety goggles when tapping the pins. If any of the metal parts were to chip, flying pieces of metal could cause eye injury.

NOTE: Only a small portion of each separator pin is visible through the access hole. See **Fig. 7** and **Fig. 8**.

14. To ensure that all four separator pins are flush against the flywheel, insert a 1/4-inch (6-mm) diameter flat-nose punch through the access holes and lightly tap each of them toward the flywheel. See **Fig. 9**.

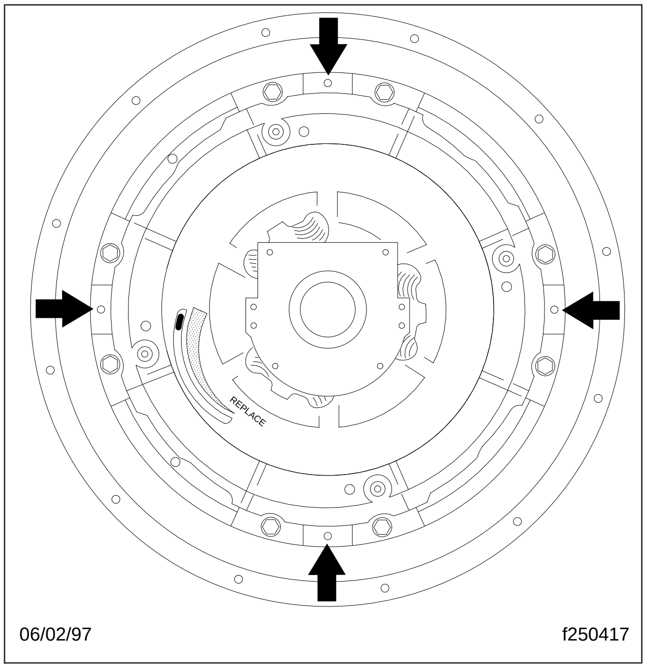
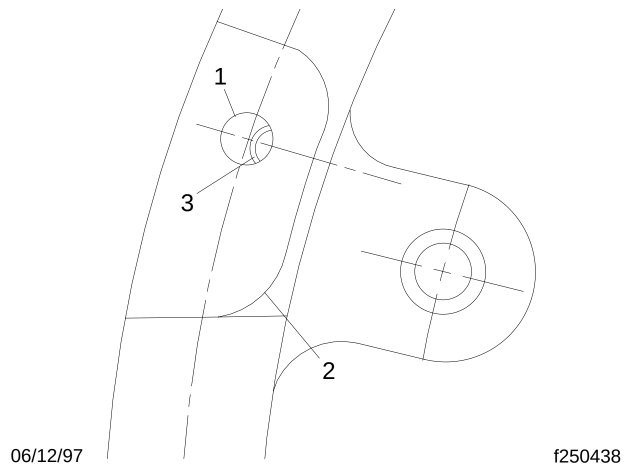


Fig. 7, Separator Pin Access Holes

NOTE: Do this step to ensure that all four pins are flush against the flywheel. This allows an equal gap on all sides of the intermediate plate during clutch disengagement.

15. Using a clean cloth, remove all grease from the input shaft.
16. Lubricate the release fork fingers. See **Fig. 10**.



NOTE: Only a small portion of the pin is visible through the access hole.

1. Access Hole
2. Clutch Cover
3. Separator Pin

Fig. 8, Separator Pin Access

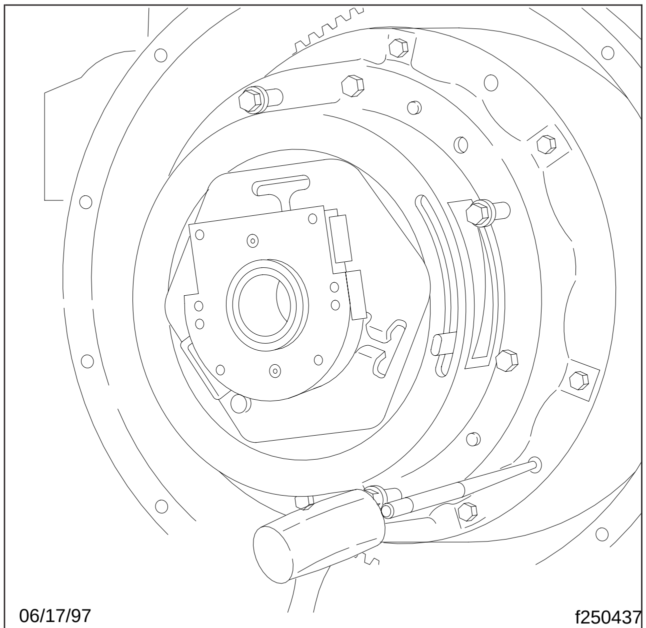
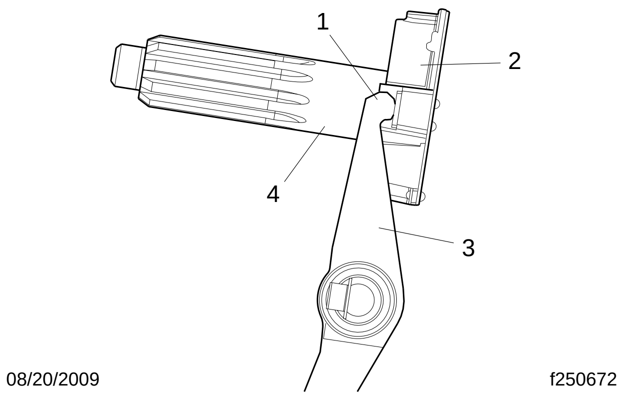


Fig. 9, Setting the Separator Pins

17. Shift the transmission into gear so that during assembly the transmission input shaft can be rotated into line with the clutch driven-disc hub splines.
18. Install the clutch brake, if equipped.

14-Inch Dual Disc Clutch Installation



1. Release Fork Finger
2. Release Bearing
3. Release Fork
4. Input Shaft

Fig. 10, Release Fork

NOTICE

Do not excessively force the transmission into the clutch assembly or engine housing. If it does not enter freely, investigate the cause of the problem and then make any necessary changes. Do not let the transmission drop or hang unsupported in the driven discs. If this should occur, the rear disc will become bent or distorted, causing the clutch to drag (not release).

19. Install the transmission and attach the clutch linkage. For instructions, see **Group 26**.
20. Lubricate the release bearing. Eaton Fuller recommends a lithium-base grease that can operate up to at least 325°F (163°C) and meets the NLGI Grade 1 or 2 specification.

Installation

1. Do the clutch pre-installation procedures in **Subject 110** before installing the clutch.
2. If not already installed, insert two 7/16–14 x 5 guide studs in the upper mounting holes of the flywheel. See **Fig. 1**. Rotate the flywheel to level the guide studs.

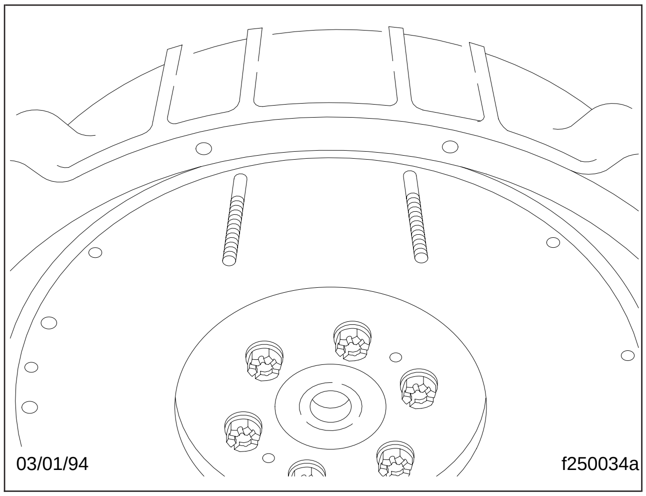


Fig. 1, Installing the Guide Studs

3. If installing a new clutch, remove the protective coating from the pressure plate and the intermediate plate.
4. Set the clutch cover upright, and insert a spline aligning tool through the release bearing sleeve. See **Fig. 2**.
5. Install the rear driven disc and intermediate plate, as follows.
   - 5.1 Install the rear driven disc on the aligning tool, with the side stamped *INTERMEDIATE PLATE SIDE* facing away from the clutch cover. See **Fig. 3**.
   - 5.2 Place the intermediate plate in the clutch cover. Align the drive lugs of the plate with the notches in the cover. See **Fig. 4**.
   - 5.3 Make sure the separator pins protrude toward the flywheel side. See **Fig. 4**. The pins should be flush on the pressure-plate side.

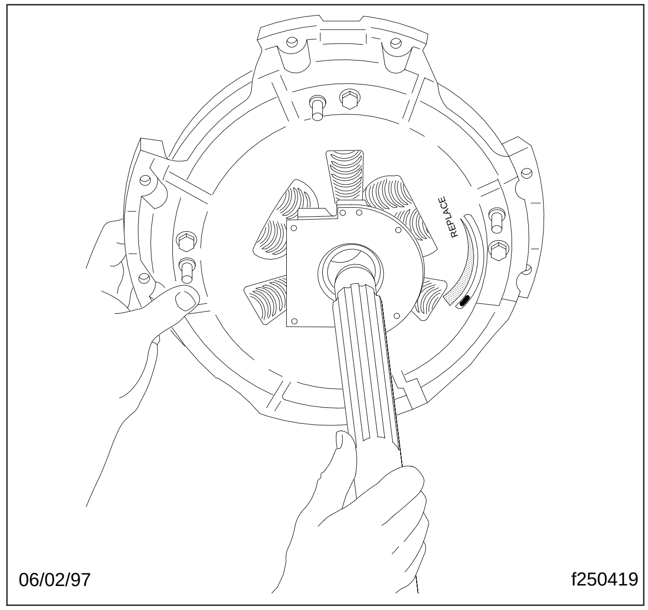


Fig. 2, Inserting an Aligning Tool

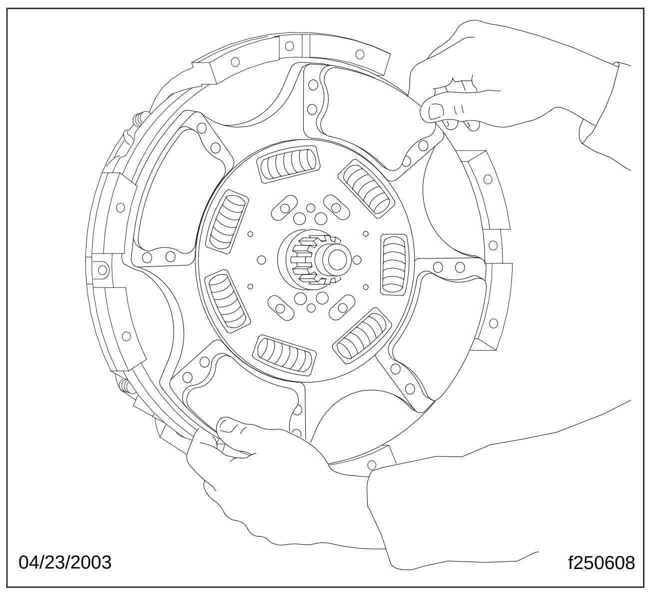
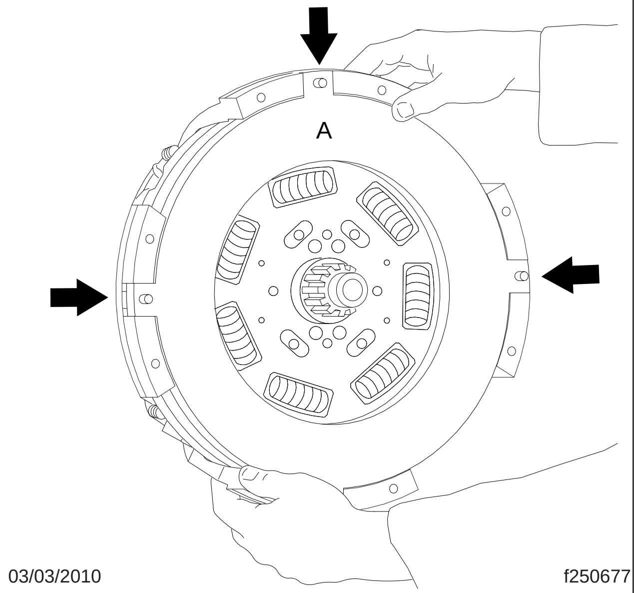


Fig. 3, Installing the Rear Driven Disc

6. Install the front driven disc on the aligning tool, with the side stamped *INTERMEDIATE PLATE SIDE* facing the intermediate plate. See **Fig. 5**.

15.5-Inch Clutch Installation



The separator pins should protrude to the flywheel side.
A. Flywheel Side

Fig. 4, Positioning the Intermediate Plate

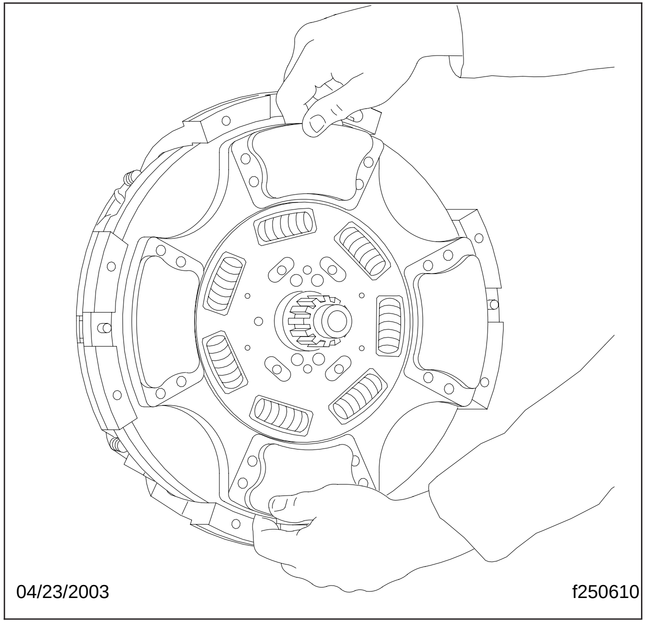


Fig. 5, Installing the Front Driven Disc

⚠ WARNING

The clutch assembly is heavy. It should be removed and installed only with a lifting device. If the assembly is lifted incorrectly or dropped, it could cause serious personal injury.

7. Position the clutch over the two guide studs, and slide the assembly forward until contact is made with the flywheel surface. See **Fig. 6**.

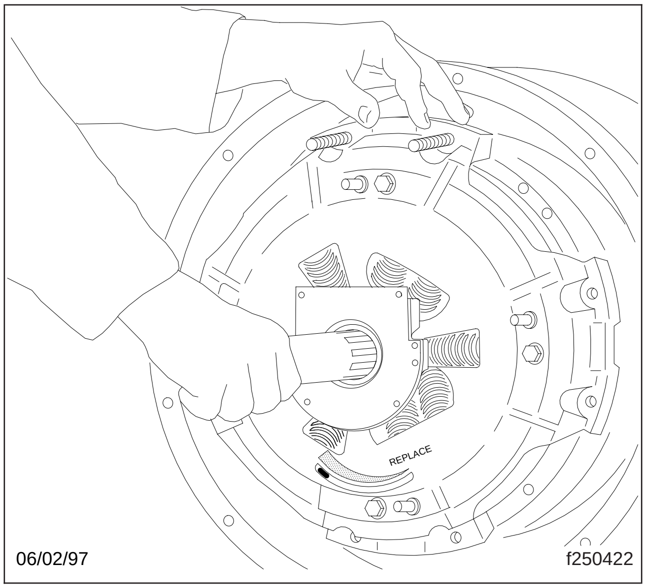


Fig. 6, Positioning the Clutch Cover

8. Install the mounting capscrews, as follows.
   - 8.1 Start six 7/16–14 x 2-1/4 (grade 5 or better) mounting capscrews with lockwashers, and tighten them finger-tight.
   - 8.2 Tap the aligning tool to make sure it is centered and seated in the pilot bearing. See **Fig. 7**.
   - 8.3 Remove the two guide studs and replace them with the two remaining 7/16–14 x 2-1/4 mounting capscrews and lockwashers.
9. Tighten the eight mounting capscrews progressively, in a crisscross pattern as shown in **Fig. 8**. Final torque is 40 to 50 lbf·ft (54 to 68 N·m).

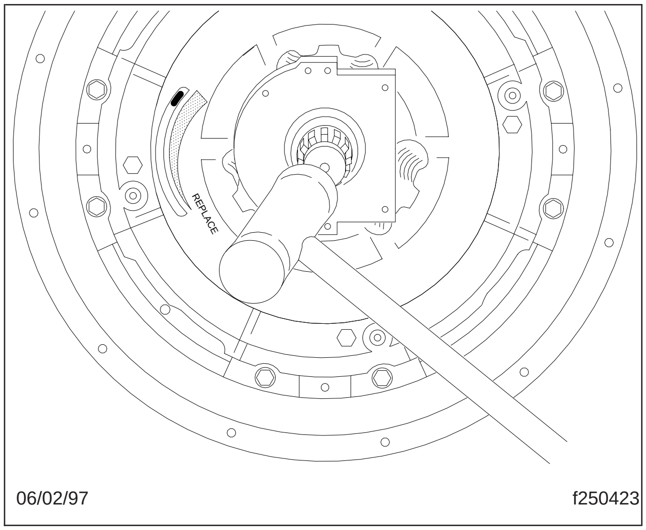


Fig. 7, Tap Aligning Tool

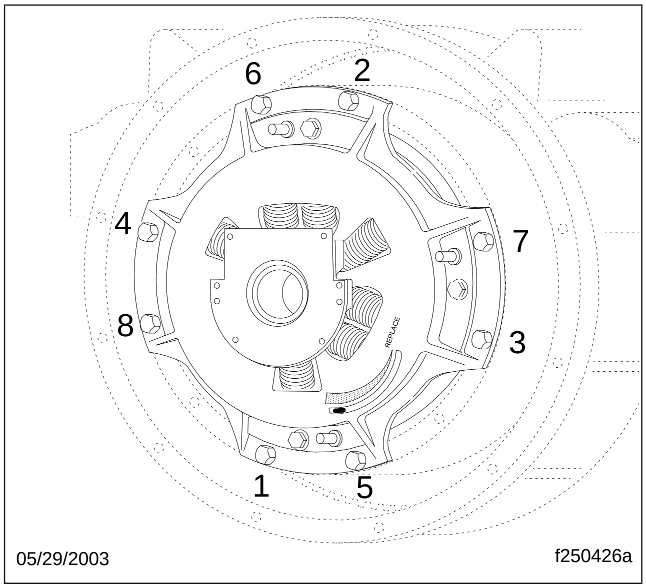


Fig. 8, Tightening Sequence

NOTICE

Failure to tighten the bolts according to this procedure can have the following effects:

- preventing the clutch cover from centering into the pilot area of the flywheel;
- causing the clutch assembly to be out-of-balance with the flywheel;
- causing permanent damage to the clutch cover.

10. Following a crisscross pattern, remove and retain the four shipping bolts from the clutch cover. See **Fig. 9**.

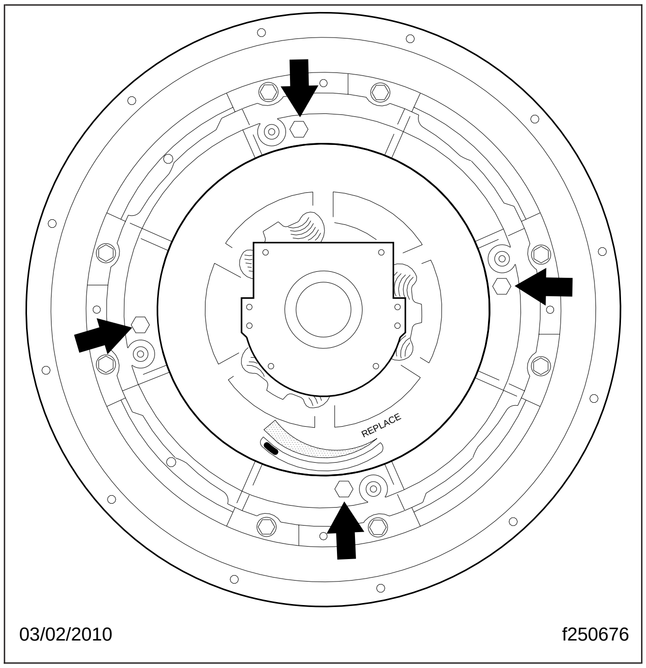


Fig. 9, Installed Shipping Bolts

NOTE: These bolts will be needed to secure future clutch assemblies during removal and installation.

11. Remove the aligning tool.

NOTE: Do not be concerned if the release bearing housing touches the clutch cover.

WARNING

Wear safety goggles when tapping the pins. If any of the metal parts were to chip, flying pieces of metal could cause eye injury.

12. To ensure that all four separator pins are flush against the flywheel, insert a 1/4-inch (6-mm) diameter flat-nose punch through the access holes and *lightly* tap each of them toward the flywheel. See **Fig. 10** and **Fig. 11**.

NOTE: Failure to perform this step properly may cause the clutch to drag or not release.

15.5-Inch Clutch Installation

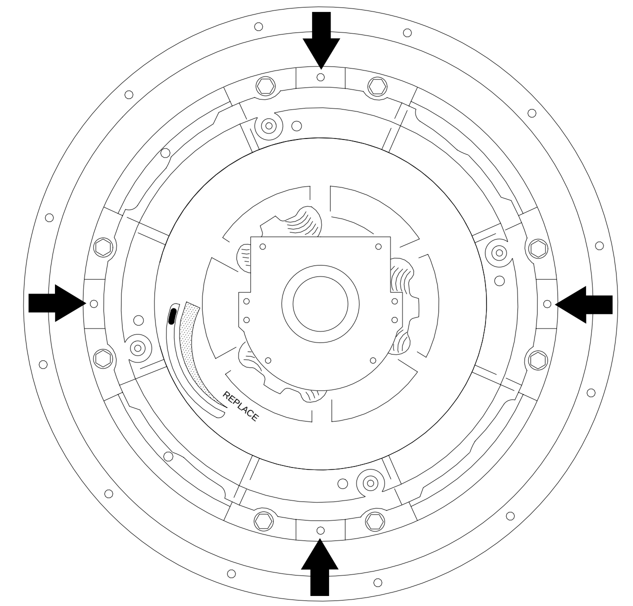
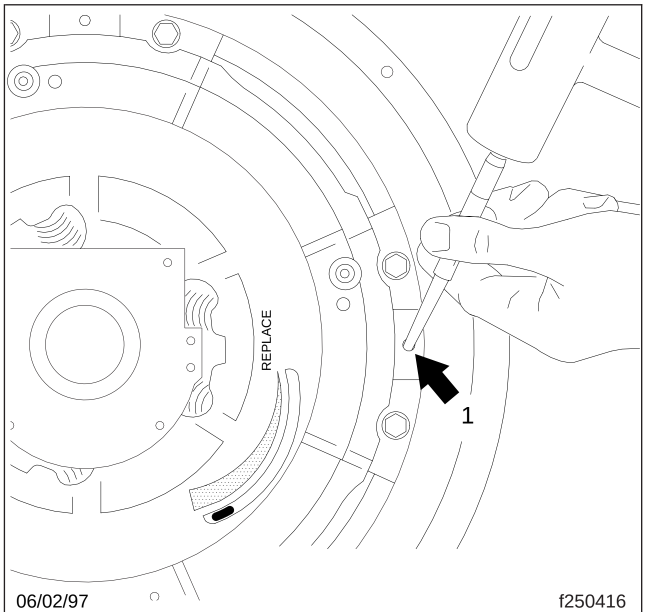


Fig. 10, Separator Pin Access Holes



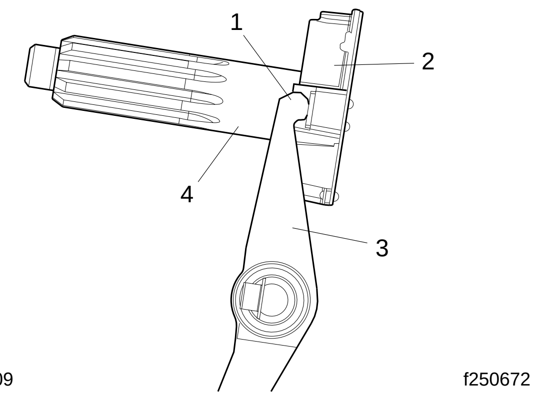
1. Pin Access Hole

Fig. 11, Tapping A Separator Pin

13. Using a clean cloth, remove all grease from the input shaft.

NOTE: For lubrication of the release fork fingers, Eaton Fuller recommends a lithium-base grease that can operate up to at least 325°F (163°C) and meets the NLGI Grade 1 or 2 specification.

14. Lubricate the release fork fingers. See **Fig. 12**.



1. Release Fork Finger
2. Release Bearing
3. Release Fork
4. Input Shaft

Fig. 12, Release Fork

15. Shift the transmission into gear so that during assembly the transmission input shaft can be rotated into line with the clutch driven-disc hub splines.
16. Install the clutch brake.

NOTICE

Do not excessively force the transmission into the clutch assembly or engine housing. If it doesn't enter freely, investigate the cause of the problem and then make any necessary changes. Don't let the transmission drop or hang unsupported in the driven discs. If this should occur, the rear disc will become bent or distorted, causing the clutch to drag (not release).

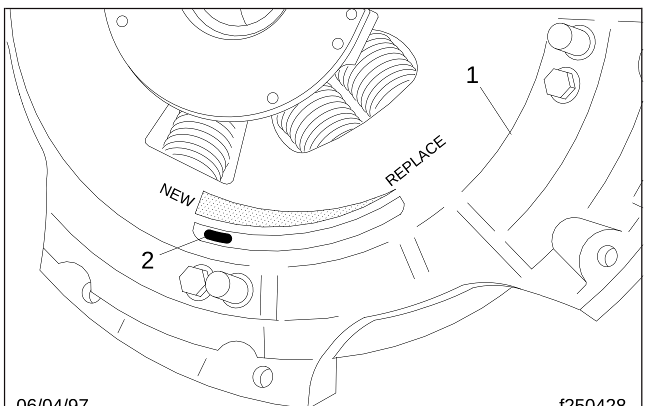
17. Install the transmission and attach the clutch linkage.
18. Lubricate the release bearing as needed; for instructions and recommended lubricants, see **Group 25** of the *Business Class M2 Maintenance Manual*.

When there is excessive free pedal, try resetting the clutch.

Resetting

NOTE: This procedure requires two persons; one under the vehicle with access to the wear indicating tab, and the other in the vehicle to operate the clutch pedal.

1. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the tires.
2. Inside the cab, press the clutch pedal all the way down, and hold it there until instructed to release it later in this procedure.
3. Through the clutch cover inspection panel, use moderate force to slide the wear indicating tab leftward until it is at the NEW position on the indicator. See **Fig. 1**. If the tab does not move, use the clutch reset tool as described later in this subject.



06/04/97 f250428

With the clutch pedal down, set the tab to the "NEW" position on the indicator.

1. Clutch Cover 2. Wear Indicating Tab

Fig. 1, Resetting the Wear Indicating Tab

4. Release the clutch pedal.
5. Through the clutch inspection cover, remove the gap between the sleeve and the pin, as follows. See **Fig. 2**.

   For a 14-inch clutch, install four 3/8–16 x 1-1/4 shipping bolts (if available) or hexhead machine screws into the four clutch cover holes, and use a hand tool to tighten them until the gap is removed and the bolts are snug.

   For a 15.5-inch clutch, install four 7/16–14 x 1-3/4 shipping bolts (if available) or hexhead machine screws into the four clutch cover holes, and use a hand tool to tighten them until the gap is removed and the bolts are snug.
6. Remove the bolts.
7. Press the clutch pedal all the way down, and squeeze the clutch brake five times to reposition the bearing.

NOTE: The release bearing travel tool A02–12419 may be used in the following step. This tool is available through the PDCs.

8. Measure the distance between the clutch brake and the release bearing. It should be between 0.49 and 0.56 inch (12.5 to 14.2 mm). If it is not within this range, refer to the literature available on the Roadranger website, **www.roadranger.com**.

   If you are using the release bearing travel tool A02–12419 (see **Fig. 3**) for this measurement, position it so that the legs at the blue 0.56-inch (14.3-mm) end straddle the transmission input shaft. If it fits loosely, the gap is too wide. If it does not fit in the gap, try inserting the green 0.50-inch (12.7-mm) end. If the green end of the tool fits, snug or loose, then no adjustment is needed. If the gap is too wide or the green end does not fit in the gap, refer to literature available on the Roadranger website, **www.roadranger.com**.

Using the Clutch Reset Tool

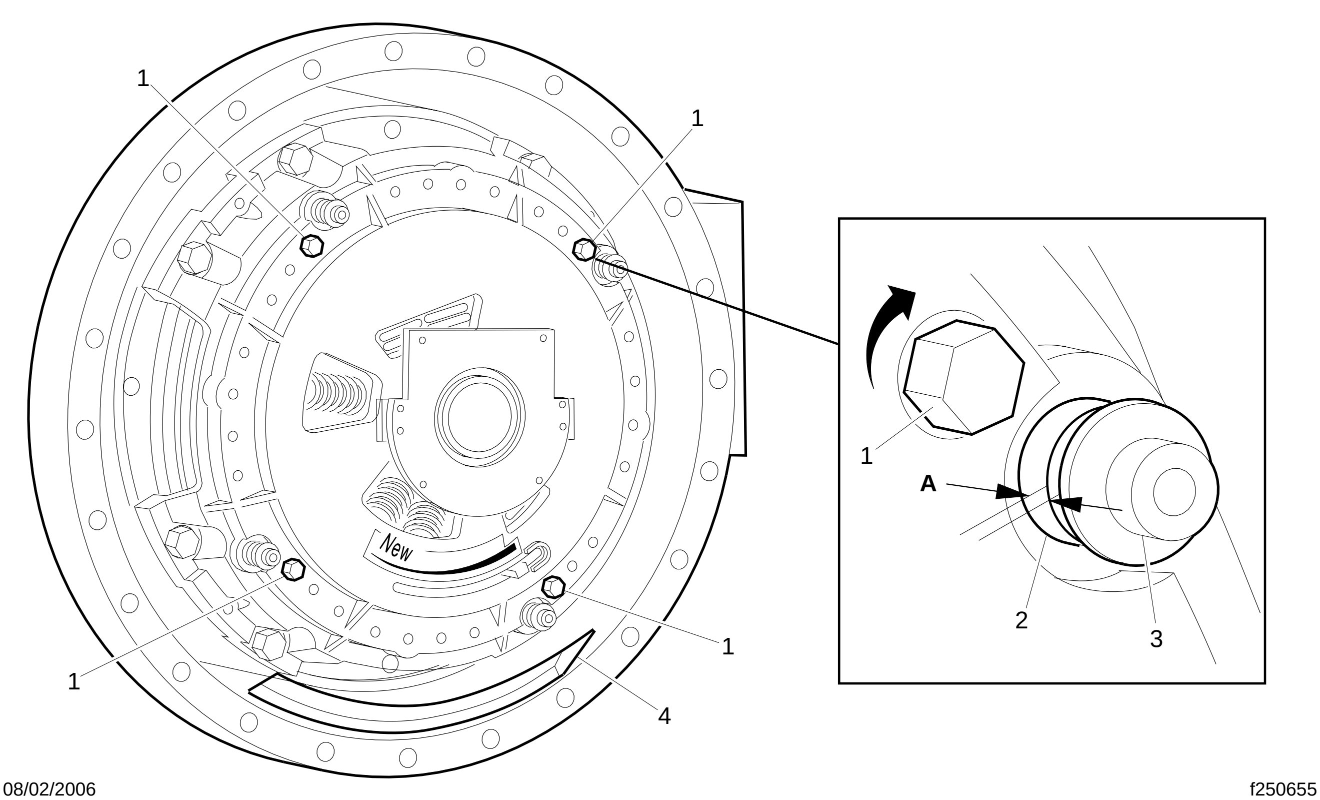
See **Table 1** for more information about the clutch reset tool.

1. While an assistant holds down the clutch pedal, insert the tip of the clutch reset tool through the access panel and position it under the bearing. Align the tool so that the threaded bolt extends into the slot in the cam. See **Fig. 4**.

NOTICE

Use the clutch reset tool carefully. Do not use heavy force on it; heavy force can break the cam.

Resetting the Clutch



NOTE: The bell housing is shown transparent to provide a clear view of clutch components.

A. Gap Between the Sleeve and the Pin

1. Bolt
2. Sleeve
3. Pin
4. Access Panel

Fig. 2, Removing the Gap Between the Sleeve and the Pin

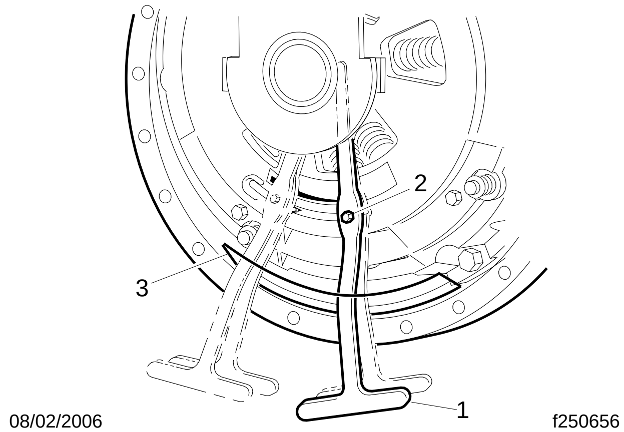
A. 0.50 inch (12.7 mm) B. 0.56 inch (14.3 mm)

Fig. 3, Release Bearing Travel Tool A02–12419

2. Using the tool, carefully try to move the cam toward the NEW position.

   If the cam moves easily, resume the resetting procedure.

   If the cam does not move, go to the next step.
3. Loosen the transmission, and install 1/4" spacers between the flywheel housing and bell housing.
4. While an assistant holds down the clutch pedal, use the clutch reset tool to move the tab to the NEW position.
5. Once the tab is in the NEW position, release the clutch pedal and remove the spacers.
6. Tighten the transmission mounting bolts; see **Group 26** for torque values.
7. Resume the resetting procedure.



1. Clutch Reset Tool
2. Threaded Bolt
3. Access Panel

Fig. 4, Resetting the Clutch with the Clutch Reset Tool

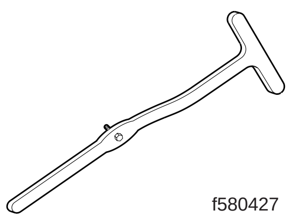
Clutch Reset Tool		
Tool	**Description**	**Eaton Tool Part Code**
 f580427	Clutch Reset Tool	CLPI-SOLOTOOL

Table 1, Clutch Reset Tool

Troubleshooting Tables

Problem—The Clutch Does Not Release Completely

Problem—The Clutch Does Not Release Completely	
Possible Cause	**Remedy**
The clutch pedal height is incorrect.	Make adjustments to obtain the following settings: • 1/2 to 9/16 inch (12.7 to 14.3 mm) release bearing travel; • 1/2 to 1 inch (12.7 to 25.4 mm) clutch brake squeeze. For clutches with mechanical linkage, also make adjustments to obtain 0.105 to 0.145 inch (2.7 to 3.7 mm) release yoke free-travel. (Clutches with hydraulic linkage will have constant contact between the yoke and clutch bearing pads.)
The bushing in the release bearing sleeve assembly is damaged.	Replace the clutch cover.
The clutch cover assembly is not properly seated into the flywheel.	Re-seat the clutch cover assembly into the flywheel. Use a crisscross pattern when tightening the mounting bolts.
The intermediate plate and/or pressure plate is cracked or broken.	Replace any damaged parts.
The cross shafts protrude through the release yoke (a side-loading condition exists).	Check for protruding cross shafts. Repair or replace as necessary.
The release yoke fingers are bent or worn (a side-loading condition exists).	Install a new release yoke.
The engine housing and bell housing are misaligned (a side-loading condition exists).	Check for loose transmission mounting bolts. Tighten the transmission mounting bolts to the proper torque.
The clutch linkage is set up improperly (a side-loading condition exists).	Thoroughly examine the clutch linkage and adjust as necessary.
The driven discs are distorted or warped.	Replace any distorted or warped driven discs. If the transmission is allowed to hang unsupported during clutch installation, the driven discs may become distorted.
The driven discs are installed backwards, or the front and rear driven discs were switched with each other.	Install new driven discs. Also, check the clutch cover for any damage. Replace the clutch cover if damaged.
The input shaft spline is worn.	Replace the input shaft. Also, check the driven disc hubs for wear. Replace the driven discs if worn.
The input shaft spline is coated with grease, anti-seize compound, etc.	Clean and dry the input shaft spline before installation.
The input shaft splines are twisted.	Select a new driven disc and slide it along the full length of the splines. If the disc does not slide freely, replace the input shaft.
The input-shaft bearing cap is worn.	Replace the input-shaft bearing.
The flywheel pilot bearing fits either too tight or too loose in the flywheel and/or end of input shaft.	Check the pilot bearing for proper fit and replace it if worn.
The pilot bearing is dry or damaged.	Replace the pilot bearing.

Troubleshooting

Problem—The Clutch Does Not Release Completely	
Possible Cause	**Remedy**
The separator pins are bent, damaged or incorrectly set.	Be sure to use the proper tool when setting the separator pins. Also, take great care when handling the intermediate plate. For procedures, see the appropriate clutch installation subject.
The clutch brake is damaged and/or not functioning.	Install a new clutch brake.
The driven disc faces are coated with oil or grease.	Replace the driven disc assemblies. Cleaning the old driven discs is not recommended.
There is foreign material (dirt, chaff, salt, etc.) inside the clutch cover.	Remove the foreign material and make sure the clutch inspection cover is installed.

Problem—The Clutch Rattles or Is Noisy

Problem—The Clutch Rattles or Is Noisy	
Possible Cause	**Remedy**
There is excessive flywheel runout.	Repair or replace the flywheel. For procedures, see the engine manufacturer’s manual.
There is corrosion between the input shaft spline and the driven disc hubs.	Clean the mating parts between the input shaft and driven discs to ensure that the discs slide freely over the input shaft spline.
The engine idle is too fast.	Readjust engine idle to proper idling speed.
The clutch release bearing is dry or damaged.	Lubricate the clutch release bearing. If the noise persists, install a new clutch cover.
The flywheel pilot bearing is dry or damaged.	Replace the flywheel pilot bearing.
The bridge of the release yoke is hitting the clutch cover (an over-stroking condition exists).	Check for a worn, broken or missing clutch brake. Also, check the release yoke and input-shaft bearing cap for wear. Replace any worn parts.
The release yoke fingers are hitting the clutch cover.	Check if the release bearing, clutch cover, or release yoke fingers are worn or broken. Replace worn parts.
The clutch inspection cover is not installed.	Re-install the clutch inspection cover.
The sleeve bushings are worn.	Investigate for any side-loading conditions on the release bearing housing. If there is a side-loading condition, determine its cause. Also, before installing the new clutch, make sure that the side-loading condition has been corrected.
The clutch linkage is rattling excessively.	Clean, lubricate and reassemble or replace missing/worn parts.
An idle gear rattle is coming from the transmission.	Specify low-vibration driven discs. Check the engine for correct idle speed. For procedures, consult the engine manufacturer’s manual.
The damper spring cover of the driven disc assembly is interfering with the flywheel.	Install the correct clutch assembly.

Problem—The Clutch Vibrates

Problem—The Clutch Vibrates	
Possible Cause	**Remedy**
The flywheel is loose.	Retighten the flywheel mounting bolts to the proper specifications.
The universal joints are worn.	Replace the worn parts.
The driveshaft is not properly phased.	Investigate and correct the phasing of the driveshaft.
The driveshaft is not balanced.	Balance and straighten the driveshaft.
The driveline angles are incorrect.	Shim the drivetrain components to equalize universal joint angles.
The flywheel is not balanced.	Balance the flywheel.
The pilot area of the clutch is not completely seated into the flywheel.	Ensure that no dirt, burrs, etc., are preventing the clutch cover from completely seating into the flywheel mounting surface.
The engine mounts are loose, damaged, or worn out.	Replace any worn or damaged parts. Retighten all bolts to proper specifications.
The engine is misfiring.	The engine is not in tune. To correct the problem, see the engine manufacturer's manual.
There is excessive flywheel runout.	Repair or replace the flywheel. For procedures, see the engine manufacturer's manual.

Problem—The Clutch Needs Frequent Adjustments

Problem—The Clutch Needs Frequent Adjustments	
Possible Cause	**Remedy**
The clutch specification is incorrect.	Check the clutch specifications in **Subject 400**. Install a new clutch with the proper specifications, if necessary.
The cross shafts and/or clutch linkage system is worn.	Investigate the entire clutch linkage system to determine if it is binding or operating sporadically and/or worn excessively.
The clutch driven discs are worn down to the rivets.	Install a new clutch.
The crankshaft has excessive end play.	Repair or replace the crankshaft. Consult the engine manufacturer's manual for procedures.

Problem—The Clutch Slips

Problem—The Clutch Slips	
Possible Cause	**Remedy**
The clutch is overloaded.	Verify that the proper clutch has been specified for the particular vehicle application.
The release mechanism is binding.	Free up the release mechanism and linkage. Also, check the clutch linkage adjustment.
The driven disc faces are coated with oil or grease.	Replace the driven disc assembly.
The driver is riding the clutch pedal.	Use correct driving procedures.
The input shaft spline is worn.	Replace the input shaft.

Troubleshooting

Problem—The Clutch Grabs or Chatters

Problem—The Clutch Grabs or Chatters	
Possible Cause	**Remedy**
The clutch is worn out.	Replace the clutch and all worn components.
The linkage system is not operating freely.	Check the clutch linkage for binding or excessive wear. Replace all worn parts.
The driven disc faces are coated with oil or grease.	Replace the driven disc assembly.
The engine mounts are loose.	Retighten the engine mounts to manufacturer’s specifications.
The release yoke fingers and/or the release bearing wear pads are worn excessively.	Replace all the worn parts.

Specifications

Clutch Torque Values			
Description	**Size**	**Grade**	**Torque: lbf·ft (N·m)**
Mounting Bolts, Clutch Cover to Flywheel on 14-inch clutch	3/8–16 x 1-1/4	5	30–35 (40–47)
Mounting Bolts, Clutch Cover to Flywheel on 15.5-inch clutch	7/16–14 x 2-1/4	5	40–50 (54–68)

Table 1, Clutch Torque Values

Minimum Flywheel Bores	
Disc Type	**Minimum Flywheel Bore in inch (mm)**
10-Spring	8.562 (217.48)
9-Spring	9.750 (247.65)
8-Spring	7.250 (184.15)
7-Spring	9.750 (247.65)
6-Spring	9.750 (247.65)

Table 2, Minimum Flywheel Bores

General Information

The clutch linkage transfers the motion of the clutch pedal to the clutch release bearing.

Free play in the clutch pedal is required to ensure that the fingers of the release bearing do not run against the release bearing. There should not be any play or looseness in the connections and joints of the clutch linkage.

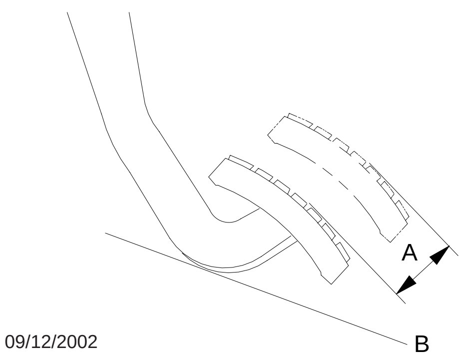
There are two types of clutches: the pull-type and the push-type.

- On push-type clutches, depressing the clutch pedal moves the release bearing toward the engine flywheel. As the clutch is depressed, the pressure plate moves away from the driven disc assembly, and the clutch is disengaged. As the clutch pedal is released, the release bearing and clutch levers move away from the engine flywheel. This locks the driven disc between the friction surfaces of the pressure plate and the engine flywheel. The clutch is then engaged.
- On pull-type clutches, depressing the clutch pedal moves the release bearing away from the pressure plate, disengaging the clutch. As the clutch pedal is released, the pressure plate is forced toward the engine flywheel until the driving and driven discs turn at the same speeds, engaging the clutch.

IMPORTANT: On pull-type clutches, release bearing and release fork clearance are internal clutch adjustments, and *can not be adjusted* by adjusting the clutch linkage. For internal clutch adjustments, see the clutch manufacturer's service literature.

Adjustment

1. Observe the following points before beginning clutch linkage adjustment:
   - If the clutch pedal free play is less than 3/4 inch (19 mm), adjust the clutch internally, not at the linkage. See **Fig. 1**.
   - Be sure internal clutch adjustments are correct before making adjustments to the clutch linkage.
   - Adjust the clutch linkage only after repair or replacement of the clutch or clutch linkage components.
   - If the cab is equipped with an air suspension, be sure the air springs are properly inflated. If the air springs are not inflated, the clutch linkage can't be adjusted correctly.



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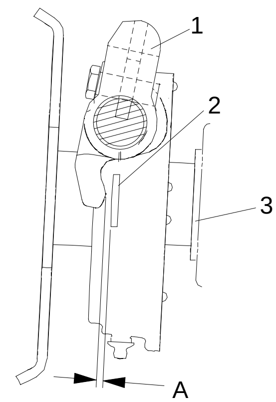
Clutch pedal free play should be about one inch (25 mm) from the top end of the pedal stroke.

A. Clutch Pedal Free Play
B. End of Free Play; Start of Disengagement

Fig. 1, Clutch Pedal Free Play

2. Raise the hood, apply the parking brakes, and chock the front tires.
3. Remove the clutch inspection cover from the bottom of the bell housing.
4. Be sure the clutch pedal is all the way up, against the upper stop.
5. Check the internal clutch adjustment. For procedures, see the clutch manufacturer's manual.
6. Measure the distance between the release yoke and the release bearing.

   If this measurement is 0.125 to 0.145 inch (3.2 to 3.8 mm), no further work is needed. See **Fig. 2**. If the measurement is incorrect, do all of the remaining steps.



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A. Clearance Between Release Yoke and Release Bearing: 0.125 inch (3.2 mm) minimum

1. Release Yoke
2. Release Bearing
3. Transmission

Fig. 2, Clutch Adjustments

7. Disconnect the clutch linkage. See **Fig. 3**.

   7.1 Remove the nut that attaches the clutch rod to the upper lever arm.

   7.2 Disconnect the clutch rod from the upper lever arm.

   7.3 Loosen the jam nut on the clutch rod.

8. Adjust the clutch linkage.

   8.1 Hold the clutch rod in the same position. Adjust the rod length in or out, as needed. Shorten the rod to increase the clearance. Lengthen the rod to decrease the clearance.

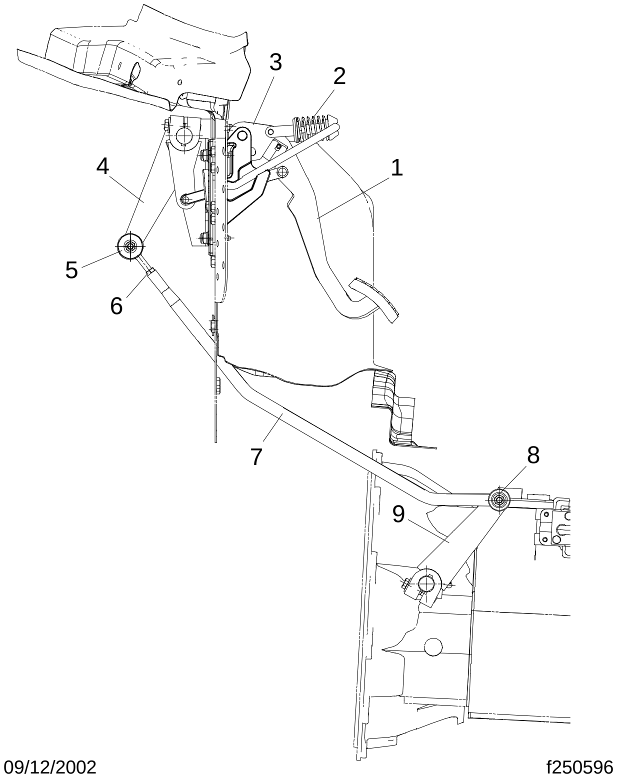
   8.2 Attach the rod end to the upper lever arm.

   8.3 Tighten the nut on the upper lever arm 23 to 29 lbf·ft (31 to 39 N·m).

   8.4 Tighten the jam nut on the clutch rod 12 to 15 lbf·ft (16 to 20 N·m).

   NOTE: Each complete turn of the rod equals about .04 inch (1 mm) of movement. After lengthening the linkage, at least 3/8 inch

Clutch Linkage Adjustment



1. Clutch Pedal
2. Return Spring
3. Spring Bracket
4. Upper Lever Arm
5. Upper Lever Arm Nut
6. Jam Nut
7. Clutch Rod
8. Lower Lever Arm Nut
9. Lower Lever Arm

Fig. 3, Clutch Linkage

(9.5 mm) of thread must remain engaged in the clutch rod (nine turns of the rod end).

9. Measure the distance between the release yoke and the release bearing. If this measurement is 0.125 to 0.145 inch (3.2 to 3.8 mm), go to the next step. If the measurement is not within these limits, go back to the "Disconnect the clutch linkage" step and adjust the linkage until it is correct.
10. Install the inspection cover on the bottom of the bell housing.
11. Check the clutch pedal free play. See **Fig. 1**.
12. Remove the chocks from the front tires.

Specifications

Description	Torque in lbf·ft (N·m)
Jam Nut	12 to 15 (16 to 20)
Upper Lever Arm Nut	23 to 29 (31 to 39)

Table 1, Torque Values, Clutch Linkage Adjustment

General Information

The hydraulic clutch control system consists of a pedal unit and a slave cylinder, connected by a hydraulic hose that is fastened with quick-disconnect clips. See **Fig. 1**. The hydraulic system is self-adjusting, and it uses DOT 4 brake fluid.

The pedal unit includes a hydraulic subassembly, composed of the master cylinder and reservoir, which can be removed from the pedal unit for service purposes; see **Subject 110** for instructions.

Principles of Operation

When the clutch pedal is pressed, the fluid in the master cylinder is forced through a hydraulic line to the slave cylinder. The fluid pressure moves the slave cylinder piston, pushing the plunger rod and clutch release lever, which disengages the clutch.

Clutches

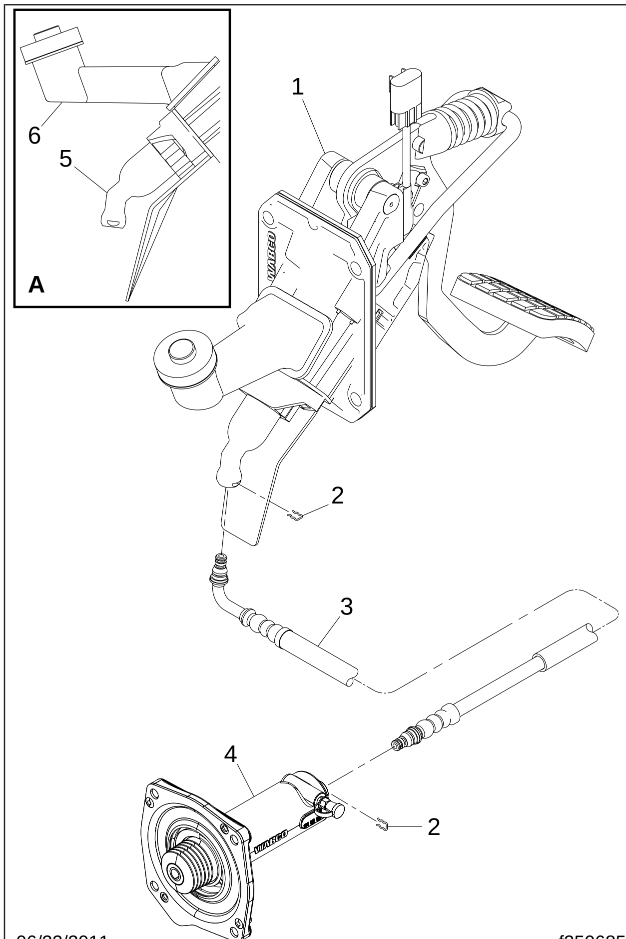
The hydraulic system has been designed to work with three types of clutches: adjustment-free, manually adjusted, and self adjusting. Check the adjustment of manually adjusted clutches regularly.

NOTICE

Operating a vehicle with a manually adjusted clutch that is incorrectly adjusted could result in failure of the clutch or clutch brake.

The SACHS 365 mm (adjustment-free) and 395 XTend (self-adjusting) are push-type clutches that are part of the hydraulic clutch systems for the MBT520 and MBT660 medium-duty transmissions. They do not need to be manually adjusted. For removal and installation procedures, see **Subject 130** for the SACHS 365 mm, and **Subject 180** for the 395 XTend.

Eaton Stamped Angle-Spring and Easy-Pedal clutches are optional with some Eaton transmissions. These clutches are manually adjusted. When combined with a hydraulic clutch system, there is no "free pedal" to tell the driver when the clutch needs adjustment. Periodic inspection and manual adjustment is required to maintain proper release bearing travel and prevent premature clutch wear. Release bearing travel is the clearance between the rear surface of the release bearing housing and the forward surface of the clutch brake disc. This distance must be maintained between 1/2 and 9/16 inch (12.7 and 14.3 mm). For the adjustment procedure, see **Subject 190**.



A. Hydraulic Subassembly

1. Pedal Unit
2. Clip
3. Hydraulic Hose
4. Slave Cylinder
5. Master Cylinder
6. Reservoir

Fig. 1, Components, Hydraulic Clutch Control

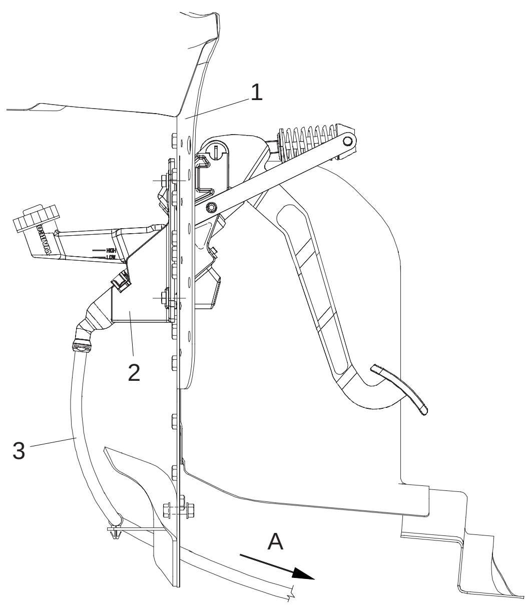
Pedal Unit Removal and Installation

Removal

WARNING

Clutch hydraulic fluid (DOT 4 brake fluid) is hazardous. It may be a skin irritant and can cause blindness if it gets in your eyes. Always wear safety glasses when handling clutch hydraulic fluid or bleeding hydraulic lines. If you get clutch hydraulic fluid on your skin, wash it off as soon as possible.

1. Shut down the engine.
2. Apply the parking brakes, chock the front and rear tires, and open the hood.
3. Using a flat-head screwdriver, remove the quick-disconnect clamp that attaches the hydraulic hose to the pedal unit. See **Fig. 1**. Retain the clamp for later installation.



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A. To Slave Cylinder
1. Frontwall
2. Pedal Unit
3. Hydraulic Hose

Fig. 1, Pedal Unit and Hose

4. Drain the hydraulic fluid from the entire system.
   - 4.1 Using a drain pan or other suitable container, collect the fluid that drains from the pedal unit, not more than 0.5 quarts (0.5 liters).
   - 4.2 Allow the open end of the drain hose to remain over the drain pan.
   - 4.3 Press down on the pedal several times, until no more fluid drains from the pedal unit.
   - 4.4 Cover the hose to avoid contamination of the hydraulic fluid.
5. Disconnect the clutch control electrical connector located under the dash above the clutch pedal.
6. Remove the rubber pedal pad from the pedal. Retain the pedal pad for later installation.
7. Loosen the four mounting plate capscrews attaching the pedal unit to the frontwall.
8. After bracing the pedal unit so that it does not fall, remove the four mounting plate capscrews. Retain the capscrews for later installation.

WARNING

Do not attempt to disassemble the preloaded assist spring. Sudden release of the assist spring could cause property damage and serious personal injury.

9. Remove the pedal unit from the vehicle. Drain any remaining fluid and discard the gasket.

IMPORTANT: Handle the pedal unit carefully to prevent spillage.

Installation

1. Mount the pedal unit on the frontwall, as removed. Install a new gasket.
2. Install the four mounting plate capscrews and tighten them 13 lbf·ft (18 N·m).
3. Fit the rubber pedal pad over the pedal.
4. Connect the hydraulic hose to the pedal unit.
5. Install the clamp, as removed.
   - 5.1 Install the clamp in the recessed area on the nozzle of the master cylinder.

Pedal Unit Removal and Installation

5.2 Snap the hydraulic hose into place.

5.3 Tug on the hose to make sure it is installed correctly. The hose should not pull out easily.

NOTE: Don’t force the hose into the master cylinder. If the clamp is incorrectly installed, the hose will not snap into place.

WARNING

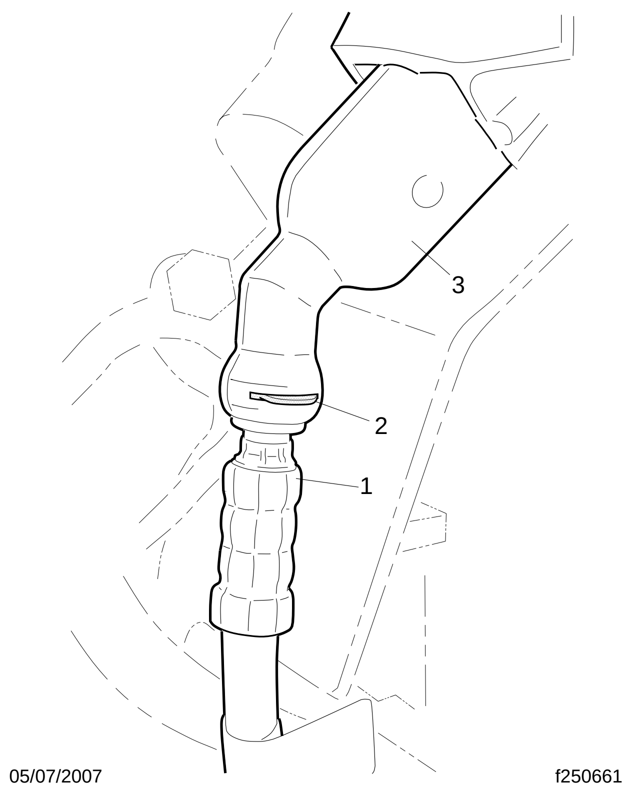
Use only approved clutch hydraulic fluid (DOT 4 brake fluid). Do not mix different types of brake fluid. The wrong fluid will damage the rubber parts of the system, causing loss of clutch function and the risk of serious personal injury.

6. Fill the reservoir with approved DOT 4 hydraulic brake fluid and bleed the system according to the procedures in **Subject 140**.

7. Connect the clutch control electrical connector, and check the function of the clutch actuation system according to the procedures under the heading "Clutch Actuation System Check" in **Troubleshooting, 300**.

Replacement

1. Place a suitable container under the master cylinder to collect the fluid that will drain as the hose is removed from the master cylinder.
2. Use a flat-tip screwdriver to remove the quick-disconnect clip that locks the hydraulic hose into the master cylinder. See **Fig. 1**. Remove the hose and, with the end pointing upwards to prevent fluid spillage, secure it temporarily to a safe point on the vehicle. Retain the clip for later installation.



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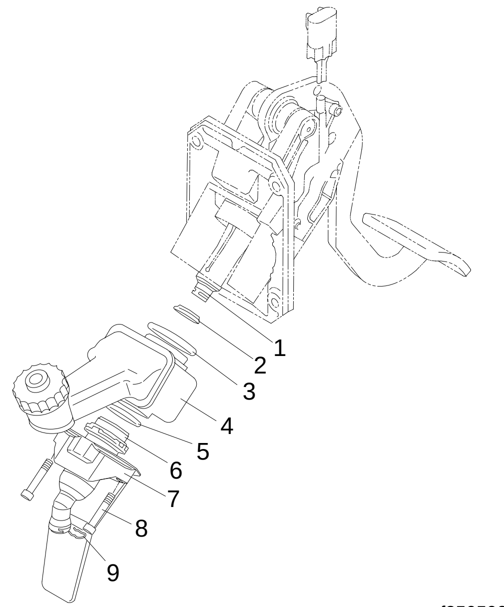
1. Hydraulic Hose
2. Quick-Disconnect Clip
3. Master Cylinder

Fig. 1, Quick-Disconnect Clip at the Master Cylinder

3. Drain the fluid from the master cylinder.
4. Remove the two screws that attach the hydraulic subassembly to the mounting plate. See **Fig. 2**.



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1. Piston
2. Lip Seal
3. Reservoir O-Ring
4. Reservoir
5. Body O-Ring
6. Hydraulic Body
7. Base
8. Screw
9. Clip

Fig. 2, Hydraulic Subassembly

5. Pull carefully on the hydraulic subassembly until it comes loose from the pedal unit. Discard the old hydraulic subassembly.
6. Carefully remove the lip seal from the piston of the master cylinder. Discard the lip seal.

NOTE: Avoid damaging the piston.

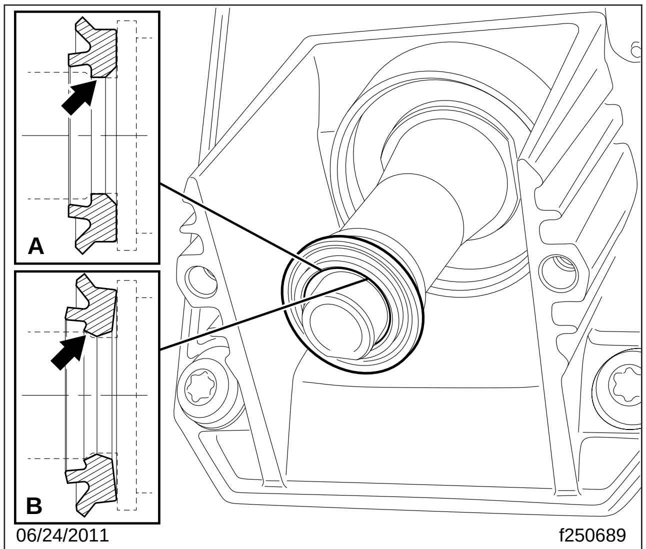
7. Lubricate a new lip seal and mount it on the piston. See **Fig. 3**.

NOTICE

Use only the special grease provided in the assembly kit. Do not use mineral oil or any other lubricant which could damage the seals and cause loss of clutch function.

8. Lubricate the new O-rings and the O-ring seats in the new reservoir and hydraulic body.
9. Put the reservoir and hydraulic body together with the O-rings properly seated and lubricated.

Hydraulic Subassembly Replacement



A. Correct Installation
B. Incorrect Installation

Fig. 3, Hydraulic Subassembly

10. While holding the reservoir and hydraulic body together, insert the base over the hydraulic body.
11. Install the screws, and tighten them to 44 lbf·in (500 N·cm).
12. Install the quick-disconnect clip and hydraulic hose, as follows.

    12.1 Insert the clip arms into the recessed areas on the nozzle of the master cylinder.

    12.2 Snap the hydraulic hose into place.

    12.3 Tug on the hose to make sure it is installed correctly. The hose should not pull out.

    IMPORTANT: Do not force the hose into the slave cylinder. If the clip is incorrectly installed, the hose will not snap into place.

WARNING

Use only approved clutch hydraulic fluid (DOT 4 brake fluid). Do not mix different types of brake fluid. The wrong fluid will damage the rubber parts of the system, causing loss of clutch function and the risk of serious personal injury.

13. Fill the reservoir with approved DOT 4 hydraulic brake fluid and bleed the system as instructed in **Subject 130**.
14. Check the function of the clutch actuation system as instructed in **Subject 300**.

Replacement

WARNING

Clutch hydraulic fluid (DOT 4 brake fluid) is hazardous. It may be a skin irritant and can cause blindness if it gets in your eyes. Always wear safety glasses when handling clutch hydraulic fluid or bleeding hydraulic lines. If you get clutch hydraulic fluid on your skin, wash it off as soon as possible.

1. Shut down the engine.
2. Apply the parking brakes, chock the front and rear tires, and open the hood.
3. Using a flat-head screwdriver, remove the quick-disconnect clamp that attaches the hydraulic hose to the slave cylinder. Retain the clamp for later installation.

WARNING

Never remove the slave cylinder from the gear case while it is still connected to the hydraulic hose and the system is filled with hydraulic fluid. Depressing the pedal in this situation could release, at high speed, the metal pushrod inside the cylinder, causing component damage and serious personal injury.

4. Drain the hydraulic fluid from the entire system. See **Fig. 1**. For detailed procedures, see **Subject 100**.
5. Loosen the four M8 slave cylinder mounting capscrews attaching the slave cylinder to the bell housing.
6. After bracing the slave cylinder so that it does not fall, remove the four slave cylinder mounting capscrews. Retain the capscrews for later installation.

IMPORTANT: Handle the slave cylinder carefully to prevent spillage.

7. Remove the slave cylinder from the gear case. Drain any remaining fluid.

IMPORTANT: Be sure to mount the slave cylinder with the bleed valve on top of the unit and horizontal to the ground, as shown in **Fig. 1**.

8. Mount the slave cylinder on the gear case, as removed.
   - 8.1 Make sure that the pushrod is attached to the clutch fork and inserted into the pushrod bore in the slave cylinder.
   - 8.2 Push the slave cylinder against the gear case to compress the internal spring.
9. Install the four slave cylinder mounting capscrews and tighten them 13 lbf·ft (18 N·m).
10. Connect the hydraulic hose to the slave cylinder.
11. Install the clamp, as removed.
   - 11.1 Install the clamp in the recessed area on the nozzle of the master cylinder.
   - 11.2 Snap the hydraulic hose into place.
   - 11.3 Tug on the hose to make sure it is installed correctly. The hose should not pull out easily.

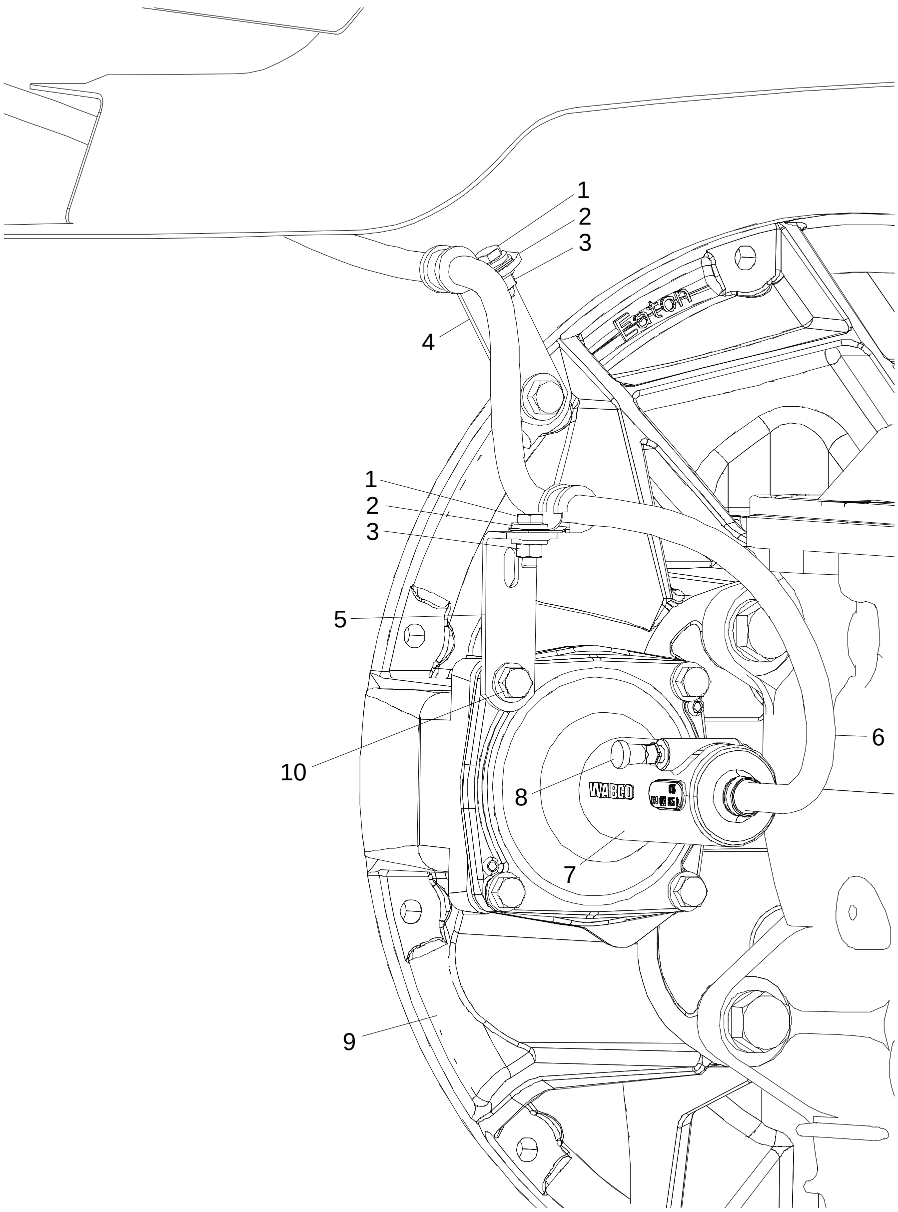
   NOTE: Don't force the hose into the master cylinder. If the clamp is incorrectly installed, the hose will not snap into place.

WARNING

Use only approved clutch hydraulic fluid (DOT 4 brake fluid). Do not mix different types of brake fluid. The wrong fluid will damage the rubber parts of the system, causing loss of clutch function and the risk of serious personal injury.

12. Fill the reservoir with approved DOT 4 hydraulic brake fluid. Flush and bleed the system according to the procedures in **Subject 140**.
13. Check the function of the clutch actuation system according to the procedures under the heading "Clutch Actuation System Check" in **Troubleshooting, 300**.

Slave Cylinder Replacement



Mount the slave cylinder with the bleed valve on top of the unit and horizontal to the ground.

1. Clamp Mounting Bolt, 1/4–20
2. Steel-Plated Washer
3. Locknut, 1/4–20
4. Bell Housing Standoff Bracket
5. Slave Cylinder Standoff Bracket
6. Hydraulic Hose
7. Slave Cylinder
8. Bleed Valve
9. Bell Housing
10. Slave Cylinder Mounting Capscrew, M8

Fig. 1, Clutch Slave Cylinder

SACHS 365 mm Clutch Removal and Installation

Special Tools

A special tool is used for this procedure. See **Table 1**.

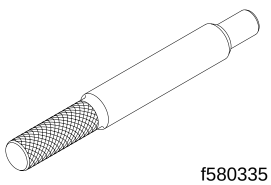
Special Tool			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580335	Clutch Centering Pin	Kent-Moore	J-45719

Table 1, Special Tool

NOTE: To check tool availability, and to order tools, call SPX Kent-Moore at 1-800-328-6657.

Removal

1. Remove the transmission from the engine.
    - For instructions for the Mercedes-Benz Automated Transmission, see **Section 26.03, Subject 100**.
    - For instructions for the Mercedes-Benz Manual Transmission, see **Section 26.04, Subject 100**.
2. Insert the centering pin (**Table 1**) through the clutch disc and into the pilot bearing.

IMPORTANT: The clutch is under tension. If one capscrew is loosened too much, it places too much tension on the cover assembly.

3. Remove the cover assembly. See **Fig. 1**. In a star pattern, incrementally loosen the capscrews; take care not to loosen any one capscrew too much before loosening the next one.
4. Remove the clutch disc assembly.

Installation

1. Grease the splines of the input shaft and the hub of the disc assembly. Remove any excess grease.

NOTE: Do not grease the guide of the release bearing. Greasing it would attract dirt particles that lead to excessive wear.

2. Insert the centering pin (**Table 1**) into the pilot bearing. Then, with the clutch disc assembly oriented so the side marked "flywheel side" faces the flywheel, center the disc assembly on the flywheel.

IMPORTANT: Do not remove the centering pin until the clutch is completely installed.

3. Install "guide pins" at the 10 o'clock and 2 o'clock positions to ensure proper centering of the clutch cover assembly. See **Fig. 2**.

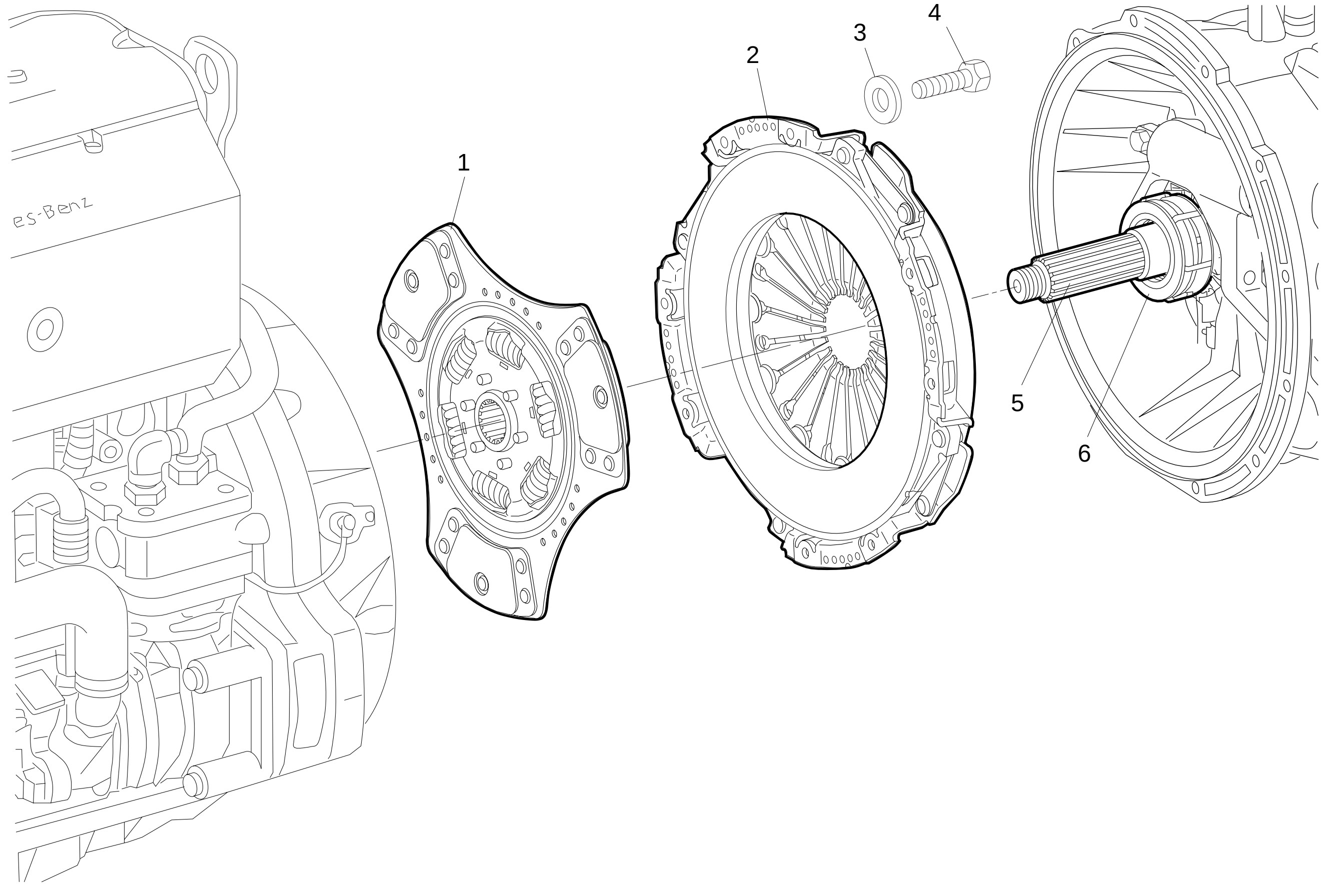
    "Guide pins" are long, headless capscrews that are temporarily installed in the flywheel to support the weight of the clutch, allowing you to align it precisely with the flywheel. *Without guide pins, proper clutch installation is extremely difficult*. If necessary, cut off the heads of two 6-inch (15 cm) capscrews to make a set.
4. Install the cover assembly, as follows.

    IMPORTANT: Never allow the diaphragm spring to rest on the centering pin.

    4.1 Slide the clutch cover assembly onto the guide pins, and position it inside the raised rim of the flywheel. See **Fig. 3**.

    4.2 Ensure the cover assembly is situated completely within the rim of the flywheel

SACHS 365 mm Clutch Removal and Installation



1. Disc Assembly
2. Cover Assembly
3. Washer
4. Clutch Capscrews, 3/8–16 x 13/16
5. Input Shaft
6. Release Bearing

Fig. 1, Clutch Assembly

and not overlapping it. Use a flashlight to help verify the positioning if needed.

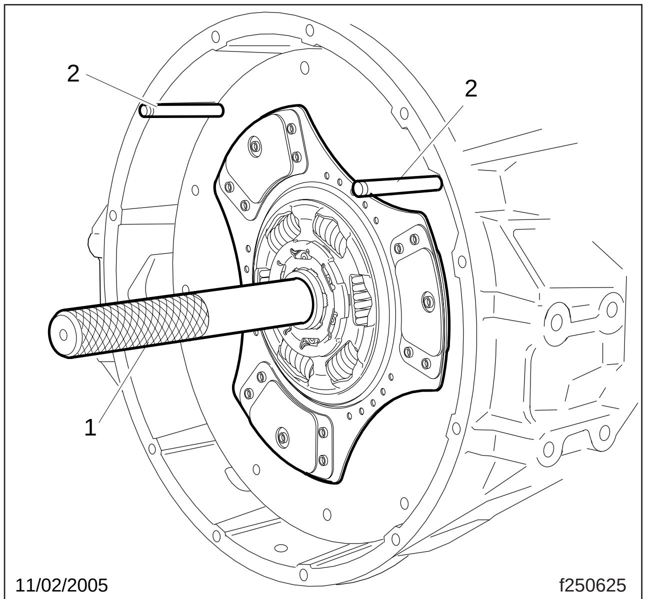
4.3 Install and hand-tighten six of the eight capscrews using the sequence shown in **Fig. 4** (skipping the guide pin positions).

4.4 Remove the two guide pins, then install and hand-tighten the remaining two capscrews.

4.5 Using the sequence shown in **Fig. 4**, tighten the eight clutch capscrews progressively: first to 20 lbf·ft (27 N·m), and finally to 37 lbf·ft (50 N·m). Do not put more tension on one side of the clutch than the other.

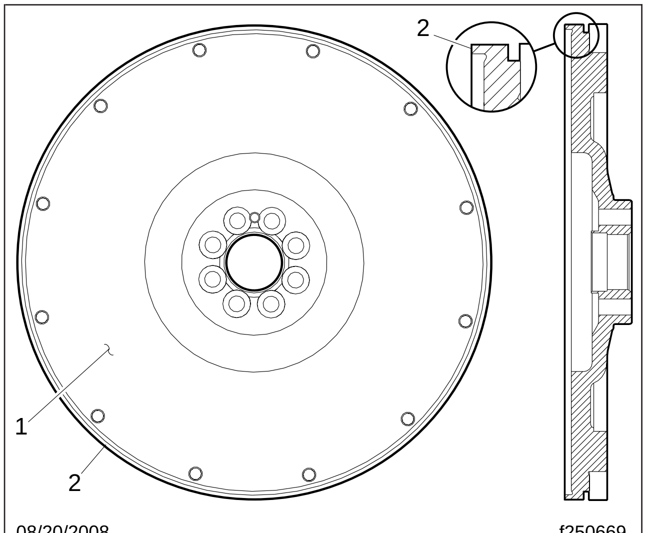
5. When all capscrews have been tightened, remove the centering pin.
6. Install the transmission on the engine.
   - For instructions for the Mercedes-Benz Automated Transmission, see **Section 26.03, Subject 100**.
   - For instructions for the Mercedes-Benz Manual Transmission, see **Section 26.04, Subject 100**.

SACHS 365 mm Clutch Removal and Installation



1. Centering Pin
2. Guide Pin

Fig. 2, Centering the Clutch



1. Flywheel
2. Flywheel Rim

Fig. 3, Flywheel Rim

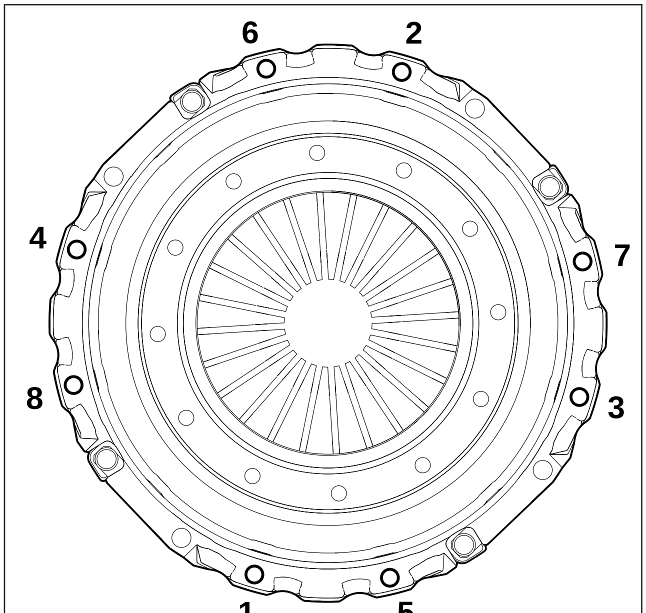


Fig. 4, Capscrew Tightening Sequence

WARNING

Hydraulic clutch control fluid (DOT 4 brake fluid) is hazardous. It may be a skin irritant and can cause blindness if it gets in your eyes. Always wear safety glasses when handling it or bleeding hydraulic lines. If you get it on your skin, wash it off as soon as possible.

NOTICE

Do not spill hydraulic clutch control fluid on the cab paint. Clean it off immediately if any is spilled. Brake fluid can damage paint.

Filling

The hydraulic system holds approximately 0.5 quart (0.5 liter) of fluid. Use new DOT 4 brake fluid from a tightly sealed container to fill the system until the fluid level is between the MIN and MAX lines marked on the side of the reservoir.

Bleeding

The hydraulic clutch control can be bled by using a pressure adaptor or manual bleeding. Pressure bleeding can be done by one person and manual bleeding requires two.

Pressure Bleeding

A pressure bleeder hose (J-29532) and a bleed adaptor (J-35798) for the fluid reservoir are available through SPX Kent-Moore Tools and may be used to complete the pressure bleeding procedure. To order these parts, call Kent-Moore at 1-800-328-6657.

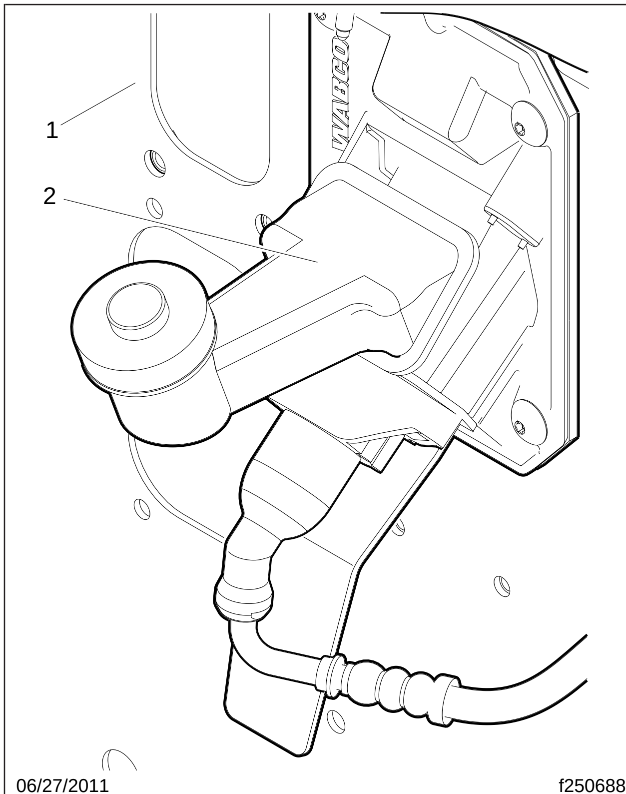
1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Open the hood.
3. Prepare the pressure bleeding equipment according to the manufacturer's instructions. Use new DOT 4 brake fluid from a tightly sealed container. Pressurize the bleed adaptor to 15 psi (103 kPa).
4. Remove the reservoir cap (see **Fig. 1**) and install the pressure bleed adaptor on the reservoir.
5. Pressurize the reservoir to fill the system. Open the bleed valve on the bleed tank of the adaptor.

NOTE: The hydraulic system holds approximately 0.5 quart (0.5 liter) of fluid. It may need to be refilled during the bleeding process to prevent air from re-entering the system.

6. Bleed the hydraulic system as follows.

   6.1 Remove the cap from the bleed valve of the slave cylinder. See **Fig. 2**. On the valve, install a transparent drain hose connected to a catch bottle. The hose needs to fit the bleed valve tight enough so it does not fall off when fluid is pumped out.

   6.2 Open the bleed valve on the slave cylinder.

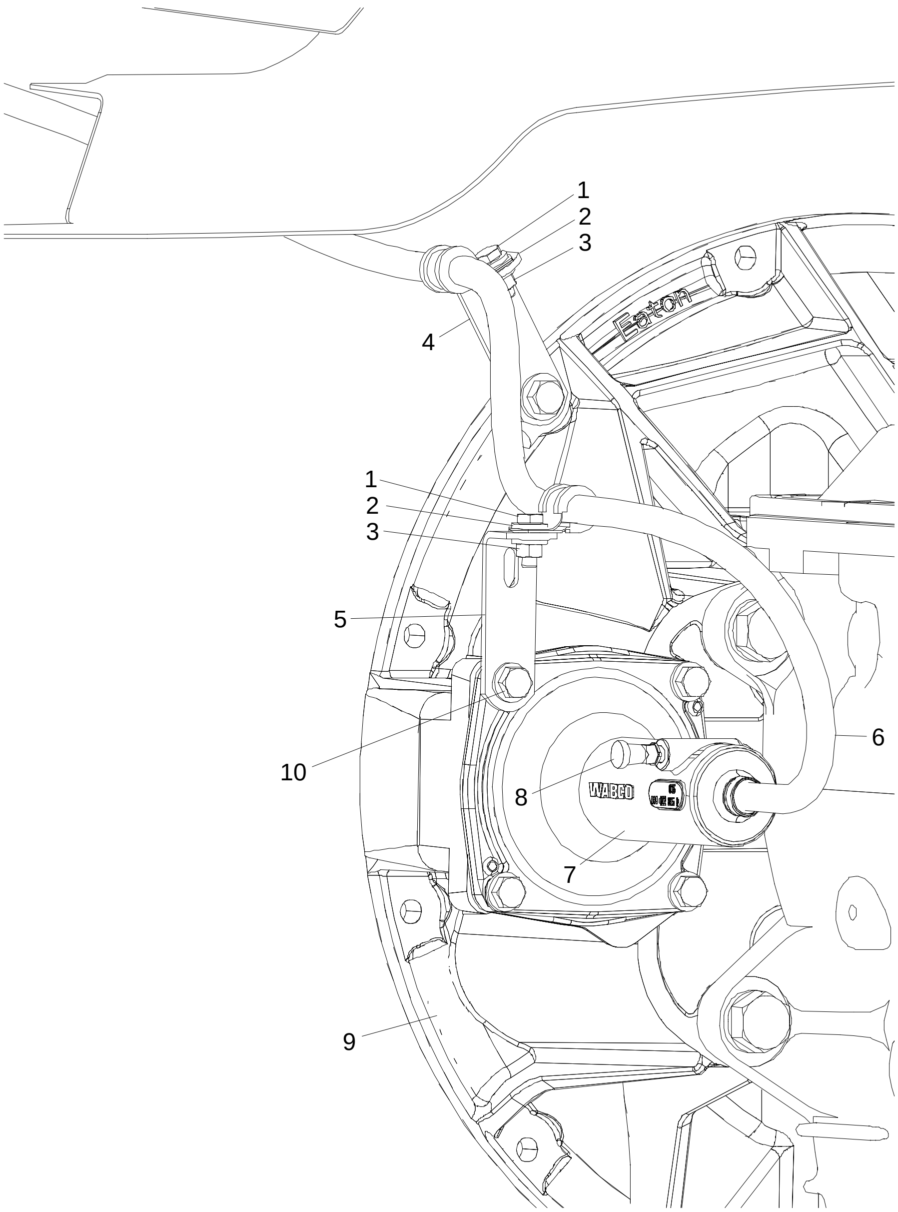


1. Frontwall
2. Reservoir

Fig. 1, Master Cylinder, Hydraulic Clutch Control

   6.3 When the draining fluid is clear and free of air bubbles, close the bleed valve.

Fluid Filling and Bleeding



1. Clamp Mounting Bolt, 1/4–20
2. Steel-Plated Washer
3. Locknut, 1/4–20
4. Bell Housing Standoff Bracket
5. Slave Cylinder Standoff Bracket
6. Hydraulic Hose
7. Slave Cylinder
8. Bleed Valve
9. Bell Housing
10. Slave Cylinder Mounting Capscrew, M8

Fig. 2, Slave Cylinder, Hydraulic Clutch Control

7. Disconnect the transparent hose. Tighten the bleed valve 88 lbf·in (1000 N·cm) and install the cap on the slave cylinder bleed valve.
8. Check the fluid level in the reservoir. If necessary, add or drain fluid to bring the fluid level to between the MIN and MAX lines marked on the side of the reservoir. Install the reservoir cap.
9. Depress the clutch pedal a few times. There should be resistance over the full pedal stroke.

Manual Bleeding

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Open the hood.

NOTE: The hydraulic system holds approximately 0.5 quart (0.5 liter) of fluid. It may need to be refilled during the bleeding process to prevent air from re-entering the system.

3. Remove the reservoir cap (see **Fig. 1**) and fill the reservoir with new DOT 4 brake fluid from a tightly sealed container.
4. Remove the cap from the bleed valve of the slave cylinder. See **Fig. 2**. On the valve, install a transparent drain hose connected to a catch bottle. The hose needs to fit the bleed valve tight enough so it does not fall off when fluid is pumped out.
5. Open the slave cylinder bleed valve. Observe the flow of clutch hydraulic fluid through the drain hose.
6. Have an assistant slowly pump the clutch pedal to purge the fluid/air mixture.
7. When the draining fluid is clear and free of air bubbles, close the bleed valve.
8. Disconnect the transparent hose. Tighten the bleed valve 88 lbf·in (1000 N·cm) and install the cap on the slave cylinder bleed valve.
9. Check the fluid level in the reservoir. If necessary, add or drain fluid to bring the fluid level to between the MIN and MAX lines marked on the side of the reservoir. Install the reservoir cap.
10. Depress the clutch pedal a few times. There should be resistance over the full pedal stroke.

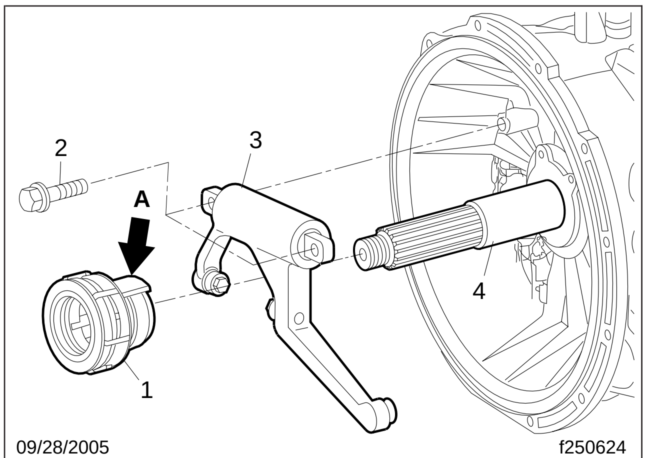
Release Bearing and Yoke Assembly Replacement

Replacement

1. Remove the transmission from the engine.
   - For instructions for Eaton Fuller Transmissions, see **Section 26.00, Subject 100**.
   - For instructions for the Mercedes-Benz Automated Transmission, see **Section 26.03, Subject 100**.
   - For instructions for the Mercedes-Benz Manual Transmission, see **Section 26.04, Subject 100**.
2. Remove the release bearing from the release yoke. See **Fig. 1**.

IMPORTANT: The clips that secure the bearing to the bearing guide must be handled carefully. Repositioning or damaging these clips can lead to premature clutch failure. See **Fig. 2**.

3. Remove the two capscrews that attach the release yoke to the bell housing. Remove the release yoke from the transmission.



A. Position the stop pin at 12 o’clock between the arms of the release yoke.

1. Release Bearing
2. Capscrew
3. Release Yoke
4. Input Shaft

Fig. 1, Release Yoke Installation

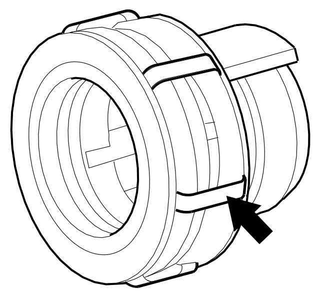
4. Install the release yoke. Tighten the two capscrews 33 lbf·ft (45 N·m).

IMPORTANT: Position the release bearing with the stop pin located at 12 o’clock between the two arms of the release yoke. See **Fig. 1**.

5. Install the bearing onto the release yoke.

NOTE: Do not grease the guide of the release bearing. It is made from an advanced composite with embedded lubricating elements, and greasing it would attract dirt particles that lead to excessive wear.

6. Install the transmission on the engine.
   - For instructions for Eaton Fuller Transmissions, see **Section 26.00, Subject 100**.
   - For instructions for the Mercedes-Benz Automated Transmission, see **Section 26.03, Subject 100**.
   - For instructions for the Mercedes-Benz Manual Transmission, see **Section 26.04, Subject 100**.



Handle the release bearing carefully. Do not bend or reposition the clips.

Fig. 2, Release Bearing Clip

Replacement

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Open the hood.

WARNING

Clutch hydraulic fluid (DOT 4 brake fluid) is hazardous. It may be a skin irritant and can cause blindness if it gets in your eyes. Always wear safety glasses when handling clutch hydraulic fluid or bleeding hydraulic lines. If you get clutch hydraulic fluid on your skin, wash it off as soon as possible.

3. Using a flat-tip screwdriver, remove the quick-disconnect clip that attaches the hydraulic hose to the slave cylinder. Retain the clip. See **Fig. 1**.
4. Drain the hydraulic fluid from the entire system.
5. At the quick-disconnect clip that attaches the hydraulic hose to the master cylinder, note the position of the clip for later installation, then remove it using a flat-tip screwdriver. See **Fig. 2**.
6. Route the new hydraulic hose between the slave cylinder and the master cylinder.
7. Install the quick-disconnect clip and hydraulic hose, as follows.

   7.1 Insert the clip arms into the recessed areas on the nozzle of the master cylinder.

   IMPORTANT: Do not force the hose into the slave cylinder. If the clip is incorrectly installed, the hose will not snap into place.

   7.2 Snap the hydraulic hose into place.

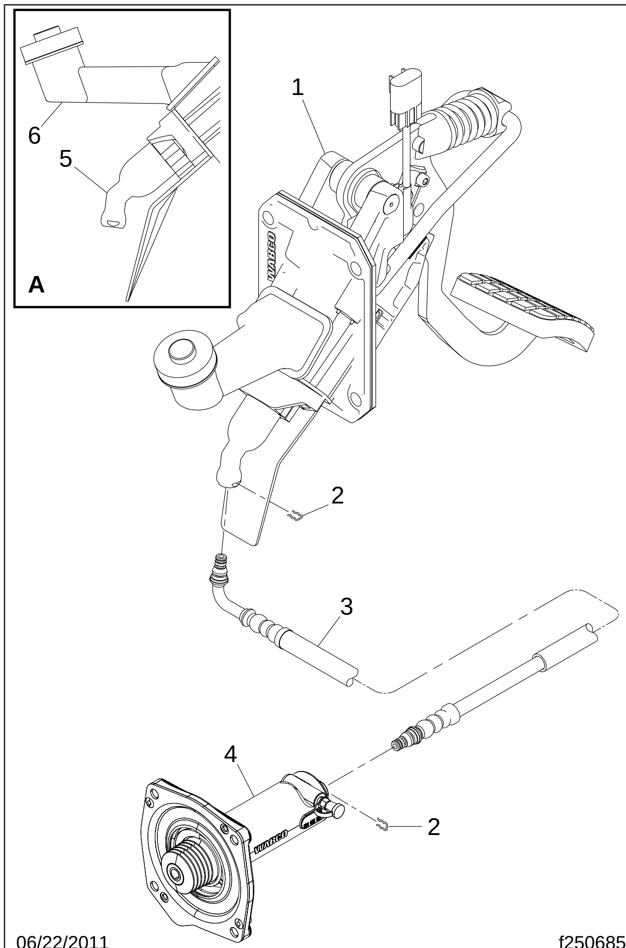
   7.3 Tug on the hose to make sure it is installed correctly. The hose should not pull out.

   7.4 Insert the clip at the slave cylinder, and install the hose as described above.

WARNING

Use only approved clutch hydraulic fluid (DOT 4 brake fluid). Do not mix different types of brake fluid. The wrong fluid will damage the rubber parts of the system, causing loss of clutch function and the risk of serious personal injury.

8. Fill the reservoir with approved DOT 4 hydraulic brake fluid and bleed the system as instructed in **Subject 130**.
9. Check the function of the clutch actuation system as instructed in **Subject 300**.

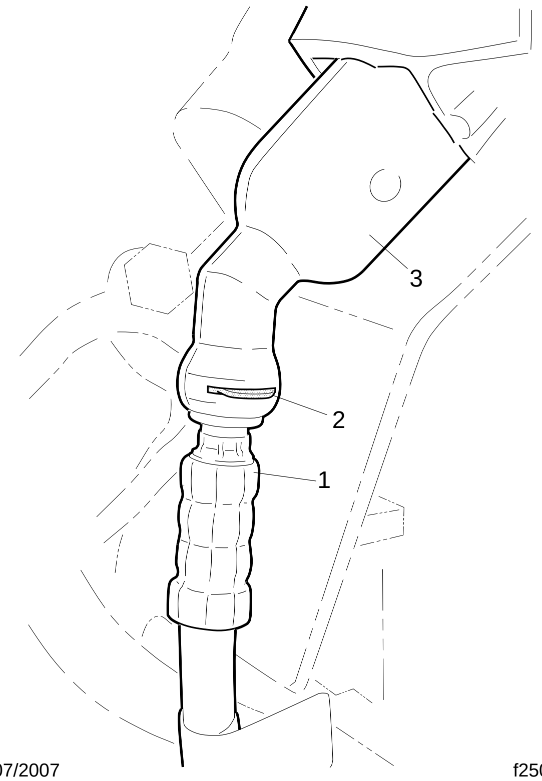


A. Hydraulic Subassembly

1. Pedal Unit
2. Clip
3. Hydraulic Hose
4. Slave Cylinder
5. Master Cylinder
6. Reservoir

Fig. 1, Components, Hydraulic Clutch Control

Hydraulic Hose Replacement



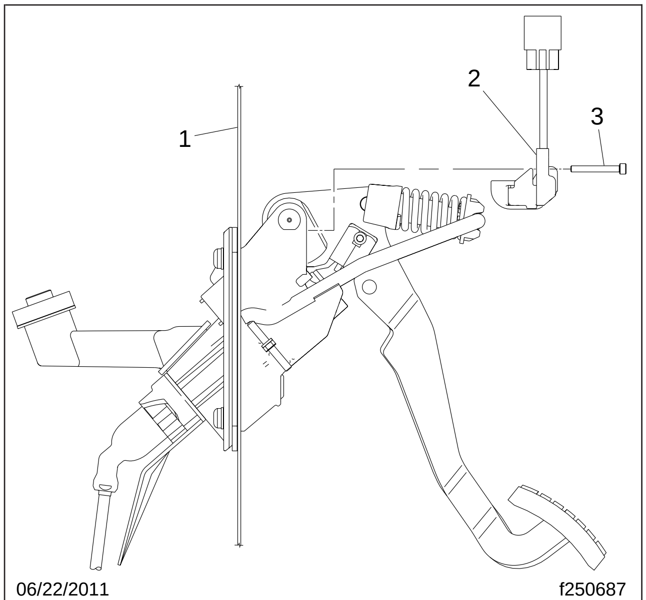
1. Hydraulic Hose
2. Quick-Disconnect Clip
3. Master Cylinder

Fig. 2, Quick-Disconnect Clip at the Master Cylinder

Clutch Switch Replacement

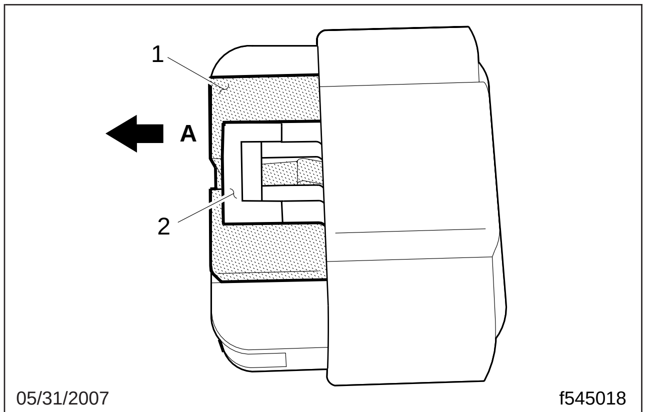
Replacement

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Open the hood.
3. Disconnect the clutch control switch located under the dash and above the clutch pedal, as follows. See **Fig. 1**.
   3.1 Retract the secondary lock. See **Fig. 2**.
   3.2 Depress the latch to unlock the switch connector, then separate the clutch control switch from the wire harness.
4. Remove the screw that holds the switch assembly to the pedal unit, and remove the switch.
5. Mount the new switch assembly on the connector and tighten the M5 screw 23 lbf·in (260 N·cm).
6. Check the function of the clutch actuation system as instructed in **Subject 300**.



1. Frontwall
2. Clutch Control Switch
3. Screw

Fig. 1, Clutch Control Switch



A. Retract the secondary lock, then depress the latch to release the connector.

1. Secondary Lock
2. Latch

Fig. 2, Clutch Control Switch Connector

SACHS 395 XTend Clutch Removal and Installation

Special Tools

A special tool is used for this procedure. See **Table 1**.

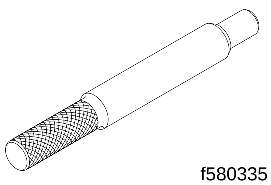
Special Tool			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580335	Clutch Centering Pin	Kent-Moore	J-45719

Table 1, Special Tool

NOTE: To check tool availability, and to order tools, call SPX Kent-Moore at 1-800-328-6657.

Removal

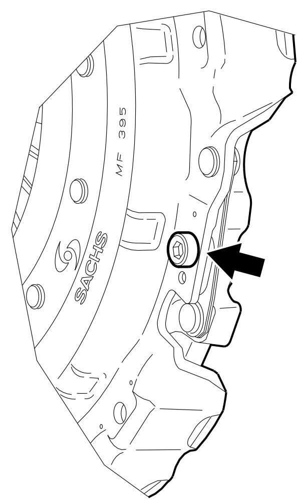
1. Remove the transmission from the engine.
   - For instructions for the Mercedes-Benz Automated Transmission, see **Section 26.03, Subject 100**.
   - For instructions for the Mercedes-Benz Manual Transmission, see **Section 26.04, Subject 100**.
2. Insert the centering pin (**Table 1**) through the clutch disc and into the pilot bearing.

IMPORTANT: Do not remove the stop bolt. Also, forgetting to loosen this bolt may cause internal components to dislodge and render the clutch unusable.

3. Loosen the stop bolt about two turns. See **Fig. 1** for the stop bolt location.

IMPORTANT: The clutch disc is under tension. If one capscrew is loosened too much, it places excessive tension on the cover assembly.

4. Remove the cover assembly. See **Fig. 2**. Loosen the capscrews in a star pattern, taking care not to loosen any one capscrew too much before loosening the next one.
5. Remove the clutch disc assembly.



09/26/2005 f250628

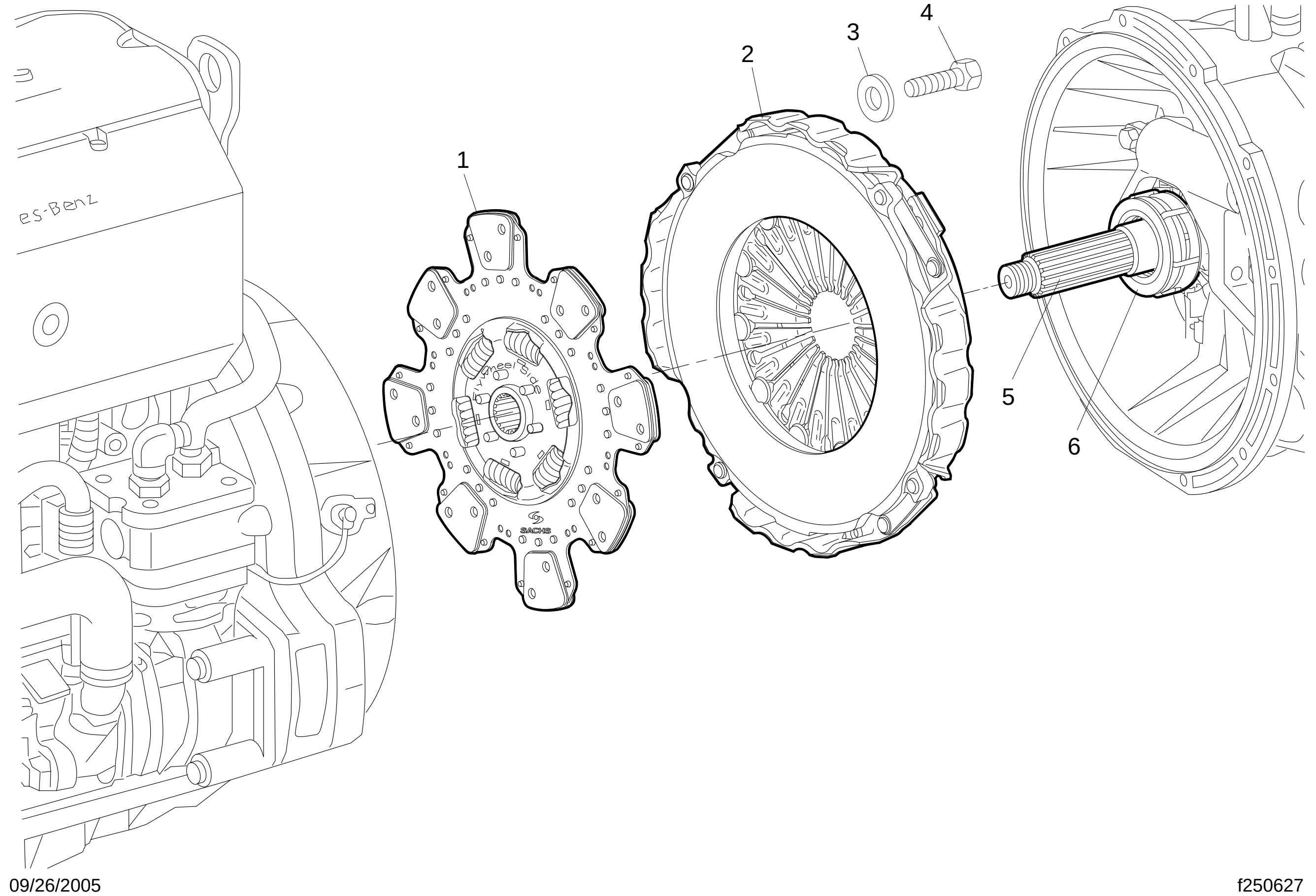
Fig. 1, Stop Bolt

NOTE: If a SACHS 395 XTend cover assembly is covered with oil (e.g. defective shaft seal) or grease, do not reinstall it—even if it has been cleaned.

Installation

NOTE: When replacing a SACHS 365 mm clutch with a 395 XTend, replace the flywheel as well. For instructions, see the manufacturer's service literature.

SACHS 395 XTend Clutch Removal and Installation



1. Disc Assembly
2. Cover Assembly
3. Washer
4. Clutch Capscrews, M10 x 80
5. Input Shaft
6. Release Bearing

Fig. 2, Clutch Assembly

1. Grease the splines of the input shaft and the hub of the disc assembly. Remove any excess grease.

NOTE: Do not grease the guide of the release bearing. It is made from an advanced composite with embedded lubricating elements, and greasing it would attract dirt particles that lead to excessive wear.

2. Insert the centering pin (**Table 1**) into the pilot bearing. Then, with the clutch disc assembly oriented so the side marked "flywheel side" faces the flywheel, center the disc assembly on the flywheel.

IMPORTANT: Do not remove the centering pin until the clutch is completely installed.

3. Install guide pins at the 10 o'clock and 2 o'clock positions to ensure proper centering of the clutch cover assembly. See **Fig. 3**.

   "Guide pins" are long, headless capscrews that are temporarily installed in the flywheel to support the weight of the clutch, allowing you to align it precisely with the flywheel. *Without guide pins, proper clutch installation is extremely difficult*. If necessary, cut off the heads of two 6-inch (15 cm) capscrews to make a set.

4. Install the cover assembly, as follows.

SACHS 395 XTend Clutch Removal and Installation

IMPORTANT: Never allow the diaphragm spring to rest on the centering pin.

4.1 Slide the clutch cover assembly onto the guide pins, and position it inside the raised rim of the flywheel. See **Fig. 4**.

4.2 Ensure the cover assembly is situated completely within the rim of the flywheel. Use a flashlight to help verify the positioning if needed.

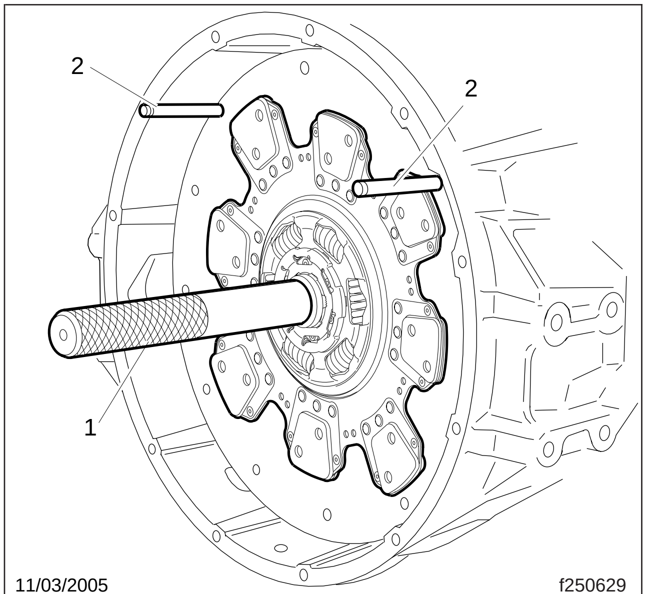
4.3 Install and hand-tighten six of the eight capscrews using the sequence shown in **Fig. 5** (skipping the guide pin positions).

4.4 Remove the two guide pins, then install and hand-tighten the remaining two capscrews.

4.5 Using the sequence shown in **Fig. 5**, tighten the eight clutch capscrews progressively: first to 20 lbf·ft (27 N·m), and finally to 33 lbf·ft (44 N·m). Do not put more tension on one side of the clutch than the other.

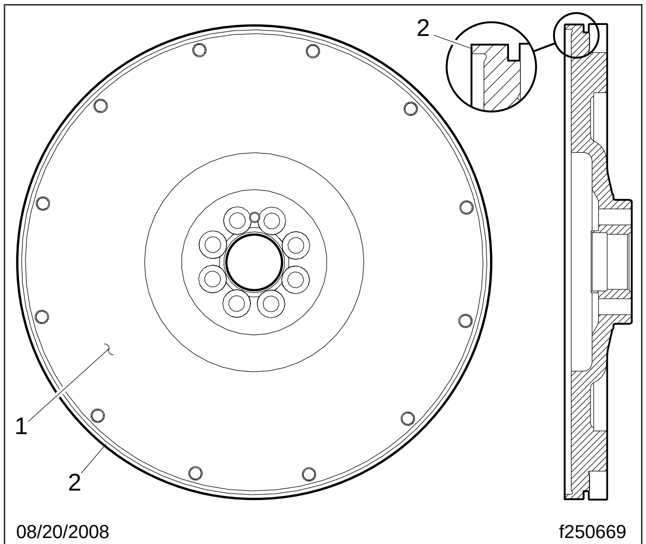
4.6 If the clutch was previously mounted and the stop bolt loosened for removal, tighten the stop bolt to 26 to 32 lbf·ft (35 to 43 N·m). If it is a new clutch, do not tighten the stop bolt.

5. When all capscrews have been tightened, remove the centering pin.
6. Install the transmission on the engine.
   - For instructions for the Mercedes-Benz Automated Transmission, see **Section 26.03, Subject 100**.
   - For instructions for the Mercedes-Benz Manual Transmission, see **Section 26.04, Subject 100**.



1. Centering Pin
2. Guide Pin

Fig. 3, Centering the Clutch



1. Flywheel
2. Flywheel Rim

Fig. 4, Flywheel Rim

SACHS 395 XTend Clutch Removal and Installation

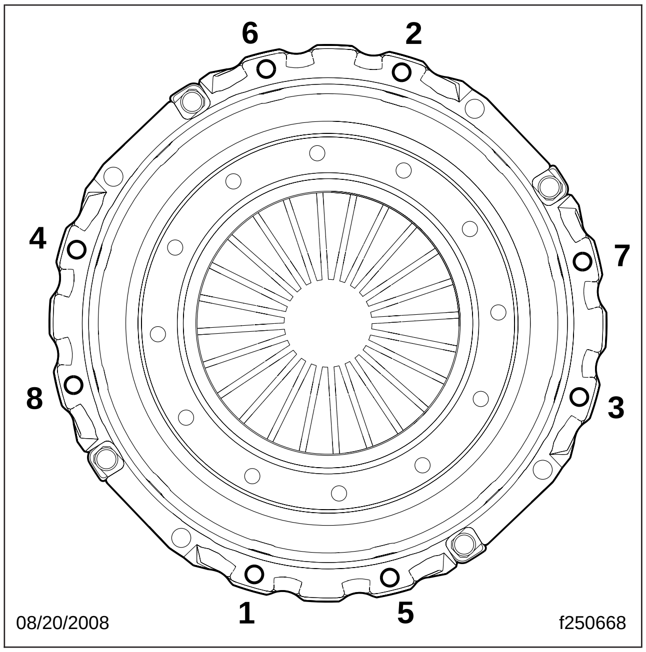


Fig. 5, Capscrew Tightening Sequence

General Information

Most hydraulically actuated clutches are auto-adjusting and require no manual adjustment under normal operating conditions. Eaton Easy-Pedal and Stamped Angle Spring clutches are manually adjusted models, and require periodic inspection and adjusting to maintain proper clutch clearance and achieve maximum clutch disc life. Approximately 75 percent of Business Class® M2 vehicles equipped with non-synchronized transmissions and hydraulically actuated clutches are equipped with manually adjusted clutches. This combination of components (hydraulic actuation and manual adjustment) does not allow the driver to feel when the clutch must be adjusted, because the clutch pedal has no free travel.

Release bearing travel is the clearance between the rear surface of the release bearing housing and the forward surface of the clutch brake disc. This distance must be maintained between 1/2 and 9/16 inch (12.7 and 14.3 mm).

Clutch Adjustment

1. Apply the parking brakes and chock all the tires.
2. Remove the clutch inspection cover from the bell housing. See **Fig. 1**.
3. Slide the clutch brake tight against the transmission input-shaft bearing cap.

IMPORTANT: Release bearing travel tool A02-12419-000 is available through the PDCs. One end of the tool has green tape on it and is 0.50 inch (12.7 mm) in diameter; the other end has blue tape on it and is 0.56 inch (14.3 mm) in diameter. See **Fig. 2**.

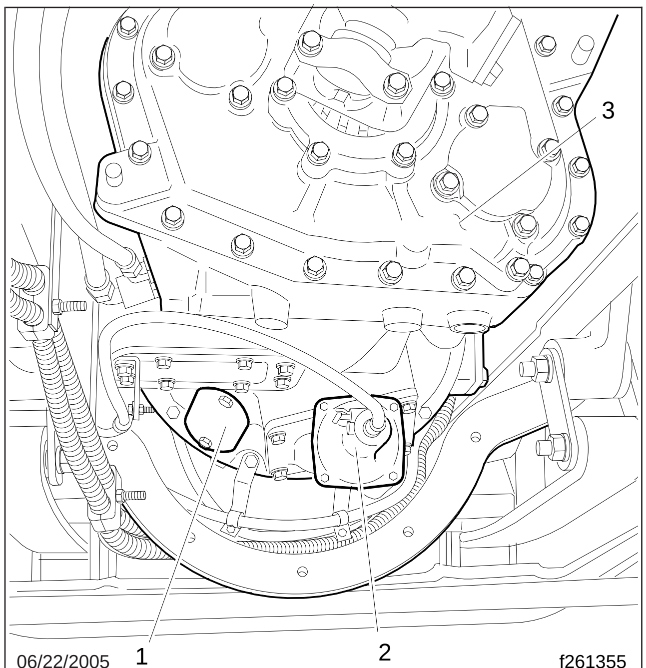
4. Measure the release bearing travel. See **Fig. 3** for the correct dimension to measure. Using both ends of the release bearing travel tool, check this gap as follows:

   Position the tool so that the legs at the blue 0.56-inch (14.3-mm) end straddle the transmission input shaft. If the tool fits loosely, the gap is too wide and adjustment is needed. Go to the next step.

   If the blue 0.56-inch (14.3-mm) end can't be inserted in the gap, then try to insert the green 0.50-inch (12.7-mm) end.

   If the green end of the tool can't be inserted in the gap, adjustment is needed. Go to the next step.

   If the green end of the tool fits — snugly or loosely — then no adjustment is needed. Nothing more needs to be done. Install the clutch inspection cover and remove the chocks from the tires.



1. Clutch Inspection Cover
2. Hydraulic Slave Cylinder
3. Transmission

Fig. 1, View from Underneath the Vehicle Looking Forward

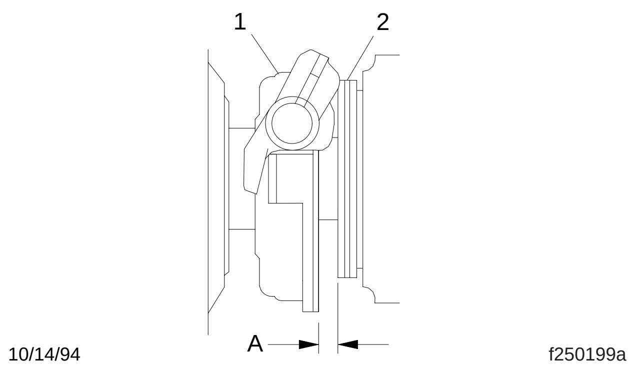
5. Turn the engine flywheel until the lockstrap is aligned with the clutch inspection-cover opening.
6. Release the clutch by depressing the pedal. Block the pedal in the released position, or have someone assist you by holding the pedal down during the adjustment procedure.

NOTE: An open-end wrench is not recommended for the following step.

Hydraulic Clutch Adjustment

A. Green End (0.50 inch or 12.7 mm)
B. Blue End (0.56 inch or 14.3 mm)

Fig. 2, Release Bearing Travel Tool A02-12419-000



A. Clearance between release bearing housing and clutch brake (release bearing travel) must be 1/2 to 9/16 inch (12.7 to 14.3 mm).

1. Release Bearing Housing
2. Clutch Brake

Fig. 3, Release Bearing Travel Measurement

7. Adjust the clutch, using a 5/8-inch box-end or socket wrench on the adjustment bolt. See **Fig. 4**.

   7.1 Insert the 5/8-inch box-end or socket wrench through the inspection cover opening.

   7.2 To begin the adjustment, release the adjustment bolt by pressing down on the bolt head.

   NOTE: Normal wear increases the gap between the release bearing and the transmission. See **Fig. 3**, dimension A.

   7.3 *To decrease the gap*: If clearance between the release bearing housing and the clutch brake is *more than* 9/16 inch (14.3 mm), turn the adjustment bolt clockwise (the release bearing moves toward the transmission).

   To increase the gap: If clearance between the release bearing housing and the clutch brake is *less than* 1/2 inch (12.7 mm), turn the adjustment bolt counterclockwise (the release bearing moves toward the engine).

   7.4 When the adjustment is complete, make sure the adjustment bolt is locked (pulled up flush with the mounting bolts).

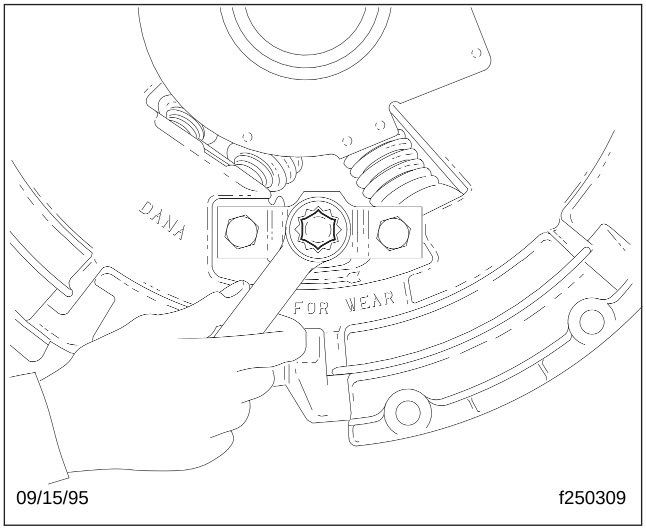


Fig. 4, Adjustment with Kwik-Adjust (bell housing shown removed)

NOTE: On Easy-Pedal 2000 clutches, each complete turn of the adjustment bolt represents about 0.125 inch (3 mm) of release bearing movement. On earlier Easy-Pedal models, each complete turn of the adjustment bolt represents about 0.02 inch (0.5 mm) of release bearing movement.

8. After adjusting, release the pedal and check the clearance between the release bearing housing and the clutch brake. When the adjustment is correct, the green end of the tool should go in and the blue should not (clearance of 1/2 to 9/16 inch, or 12.7 to 14.3 mm).
9. Install the clutch inspection cover on the bell housing.
10. Remove the chocks from the tires.

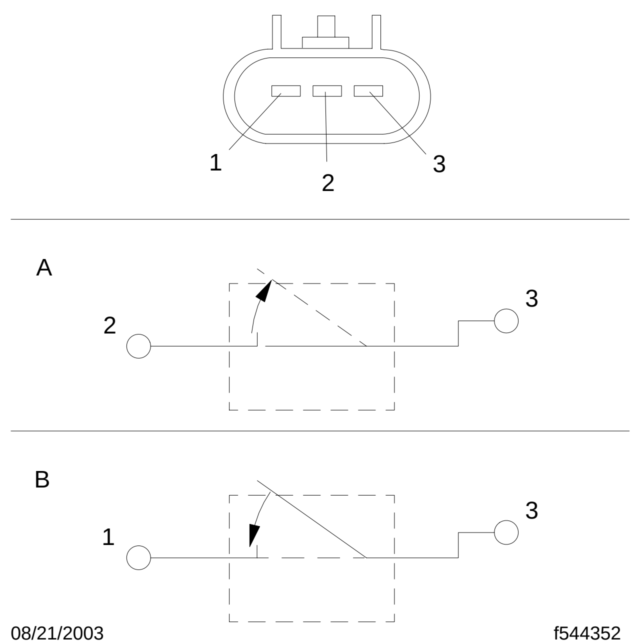
Diagnostic Checks

IMPORTANT: If any problems are noticed during these diagnostic checks, take corrective action using the information under the heading "Troubleshooting Tables."

When repairing any components, bleed the clutch hydraulic system before restoring the vehicle to service. This will prevent air from remaining in the system.

Clutch Switch Check

1. Shut down the engine.
2. Apply the parking brakes, chock the front and rear tires, and open the hood.
3. Disconnect the clutch control switch connector located under the dash just above the clutch pedal.
4. To check the upper position switch, do a continuity check between pin 2 and pin 3 of the connector. See **Fig. 1**.
   - 4.1 With the pedal not pressed, the circuit should be closed (continuity should be present).
   - 4.2 With the pedal pressed down about 4 inches (10 cm), the circuit should be open (no indication of continuity).
5. To check the lower position switch, do a continuity check between pin 1 and pin 3 of the connector.
   - 5.1 With the pedal not pressed, the circuit should be open (no indication of continuity).
   - 5.2 With the pedal pressed down all the way to the floor, the circuit should be closed (continuity should be present).
6. If either check gives an incorrect result, replace the clutch switch.



A. Upper Position Switch–The switch is open when the pedal is pressed down about four inches (10 cm).
B. Lower Position Switch–The switch closes when the pedal is pressed down to the floor.
1. Pin 1
2. Pin 2
3. Pin 3

Fig. 1, Clutch Switch

Clutch Actuation System Check

WARNING

Air in the clutch hydraulic system can prevent the gears from engaging properly, and cause a serious accident resulting in personal injury.

1. Shut down the engine.
2. Apply the parking brakes and chock the front and rear tires.
3. Do the "Clutch Actuation System Leak Check."
4. Press the pedal all the way to the floor several times and check the action of the pedal. The pedal should be easy to operate and return without difficulty to its original position. It should feel firm and responsive, not soft or spongy.

5. With both the brake and the clutch pedals pressed down, start the engine.
   5.1 If the engine does not start, take corrective action using the information under the heading "Troubleshooting Tables."
   5.2 If the clutch does not disengage properly, take corrective action using the information under the heading "Troubleshooting Tables."
6. Remove the chocks from the front and rear tires.
7. Test drive the vehicle.
   7.1 Check for proper clutch functioning while shifting gears.
   7.2 If the clutch makes noise when shifting out of neutral into another gear, do the "Clutch Incomplete Disengagement Check."
   7.3 With cruise control on, press the clutch pedal down. If cruise control does not deactivate, take corrective action using the information under the heading "Troubleshooting Tables."

Clutch Actuation System Leak Check

1. Shut down the engine.
2. Apply the parking brakes, chock the front and rear tires, and open the hood.

NOTE: This step requires two persons.

3. Have one person press down on the clutch pedal while the other person checks the clutch hydraulic system for signs of leakage.

Clutch Incomplete Disengagement Check

NOTE: Do this check only on vehicles with synchronized transmissions.

1. Chock the front tires and apply the parking brake.
2. Put the gear shift lever in neutral.
3. Start the engine.
4. Press the clutch pedal all the way to the floor.
5. Shift the transmission into 1st gear.
6. With the clutch pedal still on the floor, shift into 2nd gear.
7. Listen for noise and feel for difficult shifting. If there is noise or difficulty in getting the gears to shift, the clutch is not completely disengaged. Take corrective action using the information under the heading "Troubleshooting Tables."

Troubleshooting Tables

Problem–The Clutch Pedal Feels Soft or Spongy

Problem–The Clutch Pedal Feels Soft or Spongy	
Possible Cause	**Remedy**
There is air in the hydraulic system.	Bleed the hydraulic system. See **Subject 140** for instructions.
There is a hydraulic fluid leak.	Check the fluid level. Check for leakage and replace any components found to be leaking. Fill and bleed the hydraulic system.

Problem–The Clutch Pedal Is Unusually Hard To Operate

Problem–The Clutch Pedal Is Unusually Hard To Operate	
Possible Cause	**Remedy**
The clutch is damaged.	Remove the clutch and inspect it for damage. Replace the clutch if damaged, or make any necessary repairs. For the SACHS 365 mm clutch, see **Subject 130**. For the SACHS 395 XTend clutch, see **Subject 180**.
The clutch is not functioning properly.	Check clutch function and make any necessary repairs. See the instructions under the heading "Clutch Actuation System Check."

Problem–The Clutch Pedal Is Unusually Hard To Operate	
Possible Cause	**Remedy**
The return or assist spring is broken.	Replace the pedal unit. See **Subject 100** for instructions. **WARNING** **Do not attempt to disassemble the preloaded assist spring. Sudden release of the assist spring could cause property damage and serious personal injury.**
The pedal assembly is worn or jammed.	Replace the pedal unit. See **Subject 100** for instructions.
The master cylinder has components that are jammed or broken.	Replace the hydraulic subassembly. See **Subject 110** for instructions.

Problem–The Clutch Does Not Completely Disengage; Shifting Is Difficult and Noisy

Problem–The Clutch Does Not Completely Disengage; Shifting Is Difficult and Noisy	
Possible Cause	**Remedy**
There is air in the hydraulic system.	Bleed the hydraulic system. See **Subject 140** for instructions.
There is a hydraulic fluid leak.	Check the fluid level. Check for leakage and replace any components found to be leaking. Fill and bleed the hydraulic system.
Components of the pedal unit are defective.	Replace the pedal unit. See **Subject 100** for instructions.
The slave cylinder is defective.	Replace the slave cylinder. See **Subject 120** for instructions.
The slave cylinder is loose.	Tighten the M8 slave cylinder mounting capscrews 12 lbf·ft (16 N·m).
The wrong type of brake fluid was used.	Replace the complete system. Fill only with approved DOT 4 brake fluid.

Problem–The Clutch Is Slipping

Problem–The Clutch Is Slipping	
Possible Cause	**Remedy**
The clutch is worn.	Replace the clutch. For the SACHS 365 mm clutch, see **Subject 130**. For the SACHS 395 XTend clutch, see **Subject 180**.
Contamination (e.g. oil, grease, etc.).	Replace the clutch. For the SACHS 365 mm clutch, see **Subject 130**. For the SACHS 395 XTend clutch, see **Subject 180**.
The clutch actuation system is "preloading."	Check the clutch actuation system. See the procedures under the heading "Clutch Actuation System Check."

Problem–The Clutch Switch Does Not Activate

Problem–The Clutch Switch Does Not Activate	
Possible Cause	**Remedy**
The switch contacts are damaged or worn.	Replace the clutch switch assembly. See **Subject 170** for instructions.
The switch wiring is damaged.	Repair the wiring. See **Section 54.03** for instructions.
The switch cam is damaged.	Replace the pedal unit. See **Subject 100** for instructions.

Troubleshooting

Problem–The Clutch Pedal Does Not Return

Problem–The Clutch Pedal Does Not Return	
Possible Cause	**Remedy**
The return or assist spring is broken.	Replace the pedal unit. See **Subject 100** for instructions. **WARNING** **Do not attempt to disassemble the preloaded assist spring. Sudden release of the assist spring could cause property damage and serious personal injury.**

Problem–Cruise Control or Engine Brake Does Not Deactivate When the Clutch Pedal Is Pressed Down

Problem–Cruise Control or Engine Brake Does Not Deactivate When the Clutch Pedal Is Pressed Down	
Possible Cause	**Remedy**
The upper position switch is damaged.	Check switch function and make any necessary repairs. See the instructions under the heading "Clutch Switch Check."
There has been an external electrical failure.	See **Section 54.03** for instructions.

Problem–Starter Does Not Operate

Problem–Starter Does Not Operate	
Possible Cause	**Remedy**
The lower position switch is damaged.	Check switch function and make any necessary repairs. See the instructions under the heading "Clutch Switch Check."
There has been an external electrical failure.	See **Section 54.03** for instructions.

Specifications

For fastener torque values, see the tables below.

Description	Size	Grade/Class	Torque: lbf·ft (N·m)	Torque: lbf·in (N·cm)
Bleed Screw	M7	—	—	88 (1000)
Clutch Capscrews	3/8–16	5	37 (50)	—
Clutch Switch Mounting Screw	M5	—	—	23 (260)
Hydraulic Sub-Assembly Retainer	—	—	—	44 (500)
Pedal Unit Mounting Plate Capscrews	M8	8.8	13 (18)	—
Release Yoke Mounting Capscrews	—	—	33 (45)	—
Slave Cylinder Mounting Capscrews	M8	10.9	13 (18)	—
Standoff Bracket Mounting Capscrews	1/4–20	8	10 (14)	—

Table 1, Torque Values, SACHS 365 mm Clutch

Description	Size	Grade/Class	Torque: lbf·ft (N·m)	Torque: lbf·in (N·cm)
Bleed Screw	M7	—	—	88 (1000)
Clutch Capscrews	M10	10.9	33 (45)	—
Clutch Switch Mounting Screw	M5	—	—	23 (260)
Hydraulic Sub-Assembly Retainer	—	—	—	44 (500)
Pedal Unit Mounting Plate Capscrews	M8	8.8	13 (18)	—
Release Yoke Mounting Capscrews	—	—	33 (45)	—
Slave Cylinder Mounting Capscrews	M8	10.9	13 (18)	—
Standoff Bracket Mounting Capscrews	1/4–20	8	10 (14)	—
Stop Bolt	—	—	29 (41)	—

Table 2, Torque Values, SACHS 395 XTend Clutch

Special Tools

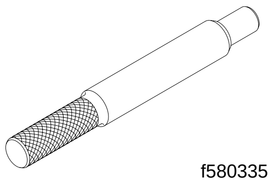
Special Tools			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580335	Clutch Centering Pin	Kent-Moore	J-45719
 f580133a	Clutch Release Bearing Travel Tool	PDC	A02-12419-000

Table 1, Special Tools

Removal

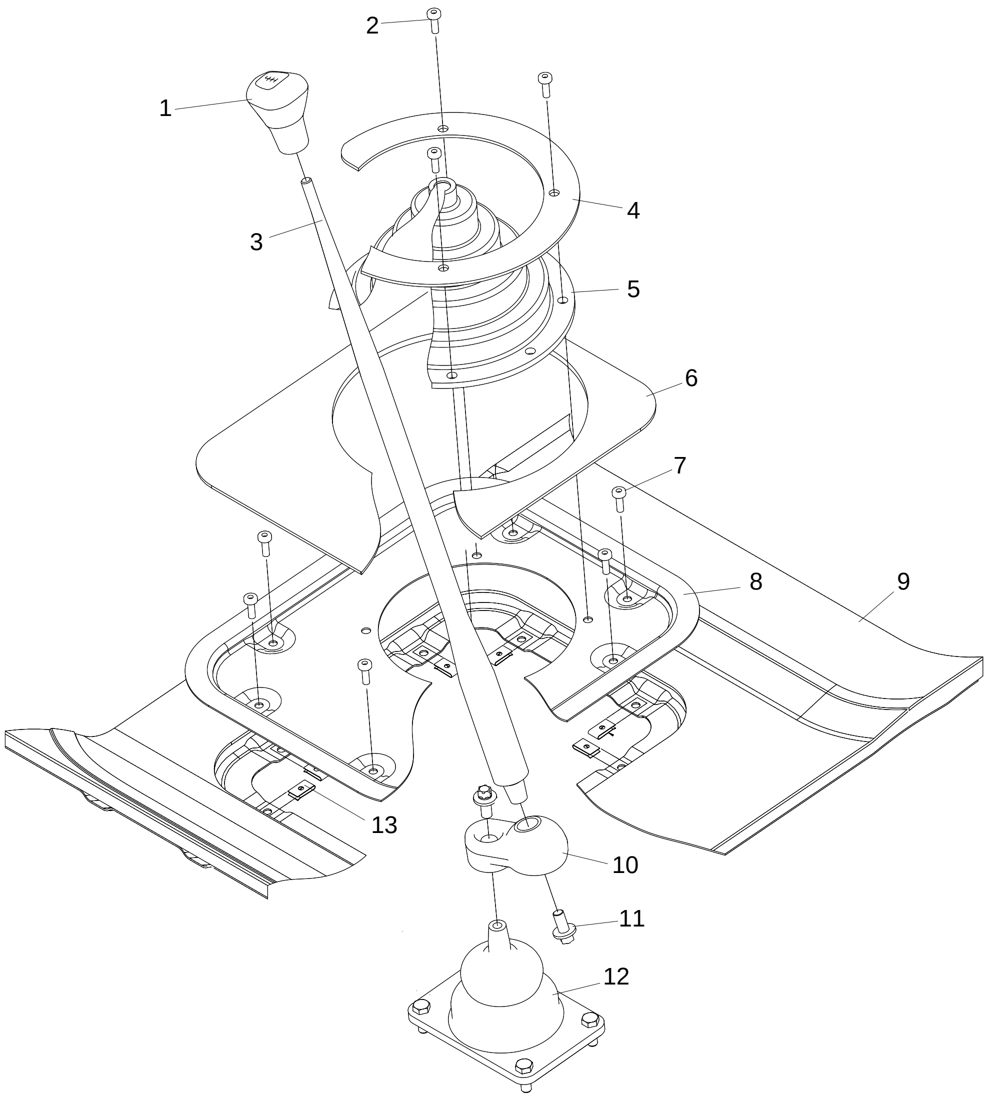
1. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the rear tires.
2. From inside the cab, remove the shift lever and shift tower from the transmission top cover. See **Fig. 1**.
   - 2.1 Before removing the shift lever, place the transmission in high gear.
   - 2.2 If installed, disconnect any electrical connector(s) on the shift lever.
   - 2.3 Remove the four M6 screws from the retaining ring around the shift lever boot. Remove the retaining ring and boot from the cover plate.
   - 2.4 Remove the eight M6 screws from the spring nuts in the cover plate. Remove the cover plate from the cab floor.
   - 2.5 Remove the four 3/8–16 shift tower mounting capscrews from the shift tower. Remove the shift tower and shift lever from the transmission top cover. See **Fig. 2**.
3. If necessary to replace the shift lever or components of the shift linkage, disassemble the shift linkage.
   - 3.1 If necessary to replace the shift lever, remove the M10 shift linkage flange screw attaching the shift lever to the shift linkage adaptor. Remove the end of the shift lever from the shift linkage adaptor on the transmission.
   - 3.2 If necessary to replace the shift linkage adaptor, remove the M10 shift linkage flange screw attaching the shift linkage adaptor to the shift tower. Remove the shift linkage adaptor from the shift tower.
4. From underneath the vehicle, disconnect the driveshaft from the transmission.
   - 4.1 Support the midship bearing.
   - 4.2 Remove the bolts from the U-joint end caps and slide the front of the driveshaft out of the transmission output yoke. See **Fig. 3**.
   - 4.3 Remove the midship bearing bracket. See **Fig. 4**.
   - 4.4 Support the disconnected driveshaft and chain it out of the way. See **Fig. 5**.
5. Drain the transmission fluid. See **Fig. 6** for the location of the drain plug.
6. Remove the transmission temperature sensor and fitting from the transmission top cover.
7. Remove the fuel lines and the fuel line standoff bracket from the transmission. See **Fig. 7**.
8. Unplug the electrical connector on the speedometer sensor. Disconnect any other sensors (neutral start switch, back-up switch, etc.), if installed.

WARNING

Do not press down on the clutch pedal after removing the slave cylinder. Clutch hydraulic fluid (DOT 4 brake fluid) may squirt out, causing personal injury and damage to the vehicle.

9. Remove the bolts attaching the clutch slave cylinder to the mounting flange on the bell housing. Move the slave cylinder out of the way. See **Fig. 8**.
10. Remove the battery cable bracket(s) around the transmission and move the battery cables out of the way. See **Fig. 9**.
11. Remove the exhaust pipe hanger bracket from the gear case. See **Fig. 10**.
12. If the vehicle is equipped with optional dual fuel tanks, remove the fuel cross-over line and its support between the tanks.
13. Support the transmission with a jack. See **Fig. 11**.
    - 13.1 Except for the top two, remove all the bolts attaching the transmission bell housing to the engine flywheel housing.
    - 13.2 Position a transmission jack under the transmission and raise its support plates against the base of the transmission.
    - 13.3 Adjust the support plates to cradle the transmission.
    - 13.4 Using a chain, secure the transmission to the jack.

Removal and Installation



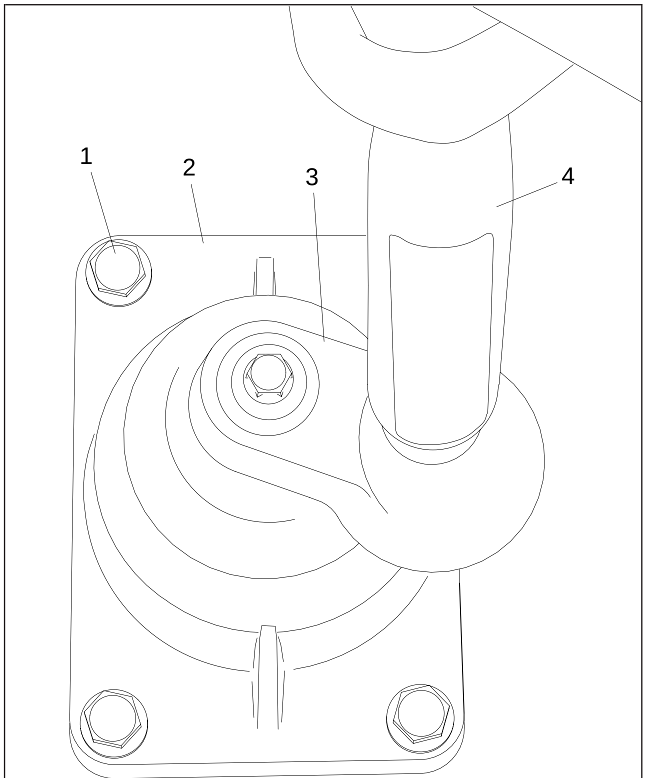
1. Shift Knob
2. Retaining Ring Screw, M6 (4 qty.)
3. Shift Lever
4. Retaining Ring
5. Boot
6. Floor Covering
7. Cover Plate Screw, M6 (8 qty.)
8. Cover Plate
9. Insulation
10. Shift Linkage Adaptor
11. Shift Linkage Flange Screw, M10 (2 qty.)
12. Shift Tower
13. Spring Nut, 1/4–20 (8 qty.)

Fig. 1, Shift Lever and Boot

13.5 Remove the last two bolts attaching the bell housing to the flywheel housing.

CAUTION

Do not allow the rear of the transmission to drop, and do not allow the transmission to hang un-supported. Keep the flange of the bell housing



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1. Shift Tower Mounting Capscrew, 3/8–16 (4 qty.)
2. Shift Tower
3. Shift Linkage Adaptor
4. Shift Lever

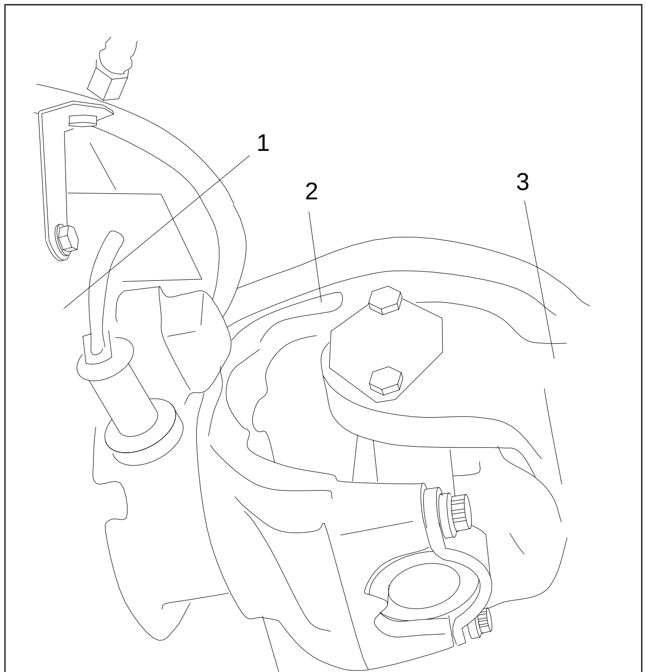
Fig. 2, Shift Linkage Connection

parallel (all the way around) to the flange of the flywheel housing until the input shaft is clear of the flywheel. Taking these precautions will prevent damage to the input shaft, flywheel, and clutch.

14. Remove the transmission. See Fig. 12.

    14.1 Pull the transmission and jack straight back until the transmission input shaft is clear of the clutch.

    14.2 Pull the transmission away from the vehicle. If there is not enough clearance to allow it to go straight out the back, use the space behind the front wheel on the driver's side.



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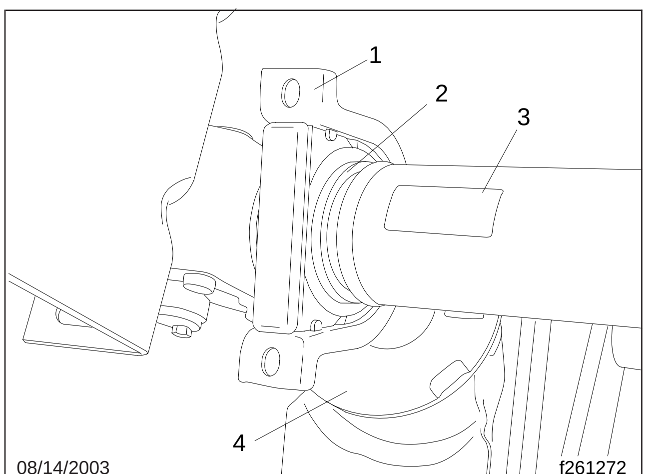
1. Transmission
2. Output Yoke
3. Driveline

Fig. 3, Output Yoke



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1. Midship Bracket
2. Midship Bearing
3. Driveshaft
4. Jack

Fig. 4, Midship Bearing Bracket

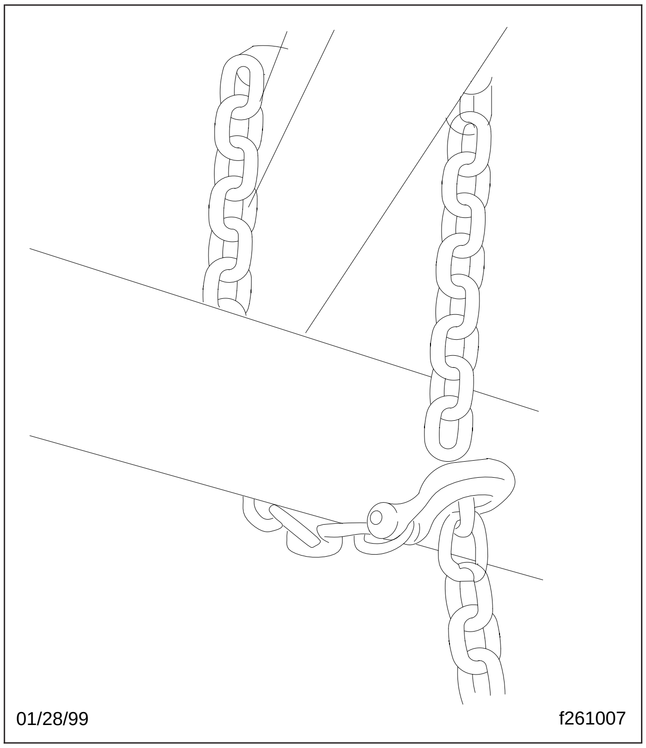


Fig. 5, Support the Driveline

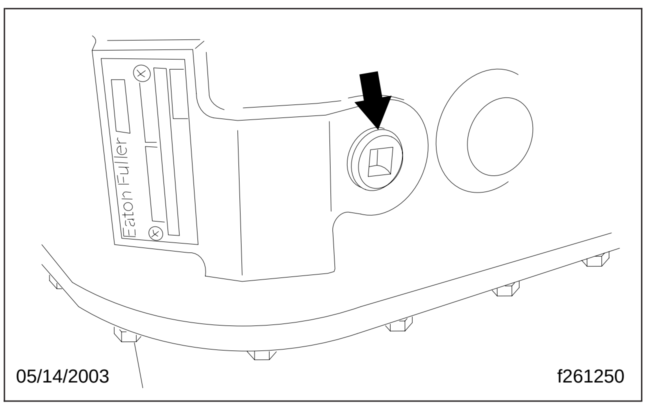
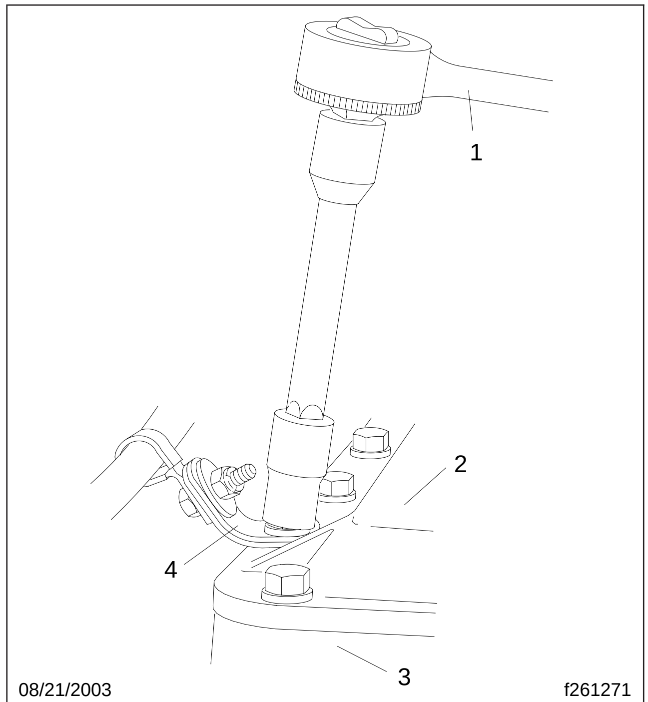


Fig. 6, Transmission Drain Plug

Installation

IMPORTANT: Before installing the transmission, make sure that the rear tires are chocked and that the transmission is securely chained to the support plates on the transmission jack.

1. Install the transmission. See **Fig. 13**.



1. Socket Wrench
2. Transmission Top Cover
3. Gear Case
4. Bracket

Fig. 7, Fuel Line Standoff Bracket

1.1 Align the jack and the transmission behind the engine. Make sure the fingers of the release yoke are rotated to clear the release bearing housing.

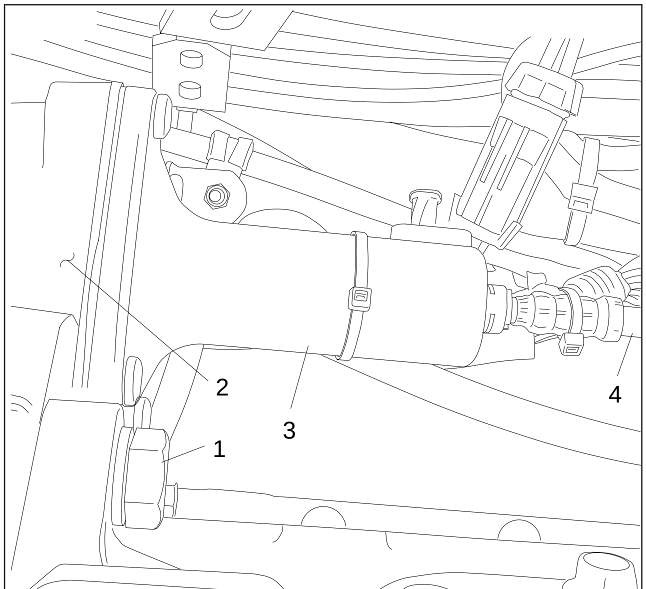
1.2 Coat the splines of the input shaft with antiseize compound.

1.3 Raise the transmission and adjust the angle of the jack until the bell housing and the flange of the flywheel housing are parallel.

1.4 Push the transmission and jack straight forward.

NOTE: Before installing, coat the threads of each bolt with Loctite 262 (or equivalent thread-locking compound).

1.5 Install the capscrews holding the bell housing to the flywheel housing. Use a crossover pattern. Do a final tightening of the capscrews to 33 lbf·ft (45 N·m).



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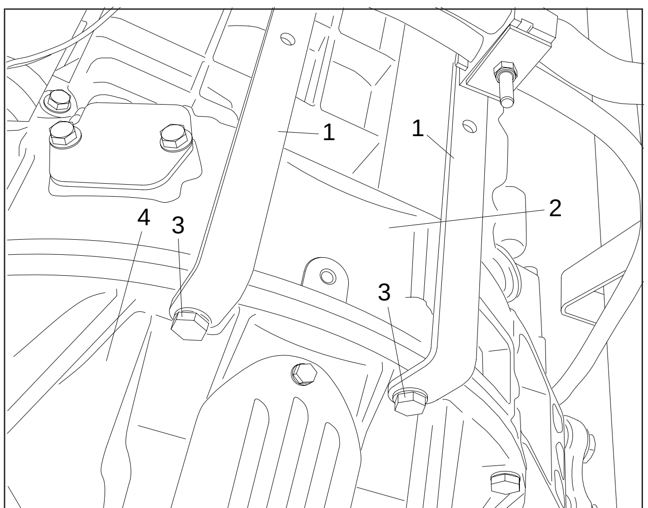
1. Hydraulic Line
2. Slave Cylinder
3. Mounting Screw
4. Bell Housing

Fig. 8, Hydraulic Clutch Slave Cylinder



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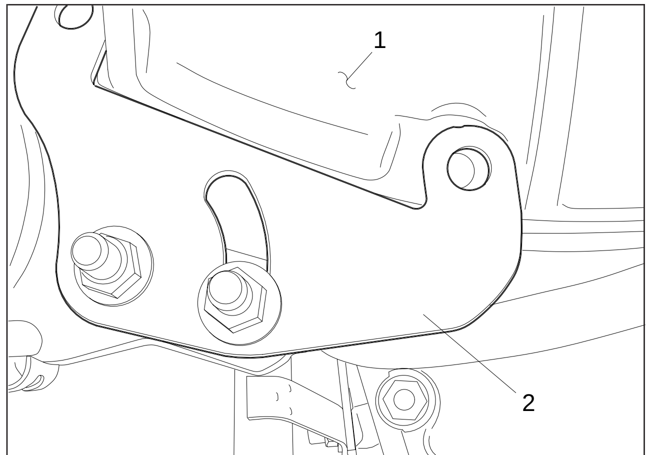
1. Battery Cable Bracket
2. Engine Flywheel Housing
3. Bell Housing
4. Bell Housing-to-Flywheel Housing Bolt

Fig. 9, Battery Cable Brackets



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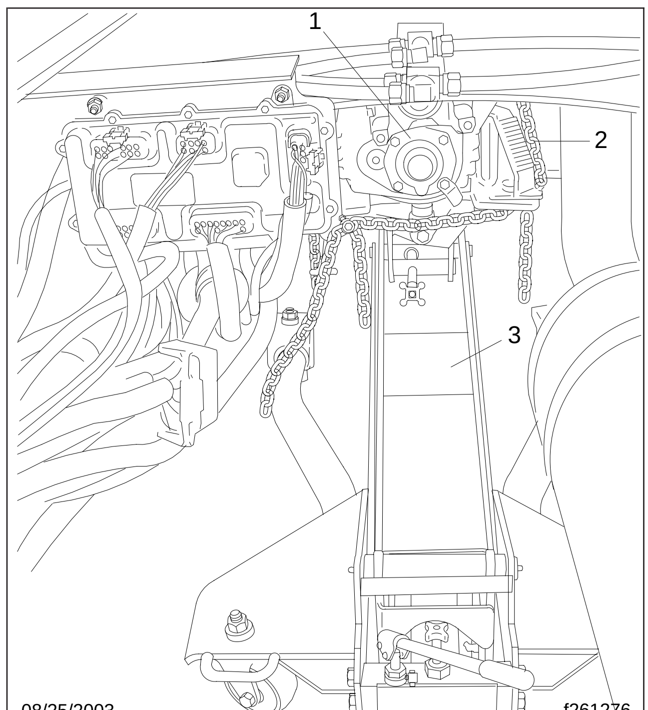
1. Gear Case
2. Hanger Bracket

Fig. 10, Exhaust Pipe Hanger Bracket



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1. Transmission
2. Chain
3. Jack

Fig. 11, Supporting the Transmission

1.6 While installing the bell housing-to-flywheel housing capscrews, also install the battery cable brackets, as removed.

Removal and Installation

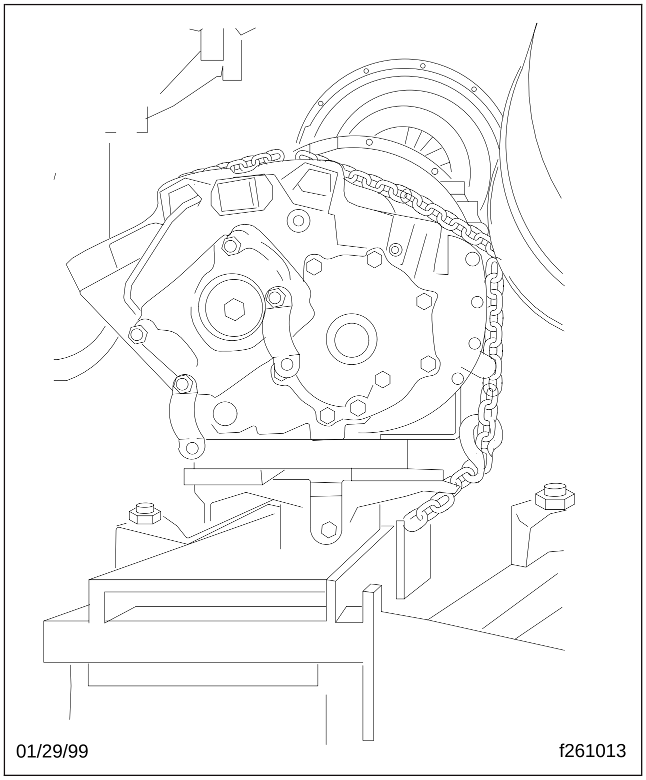


Fig. 12, Remove the Transmission

1.7 Remove the chain securing the transmission to the jack; then remove the jack.

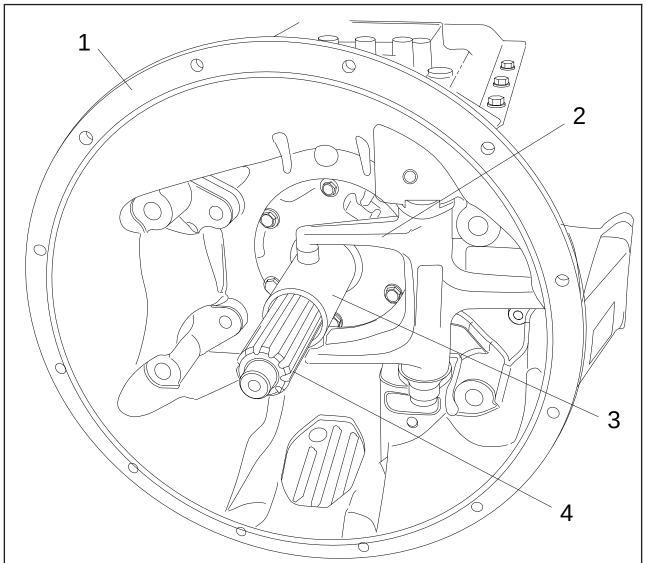
2. Through the inspection opening in the bell housing, make sure the fingers of the release yoke are inserted into the embossed area on the release bearing housing. See **Fig. 14**.

3. If the vehicle is equipped with the optional dual fuel tanks, install the fuel cross-over line and its support between the tanks. Tighten the clamps 40 lbf·ft (54 N·m) and the mounting bolts 95 lbf·ft (129 N·m).

4. Connect the driveshaft.

   4.1 Slide the front of the driveshaft into the transmission output yoke.

   4.2 Install the U-joint end caps on the output yoke. Tighten the bolt heads 50 lbf·ft (68 N·m) for 3/8-inch end cap bolts and 110 lbf·ft (149 N·m) for 1/2-inch end cap bolts.



Make sure the fingers of the release yoke are rotated to clear the release bearing.

1. Bell Housing
2. Release Yoke
3. Input Shaft
4. Input Shaft Splines

Fig. 13, Install the Transmission

   4.3 Install the bolts and nuts on the midship bearing bracket. Tighten the nuts 95 lbf·ft (129 N·m).

5. Install the fuel line standoff bracket and connect the fuel lines to the bracket.

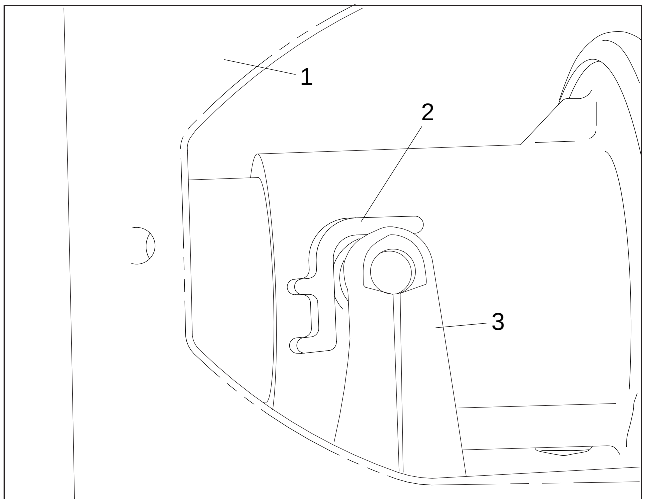
6. Connect the electrical connectors. Connect the electrical cable to the speedometer sensor.

7. If necessary, assemble the shift linkage. See **Fig. 1**.

   7.1 Before installing, apply three to four drops of Loctite 262 (or equivalent thread-locking compound) halfway down the threads of both shift linkage flange screws.

   7.2 Attach the shift linkage adaptor to the shift tower. Tighten the M10 shift linkage flange screw 25 lbf·ft (34 N·m).

   7.3 Fit the shift lever onto the remaining hole in the shift linkage adaptor. Tighten the other M10 shift linkage flange screw 25 lbf·ft (34 N·m).



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The finger of the release yoke must fit as shown into the embossed area of the release bearing housing.

1. Bell Housing
2. Embossed Area of Release Bearing Housing
3. Finger of Release Yoke

Fig. 14, Release Yoke Alignment

8. From inside the cab, install the shift tower and shift lever, as removed, on the transmission top cover. See **Fig. 2**.

   8.1 If removed, connect any electrical connectors to the shift lever.

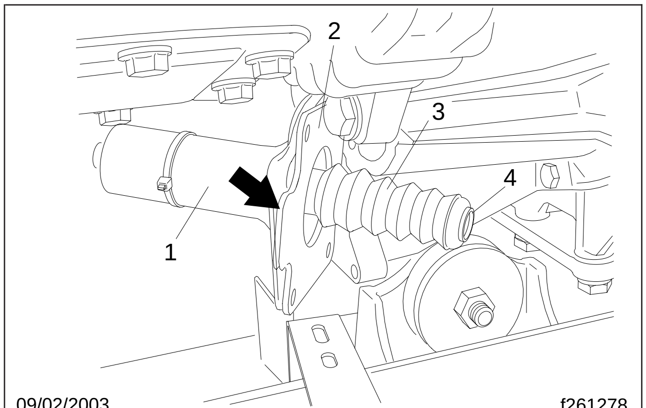
   8.2 Install the cover plate, with spring nuts inserted, on the cab floor. Tighten the eight M6 cover plate screws 60 lbf·in (680 N·cm).

   8.3 Install the rubber boot and the metal retaining ring. Tighten the four M6 retaining ring screws 60 lbf·in (680 N·cm).

   8.4 Check the position of the shift lever to be sure it is still positioned in high gear, as removed, and that the gears shift normally.

   8.5 Tighten the four 3/8–16 shift tower mounting capscrews 30 to 35 lbf·ft (40 to 47 N·m).

9. From underneath the vehicle, fasten the clutch slave cylinder, with the plunger fully extended to contact the release yoke, to the mounting flange on the bell housing. Make sure the tab on the spacer points inboard as shown in **Fig. 15**. Tighten the four mounting bolts 15 lbf·ft (20 N·m).



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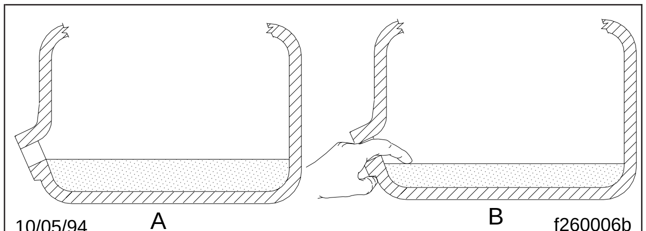
The tab on the spacer must face inboard.

1. Slave Cylinder
2. Spacer
3. Boot
4. Plunger (inside boot)

Fig. 15, Slave Cylinder Installation

10. If necessary, bleed the hydraulic clutch system. For detailed instructions, see **Section 25.02**, Subject 140.
11. Clean the transmission drain plug and install it on the transmission, along with a new aluminum gasket. Tighten the drain plug 50 lbf·ft (68 N·m).
12. Add transmission fluid until it is level with the lower edge of the fill opening. See **Fig. 16** for the correct level. See Group 26 of the *Business Class® M2 Maintenance Manual* for approved transmission lubricants and lubricant capacities.



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A. Full
B. Low

Fig. 16, Transmission Fluid Level Checking

13. Clean the transmission fill plug and install it on the transmission, along with a new aluminum gasket. Tighten the plug as follows:

- 25 to 35 lbf·ft (34 to 48 N·m) for Eaton Fuller transmissions with 3/4-inch pipe threads.
- 60 to 75 lbf·ft (81 to 102 N·m) for Eaton Fuller transmissions with 1-1/4-inch pipe threads.

14. Remove the chocks from the rear tires.

Torque Values, Eaton Fuller Transmissions				
Description	Size	Grade	Torque: lbf·ft (N·m)	Torque: lbf·in (N·cm)
Bell Housing-to-Timing Case Capscrews	M10 x 1.5	8.8	33 (45)	—
Clutch Slave Cylinder Bracket Mounting Bolts	M8	8.8	15 (20)	—
Fuel Cross-Over Line Mounting Bolts	—	—	95 (129)	—
Fuel Cross-Over Line Mounting Clamps	—	—	40 (54)	—
Midship Bearing Bracket Capscrews	3/4–11	—	95 (129)	—
Shift Lever Cover Plate Screws	M6	8.8	—	60 (680)
Shift Lever Retaining Ring Screws	M6	8.8	—	60 (680)
Shift Linkage Flange Screws	M10 x 1.5	8.8	25 (34)	—
Shift Tower Mounting Capscrews	3/8–16	—	30-35 (40-47)	—
Transmission Fluid Drain Plug	—	—	50 (68)	—
Transmission Fluid Fill Plug (with 3/4-inch pipe fittings)	—	—	25-35 (34-47)	—
Transmission Fluid Fill Plug (with 1-1/4-inch pipe fittings)	—	—	60-75 (81-102)	—
U-Joint End Cap Bolts	3/8–24	—	50 (68)	—
	1/2–20	—	110 (149)	—

Table 1, Torque Values, Eaton Fuller Transmissions

Removal

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Disconnect the batteries.
3. Remove the transmission drain plug from the bottom of the transmission and drain the automatic transmission fluid (ATF). Install the drain plug and tighten it 18 to 24 lbf·ft (25 to 32 N·m).
4. Support the driveline with a jack stand between the midship bearing and rear axle.
5. Disconnect the driveline from the transmission, as follow.

   5.1 Loosen the bolts that attach the midship bearing bracket, so the driveshaft can slide to the rear. See **Fig. 1**.

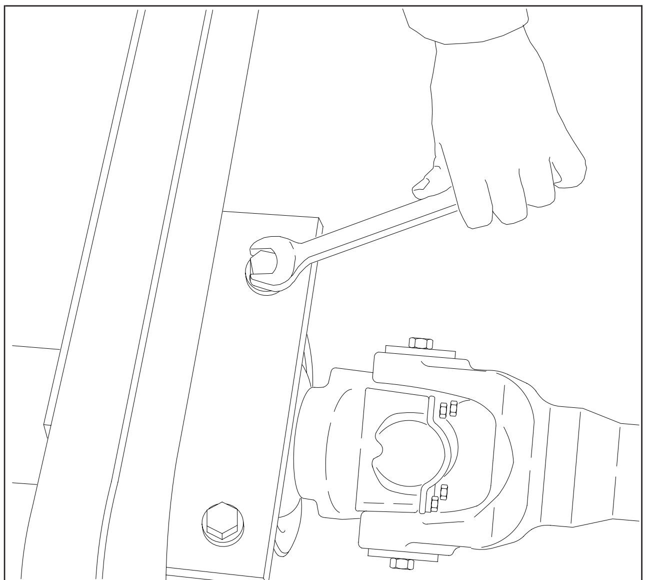


Fig. 1, Midship Bearing Fastener

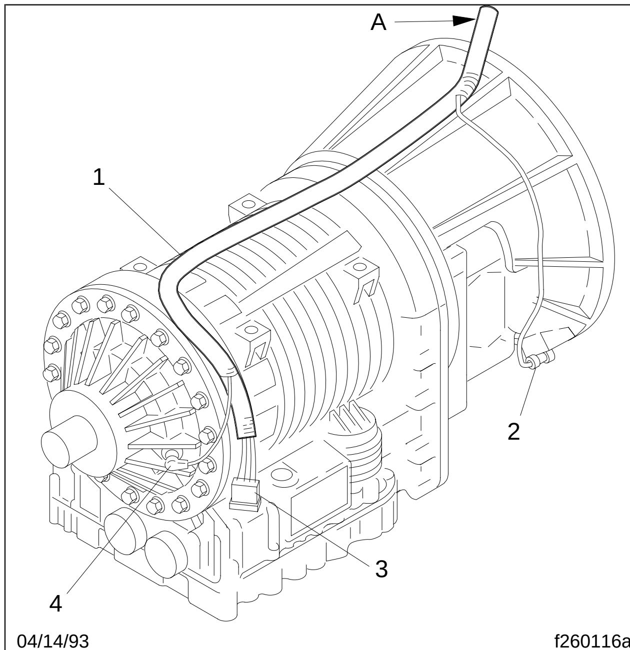
   5.2 Remove the transmission yoke U-joint end caps or lock straps. Separate the driveline from the transmission output yoke.

   5.3 Remove the driveline companion flange from the transmission companion flange.

   NOTE: It may be necessary to remove the mounting bolts from the midship bearing bracket so the driveshaft can be moved far enough back.

   5.4 Support the disconnected driveshaft and tie it to the frame rail.

6. Disconnect the three electrical connections to the transmission. See **Fig. 2**. For instructions, see **Subject 120**.



A. To bulkhead connector

1. Transmission Wiring Harness
2. Engine Speed Sensor
3. Transmission Control Connector
4. Output Speed Sensor

Fig. 2, Transmission Electrical Connections

7. Remove the ATF fill/dipstick tube, as follows.

   7.1 Remove the capscrew and clamp that hold the fill/dipstick tube.

   7.2 Pull the fill/dipstick tube out of the transmission case.

   7.3 Plug the hole with a clean shop towel to prevent entry of foreign material.

8. Disconnect the flexplate from the transmission, as follows.

Removal and Installation

8.1 Remove the capscrews that attach the ring gear access cover, then remove the cover. See **Fig. 3**.

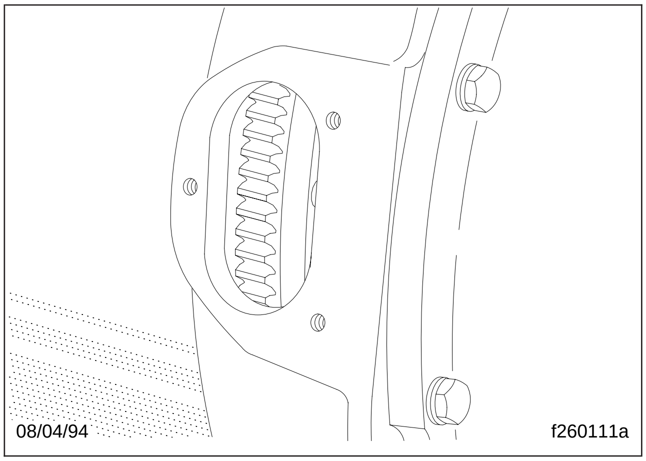
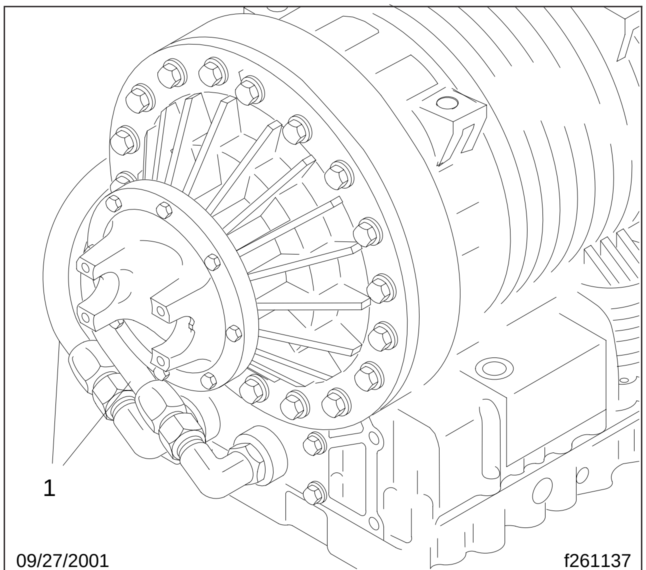


Fig. 3, Ring Gear Access

NOTE: For easier access on Mercedes-Benz engines, first remove the three bolts that hold the exhaust pipe to the turbocharger exhaust elbow, then lower the exhaust pipe.

8.2 Using a screwdriver, turn the ring gear until one of the capscrews that attach the flexplate adapter to the torque converter can be removed. Continue turning the ring gear and removing the capscrews through the access hole until all 12 are removed.

9. Disconnect the transmission fluid cooler lines from the transmission, and drain the remaining ATF. See **Fig. 4**.
10. Place a piece of plywood on a transmission jack to support the transmission.
11. Slide the jack into place under the transmission. Secure the transmission with a chain. Anchor the chain with bolts at the front lifting bosses on the top of the transmission. See **Fig. 5**.
12. If equipped, remove the two bolts that attach the transmission to the rear overslung transverse support spring. Remove the spring. See **Fig. 6**.
13. Remove the 12 transmission-flange bolts. See **Fig. 7**.
14. Remove the muffler support bracket that is supported by two of the companion-flange bolts.



NOTE: Rear-mounted hoses shown, but hoses may be attached at the front of the transmission.

1. ATF Cooler Hoses

Fig. 4, Fluid Cooler Lines

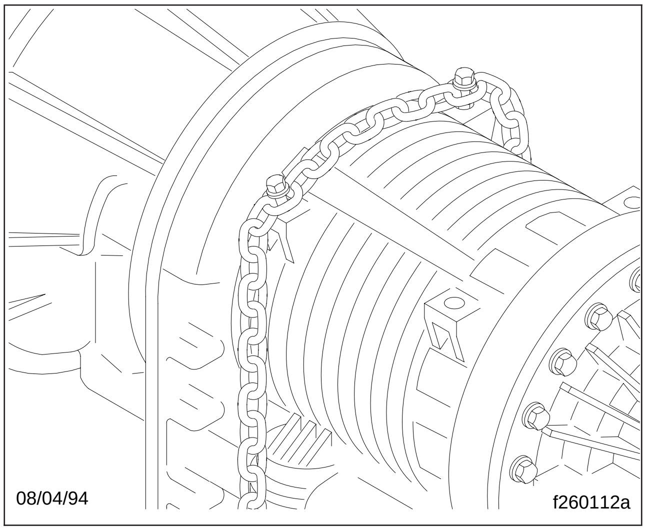
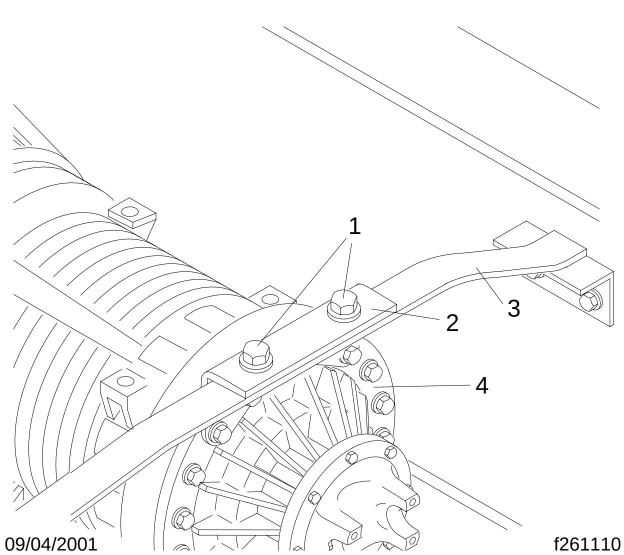


Fig. 5, Chain Around Transmission

15. Move the transmission jack to the rear. Lower the jack and lift the vehicle, as needed, so the transmission clears the frame rail and any attached components. Support the vehicle frame with jack stands.



1. Bracket Bolts
2. Transmission L-Bracket
3. Transverse Support Spring
4. Transmission

Fig. 6, Transverse Support Bracket

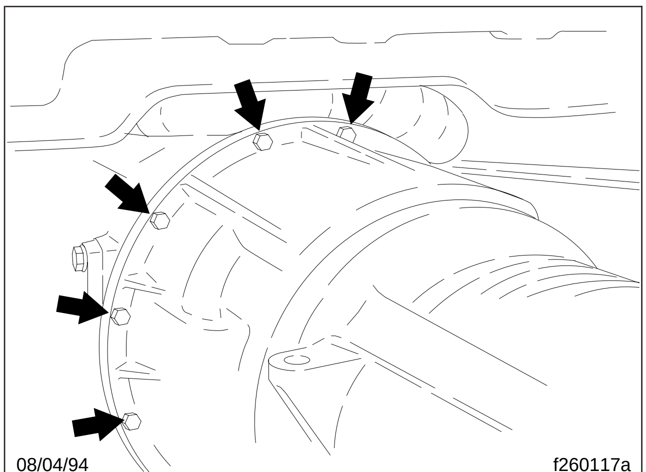


Fig. 7, Transmission-Flange Bolts

16. Roll the transmission jack rearward, and remove the transmission.

Installation

IMPORTANT: Before installing the transmission, make sure the rear tires are chocked and the transmission is securely chained to the transmission jack.

1. Raise the vehicle frame with a hydraulic jack to obtain adequate clearance for installing the transmission. Place jack stands under the front of the vehicle.
2. With the transmission on a jack, roll the transmission into place behind the flexplate. Remove the jack stands, and lower the vehicle frame.
3. Raise the jack until the transmission lines up with the flexplate.
4. Push the transmission toward the engine until it seats squarely against the engine flywheel housing, with the bolt holes in the transmission housing aligned with those in the flywheel housing.

NOTE: No force is required. If interference is encountered, move the transmission away from the engine and correct the problem.

5. Install the transmission-flange bolts finger-tight.
6. Install the 12 flexplate adapter capscrews, as follows.

6.1 Turning the ring gear for access, install all the capscrews through the access hole. Don’t tighten them now.

Be careful not to drop the capscrews inside the flywheel housing. The transmission must be removed to get them out.

IMPORTANT: Install all capscrews before tightening any of them to prevent cocking of the flexplate adapter.

6.2 Tighten the capscrews, in a star pattern, to the following specifications based on the model number:

- 1000 and 2000 Families: 6 bolts to 46 lbf·ft (62 N·m)
- 3000 Family: 6 bolts to 50 lbf·ft (68 N·m)
- 4000 Family: 12 bolts to 27 lbf·ft (37 N·m)

6.3 Install the access cover and its capscrews. There are four capscrews on Caterpillar engines, three capscrews on Mercedes-Benz engines, and two on Cummins and Detroit Diesel engines.

Removal and Installation

7. Tighten the 12 M10 transmission-flange bolts 38 to 45 lbf·ft (51 to 61 N·m) in a star pattern. See **Fig. 7**.
8. If previously removed, install the transverse support spring at the rear of the transmission. Install the two bolts and washers. Tighten the bolts 136 lbf·ft (184 N·m). See **Fig. 6**.
9. Remove the chain that holds the transmission to the transmission jack.
10. Lower the transmission jack and remove it.
11. Connect the transmission fluid cooler hoses to the transmission, and tighten the fittings to the applicable values in **Table 1**. See **Fig. 4**.
12. Install the muffler bracket.
13. Connect the driveshaft, as follows.

    13.1 Slide the front of the driveshaft into the transmission output yoke.

    13.2 Install the transmission yoke U-joint end caps and lock straps.

    13.3 If the midship bearing bracket bolts and nuts were removed, install them. Tighten the nuts 95 lbf·ft (129 N·m).
14. On Mercedes-Benz engines, if the exhaust pipe was disconnected from the turbocharger exhaust elbow, connect the pipe and tighten the bolts 60 lbf·ft (81 N·m).
15. Install the ATF fill/dipstick tube, as follows.

    15.1 Inspect the fill/dipstick tube seal. Replace it if damaged.

    15.2 Install the fill/dipstick tube and clamp. Tighten the self-tapping screw until it is firmly seated, approximately 18 to 21 lbf·ft (24 to 28 N·m).
16. Install the standoff bracket on the right side of the transmission.

    Make sure the air line and the wiring harness are securely attached to the standoff bracket.
17. Connect all electrical lines to the transmission, as follows.

    17.1 Connect the transmission control connector.

    17.2 Connect the cable to the output speed sensor.

    17.3 Connect the cable to the engine speed sensor.

    17.4 Using tie straps, secure the cables where necessary.
18. Fill the transmission with ATF.
19. Connect the batteries.
20. Start the engine, and check for any leaks. Repair leaks as needed.
21. Check the ATF level. Add fluid as needed.
22. Remove the chocks from the tires.
23. Road test the vehicle, and check for correct transmission operation.

Series/Family	Description	SAE Size	Torque: lbf·ft (N·m)
1000 and 2000	Front Ports	12	25–35 (34–47)
3000	Non-retarder, Front Ports	12	25–35 (34–47)
	Non-retarder, Rear Ports	16	40–50 (54–68)
	Retarder, Rear Ports	16	40–50 (54–68)
4000	Non-retarder, Front Ports	16	40–50 (54–68)
	Non-retarder, Rear Ports	16	40–50 (54–68)
	Retarder, Rear Ports	20	50–60 (68–81)

Table 1, Torque Values for Transmission Fluid Cooler Hoses

NOTE: If the vehicle is equipped with the integral radiator/cooler, see **Section 20.01** for replacement instructions.

Replacement

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.

WARNING

Drain the coolant system only when the coolant and engine are cool. Draining it when these are hot could cause severe personal injury due to scalding.

2. With the engine cool, loosen the surge tank cap to release cooling system pressure.
3. Place a suitable container under the radiator. Open the drain petcock at the bottom of the radiator and drain the cooling system. Close the drain petcock.
4. Remove the two radiator hoses at the transmission cooler, draining any excess engine coolant into a pan.

CAUTION

The transmission fluid hoses at the cooler have quick-connect fittings. DO NOT attempt to unscrew the fitting at the cooler. It is welded to the cooler. See Fig. 1. If the fittings at the cooler are turned, internal cooler leakage will occur which can cause transmission failure.

5. Disconnect the coolant hoses from the fittings at both sides of the automatic transmission fluid (ATF) cooler.

   5.1 Pull back the safety collar on the hose fitting accessing the retaining clip. See **Fig. 2**.

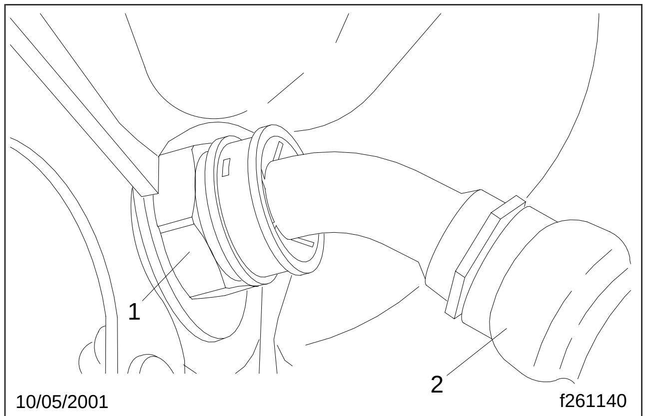
   5.2 Using a small flat-head screw driver, remove the retaining clip from the cooler fitting. See **Fig. 3**. Discard the clip.

CAUTION

Protect the ends of the cooler hoses. Failure to do so can cause damage to the hose end, which can tear the internal O-ring at the cooler fitting. If the O-ring tears and leaks ATF, the cooler will have to replaced.

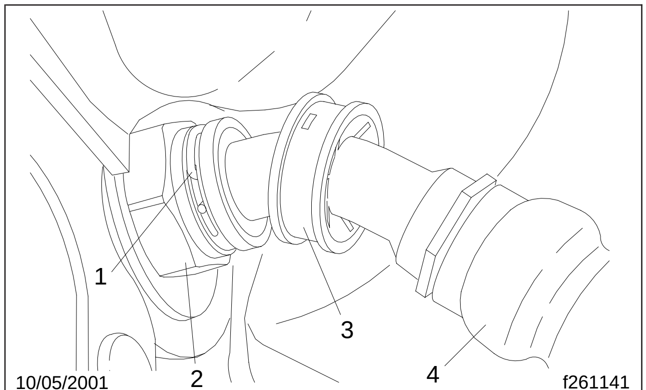
   5.3 Over a drain pan, pull the cooler hose out of the fitting. See **Fig. 4**. Catch the ATF by directing the disconnected end of each hose into a drain pan. When the ATF stops draining, plug the hoses.

   Protect the ends of the cooler hoses, wrapping them in shop towels or similar material.



1. Cooler Fitting (welded to cooler)
2. Transmission Hose

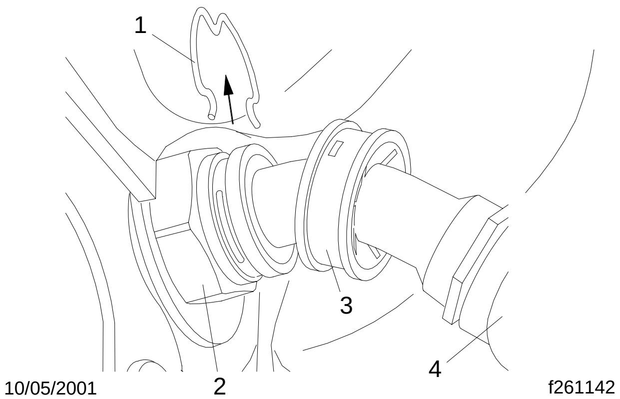
Fig. 1, ATF Hose Connection at Transmission Cooler



1. Retaining Clip
2. Cooler Fitting (welded to cooler)
3. Safety Collar
4. Transmission Hose

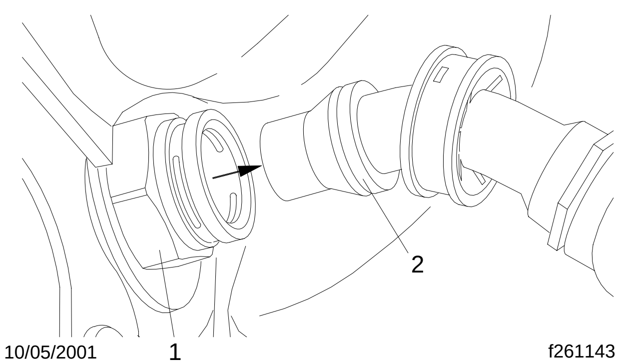
Fig. 2, Safety Collar Removal

ATF Cooler Replacment (stand-alone unit)



1. Retaining Clip
2. Cooler Fitting (welded to cooler)
3. Safety Collar
4. Transmission Hose

Fig. 3, Retaining Clip Removal



1. Cooler Fitting (welded to cooler)
2. Transmission Hose End (protect when removed)

Fig. 4, Cooler Hose Removal

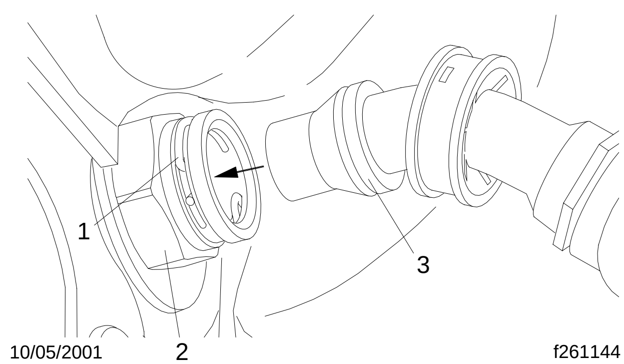
6. Remove the four fasteners that attach the ATF cooler to the mounting bracket assembly, and remove the ATF cooler. Drain the ATF cooler into a drain pan.
7. Hold the ATF cooler in place; then install the fasteners on the mounting bracket. Tighten the fasteners 28 lbf·ft (38 N·m).
8. Attach the transmission hoses to the fittings at both sides of the cooler.

CAUTION

DO NOT reuse the retaining clips. Use a new retaining clip each time the hoses are removed. Failure to do so could result in the cooler hoses coming out of the cooler during vehicle operation, leaking ATF and causing permanent damage to the transmission. New retaining clips are available from the PDCs.

8.1 Install a new retaining clip in the fitting at the cooler. The clip should be completely seated as it was before the hose was removed.

8.2 Carefully insert the end of the transmission hose into the cooler fitting until the end seats at the retaining clip. See **Fig. 5**. Gently pull the hose to make sure it is fully seated.



1. Retaining Clip
2. Cooler Fitting (welded to cooler)
3. Transmission Hose

Fig. 5, Transmission Hose Installation

8.3 Push the safety collar back up and around the cooler fitting and retaining clip. See **Fig. 1**.

9. Install the two radiator hoses and tighten the hose clamps.
10. Fill the coolant system and install the surge tank cap.
11. Start the engine and operate the transmission for 1 or 2 minutes, then add the correct ATF to the transmission as needed. For instructions and lubricant specifications, see Group 26 of the *Business Class M2 Maintenance Manual.*

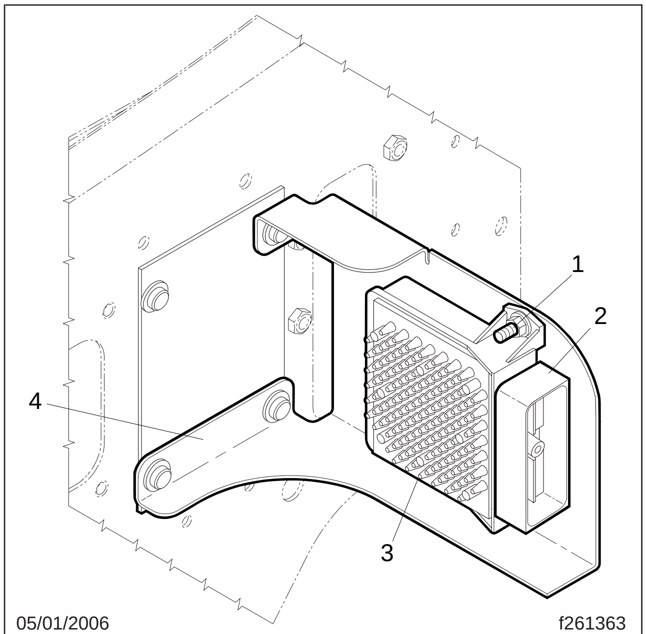
ATF Cooler Replacment (stand-alone unit)

12. Check the coolant level and add as needed.
13. Remove the tire chocks.

A new transmission control module (TCM) was introduced by Allison Transmissions in mid-2006. This control — known as "fourth generation" — replaced the previous electronic control unit (ECU) that is commonly referred to as "WTEC III". Replacement procedures for both are provided below.

Fourth Generation TCM Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Disconnect the batteries.
3. Open the hood and locate the TCM attached to the frontwall panel.
4. Disconnect the electrical harness from the TCM. See **Fig. 1**.



1. Mounting Post
2. Harness Connector
3. TCM
4. Mounting Plate

Fig. 1, Allison Fourth Generation Transmission TCM

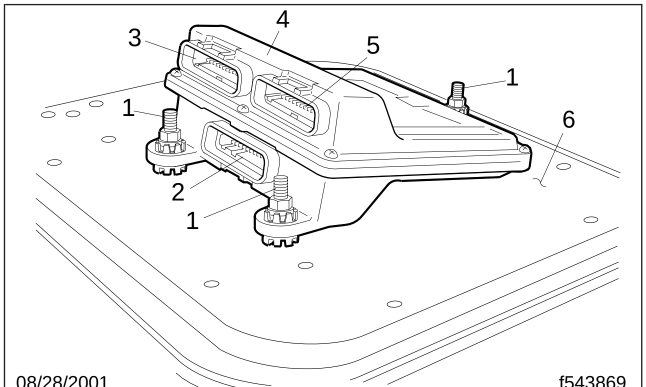
5. Remove the nuts and washers from each TCM mounting post, then remove the TCM.
6. Place the new TCM over the mounting posts, and install the washers and nuts. Tighten the nuts 24 lbf·in (271 N·cm).

IMPORTANT: Be careful when attaching the 80-way connector to the TCM. Do not bend the pins.

7. Connect the electrical harness to the TCM.
8. Connect the batteries.
9. Close the hood and remove the chocks from the tires.

WTEC III ECU Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Disconnect the batteries.
3. Locate the ECU either on the frame or behind the left fender, and disconnect the black, gray, and blue harness connectors from the ECU.
4. Remove the nuts, washers, and spacers from each ECU mounting post, and remove the ECU. See **Fig. 2**.



1. Mounting Post
2. Blue Harness Connector Port
3. Black Harness Connector Port
4. ECU
5. Gray Harness Connector Port
6. ECU Access/Mounting Plate

Fig. 2, Allison WTEC III Transmission ECU

5. Place the new ECU over the mounting posts and install the spacers, washers, and nuts. Tighten the nuts firmly.

Transmission ECU Replacement

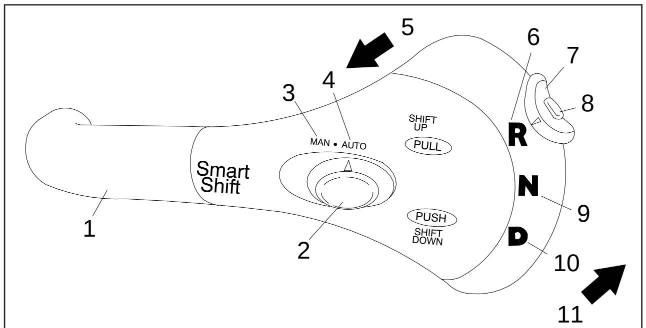
6. Connect the blue, black, and gray electrical harnesses to the appropriate ports on the ECU.
7. Remove the chocks from the tires.

General Information

The SmartShift™ transmission shift control is an electronic transmission control device. It is applicable to automated mechanical transmissions and is required with the Mercedes-Benz AGS Automated Gear Shift transmission, and the Eaton® Fuller® UltraShift™ transmission. It replaces either the typical floor-mounted shift lever or dash-mounted pushbutton control.

The SmartShift control mounts to the right-hand side of the steering column and is operated by the driver's right hand. There are two versions of the control:

- See **Fig. 1** for the AGS control.



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To upshift manually, pull the control up (towards you). To downshift manually, push the control down (away from you).

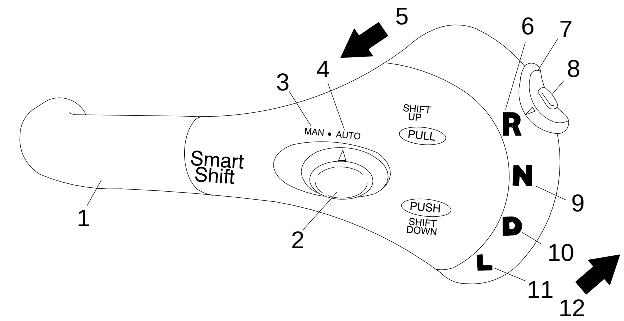
1. SmartShift Control
2. Slide Switch (forward driving mode switch)
3. MAN Position (of slide switch)
4. AUTO Position (of slide switch)
5. Upshift Direction
6. Reverse Position (of selector switch)
7. Selector Switch
8. Neutral Lock Button
9. Neutral Position (of selector switch)
10. Drive Position (of selector switch)
11. Downshift Direction

Fig. 1, SmartShift Control (for AGS transmission)

- See **Fig. 2** for the UltraShift control.

SmartShift accepts driver requests for transmission functions and transmits them through hard wiring to the transmission control unit (TCU). SmartShift is a true shift-by-wire system.

SmartShift offers two main advantages over conventional transmission control devices. Usable cab



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To upshift manually, pull the control up (towards you). To downshift manually, push the control down (away from you).

1. SmartShift Control
2. Slide Switch (forward driving mode switch)
3. MAN Position (of slide switch)
4. AUTO Position (of slide switch)
5. Upshift Direction
6. Reverse Position (of selector switch)
7. Selector Switch
8. Neutral Lock Button
9. Neutral Position (of selector switch)
10. Drive Position (of selector switch)
11. Low Position (of selector switch)
12. Downshift Direction

Fig. 2, SmartShift Control (for UltraShift transmission)

space is increased and access to the sleeper is improved by removing the shift lever from the floor. Because of the steering column mounting, the transmission control is within fingertip reach of the steering wheel, which enhances safety.

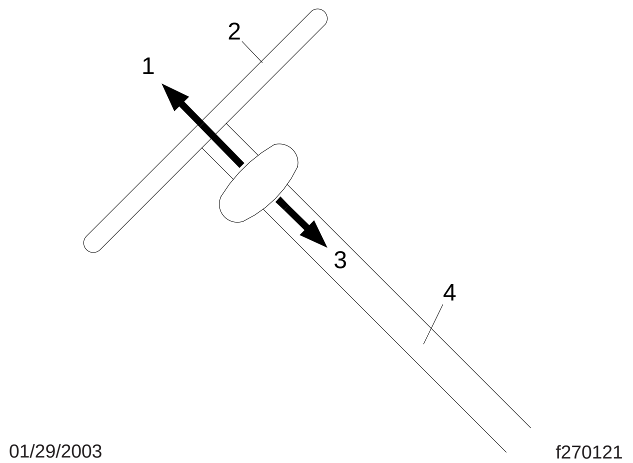
In automatic drive mode, forward drive gears are shifted automatically, without driver interaction. On SmartShift, a slide switch allows the driver to choose between automatic and manual forward driving modes. In manual mode the driver has direct control over gear shifts.

Manual gear shifts are accomplished by a momentary pull or push on the control in the plane perpendicular to the steering wheel. See **Fig. 3**. All shifts into reverse (R) are done manually.

Pull upward (toward you) on the control to upshift and push downward (away from you) to downshift. The control is spring-loaded and returns to mid-position when released after an upshift or downshift.

The selector switch is located at the end of the control. There are two different versions:

General Information



1. Upshift (in manual mode, pull upward)
2. Steering Wheel
3. Downshift (in manual mode, push downward)
4. Steering Column

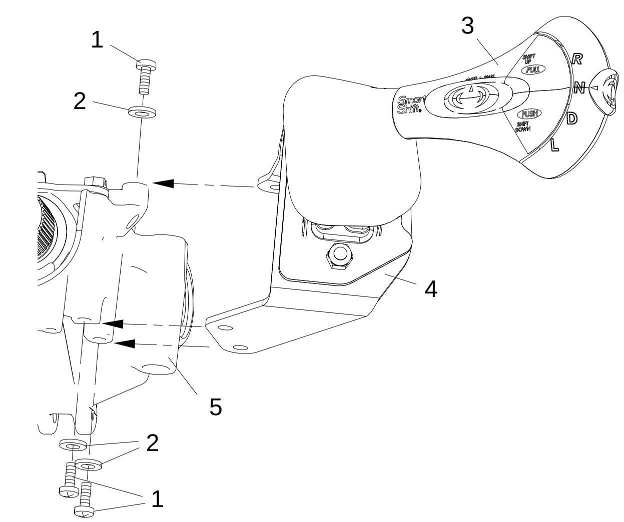
Fig. 3, SmartShift Control Operation

- For AGS, the selector switch has three positions (R, N, D). See **Fig. 1**.
- For UltraShift, the selector switch has four positions (R, N, D, L). See **Fig. 2**.

Embedded in the selector switch is a small neutral lock button to prevent accidental shifts into gear from neutral (N). Any time you shift through N, press the neutral lock button to move the switch from N to another gear, such as drive (D), low (L), or reverse (R). When shifting to N, it is not necessary to press the neutral lock button.

Replacement

1. Shut down the engine, set the parking brakes, and chock the rear tires.
2. Remove the steering column covers. For detailed procedures, see **Section 46.02**, Subject 110.
3. Disconnect the electrical connector from the SmartShift module.
4. Remove the three mounting capscrews and washers that attach the bracket assembly to the steering column. See **Fig. 1**.



1. Mounting Capscrew(s)
2. Washer(s)
3. SmartShift Lever
4. Bracket Assembly
5. Steering Column

Fig. 1, SmartShift Lever Replacement

5. Remove the bracket assembly from the vehicle with the SmartShift lever attached.
6. Position the new bracket assembly on the steering column. Install the mounting capscrews and washers. Tighten the capscrews 80 lbf·in (900 N·cm).
7. Connect the electrical connector to the SmartShift module.
8. Install the steering column covers, as removed.
9. Remove the chocks from the rear tires.

General Information

The following information is provided to help determine whether a potential transmission problem is actually the transmission or possibly the Freightliner SmartShift® Transmission Shift Control.

Resistance checks at the SmartShift connector can help determine connection problems.

DataLink Software can be used to test the SmartShift control. The tests require a ServiceLink computer connected to the vehicle. If the tests confirm the shift control is defective, this subject also includes connector resistance checks to rule out wiring issues.

For transmissions other than Mercedes-Benz Automated Gear Shift (AGS), follow the procedures below for resistance checking and Freightliner SmartShift testing using DataLink Monitor and dash displays. For AGS transmissions, see **Section 26.03, Subject 302**.

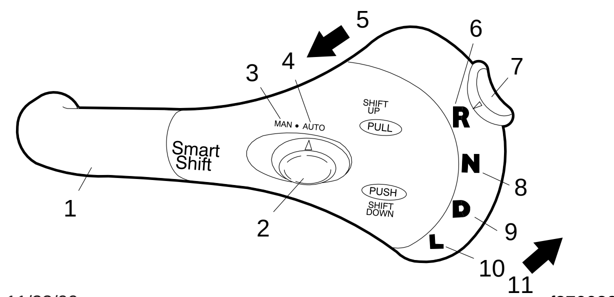
To determine which transmission is installed on the vehicle, check the shift pattern decal on the dash or visor.

NOTE: SmartShift controls designed for one transmission model should not be used with other models of transmission.

For Eaton Fuller AutoShift, the four-position selector switch is marked "R-N-D-L". A slide switch is present. See **Fig. 1**.

For ZF Meritor SureShift, the three-position selector switch is marked "R-N-F" (older models) or "R-N-D" (newer models). In addition, there is no slide switch. See **Fig. 2**.

For ZF Meritor FreedomLine and Mercedes-Benz AGS, the three-position selector switch is marked "R-N-D". A slide switch is present. See **Fig. 3**.



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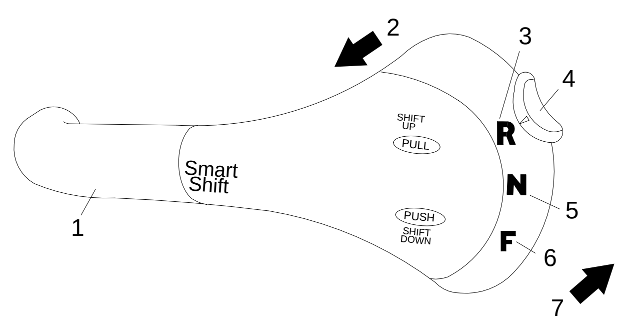
1. SmartShift Control
2. Slide Switch (forward driving mode switch)
3. MAN Position (on slide switch)
4. AUTO Position (on slide switch)
5. Upshift Direction
6. Reverse Position (on selector switch)
7. Selector Switch
8. Neutral Position (on selector switch)
9. Drive Position (on selector switch)
10. Low Position (on selector switch)
11. Downshift Direction

Fig. 1, SmartShift Control (with Eaton Fuller AutoShift)



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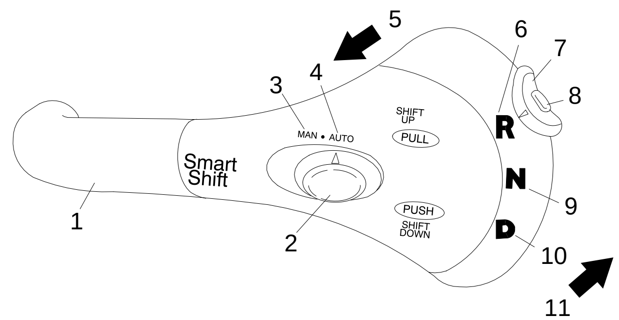
NOTE: Newer SureShift models have a "D" (for drive) in place of the "F" (for forward).

1. SmartShift Control
2. Upshift Direction
3. Reverse Position (on selector switch)
4. Selector Switch
5. Neutral Position (on selector switch)
6. Forward Position (on selector switch)
7. Downshift Direction

Fig. 2, SmartShift Control (with ZF Meritor SureShift)

Troubleshooting



1. SmartShift Control
2. Slide Switch (forward driving mode switch)
3. MAN Position (on slide switch)
4. AUTO Position (on slide switch)
5. Upshift Direction
6. Reverse Position (on selector switch)
7. Selector Switch
8. Neutral Lock Button
9. Neutral Position (on selector switch)
10. Drive Position (on selector switch)
11. Downshift Direction

Fig. 3, SmartShift Control (with ZF Meritor FreedomLine and Mercedes-Benz AGS)

Shift Control Resistance Checking

Parts

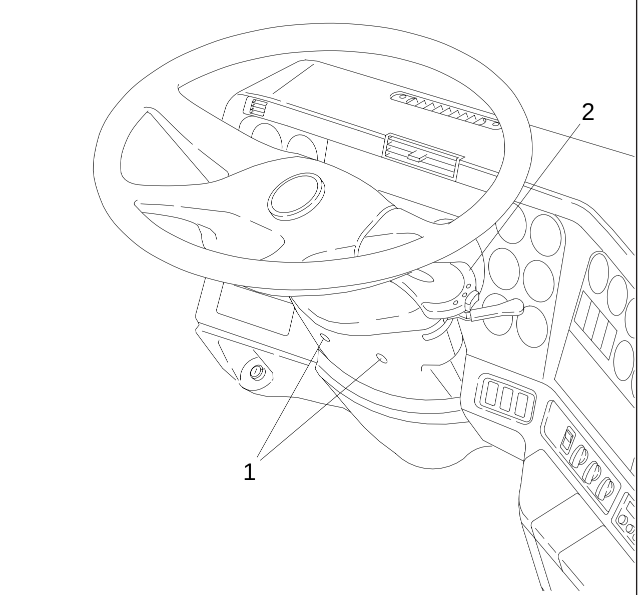
Parts for Wire Extension*		
Part Number	**Description**	**Qty.**
PAC12110847	Metri-Pack Terminal	3
PAC12047767	Connector Terminal	3
48-02493-184	18GA GTX Wire, Yellow	3 ft x 3
PAC12047781	3-Pin Connector	1
PAC12047783	Connector Lock	1

* Parts are available through the PDCs.

Table 1, Parts for Wire Extension

Procedure

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Remove the screws that secure the steering column trim panels, and separate the forward and rear panels to access the shift control. See **Fig. 4**.
3. Disconnect the electrical connector from the plug on the shift control unit. See **Fig. 5**.

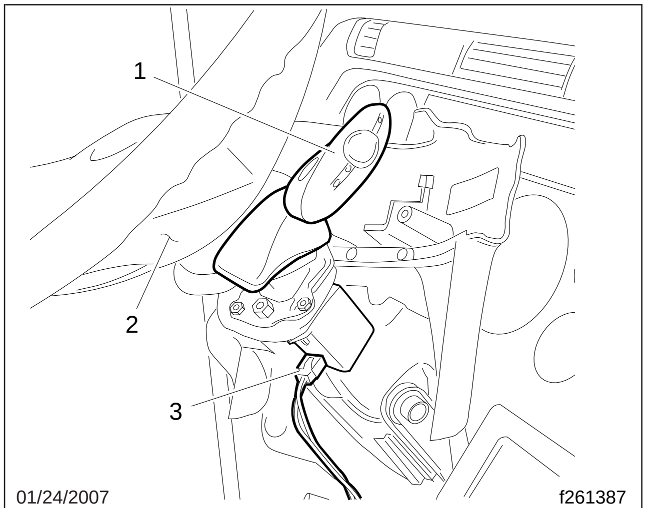


1. Steering Column Panel Capscrews
2. Shift Control

Fig. 4, Steering Column Panel

4. Assemble the wire extension from the parts in **Table 1** to allow for easy resistance testing, as follows.
   - 4.1 Crimp the connector terminals at the end of each 3-foot (1-meter) wire.
   - 4.2 Assemble the 3-pin connector with the connector terminals and connector lock.
   - 4.3 Crimp the Metri-Pack terminals on the other end of the wires.
5. Plug the wire extension into the plug on the shift control unit. See **Fig. 6** for SmartShift terminal positions.

NOTE: Using this new wire extension prevents the need to remove the shift control.



1. Shift Control
2. Steering Wheel
3. Electrical Connector

Fig. 5, SmartShift Components

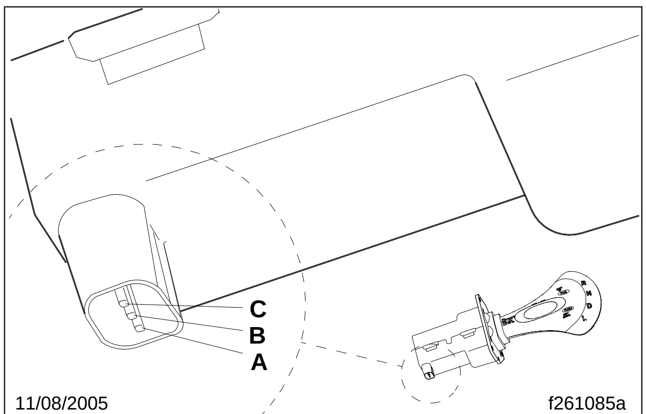


Fig. 6, SmartShift Terminal Positions

6. Check the resistance at the other end of the wires. See **Fig. 7**.

   Use **Table 2** and **Table 3** for all SmartShift applications except Meritor SureShift.

   Use **Table 4** for Meritor SureShift applications.

Resistance on SmartShift Controls at B and C (Except Meritor SureShift)	
Selector Switch Position	**Reading: kOhm**
R	2.947–3.067
N	0.347–0.361
D	0.606–0.630
L*	1.65–1.72

* Applies to four-position (R-N-D-L) controls only.

Table 2, Resistance on SmartShift Controls at B and C (Except Meritor SureShift)

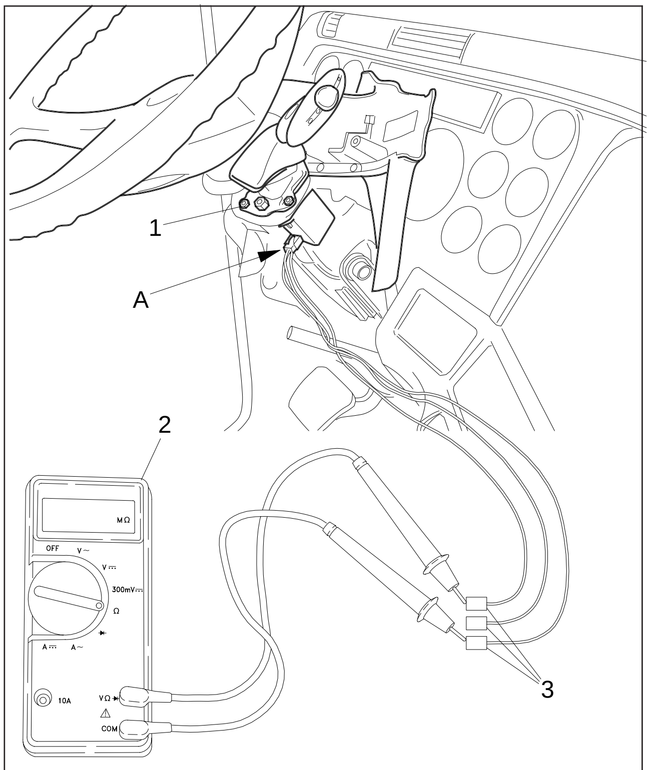
Resistance on SmartShift Controls at A and C (Except Meritor SureShift)	
Slide Switch + Lever Position	**Reading: kOhm**
Manual	2.865–2.981
Manual + Up	0.531–0.553
Manual + Down	1.150–1.197
Auto	11.27–11.73

Table 3, Resistance on SmartShift Controls at A and C (Except Meritor SureShift)

Resistance on the SmartShift Control, Meritor SureShift	
Selector Switch + Lever Position	**Reading: kOhm**
R	10.2–10.6
N	1.65–1.71
F or D	2.65–2.75
R + Up	4.14–4.3
R + Down	6.07–6.31

Table 4, Resistance on SmartShift Controls at A and C (Meritor SureShift)

7. After checking the resistance, unplug the wire extension, and reconnect the electrical connector.
8. Install the steering column trim panels.
9. Remove the chocks from the tires.



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A. Plug the newly assembled wire extension into the plug on the shift control unit.

1. Shift Control Unit
2. Digital Multimeter (set to ohms)
3. Metri-Pack Terminals (at wire ends)

Fig. 7, Resistance Checking at Shift Control

SmartShift Control Checking Using DataLink Monitor (DLM)

1. With the wheels chocked, start the engine.
2. Connect the service computer to the engine and start ServiceLink.
3. Click on the **Transmission** icon on the left screen.
4. Click on the **Templates** tab. An overview of available templates will be shown.
5. If the vehicle is equipped with Eaton® Fuller® AutoShift™, click on **SmartShift with Eaton AutoShift**. If the vehicle is equipped with ZF Meritor™ SureShift™, click on **SmartShift with Meritor SureShift**.

NOTE: The DLM template for the SureShift transmission will not work with the ZF Meritor FreedomLine transmission. For further diagnostic assistance on FreedomLine transmissions, use Meritor's TransSoft software.

6. Go directly to the appropriate heading in this subject, "SmartShift Control Testing for Eaton AutoShift" or "SmartShift Control Testing for ZF Meritor SureShift and FreedomLine".

SmartShift Control Testing for Eaton AutoShift

The AutoShift DataLink Monitor template (see **Fig. 8**) will display the current vehicle status and will reflect change in status. Vehicle information is retrieved from the transmission ECU on the datalink. The monitor can also be used to verify readings on the instrument panel.

To test the shift control using the datalink, the vehicle can be placed into a mode that allows the gears to be shifted without the engine running. The following step explains how to enter that mode.

1. Turn the ignition OFF, then turn the ignition back ON, but don't start the engine. The transmission controller will still be in the Engine ON mode, thereby allowing the gears to be shifted.
2. Test the operation of the shift control for Reverse (R) and Neutral (N), as follows.
   2.1 Select R on the selector switch. In the *Range Selected* field of the template an R should be displayed.
   2.2 Select N on the selector switch. In the *Range Selected* field of the template an N should be displayed.
3. Test the operation of the shift control for Drive (D), as follows.
   3.1 Select D on the selector switch and turn the slide switch (reading "Automatic/Manual") to Automatic. In the *Range Selected* field of the template, a D should be displayed.

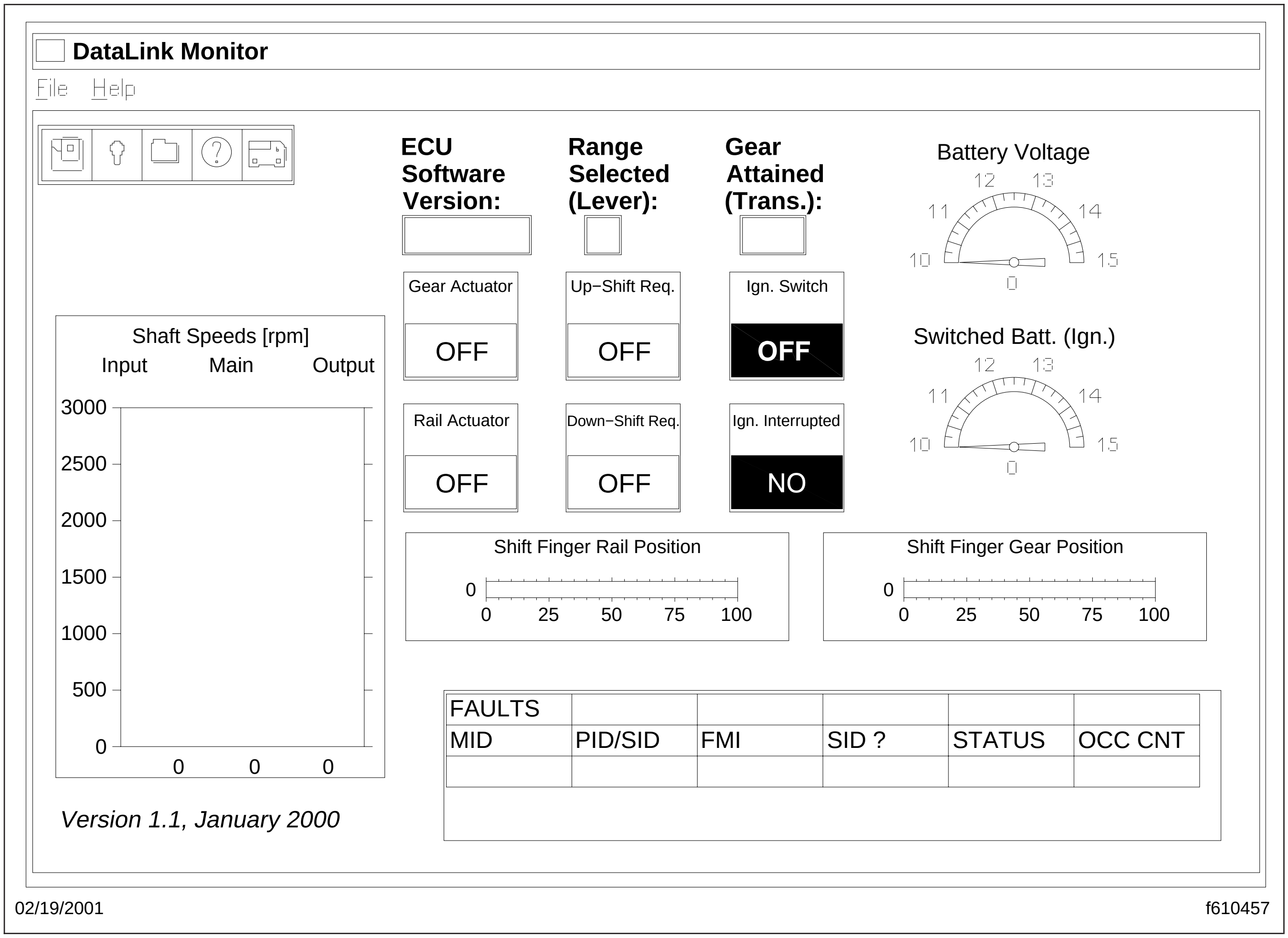


Fig. 8, DataLink Monitor Template for Eaton Fuller AutoShift

3.2 With the selector switch still on D, toggle the slide switch from Automatic to Manual and back. Confirm that the *Range Selected* field shows a D while in Automatic and an H (High) while in Manual.

3.3 While in Manual mode, change the selector switch to L (Low) and confirm that the *Range Selected* field changes from H to L.

4. Test upshifting and downshifting, as follows.

4.1 With the selector switch on D, pull and hold the shift control lever. The *Up-Shift Req.* field will turn green and read ON for 3 seconds.

4.2 Push and hold the shift control lever. The *Down-Shift Req.* field will turn green and read ON for 3 seconds.

NOTE: A blinking display indicates that the transmission is attempting to shift into the gear position. A solid display shows the current gear position attained.

5. When the selector switch is in any position but N (Neutral), the *Ign. Interrupt* field on the Monitor template will read YES.

SmartShift Control Testing for ZF Meritor SureShift and FreedomLine

The SmartShift control test for a ZF Meritor SureShift system can be performed by using the dash-mounted gear display. The SureShift DataLink Monitor (DLM) template can be used if further testing of the system is necessary, for example, to confirm dash display readings or gear positions. See Fig. 9.

NOTE: The DLM template for the SureShift transmission will not work with the FreedomLine transmission. For further diagnostic assistance on FreedomLine transmissions, use Meritor's TransSoft software.

WARNING

For SureShift transmissions, do not depress the clutch pedal during these tests. Doing so could result in the vehicle moving, possibly causing vehicle damage or personal injury.

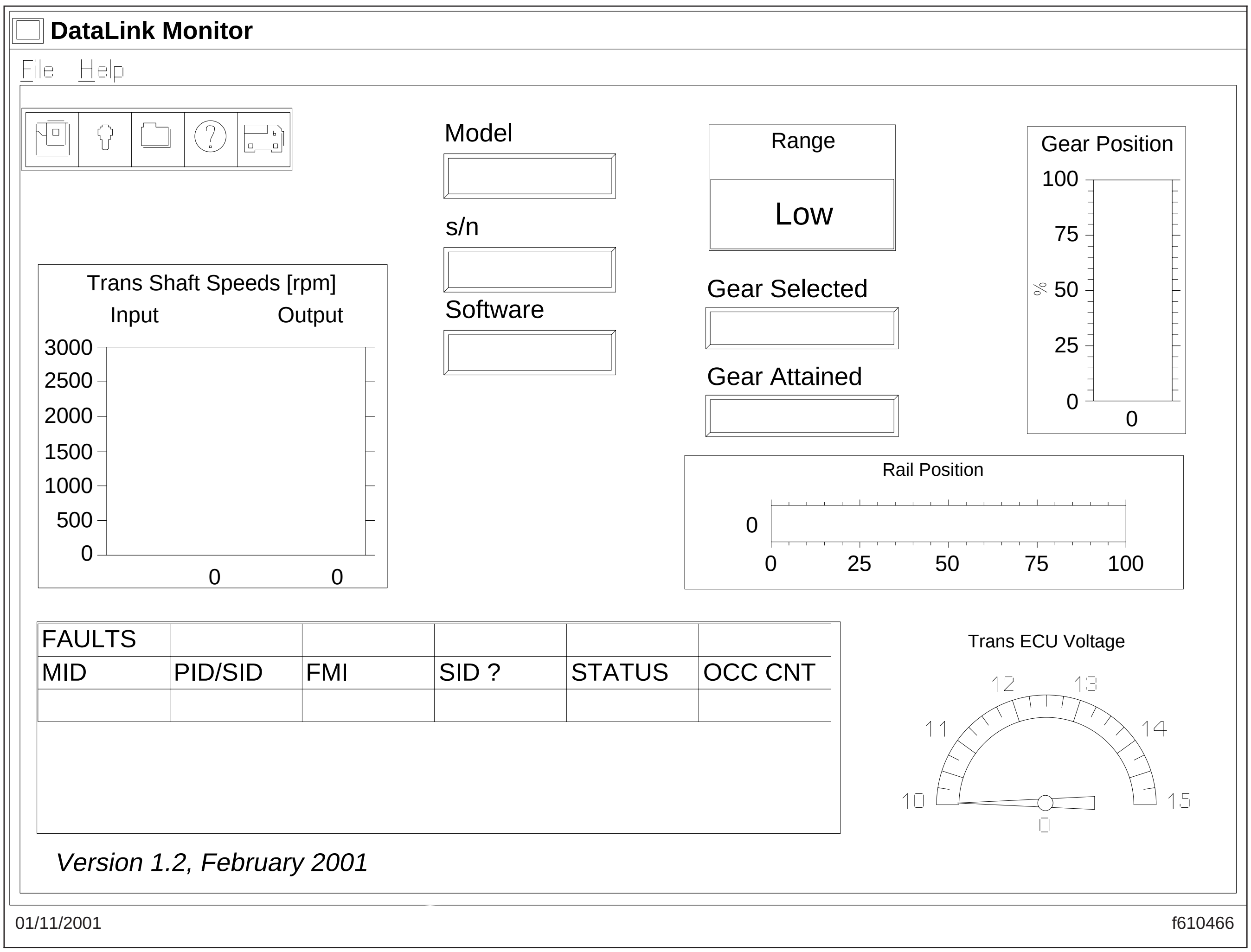


Fig. 9, DataLink Monitor Template for ZF Meritor SureShift

Troubleshooting

Make sure all tires are chocked and the parking brake is set before performing the following tests. These tests require the vehicle to be started, and precautions need to be taken to ensure the vehicle will not move.

1. Test the operation of the shift control for Reverse (R) and Neutral (N), as follows.

   1.1 Move the selector switch to R. Confirm that the display is changing from N to RL (Reverse Low), the default reverse gear. The display will change to CL (Clutch) after one second. Repeat this step if the reading disappeared quickly.

   1.2 Pull the shift control lever once to upshift to High Reverse. Confirm the display changes to RH (Reverse High).

2. Test the operation of the shift control for F or D, as follows.

   2.1 Move the selector switch to F (Forward) or Drive (D).

   2.2 Test upshifting and downshifting. Push, then pull, the shift control lever through all the gears and verify that each gear displays correctly on the dash display.

If the display or the DLM template does not confirm the SmartShift control position, the shift control should be tested. See the shift control resistance checking procedure herein.

General Information

Mercedes-Benz AGS Automated Gear Shift transmissions are fully automated manual transmissions that were installed on M2 vehicles for years. In 2010, the name changed to Freightliner AMT3™ Automated-Manual Transmission, and new model numbers were applied. See **Table 1** for model numbers.

NOTE: In this workshop manual, the term "AGS transmission" refers collectively to the transmission models in **Table 1**, and the information in this section applies equally to those models.

An AGS transmission gear case holds 9.5 quarts (9.0 liters) of oil. MobilTrans SHC® DC is the approved oil.

No clutch pedal is needed to change gears. The clutch is activated by a hydraulic system that also controls the shifting mechanism. After any service, the clutch must be recalibrated.

The hydraulic system is a self-contained AGS unit that attaches to the left-hand side of the gear case. See **Fig. 1**.

The AGS unit has four major components:

- The x-y actuator, which controls the movements of the shift mechanism
- The reservoir, which holds the supply of hydraulic fluid
- The pressure accumulator, which maintains a maximum hydraulic pressure of 1230 psi (8500 kPa)
- The central unit, which controls both electrical and hydraulic inputs

The central unit of the AGS contains the transmission control unit (TCU) and the hydraulic body. On the rear of the hydraulic body are a hydraulic pump and an electric motor.

The TCU is the electronic center of the AGS. It controls gear changes and monitors the positions of the clutch and the shift mechanism. It receives requests from the shift lever to change drive modes and gears. It broadcasts error messages to the J1587 databus. It communicates to the engine, antilock brakes, and bulkhead module over the J1939 network.

The hydraulic body distributes hydraulic fluid to the clutch, x-y actuator, and accumulator. The hydraulic pump is driven by an electric motor with its own connection to the power distribution module, protected by a 40-amp fuse.

The hydraulic pump comes on automatically when the ignition is turned on, producing a distinctive humming noise that is a characteristic of this transmission. When the noise stops, the hydraulic system is pressurized.

The hydraulic reservoir holds about 1.05 quarts (one liter) of hydraulic fluid. The only fluid used in this system is Pentosin. No other fluid can be substituted.

Both high-pressure and low-pressure hydraulic fittings are not threaded. They can be removed by pressing a brass ring against a soft O-ring and thereby compressing it enough to break the seal and open the line. See **Fig. 2** for the line removal tools.

Certain fasteners used on this transmission contain small amounts of chemical in micro-capsules embedded in the thread. This chemical has sealant and/or thread-locking properties. These fasteners must be replaced at every service for the micro-encapsulated chemical to keep its properties.

IMPORTANT: Do not use Loctite® or sealant on these fasteners.

Transmission Model Numbers			
Mercedes-Benz AGS	**Freightliner AMT3**	**Engine Rating**	**Drive**
MBT520-6DA	AMT3-520-6DA	520 lbf·ft	Direct Drive
MBT660-6OA	AMT3-660-6OA	660 lbf·ft	Overdrive

Table 1, Transmission Model Numbers

General Information

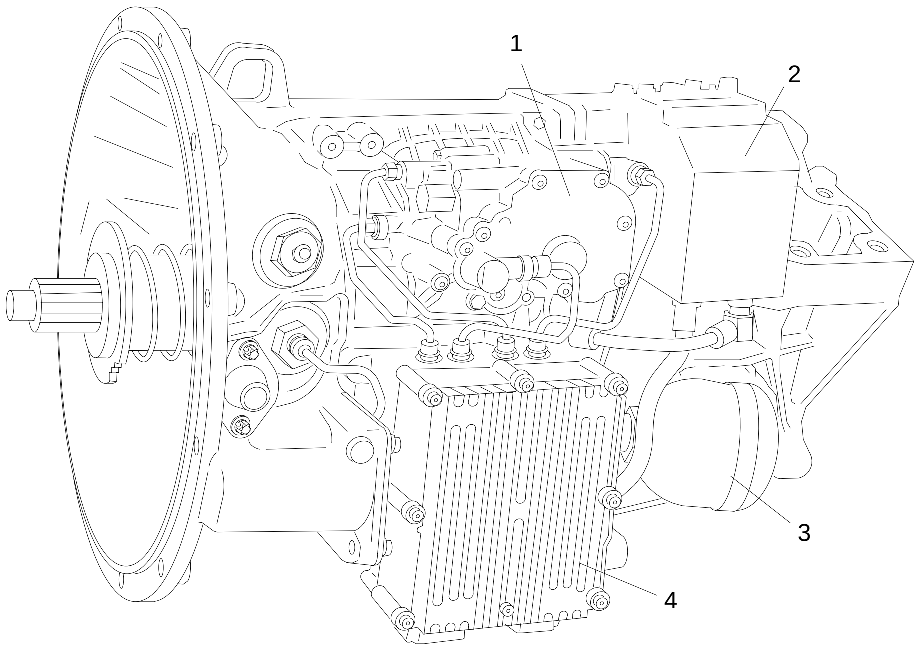
Principles of Operation

A shift can be requested either manually, by pushing or pulling the SmartShift lever, or automatically. The AGS judges when to shift automatically through information provided by rotational speed (rpm) sensors. One sensor reads input shaft speed (this sensor is located aft of the central unit, on the countershaft). Two rear sensors read output shaft speed and direction of rotation.

When a shift is requested, hydraulic pressure disengages the clutch. A position sensor attached to the clutch release bearing housing ensures smooth disengagement and engagement.

The x-y actuator moves the shift rod in two dimensions (this is why it is called x-y actuation). With the clutch disengaged, the actuator uses hydraulic pressure to move the shift rod until it is over the correct shift rail. Then it turns the shift rod a precise amount so that the shift finger can engage the shift rail for the correct gear. Two shift position sensors, a gear position sensor and a rail position sensor, assure correct positioning of the shift rod and the shift rail.

From this point on, the mechanism operates in exactly the same way as in any other Mercedes-Benz manual transmission. The notch in the shift rail contacts the shift fork, which moves the synchro slide onto the correct gear wheel.



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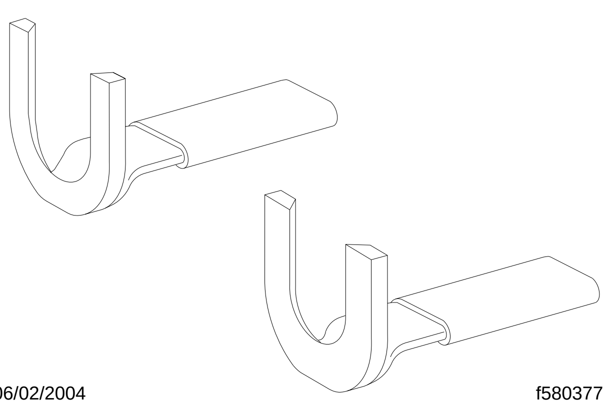
1. X-Y Actuator
2. Reservoir
3. Accumulator
4. Central Unit

Fig. 1, AGS Unit Components



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NOTE: The tool with the large opening (top) is used to disconnect the low-pressure hoses. The tool with the small opening (bottom) is used to disconnect the high-pressure lines.

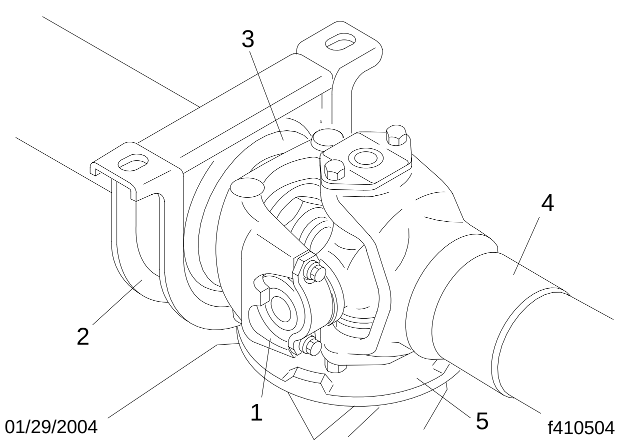
Fig. 2, Hydraulic Fitting Disconnect Tools

Removal

1. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the rear tires.

IMPORTANT: To prevent loss of hydraulic fluid, depressurize the hydraulic system before removing the transmission.

2. Depressurize the hydraulic system. For detailed procedures, see **Subject 160**.
3. Disconnect the batteries.
4. Disconnect the driveshaft from the transmission. See **Fig. 1**.



1. U-Joint
2. Midship Bracket
3. Midship Bearing
4. Drive Shaft
5. Jack

Fig. 1, Midship Bearing

4.1 Support the driveline with a jack underneath the aft midship bearing.

4.2 Remove the bolts from the aft midship bearing bracket.

4.3 Remove the forward midship bracket.

4.4 Remove the transmission yoke U-joint from the transmission.

4.5 Support the disconnected driveshaft.

5. Remove the cab floor plate and cover plate. See **Fig. 2**.
6. Remove all brackets attached to the transmission mounting bolts. Remove all the transmission mounting bolts from the bell housing except for the top two. See **Fig. 3**.
7. Remove the two screws attaching the splash guard to the TCU. See **Fig. 4**.
8. Remove the main vehicle harness (X1 connector) and electric motor harness (X3 connector). Remove tie straps as necessary. See **Fig. 5**.
9. Support the transmission with a jack. See **Fig. 6**.

9.1 Position a transmission jack under the transmission and raise its support plates against the base of the transmission.

9.2 Adjust the support plates to cradle the transmission.

9.3 Using a chain, secure the transmission to the jack.

10. Remove the top two transmission mounting bolts attaching the timing case to the bell housing.

CAUTION

Do not allow the rear of the transmission to drop, and do not allow the transmission to hang unsupported. Keep the flange of the bell housing parallel (all the way around) to the flange of the timing case, until the input shaft is clear of the flywheel. Taking these precautions will prevent damage to the input shaft, flywheel, and clutch.

11. Remove the transmission. See **Fig. 7**.

11.1 Pull the transmission and jack straight back until the transmission input shaft is clear of the engine.

11.2 If necessary, lower the jack supporting the transmission. It might also be necessary to jack up the truck to get enough clearance to allow the transmission to pass.

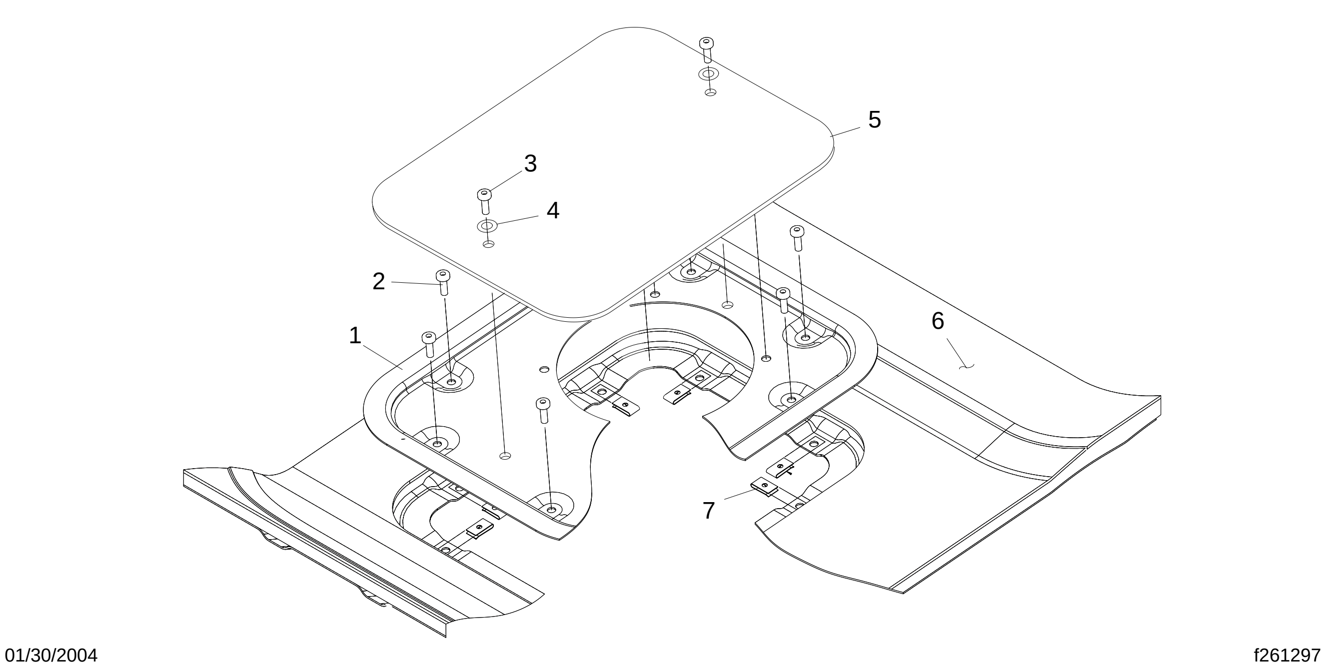
IMPORTANT: Watch closely the clearance between the bell housing and the frame rail.

11.3 Pull the transmission out through the space behind the cab.

Installation

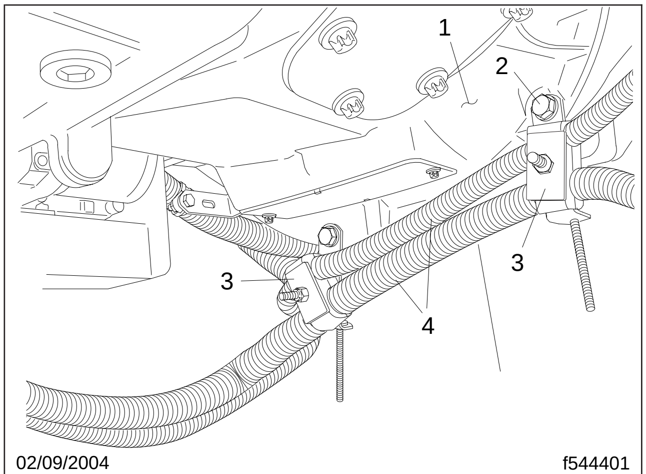
IMPORTANT: Before installing the transmission, make sure that the rear tires are chocked and

Transmission Removal and Installation



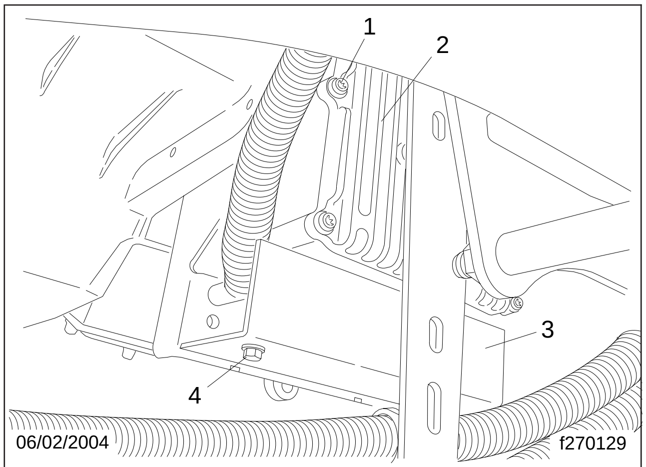
1. Cover Plate
2. Mounting Bolt, Cover Plate
3. Mounting Bolt, Floor Plate
4. Washer
5. Floor Plate
6. Cab Floor
7. Spring Clip

Fig. 2, Floor Access



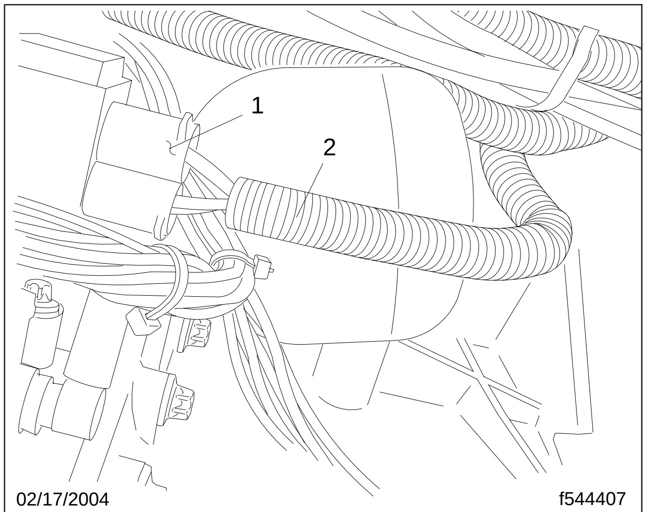
1. Bell Housing
2. Transmission Mounting Bolt
3. Battery Clamp
4. Battery Cables

Fig. 3, Battery Cable Brackets



1. TCU Mounting Bolt
2. TCU
3. Splash Guard
4. Splash Guard Mounting Bolt

Fig. 4, TCU Splash Guard



1. X3 Connector
2. Electric Motor Harness

Fig. 5, Harness Connector

that the transmission is securely chained to the support plates on the transmission jack.

1. Align the input shaft so that its splines engage the clutch.

   1.1 Align the jack and the transmission behind the engine.

   1.2 Raise the transmission and adjust the angle of the jack until the bell housing and the timing case flange are parallel.

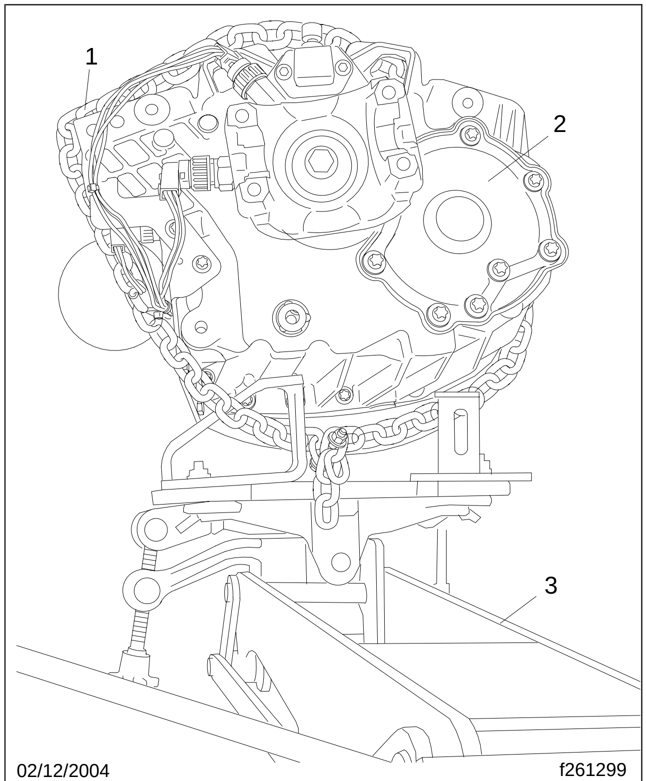
   1.3 Push the transmission and jack straight forward.

   NOTE: The AGS transmission automatically selects neutral when shut off. To make sure the clutch and input shaft are properly aligned, this substep requires two persons.

   1.4 While one person continues to push the transmission forward, the other person uses channel locks or other locking pliers to grip the input shaft and twist it slightly.

   1.5 When the input shaft and the clutch are aligned, work the transmission further towards the engine and line up the bolt holes in the flywheel housing with those in the bell housing.

2. Install the transmission.



1. Chain
2. Transmission
3. Jack

Fig. 6, Supporting the Transmission

   2.1 Install the M10 transmission mounting bolts holding the bell housing to the timing case. Use a crossover pattern.

   2.2 While installing the transmission mounting bolts, also install the all the bracket(s) on the bell housing, as removed.

   2.3 Remove the chain securing the transmission to the jack; then remove the jack.

   2.4 Do a final tightening of the mounting bolts to 33 lbf·ft (45 N·m).

3. Connect the X1 and X3 electrical connectors. Be sure the yellow safety slide on the X1 connector snaps into place.

4. Install the cab floor plate and cover plate. See **Fig. 2**.

5. Connect the driveshaft.

Transmission Removal and Installation

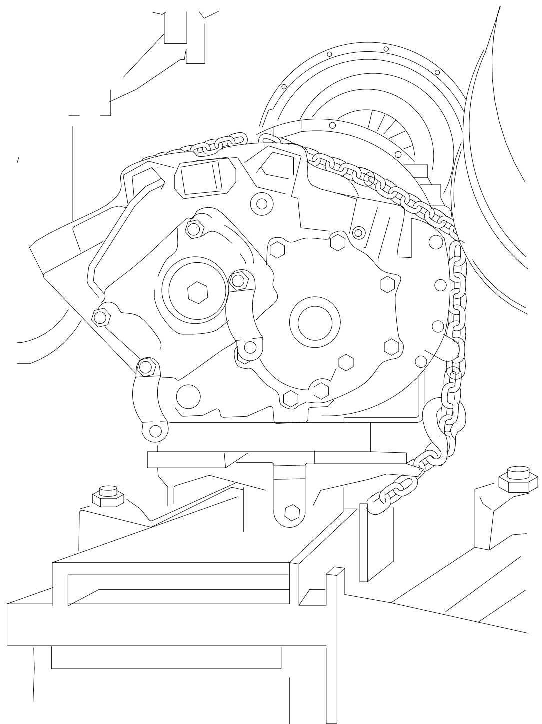


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Fig. 7, Remove the Transmission

5.1 Slide the front of the driveshaft into the transmission output yoke.

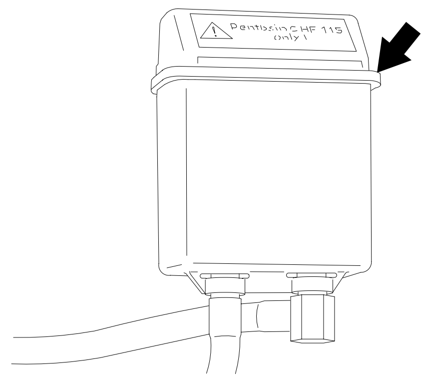
5.2 Install the U-joint end caps on the output yoke. Tighten the bolt heads 50 lbf·ft (68 N·m) for 3/8-inch end cap bolts and 110 lbf·ft (149 N·m) for 1/2-inch end cap bolts.

5.3 Install the bolts and nuts on the midship bearing brackets. Tighten the nuts 91 lbf·ft (123 N·m).

6. Check the hydraulic fluid level and add more Pentosin if needed. See **Fig. 8**. For detailed procedures, see **Subject 150**.

IMPORTANT: Use only Pentosin in the hydraulic reservoir. No other fluid can be substituted.

7. Connect the batteries.
8. Bleed the hydraulic system and recalibrate the transmission according to the procedures in **Subject 130**.
9. Check the transmission fluid level. If low, add transmission fluid until it is level with the lower



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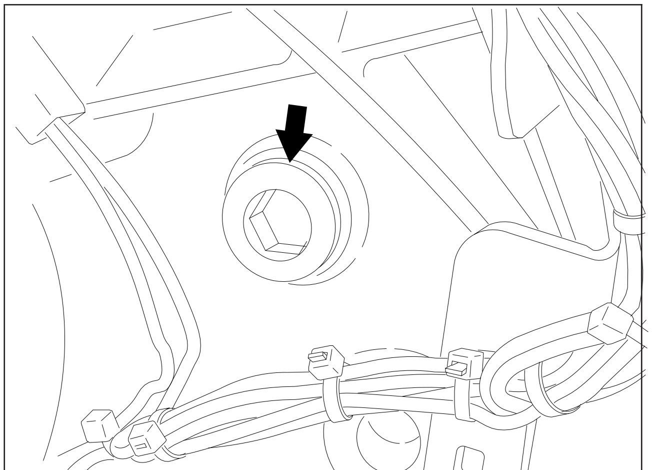
Fill the reservoir to the level indicated by the arrow.

Fig. 8, Hydraulic Fluid Fill Level

edge of the fill opening. See **Fig. 9** for the location of the fill plug and **Fig. 10** for the correct level. See **Group 26** of the *Business Class® M2 Maintenance Manual* for approved transmission lubricants and lubricant capacities.



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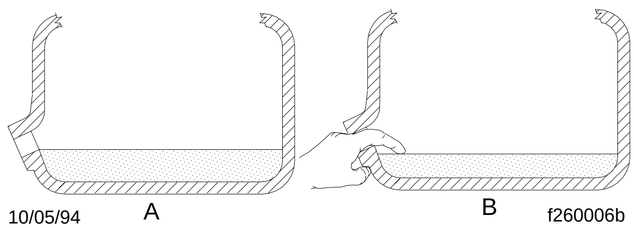
The fill plug is located on the left-hand side of the rear gear case, just behind the accumulator.

Fig. 9, Fill Plug

10. Clean the transmission fill plug and install it on the transmission, along with a new aluminum gasket. Tighten the fill plug 42 lbf·ft (57 N·m).
11. Remove the chocks from the rear tires.



A. Full
B. Low

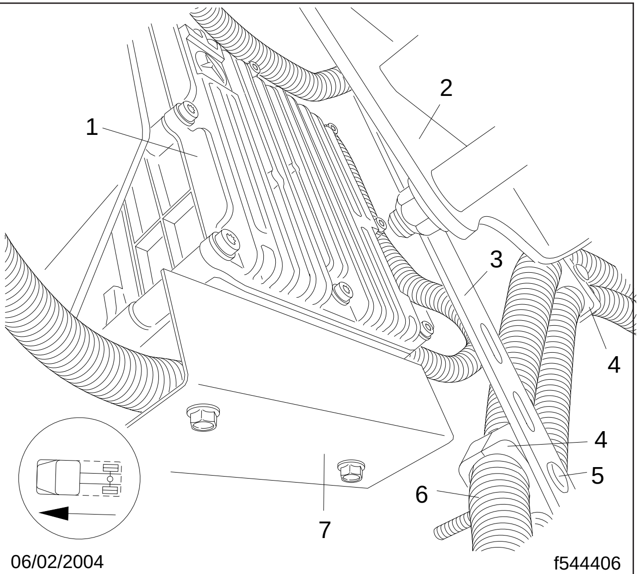
Fig. 10, Transmission Fluid Level Checking

AGS Transmission Control Unit Replacement

IMPORTANT: To successfully replace the transmission control unit (TCU) on the vehicle, there must be at least 2-3/4 inches (70 mm) clearance between the TCU and the frame rail.

Replacement

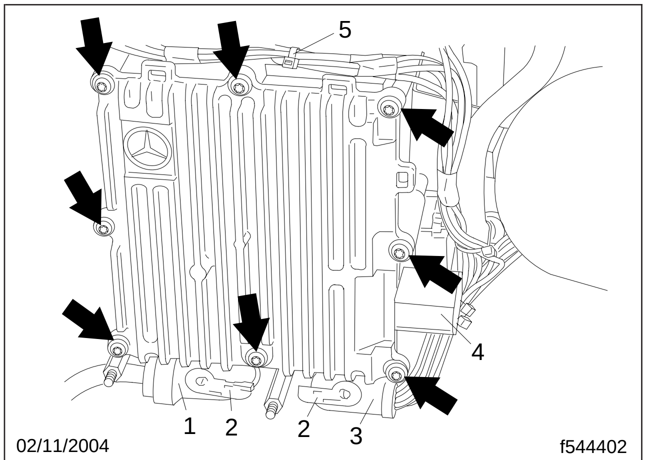
1. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the rear tires.
2. Disconnect the batteries.
3. Before starting the replacement procedure, clean all screws and fittings by spraying with a light penetrating oil.
4. Remove the two mounting capscrews attaching the splash guard to the TCU. See **Fig. 1**.



1. TCU
2. Front Hanger Bracket
3. Cable Bracket
4. Cable Clamp
5. Clamp Mounting Bolt
6. Battery Cable
7. Splash Guard

Fig. 1, Area of TCU

5. Disconnect the X1 (main vehicle), X2 (transmission), and X3 (electric motor) electrical connectors from the base and aft side of the TCU. See **Fig. 2**. Remove tie straps and clamps as needed.



Remove the eight Torx screws (arrows) attaching the TCU to the hydraulic body.

1. X1 (main vehicle) Connector
2. Safety Slide
3. X2 (transmission) Connector
4. X3 (electric motor) Connector
5. Tie Strap

Fig. 2, TCU

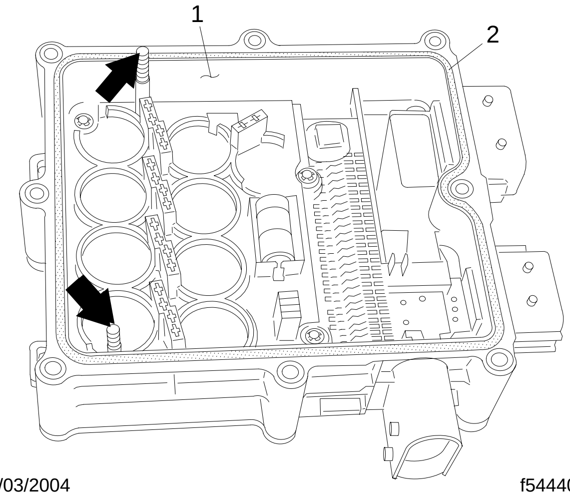
IMPORTANT: When cutting tie straps at the top of the TCU, use extreme care. Do not cut the wires in the electrical harness.

6. Remove the eight Torx® screws attaching the TCU to the hydraulic body. Pull the TCU straight back until all the internal connections are disengaged.

NOTE: Expect some resistance as the internal connections disengage.

7. Install the new TCU on the hydraulic body. See **Fig. 3**.
   - 7.1 Align the new seal ring in the groove provided in the inside of the new TCU.
   - 7.2 Coat the seal ring with enough bearing grease to ensure that the seal ring will not fall out of its groove during installation.
   - 7.3 Make sure all spade connectors are straight.
   - 7.4 Square up the TCU on the hydraulic body using the guide pins on the inside of the TCU. This will ensure that the internal connectors line up properly.

AGS Transmission Control Unit Replacement



When installing the new TCU, be sure to align the guide pins (arrows).

1. TCU
2. Seal Ring

Fig. 3, TCU Seal Ring

7.5 Check that the seal ring does not get pinched along the line where the TCU meets the hydraulic body.

NOTE: Make sure the TCU is seated firmly on the hydraulic body before installing the mounting screws. Do not use the screws to pull the TCU into position.

7.6 Install the mounting screws and tighten them 44 to 53 lbf·in (500 to 600 N·cm).

8. Attach the electrical connectors. Be sure the yellow slide on the X1 and X2 connector snaps into place. See **Fig. 2**.
9. Replace tie straps and cable clamps as needed.
10. Install the splash guard. Tighten the mounting capscrews 17 lbf·ft (23 N·m). See **Fig. 1**.
11. Recalibrate the transmission according to the procedures in **Subject 130**.
12. Remove the chocks from the rear tires.

AGS Transmission Sensor Replacement

Replacement

IMPORTANT: Depressurize the hydraulic system before replacing any of the hydraulic components—such as the Clutch Position Sensor, Gear Position Sensor, Rail Position Sensor, and Fluid Level Sensor.

For detailed hydraulic system depressurization procedures, see **Subject 160**. For a diagram of transmission sensors, see **Fig. 1**.

Clutch Position Sensor

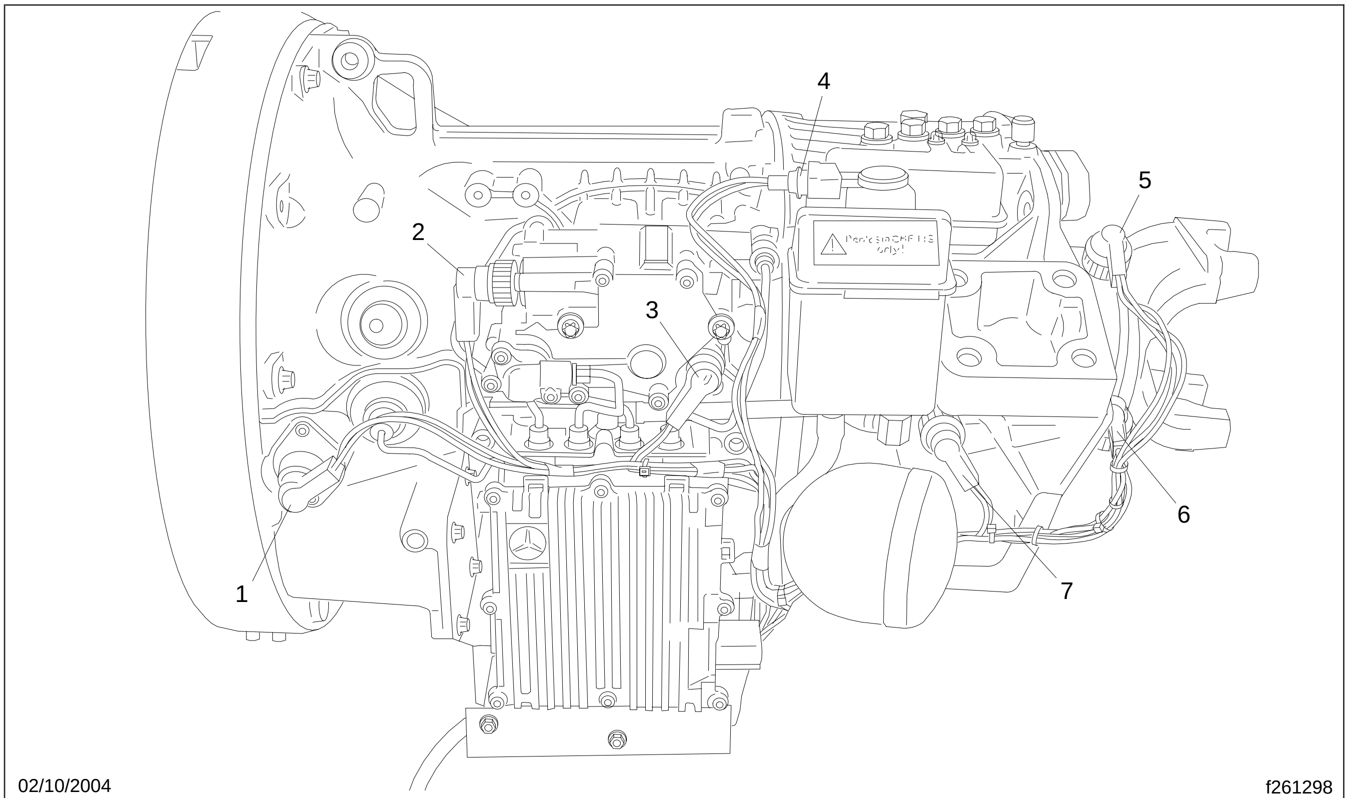
The clutch position sensor is integral to the clutch actuator and cannot be replaced without replacing the clutch actuator. For detailed procedures, see **Subject 210**.

Shift Position Sensors

The shift position sensors, shown in **Fig. 2**, are integral to the x-y actuator and cannot be replaced without replacing the x-y actuator. Replacement of the x-y actuator requires removing the transmission from the vehicle. For detailed procedures, see **Subject 170**.

Fluid Level Sensor

1. Clean around the area of the reservoir cap. Take care not to introduce dirt into the reservoir.
2. If not already done, depressurize the hydraulic system. For detailed procedures, see **Subject 160**.



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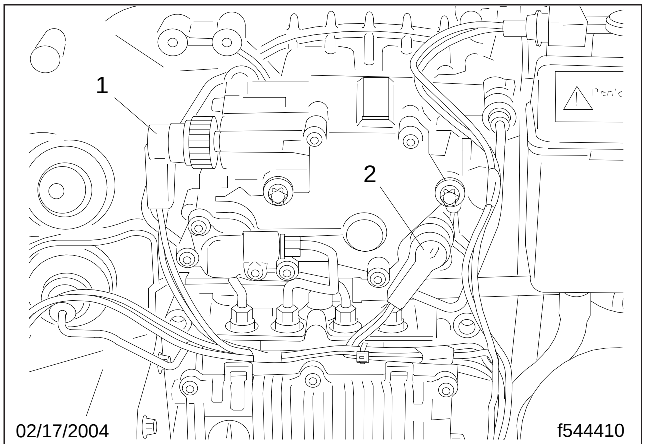
1. Clutch Position Sensor
2. Gear Position Sensor
3. Rail Position Sensor
4. Fluid Level Sensor
5. Output Shaft Speed Sensor #1
6. Output Shaft Speed Sensor #2
7. Input Shaft Speed Sensor

Fig. 1, Transmission Sensors

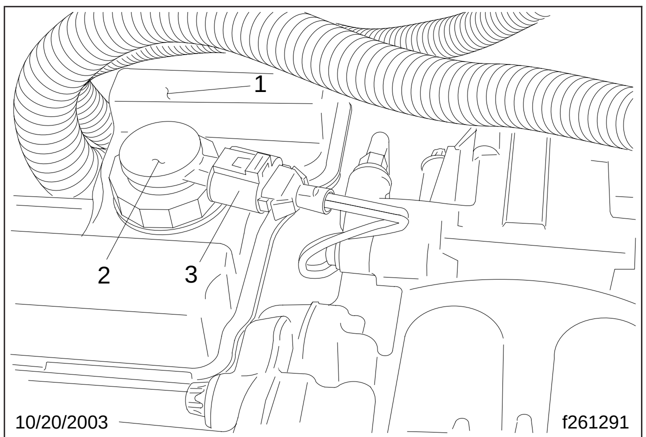
AGS Transmission Sensor Replacement



1. Gear Position Sensor
2. Rail Position Sensor

Fig. 2, Shift Position Sensors

3. Remove the electrical connector from the reservoir cap. See **Fig. 3**.



1. Reservoir
2. Cap
3. Connector

Fig. 3, Fluid Level Sensor

  3.1 Insert a small screwdriver into the opening at the top of the connector.

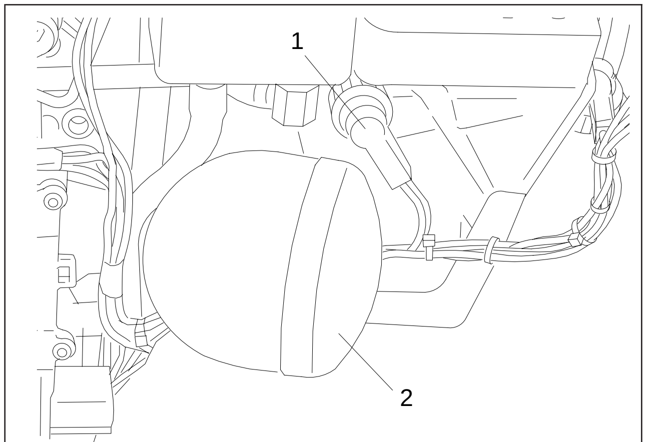
  3.2 Pull back (aft) on the clip until it releases. A click can be heard when it releases.

  3.3 Remove the connector from the plug on the reservoir cap.

4. Unscrew the reservoir cap and remove the cap and probe from the hydraulic reservoir.
5. Insert a new cap with probe into the hydraulic reservoir.
6. Attach the electrical connector to the new cap and make sure the new cap is tightly fastened.

Speed Sensors

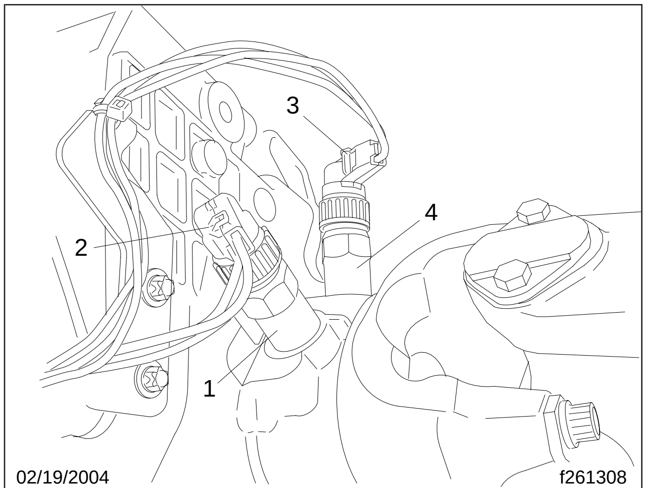
1. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the rear tires.
2. Unscrew the electrical connector from the sensor. See **Fig. 4** for the input shaft speed sensor and **Fig. 5** for the two output shaft speed sensors.



1. Input Shaft Speed Sensor
2. Accumulator

Fig. 4, Input Shaft Speed Sensor

3. Using a wrench, remove the sensor from the rear gear case.
4. Install a new sensor on the rear gear case. Tighten the sensor 28 lbf·ft (38 N·m).
5. Install the electrical connector on the end of the sensor.
6. Remove the chocks from the rear tires.



1. Output Shaft Speed Sensor #2
2. Connector, Sensor #2
3. Connector, Sensor #1
4. Output Shaft Speed Sensor #1

Fig. 5, Output Shaft Speed Sensors

Bleeding

IMPORTANT: Bleed the hydraulic system after any repair.

1. Shut down the engine, set the parking brake, and chock the rear tires.

NOTE: To gain access to the reservoir cap, it may be more convenient to open the floor access plate. See **Subject 100** for procedures.

2. Clean around the area of the bleed screw and the reservoir cap. Keep the reservoir cap clean and take care not to introduce dirt into the reservoir.
3. With the hydraulic system depressurized (for detailed procedures, see **Subject 160**), remove the plastic cap from the bleed screw. Insert a clear hose onto the bleed valve on the bell housing. Remove the reservoir cap and place the other end of the hose inside the hydraulic reservoir.

IMPORTANT: Do not start the engine.

4. Turn on the ignition switch and put the transmission into 1st gear.
5. Slowly open the bleed screw. Allow the hydraulic fluid to circulate until no air bubbles are visible and the fluid is clear.
6. Tighten the bleed screw 13 lbf·ft (17 N·m).
7. Remove the bleed hose and install the reservoir cap.
8. Install the plastic cap on the bleed screw.
9. Recalibrate the transmission using the procedure under the heading "Recalibration" in this subject.
10. Check the hydraulic fluid level and add more Pentosin as needed. See **Subject 150** for procedures.

Recalibration

IMPORTANT: Use this procedure when a new transmission is installed, the TCU is replaced, and to correct complaints of rough shifting.

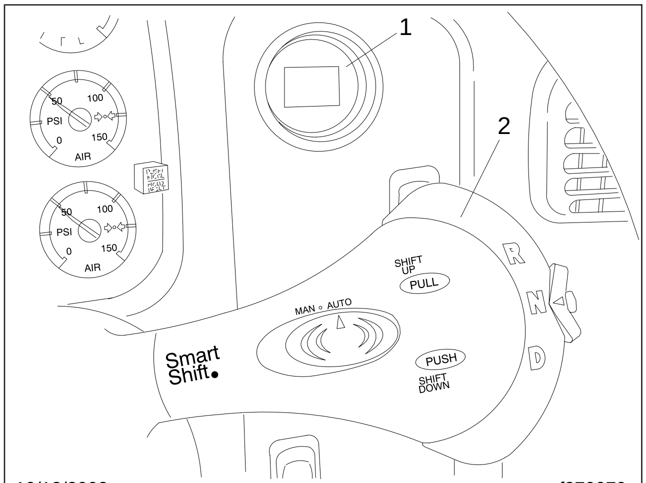
1. Shut down the engine and set the parking brake.
2. Pressurize the hydraulic pump, as follows.

NOTE: As the hydraulic pump builds pressure, you may hear it humming.

2.1 Turn on the ignition, and wait one minute. Then turn off the ignition, and wait one minute. Verify that the current gear indicator is blank.

2.2 Again, turn on the ignition, and wait one minute. Then turn off the ignition, and wait one minute. Verify that the current gear indicator is blank.

3. Verify that the current gear indicator is blank. Set the selector switch on the SmartShift control to "N" (neutral). See **Fig. 1**.



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Make sure the current gear indicator is blank and the selector switch is set to "N".

1. Current Gear Indicator
2. SmartShift Control

Fig. 1, Ready to Recalibrate

NOTE: For the recalibration procedure to succeed, the selector switch must remain in neutral until instructed differently later in this procedure.

4. With the selector switch in neutral, pull the SmartShift lever up (towards you) and hold it there until instructed to release it later in this procedure.
5. While holding the SmartShift lever up, turn on the ignition. When the letter "X" displays on the current gear indicator, recalibration is in progress. See **Fig. 2**. Do not start the engine at this time.

AGS Transmission Bleeding and Recalibration

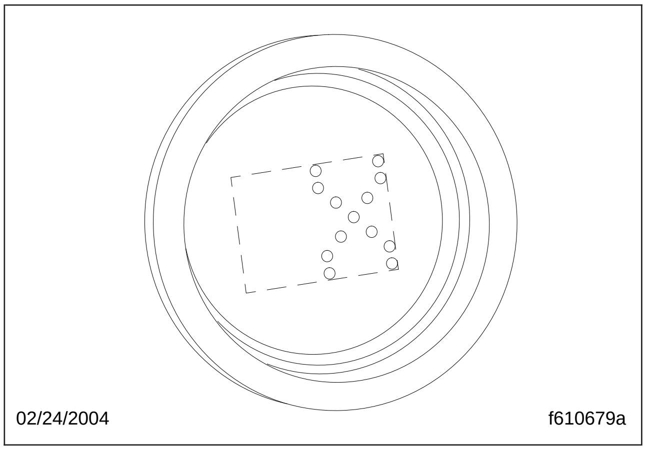


Fig. 2, Recalibration In Progress

NOTE: If the letter "X" does not appear, turn off the ignition, wait one minute, and try again.

6. Wait for the letter "N" to display on the current gear indicator and the audible alert to sound. See **Fig. 3**. Start the engine within 10 seconds.

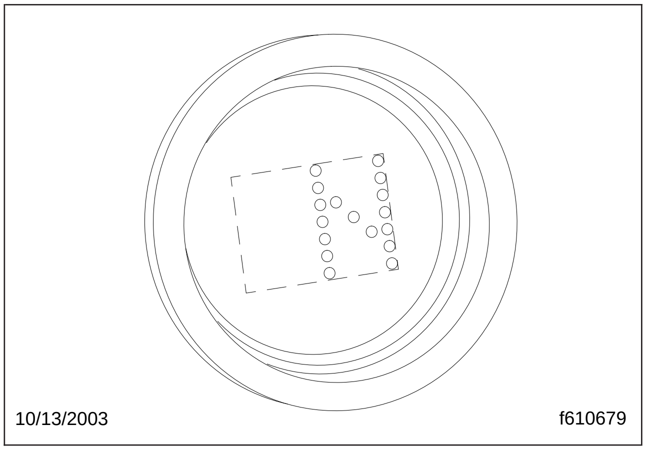


Fig. 3, Neutral Display

7. The next time the alert sounds, release the SmartShift lever and shut down the engine. Wait two minutes, turn on the ignition, and do one of the following:
   - If the current gear indicator displays "N", proceed to the next step.
   - If the current gear indicator flashes "SM-N", turn off the ignition and wait two minutes for the display to clear. Then turn on the ignition. If the current gear indicator displays "N", proceed to the next step. If it flashes "SM-N", turn off the ignition, wait two minutes or until the display clears, and proceed to the next step.
   - If the current gear indicator flashes "SM-X", stop, and repeat the recalibration procedure from the beginning.
8. If necessary, turn on the ignition and wait for the letter "N" to display on the current gear indicator. Now select "D" on the SmartShift control, and wait for the numeral "1" to display on the current gear indicator. Then select "R" and wait for "R" to display on the current gear indicator.

IMPORTANT: If the current gear indicator displays "SM" or any other problem occurs, repeat the recalibration procedure from the beginning.

Accumulator Replacement

Special Tool

A special tool is required for this procedure. See **Table 1**.

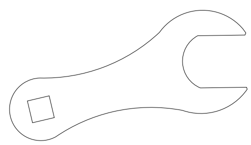
Special Tool for Accumulator Replacement			
Tool	Description	Manufacturer	Part Number
 f580381	Accumulator Torque Adaptor	Kent-Moore	J-47291

Table 1, Special Tool for Accumulator Replacement

Replacement

1. Shut down the engine, set the parking brake and chock the rear tires.

IMPORTANT: Depressurize the hydraulic system before replacing any hydraulic components.

2. Depressurize the hydraulic system. For detailed procedures, see **Subject 160**.

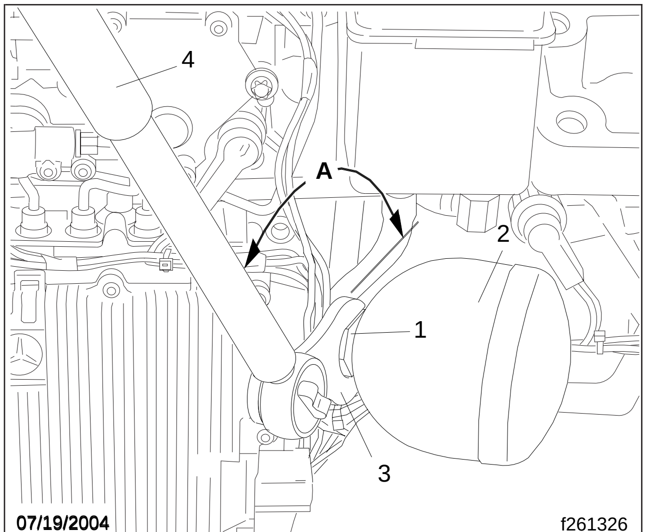
WARNING

This system is under extremely high pressure. Do not attempt to loosen the accumulator until the system has been depressurized. Hydraulic fluid could spray out at high speed, causing a personal injury.

3. Using a socket wrench and the accumulator torque adaptor (**Table 1**), loosen the M30 fitting on the accumulator.
4. Remove the accumulator from the hydraulic body of the AGS central unit.
5. Install the accumulator. See **Fig. 1**.

   5.1 Position the new accumulator on the threaded hole and screw it onto the hydraulic body.

   5.2 Assemble the torque wrench and the accumulator torque adaptor (**Table 1**) with the torque adaptor set at a 90-degree angle to the wrench.



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To obtain the correct torque, set the torque adaptor at a 90-degree angle to the wrench.

A. 90-degree Angle

1. Fitting, M30
2. Accumulator
3. Accumulator Torque Adaptor
4. Torque Wrench

Fig. 1, Install the Accumulator

IMPORTANT: If the torque adaptor is not set at a 90-degree angle to the wrench, the M30 fitting will not receive the correct torque.

Accumulator Replacement

5.3 Using the torque wrench and adaptor assembly, tighten the M30 fitting 55 lbf·ft (75 N·m).

6. Check the hydraulic fluid level and add more Pentosin if needed. For detailed procedures, see **Subject 150**.

IMPORTANT: Use only Pentosin in the hydraulic reservoir. No other fluid can be substituted.

7. Start the engine and allow the system to pressurize. Shift back and forth a few times from drive to reverse and back to neutral.

NOTE: The first few shifts after draining and refilling the hydraulic system will take longer than usual.

8. Check the hydraulic system for leaks and repair if necessary. When done, shut down the engine.
9. Remove the chocks from the rear tires.

Hydraulic Fluid Reservoir Replacement

Special Tool

A special tool is required for this procedure. See **Table 1**.

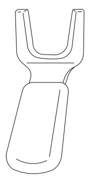
Special Tool for Hydraulic Fluid Reservoir Replacement			
Tool	Description	Manufacturer	Part Number
 f580379a	Low-Pressure Hose Disconnect Tool	Kent-Moore	J-47202

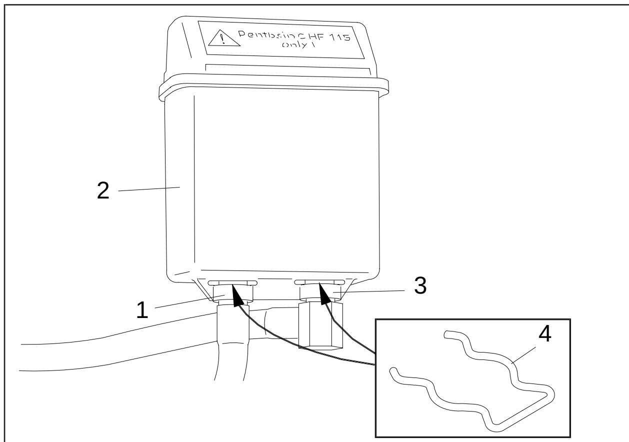
Table 1, Special Tool for Hydraulic Fluid Reservoir Replacement

Replacement

1. Shut down the engine, set the parking brake and chock the rear tires.

IMPORTANT: Depressurize the hydraulic system before replacing any hydraulic components.

2. Depressurize the hydraulic system. For detailed procedures, see **Subject 160**.
3. Drain the hydraulic fluid. See **Fig. 1**.



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Install the spring clips in the slots provided in the base of the reservoir.

1. Low-Pressure Hose
2. Reservoir
3. Return Hose
4. Spring Clip

Fig. 1, Hydraulic Hoses

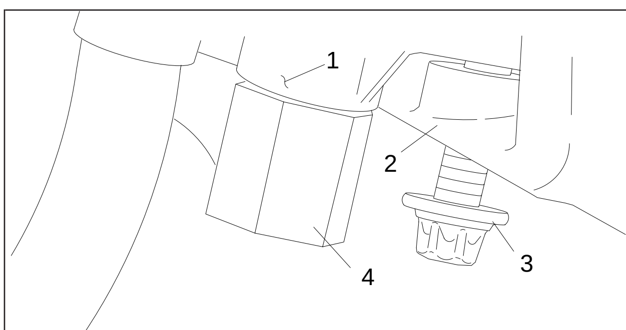
3.1 Place a receptacle under the reservoir to catch the drained fluid.

3.2 Pull out the spring clips that secure the low-pressure hydraulic hoses to the fittings at the base of the reservoir.

3.3 Using the low-pressure hose disconnect tool (**Table 1**), remove the two low-pressure hydraulic hoses from the reservoir.

3.4 Allow the hoses to drain into the container and cap them when fluid no longer drains out.

4. Carefully remove the inverted-Torx® M8 fastener at the base of the reservoir. Discard this fastener. See **Fig. 2**.



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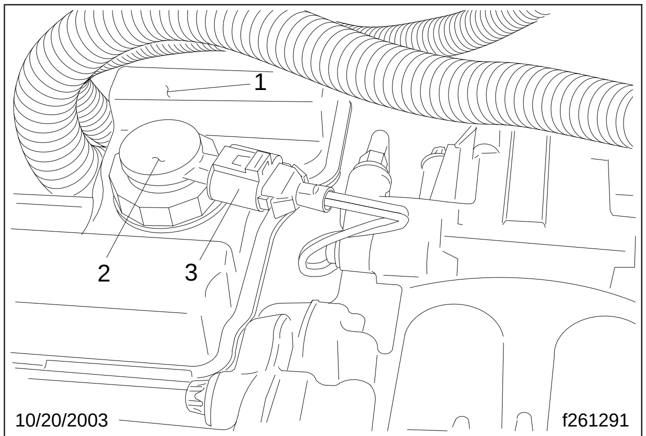
1. Reservoir
2. Lip of Gear Case
3. Fastener, M8
4. Hydraulic Fitting

Fig. 2, Fastener, Reservoir Base

Hydraulic Fluid Reservoir Replacement

5. Remove the electrical connector from the reservoir cap. See **Fig. 3**.



1. Reservoir
2. Reservoir Cap
3. Fluid Level Sensor

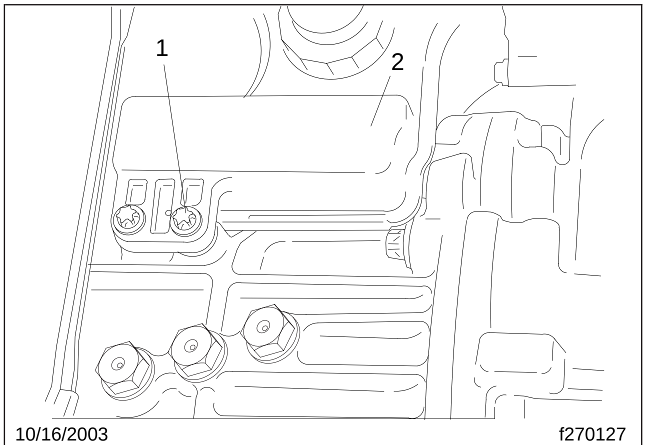
Fig. 3, Reservoir Cap

5.1 Insert a small screwdriver into the opening at the top of the connector.

5.2 Pull back (aft) on the clip until it releases. A click can be heard when it releases.

5.3 Remove the connector from the plug on the reservoir cap.

6. Remove the two inverted-Torx M6 fasteners fastening the top of the reservoir to the transmission gear box. See **Fig. 4**.



1. Fastener, M6
2. Reservoir

Fig. 4, Fasteners, Reservoir Top

7. Remove the reservoir from the transmission.
8. Position the new reservoir in the transmission. Install the two M6 fasteners that fasten it to the gear box and tighten them 71 lbf·in (800 N·cm).
9. Attach the electrical connector to the reservoir cap. Tug lightly on the connector to make sure it has snapped into place.
10. Install a new M8 fastener into the groove at the base of the reservoir. See **Fig. 2**. Tighten the M8 fastener 11 lbf·ft (18 N·m).

IMPORTANT: Do not use Loctite® or sealant on this fastener.

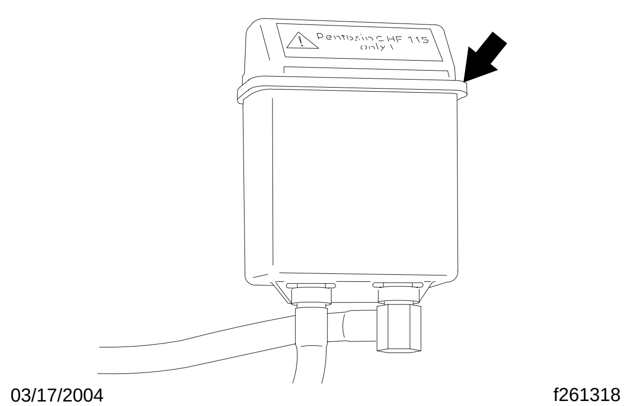
11. Install the low-pressure hydraulic hoses at the base of the reservoir. See **Fig. 1**.

11.1 Install the spring clips in the slots provided.

11.2 Insert the two hydraulic hoses through the spring clips until they snap into place. Tug lightly on the lines to make sure they are securely fastened.

NOTE: After depressurizing, wait five minutes before checking the hydraulic fluid level. This will allow any foam in the fluid to settle.

12. Check the hydraulic fluid level. Add Pentosin as needed until the level reaches the joint between the upper and lower sections of the reservoir. See **Fig. 5**.



Fill the reservoir to the level indicated by the arrow.

Fig. 5, Hydraulic Fluid Fill Level

IMPORTANT: Use only Pentosin in the hydraulic reservoir. No other fluid can be substituted.

13. Start the engine and allow the system to pressurize. Shift back and forth a few times from drive to reverse and back to neutral.

NOTE: The first few shifts after draining and refilling the hydraulic system will take longer than usual.

14. Check the hydraulic system for leaks and repair if necessary. When done, shut down the engine.
15. Remove the chocks from the tires.

AGS Hydraulic System Depressurization

IMPORTANT: Depressurize the hydraulic system before removing the transmission or replacing any hydraulic components.

Depressurization

Normal Procedure

1. Shut down the engine and set the parking brake.
2. Connect ServiceLink to the vehicle. Start the "AGS Procedures" template and follow the instructions on the screen to depressurize the system. See **Fig. 1**.
   - 2.1 Press the "Start Communications" button.
   - 2.2 Select "Start Diagnostic Mode."
   - 2.3 Select the "Reduce Hyd Pressure" button to depressurize the system.
3. Turn off the ignition switch. Wait for the system to depressurize. When the system depressurizes, the accumulator will dump its fluid into the reservoir, causing an obvious rise in the reservoir level.

IMPORTANT: If the reservoir level fails to rise, or any other problem prevents the system from depressurizing, use the alternate procedure. Do not use the alternate procedure unless the normal procedure fails.

4. Disconnect ServiceLink from the vehicle.

Alternate Procedure

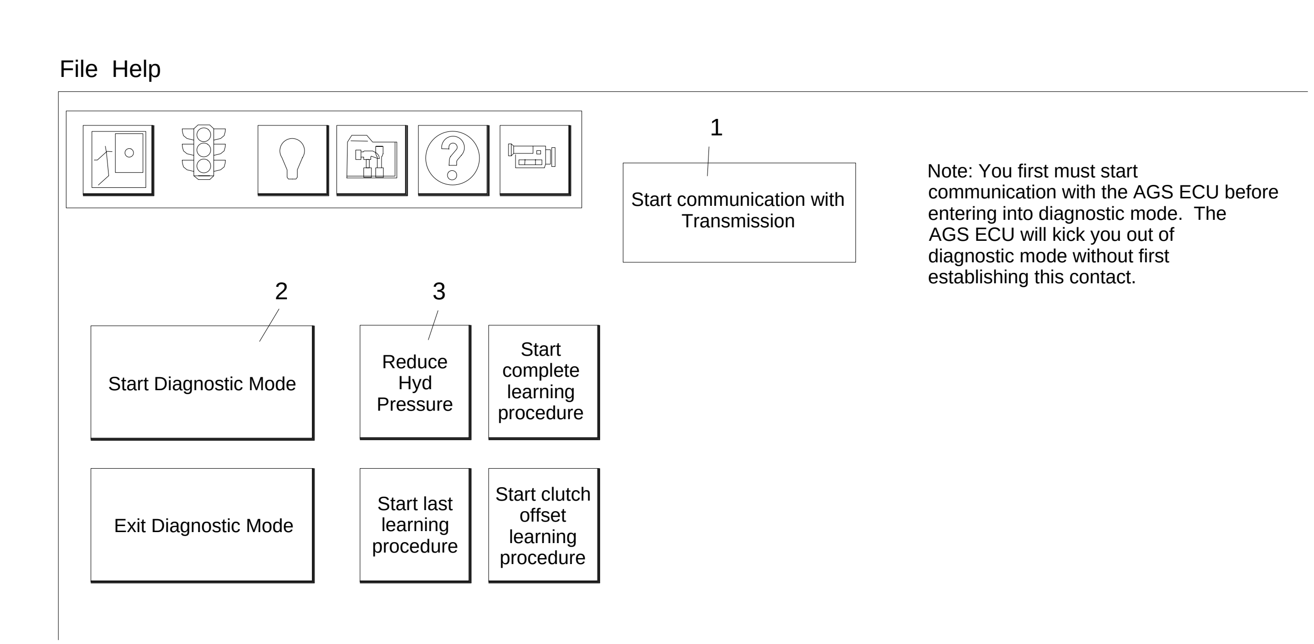
NOTE: The pressure-limiting valve is designed to be opened a limited number of times. Do not use it routinely to depressurize the system.

1. Open the pressure-limiting valve embedded in the forward side of the x-y actuator. Loosen the M6 adjusting screw carefully one quarter-turn. See **Fig. 2**.

IMPORTANT: Do not loosen the adjusting screw more than one quarter-turn. If the pressure-limiting valve is opened wider than that, it can cause the accumulator to discharge.

2. Close the M6 adjusting screw when depressurization is complete. Tighten it 62 to 71 lbf·in (700 to 800 N·cm).

AGS Hydraulic System Depressurization



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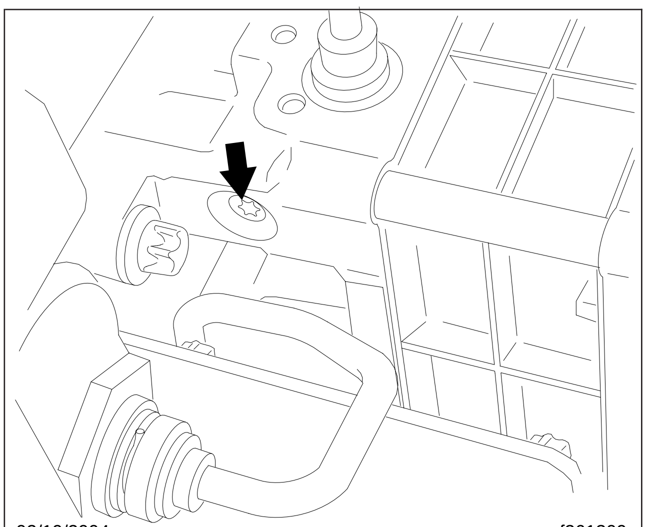
NOTE: This screen is provisional and subject to change.

1. Start Communications
2. Start Diagnostic Mode
3. Reduce Hydraulic Pressure

Fig. 1, ServiceLink Depressurization Screen



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If the normal procedure fails, open the pressure-limiting valve by turning the adjusting screw (arrow).

Fig. 2, Alternate Procedure

Special Tool

A special tool is required for this procedure. See **Table 1**.

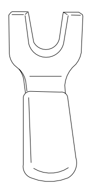
Special Tool for X-Y Actuator Replacement			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580379	High-Pressure Line Disconnect Tool	Kent-Moore	J-47201

Table 1, Special Tool for X-Y Actuator Replacement

Replacement

1. Shut down the engine, set the parking brake and chock the rear tires.

NOTE: Replacement of the x-y actuator requires removing the transmission from the vehicle.

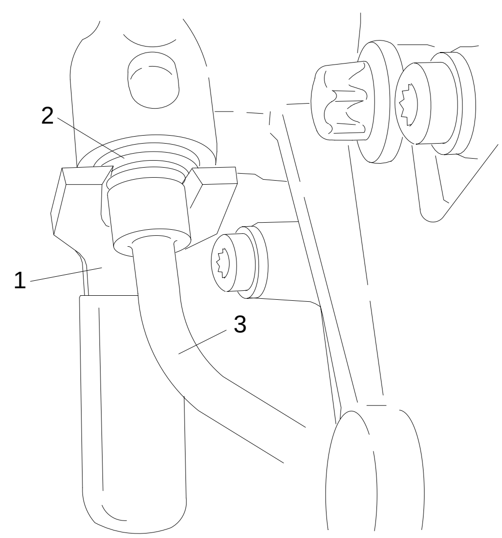
2. Remove the transmission from the vehicle. For detailed procedures, see **Subject 100**.

IMPORTANT: Depressurize the hydraulic system before replacing any hydraulic components.

3. If not already done, depressurize the hydraulic system. For detailed procedures, see **Subject 160**.
4. Remove the AGS assembly from the transmission. For detailed procedures, see **Subject 200**.
5. Before starting the replacement procedure, clean all screws and fittings by spraying with a light penetrating oil.
6. Using the high-pressure hydraulic line disconnect tool (**Table 1**), remove the high-pressure hydraulic lines from the actuator. See **Fig. 1**.

    6.1 Mark each line and attachment point with a paint pen for ease of installation.

    6.2 Place the high-pressure line tool in front of the metal ring. Use the tool to pull on the line and shake it slightly until the line comes free.



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1. High-Pressure Line Disconnect Tool
2. Metal Ring
3. High-Pressure Hydraulic Line

Fig. 1, Removing the High-Pressure Hydraulic Lines

    6.3 Carefully pull the line away from the attachment point and pull it free of the actuator.

CAUTION

Be careful not to bend or damage the lines or the O-rings when removing them.

X-Y Actuator Replacement

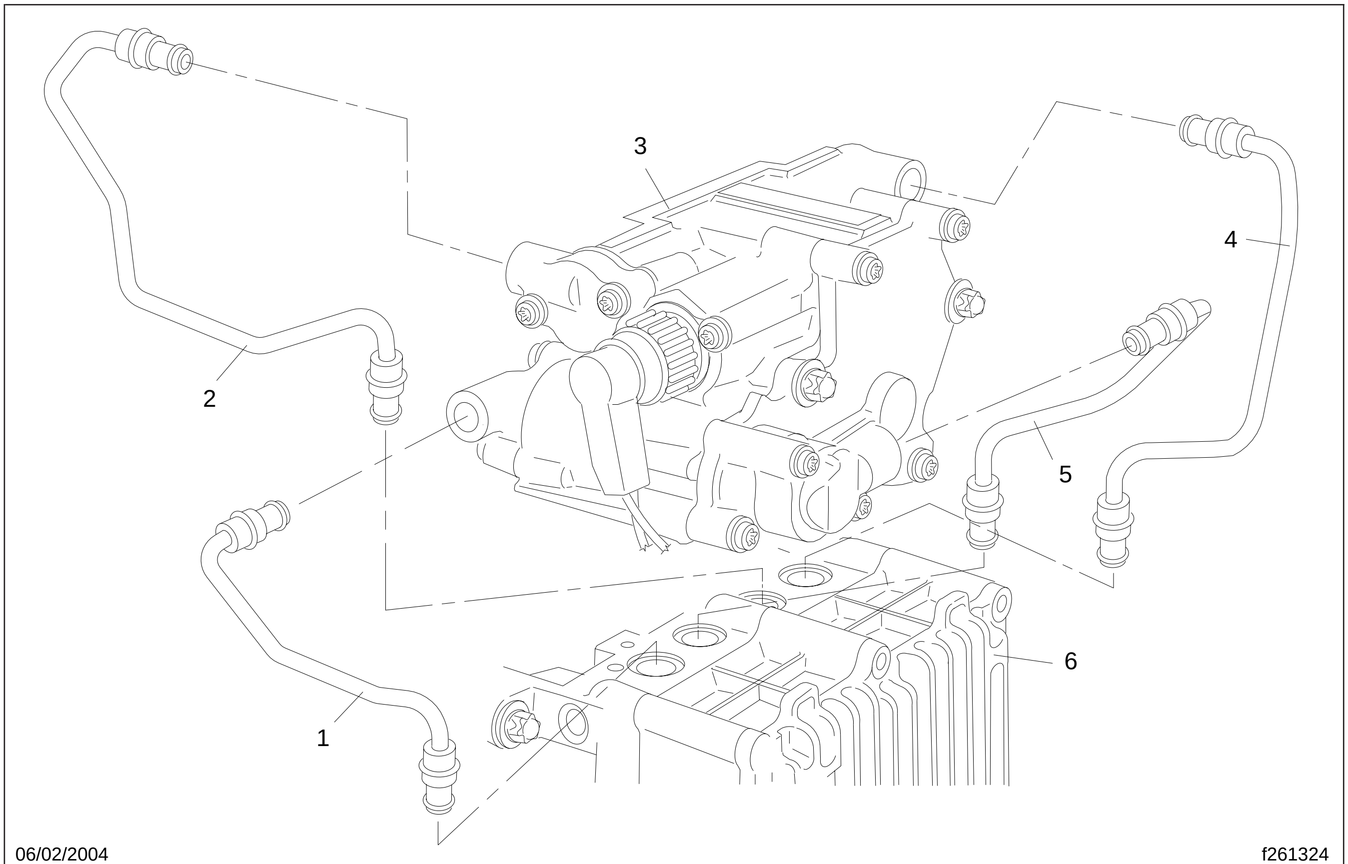
NOTE: Make sure the actuator is seated firmly on the mounting flange. Do not use the mounting capscrews to pull the actuator into position.

7. Install the four M8 mounting capscrews finger-tight in the actuator. Make sure they are firm all around. Then tighten them 17 lbf·ft (23 N·m).

CAUTION

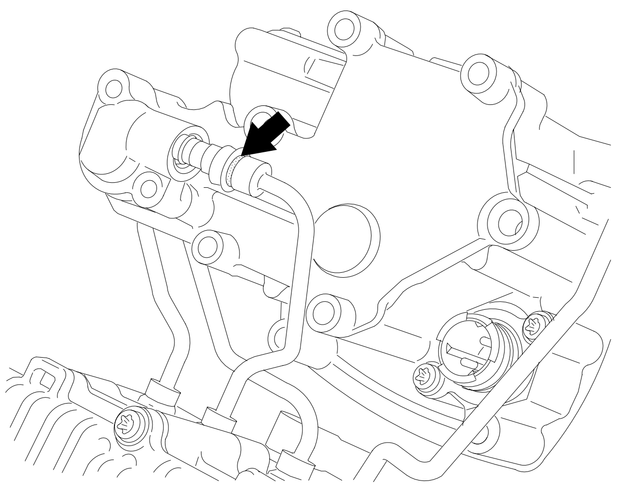
Do not twist or bend the hydraulic lines. This will make installation more difficult and could damage the lines.

8. Install the hydraulic lines in the actuator, as removed. See **Fig. 2**.
   - 8.1 The lines snap into place with an audible click. When the installation is correct, the outermost O-ring is no longer visible. See **Fig. 3**.
   - 8.2 Tug lightly on each line to make sure it is locked in place.
9. Install the connectors for the two position sensors on the actuator.
10. Install the AGS assembly on the transmission. For detailed procedures, see **Subject 200**.
11. Install the transmission on the vehicle. For detailed procedures, see **Subject 100**.



1. Rail Select Line (high)
2. Gear Select Line (fore)
3. X-Y Actuator
4. Gear Select Line (aft)
5. Rail Select Line (low)
6. Hydraulic Body

Fig. 2, Install the Hydraulic Lines



The outermost O-ring (arrow) is not visible when the line is installed correctly.

Fig. 3, Snap the Lines Into Place

12. Start the engine and allow the system to pressurize. Shift back and forth a few times from drive to reverse and back to neutral.

NOTE: The first few shifts after draining and refilling the hydraulic system will take longer than usual.

13. Check the hydraulic system for leaks and repair if necessary. When done, shut down the engine.
14. Check the hydraulic fluid level and add more Pentosin as needed. For detailed procedures, see **Subject 150**.

IMPORTANT: Use only Pentosin in the hydraulic reservoir. No other fluid can be substituted.

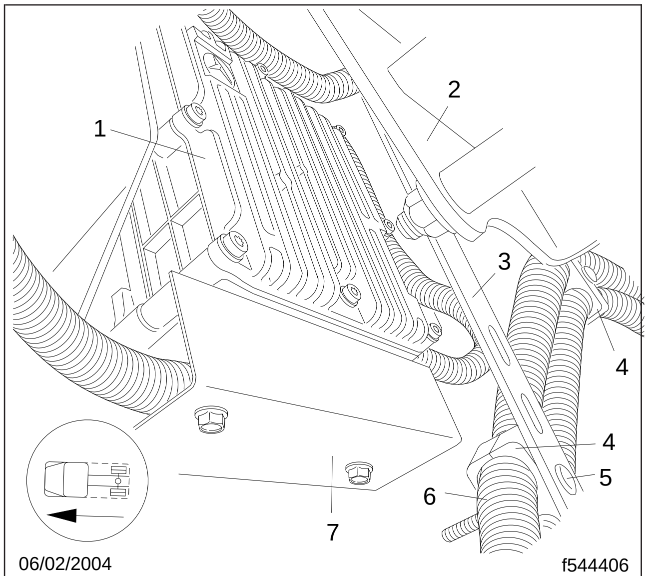
15. Remove the chocks from the rear tires.

AGS Transmission Harness Replacement

Replacement

NOTE: This procedure can be done with the transmission either installed on, or removed from, the vehicle.

1. Disconnect the batteries.
2. Remove the two mounting capscrews that attach the splash guard to the TCU. See **Fig. 1**.



1. TCU
2. Front Hanger Bracket
3. Cable Bracket
4. Cable Clamp
5. Clamp Mounting Bolt
6. Battery Cable
7. Splash Guard

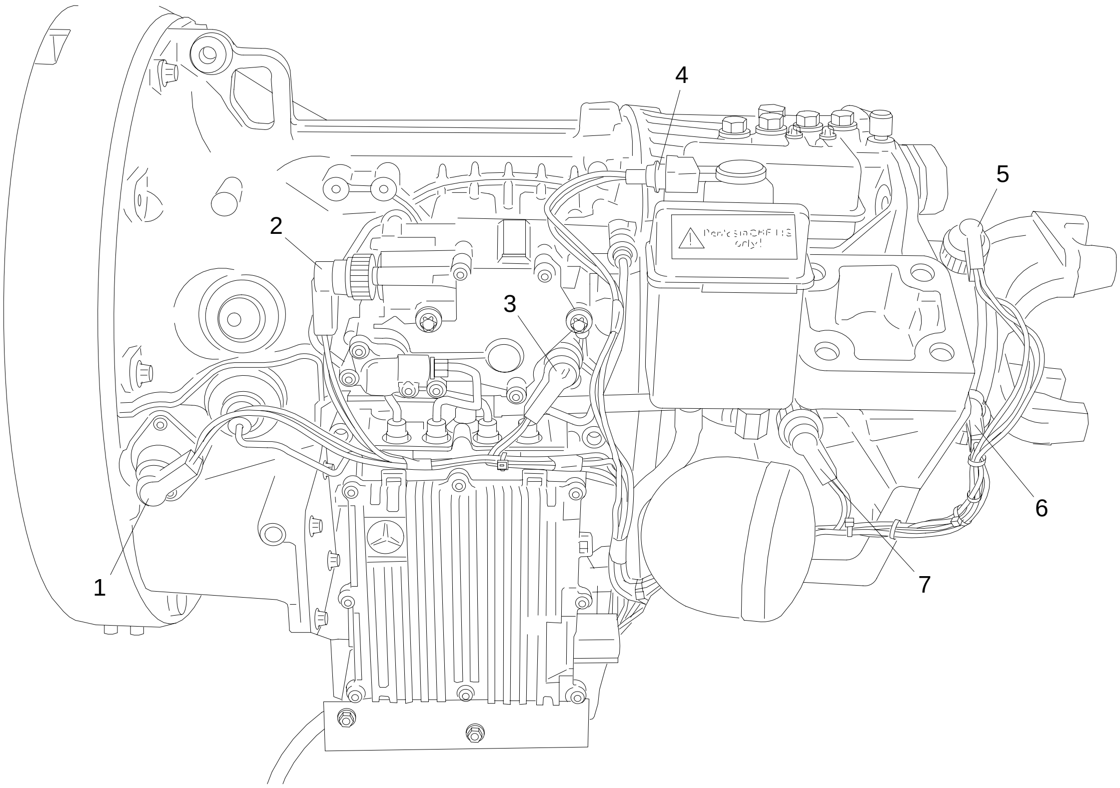
Fig. 1, Area of TCU

3. Remove the X2 (transmission) connector from the transmission control unit (TCU).
4. Unscrew the electrical connector cap from the clutch position sensor plug on the bell housing. See **Fig. 2**. Mark the cap of the connector and the plug with a paint pen.
5. Remove the electrical connector from the reservoir cap.
   - 5.1 Insert a small screwdriver into the opening at the top of the connector.
   - 5.2 Pull back (aft) on the clip until it releases. A click can be heard when it releases.
   - 5.3 Remove the connector from the plug on the reservoir cap.
6. Unscrew the electrical connectors from the gear and rail position sensors on the x-y actuator. Mark the cap and plug of each connector with a paint pen.
7. Unscrew the electrical connector from the input shaft speed sensor on the left-hand side of the rear gear case just aft of the accumulator. Mark the cap and plug of the connector with a paint pen.
8. Unscrew the electrical connectors from the two output shaft speed sensors on the aft end of the rear gear case. Mark the cap and plug of each connector with a paint pen.
9. Cut tie straps as needed to remove the harness from the transmission.

IMPORTANT: Be careful to color-code each connector. If the connectors are not installed in the correct locations, the transmission will not operate properly.

10. Lay the old harness next to the new harness on a table. Match up each connector on the new harness with the corresponding connector on the old harness. Use paint pens to mark each connector on the new harness with the color of its corresponding connector on the old harness.
11. Install the X2 (transmission) connector on the aft side of the TCU. Make sure the yellow safety slide snaps into place.
12. Install the two mounting capscrews that attach the splash guard to the TCU.
13. Install the new harness, matching each connector by color. Install new tie straps as needed.
14. Connect the batteries. Start the engine and check the electrical system for proper operation.

AGS Transmission Harness Replacement



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1. Clutch Position Sensor
2. Gear Position Sensor
3. Rail Position Sensor
4. Fluid Level Sensor
5. Output Shaft Speed Sensor #1
6. Output Shaft Speed Sensor #2
7. Input Shaft Speed Sensor

Fig. 2, Transmission Sensors

Special Tool

A special tool is required for this procedure. See **Table 1**.

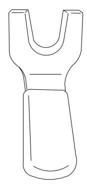
Special Tool for X-Y Actuator Replacement			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580379	High-Pressure Line Disconnect Tool	Kent-Moore	J-47201

Table 1, Special Tool for X-Y Actuator Replacement

Replacement

1. Shut down the engine, set the parking brake and chock the rear tires.

NOTE: Replacement of the x-y actuator requires removing the transmission from the vehicle.

2. Remove the transmission from the vehicle. For detailed procedures, see **Subject 100**.

IMPORTANT: Depressurize the hydraulic system before replacing any hydraulic components.

3. If not already done, depressurize the hydraulic system. For detailed procedures, see **Subject 160**.
4. Remove the AGS assembly from the transmission. For detailed procedures, see **Subject 200**.

CAUTION

Make sure the AGS assembly is well supported before working on the hydraulic lines. If necessary, call another person to help support it. The weight of the assembly components could cause damage to the lines.

5. Before starting the replacement procedure, clean all screws and fittings by spraying with a light penetrating oil.
6. Using the high-pressure hydraulic line disconnect tool (**Table 1**), remove the four high-pressure hydraulic lines from the x-y actuator. For procedures, see **Subject 170**.

CAUTION

Be careful not to bend or damage the lines or the O-rings when removing them.

NOTE: The central unit has two parts: in front is the transmission control unit (TCU), and behind it is the hydraulic body.

7. Still using the high-pressure hydraulic line disconnect tool, remove the high-pressure hydraulic lines from the central unit. See **Fig. 1**.

   NOTE: There are five lines that connect to the hydraulic body of the central unit. One line connects to the clutch and four lines connect to the x-y actuator.

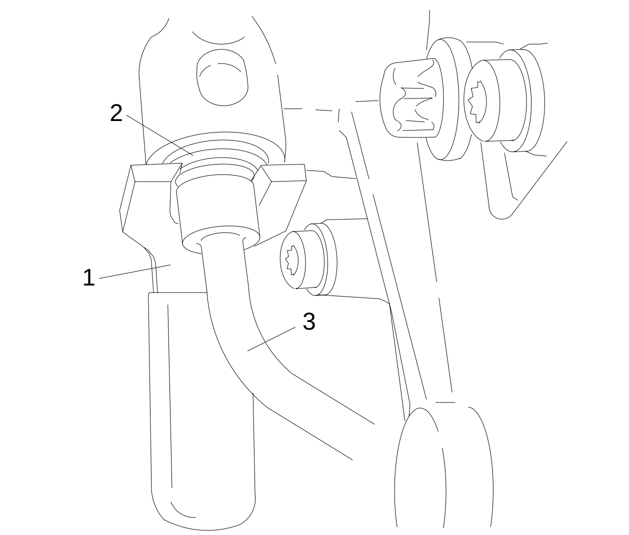
   7.1 Mark each line and attachment point with a paint pen for ease of installation. On the top of the hydraulic body, remove the outer lines first.

   IMPORTANT: Don't use the tool as a lever. Work it in until it is fully engaged and then wiggle until the line comes free.

   7.2 Place the high-pressure line tool in front of the metal ring. Press down to compress the locking device, and then pull outward and shake the tool slightly until the line comes free.

   7.3 Once all the lines are unlocked, carefully separate the central unit from the rest of the AGS assembly.

AGS Central Unit Replacement



1. High-Pressure Line Disconnect Tool
2. Metal Ring
3. High-Pressure Hydraulic Line

Fig. 1, Using the High-Pressure Line Disconnect Tool

CAUTION

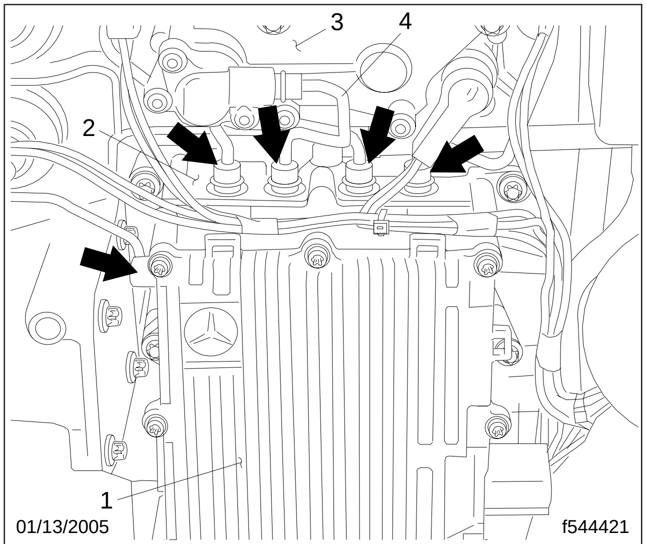
Do not twist or bend the hydraulic lines. This will make installation more difficult and could damage the lines.

8. Install the hydraulic lines in the central unit, as removed. See **Fig. 2**.

   8.1 The lines snap into place with an audible click. When the installation is correct, the outermost O-ring is no longer visible. See **Fig. 3**.

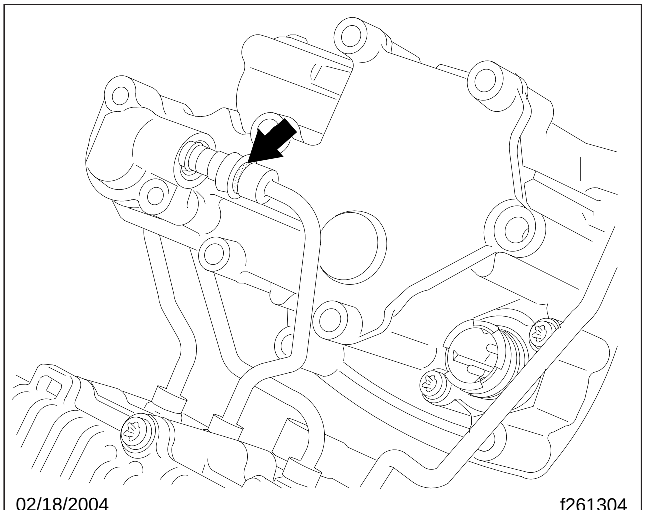
   8.2 Tug lightly on each line to make sure it is locked in place.

9. Install the high-pressure hydraulic lines on the x-y actuator, as removed. For procedures, see **Subject 170**.
10. Install the AGS assembly on the transmission. For detailed procedures, see **Subject 200**.
11. Install the transmission on the vehicle. For detailed procedures, see **Subject 100**.
12. Start the engine and allow the system to pressurize. Shift back and forth a few times from drive to reverse and back to neutral.



1. TCU
2. Hydraulic Body
3. X-Y Actuator
4. Hydraulic Line

Fig. 2, Hydraulic Lines on the Central Unit



The outermost O-ring (arrow) is not visible when the line is installed correctly.

Fig. 3, Snap the Lines Into Place

NOTE: The first few shifts after draining and refilling the hydraulic system will take longer than usual.

13. Check the hydraulic system for leaks and repair if necessary. When done, shut down the engine.

14. Check the hydraulic fluid level and add more Pentosin as needed. For detailed procedures, see **Subject 150**.

IMPORTANT: Use only Pentosin in the hydraulic reservoir. No other fluid can be substituted.

15. Remove the chocks from the rear tires.

AGS Assembly Removal and Installation

Special Tools

Special tools are required for this procedure. See **Table 1**.

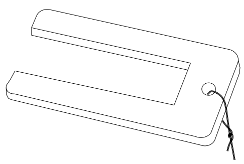
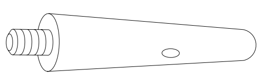
Special Tools for AGS Assembly Installation			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580380	Shift Finger Alignment Fork	Kent-Moore	J-47204
 f580382	Shift Mechanism End Guide	Kent-Moore	J-47203

Table 1, Special Tools for AGS Assembly Installation

Removal

1. Shut down the engine, set the parking brake and chock the rear tires.

NOTE: Replacement of the AGS assembly requires removing the transmission from the vehicle.

2. Remove the transmission from the vehicle. For detailed procedures, see **Subject 100**.

IMPORTANT: Depressurize the hydraulic system before replacing any hydraulic components.

3. If not already done, depressurize the hydraulic system. For detailed procedures, see **Subject 160**.
4. Remove the two mounting capscrews attaching the splash guard to the transmission control unit (TCU). See **Subject 110** for instructions.
5. Disconnect the X1 (main vehicle) and X3 (electric motor) electrical connectors from the base and aft side of the TCU. Mark both the cap and plug of the connector with a paint pen for ease of installation. Remove tie straps and clamps as needed.
6. Remove the electrical connectors from the clutch position sensor at the bell housing, and from the three speed sensors on the rear gear case. Mark both the cap and plug of the connector with a paint pen for ease of installation.
7. Remove the high-pressure clutch hydraulic line from the bell housing. For procedures, see **Subject 120**.
8. Remove the accumulator. For detailed procedures, see **Subject 140**.
9. Remove the hydraulic fluid reservoir. For detailed procedures, see **Subject 150**.

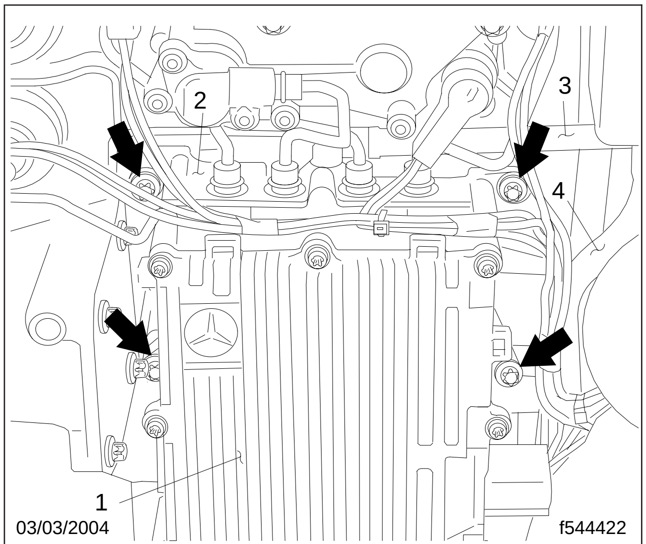
NOTE: The central unit has two parts: in front is the TCU and behind it is the hydraulic body.

10. Remove the four inverted-Torx® capscrews that attach the central unit to the transmission. See **Fig. 1**. See **Fig. 2**.
11. Remove the four inverted-Torx capscrews that attach the x-y actuator to the transmission. See **Fig. 2**.

NOTE: The two upper capscrews are 110 mm long; the two lower capscrews are 60 mm long.

12. Remove the x-y actuator assembly from the front gear case.

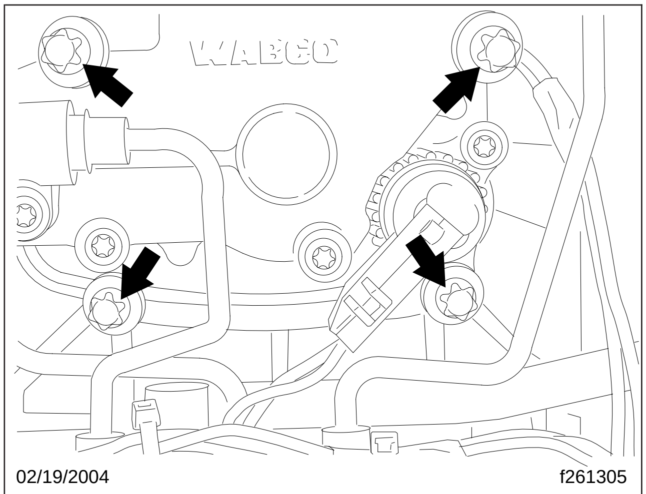
AGS Assembly Removal and Installation



Remove the four inverted-Torx capscrews (arrows) that attach the central unit to the transmission.

1. Transmission Control Unit (TCU)
2. Hydraulic Body
3. Low-Pressure Return Hose
4. Low-Pressure Supply Hose

Fig. 1, AGS Central Unit Mounting Capscrews

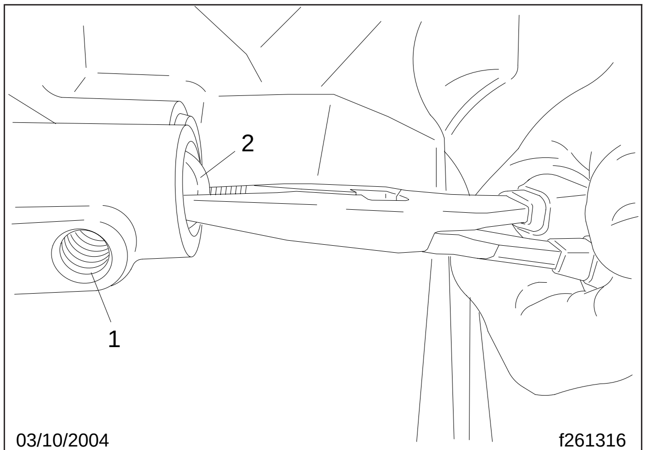


Remove the four large inverted-Torx capscrews (arrows) that attach the x-y actuator to the transmission.

Fig. 2, X-Y Actuator Mounting Capscrews

12.1 From the right-hand side of the transmission, remove the setscrew that holds the end of the shift rod.

12.2 Remove the sheet metal shift cover at the end of the shift cover housing. See **Fig. 3**. Tap the shift cover with a drift to dislodge it, and then pull it out of the shift cover housing with pliers. Discard this shift cover.



1. Setscrew Hole
2. Shift Cover

Fig. 3, Removing the Shift Cover

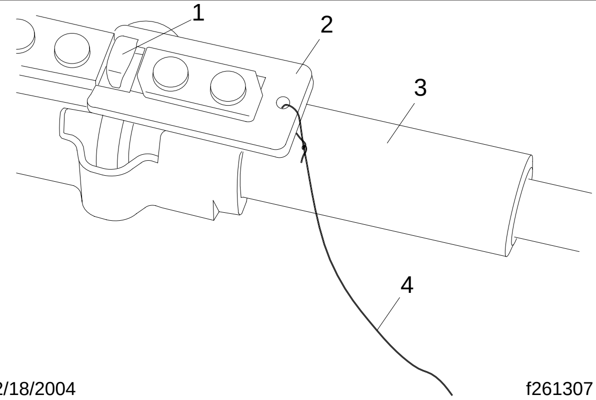
12.3 Pull the actuator assembly, complete with the shift rod, out of the front gear case.

IMPORTANT: If there is difficulty in separating the x-y actuator from the gear case, install the shift mechanism end guide on the end of the shift rod. Then use a rubber mallet to pound gently on the end guide until the actuator comes free.

13. Carefully remove the entire AGS assembly from the transmission.
14. If necessary due to wear, file around the setscrew bore at the end of the shift rod. When finished filing, be sure to remove any metal scraps, shavings, or other residue.

Installation

1. Using the shift finger alignment fork (**Table 1**), align the shift finger. See **Fig. 4**. Leave the fork in place until the shift rod is installed in the front gear case. Screw the shift mechanism end guide (**Table 1**) onto the shift rod.



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1. Shift Finger
2. Alignment Fork
3. Shift Rod
4. Removal Cord

Fig. 4, Align the Shift Finger

NOTE: Turn the shift rod to make sure the countersunk bore for the setscrew is rotated at a 90-degree angle away from the shift finger.

2. Install the actuator assembly in the front gear case.

2.1 Clean the mating surface between the actuator assembly and the front gear case. Coat the mating surface with Loctite® 509 or equivalent sealing compound.

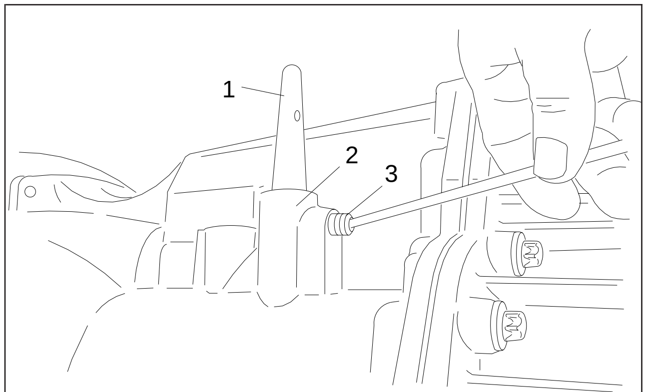
2.2 Insert the actuator assembly into the front gear case. Make sure that the removal cord attached to the end of the alignment fork is accessible.

NOTE: For ease of entry, it helps to tip the shift fork slightly downwards and to the rear.

2.3 When the shift rod is in far enough to engage the shift finger, there will be about a two-inch (50-mm) gap between the back of the x-y actuator and the mating surface on the front gear case. Use the removal cord to pull out the alignment fork.

2.4 Set the x-y actuator against the mating surface. If necessary, turn the shift rod in a clockwise direction until the setscrew bore is visible through the hole provided.

2.5 Install the M12 setscrew in the countersunk bore in the shift rod, but do not tighten it yet. See **Fig. 5**.



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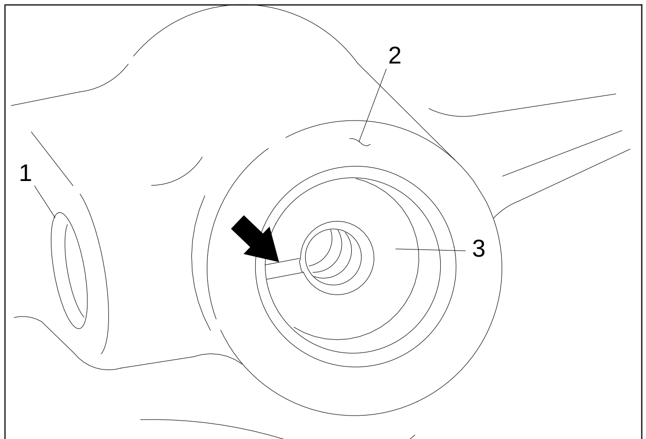
1. End Guide
2. Shift Cover Housing
3. Setscrew

Fig. 5, Install the Setscrew

2.6 When the shift rod is all the way in, unscrew the end guide.

2.7 Turn the shift rod until the indent on the end of the shift rod is at the 9 o'clock position. See **Fig. 6**.



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The indent (arrow) must be at the 9 o'clock position.

1. Setscrew Hole
2. Shift Cover Housing
3. End of Shift Rod

Fig. 6, Indent at Shift Rod End

2.8 Before tightening, make sure the setscrew is firmly seated in the shift rod. Tighten the setscrew 22 lbf·ft (30 N·m).

AGS Assembly Removal and Installation

2.9 Press a new shift cover onto the shift cover housing.

3. Install the hydraulic fluid reservoir. For detailed procedures, see **Subject 150**.
4. Install the accumulator. For detailed procedures, see **Subject 140**.
5. Install the high-pressure clutch hydraulic line, as removed.
6. Coat the threads of the four inverted-Torx actuator mounting capscrews with Loctite 509 or equivalent thread-locking compound. Install the four capscrews on the x-y actuator and tighten them 17 lbf·ft (23 N·m).
7. Coat the threads of the four inverted-Torx central unit mounting capscrews with Loctite 509 or equivalent thread-locking compound. Install the four capscrews on the central unit and tighten them 17 lbf·ft (23 N·m).
8. Connect all the electrical connectors, as removed.
9. Bleed the hydraulic system. For procedures, see **Subject 130**.
10. Add Pentosin as needed until the level reaches the joint between the upper and lower sections of the reservoir. For detailed procedures, see **Subject 150**.

IMPORTANT: Use only Pentosin in the hydraulic reservoir. No other fluid can be substituted.

11. Install the splash guard before installing the transmission. Tighten the mounting screws 17 lbf·ft (23 N·m). See **Subject 110** for instructions.
12. Install the transmission on the vehicle. For detailed procedures, see **Subject 100**.
13. Start the engine and allow the system to pressurize. Shift back and forth a few times from drive to reverse and back to neutral.

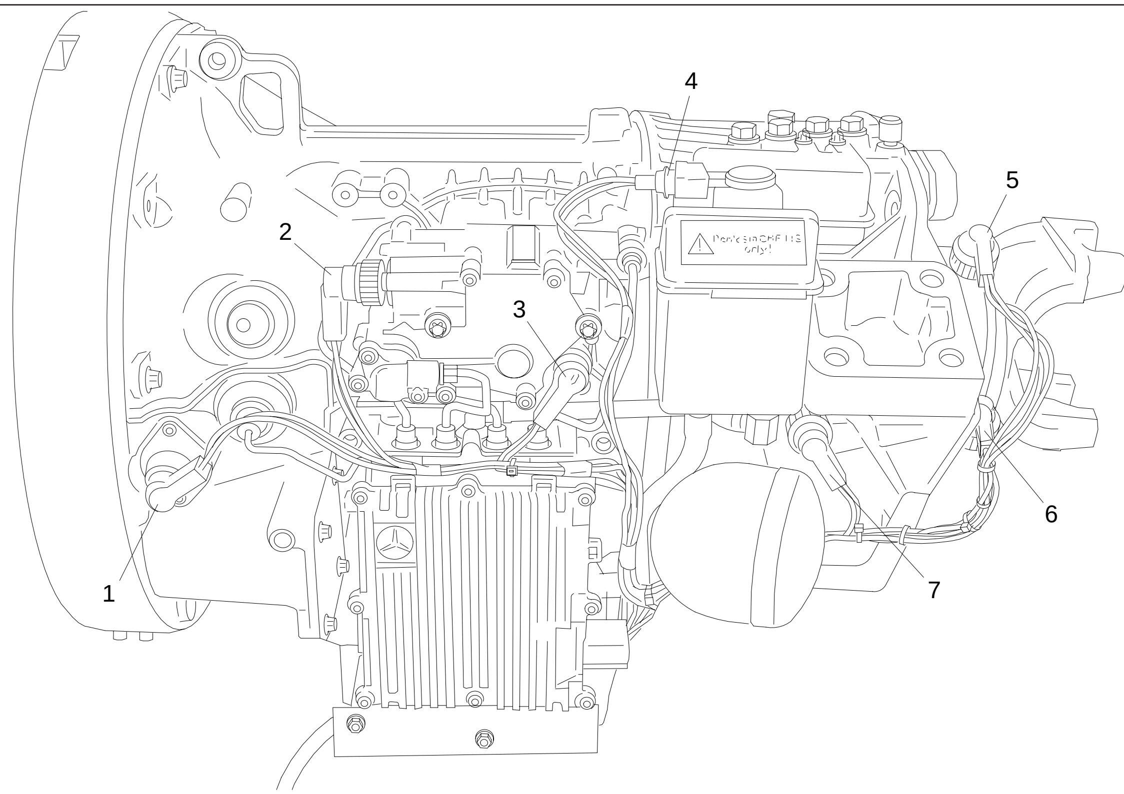
NOTE: The first few shifts after draining and refilling the hydraulic system will take longer than usual.

14. Check the hydraulic fluid level and add more Pentosin as needed. For detailed procedures, see **Subject 150**.
15. Check the hydraulic system for leaks and repair if necessary. When done, shut down the engine.
16. Remove the chocks from the rear tires.

Replacement

NOTE: Replacement of the clutch actuator requires removing the transmission from the vehicle.

1. Remove the transmission from the vehicle. For detailed procedures, see **Subject 100**.
2. If not already done, depressurize the hydraulic system. For detailed procedures, see **Subject 160**.
3. Unlock the electrical connector cap from the clutch position sensor. See **Fig. 1**. Turn the lock collar on the connector plug 90 degrees counterclockwise and remove it. Then remove the connector plug and the position sensor wire from the bell housing.
4. Loosen the clutch actuator mounting capscrews, but do not remove them yet.
5. Lift up the spring clip from the hydraulic line and carefully pull the hydraulic line straight out, using a minimum of force. See **Fig. 2**.
6. Remove the clutch actuator (release bearing housing and concentric slave cylinder). See **Fig. 3**.
   - 6.1 Remove both 30-mm hexhead hydraulic fittings from the bell housing.
   - 6.2 Remove the clutch actuator mounting capscrews that attach the clutch actuator to the bell housing.
   - 6.3 Slide the clutch actuator off the transmission input shaft.



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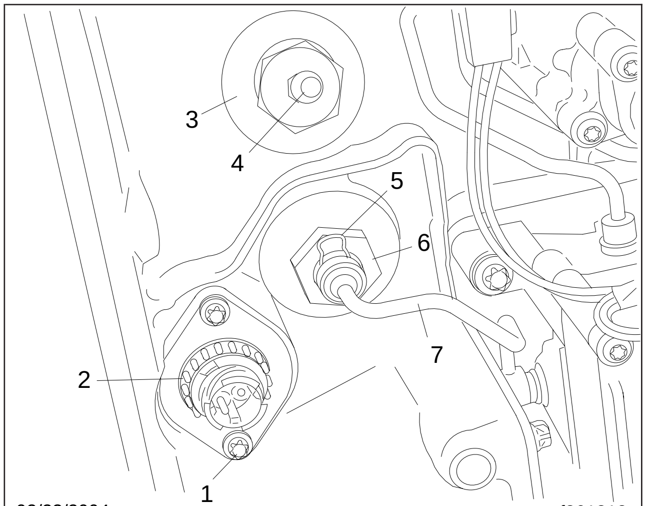
1. Clutch Position Sensor
2. Gear Position Sensor
3. Rail Position Sensor
4. Fluid Level Sensor
5. Output Shaft Speed Sensor #1
6. Output Shaft Speed Sensor #2
7. Input Shaft Speed Sensor

Fig. 1, Transmission Sensors

Clutch Actuator Replacement



1. Mounting Plate Capscrew
2. Connector Plug
3. 30-mm Hexhead Hydraulic Bleed Fitting
4. Bleed Screw
5. Spring Clip
6. 30-mm Hexhead Hydraulic Pressure Fitting
7. Hydraulic Line

Fig. 2, Clutch Components on Bell Housing

7. Slide the clutch actuator onto the input shaft. Install the clutch actuator on the bell housing.

    7.1 Install new clutch actuator mounting capscrews and tighten 17 lbf·ft (23 N·m).

    IMPORTANT: Do not use Loctite® or sealant on these fasteners.

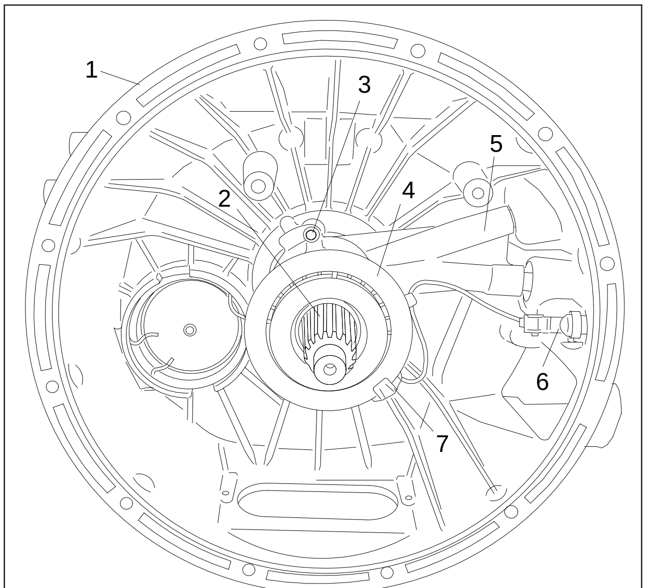
    7.2 Connect the hydraulic line and the fitting that attaches it to the bell housing. Make sure the spring clip engages properly.

    7.3 Install the bleed screw and the fitting that attaches it to the bell housing.

    7.4 Attach the sensor wire, connector, and connector plug assembly to the bell housing. Lock the electrical connector cap onto the connector plug.

    7.5 Tighten all hydraulic fittings 37 lbf·ft (50 N·m).

8. Install the transmission in the vehicle. For detailed procedures, see **Subject 100**.



1. Lip of Bell Housing
2. Input Shaft
3. Clutch Actuator Mounting Capscrew
4. Release Bearing Housing
5. Concentric Slave Cylinder
6. Position Sensor Connector
7. Clutch Position Sensor

Fig. 3, Clutch Actuator

IMPORTANT: Always use ServiceLink when attempting to diagnose problems with the AGS (Automated Gear Shift) transmission.

How To Start

To gain a baseline for troubleshooting when there is no definite problem, when the malfunction is erratic or intermittent, or to determine the general health of the electrical system, start with the electrical pre-test in **Subject 301**.

In a few cases there will be a definite problem and no J1587 fault code will be sent (engine will not crank, no information on gear display, fluid level fault). For these problems, see the appropriate table in **Subject 301**.

But in most cases, the J1587 fault code is the starting point for the troubleshooting procedures. See **Table 1** to find information for SID fault codes. See **Table 2** to find information for PID fault codes.

Before starting any procedures, use ServiceLink to depressurize the AGS hydraulic system. For detailed procedures, see **Subject 160**.

Fault Code Guide

To troubleshoot a given fault code, look up the subject number in **Table 1** (for SIDs) and **Table 2** (for PIDs). Follow the procedures for that fault code until the fault is corrected.

Fault Code Guide (MID 130 SIDs)				
SID	**FMI**	**Text Message**	**Failure Reason**	**Procedure**
18	02	Prim Selector Erratic	The shift lever does not shift gears.	See **Subject 302**.
33	03	MultiPress Ind Short Hi	The hydraulic pressure sensor circuit is shorted to power.	See **Subject 303**.
33	04	MultiPress Ind Short Lo	The hydraulic pressure sensor circuit is shorted to ground.	See **Subject 303**.
33	05	MultiPress Ind OPEN	The hydraulic pressure sensor circuit is open.	See **Subject 303**.
52	05	Hydraulic Sys OPEN	The hydraulic pump circuit is open.	See **Subject 304**.
52	07	Hydraulic Sys NoRESPONSE	The hydraulic pressure does not increase even though the hydraulic pump is activated.	See **Subject 304**.
52	11	Clutch Act Not Known	The hydraulic pump temperature is too high.	See **Subject 304**.
55	00	Clutch Act HIGH	The clutch is too hot.	See **Subject 305**.
55	07	Clutch Act NoRESPONSE	The clutch does not operate properly.	See **Subject 305**.
55	13	Clutch Act Calibrate	The clutch needs to be calibrated.	See **Subject 305**.
231	02	SAE J1939 Datalink Erratic	The J1939 datalink is not communicating properly.	See **Subject 306**.
231	09	SAE J1939 Datalink UPDATE	The J1939 datalink has timed out.	See **Subject 306**.
231	12	SAE J1939 Datalink Bad	The J1939 datalink is not communicating with the transmission.	See **Subject 306**.
251	00	POWER SUPPLY HIGH	The power supply voltage is too high.	See **Subject 307**.
251	01	POWER SUPPLY Low	The power supply voltage is too low.	See **Subject 307**.
251	05	POWER SUPPLY OPEN	There is no power to the transmission with the engine running.	See **Subject 307**.
251	14	POWER SUPPLY RSRVD	The power supply is not properly grounded.	See **Subject 307**.
253	02	Calibration Memory Erratic	The transmission needs to be recalibrated.	See **Subject 308**.
253	12	Calibration Memory Bad	The transmission needs to be recalibrated.	See **Subject 308**.
253	13	Calibration Memory Calibrate	The transmission needs to be recalibrated.	See **Subject 308**.
253	14	Calibration Memory RSRVD	The transmission needs to be recalibrated.	See **Subject 308**.

General Troubleshooting

Fault Code Guide (MID 130 SIDs)				
SID	FMI	Text Message	Failure Reason	Procedure
254	04	Controller Short Lo	The TCU is shorted to ground.	See **Subject 309**.
254	05	Controller OPEN	The TCU has an open circuit.	See **Subject 309**.
254	11	Controller Not Known	The TCU AUTO mode software module has an error.	See **Subject 309**.
254	12	Controller Bad	The TCU has a hardware problem.	See **Subject 309**.
254	13	Controller Calibrate	The TCU has a software memory problem.	See **Subject 309**.

Table 1, Fault Code Guide (SIDs)

Fault Code Guide (MID 130 PIDs)				
PID	FMI	Text Message	Failure Reason	Procedure
33	02	Erratic	The clutch position sensor gives invalid data.	See **Subject 310**.
33	03	Short Hi	The clutch position sensor circuit is shorted to power.	See **Subject 310**.
33	04	Short Lo	The clutch position sensor circuit is shorted to ground.	See **Subject 310**.
33	05	OPEN	The clutch position sensor circuit is open.	See **Subject 310**.
33	14	RSRVD	The clutch position sensor gives incorrect resistance readings.	See **Subject 310**.
59	02	Shift FNGR Gear Erratic	The shift rod position sensor gives invalid data.	See **Subject 311**.
59	03	Shift FNGR Gear Short Hi	The gear position sensor circuit is shorted to power.	See **Subject 311**.
59	04	Shift FNGR Gear Short Lo	The gear position sensor circuit is shorted to ground.	See **Subject 311**.
59	05	Shift FNGR Gear OPEN	The gear position sensor circuit is open.	See **Subject 311**.
59	14	Shift FNGR Gear RSRVD	The gear position sensor gives incorrect resistance readings.	See **Subject 311**.
60	02	Shift FNGR Rail Erratic	The rail position sensor circuit gives invalid data.	See **Subject 312**.
60	03	Shift FNGR Rail Short Hi	The rail position sensor circuit is shorted to power.	See **Subject 312**.
60	04	Shift FNGR Rail Short Lo	The rail position sensor circuit is shorted to ground.	See **Subject 312**.
60	05	Shift FNGR Rail OPEN	The rail position sensor circuit is open.	See **Subject 312**.
60	14	Shift FNGR Rail RSRVD	The rail position sensor gives incorrect resistance readings.	See **Subject 312**.
64	09	Dir Switch Update	The output shaft speed sensor is not providing accurate directional information.	See **Subject 313**.
64	11	Dir Switch Not Known	The output shaft speed sensor is not providing accurate directional information.	See **Subject 313**.
158	00	Volts (BattSw) HIGH	The voltage in the ignition power circuit is too high.	See **Subject 314**.
158	01	Volts (BattSw) Low	The voltage in the ignition power circuit is too low.	See **Subject 314**.
161	02	In shaft SPEED Erratic	The input shaft speed sensor circuit gives invalid data.	See **Subject 315**.
161	03	In shaft SPEED Short Hi	The input shaft speed sensor circuit is shorted to power.	See **Subject 315**.
161	04	In shaft SPEED Short Lo	The input shaft speed sensor circuit is shorted to ground.	See **Subject 315**.
161	05	In shaft SPEED OPEN	The input shaft speed sensor circuit is open.	See **Subject 315**.
161	08	In shaft SPEED Update	The input shaft speed sensor circuit is broadcasting an abnormal frequency.	See **Subject 315**.

Fault Code Guide (MID 130 PIDs)				
PID	**FMI**	**Text Message**	**Failure Reason**	**Procedure**
162	02	RANGE Selected Erratic	The transmission is not properly calibrated.	See **Subject 316**.
163	02	RANGE Attained Erratic	The gears do not shift properly.	See **Subject 316**.
191	02	OUTPUT SPEED Erratic	One or both of the output shaft speed sensor circuits give invalid data.	See **Subject 317**.
191	05	OUTPUT SPEED OPEN	One or both of the output shaft speed sensor circuits are open.	See **Subject 317**.
191	08	OUTPUT SPEED SIGNAL	There is no signal coming from one or both output shaft speed sensors.	See **Subject 317**.
191	14	OUTPUT SPEED RSRVD	The output shaft speed sensor is providing invalid data.	See **Subject 317**.

Table 2, Fault Code Guide (PIDs)

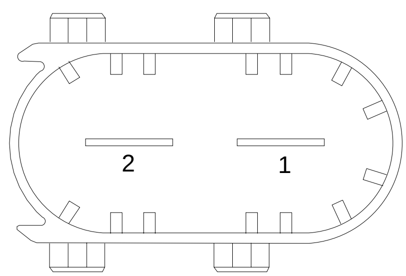
IMPORTANT: Always use ServiceLink when attempting to diagnose problems with the automated gear shift (AGS) transmission.

In most cases, the J1587 fault code is the starting point for the troubleshooting procedures. See **Subject 300** for a list of fault codes and the location of troubleshooting procedures for each code.

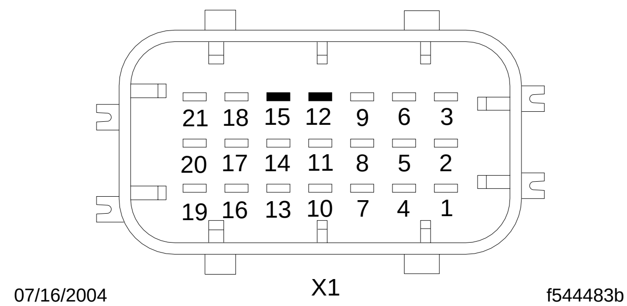
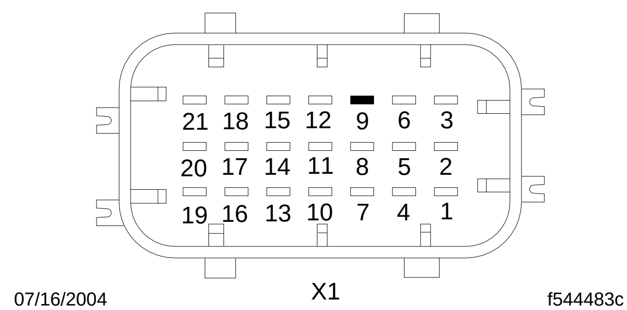
Electrical Pre-Test Instructions

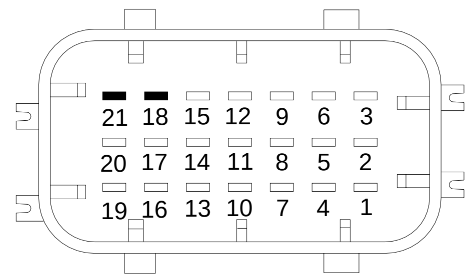
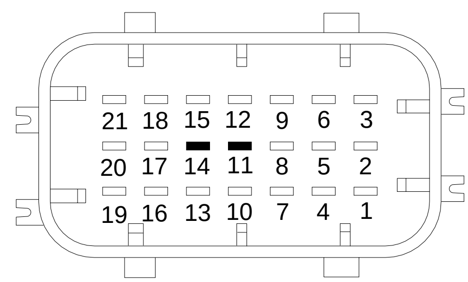
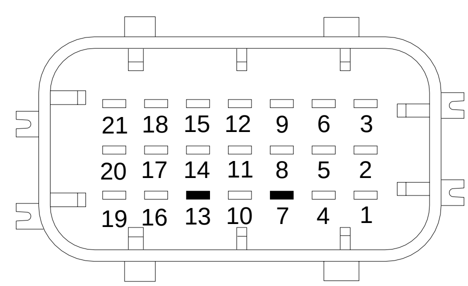
Before starting any procedures, use ServiceLink to depressurize the AGS hydraulic system. For detailed procedures, see **Subject 160**.

Use the electrical pre-test instructions given in **Table 1** as a baseline for troubleshooting when there is no definite problem, the malfunction is erratic or intermittent, or as an informational step to determine the general health of the electrical system. To record your findings, a result sheet is provided at the end of this subject. For locations of serial numbers, see **Fig. 1** and **Fig. 2**.

Electrical Pre-Test		
Procedure	**Result**	**Action**
Make sure that the selector switch on the SmartShift lever is set to N. Turn on the ignition switch to power up the transmission. NOTE: If the hydraulic pump starts up with its characteristic humming noise, this means the main power cables are OK (see the steps below to check the X3 connector).	The current gear indicator does not power up normally. No fault codes display.	Troubleshoot the current gear indicator. See **Table 4**.
	The current gear indicator goes through its normal power-up sequence, ending by displaying "N."	Turn off the ignition switch and go to the next row in the table.
With the ignition switch off, check the voltage at the battery.	Voltage is less than 11 or greater than 13 volts.	Charge or replace the battery. For battery charging procedures, see **Section 54.12**, Subject 150.
	Voltage is between 11 and 13 volts.	Go to the next row in the table.
Remove the X3 (electric motor 2-pin) connector from the transmission control unit (TCU). Check the electric motor power circuit.	 06/01/2004 X3 f544485	
Check for voltage between pin 1 (power circuit 232) of the X3 connector and the battery ground terminal.	Voltage drops more than 0.2 volts from the voltage measured at the battery.	Repair or replace the wiring as needed. See **Section 54.06**, Subject 100.
	Voltage is within 0.2 volts of the voltage measured at the battery.	Go to the next row in the table.

Troubleshooting Without Fault Codes

Electrical Pre-Test		
Procedure	**Result**	**Action**
Check for resistance between pin 2 (ground) of the X3 connector and the battery ground terminal.	Resistance is greater than 0.3 ohms.	Repair or replace the wiring as needed. See **Section 54.06**, Subject 100.
	Resistance is 0.3 ohms or less.	Go to the next row in the table.
Remove the X1 (vehicle 21-pin) connector from the transmission control unit (TCU). Check the battery power circuit.		
Check for voltage from pins 12 and 15 (battery power circuit 232D) of the X1 connector to the battery ground terminal.	Voltage drops more than 0.2 volts from the voltage measured at the battery.	Repair or replace the wiring as needed. See **Section 54.06**, Subject 100.
	Voltage is within 0.2 volts of the voltage measured at the battery.	Go to the next row in the table.
Turn on the ignition switch. Check the ignition power circuit.		
Check for voltage from pin 9 (ignition power circuit 232E) of the X1 connector to the battery ground terminal.	Voltage drops more than 0.2 volts from the voltage measured at the battery.	Repair or replace the wiring as needed. See **Section 54.06**, Subject 100.
	Voltage is within 0.2 volts of the voltage measured at the battery.	Go to the next row in the table.

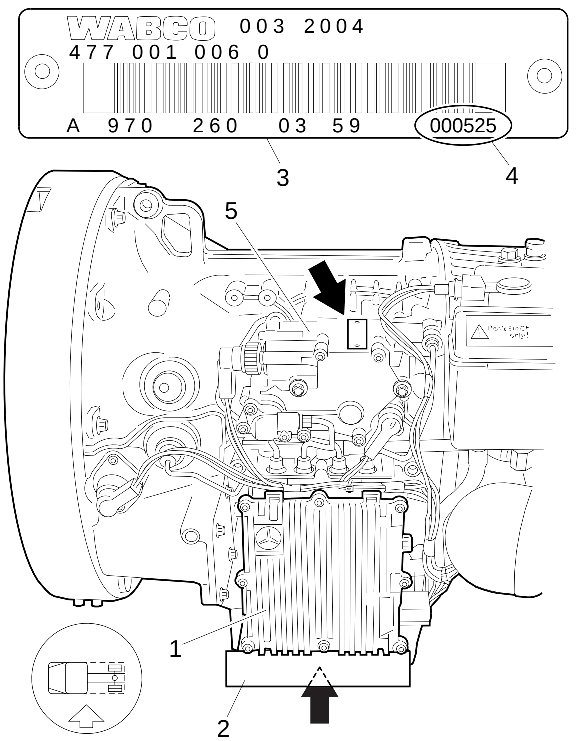
Electrical Pre-Test		
Procedure	**Result**	**Action**
Turn off the ignition switch. Check the ignition ground circuit.	 07/21/2004 X1 f544483d	
With the ignition switch off, check for resistance between pins 18 and 21 (ground) of the X1 connector and the battery ground terminal.	Resistance is greater than 0.3 ohms.	Repair or replace the wiring as needed. See **Section 54.06**, Subject 100.
	Resistance is 0.3 ohms or less.	Go to the next row in the table.
Turn off the ignition switch. Check the J1587 wiring.	 07/21/2004 X1 f544483e	
Check for DC voltage from pins 11 and 14 (J1587 datalink) of the X1 connector to the battery ground terminal. NOTE: If the meter cannot display the rapidly shifting DC voltage, measure AC voltage instead.	Voltage is less than 1 or more than 4 volt(s) for DC (less than 1 or more than 3 for AC).	Troubleshoot the J1587 datalink.
	Voltage is between 1 and 4 volts for DC (1–3 volts AC).	Go to the next row in the table.
Turn off the ignition switch. Check the J1939 wiring.	 07/16/2004 X1 f544483a	

Troubleshooting Without Fault Codes

Electrical Pre-Test		
Procedure	**Result**	**Action**
With the ignition switch off, remove the X1 connector from the TCU and check for resistance between pins 7 and 13 (J1939 datalink).	Resistance is less than 55 or greater than 65 ohms.	Troubleshoot the J1939 datalink. See Freightliner **Service Bulletin 54-133**.
	Resistance is between 55 and 65 ohms.	The vehicle has passed the electrical pre-test. Troubleshoot active fault codes, if any.

Table 1, Electrical Pre-Test

NOTE: To see the identification plate on the TCU it may be necessary to remove the splash guard.



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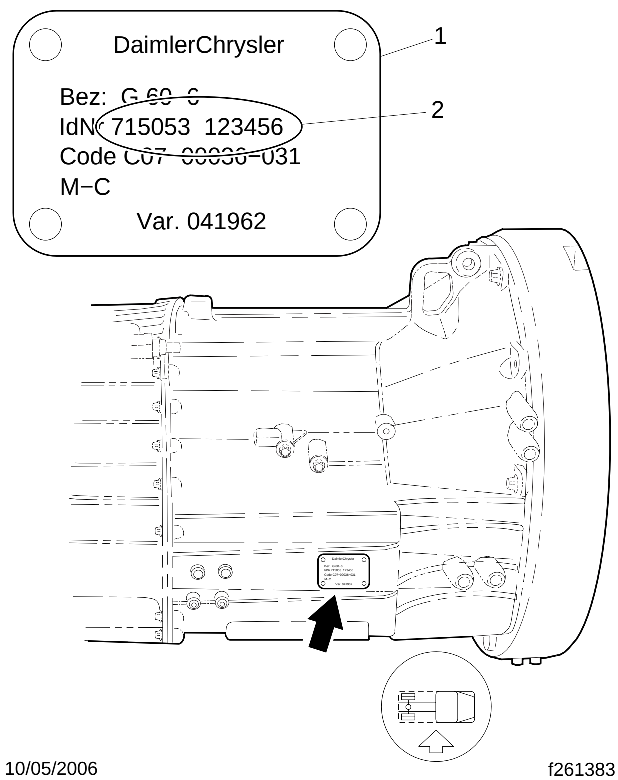
NOTE: The TCU and X-Y Actuator each have their own WABCO identification plate (arrows) with unique serial numbers.

1. TCU (Transmission Control Unit)
2. Splash Guard
3. WABCO Identification Plate
4. Serial Number
5. X-Y Actuator

Fig. 1, Serial Numbers for TCU and X-Y Actuator



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1. Transmission Identification Plate
2. Serial Number

Fig. 2, Transmission Serial Number

Troubleshooting Tables, No Fault Codes

In a few cases there will be a definite problem and no J1587 fault code will be sent.

- If the engine will not crank and there are no transmission fault codes, see **Table 2**.

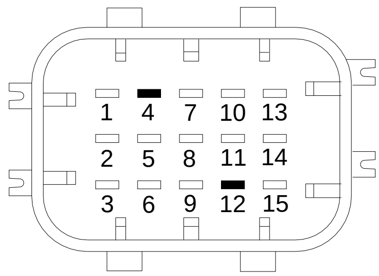
- If the current gear indicator displays "FL," and the CHECK TRANS light comes on, there is a low fluid level fault. See **Table 3**. Low fluid level faults do not generate a J1587 fault code.
- If the transmission is fully functional, but there is no information on the current gear indicator, see **Table 4**.

No J1587 Fault Code—The Engine Will Not Crank		
Procedure	**Result**	**Action**
Make sure that the selector switch on the SmartShift lever is set to N. Power up the transmission.	The current gear display shows "N."	Verify that the BHM is correctly programmed to allow for "AGS start enabling" and that the J1939 communications systems is functioning properly.
	There is a J1587 fault code in MID 128 (engine) for missing J1939 information.	Check the wiring for loose terminals and corroded connector pins.
	The gear display is blank and there is no response to the J1587 roll call. The hydraulic pump does not come on.	Check pin 9 on the X1 connector to verify the presence of ignition voltage.
	There is a J1587 roll call and it reports other ECUs but not the TCU.	Go to the next row in the table.
Remove the X1 connector and check it for bent or missing pins.	Pins are damaged or missing.	Straighten bent pins and replace a damaged connector.
	The connector is intact and serviceable.	Go to the next row in the table.
Check both transmission fuses in the bulkhead module.	Either or both fuses are blown.	Replace any blown fuses.
	The fuses are good.	Go to the next row in the table.
Check the datalink communication again.	There is no datalink communication.	Check for a wiring problem (most likely at a common connector).
	The datalink is OK.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet. See **Fig. 3**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 2, The Engine Will Not Crank

No J1587 Fault Code—"FL" on Current Gear Indicator; CHECK TRANS Light Illuminates*		
Problem	**Procedure**	**Result/Action**
The hydraulic fluid level is low.	Use ServiceLink to check the hydraulic fluid level.	If the fluid level is low, add Pentosin to the hydraulic reservoir.

Troubleshooting Without Fault Codes

No J1587 Fault Code—"FL" on Current Gear Indicator; CHECK TRANS Light Illuminates*		
Problem	**Procedure**	**Result/Action**
The fluid level sensor is defective.	Disconnect the sensor connector from the reservoir cap. Check for continuity across pins 1 and 2 of the sensor connector. NOTE: When the reservoir is full, the float in the sensor rises up, and the two pins in the connector create a complete circuit.	If no continuity, replace the sensor. See **Subject 150**.
Turn off the ignition switch. Check the fluid level sensor wiring.	 07/16/2004 X2 f544484l	
The wiring between the TCU and the fluid level sensor is defective.	Check resistance from pin 4 on the X2 connector to pin 2 on the sensor connector. Check resistance from pin 12 on the X2 connector to pin 1 on the sensor connector.	If no resistance, repair or replace the X2 transmission harness. See **Subject 180**.
There is an internal electrical failure in the TCU.	Check the TCU for leakage or damage.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet. See **Fig. 3**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

* Even though the CHECK TRANS light illuminates, it is normal to see no active fault code.

Table 3, Low Fluid Level Indication

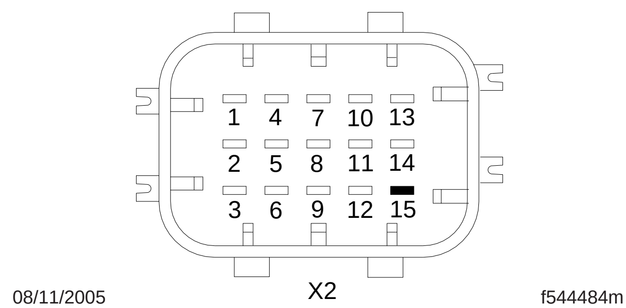
<table>
<tr><th colspan="4">No J1587 Fault Code—Transmission Fully Functional; No Information on Current Gear Indicator</th></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">The wiring from the X1 connector to the current gear indicator is defective.</td><td rowspan="2">Power up the transmission.</td><td>The current gear indicator displays "--."</td><td>Repair or replace the X1 connector harness as needed. See Section 54.06, Subject 100.</td></tr>
<tr><td>The current gear indicator displays something other than "--."</td><td>See the messages in Table 5 for possible error codes.</td></tr>
<tr><td colspan="2">Remove the X2 connector. Check the speed sensor wiring.</td><td colspan="2">
</td></tr>
<tr><td rowspan="2">The wiring from the output shaft speed sensor to the current gear indicator is shorted to ground.</td><td rowspan="2">Check the wiring between pin 15 on the X2 connector and pin 1 on both speed sensors.</td><td>Both speed sensors are shorted to ground.</td><td>Replace the X2 wiring harness. See Subject 180.</td></tr>
<tr><td>At least one speed sensor is OK.</td><td>Go to the next row in the table.</td></tr>
<tr><td rowspan="2">The wiring from the X1 connector to the J1587 datalink is defective.</td><td rowspan="2">Check for J1587 communication on ServiceLink.</td><td>AGS2 is not reporting on ServiceLink.</td><td>Repair or replace the X1 connector wiring as needed. See Section 54.06, Subject 100.</td></tr>
<tr><td>AGS2 is reporting on ServiceLink.</td><td>Go to the next row in the table.</td></tr>
<tr><td rowspan="2">The current gear indicator or its wiring is defective.</td><td rowspan="2">Check the wiring from the current gear indicator to power, ground, and the J1587 datalink.</td><td>The wiring is damaged.</td><td>Repair or replace the power, ground, or J1587 datalink wiring as needed. See Section 54.06, Subject 100.</td></tr>
<tr><td>The wiring is OK.</td><td>Replace the current gear indicator.</td></tr>
</table>

Table 4, Transmission Fully Functional; No Information on Current Gear Indicator

AGS Messages on the Current Gear Indicator	
Code	**Error**
SM	System Malfunction (this is a code that could affect driveability)
CO	Clutch Overload (clutch has begun to overheat)
FL	Low Hydraulic Fluid Level

Troubleshooting Without Fault Codes

AGS Messages on the Current Gear Indicator	
Code	**Error**
X	Undefined Gear Position
	Incomplete Calibration
	Gear or Rail Position Sensor Error
"—"	No J1587 Communication
"(blank screen)"	No Power to Gear Display
	No J1587 Communication
N	Normal Operation (neutral gear)
R	Normal Operation (reverse gear)
1-6	Normal Operation (forward gears)

Table 5, AGS Messages on the Current Gear indicator

VIN: ____________ Mileage: ____________ Date: ____________

Serial Numbers			
TCU:		X−Y Actuator:	
AGS:			

ABS Codes: (136)	SID/PID	FMI	Eng Codes: (128)	SID/PID	FMI

Pentosin level: (with system depres-surized)	Full ☐ Empty ☐	Below seam ☐ inches ☐	Above seam ☐ inches ☐	Gear display power up:	Yes ☐	No ☐	Gear display show "N":	Yes ☐	No ☐

Customer complaint description:	

Battery voltage:			Battery voltage at X3 pin 1:			Ground at X3 pin 2:	
Key power at X1 pin 9:			Battery voltage at X1 pins 12 & 15:			Ground at X1 pins 18 & 21:	
J1587 Datalink good:	OK ☐	Failed ☐	J1939 Datalink good:	OK ☐	Failed ☐		

Notes: ____

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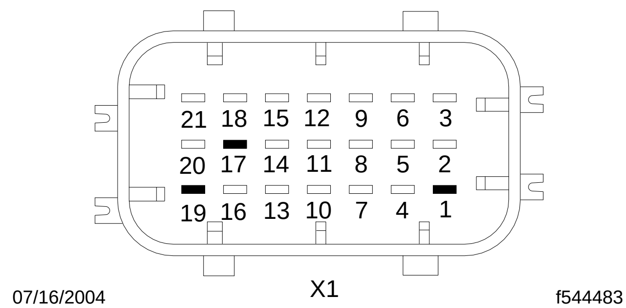
Fig. 3, Electrical Pre-Test Result Sheet

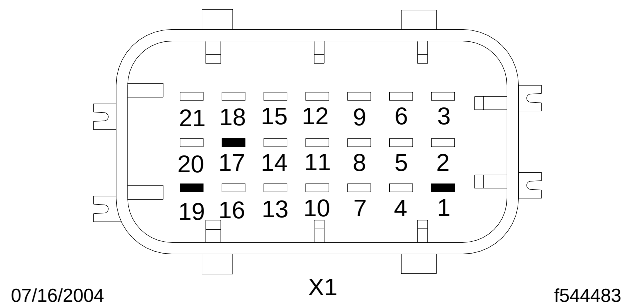
SmartShift Fault

There is one SmartShift fault covered in these procedures. In addition to the troubleshooting table, two tables of resistance values are provided.

- For SID 18, FMI 02, see **Table 1** for procedures and pin identification.
- To check resistance on the SmartShift up/downshift circuit, see **Table 2**.
- To check resistance on the SmartShift gear selection circuit, see **Table 3**.

<table>
<tr><th colspan="3">SID 18, FMI 02—The Shift Lever Does Not Shift Gears</th></tr>
<tr><td>Failure Reason:
• There is a defect in the shift lever.
• There is a defect in the wiring.
• There is a defect in the TCU.</td><td colspan="2">
</td></tr>
<tr><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">On the SmartShift control lever, move the slide switch to AUTO and the selector switch to N. Remove connector X1 from the transmission control unit (TCU). Do not remove the connector from the SmartShift lever. Check for resistance between pin 1 (circuit 464C) and pin 17 (circuit 464A).</td><td>Open circuit or value out of range</td><td>Check the wiring for loose terminals and corroded connector pins.</td></tr>
<tr><td>11K to 12K ohms</td><td>Go to the next row in the table.</td></tr>
<tr><td rowspan="2">Check for resistance between pin 1 (circuit 464C) and pin 19 (circuit 464B).</td><td>Open circuit or value out of range</td><td>Check the wiring for loose terminals and corroded connector pins.</td></tr>
<tr><td>345 to 385 ohms</td><td>Go to the next row in the table.</td></tr>
<tr><td rowspan="2">Remove the three-pin connector from the SmartShift lever. Check for resistance between pin 1 (circuit 464C) and pin 17 (circuit 464A).</td><td>Short circuit</td><td>Repair or replace the wiring as needed (see Section 54.06, Subject 100).</td></tr>
<tr><td>11K to 12K ohms</td><td>Go to the next row in the table.</td></tr>
<tr><td rowspan="2">Check for resistance between pin 1 (circuit 464C) and pin 19 (circuit 464B).</td><td>Short circuit</td><td>Repair or replace the wiring as needed (see Section 54.06, Subject 100).</td></tr>
<tr><td>345 to 385 ohms</td><td>Go to the next row in the table.</td></tr>
</table>

SmartShift Fault (SID 18)

<table>
<tr><th colspan="3">SID 18, FMI 02—The Shift Lever Does Not Shift Gears</th></tr>
<tr><td>Failure Reason:
• There is a defect in the shift lever.
• There is a defect in the wiring.
• There is a defect in the TCU.</td><td colspan="2">
</td></tr>
<tr><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">If intermittent faults persist, check resistance values at other positions of the SmartShift lever. Use the pins on the SmartShift lever connector and see Table 2 and Table 3. If available, use a SmartShift lever known to be good to check the correct resistance values.</td><td>SmartShift failure</td><td>Replace the SmartShift lever (see Section 26.02, Subject 100).</td></tr>
<tr><td>SmartShift OK</td><td>Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test.

NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test.

1. Using ServiceLink, print the AGS codes (130).

2. Complete the electrical pre-test result sheet in Subject 301.

3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).</td></tr>
</table>

Table 1, The Shift Lever Does Not Shift Gears

Resistance Check for the Up/Downshift Circuit (Pin A to Pin C)	
Slide Switch + Lever Position	**Reading: kOhm**
AUTO	10.969–12.084
MAN	2.838–3.020
MAN + Up	0.527–0.564
MAN + Down	1.142–1.213
AUTO + Up	0.611–0.653
AUTO + Down	1.628–1.729

Table 2, Resistance Check for the Up/Downshift Circuit

Resistance Check for the Gear Selection Circuit (Pin B to Pin C)	
Selector Switch Position	**Reading: kOhm**
R	2.922–3.100
N	0.342–0.389
D	0.576–0.670

Table 3, Resistance Check for the Gear Selection Circuit

Hydraulic Pressure Sensor Faults

There are three hydraulic pressure sensor faults covered in these procedures. The same troubleshooting procedure is used for all.

- For SID 33, FMI 03, FMI 04, and FMI 05, see **Table 1** for procedures.

SID 33, FMI 03, 04, 05—The Pressure Sensor Is Shorted or Open		
Failure Reason: • The contacts on the pressure sensor terminal are not straight. • There is a defect in the pressure sensor. • There is a defect in the TCU.		
Procedure	**Result**	**Action**
Do a visual check of the pressure sensor connector.	The pressure sensor contacts are bent or crooked.	Straighten any bent pins or plugs.
	The contacts are OK.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Pressure Sensor Is Shorted or Open

Hydraulic Pump Faults

There are three hydraulic pump faults covered in these procedures. FMI 05 and FMI 07 are covered by the same troubleshooting procedure.

When both fault codes (SID 52 FMI 05 and SID 52 FMI 07) are active at the same time, a wiring problem is the most likely cause.

- For SID 52, FMI 05 and FMI 07, see **Table 1** for procedures.
- For SID 52, FMI 11, see **Table 2** for procedures.

SID 52, FMI 05, 07—The Hydraulic Pump Pressure Does Not Increase

Failure Reason:

- The hydraulic fluid level is low.
- The hydraulic system is leaking.
- There is air in the hydraulic system.
- The fuse in connector X3 is blown.
- The accumulator has failed.
- The pump or pressure sensor has failed.
- The hydraulic lines are pinched, kinked, or blocked.
- The TCU has failed.

Problem	Remedy	
	Procedure	Action
The hydraulic fluid level is low.	Check the hydraulic fluid level.	Add Pentosin to the hydraulic reservoir.
There are leaks in the hydraulic system.	Do a visual check of the hydraulic system for leaks and loose fittings. Tug on all the hydraulic fittings to make sure they are properly fastened.	Replace any leaking or damaged tubing. Make sure all the hydraulic fittings are properly fastened. See **Subject 200** for procedures.
There is air in the hydraulic system.	Bleed the hydraulic system. See **Subject 130** for procedures.	Test the hydraulic pump and make sure the pressure does increase.
The hydraulic pump circuit is open.	Check the 40-amp fuse. Remove the X3 connector and check the wiring at both pins.	Replace the 40-amp fuse if necessary. Repair or replace the wiring if necessary.
The pressure accumulator has failed.	Check the pressure accumulator for leaks or damage.	Replace the pressure accumulator. See **Subject 140** for procedures.

Hydraulic Pump Faults (SID 52)

SID 52, FMI 05, 07—The Hydraulic Pump Pressure Does Not Increase		
Failure Reason: • The hydraulic fluid level is low. • The hydraulic system is leaking. • There is air in the hydraulic system. • The fuse in connector X3 is blown. • The accumulator has failed. • The pump or pressure sensor has failed. • The hydraulic lines are pinched, kinked, or blocked. • The TCU has failed.		
Problem	**Remedy**	
	Procedure	**Action**
The pump or pressure sensor has failed, or there is an internal electrical failure in the TCU.	Check the AGS central unit for leakage or damage.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Hydraulic Pump Pressure Does Not Increase

SID 52, FMI 11—The Hydraulic Pump Temperature Is Too High		
Failure Reason: • The pump motor has been operating for too long. • There has been a failure of the hydraulic system.		
Problem	**Remedy**	
	Procedure	**Action**
The pump motor is overheated.	Wait. Allow the motor to cool.	If the fault goes away, and there are no other active fault codes, no action is needed.

Hydraulic Pump Faults (SID 52)

<table>
<tr><th colspan="3">SID 52, FMI 11—The Hydraulic Pump Temperature Is Too High</th></tr>
<tr><td colspan="3">Failure Reason:
The pump motor has been operating for too long.
There has been a failure of the hydraulic system.</td></tr>
<tr><th rowspan="2">Problem</th><th colspan="2">Remedy</th></tr>
<tr><th>Procedure</th><th>Action</th></tr>
<tr><td>There has been a failure of the hydraulic system. Failure is persistent and continues under all conditions.</td><td>Check the hydraulic system for leaks and troubleshoot other fault codes.</td><td>Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test.

NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test.

1. Using ServiceLink, print the AGS codes (130).

2. Complete the electrical pre-test result sheet in Subject 301.

3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).</td></tr>
</table>

Table 2, The Hydraulic Pump Temperature Is Too High

Clutch Actuator Faults

There are three clutch actuator faults covered in these procedures. Each one requires a different troubleshooting procedure. FMI 00 is often a temporary fault that goes away when the clutch is allowed to cool.

- For SID 55, FMI 00, see **Table 1** for procedures.
- For SID 55, FMI 07, see **Table 2** for procedures.
- For SID 55, FMI 13, see **Table 3** for procedures.

SID 55, FMI 00—The Clutch Is Too Hot*

Failure Reason:

- The clutch has temporarily overheated due to excessive use.
- There is a fault in the clutch actuator sensor.
- There is a mechanical defect in the clutch system.

Problem	Procedure	Result	Action
The clutch is too hot. NOTE: Excessive clutch use may have been caused by maneuvering in heavy traffic or using the clutch to hold the truck on a hill.	Allow the clutch to cool.	Fault code goes away after clutch has cooled.	No corrective action is needed.
		Fault code does not go away after clutch has cooled.	Go to the next step in the table.
There is a problem with an output shaft speed sensor.	Check for other MID 130 (transmission) fault codes.	Other fault codes are active.	Troubleshoot the other active fault codes.
		No other fault codes are active.	Go to the next step in the table.
The clutch is slipping.	Test drive the vehicle. Is the fault code active during normal driving conditions (without a lot of gear changes)?	The fault code remains active.	Check the mechanical components of the clutch system. See **Section 25.02**.

* When this fault appears, it is usual to see the CHECK TRANS light illuminate and "CO" (clutch overload) display on the current gear indicator.

Table 1, The Clutch Is Too Hot

SID 55, FMI 07—The Clutch Does Not Operate Properly

Failure Reason:

- The hydraulic system is leaking.
- There is a defect in the clutch actuator.
- There is a mechanical defect in the clutch system.
- There is a mechanical defect in the solenoid valves of the AGS central unit.

Problem	Procedure	Result	Action
There are other active transmission faults.	Check for other MID 130 fault codes.	Other fault codes are active.	Troubleshoot the other active fault codes.
		No other fault codes are active.	Go to the next step in the table.

Clutch Actuator Faults (SID 55)

<table>
<tr><th colspan="4">SID 55, FMI 07—The Clutch Does Not Operate Properly</th></tr>
<tr><td colspan="4">Failure Reason:
The hydraulic system is leaking.
There is a defect in the clutch actuator.
There is a mechanical defect in the clutch system.
There is a mechanical defect in the solenoid valves of the AGS central unit.</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">The hydraulic system is leaking or fluid flow is restricted to the clutch actuator.</td><td rowspan="2">Do a visual check of the fluid lines for leaks, kinked lines, or blockage.</td><td>Leaks, kinked lines, or blockage is found.</td><td>Make sure all lines are tight. Replace any damaged components.</td></tr>
<tr><td>There are no defects in the fluid lines.</td><td>Go to the next step in the table.</td></tr>
<tr><td rowspan="2">The clutch is slipping.</td><td rowspan="2">Test drive the vehicle. Does the system respond well to a wide range of driving condition and gear changes?</td><td>There are problems changing gears (shuddering, noises, slow to shift).</td><td>Check the mechanical components of the clutch system. See Section 25.02.</td></tr>
<tr><td>There are no problems.</td><td>Replace the clutch actuator. See Subject 120.</td></tr>
<tr><td rowspan="2">There is a mechanical defect in the solenoid valves.</td><td rowspan="2">Test drive the vehicle. Is the fault code active during normal driving conditions (without a lot of gear changes)?</td><td>The fault code remains active.</td><td>Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test.

NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test.

1. Using ServiceLink, print the AGS codes (130).

2. Complete the electrical pre-test result sheet in Subject 301.

3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).</td></tr>
<tr><td>No fault codes.</td><td>Complete a learning procedure using ServiceLink.</td></tr>
</table>

Table 2, The Clutch Does Not Operate Properly

<table>
<tr><th colspan="4">SID 55, FMI 13—The Clutch Needs To Be Calibrated</th></tr>
<tr><td colspan="4">Failure Reason:
• The clutch is not calibrated properly.
• There is a mechanical defect in the clutch system.</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">Missing or incomplete clutch calibration (often occurs after service procedures such as clutch replacement, clutch actuator replacement, or engine/ transmission separation).</td><td rowspan="2">Complete a learning procedure using either ServiceLink or the SmartShift control.

To complete a learning procedure using the SmartShift control:

1. Ensure that the parking brake is set.

2. With the ignition turned off, pull and hold the SmartShift control toward steering wheel.

NOTE: The SmartShift control must be kept in this position until the gear display clears at the end of the procedure.

3. Turn on the ignition. The normal warm up procedure will initiate and an ’X’ will display on the current gear indicator. Your transmission may be heard shifting.

4. Wait until the current gear indicator displays an ’N’ (about 30 seconds) and an audible alert sounds. Start the engine within 10 seconds of the audible alert.

5. The engine will raise a few rpm, then fall back to idle, and an audible alert will sound. Turn off the engine within 10 seconds of audible alert. When the gear display clears, this procedure is complete.

NOTE: If during this procedure an ’SM’ or ’X’ (after the warm up procedure) appears in the gear display, stop, turn off the ignition, and wait for the gear display to go dark. Then start over. This may need to be repeated several times.</td><td>The fault is no longer active.</td><td>No action is needed.</td></tr>
<tr><td>The fault is still active.</td><td>Go to the next step in the table.</td></tr>
<tr><td rowspan="2">There are other active transmission faults.</td><td rowspan="2">Check for other MID 130 fault codes.</td><td>Other fault codes are active.</td><td>Troubleshoot the other active fault codes.</td></tr>
<tr><td>No other fault codes are active.</td><td>Check the mechanical components of the clutch system. See Section 25.02.</td></tr>
</table>

Table 3, The Clutch Needs To Be Calibrated

J1939 Datalink Faults

There are three J1939 datalink faults covered in these procedures. If more than one of these faults is active, check FMI 12 first for best results. This can often resolve the other two faults as well.

- For SID 231, FMI 02, see **Table 1** for procedures.
- For SID 231, FMI 09, see **Table 2** for procedures.
- For SID 231, FMI 12, see **Table 3** for procedures and pin identification.

SID 231, FMI 02—The J1939 Datalink Is Not Communicating Properly			
Failure Reason: • There has been a failure in the data content received by the J1939 datalink from the other control units (engine ECU, bulkhead module, ABS ECU). • The J1939 wiring is defective. • There is interference from other control units on the J1939 datalink.			
Problem	**Procedure**	**Result**	**Action**
There is no power to the transmission.	Check for fault code SID 231, FMI 09 and/or SID 231, FMI 12.	SID 231, FMI 09 and/or 12 are (is) active.	Troubleshoot SID 231, FMI 09 and/or 12. See **Table 2** and/or **Table 3**.
		SID 231, FMI 09 and 12 are not active.	Go to the next step in the table.
The J1939 data are not plausible.	Check the J1939 datalink connections to other systems, particularly the engine (MID 128), the antilock brakes (MID 136) and the bulkhead module (MID 164).	There are other problems with the J1939 datalink.	Troubleshoot the J1939 datalink. See Freightliner **Service Bulletin 54-133**.

Table 1, The J1939 Datalink Is Not Communicating Properly

SID 231, FMI 09—The J1939 Datalink Message Has Timed Out			
Failure Reason: • The J1939 datalink is not receiving messages from other control units (engine ECU, bulkhead module, ABS ECU). • The J1939 wiring is defective. • There is interference from other control units on the J1939 datalink.			
Problem	**Procedure**	**Result**	**Action**
The power supply has been interrupted.	Check for fault code SID 231, FMI 12.	SID 231, FMI 12 is active.	Troubleshoot SID 231, FMI 12. See **Table 3**.
		SID 231, FMI 12 is not active.	Go to the next step in the table.
Other active fault codes are causing a breakdown in J1939 communications.	Check for other active fault codes in other systems.	Other active fault codes are found.	Troubleshoot the other active fault codes.
		No other active fault codes are found.	Go to the next step in the table.

J1939 Datalink Faults (SID 231)

SID 231, FMI 09—The J1939 Datalink Message Has Timed Out

Failure Reason:

- The J1939 datalink is not receiving messages from other control units (engine ECU, bulkhead module, ABS ECU).
- The J1939 wiring is defective.
- There is interference from other control units on the J1939 datalink.

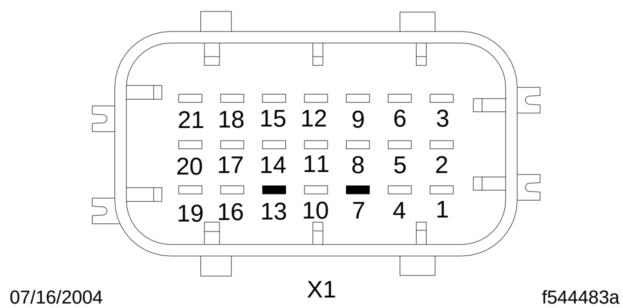
Problem	Procedure	Result	Action
The J1939 data are not plausible.	Check the J1939 datalink connections to other systems, particularly the engine (MID 128), the antilock brakes (MID 136) and the bulkhead module (MID 164).	There are other problems with the J1939 datalink.	Troubleshoot the J1939 datalink. See Freightliner **Service Bulletin 54-133**.

Table 2, The J1939 Datalink Message Has Timed Out

SID 231, FMI 12—The J1939 Datalink Is Not Communicating With the Transmission

Failure Reason:

- The J1939 datalink has defective components.
- The terminating resistors on the J1939 backbone are missing, or there are extra resistors.
- The J1939 wiring is defective.
- The signal on the J1939 datalink is distorted.
- There is a defect in the TCU.

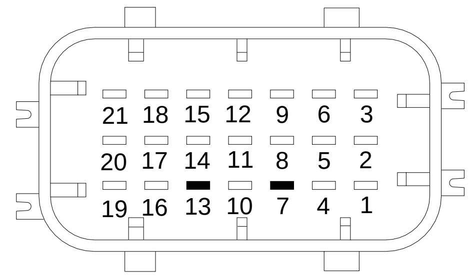


Problem	Procedure	Result	Action
Pins on the connector have been bent or damaged.	Remove the X1 connector. Visually inspect the pins and connector.	The connector has been damaged.	Straighten any bent pins. Repair or replace the connector.
		The connector has not been damaged.	Go to the next step in the table.
The J1939 datalink is defective.	With the X1 connector removed, check for resistance between pin 7 and pin 13.	The resistance is less than 54 or more than 66 ohms.	Troubleshoot the J1939 datalink. See Freightliner **Service Bulletin 54-133**.
		The resistance is between 54 and 66 ohms.	Go to the next step in the table.
There is a short circuit in the J1939 wiring.	With the X1 connector removed, check for resistance between pin 7 and all other pins on the connector.	A short circuit is found.	Check the J1939 wiring behind pins 7 and 13 and repair it as needed.
		An open circuit is found.	Go to the next step in the table.

SID 231, FMI 12—The J1939 Datalink Is Not Communicating With the Transmission

Failure Reason:

- The J1939 datalink has defective components.
- The terminating resistors on the J1939 backbone are missing, or there are extra resistors.
- The J1939 wiring is defective.
- The signal on the J1939 datalink is distorted.
- There is a defect in the TCU.



X1

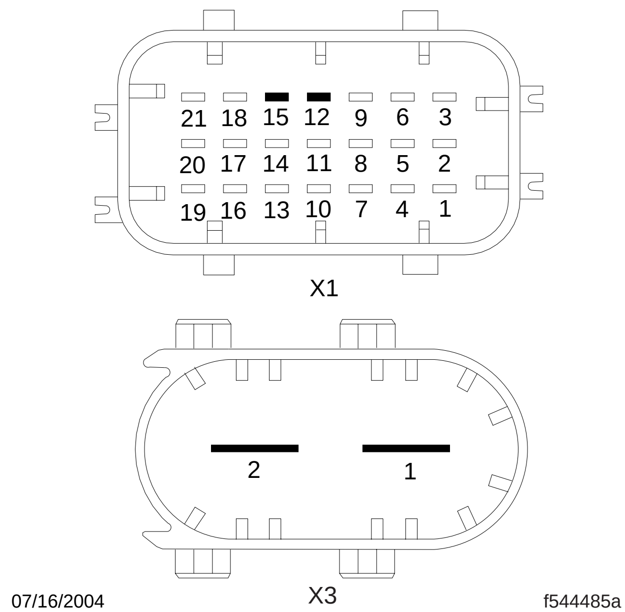
Problem	Procedure	Result	Action
There is a wiring failure in the TCU.	With the X1 connector removed, check whether other systems have the identical fault code active (SID 231, FMI 12).	SID 231, FMI 12 is active for other systems (MIDs).	Troubleshoot the J1939 datalink for the other systems. See Freightliner **Service Bulletin 54-133**.
		This fault is not active for other systems (MIDs).	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 3, The J1939 Datalink Is Not Communicating With the Transmission

Battery Power Supply Faults

There are four battery power supply faults covered in these procedures. Each one requires a different electrical test.

- For SID 251, FMI 00, see **Table 1** for procedures and pin identification.
- For SID 251, FMI 01, see **Table 2** for procedures and pin identification.
- For SID 251, FMI 05, see **Table 3** for procedures and pin identification.
- For SID 251, FMI 14, see **Table 4** for procedures and pin identification.

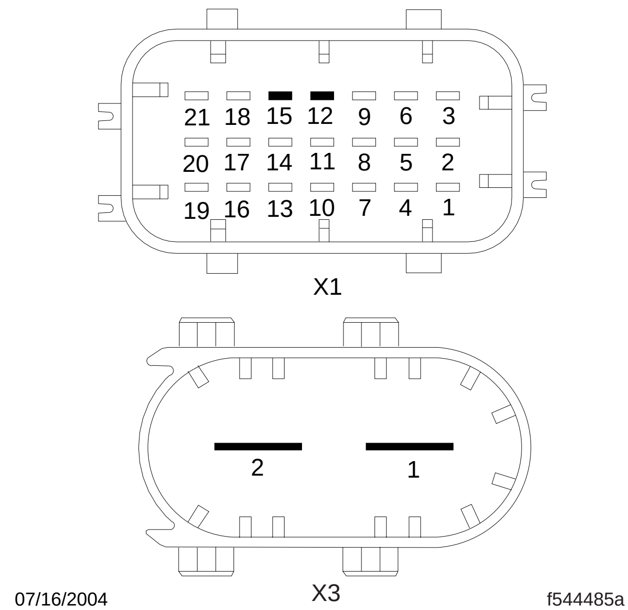
SID 251, FMI 00—The Battery Voltage Is Too High		
Failure Reason: • There is a failure of the vehicle charging system. • External power connected to the vehicle for a jump start. • Voltage spikes on the battery power and/or ground circuits.		
Procedure	**Results**	**Action**
Remove the X3 connector. Start the engine and check the voltage between plug 1 and plug 2 on the female connector.	The voltage is greater than 16V and constant for more than one second with the engine running.	Check the vehicle charging system. See **Section 15.00**, Subject 300.
	The voltage is greater than 8V and less than 15.9V.	Go to the next step in the table.

Battery Power Supply Faults (SID 251)

SID 251, FMI 00—The Battery Voltage Is Too High

Failure Reason:

- There is a failure of the vehicle charging system.
- External power connected to the vehicle for a jump start.
- Voltage spikes on the battery power and/or ground circuits.



Procedure	Results	Action
Remove the X1 connector. Start the engine and check the voltage to ground from plug 12 and plug 15 on the female connector.	The voltage is greater than 16V and constant for more than one second with the engine running.	Check the vehicle charging system. See **Section 15.00**, Subject 300.
	The voltage is greater than 8V and less than 15.9V.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

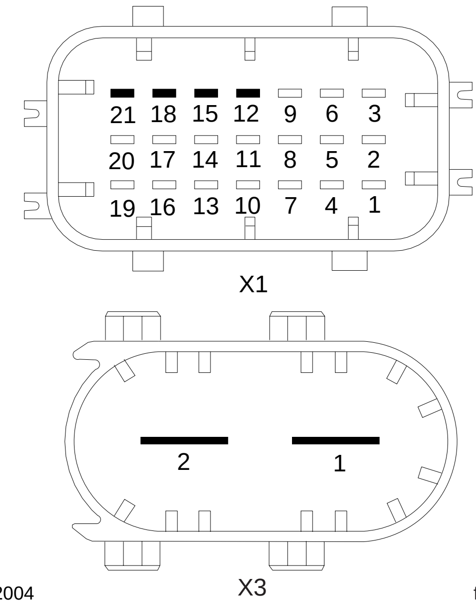
Table 1, The Battery Voltage Is Too High

Battery Power Supply Faults (SID 251)

SID 251, FMI 01—The Battery Voltage Is Too Low

Failure Reason:

- There is a failure of the vehicle charging system.
- The power circuits lack continuity to ground.
- Voltage drops on the battery power and/or ground circuits.



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Procedure	Results	Action
Check the 30-amp fuse at position F4 and the 20-amp fuse at position F9 in the fuse box under the hood next to the bulkhead module. Check the 40-amp maxifuse on hydraulic pump circuit.	One or more fuses are blown.	Replace any blown fuses.
	The fuses are OK.	Go to the next step in the table.
Start the engine. Remove the X1 and X3 connectors. Check for steady battery voltage from plug 12 and plug 15 on the X1 female connector to pin 1 on the X3 connector.	The voltage is greater than 16V and constant for more than one second with the engine running.	Check the vehicle charging system. See **Section 15.00**, Subject 300.
	The voltage is greater than 8V and less than 15.9V.	Go to the next step in the table.

Battery Power Supply Faults (SID 251)

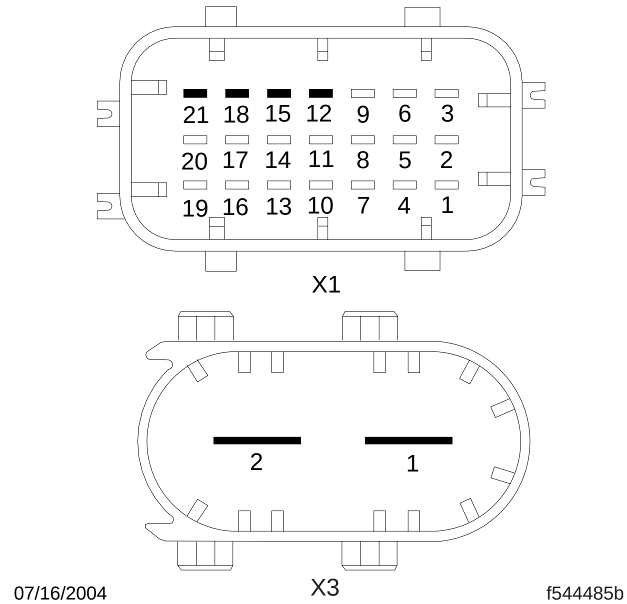
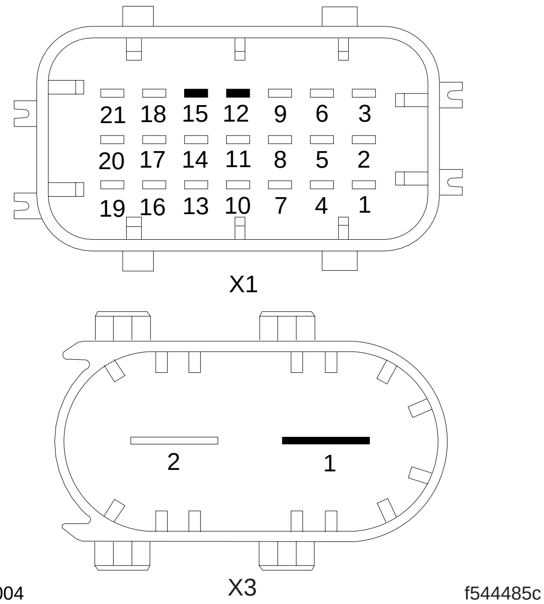
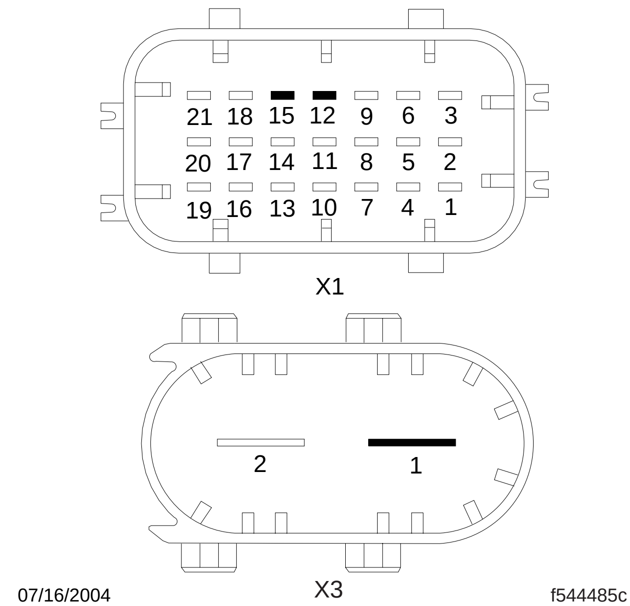
SID 251, FMI 01—The Battery Voltage Is Too Low		
Failure Reason: • There is a failure of the vehicle charging system. • The power circuits lack continuity to ground. • Voltage drops on the battery power and/or ground circuits.		
Procedure	**Results**	**Action**
With the engine running, check for continuity to ground from plug 18 and plug 21 on the X1 female connector to pin 2 on the X3 connector.	No continuity is present.	Repair or replace the wiring as needed. See **Section 54.06**, Subject 100.
	Continuity is present.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 2, The Battery Voltage Is Too Low

Battery Power Supply Faults (SID 251)

<table>
<tr><th colspan="3">SID 251, FMI 05—There Is No Power to the Transmission With the Engine Running</th></tr>
<tr><td>Failure Reason:
• A fuse is blown.
• There is a defect in the wiring.</td><td colspan="2">
</td></tr>
<tr><th>Procedure</th><th>Results</th><th>Action</th></tr>
<tr><td rowspan="2">Check the 30-amp fuse at position F4 and the 20-amp fuse at position F9 in the fuse box under the hood next to the bulkhead module. Check the 40-amp maxifuse on hydraulic pump circuit.</td><td>One or more fuses are blown.</td><td>Replace any blown fuses.</td></tr>
<tr><td>The fuses are OK.</td><td>Go to the next step in the table.</td></tr>
</table>

Battery Power Supply Faults (SID 251)

<table>
<tr><th colspan="3">SID 251, FMI 05—There Is No Power to the Transmission With the Engine Running</th></tr>
<tr><td>Failure Reason:
• A fuse is blown.
• There is a defect in the wiring.</td><td colspan="2">
</td></tr>
<tr><th>Procedure</th><th>Results</th><th>Action</th></tr>
<tr><td rowspan="2">Start the engine. Remove the X1 and X3 connectors. Check for steady battery voltage from plug 12 and from plug 15 on the X1 female connector to pin 1 on the X3 connector.</td><td>The circuit is open.</td><td>Repair or replace the wiring as needed. See Section 54.06, Subject 100.</td></tr>
<tr><td>The voltage is greater than 1V.</td><td>Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test.

NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test.

1. Using ServiceLink, print the AGS codes (130).

2. Complete the electrical pre-test result sheet in Subject 301.

3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).</td></tr>
</table>

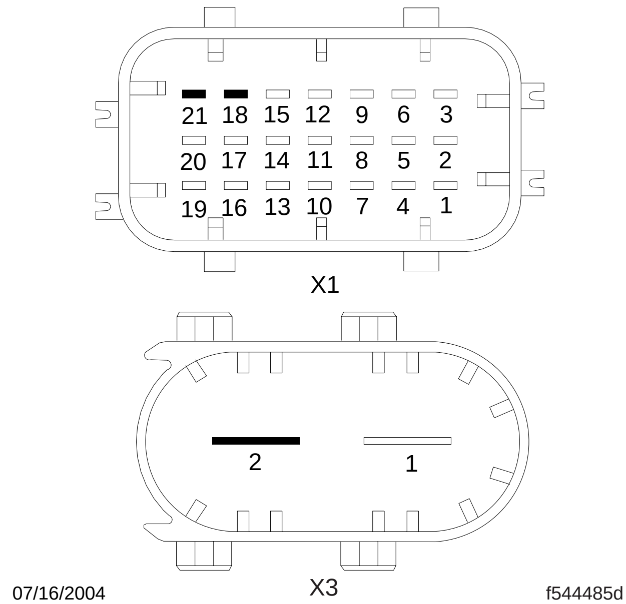
Table 3, There Is No Power to the Transmission With the Engine Running

Battery Power Supply Faults (SID 251)

SID 251, FMI 14—The Power Supply Is Not Properly Grounded

Failure Reason:

- There is a defect in the wiring.
- There is a defect in the TCU.



Procedure	Results	Action
With the engine running, check for continuity to ground from plug 18 and plug 21 on the X1 female connector to pin 2 on the X3 male connector.	No continuity is found.	Repair or replace the wiring as needed. See **Section 54.06**, Subject 100.
	Continuity is found.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 4, The Power Supply Is Not Properly Grounded

Calibration Memory Faults

There are four calibration memory faults covered in these procedures. The same troubleshooting procedure is used for all.

- For SID 253, FMI 02, FMI 12, FMI 13, and FMI 14, see **Table 1** for procedures.

<table>
<tr><th colspan="3">SID 253, FMI 02, 12, 13, 14—The Transmission Needs To Be Recalibrated</th></tr>
<tr><td colspan="3">Failure Reason:
• There is a failure of programmable memory.
• The transmission has not been properly calibrated, or the calibration procedure failed.
• The TCU has suffered an internal electrical failure.</td></tr>
<tr><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">Complete a learning procedure using either ServiceLink or the SmartShift control.

To complete a learning procedure using the SmartShift control:

1. Ensure that the parking brake is set.

2. With the ignition turned off, pull and hold the SmartShift control toward steering wheel.

NOTE: The SmartShift control must be kept in this position until the gear display clears at the end of the procedure.

3. Turn on the ignition. The normal warm up procedure will initiate and an ’X’ will display on the current gear indicator. Your transmission may be heard shifting.

4. Wait until the current gear indicator displays an ’N’ (about 30 seconds) and an audible alert sounds. Start the engine within 10 seconds of the audible alert.

5. The engine will raise a few rpm, then fall back to idle, and an audible alert will sound. Turn off the engine within 10 seconds of audible alert. When the gear display clears, this procedure is complete.

NOTE: If during this procedure an ’SM’ or ’X’ (after the warm up procedure) appears in the gear display, stop, turn off the ignition, and wait for the gear display to go dark. Then start over. This may need to be repeated several times.</td><td>Calibration is successful.</td><td>No further action is needed.</td></tr>
<tr><td>Calibration fails.</td><td>Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test.

NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test.

1. Using ServiceLink, print the AGS codes (130).

2. Complete the electrical pre-test result sheet in Subject 301.

3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).</td></tr>
</table>

Table 1, The Transmission Needs To Be Recalibrated

Transmission Control Unit Faults

There are five transmission control unit (TCU) faults covered in these procedures. FMI 04 and FMI 05 are covered by the same procedure.

- For SID 254, FMI 04 and FMI 05, see **Table 1** for procedures.
- For SID 254, FMI 11, see **Table 2** for procedures.
- For SID 254, FMI 12, see **Table 3** for procedures.
- For SID 254, FMI 13, see **Table 4** for procedures.

SID 254, FMI 04, 05—The TCU Is Shorted to Ground or Open		
Failure Reason: • There is a short circuit to ground in the solenoid valve. • There is an open circuit in the solenoid valve.		
Procedure	**Results**	**Action**
Turn the ignition switch off and wait for the current gear indicator to power down. Turn the switch on and check to see if the fault is still active.	The fault has become inactive.	No action is needed.
	The fault is still active.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The TCU Is Shorted to Ground or Open

Transmission Control Unit Faults (SID 254)

<table>
<tr><th colspan="4">SID 254, FMI 11—The TCU AUTO Mode Software Module Has an Error</th></tr>
<tr><td colspan="4">Failure Reason:
• The engine ECU is not providing valid data.
• There is faulty data in programmable memory (EEPROM).
• The SmartShift lever is defective.
• One of the shift position sensors (gear or rail) has failed.
• One of the output shaft speed sensors has failed.
• The transmission is not properly calibrated.
• There is a defect in the brake pedal switch.
• There is a defect in the throttle pedal switch.</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">The TCU is receiving faulty data.</td><td rowspan="2">Check for other MID 130 fault codes.</td><td>Other fault codes are active.</td><td>Troubleshoot the other active fault codes.</td></tr>
<tr><td>No other fault codes are active.</td><td>Go to the next step in the table.</td></tr>
<tr><td rowspan="2">The transmission needs to be recalibrated.</td><td rowspan="2">Complete a learning procedure using either ServiceLink or the SmartShift control.

To complete a learning procedure using the SmartShift control:

1. Ensure that the parking brake is set.

2. With the ignition turned off, pull and hold the SmartShift control toward steering wheel.

NOTE: The SmartShift control must be kept in this position until the gear display clears at the end of the procedure.

3. Turn on the ignition. The normal warm up procedure will initiate and an ’X’ will display on the current gear indicator. Your transmission may be heard shifting.

4. Wait until the current gear indicator displays an ’N’ (about 30 seconds) and an audible alert sounds. Start the engine within 10 seconds of the audible alert.

5. The engine will raise a few rpm, then fall back to idle, and an audible alert will sound. Turn off the engine within 10 seconds of audible alert. When the gear display clears, this procedure is complete.

NOTE: If during this procedure an ’SM’ or ’X’ (after the warm up procedure) appears in the gear display, stop, turn off the ignition, and wait for the gear display to go dark. Then start over. This may need to be repeated several times.</td><td>The fault is no longer active.</td><td>No further action is needed.</td></tr>
<tr><td>The fault is still active.</td><td>Go to the next step in the table.</td></tr>
</table>

Transmission Control Unit Faults (SID 254)

SID 254, FMI 11—The TCU AUTO Mode Software Module Has an Error			
Failure Reason: • The engine ECU is not providing valid data. • There is faulty data in programmable memory (EEPROM). • The SmartShift lever is defective. • One of the shift position sensors (gear or rail) has failed. • One of the output shaft speed sensors has failed. • The transmission is not properly calibrated. • There is a defect in the brake pedal switch. • There is a defect in the throttle pedal switch.			
Problem	**Procedure**	**Result**	**Action**
The brake pedal switch is defective.	Use the ServiceLink AGS template to check the functionality of the brake pedal switch.	The template does not show brake pedal activation.	Check the function of the brake pedal. See **Section 25.02** for procedures.
		The template shows brake pedal activation.	Go to the next step in the table.
The throttle pedal switch is defective.	Use the ServiceLink AGS template to check the functionality of the throttle pedal switch.	The template does not show throttle pedal activation.	Check the function of the throttle pedal. See **Section 25.02** for procedures.
		The template shows throttle pedal activation.	Contact Freightliner Technical Service Support.

Table 2, The TCU AUTO Mode Software Module Has an Error

SID 254, FMI 12—The TCU Has a Hardware Problem			
Failure Reason: • There is a short circuit to ground in the external power supply. • There is a short circuit to ground through the output shaft speed sensor. • There has been an internal hardware failure of the TCU.			
Problem	**Procedure**	**Result**	**Action**
The power supply is short-circuited to ground.	Remove the X1 connector. Check for short circuit to ground from pin 6.	The current gear indicator displays something other than "N" and/or there are speed sensor error codes.	Repair or replace the wiring as needed. See **Section 54.06**, Subject 100.
		The current gear indicator displays "N."	Go to the next step in the table.
The power supply is short-circuited through the output shaft speed sensor.	Remove the X2 connector. Check for short circuit to ground from pin 15.	There are no active speed sensor (PID 191) error codes.	Repair or replace the wiring as needed. See **Section 54.06**, Subject 100.
		There are active speed sensor (PID 191) error codes.	Go to the next step in the table.

Transmission Control Unit Faults (SID 254)

SID 254, FMI 12—The TCU Has a Hardware Problem			
Failure Reason: • There is a short circuit to ground in the external power supply. • There is a short circuit to ground through the output shaft speed sensor. • There has been an internal hardware failure of the TCU.			
Problem	**Procedure**	**Result**	**Action**
There has been an internal electrical problem of the TCU.	Turn off the ignition switch, wait for the current gear indicator to power down, and turn the ignition switch on again.	The fault is no longer active.	Troubleshoot the other active fault codes.
		The fault is still active.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 3, The TCU Has a Hardware Problem

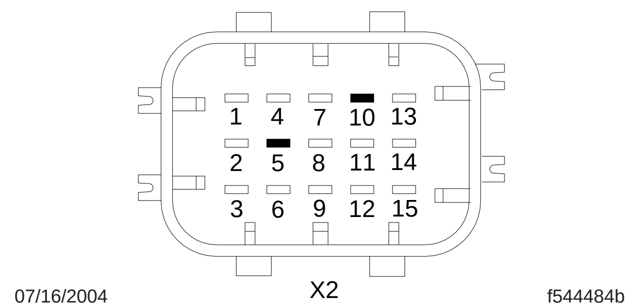
SID 254, FMI 13—The TCU Has a Software Memory Problem			
Failure Reason: • There has been an internal software failure of the TCU.			
Problem	**Procedure**	**Result**	**Action**
There has been an internal electrical problem of the TCU.	Turn off the ignition switch, wait for the current gear indicator to power down, and turn the ignition switch on again.	The fault is no longer active.	Continue to monitor the TCU.
		The fault is still active.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 4, The TCU Has a Software Memory Problem

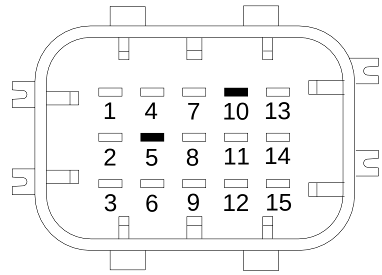
Clutch Position Sensor Faults

There are five clutch position sensor faults covered in these procedures. Each one requires a separate electrical test.

- For PID 33, FMI 02, see **Table 1** for procedures and pin identification.
- For PID 33, FMI 03, see **Table 2** for procedures and pin identification.
- For PID 33, FMI 04, see **Table 3** for procedures and pin identification.
- For PID 33, FMI 05, see **Table 4** for procedures and pin identification.
- For PID 33, FMI 14, see **Table 5** for procedures and pin identification.

<table>
<tr><th colspan="4">PID 33, FMI 02—The Clutch Position Sensor Is Providing Invalid Data</th></tr>
<tr><td colspan="2">Failure Reason:
• There is a defect in the wiring.
• There is a defect in the clutch position sensor.
• There is a defect in the TCU.</td><td colspan="2">
</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">Pins on the X2 connector or the clutch position sensor connector are not making good contact.</td><td rowspan="2">Do the "Harness Visual Check, Clutch Position Sensor."</td><td>Connectors and/or pins are damaged, soiled, worn, broken, or corroded.</td><td>Replace the damaged components.</td></tr>
<tr><td>All connectors and pins are OK.</td><td>Go to the next row in the table.</td></tr>
<tr><td rowspan="2">The clutch position sensor is not providing the correct resistance data.</td><td rowspan="2">Remove the clutch position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.</td><td>The resistance is less than 35.8 or greater than 126.2 ohms.</td><td>Replace the clutch actuator. See Subject 120.</td></tr>
<tr><td>The resistance is between 35.8 and 126.2 ohms.</td><td>Go to the next row in the table.</td></tr>
<tr><td rowspan="4">The transmission harness has an open circuit.</td><td rowspan="2">With the sensor wiring disconnected, remove the X2 connector from the TCU. Check for resistance on the female connectors from X2 connector plug 10 to sensor connector plug 2.</td><td>The circuit is open.</td><td>Replace the transmission harness. See Subject 180.</td></tr>
<tr><td>There is measurable resistance of 0.5 to 1.5 ohms.</td><td>Go to the next resistance check.</td></tr>
<tr><td rowspan="2">With the transmission harness wiring disconnected, check for resistance on the female connectors from X2 connector plug 5 to sensor connector plug 1.</td><td>The circuit is open.</td><td>Replace the transmission harness. See Subject 180.</td></tr>
<tr><td>There is measurable resistance of 0.5 to 1.5 ohms.</td><td>Go to the next row in the table.</td></tr>
</table>

Clutch Position Sensor Faults (PID 33)

<table>
<tr><th colspan="4">PID 33, FMI 02—The Clutch Position Sensor Is Providing Invalid Data</th></tr>
<tr><td colspan="2">Failure Reason:
• There is a defect in the wiring.
• There is a defect in the clutch position sensor.
• There is a defect in the TCU.</td><td colspan="2">

07/16/2004 X2 f544484b</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="4">The transmission harness or the TCU has a wiring problem.</td><td rowspan="2">With the transmission harness wiring still disconnected, check for shorts on the X2 female connector from plug 10 to plug 15.</td><td>A short circuit is found.</td><td>Replace the transmission harness. See Subject 180.</td></tr>
<tr><td>The circuit is open.</td><td>Go to the next short circuit check.</td></tr>
<tr><td rowspan="2">In a similar manner, continue to check for shorts on the X2 female connector from plug 5 to plugs 1, 2, 4, 7, 10, 13, and 15.</td><td>There are one or more short circuits.</td><td>Replace the transmission harness. See Subject 180.</td></tr>
<tr><td>All the circuits are open.</td><td>Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test.

NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test.

1. Using ServiceLink, print the AGS codes (130).

2. Complete the electrical pre-test result sheet in Subject 301.

3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).</td></tr>
</table>

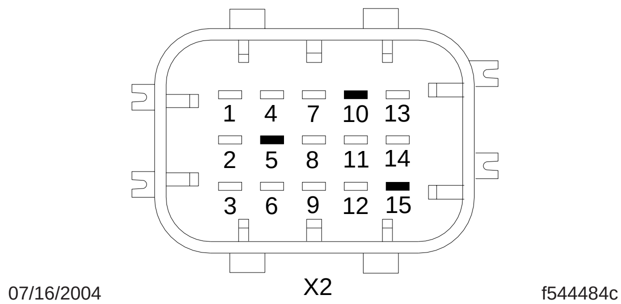
Table 1, The Clutch Position Sensor Is Providing Invalid Data

Clutch Position Sensor Faults (PID 33)

PID 33, FMI 03—The Clutch Position Sensor Circuit Is Shorted to Power

Failure Reason:

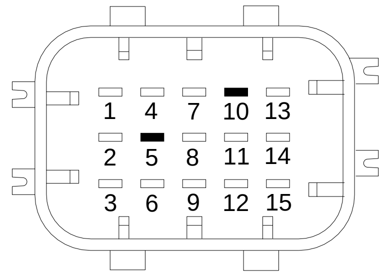
- There is a defect in the wiring.
- There is a defect in the TCU.



Problem	Procedure	Result	Action
Pins on the X2 connector or the clutch position sensor connector are not making good contact.	Do the "Harness Visual Check, Clutch Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The transmission harness or TCU has a wiring problem.	Turn off the ignition and wait for the gear display to power down. Remove the X2 connector from the TCU. Check on the female connector from plug 15 to plug 5 for a short circuit.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Go to the next short circuit check.
	With the X2 connector removed, check on the female connector from plug 15 to plug 10 for a short circuit.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 2, The Clutch Position Sensor Circuit Is Shorted to Power

Clutch Position Sensor Faults (PID 33)

<table>
<tr><th colspan="4">PID 33, FMI 04—The Clutch Position Sensor Circuit Is Shorted to Ground</th></tr>
<tr><td colspan="2">Failure Reason:
• There is a defect in the wiring.
• There is a defect in the clutch position sensor.
• There is a defect in the TCU.</td><td colspan="2">

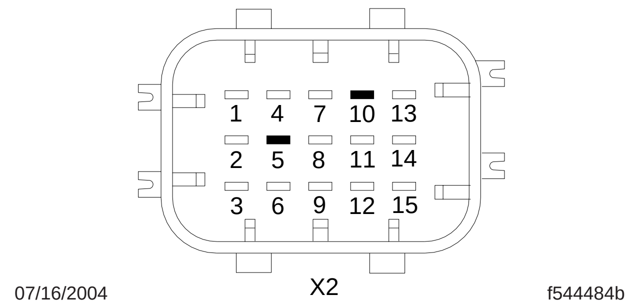
07/16/2004 X2 f544484b</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">Pins on the X2 connector or the clutch position sensor connector are not making good contact.</td><td rowspan="2">Do the "Harness Visual Check, Clutch Position Sensor."</td><td>Connectors and/or pins are damaged, soiled, worn, broken, or corroded.</td><td>Replace the damaged components.</td></tr>
<tr><td>All connectors and pins are OK.</td><td>Go to the next row in the table.</td></tr>
<tr><td rowspan="2">The clutch position sensor is not providing the correct resistance data.</td><td rowspan="2">Remove the clutch position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.</td><td>The resistance is less than 35.8 or greater than 126.2 ohms.</td><td>Replace the clutch actuator. See Subject 120.</td></tr>
<tr><td>The resistance is between 35.8 and 126.2 ohms.</td><td>Go to the next row in the table.</td></tr>
</table>

Clutch Position Sensor Faults (PID 33)

PID 33, FMI 04—The Clutch Position Sensor Circuit Is Shorted to Ground

Failure Reason:

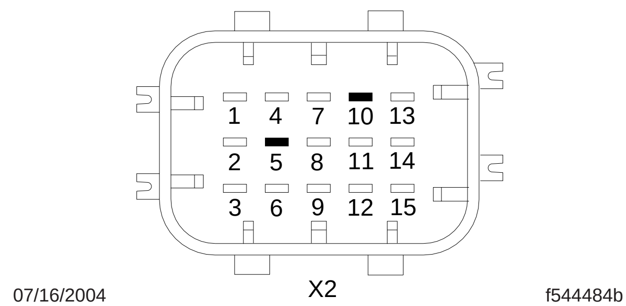
- There is a defect in the wiring.
- There is a defect in the clutch position sensor.
- There is a defect in the TCU.



Problem	Procedure	Result	Action
The transmission harness or the TCU has a wiring problem.	With the sensor wiring disconnected, remove the X2 connector from the TCU. Check plugs 5 and 10 on the female connector for short circuit to ground.	A short to ground is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Go to the next short circuit check.
	In a similar manner, continue to check for shorts on the female connector from plug 5 to plugs 1, 2, 4, 7, and 13.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All circuits are open.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 3, The Clutch Position Sensor Circuit Is Shorted to Ground

Clutch Position Sensor Faults (PID 33)

PID 33, FMI 05—The Clutch Position Sensor Circuit Is Open	
Failure Reason: • There is a defect in the wiring. • There is a defect in the clutch position sensor. • There is a defect in the TCU.	

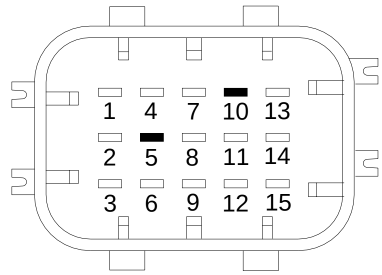
Problem	Procedure	Result	Action
Pins on the X2 connector or the clutch position sensor connector are not making good contact.	Do the "Harness Visual Check, Clutch Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The clutch position sensor is not providing the correct resistance data.	Remove the clutch position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 35.8 or greater than 126.2 ohms.	Replace the clutch actuator. See **Subject 120**.
		The resistance is between 35.8 and 126.2 ohms.	Go to the next row in the table.

Clutch Position Sensor Faults (PID 33)

PID 33, FMI 05—The Clutch Position Sensor Circuit Is Open

Failure Reason:

- There is a defect in the wiring.
- There is a defect in the clutch position sensor.
- There is a defect in the TCU.



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Problem	Procedure	Result	Action
The transmission harness or the TCU has a wiring problem.	Check for resistance on the female connectors from X2 connector plug 10 to sensor connector plug 2.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	Check for resistance on the female connectors from X2 connector plug 5 to sensor connector plug 1.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

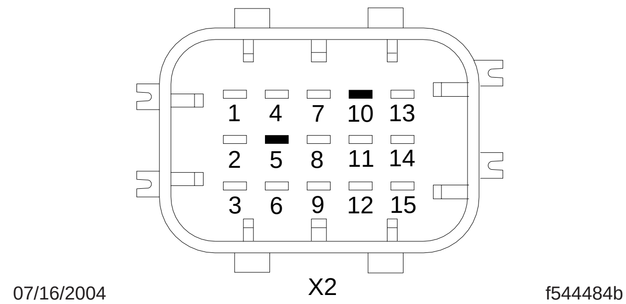
Table 4, The Clutch Position Sensor Circuit Is Open

Clutch Position Sensor Faults (PID 33)

PID 33, FMI 14—The Clutch Position Sensor Gives Incorrect Resistance Readings

Failure Reason:

- The resistance values broadcast on the datalink are not plausible.
- There is a defect in the wiring.
- There is a defect in the clutch position sensor.
- There is a defect in the TCU.



Problem	Procedure	Result	Action
Pins on the X2 connector or the clutch position sensor connector are not making good contact.	Do the "Harness Visual Check, Clutch Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The clutch position sensor is not providing the correct resistance data.	Disconnect the rail position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 35.8 or greater than 126.2 ohms.	Replace the clutch actuator. See **Subject 120**.
		The resistance is between 35.8 and 126.2 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 5, The Clutch Position Sensor Gives Incorrect Resistance Readings

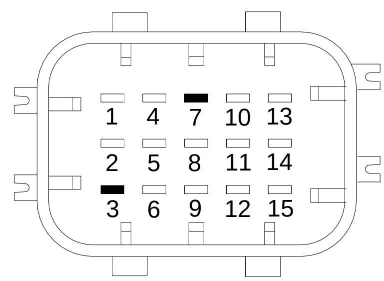
Harness Visual Check, Clutch Position Sensor

1. Remove the X2 female connector from the TCU. Check the plugs on the connector. If any plug(s) in the connector is damaged, soiled, worn, broken, or corroded, replace the connector. If no female connectors are available, replace the transmission wiring harness. See **Subject 180** for procedures.
2. Check the pins on the X2 male connector. If any pin(s) on the connector is damaged, soiled, worn, broken, or corroded, replace the TCU. See **Subject 110** for procedures.
3. Remove the female connector from the clutch position sensor. If any plug(s) in the connector is damaged, soiled, worn, broken, or corroded, replace the connector. If no female connectors are available, replace the transmission wiring harness. See **Subject 180** for procedures.
4. Check the pins on the male connector of the clutch position sensor. If any pin(s) on the connector is damaged, soiled, worn, broken, or corroded, replace the clutch actuator assembly. See **Subject 120** for procedures.

Gear Position Sensor Faults

There are five gear position sensor faults covered in these procedures. Each one requires a separate electrical test.

- For PID 59, FMI 02, see **Table 1** for procedures and pin identification.
- For PID 59, FMI 03, see **Table 2** for procedures and pin identification.
- For PID 59, FMI 04, see **Table 3** for procedures and pin identification.
- For PID 59, FMI 05, see **Table 4** for procedures and pin identification.
- For PID 59, FMI 14, see **Table 5** for procedures and pin identification.

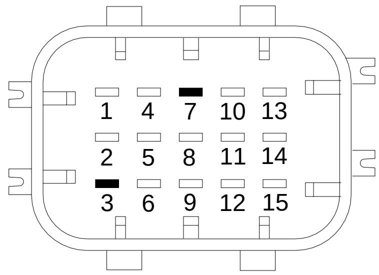
<table>
<tr><th colspan="4">PID 59, FMI 02—The Gear Position Sensor Is Providing Invalid Data</th></tr>
<tr><td colspan="2">Failure Reason:
• There is a defect in the wiring.
• There is a defect in the gear position sensor.
• There is a defect in the TCU.</td><td colspan="2">
07/16/2004 X2 f544484d</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">Pins on the X2 connector or the gear position sensor connector are not making good contact.</td><td rowspan="2">Do the "Harness Visual Check, Gear Position Sensor."</td><td>Connectors and/or pins are damaged, soiled, worn, broken, or corroded.</td><td>Replace the damaged components.</td></tr>
<tr><td>All connectors and pins are OK.</td><td>Go to the next row in the table.</td></tr>
</table>

Gear Position Sensor Faults (PID 59)

PID 59, FMI 02—The Gear Position Sensor Is Providing Invalid Data

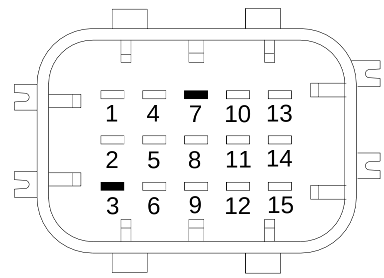
Failure Reason:

- There is a defect in the wiring.
- There is a defect in the gear position sensor.
- There is a defect in the TCU.



Problem	Procedure	Result	Action
The gear position sensor is not providing the correct resistance data.	Disconnect the gear position sensor wiring. Check for resistance between pins 1 and 2 of the gear position sensor connector.	The resistance is less than 34 or greater than 122 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).
		The resistance is between 34 and 122 ohms.	The sensor is OK. Go to the next row in the table.

Gear Position Sensor Faults (PID 59)

<table>
<tr><th colspan="4">PID 59, FMI 02—The Gear Position Sensor Is Providing Invalid Data</th></tr>
<tr><td colspan="2">Failure Reason:
There is a defect in the wiring.
There is a defect in the gear position sensor.
There is a defect in the TCU.</td><td colspan="2">

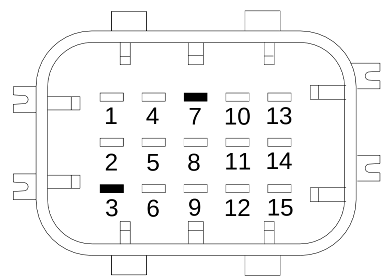
07/16/2004 f544484d</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="4">The transmission harness has an open circuit.</td><td rowspan="2">With the sensor wiring disconnected, remove the X2 connector from the TCU. Check for resistance on the female connectors from X2 connector plug 7 to sensor connector plug 2.</td><td>The circuit is open.</td><td>Replace the transmission harness. See Subject 180.</td></tr>
<tr><td>There is measurable resistance of 0.5 to 1.5 ohms.</td><td>Go to the next resistance check.</td></tr>
<tr><td rowspan="2">With the transmission harness wiring disconnected, check for resistance on the female connectors from X2 connector plug 3 to sensor connector plug 1.</td><td>The circuit is open.</td><td>Replace the transmission harness. See Subject 180.</td></tr>
<tr><td>There is measurable resistance of 0.5 to 1.5 ohms.</td><td>Go to the next row in the table.</td></tr>
</table>

Gear Position Sensor Faults (PID 59)

PID 59, FMI 02—The Gear Position Sensor Is Providing Invalid Data

Failure Reason:

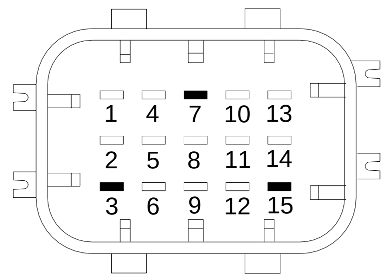
- There is a defect in the wiring.
- There is a defect in the gear position sensor.
- There is a defect in the TCU.



Problem	Procedure	Result	Action
The transmission harness or the TCU has a wiring problem.	With the transmission harness wiring still disconnected, check for shorts on the X2 female connector from plug 7 to plug 15.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Go to the next short circuit check.
	In a similar manner, continue to check for shorts on the X2 female connector from plug 3 to plugs 1, 2, 4, 7, 10, 13, and 15.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All the circuits are open.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Gear Position Sensor Is Providing Invalid Data

Gear Position Sensor Faults (PID 59)

<table>
<tr><th colspan="4">PID 59, FMI 03—The Gear Position Sensor Circuit Is Shorted to Power</th></tr>
<tr><td colspan="2">Failure Reason:
• There is a defect in the wiring.
• There is a defect in the TCU.</td><td colspan="2">

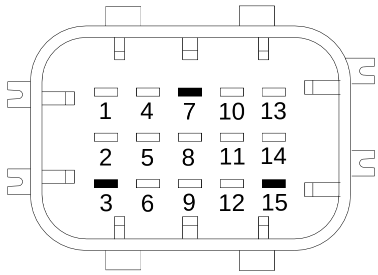
07/16/2004 X2 f544484e</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">Pins on the X2 connector or the gear position sensor connector are not making good contact.</td><td rowspan="2">Do the "Harness Visual Check, Gear Position Sensor."</td><td>Connectors and/or pins are damaged, soiled, worn, broken, or corroded.</td><td>Replace the damaged components.</td></tr>
<tr><td>All connectors and pins are OK.</td><td>Go to the next row in the table.</td></tr>
</table>

Gear Position Sensor Faults (PID 59)

PID 59, FMI 03—The Gear Position Sensor Circuit Is Shorted to Power

Failure Reason:

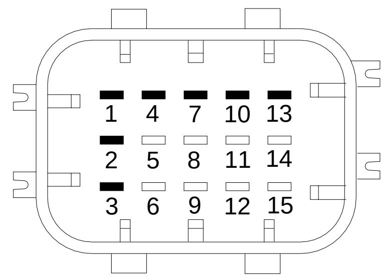
- There is a defect in the wiring.
- There is a defect in the TCU.



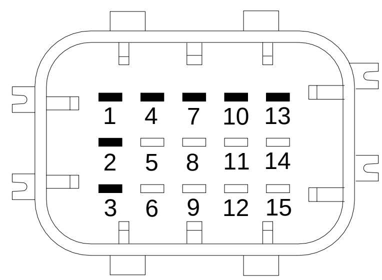
07/16/2004 f544484e

Problem	Procedure	Result	Action
The transmission harness or the TCU has a wiring problem.	Turn off the ignition and wait for the gear display to power down. Remove the X2 connector from the TCU. On the female connector, check plug 15 to plug 3 for a short circuit.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Go to the next short circuit check.
	With the X2 connector removed, check plug 15 to plug 7 on the X2 female connector for a short circuit.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 2, The Gear Position Sensor Circuit Is Shorted to Power

PID 59, FMI 04—The Gear Position Sensor Circuit Is Shorted to Ground			
Failure Reason: • There is a defect in the wiring. • There is a defect in the gear position sensor. • There is a defect in the TCU.			
Problem	**Procedure**	**Result**	**Action**
Pins on the X2 connector or the gear position sensor connector are not making good contact.	Do the "Harness Visual Check, Gear Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The gear position sensor is not providing the correct resistance data.	Remove the gear position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 34 or greater than 122 ohms.	Replace the x-y actuator. See **Subject 170**.
		The resistance is between 34 and 122 ohms.	Go the next row in the table.

Gear Position Sensor Faults (PID 59)

<table>
<tr><th colspan="4">PID 59, FMI 04—The Gear Position Sensor Circuit Is Shorted to Ground</th></tr>
<tr><td colspan="2">Failure Reason:
There is a defect in the wiring.
There is a defect in the gear position sensor.
There is a defect in the TCU.</td><td colspan="2">

07/16/2004 f544484f</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="4">The transmission harness or the TCU has a wiring problem.</td><td rowspan="2">With the sensor wiring disconnected, remove the X2 connector from the TCU. Check plugs 3 and 7 on the female connector for short circuit to ground.</td><td>The circuit is shorted to ground.</td><td>Replace the transmission harness. See Subject 180.</td></tr>
<tr><td>The circuit is open.</td><td>Go to the next short circuit check.</td></tr>
<tr><td rowspan="2">In a similar manner, continue to check for shorts on the X2 female connector from plugs 3 and 7 to plugs 1, 2, 4, 10, and 13.</td><td>There are one or more short circuits.</td><td>Replace the transmission harness. See Subject 180.</td></tr>
<tr><td>All circuits are open.</td><td>Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test.

NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test.

1. Using ServiceLink, print the AGS codes (130).

2. Complete the electrical pre-test result sheet in Subject 301.

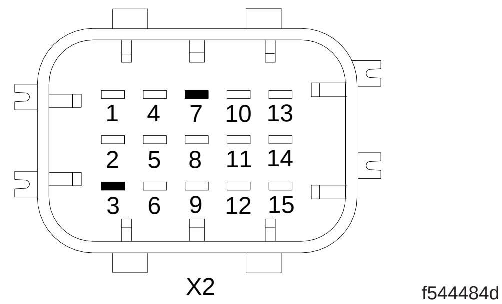
3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).</td></tr>
</table>

Table 3, The Gear Position Sensor Circuit Is Shorted to Ground

PID 59, FMI 05—The Gear Position Sensor Circuit Is Open

Failure Reason:

- There is a defect in the wiring.
- There is a defect in the gear position sensor.
- There is a defect in the TCU.



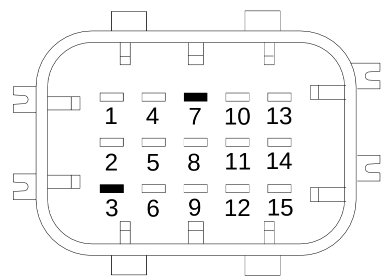
Problem	Procedure	Result	Action
Pins on the X2 connector or the gear position sensor connector are not making good contact.	Do the "Harness Visual Check, Gear Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The gear position sensor is not providing the correct resistance data.	Remove the gear position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 34 or greater than 122 ohms.	Replace the x-y actuator. See **Subject 170**.
		The resistance is between 34 and 122 ohms.	Go to the next row in the table.

Gear Position Sensor Faults (PID 59)

PID 59, FMI 05—The Gear Position Sensor Circuit Is Open

Failure Reason:

- There is a defect in the wiring.
- There is a defect in the gear position sensor.
- There is a defect in the TCU.



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Problem	Procedure	Result	Action
The transmission harness or the TCU has a wiring problem.	Check for resistance on the female connectors from X2 connector plug 7 to sensor connector plug 2.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	Check for resistance on the female connectors from X2 connector plug 3 to sensor connector plug 1.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 4, The Gear Position Sensor Circuit Is Open

PID 59, FMI 14—The Gear Position Sensor Gives Incorrect Resistance Readings

Failure Reason:

- The resistance values broadcast on the datalink are not plausible.
- There is a defect in the wiring.
- There is a defect in the gear position sensor.
- There is a defect in the TCU.

Problem	Procedure	Result	Action
Pins on the X2 connector or the gear position sensor connector are not making good contact.	Do the "Harness Visual Check, Gear Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The gear position sensor is not providing the correct resistance data.	Disconnect the gear position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 34 or greater than 122 ohms.	Replace the x-y actuator. See **Subject 170**.
		The resistance is between 34 and 122 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 5, The Gear Position Sensor Gives Incorrect Resistance Readings

Harness Visual Check, Gear Position Sensor

1. Remove the X2 female connector from the TCU. Check the plugs on the connector. If any plug(s) in the connector is damaged, soiled, worn, broken, or corroded, replace the connector. If no female connectors are available, replace the transmission wiring harness. See **Subject 180** for procedures.
2. Check the pins on the X2 male connector. If any pin(s) on the connector is damaged, soiled, worn, broken, or corroded, replace the TCU. See **Subject 110** for procedures.
3. Remove the female connector from the gear position sensor. If any plug(s) in the connector is

Gear Position Sensor Faults (PID 59)

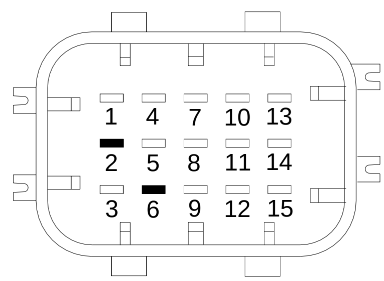
damaged, soiled, worn, broken, or corroded, replace the connector. If no female connectors are available, replace the transmission wiring harness. See **Subject 180** for procedures.

4. Check the pins on the male connector of the gear position sensor. If any pin(s) on the connector is damaged, soiled, worn, broken, or corroded, replace the x-y actuator assembly. See **Subject 170** for procedures.

Rail Position Sensor Faults

There are five rail position sensor faults covered in these procedures. Each one requires a separate electrical test.

- For PID 60, FMI 02, see **Table 1** for procedures and pin identification.
- For PID 60, FMI 03, see **Table 2** for procedures and pin identification.
- For PID 60, FMI 04, see **Table 3** for procedures and pin identification.
- For PID 60, FMI 05, see **Table 4** for procedures and pin identification.
- For PID 60, FMI 14, see **Table 5** for procedures and pin identification.

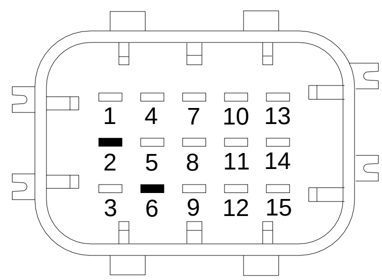
PID 60, FMI 02—The Rail Position Sensor Is Providing Invalid Data			
Failure Reason: • There is a defect in the wiring. • There is a defect in the rail position sensor. • There is a defect in the TCU.		 07/16/2004 X2 f544484g	
Problem	**Procedure**	**Result**	**Action**
Pins on the X2 connector or the rail position sensor connector are not making good contact.	Do the "Harness Visual Check, Rail Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The rail position sensor is not providing the correct resistance data.	Disconnect the rail position sensor wiring. Check for resistance between pins 1 and 2 of the rail position sensor connector.	The resistance is less than 34 or greater than 122 ohms.	Replace the x-y actuator. See **Subject 170**.
		The resistance is between 34 and 122 ohms.	Go to the next row in the table.
The transmission harness has an open circuit.	With the sensor wiring disconnected, remove the X2 connector from the TCU. Check for resistance on the female connectors from X2 connector plug 6 to sensor connector plug 1.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	With the transmission harness wiring disconnected, check for resistance on the female connectors from X2 connector plug 2 to sensor connector plug 2.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next row in the table.

Rail Position Sensor Faults (PID 60)

PID 60, FMI 02—The Rail Position Sensor Is Providing Invalid Data

Failure Reason:

- There is a defect in the wiring.
- There is a defect in the rail position sensor.
- There is a defect in the TCU.



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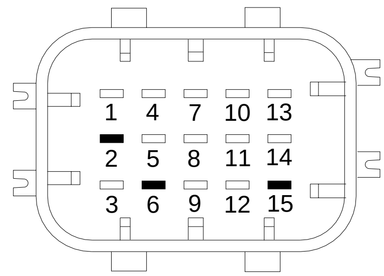
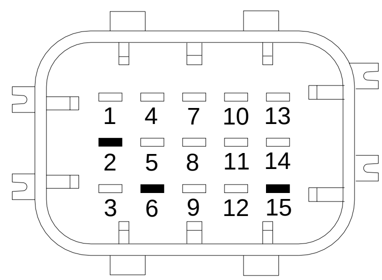
Problem	Procedure	Result	Action
The transmission harness or the TCU has a wiring problem.	With the transmission harness wiring still disconnected, check for shorts on the X2 female connector from plug 2 to plug 15.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Go to the next short circuit check.
	In a similar manner, continue to check for shorts on the X2 female connector from plug 6 to plugs 1, 2, 4, 7, 10, 13, and 15.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All the circuits are open.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Rail Position Sensor Is Providing Invalid Data

Rail Position Sensor Faults (PID 60)

PID 60, FMI 03—The Rail Position Sensor Circuit Is Shorted to Power			
Failure Reason: • There is a defect in the wiring. • There is a defect in the TCU.		 07/16/2004 X2 f544484h	
Problem	**Procedure**	**Result**	**Action**
Pins on the X2 connector or the rail position sensor connector are not making good contact.	Do the "Harness Visual Check, Rail Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.

Rail Position Sensor Faults (PID 60)

<table>
<tr><th colspan="4">PID 60, FMI 03—The Rail Position Sensor Circuit Is Shorted to Power</th></tr>
<tr><td colspan="2">Failure Reason:
• There is a defect in the wiring.
• There is a defect in the TCU.</td><td colspan="2">

07/16/2004 X2 f544484h</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="4">The transmission harness or the TCU has a wiring problem.</td><td rowspan="2">Turn off the ignition and wait for the gear display to power down. Remove the X2 connector from the TCU. On the female connector, check plug 15 to plug 2 for a short circuit.</td><td>A short circuit is found.</td><td>Replace the transmission harness. See Subject 180.</td></tr>
<tr><td>The circuit is open.</td><td>Go to the next short circuit check.</td></tr>
<tr><td rowspan="2">With the X2 connector removed, check plug 15 to plug 6 on the X2 female connector for a short circuit.</td><td>A short circuit is found.</td><td>Replace the transmission harness. See Subject 180.</td></tr>
<tr><td>The circuit is open.</td><td>Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test.

NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test.

1. Using ServiceLink, print the AGS codes (130).

2. Complete the electrical pre-test result sheet in Subject 301.

3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).</td></tr>
</table>

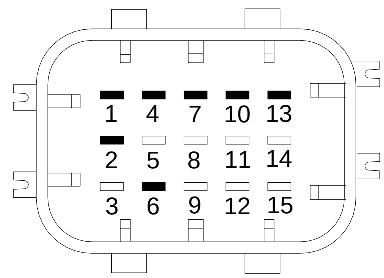
Table 2, The Rail Position Sensor Circuit Is Shorted to Power

Rail Position Sensor Faults (PID 60)

PID 60, FMI 04—The Rail Position Sensor Circuit Is Shorted to Ground

Failure Reason:

- There is a defect in the wiring.
- There is a defect in the rail position sensor.
- There is a defect in the TCU.



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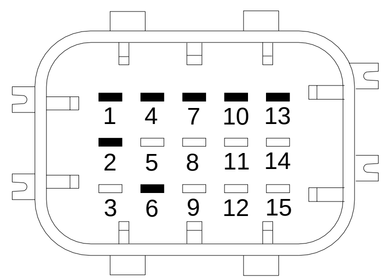
Problem	Procedure	Result	Action
Pins on the X2 connector or the rail position sensor connector are not making good contact.	Do the "Harness Visual Check, Rail Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The rail position sensor is not providing the correct resistance data.	Remove the rail position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 34 or greater than 122 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).
		The resistance is between 34 and 122 ohms.	Go to the next row in the table.

Rail Position Sensor Faults (PID 60)

<table>
<tr><th colspan="4">PID 60, FMI 04—The Rail Position Sensor Circuit Is Shorted to Ground</th></tr>
<tr><td colspan="2">Failure Reason:
• There is a defect in the wiring.
• There is a defect in the rail position sensor.
• There is a defect in the TCU.</td><td colspan="2">

08/11/2005 X2 f544484i</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="4">The transmission harness or the TCU has a wiring problem.</td><td rowspan="2">With the sensor wiring disconnected, remove the X2 connector from the TCU. Check plugs 2 and 6 on the female connector for short circuit to ground.</td><td>The circuit is shorted to ground.</td><td>Replace the transmission harness. See Subject 180.</td></tr>
<tr><td>The circuit is open.</td><td>Go to the next short circuit check.</td></tr>
<tr><td rowspan="2">In a similar manner, continue to check for shorts on the X2 female connector from plug 6 to plugs 1, 4, 7,10, and 13.</td><td>There are one or more short circuits.</td><td>Replace the transmission harness. See Subject 180.</td></tr>
<tr><td>All circuits are open.</td><td>Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test.

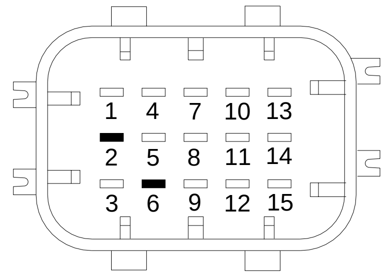
NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test.

1. Using ServiceLink, print the AGS codes (130).

2. Complete the electrical pre-test result sheet in Subject 301.

3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).</td></tr>
</table>

Table 3, The Rail Position Sensor Circuit Is Shorted to Ground

<table>
<tr><th colspan="4">PID 60, FMI 05—The Rail Position Sensor Circuit Is Open</th></tr>
<tr><td colspan="2">Failure Reason:
• There is a defect in the wiring.
• There is a defect in the rail position sensor.
• There is a defect in the TCU.</td><td colspan="2">

07/16/2004 X2 f544484g</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">Pins on the X2 connector or the rail position sensor connector are not making good contact.</td><td rowspan="2">Do the "Harness Visual Check, Rail Position Sensor."</td><td>Connectors and/or pins are damaged, soiled, worn, broken, or corroded.</td><td>Replace the damaged components.</td></tr>
<tr><td>All connectors and pins are OK.</td><td>Go to the next row in the table.</td></tr>
<tr><td rowspan="2">The rail position sensor is not providing the correct resistance data.</td><td rowspan="2">Remove the rail position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.</td><td>The resistance is less than 34 or greater than 122 ohms.</td><td>Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test.

NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test.

1. Using ServiceLink, print the AGS codes (130).

2. Complete the electrical pre-test result sheet in Subject 301.

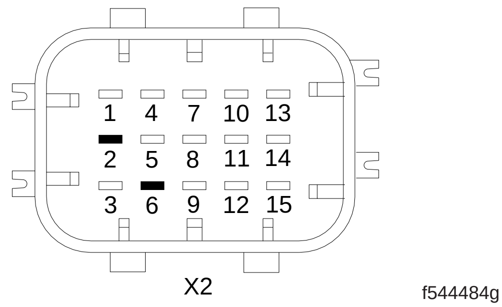
3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).</td></tr>
<tr><td>The resistance is between 34 and 122 ohms.</td><td>Go to the next row in the table.</td></tr>
</table>

Rail Position Sensor Faults (PID 60)

PID 60, FMI 05—The Rail Position Sensor Circuit Is Open

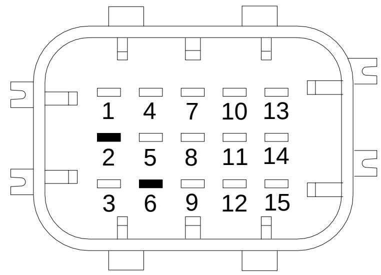
Failure Reason:

- There is a defect in the wiring.
- There is a defect in the rail position sensor.
- There is a defect in the TCU.



Problem	Procedure	Result	Action
The transmission harness or the TCU has a wiring problem.	Check for resistance on the female connectors from X2 connector plug 2 to sensor connector plug 2.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	Check for resistance on the female connectors from X2 connector plug 6 to sensor connector plug 1.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 4, The Rail Position Sensor Circuit Is Open

<table>
<tr><th colspan="3">PID 60, FMI 14—The Rail Position Sensor Gives Incorrect Resistance Readings</th></tr>
<tr><td colspan="2">Failure Reason:
• The resistance values broadcast on the datalink are not plausible.
• There is a defect in the wiring.
• There is a defect in the rail position sensor.
• There is a defect in the TCU.</td><td>

07/16/2004 X2 f544484g</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Action</th></tr>
<tr><td rowspan="2">Pins on the X2 connector or the rail position sensor connector are not making good contact.</td><td rowspan="2">Do the "Harness Visual Check, Rail Position Sensor."</td><td>If the connectors and/or pins are damaged, soiled, worn, broken, or corroded, replace the damaged components.</td></tr>
<tr><td>If all connectors and pins are OK, go to the next row in the table.</td></tr>
<tr><td>The rail position sensor is not providing the correct resistance data.</td><td>Disconnect the rail position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.</td><td>Contact Mercedes-Benz Transmissions Service Support with the resistance values, AGS codes, and results of the electrical pre-test.
NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test.
1. Using ServiceLink, print the AGS codes (130).
2. Complete the electrical pre-test result sheet in Subject 301.
3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).</td></tr>
</table>

Table 5, The Rail Position Sensor Gives Incorrect Resistance Readings

Harness Visual Check, Rail Position Sensor

1. Remove the X2 female connector from the TCU. Check the plugs on the connector. If any plug(s) in the connector is damaged, soiled, worn, broken, or corroded, replace the connector. If no female connectors are available, replace the transmission wiring harness. See **Subject 180** for procedures.
2. Check the pins on the X2 male connector. If any pin(s) on the connector is damaged, soiled, worn, broken, or corroded, replace the TCU. See **Subject 110** for procedures.
3. Remove the female connector from the rail position sensor. If any plug(s) in the connector is damaged, soiled, worn, broken, or corroded, replace the connector. If no female connectors are available, replace the transmission wiring harness. See **Subject 180** for procedures.
4. Check the pins on the male connector of the rail position sensor. If any pin(s) on the connector is damaged, soiled, worn, broken, or corroded, replace the x-y actuator assembly. See **Subject 170** for procedures.

Vehicle Direction Signal Faults

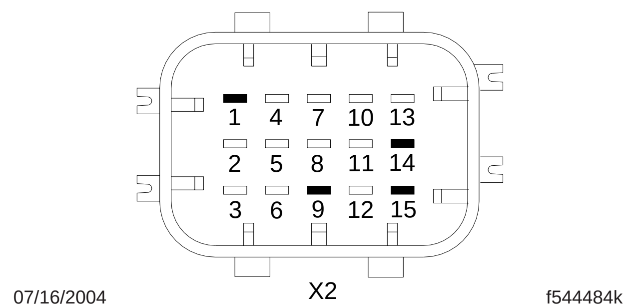
There are two vehicle direction signal faults covered in these procedures. There is one procedure to correct both faults.

- For PID 64, FMI 09, see **Table 1** for procedures.
- For PID 64, FMI 11, see **Table 1** for procedures.

PID 64, FMI 09, 11—The Output Shaft Speed Sensor Is Not Providing Accurate Data

Failure Reason:

- There is a defect in one or both of the output shaft speed sensors.
- There is a defect in the wiring.
- There is a defect in the TCU.



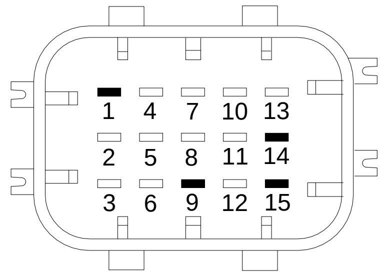
Problem	Procedure	Result	Action
One or both of the sensors is damaged or broken.	Do a visual check of both speed sensors.	A sensor is damaged or broken.	Replace the affected sensor. See **Subject 120**.
		Both sensors are OK.	Go to the next row in the table.
One or both of the sensors is loose.	Check both speed sensors for tightness.	A sensor is loose.	Tighten the affected sensor 28 lbf·ft (38 N·m).
		Both sensors are firmly attached and tightened to the correct specifications.	Go to the next row in the table.
One or both of the sensors has a wiring problem.	Check the sensor wiring.	A sensor is wired wrong.	Wire the affected sensor correctly.
		Both sensors are wired correctly.	Go to the next row in the table.
Pins on the X2 connector are not making good contact.	Disconnect the transmission harness from the X2 connector. Do a visual check of the X2 connector halves (both male and female).	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
Pins on the output shaft speed sensor connectors are not making good contact.	Disconnect the transmission harness from the two sensor connectors. Do a visual check of both sensor connector halves (both male and female).	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.

Vehicle Direction Signal Faults (PID 64)

PID 64, FMI 09, 11—The Output Shaft Speed Sensor Is Not Providing Accurate Data

Failure Reason:

- There is a defect in one or both of the output shaft speed sensors.
- There is a defect in the wiring.
- There is a defect in the TCU.



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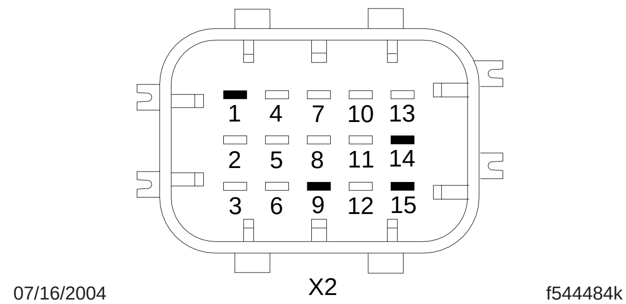
Problem	Procedure	Result	Action
The wiring of the #1 output shaft speed sensor (at the 11:00 position) has an open circuit.	With the sensor wiring still disconnected, check for resistance on the female connectors from X2 connector plug 1 to output shaft speed sensor #1 connector plug 2.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	Check for resistance on the female connectors from X2 connector plug 15 to output shaft speed sensor #1 connector plug 1.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	Check for resistance on the female connectors from X2 connector plug 14 to output shaft speed sensor #1 connector plug 4.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next row in the table.
The wiring of the #2 output shaft speed sensor (at the 9:00 position) has an open circuit.	With the sensor wiring still disconnected, check for resistance on the female connectors from X2 connector plug 1 to output shaft speed sensor #2 connector plug 2.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	Check for resistance on the female connectors from X2 connector plug 15 to output shaft speed sensor #2 connector plug 1.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	Check for resistance on the female connectors from X2 connector plug 9 to output shaft speed sensor #2 connector plug 3.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next row in the table.

Vehicle Direction Signal Faults (PID 64)

PID 64, FMI 09, 11—The Output Shaft Speed Sensor Is Not Providing Accurate Data

Failure Reason:

- There is a defect in one or both of the output shaft speed sensors.
- There is a defect in the wiring.
- There is a defect in the TCU.



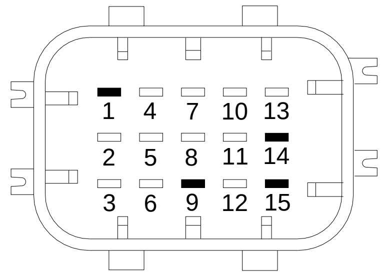
Problem	Procedure	Result	Action
There is a short circuit in the output shaft speed sensor wiring.	With the sensor wiring still disconnected, check for a short circuit on the female connectors from X2 connector plug 1 to X2 connector plugs 3, 5, 6, 9, 11, 12, 14, and 15.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All circuits are open.	Go to the next short circuit check.
	Check for a short circuit on the female connectors from X2 connector plug 9 to X2 connector plugs 2, 3, 4, 5, 6, 7, 10, 11, 12, and 13.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All circuits are open.	Go to the next short circuit check.
	Check for a short circuit on the female connectors from X2 connector plug 14 to X2 connector plugs 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, and 13.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All circuits are open.	Go to the next short circuit check.
	Check for a short circuit on the female connectors from X2 connector plug 15 to X2 connector plugs 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, and 14.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All circuits are open.	Go to the next row in the table.

Vehicle Direction Signal Faults (PID 64)

PID 64, FMI 09, 11—The Output Shaft Speed Sensor Is Not Providing Accurate Data

Failure Reason:

- There is a defect in one or both of the output shaft speed sensors.
- There is a defect in the wiring.
- There is a defect in the TCU.



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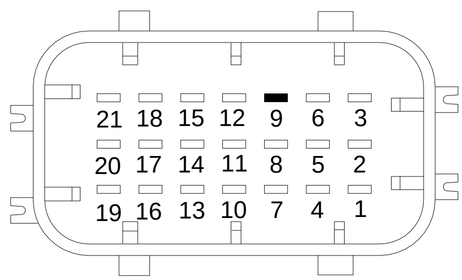
Problem	Procedure	Result	Action
There is a wiring problem that affects either the output shaft speed sensors or the TCU.	With the wiring still disconnected, check the fault code again.	The fault code is still active.	Replace both sensors. See **Subject 120**.
		The fault code is no longer active.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Output Shaft Speed Sensor Is Not Providing Accurate Data

Ignition Power Supply Faults

There are two ignition power circuit faults covered in these procedures. Each one requires a different electrical test.

- For PID 158, FMI 00, see **Table 1** for procedures and pin identification.
- For PID 158, FMI 01, see **Table 2** for procedures and pin identification.

<table>
<tr><th colspan="4">PID 158, FMI 00—The Voltage in the Ignition Power Circuit Is Too High</th></tr>
<tr><td colspan="2">Failure Reason:
• There is a problem in the vehicle starting and/or charging system.
• There is a defect in the wiring.</td><td colspan="2">

07/16/2004 f544483c</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">The battery voltage is too high.</td><td rowspan="2">Disconnect the X1 connector. Check voltage from plug 9 (on the female connector) to ground.</td><td>Voltage is more than 14V and remains constant for more than one second.</td><td>Check the starting and charging system on the vehicle.</td></tr>
<tr><td>Voltage is between 12V and 14V.</td><td>Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test.

NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test.

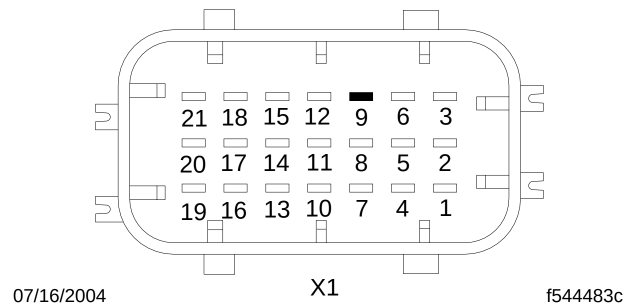
1. Using ServiceLink, print the AGS codes (130).

2. Complete the electrical pre-test result sheet in Subject 301.

3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).</td></tr>
</table>

Table 1, The Voltage in the Ignition Power Circuit Is Too High

Ignition Power Supply Faults (PID 158)

<table>
<tr><th colspan="4">PID 158, FMI 01—The Voltage in the Ignition Power Circuit Is Too Low</th></tr>
<tr><td colspan="2">Failure Reason:
The battery needs charging or replacing.
There is a defect in the wiring.
There is a defect in the TCU.</td><td colspan="2">
</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">The battery voltage is too low.</td><td rowspan="2">With the engine running, disconnect the X1 connector. Check voltage from plug 9 (on the female connector) to ground.</td><td>Voltage is less than 12V and remains constant for more than one second.</td><td>Charge or replace the battery. See Section 54.12.</td></tr>
<tr><td>Voltage is between 12V and 14V.</td><td>Go to the next step.</td></tr>
<tr><td rowspan="3">Pins on the X1 connector are not making good contact.</td><td rowspan="3">Disconnect the vehicle harness from the X1 connector. Do a visual check of the X1 connector halves (both male and female).</td><td>On the female half, the connector and/or plugs are damaged, soiled, worn, broken, or corroded.</td><td>Replace the damaged components.</td></tr>
<tr><td>On the male half, the connector and/or pins are damaged, soiled, worn, broken, or corroded.</td><td rowspan="2">Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test.

NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test.

1. Using ServiceLink, print the AGS codes (130).

2. Complete the electrical pre-test result sheet in Subject 301.

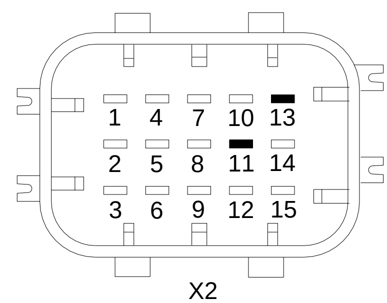
3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).</td></tr>
<tr><td>All connectors and pins are OK.</td></tr>
</table>

Table 2, The Voltage in the Ignition Power Circuit Is Too Low

Input Shaft Speed Sensor Faults

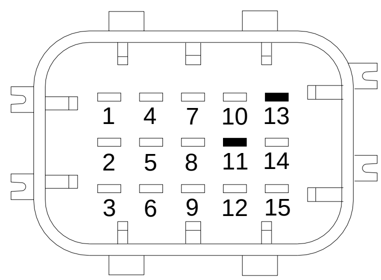
There are five input shaft speed sensor faults covered in these procedures. One troubleshooting procedure is used to correct FMI 02, 03, 04, and 05. A separate procedure is used for FMI 08.

- For PID 161, FMI 02, 03, 04, and 05, see **Table 1** for procedures.
- For PID 161, FMI 08, see **Table 2** for procedures.

<table>
<tr><th colspan="3">PID 161, FMI 02, 03, 04, 05—The Input Shaft Speed Sensor Circuit Gives Invalid Data, Is Shorted, or Open</th></tr>
<tr><td>Failure Reason
• There is a defect in the input shaft speed sensor.
• There is a defect in the wiring.
• There is a defect in the TCU.
• The resistance values broadcast on the datalink are not plausible.</td><td colspan="2">

07/16/2004 f544484j</td></tr>
<tr><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">Turn off the ignition switch and wait for the current gear display to power down. Remove the X2 connector from the TCU. At room temperature, measure the resistance between pins 11 and 13.</td><td>Resistance is less than 900 or more than 1200 ohms.</td><td>Go to the next row in the table and check for a defective sensor.</td></tr>
<tr><td>Resistance is between 900 and 1200 ohms.</td><td>Go to the bottom row in the table and check for a defective wiring harness or TCU.</td></tr>
<tr><td rowspan="2">Unlock the connector cap from the sensor. At room temperature, measure the resistance between the two pins of the sensor.</td><td>Resistance is less than 900 or more than 1200 ohms.</td><td>Replace the input shaft speed sensor (see Subject 120).</td></tr>
<tr><td>Resistance is between 900 and 1200 ohms.</td><td>Go to the bottom row in the table.</td></tr>
</table>

Input Shaft Speed Sensor Faults (PID 161)

<table>
<tr><th colspan="3">PID 161, FMI 02, 03, 04, 05—The Input Shaft Speed Sensor Circuit Gives Invalid Data, Is Shorted, or Open</th></tr>
<tr><td>Failure Reason
• There is a defect in the input shaft speed sensor.
• There is a defect in the wiring.
• There is a defect in the TCU.
• The resistance values broadcast on the datalink are not plausible.</td><td colspan="2"></td></tr>
<tr><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="2">Check the transmission wiring harness between the TCU and the sensor for damage.</td><td>Damage is found.</td><td>Replace the transmission wiring harness (see Subject 180).</td></tr>
<tr><td>No damage is found.</td><td>Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test.

NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test.

1. Using ServiceLink, print the AGS codes (130).

2. Complete the electrical pre-test result sheet in Subject 301.

3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).</td></tr>
</table>

Table 1, The Input Shaft Speed Sensor Circuit Gives Invalid Data, Is Shorted, or Open

Input Shaft Speed Sensor Faults (PID 161)

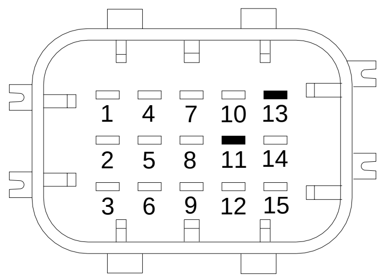
PID 161, FMI 08—The Input Shaft Speed Sensor Is Broadcasting an Abnormal Frequency		
Failure Reason • There is a defect in the input shaft speed sensor. • The input shaft speed sensor is improperly mounted. • There is a defect in the TCU. • The datalink does not recognize the transmission type.	 07/16/2004 X2 f544484j	
Procedure	**Result**	**Action**
Remove and inspect the speed sensor.	The sensor is damaged.	Replace the input shaft speed sensor if necessary and mount it correctly. See **Subject 120** for procedures.
	The sensor is OK, but the fault code is still active.	Go the next row in the table.
Remove the X2 connector and start the engine. Test for AC voltage between pins 11 and 13.	The AC voltage is less than 1.10V or more than 1.14V.	Replace the input shaft speed sensor. See **Subject 120** for procedures.
	The AC voltage is between 1.10V and 1.14V.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 2, The Input Shaft Speed Sensor Is Broadcasting an Abnormal Frequency

Transmission Range Faults

Transmission Range-Selected Faults (PID 162)

There is one transmission range-selected fault covered in these procedures.

- For PID 162, FMI 02, see **Table 1** for procedures.

Transmission Range-Attained Faults (PID 163)

There is one transmission range-attained fault covered in these procedures.

- For PID 163, FMI 02, see **Table 2** for procedures.

PID 162, FMI 02—The Transmission Is Not Properly Calibrated			
Failure Reason: • The gears are caught in an intermediate position. • The transmission software does not allow shifting.			
Problem	**Procedure**	**Result**	**Action**
There are other active transmission faults.	Check for other MID 130 fault codes.	Other fault codes are active.	Troubleshoot the other active fault codes.
		No other fault codes are active.	Go to the next step in the table.
The transmission needs to be recalibrated.	Complete a learning procedure using either ServiceLink or the SmartShift control. To complete a learning procedure using the SmartShift control: 1. Ensure that the parking brake is set. 2. With the ignition turned off, pull and hold the SmartShift control toward steering wheel. NOTE: The SmartShift control must be kept in this position until the gear display clears at the end of the procedure. 3. Turn on the ignition. The normal warm up procedure will initiate and an 'X' will display on the current gear indicator. Your transmission may be heard shifting. 4. Wait until the current gear indicator displays an 'N' (about 30 seconds) and an audible alert sounds. Start the engine within 10 seconds of the audible alert. 5. The engine will raise a few rpm, then fall back to idle, and an audible alert will sound. Turn off the engine within 10 seconds of audible alert. When the gear display clears, this procedure is complete. NOTE: If during this procedure an 'SM' or 'X' (after the warm up procedure) appears in the gear display, stop, turn off the ignition, and wait for the gear display to go dark. Then start over. This may need to be repeated several times.	The fault is no longer active.	No further action is needed.
		The fault is still active.	Contact Freightliner Technical Service Support.

Table 1, The Transmission Is Not Properly Calibrated

Transmission Range Faults (PID 162 and 163)

PID 163, FMI 02—The Gears Do Not Shift Properly

Failure Reason:

- There is a defect in the TCU.
- There is a defect in the speed sensor.
- There is a defect in the actuator.
- The transmission software is not properly programmed.
- The datalink does not recognize the transmission type.

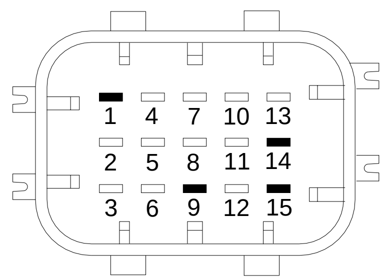
Problem	Procedure	Result	Action
There are other active transmission faults.	Check for other MID 130 fault codes.	Other fault codes are active.	Troubleshoot the other active fault codes.
		No other fault codes are active.	Go to the next step in the table.
There is a transmission software problem.	Using the ServiceLink diagnostics template, view the different gear positions, check that the clutch opens and closes, and that the x-y actuator moves from reverse, 1st, and 2nd gears.	The x-y actuator responds properly and the fault clears.	No further action is needed.
		The fault is still active.	Go to the next step in the table.
There is component damage in the transmission.	Do a visual inspection of the x-y actuator, the hydraulic system, and the transmission shift system.	Damaged components are found.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).
		No damaged components are found.	

Table 2, The Gears Do Not Shift Properly

Output Shaft Speed Sensor Faults (PID 191)

There are four output shaft speed sensor faults covered in these procedures. One troubleshooting procedure is used to correct FMI 02, 05, and 08. A separate procedure is used for FMI 14.

- For PID 191, FMI 02, 05, and 08 see **Table 1** for procedures and pin identification.
- For PID 191, FMI 14, see **Table 2** for procedures.

<table>
<tr><th colspan="3">PID 191, FMI 02, 05, 08—The Output Shaft Speed Sensor Circuit Gives Invalid Data, Is Open, or Not Broadcasting a Signal</th></tr>
<tr><td>Failure Reason:
• The TCU has a hardware problem.
• The sensor is mounted too loose (air gap too big).
• The sensor connectors are damaged or bent.
• The wiring harness has had an electrical failure.
• Either one of the sensors or the TCU has failed.</td><td colspan="2">

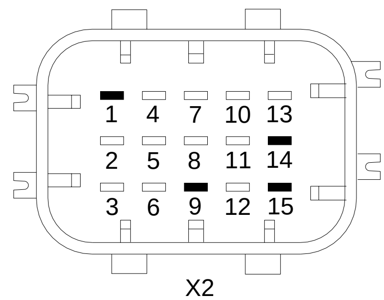
07/16/2004 X2 f544484k</td></tr>
<tr><th>Procedure</th><th>Results</th><th>Action</th></tr>
<tr><td rowspan="2">Turn on the ignition switch and wait for the current gear display to power up.</td><td>Fault code SID 254, FMI 12 is active.</td><td>Go to Subject 309 and troubleshoot SID 254, FMI 12.</td></tr>
<tr><td>SID 254, FMI 12 is not active.</td><td>Go to the next row in the table.</td></tr>
<tr><td rowspan="2">Remove both output shaft speed sensors. Reinstall and tighten the sensor 28 lbf·ft (38 N·m).</td><td>The fault clears after a test drive.</td><td>No further action needed.</td></tr>
<tr><td>The fault remains active.</td><td>Go to the next row in the table.</td></tr>
<tr><td rowspan="2">Turn off the ignition switch and wait for the current gear display to power down. Remove both sensor connectors and visually inspect the pins.</td><td>The connector pins are damaged or bent.</td><td>Repair or replace the damage.</td></tr>
<tr><td>There is no damage to either connector.</td><td>Go to the next row in the table.</td></tr>
<tr><td rowspan="2">Check the upper sensor for continuity:
(1) X2 connector pin 1 to sensor pin 2;
(2) X2 connector pin 15 to sensor pin 1;
(3) X2 connector pin 14 to sensor pin 4.</td><td>There is an open circuit.</td><td>Replace the transmission wiring harness (see Subject 180).</td></tr>
<tr><td>The wiring is OK.</td><td>Go to the next row in the table.</td></tr>
<tr><td rowspan="2">Check the lower sensor for continuity:
(1) X2 connector pin 1 to sensor pin 2;
(2) X2 connector pin 15 to sensor pin 1;
(3) X2 connector pin 9 to sensor pin 3.</td><td>There is an open circuit.</td><td>Replace the transmission wiring harness (see Subject 180).</td></tr>
<tr><td>The wiring is OK.</td><td>Go to the next row in the table.</td></tr>
<tr><td rowspan="2">Check all four pins of each sensor connector for voltage and for continuity to ground.</td><td>Voltage or continuity is found.</td><td>Replace the transmission wiring harness (see Subject 180).</td></tr>
<tr><td>There is zero voltage and no continuity.</td><td>Go to the next row in the table.</td></tr>
</table>

Output Shaft Speed Sensor Faults (PID 191)

PID 191, FMI 02, 05, 08—The Output Shaft Speed Sensor Circuit Gives Invalid Data, Is Open, or Not Broadcasting a Signal

Failure Reason:

- The TCU has a hardware problem.
- The sensor is mounted too loose (air gap too big).
- The sensor connectors are damaged or bent.
- The wiring harness has had an electrical failure.
- Either one of the sensors or the TCU has failed.



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Procedure	Results	Action
Using a sensor known to be good, replace each sensor in turn (see **Subject 120** for procedures).	The fault becomes inactive.	No further action needed.
	The fault is still active.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@ Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Output Shaft Speed Sensor Circuit Gives Invalid Data, Is Open, or Not Broadcasting a Signal

PID 191, FMI 14—The Output Shaft Speed Sensor Is Providing Invalid Data

Failure Reason

- The antilock brake system (ABS) is not broadcasting wheel speed data.
- There is a defective output shaft speed sensor.

Procedure	Result	Action
Check for other PID 191 fault codes.	Other PID 191 fault codes are active.	Troubleshoot PID 191. See **Table 1**.
	No other PID 191 fault codes are active.	Go to the next step in the table.

Output Shaft Speed Sensor Faults (PID 191)

PID 191, FMI 14—The Output Shaft Speed Sensor Is Providing Invalid Data		
Failure Reason • The antilock brake system (ABS) is not broadcasting wheel speed data. • There is a defective output shaft speed sensor.		
Procedure	**Result**	**Action**
Check for active fault codes in MID 136 (ABS).	Active MID 136 fault codes are found.	Troubleshoot the ABS system (see the applicable section in **Group 42**).

Table 2, The Output Shaft Speed Sensor Is Providing Invalid Data

For a schematic of the AGS transmission wiring behind the X2 (transmission) connector, see **Fig. 1**. For a schematic of the AGS transmission wiring behind the X1 (main vehicle) and X3 (electric motor) connectors, see drawing G06-49466.

For a list of special tools, see **Table 1**.

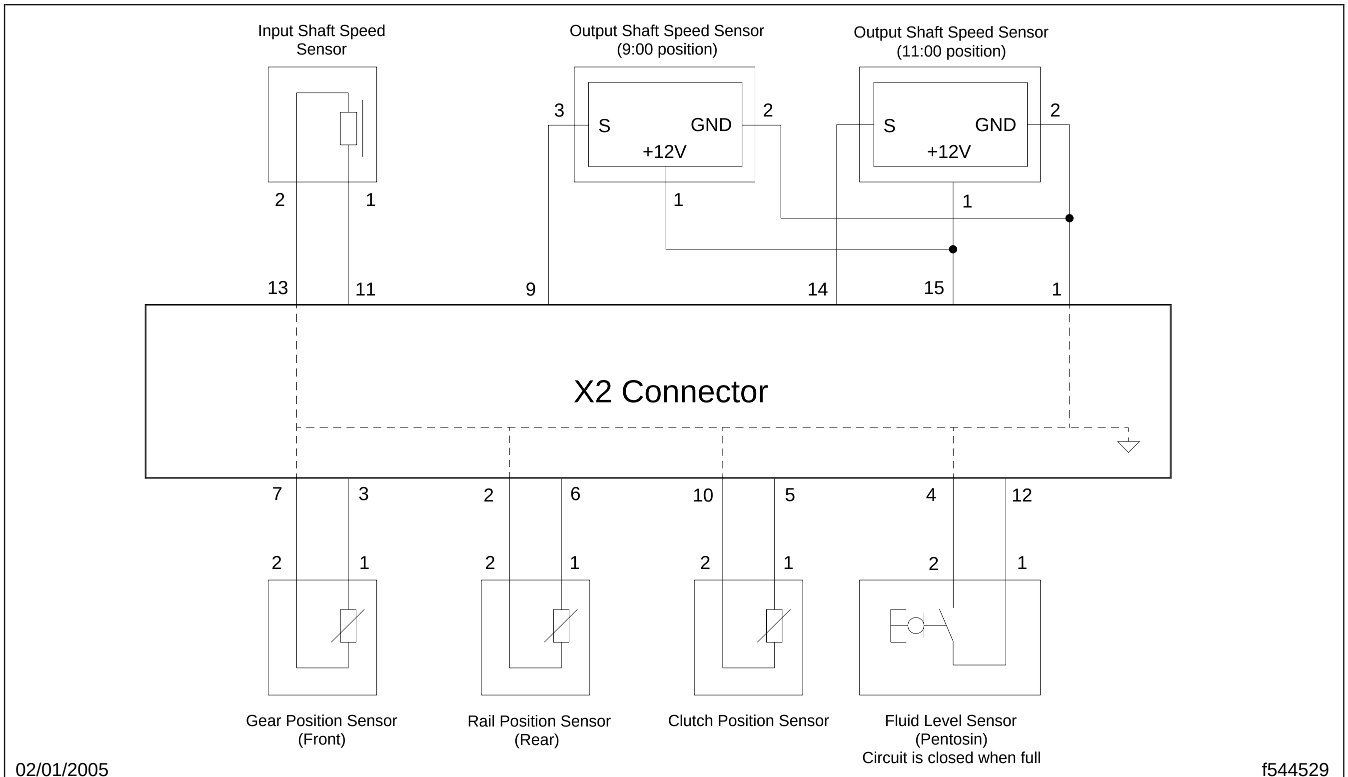
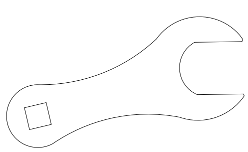
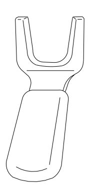


Fig. 1, AGS Transmission Wiring, X2 Connector

Special Tools for AGS Transmission			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580381	Accumulator Torque Adaptor	Kent-Moore	J-47291
 f580379a	Low-Pressure Hose Disconnect Tool	Kent-Moore	J-47202

Specifications

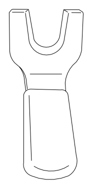
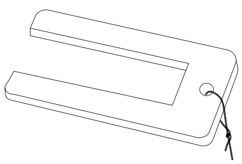
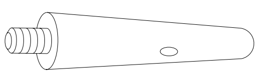
Special Tools for AGS Transmission			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580379	High-Pressure Line Disconnect Tool	Kent-Moore	J-47201
 f580380	Shift Finger Alignment Fork	Kent-Moore	J-47204
 f580382	Shift Mechanism End Guide	Kent-Moore	J-47203

Table 1, Special Tools for AGS Transmission

For transmission installation torque values, see **Table 2**.

Transmission Installation Torque Values			
Description	**Size**	**Class**	**Torque: lbf·ft (N·m)**
Midship Bearing Bracket Capscrews	3/4–11	—	91 (123)
Power Takeoff Unit (PTO) Mounting Capscrews	M10	10.9	43 (58)
Transmission Fluid Drain Plug	M24	—	42 (57)
Transmission Fluid Fill Plug	M24	—	42 (57)
Transmission Mounting Bolts	M10 x 1.5	8.8	33 (45)
U-Joint End Cap Bolts	3/8–24	—	50 (68)
	1/2–20	—	110 (149)

Table 2, Transmission Installation Torque Values

For AGS assembly torque values, see **Table 3**.

AGS Assembly Torque Values			
Description	**Size**	**Torque: lbf·ft (N·m)**	**Torque: lbf·in (N·cm)**
Accumulator Hydraulic Fitting	M30	59 (80)	—
X-Y Actuator Mounting Capscrews	M8	17 (23)	—

AGS Assembly Torque Values			
Description	**Size**	**Torque: lbf·ft (N·m)**	**Torque: lbf·in (N·cm)**
AGS Central Unit Mounting Capscrews	M8	17 (23)	—
Clutch Actuator Hydraulic Fittings	M30	37 (50)	—
Clutch Actuator Mounting Capscrews	M8	17 (23)	—
Pressure-Limiting Valve Adjusting Screw	M6	—	63–71 (700–800)
Reservoir Base Fasteners	M8	11 (15)	—
Reservoir Top Fasteners	M6	—	71 (800)
Rotational Speed (RPM) Sensors	—	28 (38)	—
Shift Rod Setscrew	M12	22 (30)	—
Transmission Control Unit (TCU) Mounting Screws	M8	—	44–53 (500–600)
TCU Splash Guard Mounting Capscrews	M8	17 (23)	—

Table 3, AGS Assembly Torque Values

For AGS transmission gear ratios, see **Table 4**.

AGS Transmission Gear Ratios		
Model	**Gear**	**Ratio**
MBT520-6DA	1	9.201
	2	5.230
	3	3.145
	4	2.034
	5	1.374
	6	1.000
	R	8.649
MBT660-6OA	1	6.700
	2	3.810
	3	2.290
	4	1.480
	5	1.000
	6	0.730
	R	6.290

Table 4, AGS Transmission Gear Ratios

For a list of proprietary fault codes viewable on ServiceLink, see **Table 5**.

AGS Proprietary Fault Codes (J1708)	
Fault Code	**Description**
3000109	High voltage supply voltage—external (connector X1/12 and X1/15)

Specifications

AGS Proprietary Fault Codes (J1708)	
Fault Code	Description
3000113	High voltage ignition key line—external (connector X1/9)
3000209	Low voltage supply voltage—external (connector X1/12 and X1/15)
3000213	Low voltage ignition key line—external (connector X1/9)
3001210	EEPROM parameter values error—internal
3001510	Clutch displacement control module parameter error—internal
3001781	Clutch calibration offset off limit—internal
3002009	Open load supply voltage—external (connector X1/12 and X1/15)
3002016	Open load/Short circuit VCC temperature sensor circuit board—internal
3002017	Open load/Short circuit VCC temperature sensor pump—internal
3002116	Short circuit GND temperature sensor circuit board—internal
3002117	Short circuit GND temperature sensor pump—internal
3002214	Short circuit VCC peripherals supply—external (connector X2/15)
3003001	EBC1 message timeout—external (J1939)
3003101	EEC1 message timeout—external (J1939)
3003201	EEC2 message timeout—external (J1939)
3003301	EEC3 message timeout—external (J1939)
3003401	ERC1 message timeout—external (J1939)
3003501	Wheel speed information message timeout—external (J1939)
3003601	CruiseControl (VCU) message timeout—external (J1939)
3003701	CruiseControl (bulkhead) message timeout—external (J1939)
3003801	Engine configuration message timeout—external (J1939)
3003901	Retarder configuration message timeout—external (J1939)
3004001	Component identification message timeout—external (J1939)
3004101	PTO information message timeout—external (J1939)
3006101	Incorrect engine data—external (J1939)
3006201	Timeout converted engine data for clutch module (low priority)—internal
3006701	Incorrect retarder data—external (J1939)
3006801	Incorrect ABS data—external (J1939)
3006901	Incorrect internal data—internal
3007001	Incorrect clutch module data—internal
3007101	Incorrect automated gear shift module data—internal
3007201	Incorrect internal data—internal
3008881	Clutch overload—internal
3009280	Plausibility error actual transmission gear ratio—internal
3009710	Test software—internal
3009810	Test electronic—internal

AGS Proprietary Fault Codes (J1708)	
Fault Code	**Description**
3009910	Test bench mode activated—internal
3010390	Automatic module: signal group cruise control / retarder—internal
3010690	Automatic module: signal output speed—internal
3010790	Automatic module: signal group MR—internal
3010890	Automatic module: signal group gear ratio—internal
3010990	Automatic module: learning values engine—internal
3011081	Plausibility error intended clutch position can not be reached within specified time—internal
3011090	Automatic module: learning values transmission—internal
3011310	Clutch calibration data missing/error—internal
3011410	Clutch parameter error—internal
3011590	Automatic module: signal group shifting time—internal
3011690	Automatic module: signal group ABS—internal
3011790	Automatic module: signal group pedal activation—internal
3011890	Automatic module: signal group lever—internal
3011990	Automatic module: error target system—internal
3012014	Open load peripherals supply—external (connector X2/15)
3012019	Plausibility error valve relay V-V2 on—internal
3012035	Open load power stage solenoid valve (clutch open 1)—internal
3012036	Open load power stage solenoid valve (clutch open 2)—internal
3012037	Open load power stage solenoid valve (clutch close 1)—internal
3012038	Open load power stage solenoid valve (clutch close 2)—internal
3012050	Open load speed sensor transmission output (DZ1)—external (connector X2/14)
3012051	Open load speed sensor transmission input—external (connector X2/11)
3012052	Open load speed sensor transmission output (D3)—external (connector X2/9)
3012090	Automatic module: system identification gearshift module—internal
3012114	Short circuit to GND peripherals supply—external (connector X2/15)
3012118	Plausibility error valve relay V-V1 off—internal
3012119	Plausibility error valve relay V-V2 off—internal
3012136	Short circuit GND power stage solenoid valve (clutch open 2)—internal
3012138	Short circuit GND power stage solenoid valve (clutch close 2)—internal
3012151	Short circuit GND speed sensor transmission input—external (connector X2/11
3012251	Short circuit VCC speed sensor transmission input—external (connector X2/11)
3012461	Hydraulic level too low external—external
3016201	Timeout converted engine data for clutch module (medium priority)—internal
3016401	Timeout driving direction information—internal
3016501	Timeout internal communication shift module to clutch module (medium priority)—internal

Specifications

AGS Proprietary Fault Codes (J1708)	
Fault Code	**Description**
3018681	Plausibility error clutch open request while inlet valves are closed—internal
3018781	Plausibility error clutch open request while outlet valves are closed—internal
3019480	Plausibility error driving direction—internal
3019621	SmartShift lever data invalid—external (connector X1/8, X1/11, X1/14)
3019650	Tooth signal interruption speed sensor transmission output (DZ1)—external (connector X2/14)
3019651	Tooth signal interruption speed sensor transmission input—external (connector X2/11)
3019652	Tooth signal interruption speed sensor transmission output (D3)—external (connector X2/9)
3020110	High voltage distance sensor supply—internal
3020111	Power supply high voltage—external (connector X3/1)
3020210	Low voltage distance sensor supply—internal
3020211	Power supply low voltage—external (connector X3/1)
3021010	Flash checksum error—internal
3021110	EEPROM calibration values error—internal
3021610	Clutch displacement offset failure—internal
3022011	Supply voltage open load—external (connector X3/1)
3022012	Open load GND connection—external (connector X1/18 and X1/21)
3022015	Open load pressure sensor signal—internal
3022018	Plausibility error valve relay V-V1 on—internal
3022020	Open load GND pump motor—external (connector X3/2)
3022030	Open load power stage solenoid valve (selection direction R)—internal
3022031	Open load power stage solenoid valve (selection direction 5/6)—internal
3022032	Open load power stage solenoid valve—internal
3022033	Open load power stage solenoid valve (gear direction 1,3,5)—internal
3022034	Open load power stage solenoid valve (pressure regulation)—internal
3022041	Open load distance sensor (gear)—internal
3022042	Open load distance sensor (selection)—internal
3022044	Open load distance sensor (clutch)—internal
3022060	Open loop power stage pump motor—internal
3022115	Short circuit GND pressure sensor signal—internal
3022130	Short circuit GND power stage solenoid valve (selection direction R)—internal
3022131	Short circuit GND power stage solenoid valve (selection direction 5/6)—internal
3022132	Short circuit GND power stage solenoid valve (gear direction R,2,4,6)—internal
3022133	Short circuit GND power stage solenoid valve (gear direction 1,3,5)—internal
3022134	Short circuit GND power stage solenoid valve (pressure regulation)—internal
3022135	Short circuit GND power stage solenoid valve (clutch open 1)—internal
3022137	Short circuit GND power stage solenoid valve (clutch close 1)—internal

AGS Proprietary Fault Codes (J1708)	
Fault Code	**Description**
3022141	Short circuit GND distance sensor (gear)—internal
3022142	Short circuit GND distance sensor (selection)—internal
3022144	Short circuit GND distance sensor (clutch)—internal
3022160	Short circuit GND power stage pump motor—internal
3022215	Short circuit VCC pressure sensor signal—internal
3022241	Short circuit VCC distance sensor (gear)—internal
3022242	Short circuit VCC distance sensor (selection)—internal
3022244	Short circuit VCC distance sensor (clutch)—internal
3022317	Over temperature power stage pump motor—internal
3022590	Automatic module: no signal vehicle speed—internal
3022690	Automatic module: signal group MR (high priority)—internal
3022790	Automatic module: signal group gear ratio (high priority)—internal
3022890	Automatic module: learning values engine (high priority)—internal
3022990	Automatic module: learning values transmission (high priority)—internal
3024341	Erratic distance sensor (gear)—internal
3024342	Erratic distance sensor (selection)—internal
3024344	Erratic distance sensor (clutch)—internal
3024441	Wrong coil resistance value distance sensor (gear)—internal
3024442	Incorrect coil resistance value distance sensor (selection)—internal
3024444	Incorrect coil resistance value distance sensor (clutch)—internal
3024610	Timeout displacement sensor value—internal
3026001	CAN bus off—external (connector X1/13 and X1/7)
3026301	Timeout converted engine data for clutch module (high priority)—internal
3026501	Timeout internal communication shift module to clutch module (high priority)—internal
3027401	No J1939 communication—internal / external (connector X1/13 and X1/7)
3027501	Timeout internal communication shift module to clutch module (high priority)—internal
3028581	Clutch displacement control failure—internal
3029180	No calculation of redundant transmission output speed—internal
3029380	Incorrect transmission type—internal
3029580	Plausibility error pressure build up—internal

Table 5, AGS Proprietary Fault Codes (J1708)

For a list of learning procedure errors, see **Table 6**.

Learning Procedure Errors	
Error	**Description**
56	Offset of clutch position out of range

Specifications

Learning Procedure Errors	
Error	**Description**
57	Offset of pressure modulation valve out of range
58	Gear position "neutral" out of range
61	Low gear position out of range
62	High gear position out of range
63	Low select position out of range
66	High select position out of range
68	Valve or sensor failure
69	Vehicle is moving
70	Low voltage or high voltage
71	Clutch open/closed
72	Stalk lever position changed during learning procedure
73	Type of gear box invalid
74	Park brake not activated
76	Engine is running
77	Engine torque invalid or out of range
78	Engine was not started in time
80	Accelerator pedal not idle
82	Countershaft speed not zero

Table 6, Learning Procedure Errors

General Information

The Mercedes-Benz transmission (MBT) is offered in two 6-speed models:

- MBT520S-6D, direct drive, 520 lb·ft torque rating
- MBT660S-6O, overdrive, 660 lb·ft torque rating

The gear case holds 9.5 quarts (9.0 liters) of oil. MobilTrans SHC® DC is the approved oil.

Both models are fully synchronized for reduced shifting effort. Equipped with six forward speeds and one reverse speed, both models show a particularly large overall ratio between low and top gear. See **Specifications, 400** for gear ratios for each model.

To reduce fluid change intervals and to increase bearing life, MBT transmissions are designed with "clean" bearings. These bearings have covers on both sides. They cannot be damaged by the wear particles that accumulate in the fluid. The geometry of the gear teeth has been optimized to provide low-noise operation and extended gear life.

The bell housing has been designed around standard SAE bolt patterns. SAE2 is standard on both MBT660S-6O and MBT520S-6D models.

Other features of the MBT transmissions include:

- Light metal gear cases with integrated bell housings;
- Low installation height (the shift interface is positioned laterally);
- Double synchronization from 1st gear to 4th gear;
- Electronic vehicle speed sensor;
- Longer oil change intervals;
- Full range of PTO units available.

Each model requires a hydraulic clutch system. No clutches with manual control can be installed for use on MBT transmissions. With the hydraulic system installed, the clutch linkage is self-adjusting.

The hydraulic clutch system consists of the following parts:

- Hydraulic fluid reservoir;
- Clutch pedal unit;
- Master cylinder;
- Slave cylinder;
- Hydraulic lines connecting the various parts of the system.

The MBT transmission removal and installation procedures have been moved to **Subject 100** from their previous location in **Section 26.00**.

The teardown procedures included in this section also apply to the AGS automated transmission, with slight changes which are indicated at appropriate places in the procedures. If it is necessary to tear down the AGS transmission, be sure to remove the AGS assembly before proceeding. See **Section 26.03, Subject 200** for procedures.

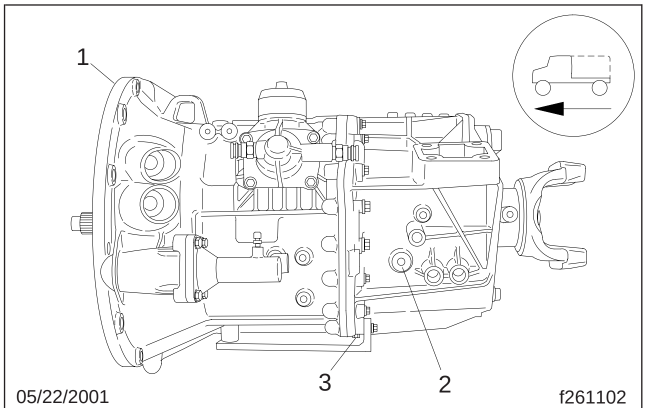
On all transmissions, disassembly of the transmission main shaft is not recommended except when it is necessary to check for synchronizer wear. Disassembly of the countershaft is not recommended in any case.

It is important to check main shaft end play if either gear case half, the main shaft bearings, or the input shaft is replaced. For detailed procedures, see **Subject 250**.

To prevent premature tool wear, use extreme pressure lubricant such as Kent-Moore J 23444-A or equivalent on tool threads and at all friction and contact points.

Removal

1. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the rear tires.
2. Drain the transmission fluid. See **Fig. 1** for the location of the drain plug.



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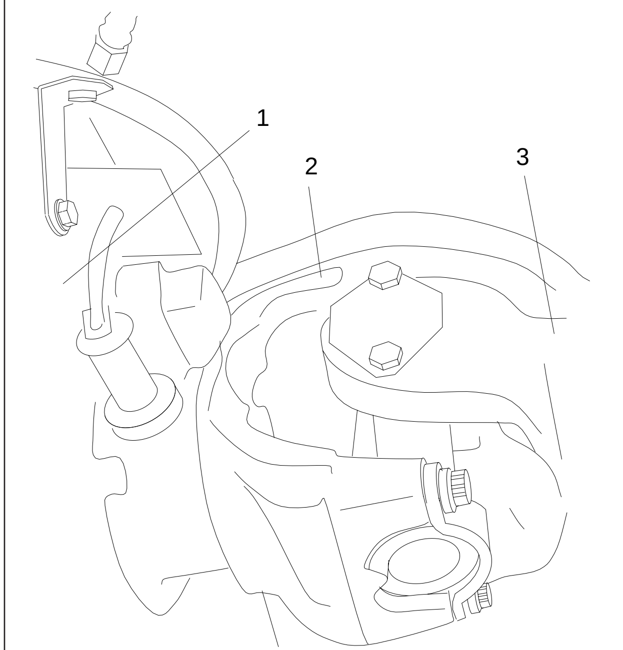
NOTE: The transmission is shown from the left-hand side.

1. Transmission
2. Fill Plug
3. Drain Plug

Fig. 1, Transmission Drain and Fill Plugs

3. Disconnect the driveshaft from the transmission.
   - 3.1 Support the midship bearing.
   - 3.2 Remove the bolts from the U-joint end caps and slide the front of the driveshaft out of the transmission output yoke. See **Fig. 2**.
   - 3.3 Remove the midship bearing bracket. See **Fig. 3**.
   - 3.4 Support the disconnected driveshaft and chain it out of the way. See **Fig. 4**.
4. Remove the shift lever from the transmission.
   - 4.1 Before removing the shift lever, place the transmission in high gear.
   - 4.2 Remove the four screws from the retaining ring around the shift lever boot. See **Fig. 5**. Remove the ring and the boot.
   - 4.3 Remove the head of the shift lever from the transmission. See **Fig. 6**. For ease of installation, mark the head of the shift lever and the attachment point on the transmission with a paint pen.



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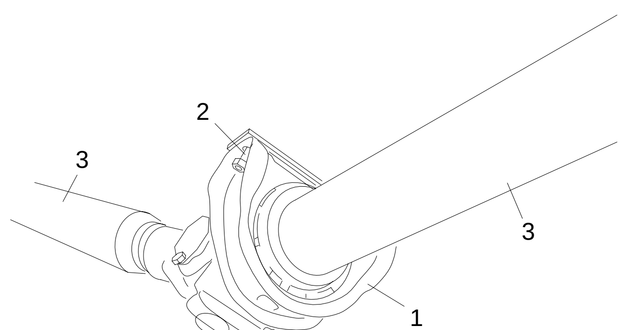
1. Transmission
2. Output Yoke
3. Driveshaft

Fig. 2, Output Yoke



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1. Midship Bracket
2. Mounting Bolt
3. Driveshaft

Fig. 3, Midship Bearing Bracket

5. Remove the fuel lines and the fuel line standoff bracket from the transmission. See **Fig. 7**.

Transmission Removal and Installation

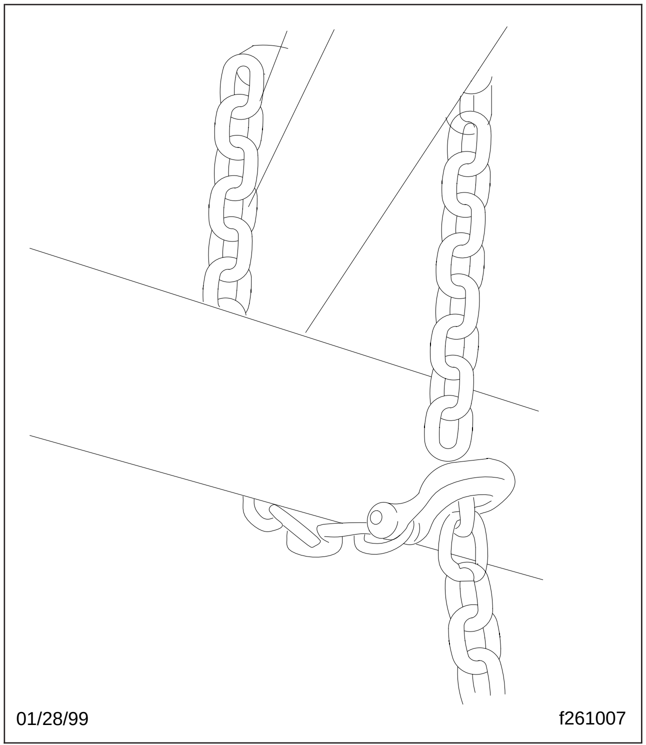


Fig. 4, Supporting the Driveshaft

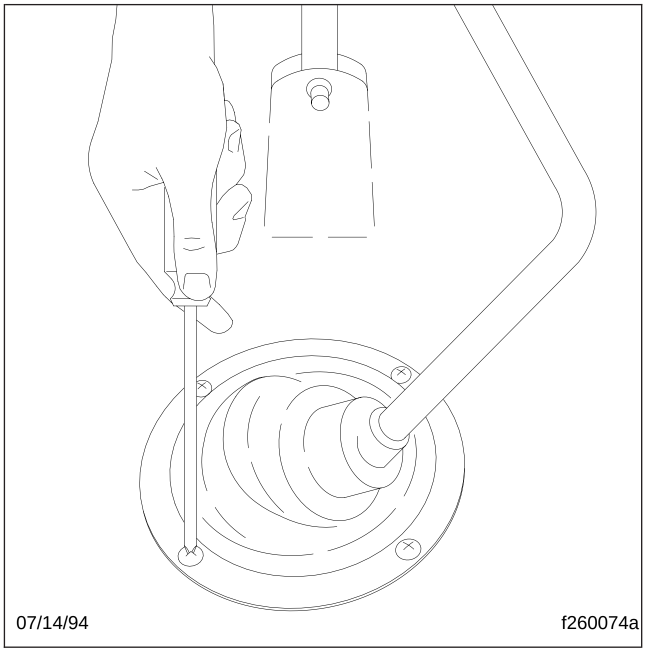
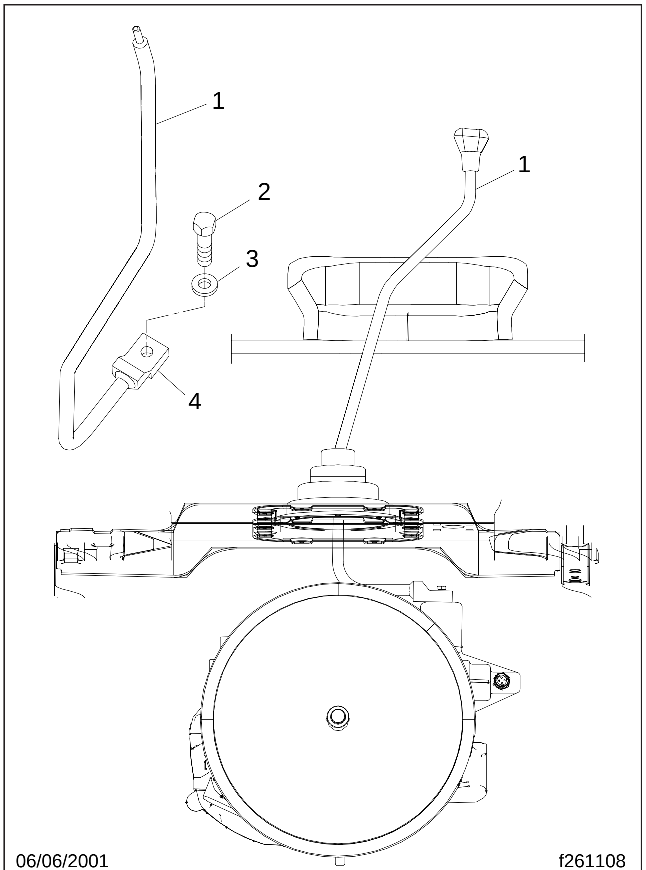


Fig. 5, Shift Lever and Boot



1. Shift Lever
2. Shift Lever Mounting Bolt
3. Thick Washer
4. Head of Shift Lever

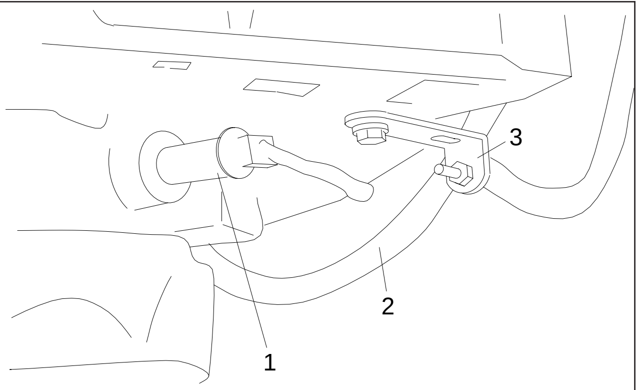
Fig. 6, Shift Lever Connection

6. Disconnect the electrical connectors for the reverse gear switch and the optional starter lock switch (if installed). Mark with a paint pen for ease of installation.

WARNING

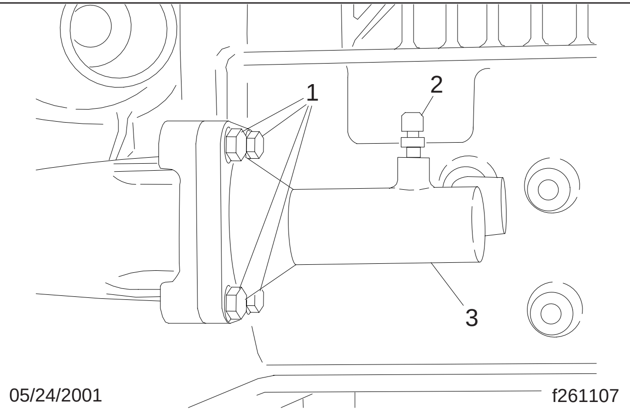
Do not press down on the clutch pedal after removing the slave cylinder. Hydraulic brake fluid may squirt out, causing personal injury and damage to the vehicle.

7. Remove the bolts that attach the clutch slave cylinder to the mounting flange on the gear case. Move the slave cylinder out of the way. See **Fig. 8**.



1. Speedometer Sensor
2. Fuel Line
3. Standoff Bracket

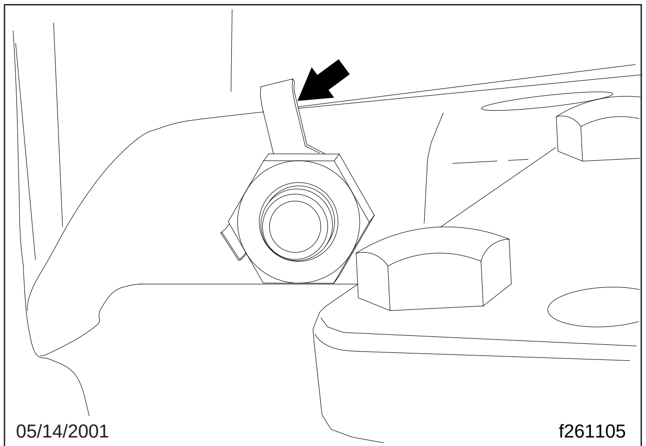
Fig. 7, Fuel Line Standoff Bracket and Speedometer Sensor



1. M8 Bolts
2. Bleed Valve
3. Slave Cylinder

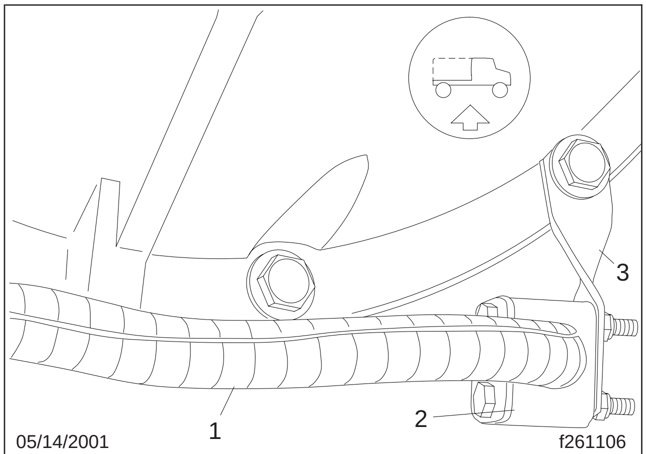
Fig. 8, Hydraulic Clutch Slave Cylinder

8. Bend back the nut retainers and remove the power take-off unit (PTO), if installed. See **Fig. 9**.
9. If the vehicle is equipped with optional dual fuel tanks, remove the fuel cross-over line and its support between the tanks.
10. Disconnect the electrical cable from the speedometer sensor and mark it with a paint pen for ease of installation. See **Fig. 7**.
11. Remove the battery cable bracket(s) around the transmission and move the battery cables out of the way. See **Fig. 10**.



Bend back the nut retainer (arrow).

Fig. 9, Power Take-Off Unit (PTO) Nut Retainers

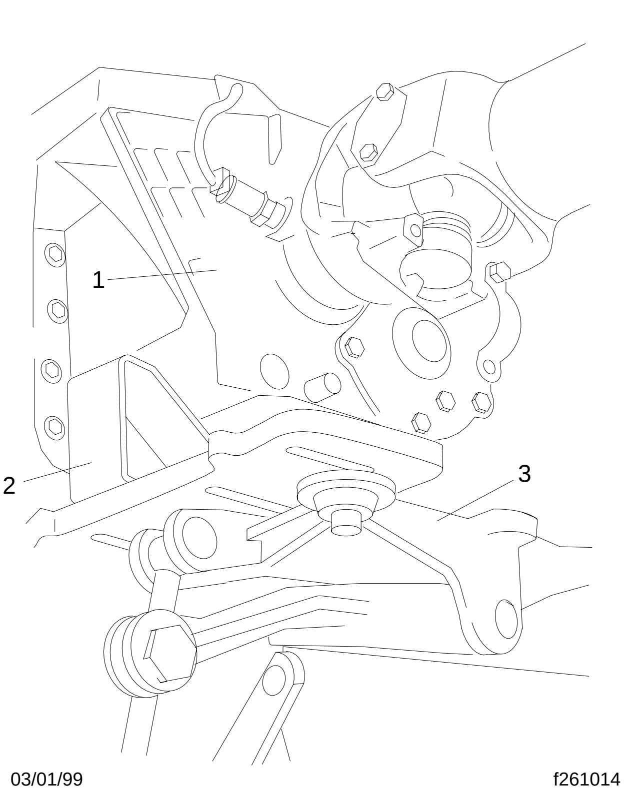


1. Battery Cable
2. Battery Cable Clamp
3. Battery Cable Bracket

Fig. 10, Battery Cable Routing

12. Remove the exhaust clamp at the exhaust elbow. For ease of transmission removal and installation, move the exhaust pipe to the side and out of the way.
13. Support the transmission with a jack. See **Fig. 11**.
    - 13.1 Position a transmission jack under the transmission and raise its support plates against the base of the transmission.
    - 13.2 Adjust the support plates to cradle the transmission.

Transmission Removal and Installation



1. Transmission
2. Support Plate
3. Jack

Fig. 11, Supporting the Transmission

13.3 Using a chain, secure the transmission to the jack.

14. Remove the 16-mm transmission mounting capscrews that attach the timing case to the bell housing. See **Fig. 12**.

    14.1 Remove the eleven transmission mounting capscrews.

    14.2 After removing the transmission, insert the capscrews into the holes in the timing case, rather than in the bell housing.

CAUTION

Do not allow the rear of the transmission to drop, and do not allow the transmission to hang unsupported. Keep the flange of the bell housing parallel (all the way around) to the flange of the timing case, until the input shaft is clear of the flywheel. Taking these precautions will prevent damage to the input shaft, flywheel, and clutch.

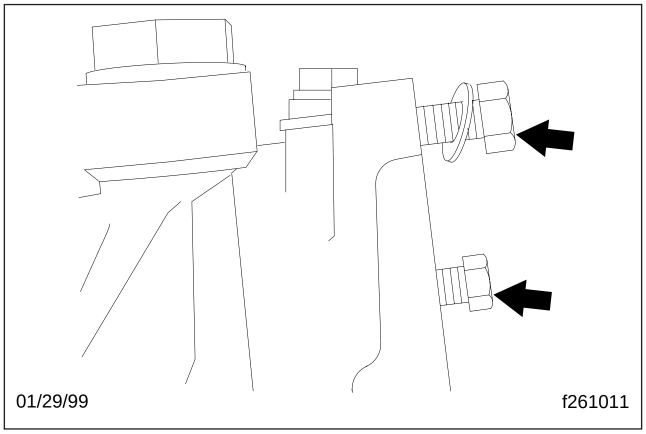
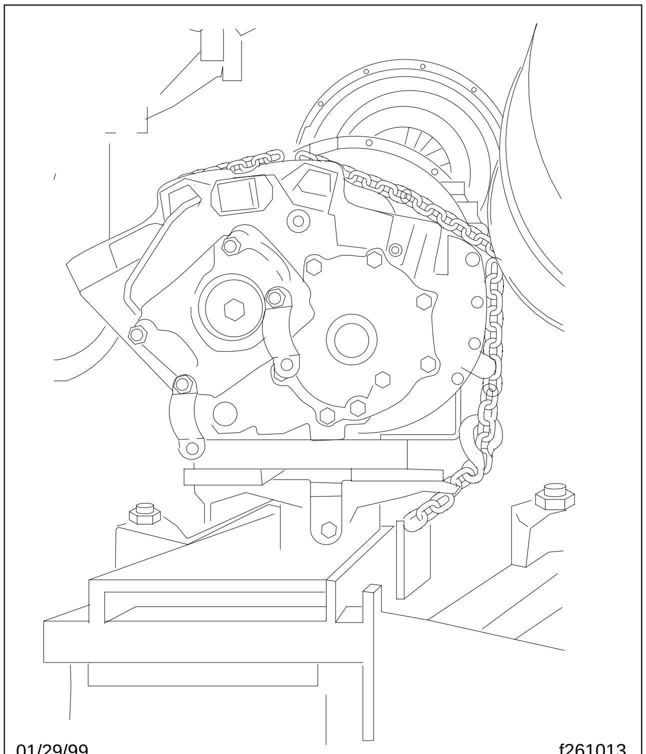


Fig. 12, Capscrews Left in the Timing Case

15. After making sure that the transmission is firmly secured and well supported, remove the transmission from the vehicle. See **Fig. 13**.



Make sure that the transmission is firmly secured and well supported.

Fig. 13, Transmission Ready To Remove

15.1 Pull the transmission and jack straight back until the transmission input shaft is clear of the clutch.

15.2 Turn the left-hand front wheel to allow room for the transmission to pass. If necessary, lower the jack supporting the transmission. It might also be necessary to jack up the truck to get enough clearance to allow the transmission to pass.

IMPORTANT: Watch closely the clearance between the bell housing and the leaf spring.

15.3 Pull the transmission out through the space behind the front wheel.

Installation

IMPORTANT: Before installing the transmission, make sure that the rear tires are chocked and that the transmission is securely chained to the support plates on the transmission jack.

1. Install the transmission. See **Fig. 14**.

    1.1 Align the jack and the transmission behind the engine.

    1.2 Raise the transmission and adjust the angle of the jack until the bell housing and the timing case flange are parallel.

    1.3 Push the transmission and jack straight forward.

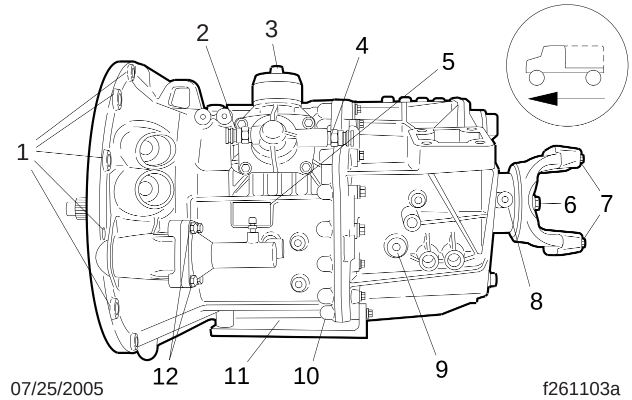
    NOTE: While installing the transmission mounting capscrews, also install the battery cable bracket(s), as removed.

    1.4 Install the eleven M10 transmission mounting capscrews. Use a crossover pattern. Do a final tightening of the capscrews to 33 lbf·ft (45 N·m).

    1.5 Remove the chain around the transmission and the jack; then remove the jack.

2. Install the exhaust clamp at the exhaust elbow, as removed.

3. If the vehicle is equipped with the optional dual fuel tanks, install the fuel cross-over line and its support between the tanks. Tighten the clamps 40 lbf·ft (54 N·m) and the mounting bolts 95 lbf·ft (129 N·m).



NOTE: The transmission is shown from the left-hand side.

1. Transmission Mounting Capscrews
2. Reverse Gear Switch
3. Shift Lever Mounting Bolt
4. Starter Lock Switch
5. Nameplate
6. Output Yoke Pressure Plate Mounting Capscrew
7. U-Joint End Cap Bolts
8. Speedometer Sensor Lock
9. Transmission Fluid Fill Plug
10. Transmission Fluid Drain Plug
11. PTO Mounting Capscrews
12. Clutch Slave Cylinder Mounting Bolts

Fig. 14, Transmission Fasteners

4. If removed, coat the mating surface of the PTO cover with Loctite® 509 or equivalent sealing compound. Install the PTO cover on the transmission. Tighten the M10 hardened mounting capscrews 43 lbf·ft (58 N·m). Lock the nut retainers in place.

5. Connect the driveshaft.

    5.1 Slide the front of the driveshaft into the transmission output yoke.

    5.2 Install the U-joint end caps on the output yoke. Tighten the bolt heads 50 lbf·ft (68 N·m) for 3/8-inch end cap bolts and 110 lbf·ft (149 N·m) for 1/2-inch end cap bolts.

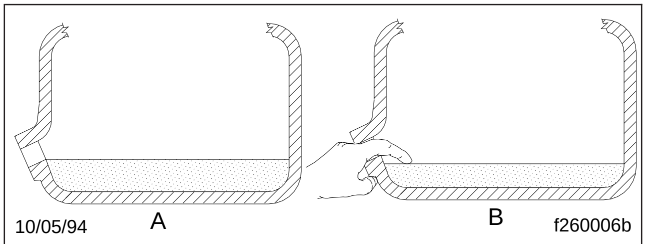
    5.3 Install the midship bearing bracket, as removed. Tighten the nuts 95 lbf·ft (129 N·m).

Transmission Removal and Installation

6. Install the fuel line standoff bracket and connect the fuel lines to the bracket.
7. Connect the electrical connectors. Connect the electrical cable to the speedometer sensor. Connect the electrical connector(s) on the shift lever.
8. Install the shift lever.
   8.1 Fit the shift lever over the cone of the transmission tower.
   8.2 Coat the hardened M10 x 20 shift lever mounting bolt with Loctite 242 or equivalent thread-locking compound.
   8.3 Insert the M10 bolt and a thick washer into the hole in the shift lever. See **Fig. 6**. Use the markings made during removal to install the shift lever in the correct orientation, so as to avoid cab floor interference.

   IMPORTANT: Don't forget to install the washer. Without the washer, the shift lever may loosen. The driver could lose control of the vehicle.

   8.4 Tighten the M10 bolt 50 lbf·ft (68 N·m).
   8.5 Work the shift lever around to make sure it shifts comfortably in all gears.
   8.6 Install the rubber boot and the metal retaining ring. Install the four screws and tighten against the cab floor 28 lbf·ft (38 N·m). See **Fig. 5**.
9. Fasten the clutch slave cylinder to the mounting flange on the gear case and tighten the four M8 slave cylinder mounting bolts 15 lbf·ft (20 N·m).
10. If necessary, bleed the hydraulic clutch system. See **Section 25.02, Subject 140** for detailed instructions.
11. Clean the transmission drain plug and install it in the gear case, along with a new aluminum gasket. Tighten the drain plug 42 lbf·ft (57 N·m).
12. Add Mobiltrans SHC® DC until the transmission fluid is level with the lower edge of the fill opening. See **Fig. 1** for the location of the fill plug and **Fig. 15** for checking the correct level. About 9.5 quarts (9.0 liters) is needed.
13. Clean the transmission fill plug and install it in the gear case, along with a new aluminum gasket. Tighten the fill plug 42 lbf·ft (57 N·m).



A. Full
B. Low

Fig. 15, Transmission Fluid Level Checking

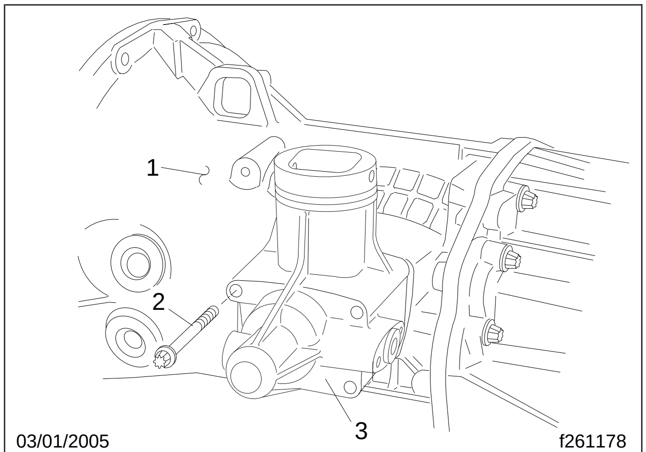
14. Remove the chocks from the rear tires.

Shift Mechanism Removal and Installation

NOTE: These procedures are for the manual transmission with shift lever only. For the automated AGS transmission, see **Section 26.03, Subject 200**.

Removal

1. Remove the transmission. For detailed procedures, see **Subject 100**.
2. Secure the transmission on a wooden pallet, or other device to keep it from moving.
3. Make sure the transmission is in neutral.
4. Remove the four capscrews that attach the shift rod housing to the flange on the front gear case. See **Fig. 1**.



1. Front Gear Case
2. Shift Rod Housing Capscrew
3. Shift Rod Housing

Fig. 1, Shift Mechanism

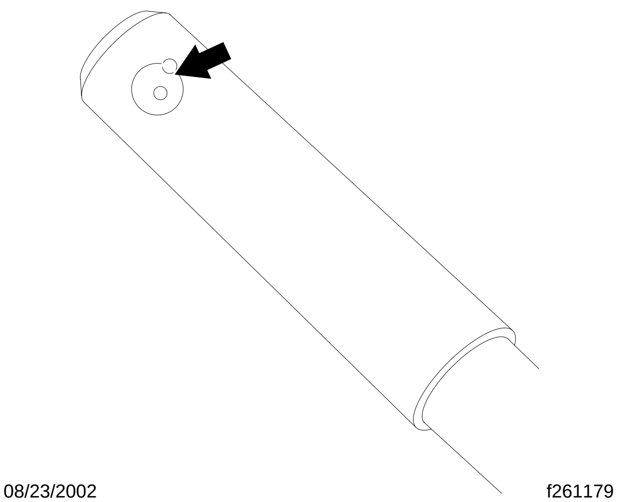
5. Remove the shift rod from the front gear case.
   - 5.1 From the right-hand side of the transmission, remove the setscrew that holds the end of the shift rod. Discard the old setscrew.
   - 5.2 Remove and discard the shift rod cover from the right-hand side of the gear case.
   - 5.3 Pull the shift rod all the way out of the gear case.

Installation

NOTE: See the installation procedure in **Section 26.03, Subject 200** for more information on the proper alignment of the shift finger in the shift rod.

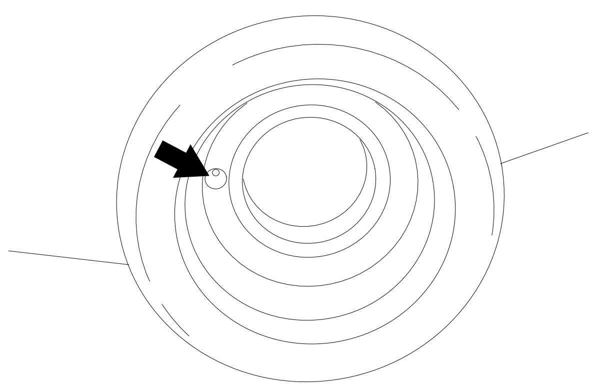
1. Make sure that the indent in the shift rod end (shown by the arrow in **Fig. 2**) is facing aft for proper engagement with the setscrew.
2. Install the shift rod in the front gear case.
   - 2.1 Insert the shift rod into the front gear case.
   - 2.2 Turn the shift rod until the dimple is at the 9 o'clock position.
3. Install the shift rod housing on the front gear case.
   - 3.1 Push the housing in until the indent in the rod end is showing in the setscrew hole.
   - 3.2 Coat the threads of a new setscrew with Loctite® 242 or equivalent thread-locking compound. Insert the new setscrew and tighten it 30 lbf·ft (40 N·m). See **Fig. 3**.
   - 3.3 Install a new shift rod cover in the shift cover housing.
   - 3.4 Position the shift rod housing over the flange in the front gear case. Coat the mating surfaces with a bead of Loctite 509 or equivalent sealing compound.
   - 3.5 Install the four capscrews that attach the shift rod housing to the front gear case. Coat the threads of the two lower capscrews with Loctite 242 or equivalent thread-locking compound. Tighten all four capscrews 18 lbf·ft (25 N·m).
4. Install the transmission. For detailed procedures, see **Subject 100**.

Shift Mechanism Removal and Installation


08/23/2002 f261179

Indent must face aft as shift rod is installed.

Fig. 2, Shift Rod End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Dimple must be at the 9 o’clock position.

Fig. 3, Shift Mechanism Setscrew

Special Tools

A special tool is required for this procedure. See **Table 1**.

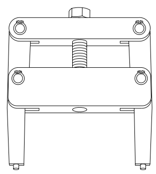
Special Tool for Input Shaft Replacement			
Tool	Description	Manufacturer	Part Number
 f580393	Snap Ring Removal Tool	Kent-Moore	J-46730

Table 1, Special Tool for Input Shaft Replacement

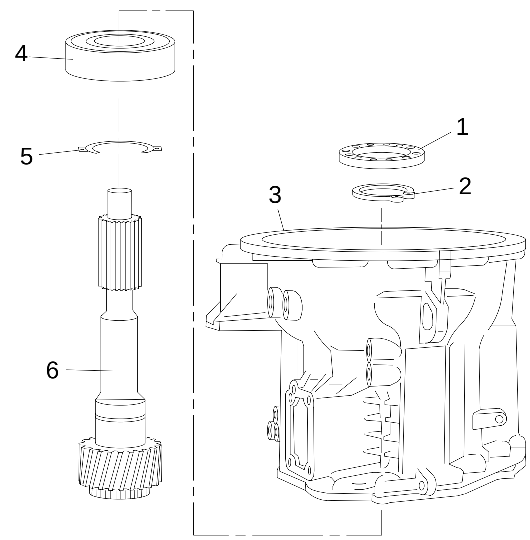
Removal

1. With the transmission removed from the vehicle and secured to keep it from moving, remove the shift mechanism. For instructions, see **Subject 110**.
2. Remove the front gear case. For instructions, see **Subject 150**.
3. Remove the input shaft radial seal. For instructions, see **Subject 130**.
4. Remove and discard the upper snap ring underneath the radial seal. See **Fig. 1**.
5. Press the input shaft out of the front gear case.
6. Using the snap ring removal tool, remove and discard the half-round snap ring under the deep-groove ball bearing. See **Table 1** for tool information and **Fig. 2** for tool application.
7. Press the deep-groove ball bearing out of the front gear case.

Installation

1. Heat the front gear case in the area of the bearing seat to 176°F (80°C).

IMPORTANT: Press only on the outer race of the deep-groove ball bearing.



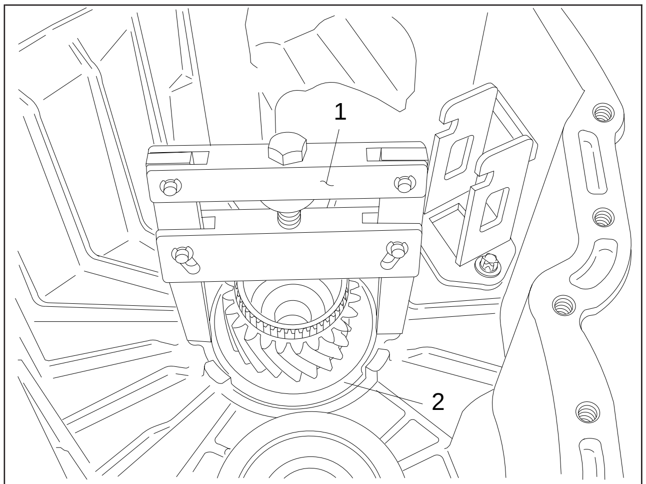
10/11/2002 f261222

1. Input Shaft Radial Seal
2. Upper Snap Ring
3. Front Gear Case
4. Deep-Groove Ball Bearing
5. Half-Round Snap Ring
6. Input Shaft

Fig. 1, Input Shaft Assembly

2. When the gear case is properly heated, install the deep-groove ball bearing into its seat. Install a new half-round snap ring.
3. Using a feeler gauge, measure the gap between the deep-groove ball bearing and the half-round

Input Shaft Removal and Installation



1. Snap Ring Removal Tool
2. Half-Round Snap Ring

Fig. 2, Half-Round Snap Ring Removal

snap ring. This measurement should not be more than 0.0003 inch (0.007 mm).

4. Heat the deep-groove ball bearing 176°F (80°C).
5. When the bearing is properly heated, install the input shaft into the seat in the front gear case. Install a new upper snap ring.
6. Using a feeler gauge, measure the gap between the deep-groove ball bearing and the upper snap ring. This measurement should not be more than 0.0003 inch (0.007 mm).
7. Check main shaft end play. For procedures, see **Subject 250**.
8. Install the input shaft radial seal. For instructions, see **Subject 130**.
9. Install the front gear case. For instructions, see **Subject 150**.
10. Install the shift mechanism. For instructions, see **Subject 110**.

Special Tools

A special tool is required for this procedure. See **Table 1**.

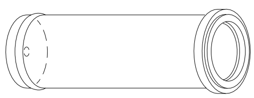
Special Tool for Input Shaft Radial Seal Replacement			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580401	Input Shaft Seal Installer	Kent-Moore	J-47901

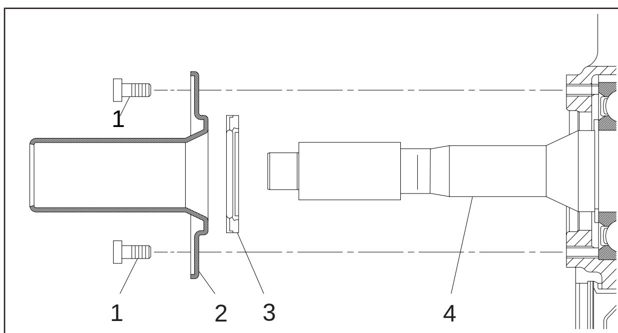
Table 1, Special Tool for Input Shaft Radial Seal Replacement

Replacement

1. Remove the transmission. For detailed procedures, see **Subject 100**.
2. Secure the transmission on a wooden pallet, or other device to keep it from moving.
3. Remove the release fork and release bearing.

NOTE: On AGS transmissions, remove the clutch actuator. For procedures, see **Section 26.03, Subject 120**.

4. Remove the guide tube from the transmission case. Discard the mounting bolts. See **Fig. 1**.
5. Remove the radial seal from the input shaft. Discard the old radial seal.



02/22/2005 f261100a

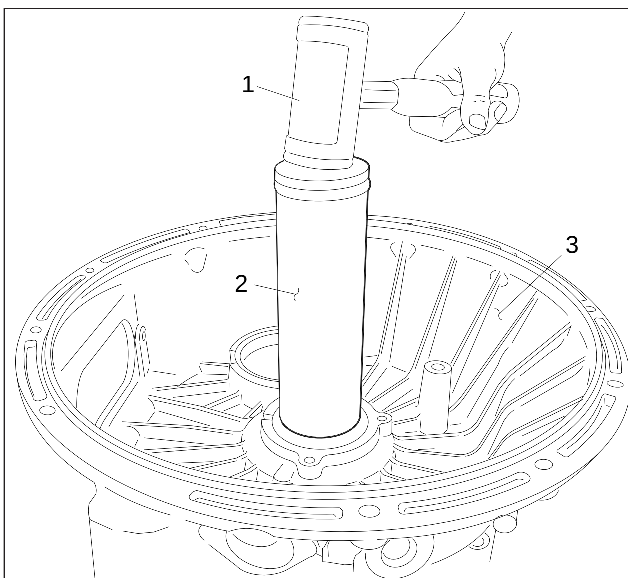
1. Guide Tube Mounting Capscrew
2. Guide Tube
3. Radial Seal
4. Input Shaft

Fig. 1, Input Shaft Radial Seal Replacement

CAUTION

To prevent damage, make sure that the new radial seal is not installed on the race of the old seal.

6. Using the input shaft seal installer, install a new radial seal on the input shaft. See **Table 1** for tool information and **Fig. 2** for tool application.



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1. Plastic Hammer
2. Input Seal Installer
3. Front Gear Case

Fig. 2, Installing the Input Shaft Radial Seal

Input Shaft Radial Seal Replacement

7. Install the guide tube on the transmission case. Use new M8 x 18 low-profile guide tube mounting capscrews. Tighten the capscrews 17 lbf·ft (23 N·m).
8. Install the release fork and release bearing. Tighten the release fork mounting capscrews 26 lbf·ft (36 N·m).
9. Install the transmission. For detailed procedures, see **Subject 100**.

Special Tools

Special tools are required for this procedure. See **Table 1**.

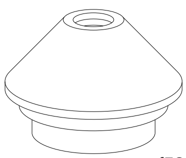
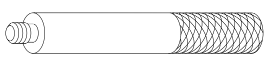
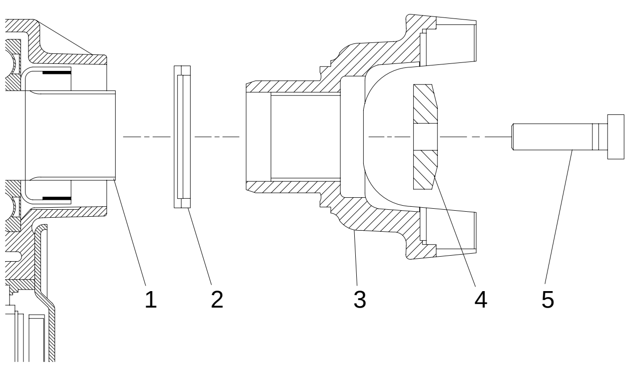
Special Tools for Output Shaft Radial Seal Installation			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580398	Output Shaft Seal Installer	Kent-Moore	J-47863
 f580400	Universal Handle	Kent-Moore	J-8901

Table 1, Special Tools for Output Shaft Radial Seal Installation

Replacement

1. Secure the output yoke so that it cannot turn the output shaft.
2. Remove the pressure plate mounting capscrew. Remove the pressure plate. See **Fig. 1**.



05/03/2001 f261099

1. Output Shaft
2. Radial Seal
3. Output Yoke
4. Pressure Plate
5. Pressure Plate Mounting Capscrew

Fig. 1, Output Yoke Assembly

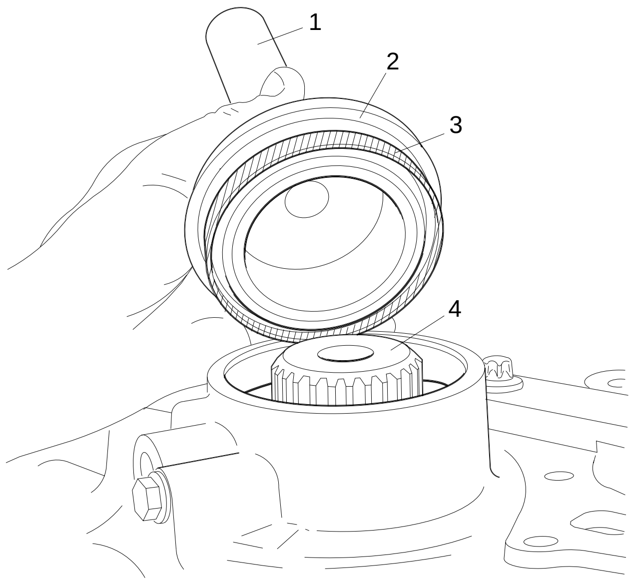
3. Remove the output yoke. Use a suitable extractor tool.
4. Remove the radial seal from the output shaft. Discard the old radial seal.
5. Assemble the output shaft seal installer onto the threaded end of the universal handle. See **Table 1**.

CAUTION

To prevent damage, make sure that the new radial seal is not installed on the race of the old seal.

6. Using the output shaft seal installer assembly, install a new radial seal on the output shaft. See **Fig. 2**.
7. If the output yoke cannot be pressed on cold, preheat the output yoke to 176°F (80°C) and try again.
8. Position the pressure plate on the output shaft. Secure it to the shaft using the pressure plate mounting capscrew. Tighten the M16 capscrew 190 lbf·ft (258 N·m).

Output Shaft Radial Seal Replacement



1. Universal Handle
2. Seal Installer
3. Radial Seal
4. Output Shaft

Fig. 2, Output Shaft Radial Seal Ready to Install

Front Gear Case Removal and Installation

Special Tools

Special tools are required for these procedures. See **Table 1**.

To prevent premature tool wear, use extreme pressure lubricant such as Kent-Moore J 23444-A or equivalent on tool threads and at all friction and contact points.

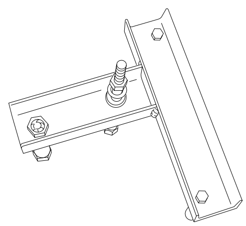
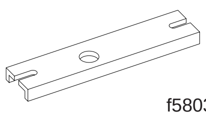
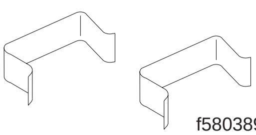
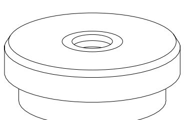
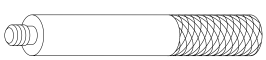
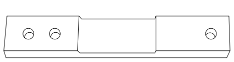
Special Tools for Front Gear Case Removal and Installation			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580397	Rear Case Puller/Installer/Stand	Kent-Moore	J-46739
 f580390	Front Gear Case Bridge	Kent-Moore	J-46727
 f580389	Synchro Retainer Clips	Kent-Moore	J-46726
 f580399	Countershaft Seal Cover Installer	Kent-Moore	J-47901
 f580400	Universal Handle	Kent-Moore	J-8901
 f580396	Countershaft Retainer	Kent-Moore	J-46733

Table 1, Special Tools for Front Gear Case Removal and Installation

Front Gear Case Removal and Installation

Removal

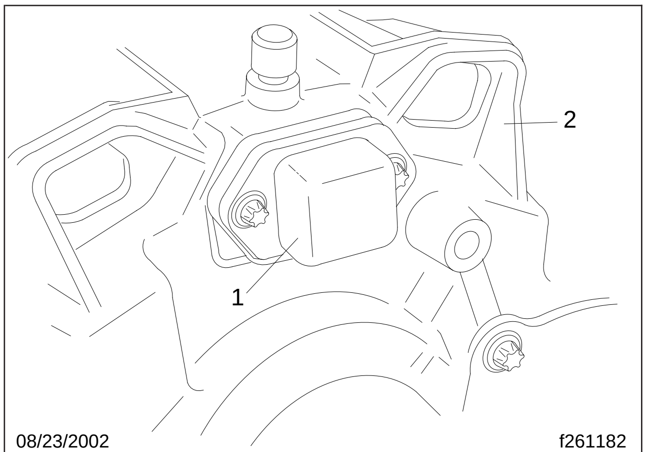
1. With the transmission removed from the vehicle and secured to keep it from moving, remove the shift mechanism. For instructions, see **Subject 110**.

NOTE: Take care that the tone wheel does not gouge the walls of the rear case where it opens to admit the output shaft.

2. Remove the output yoke and output shaft radial seal from the rear gear case.
3. Remove the rear countershaft cover from the output end of the rear gear case.
4. Remove the speed sensor from the output shaft. Remove the plug for the oil temperature sensor on the back of the rear gear case.

NOTE: On AGS transmissions, remove two speed sensors on the output shaft and one on the lower left-hand side of the rear gear case.

5. Remove the shift rail detent bolts.
6. Remove the shift rail cover from the output end of the rear gear case. See **Fig. 1**.



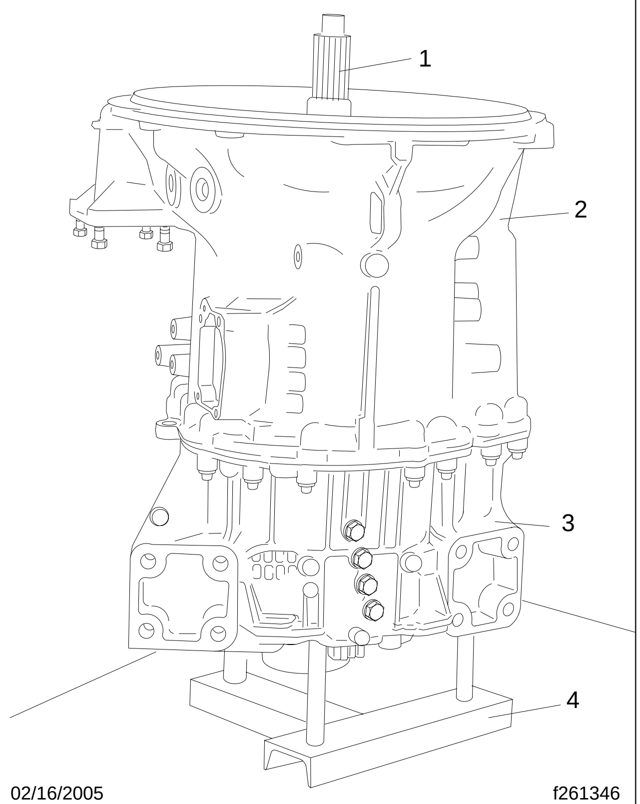
1. Shift Rail Cover
2. Rear Gear Case

Fig. 1, Shift Rail Cover

7. Attach the rear case puller/installer/stand to the output end of the rear gear case. See **Table 1**. Coat the all-thread rod with J 23444-A extreme pressure lubricant.

NOTE: J 23444-A extreme pressure lubricant can be ordered from SPX Kent-Moore at 1-800-345-2233.

8. Stand the transmission on the puller/installer/stand. See **Fig. 2**.

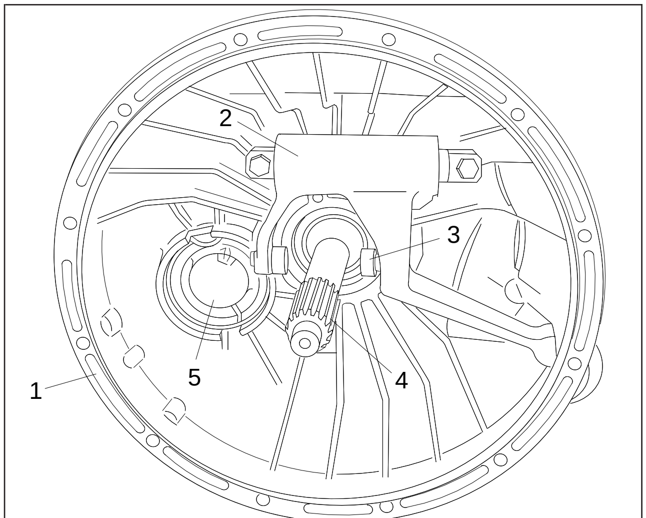


NOTE: The release bearing has been removed for clarity.

1. Input Shaft
2. Front Gear Case
3. Rear Gear Case
4. Puller/Installer/Stand

Fig. 2, Transmission on the Puller/Installer/Stand

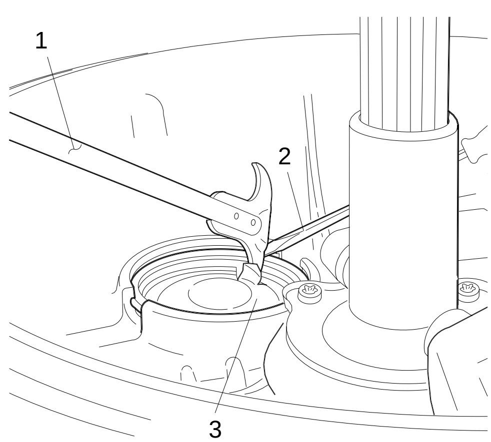
9. Remove the guide tube, the input shaft radial seal, and the inner snap ring. For instructions, including removal of the clutch release bearing and release fork, see **Subject 130**.
10. Remove the snap ring on the front countershaft seal cover. See **Fig. 3**.
11. Remove and discard the front countershaft seal cover. The seal cover may be difficult to remove. Use a pry tool and/or screwdriver as shown in **Fig. 4**.



NOTE: The release bearing has been removed for clarity.

1. Front Gear Case
2. Release Fork
3. Pressure Point
4. Input Shaft
5. Front Countershaft Seal Cover

Fig. 3, Front End of Transmission

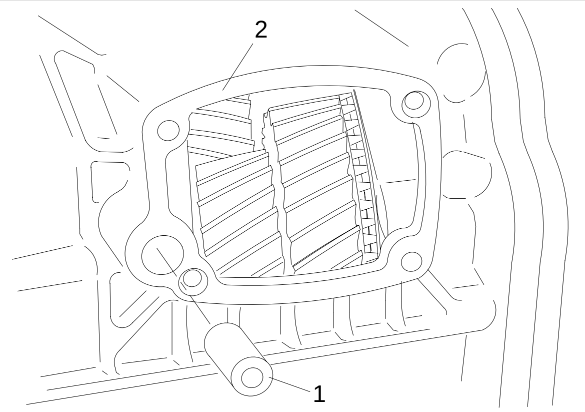


1. Pry Tool
2. Screwdriver
3. Front Countershaft Seal Cover

Fig. 4, Prying Out the Front Countershaft Seal Cover

12. Remove the two snap rings on the countershaft ball bearing. Discard the snap rings.

13. On model 660 only, pull out the two shift fork guide pins, one located on the left-hand side in the flanged mating surface of the shift rod housing and the other on the right-hand side of the front gear case next to the shift cover (this pin has a T60 Torx® head). See **Fig. 5**.



NOTE: The shift fork guide pins are installed on Model 660 only.

1. Shift Fork Guide Pin (left-hand side)
2. Flange

Fig. 5, Pulling the Left-Hand Shift Fork Guide Pin

14. Remove the gear case capscrews that attach the front gear case to the rear gear case. See **Fig. 6**.

15. After removing the capscrews, pry up on the front gear case to break the seal. Do not remove the front gear case at this time.

16. Using the front gear case bridge, remove the front gear case from the rear gear case and twin transmission shafts. See **Table 1** for more information about the special tool.

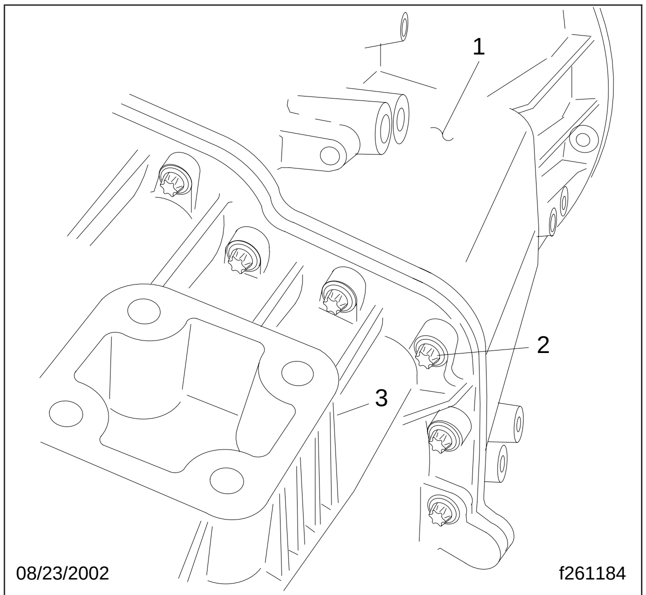
    16.1 Install the front gear case bridge so the hole is centered over the countershaft. Fasten it to the lip of the gear case with two gear case capscrews. See **Fig. 7**.

    16.2 Carefully press the front gear case off the countershaft and rear gear case. See **Fig. 8**.

17. Clean any remnants of sealant from the mating surfaces of the two gear case halves.

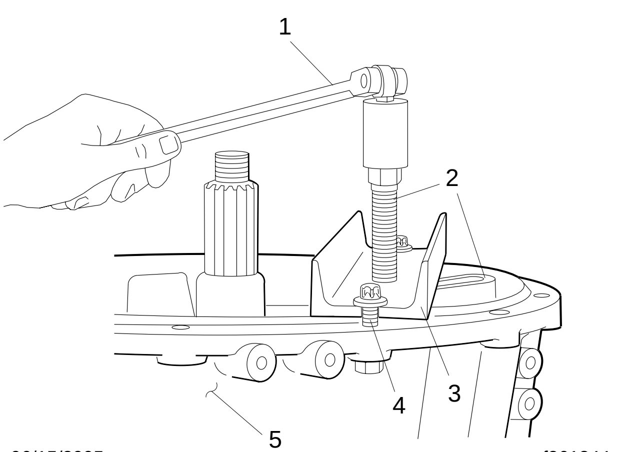
18. On model 660 only, remove the 5th/6th gear fork on the 5th/6th gear synchro slide and shift rail.

Front Gear Case Removal and Installation



1. Front Gear Case
2. Gear Case Capscrew
3. Rear Gear Case

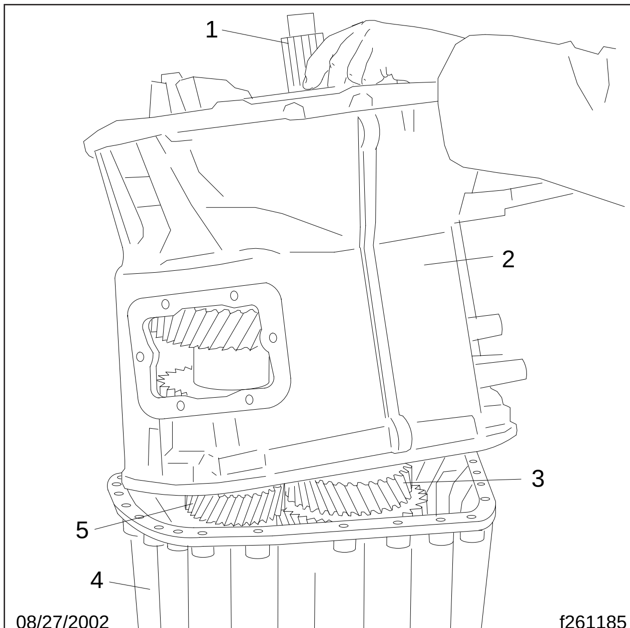
Fig. 6, Gear Case Capscrews



1. Socket Wrench
2. T-Bar Puller
3. Bridge
4. Gear Case Capscrew (used to fasten bridge)
5. Front Gear Case

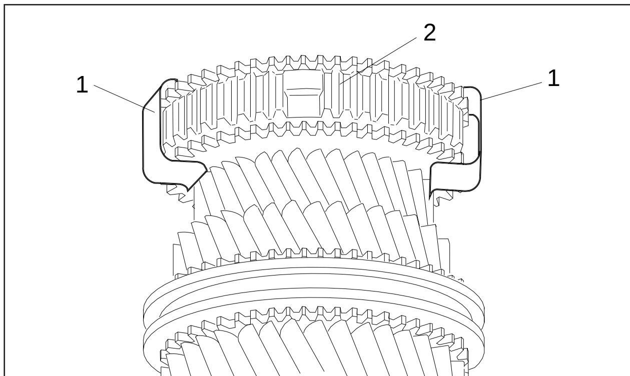
Fig. 7, Front Gear Case Bridge

19. After the case comes off, install the synchro retainer clips on the 5th/6th gear synchros. See Fig. 9 for the installation and Table 1 for more information about the special tool.
20. Remove the countershaft ball bearing from the front gear case.
21. Remove the pilot bearing from the main shaft.



1. Input Shaft
2. Front Gear Case
3. Main Shaft
4. Rear Gear Case
5. Countershaft

Fig. 8, Removing the Front Gear Case



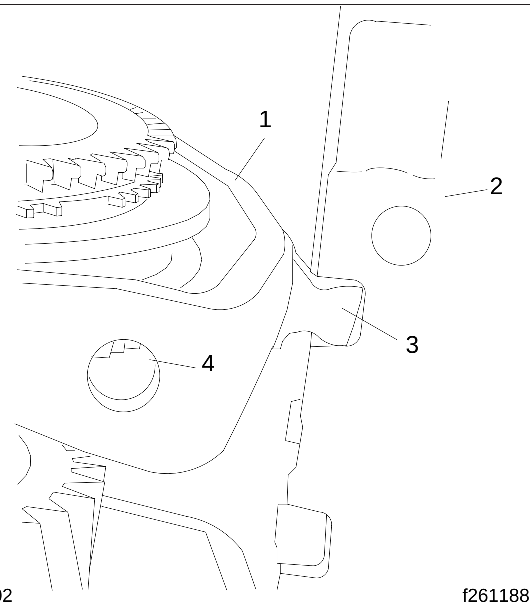
1. Synchro Retainer Clip
2. 5th/6th Gear Synchros

Fig. 9, Installing the Synchro Retainer Clips

Installation

NOTE: If either gear case half, the main shaft bearings, or the input shaft was replaced, check the main shaft end play. For detailed procedures, see **Subject 250**.

1. Lubricate the pilot bearing with approved transmission oil. Install the pilot bearing on the main shaft.
2. Remove the synchro retainer clips from the 5th/6th gear synchros.
3. On model 660 only, install the 5th/6th gear fork on the 5th/6th gear synchro slide and shift rail. Make sure the shoes on the fork are properly positioned. The finger of the 5th/6th gear fork must engage the available notch in the shift rail. See **Fig. 10**.
4. Apply a bead of Loctite® 509 or equivalent sealing compound along the entire mating surface of the rear gear case, going fully around each hole and cavity.
5. Lift the front gear case onto the rear gear case. Carefully align the case over the shift rods. Install the gear case capscrews and tighten them 22 lbf·ft (30 N·m).
6. On model 660 only, check the 5th/6th gear fork through the opening for the shift rod housing to make sure the correct engagement of the finger has been maintained. See **Fig. 10**. Install the shift rail detent bolts finger-tight.
7. Install the shift fork guide pins, if removed (model 660 only). See **Fig. 11**.
    - 7.1 On the left-hand side, the pin slides in and is held in place by the shift mechanism when installed.
    - 7.2 On the right-hand side, coat the threads of the T60 Torx fastener with Loctite 242 or equivalent thread-locking compound, and tighten the fastener 88 lbf·ft (120 N·m).
8. Using a heat gun, warm the countershaft bearing seat to 176°F (80°C). Install the countershaft ball bearing on the countershaft by pressing on the inner race. Install two new snap rings.
9. Assemble the countershaft seal cover installer onto the threaded end of the universal handle. See **Table 1**.



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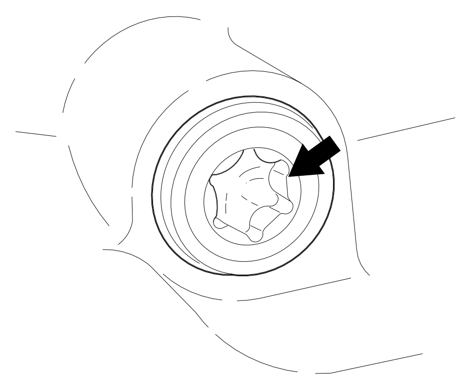
The finger of the 5th/6th gear fork must continue to engage the available notch in the shift rail.

1. 5th/6th Gear Fork
2. Shift Rail
3. Finger
4. Hole for Insertion of Shift Fork Guide Pin (model 660 only)

Fig. 10, Correct Finger Engagement



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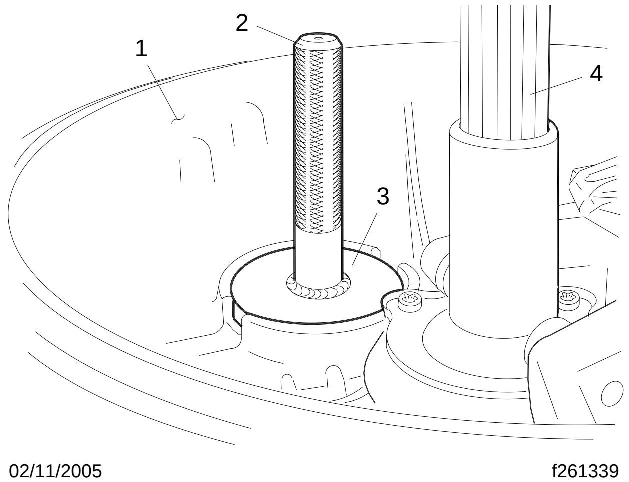
Install the shift fork guide pins. On the right-hand side, tighten the T60 Torx fastener (arrow).

NOTE: The shift fork guide pins are installed on Model 660 only.

Fig. 11, Tighten the T60 Fastener

Front Gear Case Removal and Installation

10. Using the countershaft seal cover installer assembly, carefully press the front countershaft seal cover onto the countershaft. See **Fig. 12**.



1. Front Gear Case
2. Universal Handle
3. Countershaft Seal Cover Installer
4. Input Shaft

Fig. 12, Pressing the Front Countershaft Seal Cover

11. Install the snap ring on the front countershaft seal cover. Remove the countershaft retainer from the rear gear case. See **Table 1** for more information about the countershaft retainer.
12. Install the input shaft radial seal. For instructions, including installation of the clutch release bearing and release fork, see **Subject 130**.
13. Turn the transmission so the output end is exposed. Remove the puller/installer/stand.
14. Install the speed sensor on the output shaft, as removed. Install the plug for the oil temperature sensor on the back of the rear gear case.

NOTE: On AGS transmissions, install two speed sensors on the output shaft and one on the lower left-hand side of the rear gear case.

15. Coat the mating surface of the shift rail cover with Loctite 509 or equivalent sealing compound. Install the shift rail cover on the output end of the rear gear case. Tighten the shift rail cover capscrews 29 lbf·ft (39 N·m).
16. Tighten the shift rail detent bolts 22 lbf·ft (30 N·m).
17. Coat the mating surface of the rear countershaft cover with Loctite 509 or equivalent sealing compound. Install the rear countershaft cover. Tighten the rear countershaft cover capscrews 18 lbf·ft (25 N·m).
18. Install the output shaft radial seal. For procedures, see **Subject 140**. Install the output yoke on the rear gear case.
19. Install the shift mechanism. For instructions, see **Subject 110**.

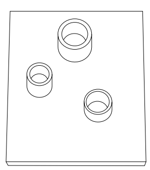
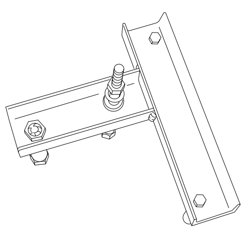
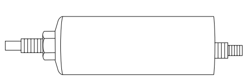
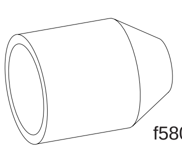
Special Tools

Special tools are required for these procedures. See **Table 1**.

To prevent premature tool wear, use extreme pressure lubricant such as Kent-Moore J 23444-A or equivalent on tool threads and at all friction and contact points.

Removal

1. Secure the transmission on a wooden pallet, or other device to keep it from moving.
2. Remove the front gear case. For instructions, see **Subject 150**.
3. Install the main shaft/countershaft stand on the exposed gear shafts. For more information about the main shaft/countershaft stand, see **Table 1** and **Fig. 1**.
4. Turn the transmission over and set it down with the rear case up. See **Table 1** for more information about the puller/installer/stand.

Special Tools for Rear Gear Case Removal and Installation			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580395	Main Shaft/Countershaft Stand	Kent-Moore	J-46732
 f580397	Rear Case Puller/Installer/Stand	Kent-Moore	J-46739
 f580394	Reverse Idler Shaft Puller	Kent-Moore	J-46731
 f580391	Countershaft Guide	Kent-Moore	J-46728

Rear Gear Case Removal and Installation

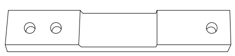
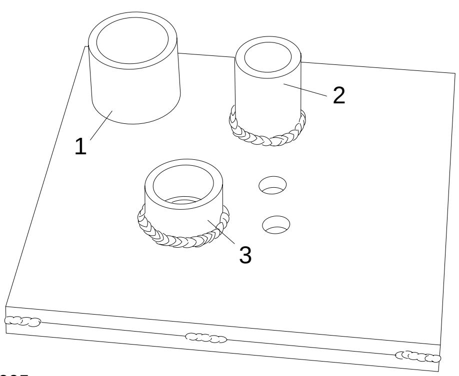
Special Tools for Rear Gear Case Removal and Installation			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580396	Countershaft Retainer	Kent-Moore	J-46733

Table 1, Special Tools for Rear Gear Case Removal and Installation

5. Stand the transmission on the main shaft/countershaft stand and secure the stand to the table with a clamp. See **Fig. 2**.



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1. Main Shaft Support (output end)
2. Main Shaft Support (input end)
3. Countershaft Support

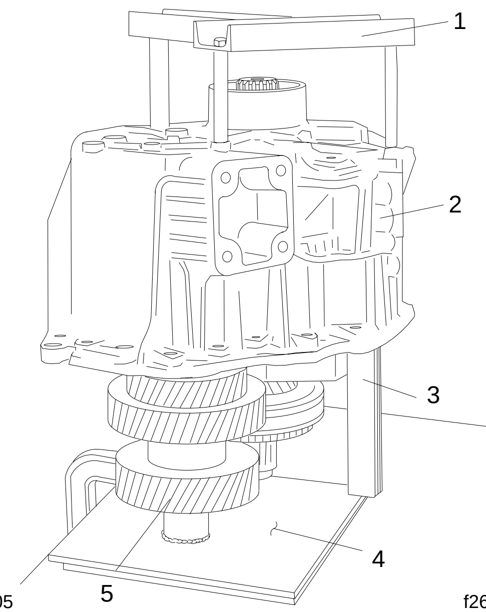
Fig. 1, Main Shaft/Countershaft Stand

6. Using the reverse idler shaft puller, remove the reverse idler shaft. For more information about the reverse idler shaft puller, see **Table 1**.

   6.1 Coat the forcing screw running through the puller body with J 23444-A extreme pressure lubricant.

   NOTE: J 23444-A extreme pressure lubricant can be ordered from SPX Kent-Moore at 1-800-345-2233.

   6.2 Insert the small-diameter threaded end of the forcing screw into the reverse idler shaft. Tighten the locknut on the forcing screw against the reverse idler shaft. **Figure 3** shows the reverse idler shaft puller installed.



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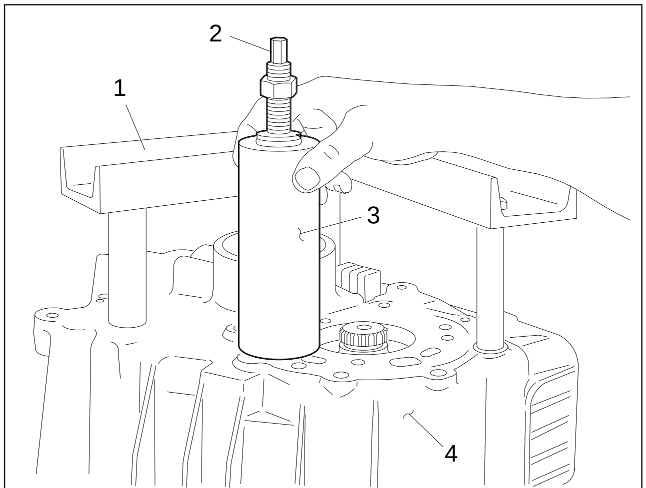
1. Puller/Installer/Stand
2. Rear Gear Case
3. Shift Rails
4. Main Shaft/Countershaft Stand
5. Main Shaft

Fig. 2, Transmission with the Rear Case Up

   6.3 Attach a suitable wrench, socket or box-end, to the nut at the top end of the forcing screw, and turn the large nut clockwise until the reverse idler shaft is pulled up. **Figure 4** shows the reverse idler shaft ready for removal.

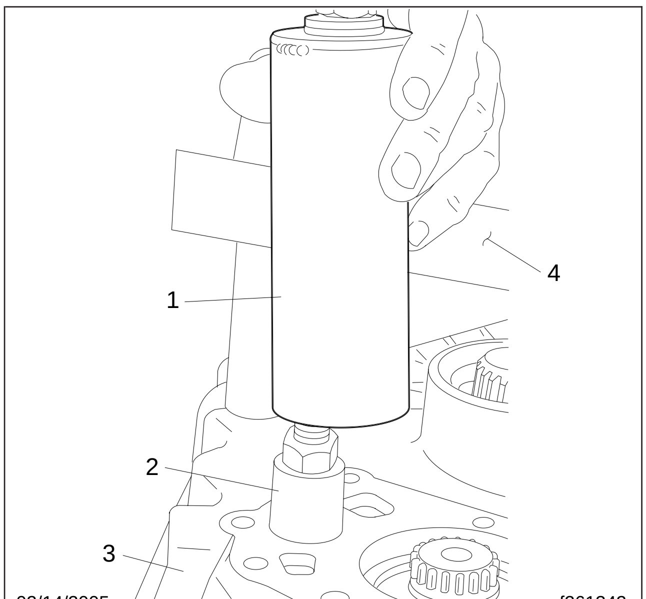
   6.4 Remove the reverse idler shaft and puller from the rear gear case. Separate the reverse idler shaft from the puller.

7. Make sure the speed sensor has been removed.



1. Puller/Installer/Stand
2. Forcing Screw
3. Reverse Idler Shaft Puller
4. Rear Gear Case

Fig. 3, Reverse Idler Shaft Puller Installed

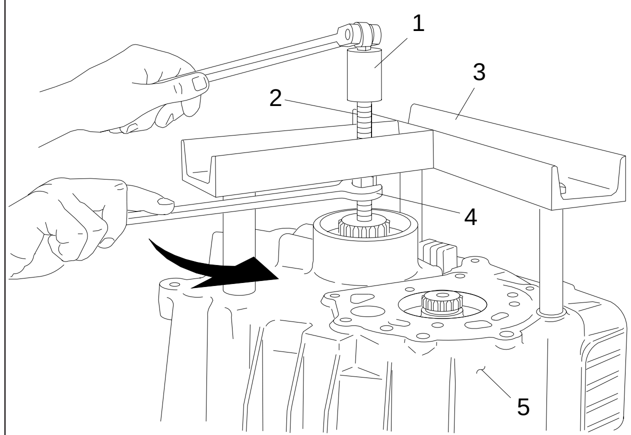


1. Reverse Idler Shaft Puller
2. Reverse Idler Shaft (pulled up)
3. Rear Gear Case
4. Puller/Installer/Stand

Fig. 4, Reverse Idler Shaft (ready for removal)

IMPORTANT: On AGS transmissions, there are three speed sensors on the rear gear case: the input shaft speed sensor on the lower left-hand side, and the two output shaft speed sensors on the rear output flange.

8. Pull the rear gear case from the twin gear shafts. See **Fig. 5**.



Hold with the socket wrench and turn with the open-end wrench in the direction of the arrow.

1. Socket Wrench on Jam Nut
2. All-Thread Rod
3. Puller/Installer/Stand
4. Open-End Wrench on Working Nut
5. Rear Gear Case

Fig. 5, Raising the Rear Gear Case

8.1 Install the all-thread rod and two nuts through the puller/installer/stand and into the output shaft. Lubricate the rod threads with high-pressure grease. Tighten one nut against the other to create a jam nut.

8.2 Using a socket wrench, hold the jam nut at the head of the all-thread rod.

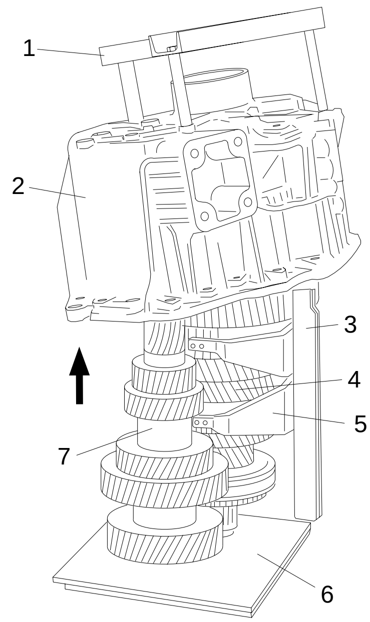
8.3 Install two washers between the puller/installer/stand and the working nut. Using an open-end wrench, turn the working nut counterclockwise.

8.4 Keep turning the working nut until the rear case releases from the main shaft.

8.5 Remove the all-thread rod from the output shaft.

Rear Gear Case Removal and Installation

9. Carefully lift the rear gear case off the gear shafts. See **Fig. 6**. Leave the puller/installer/stand installed.



Lift the rear gear case carefully.
1. Puller/Installer/Stand
2. Rear Gear Case
3. Shift Rail
4. Main Shaft
5. Shift Fork
6. Main Shaft/Countershaft Stand
7. Countershaft

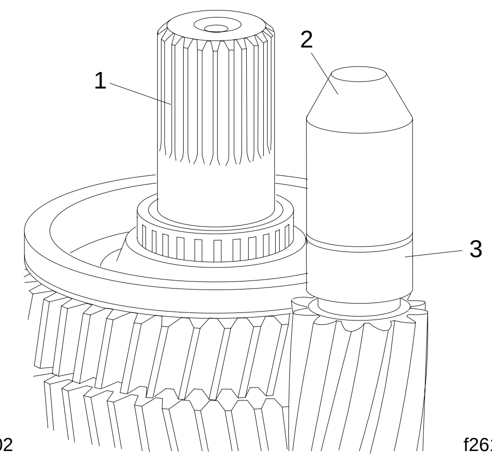
Fig. 6, Removing the Rear Gear Case

10. The reverse idler gear may hang up on the gear below it. Carefully remove the reverse idler gear and needle bearing. Inspect them for damage.
11. Separate the puller/installer/stand from the rear gear case.

Installation

NOTE: During installation, the transmission should be standing on the main shaft/countershaft stand with the output end of the rear gear case exposed.

1. Place the reverse idler gear and needle bearing in the rear gear case.
2. Install the shift rails and forward shift forks on the gear shafts.
3. Install the countershaft guide. For more information about the countershaft guide, see **Table 1**. **Figure 7** shows the guide installed on the countershaft.



1. Main Shaft
2. Countershaft Guide
3. Countershaft

Fig. 7, Countershaft Guide

4. Install the rear gear case, with the puller/installer/stand on the exposed gear shafts. See **Fig. 8**.
5. Lower the rear gear case onto the gear shafts.

   5.1 Install the all-thread rod into the output shaft.

   IMPORTANT: As the rear gear case is being lowered, carefully inspect the reverse idler gear and make sure that it meshes.

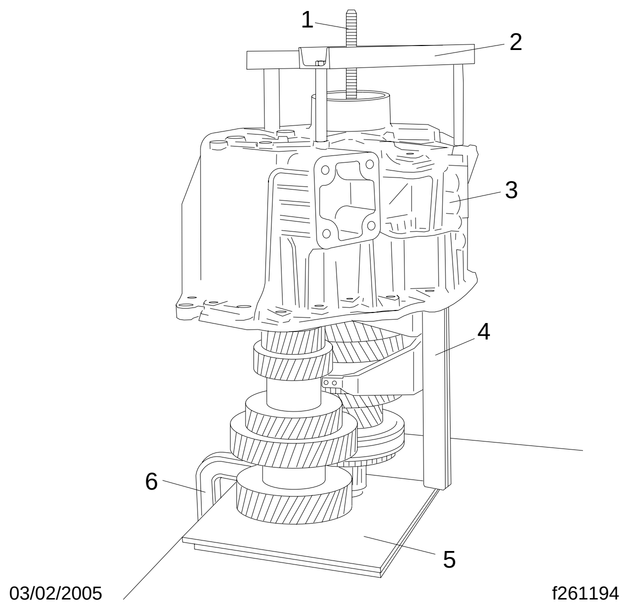
   5.2 Hold a socket wrench on the bolt head.

   5.3 Using an open-end wrench, turn the nut.

   5.4 Continue the process of turning the nut until the rear case bottoms out.

NOTE: At the start, only a small bit of the machined surface of the idler shaft will be visible. When finished, the idler shaft must be flush with the surface of the gear case.

6. Install the reverse idler shaft in the rear gear case. Use two hammers as shown in **Fig. 9**, with the metal-faced hammer doing the striking, and



1. All-Thread Rod
2. Puller/Installer/Stand
3. Rear Gear Case
4. Shift Rails
5. Main Shaft/Countershaft Stand
6. Clamp

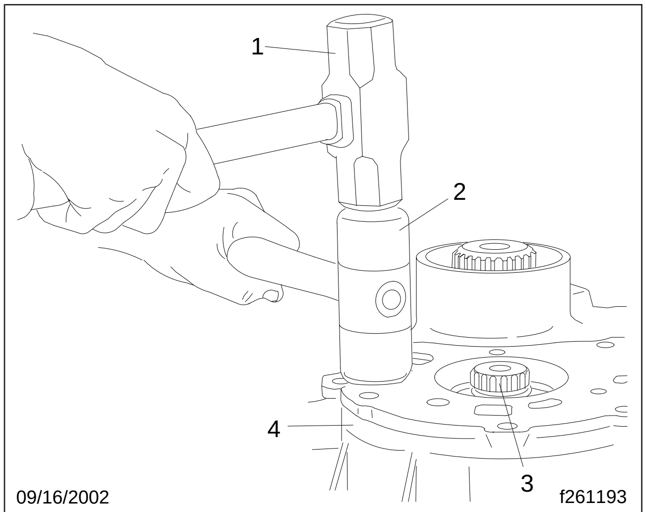
Fig. 8, Installing the Rear Gear Case

the dead-blow hammer transmitting the force of the blow to the reverse idler shaft.

7. Install the countershaft retainer on the rear gear case. **Figure 10** shows the countershaft retainer installed. See **Table 1** for more information about the countershaft retainer.
8. Remove the all-thread rod from the puller/installer/stand. Turn the transmission over and place it rear case down on the puller/installer/stand. Remove the main shaft/countershaft stand.
9. Align the detents in each shift rail with the bolt holes in the rear case. See **Fig. 11**.

NOTE: Check the main shaft end play. For detailed procedures, see **Subject 250**.

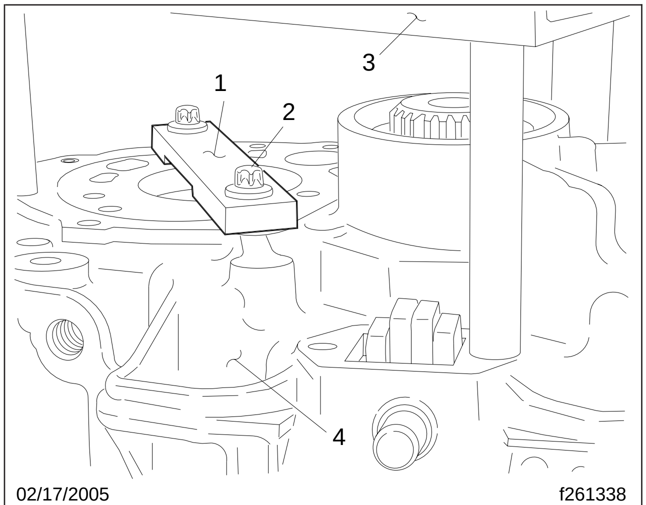
10. Turn the transmission over and set it down with the rear case down. Remove the main shaft/countershaft stand.
11. Install the front gear case. For instructions, see **Subject 150**.



Use two hammers: a metal-faced one to strike with, and a dead-blow hammer to transmit the force of the blow.

1. Metal-Faced Hammer
2. Dead-Blow Hammer
3. Countershaft
4. Rear Gear Case

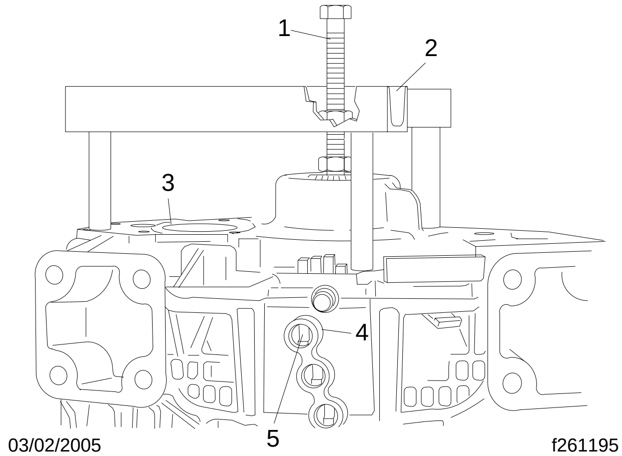
Fig. 9, Installing the Reverse Idler Shaft



1. Countershaft Retainer
2. Gear Case Capscrew (used to fasten retainer)
3. Puller/Installer/Stand
4. Rear Gear Case

Fig. 10, Countershaft Retainer Installed

Rear Gear Case Removal and Installation



1. All-Thread Rod
2. Puller/Installer/Stand
3. Rear Gear Case
4. Bolt Hole
5. Detent (in shift rail)

Fig. 11, Shift Rail Detents

Reverse, First, and Second Gear Disassembly

Special Tools

A special tool is required for these procedures. See **Table 1**.

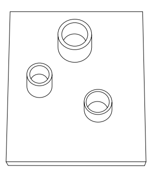
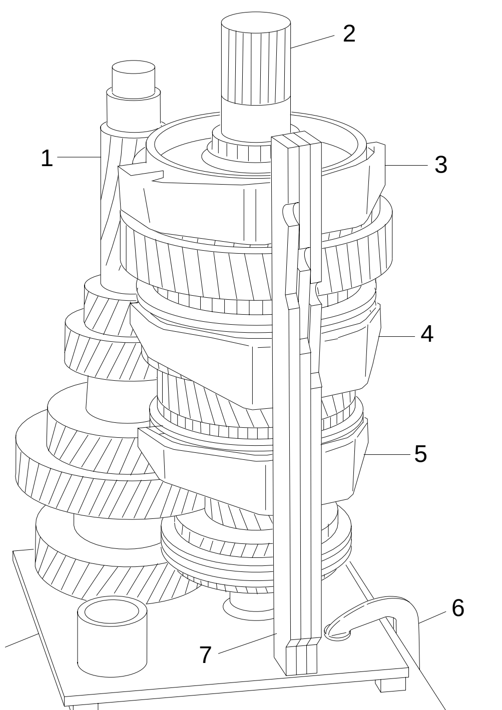
Special Tool for Reverse, First, and Second Gear Disassembly			
Tool	**Description**	**Manufacturer**	**Part Number**
	Main Shaft/Countershaft Stand	Kent-Moore	J-46732

Table 1, Special Tool for Reverse, First, and Second Gear Disassembly

Reverse Gear

1. Secure the transmission on a wooden pallet, or other device to keep it from moving.
2. Remove the shift mechanism. For instructions, see **Subject 110**.
3. Remove the front gear case. For instructions, see **Subject 150**.
4. Remove the rear gear case. For instructions, see **Subject 160**.
5. Make sure the twin gear shafts are supported on the main shaft/countershaft stand. See **Table 1**.
6. Remove the shift bars and shift forks from the transmission. See **Fig. 1**.
   - 6.1 Lift the 5th/6th gear fork off the shift bars.
   - 6.2 Pull the remaining shift forks and shift bars away from the main shaft as a group.
   - 6.3 Tie the shift bars and forks together.
7. Inspect the synchro rings for compliance with the wear limits given in **Subject 240**.
8. Remove the reverse gear wheel and needle bearing from the main shaft.



1. Countershaft
2. Main Shaft
3. 5th/6th Gear Fork
4. 3rd/4th Gear Fork
5. 1st/2nd Gear Fork
6. Clamp
7. Shift Bars
8. Stand

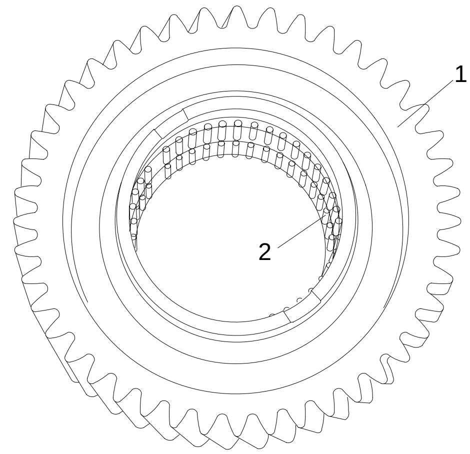
Fig. 1, Shift Bars and Forks

First Gear

1. Using suitable snap ring pliers, remove the 1st gear snap ring from the main shaft. Measure the snap ring thickness and record it. Discard the snap ring after recording its thickness.

Reverse, First, and Second Gear Disassembly

2. Remove the inner gear wheel.
3. Remove the 1st gear wheel and the needle bearing. See **Fig. 2**.



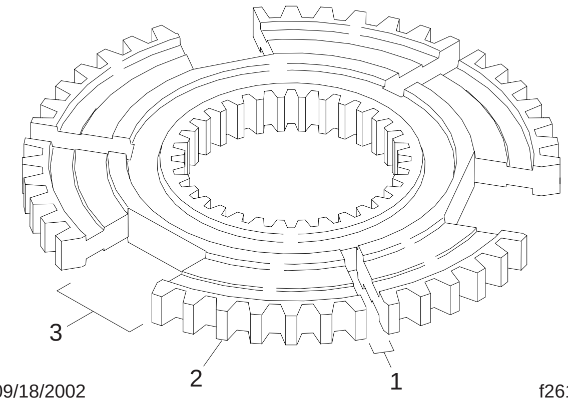
1. 1st Gear Wheel 2. Needle Bearing

Fig. 2, 1st Gear Wheel and Needle Bearing

4. Remove the 1st gear inner synchro cone.
5. Remove the 1st gear synchro ring.
6. Remove the 1st gear outer synchro cup.

Second Gear

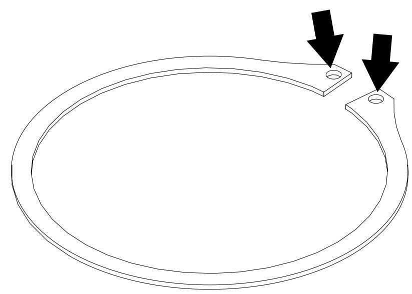
1. Remove the 1st/2nd gear synchro slide collar carefully from the synchro body.
2. Remove the compression springs and spring holders from the synchro body. Remove the synchro body from the main shaft. See **Fig. 3**.
3. Using snap ring pliers, remove the 2nd gear snap ring from the synchro body. Measure the snap ring thickness and record it. Discard the snap ring after recording its thickness. See **Fig. 4**.
4. Remove the synchro body from the main shaft.
5. Remove the 2nd gear outer synchro cup.
6. Remove the 2nd gear synchro ring and inner synchro cone.
7. Remove the 2nd gear driver, wheel, and needle bearing. See **Fig. 5**.



NOTE: The mounts of the 2nd gear outer synchro cup must engage in the large recesses in the synchro body.

1. Slot for Compression Spring
2. Tooth Flank
3. Large Recess

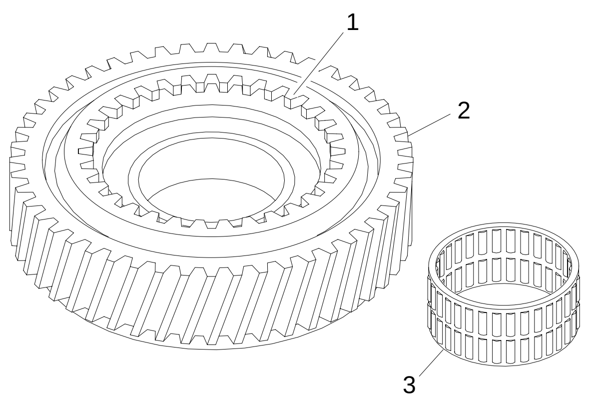
Fig. 3, 1st/2nd Gear Synchro Body



Insert the snap ring pliers here.

Fig. 4, 2nd Gear Snap Ring

Reverse, First, and Second Gear Disassembly



1. Short Teeth
2. 2nd Gear Wheel
3. Needle Bearing

Fig. 5, 2nd Gear Wheel and Needle Bearing

Special Tools

Special tools are required for this procedure. See **Table 1**.

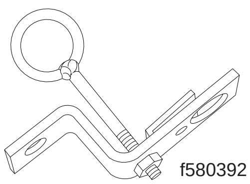
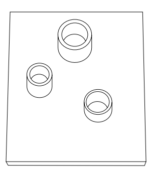
Special Tools for Countershaft Removal and Installation			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580392	Main Shaft/Countershaft Lifting Device	Kent-Moore	J-46729
 f580395	Main Shaft/Countershaft Stand	Kent-Moore	J-46732

Table 1, Special Tools for Countershaft Removal and Installation

Removal

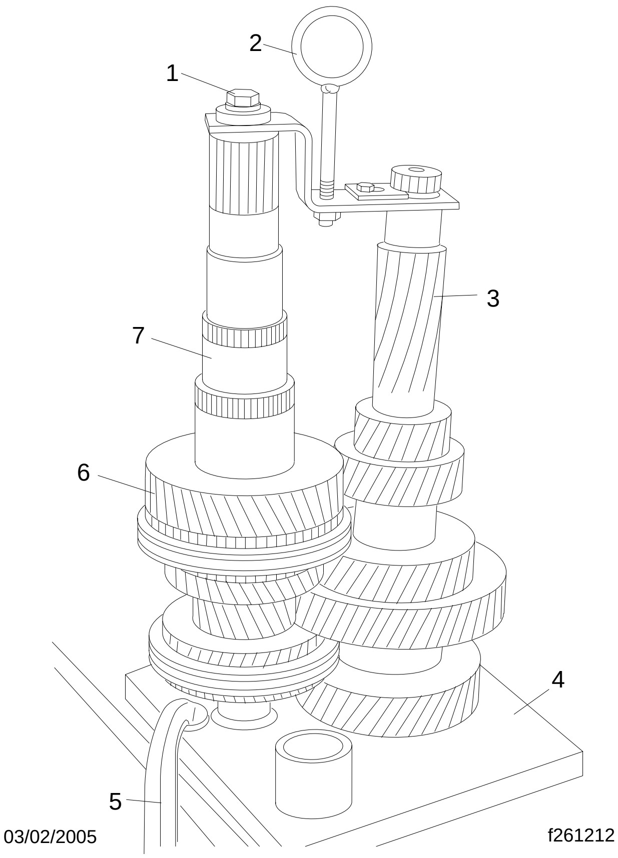
1. Remove the front gear case. For instructions, see **Subject 150**.
2. Remove the rear gear case. For instructions, see **Subject 160**.
3. Remove the reverse gear and the 1st gear from the main shaft. For instructions, see **Subject 170**.
4. Remove the 2nd gear from the main shaft. See **Subject 170** for instructions.
5. Attach the main shaft/countershaft lifting device to the input ends of the main shaft and countershaft. For more information about the special tool, see **Table 1**. See **Fig. 1** for the countershaft with the tool installed.
6. Attach a hoist to the ring of the lifting device. Lift the two shafts in the air.
7. Remove the main shaft/countershaft stand.
8. Remove the bolt attaching the lifting device to the main shaft. Carefully separate the countershaft gears from the main-shaft gears. See **Fig. 2**.
9. Replace the main shaft on the main shaft/countershaft stand, with the output end down. See **Table 1**.
10. Remove the lifting device from the countershaft.

NOTE: Do not attempt to disassemble the countershaft. If there is damage, replace the entire countershaft. For further disassembly of the main shaft gears, see **Subject 190** and **Subject 200**.

Installation

1. Carefully mesh the teeth of the countershaft gears with the teeth of the main shaft gears.
2. Lay the main shaft on the bench and attach a hoist or other lifting device to the ring of the lifting device and raise the main shaft off the stand.
3. Fasten the countershaft to the lifting device.

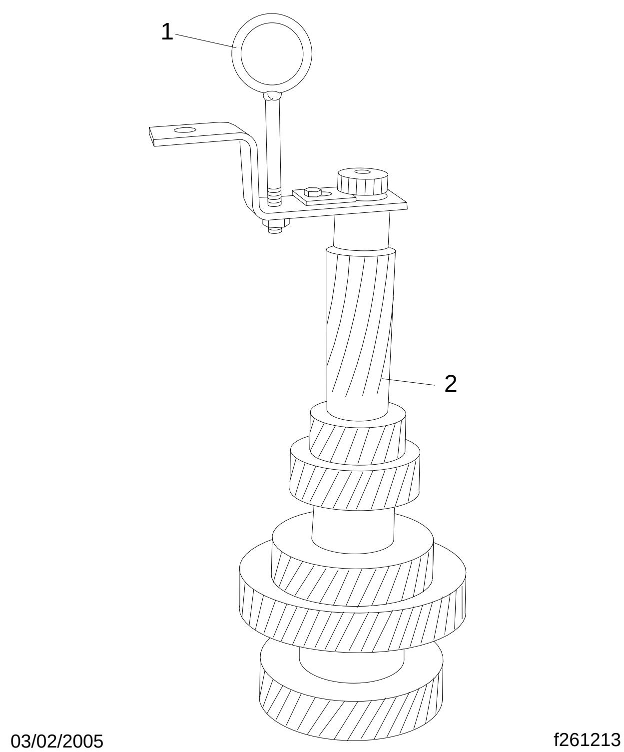
Countershaft Removal and Installation



1. Bolt
2. Lifting Device
3. Countershaft
4. Stand
5. Clamp
6. Third Gear Wheel
7. Main Shaft (stripped area)

Fig. 1, Countershaft Ready to Remove

4. Lower the hoist and place both shafts on the stand. Remove the hoist from the lifting device.
5. Install the 2nd gear on the main shaft. For instructions, see **Subject 230**.
6. Install the reverse gear and the 1st gear on the main shaft. For instructions, see **Subject 230**.
7. Install the rear gear case. For instructions, see **Subject 160**.
8. Install the front gear case. For instructions, see **Subject 150**.



1. Lifting Device
2. Countershaft

Fig. 2, Countershaft Separated From Main Shaft

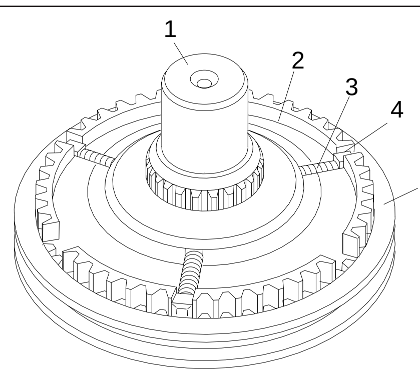
Fifth and Sixth Gear Disassembly

Fifth Gear

1. Remove the front gear case. For instructions, see **Subject 150**.
2. Remove the rear gear case. For instructions, see **Subject 160**.
3. Remove the reverse gear and the 1st gear from the main shaft. For instructions, see **Subject 170**.
4. Remove the 2nd gear from the main shaft. For instructions, see **Subject 170**.
5. Separate the countershaft from the main shaft. For instructions, see **Subject 180**.
6. Remove the 5th gear synchro cone and synchro ring from the main shaft.

Sixth Gear

1. Carefully remove the 5th/6th gear synchro slide collar from the synchro body. Take care to extract the compression springs and spring holders from the synchro body. See **Fig. 1**.



1. Main Shaft
2. Synchro Body
3. Compression Spring
4. Spring Holder
5. Synchro Slide Collar

Fig. 1, 5th/6th Gear Synchronizers

2. Using snap ring pliers, remove the 5th/6th gear snap ring from the main shaft. Measure the snap ring thickness and record it. Discard the snap ring after recording its thickness. See **Fig. 2**.
3. Remove the 5th/6th gear synchro body from the main shaft.

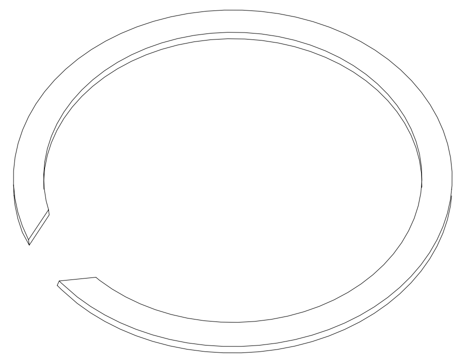
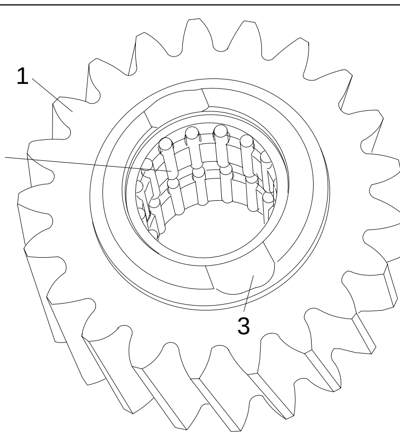


Fig. 2, 5th/6th Gear Snap Ring

4. Remove the 6th gear synchro ring and cone.
5. Inspect the synchro rings for compliance with the wear limits given in **Subject 240**.
6. Remove the 6th gear wheel and needle bearing. See **Fig. 3**.



1. 6th Gear Wheel
2. Needle Bearing
3. Oil Groove

Fig. 3, 6th Gear Wheel and Needle Bearing

Fourth Gear

1. Remove the front gear case. For instructions, see **Subject 150**.
2. Remove the rear gear case. For instructions, see **Subject 160**.
3. Remove the reverse gear and the 1st gear from the main shaft. For instructions, see **Subject 170**.
4. Remove the 2nd gear from the main shaft. For instructions, see **Subject 170**.
5. Separate the countershaft from the main shaft. For instructions, see **Subject 180**.
6. Remove the 5th and 6th gears from the main shaft. For instructions, see **Subject 190**.
7. Using snap ring pliers, remove the 4th gear snap ring from the main shaft. Measure the snap ring thickness and record it. Discard the snap ring after recording its thickness. See **Fig. 1**.

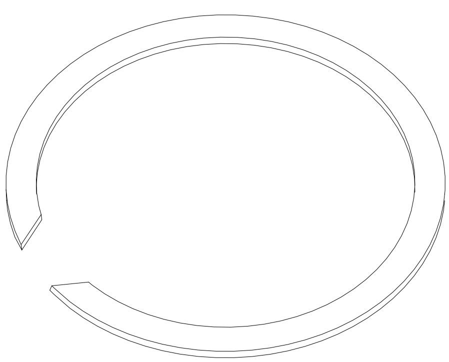


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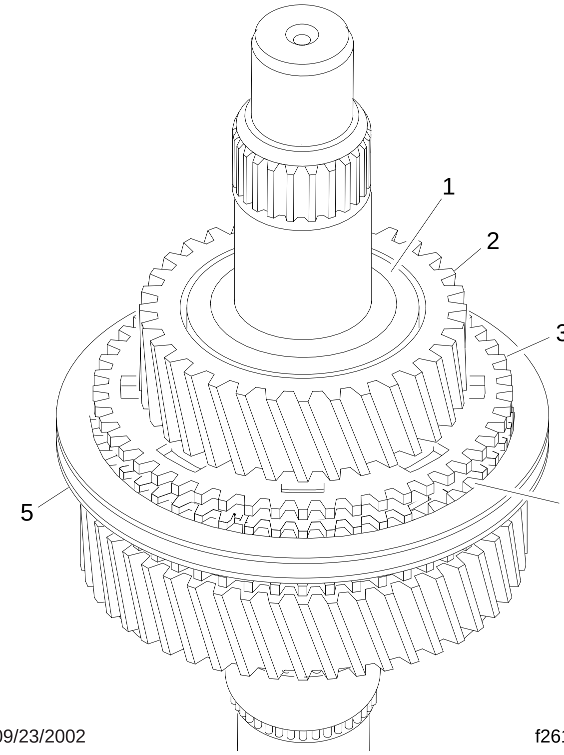
Fig. 1, 4th Gear Snap Ring

8. Remove the 4th gear wheel and thrust washer from the main shaft. See **Fig. 2**.
9. Lift the driver off the main shaft.

NOTE: On some models, the driver is welded to the 4th gear wheel.

10. Remove the needle bearing.
11. Remove the 4th gear inner synchro cone, synchro ring, and outer synchro cup. See **Fig. 3**.



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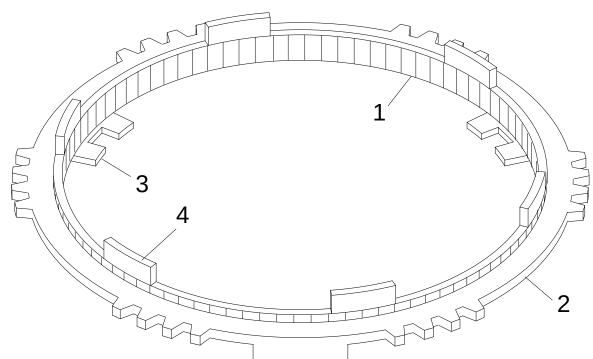
1. Thrust Washer
2. 4th Gear Wheel
3. Driver Teeth
4. Teeth of Slide
5. 3rd/4th Gear Synchro Slide Collar

Fig. 2, 4th Gear Synchronizers



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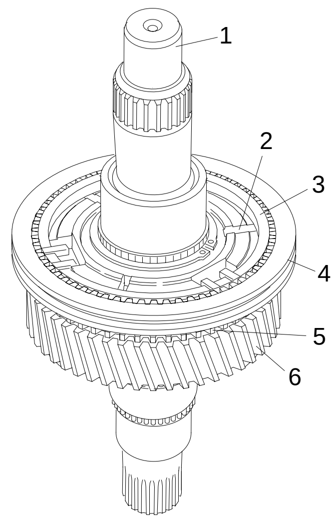
1. Synchro Ring
2. Outer Synchro Cup
3. Mount
4. Stop Lug

Fig. 3, 4th Gear Synchro Ring and Outer Cup

Fourth and Third Gear Disassembly

Third Gear

1. Carefully remove the 3rd/4th gear synchro slide collar from the synchro body. Take care to extract the compression springs and spring holders from the synchro body. See **Fig. 4**.



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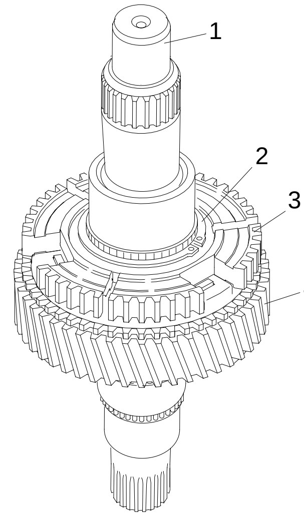
1. Main Shaft
2. Synchro Body
3. Inner Cone
4. Synchro Slide Collar
5. Outer Cone
6. 3rd Gear Wheel

Fig. 4, 3rd Gear Synchronizers

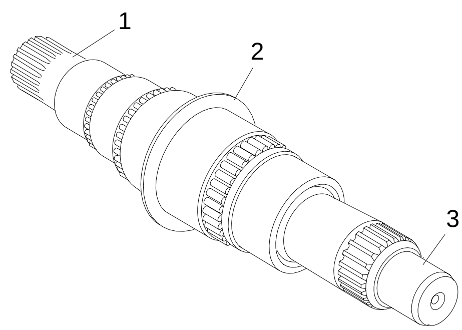
2. Using snap ring pliers, remove the 3rd gear snap ring from the synchro body. Measure the snap ring thickness and record it. Discard the snap ring after recording its thickness. See **Fig. 5**.
3. Remove the 3rd gear synchro body from the main shaft.
4. Remove the 3rd gear outer synchro cup, synchro ring and inner synchro cone from the main shaft.
5. Lift the driver off the 3rd gear wheel.
6. Inspect the synchro rings for compliance with the wear limits given in **Subject 240**.
7. Remove the 3rd gear wheel and needle bearing, leaving the main shaft stripped. See **Fig. 6**.



09/23/2002 f261208

1. Main Shaft
2. Snap Ring
3. Synchro Body
4. 3rd Gear Wheel

Fig. 5, 3rd Gear Snap Ring



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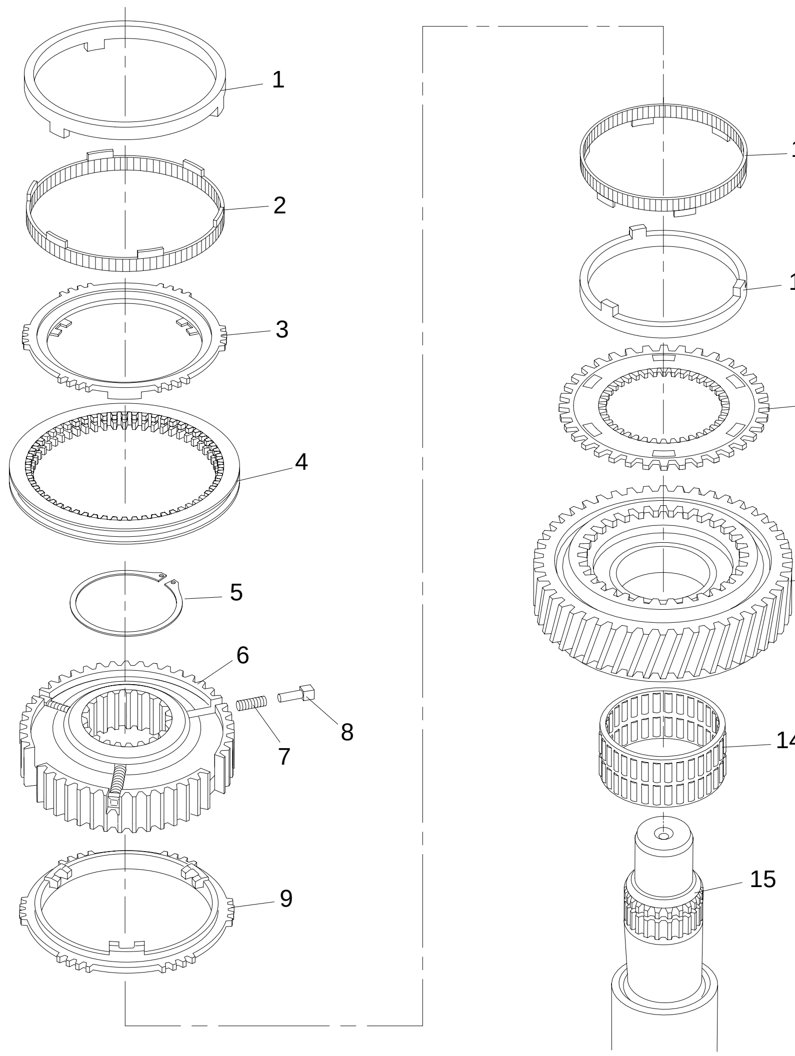
1. Main Shaft (output end)
2. Partition
3. Main Shaft (input end)

Fig. 6, Main Shaft (stripped)

Third Gear

For an exploded view of this assembly, see **Fig. 1**.

1. Apply a coating of MobilTrans SHC® DC (the approved transmission oil) to the needle bearing.



1. 4th Gear Inner Synchro Cone
2. 4th Gear Synchro Ring
3. 4th Gear Outer Synchro Cup
4. 3rd/4th Gear Synchro Slide Collar
5. 4th Gear Snap Ring
6. 3rd/4th Gear Synchro Body
7. Compression Spring
8. Spring Holder
9. 3rd Gear Outer Synchro Cup
10. 3rd Gear Synchro Ring
11. 3rd Gear Inner Synchro Cone
12. 3rd Gear Driver
13. 3rd Gear Wheel
14. 3rd Gear Needle Bearing
15. Main Shaft (input end)

Fig. 1, 3rd Gear Assembly

Third and Fourth Gear Assembly

2. Fit the needle bearing onto the main shaft. Mount the 3rd gear wheel over the needle bearing with the short splines facing up.

IMPORTANT: When installing the gear wheel, spin it and let it drop. This helps prevent damage to the bearings.

3. Place the driver on the 3rd gear wheel with the chamfered teeth facing up.
4. Place the 3rd gear inner synchro cone on the driver with the stop lugs facing up.
5. Apply a coating of approved transmission oil to the 3rd gear synchro ring. Fit the synchro ring onto the synchro cone with the stop lugs facing down. The stop lugs must engage the slotted holes in the driver.
6. Install the 3rd gear outer synchro cup on the synchro ring. The mounts on the outer cup must engage the stop lugs of the inner cone.

NOTE: Make sure the synchro body is installed right side up, with the ridge for the snap ring exposed.

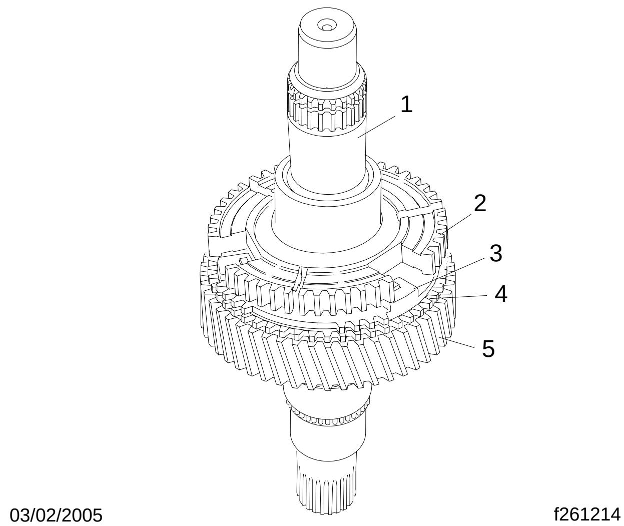
7. Fit the 3rd/4th gear synchro body onto the main shaft. If there is resistance, heat the synchro body using a heat gun. The stop lugs of the outer synchro cup must mesh with the large recesses in the synchro body. See **Fig. 2**.
8. Using snap ring pliers, install a new snap ring. Make sure the snap ring is tight when installed, with no free play.

IMPORTANT: If there is free play, remove the snap ring and replace it with a snap ring of the correct thickness to eliminate any free play.

9. Install the synchro slide collar on the synchro body as far as the stop.
10. Install the three compression springs into the slots in the synchro body. Using a short-bladed screwdriver, press them in until the spring holder engages the tooth of the synchro slide collar. See **Fig. 3**.

Fourth Gear

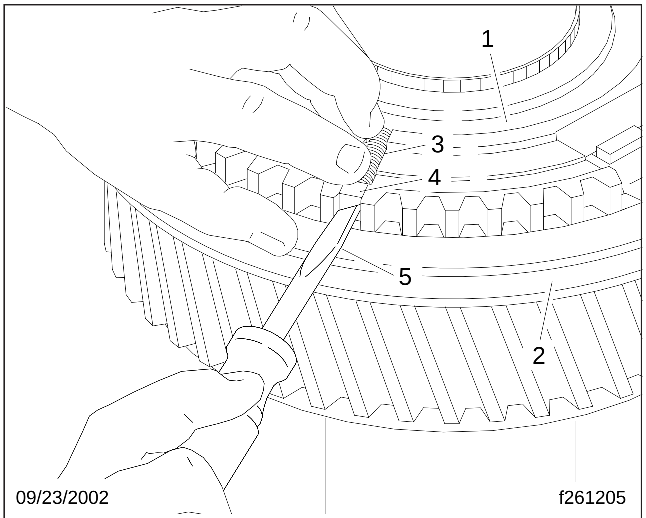
1. Insert the 4th gear outer synchro cup into the synchro body. The mounts of the outer cup must engage with the recesses in the synchro body.



If there is resistance, heat the synchro body using a heat gun.

1. Main Shaft
2. Synchro Body
3. Stop Lug
4. Driver
5. 3rd Gear Wheel

Fig. 2, Fitting the Synchro Body

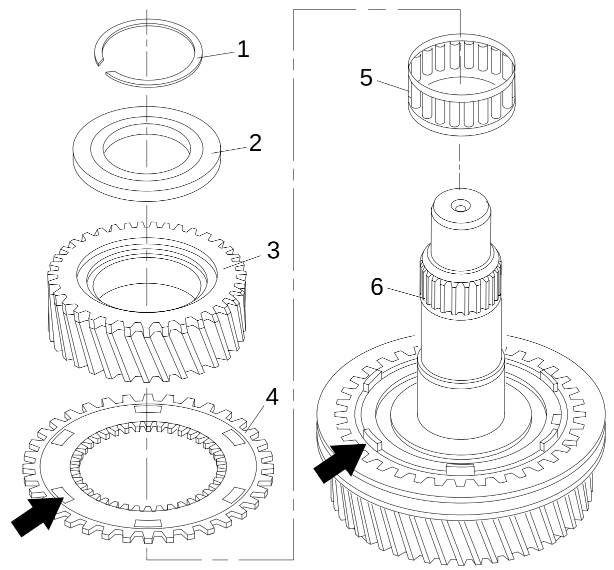


Press in the compression spring until the spring holder engages the tooth of the synchro slide.

1. Synchro Body
2. Synchro Slide Collar
3. Compression Spring
4. Spring Holder
5. Short-Bladed Screwdriver

Fig. 3, Pressing in the Compression Springs

2. Apply a coating of approved transmission oil to the 4th gear synchro ring. Mount the synchro ring on the outer cup with the stop lugs facing up.
3. Slide the 4th gear inner synchro cone into the synchro ring with the stop lugs down. The stop lugs of the inner cone must fit into the mounts on the outer cup.
4. Apply a coating of approved transmission oil to the needle bearing. Fit the needle bearing onto the main shaft.
5. Mount the driver on the main shaft. The asymmetrical tooth tips must face down and the stop lugs up. See **Fig. 4**.



Mount the 4th gear driver with the asymmetric tooth tips facing down and the stop lugs up.

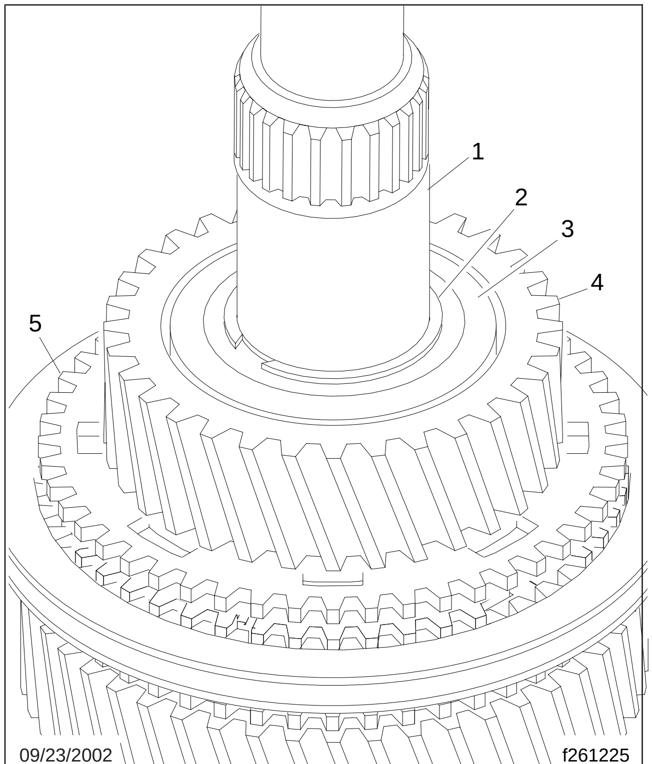
1. 4th Gear Snap Ring
2. Thrust Washer
3. 4th Gear Wheel
4. Driver Teeth
5. Needle Bearing
6. Main Shaft (output end)

Fig. 4, 4th Gear Assembly

6. Mount the 4th gear wheel on the driver. Make sure the slots in the 4th gear wheel engage the stop lugs on the top of the driver.
7. Heat the thrust washer to 176°F (80°C). When heated, press it into the main shaft.

NOTE: Before installing, test the thickness of the snap ring by inserting it into the gap between the main shaft and the thrust washer.

8. Install a new snap ring inside the synchro body. Make sure the snap ring is tight when installed, with no free play. See **Fig. 5**.



1. Main Shaft
2. 4th Gear Snap Ring
3. Thrust Washer
4. 4th Gear Wheel
5. Driver Teeth

Fig. 5, Snap Ring Installed

9. Install the 5th and 6th gears on the main shaft. For instructions, see **Subject 220**.
10. Install the countershaft on the main shaft. For instructions, see **Subject 190**.
11. Install the 2nd gear on the main shaft. For instructions, see **Subject 230**.

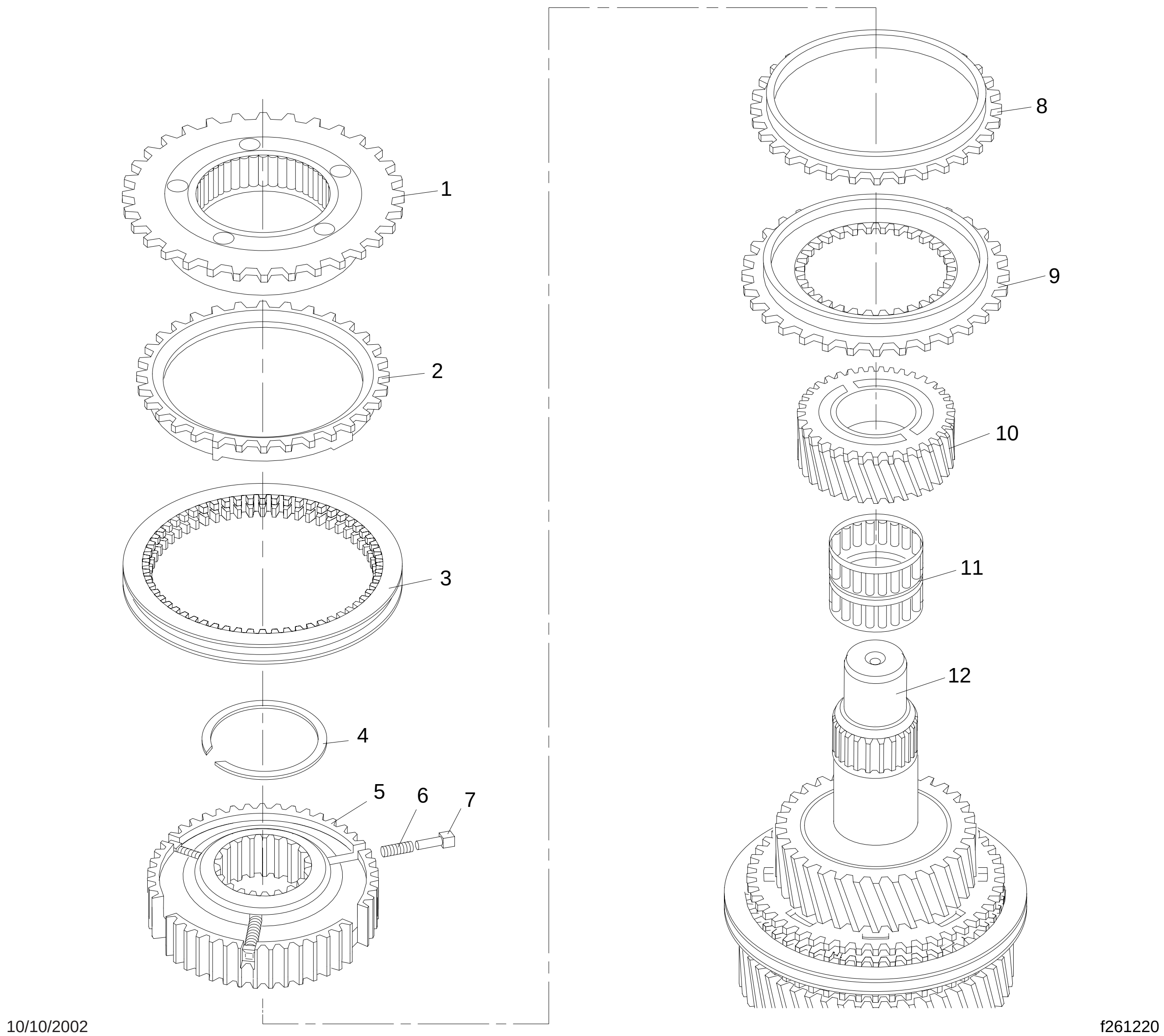
Third and Fourth Gear Assembly

12. Install the reverse gear and the 1st gear on the main shaft. For instructions, see **Subject 230**.
13. Install the rear gear case. For instructions, see **Subject 160**.
14. Install the front gear case. For instructions, see **Subject 150**.

Sixth Gear

For an exploded view of this assembly, see **Fig. 1**.

1. Apply a coating of approved transmission oil to the needle bearing. Fit the needle bearing onto the main shaft.

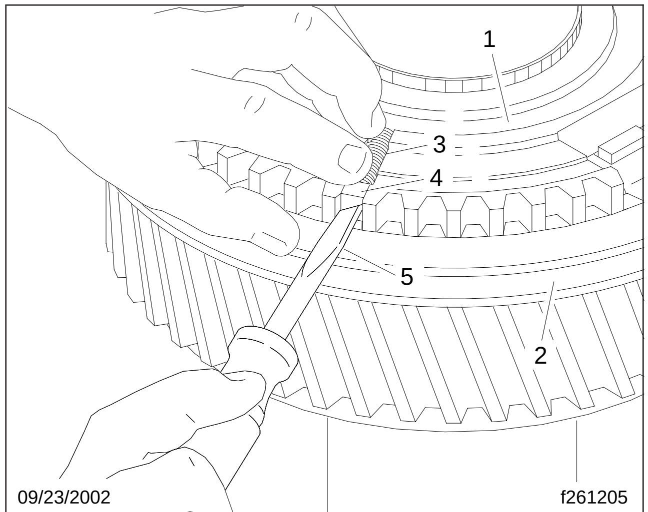


1. 5th Gear Synchro Cone
2. 5th Gear Synchro Ring
3. 5th/6th Gear Synchro Slide Collar
4. Snap Ring
5. 5th/6th Gear Synchro Body
6. Compression Spring
7. Spring Holder
8. 6th Gear Synchro Ring
9. 6th Gear Synchro Cone
10. 6th Gear Wheel
11. 6th Gear Needle Bearing
12. Main Shaft (input end)

Fig. 1, 5th and 6th Gear Assembly

Sixth and Fifth Gear Assembly

2. Mount the 6th gear wheel over the needle bearing with the undercut teeth facing up.
3. Install the 6th gear synchro cone. The oil grooves on the synchro cone must align with the oil grooves on the 6th gear wheel. See **Fig. 1**.
4. Apply a coating of approved transmission oil to the 6th gear synchro ring. Fit the synchro ring onto the synchro cone.
5. Fit the 5th/6th gear synchro body onto the main shaft. If there is resistance, warm the synchro body using a heat gun. The large stop lugs of the 6th gear synchro ring must mesh with the large recesses in the synchro body.
6. Install a new snap ring inside the synchro body. Make sure the snap ring is tight when installed, with no free play.
7. Install the 5th/6th gear synchro slide collar on the synchro body as far as the stop.
8. Install the three compression springs into the slots in the synchro body. Using a short-bladed screwdriver, press them in until the spring holder engages the tooth of the synchro slide collar. See **Fig. 2**.



Press in the compression spring until the spring holder engages the tooth of the synchro slide collar.

1. Synchro Body
2. Synchro Slide Collar
3. Compression Spring
4. Spring Holder
5. Short-Bladed Screwdriver

Fig. 2, Pressing in the Compression Springs

Fifth Gear

1. Insert the 5th gear synchro ring into the synchro body. The large stop lugs of the 5th gear synchro ring must engage in the large recesses of the synchro body.
2. Insert the 5th gear synchro cone into the 5th gear synchro ring.
3. Move the 5th/6th gear synchro slide collar into neutral position.
4. Install the countershaft on the main shaft. For instructions, see **Subject 180**.
5. Install the 2nd gear on the main shaft. For instructions, see **Subject 230**.
6. Install the reverse gear and the 1st gear on the main shaft. For instructions, see **Subject 230**.
7. Install the rear gear case. For instructions, see **Subject 160**.
8. Install the front gear case. For instructions, see **Subject 150**.

Second Gear

For an exploded view of this assembly, see **Fig. 1**.

1. Apply a coating of approved transmission oil to the needle bearing. Fit the needle bearing onto the main shaft.
2. Mount the 2nd gear wheel over the needle bearing with the short teeth facing up.
3. Apply a coating of approved transmission oil to the 2nd gear outer synchro cup and 2nd gear synchro ring. Install the outer cup with the stop lugs facing up. Install the 2nd gear inner ring with the stop lugs facing down and engaging the recesses in the 2nd gear wheel.
4. Install the 2nd gear inner synchro cone. The mounts on the synchro cone must engage the stop lugs of the outer cup.
5. Fit the 1st/2nd gear synchro body onto the main shaft. If there is resistance, warm the synchro body using a heat gun. The mounts of the 2nd gear outer synchro cup must engage in the large recesses in the synchro body. See **Fig. 2**.
6. Install a new snap ring and press it into place inside the synchro body. Make sure the snap ring is tight when installed, with no free play.
7. Install the 1st/2nd gear synchro slide collar on the synchro body with the asymmetric tips of the tooth flanks facing up. See **Fig. 3**.

IMPORTANT: On each synchro slide collar, there are three shortened tooth flanks, evenly spaced around the perimeter. The shortened tooth flanks of the synchro slide collar should be lined up with the shortened tooth flanks of the synchro body.

8. Install the three compression springs into the slots in the synchro body. Using a short-bladed screwdriver, press them in until the spring holder engages the tooth of the synchro slide collar. See **Fig. 4**.

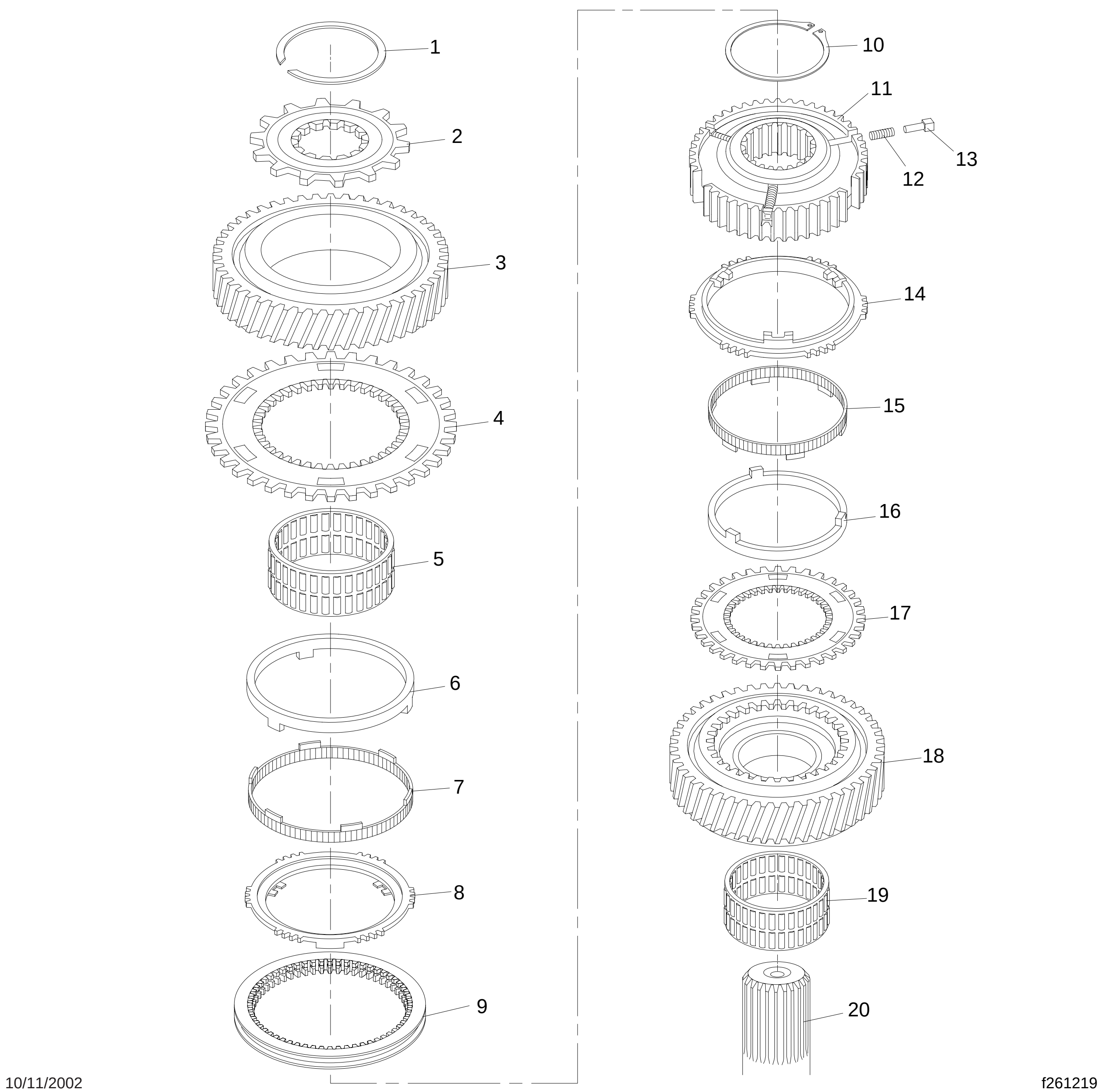
First Gear

1. Install the 1st gear outer synchro cup on the 1st/2nd gear synchro body. The mounts of the outer cup must engage in the recesses of the synchro body.
2. Apply a coating of approved transmission oil to the synchro ring. Install the ring with the stop lugs facing up. Install the inner cone with the stop lugs facing down and engaging the mounts of the outer cup.
3. Apply a coating of approved transmission oil to the needle bearing. Fit the needle bearing onto the main shaft.
4. Mount the 1st gear wheel over the needle bearing with the helical teeth facing up.
5. Install the inner gear wheel with the rounded teeth facing up.
6. Install a new snap ring and press it into place. Make sure the snap ring is tight when installed, with no free play.

Reverse Gear

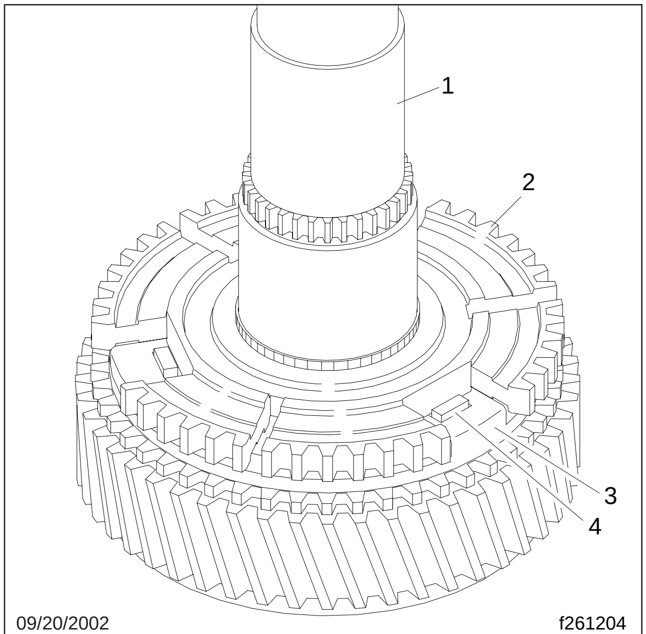
1. Install the reverse gear.
2. Install the shift bars and forks.
3. Install the rear gear case. For instructions, see **Subject 120**.
4. Install the front gear case. For instructions, see **Subject 110**.
5. Install the shift mechanism. For instructions, see **Subject 100**.

Second, First, and Reverse Gear Assembly



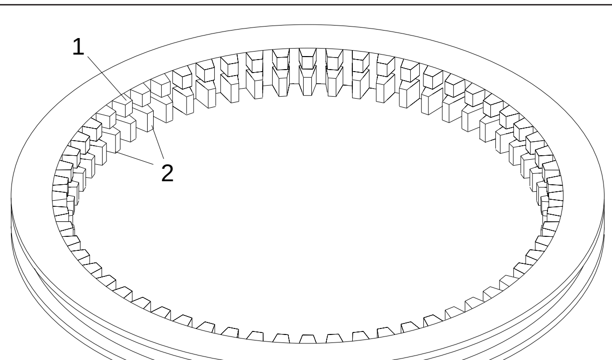
1. 1st Gear Snap Ring
2. Inner Gear Wheel
3. 1st Gear Wheel
4. 1st Gear Driver
5. 1st Gear Needle Bearing
6. 1st Gear Inner Synchro Cone
7. 1st Gear Synchro Ring
8. 1st Gear Outer Synchro Cup
9. 1st/2nd Gear Synchro Slide Collar
10. 2nd Gear Snap Ring
11. 1st/2nd Gear Synchro Body
12. Compression Spring
13. Spring Holder
14. 2nd Gear Outer Synchro Cup
15. 2nd Gear Synchro Ring
16. 2nd Gear Inner Synchro Cone
17. 2nd Gear Driver
18. 2nd Gear Wheel
19. 2nd Gear Needle Bearing
20. Main Shaft (output end)

Fig. 1, 1st and 2nd Gear Assembly



1. Main Shaft
2. 1st/2nd Gear Synchro Body
3. Outer Cup Stop Lug
4. Inner Cone Mount

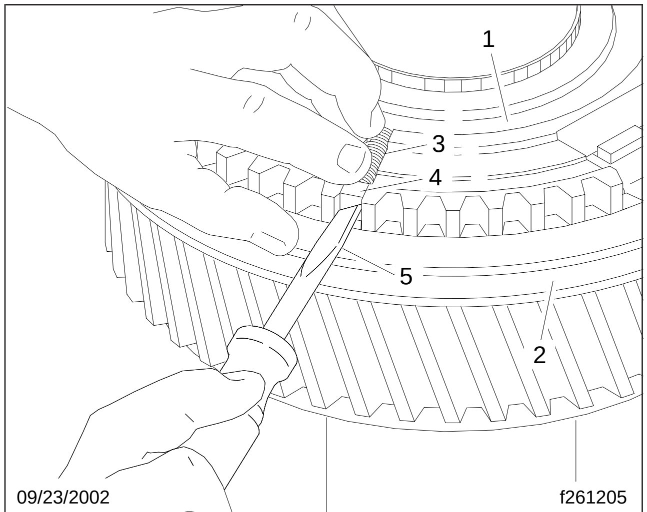
Fig. 2, 2nd Gear Synchronizers



Line up the shortened tooth flanks of the synchro slide collar with the shortened tooth flanks of the synchro body.

1. Shortened Tooth Flank
2. Long Tooth Flanks

Fig. 3, Synchro Slide Collar



Press in the compression spring until the spring holder engages the tooth of the synchro slide collar.

1. Synchro Body
2. Synchro Slide Collar
3. Compression Spring
4. Spring Holder
5. Short-Bladed Screwdriver

Fig. 4, Pressing in the Compression Springs

Synchro Ring Wear Limit Inspection

Special Tools

A special tool is required for this procedure. See **Table 1**.

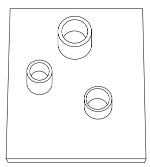
Special Tool for Reverse, First, and Second Gear Disassembly			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580395	Main Shaft/Countershaft Stand	Kent-Moore	J-46732

Table 1, Special Tool for Reverse, First, and Second Gear Disassembly

Fifth/Sixth Gear Inspection

1. Remove the front gear case. For instructions, see **Subject 150**.
2. Remove the rear gear case. For instructions, see **Subject 160**.
3. Remove the reverse gear wheel and needle bearing from the main shaft. For instructions, see **Subject 170**. Do not remove the 1st gear wheel.
4. Place the main shaft on the main shaft/ countershaft stand. See **Table 1**.
5. Move the 5th/6th gear synchro slide collar into the neutral position.

NOTE: Do not tilt or twist the synchro ring. This can cause the measurement to be incorrect.

6. Put the 5th gear synchro ring into position to measure the 5th gear synchromesh reserve.
   - 6.1 Using the synchro slide collar, push the synchro ring up against the 5th gear synchro cone.
   - 6.2 While pushing the synchro slide collar up, press down on the synchro cone and turn it. Verify that the synchro cup and cone are squarely seated, without sliding into gear.

NOTE: This step requires two persons.

7. While one person holds the synchro ring and cone in place, the other person, using a feeler gauge, measures the synchromesh reserve of the 5th gear. See **Table 2** for specified and minimum dimensions.

Synchromesh Reserve, MBT		
Gear	**Minimum Dimension in inches (mm)**	**Specified Dimension in inches (mm)**
1st	0.03 (0.7)	0.08 (2.0)
2nd	0.03 (0.7)	0.08 (2.0)
3rd	0.03 (0.7)	0.08 (2.0)
4th	0.03 (0.7)	0.08 (2.0)
5th	0.02 (0.5)	0.06 (1.5)
6th	0.02 (0.5)	0.06 (1.5)

Table 2, Synchromesh Reserve, MBT

   - 7.1 Measure the synchromesh reserve over the entire circumference of the ring.
   - 7.2 Calculate the average value of the synchromesh reserve.
   - 7.3 If the average value of the synchromesh reserve is below the minimum dimension, replace the 5th gear synchro ring.

NOTE: Do not tilt or twist the synchro ring. This can cause the measurement to be incorrect.

8. Put the 6th gear synchro ring into position to measure the 6th gear synchromesh reserve.

Synchro Ring Wear Limit Inspection

8.1 Using the synchro slide collar, press the 6th gear synchro ring down against the 6th gear wheel.

8.2 While pressing the synchro slide collar down, turn the 6th gear wheel.

NOTE: This step requires two persons.

9. While one person holds the synchro ring and gear wheel in place, the other person, using a feeler gauge, measures the synchromesh reserve of the 6th gear. See **Table 2** for specified and minimum dimensions.

   9.1 Measure the synchromesh reserve over the entire circumference of the ring.

   9.2 Calculate the average value of the synchromesh reserve.

   9.3 If the average value of the synchromesh reserve is below the minimum dimension, replace the 6th gear synchro ring.

Fourth/Third Gear Inspection

1. Move the 3rd/4th gear synchro slide collar into the neutral position.

NOTE: Do not tilt or twist the synchro ring. This can cause the measurement to be incorrect.

2. Put the 4th gear outer synchro cup into position to measure the 4th gear synchromesh reserve.

   2.1 Using the synchro slide collar, push the outer synchro cup up against the 4th gear wheel.

   2.2 While pushing the synchro slide collar up, turn the 4th gear wheel. Verify that the synchro cup and cone are squarely seated, without sliding into gear.

NOTE: This step requires two persons.

3. While one person holds the outer synchro cup and gear wheel in place, the other person, using a feeler gauge, measures the synchromesh reserve of the 4th gear. See **Table 2** for specified and minimum dimensions.

   3.1 Measure the synchromesh reserve over the entire circumference of the outer synchro cup.

   3.2 Calculate the average value of the synchromesh reserve.

   3.3 If the average value of the synchromesh reserve is below the minimum dimension, replace the 4th gear synchro ring.

NOTE: Do not tilt or twist the synchro ring. This can cause the measurement to be incorrect.

4. Put the 3rd gear outer synchro cup into position to measure the 3rd gear synchromesh reserve.

   4.1 Using the synchro slide collar, press the outer synchro cup down against the 3rd gear wheel.

   4.2 While pressing the synchro slide collar down, turn the 3rd gear wheel.

NOTE: This step requires two persons.

5. While one person holds the outer synchro cup and gear wheel in place, the other person, using a feeler gauge, measures the synchromesh reserve of the 3rd gear. See **Table 2** for specified and minimum dimensions.

   5.1 Measure the synchromesh reserve over the entire circumference of the outer synchro cup.

   5.2 Calculate the average value of the synchromesh reserve.

   5.3 If the average value of the synchromesh reserve is below the minimum dimension, replace the 3rd gear synchro ring.

Second/First Gear Inspection

1. Move the 1st/2nd gear synchro slide collar into the neutral position.

NOTE: Do not tilt or twist the synchro ring. This can cause the measurement to be incorrect.

2. Put the 2nd gear outer synchro cup into position to measure the 2nd gear synchromesh reserve.

   2.1 Using the synchro slide collar, push the outer synchro cup up against the 2nd gear wheel.

   2.2 While pushing the synchro slide collar up, turn the 2nd gear wheel. Verify that the synchro cup and cone are squarely seated, without sliding into gear.

NOTE: This step requires two persons.

3. While one person holds the outer synchro cup and gear wheel in place, the other person, using a feeler gauge, measures the synchromesh reserve of the 2nd gear. See **Table 2** for specified and minimum dimensions.
   3.1 Measure the synchromesh reserve over the entire circumference of the outer synchro cup.
   3.2 Calculate the average value of the synchromesh reserve.
   3.3 If the average value of the synchromesh reserve is below the minimum dimension, replace the 2nd gear synchro ring.

NOTE: Do not tilt or twist the synchro ring. This can cause the measurement to be incorrect.

4. Put the 1st gear outer synchro cup into position to measure the 1st gear synchromesh reserve.
   4.1 Using the synchro slide collar, press the outer synchro cup down against the 1st gear wheel.
   4.2 While pressing the synchro slide collar down, turn the 1st gear wheel.

NOTE: This step requires two persons.

5. While one person holds the outer synchro cup and gear wheel in place, the other person, using a feeler gauge, measures the synchromesh reserve of the 1st gear. See **Table 2** for specified and minimum dimensions.
   5.1 Measure the synchromesh reserve over the entire circumference of the outer synchro cup.
   5.2 Calculate the average value of the synchromesh reserve.
   5.3 If the average value of the synchromesh reserve is below the minimum dimension, replace the 1st gear synchro ring.
6. Install the reverse gear wheel and needle bearing on the main shaft. For instructions, see **Subject 170**.
7. Install the rear gear case. For instructions, see **Subject 160**.
8. Install the front gear case. For instructions, see **Subject 150**.

Special Tools

Special tools are required for this procedure. See **Table 1**.

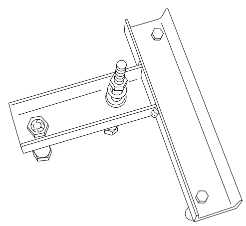
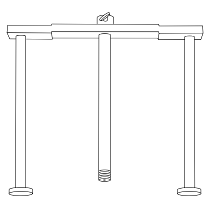
Special Tools for End Play Measurement			
Tool	Description	Manufacturer	Part Number
 f580397	Puller/Installer/Stand	Kent-Moore	J-46739
 f580402	Main Shaft End Play Measuring Fixture	Kent-Moore	J-47903

Table 1, Special Tools for End Play Measurement

Measurement

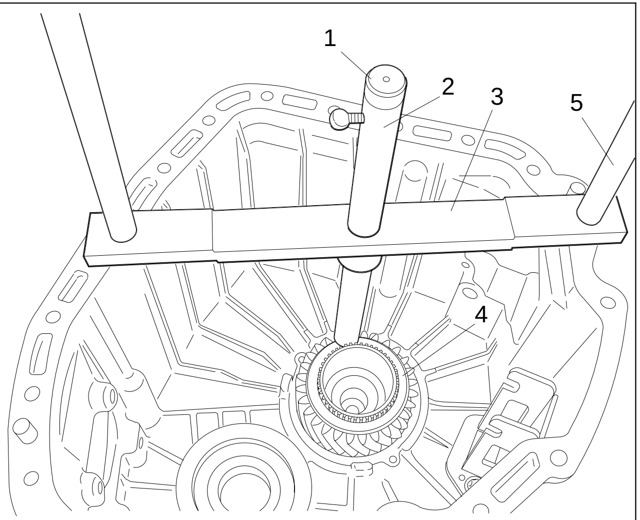
NOTE: Do this procedure whenever the gear case halves, main shaft, bearings, or input shaft are removed. Perform this procedure with the transmission partially assembled, and with the front gear case removed.

1. Place the front case nose down. Install the rear case on the puller/installer/stand, if not already done.
2. Set up the main shaft end play measuring fixture on the front gear case with the crossbar flat on the gear case flange and its legs in the air. See **Table 1**. Lock down the upper thumbscrew at the point where the center shaft of the measuring fixture just touches the contact surface of the input shaft gear wheel. See **Fig. 1**.
3. Turn the end play measuringfixture over and set it up on the rear gear case with the legs down, resting on the gear case flange.
4. Lock down the lower thumbscrew at the point where the end cap of the measuring fixture just touches the contact surface of the input shaft mating wheel. See **Fig. 2**.
5. Using a feeler gauge, measure the gap between the shaft and the end cap. This gap is the end play. See **Fig. 3**.
6. If the end play is within acceptable limits, continue on to the next step. See **Table 2** for acceptable limits.

   If the end play is less than the acceptable limit, install a thinner thrust washer and repeat the measurements until the end play is acceptable.

   If the end play is more than the acceptable limit, install a thicker thrust washer and repeat the measurements until the end play is acceptable.

Main Shaft End Play Measurement



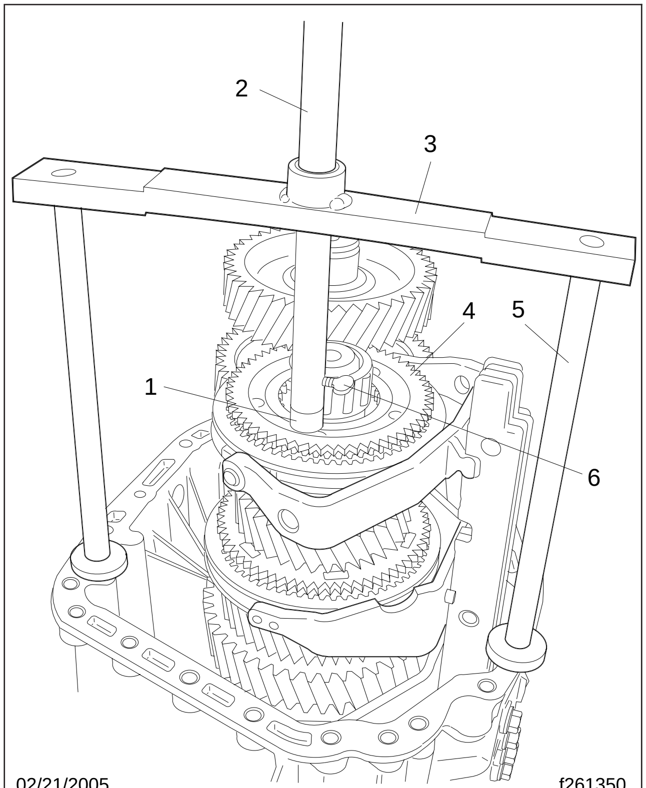
1. Measuring Fixture End Cap
2. Measuring Fixture Center Shaft
3. Measuring Fixture Crossbar
4. Input Shaft Gear Wheel
5. Leg of Measuring Fixture

Fig. 1, Taking the First Measurement

Main Shaft End Play Limits		
Model	**Minimum Dimension in inches (mm)**	**Maximum Dimension in inches (mm)**
520	0.041 (1.05)	0.049 (1.25)
660	0.037 (0.95)	0.049 (1.25)

Table 2, Main Shaft End Play Limits

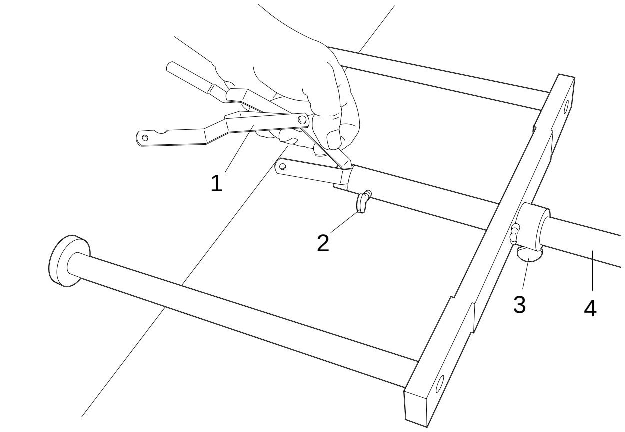
7. Install the input shaft. For instructions, see **Subject 120**.
8. Install the front gear case. For instructions, see **Subject 150**.



1. Measuring Fixture End Cap
2. Measuring Fixture Center Shaft
3. Measuring Fixture Crossbar
4. Input Shaft Mating Wheel
5. Leg of Measuring Fixture
6. Lower Thumbscrew

Fig. 2, Taking the Second Measurement

Main Shaft End Play Measurement



Using a feeler gauge,measure the gap (arrow) between the center shaft and the end cap.

1. Feeler Gauge
2. Lower Thumbscrew
3. Upper Thumbscrew
4. Measuring Fixture Center Shaft

Fig. 3, Measuring the End Play with a Feeler Gauge

Torque Values, MBT Transmission Removal and Installation			
Fastener	**Size**	**Class**	**Torque: lbf·ft (N·m)**
Bell Housing-to-Timing Case Capscrews	M10 x 1.5	8.8	33 (45)
Clutch Slave Cylinder Bracket Mounting Bolts	M8	8.8	15 (20)
Fuel Cross-Over Line Mounting Bolts	—	—	95 (129)
Fuel Cross-Over Line Mounting Clamps	—	—	40 (54)
Midship Bearing Bracket Capscrews	3/4–11	—	95 (129)
Power Take-Off Unit (PTO) Mounting Capscrews	M10	10.9	43 (58)
Reverse Gear Switch	M20	8.8	42 (57)
Shift Lever Mounting Bolt	M10 x 1.5	10.9	50 (68)
Shift Lever Retaining Ring Screws	—	—	28 (38)
Speedometer Sensor Lock	M8	8.8	28 (38)
Starter Lock Switch (optional)	M20	8.8	42 (57)
Transmission Fluid Drain Plug	M24	8.8	42 (57)
Transmission Fluid Fill Plug	M24	8.8	42 (57)
U-Joint End Cap Bolts	3/8–24	—	50 (68)
	1/2–20	—	110 (149)

Table 1, Torque Values, MBT Transmission Removal and installation

Torque Values, MBT Transmission Teardown	
Fastener	**Torque: lbf·ft (N·m)**
Clutch Release Fork Mounting Capscrew	26 (36)
Gear Case Capscrews	22 (30)
Input Shaft Guide Tube Low-Profile Mounting Capscrew	17 (23)
Output Shaft Pressure Plate Mounting Capscrew	190 (258)
Rear Countershaft Cover Capscrew	18 (25)
Shift Rail Cover Capscrew	29 (39)
Shift Rail Detent Bolt	22 (30)
Shift Rod Housing Capscrews	18 (25)
Shift Rod Setscrew	30 (40)
Shifter Pin T60 Capscrew (model 660 only)	88 (120)

Table 2, Torque Values, MBT Transmission Teardown

Specifications

Gear Ratios		
Model	**Gear**	**Ratio**
MBT520S-6D	1	9.201
	2	5.230
	3	3.145
	4	2.034
	5	1.374
	6	1.000
	R	8.649
MBT660S-6O	1	6.700
	2	3.810
	3	2.290
	4	1.480
	5	1.000
	6	0.730
	R	6.290

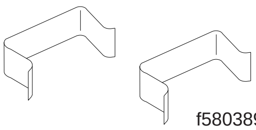
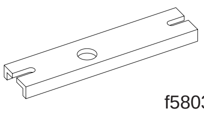
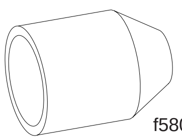
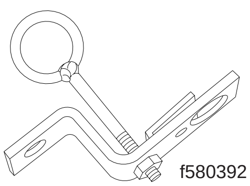
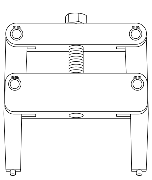
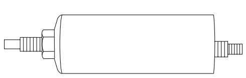
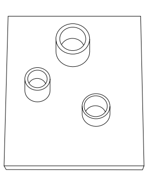
Table 3, Gear Ratios

Synchromesh Reserve, MBT		
Gear	**Minimum Dimension: inch (mm)**	**Specified Dimension: inch (mm)**
1st	0.03 (0.7)	0. 08 (2.0)
2nd	0.03 (0.7)	0. 08 (2.0)
3rd	0.03 (0.7)	0. 08 (2.0)
4th	0.03 (0.7)	0. 08 (2.0)
5th	0.02 (0.5)	0. 06 (1.5)
6th	0.02 (0.5)	0. 06 (1.5)

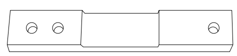
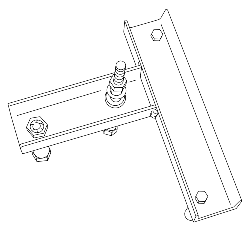
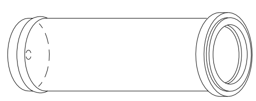
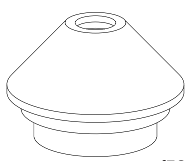
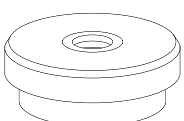
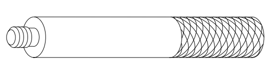
Table 4, Synchromesh Reserve, MBT

Main Shaft End Play Limits		
Model	**Minimum Dimension: inch (mm)**	**Maximum Dimension: inch (mm)**
520	0.041 (1.05)	0.049 (1.25)
660	0.037 (0.95)	0.049 (1.25)

Table 5, Main Shaft End Play Limits

Special Tools for MBT Transmissions			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580389	Synchro Retainer Clips	Kent-Moore	J-46726
 f580390	Front Gear Case Bridge	Kent-Moore	J-46727
 f580391	Countershaft Guide	Kent-Moore	J-46728
 f580392	Main Shaft/Countershaft Lifting Device	Kent-Moore	J-46729
 f580393	Snap Ring Removal Tool	Kent-Moore	J-46730
 f580394	Reverse Idler Shaft Puller	Kent-Moore	J-46731
 f580395	Main Shaft/Countershaft Stand	Kent-Moore	J-46732

Specifications

Special Tools for MBT Transmissions			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580396	Countershaft Retainer	Kent-Moore	J-46733
 f580397	Rear Case Puller/Installer/Stand	Kent-Moore	J-46739
 f580401	Input Shaft Seal Installer	Kent-Moore	J-47901
 f580398	Output Shaft Seal Installer	Kent-Moore	J-47863
 f580399	Countershaft Seal Cap Installer	Kent-Moore	J-47901
 f580400	Universal Handle	Kent-Moore	J-8901

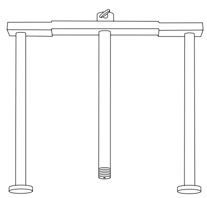
Special Tools for MBT Transmissions			
Tool	Description	Manufacturer	Part Number
 f580402	Main Shaft End Play Measuring Fixture	Kent-Moore	J-47903

Table 6, Special Tools for MBT Transmissions

Standard Shop Tools for MBT Transmission	
Tool Description	Remarks
Torx® bit set	Must include a size T60 bit
Inverted-Torx bit set	Must include size E12 and E14 bits
Large snap ring pliers	Similar to Snap-On p/n PR7
Large duck-bill snap ring pliers	Similar to Craftsman p/n 9 47386 or Snap-On p/n SRP4
Seal remover	Similar to Craftsman p/n 9 47645 or Snap-On p/n YA105
A pair of lifting straps of 300 lb capacity or more	A 1" x 4' loop-type strap handles this unit
Large soft-faced dead-blow hammer (5-lb. weight)	Similar to Snap-On p/n BC7A
Large T-bar puller	Similar to OTC p/n 522

Table 7, Standard Shop Tools for MBT Transmission

Service Material Specifications		
Purpose	Product	Color
Thread-locking compound	Loctite® 242 or equivalent	Blue
Sealant	Loctite 509 or equivalent	Blue to green
Extreme pressure lubricant	J 23444-A	Dark gray

Table 8, Service Material Specifications

Transmission Model	Lubricant Type	Refill Capacity:* qt (L)
MBT660S-6O	Mobiltrans SHC® DC	9.5 (9.0)
MBT520S-6D		

* Quantities listed are approximate. Fill the transmission until the lubricant is level with the bottom of the fill hole, with the vehicle in normal operating position.

Table 9, MBT Transmission Approved Lubricant Type and Capacity

A hybrid electric vehicle (HEV) has both a diesel engine and an electric motor. The electric motor is powered by high-voltage batteries, which are charged by regenerative braking and, on vehicles equipped with the ePTO option, the diesel engine. With regenerative braking, when the service brake is depressed (or when the accelerator pedal is at idle while coasting), the vehicle's kinetic energy is captured and stored in the high-voltage batteries. When the batteries are fully charged, regenerative braking is disabled.

Hybrid Electric and Cooling Systems Overview

Eaton Corporation developed and supplies the hybrid electric system for Freightliner Trucks. The primary system components are the hybrid drive unit (or "HDU", which includes the electric generator/motor and automated transmission), Power Electronics Carrier (or "PEC", which contains the high-voltage, lithium-ion batteries), and the inverter (which changes DC to AC, and AC to DC). Electric Power Take-Off (ePTO) and auxiliary power generator (APG) components are optional on the HEV system. For more information on the hybrid electric system, see Eaton's website, **www.roadranger.com**.

The hybrid electric system has its own liquid cooling system for the motor, inverter, DC/DC Converter (if ePTO equipped), and APG (if equipped). The system includes a radiator and fan, pump, reservoir, and plumbing that are separate from the engine cooling system. See **Fig. 1**. For coolant, it uses a mixture of 50 percent ethylene glycol and 50 percent water.

Safety Features

The HEV has high-voltage cables and a service switch on the PEC. The high-voltage cables are covered in orange insulation and conduit. High-voltage components are tagged with a warning or danger label.

IMPORTANT: The service switch on the PEC should only be used for an emergency shutdown or when the troubleshooting guide or service manual calls for work on the high-voltage system. The troubleshooting guide and service manual for the hybrid electric system are available from **www.roadranger.com**.

The red service switch is located next to the high-voltage cable connections at one end of the PEC. Push in the red service switch and shut down the engine. The hybrid system will be disabled, and the high-voltage batteries in the PEC, though still live, are isolated in the PEC.

NOTE: The PEC may be mounted in an area with limited access.

Vehicles with the ePTO option are designed with a safety switch to ensure the diesel engine does not start when the hood is open.

Safety Precautions

The HEV has high-voltage components, including 340-volt DC batteries and a 500-volt AC motor. Never cut high-voltage cables or connectors. Do not paint high-voltage cables.

Avoid direct pressure wash on high-voltage connections (PEC, DC/DC Converter) and the air intake and exhaust on the PEC.

Emergency Shutdown

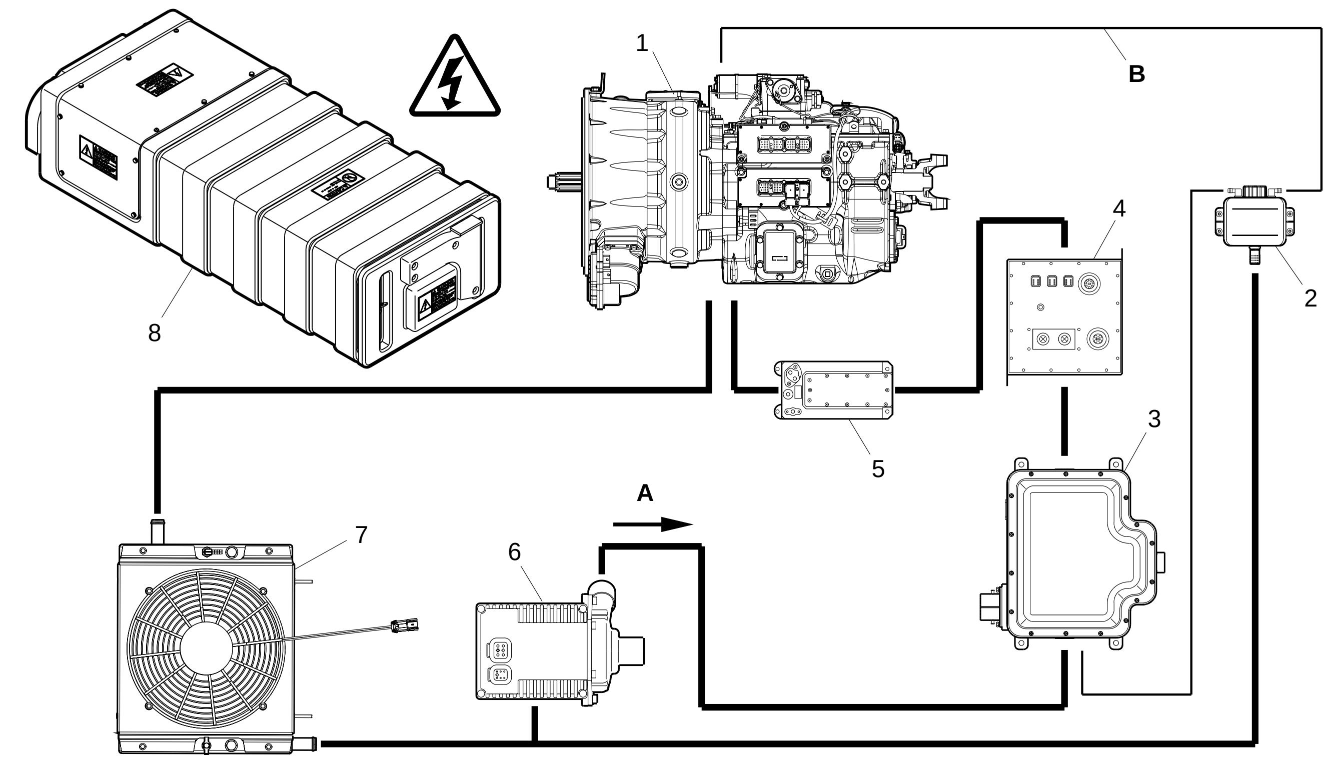
WARNING

After disabling the vehicle, power is maintained in the high-voltage electrical system for up to five minutes. Unprotected contact with any "live" high voltage components can cause serious injury or even death.

There are two options for performing an emergency shutdown. The preferred method is to turn off the ignition key. The other option is to disconnect the low-voltage (12-volt) vehicle batteries. In either case, the engine will shut down, dash lights will shut down, the hybrid electrical system will shut down, and the high-voltage batteries in the Power Electronics Carrier (PEC) will remain "live" but isolated in the PEC.

NOTE: In an emergency, if the service switch on the PEC is accessible, it may be pushed in to shut down the hybrid electrical system and isolate the "live" HEV batteries in the PEC.

General Information



A. Direction of flow.
B. Installed on vehicles December 2008 and later.

1. Hybrid Drive Unit (HDU)
2. Coolant Reservoir
3. Inverter
4. Auxiliary Power Generator (optional)
5. DC/DC Converter (ePTO vehicles only)
6. Coolant Pump
7. Hybrid Cooler and Fan
8. Power Electronics Carrier (air-cooled)

Fig. 1, HEV Electric and Cooling Systems

In Case of a Fire or Accident

If the HEV becomes involved in an accident or fire, be aware of the following.

- Use CO2 or dry chemical extinguishers. The batteries in the power electronics carrier (PEC) are lithium ion.
- Do not cut into high-voltage cables. The high-voltage wiring is covered in orange insulation or convoluted tubing and marked with warning labels at the connectors.
- Do not cut into or open the PEC.
- Do not cut into or open the DC/DC converter.
- Do not cut into or open the inverter.

Specifications

Torque Values, Hybrid Electric Vehicle	
Description	**Torque: lbf·ft (N·m)**
Capscrews, Bell Housing to Flywheel Housing	35–45 (47–61)

Table 1, Torque Values, Hybrid Electric Vehicle

NOTE: Torque values for components of the hybrid electric system are available from Eaton. For more information, see Eaton's website, **www.roadranger.com**.

Accelerator Pedal Assembly

The Williams electronic suspended accelerator pedal provides an electrical signal to the engine in response to the driver's demand for more engine power. The accelerator pedal converts downward pressure into an electrical signal via the pedal position sensor.

Pedal Position Sensor

Freightliner uses various pedal position sensors, depending on the engine. The pedal position sensor is mounted to the side of the pedal assembly. The sensor and the pedal assembly are both separately replaceable.

NOTE: Vehicles manufactured on or after April 2, 2007, do not have replaceable sensors. The new pedal assemblies use thread-forming screws to mount the sensor to the pedal housing. Sensor replacement will strip the threads, so the entire pedal assembly must be replaced when a new sensor is needed.

There are three basic technologies employed on pedal position sensors used with electronic engines:

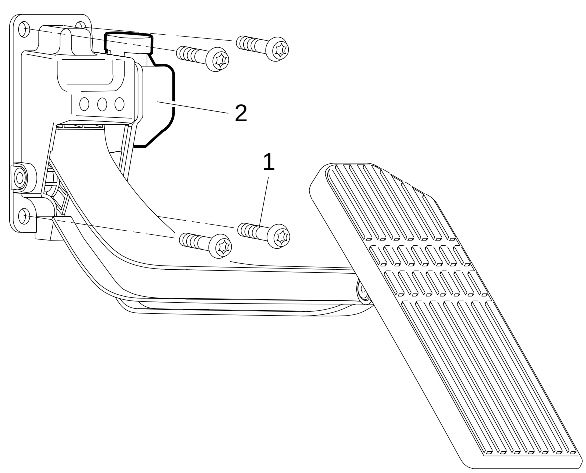
- A ratiometric sensor that generates a DC voltage output in proportion to the pedal position. The ratiometric sensor is used on Detroit Diesel, Mercedes-Benz, and pre-EPA07 Cummins engines.
- A pulse-width-modulating (PWM) sensor that generates a series of discrete voltage pulses. The width of the pulses is proportional to the pedal position. A narrower pulse width indicates a smaller accelerator pedal request and a wider pulse width indicates a larger pedal request. The PWM sensor is used on Caterpillar engines.
- A dual ratiometric sensor that uses Hall effect technology to generate two analog outputs that are proportional to the pedal position. The primary output is twice the voltage of the secondary output. The dual sensor is used on EPA07 Cummins engines.

An idle validation switch (IVS) is integrated into some ratiometric pedal position sensors. The IVS is a single-pole, double-throw switch. Some engine models monitor both switched poles, and some monitor only one pole. When the accelerator pedal returns to idle, the IVS moves to the "idle" position to signal the engine that the pedal has returned to idle. The IVS is not a serviceable part. If the IVS malfunctions, the sensor must be replaced.

Accelerator Pedal Removal and Installation

Removal

1. Apply the parking brakes and chock the tires.
2. Disconnect the batteries.
3. Remove the tie strap that attaches the pedal position sensor wiring harness to the air line. Disconnect the pedal position sensor wiring harness.
4. Remove the four fasteners that secure the accelerator pedal base cup to the inside of the bulkhead. See **Fig. 1**.
5. Remove the pedal assembly.



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NOTE: Washers not shown

1. Fastener (4 qty.)
2. Pedal Position Sensor

Fig. 1, Throttle Pedal

Installation

1. Align the accelerator pedal assembly with the mounting holes on the inside of the bulkhead.
2. Install the pedal assembly mounting fasteners and tighten them 7 to 10 lbf·ft (9 to 14 N·m).
3. Connect the pedal position sensor wiring harness. Using a tie strap, secure the wiring harness to the air line.
4. Depress the accelerator pedal several times and ensure that the pedal does not stick or bind.
5. Connect the batteries.
6. Test the pedal operation using the diagnostic software tool specified in **Table 1**.

Diagnostic Software Tools	
Engine Manufacturer	**Software Tool**
Caterpillar	Caterpillar Electronic Technician (CAT ET)
Cummins	INSITE
Mercedes-Benz	Detroit Diesel Diagnostic Link

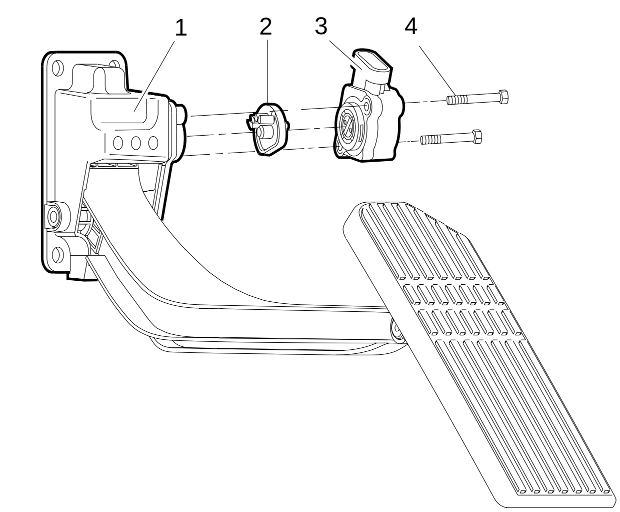
Table 1, Diagnostic Software Tools

Replacement

NOTE: Vehicles manufactured on or after April 2, 2007, do not have replaceable sensors. The new pedal assemblies use thread-forming screws to mount the sensor to the pedal housing. Sensor replacement will strip the threads, so the entire pedal assembly must be replaced when a new sensor is needed. See **Subject 100** for instructions.

Replace the pedal position sensor as follows:

1. Apply the parking brakes and chock the tires.
2. Remove the pedal assembly. See **Subject 100** for instructions.
3. Remove the two sensor mounting screws that connect the sensor to the pedal assembly. See **Fig. 1**. Remove the pedal position sensor from the pedal assembly.



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1. Accelerator Pedal Assembly
2. Pinion Gear
3. Pedal Position Sensor
4. Mounting Screws

Fig. 1, Pedal Position Sensor Installation

4. Align the new sensor with the spline on the pinion gear, then push it into the pedal assembly. Rotate the sensor slightly so the mounting holes line up with the pedal assembly. See **Fig. 1**.
5. Install the sensor mounting fasteners and tighten them 25 to 30 lbf·in (280 to 340 N·cm).
6. Install the pedal assembly and test its operation as instructed in **Subject 100**.

Complete the following procedures to diagnose accelerator pedal assembly and pedal position sensor problems.

Common Problems and Indications

The accelerator pedal assembly was designed so that the pedal position sensor will not reach the internal stop points when it is mounted to the pedal assembly. Attempting to modify the sensor or forcing the sensor shaft beyond the internal stop points will result in severe damage to the sensor.

A number of symptoms may be reported that can indicate a problem with the accelerator pedal, pedal position sensor, or wiring to the engine, including:

- low power or poor acceleration
- slow deceleration
- vehicle does not reach top speed
- engine is stuck at idle
- engine brake does not function
- check engine light comes on
- engine fault code indicates a pedal position sensor problem

A thorough diagnosis of the entire sensor system must be performed to ensure that a pedal position sensor is faulty. Symptoms may disappear when the pedal position sensor is replaced even if the sensor is not faulty.

Diagnostics

IMPORTANT: Vehicles manufactured on or after April 2, 2007, do not have replaceable sensors. The new pedal assemblies use thread-forming screws to mount the sensor to the pedal housing. Sensor replacement will strip the threads, so the entire pedal assembly must be replaced when a new sensor is needed. See **Subject 100** for instructions on replacing the entire pedal assembly.

1. Connect the vehicle to the appropriate diagnostic software tool. See **Table 1** for a list of diagnostic software tools for each engine.

Diagnostic Software Tools	
Engine Manufacturer	**Software Tool**
Caterpillar	Caterpillar Electronic Technician (CAT ET)
Cummins	INSITE
Mercedes-Benz	Detroit Diesel Diagnostic Link

Table 1, Diagnostic Software Tools

2. Make a note of the signal values at idle. See **Table 2** for the correct signal values.

NOTE: All desired signal values are approximate. Each individual vehicle and electrical system will exhibit some variation in signal values. The engine control system compensates for this variation. These diagnostic procedures are designed to identify malfunctioning components of the pedal assembly and electrical system.

3. Slowly depress the accelerator pedal and monitor the signals.

NOTE: There is a short time delay between pedal movement and display of the corresponding data.

4. Make a note of all signal values when the pedal has been pressed halfway.
5. Make a note of all signal values at full throttle.
6. Verify idle validation signal (IVS) inputs, if equipped.

NOTE: The pedal position sensor used with Caterpillar engines is a pulse-width modulated (PWM) sensor. It cannot be diagnosed using a digital multimeter set to measure voltage or resistance. A multimeter capable of measuring "duty cycle" may be used to view the sensor output.

The pedal position sensor used with EPA07 Cummins engines uses Hall effect technology. Attempting to measure resistance across the sensor will not provide valid results and may damage the sensor.

7. If any signal does not change, measure the sensor voltage supply and ground circuits with a digital multimeter as follows.

Troubleshooting

7.1 Use EZWiring™ in ServicePro or PartsPro to identify the circuit(s) that supply voltage to the pedal position sensor.

IMPORTANT: The ignition key must be in the ON position.

7.2 Disconnect the connector nearest the pedal and measure the voltage supply.

8. If a 5-volt supply is not present, look for a fault in the circuit between the pedal and the common powertrain controller (Mercedes-Benz) or the motor control module (Caterpillar and Cummins engines).

9. Inspect and ensure that all connector pins at the pedal position sensor, frontwall, and the engine controller are free of corrosion and are not bent or damaged. Inspect and ensure that the connections between the pins and the wires are secure and also free of corrosion.

10. If the problem has not been resolved, the problem is not with the pedal position sensor. See the engine manufacturer's service literature for further guidance.

Diagnostic Software Values*			
Engine	**Signal**	**Pedal Position**	**Desired Value†**
Caterpillar, pre-EPA07	Throttle Position	Idle	0%
		Full throttle	100%
		Between idle/full throttle	Varies smoothly between 0% and 100%
	Duty Cycle	Idle	15%
		Full throttle	85%
		Between idle/full throttle	Varies smoothly between 15% and 85%
Caterpillar, EPA07	Accelerator Pedal Position	Idle	0%
		Full throttle	100%
		Between idle/full throttle	Varies smoothly between 0% and 100%
	Throttle Position	Idle	0%
		Full throttle	100%
		Between idle/full throttle	Varies smoothly between 0% and 100%
	Duty Cycle	Idle	15%
		Full throttle	85%
		Between idle/full throttle	Varies smoothly between 15% and 85%

Diagnostic Software Values*			
Engine	**Signal**	**Pedal Position**	**Desired Value†**
Cummins, pre-EPA07	Accelerator Pedal Position	Idle	0%
		Full throttle	100%
		Between idle/full throttle	Varies smoothly between 0% and 100%
	Accelerator Pedal Sensor	Idle	0.5 volts
		Full throttle	4.5 volts
		Between idle/full throttle	Varies smoothly between 0.5 and 4.5 volts
	IVS	Idle	ON
		Full throttle	OFF
	Sensor Supply	Idle	5.0 volts
		Full throttle	5.0 volts
		Between idle/full throttle	5.0 volts
Cummins, EPA07	Accelerator Pedal Position	Idle	0%
		Full throttle	100%
		Between idle/full throttle	Varies smoothly between 0% and 100%
	Accelerator Pedal Sensor	Idle	1.0 volts
		Full throttle	4.5 volts
		Between idle/full throttle	Varies smoothly between 1.0 and 4.5 volts
	Accelerator Pedal Sensor 2	Idle	0.5 volts
		Full throttle	2.25 volts
		Between idle/full throttle	Varies smoothly between 0.5 and 2.25 volts
	Sensor Supply (both)	Idle	5.0 volts
		Full throttle	5.0 volts
		Between idle/full throttle	5.0 volts
Mercedes-Benz, pre-EPA07	Accelerator Pedal Raw Sensor	Idle	15%
		Full throttle	75%
		Between idle/full throttle	Varies smoothly between 15% and 75%
	Accelerator Pedal Position	Idle	0%
		Full throttle	100%
		Between idle/full throttle	Varies smoothly between 0% and 100%
	IVS	Idle	ON (grounded)
		Full throttle	OFF (open)
	Supply Analog Accelerator Pedal	Idle	5.0 volts
		Full throttle	5.0 volts
		Between idle/full throttle	5.0 volts

Troubleshooting

Diagnostic Software Values*			
Engine	**Signal**	**Pedal Position**	**Desired Value†**
Mercedes-Benz, EPA07	Accelerator Pedal Raw Sensor	Idle	15%
		Full throttle	75%
		Between idle/full throttle	Varies smoothly between 15% and 75%
	Accelerator Pedal Position	Idle	0%
		Full throttle	100%
		Between idle/full throttle	Varies smoothly between 0% and 100%
	IVS1	Idle	ON (grounded)
		Full throttle	OFF (open)
	IVS2	Idle	OFF (open)
		Full throttle	ON (grounded)
	Supply Analog Accelerator Pedal	Idle	5.0 volts
		Full throttle	5.0 volts
		Between idle/full throttle	5.0 volts

* All desired signal values are approximate. Each individual vehicle and electrical system will exhibit some variation in signal values.

† There is a short time delay between pedal movement and display of the corresponding data.

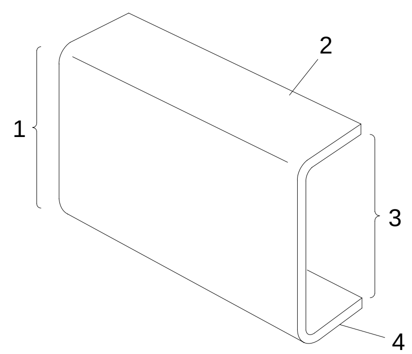
Table 2, Diagnostic Software Values

General Description

IMPORTANT: This workshop manual *does not cover* the procedures and calculations necessary to do frame modifications. Before doing any modification to the frame rails, consult with the Freightliner LLC Engineering Department.

The main body of the frame consists of two frame rails connected by a series of crossmembers. The frame supports the rest of the chassis and body.

The frame rails are made of steel, and both have identical specifications. Each rail has an upper flange, lower flange, and web (the surface area between the flanges). The inside area of the frame rail is called the channel. See **Fig. 1**.



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1. Web
2. Upper Flange
3. Channel
4. Lower Flange

Fig. 1, Frame Terminology

The crossmembers control axial rotation and longitudinal motion of the rails, and reduce torsional stress transmitted from one rail to the other. Crossmembers are also used for vehicle component mounting, and protecting the wires and tubing that are routed from one side of the vehicle to the other.

Follow the guidelines in this section when servicing the frame.

Frame Stations

A frame station is a reference point on the frame rail from which the location of each component (mounted on the frame rail) is measured.

There is no identifying mark for station zero (usually written as 0.00"). It is located at a given reference point to the rear of the most forward edge of the frame rail.

The vehicle’s frame drilling chart lists the location of each frame rail component. For example: if a component is given a location of 2500, then that component is installed on the frame rail 98-7/16 inches (2500 mm) aft of station zero.

Handling

Whenever the frame rails are lifted or moved, take care to avoid anything that may scratch, cut, or damage the exposed frame assembly. Cushion all chain hoists or cable slings with a section of heavy hose. If the frame rail is raised with a jack, place a block of wood between the jack and the frame rail.

Never heat the frame rails for straightening purposes. Such work should be done cold, as the frame rails have been heat-treated.

CAUTION

Heating the frame rail for straightening purposes will reduce the strength of the rail in localized areas, which can result in structural failure of the frame rail.

Use pencil lines or soapstone marking for any work that requires marking of the frame rail. High visibility can be obtained by first chalking the surface of the frame rail, then making the pencil marks.

Repairing Cracks

IMPORTANT: Freightliner LLC recommends that cracked or damaged frame rails be replaced. In some cases it may be necessary to repair minor damage; before attempting any repairs, contact your regional service representative for approval.

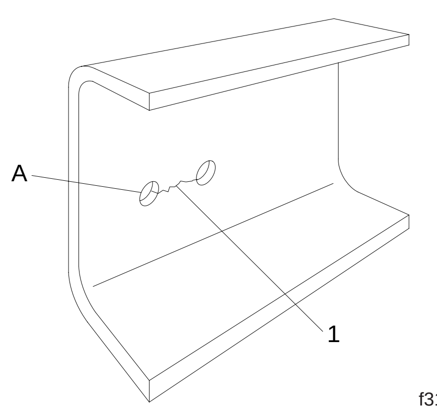
CAUTION

Before performing any electric welding on a vehicle, read and understand the welding precautions in Subject 110. Disconnect the battery power and ground cables and any electronic control units (ECUs) installed on the vehicle. Electric currents produced during electric welding can damage various electrical components on the vehicle, such as alternator diodes and ECUs.

Freightliner LLC vehicle components that typically use ECUs include electronic engine, electronic automatic transmission, and ABS (antilock braking system).

For any ECU with a battery power harness, disconnect its ground terminal from the chassis ground, and disconnect its power terminal from the battery positive post, or disconnect the main connection at the ECU.

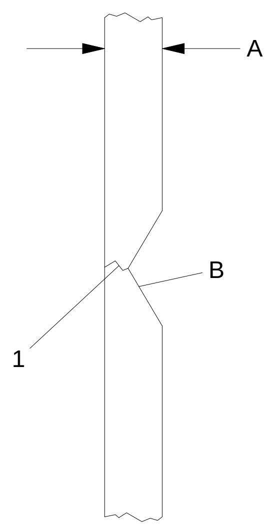
1. Drill a 1/8-inch (3-mm) diameter hole at each end of the crack to prevent further spreading of the crack. See **Fig. 1**.



A. 1/8-inch (3-mm) Diameter Hole
1. Crack

Fig. 1, Preventing Cracks from Spreading

2. Grind a V-groove to a depth of two-thirds of the stock thickness. See **Fig. 2**.



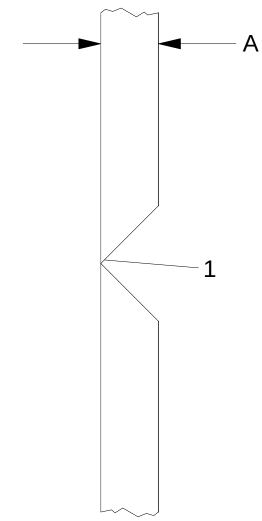
A. Frame Rail Thickness
B. Grind V-groove to 2/3 depth of stock thickness.
1. Crack

Fig. 2, Cross-Section View

NOTE: If it will not be possible to grind both sides of the frame rail, then grind the V-groove on one side to the full depth of the stock thickness. See **Fig. 3**.

3. Clamp a copper or aluminum bar on the opposite side of the groove. The bar will act as a "chill strip," keeping the heat from spreading to the surrounding area of the frame rail. See **Fig. 4**. Deposit the weld material using the applicable welding method described in this section.
4. Grind the weld flush with the frame rail. See **Fig. 5**.
5. Cut a deep enough V-groove on the opposite side of the frame rail to reach the weld metal. See **Fig. 6**.
6. Clamp the chill strip on the opposite side of the groove. See **Fig. 7**. Weld the V-groove, as instructed above. Make full penetration of the weld.
7. Grind the weld flush with the frame rail. See **Fig. 8**.

Frame Rail Repair



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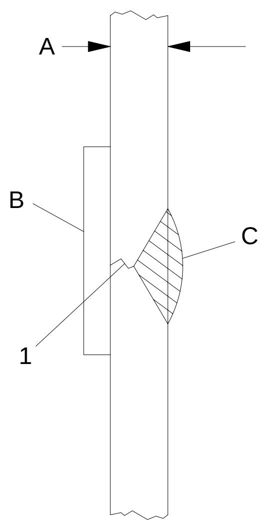
A. Frame Rail Thickness
1. V-Groove (full depth)

Fig. 3, Full Depth Groove



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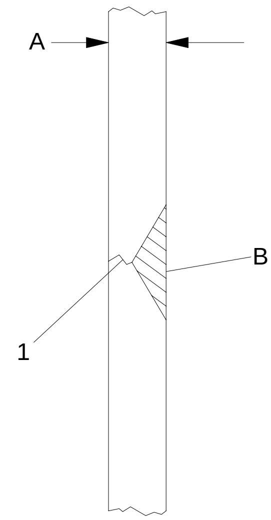
A. Frame Rail Thickness
B. Clamp the chill strip on the opposite side of the groove.
C. Deposit weld material.
1. Crack

Fig. 4, Using a Chill Strip



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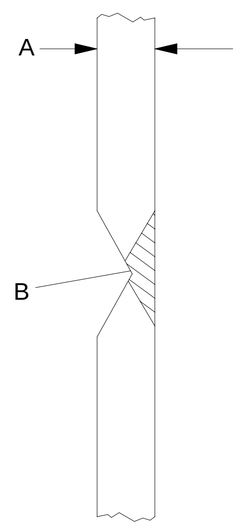
A. Frame Rail Thickness
B. Grind the weld flush with the frame rail.
1. Crack

Fig. 5, Weld Ground Flush



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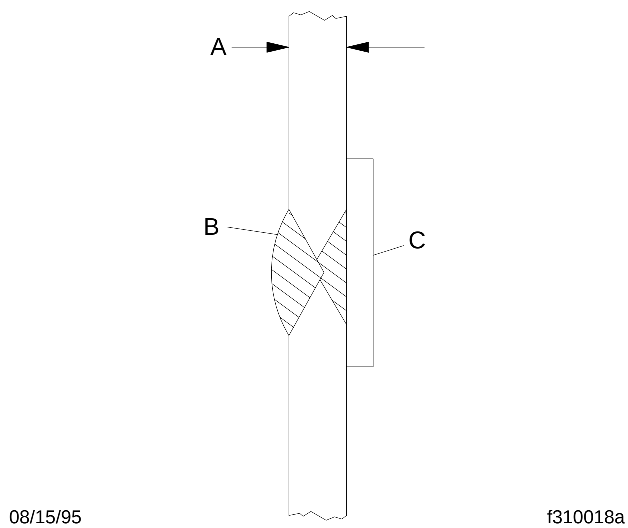
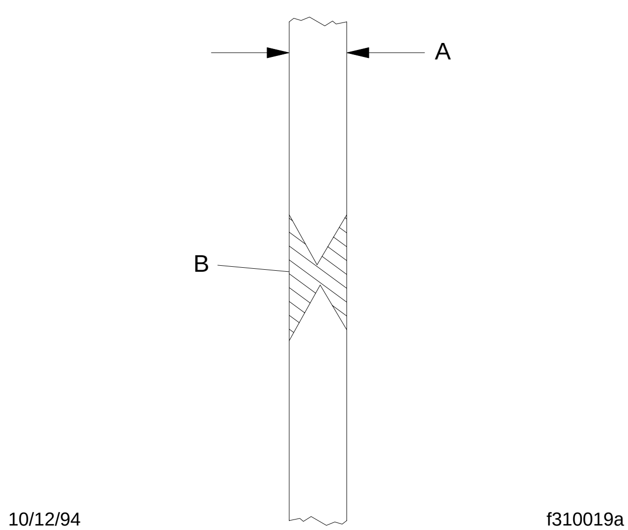
A. Frame Rail Thickness
B. Grind the V-groove deep enough to reach the weld.

Fig. 6, Cross-Section View



A. Frame Rail Thickness
B. Deposit weld material to penetrate opposite weld.
C. Clamp the "chill" strip on opposite side of groove.

Fig. 7, Second Weld



A. Frame Rail Thickness
B. Grind weld flush with frame rail.

Fig. 8, Second Weld Ground Flush

Filling Unused Holes

1. Fill all unused holes in the frame assembly with the applicable nut, washer, and bolt combination.
2. If the diameter of a hole is less than 3/8 inch (9.5 mm), enlarge it to 3/8 inch (9.5 mm), and fill it with the applicable nut, washer, and bolt combination.
3. Tighten the fasteners to the applicable torque value. For proper frame fastening instructions, refer elsewhere in this group.

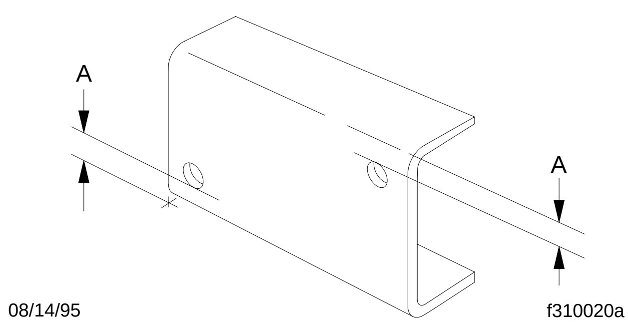
Drilling Holes

During vehicle manufacture, holes are drilled or punched in the frame rail only as specified on the vehicle frame drilling chart. If any additional holes need to be drilled, contact your regional service representative for approval.

A single exception to this rule is that holes may be drilled for tubing clips and the like through the web portion of the channel only, with the following restrictions:

- The *edge* (not the center) of the hole must be no closer than 1-11/32 inches (34 mm) from the outer face of the flange. See **Fig. 9** for the minimum distance to the flanges that holes can be placed on the web.
- Material between the centerline of the hole and the outside of the upper or lower flange must be at least 2-13/32 inches (60 mm).
- Minimum material between hole centerlines must be 2 inches (50 mm).
- All attaching fasteners must be Grade 8. Flat washers must be made with high strength steel.
- The minimum material between the rear suspension bracket and the end of the frame must be at least 2 inches (50 mm).
- Holes between the front axle centerline and the rear axle centerline cannot exceed 3/4 inches (19 mm).

Frame Rail Repair



A. 1-11/32 inches (34 mm)

Fig. 9, Minimum Distance for Drilling Holes

Safety Precautions

CAUTION

Before performing any electric welding on a vehicle, disconnect the battery power and ground cable, and any electronic control units (ECUs) or similar devices installed on the vehicle. Electric currents produced during electric welding can damage various electrical components on the vehicle, such as alternator diodes and ECUs.

Vehicle components that typically use ECUs include the electronic engine, electronic automatic transmissions, and the antilock braking system (ABS).

1. For any ECU with a battery power harness, disconnect its ground terminal from the chassis ground. Disconnect the power terminal from the positive post of the battery.

NOTE: It is also possible to disconnect the main connection at the ECU.

2. Disconnect the batteries, including any isolated battery. Attach the welding ground strap as close to the work being done as safely possible.

Welding Frame Rails

WARNING

Wear protective welding masks and gloves when welding. Failure to do so could result in personal injury, due to the intensity of heat, sparks, and flying debris.

CAUTION

Weld only as instructed in this subject; all precautions and methods must be strictly followed. Failure to do so can reduce the structural strength in the welded area of the frame rail.

IMPORTANT: Before any welding is done, contact your regional service representative for approval. There are very few cases in which welding a heat-treated frame rail is allowable. If possible, avoid direct welding of the frame rail web.

1. Do not weld attachments to the frame rail. For guidelines on the attachment of equipment on the frame rails, refer elsewhere in this group.
2. Use only the applicable welding method under "Welding Methods."
3. Before welding, clean off any oil, grease, paint, scale, and other contaminants. Wipe dry with a clean cloth.
4. Do not weld in an area that allows drafts from any source such as windows, engines, or fans, as it will affect the soft flow of gas from the welding gun.
5. Do not weld into the radius of the frame rail flanges or along the edge of the flange.
6. Do not weld square with the frame side rail. Make all reinforcing welds at least 30 degrees from square. This will distribute the weld stresses over a larger area.
7. Do not notch, undercut, or leave craters during the welding process.
8. Keep as close to the weld centerline as possible.

Welding Methods

Gas-metal arc welding is the recommended method. If gas-metal arc welding is not available, coated-electrode arc welding can be used. Gas-metal arc welding uses DC current only (MIG welding). Use either a short arc beading technique or a narrow weave technique.

Gas-Metal Arc Welding

For the gas-metal arc welding method, use the following:

1. Use weld wire that meets American Welding Society (AWS) specification A 5.28, Class E110S.
2. Use Linde M-5 gas or an equivalent argon-oxygen mixture of 5 percent oxygen.
3. For machine settings, see **Specifications, 400**.

Coated-Electrode Arc Welding

For the coated-electrode arc welding method, use the following:

1. Use weld rod type AWS-E-11018, 1/8-inch thick.

Welding Frame Rails

NOTE: AWS-E-11018 is the recommended type of weld rod. However, on 1/4-inch thick frame rails only, weld rod of type AWS-E-9018 can be used.

2. For the amperage and voltage settings for each weld position, see **Specifications, 400**.
3. Always keep the weld rod free of moisture. A weld rod that has been exposed to the atmosphere longer than one-half hour must be dried before use.

IMPORTANT: Take weld rod directly from a hermetically sealed container, or dry it for at least one hour in a 700 to 800°F (371 to 427°C) oven. Immediately after removal from the sealed container or after drying, store the weld rod in an oven at 250°F (121°C).

Extending Frame Rails

CAUTION

Before performing any electric welding on a vehicle, read and understand the welding precautions in Subject 110. Disconnect the battery power and ground cables and any electronic control units (ECUs) installed on the vehicle. Electric currents produced during electric welding can damage various electrical components on the vehicle, such as alternator diodes and ECUs.

Steel frame rails can be lengthened by welding a frame rail extension onto the rear of the frame rail. The frame rail end and the extension piece are cut so that they overlap each other. Obtain approval from your regional service representative before welding and lengthening the frame rail.

For any ECU with a battery power harness, disconnect its ground terminal from the chassis ground, and disconnect its power terminal from the battery positive post. Or else disconnect the main connection at the ECU.

Freightliner vehicle components that typically use ECUs include the electronic engine, electronic automatic transmission, and the antilock braking system (ABS).

1. Cut the frame rail end and extension to the specified applicable dimensions. See **Fig. 1**.

NOTE: If the length of the extension is to be 6 inches (152 mm) or less, then straight-cut the frame rail end and extension.

2. Grind the cut ends of the frame rail and extension to the dimensions in **Fig. 2**.

3. Align the cut ends of the extension piece with the cut ends of the frame rail so that there is a 1/16 to 1/8-inch (1.6 to 3.2-mm) gap between them. See **Fig. 3**. Using a torch, heat the cut ends to 70°F (21°C), if necessary, before welding.

NOTE: A 1/16-inch (1.6-mm) gap is recommended. The ends must not contact each other. Maintain the joint spacing by placing a short piece of clean, 1/16-inch (1.6-mm) diameter bare steel wire between the extension and frame rail. The wire sections must be short enough to be completely fused by the welding process.

4. Using one of the methods in **Subject 110**, weld the extension to the frame rail, making full penetration. See **Fig. 3**. Remove any slag between passes, and back-gouge the root of the first vee before welding the other side.

CAUTION

Residual stresses will occur in the weld if the web area is not welded first, or if the flanges contact each other when welding the web.

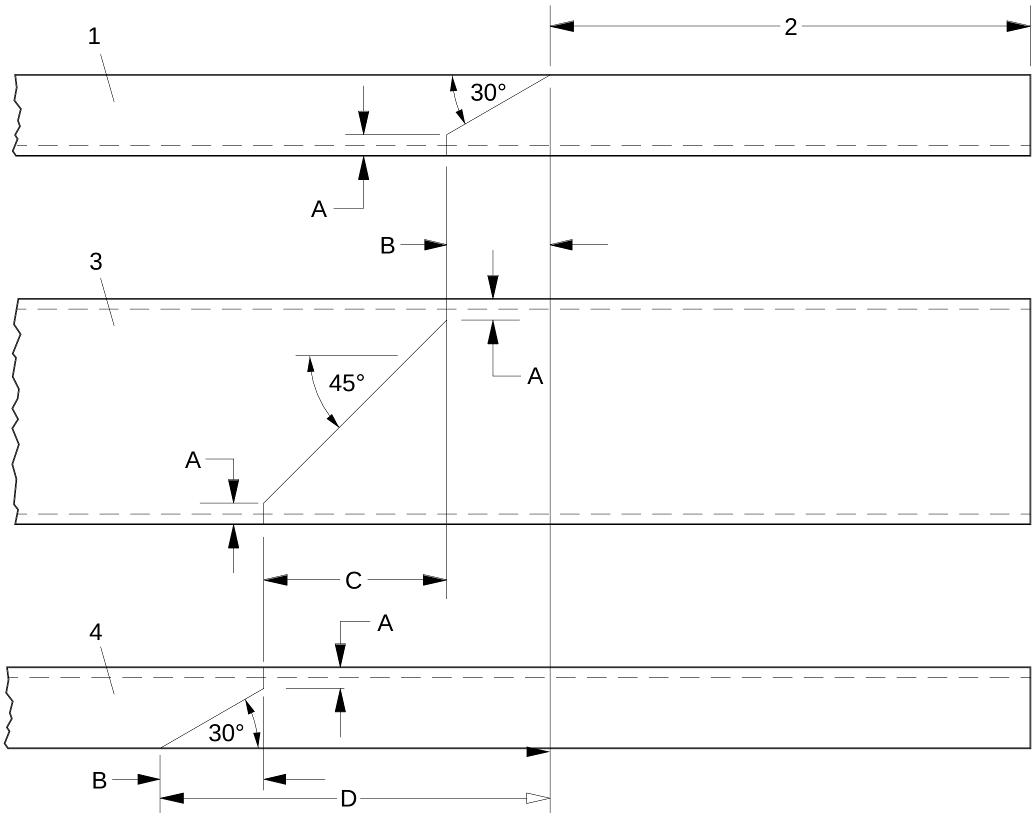
IMPORTANT: Weld the web area first, then the flange, working from the inside of the channel. When welding the web, make sure that the flanges do not contact each other.

5. When finished welding, sand the joint for appearance. Hold the sander so that the grind runs parallel with the length of the frame rail.

CAUTION

Do not "hollow grind" the weld. Small depressions from improper grinding of the weld will reduce the strength of the frame rail.

Extending Frame Rails



NOTE: Left rail shown; right rail will be opposite dimensions.

FRAME RAIL SIZE inches	DIMENSION			
	A inches (mm)	B inches (mm)	C inches (mm)	D inches (mm)
10.06	0.69 (17.5)	5.00 (127.0)	8.75 (222.2)	18.75 (476.2)
10.12	0.69 (17.5)	5.00 (127.0)	8.75 (222.2)	18.75 (476.2)

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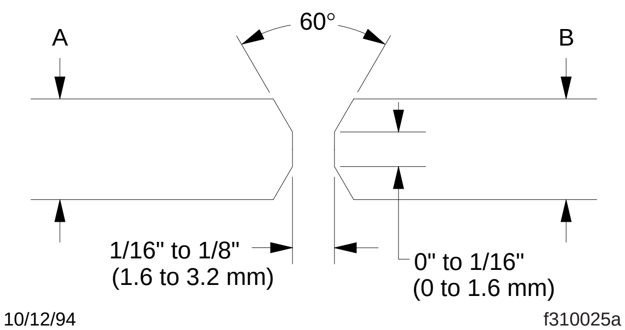
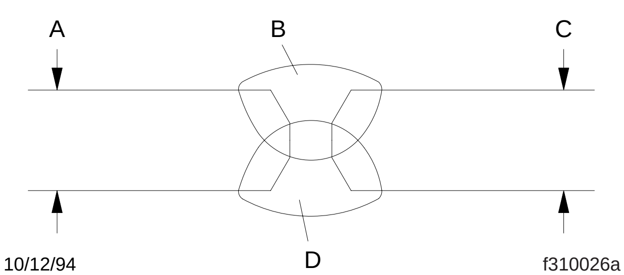
1. Upper Flange
2. Extension Length
3. Web
4. Lower Flange

Fig. 1, Frame Rail and Extension Cutting Dimensions



A. Frame Rail Thickness
B. Extension Thickness

Fig. 2, Grinding Dimensions



A. Frame Rail Thickness
B. First Weld
C. Extension Thickness
D. Second weld penetrates the first weld.

Fig. 3, Correct Weld Penetration

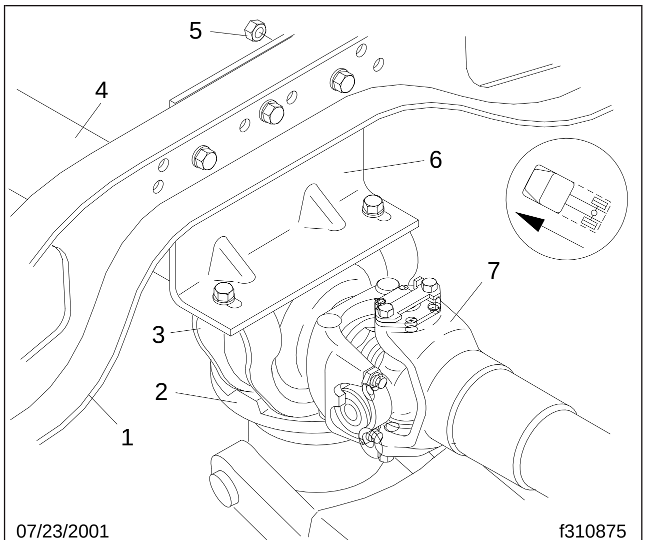
CAUTION

The placement of crossmembers affects the overall stability of the frame and prevents damage to the vehicle. Before eliminating, adding, or relocating any crossmember, contact your regional service representative for instructions and approval.

Splayed Crossmember, Midship

Removal

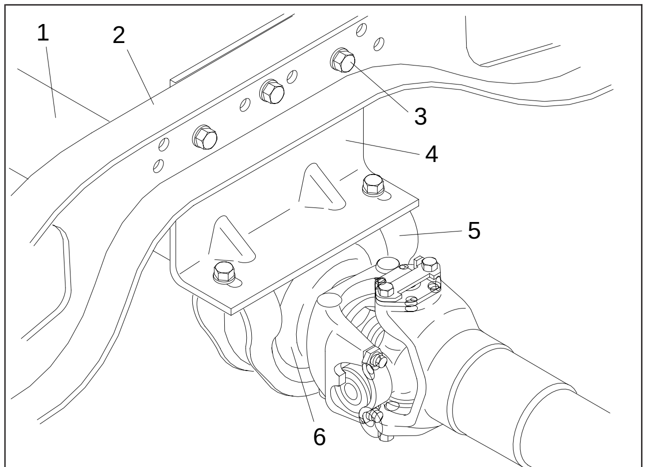
1. Park the vehicle on a level surface and set the parking brake. Shut down the engine and chock the rear tires.
2. Remove any clamps or tie straps that attach air lines or wiring to the crossmember.
3. Using a floor jack, support the midship bearing and driveshaft. See **Fig. 1**.



1. Midship Crossmember
2. Floor Jack
3. Midship Bearing Holder
4. Driveshaft
5. Bracket Locknut
6. Midship Bracket
7. U-Joint Yoke

Fig. 1, Support the Driveline

4. Remove the three mounting bolts on the midship bracket. See **Fig. 2**. Lower the driveshaft slightly.



1. Driveshaft
2. Midship Crossmember
3. Midship Bracket Mounting Bolt
4. Midship Bracket
5. Midship Bearing Holder
6. Midship Bearing

Fig. 2, Midship Bracket Mounting

5. Remove the bolts that attach the crossmember to the web of each frame rail. See **Fig. 3**.

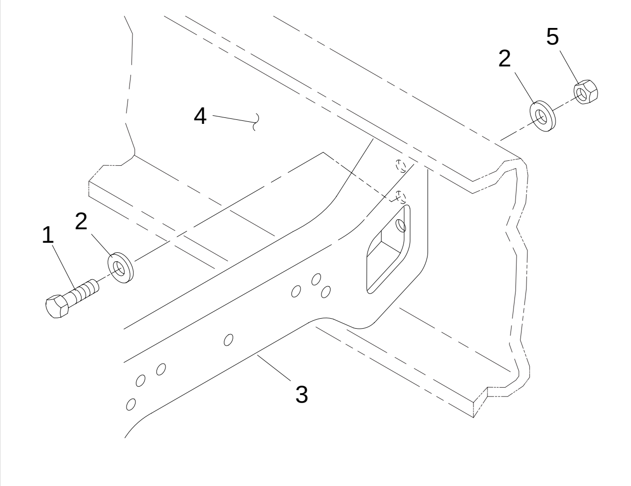
NOTE: If threaded fasteners are used, save them for later installation. If Huck® fasteners are used, see **Subject 160** for removal and installation information.

6. Support the driveshaft on a jack stand. Remove the floor jack. See **Fig. 4**.
7. Using a rubber mallet, tap against the curved portion of the crossmember on the closed-channel side until it is no longer wedged between the frame rails.
8. Remove the crossmember from the vehicle.

Installation

1. Position the crossmember between the frame rails with the open channel facing the same direction as it did before removal.
2. Tap the crossmember into place until the mounting holes at both ends of the crossmember are aligned with the holes in the frame rail.

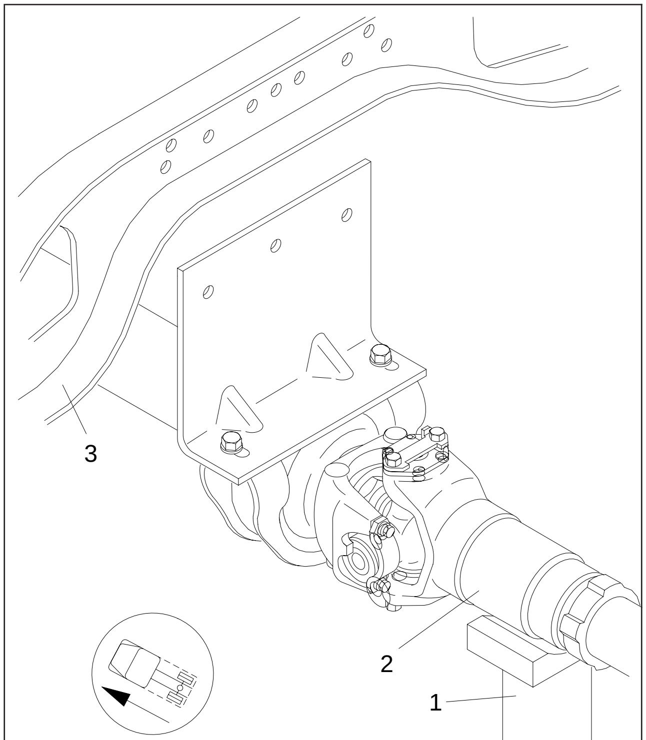
Frame Crossmember Removal and Installation



1. Web Bolt, 5/8–11
2. Hardened Flatwasher
3. Midship Crossmember
4. Frame Rail
5. Locknut, 5/8–11

Fig. 3, Midship Crossmember Fasteners

3. Install the web bolts, washers, and nuts fastening the crossmember to the frame rail. See **Fig. 5**.
    3.1 Install the fasteners in one end of the crossmember and frame rail. Tighten the locknuts finger-tight only.
    3.2 Install the fasteners on the other end of the crossmember and frame rail.
    3.3 Tighten all of the 5/8–11 locknuts 128 lbf·ft (173 N·m).
4. Install the midship bracket.
    4.1 Adjust the height of the jack stand holding the driveline, as necessary to line up the bolt holes in the midship bracket with those in the crossmember.
    4.2 Install the midship bracket fasteners, as removed.
    4.3 Tighten all of the 5/8–11 hexnuts 128 lbf·ft (173 N·m).
5. Install any clamps or tie straps that attach air lines or wiring to the crossmember.
6. Remove the chocks from the rear tires.



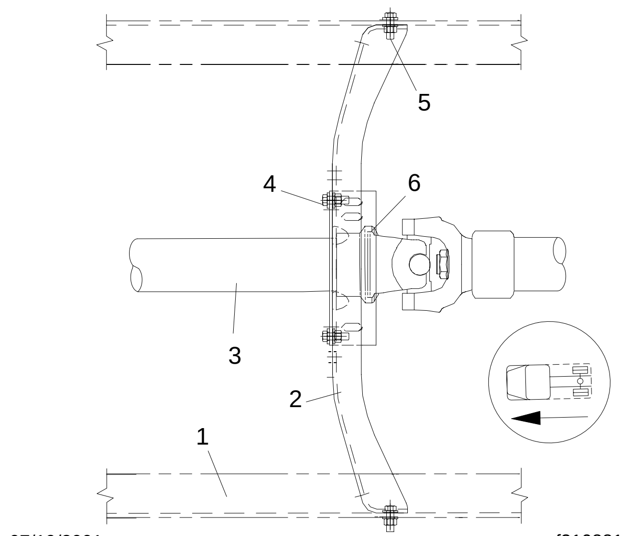
1. Jack Stand
2. Driveshaft
3. Midship Crossmember

Fig. 4, Support the Driveshaft

Double Splayed Crossmember, Axle

Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine and chock the front tires.
2. Jack up the vehicle.
    2.1 Place a jack stand under each frame rail.
    2.2 Using a floor jack, jack up the axle until the frame rails are high enough to suspend the wheels. See **Fig. 6**.
    2.3 Raise the jack stands until the frame rails are resting on the jack stands. See **Fig. 7**.



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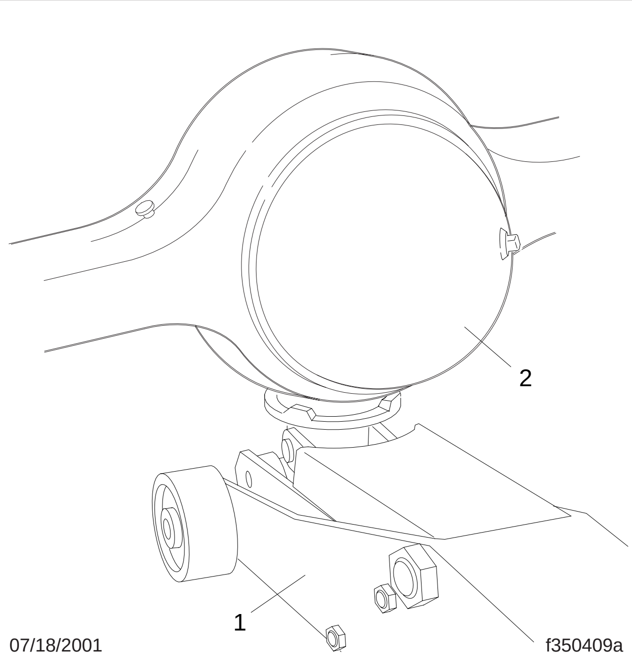
1. Frame Rail
2. Crossmember
3. Driveshaft
4. Midship Bracket
5. Web Bolt, 5/8–11
6. Midship Bearing

Fig. 5, Crossmember Installation



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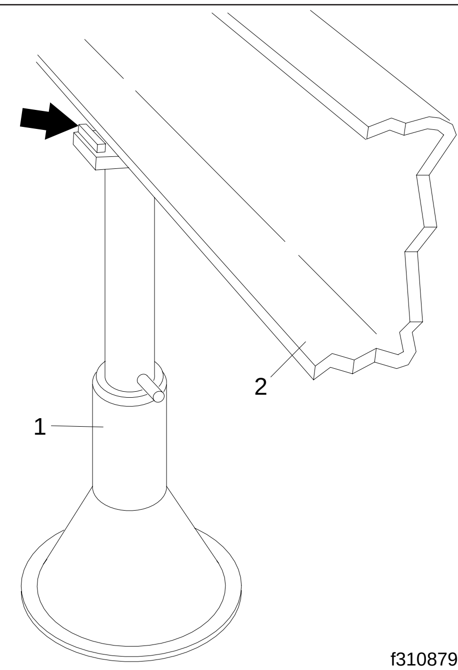
1. Floor Jack
2. Axle

Fig. 6, Jack Up the Axle



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Make sure the lip of the jack stand is clear of the frame rail.

1. Jack Stand
2. Frame Rail

Fig. 7, Place Jack Stands Under the Frame Rails

2.4 Jack up the axle again to center the frame rails and move the springs away from the hanger bolts. See **Fig. 8**.

2.5 Place another set of jack stands on the axle. See **Fig. 9**.

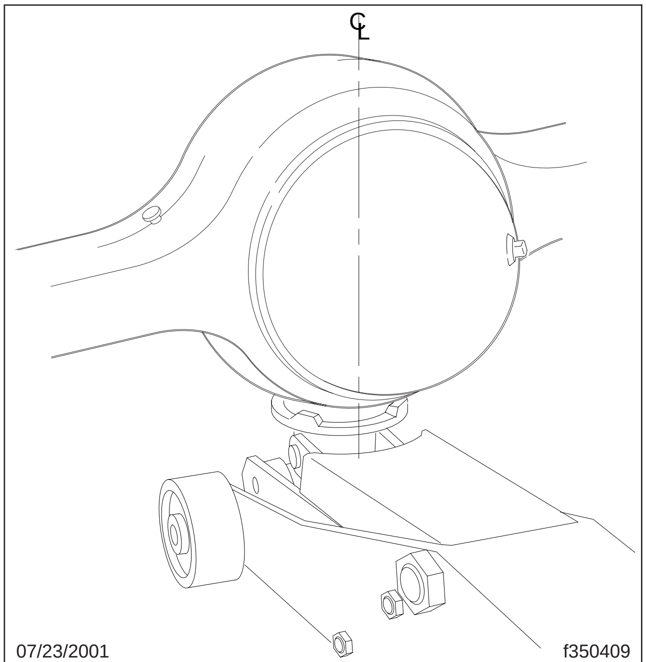
3. Remove any clamps or tie straps that attach air lines or wiring to the crossmember.
4. Remove the lower rear hanger bolt. See **Fig. 10**.

NOTE: There is a clearance problem with the leaf spring for this bolt. The lower edge of the hanger bolt must clear the top edge of the leaf spring. Adjust the axle jack as necessary. See **Fig. 11**.

5. Remove the fasteners holding the two cross-members together.
6. Remove the rest of the hanger bolts.

NOTE: If threaded fasteners are used, save them for later installation. If Huck® fasteners are

Frame Crossmember Removal and Installation



Center the jack on the axle.

Fig. 8, Center the Frame Rails

used, see **Subject 160** for removal and installation information.

7. Using a rubber mallet, tap against the curved portion of one crossmember until the crossmembers are no longer wedged between the frame rails. Separate the crossmembers and remove them from the vehicle.

Installation

1. Position the two crossmembers between the frame rails, as removed. Tap the crossmember into place until the mounting holes at both ends of the crossmember are aligned with the holes in the frame rail.
2. Install the fasteners holding the two crossmembers together. Tighten the locknuts finger-tight only. See **Fig. 12**.
3. Install the hanger bolts, washers and locknuts attaching the hanger bracket and the two crossmembers to the frame rail. Tighten the locknuts finger-tight only. See **Fig. 13**.

NOTE: Using the axle jack, raise the axle to lower the springs and allow enough clearance to install the lower rear bolt.

4. Adjust the hanger bracket position as necessary. Tighten all of the 5/8–11 hanger locknuts 128 lbf·ft (173 N·m).
5. Tighten all of the 1/2–13 crossmember joining locknuts 68 lbf·ft (92 N·m).
6. Install any clamps or tie straps that attach air lines or wiring to the crossmember.
7. Remove the chocks from the front tires.

Five-Piece Bolted Crossmember

Removal

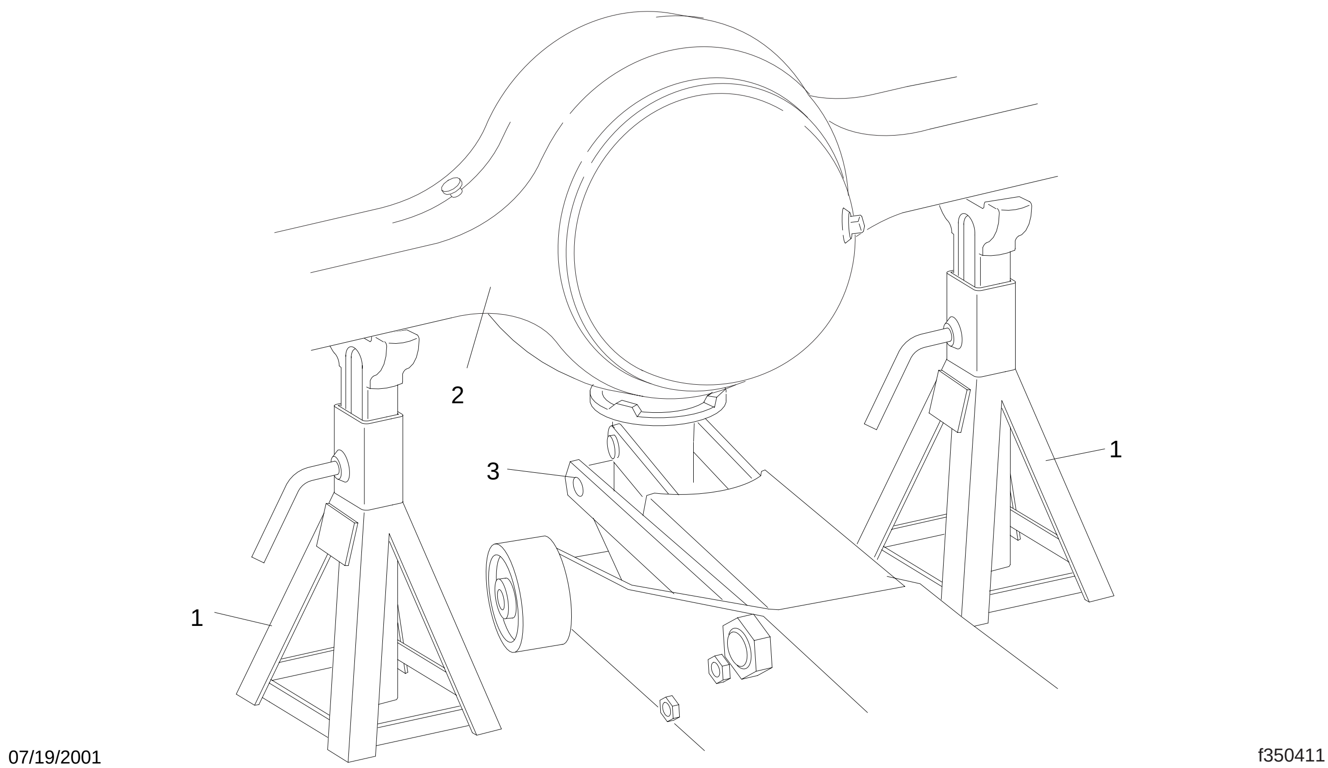
1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the front and rear tires.
2. If any air brake valve is attached to the crossmember, drain the air reservoirs, then remove the valve(s) from the crossmember.

   Remove any clamps that attach air lines or wiring to the crossmember, and secure the lines or wiring away from the crossmember.
3. If rear suspension brackets are attached to the frame rails with the same fasteners that attach the crossmember, use safety stands to support the rear of the frame at the normal ride height.
4. Remove the fasteners that attach the gussets to the crossmember. See **Fig. 14**.
5. Remove the fasteners that attach the gussets to the frame rail.
6. Using a rubber mallet, tap against the crossmember until it is no longer wedged against the frame rails.
7. Remove the crossmember from the vehicle.

Installation

1. Attach one upper gusset to the crossmember channel. Tighten the fasteners snugly, but not to their final torque value.

Frame Crossmember Removal and Installation



1. Jack Stand 2. Rear Axle 3. Axle Jack

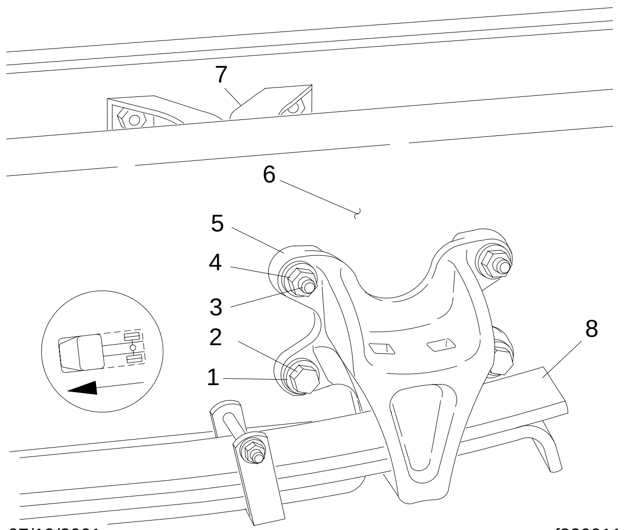
Fig. 9, Place Jack Stands on the Axle

2. Place the crossmember channel and gusset in the frame rails with the channel opening facing the same direction as the original crossmember. Position the crossmember so its channel is resting on the lower flanges of both frame rails.
3. Slide the other upper gusset into position and attach it to the crossmember channel. Tighten the fasteners snugly, but not to their final torque value.
4. With the crossmember channel still resting on the lower flanges of both frame rails, tighten the locknuts on the button-head capscrews at the outboard end of both upper gussets 68 lbf·ft (92 N·m).

NOTE: The locknuts must be tightened now since, when the crossmember is in place, the upper flange of the frame blocks access to the capscrews.

5. Using a rubber mallet, tap the crossmember into place. Align the mounting holes of the upper gussets with the holes in the frame rails. Install the fasteners, but don't tighten them.
6. Place the lower gussets in position against the crossmember channel and insert the fasteners that secure the gussets to the channel. Do not tighten the fasteners.
7. Install the fasteners that attach the gussets to the frame rails. If the crossmember was secured by Huck fasteners, see **Subject 160** for installation information.
8. Tighten the fasteners that secure the gussets to the frame rails 136 lbf·ft (184 N·m). Then, tighten the fasteners that secure the gussets to the crossmember 68 lbf·ft (92 N·m).
9. If any air brake valve was removed from the old crossmember, install the valve(s) on the new crossmember and install any clamps attaching air lines or wiring to the crossmember.

Frame Crossmember Removal and Installation



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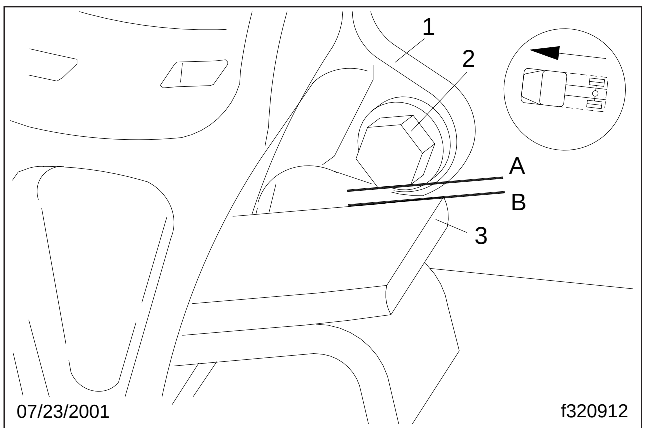
1. Hardened Washer
2. Hanger Bolt (head end)
3. Hanger Bolt (threaded end)
4. Locknut, 5/8–11
5. Hanger Bracket
6. Frame Rail
7. Double Splayed Crossmember
8. Leaf Spring

Fig. 10, Remove the Hanger Bolts



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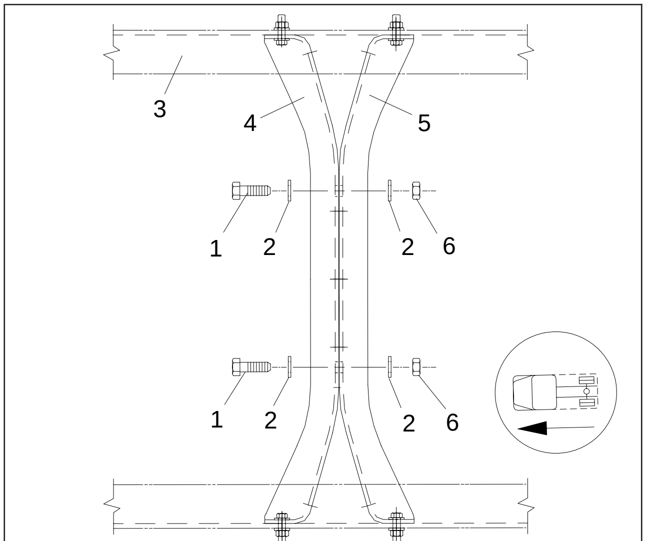
NOTE: The lower edge of the lower rear hanger bolt must clear the top of the leaf spring.

A. Lower Edge of Bolt
B. Top of Leaf Spring

1. Hanger Bracket
2. Hanger Bolt
3. Leaf Spring

Fig. 11, Clearance Between the Leaf Spring and the Hanger Bolt

10. Remove the chocks from the front and rear tires.



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1. Bolt, 1/2–13
2. Washer
3. Frame Rail
4. Forward Crossmember
5. Aft Crossmember
6. Locknut, 1/2–13

Fig. 12, Install the Double Crossmembers

Overslung Crossmember

Removal

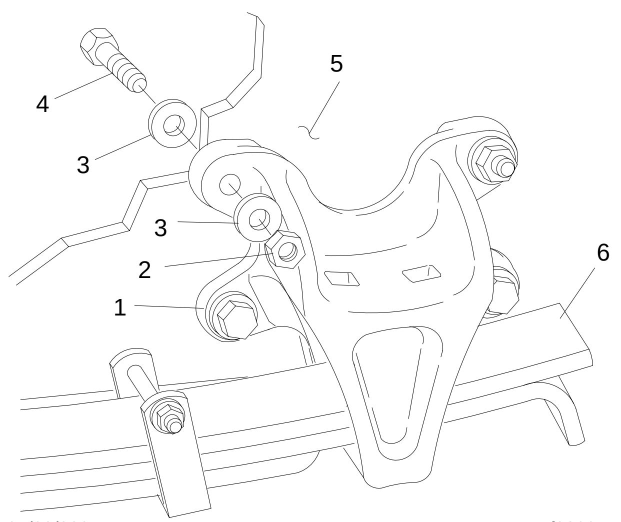
IMPORTANT: An underslung crossmember is used in a few, limited applications. To remove an underslung crossmember, use the same procedures as for an overslung crossmember.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the front tires.

NOTE: Note the position of the crossmember to the mounting bracket before removal.

2. Support the overslung crossmember. Remove the mounting bolts that hold each side of the crossmember to the mounting brackets. See **Fig. 15**.

3. Lower the overslung crossmember from the mounting brackets.



NOTE: The frame rail has been cut away to show the hanger bracket fasteners.

1. Hanger Bracket
2. Locknut, 5/8–11
3. Washer
4. Hanger Bolt, 5/8–11 x 3
5. Frame Rail
6. Leaf Spring

Fig. 13, Install the Hanger Bolts

Installation

1. Install the new crossmember into place. Put the crossmember on the same side of the mounting brackets as removed.
2. Install the four 5/8–11 mounting bolts (two on each side) that hold the crossmember to its mounting brackets. Install them with the bolt heads facing the inside of the frame rail. Tighten the fasteners 136 lbf·ft (184 N·m).
3. Remove the chocks from the rear tires.

Rear-Closing Crossmember

Removal

1. Apply the parking brakes, then chock the front and rear tires.
2. Remove any components installed on the cross-member.

    2.1 If so equipped, remove the backup alarm from the crossmember.

    2.2 If any air brake valve is attached to the crossmember, drain the air reservoirs, then remove the valve(s) from the cross-member.

    2.3 Remove any clamps that attach air lines or wiring to the crossmember.

    2.4 If the leveling valve for an AirLiner suspension is attached to the crossmember, remove the valve. For instructions, refer to **Group 32** of this manual.
3. Remove the fasteners that attach the crossmember to the front angle brackets. See **Fig. 16**.
4. If rear suspension brackets are attached to the frame rails with the same fasteners that attach the angle brackets, support the rear of the frame at its normal ride height, using safety stands.
5. Remove the fasteners that attach the rear angle brackets to each frame rail.
6. Remove, as an assembly, the rear brackets and the crossmember.
7. If needed, remove the front angle brackets and their fasteners. If applicable, after removing the fasteners, remove the rear suspension brackets from the springs.

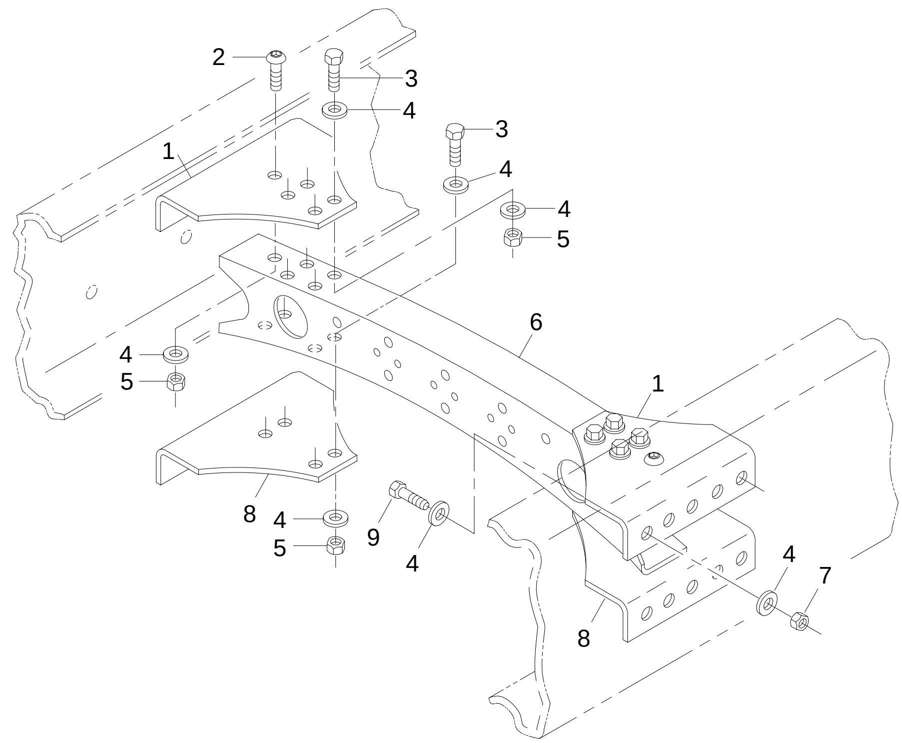
Installation

1. If they were removed, install the front angle brackets and their fasteners, but don’t tighten the fasteners at this time. If applicable, install the rear suspension brackets on the springs.
2. Slide the crossmember into the opening at the rear of the frame rails, then turn it upright, to position it against the front angle brackets.
3. Attach the rear angle brackets to the frame rails, but don’t tighten the fasteners at this time.
4. Install but do not tighten the fasteners that attach the crossmember to the front angle brackets.
5. Install any components, as removed.

    5.1 If removed, install any air brake valves, and securely tighten the fasteners.

    5.2 If removed, install the backup alarm.

Frame Crossmember Removal and Installation



1. Upper Gusset
2. 1/2–13 Button-Head Capscrew
3. 1/2–13 Grade 8 Hexbolt
4. Hardened Steel Flatwasher
5. 1/2–13 Locknut
6. Crossmember Channel
7. 5/8–11 Locknut
8. Lower Gusset
9. 5/8–11 Grade 8 Hexbolt

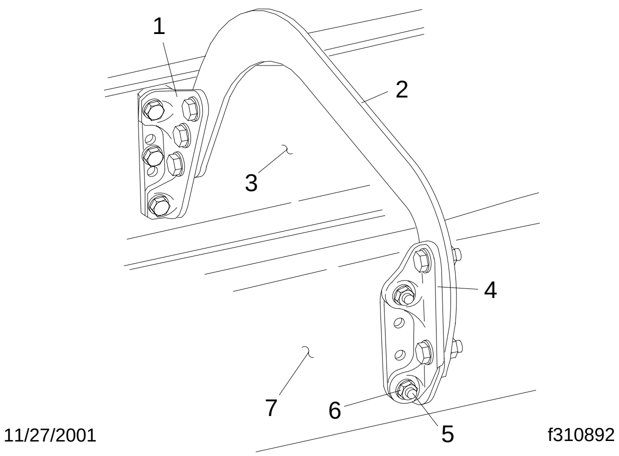
Fig. 14, Bolted 5-Piece Crossmember Assembly

5.3 Install any clamps that attach air lines or wiring to the crossmember.

5.4 If removed, install the leveling valve for the AirLiner suspension. For instructions, see **Group 32** of this manual.

6. Tighten the fasteners that attach the angle brackets to the frame rails, then tighten the fasteners that attach the crossmember to the angle brackets. Tighten all fasteners 136 lbf·ft (184 N·m).
7. Remove the chocks from the front and rear tires.

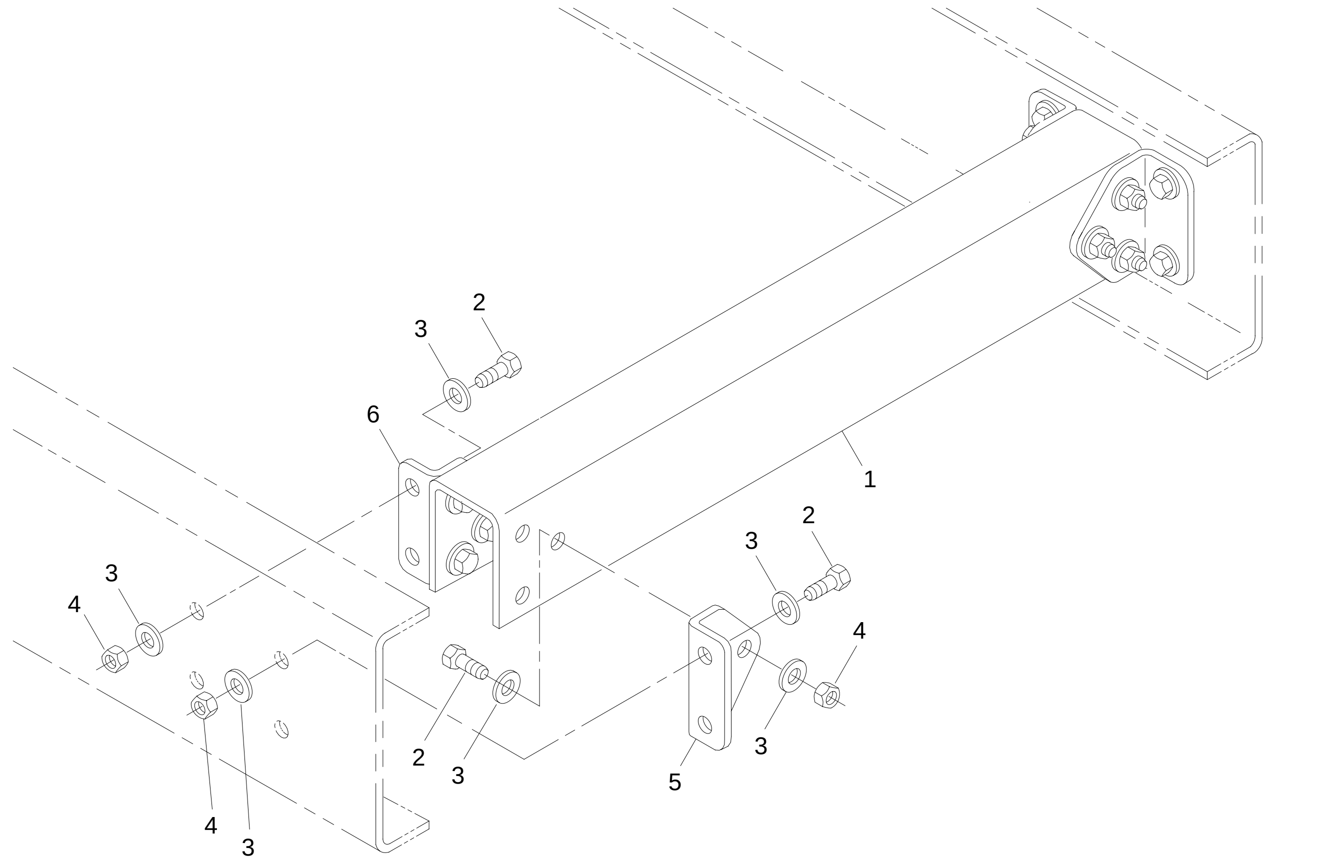
Frame Crossmember Removal and Installation



1. Right Mounting Bracket
2. Overslung Crossmember
3. Right Frame Rail
4. Left Mounting Bracket
5. Mounting Bolt, 5/8-inch
6. Hexnut and Washer, 5/8-inch
7. Left Frame Rail

Fig. 15, Overslung Crossmember

Frame Crossmember Removal and Installation



1. Rear-Closing Crossmember
2. 5/8–11 Grade 8 Bolt
3. Hardened Steel Flatwasher
4. 5/8–11 Locknut
5. Rear Angle Bracket
6. Front Angle Bracket

Fig. 16, Rear-Closing Crossmember Installation

Frame Rail Alignment

Frame rail alignment is checked by measuring the distances from two sets of points on the upper flanges of the frame rails. The aft set of points must be as far back as possible from the forward set of points. There must be no obstruction along or between the frame rails that would prevent measuring from any one of the four points to the other three points.

There are no marks or bolt holes in the top flanges of the frame rails. Therefore, the points must be projected from the frame station marks and from the bolt holes on the frame rail webs.

IMPORTANT: Use a pencil or soapstone to make all lines, points, or other marks. Do not use any marker or tool that will scratch the surface of the frame rail. Use a machinist's square to project all points from the webs to the upper flanges, and to measure inboard from the outside face of the frame rails.

1. Locate a forward set of points. The forward points must be at identical locations on both frame rails.
   - 1.1 Mark the most forward point at which the upper flanges of both frame rails are clear and unobstructed.
   - 1.2 On each frame rail, find a bolt hole on the frame rail web, that is aligned with, or just rearward of, this forward point. The bolt holes must be at exactly the same location in each frame rail.
   - 1.3 Project the exact vertical centerline of each bolt hole, and mark a line across the top flange of its respective frame rail.
   - 1.4 Find the exact center of the width of each upper flange, and mark the point on each projected line. This will be the forward set of points.

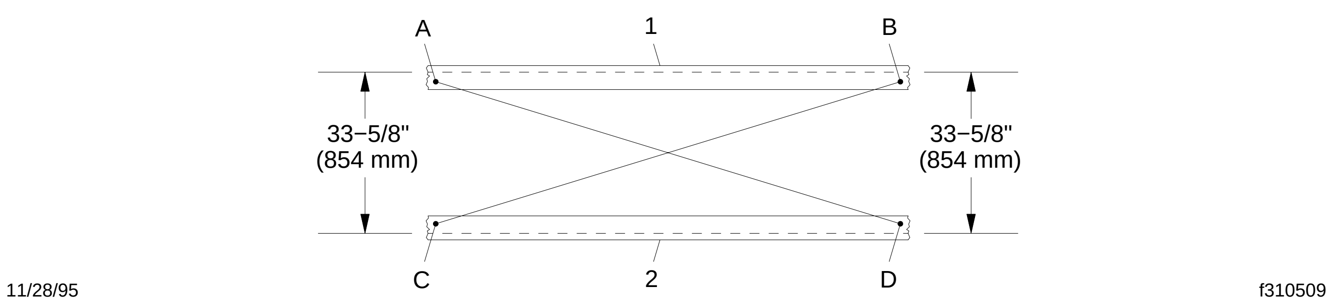
IMPORTANT: Use a pencil or soapstone to make all lines, points, or other marks. Do not use any marker or tool that will scratch the surface of the frame rail. Use a machinist's square to project all points from the webs to the upper flanges, and to measure inboard from the outside face of the frame rails.

2. Locate an aft set of points. The aft points also must be at identical locations on both frame rails.
   - 2.1 Measuring back along each frame rail, find a set of bolt holes *at least* six feet (1.8 m) aft of the forward set of points. The bolt holes must be at exactly the same location in each frame rail.

   IMPORTANT: If, because of obstructions, the distance must be less than six feet (1.8 m), the distance must be the maximum that is possible.

   - 2.2 Project the exact vertical centerline of each bolt hole, and mark a line across the top flange of its respective frame rail.
   - 2.3 Along each line, measure and mark a point two inches (5 cm) inboard from the outside face of its respective frame rail. This will be the aft set of points.
3. Measure the width of the frame, from the outside face of each frame rail. At both locations, this distance must be 33-5/8 inches (854 mm). See **Fig. 1**.
   - 3.1 At the forward set of points, measure the width of the frame. Measure from the outside face of one frame rail to the outside face of the other. Record this measurement.
   - 3.2 At the aft set of points, measure the width of the frame again, from the outside face of one frame rail to the outside face of the other. Compare this measurement to the one taken at the forward set of points.
4. Check the alignment of the frame rails. See **Fig. 1**.
   - 4.1 Measure the distance from the forward point on one frame rail to the aft point on the opposite frame rail. Record this measurement.
   - 4.2 Then measure the distance from the other forward point to the aft point on its opposite frame rail. Record this measurement.
   - 4.3 Compare the two measurements.
   - 4.4 If the values differ by more than 1/8 inch (3 mm), proceed to the next step.

Frame Rail Alignment



A. Right Forward Point or Bolt Hole
B. Right Rear Point or Hole
1. Right Frame Rail
C. Left Forward Point or Bolt Hole
D. Left Rear Point or Hole
2. Left Frame Rail

Fig. 1, Frame Rail Squaring

If the measurements are within 1/8 inch (3 mm) of each other, the frame rails do not need to be aligned. If any frame fasteners are loose, tighten as described below.

IMPORTANT: To align the frame rails, the frame assembly must be assembled with all of the crossmembers in place, but the attachment fasteners not tightened.

5. Align the frame rails, if needed.
   - 5.1 Loosen all of the frame fasteners just enough to allow movement of the parts when force is applied.
   - 5.2 Place a large wooden block against the rear end of the longer frame rail (defined as the one with its aft point the greater distance from its opposite rail's front point). Tap the block until the measurements are within 1/8 inch (3 mm) of each other.
   - 5.3 Using a large hammer, tap the block until the measurements are within 1/8 inch (3 mm) of each other.
   - 5.4 Tighten the fasteners for the front closing crossmember and the rear crossmember to their applicable torque values, as given in **Specifications, 400**.
6. Check the frame rail alignment again to be sure it is correct.
7. Tighten all of the frame fasteners, starting at the middle of the frame and working alternately toward both ends. Tighten each fastener to the torque value appropriate to its size, as given in **Specifications, 400**.
   - 7.1 First, tighten each fastener that attaches a crossmember to the frame.
   - 7.2 Tighten each fastener that attaches an upper strut, lower strut, or gusset to the frame.
   - 7.3 Finally, tighten each fastener that attaches a lower strut or gusset to a crossmember.
8. If the frame rails did need aligning, check the rear axle alignment. See **Group 35** for instructions.

Frame Shaping

IMPORTANT: Obtain approval from your regional service representative before doing any cutting or frame shaping.

If the flange of a frame rail is cut (for relief cuts or notches), shape the edges of the flange to form a smooth-ground edge radius of 0.06 to 0.12 inch (1.5 to 3.0 mm) over the entire length of the cut. Figure 1 shows this dimension of the edge radius.

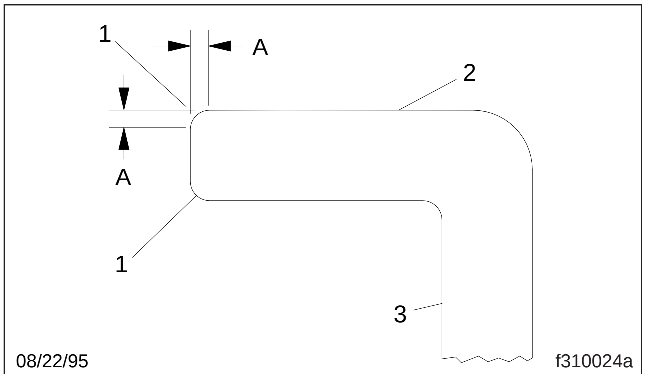
WARNING

Wear protective eye and face gear when grinding. Failure to wear this gear can result in personal injury due to flying metal debris from the grinding process.

Using a clean, sharp, rotary drum grinder or flapper wheel grinder, apply light pressure and grind the cut edges in the direction of the length of the frame rail, to form the radius. Do not grind across the edges. See Fig. 2.

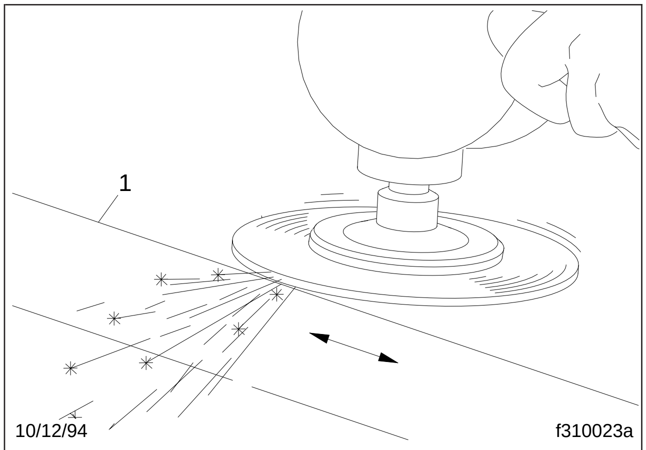
CAUTION

Apply light pressure only. Heavy pressure can result in harmful overheating and a loss of surface temper. Grind only in the direction of the cut. See Fig. 2. Grinding across the direction of the cut can reduce the structural strength of the frame rail.



A. 0.06" to 0.12" (1.5 to 3 mm)
1. Edge Radius
2. Flange
3. Web

Fig. 1, Radius Dimensions

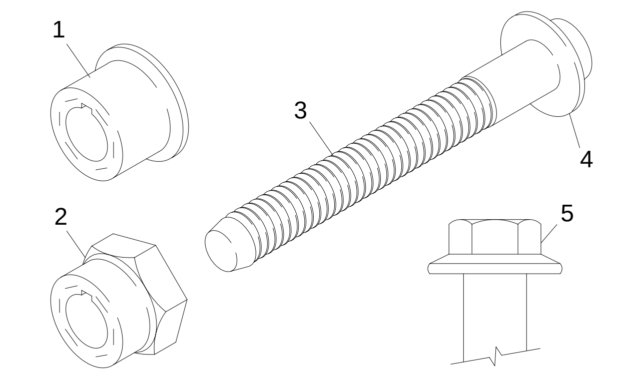


1. Flange

Fig. 2, Direction of Grind

Replacement

Either Huck® fasteners or Grade 8 hexhead bolts and Grade C prevailing torque locknuts are used for frame attachments. See **Fig. 1** and **Fig. 2**. For attachments where clearance is minimal, low-profile hexhead bolts and Grade C prevailing torque locknuts are used. Prevailing torque locknuts of both bolt types have distorted sections of threads to provide torque retention.



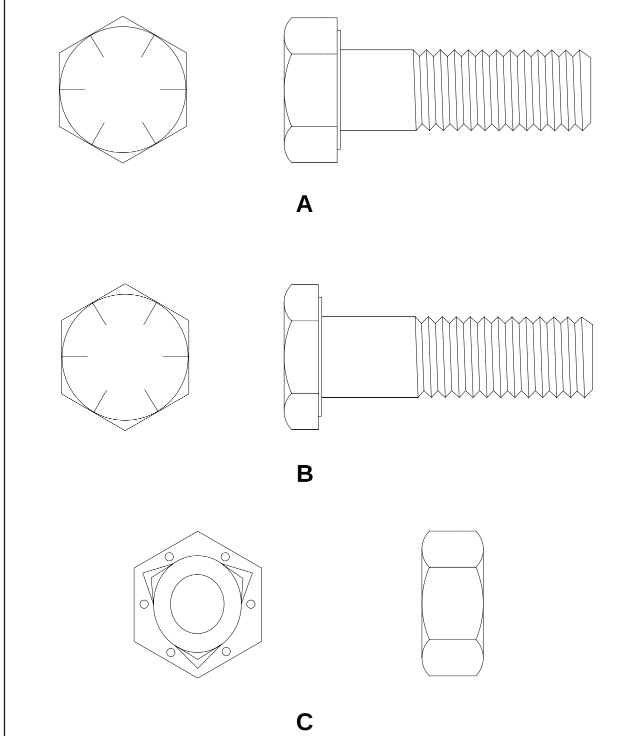
1. Spin Collar with Round Head
2. Spin Collar with Hexhead
3. Lock Pin
4. Round Head
5. Hexhead

Fig. 1, Huck Fastener

When hexhead bolts and locknuts are used on an attached part, a hardened flatwasher is required to prevent the bolt head or nut from embedding in the part. In general, hardened washers are used to distribute the load, and to prevent localized overstressing of the frame rails, brackets, and other parts. They are placed directly against the part, under the nut or bolt head. These special hardened washers are used on the frame rails and for the engine rear supports, rear and suspension brackets. They are cadmium- or zinc-plated, and have a hardness rating of 38 to 45 HRC.

Hexhead Bolt Replacement

1. Replace hexhead bolts with identical fasteners. See the Freightliner LLC Parts Book for fastener specifications.



A. Grade 8 Hexhead Bolt
B. Grade 8 Low-Profile Hexhead Bolt
C. Grade C Prevailing Torque Locknut

Fig. 2, Hexhead Fasteners

CAUTION

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel parts contact each other, could lead to corrosion of the metals, resulting in damage to the frame or parts.

2. Apply Alumilastic® compound, or an equivalent, to all surfaces where steel and aluminum parts contact each other.
3. Never hammer or screw bolts into place. Align the holes of the frame and the part being attached to it, so that the nut and bolt surfaces are flush against the frame and the part.
   3.1 For bolts 4 inches (102 mm) or less in length, make sure that at least 1-1/2

Frame Fastener Replacement

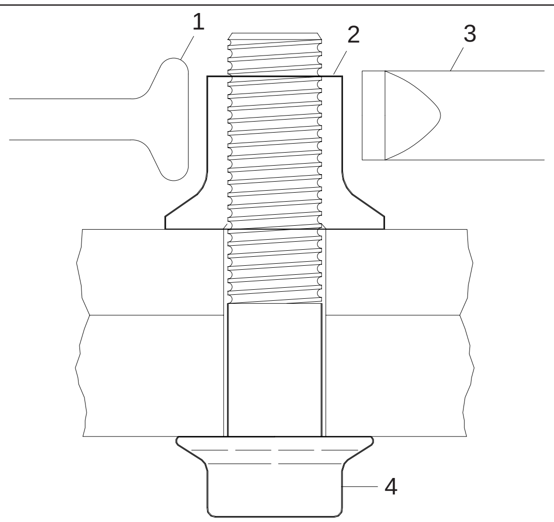
threads and no more than 5/8-inch (16-mm) bolt length extend through the self-locking nut after it has been tightened.

3.2 For bolts longer than 4 inches (102 mm), allow a minimum of 3 threads and a maximum of 3/4-inch (19-mm) bolt length.

Huck Fastener Removal

1. The collar for Huck fasteners is spun on when they are installed. If a hexhead collar is used, it can be removed with an impact wrench.

   In the event a collar without the hexhead is used, it cannot be unscrewed. If the Collar Cutter isn't available, split the collar with an air chisel while supporting the opposite side of the collar with an anvil. See **Fig. 3**.



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1. Anvil
2. Spin Collar
3. Chisel
4. Lock Pin

Fig. 3, Huck Fastener Removal

2. Drive out the lock pin with a punch.
3. Discard the fastener after removing it.

CAUTION

Never attempt to reuse any Huck fastener that has been removed. Reusing any Huck frame fastener can result in damage to the vehicle frame or components attached to the frame.

4. Replace Huck fasteners with standard Grade 8 threaded fasteners if the repair location does not have the equipment to properly install replacement Huck fasteners.

Frame Fastener Tightening

CAUTION

Tighten standard frame fasteners periodically. Continued vehicle operation with loose fasteners could result in component, bracket, and frame damage.

1. Tighten hexhead bolts and locknuts periodically to offset the effects of "bedding in" (seating).
2. When tightening the fasteners, tighten the nut, not the bolt head. This will give a true torque reading by eliminating bolt body friction. For torque specifications, see **Specifications, 400**.

NOTE: Huck fasteners do not require periodic tightening.

Specifications

See **Fig. 1** for frame rail and extension cutting dimensions.

Machine Settings for Gas-Metal Arc Welding				
Wire Diameter	Current (amperes)		Wire Extension	
			Optimum	Maximum
inches (mm)	Minimum	Maximum	inches (mm)	inches (mm)
0.045 (1.14)	160	320	1/2 (13)	3/4 (19)
1/16 (1.6)	300	600	3/4 (19)	1-1/8 (29)
5/64 (2.0)	480	960	1 (25)	1-1/2 (38)

Table 1, Machine Settings for Gas-Metal Arc Welding

Amperage and Voltage Settings for Coated-Electrode Arc Welding		
Weld Position	Amperes	Volts
Downhand	130/140	21/23
Overhead	130/140	21/23
Vertical Up	110/120	22/24

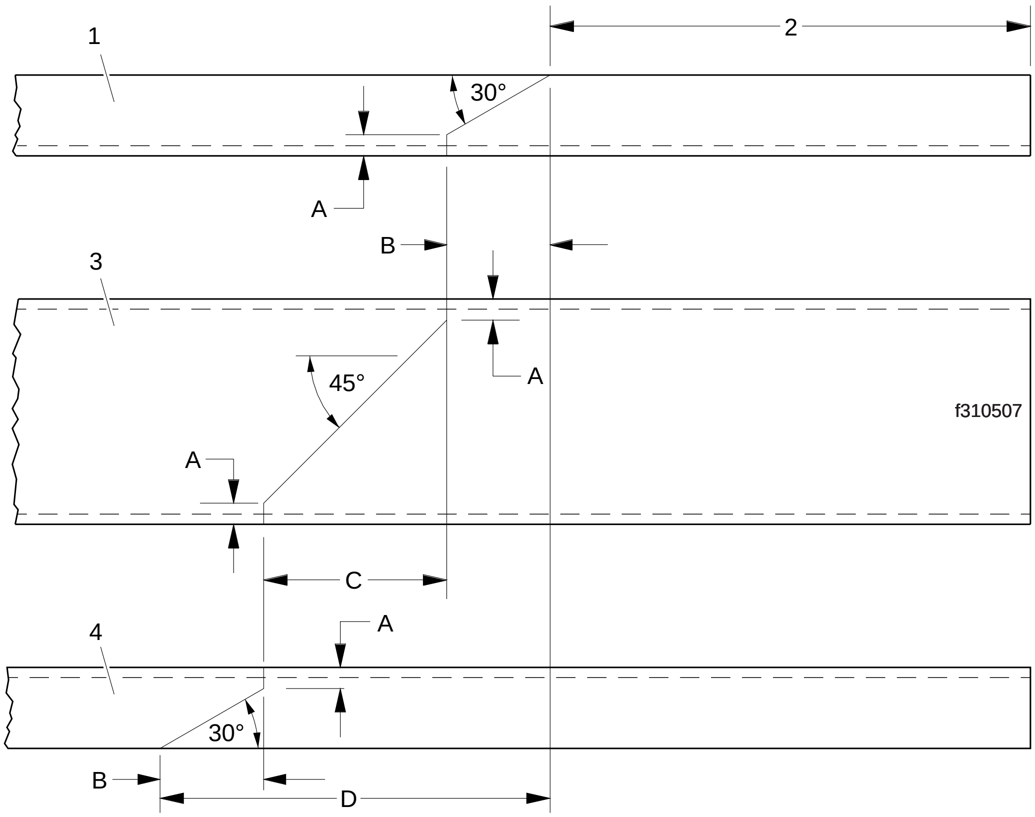
Table 2, Amperage and Voltage Settings for Coated-Electrode Arc Welding

Torque Values for Frame Fasteners	
Size	Torque: * lbf·ft (N·m)
1/2–13	68 (92)
9/16–12	98 (133)
5/8–11	136 (184)
3/4–10	241 (327)
3/4–16	269 (365)
7/8–9	388 (526)
7/8–14	427 (579)

* Lubricated or plated threads.

Table 3, Torque Values for Frame Fasteners

Specifications



NOTE: Left rail shown; right rail will be opposite dimensions.

FRAME RAIL SIZE inches	DIMENSION			
	A inches (mm)	B inches (mm)	C inches (mm)	D inches (mm)
10.06	0.69 (17.5)	5.00 (127.0)	8.75 (222.2)	18.75 (476.2)
10.12	0.69 (17.5)	5.00 (127.0)	8.75 (222.2)	18.75 (476.2)

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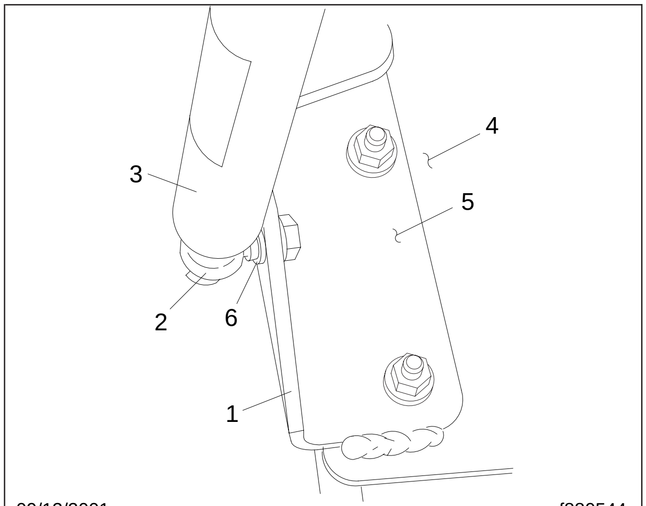
1. Upper Flange
2. Extension Length
3. Web
4. Lower Flange

Fig. 1, Frame Rail and Extension Cutting Dimensions

Removal

1. Chock the front tires.
2. Raise the hood.
3. On the right-hand side of the vehicle, remove the lower end of the damper from the ball stud. Lift the steel spring clip with a small screwdriver and pop the end of the damper off. Pivot the hood damper on the upper ball stud and move it out of the way. See **Fig. 1**.



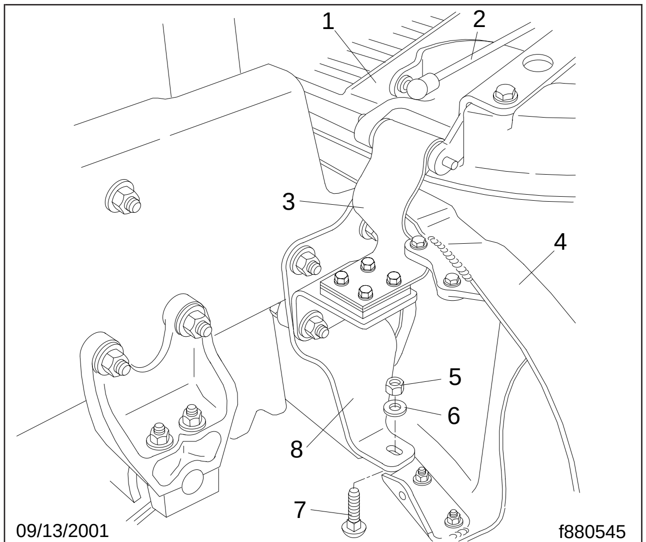
1. Flange of Reinforcement
2. Ball Stud
3. Hood Damper
4. Bumper
5. Bumper Reinforcement
6. M8 Ball Stud Fastener

Fig. 1, Hood Damper

NOTE: It is not necessary to remove the upper ball stud on the hood damper.

4. On each side of the vehicle, remove the lower bumper mounting bolt, washer, and locknut attaching the bumper to the bumper mounting bracket. See **Fig. 2**.
5. On each side of the vehicle, loosen the upper bumper mounting bolt and remove the nut and washer. Push up slightly on the hood to gain clearance, and remove both upper mounting bolts through the top of the bumper. See **Fig. 3**.

NOTE: Two persons are required for this step.



The right-hand side is shown; the left-hand side is similar.

1. Hood
2. Hood Damper
3. Hood Pivot
4. Bumper
5. Bumper Locknut, 1/2–13
6. Washer
7. Lower Bumper Mounting Bolt, 1/2–13
8. Bumper Mounting Bracket

Fig. 2, Lower Bumper Mounting Bolt

6. With a helper, remove the bumper from the vehicle.

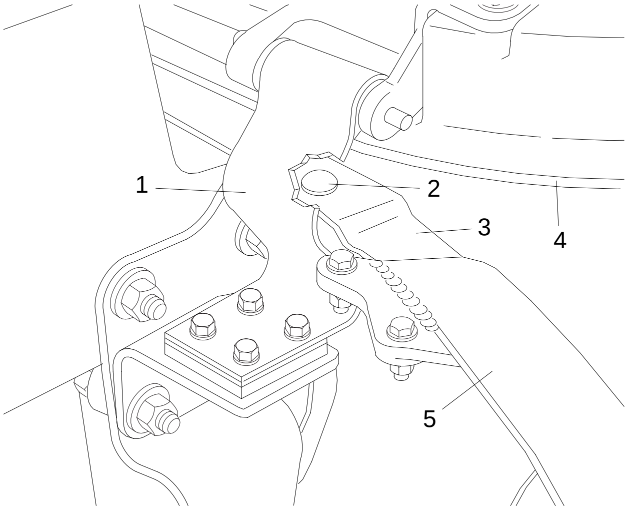
Installation

NOTE: Two persons are required for this step.

1. With a helper, position the bumper on the support brackets so that the holes for the mounting bolts line up. Install the upper and lower mounting bolts, nuts and washers.
2. On each side of the vehicle, tighten the 1/2–13 grade 8 locknuts 68 lbf·ft (92 N·m).
3. Fasten the bottom end of the hood damper to the bumper.

   3.1 Pivot the hood damper down and line up the ball stud with the fastener hole in the flange of the bumper reinforcement.

Bumper Removal and Installation



The right-hand side is shown; the left-hand side is similar.

1. Hood Pivot
2. Upper Bumper Mounting Bolt, 1/2–13
3. Bumper
4. Hood
5. Bumper End Cap

Fig. 3, Upper Bumper Mounting Bolt

3.2 Attach the M8 ball stud fastener to the ball stud.

3.3 Tighten the fastener 13 lbf·ft (18 N·m).

4. Lower the hood.
5. Remove the chocks from the tires.

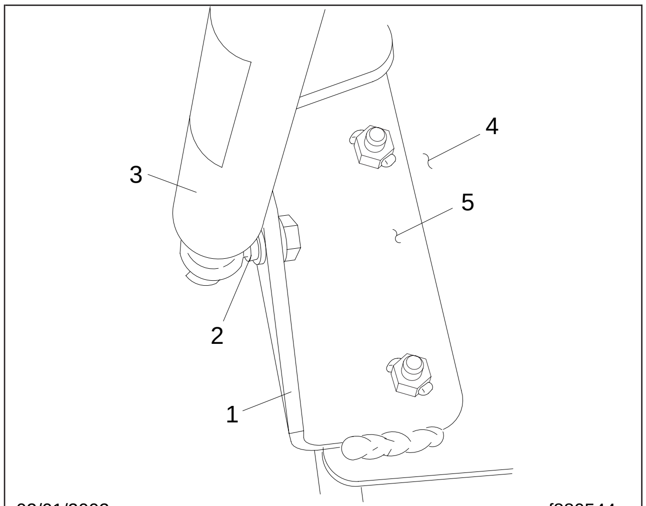
Bumper End Cap Removal and Installation

Removal

1. Chock the front tires.
2. Raise the hood.

NOTE: It is not necessary to remove the lower end of the damper for this procedure. The lower end of the damper is attached to the center bumper and the end caps can be removed with it installed. However, it is easier and quicker to do the following steps with the damper out of the way.

3. On the right-hand side of the vehicle, remove the lower end of the damper from the ball stud. Lift the steel spring clip with a small screwdriver and pop the end of the damper off. Pivot the hood damper on the upper ball stud and move it out of the way. See **Fig. 1**.



1. Flange of Reinforcement
2. Ball Stud
3. Hood Damper
4. Bumper
5. Bumper Reinforcement

Fig. 1, Hood Damper

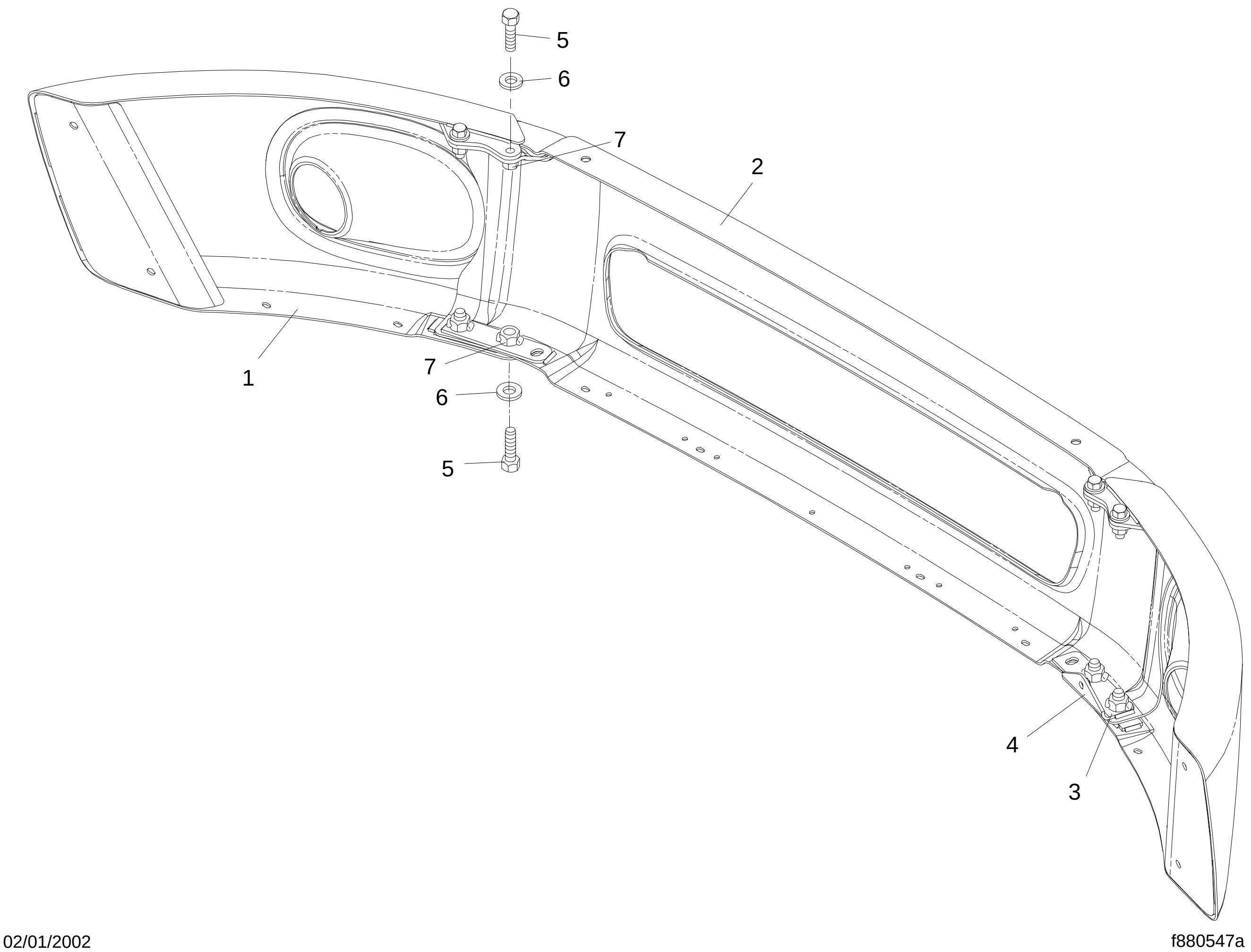
NOTE: It is not necessary to remove the upper ball stud on the hood damper.

4. On one side of the vehicle, remove the end cap from the bumper. See **Fig. 2**.
   - 4.1 Remove the lower end cap mounting bolt and washer attaching the end cap to the bumper center section.
   - 4.2 Remove the upper end cap mounting bolt and washer attaching the end cap to the bumper center section.
   - 4.3 Remove the end cap from the bumper center section.
5. On the other side of the vehicle, remove the other end cap following the same procedure.

Installation

1. Install one end cap on either end of the bumper center.
   - 1.1 Position one end cap on either end of the bumper center so that the holes for the mounting bolts line up.
   - 1.2 Install the upper and lower mounting bolts and washers.
2. Install the other end cap, following the same procedure.
3. On each side of the vehicle, tighten the 3/8–16 grade 5 mounting bolts 26 lbf·ft (36 N·m).
4. Fasten the bottom end of the hood damper to the bumper.
   - 4.1 Pivot the hood damper down and line up the ball stud with the fastener hole in the flange of the bumper reinforcement.
   - 4.2 Attach the M8 ball stud fastener to the ball stud.
   - 4.3 Tighten the fastener 13 lbf·ft (18 N·m).
5. Lower the hood.
6. Remove the chocks from the tires.

Bumper End Cap Removal and Installation



1. End Cap
2. Bumper Center Section
3. Reinforcement
4. Flange
5. End Cap Mounting Bolt, 3/8–16
6. Washer
7. Weld Nut on Center Reinforcement

Fig. 2, Bumper End Caps

Three-Piece Bumper Removal and Installation, Models with Bolt-On Front Frame Brackets

Removal

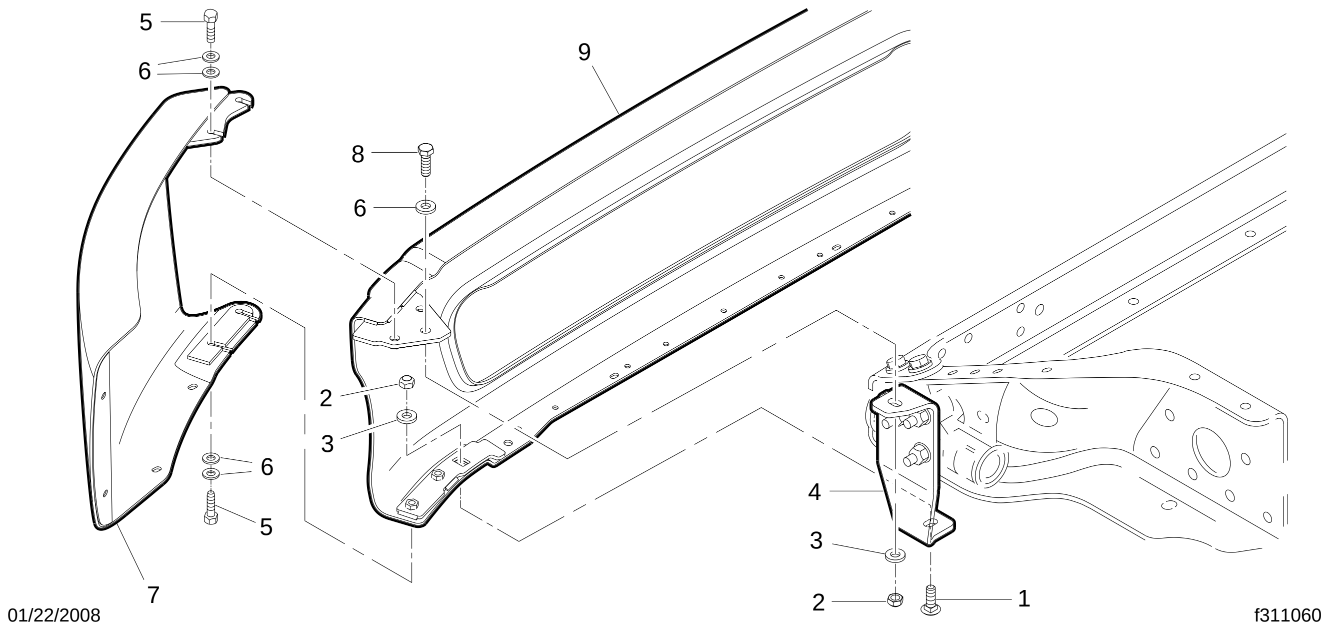
1. Chock the front tires.
2. Raise the hood.
3. If the bumper is equipped with fog lights, disconnect them.
4. At the underside of one end piece, remove the two capscrews that attach the end piece to the center piece. Then remove the two capscrews from the top of the end piece along with the end piece itself. See **Fig. 1**.
5. Repeat the previous step for the other end piece.

NOTE: Leave the upper bolts in place until you are ready to remove the center piece.

6. At one side of the center piece, remove the lower fasteners that attach the center piece to the bumper mounting bracket. Then remove the upper hexnut and washer but *not the upper bolt or its washer*.
7. Repeat the previous step at the opposite end of the center piece.
8. With the center piece securely grasped, remove the upper bolts that are supporting it, then remove the center piece from the vehicle.

Installation

1. Align the center piece with the bores for the tow hooks, and install the upper bolts to secure it to the bumper mounting brackets.
2. Install and hand tighten the remaining fasteners that attach the center piece to the bumper mounting bracket.
3. Ensure that there is an even gap between the center piece and hood. The bumper mounting brackets are designed to allow for angle adjustments.
4. Install and hand tighten the fasteners that attach the end pieces to the center piece.
5. If the bolts that attach the center piece to the bumper mounting bracket are 1/2-inch, grade 5, zinc-plated, tighten them 64 lbf·ft (87 N·m).



1. Round-Head Bolt
2. Hexnut
3. Hardened Steel Flatwasher
4. Bumper Mounting Bracket
5. 3/8" Capscrew
6. Stainless Steel Flatwasher
7. Bumper End Piece
8. Upper Bolt
9. Bumper Center Piece

Fig. 1, Three-Piece Bumper Installation

Three-Piece Bumper Removal and Installation, Models with Bolt-On Front Frame Brackets

If the bolts are 1/2-inch, grade 8, phosphate and oil, tighten them 68 lbf·ft (92 N·m).

6. Tighten the fasteners that attach the end pieces to the center piece 23 lbf·ft (31 N·m).
7. If the bumper is equipped with fog lights, connect them; use tie wraps to secure the wiring harnesses to the frame.
8. Lower the hood.
9. Remove the chocks from the tires.

Specifications

Bumper Torque Values			
Description	**Size**	**Grade**	**Torque in lbf·ft (N·m)**
Ball Stud Fastener, Hood Damper	M8	8.8	13 (18)
Bumper Mounting Bolts	1/2–13	5	68 (92)
Bumper End Cap Mounting Bolts	3/8–16	SST	26 (36)

Table 1, Bumper Torque Values

General Information

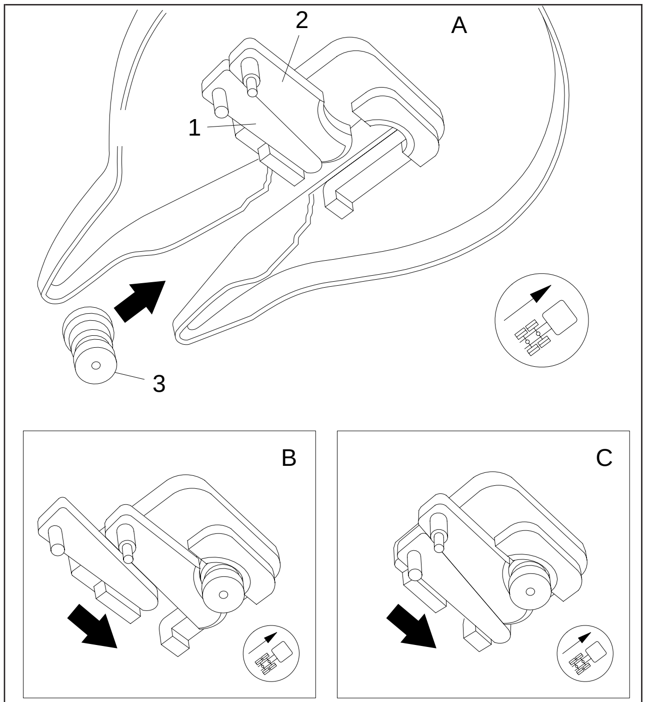
The Fontaine 6000 series fifth wheel couples to trailers having the standard kingpin. When installed with an A36 angle mount, the fifth wheel is bracket-mounted to the tractor frame in a position that best distributes the trailer load over the tractor axles.

The Fontaine fifth wheel lock mechanism for the trailer kingpin consists of a spring-loaded jaw and a sliding wedge. Kingpin release is accomplished by pulling a manual lock control handle located on either the right side or the left side of the fifth wheel. Kingpin lockup occurs when the kingpin enters the throat of the fifth wheel, triggers the jaw and wedge to slide into place behind the kingpin, and moves the lock control handle into the locked position.

As the kingpin enters the lock mechanism, the jaw is moved first with the spring-loaded wedge sliding in place against the jaw. See **Fig. 1**. The jaw will move behind the kingpin, followed by the wedge. The wedge reinforces the jaw and automatically adjusts for slack around the kingpin.

Placing the lock control handle in the unlocked position moves the wedge and jaw out from behind the kingpin and unlocks the fifth wheel.

See Chapter 10 in the *Business Class M2 Driver's Manual* for complete operating instructions.



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A. Unlocked Position
B. Locking
C. Locked

1. Jaw
2. Wedge
3. Trailer Kingpin

Fig. 1, Fontaine Kingpin Lock Mechanism

Removal

WARNING

All fifth wheel maintenance, adjustment and rebuilding must be done by a qualified mechanic. Improper or incomplete procedures could result in disengagement of the trailer from the tractor, leading to personal injury or property damage.

Parts are under spring compression. Wear safety goggles during disassembly and assembly. Failure to do so can result in personal injury, due to parts ejecting with force.

1. Steam clean the top plate.
2. Remove the top plate from the mount. See **Fig. 1**.
   - 2.1 Remove the cotter pin from each bracket retainer pin.
   - 2.2 Remove a retainer pin and bracket pin from each side of the top plate.
3. Using an overhead hoist, lift the fifth wheel off the mount and tractor frame.
4. Turn the fifth wheel upside down and check it for cracks and for missing or damaged parts.

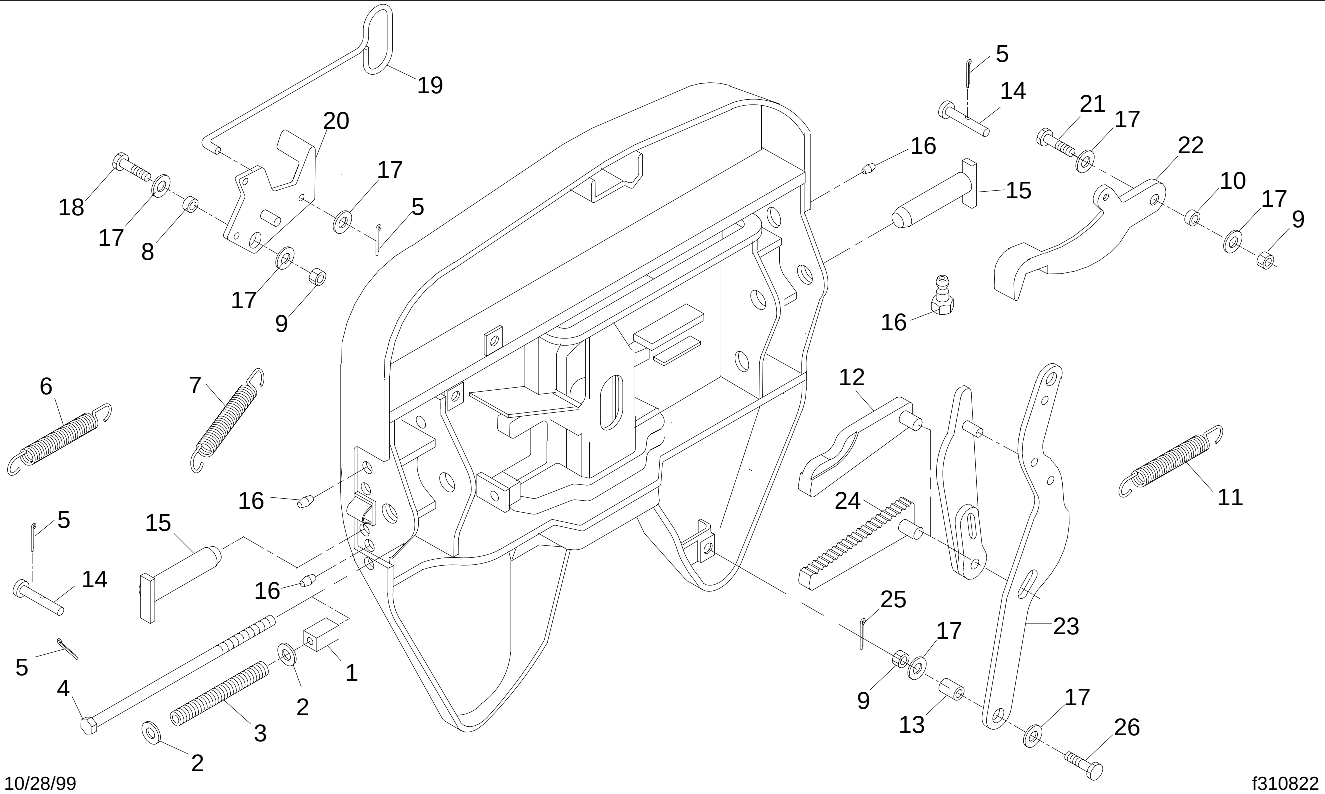
Disassembly

WARNING

Do not attempt to repair or rebuild the top plate if it is cracked or if parts are damaged. The top plate or parts could malfunction. This could result in disengagement of the trailer during vehicle travel, possibly causing personal injury and property damage.

1. Remove the handle spring. See **Fig. 2**. Remove the cotter pin and flatwasher holding the pull handle to the secondary lock and remove the pull handle. Remove the bumper spring.
2. Unbolt and remove the secondary lock from the operating handle. See **Fig. 3**.
3. Unbolt and remove the bumper from the operating handle. See **Fig. 4**.
4. Unbolt the operating handle from the pivot mount and remove the operating handle. See **Fig. 5**.
5. Remove the timer spring and timer. See **Fig. 6**.
6. Remove the jaw and wedge. See **Fig. 7**.

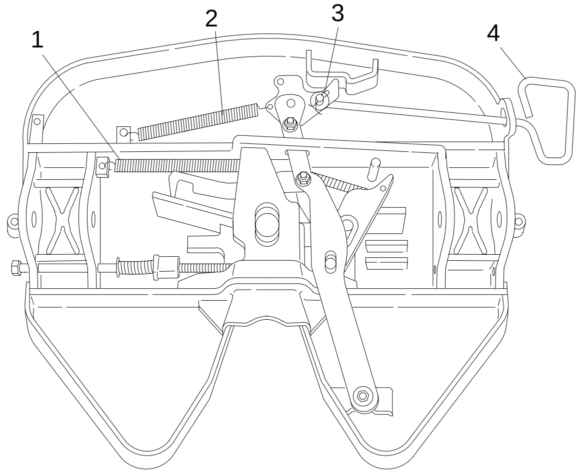
Fifth Wheel Removal and Disassembly



1. Wedge Stop Rod Nut
2. Flatwasher, 5/8-Inch
3. Wedge Stop Rod Spring
4. Wedge Stop Rod
5. Cotter Pin, 3/16 x 1-Inch
6. Bumper Spring
7. Handle Spring
8. Bushing, 7/16-Inch
9. Hex Locknut, 1/2–13, Grade B
10. Bushing, 5/16-Inch
11. Timer Spring
12. Jaw
13. Bushing
14. Bracket Retainer Pin
15. Bracket Pin
16. Grease Fitting
17. Flatwasher, 1/2-Inch
18. Hexhead Bolt, 1/2–13 x 1.5
19. Pull Handle
20. Secondary Lock
21. Hexhead Bolt, 1/2–13 x 1.75
22. Bumper
23. Operating Handle
24. Wedge
25. Hair Pin Cotter
26. Hexhead Bolt, 1/2–13 x 2.25

Fig. 1, Fontaine 6A36 Fifth Wheel (left-side release shown)

Fifth Wheel Removal and Disassembly



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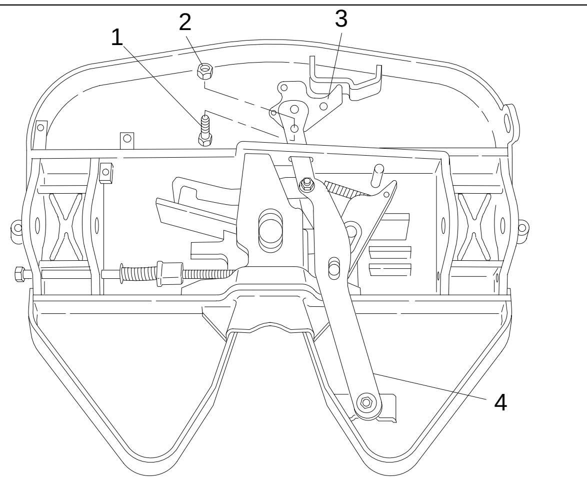
1. Bumper Spring
2. Handle Spring
3. Secondary Lock
4. Pull Handle

Fig. 2, Pull Handle Removal



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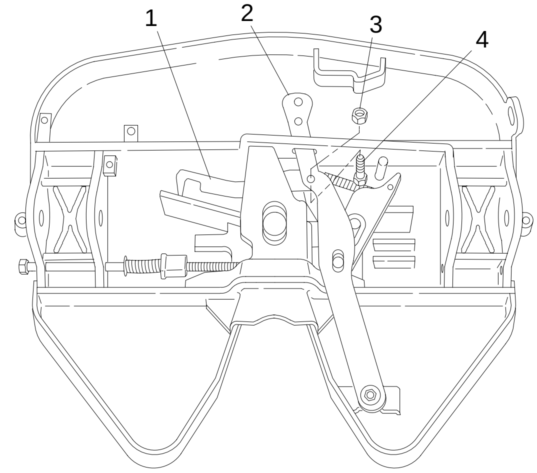
1. Hexhead Bolt, 1/2–13 x 1.5
2. Locknut, 1/2–13
3. Secondary Lock
4. Operating Handle

Fig. 3, Secondary Lock Removal



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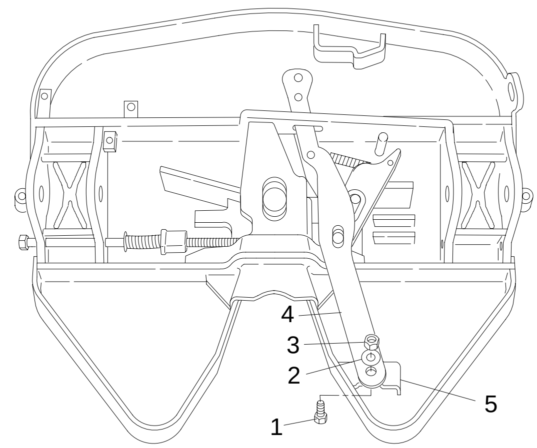
1. Bumper
2. Operating Handle
3. Locknut, 1/2–13
4. Hexhead Bolt, 1/2–13 x 1.75

Fig. 4, Bumper Removal



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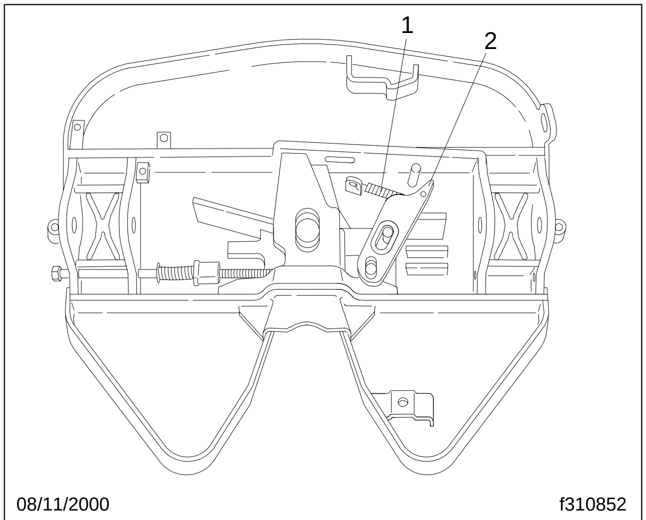
1. Hexhead Bolt, 1/2–13 x 2.25
2. Flatwasher
3. Locknut, 1/2–13
4. Operating Handle
5. Pivot Mount

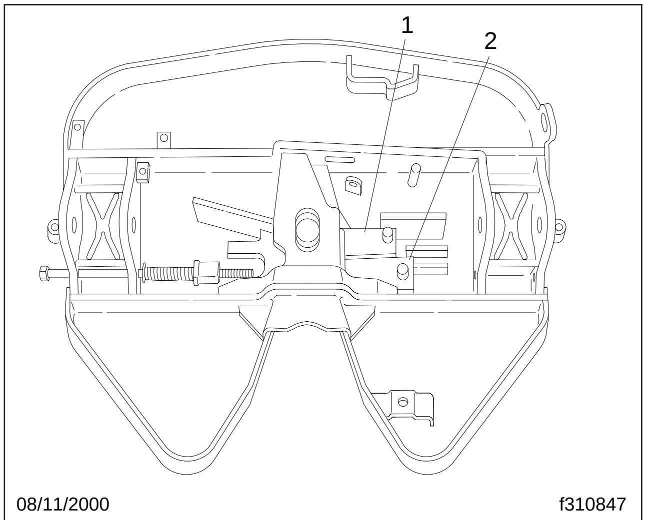
Fig. 5, Operating Handle Removal

Fifth Wheel Removal and Disassembly



1. Timer Spring 2. Timer

Fig. 6, Timer Spring and Timer Removal



1. Jaw 2. Wedge

Fig. 7, Jaw and Wedge Removal

Assembly

WARNING

All fifth wheel maintenance, adjustment and rebuilding must be done by a qualified mechanic. Improper or incomplete procedures could result in possible disengagement of the trailer from the tractor, leading to personal injury and property damage.

Parts are under spring compression. Wear safety goggles during disassembly and assembly. Failure to do so can result in personal injury, due to parts ejecting with force.

IMPORTANT: Replace any parts that show signs of wear, damage or deterioration. See **Fig. 1**.

1. Clean all moving parts with No. 2 diesel fuel before assembly.
2. Insert the jaw and wedge. See **Fig. 2**.
3. Insert the timer and timer spring. See **Fig. 3**.
4. Insert the operating handle and bolt it to the pivot mount. See **Fig. 4**.
5. Install the bumper and bolt it to the operating handle. See **Fig. 5**.
6. Insert the secondary lock and bolt it to the operating handle. See **Fig. 6**.
7. Position the pull handle and install the flatwasher and a new cotter pin. Attach the handle spring and the bumper spring. See **Fig. 7**.

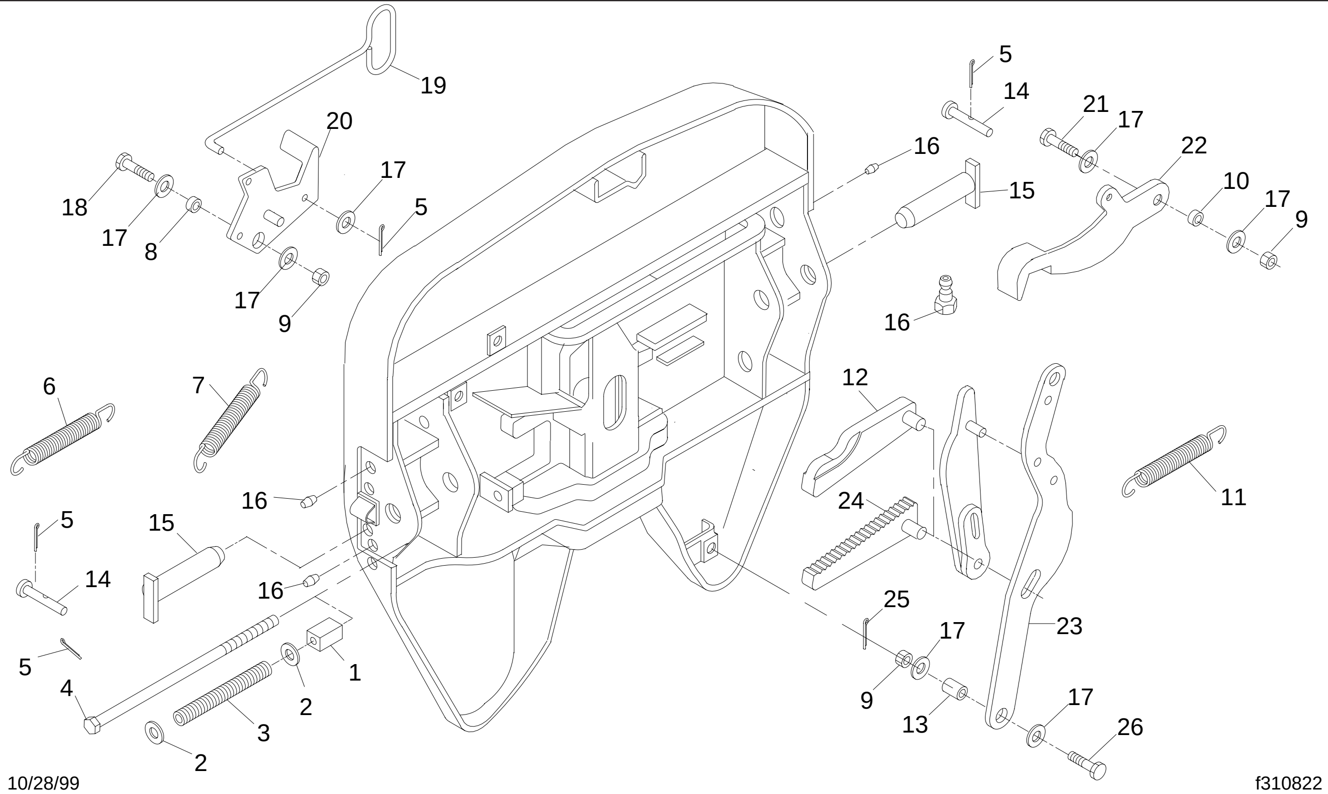
Installation

WARNING

If the fifth wheel does not operate properly, do not use it. The fifth wheel could malfunction, resulting in personal injury or property damage due to possible disengagement of the trailer from the tractor.

1. Using an overhead hoist, position the fifth wheel on the mount assembly. Insert the bracket pins. Install the bracket retainer pins and lock them with new 1-inch long cotter pins.
2. Close the fifth wheel several times with a standard 2-inch kingpin tool. With the lock closed, adjust the wedge stop rod so the end is 1/4-inch from the wedge. See **Troubleshooting, 300** for additional information.

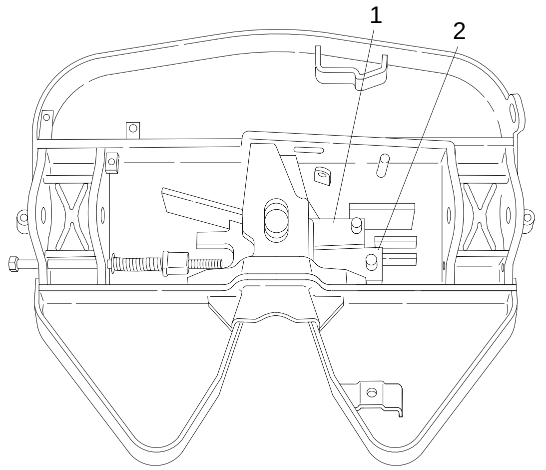
Fifth Wheel Assembly and Installation



1. Wedge Stop Rod Nut
2. Flatwasher, 5/8-Inch
3. Wedge Stop Rod Spring
4. Wedge Stop Rod
5. Cotter Pin, 3/16 x 1-Inch
6. Bumper Spring
7. Handle Spring
8. Bushing, 7/16-Inch
9. Hex Locknut, 1/2–13, Grade B
10. Bushing, 5/16-Inch
11. Timer Spring
12. Jaw
13. Bushing
14. Bracket Retainer Pin
15. Bracket Pin
16. Grease Fitting
17. Flatwasher, 1/2-Inch
18. Hexhead Bolt, 1/2–13 x 1.5
19. Pull Handle
20. Secondary Lock
21. Hexhead Bolt, 1/2–13 x 1.75
22. Bumper
23. Operating Handle
24. Wedge
25. Hair Pin Cotter
26. Hexhead Bolt, 1/2–13 x 2.25

Fig. 1, Fontaine 6A36 Fifth Wheel (left-side release shown)

Fifth Wheel Assembly and Installation



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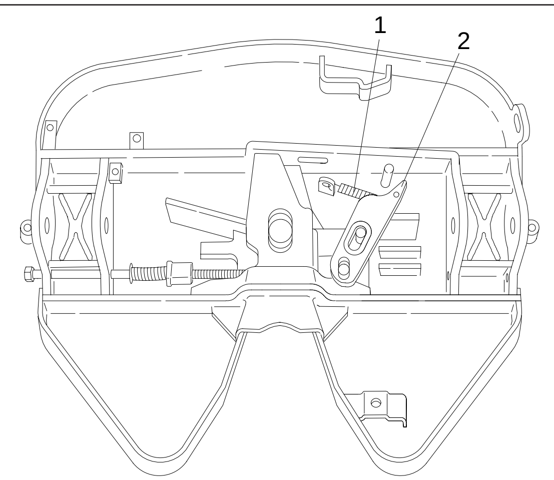
1. Jaw
2. Wedge

Fig. 2, Wedge and Jaw Installation



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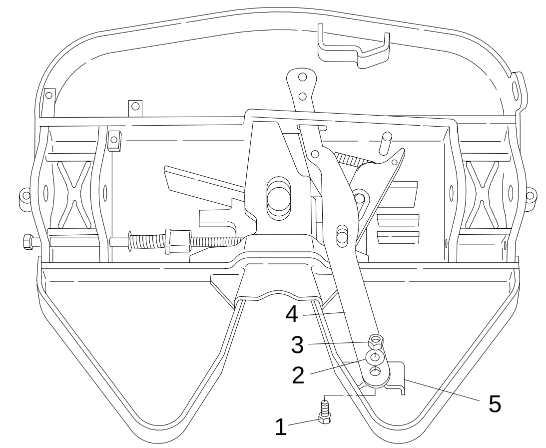
1. Timer Spring
2. Timer

Fig. 3, Timer and Timer Spring Installation



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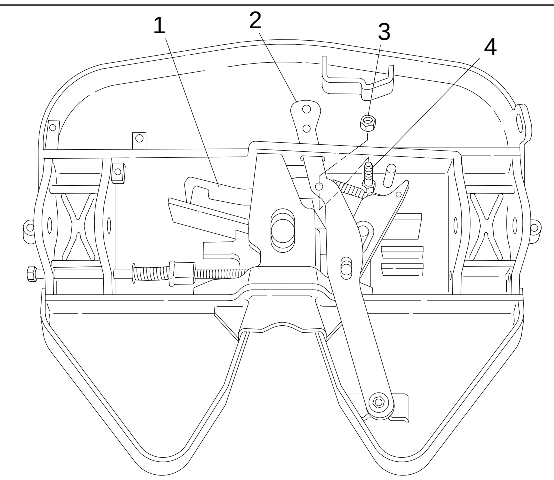
1. Hexhead Bolt, 1/2–13 x 2.25
2. Flatwasher
3. Locknut, 1/2–13
4. Operating Handle
5. Pivot Mount

Fig. 4, Operating Handle Installation



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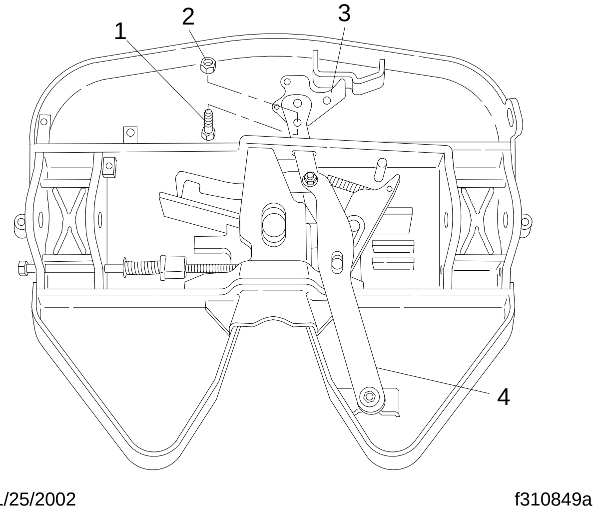
1. Bumper
2. Operating Handle
3. Locknut, 1/2–13
4. Hexhead Bolt, 1/2–13 x 1.75

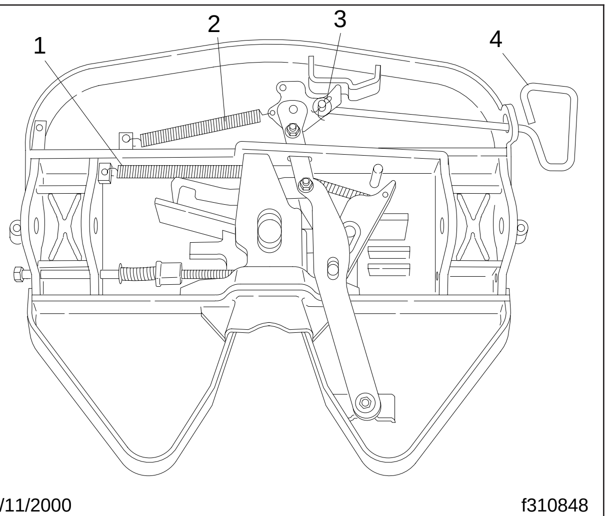
Fig. 5, Bumper Installation

Fifth Wheel Assembly and Installation



1. Hexhead Bolt, 1/2–13 x 1.5
2. Locknut, 1/2–13
3. Secondary Lock
4. Operating Handle

Fig. 6, Secondary Lock Installation



1. Bumper Spring
2. Handle Spring
3. Secondary Lock
4. Pull Handle

Fig. 7, Pull Handle Installation

Troubleshooting Tables

Problem—Difficult Coupling

Problem—Difficult Coupling	
Possible Cause	**Remedy**
The kingpin is too high to trip the latch.	Lower the landing gear.
The trailer plate or kingpin is damaged.	Check the trailer plate for flatness. Check the kingpin for squareness with the trailer plate.

Problem—Excessive Wear on the Fifth Wheel Top Plate

Problem—Excessive Wear on the Fifth Wheel Top Plate	
Possible Cause	**Remedy**
The trailer plate is damaged.	If the trailer plate is not flat, replace it.

Problem—Difficult Uncoupling

Problem—Difficult Uncoupling	
Possible Cause	**Remedy**
The tractor has drifted apart from the trailer, putting excess pressure on the lock mechanism.	Back up the tractor and set the brakes. Strike the wedge stop rod which protrudes through the side of the fifth wheel. This spring-loaded rod will release the pressure on the locking mechanism.

Problem—Excessive Slack

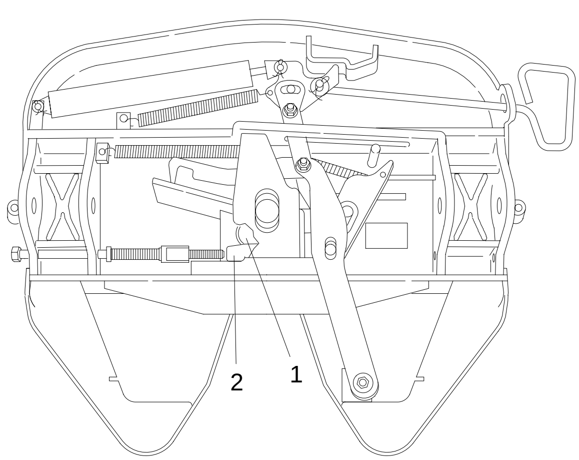
Problem—Excessive Slack	
Possible Cause	**Remedy**
The wedge is improperly adjusted.	Open the fifth wheel and insert a 2-inch kingpin or a shaft with a 2-inch diameter. Trip the lock and adjust the wedge stop rod so that it is 1/4-inch from the end of the wedge.
The kingpin is undersized.	Replace the kingpin if it is worn greater than 1/8-inch (3-mm) at the 2-inch (5-cm) diameter.
The jaw and wedge are worn.	Replace the jaw and wedge.

General Information

Fontaine 6000 and 7000 series fifth wheels couple to trailers having the standard 2 inch kingpin. When installed as a stationary mount, the fifth wheel is bracket-mounted to the tractor frame in a position that best distributes the trailer load over the tractor axles. Sliding fifth wheels are mounted on the Fontaine AWB or MWS model slide mounts.

The Fontaine fifth wheel lock mechanism for the trailer kingpin consists of a spring-loaded jaw and sliding wedge. Kingpin release is accomplished by pulling a manual lock control handle located on either the right side (curbside) or left side (roadside) of the fifth wheel. Kingpin coupling occurs when the kingpin enters the throat of the fifth wheel, triggers the jaw and wedge to slide into place behind the kingpin, and moves the lock control handle into the locked position.

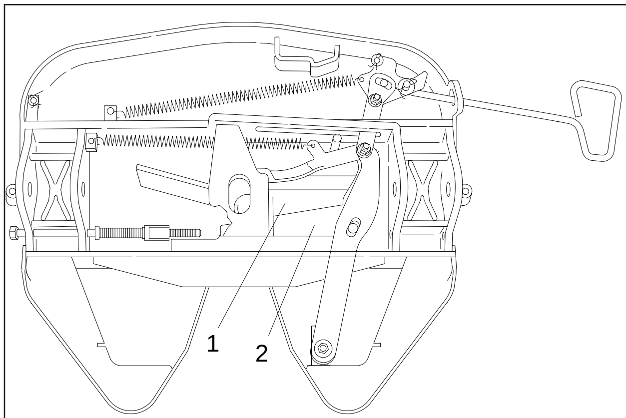
As the kingpin enters the lock mechanism, the jaw is moved first with the spring-loaded wedge sliding in place against the jaw. The jaw will move behind the kingpin, followed by the wedge. The wedge reinforces the jaw and automatically adjusts for slack around the kingpin. See **Fig. 1** for an illustration of the jaw and wedge in the locked position.



1. Jaw
2. Wedge

Fig. 1, Locked Position

Placing the lock control handle in the unlocked position moves the wedge and jaw out from behind the kingpin and unlocks the fifth wheel. See **Fig. 2** for an illustration of the jaw and wedge in the unlocked postition.

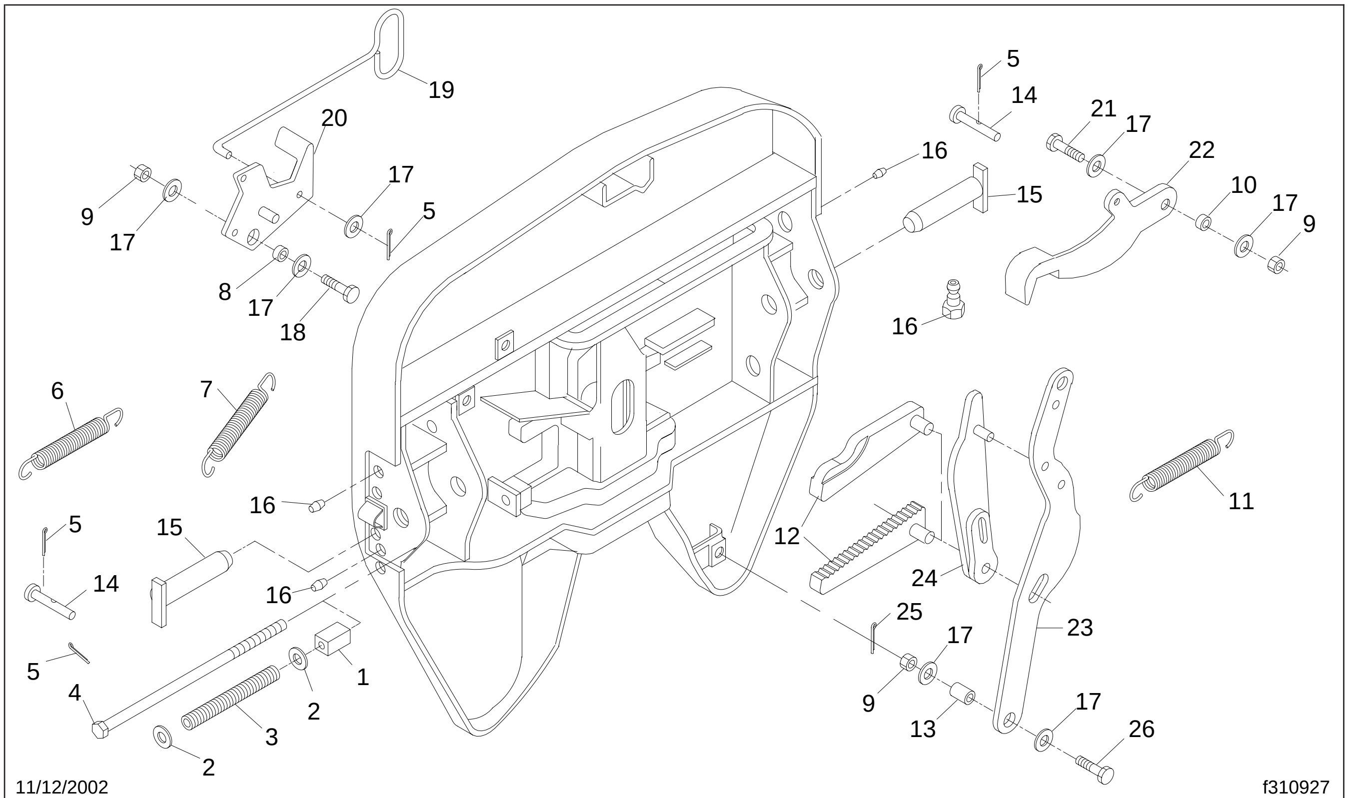


1. Jaw
2. Wedge

Fig. 2, Unlocked Position

Fifth Wheel Removal and Disassembly

See **Fig. 1** for an exploded view of a Fontaine® 6000 or 7000 No-Slack II series fifth wheel.



1. Wedge Stop Rod Nut
2. Flatwasher, 5/8", Plain
3. Wedge Stop Rod Spring
4. Wedge Stop Rod
5. Cotter Pin, 3/16 x 1"
6. Bumper Spring
7. Handle Spring
8. Bushing, 7/16"
9. Hex Locknut, 1/2–13
10. Bushing, 5/16"
11. Timer Spring
12. Step Jaw and Wedge Set
13. Bushing
14. Bracket Retainer Pin
15. Bracket Pin
16. Grease Fitting
17. Flatwasher, 1/2" I.D. x 1-3/4" O.D., Plain
18. Hexhead Bolt, 1/2–13 x 1-1/2", Grade 5
19. Pull Handle
20. Secondary Lock
21. Hexhead Bolt, 1/2–13 x 1-3/4", Grade 5
22. Bumper
23. Operating Handle
24. Timer
25. Hairpin Cotter Pin
26. Hexhead Bolt, 1/2–13 x 2-3/4", Grade 5

Fig. 1, Fontaine 6000 and 7000 No-slack II Series Fifth Wheel (left side release shown)

⚠ WARNING

All fifth wheel maintenance, adjustment, and rebuilding must be done only by a qualified mechanic. Improper or incomplete procedures could result in disengagement of the trailer from the tractor, leading to personal injury or property damage.

Parts are under spring compression. Wear safety goggles during disassembly and assembly. Failure to do so can result in personal injury, due to parts ejecting with force.

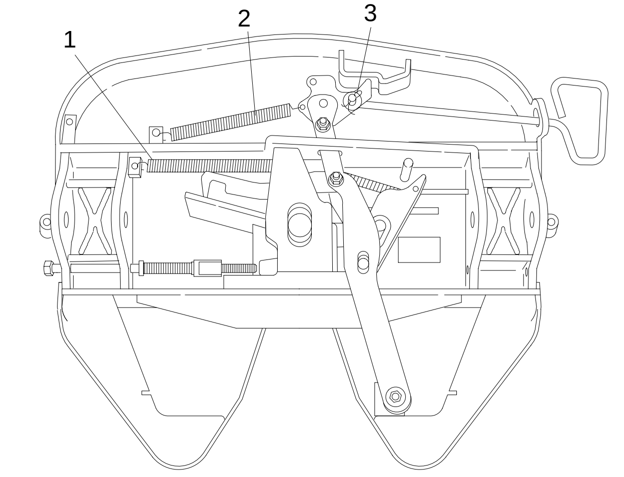
1. Steam clean the top plate. Remove it from the sliding mount by removing the cotter pins from the retaining pins. Remove the retaining pins and bushing pins from both sides of the top plate.

Removal and Disassembly

2. Using an overhead hoist, lift the fifth wheel off the sliding mount and tractor frame.
3. Turn the fifth wheel upside down.

NOTE: While disassembling the fifth wheel, check it for cracks and for missing or damaged parts.

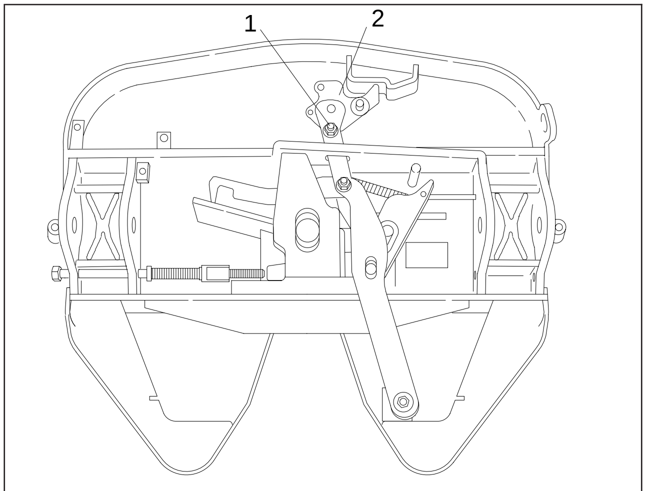
4. Remove the secondary lock spring and bumper spring. See **Fig. 2**. Remove the pull handle cotter pin and washer, then slide out the pull handle.



1. Bumper Spring
2. Secondary Lock Spring
3. Pull Handle Cotter Pin

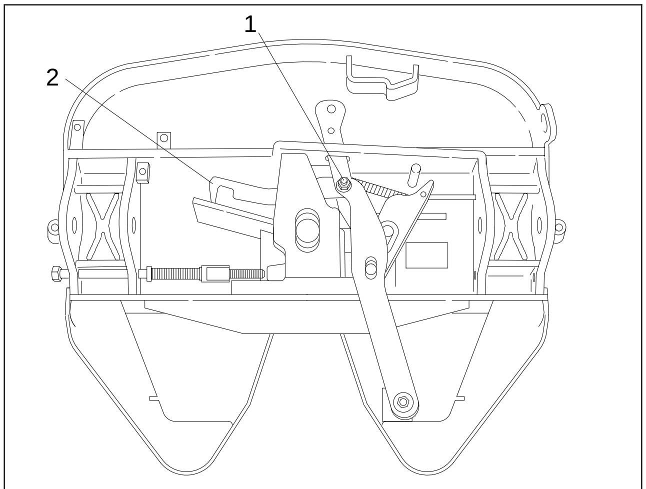
Fig. 2, Pull Handle

5. Unbolt and remove the secondary lock from the operating handle. Discard the locknut and bushing. See **Fig. 3**.
6. Unbolt and remove the bumper from the operating handle. Discard the locknut and bushing. See **Fig. 4**.
7. Unbolt the operating handle from the pivot mount and remove. Discard the locknut. See **Fig. 5**.
8. Remove the timer spring and timer. See **Fig. 6**.
9. Remove the jaw and wedge. See **Fig. 7**.



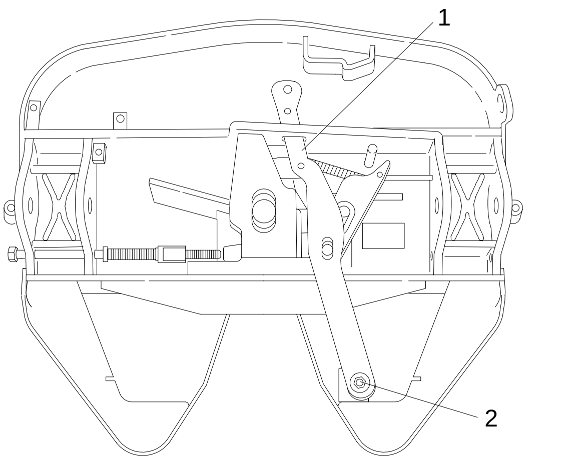
1. Bolt
2. Secondary Lock

Fig. 3, Secondary Lock



1. Bolt
2. Bumper

Fig. 4, Bumper



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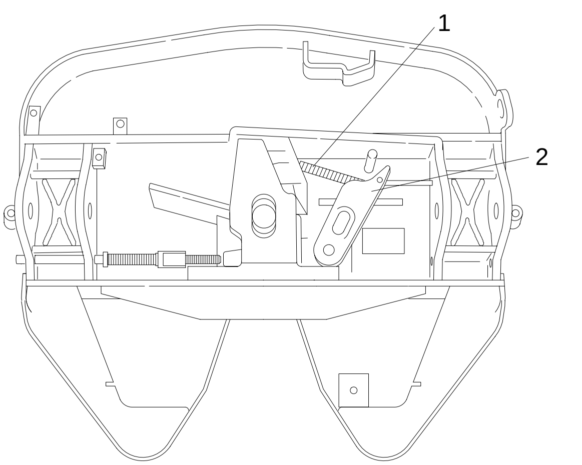
1. Operating Handle
2. Bolt

Fig. 5, Operating Handle



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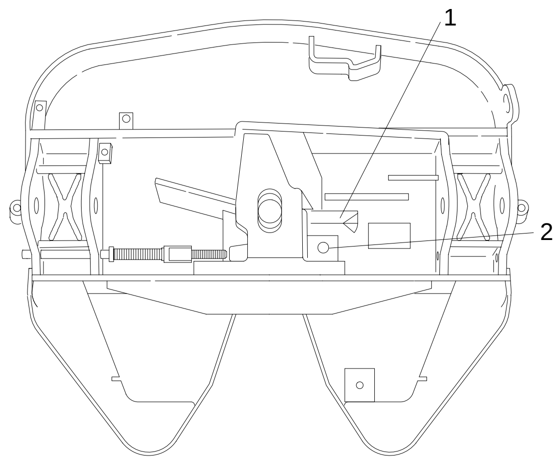
1. Timer Spring
2. Timer

Fig. 6, Timer Spring and Timer



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1. Jaw
2. Wedge

Fig. 7, Jaw and Wedge

Assembly and Installation

WARNING

Before rebuilding the assembly, check to make sure that there are no cracks in the crossmembers or other components. Also check the bracket pin holes to ensure they are not worn oversize (pins should fit snugly). Under no circumstances should a fifth wheel be repaired or used if any component (crossmember, saddle bearing, etc.) is cracked. Operating a fifth wheel with damaged components could result in disengagement of the trailer from the tractor, leading to personal injury or property damage.

Use a Moly-based lubricant such as Mobil grease Moly 50 or equivalent when applying lubricant to the locking jaw and wedge. Lightly oil other moving parts in the fifth wheel.

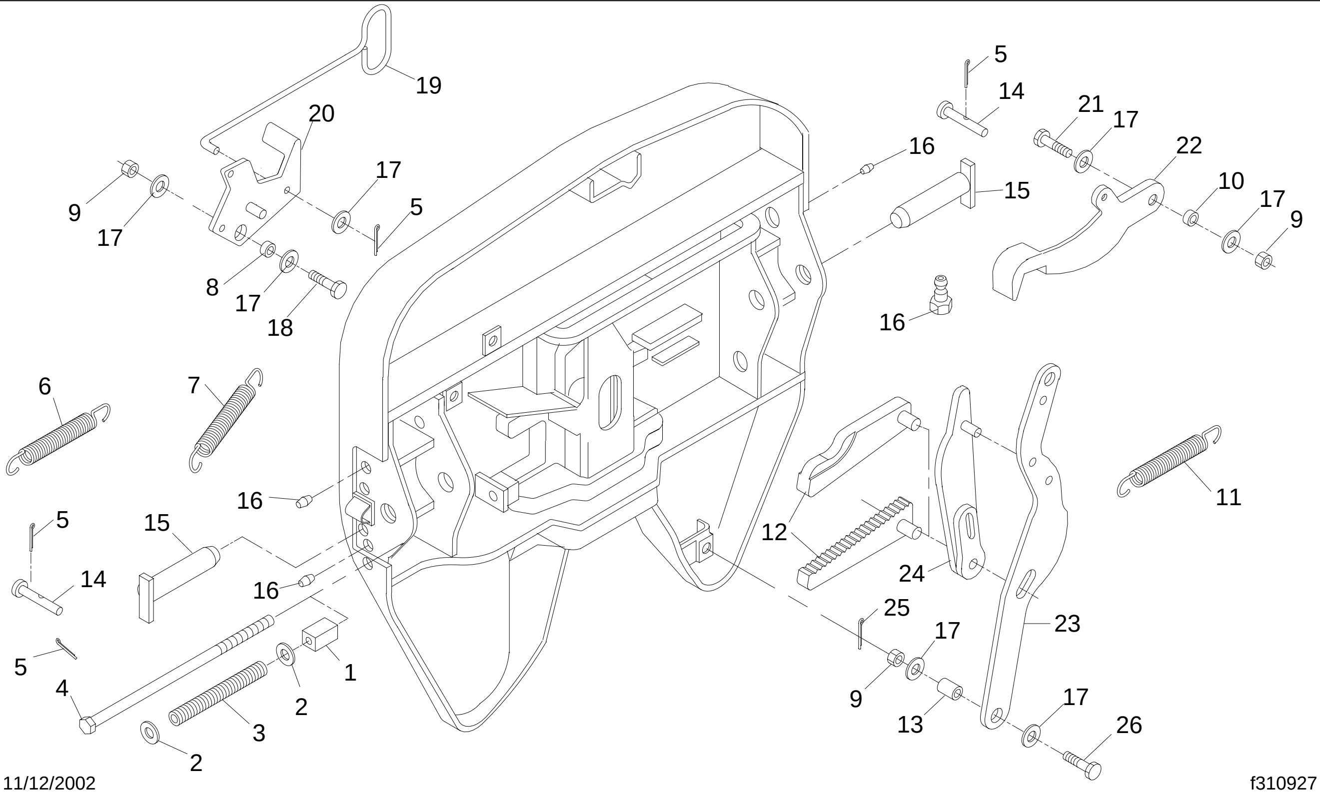
See **Fig. 1** for an exploded view of a Fontaine® 6000 or 7000 No-Slack II series fifth wheel.

1. Always assemble parts around a 2-inch kingpin or a 2-inch-diameter shaft. Insert the jaw first, then the wedge below it. See **Fig. 2**. Grease the jaw and wedge on the top and bottom.
2. Install the timer and the timer spring. See **Fig. 3**.
3. Install the operating handle and bolt to the pivot mount. See **Fig. 4**. Use the existing bolt, washer, hairpin cotter pin and bushing. Inspect the bushing for wear before using it and replace it if necessary. Use the new locknut that is supplied in the repair kit. Note the orientation of the bolt (**Fig. 1**).
4. Install the bumper and bolt it to the operating handle. See **Fig. 5**. Use the existing bolt and washers (inspect for wear before using and replace if necessary). Use the new locknut and bushing that is supplied in the repair kit. Note the orientation of the bolt (**Fig. 1**). After installing the bumper, check to make sure that it can pivot freely.
5. Insert the secondary lock and bolt it to the operating handle. See **Fig. 6**. Use the existing bolt and washers (inspect for wear before using and replace if necessary). Use the new locknut and bushing that is supplied in the repair kit. Note the orientation of the bolt (**Fig. 1**).
6. Install the pull handle. See **Fig. 7**. Use the existing washer and cotter pin (inspect for wear before using and replace if necessary). Attach the new secondary lock/bumper spring that is supplied in the repair kit. Open and close the fifth wheel to ensure that it works properly. The fifth wheel must be properly lubricated before opening and closing the wheel.

Use a Moly-based lubricant such as Mobil grease Moly 50 or equivalent when applying lubricant to the locking jaw and wedge. Lightly oil other moving parts in the fifth wheel.

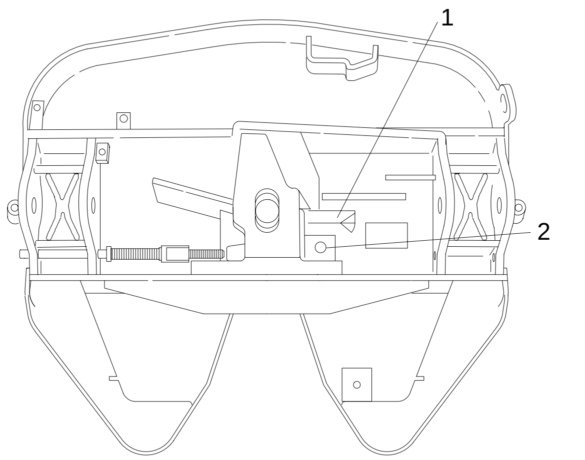
7. Close the fifth wheel several times with a standard 2-inch kingpin tool. With the lock closed, adjust the wedge stop rod so that the end is 1/4 inch (6 mm) from the wedge. See **Fig. 8**.
8. Using an overhead hoist, position the fifth wheel on the sliding mount assembly. Insert the bushing pins. Install the retaining pins and the 1-inch-long cotter pins.

Assembly and Installation



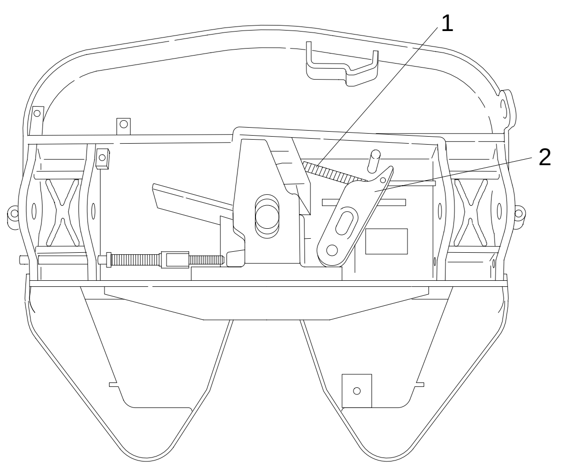
1. Wedge Stop Rod Nut
2. Flatwasher, 5/8", Plain
3. Wedge Stop Rod Spring
4. Wedge Stop Rod
5. Cotter Pin, 3/16 x 1"
6. Bumper Spring
7. Handle Spring
8. Bushing, 7/16"
9. Hex Locknut, 1/2–13
10. Bushing, 5/16"
11. Timer Spring
12. Step Jaw and Wedge Set
13. Bushing
14. Bracket Retainer Pin
15. Bracket Pin
16. Grease Fitting
17. Flatwasher, 1/2" I.D. x 1-3/4" O.D., Plain
18. Hexhead Bolt, 1/2–13 x 1-1/2", Grade 5
19. Pull Handle
20. Secondary Lock
21. Hexhead Bolt, 1/2–13 x 1-3/4", Grade 5
22. Bumper
23. Operating Handle
24. Timer
25. Hairpin Cotter Pin
26. Hexhead Bolt, 1/2–13 x 2-3/4", Grade 5

Fig. 1, Fontaine 6000 and 7000 No-slack II Series (left-side release shown)



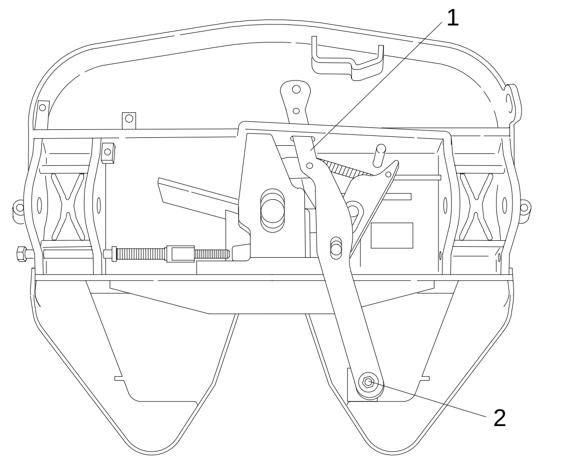
1. Jaw
2. Wedge

Fig. 2, Jaw and Wedge



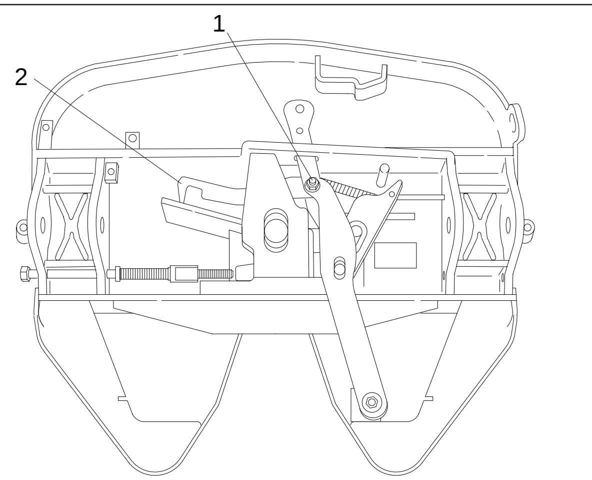
1. Timer Spring
2. Timer

Fig. 3, Timer Spring and Timer



1. Operating Handle
2. Bolt

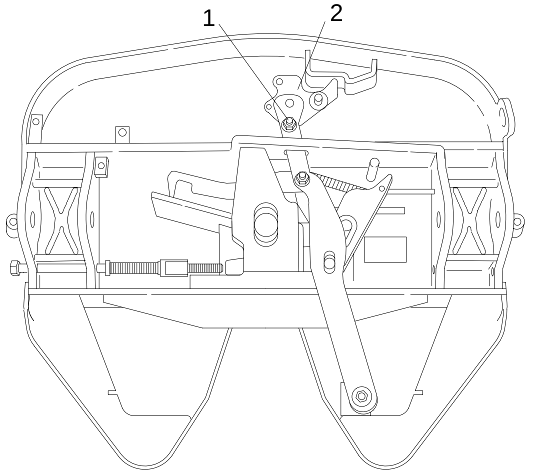
Fig. 4, Operating Handle



1. Bolt
2. Bumper

Fig. 5, Bumper

Assembly and Installation



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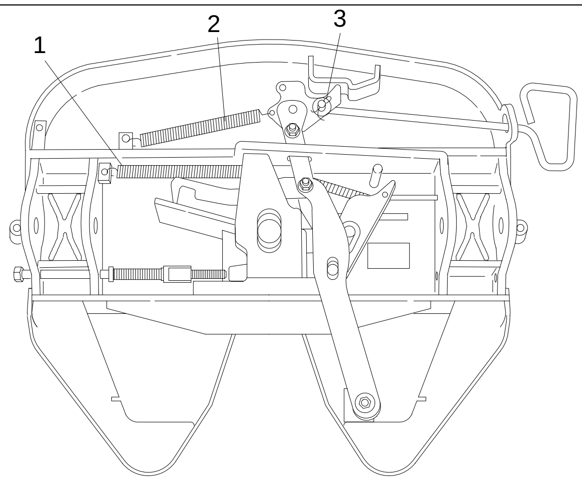
1. Bolt
2. Secondary Lock

Fig. 6, Secondary Lock



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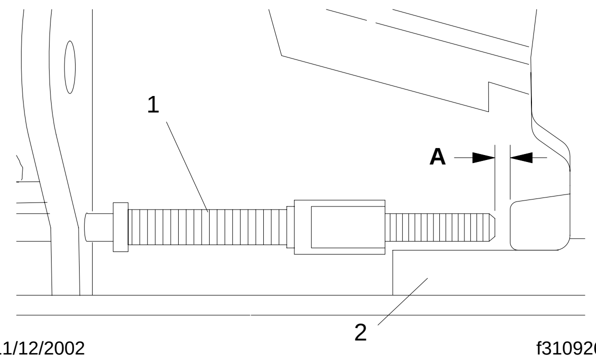
1. Bumper Spring
2. Secondary Lock Spring
3. Pull Handle Cotter Pin

Fig. 7, Pull Handle



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A. 1/4 inch (6 mm)

1. Stop Rod
2. Wedge

Fig. 8, Wedge Stop Rod Adjustment

Troubleshooting Tables

Problem—Difficulty Coupling

Possible Cause	Remedy
The kingpin is too high to trip the latch	Lower the landing gear.
The trailer plate or kingpin is damaged	Check the trailer plate for flatness. Check the kingpin for squareness with the trailer plate.

Problem—Excessive Wear on the Fifth Wheel Top Plate

Possible Cause	Remedy
Damaged trailer plate	If the trailer plate is not flat, replace it.

Problem—Difficulty Uncoupling

Possible Cause	Remedy
Pressure on the locking mechanism caused by truck drifting apart from the trailer putting excess pressure on the lock	Back up the trailer and set the brakes. Strike the wedge stop rod which protrudes through the side of the fifth wheel. This spring-loaded rod will release the pressure on the locking mechanism.
Oval-shaped kingpin	Lower the landing gear.
Debris build-up in the grease	

Problem—Slack

Possible Cause	Remedy
Undersized kingpin	Replace the kingpin if worn greater than 1/8 inch (3 mm) at the 2-inch (5-cm) diameter.
Worn jaw and wedge	Jaw and wedge could have excessive wear. Replace them.

General Information

Fontaine H5092 series fifth wheels couple to trailers having the standard 2-inch kingpin. When installed as a stationary mount, the fifth wheel is bracket-mounted to the tractor frame in a position that best distributes the trailer load over the tractor axles. Sliding fifth wheels (**Fig. 1**), are mounted on the Fontaine HAWB or HMWS (previously called 5AWB and 5MWS) model slide mounts.

The Fontaine fifth wheel lock mechanism for the trailer kingpin consists of a spring-loaded jaw and sliding wedge. Kingpin release is accomplished by pulling a manual lock control handle located on either the right side (curbside) or left side (roadside) of the fifth wheel. Kingpin coupling occurs when the kingpin enters the throat of the fifth wheel, triggers the jaw and wedge to slide into place behind the kingpin, and moves the lock control handle into the locked position.

As the kingpin enters the lock mechanism, the jaw is moved first with the spring-loaded wedge sliding in place against the jaw. The jaw will move behind the kingpin, followed by the wedge. The wedge reinforces the jaw and automatically adjusts for slack around the kingpin. See **Fig. 2** for an illustration of the jaw and wedge in the locked position.

Placing the lock control handle in the unlocked position moves the wedge and jaw out from behind the kingpin and unlocks the fifth wheel. See **Fig. 3** for an illustration of the jaw and wedge in the unlocked postition.

General Information

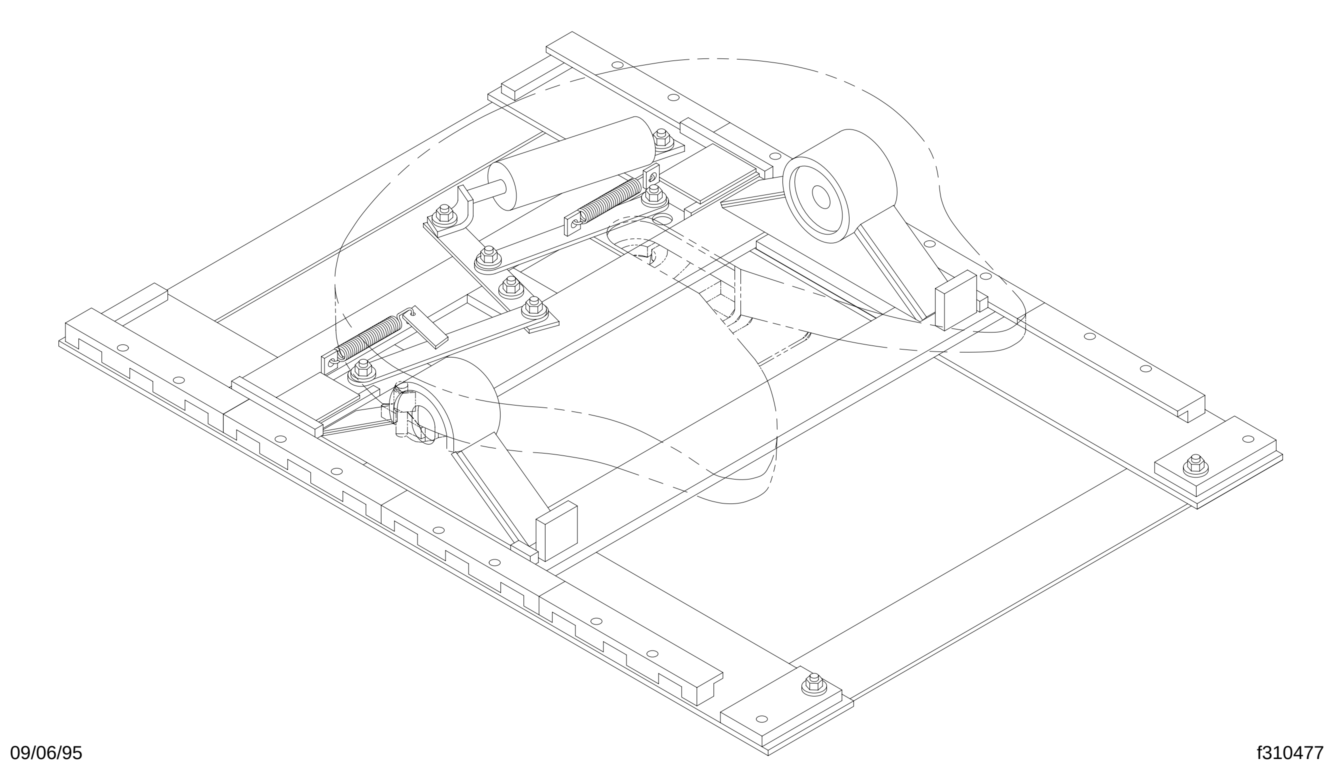
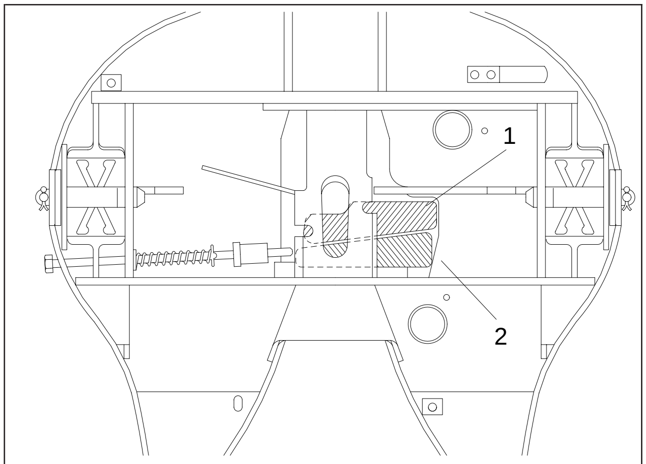
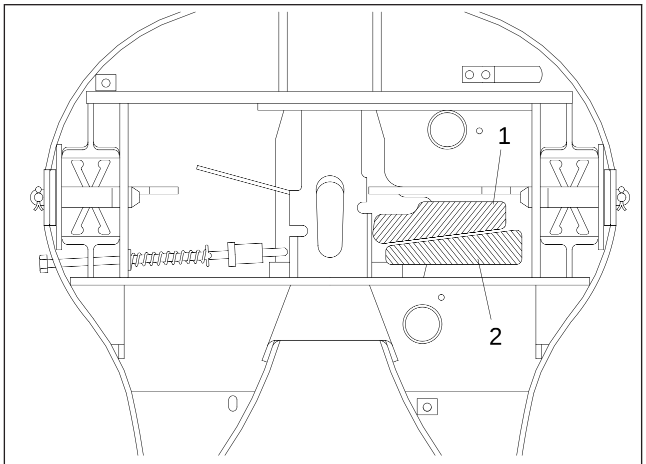


Fig. 1, Fontaine H5092 Series Air Slide Fifth Wheel



1. Jaw
2. Wedge

Fig. 2, Locked Position

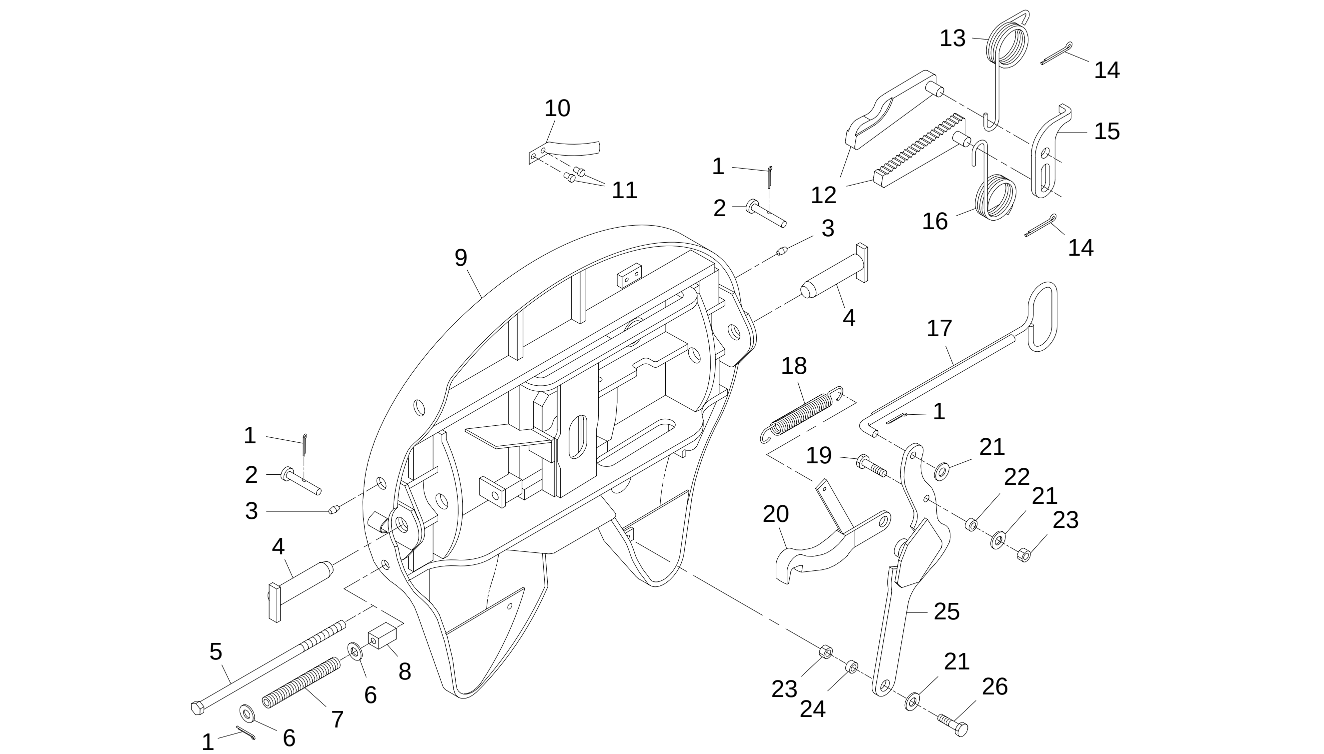


1. Jaw
2. Wedge

Fig. 3, Unlocked Position

Fifth Wheel Removal and Disassembly

See **Fig. 1** for an exploded view of the Fontaine® H5092 fifth wheel.



1. Wedge Stop Rod Nut
2. Flatwasher, 5/8", Plain
3. Wedge Stop Rod Spring
4. Wedge Stop Rod
5. Cotter Pin, 3/16 x 1"
6. Bumper Spring
7. Handle Spring
8. Bushing, 7/16"
9. Hex Locknut, 1/2–13
10. Bushing, 5/16"
11. Timer Spring
12. Step Jaw and Wedge Set
13. Bushing
14. Bracket Retainer Pin
15. Bracket Pin
16. Grease Fitting
17. Flatwasher, 1/2" I.D. x 1-3/4" O.D., Plain
18. Hexhead Bolt, 1/2–13 x 1-1/2", Grade 5
19. Pull Handle
20. Secondary Lock
21. Hexhead Bolt, 1/2–13 x 1-3/4", Grade 5
22. Bumper
23. Operating Handle
24. Timer
25. Hairpin Cotter Pin
26. Hexhead Bolt, 1/2–13 x 2-3/4", Grade 5

Fig. 1, Fontaine H5092 Series Fifth Wheel (left-side release shown)

WARNING

All fifth wheel maintenance, adjustment, and rebuilding must be done only by a qualified mechanic. Improper or incomplete procedures could result in disengagement of the trailer from the tractor, leading to personal injury or property damage.

Parts are under spring compression. Wear safety goggles during disassembly and assembly. Failure to do so can result in personal injury, due to parts ejecting with force.

1. Steam clean the top plate. Remove it from the sliding mount by removing the cotter pins from the retaining pins. Remove the retaining pins and bushing pins from both sides of the top plate.

Removal and Disassembly

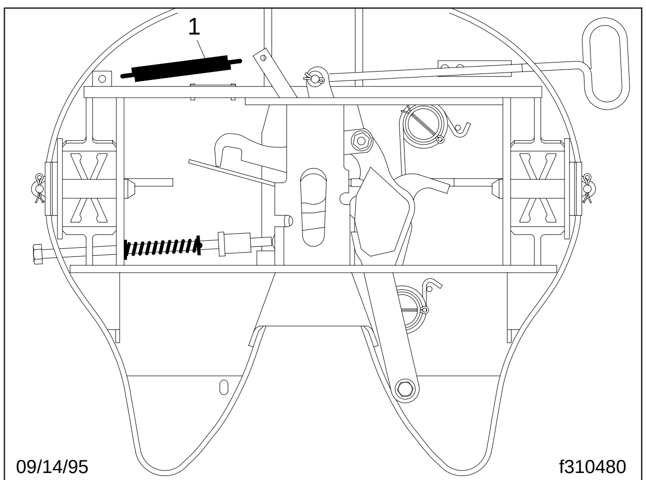
2. Using an overhead hoist, lift the fifth wheel off the sliding mount and tractor frame.
3. Turn the fifth wheel upside down.

NOTE: While disassembling the fifth wheel, check it for cracks and for missing or damaged parts.

WARNING

Do not attempt to repair or rebuild the top plate if it is cracked or if parts are damaged. The top plate or parts could malfunction. This could result in disengagement of the trailer during vehicle travel, possibly causing personal injury and property damage.

4. Set the fifth wheel in a locked position, then unhook the bumper spring from the bumper tang and the tab on the side of the fifth wheel substructure. See Fig. 2. Remove the bumper spring.



1. Bumper Spring

Fig. 2, Bumper Spring Removal

5. Remove the two bolts on the operating handle. Fig. 3. Each bolt has a nut, washer, and bushing. Discard the bushings.
6. Remove the cotter pin and washer that holds the pull handle to the operating handle. Slide the pull handle out through the side of the fifth wheel. See Fig. 4.

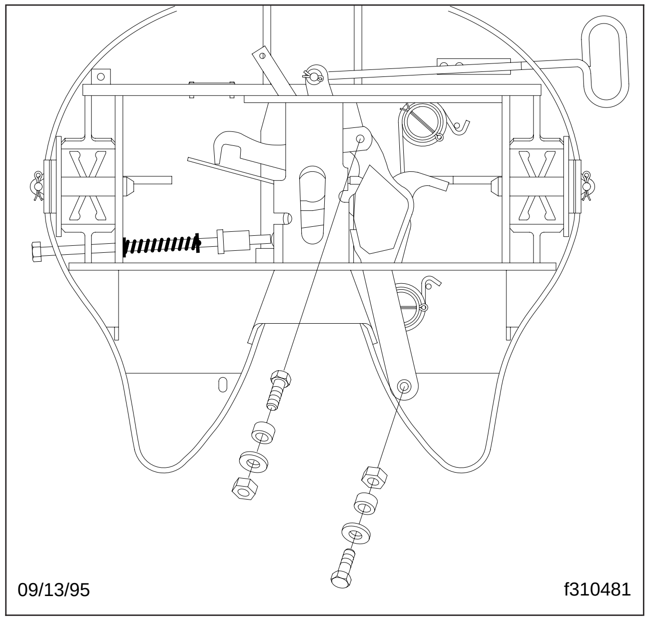


Fig. 3, Bolt Removal

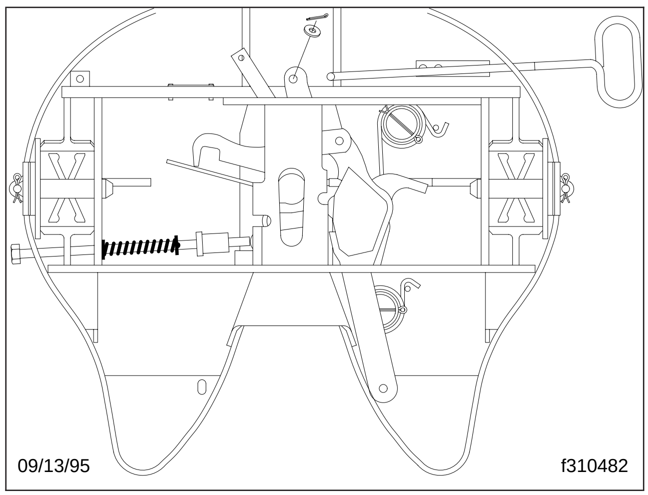
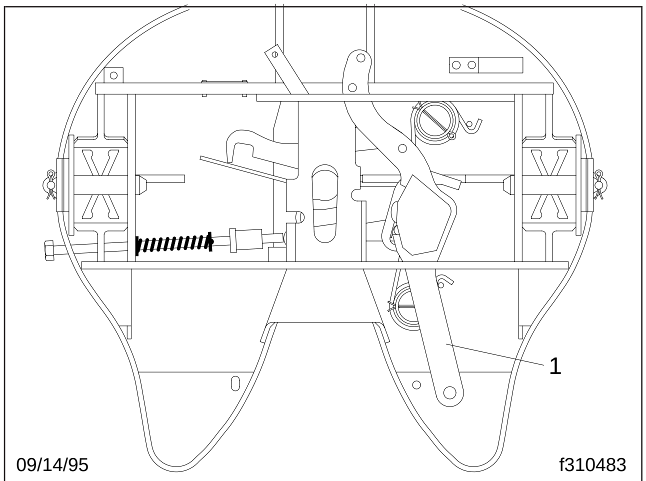


Fig. 4, Pull Handle Removal

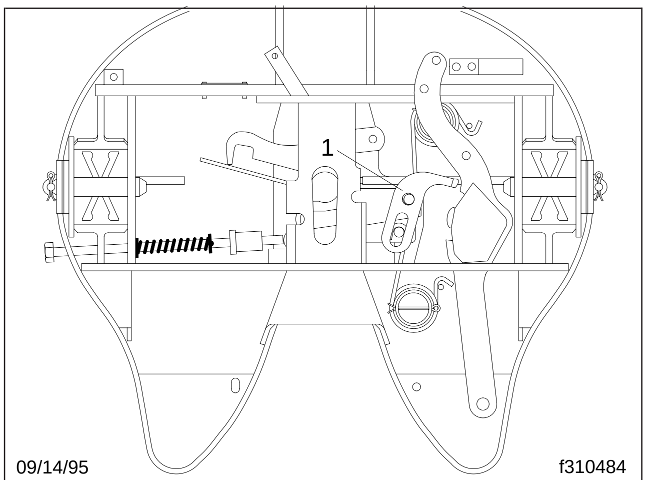
7. Slide the operating handle over to the side of the fifth wheel. Slide the bottom part first. This will allow the handle to clear the jaw and wedge studs on the underside and clear the timer. See Fig. 5.
8. Remove the timer by lifting upward. See Fig. 6.
9. Slide the operating handle out through the slot in the rear crossmember of the fifthwheel. See Fig. 7.

Removal and Disassembly



1. Operating Handle

Fig. 5, Operating Handle Positioning



1. Timer

Fig. 6, Timer Removal

10. Slide the bumper toward the operating handle slot and to the rear of the fifth wheel until the bumper tang clears the operating handle slot. Lift upward and remove. See **Fig. 8**.

WARNING

The wedge spring is under extreme tension. Always wear safety glasses. Do not stand directly over the springs. A flying spring could cause personal injury.

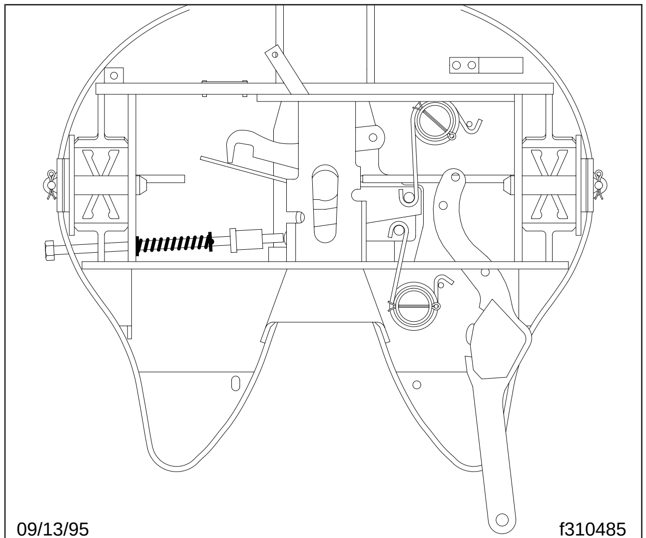
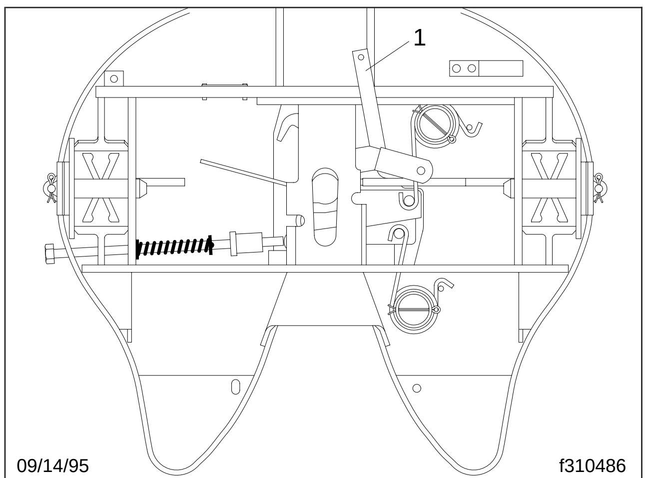


Fig. 7, Operating Handle Removal



1. Bumper

Fig. 8, Bumper Removal

11. Remove the cotter pins from the jaw and wedge springs. Discard the cotter pins, and pry the small hooked tail of the jaw and wedge spring up over the jaw and wedge studs. Remove and discard both springs. See **Fig. 9**.

12. Remove the wedge first, and then the jaw. Discard the jaw and wedge. See **Fig. 10**.

Removal and Disassembly

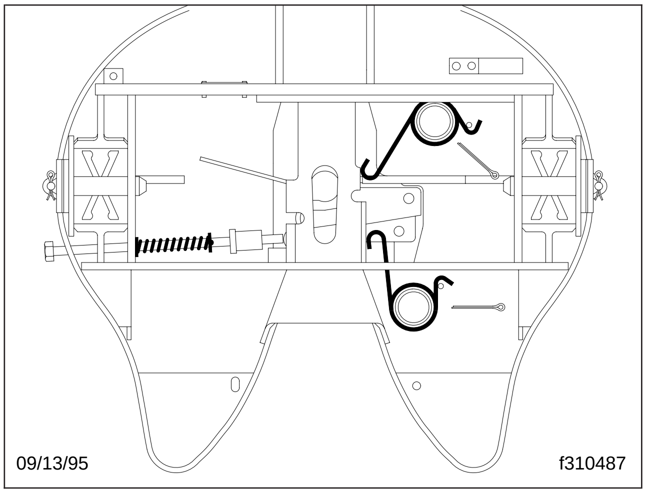


Fig. 9, Spring Removal

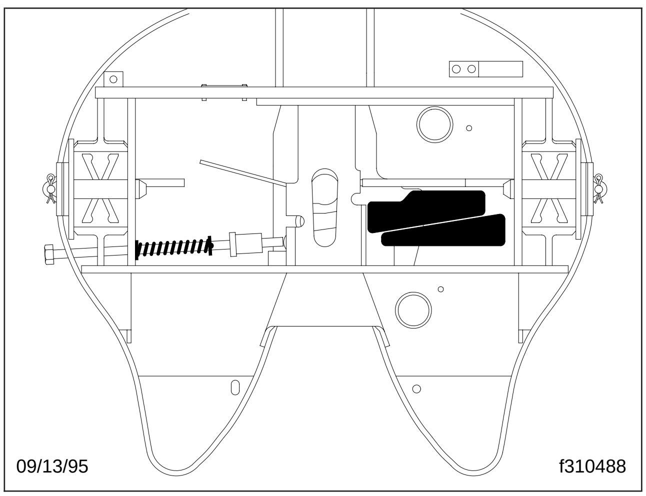
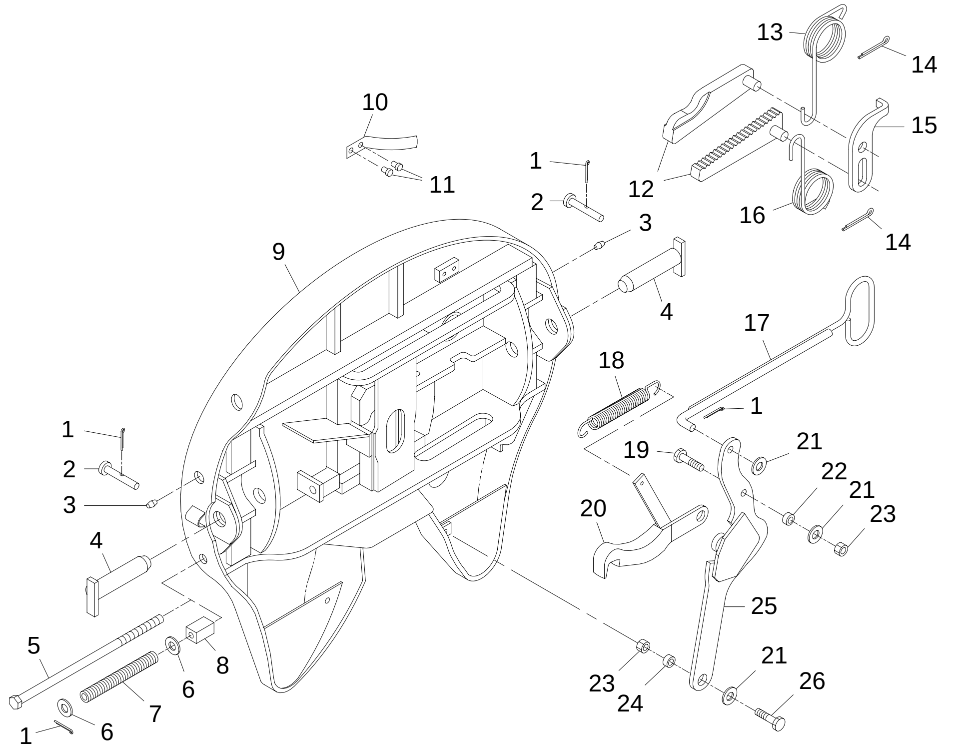


Fig. 10, Jaw and Wedge Removal

Assembly and Installation

See **Fig. 1** for an exploded view of a Fontaine® H5092 fifth wheel.



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1. Cotter Pin, 3/16" x 1"
2. Lower Bracket Retainer Pin
3. Grease Fitting
4. Lower Bracket Pin
5. Wedge Stop Rod
6. Flatwasher
7. Wedge Stop Rod Spring
8. Nut, Wedge Stop Rod
9. Upper Assembly, Side Release
10. Leaf Spring
11. Thread-Cutting Screw, 1/4–20 x 3/8"
12. Step Jaw and Wedge
13. Jaw Spring
14. Cotter Pin, 1/4" x 3"
15. Timer
16. Wedge Spring
17. Pull Handle
18. Bumper Handle Spring
19. Hexhead Bolt, 1/2–13 x 2", Bumper Pivot
20. Bumper
21. Flatwasher
22. Bushing, 5/16", Bumper Pivot
23. Hex Locknut, 1/2–13
24. Bushing, 7/16", Handle Pivot
25. Operating Handle, Side Release Only
26. Hexhead Bolt, 1/2–13 x 2", Handle Pivot

Fig. 1, Fontaine H5092 Series Fifth Wheel (left-side release shown)

WARNING

All fifth wheel maintenance, adjustment, and rebuilding must be done only by a qualified mechanic. Improper or incomplete procedures could result in possible disengagement of the trailer from the tractor, leading to personal injury and property damage.

Parts are under spring compression. Wear safety goggles during disassembly and assembly. Failure to do so can result in personal injury, due to parts ejecting with force.

IMPORTANT: Replace any parts that show signs of wear, damage, or deterioration.

Fifth Wheel Assembly and Installation

1. Clean all moving parts with no. 2 diesel fuel before assembly.
2. Always assemble the parts around a 2-inch kingpin or a shaft with a 2-inch diameter. Insert the jaw first and then the new wedge below it. Apply a moderate amount of grease having EP (extra pressure) additives to the sides and serrated edges of the jaw and wedge. Also apply grease to the stationary jaw in the throat of the fifth wheel. See **Fig. 2**.

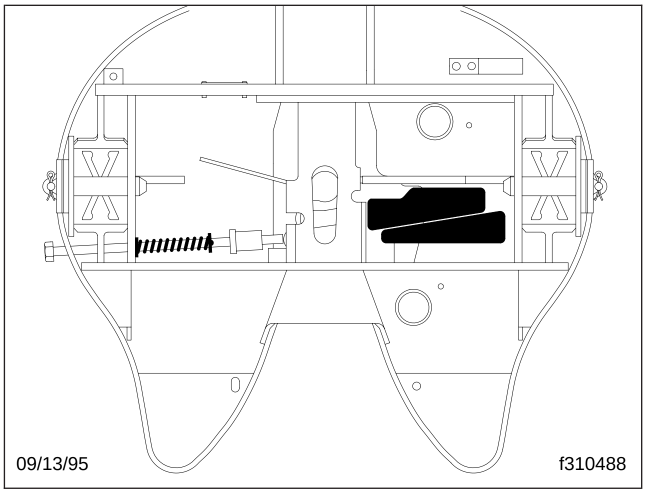


Fig. 2, Wedge and Jaw Installation

3. Insert the new wedge spring through the slot in the rear crossmember and lay the coil over the spring boss. Using a spring tool, engage the small hooked tail of the wedge spring and wind it around until it is directly over the small stud at the back of the bracket. Using a hammer, nudge the spring downward allowing it to catch on the stud. Insert a new cotter pin. See **Fig. 3**.

   Repeat these steps to replace the jaw spring.

NOTE: The jaw spring has minimal tension and can be replaced by hand.

4. Place the bumper back in position, sliding the bumper tang through the operating handle guide slot and toward the tab on the side of the fifth wheel substructure. See **Fig. 4**.
5. Apply a liberal amount of grease to the grooved middle section of the operating handle, then insert the operating handle and move it over to the side of the wheel. See **Fig. 5**.

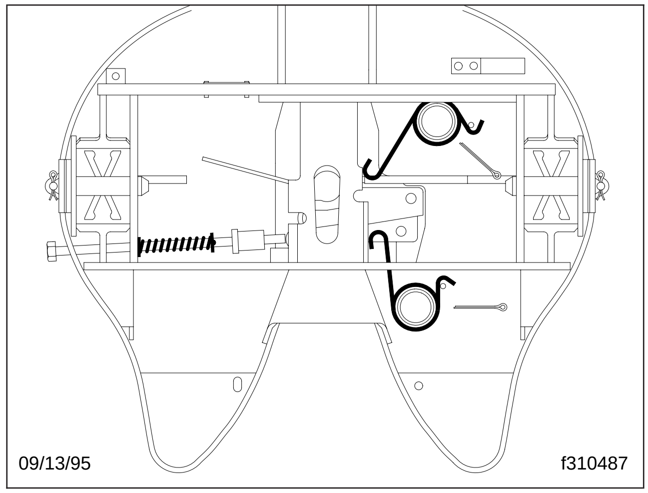


Fig. 3, Spring Installation

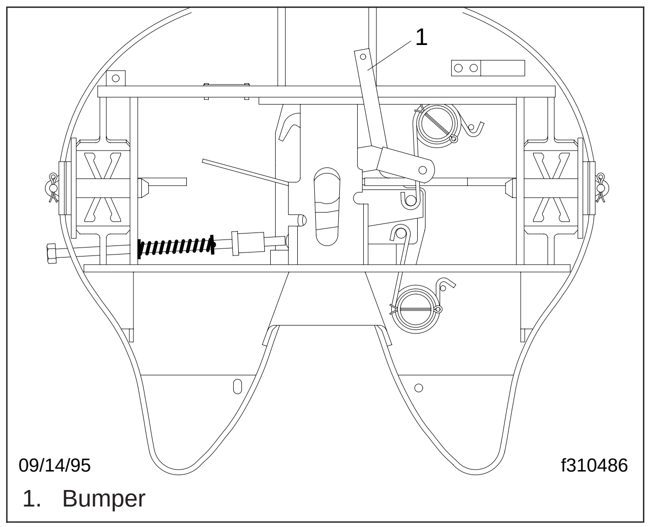


Fig. 4, Bumper Installation

6. Insert the timer over the jaw and wedge studs. the small hole on the timer fits over the jaw stud and the slotted hole fits over the wedge stud. Be certain the small bent arm of the timer is facing downward. See **Fig. 6**.
7. Slide the operating handle toward the center of the wheel to engage the handle with the studs on the jaw and wedge. Slide the top part first. This will ensure that the grooves on the operating handle are aligned with the studs. A correctly aligned operating handle should be in a vertical position once it goes over the studs. See **Fig. 7**.

Fifth Wheel Assembly and Installation

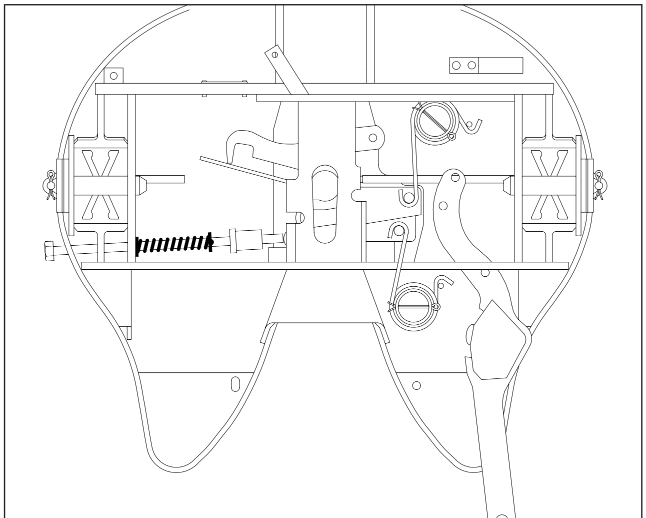
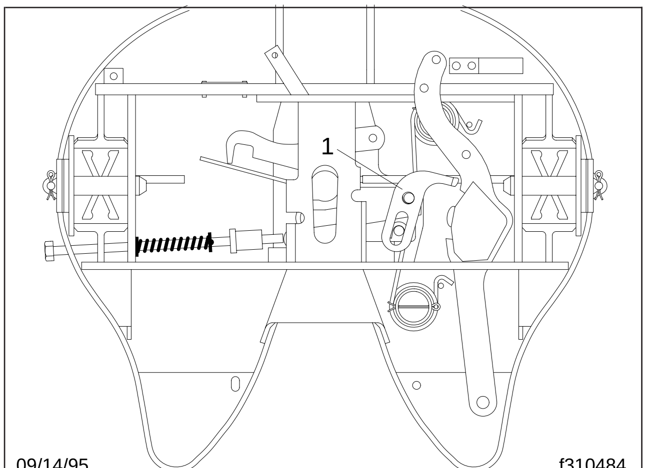


Fig. 5, Operating Handle Installation

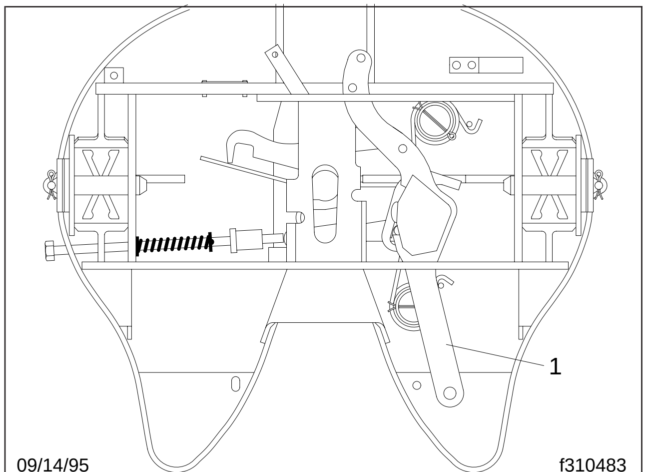


1. Timer

Fig. 6, Timer Installation

8. Slide the pull handle in through the safety lock and using the cotter pin and washer, fasten it in the top hole of the operating handle. See **Fig. 8**.

9. Align the bumper hole with the hole in the operating handle. Replace the bolts on the operating handle. The bolt which fastens the operating handle to the bumper must be inserted with the threads facing toward you to prevent interference with the jaw springs. The other bolt should be positioned with the threads facing downward. Each bolt has a nut, washer, and new bushings.



1. Operating Handle

Fig. 7, Operating Handle Positioning

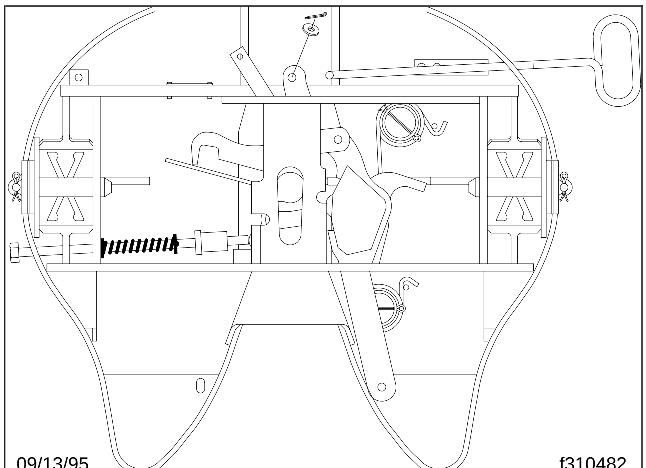


Fig. 8, Pull Handle Installation

Apply grease to the bolt parts and where there is metal to metal contact with the operating handle. See **Fig. 9**. Do not overtighten the bolts. Lubricate all pivot points.

IMPORTANT: The fifth wheel must be well lubricated to operate correctly. Refer to Group 31 of the *Business Class M2 Maintenance Manual* for complete maintenance and lubrication instructions for the fifth wheel assembly.

10. Connect the bumper spring to its clasp. Apply grease to the bracket pockets and to the grease fittings on the side of the fifth wheel until grease

Fifth Wheel Assembly and Installation

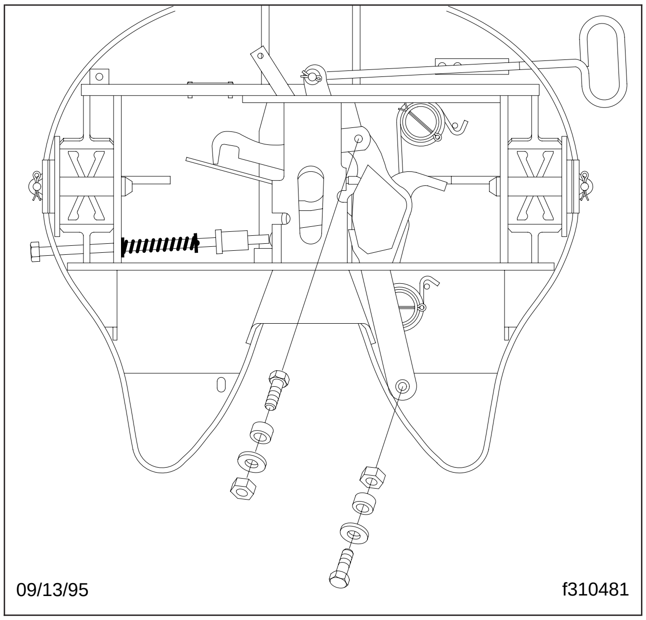
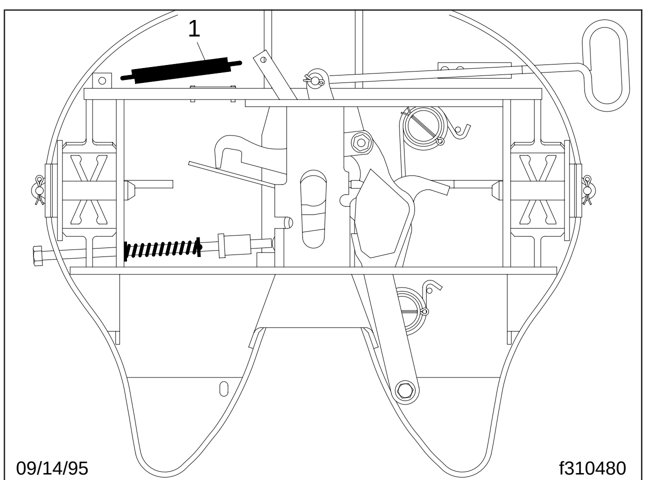


Fig. 9, Bolt Installation

flows into the upper brackets. Also apply a liberal amount of grease to the top plate. See **Fig. 10**.



1. Bumper Spring

Fig. 10, Spring Installation

WARNING

If the fifth wheel does not operate properly, do not use it. The fifth wheel could malfunction, resulting in personal injury or property damage due to possible disengagement of the trailer from the tractor.

11. Using an overhead hoist, position the fifth wheel on the sliding mount assembly. Insert the bushing pins. Install the retaining pins and the 1-inch-long cotter pins.

Troubleshooting Tables

Problem—Difficulty Coupling

Problem—Difficulty Coupling	
Possible Cause	**Remedy**
The kingpin is too high to trip the latch	Lower the landing gear.
The trailer plate or kingpin is damaged	Check the trailer plate for flatness. Check the kingpin for squareness with the trailer plate.

Problem—Excessive Wear on the Fifth Wheel Top Plate

Problem—Excessive Wear on the Fifth Wheel Top Plate	
Possible Cause	**Remedy**
Damaged trailer plate	If the trailer plate is not flat, replace it.

Problem—Difficulty Uncoupling

Problem—Difficulty Uncoupling	
Possible Cause	**Remedy**
Pressure on the locking mechanism caused by truck drifting apart from the trailer putting excess pressure on the lock	Back up the trailer and set the brakes. Strike the wedge stop rod which protrudes through the side of the fifth wheel. This spring-loaded rod will release the pressure on the locking mechanism.
Oval-shaped kingpin	Lower the landing gear.
Debris build-up in the grease	

Problem—Slack

Problem—Slack	
Possible Cause	**Remedy**
Undersized kingpin	Replace the kingpin if worn greater than 1/8 inch (3 mm) at the 2-inch (5-cm) diameter.
Worn jaw and wedge	Jaw and wedge could have excessive wear. Replace them.

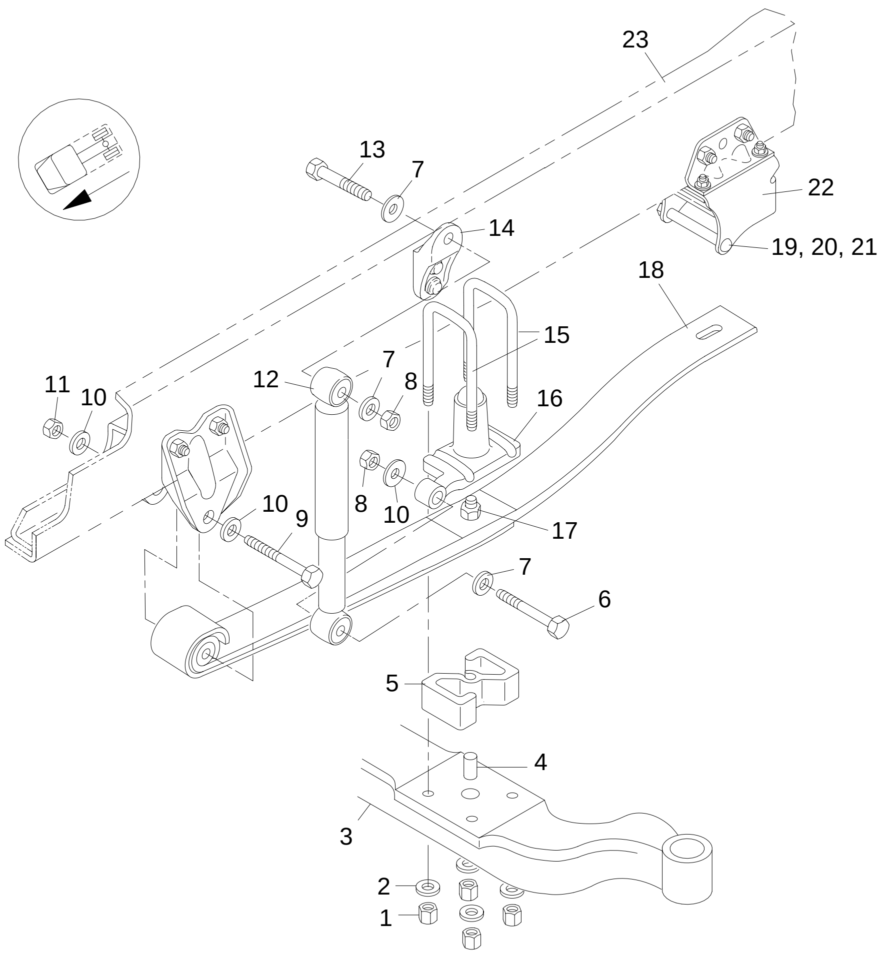
General Information

Freightliner Business Class M2 front suspensions use either a tapered leaf or a flat leaf assembly. The tapered leaf suspensions are available in varying capacities from 6,000-pound (2 722 kg) to 18,000-pound (8 165 kg). Shock absorbers are standard. The flat leaf suspensions are available in varying capacities from 14,600-pound (6 622 kg) to 18,000-pound (8 165 kg), and shock absorbers are optional.

The spring assemblies are attached to the axle with U-bolts, hardened washers, and high nuts. See **Fig. 1** and **Fig. 2**. The forward end of each spring mounts to a stationary front spring bracket. The rear of each spring mounts to either a spring shackle suspended from a frame-mounted bracket, or fits straight into the frame-mounted bracket, and is locked in place by a carriage bolt. See **Fig. 1**. The shackle or deflection pad allows for variations in spring length as the spring flexes.

The leaf spring assembly absorbs and stores energy over bumps, releasing it at a controlled rate to smooth the ride. Individual spring leaves are held together by a center bolt. Alignment clips limit the sideways spread and vertical separation of the individual leaves.

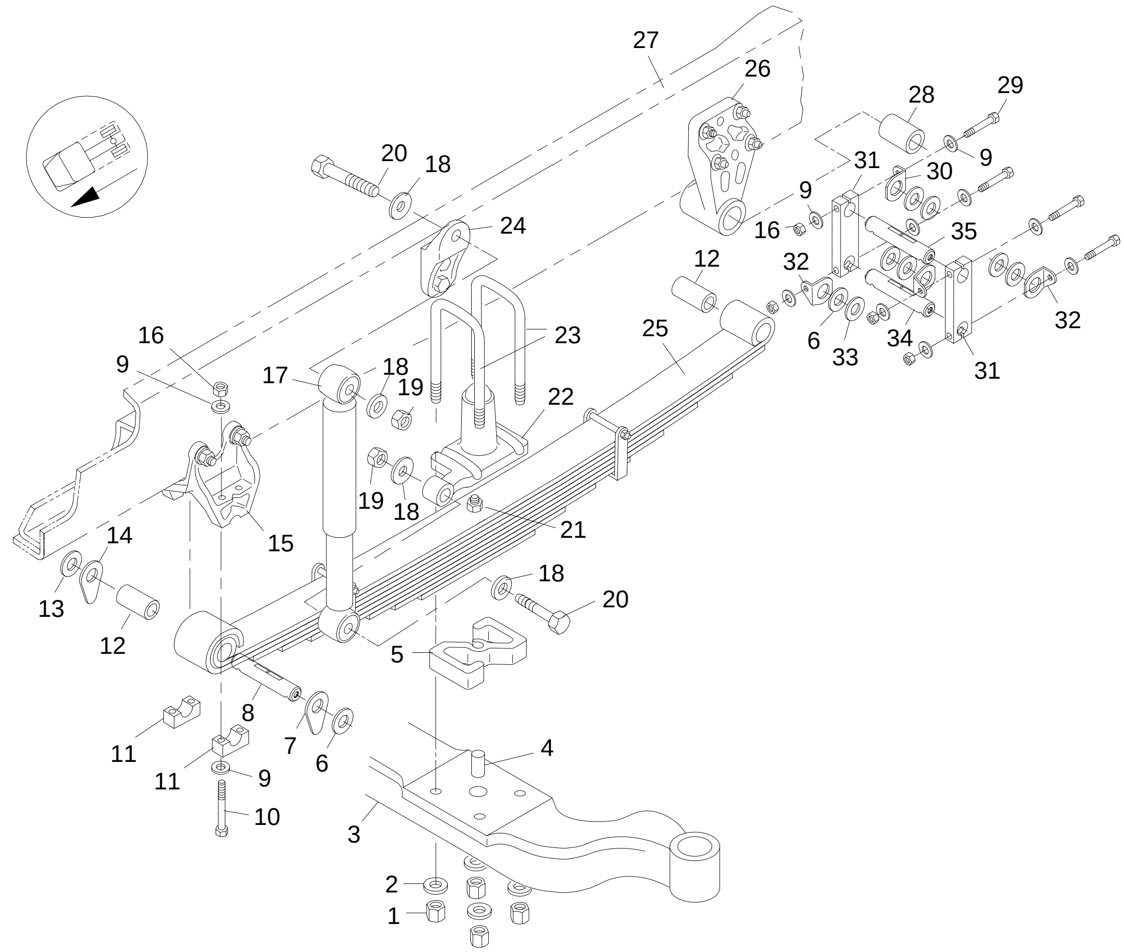
General Information



1. U-Bolt High Nut
2. Bearing Washer
3. Axle
4. Dowel
5. Spacer
6. Hexbolt, 3/4–10
7. Flatwasher
8. Hexnut, 3/4–10
9. Hexbolt, 3/4–10
10. Flatwasher
11. Hexnut, 3/4–10
12. Shock Absorber
13. Hexbolt, 3/4–10
14. Shock Absorber Upper Mounting Bracket
15. U-Bolts
16. Axle Stop and Shock Absorber Lower Mounting Bracket
17. Spring Center-Bolt and Nut
18. Leaf Spring (leaf-and-a-half)
19. Carriage Bolt, 1/2–13
20. Washer
21. Hexnut, 1/2–13
22. Rear Spring Hanger
23. Left Frame Rail

Fig. 1, Front Suspension (standard application)

General Information



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1. U-Bolt High Nut
2. Bearing Washer
3. Axle
4. Dowel
5. Spacer
6. Outboard Spacing Washer(s)
7. Outboard Spring Spacer
8. Spring Pin, Forward Spring Eye
9. Hardened Washer, 1/2–13
10. Hexbolt, 1/2–13 x 5"
11. Spring Pin Retainer
12. Spring-Eye Bushing
13. Hardened Washer
14. Inboard Spring Spacer
15. Front Suspension Bracket
16. Locknut, 3/4–10
17. Shock Absorber
18. Hardened Washer
19. Locknut, 3/4–10
20. Hexbolt, 3/4–10
21. Spring Center-Bolt and Nut
22. Axle Stop and Shock Absorber Lower Mounting Bracket
23. U-Bolt
24. Shock Absorber Upper Mounting Bracket
25. Leaf Spring
26. Shackle Bracket
27. Frame Rail
28. Shackle Bracket Bushing
29. Pinch Bolt, 1/2–13 x 4"
30. Inboard Wear Plate
31. Shackle
32. Outboard Wear Plate
33. Hardened Washer, 2-1/4" o.d.
34. Spring Pin, Rear Spring Eye
35. Shackle Bracket Pin

Fig. 2, Front Suspension with Bronze Bushings

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

Removal

1. Park the vehicle on a level surface. Shut down the engine, set the parking brakes, and chock the rear tires.
2. Tilt the hood.
3. Remove the front bumper end cap. For instructions, see **Group 31**.
4. Remove the wheel and tire for access to the leaf spring. For instructions, see **Group 40**.

IMPORTANT: Make sure the frame rails are level and an equal distance off the ground.

5. Raise the front of the vehicle until both wheels are off the ground and the frame is supported with safety stands. The axle and leaf springs can then be manipulated with the floor jack.
6. Support the frame and axle with safety stands.

WARNING

Use safety stands to securely support all axle and frame weight during suspension repairs. Unsecured components may drop when fasteners are loosened or removed, causing component damage and serious personal injury.

7. Remove the leaf spring assembly.

   NOTE: Leaf spring assemblies on vehicles with suspensions manufactured at 14,600-pound (6 622 kg) and 18,000-pound (8 165 kg) weight ratings have multiple leaf springs, heavy duty brackets, U-bolts, and other components.

   7.1 Remove the U-bolt high nuts and washers; then, remove the U-bolts.

   7.2 If so equipped, remove the shock absorber lower mounting bolt. Swing the shock absorber out of the way.

   7.3 If so equipped, remove the spring shackle lower bolt. See **Fig. 1**.

   If equipped with spring pins, remove the lower pinch bolts from the spring shackle.

   7.4 Remove the fasteners from forward spring eye.

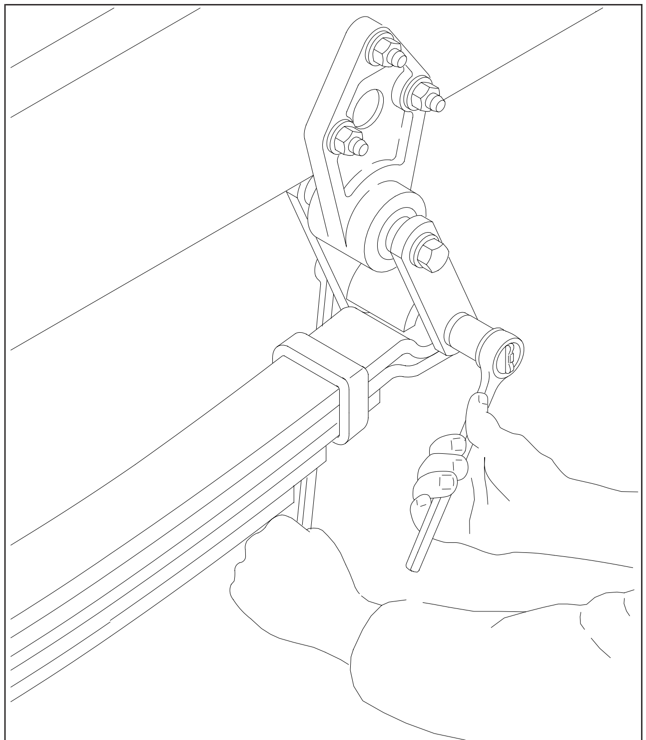


Fig. 1, Spring Shackle Lower Bolt Removal/Installation (typical)

   If equipped with spring bolts: Remove the bolt, nuts and washers from the forward spring eye. See **Fig. 2**.

   If equipped with spring pins: Remove the front spring pin by removing the fasteners holding the spring pin retainers in place. Remove the spring pin.

   NOTE: If removing the driver's side spring, the steering must be at right full-lock so the bolt can clear the drag link.

   7.5 Support the front axle with a jack. Remove the safety stand; then, lower the front axle enough to allow removal of the spring. Note the location of the spring spacer and any caster adjustment shims.

WARNING

The spring assembly is heavy. To prevent bodily injury, always use two people to remove it.

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

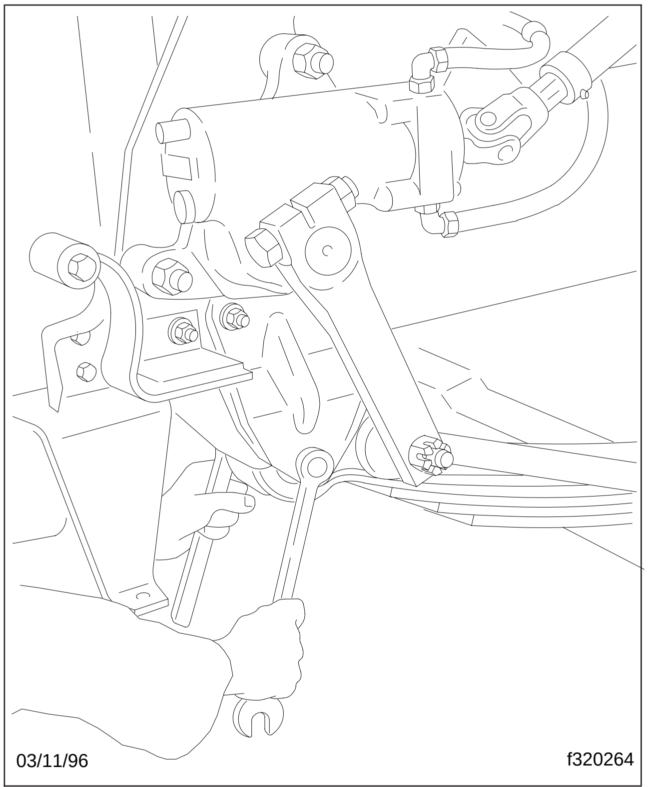


Fig. 2, Forward Spring Eye Bolt Removal/Installation (typical)

7.6 Remove the spring by sliding it toward the front of the vehicle. See **Fig. 3**.

8. If so equipped, remove the shackle upper bolt and nut. Press out the bushing. Remove the fasteners that hold the shackle bracket to the frame and remove the bracket.

Cleaning and Inspection

1. Using a wire brush and solvent or steam cleaning equipment, wash all parts to remove dirt, grease, and scale.

IMPORTANT: When using a solvent, follow all of the solvent manufacturer's warnings, cautions, and instructions.

2. Inspect all components for damage.

2.1 If so equipped, inspect the spring shackles and the shackle bracket for cracks, wear, and other damage. Replace any damaged parts.

2.2 Inspect the leaf spring assembly for cracks or corrosion. If any leaves are cracked or broken, replace the *entire spring assembly.*

WARNING

Do not replace individual leaves of a leaf spring assembly; replace the complete spring assembly. Visible damage (cracks or breaks) to one leaf causes hidden damage to other leaves. Replacement of only the visibly damaged part(s) is no assurance that the spring is safe. On front spring assemblies, if cracks or breaks exist in the two top leaves, a loss of vehicle control could occur. Failure to replace a damaged spring assembly could cause an accident resulting in serious personal injury or property damage.

2.3 If the protective coating is gone from some areas of the spring, paint the cleaned areas with a rust-inhibiting paint. If rusting or corrosion is severe, replace the spring assembly.

Installation

IMPORTANT: For normal highway operation do not install springs of two different designs or load capacities on the front axle. In order to maintain a balanced front suspension system, install identical spring assemblies.

1. If the shackle bracket was removed, install it. Tighten the mounting bolts 135 lbf·ft (183 N·m).

NOTE: All suspension bracket (frame) fasteners require periodic retightening. Refer to Group 00 of the *Business Class M2 Maintenance Manual* for the recommended intervals.

2. If the spring shackle was removed, install it. Don't tighten the upper bolt in the shackle at this time.

WARNING

The spring assembly is heavy. To prevent injury, always use two people to install it.

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

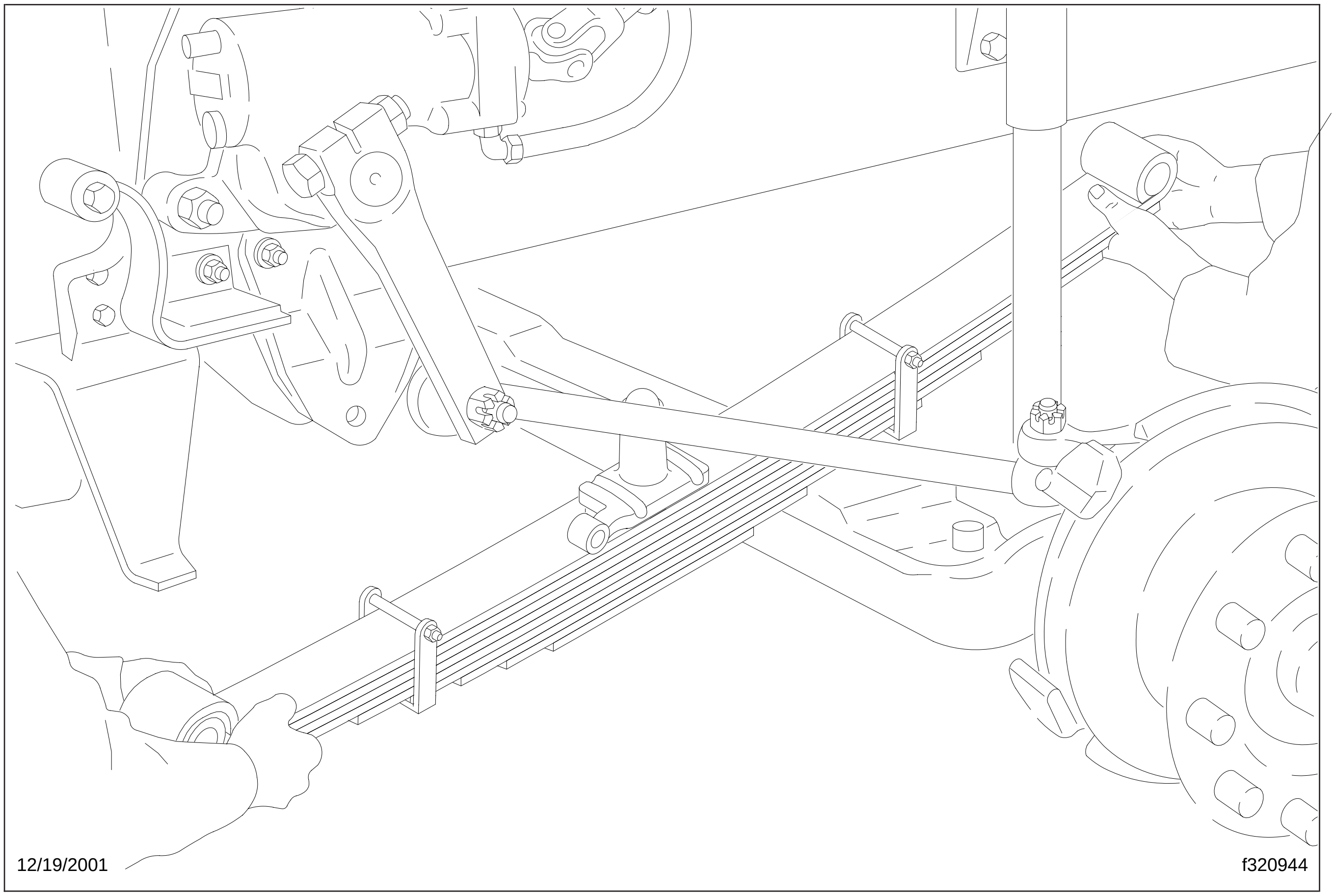


Fig. 3, Spring Removal/Installation (typical)

3. Install the spring assembly.

   NOTE: Leaf spring assemblies on vehicles with suspensions manufactured at 14,600-pound (6 662 kg) and 18,000-pound (8 165 kg) weight ratings have multiple leaf springs, heavy duty brackets, U-bolts, and other components.

   3.1 Lift the spring into position. See **Fig. 3**

   3.2 Install the fasteners into the forward spring eye.

   If equipped with spring bolts: Install the mounting bolt and washer into the forward spring eye. Install the other washer and nut. Tighten 240 lbf·ft (325 N·m).

   If equipped with spring pins: Install the spring pin into the forward spring eye. Install the spring pin retainers. Tighten the fasteners 250 lbf·ft (339 N·m).

   3.3 Install the fasteners into the rear spring eye.

   If equipped with spring bolts: Install the lower shackle bolt, nut and washers. Tighten the upper and lower bolts 240 lbf·ft (325 N·m).

   If equipped with spring pins: Install the lower spring pin assembly through the spring eye and the lower shackle. Install the pinchbolts into the bottom of the shackle.

   Tighten the upper and lower shackle pinch bolts 45 lbf·ft (61 N·m), for aluminum shackles, or 70 lbf·ft (95 N·m) for steel shackles.

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

3.4 Apply Alumilastic® or a similar compound to the top and bottom of the spring spacer and any caster adjustment shims.

CAUTION

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel parts contact each other, could lead to corrosion of the metals, resulting in damage to suspension parts.

3.5 Place the dowel, caster adjustment shim, and the spring spacer on the axle.

3.6 Place the axle stop/shock absorber lower mounting bracket in position on the leaf spring.

3.7 Using a jack, lift the axle into position.

3.8 Install the U-bolts over the shock absorber lower mounting bracket, the spring leaves, spring spacer, caster adjustment shims, and through the front axle.

3.9 Install the high nuts on the U-bolts and tighten them as described in **Specifications 400**.

4. Attach the shock absorber to its lower mounting bracket. Tighten the nut 140 lbf·ft (190 N·m).
5. Remove the floor jack and safety stands.
6. Install the wheel and tire. See **Group 40** for instructions.
7. Install the front bumper end cap. See **Group 31** for instructions.
8. Lower the hood, and remove the chocks from the tires.

Shackle Bracket Bushing Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brakes, and chock the rear tires.
2. Tilt the hood.
3. Remove the front bumper end cap. For instructions, see **Group 31**. Remove the wheel and tire for access to the leaf spring. For instructions, see **Group 40**.
4. Remove the shackle bracket from the vehicle.
   4.1 Jack up the frame until the shackle lower bolt can be removed. Remove the bolt.
   4.2 Remove the shackle upper bolt and the spring shackle.
   4.3 Remove the shackle bracket from the frame.
5. Using a press, remove the bushing from the shackle bracket.
6. Inspect the shackle bracket and new bushing.
   6.1 With an inside micrometer or bore gauge, check whether the bracket bore is out-of-round. Replace the bracket if the bushing bore is out-of-round.
   6.2 Before installing the new bushing, check the shackle bracket bolt for ease of fit in the bushing. There should be an easy slip fit without wobble between the bolt and the bushing.
7. Using a press, insert the new bushing into the bracket until the bushing is centered in the bracket.

IMPORTANT: Do not press in the bushing by the center sleeve. This could damage the bushing.

8. Check the shackle bracket bolt again for ease of fit in the bushing. It should still fit easily without wobble between the bolt and the bushing. If it binds, the bushing may have been distorted during installation. Replace the bushing and check again for proper fit.
9. Install the shackle bracket. Install the fasteners and tighten them 135 lbf·ft (183 N·m).
10. Connect the leaf spring.
    10.1 Install the spring shackle and the shackle upper bolt.
    10.2 Adjust the height of the jack supporting the frame until the bushing at the rear of the leaf spring lines up with the hole for the shackle lower bolt.
    10.3 Install the shackle lower bolt. Tighten it 240 lbf·ft (325 N·m).
11. Install the wheel and tire. For instructions, see **Group 40**.
12. Install the front bumper end cap. For instructions, see **Group 31**.
13. Lower the hood and remove the chocks from the tires.

Spring Bushing Replacement

1. Remove the leaf spring from the vehicle. See **Subject 100** for instructions.
2. Using a press, remove the worn or damaged bushing.
3. Using a press, insert the new bushing into the spring eye until the bushing is flush with the edges of the spring eye.

IMPORTANT: Do not press in the bushing by the center sleeve. This could damage the bushing.

4. Install the leaf spring. See **Subject 100** for instructions.

Replacement

1. Apply the parking brake, chock the rear tires, and tilt the hood.
2. Remove the shock absorber.
   - 2.1 Remove the locknut from the shock absorber upper mount; then, remove the 3/4–10 hexbolt and washers.
   - 2.2 Remove the locknut from the shock absorber lower mount; then, remove the 3/4–10 hexbolt and washers.
   - 2.3 Remove the shock absorber.
3. Install the new shock absorber. Tighten the locknuts 140 lbf·ft (190 N·m).
4. Lower the hood, and remove the chocks from the tires.

Vehicle Lean Inspection

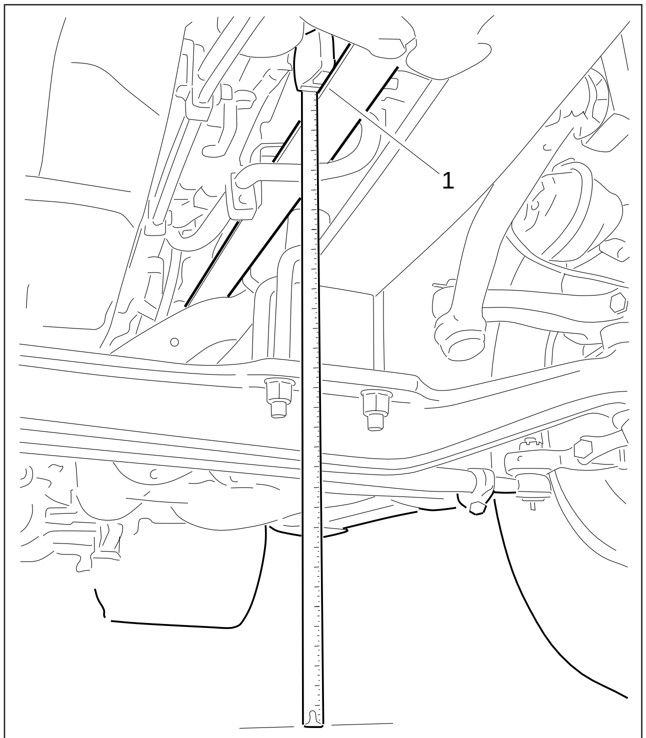
IMPORTANT: Chassis lean can be caused by several factors such as uneven vehicle weight distribution, mismatched springs, or improper spacer installation. The following instructions detail inspecting for and correcting chassis lean due to improper spring or spacer installation. Additional troubleshooting procedures may also be found at the **Hendrickson** website: **www.hendrickson-intl.com/literature/pdfs_tech_airtek_freightliner.asp**.

1. Park the vehicle on a level surface with the wheels pointing straight ahead. Set the parking brake, turn off the engine, and chock the tires. When exiting the vehicle, try not to rock the vehicle.

NOTE: The vehicle should be unloaded when performing the following inspection.

2. Check tire pressure and tire size. Pressures should be within 2 psi of each other. Tire size should be the same on each axle.
3. Check that the rear axle alignment and rear suspension ride height are within specification. Refer to the applicable sections in **Group 32** or **Group 35** in this manual.
4. Check the springs, bushings and spring mounting hardware for damage. Replace damaged components before checking for chassis lean.
5. Measure the weight of the vehicle at each wheel position. Weight imbalance will cause the vehicle to lean. If the vehicle weight differs from side to side, check the cab alignment and the fuel tank levels, and correct if necessary.
6. Measure the distance from the bottom of the lower frame flange to the ground, forward of the front axle center line. This is frame height. See **Fig. 1**.
7. If the frame height differs from side to side by 3/8 inch (9.53 mm) or more, inspect the spring part numbers, and (if present) markings on the top side of the springs with a label marking plus (+) or minus (–). Verify that both spring labels match.

   If the labels or part numbers do not match, replace one or both springs so the vehicle has matching springs. See **Fig. 2**.



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1. Lower Frame Flange

Fig. 1, Measuring Frame Height

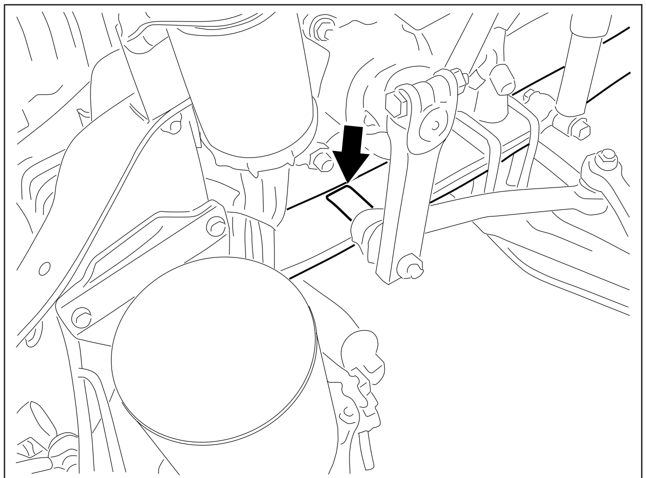

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Fig. 2, Spring Label Location

8. Measure the height difference at the end of the frame rails to ground. If this measurement is greater than 3/8 inch (9.53 mm), the front axle

Troubleshooting

spacer adjustments will have minimal effect on lean and other actions are required. If the end of frame to ground measurements are less than 3/8 inch (9.53 mm) difference, correct the lean by increasing the low side front axle spacer thickness by no more than 1/2 inch (13 mm). Use a 45, 55, or 65-mm spacer in place of the existing spacer.

See **Table 1** for parts information.

9. Check the frame height again. If the difference between measurements is still equal to or greater than 3/8 inch (9.53 mm), swap springs from side to side and check the measurements again.

   If the chassis lean is still the same, the problem is with the vehicle. If the lean has changed sides, replace both springs.

10. **Figure 3** represents a checklist for weak or sagging springs.

    Use this checklist as the information may be requested when filing a warranty claim.

Parts Information		
Part Description	**Part Number**	**Quantity**
Axle Spacer, 45 mm	16-15105-040	As Required
Axle Spacer, 55 mm	16-15105-055	As Required
Axle Spacer, 65 mm	16-15105-065	As Required

Table 1, Parts Information

Troubleshooting Tables

Problem—Vehicle Wanders

Problem—Vehicle Wanders	
Possible Cause	**Remedy**
One or more spring leaves are broken.	Replace the spring assembly.
The wheels are out of alignment.	Adjust the wheel alignment using the instructions in **Group 33** of this manual.
Caster is incorrect.	Install correct caster shims. Refer to **Group 33** of this manual for specifications.
Steering gear is not centered.	Adjust steering using the instructions in **Group 46** of this manual.
Drive axles are out of alignment.	Align the drive axles using the instructions in **Group 35** of this manual.

Problem—Vehicle Bottoms Out

Problem—Vehicle Bottoms Out	
Possible Cause	**Remedy**
Excessive weight on the vehicle is causing an overload.	Reduce the loaded vehicle weight to the maximum spring capacities.
One or more spring leaves are broken.	Replace the spring assembly.
The spring assembly is weak or fatigued.	Replace the spring assembly.

Problem—Frequent Spring Breakage

Problem—Frequent Spring Breakage	
Possible Cause	**Remedy**
The vehicle is overloaded or operated under severe conditions.	Reduce the loaded vehicle weight to the maximum spring capacities. Caution the driver on improper vehicle handling.
There is insufficient torque on the U-bolt high nuts.	Torque the U-bolt high nuts to the value listed in the torque table in **Specifications, 400**.

Problem—Frequent Spring Breakage	
Possible Cause	**Remedy**
A loose center bolt is allowing the spring leaves to slip.	Check the spring leaves for damage. If damaged, replace the spring assembly. If not, tighten the center-bolt nut to the value listed in torque table in **Specifications, 400**.
Worn or damaged spring pin bushings are allowing spring end-play.	Replace the spring pin and bushing.

Problem—Noisy Spring

Problem—Noisy Spring	
Possible Cause	**Remedy**
A loose U-bolt nut or center bolt is allowing spring leaf slippage.	Inspect the components for damage. Replace damaged components as necessary. Torque the fasteners to the values listed in the torque table in **Specifications, 400**.
A loose, bent, or broken spring shackle or front suspension bracket is impairing the spring flex.	Inspect the shackles and brackets for damage. Replace damaged components as necessary. Torque the fasteners to the values listed in the torque table in **Specifications, 400**.
Worn or damaged spring pins are allowing spring end-play.	Replace any worn or damaged spring pins.

Problem—Rough Ride

Problem—Rough Ride	
Possible Cause	**Remedy**
Refer to the applicable suspension section in this manual.	

Troubleshooting

The following is a checklist for weak or sagging springs. This information may be requested when filing for warranty.

Conditions

☐ Is the ground level?

(If ground is not level move the truck to a level location)

☐ Is the vehicle loaded?

(Vehicle should be measured unloaded)

☐ Are the spring part numbers the same?

(Part numbers should be the same)

☐ Is there any visible damage to the spring or bushings?

(Any damage to the springs, bushings, shocks, or suspension brackets should be repaired)

Tires

☐ Are the tire pressures and sizes the same?

(Tire pressure should be within 2 psi from side to side)

☐ Do the tires have the same amount of wear?

☐ Are the tires the same size?

Measurements

☐ Measure the distance from the floor to the bottom of the frame rail on each side of the truck as close to the front axle as possible.

Passenger Side __________

Driver Side __________

(Measurements should be within 3/8” from side to side)

Weight

☐ Measure the weight of the vehicle at each forward axle position.

Passenger Side __________

Driver Side __________

(Weight should be equal from side to side. If weight is more on one side, check that the cab is centered on the frame rails, and if equipped with dual tanks, that the fuel level is equal on both sides. Due to the many options available for mounting components, the vehicle may have a weight bias to one side. If the vehicle does have a weight bias to one side, the spring can be shimmed to level the vehicle.)

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Fig. 3, Checklist for Weak or Sagging Springs

Front Suspension Fastener Torque Values		
Description	**Size**	**Torque: lbf·ft (N·m)**
Shackle Bracket-to-Frame Locknut	3/4–10	240 (325)
Spring Shackle Pinch-Bolt Locknuts	1/2–13	Aluminum Shackles: 45 (61) Steel Shackles: 70 (95)
Spring Pin Retainer Hexbolts	1/2–13	60–76 (81–103)
Forward Spring-Eye Bolt	3/4–10	240 (325)
Upper and Lower Shackle Bolt	3/4–10	240 (325)
Axle U-bolt High Nuts (Tighten in a diagonal pattern as shown in **Fig. 1**.)	5/8–18	Stage 1: Hand tighten Stage 2: 60 (81) Stage 3: 180–230 (245–313)
	3/4–16	Stage 1: Hand tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 270–330 (367–449)
	7/8–14	Stage 1: Hand tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 420–500 (571–680)
Shock Absorber Upper and Lower Mounting Locknuts	3/4–10	140 (190)

Table 1, Front Suspension Fastener Torque Values

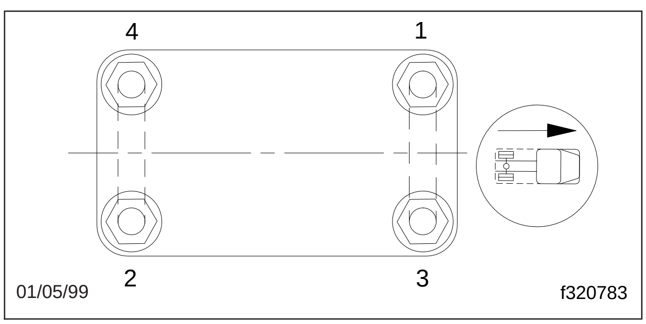


Fig. 1, Tightening Pattern for U-bolt High Nuts

General Information

The rear leaf-spring suspension for Business Class M2 vehicles uses either 60-inch taper-leaf or 52-inch multi-leaf springs with varying capacities. See **Fig. 1**, **Fig. 2**, **Fig. 3** or **Fig. 4**.

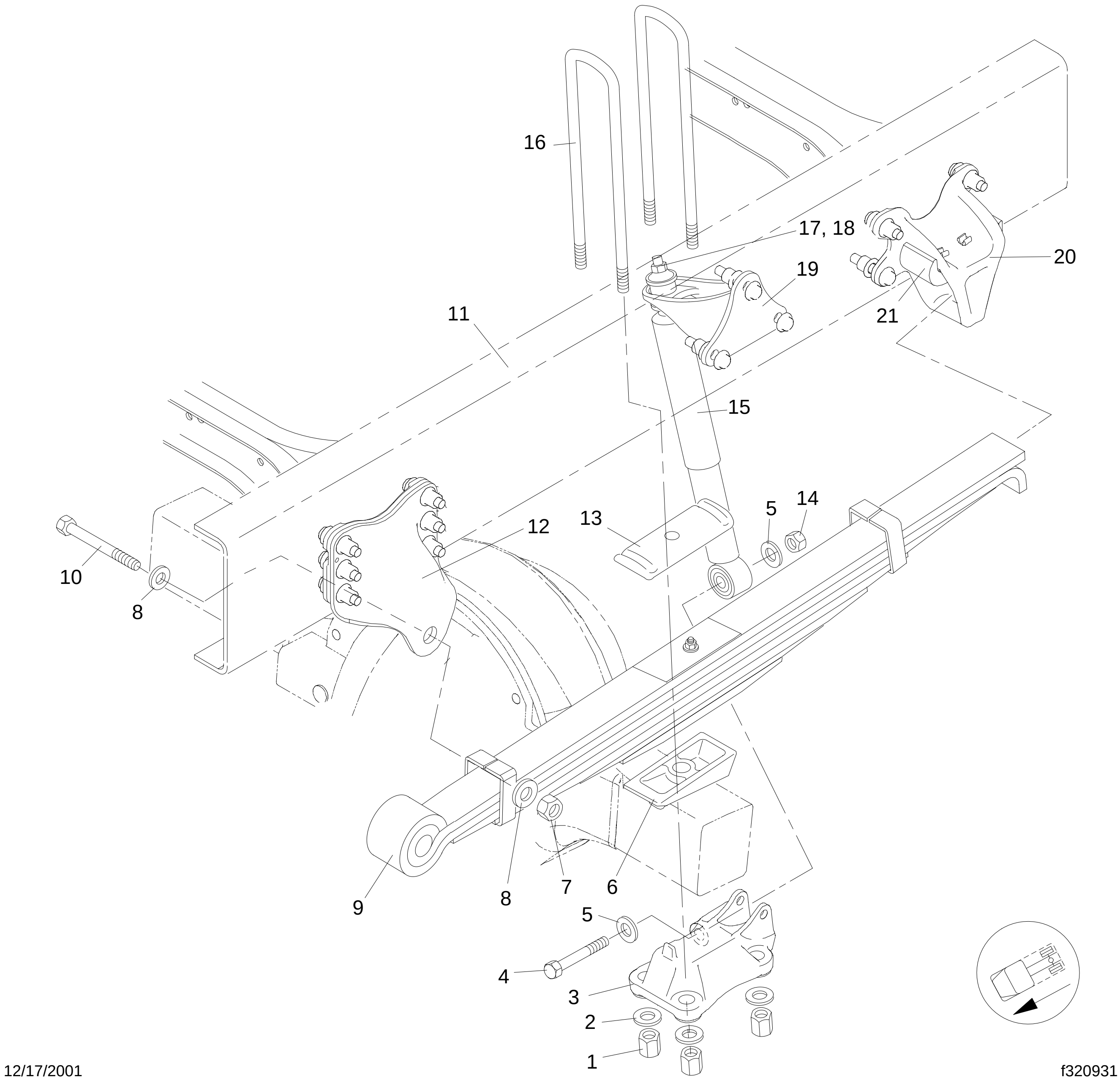
Taper-leaf springs have shackles and pins to secure the rear spring end, while multi-leaf spring applications use a slip spring design in which the rear spring end rides in a cast iron bracket mounted on the frame rail.

The 52-inch multi-leaf spring suspension is available with a rubber or leaf-spring helper. A rubber helper is standard with the 60-inch taper-leaf spring suspension.

Both types of helper provide additional spring rate for extra load-carrying capacity and increased roll stability.

Both types of spring assemblies are attached to the axle with U-bolt assemblies. Shock absorbers are optional with the 52-inch multi-leaf suspension, and are standard with the 60-inch taper-leaf suspension.

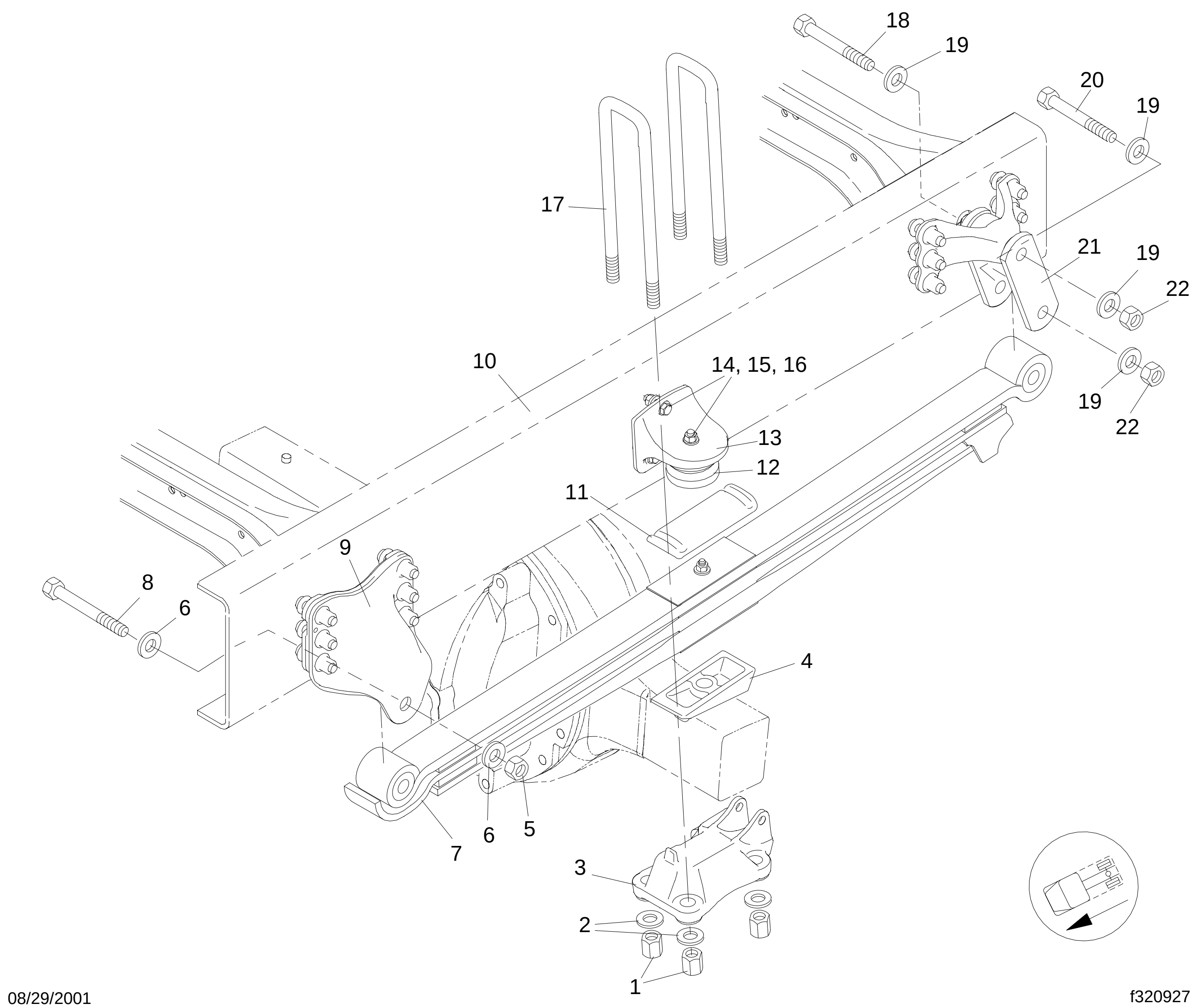
General Information



1. U-Bolt High Nut (4 qty.)
2. Flatwashers
3. U-Bolt Retainer
4. Lower Shock Absorber Bolt
5. Flatwasher
6. Axle Seat
7. Hexnut, 3/4–10
8. Flatwasher
9. Leaf Spring Assembly
10. Forward Spring-Eye Bolt
11. Left Frame Rail
12. Forward Spring Hanger
13. U-Bolt Pad
14. Hexnut, 3/4–10
15. Shock Absorber
16. U-Bolt
17. Hexnut, 5/8–18
18. Flatwasher
19. Upper Shock Absorber Bracket
20. Rear Spring Hanger
21. Wear Pad

Fig. 1, 52-Inch Multi-Leaf Spring Suspension (with optional shock absorbers)

General Information

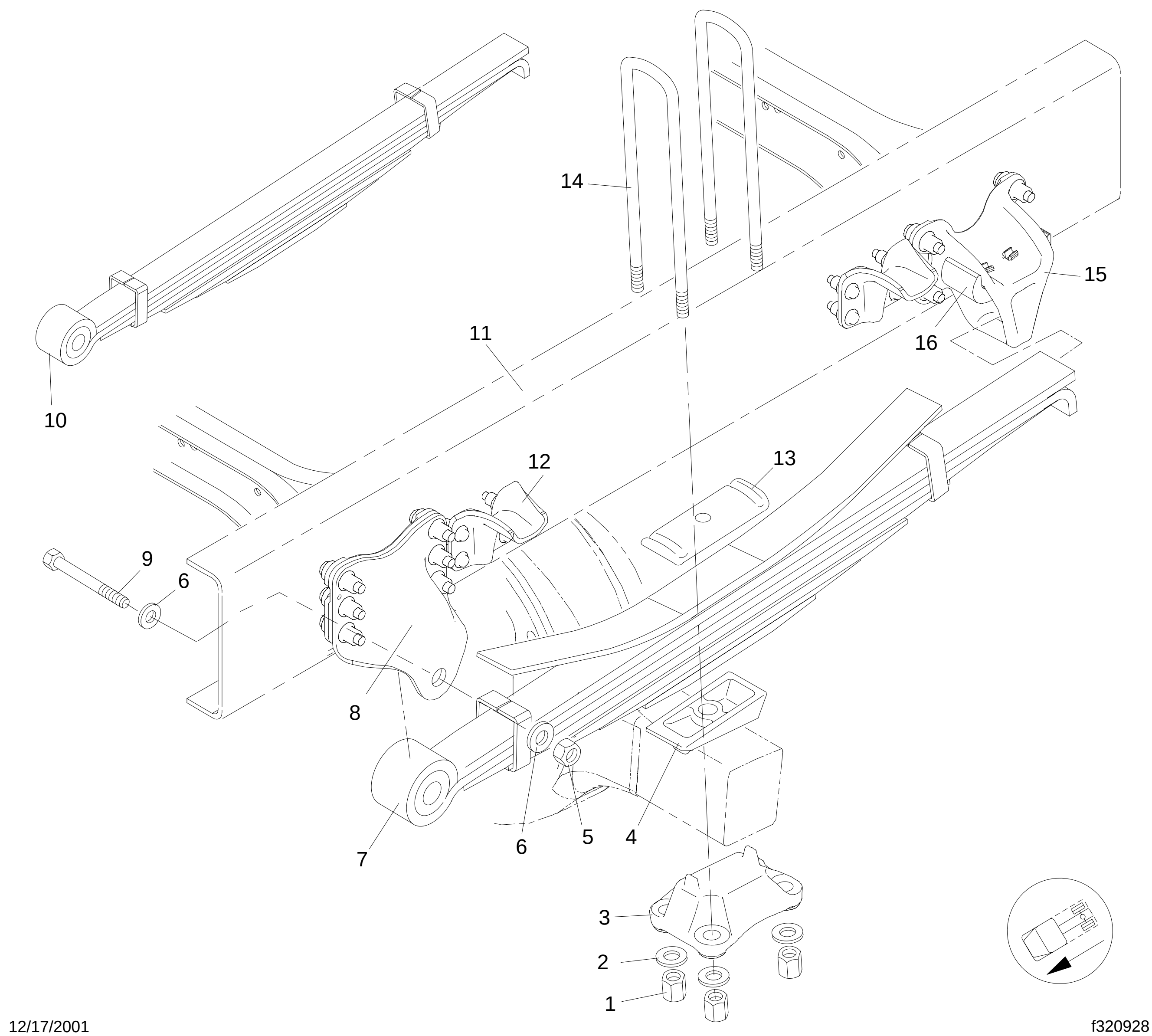


NOTE: Shock absorbers (standard with this suspension) not shown.

1. U-Bolt High Nuts
2. Flatwashers
3. U-Bolt Retainer
4. Axle Seat
5. Hexnut, 3/4–10
6. Flatwasher
7. Leaf Spring Assembly
8. Forward Spring-Eye Bolt
9. Forward Spring Hanger
10. Left Frame Rail
11. U-Bolt Pad
12. Rubber Helper
13. Helper Bracket
14. Hexbolt, 1/2–13
15. Hexnut, 1/2–13
16. Flatwasher
17. U-Bolts
18. Upper Shackle Bolt
19. Flatwasher
20. Lower Shackle Bolt
21. Rear Spring Shackle
22. Hexnut, 3/4–10

Fig. 2, 60-Inch Taper-Leaf Spring Suspension

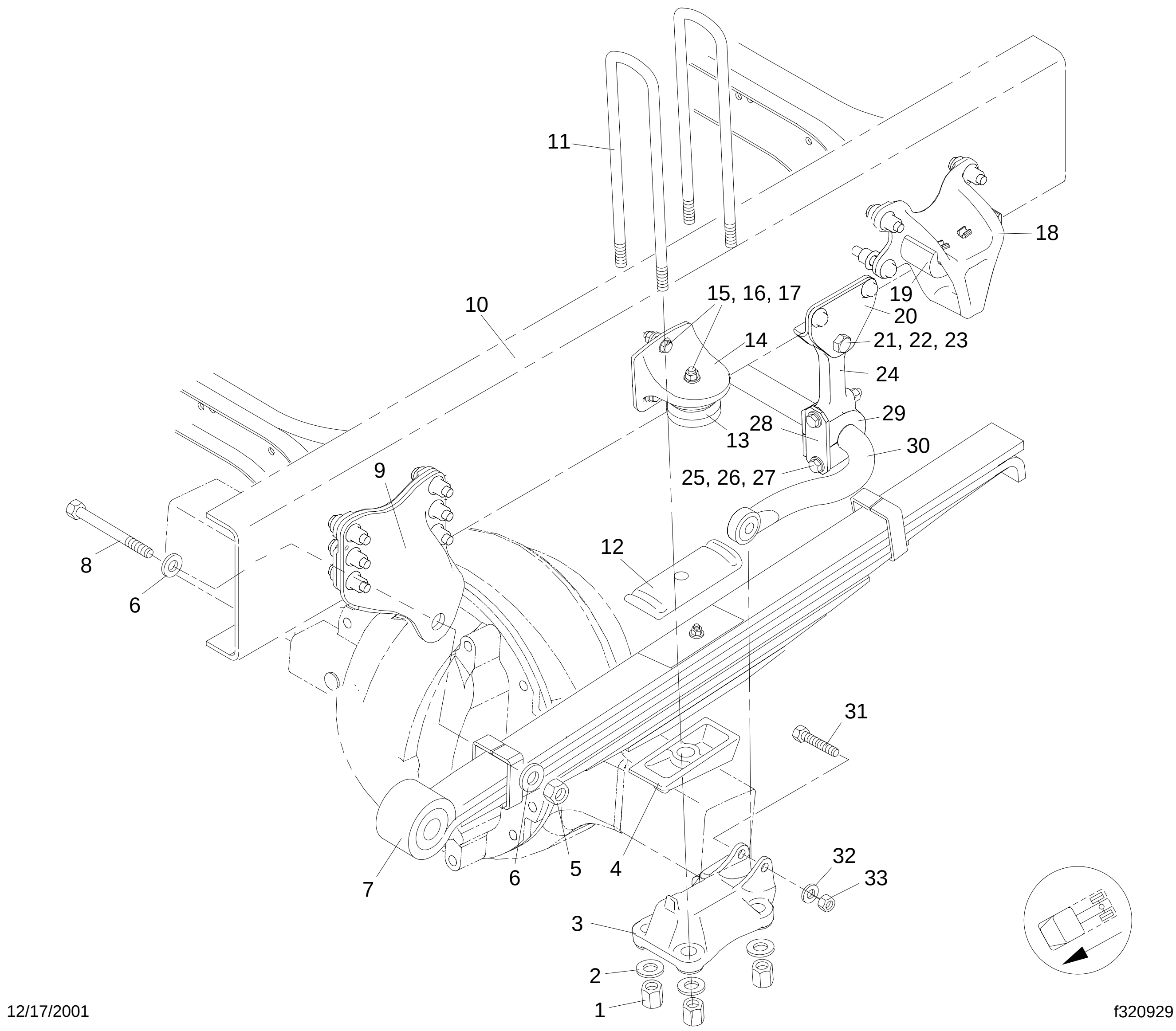
General Information



1. U-Bolt High Nut (8 qty.)
2. Flatwashers
3. U-Bolt Retainer
4. Axle Seat
5. Hexnut, 3/4–10
6. Flatwasher
7. Leaf Spring (with helper)
8. Forward Spring Hanger
9. Forward Spring-Eye Bolt
10. Leaf Spring (no helper)
11. Left Frame Rail
12. Spring Stop
13. U-Bolt Pad
14. U-Bolt Hexbolt
15. Rear Spring Hanger
16. Wear Pad

Fig. 3, 52-Inch Multi-Leaf Spring Suspension

General Information



1. U-Bolt High Nuts
2. Flatwashers
3. U-Bolt Retainer
4. Axle Seat
5. Hexnut, 3/4–10
6. Flatwasher
7. Leaf Spring Assembly
8. Forward Spring-Eye Bolt
9. Forward Spring Hanger
10. Left Frame Rail
11. U-Bolt
12. U-Bolt Pad
13. Rubber Helper
14. Helper Bracket
15. Hexnut, 1/2–13
16. Hexbolt, 1/2–13
17. Flatwasher
18. Rear Spring Hanger
19. Wear Pad
20. Stabilizer Link Bracket
21. Hexbolt, 5/8–11
22. Hexnut, 5/8–11
23. Flatwasher
24. Stabilizer Bar Link
25. Hexbolt, 1/2–13
26. Hexnut, 1/2–13
27. Flatwasher
28. Strap
29. Stabilizer Bar Bushing
30. Stabilizer Bar
31. Hexbolt, 5/8–11
32. Flatwasher
33. Hexnut, 5/8–11

Fig. 4, 52-Inch Multi-Leaf Spring Suspension (with optional rubber helper and stabilizer bar)

Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brakes and chock the front tires.
2. Remove the rear tires. For instructions, see **Group 40**.

WARNING

Use safety stands to securely support all axle and frame weight during suspension repairs. Unsecured components may drop when fasteners are loosened or removed, causing component damage and serious personal injury.

3. Lift the rear axle and support it with safety stands. Lift the vehicle frame to take weight off the rear springs.
4. Remove the U-bolt high nuts; then remove the U-bolts.
5. Remove the spring assembly.
   - 5.1 If the vehicle is equipped with the optional helper spring, lift it off.
   - 5.2 If equipped with rear shackles, remove the lower shackle bolt.
   - 5.3 Remove the front spring-eye bolt.
   - 5.4 Slide the leaf spring assembly forward and remove it from the vehicle.
6. For 52-inch multi-leaf suspensions, inspect the wear pads for wear. Replace them if needed. For instructions, see **Subject 120**.
7. Install the new spring assembly.
   - 7.1 *For 52-inch multi-leaf springs only,* slide the rear end of the spring into the rear spring hanger.
   - 7.2 Position the new spring on the axle seat.

   NOTE: It may be necessary to raise the frame slightly.

   - 7.3 Lower the frame or raise the axle until the front spring eye lines up with the hole in the forward spring bracket.
   - 7.4 Install the foward spring-eye bolt, nut and washers. Make sure the bolt is inboard. Tighten 240 lbf·ft (325 N·m).
   - 7.5 If equipped with the optional helper leaf spring, place it on the main spring.
   - 7.6 For 60-inch taper-leaf springs, raise the spring assembly until the rear spring eye is lined up with the lower shackle holes. Install the shackle fasteners, making sure the bolt head is inboard. Tighten 240 lbf·ft (325 N·m).
8. Install the U-bolts and the U-bolt retainer. Make sure the taller end of the retainer is toward the front of the vehicle.
9. Install the U-bolt high nuts, but don't tighten yet.
10. Tighten the U-bolt high nuts in sequence. See **Specifications 400** for complete instructions.
11. Install the rear tires. For instructions, see **Group 40**.
12. Raise the vehicle, remove the jack or safety stands from the rear axle and the frame, then lower the vehicle
13. Remove the chocks from the tires.

Shock Absorber Replacement

Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brakes, and chock the tires.
2. Remove the locknut, retainers, and bushings (if applicable) from the shock absorber lower mount.
3. Remove the fasteners from the shock absorber upper mount.
4. Remove the shock absorber.
5. Install the replacement shock absorber.
6. Install the capscrew and locknut in the upper mount. Hand-tighten them at this time.
7. Install the replacement bushings, retainers, and locknut.

WARNING

Use only the retainers included with the replacement shock absorber. Do not use washers. They can be pushed over the nut and be ejected violently, possibly causing personal injury and property damage.

8. Tighten the shock absorber upper mounting locknut until the rubber bushings expand to the same size as the retainer washer.
9. Tighten the shock absorber lower mounting fasteners to 240 lbf·ft (325 N·m).
10. Remove the chocks from the tires.

Wear Pad Replacement

Replacement

NOTE: Wear pads, used only on 52-inch multi-leaf suspensions, can be replaced without removing the leaf spring assemblies. They are located on the rear spring hangers.

1. Park the vehicle on a level surface, shut down the engine, set the parking brakes, and chock the front tires.
2. Using a floor jack or a crane, take the weight off the frame rail so there is no contact between the spring and the wear pad.
3. Using a suitable pair of pliers, pinch the tabs of the wear pad together and push them out of the slot in the upper part of the rear spring hanger. Remove and discard the wear pad.
4. Install the new wear pad so that the thicker portion of the pad is toward the axle. Pinch the tabs together so they fit through the slot in the spring hanger. Push the wear pad up into place.
5. Lower the frame rail.
6. Remove the chocks from the tires.

Specifications

Torque Values			
Description	**Size**	**Grade**	**Torque lbf·ft (N·m)**
Forward Spring Bolt *	3/4–10	—	240 (325)
Rear Spring Shackle Bolts *	3/4–10	—	240 (325)
Axle U-Bolt High Nuts †	5/8–18 (10 to 16,000-lb. ratings)	C	Stage 1: Hand tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 180 to 230 (245 to 313)
	7/8–14 (18 to 23,000 lb.-ratings)	C	Stage 1: Hand tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 420 to 500 (570 to 678)
Helper Bracket Hexbolts	1/2–13	—	68 (92)
Shock Absorber Lower Locknuts ‡	—	C	240 (325)

* Cadmium-plated, wax-coated nuts, and grade 8 hexbolts with phosphate- and oil-coated threads; both used with hardened washers.
† Tighten in a diagonal pattern as shown in **Fig. 1**.
‡ See **Subject 110** for shock absorber upper locknut tightening instructions.

Table 1, Torque Values

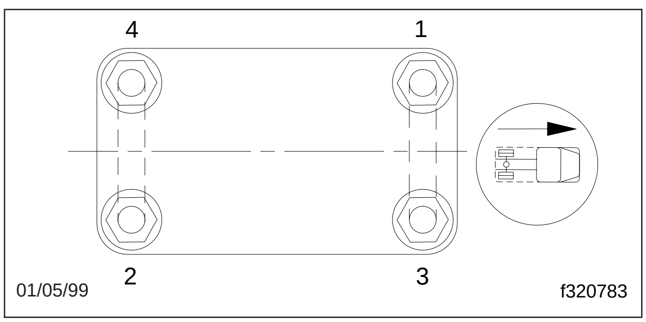


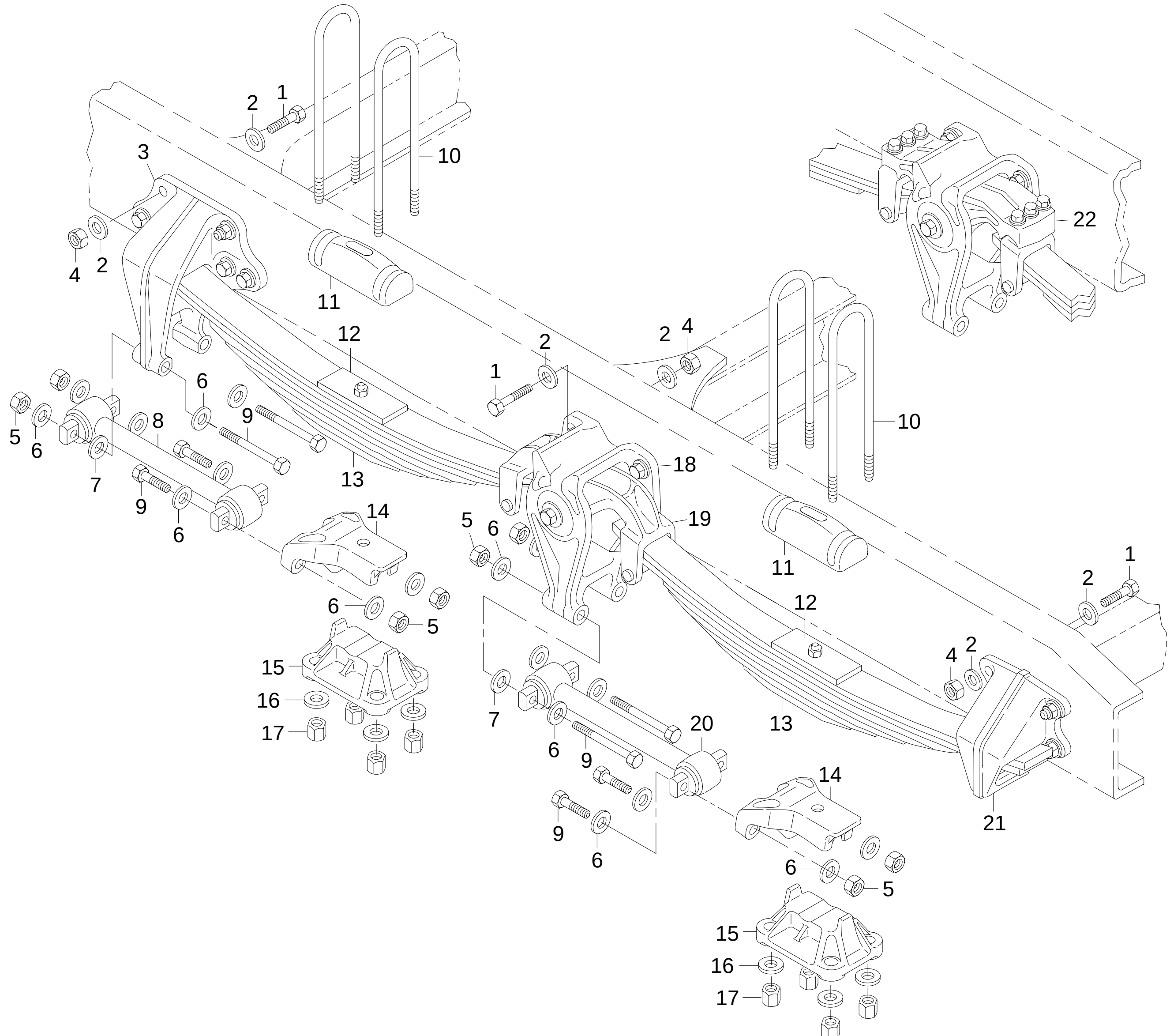
Fig. 1, Tightening Pattern for U-bolt High Nuts

General Information

The tandem-axle rear spring suspension uses a six-point equalizing leaf spring design, which compensates for axle articulation, from side-to-side, and front-to-rear. See **Fig. 1**. Four semi-elliptical spring assemblies are attached to the axles with U-bolts. On both sides of the vehicle, the forward end of the forward spring and the rear end of the rear spring ride in aluminum brackets that are mounted on the frame rails. Steel wear shoes are cast into each bracket.

At the center, between the forward and rear springs, the springs ride on an equalizer, which pivots on a sleeve in the equalizer bracket. Equalizer travel is stopped when the top of the equalizer and the equalizer bracket make contact. Each axle is held in alignment by a pair of radius rods that extend forward from the axle seats to the forward spring brackets for the forward-rear axle, and to the equalizer brackets for the rearmost axle.

General Information



NOTE: Huck fasteners may be used to attach brackets to frame rails.

1. Suspension Bracket Hexbolt
2. Hardened Washer
3. Forward Spring Bracket
4. Suspension Bracket Hex Locknut
5. Radius Rod Hex Locknut
6. Hardened Washer
7. Axle Alignment Washer
8. Forward Radius Rod
9. Radius Rod Hexbolt
10. U-Bolt
11. U-Bolt Pad
12. Spring Liner
13. Leaf Spring Assembly
14. Spring Seat
15. U-Bolt Retainer
16. Hardened Washer
17. U-Bolt High Nut
18. Equalizer Bracket
19. Equalizer, One-Piece (tandem drive axles)
20. Rear Radius Rod
21. Rear Spring Bracket
22. Equalizer, Three-Piece (tag or pusher axle)

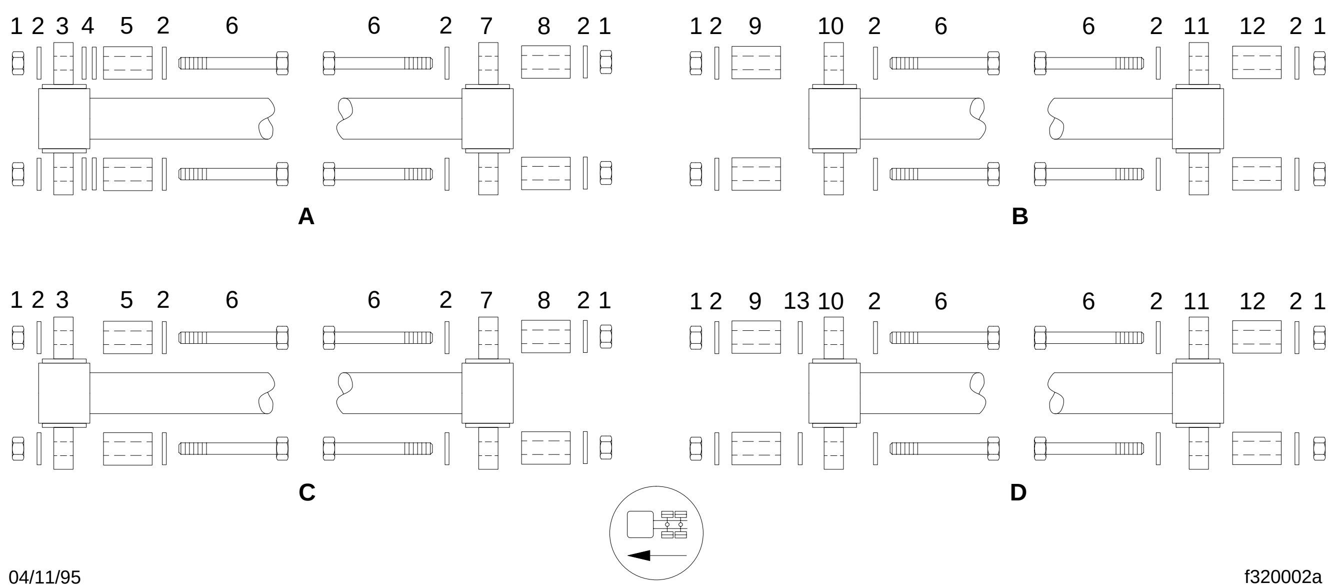
Fig. 1, Tandem-Axle Spring Suspension

Radius Rod Removal and Installation

Removal

NOTE: See **Fig. 1** for this procedure.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.



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A. Forward Right-Side Radius Rod
B. Rear Right-Side Radius Rod
C. Forward Left-Side Radius Rod
D. Rear Left-Side Radius Rod

1. Hex Locknut
2. Hardened Washer
3. Forward Radius Rod Front Pin
4. Alignment Washers (install only on one side of front axle; right-side installation shown)
5. Forward Spring Bracket
6. Hexhead Bolt
7. Forward Radius Rod Rear Pin
8. Forward Axle Seat
9. Equalizer Bracket
10. Rear Radius Rod Front Pin
11. Rear Radius Rod Rear Pin
12. Rear Axle Seat
13. Alignment Washer (install only on one side of rear axle; left-side installation shown)

Fig. 1, Radius Rod Attachment (top view)

2. Note the number of axle alignment washers at the forward end of each radius rod that is being removed.
3. Remove the fasteners that attach the radius rod to the forward spring bracket or equalizer bracket, and to the axle seat.
4. Remove the radius rod and any axle alignment washers.

Installation

IMPORTANT: At all points where steel parts (including bolts, washers, and nuts) contact aluminum brackets, apply Alumilastic® compound, or an equivalent, on the mating surfaces.

CAUTION

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel parts contact each other, could lead to corrosion of the metals, resulting in damage to the suspension.

If installing forward and rear radius rods, install the forward radius rod before installing the rear radius rod.

Radius Rod Removal and Installation

1. If installing a forward radius rod, place the radius rod front pin on the front side of the forward spring bracket, and place the radius rod rear pin in front of the axle seat.

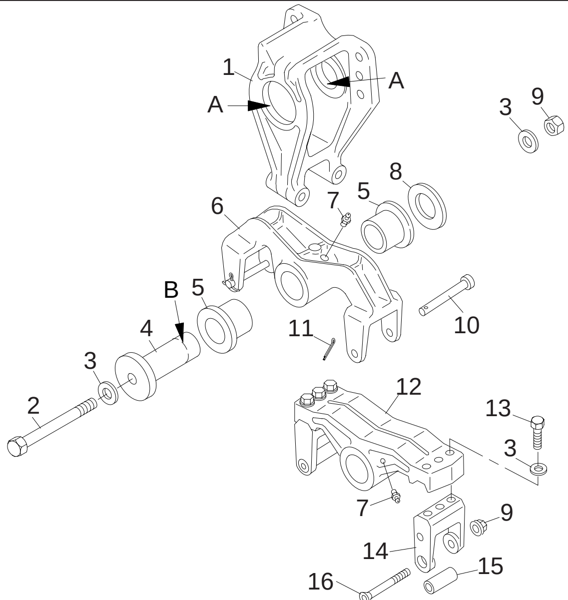
   If installing a rear radius rod, place the radius rod pins between the rear side of the equalizer bracket and the front side of the axle seat.
2. Install a hexhead bolt with a hardened washer through each end of the radius rod rear pin and the axle seat ears. Install the hardened washers and locknuts.
3. If installing a forward radius rod, install any previously removed axle alignment washers between the radius rod front pin and the forward spring bracket. Install the hexhead bolts, hardened washers, and locknuts.

   If installing a rear radius rod, install any previously removed axle alignment washers between the radius rod front pin and the equalizer bracket. Install the hexhead bolts, hardened washers, and locknuts.
4. Tighten the radius rod locknuts to the torque value in **Specifications 400**.
5. After all of the radius rods are installed, check the rear axle alignment. For instructions, refer to **Group 35**. If necessary, adjust the axle alignment, using the instructions in **Subject 140**.
6. Remove the chocks from the tires.

Equalizer Removal, Inspection, and Installation

Removal

NOTE: See **Fig. 1** for this procedure.



A. Apply Loctite here. B. No grease here.

1. Equalizer Bracket
2. Hexbolt
3. Bearing Washer
4. Cap and Tube Assembly
5. Equalizer Assembly Bushing
6. Equalizer, One-Piece (tandem drive axles)
7. Grease Fitting
8. Wear Washer(s)
9. Locknut
10. Spring Retainer Pin
11. Cotter Pin
12. Equalizer, Three-Piece (tag or pusher axle)
13. Capscrew
14. Wear-Shoe Side-Restraint
15. Side-Restraint Sleeve
16. Flathead Bolt

Fig. 1, Equalizer Assembly

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Raise the rear of the vehicle, and block the axles with safety stands. Raise the vehicle frame so that all weight is removed from the leaf springs. Block the frame with safety stands. Make sure the stands will securely support the weight of the axles and frame. To allow access to the equalizer, remove the wheel assemblies on that side, using the instructions found in **Group 40**.
3. If removing an equalizer from a vehicle with two drive axles, remove the cotter pin from the outboard end of each spring retainer pin. Remove the retainer pins.

   If removing an equalizer from a vehicle with a pusher or tag axle, remove the nuts from the flathead bolts in the wear-shoe side-restraints, on each end of the equalizer. Remove the flathead bolts and side-restraint sleeves. Remove the six capscrews and washers, and remove both wear-shoe side-restraints from the equalizer.
4. Remove the cap and tube assembly locknut, inboard bearing washer, bolt, and outboard bearing washer.
5. Insert a bar between the bottom of the equalizer and the equalizer bracket. Gently lever the weight of the equalizer off the cap and tube assembly. Insert a piece of barstock through the inboard cap and tube assembly bolt hole, and lightly tap the cap and tube assembly out of the equalizer.
6. Remove the equalizer from the equalizer bracket. Remove the wear washer(s) and equalizer bushings from the equalizer.

Inspection

1. Thoroughly clean the equalizer with steam or a hot soap solution. Inspect it for wear, cracks, or other damage. Replace the equalizer if any of these conditions are present.

WARNING

Replace a worn or damaged equalizer. A broken equalizer could cause a loss of vehicle control, resulting in personal injury or property damage.

2. Inspect the equalizer bushings, cap and tube assembly, and the equalizer bracket. If wear, cracks, or other damage are present, replace the bushings, cap and tube assembly, or bracket.

Equalizer Removal, Inspection, and Installation

Installation

1. Apply a thin film of multipurpose chassis grease to the outside of the equalizer bushings. Install the bushings in the equalizer.

NOTE: The equalizer is *not* symmetrical. To ensure that the equalizer is installed in the proper direction, an arrow is cast into its top surface.

2. Install the equalizer in the equalizer bracket. Make sure that the arrow cast into the top of the equalizer is pointing toward the frame rail. See **Fig. 2**.

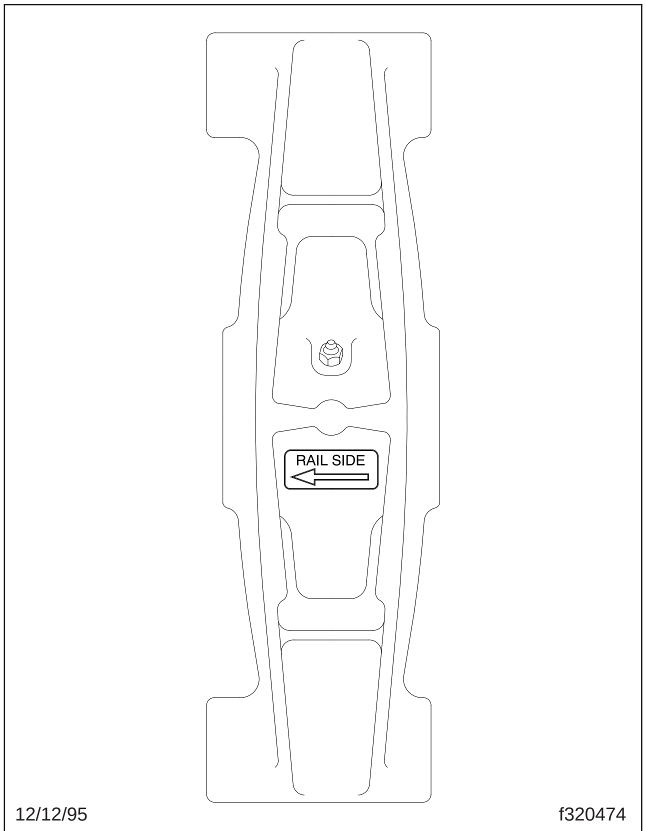


Fig. 2, Equalizer Marking

NOTE: The next four steps must be completed before the Loctite® begins to cure (approximately 5 to 10 minutes).

IMPORTANT: Be careful to prevent grease from contacting the inboard surface of the cap and tube assembly, where the Loctite is applied.

3. Apply Loctite 680 to both interior surfaces of the equalizer bracket, where the cap and tube assembly is inserted. Apply multipurpose chassis grease to the cap and tube assembly, except the last inch which connects to the equalizer bracket. See **Fig. 1** . Start the cap and tube assembly into the equalizer, through the equalizer bracket.
4. Push the cap and tube assembly part way through the equalizer. Place the wear washer(s) between the inboard equalizer bushing and the equalizer bracket. Push the cap and tube assembly the rest of the way into the equalizer bracket.
5. Place the outboard bearing washer on the equalizer cap and tube assembly bolt, and install the bolt in the cap and tube assembly.
6. Install the inboard bearing washer and locknut on the cap and tube assembly bolt. Tighten the locknut to the torque value in **Specifications 400**.
7. Lubricate the equalizer assembly by applying multipurpose chassis grease at the grease fitting. Lubricate with a hand gun or pressure gun until grease is forced past the bushing seals, or if equipped with a pressure-relief grease fitting, until grease is forced out from the base of the pressure relief fitting.
8. If installing an equalizer on a vehicle with two drive axles, apply Alumilastic® compound, or an equivalent, to the spring retainer pins. Install them from the inboard side. Be sure the hooked ends of the spring leaves are above the retainer pins. Install a cotter pin in the outboard end of each retainer pin, and lock it in place.

   If installing an equalizer on a vehicle with a pusher or tag axle, apply Alumilastic compound, or an equivalent, to the surfaces where the wear-shoe side-restraints contact the equalizer. Attach the side-restraints to the equalizer, offsetting them toward the inboard side of the equalizer. Tighten the equalizer wear-shoe capscrews to the torque value in **Specifications 400**. Install the side-restraint sleeves and flathead bolts in the wear-shoe side-restraints. Be sure the hooked ends of the spring leaves are above the side-restraint sleeves. Install the nuts, and tighten them to the applicable torque value in **Specifications 400**.

Equalizer Removal, Inspection, and Installation

CAUTION

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel contact each other, could lead to corrosion of the metals, resulting in suspension damage.

9. Install the wheel assemblies, using the instructions found in **Group 40**. Remove the safety stands from under the frame and axle, and lower the vehicle.
10. If the radius rods have been loosened, or the equalizer bracket has been removed, check the rear axle alignment. For instructions, refer to **Group 35**. If necessary, adjust the axle alignment using the instructions in **Subject 140**.
11. Remove the chocks from the front tires.

Spring Assembly Replacement

Replacement

NOTE: See **Fig. 1** for this procedure.

WARNING

Do not replace individual leaves of a damaged leaf spring assembly; replace the complete spring assembly. Visible damage (cracks or breaks) to one leaf causes hidden damage to other leaves. Replacement of only the visibly damaged part(s) is no assurance that the spring is safe. Failure to replace a damaged spring assembly could cause an accident resulting in serious personal injury or property damage.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Raise the frame so that all weight is removed from the leaf springs. Block the frame with safety stands. Raise the rear axle until the spring no longer contacts the spring bracket wear shoes and the spring retainer pin (or side-restraint sleeve). Block the axle. Make sure the stands will securely support the weight of the axles and frame. To access the spring assembly, remove the wheel assembly. See **Group 40** for instructions.
3. If equipped with two drive axles, remove the cotter pin from the spring retainer pin on the end of the equalizer where the spring is being replaced. Drive the spring retainer pin out of the equalizer.

   If equipped with a pusher or tag axle, remove the nut from the flathead bolt on the end of the equalizer where the spring is being replaced. Remove the bolt and the side-restraint sleeve from the wear-shoe side-restraint.
4. Remove the U-bolt high nuts, hardened washers, U-bolt retainer, U-bolts, and upper U-bolt pad.
5. Remove the spring assembly by lifting it off the axle seat, then moving it toward the equalizer, out of the forward or rear spring bracket.
6. Using chassis grease, lubricate the new spring assembly where the ends will contact the stationary wear shoes in the spring bracket and equalizer.
7. Place the new spring assembly in the spring bracket and on the axle seat. Make sure the spring center-bolt head seats in the axle seat hole.
8. If the upper U-bolt pad is aluminum, apply Alumilastic® compound, or an equivalent, to those areas of the pad that will come in contact with the U-bolts and with the upper spring leaf.

CAUTION

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel contact each other, could lead to corrosion of the metals, resulting in suspension damage.

9. Place the upper U-bolt pad on the spring assembly. Place the U-bolts over the upper U-bolt pad and the spring assembly.
10. Install the U-bolt retainer, hardened washers, and U-bolt high nuts. Tighten the high nuts until snug.
11. If installing a spring assembly on a vehicle with two drive axles, apply Alumilastic compound, or an equivalent, to the spring retainer pins. Install them from the inboard side. Be sure the hooked ends of the spring leaves are above the retainer pins. Install a cotter pin in the outboard end of each retainer pin, and lock it in place.

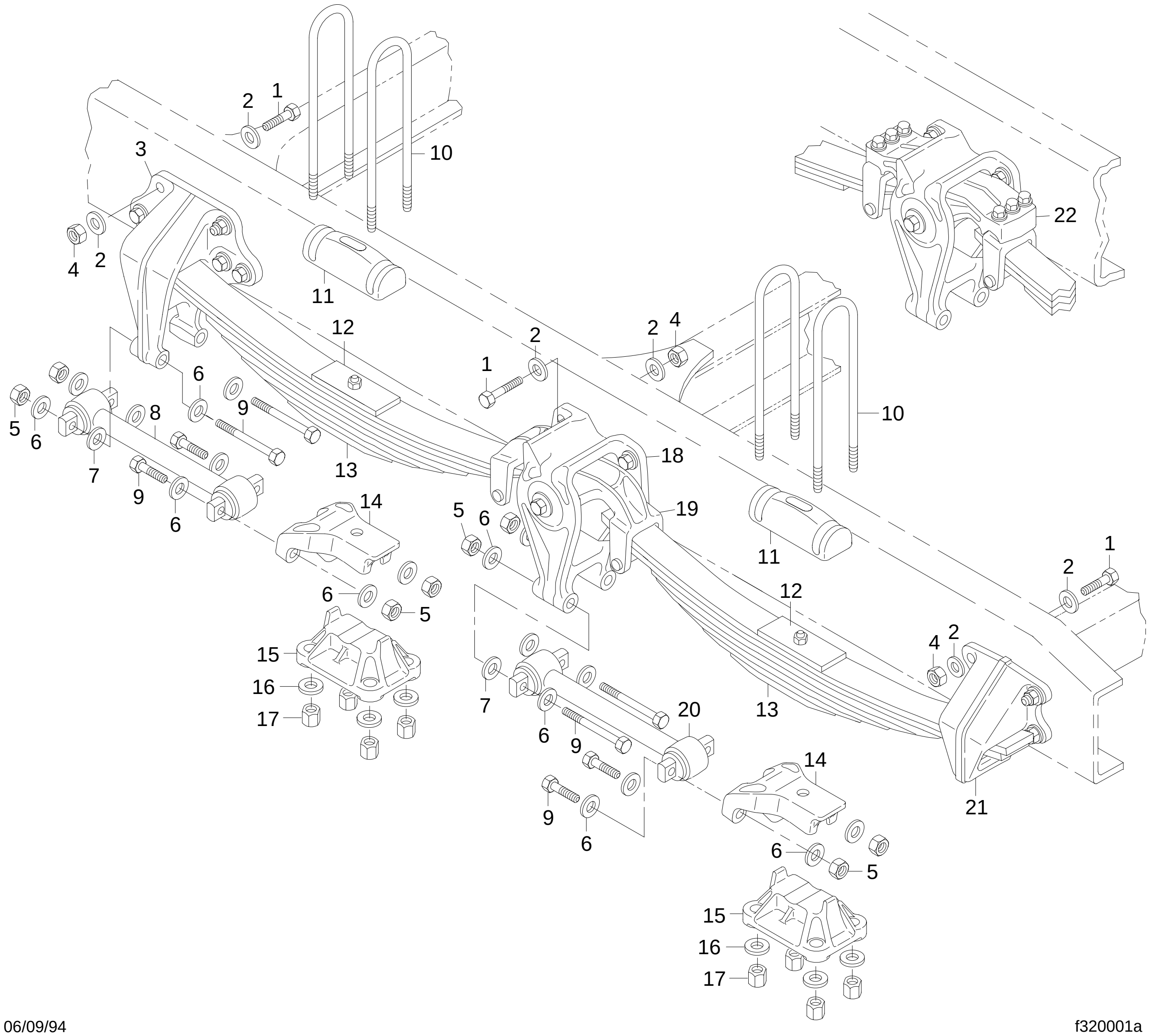
    If installing a spring assembly on a vehicle with a pusher or tag axle, install the side-restraint sleeves and flathead bolts in the wear-shoe side-restraints. Be sure the hooked ends of the spring leaves are above the side-restraint sleeves. Install the nuts, and tighten them to the applicable torque value in **Specifications 400**.
12. Tighten the axle U-bolt high nuts as described in **Specifications 400**.

CAUTION

Failure to periodically torque the suspension fasteners can result in abnormal tire wear, and damage to the springs, spring brackets, and frame rail.

IMPORTANT: All suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking intervals and instructions, see Group 32 of the *Business Class M2 Maintenance Manual*.

Spring Assembly Replacement



NOTE: Huck fasteners may be used to attach brackets to frame rails.

1. Suspension Bracket Hexbolt
2. Hardened Washer
3. Forward Spring Bracket
4. Suspension Bracket Hex Locknut
5. Torque Arm Hex Locknut
6. Hardened Washer
7. Axle Alignment Washer
8. Forward Torque Arm
9. Torque Arm Hexbolt
10. U-Bolt
11. U-Bolt Pad
12. Spring Liner
13. Leaf Spring Assembly
14. Spring Seat
15. U-Bolt Retainer
16. Hardened Washer
17. U-Bolt High Nut
18. Equalizer Bracket
19. Equalizer, One-Piece (tandem drive axles)
20. Rear Torque Arm
21. Rear Spring Bracket
22. Equalizer, Three-Piece (tag or pusher axle)

Fig. 1, Tandem-Axle Spring Suspension

Spring Assembly Replacement

13. Install the wheel assembly, using the instructions found in **Group 40**. Remove the safety stands from under the frame and axle, and lower the vehicle.
14. Check the rear axle alignment. For instructions, see **Group 35**. If necessary, adjust the axle alignment, using the instructions in **Subject 140**.
15. Remove the chocks from the tires.

Spring Bracket and Equalizer Bracket Replacement

Replacement

NOTE: See **Fig. 1** for this procedure.

WARNING

Failure to replace worn, cracked, or damaged spring brackets or equalizer brackets could result in breakage of the bracket, which could cause a loss of vehicle control, resulting in personal injury or property damage.

IMPORTANT: At all points where steel parts (including bolts, washers, and nuts) contact the aluminum spring brackets, apply Alumilastic® compound, or an equivalent, on the mating surfaces.

CAUTION

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel parts contact each other, could lead to corrosion of the metals, resulting in damage to the suspension.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Raise the rear of the vehicle, and block the axles with safety stands. Raise the vehicle frame so that all weight is removed from the leaf springs. Block the frame with safety stands. Make sure the stands will securely support the weight of the axles and frame.
3. If removing the forward spring bracket or the equalizer bracket, note the number of any axle alignment washers. Remove the fasteners that attach the radius rod to the forward spring bracket or equalizer bracket. Remove any axle alignment washers.
4. If removing an equalizer bracket, remove the equalizer. For instructions, see **Subject 110**.
5. Remove the fasteners that attach the forward or rear spring bracket, or equalizer bracket, to the frame rail. Remove the bracket.
6. Place the new spring bracket or equalizer bracket on the frame rail. Align the mounting holes, and install the fasteners.

NOTE: If installing the forward spring bracket, install the nuts for the top two bolts on the outboard side of the frame rail, and install the nuts for the bottom four bolts on the inboard side of the frame rail. See **Fig. 2**.

NOTE: If installing the equalizer bracket, for clearance, install all of the nuts on the inboard side of the frame rail. See **Fig. 2**.

NOTE: If installing the rear spring bracket, install the nuts for the top two bolts on the outboard side of the frame rail, and install the nuts for the bottom two bolts on the inboard side of the frame rail. See **Fig. 2**.

7. Tighten the bracket mounting locknuts to the applicable torque value in **Specifications 400**.

CAUTION

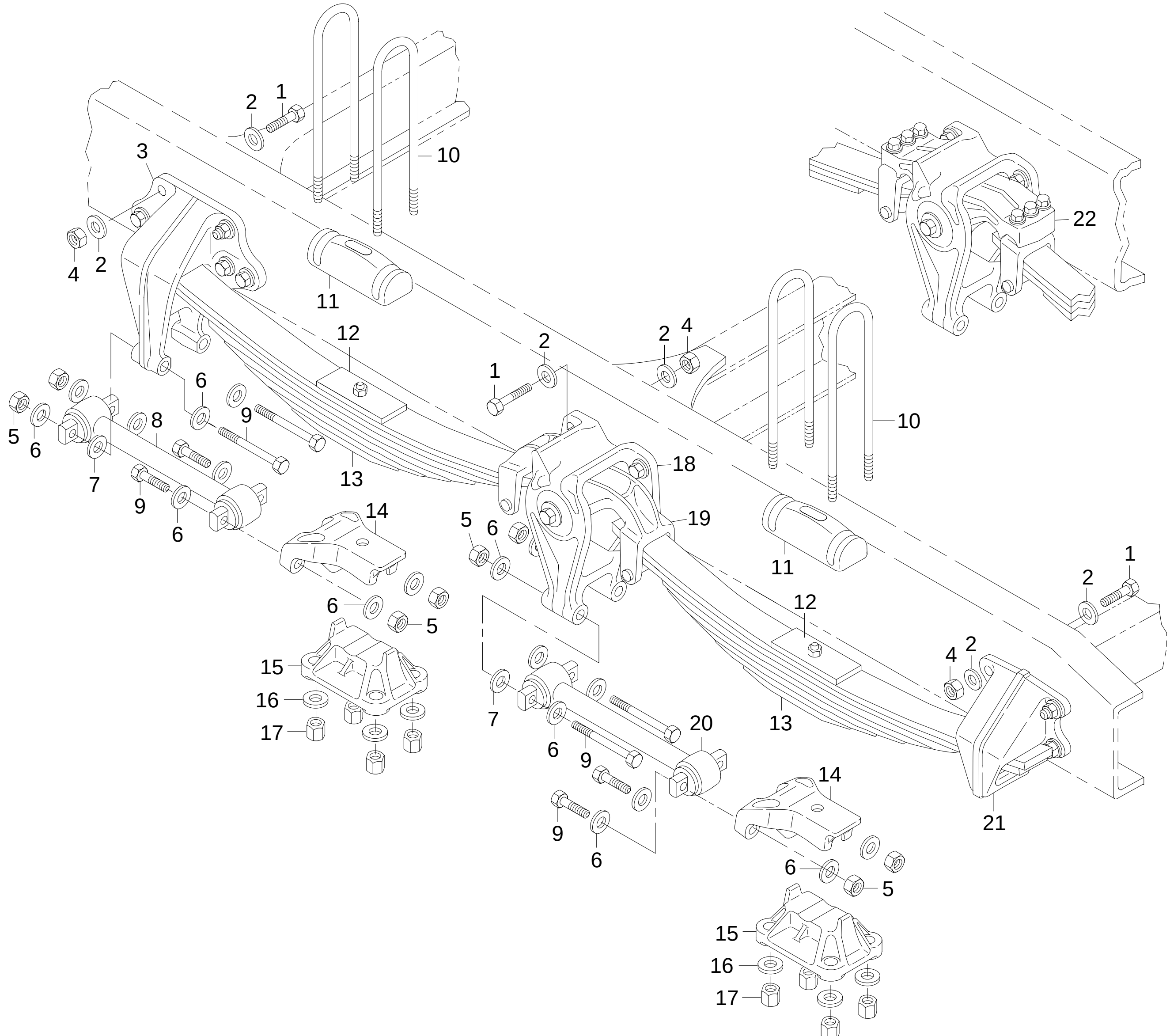
Failure to periodically torque the suspension fasteners can result in abnormal tire wear, and damage to the springs, spring brackets, and frame rail.

IMPORTANT: All suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking intervals and instructions, see Group 32 of the *Business Class M2 Maintenance Manual*.

8. When replacing the forward spring bracket or equalizer bracket, install any previously removed axle alignment washers between the forward radius rod front pin and the forward spring bracket, or between the rear radius rod front pin and the equalizer bracket, as applicable. See **Fig. 3**.

   Install bolts with hardened washers in the radius rod front pin, and the forward spring bracket or equalizer bracket. Install the hardened washers and locknuts, and tighten the locknuts to the torque value in **Specifications 400**.
9. If replacing an equalizer bracket, install the equalizer. For instructions, see **Subject 110**.
10. Remove the safety stands from under the frame and axle, and lower the vehicle.
11. Remove the chocks from the tires.

Spring Bracket and Equalizer Bracket Replacement

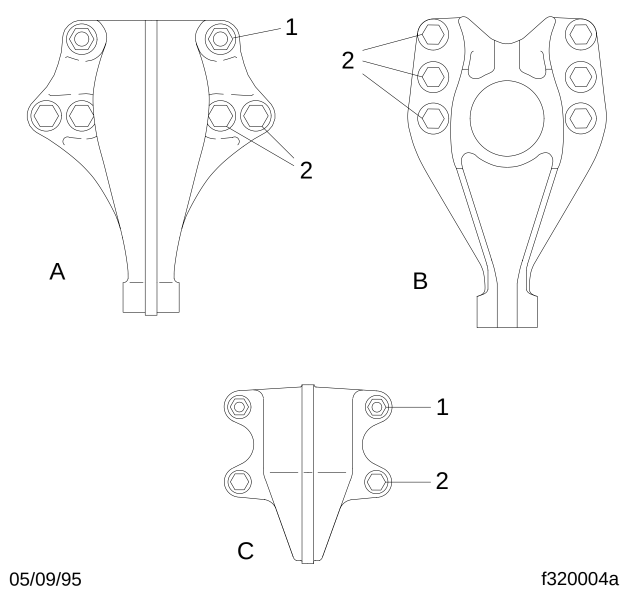


NOTE: Huck fasteners may be used to attach brackets to frame rails.

1. Suspension Bracket Hexbolt
2. Hardened Washer
3. Forward Spring Bracket
4. Suspension Bracket Hex Locknut
5. Radius Rod Hex Locknut
6. Hardened Washer
7. Axle Alignment Washer
8. Forward Radius Rod
9. Radius Rod Hexbolt
10. U-Bolt
11. U-Bolt Pad
12. Spring Liner
13. Leaf Spring Assembly
14. Spring Seat
15. U-Bolt Retainer
16. Hardened Washer
17. U-Bolt High Nut
18. Equalizer Bracket
19. Equalizer, One-Piece (tandem drive axles)
20. Rear Radius Rod
21. Rear Spring Bracket
22. Equalizer, Three-Piece (tag or pusher axle)

Fig. 1, Tandem-Axle Spring Suspension

Spring Bracket and Equalizer Bracket Replacement

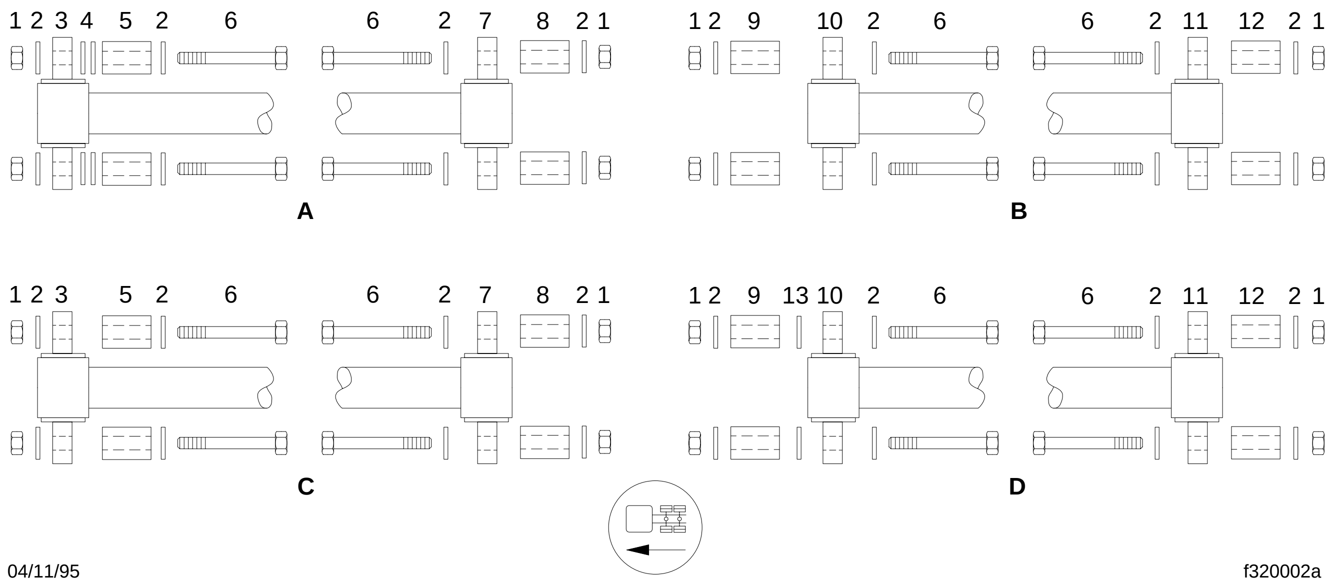


A. Forward Spring Bracket
B. Equalizer Bracket
C. Rear Spring Bracket
1. Nut (outboard)
2. Bolt Heads (outboard)

Fig. 2, Frame Brackets

12. Check the rear axle alignment. For instructions, see **Group 35**. If necessary, adjust the axle alignment, using the instructions in **Subject 140**.

Spring Bracket and Equalizer Bracket Replacement



A. Forward Right-Side Radius Rod
B. Rear Right-Side Radius Rod
1. Hex Locknut
2. Hardened Washer
3. Forward Radius Rod Front Pin
4. Alignment Washers (install only on one side of front axle; right-side installation shown)
5. Forward Spring Bracket
6. Hexhead Bolt
7. Forward Radius Rod Rear Pin

C. Forward Left-Side Radius Rod
D. Rear Left-Side Radius Rod
8. Forward Axle Seat
9. Equalizer Bracket
10. Rear Radius Rod Front Pin
11. Rear Radius Rod Rear Pin
12. Rear Axle Seat
13. Alignment Washer (install only on one side of rear axle; left-side installation shown)

Fig. 3, Radius Rod Attachment (top view)

Rear Axle Alignment Adjustment

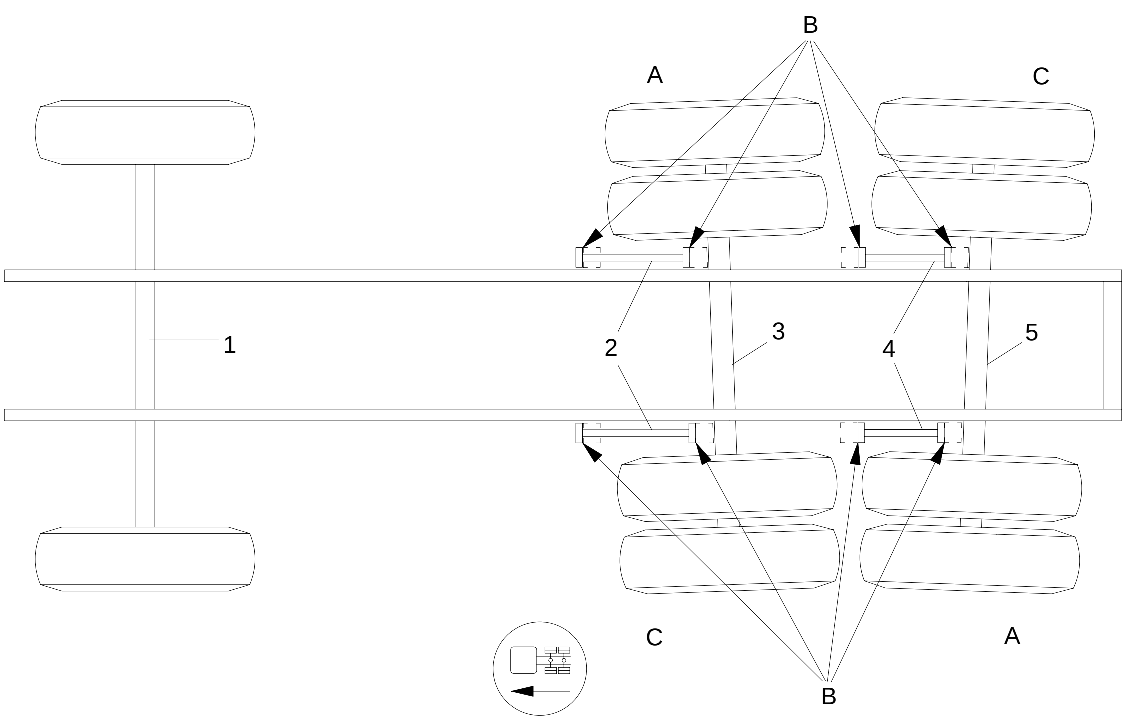
Adjustment

1. Using a straightedge and a tape measure, determine the amount of adjustment needed to align the forward-rear axle at a right angle to the frame. For instructions, see **Group 35**. The difference in measurements between the sides of the vehicle is the approximate amount that the trailing end of the forward-rear axle will have to be brought forward, or the leading end will have to be moved back to align it at a right angle to the frame. See **Fig. 1**.

   If the forward-rear axle alignment is within specifications, go to step 12.
2. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
3. On both sides of the forward-rear axle, loosen the axle U-bolts enough to allow the springs to shift on the axle seats.
4. On the side of the vehicle that is to be adjusted, remove the fasteners that attach the forward radius rod to the forward spring bracket. Remove any axle alignment washers.

NOTE: To move the leading end of the forward-rear axle rearward, *remove* alignment washers from between the radius rod and the leading end of the forward spring bracket or *add* alignment washers between the radius rod and the forward-rear axle seat.

NOTE: To move the trailing end of the forward-rear axle forward, *remove* alignment washers



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A. Leading End
B. Possible Adjustment Points
C. Trailing End

1. Front Axle
2. Forward-Rear Axle Radius Rod
3. Forward-Rear Axle
4. Rearmost Axle Radius Rod
5. Rearmost Axle

Fig. 1, Tandem Axle, Shown Out of Alignment

Rear Axle Alignment Adjustment

from between the radius rod and the forward-rear axle seat on the trailing end.

NOTE: Whenever possible, alignment washers should be *removed* instead of added.

5. Raise the frame just enough to relieve the weight from the springs. Place safety stands under the frame. Make sure the stands will securely support the weight of the frame.
6. Rolling the wheels, move the loosened end of the axle forward or backward as needed.
7. Insert or remove axle alignment washers at the appropriate location (front or rear of the left-hand or right-hand radius rod) to bring the forward-rear axle into alignment. Install the hexhead bolt, hardened washers, and locknut in the radius rod pin and forward spring bracket or axle seat.
8. Place an equal thickness of washers on the other end of the radius rod pin, and install the fasteners.
9. Tighten the radius rod locknuts to the torque value in **Specifications 400**.
10. Remove the safety stands, and lower the vehicle.
11. Check the forward-rear axle alignment with the straightedge and the tape measure. If alignment is within specifications, center the spring in the forward spring bracket, if needed. Tighten the axle U-bolt nuts to the torque value in **Specifications 400**.

    If not in alignment, repeat all of the steps above.

CAUTION

Failure to periodically torque the suspension fasteners can result in abnormal tire wear, and damage to the springs, spring brackets, and frame rail.

IMPORTANT: All suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking intervals and instructions, see Group 32 in the *Business Class M2 Maintenance Manual*.

12. Using a center-point bar, determine the difference between the forward-rear and the rearmost axles' center-to-center measurements on each side of the vehicle. For instructions, see **Group 35**. This difference is the approximate distance that the leading end of the rearmost axle will have to be adjusted rearward, or that the trailing end will have to be adjusted forward, to align it at a right angle to the frame, and to align it parallel to the forward-rear axle. See **Fig. 1**.
13. On both sides of the rearmost axle, loosen the axle U-bolts enough to allow the springs to shift on the axle seats.
14. On the side of the vehicle that is to be adjusted, remove the fasteners that attach the rear radius rod to the equalizer bracket. Remove any axle alignment washers.
15. Raise the frame just enough to relieve the weight from the springs. Place safety stands under the frame. Make sure the stands will securely support the weight of the frame.
16. Move the loosened end of the axle forward or backward, by rolling the wheels. Move the axle just enough to provide space to allow installation of alignment washers between the equalizer bracket and the radius rod pin.
17. Between one end of the radius rod pin and the equalizer bracket, insert the additional thickness of alignment washers needed to make up for the difference in center-point bar measurements.

    For example, if one end of the axle was equipped with a 3/16-inch (4.5-mm) thickness of washers, and the difference in the center-point bar measurements is 1/4 inch (6 mm) less on that side, add an additional 1/4 inch (6 mm) of washers (for a total of 7/16 inch [10.5 mm]) to correct the alignment.

    Or, if one end of the axle was equipped with a 1/4-inch (6-mm) thickness of washers, and the difference in center-point bar measurements is 3/16 inch (4.5 mm) more on that side, install a 1/16-inch (1.6-mm) thickness of washers in place of the 1/4-inch (6-mm) thickness.
18. Install the bolt, hardened washers, and locknut in the equalizer bracket and the radius rod pin. Place an equal thickness of alignment washers on the other end of the radius rod pin, and install the fasteners at that end.
19. Tighten the radius rod locknuts to the torque value in **Specifications 400**.
20. Remove the safety stands, and lower the vehicle.

Rear Axle Alignment Adjustment

21. Remove the chocks from the front tires.
22. Using the center-point bar, check the rearmost axle alignment. If alignment is within specifications, center the spring in the rear spring bracket, if needed. Tighten the axle U-bolt nuts to the applicable torque value in **Specifications 400**.

    If not in alignment, repeat the applicable steps above.

CAUTION

Failure to periodically torque the suspension fasteners can result in abnormal tire wear, and damage to the springs, spring brackets and frame rail.

IMPORTANT: All suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking intervals and instructions, see Group 32 of the *Business Class M2 Maintenance Manual*.

Specifications

Torque Values			
Description	**Size**	**IFI Grade**	**Torque: lbf·ft (N·m)**
Equalizer Bracket-to-Frame Rail Locknut *	3/4–10	C	240 (325)
Forward Spring Bracket-to-Frame Rail Locknut *	3/4–10	C	240 (325)
Rear Spring Bracket-to-Frame Rail Locknut *	5/8–11	C	135 (180)
Axle U-Bolt High Nuts (Tighten in a diagonal pattern as shown in Fig. 1.)	7/8–14	C	Stage 1: Hand-Tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 420 to 500 (571 to 680)
Radius Rod Locknut *	5/8–18	C	135 (184)
Equalizer Cap and Tube Assembly Locknut *	3/4–16	C	270 (365)
Equalizer Wear Shoe Capscrew	5/8–11	8	135 (184)
Side-Restraint Sleeve Locknut	1/2–13	C	68 (93)

* Cadmium-plated, wax-coated nuts and grade 8 hexbolts with phosphate- and oil-coated threads; both used with hardened washers.

Table 1, Torque Values

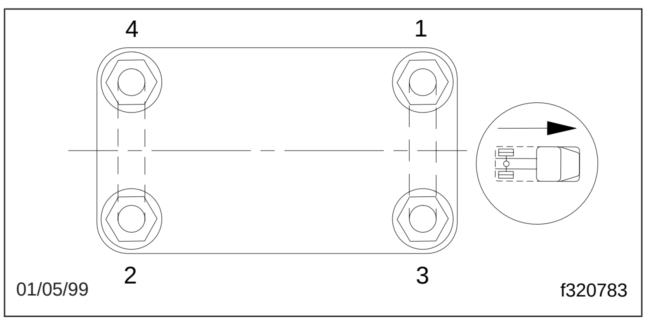


Fig. 1, Tightening Pattern for U-Bolt High Nuts

General Information

General Description

There are two terms used to describe rough ride conditions: harmonic and harsh. Harmonic ride problems are those in which the once-per-revolution energy input from such things as bent or imbalanced wheels match the natural frequency of the frame flexing. This produces a fore-and-aft motion in the cab, which continues as long as the critical road speed is maintained. Harmonic ride problems can occur on smooth roads.

Harsh ride problems are those in which the suspension transfers, rather than absorbs, the momentary energy inputs produced when the tires hit bumps or holes in the road. Wavy asphalt, or a series of bumps, may cause repetition of the harsh, jarring motion in the cab, but the motion stops after the tires pass over the bumps. Harsh ride problems occur on rough roads.

This section is designed for use as an aid in locating and correcting rough ride problems. It is not intended for use as a replacement for the detailed service information located in the applicable subjects in this manual, or in the component manufacturer’s service manuals.

Harmonic and Harsh Ride Checks

Harmonic Ride Checks

1. Visually check the vehicle for signs of damaged or missing suspension components. Repair or replace the components using the instructions in the applicable sections in this manual.
2. Test drive the vehicle.

NOTE: When test driving the vehicle, duplicate as closely as possible the conditions under which the problem occurs. Note the area of the vehicle where the problem seems to be coming from. Pay special attention to this area during the service operations.

WARNING

Use safety stands to securely support all of the wheel and frame weight during suspension repairs. Unsecured components may drop when the fasteners are loosened or removed, causing serious personal injury and component damage.

3. Raise the vehicle until the tires are off the ground, and all of the weight is removed from the leaf springs. Block the axle and frame with safety stands. Perform the corrections under "Harmonic Ride, Tires Off the Ground" in **Troubleshooting, 300**.
4. Remove the safety stands from under the frame and axle, then lower the vehicle. Perform the corrections under "Harmonic Ride, Tires On the Ground" in **Troubleshooting, 300**.

Harsh Ride Checks

1. Visually check the vehicle for signs of damaged or missing suspension components. Repair or replace the components using the instructions in the applicable sections in this manual.
2. Test drive the vehicle.

NOTE: When test driving the vehicle, duplicate as closely as possible the conditions under which the problem occurs. Note the area of the vehicle where the problem seems to be coming from. Pay special attention to this area during the service operations.

WARNING

Use safety stands to securely support all of the wheel and frame weight during suspension repairs. Unsecured components may drop when the fasteners are loosened or removed, causing serious personal injury and component damage.

3. Raise the vehicle until the tires are off the ground, and all of the weight is removed from the leaf springs. Block the axle and frame with safety stands. Perform the corrections under "Harsh Ride, Tires Off the Ground" in **Troubleshooting, 300**.
4. Remove the safety stands from under the frame and axle, then lower the vehicle. Perform the corrections under "Harsh Ride, Tires On the Ground" in **Troubleshooting, 300**.
5. If the problem persists, perform the harmonic ride checks in this subject. Occasionally, ride problems associated with rough roads are harmonic ride problems masked by the road conditions.

Troubleshooting Tables

Problem—Harmonic Ride, Tires Off the Ground

Problem—Harmonic Ride, Tires Off the Ground	
Possible Cause	**Remedy**
Bent, distorted, or out-of-round wheels or rims are causing a rough ride.	Inspect and repair the assemblies using the instructions in **Group 40**.
Bent, distorted, or out-of-round brake drums or hubs are causing a rough ride.	Replace damaged components using the instructions in **Group 33** or **Group 35**.
An improperly seated tire-to-rim bead is causing an out-of-round assembly.	Inspect the tires and rims for proper bead seating. Correct the problem using the instructions in **Group 40**.
A tire and rim assembly on spoke wheels is improperly installed, causing an out-of-round assembly.	Remove and install the tire and rim assembly using the instructions in **Group 40**.
Worn or distorted rim spacers are causing an out-of-round assembly.	Replace damaged spacers using the instructions in **Group 40**.
The wheels, brake drums, or hub assemblies are out of balance.	Inspect the components for missing balance weights. Balance, as necessary.
Radial force variations in the tires are causing a rough ride.	Exchange the tires and wheels with a set that is known to cause no ride problems. If this corrects the problem, discard the old tires. For instructions, see **Group 40**.

Problem—Harmonic Ride, Tires On the Ground

Problem—Harmonic Ride, Tires On the Ground	
Possible Cause	**Remedy**
Worn or loose cab mounts allow the cab to bounce.	With a long bar, lever the cab legs up and down. If there is looseness, replace or tighten the mounts, as necessary.
Forces from the trailer suspension are pushing on the tractor fifth wheel.	Review the ride problems that apply to the trailer suspension. Contact the trailer manufacturer for instructions. Perform the corrections, as necessary.

Problem—Harsh Ride, Tires Off the Ground

Problem—Harsh Ride, Tires Off the Ground	
Possible Cause	**Remedy**
Seized front spring shackle pins are not allowing the springs to flex.	Replace seized shackle pins. For instructions, refer to the applicable suspension section in this group.

Problem—Harsh Ride, Tires On the Ground

Problem—Harsh Ride, Tires On the Ground	
Possible Cause	**Remedy**
The tires are improperly inflated.	Adjust the tire pressure using the instructions in Group 40 of the *Business Class M2 Maintenance Manual*.

Troubleshooting

Problem—Harsh Ride, Tires On the Ground	
Possible Cause	**Remedy**
The frame is bottoming out against the suspension.	Check the suspension for weak or damaged springs or components. Inspect the springs for "gull-winging" when the vehicle is loaded. Replace the spring assembly, as necessary, using the instructions in the applicable suspension section in this group.
	Reduce the overall loaded weight on each axle to conform with the maximum spring load capacities on the vehicle specification sheet. Do not exceed the maximum spring load capacities.
	Adjust the air spring height using the instructions in the applicable suspension section in this group.
The vehicle normal loaded weight is markedly below the spring load capacity.	Contact the Freightliner Service Operations Regional Office for the correct application of a lower rated spring. Replace the spring assembly using the instructions in the applicable suspension section in this group.
When the vehicle is loaded, the front axle spring shackle angle is not within the rearward 3- to 18-degree angle.	Contact the Freightliner Service Operations Regional Office for shackle angle corrective measures. Refer to the applicable suspension section in this group for service instructions.
The weight on the tractor fifth wheel is causing overloading on the front axle springs.	If possible, move the fifth wheel toward the rear of the vehicle;otherwise, change the loading pattern on the trailer.
There is a loaded weight differential between the rear axles greater than 800 pounds (363 kg).	Contact the Freightliner Service Operations Regional Office for corrective measures.
Forces from the trailer suspension are pushing on the tractor fifth wheel causing a rough ride condition.	Review the ride problems that apply to the trailer suspension. Contact the trailer manufacturer for instructions. Perform the corrections, as necessary.

General Information

The Freightliner AirLiner Suspension is a single axle or tandem axle suspension that uses a combination of air and leaf springs. The suspension is manufactured at numerous weight ratings up to 46,000 pounds (20 865 kg). The top of the air spring is bolted to a bracket on the frame rail or through the bottom flange of the frame rail; the bottom is bolted to the rear end of the tapered leaf spring assembly or, for the 23,000-pound (10 433 kg) and 46,000-pound suspensions, to a cross bar. The axle housing is fastened to the leaf spring assembly by U-bolts. A control rod, mounted between the axle housing and the frame rail, can be used to help locate the assembly laterally.

The air springs compensate for changes in road conditions and vehicle load, maintaining vehicle height. The air springs also absorb road shock.

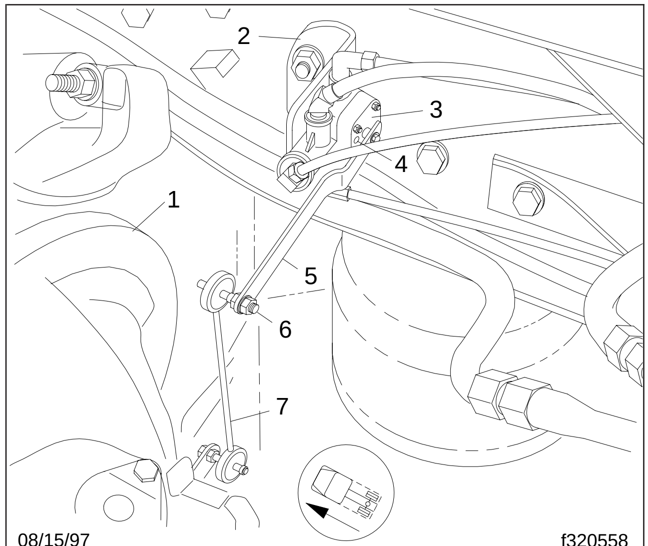
A height-control valve regulates the air flow into or out of all the air springs; see **Fig. 1**. As the air spring compresses or expands, changes in the clearance between the vehicle frame and the differential housing activate the height-control valve.

The height-control valve is mounted on the frame rail; see **Fig. 1** and **Fig. 2**. A horizontal control lever extends from the end of the valve control shaft to a vertical linkage that connects to the height-control valve linkage bracket welded to the differential housing.

When the load changes, the horizontal control lever turns the height-control valve control shaft, activating either the intake or exhaust function of the height-control valve. This adjusts the volume of air in the air springs, until the frame returns to the normal ride height, and the horizontal control lever returns to the horizontal (neutral) position.

A side-to-side restriction valve inside the height-control valve maintains vehicle roll stability by preventing inflation of the air spring on one side and deflation on the other side during curves.

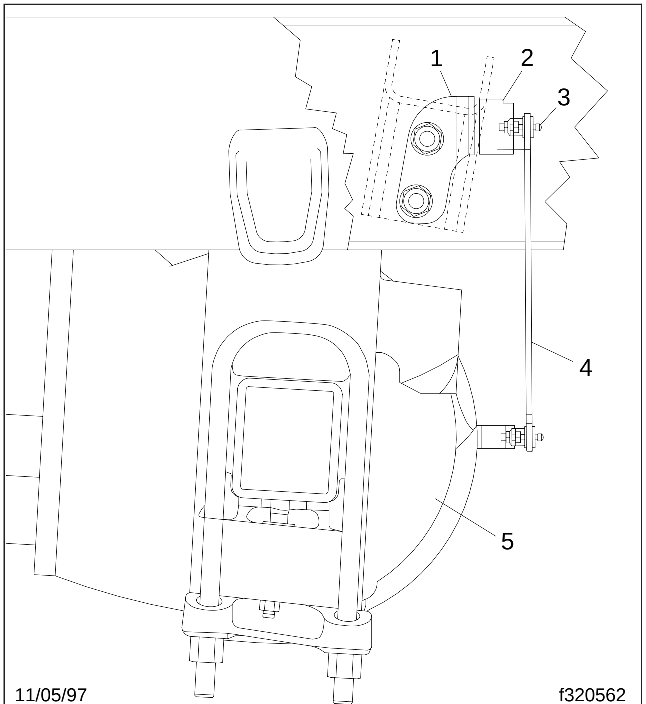
A pressure holding valve, located in the air line to the height-control valve, is preset to maintain a minimum pressure of 65 psi (448 kPa) in the vehicle secondary air system if a leak should occur in the air suspension system.



1. Forward Drive Axle
2. Valve Mounting Bracket
3. Height-Control Valve
4. Neutral-Position Hole
5. Horizontal Control Lever
6. Stud Bolt
7. Vertical Linkage

Fig. 1, Barksdale Height-Control Valve Assembly

General Information



1. Valve Mounting Bracket
2. Height-Control Valve
3. Stud Bolt
4. Vertical Linkage Rod
5. Axle

Fig. 2, Barksdale Height-Control Valve Installation, Side View

General Guidelines

To keep the air suspension system operating reliably, the air system must be kept free of any oil, moisture, or foreign material. Inspect and maintain the air system components regularly. Refer to Group 42 of the *Business Class® M2 Maintenance Manual* for maintenance operations.

CAUTION

Failure to take precautions against the entry of moisture, oil, or other foreign material into the air suspension system could eventually lead to sludge forming in the air system. Sludge could adversely affect the operation of the air suspension system and other air system components.

Use only SAE grade 8 hexbolts and grade G prevailing torque locknuts to attach spring hangers and brackets to the frame.

For suspension component inspecting, lubricating, and fastener torque checking intervals and instructions, refer to the maintenance schedule in Group 00 and the suspension section in Group 32 of the *Business Class® M2 Maintenance Manual*.

Ride Height Adjustment

NOTICE

Failure to adjust the suspension ride height could adversely affect driveline angles. Also, if the air springs are set too high, the driver may have difficulty (or be prevented from) backing the vehicle under a trailer. If the air springs are set too low, rapid wear of suspension parts will result.

IMPORTANT: Before checking the suspension height, make sure there is no load on the chassis. For tractors, unhitch the trailer. Trucks must be empty.

1. Park the vehicle on a level surface, using a light application of the brakes. Do not apply the parking brakes. Put the transmission in neutral. Build the secondary air pressure to at least 100 psi (690 kPa). Shut down the engine.
2. Mark the location of the front and rear tires on the floor, then chock the tires on one axle only.

NOTE: The stud bolt that fastens the horizontal control lever to the vertical linkage is oriented correctly when the linkage rod is vertical as viewed from the side of the vehicle; see **Fig. 1**.

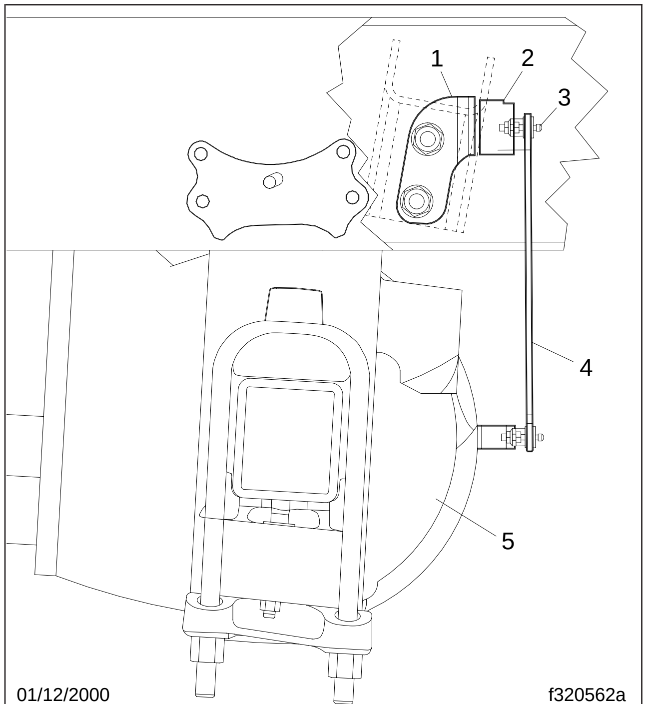
3. Measure the distance between the left forward-most axle stop and the suspension as indicated; see **Table 1**, **Table 2**, **Table 3**, **Table 4**, and **Table 5** for an acceptable range of heights for each suspension.

IMPORTANT: **Suspensions with Dual-Leaf Springs, and all Vehicles built before August 24, 2001:** Measure between the top of the U-bolt and the bottom of the axle stop (distance A).

Suspensions with Single-Leaf Springs, built after August 24, 2001: Measure between the top of the U-bolt **pad** and the bottom of the axle stop (distance B).

4. If the distance is within the acceptable range, ride height is adjusted correctly.

   If the measurement is not within the acceptable range, go to the next step.



1. Valve Mounting Bracket
2. Height-Control Valve
3. Stud Bolt
4. Vertical Linkage
5. Axle

Fig. 1, Barksdale Height-Control Valve Installation (side view)

NOTICE

When loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

5. While holding the height-control valve mounting studs in place with an Allen wrench, loosen the nuts that attach the valve to the mounting bracket.
6. Adjust the position of the valve body, until the distance from the bottom of the left axle stop to

Suspension Ride Height Adjustment

the top of the U-bolt or U-bolt pad is the target measurement from the applicable *Suspension Ride Height Measurement* table.

7. Center the horizontal control lever on the valve by inserting a 5/32-inch (4-mm) pin or drill bit into the neutral-position hole in the height-control valve and the horizontal control lever.
8. While holding the height-control valve mounting studs in place with an Allen wrench, tighten the nuts 95 lbf·in (1100 N·cm). Do not overtighten.
9. Remove the pin or drill bit previously inserted in the height-control valve.
10. Drive the vehicle unloaded for about 1/4 mile (1/2 km), then stop the vehicle in the exact location (as previously marked) of the original measurement.

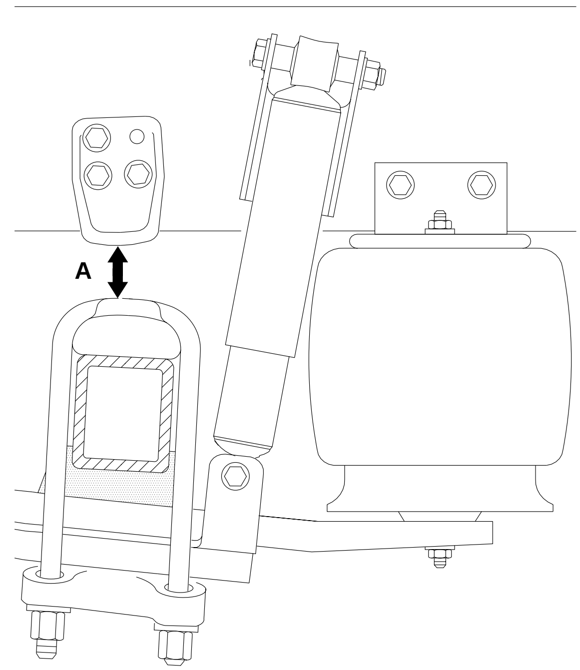
    Park the vehicle using a light brake application. Chock the tires on one axle only, and put the transmission in neutral. Do not apply the parking brakes.
11. Check the distance between the bottom of the left axle stop and the top of the axle U-bolt or U-bolt pad.

IMPORTANT: **Suspensions with Dual-Leaf Springs, and all Vehicles built before August 24, 2001:** Measure between the top of the U-bolt and the bottom of the axle stop (distance A).

Suspensions with Single-Leaf Springs, built after August 24, 2001: Measure between the top of the U-bolt *pad* and the bottom of the axle stop (distance B).

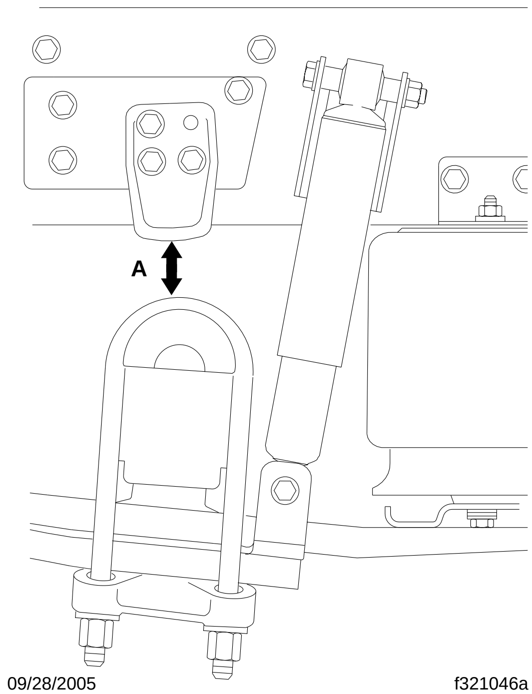
12. If the distance is within the acceptable range, the ride height is adjusted correctly.

    If the distance is not within the acceptable range, repeat the adjustment procedure.



Measure Point	Suspension Height Measurement (A)		
	Min	Target	Max
A = Measure Here	2-3/8 inch (60 mm)	2-5/8 inch (67 mm)	2-7/8 inch (73 mm)

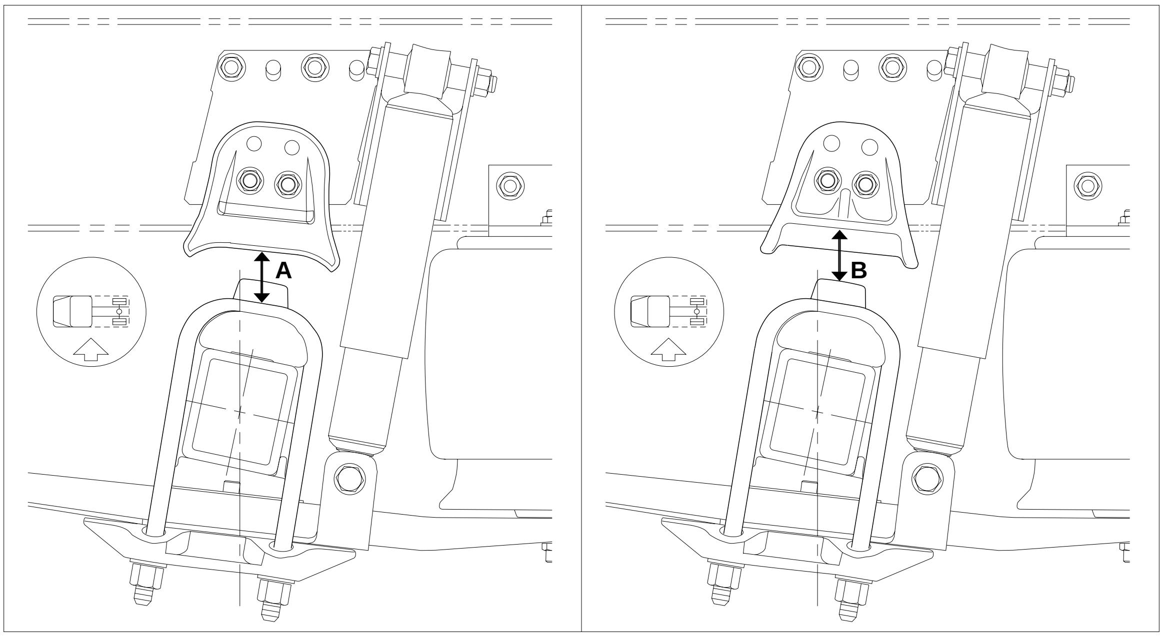
Table 1, Suspension Ride Height Measurement, Dual-Leaf Spring, 20k/40k High Ride



Measure Point	Suspension Height Measurement (A)		
	Min	Target	Max
A = Measure Here	2-3/4 inch (70 mm)	3 inch (76 mm)	3-1/4 inch (83 mm)

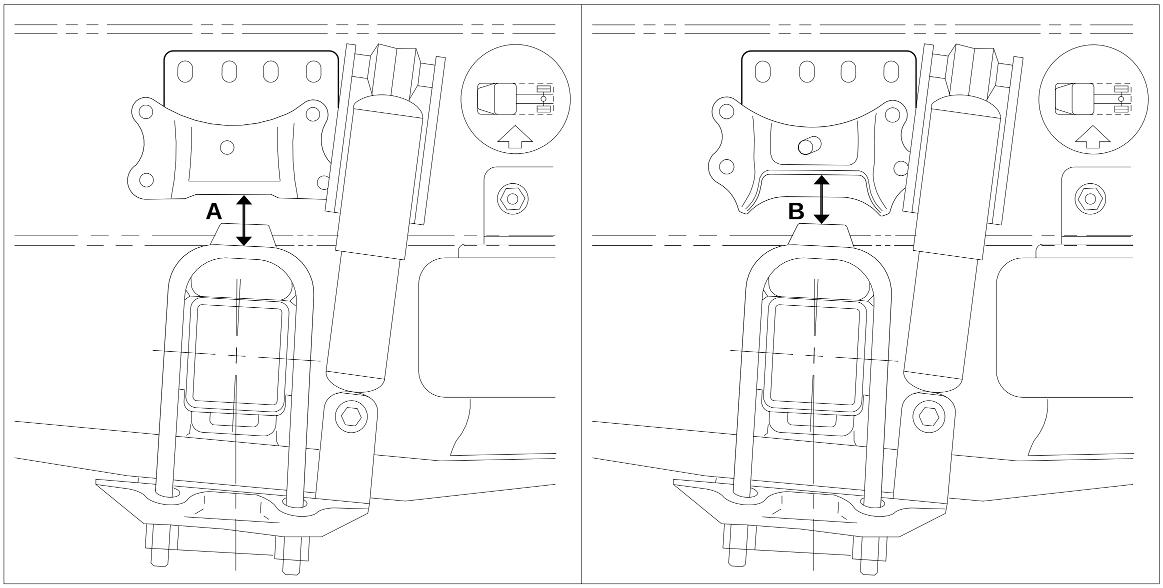
Table 2, Suspension Ride Height Measurement, Dual-Leaf Spring, 23k/46k/69k High Ride

Suspension Ride Height Adjustment



Measure Point	Suspension Height Measurement (A or B)		
	Min	Target	Max
A = Measure Here if Built Before August 24, 2001 B = Measure Here if Built After August 24, 2001	2-3/8 inch (60 mm)	2-5/8 inch (67 mm)	2-7/8 inch (73 mm)

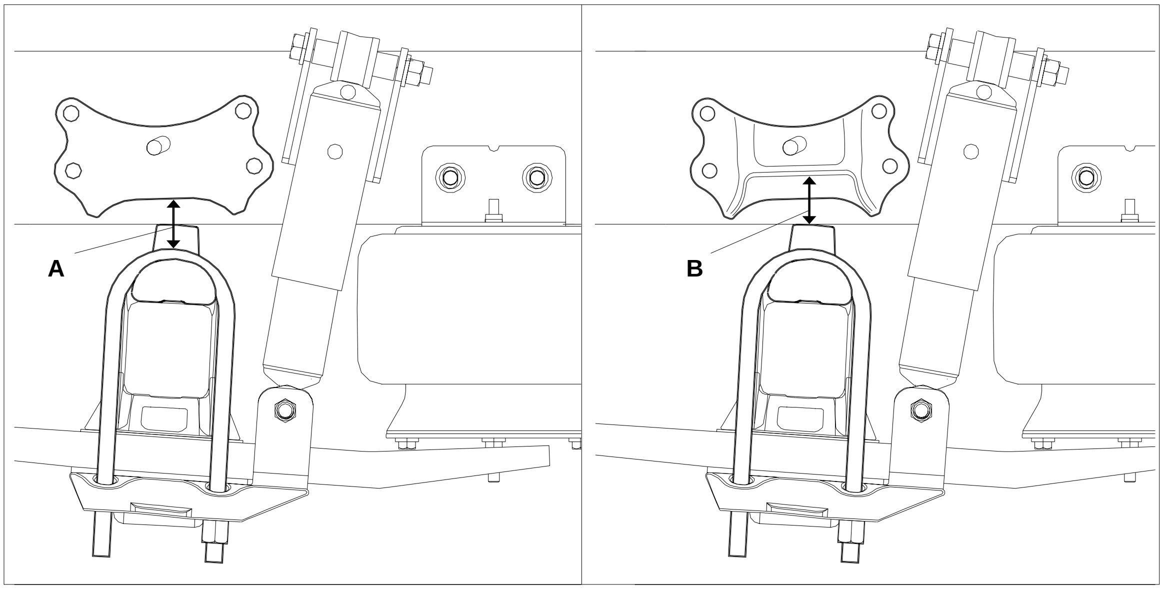
Table 3, Suspension Ride Height Measurement, Single-Leaf Spring, 20k/40k, High Ride Height



Measure Point	Suspension Height Measurement (A or B)		
	Min	Target	Max
A = Measure Here if Built Before August 24, 2001 B = Measure Here if Built After August 24, 2001	2-3/8 inch (60 mm)	2-1/2 inch (64 mm)	2-7/8 inch (73 mm)

Table 4, Suspension Ride Height Measurement, Single-Leaf Spring, 10k/12k/15k/18k Mid Ride Height and 40k Low and Mid Ride Height

Suspension Ride Height Adjustment



Measure Point	Suspension Height Measurement (A or B)		
	Min	Target	Max
A = Measure Here if Built Before August 24, 2001 B = Measure Here if Built After August 24, 2001	2-1/8 inch (54 mm)	2-9/32 inch (58 mm)	2-5/8 inch (67 mm)

Table 5, Suspension Ride Height Measurement, Single-Leaf Spring, 10k/12k/15k Low or Extra Low Ride Height

Height-Control Valve Checking

It is normal to hear air escaping from the height-control valve for as much as 10 minutes after getting out of the vehicle when it is in an unladen condition. This air "leaking" is just the height-control valve exhausting air from the suspension air springs in order to return to the neutral mode.

The height-control valves used on the Business Class M2 are Barksdale valves. Two methods are available to check the operation of the Barksdale height-control valves. A leak in the valve may be discovered without using a test kit, but a test kit is necessary to determine if the valve has an unacceptable rate of leakage.

Some Barksdale height-control valves have been returned for warranty because the four bolts in the valve housing were overtightened, often, enough to crack the valve housing. These bolts should not be loose, and should not normally require tightening, as there are no serviceable parts in the valve.

IMPORTANT: To prevent voiding the warranty on Barksdale height-control valves, note the following:

- Do not overtighten the bolts in the Barksdale height-control valve housing if you detect leaks in the housing. The bolts should not be loose, and should not require tightening. Only if necessary, tighten the valve housing bolts 45 lbf·in (500 N·cm). Any damage to the valve housing will void the warranty.
- Do not attempt to disassemble the Barksdale valve body or the control lever. There are no serviceable parts in the valve, and any disassembly will void the warranty.

NOTICE

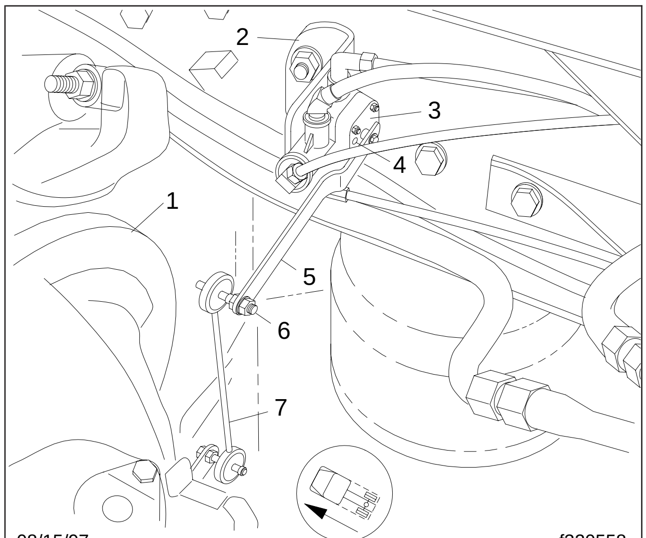
When removing or loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

Checking the Height-Control Valve Without Using a Test Kit

1. Apply the parking brakes and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa).
3. Shut off the engine and wait 5 to 10 minutes for the air suspension system to equalize.

NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal, and does not indicate a defective valve.

4. Disconnect the vertical linkage from the control lever; see **Fig. 1**.



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1. Forward Drive Axle
2. Valve Mounting Bracket
3. Height-Control Valve
4. Neutral-Position Hole
5. Horizontal Control Lever
6. Stud Bolt
7. Vertical Linkage

Fig. 1, Barksdale Height-Control Valve Assembly

5. Pull the control lever up about 45 degrees for 6 to 8 seconds. If air passes through the valve, that section of the valve is working.

Height-Control Valve Checking

6. Return the control lever to the neutral position. Air should stop flowing. If so, that section of the valve is working.
7. Push the control lever down about 45 degrees for 6 to 8 seconds. If air exhausts from the valve, that section of the valve is working.
8. Return the control lever to the neutral position. If the air stops again in the neutral position, the valve is working correctly.
9. If the valve works as stated in all of the above steps, then no further checking is necessary. Connect the vertical linkage to the control lever, then tighten the linkage nut.

   If needed, adjust the ride height or replace the height-control valve. For adjustment of the ride height, see **Subject 110**. For replacement of the height-control valve, see **Subject 130**.

NOTE: If a leak is detected on a Barksdale height-control valve, go to "Checking the Height-Control Valve Using a Test Kit". Barksdale valves have an acceptable leak rate of 3 cubic inches (50 cc) per minute. You can determine if a leak is acceptable only by using the Barksdale test kit.

Checking the Height-Control Valve Using a Test Kit

IMPORTANT: The procedure described below is for use on Barksdale height-control valves only.

NOTE: The Barksdale field test kit is designed to be used with the height-control valve installed on the vehicle. Refer to **Specifications 400** for information on ordering the Barksdale height-control valve test kit KD2264.

1. If not already done, park the vehicle on a level surface, apply the parking brakes, and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa).
3. Shut off the engine and wait 5 to 10 minutes for the air suspension system to equalize.

NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal, and does not indicate a defective valve.

4. For valves without an integral dump port, go to the next step.

   For valves with an integral dump port, check the rubber exhaust flapper at the back of the valve housing for leaks; see **Fig. 2**. Use a soapy solution.

   If a leak is found, there may be contaminants blocking the piston. Cycle the height-control valve switch inside the cab for two-second bursts, four or five times, to clear away any contaminants.

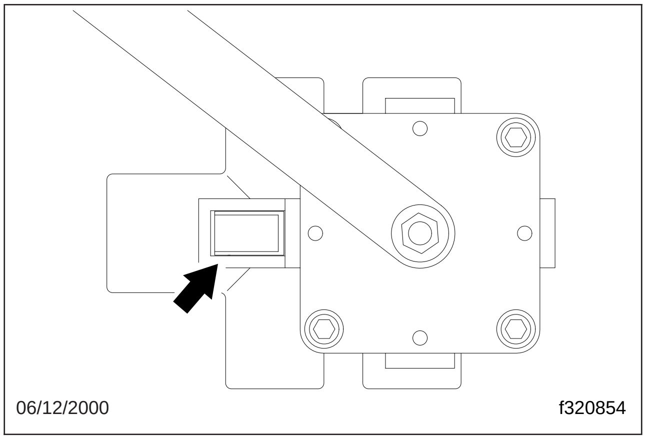
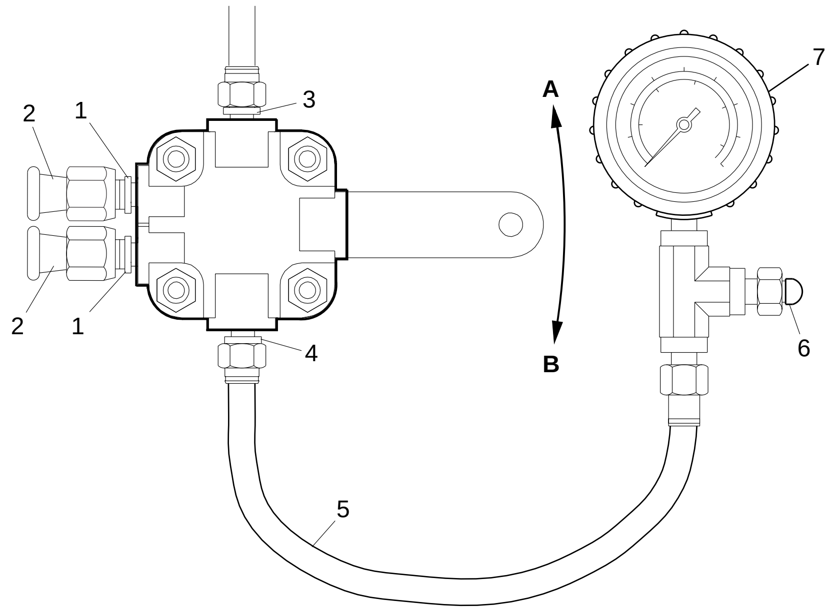


Fig. 2, Exhaust Flap Location (height-control valve with integral dump port)

5. Disconnect the vertical linkage from the horizontal control lever.
6. Rotate and hold the horizontal control lever down at about 45 degrees to exhaust air from the air springs.
7. *If equipped with an integral dump port,* turn on the quick dump switch on the dash. Leave the switch on until testing is complete.

   If not equipped with an integral dump port, disconnect the air lines from the air spring ports on the height-control valve. Leave the elbow fittings (if equipped) in place. Install a Parker plug into each air spring port (or elbow fitting); see **Fig. 3**.
8. If a flapper is present on the exhaust port of the height-control valve, remove it using needlenose pliers.



A. Fill
B. Exhaust

1. Air Spring Port
2. Parker Plug
3. Air Intake Port
4. Exhaust Port Test Fitting
5. Air Line
6. Reset Button
7. Test Gauge Assembly

Fig. 3, Test Connections

9. Clean the surface around the exhaust port, then install the test fitting into the exhaust port. The centering pin on the fitting must align with the slot on the exhaust port. Rotate the test fitting 45 degrees clockwise to lock it in place; see **Fig. 3**.

NOTE: It may be necessary to cut the tie straps that hold the chassis wiring running below the height-control valve, in order to access the exhaust port.

10. Connect one end of the air hose from the kit to the test connector on the exhaust port, and the other end to the test gauge.

11. Check the height-control valve in the fill mode, as follows.

    11.1 Rotate the valve control lever up 45 degrees from the horizontal to the fill position.

    11.2 Press the reset button on the test gauge.

    11.3 Observe the test gauge for 30 seconds. Refer to **Fig. 4** for the maximum allowable exhaust pressure change versus inlet pressure.

    The valve is not working correctly if the gauge pressure reading exceeds the maximum allowable within 30 seconds.

    If the gauge reads less than the maximum allowable pressure change in 30 seconds, the valve is okay.

NOTE: The test gauge will register the exhausting air. *This does not indicate a defective valve.*

12. Check the height-control valve in the exhaust mode, as follows.

    12.1 Rotate the valve control lever down 45 degrees from the horizontal to the exhaust position.

    12.2 Press the reset button on the test gauge.

    12.3 Observe the test gauge for 30 seconds. Refer to **Fig. 4** for the maximum allowable

Height-Control Valve Checking

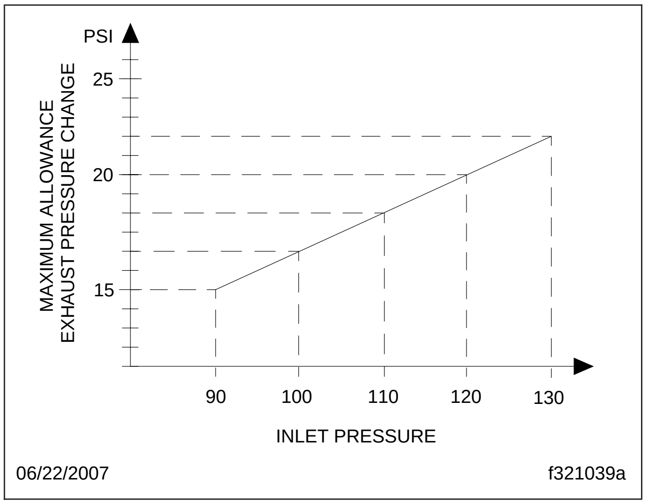


Fig. 4, Inlet Pressure vs. Exhaust Pressure Change in 30 Seconds

exhaust pressure change versus inlet pressure.

The valve is not working correctly if the gauge pressure reading exceeds the maximum allowable within 30 seconds.

If the gauge reads less than the maximum allowable pressure change in 30 seconds, the valve is okay.

NOTE: The test gauge will register the exhausting air. *This does not indicate a defective valve.*

13. Disconnect the test gauge and connector from the valve exhaust port.
14. If the height-control valve is defective, replace it; see **Subject 130**.
15. Install the flapper on the exhaust port by pressing it into place.
16. *For height-control valves with an integral dump port,* connect the vertical linkage to the height-control valve control lever. Turn off the quick dump switch on the dash. The ride height will automatically return to the correct position.

    For height-control valves without an integral dump port, remove the two Parker plugs from the air spring ports, and connect the air lines to the air spring ports (or elbow fittings). Connect the vertical linkage to the height-control valve control lever. The ride height will automatically return to the correct position.

Barksdale Height-Control Valve Replacement

The Barksdale valve does not use an adjustable linkage rod. To adjust the Barksdale valve, see **Subject 110**.

1. Apply the parking brakes and chock the tires.

WARNING

Keep your hands and all objects away from the area under and around the slack adjusters and suspension components when removing the pressure from the air system. These parts will move as the air is released and can cause personal injury or damage to any objects that are between the moving parts.

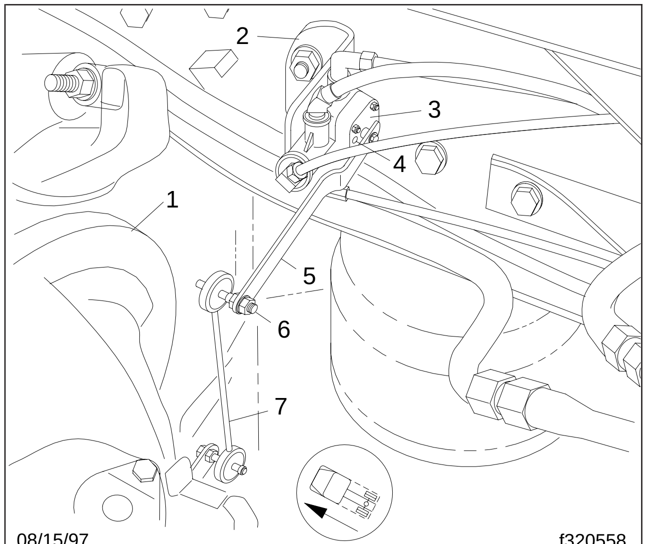
2. Drain all air from the air tanks.

WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

3. Remove the nut and washer that attaches the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the control lever; see **Fig. 1**.
4. Rotate and hold the horizontal control lever down until all air is exhausted from the air springs.
5. Disconnect the air lines at the height-control valve, and mark the lines for later reference. Using tape, cover the open ends of the air lines and fittings to prevent dirt or foreign material from entering.

IMPORTANT: For quick-connect tube fittings, do not remove the tube by cutting it close to the fitting. If the remaining part of the tube cannot be pulled from the fitting, the fitting will not be reusable and the warranty on that unit will be void.



1. Forward Drive Axle
2. Valve Mounting Bracket
3. Height-Control Valve
4. Neutral-Position Hole
5. Horizontal Control Lever
6. Stud Bolt
7. Vertical Linkage

Fig. 1, Barksdale Height-Control Valve

NOTICE

When removing or loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

6. While holding the height-control valve mounting studs in place with an Allen wrench, remove the nuts and washers that attach the valve to the mounting bracket. Remove the height-control valve.
7. Position the new height-control valve on the height-control bracket. While holding the height-control valve mounting studs in place with an Allen wrench, install the nuts and washers, and

Height-Control Valve Replacement

tighten the nuts 95 lbf·in (1100 N·cm). Do not overtighten.

8. Remove the tape from the air lines and fittings, and connect the air lines to the height-control valve as marked earlier. Tighten nylon tube air fittings until only two threads show on the fitting. On wire-braid hose fittings, tighten the nut with a wrench until there is firm resistance, then tighten one-sixth turn more.
9. Close the drain cocks on all reservoirs.
10. Build up normal operating pressure in the air system. Check all air lines and connections for leaks. Eliminate all leaks.
11. Adjust the height-control valve; see **Subject 110**.

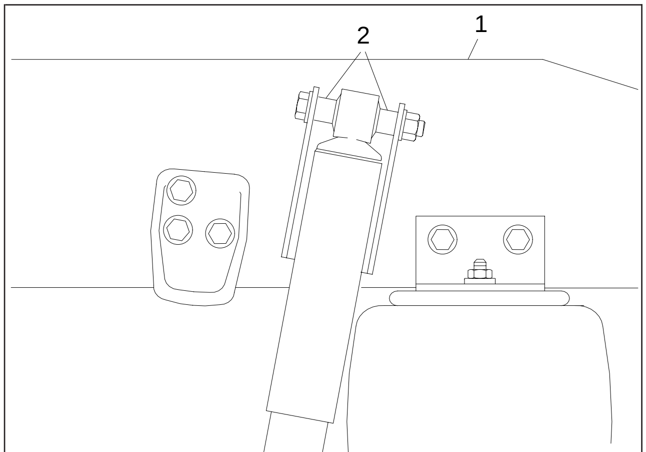
Shock Absorber Replacement

1. Chock the tires.
2. Remove the locknut, bolt, and spacer from the shock absorber lower mounting bracket. See **Fig. 1**.
3. Remove the nut, upper retainer, and upper bushing from the top of the shock absorber.
4. Pull the shock absorber out of the upper mounting bracket, and remove the retainer and bushing.
5. Install the replacement shock absorber, making sure the new bushings and retainers are correctly positioned. See **Fig. 1**.

WARNING

Use only the retainers included with the replacement shock absorber. Do not use washers. They can be extruded over the nut and be ejected violently, possibly causing personal injury and property damage.

6. Tighten the shock absorber lower mounting locknut 170 lbf·ft (230 N·m).
7. Tighten the shock absorber upper mounting nut to compress the bushings to the dimension as shown in **Fig. 1**.



1. Frame Rail
2. Bushings

Fig. 1, Shock Absorber Installation

Air Spring Replacement

IMPORTANT: Effective March 2011, the steel bead on the inside of the air bag where it attaches to the piston, changed to a square bead to increase the pull-off force between the air bag and piston. The new air bag is stamped “BD8” and “Do Not Re-Assemble Rubber Bellow to Piston.” See **Fig. 1**. With this design change it is not possible to reseat the air bag to the piston. In the event of an air bag failure, or separation from the piston, the complete air-spring assembly must be replaced. For service it is acceptable to have a replacement air-spring assembly on one side of the vehicle, and an older style on the other side.

NOTE: The air-spring-to-frame-rail mounting bracket is not supplied with the air-spring assembly. If it needs to be replaced it must be ordered separately.

Follow these steps to replace the air-spring and piston assembly.

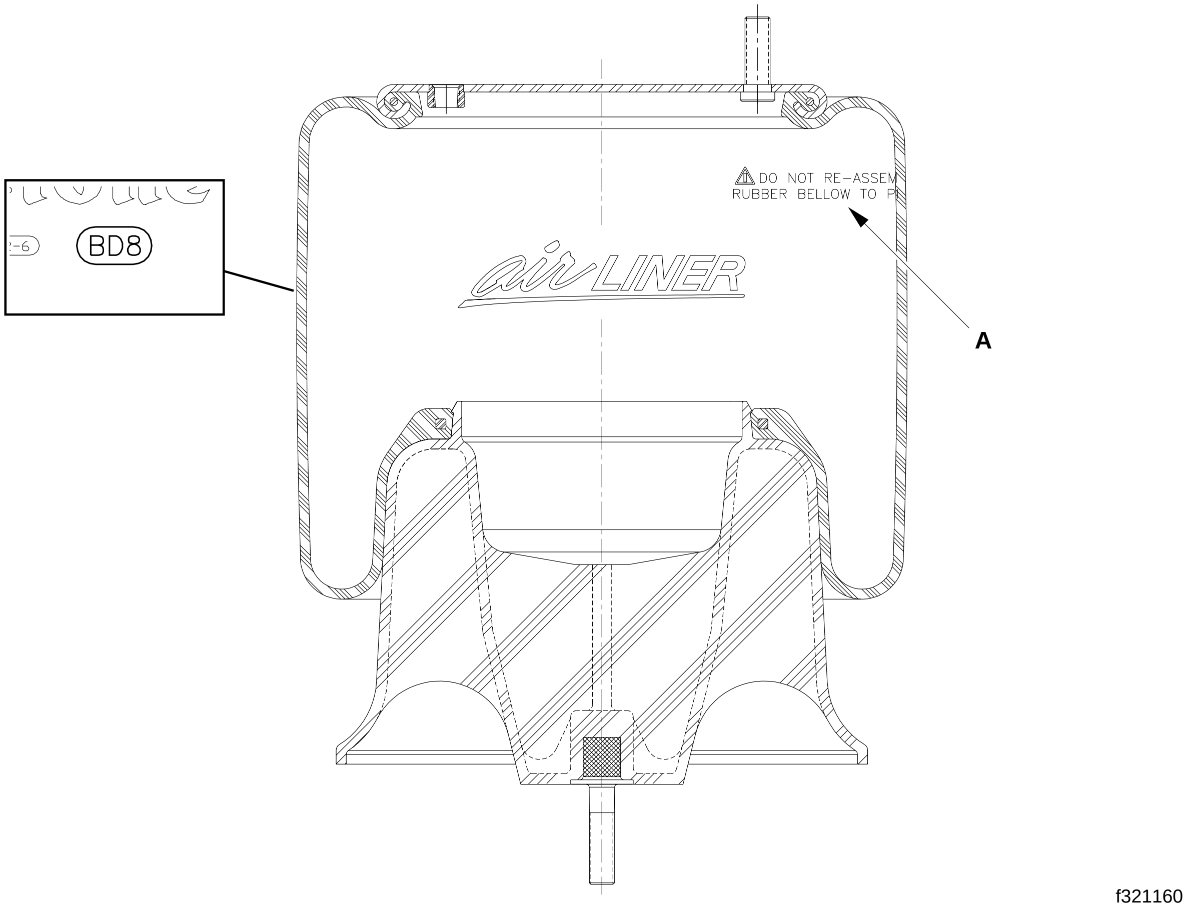
1. Chock the front tires. Raise the vehicle frame and support it with safety stands to remove all weight from the air springs. The leveling valve automatically releases air from the air springs when all weight is removed from the suspension.
2. Disconnect the air supply line, including the brass tee, from the air spring. Using tape, cover the ends of the air supply line and the fitting to prevent dirt or foreign material from entering.
3. Remove the locknuts and washers that connect the air spring to the upper mounting bracket, or to the frame rail flange. See **Fig. 2** and **Fig. 3**.
4. Remove the capscrews and lockwashers that connect the air spring to the rear of the leaf spring. Remove the air spring. See **Fig. 4**.

NOTE: Suspensions manufactured to a 46,000(20 865kg) or 23,000-pound (10 433 kg) weight rating have a different leaf spring, and an additional crossbar attached between the air spring and rear of the leaf spring. See **Fig. 5**.

5. Place the new air spring on the rear of the leaf spring (or the crossbar on the 23,000 and 46,000-pound suspensions), and install the washer and locknut that hold the air spring (and crossbar) in place. See **Fig. 4**. Tighten the locknut 55 lbf·ft (75 N·m).
6. *For bracket-mounted air springs:* Attach the air spring to the upper mounting bracket, using the 1/2–13 locknut on the outside of the frame rail and the 3/4–16 locknut on the inside. See **Fig. 2**. Tighten the 3/4–16 locknut 45 lbf·ft (61 N·m); tighten the 1/2–13 locknut 23 lbf·ft (31 N·m).

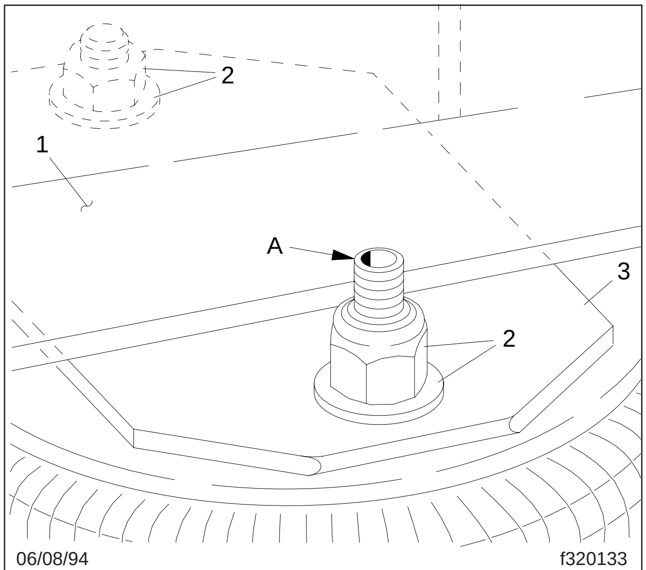
   For flange-mounted air springs: Attach the air spring to the frame rail flange, using the 3/4–16 locknut on the forward stud of the air spring, and the 1/2–13 locknut on the rear stud. See **Fig. 3**. Tighten the 3/4–16 locknut 45 lbf·ft (61 N·m); tighten the 1/2–13 locknut 23 lbf·ft (31 N·m).
7. Remove the tape from the ends of the air supply line, the fitting, and the brass tee. Connect the air supply line to the air spring. Tighten nylon tube air fittings until only two threads show on the fitting. On wire-braid hose fittings, tighten the nut with a wrench until there is firm resistance, then tighten one-sixth turn more.
8. Remove the safety stands, and lower the vehicle. Remove the chocks from the tires.

Air Spring Replacement



A. Caution: Do Not Re-Assemble Rubber Bellow to Piston

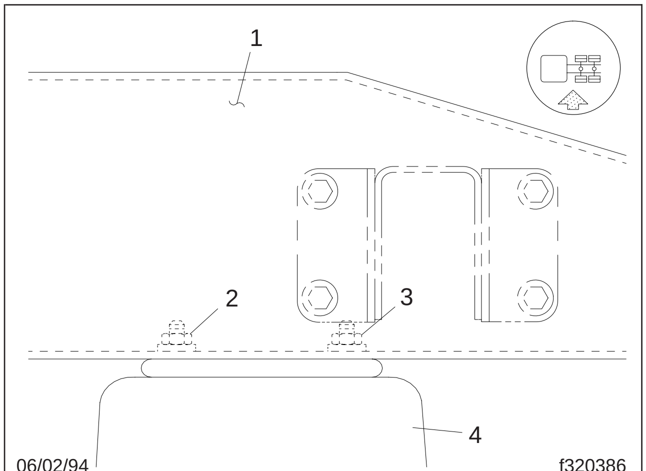
Fig. 1, Air-Spring and Piston Assembly



A. Air line connects here.

1. Right Frame Rail Flange
2. Locknut and Washer
3. Upper Mounting Bracket

Fig. 2, Bracket-Mounted Air Spring



1. Frame Rail (left)
2. 3/4–16 Locknut and Washer
3. 1/2–13 Locknut and Washer
4. Air Spring

Fig. 3, Flange-Mounted Air Spring

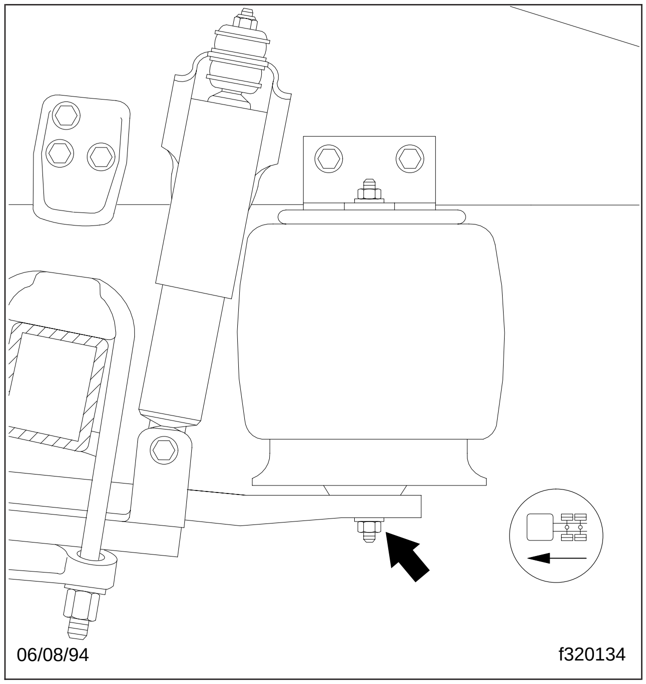
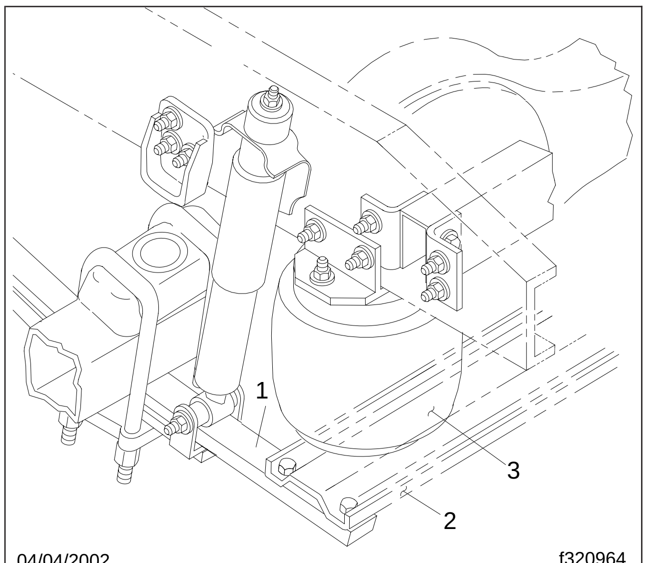


Fig. 4, Capscrew Connecting Leaf Spring and Air Spring



1. Leaf Spring
2. Crossbar
3. Air Spring

Fig. 5, Leaf Spring and Air Spring Assembly (23,000 and 46,000- pound suspensions)

Leaf Spring Replacement

NOTE: See **Fig. 1** for this procedure.

WARNING

Do not replace individual leaves of a damaged leaf spring assembly; replace the complete spring assembly. Visible damage (cracks or breaks) to one leaf causes hidden damage to other leaves. Replacement of only the visibly damaged part(s) is no assurance that the spring is safe. Failure to replace a damaged spring assembly could cause an accident resulting in serious personal injury or property damage.

1. Chock the front tires.
2. Raise the rear of the vehicle, and support the rear axle(s) with safety stands. Raise the vehicle so that all weight is removed from the leaf springs, then securely support the frame with safety stands. Remove the wheel and tire assembly to easily access the suspension. See **Group 40** of this manual for instructions.
3. Remove the nut, bolt, and washers from the shock absorber lower mounting bracket. Remove the high nuts, flatwashers, and axle clamp from each U-bolt. Support the leaf spring assembly with a jack.
4. If the air spring mounts to the leaf spring, disconnect the bottom of the air spring from the leaf spring.

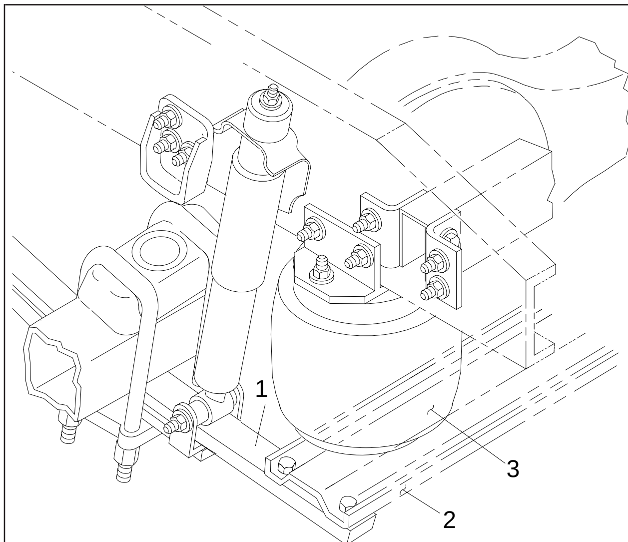
   If the air spring mounts to a crossbar, disconnect the crossbar from the leaf spring by removing the capscrews, nuts, and washers. See **Fig. 1**.
5. Note the number and position of the alignment shims on the spring mounting bolt. See **Fig. 2**.
6. Remove the hexnut, washers, alignment shim(s), spring mounting bolt, and wear shoe clip from the spring hanger. See **Fig. 2**.

WARNING

The leaf spring assembly is heavy. Use care when handling it to prevent injury.

7. Remove and discard the leaf spring assembly.
8. While supporting a new leaf spring assembly with a jack, position the assembly on the spring hanger. Install the bolts, wear shoe clips, washers, alignment shims, and hexnuts. Tighten the bolts just enough to hold the leaf spring assembly in place.
9. If the air spring mounts to the leaf spring, attach the air spring to the leaf spring assembly. Install the washer and locknut. Tighten the locknut 55 lbf·ft (75 N·m).

   If the air spring mounts to a crossbar, attach the crossbar to the leaf spring assembly. The longer capscrews attach in the forwardmost holes; the shorter capscrews attach in the aft holes.
10. Making sure that the U-bolt pads are in place on the top of the axle, fasten the leaf spring assembly to the axle using the U-bolts, axle clamp, washers, and high nuts making sure the U-bolt pads and axle clamps are positioned correctly.



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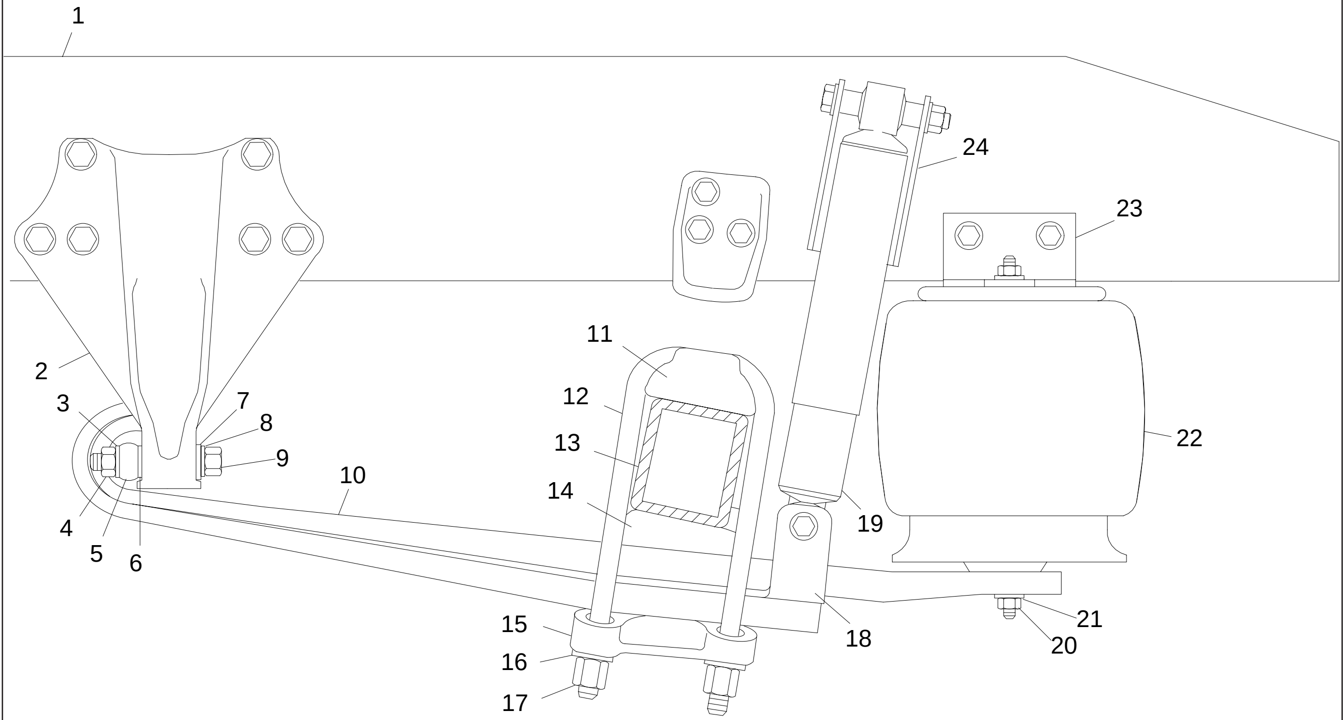
1. Leaf Spring
2. Crossbar
3. Air Spring

Fig. 1, Leaf Spring and Air Spring Assembly (23,000- and 46,000-pound suspensions)

NOTE: On single-drive axles angled 5 degrees, the arrow on the U-bolt pads must point to the front of the axle housing. See **Fig. 3**. On single-drive axles angled 3 degrees, there is no arrow. Make sure that the axle bump stop on the U-bolt pad is positioned toward the vehicle centerline. See **Fig. 4**.

Leaf Spring Replacement



1. Frame Rail
2. Spring Hanger
3. Washer
4. Hexnut
5. Spring Mounting Eye Pin
6. Alignment Shim
7. Wear Shoe Clip
8. Washer
9. Spring Mounting Bolt
10. Leaf Spring Assembly
11. U-Bolt Pad
12. U-Bolt
13. Axle
14. Axle Seat
15. Axle Clamp
16. Flatwasher
17. High Nut
18. Shock Absorber Lower Mounting Bracket
19. Shock Absorber
20. Nylon Locknut
21. Washer
22. Air Spring
23. Air Spring Mounting Bracket
24. Shock Absorber Upper Mounting Bracket

Fig. 2, AirLiner Leaf Spring Assembly

With both 5- and 3-degree single-drive axle angles, the arrow on the bottom of the axle clamp must point toward the rear of the vehicle. See **Fig. 2**.

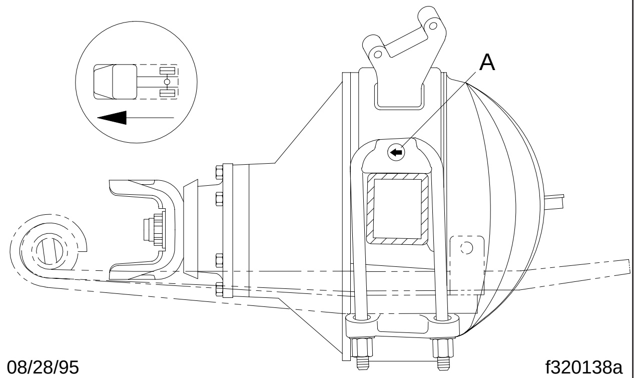
On tandem axle suspensions, refer to **Table 1** for U-bolt pad orientation. The arrow on the bottom of the axle clamp must point toward the rear of the vehicle on the forward rear axle and toward the front of the vehicle on the rearmost axle.

11. Hand tighten the high nuts. In a diagonal pattern, tighten the axle U-bolt high nuts 60 lbf·ft (81 N·m). Then, in the same pattern, tighten them 200 lbf·ft (271 N·m); then, torque to the final value of 400 to 460 lbf·ft (542 to 624 N·m).

    For the 23,000-pound and 46,000-pound suspensions, tighten the high nuts in a diagonal pattern to a final torque value of 520 to 600 lbf·ft (705 to 813 N·m).

12. Install the bolt, washers, and hexnut to connect the shock absorber to its lower mounting bracket. Tighten the hexnut 170 lbf·ft (230 N·m).

13. Tighten the locknut on the bottom of the air spring 55 lbf·ft (75 N·m).



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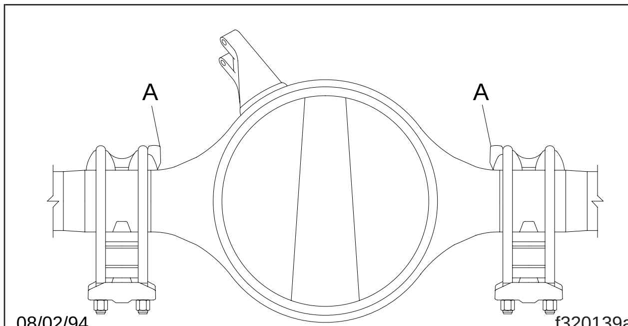
A. Arrow on U-Bolt Pad

Fig. 3, U-Bolt Pad Arrow Positioning

On 23,000-pound and 46,000-pound suspensions, tighten the locknuts on the bottom of the crossbar 241 lbf·ft (327 N·m).

14. Tighten the hexnuts at the front of the leaf spring 170 lbf·ft (230 N·m).
15. Install the wheel and tire assembly. For instructions, refer to **Group 40** of this manual. Remove the safety stands, and lower the vehicle.



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A. Axle Bump Stop

Fig. 4, Axle Bump Stop Positioning

16. Check the rear axle alignment. For instructions, refer to the rear axle section in this manual. If necessary, adjust the rear axle alignment using the instructions in **Subject 180**.

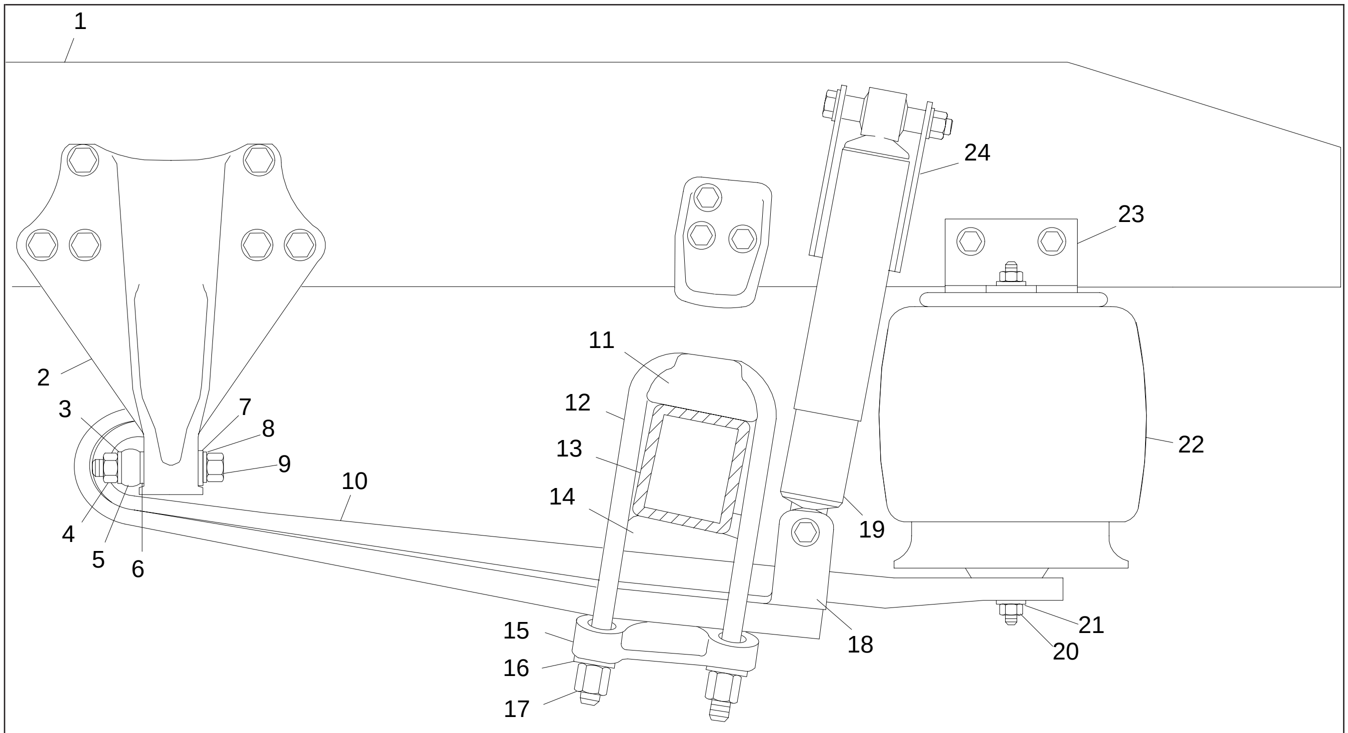
Interaxle Spacing: inches (cm)	Axle Designation		U-Bolt Pad Orientation
51 (130) 55 (140)	All	Forward Rear Axle	No arrow; axle bump stop toward vehicle centerline.
		Rearmost Axle	Arrow toward front of vehicle.
59 (150)	Meritor RT40-160	Forward Rear Axle	No arrow; axle bump stop toward vehicle centerline.
		Rearmost Axle	Arrow toward front of vehicle.
	All except Meritor RT46-160	Forward Rear Axle	No arrow; axle bump stop toward vehicle centerline.
		Rearmost Axle	No arrow; axle bump stop toward vehicle centerline.

Table 1, U-Bolt Pad Orientation for Axles

Rear Axle Alignment Adjusting

NOTE: See **Fig. 1**.

Follow the instructions in **Group 35** to see if rear axle alignment adjustment is needed. If adjustment is needed, proceed as follows:



1. Frame Rail
2. Spring Hanger
3. Washer
4. Hexnut
5. Spring Pin
6. Alignment Shim
7. Wear Shoe Clip
8. Washer
9. Spring Pinch Bolt
10 Leaf Spring Assembly
11. U-Bolt Pad
12. U-Bolt
13. Axle
14. Axle Seat
15. Axle Clamp
16. Flatwasher
17. High Nut
18. Shock Absorber Lower Mounting Bracket
19. Shock Absorber
20. Nylon Locknut
21. Washer
22. Air Spring /CALLOUTTEXT>
23. Air Spring Mounting Bracket
24. Shock Absorber Upper Mounting Bracket

Fig. 1, Rear Axle Suspension

1. Loosen the spring pinch bolts so that the forward end of the leaf spring can slide fore and aft in the spring hanger.
2. Move the axle forward or backward until it is aligned within the tolerances in **Group 35**.
3. When the axle is in alignment, install alignment shim(s) to take up the slack between the spring hanger and the spring pin.

IMPORTANT: Make sure the same number of shims is installed on both ends of the spring pin.

4. Tighten the spring pinch bolts 170 lbf·ft (230 N·m).
5. Check the axle alignment again. If necessary, repeat the above procedure until the alignment is within tolerances.

Rear Axle Alignment

Rear Axle Tracking Adjustment

Single Axle

1. At the forward edge of the right rear tire, measure the distance from the inner side of the tire to the outer side of the right frame rail. See **Fig. 2**.

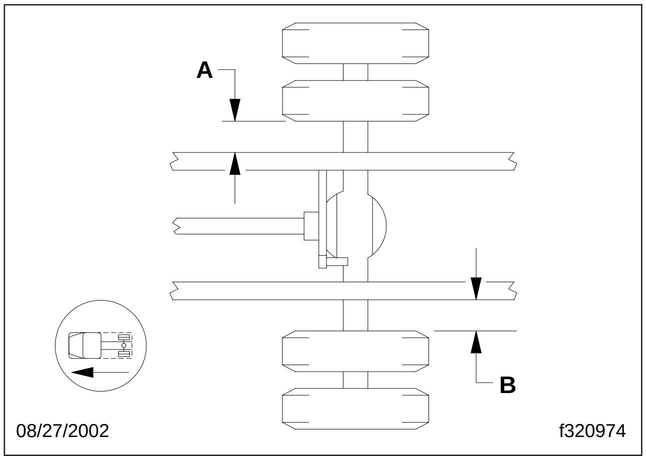


Fig. 2, Rear Axle Tracking Measurements (single axle)

2. At the rear edge of the left rear tire, measure the distance from the inner side of the tire to the outer side of the left frame rail. See **Fig. 2**.

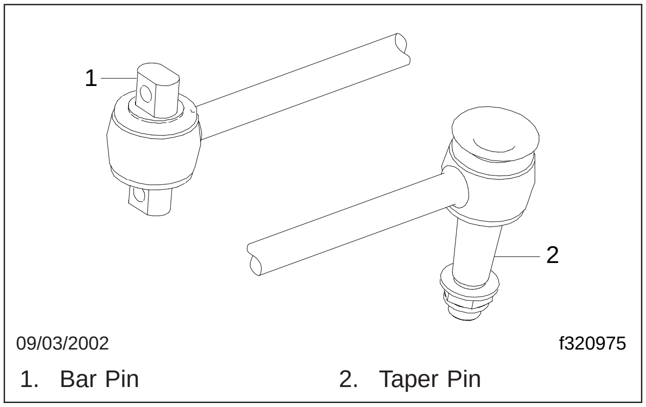
IMPORTANT: Measurement "A" should not vary by more than 1/4-inch (6 mm) from measurement "B."

3. If measurements "A" and "B" vary by more than 1/4-inch (6 mm), loosen the fasteners holding the lateral torque rod to the frame rail. Add or remove torque-rod shims as needed.
4. For bar-pin style torque rods, tighten the fasteners 136 lbf·ft (184 N·m).

   For taper-pin style torque rods, tighten the fasteners 165 lbf·ft (224 N·m). See **Fig. 3**.

Tandem Axles

1. Check the tracking of the forward-rear axle. For instructions, see "Single Axle" in this subject. Adjust the tracking if needed.
2. At the forward-rear drive axle, measure the distance from the inner side of the right rear tire to the outer side of the right frame rail. Measure at the forward edge of the tire. See **Fig. 4**.



1. Bar Pin 2. Taper Pin

Fig. 3, Torque Rod Types

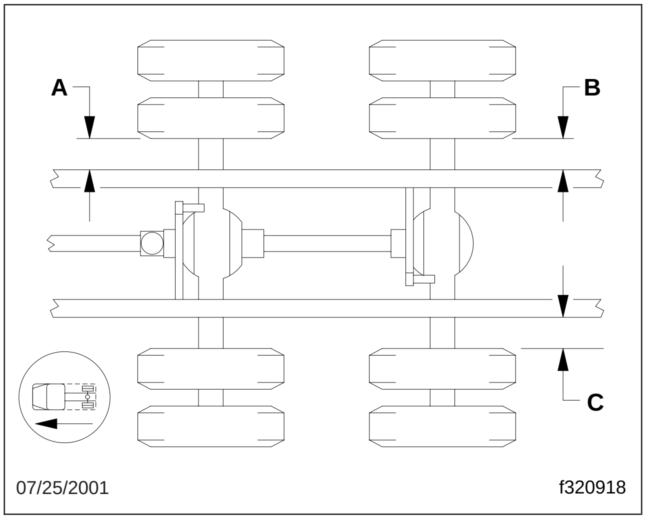


Fig. 4, Rear Axle Tracking Measurements (tandem axles)

3. At both sides of the rear-rear drive axle, measure the distance from the inner side of the rear tires to the outer side of each frame rail. Measure at the rear edge of each tire. See **Fig. 4**.

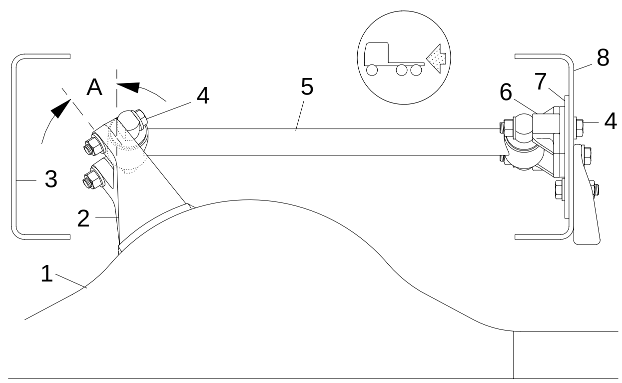
IMPORTANT: Measurements "B" and "C" should not vary by more than 1/4-inch (6 mm) from measurement "A."

4. If measurements "B" and "C" vary by more than 1/4-inch (6 mm) from measurement "A," loosen the fasteners holding the axle lateral torque rod at the rear-rear drive axle to the frame rail. Add or remove torque-rod shims as needed.

5. For bar-pin style torque rods, tighten the fasteners 136 lbf·ft (184 N·m). For taper-pin style torque rods, tighten the fasteners 165 lbf·ft (224 N·m). See **Fig. 3**.

Replacement

1. Park the vehicle. Shut down the engine, and apply the parking brakes.
2. Chock the tires. Raise the vehicle. Support the frame rails with jack stands.
3. Remove the fasteners holding the control rod to the frame rail bracket. Remove the shims, and set the shims aside.
4. Remove the control rod.
5. Position the new control rod so that the end with the fasteners angled up at 35 degrees is installed in the axle housing bracket. See **Fig. 1**.



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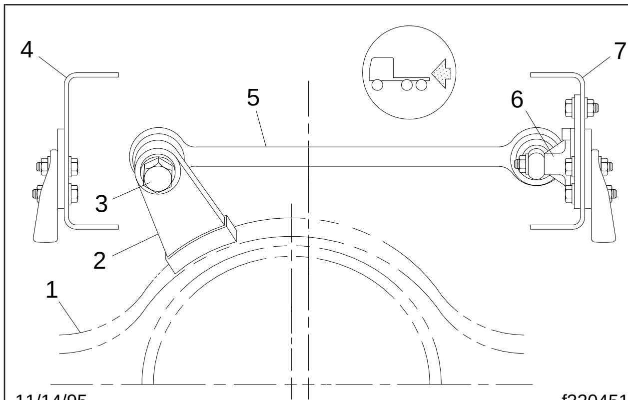
A. Angle: 35 degrees

1. Axle Housing
2. Control Rod Axle Bracket
3. Left Frame Rail
4. Bolt
5. Control Rod
6. Control Rod Frame Bracket
7. Shim
8. Right Frame Rail

Fig. 1, AirLiner Control Rod Installation

6. Install the fasteners with the bolt heads facing up. Tighten the fasteners enough to hold the control rod in place.
7. Install the shims that were previously removed.
8. Install the other end of the control rod in the frame rail bracket; then, install the fasteners. Tighten the fasteners enough to hold the control rod in place.
9. Tighten all the fasteners 136 lbf·ft (184 N·m).
10. Remove the jack stands. Lower the vehicle. Remove chocks.



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1. Axle Housing
2. Control Rod Axle Bracket
3. Bolt
4. Left Frame Rail
5. Control Rod
6. Control Rod Frame Bracket
7. Right Frame Rail

Fig. 2, Control Rod Installation on 23,000- and 46,000-pound AirLiner Suspensions

NOTE: Control rods on suspensions manufactured to a 23,000-pound (10 433 kg) or 46,000-pound (20 865 kg) weight rating are larger and are attached to the axle bracket with a single bolt. Tighten the fasteners attaching the control rod frame bracket to the frame rail 160 to 170 lbf·ft (217 to 230 N·m), and the bolt connecting the control rod to the axle housing 175 to 225 lbf·ft (237 to 305 N·m). See **Fig. 2**.

Replacement

WARNING

Do not replace individual leaves of a damaged leaf spring assembly; replace the complete spring assembly. Visible damage (cracks or breaks) to one leaf causes hidden damage to other leaves. Replacement of only the visibly damaged part(s) is no assurance that the spring is safe. Failure to replace a damaged spring assembly could cause an accident resulting in serious personal injury or property damage.

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front tires.
2. Raise the rear of the vehicle, and support the rear axle(s) with safety stands. Raise the vehicle so that all weight is removed from the leaf springs, then securely support the frame with safety stands.
3. Remove the wheel and tire assembly to easily access the suspension. For instructions, see the information in **Group 40** of this manual.
4. Remove the leaf spring assembly. See removal information in **Subject 170**.

WARNING

The leaf spring assembly is heavy. Use care when handling it to prevent injury.

5. Remove the bushing from the leaf spring eye.

WARNING

Do not use a cutting torch to remove the outer metal of the bushing from the spring eye. Welding, torching or cutting the leaf spring assembly can damage the leaf spring material, which may result in the failure of the components and cause serious personal injury, death, or property damage.

5.1 Using a shop press with a capacity of at least 10 tons (9 072 kg), place the spring assembly in the shop press with the spring assembly squarely supported on the press bed for safety and to avoid bending the spring assembly.

5.2 Center the bushing tool on the outer metal of the bushing and push the bushing from the spring eye.

5.3 Remove any burrs or material left behind by the old bushing.

6. Install the new bushing in the leaf spring eye.

6.1 Position the bushing on the shop press.

6.2 Apply a bonding agent, either Permabond HM–160 or Loctite RC–609 or 680, liberally around the outside surface of the bushing.

6.3 Press the bushing into place.

6.4 Allow the bonding agent to cure for 24 hours.

NOTE: After the curing time, the bushing must resist a minimum 7,700 lb (3 490 kg) pushout force.

7. Install the leaf spring assembly. See the information in **Subject 170**.
8. Install the wheel and tire assembly. For instructions, see **Group 40** of this manual. Remove the safety stands, and lower the vehicle.
9. Check the rear axle alignment. For instructions, see **Group 35** of this manual. If necessary, adjust the rear axle alignment using the instructions in **Group 35** of this manual.
10. Remove the chocks from the tires.

Torque Specifications

For fastener torque values, see Table 1.

Torque Values for AirLiner Suspension			
Description	Size	Torque	
		lbf·ft (N·m)	lbf·in (N·cm)
Height-Control Valve Housing Bolts*	1/4–20	—	45 (500)
Height-Control Valve Mounting Locknuts*	1/4–20	—	95 (1100)
Shock Absorber Mounting Locknuts	3/4–10	165 (220)	—
Air Spring Upper Mounting Locknuts	3/4–16	45 (61)	—
	1/2–13	23 (31)	—
Air Spring Lower Mounting Locknuts	1/2–13	55 (75)	—
Leaf Spring Mounting Eye Bolt Locknuts	3/4–10	241 (327)	—
Control Rod Mounting Bolt Locknuts	5/8–11	136 (184)	—
Axle U-bolt High Nuts Tighten in a diagonal pattern as shown in Fig. 1.	7/8–14	Stage 1: Hand tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 420 to 500 (571 to 680)	—
	1–14	Stage 1: Hand tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 520 to 600 (707 to 816)	—
Air Spring Upper Mounting Bracket	5/8–11	136 (184)	—
Spring Hanger Mounting Locknuts	3/4–10	240 (325)	—

* See the cautionary statements below.

Table 1, Torque Values for AirLiner Suspension

IMPORTANT: To prevent voiding the warranty on Barksdale height-control valves, note the following:

- Do not overtighten the bolts in the Barksdale height-control valve housing. The bolts should not be loose, and should not require tightening. Only if necessary, tighten the valve housing bolts 45 lbf·in (500 N·cm). Any damage to the valve housing will void the warranty.
- Do not attempt to disassemble the Barksdale valve body or the control lever. There are no serviceable parts in the valve, and any disassembly will void the warranty.

NOTICE

When removing or loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the

Specifications

valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

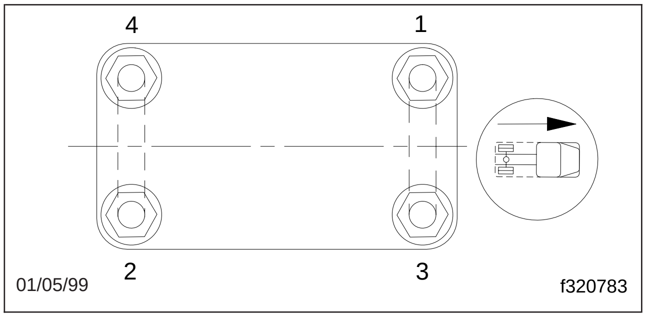
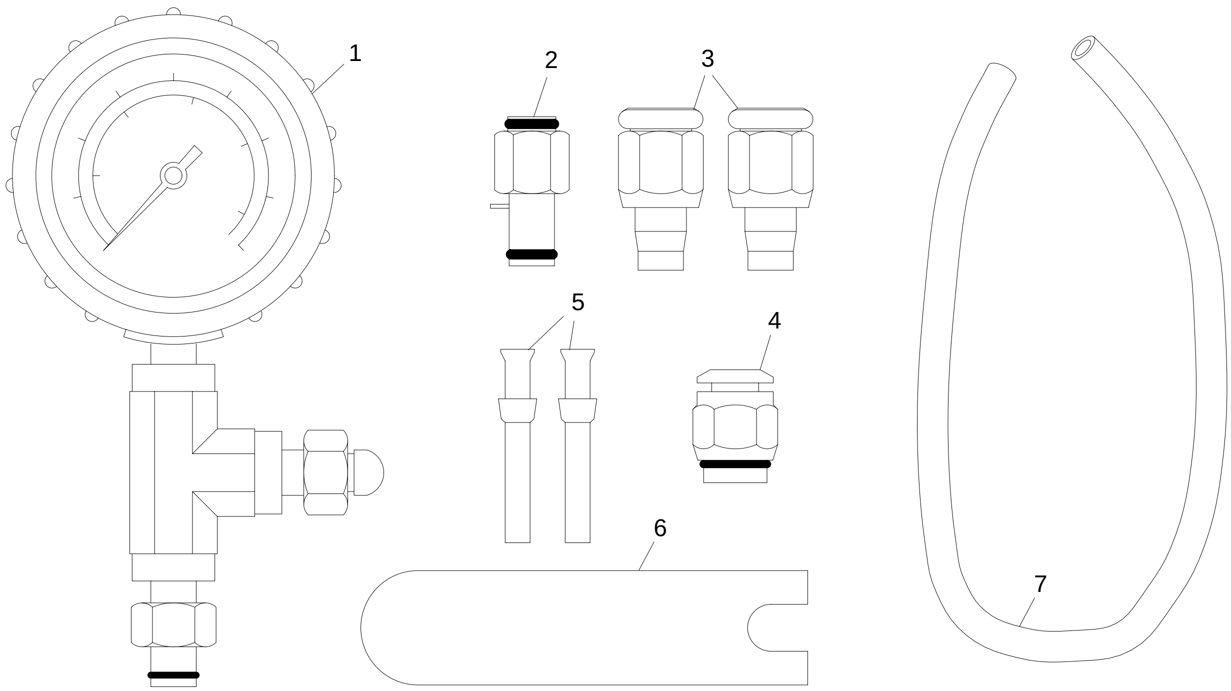


Fig. 1, Tightening Pattern for U-Bolt High Nuts

Special Tools

Use the kit shown in **Fig. 2** to test a Barksdale height-control valve. Test kit BKS KD2264 is available via the Direct Ship program in Paragon.



NOTE: Parts for cab suspension valve testing included.

1. Test Gauge Assembly with Reset Button
2. Exhaust Port Test Connector for Cab Suspension Valve (used for cab suspension valve testing)
3. Parker Plugs
4. Exhaust Port Test Connector for Chassis Suspension Valve
5. Test Plugs for Cab Suspension Valve (used for cab suspension valve testing)
6. Special Tool for Disconnecting Air Line
7. Air Line

Fig. 2, Barksdale Height-Control Valve Test Kit BKS KD2264

General Information

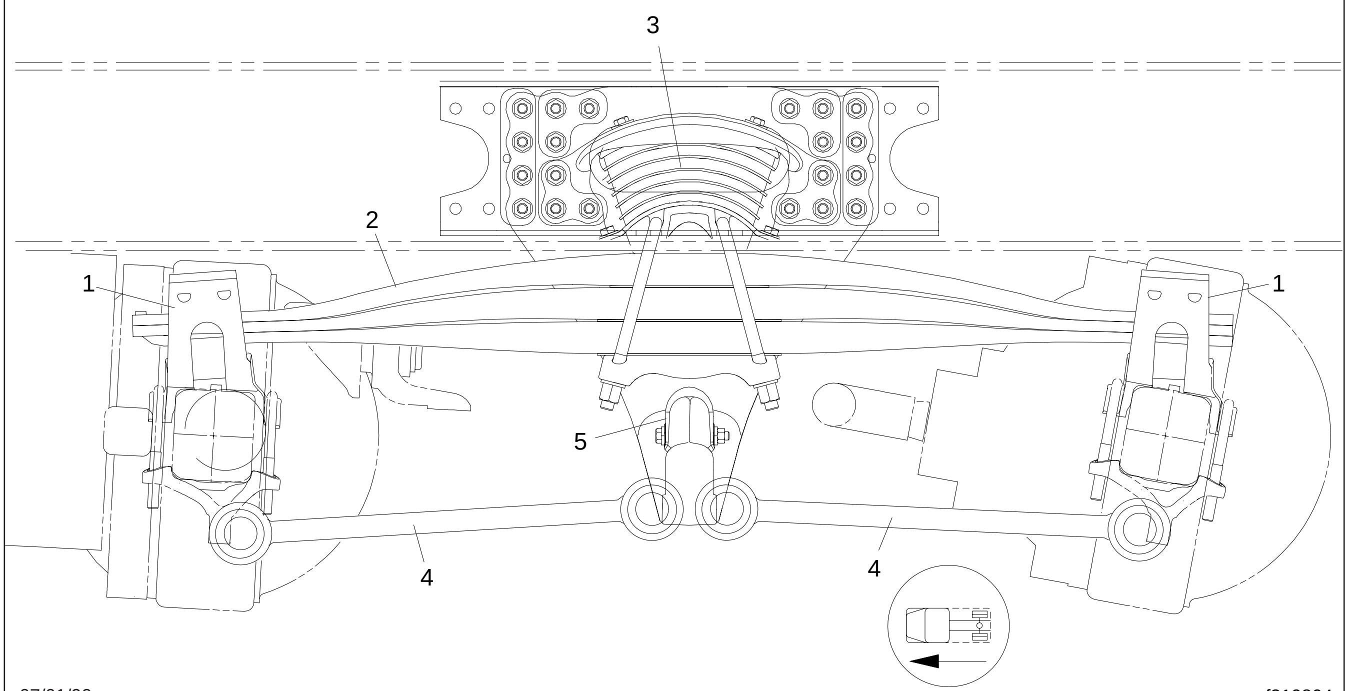
The TufTrac Suspension is heavy-duty "six rod" tandem-axle suspension option for trucks built for severe on/off highway work. See **Fig. 1**. The TufTrac design allows a truck to maneuver over bumps, ridges and washboard roads that typically generate high rates of axle articulation, without bottoming out the suspension or losing traction.

The TufTrac suspension is available in two weight ratings: 40,000-, and 46,000-pound (18 144- and 20 865-kilogram) capacities. The 40,000-pound (18 144-kilogram) capacity suspension uses two taper leaf springs and has an axle spacing of 54 inches. The 46,000-pound (20 865-kilogram) capacity suspension has three leaf springs (shown in this section). The 46,000-pound (20 865-kilogram) suspension has a standard axle spacing of 56 inches.

Principles of Operation

Six functional links in the TufTrac suspension maintain the positions of the axles. Side-to-side axle movement is controlled by two V-rods from the frame to the axles at the top of the differentials. Four control rods from the frame to the axles at the bottom control the forces of driving and braking as well as fore-and-aft road shocks. Vertical loads are carried by the rubber-isolated parabolic taper leaf spring packs.

General Information



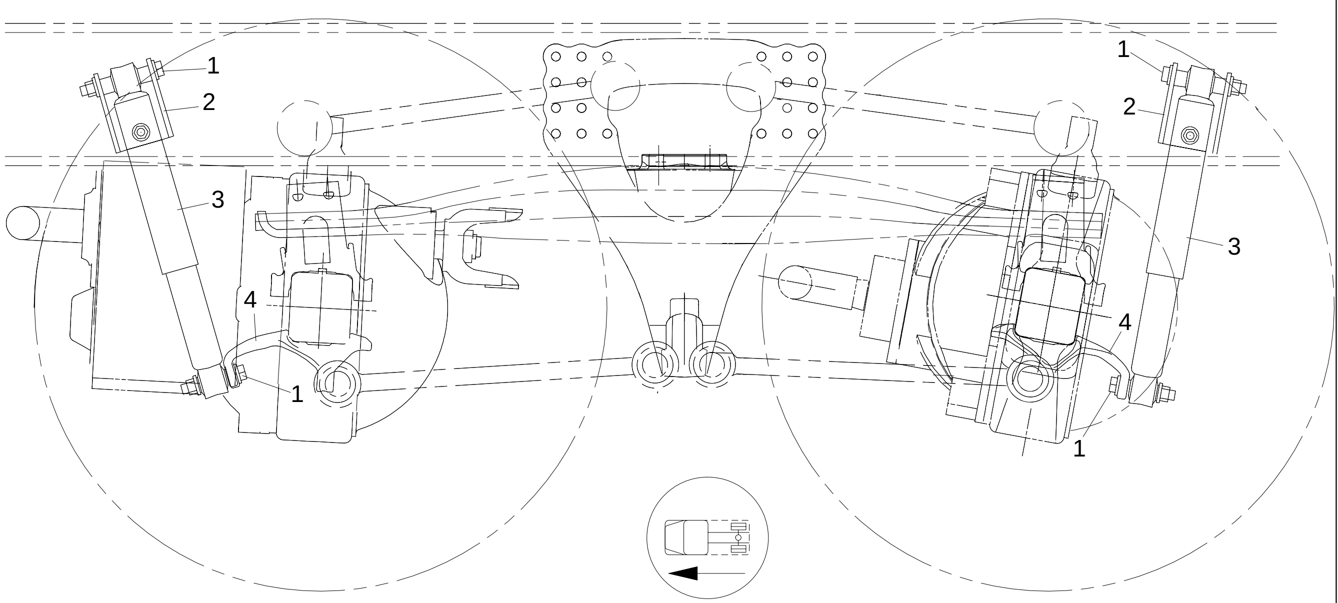
1. Axle Clamps
2. Leaf Springs
3. Center Bearing
4. Lower Control Rods
5. Rebound Stop

Fig. 1, TufTrac Suspension (46,000-pound [20 865-kilogram] version shown)

Replacement

NOTE: See **Fig. 1** for this procedure.

1. Park the vehicle on a level surface, shut down the engine and apply the parking brakes. Chock the tires.
2. Remove the lower shock mounting nut and washer.
3. Remove the upper shock mounting nut and washer.
4. Remove the upper and lower mounting bolts and remove the shock absorber.
5. Position the new shock absorber in place and install the mounting bolts.
6. Loosely fasten the bolts with the nuts and washers removed from the old shock absorber.
7. Torque each mounting nut 241 lbf·ft (327 N·m).
8. Remove the chocks from the tires.

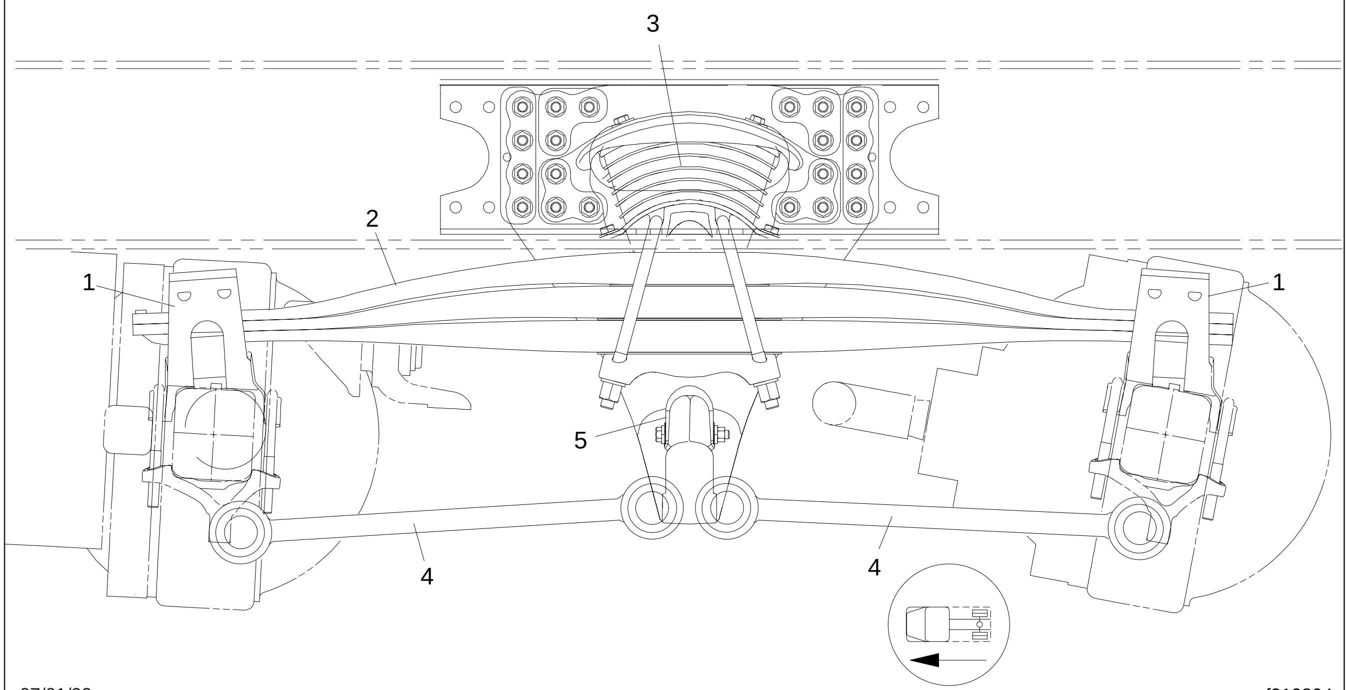


1. Mounting Bolt
2. Upper Mounting Bracket
3. Shock Absorber
4. Lower Mounting Bracket

Fig. 1, Shock Absorber Replacement

Replacement

1. Park the vehicle on a level surface, shut down the engine and apply the parking brakes. Chock the tires.
2. Remove the rebound stop from the suspension. See **Fig. 1**.



07/01/99 f310804

1. Axle Clamps
2. Leaf Springs
3. Center Bearing
4. Lower Control Rods
5. Rebound Stop

Fig. 1, TufTrac Suspension (46,000-pound [20 865-kilogram] version shown)

   2.1 Remove the nut and bolt securing the rebound stop to the mounting bracket.

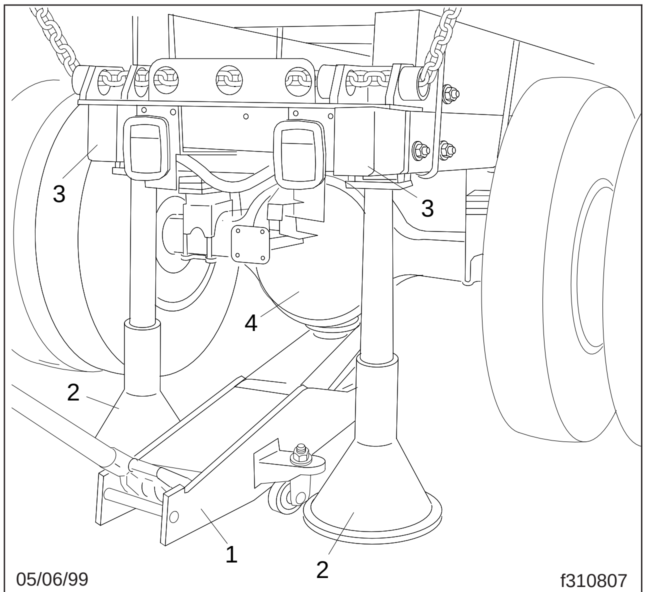
   2.2 Slide the rebound stop from the mounting bracket.

3. Remove the upper two fasteners on the center bearing.
4. Jack up the vehicle under the rear axle.
5. Support the rear frame rails with jack stands, then lower the jack. This will clear the center bearing from the top of the mounting bracket. See **Fig. 2**.
6. Remove the lower center bearing bolts attached to the spring assembly casting. Discard the bolts.
7. Remove the center bearing. See **Fig. 3**.
8. Position the new center bearing in the mounting bracket.
9. Install the upper mounting bolts and tighten 68 lbf·ft (92 N·m).
10. With the jack, raise the rear axle until bottom of the center bearing meets the mounting bracket on the leaf springs.

IMPORTANT: Be sure to use new bolts with Loctite (p/n 23-12576-125) when attaching the center bearing to the leaf spring casting.

11. Install new lower mounting bracket bolts (p/n 23-12576-125). Tighten the bolts 155 lbf·ft (210 N·m).

Center Bearing Replacement



1. Jack
2. Jack Stand
3. Frame Rail
4. Rear Axle

Fig. 2, Jack and Jack Stand Placement

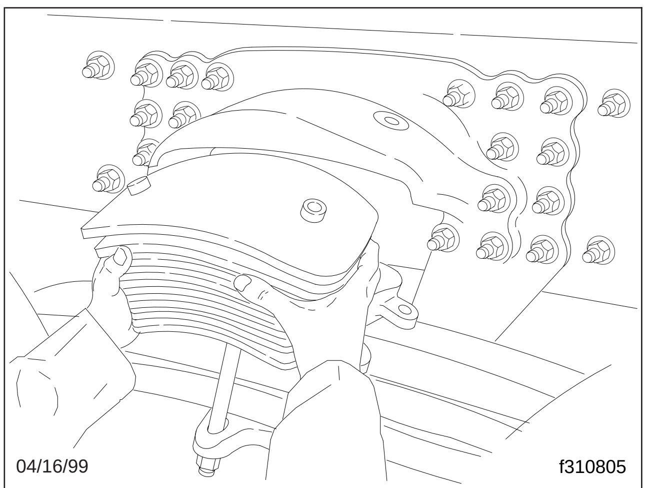


Fig. 3, Center Bearing Removal

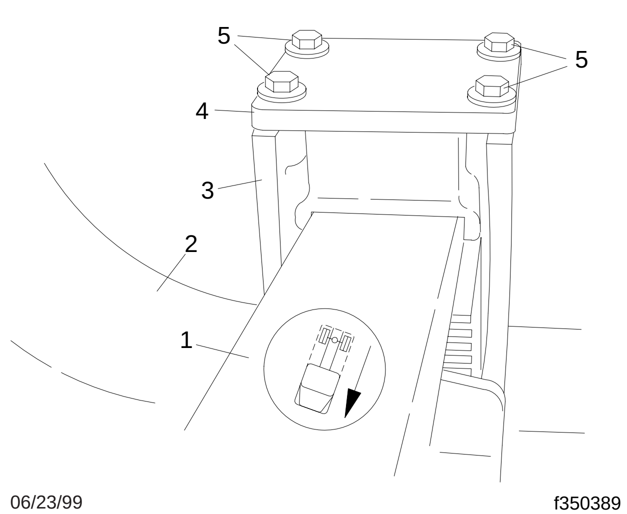
12. Return the vehicle to its normal operating position.
13. Install the rebound stop.
14. Remove the chocks from the tires.

Spring Assembly Removal, Assembly and Installation

IMPORTANT: The spring pack assembly is not available as an assembled unit in the aftermarket. If the spring pack assembly is to be replaced with a new assembly, the springs, center bearing seat and retainer bracket must be assembled before installation on the vehicle.

Removal

1. Park the vehicle on a level surface. Shut down the engine and apply the parking brakes. Chock the tires.
2. Remove the tip pad bolts above each axle on the axle clamp. There are four bolts on each pad. See **Fig. 1**.



1. Leaf Springs
2. Axle
3. Axle Pad
4. Tip Pad
5. Tip Pad Bolts

Fig. 1, Tip Pad Installation

3. Remove the center bearing. See **Subject 110**.
4. With the vehicle still raised, remove the wheels on both rear axles on the side the spring assembly will be replaced. For instructions, see **Group 40**.

WARNING

Do not attempt to remove the spring assembly by hand. The assembly is very heavy and attempting to lift it could result in bodily injury.

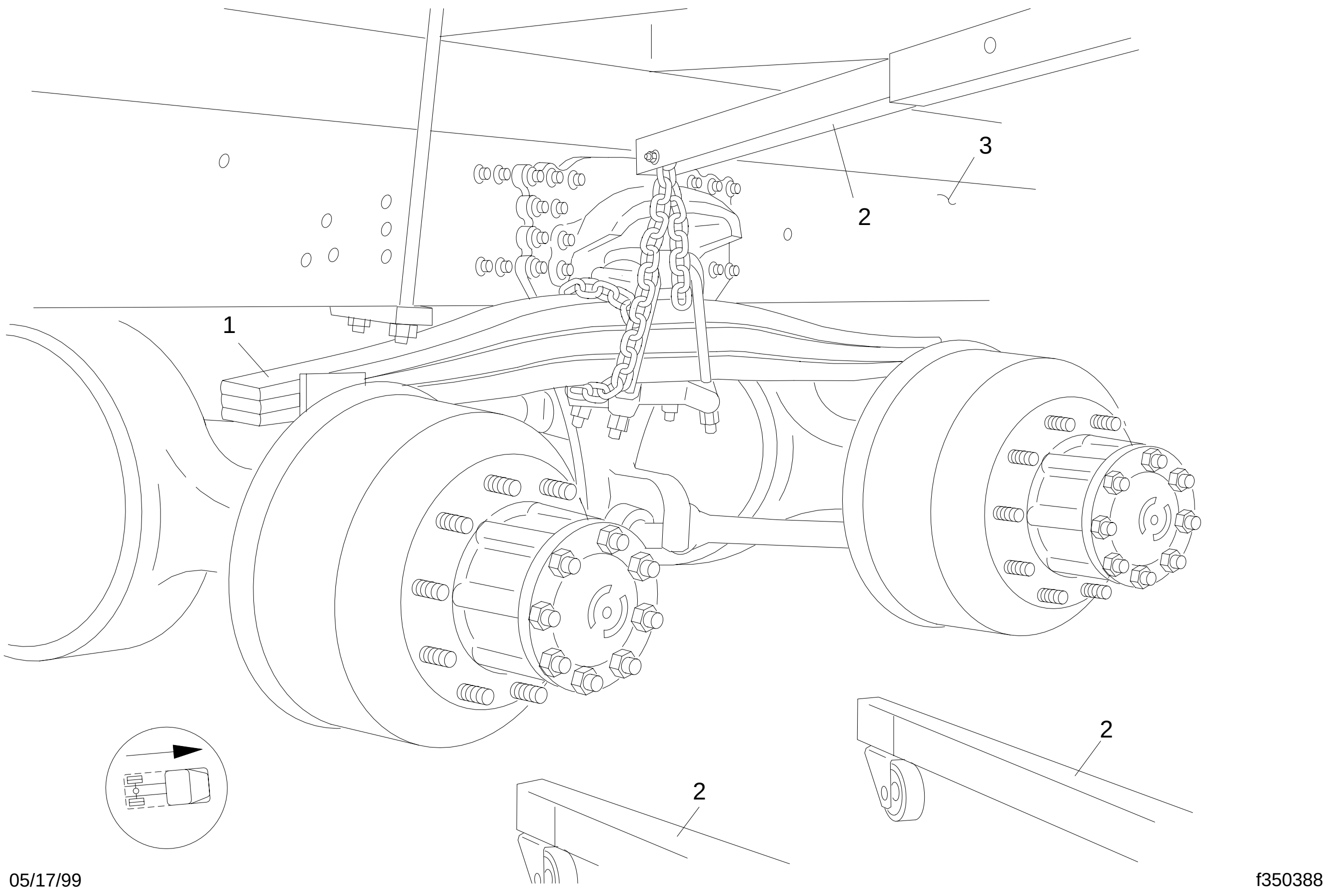
5. Using a lift (i.e. engine hoist), remove the leaf spring assembly from the vehicle. See **Fig. 2**.

Assembly

IMPORTANT: Leaf springs in a spring pack assembly cannot be replaced individually. The entire spring pack assembly must be replaced.

1. Support both sides of the new spring pack assembly on jack stands. Make sure all the leaf springs are interlocking with the studs and dimples at the centers of the leaf springs.
2. If the assembly contains a spacer, place it on the center of the top leaf spring. Make sure the dimple in the spacer is aligned with the stud in the center of the top leaf spring.
3. Place the center bearing seat on the top of the spacer or leaf spring, as applicable. Make sure the dimple in the middle of the center bearing seat aligns with the stud in the middle of the leaf spring or the spacer.
4. Install the two 3/4-inch U-bolts over the center bearing seat. Make sure the U-bolts rest in the grooves of the center bearing seat.
5. At the bottom of the spring pack, install the U-bolt retainer bracket over the threaded ends of the U-bolts.
6. Holding the retainer bracket in place, install a hardened washer and hexnut over the threaded end of each U-bolt.
7. Tighten the U-bolts in a diagonal sequence as follows:
   - Stage 1: 60 lbf·ft (81 N·m)
   - Stage 2: 200 lbf·ft (271 N·m)
   - Stage 3: 300 lbf·ft (407 N·m)

Spring Assembly Removal, Assembly and Installation



1. Springs
2. Lift (hoist)
3. Frame Rail

Fig. 2, Leaf Spring Replacement

Installation

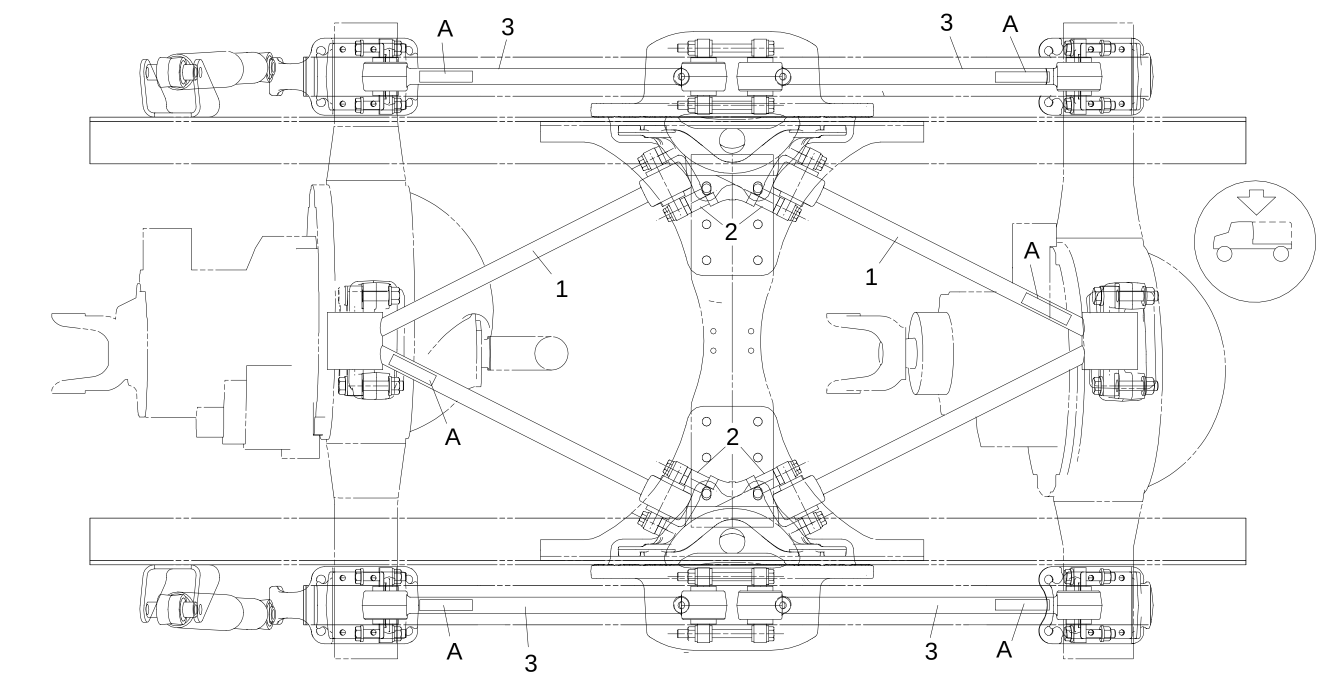
⚠ WARNING

Do not attempt to install the spring assembly by hand. The assembly is very heavy and attempting to lift it could result in bodily injury.

1. Place the new spring assembly on the vehicle.
   1.1 Attach the new assembly to the lift.
   1.2 Using the lift (hoist), lift the assembly into place on the axle clamps.
2. Install the center bearing. For instructions, see **Subject 110**.
3. Install the tip pad and bolts on each axle clamp. Tighten the bolts 37 lbf·ft (50 N·m). See **Fig. 1**.
4. If not already installed, install the rebound stop and mounting bolt. Tighten the nut 68 lbf·ft (92 N·m).
5. Install the wheels. For instructions, see **Group 40**.
6. Return the vehicle to its normal operating position.
7. Remove the chocks from the tires.

Lower Control Rod Replacement

NOTE: See **Fig. 1** for this procedure.



A. Label
1. V-Rod
2. Spacer
3. Lower Control Rod

Fig. 1, Control and V-Rod Assembly

1. Park the vehicle on a level surface, shut down the engine, and apply the parking brakes. Chock the front tires.
2. Raise the rear axle and support the frame rails with jack stands.
3. Lower the jack under the axle. See **Fig. 2**.
4. Remove the bolts holding both rods between the rear axles, below the rebound stop. See **Fig. 3**.
5. Remove the nut and bolt from the axle clamp.
6. Remove the control rod from the vehicle.

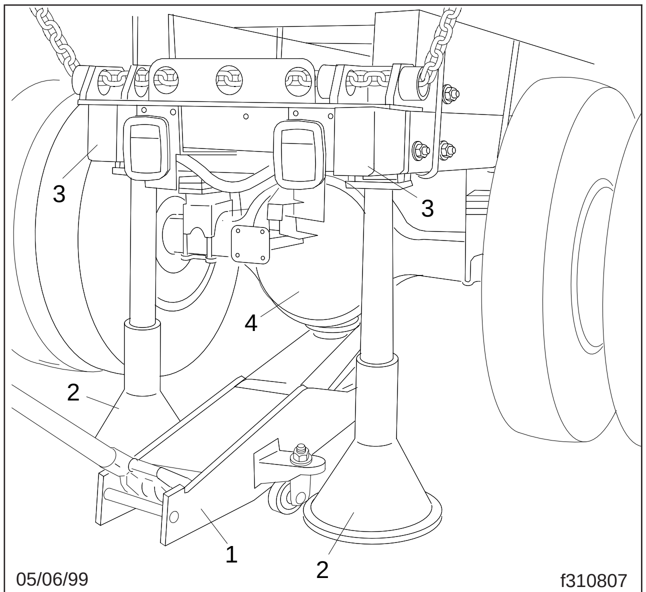
IMPORTANT: When installing the rods make sure the labels on the rods are facing upward. Forward axle rods are marked "FDA" and rear axle rods "RDA."

7. Fasten the new control rod to the axle clamp. Tighten the nut 136 lbf·ft (184 N·m).
8. Fasten the other end of the rod to the bracket below the rebound stop. Tighten the nut 136 lbf·ft (184 N·m).
9. Remove the chocks from the tires.

V-Rod Replacement

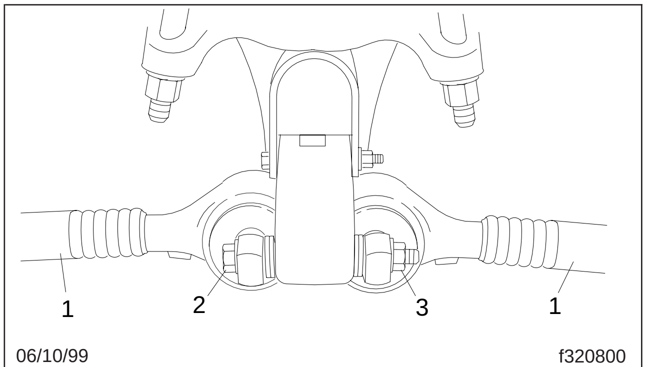
1. Park the vehicle on a level surface, shut down the engine, and apply the parking brakes. Chock the tires.
2. Raise the rear axle and support the frame rails with jack stands.
3. Lower the jack under the axle. See **Fig. 2**.

Lower Control Rod and V-Rod Replacement



1. Jack
2. Jack Stand
3. Frame Rail
4. Rear Axle

Fig. 2, Jack and Jack Stand Placement



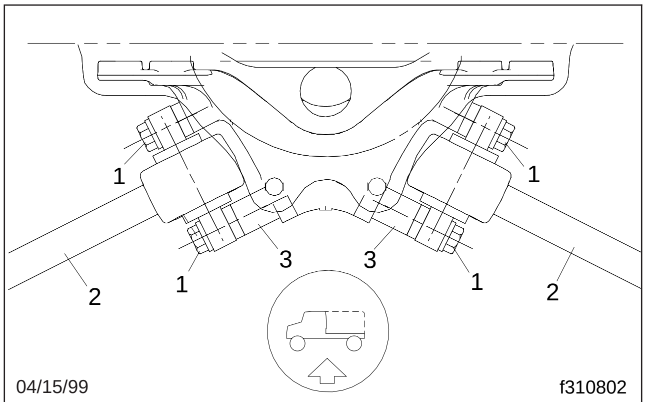
1. Lower Control Rod
2. Mounting Bolt
3. Mounting Nut

Fig. 3, Lower Control Rods

4. Remove all six mounting bolts securing the V-rod to the chassis and axle.
5. Remove the V-rod from the chassis.

IMPORTANT: When installing the rods make sure the labels on the rods are facing upward. Forward axle rods are marked "FDA" and rear axle "RDA."

6. Install the V-rod. See **Fig. 4**.



1. Mounting Bolt
2. V-Rod
3. Spacer

Fig. 4, V-Rod Installation

6.1 Place the new rod in position between the frame rails.

6.2 Install the bolts and spacers and loosely tighten all connections.

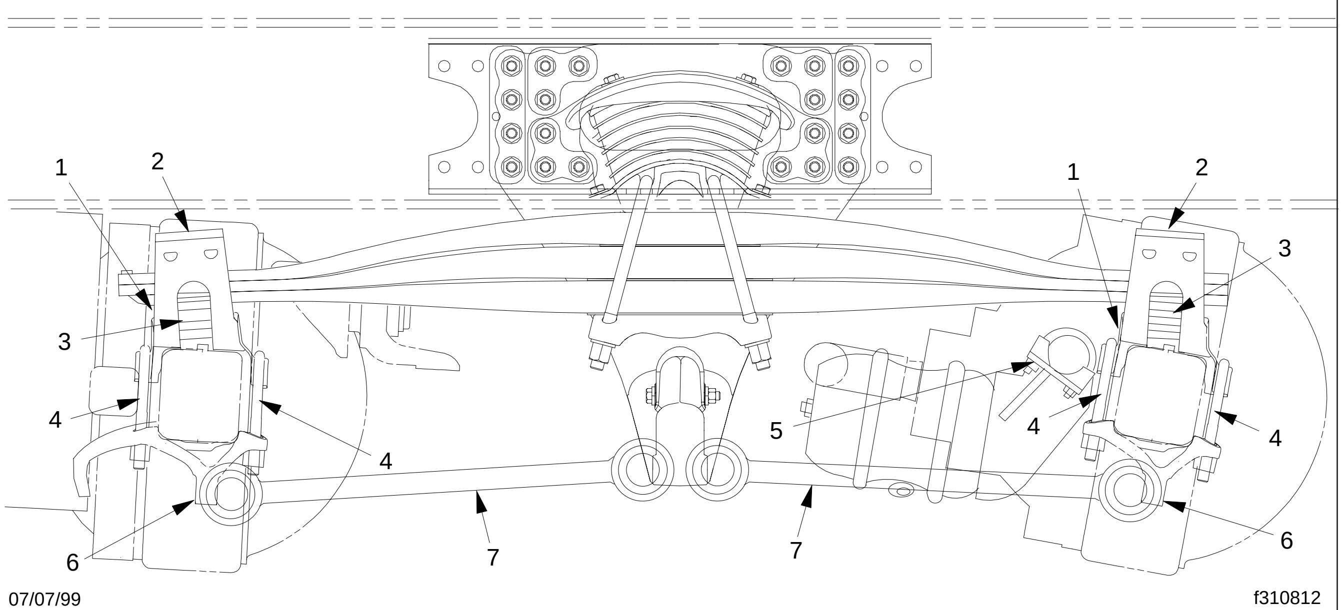
6.3 After all fasteners and spacers are installed, torque as follows:

- Tighten the bolts at the frame bracket 136 lbf·ft (184 N·m).
- Tighten the bolts at the axle bracket 427 lbf·ft (579 N·m).

7. Remove the chocks from the tires.

Replacement

See **Fig. 1** for this procedure.



1. Upper Axle Clamp
2. Upper Spring Tip Pad
3. Lower Spring Tip Pad
4. U-Bolt
5. Brake Cam Tube Support Bracket
6. Lower Axle Retainer
7. Lower Control Rods

Fig. 1, TufTrac Suspension (left-side view)

1. Park the vehicle on a level surface, shut down the engine and chock the tires.
2. Remove the two upper spring tip pads and bolts from the left suspension spring.
3. Disconnect the shock absorbers from the lower axle retainer on the left suspension spring.
   3.1 Remove the lower shock mounting nuts and washers.
   3.2 Remove the lower shock absorber mounting bolts.
4. Disconnect the two lower torque control rods from the lower axle retainers on the left side of the vehicle.
5. Loosen and remove the U-bolt nuts and washers, and discard.
6. Remove the brake cam tube support bracket from the left rear axle.
7. Remove the lower axle retainers from the left forward and left rear drive axles, and discard.
8. Remove the axle U-bolts from the left forward drive axle and the left rear drive axle, and discard.
9. Jack up the center of the left suspension spring (at the center bearing, between the tandem) and support with the jack stands at the frame. See **Fig. 2**. Make sure that all of the weight has been relieved from the axle clamp group and that there is sufficient clearance to remove the upper axle clamp.
10. Remove the lower spring tip pads from the left forward and left rear drive axles.
11. Remove the upper axle clamps from the left forward and left rear drive axles. Discard the clamps.

Axle Clamp and Retainer Replacement

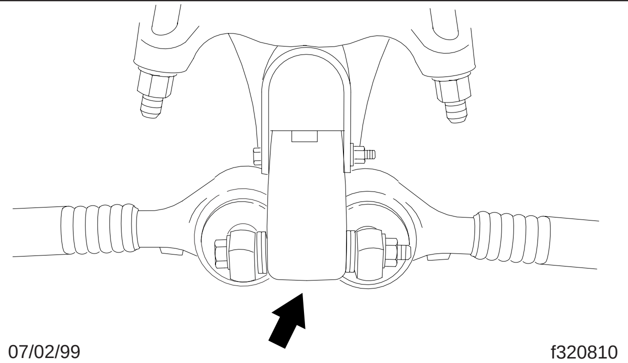


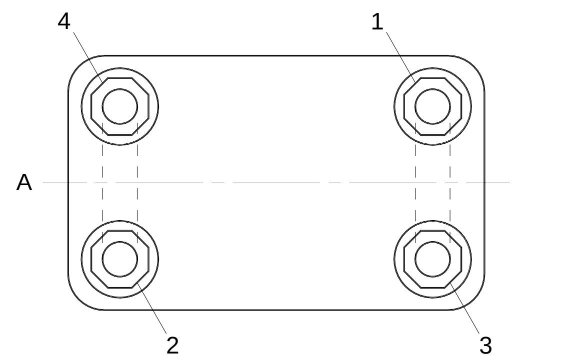
Fig. 2, Jack the Vehicle Here

12. Install the new upper axle clamps onto the left forward and left rear drive axles. Locate the dowel pin through the hole in the bottom of each axle clamp to confirm proper alignment
13. Install the lower spring tip pads into the left front and rear axle clamps.
14. Jack up the left suspension spring, remove the jack stands, and lower the suspension spring. Ensure while the spring is being lowered that it is seated correctly onto the lower spring tip pads.
15. Install the new lower axle retainers onto the left forward and rear drive axles.
16. Install the brake cam tube support bracket onto the left rear axle.
17. Install the U-bolts on the left forward and rear drive axles.
    - 17.1 Install each U-bolt over the U-bolt saddle in the upper axle clamp and through the holes in the lower axle retainer.
    - 17.2 Install the washers and finger-tighten the nuts in the order shown in **Fig. 3**.

      Make sure all brackets are snug against the axle housing before proceeding to the next step.

    IMPORTANT: U-bolt nuts must be tightened in the order shown in **Fig. 3**.

    - 17.3 Tighten the nuts 60 lbf·ft (81 N·m) and then to 200 lbf·ft (271 N·m) in two separate rotations following the order shown in **Fig. 3**.



A. Centerline of Spring
1. Tighten First
2. Tighten Second
3. Tighten Third
4. Tighten Fourth

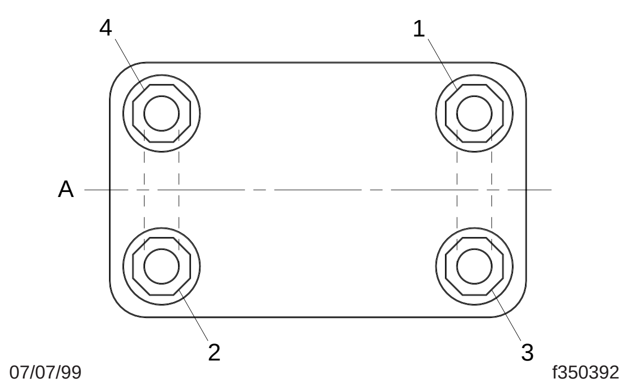
Fig. 3, U-Bolt Nut Tightening Sequence

18. Install the lower torque control rods to the lower axle retainers on the left side of the vehicle and tighten 136 lbf·ft (184 N·m).
19. Install the shock absorbers to the lower axle retainers.
    - 19.1 Install the lower shock mounting bolts.
    - 19.2 Install the lower shock absorber mounting washers and nuts and tighten by hand.
    - 19.3 Tighten the lower shock absorber mounting nuts to 241 lbf·ft (327 N·m).
20. Install the spring tip pads to the left suspension spring.
    - 20.1 Install the spring tip pads to the upper axle clamps.
    - 20.2 Install the bolts to secure each upper spring tip pad and tighten 37 lbf·ft (50 N·m).
21. Repeat the above steps for the right suspension spring.
22. Remove the chocks from the tires.

Specifications

Torque Specifications	
Description	**Torque: lbf·ft (N·m)**
Shock Absorber Mounting Bolt	241 (327)
Center Bearing Upper Mounting Bolts	68 (92)
Center Bearing Lower Mounting Bolts	155 (210)
Tip Pad Bolts	37 (50)
Rebound Stop Mounting Bolt	68 (92)
Lower Control Rod Mounting Bolts	136 (184)
V-Rod Frame Bracket Mounting Bolts	136 (184)
V-Rod Axle Bracket Mounting Bolts	427 (579)
5/8–18 Axle Clamp U-Bolt Nuts (Tighten as shown in Fig. 1.)	Stage 1: Hand-Tighten Stage 2: 60 (81) Stage 3: 200 (271)
3/4-Inch Spring Pack U-Bolt Nuts	Stage 1: 60 (81) Stage 2: 200 (271) Stage 3: 300 (407)

Table 1, Torque Specifications



A. Centerline of Spring
1. Tighten First
2. Tighten Second
3. Tighten Third
4. Tighten Fourth

Fig. 1, U-Bolt Nut Tightening Sequence

General Description

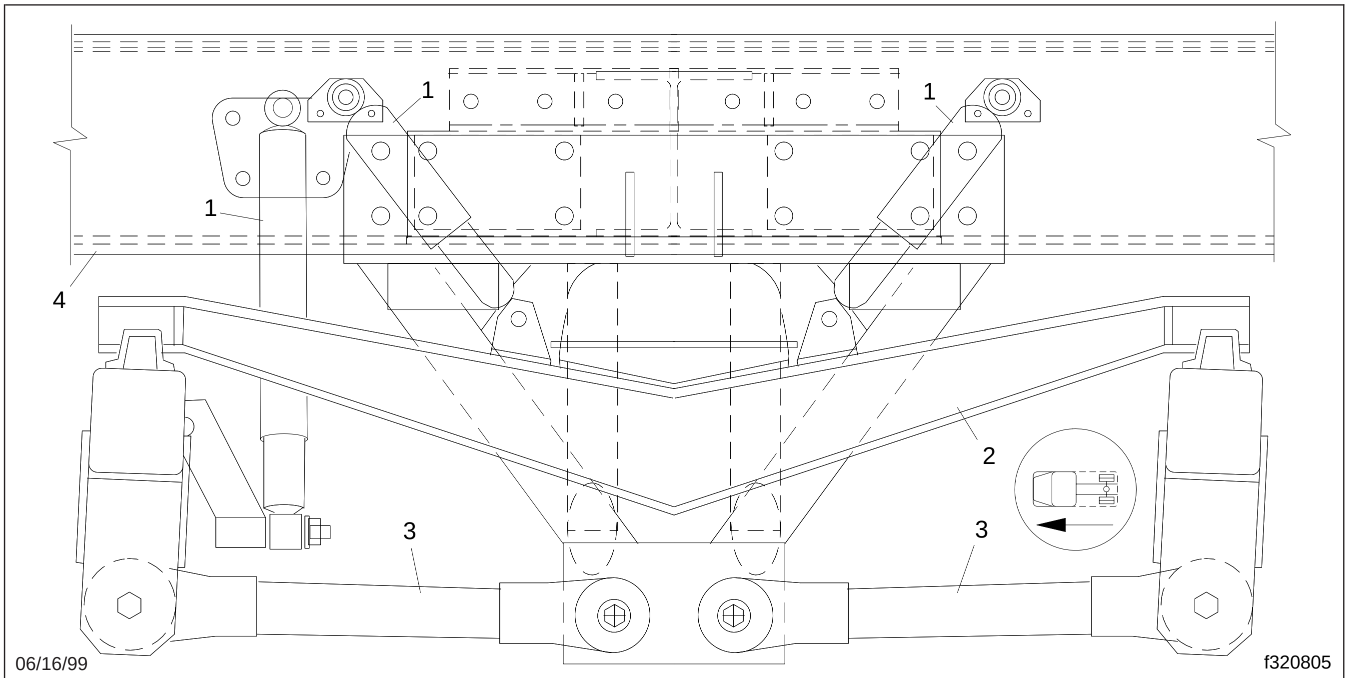
The Chalmers 854 rear suspension (**Fig. 1** and **Fig. 2**) is a walking beam-type tandem axle suspension that uses hollow rubber springs instead of leaf springs or air bags. Each hollow rubber spring is mounted between a frame-rail plate and the center (front-to-rear) of the steel walking beam. A sawhorse bracket assembly is attached to the frame and provides mounting points for the lower torque rods that tie the axles to the frame. The upper torque rods are fastened to brackets that bolt to the frame side rails and to tower assemblies that are welded to the top of the differential housings.

The 854 rear suspension allows a high degree of both parallel and diagonal articulation, while maintaining wheel load equalization to within 3 percent.

The Chalmers suspension design separates the rear suspension's responsibility for supporting/cushioning the load from that of locating/guiding the axles. The suspension is very light, relative to its load carrying capacity, but requires very little maintenance. In fact, there are no lubrication fittings since grease and oil are never needed.

The 854 rear suspension is available in three different maximum load capacities: 40,000 lb. (18 000 kg), 46,000 lb. (21 000 kg), and 52,000 lb. (23 600 kg). The 40,000 lb. (18 000 kg) version is easily distinguished from the other two versions since the upper torque rods do not cross over one another on the 40,000 lb. (18 000 kg) version.

The 854 suspension is available in a 54-inch axle spacing. The axle-to-axle spacing dimension is often included as part of the suspension name, such as "Chalmers 852 Rear Suspension" or "Chalmers 854 Suspension."



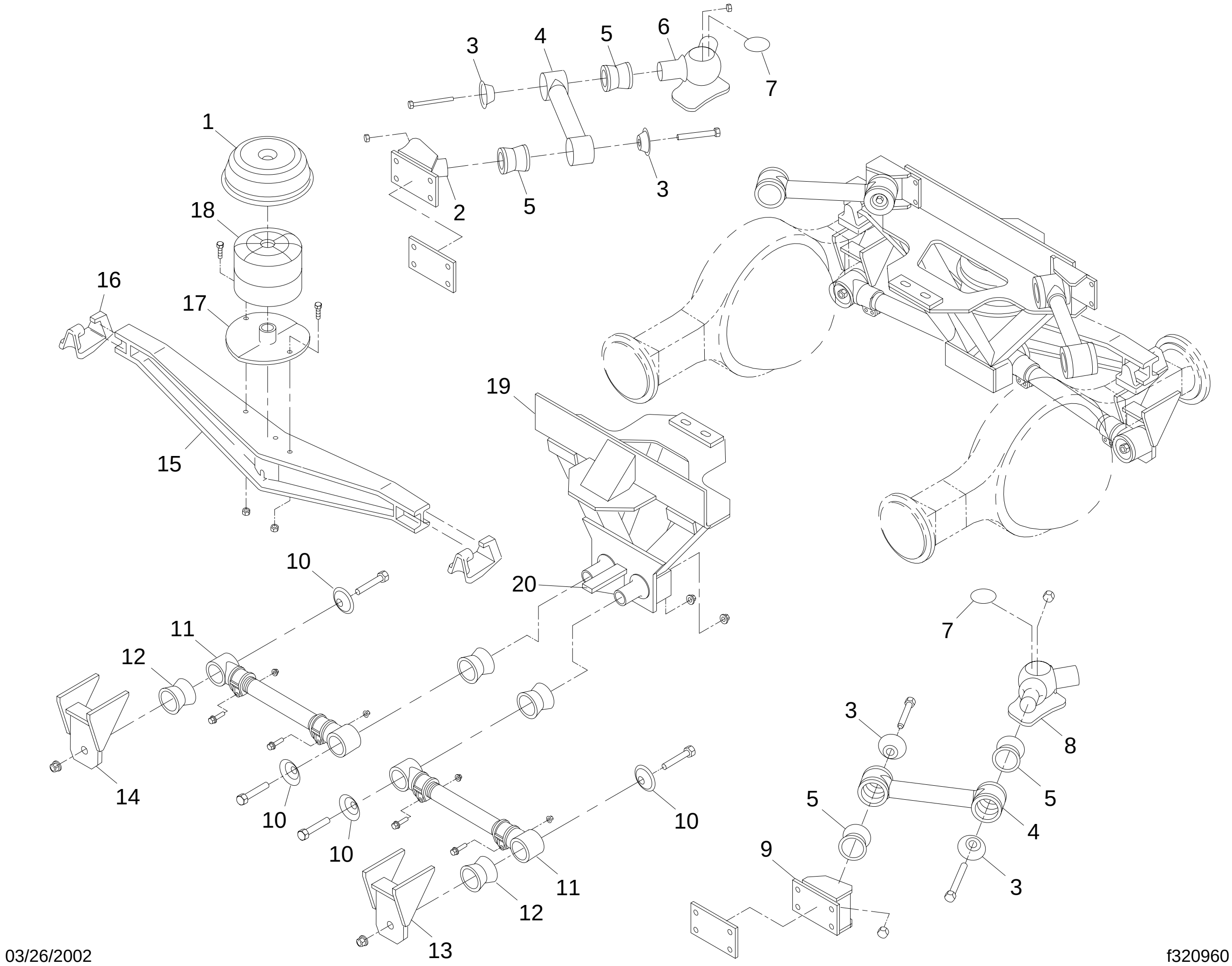
1. Shock Absorber
2. Beam
3. Lower Torque Rod
4. Frame Rail

Fig. 1, Chalmers 854 Tandem Axle Suspension

Shock absorbers are included on all versions of the suspension, and are beam-mounted.

The rear suspension may be precision-aligned by adjusting the length of the lower torque rods. These rods have both left- and right-hand threads cut on the same tube so rotating the tube changes the effective length of the tube.

General Information



1. Restrictor Can
2. Upper Torque Rod Frame Bracket (LH forward)
3. Spigot Cap (upper)
4. Upper Torque Rod
5. Torque Rod Bushing (upper)
6. Forward Rear Axle Tower
7. Rear Axle Tower Plug
8. Rearmost Rear Axle Tower
9. Upper Torque Rod Frame Bracket (LH rear)
10. Spigot Cap (lower)
11. Lower Torque Rod (adjustable)
12. Torque Rod Bushing (lower)
13. Lower Torque Rod Axle Housing Bracket (LH rear)
14. Lower Torque Rod Axle Housing Bracket (LH forward)
15. Beam
16. Axle Housing Beam Saddle Bracket
17. Beam Spring Plate
18. Hollow Rubber Spring
19. Sawhorse Bracket Assembly
20. Beam Stop

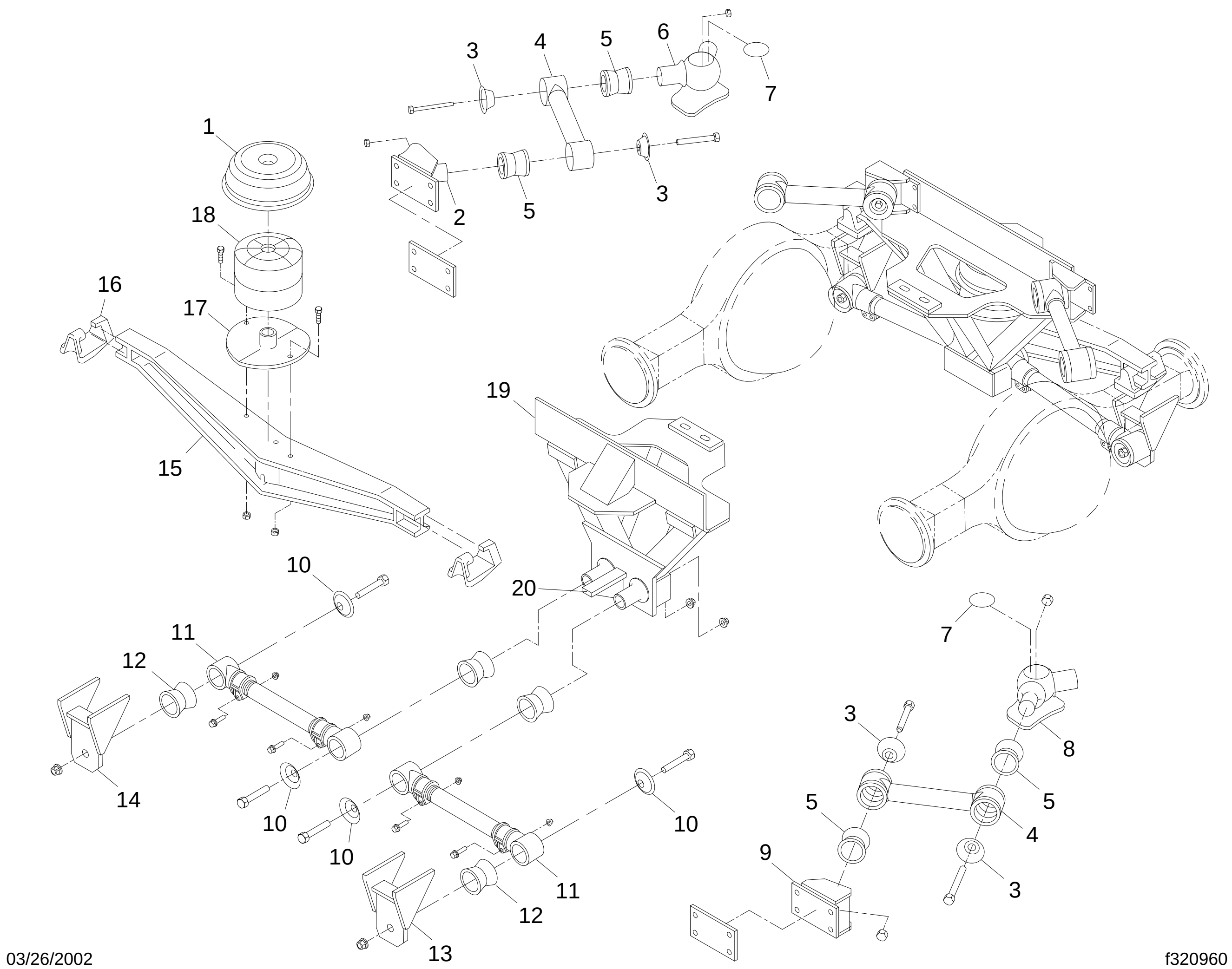
Fig. 2, Chalmers 854 Tandem Axle Suspension (40,000-pound capacity without shock absorbers shown)

Restrictor Can Removal, Inspection, and Installation

Removal

NOTE: See **Fig. 1** for this procedure.

1. If necessary, power wash the spring restrictor can area to remove road dirt accumulation.



1. Restrictor Can
2. Upper Torque Rod Frame Bracket (LH forward)
3. Spigot Cap (upper)
4. Upper Torque Rod
5. Torque Rod Bushing (upper)
6. Forward Rear Axle Tower
7. Rear Axle Tower Plug
8. Rearmost Rear Axle Tower
9. Upper Torque Rod Frame Bracket (LH rear)
10. Spigot Cap (lower)
11. Lower Torque Rod (adjustable)
12. Torque Rod Bushing (lower)
13. Lower Torque Rod Axle Housing Bracket (LH rear)
14. Lower Torque Rod Axle Housing Bracket (LH forward)
15. Beam
16. Axle Housing Beam Saddle Bracket
17. Beam Spring Plate
18. Hollow Rubber Spring
19. Sawhorse Bracket Assembly
20. Beam Stop

Fig. 1, Chalmers 800 Series Tandem Axle Suspension (40,000-pound capacity without shock absorbers shown)

Restrictor Can Removal, Inspection, and Installation

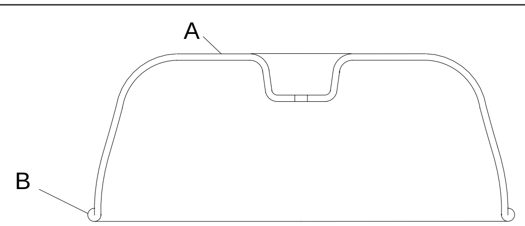
2. Chock the front tires to prevent vehicle movement.
3. Raise the rear of the vehicle just enough to remove all weight from the rear axles, and place safety stands under the frame to support the vehicle in its raised position.
4. Remove the two bolts and nuts that secure the walking beam spring plate (**Fig. 1**, Ref. 17) to the walking beam assembly. Discard the fasteners.

NOTE: On 54-inch spread suspensions, it may be necessary to remove either the front or rear tires to allow spring assembly removal.

5. Pull the lower spring plate, rubber spring, and restrictor can as one assembly outward, off the beam assembly. See **Fig. 1**, Refs. 1, 17, 18.
6. Separate the restrictor can, spring, and spring plate.

Inspection

1. Carefully inspect the restrictor can for cracks or severe corrosion. Pay special attention to the top surface of the can and the can rim. See **Fig. 2** .



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A. Inspect top surface for cracks or severe corrosion.
B. Carefully inspect can rim for cracks.

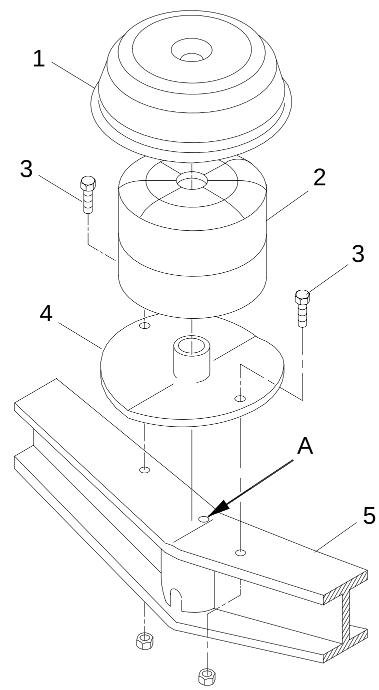
Fig. 2, Restrictor Can Inspection Areas

NOTE: It is recommended that both restrictor cans be replaced at the same time to ensure evenness of ride and handling characteristics.

2. Replace a cracked or severely corroded restrictor can.

Installation

1. Using a stiff wire brush or gasket scraper, clean rust and road dirt from the spring plate. Also, make sure that the center vent holes in the plate and in the walking beam are free of rust and debris. See **Fig. 3**.



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A. Make sure that the vent hole in the walking beam is free of rust and debris.

1. Spring Restrictor Can
2. Hollow Rubber Spring
3. Spring Plate Bolt
4. Spring Plate
5. Walking Beam

Fig. 3, Spring Assembly Components

2. Inspect the spring plate for cracks; replace it if any are present.

IMPORTANT: Never use any mineral based oils, greases, jellies, or solvent soaps to aid in the assembly of rubber suspension parts. Use only lubricants specifically designed for use with rubber compounds.

3. Position the rubber spring on the spring plate so it is upside down, relative to its original orientation. Make sure that the spring vent hole is centered on the spring plate tube. Place the new restrictor can over the spring; make sure the can is centered on the spring.

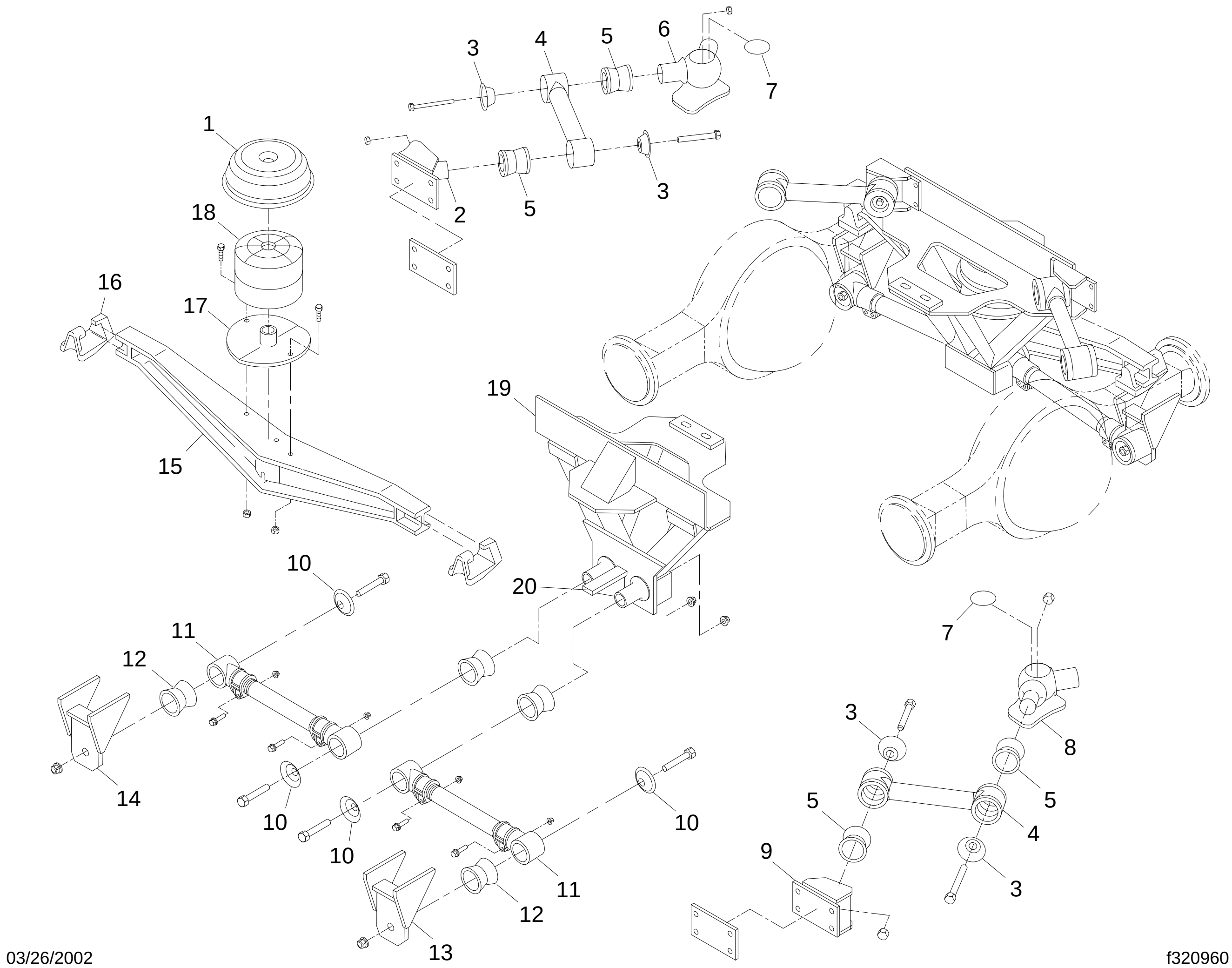
Restrictor Can Removal, Inspection, and Installation

4. Slide, as one assembly, the spring plate, spring, and restrictor cap, into position on the walking beam.
5. Install and tighten the spring plate fasteners 35 lbf·ft (47 N·m).
6. Check the gap between the spring and the restrictor can to make sure it is even, all the way around the can. Rotate the spring and/or can as necessary to make the gap even.
7. Remove the safety stands from under the vehicle, then lower the vehicle.
8. Remove the chocks from the tires.

Removal

NOTE: See **Fig. 1** for this procedure.

1. If necessary, power wash the spring restrictor can area to remove road dirt accumulation.



1. Restrictor Can
2. Upper Torque Rod Frame Bracket (LH forward)
3. Spigot Cap (upper)
4. Upper Torque Rod
5. Torque Rod Bushing (upper)
6. Forward Rear Axle Tower
7. Rear Axle Tower Plug
8. Rearmost Rear Axle Tower
9. Upper Torque Rod Frame Bracket (LH rear)
10. Spigot Cap (lower)
11. Lower Torque Rod (adjustable)
12. Torque Rod Bushing (lower)
13. Lower Torque Rod Axle Housing Bracket (LH rear)
14. Lower Torque Rod Axle Housing Bracket (LH forward)
15. Beam
16. Axle Housing Beam Saddle Bracket
17. Beam Spring Plate
18. Hollow Rubber Spring
19. Sawhorse Bracket Assembly
20. Beam Stop

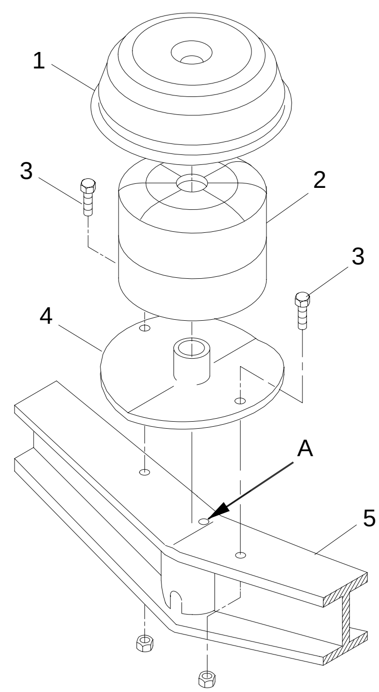
Fig. 1, Chalmers 854 Tandem Axle Suspension (40,000-pound capacity without shock absorbers shown)

Rubber Spring Replacement

2. Chock the front tires to prevent vehicle movement.
3. Raise the rear of the vehicle just enough to remove all weight from the rear axles, and place safety stands under the frame to support the vehicle in its raised position.
4. Remove the two bolts and nuts that secure the walking beam spring plate (**Fig. 1**) to the walking beam assembly. Discard the fasteners.
5. Pull the lower spring plate, rubber spring, and restrictor can as one assembly outward, off the beam assembly. See **Fig. 1**.
6. Separate the restrictor can, spring, and spring plate; discard the spring.
7. Using a stiff wire brush or gasket scraper, clean rust and road dirt from the spring plate. Also, make sure that the center vent holes in the plate and in the walking beam are free of rust and debris. See **Fig. 2**.
8. Inspect the spring plate for cracks; replace if it any are present.

IMPORTANT: Never use any mineral based oils, greases, jellies, or solvent soaps to aid in the assembly of rubber suspension parts. Use only lubricants specifically designed for use with rubber compounds.

9. Position the new rubber spring on the spring plate, making sure that the vent hole is centered on the spring plate tube. Place the restrictor can over the spring; make sure the can is centered on the spring.
10. Slide, as one assembly, the spring plate, spring and restrictor cap, into position on the walking beam.
11. Install and tighten the spring plate fasteners 35 lbf·ft (47 N·m).
12. Remove the safety stands from under the vehicle, then lower the vehicle.
13. Remove the chocks from the tires.



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A. Make sure that the vent hole in the walking beam is free of rust and debris.

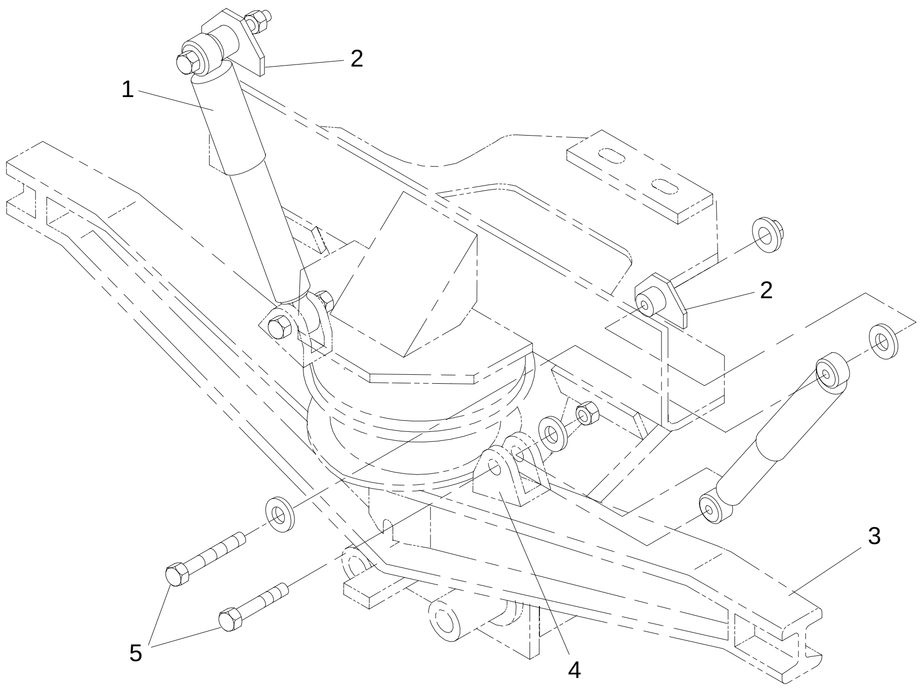
1. Spring Restrictor Can
2. Hollow Rubber Spring
3. Spring Plate Bolt
4. Spring Plate
5. Walking Beam

Fig. 2, Spring Assembly Components

Shock Absorber Replacement

Replacement

The Chalmers 854 rear suspension is fitted with beam-mounted shock absorbers. See **Fig. 1**.



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1. Shock Absorber
2. Frame-Mounted Bracket
3. Walking Beam
4. Beam-Mounted Bracket
5. 3/4" Mounting Bolts

Fig. 1, Beam-Mounted Shock Absorbers

1. If necessary, power wash the rear suspension to remove road dirt accumulation.
2. Chock the front tires to prevent vehicle movement.
3. Remove the shock absorber mounting fasteners.
   3.1 Remove the upper and lower bolts. See **Fig. 1**.
   3.2 Discard the fasteners.
4. Remove and discard the shock absorber.
5. Install the new shock absorbers.

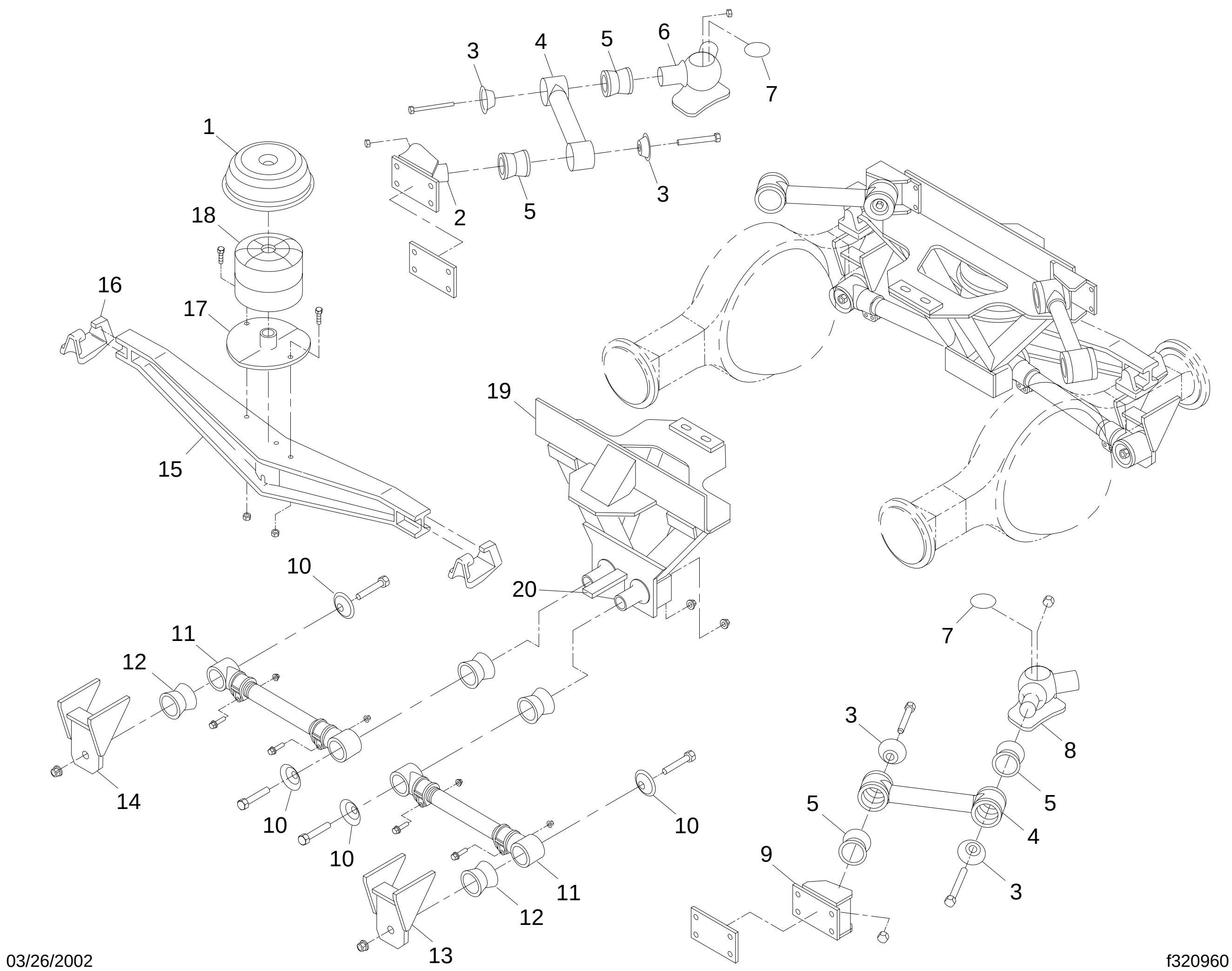
   Extend or compress the shock absorber as necessary to install the mounting bolts. Install the locknuts and tighten the fasteners 170 lbf·ft (230 N·m).
6. Remove the chocks from the tires.

Walking Beam Removal, Inspection, and Installation

Removal

NOTE: See **Fig. 1** for this procedure.

1. If necessary, power wash the walking beams and axle housing ends to remove road dirt accumulation.



1. Restrictor Can
2. Upper Torque Rod Frame Bracket (LH forward)
3. Spigot Cap (upper)
4. Upper Torque Rod
5. Torque Rod Bushing (upper)
6. Forward Rear Axle Tower
7. Rear Axle Tower Plug
8. Rearmost Rear Axle Tower
9. Upper Torque Rod Frame Bracket (LH rear)
10. Spigot Cap (lower)
11. Lower Torque Rod (adjustable)
12. Torque Rod Bushing (lower)
13. Lower Torque Rod Axle Housing Bracket (LH rear)
14. Lower Torque Rod Axle Housing Bracket (LH forward)
15. Beam
16. Axle Housing Beam Saddle Bracket
17. Beam Spring Plate
18. Hollow Rubber Spring
19. Sawhorse Bracket Assembly
20. Beam Stop

Fig. 1, Chalmers 854 Tandem Axle Suspension (40,000-pound capacity without shock absorbers shown)

Walking Beam Removal, Inspection, and Installation

2. Chock the front tires to prevent vehicle movement.
3. Relieve all drive axle brake or wind-up loads by placing the transmission in neutral and releasing the spring or driveline brakes.
4. Raise the rear of the vehicle to remove all weight from the rear axles, and place safety stands under the frame to secure the vehicle in its raised position.
5. If equipped, disconnect beam-mounted shock absorbers from the walking beam being replaced. See **Subject 120**, if necessary.
6. Remove the two bolts and nuts that secure the walking beam spring plate (**Fig. 1**) to the walking beam assembly. Discard the fasteners.
7. Pull the lower spring plate, rubber spring, and restrictor can as one assembly outward, off the beam assembly. See **Fig. 1**.

NOTE: Tag or otherwise mark each torque rod to ensure that it can be re-installed in the same position and orientation.

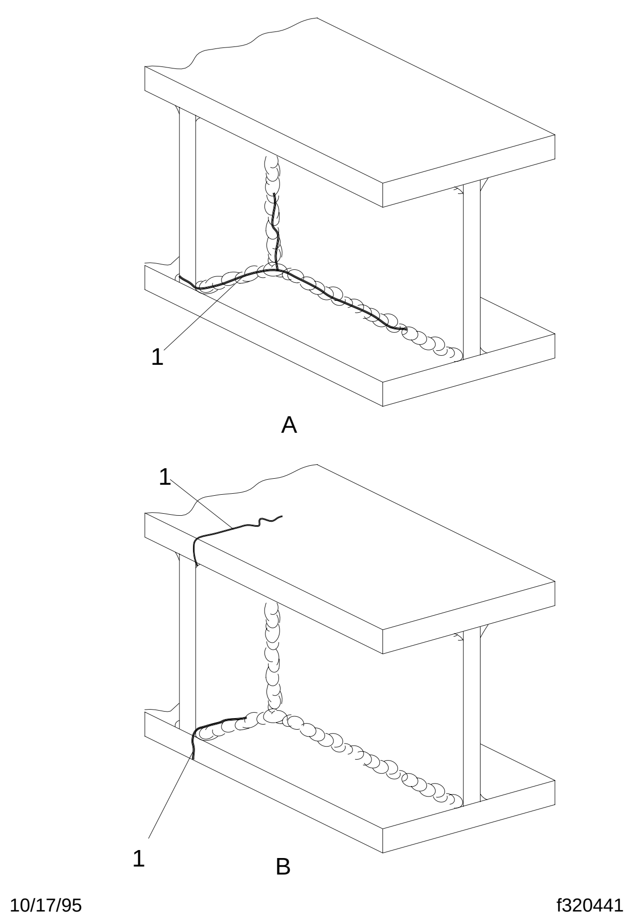
8. Disconnect the rearmost axle's upper torque rods from the rear axle tower and the lower torque rods from the rear axle housing brackets. See **Fig. 1**.
9. Roll the rear axle rearward just enough to disengage the axle saddles from the walking beam ends.
10. Lift up the free end of the walking beam and slide the beam rearward to disengage it from the front axle saddle; remove the walking beam.

Inspection

1. Inspect the beam ends carefully, looking for cracks. Cracks along weld lines may be repairable, while cracks in or across the beam flanges require walking beam replacement. See **Fig. 2**.

NOTE: Take flange thickness measurements at least 1/2" (12 mm) from the flange edges. Measurements taken at the flange edges are not an accurate indication of beam wear and may lead to unnecessary beam repair/replacement.

2. Check for excessive wear on the beam flanges, where they contact the axle housing saddle brackets.



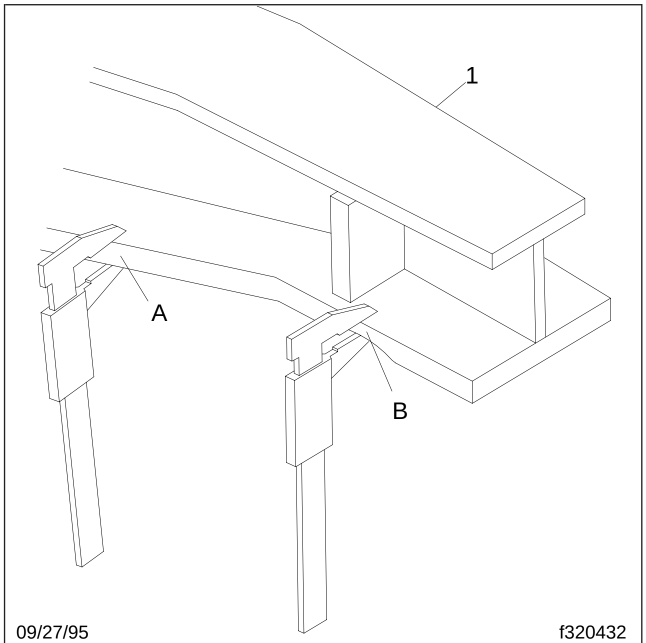
A. Repairable Walking Beam
B. Non-repairable Walking Beam
1. Cracks

Fig. 2, Repairable/Non-repairable Beam Cracks

If flange wear is significant, use a micrometer or vernier calipers to take measurements at both unworn and worn areas. The maximum allowable difference between unworn and worn areas is 0.062 inch (1.5 mm). See **Fig. 3**.

3. Beams showing excessive wear must be repaired or replaced. See **Subject 140** for beam repair information.

Walking Beam Removal, Inspection, and Installation



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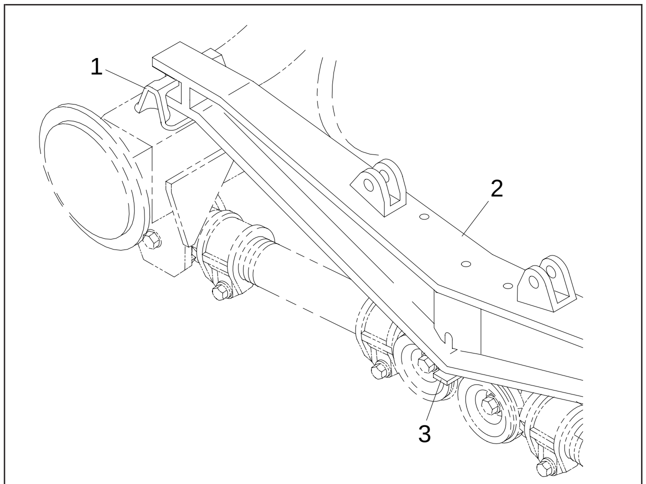
A. Flange thickness measurement taken at unworn area for reference.
B. Flange thickness measurement taken at wear area to assess beam condition.

1. Walking Beam

Fig. 3, Beam Wear Measurement

Installation

1. Position the new or repaired walking beam over the rearmost rear axle, with the front end of the beam tilted downward.
2. Slide the beam forward and downward so the front end of the beam enters the axle housing saddle bracket. See **Fig. 4**. Let the middle of the beam rest on the sawhorse bracket beam stop.
3. Carefully roll the rearmost rear axle forward, while lifting the rear end of the walking beam enough so the beam end enters the axle housing saddle bracket.
4. Connect the rearmost axle's upper and lower torque rods to the axle housing brackets. Install and tighten the torque rod bushing through-bolts 135 lbf·ft (183 N·m).
5. Slide, as one assembly, the spring plate, rubber spring, and restrictor cap, into position on the walking beam.



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1. Front Axle Housing, Beam Saddle Bracket
2. Walking Beam
3. Beam Stop

Fig. 4, Beam/Saddle Bracket Alignment

6. Install and tighten the spring plate fasteners 35 lbf·ft (47 N·m).
7. If so equipped, connect the beam-mounted shock absorbers to the beam brackets and tighten the fasteners 170 lbf·ft (230 N·m).
8. Remove the safety stands from under the vehicle, then lower the vehicle.
9. Remove the chocks from the tires.

Repair

NOTE: This subject addresses only instances where excessive beam flange wear occurs, but cracks in the web or flange are not present.

Cracked webs and/or flanges require walking beam replacement.

Walking beams with excessive flange wear, however, can be repaired by welding a Chalmers Wear Plate over the worn areas as described below.

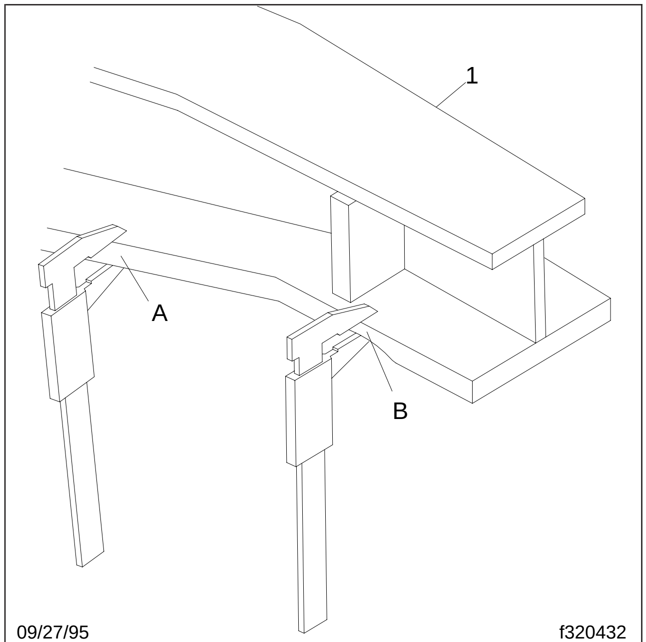
1. Remove the walking beam assembly. See **Subject 130** for information.

NOTE: Take flange thickness measurements at least 1/2 inch (12 mm) from the flange edges. Measurements taken at the flange edges are not an accurate indication of beam wear and may lead to unnecessary beam repair/ replacement.

2. Confirm that flange wear is severe enough to warrant repairs. Use a micrometer or vernier calipers to take flange thickness measurements at both unworn and worn areas. The maximum allowable difference between unworn and worn areas is 0.062 inch (1.5 mm). See **Fig. 1**.
3. If repair is required, clean the worn area of the beam thoroughly. Make sure that any oil or grease is removed, as well as rust or road dirt accumulation. If necessary, slight grinding of the beam is allowed to smooth raised areas.
4. Clamp Chalmers Wear Plate #700313 to the bottom flange of the beam. Make sure the plate is centered and has good surface-to-surface contact with the beam. Slight grinding is allowable to obtain good plate-to-beam contact.
5. Tack weld the plate to the beam, welding on the sides of the plate only.

CAUTION

Weld at the sides of the wear plate and beam only. Never weld at the ends of the wear plate. Welding the ends of the wear plate does not allow the wear plate to properly slightly expand nor contract, an action which, if the ends are welded, can cause cracks in the welds.

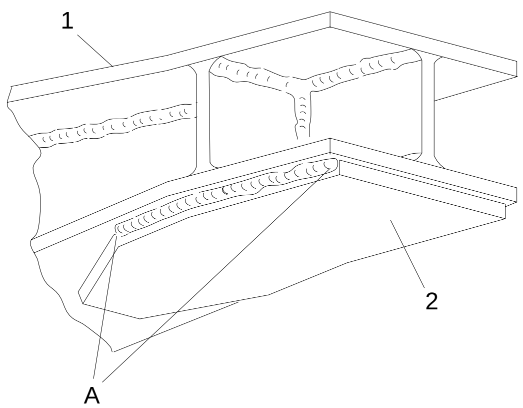


A. Flange thickness measurement taken at unworn area for reference.
B. Flange thickness measurement taken at wear area to assess beam condition.
1. Walking Beam

Fig. 1, Beam Wear Measurement

6. Remove the clamps and weld the plate to the beam, again, welding on the sides of the plate only. See **Fig. 2**.
7. Prime and paint the repaired area.
8. Install the repaired walking beam assembly. See **Subject 130** for information.

Walking Beam Repair



A. Limit weld to this area only.
1. Walking Beam
2. Wear Plate

Fig. 2, Chalmers Wear Plate Welding

Torque Rod Removal and Installation

The torque rods hold the rear axles in place, maintaining both axle alignment and pinion nose angle. When servicing the torque rods, it is good practice to remove and install them one at a time to avoid the possibility of mixing them up and affecting the alignment or pinion nose angle.

Several different styles of torque rods and bushing spigots exist. On the 40,000-pound version of the 852 suspension, the torque rods have tubular steel bodies and the upper rods do not cross over one another. On the 46,000- and 52,000-pound versions, the lower torque rods have tubular steel bodies, but the upper torque rods are made of "I-beam" shaped ductile iron. These upper torque rods do cross over one another. See **Fig. 1** and **Fig. 2**.

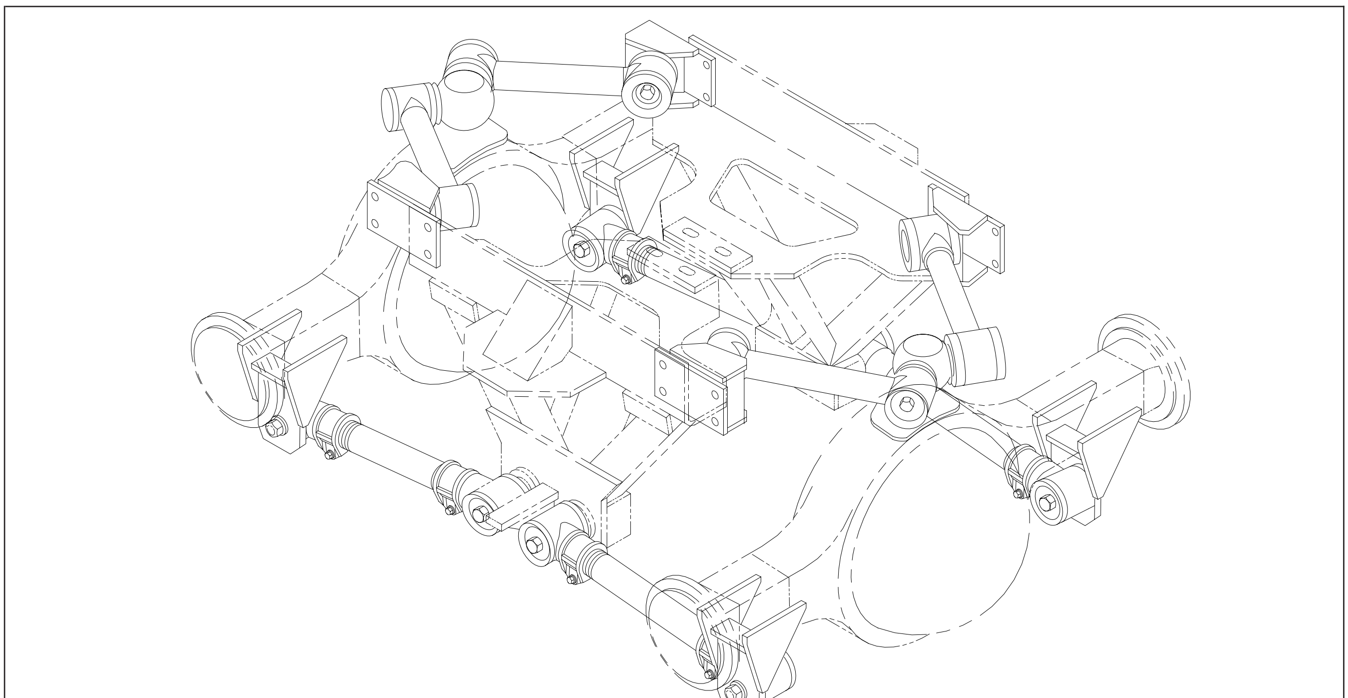


Fig. 1, Torque Rod Arrangement, 40,000-Pound Capacity Suspension

Removal

NOTE: Inspect torque rod bushings for free play before removing the torque rods. See **Subject 160** for torque rod bushing inspection information.

1. If necessary, power wash the rear suspension to remove road dirt accumulation.
2. Chock the front tires to prevent vehicle movement.
3. Relieve all drive axle brake or wind-up loads by placing the transmission in neutral and releasing the spring or driveline brakes.
4. Raise the rear of the vehicle to remove all weight from the rear axles, and place safety stands under the frame to secure the vehicle in its raised position.
5. Working on one torque rod at a time, remove the torque rod bolts and spigot caps. Discard th bolts. Set the spigot caps aside for cleaning and inspection.

   Remove the torque rods by prying between the torque rod eye and the spigot base or frame bracket.

NOTE: At the axle housing towers, pry off the tower cap to access the torque rod fasteners.

Torque Rod Removal and Installation

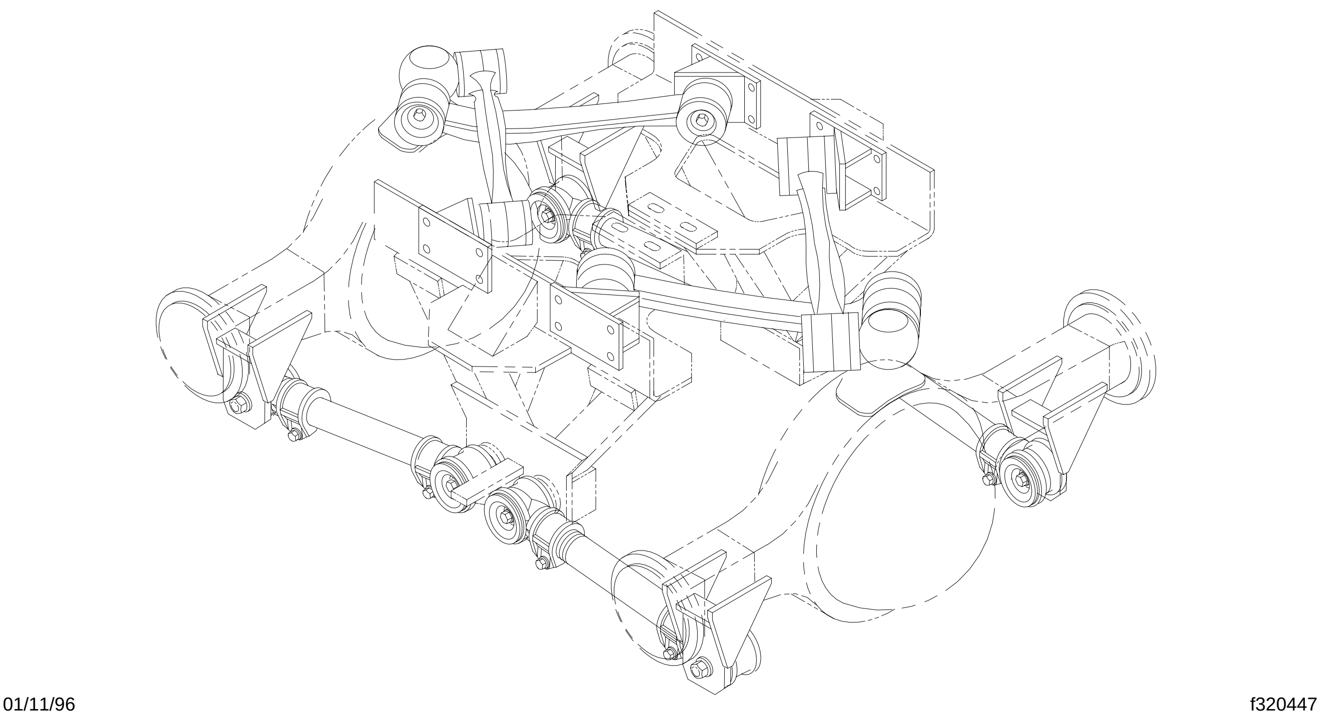
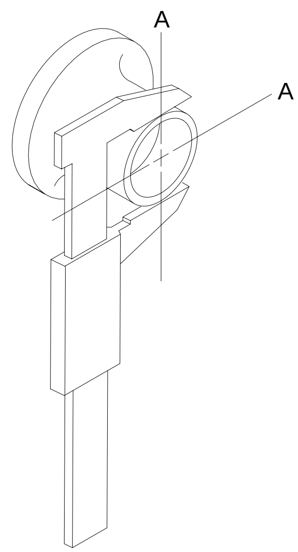


Fig. 2, Torque Rod Arrangement, 46,000- and 52,000-Pound Capacity Suspensions

6. Replace worn or damaged bushings following the instructions in **Subject 160**.
7. Inspect the spigots for extensive wear. See **Fig. 3** and **Table 1**.

   The smaller of the two measurements should be used as the spigot diameter.

   If a spigot is worn, replace the existing torque rod bushings with oversize bushings.



A. Measure outside diameter at two locations, 90 degrees apart.

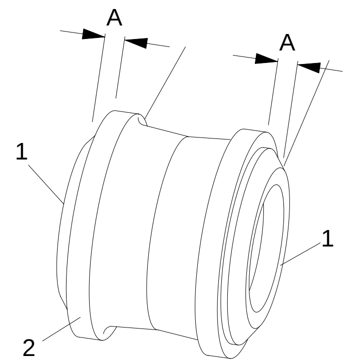
Fig. 3, Spigot Measurement Points

Installation

1. Check the torque rod bushings to make sure they are properly installed. They must be centered within the torque rod eye. See **Fig. 4**.

IMPORTANT: Never use any mineral-based oils, greases, jellies, or solvent soaps to aid in the assembly of rubber suspension parts. Use only lubricants specifically designed for use with rubber compounds.

2. Lubricate the outside of the spigots and the inside of the rubber bushings with a generous



A. The amount of rubber protruding from each side of the torque rod eye must be equal.
1. Torque Rod Bushing 2. Torque Rod Eye

Fig. 4, Torque Rod Bushing Protrusion

amount of rubber lubricant such as Rimslip® or equivalent.

3. Push the torque rod into position on its spigots. After the torque rod is partially installed, use a heavy soft-faced mallet to drive the torque rod into position until the bushing contacts the spigot bottom face.

NOTE: For easier installation, alternate mallet blows between ends of the torque rod to drive it onto the spigots evenly.

4. Install the spigot caps.
5. Install and tighten the torque rod bushing through-bolts 135 lbf·ft (183 N·m).
6. Remove the safety stands from under the vehicle, then lower the vehicle. Remove the chocks.

Spigot Size	Spigot Part #	Usage	Minimum Spigot Diameter With Standard Bushing: inch (mm)	Minimum Spigot Diameter With Oversize Bushing: inch (mm)
1	800200	40,000 lb. capacity—all	2.350 (60)	2.300 (58)
2	800021	46,000 and 52,000 lb. capacity—all	2.530 (64)	2.500 (63)

Table 1, Spigot Wear Limits

Torque Rod Bushing Inspection and Replacement

Inspection

1. If necessary, power wash the upper and lower torque rods to remove road dirt accumulation.
2. Chock the front tires to prevent vehicle movement.
3. Relieve all drive axle brake or wind-up loads by placing the transmission in neutral and releasing the spring or driveline brakes.
4. Using your hands only, attempt to move the torque rod ends, checking for free play. Some movement as the bushings "give" is normal, but only free play is cause for bushing replacement.

NOTE: Never use a lever or pry bar to check for torque rod bushing free play. To do so may result in unnecessary bushing replacement.

5. If free play is detected, replace the bushing as described below.

Replacement

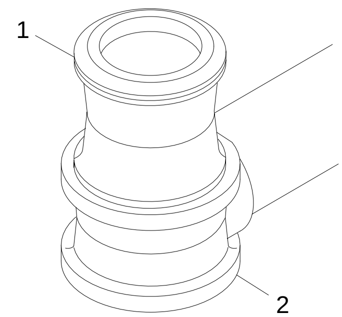
1. Remove the torque rod containing the worn out bushing. If necessary, see **Subject 150**.

NOTE: Remove only one torque rod at a time to avoid mixing-up torque rod positions.

2. Place the torque rod on the floor or a workbench with a bushing open end facing upward. Push the tip of a large screwdriver down between the torque rod eye and the bushing and pry out the bushing. Discard removed bushings.
3. Use a wire brush and/or scraper to clean the torque rod eyes, removing all rust, scale, and rubber accumulations.
4. Inspect the torque rod eyes looking for cracks, distortion, or severe corrosion. Replace torque rods with damaged bushing eyes.

IMPORTANT: Never use any mineral based oils, greases, jellies, or solvent soaps to aid in the assembly of rubber suspension parts. Use only lubricants specifically designed for use with rubber compounds.

5. Lubricate both the inside of the torque rod eye and the outside of the new bushing with a generous amount of rubber lubricant, such as Rimslip® or equivalent.
6. Place the torque rod on a solid level floor with an open end of the eye facing upward. Position a lubricated bushing on the eye, making sure that the tapered shoulder of the bushing is centered on the eye. See **Fig. 1**.



1. Torque Rod Bushing 2. Torque Rod Eye

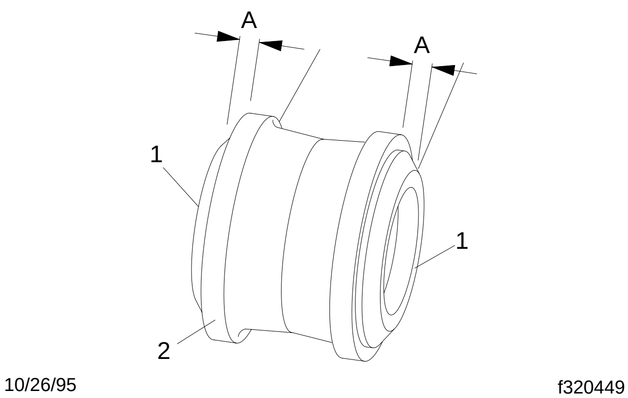
Fig. 1, Torque Rod Bushing Installation

7. Using a heavy, soft-faced mallet, strike the bushing squarely to drive it into the torque rod eye. Then, flip the torque rod over 180 degrees and tap on the torque rod shaft with the mallet while the bushing rests on the floor.

NOTE: If available, a small press may be used instead of a mallet for bushing installation.

8. The bushing is completely installed when it is centered within the torque rod eye. See **Fig. 2**.
9. Install the re-bushed torque rod. See **Subject 150**, if necessary.

Torque Rod Bushing Inspection and Replacement



A. The amount of rubber protruding from each side of the torque rod eye must be equal.
1. Torque Rod Bushing
2. Torque Rod Eye

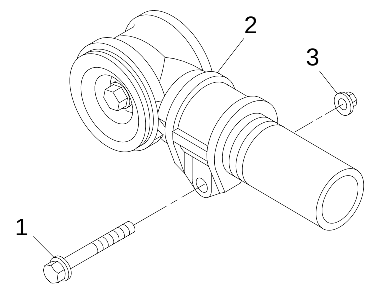
Fig. 2, Torque Rod Bushing Protrusion

Adjustment

On the Chalmers 854 Rear Suspension, the lower torque rods provide the only means for adjusting rear axle alignment. The upper torque rods play no part in the axle alignment process.

The lower torque rod bodies consist of steel tubes, with fine threads cut into the ends of the tube. Left-hand threads are cut into one end of the tube, right-hand threads into the other end. Therefore, by simply twisting the tube body while restraining the ends, the effective length of the tube is changed.

A single 5/8-inch pinch bolt is used to secure the rod end to the tube. See **Fig. 1**.

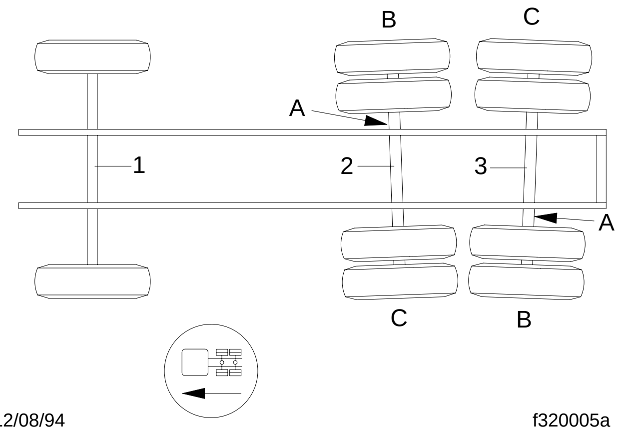


1. Pinch Bolt, 5/8 UNC
2. Joint
3. Flanged Hexnut, 5/8-Inch

Fig. 1, Adjustable Torque Rod End

1. Ensure that the torque rod bushings are in a fully relaxed, neutral state by slowly moving the vehicle back and forth a few times. Apply the service brakes, *not the parking brakes*.
2. Chock the front tires to prevent vehicle movement.
3. Relieve drive axle brake or wind-up loads by placing the transmission in neutral and releasing the brakes.
4. Using a straightedge and a tape measure, determine the amount of adjustment needed to align the forward-rear axle at right angles to the frame. For instructions, see **Group 35** of this manual. The difference in measurements between the sides of the vehicle is the approximate amount that the trailing end of the forward-rear axle will have to be brought forward, or the leading end will have to be moved back to align it at a right angle to the frame. See **Fig. 2**.

If the forward-rear axle alignment is within specifications, go to the step that begins "Using a center-point bar, determine...".



A. Axle Out of Alignment
B. Leading End
C. Trailing End
1. Front Axle
2. Forward Rear Axle
3. Rearmost Axle

Fig. 2, Tandem Axle, Shown Out of Alignment

5. On the side of the vehicle that is to be adjusted forward or rearward, loosen the torque rod end pinch bolts at both ends of the torque rod.

NOTE: If the pinch bolts are badly corroded or otherwise damaged, remove and discard them. Install new Chalmers fasteners.

6. Attach a pipe wrench to the tube body (chain type preferred) and rotate the tube to shorten or lengthen the torque rod. Continue to rotate the tube until the forward-rear axle is square to the frame.

NOTE: If the torque rod tube is difficult to rotate, apply penetrating oil to the tube threads. If this does not help, remove the pinch bolts and drive wedges between the eye lugs to relieve the clamping effect.

7. When the forward-rear axle is square with the frame, tighten the 5/8-inch UNC pinch bolts 135 lbf·ft (183 N·m).

Rear Axle Alignment Adjustment

8. Using a center-point bar, determine the difference between the forward-rear and the rearmost axles' center-to-center measurements on each side of the vehicle. For instructions, see **Group 35** of this manual. This difference is the approximate distance that the leading end of the rearmost axle will have to be adjusted rearward, or that the trailing end will have to be adjusted forward, to align it at a right angle to the frame, and to align it parallel to the forward-rear axle. See **Fig. 2**.
9. On the side of the vehicle that is to be adjusted forward or rearward, loosen the torque rod end pinch bolts at both ends of the torque rod.

NOTE: If the pinch bolts are badly corroded or otherwise damaged, remove and discard them. Install new Chalmers fasteners.

10. Attach a pipe wrench to the tube body (chain type preferred) and rotate the tube to shorten or lengthen the torque rod. Continue to rotate the tube until the rearmost axle is square to the frame.

NOTE: If the torque rod tube is difficult to rotate, apply penetrating oil to the tube threads. If this does not help, remove the pinch bolts and drive wedges between the eye lugs to relieve the clamping effect.

11. When the rearmost axle is square with the frame, tighten the 5/8-inch UNC pinch bolts 135 lbf·ft (183 N·m).
12. Remove the safety stands, and lower the vehicle. Remove the chocks from the front tires.
13. Using the center-point bar, check the rearmost axle alignment. If alignment is not within specifications, repeat the applicable steps above.

CAUTION

Failure to periodically torque the suspension fasteners can result in abnormal tire wear, and damage to the suspension.

IMPORTANT: All suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking intervals and instructions, see Group 32 of the *Business Class M2 Maintenance Manual*.

Specifications

Description	Bolt Size	IFI Grade	Torque: lbf·ft (N·m)
Beam Spring Plate Bolt	3/8 UNC	8	35 (47)
Torque Rod End Through Bolts	5/8 UNC	8	135 (183)
Shock Absorber Bolt	3/4	8	170 (230)
Torque Rod End Pinch Bolts	5/8 UNC	8	135 (183)

Table 1, Fastener Torques, 854 Suspension

General Information

General Description

The Hendrickson RT series suspension (see **Fig. 1**) uses leaf springs to lessen road shocks. The forward and rear ends of the spring assembly ride in hangers. At the forward end, the springs are attached to the hanger with pins. At the rear end, the springs have no rigid attachment to the hangers, and are free to move forward and backward to compensate for spring deflection.

The RTE series suspension (see **Fig. 2**) is basically the same as the RT suspension. However, the RTE series uses a different spring assembly and a third spring hanger. This design provides a two-stage spring rate, depending on vehicle load condition. When the vehicle is unloaded, a gap exists between the top spring leaf and the no. 2 spring hanger. The weight of the vehicle is then carried through the no. 3 spring hanger, and most of the spring deflection through the top extended leaves (see **Fig. 3**). When the vehicle is loaded, the top extended leaf contacts the no. 2 spring hanger and the spring weight is carried through the nos. 1 and 2 spring hangers (see **Fig. 4**).

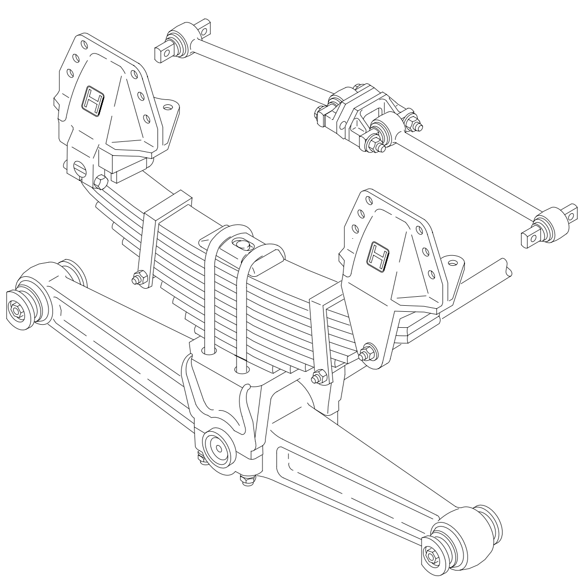


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Fig. 1, RT Series Suspension

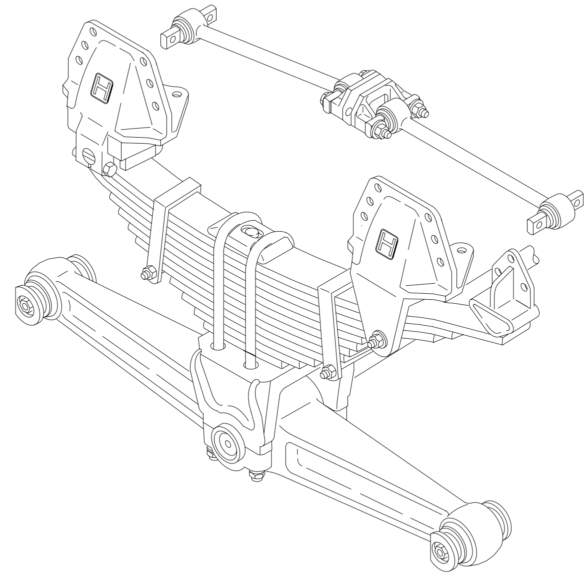

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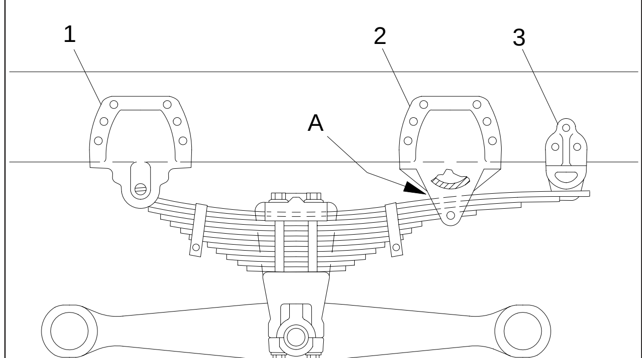
Fig. 2, RTE Series Suspension

CAUTION

Failure to apply Alumilastic® compound, or an equivalent, to areas where aluminum and steel parts contact each other, could lead to corrosion of the metals, resulting in damage to the components or parts.



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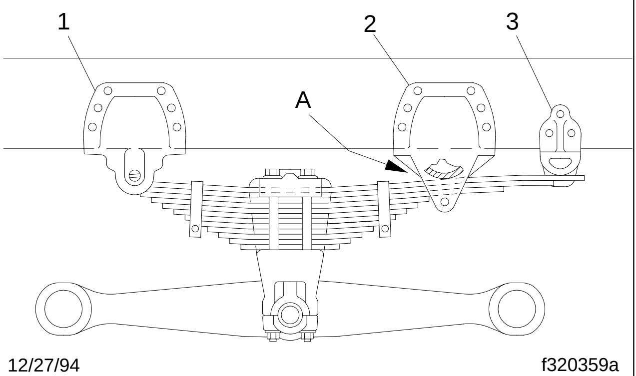
A. Gap
1. No. 1 Spring Hanger
2. No. 2 Spring Hanger
3. No. 3 Spring Hanger

Fig. 3, Unloaded RTE Spring

General Information



A. Gap
1. No. 1 Spring Hanger
2. No. 2 Spring Hanger
3. No. 3 Spring Hanger

Fig. 4, Loaded RTE Spring

The axles are attached to beam hangers at the ends of the equalizer beams, allowing an articulating action between the axles to lessen road shock. Torque rods, mounted between the axles and frame rails, stabilize axle and vehicle movement caused by accelerating and braking.

All suspension fasteners require periodic tightening. For suspension inspecting, lubricating, and fastener torque checking instructions, see Group 32 of the *Business Class® M2 Maintenance Manual.*

WARNING

Failure to periodically torque the suspension fasteners could result in damage to the frame hangers or separation of components. This could cause a loss of vehicle control, resulting in injury or property damage.

Removal

NOTE: See Fig. 1 for this procedure.

1. Chock the front tires.
2. Drain the vehicle air system.
3. Disconnect all air lines leading to the rear axles, marking the lines for later assembly reference.

   Plug or cap all lines and fittings to prevent dirt from entering the system.
4. Disconnect the driveline rear universal joint from the forward-rear axle. Then remove the interaxle driveline. For instructions, see **Group 41** of this manual.
5. Manually release the spring brake chambers. For instructions, see **Group 42** of this manual.

WARNING

When the torque rods are disconnected from the axle brackets, the axles become free to pivot on the equalizer beam end bushings. Keep clear of the beam hangers and beam ends to avoid possible injury.

6. Remove the torque rods. For instructions, see **Subject 180**.
7. Raise the rear of the vehicle so that all weight is removed from the suspension. Then, block the axles and the frame with safety stands. Make sure the stands will securely support the weight of the axles and the frame.

NOTE: Do not raise the vehicle to the point where the weight of the suspension and axles hangs from the vehicle.

8. Remove the saddle cap nuts and washers from each side of the vehicle, and remove the saddle caps.

NOTE: If the saddle cap studs are damaged, replace them.

9. Raise the rear of the vehicle frame until there is enough clearance to roll the axles out from under the vehicle. Install safety stands under the frame, then roll the axles—with the equalizer beams attached—out from under the vehicle.

Installation

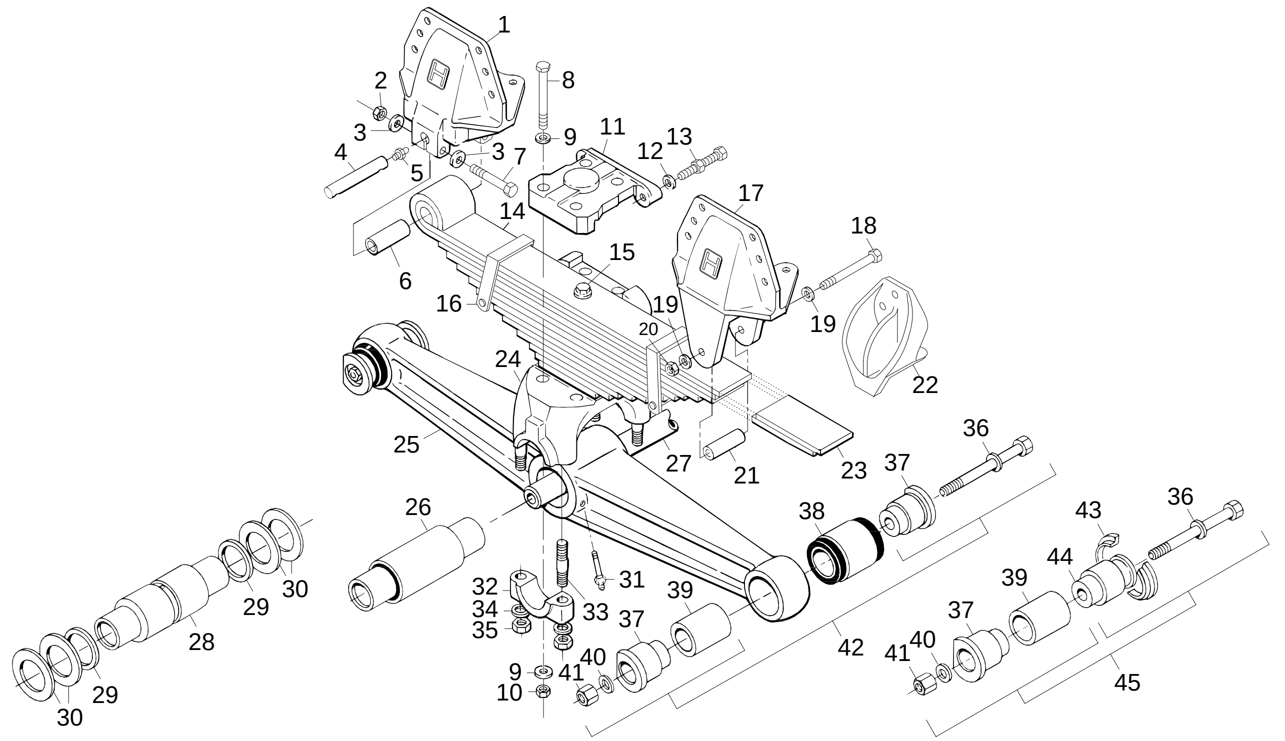
NOTE: See Fig. 1 for this procedure.

1. Roll the axles under the vehicle frame. Align the center bushing of each equalizer beam with the center of the saddle legs.
2. Raise the vehicle frame off the safety stands, then remove the safety stands.
3. Lower the frame, centering the saddles on the beam center bushings.
4. Lubricate the saddle cap studs with SAE 20 oil. Install the saddle caps, washers and new self-locking nuts. Do not tighten.
5. Install the torque rods. For instructions, see **Subject 180**.
6. Tighten the saddle cap locknuts 225 to 275 lbf·ft (305 to 373 N·m).

NOTE: Maintain an even gap between the saddle cap and the saddle when tightening the self-locking nuts. See Fig. 2.

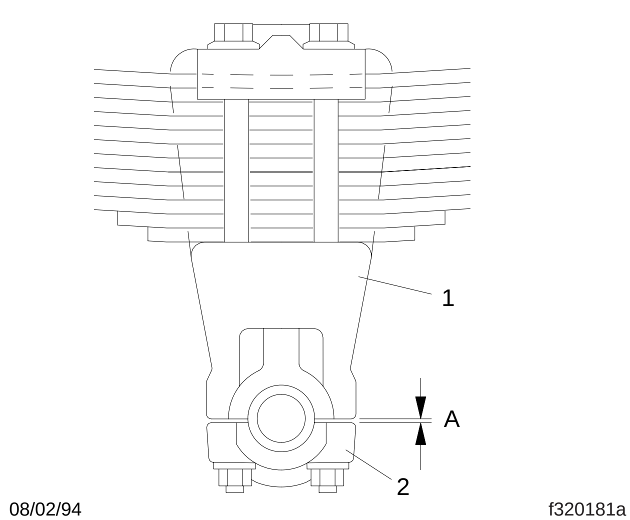
7. Remove the safety stands from under the frame and axle, and lower the vehicle.
8. Manually reset the spring brake chambers. For instructions, see **Group 42** of this manual.
9. Connect the driveline rear universal joint to the forward-rear axle. Connect the interaxle driveline. For instructions, refer to the driveline section of this manual.
10. Uncap all air lines and fittings, then connect the lines leading to the rear axles.
11. Check the axle pinion angle. For instructions, refer to the driveline section of this manual.

Suspension Removal and Installation



1. Forward (no. 1) Spring Hanger	16. Spring Alignment Clip	31. Grease Fitting (bronze bushing)
2. Locknut	17. Rear (no.2) Spring Hanger	32. Saddle Cap
3. Washer	18. Rebound Spacer Bolt	33. Saddle Cap Stud
4. Spring Pin	19. Spacer Bolt Washer	34. Saddle Cap Washer
5. Grease Fitting	20. Spacer Bolt Locknut	35. Saddle Cap Nut
6. Spring Eye Bushing	21. Rebound Spacer	36. Adapter Bolt and Washer
7. Lockbolt	22. RTE Rear (no.3) Spring Hanger	37. Adapter
8. Top Pad Bolt	23. RTE Spring Extension	38. End Bushing
9. Top Pad Washer	24. Saddle Assembly	39. Intermediate Tube
10. Top Pad Locknut	25. Equalizer Beam Assembly	40. Adapter Bolt Washer
11. Top Pad	26. Rubber Center Bushing	41. Adapter Bolt Nut
12. Setscrew Washer	27. Crosstube	42. Adapter-Type End
13. Setscrew and Locknut	28. Bronze Center Bushing	43. Split-Ring
14. Spring Assembly	29. Bushing Grease Seal	44. Adapter Plug
15. Spring Center Bolt and Nut	30. Thrustwashers (4 qty.)	45. Split-Ring Adapter Assembly

Fig. 1, RT and RTE Series (exploded view)



A. Maintain an even gap.
1. Saddle
2. Saddle Cap

Fig. 2, Side View

Spring and Saddle Removal and Installation

Removal

1. Remove the suspension. For instructions, see **Subject 100**.
2. Support the spring and saddle assembly with a floor jack.
3. Remove the locknuts from the spring pin lockbolts; then remove the lockbolts and washers from the number one spring hanger.
4. Using a suitable drift, drive the spring pin through the no. 1 spring hanger and out the inboard side of the spring hanger. See **Fig. 1**.

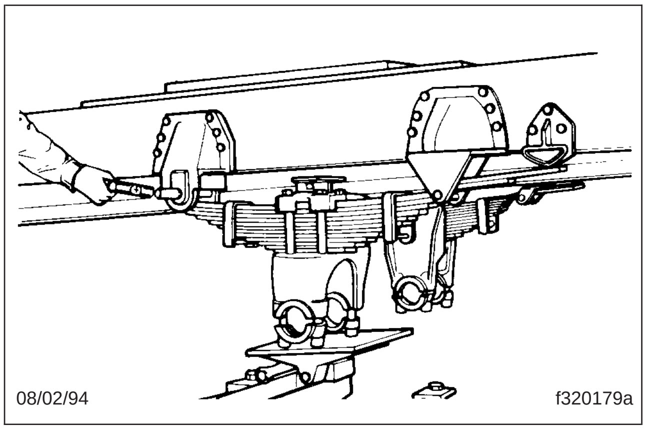


Fig. 1, Driving Out the Spring Pin

5. Remove the locknut and lockwasher from the rebound spacer bolt in the no. 2 spring hanger. Remove the rebound spacer bolt and the spacer.

WARNING

The leaf spring assembly is heavy. Use care when handling it to prevent injury.

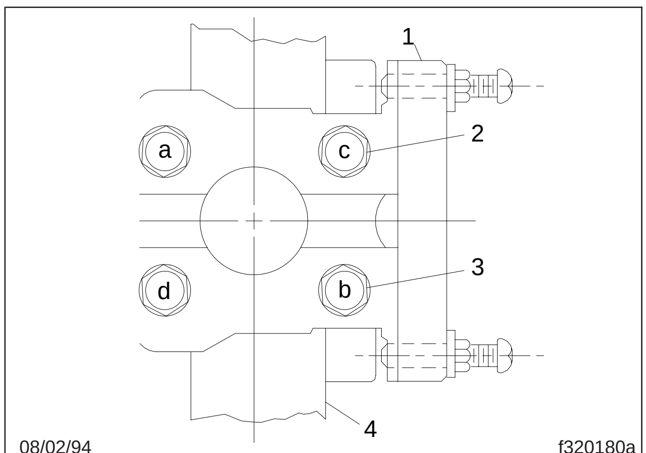
6. Lower the spring and saddle assembly from the spring hangers.
7. Loosen the spring alignment setscrews on the top pad. Remove the top pad nuts, washers, and bolts.
8. Remove the top pad from the spring assembly, then remove the spring from the saddle.

Installation

1. Seat the leaf spring assembly on the saddle.
2. Position the top pad on the spring assembly. Check that the top pad is properly seated.

NOTE: The main leaf has a cup that is forged upward at the center bolt. This cup serves as a pilot when installing the top pad, and ensures correct alignment of the spring assembly.

3. Lubricate the threads on the top pad bolts with SAE 20 oil, then install the washers and bolts through the top pad and saddle. Install new nuts and washers finger-tight. Do not tighten at this time.
4. Lubricate the threads on the spring setscrews with SAE 20 oil. Hand-tighten the spring setscrews against the leaf springs. Tighten the setscrews 100 to 150 lbf·ft (135 to 203 N·m), then tighten the setscrew locknuts until the lockwasher is locked.
5. Tighten the top pad nuts 275 to 400 lbf·ft (373 to 542 N·m). Use the tightening sequence shown in **Fig. 2**.
6. Position the spring and saddle assembly into the no. 1 and no. 2 spring hangers.



1. Top Pad
2. Top Pad Bolt
3. Hardened Washer
4. Spring

Fig. 2, Top Pad Bolt Tightening Sequence

Spring and Saddle Removal and Installation

7. Coat the spring pin and the inside diameter of the spring eye bushing with multipurpose chassis grease.
8. Align the spring pin with the spring eye bushing in the forward spring hanger.
9. From the outboard side of the spring hanger, tap the spring pin into the bushing with a soft hammer. If necessary, adjust the spring to assist spring pin entry.
10. Place washers on the spring pin lockbolts, and insert the lockbolts through the spring hanger. If necessary, use a screwdriver to turn the spring pin until the lockbolts can slide past it.
11. Lubricate the lockbolt threads with SAE 20 oil. Install the lockwashers and locknuts. Tighten the locknuts 45 to 63 lbf·ft (61 to 85 N·m).
12. Position the rebound spacer in the no. 2 spring hanger leg, then install the rebound spacer bolt, lockwasher, and locknut. Tighten the locknut 38 to 45 lbf·ft (51 to 61 N·m).
13. Install the grease fittings in both spring eye pins. Apply multipurpose chassis grease to the grease fittings until grease appears on both sides of the spring eye bushings.
14. Install the suspension. See **Subject 100** for instructions.

Spring Leaf, Spring Pin, and Spring Eye Bushing Replacement

Replacement

1. Remove the spring and saddle assembly. For instructions, see **Subject 110**.
2. Using a C-clamp to hold the spring leaves together, remove the center bolt and nut, and the spring alignment clips. Remove the C-clamp and separate the leaves.

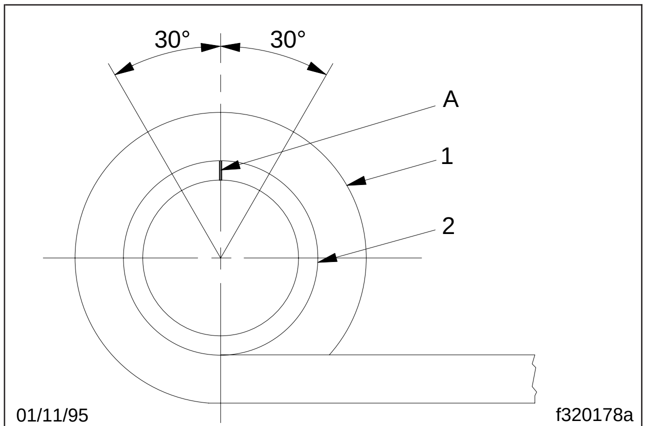
WARNING

Commercial cleaning solvents are toxic, can cause severe skin irritation, and may be fire hazards. When using solvents, follow the safety precautions recommended by the solvent manufacturer.

3. Using a wire brush and solvent, clean all grease, dirt, and rust from the spring leaves. Inspect the spring leaves for cracks, gouges, wear, or abnormal bends. The no. 1 main and no. 2 wrapper spring leaves (the top two spring leaves) may each be replaced; if equipped with the RTE series suspension, the nos. 1, 2, and 3 spring leaves (the top three spring leaves) may each be replaced. If a spring leaf is damaged below these numbers in a pack, replace the spring assembly. Replace both spring assemblies to ensure even spring deflection.
4. Inspect the spring pin and spring eye bushing for wear or damage. If the pin diameter is less than 1.367 inch, replace it. If the inside diameter of the spring eye bushing is more than 1.395 inch, replace it.

NOTE: If necessary, press out the bushing with a hydraulic press. Install the new bushing with the split of the bushing positioned at the top (30 degrees) of the spring eye. See **Fig. 1**.

5. Position the spring leaves in order, then insert a drift through the center bolt hole to align the leaves.
6. Compress the leaves with a C-clamp, then install the spring alignment clips on the spring leaves. Install the spring alignment clip nuts and bolts. Tighten the nuts 15 lbf·ft (20 N·m).
7. Remove the drift punch. At the bottom of the spring, insert a new center bolt. Install a new center bolt nut and tighten to the value in the table under **Specifications 400**.
8. Install the spring and saddle assembly. For instructions, see **Subject 110**.



A. Split
1. Main Spring Plate
2. Spring Eye Bushing

Fig. 1, Installing New Spring-Eye Bushing

Equalizer Beam Adapter- and Tube-Type End Support Removal and Installation

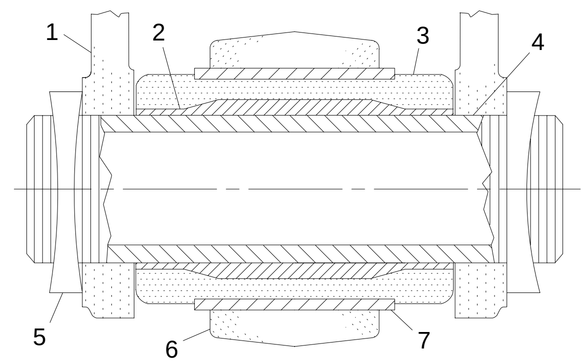
Removal

IMPORTANT: To ensure that the required tools are available, see the applicable table under **Specifications 400** before beginning these procedures. Special tools are available from the Owatonna Tool Company, Owatonna, Minnesota, or an affiliated dealer. Although these tools are recommended, shop-made adapters can be used if a vertical hydraulic press with a 50-ton capacity is available. Dimensions for the shop-made adapters are provided in **Specifications 400**.

1. Chock the front tires.
2. Remove the saddle cap nuts and washers, then remove the saddle cap. Support the equalizer beam with safety stands.
3. Raise the rear of the vehicle until the saddle studs clear the equalizer beam. Block the axles and frame with safety stands.
4. Remove the wheels and tires. For instructions, refer to the wheels and tires section of this manual.
5. Remove the brake shoes, brake spider, and brake backing plate (dust shield). Refer to the brake section of this manual for instructions.
6. Apply a penetrating oil to all beam end connections.
7. On a tube-type end support, remove the tube nuts from both sides of the beam end tube. See **Fig. 1**.

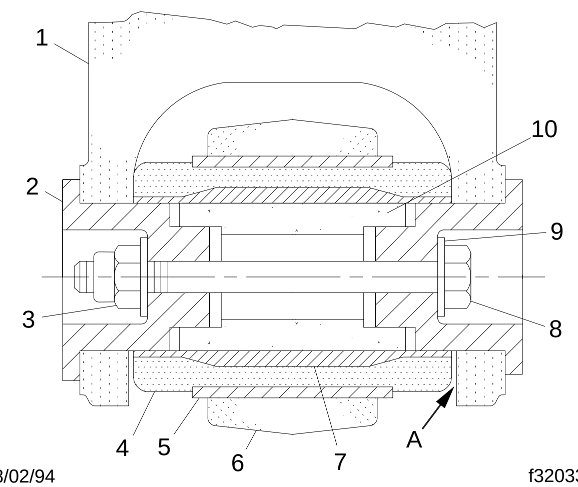
   On an adapter-type end support, remove the nut, washers, and the adapter bolt. See **Fig. 2**.
8. If using Owatonna tools, remove the tube-type end supports by positioning the receiving tube over the outboard end of the beam end tube. Position the hydraulic ram, pulling screw, speed nut, and the removing adapter. See **Fig. 3**. Connect a hydraulic pumping unit to the ram, and apply pressure to remove the beam end tube.
9. If using Owatonna tools, remove the adapter-type end supports as follows:

   9.1 Using either a 7/8- or 15/16-inch hand-tap, tap the adapter bolt hole (outboard side) to a depth of about 1-1/2 inches (38 mm). See **Fig. 4**.



1. Axle Beam Hanger
2. Bushing Inner Sleeve
3. Rubber End Bushing
4. Beam End Tube
5. End Tube Nut
6. Equalizer Beam
7. Bushing Outer Sleeve

Fig. 1, Equalizer Beam Tube-Type End Support



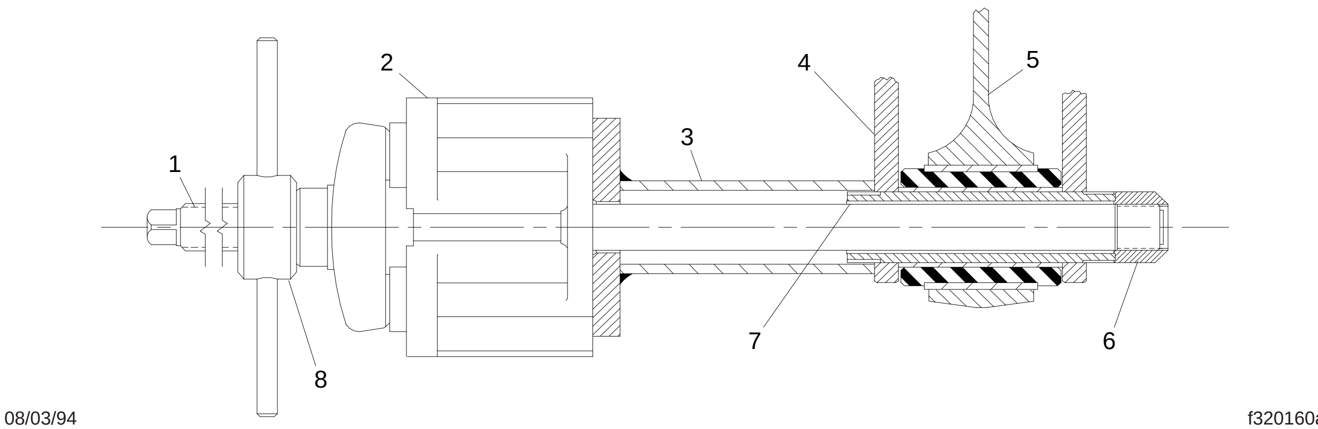
A. The new busing will have a small gap here.

1. Axle Beam Hanger
2. Adapter
3. Adapter Bolt Nut
4. Rubber End Bushing
5. Bushing Outer Sleeve
6. Equalizer Beam
7. Bushing Inner Sleeve
8. Adapter Bolt
9. Washer (both ends)
10. Intermediate Tube

Fig. 2, Equalizer Beam Adapter-Type End Support

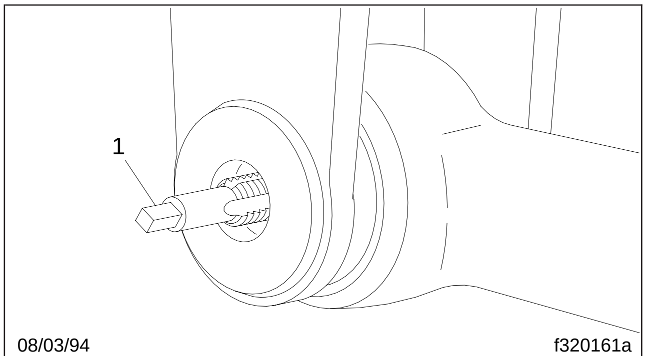
NOTE: Determine the correct size of hand-tap by using the plug gauge. If the gauge

Equalizer Beam Adapter- and Tube-Type End Support Removal and Installation



1. Pulling Screw
2. Ram
3. Receiving Tube
4. Beam Hanger
5. Equalizer Beam
6. Removing Adapter
7. Tube-Type Hanger Pin
8. Speed Nut

Fig. 3, Tube-Type Beam End Removal



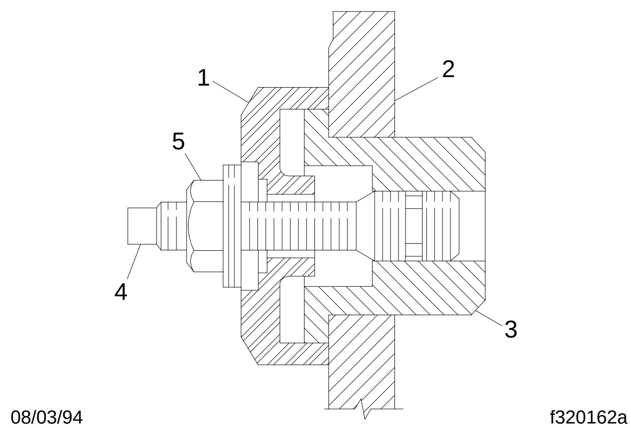
1. Hand-Tap

Fig. 4, Tapping the Adapter

passes through the adapter bolt hole, use a 15/16-inch tap; if it doesn't, use a 7/8-inch tap.

9.2 On the outboard side of the axle, thread the removing screw into the tapped hole. Position the receiving cup and hexnut on the removing screw. See **Fig. 5**.

Turn the hexnut until the adapter plug breaks loose and bottoms on the inside of the receiving cup. If needed, add spacers to complete removal of the adapter plug. See **Fig. 6**.



1. Receiving Cup
2. End Beam Hanger
3. End Beam Adapter Plug
4. Removing Screw

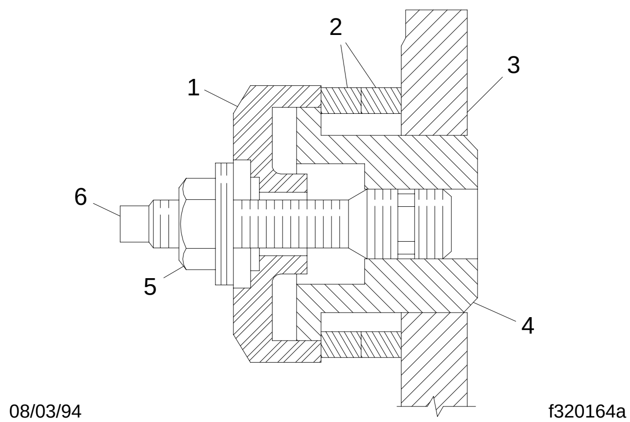
Fig. 5, Cross-Sectional View

9.3 On the inboard side of the axle, position the receiving cup over the adapter plug.

On the outboard side of the axle, insert the removing screw through the receiving cup and secure it with the hexnut. See **Fig. 7**.

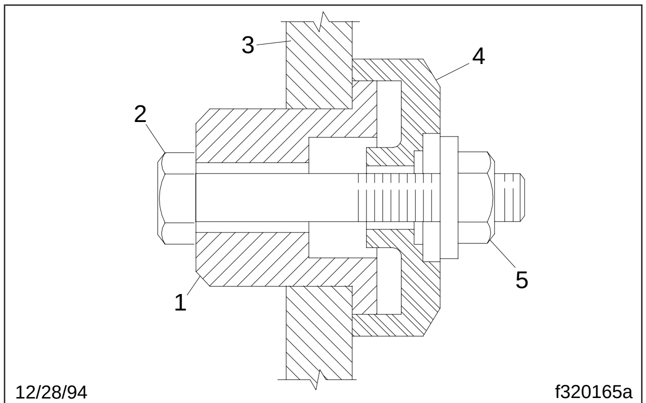
9.4 Hold the removing screw and turn the nut with a 1-1/2 inch open-or box-end wrench.

Equalizer Beam Adapter- and Tube-Type End Support Removal and Installation



1. Receiving Cup
2. Spacers
3. End Beam Hanger
4. End Beam Adapter Plug
5. Hexnut
6. Removing Screw

Fig. 6, Adding Spacers



1. End Beam Adapter Plug
2. Removing Screw
3. End Beam Hanger
4. Receiving Cup
5. Hexnut

Fig. 7, Outboard View

Turn the nut until the adapter plug bottoms on the inside of the receiving cup.

10. If not using Owatonna tools, remove the end supports as follows:

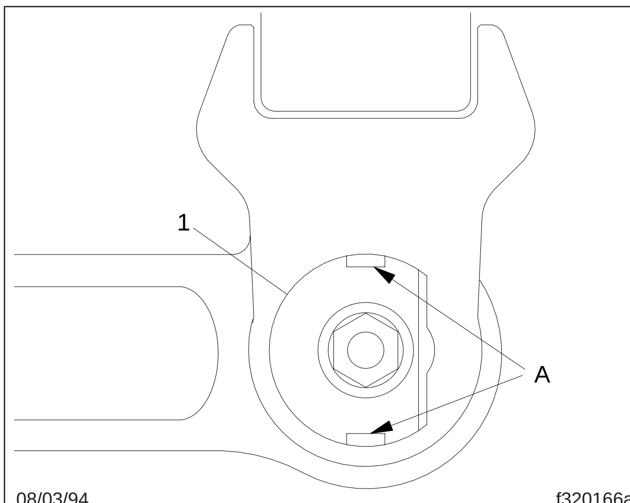
    10.1 For tube-type end supports, install a spacer bushing between one end-tube nut and the beam hanger. Tighten the nut to pull the end tube out of the beam end bushing. If the tube doesn't come loose, use a hacksaw and saw the tube along the inside surface of both axle beam hanger legs.

WARNING

Don't use a cutting torch to remove the equalizer beams from the beam hangers. The equalizer beams are heat-treated, and using a cutting torch could weaken them. This could result in a loss of vehicle control and possible personal injury.

    10.2 For adapter-type end supports, a relief is located on each side of the adapter. See Fig. 8. Turn the adapter with an air chisel, then insert a chisel into the relief on the inboard adapter. Drive the chisel in and wedge the adapter out of the beam hanger. Do the same on the outboard adapter.

    If a split-ring adapter is used, drive a chisel between the two halves to remove the end support plug. Drive the plug into the equalizer beam end bushing until it is clear of the beam hanger. After the equalizer beam is removed, drive the adapter plug out of the bushing.



A. Chisel Reliefs

1. Adapter

Fig. 8, Chisel Relief Locations

11. Remove the ends of the equalizer beams from the axle beam hangers.

Equalizer Beam Adapter- and Tube-Type End Support Removal and Installation

12. Lower the equalizer beams and the crosstube to the ground. Remove the thrustwashers and pull the beams from the crosstube.

Installation

1. On adapter-type end supports, apply Texaco Compound L or an equivalent rust preventive lubricant to the axle beam hanger eyes, beam end bushing inner sleeve, end support adapters, outside surface of the bushing intermediate tubes, and the ends of the crosstube.

   Install the crosstube and thrustwashers in both equalizer beam center bushings.

   On tube-type end supports, apply Texaco Compound L, or an equivalent rust preventive lubricant, to the axle beam hanger eyes, beam end bushing inner sleeve, outer surface of the beam end tubes, beam center bushing inner sleeves, and the ends of the crosstube.

   Using SAE 20 oil, lubricate the threads of the beam end tube, then install the crosstube and thrustwashers in both equalizer beam center bushings.
2. Position the equalizer beam assembly under the axles, then raise the assembly and place the forward ends of each beam in the forward-rear axle beam hangers. Align the beam end bushings with the beam hangers.

   On adapter-type end supports, install the intermediate tubes, the adapters, the adapter bolt, washers, and nut in each beam end to hold the beam in the axle beam hangers. Do not tighten.

   On tube-type end supports, install the beam end tubes through the beam hangers and the beam end bushings. Hand-tighten both nuts on the beam end tubes.
3. Place the rear ends of each beam in the rearmost axle beam hangers. Align the beam end bushings with the beam hangers.

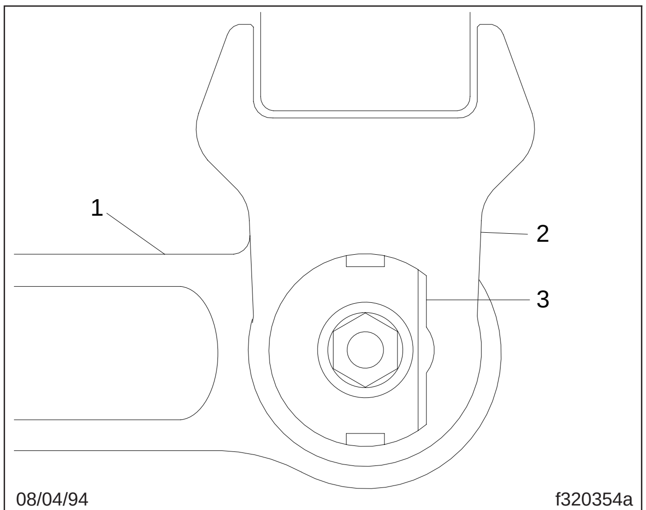
   On adapter-type end supports, install the intermediate tubes, the adapters, the adapter bolt, washers, and nut in each beam end to hold the beam in the axle beam hangers. Do not tighten.

   On tube-type end supports, install the beam end tubes through the beam hangers and the beam end bushings. Hand-tighten both nuts on the beam end tubes.
4. Position the saddle caps on the saddle cap studs, then install the washers and new self-locking nuts. Tighten the nuts 225 to 275 lbf·ft (305 to 373 N·m).
5. Tighten the adapter bolt nuts 210 to 240 lbf·ft (285 to 325 N·m). Make sure the flat section of the adapter flange is in the vertical position. See **Fig. 9**.
6. Tighten the end tube nuts 375 to 425 lbf·ft (508 to 576 N·m).

WARNING

The adapter bolt nuts and end tube nuts must be tightened to the values in the previous two steps. If not, the metal surfaces of the end support assembly will rub, and excessive wear to the beam hanger legs and end bushing inner sleeves will occur. This could result in separation of suspension components, loss of vehicle control, and possible injury or property damage.

7. Install the brake backing plate (dust shield), brake spider, and brake shoes. Refer to the brake section of this manual for instructions.
8. Install the wheels and tires. For instructions, see **Group 40** of this manual.



1. Equalizer Beam
2. Axle Bracket
3. Adapter Flat Side

Fig. 9, Tightening the Adapter Bolt Nuts

Equalizer Beam End Bushing Removal and Installation

Removal

WARNING

Don’t use a cutting torch to remove the beam end bushing. Equalizer beams are heat-treated by the manufacturer. Using a cutting torch could weaken the beams, and may result in a loss of vehicle control. This could cause personal injury or property damage.

1. Remove the equalizer beam ends from the axle beam hangers. For instructions, see **Subject 130**.

2. Cut off the protruding rubber from one side of each beam end bushing. See **Fig. 1**.

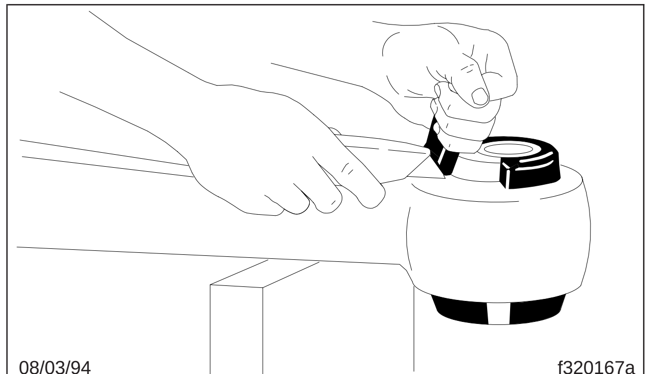


Fig. 1, Cutting Off the Protruding Rubber

3. If using Owatonna tools, remove the beam end bushings as follows (see **Fig. 2**):

   3.1 Install the receiving adapter on the receiving tube.

   3.2 Position the hydraulic ram and slide the pulling screw through the end bushing.

   3.3 Install the end bushing removing adapter on the inboard side of the beam end bushing. Check that the cone-shaped surface of the adapter is facing the equalizer beam.

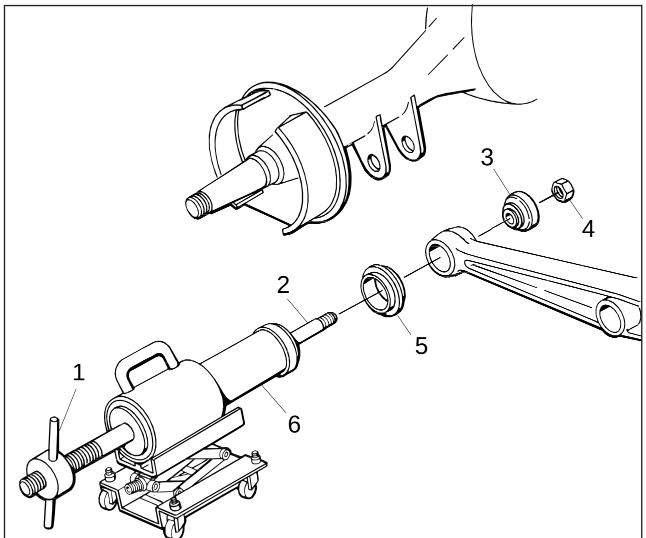
   IMPORTANT: Align the receiving tube so that the bushing will clear the edges of the tube when force is exerted against the beam. Align the removing adapter so that force is exerted only on the bushing to ensure a clean pull through the beam.

   3.4 Install the hexnut on the pulling screw. Full thread engagement is needed.

   3.5 Connect a hydraulic pumping unit to the ram and apply force until the ram cylinder reaches its stroke limit.

   3.6 Release the pressure, add spacers, and tighten the speed nut. About three adjustments are needed to completely remove the end bushing.

   NOTE: If the pressure gauge on the hydraulic pumping unit reads 10,000 psi (68 950 kPa) and the bushing has not broken loose, stop and check the alignment of the receiving tool and removal adapter. If both tools are aligned correctly, attach a sledging adapter on the speed nut end of the pulling screw. Maintaining hydraulic pressure, strike the sledging adapter with a heavy hammer. A loud noise followed by a sudden drop of the pressure gauge reading indicate the bushing has broken loose.



1. Speed Nut
2. Pulling Screw
3. Removing Adapter
4. Hexnut
5. Receiving Adapter
5. Receiving Tube

Fig. 2, Removing The Beam End Bushing

4. If using shop-made adapters, remove the beam end bushings as follows:

Equalizer Beam End Bushing Removal and Installation

4.1 Remove the equalizer beams. For instructions, see **Subject 130**.

4.2 Position the equalizer beam on a 50-ton vertical hydraulic press.

4.3 Center the shop-made adapter (refer to the applicable table under **Specifications 400**) on the trimmed end of the equalizer beam bushing. Press the end bushing from the beam eye.

Installation

1. Using emery cloth, remove all scale, rust, or corrosion from the beam eyes. Inspect the equalizer beam eyes for cracks, gouges, or damage. Replace the equalizer beam if any of these conditions exist.
2. Using emery cloth, clean the outer sleeves of the new equalizer beam end bushings. Apply a thin coating of Texaco Compound L, or an equivalent rust preventive lubricant, to the surface of the outer sleeves on the new bushing.
3. If using Owatonna tools, install the beam end bushings as follows (see **Fig. 3**):

3.1 Fit the adapter clamp over the exposed rubber on the new bushing. Tighten the clamp nuts until the clamp is flush against the bushing outer sleeve.

3.2 Install the receiving adapter on the receiving tube.

3.3 Position the hydraulic ram and slide the pulling screw through the end bushing.

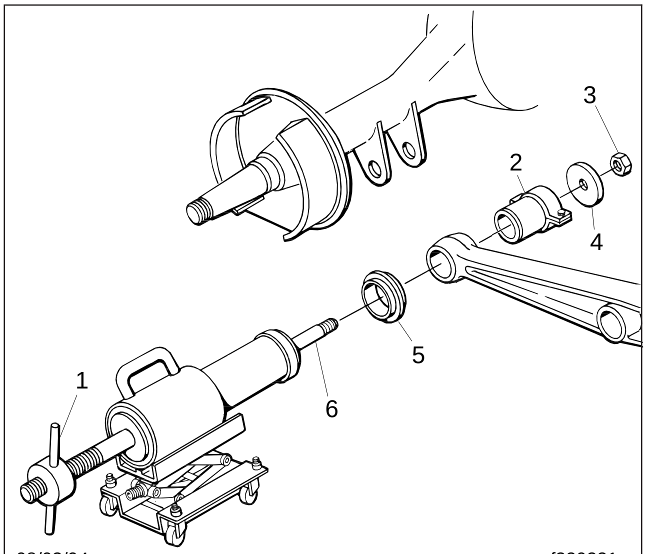
3.4 Center the adapter clamp and bushing on the inboard side of the beam end.

3.5 Install the adapter plate and secure it with the hexnut.

IMPORTANT: Check that the new bushing and the installation tools are centered so that the bushing will clear the receiving tube when force is exerted against the beam.

3.6 Tighten the speed nut and remove any slack in the assembly.

3.7 Connect a hydraulic pumping unit to the ram and apply force until the ram cylinder reaches its stroke limit.



1. Speed Nut
2. Adapter Clamp
3. Hexnut
4. Plate
5. Receiving Adapter
6. Pulling Screw

Fig. 3, Installing the Beam End Bushing

3.8 Release the pressure, add spacers, and tighten the speed nut. About three adjustments are needed to completely install the end bushing.

NOTE: The pressure gauge on the pumping unit should read 4,000 to 5,500 psi (27 580 to 37 920 kPa) during installation. If the reading reaches the operating limit of 10,000 psi (68 950 kPa) and the bushing is not going into the beam end, check the alignment of the bushing, tooling, and hydraulic equipment. Installation is complete when the adapter clamp is flush against the beam.

3.9 Install the equalizer beam ends on the axle beam hangers. For instructions, see **Subject 130**.

4. If using shop-made adapters, install the beam end bushings as follows (see **Fig. 4**):

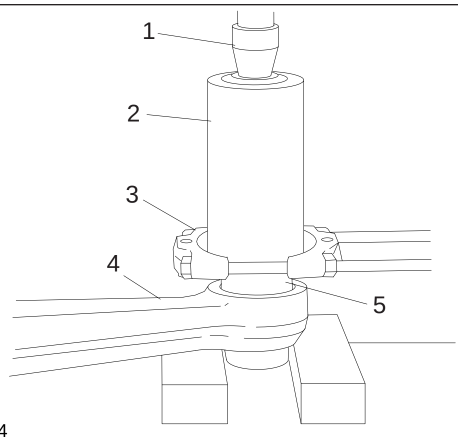
4.1 Position the equalizer beam on a 50-ton hydraulic press.

4.2 Using a sheave puller, compress the exposed rubber of the bushing until the puller jaws are flush against the end of the bushing outer sleeve.

Equalizer Beam End Bushing Removal and Installation

4.3 Position the shop-made adapter (refer to the table under **Specifications 400**) against the jaws of the sheave puller. Press the new bushing into the beam eye.

4.4 Install the equalizer beam. For instructions, see **Subject 130**.



1. Press
2. Adapter
3. Sheave Puller
4. Equalizer Bar
5. Bushing

Fig. 4, Removing the End Plug

Equalizer Beam Bar Pin/Bushing Assembly Removal, Installation, and Alignment

Removal

NOTE: Most Hendrickson suspensions are manufactured with a bar pin-type bushing assembly that connects the equalizer beam to the axle. The bar pin/bushing assembly can be serviced without removing the brake assembly.

WARNING

Do not use a cutting torch to remove the equalizer beams from the beam hangers. The equalizer beams are heat-treated, and using a cutting torch could weaken them. This could result in a loss of vehicle control, possible personal injury, or property damage.

1. Shut down the engine and set the parking brake.
2. Chock the front tires.
3. Support the equalizer beams with jack stands.
4. Remove the four bolts attaching the equalizer beam to the saddle.
5. Apply a penetrating oil to the threads of the two 1-inch (25 mm) bolts and locknuts attaching each bar pin/bushing assembly to the axle brackets.
6. Remove the bolts. If the fasteners are rusted in place, an air hammer chisel may be used to loosen the bolts attaching the bar pin/bushing assembly to the axle brackets.

NOTE: The upper torque rods may have to be disconnected at the top of the axle, and the axle rotated to a more vertical position to assist in the removal of the equalizer beam from the axle bracket.

7. Remove the equalizer beam from the axle beam hangers.
8. The bar pin/bushing assemblies can be removed from the equalizer beams with Owatonna tools. To do so, follow Owatonna recommendations.
9. If shop-made tools are used, remove the bar pin/bushing assemblies from the beam ends as follows:
   - 9.1 Position the equalizer beam on a 50-ton vertical hydraulic press.
   - 9.2 Center the shop-made tool, and press the bar pin/bushing assembly from the beam end eye.

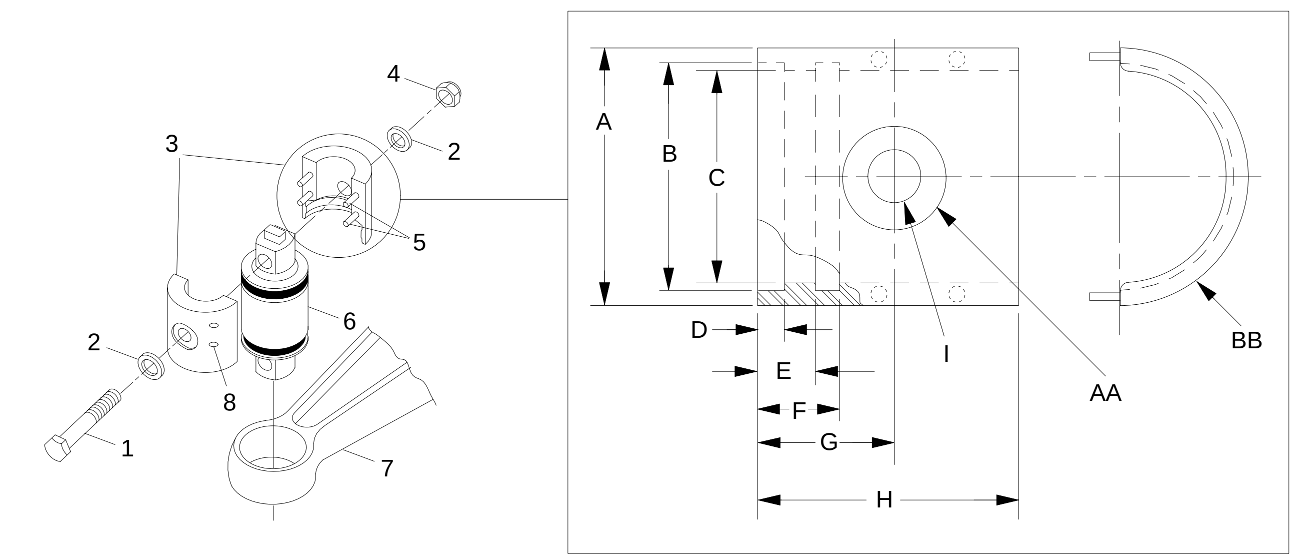
Installation

IMPORTANT: Do not reuse the old fasteners. Replace them during installation.

1. Using emery cloth, remove all scale, rust, or corrosion from the beam eyes. Inspect the equalizer beam eyes for cracks, gouges, or damage. Replace the equalizer beam if any of these conditions exist.
2. The outer metals of some Hendrickson rubber bushings are covered with a phosphate coating that acts as a rust preventive. This coating must be removed with emery cloth before installation. Also apply a coating of grease to the cleaned outer metals of the bar pin/bushing assembly, and to the beam end eyes to help when pressing the bar pin/bushing assembly into the beam end eye.
3. If using Owatonna tools, install the bar pin/bushing assemblies using Owatonna recommendations.
4. If using shop-made tools, create the needed assembly tool from a 5-inch (127 mm) length of 5-inch (127 mm) O.D. steel tubing with 1/2-inch (13 mm) wall thickness. See Fig. 1. The assembly tool must be split in half, then clamped or bolted together to compress the rubber to allow contact with the bushing outer metal.
   - 4.1 Position the equalizer beam on a 50-ton hydraulic press with the beam end bore squarely supported on the bed for safety and to avoid bending the equalizer beam.
   - 4.2 Before pressing the bar pin/bushing assembly, align the holes in the end of the bar pin/bushing assembly with the center line of the equalizer beam. This will help assembly into the axle brackets. Care should be taken during the assembly process to ensure the orientation of the bar pin/bushing assembly in the beam eye.

   NOTE: After installation, verify that the bar pin/bushing assembly is centered in the end of the beam.

Equalizer Beam Bar Pin/Bushing Assembly Removal, Installation, and Alignment



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The material used to make the tool is: 0.50" (13 mm) wall x 5.0" (127 mm) o.d. x 5.0" (127 mm) long steel tubing.

NOTE: The assembly tool must be split in half as shown.

A. 5.0" (127 mm)
B. 4.43" (113 mm)
C. 4.12" (105 mm)
D. 0.50" (13 mm)
E. 1.07" (27 mm)
F. 1.54" (39 mm)
G. 2.62" (67 mm)
H. 5.0" (127 mm)
I. 1.0" (25 mm)
AA. Recess flat counter bore, 2.0" (51 mm) x 0.25" (6 mm) deep.
BB. Tool wall, 0.50" (13 mm), top view.

1. Bolt, 1" (25 mm)
2. Washer, 1" (25 mm) o.d.
3. Assembly Tool
4. Locknut
5. Alignment Pins
6. Bar Pin/Bushing Assembly
7. Equalizer Beam
8. Alignment Pin Hole

Fig. 1, Assembly Tool (exploded view, with manufacturing information)

5. Install the equalizer beam on the axle hangers.
6. Attach the bar pin/bushing assembly to the axle brackets. Tighten the 1-inch (25 mm) bolts 450 to 600 lbf·ft (610 to 813 N·m).

NOTE: Bar pin/bushing assembly kits are available with or without alignment shims.

7. Install the four bolts attaching the equalizer beam to the saddle. Tighten 225 to 275 lbf·ft (305 to 375 N·m).
8. Remove the jack stands.
9. Remove the chocks from the tires.

Alignment

For a detailed adjustment procedure, refer to Hendrickson's service literature, *Bar Pin Alignment Instructions, Technical Publication No. 17730-213*.

The instruction publication may be obtained from:

Hendrickson Truck Suspension Systems
1-630-910-2800
1-800-973-0360
(fax) 1-630-378-4849
800 South Frontage Road
Woodridge, IL 60517-4904

Equalizer Beam Rubber Center Bushing Removal and Installation

Removal

NOTE: If using Owatonna tools, it is not necessary to remove the equalizer beam to remove or install the rubber center bushing.

1. Chock the front tires.
2. Raise the rear of the vehicle so that all weight is removed from the suspension. Block the axles and the frame with safety stands. Make sure the stands will securely support the weight of the axles and the frame.

NOTE: Do not raise the vehicle to the point where the weight of the suspension and axles hangs from the vehicle.

3. Remove the saddle cap nuts and washers from each side of the vehicle, and remove the saddle caps.
4. Raise the rear of the truck frame until the saddle studs clear the equalizer beam. Install safety stands under the frame.
5. Using a 2-1/2 inch diameter hole saw (see **Fig. 1**), cut out the end plug from the center bushing on each side of the suspension, and remove the crosstube.

CAUTION

Do not use a cutting torch to burn out the end plugs. The equalizer beams are heat-treated, and the use of a cutting torch could weaken the beam.

6. On the inboard side of the equalizer beam, inspect the exposed edge of the bushing's outer sleeve.
7. Chisel or grind off any portion of the outer sleeve that has flared over the surface of the equalizer beam.
8. If using Owatonna tools, remove the rubber center bushings as follows (see **Fig. 2**):

    8.1 Position the hydraulic ram and slide the pulling screw through the center bushing.

    8.2 Install the center bushing removing adapter on the inboard side of the beam eye.

IMPORTANT: Align the receiving tube so that the bushing will clear the edges of the tube when force is exerted against the beam. Align the removing adapter so that force is exerted only on the bushing to ensure a clean pull through the beam.

    8.3 Install the hexnut on the pulling screw. Full thread engagement is needed.

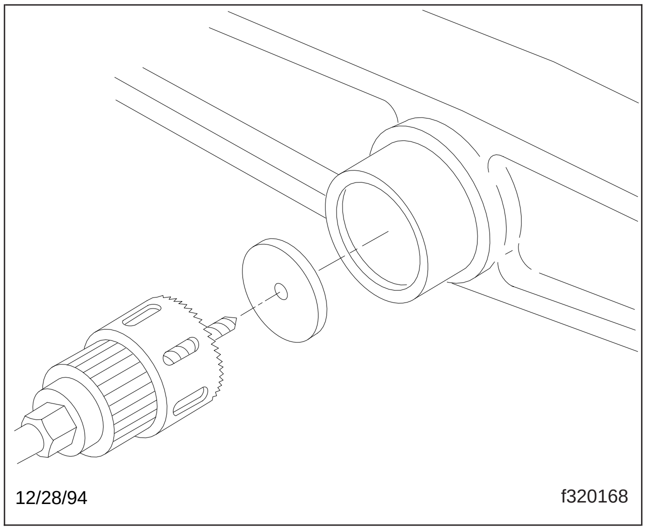
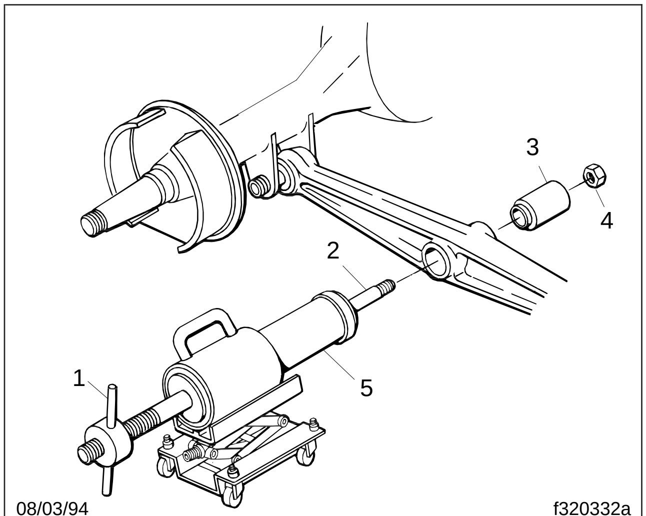


Fig. 1, Removing the End Plug



1. Speed Nut
2. Pulling Screw
3. Removing Adapter
4. Hexnut
5. Receiving Tube

Fig. 2, Removal of the Rubber Center Bushing

Equalizer Beam Rubber Center Bushing Removal and Installation

8.4 Install spacers between the ram cylinder and the speed nut. Tighten the speed nut and remove any slack in the assembly.

8.5 Connect a hydraulic pumping unit to the ram and apply force until the ram cylinder reaches its stroke limit.

8.6 Release the pressure, add spacers, and tighten the speed nut. About three adjustments are needed to completely remove the bushing.

NOTE: If the pressure gauge on the hydraulic pumping unit reads 10,000 psi (68 950 kPa) and the bushing has not broken loose, stop and check the alignment of the receiving tool and removal adapter. If both tools are aligned correctly, attach a sledging adapter on the speed nut end of the pulling screw. Maintaining hydraulic pressure, strike the sledging adapter with a heavy hammer. A loud noise followed by a sudden drop of the pressure gauge reading indicate that the bushing has broken loose.

9. If using shop-made adapters, remove the equalizer beams. For instructions, see **Subject 130**.

9.1 Position the equalizer beam on a 50-ton vertical hydraulic press.

9.2 Center the shop-made adapter (refer to the applicable table under **Specifications 400**) on the trimmed end of the equalizer beam bushing. Press the center bushing from the beam eye.

Installation

1. Using emery cloth, remove all scale, rust, or corrosion from the beam eyes. Inspect the equalizer beam eyes for cracks, gouges, or damage. Replace the equalizer beam if any of these conditions exist.
2. Using emery cloth, clean the outer sleeves of the new equalizer beam center bushings. Apply a thin coating of Texaco Compound L, or an equivalent rust preventive lubricant, to the surface of the outer sleeves on the new bushing.
3. If using Owatonna tools, install the rubber center bushings as follows (see **Fig. 3**):

3.1 Center the hydraulic ram and slide the pulling screw through the beam eye.

3.2 Position the bushing on the inboard side of the beam eye.

IMPORTANT: Center the new bushing to ensure a clean pull through the beam eye.

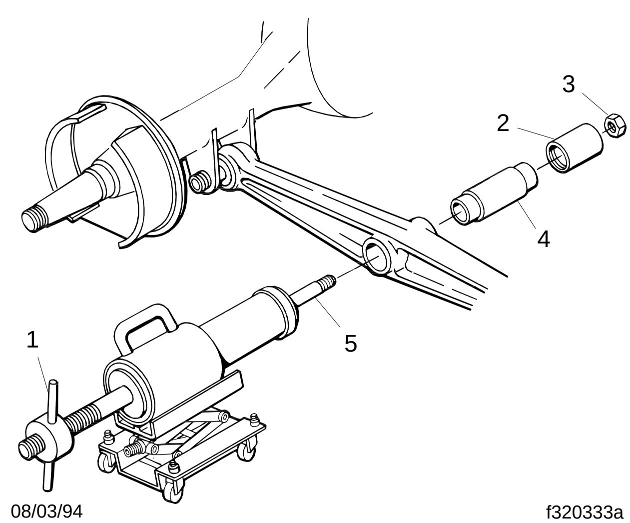
3.3 Fit the installing adapter over the inner sleeve and against the outer sleeve of the bushing.

3.4 Install the hexnut on the pulling screw. Full thread engagement is needed.

3.5 Install spacers between the ram cylinder and the speed nut. Tighten the speed nut and remove any slack in the assembly.

3.6 Connect a hydraulic pumping unit to the ram and apply force until the ram cylinder reaches its stroke limit.

3.7 Release the pressure, add spacers, and tighten the speed nut. About three adjustments are needed to completely install the center bushing.



1. Speed Nut
2. Installing Adapter
3. Hexnut
4. Bushing
5. Pulling Screw

Fig. 3, Installing the Rubber Center Bushing

NOTE: The pressure gauge on the pumping unit should read 4,000 to 5,500 psi (27 580 to 37 920 kPa) during installation. If the

Equalizer Beam Rubber Center Bushing Removal and Installation

reading reaches the operating limit of 10,000 psi (68 950 kPa) and the bushing is not going into the beam, check the alignment of the bushing, tooling, and hydraulic equipment. Installation is complete when the installing adapter is flush against the beam.

3.8 Position the crosstube in the center bushings.

WARNING

Wear protective welding masks and gloves when welding. Failure to do so could result in personal injury due to the intensity of heat, sparks, and flying debris from the welding process.

3.9 Arc weld new end plugs to the tire side of each center bushing inner sleeve.

NOTE: Heat from welding the end plugs will not affect the beam or the new rubber bushings because of their distance from the point of welding.

4. Position the saddle caps on the saddle cap studs, then install the washers and new self-locking nuts. Tighten the nuts 225 to 275 lbf·ft (305 to 373 N·m).

5. If using shop-made adapters, position the equalizer beam on a 50-ton hydraulic press.

5.1 Using standard center bushings with the end plugs welded in place, position the shop-made adapter (refer to the applicable table under **Specifications 400**) over the inner sleeve of the bushing. Check that the adapter bottoms against the bushing outer sleeve, then press the new bushing into the beam eye.

5.2 Install the equalizer beams. For instructions, see **Subject 130**.

Equalizer Beam Bronze Center Bushing Removal and Installation

Removal

NOTE: If using Owatonna tools, you can remove or install the bronze center bushing without removing the equalizer beam.

1. Chock the front tires.
2. Raise the rear of the vehicle so that all weight is removed from the suspension. Block the axles and the frame with safety stands. Make sure the stands will securely support the weight of the axles and the frame.

NOTE: Do not raise the vehicle to the point where the weight of the suspension and axles hangs from the vehicle.

3. Remove the saddle cap nut and washers from each side of the suspension, and remove the saddle caps.
4. Raise the rear of the truck frame until the saddle studs clear the equalizer beam. Install safety stands under the frame.
5. Using a 2-1/2 inch diameter hole saw, cut out the retaining disk from the center bushing on each side of the suspension, and remove the cross-tube.

CAUTION

Do not use a cutting torch to burn out the retaining disk. The equalizer beams are heat treated, and the use of a cutting torch could weaken the beam.

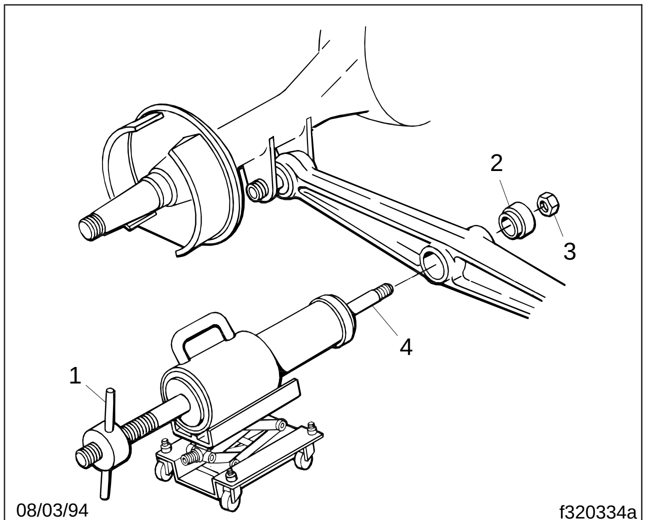
6. If using Owatonna tools, remove the bronze center bushing as follows (see **Fig. 1**):

   6.1 Position the hydraulic ram and slide the pulling screw through the center bushing.

   6.2 Install the center bushing removing adapter on the inboard side of the beam eye.

   IMPORTANT: Align the receiving tube so that the bushing will clear the edges of the tube when force is exerted against the beam. Align the removing adapter so that force is exerted only on the bushing to ensure a clean pull through the beam.

   6.3 Install the hexnut on the pulling screw. Full thread engagement is needed.



1. Speed Nut
2. Removing Adapter
3. Hexnut
4. Pulling Screw

Fig. 1, Removal of Bronze Center Bushing

   6.4 Install spacers between the ram cylinder and the speed nut. Tighten the speed nut and remove any slack in the assembly.

   6.5 Connect a hydraulic pumping unit to the ram and apply force until the ram cylinder reaches its stroke limit.

   6.6 Release the pressure, add spacers, and tighten the speed nut. About three adjustments are needed to completely remove the center bushing.

NOTE: If the pressure gauge on the hydraulic pumping unit reads 10,000 psi (68 950 kPa) and the bushing has not broken loose, stop and check the alignment of the receiving tool and removal adapter. If both tools are aligned correctly, attach a sledging adapter on the speed nut end of the pulling screw. Maintaining hydraulic pressure, strike the sledging adapter with a heavy hammer. A loud noise followed by a sudden drop of the pressure gauge reading indicate that the bushing has broken loose.

Equalizer Beam Bronze Center Bushing Removal and Installation

7. If using shop-made adapters, remove the equalizer beams. For instructions, refer to **Subject 130**.

   7.1 Position the equalizer beam on a 50-ton vertical hydraulic press.

   7.2 Center the shop-made adapter (refer to the applicable table under **Specifications 400**) on the center bushing. Press the bushing from the beam eye.

Installation

1. Using emery cloth, remove all scale, rust, or corrosion from the beam eyes. Inspect the equalizer beam eyes for cracks, gouges, or damage. Replace the equalizer beam if any of these conditions exist.
2. Using emery cloth, clean the outer sleeves of the new equalizer beam center bushings. Apply a thin coating of Texaco Compound L, or an equivalent rust preventive lubricant, to the surface of the outer sleeves on the new bushing, and to the inside surface of the beam eye.
3. Position the bushing on the equalizer beam eye.
4. If using Owatonna tools, install the bronze center bushings as follows (see **Fig. 2**):

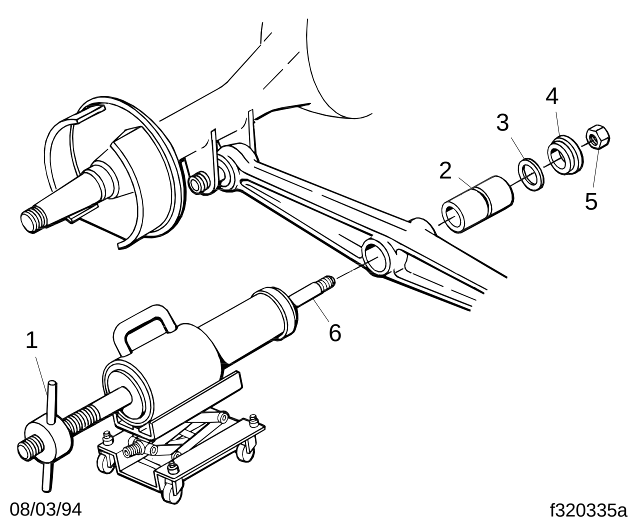
   4.1 Center the hydraulic ram and slide the pulling screw through the beam eye.

   4.2 Position the bushing on the inboard side of the beam eye. Check that the grooves of the bushing are aligned with the vertical centerline of the equalizer beam. See **Fig. 3**.

   4.3 Fit the installing adapter and the removing/installing adapter against the outer sleeve of the bushing. Make sure the deep ridge on the installing adapter is positioned against the bronze bushing. See **Fig. 4**.

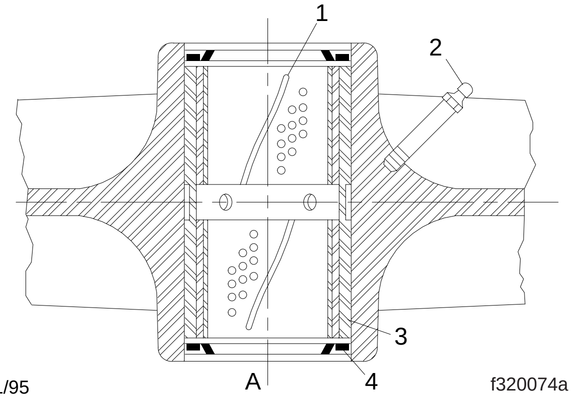
   4.4 Install the hexnut on the pulling screw. Full thread engagement is needed.

   4.5 Install spacers between the ram cylinder and the speed nut. Tighten the speed nut and remove any slack in the assembly.



1. Speed Nut
2. Bushing
3. Installing Adapter
4. Installing Adapter
5. Hexnut
6. Pulling Screw

Fig. 2, Installing the Bronze Center Bushing



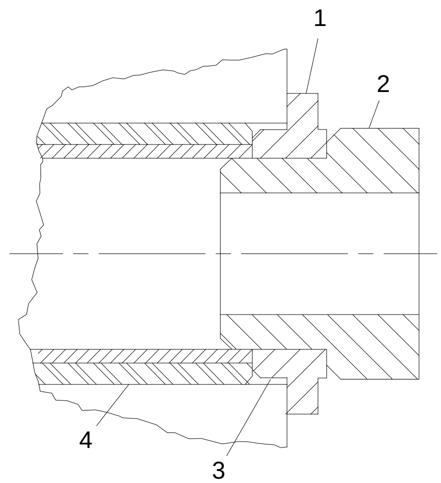
A. Vertical Centerline of Beam
1. Bushing Lube Grooves
2. Grease Fitting
3. Center Bushing Assembly
4. Seal

Fig. 3, Check Bushing Grooves

   4.6 Connect a hydraulic pumping unit to the ram and apply force until the ram cylinder reaches its stroke limit.

   4.7 Release the pressure, add spacers, and tighten the speed nut. About three adjustments are needed to completely install the center bushing.

Equalizer Beam Bronze Center Bushing Removal and Installation



1. Installing Adapter
2. Removing/Installing Adapter
3. Deep Ridge
4. Bushing

Fig. 4, Position of Adapter

NOTE: The pressure gauge on the pumping unit should read 4,000 to 5,500 psi (27 580 to 37 920 kPa) during installation. If the reading reaches the operating limit of 10,000 psi (68 950 kPa) and the bushing is not going into the beam, check the alignment of the bushing, tooling, and hydraulic equipment. Installation is complete when the installing adapter is flush against the beam.

4.8 On the inboard side of the beam, position a grease seal and installing adapter against the center bushing. Make sure the shallow end of the adapter is against the grease seal. See **Fig. 5**. Using a hammer, tap the installing adapter until it is flat against the beam. Using the same procedure, install a grease seal on the outboard side of the beam.

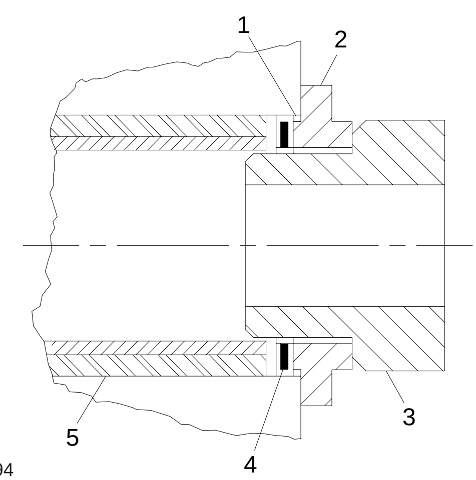
5. If using shop-made adapters, position the equalizer beam on a 50-ton hydraulic press.

5.1 Center the new bushing in the beam eye. Using a standard bushing driver, press the bushing in until there is equal spacing between both bushing ends and the sides of the beam eye.

5.2 Install the new grease seals (with the seal lips facing out).

NOTE: Check that the new seals are 1/6 inch (4 mm) inside the beam hub surface to ensure clearance and protection of the seals when the saddle cap is installed.

6. Apply a thin coating of multipurpose chassis grease to the inside surface of the center bushing. Slide the bushing center sleeve into the bushing.
7. Install the grease fitting into the beam hub. Rotate the center sleeve and apply multipurpose chassis grease in the grease fitting. Lubricate until clean grease appears at both ends of the grease seals.
8. Install the crosstube.
9. Install the saddle caps or the equalizer beam (if removed) on the axle beam hangers. For instructions, see **Subject 130**.



1. Shallow Ridge
2. Installing Adapter
3. Removing/Installing Adapter
4. Seal
5. Bushing

Fig. 5, Seating Adapter and Seal

Torque Rod and Bushing Removal and Installation

Removal

IMPORTANT: To ensure that the required tools are available, see the applicable table in **Specifications 400**, before beginning these procedures. Special tools are available from the Owatonna Tool Company, Owatonna, Minnesota, or an affiliated dealer.

WARNING

When the torque rods are disconnected from the axle brackets, the axles become free to pivot on the equalizer beam end bushings. Keep clear of the beam hangers and beam ends to avoid possible injury.

1. On fore-and-aft torque rods, remove the flanged bolts and nuts from the torque rod axle brackets, and the crossmember mounting brackets. Remove the torque rods. See **Fig. 1**.

   On transverse torque rods, remove the nuts and washers from the axle brackets, and remove the flanged bolts and nuts from the frame rail mounting brackets. Remove the torque rods. See **Fig. 1**.

NOTE: If necessary, use an impact hammer and tap the top of the axle bracket to disengage the rod stud from the axle bracket.

2. Inspect the torque rods. If bent or cracked, replace. Check the torque rod bushings. If one of the bushings is loose or damaged, replace both of the bushings.
3. Position the press plate on the hydraulic press. Check that the small counterbore of the plate hole is facing up.

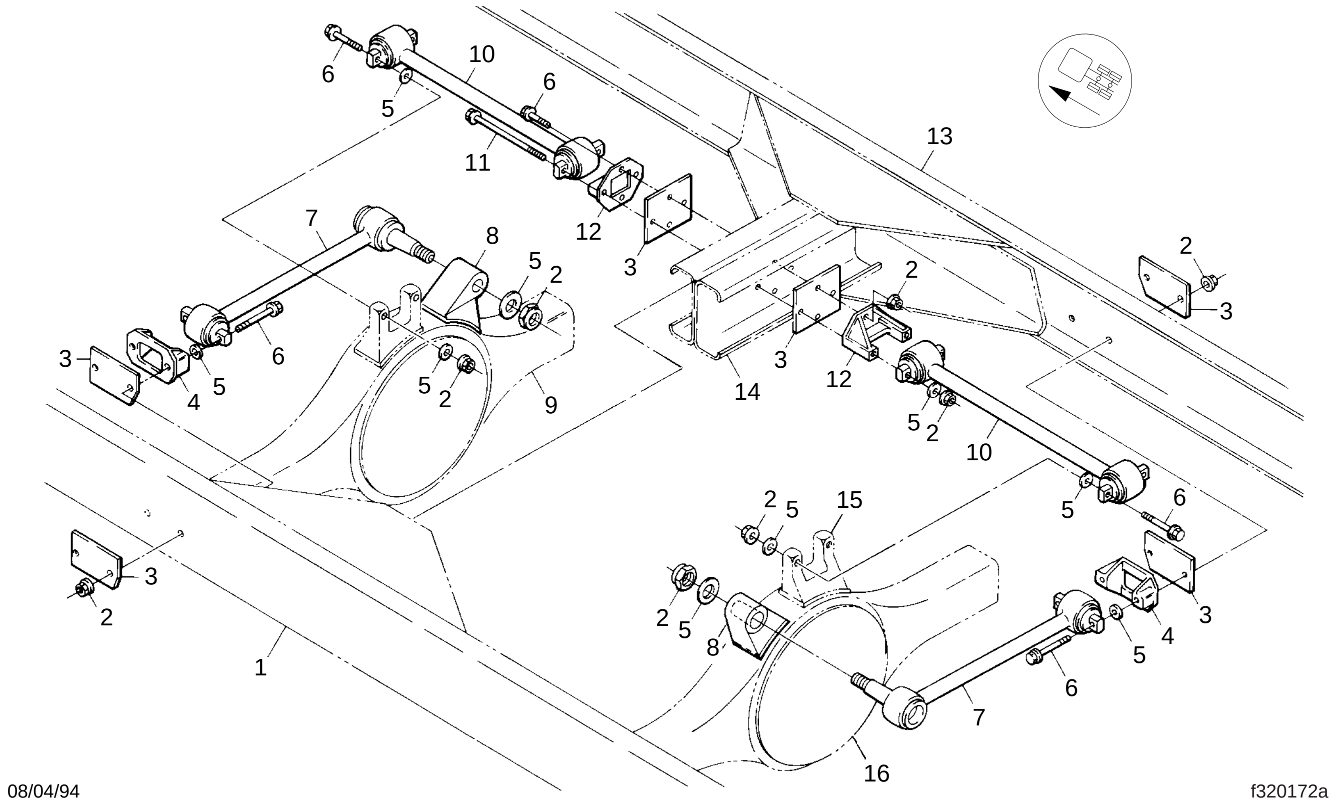
NOTE: Some tapered stud torque rod bushings have a large non-removable washer on the stud that will not fit though the press plate hole. Loosen the press plate capscrews and separate the halves (see **Fig. 2**) until the washer clears the counterbore, and the torque rod sets on the press plate. Tighten the capscrews until the press plate halves are closed.

4. Position the tapered stud removal tool (using the end with the larger inside diameter) on the torque rod stud. Apply lubricating oil (see **Fig. 3**), then press the stud out of the bushing.
5. Position the bushing remover/replacer tool (using the end with the larger outside diameter) on the bushing. Install the cap, then apply lubricating oil to the torque rod bushing.
6. Press the rubber bushing out of the torque rod eye.
7. Position the straddle mount end of the torque rod into the hole of the press plate. Tighten the press plate capscrews.
8. Position the straddle mount pin remover on the straddle mount pin. See **Fig. 4**.
9. Apply lubricating oil to the straddle mount pin. Press the straddle mount pin out of the bushing.
10. Position the end of the rubber bushing remover/replacer tool (using the end that has the larger outside diameter) on the bushing. Install the cap, then apply lubricating oil to the torque rod bushing.
11. Press the rubber bushing out of the torque rod eye.

Installation

1. Remove all dirt and grease from the torque rod ends. Apply lubricant on the new bushings and in the torque rod eyes.
2. Position the press plate on the hydraulic press. Check that the small counterbore of the plate hole is facing up.
3. Position the new bushing on the tapered stud of transverse torque rods. Position the clamp and tighten it to compress the rubber. See **Fig. 5**.
4. Place the torque rod end, the bushing, and the clamp on the press plate.
5. Place the remover/replacer tool (see **Fig. 6**) and cap on top of the clamping tool and press the bushing in the torque rod end. Check that the bushing sleeve protrudes equally on each side of the torque rod end.
6. On straddle mount end assemblies, align the clamping tool on the bushing. See **Fig. 7** . Tighten the clamp to compress the rubber of the new straddle mount bushing.

Torque Rod and Bushing Removal and Installation



1. Left-Hand Frame Rail
2. Flanged Hexnut
3. Spacer
4. Transverse Torque Rod Mounting Bracket
5. Hardened Washer
6. Flanged Hexbolt
7. Transverse Torque Rod
8. Mounting Bracket
9. Forward-Rear Axle
10. Fore-and-Aft Torque Rod
11. Capscrew
12. Mounting Bracket
13. Right-Hand Frame Rail
14. Crossmember
15. Mounting Bracket
16. Rear-Rear Axle

Fig. 1, Torque Rods Mounting

NOTE: When tightening the clamp, make sure that the position of the bushing pin is at a right angle to the center line of the torque rod shank. See **Fig. 8**.

7. Place the torque rod end, the bushing, and the clamp on the press plate.
8. Using the larger end of the remover/ replacer tool, position the tool and cap on top of the clamp assembly.
9. Press the bushing in the torque rod end. Check that the bushing's outer sleeve protrudes equally on each side of the torque rod end.
10. Install the fore-and-aft torque rods as follows (see **Fig. 1**):

    10.1 Position a torque rod straddle mount pin in the forward-rear axle bracket. Install the flanged bolts through the axle bracket and the straddle mount pin. Install a spacer and nut on each bolt, and tighten 190 lbf·ft (260 N·m).

    10.2 Position a torque rod straddle mount pin in the rearmost axle bracket. Install the flanged bolts through the axle bracket and the straddle mount pin. Install a spacer and nut on each bolt, and tighten 190 lbf·ft (260 N·m).

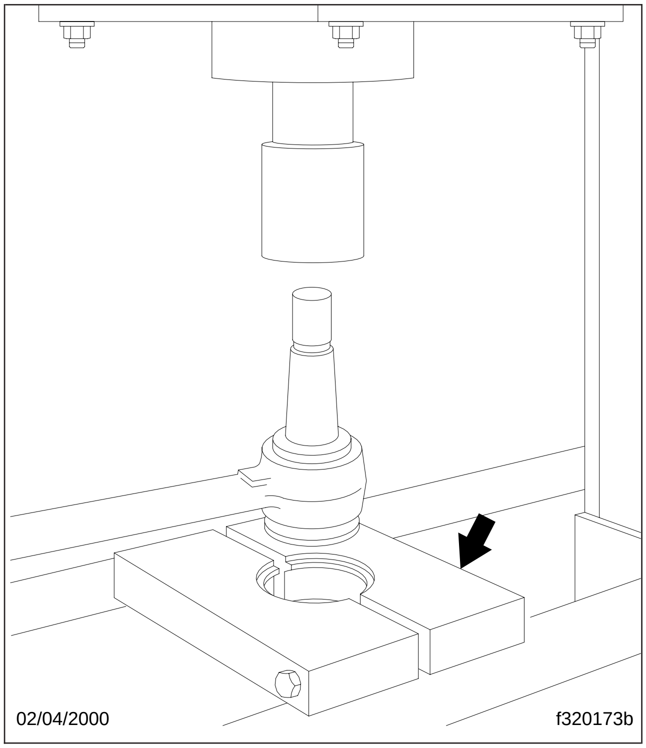


Fig. 2, Separating the Halves

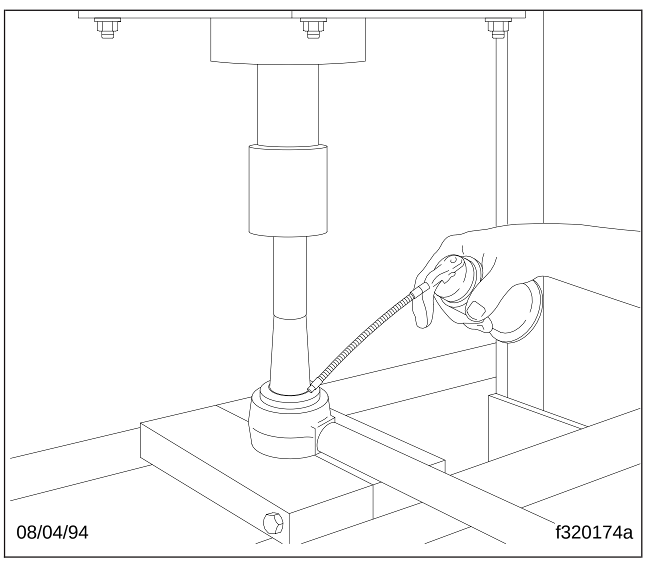


Fig. 3, Applying Oil

10.3 Position a torque rod spacer and straddle mount bracket on each side of the cross-member. Insert bolts through the upper and lower holes of the forward mounting

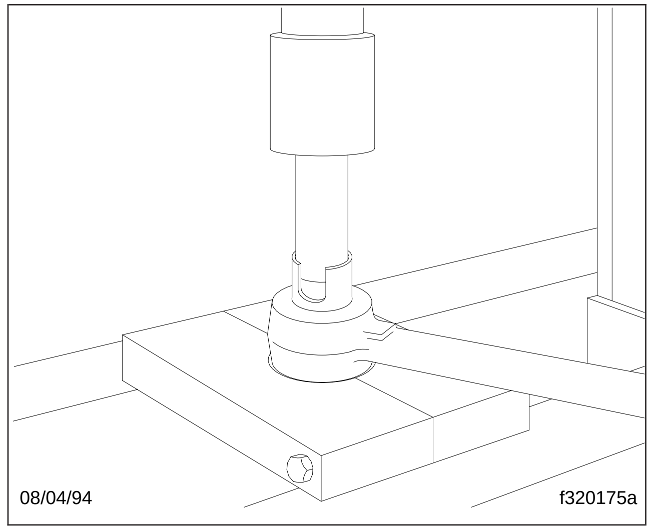
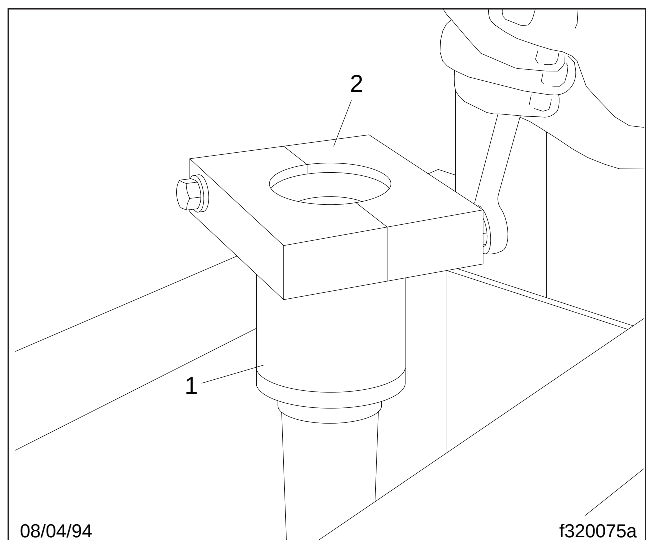


Fig. 4, Positioning the Pin Remover



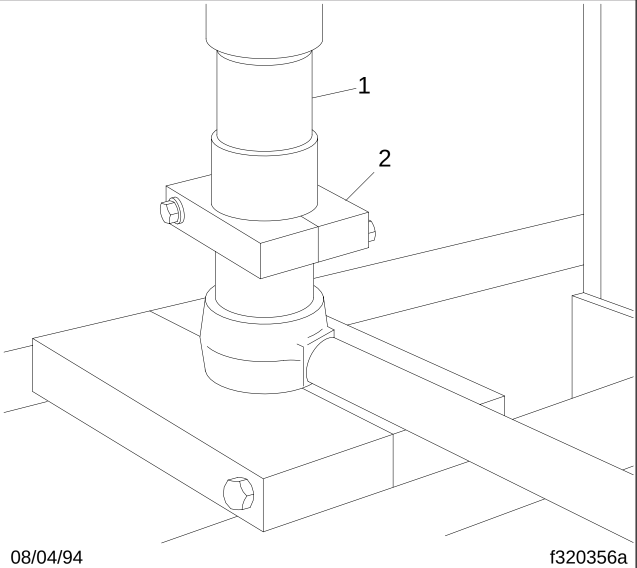
1. Bushing
2. Clamping Tool

Fig. 5, Installing the New Bushing

bracket. Install nuts and tighten 95 lbf·ft (130 N·m).

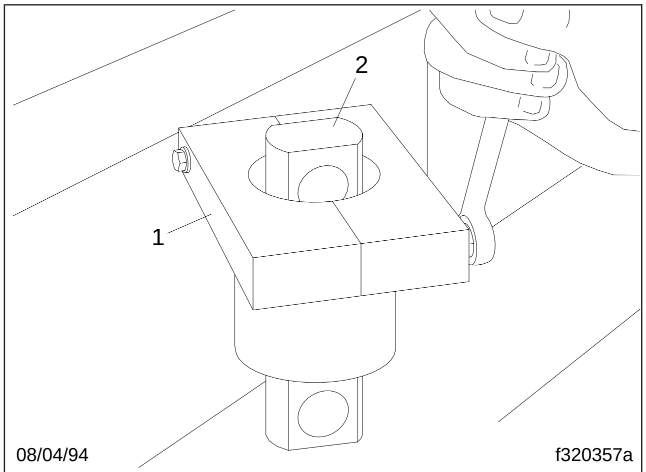
10.4 Position the straddle mount pin of the forward torque rod in the mounting bracket. Insert bolts through the forward pin, both bracket assemblies, and the straddle mount pin of the rear torque rod. Install the nuts and bearing washers. Tighten the nuts 190 lbf·ft (260 N·m).

Torque Rod and Bushing Removal and Installation



1. Remover/Replacer Tool
2. Clamping Tool

Fig. 6, Pressing In the New Bushing



1. Clamping Tool
2. Pin

Fig. 7, Aligning the Clamping Tool

11. Install the transverse torque rods as follows (see **Fig. 1**):

    11.1 Check that the tapered stud end and the tapered stud bracket hole are clean. Lubricate the tapered stud ends with SAE 20 oil.

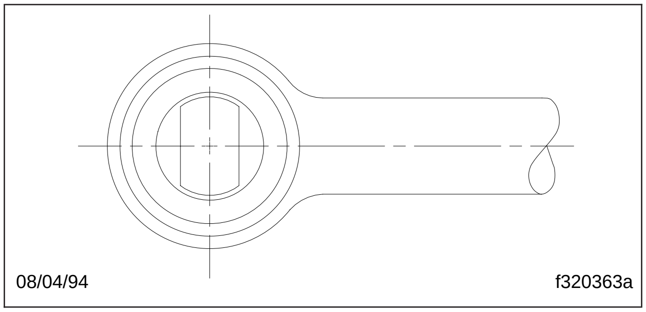


Fig. 8, Correct Bushing Pin Position

    11.2 Install the tapered stud in the axle bracket. Install a washer and nut. Tighten the nut 175 to 225 lbf·ft (235 to 305 N·m).

    11.3 Align the straddle mount end, the mounting bracket, and the spacer against the inside frame rail.

    11.4 On the inboard side of the frame rail, install the bolts through the mounting assembly and the frame rail.

    11.5 On the outboard side of the frame rail, install a spacer over the mounting bolt studs. Install the nuts and tighten them 190 lbf·ft (260 N·m).

12. Check the axle pinion angle. For instructions, see **Group 41** of this manual.

Specifications

Part Number	Tool	Usage
1745	Adapter Puller Set	Adapter-Type End Support Removal
1761	Torque Rod Set	Torque Rod Bushing Removal and Installation
28536	Installing Adapter (5-3/4" o.d.)	Bronze Center Bushing and Seal Removal and Installation
44119	Receiving Tube	Center and End Bushing Removal and Installation
45052	Adapter Clamp	End Bushing Installation
51678	80-Ton Hydraulic Ram	All Operations
51695	Jack	All Operations
206459	Plate	End Bushing Installation
302018	Spacer (3 qty.)	Center and End Bushing Removal and Installation
302019	Receiving Adapter	End Bushing Removal and Installation
302023	Pulling Screw	All Operations
302024	Removing and Installing Adapter	Bronze Center Bushing Removal and Installation
302026	Installing Adapter	Rubber Center Bushing Removal and Installation
302027	Removing Adapter	Rubber Center Bushing Removal and Installation
302028	Hexnut	All Operations
302029	Speed Nut	All Operations
302030	Removing Adapter	End Bushing Removal and Installation

Table 1, Special Tools (Owatonna Tool Company)

Tool Number	Dimensions	Usage
1	4-1/4 inch o.d. by 4 inch	Beam End Bushing Removal
2	4-1/2 inch i.d. by 4 inch	Beam End Bushing Installation
3	4-5/8 inch o.d. by 7 inch	Beam Center Bushing Removal and Installation

Table 2, Shop-Made Adapters

Description	Size	Torque: lbf·ft (N·m)
Top Pad to Spring Aligning Setscrew	—	100–150 (135–200)
Top Pad Nut	—	275–400 (375–542)
Spring Pin Locknut	1/2–13	45–63 (61–85)
Torque Rod Straddle Mount Nut	5/8–11	190 (260)
Torque Rod Stud Locknut	1-1/4–12	175–225 (235–305)
Saddle Cap Stud	7/8–14	55–65 (75–90)
Saddle Cap Locknut	7/8–14	225–275 (305–373)
Adapter-Type Beam End Locknut	3/4–16	210–240 (285–325)
Tube-Type Beam End Nut	2-1/2–12	375–425 (508–576)

Specifications

Description	Size	Torque: lbf·ft (N·m)
Spring Center Bolt	7/16–20	50–60 (70–80)
	1/2–20	65–75 (90–100)
Rebound Spacer Locknut	1/2–13	38–45 (51–61)
Spring Alignment Clip	—	15 (20)
Fore and Aft Torque Rod Mount Nut	—	95 (130)

Table 3, Torque Values

General Description

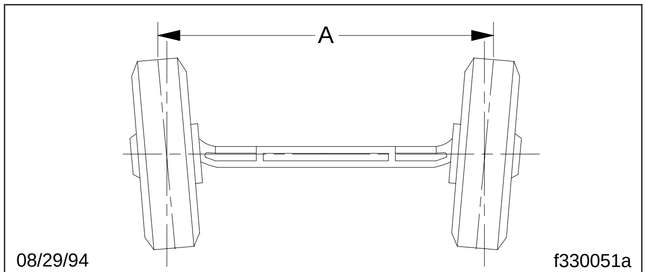
NOTE: For front axle troubleshooting procedures, refer to **Section 33.01**.

The front axle requires periodic servicing to maintain accurate wheel alignment. If the front axle is damaged enough to affect the camber angle it must be replaced. For axle removal and installation instructions, see **Subject 160**.

Correct front axle wheel alignment is needed to ensure long tire life, ease of handling, and steering stability.

Three factors are involved in wheel alignment: camber angle, caster angle, and wheel toe-in.

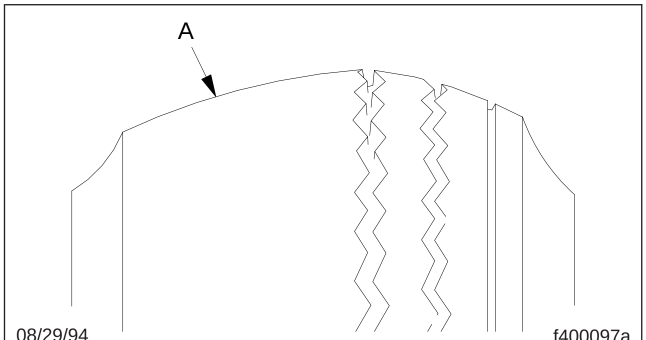
Camber angle (**Fig. 1**) is the vertical tilt of the wheel as viewed from the front of the vehicle. Camber angle is measured in degrees, and is not adjustable. Positive camber is the outward tilt of the wheel at the top. Excessive positive camber in one wheel causes the vehicle to pull in the opposite direction, rapidly wearing the outboard side of the tire tread. Negative camber is the inward tilt of the wheel at the top. Excessive negative camber in one wheel causes the vehicle to pull in the same direction that the negative-camber wheel is on, wearing the inboard side of the tire tread. If camber angles are not correct, the tires will wear smooth around the edge on one side. See **Fig. 2**.



A. Camber (Positive)

Fig. 1, Camber Angle (front view)

Caster angle (**Fig. 3**) is the tilt of the knuckle pin (or kingpin) as viewed from the side. Caster angle is measured in degrees and it is adjustable. A positive caster angle is the tilt of the top of the knuckle pin toward the rear of the vehicle. A negative caster angle is the tilt of the top of the knuckle pin toward the front of the vehicle. Caster angles are based on the design load of the vehicle. An incorrect caster angle does not cause tire wear. However, a positive caster angle that exceeds specifications could cause vehicle shimmy, road shock, and an increased steering effort. A negative caster angle that does not meet specifications could cause unstable steering. The vehicle may wander and weave, and extra steering effort may be necessary. After leaving a turn, the tendency to return to and maintain a straight-ahead position is reduced. Too much or too little caster in one wheel can cause erratic steering when the service brakes are applied to stop the vehicle.



A. One side of the tread is worn excessively.

Fig. 2, Tire Damage Due to Excessive Camber

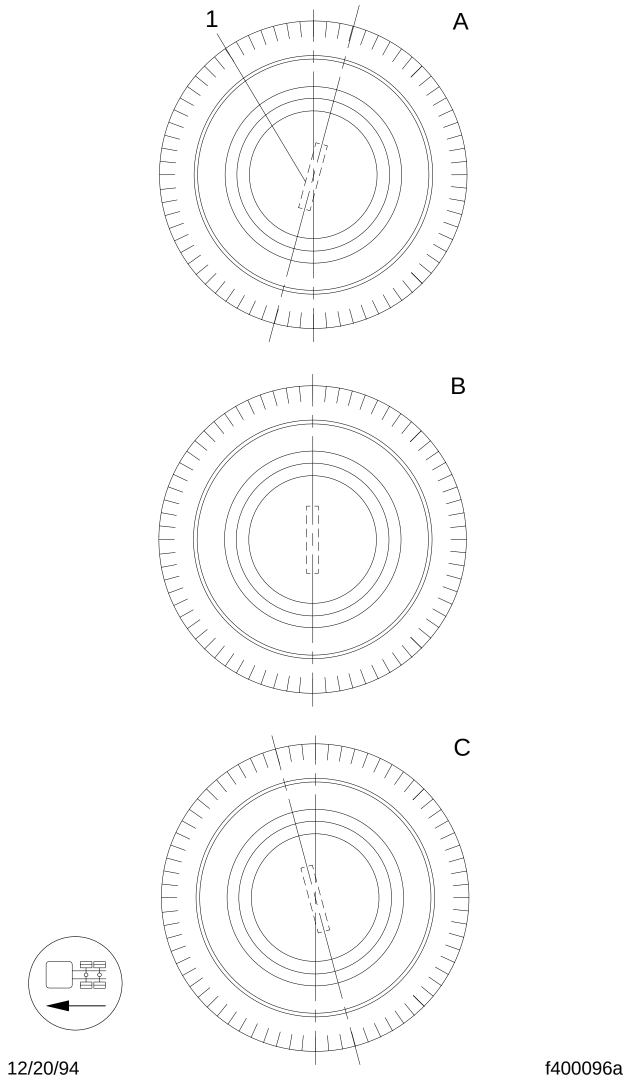
Wheel toe-in (**Fig. 4**) is the distance in inches that the front of the wheels are closer together than the rear of the wheels, as viewed from the top. Wheel toe-in is adjustable. If it is not adjusted correctly, the vehicle could pull to one side while driving. Wheel shimmy and cupped tire treads (indentations on the road contact surface of the treads) could occur. Also, rapid or severe tire wear on the steering axle could occur, usually in a feather-edged pattern. See **Fig. 5**.

Advanced wear patterns can be seen, but less severe wear patterns are detected only by rubbing the palm of your hand flat across the tire tread.

Feather-edging more often affects the front tire on the passenger's side of the vehicle, and is usually more apparent on the outside grooves of the tire.

If any of the conditions listed above occur, the vehicle could need a front end wheel alignment, and possibly, drive axle alignment. However, in some cases these conditions are not wheel alignment related; refer to **Section 33.01** for other possible causes.

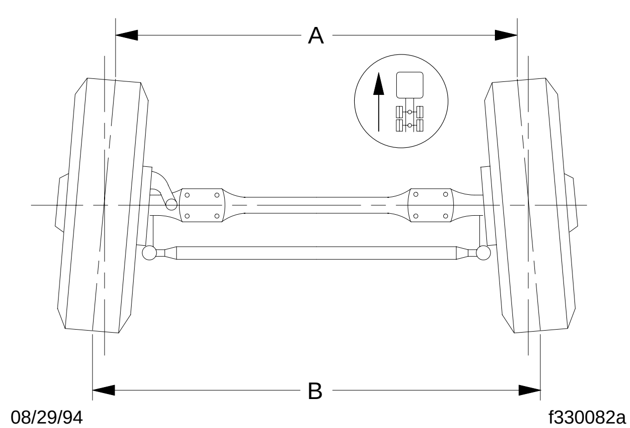
If excessive tire tread wear has resulted from incorrect wheel alignment, replace the damaged tires. For



1. Knuckle Pin (King Pin)

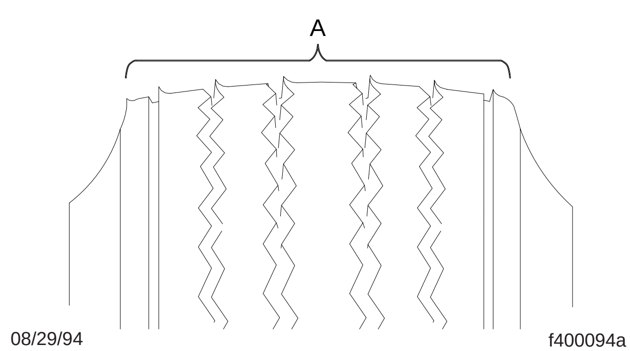
A. Positive Caster
B. Zero Caster
C. Negative Caster

Fig. 3, Caster Angle



NOTE: B minus A equals toe-in.

Fig. 4, Wheel Toe-In (overhead view)



A. Feathered Edges

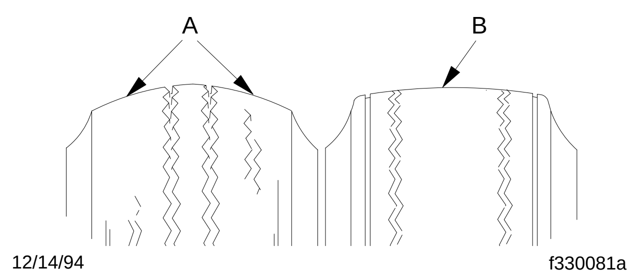
Fig. 5, Tire Damage Due to Excessive Toe-In or Incorrect Drive Axle Alignment

minimum tread wear specifications, refer to Group 40 of the *Business Class M2 Maintenance Manual*.

Preliminary Checks

IMPORTANT: When aligning the front axle, it is essential that the rear axle(s) be checked for correct alignment at the same time. Alignment of the rear axle(s) has a direct impact on how the vehicle tracks. Refer to **Section 35.00**, Specifications 400.

1. Steering axle wheel assemblies should be balanced, especially for vehicles that travel at sustained speeds of more than 50 mph (80 km/h). Off-balance wheel assemblies cause vibrations that result in severely shortened life for tires, and steering suspension parts.
2. Do not mix tires of different size, type, or weight. Tire wear should be even and not worn to limits exceeding government specifications. Refer to **Group 40** of this manual and Group 40 of the *Business Class M2 Maintenance Manual* for more information. Replace any tire that is excessively worn.
3. Check the inflation pressure of the tires. Refer to **Group 40** of this manual for recommended pressures. An underinflated tire causes tread wear completely around both tire shoulders. An overinflated tire causes tread wear in the center of the tire. See **Fig. 1**.



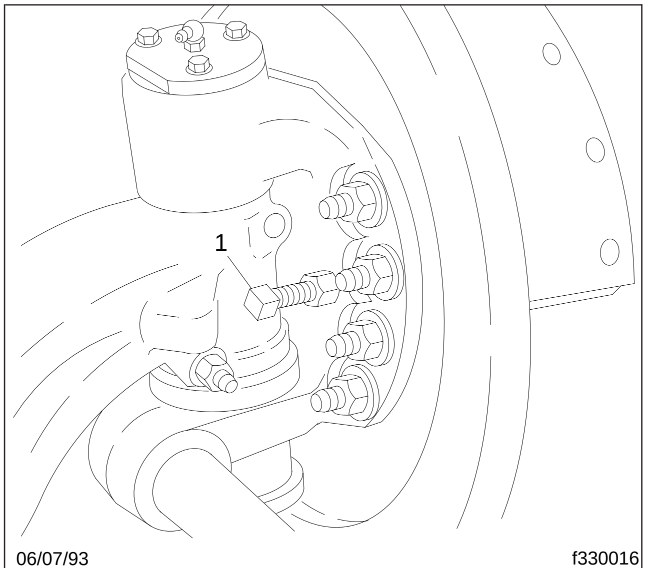
A. Underinflation Wear B. Overinflation Wear

Fig. 1, Tire Damage Due to Underinflated or Overinflated Tires

4. Check for out-of-round wheels, rims, or wheel stud holes. Replace the wheel if any of these conditions exist.
5. On each side of the vehicle, check the height of the chassis above the ground. Sagging, fatigued, or broken suspension springs create a lopsided vehicle appearance. This causes an unbalanced weight distribution. Anything that changes the ratio of weight on the springs affects the alignment angles and also the tire tread contact area. Replace damaged springs as instructed in **Group 32** of this manual.
6. Inspect the front axle beam (also called the axle center) for bends or twists. If the axle beam is bent or twisted over 1/2 degree, replace it before aligning the front axle wheels.
7. Check for damaged, worn, or bent steering gear or linkage parts. Make sure the steering gear is centered. Replace damaged components, and adjust the steering gear, using the instructions in **Group 46** of this manual.
8. Check the steering angle, and adjust the axle steering stops, as needed. Refer to **Subject 110**.
9. Check the tie-rod ends for correct adjustment, tightness, and damage. Refer to Group 46 of the *Business Class M2 Maintenance Manual* for instructions.
10. Check the front wheel bearings for wear and incorrect adjustment. Refer to **Section 33.01** for instructions.

Checking and Adjusting

Steering (or turning) angle is the degree of front wheel movement from a straight-ahead position to either an extreme right or left position. Although front wheel movement can be limited by the amount of internal travel in the steering gear, it generally depends on how much clearance there is between chassis components and the tire and wheel assemblies. All axles have adjustable stopscrew-and locknut-type axle stops (**Fig. 1**), which are located on the rear side of each front axle spindle.



1. Stopscrew and Locknut

Fig. 1, Axle Stop

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Freightliner dealers must have proof of this calibration history.

1. Make sure the steering gear is in the center of travel when the wheels are in a straight-ahead position. Center the gear, using the instructions in **Group 46**. Bottoming of the steering gear must not occur when making an extreme right or left turn.
2. If using stationary turn-plates or turntables (**Fig. 2**), drive the vehicle on the plates; the tires must be exactly straight ahead. Apply the parking brakes.

   If using portable gauges, apply the parking brakes, chock the rear tires, and raise the front of the vehicle. Place a turn-plate or turntable under each tire. With the tires exactly straight ahead, lower the vehicle so that the tires rest on the center of the gauges.

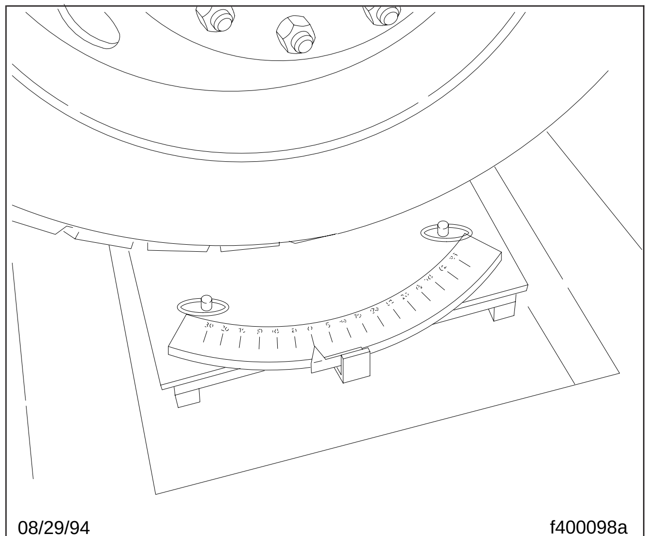


Fig. 2, Turn-Plate (Turntable), Stationary Type

3. Remove the lockpins from the gauges, and adjust the dials so that the pointers on both gauges read zero.
4. With the brakes fully applied, turn the steering wheel clockwise to the end of travel. Have someone check both sides of the vehicle for interference at the tires and wheels. There must be at least 0.50 inch (13 mm) clearance from any fixed object, and 0.75 inch (19 mm) from any moving object.

   If necessary, loosen the stopscrew locknut; adjust the stopscrew to contact the axle when the maximum turning angle of the wheels is determined.

   Tighten the locknut to the value in the torque table under **Specifications 400**.

Steering Angle Checking and Adjusting

5. Repeat the step above with the steering wheel turned counterclockwise. Adjust the axle stop, as needed.
6. If equipped with power steering, adjust the steering gear so that pressure is released ahead of the axle stop. This will prevent possible damage to the steering or axle components. For poppet valve adjustment instructions, refer to **Group 46**.
7. Drive the vehicle off the turn-plates or turntables, or remove them from under the tires and lower the vehicle.

Measuring and Adjusting Front Axle Wheel Alignment Angles

Measuring and Adjusting

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Freightliner dealers must have proof of this calibration history.

Precision instruments and equipment are needed for accurately measuring and adjusting wheel alignment. Refer to the operating instructions provided by the wheel alignment equipment manufacturer.

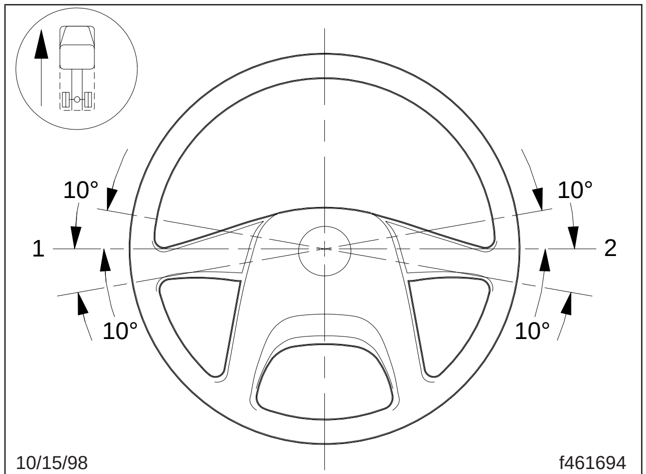
Before checking or correcting wheel alignment, make sure the vehicle is at curb weight. Curb weight is the weight of the unloaded vehicle complete with accessories and full fuel tanks.

If a road test is necessary, the route should be one that allows full left and right turns and full stops. It should also include a length of straight, level road to check the steering wheel position during straight-ahead driving.

During the road test, note any steering effort and possible roughness. Check for looseness, too much wheel play, any tendency for the vehicle to lead in one direction, and for pull during stopping.

Note the position of the steering wheel while driving on a straight, level road. When the steering gear is centered, the steering wheel spokes should be at the 3 and 9 o'clock positions, or within 10 degrees of that position. See **Fig. 1**.

If there are any problems, refer to **Section 33.01**.



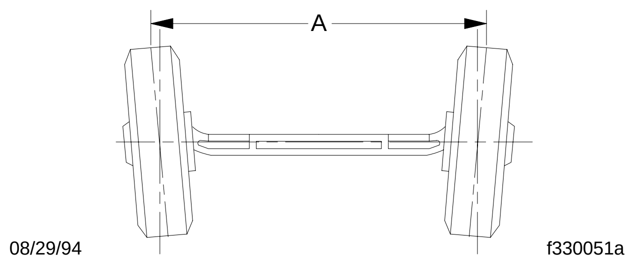
1. 9 o'Clock
2. 3 o'Clock

Fig. 1, Steering Wheel Position

Checking

IMPORTANT: Do all the preliminary checks in **Subject 100** before checking the camber angle.

Camber angle is the vertical tilt of the wheels as viewed from the front of the vehicle. See **Fig. 1**.



A. Camber (Positive)

Fig. 1, Camber Angle

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Freightliner dealers must have proof of this calibration history.

1. Apply the parking brakes, and chock the rear tires.
2. Raise the front of the vehicle until the tires clear the ground. Place safety stands under the axle; make sure the stands will support the weight of the cab, frame, and front axle.
3. Before measuring camber, check the front wheel bearings for wear and incorrect adjustment. Try moving the wheel on the axle spindle (steering knuckle) either by grasping the front tire on the top and bottom, or by using a bar for leverage. If movement between the brake drum and the backing plate or other axle-mounted reference point is 0.05 inch (1 mm) or more, the bearings may be worn or incorrectly adjusted. Inspect the wheel bearings for damage using the instructions in **Section 33.01**. If needed, replace or adjust the bearings.
4. Remove the safety stands, and lower the vehicle to the ground.
5. Using the alignment equipment manufacturer's instructions, measure the front wheel camber.
6. Compare the camber angles with those shown in the appropriate table in **Specifications 400**. Differences between the measurements taken in the step above and the angles in the table are caused by damaged (bent) axle components.

   Incorrect camber angles could be caused by damage in one or more of the following front axle components: the knuckle pin, the knuckle pin bushings, the axle spindle, or the axle beam. Replace twisted or otherwise damaged components. Don't try to straighten twisted or bent components; replace them with new components. If a bent or twisted front axle knuckle pin, axle spindle, or axle beam has been straightened, the axle warranty will be voided.

WARNING

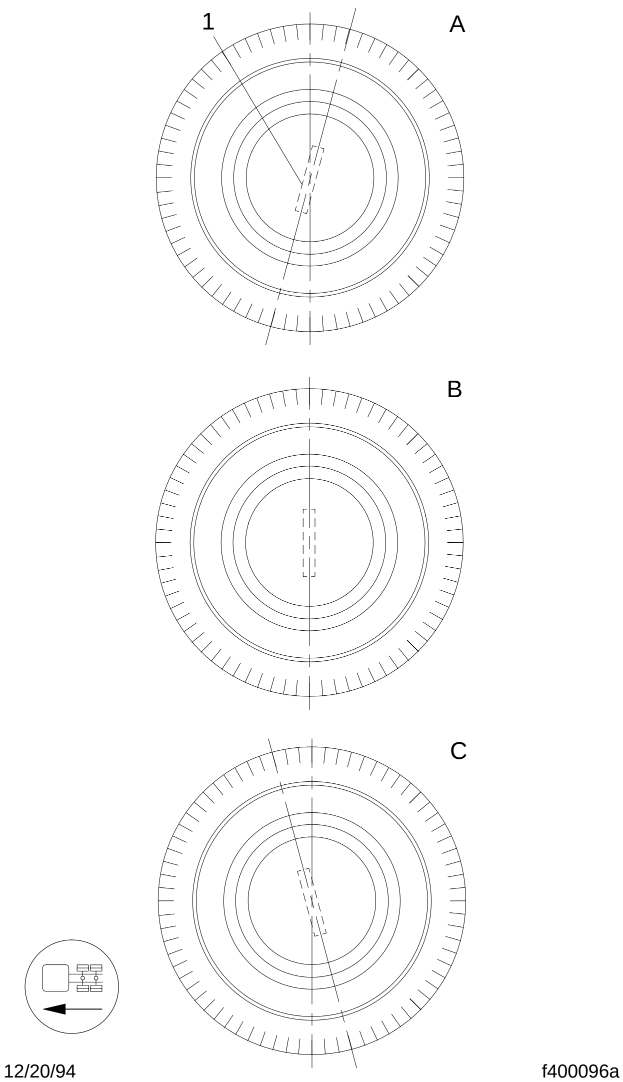
Do not attempt to straighten any twisted or bent front axle component. This could crack or weaken the component, possibly resulting in a collapsed front axle, loss of a wheel, and serious personal injury.

7. Remove the chocks from the tires.

Checking and Adjusting

IMPORTANT: Do all the preliminary checks in **Subject 100**before checking the camber angle.

Caster angle is the tilt of the knuckle pin (or kingpin) as viewed from the side. See **Fig. 1**.



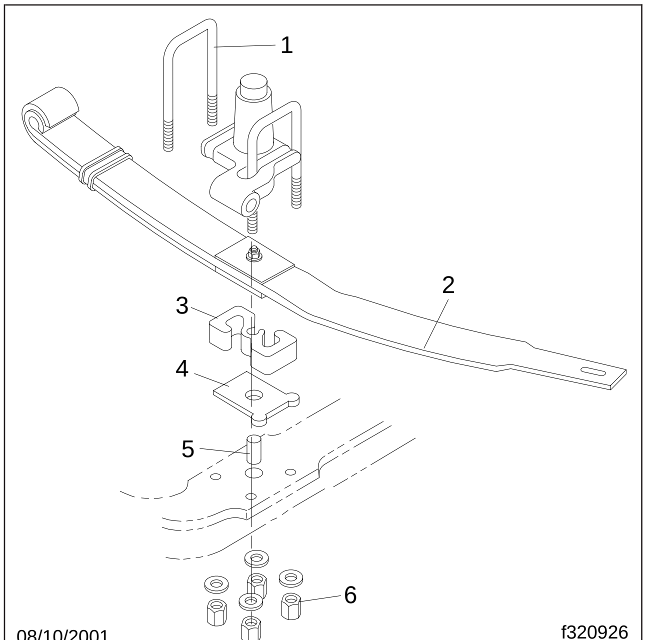
A. Positive Caster
B. Zero Caster
C. Negative Caster
1. Knuckle Pin (Kingpin)

Fig. 1, Caster Angle

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Freightliner dealers must have proof of this calibration history.

Using the alignment equipment manufacturer's operating instructions, measure the front wheel caster.

Compare the caster angles with those shown the appropriate table in **Specifications 400**. If needed, adjust the caster angle by placing wedge-shaped shims between the axle spacer and the axle beam, as follows (see **Fig. 2**):



1. Axle Spring U-Bolt
2. Leaf Spring Assembly
3. Spacer
4. Front Caster Shim
5. Dowel Pin
6. U-Bolt High Nut

Fig. 2, Axle Spring Installation (typical)

IMPORTANT: Extreme angle shims cannot be used to correct caster angles that vary by more than 2 degrees from the values in the table. Weak or broken leaf springs, or worn shackle

Caster Angle Checking and Adjusting

bushings, can cause extreme deviations to caster angles. Replace damaged parts before doing caster adjustments.

1. Apply the parking brakes, and chock the front and rear tires.
2. Back off the U-bolt nuts from the U-bolts on one side of the front axle. See **Fig. 2**.
3. Raise the spring away from the axle enough to allow removal of the front caster shim.
4. Remove the shim, and install one that will provide the correct caster angle, as specified in the table in **Specifications 400**. Install the dowel pin and check penetration.

IMPORTANT: Place front caster shims between the axle beam and the axle spacer, or between the axle beam and the shock absorber bracket. See **Fig. 2**.

5. Lower the vehicle onto the axle.
6. Coat the threaded ends of the U-bolts with chassis lube or an antiseize compound, such as Loctite® 242. Tighten the U-bolt nuts to the value in the appropriate table in **Specifications 400**.

   U-bolt nuts need periodic retightening. Refer Group 32 of the *Business Class M2 Maintenance Manual* for recommended intervals.

CAUTION

Failure to periodically retighten the U-bolt nuts could result in spring breakage and abnormal tire wear.

7. Using the steps above, replace the shim on the other side of the axle.
8. Do a final caster angle check.
9. Remove the chocks from the tires.

Checking and Adjusting

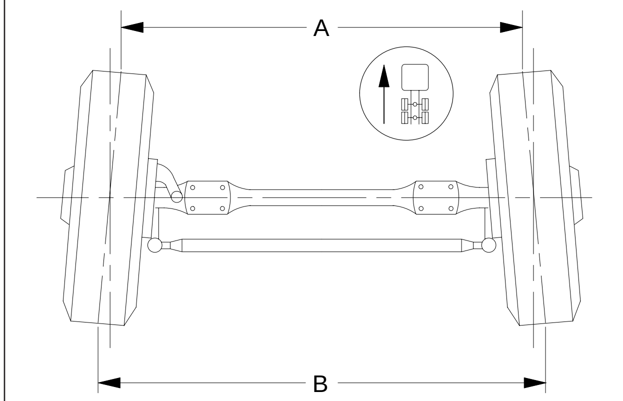
IMPORTANT: When checking wheel toe-in, it is essential that the rear axle(s) be checked for correct alignment at the same time. Alignment of the rear axle(s) has a direct impact on how the vehicle tracks. Refer to **Section 35.00**, Specifications 400.

Using the alignment equipment manufacturer's operating instructions, measure the wheel toe-in. See **Fig. 1**. Compare the measurement with that shown in the appropriate table in **Specifications 400**. If corrections are needed, go to the applicable (tie rod adjustment) step below.

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Freightliner dealers must have proof of this calibration history.

1. Apply the parking brakes, and chock the rear tires.
2. Raise the front of the vehicle until the tires clear the ground. Place safety stands under the axle. Make sure the stands will support the weight of the cab, axle, and frame.
3. Using spray paint or a piece of chalk, mark the entire center rib of each front tire.
4. Place a scribe or pointed instrument against the marked center rib of each tire, and turn the tires. The scribes must be held firmly in place so that a single straight line is scribed all the way around each tire.
5. Place a turn-plate or turntable under each tire. Remove the safety stands from under the axle, then lower the vehicle. Remove the lockpins from the gauges; make sure the tires are exactly straight ahead.

NOTE: If turn-plates or turntables are not available, lower the vehicle. Remove the chocks from the rear tires and release the parking brakes. Move the vehicle backward and then forward about 6 feet (2 meters).



NOTE: B minus A equals toe-in.

Fig. 1, Wheel Toe-In (Overhead View)

6. Place the trammel bar at the rear of the front tires; locate the trammel pointers at spindle height, and adjust the pointers to line up with the scribe lines. Lock in place. Make sure that the scale is set on zero.
7. Place the trammel bar at the front of the tires as shown in **Fig. 2**. Adjust the scale end so that the pointers line up with the scribe lines. See **Fig. 3**.
8. Read the toe-in from the scale. Compare the toe-in with the value in the appropriate table in **Specifications 400**. If corrections are needed, go to the next step.
9. Loosen the tie rod (cross tube) clamp nuts, and turn the tie rod as needed.

   If the vehicle is not on turn-plates or turntables, move the vehicle backward and then forward about 6 feet (2 meters). This is important when setting the toe-in on vehicles equipped with radial tires.

   Do a final wheel toe-in check to make sure that it is correct.

   Make sure the steering wheel is centered.

   Tighten the clamp nuts to the values in the appropriate table in **Specifications 400**.
10. If not already done, remove the chocks from the rear tires. Road test the vehicle.

Wheel Toe-In Checking and Adjusting

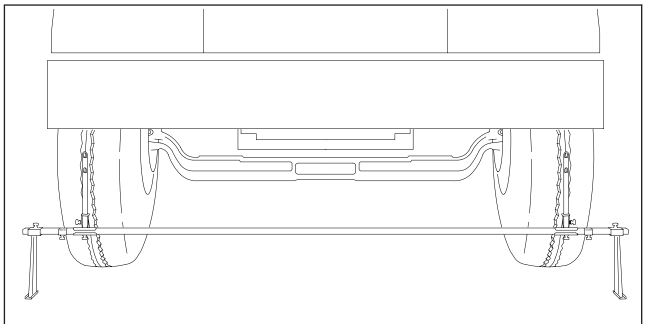


Fig. 2, Trammel Bar Positioning

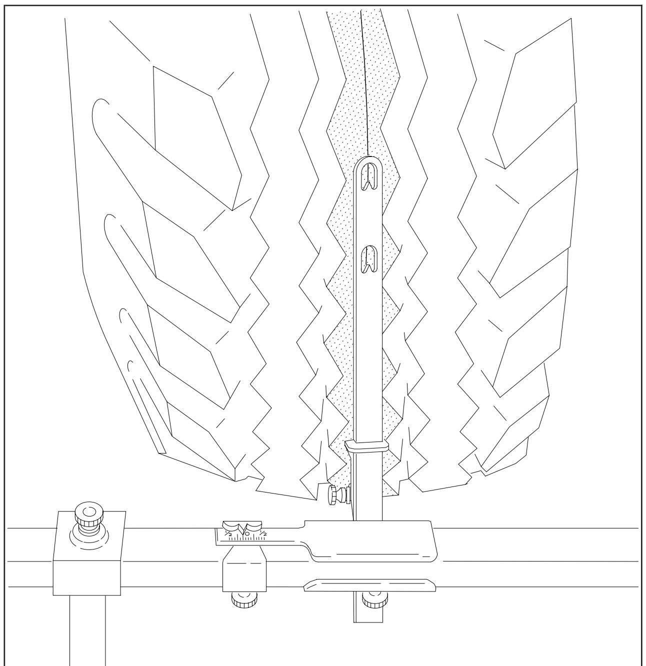


Fig. 3, Calculating Wheel Toe-In

Removal

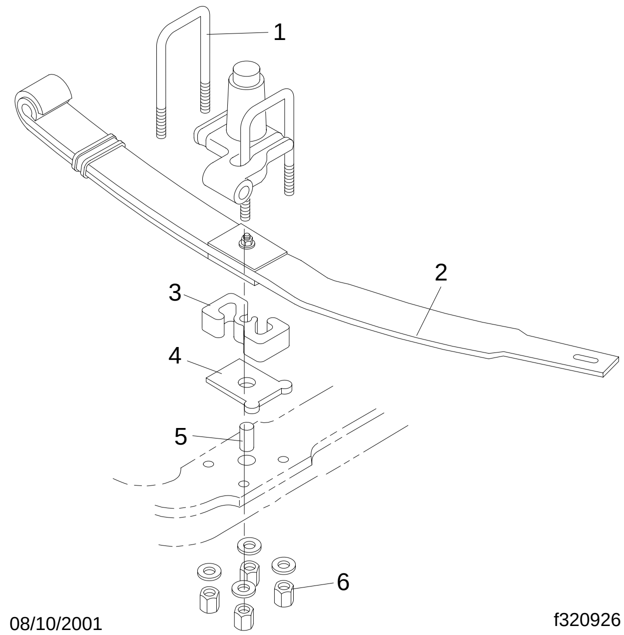
NOTE: This procedure involves removing the axle from underneath the front of the vehicle. If you cannot support the vehicle high enough for the axle to clear the bumper, then you will need to remove the bumper.

1. Park the vehicle on a level surface, set the parking brakes, then chock the rear tires.
2. Tilt the hood.
3. If needed, remove the front bumper. See **Group 31** for instructions.
4. Raise the vehicle, then support the frame rails with safety stands.

WARNING

When draining the air system, don't look into the air jets or direct them toward another person, as dirt or sludge particles may be in the airstream. Don't disconnect pressurized hoses because they may whip as air escapes from the line. Failure to take all necessary precautions while working on the air brake system can cause personal injury.

5. Drain the air tanks.
6. Remove the front tires.
7. If so equipped, disconnect the ABS sensors from the axle knuckles. Pull the sensors straight out.
8. Disconnect the air lines from the front brake chambers.
9. Remove the brake drums. See **Group 42** for instructions.
10. Remove the hubs. Refer to the applicable subject in **Section 33.01** for instructions.
11. Disconnect the steering drag link from the axle steering arm. See **Group 46** for instructions.
12. Remove the U-bolts and nuts holding the axle to the leaf springs. See **Fig. 1**.
    - 12.1 Take the weight off the leaf springs by raising the axle.
    - 12.2 On one side of the axle, remove all the U-bolt nuts and washers, then remove the two U-bolts.



1. Axle Spring U-Bolt
2. Leaf Spring Assembly
3. Spacer
4. Front Caster Shim
5. Dowel Pin
6. U-Bolt High Nut

Fig. 1, Axle Removal

    - 12.3 Repeat the procedure on the other side of the axle.

13. Remove the axle stops from the top of the leaf springs.
14. Remove the axle spacers from the top of the axle beam.
15. Using a suitable axle jack, remove the axle by sliding it out from the front of the vehicle.
16. Remove the brake shoes, cam, and spider. See **Group 42** for instructions.

Installation

1. From the front of the vehicle, and using a suitable axle jack, roll the axle into place under the leaf springs.
2. Install the axle spacers.

Front Axle Removal and Installation

3. Slowly raise the axle up to the bottom of the leaf springs, making sure the dowels on top of the axle beam line up with the holes in the axle spacers.
4. Install the axle stops onto the tops of the leaf springs.
5. Install the U-bolts.
   - 5.1 Using a suitable clamp (such as a large C-clamp) compress one of the U-bolts, then install it on one side of the axle. Do the same for the second U-bolt.
   - 5.2 Install the U-bolt nuts and washers. Tighten the nuts finger-tight.
   - 5.3 Repeat the procedure on the other side of the axle.
6. Tighten the U-bolt nuts.

   For 3/4–16 U-bolt nuts: In a diagonal pattern, tighten the U-bolt nuts successively 80 lbf·ft (108 N·m), 200 lbf·ft (270 N·m), then 300 lbf·ft (406 N·m).

   For 7/8–16 U-bolt nuts: In a diagonal pattern, tighten the U-bolt nuts successively 60 lbf·ft (81 N·m), 200 lbf·ft (270 N·m), then 460 lbf·ft (624 N·m).
7. Install the brake spider, cam, and brake shoes. See **Group 42** for instructions.
8. If so equipped, install the ABS sensors in the axle knuckles.
9. Connect the air lines to the brake chambers.
10. Connect the drag link to the steering arm. See **Group 46** for instructions.
11. Install the tires.
12. If it was removed, install the bumper. See **Group 31** for instructions.
13. Raise the vehicle, then remove the safety stands.
14. Lower the vehicle.
15. Do complete alignment procedures, including caster, camber, wheel toe-in, and rear axle alignment. Refer to the applicable subjects in this section for instructions. For rear axle alignment procedures, refer to **Section 35.00**.
16. Lower the hood.
17. Remove the chocks from the rear tires.

IMPORTANT: When aligning the front axle, it is essential that the rear axle(s) be checked for correct alignment at the same time. Alignment of the rear axle(s) has a direct impact on how the vehicle tracks. Refer to **Section 35.00**.

NOTE: The alignment specifications below are for unloaded vehicles. These specifications will vary as weight is added to the vehicle and transferred to the front axle.

Camber and Toe-In					
Axle Manufacturer	**Axle Model**	**Left Camber: degrees**	**Right Camber: degrees**	**Toe-In Limits: in (mm)**	**Toe-In Target: in (mm)**
Meritor	All	–1/4 ± 7/16	–1/4 ± 7/16	0 to +1/8* (0 to +3.2)	+1/16 (+1.6)
Freightliner	All				
Dana/Eaton	All E Series	+1/4 ± 7/16	0 ± 7/16		

* If adjustment is required, set the toe-in as close as possible to +1/16 inch (+1.6 mm).

Table 1, Camber and Toe-In

Caster					
Axle Manufacturer	**Beissbarth: degrees**	**Bee Line**		**Hunter: degrees**	**Target, All Models: degrees**
		Except LC 4000: degrees	**LC 4000: degrees**		
Meritor, Freightliner, and Dana/Eaton	+3 to +6-1/2	+3 to +6-1/2	+2-1/4 to +4-3/4	2 to 5	3.5 ± 1.5
IMPORTANT: Caster settings for the left and right sides *must* be within 1/2 degree of each other. It is necessary for only one side to be within the specifications given in this table.					

Table 2, Caster

Tie Rod Clamp Nut Torque Values				
Axle Manufacturer	**Axle Model**	**Tie Rod Clamp Nut Size**	**Plain Nut Torque: lbf·ft (N·m)***	**Locknut Torque: lbf·ft (N·m)***
Meritor	All	5/8–11	50–60 (68–81)	50–60 (68–81)
Hendrickson	STEERTEK			
Freightliner	All	5/8–11	60–80 (81–108)	60–80 (81–108)
Dana/Eaton	All E Series	5/8–18	—	40–60 (55–81)

* All torque values in this table apply to parts lightly coated with rust-preventive type oil.

Table 3, Tie Rod Clamp Nut Torque Values

Miscellaneous Torque Values	
Description	**Torque: lbf·ft (N·m)**
U-Bolt Nuts 7/8–14	400 (542)
U-Bolt Nuts 7/8–16	460 (624)
U-Bolt Nuts 3/4–16	300 (406)
U-Bolt Nuts 5/8–18	200 (271)

Specifications

Miscellaneous Torque Values	
Description	**Torque: lbf·ft (N·m)**
Meritor Stopscrew Locknut	50–65 (68–88)
Dana/Eaton Stopscrew Locknut	90–120 (122–163)

Table 4, Miscellaneous Torque Values

General Information

These vehicles are equipped with one of four different wheel end assemblies:

- The Con Met PreSet® Hub

  This wheel end has the bearings and oil seal pre-installed in a hub. To install a new hub, mount it on the axle spindle, and secure it with an Axi-Lok® nut. For instructions, see **Subject 150**. A spacer between the inner and outer bearings adjusts the bearings to near zero end-play and preload when you tighten the retaining nut.

- The Meritor Easy Steer Plus® Axle, Model MFS–12–143D

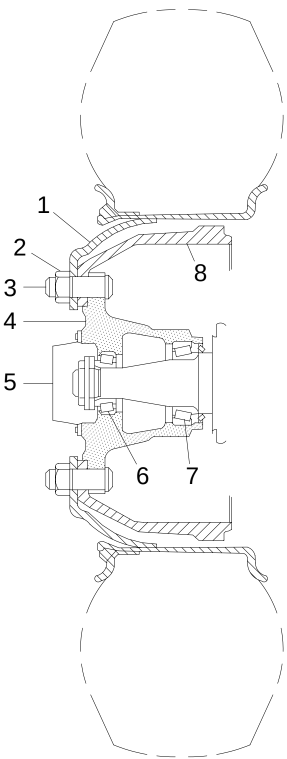
  This axle has the hubs, bearings, and oil seals factory-installed on the axle spindles. The hubs can be removed and installed on the axle, and the studs can be replaced, but the wheel bearings and oil seal are not serviceable in the field. To install a new hub, mount it on the axle spindle, and secure it. For instructions, see **Subject 140**.

- The traditional hub and bearings

  With traditional wheel ends, the bearings and oil seal must be assembled with the hub when the hub is installed on the axle spindle. First the oil seal is placed on the spindle (some brands of oil seal are installed in the hub bore), then the inner bearing and the hub are mounted on the axle spindle. Then, the outer bearing is mounted in the hub bore. A nut is installed on the axle spindle end and tightened and loosened to adjust the bearings. Finally, a locking device and jam nut are installed to secure the hub and bearings on the axle. For instructions, see **Subject 130**.

All wheel hub assemblies consist of the following components (see **Fig. 1**):

- Wheel Bearings
- Wheel Hub
- Wheel Studs
- Brake Drum



1. Disc Wheel
2. Wheel Nut
3. Wheel Stud
4. Hub
5. Hub Cap
6. Outer Wheel Bearing
7. Inner Wheel Bearing
8. Brake Drum

Fig. 1, Wheel Assembly (cutaway view)

Tapered Wheel Bearings

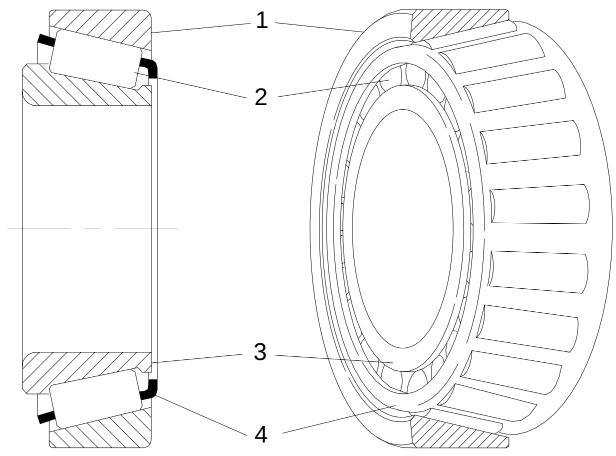
A traditional tapered wheel bearing assembly consists of a cone, tapered rollers, a roller cage, and a separate cup that is press-fit in the hub. See **Fig. 2**. All components carry the load, with the exception of the cage, which spaces the rollers around the cone.

Each hub has a set of inner and outer tapered wheel bearing assemblies. On traditional hub and bearing assemblies, the bearing setting is locked in place on the axle spindle (steering knuckle) by an adjusting nut, a locking device such as a lockring or nut-lock, and a jam nut, or a Pro-Torq nut. See **Fig. 3**.

Wheel Hub

The wheel and the brake drum are mounted on an aluminum or iron wheel hub. See **Fig. 4**.

General Information



1. Cup
2. Tapered Roller
3. Cone
4. Roller Cage

Fig. 2, Tapered Wheel Bearing Assembly

Both the inner and outer wheel bearing cups and the wheel studs are press-fit in the hub.

Wheel Studs

A headed wheel stud is used on front axle disc wheel hub assemblies and has either serrations on the stud body or a flat area on the stud's head to prevent the stud from turning in the wheel hub. See **Fig. 5**.

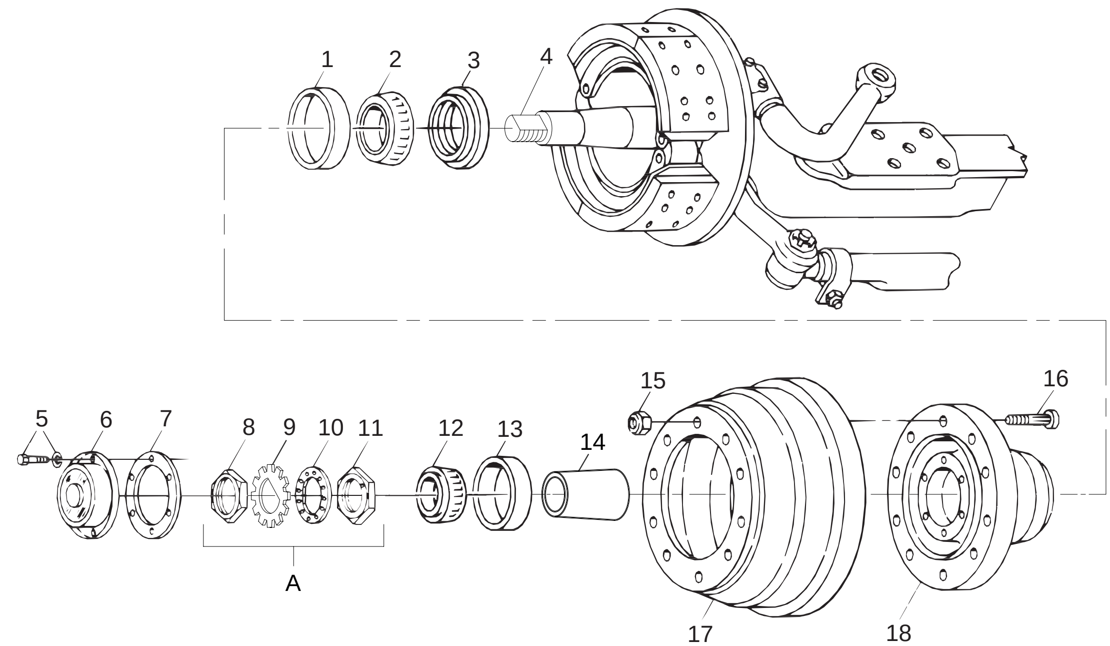
The end of the stud that faces away from the vehicle is stamped with an "L" or "R," depending on which side of the vehicle the stud is installed. Studs stamped with an "L" are left-hand threaded and are installed on the left side of the vehicle. Studs stamped with an "R" are right-hand threaded and are installed on the right side of the vehicle.

Brake Drum

The brake drum and lining work together as a mated friction pair, with the drum responsible for both heat absorption and dissipation. Lining performance and life largely depend on the condition of the drum and whether it can adequately absorb and dissipate heat generated by braking action.

The brake drum is mounted on the outboard face of the hub and fits over the wheel studs. See **Fig. 3**.

General Information



NOTE: On Meritor FF-981 Easy Steer Plus axles, the hub, wheel bearings, studs, and oil seal are assembled at Meritor and installed as an assembly.

A. Four-piece bearing system shown; Axi-Lok locking nuts are used with Con Met PreSet hubs

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Hub Cap Capscrew
6. Hub Cap
7. Gasket
8. Jam Nut
9. Nut-Lock
10. Lockring
11. Adjusting Nut
12. Outer Wheel Bearing
13. Outer Bearing Cup
14. Bearing Spacer (used only with Con Met PreSet hubs)
15. Wheel Nut
16. Wheel Stud
17. Brake Drum
18. Hub

Fig. 3, Typical Wheel and Axle Assembly

General Information

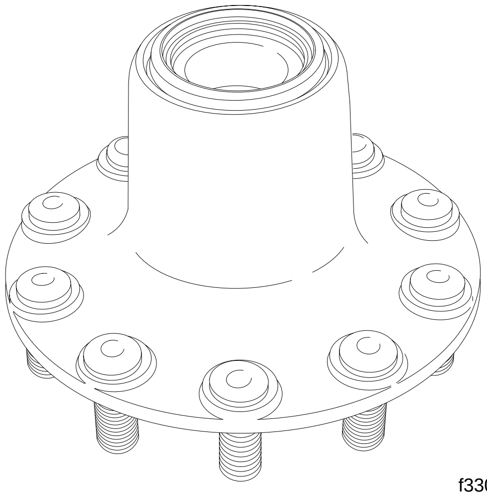
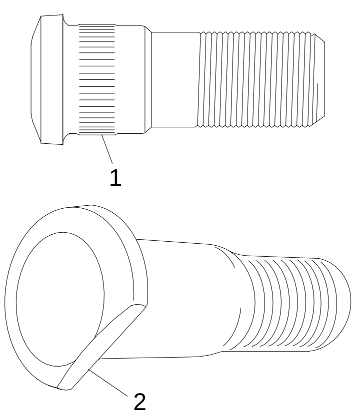


Fig. 4, Front Axle Wheel Hub



1. Serrations
2. Clipped Head

Fig. 5, Typical Wheel Studs

Hub Assembly Removal and Installation

Removal

1. Chock the rear tires.
2. Raise the front of the vehicle until the tires clear the ground. Place safety stands under the axle.

WARNING

Never work under a vehicle that is supported only by a jack. Jacks can slip, causing the vehicle to fall. This could result in a person being pinned under or crushed by the vehicle, causing severe personal injury or death. Always use safety stands to support the vehicle.

3. Back off the slack adjuster to release the front axle brake shoes.
4. Remove the wheel and tire assembly. See **Group 40** for instructions.

WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

5. Remove the brake drum. For instructions, see **Subject 160**.

NOTE: Oil will spill as the hub cap and wheel hub are removed. Place a suitable container under the axle spindle to catch any spilled oil, and avoid contaminating the brake shoes with oil. Dispose of the oil properly.

6. Remove the capscrews, washers, and hub cap. Remove and discard the hub cap gasket. See **Fig. 1**.
7. If working with ConMet PreSet® or Meritor Easy Steer Plus® hubs, remove the nut(s) and locking device, then remove the wheel end (hub, bearings, and oil seal) as a unit.

   If working with a traditional dual-nut hub and bearing assembly, remove the jam nut, locking device(s), and adjusting nut. See **Fig. 1**.

NOTICE

Be careful not to let the outer wheel bearing drop from the axle spindle. Dropping the bearing can warp the cage or damage the rollers, ruining the bearing. On vehicles equipped with WABCO ABS, use care when working with the hubs. To prevent damage to the tone wheel, do not drop the hub, or lay it down in a way that would damage the tone wheel.

7.1 If working with a traditional dual-nut hub and bearing assembly, move the hub about 1/2 inch (13 mm) to jar loose the outer wheel bearing (allow the hub-only assembly to rest on the axle spindle; be careful not to damage the axle spindle threads).

7.2 Carefully remove the outer wheel bearing; handle the bearings with clean, dry hands. Wrap the bearings in either clean oil-proof paper or lint-free rags.

NOTICE

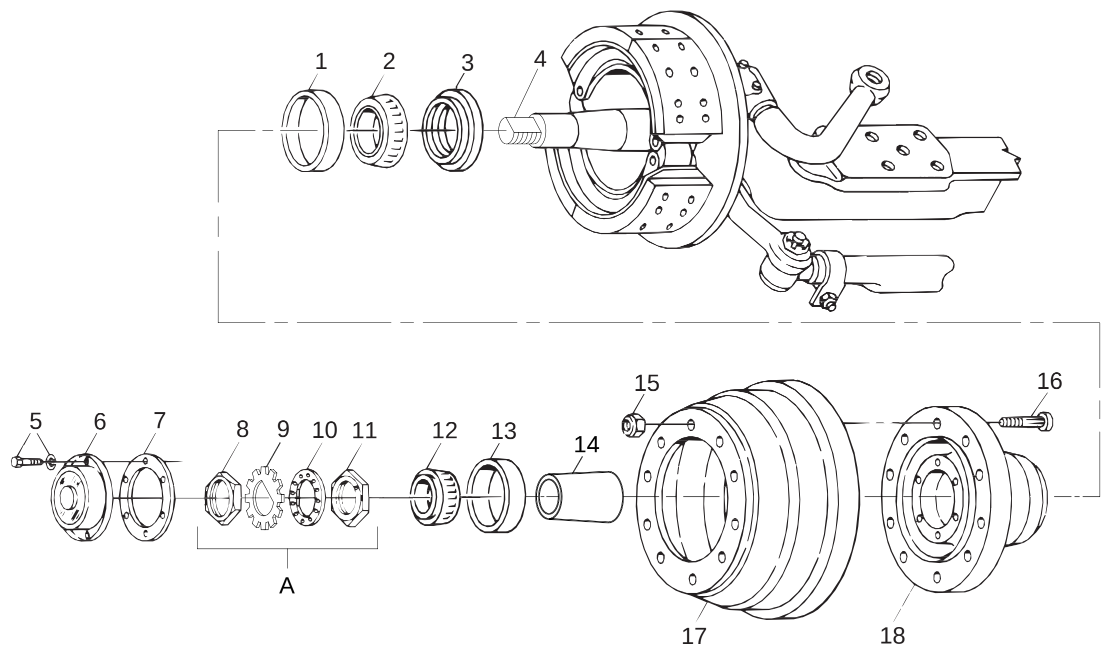
Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

7.3 Remove the hub from the axle spindle. Be careful not to damage the axle spindle threads as the assembly is removed.

7.4 Remove the inner wheel bearing from the axle; handle the bearings with clean, dry hands. Wrap the bearings in clean, oil-proof paper or lint-free rags. Occasionally, the inner wheel bearing will remain in the hub after the hub is removed. In those cases, place a protective cushion where it will catch the bearings. Use a hardwood drift and a light hammer to gently tap the bearing (and seal, if necessary) out of the cup.

7.5 Remove the oil seal from the axle spindle, if not already removed. See **Section 33.02** for additional information.

Hub Assembly Removal and Installation



NOTE: On some axles, the hub, wheel bearings, studs, and oil seal are installed as a unitized wheel-end assembly. These wheel ends must be replaced as a unit.

A. Dual-nut bearing lock system shown; Axilok® locking nuts are used with ConMet PreSet® hubs.

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Hub Cap Capscrew
6. Hub Cap
7. Gasket
8. Jam Nut
9. Nut-Lock
10. Lockring
11. Adjusting Nut
12. Outer Wheel Bearing
13. Outer Bearing Cup
14. Bearing Spacer (used only with ConMet PreSet hubs)
15. Wheel Nut
16. Wheel Stud
17. Brake Drum
18. Hub

Fig. 1, Typical Front Axle Assembly

Installation

1. Remove the old oil from the axle spindle (steering knuckle) and the disassembled parts. Follow the solvent manufacturer's warnings and cautions when using it. Allow the parts to dry or dry them with a clean, absorbent, and lint-free cloth or paper. Wrap a protective layer of friction tape on the axle spindle threads.
2. On brake drum assemblies with an aluminum hub, coat the hub and drum contact surfaces with Alumilastic® compound or an equivalent.

NOTICE

Make sure that both bearing assemblies are coated with fresh oil. Use only fresh oil on the bearing assemblies; old oil could be contaminated with dirt or water (both are corrosive) and could cause damage to both wheel bearing assemblies and the wheel hub.

3. If working with traditional dual-nut hub and bearing assemblies, coat both bearing assemblies with fresh oil. Install the inner wheel bearings and oil seal. Handle the bearings with clean, dry hands. See **Section 33.02** for oil seal installation instructions.

4. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.

NOTICE

On vehicles equipped with WABCO ABS, use care when installing the hubs. To prevent damage to the tone wheel, do not drop the hub or lay it down in a way that would damage the tone wheel.

5. Mount the hub assembly on the axle spindle.
6. Adjust the wheel bearings according to the instructions in the applicable wheel bearing subject in this section.

   For traditional dual-nut hub and bearing assemblies, see **Subject 130**.

   For ConMet PreSet hubs, see **Subject 150**.

   For Meritor Easy Steer Plus axle ends, see **Subject 140**.
7. Place the hub cap and a new gasket in position, then install the washers and capscrews. Tighten the capscrews 15 lbf·ft (20 N·m).
8. If applicable, add fresh oil to the wheel hub to the level indicated on the hub cap. For the recommended axle lubricants, see **Specifications 400**.

WARNING

Failure to add oil to the wheel hub after the hub has been serviced will cause the wheel bearings to overheat and seize during vehicle operation. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury.

9. Install the brake drum on the wheel hub. For instructions, see **Subject 160**.

WARNING

If the wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking action, and the wheel hub flange is probably damaged. In this case, replace it with a new wheel hub assembly. Failure to replace the wheel hub assembly when the conditions described above exist could result in the loss of a wheel or loss of vehicle control, and possible personal injury.

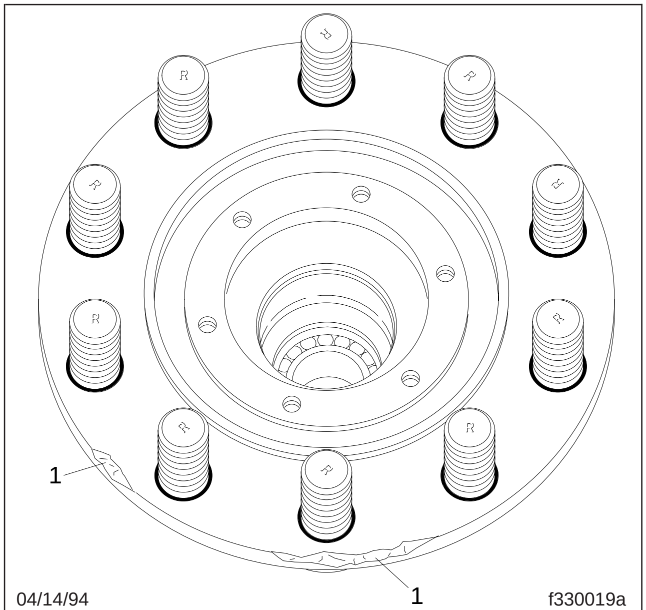
10. Install the wheel and tire assembly. See **Group 40** for instructions.
11. Adjust the front axle brakes. For instructions, see the applicable service brake section in **Group 42**.
12. Raise the vehicle and remove the safety stands from under the axle. Lower the vehicle.
13. Remove the chocks from the rear tires.

Axle Components Cleaning and Inspection

Wheel Hub Assembly Inspection

1. Inspect the wheel hub mounting flange. A loose wheel assembly will cause the flange to be worn, jagged, or warped. See **Fig. 1**. Replace the wheel hub if any of these conditions exist.

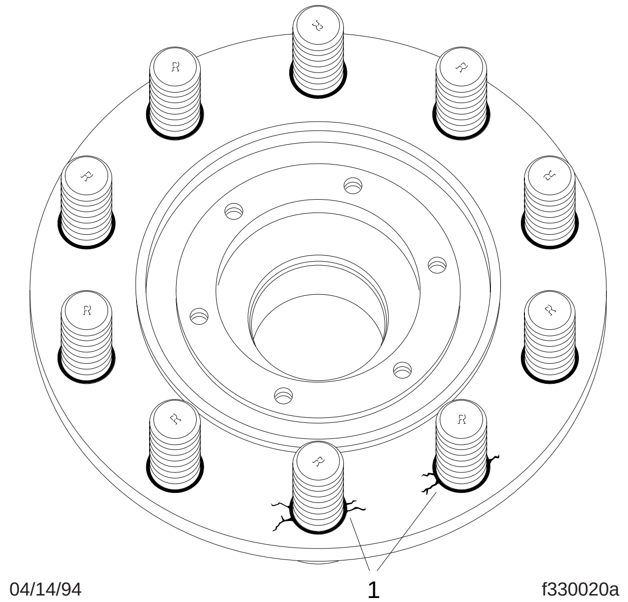
   Inspect the flange surface around the wheel studs. Improperly torqued wheel nuts will cause worn or cracked stud grooves on the hub. See **Fig. 2**. If wear spots or cracks appear anywhere on the hub, or if the hub is otherwise damaged, replace it with a new one.



1. Wear Spots

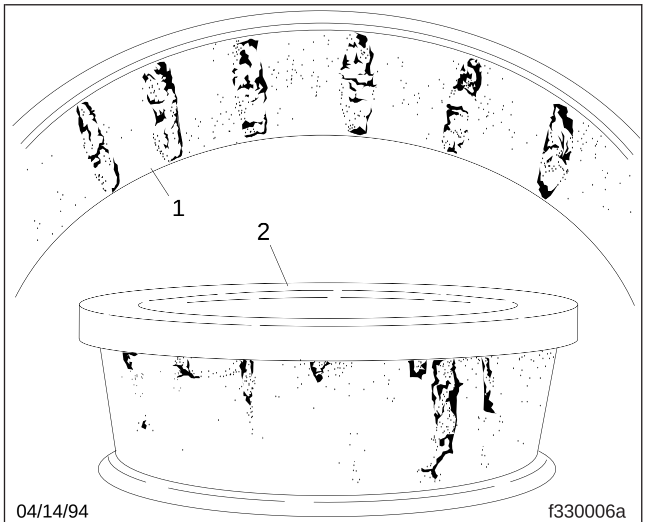
Fig. 1, Damaged Front Axle Wheel Hub

2. Remove all of the old oil from the wheel hub cavity. Inspect the inner surface of the hub for cracks, dents, wear, or other damage. Replace the wheel hub if damage exists.
3. Remove all the old grease or oil from the surfaces of the wheel bearing cups. Inspect the wheel bearing cups for cracks, wear, spalling, or flaking. See **Fig. 3**. Replace the cups if damaged in any way. For instructions, see **Subject 120**.
4. Inspect the wheel nuts on disc wheel installations, or the rim nuts on spoke-wheel installations. Damaged nuts (**Fig. 4**), usually caused by inadequate tightening, must be replaced with new ones.



1. Cracked Stud Grooves

Fig. 2, Damaged Front Axle Wheel Hub



1. Cup
2. Cone

Fig. 3, Spalling (Flaking) of Wheel Bearing Assembly

Axle Components Cleaning and Inspection

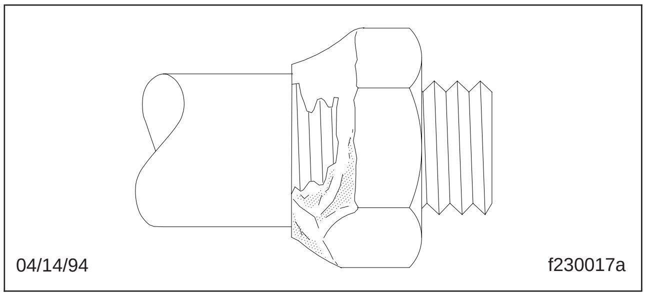


Fig. 4, Damaged Wheel Stud Nut

5. Inspect the wheel or rim studs. Replace studs that are stripped, broken, bent, or otherwise damaged. For instructions, see **Subject 180**.

Wheel Bearing Inspection

Wheel bearings should be very closely inspected at the time of disassembly. Optimal inspection conditions are possible only after the bearings have been thoroughly cleaned using kerosene or diesel fuel oil, and a stiff brush. Before inspecting, clean the bearings.

1. Remove the wheel hub and bearing cones. For instructions, see **Subject 100**.
2. Clean all old oil from the bearings and hub cavity with kerosene or diesel fuel and a stiff brush. Don't use gasoline or heated solvent.
3. Allow the cleaned parts to dry, or dry them with a clean absorbent cloth or paper. Clean and dry your hands and all tools used in the maintenance operation. Oil will not stick to a surface that is wet with kerosene or diesel fuel, and the kerosene or diesel fuel may dilute the lubricant.

CAUTION

Do not spin the bearing rollers at any time. Dirt or grit can scratch the roller surface and cause premature wear of the bearing assembly. Treat a used bearing as carefully as a new one.

4. After the bearings are cleaned, inspect the assemblies, which include the rollers, cones, cups, and cages. If any of the following conditions exist, replace the bearing assemblies:

   4.1 Large ends of rollers worn flush to the recess, or radii at the large ends of the rollers worn sharp. These are indications of advanced wear. See **Fig. 5**.

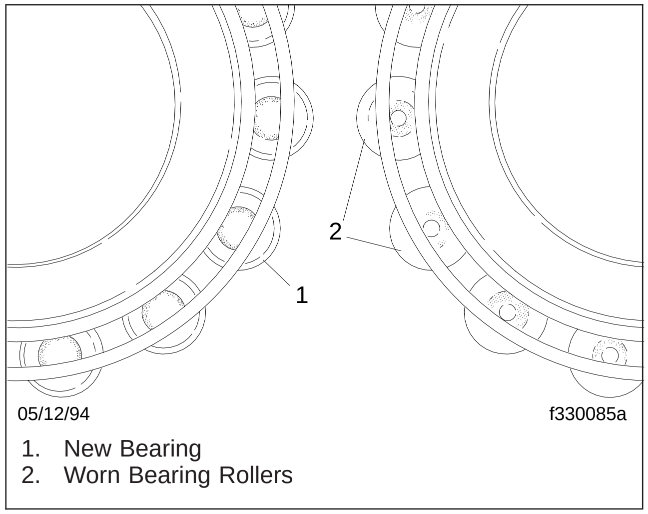


Fig. 5, Wheel Bearing Roller Wear

   4.2 Visible step wear, particularly at the small end of the roller track. Deep indentations, cracks, or breaks in the cone surfaces. See **Fig. 6**.

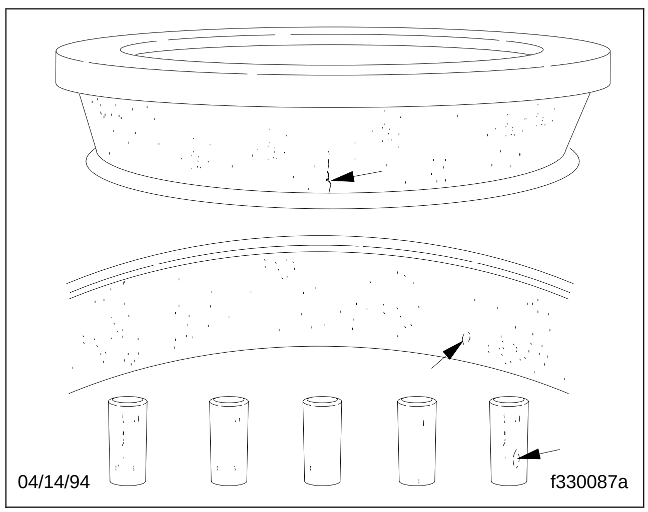


Fig. 6, Indentations, Cracks, or Breaks in Bearing Surfaces

   4.3 Bright rubbing marks on the dark phosphate surfaces of the bearing cage. See **Fig. 7**.

   4.4 Water etch on any bearing surface. Water etch appears as gray or black stains on

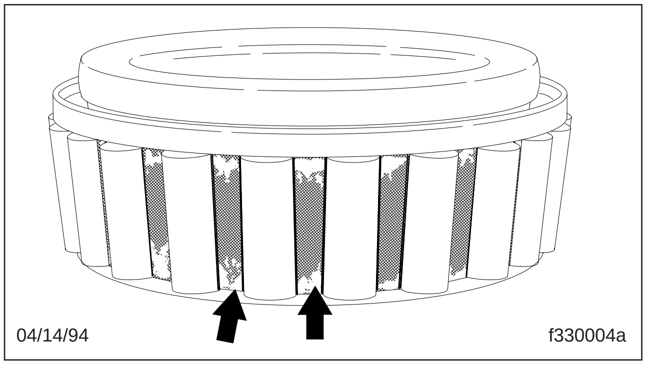


Fig. 7, Rubbing Marks on Bearing Cage

the steel surface, and it greatly weakens the affected area. If water etch is present, replace the bearing seals.

4.5 Etching or pitting on functioning surfaces. See **Fig. 8**.

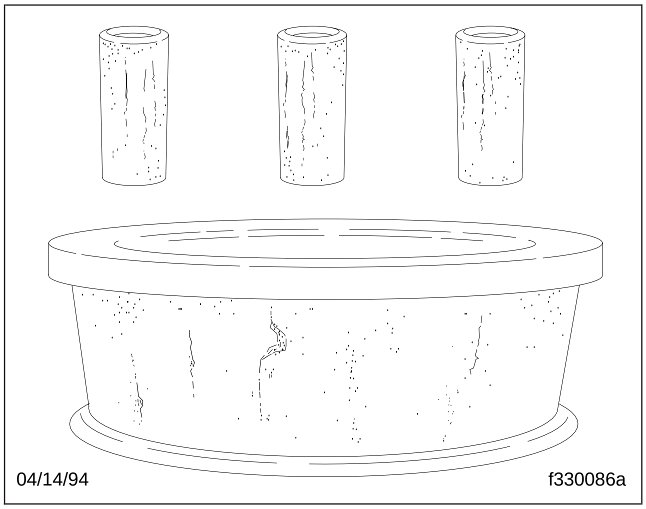


Fig. 8, Etching (Pitting) on Bearing Surfaces

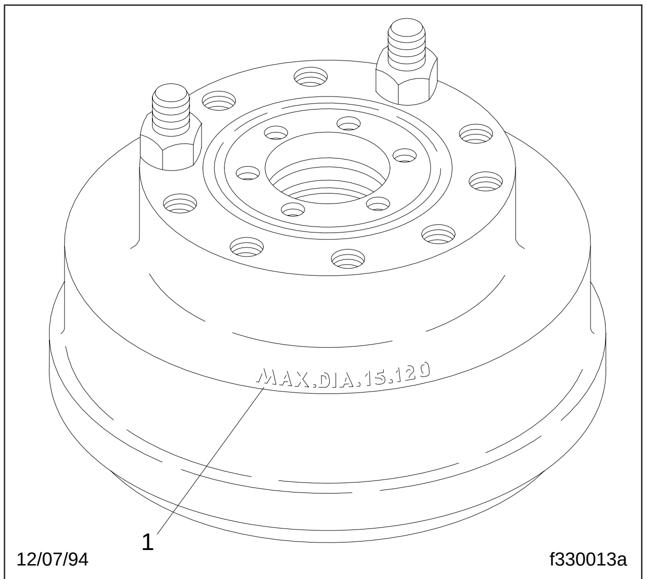
4.6 Spalling (flaking) of the bearing cup, roller, or cone surfaces. See **Fig. 3**.

After inspection, brush the bearings with fresh axle lubricant.

Brake Drum Inspection

New brake drums are purposely undersized to allow for turning (remachining), since in mounting drums on the hub, there can be some eccentricity. If a new drum is installed, the protective coating on the inner friction surface must be removed with a solvent, prior to drum installation, then rinsed with a hot water wash. Use a clean rag to remove any oily residue or metal chips from the friction surface.

If a drum must be turned or replaced, the other same-axle drum must be similarly turned or replaced to provide the same braking power on both wheels. Turned drums should not exceed the maximum allowable diameter, which is stamped on the outside surface of the drum. See **Fig. 9** for a typical location of this stamp.



1. Maximum Diameter Stamp

Fig. 9, Outboard Mounted Hub and Drum Assembly

NOTE: Drums that have been turned should then be cleaned by using fine emery cloth followed with a hot water wash. Drums that have been renewed using emery cloth should also be followed with a hot water wash.

CAUTION

Failure to replace drums when worn or turned to limits exceeding the maximum allowable diameter will cause drum weakness and reduced braking capacity, which can lead to distortion, higher drum temperatures, and ultimate drum breakage.

If the drums are turned or replaced, replace the brake linings. See **Group 42** for instructions.

Axle Components Cleaning and Inspection

1. Inspect the inner friction surface. If a veneered (highly glossed) or glazed surface exists, renew the drum by using 80-grit emery cloth or by turning the drums.
2. Inspect for heat checking, which is a form of buckling (cracking) resulting from a temperature differential in the drum wall between a relatively cool exterior and a hot friction surface. Heat checking is normal on all drums and may not impair performance and lining life if the network of fine hairline cracks remains small. Examine heat checks of drums frequently to be certain the checks have not widened into drum weakening cracks (substantial cracks extending to the open edge of the drum). Replace the same-axle drums if substantial cracks are present, or if widening of the fine hairline cracks occurs.

NOTE: If normal heat checking as described above is present, inspect the drums at least every 12,000 miles (19 300 km) thereafter. Inspect the drums (using a flashlight from the inboard side of the wheels) every 6000 miles (9700 km). Inspect more often under adverse operating conditions.

3. Check for a contaminated inner friction surface. If fluids are present, such as oil or grease, remove the contaminants. Locate and correct the source of the contamination. If the brake drums are contaminated with fluids, the brake linings will also be affected. Since oil or grease saturated linings cannot be salvaged, they must be replaced. For brake lining replacement procedures, see **Group 42**.

WARNING

If the brake drums are contaminated with fluids, replace the brake linings. Failure to replace fluid contaminated brake linings could result in a partial loss of braking capacity, which could lead to personal injury or property damage.

4. Measure the inside diameter of the drum. If the measured diameter is greater than the maximum allowable diameter, replace the same-axle drums and linings.
5. Check for a variation in gauge readings at different points on the radius of the drum's working surface. If the variation is more than 0.010 inch (0.25 mm) at any point, the drum is out-of-round to unacceptable limits. Remachine or replace the same-axle drums.
6. Inspect the outside surface of the drum. Remove any accumulation of mud, dirt, or rust; foreign matter acts as an insulator, trapping heat within the drum.
7. Check for hard, slightly raised dark-colored spots on the inner friction surface or for a bluish cast on the brake parts, both of which are caused by high temperatures. If the drums' maximum allowable diameters have not been exceeded, remachine both same-axle drums. If the spots or discoloration cannot be removed, or if remachining is not possible, replace the drums. Also replace the brake shoe return springs.

Wheel Bearing Cup Removal and Installation, Ferrous Hubs

Removal

Wheel bearing cups on ferrous hubs are removed and installed by driving them out and pressing them in without heating the hub.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly.
2. Using a mild-steel rod through the opposite end of the hub, drive against the inner edge of the bearing cup. Alternately drive on opposite sides of the cup to avoid cocking the cup and damaging the inside of the hub.

Installation

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly, including the bearing cup bores.
2. Inspect the bearing cup bores of the hub for warpage or uneven surfaces. If a bearing cup bore is damaged, replace the wheel hub assembly.
3. Coat the replacement bearing cup hub contact surface with a film of grease.
4. Position the cup in the hub and press it into place, using a suitable driving tool. Cups must seat against the shoulder in the hub.
5. Wipe off the accumulation of grease left after the bearing cup has been seated. Then, using a clean lint-free cloth dampened with kerosene or diesel fuel oil, clean the inner surface of the bearing cup. Wipe the surface dry using a clean, absorbent, and lint-free cloth or paper.

Dual-Nut Wheel Bearing Lock System Installation and Adjustment

Installation and Adjustment

1. Carefully mount the hub and inner wheel bearing assembly on the axle spindle. Be careful not to unseat the inner wheel bearing or seal.
2. Fill the hub cavity with oil, then install the outer wheel bearing. Handle the bearings with clean, dry hands. Be careful not to damage the bearings, as they are seated in the bearing cups.
3. Install the wheel bearing adjusting nut. See **Fig. 1**.

   3.1 After the wheel hub and bearings are assembled on the spindle, tighten the inner adjusting nut finger-tight.

   3.2 While rotating the wheel hub assembly, tighten the adjusting nut 100 lbf·ft (136 N·m).

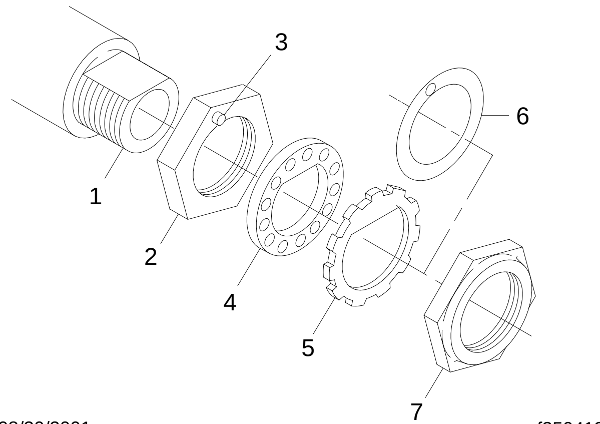
   3.3 Back off the adjusting nut completely.

   3.4 Tighten the adjusting nut 20 lbf·ft (27 N·m) while rotating the wheel hub assembly.

   3.5 Back off the adjusting nut one-third turn (two flats of the adjusting nut).
4. Install the locking device and jam nut.

   4.1 Install the locking device.

   NOTE: If no hole in the lockring aligns with the dowel on the adjusting nut, remove the lockring, turn it over and install it again. If still no hole aligns with the dowel, loosen the adjusting nut just enough to align the dowel with a hole in the lockring.



1. Axle Spindle
2. Adjusting Nut
3. Dowel
4. Lockring
5. Nut-Lock
6. Retaining Washer (may be used in place of nut-lock)
7. Jam Nut

Fig. 1, Axle with Nut-Lock and Lockring

   4.2 Then install the jam nut, and tighten it to the applicable torque value in **Table 1**.
5. With the jam nut installed and tightened, adjust the bearings.

Torque Values		
Retention Method	**Size**	**Torque: lbf·ft (N·m)**
Jam Nut (with Wheel Bearing Nut, Pierced Lockwasher, or Bendable Lockwasher)	1-1/8	Target: 175 (235) Permissible Range: 150–225 (205–305)
	1-1/2 to 2-1/2	Target: 250 (340) Permissible Range: 200–300 (270–405)
	2-5/8 or Larger	Target: 310 (420) Permissible Range: 250–400 (340–540)

Table 1, Torque Values

IMPORTANT: Do not adjust the wheel bearings with the wheel mounted on the hub. You cannot accurately adjust or measure bearing end play with the wheel mounted on the hub.

Dual-Nut Wheel Bearing Lock System Installation and Adjustment

5.1 Attach a dial indicator to the hub and set the point of the indicator in line with the end of the axle spindle.

If using aluminum hubs, you may have to install the brake drum on the hub to provide a steel base for the magnet of the dial indicator. Mount the drum on the hub’s drum pilot, then adjust the brake or have someone apply the brakes, to hold the drum securely, while you secure the drum using the stud at the 12 o’clock position, then the studs at about the 4 o’clock and 8 o’clock positions.

NOTE: If using a stud-piloted hub and a steel drum, install 1-1/4 inch washers between the nuts and the drum.

5.2 Release the brakes, if you used them to hold the drum for installation.

5.3 Grip the sides of the hub at the three o’clock and nine o’clock positions. Push in on the hub (and drum, if applicable), to seat the inboard bearing set. Zero the dial indicator.

5.4 Once again, grip the sides of the hub at the three o’clock and nine o’clock positions. This time, pull out on the hub (and drum, if applicable). Read the dial indicator, and note the end play.

5.5 Push the hub back in to confirm that the needle of the dial indicator returns to zero.

6. The end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm). If the end play is not within this range, adjust the end play.

6.1 Remove the jam nut and locking device, and back off or tighten the inner adjusting nut.

6.2 Install the locking device and jam nut as described earlier, and measure the end play. If the end play is not between 0.001 and 0.005 inch (0.03 and 0.13 mm), turn the adjusting nut again.

6.3 Once the end play is correct, bend two tabs of the nut-lock over opposing flats on the jam nut.

6.4 Rotate the hub in both directions. It should turn freely with no dragging or binding.

End play should be between 0.001 and 0.005 inch (0.03 to 0.13 mm).

Meritor Easy Steer Plus Hub Installation and Adjustment

Installation and Adjustment

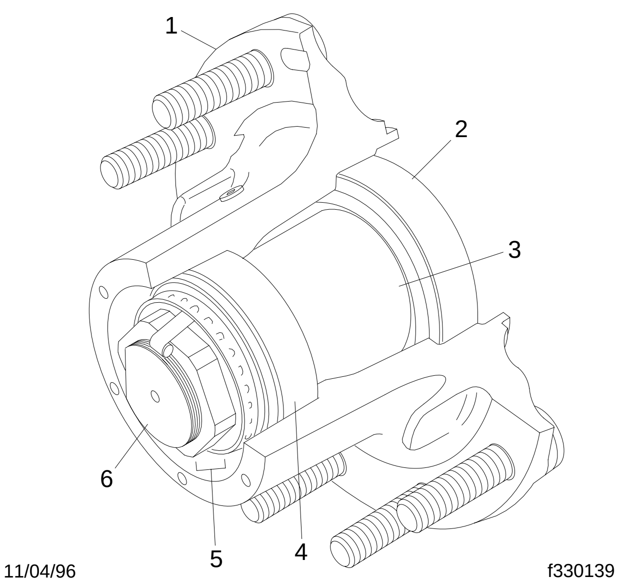
1. With the hub mounted on the axle spindle, install the inner (adjusting) nut and tighten it 600 lbf·ft (815 N·m).
2. Install the locking device (nut-lock, lockwasher, or both).
3. Install the jam nut and tighten 250 lbf·ft (340 N·m).
4. Bend two opposing tangs of the nut-lock as needed, to lock the jam nut and adjusting nut.
5. Install the hub cab and tighten 350 lbf·ft (475 N·m).

ConMet PreSet® Hub Installation and Adjustment

General Information

ConMet PreSet steer axle hubs are equipped with a special tubular spacer inside the hub, between the inner and outer bearings. See **Fig. 1**.

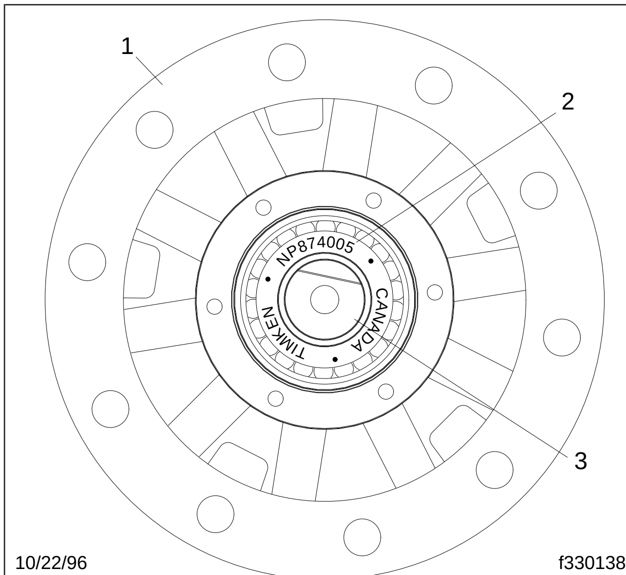
Wheel bearing adjustment is unnecessary when installing these hubs, because the spacer, together with specially toleranced bearings, automatically sets the bearing end-play. Front axle PreSet hubs can be identified by the part number NP874005 stamped on the outer bearing cone. The outer bearing cone is visible when the retaining nut is removed. See **Fig. 2**.



1. Hub
2. Inner Bearing
3. Bearing Spacer
4. Outer Bearing
5. Axilok Retaining Nut
6. Axle Spindle

Fig. 1, ConMet PreSet Hub, Cut-Away View

NOTE: If you are replacing the bearings for a PreSet hub, and the required bearings are not available, use standard wheel bearings. Remove the bearing spacer and adjust the bearings manually. See the installation instructions for "Standard Bearings," under "Installation."



1. Front Axle Hub
2. Outer Bearing Cone and Part Number
3. Axle Spindle

Fig. 2, Identifying a ConMet PreSet Hub

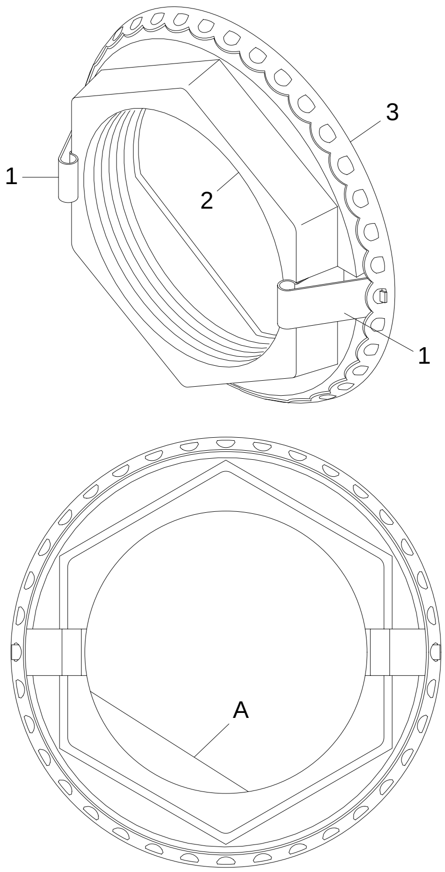
NOTICE

Do not use the bearing spacer with standard wheel bearings. To do so may result in too much bearing end-play, which could damage the wheel bearings, oil seals, the axle spindle, and the hub.

ConMet PreSet hubs use Axilok® retaining nuts. See **Fig. 3** and **Fig. 4**. Axilok retaining nuts can be damaged if they are not removed or installed correctly. Use the following guidelines when removing and installing Axilok retaining nuts.

- Use only the correct size, *six-point* socket to remove or install Axilok retaining nuts. Do not use a worn or loose-fitting socket. *Do not use a 12-point socket.*
- Do not use hammers, chisels, pliers, wrenches, or power tools to remove or install Axilok nuts.
- Do not use an Axilok nut if the locking clips are damaged or missing, or if the retainer cage tab or D-flat is damaged or missing.
- Never try to repair a damaged Axilok nut; always replace it with a new one.
- Always start an Axilok installation by hand. A good-fitting six-point socket will completely dis-

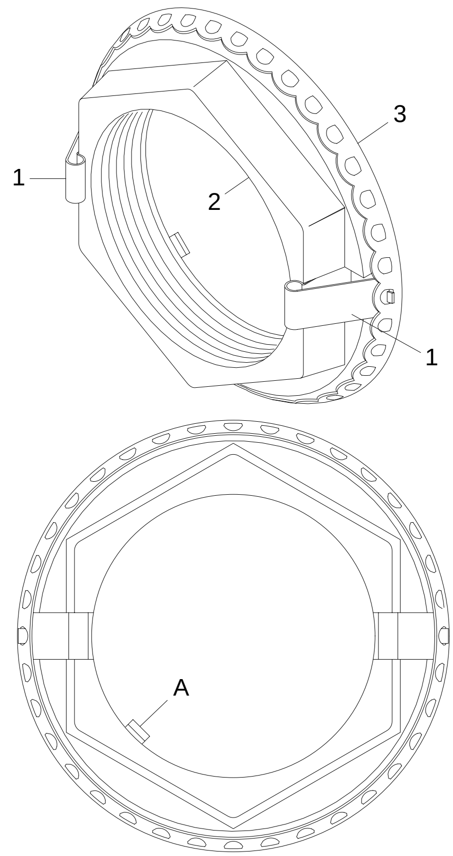
ConmMet PreSet® Hub Installation and Adjustment



A. The flat side of the retainer must engage the flat side of the axle spindle.

1. Locking Clip
2. Nut
3. Retainer

Fig. 3, Axilok Retaining Nut, Meritor Front Axle



A. This retainer tab must engage the keyway of the axle spindle.

1. Locking Clip
2. Nut
3. Retainer Cage

Fig. 4, Axilok Retaining Nut, Eaton Front Axle

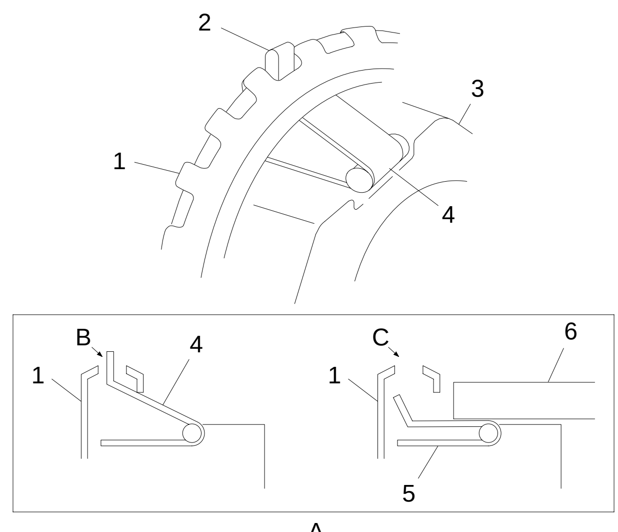
engage the nut's locking clips, allowing it to spin freely by hand. See **Fig. 5**. Use an accurately calibrated torque wrench to tighten the nut to its final torque value.

- After the nut is installed, always make sure that both locking clips are present and engaged in the retainer cage. See **Fig. 5**. If the locking clips are not engaged, the nut is not locked in position and can rotate freely.

Installation

Using Preset Bearings

1. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.
2. If present, remove the temporary plastic bearing cover from the front of the hub.
3. Install the PreSet hub assembly all the way onto the axle spindle. A temporary plastic alignment



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A. Cross-Section View
B. The tab is engaged.
C. The tab is disengaged.

1. Retainer Cage
2. Locking Clip Tab
3. Nut
4. Locking Clip
5. Locking Clip (compressed)
6. Six-Point Socket

Fig. 5, Axilok Nut, Checking the Position of the Locking Clip

sleeve may be installed in the center of a new hub. It will be pushed out when the hub is installed on the axle spindle. If it is present, remove and discard this sleeve.

NOTICE

Do not remove the outer wheel bearing once the hub is installed on the axle. Removing the outer bearing could cause the oil seal to become misaligned, which could cause damage to the wheel bearings, the hub, and the axle spindle.

WARNING

Follow the guidelines at the beginning of this subject when installing an Axilok nut. Axilok retaining nuts secure the hub assemblies on the axle. If the Axilok nut is not correctly installed, the hub could separate from the axle, resulting in severe personal injury or death.

4. Install the Axilok retaining nut onto the axle spindle. See **Fig. 3** or **Fig. 4**.
5. Tighten the retaining nut 250 lbf·ft (339 N·m). Do not back off the retaining nut. The nut should lock in place when you remove the wrench. If it does not, advance it until it does.
6. Install the hub cap, using a new gasket. Tighten the capscrews 15 lbf·ft (20 N·m).

WARNING

Failure to add oil to the wheel hub after the hub has been serviced will cause the wheel bearings to overheat and seize during vehicle operation. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury.

7. Fill the hub with fresh oil to the level shown on the hub cap. Do not overfill.

Using Standard Bearings

NOTE: Save the spacer for use when converting the hub back to the PreSet system.

NOTICE

Do not use the spacer with standard wheel bearings. To do so may result in too much bearing end-play, which could damage the wheel bearings, oil seals, the axle spindle, and the hub.

1. If not already done, remove the tubular spacer from inside the hub. Save it for future use to convert the hub back to the PreSet system.
2. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.
3. Coat both bearing assemblies with fresh oil. Install the inner wheel bearing and oil seal in the hub. See **Section 33.02** for instructions on installing the various types of oil seals.
4. Install the hub with the inner bearing and oil seal onto the axle spindle. Be careful not to unseat the inner bearing or oil seal.
5. Fill the hub cavity with oil, and install the outer wheel bearing.

ConMet PreSet® Hub Installation and Adjustment

NOTICE

Do not remove the outer wheel bearing once the hub is installed on the axle. Removing the outer bearing could cause the oil seal to become misaligned, which could cause damage to the wheel bearings, the hub, and the axle spindle.

6. Adjust the wheel bearings, as follows.

WARNING

Follow the guidelines at the beginning of this subject when installing an Axilok nut. Axilok retaining nuts secure the hub assemblies on the axle. If the Axilok nut is not correctly installed, the hub could separate from the axle, resulting in severe personal injury or death.

6.1 Install the Axilok nut. See **Fig. 3** or **Fig. 4**. Turn the nut against the bearing while spinning the wheel.

6.2 Tighten the nut 90 to 110 lbf·ft (122 to 149 N·m) while spinning the wheel in both directions.

6.3 Loosen the nut to zero torque and spin the wheel a few turns.

6.4 Tighten the nut 50 lbf·ft (68 N·m) while spinning the wheel in both directions. Back off the nut one-eighth to one-sixth turn.

6.5 Remove the wrench from the nut. The Axilok nut should automatically lock in place. If it does not, advance it until it does.

7. Using a dial indicator, measure the end play, as follows.

IMPORTANT: Do not measure the wheel bearings with the wheel mounted on the hub. You cannot accurately measure or adjust bearing end play with the wheel mounted on the hub.

7.1 Attach a dial indicator to the hub and set the point of the indicator in line with the end of the axle spindle. The point of the indicator should be parallel to the spindle axis.

If equipped with aluminum hubs and air brakes, it may be necessary to install the brake drum onto the hub to provide a steel base for the magnet of the dial indicator. Mount the drum on the hub's drum pilot. Adjust the brake or have someone apply the brakes to hold the drum secure. Secure the drum using the stud at the 12 o'clock position. Then secure the studs at about the 4 o'clock and 8 o'clock positions.

If using a stud-piloted hub and a steel drum, install 1-1/4-inch washers between the nuts and the drum.

7.2 Grip the sides of the hub at the three o'clock and nine o'clock positions. Push in on the hub (and drum, if applicable), to seat the inboard bearing set. Zero the dial indicator.

7.3 Again, grip the sides of the hub at the three o'clock and nine o'clock positions. This time, pull out on the hub (and drum, if applicable). Read the dial indicator, and note the end play.

7.4 Push the hub back in to confirm that the needle of the dial indicator returns to zero.

WARNING

The wheel-bearing end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm). Correct end play is crucial: if the wheel-bearing end play is not correct, the wheel bearings could fail. This could cause the loss of the wheel and hub assembly, resulting in an accident causing serious injury or property damage. Use the dial indicator to measure the end play.

8. **The end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm)**. If it is not within this range, remove the Axilok nut, and repeat the tightening sequence as described earlier in this procedure. Once the end play is correct, go to the next step.

9. Go to **Subject 100**, and complete the hub assembly installation procedure.

Outboard-Mounted Drum Removal and Installation

WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

For an exploded view of a typical wheel and axle assembly, including the brake drum, see **Fig. 1**.

Removal

1. Chock the rear tires to prevent vehicle movement. Apply the parking brakes.
2. Raise the front of the vehicle until the tires clear the ground. Then place safety stands under the axle.

WARNING

Never work under a vehicle that is supported only by a jack. Jacks can slip, causing the vehicle to fall. This could result in a person being pinned under or crushed by the vehicle, causing severe personal injury or death. Always use safety stands to support a vehicle.

3. Back off the slack adjuster to release the front axle brake shoes.

WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

4. Remove the wheel and tire assembly. See **Group 40** for instructions.

   To minimize the possibility of creating airborne brake lining dust, clean the dust from the brake drum, brake backing plate, and brake assembly, using an industrial-type vacuum cleaner equipped with a high-efficiency filter system. Then, using a rag soaked in water and wrung until nearly dry, remove any remaining dust. Don’t use compressed air or dry brushing to clean the brake assembly.
5. Remove the brake drum.
6. Inspect the drum. See **Subject 110** for instructions.

Installation

1. On brake drum assemblies with an aluminum hub, coat the hub and drum contact surfaces with Alumilastic® compound or an equivalent.
2. Install the brake drum on the wheel hub. See **Fig. 1**.

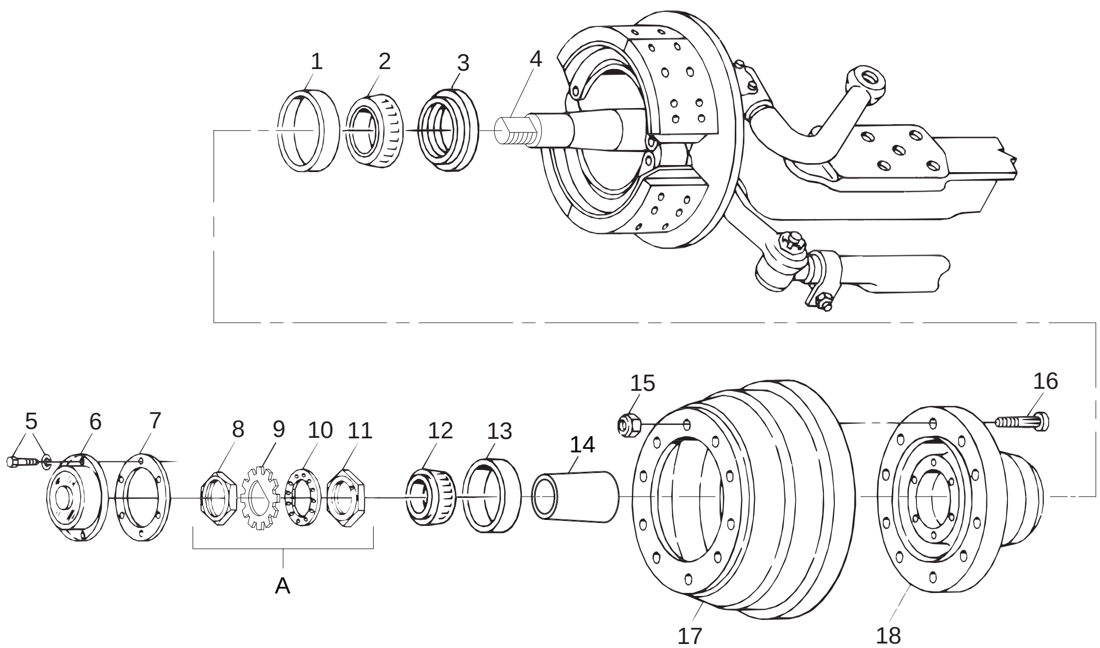
   2.1 On hub-piloted drums, position the brake drum on the top step of the pilot pad. One of the hub’s pilot pads should be at the 12 o’clock (top center) position. See **Fig. 2**.

   IMPORTANT: If the drum is not positioned correctly, the pilot pad could be damaged when the wheel nuts are torqued.

   2.2 Make sure that the pilot pads securely center the drum (space between drum and hub is equal all around the hub).

   IMPORTANT: If damage to the pads prevents the drum from centering, replace the hub. If necessary to hold the drum in position, adjust the brakes before installing the wheels.
3. Install the wheel and tire assembly. To ensure that the drum does not slip off the pilot pad, follow the proper nut tightening sequence. For instructions, see **Group 40**.

Outboard-Mounted Drum Removal and Installation



NOTE: On Meritor FF-981 Easy Steer Plus axles, the hub, wheel bearings, studs, and oil seal are assembled at Meritor and installed as an assembly.

A. Four-piece bearing system shown. Axi-Lok locking nuts are used for Con Met PreSet® hubs.

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Hub Cap Capscrew
6. Hub Cap
7. Gasket
8. Jam Nut
9. Nut-Lock
10. Lockring
11. Adjusting Nut
12. Outer Wheel Bearing
13. Outer Bearing Cup
14. Bearing Spacer (used only with Con-Met PreSet hubs)
15. Wheel Nut
16. Wheel Stud
17. Brake Drum
18. Hub

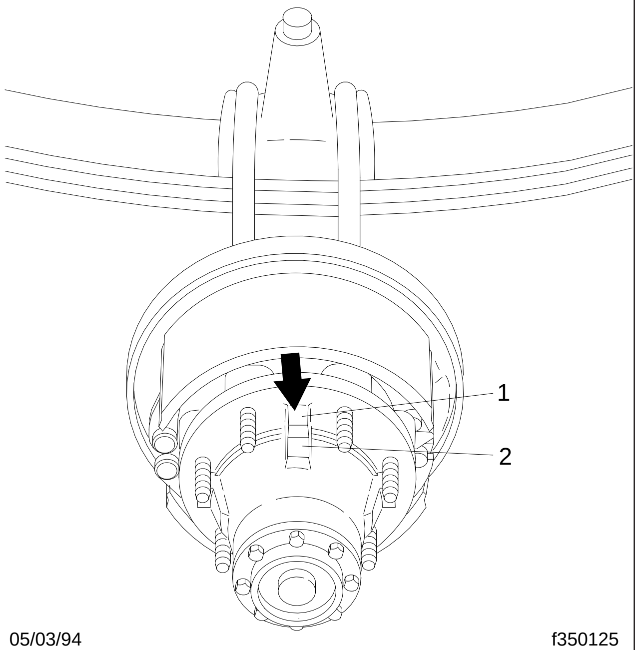
Fig. 1, Typical Wheel and Axle Assembly

WARNING

If the wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking ability, and the hub flange is probably damaged. In this case, replace it with a new wheel hub assembly. Failure to replace the wheel hub assembly when the conditions described above exist, could result in the loss of a wheel or loss of vehicle control, and possible personal injury.

4. Adjust the front axle brakes. Refer to Group 42 of the *Business Class M2 Maintenance Manual*.
5. Raise the vehicle and remove the safety stands from under the axle. Lower the vehicle.
6. Remove the chocks from the rear tires.

Outboard-Mounted Drum Removal and Installation



NOTE: Pilot pad at 12 o’clock position
1. Drum Pilot
2. Wheel Pilot

Fig. 2, Hub Pilot Pads

Wheel Bearing Cup Removal and Installation, Aluminum Hubs

Removal

To insure a tight fit, wheel bearing cups are purposely larger than the wheel hub bores they occupy. See **Fig. 1**. To remove the bearing cups, aluminum hub bores must be temporarily expanded by heating the hub in an oven (the bearing cups will also expand, but to a considerably lesser extent). If adequate heating facilities are not available, replace the hub, wheel stud, and bearing cup assembly.

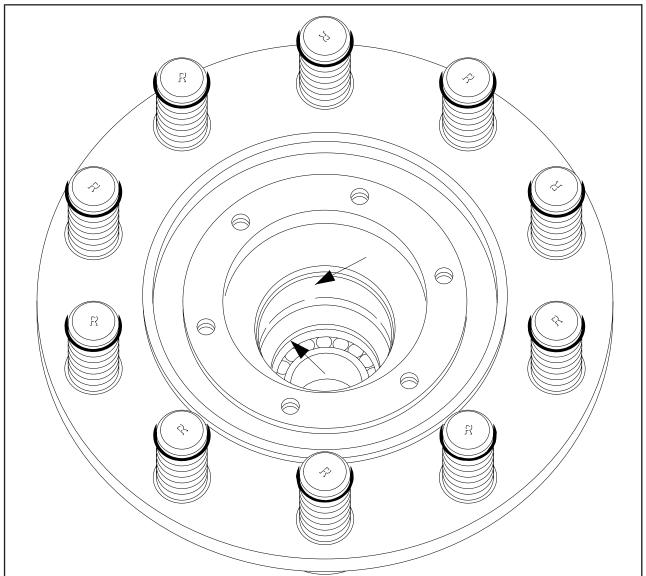


Fig. 1, Wheel Bearing Cup Locations

1. Completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly.
2. Oven-heat the hub to a temperature range of 240° to 280°F (116° to 138°C). Make sure the oven thermostat is accurately set; if unsure, use an oven thermometer to check the temperature of the oven before placing the hub inside.

   If adequate heating facilities are not available, replace the hub, wheel stud, and bearing cup assembly.

WARNING

Do not use oxyacetylene equipment or similar equipment to heat the hub. Oxyacetylene equipment or similar equipment will cause cracks in the hub that could cause loss of a wheel and loss of vehicle control, leading to personal injury or property damage.

3. Wearing heavy protective gloves, remove the hub from the oven. Place the hub on a suitable press so that the base is fully supported. Quickly press out the bearing cups.

Installation

To install the bearing cups, aluminum hubs must again be temporarily expanded using oven heating. When the hub is properly heated, the bearing cup and hub can be press-fit together, using a suitable press.

1. Completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly, including the bearing cup bores.
2. Inspect the bearing cup bores of the hub for warpage or uneven surfaces. If a bearing cup bore is damaged, replace the wheel hub assembly.
3. Oven-heat the hub to a temperature range of 240° to 280°F (116° to 138°C). Make sure the oven thermostat is accurately set; if unsure, use an oven thermometer to check the temperature of the oven before placing the hub inside.

WARNING

Do not use oxyacetylene equipment or similar equipment to heat the hub. Oxyacetylene equipment or similar equipment will cause cracks in the hub that could cause loss of a wheel and loss of vehicle control, leading to personal injury or property damage.

4. Coat the replacement bearing cup hub contact surface with a film of grease.
5. Wearing heavy protective gloves, remove the hub from the oven.
6. Place the hub on a suitable press so that the base is fully supported. Quickly press-fit the bearing cup into the wheel hub until it is completely and evenly seated. Be careful not to shave the sides of the bearing cup bore as the bearing cup is seated. The accumulation of debris will prevent the cup from being seated and

Wheel Bearing Cup Removal and Installation, Aluminum Hubs

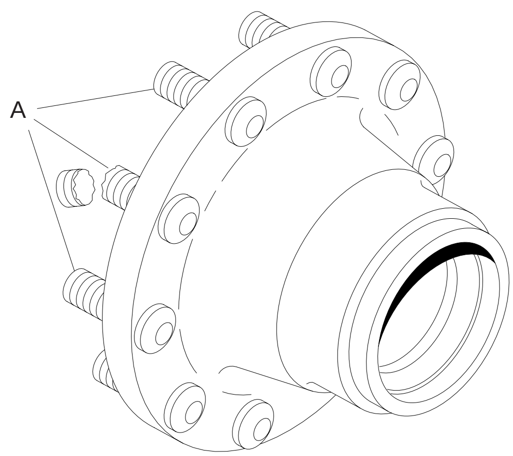
will also cause permanent damage to the wheel hub. If the sides of the bearing cup bore are damaged during installation, replace the wheel hub assembly.

7. Allow the wheel hub to cool before handling. Then, using a 0.0015-inch feeler gauge, check at several places for the seating of the bearing cup in the bearing cup bore. The gauge should not enter beneath the cup. If it does, there is probably dirt or debris preventing the cup from seating. Using the instructions above, remove the cup, then remove the foreign matter. Reinstall the cup.
8. Wipe off the accumulation of grease left after the bearing cup has been seated. Then, using a clean, lint-free cloth dampened with kerosene or diesel fuel oil, clean the inner surface of the bearing cup. Wipe the surface dry using a clean, absorbent, and lint-free cloth or paper.

Replacement

WARNING

If a wheel stud breaks, the remaining studs are subjected to undue strain and could fail due to fatigue. When a broken stud is replaced, replace the stud on each side of it. See Fig. 1. If more than one stud is broken, replace all of the studs. Failure to replace the studs could result in the loss of a wheel or loss of vehicle control, possibly resulting in personal injury.



A. Replace

Fig. 1, Wheel Stud Replacement

1. Remove the wheel hub from the axle. For instructions, see **Subject 100**.
2. If a bent portion of a wheel stud will have to pass through the wheel stud bore, cut off the bent portion before removing the wheel stud.
3. Place the wheel hub on a suitable press; make sure the hub flange is supported evenly around and next to the stud being removed. With steady movement, press the damaged stud out of the hub.

CAUTION

Do not use a drift and hammer or concentrated heat for removing and installing the wheel studs. Constant, smooth movement of the wheel stud is necessary to ensure the least amount of metal removal from the wheel stud bore. Concentrated heat will damage the hub. If the hub is damaged during wheel stud removal or installation, replace it.

4. Apply a coating of clean axle grease to the entire shaft on headed studs.
5. With the hub on a suitable press, make sure the hub flange is supported evenly around and next to the stud being installed.
6. Position the stud in its hole. *Be sure the flat edge of the head flange on clipped studs is in line with the shoulder on the hub.*

CAUTION

If headed studs with serrations are being installed, position the teeth of the serrated portion in the notches carved by the original wheel studs during factory installation. If additional metal is scraped from the wheel stud bores, the locking action provided by the serrations will be greatly weakened. Loss of locking action will prevent achieving final torque of the wheel nuts during wheel installation. If final wheel nut torques during wheel installation cannot be achieved, replace the wheel hub assembly.

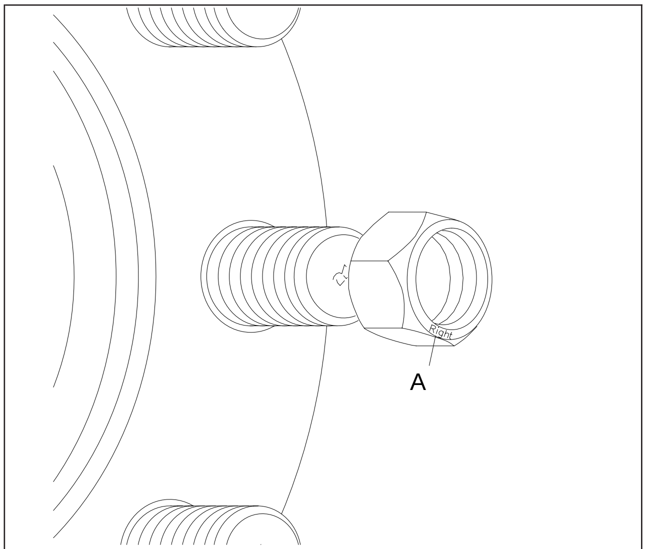
NOTE: If the left side of the vehicle is being serviced, the replacement wheel stud must be stamped with an "L" (left-hand threaded), and the nut's face must be stamped "Left" If the right side of the vehicle is being serviced, the replacement stud must be stamped with an "R" (right-hand threaded), and the nut's face must be stamped "Right." See **Fig. 2**.

7. With steady movement, press the new stud all the way into the hub.
8. Make sure the stud is fully seated and that its head (flange) is not embedded into the hub. If the head of the stud is embedded into the hub, replace the hub.

WARNING

Don't embed the wheel stud heads in the wheel hub. Wheel studs with heads embedded in the wheel hub will weaken the wheel hub flange. Weakness in the wheel hub can result in the loss

Wheel Stud Replacement



A. "Right"

Fig. 2, Thread Stamp Location

of a wheel or loss of steering control, possibly resulting in personal injury.

9. Wipe off any grease on the wheel studs and wheel hub. Install wheel nuts on dry wheel studs only.
10. Install the wheel hub on the axle. For instructions, see **Subject 100**.

Troubleshooting Tables

Problem — Noisy Bearings or Excessive Bearing Replacement Intervals

Problem — Noisy Bearings or Excessive Bearing Replacement Intervals	
Possible Cause	**Remedy**
Not enough oil was used on the bearings, or the wrong type of oil was used.	Clean, then inspect the bearings for wear. Replace worn seals. Coat the bearing assemblies with fresh oil.
Foreign matter or corrosive agents entered the bearing assembly. Dirt or metallic debris from the bearings was not removed.	Clean, then inspect the bearings for wear. Replace worn seals. Also clean the wheel hub, the axle spindle, and any other component in contact with the bearing lubricant.
An incorrect adjustment of the wheel bearings is causing noise and wear.	Adjust the wheel bearings, following the applicable instructions in this section.
Flat spots or dents on the roller surface were caused by skidding of the roller, or improper handling of the wheel bearing during installation.	Clean, then inspect the bearing rollers. Replace the bearing if damaged. Coat the replacement bearings with fresh oil. For lubricant specifications, see **Specifications 400**.

Problem — Broken Wheel or Rim Studs

Problem — Broken Wheel or Rim Studs	
Possible Cause	**Remedy**
The wheel or rim nuts were overtightened.	Replace the wheel or rim studs. See **Group 40** for the wheel or rim nut tightening sequence.
An incorrect nut tightening sequence was used.	
The wrong brake drums were installed.	Install new brake drums.
Wheels are mismatched (hub-piloted wheels are mixed with stud-piloted wheels).	Install properly matched wheels.
The vehicle is being overloaded.	Do not exceed the maximum load-carrying capacity of the vehicle.

Problem — Damaged Hub

Problem — Damaged Hub	
Possible Cause	**Remedy**
(Cracked hub) Local surface of an aluminum hub was heated higher than 350°F (177°C) during bearing cup removal.	Replace the hub assembly. When removing the bearing cup, oven-heat the hub.
(Bent flange) Incorrect installation of the wheel studs, such as using a hammer and drift, or the hub flange was not fully supported on the press during wheel stud replacement.	Replace the hub assembly. Replace the wheel studs.
The wrong brake drums were installed.	Install new brake drums.
Insufficient tightening of the wheel nuts to the wheel hub.	Replace the hub assembly and tighten the wheel nuts to the values in the torque table in **Specifications 400**.

Troubleshooting

Problem — Loss of Lubricant from the Wheel Hubs

Problem — Loss of Lubricant from the Wheel Hubs	
Possible Cause	**Remedy**
The seals or gaskets are worn or damaged.	Replace worn or damaged parts.

Problem — Vehicle Does Not Slow Down Quickly Enough When Brakes Are Applied

Problem — Vehicle Does Not Slow Down Quickly Enough When Brakes Are Applied	
Possible Cause	**Remedy**
Dirt or grease has built up on the brake linings (glazing), or the brake linings have worn excessively.	Install new brake linings on both sets of axle brake shoes. Clean, turn, or replace the drums.
The brake drums are worn, heat-checked or cracked.	Install new brake drums.

Problem — Service Brakes Grab or Pull

Problem — Service Brakes Grab or Pull	
Possible Cause	**Remedy**
For detailed information, see **Group 42**.	

Problem — Poor Lining-to-Drum Contact

Problem — Poor Lining-to-Drum Contact	
Possible Cause	**Remedy**
The inside surface of the brake drum is scored or grooved.	Install new brake linings on both sets of axle brake shoes. Install new brake drums or turn the drums.
The brake shoes are stretched or bent.	Replace the brake shoes.
Undersized linings were installed.	Install new brake linings on both sets of axle brake shoes.
An incorrect grind was used on the brake linings.	
The wrong brake drums were installed.	Install new brake drums.
An incorrect adjustment of the wheel bearings is causing wheel instability.	Adjust the wheel bearings following the applicable instructions in this section.

Problem — Brake Linings Are Tapered Across the Width

Problem — Brake Linings Are Tapered Across the Width	
Possible Cause	**Remedy**
The inside surface of the brake drum is scored or grooved.	Install new brake linings on both sets of axle brake shoes. Turn or replace the drums.
The brake shoes are bent.	Replace the brake shoes.
An incorrect adjustment of the wheel bearings is causing wheel instability.	Adjust the wheel bearings following the applicable instructions in this section

Problem — Brake Shoes on the Same Brake Are Wearing Unequally

Problem — Brake Shoes on the Same Brake Are Wearing Unequally	
Possible Cause	**Remedy**
The brake linings are not a matched set. Different friction codes or different brands of brake linings are installed.	Install a new matched set of brake linings on both sets of axle brake shoes. Clean, turn, or replace the drums.
The brake shoes are stretched.	Replace the brake shoes.

Problem — Shoes on Each Side of the Axle (Side-to-Side Brakes) Are Wearing Unequally

Problem — Shoes on Each Side of the Axle (Side-to-Side Brakes) Are Wearing Unequally	
Possible Cause	**Remedy**
The brake linings are not a matched set. Different friction codes or different brands of brake linings are installed.	Install a new matched set of brake linings on both sets of axle brake shoes. Clean, turn, or replace the drums.
The inside surface of the brake drum is in poor condition.	Turn or replace the drums.
The wheel bearings are out of adjustment.	Adjust the wheel bearings following the applicable instructions in this section.

Problem — Edge of the Lining Is Showing Wear

Problem — Edge of the Lining Is Showing Wear	
Possible Cause	**Remedy**
The brake lining is too wide.	Install new brake linings on both sets of axle brake shoes.
The brake linings are misaligned because of incorrectly drilled brake lining holes.	
Undersized brake drums were installed.	Install new brake drums.
The wheel bearings are out of adjustment.	Adjust the wheel bearings following the applicable instructions in this section.
There is an incorrect fit of the wheel onto the spindle due to the wrong wheel bearings.	Install new wheel bearings and adjust them following the applicable instructions in this section.
The brake shoes are bent.	Replace the brake shoes.

Problem — Brake Linings Are Scored or Grooved

Problem — Brake Linings Are Scored or Grooved	
Possible Cause	**Remedy**
Worn or scored brake drums have been causing poor contact with the brake linings.	Install new brake linings on both sets of axle brake shoes. Turn or replace the brake drums.
There is abrasive material between the lining and the drum.	

Troubleshooting

Problem — Brake Linings Are Loose

Problem — Brake Linings Are Loose	
Possible Cause	**Remedy**
The rivet holes in the brake shoes are to large.	Replace the brake shoes.
Incorrectly crimped rivets are working loose and allowing the linings to move.	Replace the rivets.
Rust has built up on the shoe table.	Clean the brake shoe table of all rust, dirt, scale, and paint.

Problem — Brake Lining Is Cracked at the Rivet Holes or Bolt Holes

Problem — Brake Lining Is Cracked at the Rivet Holes or Bolt Holes	
Possible Cause	**Remedy**
Overtightening of the lining bolts is causing cracks.	Install new brake linings. Replace the rivets or bolts with the correct size.
The wrong size counter bore for the rivet holes was made.	
The wrong rivets or bolts were used.	Replace the rivets or bolts with the correct size.
Incorrectly crimped rivets are working loose and allowing the linings to move.	Replace the rivets.
Rust has built up on the shoe table.	Clean the brake shoe table of all rust, dirt, scale, and paint.

Problem — Out-of-Round Rivet Holes or Bolt Holes

Problem — Out-of-Round Rivet Holes or Bolt Holes	
Possible Cause	**Remedy**
The rivets or bolts are loose.	Replace the brake shoes or linings.

Problem — Brake Drums Are Heat-Checked

Problem — Brake Drums Are Heat-Checked	
Possible Cause	**Remedy**
The brake drums are out-of-round.	Turn or replace the brake drums.
The wrong brake drums were installed.	Install new brake drums.
The wheel bearings are out of adjustment.	Adjust the wheel bearings following the applicable instructions in this section.
The brake linings are glazed (dirt or grease build-up) or are worn unevenly.	Install new brake linings on both sets of axle brake shoes. Clean, turn, or replace the drums.
The lining friction material for the operation of the vehicle is incorrect.	
There is a brake imbalance between the tractor and the trailer.	Do a brake balance test (tractor versus trailer). Contact the District Service Manager if help is needed.

Problem — Brake Drums Are Heavily Scored

Problem — Brake Drums Are Heavily Scored	
Possible Cause	**Remedy**
The brake linings are damaged.	Install new brake linings on both sets of axle brake shoes. Clean, turn, or replace the drums.
There is excessive wear on the linings.	
On the last brake reline, the drums were not turned.	Turn the brake drums.

Problem — Excessive Brake Lining Wear

Problem — Excessive Brake Lining Wear	
Possible Cause	**Remedy**
There is a brake imbalance between the tractor and the trailer.	Do a brake balance test (tractor versus trailer). Contact the District Service Manager if help is needed.

Problem — Hard Steering

Problem — Hard Steering	
Possible Cause	**Remedy**
Tire pressure is low in one or both front tires.	Inflate tires to the correct pressure.
Binding in the steering gear due to a lack of lubrication.	Test the steering system for binding with the front tires off the ground. For instructions, see **Group 46**.
Too much caster angle in the front wheels.	Check the caster angle and adjust as needed.
The front suspension is sagging due to a damaged spring.	Repair or replace the spring as needed. For instructions, see **Group 32**.
The axle spindle is bent.	Replace the spindle.
The frame is misaligned.	Check the frame alignment; correct, as needed.

Problem — Erratic Steering When the Brakes are Applied

Problem — Erratic Steering When the Brakes are Applied	
Possible Cause	**Remedy**
Tire pressure is low in one or both front tires.	Inflate the tires to the correct pressure.
One or more front axle spring U-bolt nuts are loose.	Check the U-bolt nuts for looseness. If loose, check the U-bolt for damage. Replace damaged parts; tighten loose nuts.
The brakes are not adjusted evenly.	Adjust the brakes on all axles. Also, check the operation of the slack adjusters.
Grease or oil contamination of the brake linings is reducing brake effectiveness.	Replace the brake linings and clean the drums. Find and correct the cause of grease or oil contamination.
The caster angle is wrong.	Check, and adjust as needed.
An axle spindle is bent.	Replace the axle spindle.

Troubleshooting

Problem — Erratic Steering When the Brakes are Applied	
Possible Cause	**Remedy**
The front axle wheel bearings are worn or were incorrectly adjusted.	Check the bearings for wear or damage; replace as needed.

Problem — Vehicle Pulls to One Side During Operation

Problem — Vehicle Pulls to One Side During Operation	
Possible Cause	**Remedy**
Tire pressure is low in one or both front tires.	Inflate the tires to the correct pressure.
One or more of the alignment measurements are incorrect.	Check all the alignment measurements. Correct as needed.
The wheels or tires are out-of-round.	Inspect the wheels and tires. Replace out-of-round parts.
The front axle wheel bearings are too tightly adjusted.	Check the bearings for wear or other damage. Replace the bearings if needed.
The front suspension is sagging due to a damaged spring.	Repair or replace the spring as needed. For instructions, see **Group 32**.
The axle spindle is bent.	Replace the spindle.
The frame is misaligned.	Check the frame alignment; correct as needed.
The rear axle(s) is out of alignment.	Check, and if needed, adjust the rear axle alignment.

Problem — Front Wheel Wander

Problem — Front Wheel Wander	
Possible Cause	**Remedy**
One or more wheels or brake drums are out-of-balance.	Balance the wheels. Check for out-of-round brake drums; correct as needed.
One of the front springs is weak or broken.	Repair or replace the spring as needed. For instructions, see **Group 32**.

Problem — Front Wheel Shimmy

Problem — Front Wheel Shimmy	
Possible Cause	**Remedy**
Tire pressure is low in one or both front tires.	Inflate the tires to the correct pressure.
One or more wheels or brake drums are out-of-balance.	Balance the wheels. Check for out-of-round brake drums, correct or replace as needed.
One or more tires are out-of-round or bulged.	Replace the tire.
The front axle wheel bearings are worn or were incorrectly adjusted.	Check the bearings for wear or other damage. Replace the bearings if needed.
Parts of the steering gear or linkage are worn.	Test for play in the steering gear and linkage with the front tires off the ground. Replace parts as needed.

Problem — Front Wheel Shimmy	
Possible Cause	**Remedy**
The axle spindle is bent.	Replace the spindle.
One or more of the alignment measurements are incorrect.	Check all alignment measurements and correct as needed.
The knuckle pin is loose due to worn bushings.	Inspect the knuckle pin and bushings for damage. Replace worn or damaged parts as needed.
Shock absorbers are worn or damaged.	Check the shock absorbers and replace if needed.

Problem — Vehicle Wanders

Problem — Vehicle Wanders	
Possible Cause	**Remedy**
Tire pressure is low in one or both front tires.	Inflate the tires to the correct pressure.
One or more of the alignment measurements are incorrect.	Check all of the alignment measurements; correct as needed.
The rear axle(s) is out of alignment.	Check the rear axle alignment and adjust as needed.
Parts of the steering gear or linkage are worn.	Test for play in the steering gear and linkage with the front tires off the ground. Replace parts as needed.
A knuckle pin is loose due to worn bushings.	Inspect the knuckle pin and bushings for damage. Replace worn or damaged parts.
The axle spindle is bent.	Replace the spindle.

Problem — Cupped Tires

Problem — Cupped Tires	
Possible Cause	**Remedy**
Tire pressure is too low or too high in one or both front tires.	Inflate or deflate the tires to the correct pressure.
One or more wheels or brake drums are out-of-balance.	Balance the wheels. Check for eccentric brake drums; correct or replace as needed.
The wheel toe-in in not correct.	Adjust the wheel toe-in.
The brakes are not adjusted evenly.	Adjust the brakes on all axles. Also, check the operation of the slack adjusters.
The front axle wheel bearings are worn or were not adjusted correctly.	Check the bearings for wear or other damage; replace them if needed.
The camber angle is not within specifications.	Check the front wheel camber angle. If not correct, find and replace the damaged axle component.

Troubleshooting

Problem — Steering Wheel Spokes Do Not Point at the 3 and 9 O'clock Positions

Problem — Steering Wheel Spokes Do Not Point at the 3 and 9 O'clock Positions	
Possible Cause	**Remedy**
The steering gear is not centered.	Center the steering gear.
If adjustable, the drag link is out of adjustment.	Adjust the drag link.
The steering wheel was not installed (positioned) correctly on the steering column.	Reposition the steering wheel on the steering column.
The pitman arm is not correctly aligned with the timing mark on the steering gear output shaft.	Reposition the pitman arm on the steering gear output shaft. For instructions, see **Group 46**.

Dual-Nut Wheel Bearing Lock Torque Values		
Application	Size	Torque: lbf·ft (N·m)
Adjusting Nut	—	Stage 1: Tighten to 100 (135).
		Stage 2: Back Off Completely.
		Stage 3: Tighten to 20 (25) While Rotating Hub.
		Stage 4: Back Off 1/3 Turn (two flats of the adjusting nut).
Jam Nut (with Wheel Bearing Nut, Pierced Lockwasher, and Bendable Lockwasher)	1-1/8	Target: 175 (235) Permissible Range: 150–225 (205–305)
	1-1/2 to 2-1/2	Target: 250 (340) Permissible Range: 200–300 (270–405)
	2-5/8 or Larger	Target: 325 (440) Permissible Range: 250–400 (340–540)

Table 1, Dual-Nut Wheel Bearing Lock Torque Values

Dana Spicer® Axle Recommended Lubricant		
Lubricant Type	Condition	SAE Viscosity Grade
Eaton Roadranger® Synthetic Axle Lubricants, or Equivalent with Military Specification MIL–L–2105D	Over-the-Road Service	75W–90
	Off-Highway Equipment, or Under Extra Heavy Loads	80W–140

Table 2, Dana Spicer Axle Recommended Lubricant

Meritor Axle Recommended Lubricant			
Lubricant Type	Ambient Temperature	SAE Viscosity Grade	Meritor Specification
Hypoid Gear Oil API Service Classification GL–5	+10°F (–12.2°C) and up*	85W–140	0–76–A
	–15°F (–26.1°C) and up*	80W–140	0–76–B
	–15°F (–26.1°C) and up*	80W–90	0–76–D
	–40°F (–40°C) and up*	75W–90	0–76–E
	–40°F (–40°C) to +35°F (+2°C)	75W	0–76–J
	–40°F (–40°C) and up*	75W–140	0–76–L
Synthetic Gear Oil	–40°F (–40°C) and up*	75W–90	0–76–N
	–40°F (–40°C) and up*	75W–140	0–76–M

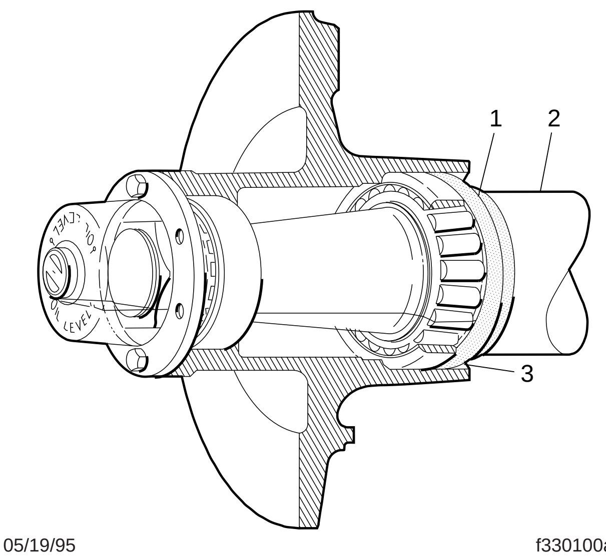
* There is no upper limit on these ambient temperatures, but axle sump temperature must never exceed 250°F (121°C).

Table 3, Meritor Axle Recommended Lubricant

General Information

Wheel oil seals (also called "oil bath seals" or "hub seals") work as a dam to keep oil in the hub cavity so that it constantly "bathes" the wheel bearings. The seals also protect the wheel bearings by keeping dirt, dust, and water out of the hub.

The oil seal fits between the hub bore and the axle spindle (see **Fig. 1**), and the sealing element either turns with the wheel (*hub-mounted seals*) and seals against the axle spindle, or the sealing element stays stationary with the axle spindle (*spindle-mounted seals*) and seals against the turning hub.



1. Wheel Oil Seal
2. Axle Spindle
3. Wheel Hub Bore

Fig. 1, Spindle-Mounted Wheel Oil Seal (typical)

Most wheel oil seals consist of four basic parts (**Fig. 2**):

- The outside edge (also called the outer "cup" or "case")
- The inside edge (also called the inner "cup" or "case")
- The sealing element
- The garter spring

The outside edge is usually metal coated with rubber or another sealing agent so that it grips the hub bore tightly enough to prevent oil escaping between the outer edge of the seal and the hub bore.

The inside edge is usually metal or rubber with a metal ring within it to prevent the sealing element from wearing a groove in the axle spindle.

The sealing element is usually molded rubber, leather, or a synthetic such as nitrile or silicone. The element is molded into lips which will seal against the axle spindle or against the outside or inside edge described above. The innermost lip, called the "primary lip," keeps the oil inside the hub cavity. The outermost lip, called the "secondary lip," keeps dirt out of the hub cavity.

The garter spring is a coiled wire spring with its ends connected to make a loop. On hub-mounted seals, the spring runs around the outside of the sealing element to press the element inwards against the sealing surface. On spindle-mounted seals, the spring runs around the inside of the sealing element to press the element outward against the sealing surface.

Two brands of axle oil seals are used on this vehicle:

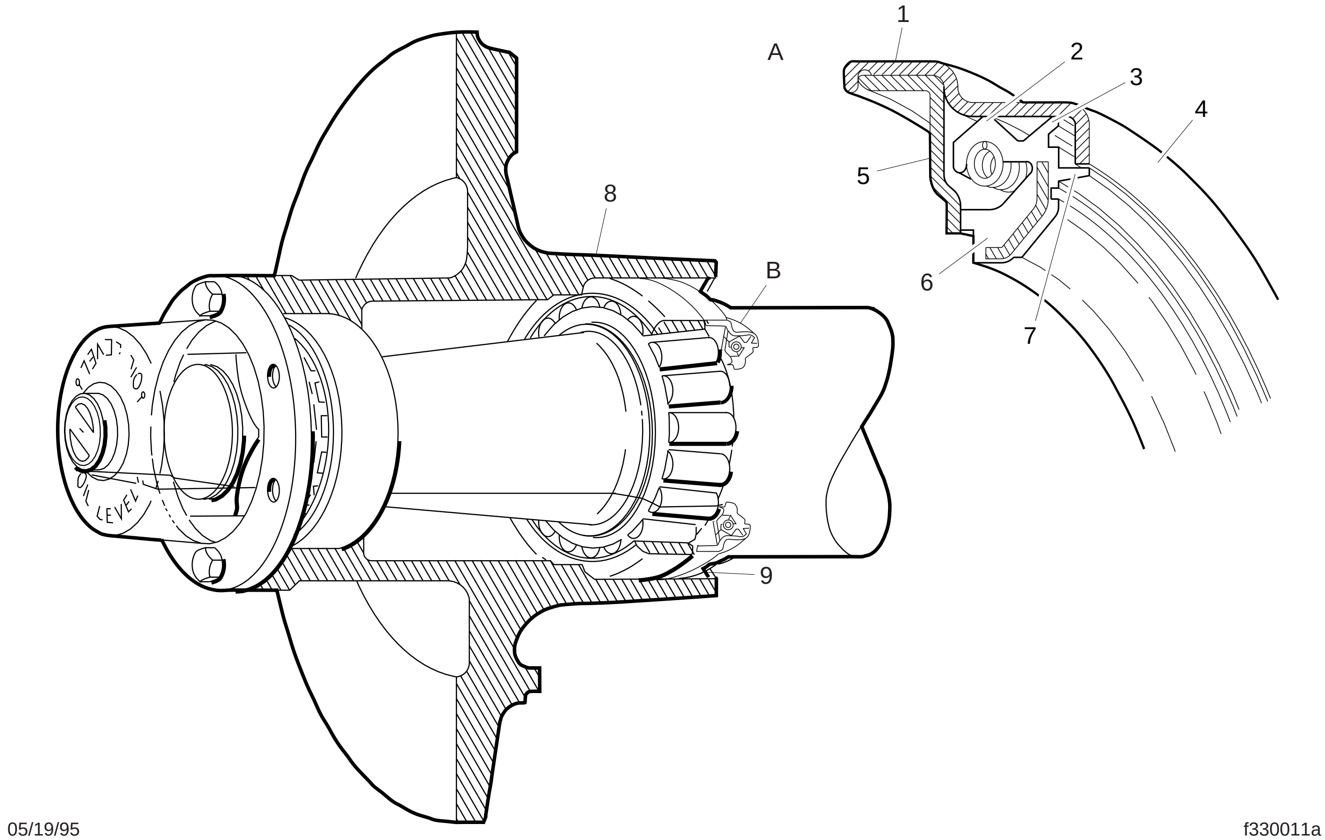
- Chicago Rawhide (Scotseal® and Scotseal Plus®)
- Dana Spicer (Outrunner™)

Chicago Rawhide

The Chicago Rawhide Scotseal is a unitized, one-piece design consisting of a sealing element (packing) that is assembled between metal outer and inner cups. See **Fig. 2**. The sealing element consists of three sealing lips; a spring-loaded primary sealing lip that is factory pre-lubed and two dirt exclusion lips. The seal is press fit into the hub bore using Scotseal service installation tools. *Do not install the Scotseal directly onto the axle spindle.*

Although you install the Scotseal into the hub bore, the seal's element grips the axle spindle tightly enough that the sealing element stays stationary with the spindle and seals against the outer cup which turns with the hub.

The Chicago Rawhide Scotseal maintains a metal-to-metal contact between the outer cup and the hub bore surface as well as a metal-to-metal contact between the sealing element inside edge and the axle spindle.



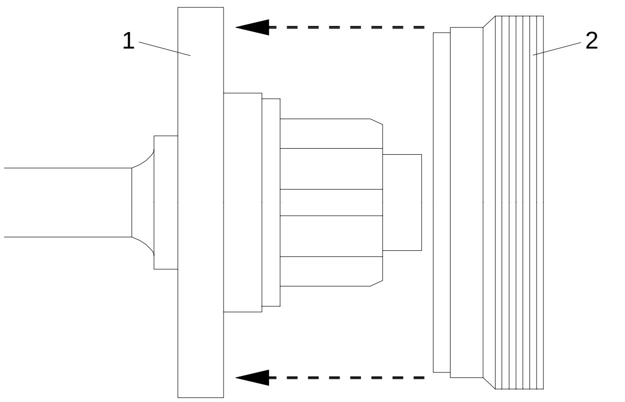
A. Detail A
B. Oil Seal (See detail A)

1. Bore-Tite® Coating
2 Primary Sealing Lip
3. Dirt Lip
4. Outer Cup
5. Inner Cup
6. Sealing Element (Packing)
7. Bumper Lip
8. Hub
9. Hub Bore

Fig. 2, Chicago Rawhide Scotseal

Dana Spicer

The Dana Spicer Outrunner has a rubber-coated outside edge and is installed in the hub bore using Dana Spicer installation tools. See **Fig. 3**.



1. Dana Spicer Outrunner Installation Tool
2. Dana Spicer Outrunner Seal

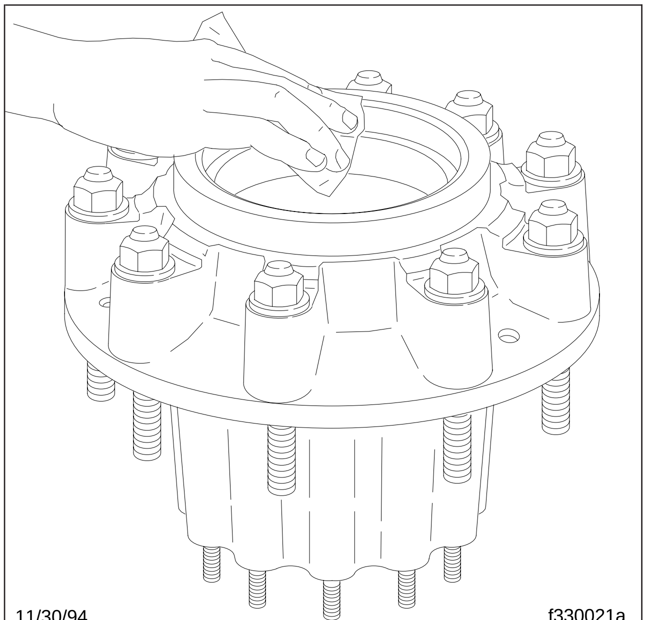
Fig. 3, Dana Spicer Outrunner Seal

Seal Replacement, Chicago Rawhide

Replacement

NOTE: This procedure applies to the Chicago Rawhide Scotseal®.

1. Remove the wheel, drum, and hub from the axle. For instructions, see **Section 33.01**, Subject 100.
2. Remove the oil seal from the hub.
3. Remove the inner wheel bearing assembly from the hub. Handling the bearings with clean dry hands, wrap the bearings in clean oil-proof paper or lint-free cloths. Occasionally, the inner wheel bearing cone assembly will remain in the hub after the seal is removed. In those cases, place a protective cushion to catch the bearing assembly. Using a hardwood drift and a light hammer, gently tap the bearing out of the inner wheel bearing cup.
4. Clean the spindle, spindle threads, seal bore, and the hub cavity. See **Fig. 1** and **Fig. 2**.
5. Remove all burrs from the shoulder and the seal bore with an emery cloth or a file. Clean any metal filings from the components.



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NOTE: Rear hub shown.

Fig. 1, Clean the Hub

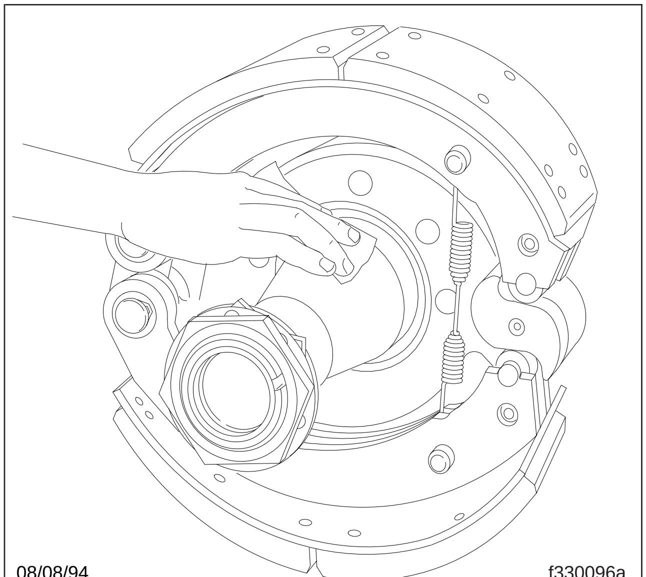

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Fig. 2, Clean the Spindle

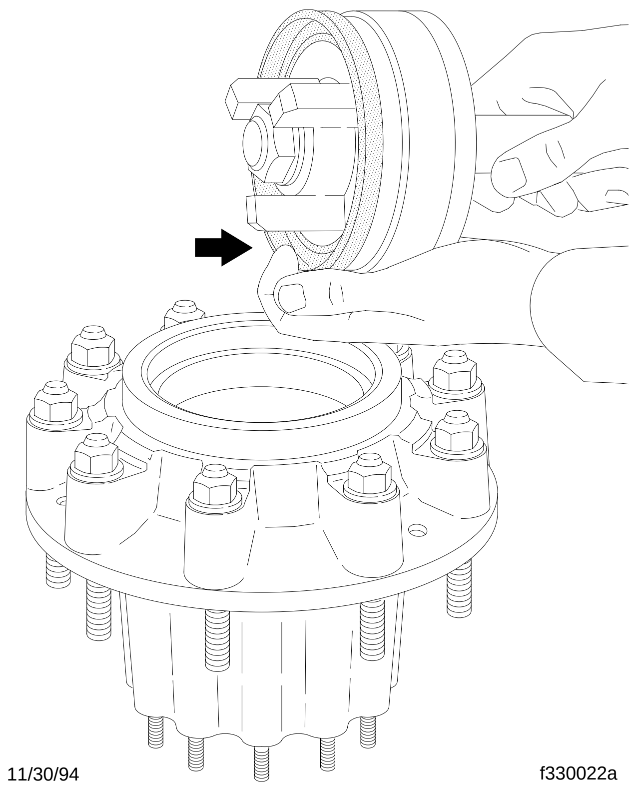
CAUTION

Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other contaminants can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

6. Inspect the bearings and hub components for wear or damage. Replace any worn or damaged components as necessary.
7. Coat the wheel bearing cones with oil.
8. Install the inner wheel bearing cone in the inner wheel bearing cup.
9. Seat the small outside edge of the seal in the recess of the tool adaptor. See **Fig. 3**. The correct adaptor is identified on the box.
10. Insert the centering plug of the tool in the bore of the inner bearing cone. See **Fig. 4**. The plug prevents cocking of the seal in the bore.
11. Hold the tool handle firmly, and strike it until the sound of the impact changes as the seal bottoms

Seal Replacement, Chicago Rawhide



NOTE: Rear hub shown.

Fig. 3, Place the Seal on the Installation Tool

out. See **Fig. 5**. Hold the tool firmly to avoid bounce or unseating of the seal from the adaptor.

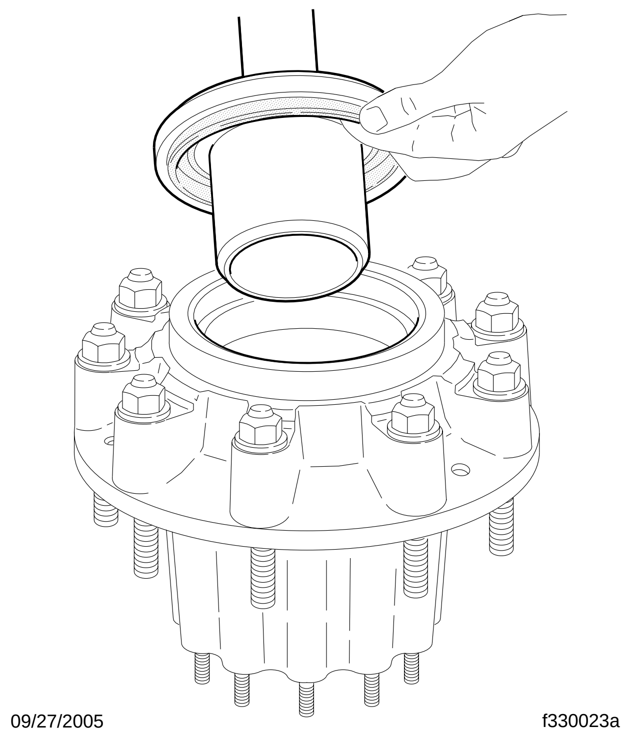
12. After the seal is bottomed in the bore, check for freedom of movement by manually moving the interior rubber part of the seal back and forth. A slight movement indicates a damage-free installation.

13. Install the wheel hub on the axle, and adjust the wheel bearings. For instructions, see **Section 33.01**, Subject 100.

IMPORTANT: When starting the wheel on the spindle, center the hub carefully to avoid seal damage from the leading edge of the spindle.

14. Place the hubcap and a new gasket in position, then install the capscrews. Tighten the capscrews 15 lbf·in (20 N·m).

15. Fill the hub with oil to the level shown on the hubcap. See **Fig. 6**. Do not overfill.



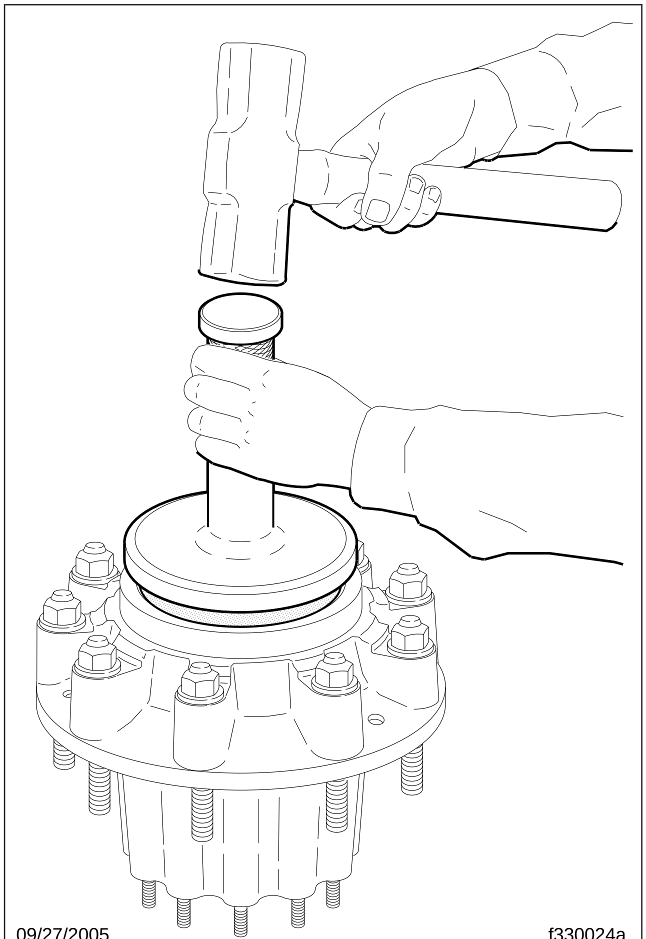
NOTE: Rear hub shown.

Fig. 4, Insert the Tool in the Hub Bore

16. Spin the wheel and check the oil level.

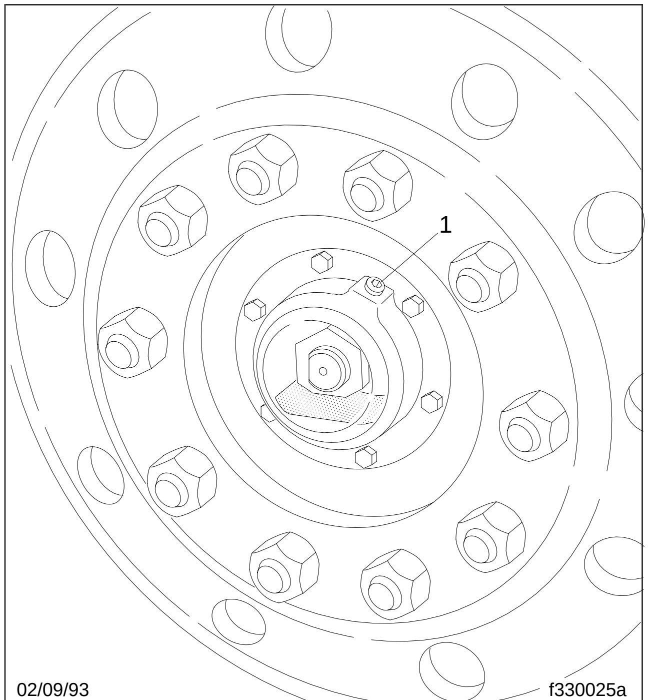
17. Adjust the brake shoe-to-drum clearance. For instructions, see Group 42 of the *Business Class M2 Maintenance Manual*.

Seal Replacement, Chicago Rawhide



NOTE: Rear hub shown.

Fig. 5, Strike the Tool



1. Filler Plug

Fig. 6, Fill the Hub with Oil

Replacement

NOTE: This procedure applies to the Dana Spicer Outrunner™ seal.

1. Remove the wheel, drum, and hub from the axle. For instructions, see **Section 33.01**, Subject 100.
2. Remove the oil seal from the hub.
3. Remove the inner wheel bearing assembly from the hub. Handling the bearings with clean dry hands, wrap the bearings in clean oil-proof paper or lint-free cloths. Occasionally, the inner wheel bearing cone assembly will remain in the hub after the seal is removed. In those cases, place a protective cushion to catch the bearing assembly. Using a hardwood drift and a light hammer, gently tap the bearing out of the inner wheel bearing cup.
4. Clean and inspect the bearings, the spindle, spindle threads, seal bore, and the hub cavity.

   IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other contaminants can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

   4.1 Inspect the inner hub bore. Remove dirt and contaminants from all recesses and corners. Smooth any sharp edges with emery cloth, and fill in any grooves with filler. See **Fig. 1**.

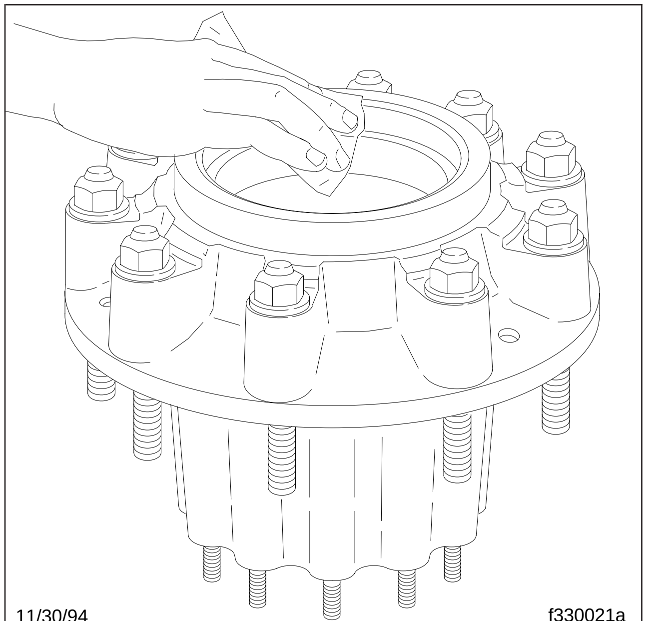
   4.2 Wipe the hub area with a clean shop cloth.

   4.3 After removing the hub, inspect the spindle. Remove any sharp edges and burrs from the leading edges and the shoulder area. Repair deep gouges with filler and smooth with an emery cloth. See **Fig. 2**.

   4.4 Wipe the seal and shoulder area with a clean shop cloth.

CAUTION

Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.



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NOTE: Rear hub shown.

Fig. 1, Clean and Inspect the Hub Bore

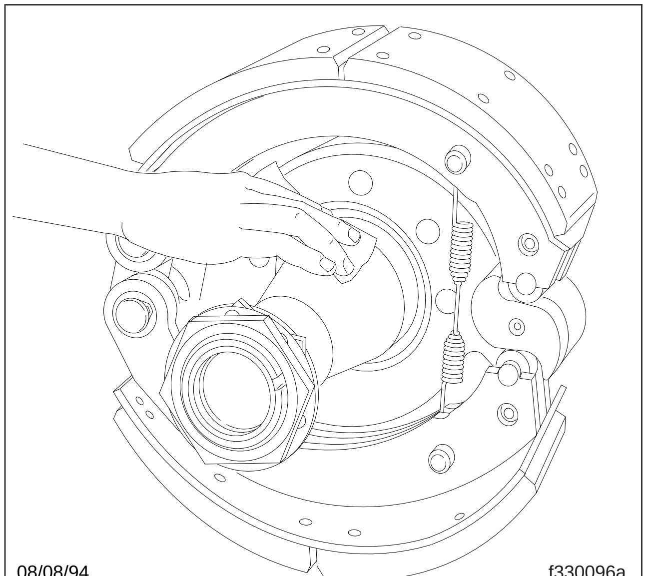

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Fig. 2, Clean and Inspect the Axle Spindle

Seal Replacement, Dana Spicer

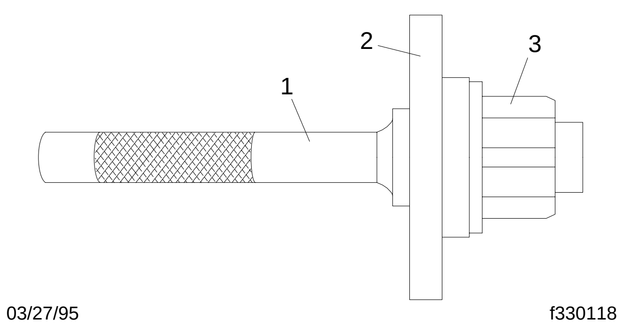
4.5 Inspect the bearings and hub components for wear or damage. Replace any worn or damaged components as necessary.

4.6 Coat the wheel bearing cones with oil.

5. Install the inner wheel bearing cone in the inner wheel bearing cup.

IMPORTANT: Use the Dana Spicer Outrunner installation tool *with the centering tool* when installing the seal. See **Fig. 3**.

6. Install the oil seal in the hub bore.



1. Outrunner Handle
2. Outrunner Adapter Plate
3. Bearing Centering Tool

Fig. 3, Dana Spicer Outrunner Installation Tool

CAUTION

Do not use any silicone or permatex type bore sealant with this seal. The Dana Spicer Corporation recommends a light coating of bearing oil on the outer circumference of the seal.

Do not mix lubricants of different grades. Do not mix mineral and synthetic lubricants. Do not pack the bearings with grease when using an oil bath system. Failure to follow these installation guidelines will result in less than desired performance of the Outrunner seal, and installation-related failures are not covered under warranty.

6.1 Place the outrunner seal tool with the words "air side" facing the adaptor plate of the installation tool. See **Fig. 4**. Lubricate the seal outer circumference with wheel bearing oil.

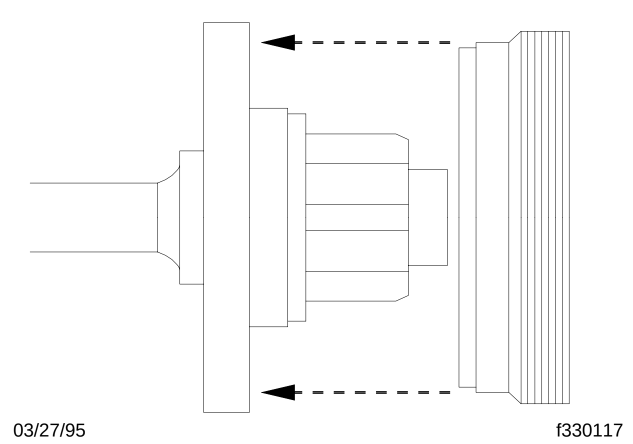


Fig. 4, Seal Placement on Tool

IMPORTANT: Install the seal in the hub bore with the hub laid flat. Do not install the seal with the hub in the vertical (upright) position.

6.2 With the hub and the wheel assembly laid flat on the floor, place the inner bearing cone in the cup.

6.3 Position the oil seal in the hub bore. Before striking the handle of the installation tool, tap the adaptor plate around the outer edge to position the seal. See **Fig. 5**.

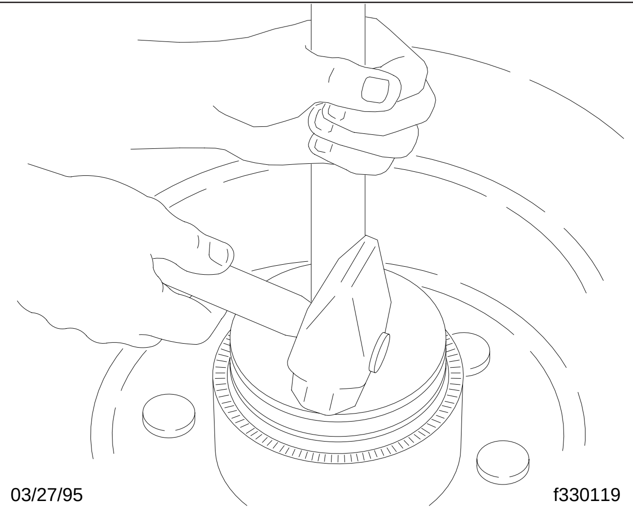


Fig. 5, Position the Seal

Seal Replacement, Dana Spicer

6.4 Hit the handle of the installation tool *gently*. See **Fig. 6**.

Because of the rubber outer circumference, the Outrunner seal is easier to install than seals with metal outer circumferences. When the adaptor plate bottoms out on the hub surface, the seal is installed correctly. You will hear a metal-to-metal sound.

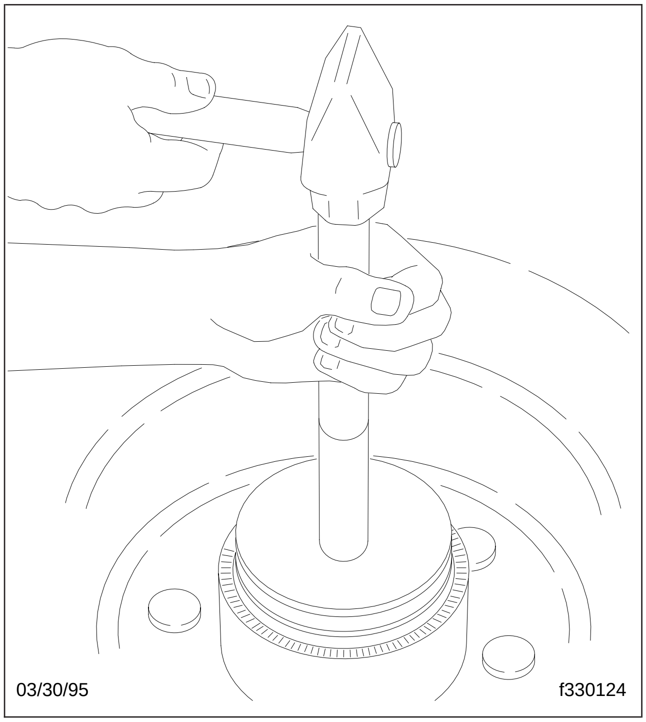


Fig. 6, Install the Seal

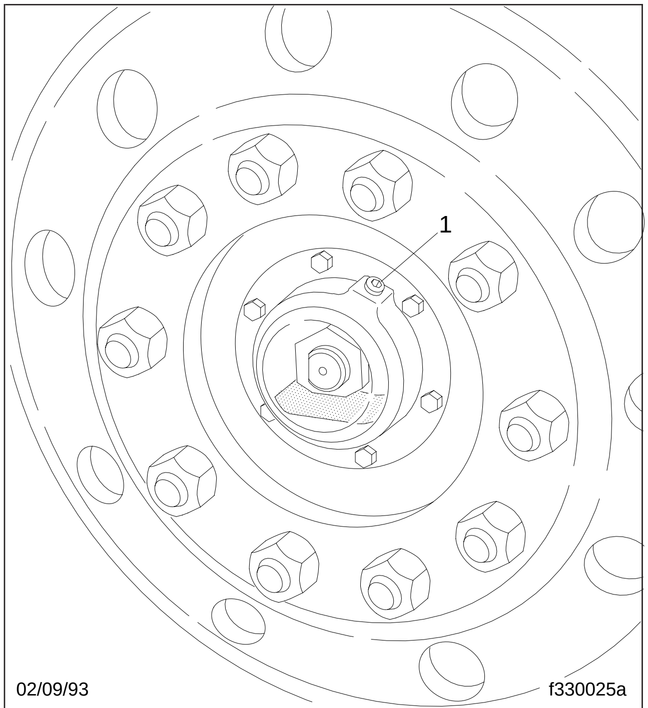
6.5 Check that the seal is not cocked, and that the unitized seal inner circumference and inner bearing turn freely.

6.6 Lubricate the inner circumference of the seal with a light film of clean bearing oil.

7. Install the wheel hub on the axle, and adjust the wheel bearings. For instructions, see **Section 33.01**, Subject 100.

IMPORTANT: When starting the wheel on the spindle, center the hub carefully to avoid seal damage from the leading edge of the spindle.

8. Place the hubcap and a new gasket in position, then install the capscrews. Tighten the capscrews 15 lbf·ft (20 N·m).
9. Fill the hub with oil to the level shown on the hubcap. See **Fig. 7**. Do not overfill.



1. Filler Plug

Fig. 7, Fill the Hub with Oil

10. Spin the wheel and check the oil level.
11. Adjust the brake shoe-to-drum clearance. For instructions, see Group 42 of the *Business Class M2 Maintenance Manual*.

Replacement

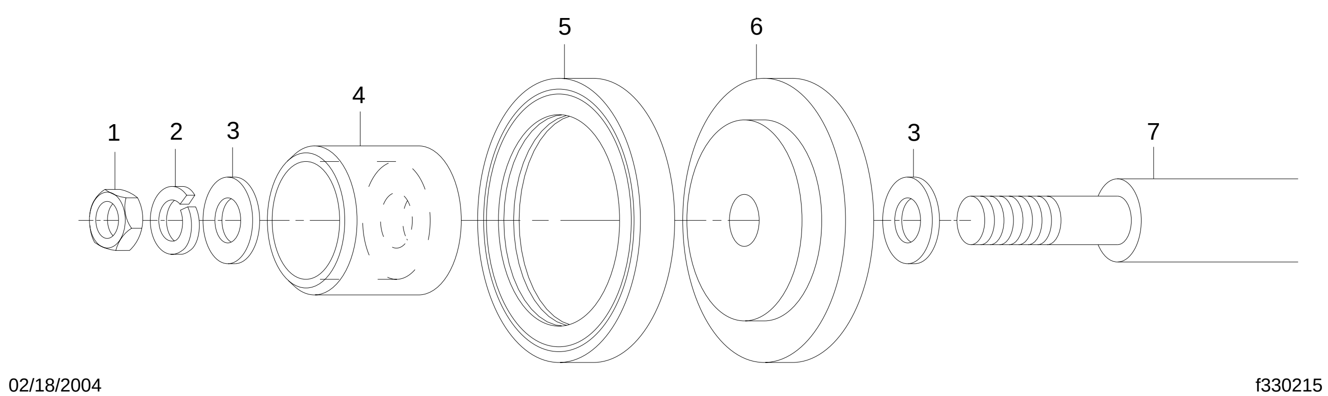
NOTE: This procedure applies to the National® oil seal.

1. If not already done, remove the hub from the axle spindle. For instructions, see **Section 33.01, Subject 100**.
2. Remove the old oil seal from the hub or axle spindle, as applicable. Be careful not to damage the axle spindle.
3. Inspect the hub chamfer and bore for burrs, nicks, roughness, deep scratches, and other imperfections. Clean any imperfections with an emery cloth. Wipe the surface clean.
4. If using a press, put the hub onto a centering fixture, inboard side up.

   If you are manually installing the oil seal, put the hub (inboard side up) on a firm, level surface.
5. Using approved gear oil, lubricate the inner bearing. For approved gear oil, see **Section 33.01, Specifications, 400**.
6. Install the inner bearing into the hub.
7. Put a light coating of gear oil on the inner and outer surfaces of the oil seal.
8. Install the adapter plate and bearing pilot on the steel handle, using the hexnut and washers provided. See **Fig. 1**.
9. Put the oil seal on the adapter plate, making sure the words "Air Side" on the oil seal are facing the adapter plate surface.
10. Making sure the oil seal is aligned straight with the hub bore, install it into the hub. See **Fig. 2**.

    If using a press, press the oil seal into the hub with 3000 to 5000 psi (20 684 to 34 474 kPa) of pressure.

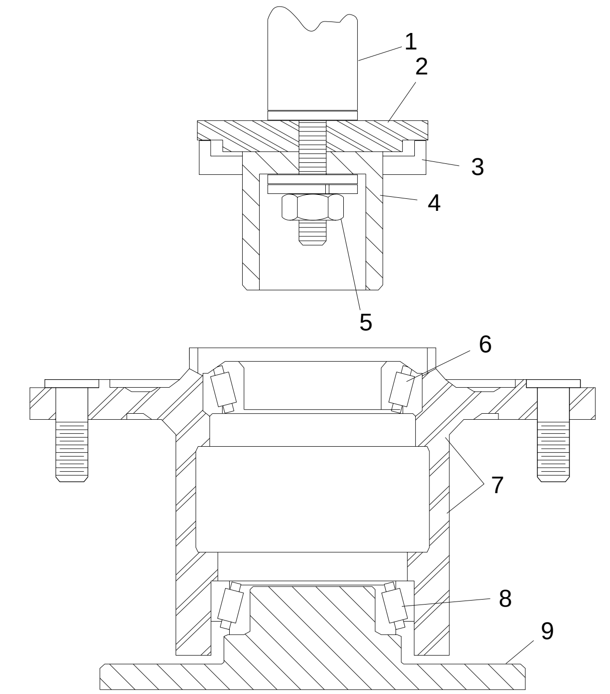
    If manually installing the seal, strike the end of the installation tool with a heavy mallet. Continue striking until the sound changes.
11. Make sure the oil seal is correctly installed in the hub bore. The face of the seal (the side with the words "Air Side") should be flush with the face of the hub.
12. Wipe off any excess oil from the face of the oil seal.
13. Install the hub on the axle spindle. For instructions, see **Section 33.01, Subject 100**.
14. Check the other side of the vehicle for front-axle oil seal leakage. If needed, repeat the procedure on the other side of the vehicle.



1. Hexnut, 3/4–10
2. Lockwasher
3. Flatwasher
4. Bearing Pilot
5. Oil Seal
6. Adapter Plate
7. Installation Handle

Fig. 1, Oil Seal and Installation Tools

Seal Replacement, National



1. Installation Handle
2. Adapter Plate
3. Oil Seal
4. Bearing Pilot
5. Hexnut, 3/4–10
6. Inner Bearing
7. Hub
8. Outer Bearing
9. Centering Fixture

Fig. 2, Installing the Oil Seal Into the Hub (cross-sectional view)

General Information

Although these axles are a Freightliner proprietary product, they may be referred to in some applications as "MB components."

Freightliner front axles have a unique steering knuckle design that reduces vibration and wear. Low-friction and high-strength needle bearings roll on a large diameter kingpin, replacing the conventional bushings.

They are compatible with all standard industry model brakes, hubs, and wheel bearings.

Use the procedures in **Subject 100** to remove and install the axle, and in **Subject 110** to disassemble and assemble the steering knuckle.

There are three basic models for the Freightliner front axle: Model 2, Model 3, and Model 5. The basic model is indicated by the numbers on the axle's identification tag.

The following explains a typical model number.

Typical Model Number: AF-12-3.

- *AF* = front axle
- *12* = Weight Rating (times 1000 lb)
- *3* = Model Number

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the rear tires. Put the transmission in neutral.
2. At both ends of the front axle, loosen all the wheel nuts.

WARNING

Never work around or under a vehicle that is supported only by a jack. Always support the vehicle with safety stands. Jacks can slip, causing the vehicle to fall, which could result in serious injury or death.

3. Raise the front of the vehicle and support it with safety stands.
4. Drain the air system.
5. Remove the front wheel and tire assemblies. For instructions, see **Group 40**.
6. Remove the brake drums. For instructions, see the applicable section in **Group 42**.
7. Remove the front hubs from the axle. For instructions, see **Section 33.01**.
8. Remove the brake shoes. For instructions, see the applicable section in **Group 42**.
9. Remove the ABS sensors and wiring from the brake anchor plates and secure them and their wiring out of the way.
10. Remove the brake air chambers and the slack adjusters. For instructions, see the applicable section in **Group 42**.
11. Remove the brake anchor plates from the axle ends.
12. Disconnect the drag link from the axle steering arm.
13. If so equipped, disconnect the sway bar from the axle brackets.
14. Using a suitable jack, support the front axle.
15. Remove the U-bolt nuts or remove the nuts that hold the axle beam to the leaf springs and the air bag brackets, as applicable.
16. Remove the U-bolts, if applicable.
17. Remove the axle from the vehicle.
18. If you are replacing the steering knuckles, put the axle on a suitable stand and secure it to prevent it from moving.

Installation

1. With the axle on a suitable jack, position it under the vehicle.
2. For vehicles with front air suspension, raise the axle so that the holes in the axle beam line up with the bolts that hold the air bags to the leaf springs. Install the nuts and washers and tighten the nuts 220 lbf·ft (298 N·m).

   For vehicles with a leaf-spring front suspension, install the U-bolts and nuts. For instructions on tightening U-bolt nuts, see the applicable section in **Group 32**.
3. If so equipped, connect the sway bar to the axle brackets. Tighten the sway bar fasteners 100 lbf·ft (136 N·m).
4. Connect the drag link to the steering arm. For instructions, see the applicable section in **Group 46**.
5. Install the brake anchor plates to the axle ends. For instructions, see the applicable section in **Group 42**.
6. Install the brake air chambers and slack adjusters on the axle. For instructions, see the applicable section in **Group 42**.
7. Install the ABS sensors.
8. Install the brake shoes. For instructions, see the applicable section in **Group 42**.
9. Install the hubs and adjust the wheel bearings. For instructions, see **Section 33.01**.
10. Install the brake drums.
11. Adjust the slack adjusters. For instructions, see the applicable section in **Group 42**.
12. Install the tire and wheel assemblies. For instructions, see **Group 40**.
13. Raise the vehicle, remove the safety stands, and lower the vehicle.
14. Start the engine and build the air pressure.

Axle Removal and Installation

15. If equipped with a front air suspension, check that the suspension air bags are inflating correctly.
16. Remove the chocks from the rear tires.

Steering Knuckle Disassembly and Assembly

Disassembly

NOTE: The following procedures can be done with the axle installed on the vehicle or with the axle removed from the vehicle.

1. If the axle has been removed, make sure it is securely mounted on a suitable stand. Go to the step for removing the tie rod from the tie-rod arm.

   If the axle is on the vehicle, park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the rear tires. Drain the air system.

2. If the axle is on the vehicle, do the following sub-steps to gain access to the steering knuckle:

   2.1 Remove the wheel and tire assembly from the applicable side of the vehicle.

   2.2 Remove the hub and brake drum. For instructions, see **Section 33.01**.

   2.3 Remove the brake shoes. For instructions, see the applicable section in **Group 42**.

   2.4 If so equipped, remove the ABS sensor and wiring from the brake anchor plates and secure the sensor and the wiring out of the way.

   2.5 Disconnect the air line from the brake air chamber, then remove the air chamber and the slack adjusters. For instructions, see the applicable section in **Group 42**.

   2.6 Disconnect the drag link from the steering arm, if present.

   NOTE: On the driver's side of the vehicle, the steering arm connects to the steering knuckle. On the passenger's side, no steering arm is present.

3. If not already done, disconnect the tie rod from the tie-rod arm.

4. Remove the tie-rod arm from the steering knuckle. See **Fig. 1**.

5. If applicable, remove the steering arm. See **Fig. 1**.

6. Remove the steering knuckle and spindle assembly from the axle beam. See **Fig. 1**.

   6.1 Remove the upper and lower snap rings that hold the cover plates in place. See **Fig. 1**.

   6.2 Remove the upper and lower cover plates from the steering knuckle.

   6.3 Remove and discard the O-ring from the edges of each cover plate.

   6.4 Note the orientation of the draw keys and the kingpin, then remove the draw keys and nuts that hold the kingpin in place.

   6.5 Using a brass drift, remove the kingpin by driving it downward. Make a note of where the needle bearings were installed.

   6.6 Remove the spacer(s) and shim(s) from the upper surface of the axle beam bore.

   6.7 Push down on the steering knuckle and spindle assembly to clear the lip on the thrust friction bearing and remove the assembly from the axle beam bore.

NOTE: The steering knuckle on the passenger's side (side without a steering arm) has a thrust roller bearing instead of a thrust friction bearing. Unlike the thrust friction bearing, the thrust roller bearing has no protruding lip at the top. When removing the thrust roller bearing from the axle beam bore, it is not necessary to push down on the steering knuckle.

7. Remove the grease seal from the upper steering-knuckle bore.

8. Remove the thrust friction bearing (driver's side) or the thrust roller bearing (passenger's side) from the top of the lower steering knuckle bore.

NOTE: If removing the thrust friction bearing (driver's side), note the orientation of the bearing for future reference.

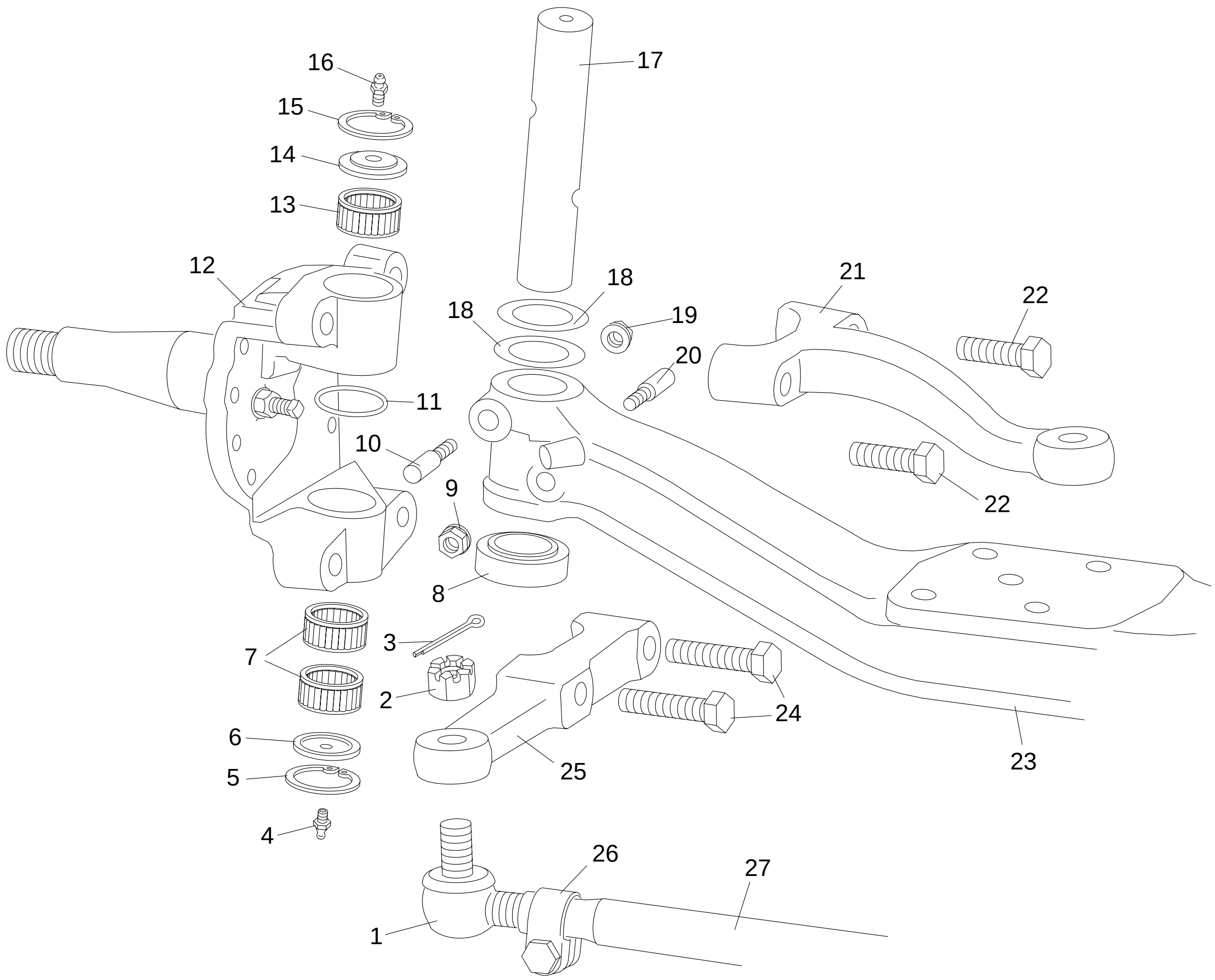
9. Using a brass drift, drive out the needle bearings from the steering knuckle bores.

10. If needed, repeat the entire procedure for the other side of the axle assembly.

Assembly

IMPORTANT: If replacing the kingpin, use a complete rebuild kit with all new components.

Steering Knuckle Disassembly and Assembly



NOTE: The number of upper and lower needle bearing sets may vary, depending on the axle model.

1. Tie-Rod Ball Joint
2. Castle Nut
3. Cotter Pin
4. Lower Grease Fitting
5. Lower Snap Ring
6. Lower Cover Plate
7. Lower Needle Bearings (may be one or two sets)
8. Thrust Friction Bearing (thrust roller bearing on the passenger side)
9. Lower Draw Key Nut
10. Upper Draw Key
11. Grease Seal
12. Steering Knuckle
13. Upper Needle Bearing (may be one or two sets)
14. Upper Cover Plate
15. Upper Snap Ring
16. Upper Grease Fitting
17. Kingpin
18. Shim
19. Upper Draw Key Nut
20. Lower Draw Key
21. Steering Arm
22. Steering Arm Capscrew
23. Axle Beam
24. Tie-Rod Arm Capscrews
25. Tie-Rod Arm
26. Tie-Rod Clamp
27. Tie-Rod Tube

Fig. 1, Front Axle Components (driver side shown)

1. Clean the steering knuckle bores and the axle beam bores. Check for damage such as grooves, scratches, and pitting. If any bores show significant damage, replace the component.

2. Install the grease seal — with the grooved side down (toward the road) — into the top of the upper steering knuckle bore. Carefully drive the seal down into the bore until the outer edge of the seal is flush with the bottom edge of the bore. Make sure the seal is not cocked.
3. Install new needle bearings into the bores of one of the steering knuckles. Install the same number of bearings as was removed.

NOTE: Install the needle bearings just far enough into the bores so that the cover plates can be installed.

4. Install a new thrust friction bearing (driver's side) or thrust roller bearing (passenger's side) into the top of the lower steering knuckle bore. Install the thrust friction bearing (or thrust roller bearing) with the sealed side up.

NOTE: The thrust friction bearing has a protruding lip at the top. The thrust roller bearing has no such protruding lip.

5. Partially install the steering knuckle on the axle beam.

   5.1 Making sure the flats on the kingpin are aligned with the draw-key holes in the axle beam, put the new kingpin into the top bore of the steering knuckle. Note that the top of the new kingpin is clearly marked. Push the kingpin through the axle beam bore until the upper end of the kingpin is flush with the upper surface of the axle beam bore.

   5.2 Align the steering knuckle with the axle beam, then check the clearance between the axle beam bore and the upper steering knuckle bore. Clearance is to be a maximum of 0.003 inch (0.08 mm).

   IMPORTANT: To correctly check the clearance, the thrust friction or thrust roller bearing must be installed correctly, and upward pressure must be applied to the steering knuckle.

   5.3 If needed, install sufficient spacers to reduce the clearance to 0.002 to 0.003 inch (0.05 to 0.08 mm).

6. Install the kingpin fully into the steering knuckle bores, making sure the flats on the kingpin are still aligned with the draw-key holes in the axle beam.
7. Install new upper and lower draw keys and nuts. See **Fig. 1**.

   7.1 Install the upper draw key from the back of the axle, and the lower one from the front of the axle.

   IMPORTANT: Make sure the new draw keys are the same length as those removed. On some axle models the lower draw key is longer than the upper one.

   7.2 Tighten the draw-key nuts 30 to 55 lbf·ft (40 to 75 N·m).

8. Install new grease fittings and cover plates.

   8.1 Install the new upper cover plate (with a new O-ring) and the snap ring. Install the new grease fitting into the cover plate.

   8.2 Install the new lower cover plate (with a new O-ring) and the snap ring. Install the new grease fitting into the cover plate.

9. Install the steering arm. Apply Loctite® 277 to the threads and tighten the steering arm capscrews: if M20 capscrews are used, tighten them 425 lbf·ft (575 N·m); if M24 capscrews are used, tighten them 664 lbf·ft (900 N·m).
10. Attach the tie-rod arm to the steering knuckle. Apply Loctite® 277 to the threads and tighten the tie-rod arm capscrews: if M20 capscrews are used, tighten them 425 lbf·ft (575 N·m); if M24 capscrews are used, tighten them 664 lbf·ft (900 N·m).
11. If applicable, repeat the entire procedure for the other side of the axle assembly.
12. Attach the tie-rod arm to the tie rod. Tighten the castle nut 120 to 170 lbf·ft (163 to 230 N·m) plus a maximum of one-sixth of a turn to align a slot in the castle nut with the cotter pin hole in the tie rod stud. Insert the cotter pin and bend the tangs to secure it.
13. If removed, install the axle.
14. If removed, connect the drag link to the steering arm.

Steering Knuckle Disassembly and Assembly

15. Install the brake anchor plates on the axle ends. For instructions, see the applicable section in **Group 42**.
16. Install the brake air chambers and slack adjusters on the axle. For instructions, see the applicable section in **Group 42**.
17. Install the ABS sensor.
18. Install the brake shoes. For instructions, see the applicable section in **Group 42**.
19. Install the hub and adjust the wheel bearings. For instructions, see **Section 33.01**.
20. Install the brake drum.
21. Install the tire and wheel assembly. For instructions, see **Group 40**.
22. If necessary, repeat the entire procedure for the other side of the vehicle.
23. Raise the vehicle, remove the safety stand, then lower the vehicle.
24. Remove the chocks from the tires.

Specifications

Torque Values			
Application	**Size**	**Class**	**Torque: lbf·ft (N·m)**
Air Bag-to-Leaf Spring Nuts	—	—	220 (298)
Draw-Key Nuts	—	—	30–55 (40–75)
Steering Arm Capscrews	M20 x 1.5	10.9	480 (650)
Sway Bar Fasteners	—	—	100 (136)
Tie-Rod Arm Capscrews	M20 x 1.5	10.9	480 (650)

Table 1, Torque Values

General Information

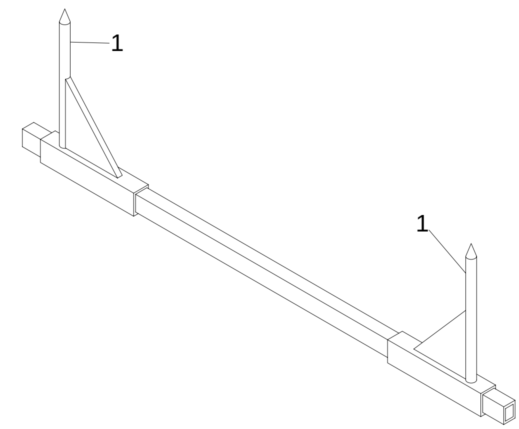
Rear axle alignment should be checked whenever rear axle or suspension components are replaced. It should also be checked when there is excessive front and rear tire wear, or hard or erratic steering.

Manufacturers of axle alignment equipment offer a variety of systems to precisely measure and correct rear axle alignment. If this type of equipment is not available, the basic tools needed for checking rear axle alignment on tandem or single axles are a straightedge (that is nonflexible and at least as long as the axle), steel tape rule, and trammel bar or center point bar.

The straightedge is used to see if a single axle, or a forward-rear axle of a tandem axle installation, is in alignment with the frame. The distance from the straightedge to the center of the wheel hub is measured on each side of the vehicle; any difference in the measurements means that the axle is out of alignment.

A center point bar (**Fig. 1**) is used to see if the forward-rear axle and rearmost axle of a tandem installation are aligned with each other (parallel). It has adjustable pointers at each end, which are inserted into the axle cap holes of each axle. By comparing the distance between the two axles on one side to the distance on the other side, it can be determined if the axles are parallel.

Instructions and a list of materials for making a center point bar are in **Subject 130**.



1. Adjustable Pointer

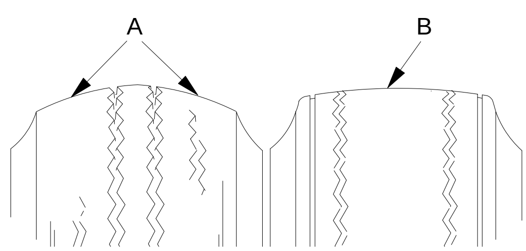
Fig. 1, Center Point Bar

The following preliminary checks should be completed before checking any alignment measurements.

Preliminary Checks

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. Relieve internal stresses in the suspension by driving the vehicle back and forth in a straight line.

1. Wheel assemblies should be balanced, especially for vehicles that travel at sustained speeds of more than 50 mph (80 km/h). Off-balance wheel assemblies cause vibrations that result in severely shortened life for tires and suspension parts.
2. Do not mix tires of different size, type, or weight. Tire wear should be even and not worn to limits exceeding government specifications. Refer to **Group 40** in this manual and **Group 40** in the *Business Class® M2 Maintenance Manual* for more information. Replace any tire that is excessively worn.
3. Check the inflation pressure of the tires. Refer to **Group 40** in this manual for recommended pressures. An underinflated tire causes tread wear completely around both tire shoulders. An overinflated tire causes tread wear in the center of the tire. See **Fig. 1.**



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A. Underinflation Wear B. Overinflation Wear

Fig. 1, Tire Damage Due to Underinflated or Overinflated Tires

4. Check for out-of-round wheels and wheel stud holes. Replace the wheel if any of these conditions exist.
5. On each side of the vehicle, check the height of the chassis above the ground; for instructions, see **Group 32** in this manual or the suspension manufacturer's service literature. Sagging, fatigued, or broken suspension springs create a lopsided vehicle appearance and an unbalanced weight distribution. Anything that changes the ratio of weight on the springs affects the alignment angles and also the tire tread contact area. Replace damaged springs as instructed in the applicable suspension section.
6. Check and, if necessary, correct frame rail alignment as instructed in **Group 31** in this manual.
7. Check and, if necessary, adjust rear axle tracking. For instructions, see **Group 32** in this manual or the suspension manufacturer's service literature.
8. Check the rear axle wheel bearings for wear and incorrect adjustment. Refer to **Section 35.01** for instructions.

Checking Using Computerized Alignment Systems

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Freightliner dealers must have proof of this calibration history.

Follow the manufacturer's instructions for use of the alignment equipment, and use the alignment measurements given in **Fig. 1** and the applicable tables in **Specifications 400**.

Checking Using the Manual Method

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction.

1. Park the vehicle on a level surface. Relieve internal stresses in the suspension by driving the vehicle back and forth in a straight line, or by jacking the axle up and letting it down.
2. Chock the front tires and place the transmission in neutral. Release the parking brakes.

NOTICE

Do not use scribe lines for marking on frame rails. Scribe lines, which cut or scratch the metal, can develop into starting points for structural damage to the frame.

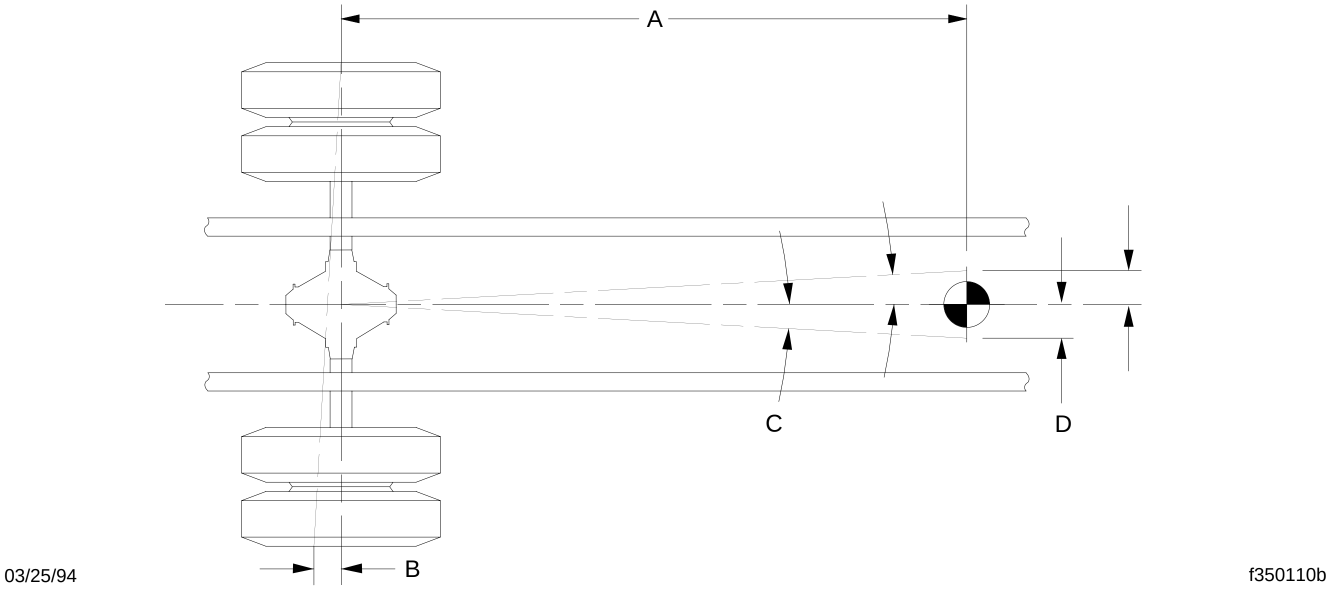
3. Select a point on the frame rail forward of the rear axle, and mark it using a pencil or soapstone. Then mark two other points, exactly 4 inches (102 mm) forward and to the rear of the original point. Make sure that all three marks are aligned and of equal distance from the outside edge of the frame rail. Using a center point or trammel bar, place one pointer on the forwardmost point, and make an arc with a pencil or soapstone on the opposite frame rail. Then place the pointer on the rearmost point and make an arc on the opposite frame rail intersecting the first arc. See **Fig. 2**. The point where the two arcs intersect and the original (or middle) point on the opposite frame rail have matching locations.
4. Line up the straightedge with the two matching points. Check that the straightedge extends out about the same distance on each side of the frame rail. Using C-clamps, clamp the straightedge to the frame; see **Fig. 3**. The straightedge must line up exactly with the points.
5. Measuring from the outside edge of each frame rail, mark the straightedge on both sides of the frame. The marks (**Fig. 3**, Ref. A) must be of equal distance from the frame and as far from the frame rail as the tires are at their farthest point from the frame.

IMPORTANT: The distance between the mark on the straightedge and the frame rail must be equal on both sides of the vehicle.

6. On each side of the vehicle, measure the distance from the mark on the straightedge to the center of the wheel hub. See **Fig. 3**.

   The difference between these measurements should be 1/4 inch (6 mm) or less. See **Fig. 1**. If the difference is more than 1/4 inch (6 mm), adjust the axle alignment. For instructions, see **Group 32** in this manual, or the suspension manufacturer's service literature.

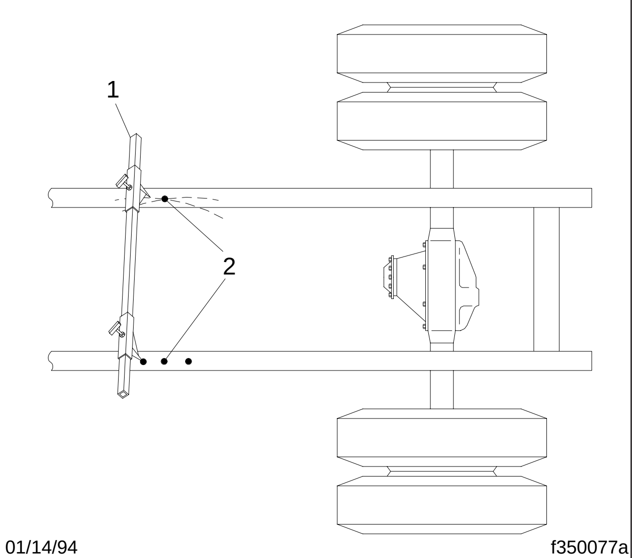
Alignment Checking, Single Axle



For items A and D, see Specifications 400.

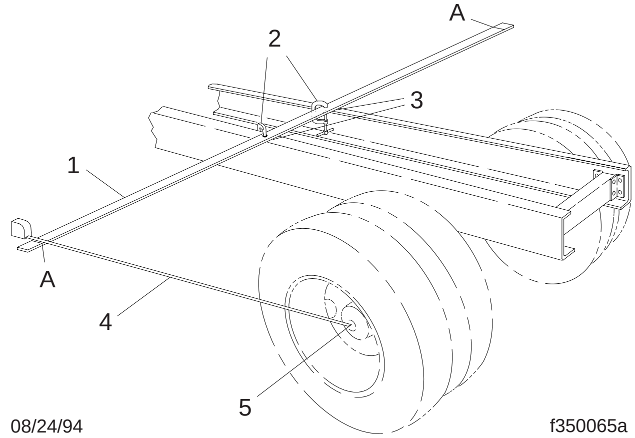
A. Distance from Rear Axle to Target (using Bee Line Alignment Tools)
B. Maximum Allowable Difference if Aligned Manually = ±1/4 inch (6 mm)
C. Maximum Allowable Tolerance if Aligned with Hunter Tools = ±0.18 degree
D. Maximum Allowable Tolerance if Aligned with Bee Line Tools

Fig. 1, Alignment Measurements



1. Center Point/Trammel Bar
2. Matching Points

Fig. 2, Marking an Arc



A. Marks

1. Straightedge
2. C-Clamps
3. Matching Points
4. Tape Measure
5. Wheel Hub

Fig. 3, Straightedge to Wheel Hub Measurement

To align a tandem axle, first, check and (if needed) align the rearmost axle; then, check and (if needed) align the forward-rear axle.

Checking Using Computerized Alignment Systems

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Freightliner dealers must have proof of this calibration history.

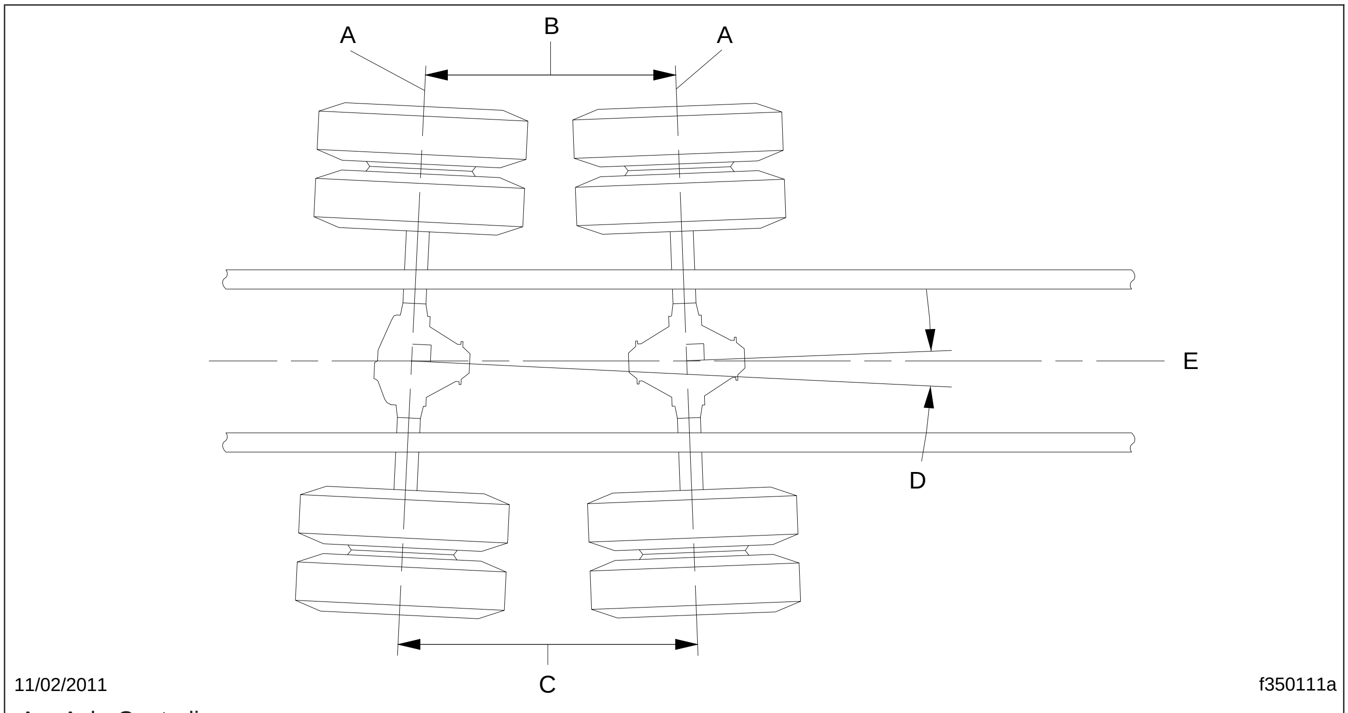
Follow the manufacturer's instructions for use of the alignment equipment, and use the alignment measurements given in **Fig. 1** and the applicable tables in **Specifications 400**.

Checking Using the Manual Method

A straightedge and a center point bar are needed to manually align a tandem axle. For instructions for making a center point bar, see **Subject 130**.

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction.

1. Using the instructions in **Subject 110**, check and align the rearmost axle.
2. Using a center point bar, set the two points into the axle cap holes as shown in **Fig. 2**. Lock them in place by tightening the setscrews.
3. With the points still locked in place, move the center point bar to the other side of the vehicle, set the two points into the axle cap holes, and compare the axle spacing. If there is a difference



A. Axle Centerline
B. Left-Hand Axle End Spacing, Measured Manually or with Bee Line Alignment Tools
C. Right-Hand Axle End Spacing, Measured Manually or with Bee Line Alignment Tools
D. Maximum Tolerance as Measured with Hunter Alignment Tools = ±0.08 degree
E. Vehicle Centerline

Fig. 1, Tandem Axle Measurements

Alignment Checking, Tandem Axle

of 1/8 inch (3 mm) or less between the spacing on one side of the vehicle compared to the other, no further action is necessary. If the difference is more than 1/8 inch (3 mm), adjust the forward-rear axle alignment. See **Fig. 1**. For instructions, see **Group 32** in this manual, or the suspension manufacturer's service literature.

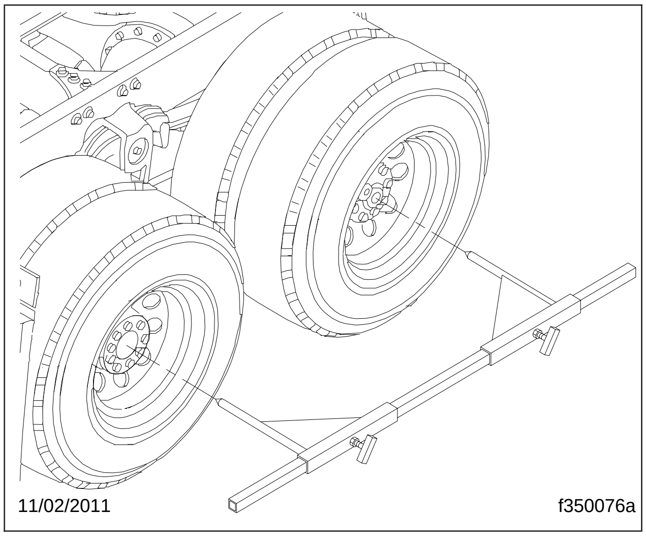


Fig. 2, Center Point Bar Placement

Center Point Bar Construction

Materials Required

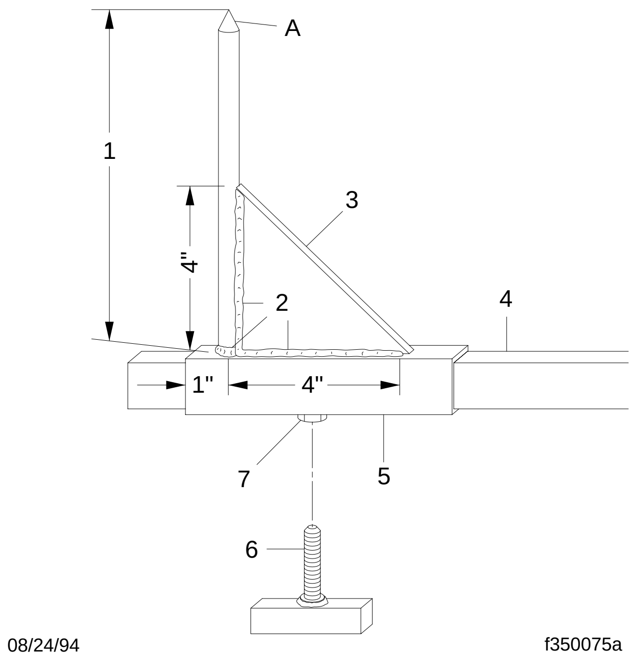
NOTE: To obtain metric conversions (millimeters), multiply the number of inches by 25.4.

The following materials are required:

- 62" of square steel tube (1" x 1", measured outside)
- 12" of square steel tube (1-1/8" x 1-1/8", measured inside)
- 20" of 3/8" steel rod
- two 1/2" x 3" pieces of steel square-bar stock
- one 4" x 4" steel plate, 1/8" thick
- two 3/8–16 capscrews (grade 5), 2" long
- two 3/8–16 hexnuts (equivalent to grade 5)

Construction

1. Cut the 1-1/8 x 1-1/8 inch (inside measurement) square steel tube in half to obtain two pieces 6 inches long. These will be the sliding members (slides) of the center point bar.
2. Cut the 4-inch by 4-inch steel plate diagonally into two pieces (gussets). Weld one gusset to each slide, as shown in **Fig. 1**.
3. Cut the steel rod in half to obtain two 10-inch rods. Grind one end of each to form a point.
4. Weld the pointed steel rods to the slides and gussets, as shown in **Fig. 1**.
5. Drill a 1/2-inch hole in the center of each slide, on the side opposite where the pointer was welded. Drill through only one side of the tube.
6. Directly over each hole drilled in the step above, weld a 3/8–16 nut (equivalent to grade 5).
7. Weld a piece of steel stock, about 1/2-inch wide by 3-inches long, over the head of each of two 3/8–16 by 2-inch long capscrews.
8. Place a slide over each end of the 60-inch piece of steel tube, with the pointed rods to the outside. Screw the handscrews (made in the step above) into the slides until they are clamped tightly to the cross tube.



A. Grind to a point.

1. 3/8-Inch Diameter Rod
2. Weld
3. Gusset
4. 1-Inch Square Steel Tube
5. 1–1/8 Inch Square Steel Tube
6. 3/8–16 Bolt
7. 3/8–16 Nut

Fig. 1, Center Point Bar Construction

Specifications

Method	Maximum Tolerance ± from Perpendicular
Manual	1/4-inch (6 mm)

Table 1, Maximum Tolerance from Perpendicular, Manual Method

Method	Maximum Tolerance ± from Perpendicular
Hunter *	±0.18 degree

* To use Hunter alignment equipment, refer to the applicable Hunter service literature.

Table 2, Maximum Tolerance from Perpendicular, Hunter Equipment

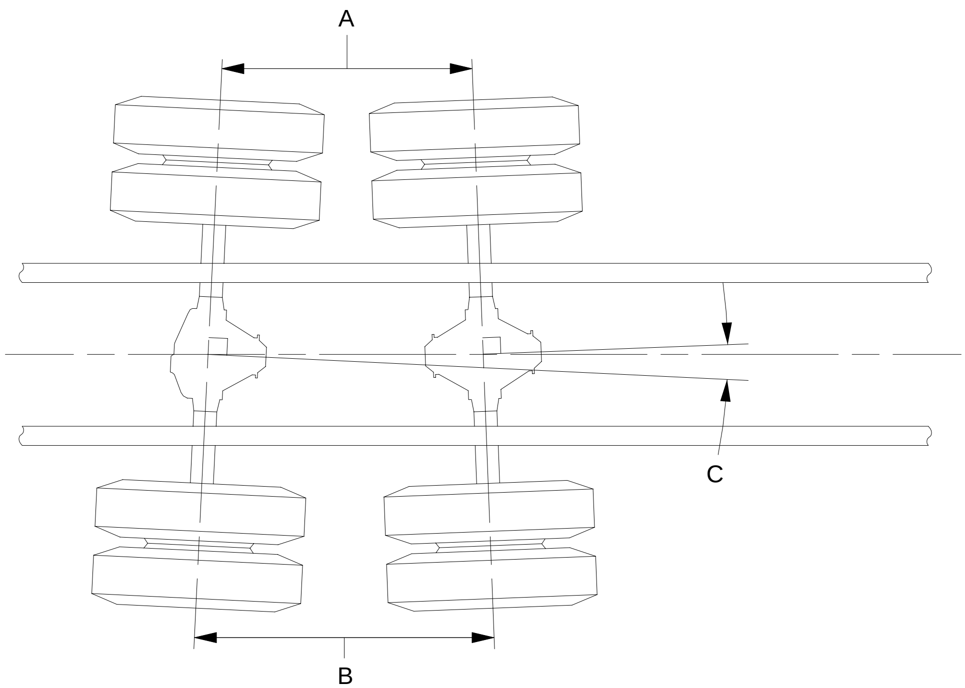
Maximum Tolerance from Perpendicular at Target, Bee Line Equipment	
Distance from the Forward or Rear Drive Axle to Target inches (mm)	Maximum Tolerance ± from Perpendicular inches (mm)
100 (2540)	5/16 (8)
120 (3048)	3/8 (10)
140 (3556)	7/16 (11)
160 (4064)	1/2 (13)
180 (4572)	9/16 (14)
200 (5080)	5/8 (16)
220 (5588)	11/16 (17)
240 (6096)	3/4 (19)
260 (6604)	13/16 (21)

Table 3, Maximum Tolerance from Perpendicular at Target, Bee Line Equipment

Rear Axle Parallelism Specifications	
Method	Maximum Tolerance
Hunter	±0.08 degree maximum axle-to-axle difference; reference "C" in Fig. 1.
Bee Line or Manual	±1/8-inch maximum difference in axle end-spacing; reference "B" minus "A" in Fig. 1.

Table 4, Rear Axle Parallelism Specifications

Specifications



NOTE: See **Table 4** for values corresponding to callouts A, B, and C.

Fig. 1, Tandem Axle Measurements

General Information

These vehicles are equipped with one of two different wheel end assemblies:

- The Con Met PreSet® hub

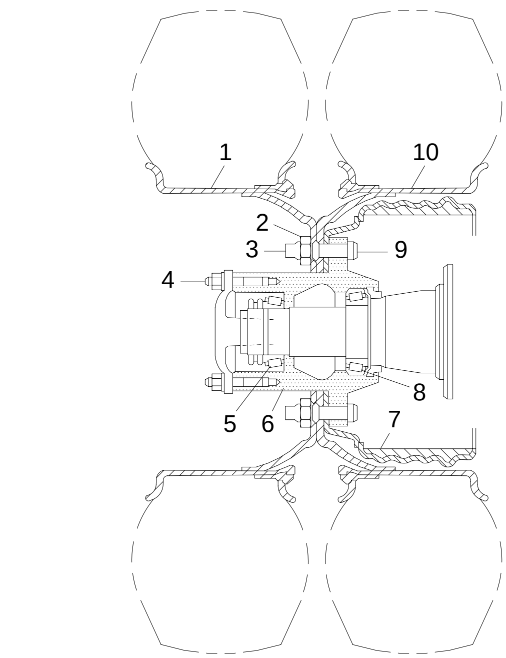
  This wheel end has the bearings and oil seal pre-installed in a hub. To install a new hub, mount it on the axle spindle, and secure it with an Axi-Lok® nut. For instructions, see **Subject 150**. A spacer between the inner and outer bearings adjusts the bearings to near zero end-play and preload when you tighten the retaining nut.

- The traditional hub and bearings

  With traditional wheel ends, the bearings and oil seal must be assembled with the hub when the hub is installed on the axle spindle. First the inner bearing is installed in the hub. The oil seal is pressed into the hub bore. The inner bearing and the hub are then mounted onto the axle spindle. Then the outer bearing is mounted in the hub bore. A nut is installed on the axle spindle end and tightened and loosened to adjust the bearings. Finally, a locking device and jam nut are installed to secure the hub and bearings on the axle. For instructions, see **Subject 140**.

All wheel end assemblies consist of the following components (see **Fig. 1**):

- Wheel Bearings
- Axle Spindle
- Wheel Hub
- Brake Drum
- Wheel Studs



1. Outer Wheel
2. Outer Wheel Nut
3. Wheel Stud
4. Drive Axle Stud
5. Outer Wheel Bearing
6. Hub
7. Brake Drum
8. Inner Wheel Bearing
9. Wheel Stud
10. Inner Wheel

Fig. 1, Wheel Hub and Brake Drum Assembly

Tapered Wheel Bearings

A typical tapered wheel bearing assembly consists of a cone, tapered rollers, a roller cage, and a separate cup that is press-fit in the hub. See **Fig. 2**. All components carry the load, with the exception of the cage, which spaces the rollers around the cone.

Each hub has a set of inner and outer tapered wheel bearing assemblies. On traditional hub and bearing assemblies, the bearing setting is locked in place on the axle spindle by an adjusting nut, a locking device such as a lockring or nut-lock, and a jam nut. See **Fig. 3**.

Drive Axle Spindle Assembly

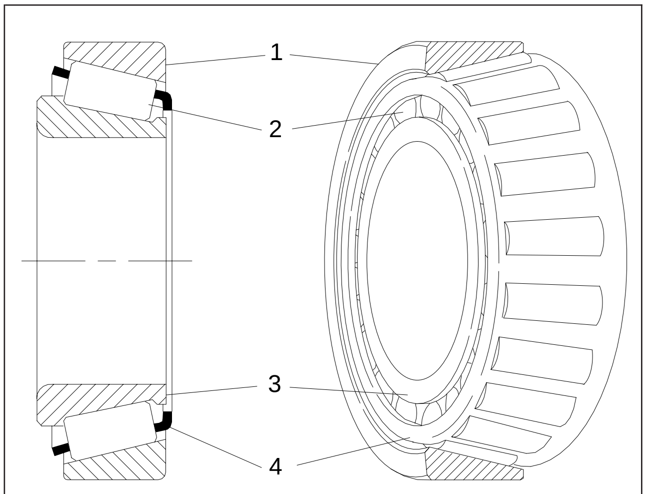
The drive axle spindle assembly is made up of a drive axle flange and shaft, drive axle studs and stud nuts, a flange gasket, an axle spindle, an oil seal, and the locking assembly described above

The surfaces of the spindle and the nut threads are machined. When these surfaces become damaged, repairs are necessary. There are standard methods for performing those repairs that preserve the proper alignment of the axle spindle assembly. Refer to the axle manufacturer for instructions.

CAUTION

The National Highway Traffic Safety Administration (NHTSA) has warned against repairs that in-

General Information



1. Cup
2. Tapered Roller
3. Cone
4. Roller Cage

Fig. 2, Tapered Wheel Bearing Assembly

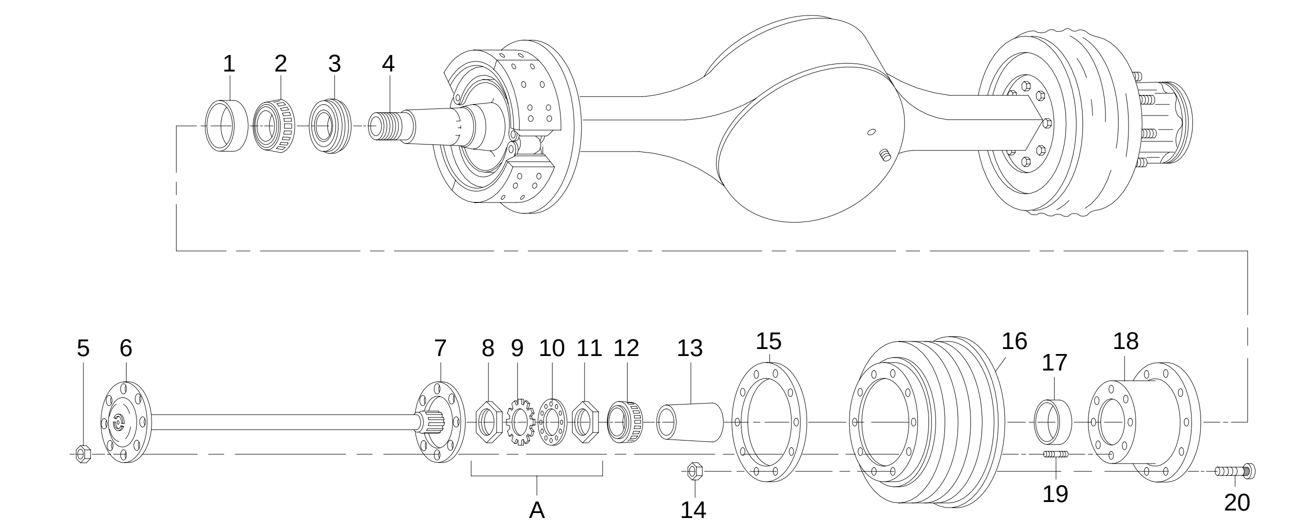
volve cutting off a portion of a damaged spindle and welding on a replacement part. The heat of welding can reduce the strength of spindles made with heat-treated materials and lead to spindle failure. After the cutting and welding operations, the replacement part may not be correctly aligned on the spindle. This can cause damage to the spindle nut.

Wheel Hub

The inner disc wheel and/or brake drum is mounted on an aluminum or iron wheel hub. See **Fig. 3**. Both the inner and outer bearing cups and certain types of wheel studs are press-fit in the hub. The hub is also the interconnecting point for the drive axle shaft and wheels.

Brake Drum

The brake drum and lining work together as a mated friction pair, with the drum responsible for both heat



A. Four-piece bearing system shown; an Axi-Lok locking nut could be used.

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Drive Axle Stud Nut
6. Drive Axle Flange and Shaft
7. Gasket
8. Jam Nut
9. Nut-Lock
10. Lockring
11. Adjusting Nut
12. Outer Wheel Bearing
13. Bearing Spacer (used only with Con-Met PreSet hubs)
14. Brake Drum Nut
15. Hub Spacer
16. Brake Drum
17. Outer Wheel Bearing Cup
18. Hub
19. Drive Axle Stud
20. Wheel Stud

Fig. 3, Typical Drive Axle and Hub Assembly (exploded view)

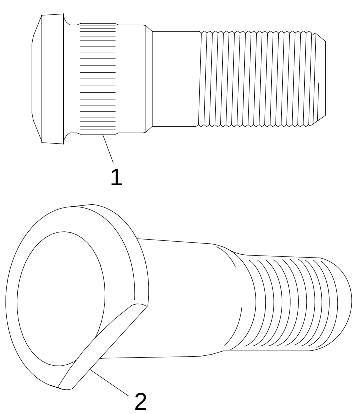
absorption and dissipation. Lining performance and life largely depend on the condition of the drum and whether it can adequately absorb and dissipate heat generated by braking action.

The brake drum is mounted on the outboard face of the hub and fits over the wheel studs. See **Fig. 3**.

Wheel Studs

A headed wheel stud is used on rear axle disc wheel hub assemblies and has either serrations on the stud body or a flat area on the stud's head to prevent the stud from turning in the wheel hub. See **Fig. 4**.

The end of the stud that faces away from the vehicle is stamped with an "L" or "R," depending on which side of the vehicle the stud is installed. Studs stamped with an "L" are left-hand threaded and are installed on the left side of the vehicle. Studs stamped with an "R" are right-hand threaded and are installed on the right side of the vehicle.



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1. Serrations
2. Clipped Head

Fig. 4, Typical Headed Wheel Studs

Hub Assembly Removal and Installation

Removal

1. Park the vehicle, shut down the engine, and chock the front tires. Release the parking brakes.
2. Raise the rear of the vehicle until the tires clear the ground. Then place safety stands under the axle.
3. Back off the slack adjuster to release the rear axle brake shoes.
4. Remove both wheel and tire assemblies. For instructions, see **Group 40**.
5. Remove the brake drum. See **Fig. 1**. For instructions, see **Subject 160**.

NOTE: Oil will spill as the drive axle shaft (or hub cap) and the wheel hub are removed. Place a suitable container under the drive axle flange or hub cap to catch any spilled oil. Dispose of the oil properly.

6. Remove the drive axle stud nuts and washers. See **Fig. 2**.
7. Using a hammer and a soft drift, such as one made of brass, sharply tap the center portion of the drive axle flange. The shaft will usually spring slightly outward after the seal has broken. Remove the drive axle shaft.

CAUTION

When tapping the drive axle flange, avoid striking the drive axle studs. If struck, the studs may bend or break, or the stud threads can be damaged. Replace damaged studs.

NOTE: Even if the drive axle shaft doesn't spring outward, the seal may have loosened enough to allow the shaft to be pulled from the axle housing. If the seal has not broken, repeat the step above.

8. If so equipped, remove the tapered dowels and washers from the drive axle flange.
9. Remove and discard the gasket.
10. Remove the wheel bearing locking device.

    If the axle is equipped with ConMet PreSet hubs, see **Subject 150**.

    If the axle is equipped with a dual-nut wheel bearing lock system, see **Subject 140**.

11. Move the hub about 1/2 inch (13 mm) to jar loose the outer wheel bearing (allow the hub-only assembly to rest on the axle spindle; be careful not to damage the axle spindle threads).

CAUTION

Be careful not to let the outer wheel bearing drop from the axle spindle. Dropping the bearing can warp the cage or damage the rollers, ruining the bearing. On vehicles equipped with WABCO ABS, use care when working with the hubs. To prevent damage to the tone wheel, do not drop the hub, or lay it down in a way that would damage the tone wheel.

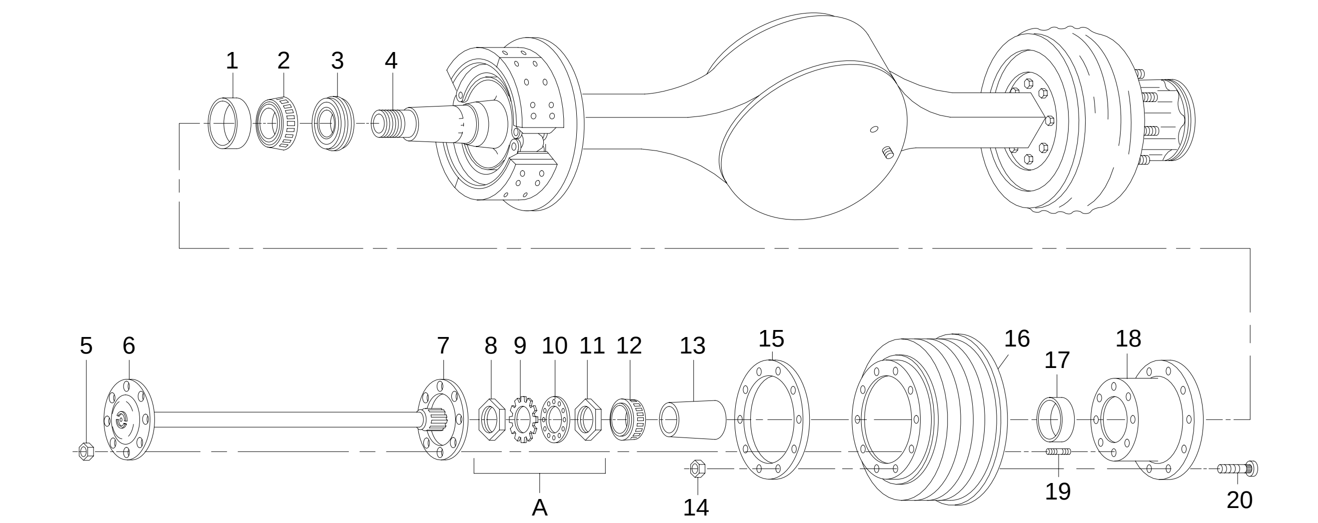
12. Carefully remove the outer wheel bearing; handle the bearings with clean, dry hands. Wrap the bearings in either clean oil-proof paper or lint-free rags.

CAUTION

Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

13. Remove the hub. Be careful not to damage the axle spindle threads as the assembly is removed.
14. Remove the oil seal from the hub.
15. Remove the inner wheel bearing from the hub. Handle the bearings with clean, dry hands, then wrap the bearings in either clean oil-proof paper or lint-free rags. Occasionally, the inner wheel bearing will remain in the hub after the oil seal is removed from the hub. In those cases, place a protective cushion where it will catch the bearings. Then use a hardwood drift and a light hammer to gently tap the bearing out of the cup.

Hub Assembly Removal and Installation



A. Dual-nut wheel bearing lock system shown; an Axi-Lok® locking nut could be used.

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Drive Axle Stud Nut
6. Drive Axle Flange and Shaft
7. Gasket
8. Jam Nut
9. Nut-Lock
10. Lockring
11. Adjusting Nut
12. Outer Wheel Bearing
13. Bearing Spacer (used only with ConMet PreSet® hubs and bearings)
14. Brake Drum Nut
15. Hub Spacer
16. Brake Drum
17. Outer Wheel Bearing Cup
18. Hub
19. Drive Axle Stud
20. Wheel Stud

Fig. 1, Typical Drive Axle and Hub Assembly (exploded view)

Installation

WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

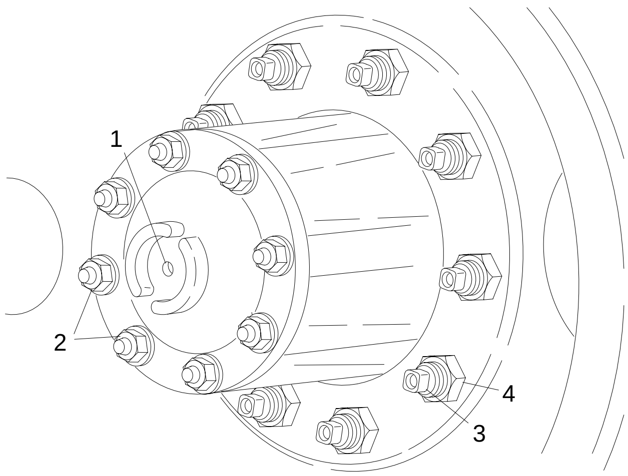
1. Using cleaning solvent, remove the old oil from the axle spindle and the disassembled parts. Allow the parts to dry, or dry them with a clean, absorbent, and lint-free cloth or paper. Wrap a protective layer of friction tape on the axle spindle threads.

IMPORTANT: Be sure to follow all the manufacturer's warnings and instructions when using any solvent.

2. On brake drum assemblies with an aluminum hub, coat the hub and drum contact surfaces with Alumilastic compound or an equivalent.
3. Coat both bearing assemblies with fresh oil. Install the inner wheel bearing and oil seal. Handle the bearings with clean, dry hands. See Section 35.02 for oil seal installation instructions.

CAUTION

Use only fresh oil on the bearing assemblies; old oil could be contaminated with dirt or water (both are corrosives) and could cause damage to both wheel bearing assemblies and the wheel hub.



1. Center Portion of Drive Axle Flange
2. Drive Axle Studs and Nuts
3. Inner Wheel Nut
4. Outer Wheel Nut

Fig. 2, Wheel Assembly and Hub

4. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.

CAUTION

On vehicles equipped with WABCO ABS, use care when installing the hubs. To prevent damage to the tone wheel, do not drop the hub or lay it down in a way that would damage the tone wheel.

5. Mount the bearings and hub on the spindle. Then adjust and secure the bearings.

   If the axle is equipped with ConMet PreSet hubs, see **Subject 150**.

   If the axle is equipped with a dual-nut wheel bearing lock system, see **Subject 140**.

6. Install a new gasket on the drive axle studs.
7. Install the drive axle shaft or, on non-drive axles, the hub cap. The splined end of the axle shaft must seat before the drive axle flange will fit over the studs.
8. If equipped, install the dowels and washers on the drive axle studs. Install the drive axle stud nuts. Using the sequence shown in **Fig. 3**, tighten the nuts 150 to 170 lbf·ft (203 to 230 N·m).

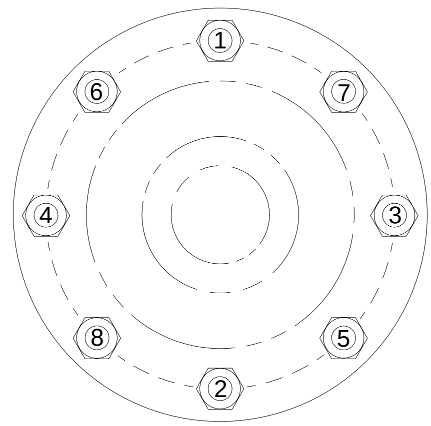


Fig. 3, Tightening Sequence, Drive Axle Stud Nuts

9. Install the brake drum on the wheel hub. For instructions, see **Subject 160**.

WARNING

If the inner wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking action, and the hub flange is probably damaged. In this case, replace it with a new wheel hub assembly. Failure to replace the wheel hub assembly when the conditions described above exist, could result in loss of a wheel or loss of vehicle control, and possible personal injury.

10. Install the inner and outer wheel and tire assemblies. For instructions, see **Group 40**.

WARNING

Add oil to the axle housing bowl or the wheel hub after the drive axle shaft and wheel hub have been serviced. Failure to add oil will damage the wheel bearings and cause them to seize during vehicle operation. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury.

11. For drive axles, pour the recommended drive axle lubricant through the axle housing filler hole.

Hub Assembly Removal and Installation

On Meritor axles, tighten the oil filler plug 35 lbf·ft (47 N·m).

12. Tilt the axle to the left and right, by jacking the opposite side. Hold the tilted position for one minute on each side, to allow oil to run into the wheel end. Return the axle to a level position, and add oil through the axle housing filler hole. About 2 extra pints (1 L) of lubricant will be needed, to bring the oil level even with the base of the filler hole.

NOTE: Drive axle wheel bearings are lubricated by oil drawn from the axle housing bowl section. This method ensures good exchange of heat, prevents stagnation, and minimizes the maintenance required on bearings and hub assemblies.

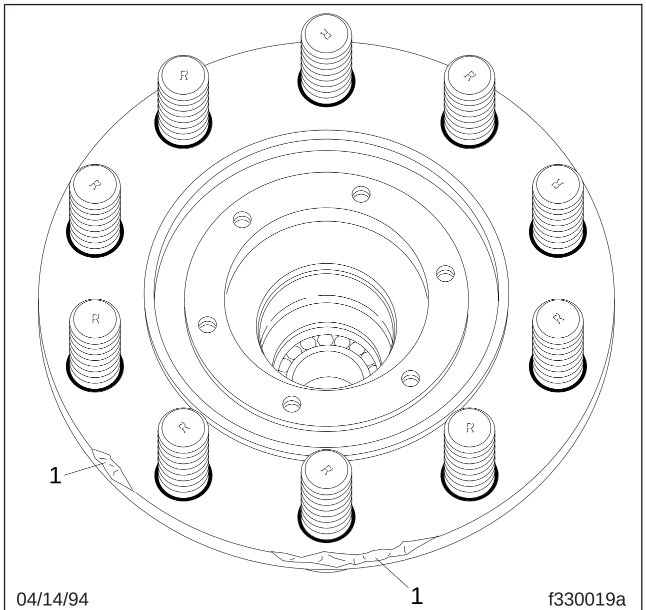
13. For non-drive axles, add about 1 to 1-1/2 pints (0.5 to 0.7 L) of oil to the level shown on the hub cap. Do not overfill. Install the vent plug or threaded filler plug.
14. Turn the wheels, and check the lubricant level.
15. Adjust the rear axle brakes. For instructions, see **Group 42**.
16. Remove the safety stands from under the axle, then lower the vehicle.
17. Apply the parking brakes, then remove the chocks from the front tires.

Axle Components Cleaning and Inspection

Wheel Hub Assembly Inspection

1. Inspect the wheel hub mounting flange. A loose wheel assembly will cause the flange to be worn, jagged, or warped. See **Fig. 1**. Replace the wheel hub if any of these conditions exist.

   Inspect the flange surface around the wheel studs. Improperly torqued wheel nuts will cause worn or cracked stud grooves on the hub. See **Fig. 2**. If wear spots or cracks appear anywhere on the hub, or if the hub is otherwise damaged, replace it with a new one.

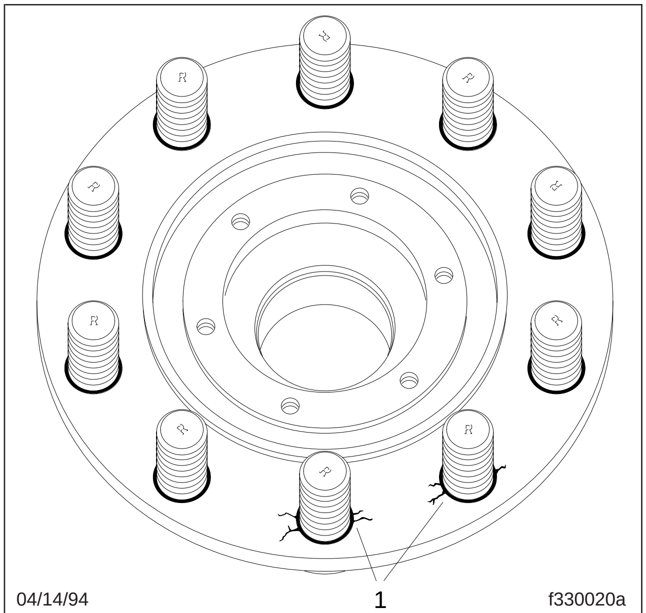


1. Wear Spots

Fig. 1, Damaged Front Axle Wheel Hub

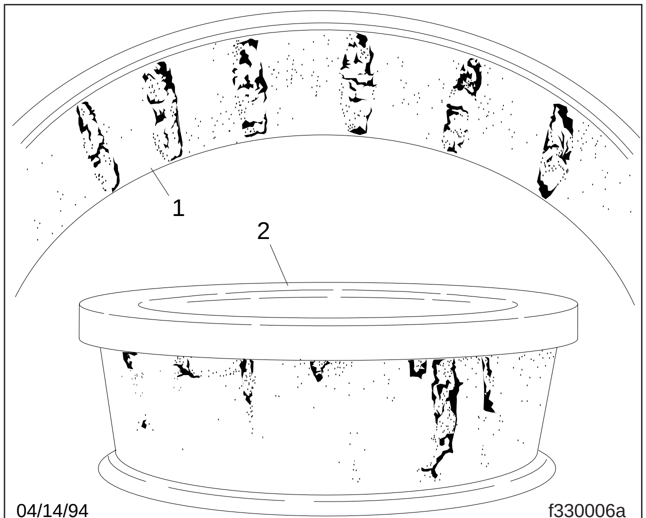
2. Remove all the old oil from the wheel hub cavity. Inspect the inner surface of the hub for cracks, dents, wear, or other damage. Replace the wheel hub if damage exists.

3. Remove all the old grease or oil from the surfaces of the wheel bearing cups. Inspect the wheel bearing cups for cracks, wear, spalling, or flaking. See **Fig. 3**. Replace the cups if damaged in any way. For instructions, see **Subject 120** or **Subject 170**.



1. Cracked Stud Grooves

Fig. 2, Damaged Front Axle Wheel Hub



1. Cup
2. Cone

Fig. 3, Spalling (Flaking) of Wheel Bearing Assembly

4. Inspect the wheel nuts on disc wheel installations, or the rim nuts on spoke-wheel installations. Damaged nuts are usually caused by inadequate tightening and must be replaced with new ones. See **Fig. 4**.

Axle Components Cleaning and Inspection

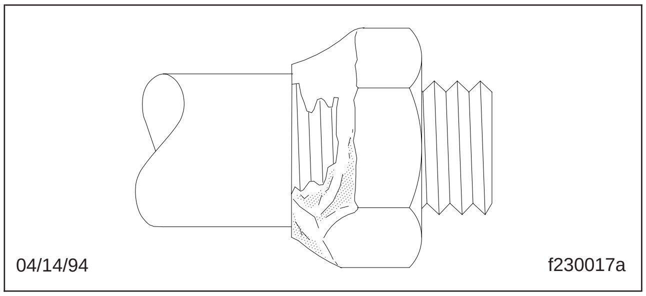


Fig. 4, Damaged Wheel Stud Nut

5. Inspect the wheel or rim studs. Replace studs that are stripped, broken, bent, or otherwise damaged. For instructions, see **Subject 180**.

Wheel Bearing Inspection

Wheel bearings should be very closely inspected at the time of disassembly. Optimal inspection conditions are possible only after the bearings have been thoroughly cleaned using kerosene or diesel fuel oil, and a stiff brush. Before inspecting, clean the bearings.

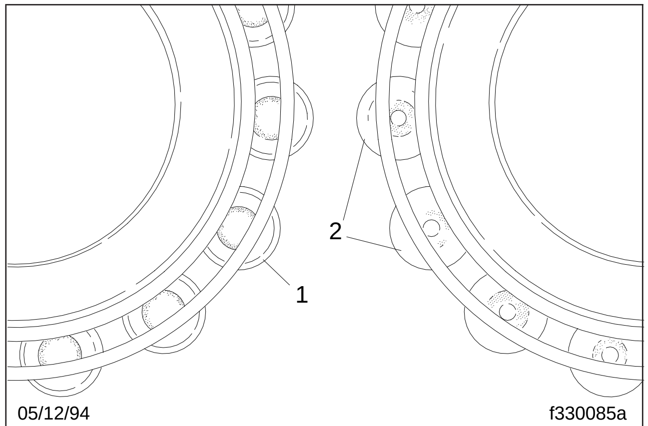
1. Remove the wheel hub and bearing cones. For instructions, see **Subject 100**.
2. Clean all old oil from the bearings and hub cavity with kerosene or diesel fuel and a stiff brush. Don't use gasoline or heated solvent.
3. Allow the cleaned parts to dry, or dry them with a clean absorbent cloth or paper. Clean and dry your hands and all tools used in the maintenance operation. Oil will not stick to a surface which is wet with kerosene or diesel fuel, and the kerosene or diesel fuel may dilute the lubricant.

CAUTION

Do not spin the bearing rollers at any time. Dirt or grit can scratch the roller surface and cause premature wear of the bearing assembly. Treat a used bearing as carefully as a new one.

4. After the bearings are cleaned, inspect the assemblies, which include the rollers, cones, cups, and cages. If any of the following conditions exist, replace the bearing assemblies.

   4.1 Large ends of rollers worn flush to the recess, or radii at the large ends of the rollers worn sharp. These are indications of advanced wear. See **Fig. 5**.



1. New Bearing
2. Worn Bearing Rollers

Fig. 5, Wheel Bearing Roller Wear

   4.2 Visible step wear, particularly at the small end of the roller track. Deep indentations, cracks, or breaks in the cone surfaces. See **Fig. 6**.

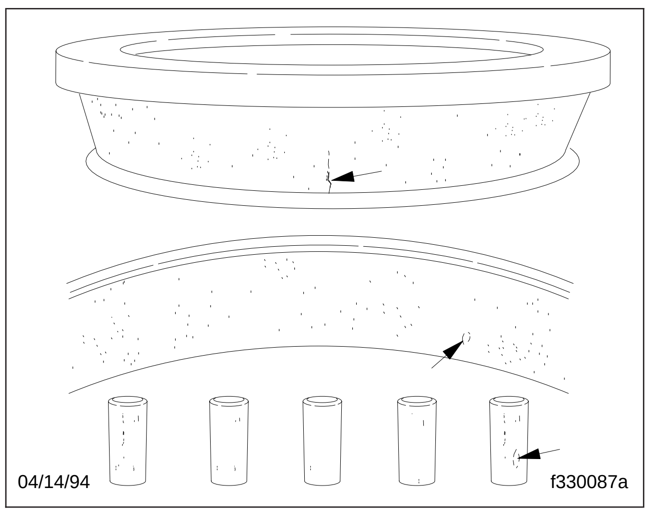


Fig. 6, Indentations, Cracks, or Breaks in Bearing Surfaces

   4.3 Bright rubbing marks on the dark phosphate surfaces of the bearing cage. See **Fig. 7**.

   4.4 Water etch on any bearing surface. Water etch appears as gray or black stains on

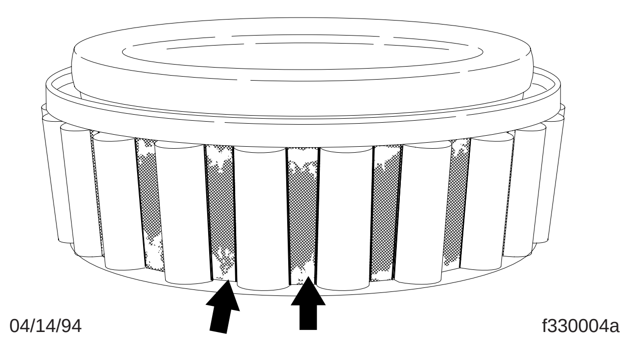


Fig. 7, Rubbing Marks on Bearing Cage

the steel surface, and it greatly weakens the affected area. If water etch is present, replace the bearing seals.

4.5 Etching or pitting on functioning surfaces. See Fig. 8.

4.6 Spalling (flaking) of the bearing cup, roller, or cone surfaces. See Fig. 3.

After inspection, brush the bearings with fresh axle lubricant.

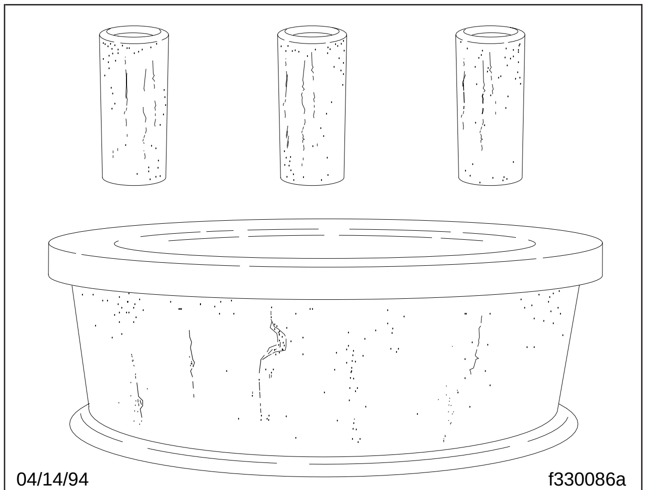
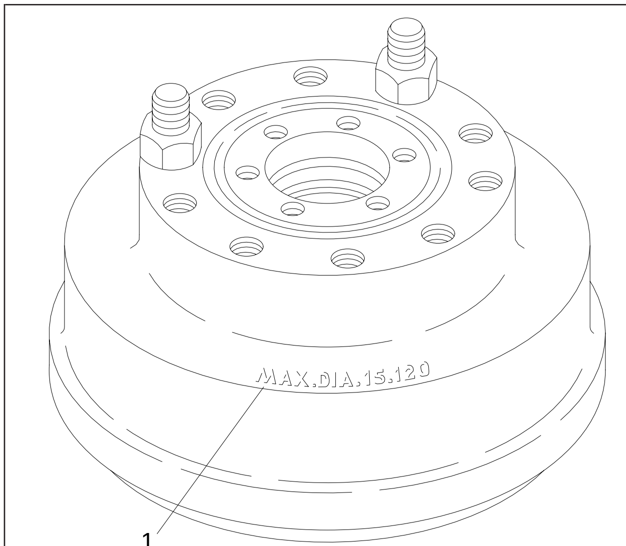


Fig. 8, Etching (Pitting) on Bearing Surfaces

Brake Drum Inspection

New brake drums are purposely undersized to allow for turning (remachining), since in mounting drums on the hub, there can be some eccentricity. If a new drum is installed, the protective coating on the inner friction surface must be removed with a solvent, prior to drum installation, then rinsed with a hot water wash. Use a clean rag to remove any oily residue or metal chips from the friction surface.

If a drum must be turned or replaced, the other same-axle drum must be similarly turned or replaced to provide the same braking power on both wheels. Turned drums should not exceed the maximum allowable diameter, which is stamped on the outside surface of the drum. See Fig. 9 for a typical location of this stamp.



1. Maximum Diameter Stamp

Fig. 9, Outboard Mounted Hub and Drum Assembly

NOTE: Drums that have been turned should then be cleaned by using fine emery cloth followed with a hot water wash. Drums that have been renewed using emery cloth should also be followed with a hot water wash.

CAUTION

Failure to replace drums when worn or turned to limits exceeding the maximum allowable diameter will cause drum weakness and reduced braking capacity, which can lead to distortion, higher drum temperatures, and ultimate drum breakage.

If the drums are turned or replaced, replace the brake linings. See Group 42 for instructions.

Axle Components Cleaning and Inspection

1. Inspect the inner friction surface. If a veneered (highly glossed) or glazed surface exists, renew the drum by using 80-grit emery cloth or by turning the drums.
2. Inspect for heat checking, which is a form of buckling (cracking) resulting from a temperature differential in the drum wall between a relatively cool exterior and a hot friction surface. Heat checking is normal on all drums and may not impair performance and lining life if the network of fine hairline cracks remains small. Examine heat checks of drums frequently to be certain the checks have not widened into drum weakening cracks (substantial cracks extending to the open edge of the drum). Replace the same-axle drums if substantial cracks are present, or if widening of the fine hairline cracks occurs.

NOTE: If normal heat checking as described above is present, inspect the drums at least every 12,000 miles (19 300 km) thereafter. Inspect the drums (using a flashlight from the inboard side of the wheels) every 6000 miles (9700 km). Inspect more often under adverse operating conditions.

3. Check for a contaminated inner friction surface. If fluids are present, such as oil or grease, remove the contaminants. Locate and correct the source of the contamination. If the brake drums are contaminated with fluids, the brake linings will also be affected. Since oil or grease saturated linings cannot be salvaged, they must be replaced. For brake lining replacement procedures, see **Group 42**.

WARNING

If the brake drums are contaminated with fluids, replace the brake linings. Failure to replace fluid contaminated brake linings could result in a partial loss of braking capacity, which could lead to personal injury or property damage.

4. Measure the inside diameter of the drum. If the measured diameter is greater than the maximum allowable diameter, replace the same-axle drums and linings.
5. Check for a variation in gauge readings at different points on the radius of the drum's working surface. If the variation is more than 0.010 inch (0.25 mm) at any point, the drum is out-of-round to unacceptable limits. Remachine or replace the same-axle drums.
6. Inspect the outside surface of the drum. Remove any accumulation of mud, dirt, or rust; foreign matter acts as an insulator, trapping heat within the drum.
7. Check for hard, slightly raised dark-colored spots on the inner friction surface or for a bluish cast on the brake parts, both of which are caused by high temperatures. If the drums' maximum allowable diameters have not been exceeded, remachine both same-axle drums. If the spots or discoloration cannot be removed, or if remachining is not possible, replace the drums. Also replace the brake shoe return springs.

Wheel Bearing Cup Removal and Installation, Ferrous Hubs

Removal

Wheel bearing cups on ferrous hubs are removed and installed by driving them out and pressing them in without heating the hub.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly.
2. Using a mild-steel rod through the opposite end of the hub, drive against the inner edge of the bearing cup. Alternately drive on opposite sides of the cup to avoid cocking the cup and damaging the inside of the hub.

Installation

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly, including the bearing cup bores.
2. Inspect the bearing cup bores of the hub for warpage or uneven surfaces. If a bearing cup bore is damaged, replace the wheel hub assembly.
3. Coat the replacement bearing cup hub contact surface with a film of grease.
4. Position the cup in the hub and press it into place, using a suitable driving tool. Cups must seat against the shoulder in the hub.

WARNING

To prevent skin irritation, wear chemical resistant gloves when working with diesel fuel or kerosene. Also, do not expose these fluids to flames or heat exceeding 100°F (38°C); both are combustible, and could cause personal injury or property damage if ignited.

5. Wipe off the accumulation of grease left after the bearing cup has been seated. Then, using a clean lint-free cloth dampened with kerosene or diesel fuel oil, clean the inner surface of the bearing cup. Wipe the surface dry using a clean, absorbent, and lint-free cloth or paper.

Replacement

1. Remove the wheel hub from the axle. For instructions, see **Subject 100**.
2. If enough threads remain on the damaged stud, remove it by double-nutting the stud. Turn the inner nut with a wrench in order to remove the stud. Then, proceed to the next step.

   If the drive axle stud is broken near the surface of the hub, the stud should be center-drilled using a high-speed drill, and then removed with an easy-out tool. If needed, grind off a flat surface on the damaged stud, then center-punch the surface as a starting point for drilling. Follow these recommendations:

   2.1 Determine the correct drill diameter by referring to the easy-out tool manufacturer's guidelines. At no time should it be large enough to penetrate the threads of the stud; if the stud threads in the wheel hub are damaged, replace the hub.

   2.2 Do not drill more than 1.25 inches (32 mm) into the broken stud, as measured at the stud's entrance into the wheel hub. Drilling through the bottom of the drive axle stud could damage the hub. If the wheel hub is drilled into, replace it.

   2.3 While drilling, keep the cutting surfaces of the drill well lubricated with oil, which acts as a coolant. Allow the drill and drill bit to cool frequently.
3. After the damaged stud is removed, tap out the drive axle stud hole in the wheel to rid the threads of old stud-locking compound. Use an appropriate sized tap, depending on the original drive axle stud installation size.
4. Be sure the threads of the new stud are clean and dry. Then, coat the insertion end of the drive axle stud (the coarse threads) with an anaerobic thread-lock compound.
5. Using double nuts on the fine-thread portion of the stud, install the new stud. Seat the drive axle stud using the torque values in **Specifications 400**.
6. Allow sufficient time for the thread-lock compound to set, as suggested by the manufacturer.
7. If the hub was removed from the axle, see **Subject 100** for installation instructions.

Dual-Nut Wheel Bearing System Installation and Adjustment

Installation and Adjustment

1. Carefully mount the hub and inner wheel bearing assembly on the axle spindle. Be careful not to unseat the inner wheel bearing or seal.
2. Fill the hub cavity with oil, then install the outer wheel bearing; handle the bearings with clean, dry hands. Use care not to damage the bearings as they are seated in the bearing cups. Remove the friction tape from the axle spindle threads.
3. Install the wheel bearing adjusting nut. See **Fig. 1**.

   3.1 After the wheel hub and bearings are assembled on the spindle, tighten the inner adjusting nut finger-tight.

   3.2 While rotating the wheel hub assembly, tighten the adjusting nut 100 lbf·ft (136 N·m).

   3.3 Back off the adjusting nut completely.

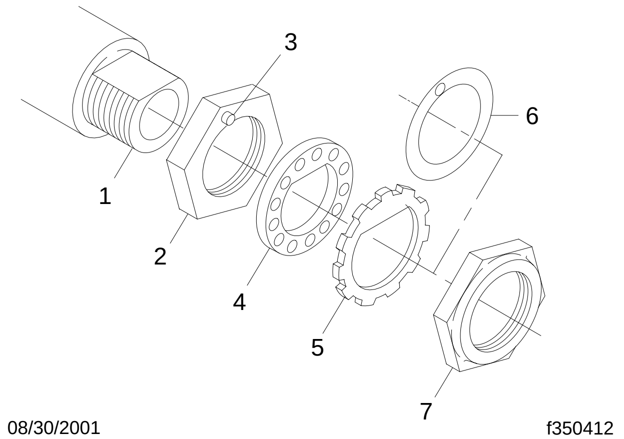
   3.4 Tighten the adjusting nut 20 lbf·ft (27 N·m) while rotating the wheel hub assembly.

   3.5 Back off the adjusting nut one-third turn.
4. Install the locking device and jam nut.

   4.1 Install the locking device.

   NOTE: If no hole in the lockring aligns with the dowel on the adjusting nut, remove the lockring, turn it over and install it again. If a hole still doesn't align with the dowel, loosen the adjusting nut, but only enough to align the dowel with a hole in the lockring.

   4.2 Then install the jam nut, and tighten it to the applicable torque value in **Table 1**.



1. Axle Spindle
2. Adjusting Nut
3. Dowel
4. Lockring
5. Nut-Lock
6. Retaining Washer (may be used in place of nut-lock)
7. Jam Nut

Fig. 1, Axle With Nut-Lock (or washer) and Lockring

Dual-Nut Wheel Bearing Lock Torque Values		
Application	**Size**	**Torque: lbf·ft (N·m)**
Adjusting Nut	—	Stage 1: Tighten to 100 (135)
		Stage 2: Back Off Completely
		Stage 3: Tighten to 20 (25) While Rotating Hub
		Stage 4: Back Off 1/3 Turn
Jam Nut (with Wheel Bearing Nut, Pierced Lockwasher, and Bendable Lockwasher)	1-1/8	Target: 175 (235) Permissible Range: 150–225 (205–305)
	1-1/2 to 2-1/2	Target: 250 (340) Permissible Range: 200–300 (270–405)
	2-5/8 or Larger	Target: 325 (440) Permissible Range: 250–400 (340–540)

Table 1, Dual-Nut Wheel Bearing Lock Torque Values

Dual-Nut Wheel Bearing System Installation and Adjustment

5. With the jam nut installed and tightened, adjust the bearings.

   IMPORTANT: Do not adjust the wheel bearings with the wheel mounted on the hub. You cannot accurately adjust or measure bearing end play with the wheel mounted on the hub.

   5.1 Attach a dial indicator to the hub and set the point of the indicator in line with the end of the axle spindle.

   If using aluminum hubs, you may have to install the brake drum on the hub to provide a steel base for the magnet of the dial indicator. Mount the drum on the hub's drum pilot, then adjust the brake or have someone apply the brakes to hold the drum securely while you secure the drum using the stud at the 12 o'clock position, then the studs at about the 4 o'clock and 8 o'clock positions.

   NOTE: If using a stud-piloted hub and a steel drum, install 1-1/4 inch washers between the nuts and the drum.

   5.2 Release the brakes if you used them to hold the drum while installing it.

   5.3 Grip the sides of the hub at the three o'clock and nine o'clock positions. Push in on the hub (and drum, if applicable), to seat the inboard bearing set. Zero the dial indicator.

   5.4 Once again, grip the sides of the hub at the three o'clock and nine o'clock positions. This time, pull out on the hub (and drum, if applicable). Read the dial indicator, and note the end play.

   5.5 Push the hub back in to confirm that the needle of the dial indicator returns to zero.

6. The end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm). If the end play is not within this range, adjust the end play.

   6.1 Remove the jam nut and locking device, and back off or tighten the inner adjusting nut.

   6.2 Install the locking device and jam nut as described earlier, and measure the end play. If the end play is not between 0.001 and 0.005 inch (0.03 and 0.13 mm), turn the adjusting nut again.

   6.3 Once the end play is correct, bend two tabs of the nut-lock over opposing flats on the jam nut.

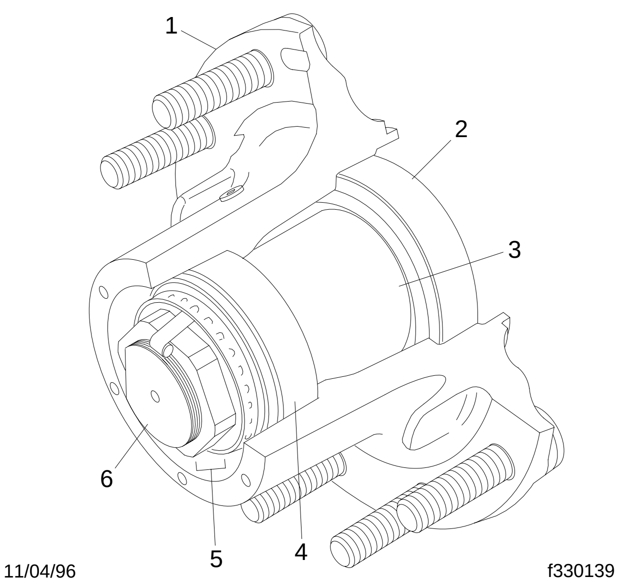
   6.4 Rotate the hub in both directions. It should turn freely with no dragging or binding. End play should be between 0.001 and 0.005 inch (0.03 to 0.13 mm).

ConMet PreSet® Hub Installation and Adjustment

General Information

ConMet PreSet® drive axle hubs are equipped with a special tubular spacer inside the hub, between the inner and outer bearings. See **Fig. 1**.

Wheel bearing adjustment is unnecessary when installing these hubs, because the spacer, together with specially toleranced bearings, automatically sets the bearing end-play to zero. Rear axle PreSet hubs can be identified by the part number NP840302 stamped on the outer bearing cone. The outer bearing cone is visible when the retaining nut is removed. See **Fig. 2**.



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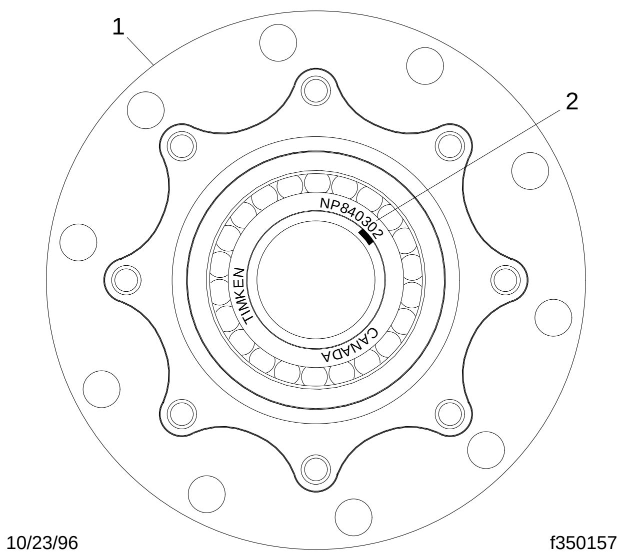
NOTE: Front axle hub shown.

1. Hub
2. Inner Bearing
3. Bearing Spacer
4. Outer Bearing
5. Axilok Retaining Nut
6. Axle Spindle

Fig. 1, ConMet PreSet Hub (cut-away view)

NOTE: If you are replacing the bearings for a PreSet hub, and the required bearings are not available, use standard wheel bearings. Remove the bearing spacer and adjust the bearings manually. See the installation instructions for "Using Standard Bearings," under "Installation and Adjustment."



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1. Rear Axle Hub
2. Outer Bearing Cone and Part Number

Fig. 2, Identifying a ConMet PreSet Hub

CAUTION

Do not use the bearing spacer with standard wheel bearings. To do so may result in too much bearing end-play, which could damage the wheel bearings, oil seals, the axle spindle, and the hub.

ConMet PreSet hubs use Axilok® retaining nuts. See **Fig. 3**. Axilok retaining nuts can be damaged if they are not removed or installed correctly. Use the following guidelines when removing and installing Axilok retaining nuts.

- Use only the correct size, *six-point* socket to remove or install Axilok spindle nuts. Do not use a worn or loose-fitting socket. *Do not use a 12-point socket.*
- Do not use hammers, chisels, pliers, wrenches, or power tools to remove or install Axilok nuts.
- Do not use an Axilok nut if the locking clips are damaged or missing, or if the retainer cage tab or D-flat is damaged or missing.
- Never try to repair a damaged Axilok nut; always replace it with a new one.
- Always start an Axilok installation by hand. A good-fitting six-point socket will completely dis-

ConMet PreSet® Hub Installation and Adjustment

engage the nut's locking clips, allowing it to spin freely by hand. See **Fig. 4**. Use an accurately calibrated torque wrench to tighten the nut to its final torque value.

- After the nut is installed, always make sure that both locking clips are present and engaged in the retainer cage. See **Fig. 4**. If the locking clips are not engaged, the nut is not locked in position and can rotate freely.

Installation and Adjustment

Using Preset Bearings

1. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.
2. If present, remove the temporary plastic bearing cover from the front of the hub.
3. Install the PreSet hub assembly all the way onto the axle spindle. A temporary plastic alignment sleeve may be installed in the center of a new hub. It will be pushed out when the hub is installed on the axle spindle. If it is present, remove and discard this sleeve.

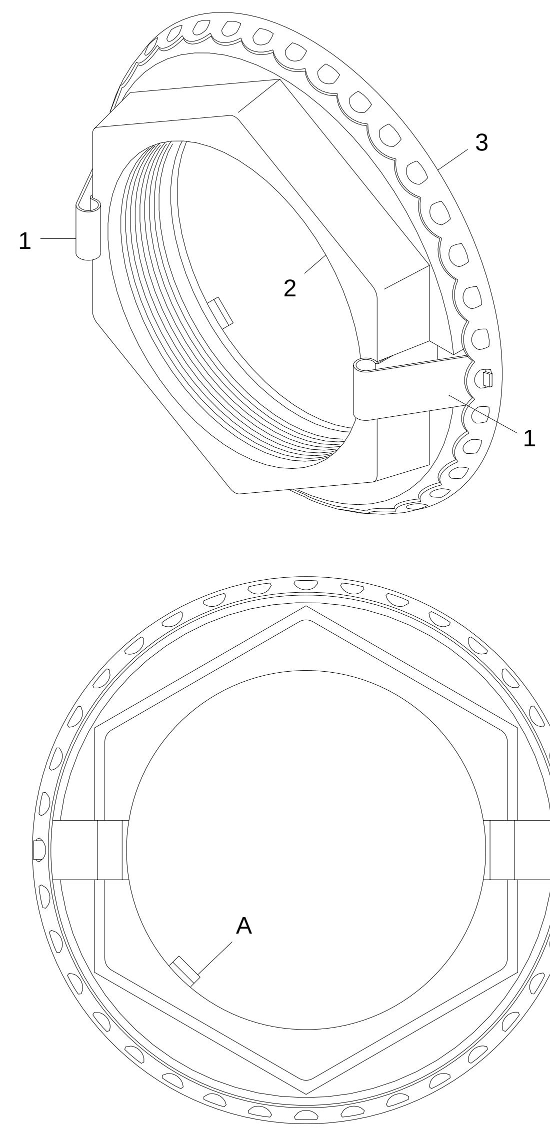
CAUTION

Do not remove the outer wheel bearing once the hub is installed on the axle. Removing the outer bearing could cause the oil seal to become misaligned, which could cause damage to the wheel bearings, the hub, and the axle spindle.

WARNING

Follow the guidelines at the beginning of this subject when installing an Axilok nut. Axilok retaining nuts secure the hub assemblies on the axle. If the Axilok nut is not correctly installed, the hub could separate from the axle, resulting in severe personal injury or death.

4. Install the Axilok retaining nut onto the axle spindle. See **Fig. 3**.
5. Tighten the retaining nut 250 lbf·ft (339 N·m). Do not back off the retaining nut. The nut should lock in place when you remove the wrench. If it does not, advance it until it does.



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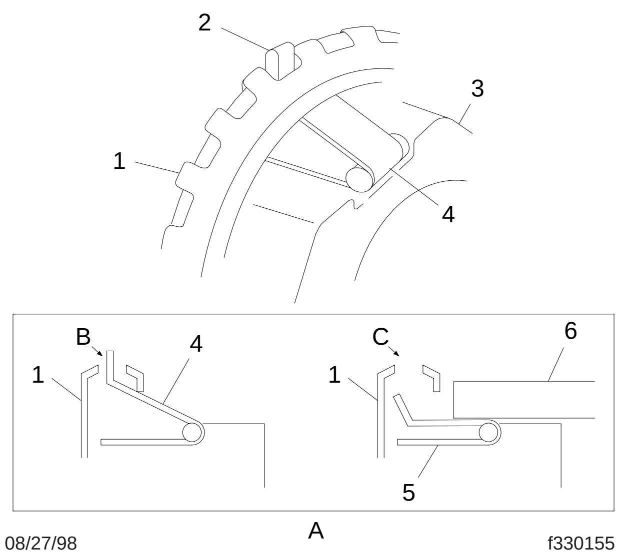
A. The retainer tab must engage the keyway of the axle spindle.

1. Locking Clip
2. Nut
3. Retainer

Fig. 3, Rear Axle Axilok Nut

6. Install the axle shaft, using a new gasket. See **Subject 100** for instructions.

ConMet PreSet® Hub Installation and Adjustment



A. Cross-Section View
B. The tab is engaged.
C. The tab is disengaged.

1. Retainer Cage
2. Locking Clip Tab
3. Nut
4. Locking Clip
5. Locking Clip (compressed)
6. Six-Point Socket

Fig. 4, Axilok Nut, Checking the Position of the Locking Clip

WARNING

Add oil to the axle housing bowl or the wheel hub after the drive axle shaft and wheel hub have been serviced. Failure to add oil will damage the wheel bearings and cause them to seize during vehicle operation. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury.

7. Pour the recommended drive axle oil through the axle housing filler hole.

Using Standard Bearings

1. If not already done, remove the tubular spacer from inside the hub. Save it for future use to convert the hub back to the PreSet system.
2. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.
3. Coat both bearing assemblies with fresh oil. Install the inner wheel bearing and oil seal in the hub. See **Section 35.02** for instructions on installing the various types of oil seals.
4. Install the hub with the inner bearing and oil seal onto the axle spindle. Be careful not to unseat the inner bearing or oil seal.
5. Fill the hub cavity with oil, and install the outer wheel bearing.

CAUTION

Do not remove the outer wheel bearing once the hub is installed on the axle. Removing the outer bearing could cause the oil seal to become misaligned, which could cause damage to the wheel bearings, the hub, and the axle spindle.

WARNING

Follow the guidelines at the beginning of this subject when installing an Axilok nut. Axilok retaining nuts secure the hub assemblies on the axle. If the Axilok nut is not correctly installed, the hub could separate from the axle, resulting in severe personal injury or death.

6. Adjust the wheel bearings.
   - 6.1 Install the Axilok nut and turn it against the bearing while spinning the wheel. See **Fig. 3**.
   - 6.2 Tighten the nut 90 to 110 lbf·ft (122 to 149 N·m) while spinning the wheel in both directions.
   - 6.3 Loosen the nut to zero torque and spin the wheel a few turns.
   - 6.4 Tighten the nut 50 lbf·ft (68 N·m) while spinning the wheel in both directions. Back off the nut one-eighth to one-sixth turn.
   - 6.5 Remove the wrench from the nut. The Axilok nut should automatically lock in place. If it does not, advance it until it does.
7. Install the axle shaft, using a new gasket. See **Subject 100** for instructions.

ConMet PreSet® Hub Installation and Adjustment

WARNING

Add oil to the axle housing bowl or the wheel hub after the drive axle shaft and wheel hub have been serviced. Failure to add oil will damage the wheel bearings and cause them to seize during vehicle operation. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury.

8. Remove the fill plug from axle housing, then pour the recommended drive axle oil through the axle housing filler hole. Install the filler plug.

Outboard-Mounted Drum Removal and Installation

WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

For an exploded view of a typical wheel and axle assembly, including the brake drum, see **Fig. 1**.

Removal

1. Park the vehicle, shut down the engine, release the parking brakes and chock the front tires.
2. Raise the rear of the vehicle until the tires clear the ground. Then place safety stands under the axle.
3. Back off the slack adjuster to release the rear axle brake shoes.

WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

4. Remove the wheel and tire assembly. See **Group 40** for instructions.

   To minimize the possibility of creating airborne brake lining dust, clean the dust from the brake drum, brake backing plate, and brake assembly, using an industrial-type vacuum cleaner equipped with a high-efficiency filter system. Then, using a rag soaked in water and wrung until nearly dry, remove any remaining dust. Don't use compressed air or dry brushing to clean the brake assembly.
5. Remove the brake drum. See **Fig. 1**.

Installation

1. On brake drum assemblies with an aluminum hub, coat the hub and drum contact surfaces with Alumilastic® compound or an equivalent.
2. Install the brake drum on the wheel hub.

   2.1 On hub-piloted drums, position the brake drum on the top step of the pilot pad. One of the hub's pilot pads should be at the twelve o'clock (top center) position. See **Fig. 2**.

   IMPORTANT: If the drum is not positioned correctly, the pilot pad could be damaged when the wheel nuts are torqued.

   2.2 Make sure that the pilot pads securely center the drum (space between drum and hub is equal all around the hub).

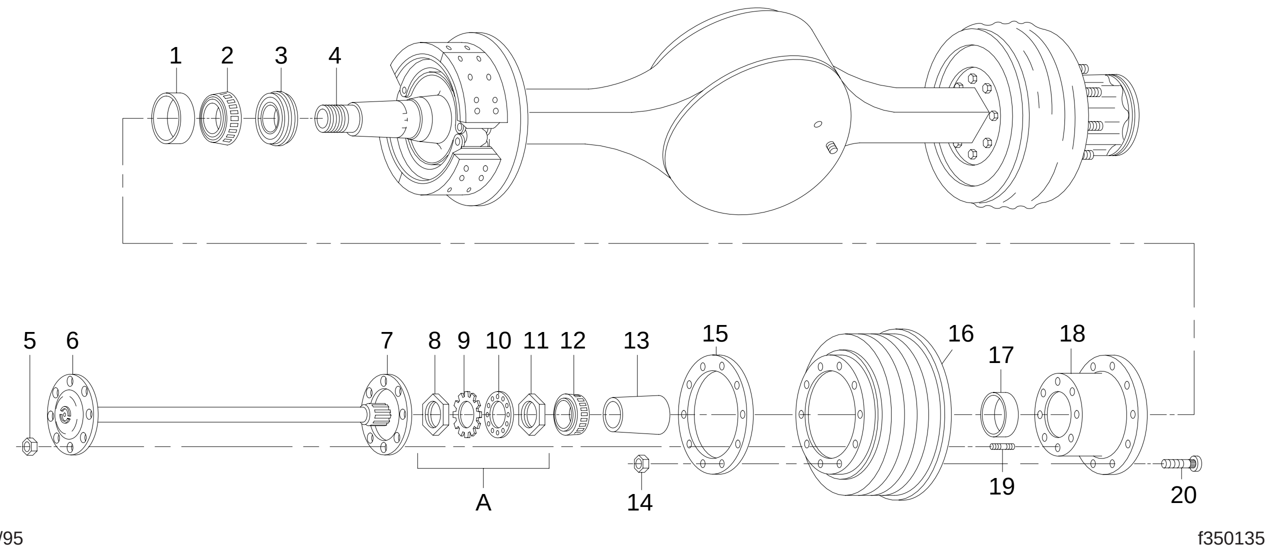
   IMPORTANT: If damage to the pads prevents the drum from centering, replace the hub. If necessary to hold the drum in position, adjust the brakes before installing the wheels.
3. Install the wheel and tire assembly. To ensure that the drum does not slip off the pilot pad, follow the correct nut tightening sequence. For instructions, see **Group 40**.

WARNING

If the wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking ability, and the hub flange is probably damaged. In this case, replace it with a new wheel hub assembly. Failure to replace the wheel hub assembly when the conditions described above exist, could result in the loss of a wheel or loss of vehicle control, and possible personal injury.

4. Adjust the rear axle brakes. For instructions, see **Group 42**.

Outboard-Mounted Drum Removal and Installation



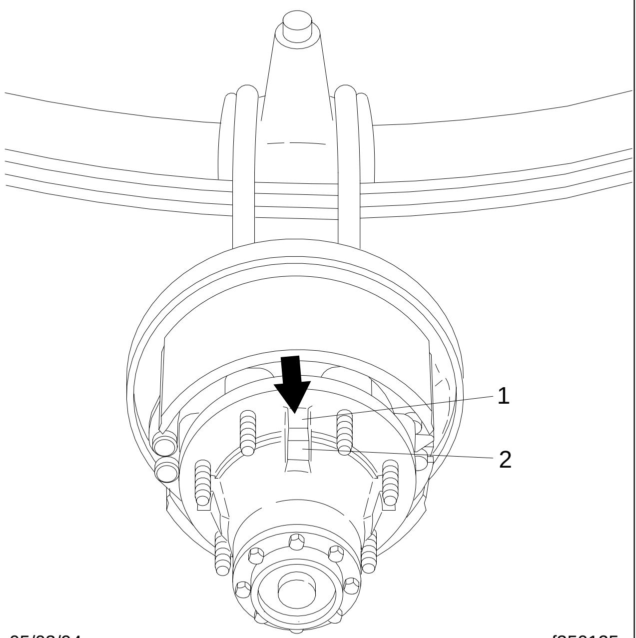
A. Four-piece bearing system shown; an Axi-Lok locking nut could be used.

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Drive Axle Stud Nut
6. Drive Axle Flange and Shaft
7. Gasket
8. Jam Nut
9. Nut-Lock
10. Lockring
11. Adjusting Nut
12. Outer Wheel Bearing
13. Bearing Spacer (used only with Con-Met integral wheel bearing packs)
14. Brake Drum Nut
15. Hub Spacer
16. Brake Drum
17. Outer Wheel Bearing Cup
18. Hub
19. Drive Axle Stud
20. Wheel Stud

Fig. 1, Typical Drive Axle and Hub Assembly (exploded view)

5. Remove the safety stands from under the axle; lower the vehicle.
6. Remove the chocks from the tires.

Outboard-Mounted Drum Removal and Installation



NOTE: Pilot pad at 12 o’clock position
1. Drum Pilot
2. Wheel Pilot

Fig. 2, Hub Pilot Pads

Wheel Bearing Cup Removal and Installation, Aluminum Hubs

Removal

To ensure a tight fit, wheel bearing cups are purposely larger than the wheel hub bores they occupy. To remove the bearing cups, aluminum hub bores must be temporarily expanded by heating the hub in an oven (the bearing cups will also expand, but to a considerably lesser extent). If adequate heating facilities are not available, replace the hub, wheel stud, and bearing cup assembly.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly.

IMPORTANT: Be sure to follow all the manufacturer's warnings and instructions when using any solvent.

2. Oven-heat the hub to a temperature range of 240 to 280°F (116 to 138°C). Make sure the oven thermostat is accurately set; if unsure, use an oven thermometer to check the temperature of the oven before placing the hub inside.

   If adequate heating facilities are not available, replace the hub, wheel stud, and bearing cup assembly.

WARNING

Do not use oxyacetylene equipment or similar equipment to heat the hub. Oxyacetylene equipment or similar equipment will cause cracks in the hub which could cause loss of a wheel and loss of vehicle control, leading to personal injury or property damage.

3. Wearing heavy protective gloves, remove the hub from the oven. Place the hub on a suitable press so that the base is fully supported. Quickly press out the bearing cups.

Installation

To install the bearing cups, aluminum hubs must again be temporarily expanded using oven heating. When the hub is properly heated, the bearing cup and hub can be press-fit together, using a suitable press.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly, including the bearing cup bores.
2. Inspect the bearing cup bores of the hub for warpage or uneven surfaces. If a bearing cup bore is damaged, replace the wheel hub assembly.
3. Oven-heat the hub to a temperature range of 240 to 280°F (116 to 138°C). Make sure the oven thermostat is accurately set; if unsure, use an oven thermometer to check the temperature of the oven before placing the hub inside.

WARNING

Do not use oxyacetylene equipment or similar equipment to heat the hub. Oxyacetylene equipment or similar equipment will cause cracks in the hub which could cause loss of a wheel and loss of vehicle control, leading to personal injury or property damage.

4. Coat the replacement bearing cup hub contact surface with a film of grease.
5. Wearing heavy protective gloves, remove the hub from the oven.
6. Place the hub on a suitable press so that the base is fully supported. Quickly press-fit the bearing cup into the wheel hub until it is completely and evenly seated. Be careful not to shave the sides of the bearing cup bore as the bearing cup is seated. The accumulation of debris will prevent the cup from being seated and will also cause permanent damage to the wheel hub. If the sides of the bearing cup bore are damaged during installation, replace the wheel hub assembly.
7. Allow the wheel hub to cool before handling. Then, using a 0.0015-inch feeler gauge, check at several places for the seating of the bearing cup in the bearing cup bore. The gauge should not enter beneath the cup. If it does, there is probably dirt or debris preventing the cup from seating. Using the instructions above, remove the cup, then remove the foreign matter. Reinstall the cup.

Wheel Bearing Cup Removal and Installation, Aluminum Hubs

WARNING

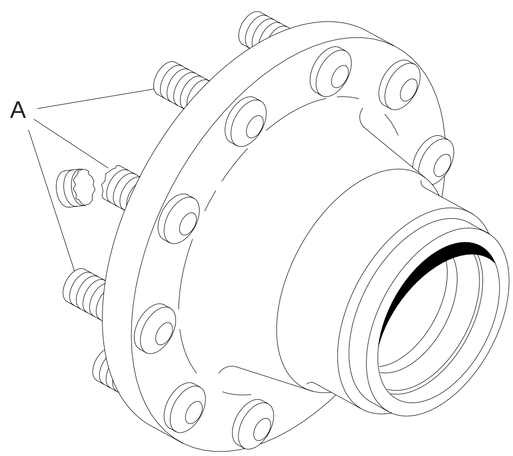
To prevent skin irritation, wear chemical-resistant gloves when using kerosene or diesel fuel. Also, do not expose these fluids to flames or heat exceeding 100°F (38°C); both are cumbustible and could cause personal injury or property damage if ignited.

8. Wipe off the accumulation of grease left after the bearing cup has been seated. Then, using a clean, lint-free cloth dampened with kerosene or diesel fuel oil, clean the inner surface of the bearing cup. Wipe the surface dry using a clean, absorbent, and lint-free cloth or paper.

Replacement

WARNING

If a wheel stud breaks, the remaining studs are subjected to undue strain and could fail due to fatigue. When a broken stud is replaced, replace the stud on each side of it. See Fig. 1. If more than one stud is broken, replace all of the studs. Failure to replace the studs could result in the loss of a wheel or loss of vehicle control, possibly resulting in personal injury.



NOTE: Front hub shown.

A. Replace

Fig. 1, Wheel Stud Replacement

1. Remove the wheel hub from the axle. For instructions, see **Subject 100**.
2. If a bent portion of a wheel stud will have to pass through the wheel stud bore, cut off the bent portion before removing the wheel stud.
3. Place the wheel hub on a suitable press; make sure the hub flange is supported evenly around and next to the stud being removed. With steady movement, press the damaged stud out of the hub.

CAUTION

Do not use a drift and hammer or concentrated heat for removing and installing the wheel studs. Constant, smooth movement of the wheel stud is necessary to ensure the least amount of metal removal from the wheel stud bore. Concentrated heat will damage the hub. If the hub is damaged during wheel stud removal or installation, replace it.

4. Apply a coating of clean axle grease to the entire shaft on headed studs.
5. With the hub on a suitable press, make sure the hub flange is supported evenly around and next to the stud being installed.
6. Position the stud in its hole. *Be sure the flat edge of the head flange on clipped studs is in line with the shoulder on the hub.*

CAUTION

If headed studs with serrations are being installed, position the teeth of the serrated portion in the notches carved by the original wheel studs during factory installation. If additional metal is scraped from the wheel stud bores, the locking action provided by the serrations will be greatly weakened. Loss of locking action will prevent achieving final torque of the wheel nuts during wheel installation. If final wheel nut torques during wheel installation cannot be achieved, replace the wheel hub assembly.

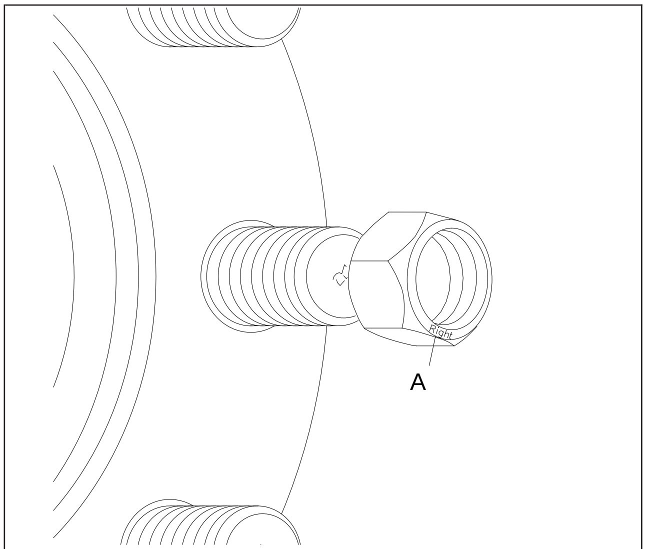
NOTE: If the left side of the vehicle is being serviced, the replacement wheel stud must be stamped with an "L" (left-hand threaded), and the face of the nut must be stamped "Left." If the right side of the vehicle is being serviced, the replacement stud must be stamped with an "R" (right-hand threaded), and the face of the nut must be stamped "Right." See **Fig. 2**.

7. With steady movement, press the new stud all the way into the hub.
8. Make sure the stud is fully seated and that its head (flange) is not embedded into the hub. If the head of the stud is embedded into the hub, replace the hub.

WARNING

Don’t embed the wheel stud heads in the wheel hub. Wheel studs with heads embedded in the wheel hub will weaken the wheel hub flange.

Wheel Stud Replacement



A. "Right"

Fig. 2, Thread Stamp Location

Weakness in the wheel hub can result in the loss of a wheel or loss of steering control, possibly resulting in personal injury.

9. Wipe off any grease on the wheel studs and wheel hub. Install wheel nuts on dry wheel studs only.
10. Install the wheel hub on the axle. For instructions, see **Subject 100**.

Troubleshooting Tables

Problem — Noisy Bearings or Excessive Bearing Replacement Intervals

Problem — Noisy Bearings or Excessive Bearing Replacement Intervals	
Possible Cause	**Remedy**
Not enough oil was used on the bearings, or the wrong type of oil was used.	Clean, then inspect the bearings for wear. Replace worn seals. Coat the bearing assemblies with fresh oil. For lubricant specifications, see **Specifications 400**.
Foreign matter or corrosive agents entered the bearing assembly. Dirt or metallic debris from the bearings was not removed.	Clean, then inspect the bearings for wear. Replace worn seals. Also clean the wheel hub, the axle spindle, and any other component in contact with the bearing lubricant.
An incorrect adjustment of the wheel bearings is causing noise and wear.	Adjust the wheel bearings following the instructions in **Subject 140** or **Subject 150**.
Flat spots or dents on the roller surface were caused by skidding of the roller or improper handling of the wheel bearing during installation.	Clean, then inspect the bearing rollers. Replace the bearing if damaged. Coat the replacement bearings with fresh oil. For lubricant specifications, see **Specifications 400**.

Problem — Broken Wheel or Rim Studs

Problem — Broken Wheel or Rim Studs	
Possible Cause	**Remedy**
The wheel or rim nuts were overtightened.	Replace the wheel or rim studs. See Group 40 of the *Business Class M2 Maintenance Manual* for the wheel or rim nut tightening sequence.
An incorrect nut tightening sequence was used.	
The wrong brake drums were installed.	Install new brake drums.
Wheels are mismatched (hub-piloted wheels are mixed with stud-piloted wheels).	Install properly matched wheels.
The vehicle is being overloaded.	Do not exceed the maximum load-carrying capacity of the vehicle.

Problem — Damaged Hub

Problem — Damaged Hub	
Possible Cause	**Remedy**
(Cracked hub) Local surface of an aluminum hub was heated higher than 350°F (177°C) during bearing cup removal.	Replace the hub assembly. When removing the bearing cup, oven-heat the hub.
(Bent flange) Incorrect installation of the wheel studs, such as using a hammer and drift, or the hub flange was not fully supported on the press during wheel stud replacement.	Replace the hub assembly. Replace the wheel studs as instructed in **Subject 180**.
The wrong brake drums were installed.	Install new brake drums.
Insufficient tightening of the wheel nuts to the wheel hub.	Replace the hub assembly and tighten the wheel nuts to the values in **Specifications 400**.

Troubleshooting

Problem — Loss of Lubricant From the Wheel Hubs

Problem — Loss of Lubricant From the Wheel Hubs	
Possible Cause	**Remedy**
The drive axle studs are loose.	Tighten the nuts to the torque values in **Specifications 400**. Add lubricant to the axle housing or to the wheel hub.
The seals or gaskets are worn or damaged.	Replace worn or damaged parts.
Minor burrs or rough spots are on the inboard portion of the drive axle flange.	Use fine-grit emery cloth to remove the burrs or rough spots. If they cannot be removed, replace the drive axle shaft.

Problem — Vehicle Does Not Slow Down Quickly Enough When Brakes Are Applied

Problem — Vehicle Does Not Slow Down Quickly Enough When Brakes Are Applied	
Possible Cause	**Remedy**
The brake linings are glazed (dirt or grease build-up) or are worn unevenly.	Install new brake linings on both sets of axle brake shoes. Clean, turn, or replace the drums.
The brake drums are worn, heat-checked, or cracked.	Install new brake drums.

Problem — Service Brakes Grab or Pull

Problem — Service Brakes Grab or Pull	
Possible Cause	**Remedy**
The drum could be out of round if it was not correctly positioned on the drum pilot tabs before the wheel was installed.	Position one of the hub-piloted tabs in the top position before placing the drum on the hub. When doing so, be sure the drum is located flat against the hub and on the largest-diameter portion of the pilot tabs. After placing the wheel(s) on the studs, firmly hand-tighten the nut on the stud closest to the top position. Proceed with the other nuts.
See the air brake system troubleshooting section in **Group 42**.	

Problem — Poor Lining-to-Drum Contact

Problem — Poor Lining-to-Drum Contact	
Possible Cause	**Remedy**
The inside surface of the brake drum is scored or grooved.	Install new brake linings on both sets of axle brake shoes. Turn or replace the brake drums.
The brake shoes are stretched or bent.	Replace the brake shoes.
Undersized linings were installed.	Install new brake linings on both sets of axle brake shoes.
An incorrect grind was used on the brake linings.	
The wrong brake drums were installed.	Install new brake drums.
An incorrect adjustment of the wheel bearings is causing wheel instability.	Adjust the wheel bearings following the instructions in **Subject 140** or **Subject 150**.

Problem — Brake Linings Are Tapered Across the Width

Problem — Brake Linings Are Tapered Across the Width	
Possible Cause	**Remedy**
The inside surface of the brake drum is scored or grooved.	Install new brake linings on both sets of axle brake shoes. Turn or replace the brake drums.
The brake shoes are bent.	Replace the brake shoes.
An incorrect adjustment of the wheel bearings is causing wheel instability.	Adjust the wheel bearings following the instructions in **Subject 140** or **Subject 150**.

Problem — Brake Shoes on the Same Brake Are Wearing Unequally

Problem — Brake Shoes on the Same Brake Are Wearing Unequally	
Possible Cause	**Remedy**
The brake linings are not a matched set. Different friction codes or different brands of brake linings are installed.	Install a new matched set of brake linings on both sets of axle brake shoes. Clean, turn, or replace the drums.
The inside surface of the brake drum is in poor condition.	Turn or replace the brake drums.
The wheel bearings are out of adjustment.	Adjust the wheel bearings following the instructions in **Subject 140** or **Subject 150**.

Problem — Edge of the Lining Is Showing Wear

Problem — Edge of the Lining Is Showing Wear	
Possible Cause	**Remedy**
The brake lining is too wide.	Install new brake linings on both sets of axle brake shoes.
The brake linings are misaligned because their holes were incorrectly drilled.	
Undersized brake drums were installed.	Install new brake drums.
The wheel bearings are out of adjustment.	Adjust the wheel bearings following the instructions in **Subject 140** or **Subject 150**.
There is an improper fit of the wheel onto the spindle due to the wrong wheel bearings or cone.	Install and adjust the new wheel bearings and cone.
The brake shoes are bent.	Replace the brake shoes.

Problem — Brake Linings Are Scored or Grooved

Problem — Brake Linings Are Scored or Grooved	
Possible Cause	**Remedy**
Worn or scored brake drums have been causing poor contact with the brake linings.	Install new brake linings on both sets of axle brake shoes. Turn or replace the brake drums.
There is abrasive material between the lining and the drum.	

Troubleshooting

Problem — Brake Linings Are Loose

Problem — Brake Linings Are Loose	
Possible Cause	**Remedy**
The rivet holes in the brake shoes are too large.	Replace the brake shoes.
Improperly crimped rivets are working loose and allowing the linings to move.	Replace the rivets.
Rust has built up on the shoe table.	Clean the brake shoe table of all rust, dirt, scale, and paint.

Problem — Brake Lining is Cracked at the Rivet Holes or Bolt Holes

Problem — Brake Lining is Cracked at the Rivet Holes or Bolt Holes	
Possible Cause	**Remedy**
Overtightening of the lining bolts is causing cracks.	Replace the brake linings. Replace the rivets or bolts with the correct size.
The wrong size counter bore for the rivet holes was made.	
The wrong rivets or bolts were used.	Replace the rivets or bolts with the correct size.
Improperly crimped rivets are working loose and allowing the linings to move.	Replace the rivets.
Rust has built up on the shoe table.	Clean the brake shoe table of all rust, dirt, scale, and paint.

Problem — Out-of-Round Rivet Holes or Bolt Holes

Problem — Out-of-Round Rivet Holes or Bolt Holes	
Possible Cause	**Remedy**
The rivets or bolts are loose.	Replace the brake shoes or linings.

Problem — Brake Drums Are Heat-Checked

Problem — Brake Drums Are Heat-Checked	
Possible Cause	**Remedy**
The brake drums are out-of-round.	Turn or replace the brake drums.
The wrong brake drums were installed.	Install new brake drums.
The wheel bearings are out of adjustment.	Adjust the wheel bearings following the instructions in **Subject 140** or **Subject 150**.
The brake linings are glazed (dirt or grease build-up) or are worn unevenly.	Install new brake linings on both sets of axle brake shoes. Clean, turn, or replace the drums.
The lining friction material for the operation of the vehicle is incorrect.	
There is a brake imbalance between the tractor and the trailer.	Do a brake balance test (tractor versus trailer). Contact the District Service Manager if help is needed.

Troubleshooting

Problem — Brake Drums Are Heavily Scored

Problem — Brake Drums Are Heavily Scored	
Possible Cause	**Remedy**
The brake linings are damaged.	Install new brake linings on both sets of axle brake shoes. Turn or replace the drums.
There is excessive wear on the linings.	
On the last brake reline, the drums were not turned.	Turn the brake drums.

Problem — Excessive Brake Lining Wear

Problem — Excessive Brake Lining Wear	
Possible Cause	**Remedy**
There is a brake imbalance between the tractor and the trailer.	Do a brake balance test (tractor versus trailer). Contact the District Service Manager if help is needed.

Specifications

Torque Values		
Application	**Size (grade 8)**	**Torque: lbf·ft (N·m)**
Drive Axle Studs (to hub)	1/2–13	70 (95)
	5/8–11	135 (185)
Drive Axle Stud Nuts	5/8–18	150–170 (203–230)
Axilok® Wheel Bearing Nuts		
Axilok Nut, ConMet Preset® Bearings	—	250 (339)
Axilok Nut, Standard Bearings	—	Stage 1: Tighten to 90–110 (122–149) While Spinning Hub in Both Directions
		Stage 2: Back Off Completely
		Stage 3: Tighten to 50 (68) While Spinning Hub in Both Directions
		Stage 4: Back Off 1/6 Turn
Dual-Nut Wheel Bearing Lock System, Standard Hub		
Adjusting Nut	—	Stage 1: Tighten to 100 (136)
		Stage 2: Back Off Completely
		Stage 3: Tighten to 20 (27) While Rotating Hub
		Stage 4: Back Off 1/3 Turn
Jam Nut (with Nut-Lock and Lockring)	1-1/8 to 2-1/2	200–300 (271–407)
	2-5/8 or larger	250–400 (339–542)

Table 1, Torque Values

General Information

Wheel oil seals (also called "oil bath seals" or "hub seals") work as a dam to keep oil in the hub cavity so that it constantly "bathes" the wheel bearings. The seals also protect the wheel bearings by keeping dirt, dust, and water out of the hub.

The oil seal fits between the hub bore and the axle spindle, and the sealing element either turns with the wheel (*hub-mounted seals*) and seals against the axle spindle, or the sealing element stays stationary with the axle spindle (*spindle-mounted seals*) and seals against the turning hub.

Most wheel oil seals consist of four basic parts:

- The outside edge (also called the outer "cup" or "case")
- The inside edge (also called the inner "cup" or "case")
- The sealing element
- The garter spring

The outside edge is usually metal coated with rubber or another sealing agent so that it grips the hub bore tight enough to prevent oil escaping between the outer edge of the seal and the hub bore.

The inside edge is usually metal or rubber with a metal ring within it to prevent the sealing element from wearing a groove in the axle spindle.

The sealing element is usually molded rubber, leather, or a synthetic such as nitrile or silicone. The element is molded into lips which will seal against the axle spindle or against the outside or inside edge described above. The innermost lip, called the "primary lip," keeps the oil inside the hub cavity. The outermost lip, called the "secondary lip," keeps dirt out of the hub cavity.

The garter spring is a coiled wire spring with its ends connected to make a loop. On hub-mounted seals, the spring runs around the outside of the sealing element to press the element inwards against the sealing surface. On spindle-mounted seals, the spring runs around the inside of the sealing element to press the element outward against the sealing surface.

Freightliner uses two brands of axle oil seals:

- Chicago Rawhide (Scotseal® and Scotseal Plus®)
- Dana Spicer (Outrunner™)

Chicago Rawhide

The Chicago Rawhide Scotseal is a unitized, one-piece design consisting of a sealing element (packing) that is assembled between metal outer and inner cups. See **Fig. 1**. The sealing element consists of three sealing lips; a spring-loaded primary sealing lip that is factory pre-lubed and two dirt exclusion lips. The seal is press fit into the hub bore using Scotseal service installation tools. *Do not install the Scotseal directly onto the axle spindle.*

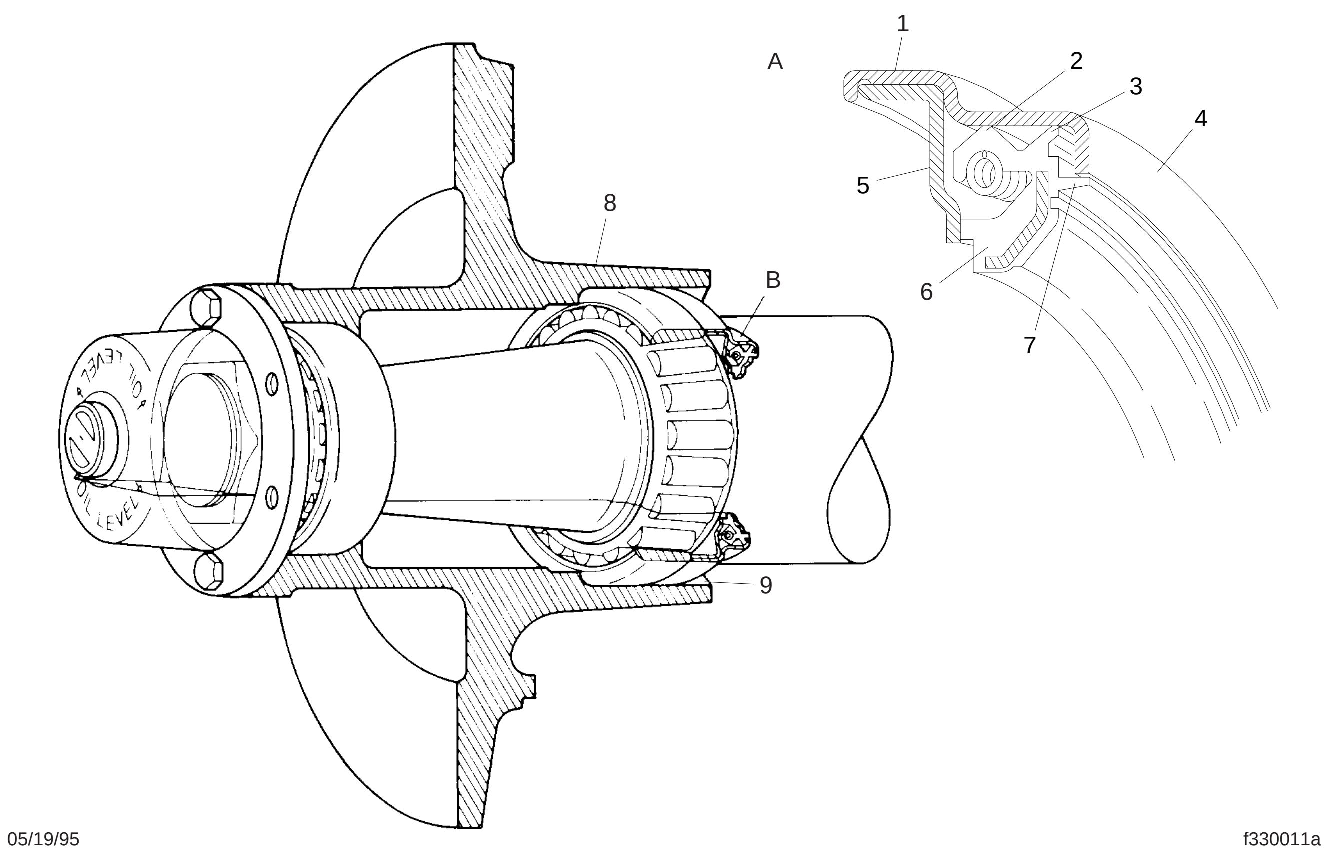
Although you install the Scotseal into the hub bore, the seal's element grips the axle spindle tightly enough that the sealing element stays stationary with the spindle and seals against the outer cup which turns with the hub.

The Chicago Rawhide Scotseal maintains a metal-to-metal contact between the outer cup and the hub bore surface as well as a metal-to-metal contact between the sealing element inside edge and the axle spindle.

Dana Spicer

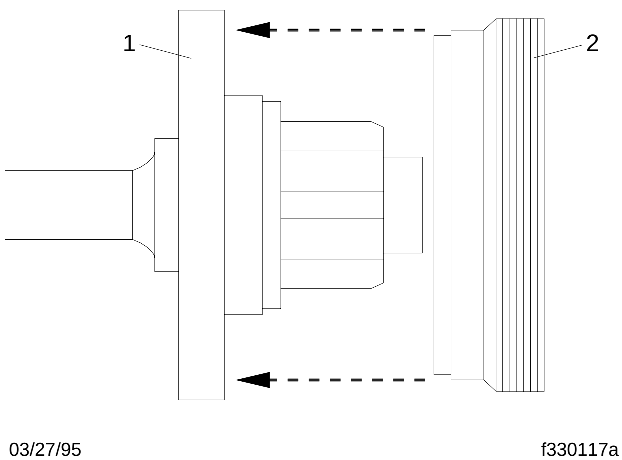
The Dana Spicer Outrunner has a rubber-coated outside edge and is installed in the hub bore using Dana Spicer installation tools. See **Fig. 2**.

General Information



A. Detail A
B. Oil Seal (See detail A)
1. Bore-Tite® Coating
2 Primary Sealing Lip
3. Dirt Lip
4. Outer Cup
5. Inner Cup
6. Sealing Element (Packing)
7. Bumper Lip
8. Hub
9. Hub Bore

Fig. 1, Chicago Rawhide Scotseal



1. Dana Spicer Outrunner Installation Tool
2. Dana Spicer Outrunner Seal

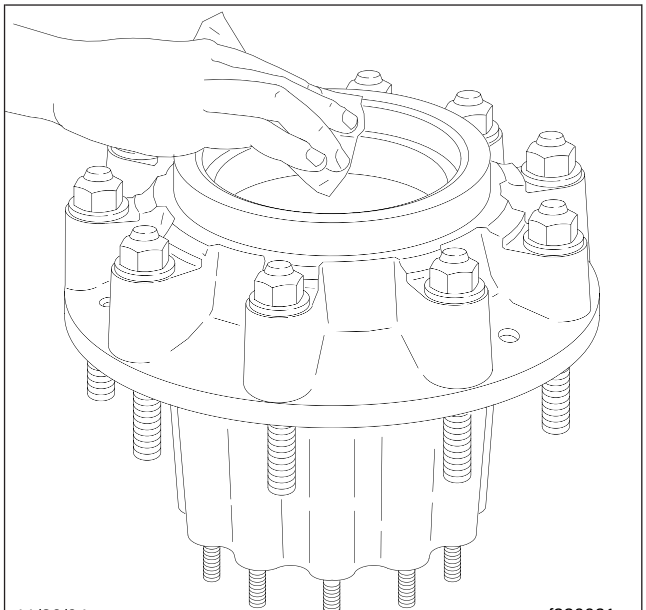
Fig. 2, Dana Spicer Outrunner Seal

Seal Replacement, Chicago Rawhide

Replacement

NOTE: This procedure applies to the Chicago Rawhide Scotseal®.

1. Remove the wheel, drum, and hub from the axle. For instructions, see **Section 35.01**, Subject 100.
2. Remove the oil seal from the hub.
3. Remove the inner wheel bearing assembly from the hub. Handling the bearings with clean dry hands, wrap the bearings in clean oil-proof paper or lint-free cloths. Occasionally, the inner wheel bearing cone assembly will remain in the hub after the seal is removed. In those cases, place a protective cushion to catch the bearing assembly. Using a hardwood drift and a light hammer, gently tap the bearing out of the inner wheel bearing cup.
4. Clean the spindle, spindle threads, seal bore, and the hub cavity. See **Fig. 1** and **Fig. 2**.
5. Remove all burrs from the shoulder and the seal bore with an emery cloth or a file. Clean any metal filings from the components.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NOTE: Rear hub shown.

Fig. 1, Clean the Hub

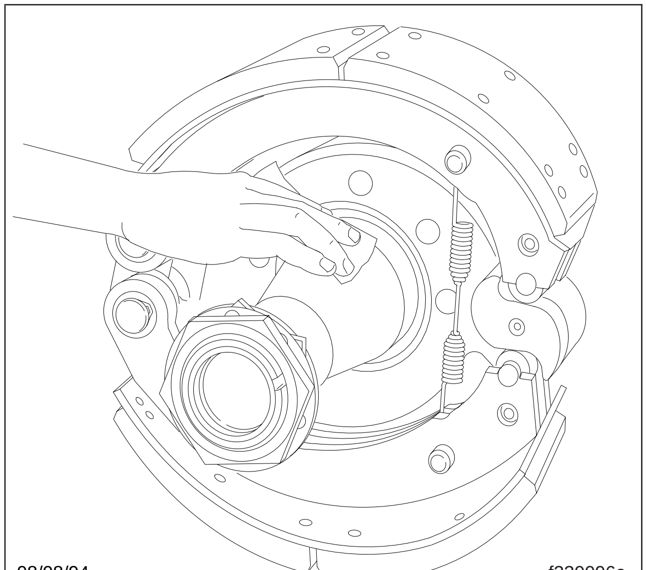
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Fig. 2, Clean the Spindle

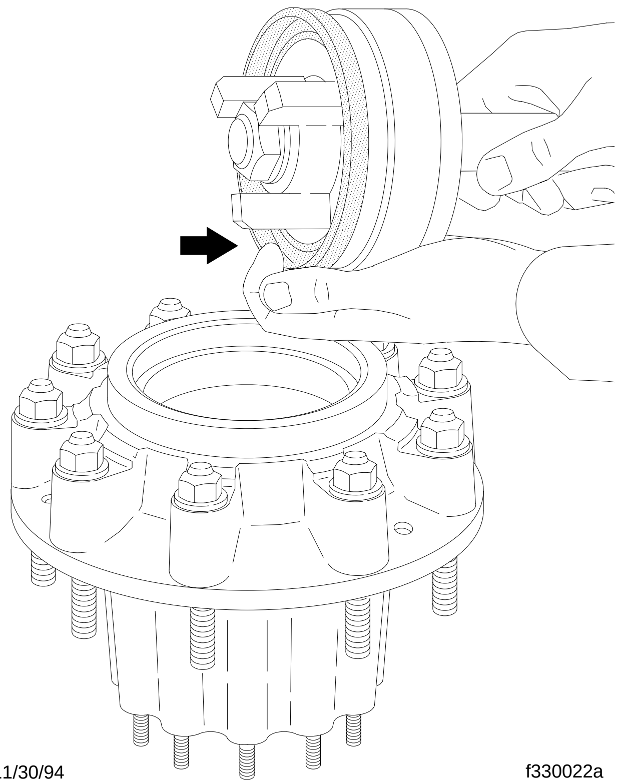
⚠ CAUTION

Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other contaminants can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

6. Inspect the bearings and hub components for wear or damage. Replace any worn or damaged components as necessary.
7. Coat the wheel bearing cones with oil.
8. Install the inner wheel bearing cone in the inner wheel bearing cup.
9. Seat the small outside edge of the seal in the recess of the tool adaptor. See **Fig. 3**. The correct adaptor is identified on the box.
10. Insert the centering plug of the tool in the bore of the inner bearing cone. See **Fig. 4**. The plug prevents cocking of the seal in the bore.
11. Hold the tool handle firmly, and strike it until the sound of the impact changes as the seal bottoms

Seal Replacement, Chicago Rawhide



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NOTE: Rear hub shown.

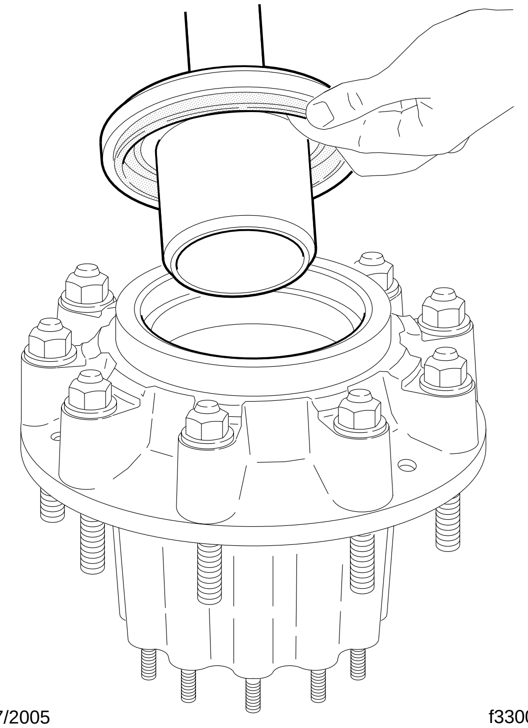
Fig. 3, Place the Seal on the Installation Tool

out. See **Fig. 5**. Hold the tool firmly to avoid bounce or unseating of the seal from the adaptor.

12. After the seal is bottomed in the bore, check for freedom of movement by manually moving the interior rubber part of the seal back and forth. A slight movement indicates a damage-free installation.
13. Install the wheel hub on the axle, and adjust the wheel bearings. For instructions, see **Section 35.01**, Subject 100.

IMPORTANT: When starting the wheel on the spindle, center the hub carefully to avoid seal damage from the leading edge of the spindle.

14. Place the hubcap and a new gasket in position, then install the capscrews. Tighten the capscrews 15 lbf·in (20 N·m).
15. Fill the hub with oil to the level shown on the hubcap. See **Fig. 6**. Do not overfill.



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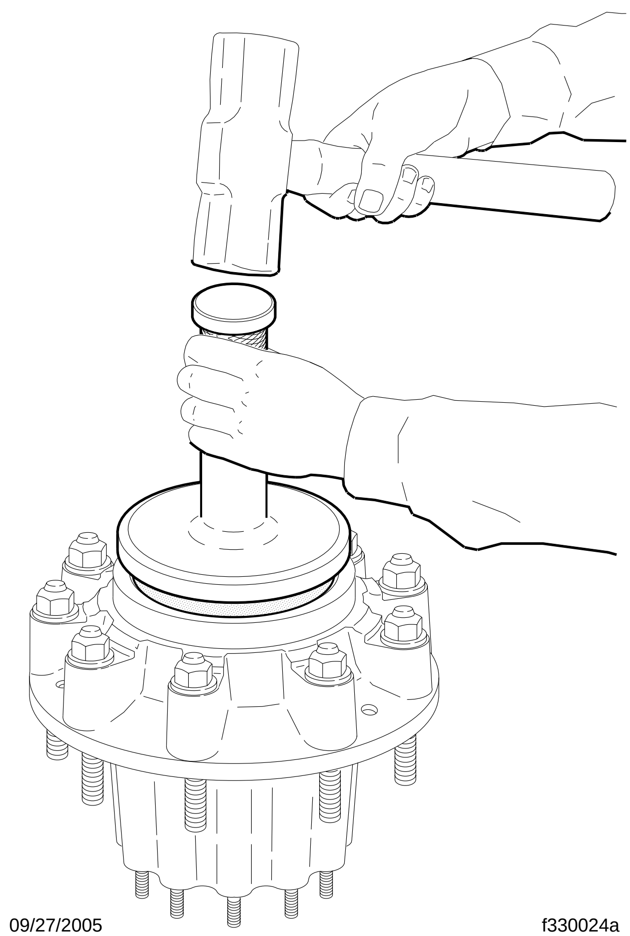
NOTE: Rear hub shown.

Fig. 4, Insert the Tool in the Hub Bore

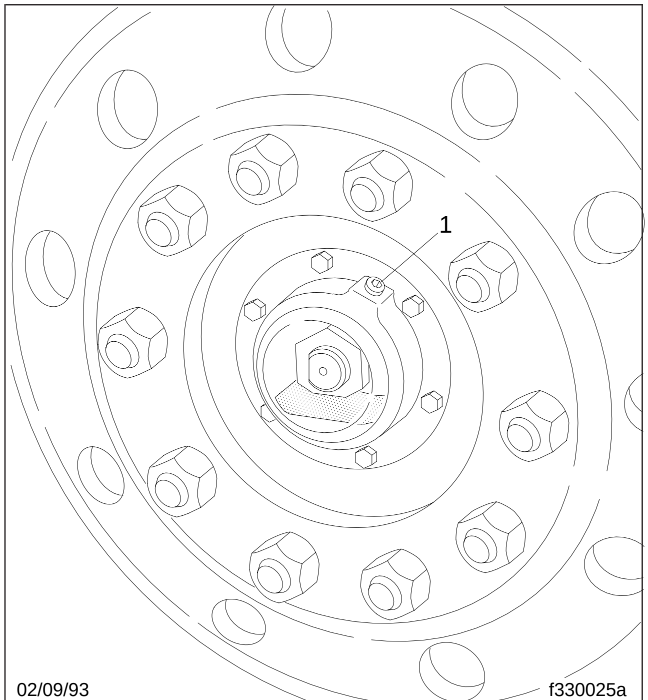
16. Spin the wheel and check the oil level.
17. Adjust the brake shoe-to-drum clearance. For instructions, see Group 42 of the *Business Class M2 Maintenance Manual*.

Seal Replacement, Chicago Rawhide



NOTE: Rear hub shown.

Fig. 5, Strike the Tool



1. Filler Plug

Fig. 6, Fill the Hub with Oil

Seal Replacement, Dana Spicer

Replacement

NOTE: This procedure applies to the Dana Spicer Outrunner™ seal.

1. Remove the wheel, drum, and hub from the axle. For instructions, see **Section 35.01**, Subject 100.
2. Remove the oil seal from the hub.
3. Remove the inner wheel bearing assembly from the hub. Handling the bearings with clean dry hands, wrap the bearings in clean oil-proof paper or lint-free cloths. Occasionally, the inner wheel bearing cone assembly will remain in the hub after the seal is removed. In those cases, place a protective cushion to catch the bearing assembly. Using a hardwood drift and a light hammer, gently tap the bearing out of the inner wheel bearing cup.
4. Clean and inspect the bearings, the spindle, spindle threads, seal bore, and the hub cavity.

   IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other contaminants can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

   4.1 Inspect the inner hub bore. Remove dirt and contaminants from all recesses and corners. Smooth any sharp edges with emery cloth, and fill in any grooves with filler. See **Fig. 1**.

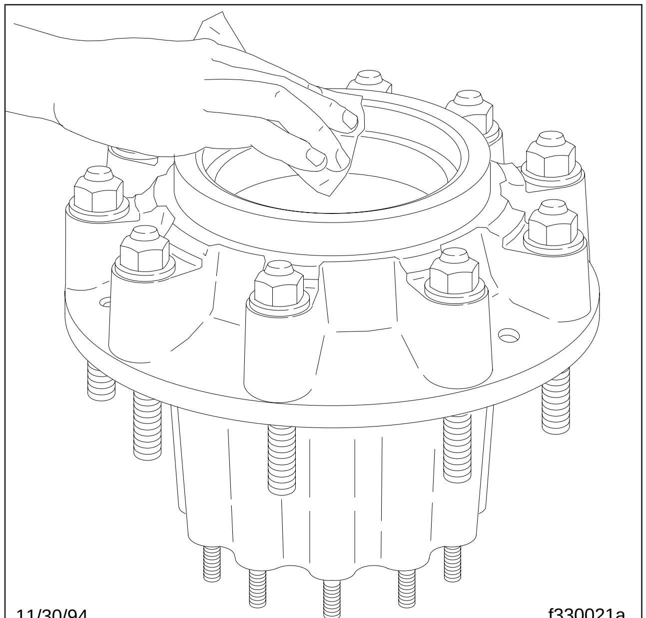
   4.2 Wipe the hub area with a clean shop cloth.

   4.3 After removing the hub, inspect the spindle. Remove any sharp edges and burrs from the leading edges and the shoulder area. Repair deep gouges with filler and smooth with an emery cloth. See **Fig. 2**.

   4.4 Wipe the seal and shoulder area with a clean shop cloth.

CAUTION

Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.



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NOTE: Rear hub shown.

Fig. 1, Clean and Inspect the Hub Bore

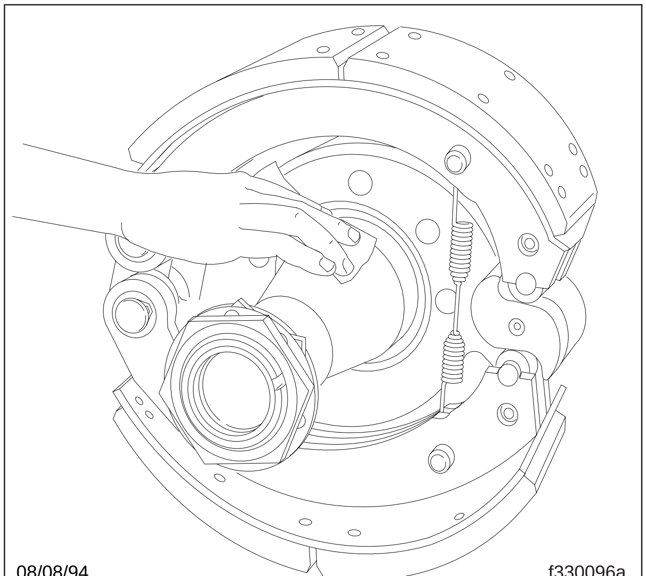

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Fig. 2, Clean and Inspect the Axle Spindle

Seal Replacement, Dana Spicer

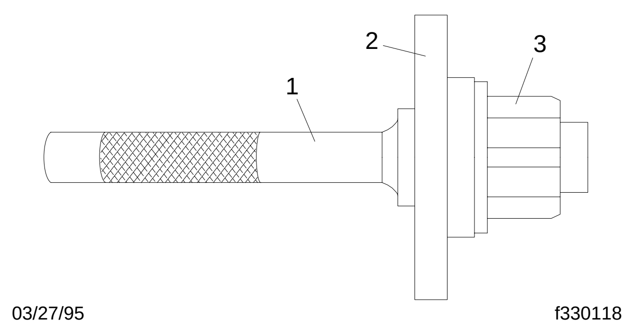
4.5 Inspect the bearings and hub components for wear or damage. Replace any worn or damaged components as necessary.

4.6 Coat the wheel bearing cones with oil.

5. Install the inner wheel bearing cone in the inner wheel bearing cup.

IMPORTANT: Use the Dana Spicer Outrunner installation tool *with the centering tool* when installing the seal. See **Fig. 3**.

6. Install the oil seal in the hub bore.



1. Outrunner Handle
2. Outrunner Adapter Plate
3. Bearing Centering Tool

Fig. 3, Dana Spicer Outrunner Installation Tool

CAUTION

Do not use any silicone or permatex type bore sealant with this seal. The Dana Spicer Corporation recommends a light coating of bearing oil on the outer circumference of the seal.

Do not mix lubricants of different grades. Do not mix mineral and synthetic lubricants. Do not pack the bearings with grease when using an oil bath system. Failure to follow these installation guidelines will result in less than desired performance of the Outrunner seal, and installation-related failures are not covered under warranty.

6.1 Place the Outrunner seal tool with the words "air side" facing the adaptor plate of the installation tool. See **Fig. 4**. Lubricate the seal outer circumference with wheel bearing oil.

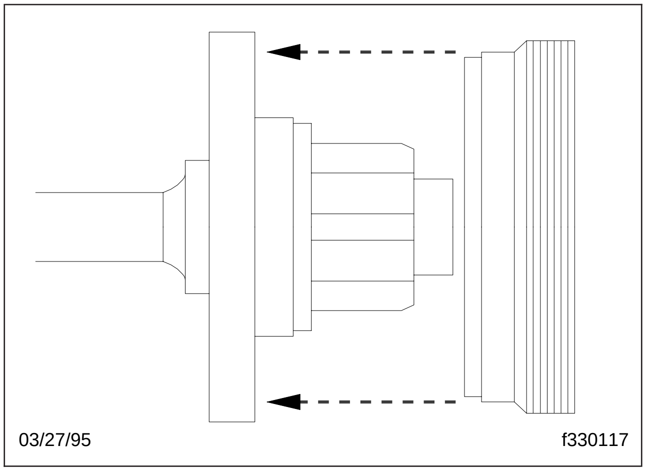


Fig. 4, Seal Placement on Tool

IMPORTANT: Install the seal in the hub bore with the hub laid flat. Do not install the seal with the hub in the vertical (upright) position.

6.2 With the hub and the wheel assembly laid flat on the floor, place the inner bearing cone in the cup.

6.3 Position the oil seal in the hub bore. Before striking the handle of the installation tool, tap the adaptor plate around the outer edge to position the seal. See **Fig. 5**.

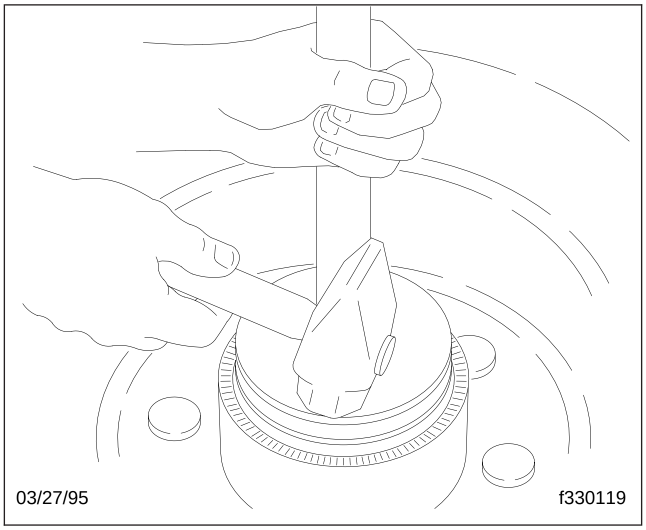


Fig. 5, Position the Seal

Seal Replacement, Dana Spicer

6.4 Hit the handle of the installation tool *gently*. See **Fig. 6**.

Because of the rubber outer circumference, the Outrunner seal is easier to install than seals with metal outer circumferences. When the adaptor plate bottoms out on the hub surface, the seal is installed correctly. You will hear a metal-to-metal sound.

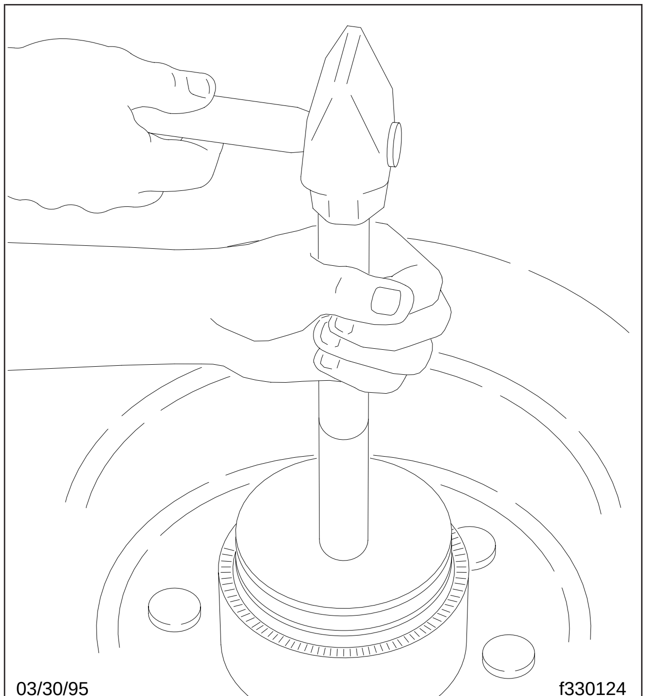


Fig. 6, Install the Seal

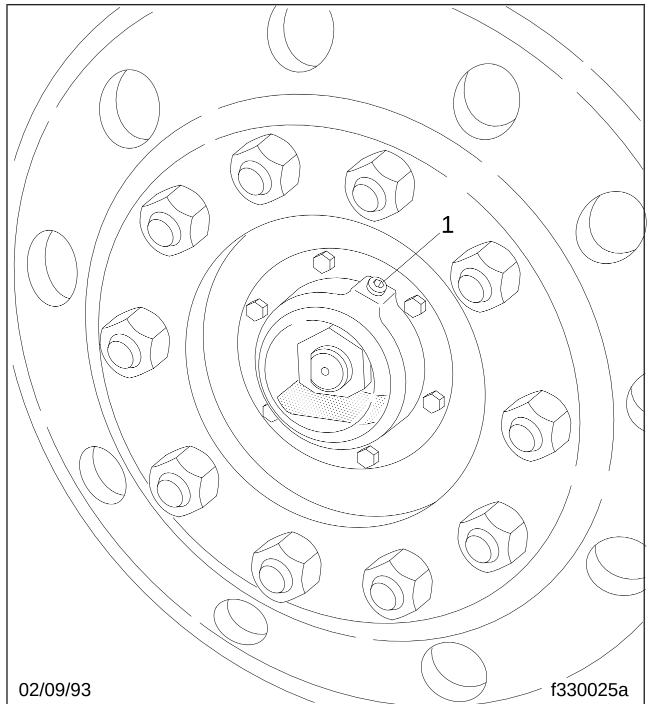
6.5 Check that the seal is not cocked, and that the unitized seal inner circumference and inner bearing turn freely.

6.6 Lubricate the inner circumference of the seal with a light film of clean bearing oil.

7. Install the wheel hub on the axle, and adjust the wheel bearings. For instructions, see **Section 35.01**, Subject 100.

IMPORTANT: When starting the wheel on the spindle, center the hub carefully to avoid seal damage from the leading edge of the spindle.

8. Place the hubcap and a new gasket in position, then install the capscrews. Tighten the capscrews 15 lbf·ft (20 N·m).
9. Fill the hub with oil to the level shown on the hubcap. See **Fig. 7.** Do not overfill.



1. Filler Plug

Fig. 7, Fill the Hub with Oil

10. Spin the wheel and check the oil level.
11. Adjust the brake shoe-to-drum clearance. For instructions, see Group 42 of the *Business Class M2 Maintenance Manual*.

General Information

Although these axles are a Freightliner proprietary product, in some applications they may be referred to as "MB components."

Freightliner rear axles are compatible with industry-standard brakes, hubs, and wheel bearings.

The following explains an example of the number found on a Freightliner rear axle identification tag, which is located on the carrier. See **Fig. 1**.

Typical Model Number: ART-40.0-4

- *ART* = tandem rear axle
- *40.0* = weight rating (times 1000 lb)
- *4* = basic model number

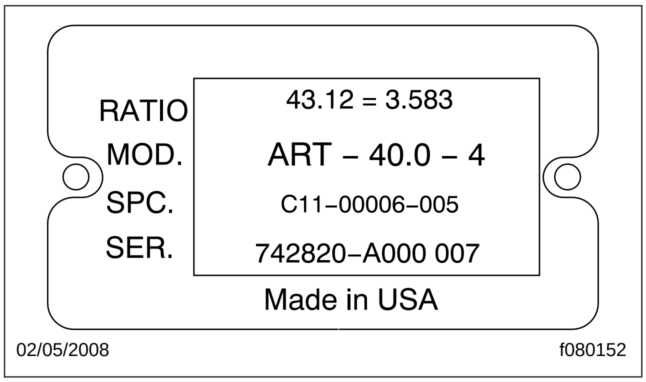


Fig. 1, Rear Axle ID Tag

Freightliner rear axles may have a main differential lock, which is commonly known as the "DCDL" (Driver-Controlled Differential Lock). The DCDL is an optional feature that can lock the differential assembly. When the differential lock is engaged, the clutch collar completely locks the differential case, gearing, and axle shafts together to maximize traction of both wheels and protect against spinout. Each part of the DCDL is replaceable; see **Subject 180** for Model 2 axles, and **Subject 190** for Model 4 axles.

On tandem axles there are three possible differential lock options: forward-rear carrier only, rear-rear carrier only, or both rear carriers.

Single or Rearmost Axle Removal and Installation

Removal

For rear axle components, see **Fig. 1**.

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires. Put the transmission in neutral.
2. Using a suitable jack, raise the vehicle enough to take the weight off the axles, but not enough to raise the tires off the ground.
3. At both ends of the axle, loosen all the wheel nuts.
4. Continue to raise the vehicle evenly until there is room to fit a stand underneath the axle housing.

WARNING

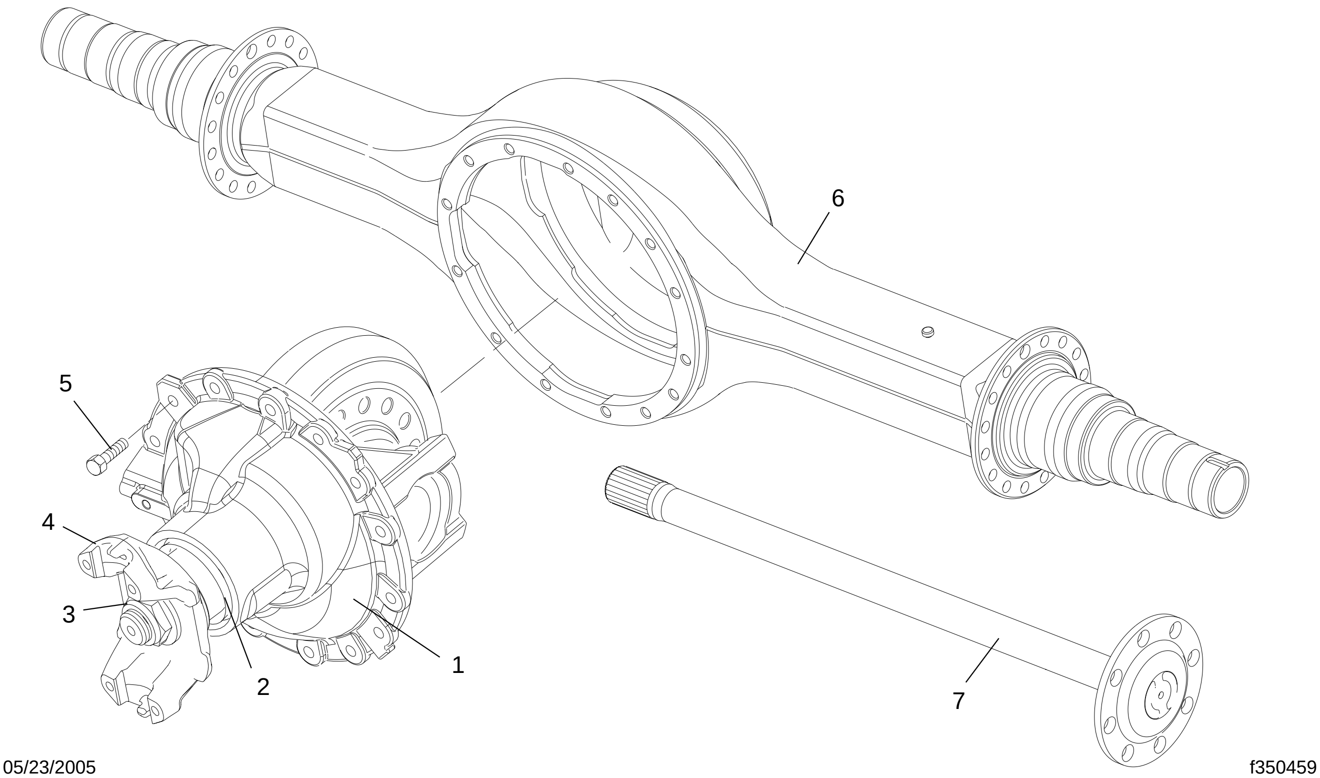
Never work around or under a vehicle that is supported only by a jack. Always support the vehicle with safety stands. Jacks can slip, allowing the vehicle to fall, which could result in serious injury or death.

5. Support the vehicle with safety stands.
6. Remove the tire and wheel assemblies. For instructions, see **Group 40**.
7. Remove the oil drain plug from the bottom of the differential housing and drain the oil. Install the drain plug after emptying.
8. Disconnect the driveshaft from the differential carrier. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
9. Release the parking brakes.
10. Cage the parking brake springs to prevent the parking brakes from engaging. For instructions, see **Group 42**.
11. If DCDL is installed on the vehicle, use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged. Turn the appropriate wheels to ensure the lock is fully engaged.

IMPORTANT: The wheel lock must be fully engaged to prevent the possibility of damage to wheel lock components while the axle shafts are being removed.

12. Place a basin under the axle shaft flanges to catch any oil, then remove the axle shafts. For instructions, see **Subject 120**.
13. Drain the air system, if installed.
14. If installed, disconnect the DCDL air line from the carrier housing.
15. If necessary, back off the slack adjusters. Remove the brake drums.
16. Remove the hubs from the axle spindles. For instructions, see **Section 35.00, Subject 100**.
17. Remove the brake shoes. For instructions, see the applicable service brake section in **Group 42**.
18. If applicable, disconnect the leveling valve rod(s) from the suspension.
19. If installed, disconnect the air lines from the rear brake chambers. Then remove the brake air chambers and the slack adjusters from the axle housing. For instructions, see **Group 42**.
20. Remove the brake spiders from the axle flanges.
    - 20.1 At the frame rail or crossmember, disconnect the wiring for the ABS sensors. Remove any tie straps that hold the wires to the frame rails.
    - 20.2 Remove the ABS sensors and wiring.
    - 20.3 Remove the fasteners that hold the brake spiders to the axle flanges. Remove the spiders from the axle.
21. Using a suitable jack, support the axle housing.
22. If applicable, remove the hexnuts that hold the bottom of each suspension air bag to its suspension bracket.
23. Remove the suspension components that attach the axle to the vehicle. If applicable, remove the U-bolt nuts from the U-bolts. Discard the U-bolt nuts and U-bolts.
24. Lower the axle enough to clear the suspension components.
25. Remove the axle from the vehicle.
26. If you are going to replace the differential carrier, place the axle on a secure axle stand.

Single or Rearmost Axle Removal and Installation



1. Differential Carrier
2. Radial Shaft Seal
3. Yoke Nut
4. Carrier Yoke
5. Carrier Capscrew
6. Rear Axle Housing
7. Axle Shaft

Fig. 1, Single or Rearmost Axle Components

Installation

1. Position the axle underneath the vehicle.
2. Install the suspension components that attach the axle to the vehicle, as follows.

   NOTE: U-bolts and U-bolt nuts cannot be reused.

   2.1 On vehicles with conventional suspensions, install the upper U-bolt brackets, new U-bolts, lower U-bolt brackets, and new U-bolt nuts.

   On vehicles with air suspensions, in addition to the U-bolts, install the hexnuts that attach the air springs to the suspension brackets. For torque values, see **Group 32**.

   On vehicles without U-bolts, install the walking beams.

   2.2 If applicable, tighten the new U-bolt nuts in a diagonal pattern. For torque values, see **Group 32**.
3. Connect the driveshaft to the differential carrier yoke. For instructions, see **Section 41.00, Subject 120**.
4. Install the brake spiders on the axle flanges. For instructions, see the applicable service brake section in **Group 42**.
5. Install the ABS sensors and connect the wiring at the frame rail. Secure the wiring with tie straps as needed.
6. Install the brake air chambers (if removed) and slack adjusters on the axle housing brackets. For instructions, see **Group 42**.

7. Connect the air lines to the brake air chambers.
8. Install the brake shoes, as removed. For instructions, see the applicable service brake section in **Group 42**.
9. Fill each hub with approved axle oil until you can see a small amount of oil trickling out of the back of the hub (fill with about 0.8 quart, or 0.75 liter). Install the hubs on the axle spindles, and adjust the wheel bearings. For instructions, see **Section 35.00**.

NOTE: See **Table 1** for approved axle oils.

10. If DCDL is installed on the vehicle, connect the DCDL air line, fill the air system, and use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged.

IMPORTANT: The wheel lock must be fully engaged to prevent the possibility of damage to wheel lock components while the axle shafts are being installed.

11. Using new gaskets, install the axle shafts. For instructions, see **Subject 120**.
12. Install the brake drums on the hubs.
13. Install the tire and wheel assemblies. For instructions, see **Group 40**.
14. Adjust the brakes. For instructions, see the applicable service brake section in **Group 42**.
15. Uncage the parking brake springs.
16. Using approved axle oil, fill the axle housing to the bottom of the fill hole, or until filled to capacity as shown in **Table 1**.

Approved Single Rear Axle Oil Type and Capacity				
Model	Oil Type		Capacity: quarts (liters)	
	Mineral	Synthetic	Hubs Full	Hubs Dry
2	80W-90	75W-90	5.8 (5.5)	7.4 (7.0)
4			10.6 (10.0)	12.2 (11.5)

Table 1, Approved Single Rear Axle Oil Type and Capacity

17. If the hubs are dry, raise one side of the vehicle about 8 inches (20 cm) to let the oil flow into the hub on the opposite side, then raise the other side in the same manner. On each side, hold the tilted position for three minutes to allow oil to run into the wheel end.

NOTICE

Make sure the hubs are filled. Driving with the hubs dry will cause bearing damage.

18. Turn the wheels, wait one minute, and check the lubricant level.
19. Raise the vehicle, remove the safety stands, then lower the vehicle.
20. If applicable, connect the suspension leveling valve(s). Start the engine, build the air pressure, and make sure the suspension air bags inflate correctly. Make sure the ride height is correct. For instructions, see **Group 32**.
21. Check the operation of the DCDL, if installed.
22. Check the oil level in the axle housing. The level should be up to the bottom of the fill hole. Add approved axle oil, if needed.
23. Set the parking brake, then remove the chocks from the front tires.

Single or Rearmost Axle Differential Carrier Removal and Installation

Do not disassemble the differential carrier. There are no serviceable parts in the differential assembly; it must be replaced as a unit. However, it is possible to remove the differential carrier to repair an oil leak, or to remove the wheel lock (differential lock).

When the wheel lock is removed, inspect the carrier for damage and replace it if damage is found. If no damage is found, install the carrier again.

Removal

NOTE: The differential carrier can be removed either with the rear axle installed on the vehicle or with the rear axle removed from the vehicle.

Axle Installed on Vehicle

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires. Put the transmission in neutral.
2. If applicable, release the suspension air pressure.
3. Using suitable jacks, raise the vehicle evenly until there is room to fit a stand underneath the axle housing.
4. Remove the tire and wheel assemblies. For instructions, see **Group 40**.
5. Remove the oil drain plug from the bottom of the rear axle housing and drain the oil. Install the drain plug after emptying.
6. If DCDL is installed on the vehicle, use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged. Turn the appropriate wheels to ensure the lock is fully engaged.
7. Disconnect the driveshaft from the carrier input yoke. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
8. Place a basin under the axle shaft flanges, then remove the axle shafts. For instructions, see **Subject 120**.
9. Do the steps under the heading, "Axle Removed from Vehicle."

Axle Removed from Vehicle

WARNING

The differential carrier is heavy. Do not try to move it without a suitable support. To do so could result in the carrier falling, which could cause serious personal injury and component damage. Support the carrier with a suitable jack and chain it to the jack, or use a hoist if the axle has been removed from the vehicle.

1. Using a suitable jack, support the differential carrier. Chain the differential carrier to the jack.
2. If DCDL is installed on the vehicle, ensure the lock is engaged. Turn the appropriate wheels to verify it is fully engaged.
3. Remove the carrier capscrews that hold the differential carrier to the axle housing. See **Fig. 1**.
4. With the differential carrier securely supported, remove it from the axle housing.

Installation

IMPORTANT: If you replace the yoke on the differential carrier, use a *new* nut when installing the new yoke.

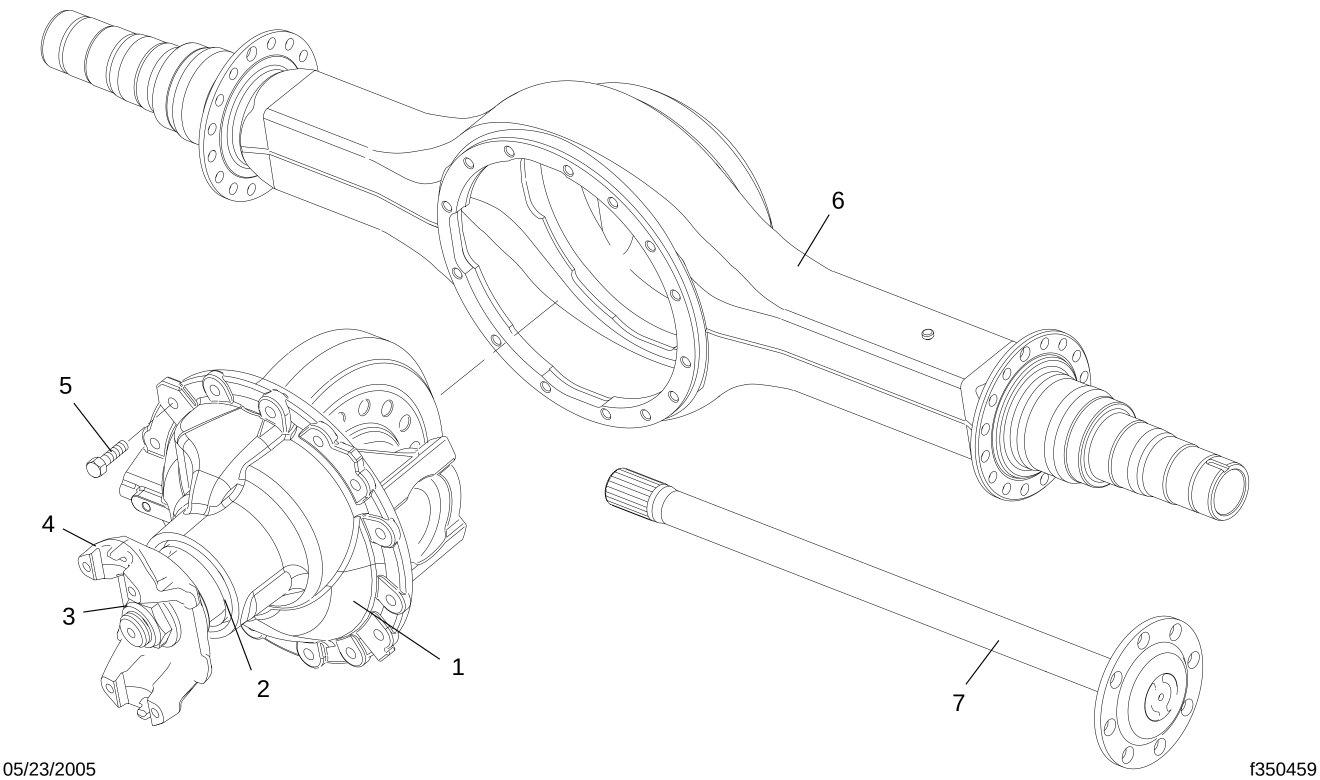
NOTE: Use a cleaning solvent and clean rags to remove dirt. Blow dry the cleaned areas with air.

1. Remove any old sealant material from the mating surfaces of the axle housing. Clean the inside of the rear axle housing and the forward carrier mating surface.
2. Inspect the axle housing for damage. Repair or replace the axle housing as necessary.
3. Apply a thin bead of Loctite® 5900 sealant all the way around the mating surface of the axle housing, and around each bolt hole.

NOTE: Alignment dowels for installing the differential carrier can be made by sawing off the heads of two M12 x 1.5 x 100 mm bolts (for Model 2 axles) or M16 x 1.5 x 100 mm bolts (for Model 4 axles).

4. Install alignment dowels 180 degrees apart at the 3 o’clock and 9 o’clock positions on the axle housing flange.

Single or Rearmost Axle Differential Carrier Removal and Installation



1. Differential Carrier
2. Radial Shaft Seal
3. Yoke Nut
4. Carrier Yoke
5. Carrier Capscrew
6. Rear Axle Housing
7. Axle Shaft

Fig. 1, Single or Rearmost Axle Components

5. If DCDL is installed on the vehicle, ensure it is engaged.

NOTICE

Make sure the differential carrier is centered and straight on the axle housing before you install the mounting capscrews. Attempting to install the carrier when it is not centered or straight may cause damage to the carrier.

6. Using a hoist (if the axle is removed from the vehicle) or a suitable transmission jack, install the differential carrier into the axle housing. Use the alignment dowels to center the carrier on the axle housing.
7. Install the end caps at the sides of the carrier into the corresponding slots in the axle housing. See **Fig. 2**.

7.1 For the last 3/4 inch (19 mm) or so of travel, walk the carrier slowly into the housing.

IMPORTANT: The end caps fit tightly into the axle housing. Be very careful not to cock the carrier.

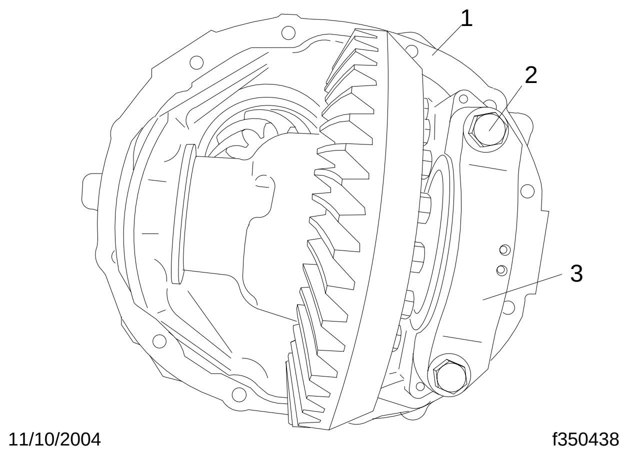
7.2 Install the carrier capscrews finger-tight. Make sure the carrier capscrews turn easily in the axle housing.

7.3 In a star pattern, gradually tighten the carrier capscrews to the values given.

- M12 capscrews: 115 lbf·ft (156 N·m)
- M16 capscrews: 200 lbf·ft (270 N·m)

8. If removed, install the axle on the vehicle. For instructions, see **Subject 100**.

Single or Rearmost Axle Differential Carrier Removal and Installation



1. Differential Carrier
2. End Cap Bolt
3. End Cap

Fig. 2, Carrier End Caps

If the axle is already on the vehicle, go to the next step.

9. Connect the driveshaft to the carrier input yoke. For instructions, see **Section 41.00, Subject 120**.
10. Using new gaskets, install the axle shafts. For instructions, see **Subject 120**.
11. Install the tire and wheel assemblies. For instructions, see **Group 40**.
12. Using approved axle oil, fill the axle housing to the bottom of the fill hole, or until filled to capacity as shown in **Table 1**.

Approved Single Rear Axle Oil Type and Capacity				
Model	Oil Type		Capacity: quarts (liters)	
	Mineral	Synthetic	Hubs Full	Hubs Dry
2	80W-90	75W-90	5.8 (5.5)	7.4 (7.0)
4			10.6 (10.0)	12.2 (11.5)

Table 1, Approved Single Rear Axle Oil Type and Capacity

13. Raise one side of the vehicle about 8 inches (20 cm) to let the oil flow into the hub on the opposite side, then raise the other side in the same manner. On each side, hold the tilted position for three minutes to allow oil to run into the wheel end.

NOTICE

Make sure the hubs are filled. Driving with the hubs dry will cause bearing damage.

14. Turn the wheels, wait one minute, and check the lubricant level.
15. Raise the vehicle, remove the safety stands, then lower the vehicle.
16. Start the engine, build the air pressure, and check that the suspension air bags inflate evenly and correctly. Make sure the ride height is correct.
17. Check the oil level in the axle housing. The level should be up to the bottom of the fill hole. Add approved axle oil, if needed.
18. Remove the chocks from the front tires.

Removal

1. Chock the front tires.
2. If DCDL is installed on the vehicle, use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged. Turn the appropriate wheels to ensure the lock is fully engaged.
3. Raise the rear of the vehicle with a suitable jack high enough to clear the axle. Support the axle with jack stands.
4. Place a basin under the axle shaft flanges to catch any oil. Dispose of used oil properly.
5. If necessary, remove the rear wheels and tires. For procedures, see **Group 40**.

NOTE: This procedure can be done with the wheels and tires installed or with the wheels and tires removed.

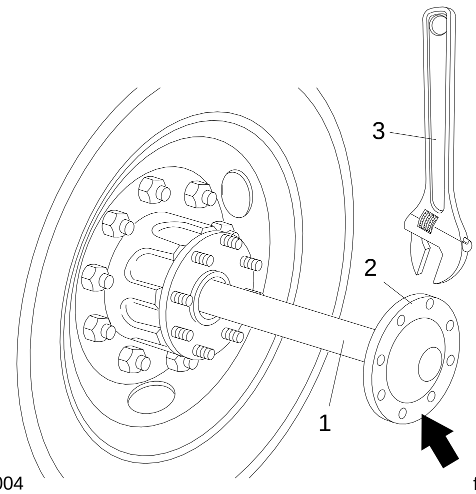
6. Remove the drive axle stud nuts that attach the axle shaft to the wheel hub.
7. If DCDL is installed on the vehicle, use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged. Turn the appropriate wheels to ensure the lock is fully engaged.
8. Tap the axle shaft flange if necessary to loosen it and slide the axle shaft out of the axle. Remove and discard the gasket.

Installation

1. Position a new gasket on the axle shaft flange.
2. If DCDL is installed on the vehicle, ensure it is engaged.

IMPORTANT: The wheel lock must be fully engaged to prevent the possibility of damage to wheel lock components while the axle shafts are being installed.

3. Install the axle shaft, as follows. See **Fig. 1**.
   - 3.1 Carefully raise the axle with the floor jack, and support the axle with jack stands. Slide the axle shaft into the axle.
   - 3.2 Apply light pressure with the hand or knee to the axle flange.



Apply light pressure with the hand or knee at the arrow. Use the adjustable wrench to center the shaft.
1. Axle Shaft
2. Axle Flange
3. Adjustable Wrench

Fig. 1, Installing the Axle Shaft

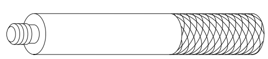
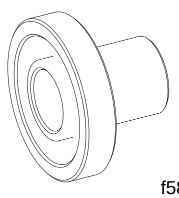
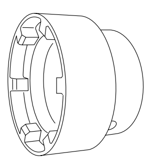
   - 3.3 Use an adjustable wrench to center the shaft. Turn the shaft with a slight rotating motion.
   - 3.4 Install the drive axle stud nuts and tighten them to the values given.
     - 1/2–20 nuts: 75 to 115 lbf·ft (102 to 156 N·m)
     - 5/8–18 nuts: 150 to 170 lbf·ft (203 to 230 N·m)

4. If removed, install the rear wheels and tires. Tighten the wheel nuts according to the procedures in **Group 40**.
5. Remove the supports and lower the vehicle.
6. As needed, replace any oil that was drained from the hub when the axle shaft was removed.
7. Remove the chocks from the front tires.

Single or Rearmost Axle Yoke and Seal Replacement, Model 4 Axles

Special Tools

Special tools are required for this procedure. See **Table 1**.

Special Tools			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580400	Universal Handle*	Kent-Moore	J-8092
 f580406	Rear Pinion Seal Installer*	Kent-Moore	J-47354
 f580450	Yoke Nut Socket†	Axle Alliance Special Tool	DDE W742589020700

* To order Kent-Moore tools call 1-800-328-6657.

† The yoke nut socket is needed to remove the round, slotted yoke nut installed on some vehicles. It can be ordered through Paragon.

Table 1, Special Tools

Replacement

1. Disconnect the driveshaft from the differential carrier. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
2. Remove the yoke nut from the center of the carrier yoke. If the yoke nut is round and slotted, use the yoke nut socket shown in **Table 1**. See **Fig. 1**. Be careful not to damage the seal bore.
3. Remove the carrier yoke from the input shaft.
4. Pry up the seal, using a prybar or large screwdriver. Clean any old sealant from the axle housing. Do not allow dirt or grease to contaminate the seal bore or shaft bearings. See **Fig. 2**.
5. Install the rear pinion seal on the rear input shaft, as follows. See **Fig. 3**.

   5.1 Inspect the area around the seal for damage. Use emery paper to remove scratches, nicks, or burrs on the seal bore.

   5.2 Assemble the rear pinion seal installer onto the threaded end of the universal handle. See **Table 1**.

   IMPORTANT: Be careful not to cock the seal during installation.

   5.3 Using the rear pinion seal installer assembly, press the seal into the bore until the seal surface is flush with the bottom surface of the counterbore.

Single or Rearmost Axle Yoke and Seal Replacement, Model 4 Axles

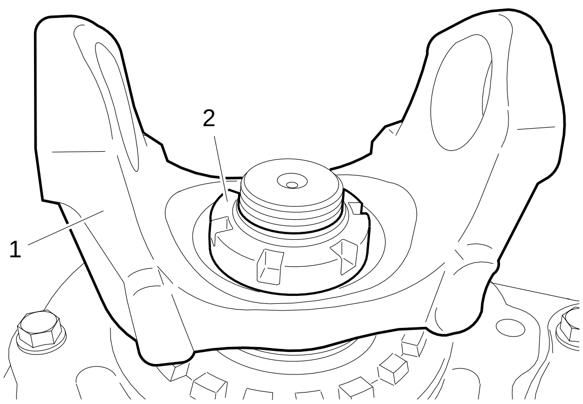
6. Install the carrier yoke on the input shaft. If the yoke is damaged or worn, install a new yoke.

NOTE: It is not necessary to replace the yoke when replacing the seal.

7. Install a new M45 x 1.5 yoke nut on the carrier yoke and tighten 627 lbf·ft (850 N·m).
8. Punch in the cylindrical area at the pinion groove to lock the nut in place.

IMPORTANT: The bent area has to reach the bottom of the pinion groove.

9. Connect the driveshaft. For instructions, see **Section 41.00, Subject 120**.



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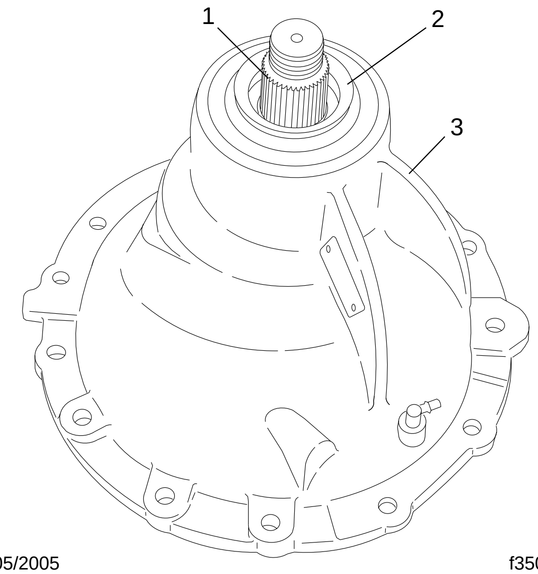
NOTE: The yoke nut may be a hexnut rather than the round, slotted nut shown here.

1. Yoke
2. Yoke Nut

Fig. 1, Yoke Nut on the Carrier



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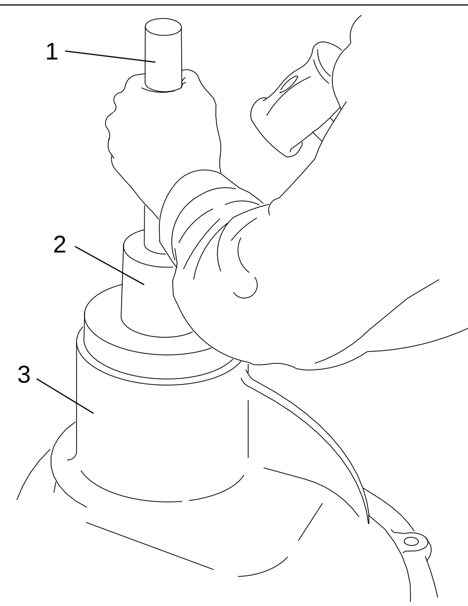
1. Input Shaft
2. Rear Pinion Seal
3. Carrier Housing

Fig. 2, Rear Pinion Seal



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1. Universal Handle
2. Rear Pinion Seal Installer
3. Carrier Housing

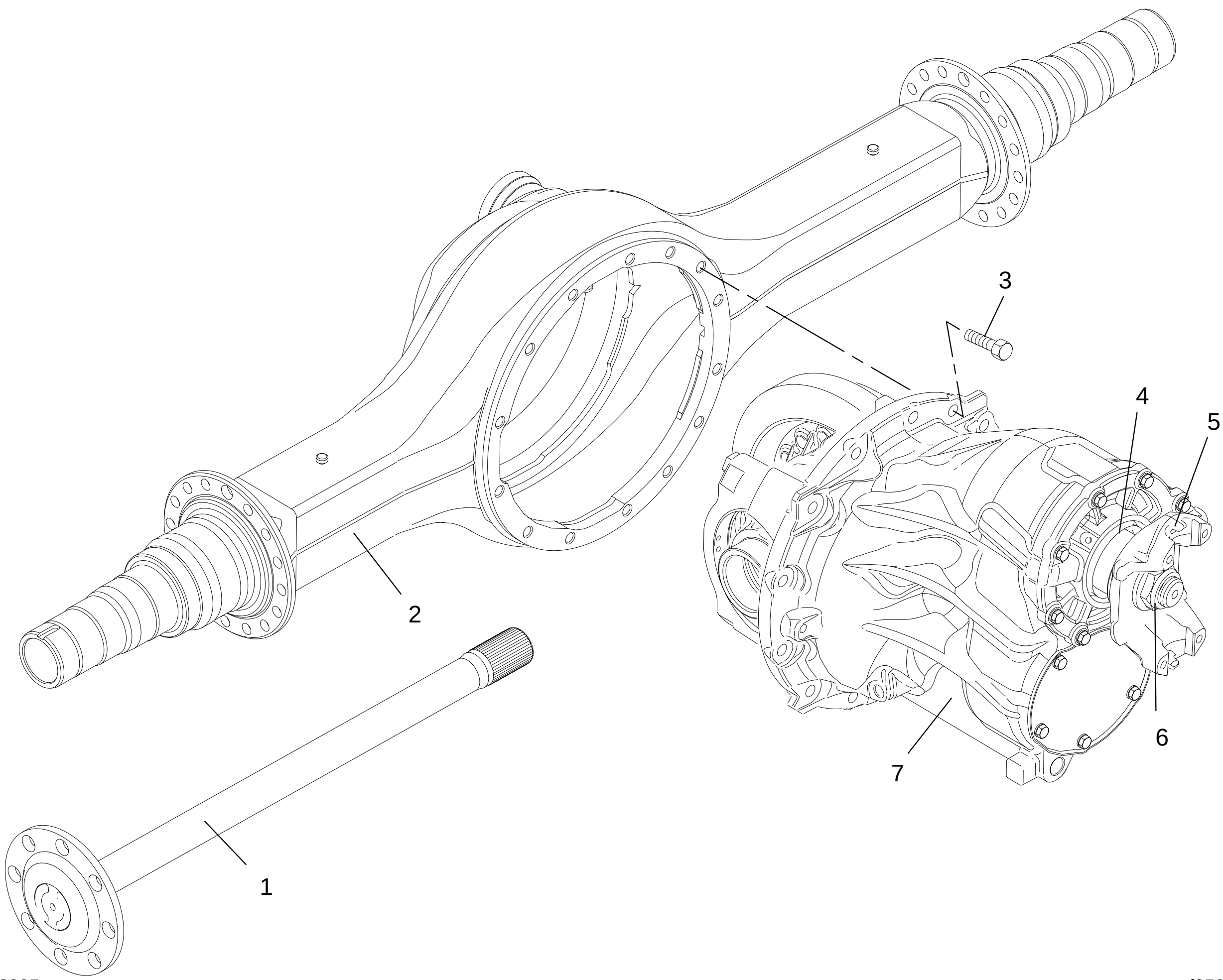
Fig. 3, Installing the Rear Pinion Seal

Forward-Rear Axle Removal and Installation

Removal

For forward-rear axle components of a tandem installation, see **Fig. 1**.

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires. Put the transmission in neutral.
2. Using a suitable jack, raise the vehicle enough to take the weight off the axles, but not enough to raise the tires off the ground.
3. At both ends of the axle, loosen all the wheel nuts.
4. Using a suitable jack, continue to raise the vehicle evenly until there is room to fit a stand underneath the axle housing.



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1. Axle Shaft
2. Forward-Rear Axle Housing
3. Carrier Capscrew
4. Input Seal
5. Carrier Yoke
6. Input Yoke Nut
7. Forward Differential Carrier

Fig. 1, Forward-Rear Axle Components

Forward-Rear Axle Removal and Installation

⚠ WARNING

Never work around or under a vehicle that is supported only by a jack. Always support the vehicle with safety stands. Jacks can slip, allowing the vehicle to fall, which could result in serious injury or death.

5. Support the vehicle with safety stands.
6. Remove the oil drain plug from the bottom of the axle housing and drain the oil from the axle housing. Install the drain plug after emptying.
7. Remove the tire and wheel assemblies. For instructions, see **Group 40**.
8. Release the parking brakes.
9. If necessary, back off the slack adjusters. Then remove the brake drums.
10. If installed, make sure the optional DCDL (main differential lock) has been shifted into the engaged (locked) position.

IMPORTANT: The wheel lock must be fully engaged to prevent the possibility of damage to wheel lock components while the axle shafts are being removed.

11. If not done previously, disconnect the air lines at the interaxle lock and (if installed) the wheel lock.
12. Disconnect the main driveshaft from the forward differential carrier. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
13. Disconnect the interaxle driveshaft from the output yoke of the forward-rear axle, and the input yoke of the rearmost axle. For instructions, see **Section 41.00, Subject 120**.
14. Cage the parking brake springs to prevent the parking brakes from engaging. For instructions, see **Group 42**.
15. Drain the air system.
16. Place a basin under the axle shaft flanges to catch any oil; then remove the axle shafts. For instructions, see **Subject 120**.
17. Remove the hubs from the axle spindles. For instructions, see **Section 35.01, Subject 100**.
18. Remove the brake shoes. For instructions, see the applicable service brake section in **Group 42**.
19. Remove the ABS sensors and wiring, and the fasteners that hold the brake spiders to the axle flanges. Remove the spiders from the axle.
20. If applicable, disconnect the leveling valve rod(s) from the suspension.
21. At the frame rail or crossmember, disconnect the wiring for the ABS sensors. Remove any tie straps that hold the wires to the frame rails.
22. Disconnect the air lines from the rear brake chambers. Remove the brake air chambers and the slack adjusters from the axle housing. For instructions, see **Group 42**.
23. Using a suitable jack, support the axle housing.
24. If applicable, remove the hexnuts that hold the bottom of each suspension air bag to its suspension bracket.
25. Remove the suspension components that attach the axle to the vehicle. If applicable, remove the U-bolt nuts from the U-bolts. Discard the U-bolt nuts and U-bolts.
26. Lower the axle enough to clear the suspension components.
27. Remove the axle from the vehicle.
28. If you are going to replace the differential carrier, place the axle on a secure axle stand.

Installation

1. Position the axle underneath the vehicle.
2. Install the suspension components that attach the axle to the vehicle, as follows.

   NOTE: U-bolts and U-bolt nuts cannot be reused.

   2.1 On vehicles with conventional suspensions, install the upper U-bolt brackets, new U-bolts, lower U-bolt brackets, and new U-bolt nuts.

   On vehicles with air suspensions, in addition to the U-bolts, install the hexnuts that attach the air springs to the suspension brackets. For torque values, see **Group 32**.

On vehicles without U-bolts, install the walking beams.

2.2 If applicable, tighten the new U-bolt nuts in a diagonal pattern. For torque values, see **Group 32**.

3. Connect the interaxle driveshaft to the output yoke of the forward carrier and the input yoke of the rear carrier. For instructions, see **Section 41.00, Subject 120**.
4. Install the brake spiders on the axle flanges. For instructions, see the applicable service brake section in **Group 42**.
5. Install the ABS sensors and connect the wiring at the frame rail. Secure the wiring with tie straps as needed.
6. Install the brake air chambers and slack adjusters on the axle housing brackets. For instructions, see **Group 42**.
7. Connect the air lines to the brake air chambers.
8. Install the brake shoes, as removed. For instructions, see the applicable service brake section in **Group 42**.
9. If equipped with a wheel lock, engage the lock with air.

IMPORTANT: The wheel lock must be fully engaged to prevent the possibility of damage to wheel lock components while the axle shafts are being removed.

10. Using new gaskets, install the axle shafts. For instructions, see **Subject 120**.
11. Connect the main driveshaft to the forward input yoke. For instructions, see **Section 41.00, Subject 120**.
12. Connect the air hoses to the air cylinder for the interaxle lock and (if installed) the wheel lock.
13. Connect the electrical connector of the sensor unit for axles equipped with a wheel lock.
14. Fill each hub with approved axle oil until you can see a little amount of oil trickling out of the back of the hub (fill with about 0.8 quart, or 0.75 liter). Install the hubs on the axle spindles, and adjust the wheel bearings. For instructions, see **Section 35.00, Subject 100**. See **Table 1** for approved axle oils.
15. Install the brake drums on the hubs.
16. Install the tire and wheel assemblies. For instructions, see **Group 40**.
17. Adjust the brakes. For instructions, see the applicable service brake section in **Group 42**.
18. Uncage the parking brake springs.
19. Using approved axle oil, fill the forward-rear axle housing to the bottom of the fill hole, or until filled to capacity as shown in **Table 1**.

Forward-Rear Axle Oil Type and Capacity		
Approved Oil Type	Capacity: quarts (liters)	
	Hubs Full	Hubs Dry
80W-90 Gear Oil	14.3 (13.5)	15.9 (15.0)
75W-90 Synthetic Gear Oil		

Table 1, Forward-Rear Axle Oil Type and Capacity

20. Raise one side of the vehicle about 8 inches (20 cm) to let the oil flow into the hubs on the opposite side, then raise the other side in the same manner.
21. Raise the vehicle, remove the safety stands, then lower the vehicle.
22. If applicable, connect the suspension leveling valve(s). Start the engine, build the air pressure, and make sure the suspension air bags inflate correctly. Make sure the ride height is correct. For instructions, see **Group 32**.
23. Check the operation of the wheel lock, if installed.
24. Check the oil level in the axle housing. The level should be up to the bottom of the fill hole. Add approved axle oil, if needed.
25. Set the parking brake, then remove the chocks from the front tires.

Forward-Rear Axle Differential Carrier Removal and Installation

For forward-rear axle components of a tandem installation, see **Fig. 1**.

Do not disassemble either differential carrier. There are no serviceable parts in the differential assembly; it must be replaced as a unit. However, it is possible to remove the differential carrier to repair an oil leak, or to remove the wheel lock (differential lock).

When the wheel lock is removed, inspect the carrier for damage and replace it if damage is found. If no damage is found, install the carrier again.

Forward-Rear Axle Differential Carrier

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires. Put the transmission in neutral.
2. If applicable, release the suspension air pressure.
3. Using suitable jacks, raise the vehicle evenly until there is room to fit a stand underneath the axle housing.
4. Remove the tire and wheel assemblies. For instructions, see **Group 40**.
5. Remove the oil drain plug from the bottom of the axle housing and drain the oil from the axle housing. Install the drain plug after emptying.
6. Disconnect the driveshaft from the carrier yoke. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
7. Place a basin under the axle shaft flanges to catch any oil; then remove the axle shafts. For instructions, see **Subject 120**.

WARNING

The differential carrier is heavy. Do not try to move it without a suitable support. To do so could result in the carrier falling, which could cause serious personal injury and component damage. Support the carrier with a suitable jack and chain it to the jack, or use a hoist if the axle has been removed from the vehicle.

8. Using a suitable jack, support the differential carrier. Chain the differential carrier to the jack.

NOTICE

When using a pry bar, be careful not to damage the carrier or housing flange. Damage to these surfaces will cause oil leaks.

9. Remove the differential carrier from the axle housing, as follows. See **Fig. 1**.
   - 9.1 If equipped with a wheel lock, engage the lock with air. This will help separate the carrier from the axle housing.
   - 9.2 Remove all but the top two carrier capscrews.
   - 9.3 Loosen and back off, but do not remove, the top two carrier capscrews. The capscrews will hold the carrier in the housing.
   - 9.4 Using a pry bar, separate the mating surfaces of the forward differential carrier and axle housing.

   NOTE: Use a pry bar that has a round end to help separate the carrier from the housing.

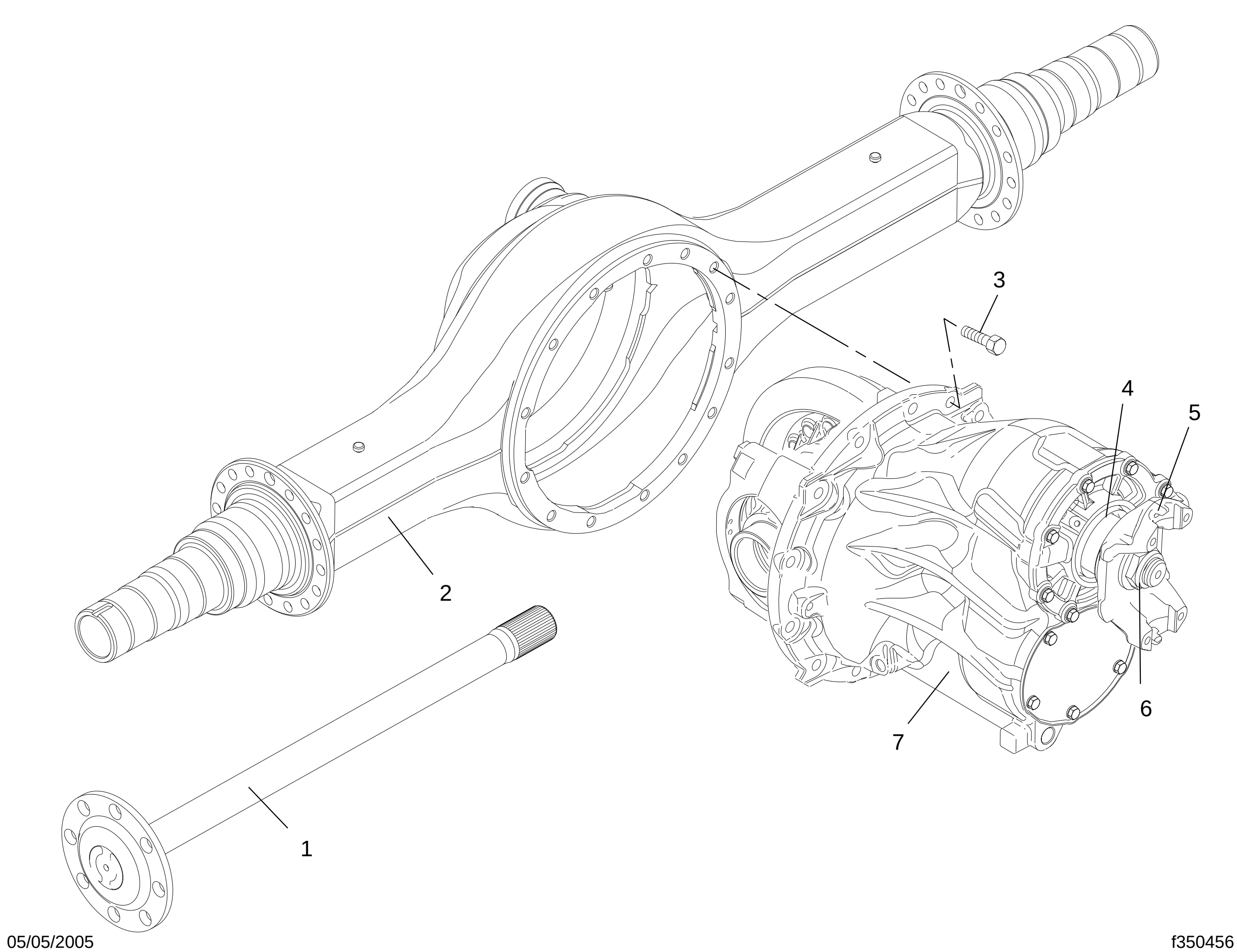
   - 9.5 When the surfaces are separated, remove the top two capscrews.
   - 9.6 With the carrier on the jack, slide the carrier away from the axle housing.
   - 9.7 Lift the carrier assembly onto a suitable stand.

Installation

NOTE: Use a cleaning solvent and clean rags to remove dirt. Blow dry the cleaned areas with air.

1. Remove any old sealant material from the mating surfaces of the axle housing. Clean the inside of the axle housing and the carrier mating surface.
2. Inspect the axle housing for damage. Repair or replace the axle housing as necessary.
3. Apply a thin bead of Loctite® 5900 sealant all the way around the mating surface of the axle housing, and around each bolt hole.

Forward-Rear Axle Differential Carrier Removal and Installation



1. Axle Shaft
2. Forward-Rear Axle Housing
3. Carrier Capscrew
4. Input Seal
5. Carrier Yoke
6. Input Yoke Nut
7. Forward Differential Carrier

Fig. 1, Forward-Rear Axle Components

NOTE: Alignment dowels for installing the differential carrier can be made by sawing off the heads of two M16 x 1.5 x 100 mm bolts.

4. Install alignment dowels 180 degrees apart at the 3 o'clock and 9 o'clock positions on the axle housing flange.

WARNING

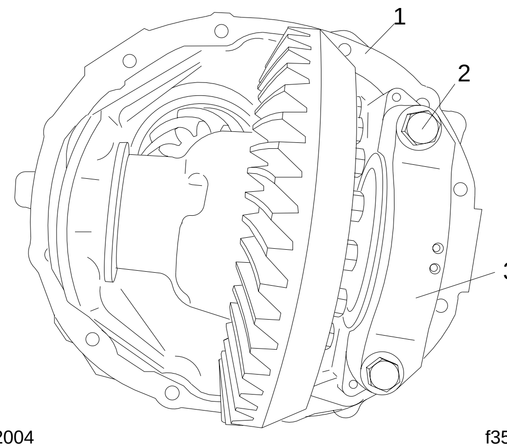
The differential carrier is heavy. Do not try to move it without a suitable support. To do so could result in the carrier falling, which could cause serious personal injury and component damage. Support the carrier with a suitable jack and chain it to the jack, or use a hoist if the axle has been removed from the vehicle.

5. Position the forward differential carrier in front of the axle housing, using an axle jack or other suitable lifting tool.
6. If equipped with a wheel lock, engage the lock with air. This will help the carrier assembly join the axle housing.

NOTICE

Do not use a hammer or a mallet to install the differential carrier. A hammer or a mallet will damage the mounting flange of the carrier and cause oil leaks.

7. Install the end caps at the sides of the forward differential carrier into the corresponding slots in the axle housing. See Fig. 2.



1. Differential Carrier
2. End Cap Bolt
3. End Cap

Fig. 2, Carrier End Caps

7.1 For the last 3/4 inch (19 mm) or so of travel, walk the carrier slowly into the housing.

IMPORTANT: The end caps fit tightly into the axle housing. Be very careful not to cock the carrier.

7.2 Install the carrier capscrews finger-tight. Make sure the carrier capscrews turn easily in the axle housing.

7.3 In a star pattern, gradually tighten the capscrews 200 lbf·ft (270 N·m).

8. Connect the driveshaft to the forward input yoke. For instructions, see **Section 41.00, Subject 120**.
9. Using new gaskets, install the axle shafts. For instructions, see **Subject 120**.
10. Install the tire and wheel assemblies. For instructions, see **Group 40**.
11. Using approved axle oil, fill the axle housing to the bottom of the fill hole, or until filled to capacity as shown in **Table 1**.

Forward-Rear Axle Oil Type and Capacity		
Approved Oil Type	Capacity: quarts (liters)	
	Hubs Full	Hubs Dry
80W-90 Gear Oil	14.3 (13.5)	15.9 (15.0)
75W-90 Synthetic Gear Oil		

Table 1, Forward-Rear Axle Oil Type and Capacity

12. If the hubs are dry, raise one side of the vehicle about 8 inches (20 cm) to let the oil flow into the hub on the opposite side, then raise the other side in the same manner. On each side, hold the tilted position for three minutes to allow oil to run into the wheel end.

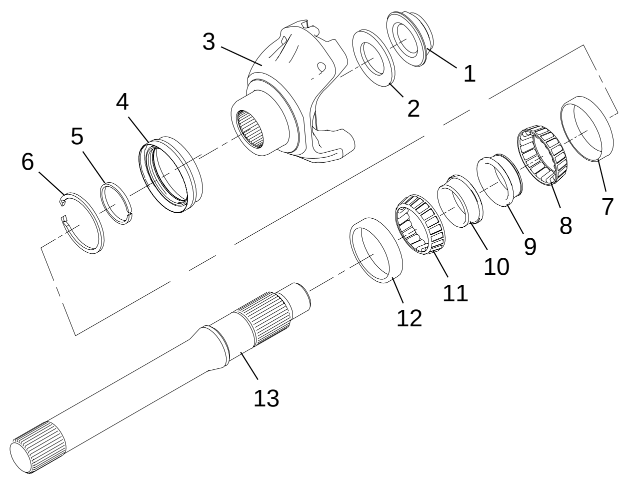
NOTICE

Make sure the hubs are filled. Driving with the hubs dry will cause bearing damage.

13. Turn the wheels, wait one minute, and check the lubricant level.
14. Raise the vehicle, remove the safety stands, then lower the vehicle.
15. Start the engine, build the air pressure, and check that the suspension air bags inflate evenly and correctly. Make sure the ride height is correct.
16. Check the oil level in the axle housing. The level should be up to the bottom of the fill hole. Add approved axle oil, if needed.
17. Remove the chocks.

Repair

1. Remove the output yoke nut, washer, and output yoke; see **Subject 170**.
2. Remove the output oil seal from the thru-shaft bore; see **Subject 170**.
3. Remove the snap ring and spacer from the thru-shaft. See **Fig. 1**.



1. Output Yoke Nut
2. Washer
3. Output Yoke
4. Output Oil Seal
5. Spacer
6. Snap Ring
7. Outer Bearing Race
8. Outer Bearing
9. Outer Bearing Cup
10. Inner Bearing Cup
11. Inner Bearing
12. Inner Bearing Race
13. Thru-Shaft

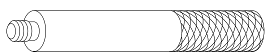
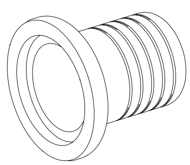
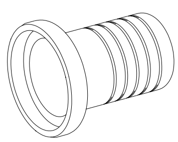
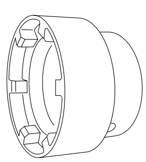
Fig. 1, Thru-Shaft Components

4. Using a suitable shaft puller, draw the thru-shaft out of the bore.
5. Using a suitable bearing puller on the outer races, remove both the inner and outer bearings from the thru-shaft.
6. Inspect the bearings for wear and damage. Replace both bearings if any damage is found.
7. Install the inner bearing race in the thru-shaft bore.
8. Using an arbor press or other suitable pressing tool, press the bearings and bearing cups onto the thru-shaft.
9. Insert the thru-shaft into its bore.
10. Install the outer bearing race onto the thru-shaft and bore.
11. Install the snap ring and spacer. Use the next thicker snap ring from the snap ring pack supplied with the bearings.
12. Install the output oil seal; see **Subject 170**.
13. Install the output yoke, nut, and washer; see **Subject 170**. Make sure the output yoke nut is firmly tightened, but do not tighten the nut to specifications at this time.
14. Attach a dial indicator to the flat surface of the output yoke.
15. Using a pry bar or other lever, apply force to the base of the output yoke. If the dial indicator shows a deflection of 0.0012 to 0.0024 inches (0.03 to 0.06 mm), the end play is correct.

    If the deflection is too large, use a thicker snap ring. If the deflection is too small, use a thinner snap ring.
16. Coat the threads of the nut with Loctite® 577. Tighten the output yoke nut 516 lbf·ft (700 N·m).

Special Tools

Special tools are required for this procedure. See **Table 1**.

Special Tools for Forward-Rear Axle Yoke and Seal Replacement			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580400	Universal Handle*	Kent-Moore	J-8092
 f580410	Input Seal Installer*	Kent-Moore	J-47369
 f580408	Output Seal Installer*	Kent-Moore	J-47368
 f580450	Yoke Nut Socket†	Axle Alliance Special Tool	DDE W742589020700

* To order Kent-Moore tools call 1-800-328-6657.

† The yoke nut socket is needed to remove the round, slotted yoke nut installed on some vehicles. It can be ordered through Paragon.

Table 1, Special Tools for Forward-Rear Axle Yoke and Seal Replacement

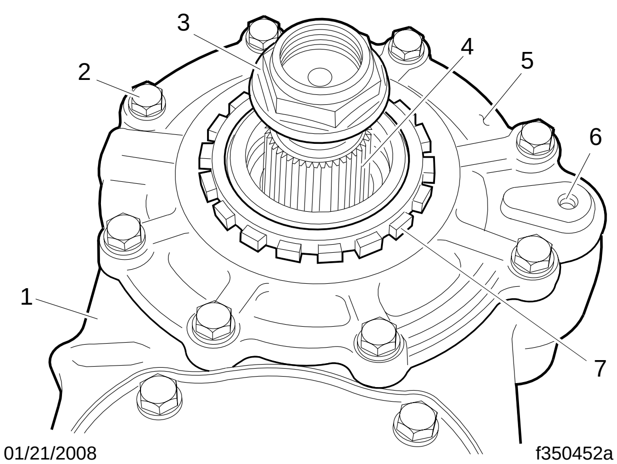
Replacement

Forward Carrier Input Yoke and Seal

1. Disconnect the main driveshaft from the forward carrier input yoke. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
2. Remove the input yoke nut and washer from the center of the forward carrier input yoke.
3. Remove the old forward carrier input yoke from the forward input shaft.
4. If there is an oil leak at the threaded ring, repair it; for instructions, see **Subject 200**.

Forward-Rear Axle Yoke and Seal Replacement

5. If there is a leak between the bearing cage and the carrier housing, remove the bearing cage, as follows. See Fig. 1.



1. Forward Carrier Housing
2. Bearing Cage Mounting Capscrew
3. Input Yoke Nut
4. Input Shaft
5. Bearing Cage
6. Interaxle Lock Bore
7. Threaded Ring

Fig. 1, Bearing Cage

5.1 Remove the bearing cage capscrews from the bearing cage.

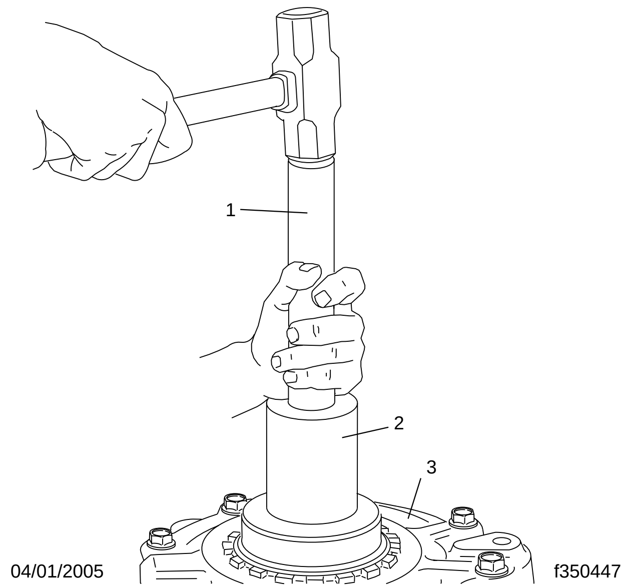
5.2 Pry the bearing cage from the forward carrier housing. Clean any remnants of sealant clinging to the mating surfaces of the carrier housing and the bearing cage.

6. Pry up the input seal, using a prybar or large screwdriver. Clean any old sealant from the axle housing. Do not allow dirt or grease to contaminate the seal bore or shaft bearings.

7. Install the seal in the input shaft bore, as follows. See Fig. 2.

7.1 Inspect the area around the seal for damage. Use emery paper to remove scratches, nicks, or burrs on the seal bore.

7.2 Assemble the input seal installer onto the threaded end of the universal handle. See Table 1.



1. Universal Handle
2. Input Seal Installer
3. Carrier Housing

Fig. 2, Installing the Forward Carrier Input Seal

7.3 Using the input seal installer assembly, press the seal into the bore until the seal surface is flush with the threaded ring.

8. On the mating surface of the bearing cage, lay down a bead of Loctite® 5900 sealant, or equivalent. Go around all of the bolt holes and other openings in the inside cover of the bearing cage. See Fig. 3.

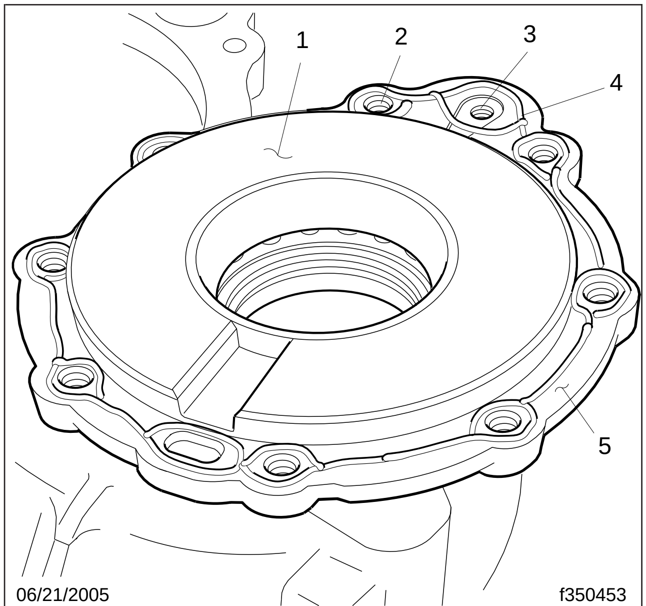
IMPORTANT: Do not allow sealant to get into the interaxle lock bore. See Fig. 4. Do not attempt to repair the interaxle differential lock (IAD). No repairs to this component are possible.

9. Install the bearing cage onto the forward carrier housing. Tighten the M12 bearing cage capscrews 107 lbf·ft (145 N·m).

10. Install the forward carrier input yoke on the forward input shaft. If the yoke is damaged or worn, install a new yoke.

NOTE: It is not necessary to replace the yoke when replacing the seal.

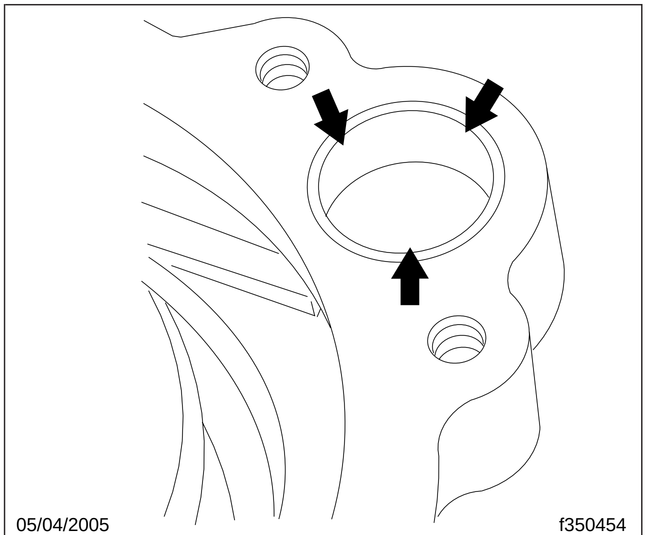
11. Coat the threads of a new M45 x 1.5 input yoke nut with Loctite® 277. Install the new washer and



Apply a bead of sealant to the inner mating surface as shown.

1. Inside Cover
2. Mounting Capscrew Hole
3. Interaxle Lock Bore
4. Sealant
5. Mating Surface

Fig. 3, Sealant Application



Keep sealant away from this bore.

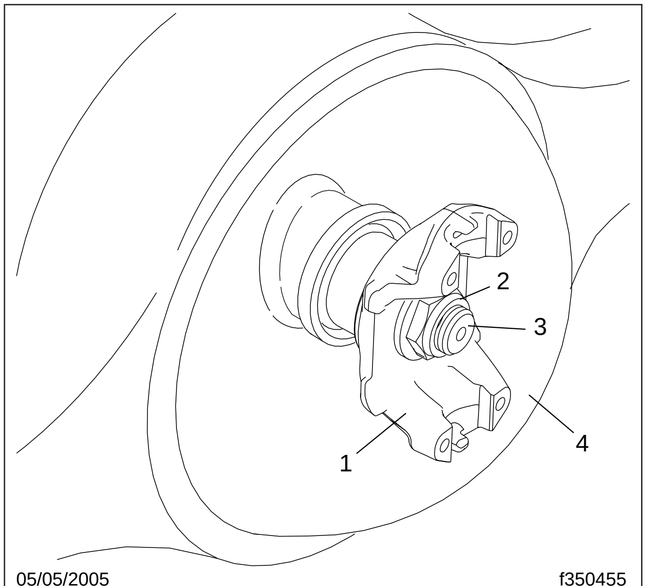
Fig. 4, Interaxle Lock Bore

input yoke nut on the forward carrier input yoke. Tighten the nut 627 lbf·ft (850 N·m).

12. Connect the main driveshaft; see **Section 41.00, Subject 120**.

Output Yoke and Seal

1. Disconnect the interaxle driveshaft from the output yoke; see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
2. Remove the output yoke nut and washer from the center of the output yoke.
3. Remove the output yoke from the thru-shaft. See **Fig. 5**.



1. Output Yoke
2. Output Yoke Nut
3. Thru-Shaft
4. Axle Housing

Fig. 5, Output Yoke

4. Pry up the output oil seal, using a prybar or large screwdriver. Clean any old sealant from the axle housing. Do not allow dirt or grease to contaminate the seal bore or thru-shaft bearings.
5. Install the seal on the thru-shaft, as follows.
   5.1 Inspect the area around the output oil seal for damage. Use emery paper to remove scratches, nicks, or burrs on the seal bore.

Forward-Rear Axle Yoke and Seal Replacement

5.2 Assemble the output seal installer onto the threaded end of the universal handle. See **Table 1**.

5.3 Using the output seal installer assembly, press the seal into the bore until the seal surface is flush with the thru-shaft receptacle.

6. Install the output yoke on the thru-shaft. If the yoke is damaged or worn, install a new yoke.

NOTE: It is not necessary to replace the yoke when replacing the seal.

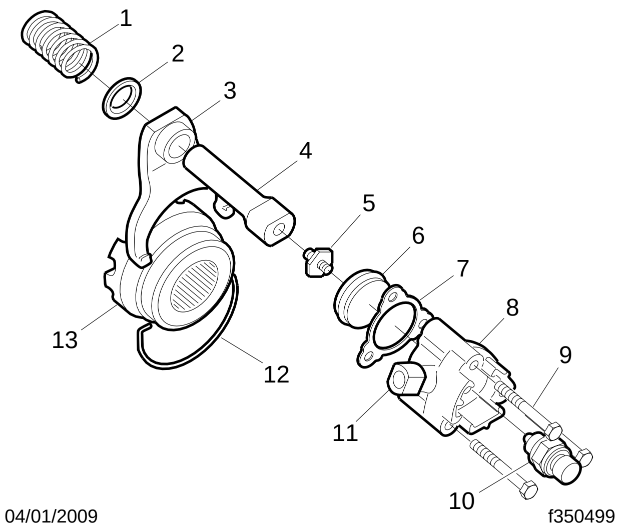
7. Coat the threads of a new M39 x 1.5 output yoke nut with Loctite® 577. Install the new washer and output yoke nut on the forward carrier output yoke. Tighten the nut 516 lbf·ft (700 N·m).
8. Connect the interaxle driveshaft; see **Section 41.00, Subject 120**.

Main Differential Lock Disassembly and Assembly, Model 2 Axles

General Information

Commonly known as DCDL (Driver-Controlled Differential Lock), a main differential lock is available on single and tandem rear axles. The following procedures only apply to Model 2 rear axles equipped with the optional DCDL.

Each part of the main differential lock is replaceable. See **Fig. 1**.



1. Spring
2. Spacer
3. Shift Fork
4. Shift Shaft
5. Adjustment Screw (with locknut)
6. Piston (with O-Ring)
7. Gasket
8. Differential Lock Cover
9. Capscrew
10. DCDL Control Switch
11. Air Interface Connection
12. Retaining Clip
13. Clutch Collar

Fig. 1, DCDL Components, Model 2 Axles

Disassembly

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires.
2. Remove the differential carrier, and place it on a work stand.

   To remove a Model 2 axle differential carrier, see **Subject 110**.
3. Remove the capscrews that attach the differential lock cover to the carrier housing. See **Fig. 1**.
4. Remove the DCDL control switch.
5. Remove the differential lock cover (including the air interface connection).
6. Remove the gasket, piston, and adjustment screw.
7. Unlatch the retaining clip, and remove it.
8. Remove the clutch collar.
9. Carefully remove the shift shaft from the bore in the carrier housing.
10. Due to spring tension, carefully remove the shift fork, spacer, and spring from the carrier housing.

Assembly

1. Install the spring in the carrier housing, and compress it to install the spacer and shift fork in the housing. Ensure that the spring is centered in the bore.
2. Install the shift shaft into the bore in the carrier housing and through the shift fork, spacer, and spring, being careful to properly align it in the bore. Do not force the shift shaft into the bore.
3. Install the clutch collar, and secure it by installing the retaining clip on the shift fork.
4. Install the adjustment screw as follows.

   4.1 Press the shift shaft in until the clutch collar teeth are fully engaged with the ring gear.

   4.2 Install the adjustment screw, and tighten it until the outer end of it is 0.02 – 0.06 inch (0.5 – 1.5 mm) below the top of the bore in the carrier housing. The screw advances 0.04 inch (1.0 mm) per full revolution, so one complete turn should be sufficient. Use an inside micrometer or depth micrometer to measure the gap.

   4.3 Hold the shift shaft and adjustment screw in a fixed position, and tighten the locknut on the adjustment screw to 18 lbf·ft (24 N·m).
5. Grease the o-ring on the piston.
6. Place the gasket on the differential lock cover, and press the flat side of the piston into the differential lock cover.

Main Differential Lock Disassembly and Assembly, Model 2 Axles

7. Place the differential lock cover over the capscrew bores in the carrier housing, and install the DCDL control switch. Tighten the nut 21 lbf·ft (28 N·m).
8. Install the differential lock cover, and in a regular sequence that seats the cover evenly, tighten the capscrews 18 lbf·ft (24 N·m).
9. Connect the DCDL air line, and engage the DCDL. Ensure the teeth of the lock fully engage the teeth of the gear inside the carrier housing.
10. Install the differential carrier; for instructions, see **Subject 110**.

Main Differential Lock Disassembly and Assembly, Model 4 Axles

Special Tool

A special tool is required for this procedure. See **Table 1**.

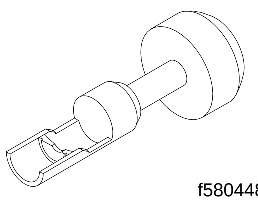
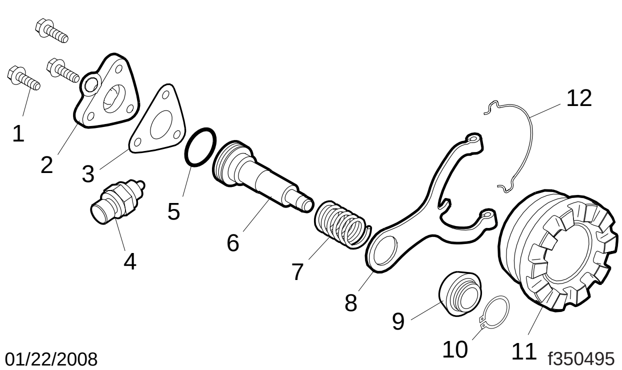
Special Tool for Main Differential Lock Disassembly and Assembly			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580448	Spring Compression Tool	Axle Alliance Special Tool	W742 589 00 16 00

Table 1, Special Tool for Main Differential Lock Disassembly and Assembly

General Information

Commonly known as DCDL (Driver-Controlled Differential Lock), a main differential lock is available on single and tandem rear axles. On tandem rear axles DCDL is available for the forward, rear, or both axles. The following procedures only apply to Model 4 rear axles with optional DCDL.

Each part of the main differential lock is replaceable. See **Fig. 1**.



1. Capscrew
2. Air Intake
3. Air Interface Gasket
4. Sending Unit
5. O-Ring
6. Shift Shaft Piston
7. Spring
8. Fork
9. Alignment Boss
10. Snap Ring
11. Clutch Collar
12. Retaining Clip

Fig. 1, DCDL Components, Model 4 Axles

Disassembly

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires.
2. Remove the differential carrier, and place it on a work stand.

   To remove a single or rearmost axle differential carrier, see **Subject 110**.

   To remove a forward-rear differential carrier, see **Subject 150**.
3. Unlatch the retaining clip, and remove it. See **Fig. 1**.
4. Remove the clutch collar.
5. Remove the DCDL sending unit from the carrier housing.
6. Remove the three bolts that attach the air interface to the carrier housing.
7. Remove the air interface and gasket.
8. Remove the shift shaft piston from the bore in the carrier housing, and note the number of shims found on the piston. There should be at least one shim, and a maximum of three.
9. Using the spring compression tool (see **Table 1**), compress the spring and pull the shift fork from the carrier housing.
10. Remove the spring from the carrier housing.

Main Differential Lock Disassembly and Assembly, Model 4 Axles

Assembly

1. Install the spring in the carrier housing, and, using the spring compression tool, compress it to install the shift fork in the housing. Ensure that the spring is centered in the bore.
2. Ensure the O-ring on the shift shaft piston is properly installed and lubricated. Then install the piston, being careful to properly align it in the bore. Do not force the piston into the bore.
3. Place the air interface and gasket over the air interface bore, and insert the three capscrews that attach the air interface to the carrier housing. Tighten the capscrews in a regular sequence that ensures it seats evenly. Tighten the capscrews 19 lbf·ft (25 N·m).
4. Install the clutch collar.
5. Install the retaining clip on the shift fork.
6. Install the DCDL sending unit in the carrier housing, as removed.
7. Connect the DCDL air line, and engage the DCDL. Ensure the teeth of the lock fully engage the teeth of the gear inside the carrier housing.
8. The clearance between the clutch collar and ring gear must be between 0.4 and 1.4 mm. Engage the DCDL, and use a feeler gauge to measure the gap.

   If the gap between the clutch collar and ring gear measured between 0.4 and 1.4 mm, ensure the same number of shims are on the shift shaft piston (as when it was removed).

   If the gap between the clutch collar and ring gear was not between 0.4 and 1.4 mm, add or remove shims to vary the gap until it measures within the acceptable range. The acceptable maximum number of shims is three, and the minimum is one.
9. Install the differential carrier.

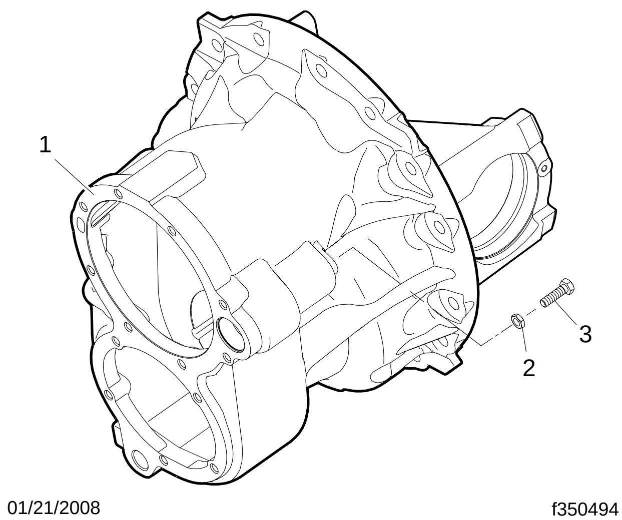
   For instructions on installing a single or rearmost axle differential carrier, see **Subject 110**.

   For instructions on installing a forward-rear axle differential carrier, see **Subject 150**.
10. Remove the chocks.

Adjustment

The Interaxle Differential (IAD) has an adjustment screw that can become loose or even fall out, causing an oil leak, and malfunction of the IAD. To ensure the adjustment screw is properly tightened and secured, follow the steps below. The IAD is sometimes called the power divider. See **Fig. 1**.

1. Chock the front tires.
2. Use the IAD switch in the cab to engage the lock.
3. Using a suitable jack, raise the vehicle until the tires are off the ground.
4. Support the vehicle with safety stands.
5. At the forward-rear axle, rotate one of the wheels to ensure the teeth of the lock fully engage the teeth of the gear inside the carrier housing.
6. Remove the adjustment screw, and using a suitable solvent (such as brake cleaner), clean the threads of the screw and bore. Dry the surfaces completely, making sure no cleaning solvent remains.
7. Coat the threads of the adjustment screw with Loctite® 577, install it, and hand-tighten it until it hits the shaft.
8. Disengage the IAD to relieve the air pressure exerted on the adjustment screw.
9. Hand-tighten the adjustment screw one quarter turn, then tighten the locknut 30 lbf·ft (41 N·m).
10. Raise the vehicle, remove the safety stands, then lower the vehicle.

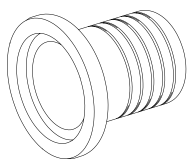


1. Carrier Housing
2. Lock Nut
3. Adjustment Screw

Fig. 1, Interaxle Differential and Adjustment Screw

Special Tools

Special tools are required for this procedure. See **Table 1**.

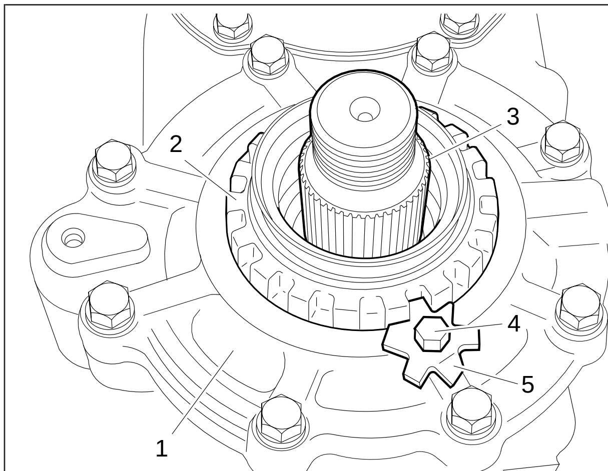
Special Tools for Threaded Ring Repair			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580400	Universal Handle*	Kent-Moore	J-8092
 f580410	Input Seal Installer*	Kent-Moore	J-47369

* To order Kent-Moore tools call 1-800-328-6657.

Table 1, Special Tools for Threaded Ring Repair

Repair

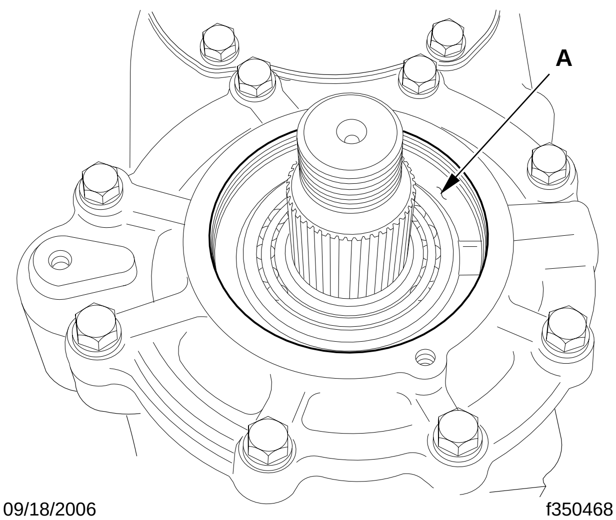
1. Apply the parking brakes, shut down the engine, and chock the tires.
2. Disconnect the main driveshaft from the forward carrier input yoke. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
3. Remove the yoke nut and washer from the input shaft of the forward differential carrier, then remove the yoke.
4. Remove the capscrew and the locking plate from the bearing cage on the front of the differential carrier. See **Fig. 1**.
5. Using a spanner wrench, remove the threaded ring to expose the bearing cavity. See **Fig. 2**.
6. Using a suitable solvent, such as brake cleaner, clean the surface of the bearing cavity. See **Fig. 2**. Dry the surface, making sure no cleaning solvent remains.
7. Coat the threads of the threaded ring with Loctite® 577 sealant. Apply a 1/8-inch (3-mm) diameter bead all the way around the bottom thread, then spread the sealant evenly over the threads, so that all threads are thoroughly covered with the sealant.



1. Bearing Cage
2. Threaded Ring
3. Input Shaft (yoke removed)
4. Capscrew
5. Locking Plate

Fig. 1, Forward-Rear Axle Differential Housing

Threaded Ring Repair



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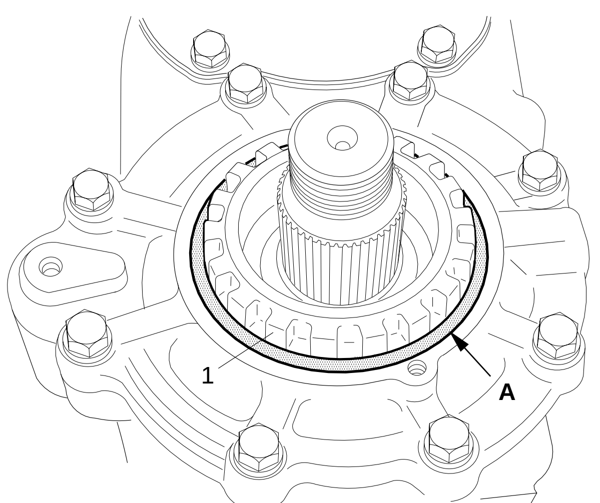
A. Clean and dry this entire surface.

Fig. 2, Bearing Cavity Exposed

8. Install the threaded ring (without the new input-shaft seal) and turn it clockwise (tighten it) enough to form a uniform bead of sealant all the way around the threaded ring. See **Fig. 3**.



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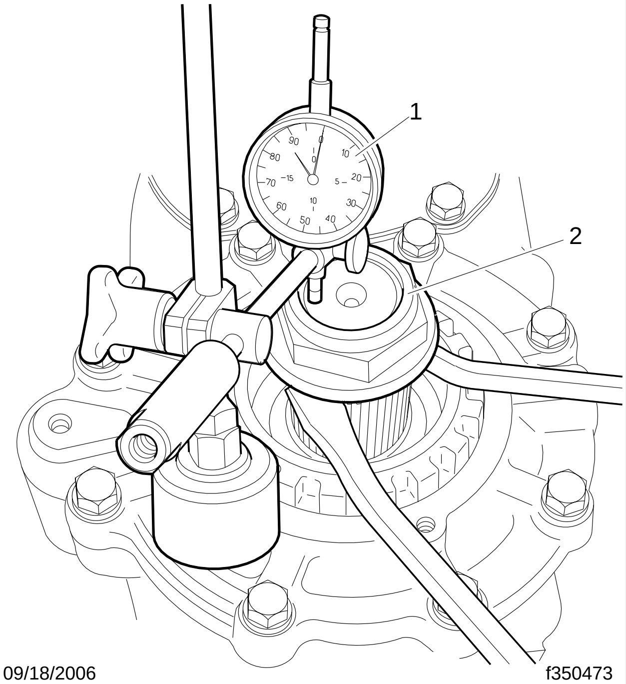
A. Loctite Bead from the Threads

1. Threaded Ring

Fig. 3, Preliminary Installation of the New Threaded Ring

9. Install the old yoke nut on the input shaft to protect the threads, then strike the nut sharply with a brass mallet to unseat the bearing.
10. Adjust the initial bearing preload to 0.002 inch (0.05 mm), as follows:

    10.1 Install a dial indicator on the bearing cage, and using two pry bars, pry up evenly on the yoke nut (and the input shaft) to determine the bearing preload. See **Fig. 4**.



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1. Dial Indicator 2. Old Yoke Nut

Fig. 4, Measuring Bearing Preload

    10.2 Tighten the threaded ring until the dial indicator reads 0.002 inch (0.05 mm).

11. Using a suitable marker or paint, mark the center of one of the teeth on the threaded ring and the surface of the bearing cage. See **Fig. 5**.

IMPORTANT: The next step is critical. Tightening the threaded ring by advancing it one tooth will set the bearing preload to 0.00 to 0.0012 inch (0.00 to 0.03 mm). If you tighten the threaded ring beyond this tolerance, you cannot back it off; you will need to remove the threaded ring and repeat the entire installation procedure.

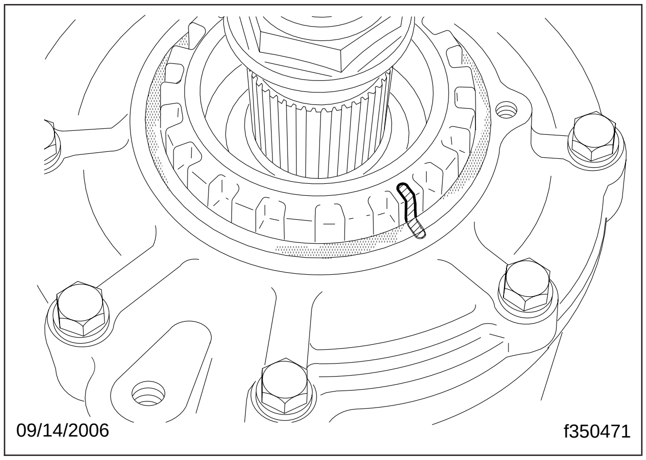


Fig. 5, Marking the Tooth and Bearing Cage

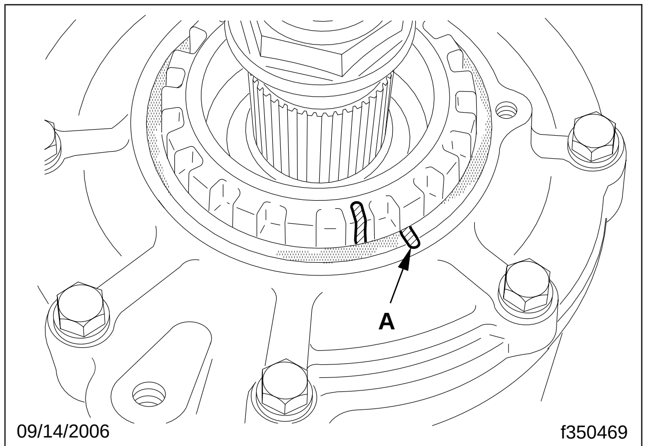
12. Very carefully advance the threaded ring one tooth while checking the paint mark. Stay close to a one-tooth advancement when making the final adjustment. Bear in mind that the new locking plate must fit into place once the correct tightness is achieved. The locking tab should fit in place either slightly before or slightly past a one-tooth advancement of the threaded ring. *You cannot back off the threaded ring once it is tightened.*

    Try fitting the new locking plate in place by turning and flipping it over as you slowly tighten the threaded ring. Tighten the threaded ring so the bearing preload is 0.00 to 0.0012 inch (0.00 to 0.03 mm). When the correct tolerance is reached, the mark on the surface of the bearing cage should line up with the center of the next tooth. See **Fig. 6**. Do not tighten the threaded ring any further.
13. When the bearing preload is correct, install the new locking plate and capscrew. Tighten the capscrew 18 lbf·ft (24 N·m).
14. Install the new input-shaft seal as follows (see **Fig. 7**):

    14.1 Inspect the area around the seal for damage. Use emery paper to remove scratches, nicks, or burrs on the seal bore.

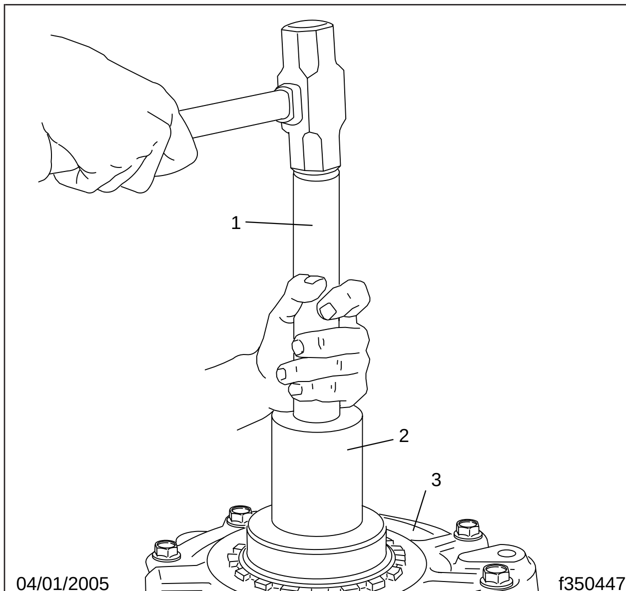
    14.2 Apply a light coating of axle oil to the seal bore.

    14.3 Coat the mating surfaces of the new seal with Loctite® 5900 sealant, or equivalent.



A. Measure preload at this point. At final tightening, this mark should be opposite the center of the next tooth, but no further.

Fig. 6, Advancing the Threaded Ring



1. Universal Handle (Kent-Moore tool, J-8092)
2. Input Seal Installer (Kent-Moore tool, J-47369)
3. Carrier Housing

Fig. 7, Installing the Forward Carrier Input Seal

    14.4 Assemble the input shaft seal installer onto the threaded end of the universal handle. See **Fig. 7**.

Threaded Ring Repair

14.5 Using the input shaft seal installer assembly, press the seal into the bore until the seal surface is flush with the threaded ring.

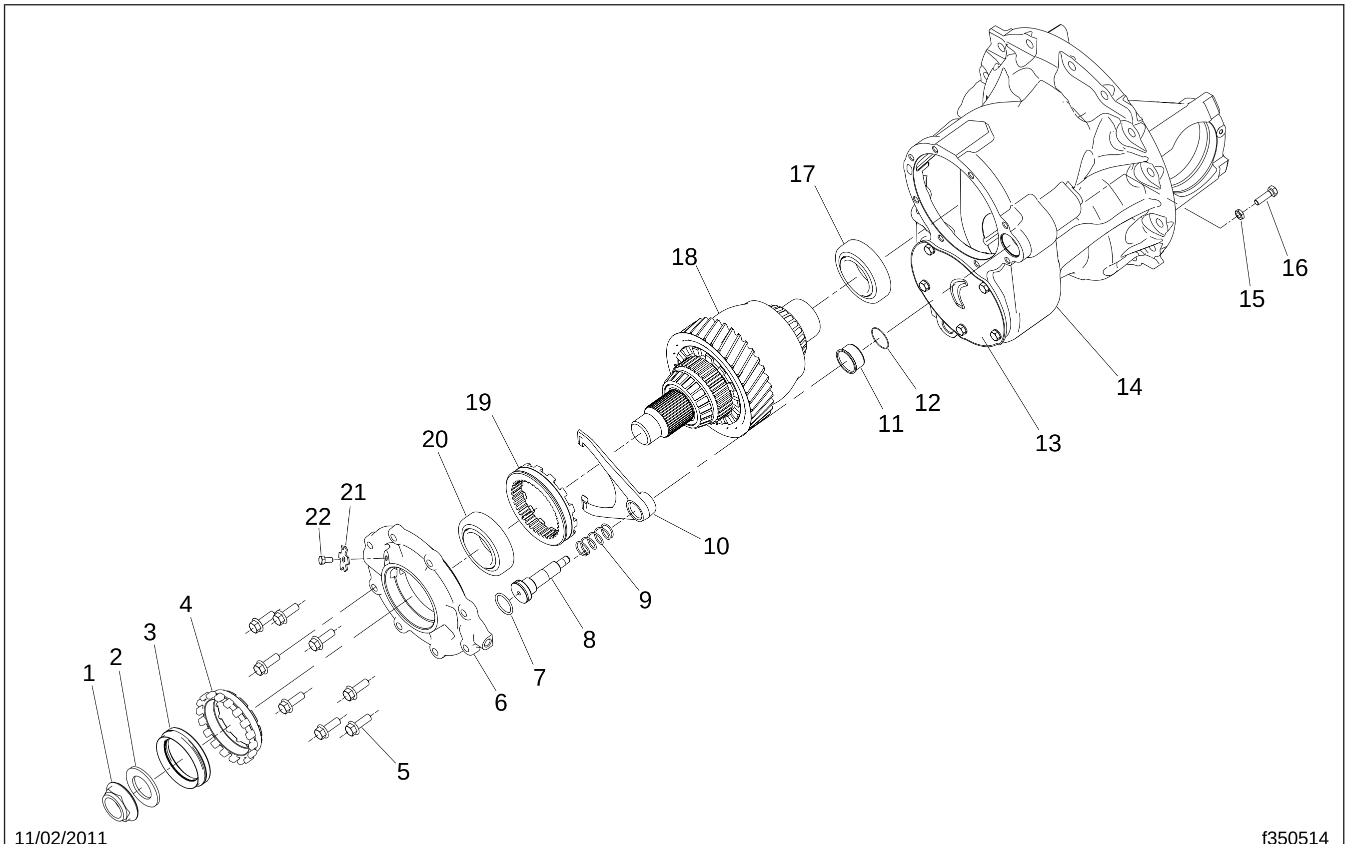
15. Apply Loctite 242 to the threads of the new yoke nut, then using it and a new washer, install the existing yoke on the input shaft. Tighten the yoke nut 628 lbf·ft (850 N·m).
16. Connect the main driveshaft to the input shaft. For instructions, see **Section 41.00, Subject 120**.
17. Remove the chocks.

Interaxle Differential Replacement

The following on-vehicle procedure replaces the interaxle differential (IAD) assembly and accomplishes a minor carrier rebuild by replacing the bearing races and, as needed, the shift shaft bushing. The front cover is resealed and the input shaft seal is replaced. See **Fig 1**.

Special Tools

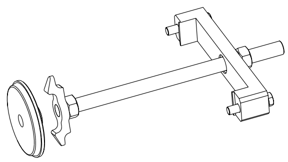
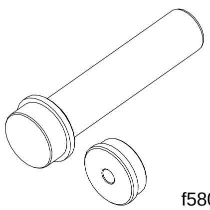
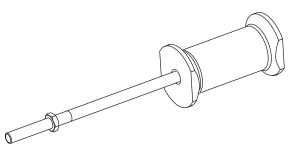
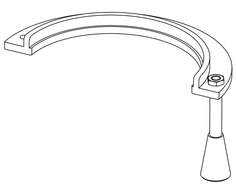
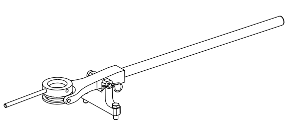
Special tools are required for this procedure. See **Table 1**.



1. Yoke Nut
2. Washer
3. Input Shaft Seal
4. Threaded Ring
5. Bearing Cage Capscrews
6. Bearing Cage
7. Shift Shaft Piston O-ring
8. Shift Shaft Piston
9. Piston Spring
10. Shift Fork
11. Shift Shaft Bushing
12. Shift Shaft Bushing O-ring
13. Cover Plate
14. Carrier Housing
15. Locknut
16. IAD Adjustment Screw
17. Output Bearing Race
18. IAD Assembly
19. Clutch Collar
20. Input Bearing Race
21. Locking Plate
22. Locking Plate Capscrew

Fig. 1, The Interaxle Differential and Carrier Housing Components

Interaxle Differential Replacement

Special Tools for Interaxle Differential Replacement			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580478	Output Bearing Remover and Installer	Axle Alliance Special Tool	MBA 420589003300
 f580480	Shift Shaft Bushing Remover and Installer	Axle Alliance Special Tool	MBA 420589013300
 f580476	Slide Hammer	Axle Alliance Special Tool	MBA 060589003300
 f580479	Half-Moon Device	Axle Alliance Special Tool	MBA 420589006300
 f580477	Push-Pull Device	Axle Alliance Special Tool	MBA 420589001600

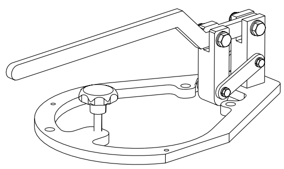
Special Tools for Interaxle Differential Replacement			
Tool	Description	Manufacturer	Part Number
 f580481	Shift Shaft Piston Installer	Axle Alliance Special Tool	MBA 420589023300

Table 1, Special Tools for Interaxle Differential Replacement

Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires.
2. Ensure the interaxle differential is disengaged and the system is charged with air. The rear wheels will need to turn near the end of this procedure.
3. Place a suitable strap around the driveshaft and frame to hold the driveshaft out of the way after it is disconnected.
4. Disconnect the main driveshaft from the forward carrier input yoke (for instructions, see **Section 41.00, Subject 120**), and support it with the strap.
5. Clean the carrier housing and surrounding area as needed to remove any debris that could enter the housing.
6. Drain the oil from the carrier housing.
7. Disconnect the air line connected to the bearing cage.
8. Remove the yoke nut and washer from the input shaft of the forward differential carrier, then remove the yoke.
9. Remove the capscrew and the locking plate. See **Fig 1**.
10. Using a spanner wrench, remove the threaded ring by turning it counterclockwise.
11. Remove the bearing cage capscrews from the bearing cage, and pry the bearing cage from the carrier housing. It may help to tap the bearing cage loose with a chisel; see **Fig. 2**.

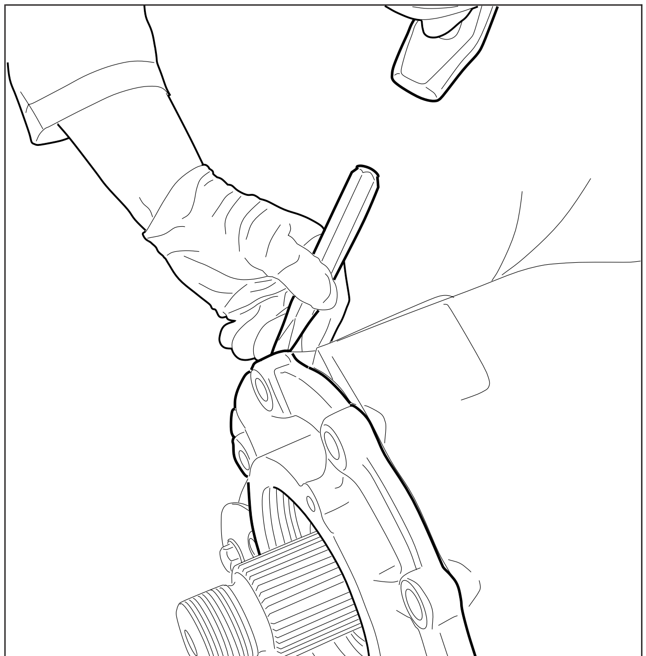

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Fig. 2, Tapping the Bearing Cage Loose

12. Remove the IAD adjustment screw and locknut.

NOTICE

When unseating the shift shaft piston, multiple taps may be needed, but use moderate force only and be careful to hit the piston only (not the housing). Stop tapping it once it protrudes from the housing. The use of excessive force, or tapping it while it protrudes from the housing can damage the piston and the housing.

13. Using a brass or plastic mallet, squarely tap the shaft shaft piston to unseat it, and then remove it from the carrier housing.
14. Remove the piston spring, clutch collar, and shift fork.

NOTICE

The IAD assembly is heavy. Use appropriate support while removing and transporting it to prevent dropping and damaging it. Do not allow it to rest on the oil slinger; see Fig. 3. Resting the IAD assembly on the oil slinger could damage the oil slinger.

15. Remove the IAD assembly.

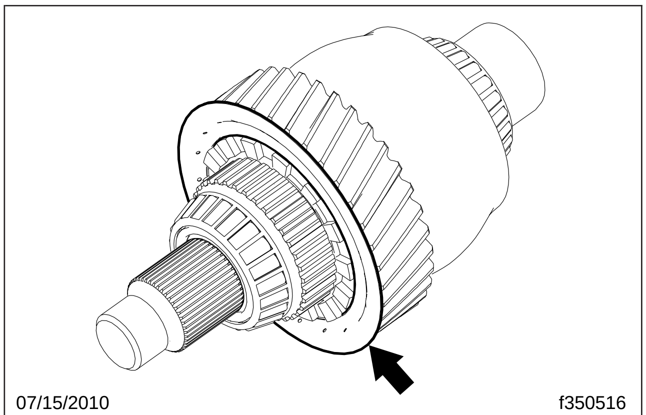


Fig. 3, Oil Slinger

16. Align the output bearing remover (see **Table 1**) with the notches in the rear of the carrier housing, then attach it to the housing with bearing cage capscrews, and use it to remove the output bearing race. See **Fig. 4**.
17. If the brass shift shaft bushing is damaged or worn, assemble the slide hammer and shift shaft bushing remover (see **Table 1**), and slide the hammer handle to remove the bushing. See **Fig. 5**.
18. Using a suitable solvent (such as brake cleaner), clean any remaining sealant from the threaded ring and mating surfaces of the carrier housing and the bearing cage. Dry the surfaces with compressed air, ensuring no cleaning solvent remains.

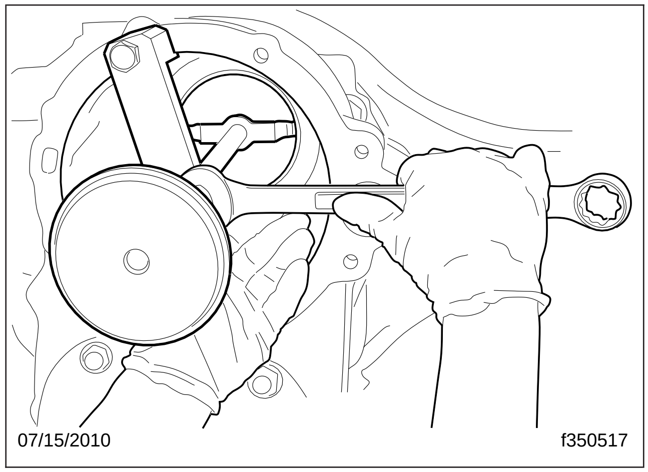
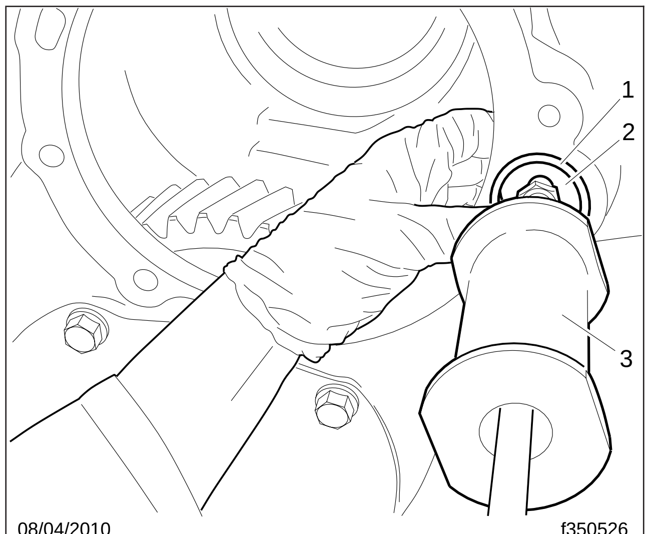


Fig. 4, Removing the Output Bearing Race

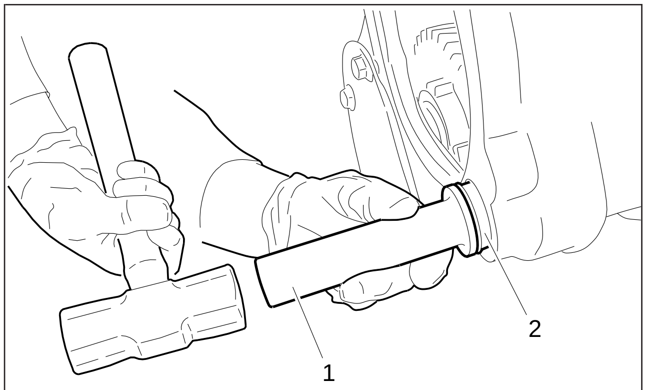


1. Shift Shaft Bushing
2. Shift Shaft Bushing Remover
3. Slide Hammer

Fig. 5, Installing the Bushing Remover

19. As in the previous step, clean the groove at the piston bushing bore.
20. If the brass shift shaft bushing was removed, install a new one using a mallet and the Shift Shaft Bushing Installer. See **Fig. 6**.
21. A new output bearing race is included with the new IAD. Install it as follows.

    21.1 To get it started, lightly tap the race into place with a hammer handle or wood block. The race must be square in the housing or damage will occur when it is pressed. See **Fig. 7**.



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1. Shift Shaft Bushing Installer
2. Shift Shaft Bushing

Fig. 6, Installing the Bushing

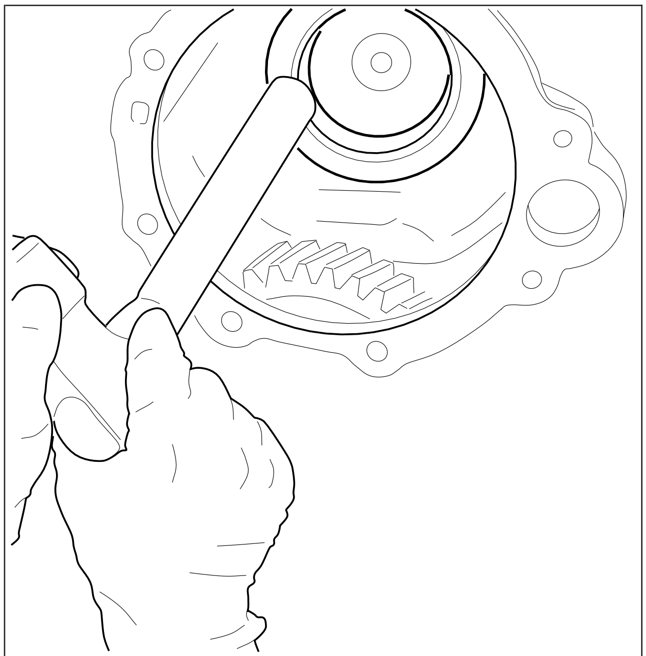

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Fig. 7, Setting the Race

21.2 Fasten the output bearing installer to the carrier housing, and use it to press the race into the housing. As the race is installed, slight jerks can be felt and heard. See **Fig. 8**.

22. Lubricate the output gear and bearing of the new IAD assembly with white grease.

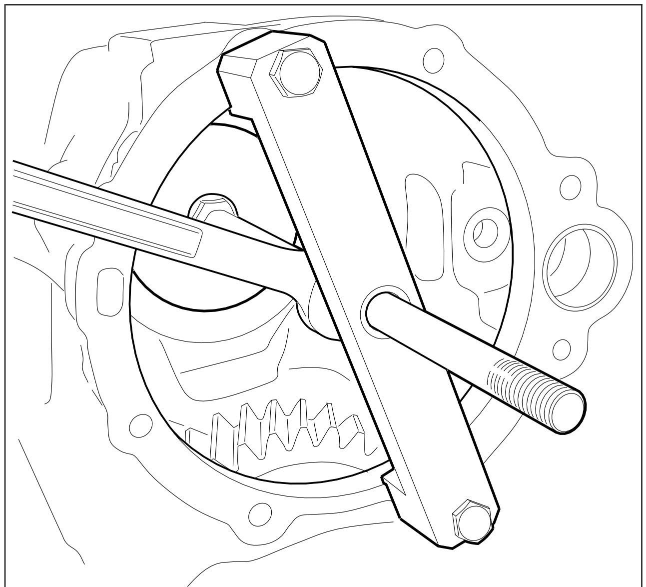

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Fig. 8, Pressing a New Race into the Housing

23. Install the IAD assembly and output gear. Do not allow the assembly to rest on the oil slinger.
24. Install the clutch collar and shift fork.
25. Apply a thin film of white grease to the shift shaft piston, and insert it with the piston spring into the housing until about 1 inch (2.5 cm) of the piston protrudes from the bore.
26. The half-moon device (see **Table 1**) helps align the shift fork and shift shaft piston. To install it, slide it between the oil slinger and the shift fork. See **Fig. 9**.
27. Install the shift shaft piston as follows.

    27.1 The shift shaft piston installer (see **Table 1**) is designed to install the piston without damaging it or the carrier housing. Use two bearing cage capscrews to mount it to the carrier housing. See **Fig. 10**.

    27.2 Adjust the hex screw until the shift fork is snug but not bound.

Interaxle Differential Replacement

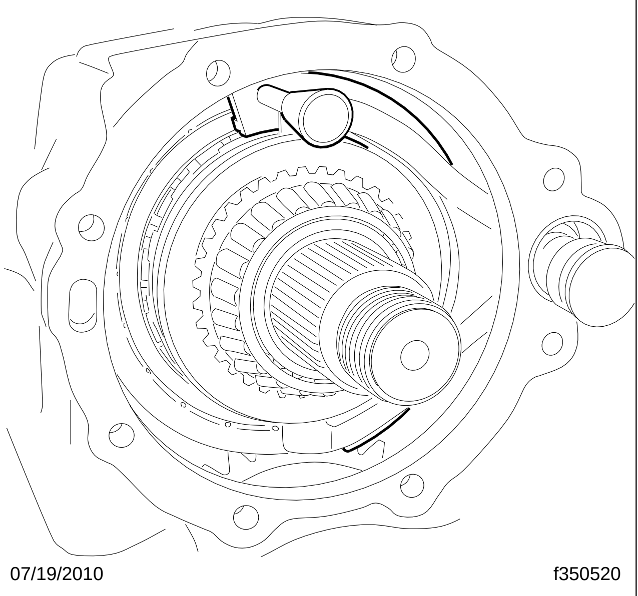
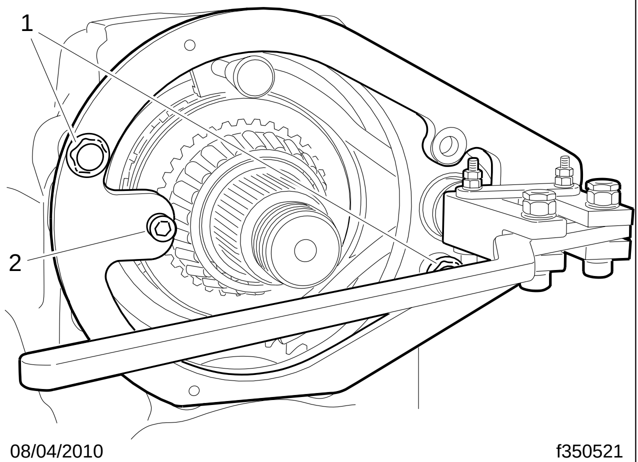


Fig. 9, The Half-Moon Device, Installed



1. Capscrews
2. Hex Screw

Fig. 10, Shift Shaft Piston Installer, Mounted

27.3 In a single movement of moderate force, use the lever of the installer to press the piston into the bore until only about 1/8 to 1/16 inch (2 to 3 mm) of the piston protrudes from the carrier housing. When the piston seats, a "click" sound may be audible. If the piston does not seat readily, adjust the hex screw, and try again.

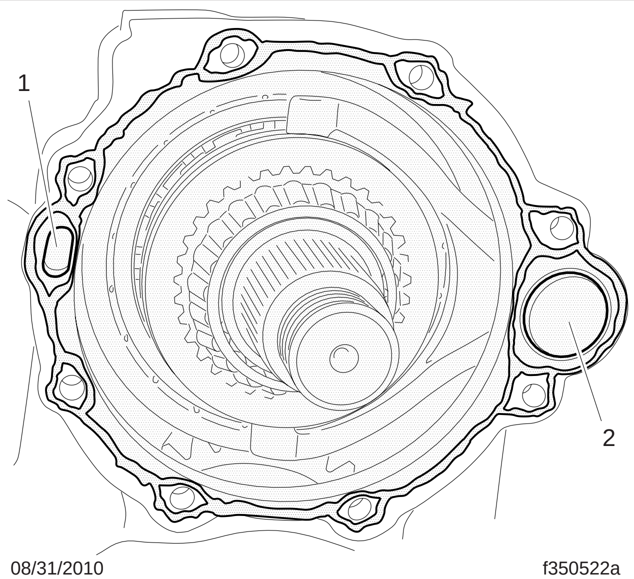
27.4 Once the piston is seated, remove the shift shaft piston installer and the half-moon device.

28. Remove the input bearing race from the bearing cage. Place the new race into the cage so that it is more forward than in the final position. As the preload is adjusted, the race will seat to its final position.

29. Apply Loctite® 577 sealant to the threads of the threaded ring and tighten it until it is snug against the race.

IMPORTANT: Do not overapply sealant. Do not allow sealant to enter the oil return or touch the shift shaft piston.

30. Apply a small bead of Loctite 5900 to the carrier housing. See **Fig. 11**. To help ensure a good seal, spread it uniformly over the surface area.



1. Oil Return
2. Shift Shaft Piston

Fig. 11, Sealant Applied to Carrier Housing

31. Install the bearing cage, and using a star pattern tighten the capscrews to 103 lbf·ft (140 N·m).

32. The push-pull device (see **Table 1**) is used to set pre-load on the input bearing. Remove the two upper capscrews from the cover plate and install the device as shown in **Fig. 12**.

33. Set the correct end play as follows.

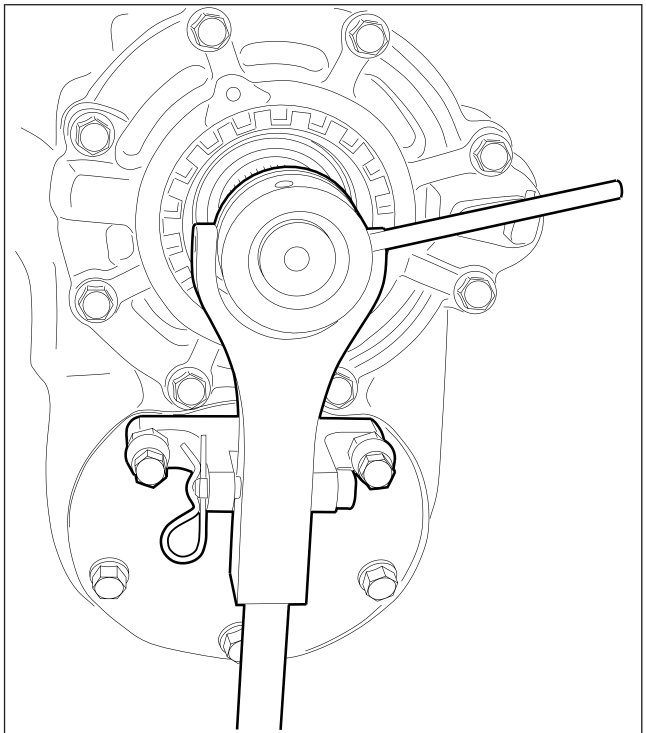


Fig. 12, Push-Pull Device, Installed

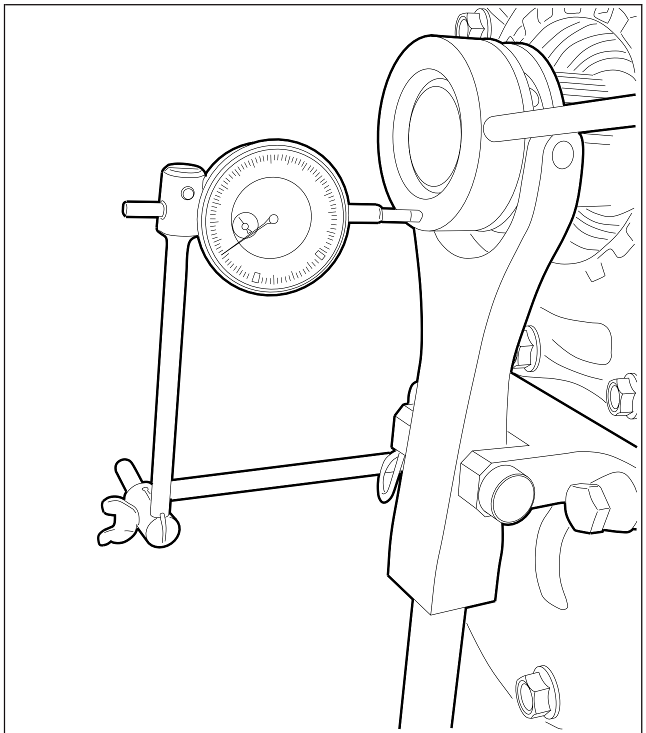


Fig. 13, Dial Indicator and Push-Pull Device

33.1 Set up a dial indicator as shown in Fig. 13.

33.2 Turn the input shaft three revolutions and tighten the threaded ring until there is between 0.002 and 0.003 inch (0.05 and 0.08 mm) of end play. Turn the input shaft three more revolutions and verify the measurement.

33.3 When there is between 0.002 and 0.003 inch (0.05 and 0.08 mm) of end play, align a mark on the threaded ring with one on the bearing cage. See Fig. 14.

33.4 Tighten the threaded ring almost one notch.

IMPORTANT: Do not loosen the threaded ring. If the threaded ring is loosened, the bearing cage must be removed and the race re-installed.

33.5 The locking plate has six positions that can lock the threaded ring. Find the position that fits best, install it, and tighten the capscrew 18 lbf·ft (24 N·m).

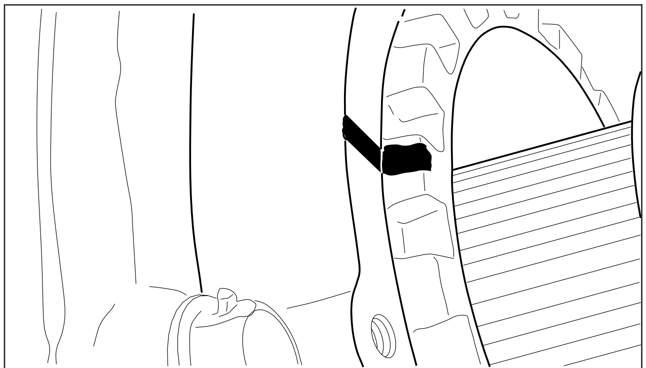


Fig. 14, Threaded Ring and Bearing Cage, Marked

33.6 Remove the push-pull device and dial indicator, and install the the two upper capscrews on the cover plate. Tighten the capscrews 63 lbf·ft (85 N·m).

Interaxle Differential Replacement

34. Install a new input shaft seal and the yoke, nut, and washer; see **Subject 170** for instructions.
35. Clean, install, and adjust the IAD adjustment screw and locknut as follows.
    35.1 Clean the IAD adjustment screw and locknut with a suitable solvent (such as brake cleaner). Dry the cleaned surfaces, ensuring no solvent remains.
    35.2 Connect an air line at the interaxle lock.
    35.3 Apply air, and by hand, turn the input shaft to ensure the gear cogs fully engage.
    35.4 Coat the threads of the adjustment screw with Loctite® 577.
    35.5 Install the adjustment screw, with the locknut, into the carrier housing, and handtighten the screw until it touches the engaged shift shaft piston.
    35.6 Disengage the IAD to relieve the air pressure exerted on the adjustment screw.
    35.7 Hand-tighten the adjustment screw one quarter turn, then tighten the locknut 30 lbf·ft (41 N·m).
36. Connect the main driveshaft; for instructions, see **Section 41.00, Subject 120**.
37. Using approved axle oil, fill the axle housing to the bottom of the fill hole, or until filled to capacity as shown in **Table 2**.

Forward-Rear Axle Oil Type and Capacity		
Approved Oil Type	Capacity: quarts (liters)	
	Hubs Full	Hubs Dry
80W-90 Gear Oil	14.3 (13.5)	15.9 (15.0)
75W-90 Synthetic Gear Oil		

Table 2, Forward-Rear Axle Oil Type and Capacity

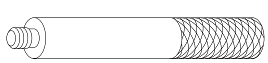
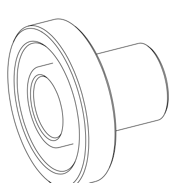
38. To lubricate the wheel ends, tilt the axle to the left and right by jacking the opposite side 8 inches (20 cm). Hold the tilted position for two minutes on each side to allow oil to run into the wheel end. Return the axle to a level position, and add oil through the axle housing filler hole. About two more pints (1 liter) of lubricant will be needed to bring the oil level even with the base of the filler hole.

Torque Values		
Application	**Size**	**Torque: lbf·ft (N·m)**
Freightliner Axles (all models)		
Carrier Capscrews	M12	115 (156)
	M16	200 (270)
Drive Axle Stud Nuts	1/2–20	75–115 (102–156)
	5/8–18	150–170 (203–230)
Pinion Nut (model 2 axles)	M40 x 1.5	370 (500)
Pinion Nut (model 4 axles)	M45 x 1.5	627 (850)
Tandem Forward Axles (Model 4 only)		
Bearing Cage Capscrews	M12	107 (145)
Input Yoke Nut	M45 x 1.5	627 (850)
Output Yoke Nut	M39 x 1.5	516 (700)

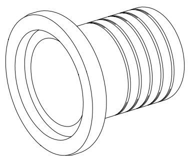
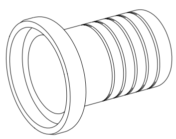
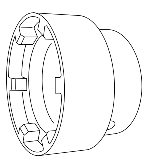
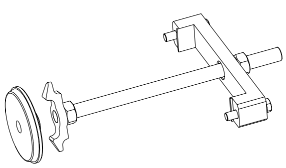
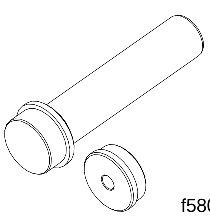
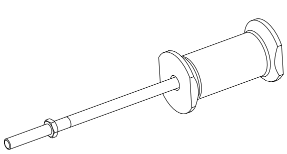
Table 1, Torque Values

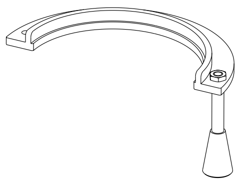
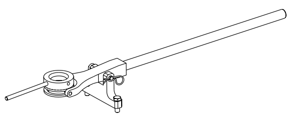
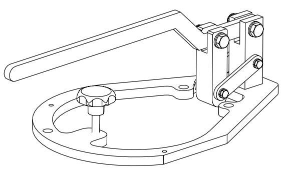
Single Rear Axle Oil Type and Capacity				
Model	**Approved Oil Type**		**Capacity: quarts (liters)**	
	Mineral	**Synthetic**	**Hubs Full**	**Hubs Dry**
Model 2	80W-90	75W-90	5.8 (5.5)	7.4 (7.0)
Model 4			10.6 (10.0)	12.2 (11.5)

Table 2, Single Rear Axle Oil Type and Capacity

Special Tools for Freightliner Rear Axles			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580400	Universal Handle*	Kent-Moore	J-8092
 f580406	Rear Pinion Seal Installer*	Kent-Moore	J-47354

Specifications

Special Tools for Freightliner Rear Axles			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580410	Input Seal Installer*	Kent-Moore	J-47369
 f580408	Output Seal Installer*	Kent-Moore	J-47368
 f580450	Yoke Nut Socket†	Axle Alliance Special Tool	MBA 742589020700
 f580478	Output Bearing Remover and Installer	Axle Alliance Special Tool	MBA 420589003300
 f580480	Shift Shaft Bushing Remover and Installer	Axle Alliance Special Tool	MBA 420589013300
 f580476	Slide Hammer	Axle Alliance Special Tool	MBA 060589003300

Special Tools for Freightliner Rear Axles			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580479	Half-Moon Device	Axle Alliance Special Tool	MBA 420589006300
 f580477	Push-Pull Device	Axle Alliance Special Tool	MBA 420589001600
 f580481	Shift Shaft Piston Installer	Axle Alliance Special Tool	MBA 420589023300

* To order Kent-Moore tools call 1-800-328-6657.

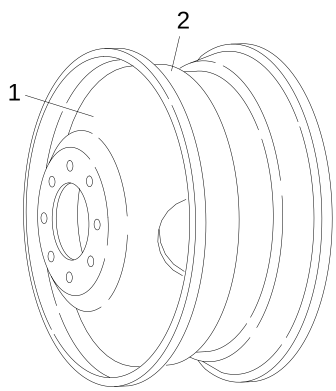
† The yoke nut socket is needed to remove the round, slotted yoke nut installed on some vehicles. It can be ordered through Paragon.

Table 3, Special Tools for Freightliner Rear Axles

General Information

The tires support the weight of the vehicle, and are integral parts of the transmission and braking systems. The wheels serve as load carrying members between the tires and the axle.

Only hub-piloted disc wheels are used on Business Class M2 vehicles. Standard eight-hole and optional ten-hole disc wheels consist of a rim and disc. The rim, the portion of the wheel on which the tire is mounted and supported, is welded to the disc (**Fig. 1**). After the tire is mounted on the wheel, the assembly is held in place on the hub with two-piece flange nuts.



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1. Disc
2. Rim

Fig. 1, Disc Wheel

Only radial tires are used on Business Class M2 vehicles. Radial tires have ply cords that run from bead to bead, and at a right angle to the belt plies and tire tread (**Fig. 2**). The belt plies constrict the radial ply cords and give rigidity to the tread.

Tire body plies and belt plies are made of polyester, rayon, nylon, fiberglass, steel, or aramids (fibrous reinforcements). In radial ply tires, these materials are used in various combinations, including steel body/steel belt, polyester body/fiberglass belt, or nylon body/steel belt.

Wheels and tires operate either with or without tubes. Tube-type tires require a tube and flap for correct assembly on a two-or three-piece rim. Tubeless tires require only the tire, and a one-piece drop-center wheel or rim. See **Fig. 1**.

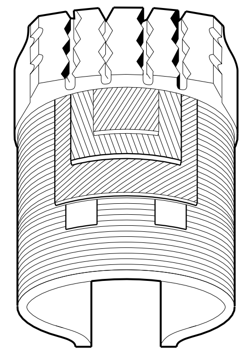

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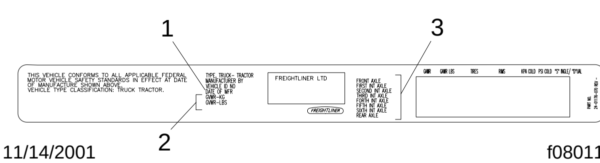
Fig. 2, Radial Ply Tire Construction

IMPORTANT: Review and follow these requirements for matching and mixing tires, before installing any tire and wheel or rim assembly on a vehicle.

Before changing wheels and tires, consider the effect that the change may have on the Gross Vehicle Weight Rating (GVWR) of the vehicle. At the time of vehicle certification, the GVWR is calculated by adding the vehicle's Gross Axle Weight Ratings (GAWR). The GVWR and each of the GAWRs are shown on a certification label (U.S.-purchased vehicles) or "Statement of Compliance" label (Canadian-purchased vehicles) attached to the left rear door post. See **Fig. 3**.



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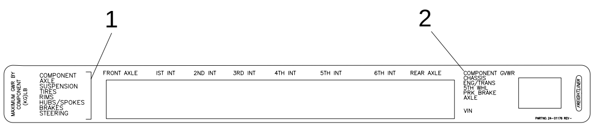
1. Date of Manufacture
2. Gross Vehicle Weight Rating
3. Gross Axle Weight Rating

Fig. 3, Certification Statement, U.S.

Tire and rim labels (**Fig. 3** and **Fig. 4**) certify the minimum tire and rim combinations that can be installed on the vehicle for the given GAWRs. Each GAWR is determined by considering each component of the axle system, including suspension, axle, wheels, and tires. The lowest component's capacity is the value used for the system. Therefore, the tires and rims installed on the vehicle at the time of vehicle manufacture may have a higher load capacity than that certified by the tire and rim label. Tires and

General Information

rims of the minimum capacity can be installed without changing the load limitations. If tires and rims are installed that have a lower load capacity than that shown on the tire and rim label, then the tires and rims determine the load limitations (the GAWRs and GVWR will be lower).



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NOTE: Examples only. Actual specifications may vary from vehicle to vehicle.

1. Gross Weight Rating by Component
2. Gross Vehicle Weight Rating By Component in Vehicle as a Whole

Fig. 4, Tire and Rim Labels

When pairing tires in a dual assembly, the tire diameters must not differ by more than 1/4 inch (6.4 mm), or the tire circumference by more than 3/4 inch (19 mm). The total tire circumference of one driving rear axle must match, as nearly as possible, the total tire circumference of the other driving rear axle.

CAUTION

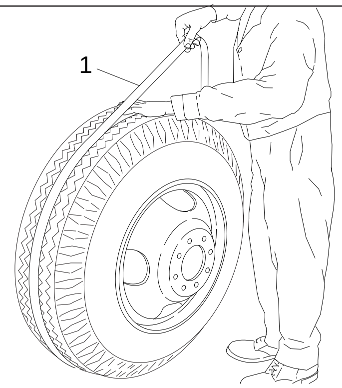
Mismatching dual tires overloads the larger diameter tire, causing it to overdeflect and overheat. The smaller diameter tire, lacking proper road contact, wears faster and unevenly. Tread or ply separation, tire body breaks, and blowouts can occur from mismatched duals.

With an endless pi tape (**Fig. 5**) or square (**Fig. 6**), measure the diameter of the tires 24 hours after inflation. A matching stick (**Fig. 7**), string gauge (**Fig. 8**), or tire straight edge (**Fig. 9**) can also be used to determine the difference in tire radius, which is then doubled to calculate the diameter difference.

When pairing tires of unequal diameters (but within the above limits), mount the larger tire on the outside.

CAUTION

Driving a vehicle on one tire of a dual assembly dangerously exceeds the carrying capacity of the single tire and wheel. Operating in this manner can cause damage to the wheel and tire.



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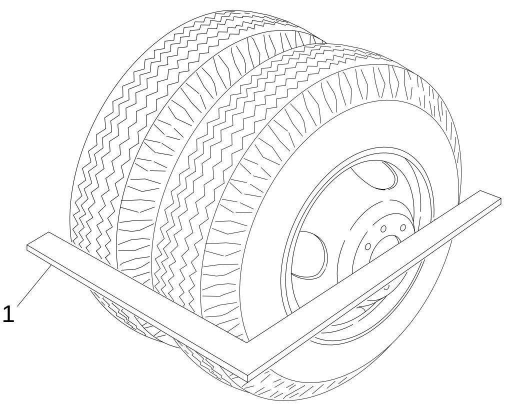
1. Endless Pi Tape

Fig. 5, Endless Pi Tape



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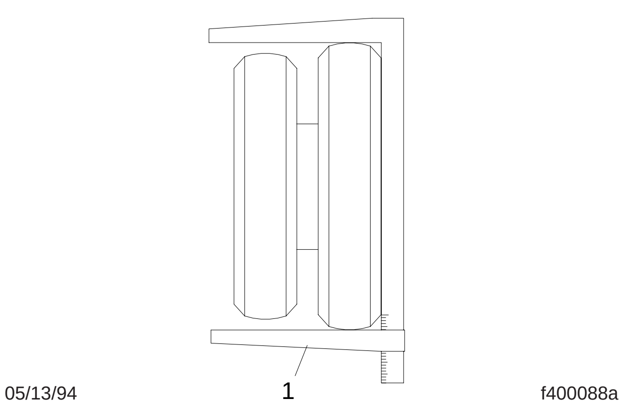
1. Square

Fig. 6, Square

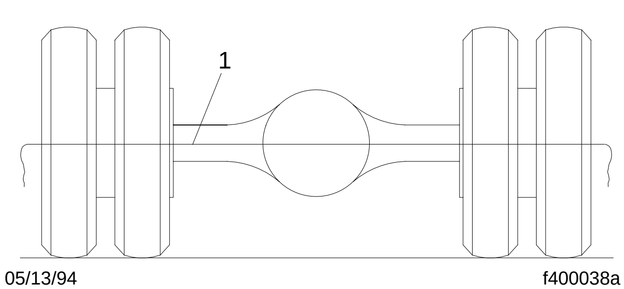
Inflate all tires on an axle, or on both axles of a tandem unit, to within 5 psi (35 kPa) of one another. For tire inflation specifications, see **Specifications, 400**.

There must be sufficient space between dual tires for air to flow and cool the tires, and to prevent them from rubbing against one another. Rims and wheels of the same size, but of different makes and types, can have different offsets, which would affect dual spacing. If there is sidewall contact between tires, or between the inside tire and the chassis, refer to the tire manufacturer's catalog to determine the minimum dual spacing. Refer to the rim or wheel manufacturer's catalog to determine the correct offset.



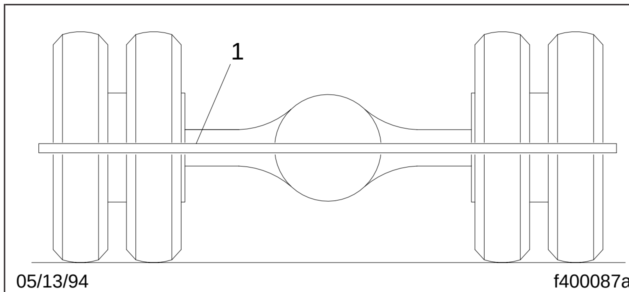
1. Matching Stick

Fig. 7, Matching Stick



1. String Gauge

Fig. 8, String Gauge



1. Tire Straight Edge

Fig. 9, Tire Straight Edge

Federal Motor Carrier Safety regulations require the removal of all tires with less than 4/32 inch (3 mm) remaining groove depth on a front axle, and tires with less than 2/32 inch (1.5 mm) remaining groove depth on a rear axle. However, tires with the word "Regroovable" on the sidewall, may be regrooved.

CAUTION

Mixing radial and bias ply tires should be done as an emergency measure only. Some loss of steering control and premature tire wear could occur when driving under such conditions.

Better tire and vehicle performance is usually obtained by using tires of the same size and construction. Using tires of different construction is permitted if the following rules are observed:

- Do not mix radial and bias ply tires on the same axle.
- If both radial and bias ply tires are used, better handling is usually obtained by using the bias ply tires on the front axle.
- Use either all radial or all bias ply tires on the non-driving rear axles of a vehicle. However, all radial or all bias ply tires must be used on vehicles with tandem drive-axles.

Disc Wheel Removal and Installation

Removal

1. Park the vehicle on a level surface. Shut down the engine.
2. To prevent vehicle movement, chock all tires that will not be serviced. If removing the front wheels and tires, apply the parking brake.
3. Raise the end of the vehicle until the tires clear the floor. Place safety stands under the axle being serviced.
4. If the tire or wheel is damaged, or if there is reason to suspect damage, deflate the tire (or tires, on a dual assembly) being serviced by removing the valve core.
5. Turn the wheel until one hub-pilot pad is in the top-center position.
6. Leaving the top and bottom nuts until last, remove the other two-piece flange nuts.
7. Place a jack or wheel-and-tire dolly under the wheel assembly being serviced. Remove the top and bottom nuts.

CAUTION

The wheel center hole and hub pilot have close tolerances. If the wheel is not kept square to the hub, it could bind during removal and damage the stud threads or pilot pads. Keep the wheel square to the hub during removal.

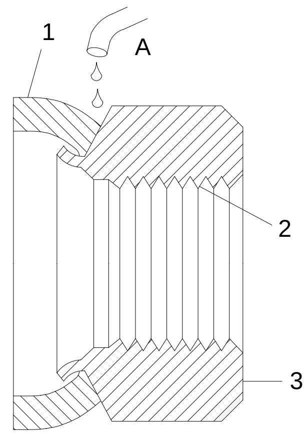
IMPORTANT: On both sides of the vehicle, the two-piece flange nuts have right-hand metric threads.

8. Remove the wheel. Do not let it drop on or drag across the stud threads.

Installation

NOTE: Before installing a wheel and tire assembly, inspect it using the instructions in **Subject 120**. Follow the tire matching and mixing requirements in **Subject 050**.

1. Clean the hub and wheel mounting surfaces, and all disc faces of dual wheels. Make sure the tire is correctly inflated. For instructions, see **Subject 130**.
2. Apply a few drops of light engine oil to the wheel studs and the area between the body and the flange of each two-piece flange nut. See **Fig. 1**. Wipe off any excess oil.



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NOTE: Apply oil here.

1. Flange
2. Nut Threads
3. Nut Body

Fig. 1, Lubricating a Two-Piece Flange Nut

CAUTION

The wheel center hole and hub pilot have close tolerances. If the wheel is not kept square to the hub, it could bind during installation and damage the stud threads or pilot pads. Keep the wheel square to the hub during installation.

IMPORTANT: Before installing the wheels, make sure the drum is positioned on the raised step of the pilot pad. One of the hub's pilot pads must be at the top location. To help keep the drum in place, it may be necessary to apply the brakes before installing the wheels.

3. Locate one hub-pilot pad in the top-center position. Using a jack or wheel-and-tire dolly, position the wheel assembly (inner wheel assembly on duals) on the hub. Make sure the wheel is square to the hub and that the threads are not damaged by contact with the wheel during installation. On dual assemblies, mount the outer wheel against the inner wheel using the same procedure.

Disc Wheel Removal and Installation

4. Make sure the hub-pilot pad is still centered at the top.

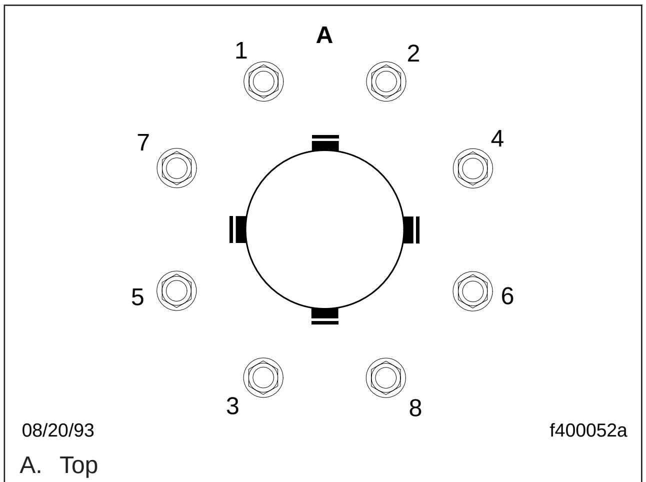
IMPORTANT: Install the wheel assembly so that the balance weight(s) on the wheels are 180 degrees opposite the balance weight(s) on the brake drum. If this causes the valve stems to be in the same wheel hole on the rear wheel assemblies, mount the outer wheel so that the outer wheel balance weight(s) is on the same side as the brake drum balance weight(s).

5. Install and hand-tighten a two-piece flange nut on the top and bottom studs.

CAUTION

The two-piece flange nuts have right-hand metric threads. Do not try to install a similar size SAE nut on a stud or the stud and nut will be damaged.

6. Install and hand-tighten the remaining two-piece flange nuts. Tighten the nuts 50 lbf·ft (68 N·m) following the sequence in **Fig. 2** or **Fig. 3**.



A. Top

Fig. 2, 8-Stud Disc Wheel Tightening Sequence

7. Check that the wheel is correctly seated against the hub and on the hub-pilot pads.
8. Following the sequence in **Fig. 2** or **Fig. 3**, tighten the two-piece flange nuts 450 to 500 lbf·ft (610 to 678 N·m).

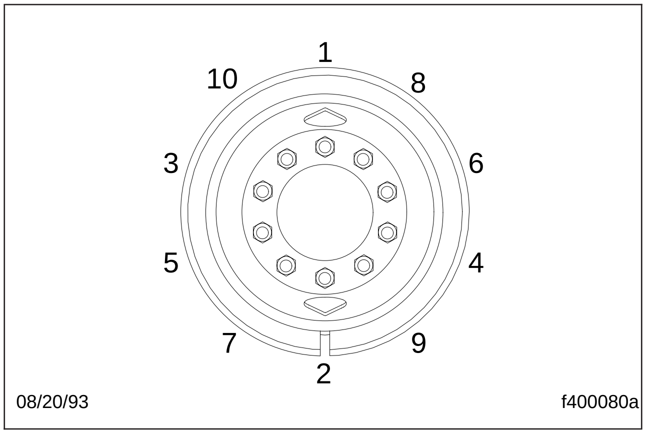


Fig. 3, 10-Stud Disc Wheel Tightening Sequence

WARNING

If the wheel nuts cannot be tightened to minimum torque values, the studs could be turning in the hub flange, having lost their locking ability. In this case, the wheel hub assembly is damaged and must be replaced with a new assembly.

Failure to reach minimum torque values could also be caused by stripped threads on the wheel studs or wheel nuts. Damaged parts must be replaced with new parts. Failure to replace damaged parts could result in the loss of a wheel or loss of vehicle control, causing property damage or personal injury.

IMPORTANT: Replace damaged parts following the instructions in **Group 33** or **Group 35**.

9. Remove the safety stands, lower the vehicle and remove the chocks.
10. After operating the vehicle for 50 to 100 miles (80 to 160 km), retighten the wheel nut 450 to 500 lbf·ft (610 to 678 N·m). Follow the sequence in **Fig. 2** or **Fig. 3**.

CAUTION

Too little wheel nut torque can cause wheel shimmy, wheel damage, stud breakage and extreme tire tread wear. Too much wheel nut torque can break studs, damage threads and crack discs in the stud hole area. Use the specified torque values and follow the tightening sequence in Fig. 2 or Fig. 3.

Disc Wheel Removal and Installation

IMPORTANT: The two-piece flange nuts seat during vehicle operation. It is necessary to periodically tighten the wheel nuts to the specified torque. Tighten the two-piece flange nuts to the specified torque 50 to 100 miles (80 to 160 km) after service work and check the torque every 10,000 miles (16 000 km).

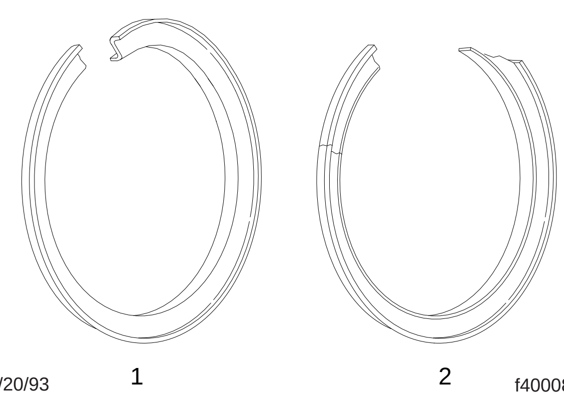
Inspection

WARNING

Inspect the tires and wheels, and correct any problems. Failure to do so could cause tire or rim damage while servicing or while in use. An incorrectly mounted tire can burst causing personal injury and equipment damage.

Examine the wheel or rim, and all parts. Remove any grease, dirt, or rust. Using a wire brush, remove any rubber from the bead seat. Use special care when cleaning the rim gutter. Rust or other foreign matter can prevent the correct fitting of side rings. Replace corroded parts. Paint the rim to prevent corrosion.

Sprung or broken rings (**Fig. 1**), a cracked rim, wheel (**Fig. 2**), or brake drum, damaged inner or outer wheel nuts (**Fig. 3**), or an out-of-round wheel or rim, requires the replacement of the damaged part. Replace the wheel if it has out-of-round stud holes.



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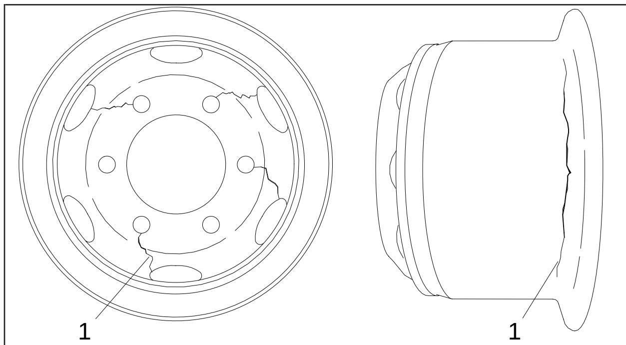
1. Sprung Side Ring
2. Broken Side Ring

Fig. 1, Sprung and Broken Side Rings

NOTE: Refer to **Group 33** and **Group 35** for inspection and service procedures for the hub, wheel studs, wheel, and brake drum assemblies.

Inspect valve cores for cracks, bends, and air retention. Replace damaged or leaky cores.

Check the clamps, rim spacer, rim studs, and wheel nuts for damage or wear. The clamps must not be excessively worn. The end of the wedge portion must be at least 1/16-inch (1.5-mm) thick. See **Fig. 4**. The rim spacer must not be bent, distorted, or crushed. Replace all damaged or broken parts.



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1. Crack

Fig. 2, Cracked Wheel and Rim

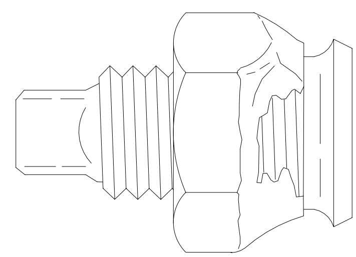

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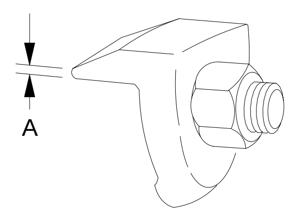
Fig. 3, Damaged Outer Wheel Nut



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A. End of wedge must be at least 1/16-inch (1.5-mm) thick.

Fig. 4, Rim Clamp

Do not attempt to rework, weld, heat, or braze any rim or wheel parts that are cracked, broken, or damaged. Use new parts or parts that are not cracked, broken, or otherwise damaged, and that are of the same size and type.

Wheel and Components Inspection

Remove all foreign matter, such as grease and dirt, from the wheel mounting surface. Smooth any projections on the mounting surface to ensure even pressure when tightening the wheel nuts.

Inspection

⚠ WARNING

Inspect the tires and wheels, and correct any problems. Failure to do so could cause tire or rim damage while servicing or while in use. An incorrectly mounted tire can burst, causing personal injury and equipment damage.

Inspect the inside and outside of the tire for out-of-roundness, loose cords, cuts, foreign objects, and other damage. Repair as needed. Contact the tire manufacturer for repair procedures.

Do not repair tires with the following problems:

- Cuts in the tread that are wire or breaker fiber deep.
- Tread worn to the wire or breaker fibers.
- Tread that is scalloped or otherwise worn unevenly.
- Visible, broken, deformed, or otherwise damaged bead wires.
- Deteriorated rubber.
- Rubber cracked to the wire or cord.
- Separations in the casing.
- Exposed cord (for example, due to weather checking or sidewall scuffing).

Inspect the tread for abnormal or excessive wear. Refer to **Troubleshooting, 300** for possible causes of abnormal wear. If the tires are wearing irregularly, they should be rotated. If the front axle tires become irregularly worn, they should be moved to the drive axle(s) or trailer axles. The front-end alignment should be checked. In a dual assembly, if one tire wears faster than its mate, the position of the two tires should be reversed. See Group 40 of the *Business Class M2 Maintenance Manual* for tire rotation procedures.

Government regulations require the removal of any tire with less than 2/32-inch (1.5-mm) tread remaining. Retread the tire (if possible), regroove it (only if marked "Regroovable" on the sidewall), or discard it.

Clean and inspect the tube and flap of tube-type tires. Discard tubes or flaps that are buckled or creased. Do not use an old tube in a new tire, and always mount a used flap in the same size tire and on the same size rim as the one from which it was removed. Michelin Tire Corporation recommends using only new tubes, flaps, valve cores, caps, and O-rings in a new mounting.

Tire Inflation

1. Check all parts to make sure they are correctly seated prior to inflation.

NOTE: Inflate tires in a safety cage (**Fig. 1**) or an approved portable restraining device. Always use a clip-on chuck with an inline valve and gauge. Make sure the inflation hose is long enough to permit standing to the side of the tire during inflation. Never sit on or stand in front of an assembly that is being inflated.

WARNING

During initial tire inflation, there is the possibility of an explosion of the assembly. Observe the following safety rules to reduce the possibility of serious physical injury in the event of an explosion.

IMPORTANT: Inflate tires immediately after mounting, before the tire lubricant dries. Once the lubricant dries, bead positioning is not possible, even with increased inflation pressure.

Water in the tire can cause ply separation. During tire inflation, air tank reservoirs and lines must be dry. Use well-maintained air line moisture traps, and service them regularly.

2. After placing the tire in a safety cage, or an approved portable restraining device, inflate the tire to 10 psi (69 kPa). Check the parts for correct seating. If the seating is not correct, completely deflate the tire and correct the problem. Never attempt to seat rings or other parts by hammering on an inflated or partially inflated tire.

IMPORTANT: Due to the different flex characteristics of radial sidewalls, it may be necessary to use an inflation aid to help seat tubeless tire beads:

- Metal rings, which use a blast of compressed air to seat the beads.
- Rubber rings, which seal between the tire bead and rim, allowing the bead to move out and seat correctly. A well-lubricated, heavy-duty bicycle tube can be used to help seal between the tire bead and rim.

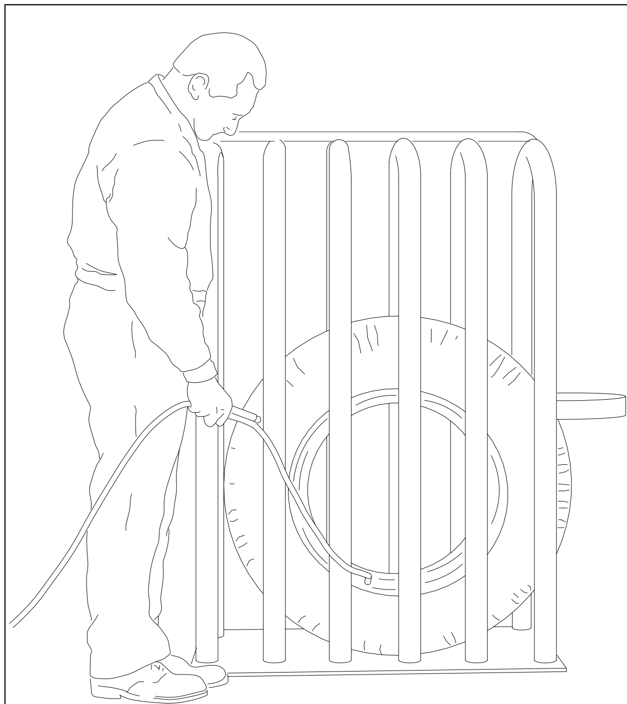


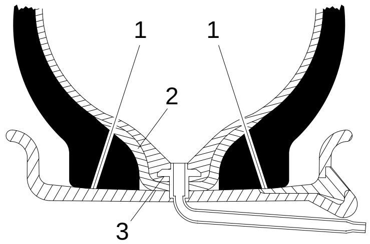
Fig. 1, Safety Cage

3. If there are no problems with the assembly at 10 psi (69 kPa), continue to inflate the tire to the recommended pressure. See **Specifications, 400** for correct cold inflation pressures. Michelin Tire Corporation recommends an initial inflation pressure of 90 to 100 psi (620 to 690 kPa) to correctly seat the tire beads.

NOTE: The position of the beads, flap, and tube with 4 to 5 psi (28 to 35 kPa) pressure is shown in **Fig. 2**. The tube is fully rounded-out within the tire, but there isn't enough pressure to move the beads on wide-base rims. Depending on the tire size and rim condition, from 20 to 40 psi (140 to 275 kPa) pressure is needed to push the beads onto the bead seat. See **Fig. 3**.

4. After the initial inflation, completely deflate the tire by removing the valve core. This ensures correct bead seating, and prevents buckling or overstretching the tube in tube-type tires. Then inflate the tire to the recommended cold inflation pressure listed in **Specifications, 400**. Install the valve caps and tighten them finger-tight.

Tire Inflation



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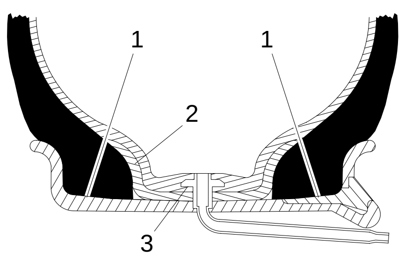
1. Tapered Bead Seat
2. Flap
3. Valve Base

Fig. 2, Position of Beads, Flap, and Tube at 4 to 5 psi (28 to 35 kPa)



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1. Tapered Bead Seat
2. Flap
3. Valve Base

Fig. 3, Beads Pressured Onto the Bead Seat

CAUTION

Improperly inflating tube-type tires can crack or tear the edge or inside of the valve base. Once seated, the tube can stretch only in the rim area. Because resistance to stretch is greatest at the valve base, there is often enough tension to break the tube at the edge of the valve base or in the valve base.

IMPORTANT: Use tires of the same size, type, and capacity to carry the load at the recommended cold pressure. Attempting to increase the load capacity of a tire by overinflation will damage the tire assembly.

NOTE: Inflate the tires to the recommended pressure. Driving on overinflated tires will weaken the cords by reducing their ability to absorb road shocks, and will increase the danger of cuts, snags, and punctures. Overinflation will overstress and damage the rims. Driving on underinflated tires will generate excessive heat. This weakens the tire body, and reduces tire strength.

WARNING

Inflate tires to the specified pressure. Tire underinflation or overinflation will damage wheels and tires, and could result in a blowout, causing possible personal injury and property damage.

5. Check the inflation pressure 24 hours after mounting new tires.

NOTE: When testing a vehicle on a dynamometer, severe tire damage can occur. Because the manufacturers differ in their recommendations for preventing tire damage, refer to the manufacturer's instructions for testing a vehicle on a dynamometer.

Tire Demounting and Mounting Service Precautions

Service Precautions

WARNING

Read the following information. Failure to follow the safety precautions, before and during tire demounting and mounting, could cause tire or rim damage while servicing or in use. An incorrectly mounted tire can burst causing personal injury and equipment damage.

IMPORTANT: Don't mount or demount tires without proper training as required in Occupational Safety and Health Administration (OSHA) Rules and Regulations 1910.177, *Servicing Multi-Piece and Single Piece Rim Wheels*. Service information containing mounting and demounting instructions are available through your rim supplier. Charts detailing service procedures are available through OSHA area offices. The address and telephone number of the nearest OSHA area office can be obtained by looking in the local telephone directory under U.S. Government, Labor Department of Occupational Safety and Health Administration.

Use the information from the above sources with the following precautions before and during the demounting and mounting of tires:

- Examine all wheel and tire parts as explained in **Subject 110** and **Subject 120**. Replace damaged, rusted, or worn parts.
- Since wheels and rims are under stress, and are dangerous if improperly assembled, be sure all parts of an assembly match in size, manufacturer, and classification within a manufacturer's line. Before assembling the wheel or rim, check the catalog issued by the wheel or rim manufacturer for the correct part numbers and sizes of approved parts. Never use a part that does not bear clear, legible, and correct numbers and manufacturer's identification, even if that part appears to fit.
- Make sure that tires are stored indoors, or outdoors under cover, to prevent water collecting inside the tire.
- Use special tools, as recommended by tire suppliers, for mounting and demounting tires. These tools must be smooth, and used with care, to avoid gouging the rim.
- Loosening tire beads may be difficult, since considerable force may be needed. The use of a machine designed for loosening tire beads is recommended.
- Handle the wheels and rims on a wooden floor or rubber mat to prevent nicking or gouging the wheel or rim.
- Do not use a duck-bill hammer, or any steel hammer on wheel or rim parts. Use rubber, leather-faced, or plastic mallets to tap parts together, if necessary.
- Lubricate the tire with an approved tire-mounting lubricant. Never use antifreeze, silicones, petroleum-based lubricants, or any flammable material (ether/starting aid).
- When lubricating a tire prior to mounting, make sure excess lubricant does not run into the tire.
- Michelin Tire Corporation recommends applying lubricant to the valley of the tire, formed by the tire and rim, before using tools to break the bead.
- Michelin also recommends applying a sufficient but sparing amount of lubricant to the entire rim face when mounting a tire on a rim, to ensure correct bead seating and ease of mounting.
- Don't reinflate a tire that has been run flat or has been run at 80 per cent or less of its recommended operating pressure. Use your spare. Before removing the low tire from the vehicle, make sure it is completely deflated. Later, have the assembly taken apart and all the parts checked for damage, including the side or lockrings.
- The air pressure contained in a tire is dangerous. When servicing a tire, stay out of any potential path or route that a rim wheel component may travel during an explosive separation.

Demounting and Mounting Tubeless Tires

⚠ WARNING

Read the information in Subject 140. Failure to follow the precautions, before and during tire demounting and mounting, could cause tire or rim damage while servicing or in use. An incorrectly mounted tire can burst causing personal injury and equipment damage.

Five Degree Full Drop Center

To demount or mount tubeless tires on 5 degree full drop center rims, regular or safety type, follow the same procedures used to demount or mount tubeless automobile tires.

Fifteen Degree Tapered Drop Center

Demounting

1. Deflate the tire being serviced by removing the valve core. Check the valve stem by running a piece of wire through the stem to make sure it is not plugged.
2. Loosen both beads from the rim by driving the flat end of the tire tool between the tire bead and the rim flange. Holding the tool upright, hammer on the neck to free the tire bead from the rim (**Fig. 1**). Repeat at 8-inch (20 cm) intervals around the flanges, until both beads are free from the rim.
3. Place the wide side of the rim down. Lubricate the tire bead and the rim. Insert the curved end of two tire tools between the bead and the rim, and just to one side of the tire valve. Step on the side of the tire, opposite from the valve, to force the first bead into the rim well (**Fig. 2**). Hold one of the tools in place with your foot and pry with the second tool, forcing the bead over the rim flange. Continue to work the first bead off of the rim.
4. When the first bead is off the rim, and the second bead is in the rim well, stand the assembly upright with the valve stem near the top. Lubricate the second bead and rim. Insert the straight end of the tool between the tire bead and the back rim flange, hooking the tool over the second flange. Lean the tire assembly toward the tool and use a rocking or bouncing action to pry the rim out of the tire. See **Fig. 3**.
5. Clean and inspect all parts. See **Subject 110** and **Subject 120** for procedures.

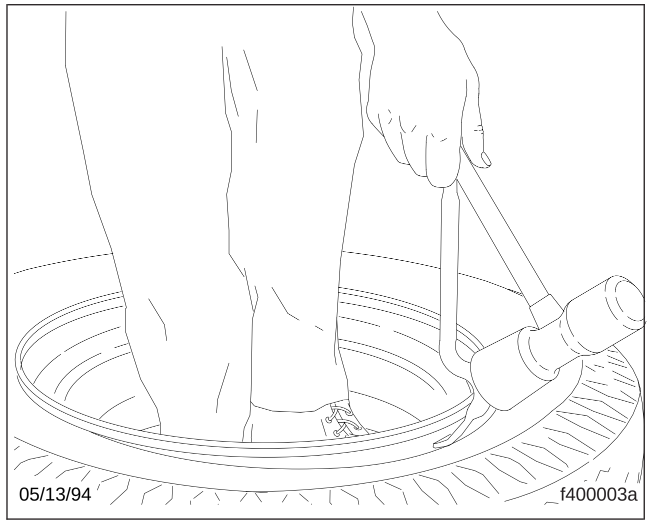


Fig. 1, Loosening the Beads

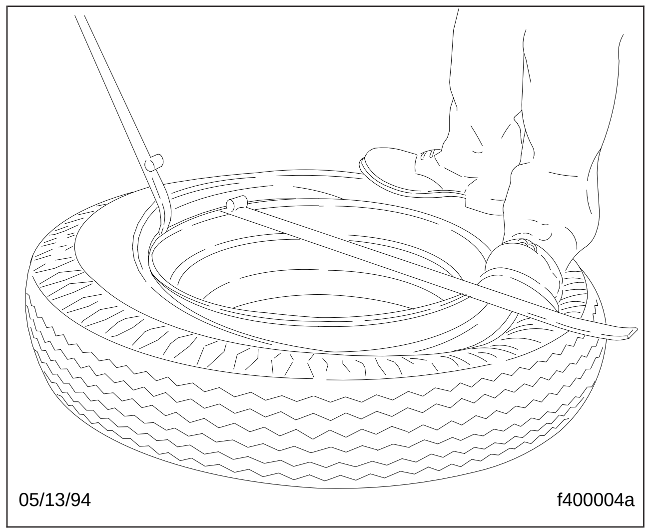


Fig. 2, Forcing Bead into the Rim Well

Mounting

1. Place the valve stem, with a rubber washer, through the valve hole from the tire side of the rim. Screw on the valve nut from the opposite side. Make sure the rubber bushing and metal

Demounting and Mounting Tubeless Tires

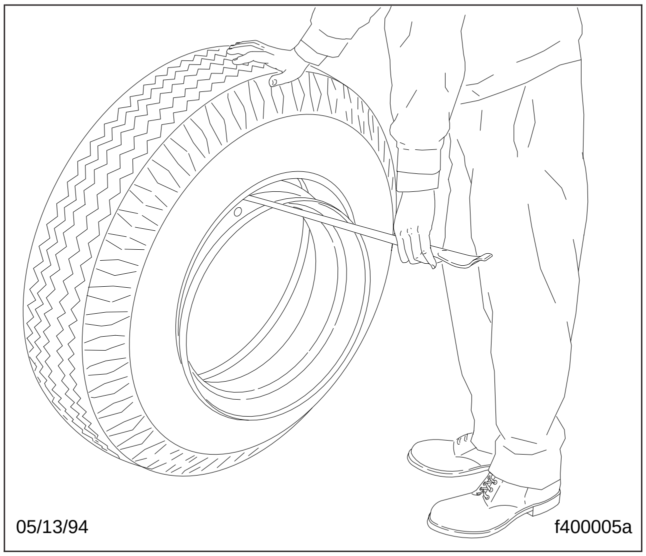


Fig. 3, Prying the Rim Out of the Tire

collar or nut are centered and fit snugly in the valve hole (**Fig. 4**). Tighten the nut securely.

Fig. 4, Valve Stem Installation

2. Place the rim on the floor with the wide side down. Using a brush or swab, lubricate both bead seats (flanges) of the rim, and both tire beads, with an approved lubricant. Apply enough lubricant to enable correct bead seating, and to make mounting easier. Don't let excess lubricant run inside the tire.

3. Lay the tire on the rim. If there is a balance mark on the tire, line up this mark with the valve stem. Push the lower bead over the flange and into the rim well. Using the straight end of the tire tool (with the stop resting on the rim flange), take small bites to work the remaining section of the bead into the rim. See **Fig. 5**.

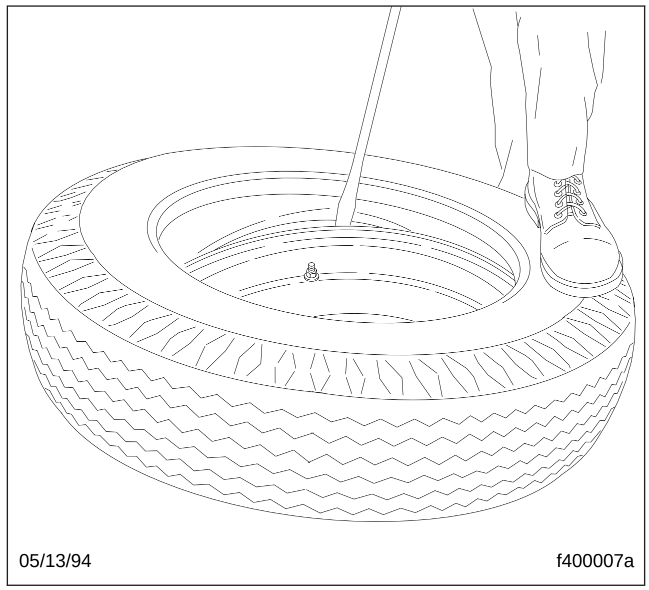


Fig. 5, Working the Lower Bead into the Rim

4. Start the upper bead over the rim flange and into the rim well by standing on the tire. If necessary, push a section of the bead into the rim well, and anchor it by attaching Vise-Grip® pliers to the rim flange (snub side toward the tire). Using the spoon end of the tire iron, with the stop toward the rim, work around the bead (**Fig. 6**). Use small bites until the bead slips over the flange and into the rim well. If necessary, insert a second tire iron and relubricate the last 8 inches (20 cm) of bead.

5. Inflate the tire. See **Subject 130** for procedures.

Demounting and Mounting Tubeless Tires

Fig. 6, Working the Upper Bead into the Rim

Troubleshooting Tables

Problem—Abnormal Tire Wear

Problem—Abnormal Tire Wear	
Possible Cause	**Remedy**
Tires are not inflated to the correct pressure	Operate the tires at the recommended inflation pressure and use the proper size tires, wheels, and rims for the load to be carried. See **Specifications, 400**.
Inflation pressures in a dual assembly are unequal.	Inflate all tires to a uniform pressure, within 5 psi (35 kPa). See **Specifications, 400** for the proper cold inflation pressures.
Dual tires are mismatched.	Examine all tires and match them according to the specifications in this section.
The vehicle is vibrating severely.	Follow the recommendations under "Vehicle Vibration" in this chart.
The brakes are grabbing.	Examine and adjust the brakes. See **Group 42** for instructions.
Axles are improperly aligned.	Align the axles. See **Group 33** and **Group 35** for instructions.
Wheel bearings are loose or damaged, or bushings are excessively worn.	Examine, and repair or replace the wheel bearings. See **Group 33** and **Group 35** for instructions.
Wear is uneven among tire sets.	Rotate the tires. See Group 40 of the *Business Class M2 Maintenance Manual* for instructions.
The driver is abusing the equipment.	Caution the driver.

Problem—Vehicle Vibration

Problem—Vehicle Vibration	
Possible Cause	**Remedy**
Axles are improperly aligned.	Align the axles. See **Group 33** and **Group 35** for instructions.
Wheels, rims, or tires are out-of-round, bent, or distorted.	Replace damaged components.
Tires, wheels, rims, or brake drums are out-of-balance.	Determine the out of balance component and balance.
Tire beads are not properly seated.	Demount and mount the tire. Make certain adequate lubrication is used and, if necessary, use an inflation aid to help seat tubeless tire beads.
Rim spacers are worn or distorted.	Replace the rim spacers.
Driveline, suspensions, or steering components are loose or worn.	Determine the location of the vibration, then repair or replace the loose or worn components.

Problem—Excessive On-the-Road Tire Failures

Problem—Excessive On-the-Road Tire Failures	
Possible Cause	**Remedy**
Tires are not inflated to the correct pressure.	Operate the tires at the recommended inflation pressure and use the proper size tires, wheels, and rims for the load to be carried. See **Specifications, 400**.
Dual tires are mismatched.	Examine all tires and match them according to the specifications in this section.

Troubleshooting

Problem—Excessive On-the-Road Tire Failures	
Possible Cause	**Remedy**
Water or foreign material is inside the casing.	Clean and dry the tires and tubes prior to mounting. Make sure excess lubricant does not flow down into the tire. Store unmounted tires indoors, or under cover, to prevent moisture from collecting inside.
Tires are contaminated with oil.	Clean the tires and inspect the engine seals, transmission seals, axle-end and drive axle seals, oil filters and oil lines for leakage. Make sure the lubricant used in mounting does not contain a petroleum derivative.
The vehicle is vibrating severely.	Follow the recommendations under "Vehicle Vibration" in this chart.
Wheel or rim components are mismatched.	Check the catalog issued by the applicable wheel or rim manufacturer for the proper part numbers and sizes of approved components. Make sure that all parts of an assembly match in size, manufacturer, and classifications within a manufacturer’s line. Never use a component which does not bear clear, legible, and proper numbers and manufacturer’s identification, even if it appears to fit.
Parts are corroded, worn, or otherwise damaged.	Clean or replace parts as necessary.

Tire Pressure

Do not reduce the pressure of a hot tire if it exceeds the specified pressure. In normal driving, tire temperature and inflation pressure increase. Increases of 10 to 15 psi (70 to 105 kPa) are common. Higher pressures may be signs of overloading, underinflation, excessive speed, improper tire size, or any combination of these factors, and must be checked when the tire is cool.

IMPORTANT: The load and cold inflation pressure must not exceed the rim or wheel manufacturer's recommendations, even though the tire may be approved for a higher load or inflation. Some rims and wheels are stamped with a maximum load and maximum cold inflation rating. If they are not stamped, consult the rim or wheel manufacturer for the correct tire inflation pressure for the vehicle load. If the load exceeds the maximum rim or wheel capacity, the load must be adjusted or reduced.

For further information on rims and tires (other than Michelin), and for inflation and load limits, refer to the "Tire and Rim Association Yearbook."

For further information on Michelin tires, refer to the Michelin web site, **www.michelin.com**. A connection to the Internet is required.

Disc Wheel Fastener Torque Values

For torque values for disc wheel fasteners, see **Table 1**.

Disc Wheel Fastener Torque			
Description	**Nut Size**	**Wheel Manufacturer**	**Torque (dry threads): lbf·ft (N·m)**
8-Hole and 10-Hole Disc Wheels With Inner and Outer Nuts			
Front Wheel Nut	1-1/8–16	Accuride	450–500 (610–680)
Rear Wheel Inner Nut	3/4–16	Accuride	450–500 (610–680)
Rear Wheel Outer Nut	1-1/8–16	Accuride	450–500 (610–680)
Wheel Stud Retainer Nut	3/4–16	Accuride	175–200 (235–270)

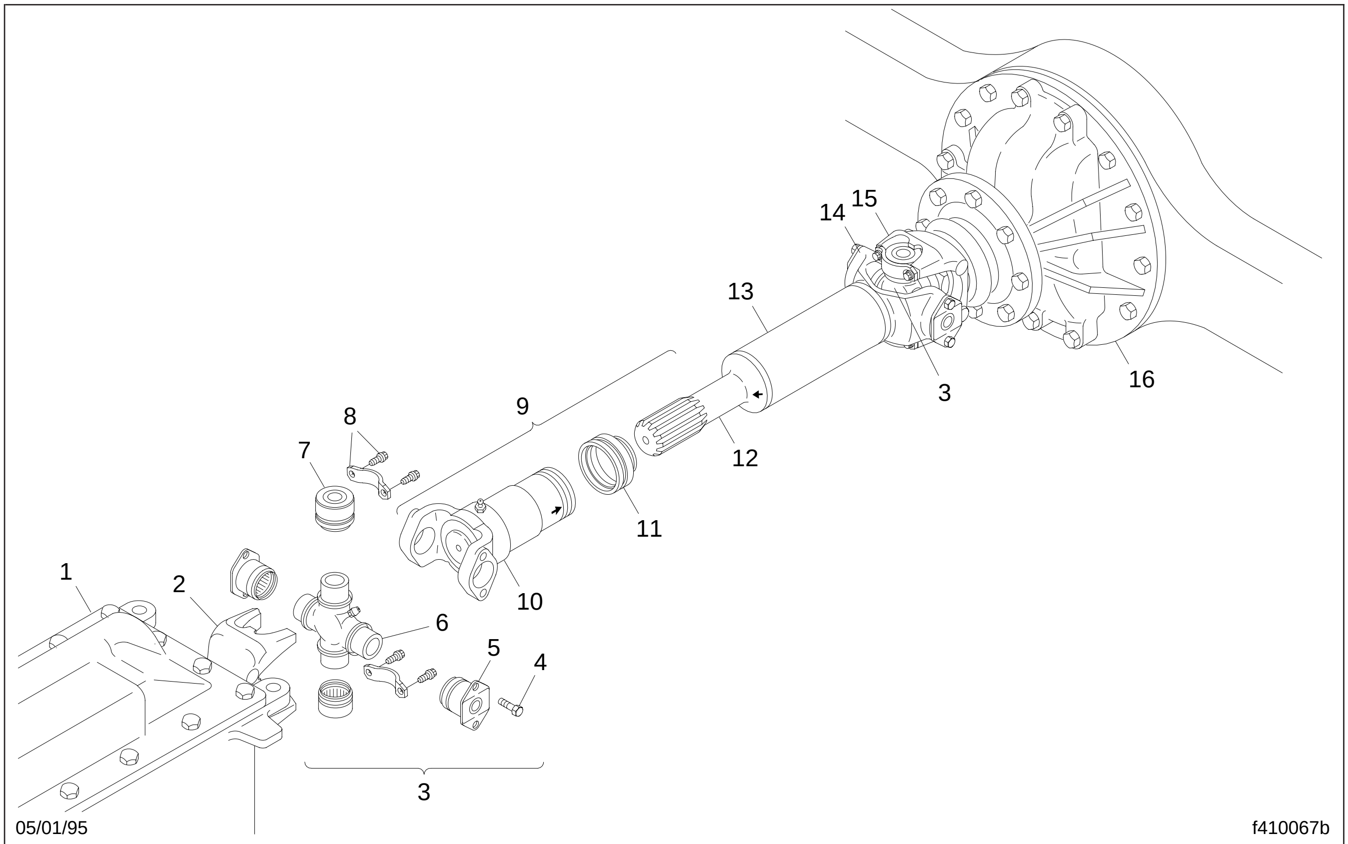
Table 1, Disc Wheel Fastener Torque

General Information

The simplest driveline consists of a transmission output-shaft end-yoke, an axle input-shaft end-yoke, and a single slip-jointed driveshaft connecting the two end-yokes. See **Fig. 1**. The driveshaft is made up of a universal joint (U-joint), a sleeve-yoke, a splined stub shaft, a driveshaft tube, a tube-yoke, and a second U-joint.

Driveline Configurations

The specific type and number of drivelines used on each vehicle depends on its number of transmissions, its number of drive axles, and its wheelbase. See **Fig. 2**. A driveline is used between each driving and driven component. A driveline connecting a main transmission (or an auxiliary transmission) to a single drive axle or forward-rear axle of a dual-drive vehicle is always referred to as a No. 2 driveline. See **Fig. 2**, examples A, B, C, D, and E. An interaxle driveline of a dual-drive vehicle is always called a No. 3 drive-



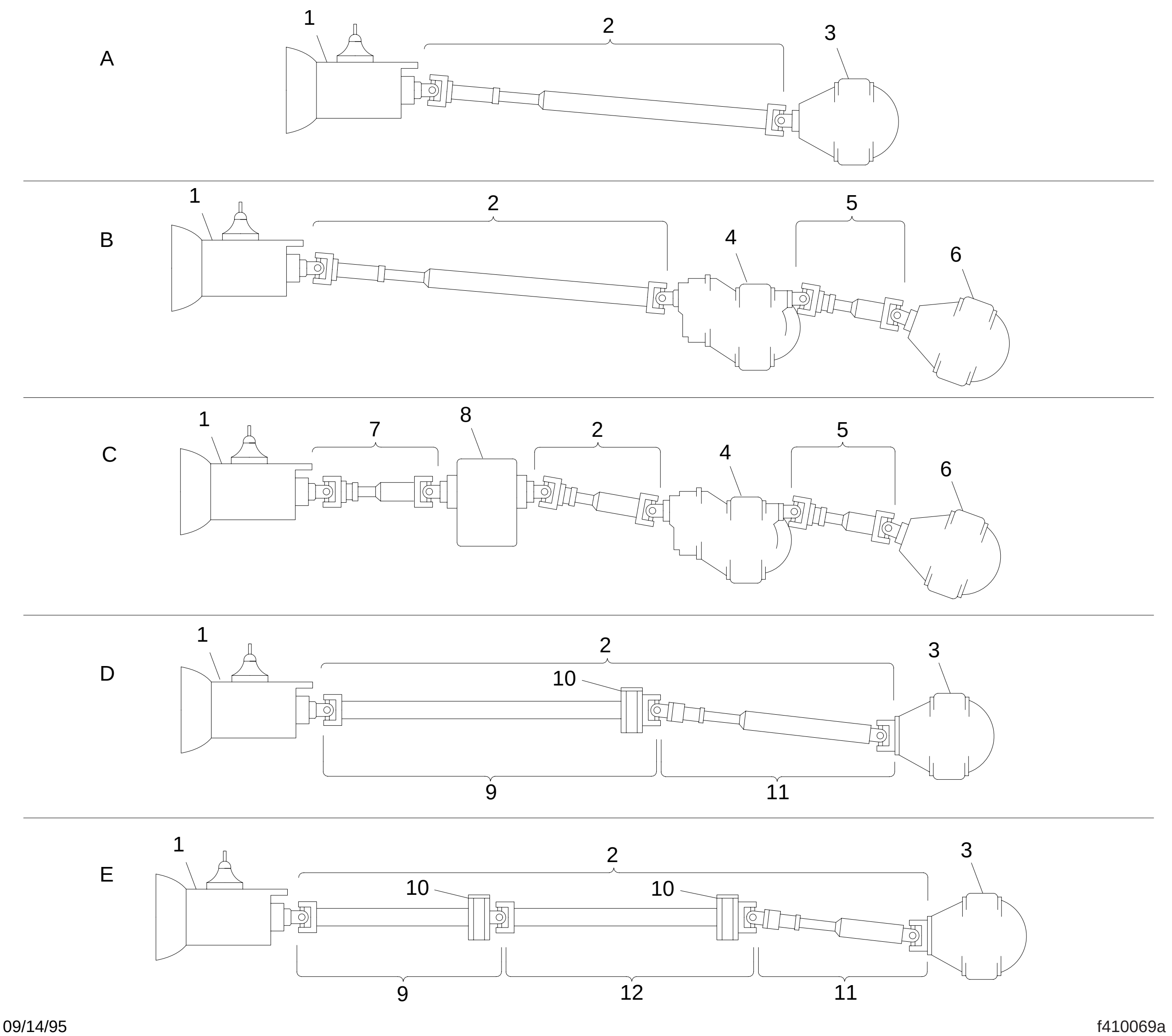
NOTE: Not all fasteners are shown.

1. Transmission
2. Transmission Output-Shaft End-Yoke (half-round)
3. U-Joint Assembly
4. Bearing Plate Self-Locking Capscrew
5. Bearing Cup (for full-round yoke)
6. U-Joint Cross
7. Bearing Cup (for half-round yoke)
8. Bearing Strap and Bearing-Strap Capscrew
9. Slip-Joint Assembly
10. Sleeve-Yoke (full-round)
11. Dust Cap
12. Splined Stub Shaft
13. Driveshaft Tube
14. Tube-Yoke (full-round)
15. Axle Input-Shaft End-Yoke (half-round)
16. Rear Axle

Fig. 1, Components of a Basic Driveline

line. See **Fig. 2**, examples B and C. A driveline connecting a main transmission to an auxiliary transmission is always referred to as a No. 1 driveline. See **Fig. 2**, example C.

A long driveshaft, supported only at its ends, will sag in the middle from its own weight. When turning at high rpm, it will flex, causing an out-of-balance vibration. Therefore, vehicles having a long wheelbase



1. Main Transmission
2. No. 2 Driveline
3. Rear Axle
4. Forward-Rear Axle
5. No. 3 Driveline
6. Rearmost Axle
7. No. 1 Driveline
8. Auxiliary Transmission
9. Primary Coupling Shaft
10. Midship Bearing
11. No. 2 Driveshaft
12. Intermediate Coupling Shaft

Fig. 2, Driveline Configurations

use a midship bearing, mounted on a frame crossmember, for additional support. See **Fig. 2**, example D. This allows the No. 2 driveline to be separated into two, shorter shafts (a coupling shaft and a No. 2 driveshaft), thus improving balance and stability.

Vehicles having an even longer wheelbase use two crossmember-mounted midship bearings, allowing the No. 2 driveline to be separated into three short shafts, joined by four U-joints. See **Fig. 2**, example E. The first shaft is the primary coupling shaft, the second is the intermediate coupling shaft, and the third is the No. 2 driveshaft.

Slip-Joints, U-Joints, and Yokes

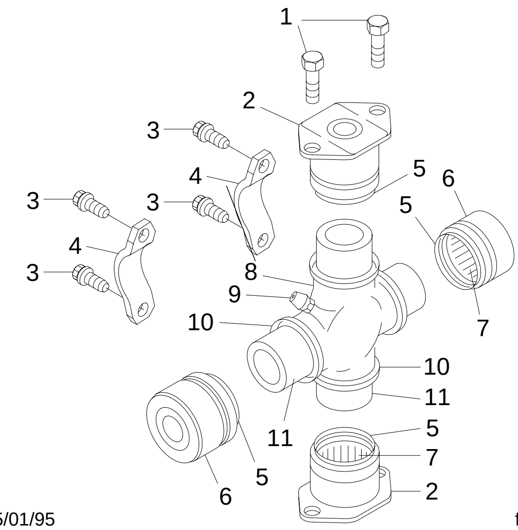
The basic function of the driveline is to send torque from the transmission to the axle in a smooth and continuous action. Because the vehicle axles are not attached directly to the frame, but are suspended by springs, they ride in an irregular, floating motion (when going over bumps or depressions), thus changing the distance between the transmission (or coupling shaft) and the rear axle, and the distance between the rear axles. The slip-joints of the No. 2 and No. 3 driveshafts, by expanding and contracting, allow for length changes between drivetrain components. Coupling shafts do not require a slip-joint.

Motion of the rear axle(s) also causes changes to the relative angles between drivetrain components. U-joints allow transfer of torque from an output shaft (or coupling shaft) to the driveshaft, and from the driveshaft to an input shaft, even though the angles between the shafts may be constantly changing.

Each U-joint consists of a cross with a close-tolerance ground cylindrical surface (trunnion) at the end of each of the four arms. Installed on each trunnion is a bearing cup lined with bearing needles. All bearing cups are sealed to retain lubricants, and to prevent entry of foreign material. See **Fig. 3**. In operation, the four bearing cups are held stationary in a pair of yokes, while the U-joint cross pivots on its trunnions.

Full-round yokes are installed at the front of coupling shafts and at both ends of the No. 2 and No. 3 driveshafts. All tube-yokes (yokes that are welded into driveshaft tubes) and all sleeve-yokes (yokes that are part of the internally splined half of slip-joints) are full-round yokes. See **Fig. 4**, items 4 and 9.

An end-yoke is an internally splined yoke, held on an externally splined shaft by a locknut. As standard



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1. Bearing-Plate Capscrews
2. Bearing Cup (for full-round yoke)
3. Bearing-Strap Capscrew
4. Bearing Strap
5. Bearing-Cup Seal
6. Bearing Cup (for half-round yoke)
7. Bearing Needles
8. U-Joint Cross
9. Grease Fitting
10. U-Joint Cross Slinger
11. Trunnion

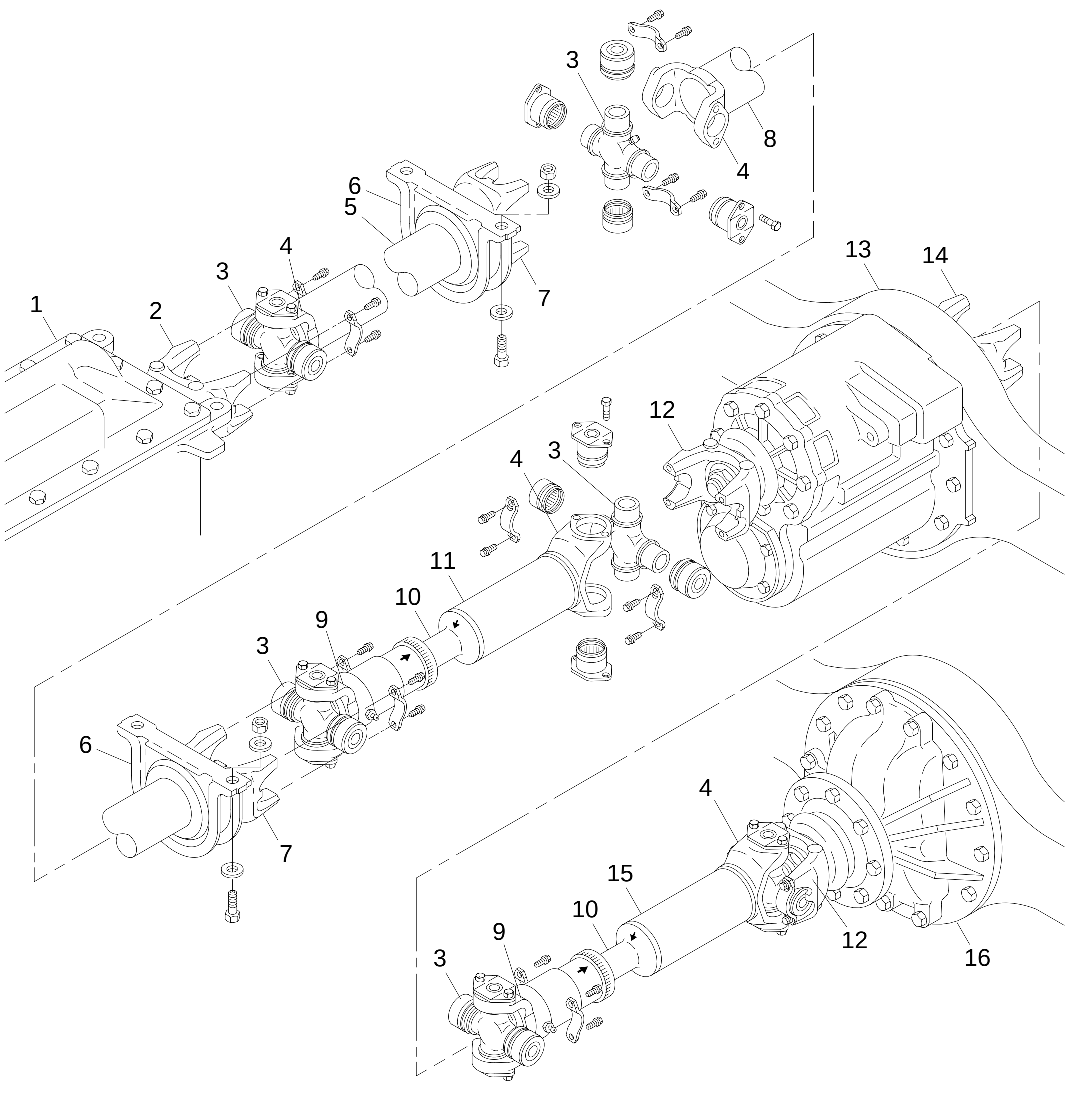
Fig. 3, Typical U-Joint

equipment, all No. 2 driveline end-yokes are half-round, with full-round optional. And, as standard equipment, all No. 3 driveline end-yokes are full-round, with half-round optional. End-yokes are installed on the transmission output shaft, on each axle input and output shaft, and behind the midship bearing of most coupling shafts. See **Fig. 4**, items 2, 7, 12, and 14.

Meritor 17T and 18T U-joints are coupled to half-round end-yokes by capscrews inserted through semicircular bearing straps that hold the bearing cups in place under tabs in the yoke cross-holes. See **Fig. 5**.

Meritor RPL Series U-joints are coupled to half-round end-yokes by capscrews inserted through the bearing cups. See **Fig. 6**.

U-joints are installed in full-round tube-yokes, sleeve-yokes, and end-yokes, by inserting the cross through from the inside of both yoke cross-holes, then install-

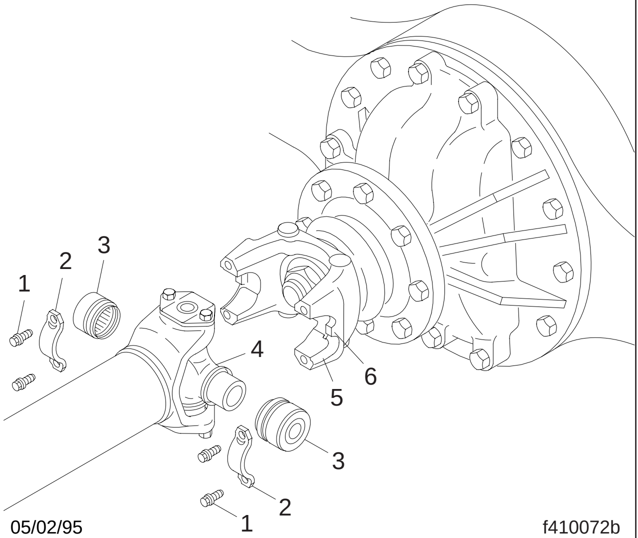


NOTE: Not all fasteners are shown.

1. Transmission
2. Transmission Output-Shaft End-Yoke (half-round)
3. U-Joint Assembly
4. Full-Round Tube-Yoke
5. Primary Coupling Shaft Tube
6. Midship Bearing Assembly
7. Coupling Shaft End-Yoke (half-round)
8. Intermediate Coupling Shaft Tube
9. Sleeve-Yoke (full-round)
10. Slip-Joint Assembly
11. No. 2 Driveshaft Tube
12. Axle Input-Shaft End-Yoke (half-round)
13. Forward-Rear Axle
14. Axle Output-Shaft End-Yoke (half-round)
15. No. 3 Driveshaft Tube
16. Rearmost Axle

Fig. 4, Dual-Drive Installation With Primary and Intermediate Coupling Shafts

ing the bearing cups into the outsides of the yoke and over the ends of the trunnions. Snap rings or self-locking capscrews are installed into the yoke to secure the cups. See **Fig. 7**.



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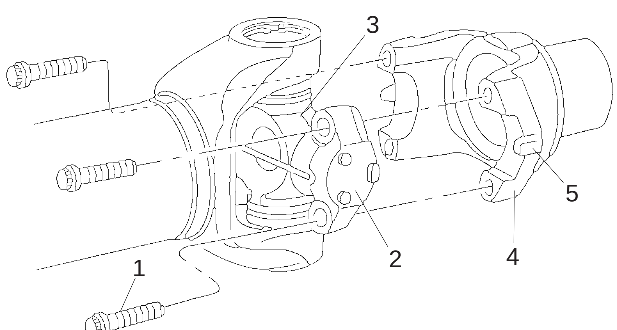
1. Bearing-Strap Capscrew
2. Bearing Strap
3. Bearing Cup
4. U-Joint Cross
5. Half-Round Yoke
6. Yoke Cross-Hole Tab

Fig. 5, Coupling of a U-Joint With a Half-Round End-Yoke



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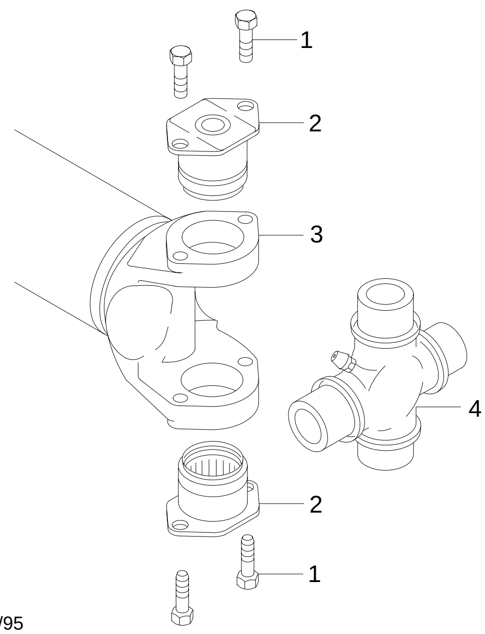
1. Capscrew
2. Bearing Cup
3. U-Joint Cross
4. Half-Round Yoke
5. Yoke Cross-Hole Tab

Fig. 6, Coupling of a RPL Series U-Joint

U-Joint Angles, Phasing, and Driveline Balance

Correct U-joint working angles, U-joint phasing, and driveline balance are vital to maintaining a quiet-running drivetrain and long life of drivetrain components (including driveline components).



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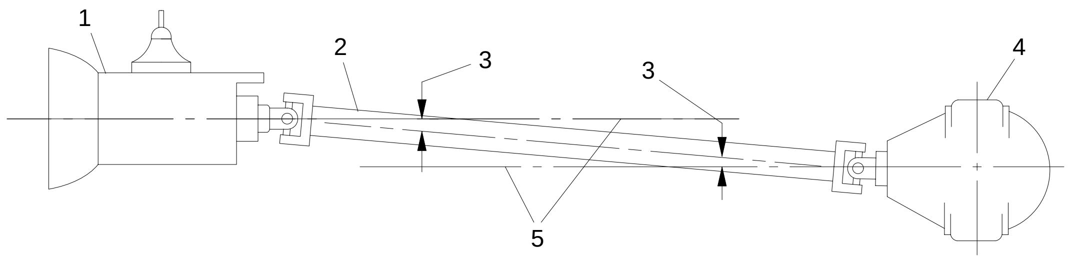
1. Bearing-Plate Self-Locking Capscrew
2. Bearing Cup (bearing-plate-type)
3. Full-Round Yoke
4. U-Joint Cross

Fig. 7, Installation of a U-Joint in a Full-Round Yoke

The U-joint working angle is the angle formed by the intersection of the driveshaft centerline and the extended centerline of the shaft of any component (or other driveshaft) to which the U-joint connects. See **Fig. 8**. Because the double oscillating motion of a U-joint that connects angled shafts causes a fluctuating speed difference between the shafts, the effect created by the U-joint at one end of the shaft must cancel the effect created by the U-joint at the other end. This is done by making U-joint working angles at both ends of the driveshaft approximately equal, with the U-joints in phase. If the yoke lugs at both ends of the shaft are lying in the same plane (a plane that bisects the shaft lengthwise) the U-joints will be in phase. See **Fig. 9**.

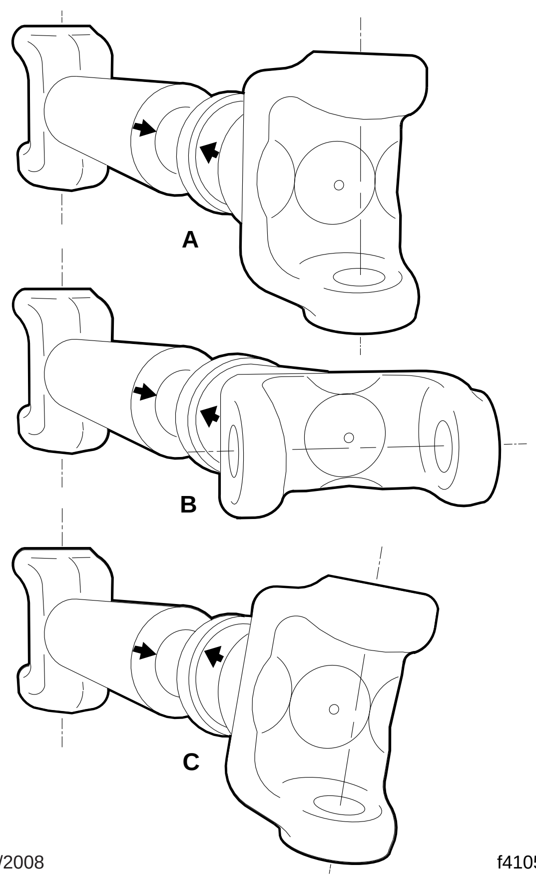
NOTE: Some driveshafts are designed and phased with their end yokes clocked 90 degrees from each other. This is referred to as cross phasing.

After manufacture, each driveline yoke is statically balanced. After assembly, each driveshaft and cou-



1. Transmission
2. No. 2 Driveshaft
3. U-Joint Working Angles
4. Rear Axle
5. Extended Centerlines

Fig. 8, U-Joint Working Angles



A. In Phase (parallel phased)
B. In Phase (cross phased)
C. Out of Phase

Fig. 9, U-Joint Phasing

pling shaft is checked for out-of-roundness, straightened as necessary, then dynamically balanced.

Avoiding Driveline Problems

To ensure that U-joints turn in phase, sleeve-yokes, splined shafts, coupling shaft end-yokes, and coupling shafts, should be marked for assembly reference before disassembly. A misaligned slip-joint will seriously affect driveline balance (and U-joint phasing). Even if a slip-joint is assembled 180 degrees from its original position (which will keep the U-joints in phase), the dynamic balance of the driveshaft will be negatively affected.

A driveline can become unbalanced or greatly weakened if a driveshaft has been dented, bent, twisted, or otherwise damaged. Operating a vehicle at speeds that exceed the speed of the driveshaft's design specifications will cause an out-of-balance vibration. Any condition that allows excessive movement of a driveshaft will cause driveline imbalance: loose end-yoke nuts, loose midship bearing mounts, loose U-joint bearing cup retaining capscrews, worn U-joint trunnions and bearings, and worn slip-joint splines.

Among the most common causes of U-joint and slip-joint damage is lack of lubrication.

To keep a vehicle operating smoothly and economically, the driveline must be carefully checked and lubricated at regular intervals. For inspection and lubrication intervals and procedures, see **Group 41** of the *Business Class M2 Maintenance Manual*.

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke

U-Joint Uncoupling

NOTE: It is easier to check driveline parts, and to replace a U-joint or midship bearing assembly if the driveshaft is removed from the vehicle. If a driveshaft requires straightening or balancing, it must be removed, and installed on a lathe or a balance machine. Removal is required for replacement of slip-joint parts, a driveshaft tube, or a tube-yoke. To remove the driveshaft, see **Subject 120**.

NOTE: Many service operations do not require driveshaft removal from the vehicle: end-yoke nut tightening; drive component shaft seal or end-yoke replacement; changing U-joint phasing at the slip-yoke; and transmission or axle removal (for overhaul, repair, or replacement). To perform these operations, uncouple the U-joint at the applicable end of the appropriate driveshaft.

1. Roll the vehicle forward or backward as needed to turn the rearmost end-yoke (of the driveline that is being uncoupled) until the centerline through its cross-holes is horizontal. See **Fig. 1**, Ref. A and Ref. B.
2. Apply the parking brakes, and chock the tires.
3. If the half-round bearing cups do not already have a retaining wire installed, install a bearing-cup retaining wire. See **Fig. 1**, Ref. C. Or, install safety wire from the retaining-wire groove of one half-round bearing cup to the other.
4. Support the driveshaft with a nylon support strap.

   When uncoupling a coupling shaft, install two or three support straps, as needed. Remove the fasteners that attach the midship bearing(s) to its bracket(s). See **Fig. 1** and **Fig. 2**.
5. Remove the capscrews that secure the bearing cups or straps to the half-round yoke. Remove the bearing straps, if equipped.
6. Compress the slip-joint to remove the U-joint from the yoke.

CAUTION

Do not expose the U-joint trunnions or bearing-cup needles to dirt or grit. The smallest bits of dirt or grit can cause rapid wear and serious damage to the U-joint.

U-Joint Coupling

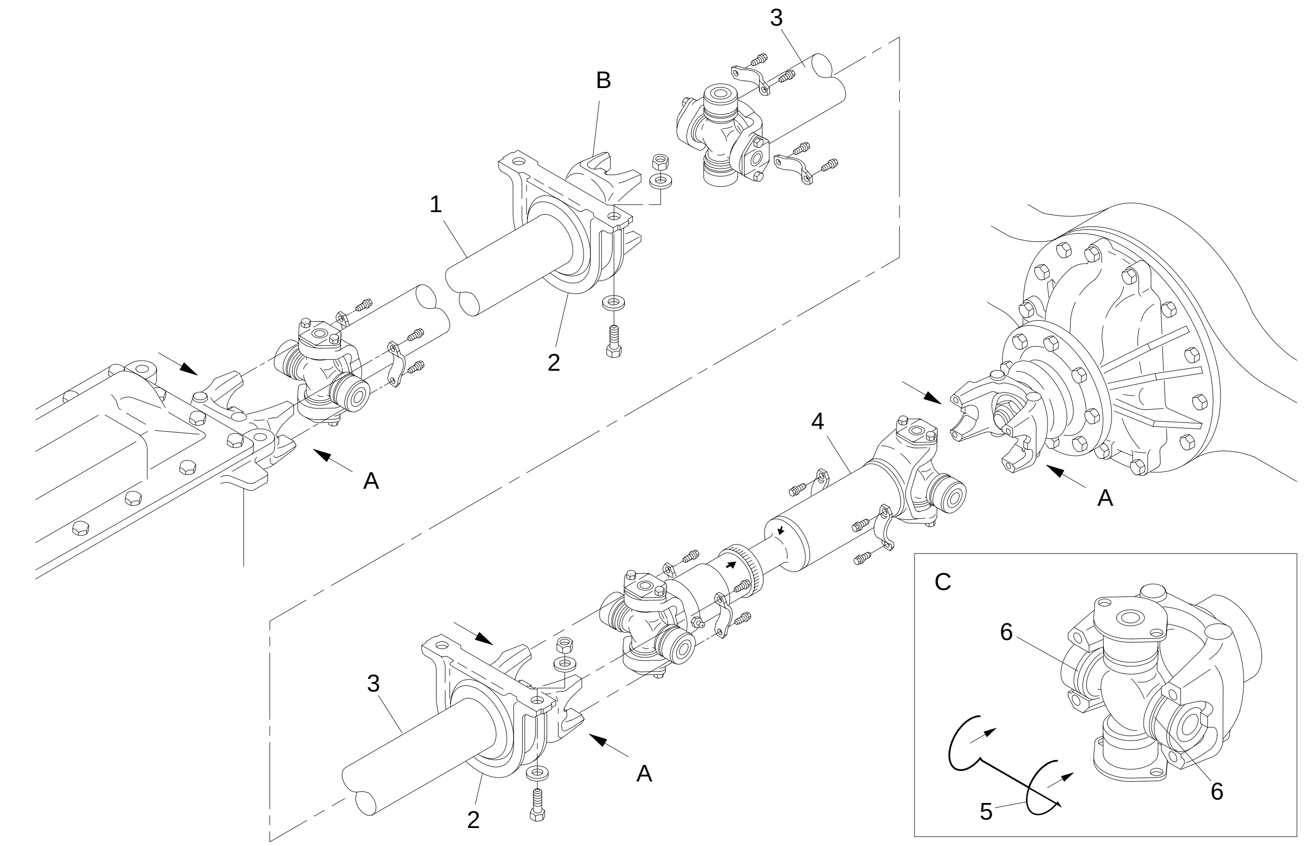
1. Check and clean the end-yoke.
   - 1.1 Check the torque on the end-yoke nut. See **Specifications 400**.
   - 1.2 Check the end-yoke cross-holes for burrs or raised metal. Using a half-round file, remove burrs or raised metal. See **Fig. 3**.
   - 1.3 Using fine emery cloth, smooth and clean the entire surface of the yoke cross-holes and bearing straps. See **Fig. 4**.
   - 1.4 Turn the end-yoke until its cross-holes are horizontal. See **Fig. 1** and **Fig. 2**.
2. Check, clean, and lubricate the U-joint.
   - 2.1 Remove the bearing-cup retaining wire or safety wire. See **Fig. 1**, Ref. C.

CAUTION

Do not expose the U-joint trunnions or bearing-cup needles to dirt or grit. The smallest bits of dirt or grit can cause rapid wear and serious damage to the U-joint.

   - 2.2 Using fine emery cloth, smooth and clean the outside surfaces of both bearing cups. See **Fig. 5**.
   - 2.3 Check the U-joint trunnions and bearing cups for minute particles of dirt or grit. Clean if necessary. See **Subject 140**.
   - 2.4 Using NLGI grade 2 grease with EP additives, wipe a small amount of grease on the needles in the bearing cups.
   - 2.5 Using a light-weight oil, lubricate the lips of the bearing-cup seals. See **Fig. 6**.
   - 2.6 Install the bearing cups on the cross.
   - 2.7 Install a bearing-cup retaining wire. See **Fig. 1**, Ref. C. Or, install safety wire from

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke



NOTE: Not all fasteners are shown.

A. End-yoke cross-hole centerline is horizontal.
B. Before uncoupling/coupling the U-joint, turn the end-yoke until its cross-hole centerline is horizontal.
C. Install a half-round bearing-cup retaining wire (or safety wire) before removing the bearing straps.

1. Primary Coupling Shaft
2. Midship Bearing
3. Intermediate Coupling Shaft
4. No. 2 Driveshaft
5. Half-Round Bearing-Cup Retaining Wire
6. Retaining-Wire Groove

Fig. 1, U-Joint Uncoupling/Coupling for Drivelines With Half-Round End-Yokes, Except RPL U-Joints

the retaining-wire groove of one half-round bearing cup to the other.

3. Extend the slip-joint, while pressing the cross and bearing cups into place in the yoke cross-holes. Using a rubber or plastic mallet, gently tap the bearing cups to seat them in the yoke. See Fig. 7.

CAUTION

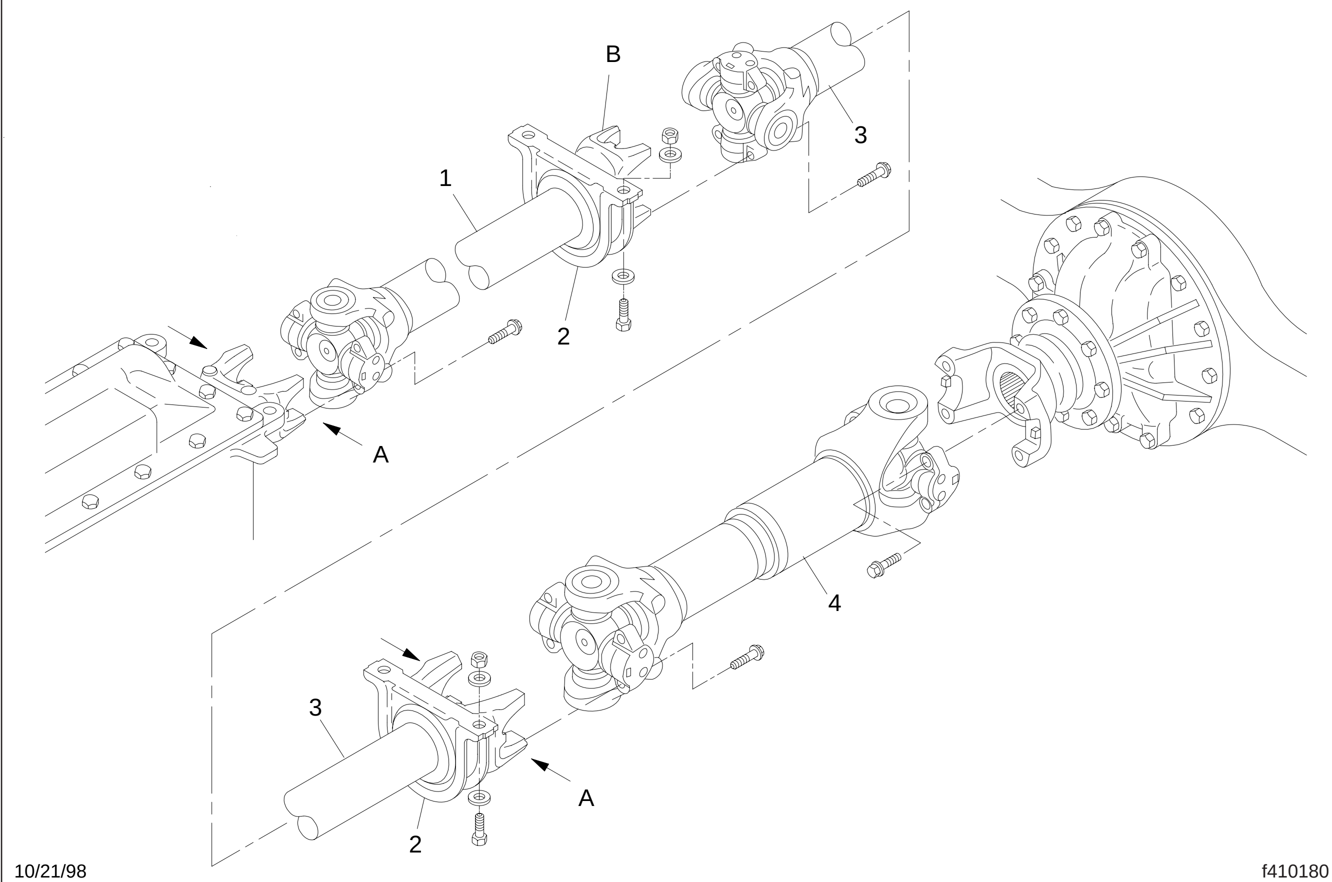
Do not use the capscrews and bearing straps (if equipped) to seat the bearing cups in the yoke. Seating the cross by tightening the bearing straps can deform the bearing straps, allowing the bearing cups to spin, which will cause rapid wear and serious damage to the U-joint.

4. Place the bearing straps (if equipped) over the cups. Install the capscrews, finger-tight.

WARNING

The self-locking capscrews must not be reused. Replace the capscrews with new ones. Also, do not undertighten or overtighten the capscrews. A

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke



NOTE: Not all fasteners are shown.

A. End-yoke cross-hole centerline is horizontal.
B. Before uncoupling/coupling the U-joint, turn the end-yoke until its cross-hole centerline is horizontal.

1. Primary Coupling Shaft
2. Midship Bearing
3. Intermediate Coupling Shaft
4. No. 2 Driveshaft

Fig. 2, U-Joint Uncoupling/Coupling for Drivelines With Half-Round End-Yokes, RPL U-Joints

loose or broken fastener at any point in the driveline weakens the driveline connection, which could cause serious vehicle damage, or could result in a driveshaft separating from the vehicle. Driveline separation can cause loss of vehicle control that could result in serious personal injury or death.

Separation of the driveline can also cause damage to the driveline, driveline components, or other areas of the vehicle.

5. Alternately tighten the capscrews in increments of 20 lbf·ft (27 N·m) to the applicable torque value in **Specifications 400**.
6. If they were removed, install the fasteners that attach each midship bearing to its bracket; tighten the flanged locknuts 91 lbf·ft (123 N·m).
7. Lubricate the U-joint, following the procedure in Group 41 of the *Business Class M2 Maintenance Manual*.

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke

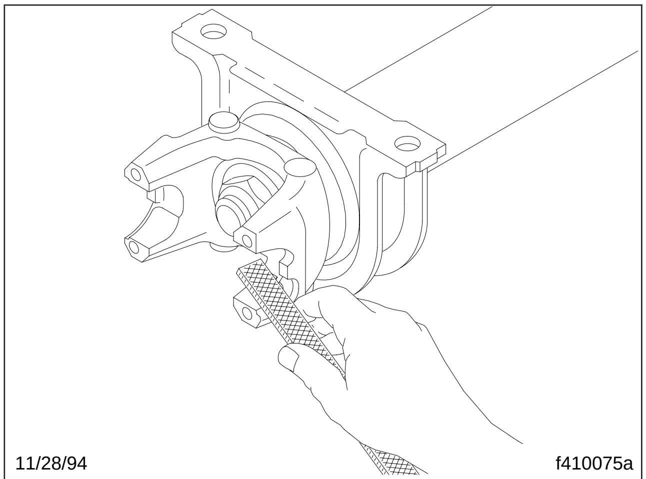
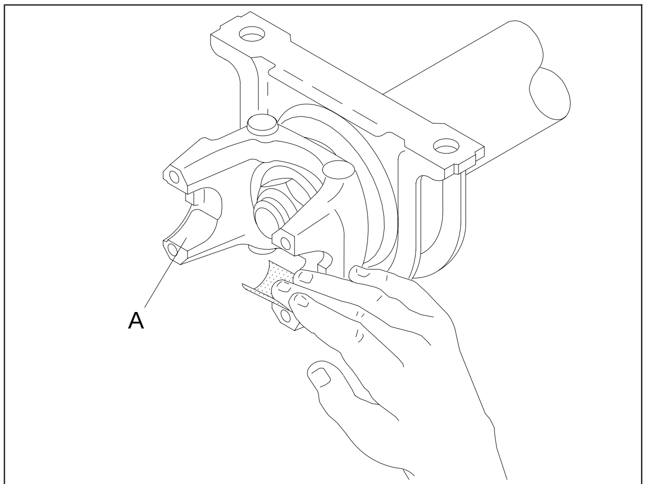


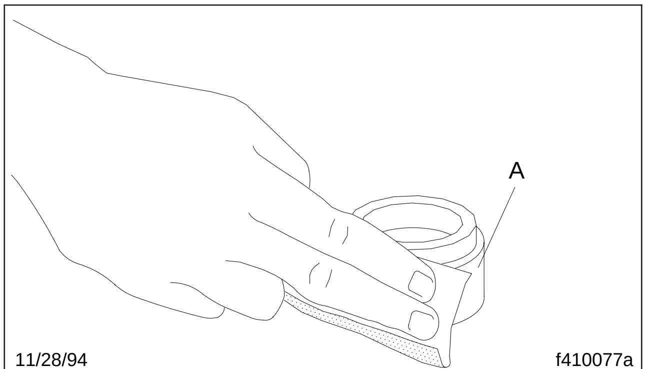
Fig. 3, Remove Burrs from a Half-Round End-Yoke Cross-Hole



A. Use fine emery cloth on this surface.

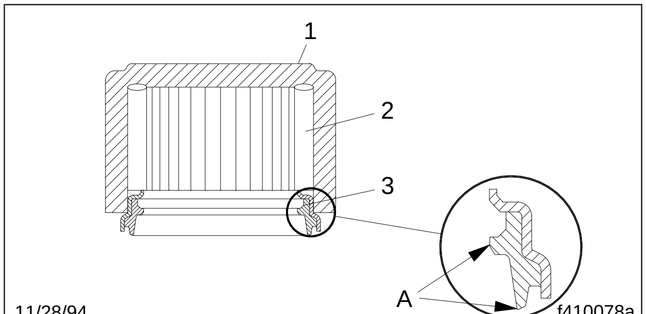
Fig. 4, Smooth a Half-Round End-Yoke Cross-Hole

8. Remove the nylon support straps, then remove the chocks.



A. Use fine emery cloth on this surface.

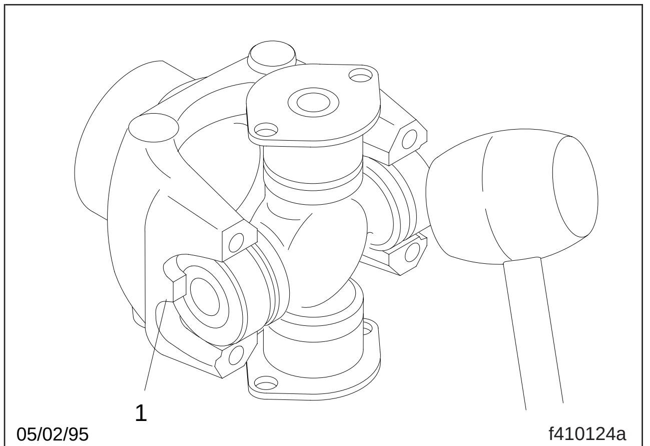
Fig. 5, Smooth a Half-Round End-Yoke U-Joint Bearing Cup



A. Lubricate seal lips here.
1. Bearing Cup
2. Bearing Needle
3. Bearing-Cup Seal

Fig. 6, Sectional View of a Half-Round End-Yoke U-Joint Bearing Cup

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke



1. Retaining Tab

Fig. 7, Seat a U-Joint in a Half-Round End-Yoke

U-Joint Uncoupling and Coupling With a Full-Round End-Yoke

U-Joint Uncoupling

NOTE: It is easier to check driveline parts, and to replace a U-joint or midship bearing assembly if the driveshaft is removed from the vehicle. If a driveshaft requires straightening or balancing, it must be removed, and installed on a lathe or a balance machine. Removal is required for replacement of slip-joint parts, a driveshaft tube, or a tube-yoke. To remove the driveshaft, see **Subject 120**.

NOTE: Many service operations do not require driveshaft removal from the vehicle: end-yoke nut tightening; drive component shaft seal or end-yoke replacement; changing U-joint phasing at the slip-yoke; and transmission or axle removal (for overhaul, repair, or replacement). To perform these operations, uncouple the U-joint at the applicable end of the appropriate driveshaft.

1. Roll the vehicle forward or backward as needed to turn the end-yoke (of the driveline that is being uncoupled) until the centerline through its cross-holes is vertical. See **Fig. 1**.
2. Apply the parking brakes, and chock the tires.
3. Support the driveshaft with a nylon support strap.

   When uncoupling a coupling shaft, install two or three support straps, as needed. Remove the fasteners that attach the midship bearing(s) to its bracket(s).
4. Remove and discard all four bearing-cup-plate self-locking capscrews.
5. Using one of the U-joint pullers listed in **Specifications 400**, remove both bearing assemblies from the end-yoke cross-holes. See **Fig. 2**.
6. Compress the slip-joint and pivot the end of the U-joint cross to remove it from the yoke. Install the bearing cups on the U-joint cross, and secure them with tape.

CAUTION

Do not expose the U-joint trunnions or bearing-cup needles to dirt or grit. The smallest bits of dirt or grit can cause rapid wear and serious damage to the U-joint.

U-Joint Coupling

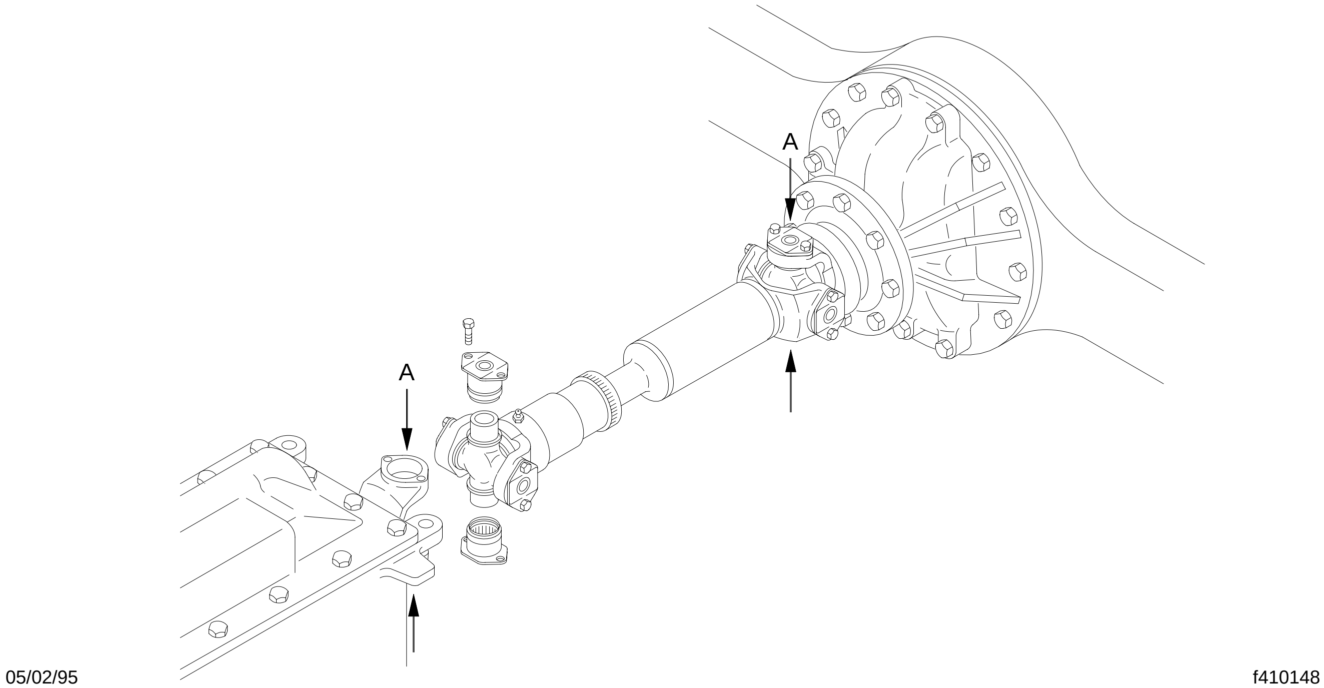
1. Check and clean the end-yoke.
   - 1.1 Check the torque on the end-yoke nut. See **Specifications 400**.
   - 1.2 Check the end-yoke cross-holes for burrs or raised metal. Using a rat-tail or half-round file, remove burrs or raised metal. See **Fig. 3**.
   - 1.3 Using a mill file, and holding it flat against the machined surface of the yoke lug, remove any burrs or raised metal. See **Fig. 4**.
   - 1.4 Using fine emery cloth, smooth and clean the entire surface of the yoke cross-holes. See **Fig. 5**.
   - 1.5 Turn the end-yoke until the centerline through its cross-holes is vertical. See **Fig. 1**.
2. Check, clean, and lubricate the U-joint.
   - 2.1 Using fine emery cloth, smooth and clean the outside surfaces of both bearing cups. See **Fig. 6**.
   - 2.2 Check the U-joint trunnions and bearing cups for minute particles of dirt or grit. Clean if necessary; see **Subject 140**.

CAUTION

Do not expose the U-joint trunnions or bearing-cup needles to dirt or grit. The smallest bits of dirt or grit can cause rapid wear and serious damage to the U-joint.

   - 2.3 Using NLGI grade 2 grease with EP additives, wipe a small amount of grease on the needles in the bearing cups.
   - 2.4 Using a light-weight oil, lubricate the lips of the bearing-cup seals. See **Fig. 7**.
3. Couple the U-joint cross to the end-yoke.
   - 3.1 Extend the slip-joint, while pivoting the U-joint cross into place in the yoke cross-holes.

U-Joint Uncoupling and Coupling With a Full-Round End-Yoke



NOTE: Not all fasteners are shown.

A. End-yoke cross-hole centerline is vertical.

Fig. 1, U-Joint Uncoupling/Coupling of a Driveline With Full-Round End-Yokes

3.2 Move one end of the cross until a trunnion projects through the cross-hole, beyond the outer machined face of the yoke lug. Using a Spicer trunnion (journal) locator (**Specifications 400**), hold the trunnions in alignment with the cross-holes, while placing a bearing assembly over the projected trunnion, and aligning it with the cross-hole. See **Fig. 8**.

IMPORTANT: A Spicer trunnion (journal) locator should be used, to prevent damage to the U-joint trunnions and slingers.

3.3 By hand, press the bearing assembly flush with the face of the yoke. If the bearing assembly binds in the cross-hole, tap the *center* of the bearing plate with a rubber or rawhide mallet; do not tap the outer edges of the bearing plate. See **Fig. 9**.

3.4 Install *new* bearing-cup-plate self-locking capscrews. See **Fig. 10**. Tighten the capscrews until all the parts are drawn down tight, with no gaps; do not tighten the capscrews to their final torque value.

WARNING

Self-locking bearing-cup-plate capscrews must not be reused; replace the capscrews with new ones. Also, do not undertighten or overtighten any bearing-cup-plate capscrews. A loose or broken fastener at any point in the driveline weakens the driveline connection, which could cause serious vehicle damage, or could result in a driveshaft separating from the vehicle, possibly causing loss of vehicle control that could result in serious personal injury or death.

3.5 Move the cross until it projects beyond the machined surface of the opposite yoke lug. Repeat applicable substeps to install the opposite bearing.

3.6 Alternately tighten the bearing-cup-plate capscrews in increments of 5 lbf·ft (7

U-Joint Uncoupling and Coupling With a Full-Round End-Yoke

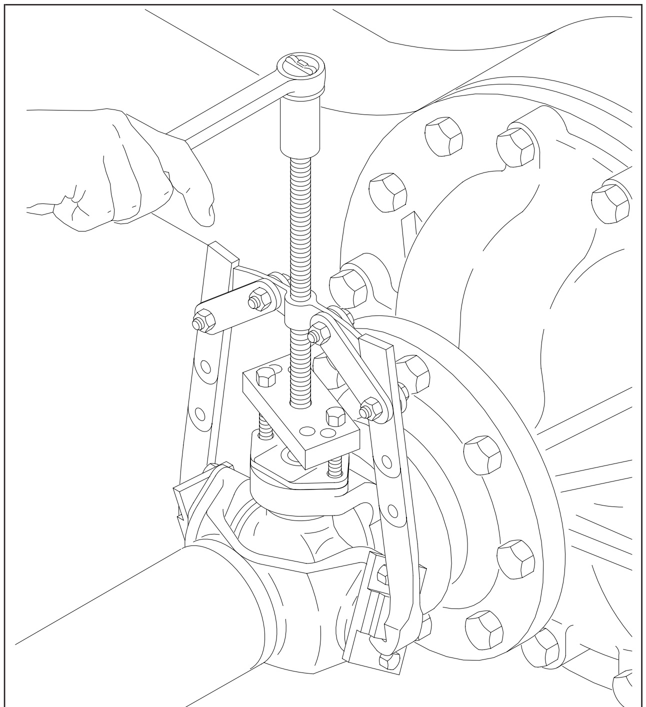


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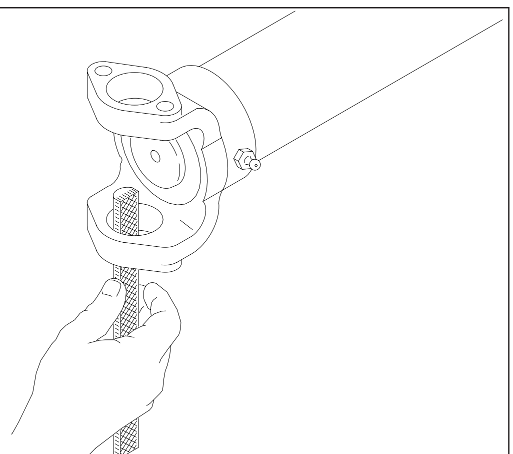
Fig. 2, Remove a Bearing Cup from a Full-Round End-Yoke



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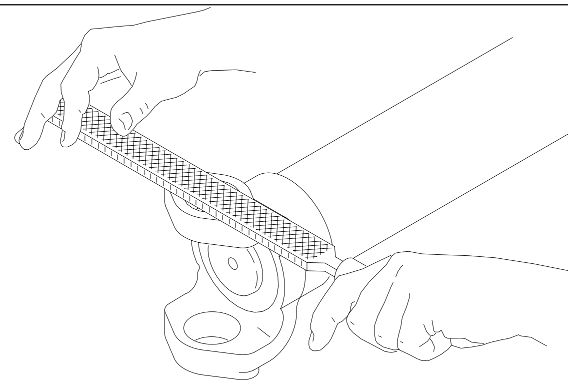
NOTE: Sleeve-yoke shown.

Fig. 3, Remove Burrs from a Full-Round Yoke Cross-Hole

N·m), to the torque value in **Specifications 400**.



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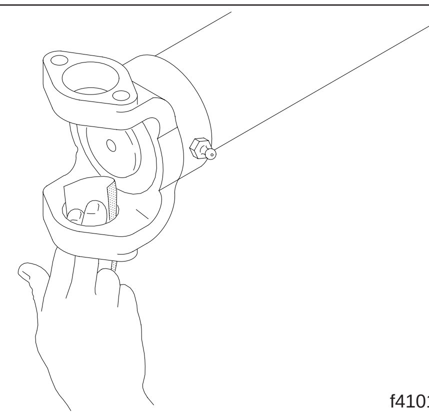
NOTE: Sleeve-yoke shown.

Fig. 4, Remove Burrs from the Machined Surface of a Full-Round Yoke Lug



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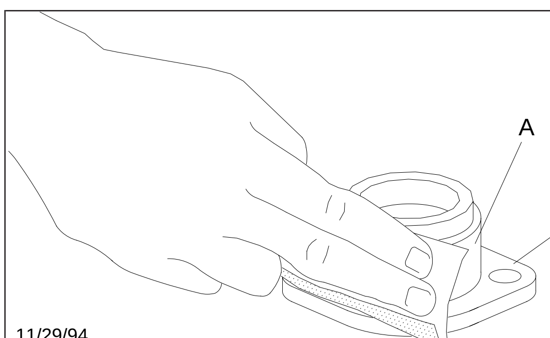
NOTE: Sleeve-yoke shown.

Fig. 5, Smooth a Full-Round Yoke Cross-Hole



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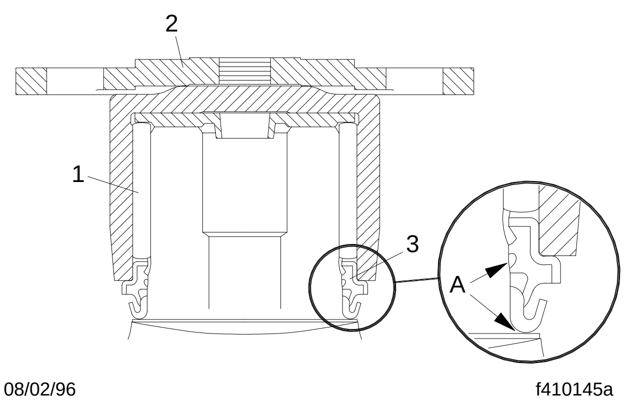
A. Use fine emery cloth on this surface.
B. Use a mill file on this surface.

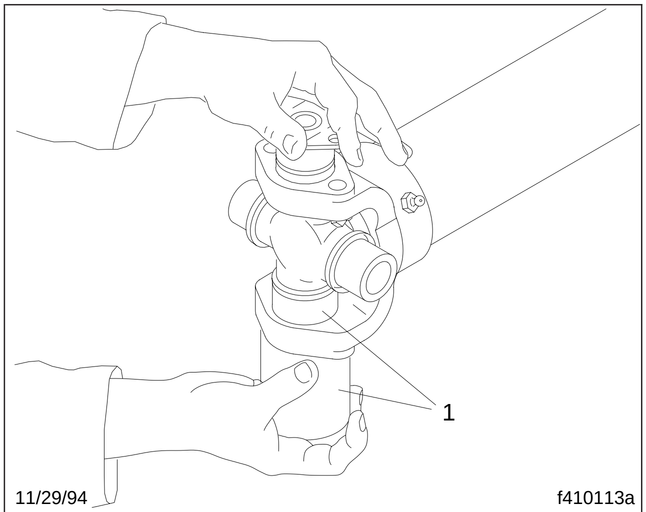
Fig. 6, Smoothing a Full-Round Yoke U-Joint Bearing Cup

U-Joint Uncoupling and Coupling With a Full-Round End-Yoke



A. Lubricate seal lips here.
1. Bearing Needle
2. Bearing-Cup Plate
3. Bearing-Cup Seal

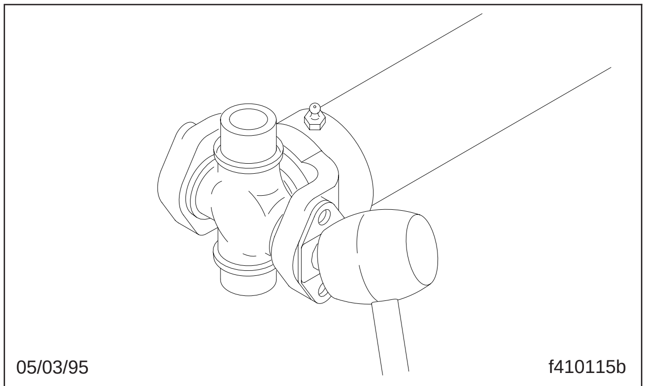
Fig. 7, Sectional View of a Full-Round Yoke U-Joint Bearing Cup



NOTE: Sleeve-yoke shown.
1. Trunnion Locator

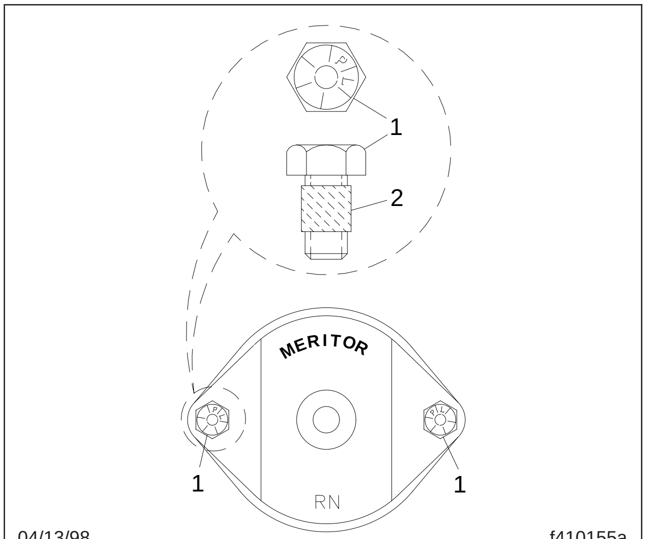
Fig. 8, Use a U-Joint Trunnion Locator

4. If they were removed, install the fasteners that attach each midship bearing to its bracket; tighten the flanged locknuts 91 lbf·ft (123 N·m).
5. Lubricate the U-joint, following the procedure in Group 41 of the *Business Class M2 Maintenance Manual*.
6. Remove the nylon support straps, then remove the chocks.



NOTE: Sleeve-yoke shown.

Fig. 9, Seat a U-Joint Bearing Cup in a Full-Round Yoke



1. Self-Locking Capscrew
2. Adhesive Band

Fig. 10, Meritor U-Joint Fasteners for Full-Round Yokes

NOTE: Many service operations do not require driveshaft removal from the vehicle: end-yoke nut tightening; drive component shaft seal or end-yoke replacement; changing U-joint phasing at the slip-yoke; and transmission or axle removal (for overhaul, repair, or replacement). To perform these operations, uncouple the U-joint at the applicable end of the appropriate driveshaft. See **Subject 100** for uncoupling from a *half-round* end-yoke, or see **Subject 110** for uncoupling from a *full-round* end-yoke.

NOTE: It is easier to check driveline parts, and to replace a U-joint or midship bearing assembly if the driveshaft is removed from the vehicle. If a driveshaft requires straightening or balancing, it must be removed, and installed on a lathe or balance machine. Removal is required for replacement of slip-joint parts, a driveshaft tube, or a tube-yoke.

No. 3 Driveshaft Removal

1. Uncouple the No. 3 driveshaft from the rearmost axle. See **Fig. 1** and **Fig. 2**. If the No. 3 driveshaft is coupled to *half-round* end-yokes, follow the uncoupling procedure in **Subject 100**. If the No. 3 driveshaft is coupled to *full-round* end-yokes, follow the uncoupling procedure in **Subject 110**.
2. Uncouple the No. 3 driveshaft from the forward-rear axle. See **Fig. 1** and **Fig. 2**. If the No. 3 driveshaft is coupled to half-round end-yokes, follow the uncoupling procedure in **Subject 100**. If the No. 3 driveshaft is coupled to full-round end-yokes, follow the uncoupling procedure in **Subject 110**.
3. Lift the No. 3 driveshaft out of the chassis.

No. 2 Driveshaft Removal

1. Uncouple the No. 2 driveshaft from the single or forward-rear axle. See **Fig. 3** and **Fig. 4** . If the No. 2 driveshaft is coupled to *half-round* end-yokes, follow the uncoupling procedure in **Subject 100**. If the No. 2 driveshaft is coupled to *full-round* end-yokes, follow the uncoupling procedure in **Subject 110**.
2. Uncouple the No. 2 driveshaft from the transmission or coupling shaft. See **Fig. 3** and **Fig. 4** . If the No. 2 driveshaft is coupled to half-round end-yokes, follow the uncoupling procedure in **Subject 100**. If the No. 2 driveshaft is coupled to full-round end-yokes, follow the uncoupling procedure in **Subject 110**.
3. Lift the No. 2 driveshaft out of the chassis.

Intermediate Coupling Shaft Removal

1. If the No. 2 driveshaft is also being removed, remove it first.

   If the No. 2 driveshaft is not being removed, use a nylon support strap to support its forward end.
2. Uncouple the intermediate coupling shaft from the No. 2 driveshaft. If the intermediate coupling shaft has a *half-round* end-yoke, follow the uncoupling procedure in **Subject 100**. If the intermediate coupling shaft has a *full-round* end-yoke, follow the uncoupling procedure in **Subject 110**.
3. Uncouple the intermediate coupling shaft from the primary coupling shaft. See **Fig. 5** and **Fig. 6**. If the primary coupling shaft has a half-round end-yoke, follow the uncoupling procedure in **Subject 100**. If the primary coupling shaft has a full-round end-yoke, follow the uncoupling procedure in **Subject 110**.
4. Lift the intermediate coupling shaft out of the chassis.

Primary Coupling Shaft Removal

1. *For a vehicle with one coupling shaft:*

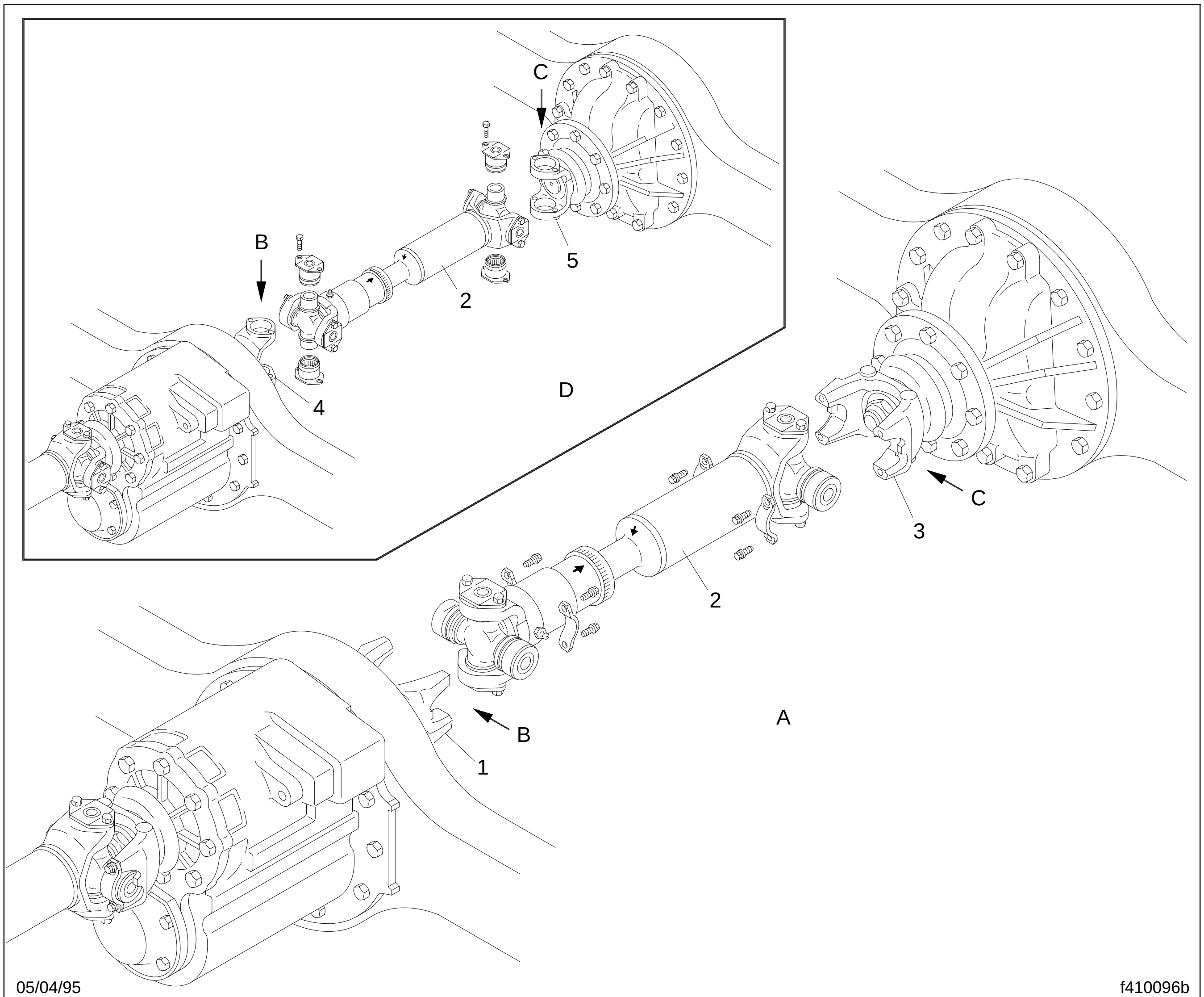
   If the No. 2 driveshaft is also being removed, remove it first.

   If the No. 2 driveshaft is not being removed, use a nylon support strap to support its forward end.

   For a vehicle with two coupling shafts:

   If the No. 2 driveshaft is also being removed, remove it first; then, remove the intermediate coupling shaft.

Driveshaft Removal and Installation



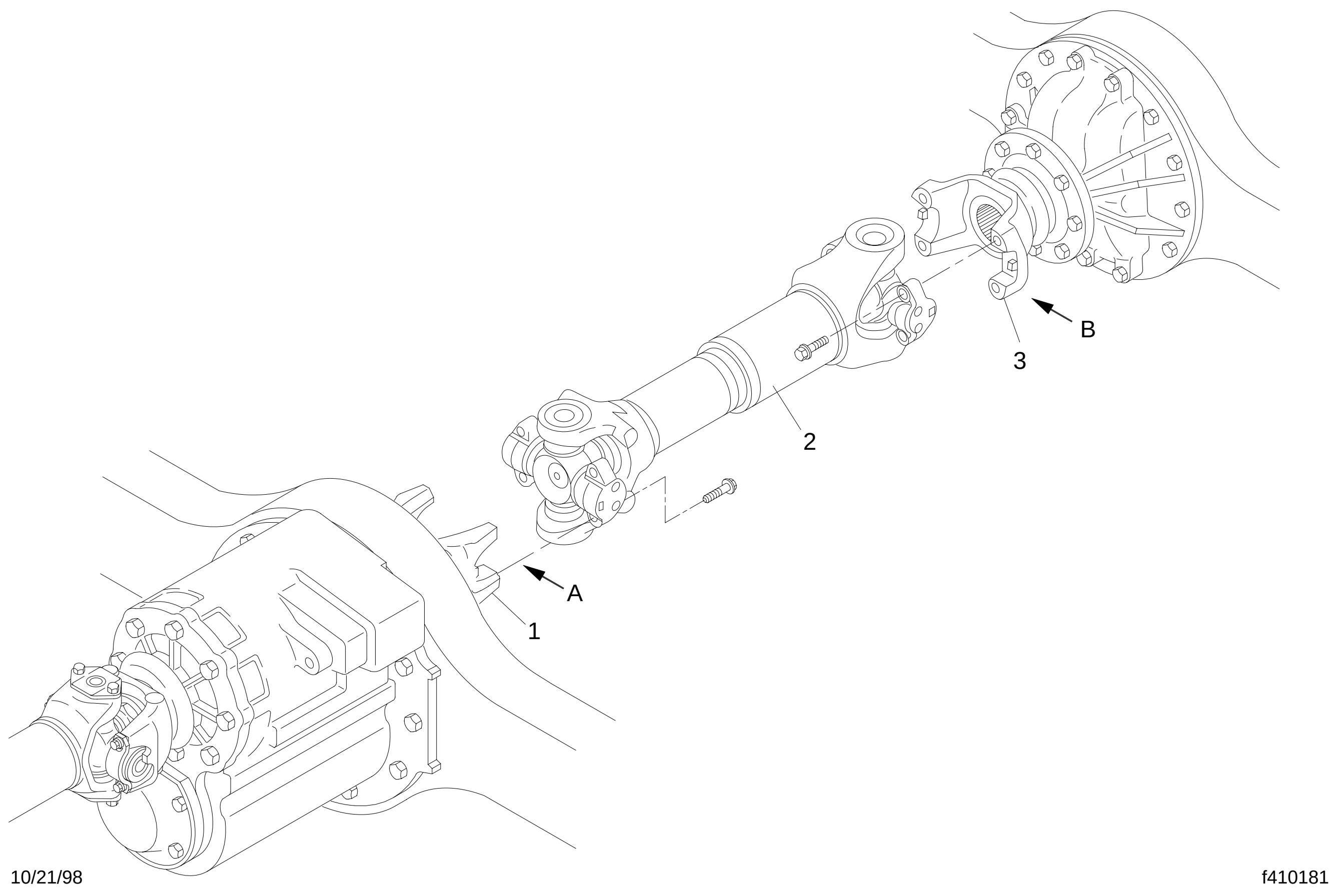
NOTE: Not all fasteners are shown.

A. No. 3 Driveshaft Coupled to Half-Round End-Yokes
B. Uncouple this end last; couple this end first.
1. Forward-Rear Axle Output-Shaft Half-Round End-Yoke
2. No. 3 Driveshaft
C. Uncouple this end first; couple this end last.
D. No. 3 Driveshaft Coupled to Full-Round End-Yokes
3. Rearmost Axle Input-Shaft Half-Round End-yoke
4. Forward-Rear Axle Output-Shaft Full-Round End-Yoke
5. Rearmost Axle Input-Shaft Full-Round End-yoke

Fig. 1, Removal/Installation of a No. 3 Driveshaft Without RPL U-Joints

If the intermediate coupling shaft is also being removed (but not the No. 2 driveshaft), remove the intermediate coupling shaft first.

If only the primary coupling shaft is being removed, use nylon support straps to support the forward end of the No. 2 driveshaft and both ends of the intermediate coupling shaft. Then, remove the fasteners that attach the intermediate coupling shaft midship bearing to its bracket. See Fig. 7 and Fig. 8.



NOTE: Not all fasteners are shown.

A. Uncouple this end last; couple this end first.
1. Forward-Rear Axle Output-Shaft Half-Round End-Yoke

B. Uncouple this end first; couple this end last.
2. No. 3 Driveshaft
3. Rearmost Axle Input-Shaft Half-Round End-Yoke

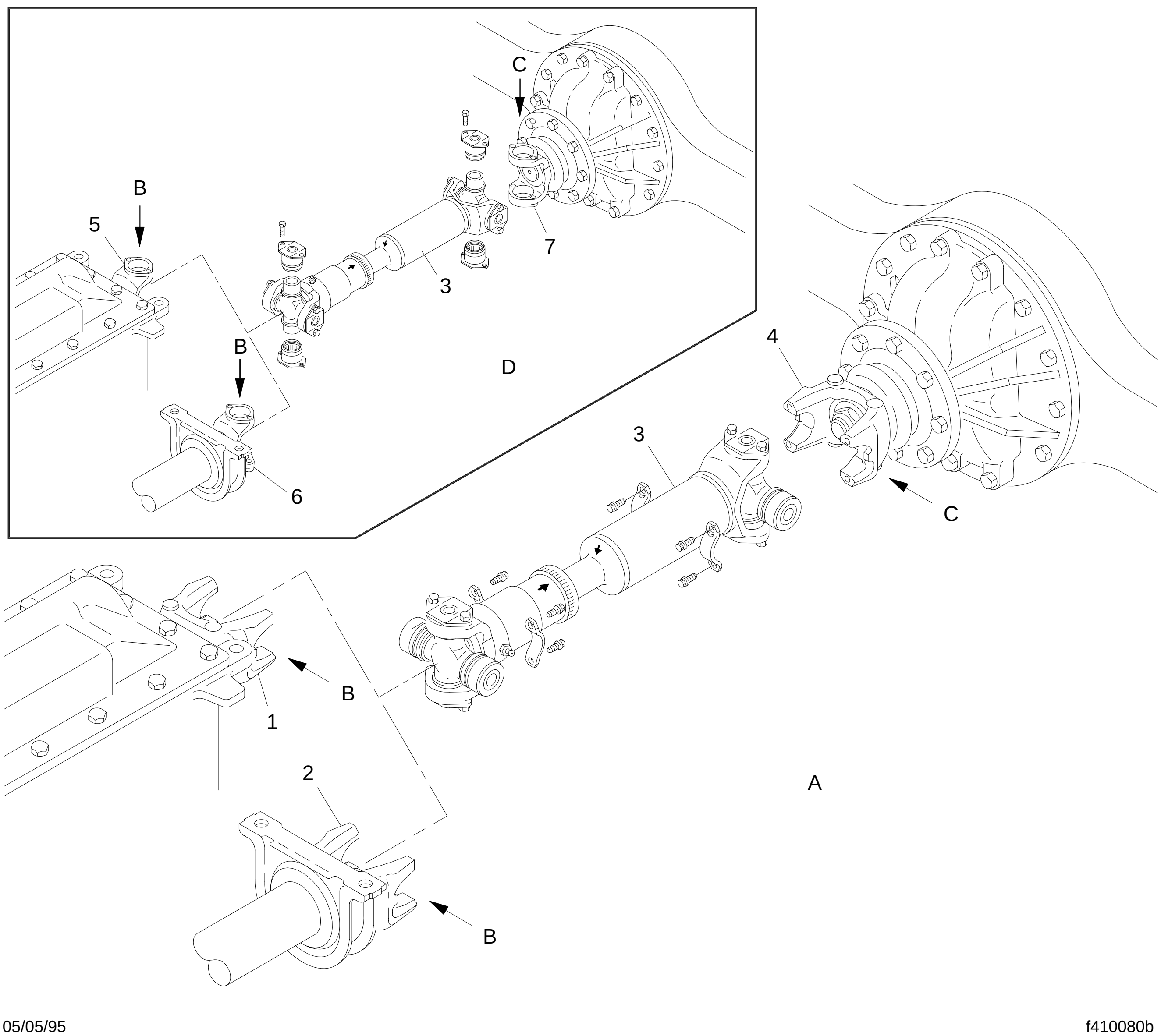
Fig. 2, Removal/Installation of a No. 3 Driveshaft With RPL U-Joints

2. If not already done, uncouple the primary coupling shaft from the No. 2 driveshaft or intermediate coupling shaft. If the primary coupling shaft has a *half-round* end-yoke, follow the uncoupling procedure in **Subject 100**. If the primary coupling shaft has a *full-round* end-yoke, follow the uncoupling procedure in **Subject 110**.
3. Using two nylon support straps, support the primary coupling shaft. Then remove the fasteners that attach the primary coupling shaft midship bearing to its bracket. See **Fig. 7** and **Fig. 8**.
4. Uncouple the primary coupling shaft from the transmission. If the primary coupling shaft is coupled to a half-round end-yoke, follow the uncoupling procedure in **Subject 100**. If the primary coupling shaft is coupled to a full-round end-yoke, follow the uncoupling procedure in **Subject 110**.
5. Lift the primary coupling shaft out of the chassis.

Primary Coupling Shaft Installation

IMPORTANT: Before installing a coupling shaft, make sure the yokes are aligned to keep the U-joints in phase. See **Fig. 9**.

Driveshaft Removal and Installation

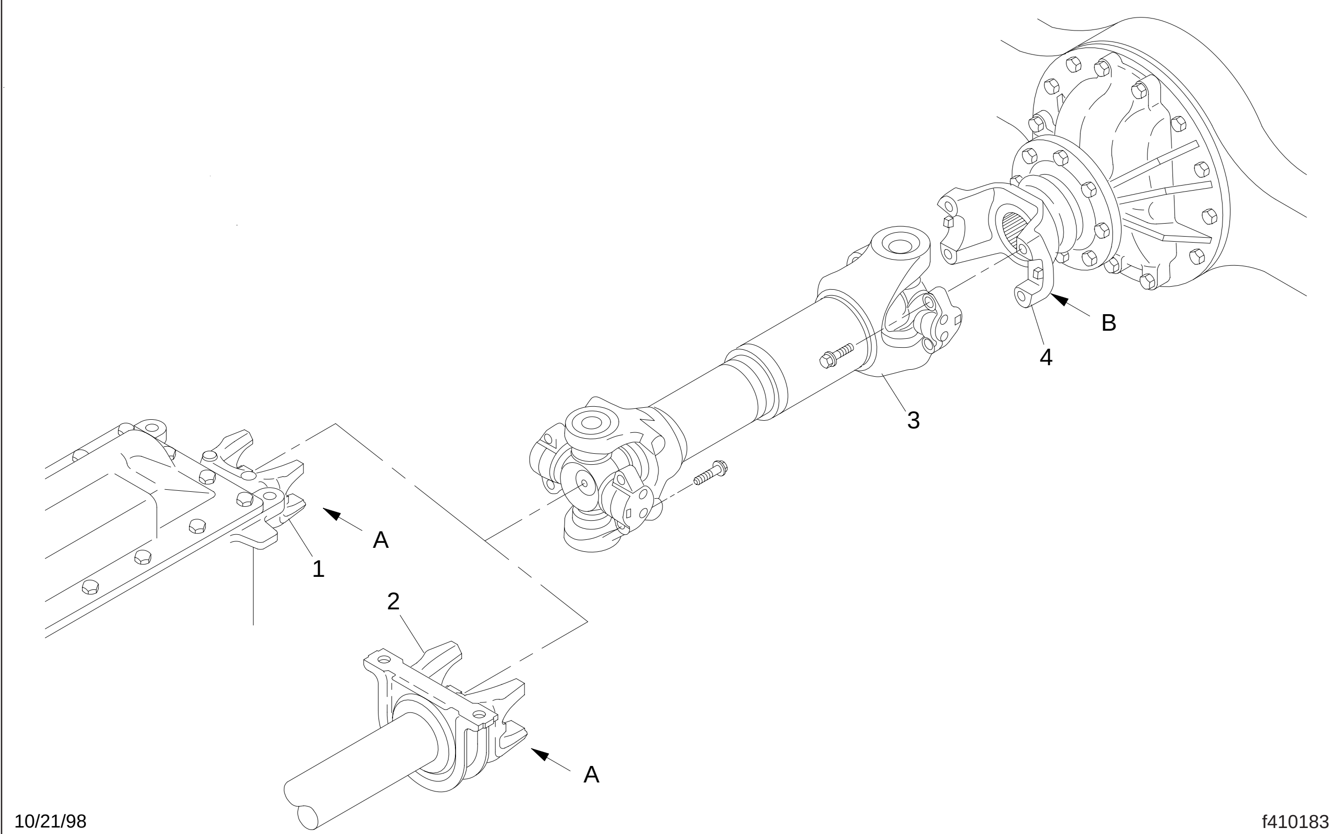


NOTE: Not all fasteners are shown.

A. No. 2 Driveshaft Coupled to Half-Round End-Yokes
B. Uncouple this end last; couple this end first.
C. Uncouple this end first; couple this end last.
D. No. 2 Driveshaft Coupled to Full-Round End-Yokes

1. Transmission Output-Shaft Half-Round End-Yoke
2. Coupling Shaft Half-Round End-Yoke
3. No. 2 Driveshaft
4. Single Axle or Forward-Rear Axle Input-Shaft Half-Round End-Yoke
5. Transmission Output-Shaft Full-Round End-Yoke
6. Coupling Shaft Full-Round End-Yoke
7. Single Axle or Forward-Rear Axle Input-Shaft Full-Round End-Yoke

Fig. 3, Removal/Installation of a No. 2 Driveshaft Without RPL U-Joints



NOTE: Not all fasteners are shown.

A. Uncouple this end last; couple this end first.
1. Transmission Output-Shaft Half-Round End-Yoke
2. Coupling Shaft Half-Round End-Yoke
3. No. 2 Driveshaft

B. Uncouple this end first; couple this end last.
4. Single Axle or Forward-Rear Axle Input-Shaft Half-Round End-Yoke

Fig. 4, Removal/Installation of a No. 2 Driveshaft With RPL U-Joints

1. Place the primary coupling shaft under the vehicle and support it with nylon support straps so it can be coupled to the transmission end-yoke.
2. Couple the shaft to the transmission end-yoke. If the primary coupling shaft was coupled to a *half-round* end-yoke, follow the coupling procedure in **Subject 100**. If the primary coupling shaft was coupled to a *full-round* end-yoke, follow the coupling procedure in **Subject 110**.
3. *For a vehicle with one coupling shaft:*

   If the No. 2 driveshaft was also removed, install it, as instructed in this subject.

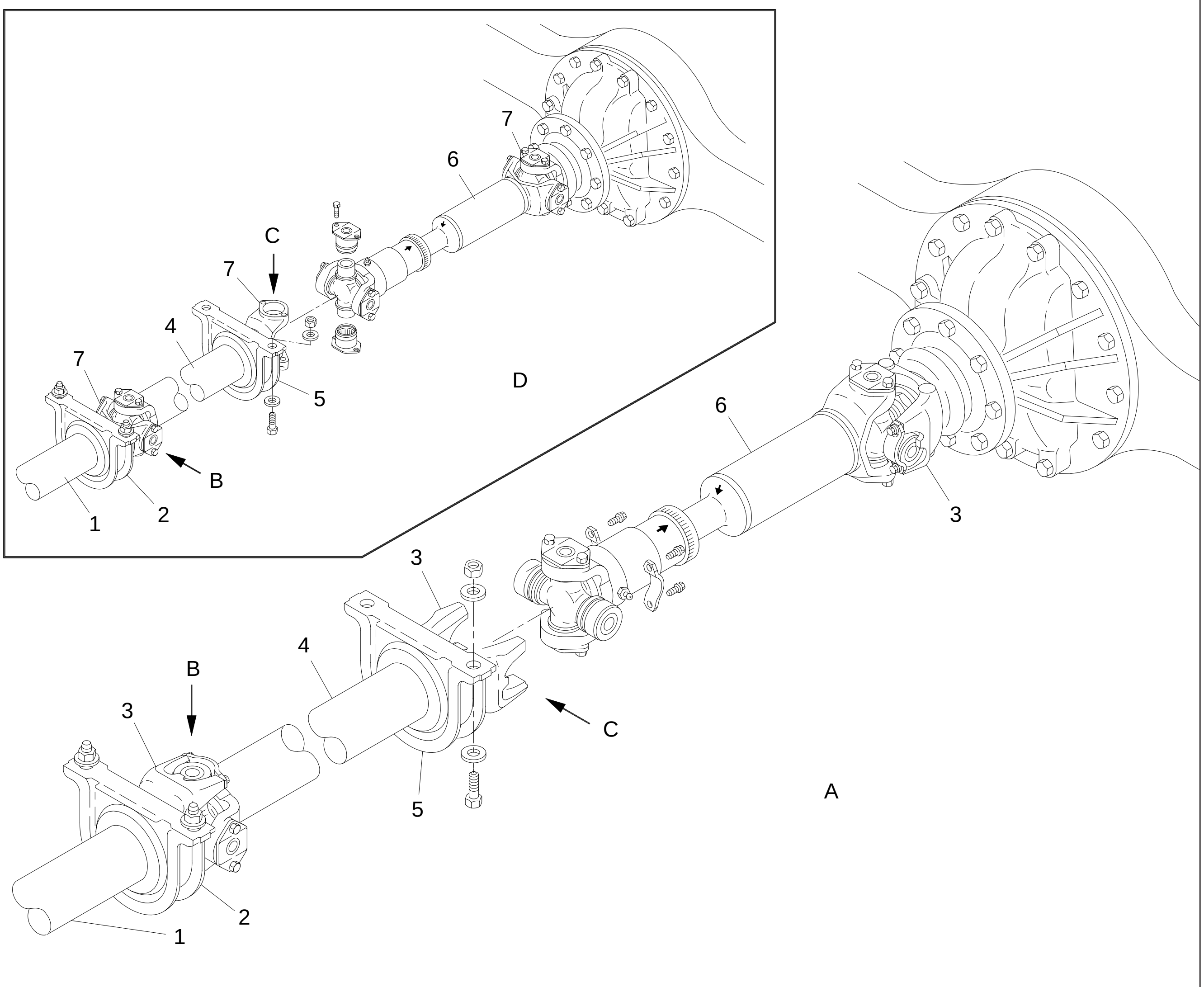
   If the No. 2 driveshaft was not removed, couple it to the primary coupling shaft end-yoke. If the primary coupling shaft has a half-round end-yoke, follow the coupling procedure in **Subject 100**. If the primary coupling shaft has a full-round end-yoke, follow the coupling procedure in **Subject 110**.

   For a vehicle with two coupling shafts:

   If the intermediate coupling shaft was also removed, install it, as instructed in this subject.

   If only the primary coupling shaft was removed, couple the intermediate coupling shaft to the primary coupling shaft end-yoke. If the primary coupling shaft has a half-round end-yoke, follow the

Driveshaft Removal and Installation



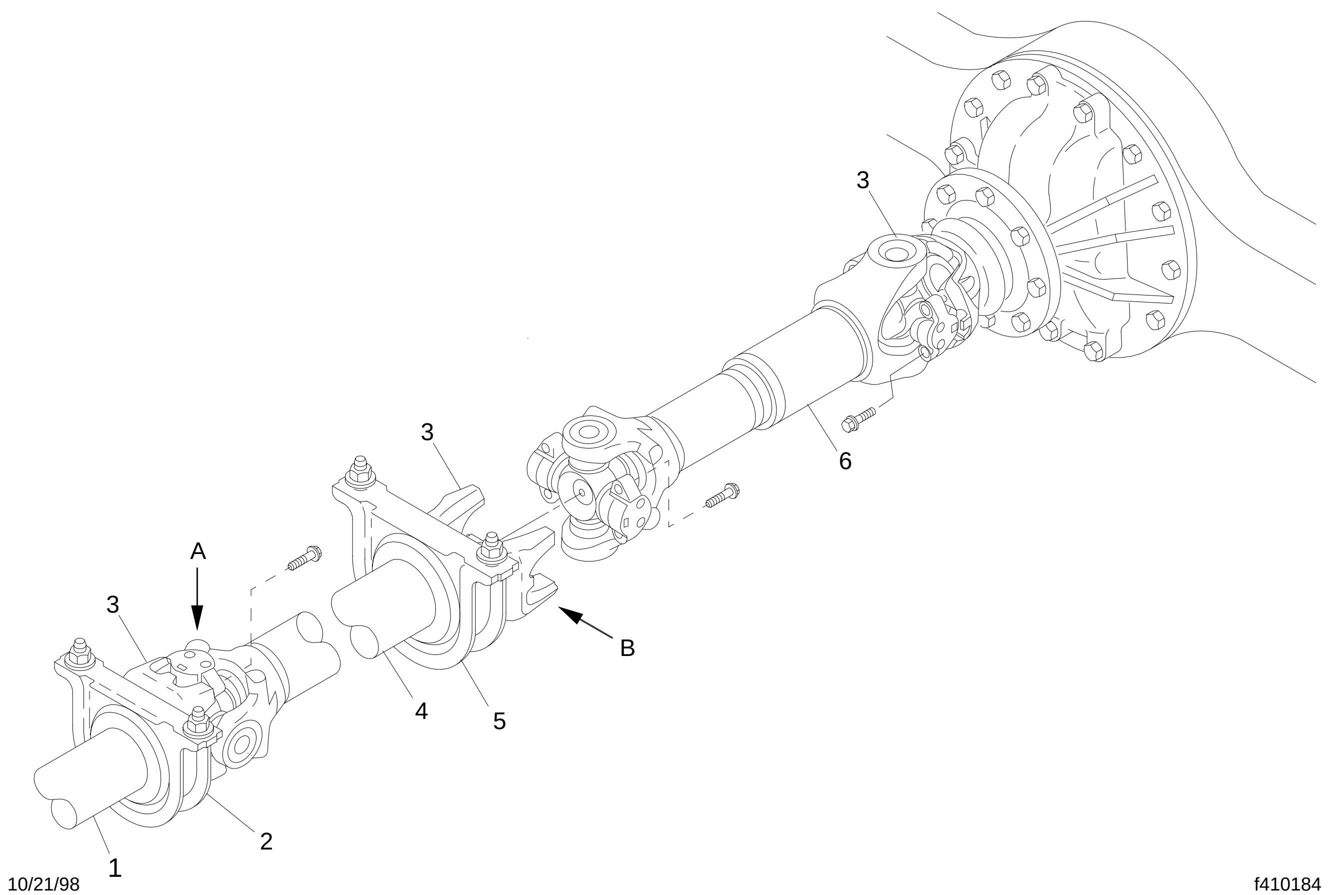
NOTE: Not all fasteners are shown.

A. No. 2 Driveline With Half-Round End-Yokes
B. Uncouple this end last; couple this end first.
C. Uncouple this end first; couple this end last.
D. No. 2 Driveline With Full-Round End-Yokes

1. Primary Coupling Shaft
2. Primary Coupling Shaft Midship Bearing
3. Half-Round End-Yoke
4. Intermediate Coupling Shaft
5. Intermediate Coupling Shaft Midship Bearing
6. No. 2 Driveshaft
7. Full-Round End-Yoke

Fig. 5, Removal/Installation of an Intermediate Coupling Shaft Without RPL U-Joints

coupling procedure in **Subject 100**. If the primary coupling shaft has a full-round end-yoke, follow the coupling procedure in **Subject 110**.



NOTE: Not all fasteners are shown.

A. Uncouple this end last; couple this end first.
B. Uncouple this end first; couple this end last.
1. Primary Coupling Shaft
2. Primary Coupling Shaft Midship Bearing
3. Half-Round End-Yoke
4. Intermediate Coupling Shaft
5. Intermediate Coupling Shaft Midship Bearing
6. No. 2 Driveshaft

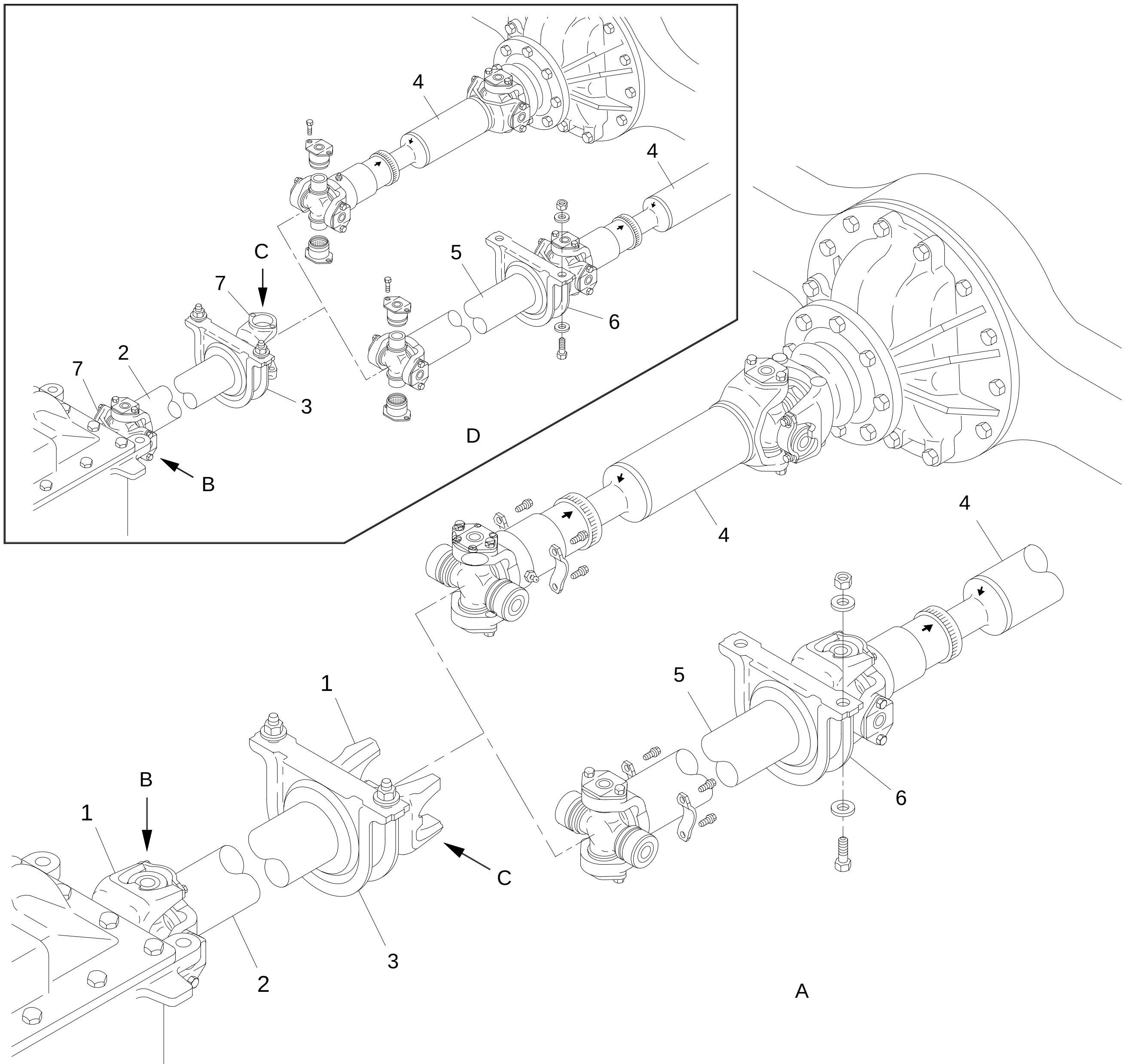
Fig. 6, Removal/Installation of an Intermediate Coupling Shaft With RPL U-Joints

Intermediate Coupling Shaft Installation

IMPORTANT: Before installing a coupling shaft, make sure the yokes are aligned to keep the U-joints in phase. See **Fig. 9**.

1. If the primary coupling shaft was also removed, install it first, as instructed in this subject.
2. Place the intermediate coupling shaft under the vehicle and support it with nylon support straps so it can be coupled to the primary coupling shaft end-yoke.
3. Couple the intermediate coupling shaft to the primary coupling shaft end-yoke. If the intermediate coupling shaft was coupled to a *half-round* end-yoke, follow the coupling procedure in **Subject 100**. If the intermediate coupling shaft was coupled to a *full-round* end-yoke, follow the coupling procedure in **Subject 110**.
4. If the No. 2 driveshaft was also removed, install it, as instructed in this subject.

Driveshaft Removal and Installation



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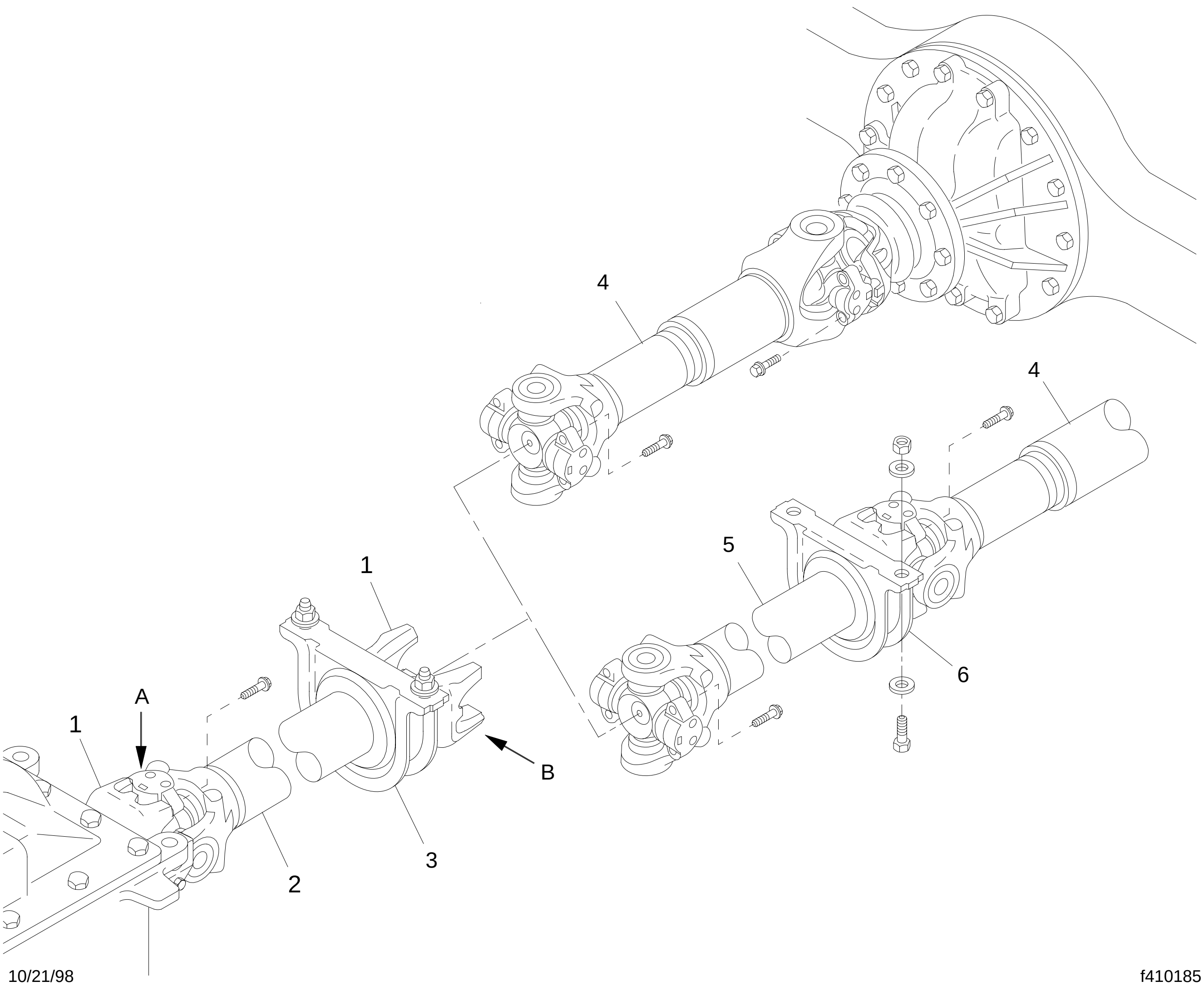
NOTE: Not all fasteners are shown.

A. No. 2 Driveline With Half-Round End-Yokes
B. Uncouple this end last; couple this end first.
C. Uncouple this end first; couple this end last.
D. No. 2 Driveline With Full-Round End-Yokes

1. Half-Round End-Yoke
2. Primary Coupling Shaft
3. Primary Coupling Shaft Midship Bearing
4. No. 2 Driveshaft
5. Intermediate Coupling Shaft
6. Intermediate Coupling Shaft Midship Bearing
7. Full-Round End-Yoke

Fig. 7, Removal/Installation of a Primary Coupling Shaft Without RPL U-Joints



NOTE: Not all fasteners are shown.

A. Uncouple this end last; couple this end first.
B. Uncouple this end first; couple this end last.

1. Half-Round End-Yoke
2. Primary Coupling Shaft
3. Primary Coupling Shaft Midship Bearing
4. No. 2 Driveshaft
5. Intermediate Coupling Shaft
6. Intermediate Coupling Shaft Midship Bearing

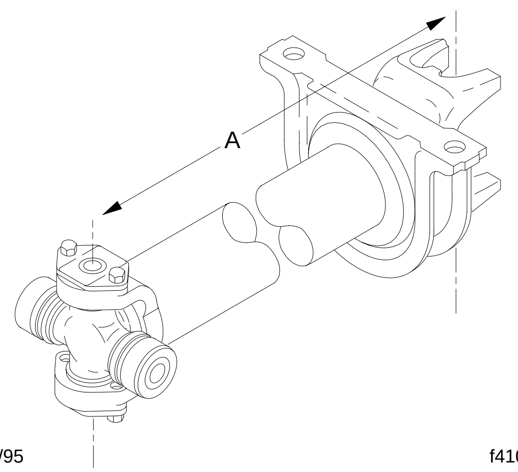
Fig. 8, Removal/Installation of a Primary Coupling Shaft With RPL U-Joints

If the No. 2 driveshaft was not removed, couple it to the intermediate coupling shaft end-yoke. If the intermediate coupling shaft has a half-round end-yoke, follow the coupling procedure in **Subject 100**. If the intermediate coupling shaft has a full-round end-yoke, follow the coupling procedure in **Subject 110**.

No. 2 Driveshaft Installation

IMPORTANT: Before installing a No. 2 driveshaft, make sure the alignment marks on the slip-joint assembly are aligned, to keep the U-joints in phase; see **Fig. 10**.

Driveshaft Removal and Installation



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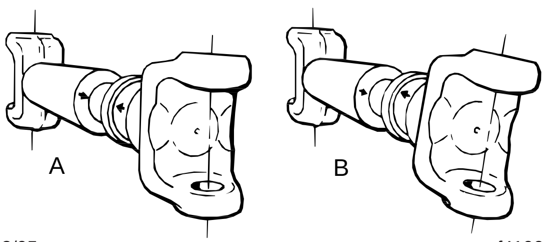
A. Cross-hole centerlines of both yokes must be in alignment.

Fig. 9, U-Joint Phasing of a Coupling Shaft



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A. In Phase B. Out of Phase

Fig. 10, U-Joint Phasing

1. If a primary coupling shaft was also removed, install it first, as instructed in this subject.
2. If an intermediate coupling shaft was also removed, install it before installing the No. 2 driveshaft.
3. Place the No. 2 driveshaft under the vehicle with its sleeve-yoke at the forward end, and support its rear end with a nylon support strap.
4. Couple the sleeve-yoke to the coupling shaft end-yoke or transmission output-shaft end-yoke, as applicable. If the No. 2 driveshaft was coupled to *half-round* end-yokes, follow the coupling procedure in **Subject 100**. If the No. 2 driveshaft was coupled to *full-round* end-yokes, follow the coupling procedure in **Subject 110**.
5. Couple the No. 2 driveshaft to the axle input-shaft end-yoke. If the No. 2 driveshaft was coupled to half-round end-yokes, follow the coupling procedure in **Subject 100**. If the No. 2 driveshaft was coupled to full-round end-yokes, follow the coupling procedure in **Subject 110**.

No. 3 Driveshaft Installation

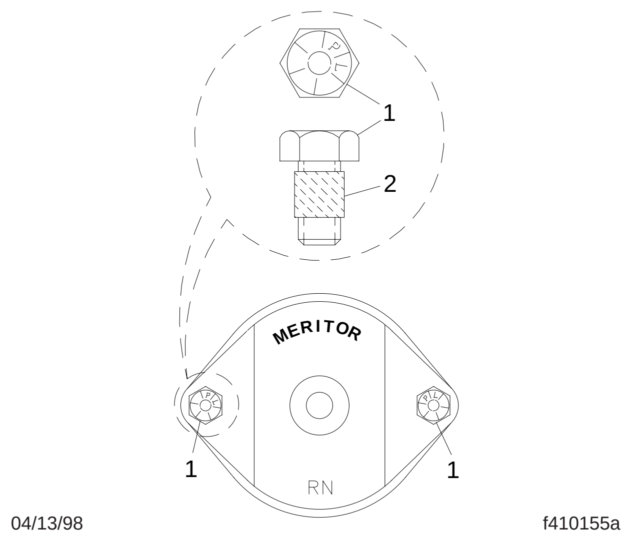
IMPORTANT: Before installing a No. 3 driveshaft, make sure the alignment marks on the slip-joint assembly are aligned, to keep the U-joints in phase; see **Fig. 10**.

1. Place the No. 3 driveshaft under the vehicle with its sleeve-yoke at the forward end, and support its rear end with a nylon support strap.
2. Couple the sleeve-yoke to the forward-rear axle output-shaft end-yoke. If the No. 3 driveshaft was coupled to *half-round* end-yokes, follow the coupling procedure in **Subject 100**. If the No. 3 driveshaft was coupled to *full-round* end-yokes, follow the coupling procedure in **Subject 110**.
3. Couple the No. 3 driveshaft to the axle input-shaft end-yoke. If the No. 3 driveshaft was coupled to half-round end-yokes, follow the coupling procedure in **Subject 100**. If the No. 3 driveshaft was coupled to full-round end-yokes, follow the coupling procedure in **Subject 110**.

U-Joint Removal

Full-Round Yokes

1. Remove the driveshaft from the vehicle. See **Subject 120**.
2. Place the driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
3. Remove and discard all four bearing-plate self-locking capscrews. See **Fig. 1**.



1. Self-Locking Capscrew
2. Adhesive Band

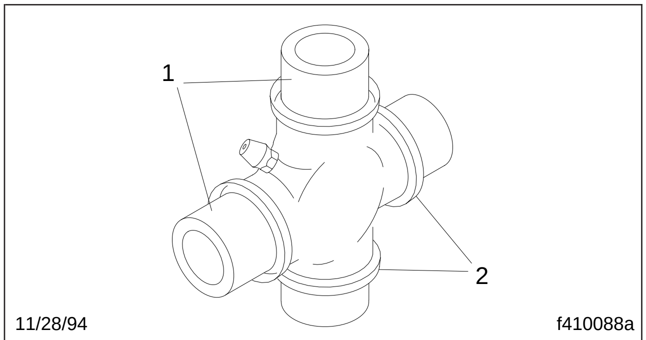
Fig. 1, Meritor U-Joint Fasteners for Full-Round Yokes

IMPORTANT: If the U-joint will be reinstalled, use care not to nick the cross trunnions or damage the slingers. See **Fig. 2**.

4. Using one of the U-joint pullers listed in **Specifications, 400**, remove both bearing cups from the yoke cross-holes. See **Fig. 3**. Remove the cross from the yoke.

RPL Series U-Joint

NOTE: Do not reuse RPL U-joints. Always replace an RPL U-joint with a new one after they have been disassembled and removed from a driveshaft.



1. Trunnions
2. Slingers

Fig. 2, U-Joint Cross

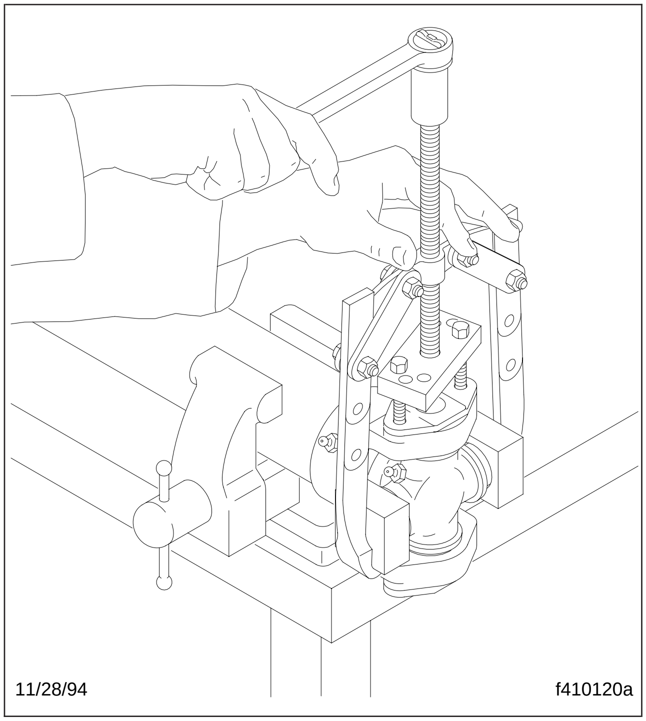
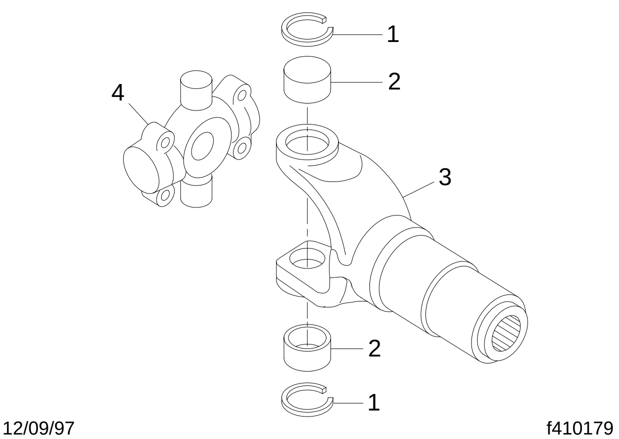


Fig. 3, Removing a Bearing Cup from a Full-Round Yoke

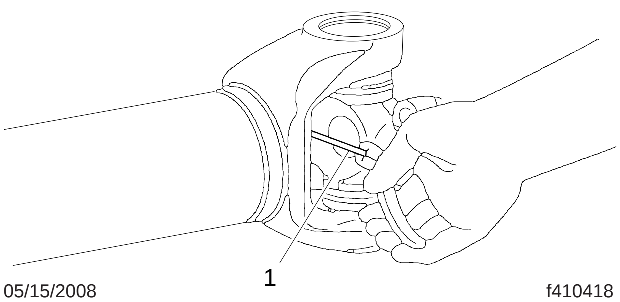
1. Remove the driveshaft from the vehicle. See **Subject 120**.
2. Place the driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
3. Remove and discard the snap rings. See **Fig. 4**.
4. Cut the weld strap that retains the bearing cups. See **Fig. 5**. Remove both bearing cups. See **Fig. 6**.

Driveline Component Removal/Disassembly



1. Snap Ring
2. Bearing Cups
3. Full Round Yoke
4. Bearing Cups (RPL Joint)

Fig. 4, RPL U-Joint Components



1. Weld-Strap

Fig. 5, Cutting the Weld-Strap

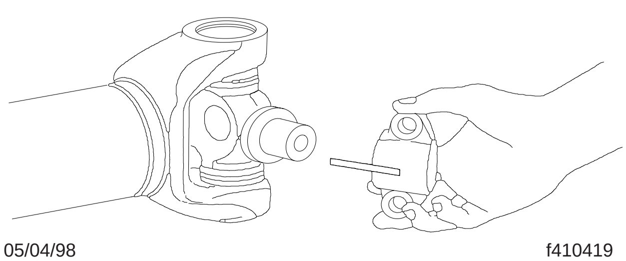
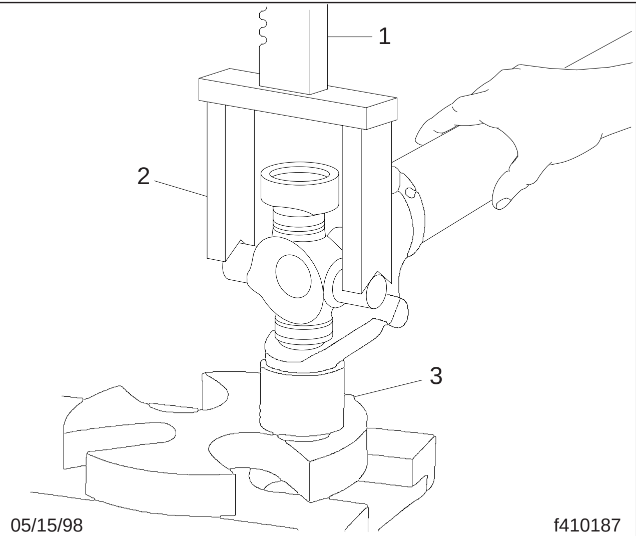


Fig. 6, Removing the Bearing Cups

5. Remove both bearing cups from the yoke cross-holes. See **Fig. 7**. Remove the cross from the yoke.



1. Press
2. Bridge
3. Bearing Cup Receiver

Fig. 7, Removing Bearing Cups from an RPL U-Joint

Slip-Joint Disassembly

Except RPL Drivelines

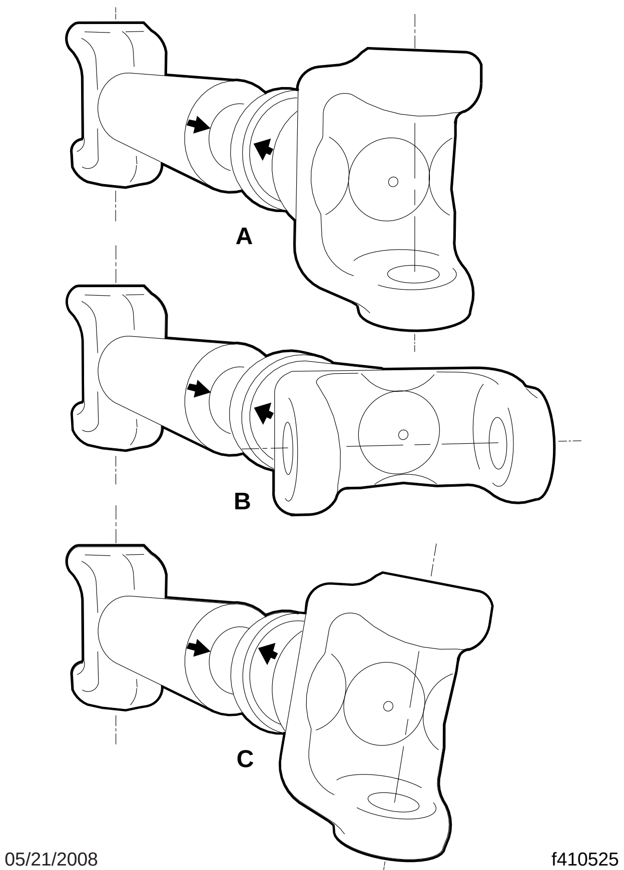
1. Check that the driveshaft yokes are aligned to hold the U-joints at either end in phase, as shown in **Fig. 8**. Using a marking stick or paint, mark the sleeve-yoke and splined shaft with alignment marks, as shown in **Fig. 9**. This will ensure proper alignment of the slip-joint components when the driveshaft is assembled.

IMPORTANT: Misaligned driveshaft yokes will cause the U-joints to be out of phase, which will cause vibration in the driveline.

2. With the driveshaft uncoupled at one end, *or* removed from the vehicle, use a strap wrench to unscrew the slip-joint dust cap from the sleeve-yoke, then pull the sleeve-yoke off of the splined shaft. Remove the dust cap, and (if so equipped) the steel washer and cork seal. See **Fig. 10**.

RPL Drivelines

1. Check that the driveshaft yokes are aligned to hold the U-joints at either end in phase, as shown in **Fig. 8**. Using a marking stick or paint, mark the sleeve-yoke and splined shaft with alignment marks, as shown in **Fig. 9**. This will



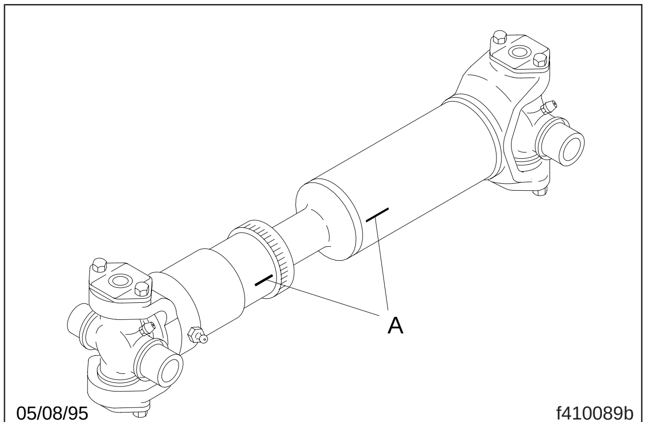
A. In Phase (parallel phased)
B. In Phase (cross phased)
C. Out of Phase

Fig. 8, U-Joint Phasing

ensure proper alignment of the slip-joint components when the driveshaft is assembled.

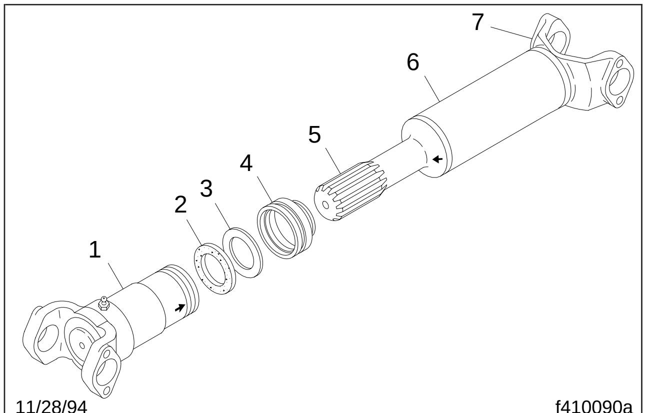
IMPORTANT: Misaligned driveshaft yokes will cause the U-joints to be out of phase, which will cause vibration in the driveline.

2. With the driveshaft uncoupled at one end, *or* removed from the vehicle, use a brass hammer and punch to tap the shroud off the slip seal. See **Fig. 11**.
3. Use a screwdriver to pry the seal out of the groove in the slip yoke, then pull the sleeve-yoke off of the splined shaft. Remove the shroud and seal.



A. Use a marking stick or paint to add alignment marks.

Fig. 9, Slip-Joint Alignment Marks



1. Sleeve-Yoke
2. Cork Washer
3. Steel Washer
4. Dust Cap
5. Splined Stub Shaft
6. Tube
7. Tube-Yoke

Fig. 10, Slip-Joint Components

Transmission/Axle End-Yoke Removal

IMPORTANT: Before removing a transmission output-shaft end-yoke or an axle shaft end-yoke, do the steps under "End-Yoke Cleaning and Inspection," in **Subject 140**.

1. Uncouple the driveshaft from the end-yoke (**Subject 100** for a half-round yoke or **Subject 110** for

Driveline Component Removal/Disassembly

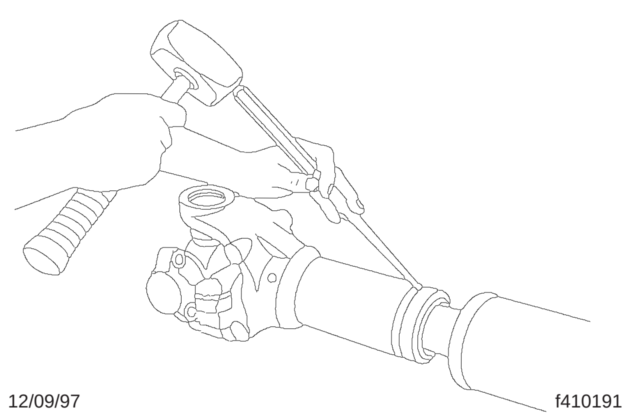


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Fig. 11, Shroud Removal

a full-round yoke), or remove the driveshaft from the vehicle (**Subject 120**).

2. Remove the end-yoke locknut. See **Fig. 12**.
3. Using a yoke puller, remove the end-yoke. See **Fig. 13** for a half-round end-yoke, or see **Fig. 14** for a full-round end-yoke.

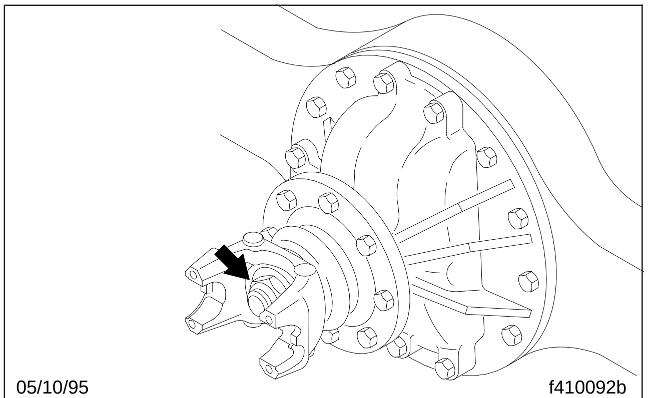

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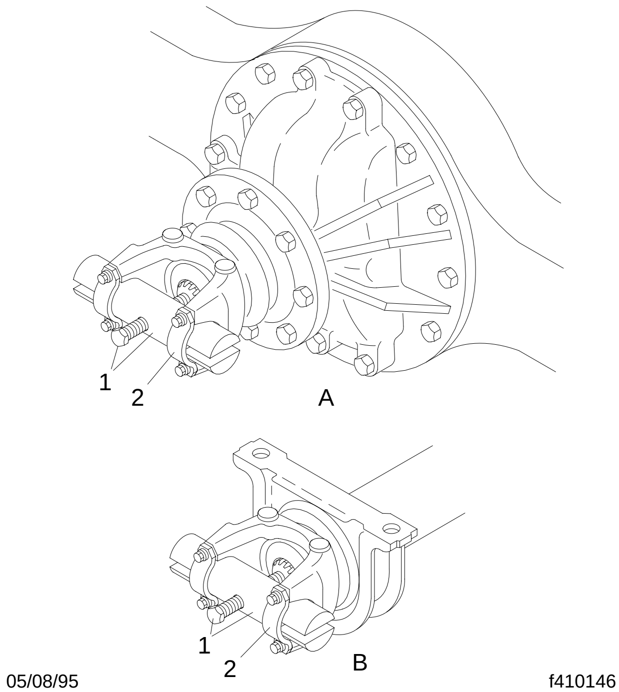
Fig. 12, Axle End-Yoke Locknut

Coupling Shaft End-Yoke and Midship Bearing Removal

1. Remove the coupling shaft from the vehicle. See **Subject 120**.
2. Clamp the coupling shaft in a soft-jawed vise; do not distort the tube with excessive grip.
3. Remove the end-yoke; see **Fig. 13** for a half-round end-yoke, or see **Fig. 14** for a full-round



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A. Axle End-Yoke
B. Coupling Shaft End-Yoke

1. Yoke Puller
2. Bearing Strap

Fig. 13, Removing a Half-Round End-Yoke

end-yoke. Then, remove the midship bearing as follows. See **Fig. 15**.

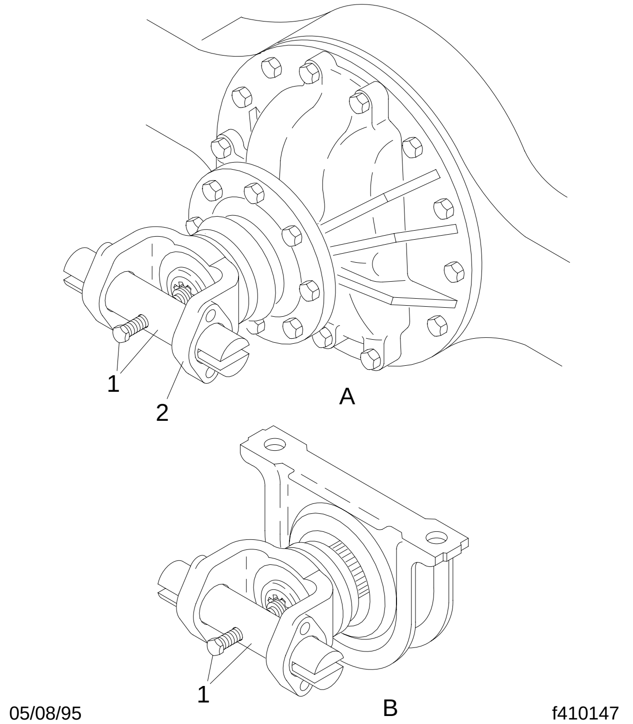
3.1 Use a marking stick or paint to mark the end-yoke and coupling shaft with alignment marks. See **Fig. 16**.

3.2 Remove the coupling shaft end-yoke locknut.

3.3 Using a yoke puller, remove the end-yoke. See **Fig. 13** for a half-round end-yoke, or see **Fig. 14** for a full-round end-yoke.

3.4 Use a hammer and a brass drift to remove the midship bearing. See **Fig. 15**.

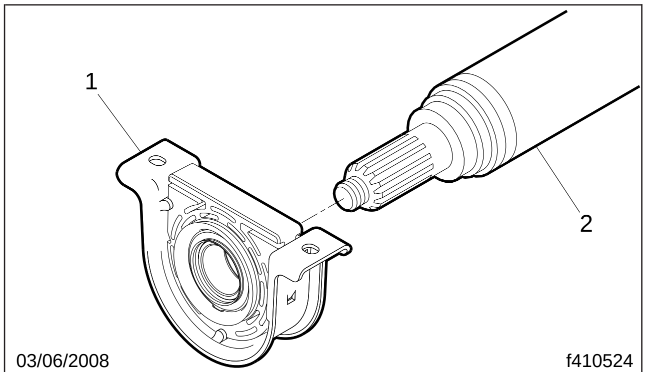
Driveline Component Removal/Disassembly



A. Axle End-Yoke
B. Coupling Shaft End-Yoke

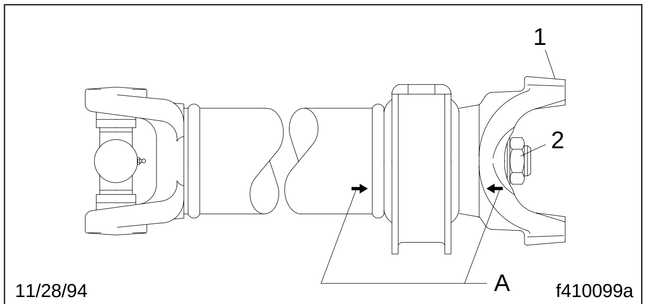
1. Yoke Puller
2. Full-Round End-Yoke

Fig. 14, Removing a Full-Round End-Yoke



1. Midship Bearing
2. Midship Bearing Shaft

Fig. 15, Midship Bearing



A. Use a marking stick or paint to mark the end-yoke and coupling shaft with alignment marks.

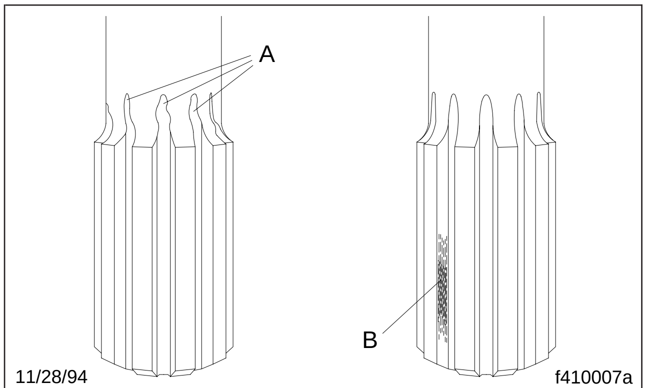
1. Half-Round End-Yoke
2. End-Yoke Locknut

Fig. 16, Alignment Marks on a Coupling Shaft With an End-Yoke

Driveshaft Tube, Slip-Joint, Sleeve-Yoke, and Tube-Yoke Cleaning and Inspection

1. With the driveshaft removed, scrape or soak away any foreign material.
2. Examine the driveshaft tube for dents, bends, twists, splitting weld-seams, and signs of missing balance weights.

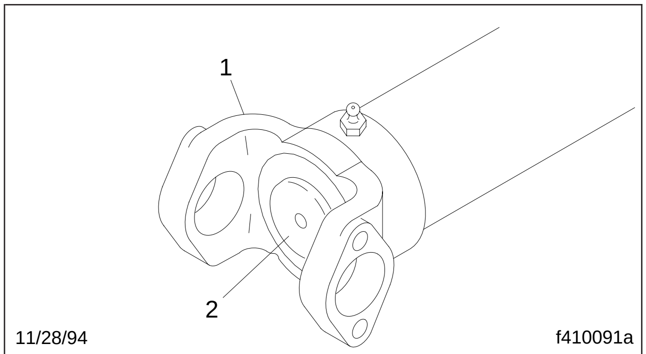
   Replace the driveshaft tube if damaged; see "Driveshaft Tube, Stub Shaft (Slip-Joint), or Tube-Yoke Replacement," in **Subject 150**. If balance weights appear to be missing, have the driveshaft balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.
3. Clean the slip-joint (male and female) splines, then check them for twisting and galling. See **Fig. 1**. Replace both the sleeve-yoke and the splined shaft if the slip-joint is damaged; see "Driveshaft Tube, Stub Shaft (Slip-Joint), or Tube-Yoke Replacement," in **Subject 150**. Remove any burrs or rough spots using fine emery cloth.



A. Twisted Splines B. Galling

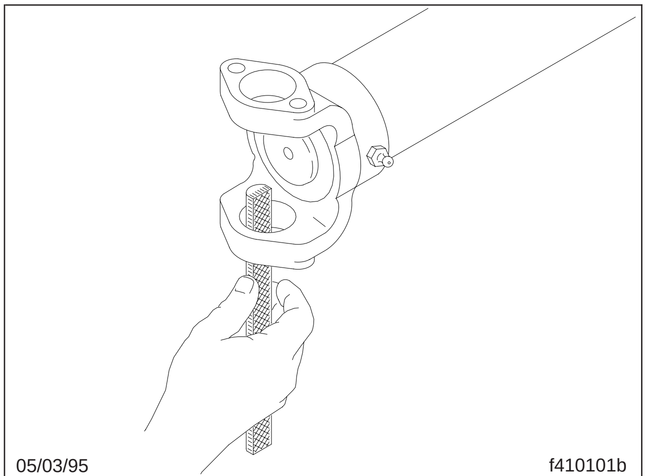
Fig. 1, Damaged Slip-Joint Splines

4. Check for a loose or missing sleeve-yoke plug. See **Fig. 2**. Repair or replace the plug as needed.
5. With the U-joint assemblies removed, check all driveshaft yoke cross-holes for raised metal. Using a rat-tail or half-round file, remove burrs or raised metal. See **Fig. 3**.



1. Sleeve-Yoke 2. Yoke Plug

Fig. 2, Sleeve-Yoke Plug



NOTE: Sleeve-yoke shown.

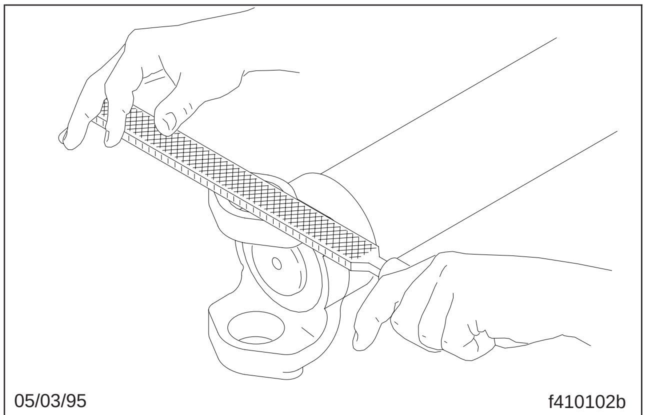
Fig. 3, Removing Burrs From a Full-Round Yoke Cross-Hole

6. Using a mill file, and holding it flat against the machined surface of the driveshaft yoke lug, file each yoke lug, to remove any burrs or raised metal. See **Fig. 4**.
7. Using fine emery cloth, smooth and clean the entire surface of all driveshaft yoke cross-holes. See **Fig. 5**.

Midship Bearing Cleaning and Inspection

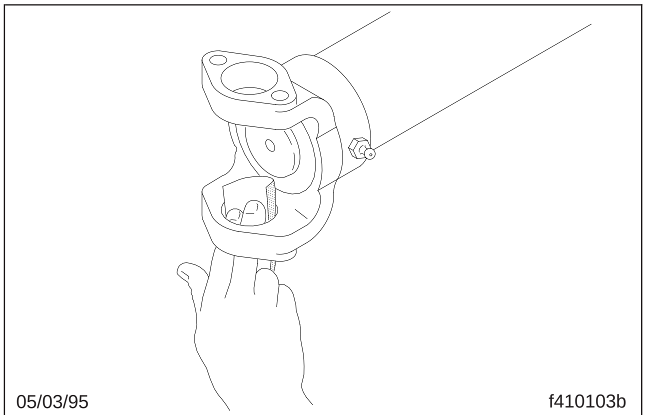
1. With the midship bearing removed from the coupling shaft, use clean rags or paper towels to

Driveline Component Cleaning and Inspection



NOTE: Sleeve-yoke shown.

Fig. 4, Removing Burrs From the Machined Surface of a Full-Round Yoke Lug



NOTE: Sleeve-yoke shown.

Fig. 5, Smoothing a Full-Round Yoke Cross-Hole

wipe off the outside of the midship bearing and rubber cushion.

IMPORTANT: Do not immerse the midship bearing in cleaning solvent. The solvent will wash out the lubricant, requiring bearing-assembly replacement.

2. Check the midship bearing for roughness or rattles by holding the outside of the bearing while manually turning the inner bearing race. Replace the bearing assembly if there are any rough spots or rattles.
3. Check the rubber cushion for deterioration or oil-soaking, and replace the midship bearing assembly if needed.

End-Yoke Cleaning and Inspection

1. With the transmission output-shaft and axle shaft end-yokes installed, check them for cracks and looseness.

   Replace cracked yokes. If the end-yoke can be moved in or out on its shaft, or can be rocked on its shaft, uncouple the driveshaft from the end-yoke. Check the drive component's shaft seal for leakage or other visible damage that may have been caused by the loose yoke. Replace the shaft seal if needed. Tighten the end-yoke nut to the torque value given in **Specifications 400**. If the end-yoke is still loose after tightening the yoke nut, install a new yoke and yoke nut.

NOTE: If the end-yoke locknut is removed for any reason, install a new one.

2. With the U-joints uncoupled from the end-yokes, check all driveshaft and input/output shaft end-yoke cross-holes for raised metal. Using a rat-tail or half-round file, remove burrs or raised metal. See **Fig. 3** for full-round yokes, or see **Fig. 6** for half-round yokes.

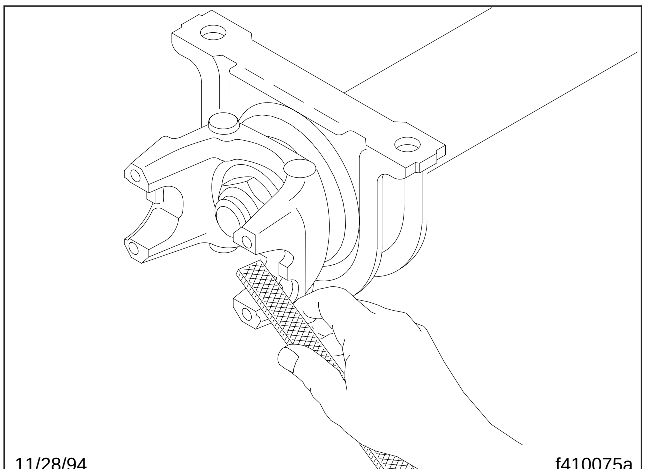
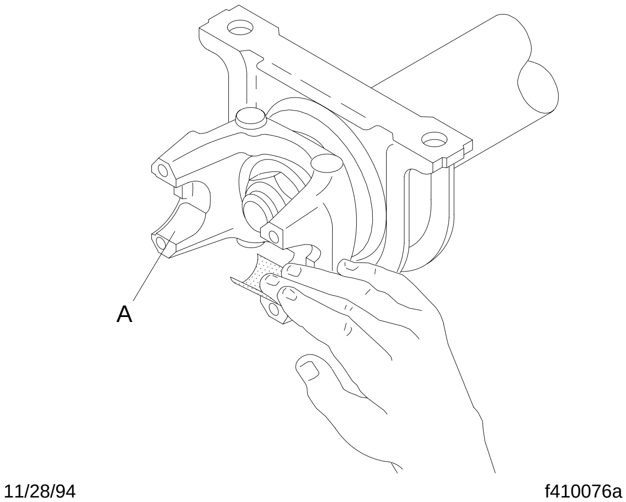


Fig. 6, Removing Burrs From a Half-Round End-Yoke Cross-Hole

3. Using a mill file, and holding it flat against the machined surface of the *full-round* end-yoke lug, file each yoke lug, to remove any burrs or raised metal. See **Fig. 4**.

4. Smooth and clean the entire surface of all end-yoke cross-holes, using fine emery cloth. See **Fig. 5** for full-round yokes, or see **Fig. 7** for half-round yokes.



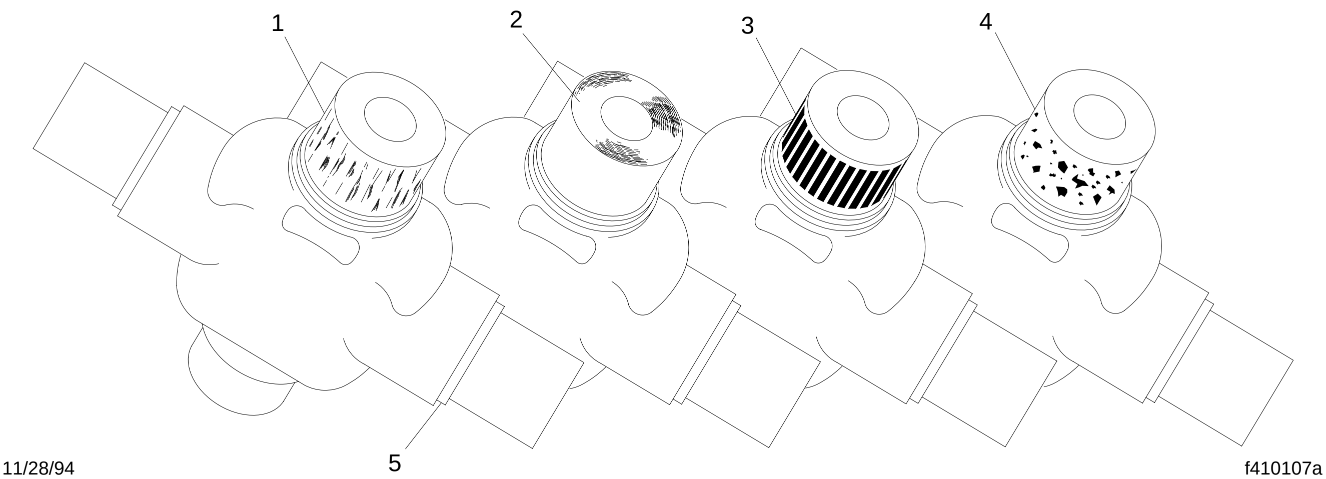
A. Use fine emery cloth on this surface.

Fig. 7, Smoothing a Half-Round End-Yoke Cross-Hole

U-Joint Cleaning and Inspection

1. With the U-joints removed from the yokes, and the bearing cups removed from the crosses, inspect the U-joint cross slingers for damage, then inspect the U-joint trunnions for spalling (flaking metal), end galling (displacement of metal), brinelling (grooves caused by bearing needles), and pitting (small craters caused by corrosion). See **Fig. 8**. If damaged, replace the U-joint assembly.
2. Using a hand-type grease gun, apply multipurpose chassis grease to the fitting on each U-joint cross until all old lubricant is forced out. See **Fig. 9**. Examine the old lubricant. If it appears rusty, gritty, or burnt, replace the U-joint assembly.
3. Soak the bearing cups in a non-flammable cleaner until particles of grease and foreign matter are loosened or dissolved. Do not disassemble the bearing cups; clean the bearing needles with a short, stiff brush, then blow them dry with compressed air. Check for minute particles of dirt or grit, and clean again if necessary.
4. Check each bearing cup for missing bearing needles. Check the bearing-cup seals for nicks. See **Fig. 10** for a half-round-yoke U-joint bearing cup, or see **Fig. 11** for a full-round-yoke U-joint bearing cup. Replace the U-joint assembly if any bearing needles are missing or any seals are damaged.
5. Apply a small quantity of multipurpose chassis grease to the bearing needles in each cup, then apply a small amount of light-weight oil to the lips of the bearing-cup seals. Rotate each bearing cup on the cross to check for wear. Replace the U-joint assembly if any bearing surfaces are worn.
6. Check the underside of each bearing-cup plate for burrs or raised metal. Use a mill file to remove any burrs or raised metal. See **Fig. 12**.
7. Using fine emery cloth, smooth and clean the outside surfaces of all bearing cups. See **Fig. 12** and **Fig. 13**.

Driveline Component Cleaning and Inspection



1. Spalling
2. End Galling
3. Brinelling
4. Pitting
5. Slinger

Fig. 8, Damaged U-Joint Crosses

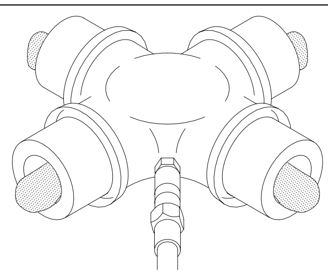
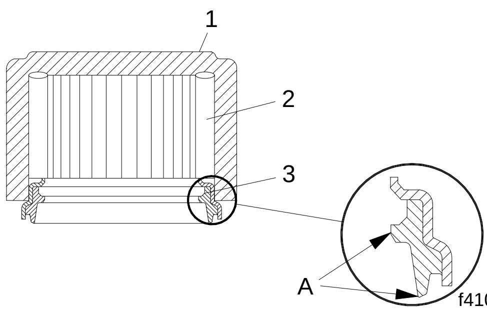


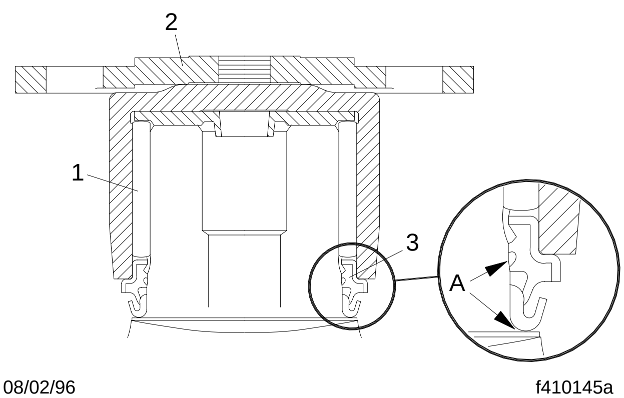
Fig. 9, Forcing Out Old Lubricant From a U-Joint Cross



A. Lubricate seal lips here.

1. Bearing Cup
2. Bearing Needle
3. Bearing-Cup Seal

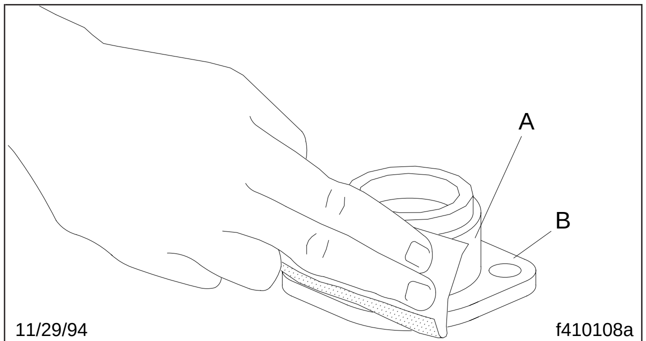
Fig. 10, Sectional View of a Half-Round End-Yoke U-Joint Bearing Cup



A. Lubricate seal lips here.

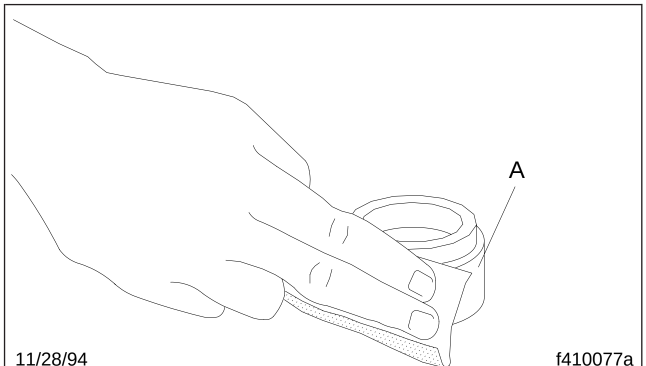
1. Bearing Needle
2. Bearing-Cup Plate
3. Bearing-Cup Seal

Fig. 11, Sectional View of a Full-Round Yoke U-Joint Bearing Cup



A. Use fine emery cloth on this surface.
B. Use a mill file on this surface.

Fig. 12, Smoothing a Full-Round Yoke U-Joint Bearing Cup



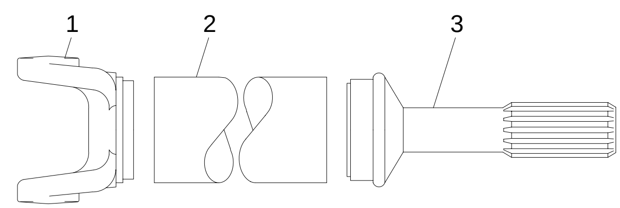
A. Use fine emery cloth on this surface.

Fig. 13, Smoothing a Half-Round Yoke U-Joint Bearing Cup

Driveshaft Tube, Stub Shaft (Slip-Joint), and Tube-Yoke Replacement

IMPORTANT: Parts for different series drivelines must not be intermixed. Incorrectly assembled or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

To replace a driveshaft tube, a tube-yoke, or a stub shaft (**Fig. 1**), the driveshaft must be chucked in a lathe, so the welds can be removed. Driveshaft rebuilding should be done by a machine shop that specializes in driveline repair.



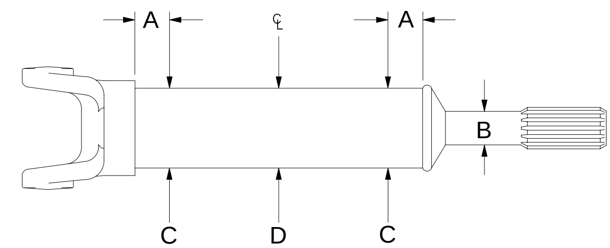
1. Tube-Yoke
2. Driveshaft Tube
3. Stub Shaft

Fig. 1, Driveshaft Tube, Stub Shaft, and Tube-Yoke

Runout limits for a new (rebuilt) driveshaft (**Fig. 2**) are:

- 0.005 inch (0.127 mm) T.I.R. (Total Indicator Reading) on the smooth portion of the stub shaft neck;
- 0.010 inch (0.254 mm) T.I.R. on the tube 3 inch (76 mm) from the front and rear welds;
- 0.015 inch (0.381 mm) T.I.R. at the center of the tube.

Balance the rebuilt driveshaft to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.



A. Measurement: 3 inches (76 mm)
B. Measurement: 0.005 inch (0.127 mm)
C. Measurement: 0.010 inch (0.2540 mm)
D. Measurement: 0.015 inch (0.381 mm)

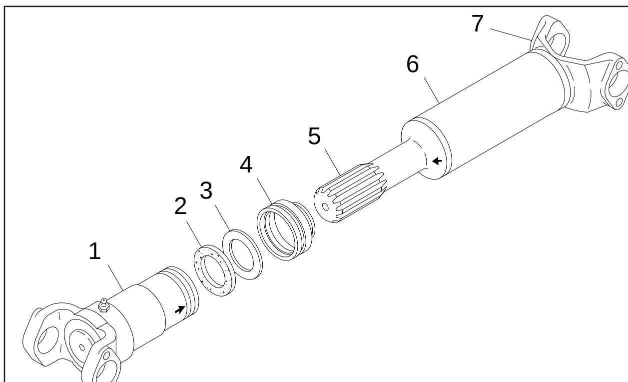
Fig. 2, Runout Specifications for a Rebuilt (or New) Driveshaft

Slip-Joint Replacement or Assembly

IMPORTANT: Parts for different series drivelines must not be intermixed. Incorrectly assembled or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

Except RPL Drivelines

1. Place the slip-joint dust cap, and (if so equipped) steel washer and cork seal, over the splined shaft. See **Fig. 3**.



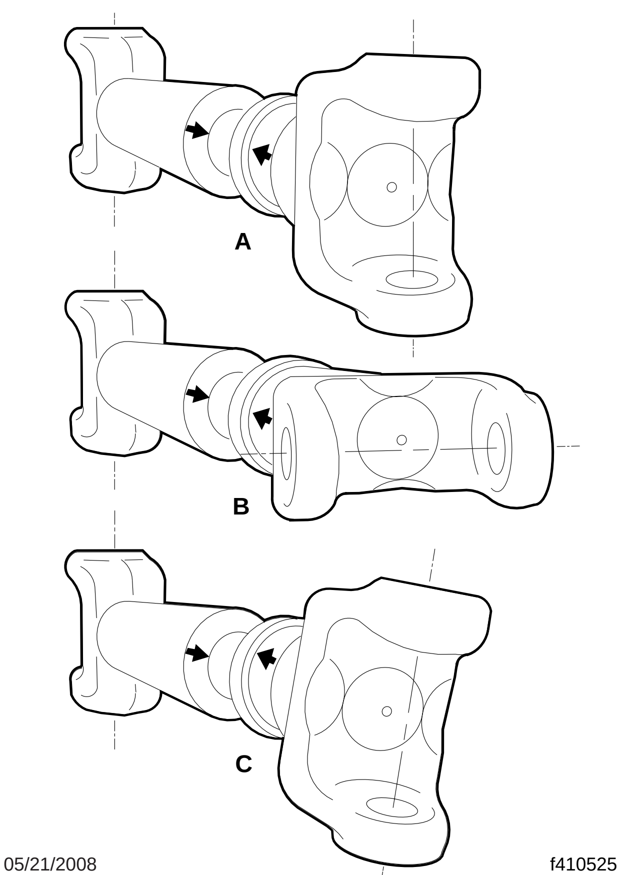
1. Sleeve-Yoke
2. Cork Washer
3. Steel Washer
4. Dust Cap
5. Splined Stub Shaft
6. Tube
7. Tube-Yoke

Fig. 3, Slip-Joint Components

2. Coat the splines of the shaft with multipurpose chassis grease.

Driveline Component Replacement or Installation/ Assembly

3. Insert the splined shaft in the sleeve-yoke, so that the alignment marks are aligned, and the U-joints at each end of the driveshaft will be in phase. See Fig. 4 and Fig. 5.

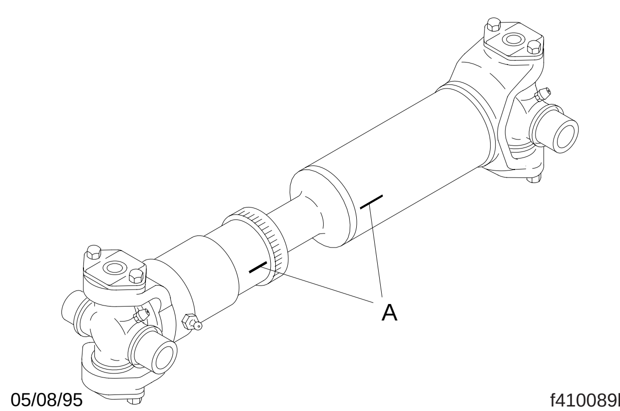


A. In Phase (parallel phased)
B. In Phase (cross phased)
C. Out of Phase

Fig. 4, U-Joint Phasing

IMPORTANT: If no alignment marks are visible, or new slip-joint components have been installed, align the yokes, assemble the slip-joint, then have the driveline balanced to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

4. Install the slip-joint dust cap. Use only enough torque to seat the steel washer and cork seal (if so equipped) snug against the end of the sleeve-yoke; do not overtighten.



A. Use a marking stick or paint to add alignment marks.

Fig. 5, Slip-Joint Alignment Marks

NOTE: The splines should slide freely, with only a slight drag from the slip-joint dust cap.

RPL Drivelines

1. Remove the grease plug from the sleeve-yoke.
2. Coat the splines of the sleeve-yoke with multipurpose chassis grease.
3. Install the shroud on the splined shaft.
4. Install the seal onto the shroud.
5. Insert the splined shaft in the sleeve-yoke so that the alignment marks are aligned, and the U-joints at each end of the driveshaft will be in phase. See Fig. 4 and Fig. 5.

IMPORTANT: If no alignment marks are visible, or new slip-joint components have been installed, align the yokes, assemble the slip-joint, then have the driveline balanced to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

6. Install the seal into the shaft groove.
7. Install the shroud. Use a brass hammer to tap the shroud over the seal.
8. Install the grease plug in the sleeve-yoke.

NOTE: The splines should slide freely, with only a slight drag from the slip-joint dust cap.

Midship Bearing and Coupling Shaft End-Yoke Replacement or Assembly

IMPORTANT: Parts for different series drivelines must not be intermixed. Incorrectly assembled or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

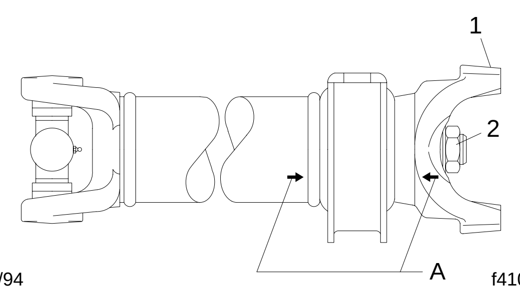
1. Place the coupling shaft in a soft-jawed vise; do not distort the tube with excessive grip.

NOTE: Midship bearings are permanently lubricated when manufactured; it is not necessary to pack the bearing with grease.

2. Install the midship bearing on the coupling shaft. Press the bearing on by hand, as far as it will go.
3. Install the end-yoke. See **Fig. 6**.

   3.1 Apply Loctite® 242 to the shaft threads where the end-yoke locknut will be installed.

   3.2 Align the marks added to the coupling shaft and end-yoke during removal, then place the end-yoke on the shaft so the yoke bores are aligned at both ends of the shaft. See **Fig. 6**.



A. Use a marking stick or paint to mark the end-yoke and coupling shaft with alignment marks.

1. Half-Round End-Yoke
2. End-Yoke Locknut

Fig. 6, Alignment Marks on a Coupling Shaft With an End-Yoke

   3.3 Install the end-yoke nut, and tighten it 475 to 525 lbf·ft (645 to 710 N·m). Then back the nut off slightly, and tighten it to the same torque.

U-Joint Replacement or Installation

IMPORTANT: Parts for different series drivelines must not be intermixed. Also, components of the various makes of U-joints may not be interchangeable, and must be assembled only with compatible products. Incorrectly assembled or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

Worn bearing assemblies used with a new cross, or new bearing assemblies used with a worn cross will wear rapidly, making another replacement necessary in a short time. Always replace the cross and all four bearing assemblies at the same time.

If the slip-joint of a No. 2 or No. 3 driveshaft has been disassembled, assemble the slip-joint before installing the U-joints.

Full-Round Yokes

1. Place the assembled driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
2. For a No. 2 or No. 3 driveshaft, check that the slip-joint alignment marks are aligned, so that the U-joints at each end of the driveshaft will be in phase. See **Fig. 4** and **Fig. 5**.

   For a coupling shaft, check that the end-yoke and tube-yoke are aligned, so that the U-joints at each end of the coupling shaft will be in phase. See **Fig. 6**.

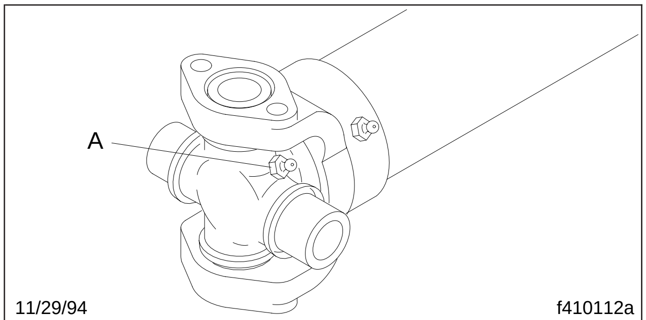
IMPORTANT: Misaligned driveshaft yokes will cause the U-joints to be out of phase, which will cause vibration in the driveline.

3. Inspect and lubricate the U-joint; see **Subject 140**.
4. Install the U-joint cross and bearing assemblies in the yoke.

   4.1 Position the U-joint cross in the driveshaft yoke so one grease fitting points toward

Driveline Component Replacement or Installation/ Assembly

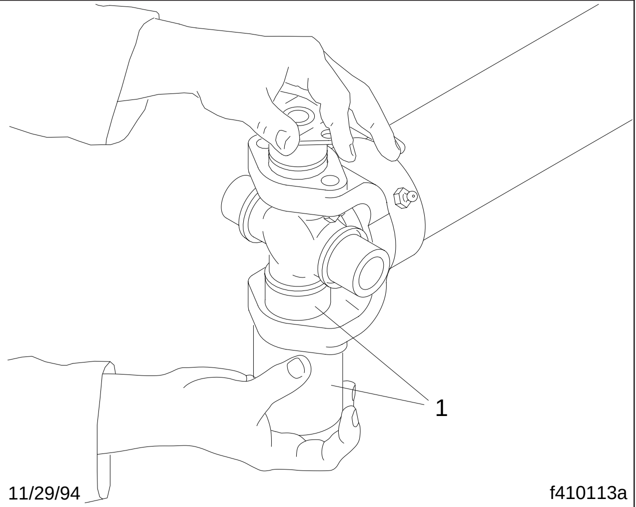
the driveshaft, and aligns with the grease fitting on the sleeve-yoke (if so equipped). See **Fig. 7**.



A. Install the cross with grease fitting pointing toward the driveshaft, and aligned with the sleeve-yoke grease fitting.

Fig. 7, U-Joint Grease Fitting Positioning

4.2 Move one end of the cross until a trunnion projects through the cross-hole, beyond the outer machined face of the yoke lug. Using a Spicer trunnion (journal) locator (see **Specifications 400**), hold the trunnions in alignment with the cross-holes, while placing a bearing cup (plate-type) over the projected trunnion, and aligning it with the cross-hole. See **Fig. 8**.



NOTE: Sleeve-yoke shown.

1. Trunnion Locator

Fig. 8, Using a U-Joint Trunnion Locator

IMPORTANT: A Spicer trunnion (journal) locator should be used to prevent damage to the U-joint trunnions and slingers.

4.3 By hand, press the bearing-cup-plate flush with the face of the yoke. If the bearing cup binds in the cross-hole, tap the *center* of the bearing-cup plate with a leather or rubber mallet; do not tap the outer edges of the plate. See **Fig. 9**.

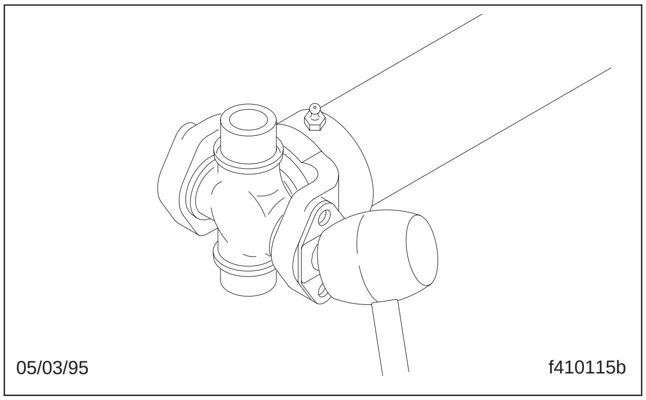


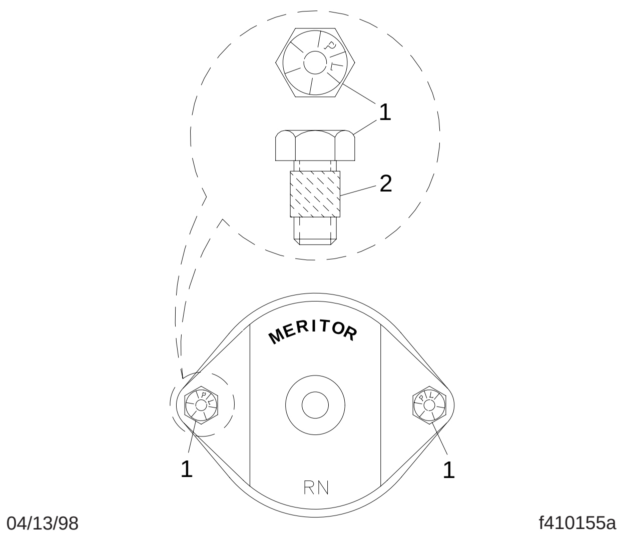
Fig. 9, Seating a U-Joint Bearing Cup In a Full-Round Yoke

4.4 Install *new* bearing-cup-plate self-locking capscrews. See **Fig. 10**. Tighten the capscrews until all the parts are drawn down tight, with no gaps; do not tighten the capscrews to their final torque value.

WARNING

Self-locking bearing-cup-plate capscrews must not be reused; replace the capscrews with new ones. Also, do not undertighten or overtighten any bearing-cup-plate capscrews. A loose or broken fastener at any point in the driveline weakens the driveline connection, which could cause serious vehicle damage, or could result in a driveshaft separating from the vehicle, possibly causing loss of vehicle control that could result in serious personal injury or death.

4.5 Move the cross until it projects beyond the machined surface of the opposite yoke lug. Using the above procedure, install the opposite bearing assembly and its fasteners.



1. Self-Locking Capscrew
2. Adhesive Band

Fig. 10, Meritor U-Joint Fasteners for Full-Round Yokes

4.6 Slightly back off all four capscrews, then alternately tighten them in increments of 5 lbf·ft (7 N·m), to the applicable torque value in **Specifications 400**.

NOTE: The U-joint should flex, and be free of excessive bind. A slight drag is the most desirable condition for new U-joints. Excessive looseness is not desirable, and may result in an unbalanced driveshaft.

RPL Series U-Joint

NOTE: Do not reuse RPL U-joints. Always replace an RPL U-joint with a new one if they have been disassembled and removed from a driveshaft.

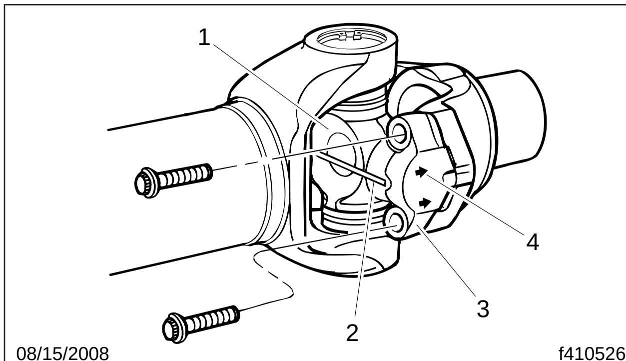
1. Place the assembled driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
2. For a No. 2 or No. 3 driveshaft, check that the slip-joint alignment marks are aligned, so that the U-joints at each end of the driveshaft will be in phase. See **Fig. 4** and **Fig. 5**.

   For a coupling shaft, check that the end-yoke and tube-yoke are aligned, so that the U-joints at each end of the coupling shaft will be in phase. See **Fig. 6**.

IMPORTANT: Misaligned driveshaft yokes will cause the U-joints to be out of phase, which will cause vibration in the driveline.

3. Inspect the U-joint. See **Subject 140**.
4. Install the U-joint cross and bearing assemblies in the yoke.

   4.1 Position the U-joint cross in the driveshaft yoke so that the wing bearing weld strap faces inboard, and the arrows point toward the end of the coupling yoke. See **Fig. 11**.



1. U-Joint Cross
2. Weld Strap
3. Wing Bushing
4. Arrows

Fig. 11, Fitting the U-Joint

4.2 Move one end of the cross until a trunnion projects through the cross-hole, beyond the outer machined face of the yoke lug. Place a bearing cup over the projected trunnion, and align it with the cross-hole.

4.3 Press the bearing cup into the yoke slightly past the snap ring groove. See **Fig. 12**. Check that the bearing cup is aligned with the universal joint trunnion.

4.4 Install the snap ring into the snap ring groove. See **Fig. 13**.

4.5 Use a snap ring installation gauge to check that the snap ring is fully seated in the snap ring groove. See **Fig. 14**.

4.6 Move the cross until it projects beyond the machined surface of the opposite yoke

Driveline Component Replacement or Installation/ Assembly

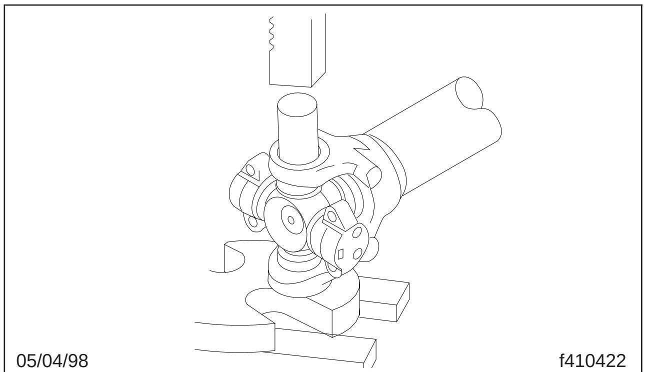
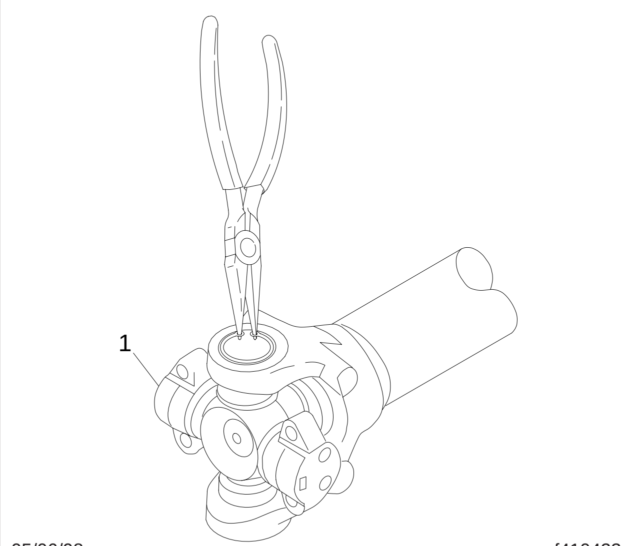


Fig. 12, Installing Bearing Cups, RPL Series U-Joint



1. U-Joint

Fig. 13, Installing the Snap Rings

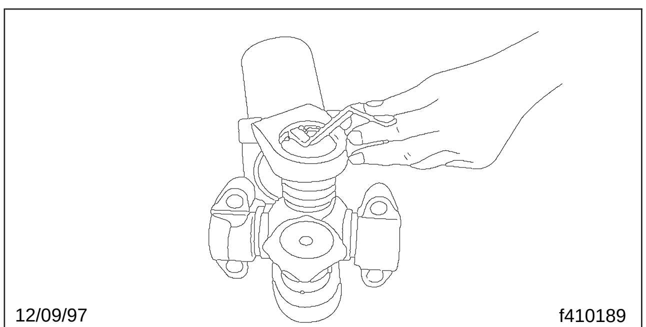
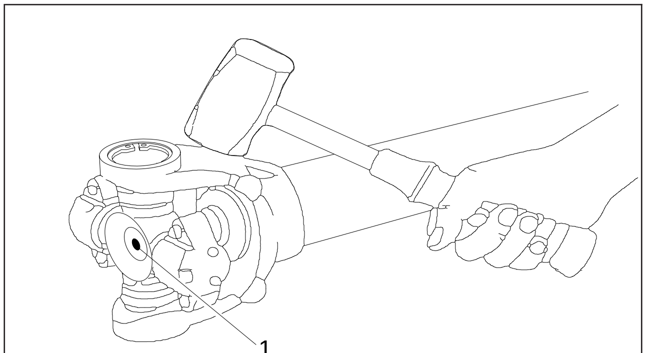


Fig. 14, Checking Snap Ring Installation

lug. Using the above procedure, install the opposite bearing cup assembly.

NOTE: The U-joint should flex, and be free of excessive bind. A slight drag is the most desirable condition for new U-joints. Excessive looseness is not desirable, and may result in an unbalanced driveshaft.

4.7 If the universal joint does not move freely, strike the yoke ear with a brass or copper hammer. See **Fig. 15**.



1. U-Joint Cross

Fig. 15, Striking the Yoke Ear

Transmission/Axle End-Yoke Replacement or Installation

IMPORTANT: Parts for different series drivelines must not be intermixed. Incorrectly assembled or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

1. Apply Loctite® 242 to the input- or output-shaft threads where the end-yoke locknut will be installed. See **Fig. 16**.
2. By hand, install the end-yoke on the input or output shaft as far as it will go.
3. Install a new end-yoke locknut, and tighten it to the applicable torque value in **Specifications 400**.

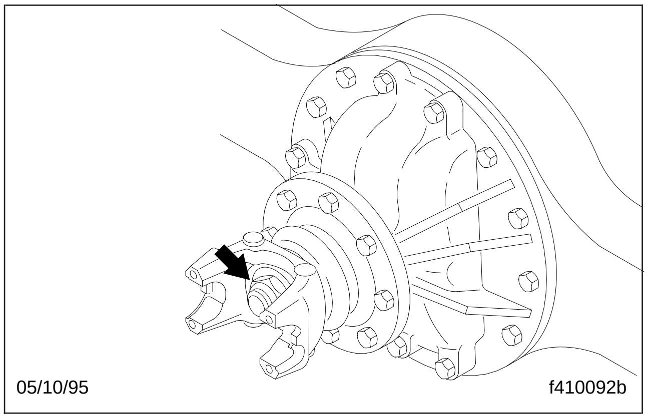


Fig. 16, Axle End-Yoke Locknut

Troubleshooting

Noise or vibration associated with the driveline can be caused by non-driveline parts. To find the cause of noise or vibration, first road test the loaded vehicle. Drive in all gears and at all speed ranges for which the vehicle was designed, including those at which problems are reported.

NOTE: Operating a vehicle at speeds that exceed its drivetrain design specifications may cause an out-of-balance vibration.

The following is a troubleshooting elimination process; checks should be made in the order listed. At each step where a problem is found, correct the problem before proceeding to the next step, then test drive the vehicle to see if other problems still exist. If no other problems exist, the elimination process may be ended at that step.

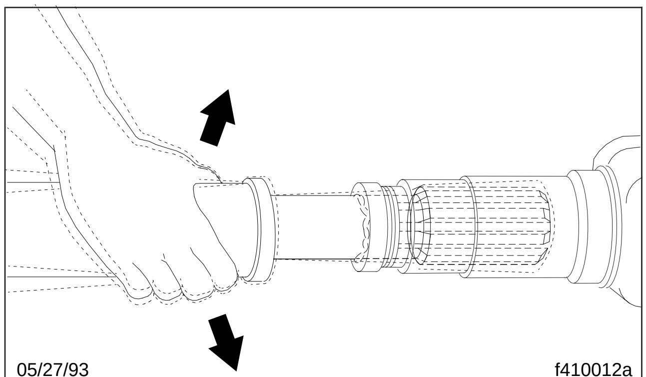
1. Check all tires for uneven wear and for out-of-roundness. Check for mismatched tires. Look for wheels and rims that are out of alignment. For instructions, see **Group 40**.
2. Check the rear suspension for loose or broken U-bolts; broken, shifted, or mismatched rear springs; or broken spring seats. If so equipped, check the air suspension for incorrect air spring height. Look for anything that could cause angular misalignment of the rear axle pinion(s). For instructions, see **Group 32**.
3. Check the frame rails and crossmembers for bends, twists, or breaks; for frame-alignment-checking and crossmember-replacement instructions, see **Group 31**.
4. Check the engine and transmission mounts; see **Group 01** (Engine) and **Group 26** (transmission). Check the coupling shaft's midship bearing mounts. Replace mountings that are deteriorated or oil-soaked; tighten loose mounting bolts. Oil-soaked or deteriorated mountings,or loose mounting bolts, can cause driveline angular misalignment.
5. Check for loose U-joint bearing-cup-plate and bearing-strap capscrews. Tighten any loose fastener to the applicable torque value in **Specifications 400**.

CAUTION

Do not overtighten the bearing-cup-plate or bearing-strap capscrews. A loose or broken fastener at any point in the driveline weakens the driveline connection, which could result in serious vehicle damage.

6. Check all U-joint assemblies, slip-joint splines, and midship bearings for wear.
   - 6.1 Try to move each driveshaft up and down, and from side to side. If movement is greater than 0.006 in (0.15 mm) of a U-joint cross in its bearings,replace the U-joint assembly.
   - 6.2 If the midship bearing rattles or is loose on its shaft, replace it.
   - 6.3 Try to bend the sleeve-yoke and splined shaft up and down, and from side to side. See **Fig. 1**. If looseness is greater than 0.007 in (0.18 mm), replace the sleeve-yoke and splined shaft.

     If driveline components must be replaced, see **Subject 150**.



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Try to bend the sleeve-yoke and splined shaft up and down, and from side to side.

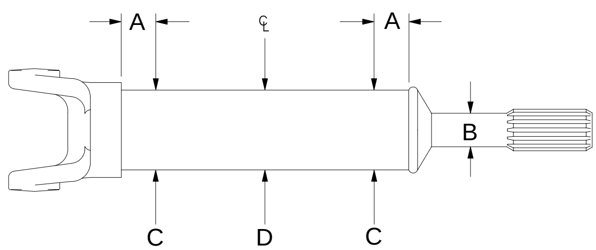
Fig. 1, Check for Slip-Joint Spline Wear

7. Check each driveshaft for an indication of missing balance weights. If any weights appear to be missing, have the driveshaft balanced to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.
8. Check each driveshaft for dents, bends, twists, or other damage.

If damaged, jack up the rear axle, support it on jackstands, place the transmission in neutral, and turn the driveshaft by hand to check runout.

The driveshaft must be straight within 0.015 inch (0.38 mm) on the slip-joint seal surface of the splined shaft, 0.020 inch (0.51 mm) on the tube 3 inch (76 mm) from the front and the rear welds, and 0.025 inch (0.635 mm) at the center of the tube. See **Fig. 2**.

If the driveshaft is not straight within specifications, replace the tube. See **Subject 150** for runout specifications for a *new* (or rebuilt) driveshaft.

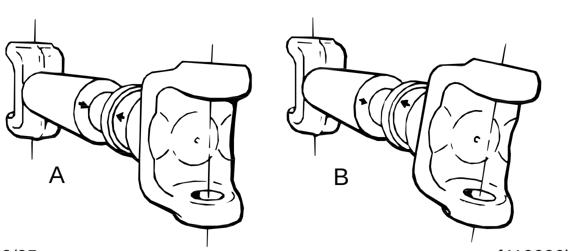


A. Measurement: 3 inch (76 mm)
B. Measurement: 0.015 inch (0.38 mm)
C. Measurement: 0.020 inch (0.51 mm)
D. Measurement: 0.025 inch (0.635 mm)

Fig. 2, Runout Specifications for a Used Driveshaft

9. Check each driveline for proper U-joint phasing. See **Fig. 3**.

9.1 On No. 2 and No. 3 driveshafts, if the U-joints are out of phase, check the slip-joint for alignment marks. If necessary, disassemble the slip-joint, and align the marks.



A. In Phase
B. Out of Phase

Fig. 3, U-Joint Phasing

NOTE: To disassemble the slip-joint, uncouple the U-joint at one end of the driveshaft, unscrew the slip-joint seal from the sleeve-yoke, then pull the sleeve-yoke and splined shaft apart. Reverse the procedure to assemble the slip-joint.

9.2 If no alignment marks are present, disassemble the slip-joint, and reassemble it with the U-joints in one of the two in-phase positions (180 degrees apart).

Test drive the vehicle, then assemble the slip-joint in the other in-phase position. Test drive the vehicle again.

Determine which in-phase position provides vibration-free operation. Assemble the slip-joint in the correct in-phase position, and mark the slip-joint with alignment marks.

9.3 If the U-joints are out of phase on a coupling shaft, uncouple the U-joint from the coupling shaft end-yoke, then remove the end-yoke nut. Remove the end-yoke, using a yoke puller. See **Fig. 4** for a half-round end-yoke, or see **Fig. 5** for a full-round end-yoke. Align the end-yoke, then install it by hand. Install the end-yoke nut, and tighten it 475 to 525 lbf·ft (645 to 710 N·m). Slightly back off the nut, and again tighten it to the same torque. Couple the coupling shaft to the driveshaft U-joint.

10. Check the torque on all of the end-yoke nuts in the drivetrain; see the applicable torque values in **Specifications 400**.

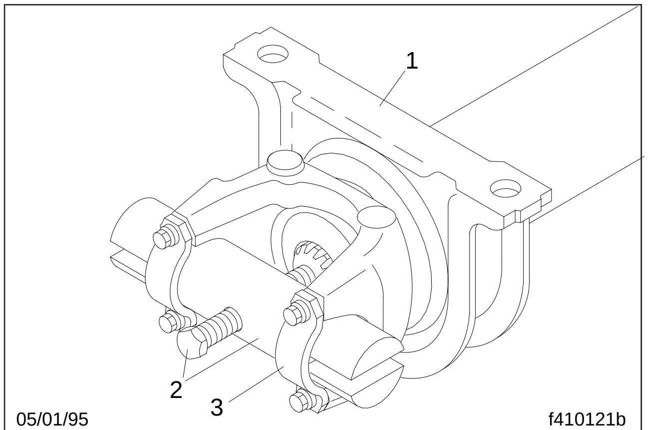
If any yoke nut was not at its specified torque, check the yoke for wear by trying to move it up and down, and back and forth. If the yoke can be rocked on its shaft, or moved in or out on its shaft, replace the yoke and yoke nut. See **Subject 150**.

If the yoke is not worn, tighten the yoke nut to its torque value.

11. *On single-drive vehicles:*

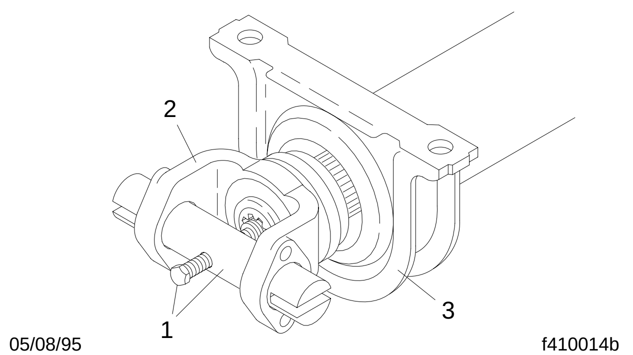
Have the No. 2 driveshaft balanced to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

On dual-drive vehicles:



1. Midship Bearing
2. Yoke Puller
3. Bearing Strap

Fig. 4, Remove a Half-Round End-Yoke from a Coupling Shaft



1. Yoke Puller
2. Full-Round Yoke
3. Midship Bearing

Fig. 5, Remove a Full-Round End-Yoke from a Coupling Shaft

11.1 Remove the No. 3 driveline; then, with the interaxle differential locked, test drive the vehicle.

11.2 If vibration still exists, install the No. 3 driveline, then have the No. 2 driveshaft balanced to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

If *no* vibration exists, check that both rear axle gear ratios are matched. If the gear ratios do not match, replace one of the gear sets with a gear set having the correct ratio, then install the No. 3 driveline.

11.3 Have the No. 3 driveshaft balanced to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

11.4 Have the No. 2 driveshaft balanced to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

12. If so equipped, balance the coupling shaft(s) to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

Fastener Torques				
Description			Size	Torque: lbf·ft (N·m)
End-Yoke Nut				
Transmission Output Shaft	Fuller	RT 8609	1-1/2–18	400–450 (542–610)
		T/X 14607 RT 8608 /7608LL RTO 11909MLL /14909MLL /11908LL RTX 16709 /15710 /16710 RT/X 11609 /11709 /12609 /12709 /13609 /13709 /14609 /14709 /11710 /12710 /13710 /14710 RTO/X 11708LL /14708LL RT/O/X 14715 /15715 RTLO 12610 /13610 /14610 /15610 /16610 /12713 /14713 /16713 /14718 /16718 /18718	2–16	450–500 (610–678)
	Meritor	RM/O/X 9–115 /–125 /–135 /–145 /–155 RM/X 10–115 /–125 /–135 /–145 /–155 /–165 RMO 13–145	2–16	450–500 (610–678)
	Allison	HD Series	2–16	600–800 (813–1085)
Single Axle Input Shaft	Eaton	23105S/D, 23080S/D	1-3/4–12	840–1020 (1139–1383)
	Meritor	RS–21–160 /–23–160 /–23–161 /–23–185 /–25–160	M45 x 1.5	996–1232 (1350–1670)
Forward-Rear Axle Input Shaft	Eaton	DT 402/P, DS/DD 404/P, DT/DP 451P	1-5/8–18	780–960 (1058–1302)
		DP/DS/DT 461P	1-7/8–12	840–1020 (1139–1383)
	Meritor	RT–40–145 /–44–145	M39 x 1.5	922–1132 (1250–1535)
		RT–46–160	M45 x 1.5	996–1232 (1350–1670)
Forward-Rear Axle Output Shaft	Eaton	DT 402/P, DS/DD 404/P, DT/DP 451P	1-1/4–12	480–600 (651–813)
		DP/DS/DT 461P	1-3/4–12	840–1020 (1139–1383)
	Meritor	RT–40–145 /–44–145 /–46–160	M39 x 1.5	600–700 (815–950)
Rearmost Axle Input Shaft	Eaton	DT 402/P, DS/DD 404/P, DT/DP 451P	1-1/2–18	560–700 (759–949)
		DP/DS/DT 461P	1-3/4–12	840–1020 (1139–1383)
	Meritor	RT–40–145 /–44–145	M39 x 1.5	922–1132 (1250–1535)
		RT–46–160	M45 x 1.5	996–1232 (1350–1670)
Midship Bearing (Coupling Shaft)			1-1/4–18	475–525 (645–710)
U-Joint Capscrew				
Bearing Plate (for full-round yoke)			3/8–24	43 (49)
Bearing Strap (for half-round yoke)			1/2–20	125 (169)
RPL U-joints			1/2–20	125 (169)
Midship Bearing Locknut				
Bracket to Crossmember			1/2–13	91 (123)

Specifications

Fastener Torques		
Description	**Size**	**Torque: lbf·ft (N·m)**
Bearing Mount to Bracket	1/2–13	91 (123)

Table 1, Fastener Torques

Driveline Angularity

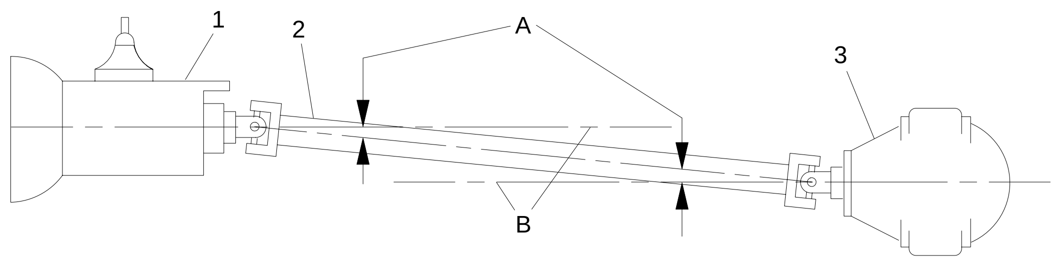
The most important consideration of driveline angularity is the U-joint working angle. A U-joint working angle is the angle formed by the intersection of the driveshaft centerline and the extended centerline of the shaft of any component to which the U-joint connects. See **Fig. 1**. Because the action of a U-joint causes a fluctuating speed difference between the shafts it connects, the effect created by the U-joint at the input-shaft end-yoke must cancel the effect created by the U-joint at the output-shaft end-yoke. This is done by making the U-joint working angles at both ends of the driveshaft approximately equal, with the U-joints in phase.

The U-joint working angles may be made approximately equal by either of two basic arrangements: a parallel arrangement (**Fig. 1**), or an intersecting arrangement (**Fig. 2**).

Driveline angularity may be adversely affected if rear suspension U-bolts are loose or broken; rear springs are broken, shifted, or mismatched; spring seats are broken; frame rails are bent, twisted, or broken; or transmission or engine mounts are loose or deteriorated.

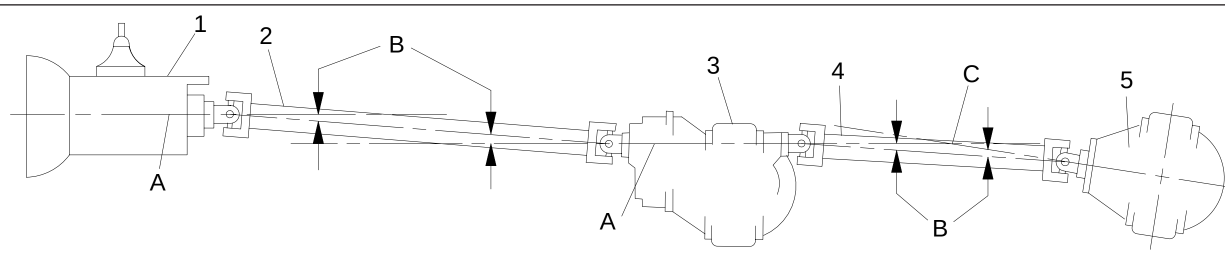
U-Joint Phasing

The fluctuating speed difference, caused by the action of a U-joint connecting angled shafts, can be cancelled only if the U-joint at the other end of the driveshaft is in phase with that U-joint (and the U-joint working angles are approximately equal). If the yoke lugs at both ends of the driveshaft are lying in the same plane (a plane that bisects the shaft lengthwise) the U-joints will be in phase. See **Fig. 3**.



A. Equal U-Joint Working Angles
B. Parallel Centerlines
1. Transmission
2. No. 2 Driveshaft
3. Rear Axle

Fig. 1, Parallel Arrangement for Single-Drive Vehicles

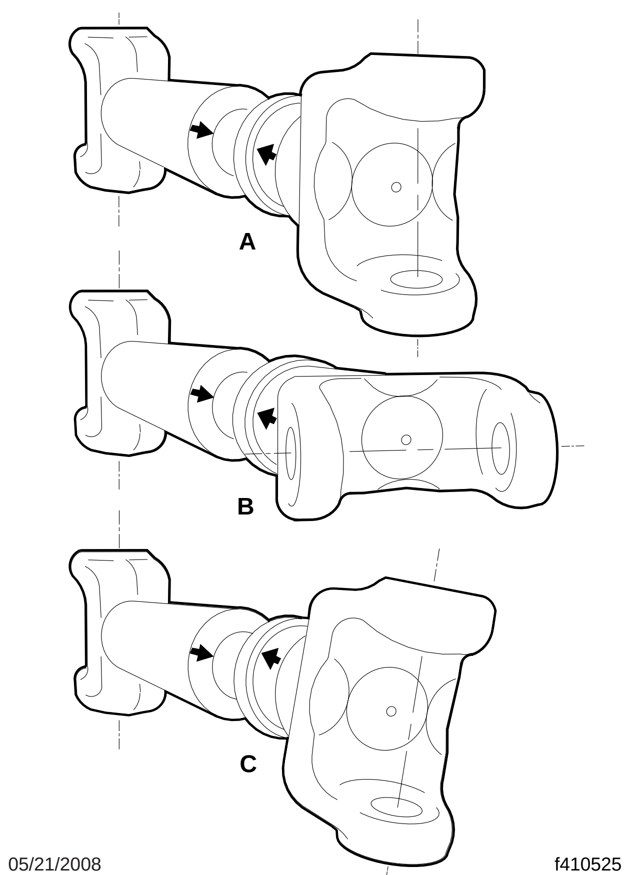


A. Parallel Centerlines
B. Equal U-Joint Working Angles
C. Intersecting Centerlines
1. Transmission
2. No. 2 Driveshaft
3. Forward-Rear Axle
4. No. 3 Driveshaft
5. Rearmost Axle

Fig. 2, Intersecting Planing Arrangements for Dual-Drive Vehicles

General Information

NOTE: Some driveshafts are designed and phased with their end yokes clocked 90 degrees from each other. This is referred to as cross phasing.



A. In Phase (parallel phased)
B. In Phase (cross phased)
C. Out of Phase

Fig. 3, Driveline U-Joint Phasing

To ensure that the U-joints turn in phase, the sleeve-yoke and splined shaft of driveshaft slip-joints, and the coupling shaft and midship bearing end-yoke, should be marked for assembly reference before disassembly.

Driveline Balance

After manufacture, each driveline yoke is statically balanced. After assembly of the slip-joint, each driveshaft is checked for out-of-roundness, and straightened as necessary; then each shaft is dynamically balanced.

If the driveshaft slip-joint is disassembled for any reason, the sleeve-yoke and splined shaft should be marked for assembly alignment. Misaligned slip-joints will seriously affect the U-joint phasing and balance of the driveline. Even if the slip-joint is assembled 180 degrees from its original position (which will keep the U-joints in phase), the dynamic balance of the driveshaft will be negatively affected.

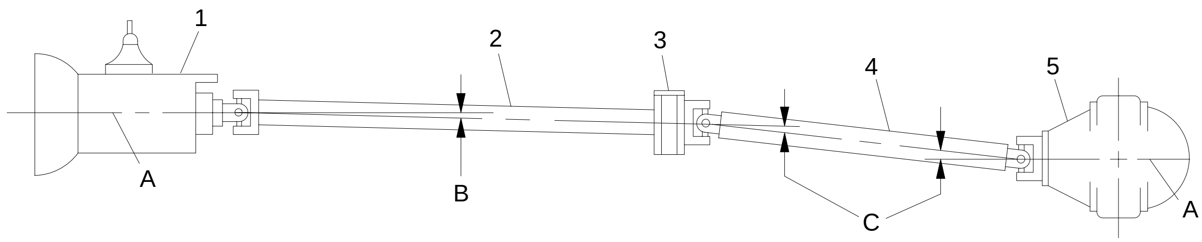
A driveline can become unbalanced or greatly weakened if a driveshaft has been dented, bent, twisted, or otherwise damaged. Operating a vehicle at speeds that exceed the speed of the driveshaft's design specifications will cause an out-of-balance vibration. Loose end-yoke nuts, loose midship bearing or auxiliary transmission mounts, loose bearing retainer capscrews, worn U-joint trunnions or bearings, and worn slip-joint splines can lead to excessive movement of the driveshaft and cause driveline imbalance.

Midship Bearings

A long driveshaft, supported only at its ends, will sag in the middle from its own weight. When turning at high rpm, it will flex, causing an out-of-balance vibration. Therefore, most vehicles having a long wheelbase use a midship bearing, mounted on a crossmember in the frame, for additional driveline support. See Fig. 4. This allows the driveshaft to be separated into two shorter shafts, thus improving balance and stability.

Angularity Standards and Drivetrain Configuration

The U-joints require a minimum working angle of 1/2 degree to ensure needle-roller movement in the U-joint bearings. Without this movement, brinelling of the trunnion bearing-contact surfaces would occur. Suspension movement causes driveshaft angles to change (and therefore, needle-roller movement) in both of the U-joints attached to driveshafts that connect to the axles. However, no angle change occurs in the U-joints attached to a driveshaft that connects the main transmission to a midship bearing or auxiliary transmission. Their working angles must be established during installation.



A. Parallel Centerlines
B. 1/2 to 1 Degree
C. Working Angles Unequal by 1/2 to 1 Degree

1. Main Transmission
2. Coupling Shaft
3. Midship Bearing
4. No. 2 Driveshaft
5. Rear Axle

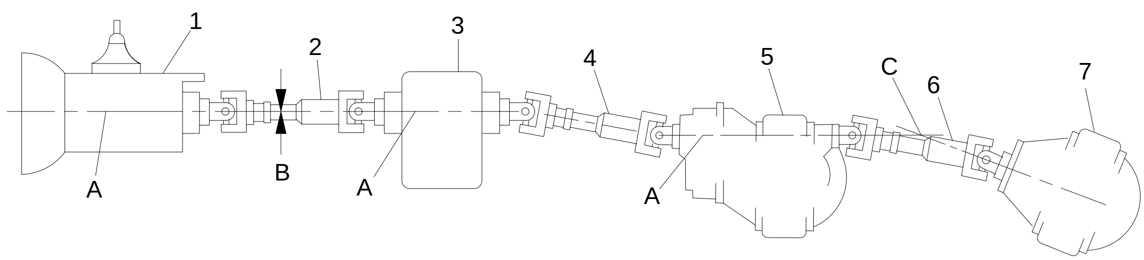
Fig. 4, Midship Bearing in a Single-Drive Vehicle

When a midship bearing is included in the drivetrain, it is installed so that the centerline of the coupling shaft is in horizontal (side-to-side) alignment within 1/2 degree, and within 1/2 to 1 degree of vertical alignment, with the centerline of the main transmission output shaft. See **Fig. 4**.

When an auxiliary transmission is included in the drivetrain, it is installed so that the centerline of the inter-transmission (no. 1) driveline is in exact horizontal (side-to-side) alignment (within 1/2 degree), and down 1/2 to 1 degree from vertical alignment, with the centerline of the main transmission output shaft. Further, the auxiliary transmission thru-shaft centerline must be parallel (horizontally and vertically) to the centerline of the main transmission output shaft, in order to achieve equal working angles. See **Fig. 5**.

Every U-joint has a maximum working angle, determined by the design and size of its cross assembly and yokes. Exceeding the maximum working angle can cause rapid U-joint wear, or in severe cases, destruction of the U-joint. For smooth operation and long drivetrain component life, the U-joint working angles must be kept small and approximately equal for each shaft.

The U-joint working angles may be made approximately equal by either of two basic arrangements: a parallel arrangement (**Fig. 1**) or an intersecting arrangement (**Fig. 2**). The parallel arrangement consists of installing the drivetrain components so that all of the input, output, and thru-shaft centerlines are approximately parallel. The intersecting arrangement (used only for some interaxle drivelines) consists of installing the drive components so that the rearmost



A. Parallel Centerlines
B. 1/2 to 1 Degree
C. Intersecting Centerlines

1. Main Transmission
2. No. 1 Driveline
3. Auxiliary Transmission
4. No. 2 Driveshaft
5. Forward-Rear Axle
6. No. 3 Driveshaft
7. Rearmost Axle

Fig. 5, Auxiliary Transmission in a Dual-Drive Vehicle

General Information

axle pinion shaft’s extended centerline intersects the forward-rear axle thru-shaft’s extended centerline approximately midway between the U-joints, when all of the other shafts (including the forward-rear axle thru-shaft) are approximately parallel.

All single-drive vehicles, and the forward-rear axles of dual-drive vehicles, use the parallel arrangement. Rearmost axles of dual-drive vehicles may use the parallel arrangement or the intersecting arrangement, depending on the drivetrain configuration.

The specific drivetrain configuration of each Freightliner vehicle consists of its wheelbase, number and type of axles, axle spacing, type of suspension, and number of transmissions. The specific drivetrain configuration determines the driveline arrangement and required installation angles of all the vehicle’s drivetrain components.

The simplest drivetrain configuration consists of a single short driveline connecting a main transmission to a single-drive axle, in a parallel arrangement. This driveshaft is always referred to as the no. 2 driveshaft. The parallel arrangement always used on single-drive vehicles is shown in **Fig. 1**.

On dual-drive vehicles that have both axle input shafts of approximately the same height, a parallel arrangement is used. The driveshaft connecting the main (or auxiliary) transmission to the forward-rear axle is always referred to as the no. 2 driveshaft; and the interaxle driveshaft is always referred to as the no. 3 driveshaft. See **Fig. 6**, which shows a parallel arrangement when used on dual-drive vehicles.

Most dual-drive vehicles have a high thru-shaft on the forward-rear axle, and a low pinion on the rearmost axle. When the vehicle is on level ground, the interaxle (no. 3) driveshaft may create very sharp U-joint working angles with the input and output shafts when they are parallel. In normal driving, the U-joints could momentarily exceed their maximum working angle, and driveline or drivetrain damage could result. By using an intersecting arrangement at the no. 3 driveshaft, smaller U-joint working angles are created, promoting longer U-joint life and reduced driveline vibration. An intersecting arrangement used on dual-drive vehicles is shown in **Fig. 2**.

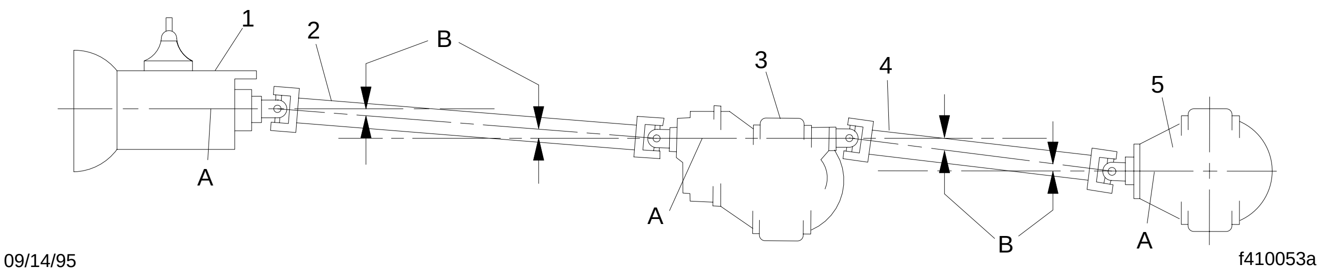
However, some axle spacings, axle models, and suspension designs allow additional axle movement or axle windup that requires additional clearances between the driveshaft and the frame or suspension components, or that creates other conditions that make the intersecting arrangement of the no. 3 driveshaft unsatisfactory. For those drivetrain configurations, it is necessary to use a modified parallel or modified-intersecting arrangement for the no. 3 driveshaft.

On drivetrain configurations that require a modified parallel arrangement, the rearmost-axle pinion shaft centerline is placed at an angle that is 2 degrees higher above horizontal than are the other input and output shafts. See **Fig. 7**.

On drivetrain configurations that require a modified-intersecting arrangement, the "proper" intersecting angle is determined, then the rearmost-axle pinion shaft centerline is placed at an angle that is 2 degrees closer to horizontal than the "proper" intersecting angle. See **Fig. 8**.

The axle pinion angles for all suspensions are factory-set for correct driveline angularity. On Freightliner spring suspensions, tapered axle planing shims at the springs maintain the correct axle pinion angle. On Hendrickson suspensions, spacers at the torque rods are used to maintain the correct axle pinion angles.

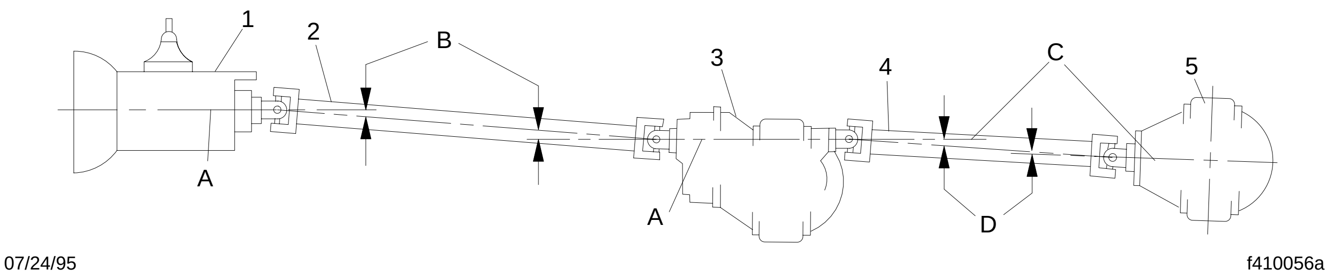
In the field, whenever axle or suspension components are changed, the axle pinion angles may also change. If this occurs, contact your district service manager for the correct axle pinion angle adjustment procedure.



A. Parallel Centerlines
B. Equal U-Joint Working Angles

1. Transmission
2. No. 2 Driveshaft
3. Forward-Rear Axle
4. No. 3 Driveshaft
5. Rearmost Axle

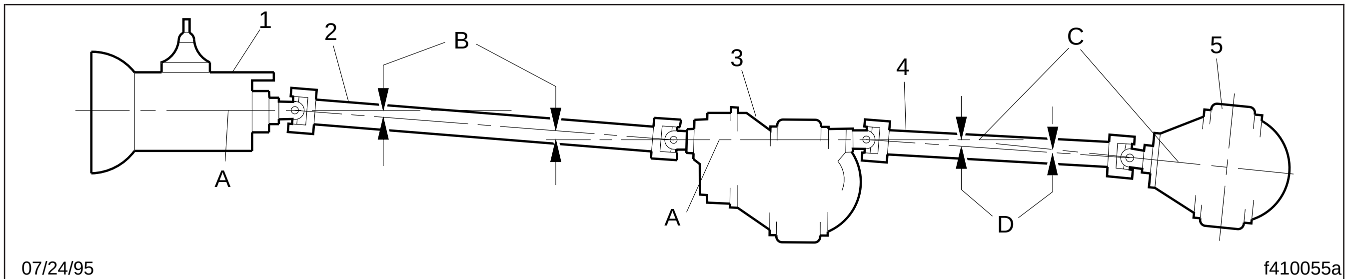
Fig. 6, Parallel Arrangement for Dual-Drive Vehicles



A. Parallel Centerlines
B. Equal U-Joint Working Angles
C. Modified-Parallel Centerlines
D. U-Joint Working Angles Not Equal by 2 Degrees

1. Transmission
2. No. 2 Driveshaft
3. Forward-Rear Axle
4. No. 3 Driveshaft
5. Rearmost Axle

Fig. 7, Modified-Parallel Arrangement for Dual-Drive Vehicles



A. Parallel Centerlines
B. Equal U-Joint Working Angles
C. Modified-Intersecting Centerlines
D. U-Joint Working Angles Not Equal by 2 Degrees

1. Transmission
2. No. 2 Driveshaft
3. Forward-Rear Axle
4. No. 3 Driveshaft
5. Rearmost Axle

Fig. 8, Modified-Intersecting Arrangement for Dual-Drive Vehicles

Engine and Pinion Angle Measurement

Before checking the pinion angles or engine angle, check that the engine and transmission mounts are tight and in good condition. Loose or deteriorated mounts will cause inaccurate readings.

IMPORTANT: When using a digital angle analyzer (DAA), be sure to always take readings from the same side of the vehicle. Also, keep the same end of the DAA pointed toward the front of the truck.

Using a DAA (**Fig. 1**), measure the engine angle, driveshaft angles, and pinion angles. Read all angles to the nearest one-tenth of a degree (6 minutes).

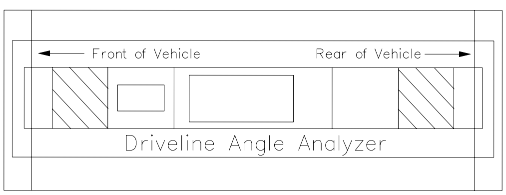


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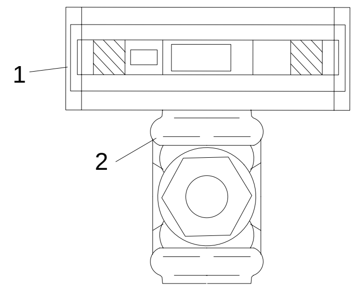
Fig. 1, Digital Angle Analyzer

After adjustment of any driveline angle, check the angle again. Also, verify ride height if the vehicle has an air suspension.

To measure the engine angle (transmission output-shaft angle) or axle pinion angles, do the following:

1. Inflate the vehicle tires to their normal operating pressure.
2. Park the unloaded vehicle on a level surface. Do not try to level the vehicle frame by jacking the front or rear axles. If the frame cannot be leveled from front to rear, determine and record the off-level inclination of the frame, and add or subtract that value from the measured values.
3. Chock the tires and place the transmission in neutral. Release the parking brakes.
4. The transmission output-shaft, coupling-shaft, and axle input- and output-yoke angles can be measured at either the top or bottom lug of the end-yoke being checked. For a full-round end-yoke, remove the bearing cup from the yoke lug. See **Section 41.00** for full-round end-yoke bearing cup removal.
5. Turn the end-yoke until the machined surface of the yoke lug is horizontal. See **Fig. 2**.



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NOTE: Full-round end-yoke is shown.

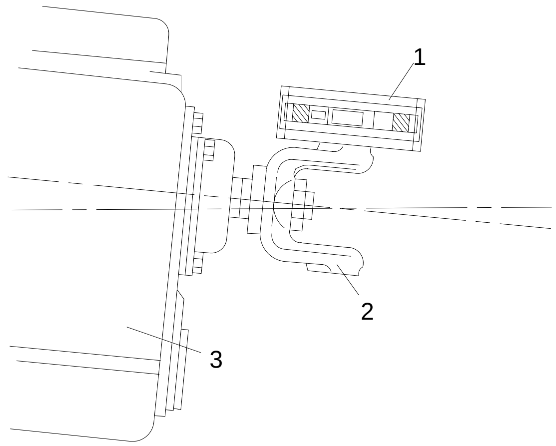
1. Digital Angle Analyzer
2. End-Yoke

Fig. 2, Horizontal Positioning of Yoke Lug Machined Surface

NOTE: To turn the driveshaft, raise one side of the rear (single-drive) or rearmost (dual-drive) axle until the tires are off the ground. Place a safety stand under the axle. With the transmission in neutral, and the interaxle differential (if equipped) unlocked, turn the tire to move the driveshaft.

6. Adjust the DAA to read 0 degrees. Position the DAA alongside the U-joint trunnion, on the machined surface of the end-yoke, and at a 90-degree angle to the frame centerline. See **Fig. 2**. Then turn the end-yoke until the bubble in the level vial is exactly between the two marks on the vial. Remove the jack stand and lower the rear axle to the ground.
7. Without changing the position of the end-yoke, turn the DAA until it is parallel to the frame centerline. See **Fig. 3**. Adjust the calibrated scale so the bubble is exactly between the two marks on the level vial. Record the calibrated scale reading opposite the "0" mark. Correct this value for any previously recorded off-level inclination.
8. For a full-round end-yoke, install the bearing cup. See **Section 41.00** for full-round end-yoke bearing cup installation.

Engine and Pinion Angle Measurement



NOTE: Full-round end-yoke is shown.
1. Digital Angle Analyzer
2. End-Yoke
3. Transmission

Fig. 3, Measuring Pinion Angles

Driveline Angle Checking

NOTE: Driveline suppliers have made angle checking software availble. Contact your local driveline representative or check the manufacturers website for the software. Angles need to be mearsure at the locations shown in **Fig. 1**.

If a vehicle is equipped with a Freightliner spring suspension, the axle pinion angles are factory-set using alignment shims at the rear springs. These shims have notches on the thick end of the shim. Count the number of notches in the thick end of each shim to make sure that the correct shim is used. Also, make sure the thick end of the shim is positioned correctly. See the applicable table in **Specifications, 400** for shim identification and use. If the axle pinion angles on these suspensions are incorrect, contact your district service manager for the adjustment procedure.

If the vehicle is equipped with an air suspension, verify ride height is correct. See **Group 32**.

If a vehicle is equipped with a Hendrickson suspension, spacers at the torque rods are used to maintain the correct axle pinion angles. If the measured axle pinion angles on these suspensions are not the same as the angles listed in the applicable table in **Specifications, 400**, contact your district service manager for the adjustment procedure.

NOTE: In any of the following steps, if an off-level inclination was added to or subtracted from the engine angle, the same figure must be added to or subtracted from the coupling shaft or axle pinion reading before comparing the angles. Also, avoid inperfections in paint.

IMPORTANT: DO NOT make any driveline angle adjustments before contacting your district service manager.

1. Check the engine angle at the transmission output-shaft end-yoke. The engine angle must be 3 degrees ±1/2 degree. For instructions, see **Subject 100**.

IMPORTANT: When using a digital angle analyzer (DAA), be sure to always take readings from the same side of the vehicle. Also, keep the same end of the DAA pointed toward the front of the truck.

2. If the driveline includes a midship bearing, place a digital angle analyzer (DAA) on top of the coupling shaft. Align the DAA with the shaft centerline. See **Fig. 2**. Read the scale to the nearest one-tenth of a degree (6 minutes). The centerline of the coupling shaft must be 1/2 degree out of vertical alignment with the transmission output shaft. See **Fig. 3**. Compare this reading with the measured engine angle.

   If the driveline angles are out of specification, contact your district service manager for midship bearing mount adjusting procedures.

3. On single-drive installations, measure the rear axle pinion angle at the back of the no. 2 driveline; for instructions, see **Subject 100**.

   The measured rear axle pinion angle must be equal ±1 degree to the measured engine angle. If the rear axle pinion angle does not meet the above specification, contact your district service manager.

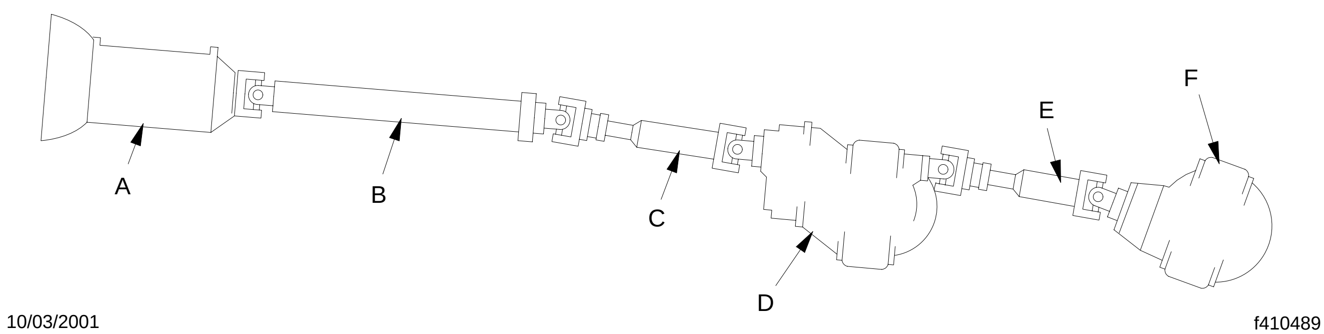
4. On dual-drive installations, measure the forward-rear-axle pinion angle (at the rear of the no. 2 driveline); for instructions, see **Subject 100**.

   The measured forward-rear-axle pinion angle must be equal ±1 degree to the measured engine angle. If the forward-rear-axle pinion angle does not meet the above specification, contact your district service manager.

   Measure the rearmost-axle pinion angle (at the rear of the no. 3 driveline); for instructions, see **Subject 100**.

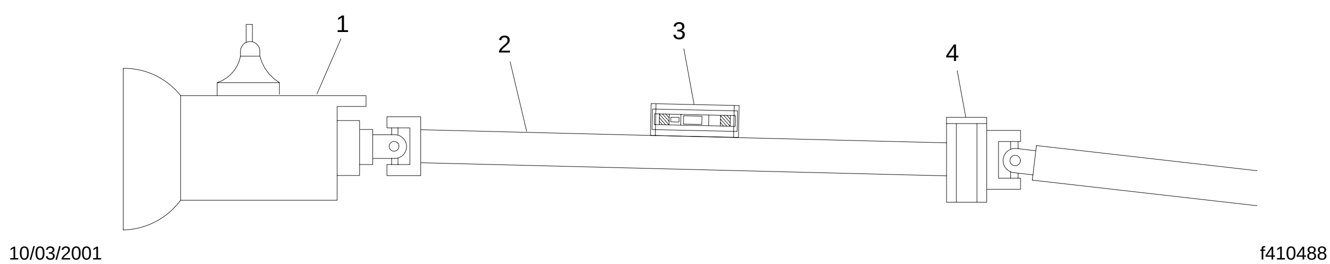
   Compare the measured angle with that shown in the applicable table in **Specifications 400**. The measured rearmost-axle pinion angle must be equal ±1 degree to the angle shown in the table. If the measured angle is incorrect, contact your district service manager.

Driveline Angle Checking



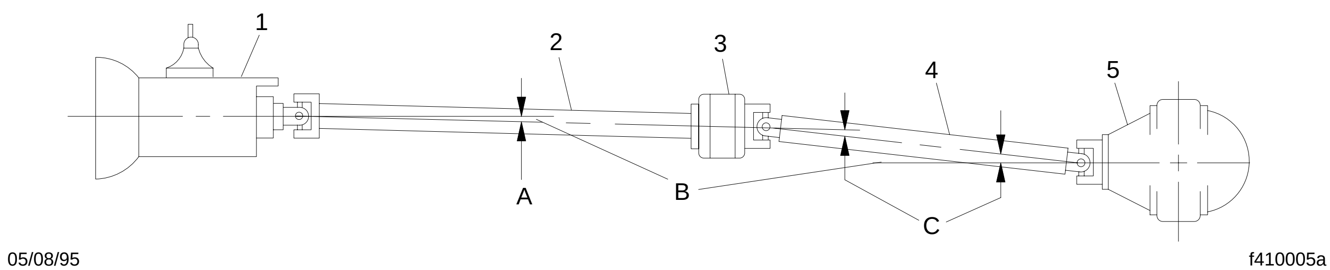
A. Tranmission
B. First Driveshaft
C. Second Driveshaft
D. Rear Drive Axle
E. Inter-Axle Driveshaft
F. Rear Drive Axle (rear-most)

Fig. 1, Driveline Angle Analysis (measuring locations)



1. Transmission
2. Coupling Shaft
3. Digital Angle Analyzer (DAA)
4. Midship Bearing

Fig. 2, Coupling Shaft Angularity



A. 1/2-Degree Minimum
B. Parallel Centerlines
C. Working Angles Unequal by 1/2 to 1 Degree

1. Transmission
2. Coupling Shaft
3. Midship Bearing
4. No. 2 Driveshaft
5. Rear Axle

Fig. 3, Midship Bearing in a Single-Drive Vehicle

Planing Angle Specifications

Engine Angle (for All Single-Drive-Axle Suspensions): Adjust to 3 or 5 degrees ±1/2 degree depending on vehicle specification in modules 101 and 109.

Engine Angle (for All Dual-Drive-Axle Suspensions): Adjust to 3-1/2 or 5 degrees ±1/2 degree depending on vehicle specification in modules 101 and 109.

Single-Drive-Axle Suspensions (All): Adjust rear axle pinion angle to 3 or 5 degrees ±1 degree depending on vehicle specification in modules 420 and 431.

Dual-Drive-Axle—Freightliner AirLiner Suspensions With Meritor RT–40/–44/–46 Axles: Adjust axle pinion angles to the values in **Table 1**, ±1 degree.

Dual-Drive-Axle—Freightliner Spring Suspensions (with Meritor RT–40/–44/–46 Axles): Adjust axle pinion angles to the values in **Table 2**, ±1 degree. See **Table 3** for shim notch decoding.

Dual-Drive-Axle—Hendrickson Suspensions With 52-Inch Axle Spacing: Adjust axle pinion angles to the values in **Table 4**, ±1 degree.

Dual-Drive-Axle—Hendrickson Suspensions With 54-Inch Axle Spacing: Adjust axle pinion angles to the values in **Table 5**, ±1 degree.

Dual-Drive-Axle—Hendrickson Suspensions With 56-Inch Axle Spacing: Adjust axle pinion angles to the values in **Table 6**, ±1 degree.

Dual-Drive-Axle—Hendrickson Suspensions With 60-Inch Axle Spacing: Adjust axle pinion angles to the values in **Table 7**, ±1 degree.

Dual-Drive-Axle—Hendrickson Suspensions With 72.5-Inch Axle Spacing: Adjust axle pinion angles to the values in **Table 8**, ±1 degree.

Business Class M2 Single Spring Suspension Ride Heights and Planning Angles in **Table 9**.

Freightliner AirLiner Suspensions With Meritor RT–40/–44/–46 Axles												
Axle Seat Angle (degrees)		Measured Suspension Height * (Inches)	Rear Suspension Load (pounds)									
			Unladen		30,000		34,000		36,000		40,000	
			Axle Pinion Angle (degrees)									
Fwd	Rear		Fwd	Rear	Fwd	Rear	Fwd	Rear	Fwd	Rear	Fwd	Rear
3.0	5.5	2.375 (min)	2.1	10.6	3.0	11.5	3.2	11.7	3.3	11.8	3.5	12.0
		2.5	2.4	10.9	3.3	11.8	3.5	12.0	3.6	12.1	3.7	12.2
		2.625	2.7	11.2	3.6	12.1	3.8	12.3	3.8	12.3	4.0	12.5
		2.75	2.9	11.4	3.9	12.4	4.0	12.5	4.1	12.6	4.3	12.8
		2.87 (max)	3.2	11.7	4.2	12.7	4.3	12.8	4.4	12.9	4.6	13.1

* Measure suspension height at the forward drive-axle stop on the driver's side; see **Section 32.04** for complete instructions.

Table 1, Freightliner AirLiner Suspensions With Meritor RT-40/-44/-46 Axles

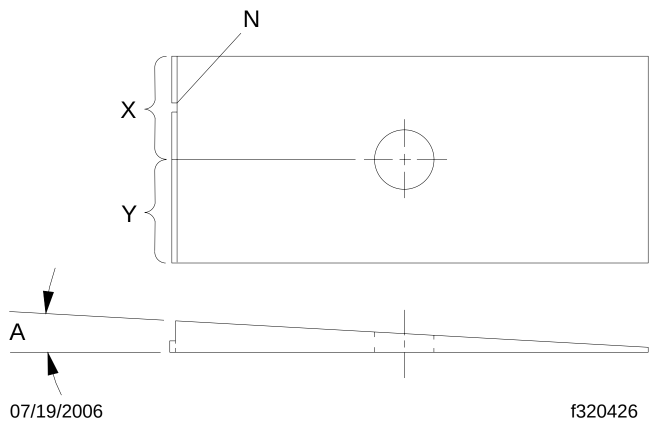
Freightliner Spring Suspensions (with Meritor RT–40/–44/–46 Axles)										
Axle Model	Forward-Rear Axle					Rearmost Axle				
	Pinion Angle (degrees)	Spring Seat Spacer	Shim Angle (degrees)	Orientation of Shim's Thick End	Number of Shim Notches *	Pinion Angle (degrees)	Spring Seat Spacer	Shim Angle (degrees)	Orientation of Shim's Thick End	Number of Shim Notches †
RT–40/–44/–46	3.0	Yes	None	—	—	11.0	None	1.0	Aft	2

* See **Table 3** for shim notch decoding.

† See **Table 3** for shim notch decoding.

Table 2, Freightliner Spring Suspensions (with Meritor RT-40/-44/-46 Axles)

Specifications



Shim Angle *A* (degrees)	Notches (N) at *X*	Notches (N) at *Y*
0.5	One (total at x plus y)	
1.0	Two	none
1.5	Three	none
2.0	Four (total at x plus y)	
2.5	Five (total at x plus y)	
3.0	Six (total at x plus y)	
3.5	Zero	Zero
4.0	One	One
4.5	Two	One

Table 3, Shim Notch Decoding

Hendrickson Suspensions With 52-Inch Axle Spacing										
Axle Model	Suspension Model	Saddle Height (inches)	Planing Angle (degrees)				Suspension Control Rod			
			Unladen		Laden		Forward Axle		Rear Axle	
			Front	Rear	Front	Rear	Rod Length (inches)	Spacer Thickness (inches)	Rod Length (inches)	Spacer Thickness (inches)
RT40/44–145(P)	RS–400, –460	12.88	3.2	11.6	3.0	11.8	22.5	—	25.75	0.125
RT40/44–145(P)	RS–400, –460	14	3.3	11.5	3.0	11.8	22.5	—	25.75	—
RT40/44–145(P)	RT2–400	7.19	4.2	12.6	3.0	11.8	22.25	—	25.75	—
RT40/44–145(P)	RT2–460	6	4.4	12.6	3.0	11.8	22.5	0.125	25.75	—
RT40/44–145(P)	RT2–460	7.19	2.8	10.8	3.0	11.8	22.5	—	26	0.125

Hendrickson Suspensions With 52-Inch Axle Spacing										
Axle Model	Suspension Model	Saddle Height (inches)	Planing Angle (degrees)				Suspension Control Rod			
			Unladen		Laden		Forward Axle		Rear Axle	
			Front	Rear	Front	Rear	Rod Length (inches)	Spacer Thickness (inches)	Rod Length (inches)	Spacer Thickness (inches)
RT40/44–145(P)	RTE2–400	7.19	4.6	12.9	3.0	11.8	22	0.125	26.25	0.125
RT40/44–145(P)	RTE2–460	7.19	4.8	12.9	3.0	11.8	22.25	—	26	—
RT46–160(P)	RS–400, –460	12.88	3.1	11.3	3.0	11.4	22.5	0.125	25.75	0.125
RT46–160(P)	RS–400, –460	14	3.2	11.1	3.0	11.4	22.5	—	25.75	0.125
RT46–160(P)	RT2–400	7.19	4.1	12.2	3.0	11.4	22.25	—	25.75	—
RT46–160(P)	RT2–460	6	4.3	12.3	3.0	11.4	22.5	0.125	25.75	—
RT46–160(P)	RT2–460	7.19	2.8	10.5	3.0	11.4	22.5	0.125	25.75	—
RT46–160(P)	RTE2–400	7.19	4.5	12.6	3.0	11.4	22	0.125	26.25	0.125
RT46–160(P)	RTE2–460	7.19	4.7	12.5	3.0	11.4	22.25	0.125	26	—

Table 4, Hendrickson Suspensions With 52-Inch Axle Spacing

Hendrickson Suspensions With 54-Inch Axle Spacing										
Axle Model	Suspension Model	Saddle Height (inches)	Planing Angle (degrees)				Suspension Control Rod			
			Unladen		Laden		Forward Axle		Rear Axle	
			Front	Rear	Front	Rear	Rod Length (inches)	Spacer Thickness (inches)	Rod Length (inches)	Spacer Thickness (inches)
RT40/44–145(P)	RS–400, –460	14	3.3	10.8	3.0	11.1	23.5	—	26.5	—
RT40/44–145(P)	RS–400, –460	12.88	3.1	10.9	3.0	11.1	23.5	—	26.5	0.125
RT40/44–145(P)	RT2–400	7.19	4.2	11.9	3.0	11.1	23.25	—	26.5	—
RT40/44–145(P)	RT2–460	6	4.4	12.0	3.0	11.1	23.5	0.125	26.5	—
RT40/44–145(P)	RTE2–400	7.19	4.6	12.2	3.0	11.1	23	—	27	—
RT40/44–145(P)	RTE2–460	7.19	4.8	12.2	3.0	11.1	23.25	0.125	26.75	—
RT46–160(P)	RS–400	14	3.2	10.6	3.0	10.8	23.5	—	26.5	0.125
RT46–160(P)	RS–460	14	3.2	10.6	3.0	10.8	23.5	—	26.5	—
RT46–160(P)	RS–400, –460	12.88	3.1	10.7	3.0	10.8	23.5	0.125	26.5	0.125
RT46–160(P)	RT2–400	7.19	4.1	11.7	3.0	10.8	23.25	—	26.5	—
RT46–160(P)	RT2–460	6	4.3	11.7	3.0	10.8	23.25	—	26.5	—
RT46–160(P)	RTE2–400	7.19	4.5	12.0	3.0	10.8	23	0.125	27	0.125
RT46–160(P)	RTE2–460	7.19	4.7	11.9	3.0	10.8	23.25	0.125	26.75	—

Table 5, Hendrickson Suspensions With 54-Inch Axle Spacing

Specifications

Hendrickson Suspensions With 56-Inch Axle Spacing										
Axle Model	Suspension Model	Saddle Height (inches)	Planing Angle (degrees)				Suspension Control Rod			
			Unladen		Laden		Forward Axle		Rear Axle	
			Front	Rear	Front	Rear	Rod Length (inches)	Spacer Thickness (inches)	Rod Length (inches)	Spacer Thickness (inches)
RT40/44–145(P)	RTE2–460	7.19	4.4	11.7	3.0	10.6	24.25	0.125	27.75	0.125
RT46–160(P)	RTE2–460	7.19	4.7	11.4	3.0	10.3	24.25	0.125	27.5	—

Table 6, Hendrickson Suspensions With 56-Inch Axle Spacing

Hendrickson Suspensions With 60-Inch Axle Spacing										
Axle Model	Suspension Model	Saddle Height (inches)	Planing Angle (degrees)				Suspension Control Rod			
			Unladen		Laden		Forward Axle		Rear Axle	
			Front	Rear	Front	Rear	Rod Length (inches)	Spacer Thickness (inches)	Rod Length (inches)	Spacer Thickness (inches)
RT40/44–145(P)	RS–400, –460	12.88	3.1	9.5	3.0	9.7	26.5	—	29	0.125
RT40/44–145(P)	RS–400, –460	14	3.2	9.4	3.0	9.7	26.5	—	29	—
RT40/44–145(P)	RT2–400	7.19	4.2	10.5	3.0	9.7	26.25	—	29	—
RT40/44–145(P)	RT2–460	6	4.3	10.6	3.0	9.7	26.5	0.125	29	—
RT40/44–145(P)	RTE2–400	7.19	4.6	10.9	3.0	9.7	26	—	29.5	—
RT40/44–145(P)	RTE2–460	7.19	4.7	10.8	3.0	9.7	26.25	0.125	29.25	—
RT46–160(P)	RS–400, –460	12.88	3.1	9.4	3.0	9.5	26.5	0.125	29	0.125
RT46–160(P)	RS–400, –460	14	3.2	9.3	3.0	9.5	26.5	—	29	—
RT46–160(P)	RT2–400	7.19	4.1	10.4	3.0	9.5	26.25	—	29	—
RT46–160(P)	RT2–460	6	4.3	10.4	3.0	9.5	26.25	—	29	—
RT46–160(P)	RTE2–400	7.19	4.5	10.7	3.0	9.5	26	0.125	29.5	—
RT46–160(P)	RTE2–460	7.19	4.6	10.8	3.0	9.5	26.25	0.125	29.25	—

Table 7, Hendrickson Suspensions With 60-Inch Axle Spacing

Hendrickson Suspensions With 72.5-Inch Axle Spacing										
Axle Model	Suspension Model	Saddle Height (inches)	Planing Angle (degrees)				Suspension Control Rod			
			Unladen		Laden		Forward Axle		Rear Axle	
			Front	Rear	Front	Rear	Rod Length (inches)	Spacer Thickness (inches)	Rod Length (inches)	Spacer Thickness (inches)
RT40/44–145(P)	RS–460	12.88	3.1	7.5	3.0	7.6	32.75	0.125	34.5	0.125
RT40/44–145(P)	RS–460	14	3.2	7.4	3.0	7.6	32.75	—	34.5	—
RT40/44–145(P)	RT2–460	6	4.3	8.5	3.0	7.6	32.75	0.125	34.5	—
RT40/44–145(P)	RTE2–460	7.19	4.6	8.6	3.0	7.6	32.5	0.125	34.75	—

Hendrickson Suspensions With 72.5-Inch Axle Spacing										
Axle Model	Suspension Model	Saddle Height (inches)	Planing Angle (degrees)				Suspension Control Rod			
			Unladen		Laden		Forward Axle		Rear Axle	
			Front	Rear	Front	Rear	Rod Length (inches)	Spacer Thickness (inches)	Rod Length (inches)	Spacer Thickness (inches)
RT46–160(P)	RS–460	12.88	3.1	7.3	3.0	7.4	32.75	0.125	34.5	0.125
RT46–160(P)	RS–460	14	3.1	7.2	3.0	7.4	32.75	0.125	34.5	—
RT46–160(P)	RT2–460	6	4.2	8.4	3.0	7.4	32.5	—	34.5	—
RT46–160(P)	RTE2–460	7.19	4.6	8.6	3.0	7.4	32.5	0.125	34.75	—

Table 8, Hendrickson Suspensions With 72.5-Inch Axle Spacing

Business Class M2 Single Spring Suspension Ride Heights / Planing Angles		
Description	Ride Height *	Available Planing Angles †
10k M2 52" Vari-Rate Spring	260 mm (unladen)	3, 5 Degrees
12.5k M2 52" Vari-Rate Spring	260 mm (unladen)	
16k M2 52" Vari-Rate Spring w/ RS 13/15-120 axles	270 mm (unladen)	
16k M2 52" Vari-Rate Spring w/ RS 17-145 axles	285 mm (unladen)	
18k w/ & w/o Helper	300 mm (unladen)	
21k w/ & w/o Helper	310 mm (unladen)	
23k w/ & w/o Helper	310 mm (unladen)	
18k 60" Taper leaf 2 stage spring	235 mm (laden)	
21k 60" Taper leaf 2 stage spring	235 mm (laden)	
23k 60" Taper leaf 2 stage spring	235 mm (laden)	

* Ride height taken from the bottom bolt of the forward suspension hanger.

† Check the vehicle specification in module 421 to determine if the suspension is 3 or 5 degrees.

Table 9, Business Class M2 Single Spring Suspension Ride Heights / Planing Angles

General Description

CAUTION

The size of the tires installed at the factory is programmed into the electronic control unit (ECU). Installing different size tires could result in a reduced braking force, leading to longer stopping distances and possibly resulting in personal injury or property damage.

Business Class M2 vehicles are equipped with a Meritor WABCO E-Version Antilock Braking System (ABS) with a frame-mounted electronic control unit.

The ABS is an electronic wheel speed monitoring and control system that works with the standard air brake system. It passively monitors vehicle wheel speed at all times, then controls wheel speed during emergency stops. As a result, the driver has full control of braking until the ECU senses that a lockup is about to occur.

The ABS includes signal-generating sensors activated by tone (tooth) wheels located on the hubs of the monitored wheels. See **Fig. 1**. The sensors transmit vehicle wheel speed information to the ECU. According to programmed specifications, the control unit signals the appropriate modulator valve to increase, reduce, or maintain air pressure in the brake chamber. This prevents front and rear wheel lockup, and enhances steering control during emergency braking situations.

Business Class M2 vehicles with a 4 x 2, 6 x 2, or 6 x 4 wheel configuration normally have the standard four-channel ABS with four wheel speed sensors and four modulator valves (4S/4M). Vehicles with tandem rear axles may be optionally equipped with a 6S/4M or 6S/6M ABS.

During normal braking conditions, the standard air brake system is in effect. If the vehicle is equipped with Automatic Traction Control (ATC), wheel spin is controlled during reduced-traction startup and acceleration.

Principles of Operation

The ABS has an electronic control unit that serves as the information processing and command center for the antilock braking system. The ECU is a digital microcomputer that receives and processes vehicle wheel speed information from the sensors. During emergency brake applications, the control unit regulates the braking force applied to each wheel by sending control signals to the modulator valves.

The major components of the Meritor WABCO pneumatic ABS system include the following:

- Wheel speed sensors
- An electronic control unit (ECU)
- Modulator valves (solenoid control valves)
- Automatic Traction Control (ATC) valve (optional)
- ABS warning and wheel-spin indicator lights

CAUTION

Before performing any electric welding on a vehicle, disconnect the battery power, ground cables, and the electrical harness connectors at the ABS electronic control unit (ECU). Electric currents produced during electric welding can damage various electronic components on the vehicle.

Wheel Speed Sensors

The wheel speed sensor assembly is a signal-generating device. The assembly includes a sensor (coil wrapped around a magnet), a tone wheel, and a sensor clip that holds the sensor in position near the tone wheel. See **Fig. 2**.

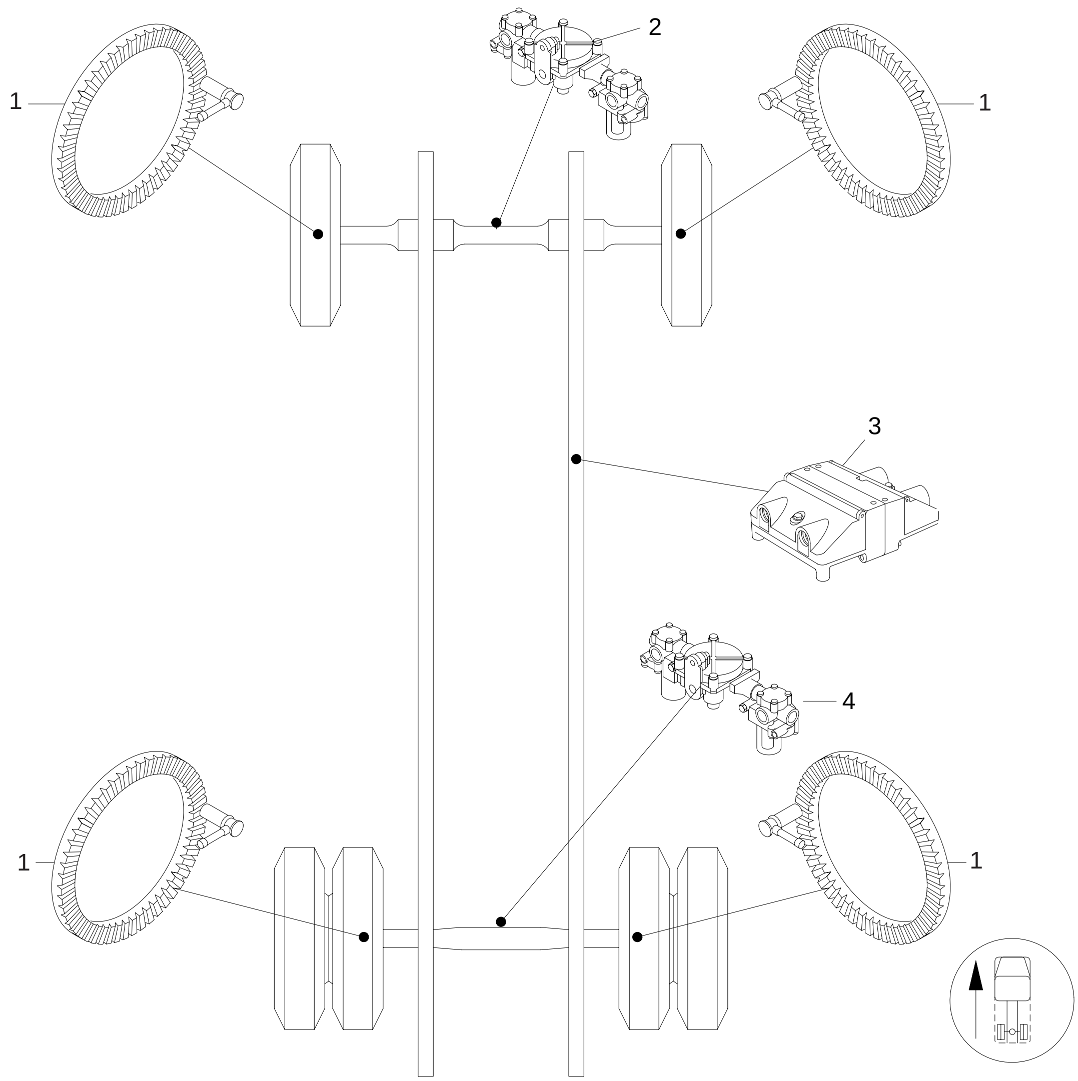
Each ABS-controlled wheel has a wheel speed sensor assembly with a tone wheel mounted on the hub. When the vehicle is moving, the teeth on the tone wheel cause interruptions in the magnetic field created by the sensor. The interruptions create electrical pulses that are sent to the electronic control unit where they are used to determine the wheel speed.

Electronic Control Unit (ECU)

The ECU contains microcomputers to monitor the front and rear control channels. See **Fig. 3**. It is mounted on the right-hand frame rail.

The ECU receives signals from the wheel speed sensors and uses them to calculate wheel speed and a vehicle reference speed. The unit is programmed to determine whether the wheels are slowing at a normal braking rate or at a higher rate, requiring ABS braking control. If the ECU senses wheel slip or

General Information



1. Tone Wheel and Sensor
2. Front Modulator Valve Assembly
3. Electronic Control Unit (ECU)
4. Rear Modulator Valve Assembly

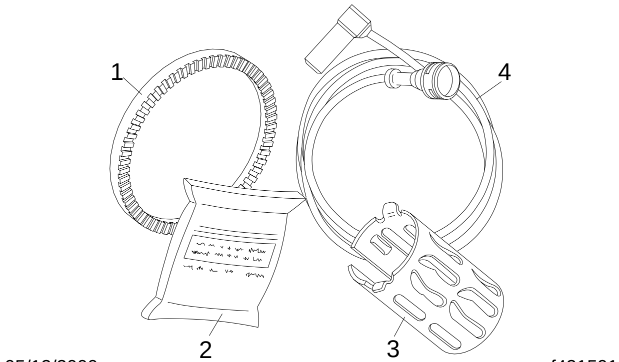
Fig. 1, ABS Component Location (4-channel, 4S/4M system shown)

lockup, the appropriate control circuit signals the modulator valve(s) to release, hold, or reapply braking pressure.

The ECU also shuts down the engine brake and the exhaust brake, if equipped, when a wheel approaches a slip or lockup condition. When the wheels return to a normal rate of speed, the engine and exhaust brakes are reactivated automatically.

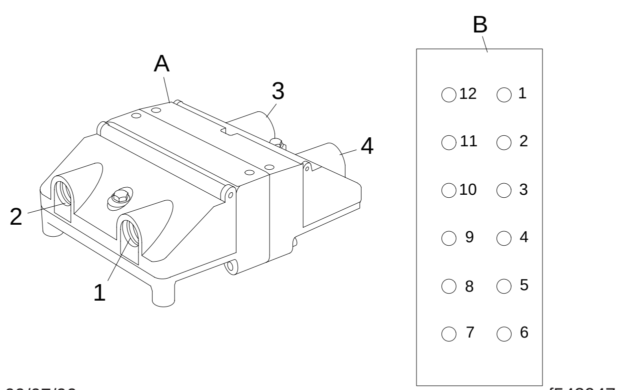
The ECU constantly monitors the wheel sensors, modulator valves, Automatic Traction Control valve (if equipped), and the electrical circuitry. After the ignition switch is turned on, the ABS warning light (TRACTOR ABS) and the ATC wheel spin indicator light (WHEEL SPIN) on the dash light for about 3 seconds. See **Fig. 4** for a typical instrument cluster.

During the self-test, the modulator valves and the ATC valve cycle on and off, creating clicking noises



1. Tone Wheel
2. Lubricant
3. Sensor Spring Clip
4. Sensor

Fig. 2, Wheel Speed Sensor Components



A. Frame-mounted ECU.
B. ECU connector pin locations.

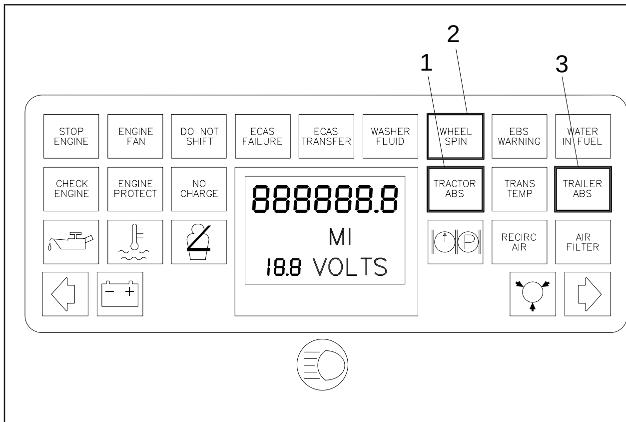
1. X1 Connector (gray)
2. X2 Connector (black)
3. X3 Connector (green)
4. X4 Connector (brown—6S/4M, 6S/6M only)

Fig. 3, Frame-Mounted ECU and Pin Locations

that may be heard inside the cab. These clicking noises are normal and do not indicate an ABS problem. After about 3 seconds, the lights go off only if all of the ABS and ATC components are functioning correctly.

On vehicles with Automatic Traction Control, after the self-test the ATC indicator light comes on if a drive wheel spins during startup or acceleration.

IMPORTANT: If the ABS warning light and the ATC indicator light do not work as described



1. Tractor ABS Warning Light
2. ATC Indicator Light
3. Trailer ABS Warning Light

Fig. 4, ABS and ATC Lights (ICU Level 1 [ICU 3] shown)

above, repair the ABS/ATC system. See **Troubleshooting, 300** for fault diagnosis.

If, during vehicle operation, the safety circuit senses a failure in any part of the ABS system (such as a sensor, modulator valve, wiring connection, or short circuit), the ABS warning light comes on, a fault code is stored in ECU memory, and the control circuit where the failure occurred is switched to normal braking action. The remaining control circuit retains the ABS effect.

Even if the ABS system is completely inoperative, normal braking is maintained. An exception would be if a modulator valve or valve assembly is damaged and inoperative. These components are an integral part of the air brake system so normal braking may be impaired or inoperative.

For troubleshooting purposes, the ECU can communicate with the Meritor WABCO PC Diagnostics (recommended), ServiceLink, a hand-held Pro-Link electronic diagnostic tool through the J1587 diagnostic datalink connector or blink codes. The connector is located near the B-pillar on the driver's side and the diagnostic switch is on the B-pillar panel. Fault codes can be retrieved through the datalink connection, when necessary.

IMPORTANT: Do not open the ECU. Opening the ECU to gain access to the internal components will void the warranty.

Modulator Valves

Modulator valves control the air pressure in each affected brake chamber during an ABS operation. Depending on the signal received from the ECU, modulator valves prevent wheel lockup by reducing, maintaining, or increasing brake pressure. During normal braking applications, the ABS system is inactive and compressed air flows freely through the modulator valves to the brake chambers.

Each ABS-monitored wheel has its own modulator valve. The front and rear modulator valve assemblies are mounted on a crossmember near the brake chambers. See **Fig. 1**. The assembly includes two modulator valves, one mounted on each side of a service relay valve. If the vehicle has an ATC system, the ATC valve is mounted on the control port of the service relay valve.

Vehicles with tandem rear axles and a 4S/4M ABS share modulator valves. One wheel is sensed but the modulator valve controls both wheels on a side.

Each modulator valve assembly includes two solenoid control valves (one supply and one exhaust) and two diaphragms. See **Fig. 5**.

- The supply diaphragm opens and closes an air passage between the supply port and delivery port. It is controlled by the supply solenoid valve.
- The exhaust diaphragm opens and closes an air passage between the exhaust port and the delivery port. It is controlled by the exhaust solenoid valve.

The ECU energizes different combinations of these solenoid valves to perform four functions: normal braking (without ABS control), ABS brake release (exhaust), ABS brake hold, and normal brake reapply.

Normal Brake Control

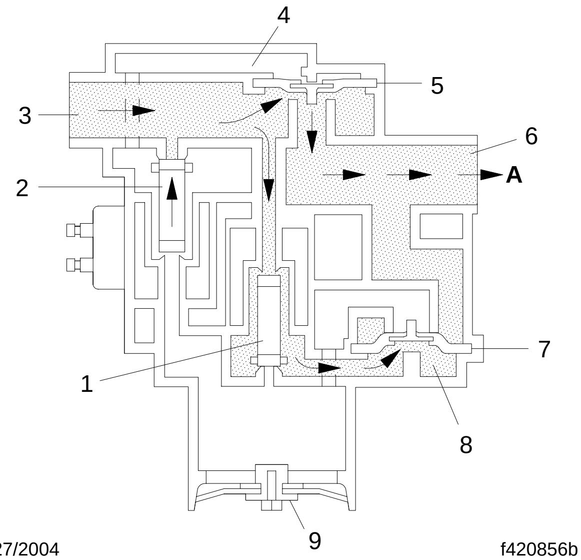
The normal brake function (without ABS control) operates as follows:

- Before braking, the supply pilot chamber is open to the atmosphere through the exhaust port.
- When the brakes are applied, both solenoid valves in the ABS modulator valve are closed (de-energized). See **Fig. 5**.
- Increased air pressure entering the supply port unseats the supply diaphragm by increasing the pressure under the diaphragm. This opens the passage to the delivery port and allows air to flow directly through the valve and into the brake chamber.
- Air also flows through the exhaust valve. The increased pressure under the exhaust diaphragm seats the diaphragm, which closes the passage between the exhaust port and the delivery port.
- When the brake pedal is released, air pressure at the supply port decreases and the higher pressure in the brake chamber reverses the flow of air in the modulator valve. Air now flows from the delivery port to the supply port until the pressure is balanced. This releases the supply diaphragm and closes the passage between the two ports.
- The reduced pressure unseats the exhaust diaphragm and air is vented through the exhaust port to the atmosphere.

Brake Release (ABS Active)

The ABS brake release (exhaust) function is triggered when the ECU determines that the brakes are about to lock.

- When a wheel is going to lock, the ECU opens (energizes) both solenoid valves in the ABS modulator valve. See **Fig. 6**.
- The open supply valve allows compressed air to enter the supply pilot chamber above the supply diaphragm. The increased pressure seats the diaphragm and stops air from entering the brake chamber.
- The open exhaust valve shuts off the supply of air entering the exhaust pilot chamber. It also creates an opening between the pilot and exhaust chambers.
- Air from the brake chamber enters through the delivery port. The pressure unseats the exhaust diaphragm, creating an opening between the delivery and exhaust chambers. Brake-chamber air is then released through the exhaust port.

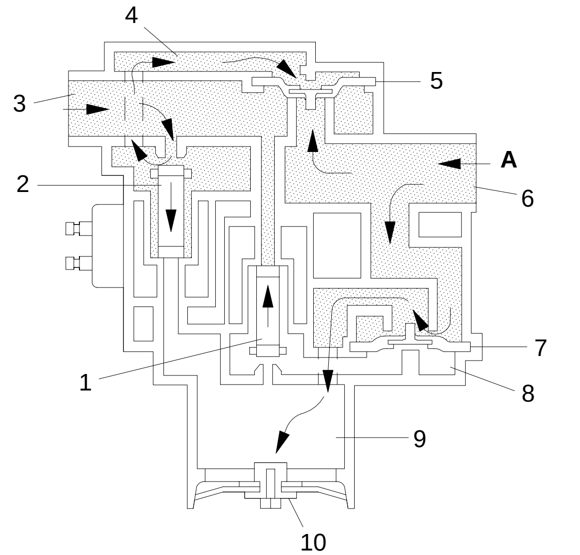


NOTE: Both solenoid valves are closed. The modulator valve is shown in the braking configuration with increased air pressure at the supply port (supply diaphragm unseated, exhaust diaphragm seated).

A. Air to brake chamber.

1. Exhaust Valve (closed)
2. Supply Valve (closed)
3. Supply Port
4. Supply Diaphragm (unseated)
5. Delivery Port
6. Exhaust Diaphragm (seated)
7. Exhaust Port

Fig. 5, Modulator Valve, Normal Brake Control (brake applied)



NOTE: Both solenoid valves are open.

A. Air from brake chamber.

1. Exhaust Valve (open)
2. Supply Valve (open)
3. Supply Port
4. Supply Pilot Chamber
5. Supply Diaphragm (seated)
6. Delivery Port
7. Exhaust Diaphragm (unseated)
8. Exhaust Pilot Chamber
9. Exhaust Chamber
10. Exhaust Port

Fig. 6, Modulator Valve, Brake Release (exhaust)

Brake Hold Control (ABS Active)

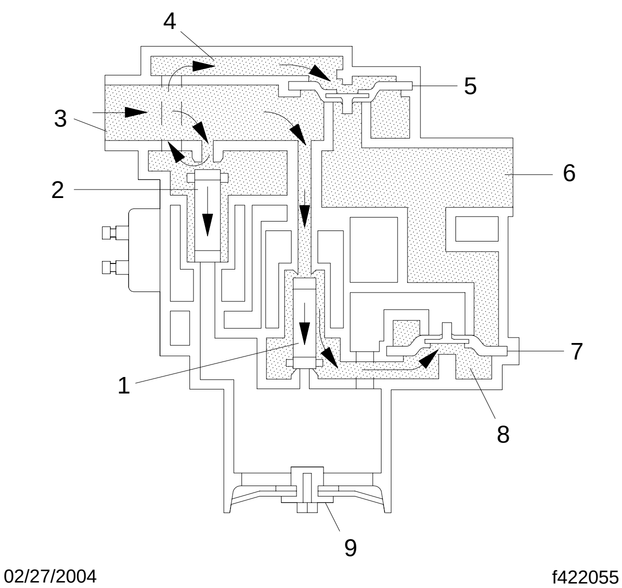
The ABS brake hold function takes control during an emergency stop when the pedal control valve delivers more air than the brakes can handle without locking. The hold function occurs after the ABS has started to control the pressure in the brake chamber by releasing some of the air.

- When enough air is released through the exhaust port to stop the wheel from locking (ABS brake release), the exhaust valve is closed and air pressure is allowed to flow into the exhaust pilot chamber. See **Fig. 7**.
- The increased pressure under the exhaust diaphragm seats the diaphragm, which closes the passage between the exhaust port and the delivery port. This stops the flow of air from the brake chamber to the exhaust port.
- The supply valve stays open to maintain pressure in the supply pilot chamber and keep the supply diaphragm seated. This prevents further buildup of pressure in the brake chamber.
- The remaining air pressure in the brake chamber is held and remains constant for stopping the vehicle in the minimum distance.

Reapply Brake Control (ABS Active)

The last ABS function is the reapply brake control. To achieve maximum braking, the ECU determines when to reapply the air pressure that the pedal control valve is delivering. When appropriate, both ABS

General Information



NOTE: The supply valve is open; the exhaust valve is closed.

1. Exhaust Valve (closed)
2. Supply Valve (open)
3. Supply Port
4. Supply Pilot Chamber
5. Supply Diaphragm (seated)
6. Delivery Port
7. Exhaust Diaphragm (seated)
8. Exhaust Port

Fig. 7, Modulator Valve, Brake Hold Control

solenoid valves are closed, which returns the system to the normal brake control state shown in **Fig. 5**.

During an ABS event, the ECU cycles the modulator valve(s) through the sequence of ABS valve states (brake release, hold, and reapply) very rapidly in order to control wheel speed. The effect is similar to manually pumping the brakes on a vehicle without an ABS.

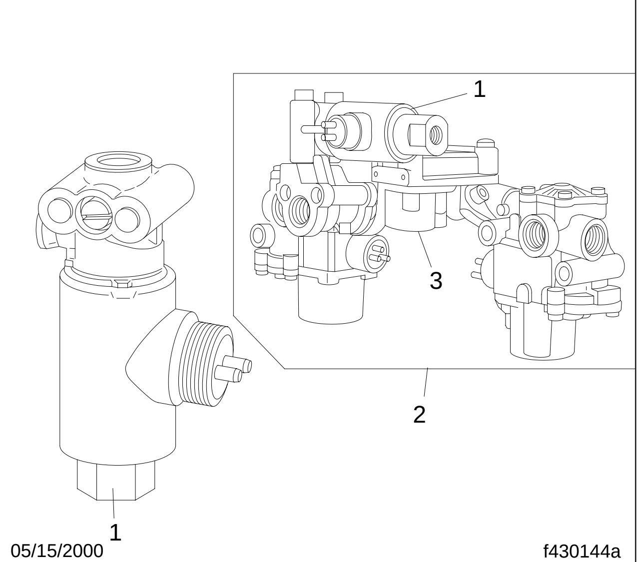
NOTE: The driver always controls the maximum amount of pressure applied to the brakes. Pressure to the brake chamber can never be more than the driver applies with the foot pedal. The ABS can override the pedal pressure to provide less brake pressure but not more.

Automatic Traction Control

If the vehicle is equipped with Automatic Traction Control (ATC), the ABS/ATC system automatically reduces wheel spin during low-traction startup or acceleration.

If a drive wheel starts to spin faster than the steer-axle wheels, the ATC system applies air pressure to brake that drive wheel. This transfers engine torque to the wheel or wheels that have better traction (differential braking). If two or more drive wheels spin, the ATC reduces the engine torque to provide improved traction, overriding the throttle pressure from the driver.

The ATC valve controls only the brake chambers for the drive wheels. It is mounted on the service relay valve (rear modulator valve assembly). See **Fig. 8**. The solenoid in the ATC valve controls an on/off air valve, which allows or prevents air flow to the control side of the service relay valve.



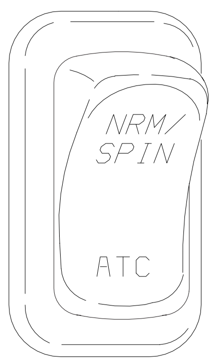
1. ATC Valve
2. Rear Modulator Valve Assembly
3. Service Relay Valve

Fig. 8, ATC Valve

If a wheel spin from one side of the vehicle is detected, the ECU signals the ATC valve to open. This allows compressed air to enter the service relay valve and the normal ABS control system determines which brake to apply.

An ATC function switch on the dash allows the driver to select from two levels of drive-axle traction control (see Fig. 9):

- In the default position, the ATC reduces drive-axle wheel spin on icy, wet, or sand-covered roads.
- Pressing the NORM/SPIN switch increases the available traction on extra soft surfaces like snow, mud, or gravel by slightly increasing the permissible wheel spin. The greater wheel spin may also be used to help burn through a thin layer of ice.



NOTE: This is a momentary rocker switch, shown in the ATC (default) position.

Fig. 9, ATC Switch for Soft Surfaces

The ATC function turns on and off automatically; drivers do not have to select this feature. If a drive wheel spins during startup or acceleration, the ATC indicator lamp comes on, indicating the ATC is active. It goes out when the drive wheel stops spinning.

The NORM/SPIN mode overrides the ATC function. It must be manually selected by pressing the NORM/SPIN spring-loaded switch briefly after the vehicle is started. The ECU indicates the activation by a constant flashing of the WHEEL SPIN lamp. This mode is disengaged by pressing NORM/SPIN on the switch again or turning the ignition switch off.

Tractor ABS Warning and ATC Indicator Lights

The tractor ABS warning light (TRACTOR ABS) receives power whenever the ignition switch is turned on. The ground path for this indicator is through the ABS ECU, the blink-code switch, and relay. During the self-test, and whenever a malfunction occurs, the ECU completes the ground path and the ABS indicator on the dash comes on. See Fig. 4. The light is also used to display blink code diagnostics.

The tractor warning light alerts the driver that the self-test is working or that an ABS system malfunction exists. After a wheel-sensor-related fault has been repaired, if the stored faults are cleared, the ABS warning light remains on until the vehicle is driven above a speed of 4 mph (6 km/h).

The ATC indicator light also receives power whenever the ignition switch is on. If the drive-axle wheels spin, the ATC indicator light turns on.

On vehicles equipped with Automatic Traction Control, if the NORM/SPIN switch is activated, the ABS ECU allows more wheel spin than normal and the ATC indicator blinks continuously until the switch is deactivated. See Fig. 9.

If the ATC wheel-spin indicator light stays on during normal vehicle operation, there is a malfunction in the ATC system.

Trailer ABS Warning Light

The trailer ABS warning lamp on the dash illuminates when a fault is detected in the trailer ABS.

In order to meet the dash-mounted trailer ABS warning lamp requirement, the trucking, truck manufacturing, and trailer manufacturing industries chose PLC4TRUCKS to control the trailer ABS lamp. There are two main reasons for this:

- It does not require additional trailer plugs, since PLC messages are broadcast over the trailer ABS power line.
- PLC4TRUCKS allows for future control enhancements, such as controlling other functions on the trailer, from the tractor, without additional wiring between the tractor and the trailer.

Both the trailer and tractor ABS electronic control unit (ECU) are equipped with special internal electronics that can transmit and receive messages through the power line to each ECU.

Each ECU has a separate power supply that passes through a PLC filter. PLC messages are in the form of a frequency modulated signal superimposed over the direct current (DC) power supply. The PLC filter allows the DC power supplies to be separate, while

General Information

allowing the PLC messages to pass from the trailer power line to the tractor ABS power line. It does this through a series of inductor coils and capacitors. See **Fig. 10**.

by the tractor ABS. The tractor ABS turns on the trailer ABS lamp on the dash. See **Fig. 11** for a simplified schematic of the overall PLC and trailer ABS warning lamp system.

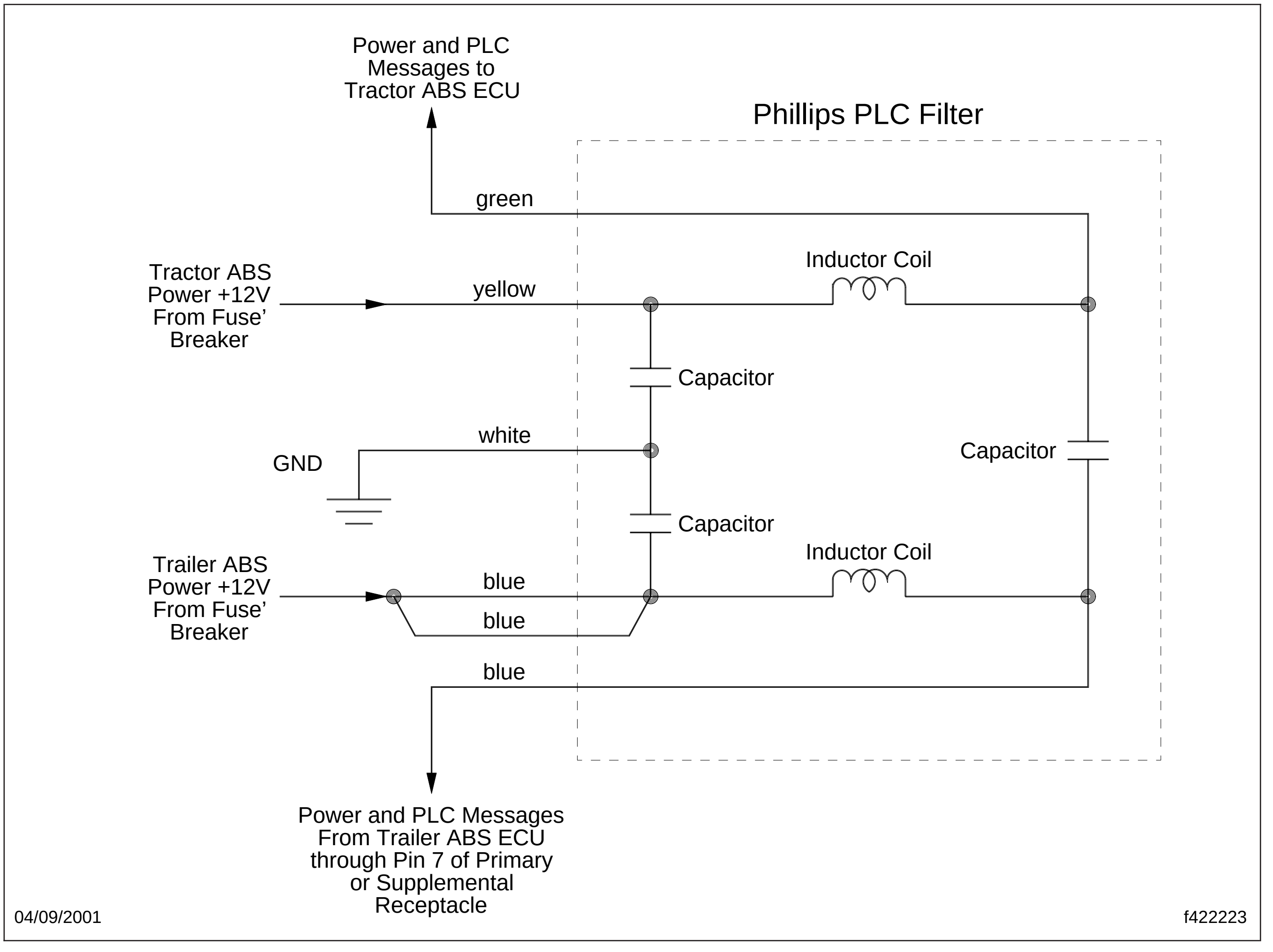


Fig. 10, PLC Wire Information

The coils pass DC current while blocking the frequency modulated signal. The capacitors pass the frequency modulated signal while blocking the DC current. The filter is sharing the PLC signal on the separate power lines, while keeping the actual power supplies to the ECUs separate. The filter also prevents interference throughout the rest of the vehicles eletrical system.

If the trailer ABS ECU detects a fault in the trailer's ABS system, the trailer ABS ECU transmits a message over the power line via PLC, which is received

A couple of key points to remember are:

- The trailer ABS warning lamp is wired directly to the tractor ABS ECU. The tractor ABS ECU provides the ground path for the lamp circuit.
- The tractor and trailer ABS systems have separate power supplies.
- The PLC filter allows the PLC messages to pass between the trailer ABS power line and the tractor ABS power line. It also prevents

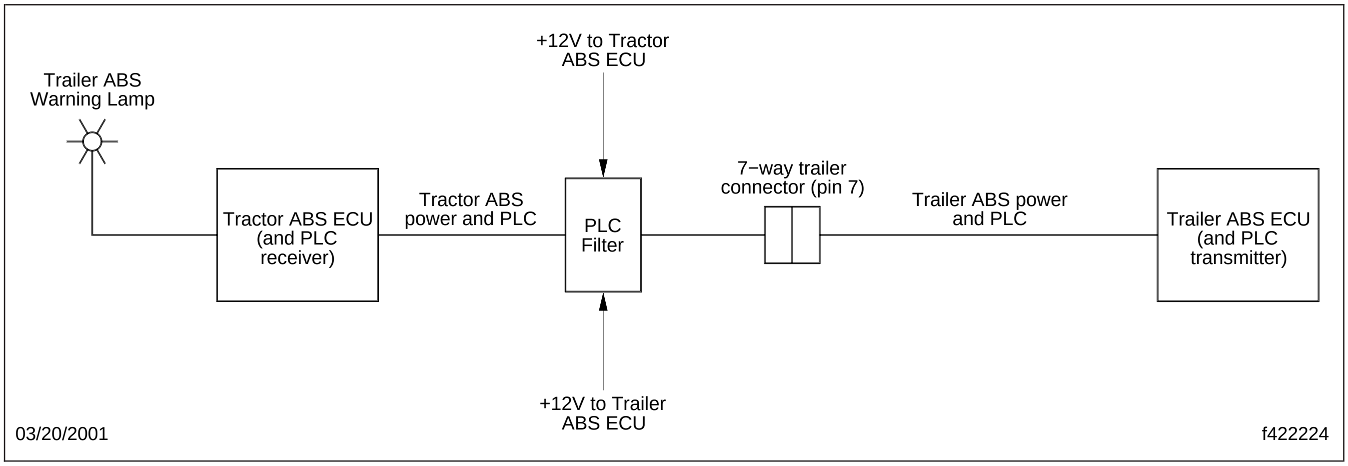


Fig. 11, PLC and Trailer ABS Warning Lamp System

interference from entering the rest of the vehicle electrical system.

When a PLC equipped tractor connects to a PLC equipped trailer, at start-up, the lamp should come on for a few seconds, then go out if no trailer ABS faults exist.

When a PLC equipped tractor is connected to a non-PLC equipped trailer, at start-up, the lamp will not come on. The tractor ABS must see PLC messages from the trailer in order for the trailer ABS lamp to function.

See **Troubleshooting, 300** to troubleshoot the PLC filter.

Tire Size

For proper ABS/ATC operation with the standard ECU, the front and rear tire sizes must be within 14 percent of each other. When the tire-size range is exceeded, system performance can be affected and the warning lamp may come on.

Call Meritor WABCO at 1-800-535-5560 if you plan a tire-size difference greater than 14 percent.

Calculate the percentage difference of the tire sizes with the following equation:

Percentage Difference = {(steer-axle tire RPM ÷ drive-axle tire RPM) – 1} x 100, where RPM equals tire revolutions per mile.

Safety Precautions

When working on or around air brake systems and components, observe the following precautions:

- Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires before working under the vehicle. Releasing air from the system can cause the vehicle to roll.
- Keep hands away from brake chamber push rods and slack adjusters; they will apply as the air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes.
- Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed the recommended air pressure.
- Always wear safety glasses when working with compressed air. Never look into air jets or direct them toward anyone.
- Never attempt to disassemble a component until you have read and understood the recommended procedures. Some components contain powerful springs and injury can result if they are not correctly disassembled. Use only the correct tools and observe all precautions regarding use of those tools.

Replacement

IMPORTANT: Do not attempt to repair the wheel sensor wire (the wire that comes with the sensor). If the wire is damaged, replace the sensor assembly.

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. Refer to **Section 54.00** for information on special terminals and connectors, and on ordering tools for them.

Front Axle

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires to prevent vehicle movement.
2. Twist and pull the sensor to remove it from the steering knuckle. See **Fig. 1**.

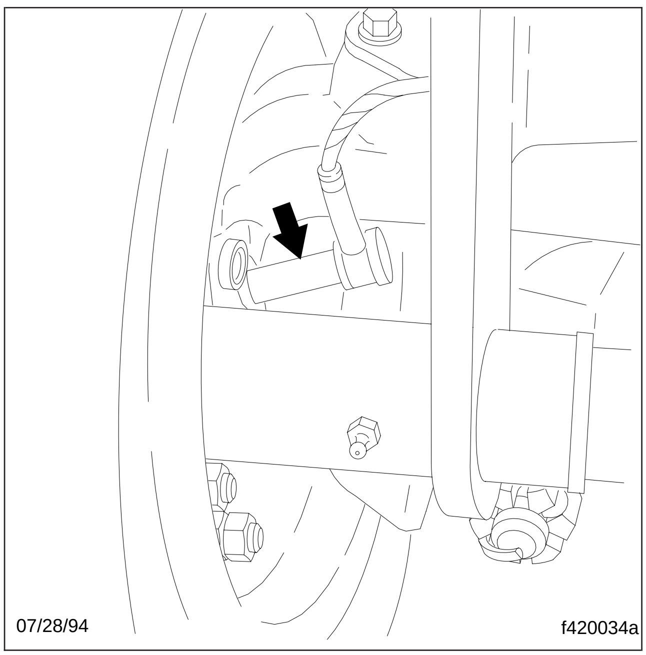


Fig. 1, Front Wheel Speed Sensor Removal

3. Remove the sensor cable from the steering knuckle top cap.
4. Disconnect the sensor cable from the chassis harness.
5. Remove the clamping bushing from the steering knuckle.
6. Connect the new sensor cable to the chassis harness.
7. Attach the sensor cable to the steering knuckle top cap.
8. Press the clamping bushing into the brake spider hole until it stops.
9. Coat the sensor with Mobil HP, Valvoline EP 633, Pennzoil 707L, or an equivalent. Press the sensor into the clamping bushing until it is stopped by the tone wheel.
10. Remove the chocks from the rear tires.

Rear Axle

1. Park the vehicle on a flat surface, set the parking brake, and shut down the engine. Chock the front tires to prevent vehicle movement.
2. Raise the rear of the vehicle until the tires clear the ground. Place safety stands under the axle.
3. Back off the slack adjuster to release the rear axle brake shoes.
4. Remove the wheel and tire assembly from the rear axle. For instructions, see **Group 40**.
5. Remove the brake drum. For instructions, refer to **Group 35**.
6. Twist and pull the sensor to remove it from the mounting block in the axle housing.
7. Remove the clamping bushing.
8. Remove the capscrew that attaches the sensor cable and the hose clamp to the axle tube.
9. Disconnect the sensor cable from the chassis harness.
10. Connect the new sensor cable to the chassis harness.
11. Attach the hose clamp and sensor cable to the axle tube located between the backing plate and the spring plate.
12. Press the clamping bushing into the mounting block until it stops.
13. Coat the sensor with Mobil HP, Valvoline EP633, Pennzoil 707L, or an equivalent. Using your

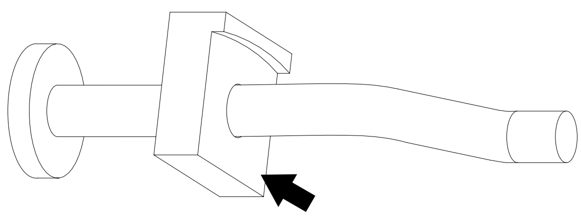
hand, push the sensor into the clamping bushing until it is stopped by the tone wheel.

14. Install the brake drum on the wheel hub. For instructions, refer to **Group 35**.
15. Adjust the rear axle brakes. For instructions, refer to the applicable brake section in this manual.
16. Install the wheel and tire assembly, and tighten the wheel nuts. Use the tightening sequence and torque values listed in **Group 40**.
17. Remove the safety stands, lower the vehicle, and remove the chocks from the front tires.

Adjustment

NOTE: The following adjustment procedure requires the use of special tool T11-17556-000. Use of this tool, available through the PDCs, eliminates the time-consuming task of removing the wheel and tire assembly, and the brake drum. See **Fig. 1**.

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the front tires.



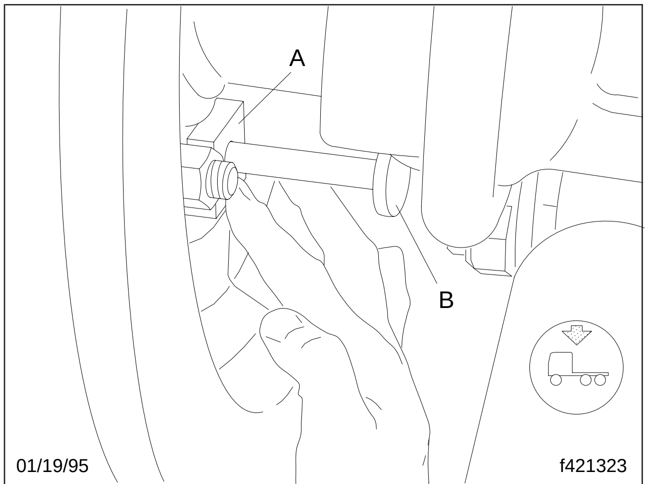
1. Adjustment Tool Slide

Fig. 1, ABS Sensor Adjustment Tool

2. Find the sensor access hole in the rear-axle flange.
    - 2.1 View the inboard side of the brake drum and axle from the rear. The ABS sensor wiring harness should be visible through a hole in the 12 o'clock position.
    - 2.2 Find the S-cam at either the 3 or 9 o'clock position.
    - 2.3 The sensor access hole is opposite the S-cam. The hole is approximately 3/4 inch (19 mm) in diameter.

IMPORTANT: Do not pry or push the sensor with sharp objects.

3. Insert service tool T11-17556-000 in the sensor access hole.
4. Place the slide of the tool on the axle flange to align the tool. See **Fig. 2**.
5. Tap the tool handle lightly with the palm of your hand. This ensures that the sensor is touching the tone wheel.
6. Remove the tool from the wheel and repeat the procedure on the other rear-axle speed sensor.



A. Place the slide against the axle flange.
B. Tap the handle with your hand.

Fig. 2, Position the Tool

7. Remove the chocks from the tires.

Removal

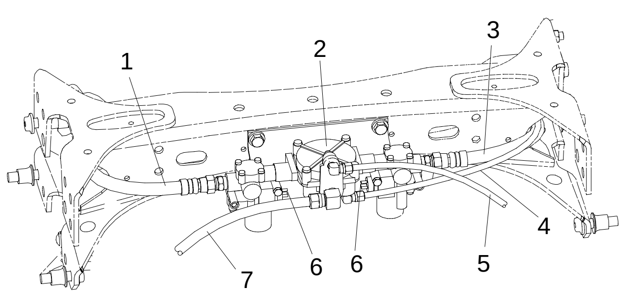
NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. See **Section 54.00** for information on special terminals and connectors, and on ordering tools for them.

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the front and rear tires.

WARNING

Release all the compressed air from the air reservoirs before disconnecting any air hose. Disconnecting air hoses from the modulator valves without first releasing the pressure in the air reservoirs can cause the hoses to swing uncontrollably, possibly resulting in personal injury or property damage. Before starting work on the brake system, read Safety Precautions, 100 in this section.

2. Release the pressure from the air reservoirs.
3. Mark the electrical connectors for ease of installation. Disconnect the wiring from the applicable modulator valve assembly. The assembly includes two modulator valves and a service relay valve. See **Fig. 1**.



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1. Delivery Air Line (to RH brake chamber)
2. Service Relay Valve
3. Delivery Air Line (to LH brake chamber)
4. Anti-compounding Line (black, to park brake quick-release/relay valve)
5. Control Air Line (green, from foot pedal valve)
6. Modulator Valve Electrical Connection
7. Supply Air Line (green, from primary air reservoir)

Fig. 1, Modulator Valve Assembly

4. Mark the air lines for ease of installation. Disconnect the air lines.
5. Remove the fasteners attaching the front modulator valve or rear valve assembly to the mounting bracket. Remove the valve or assembly.

NOTE: The modulator valve assemblies can be disassembled if replacement of the service relay valve, automatic traction control valve (if equipped), or one of the modulator valves is needed. For disassembly and assembly instructions, see **Subject 140**.

Installation

1. Install the new front modulator valve or rear modulator valve assembly on the mounting bracket. Tighten the fasteners 18 lbf·ft (24 N·m).
2. Connect the air lines to the valves, as marked during removal.
3. Connect the electrical cable connectors to the valves. Tighten only hand-tight.

Installation Checkout

1. Apply the brakes, turn the ignition switch on, and wait for the ABS indicator light to come on.
2. Listen to the modulator valves cycle one by one, then together diagonally as follows:
    - 4-Channel valve cycle: 1, 2, 3, 4; then 1 and 2 together followed by 3 and 4.
    - 6-Channel valve cycle: 1, 2, 3, 4, 5, 6; then 1, 2, and 3 together followed by 4, 5, and 6.
3. If a valve fails to cycle, turn the ignition switch off and make sure the electrical connections are tight. Then, turn the ignition switch on and listen to the valve cycle again.

    If a valve still fails to cycle, check for fault codes. See **Troubleshooting, 300** for fault-code identification.
4. Apply the brakes and check the modulator valve fittings for leaks. No air leakage is permitted.
5. Remove the chocks from the tires.

Modulator Valve Removal and Installation

6. Test drive the vehicle to verify that the ABS warning light is functioning correctly.

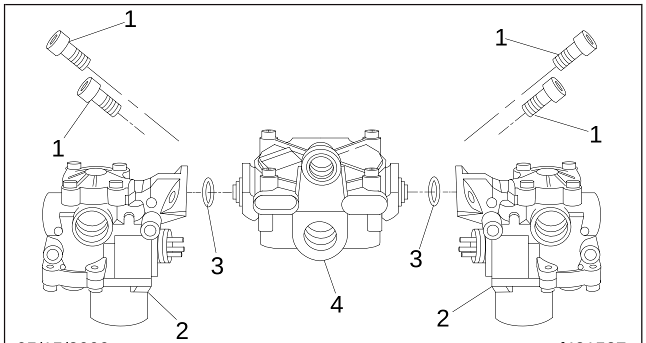
Modulator Valve Disassembly and Assembly

Disassembly

NOTE: On vehicles equipped with Automatic Traction Control (ATC), the ATC valve can be replaced without removing the modular valve assembly if there is enough room to work.

1. Remove the modulator valve assembly from the crossmember. See **Subject 130** for instructions.
2. Remove the modulator valves from the service relay valve.

   2.1 Using a 6-mm Allen wrench, remove two Allen-head capscrews that attach each modulator valve to the service relay valve. See **Fig. 1**.



1. Capscrew, Allen-Head, M8
2. Modulator Valve
3. O-Ring
4. Service Relay Valve

Fig. 1, Modulator Valve Assembly

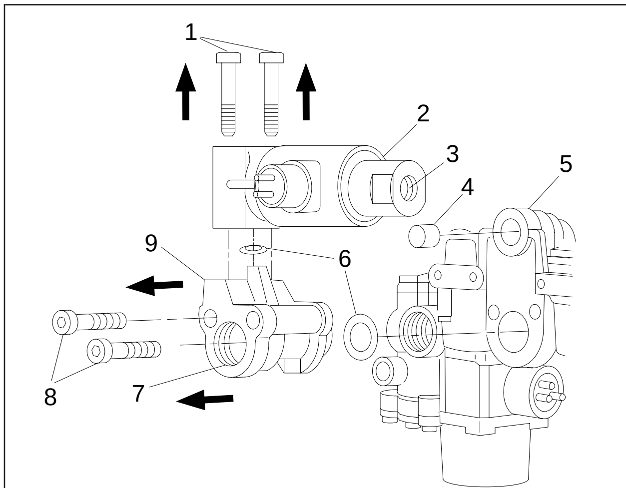
   2.2 Carefully separate the modulator valves from the service relay valve.

   2.3 Remove and discard the O-rings.

3. If the vehicle is equipped with Automatic Traction Control (ATC), remove the ATC valve from the service relay valve. See **Fig. 2**.

   3.1 Using a 5-mm Allen wrench, remove two Allen-head capscrews that attach the adaptor to the service relay valve. Remove the adapter/ATC valve assembly.

   3.2 Using a 6-mm Allen wrench, remove two Allen-head capscrews that attach the ATC valve to the adaptor. Separate the valve from the adaptor.



1. Capscrew, Allen-head, M8
2. ATC Valve
3. Control Port
4. Seal
5. Service Relay Valve
6. O-Ring
7. Supply Port
8. Capscrew, Allen-head, M6
9. Adaptor

Fig. 2, ATC Valve Mounting

   3.3 Remove and discard the seal and two O-rings.

Assembly

1. If the vehicle is equipped with Automatic Traction Control (ATC), install the ATC valve on the service relay valve.

   1.1 Clean the O-ring grooves on the adaptor. Lubricate the small replacement O-ring and install it in the top port in the adaptor.

   1.2 Using two new M8 Allen-head capscrews, install the ATC valve on the adaptor. Tighten the capscrews 12 to 13 lbf·ft (18 to 20 N·m).

   1.3 Lubricate the replacement seal and install it in the control port (upper port) of the service relay valve.

Modulator Valve Disassembly and Assembly

1.4 Lubricate the large replacement O-ring and install it in the groove in the supply port (lower port) of the service relay valve.

1.5 Using two new M6 Allen-head capscrews, install the adaptor on the service relay valve. Tighten the capscrews 48 to 60 lbf·in (542 to 678 N·cm).

2. Install the modulator valves on the service relay valve.

   2.1 Plug any unused ports on the replacement modulator valves.

   2.2 Clean the O-ring surfaces on the modulator and service relay valves. Lubricate the replacement O-rings and place them in the applicable grooves in the valves.

   2.3 Install each modulator valve on the service relay valve with two M8 Allen-head capscrews. Tighten the capscrews 13 to 15 lbf·ft (18 to 20 N·m).

3. Install the modulator valve assembly on the bracket on the crossmember. For instructions, see **Subject 130**.

Installation

IMPORTANT: Some ABS service hubs do not have a tone (tooth) ring installed on the hub. The tone ring must be ordered separately and installed on the hub before installation of the hub onto the axle. Tone rings are made of a special material and require a specific installation procedure for proper installation.

WARNING

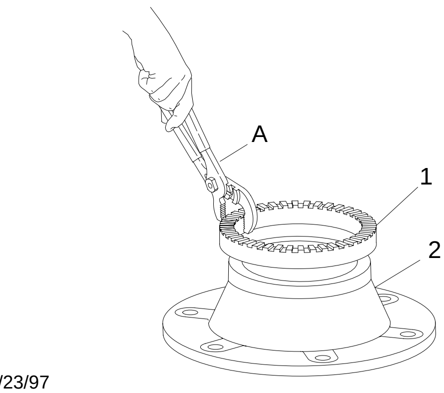
When installing an ABS system, special ABS hubs must be ordered. Machining older hubs to accommodate the installation of tone rings can cause problems due to insufficient hub bore wall thickness. Machining an older hub with insufficient hub bore wall thickness could result in cracking, causing bearing damage and wheel loss. This could cause an accident resulting in personal injury and property damage.

1. Submerge the tone ring in boiling water or place it in an oven at 250°F (121°C) for approximately 15 minutes.

CAUTION

Do not attempt to heat the tone ring with a torch as this can damage the ring.

2. Using pliers, remove the tone ring from the boiling water or oven and center it on the machined area of the hub bore. See **Fig. 1**.
3. While the tone ring is still hot, make sure it is properly centered on the machined surface. Using a rubber mallet, tap the tone ring until it bottoms out around the machined surface on the hub. See **Fig. 2**.
4. Install the hub on the axle. Place a dial indicator with a magnetic base so the dial indicator is against the tone-ring teeth. See **Fig. 3**.
5. Rotate the hub and check the ring for runout. The runout should be less than 0.005 inch (0.13 mm). See **Fig. 4**.
6. Install the wheel. For instructions, see **Group 40**.



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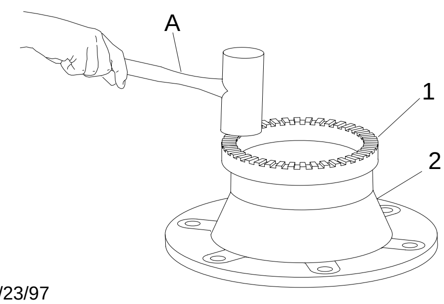
A. Use pliers to apply the ring.
1. Tone Ring 2. Hub

Fig. 1, Install the Ring on the Hub



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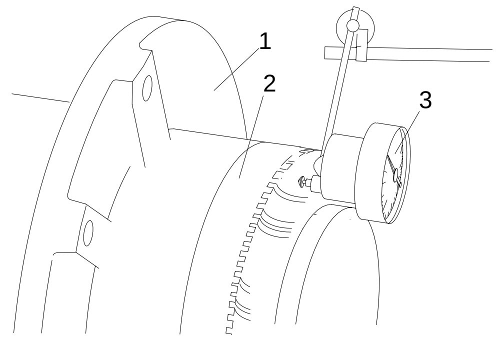
A. Use a rubber mallet.
1. Tone Ring 2. Hub

Fig. 2, Tap the Tone Ring



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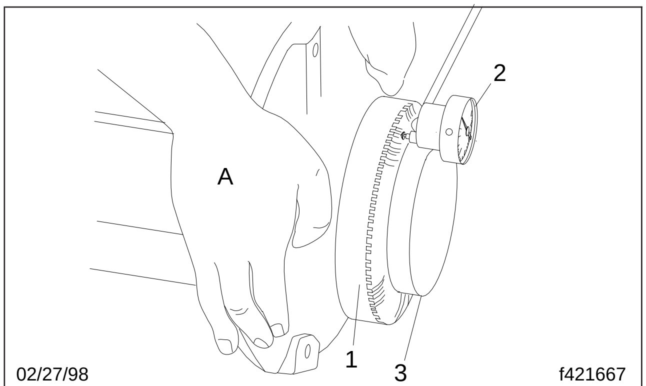
1. Hub
2. Tone Ring
3. Dial Indicator

Fig. 3, Position the Dial Indicator

ABS Tone Ring Installation on Service Hubs



A. Rotate the hub.
1. Tone Ring
2. Dial Indicator
3. Axle

Fig. 4, Check Tone-Ring Runout

Dynamometer Testing Vehicles with ATC

WARNING

Do not test a vehicle equipped with Automatic Traction Control (ATC) on a dynamometer unless the ATC system is disabled. Activation of the ATC on a dynamometer will cause unequal drive-wheel torque that can result in loss of vehicle control and personal injury or death.

Vehicles with ATC must have the ATC disabled before testing the vehicle on a dynamometer. Use one of the following methods to disable the ATC:

- Use the Meritor PC Diagnostics or the Pro-Link electronic diagnostic tool to disable the ATC.
- Press and hold the blink code switch for a least three seconds. Once the system identification code begins, the ATC system has been disabled. See **Table 1** for system ID codes.
- Removing the ABS circuit breaker or fuse, or removing the ECU power connector will disable both the ABS and ATC.

The ATC light on the dash comes on and stays on when the ATC is disabled.

System Identification Blink Codes *		
Blink Code	**Sensors/ Modulators**	**Wheel Positions**
1 Blink	6S/6M	6 x 2
2 Blinks	4S/4M	4 x 4
4 Blinks	6S/4M	6 x 4
5 Blinks	6S/6M	6 x 4

* The system identification blink code, followed by a 4-second pause, repeats until the ignition switch is turned off.

Table 1, System Identification Blink Codes

General Information

WARNING

Before testing a vehicle equipped with Automatic Traction Control (ATC) on a dynamometer, the ATC system must be disabled. See Subject 160 for instructions. Activation of the vehicle ATC on a dynamometer will cause unequal drive-wheel torque that can result in loss of vehicle control and personal injury or death.

Before testing a wheel speed sensor, modulator valve, or ATC valve, make sure the supply voltage to the antilock braking system (ABS) electronic control unit (ECU) is sufficient (see "ECU Supply Voltage Test") and check for leaks in the ABS pneumatic system.

The sensor and valve resistance tests are given in two steps. First, disconnect the applicable cable from the ECU and measure the resistance across the terminals in the cable connector. If the resistance is within the specified range, both the cable and the sensor or valve are good.

Next, if the resistance reading is not acceptable, disconnect the cable from the sensor or valve and measure the resistance across the sensor or valve terminals. This two-step procedure quickly determines whether the problem is in the cable or the component.

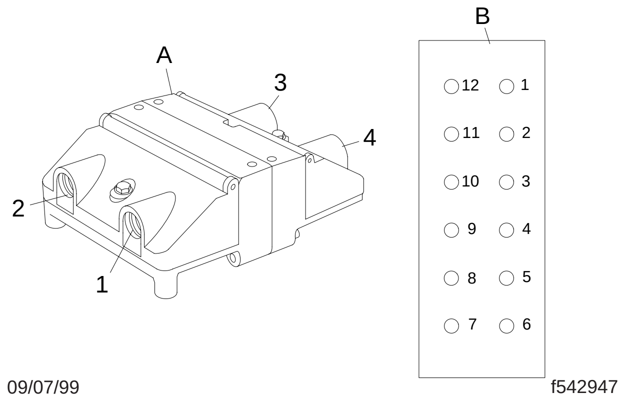
NOTE: The valve circuits and wheel sensors can be tested by Meritor PC diagnostics. If PC diagnostics indicate a problem, test the individual component to determine whether the component or the wiring has failed.

Wire Numbers and Connector Pin Locations

CAUTION

The ignition switch must be off when connecting or disconnecting connectors from the ECU. Power applied to the ECU during connector installation or removal could damage the pins.

The WABCO E-Version, frame-mounted ECU has several multi-pin connectors that must be disconnected to test the wheel speed sensors, modulator valves, or ATC valve. To disconnect the electrical connectors from the ABS ECU, remove the capscrews and lift the covers. See Fig. 1 to identify the pin locations on the ECU connector. Table 1 provides the wire numbers and circuit descriptions for testing the ABS/ATC components.



A. Frame-mounted ECU.
B. ECU connector pin locations.
1. X1 Connector (gray)
2. X2 Connector (black)
3. X3 Connector (green)
4. X4 Connector (not used)

Fig. 1, Frame-Mounted ECU and Pin Locations

ECU Supply Voltage Test

Use Meritor WABCO PC Diagnostics system to check the supply voltage to the ABS ECU. If the PC Diagnostics is not available, use the following procedure to check the voltage.

1. Park the vehicle on a level surface, set the parking brake, shut down the engine, and chock the rear tires.
2. Disconnect the X1 (gray) connector at the ABS ECU.
3. Turn the ignition switch on.
4. Connect a voltmeter between pin 1 and a good chassis ground. The voltmeter must indicate 9.5 to 14 volts.
5. Connect a voltmeter between pin 2 and a good chassis ground. The voltmeter must indicate 9.5 to 14 volts.

6. Turn the ignition switch off.
7. If the voltage at the ECU is not within the specified range, check the battery voltage and test the wiring to the ECU and to ground.
8. Connect the X1 connector to the ECU and remove the chocks from the tires.

ABS Pneumatic System Test

To check for air leaks in the ABS pneumatic system, listen for the sound of escaping air at each valve. To confirm a slow air leak, apply a soap-and-water solution to air line fittings and watch for bubbles.

Wheel Speed Sensor Tests

Wheel Speed Sensor and Circuit Resistance

To check the resistance in a wheel speed sensor circuit, perform the following test:

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Disconnect the sensor cable connector from the ABS ECU. See **Table 1**.

ABS/ATC Circuit Pin and Wire Numbers			
Pin Connector	**Pin Number**	**Wire Number**	**Circuit Description**
X1 Gray	1	376C	ECU Ignition Supply
	2	376C	ECU #2 Positive 12 Volt Supply
	3	376T	Wheel Spin Light and ATC Switch
	4	1587+	J1587+
	5	376R	Retarder Interrupt Signal
	6	1922-/1939-	J1922–/1939–
	7	1922+/1939+	J1922+/1939+
	9	1587	J1587–
	10	376L	ABS Light
	11	XGRD	ECU Ground
	12	XGRD	ECU Ground
X2 Black	1	—	Not used
	2	378LFI	Left Front Modulator Valve, In
	3	378RF0	Right Front Modulator Valve, Out
	4	378RFI	Right Front Modulator Valve, In
	5	377RF+	Right Front Sensor, High
	6	377RF–	Right Front Sensor, Low
	7	377LF–	Left Front Sensor, Low
	8	377LF+	Left Front Sensor, High
	9	378RF–	Right Front Modulator Valve, Ground
	10	378LF0	Left Front Modulator Valve, Out
	11	378LF–	Left Front Modulator Valve, Ground
	12	—	Not used

ABS/ATC Circuit Pin and Wire Numbers			
Pin Connector	Pin Number	Wire Number	Circuit Description
X3 Green	1	377LR+	Left Rear Sensor, High
	2	377LR–	Left Rear Sensor, Low
	3	377RR+	Right Rear Sensor, High
	4	377RR–	Right Rear Sensor, Low
	5	378T+	ATC Valve, High
	6	378T–	ATC Valve, Low
	7	378RR0	Right Rear Modulator Valve, Out
	8	378RR–	Right Rear Modulator Valve, Ground
	9	378RRI	Right Rear Modulator Valve, In
	10	378LR0	Left Rear Modulator Valve, Out
	11	378LR–	Left Rear Modulator Valve, Ground
	12	378LRI	Left Rear Modulator Valve, In

Table 1, ABS/ATC Circuit Pin and Wire Numbers

3. Connect ohmmeter probes to the sensor connector terminals and read the resistance.
   - If the resistance is 900 to 2000 ohms, the cable and the sensor circuit are good. Proceed to the "Wheel Speed Sensor Voltage" test.
   - If the resistance is less than 900 ohms or greater than 2000 ohms, perform the next test, "Wheel Speed Sensor Resistance."

Wheel Speed Sensor Resistance

To check the resistance in a wheel speed sensor, perform the following test:

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Disconnect the wheel sensor cable from the chassis harness.
3. Connect ohmmeter probes to the pins on the sensor and read the resistance.
   - If the resistance reading is 900 to 2000 ohms but the resistance noted in the previous test, "Wheel Speed Sensor and Circuit Resistance" was not, repair or replace the chassis harness wiring.
   - If the resistance is less than 900 ohms or greater than 2000 ohms, clean the terminals and check the resistance again.
   - If the resistance reading is still not correct, replace the sensor. See **Subject 110** for instructions.
4. Install the connectors and remove the chocks from the tires.

Wheel Speed Sensor Voltage

NOTE: PC diagnostics can be used for this test to compare speed signal output of all sensors. A problem will be indicated by low or erratic output.

To check the voltage output of a wheel speed sensor:

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine.
2. Chock the tires of the axle not being tested. Raise the vehicle and put jack stands under the axle so the wheels can rotate.
3. Disconnect the applicable connector from the ABS ECU for the sensor being tested. See **Table 1**.

4. Set a digital multimeter to the AC voltmeter mode. Connect the probes to the cable connector terminals for the sensor being tested.
5. Rotate the wheel by hand at a speed of 30 rpm (one-half revolution per second) and read the voltage output. The wheel speed sensor must generate a minimum of 0.2 volt AC.
   - If the voltage is at least 0.2 volt AC, skip to the next step.
   - If the voltage reading is less than 0.2 volt AC, push the sensor in its holder until the sensor touches the tooth wheel. See **Subject 120** for instructions. Repeat the voltage test.
   - If the sensor output is still less than 0.2 volt AC, replace the sensor.
6. Install the connector on the ECU. Remove the jack stands, lower the vehicle, and remove the chocks from the tires.

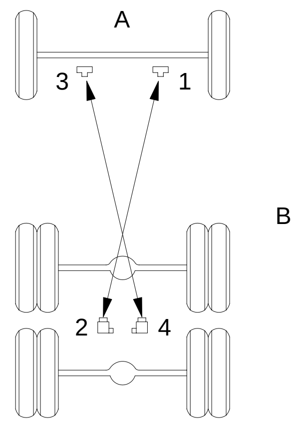
Modulator Valve Tests

Modulator Valve Function Check

NOTE: Valves can be tested using the Meritor WABCO PC Diagnostics software or the following procedure.

Modulator valves control the air pressure to each affected brake during an ABS function. To make sure the modulator valves are working, listen to them cycle during the ABS self-test.

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Turn the ignition switch on.
3. When the ABS warning light comes on, listen for the modulator valves to cycle one by one, then together diagonally. See **Fig. 2**.
   - 4-Channel valve cycle: 1, 2, 3, 4; then 1 and 2 together followed by 3 and 4.
   - 6-Channel valve cycle: 1, 2, 3, 4, 5, 6; then 1, 2, and 3 together followed by 4, 5, and 6.
4. If the valves do not all cycle correctly, turn the ignition off and check the connectors for tightness. Repeat the self-test.



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NOTE: During the self-test, the valves cycle one by one in order (1–2–3–4), then in pairs diagonally (1/2 and 3/4). A 4-channel valve cycle is shown.

A. Cab
B. Curbside
1. Right Front Modulator Valve
2. Left Rear Modulator Valve
3. Left Front Modulator Valve
4. Right Rear Modulator Valve

Fig. 2, Modulator Valve Self-Test Sequence

5. If the valves still do not cycle correctly, start the engine and check the air line connections to the valves for leaks. Shut down the engine and tighten the air line fittings. Repeat the self-test.
6. If the valves still do not cycle correctly, check for fault codes. Perform the next test, "Modulator Valve and Cable Resistance."

Modulator Valve and Cable Resistance

To check the resistance in a modulator valve and cable circuit, perform the following test:

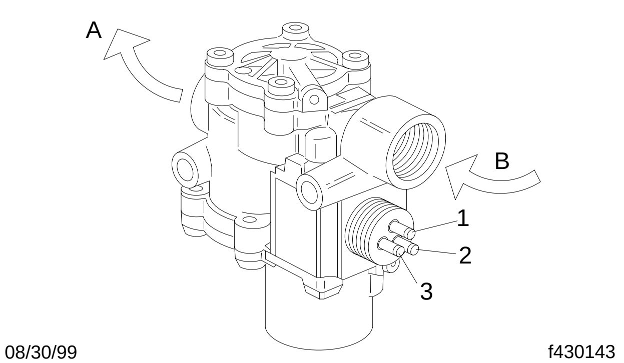
1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Disconnect the modulator valve connector from the ABS ECU. See **Table 1**.
3. Connect ohmmeter probes to the cable connector pins for the modulator valve "In" solenoid and "Ground." Read the resistance. Then, move the probes to the "Out" and "Ground" pins and read the resistance.

4. The resistance in each solenoid coil and cable circuit must be 4 to 8 ohms.
   - If the resistance in each solenoid circuit is 4 to 8 ohms, the cable and modulator valve are good. Install the connector on the ECU and remove the chocks from the tires.
   - If the resistance in either solenoid circuit is less than 4 ohms or greater than 8 ohms, go to the next test, "Modulator Valve Resistance."

Modulator Valve Resistance

To check the resistance in the solenoid coils in an ABS modulator valve, perform the following test:

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Disconnect the cable connector from the modulator valve being tested. See **Table 1**.
3. Connect ohmmeter probes to the modulator valve "In" solenoid and "Ground" terminals and read the resistance. Then, move the probes to the "Out" and "Ground" terminals and read the resistance. See **Fig. 3** for the modulator terminal locations.



A. Delivery Port
B. Supply Port
1. Ground (Common)
2. Exhaust Solenoid (Out)
3. Supply Solenoid (In)

Fig. 3, Modulator Valve Terminals

4. The resistance in each solenoid coil must be 4 to 8 ohms.
   - If the resistance in each solenoid coil is 4 to 8 ohms but the resistance noted in the previous test, "Modulator Valve and Cable Resistance" was not, repair or replace the chassis harness.
   - If the resistance is less than 4 ohms or greater than 8 ohms, clean the terminals on the modulator valve and check the resistance again.
   - If the resistance is still not correct, replace the valve. See **Subject 130** for instructions.
5. Install the cable connectors and remove the chocks from the tires.

ATC Valve Tests

ATC Valve and Cable Resistance

To check the resistance in the ATC valve and cable circuit, perform the following test:

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Disconnect the ATC valve connector (X3) from the ABS ECU. See **Table 1**.
3. Connect ohmmeter probes to the cable connector pins 5 and 6 for the ATC valve and read the resistance.
4. The resistance in the ATC solenoid coil and cable circuit must be 6.4 to 12 ohms.
   - If the resistance is 6.4 to 12 ohms, the ATC valve and cable are good. Install the cable connector on the ECU and remove the chocks from the tires.
   - If the resistance is less than 6.4 ohms or greater than 12 ohms go to the next test, "ATC Valve Resistance."

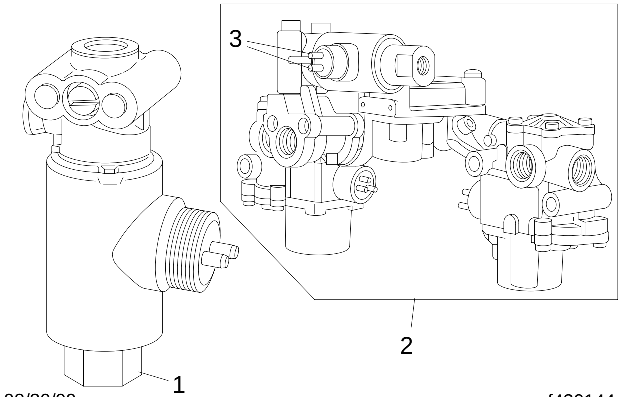
ATC Valve Resistance

To check the resistance in the solenoid coil in the ATC valve, perform the following test:

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.

Testing

2. Disconnect the cable connector from the ATC valve. See **Table 1**.
3. Connect ohmmeter probes to the ATC valve terminals and read the resistance. See **Fig. 4**.



1. ATC Valve
2. Rear Modulator Valve Assembly
3. ATC Solenoid Terminals

Fig. 4, ATC Valve Terminals

4. The resistance of the ATC solenoid coil and its wiring must be 6.4 to 12 ohms.
   - If the resistance is 6.4 to 12 ohms but the resistance noted in the previous test, "ATC Valve and Cable Resistance" was not, repair or replace the electrical cable.
   - If the resistance is less than 6.4 ohms or greater than 12 ohms, clean the terminals on the ATC valve and check the resistance again.
   - If the resistance is still not correct, replace the valve. See **Subject 140** for instructions.
5. Install the connectors and remove the chocks from the tires.

Troubleshooting Tables

Using the following tables, troubleshoot the ABS system by MID-SID.

J1587 Fault Code Cross-Reference		
MID-SID	Description	Troubleshooting Table
	Wheel Sensor	
136-001	Left Front	Table 2
136-002	Right Front	Table 3
136-003	Left Rear	Table 4
136-004	Right Rear	Table 5
	Modulator Valve	
136-007	Left Front	Table 6
136-008	Right Front	Table 7
136-009	Left Rear	Table 8
136-010	Right Rear	Table 9
136-014	Ground Faults	Table 10
136-015		Table 11
136-018	ATC Valve (if equipped)	Table 12
136-019	Auxiliary Output	Table 13
136-023	ABS Warning Lamp	See Subject 310
136-231	J1939 Datalink	Table 14
136-251	Voltage	Table 15
136-253	Configuration Errors	Table 16
136-254	Miscellaneous Faults	Table 17

Table 1, J1587 Fault Code Cross Reference

Left Front Wheel Sensor Troubleshooting (SID 001)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	001	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across pins 7 and 8 of the black X2 ECU connector while rotating the LF wheel 30 rpm.	Voltage is 0.2 Vac or greater	Sensor adjustment solved the problem.
					Voltage is less than 0.2 Vac	Check for excessive wheel bearing end play and hub runout. Repair as needed.
136	001	02	Incorrect tire size			Check for correct tire size and mixed tire sizes. Check for correct number of teeth on tone wheel. Correct as needed.
136	001	03	Sensor shorted to power	2. Measure the voltage across pins 7 of the X2 (black) connector and a good chassis ground. Repeat the test between pin 8 and ground.	Measurable voltage at either pin	Repair short to power in circuit(s) 377LF+ and 377LF– in chassis harness and sensor cable. If problem is in the sensor harness, replace the sensor.
					No voltage at either pin	Repeat the test and check for intermittent short to power in circuits 377LF+ and 377LF–. Suspect ECU is at fault if the problem persists.

ABS System Troubleshooting

Left Front Wheel Sensor Troubleshooting (SID 001)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	001	04	Short to ground	3. Measure the resistance between pin 7 of the X2 (black) connector and a good chassis ground. Repeat the test between pin 8 and ground.	Resistance between either pin and ground is less than 100,000 ohms	Repair the short to ground in circuit(s) 377LF+ and 377LF– in chassis harness or sensor cable. If problem is in sensor harness, replace the sensor.
					Resistance between either pin and ground is greater than 100,000 ohms	Repeat the test for intermittent short to ground in circuits 377LF+ and 377LF–. Suspect ECU is at fault if the problem persists.
136	001	05	Open circuit	4. Measure the resistance between pins 7u and 8 of the X2 (black) connector.	Resistance is 900–2000 ohms	Repeat the test and check for intermittent open or short in circuits 377LF+ and 377LF–. Suspect ECU at fault if the problem persists.
					Resistance is greater than 2000 ohms OR less than 900 ohm.	Perform test 5.
136	001	05	Open circuit	5. Disconnect the sensor connector from the chassis harness. Measure the resistance between the pins on the sensor connector.	Resistance is 900–2000 ohms	Repair open or short in circuit(s) 377LF+ and 377LF– in chassis harness.
					Resistance is greater than 2000 ohms OR less than 900 ohms	Replace the sensor.
136	001	06	Short circuit			Perform tests 4 and 5.
136	001	07	Damaged tone ring			Inspect tone ring for damage and missing teeth. Make sure correct tooth wheel is installed (100-tooth is normal application). Repair as needed.
136	001	08	Excessive wheel slip			Check sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.
136	001	09	Wire mismatch	6. Check for mixed sensor connection. Using Meritor PC Diagnostics, spin each wheel individually. Check that output is from the correct sensor.		Correct wiring connections, as needed.

ABS System Troubleshooting

Left Front Wheel Sensor Troubleshooting (SID 001)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	001	10	Intermittent signal	7. Adjust the sensor. Using the wheel sensor output screen in Meritor PC Diagnostics, spin the wheel or drive the vehicle and check for intermittent or erratic signal.	Signal output OK	Adjustment solved the problem. Make sure brake chatter is not causing the problem.
					Signal output incorrect	Check for intermittent wheel sensor circuit connections. Cause could be due to brake chatter. Repair as needed.
136	001	11	Erratic signal			Perform test 7.
136	001	12	Frequency too high	8. Check sensor wiring and connectors for intermittent contact.	Wiring OK	Suspect ECU at fault if problem persists.
					Wiring incorrect	Repair wheel sensor circuit, as needed.

Table 2, Left Front Wheel Sensor Troubleshooting (SID 001)

Right Front Wheel Sensor Troubleshooting (SID 002)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	002	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across pins 5 and 6 of the black X2 ECU connector while rotating the RF wheel 30 rpm.	Voltage is 0.2 Vac or greater	Sensor adjustment solved the problem.
					Voltage is less than 0.2 Vac	Check for excessive wheel bearing end play and hub runout. Repair as needed.
136	002	02	Incorrect tire size			Check for correct tire size and mixed tire sizes. Check for correct number of teeth on tone wheel. Correct as needed.
136	002	03	Sensor shorted to power	2. Measure the voltage across pin 5 of the X2 (black) connector and a good chassis ground. Repeat the test between pin 8 and ground.	Measurable voltage at either pin	Repair short to power in circuit(s) 377RF+ and 377RF– in chassis harness and sensor cable. If problem is in the sensor harness, replace the sensor.
					No voltage at either pin	Repeat the test and check for intermittent short to power in circuits 377RF+ and 377RF–. Suspect ECU is at fault if the problem persists.

ABS System Troubleshooting

Right Front Wheel Sensor Troubleshooting (SID 002)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	002	04	Short to ground	3. Measure the resistance between pin 5 of the X2 (black) connector and a good chassis ground. Repeat the test between pin 6 and ground.	Resistance between either pin and ground is less than 100,000 ohms	Repair the short to ground in circuit(s) 377RF+ and 377RF– in chassis harness or sensor cable. If problem is in sensor harness, replace the sensor.
					Resistance between either pin and ground is greater than 100,000 ohms	Repeat the test for intermittent short to ground in circuits 377RF+ and 377RF–. Suspect ECU is at fault if the problem persists.
136	002	05	Open circuit	4. Measure the resistance between pins 5 and 6 of the X2 (black) connector.	Resistance is 900–2000 ohms	Repeat the test and check for intermittent open or short in circuits 377RF+ and 377RF–. Suspect ECU at fault if the problem persists.
					Resistance is greater than 2000 ohms OR less than 900 ohm.	Perform test 5.
				5. Disconnect the sensor connector from the chassis harness. Measure the resistance between the pins on the sensor connector.	Resistance is 900–2000 ohms	Repair open or short in circuit(s) 377RF+ and 377RF– in chassis harness.
					Resistance is greater than 2000 ohms OR less than 900 ohms	Replace the sensor.
136	002	06	Short circuit			Perform tests 4 and 5.
136	002	07	Damaged tone ring			Inspect tone ring for damage and missing teeth. Make sure correct tooth wheel is installed (100-tooth is normal application). Repair as needed.
136	002	08	Excessive wheel slip			Check sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.
136	002	09	Wire mismatch	6. Check for mixed sensor connection. Using Meritor PC Diagnostics, spin each wheel individually. Check that output is from the correct sensor.		Correct wiring connections, as needed.

ABS System Troubleshooting

Right Front Wheel Sensor Troubleshooting (SID 002)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	002	10	Intermittent signal	7. Adjust the sensor. Using the wheel sensor output screen in Meritor PC Diagnostics, spin the wheel or drive the vehicle and check for intermittent or erratic signal.	Signal output OK	Adjustment solved the problem. Make sure brake chatter is not causing the problem.
					Signal output incorrect	Check for intermittent wheel sensor circuit connections. Cause could be due to brake chatter. Repair as needed.
136	002	11	Erratic signal			Perform test 7.
136	002	12	Frequency too high	8. Check sensor wiring and connectors for intermittent contact.	Wiring OK	Suspect ECU at fault if problem persists.
					Wiring incorrect	Repair wheel sensor circuit, as needed.

Table 3, Right Front Wheel Sensor Troubleshooting (SID 002)

Left Rear Wheel Sensor Troubleshooting (SID 003)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	003	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across pins 1 and 2 of the black X2 ECU connector while rotating the LR wheel 30 rpm.	Voltage is 0.2 Vac or greater	Sensor adjustment solved the problem.
					Voltage is less than 0.2 Vac	Check for excessive wheel bearing end play and hub runout. Repair as needed.
136	003	02	Incorrect tire size			Check for correct tire size and mixed tire sizes. Check for correct number of teeth on tone wheel. Correct as needed.
136	003	03	Sensor shorted to power	2. Measure the voltage across pin 1 of the X3 (green) connector and a good chassis ground. Repeat the test between pin 2 and ground.	Measurable voltage at either pin	Repair short to power in circuit(s) 377LR+ and 377LR– in chassis harness and sensor cable. If problem is in the sensor harness, replace the sensor.
					No voltage at either pin	Repeat the test and check for intermittent short to power in circuits 377LR+ and 377LR–. Suspect ECU is at fault if the problem persists.

ABS System Troubleshooting

Left Rear Wheel Sensor Troubleshooting (SID 003)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	003	04	Short to ground	3. Measure the resistance between pin 1 of the X3 (green) connector and a good chassis ground. Repeat the test between pin 2 and ground.	Resistance between either pin and ground is less than 100,000 ohms	Repair the short to ground in circuit(s) 377LR+ and 377LR– in chassis harness or sensor cable. If problem is in sensor harness, replace the sensor.
					Resistance between either pin and ground is greater than 100,000 ohms	Repeat the test for intermittent short to ground in circuits 377LR+ and 377LR–. Suspect ECU is at fault if the problem persists.
136	003	05	Open circuit	4. Measure the resistance between pins 1 and 2 of the X3 (green) connector.	Resistance is 900–2000 ohms	Repeat the test and check for intermittent open or short in circuits 377LR+ and 377LR–. Suspect ECU at fault if the problem persists.
					Resistance is greater than 2000 ohms OR less than 900 ohm.	Perform test 5.
				5. Disconnect the sensor connector from the chassis harness. Measure the resistance between the pins on the sensor connector.	Resistance is 900–2000 ohms	Repair open or short in circuit(s) 377LR+ and 377LR– in chassis harness.
					Resistance is greater than 2000 ohms OR less than 900 ohms	Replace the sensor.
136	003	06	Short circuit			Perform tests 4 and 5.
136	003	07	Damaged tone ring			Inspect tone ring for damage and missing teeth. Make sure correct tooth wheel is installed (100-tooth is normal application). Repair as needed.
136	003	08	Excessive wheel slip			Check sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.
136	003	09	Wire mismatch	6. Check for mixed sensor connection. Using Meritor PC Diagnostics, spin each wheel individually. Check that output is from the correct sensor.		Correct wiring connections, as needed.

Left Rear Wheel Sensor Troubleshooting (SID 003)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	003	10	Intermittent signal	7. Adjust the sensor. Using the wheel sensor output screen in Meritor PC Diagnostics, spin the wheel or drive the vehicle and check for intermittent or erratic signal.	Signal output OK	Adjustment solved the problem. Make sure brake chatter is not causing the problem.
					Signal output incorrect	Check for intermittent wheel sensor circuit connections. Cause could be due to brake chatter. Repair as needed.
136	003	11	Erratic signal			Perform test 7.
136	003	12	Frequency too high	8. Check sensor wiring and connectors for intermittent contact.	Wiring OK	Suspect ECU at fault if problem persists.
					Wiring incorrect	Repair wheel sensor circuit, as needed.

Table 4, Left Rear Wheel Sensor Troubleshooting (SID 003)

Right Rear Wheel Sensor Troubleshooting (SID 004)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	004	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across pins 3 and 4 of the black X2 ECU connector while rotating the RR wheel 30 rpm.	Voltage is 0.2 VAC or greater	Sensor adjustment solved the problem.
					Voltage is less than 0.2 VAC	Check for excessive wheel bearing end play and hub runout. Repair as needed.
136	004	02	Incorrect tire size			Check for correct tire size and mixed tire sizes. Check for correct number of teeth on tone wheel. Correct as needed.
136	004	03	Sensor shorted to power	2. Measure the voltage across pin 3 of the X3 (green) connector and a good chassis ground. Repeat the test between pin 4 and ground.	Measurable voltage at either pin	Repair short to power in circuit(s) 377RR+ and 377RR– in chassis harness and sensor cable. If problem is in the sensor harness, replace the sensor.
					No voltage at either pin	Repeat the test and check for intermittent short to power in circuits 377RR+ and 377RR–. Suspect ECU is at fault if the problem persists.

ABS System Troubleshooting

Right Rear Wheel Sensor Troubleshooting (SID 004)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	004	04	Short to ground	3. Measure the resistance between pin 3 of the X3 (green) connector and a good chassis ground. Repeat the test between pin 4 and ground.	Resistance between either pin and ground is less than 100,000 ohms	Repair the short to ground in circuit(s) 377RR+ and 377RR– in chassis harness or sensor cable. If problem is in sensor harness, replace the sensor.
					Resistance between either pin and ground is greater than 100,000 ohms	Repeat the test for intermittent short to ground in circuits 377RR+ and 377RR–. Suspect ECU is at fault if the problem persists.
136	004	05	Open circuit	4. Measure the resistance between pins 3 and 4 of the X3 (green) connector.	Resistance is 900–2000 ohms	Repeat the test and check for intermittent open or short in circuits 377RR+ and 377RR–. Suspect ECU at fault if the problem persists.
					Resistance is greater than 2000 ohms OR less than 900 ohm.	Perform test 5.
				5. Disconnect the sensor connector from the chassis harness. Measure the resistance between the pins on the sensor connector.	Resistance is 900–2000 ohms	Repair open or short in circuit(s) 377RR+ and 377RR– in chassis harness.
					Resistance is greater than 2000 ohms OR less than 900 ohms	Replace the sensor.
136	004	06	Short circuit			Perform tests 4 and 5.
136	004	07	Damaged tone ring			Inspect tone ring for damage and missing teeth. Make sure correct tooth wheel is installed (100-tooth is normal application). Repair as needed.
136	004	08	Excessive wheel slip			Check sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.
136	004	09	Wire mismatch	6. Check for mixed sensor connection. Using Meritor PC Diagnostics, spin each wheel individually. Check that output is from the correct sensor.		Correct wiring connections, as needed.

Right Rear Wheel Sensor Troubleshooting (SID 004)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	004	10	Intermittent signal	7. Adjust the sensor. Using the wheel sensor output screen in Meritor PC Diagnostics, spin the wheel or drive the vehicle and check for intermittent or erratic signal.	Signal output OK	Adjustment solved the problem. Make sure brake chatter is not causing the problem.
					Signal output incorrect	Check for intermittent wheel sensor circuit connections. Cause could be due to brake chatter. Repair as needed.
136	004	11	Erratic signal			Perform test 7.
136	004	12	Frequency too high	8. Check sensor wiring and connectors for intermittent contact.	Wiring OK	Suspect ECU at fault if problem persists.
					Wiring incorrect	Repair wheel sensor circuit, as needed.

Table 5, Right Rear Wheel Sensor Troubleshooting (SID 004)

Left Front Modulator Valve Troubleshooting (SID 007)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	007	03	Short to power *Inlet or outlet circuit shorted to battery supply or another modulator valve wire.*	1. Measure the voltage between pins 2, 10, and 11 of the X2 (black) connector and a good chassis ground.	No voltage at either pin	Repeat test. Check circuits 378LFI, 378LFO, and 378LF– for intermittent short to power. Check above circuits for shorts to other modulator valve wires. Repair as necessary. If problem persists, the suspect ECU is at fault.
					Measurable voltage at either pin	Repair short to power in circuit 378LFI, 378LFO, or 378LF–.
136	007	05	Open circuit Inlet or outlet circuit open.	2. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 8 ohms.	Check harness wiring circuits 378LFI, 378LFO, or 378LF–.
					Resistance in both circuits is not within 4 to 8 ohms.	Replace the modulator valve.
136	007	06	Short to ground *Inlet or outlet circuit shorted to ground.*	3. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve test.	Resistance in both circuits is within 4 to 8 ohms.	Check harness wiring circuits 378LFI, 378LFO, or 378LF– for short to ground. Repair as necessary.
					Resistance in both circuits is not within 4 to 8 ohms.	Replace modulator valve.

Table 6, Left Front Modulator Valve Troubleshooting (SID 007)

ABS System Troubleshooting

Right Front Modulator Valve Troubleshooting (SID 008)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	008	03	Short to power *Inlet or outlet circuit shorted to battery supply or another modulator valve wire.*	1. Measure the voltage between pins 3, 4, and 9 of the X2 (black) connector and a good chassis ground.	No voltage at either pin	Repeat test. Check circuits 378RFO, 378RFI, and 378RF– for intermittent short to power. Check above circuits for shorts to other modulator valve wires. Repair as necessary. If problem persists, the suspect ECU is at fault.
					Measurable voltage at either pin	Repair short to power in circuit 378RFO, 378RFI, or 378RF–.
136	008	05	Open circuit Inlet or outlet circuit open.	2. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 8 ohms.	Check harness wiring circuits 378RFO, 378RFI, or 378RF–.
					Resistance in both circuits is not within 4 to 8 ohms.	Replace the modulator valve.
136	008	06	Short to ground *Inlet or outlet circuit shorted to ground.*	3. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve test.	Resistance in both circuits is within 4 to 8 ohms.	Check harness wiring circuits 378RFO, 378RFI, or 378RF– for short to ground. Repair as necessary.
					Resistance in both circuits is not within 4 to 8 ohms.	Replace modulator valve.

Table 7, Right Front Modulator Valve Troubleshooting (SID 008)

Left Rear Modulator Valve Troubleshooting (SID 009)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	009	03	Short to power *Inlet or outlet circuit shorted to battery supply or another modulator valve wire.*	1. Measure the voltage between pins 10, 11, and 12 of the X3 (green) connector and a good chassis ground.	No voltage at either pin	Repeat test. Check circuits 378LRI, 378LRO, and 378LR– for intermittent short to power. Check above circuits for shorts to other modulator valve wires. Repair as necessary. If problem persists, the suspect ECU is at fault.
					Measurable voltage at either pin	Repair short to power in circuit 378LRI, 378LRO, or 378LR–.
136	009	05	Open circuit Inlet or outlet circuit open.	2. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 8 ohms.	Check harness wiring circuits 378LRI, 378LRO, and 378LR–.
					Resistance in both circuits is not within 4 to 8 ohms.	Replace the modulator valve.

Left Rear Modulator Valve Troubleshooting (SID 009)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	009	06	Short to ground *Inlet or outlet circuit shorted to ground.*	3. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve test.	Resistance in both circuits is within 4 to 8 ohms.	Check harness wiring circuits 378LRI, 378LRO, and 378LR– for short to ground. Repair as necessary.
					Resistance in both circuits is not within 4 to 8 ohms.	Replace modulator valve.

Table 8, Left Rear Modulator Valve Troubleshooting (SID 009)

Right Rear Modulator Valve Troubleshooting (SID 010)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	010	03	Short to power *Inlet or outlet circuit shorted to battery supply or another modulator valve wire.*	1. Measure the voltage between pins 7, 8, and 9 of the X3 (green) connector and a good chassis ground.	No voltage at either pin	Repeat test. Check circuits 378RRO, 378RR–, and 378RRI for intermittent short to power. Check above circuits for shorts to other modulator valve wires. Repair as necessary. If problem persists, the suspect ECU is at fault.
					Measurable voltage at either pin	Repair short to power in circuit 378RRO, 378RR–, or 378RRI.
136	010	05	Open circuit Inlet or outlet circuit open.	2. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve test.	Resistance in both circuits is within 4 to 8 ohms.	Check harness wiring circuits 378RRO, 378RRI, and 378RR–.
					Resistance in both circuits is not within 4 to 8 ohms.	Replace the modulator valve.
136	010	06	Short to ground *Inlet or outlet circuit shorted to ground.*	3. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve test.	Resistance in both circuits is within 4 to 8 ohms.	Check harness wiring circuits 378RRI, 378RRO, and 378RR– for short to ground. Repair as necessary.
					Resistance in both circuits is not within 4 to 8 ohms.	Replace modulator valve.

Table 9, Right Rear Modulator Valve Troubleshooting (SID 010)

ABS System Troubleshooting

Ground Faults Troubleshooting (SID 014)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	014	04	Low voltage or open circuit	1. Disconnect the X1 (gray) connector at the ABS ECU. With the ignition ON, measure the voltage between pins 1 and 12.	Voltage is 9.5 to 14 volts.	System voltage is acceptable. Check for intermittent low voltage. Check the batteries and charging system. Voltage may have been temporarily too low. Repair as necessary.
					Voltage is less than 9.5 volts.	Check vehicle batteries and charging system. Check ABS ECU power and ground circuits for open or high resistance. Repair as necessary.
136	014	05	Central group open or high resistance	2. Disconnect the X1 (gray) connector at the ABS ECU. Check the ground circuit (pin 11) for high resistance or open circuit.	Ground is okay	Verify the fault. Check the ground circuits for open or high resistance. Repair as necessary.
					Ground is open or has high resistance	Repair ground circuit as necessary.
136	014	06	Internal relay does not open			If fault repeats, replace the ABS ECU.

Table 10, Ground Faults Troubleshooting (SID 014)

Ground Faults Troubleshooting (SID 015)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	015	03	ATC valve grounded to power.	1. Disconnect the X3 (green) connector, check for voltage between pin 6 and ground.	Voltage at pin 6.	Circuit 378T- is shorted to power. Locate fault and repair as necessary.
					No voltage at pin 6.	Verify fault. Check for intermittent fault in circuit 378-, repair as necessary.
136	015	04	Low voltage or open circuit	2. Disconnect the X1 (gray) connector at the ABS ECU. With the ignition ON, measure the voltage between pin 2 and a good ground.	Voltage is 9.5 to 14 volts	System voltage is acceptable. Check for intermittent low voltage. Check the batteries and charging system. Voltage may have been temporarily too low. Repair as necessary.
					Voltage is less than 9.5 volts	Repair voltage supply to ECU.
136	015	05	ATC Valve - High Impedance			Replace ABS ECU if fault persists.
		06	ATC Valve circuit shorted to ground	Disconnect the X3 (green) connector, check resistance between pin 6 and a good ground.	Resistance is less than 10,000 ohms	Verify fault. Check for intermittent fault in circuit 378-, repair as necessary.
					Resistance is great than 10,000 ohms	Verify fault. Check for intermittent fault in circuit 378T-, repair as necessary.

Ground Faults Troubleshooting (SID 015)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	015	07	Internal relay fault			If fault repeats, replace the ABS ECU.

Table 11, Ground Faults Troubleshooting (SID 015)

ATC Valve Troubleshooting (SID 018)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	018	03	Short to power.	1. Disconnect the X3 (green) connector from the ABS ECU. Disconnect the ATC valve connector. Measure the voltage between pin 5 of the X3 (green) connector and a good chassis harness.	Voltage	Circuit 378T+ is shorted to power. Repair as necessary.
					No voltage	Check circuit 378+ for intermittent short to power. Repair as necessary. If fault persists, suspect ECU at fault.
136	018	05	Open circuit	2. Disconnect the ATC Valve connector. Measure the resistance across the two pins of the ATC valve. NOTE If the vehicle does not have an ATC valve, reconfigure the ECU.	Resistance is 7 to 14 ohms.	Go to step 3.
					Resistance is not 7 to 14 ohms.	Replace ATC Valve.
				3. Reconnect the ATC valve connector. Measure the resistance across pins 5 and 6 of the X3 connector.	Resistance is 7 to 14 ohms.	Verify fault. Check for intermittent open circuit in 376T+ and 376 T-. Repair as necessary.
					Resistance is not 7 to 14 ohms.	Repair circuit 376T+ or 376T-.
136	018	07	Short to ground.	4. Disconnect the X3 (green) connector, check resistance between pin 6 and a good ground.	Continuity	Circuit 376T+ is shorted to ground. Repair as necessary.
					No continuity	Verify fault. Check circuit 376T+ for intermittent short to ground. Repair as necessary.

Table 12, ATC Valve Troubleshooting (SID 018)

ABS System Troubleshooting

Auxiliary Output Troubleshooting (not currently used) (SID 019)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	019	03	Short to power.			This fault should not appear. Reconfigure the ECU. If fault continues to appear, check the wiring in the X2 (black) connector. This ABS ECU connector should be unused. Make sure there are no connections to these pins. If incorrect wiring is found, correct it and reconfigure the ECU. If this does not correct the problem, contact Meritor.
136	019	05	Open circuit			Verify fault. Contact Meritor WABCO if fault persists.
136	019	06	Short to ground			This fault should not appear. Reconfigure the ECU. If fault continues to appear, check the wiring in the X2 (black) connector. This ABS ECU connector should be unused. Make sure there are no connections to these pins. If incorrect wiring is found, correct it and reconfigure the ECU. If this does not correct the problem, contact Meritor.

Table 13, Auxiliary Output Troubleshooting (SID 019)

J1939 Datalink Troubleshooting (SID 231)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	231	02	J1939 speed plausibility error. NOTE: This fault indicates a discrepancy between vehicle speed reported on J1939 and ABS sensed vehicle speed.			Check the speedometer calibration. Check for the tire size mismatch. The vehicle speed reported on the J1939 databus does not agree with the wheel sensor speeds.
136	231	05	J1939 open/short	Refer to SB 54-133 for troubleshooting J1939.		Repair J1939 datalink as necessary.
136	231	06	J1939 open/short Code 13s231 05 may be active as well.	Check the driveline retarder ECU and wires. Check the J1939 Datalink. Freightliner SB 54-133		Repair J1939 datalink as necessary.

J1939 Datalink Troubleshooting (SID 231)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	231	07	J1939 time out NOTE: Fault occurs if engine retarder sends message incorrectly.	Check the driveline retarder ECU and wires. Freightliner SB 54-133		Check J1939 datalink and driveline retarder ECU. Repair as necessary.
136	231	08	J1939 time out NOTE: Fault occurs if engine retarder sends message incorrectly.	Check engine ECU and wires. Check J1939 datalink. Freightliner SB 54-133		Check J1939 datalink and engine ECU. Repair as necessary.
136	231	09	J1939 time out NOTE: Fault occurs if engine retarder sends message incorrectly.	Check engine and transmission ECUs and wires. Check J1939 datalink. Freightliner SB 54-133		Check J1939 datalink, engine ECU, transmission ECU, and wiring. Repair as necessary.
136	231	10	J1939 time out NOTE: Fault occurs if the exhaust retarder sends a message incorrectly.	Check the engine ECU and wires. Check the J1939 datalink. Freightliner SB 54-133		Check J1939 datalink and engine ECU. Repair as necessary.
136	231	12	J1939 internal error			Verify fault. Clear code from the ECU memory. If fault persists, replace the ABS ECU.

Table 14, J1939 Datalink Troubleshooting (SID 231)

Voltage Troubleshooting (SID 251)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	251	03	Overvoltage Voltage to ECU was too high for more than 5 seconds.	Using Meritor PC Diagnostics, check the diagonal voltages with the engine running at governed speed, or measure the voltage at the batteries with the engine running at governed speed.	Voltage is 9.5 to 14 volts	Check for intermittent sources of high voltage. Check condition of charging system and batteries. Verify fault.
					Voltage is greater than 14 volts.	Check charging system. Repair as necessary.

Table 15, Voltage Troubleshooting (SID 251)

ABS System Troubleshooting

Configuration Errors Troubleshooting (SID 253)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	253	01	ATC configuration error NOTE: ATC valve is detected without engine datalink (J1939).			Check J1939 for proper wiring. Check engine ECU for communication. Repair as necessary, then reconfigure ECU.
136	253	02	ABS configuration/ wheel parameter incorrect.			Reconfigure ECU. If fault repeats then the wrong ECU is installed. Replace with the correct ECU.
136	253	12	Check sum error.			Check parameter setting. Check if diagnostic device was disconnected during active diagnosis.

Table 16, Configuration Errors Troubleshooting (SID 253)

Miscellaneous Faults Troubleshooting (SID 254)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	254	05	ABS/ATC ECU, no loads			No modulator valve connected. Fault may have resulted from end of line test at factory.
136	254	08	Excessive wheel slip.			Check wheel speed sensor air gaps. One wheel was much faster than the other. May have been caused by testing vehicle on a dynamometer.
136	254	09	Modulator valve actuated too long.			Modulator valve was activated too long (more than 75% of 5 minutes). After a delay, function will return to normal.
136	254	12	Internal error			If fault persists, replace the ABS ECU.
136	254	13	Accelerometer out of range			If fault persists, replace the ABS ECU.

Miscellaneous Faults Troubleshooting (SID 254)						
MID	SID	FMI	Problem	Test	Test Result	Action
136	254	14	ECU Mounting			Check ECU mounting. Replace the ECU if fault persists.
			Extreme banked road (measured acceleration not plausible)			No correction required. This fault is for reporting only.
			Accelerometer linearity (measured acceleration not plausible)			

Table 17, Miscellaneous Faults Troubleshooting (SID 254)

PLC Troubleshooting

Special tools to test PLC are currently in development and will be available soon. It is anticipated that these tools will have the capability to do the following:

- Simulate a trailer ABS PLC message to the tractor ABS ECU to turn on the trailer ABS warning lamp. This tests the functionality of the vehicle portion of the system.
- Detect a PLC message from the trailer ABS. This tests the functionality of the trailer portion of the system.

At present, the only way to test the trailer ABS warning lamp system with PLC is to connect the vehicle to a trailer with PLC. When the ignition is turned on, the trailer ABS lamp should come on for a few seconds, then go out. This indicates that there is PLC communications, the warning lamp works, and there are no faults in the trailer ABS. If the trailer ABS lamp remains on, there is a fault in the trailer ABS. Refer to the trailer ABS manufacturer’s literature for troubleshooting the trailer ABS system.

NOTE: It is also possible that the trailer ABS lamp circuit is shorted to ground, causing the lamp to stay on.

PLC Filter Testing

Testing of the PLC filter is possible. Before performing these tests make sure the ignition is OFF. Disconnect the 2-wire connector (green/yellow wires) and the 2-wire connector (blue wires) from the filter.

The PLC filter is located near the trailer receptacle on the frame rail or crossmember. Follow the single blue wire from the PLC filter to the primary or supplemental receptacle. Whichever trailer receptacle the blue wire is connected to carries the PLC signal.

NOTE: For the following steps, you will need a digital multimeter (DMM) with capacitance measuring capability.

1. At the 2-pin connector with the green and yellow wires, use a DMM to measure the resistance across the green and yellow wires.
   - If the reading is less than 0.5 ohms, go to the next step.
   - If the reading is more than 0.5 ohms, the tractor ABS power circuit is open in the PLC filter. Replace the filter.
2. Determine the receptacle (primary or supplemental) that supplies power to the trailer ABS. Using a DMM, connect one lead to pin 7 of the receptacle that supplies power to the trailer ABS and the other lead to the 2-pin connector on the PLC filter that has the two blue wires. Measure the resistance at both pins on the 2-pin connector.
   - If the reading is less than 1.0 ohm, go to the next step.
   - If the reading is more than 1.0 ohm, there is an open circuit either between the 7-way trailer receptacle and the PLC filter, or in the PLC filter itself. Repair the harness or replace the PLC filter as necessary.

ABS System Troubleshooting

3. At the PLC filter, connect one lead of the DMM to the green wire (at the 2-pin connector with the green and yellow wires) and the other lead to one of the blue wires (at the 2-pin connector with the two blue wires). Measure the capacitance.
   - If the reading is 4.8 to 7.2 µF, go to the next step.
   - If the reading is less than 4.8 or more than 7.2 µF, one or more of the internal capacitors is faulty. This may affect PLC functionality and/or noise in the electrical system. Replace the PLC filter.
4. At the PLC filter, connect one lead of the DMM to one of the blue wires (at the 2-pin connector that has the two blue wires) and connect the other lead to the ground where the white wire terminates. Measure the capacitance.
   - If the reading is 9.91 to 11.91 µF, the PLC filter is functioning properly.
   - If the reading is less than 9.91 or more than 11.91 µF, check and clean the ground connection where the white wire terminates and retest. If the reading is still unsatisfactory, one or more of the internal capacitors is faulty. This may affect PLC functionality and/or noise in the electrical system. Replace the PLC filter.

Trailer ABS Warning Lamp Troubleshooting		
Symptom	**Possible Cause**	**Action**
Trailer ABS lamp does not come on when the ignition is turned on.	There is no trailer connected or the trailer is not equipped with PLC.	The trailer ABS lamp will not illuminate at start-up unless a trailer equipped with PLC is connected to the vehicle. Trailers manufactured on or after March 1, 2001 are equipped with PLC.
	The vehicle is not equipped with PLC.	Verify that the vehicle has PLC. Check the vehicle ABS ECU: • WABCO E-Version ABS ECUs have PLC. • Bendix ABS EC-30 ECUs have PLC unless there is a label on it that says "ECU does not control trailer ABS warning lamp." • Eaton Gen 5 ABS ECU has PLC. Check if vehicle was manufactured on or after March 1, 2001.
	The trailer ABS warning lamp bulb is burned-out.	Replace the bulb.
	There is a circuit fault between the tractor ABS ECU and the trailer ABS warning lamp in the dash.	Check and correct, if necessary. The trailer ABS warning lamp circuit can be tested at the tractor ABS ECU by grounding the pin to that circuit. This should cause the lamp to illuminate.
	There is faulty wiring (power or ground).	Check and correct as necessary.
	The PLC filter is faulty.	Check and replace as necessary.
	The tractor ABS ECU is faulty.	Be sure to check the trailer ABS lamp circuit and try connecting vehicle to a trailer where PLC is known to work. If the tractor ABS ECU is still faulty, replace.
	The trailer ABS ECU is faulty.	Be sure to check the trailer ABS lamp circuit and try connecting trailer to a vehicle where PLC is known to work. If the trailer ABS ECU is still faulty, replace.
Trailer ABS lamp stays on.	There is a trailer ABS fault.	Refer to the trailer ABS manufacturers literature for troubleshooting. Repair as necessary.
	Trailer ABS lamp circuit shorted to ground.	Repair as necessary.

Table 18, Trailer ABS Warning Lamp Troubleshooting

ABS Warning Lamp Function

The ABS warning lamp in the instrument cluster warns the driver of a malfunction in the anti-lock brake system. When the system is operating normally, the lamp should come on for a few seconds when the ignition is first turned on, then it should turn off. If a fault occurs in the system, the lamp will illuminate as long as the fault remains active. If a wheel sensor fault is repaired or if the system is reconfigured, the light will remain on until the vehicle is driven over 4 mph (6.4 km/h).

The ABS warning lamp can be controlled by any of the following ways:

- **By wire (circuit 376L1):** The ABS warning lamp is hardwired between the ABS ECU and the instrument cluster through a relay. When the circuit to pin B11 at the instrument cluster is grounded, the lamp will turn on.

  NOTE: The relay is used to invert the ground signal between the ABS ECU and the instrument cluster (ground at ABS ECU pin = lamp off, while ground at the instrument cluster pin B11 = lamp on). It also ensures that the lamp will be on if the ABS ECU is disconnected from the vehicle harness.
- **J1587 Message:** The ABS ECU can send messages over the J1587 databus to turn the warning lamp on or off.
- **J1939 Message:** The ABS ECU can send messages over the J1939 databus to turn the warning lamp on and off.

The ABS warning lamp will be illuminated if circuit 376L1 connected to pin B11 at the instrument cluster or if either J1587 or J1939 databus message is broadcast to turn on the lamp. Any one of these will cause the lamp to turn on. See **Fig. 1** for ABS lamp wiring.

The ABS ECU will monitor the hardwired lamp circuit for faults (the portion that operates the control side of the relay).

Troubleshooting Tables

ABS Lamp Troubleshooting

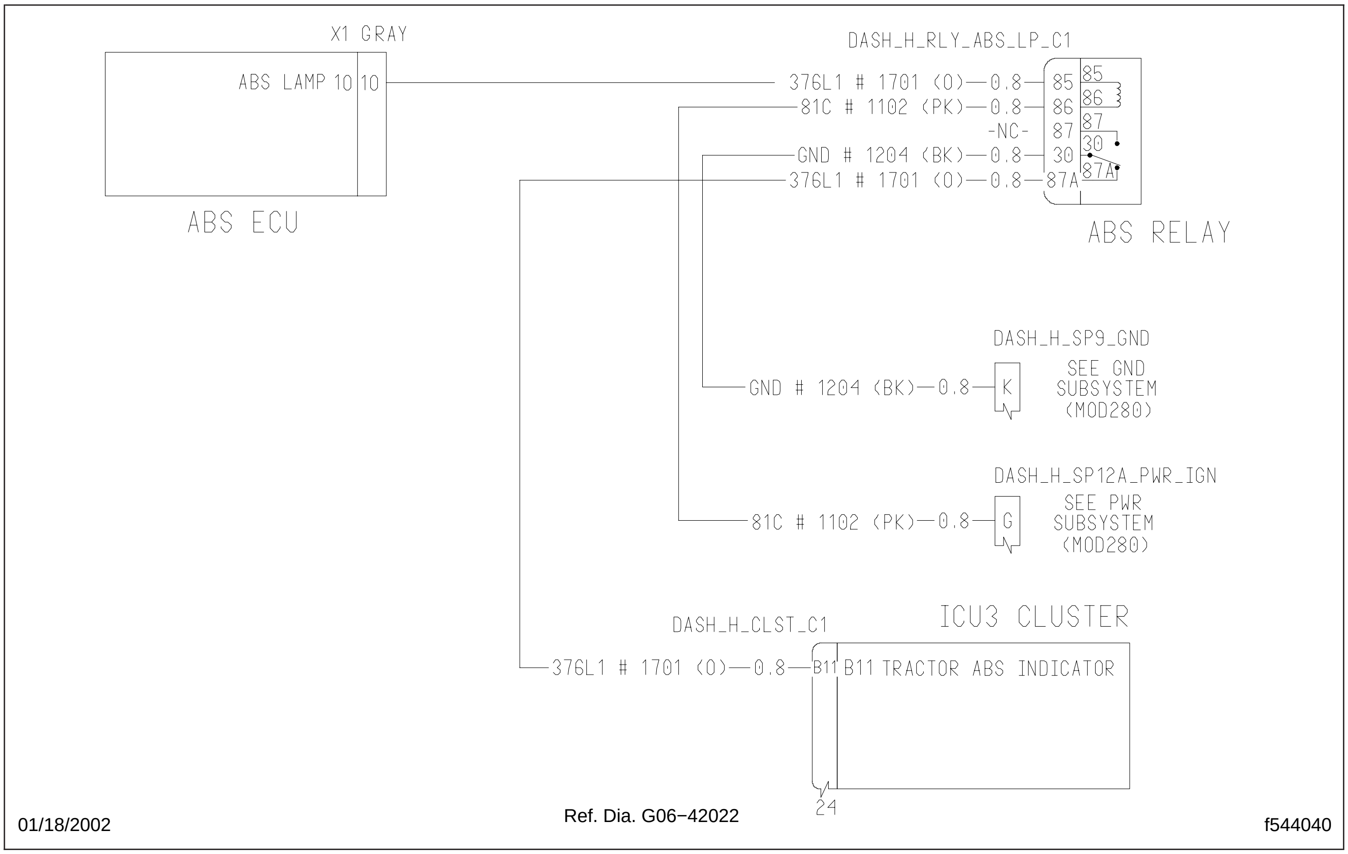


Fig. 1, ABS Warning Lamp Wiring

ABS Lamp Troubleshooting

J1587 Fault Codes (MID 136 SID 023): ABS Warning Lamp Circuit				
FMI	**Fault Description**	**Test**	**Test Result**	**Action**
05	Open Circuit	Test 1: 1. Disconnect the gray X1 connector at the ABS ECU. 2. Turn the ignition ON. 3. Check for voltage between pin 10 of the X1 connector (harness side) and a known good ground.	12V (approx.)	Go to Test 3.
			0V	Go to Test 2.
		Test 2: 1. Remove the ABS relay.Check for voltage between circuit 81C and a known good ground. 2. Locate circuit 81C (corresponds to pin 86 of the relay. 3. Turn the ignition ON. 4. Check for voltage between circuit 81C and a known good ground.	12V (approx.)	Go to Test 3.
			0V	Check circuit 81C between the relay and the BHM. If OK, refer to group 54 for diagnosing the BHM.
		Test 3: 1. Remove the ABS relay. 2. Measure resistance across pins 85 and 86 on the relay.	70-90 Ohms	No problem found. Check circuit 376L1 between the ABS ECU and the ABS relay and check circuit 81C for intermittent open circuit. If OK, replace ABS ECU.
			Greater than 90 (an open relay coil should result in a reading of 680 Ohms)	Replace the ABS relay.

Table 1, J1587 Fault Codes (MID 136 SID 023): ABS Warning Lamp Circuit

ABS Lamp Troubleshooting

Diagnosing an ABS Lamp that Remains On			
Symptom	**Test**	**Test Result**	**Action**
Warning Lamp Stays On	Test 1: Use Servicelink or Meritor Toolbox to check for J1587 fault codes (MID 136). Are there any fault codes?	Yes	Go to Test 2.
		No	Go to Test 3.
	Test 2: Is there an active fault code for the ABS warning lamp circuit? (Fault code is MID136 SID 023 FMI 05)	Yes	Refer to "Diagnosing Warning Lamp Fault Codes" in this section.
		No	Go to Test 3.
	Test 3: Did any of the following happen since the vehicle was last driven? • Historic fault codes were cleared. • A wheel sensor fault was corrected. • The ABS ECU was reconfigured.	Yes	The ABS Warning Lamp should go out after the vehicle has been driven over 4 mph (6.4 km/h).
		No	Go to Test 4.
	Test 4: 1. Remove the ABS relay. 2. Locate circuit 376L1 that corresponds to relay pin 87A (this is the circuit leading to the instrument cluster. 3. Turn the ignition ON. 4. Check for voltage between circuit 376L1 at the relay and ground.	12V (approx)	Check the ABS relay, the contacts may be stuck.
		0V	Circuit 376L1 is shorted to ground between the relay and the instrument cluster. Repair as necessary.

Table 2, Diagnosing an ABS Lamp that Remains On

Since the ABS warning lamp is controlled by three redundant methods, it is unlikely that all three would be inoperative at the same time. If the ABS warning lamp does not turn on when the ignition is switched on, manually ground pin B11 at the back of the instrument cluster (with connectors plugged in and ignition ON). If the ABS warning lamp still does not come on, replace the instrument cluster.

General Information

Meritor Q Plus brakes are standard for both front and rear axles. These Cam-Master® brakes are air-actuated, cam-operated, foundation brakes. The main components in each brake assembly (wheel end) include the following:

- an S-head camshaft
- a brake spider
- a camshaft-and-chamber bracket
- two brake shoe and lining assemblies
- two retaining springs
- a return spring
- two anchor pins

The S-head camshaft transfers braking force from the slack adjuster to the brake shoe assemblies. The camshaft passes through the brake spider and camshaft-and-chamber bracket before connecting to the slack adjuster. See **Fig. 1**.

Each brake shoe is mounted on an anchor pin on the brake spider and is controlled (moved) by either the outward braking force of the S-head camshaft or the inward restoring force of the return spring.

The heavy-duty, double-web brake shoes have notches on one end of the webs that fit on the anchor pins. Two retaining springs secure the brake shoes to each other near the anchor pins, creating a hinge for brake-shoe movement. This design makes quick-change brake service possible.

Meritor steer axles have seven 0.656-inch-diameter holes for attaching the spider to the axle flange. An oversized eighth hole (0.687-inch diameter) in the axle flange is for an antilock brake system (ABS) wheel speed sensor bushing. See **Fig. 2**. The eighth hole is in the 10 or 2 o'clock position, depending on which side of the axle is viewed.

Q Plus MX500 brakes are extended maintenance brakes. These brakes can be identified by an identification tag affixed to the brake shoe. An additional identification tag is affixed to the brake camshaft-and-chamber bracket (on top of the plugged grease hole). MX500 brakes and Meritor automatic slack adjusters do not have grease fittings.

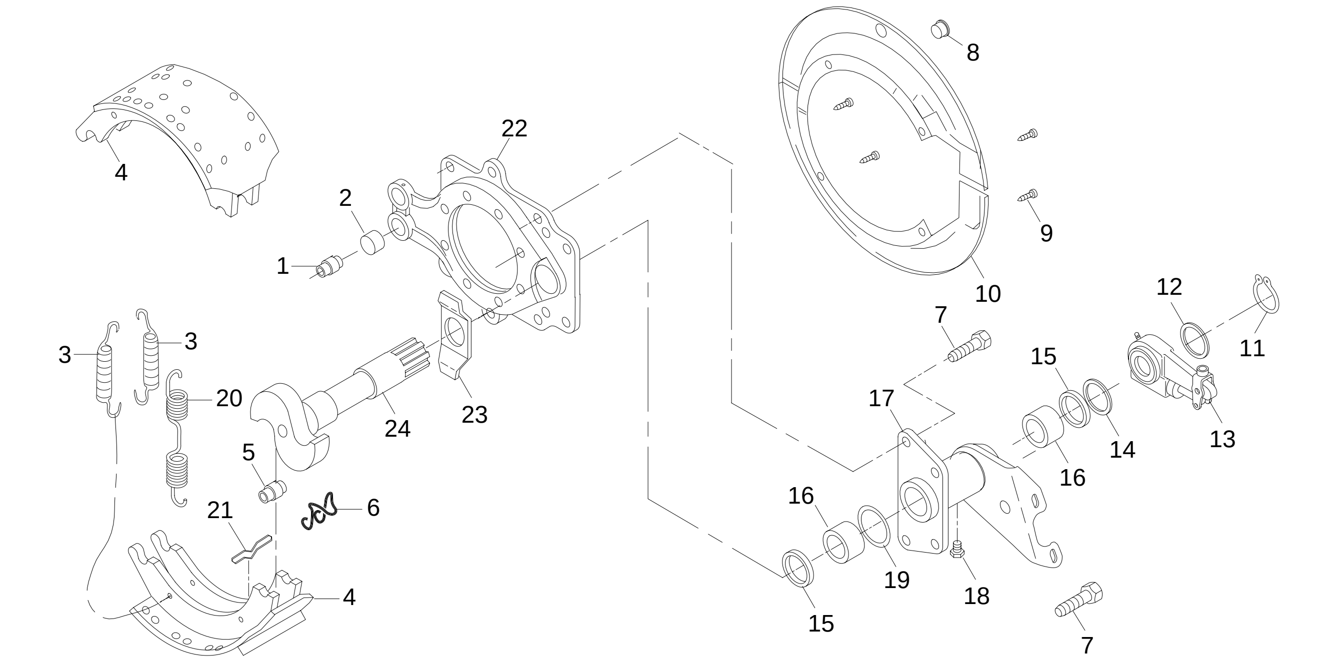
Principles of Operation

When the brake pedal is depressed, compressed air enters the brake chamber, causing the diaphragm to move a pushrod assembly.

The pushrod turns the slack adjuster and brake camshaft. As the camshaft turns, the S-type cam head forces the brake shoes against the brake drum and braking occurs.

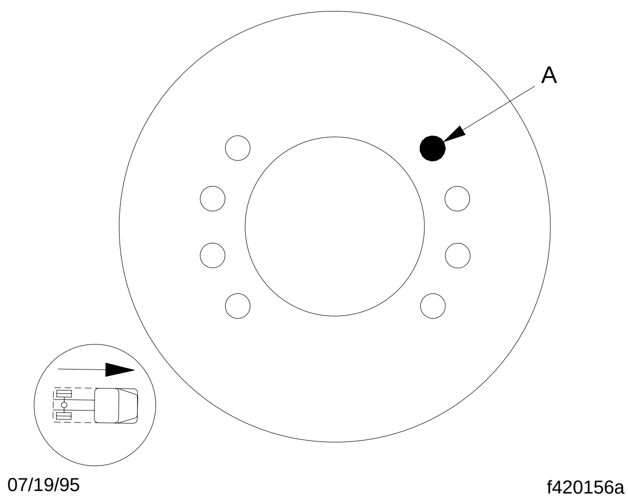
When the brakes are released and air is exhausted from the brake chamber, the actuator return spring (within the brake chamber) and the brake shoe return spring return the camshaft, brake shoes, slack adjuster, and pushrod to their released positions.

General Information



1. Anchor Pin
2. Anchor Pin Bushing
3. Retaining Spring
4. Brake Shoe and Lining Assembly
5. Cam Roller
6. Roller Retainer
7. Capscrew, Chamber Bracket
8. Plug
9. Capscrew, Dust Shield
10. Dust Shield
11. Camshaft Snap Ring
12. Washer (spacer)
13. Automatic Slack Adjuster
14. Washer (thick spacer)
15. Camshaft Grease Seal
16. Camshaft Bushing
17. Camshaft-and-Chamber Bracket
18. Grease Fitting
19. Chamber Bracket Seal
20. Return Spring
21. Return Spring Pin
22. Brake Spider
23. Washer, Camhead
24. S-Head Camshaft

Fig. 1, Meritor Cam-Master Q Plus Brake (typical)



A. Oversized Hole (10 or 2 o’clock position) for ABS bushing.

Fig. 2, Hole for ABS Wheel Speed Sensor Bushing

General Safety Precautions

WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

Asbestos and Non-Asbestos Safety

WARNING

Wear a respirator at all times when servicing the brakes, starting with the removal of the wheels and continuing through assembly. Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH.

Because some brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Exposure to airborne asbestos brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

Because medical experts believe that long-term exposure to some *non-asbestos* fibers could also be a health hazard, the following precautions should also be observed if servicing non-asbestos brake linings.

Areas where brake work is done should be separate from other operations, if possible. As required by OHSA regulations, the entrance to the areas should have a sign displayed indicating the health hazard.

During brake servicing, an air purifying respirator with high-efficiency filters must be worn. The respirator and filter must be approved by MSHA or NIOSH, and worn during all procedures.

Safety Precautions

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, the brake assembly must be cleaned in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with a HEPA filter system, remove dust from the brake drums, brake backing plates, and brake parts. After vacuuming, any remaining dust should be removed using a rag soaked in water and wrung until nearly dry. Do not use compressed air or dry brushing to clean the brake assembly.

If grinding or other machining of the brake linings is necessary, other precautions must be taken because exposure to asbestos dust is highest during such operations. In addition to the use of an approved respirator, there must be local exhaust ventilation such that worker exposure is kept as low as possible.

Work areas should be cleaned by industrial vacuums with HEPA filters or by wet wiping. Compressed air or dry sweeping should never be used for cleaning. Asbestos-containing waste, such as dirty rags, should be sealed, labeled, and disposed of as required by EPA and OSHA regulations. Respirators should be used when emptying vacuum cleaners and handling asbestos waste products.

Workers should wash before eating, drinking, or smoking, should shower after work, and should not wear work clothes home. Work clothes should be vacuumed after use and then laundered, without shaking, to prevent the release of asbestos fibers into the air.

WARNING

Before starting the procedure below, read the safety precaution information in Safety Precautions 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

IMPORTANT: When replacing the brake linings, use a dial indicator to measure the cam-to-bushing radial free play (the up-and-down and side-to-side free play of the camshaft) and the camshaft axial end play (the in-and-out end play of the camshaft).

Replace the bushings if the cam-to-bushing radial free play exceeds 0.020 inch (0.5 mm) of movement.

Remove the snap ring from the end of the slack adjuster and add shims between the slack adjuster and the snap ring if the axial end play exceeds 0.005 to 0.030 inch (0.13 to 0.80 mm) of movement.

For detailed instructions, see **Subject 150**.

Removal

1. Park the vehicle on a level surface, apply the parking brakes, and shut down the engine. Chock the tires on the axle that is not being repaired.
2. Raise the front or rear axle and place safety stands under the frame or axle. Be sure the stands will support the weight of the vehicle.

WARNING

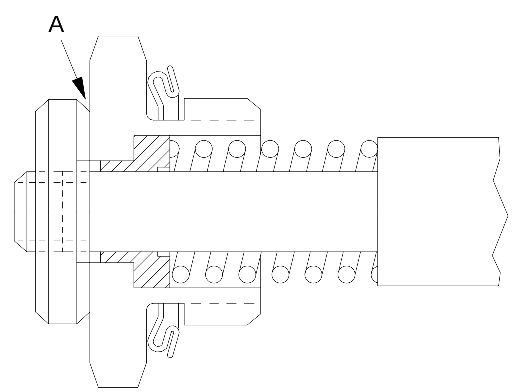
When work is being done on the spring chamber, carefully follow the service instructions of the chamber manufacturer. The sudden release of a compressed spring can cause serious personal injury.

3. If the brake has spring chambers, carefully cage and lock the springs so that the springs cannot actuate during disassembly.

CAUTION

For a Meritor automatic slack adjuster, disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

4. If your vehicle has a Meritor automatic slack adjuster, disengage the pull-pawl on the side of the adjuster.
   - 4.1 Using a screwdriver or an equivalent tool, pry the pawl button out about 1/32 inch (0.8 mm). See **Fig. 1**.
   - 4.2 Wedge the tool in place until the end of the brake shoe installation. Pull-pawls are spring loaded. When the tool is removed, the pull-pawl will engage the teeth automatically.



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A. Insert a screwdriver here to pry the pull-pawl button out about 1/32 inch (0.8 mm).

Fig. 1, Disengage the Pull-Pawl on Meritor Automatic Slack Adjusters

NOTE: On Haldex or Gunite automatic slack adjusters, an internal clutch resists turning the manual adjusting nut in the counterclockwise direction to back off the adjuster. A torque of approximately 13 lbf·ft (18 N·m) must be applied to overcome the resistance of the internal clutch.

5. For each wheel end, back off the automatic slack adjuster by turning the manual adjusting nut until

Brake Shoe Removal and Installation

the brake shoes are fully retracted and the drum clears the lining. See **Subject 130** for instructions.

- On Meritor adjustors, turn the square adjusting nut clockwise (as if tightening a right-hand threaded fastener).
- On Haldex or Gunite adjusters, turn the adjusting hexnut counterclockwise. You will hear a ratcheting sound.

6. Remove the wheels. For instructions, see **Section 40.00**.
7. Remove the brake drums. For instructions, see **Section 33.01** for front axles or **Section 35.01** for rear axles.
8. Remove the brake shoes.

   8.1 Push down on the lower brake shoe, then pull on the roller retaining clip to remove the lower cam roller. See **Fig. 2**.

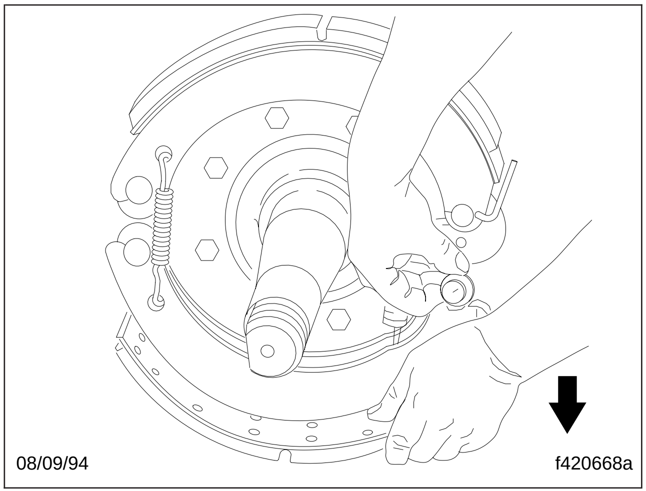


Fig. 2, Cam Roller Removal

   8.2 Lift the upper brake shoe and pull on the roller retaining clip to remove the upper cam roller.

   8.3 Lift the lower shoe to release tension on the brake return spring. Remove the spring. See **Fig. 3**.

   8.4 Rotate the lower shoe around the anchor pin on the spider to release tension on the two retaining springs. See **Fig. 4**. Remove the brake shoes.

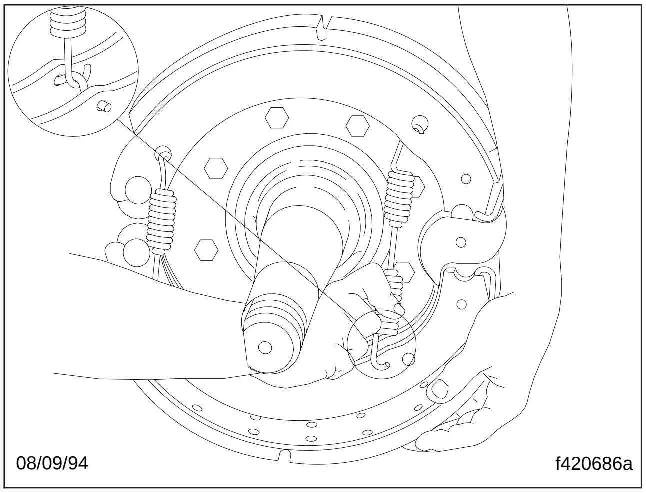


Fig. 3, Return Spring Removal

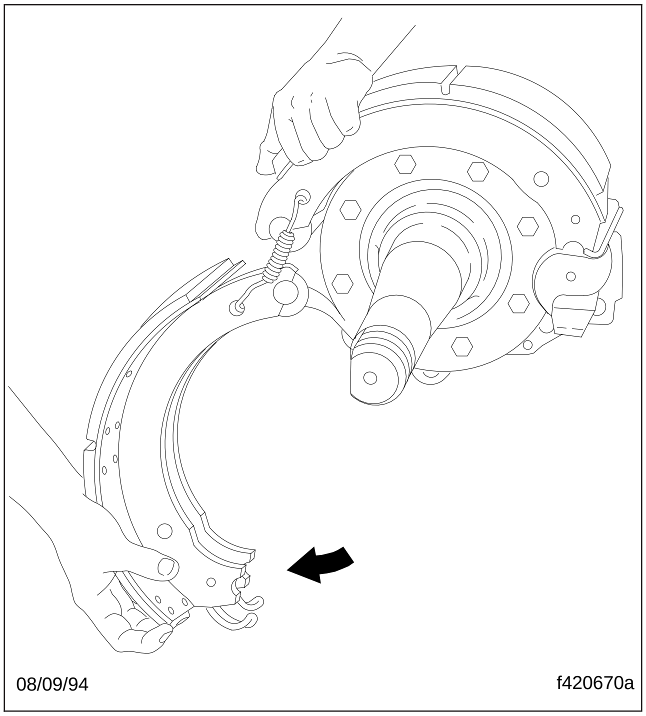


Fig. 4, Brake Shoe Removal

9. Inspect the brake shoes and linings for wear or damage. For instructions, see **Subject 120**.

IMPORTANT: If the linings are being replaced, disassemble and inspect the camshaft-and-chamber bracket. For instructions, see **Subject 150**.

Installation

IMPORTANT: For best brake performance, do not mix Q Plus brakes with other brakes.

NOTE: Springs, rollers, and anchor pins should be replaced when installing new brake linings.

1. Install the brake shoes.

   IMPORTANT: Do not lubricate the cam-head surface or the center section of the cam rollers. For efficient operation, the cam interface must remain free of oil, grease, and other contaminants.

   1.1 Using an NLGI grade 1 or 2 multipurpose chassis or temperature-resistant grease (Meritor O-616A, O-617A, O-617B, O-645, or O-692):

   - Lubricate the cam rollers on the journals where they touch the brake shoe webs.
   - Lubricate the anchor pins where they touch the brake shoe webs.

   1.2 Place the upper brake shoe in position on the upper anchor pin. Hold the lower brake shoe vertically against the lower anchor pin and install two new brake shoe retaining springs to link the upper and lower brake shoes. See **Fig. 5**.

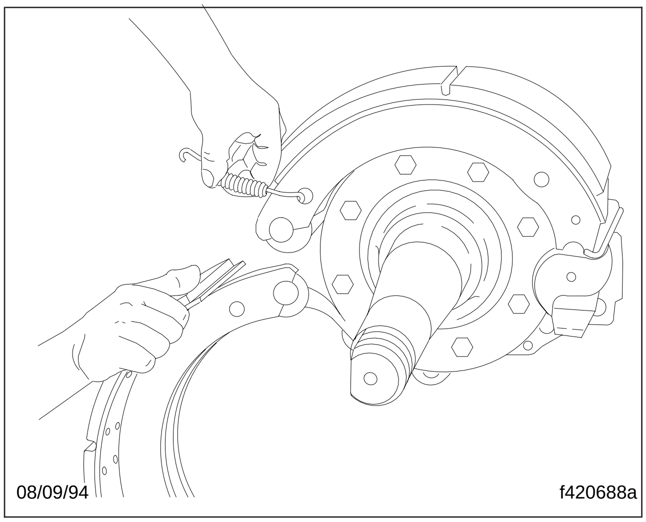


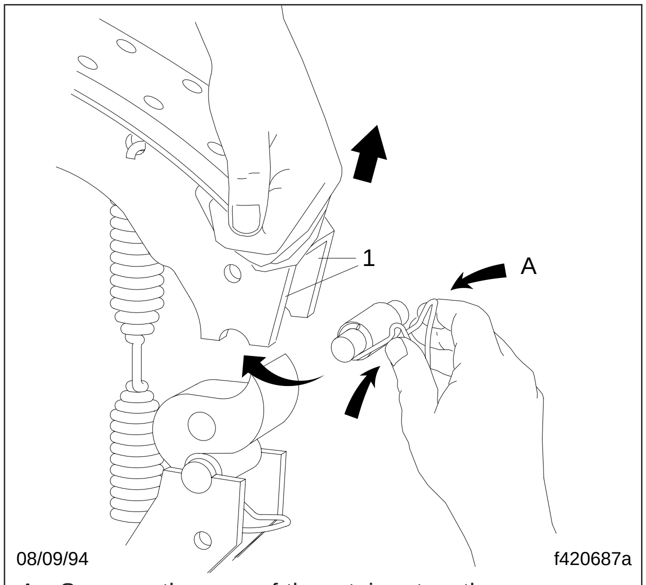
Fig. 5, Retaining Spring Installation

   1.3 Rotate the lower brake shoe forward around the hub and install a new brake shoe return spring. Install the open end of the spring hooks toward the camshaft. See **Fig. 3**.

   1.4 Pull the lower brake shoe away from the cam to allow enough space to install a new cam roller and retainer clip.

   Squeeze the ears of the retainer clip together to fit between the brake shoe webs on the cam end of the brake shoes. See **Fig. 6**.

   Push the retainer clips between the brake shoe webs until the ears lock in the holes in the webs. See **Fig. 7**.

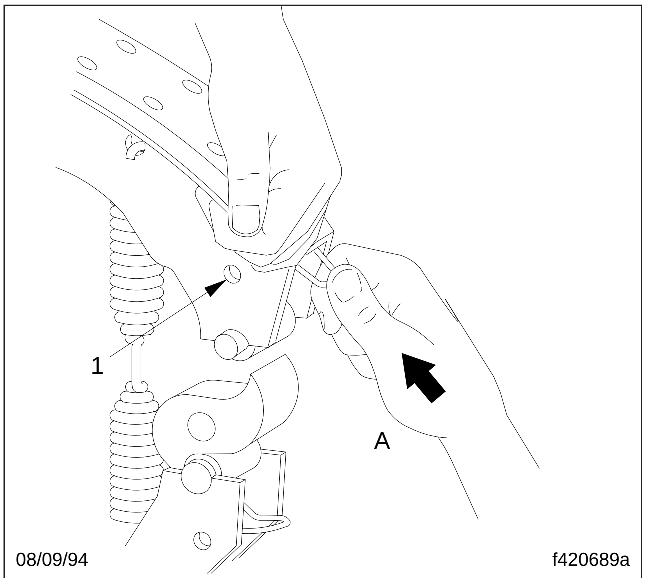


A. Squeeze the ears of the retainer together.
1. Brake Shoe Webs

Fig. 6, Squeeze the Retainer

2. Install the brake drums. For instructions, see **Section 33.01** for front axles or **Section 35.01** for rear axles.
3. Install the wheels. For instructions, see **Section 40.00**.
4. Adjust the brakes at the slack adjusters. For instructions, see **Subject 130**.
5. Remove the safety stands, lower the vehicle, and remove the chocks from the tires.

Brake Shoe Removal and Installation



A. Push the retainer until the ears lock in the holes.
1. Web Hole

Fig. 7, Roller and Retainer Clip Installation

WARNING

When work is being done on a spring chamber, carefully follow the service instructions of the chamber manufacturer. The sudden release of a compressed spring can cause serious personal injury.

6. If the brakes have spring chambers, carefully release the springs.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

7. In a safe area, check for proper brake operation before you put the vehicle in service.

   7.1 Apply and release the brakes several times to check for air leaks and proper operation of the slack adjusters.

   7.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.

   7.3 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than others shows a lack of braking effort on those wheels.

Brake Shoe and Lining Inspection

WARNING

Before starting the procedure below, read the safety precaution information in Safety Precautions 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

Inspection

1. Remove the brake shoes using the instructions in **Subject 110**.
2. Check the linings.
   2.1 If the linings are grease- or oil-soaked, cracked, or worn to less than 1/4-inch (6.4-mm) thickness at any point, replace them.

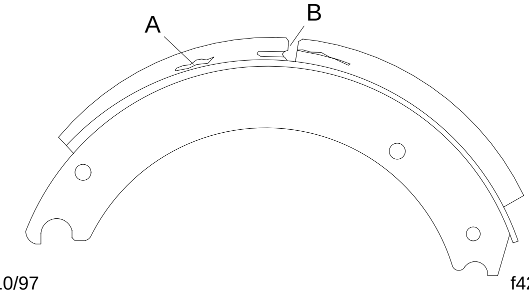
CAUTION

Do not let the brake linings wear to the point were the rivets or bolts touch the drums. Damage to the drums will occur if the linings are allowed to wear to this point.

   2.2 Replace the linings if the lining surface is closer than 1/32 inch (0.8 mm) to any rivet head.

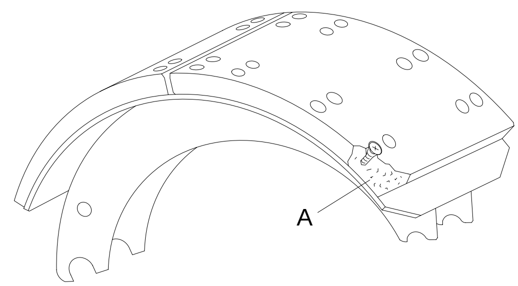
   If bolts are installed, the linings should not be allowed to wear to the point where rivets or bolts may contact the brake drums.

   2.3 The lining is considered worn-out and the vehicle should not be driven if:
   - Cracks on the lining surface exceed 1/16 inch (1.6 mm).
   - The lining edge shows cracks or voids over 1/16 inch (1.6 mm) in width and 1-1/2 inches (38 mm) in length. See **Fig. 1**.
   - Portions of the lining are missing exposing a rivet when viewed from the edge. See **Fig. 2**.
   - Cracks extend across the lining face and through the lining edge, or the lining is loose on the shoe. See **Fig. 3**.



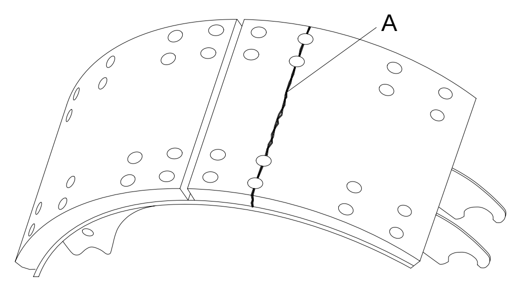
A. Cracks exceeding 1-1/2 inches (38 mm) in length.
B. Cracks or voids exceeding 1/16 inch (1.6 mm) in width.

Fig. 1, Cracks and Voids



A. Exposed fastening device.

Fig. 2, Portions of Brake Lining Missing



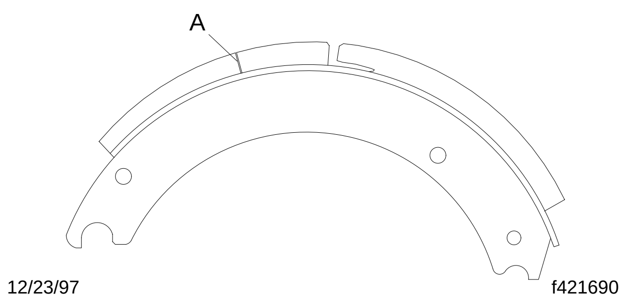
A. Cracks extending through the lining edge.

Fig. 3, Cracks in the Brake Lining

   2.4 The vehicle is still operational but the linings should be replaced as soon as possible if:
   - Horizontal or vertical cracks in the lining edge exhibit no loss of mate-

Brake Shoe and Lining Inspection

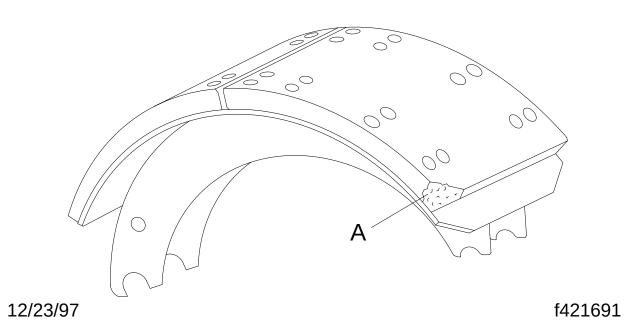
rial and do not exceed 1/16 inch (1.6 mm) in width or 1-1/2 inches (38 mm) in length. See **Fig. 4**.



A. Cracks not exceeding 1-1/2 inches (38 mm) in length or 1/16 inch (1.6 mm) in width.

Fig. 4, Cracks and Voids

- Corner portions of the lining are missing with no fastener exposed. See **Fig. 5**.



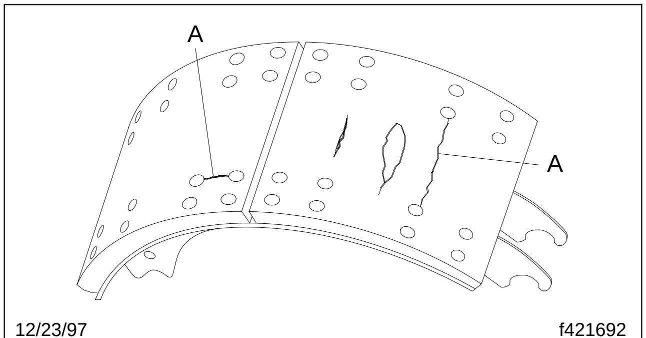
A. Corner segment is missing but no fastener is exposed.

Fig. 5, Portions of the Brake Lining Missing

- Surface cracks extend from hole to hole or if there is scoring and contamination from road debris. See **Fig. 6**.

3. Check the brake shoes for bent or cracked webs or tables, rust, broken welds, expanded or out-of-round rivet or bolt holes, and correct alignment. Replace the shoes if any of these conditions exist.

4. Check the brake shoes for visible wear (looseness) at the anchor pin holes and the camshaft roller recesses. Replace the shoe if needed.

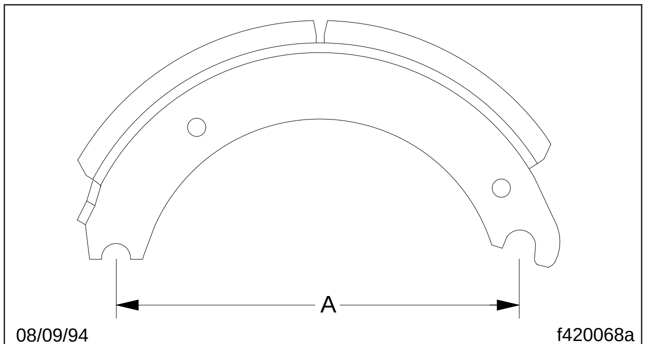


A. Cracks extending from hole to hole.

Fig. 6, Crack in the Brake Lining

5. Check the diameter of the anchor pin holes. The anchor pin holes must not exceed 1.009 inch (25.6 mm).

6. Check the distance from the center of the anchor pin hole to the center of the cam roller hole (the shoe span). The shoe span must not exceed 12-7/8 inches (327 mm). Replace the shoe if needed. See **Fig. 7**.



A. 12-7/8 inches (327 mm) maximum

Fig. 7, Measuring the Shoe Span

Pre-Adjustment Checks and General Adjustment Information

Before adjusting the brakes, check and adjust the following:

- Adjust the wheel bearings. For instructions, see **Section 33.01** or **Section 35.01** of this manual.
- Check the slack adjuster and the brake chamber for loose fasteners and tighten as necessary. For torque specifications, see **Specifications 400**.

  For slack adjuster installation instructions, see the appropriate section in this group.

Brakes with automatic slack adjusters should never have to be manually adjusted while in service. The only time automatic slack adjusters should be manually adjusted is during installation or after the brakes have been relined.

For cam brakes, there are two brake chamber stroke measurement specifications: applied chamber stroke and free-stroke.

IMPORTANT: The U.S. Department of Transportation (DOT) Federal Highway Administration has issued the applied chamber stroke specifications for cam brakes. When the applied chamber stroke is checked and adjusted, it must not be greater than the DOT specification. See **Table 1**.

The specific procedure for adjusting the brake chamber stroke at the slack adjuster's manual adjusting nut may vary, depending on which slack adjuster is installed, but there are three basic steps in completing a manual brake chamber stroke adjustment:

1. Adjusting the approximate brake chamber stroke using the manual adjusting nut on the slack adjuster (coarse adjustment).
2. Measuring and adjusting the free-stroke.
3. Measuring and adjusting the applied chamber stroke (fine adjustment).

The stroke (free or applied chamber) is the distance that the large clevis pin moves when the brakes are applied. The type of force used to move the slack adjuster from its released position to its applied position (where the brake linings contact the brake drum) distinguishes the free-stroke from the applied chamber stroke.

- The free-stroke is measured using a lever to move the slack adjuster. The length of the free-stroke equals the clearance between the brake linings and the drum when the brakes are not applied.
- The applied chamber stroke is measured using an 80 to 90 psi (550 to 620 kPa) brake application to move the slack adjuster.

With the engine off, 100 psi (689 kPa) of air tank pressure will apply the required 80 to 90 psi (550 to 620 kPa) brake application for measuring the applied chamber stroke.

Brake Adjustment

Brake Chamber Stroke Specifications		
Chamber Type (Size)	**Maximum Applied Stroke*: inch (mm)**	**Free-Stroke: inch (mm)**
Standard Stroke		
16, 20, and 24	1-3/4 (44)	
30	2 (51)	
36	2-1/4 (57)	5/8 to 3/4 (16 to 19)
Long Stroke†		
16, 20, and 24	2 (51)	
30	2-1/2 (64)	

* Specifications are relative to a brake application with 80 to 90 psi (550 to 620 kPa) air pressure in the brake chambers.
† Long stroke design is indicated by a tag, or embossing, on the brake chamber.

Table 1, Brake Chamber Stroke Specifications

The applied chamber stroke measurement can be used for diagnostic purposes. A stroke that is too long or too short may indicate excessive wear in the cam, cam bushings, return springs, or air chamber.

The applied chamber stroke should always be adjusted (minimized) to within the specified limit, but it should not be reduced to the point where the free-stroke is too short and the brakes drag. To check for brake drag, spin the wheel end, tap the rim lightly with a hammer, and listen for a drag noise (a sharp ringing sound).

Adjustment

Meritor Automatic Slack Adjuster

IMPORTANT: Before adjusting the brakes, see the pre-adjustment checks and general adjustment information at the beginning of this subject.

1. Park the vehicle on a level surface, apply the parking brakes, and shut down the engine. Chock the tires on the axle that is not being repaired.
2. Raise the front or rear axle and place safety stands under the frame or axle. Be sure the stands will support the weight of the vehicle.
3. Fully release the brakes (the air chamber push-rod must be fully retracted).
4. Check the condition of the boot on the slack adjuster. It should be held in the correct position with a retaining clip. If the boot is torn or cracked, see the appropriate section in this group for slack adjuster disassembly and inspection procedures.

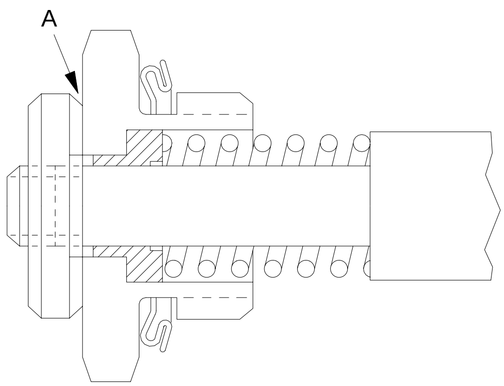
CAUTION

Before turning the manual adjusting nut on the slack adjuster, disengage the pull-pawl. Failure to do so could damage the pull-pawl teeth. A damaged pull-pawl will not allow the slack adjuster to automatically adjust the brake clearance.

5. Using a screwdriver, pry the pull-pawl button out at least 1/32 inch (0.8 mm) to disengage the pull-pawl teeth from the slack adjuster actuator. See **Fig. 1**. Wedge the screwdriver in place. The pull-pawl will need to be disengaged until the brake adjustment is complete.

NOTE: When the screwdriver is removed, the pull-pawl will engage automatically.

6. Using the manual adjusting nut on the slack adjuster, adjust the brake chamber stroke (coarse adjustment). See **Fig. 2**.
   6.1 Turn the adjusting nut counterclockwise until the brake linings touch the brake drum.
   6.2 Then, turn the adjusting nut clockwise 1/2 turn.
7. Measure and adjust the free-stroke.



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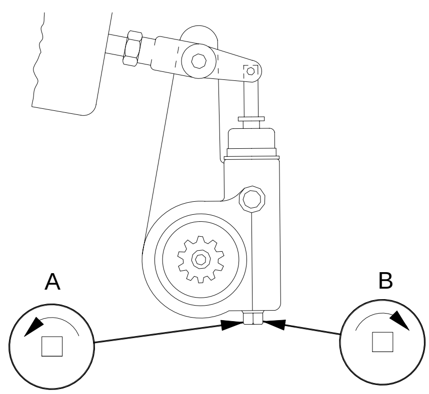
A. Insert screwdriver here.

Fig. 1, Disengage the Pull-Pawl



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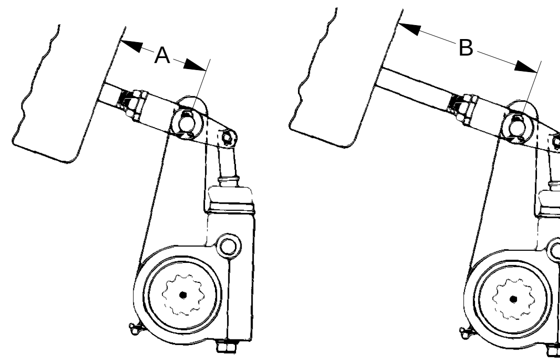
A. Shorten stroke. B. Lengthen stroke.

Fig. 2, Turn the Adjusting Nut

7.1 With the brakes released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension A. See **Fig. 3**.

7.2 Using a lever, move the slack adjuster until the brake linings contact the brake drum.

7.3 Measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension B. See **Fig. 3**.



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NOTE: For either free-stroke or applied chamber stroke, subtract measurement A from B.

A. Measurement with the brakes released.
B. Measurement with the brakes applied by manual lever (free-stroke) or pressurized brake application (applied chamber stroke).

Fig. 3, Measuring the Stroke

7.4 Subtract dimension A from dimension B. The difference between these measurements is the free-stroke.

7.5 The free-stroke should be 5/8 to 3/4 inch (16 to 19 mm). If it is not, turn the adjusting nut 1/8 turn, as shown in **Fig. 2**. Then measure the free-stroke again, and readjust it until it is correct.

8. Measure and adjust the applied chamber stroke (fine adjustment).

8.1 Start the engine and build the air pressure to 100 psi (689 kPa). Shut down the engine.

8.2 Fully apply the brakes. Then, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 3**, Ref. B. Record this measurement as dimension C.

8.3 Subtract dimension A from dimension C. The difference between these measurements is the true applied chamber stroke.

8.4 The applied chamber stroke must not exceed the maximum value specified in **Table 1**.

Brake Adjustment

CAUTION

The adjusted applied chamber stroke should be as short as possible but not so short that the free-stroke is too short and the linings drag. If the linings drag, the brakes could be damaged.

8.5 If the applied chamber stroke is incorrect, turn the adjusting nut 1/8-turn counterclockwise to shorten the stroke, or 1/8-turn clockwise to lengthen it. See **Fig. 2**. Measure the applied stroke again and readjust it until it is correct.

8.6 If the slack adjuster is not maintaining the correct applied chamber stroke, check the condition of the foundation brakes. See **Subject 150**. If necessary, replace the slack adjuster.

9. Remove the screwdriver from the pull-pawl assembly. This will engage the pull-pawl with the actuator.
10. Lower the vehicle, remove the safety stands, and remove the chocks from the tires.

WARNING

Do not operate the vehicle until the brakes have been checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

11. Check for proper brake operation. For instructions, see **Subject 110**.

Haldex Automatic Slack Adjuster

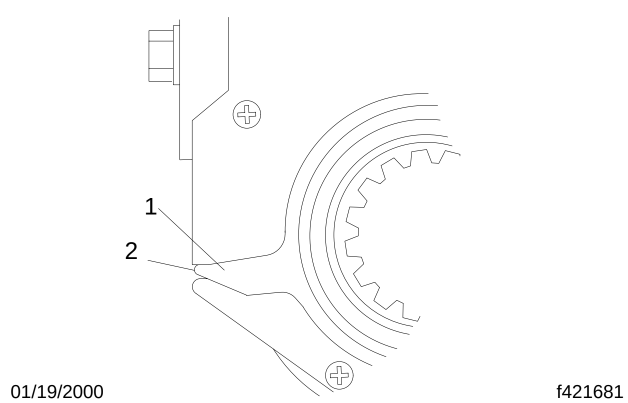
IMPORTANT: Before adjusting the brakes, see the pre-adjustment checks and general adjustment information at the beginning of this subject.

1. Park the vehicle on a level surface, apply the parking brakes, and shut down the engine. Chock the tires on the axle that is not being repaired.
2. Raise the front or rear axle. Then, place safety stands under the frame or axle. Be sure the stands will support the weight of the vehicle.
3. Fully release the brakes (the air chamber pushrod must be fully retracted).

CAUTION

The installation indicator must be aligned with the indicator notch on the slack adjuster. If the indicator is not within the notched area, the control arm is installed in the wrong position. This may result in tight brakes, excessive lining wear, and possible brake damage.

4. Make sure the installation indicator is aligned with the indicator notch on the slack adjuster. See **Fig. 4**. If the indicator is not within the notched area, the control arm is not installed correctly.



1. Installation Indicator 2. Indicator Notch

Fig. 4, Installation Indicator

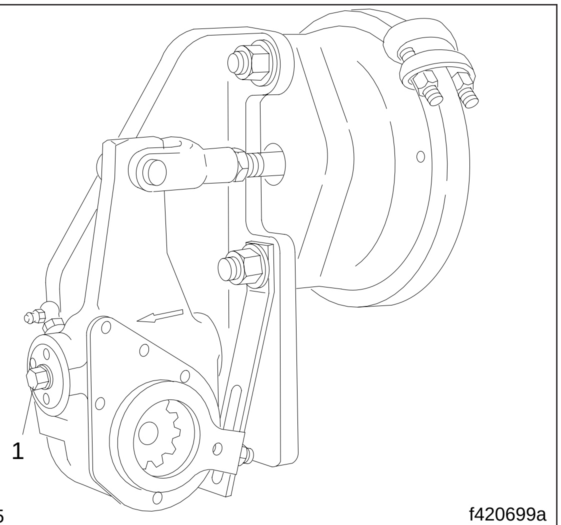
5. Measure how much torque is required to overcome the resistance of the internal clutch (internal clutch slippage).

5.1 Using a 7/16-inch torque wrench, turn the adjusting nut counterclockwise. See **Fig. 5**. You will hear a ratcheting sound.

5.2 If the clutch slips with a torque less than 13 lbf·ft (18 N·m), the slack adjuster must be replaced.

6. Using the manual adjusting nut on the slack adjuster, adjust the brake chamber stroke (coarse adjustment).

6.1 Turn the adjusting nut clockwise until the brake linings contact the brake drum.



1. Adjusting Hexnut

Fig. 5, Adjusting Hexnut

6.2 Then, turn the adjusting nut counterclockwise 1/2 turn. You will hear a ratcheting sound.

7. Measure and adjust the free-stroke.

7.1 Measure the distance from the bottom of the brake chamber to the far side of the clevis pin. See **Fig. 6**. Record this measurement as dimension A.

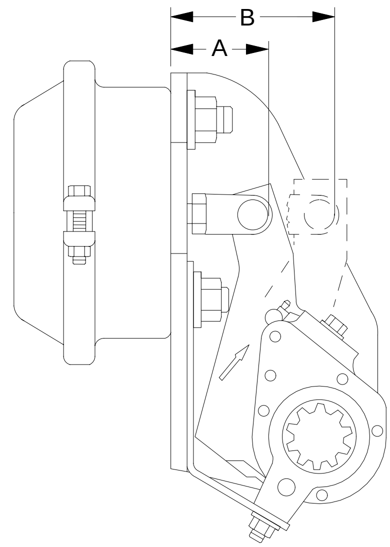
7.2 Using a lever, move the slack adjuster until the brake linings contact the brake drum. Then, measure the distance from the bottom of the brake chamber to the far side of the clevis pin. See **Fig. 6**. Record this measurement as dimension B.

7.3 Subtract dimension A from dimension B. The difference between these measurements is the free-stroke.

7.4 The free-stroke should be 5/8 to 3/4 inch (16 to 19 mm). If it is not, turn the adjusting nut in the required direction. Then, measure the free-stroke again and readjust it until it is correct.

8. Measure and adjust the applied chamber stroke (fine adjustment).

8.1 Start the engine and build the air pressure to 100 psi (689 kPa). Shut down the engine.



A. Brakes Released B. Brakes Applied

Fig. 6, Measure the Stroke

8.2 Fully apply the brakes. Then, measure the distance from the bottom of the brake chamber to the far side of the clevis pin hole. See **Fig. 6**, Ref. B. Record this measurement as dimension C.

8.3 Subtract dimension A from dimension C. The difference between these measurements is the applied chamber stroke.

8.4 The applied chamber stroke must not exceed the maximum value specified in **Table 1**. If the stroke is not correct, turn the adjusting nut in the required direction. Then, measure the applied chamber stroke again and readjust it until it is correct.

8.5 If the slack adjuster does not maintain the correct applied chamber stroke, check the condition of the foundation brakes. See **Subject 150**. If necessary, replace the slack adjuster.

9. Lower the vehicle, remove the safety stands, and remove the chocks from the tires.

Brake Adjustment

WARNING

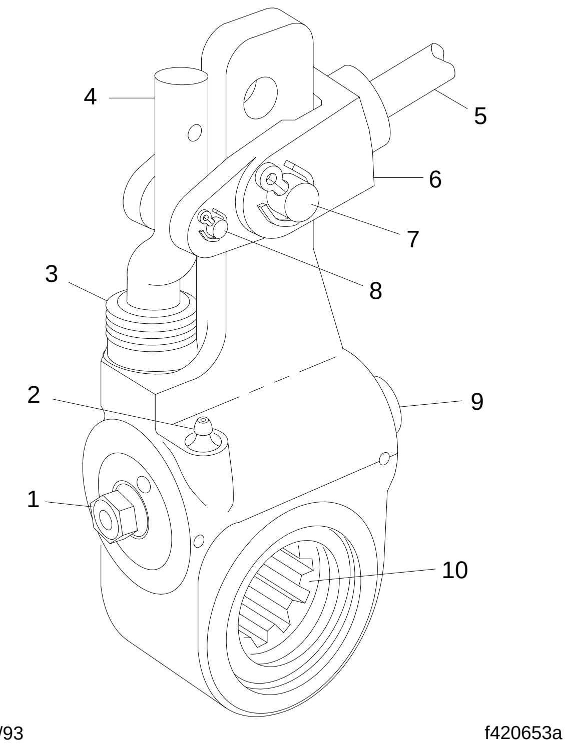
Do not operate the vehicle until the brakes have been checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

10. Check for proper brake operation. For instructions, see **Subject 110**.

Gunite Automatic Slack Adjuster

IMPORTANT: Before adjusting the brakes, see the pre-adjustment checks and general adjustment information at the beginning of this subject.

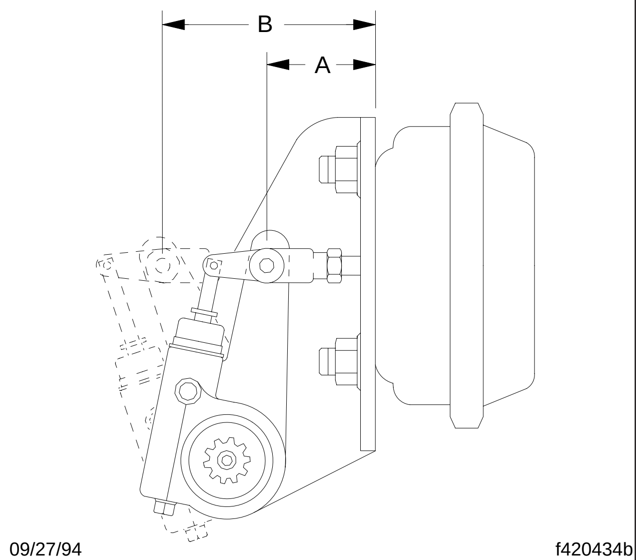
1. Park the vehicle on a level surface, apply the parking brakes, and shut down the engine. Chock the tires on the axle that is not being repaired.
2. Raise the front or rear axle. Then, place safety stands under the frame or axle. Be sure the stands will support the weight of the vehicle.
3. Fully release the brakes (the air chamber pushrod must be fully retracted).
4. Measure how much torque is required to overcome the resistance of the internal clutch (internal clutch slippage).
   - 4.1 Using a 7/16-inch torque wrench, turn the adjusting nut counterclockwise. See **Fig. 7**. You will hear a ratcheting sound.
   - 4.2 If the clutch slips with a torque less than 15 lbf·ft (20 N·m), the slack adjuster must be replaced.
5. Using the manual adjusting nut on the slack adjuster, adjust the brake chamber stroke (coarse adjustment).
   - 5.1 Turn the adjusting nut clockwise until the brake linings contact the brake drum.
   - 5.2 Turn the adjusting nut counterclockwise 1/2 turn. There should be about 30 lbf·ft (41 N·m) resistance. You will hear a ratcheting sound.
6. Measure and adjust the free-stroke.



1. Adjusting Hexnut
2. Grease Fitting
3. Boot
4. Link
5. Brake Chamber Pushrod
6. Clevis
7. Clevis Pin, 1/2-in
8. Clevis Pin, 1/4-in
9. Grease Relief Opening
10. Slack Adjuster Spline

Fig. 7, Gunite Slack Adjuster

   - 6.1 Measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 8**. Record this measurement as dimension A.
   - 6.2 Using a lever, move the slack adjuster until the brake linings contact the brake drum.
   - 6.3 Measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 8**. Record this measurement as dimension B.
   - 6.4 Subtract dimension A from dimension B. The difference between these measurements is the free-stroke.
   - 6.5 The free-stroke should be 5/8 to 3/4 inch (16 to 19 mm). If it is not, turn the adjust-



A. Brakes Released B. Brakes Applied

Fig. 8, Measure the Stroke

ing nut in the required direction. Then, measure the free-stroke again and readjust it until it is correct.

7. Measure and adjust the applied chamber stroke (fine adjustment).

   7.1 Start the engine and build air pressure to 100 psi (689 kPa). Shut down the engine.

   7.2 Fully apply the brakes. Then, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 8**, Ref. B. Record this measurement as dimension C.

   7.3 Subtract dimension A from dimension C. The difference between these measurements is the applied chamber stroke.

   7.4 The applied chamber stroke must not exceed the maximum value specified in **Table 1**. If the stroke is not correct, turn the adjusting nut in the required direction. Then, measure the applied stroke again and readjust it until it is correct.

   7.5 If the slack adjuster is not maintaining the correct applied chamber stroke, check the condition of the foundation brakes. See **Subject 150**. If necessary, replace the slack adjuster.

8. Lower the vehicle, remove the safety stands, and remove the chocks from the tires.

WARNING

Do not operate the vehicle until the brakes have been checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

9. In a safe area, check for proper brake operation before you put the vehicle in service.

   9.1 Apply and release the brakes several times to check for air leaks and proper operation of the slack adjusters.

   9.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.

   9.3 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than others shows a lack of braking effort on those wheels.

Brake Shoe Lining Replacement

⚠ WARNING

Before starting this procedure, read the information in Safety Precautions 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

Replacement

IMPORTANT: Vehicle brake systems require the correct lining material to perform as originally designed. The type of lining material that is specified for the vehicle is based on several technical considerations and Department of Transportation (DOT) braking performance regulations. To ensure fewer relines and greater compatibility with the vehicle's brake system, use the same quality of friction lining material that was installed at the factory.

Always reline both wheels of a single axle and all wheels of a tandem axle at the same time.

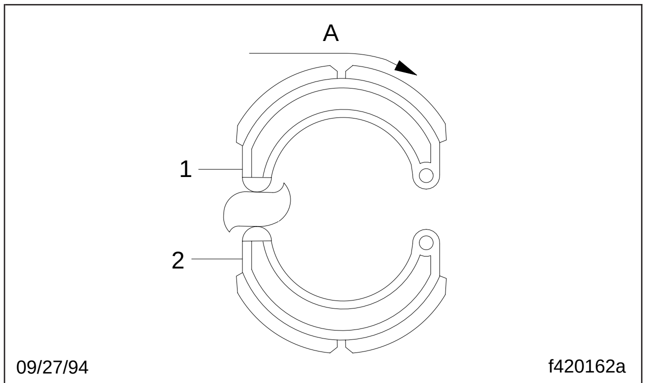
Always install the same linings and drums on both wheels of a single axle and all four wheels of a tandem axle. It is not necessary that both axles (front and rear) have the same linings and drum.

Combination linings with different friction ratings for the primary and secondary shoes are sometimes used. When combination friction lining sets are used, the lining blocks must be installed in the correct locations on the brake shoes.

NOTE: Always follow the instructions supplied with the replacement combination lining sets for correct installation. The primary linings must be installed on the primary shoe. The first shoe past the cam in the direction of the wheel rotation is the primary shoe.

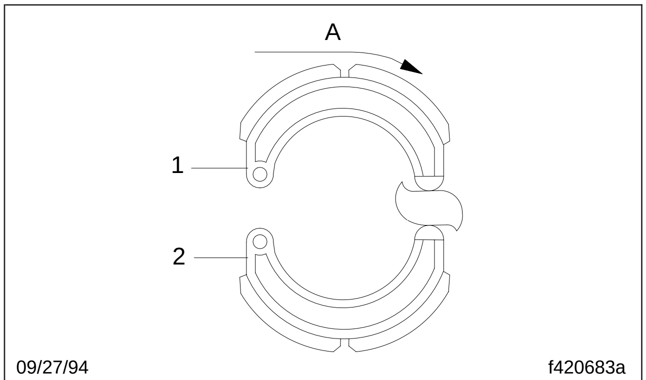
The primary shoe can be either in the upper or the lower position, depending on the location of the cam. If the cam is behind the axle, then the upper shoe is the primary shoe. See **Fig. 1**. If the cam is in front of the axle, then the lower shoe is the primary shoe. See **Fig. 2**.

1. Remove the brake shoes. See **Subject 110** for instructions.



A. Wheel rotation.
1. Primary Shoe
2. Secondary Shoe

Fig. 1, Camshaft Behind the Axle



A. Wheel rotation.
1. Secondary Shoe
2. Primary Shoe

Fig. 2, Camshaft Ahead of the Axle

2. Using a dial indicator, measure the cam-to-bushing radial free play (the up-and-down and side-to-side free play of the camshaft) and the camshaft axial end play (the in-and-out end play of the camshaft). For instructions, see **Subject 150**.
   - If the cam-to-bushing radial free play exceeds 0.020 inch (0.5 mm) of movement, replace the bushings.
   - The axial end play should be 0.005 to 0.030 inch (0.13 to 0.80 mm). If it exceeds 0.030 inch (0.80 mm) of movement, remove the snap ring securing the slack adjuster on the camshaft. Add shims between the slack adjuster and the snap ring.
3. Remove the lining blocks from the brake shoes.

Brake Shoe Lining Replacement

CAUTION

Drilling out rivets or cutting off rivet heads with a chisel can cause the rivet hole to become out-of-round, which could damage the brake shoe.

3.1 If the lining blocks are riveted, use a suitable riveting mandrel to push out the old rivets.

If the lining blocks are bolted, remove the bolts, lockwashers, and nuts.

3.2 Separate the lining blocks from the brake shoes.

4. Check the brake shoes for rust, expanded rivet or bolt holes, broken welds, and incorrect alignment. Replace the shoes if any of these conditions exist.
5. If necessary, clean each brake shoe with solvent and wire brush the shoe table. Then, paint the brake shoe with rust-inhibitive paint.
6. Install the lining blocks on the brake shoes.

IMPORTANT: Use rivets that have the correct material, shank diameter, length, head size, and shape. Use tubular rivets that are 1/4-inch diameter by 9/16-inch long, SAE no. 10, made of plated steel or brass.

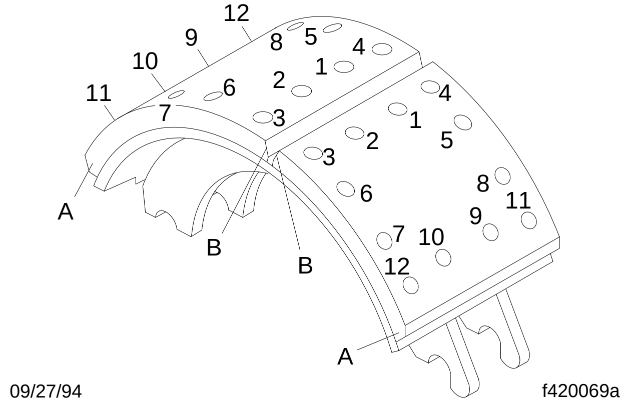
6.1 If the lining blocks are riveted, align the brake shoe rivet holes with the corresponding lining block holes. Using a C-clamp, clamp the lining block to the brake shoe.

Insert the correct size rivets in all the holes. Hold the rivets in place temporarily with masking tape.

Fasten the rivets (from the lining block to the brake shoe) in the sequence shown in **Fig. 3**.

6.2 If the lining blocks are bolted, align the brake shoe bolt holes with the corresponding lining block holes. Using a C-clamp, clamp the lining block to the brake shoe.

Insert the correct size bolts and new lockwashers into all the holes and threads. Loosely install all the nuts, then tighten them in the sequence shown in **Fig. 3**.



NOTE: The numbers represent the fastening sequence.

A. Toe B. Heel

Fig. 3, Rivet and Bolt Fastening Sequence

- Tighten 3/8-inch brass bolts 18 to 23 lbf·ft (24 to 31 N·m).
- Tighten 1/4-inch brass bolts 80 to 100 lbf·in (900 to 1120 N·cm).

7. Check the lining installation by trying to insert a 0.010-inch (0.25-mm) feeler gauge along the edges between the linings and the shoe table. See **Fig. 4**.

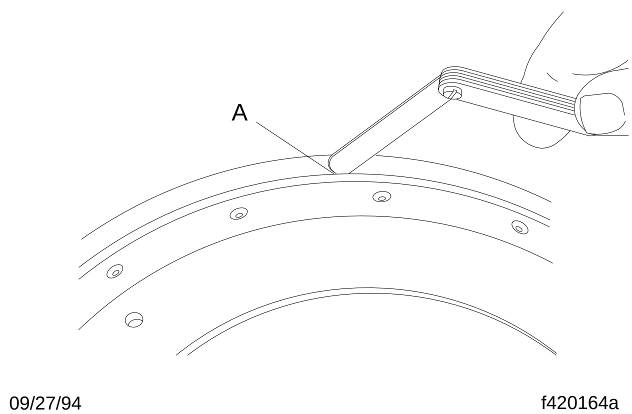
It should not be possible to insert the feeler gauge anywhere along the edge, except beyond the last row of rivets at each end. A larger clearance of up to 0.025 inch (0.64 mm) can exist at the ends. See **Fig. 5**.

8. Circle-grind the brake lining to get the correct lining-to-drum contact.

8.1 With the cam in the full-release position, grind the new brake linings 0.070 inch (1.8 mm) less than the drum diameter.

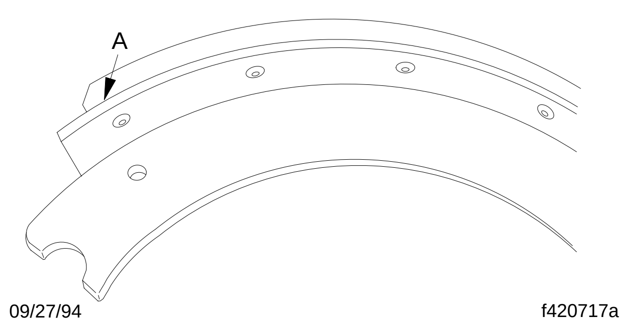
8.2 Adjust the cam and grind the lining until there is an 80 percent lining-to-drum contact, which must be continuous and in the center of the lining.

9. Install the brake shoes, see **Subject 110** for instructions.



A. The clearance between the brake lining and shoe table must be less than 0.010 inch (0.25 mm).

Fig. 4, Check Clearance Along Edge



A. The clearance between the shoe table and the ends of the brake lining can be up to 0.025 inch (0.64 mm).

Fig. 5, Check Clearance at Ends

Brake Components Disassembly, Inspection, Cleaning, and Assembly

Disassembly and Inspection

WARNING

Before starting this procedure, read the safety precaution information in Safety Precautions 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

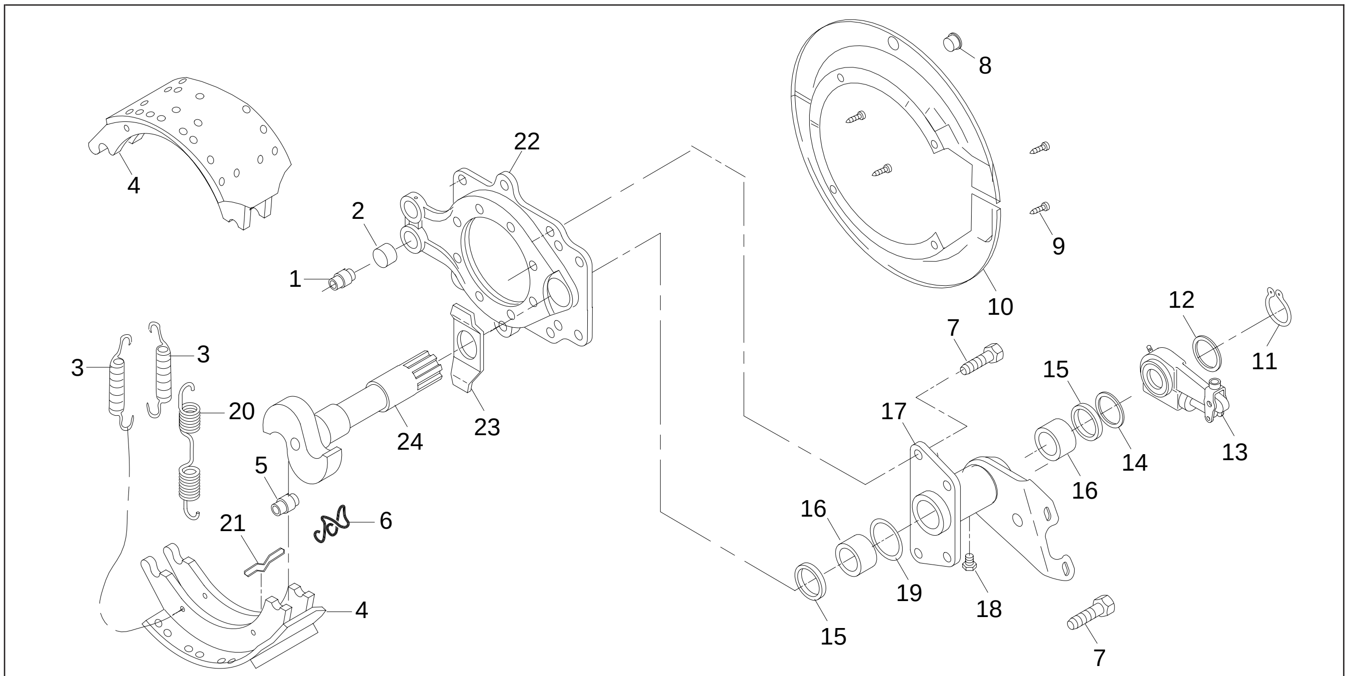
Three Q Plus brake assemblies are shown in the following figures:

- **Fig. 1**, Q Plus Brakes (other than MX500 Series)
- **Fig. 2**, MX500 Series with Cast Spider
- **Fig. 3**, MX500 Series with Stamped Spider

1. Remove the brake shoes. For instructions see **Subject 110**.

IMPORTANT: Meritor recommends that the brake drum not be turned or rebored (resurfaced). Turning or reboring drums can decrease the strength and heat capacity of the drum.

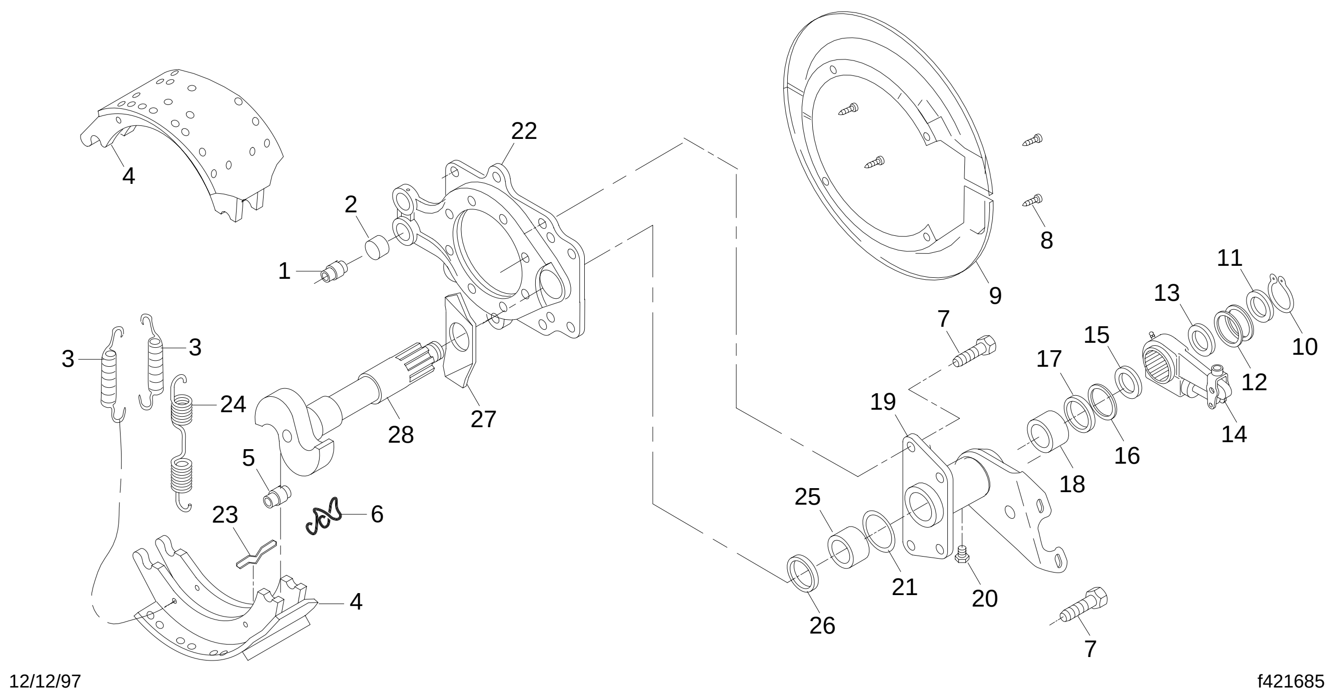
2. Inspect the brake drum. See **Fig. 4**.
   - 2.1 Check the drum for cracks. Replace any cracked drum.
   - 2.2 Check the drum for severe heat-checking, heat-spotting, scoring, pitting, distortion, and out-of-round. Some drums that are glazed, grooved, or out-of-round can be repaired. For detailed instructions, see **Section 33.01** or **Section 35.01**.



1. Anchor Pin
2. Anchor Pin Bushing
3. Retaining Spring
4. Brake Shoe and Lining Assembly
5. Cam Roller
6. Roller Retainer
7. Capscrew, Chamber Bracket
8. Plug
9. Capscrew, Dust Shield
10. Dust Shield
11. Camshaft Snap Ring
12. Washer (spacer)
13. Automatic Slack Adjuster
14. Washer (thick spacer)
15. Camshaft Grease Seal
16. Camshaft Bushing
17. Camshaft-and-Chamber Bracket
18. Grease Fitting
19. Chamber Bracket Seal
20. Return Spring
21. Return Spring Pin
22. Brake Spider
23. Camhead Thrustwasher
24. S-Head Camshaft

Fig. 1, Q Plus Brake (other than MX500 Series)

Brake Components Disassembly, Inspection, Cleaning, and Assembly



NOTE: 16-1/2 inch Q Plus MX500 brake with cast spider shown.

1. Anchor Pin
2. Anchor Pin Bushing
3. Retaining Spring
4. Brake Shoe and Lining Assembly
5. Cam Roller
6. Roller Retainer
7. Capscrew, Chamber Bracket
8. Capscrew, Dust Shield
9. Dust Shield
10. Camshaft Snap Ring
11. Washer (spacer)
12. Washer (thin spacer)
13. Orange Seal, Automatic Slack Adjuster
14. Automatic Slack Adjuster
15. Seal, Automatic Slack Adjuster
16. Washer (thick spacer)
17. Camshaft Seal
18. Camshaft Bushing, 1-1/2 in. ID
19. Camshaft-and-Chamber Bracket
20. Pipe Plug
21. Chamber Bracket Seal
22. Brake Spider, Cast
23. Return Spring Pin
24. Return Spring
25. Camshaft Bushing, 1-5/8 in. ID
26. Orange Camshaft Seal
27. Camhead Thrustwasher
28. S-Head Camshaft

Fig. 2, Q Plus MX500 Brake (with cast spider)

2.3 Using a drum caliper or other measuring device, measure the inside diameter of the drum in several locations. Replace the drum if it exceeds the maximum diameter stamped on it.

3. Disconnect the slack adjuster from the pushrod clevis. For detailed instructions, see the appropriate section in this group.

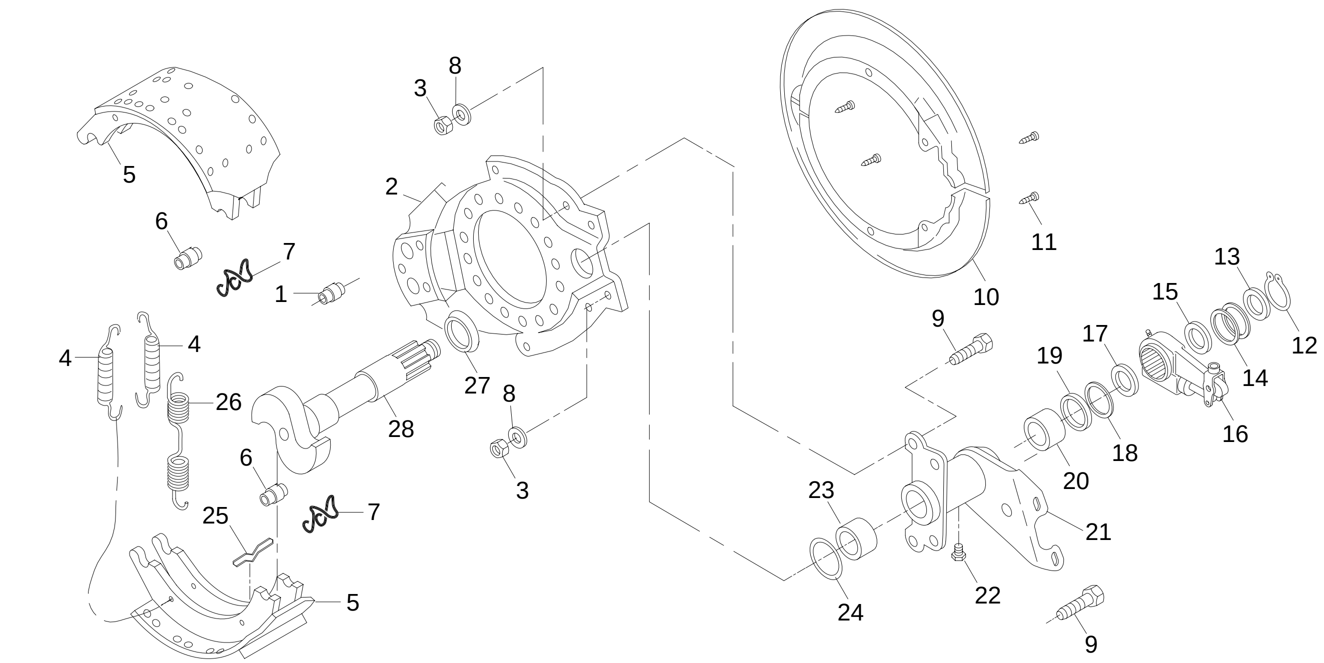
3.1 Remove the cotter pin from the clevis pin; remove the clevis pin. See **Fig. 5**.

CAUTION

For a Meritor automatic slack adjuster, disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

3.2 For a Meritor automatic slack adjuster, disengage the pull-pawl on the side of the adjuster. Using a screwdriver or an equivalent tool, pry the pawl button out about 1/32 inch (0.8 mm) and wedge the tool in place. See **Fig. 6**. Pull-pawls are spring loaded. When the tool is removed,

Brake Components Disassembly, Inspection, Cleaning, and Assembly



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NOTE: 16-1/2 inch drive axle Q Plus MX500 brake with stamped spider shown.

1. Anchor Pin
2. Brake Spider, Stamped
3. Hexnut (4 qty.)
4. Retaining Spring
5. Brake Shoe and Lining Assembly
6. Cam Roller
7. Retainer
8. Washer, Hardened (4 qty.)
9. Bolt (4 qty.)
10. Dust Shield
11. Capscrew, Dust Shield
12. Camshaft Snap Ring
13. Washer (spacer)
14. Washer (thin spacer)
15. Orange Seal, Automatic Slack Adjuster
16. Automatic Slack Adjuster
17. Seal, Automatic Slack Adjuster
18. Washer (thick spacer)
19. Camshaft Seal
20. Camshaft Bushing, 1-1/2 in. ID
21. Camshaft-and-Chamber Bracket
22. Pipe Plug
23. Camshaft Bushing, 1-5/8 in. ID
24. Orange Camshaft Seal
25. Return Spring Pin
26. Return Spring
27. Camhead Thrustwasher
28. S-Head Camshaft

Fig. 3, Q Plus MX500 Brake (with stamped spider)

the pull-pawl will engage the teeth automatically.

IMPORTANT: Never pull the slack adjuster out of the pushrod clevis. Always turn the adjusting nut for positioning.

3.3 Using a wrench, turn the manual adjusting nut to back the slack adjuster out of the clevis.

- On Meritor adjustors, turn the square adjusting nut clockwise (as if loosening a right-hand threaded fastener).
- On Haldex or Gunite adjusters, turn the adjusting hexnut counterclockwise. You will hear a ratcheting sound.

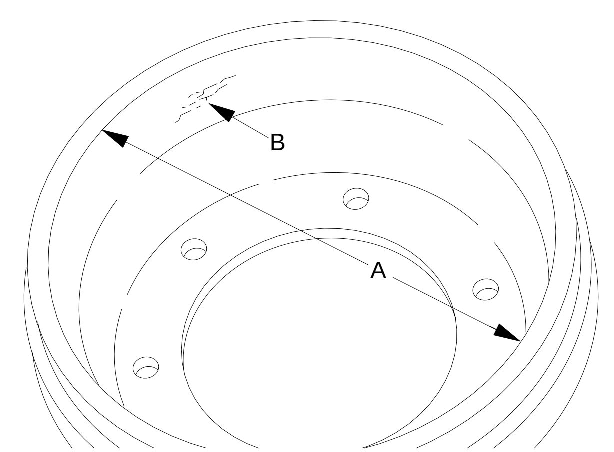
4. Check the camshaft radial free play. See **Fig. 7**.

4.1 Using a dial indicator, measure the up-and-down and side-to-side free play of the camshaft.

4.2 Replace the camshaft bushings if there is more than 0.020 inch (0.5 mm) of free play.

5. Remove the slack adjuster.

Brake Components Disassembly, Inspection, Cleaning, and Assembly



A. Check for diameter and out-of-round.
B. Check for cracks, heat checks, glazing, and grooves.

Fig. 4, Brake Drum Inspection

5.1 From the slack adjuster side of the camshaft-and-chamber bracket, remove the snap ring and any washers, spacers, and seals from the camshaft. For instructions, see the appropriate section in this group.

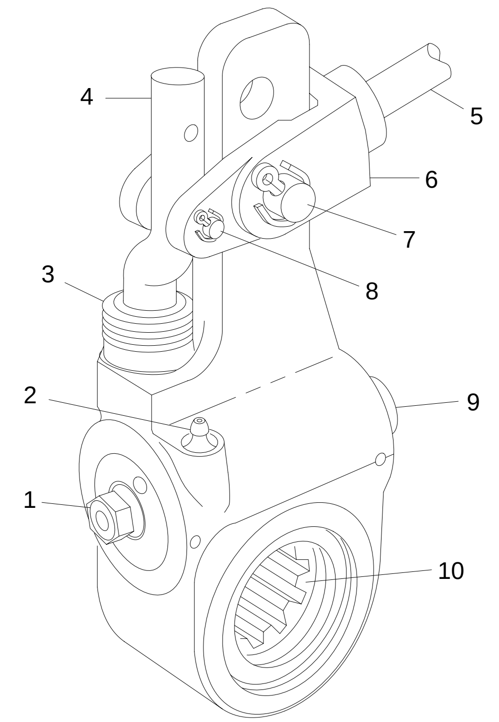
5.2 Remove the slack adjuster from the camshaft.

6. Inspect the slack adjuster for damage or binding.

6.1 Check the slack adjuster clevis for cracks or bushing wear. Check the splines for chipped teeth and deformation. Replace as needed.

NOTE: For a Haldex or a Gunite automatic slack adjuster, there is an internal clutch that resists the manual adjusting nut from being turned in the counterclockwise direction. When checking these slack adjusters for binding, only rotate the manual adjusting nut in the clockwise direction.

6.2 Using a torque wrench that measures lbf·in (or N·cm), turn the manual adjusting nut clockwise so that the worm gear rotates a full 360 degrees (typically 22 turns of the wrench).



NOTE: Gunite automatic slack adjuster shown.

1. Adjusting Hexnut
2. Grease Fitting
3. Boot
4. Link
5. Brake Chamber Pushrod
6. Clevis
7. Clevis Pin, 1/2-in
8. Clevis Pin, 1/4-in
9. Grease Relief Opening
10. Slack Adjuster Spline

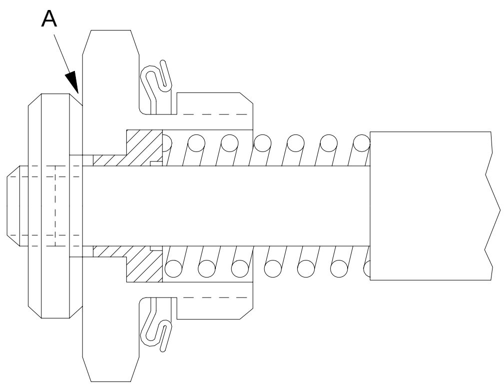
Fig. 5, Disconnect Slack Adjuster from Clevis

If there is binding, or if more than 25 lbf·in (280 N·cm) is needed to turn the slack adjuster, replace it. For instructions, see the applicable slack adjuster section in this group.

IMPORTANT: If any slack adjuster problem is found, repair or replace the unit, depending on the manufacturer's recommendations.

7. Remove the camshaft by grasping its head and pulling the camshaft outboard from the brake spider and camshaft-and-chamber bracket. See **Fig. 8**. Then, remove the thrustwasher from the camshaft.

Brake Components Disassembly, Inspection, Cleaning, and Assembly



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A. Insert a screwdriver here to pry the pull-pawl out about 1/32 inch (0.8 mm).

Fig. 6, Disengage the Pull-Pawl on Meritor Automatic Slack Adjusters

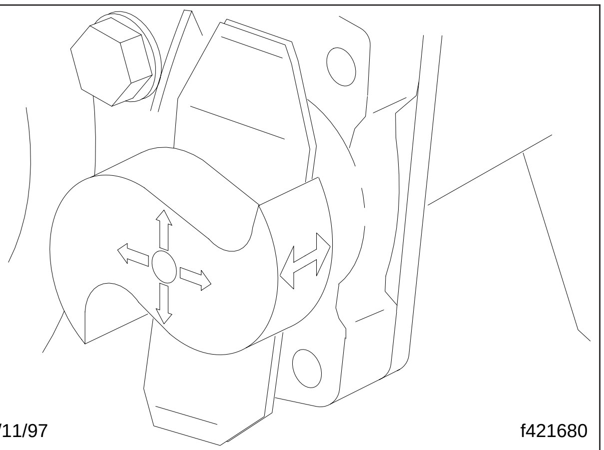

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Fig. 7, Check Free Play

8. Check the camshaft spline end for cracks, corrosion, or worn or deformed splines. Replace the camshaft if it is damaged.
9. Check the camshaft bearing journals for wear or corrosion. Replace the camshaft if it is worn or if roughness is felt in the journal area.
10. Inspect the camshaft head for brinelling, cracking, or flat spots. Replace the camshaft if a ridge can be felt between the worn area and the cam head surface.
11. From the brake spider and slack adjuster ends of the camshaft-and-chamber bracket, remove and

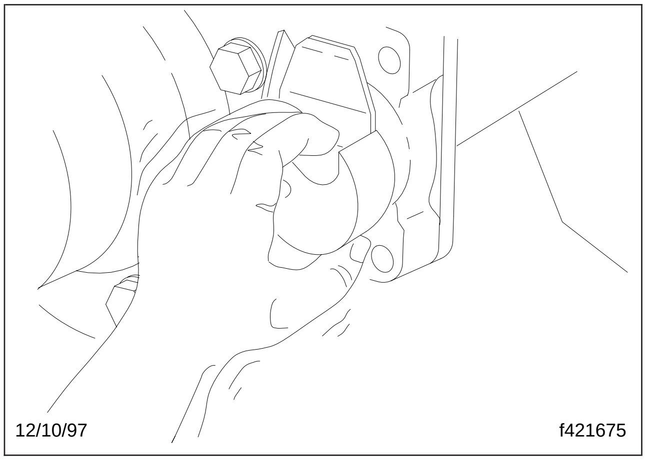

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Fig. 8, Remove the Camshaft

inspect the camshaft grease seals. If a grease seal lip is nicked, cut, or distorted, replace it.

WARNING

When removing bushings with a driver, wear eye protection. Do not hit steel parts with a steel hammer. To do so could cause steel pieces to break off, which could cause serious eye injury.

12. Using the correct size driver, remove the camshaft bushings from the camshaft-and-chamber bracket.
13. Check the camshaft bushings for wear. The inner surface must be smooth; if rough or abrasive, replace the bushings.
14. Remove the brake chamber stud nuts and lockwashers that attach the brake chamber to the camshaft-and-chamber bracket.

    Check the chamber for a cracked housing, bent pushrod, loose clamp ring, loose air fitting, air leaks, or clogged vent holes. Repair or replace brake chamber parts as needed.
15. Remove and inspect the camshaft-and-chamber bracket. Remove and discard the gasket.

    Check the bracket for a bent, broken, or cracked arm and cracked welds. Replace the bracket if any of these conditions exist.
16. Remove the brake spider-to-axle attaching nuts, hardened washers, and bolts. Remove the brake spider from the axle flange.

Brake Components Disassembly, Inspection, Cleaning, and Assembly

17. If equipped, remove the four capscrews that attach the dust shield to the brake spider; remove the dust shield.
18. Inspect the brake spider and parts for damage; replace as needed.
    18.1 Check the bolt holes, cam area, and anchor pin area for cracks and check for expanded anchor pin holes. Replace if damaged.
    18.2 Check the anchor pins. If worn or loose, replace them.
    18.3 Check the anchor pin bushings for wear. The inner surfaces must be smooth. If any surface is rough or abrasive, replace the part.

Cleaning

WARNING

Before starting the procedure below, read the information in Safety Precautions 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

CAUTION

Do not clean ground or polished metal parts in a hot solution tank or with water, steam, or alkaline solutions. These solutions will cause parts to corrode.

For corrosion protection, do not apply brake grease or corrosion-preventive materials to the brake linings or the brake drum.

After removing the brake parts being serviced, do the following:

1. Clean the camshaft journals with an emery cloth.
2. Wire brush all parts exposed to mud, road dirt, and salt, including the exterior of the drum, brake spider, camshaft-and-chamber bracket, and dust shields (if equipped). If relining the shoes, thoroughly wire-brush the shoe tables, and paint them with a rust-inhibitive coating.

CAUTION

A thick layer of oxidation and dirt on the outside of a brake drum acts as an insulator and may hinder normal heat dissipation. Make sure oxidation and dirt are removed by wire brushing, or damage to brake components could occur.

3. Using an industrial vacuum cleaner with a HEPA filter system, remove any dust accumulation from the brake parts.
4. Wipe the interior of the drums with a damp rag to remove lining dust.
5. Prepare the brake parts for assembly.
    5.1 Thoroughly clean all the brake parts.

    For ground or polished metal parts, use a cleaning solvent to clean the parts and surfaces that are ground or polished.

    For rough metal parts, use a cleaning solvent or a weak alkaline solution in a hot solution tank to clean the parts. If a hot solution tank is used, leave the rough parts in the hot solution tank until they are completely cleaned and heated. Remove the rough parts from the hot solution tank and wash them with water until the alkaline solution is removed.

    5.2 Thoroughly dry all the brake parts with either compressed air or a clean soft cloth or paper towel.

WARNING

All worn or damaged brake parts must be replaced. If the brakes are assembled with worn or damaged parts, they may not perform to their capacity and a brake failure could occur, which could cause personal injury and property damage.

    5.3 Thoroughly inspect all the brake parts for wear or damage. It is very important that all the parts be carefully inspected before they are assembled. Repair or replace any worn or damaged parts.
    5.4 For parts that will be assembled, apply a thin layer of brake grease to the parts

Brake Components Disassembly, Inspection, Cleaning, and Assembly

after they have been cleaned, dried, and inspected to protect them from corrosion.

If the parts will be stored, apply a special material that prevents corrosion and rust on all surfaces. The parts should be stored in special paper (or other material) that prevents corrosion and rust.

Assembly

WARNING

Before starting the assembly procedure, read the information in Safety Precautions 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

1. Install the dust shield, if equipped. See **Fig. 1**, **Fig. 2**, or **Fig. 3**.

   Position the dust shield against the brake spider and install the capscrews. Tighten the capscrews to the specifications in **Table 1**.

2. Install the brake spider.

   Place the brake spider on the axle flange. Install the mounting fasteners with hardened washers under the bolt head and nut. Tighten the nuts to the specifications in **Table 1** in a cross pattern. See **Fig. 9**.

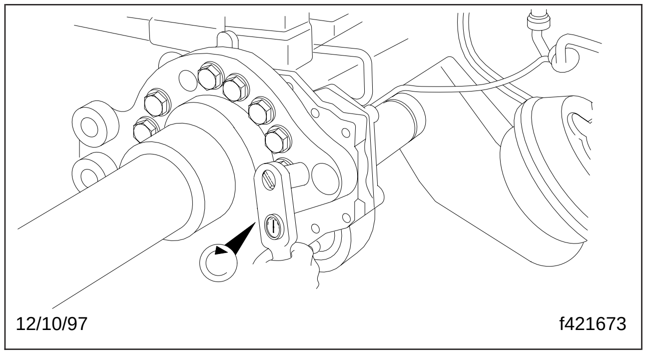


Fig. 9, Tighten the Brake Spider Fasteners

3. Install the camshaft-and-chamber bracket.

   Place the camshaft-and-chamber bracket and gasket against the brake spider and install the lockwashers and fasteners. Tighten the fasteners to the specifications in **Table 1**.

Fastener		Torque Specification	
Size	**Grade**	**lbf·ft**	**N·m**
Dust Shield Fasteners			
5/16–18	5	15 to 20	20 to 27
3/8–16	5	25 to 35	34 to 47
3/8–16	8	35 to 50	47 to 68
Brake Spider Fasteners			
7/16–20		60 to 75	81 to 102
1/2–20		85 to 115	115 to 156
9/16–18		135 to 165	176 to 224
5/8–18		180 to 230	244 to 312
Camshaft-and-Chamber Bracket Fasteners			
1/2–13 Capscrew (without nut)	5	65 to 85	88 to 116
1/2–13 Capscrew (without nut)	8	70 to 100	95 to 136
5/8–18 Bolt with Locknut		130 to 165	176 to 224
5/8–18 Bolt with Plain Hexnut		150 to 190	203 to 258

Table 1, Dust Shield, Spider, and Bracket Torque Specifications

Brake Components Disassembly, Inspection, Cleaning, and Assembly

NOTE: If replacing a brake chamber, make sure that the new chamber is the same size and make as the brake chamber on the other side of the axle.

4. Install the brake chamber.

    4.1 Place the brake chamber on the mounting flange (camshaft-and-chamber bracket) with the chamber mounting studs through the flange holes.

    4.2 Install the hardened flatwashers, lock-washers, and stud nuts.

    4.3 Tighten the brake chamber fasteners to the specifications in **Table 2**.

IMPORTANT: The grease seals are installed in both the brake spider and slack adjuster ends of the camshaft-and-chamber bracket. The grease seals must be installed with their lips toward the slack adjuster end of the camshaft-and-chamber bracket tube.

NOTE: To maximize lining life, Meritor recommends replacing the springs, rollers, anchor pins, and camshaft bushings when the linings are replaced. For Q Plus brakes with MX500 identification tags, if replacing the linings before the recommended service interval (3 years or 500,000 miles [800 000 km]), the camshaft bushings and the seals do not need to be replaced.

5. Using a seal driver, install the camshaft seals and the new camshaft bushings in the brake spider and slack adjuster ends of the camshaft-and-chamber bracket. See **Fig. 10**. Install the seals with their lips toward the slack adjuster. See **Fig. 11**.

6. Install the camshaft. See **Fig. 12**.

    6.1 Put the cam head thrustwasher on the camshaft with the bent flaps toward the brake spider.

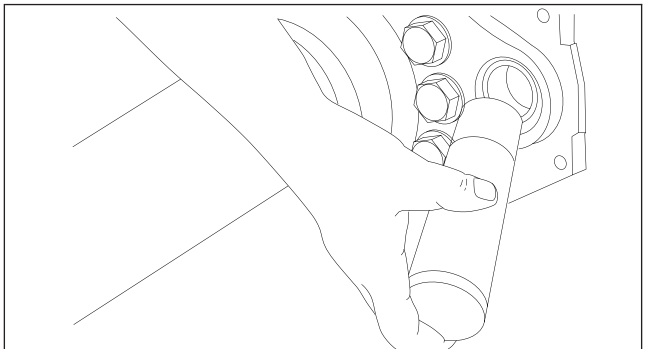
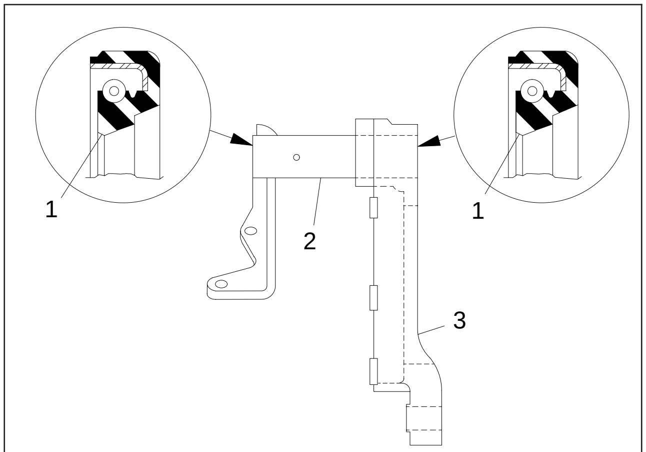


Fig. 10, Install the Seals and Bushings



NOTE: The seal faces the slack adjuster.

1. Seal Lip
2. Camshaft-and-Chamber Bracket
3. Brake Spider

Fig. 11, Positioning the Seals

Brake Components Disassembly, Inspection, Cleaning, and Assembly

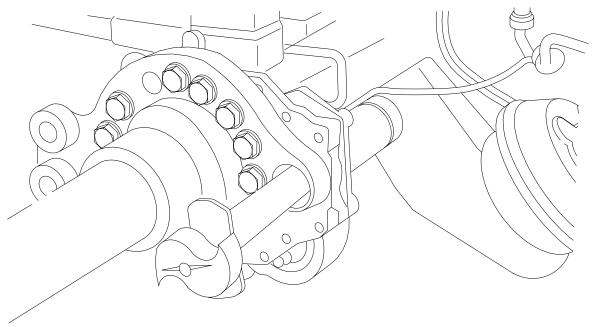


Fig. 12, Install the Camshaft

Chamber Type (Size)	Brake Chamber Torque Specifications: lbf·ft (N·m)		
	Midland	**MGM**	**Anchorlok**
16	35 to 50 (48 to 68)	35 to 40 (48 to 54)	Not Available
20	70 to 100 (95 to 136)	100 to 115 (136 to 156)	With hexnut, 110 to 115 (149 to 203) With locknut, 85 to 95 (115 to 129)
24	70 to 100 (95 to 136)	100 to 115 (136 to 156)	With hexnut, 110 to 115 (149 to 203) With locknut, 85 to 95 (115 to 129)
30	70 to 100 (95 to 136)	100 to 115 (136 to 156)	With hexnut, 110 to 115 (149 to 203) With locknut, 85 to 95 (115 to 129)
36	70 to 100 (95 to 136)	100 to 115 (136 to 156)	With hexnut, 110 to 115 (149 to 203) With locknut, 85 to 95 (115 to 129)
Spring Chamber	70 to 100 (95 to 136)	100 to 115 (136 to 156)	With hexnut, 110 to 115 (149 to 203) With locknut, 85 to 95 (115 to 129)

Table 2, Brake Chamber Torque Specifications

6.2 Apply a thin film of grease on the inside of the camshaft bushings and journals. For the recommended grease specification, see **Specifications 400**. Do not grease the camshaft head area.

6.3 Apply a thin film of rust preventive grease on the camshaft splines. For the recommended grease specification, see **Specifications 400**.

6.4 Carefully slip the camshaft in the brake spider and the camshaft-and-chamber bracket tube. The camshaft should turn freely by hand.

7. Install the slack adjuster. For instructions, see the appropriate section in this group.

WARNING

When lubricating the camshaft-and-chamber bracket, if grease leaks out under the cam head, the camshaft grease seal is worn or damaged. If the seal is not replaced, the brake linings could be contaminated by grease and the vehicle's stopping distance could be increased, which could result in personal injury or property damage.

Brake Components Disassembly, Inspection, Cleaning, and Assembly

8. For all Cam-Master Q Plus brakes except MX500, pressure lube the camshaft-and-chamber bracket bushings.

   NOTE: Use meter-type fittings with a maximum 40 psi (276 kPa) pressure relief at the shutoff.

   8.1 Pump multipurpose chassis grease (NLGI grade 1 or 2) into the camshaft-and-chamber bracket until it appears at the slack adjuster end of the bracket. Use care that no grease enters the drum cavity. For recommended grease specification, see **Specifications 400**.

   8.2 If grease leaks out under the cam head, the camshaft grease seal is worn, damaged, or installed backwards. See "Disassembly and Inspection" for grease seal replacement instructions.

NOTE: If the brake linings are being replaced on MX500 brakes before the service interval, the camshaft-and-chamber bracket and the slack adjuster do not need lubrication. The service interval is every 3 years or 500,000 miles (800 000 km), whichever comes first.

9. For MX500 brakes, when changing the brake linings at the service interval, lubricate the camshaft-and-chamber bracket and the automatic slack adjuster.

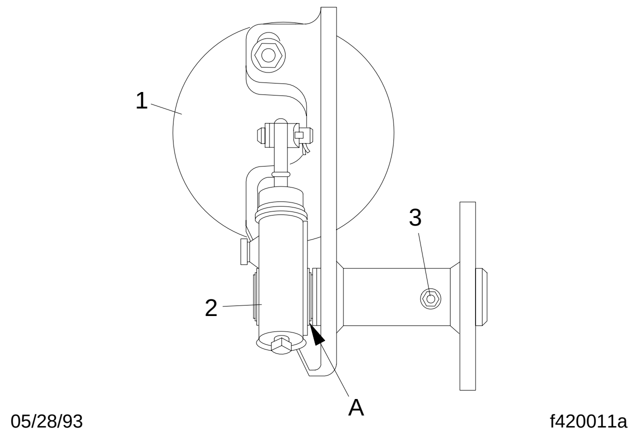
   9.1 Remove the identification tag from the camshaft-and-chamber bracket housing.

   9.2 Remove the grease plugs from both the camshaft-and-chamber bracket and the automatic slack adjuster.

   9.3 Install grease fittings.

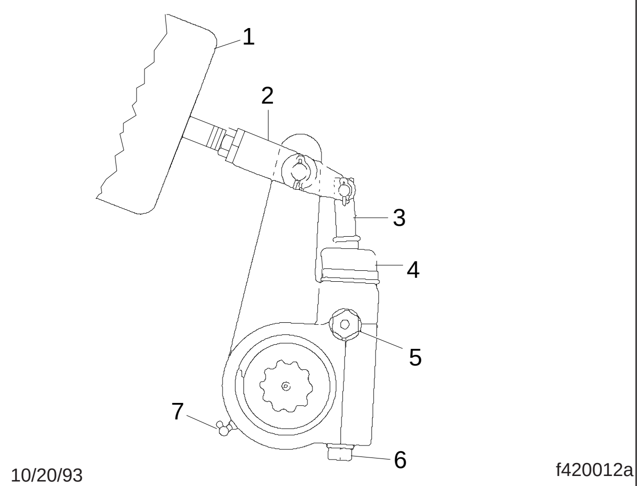
   9.4 Using Meritor-approved NLGI grade 2 synthetic polyurea grease (EVO-LUBE TEK-615), lubricate the brake assembly through the grease fitting in the bracket until new grease flows from the inboard seal. See **Fig. 13**.

   9.5 Using Meritor-approved NLGI grade 2 synthetic polyurea grease (EVO-LUBE TEK-615), lubricate the slack adjuster through the grease fitting until new grease flows out of the pull-pawl or camshaft seal. See **Fig. 14**.



A. Grease Exit
1. Brake Chamber
2. Slack Adjuster
3. Grease Fitting (or lube plug)

Fig. 13, Camshaft-and-Chamber Bracket Lubrication



1. Brake Chamber
2. Clevis
3. Actuator Rod
4. Boot
5. Pull-Pawl Seal
6. Adjusting Hexnut
7. Grease Fitting

Fig. 14, Slack Adjuster Lubrication

   9.6 Replace the grease fittings with new grease plugs and cover the bracket plug with a new identification tag.

10. Install the brake shoes. For instructions, see **Subject 110**.

Troubleshooting Tables

Problem—No Adjustment, or Adjusted Stroke is Too Long

Problem—No Adjustment, or Adjusted Stroke is Too Long	
Possible Cause	**Remedy**
The wrong slack adjuster is installed.	Replace the slack adjuster with the correct one.
The clevis is not installed correctly.	Check the slack adjuster installation. For instructions, see the appropriate slack adjuster section in this group.
There is excessive wear between the clevis and collar.	Check the gap between the clevis and the collar. The maximum allowable gap is 0.060 inch (1.5 mm). Replace the threaded clevis as necessary.
The jam nut at the clevis is loose.	Tighten the jam nut to specifications.
The large clevis pin bushing in the slack adjuster arm is worn.	Measure the inside diameter of the large clevis pin bushing. The inside diameter must not be larger than 0.53 inch (13.5 mm). Replace the bushing as necessary.
The return spring in the air chamber is weak or broken.	Check the air chamber spring force. At the first movement of the push rod, the spring force must be at least 32 lbf (142.3 N). Replace the return spring or air chamber as necessary.
The spring brake is not fully retracting.	Repair or replace the spring brake.
The pull-pawl or the actuator is worn (the teeth are stripped).	Replace the pull-pawl or the actuator in the slack adjuster.
The slack adjuster has internal damage.	Inspect the slack adjuster. Repair or replace the slack adjuster as necessary. For instructions, see the appropriate slack adjuster section in this group.
There is excessive play between the slack adjuster gear and the splines of the camshaft.	Replace the camshaft and/or the slack adjuster as necessary.
Foundation brake components are worn.	Replace the components.

Problem—Linings Dragging, or Adjusted Stroke is Too Short

Problem—Linings Dragging, or Adjusted Stroke is Too Short	
Possible Cause	**Remedy**
The incorrect brake linings are installed	Install the correct Meritor approved brake linings.
The wrong slack adjuster is installed.	Replace the slack adjuster with the correct one.
The clevis is not installed correctly.	Check the slack adjuster installation. For instructions, see the appropriate slack adjuster section in this group.
The jam nut at the clevis is loose.	Tighten the jam nut to specifications.
The spring brake is not fully retracting.	Repair or replace the spring brake.
The manual (free-stroke) adjustment is incorrect.	Adjust the free-stroke and applied chamber stroke. For instructions, see **Subject 130**.
Poor contact between the linings and the drum, or the drum is out-of-round.	Repair or replace the drum or the linings.
There is a brake temperature imbalance.	Correct the brake balance.

Specifications

Q Plus Brake Torque Specifications			
Fastener Size	**Grade**	**lbf·ft**	**N·m**
Brake Shoe Lining Nuts			
1/4 in	5	80 to 100 lbf·in	900 to 1120 N·cm
3/8 in	5	18 to 23	24 to 31
Dust Shield Fasteners			
5/16–18	5	15 to 20	20 to 27
3/8–16	5	25 to 35	34 to 47
3/8–16	8	35 to 50	47 to 68
Brake Spider Fasteners			
7/16–20	—	60 to 75	81 to 102
1/2–20	—	85 to 115	115 to 156
9/16–18	—	135 to 165	176 to 224
5/8–18	—	180 to 230	244 to 312
Camshaft-and-Chamber Bracket Fasteners			
1/2–13 Capscrew (without nut)	5	65 to 85	88 to 116
1/2–13 Capscrew (without nut)	8	70 to 100	95 to 136
5/8–18 Bolt with Locknut	—	130 to 165	176 to 224
5/8–18 Bolt with Plain Hexnut	—	150 to 190	203 to 258

Table 1, Q Plus Brake Torque Specifications

Chamber Type (Size)	Brake Chamber Torque Specifications: lbf·ft (N·m)		
	Midland	**MGM**	**Anchorlok**
16	35 to 50 (48 to 68)	35 to 40 (48 to 54)	Not Available
20, 24, 30, 36	70 to 100 (95 to 136)	100 to 115 (136 to 156)	With hexnut, 110 to 115 (149 to 203) With locknut, 85 to 95 (115 to 129)
Spring Chamber	70 to 100 (95 to 136)	100 to 115 (136 to 156)	With hexnut, 110 to 115 (149 to 203) With locknut, 85 to 95 (115 to 129)

Table 2, Brake Chamber Torque Specifications

Meritor Grease Specification			
Specification Number	**NLGI Grade**	**Grease Type**	**Outside Temperature, °F (°C)**
O-616-A	1	Clay Base	Down to –40 (–40)
O-617-A O-617-B	1 and 2	Lithium 12-Hydroxy Stearate or Lithium Complex	See Manufacturer’s Specification
O-645	2	Synthetic Oil, Clay Base	Down to –65 (–54)
O-692	1 and 2	Lithium Base	Down to –40 (–40)

Specifications

Meritor Grease Specification			
Specification Number	**NLGI Grade**	**Grease Type**	**Outside Temperature, °F (°C)**
O-637	1 and 2	Calcium Base	See Manufacturer's Specification
O-641	—	Anti-Seize	See Manufacturer's Specification
O-695	2	Synthetic Polyurea	–40 (–40)

Table 3, Meritor Grease Specification

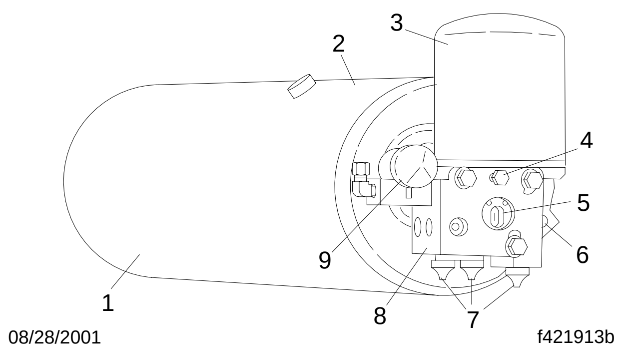
Component Lubrication						
Brake Type	**Meritor Grease Specification**					
	Clevis Pins	**Camshaft Splines**	**Anchor Pins**	**Brake Shoe Rollers**	**Camshaft Bushings**	**Slack Adjusters**
All Cam-Master Brakes Except Q Plus MX500	O-616-A O-637 O-641 O-645 O-692	O-616-A O-617-A O-617-B O-637 O-641 O-645 O-692	O-616-A O-617-A O-617-B O-645 O-692	O-616-A O-617-A O-617-B O-645 O-692	O-616-A O-617-A O-617-B O-645 O-692	O-616A O-645 O-692
Q Plus MX500 Brakes	O-695	O-695	O-617-A O-617-B O-645 O-692	O-617-A O-617-B	O-616-A O-617-A O-617-B O-645 O-692	O-695

Table 4, Component Lubrication

General Information

The function of the dryer reservoir module (DRM) (**Fig. 1**) is to provide the vehicle with an integrated air dryer, secondary reservoir, purge volume, and governor.

NOTE: Some DRM configurations also include an integrated primary reservoir.



NOTE: DRM shown without splash shield.

1. Integrated Reservoir (Secondary Volume)
2. Integrated Reservoir (Purge Volume)
3. Desiccant Cartridge
4. Safety Valve
5. Heater/Thermostat Assembly
6. Auxiliary Delivery Port
7. Pressure Protection Valves
8. AD-IS Air Dryer
9. Governor

Fig. 1, Dryer Reservoir Module

Principles of Operation

The air dryer collects and removes air system contaminants in solid, liquid, and vapor form before they enter the brake system. It provides clean, dry air to the components of the brake system, which also increases the life of the system.

CHARGE CYCLE

When the compressor is loaded, compressed air, oil, oil vapor, water, and water vapor flow through the compressor discharge line to the supply port of the air dryer body.

As air travels through the air dryer assembly, its temperature falls, causing some of the contaminants to condense and drop to the bottom of the air dryer assembly, ready to be expelled at the next purge cycle. See **Fig. 2**.

The air then flows into the desiccant cartridge. Once in the desiccant cartridge, air flows through an oil separator that removes oil and solid contaminants.

Air then flows into the desiccant drying bed. Air flowing through the desiccant becomes progressively dryer as water vapor adheres to the desiccant material.

Dry air exits the bottom of the desiccant cartridge and flows through the center of the base assembly. The air then flows to the delivery check valve, to the safety valve and also through an orifice plug into the purge volume reservoir. Air traveling through the delivery check valve flows to the governor and three pressure protection valves.

As pressure builds during the initial charge, the purge volume fills. When the air pressure reaches 103 psi (710 kPa), the first pressure protection valve opens, filling the primary reservoir. When the primary reservoir pressure reaches 109 psi (752 kPa) the second pressure protection valve opens and air is supplied to the secondary reservoir and accessory pressure protection valve. When air pressure in the secondary reservoir reaches 85 psi (586 kPa), the remaining pressure protection valve opens and supplies air to the accessories.

NOTE: There is no external air line from the air dryer to the secondary reservoir. Air is supplied by a line passing through the purge reservoir.

The air dryer will remain in the charge cycle until the air brake system pressure builds to the governor cutout setting of approximately 130 psi (896 kPa).

PURGE CYCLE

When air brake system pressure reaches the cutout setting of the governor, the governor unloads the compressor and the purge cycle begins. When the governor unloads the compressor, it pressurizes the compressor unloader mechanism and the dryer control port. The purge piston moves in response to air pressure, causing the purge valve to open and the turbo cutoff valve to close. When the purge valve opens, water and contaminants are expelled. Air flowing through the desiccant cartridge changes direction and begins to flow toward the open purge valve. Oil and solid contaminants collected in the oil separator are removed by air flowing from the purge

General Information

volume, through the desiccant drying bed, and out through the open purge valve. See **Fig. 3**.

The purge cycle lasts only a few seconds and is detected by an audible burst of air at the air dryer exhaust.

The reactivation of the desiccant drying bed begins as dry air flows from the purge volume, through the purge orifice, and into the desiccant bed. Pressurized air from the purge volume expands after passing through the purge orifice; its pressure is lowered and its volume is increased. The flow of dry air through the drying bed reactivates the desiccant material by removing the water vapor adhering to it. Approximately 30 seconds is required for the entire purge volume of a standard air dryer to flow through the desiccant dryer bed.

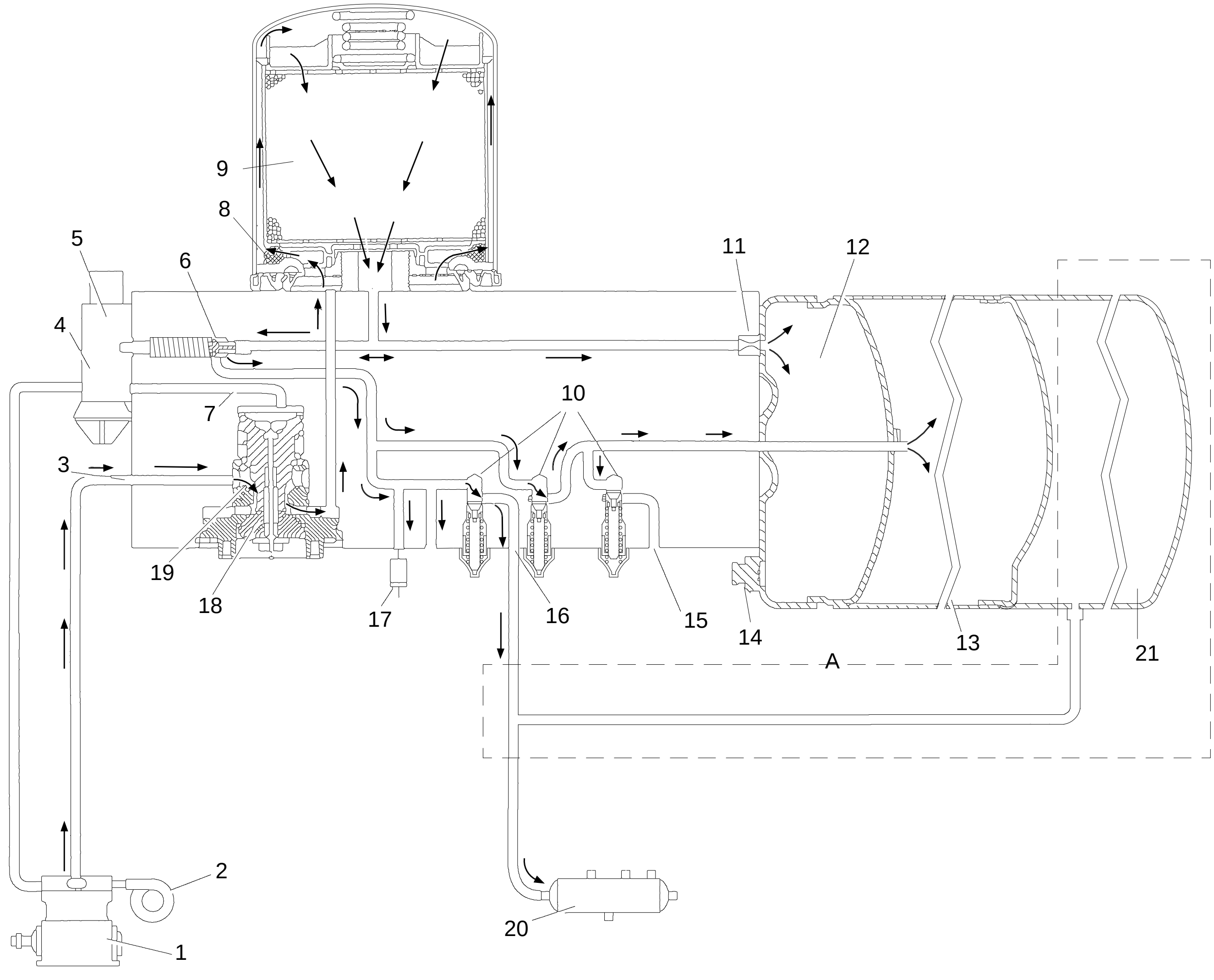
The delivery check valve assembly prevents air pressure in the brake system from returning to the air dryer during the purge cycle. After the purge cycle is complete, the air dryer is ready for the next charge cycle to begin.

Turbo Cutoff Feature

The primary function of the turbo cutoff valve is to prevent loss of turbocharger air pressure through the air dryer in systems where the compressor intake is connected to the engine turbocharger.

During the purge cycle, the downward travel of the purge piston is stopped when the turbo cutoff valve contacts its mating metal seat in the purge valve housing. With the turbo cutoff valve seated (closed position), air in the compressor discharge line and air dryer inlet port cannot enter the air dryer. This maintains turbocharger boost pressure to the engine.

General Information

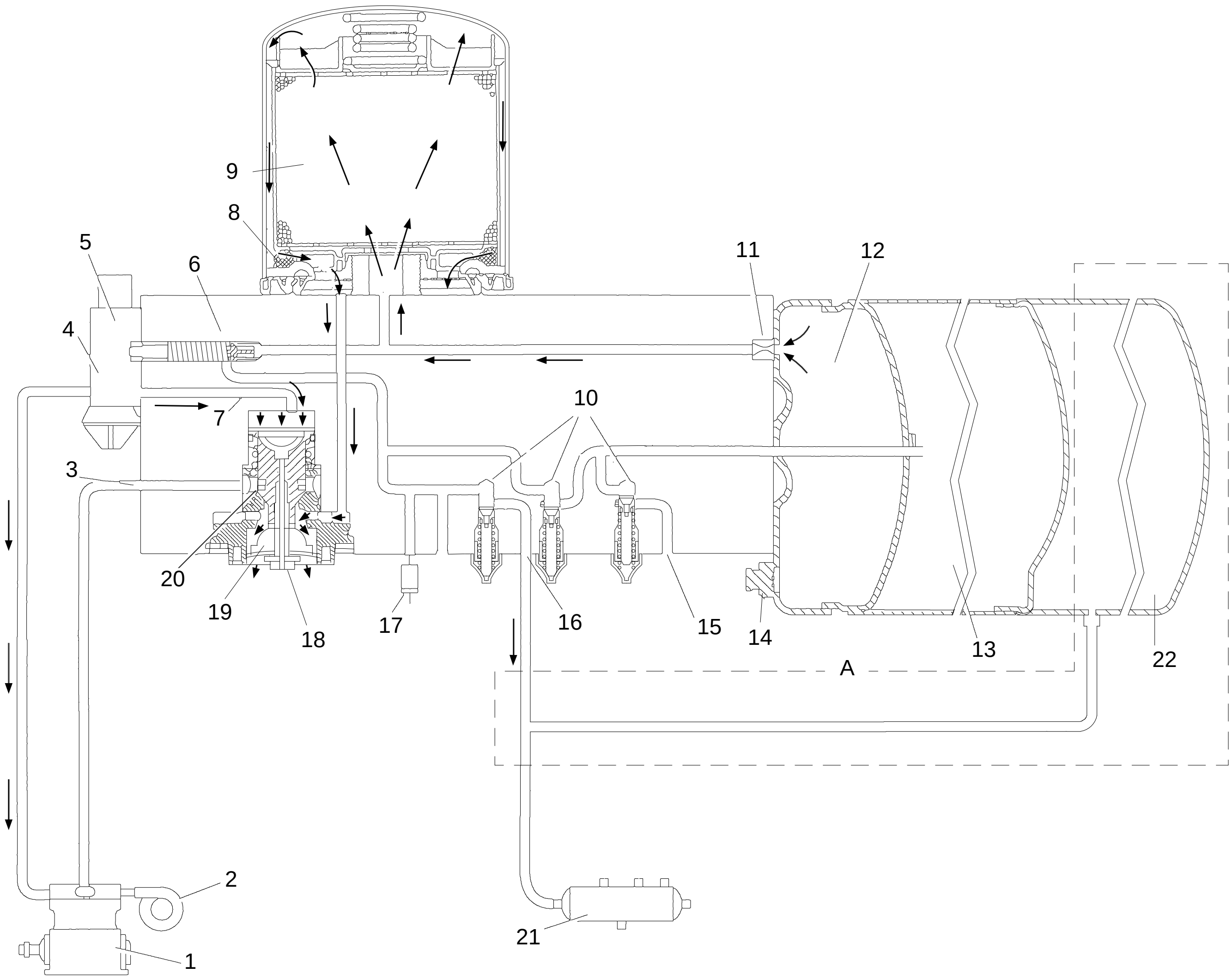


A. Class 8 vehicles have an integrated primary reservoir.

1. Compressor
2. Engine Turbo
3. Inlet Port
4. Unloader Port
5. Governor
6. Delivery Check Valve
7. Purge Control Passage
8. Oil Separator
9. Desiccant Bed
10. Pressure Protection Valves
11. Purge Orifice
12. Integrated Reservoir (Purge Volume)
13. Integrated Reservoir (Secondary Volume)
14. Purge Volume Drain Cock
15. Auxiliary Port
16. Primary Port
17. Safety Valve
18. Purge Valve (closed)
19. Turbo Cutoff Valve (open)
20. Primary Reservoir
21. Integrated Reservoir (Primary Volume)

Fig. 2, Air Dryer Charge Cycle

General Information



A. Class 8 vehicles have an integrated primary reservoir.

1. Compressor
2. Engine Turbo
3. Inlet Port
4. Unloader Port
5. Governor
6. Delivery Check Valve
7. Purge Control Passage
8. Oil Separator
9. Desiccant Bed
10. Pressure Protection Valves
11. Purge Orifice
12. Integrated Reservoir (Purge Volume)
13. Integrated Reservoir (Secondary Volume)
14. Purge Volume Drain Cock
15. Auxiliary Port
16. Primary Port
17. Safety Valve
18. Exhaust
19. Purge Valve (open)
20. Turbo Cutoff Valve (closed)
21. Primary Reservoir
22. Integrated Reservoir (Primary Volume)

Fig. 3, Air Dryer Purge Cycle

Safety Precautions

Before attempting to work on the air brake system, observe the following precautions:

- Since the compression and storage of air can be compared to energy in a coiled spring, when released, it can present a hazard if not properly recognized. The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer’s recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- Used reservoirs must not be used as replacements in order to eliminate the possibility of component failure.
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

Air Dryer Replacement

Replacement

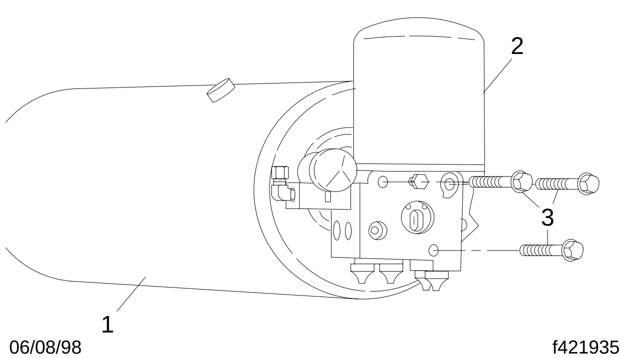
WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs, including the purge reservoir drain valve located under the air dryer.
3. Mark and remove the air lines from the air reservoir.

IMPORTANT: It may be necessary to remove the air reservoir to replace the air dryer. For instructions on air reservoir removal, see **Subject 160**.

4. Unplug the wiring harness from the heater/thermostat assembly.
5. Remove the three capscrews fastening the air dryer to the air reservoir. See **Fig. 1**.



NOTE: Splash shield not shown.

1. Air Reservoir
2. Air Dryer
3. Capscrews

Fig. 1, Air Dryer Removal and Installation

6. Remove the air dryer.
7. Remove the governor and delivery check valve from the air dryer. For instructions, see **Subject 130**.
8. Remove the desiccant cartridge. For instructions, see **Subject 120**.

Installation

1. Install the delivery check valve and governor onto the air dryer. For instructions, see **Subject 130**.
2. If removed, install the desiccant cartridge. For instructions, see **Subject 120**.
3. Install the air dryer, making sure the two O-rings are installed between the air dryer and air reservoir. Use the three capscrews to fasten the air dryer to the reservoir. Tighten the capscrews 30 to 35 lbf·ft (41 to 47 N·m). See **Fig. 1**.
4. Connect the air lines and plug the wiring harness into the heater/thermostat assembly.
5. Perform the operational tests in **Subject 170**.

Replacement

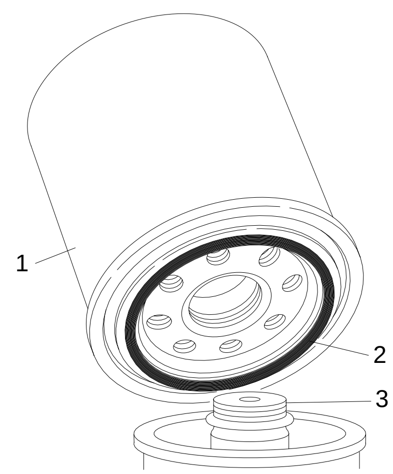
WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Park the vehicle, shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs, including the purge reservoir drain valve located under the air dryer.

IMPORTANT: It may be necessary to remove the air reservoir to replace the desiccant cartridge. For instructions on air reservoir removal and installation, see **Subject 160**.

3. Using a strap wrench or equivalent, loosen the desiccant cartridge. Spin the cartridge off by hand and discard it. See **Fig. 1**.



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1. Desiccant Cartridge
2. Cartridge Sealing Ring
3. Threaded Base Post

Fig. 1, Desiccant Cartridge Replacement

4. On the new desiccant cartridge, lubricate the sealing rings with silicone grease.

IMPORTANT: Only use the silicone grease supplied with AlliedSignal replacement kits.

5. Screw the desiccant cartridge onto the body, by hand, until the seal makes contact with the body. Rotate the cartridge clockwise about one full turn. If necessary, use a strap wrench to tighten the cartridge.
6. Remove the chocks from the tires.

Delivery Check Valve and Governor Replacement

Replacement

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs, including the purge reservoir drain valve located under the air dryer.

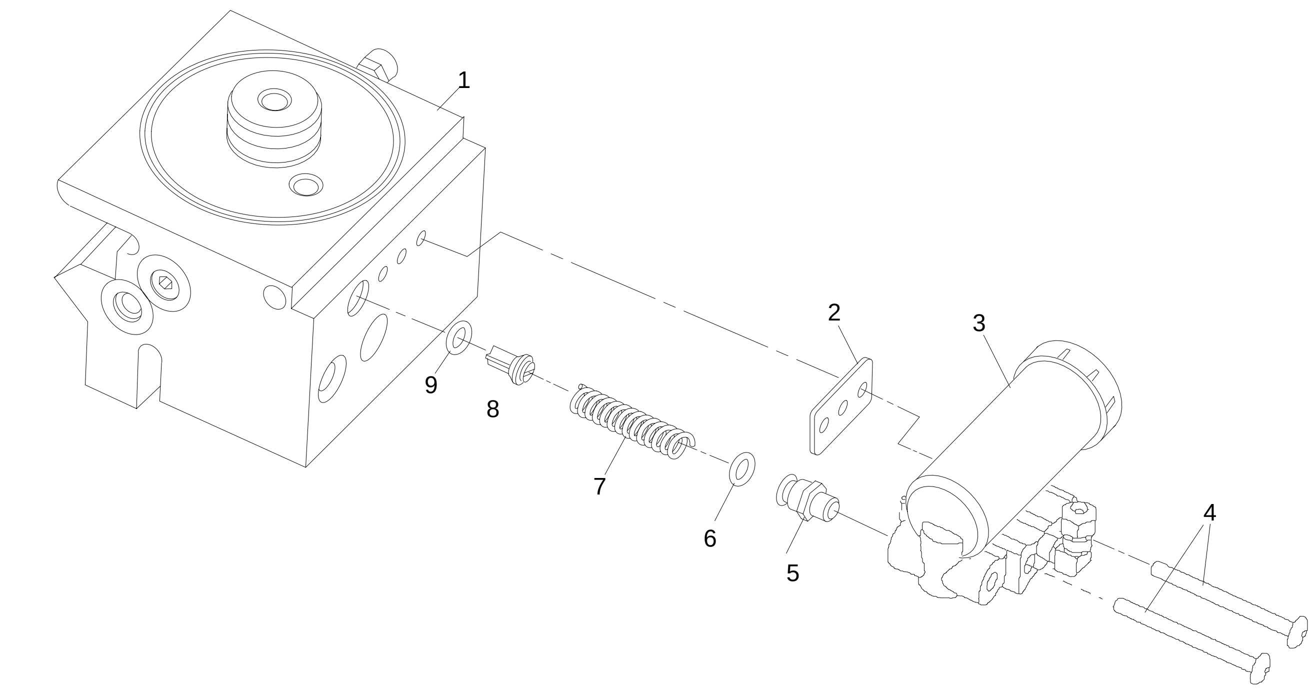
IMPORTANT: It may be necessary to remove the air reservoir to replace the delivery check valve. For instructions on air reservoir removal and installation, see **Subject 160**.

3. Disconnect the air line from the governor and mark it for later reference. Remove the capscrews attaching the governor to the air dryer. See **Fig. 1**.
4. Remove the governor, adaptor fitting, and the adaptor O-ring. Remove the governor gasket and discard.
5. Remove the spring and check valve.
6. Lubricate the new smaller O-ring and check valve body with silicone grease.

IMPORTANT: Only use the silicone grease supplied with AlliedSignal replacement kits.

7. Install the O-ring on the check valve body and push the O-ring down, over the longer set of three guide lands, until it is in the O-ring groove of the check valve body.
8. Install one end of the check valve spring over the check valve's shorter set of three guide lands. Turn the valve about 1/4 turn while holding the spring, if necessary, to secure the valve in place. Install the assembled check valve body, O-ring, and spring in the delivery port so the O-ring rests on its seat and the free end of the spring is visible.
9. Install the adaptor fitting into the governor. Using the silicone grease, lubricate the remaining larger O-ring, and install it into the groove of the adaptor. Install the gasket supplied in the kit. Install the governor and torque the capscrews 10 lbf·ft (14 N·m).
10. Perform the operational tests in **Subject 170**.
11. Remove the chocks

Delivery Check Valve and Governor Replacement



1. Air Dryer Base
2. Gasket
3. Governor
4. Capscrews
5. Adaptor
6. O-Ring
7. Spring
8. Check Valve Body
9. O-Ring

Fig. 1, Delivery Check Valve Replacement

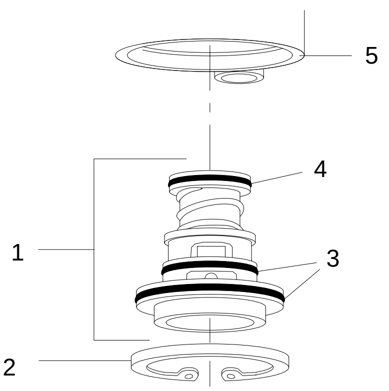
Purge Valve Replacement

Replacement

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs, including the purge reservoir drain valve located under the air dryer.
3. Remove the purge valve assembly from the air dryer end cover. See **Fig. 1**.



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1. Purge Valve Assembly
2. Retaining Ring
3. O-Rings
4. Quad-Ring
5. Air Dryer

Fig. 1, Purge Valve Replacement

    3.1 Remove and discard the snap ring that secures the purge valve assembly in the end cover.

    3.2 Remove the purge valve assembly.

4. Lubricate the new O-rings and O-ring grooves of the new purge valve assembly.
5. Lubricate the end cover bore of the new purge valve assembly.

IMPORTANT: Use only the silicone grease supplied with the AlliedSignal replacement kit.

6. Install the two new O-rings on the purge valve housing cover and the new quad-ring on the purge piston.
7. Install the new purge valve assembly in the end cover while making sure the purge valve housing is fully seated against the end cover.
8. Install the new retaining ring in its groove in the end cover.
9. Perform the operational tests in **Subject 170**.
10. Remove the chocks from the tires.

Heater and Thermostat Replacement

Replacement

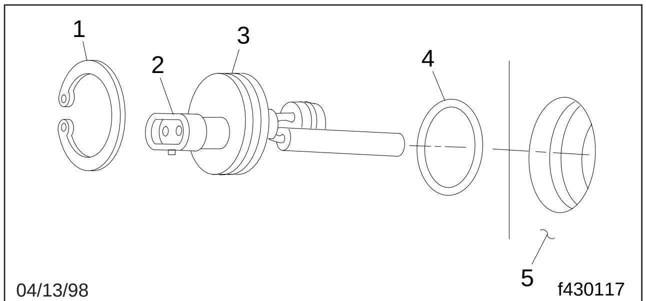
⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Shut down the vehicle, apply the parking brake, and chock the tires.

IMPORTANT: It may be necessary to remove the air reservoir to replace the heater and thermostat. For instructions on air reservoir removal, see **Subject 160**.

2. Remove the splash shield cover. It is secured with three lock tabs.
3. Lift the lock tab on the vehicle wiring harness connector and disconnect it from the air dryer base.
4. Remove and discard the retaining ring that secures the heater and thermostat assembly in the air dryer body.
5. Carefully pull the heater and thermostat assembly straight out of the air dryer body and discard it. See **Fig. 1**.



1. Retaining Ring
2. Heater/Thermostat Connector Plug
3. Heater/Thermostat Assembly
4. O-Ring
5. Air Dryer Body

Fig. 1, Heater and Thermostat Assembly

6. Using the grease provided with the AlliedSignal replacement kit, lubricate the O-ring groove and O-ring of the new assembly with silicone grease.

IMPORTANT: Do not lubricate the heater stick or thermostat.

7. Install the O-ring on the heater/thermostat assembly. Then, slide the assembly into the air dryer body, making sure not to scrape insulation from the wires.
8. Install the retaining ring in the groove of the air dryer body, making certain that it is fully seated in the groove.
9. Remove the protective cover from the assembly.
10. Before proceeding, turn the ignition on without starting the engine. Make sure vehicle power is present at the contacts of the vehicle wire harness.
11. Remove the chocks from the tires.

Replacement

NOTE: The air reservoirs are mounted in various locations, depending on the vehicle configuration. The reservoirs are typically mounted under the driver's-side steps or along the frame rail, behind the cab.

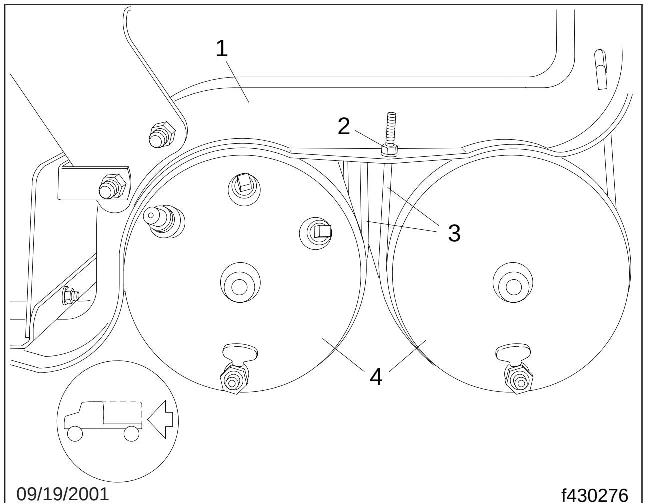
1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Drain the air reservoirs, including the purge reservoir drain valve located under the air dryer.
3. Mark and disconnect all reservoir air lines and couplers for later assembly. Cap the exposed ports tightly to keep out contaminants. If access is limited, remove the components after removing the reservoir from its mount.
4. Remove the reservoir.
   - If the reservoir is mounted under the drivers steps, remove the nuts securing the u-bolt straps and remove the reservoir (**Fig. 1**). Then, remove the air dryer. For instructions, see **Subject 110**.
   - If the reservoir is installed along the frame rail using a strap fastener, remove the air dryer. For instructions, see **Subject 110**. Then, remove the reservoir strap fasteners and remove the reservoir.

NOTE: If access is limited, connect all air lines and couplers to the new reservoir, removing the caps as each component is installed.

5. If the reservoirs are mounted under the driver's steps, install the air dryer onto the new reservoir and install the reservoir. Secure the U-bolt straps with the nuts. See **Fig. 1**.

   If the reservoir is installed along the frame rail using a strap fastener, install the reservoir using the straps. Tighten the fasteners 30 to 40 lbf·ft (41 to 54 N·m). Tighten the lower strap fastener 136 lbf·ft (184 N·m). Then, install the air dryer. For instructions, see **Subject 110**.
6. As marked earlier, connect all air lines and couplers to the new reservoir, removing the caps as each component is installed. Tighten the connections as instructed elsewhere in this group.

   Install the air dryer. For instructions, see **Subject 110**.



1. Stair and Reservoir Mounting Bracket
2. Nut
3. U-Bolt Mounting Strap
4. Air Reservoir

Fig. 1, Air Reservoir (mounted under driver's steps)

7. Perform operational test in **Subject 170**.
8. Remove the chocks from the tires.

Operational Tests

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Park the vehicle, shut down the engine, and chock the tires.
2. Install an accurate pressure gauge in one of the spare governor ports labeled "RES."
3. Close all drain cocks and start the engine. Build the air system to governor cutout and shut down the engine.
4. Check all air lines and fittings leading to and from the air dryer for leakage. Note the pressure on the air gauge after the governor cutout pressure is reached, a rapid loss of pressure could indicate a leak at the delivery check valve, governor, unloader piston in the compressor purge valve (purge piston), D-ring seals between the dryer and the reservoir, reservoirs or points downstream from the reservoirs.
5. Test the delivery check valve for leakage.

   5.1 Build system pressure to governor cutout. Wait 2 minutes for completion of purge cycle. Using soap solution at exhaust of purge valve, leakage should not exceed a 1 inch bubble in less than 5 seconds.

   5.2 Allow a full minute for the normal dryer purge cycle to empty the purge reservoir, switch off the engine and "fan" the brakes so that the system pressure reaches governor cut-in. The purge valve will return to its closed position. The purge reservoir has a drain valve which is opened by moving the center lever away from its closed position.

   5.3 Open the drain valve and wait 10 seconds to allow any residual purge pressure to be released. Release the lever, closing the drain valve.

   5.4 Carefully remove the air dryer cartridge using a strap wrench and then test for air leaking through the center of the threaded boss by applying a soap solution to the boss.

   5.5 Replace the delivery check valve if there is excessive leakage (exceeding a 1 inch bubble in 5 seconds).

   5.6 Regrease the seal on the air dryer cartridge before reinstalling. Be sure the drain valve on the purge reservoir is not leaking before restoring vehicle to service.

NOTE: If after replacing the delivery check valve, rapid loss of system air pressure continues, the delivery check valve and turbo cut-off valve are still leaking. Check the valves.

6. Check for excessive leakage around the purge valve with the compressor in the loaded mode (compressing air). Apply a soap solution to the purge valve exhaust port and observe that leakage does not exceed a 1-inch bubble in 1 second. If the leakage exceeds the maximum specified, refer to **Troubleshooting 300**.
7. Build up system pressure to governor cutout and note that AD-IS purges with an audible escape of air. Fan the service brakes to reduce system air pressure to governor cut-in. Note that the system once again builds to full pressure and is followed by an AD-IS purge. If system does not follow this pattern, refer to **Troubleshooting 300**.
8. Check the operation of the end cover heater and thermostat assembly during cold weather operation as follows:

   8.1 Check the electric power to the air dryer. With the ignition or engine kill switch in the ON position, check for voltage to the heater and thermostat assembly using a voltmeter or test-light. Unplug the electrical connector at the air dryer and place the test leads on each of the connections of the female connector on the vehicle power lead. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check to see if a good ground path exists.

   8.2 Test the thermostat and heater operation. Turn off the ignition switch and cool the thermostat and heater assembly to below 40°F (4°C). Using an ohmmeter, check

Operational Tests

the resistance between the electrical pins in the air dryer connector half. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly and 6 to 9 ohms for the 24-volt heater assembly.

Warm the thermostat and heater assembly to about 90°F (32°C) and check the resistance again. The resistance should exceed 1000 ohms. If the resistance values obtained are within the stated limits, the thermostat and heater assembly is operating properly. If the resistance values obtained are outside the stated limits, replace the heater and thermostat assembly. For instructions, see **Subject 150**.

9. Check the pressure protection valves. Observe the pressure gauges of the vehicle as system pressure builds from zero. The primary gauge should rise until it reaches approximately 109 psi (752 kPa), then level off as the second pressure protection valve opens and allow the secondary volume to build. When the secondary pressure gauge passes through approximately 85 psi (586 kPa) there should be an associated leveling off of pressure as the third and fourth pressure protection valves open. Then, both the primary and secondary gauges should reach their full pressure of about 130 psi (896 kPa)
10. Remove the chocks.

Troubleshooting Tables

Problem—Air Dryer is Constantly Purging (Cycling) or Purging Excessively

Problem—Air Dryer is Constantly Purging (Cycling) or Purging Excessively	
Possible Cause	**Remedy**
There is excessive system leakage.	Using a soap-and-water solution, test for leakage at the air line fittings, drain cock (or valve), and system valves. Repair or replace as necessary. NOTE: A drop of 3 psi (21 kPa) in system air pressure per minute is normal.
The application air lines are leaking excessively.	Check the application air line, brake valve, and the service and parking brake chambers for air leaks. Repair or replace the damaged component(s).
The delivery check valve leaking excessively.	Replace the Check Valve. See **Subject 130**.
The compressor unloader O-rings are leaking excessively.	Troubleshoot the compressor. See **Group 13**.
Defective Governor	Replace the governor. See **Subject 130**.

Problem—There is Water in the Air Reservoirs

Problem—There is Water in the Air Reservoirs	
Possible Cause	**Remedy**
Maximum air dryer inlet temperature is exceeded due to improper discharge line length or improper line material.	Check for excessive build-up in the discharge line. Replace line in necessary.
The air dryer is not purging.	See **Problem—System Will Not Charge**
Purge time is insufficient due to excessive system leakage.	See **Problem—Air Dryer is Constantly Purging (Cycling)**
The air by-passes the desiccant cartridge assembly.	If the vehicle uses a Holset compressor, inspect the feedback check valve for proper installation and operation.
The compressor is running loaded for long periods of time.	Check the vehicle air system for leakage.
The desiccant cartridge requires replacement.	Replace the desiccant cartridge. See **Subject 120**.

Problem—Safety Valve on the Air Dryer is Exhausting Air

Problem—Safety Valve on the Air Dryer is Exhausting Air	
Possible Cause	**Remedy**
There is a defective delivery check valve in the end cover of the air dryer.	Test to determine if air is passing through the check valve. Repair or replace the check valve. For replacement, see **Subject 130**.
The air system pressure is over 140 psi (965 kPa).	Replace the governor.
The safety valve setting is too low.	Replace the safety valve.

Troubleshooting

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve	
Possible Cause	**Remedy**
The air dryer purge valve is leaking excessively.	Test for leakage. With the compressor loaded, apply soap solution on the purge valve exhaust. If necessary, replace the purge valve. For instructions, see **Subject 140**.
The governor is defective.	Check the governor for proper "cut-in" and "cut-out" pressure, and excessive leakage in both positions. Repair or Replace the governor. For replacement instructions, see **Group 13**.
The purge valve is frozen open. The heater and thermostat, wiring, or blown fuse.	Perform the heater operating test in **Subject 160**.
There is excessive system leakage.	See **Problem—Air Dryer is Constantly Purging (Cycling)**
The air dryer delivery check valve is defective.	See **Problem—Air Dryer is Constantly Purging (Cycling)**
The turbo cutoff valve is leaking.	Repair or replace the turbo cutoff valve. For instructions, see **Subject 140**.
The purge valve control piston is leaking.	Repair or replace the purge valve. For instructions, see **Subject 140**.

Problem—The Air System Will Not Charge

Problem—The Air System Will Not Charge	
Possible Cause	**Remedy**
The inlet and outlet air connections are reversed.	Connect the compressor discharge to the air dryer supply port. Reconnect the lines properly.
Kinked or blocked discharge line.	Check to determine if air passes through the discharge line. Check for kinks, bends, excessive carbon deposits, or ice blockage.
There are excessive bends in the discharge line (water collects and freezes).	The discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.
The turbo cutoff valve is stuck closed.	Repair or replace the turbo cutoff valve. For instructions, see **Subject 140**.
The purge valve is leaking excessively.	Repair or replace the purge valve. For instructions, see **Subject 140**.

Problem—The Air Dryer Does Not Purge or Exhaust Air

Problem—The Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
The governor adaptor is plugged.	Test to determine if air flows through the purge control port when the compressor is unloaded. Check for adaptor obstruction. See **Problem—Constant Exhaust of Air at the Air Dryer Purge Valve**.
The air dryer purge valve is faulty.	If air is flowing through the purge valve in the "Remedy" above, repair or replace the purge valve. For replacement instructions, see **Subject 140**.
There are excessive bends in the discharge line (water collects and freezes).	The discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.
The governor is defective.	Check the governor for proper "cut-in" and "cut-out" pressure, and excessive leakage in both positions. Repair or Replace the governor. For replacement instructions, see **Group 13**.

Problem—The Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
The purge valve control piston is leaking.	Repair or replace the purge valve. For instructions, see **Subject 140**.

Problem—Desiccant Material is Being Expelled from the Air Dryer Purge Valve Exhaust

Problem—Desiccant Material is Being Expelled from the Air Dryer Purge Valve Exhaust	
Possible Cause	**Remedy**
The air dryer is not securely mounted.	Replace the air dryer. For instructions, see **Subject 110**.
The desiccant cartridge is saturated or malfunctioning.	Replace the air dryer. For instructions, see **Subject 110**.
The compressor is passing excessive oil.	Troubleshoot the compressor. See **Group 13**. If necessary, replace the air dryer. For instructions, see **Subject 110**.

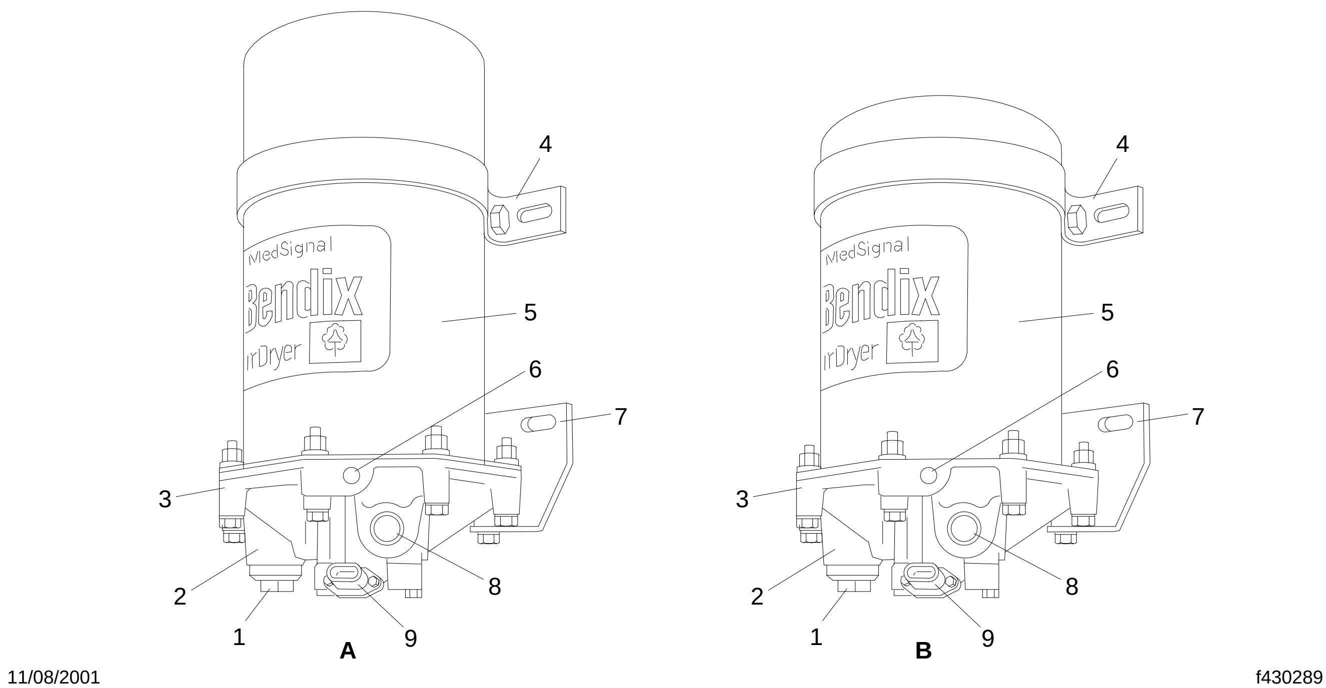
Problem—"Pinging" Noise is Excessive During Compressor Loading Cycle

Problem—"Pinging" Noise is Excessive During Compressor Loading Cycle	
Possible Cause	**Remedy**
The compressor is a single cylinder with high pulse cycles.	A slight "pinging" sound may be heard during system build up when a single cylinder compressor is used. No remedy is needed.

General Information

The function of the Bendix AD-9 air dryer (**Fig. 1**) is to collect and remove air system contaminants in solid, liquid, and vapor form before they enter the brake system.

The purge valve housing assembly, which includes the heater and thermostat assembly, and the discharge check valve assembly, can be serviced without removing the air dryer from the vehicle. The screw-in desiccant cartridge requires removal of the air dryer assembly from the vehicle.



A. Extended Purge Air Dryer
B. Standard Air Dryer

1. Delivery Port
2. Check Valve Assembly
3. End Cover
4. Upper Bracket
5. Outer Shell
6. Control Port
7. Lower Bracket
8. Supply Port
9. Wiring Harness

Fig. 1, Bendix AD-9 Air Dryer

The AD-9 air dryer consists of the desiccant cartridge and a die-cast aluminum end cover secured to a cylindrical steel outer shell with eight capscrews and nuts. The end cover contains a check valve assembly, a safety valve, three threaded air connections and the purge valve housing assembly. The removable purge valve housing assembly features a purge valve mechanism and a turbocharger cutoff that are designed to prevent loss of engine turbo boost pressure during the purge cycle of the air dryer.

To ease servicing, the desiccant cartridge and discharge check valve assembly are screw-in types.

The AD-9 has three female pipe thread air connections; each is identified as follows in **Table 1**.

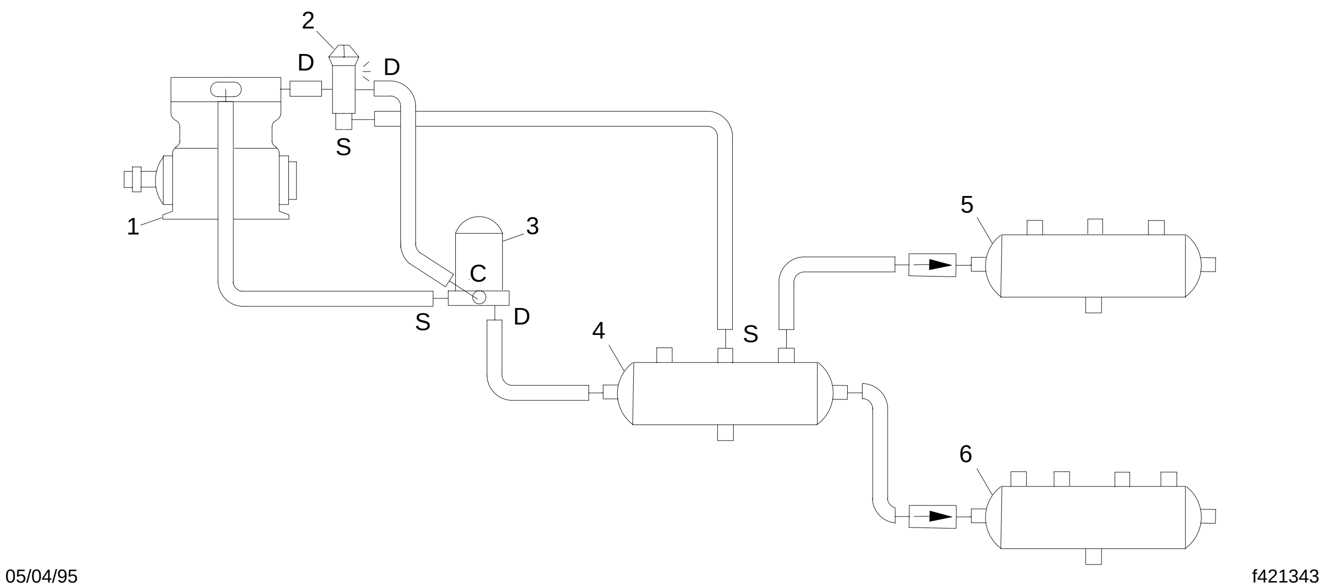
Port I.D.	Function/Connection
4-CON	Control Port (purge valve control and turbo cutoff)
11-SUP	Supply Port (air in)
2-DEL	Delivery Port (air out)

Table 1, Air Dryer Port Identification

The standard air dryer (**Fig. 2**) uses a metal seat turbo cutoff valve. The function of the metal seat is to prevent turbocharger boost pressure loss through the air dryer during the purge (compressor unloaded) mode. Some low level turbo air leakage can occur in the unloaded mode.

After exiting the end cover, air flows into the desiccant cartridge. Once in the cartridge, air first flows through an oil separator, which removes water, oil, oil vapor, and solid contaminants.

Air exits the oil separator and enters the desiccant drying bed. Air flowing through the column of desiccant becomes progressively drier as water vapor sticks to the desiccant material in a process known as adsorption. The desiccant cartridge, using the adsorption process typically removes 95 percent of the water vapor from the pressurized air.



C. Control
D. Delivery
S. Supply

1. Air Compressor
2. D-2 Governor
3. Air Dryer
4. Supply
5. Primary
6. Secondary

Fig. 2, Standard Air Dryer Plumbing Diagram

Principles of Operation

The AD-9 air dryer alternates between two operational modes or cycles during operation: the charge cycle and the purge cycle.

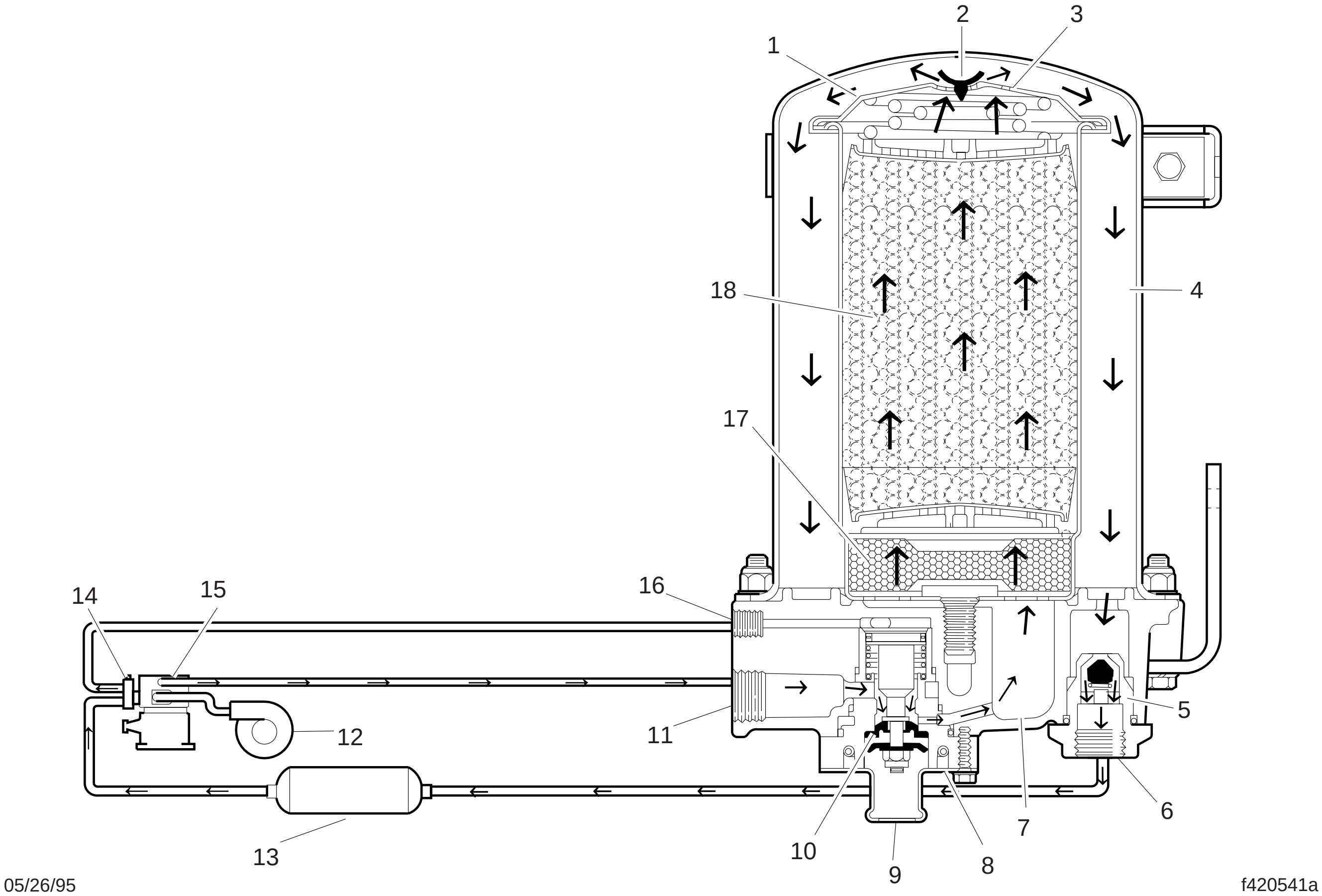
Charge Cycle

When the compressor is loaded (compressing air), pressurized air, along with oil, oil vapor, water, and water vapor flow through the compressor discharge line to the supply port of the air dryer end cover. As air travels through the end-cover assembly, its direction of flow changes several times, reducing the temperature, causing contaminants to condense and drop to the bottom or sump of the air dryer end cover. See **Fig. 3**.

Most of the dry air exits the desiccant cartridge through its integral single check valve to fill the purge volume between the desiccant cartridge and outer shell. Some air also exits the desiccant cartridge through the purge orifice adjacent to the check valve.

Dry air flows out of the purge volume through the single check valve assembly and out the delivery port to the first (supply) reservoir of the air system.

The air dryer remains in the charge cycle until air brake system pressure builds to the governor cutout setting.



1. Desiccant Cartridge
2. Check Valve
3. Orifice
4. Purge Volume
5. Check Valve Assembly
6. Delivery Port
7. Sump
8. Heater Element
9. Exhaust
10. Purge Valve
11. Supply Port
12. Engine Turbocharger
13. Reservoir
14. Governor
15. Compressor
16. Control Port
17. Oil Separator
18. Desiccant Bed

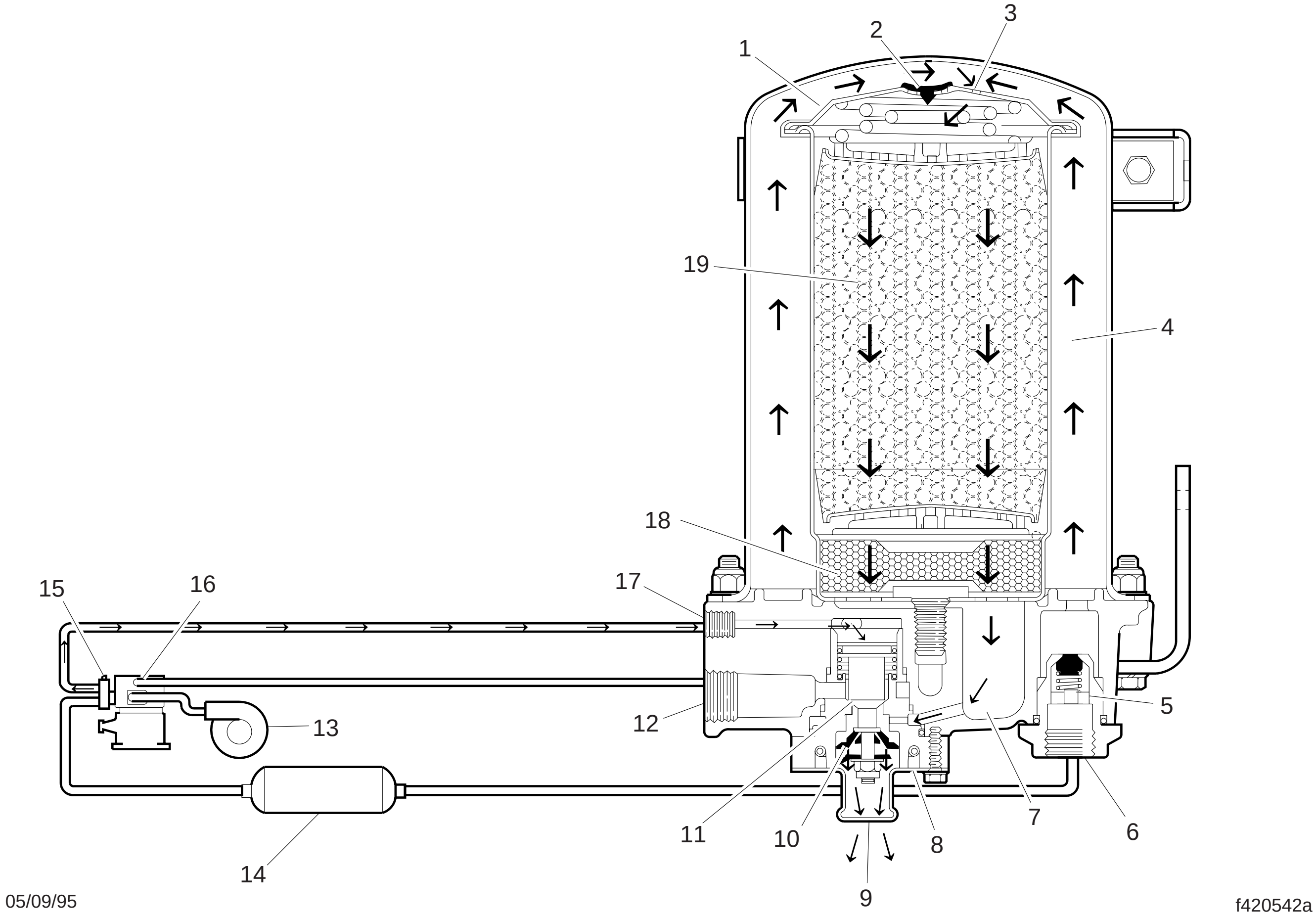
Fig. 3, AD-9 Charge Cycle

Purge Cycle

When the brake system pressure reaches the governor cutout setting, the compressor unloads (air compression stopped), and the purge cycle of the air dryer begins. See **Fig. 4**. When the governor unloads the compressor, it pressurizes the unloader mechanism and line connecting the governor unloader port to the AD-9 end cover control port. The purge piston moves in response to air pressure causing the purge valve to open to atmosphere and partially close off the supply of air from the compressor. This is further discussed under "Turbocharger Cutoff Feature."

Contaminants in the end cover sump are expelled immediately when the purge valve opens. Also, air that was flowing through the desiccant cartridge changes direction and begins to flow toward the open purge valve. Oil and solid contaminants collected by the oil separator are removed by air flowing from the desiccant drying bed to the open purge valve.

General Information



1. Desiccant Cartridge
2. Check Valve
3. Orifice
4. Purge Volume
5. Check Valve Assembly
6. Delivery Port
7. Sump
8. Heater Element
9. Exhaust
10. Purge Valve
11. Turbocharger Cutoff Piston
12. Supply Port
13. Engine Turbocharger
14. Reservoir
15. Governor
16. Compressor
17. Control Port
18. Oil Separator
19. Desiccant Bed

Fig. 4, AD-9 Purge Cycle

The initial purge and desiccant cartridge decompression last only a few seconds and are signaled by an audible burst of air at the AD-9 exhaust. The actual reactivation of the desiccant drying bed begins as dry air flows from the purge volume through the desiccant cartridge purge orifice and into the desiccant drying bed. Pressurized air from the purge volume expands after passing through the purge orifice; its pressure is lowered and its volume increased. Dry air flowing through the drying bed reactivates the desiccant material by removing the water vapor sticking to it. Generally, it takes 15 to 30 seconds for the entire purge volume of a standard AD-9 to flow through the desiccant drying bed.

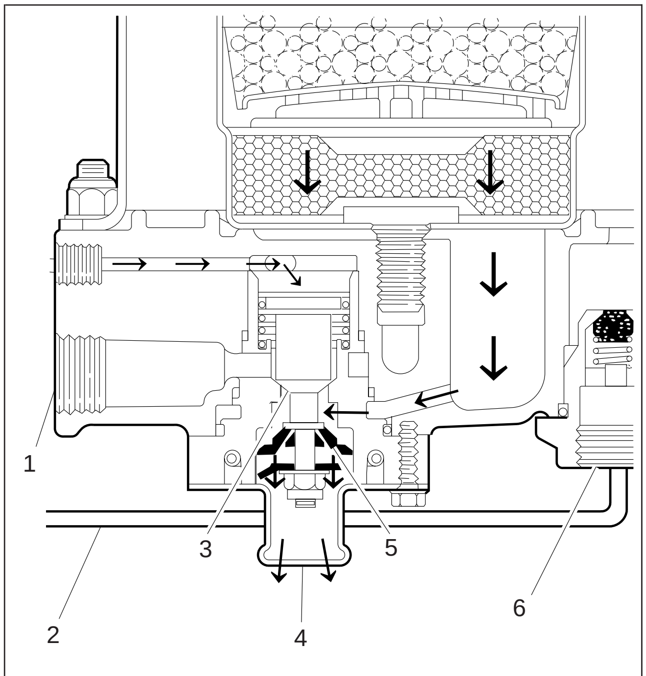
The end cover single check valve assembly prevents compressed air in the brake system from returning to the air dryer during the purge cycle. After the 30 second purge cycle is complete, the air dryer is ready for the next charge cycle to begin.

The purge valve will remain open after the purge cycle is complete, and will not close until air brake system pressure is reduced and the governor signals the compressor to charge.

NOTE: The air dryer should be periodically checked for operation and tested for leaks. Refer to Group 42 of the *Business Class M2 Maintenance Manual* for intervals and procedures.

Turbocharger Cutoff Feature

Primarily, the turbo cutoff valve prevents loss of engine turbocharger air pressure through the AD-9 in systems where the compressor intake is connected to the engine turbocharger. The turbo cutoff valve also reduces the puffing of air out the open exhaust when a naturally aspirated, single cylinder compressor equipped with an inlet check valve is in use. See **Fig. 5**.



1. Supply Port
2. Delivery Line
3. Turbocharger Cutoff Piston
4. Exhaust
5. Purge Valve
6. Check Valve Assembly

Fig. 5, AD-9 Turbo Cutoff

At the beginning of the purge cycle, the downward travel of the purge piston is stopped when the turbo cutoff valve (tapered portion of the purge piston) contacts its mating metal seat in the purge valve housing. With the turbo cutoff valve seated (closed position), air in the discharge line and AD-9 supply port is restricted from entering the air dryer. While the turbo cutoff *effectively* prevents loss of turbocharger boost pressure to the engine, some seepage of air may be detected under certain conditions of compressor, engine, and turbocharger operation. Even so, there will be low pressure trapped in the discharge line.

Safety Precautions

When working on or around air brake systems and components, observe the following precautions:

1. Chock the tires and shut down the engine before working under a vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber push rods and slack adjusters, which may apply as air pressure drops.
2. Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
3. Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
4. Don’t disassemble a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools, and observe all precautions pertaining to use of those tools.
5. Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.

   Make sure that when replacing tubing or hose, all of the original supports, clamps, or suspending devices are installed or replaced.
6. Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.

Removal

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain all reservoirs to zero pressure.

⚠ CAUTION

Compressor discharge line may still contain residual pressure.

3. Remove the air dryer.
   - 3.1 Identify and disconnect the three air lines from the end cover. Note the position of end cover ports relative to the vehicle.
   - 3.2 Unplug the vehicle wiring harness from the heater and thermostat assembly connector on the purge valve housing assembly.
   - 3.3 Loosen the hexbolt securing the upper mounting strap.
   - 3.4 Remove, save, and mark the two end cover capscrews, locknuts, and four special washers that retain the lower mounting bracket to the end cover. Also mark the two holes of the end cover. (These bolts are longer than the other six bolts.)
   - 3.5 Remove the air dryer from its mounting brackets.

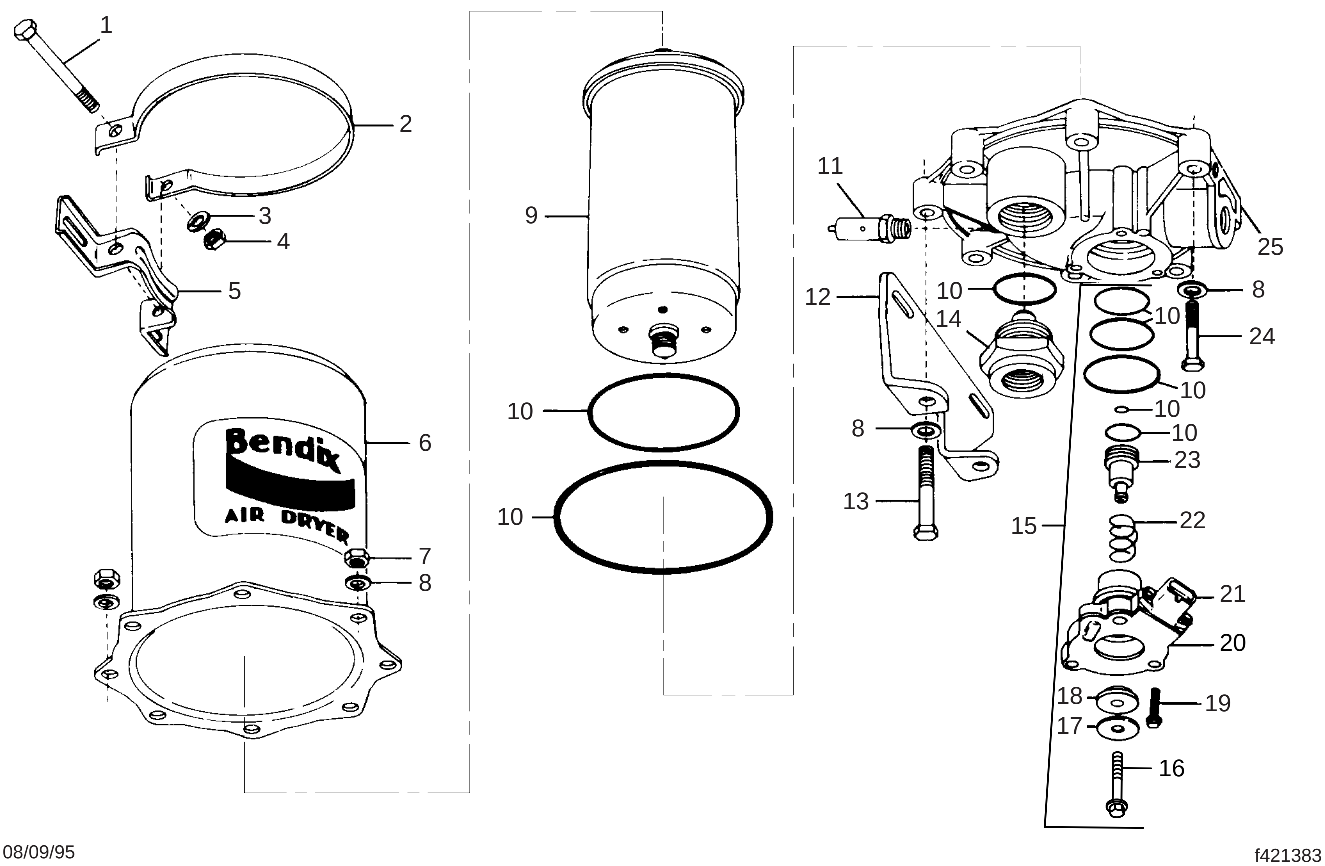
Installation

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Install the assembled air dryer on the vehicle. See **Fig. 1**.
   - 1.1 Position the air dryer into the upper mounting bracket and strap. Align the two unused holes in the end cover with the bottom mounting bracket so that the bottom bracket supports the air dryer. The end cover should rest on the bracket.
   - 1.2 Using the remaining two capscrews, four special washers, and two locknuts, secure the air dryer to the lower bracket. Tighten the two remaining capscrews 23 to 32 lbf·ft (31 to 43 N·m).
   - 1.3 Tighten the bolt and nut on the upper mounting bracket strap 80 to 120 lbf·in (900 to 1360 N·cm).
   - 1.4 Connect the three air lines to the correct ports on the end cover as identified in "Removal."
   - 1.5 Connect the vehicle wiring harness to the air dryer heater and thermostat assembly connector by plugging it into the air dryer connector until its lock tab snaps in place.
2. Test the air dryer following instructions in Group 42 of the *Business Class® M2 Maintenance Manual*.

Removal and Installation



1. 5/16-Inch x 4-1/2-Inch Upper Bracket Capscrew
2. Upper Bracket Strap
3. 5/16-Inch Lockwasher
4. 5/16-Inch Locknut
5. Upper Mounting Bracket
6. Housing
7. Locknut
8. 3/8-Inch Special Washer
9. Desiccant Cartridge
10. O-Ring
11. Safety Valve
12. Lower Mounting Bracket
13. 3/8-Inch Capscrew (Long)
14. Check Valve Assembly
15. Purge Valve Assembly
16. Purge Valve Bolt
17. Exhaust Diaphragm
18. Purge Valve
19. 1/4-Inch Tapping Screw
20. Purge Valve Housing
21. Heater and Thermostat Assembly
22. Return Spring
23. Purge Piston
24. 3/8-Inch Capscrew
25. End Cover

Fig. 1, Bendix AD-9 Air Dryer

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

NOTE: As a convenience when rebuilding the air dryer, several replacement parts and maintenance kits are available that do not require full disassembly. Use the instructions provided with these parts or kits.

Disassembly

WARNING

Before working on or around air brake systems and components, read Safety Precautions 100. Failure to do so could result in personal injury.

CAUTION

While servicing the air dryer, don't use a clamping device (vise, C-clamp, etc.) to hold any die cast aluminum part, as damage may result. To hold the end cover, install a pipe nipple in the supply port, and clamp the nipple in a vise.

1. Remove the air dryer from the vehicle. See **Subject 110**.
2. Remove the check valve assembly and O-ring. Remove the O-ring from the check valve assembly. See **Fig. 1**.
3. Remove the purge valve housing assembly. See **Fig. 1**.

   3.1 Remove the three self-tapping screws that secure the purge valve housing assembly to the end cover assembly.

   3.2 Pull the purge valve housing assembly out of the end cover assembly.

   3.3 Remove and discard the three O-rings from the exterior of the purge valve housing assembly.

   NOTE: These O-rings may lodge in and have to be removed from the end cover bores.
4. Remove the heater and thermostat assembly. See **Fig. 1**.

   4.1 Remove and discard the two screws that attach the heater and thermostat assembly to the purge valve housing.

   4.2 Gently rotate the electrical connector to the left until the thermostat clears the purge valve housing. Then, slide the heater element out, to the right and up. Discard the assembly.
5. Disassemble the purge valve housing assembly. See **Fig. 1**.

   5.1 If a flat non-extended exhaust cover is used, leave it intact while servicing the purge valve housing assembly.

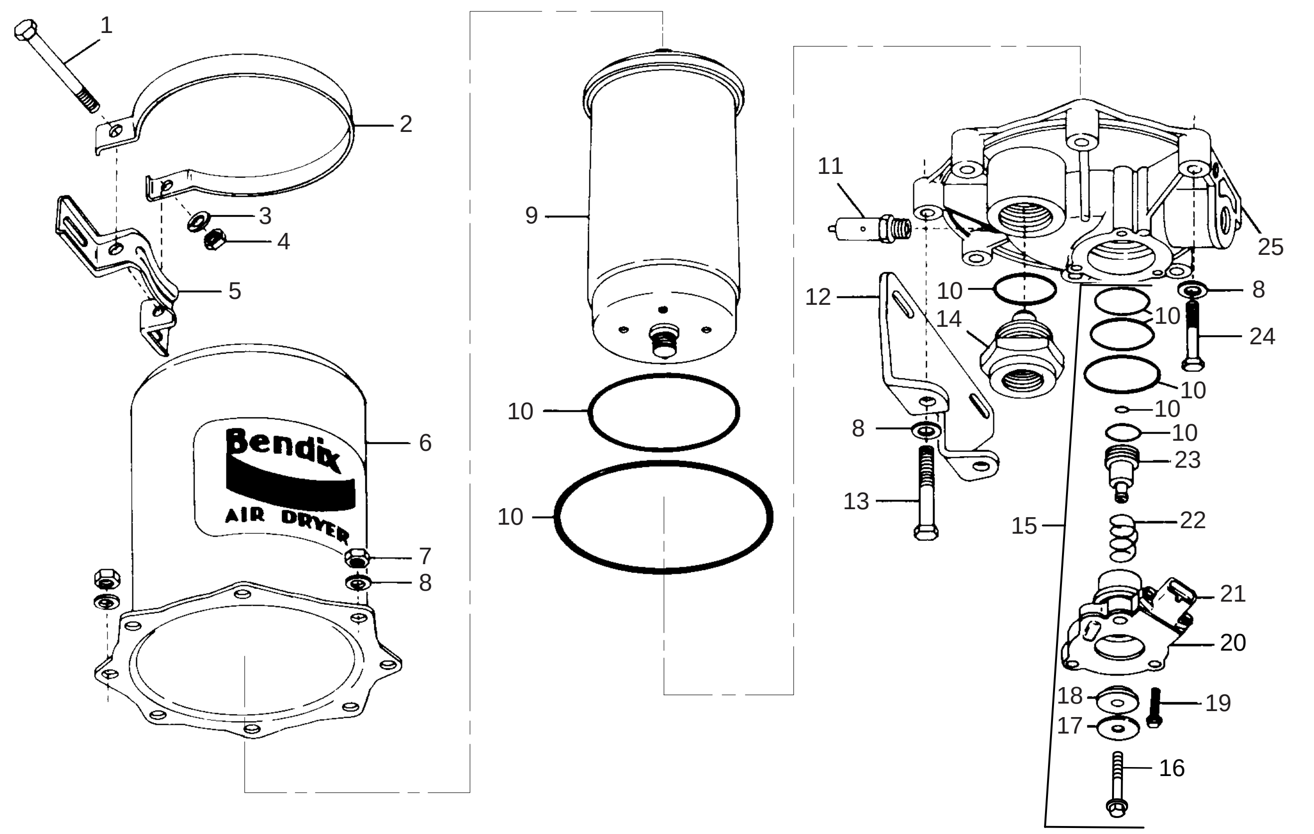
   If an extended type exhaust cover is used for the attachment of an exhaust hose, *carefully* separate the exhaust cover from the purge valve housing. *Use a thin flat blade to pry the exhaust cover off, taking care not to damage the potting material (RTV sealant) under the cover.*

   5.2 Remove the bolt from the bottom of the purge valve housing assembly. Remove the diaphragm and the purge valve from the purge valve housing.

   5.3 Remove the purge piston, the return spring and two O-rings (one on the outside and the other in the inside of the purge piston).
6. Remove the remaining six capscrews (Ref. 24), locknuts (Ref. 7), and twelve special washers (Ref. 8) that secure the end cover to the housing (Ref. 6). Separate the end cover and desiccant cartridge (Ref. 9) from the housing (Ref. 6). See **Fig. 1**.
7. Remove the end-cover-to-outer-housing O-ring. See **Fig. 1**.
8. Don't remove the safety valve (Ref. 11) from the end cover unless it is known to be inoperative. If replacement is needed, apply thread sealant or Teflon® tape on the threads of the replacement valve and tighten 120 to 400 lbf·in (1360 to 4520 N·m). Make sure the drain hole (slot) is facing down.
9. Place a strap or chain wrench around the desiccant cartridge (Ref. 9) so that it is about 2 to 3 inches (5 to 8 cm) away from the end cover. Rotate the cartridge counterclockwise until it completely separates from the end cover.

NOTE: Torque of up to 50 lbf·ft (68 N·m) may be needed to do this disassembly.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly



1. 5/16-Inch x 4-1/2 Inch Upper Bracket Capscrew
2. Upper Bracket Strap
3. 5/16-Inch Lockwasher
4. 5/16-Inch Locknut
5. Upper Mounting Bracket
6. Housing
7. Locknut
8. 3/8-Inch Special Washer
9. Desiccant Cartridge
10. O-Ring
11. Safety Valve
12. Lower Mounting Bracket
13. 3/8-Inch Capscrew (Long)
14. Check Valve Assembly
15. Purge Valve Assembly
16. Purge Valve Bolt
17. Exhaust Diaphragm
18. Purge Valve
19. 1/4-Inch Tapping Screw
20. Purge Valve Housing
21. Heater and Thermostat Assembly
22. Return Spring
23. Purge Piston
24. 3/8-Inch Capscrew
25. End Cover

Fig. 1, AD-9 (exploded view)

10. Remove the desiccant cartridge O-ring from the end cover. See **Fig. 1**.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

Cleaning and Inspection

WARNING

Before working on or around air brake systems and components, read Safety Precautions 100. Failure to do so could result in personal injury.

1. Wash all metal parts thoroughly, using a quality commercial solvent, such as mineral spirits.
2. Check for severe corrosion, pitting, and cracks on the inside and outside of all metal parts that will be reused. Superficial corrosion and pitting on the outside of the upper and lower body halves is acceptable.
3. Inspect the bores of both the end cover and the purge-valve housing for deep scuffing or gouges.
4. Make sure that all purge-valve housing and end cover passages are open and free of blockages.
5. Inspect the pipe threads in the end cover. Make sure they are clean and free of thread sealant.
6. Inspect the purge-valve housing bore and seats for excessive wear and scuffing.
7. Inspect the purge valve piston seat for excessive wear.
8. Inspect all air line fittings for corrosion. Clean all old thread sealant from the pipe threads.
9. Replace all removed O-rings with new ones that are provided in the kits.

   Replace parts that show any of the conditions described in the previous steps.

Assembly

WARNING

Before working on or around air brake systems and components, read Safety Precautions 100. Failure to do so could result in personal injury.

1. Before assembly, coat all O-rings, O-ring grooves, and bores with a generous amount of barium-base lubricant. See **Fig. 1** during assembly unless otherwise advised.

IMPORTANT: When installing the heater and thermostat assembly, make sure that the seal ring under the electrical connector is not twisted.

2. Install the heater and thermostat assembly.

   2.1 Insert the heater element into the slot in the purge valve housing until the connector contacts the housing.

   2.2 Gently push the connector and the thermostat to the left until the thermostat clears the cavity in the housing. Then, turn the connector to the right while pushing the thermostat all the way down into the cavity.

   Make sure that the connector is seated evenly against the housing.

   2.3 Install the two mounting screws. Tighten the screws 10 to 20 lbf·in (113 to 226 N·cm).

3. Assemble the purge-valve housing.

   3.1 Install the O-ring on the purge piston. Place the return spring in the purge-valve housing. Place the O-ring in the bore of the purge piston. Insert the purge piston into the spring. Push the piston into the purge-valve housing until it bottoms.

   3.2 While holding the purge piston in, install the following parts: the purge valve with its rubber side first, followed by the diaphragm and the bolt. Torque the purge valve bolt 60 to 80 lbf·in (680 to 900 N·cm).

   3.3 Install the three O-rings in their correct locations on the purge-valve housing.

   3.4 If an extended type exhaust cover was removed, install it on the purge-valve housing assembly, making sure the "bubble" portion is positioned over the thermostat.

   3.5 Install the assembled purge-valve housing in the end cover; make sure you orient both parts so that the connector is about 10 degrees clockwise from the supply port. Also, make sure the purge-valve housing is fully seated against the end cover.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

3.6 Secure the purge-valve housing to the end cover using the three self-tapping screws. Start all three screws by hand, then torque them 85 to 125 lbf·in (960 to 1400 N·cm).

4. Install an O-ring on the check-valve assembly, then install the assembly in the end cover using a socket. Tighten it 200 to 250 lbf·in (2260 to 2820 N·cm).

5. Install the desiccant cartridge in the end cover.

5.1 Install the smaller desiccant cartridge O-ring in its groove in the end cover. Using a light coat of barium grease, lubricate the bottom of the desiccant cartridge in the area that will contact the O-ring and end cover.

5.2 Screw the desiccant cartridge into the end cover until the cartridge contacts the O-ring. Using a strap or chain wrench positioned 2 to 3 inches (5 to 8 cm) from the bottom of the cartridge, turn the desiccant cartridge clockwise 180 to 225 degrees beyond the position where initial contact was made with the O-ring. Torque should not exceed 50 lbf·ft (68 N·m).

6. Install the housing over the desiccant cartridge.

6.1 Install the large O-ring on the shoulder in the end cover. Place the housing over the desiccant cartridge and align the holes.

6.2 Install the six capscrews, locknuts, and the twelve special washers, making sure they are positioned as referenced earlier. The two longer capscrews will be used to secure the air dryer to its mounting bracket.

6.3 Tighten the six capscrews and nuts in a star pattern (depending on lower bracket location) 23 to 32 lbf·ft (306 to 434 N·m). See Fig. 2.

NOTE: The two remaining bolt holes in the end cover and two 3/8-inch capscrews must be the ones marked during removal to ensure correct orientation of the ports and adequate length of the capscrews.

7. Connect the electrical connector to the heater and thermostat assembly.

8. Test the air dryer for proper operation. For instructions, see **Subject 130**.

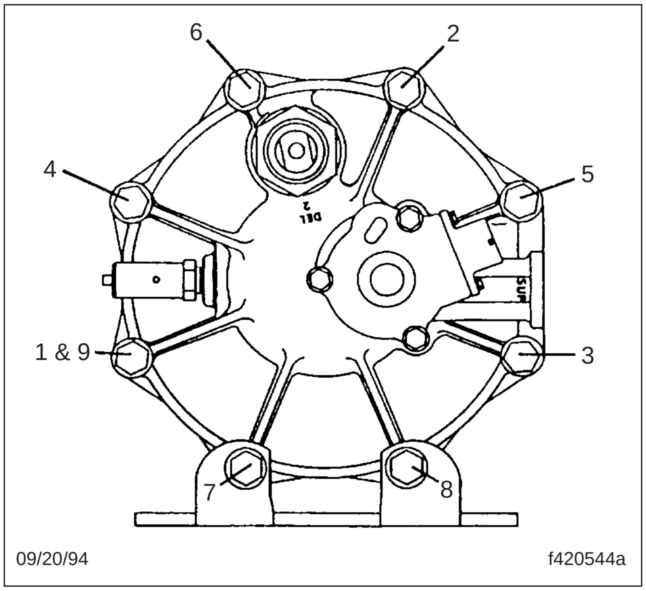


Fig. 2, End Cover to Housing Torque Pattern

Air Dryer Thermostat Testing

Testing

During cold-weather operation, check the operation of the end cover heater and thermostat assembly.

1. With the ignition on, check for voltage to the heater and thermostat assembly. Unplug the electrical connector at the air dryer, and place the test leads on each of the pins of the male connector. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check that a good ground path exists.
2. Check the thermostat and heater operation. Turn off the ignition switch and cool the end cover assembly to below 40°F (4°C). Using an ohmmeter, check the resistance between the electrical pins in the female connector. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly, and 6.8 to 9.0 ohms for the 24-volt heater assembly.
3. Warm the end cover assembly to over 90°F (32°C) and again check the resistance. It should exceed 1000 ohms. If it does, the thermostat and heater assembly is operating properly. If it doesn't, replace the purge-valve housing assembly, which includes the heater and thermostat assembly.

Troubleshooting

Problem—Air Dryer Is Constantly Cycling or Purging

Problem—Air Dryer Is Constantly Cycling or Purging	
Possible Cause	**Remedy**
Excessive system leakage.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is as follows: • Single Vehicle—1 psi/min (7 kPa/min) per service reservoir • Tractor/Trailer—3 psi/min (21 kPa/min) per service reservoir
There is excessive leakage in the fittings, hoses, and tubing connected to the compressor, air dryer, and wet tank.	Using a soap solution, test for leakage at the fittings, drain valve, and safety valve in the wet tank. Repair or replace as needed.
Check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.
Governor is inoperative.	Test the governor for proper cut-in or cut-out pressures and excessive leakage in both positions.
Leaking purge-valve housing assembly or O-rings in the air dryer end cover.	With the supply port open to atmosphere, apply 120 psi (830 kPa) at the control port. Apply a soap solution to the supply port and exhaust port (purge valve seat area). Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. Repair or replace as needed.
Compressor unloader mechanism is leaking excessively.	Remove the air strainer or fitting from the compressor inlet cavity. With the compressor unloaded, check for unloader piston leakage. Slight leakage is allowed.
Holset "E" type compressor.	Test the air dryer system. For instructions, refer to Bendix Product Bulletin PRO-08-19 entitled "Troubleshooting the Holset "E" Compressor System with Bendix Air Dryer."
Lack of air at the governor RES port (rapid cycling of the governor).	Test the governor for proper pressure at the RES port. Pressure should not drop below cut-in pressure when the compressor begins the unloaded cycle. If the pressure does drop, check for kinks or restrictions in the line connected to the RES port. The line connected to the RES port on the governor must be the same diameter, or larger than the lines connected to the UNL ports on the governor.

Problem—Water in the Vehicle Reservoirs

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Desiccant cartridge assembly contains excessive contaminants.	Replace the desiccant cartridge.
Discharge line is of improper length or material.	Discharge line must consist of at least 6 ft. (1.8m) of wire braid Teflon hose, copper tubing, or a combination of both between the discharge port of the compressor and the air dryer supply port. Discharge line lengths and inside diameter requirements are dependent on the vehicle application. Contact your local Bendix representative for further information.

Troubleshooting

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Air system was charged from an outside air source that did not pass through an air dryer.	If the system must have an outside air fill provision, the outside air should pass through an air dryer. This practice should be minimized.
Air dryer is not purging.	Refer to "Problem—Air Dryer Does Not Purge or Exhaust Air."
Purge (air exhaust) is insufficient due to excessive system leakage.	Refer to "Problem—Air Dryer Is Constantly Cycling or Purging."
Air bypasses the desiccant cartridge assembly.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed.
Purge (air exhaust) time is significantly less than the minimum allowable.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed. Replace the desiccant cartridge assembly.
Excessive air usage—air dryer not compatible with vehicle air system.	Install an accessory bypass system. Consult your Bendix representative for additional information.

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air	
Possible Cause	**Remedy**
Desiccant cartridge is plugged or saturated.	Check the compressor for excessive oil passing, or incorrect installation. Repair or replace as needed.
The check valve in the air dryer end cover is inoperative.	Test to determine if air is passing through the check valve. Repair or replace as needed.
There is a problem in the fittings, hose, or tubing between the air dryer and the wet tank.	See if air is reaching the first reservoir. Inspect for kinked tubing or hose. Check for undrilled or restricted hose or tubing fittings.
Safety valve setting is lower than the maximum system pressure.	Reduce the system pressure, or install a safety valve with a higher pressure setting.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Air dryer purge valve is leaking excessively.	With the compressor loaded, apply a soap solution on the purge valve exhaust to test for excessive leakage. Repair the purge valve as needed.
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
Purge control line is connected to the reservoir or exhaust port of the governor.	Connect the purge control line to the unloader port of the governor.
Purge valve is frozen open due to an inoperative heater or thermostat, bad wiring, or a blown fuse.	Test the heater and thermostat, following instructions in this manual.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Inlet and outlet air connections are reversed—unable to build system pressure.	Reconnect the lines properly.
Discharge line is kinked or blocked.	See if air passes through the discharge line. Check for kinks, bends, or excessive carbon deposits.
There are excessive bends in the discharge line. Water is collecting and freezing.	Discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.
System is leaking excessively.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is as follows: • Single Vehicle—1 psi/min (7 kPa/min) per service reservoir • Tractor/Trailer—3 psi/min (21 kPa/min) per service reservoir
Purge valve stays open; supply air leaks to control side.	Replace the purge valve assembly O-rings.

Problem—Air Dryer Does Not Purge or Exhaust Air

Problem—Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
Purge control line is broken, kinked, frozen, plugged, or disconnected.	See if air flows through the purge control line when the compressor is unloaded. The purge control line must be connected to the unloader port of the governor.
Air dryer purge valve isn't working.	See if air reaches the purge valve. If it does, repair the purge valve.
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
Inlet and outlet air connections are reversed—unable to build system pressure.	Reconnect the lines properly.
Discharge line is kinked or blocked.	See if air passes through the discharge line. Check for kinks, bends, or excessive carbon deposits.
There are excessive bends in the discharge line. Water is collecting and freezing.	Discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (May Look Like Whitish Liquid, Paste, or Small Beads); or, Unsatisfactory Desiccant Life

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (may look like whitish liquid, paste, or small beads) or Unsatisfactory Desiccant Life	
Possible Cause	**Remedy**
This problem usually occurs with one or more of the previous problems.	Refer to the appropriate corrections listed previously.

Troubleshooting

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (may look like whitish liquid, paste, or small beads) or Unsatisfactory Desiccant Life	
Possible Cause	**Remedy**
Air dryer is not securely mounted; there is excessive vibration.	Vibration should be held to a minimum. Tighten the mounting fasteners.
Cloth-covered perforated plate in the air dryer desiccant cartridge is damaged, or the cartridge was rebuilt incorrectly.	Replace the plate or cartridge as needed. High operating temperatures may cause deterioration of filter cloth.Check the installation.
Compressor is passing excessive oil.	Check for proper compressor installation; if symptoms persist, replace the compressor.
Heater and thermostat, wiring, or a fuse is at fault, and isn't allowing the air dryer to purge during cold weather.	Test the heater and thermostat, following instructions in this manual.
Desiccant cartridge not attached properly to the end cover.	Check the torque and tighten if necessary. Refer to **Subject 120** for instructions.

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle	
Possible Cause	**Remedy**
Pinging noise is due to a single cylinder compressor with high pulse cycles.	A slight pinging sound may be heard during system build-up when a single cylinder compressor is used. If this sound is deemed objectionable, it can be reduced substantially by increasing the discharge line volume. This is done by adding a 90 in^3 (1475 cm^3) reservoir between the compressor and the air dryer.

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)	
Possible Cause	**Remedy**
Air compressor inlet is pressurized by the engine turbocharger.	Some pressure leakage past the metal seat of the turbocharger cutoff feature of the AD-9 air dryer is normal, and may be heard. This slight loss of air will not affect the engine or turbocharger performance.
Check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode	
Possible Cause	**Remedy**
Compressor does not "unload."	Check the governor installation: there is no air line from the governor to the compressor, or the line is restricted. Repair or replace as needed.

General Information

The following air plumbing diagrams are typical cab and chassis air plumbing configurations. However, there are many possible configurations based on vehicle equipment.

For detailed plumbing diagrams for a specfic vehicle, please use PartsPro®.

Cab and Chassis Diagrams

Figure 1 is a full view of a typical plumbing diagram for an air brake installation with two rear axles. See **Fig. 2** and **Fig. 3** for left and right partial views, respectively.

Figure 4 is a full view of a typical plumbing diagram for an air brake installation with one rear axle. See **Fig. 5** and **Fig. 6** for left and right partial views, respectively.

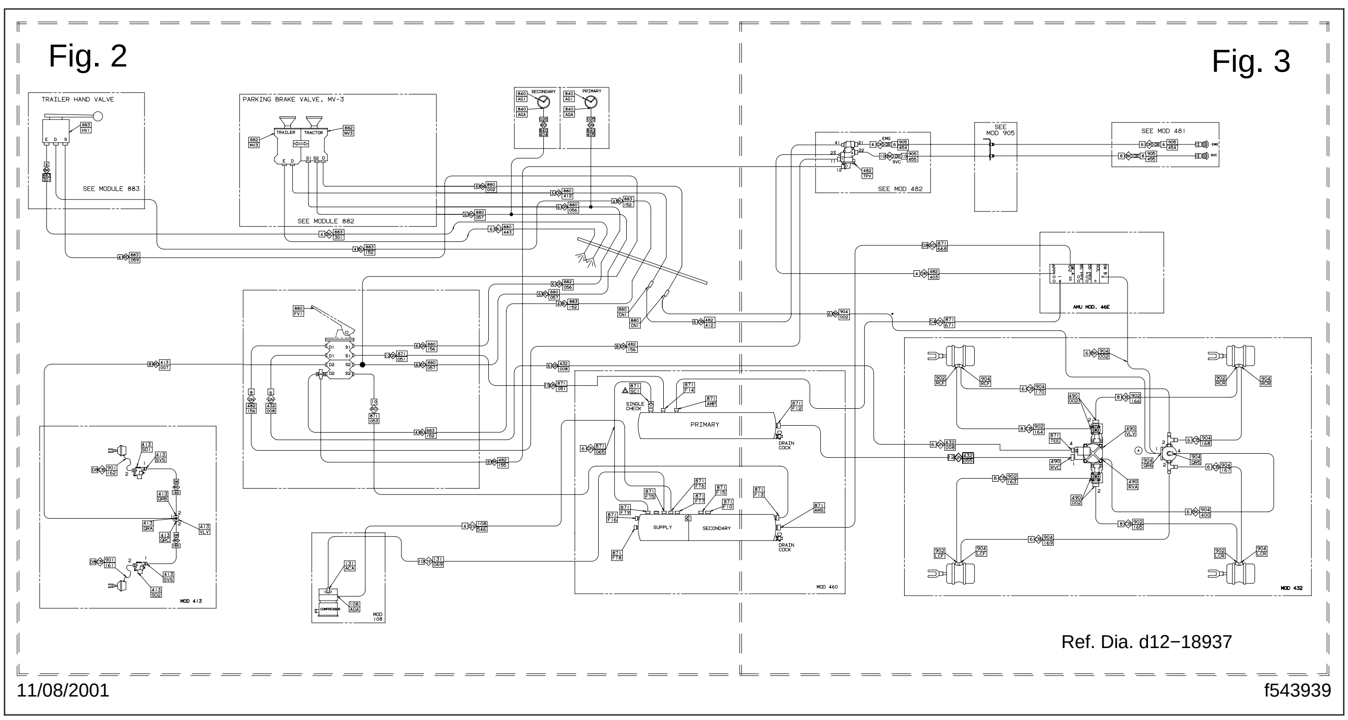


Fig. 1, Air Plumbing for Vehicles with Two Drive Axles (full view)

Cab and Chassis Diagrams

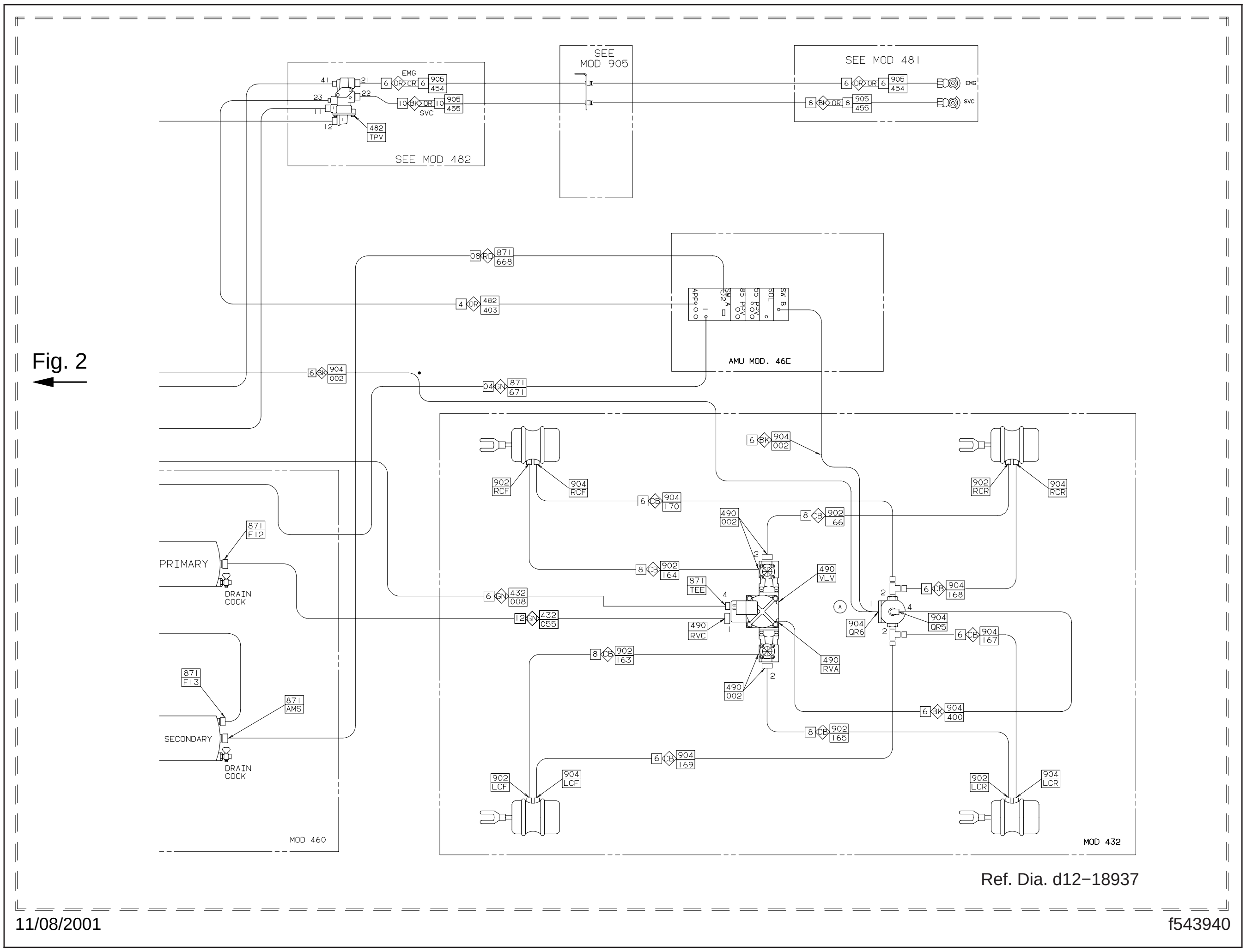


Fig. 2, Air Plumbing for Vehicles with Two Drive Axles (detailed view)

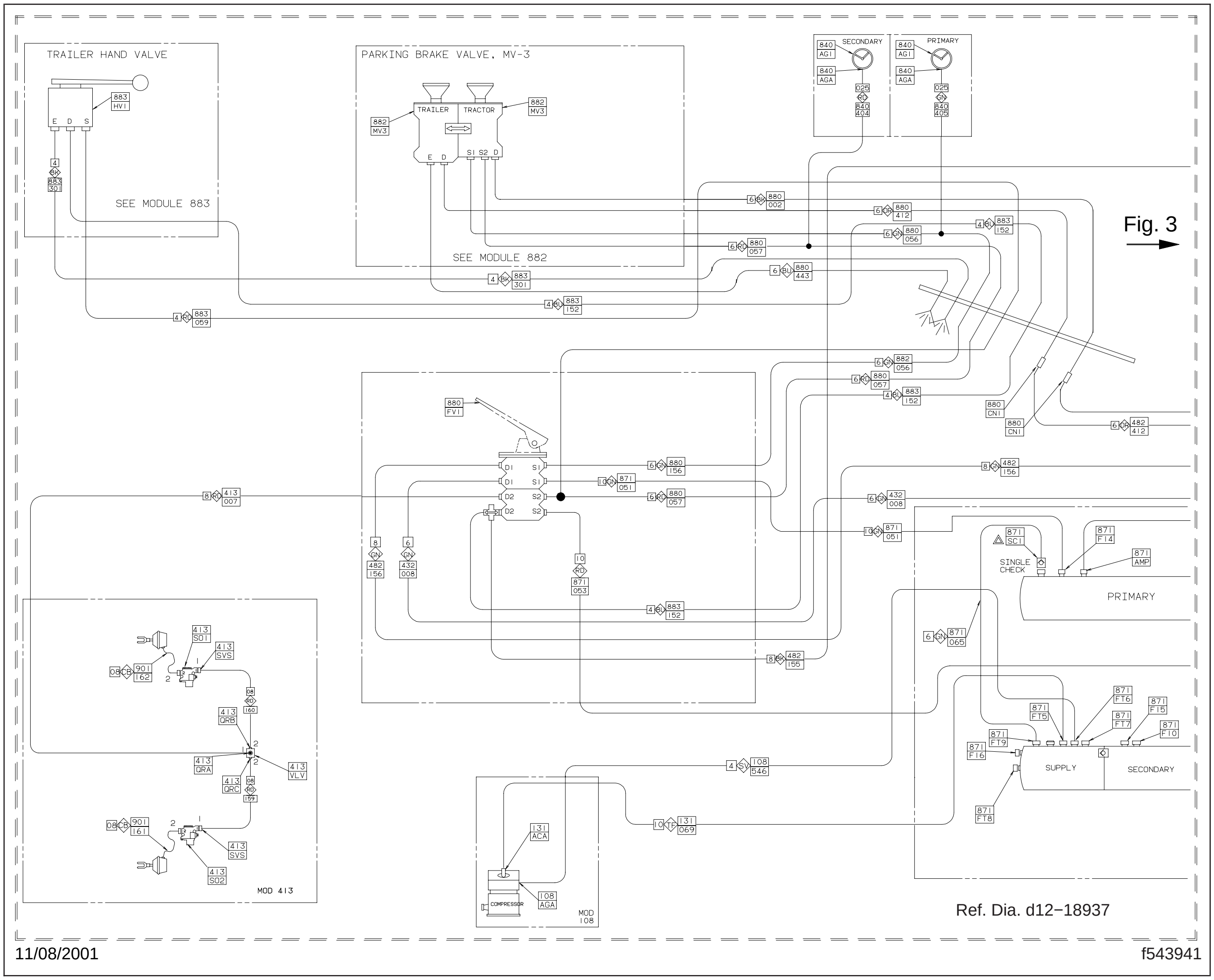


Fig. 3, Air Plumbing for Vehicles with Two Drive Axles (detailed view)

Cab and Chassis Diagrams

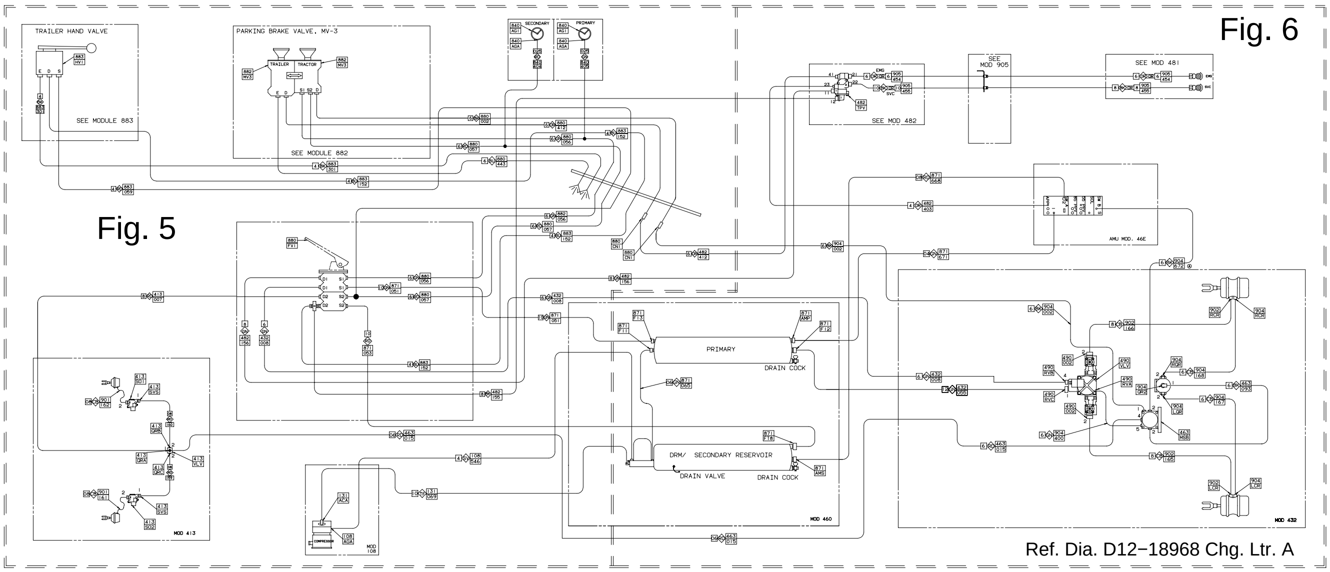


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Fig. 4, Air Plumbing for Vehicles with One Drive Axle (full view)

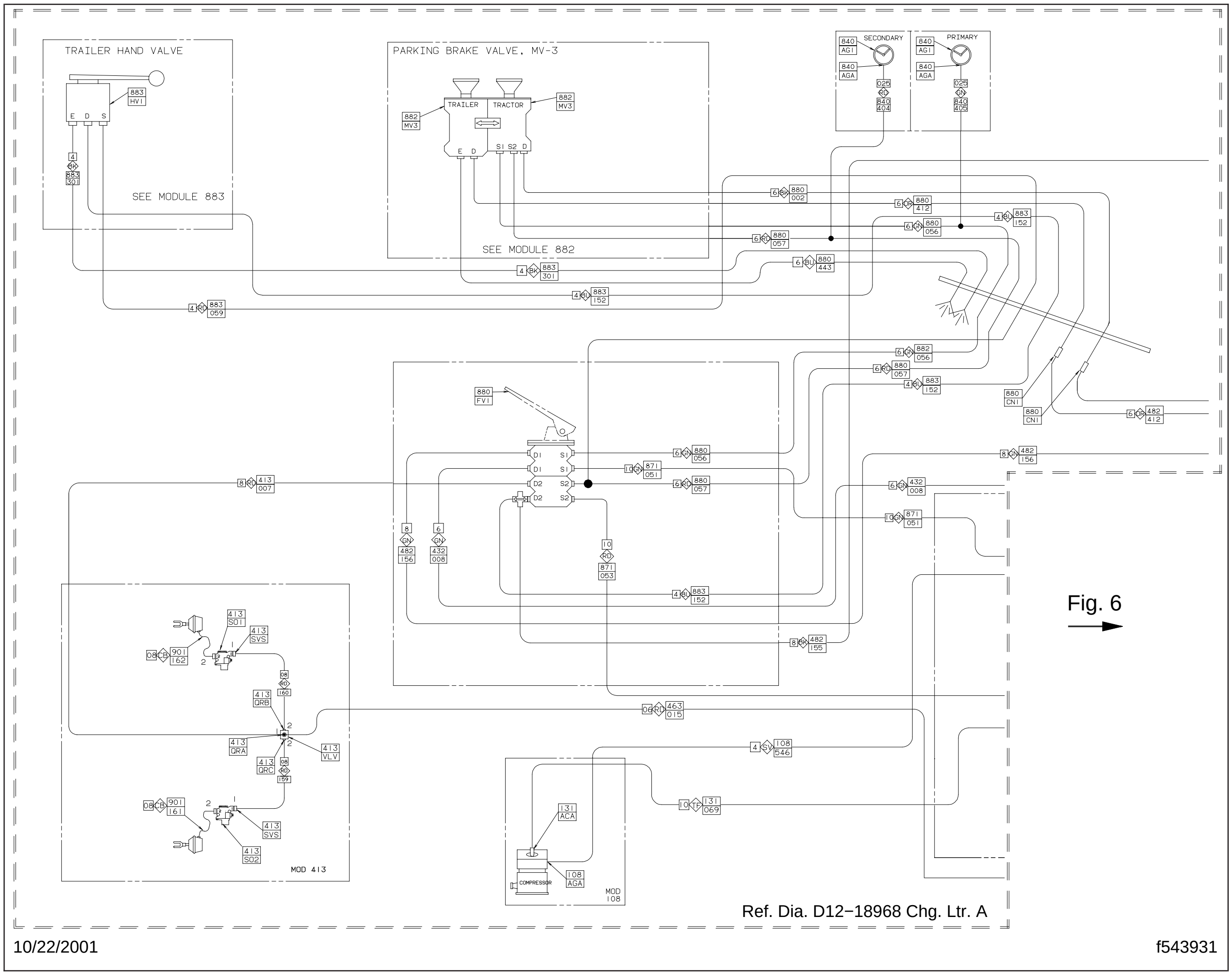


Fig. 5, Air Plumbing for Vehicles with One Drive Axle (detailed view)

Cab and Chassis Diagrams

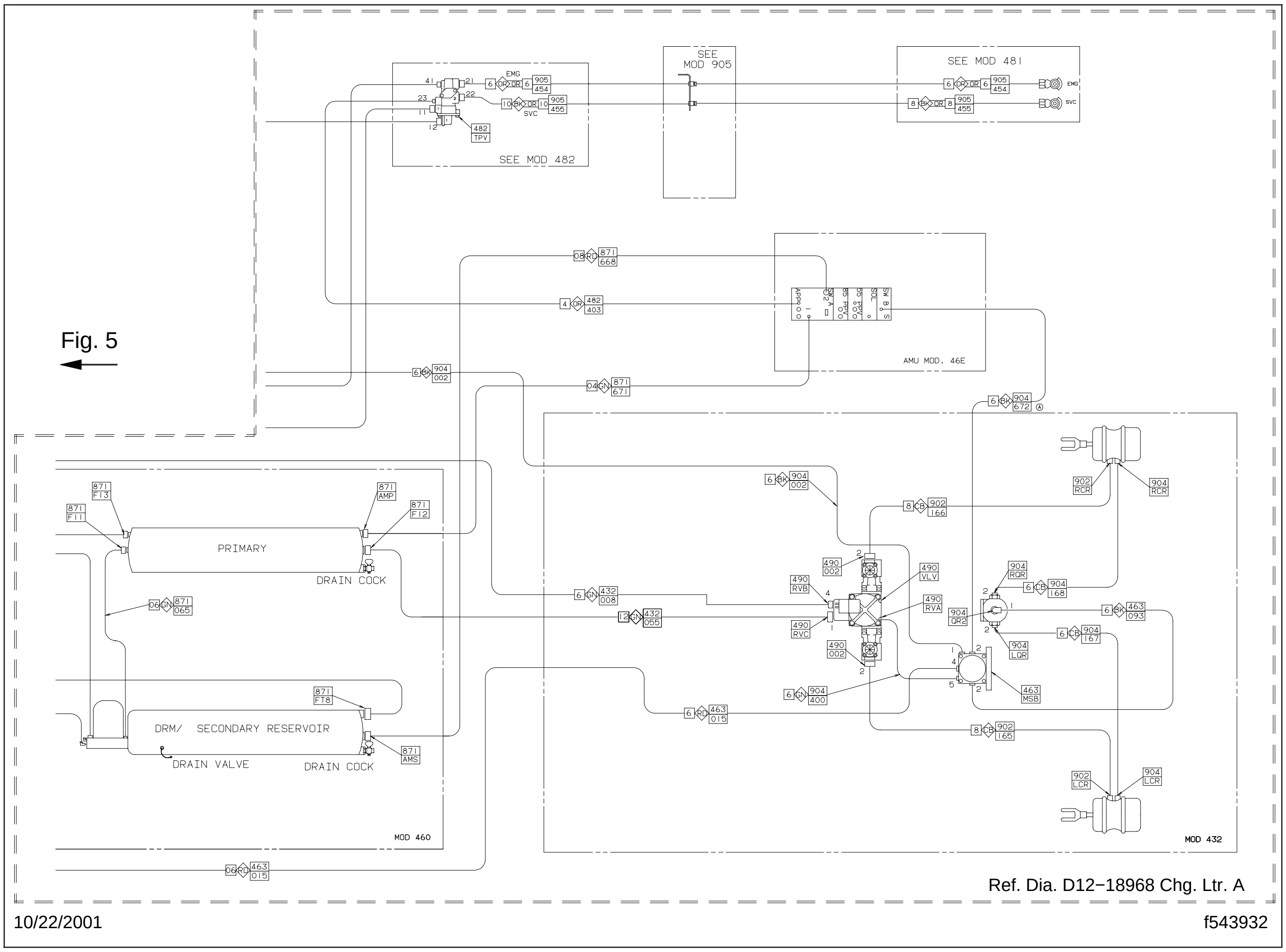


Fig. 6, Air Plumbing for Vehicles with One Drive Axle (detailed view)

General Information

Air reservoirs serve two main purposes:

1. They store compressed air used to apply the brakes and operate other air-powered devices, such as chassis suspensions, engine fan controls, and seats.
2. They provide a place where air heated during compression can cool and water vapor can condense into a liquid. Also, air reservoirs collect small amounts of oil passed by the compressor.

NOTE: If the vehicle is equipped with a Bendix Dryer Reservoir Module (DRM), the wet tank and supply tank are integrated into one large reservoir, connected to the air dryer. Some DRMs contain the supply, primary, and secondary compartments in one reservoir. For more information, see **Section 42.03**.

Each vehicle is equipped with three air reservoirs or reservoir compartments, if equipped with a dryer reservoir module (DRM). Each reservoir or compartment is identified as one of three types: supply, primary, and secondary.

The supply reservoir (or wet tank) receives compressed air directly from the compressor. It collects most of the water and oil condensate from the air, and feeds air to the other reservoirs. At the outlet port of the supply reservoir (the port leading to the primary reservoir) is a safety valve, that protects the air system against excessive air pressure build-up.

The primary reservoir is the air source for the brakes on the rear axle. At the inlet port of the primary reservoir is an in-line check valve. The check valve allows air flow in one direction only, and prevents air flow in the reverse direction in case there is a drop in upstream air pressure.

NOTE: On vehicles equipped with a DRM, there is no in-line check valve. The primary air pressure is protected by a pressure protection valve inside the DRM.

The secondary reservoir is the air source for the front axle brakes. It is equipped with an internal check valve.

The secondary reservoir supplies air to a pressure protection valve. This valve prevents complete loss of secondary air pressure if there is an air leak in any non-brake accessory.

Some vehicles are equipped with a three chamber air tank that is not part of a DRM. In the three chamber air tank, there are two internal single check valves located in the supply air chamber (wet tank). The valves are installed in elbows welded into the belled partitions between the chambers. One valve controls air movement from the supply air chamber to the secondary air chamber. The other valve controls air movement from the supply air chamber to the primary air chamber. To see the check valves, remove a fitting from the top of the supply chamber and look through the port. The check valves are not serviceable. If they are not functioning correctly, replace them.

All air reservoirs are equipped with drain valves to eject the water and oil emulsion from the tanks.

Safety Precautions

Before attempting to work on the air brake system, observe the following precautions:

- Since the compression and storage of air can be compared to energy in a coiled spring, when released, it can present a hazard if not properly recognized. The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer's recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- Used reservoirs must not be used as replacements in order to eliminate the possibility of component failure.
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

Tests

WARNING

Before working on or around air brake systems and components, see Safety Precautions, 100.

Be sure the air system is fully charged. Using a soap solution or leak detector, check for leaks on the outside surfaces of the reservoirs and drain valves. No leakage is permitted.

If leaks exist at the drain valve, note if they occur at the joint of the valve and coupler or through the valve body. See **Subject 120**.

If leaks occur on the surfaces of the air reservoir, replace the tank; see **Subject 130**.

Internal Check Valves Test, Three-Chamber Air Reservoir

The three-chamber air reservoir has two internal check valves located in the supply chamber of the reservoir. To test the check valves for proper operation, perform the following test.

NOTE: Depending on vehicle configuration, this procedure may require two people.

1. Start the engine and fully pressurize the brake system. Shut down the engine.
2. Discharge the air from the supply chamber of the reservoir.
3. Watch the dash air-pressure gauges for the primary and secondary air systems. If either system looses pressure along with the supply chamber, the check valve is bad. Replace it. See **Subject 140**.

Replacement and Leak Elimination

WARNING

Before working on or around air brake systems and components, see Safety Precautions, 100.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Using two wrenches (hold the coupler in place with one of them), unscrew the drain valve from the coupler. Clean off the threads inside the coupler on the reservoir, removing all sludge and sealant build-up.

   Obtain a new drain valve if leaks occurred through the body of the valve.

   If leaks occurred at the joint of the drain valve and coupler, clean off the sludge and sealant from the threads of the valve. Check for damaged threads on the valve and inside the coupler. Replace damaged parts. If no damage exists, leakage was probably due to inadequate tightening of the drain valve in the coupler.
4. Apply Loctite, or an equivalent sealant, to the end threads of the drain valve or coupler, as applicable, and install finger-tight. Tighten one and one-half additional turns (use two wrenches if installing the drain valve).
5. Perform a leak test after completing the installation. If leaks occur at the joint of the drain valve and coupler, tighten the valve up to one additional turn to stop the leaks.
6. Remove the chocks from the tires.

Replacement

NOTE: The air reservoirs are mounted in various locations, depending on the vehicle configuration. The reservoirs are typically mounted under the driver's-side steps or along the frame rail, behind the cab.

1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Drain the air system.
3. Mark and disconnect all reservoir air lines and couplers for later assembly. Cap the exposed ports tightly to keep out contaminants. If access is limited, remove the components after removing the reservoir from its mount.

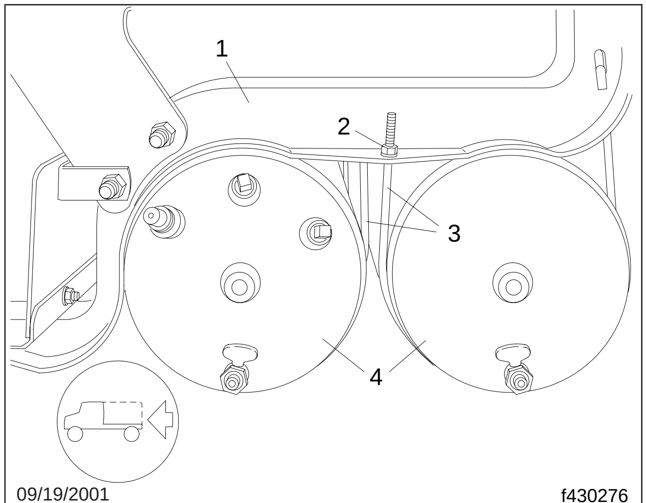
NOTE: Many reservoirs are integrated with an air dryer, called the Dryer Reservoir Module (DRM). The air dryer must be removed from the reservoir when the reservoir is being replaced. For instructions on air dryer removal and installation, see **Section 42.03, Subject 110**.

4. Remove the reservoir.
   - If the reservoir is mounted under the drivers steps, remove the nuts securing the U-bolt straps and remove the reservoir (**Fig. 1**).
   - If the reservoir is installed along the frame rail using a strap fastener, remove the air dryer, if equipped. Then, remove the reservoir strap fasteners and remove the reservoir.
   - If necessary, remove the air dryer from the reservoir.

NOTE: If access is limited, connect all air lines and couplers to the new reservoir, removing the caps as each component is installed.

5. If the reservoirs are mounted under the driver's steps, install the air dryer onto the new reservoir (if equipped) and install the reservoir. Secure the U-bolt straps with the nuts. Tighten the nuts 12 lbf·ft (16 N·m). See **Fig. 1**.

   If the reservoir is installed along the frame rail using a strap fastener, install the reservoir using the straps. Tighten the clamp nuts to 26 lbf·ft (35 N·m). Tighten the frame rail fasteners 136 lbf·ft (184 N·m).



1. Stair and Reservoir Mounting Bracket
2. Nut
3. U-Bolt Mounting Strap
4. Air Reservoir

Fig. 1, Air Reservoir (mounted under driver's steps)

6. As marked earlier, connect all air lines and couplers to the new reservoir, removing the caps as each component is installed. Tighten the connections as instructed elsewhere in this group.

   If necessary, install the air dryer. For instructions, see **Section 42.03, Subject 110**.
7. If the air dryer was removed for air reservoir replacement, perform operational tests in **Section 42.03, Subject 170**.
8. Remove the chocks from the tires.

WARNING

Before working on or around air brake systems and components, see Safety Precautions, 100.

Internal Check Valve Replacement, Two-Chamber Air Reservoir

General Information

Contamination in two chamber, wet/secondary, reservoirs may cause the inline check valve to become clogged or stuck closed. This can result in insufficient air buildup. If insufficient air buildup is noted, replace the check valve. If the check valve can not be removed (due to corrosion), it is acceptable to install a bypass line.

There are two styles of check valves that may have been installed in the tank. An internal check valve is threaded into the internal wall that separates the wet side and secondary side of the reservoir. Or an external check valve is mounted in a port on the top surface of the reservoir.

Internal Check Valve Replacement (Located in the Separator Wall of the Reservoir)

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Drain the air reservoir.
3. Disconnect the air lines and remove the reservoir from the vehicle.
4. On the supply (wet) side of the reservoir, disconnect the pressure-protection valve, and the 90-degree elbow located on the end of the reservoir.
5. The check valve is located on the interior wall that separates the sides of the reservoir. To reach it, use a 1/4-inch drive, 1/2-inch deep-well socket with a 1/4- to 3/8-inch drive adapter, and necessary 3/8-inch extensions to reach the valve. Tape the socket and extensions, to ensure the valve will stay in the socket, and that the wrench assembly will stay together inside the tank. Insert the socket assembly through the end port of the reservoir, and remove the valve. See **Fig. 1** and **Fig. 2**.

CAUTION

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel parts contact each other, could lead to corrosion of the metals, resulting in damage to the frame or parts.

6. Install a new check valve.
7. Attach the pressure-protection valve and the 90-degree elbow.
8. Install the reservoir on the vehicle and attach the air lines.
9. Charge the air system and inspect for leaks.
10. Remove the chocks from the tires.

External Check Valve Replacement (Located in the Side Port of the Reservoir)

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Drain the air reservoir.
3. Remove the check valve assembly from the top port on the reservoir. See **Fig. 3** and **Fig. 4**.
4. Install a new check valve.
5. Charge the air system and inspect for leaks.
6. Remove the chocks from the tires.

Bypass Line Installation

Check with the PDC for the appropriate bypass line kit for your vehicle.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Drain the air reservoir.
3. On the top port on both sides of the reservoir, disconnect the existing plumbing from the tank.

Internal Check Valve Replacement

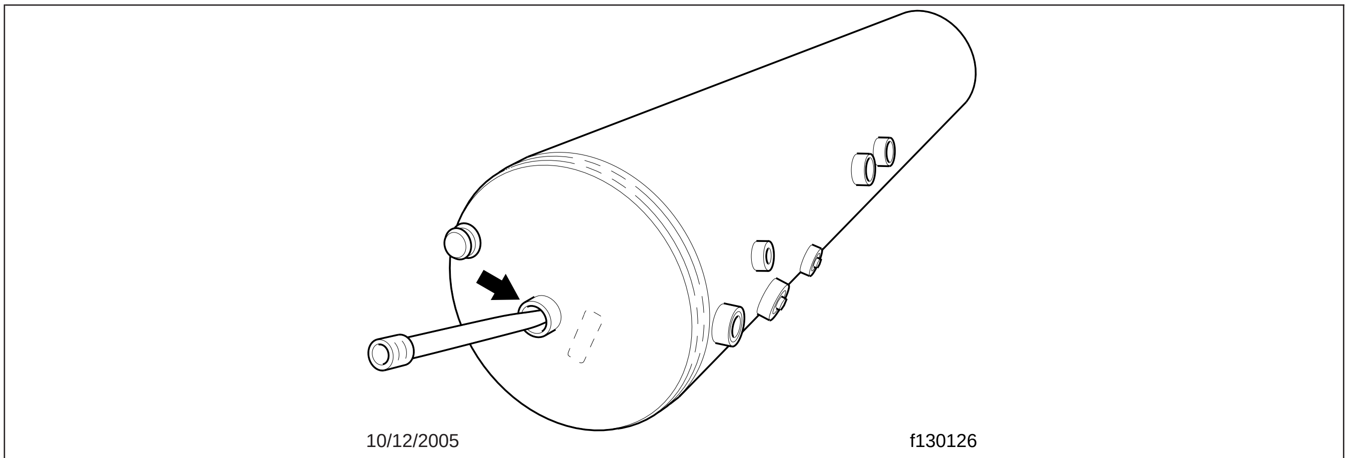
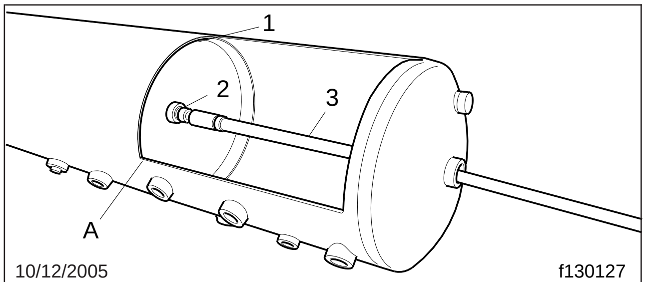
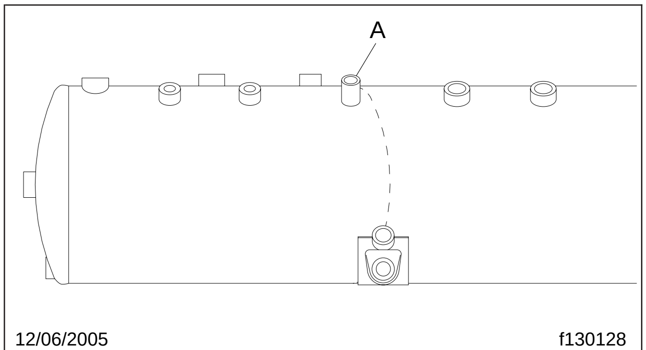


Fig. 1, Accessing the Internal Check Valve



A. Tank cut-away for clarity.
1. Interior Wall
2. Check Valve
3. Socket with Extension

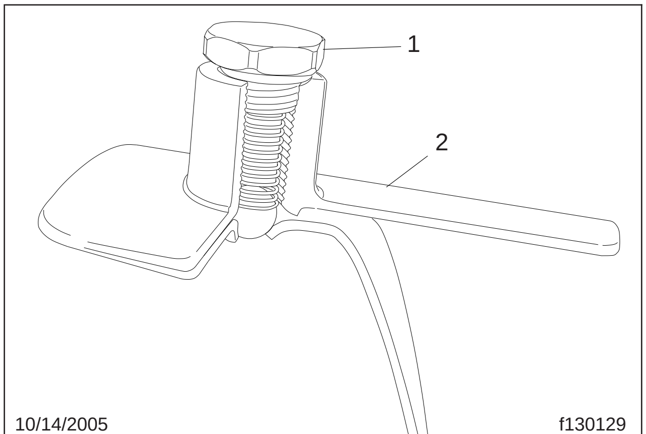
Fig. 2, Cut-Away View of Split Air Reservoir



A. Check Valve is located in this port.

Fig. 3, Check Valve Location

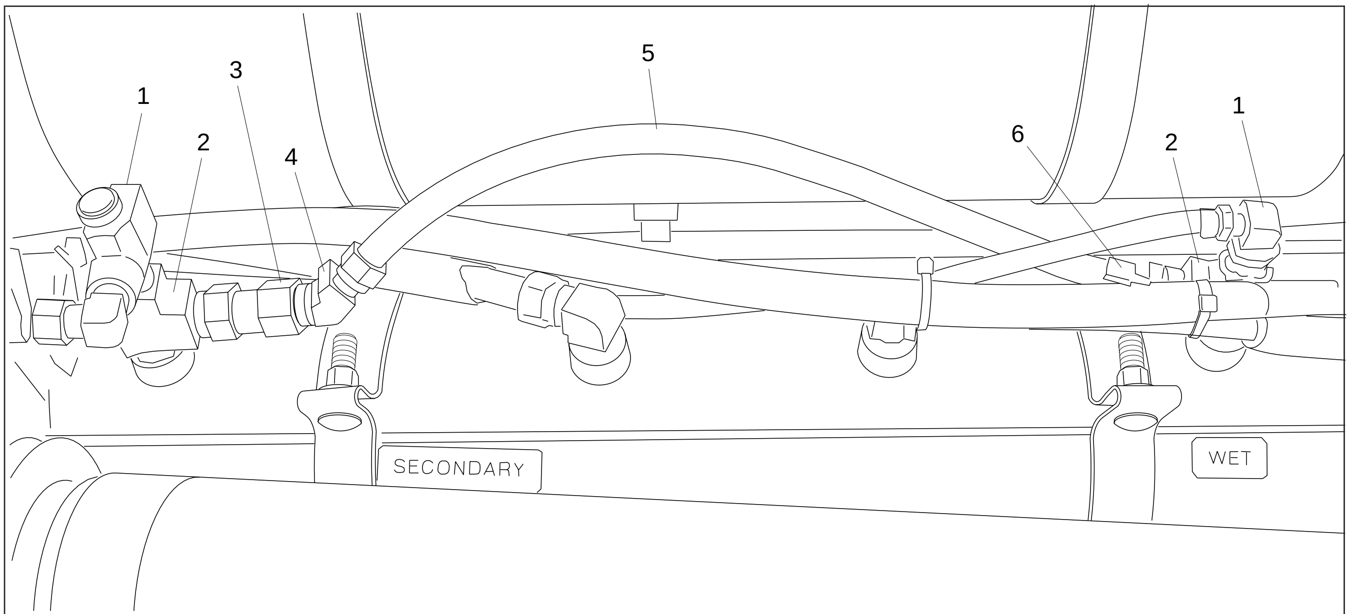
Install a T-fitting, and connect the existing plumbing to the top port of the T-fitting. See **Fig. 5**.



1. Check Valve
2. Tank Shell (Cut-Away)

Fig. 4, Cut-Away View of the Check Valve Installation

4. On the secondary (dry) side of the reservoir, on the side port of the T-fitting, install a check valve, then a 45-degree elbow.
5. On the supply (wet) side of the reservoir, on the side port of the T-fitting, install the straight brass fitting.
6. Install a 1/2-inch air line between the 45-degree elbow on the secondary (dry) side, and the brass fitting on the supply (wet) side.
7. Charge the air system and inspect for leaks.
8. Remove the chocks from the tires.



1. Existing Plumbing
2. T-Fitting
3. Check Valve
4. 45-Degree Elbow
5. 1/2-Inch Air Line
6. Brass Fitting

Fig. 5, Check Valve Bypass

Internal Check Valve Replacement, Three-Chamber Air Reservoir

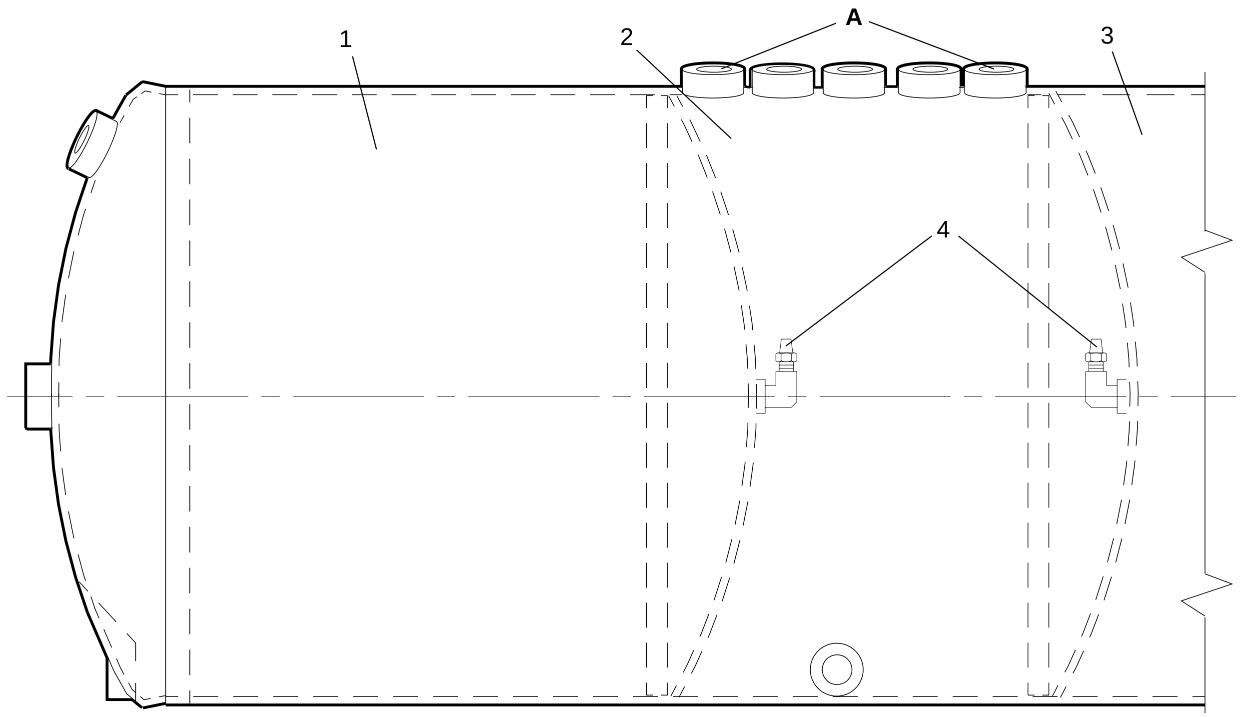
Before changing the internal check valve(s), test the system to determine which valve is bad. See **Subject 110** for the procedure.

1. Park the vehicle on a level surface, shut down the engine, and chock the tires.
2. Drain the brake air system completely.
3. Remove the appropriate fittings from the top of the supply-air chamber to access the valve(s) to be replaced. See **Fig. 6**.

NOTE: Use appropriate measures to ensure that the socket is securely attached to the extension, and that the valve is secured in the socket, so that they do not drop into the reservoir during this procedure.

4. Using a six-point, 1/2-inch, deep socket on a 10-inch extension, unscrew the valve from the fitting in the bell of the chamber partition and remove it from the reservoir.
5. Install the new valve in the fitting in the bell of the chamber partition. Tighten to 27 lbf·ft (40 N·m).
6. Install the air reservoir fittings that were removed.
7. Pressurize the air system and check for leaks around any fittings that were removed, then perform the "Internal Check Valves Test, Three-Chamber Air Reservoir" to determine that the problem has been fixed. See **Subject 110**.
8. Before returning the vehicle to service, test the brakes for proper operation.

Internal Check Valve Replacement



A. Access valves through these fittings.
1. Secondary Air Chamber
2. Supply Air Chamber
3. Primary Air Chamber
4. Check Valves (2)

Fig. 6, Internal Check Valves, Three-Chamber Air Reservoir

Safety Precautions

Before attempting to work on the air brake system, observe the following precautions:

- Since the compression and storage of air can be compared to energy in a coiled spring, when released, it can present a hazard if not properly recognized. The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer's recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- Used reservoirs must not be used as replacements in order to eliminate the possibility of component failure.
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

Replacement

CAUTION

Before working on or around air brake systems and components, review Safety Precautions 100.

If the tubing is bent to a radius smaller than the specified minimum bend radius, it may kink and shut off normal airflow to the component.

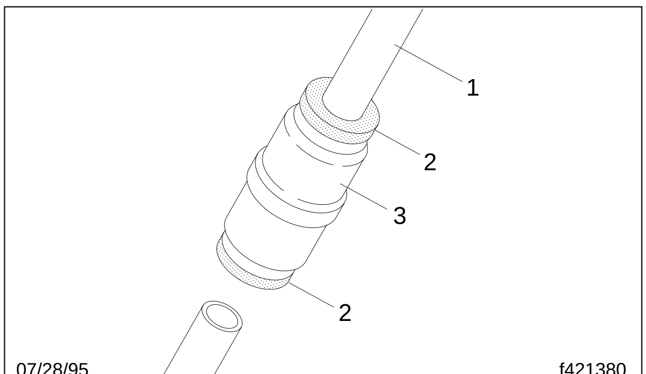
Nylon Air Lines

NOTE: When installing a nylon air line, be careful not to bend it past its minimum bend radius. For minimum bend radius values, see **Specifications 400**.

Push-to-Connect (Quick-Disconnect) Fittings

NOTE: If damaged, quick-disconnect fittings must be replaced as an assembly.

1. Push in on the fitting collar to release the air line.
2. Pull the air line out of the fitting. See **Fig. 1**.



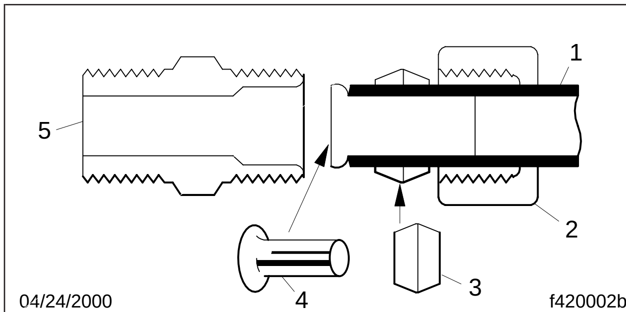
1. Air Line
2. Collar
3. Fitting

Fig. 1, Nylon Air Line and Quick-Disconnect Fitting

3. Push the air line all the way into the fitting.
4. Pull on the air line to make sure the line is installed in the fitting properly.
5. Check and make sure that the air line is seated in the fitting.

Compression Fittings

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Remove the air line.
   - 3.1 Push the stainless steel insert in, (to free sticking fittings, grip the stainless steel insert with pliers and rotate it slightly). For brass fittings, loosen the fitting nut. See **Fig. 2**.

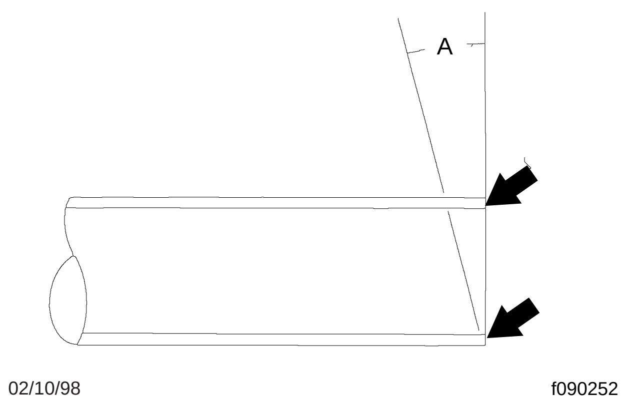


1. Nylon Tube
2. Nut
3. Sleeve
4. Stainless Steel Insert
5. Body

Fig. 2, Nylon Air Line and Compression Fitting

   - 3.2 Pull the air line out.
4. Use pliers to remove the stainless steel insert from the fitting.
5. Clean all of the fitting components.
6. Place the new stainless steel insert into the fitting body. Use thumb pressure to press it into position.
7. Check the tube end for a square cut-off that does not exceed a 15-degree angle. Check that the tube is not distorted or damaged. See **Fig. 3**.
   - 7.1 If the angle exceeds the specification, recut the air line.
   - 7.2 Use a sharp blade to prevent collapsing the tube or leaving burrs that can damage the O-ring.
8. Make sure the nylon tubing ends and fittings are free of grease and debris. If the tubing is

Air Line Replacement

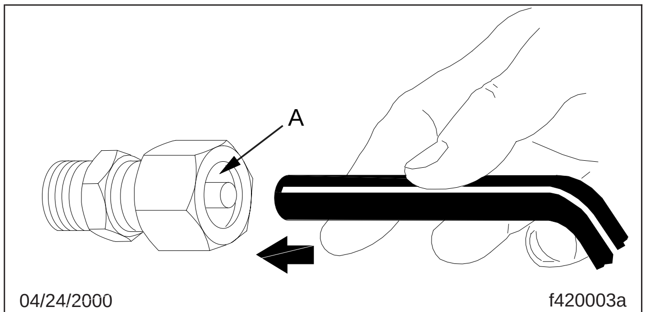


A. 15 Degrees Maximum

Fig. 3, Check Tube End Angle

crimped or otherwise damaged, replace it with new tubing.

9. Install a new sleeve in the nut. Start the threads of the nut on the fitting body.
10. Insert the squared end of the air line tubing in the fitting until it bottoms in the body of the fitting. See **Fig. 4**.



A. Tube end must bottom before tightening the nut.

Fig. 4, Installing Nylon Air Line into Compression Fitting

11. Tighten the nut until one thread remains visible.
12. Pull back on the air line to make sure the tube is fully seated.
13. Pressurize the air system. Check the air system for leaks.
14. Remove the chocks from the tires.

Wire Braid Air Lines

NOTE: When installing a wire braid hose, be careful not to bend it past its minimum bend radius. For minimum bend radius values, see **Specifications 400**.

1. Make sure the wire braid hose assembly is free of grease and dirt. Replace the assembly if the hose or fitting is crimped or otherwise damaged.
2. Install the hose and finger-tighten the nut.
3. Using two wrenches to prevent twisting of the hose, tighten the nut until it seats solidly. Tighten the nut one-sixth turn more.

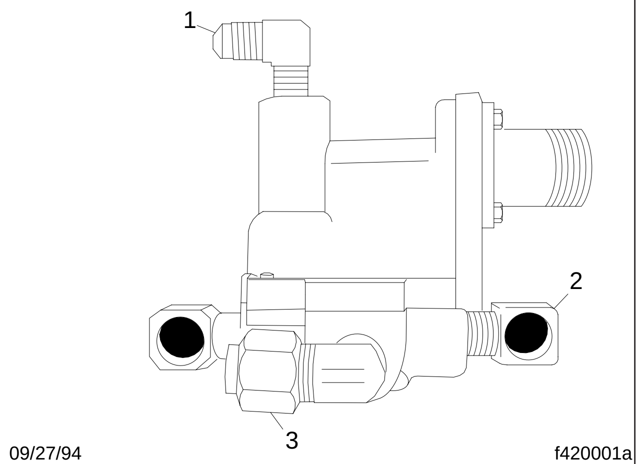
Replacement

CAUTION

Before working on or around air brake systems and components, review Safety Precautions 100.

Brass and Steel Pipe Fittings

1. Make sure the fittings (**Fig. 1**) are free of grease, dirt, and old sealant. Apply liquid thread sealant (white) to the threads, and finger-tighten securely.



1. Wire Braid Hose Fitting
2. Pipe Fitting
3. Nylon Tube Fitting

Fig. 1, Screw-On Fittings

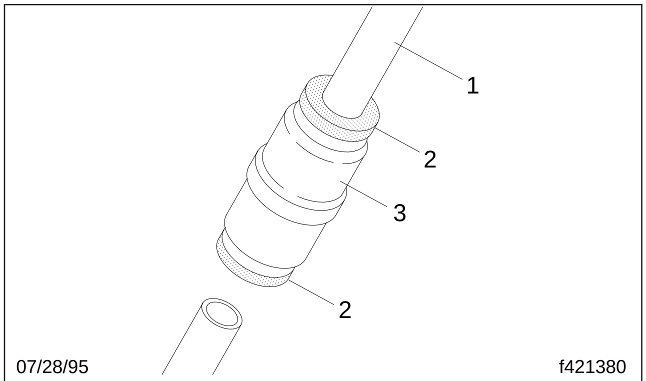
NOTE: Always apply the sealant to the external thread, so that any excess will be scraped off externally rather than internally to the joint.

2. For fittings that must be positioned, tighten one additional turn from finger-tight using a wrench.
3. Tighten the fitting until it is correctly positioned.
4. For fittings that do not require positioning, tighten 1-1/2 additional turns from finger-tight.

Quick-Disconnect Fittings

NOTE: If damaged, quick-disconnect fittings must be replaced as an assembly.

1. Push in on the fitting collar to release the air line.
2. Pull the air line out of the fitting. See **Fig. 2**.



1. Air Line
2. Collar
3. Fitting

Fig. 2, Nylon Air Line and Quick-Disconnect Fitting

3. Push the air line all the way into the fitting.
4. Pull on the air line to make sure the line is installed in the fitting properly.
5. Check and make sure that the air line is seated in the fitting.

Specifications

213 Wire Braid Hose			
Number *	Inside Diameter inch	Outside Diameter inch	Minimum Bend Radius inches (mm)
4	3/16	0.49	0.75 (19)
5	1/4	0.55	1.00 (25)
6	5/16	0.62	1.25 (32)
8	13/32	0.74	1.75 (44)
10	1/2	0.83	2.25 (57)
12	5/8	0.96	2.75 (70)
16	7/8	1.21	3.50 (89)
20	1-1/8	1.49	4.50 (114)

* 213 hose is identified by two green stripes 180 degrees apart, part numbers, and size; for example, part numbers 213-4, 213-5, and so on.

Table 1, 213 Wire Braid Hose

273 Fabric Braid Hose			
Number *	Inside Diameter inch	Outside Diameter inch	Minimum Bend Radius inches (mm)
4	1/4	5/8	1-1/2 (38)
6	3/8	3/4	1-3/4 (44)
8	1/2	7/8	2 (51)
10	5/8	1-1/16	2-1/2 (64)

* 273 hose is identified by part number and size.

Table 2, 273 Fabric Braid Hose

Additional Turns from Hand-Tight (Nylon Tube Compression Fitting Nut)	
Tube Size (inches)	Additional Turns from Hand-Tight
1/4	3
3/8 or 1/2	4
5/8 or 3/4	3-1/2

Table 3, Additional Turns from Hand-Tight (Nylon Tube Compression Fitting Nut)

Nylon Tube Bend Radius			
Number	Inside Diameter inch	Outside Diameter inch	Minimum Bend Radius inches (mm)
4	0.170	1/4	1.00 (25)

Nylon Tube Bend Radius			
Number	Inside Diameter inch	Outside Diameter inch	Minimum Bend Radius inches (mm)
6	0.251	3/8	1.50 (38)
8	0.376	1/2	2.00 (51)
10	0.441	5/8	2.50 (64)
12	0.566	3/4	3.00 (76)

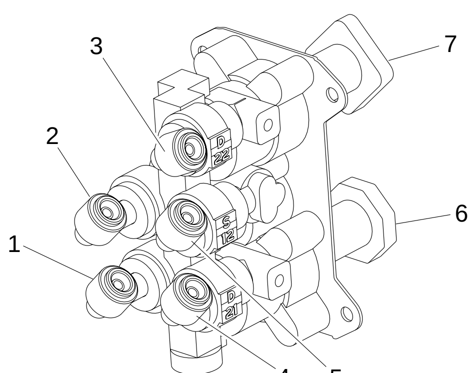
Table 4, Nylon Tube Bend Radius

General Description

The dash-mounted MV-3 control module is a two-button, push-pull control valve housed in a single body, which includes a dual circuit supply valve and a check valve.

The valve body, plungers, and spools are made out of a nonmetallic, noncorrosive material. All air connections are at the back of the valve. See **Fig. 1**.

The MV-3 module has several functions: tractor protection; trailer service air control; system park; trailer park only; trailer charge with tractor spring brakes applied (tractor park only); and supply reservoir selection.

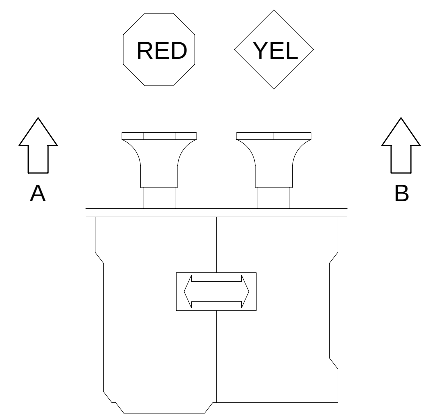


1. Exhaust
2. Primary Reservoir Supply
3. Delivery–Tractor Spring Brakes
4. Delivery–Trailer Supply
5. Secondary Reservoir Supply
6. Trailer Air Supply Knob
7. Parking Brake Control Valve Knob

Fig. 1, MV-3 Parking Brake Valve

The MV-3 includes a spring-loaded, dual-circuit supply valve, which selects the primary air reservoir as the air source for both control valves, unless the pressure in the primary air reservoir falls below that of the secondary air reservoir. Then, the dual-circuit supply valve will shuttle and establish the secondary air reservoir as the air source.

The trailer air supply valve, actuated by the red knob and the yellow knob, delivers air to the trailer supply line. See **Fig. 2**. The parking brake valve, actuated by a yellow knob, controls the spring parking brakes on the tractor, and when exhausted, simultaneously causes the trailer supply valve to trip and exhaust, thus applying both the tractor and the trailer parking brakes as required by federal regulations. See **Fig. 2**. The trailer parking brakes may be independently released by pushing only the trailer air supply valve (red) knob in.



A. Trailer Brakes Applied
B. Tractor Brakes Applied

Fig. 2, Trailer and Tractor Delivery Air Discharged (control knobs out)

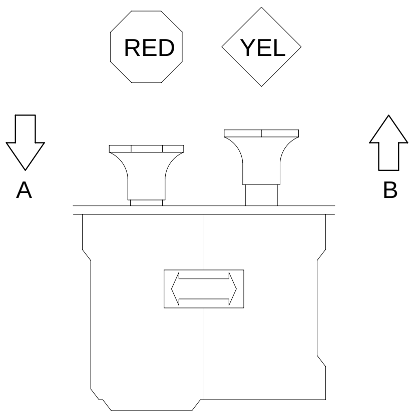
Principles of Operation

Initial Charge

With both the primary and the secondary systems completely discharged, both knobs are out. See **Fig. 2**. When system pressure reaches 65 psi (448 kPa), the red knob (trailer air supply) may be pushed in, and should stay in, charging the trailer system and releasing the trailer parking brakes. See **Fig. 3**. The yellow knob (parking brake) may now be pushed in, which will supply air to the tractor parking brakes, releasing them.

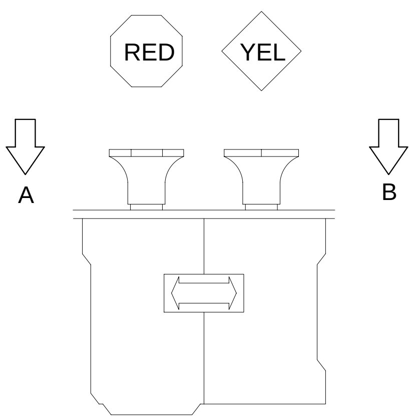
Normal Operation Position

When both knobs are pushed in, air is supplied to the trailer and the tractor parking brakes; all parking brakes are released. See **Fig. 4**. This is the normal operating mode.



A. Trailer Brakes Released
B. Tractor Brakes Applied

Fig. 3, Trailer Parking Brakes Released (red control knob pushed in)

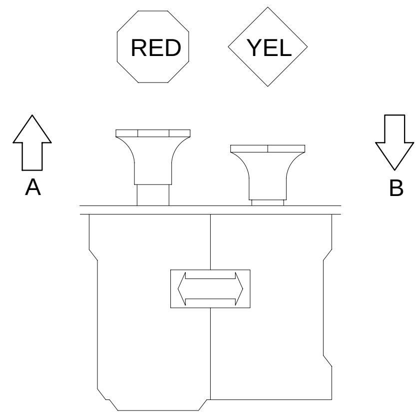


A. Trailer Brakes Released
B. Tractor Brakes Released

Fig. 4, Trailer and Tractor Brakes Released (both control knobs pushed in)

Actuation of Trailer Park or Emergency Brakes

To actuate the trailer parking brakes only, the red knob is pulled out, exhausting the trailer supply line. The trailer parking brakes are now applied, either by emergency air or parking brakes, depending on the type of trailer system. This mode would be used to uncouple from the trailer, and during bobtail operation. See **Fig. 5**.



A. Trailer Brakes Applied
B. Tractor Brakes Released

Fig. 5, Trailer Parking Brakes Applied (red control knob pulled out)

System Park

With both knobs pushed in, the parking brakes on both the tractor and the trailer may be actuated by pulling the yellow (parking brake) knob out. This exhausts the air from the tractor parking brakes and simultaneously causes the red (trailer air supply) knob to pop out, applying the trailer parking brakes (this complies with federal regulations that one control must apply all the parking brakes on the vehicle). See **Fig. 2**.

Trailer Charge

If both valves are out, parking the combination vehicle, and it is desired to recharge the trailer (leaving only the tractor parking brakes applied), the red knob may be pushed in, repressurizing the trailer supply line. This mode might also be used to park a combination vehicle with air-actuated emergency brakes on the trailer to provide demonstrated parking capability with the tractor spring brakes only. See **Fig. 3**.

Automatic Applications

If air pressure drops to 20 to 45 psi (138 to 310 kPa) in both the primary and the secondary systems, the red knob (trailer air supply valve) will automatically pop out, applying the emergency or parking brakes on the trailer. If the red knob is held in manually and the pressure decreases to 25 to 35 psi (172 to 241 kPa), a tripper piston within the MV-3 valve will move upward, exhausting the trailer supply, and applying the trailer parking brakes. If air pressure drops in both the primary and the secondary systems, the yellow (parking brake) knob will pop out at about 20 to 40 psi (138 to 276 kPa), applying the tractor parking brakes.

A warning buzzer and light are activated when pressure in either the primary or the secondary system drops below 64 to 76 psi (441 to 524 kPa).

Safety Precautions

Before attempting to work on the air brake system, observe the following precautions:

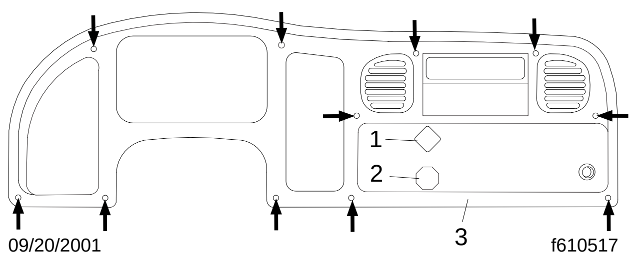
- Since the compression and storage of air can be compared to energy in a coiled spring, when released, it can present a hazard if not properly recognized. The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer’s recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- Used reservoirs must not be used as replacements in order to eliminate the possibility of component failure.
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

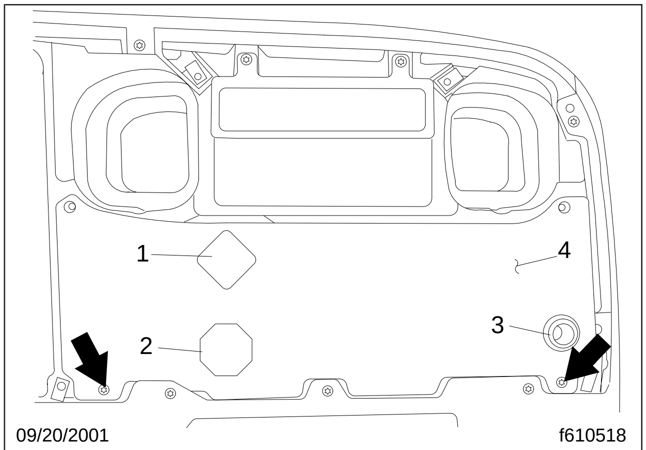
1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system and disconnect the batteries.
3. Remove the 12 screws from the dash panel and remove the panel. See **Fig. 1**.



1. Tractor Brake Module Knob (yellow)
2. Trailer Brake Module Knob (red)
3. Dash Panel

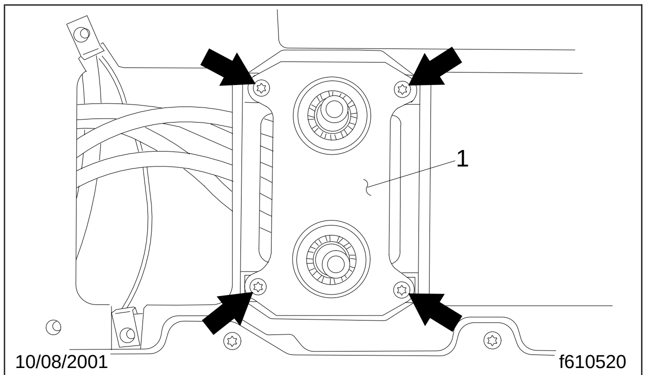
Fig. 1, Dash Panel Screws

4. Unscrew the red and yellow knobs from the stems of the spools on the MV–3 module by turning them in a counterclockwise direction. Mark the knobs in relation to the module for later reference.
5. Remove the interior panel. See **Fig. 2**.
   - 5.1 Remove the two remaining screws securing the panel to the dash.
   - 5.2 Remove the panel far enough to access the back of the cigarette lighter and mark and disconnect the two wires.
   - 5.3 Remove the panel.
6. Remove the four screws that attach the module to the mounting panel. See **Fig. 3**. Remove the module far enough to access the air line connections on the back.



1. Tractor Brake Module Knob (yellow)
2. Trailer Brake Module Knob (red)
3. Cigarette Lighter Receptacle
4. Interior Dash Panel

Fig. 2, Interior Dash Panel Screws



1. MV-3 Control Module

Fig. 3, Control Module Screws

7. Mark the air lines for later reference. Disconnect the lines from the module assembly and remove the module.

NOTE: The primary supply line is green. The exhaust line is yellow. The parking brake delivery line is black. The trailer charge delivery line is orange.

Installation

1. Position the module and connect the air lines to the applicable fittings.

Removal and Installation

2. Install the module and install the four mounting screws. See **Fig. 3**.
3. Install the interior panel.
   - 3.1 Position the interior panel and connect cigarette lighter to the power connections previous removed.
   - 3.2 Secure the panel using the Torx-head screws previously removed. See **Fig. 2**.
4. Attach the red and yellow knobs onto the threaded stems of the module spools, making sure they are correctly oriented as noted during removal.
5. Leak test the fittings following the instructions in **Subject 130**.
6. Install the dash panel and 12 screws. See **Fig. 1**.
7. Connect the batteries.
8. Remove the chocks from the tires.

Disassembly, Cleaning and Inspection, and Assembly

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Disassembly

1. Remove the control module from the vehicle. For instructions, see **Subject 110**.
2. Remove the six screws from the cover plate and carefully remove the cover plate from the module. See **Fig. 1**.
3. Remove the cap and O-ring from the bore of the tripper valve. Remove the tripper piston, large spring, small spring, and check valve. These parts will all fall out of the cavity of the MV–3 by tilting the body forward. Remove the O-ring from its groove on the piston.
4. Remove the two main spools from the body of the MV–3 module by grasping the stem and pulling firmly. Remove the spring from the bottom of each spool cavity.
5. Pull the guide cap and guide spool over the threaded end of one of the plungers. Remove the O-ring from the guide cap and the O-ring from the guide spool. Remove the other O-rings and the exhaust seal from the plunger.
6. Repeat the previous step on the remaining spool assembly.
7. Remove the retaining ring from the cavity of the MV–3 body that contains the dual-circuit supply valve.
8. Using a pair of needle-nose pliers, grasp the bar in the center of the cap and dual-circuit supply valve and remove the dual-circuit valve assembly. Remove the three O-rings from the valve or from the cavity of the body, if some have remained there. Other than the three external O-rings, do not disassemble the piston assembly further.

NOTE: If during the removal of this assembly from the body the cap dislodges from the rest of the valve, the remaining parts can be removed using bent wire. The spring, piston and O-ring that are internal to the dual circuit valve assembly are nonserviceable.

Cleaning and Inspection

The nonmetallic components making up most of the parts of the MV–3 *should not be immersed in any solvent type cleaner*. Old lubricant should be wiped out with a clean dry cloth.

If any visible damage to the body or the spools is found, replace the complete unit.

Assembly

Dual-Circuit Supply Valve

1. Lubricate all O-rings, bores, and sliding surfaces with silicone lubricant Bendix 291126, Dow Corning 55-M, or equivalent.
2. Install O-rings onto the cap and dual circuit supply valve. Install the assembly, small diameter first, into its cavity in the body.
3. Install the retaining ring making sure it is fully seated in its groove.

Spools

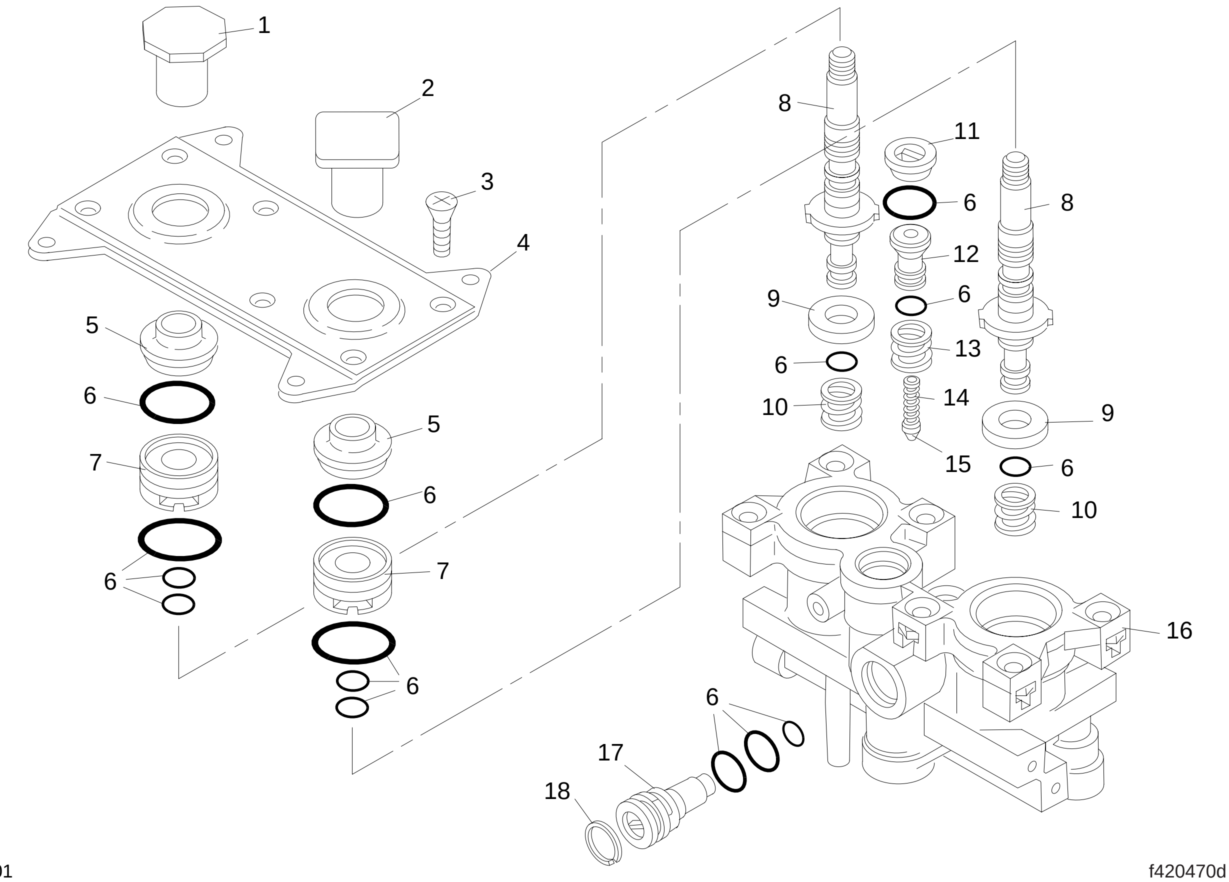
1. Install the O-rings and the exhaust seal onto the stem of the plunger.

CAUTION

The exhaust seal must be installed so that its beveled surface mates with the beveled surface of the plunger. See Fig. 2.

2. Install the O-ring onto the guide spool and the O-ring onto the guide cap. Place the guide cap on top of the guide spool, and install the entire assembly over the threaded end of the plunger; press down firmly until it snaps into place.
3. Install the spring over the boss in the bottom of the spool cavity in the body of the MV–3 module. Place the spool assembly into the body, keeping the spool square to the body. Press and turn the stem until the spool is fully seated in its cavity. Note the assembly is keyed and can be installed one way only.
4. Repeat the previous steps for the opposite spool.

Disassembly, Cleaning and Inspection, and Assembly



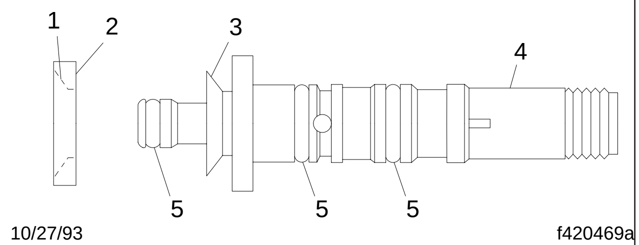
1. Red Trailer Air Supply Knob
2. Yellow Parking Brake Knob
3. Screw
4. Cover Plate
5. Guide Cap
6. O-Ring
7. Guide Spool
8. Plunger
9. Beveled Exhaust Seal
10. Spring
11. Cap
12. Tripper Piston
13. Large Diameter Spring
14. Small Diameter Spring
15. Check Valve
16. Valve Body
17. Cap and Dual-Circuit Valve Assembly
18. Retaining Ring

Fig. 1, MV-3 Module (exploded view)

Shuttle and Check Valve

1. Install the O-ring into its groove on the tripper piston. Install the O-ring onto the cap.
2. Install the large spring on the piston and the small spring on the boss of the check valve.
3. Install the spring and check valve into their cavity in the body of the MV–3 module (tapered end of the valve to enter cavity first). Make sure the spring is centered in the bore.
4. Install the piston assembly into the cavity, making sure the spring mates with the bore of the piston.
5. Install the cap and O-ring.
6. Attach the cover plate to the module body using the six screws. Torque them 25 lbf·in (280 N·cm).
7. Install the control module in the vehicle. For instructions, see **Subject 110**.

Disassembly, Cleaning and Inspection, and Assembly



1. Inside Bevel
2. Exhaust Seal
3. Mating Exhaust Seal Bevel
4. Plunger
5. O-Ring

Fig. 2, Plunger Assembly

8. Check the operation of the module using the instructions in **Subject 130**.

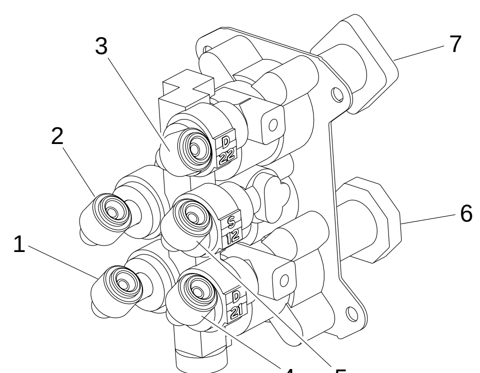
⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Tests

With the air brake system charged to 120 psi (827 kPa), check for leaks, using the following instructions. Repair or replace components as needed.

1. Apply a soap solution and check for leakage between the body and cover plate. Leakage at the exhaust port should produce less than a 1-inch (25-mm) bubble in five seconds.
2. With the trailer supply line sealed, push in the red knob. The knob must stay in. Leakage at the exhaust port must not exceed a 1-inch (25-mm) bubble in 5 seconds. See **Fig. 1**.



1. Exhaust
2. Primary Reservoir Supply
3. Delivery–Tractor Spring Brakes
4. Delivery–Trailer Supply
5. Secondary Reservoir Supply
6. Trailer Air Supply Knob
7. Parking Brake Control Valve Knob

Fig. 1, MV–3 Parking Brake Valve

3. Slowly reduce pressure in both service reservoirs. The red knob must pop out at 20 to 35 psi (138 to 310 kPa).

NOTE: Trip-on pressure is the pressure at which the valve automatically changes position or "pops out." It is advised to use an accurate pressure gauge other than those in the truck when performing tests.

4. Hold the red knob in and continue to reduce pressure in all service reservoirs. Air must start to escape from the exhaust port when the trailer line pressure reaches 20 to 35 psi (138 to 241 kPa).
5. Release the red knob and rebuild the supply pressure to 120 psi (827 kPa). Push in the yellow knob; the yellow knob must remain in. Leakage at the exhaust port should not exceed a 1-inch (25-mm) bubble in 5 seconds.
6. Pull the red knob out. Slowly reduce pressure in all service reservoirs. There is not a federal trip pressure requirement for the yellow knob, but it will pop out at 20 to 30 psi (138 to 207 kPa).
7. Charge the system to 120 psi (827 kPa), and push both knobs in. Pull the red knob out. The yellow knob must remain in. Push the red knob in and pull the yellow knob out. The red knob must pop out at once.
8. Install a gauge to monitor tractor spring brake delivery pressure. Build 120 psi (827 kPa) pressure in the primary and secondary air reservoirs. Push in the yellow knob. Delivery pressure should equal the pressure in the primary air reservoir. Reduce the pressure in the primary air reservoir. The dual-circuit supply valve shuttle should switch to the secondary air reservoir. After the primary air reservoir pressure is reduced to zero, there should not be audible leakage at the primary air reservoir opening. Stop the leak that was created in the primary air reservoir.
9. Leaving the yellow knob in, recharge the secondary air reservoir to 120 psi (827 kPa). The delivery pressure should also read 120 psi (827 kPa). Recharge the primary air reservoir to 100 psi (690 kPa). Slowly vent the secondary air reservoir. As the secondary air reservoir pressure and the delivery line pressure descend, pressure should stabilize at about 100 psi (690 kPa).
10. Close all leakage points and charge both reservoirs to 120 psi (827 kPa). Position the red knob out and the yellow knob in. Develop a leak in the spring brake delivery line and hold the yellow knob in. See **Fig. 1**. The air reservoir pressures will go to zero. The dual-circuit supply valve shuttle should cycle during the leak-down period.

Operating Tests

11. If the MV-3 fails to operate as described, or leakage exceeds the limits stated, replace or repair it using genuine Bendix parts.

General Description

The dual circuit brake valve (foot valve) controls the air supply and delivery of the dual circuit brake system. See **Fig. 1**. The brake valve is mounted on the firewall.

Applying

The primary circuit of the brake valve is controlled by the brake pedal and a plunger. When the brake pedal is depressed, the plunger applies pressure on the spring seat, rubber spring, and the primary (upper) piston. The downward movement of the primary piston closes the upper exhaust valve, and then opens the upper inlet valve, allowing high-pressure air from port 11 to flow to low-pressure port 21.

The secondary circuit is pneumatically operated by the pressure from the primary circuit. Primary circuit pressure on top of the relay piston first closes the lower exhaust valve, and then opens the lower inlet valve, allowing high-pressure from port 12 to flow to low-pressure port 22.

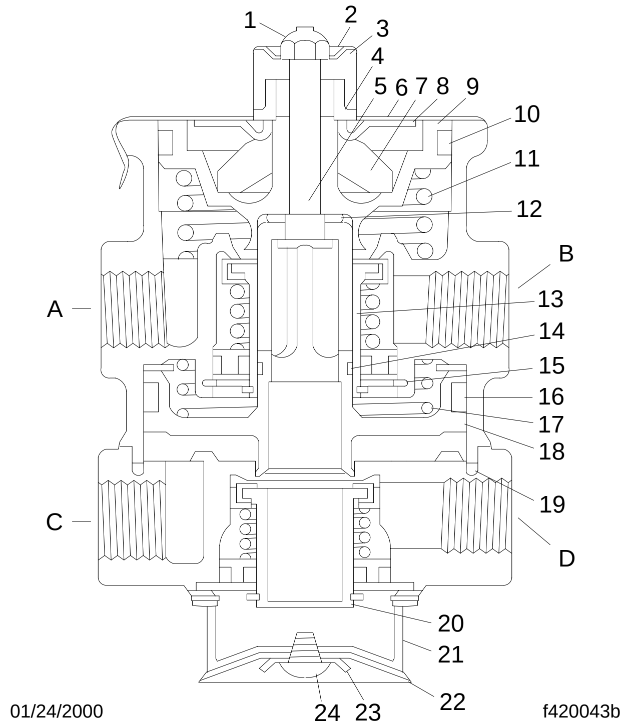
Holding

As air pressure builds in the primary circuit, the pressure under the primary piston will match the pressure of the rubber spring. This allows the piston to move up enough to close the upper inlet valve, and prevent the flow of air from the primary air tank into the brake valve. The exhaust port remains closed.

Releasing

When the pedal is released, the push rod releases pressure from the spring seat, rubber spring, and the primary (upper) piston. Air pressure builds to push the piston up, opening the upper exhaust valve and allowing air from the primary circuit to escape through the exhaust port.

In the secondary circuit, the release of primary air pressure allows air under the relay piston, pushing the piston up and opening the lower exhaust valve. All remaining air pressure is vented through the exhaust port.



A. Port 21: to primary air circuit
B. Port 11: from primary air tank
C. Port 22: to secondary air circuit
D. Port 12: from the seondary air tank

1. Locknut
2. Spring Seat
3. Stem Spring
4. Spring Seat Nut
5. Primary Piston Stem
6. Primary Piston Retainer
7. Rubber Spring
8. Spring Seat
9. Primary Piston
10. Primary Piston O-Ring
11. Primary Piston Return Spring
12. Small Washer
13. Upper Inlet and Exhaust Valve Assembly
14. Small O-Ring
15. Retaining Ring
16. Large O-Ring
17. Relay Piston Spring (if equipped)
18. Relay Piston
19. Rubber Seal Ring
20. Lower Inlet and Exhaust Valve Assembly
21. Exhaust Cover
22. Exhaust Diaphragm
23. Washer
24. Phillips Head Screw

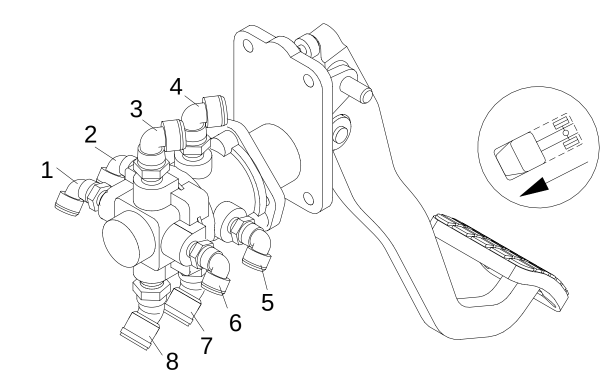
Fig. 1, Bendix E-6 Dual Circuit Foot Valve (sectional view)

Operating Checks

IMPORTANT: If there is a change in the way a vehicle brakes, or if low pressure warnings occur, check the operation of the air system. Although the brake system may continue to work, do not operate the vehicle until the braking circuits, including the pneumatic and mechanical devices, have been repaired and are operating normally. Always check the brake system for proper operation after doing brake work, and before returning the vehicle to service.

Check for the proper brake valve operation as follows:

1. Apply the parking brakes, and chock the tires.
2. Connect test gauges to the primary and secondary delivery ports (ports 21 and 22) on the brake valve. See **Fig. 1** and **Fig. 2**.



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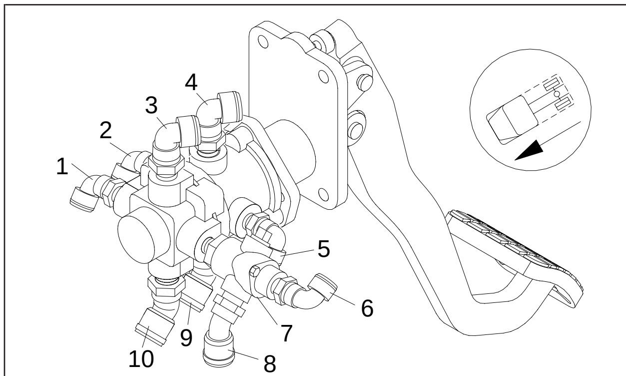
1. Secondary Delivery Circuit to Front Brake Valve
2. Delivery Circuit to Rear Brake Valve
3. Secondary Supply Circuit to Dash Valve
4. Primary Supply Circuit to Dash Valve
5. Primary Delivery Circuit to Tractor Protection Valve
6. Secondary Delivery Circuit to Tractor Protection Valve (if not equipped with a hand valve)
7. Primary Supply Circuit to Primary Supply Reservoir
8. Secondary Supply Circuit to Secondary Supply Reservoir

Fig. 1, Brake Valve Plumbing Circuits

NOTE: When checking the delivery pressure of the primary and secondary circuits, use test gauges that are accurate.



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1. Secondary Delivery Circuit to Front Brake Valve
2. Primary Delivery Circuit to Rear Brake Valve
3. Secondary Supply Circuit to Dash Valve
4. Primary Supply Circuit to Dash Valve
5. Primary Delivery Circuit to Tractor Protection Valve
6. Delivery Circuit to Trailer Hand Valve
7. Double Check Valve
8. Secondary Delivery Circuit to Tractor Protection Valve
9. Primary Supply Circuit to Primary Supply Reservoir
10. Secondary Supply Circuit to Secondary Supply Reservoir

Fig. 2, Brake Valve Plumbing Circuits (with double-check valve)

3. Start the engine and build air pressure to 120 psi (827 kPa).
4. Depress the pedal to several different positions; check the pressure on the test gauges to ensure that it varies equally and proportionately with the movement of the brake pedal.
5. Fully depress the brake pedal, then release it. After a full application is released, the reading on the test gauges should promptly fall to zero.

NOTE: Pressure in the primary delivery circuit will be about 2 psi (14 kPa) greater than pressure in the secondary delivery circuit (if both supply reservoirs are at the same pressure). This is normal for this valve.

6. Go to "Leakage Check."

Leakage Check

1. Make and hold a pressure application of 80 psi (552 kPa).

Brake Valve Operating and Leakage Checks

2. Check the air line fittings for leaks: tighten or replace fittings as needed.
3. Coat the exhaust port and body of the valve with a soap solution, and check for leakage. The leakage permitted is a 1-inch (25-mm) bubble in 3 seconds.

   If the brake valve does not function as described above, or if leakage is excessive, replace it with a new or remanufactured unit.

   Repeat the leakage test before placing the brake valve in service.
4. Remove the chocks from the tires.

Brake Valve Removal and Installation

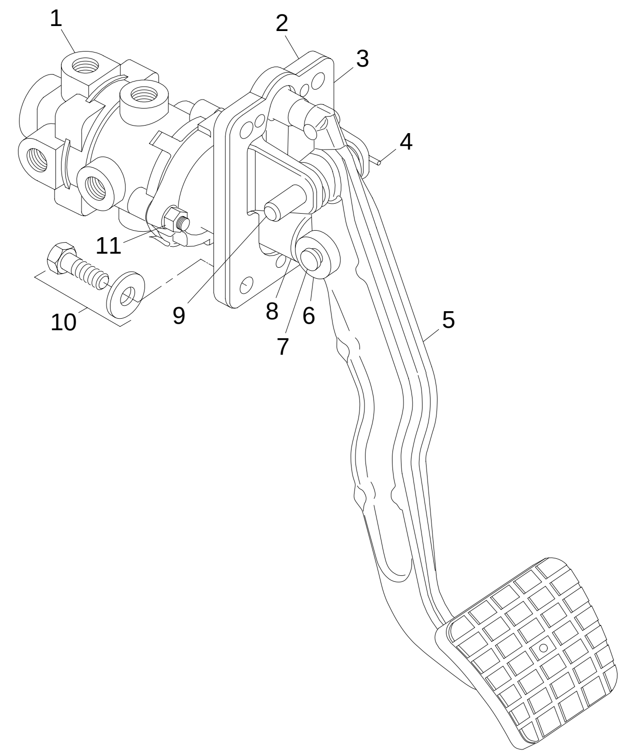
Removal

1. Chock the tires, then tilt the hood. For instructions, refer to the vehicle driver's manual.

WARNING

When draining the air system, do not look into the air lines/ports or direct them toward another person, because dirt or sludge particles may be in the airstream. Do not disconnect pressurized hoses because they may whip as air escapes from the line. Failure to take all necessary precautions during service operations of the air brake system can result in personal injury.

2. Drain all of the air reservoirs.
3. Mark the brake valve air supply and delivery lines for assembly reference. Disconnect the air lines from the brake valve, and plug them to keep out contaminants.
4. Remove the brake valve. See **Fig. 1**.
   - 4.1 Remove the 5/16-18 capscrews and flatwashers that attach the brake valve and mounting adaptor to the front cab mount plate.
   - 4.2 Remove the 5/16-18 locknuts and washers that attach the brake valve to the mounting adaptor.
   - 4.3 Remove the plunger from the mounting adaptor. Wipe off the old grease from the plunger and adaptor.
5. Note the location and position of the double check valve (if equipped), then remove it from the brake valve. Clean off the dirt and old sealant from the threads of the valve and elbows.



1. Brake Valve
2. Mounting Plate Adaptor
3. Gasket
4. Roll Pin
5. Brake Pedal Assembly
6. Roller
7. Roller Pivot Pin
8. Plunger
9. Shaft Pivot Pin
10. 5/16–18 Capscrew and Flatwasher
11. 5/16–18 Locknut and Washer

Fig. 1, Brake Valve Mounting

Installation

WARNING

When applying sealant, make sure that excess sealant doesn't get inside either the male or the female fittings. Loose foreign material inside the air plumbing may clog a valve, causing a loss of brake control, which could result in personal injury.

1. If equipped with a hand brake valve, apply a small quantity of Loctite® Pipe Sealant (with Teflon® 59241), or an equivalent sealant, to the male threads of the double check valve and the elbows.

   Install the double check valve and elbows in the ports of the brake valve. Tighten the valve finger-tight, then tighten one additional turn with a wrench. As needed, further tighten until the valve is properly positioned.

Brake Valve Removal and Installation

2. Lubricate the sliding surface of the brake plunger with barium grease, part number BW 246671 or Pennzoil Adhezoplex EP 2. Install the plunger in the mounting adaptor.
3. Using the 5/16–18 locknuts and washers, attach the mounting adaptor to the brake valve. Tighten the capscrews 10 to 13 lbf·ft (14 to 18 N·m).
4. Install the brake valve and mounting adaptor on the outside of the front cab mount plate. Install the adaptor mounting capscrews and flatwashers. Tighten the capscrews 10 to 13 lbf·ft (14 to 18 N·m). See **Fig. 1**.
5. Connect the air lines, as previously marked. Tighten the nuts finger-tight. Using a wrench, further tighten the nuts until there is resistance, then tighten one-sixth additional turn.
6. Check and secure the air lines and electrical wires so they can't interfere with the movement of the brake pedal.
7. Return the hood to the operating position. For instructions, refer to the vehicle driver's manual.
8. Perform the operating and leakage checks. For instructions, see **Subject 100**.
9. Remove the chocks from the tires.
10. Test drive the vehicle in a safe area at low speed. Make several brake applications to be sure the vehicle comes to a safe stop.

Brake Valve Disassembly, Cleaning and Inspecting, and Assembly

Disassembly

Refer to **Fig. 1** while performing the disassembly procedure.

1. Remove the valve from the vehicle. For instructions, see **Subject 110**.
2. Remove the four screws that attach the exhaust cover to the lower valve body.
3. Remove the lower inlet and exhaust valve assembly.
4. Remove the four hexhead capscrews and washers that attach the lower and upper valve bodies. Separate the valve bodies.
5. Remove the rubber seal ring from the lower valve body.

WARNING

The locknut and spring seat are used to restrain the primary piston return spring, stem spring, and the relay piston spring. The combined force of these springs is about 50 pounds (220 N). When removing these springs, use care to prevent them from flying out and possibly causing personal injury. Manually or mechanically hold down these springs when removing the locknut.

6. Using a 3/8-inch wrench, hold the locknut on the threaded end of the primary piston stem. Insert a screwdriver in the exhaust passage through the center of the valve, and engage the slotted head of the stem.
7. Using the screwdriver to keep the stem from turning, remove the locknut, spring seat, and the stem spring.
8. Being careful to avoid damaging the valve seats, remove the relay piston, relay piston spring, and the primary piston and primary piston return spring.
9. Remove the small washer from the cavity in the lower side of the primary piston.

IMPORTANT: Be sure not to damage the piston when removing the spring seat nut. A damaged piston can cause air leakage and premature wear of the piston.

10. Turn the spring seat nut counterclockwise, and separate the spring seat nut, spring seat, and the rubber spring. Remove the primary piston O-ring.
11. Remove the small and large O-rings from the relay piston.
12. Remove the retaining ring. Remove the upper inlet and exhaust valve assembly.

Cleaning and Inspecting

Wash all metal parts in mineral spirits and dry them thoroughly with compressed air. Inspect the valve seat surfaces of the pistons and the valve housings for conditions that could cause leakage. Inspect air line fittings for corrosion, and replace corroded fittings.

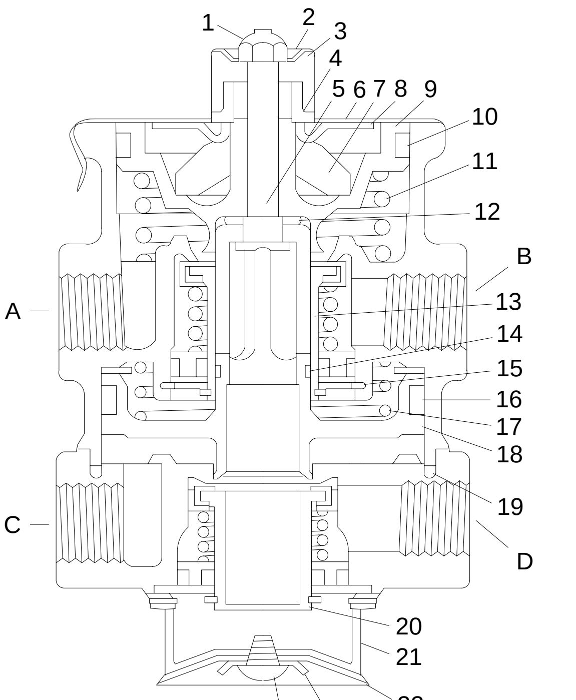
Assembly

Refer to **Fig. 1** while performing the assembly procedure.

NOTE: Keep the work area, tools, and brake valve parts clean during assembly.

1. Using Dow Corning 55-M pneumatic grease, or equivalent, lightly grease all the new O-rings, O-ring grooves, piston bores, and all sliding surfaces.
2. Place the upper inlet and exhaust assembly in the upper body, and secure the assembly with the retaining ring. Make sure that the retaining ring is seated in its groove.
3. Install the large and small O-rings on the relay piston.
4. Install the primary piston O-ring in the piston O-ring groove.
5. Install the rubber spring, concave side down, in the primary piston. Place the spring seat, flat side up, over the rubber spring.
6. Install the spring seat nut and turn the nut clockwise until the top surface of the spring seat is even with the top surface of the piston. Set this assembly aside.
7. Place the relay piston spring, if equipped, in the concave portion of the relay piston. Install the relay piston through the upper inlet and exhaust

Brake Valve Disassembly, Cleaning and Inspecting, and Assembly



A. Port 21: to primary air circuit
B. Port 11: from primary air tank
C. Port 22: to secondary air circuit
D. Port 12: from the seondary air tank

1. Locknut
2. Spring Seat
3. Stem Spring
4. Spring Seat Nut
5. Primary Piston Stem
6. Primary Piston Retainer
7. Rubber Spring
8. Spring Seat
9. Primary Piston
10. Primary Piston O-Ring
11. Primary Piston Return Spring
12. Small Washer
13. Upper Inlet and Exhaust Valve Assembly
14. Small O-Ring
15. Retaining Ring
16. Large O-Ring
17. Relay Piston Spring (if equipped)
18. Relay Piston
19. Rubber Seal Ring
20. Lower Inlet and Exhaust Valve Assembly
21. Exhaust Cover
22. Exhaust Diaphragm
23. Washer
24. Phillips Head Screw

Fig. 1, Bendix E-6 Dual Circuit Foot Valve (sectional view)

assembly, and into the underside of the upper valve body.

8. Place a screwdriver (blade up) in a vise. Place the primary piston stem in the relay piston. Position the upper valve body over the screwdriver blade, with the blade engaged in the slotted head of the piston stem.
9. Place the small washer over the stem.
10. Install the primary piston return spring in the upper valve body piston bore.
11. Install the primary piston and rubber spring assembly (assembled previously) over the stem, and into the upper valve body piston bore.

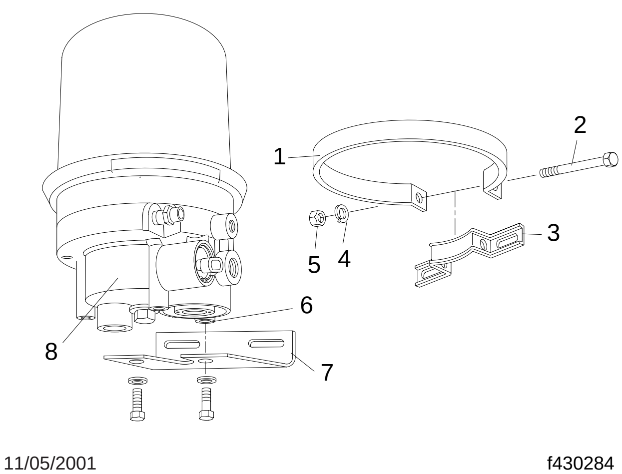
WARNING

The locknut and spring seat are used to restrain the primary piston return spring, stem spring, and the relay piston spring. The combined force of these springs is about 50 pounds (222 N). When installing these springs, use care to prevent them from flying out and possibly causing personal injury. Manually or mechanically hold down these springs when installing the locknut.

12. Push down and hold the primary and relay pistons in the upper valve body.
13. Place the stem spring over the spring seat nut (Ref. 4). Place the spring seat over the stem.
14. Install the locknut on the stem. Tighten the locknut 20 to 30 lbf·in (220 to 340 N·cm).
15. Install the rubber seal ring in the lower valve body.
16. Attach the lower and upper valve bodies. Install the four hexhead capscrews and washers. Tighten the capscrews 11 lbf·ft (15 N·m).
17. Install the lower inlet and exhaust valve assembly (Ref. 20).
18. Install the four screws that attach the exhaust cover to the lower valve body.
19. Install the brake valve. For instructions, see **Subject 110**.

General Information

The function of the AD-IP Integral Purge Air Dryer (Fig. 1) is to collect and remove air system contaminants in solid, liquid and vapor form before they enter the brake system. It provides clean, dry air to the components of the brake system which increases the life of the system and reduces maintenance costs. Daily manual draining of the reservoirs is eliminated.



1. Mounting Strap
2. 5/16-Inch Capscrew
3. Saddle Bracket
4. Lockwasher
5. Nut
6. End Cover Mounting Holes
7. Lower Mounting Bracket
8. Air Dryer

Fig. 1, Bendix AD-IP Air Dryer

The AD-IP Air Dryer consists of a desiccant cartridge secured to a die cast aluminum end cover with a single, central bolt. The end cover contains a check valve assembly, safety valve, heater and thermostat assembly, three pipe thread air connections and the purge valve assembly. The removable purge valve assembly incorporates the purge valve mechanism and a turbo charger cutoff feature that is designed to prevent loss of engine turbocharger. boost pressure during the purge cycle of the AD-IP air dryer. For ease of serviceability, all replaceable assemblies can be replaced without removal of the air dryer from its mounting on the vehicle.

To ease servicing, the desiccant cartridge and discharge check valve assembly are screw-in types. The purge valve housing assembly, which includes the heater and thermostat assembly, and the discharge check valve assembly, can be serviced WITHOUT removing the air dryer from the vehicle. The screw-in desiccant cartridge requires removal of the air dryer assembly from the vehicle.

The AD-IP has three female pipe thread air connections identified in Table 1.

Port I.D.	Function/Connection
CON 4	Control Port (purge valve control and turbo cutoff)
SUP 11	Supply Port (air in)
DEL 2	Delivery Port (air out)

Table 1, Air Dryer Port Identification

Principles of Operation

The AD-IP air dryer alternates between two operational modes or cycles during operation: the charge cycle (Fig. 2) and the purge cycle (Fig. 3).

CHARGE CYCLE

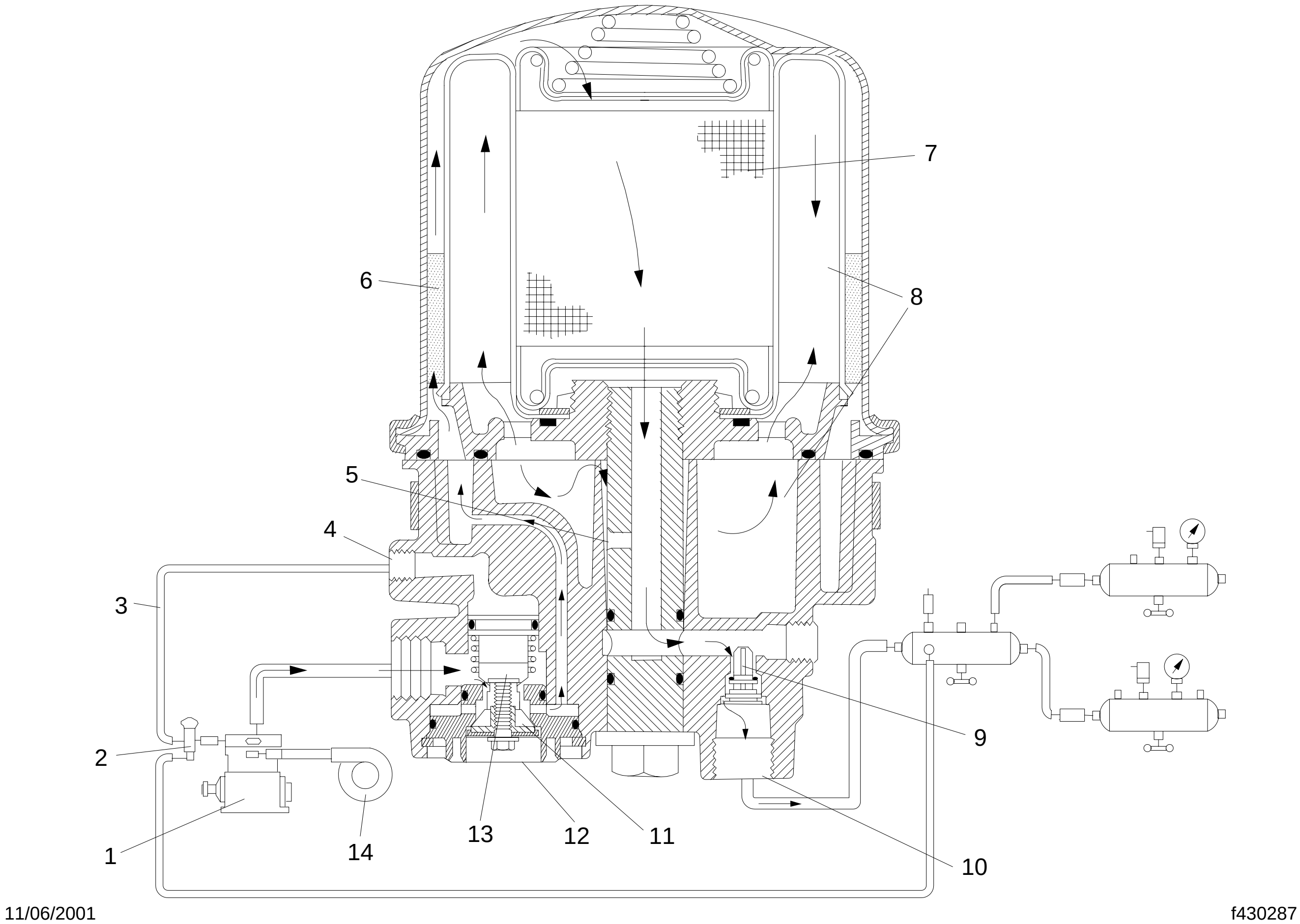
When the compressor is loaded (compressing air) compressed air, along with oil, oil vapor, water and water vapor flows through the compressor discharge line to the supply port of the air dryer body.

As air travels through the end cover assembly, its direction of flow changes several times, reducing the temperature, causing contaminants to condense and drop to the bottom or sump of the air dryer end cover.

After exiting the end cover, the air flows into the desiccant cartridge. Once in the desiccant cartridge air first flows through an oil separator located between the outer and inner shells of the cartridge. The separator removes water in liquid form as well as oil and solid contaminants.

Air, along with the remaining water vapor, is further cooled as it exits the oil separator and continues to flow upward between the outer and inner shells. Upon reaching the top of the cartridge the air reverses its direction of flow and enters the desiccant drying bed. Air flowing down through the column of desiccant becomes progressively dryer as water

General Information



1. Compressor
2. Governor
3. Purge Control Line
4. Control Port
5. Purge Orifice
6. Oil Separator
7. Desiccant Bed
8. Purge Volume
9. Delivery Check Valve
10. Discharge Port
11. Purge Valve
12. Exhaust
13. Turbo Cutoff Valve
14. Engine Turbocharger

Fig. 2, AD-IP Charge Cycle

vapor adheres to the desiccant material in a process known as "ADSORPTION" The desiccant cartridge using the adsorption process typically removes most of the water vapor from the pressurized air.

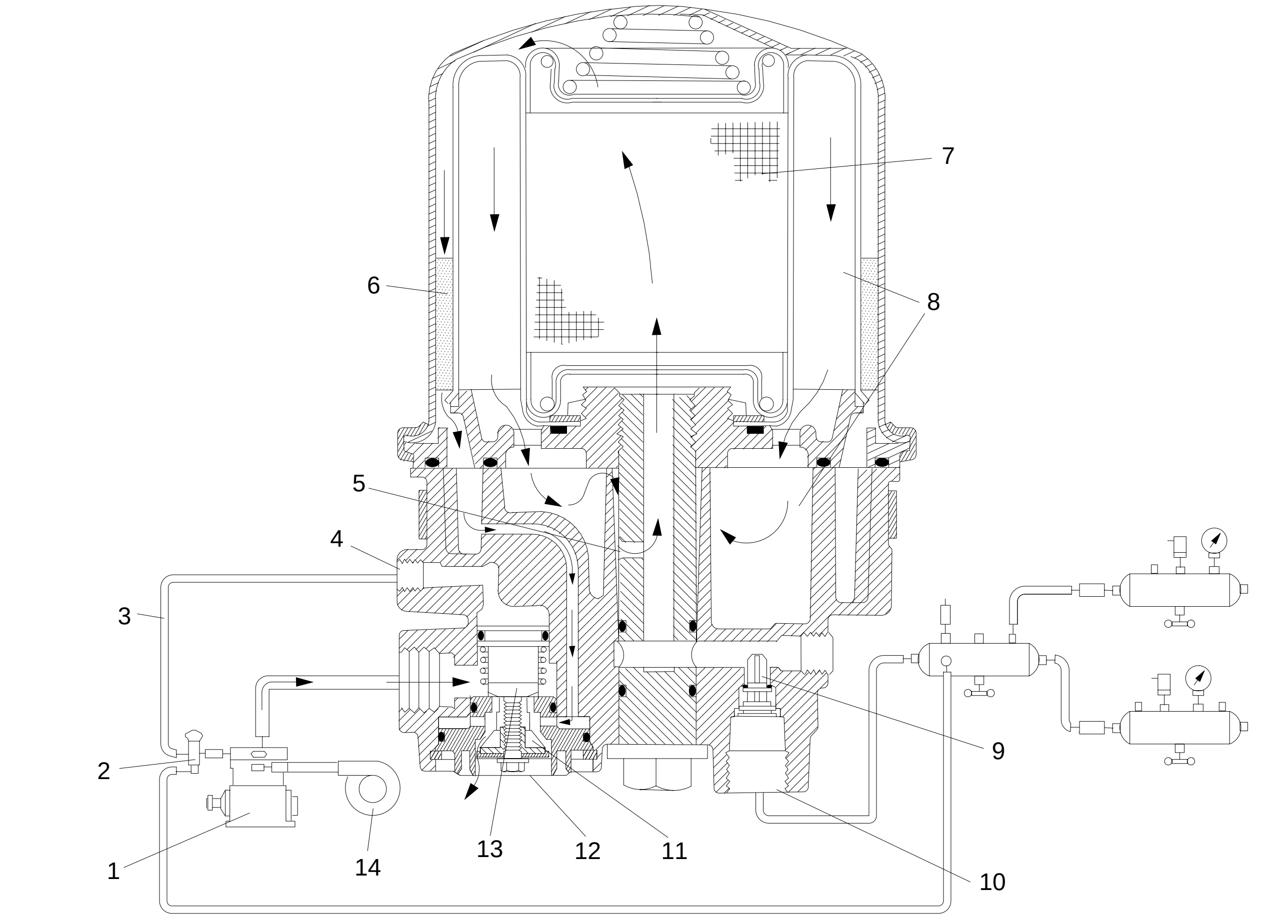
Dry air exits the bottom of the desiccant cartridge and flows through the center of the bolt used to secure the cartridge to the end cover. Air flows down the center of the desiccant cartridge bolt, through a cross drilled passage and exits the air dryer delivery port through the delivery check valve.

Dry air flowing through the center of the desiccant cartridge bolt also flows out the cross drilled purge orifice and into the purge volume.

The air dryer will remain in the charge cycle until the air brake system pressure builds to the governor cutout setting.

PURGE CYCLE

As air brake system pressure reaches the cutout setting of the governor, the governor unloads the compressor (air compressor stops compressing air) and



1. Compressor
2. Governor
3. Purge Control Line
4. Control Port
5. Purge Orifice
6. Oil Separator
7. Desiccant Bed
8. Purge Volume
9. Delivery Check Valve
10. Discharge Port
11. Purge Valve
12. Exhaust
13. Turbo Cutoff Valve
14. Engine Turbo

Fig. 3, AD-IP Purge Cycle

the purge cycle of the air dryer begins. When the governor unloads the compressor, it pressurizes the compressor unloader mechanism and the line connecting the governor unloader port to the AD-IP end cover control port. The purge piston moves in response to air pressure causing the purge valve to open to the atmosphere and the turbo cutoff valve to close off the supply of air from the compressor (this will be further discussed in the *Turbo Charger Cutoff Feature* section). Water and contaminants in the end cover sump are expelled immediately when the purge valve opens. Also, air which was flowing through the desiccant cartridge changes direction and begins to flow toward the open purge valve. Oil and solid contaminants collected by the oil separator are removed by air flowing from the purge volume through the desiccant drying bed to the open purge valve.

The initial purge and desiccant cartridge decompression lasts only a few seconds and is evidenced by an audible burst of air at the AD-IP exhaust.

The actual reactivation of the desiccant drying bed begins as dry air flows from the purge volume

General Information

through the purge orifice in the desiccant cartridge bolt, then through the center of the bolt and into the desiccant bed. Pressurized air from the purge volume expands after passing through the purge orifice; its pressure is lowered and its volume increased. The flow of dry air through the drying bed reactivates the desiccant material by removing the water vapor adhering to it. Generally 30 seconds are required for the entire purge volume of a standard AD-IP to flow through the desiccant drying bed.

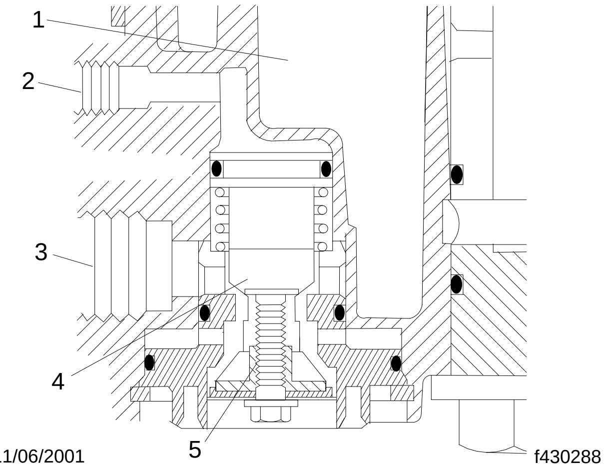
The delivery check valve assembly prevents air pressure in the brake system from returning to the air dryer during the purge cycle. After the 30-second purge cycle is complete the desiccant has been reactivated or dried. The air dryer is ready for the next charge cycle to begin. However, the purge valve will remain open and will not close until air brake system pressure is reduced and the governor signals the compressor to charge the system.

NOTE: The air dryer should be periodically checked for operation and tested for leaks. Refer to the brake section in the vehicle maintenance manual for intervals and procedures.

TURBO CHARGER CUTOFF FEATURE

The primary function of the turbo cutoff valve is to prevent loss of engine turbocharger air pressure through the AD-IP in systems where the compressor intake is connected to the engine turbocharger. The turbo cutoff valve also removes the "puffing" of air out the open purge exhaust when a naturally aspirated, single cylinder compressor, equipped with an inlet check valve, is in use. See **Fig. 4**.

At the beginning of the purge cycle, the downward travel of the purge piston is stopped when the turbo cutoff valve (tapered portion of purge piston) contacts its mating metal seat in the purge valve housing. With the turbo cutoff valve seated (closed position), air in the compressor discharge line and AD-IP inlet port cannot enter the air dryer. In this manner the turbo cutoff effectively maintains turbo charger boost pressure to the engine.



1. Purge Volume
2. Control Port
3. Supply Port
4. Turbo Cutoff Valve
5. Purge Valve

Fig. 4, AD-9 Turbo Cutoff

Safety Precautions

When working on or around air brake systems and components, observe the following precautions:

1. Chock the tires and shut down the engine before working under a vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber push rods and slack adjusters, which may apply as air pressure drops.
2. Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
3. Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
4. Don’t disassemble a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools, and observe all precautions pertaining to use of those tools.
5. Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.

   Make sure that when replacing tubing or hose, all of the original supports, clamps, or suspending devices are installed or replaced.
6. Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.

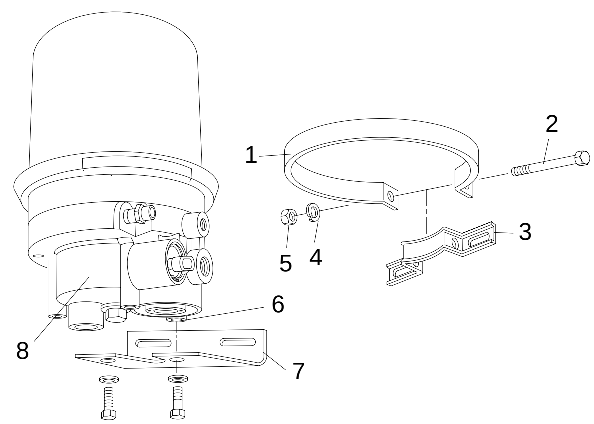
Air Dryer Removal and Installation

Removal

WARNING

Before working on or around air brake systems and components, read Safety Precautions 100. Failure to do so could result in personal injury.

1. Park the vehicle on a level surface and chock the tires.
2. Completely drain all of the reservoirs.
3. Remove the air dryer. See **Fig. 1**.



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1. Mounting Strap
2. 5/16-Inch Capscrew
3. Saddle Bracket
4. Lockwasher
5. Nut
6. End Cover Mounting Holes
7. Lower Mounting Bracket
8. Air Dryer

Fig. 1, Bendix AD-IP Air Dryer

3.1 Mark and disconnect the three air lines from the end cover, and note the position of end cover ports relative to the vehicle.

3.2 Unplug the vehicle wiring harness from the heater and thermostat assembly connector on the purge valve assembly.

3.3 Remove the four bolts that secure both the upper and lower mounting brackets to the vehicle, and remove the air dryer from the vehicle.

3.4 Mark the relationship of the saddle bracket to the end cover assembly. Remove the 5/16-inch capscrew, washer, and nut securing the upper mounting strap to the saddle bracket. Remove the upper mounting strap from the end cover assembly.

3.5 Mark the relationship of the lower bracket to the end cover assembly. Remove the two 3/8-inch end cover capscrews and two washers that retain the lower mounting bracket to the end cover.

3.6 Remove the air dryer from its mounting brackets.

Installation

WARNING

Before working on or around air brake systems and components, read Safety Precautions 100. Failure to do so could result in personal injury.

1. Install the assembled air dryer on the vehicle. See **Fig. 1**.

   1.1 Install the lower mounting bracket on the end cover and secure it using the two 3/8-inch capscrews and washers. Torque the capscrews 25 to 30 lbf·ft (34 to 40 N·m).

   1.2 Install the saddle bracket and mounting strap on the end cover, and using the 5/16-inch capscrew, washer, and nut secure the strap to the saddle bracket. Tighten the 5/16-inch nut on the upper mounting bracket. Torque to 5 to 8 lbf·ft (6.5 to 10.5 N·m).

   1.3 Install the AD-IP on the vehicle using the four bolts that secure both the upper and lower mounting brackets.

2. As marked earlier in "Removal," connect the three air lines to the ports on the end cover.
3. Connect the vehicle wiring harness to the air dryer heater and thermostat assembly connector by plugging it into the air dryer connector until its lock tab snaps in place.

Air Dryer Removal and Installation

4. Test the air dryer following instructions in Group 42 of the *Business Class M2 Maintenance Manual*.
5. Remove the chocks from the tires.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

NOTE: As a convenience when rebuilding the air dryer, several replacement parts and maintenance kits are available that do not require full disassembly. Use the instructions provided with these parts or kits.

Disassembly

NOTE: Refer to **Fig. 1** during disassembly.

WARNING

Before working on or around air brake systems and components, read Safety Precautions 100. Failure to do so could result in personal injury.

CAUTION

While servicing the air dryer, don't use a clamping device (vise, C-clamp, etc.) to hold any die cast aluminum part, as damage may result. To hold the end cover, install a pipe nipple in the supply port, and clamp the nipple in a vise.

1. Remove the air dryer from the vehicle. See **Subject 110**.
2. Using an adjustable or socket wrench, loosen the desiccant cartridge bolt, then separate the desiccant cartridge from the end cover. Pull the desiccant cartridge bolt out of the end cover. See **Fig. 1**.

CAUTION

Disassembly of the desiccant cartridge assembly should not be attempted! Detail parts for the cartridge are not available and the cartridge contains a 150 lb spring which can not be mechanically caged. Releasing the spring could cause serious personal injury.

3. Remove both O-rings from the desiccant cartridge bolt.
4. Remove the retaining ring that secures the purge valve assembly in the end cover.
5. Remove the 1/4-inch shoulder bolt from the bottom of the purge valve housing assembly using a 3/8-inch socket wrench and a large blade screw driver, inserted in the slot on top of the purge piston. Remove the exhaust diaphragm, and the purge valve from the purge valve housing.
6. Remove the O-rings from the purge valve housing.
7. Remove the purge piston and the return spring. Remove the O-ring from the purge piston.
8. Remove the retaining ring that secures the delivery check valve assembly in the end cover. Remove and separate the perforated plate, spring, check valve body and O-ring.
9. Remove the retaining ring that secures the heater and thermostat assembly in the end cover. Gently pull the heater and thermostat out of the end cover and remove the O-ring.
10. Using a 9/16-inch wrench, remove the safety valve assembly from the end cover.

Cleaning and Inspection

WARNING

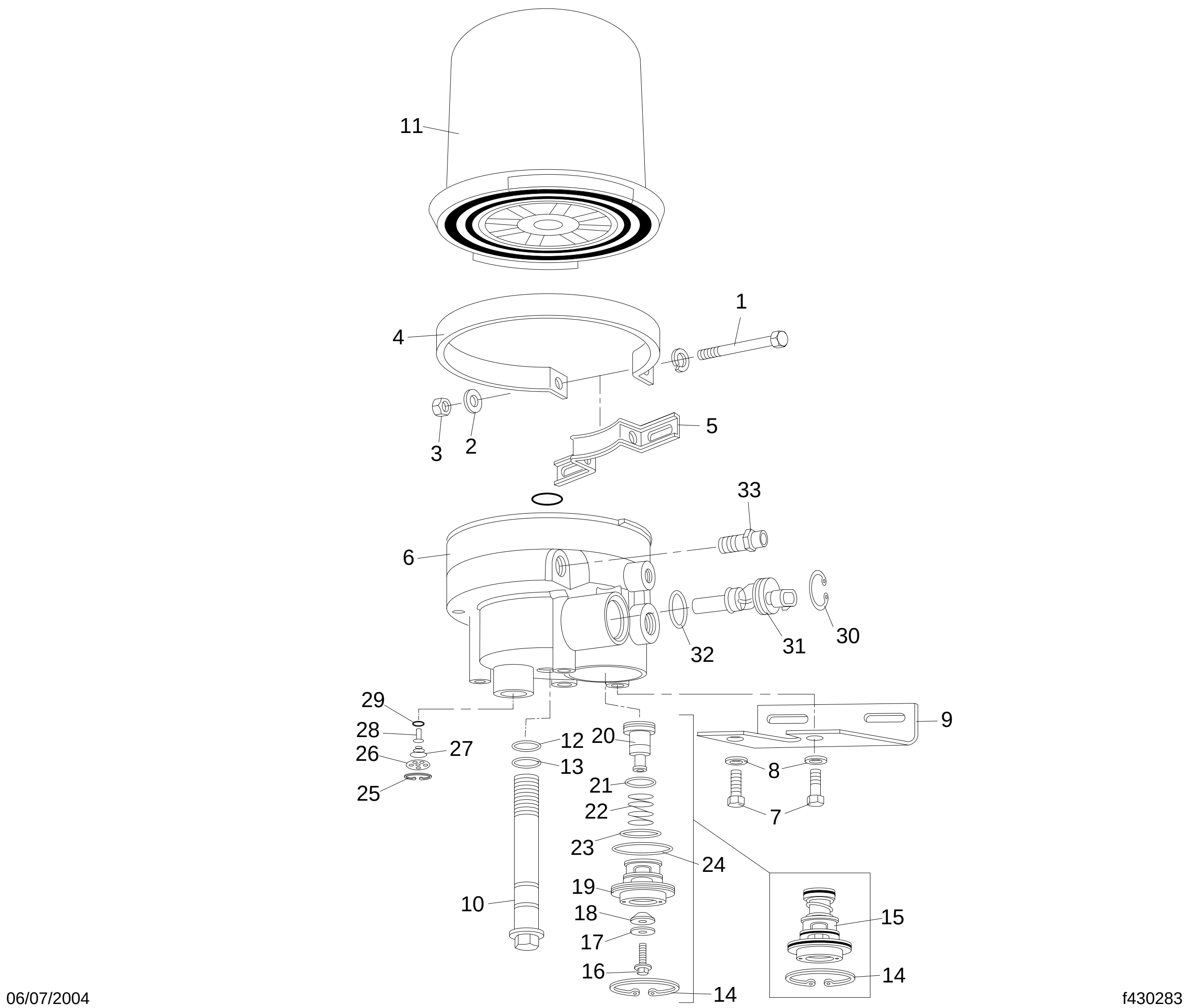
Before working on or around air brake systems and components, read Safety Precautions 100. Failure to do so could result in personal injury.

1. Wash all metal parts thoroughly, using a quality commercial solvent, such as mineral spirits.

NOTE: Don't clean the desiccant cartridge.

2. Check for severe corrosion, pitting, and cracks on the inside and outside of all metal parts that will be reused. Superficial corrosion and pitting on the outside of the upper and lower body halves is acceptable.
3. Inspect the bores of both the end cover and the purge-valve housing for deep scuffing or gouges.
4. Make sure that all purge-valve housing and end cover passages are open and free of blockages.
5. Inspect the pipe threads in the end cover. Make sure they are clean and free of thread sealant.
6. Inspect the purge-valve housing bore and seats for excessive wear and scuffing.
7. Inspect the purge valve piston seat for excessive wear.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly



1. 5/16-Inch Capscrew
2. 5/16-Inch Lockwasher
3. 5/16-Inch Locknut
4. Upper Bracket Strap
5. Saddle Bracket
6. End Cover
7. 3/8-Inch Capscrew
8. 3/8-Inch Lockwasher
9. Lower Mounting Bracket
10. Cartridge Bolt
11. Desiccant Cartridge
12. O-Ring
13. O-Ring
14. Retaining Ring
15. Purge Valve Cartridge Assembly
16. Shoulder Bolt
17. Exhaust Diaphragm
18. Purge Valve
19. Purge Valve Housing
20 Purge Valve Piston
21 O-Ring
22. Piston Return Spring
23. O-Ring
24. O-Ring
25. Retaining Ring
26. Perforated Plate
27. Check Ring Spring
28. Check Valve
29. O-Ring
30. Retaining Ring
31. Heater/Thermostat Assy.
32. O-Ring
33. Safety Valve Assembly

Fig. 1, AD-IP (exploded view)

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

8. Make certain that the purge orifice in the cartridge bolt is open and free of obstructions.
9. Inspect all air line fittings for corrosion. Clean all old thread sealant from the pipe threads.
10. Replace all removed O-rings with new ones that are provided in the kits.

    Replace parts that show any of the conditions described in the previous steps.

Assembly

WARNING

Before working on or around air brake systems and components, read Safety Precautions 100. Failure to do so could result in personal injury.

1. Before assembly, coat all O-rings, O-ring grooves, and bores with a generous amount of barium-base lubricant. See **Fig. 1** during assembly unless otherwise advised.
2. Install and center the exhaust diaphragm over the shoulder bolt making certain that the diaphragm ID is over the bolt shoulder. Then install the purge valve on the shoulder bolt making certain its metal support side is against the diaphragm.
3. Push the purge piston into the housing until it bottoms and insert a large blade screw driver in the piston's slotted head. While depressing the purge piston with the screw driver, install the shoulder bolt with exhaust diaphragm and purge valve in the piston. Torque the shoulder bolt 60 to 80 lbf·in (678 to 900 N·cm).
4. Install the two O-rings on the purge valve housing placing each in its appropriate location. Install the assembled purge valve housing in the end cover while making certain the purge valve housing is fully seated against the end cover. Secure the purge valve housing in the end cover using the retaining ring. Make certain the retaining ring is fully seated in its groove in the end cover.
5. Using a 9/16-inch wrench, install the safety valve assembly into the end cover.
6. Install the O-ring on the check valve body and push the o-ring down, over the three guide lands until it is in the O-ring groove of the check valve body. Install the check valve spring on the check valve body so that the small coils of the spring slip over the check valve body. Install the assembled check valve body, o-ring, and spring in the end cover so that the O-ring rests on its seat in the end cover and the spring is visible.
7. Install the O-ring on the heater and thermostat assembly. After making certain the sponge rubber cushion is positioned between the connector body and thermostat, gently push the heater and thermostat assembly into the end cover, making certain the heating element enters the small diameter bore in the larger heater and thermostat bore in the end cover. Secure the heater and thermostat assembly in the body using the retaining ring. Make certain the retaining ring is fully seated in its groove in the end cover.
8. Install both O-rings on the desiccant cartridge bolt and using a twisting motion, insert the assembled desiccant cartridge bolt in the end cover.
9. Install the desiccant cartridge on the end cover making certain the cartridge is properly seated and flush on the end cover.

NOTE: It may be necessary to rotate the cartridge slightly until the anti-rotation lugs are properly aligned and allow the cartridge to rest flush against the end cover.

10. Using an adjustable wrench or a socket, tighten the desiccant cartridge bolt, to secure the desiccant cartridge to the end cover. Torque the desiccant cartridge bolt to 50 lbf·ft (65 N·m).
11. Install the air dryer. For instructions, see **Subject 110**.
12. Remove the chocks from the tires.

Air Dryer Thermostat Testing

Testing

During cold-weather operation, check the operation of the end cover heater and thermostat assembly.

1. With the ignition on, check for voltage to the heater and thermostat assembly. Unplug the electrical connector at the air dryer, and place the test leads on each of the pins of the male connector. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check that a good ground path exists.
2. Check the thermostat and heater operation. Turn off the ignition switch and cool the end cover assembly to below 40°F (4°C). Using an ohmmeter, check the resistance between the electrical pins in the female connector. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly, and 6.8 to 9.0 ohms for the 24-volt heater assembly.
3. Warm the end cover assembly to over 90°F (32°C) and again check the resistance. It should exceed 1000 ohms. If it does, the thermostat and heater assembly is operating properly. If it doesn't, replace the purge-valve housing assembly, which includes the heater and thermostat assembly.

Troubleshooting

Problem—Air Dryer Is Constantly Cycling or Purging

Problem—Air Dryer Is Constantly Cycling or Purging	
Possible Cause	**Remedy**
Excessive system leakage.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is as follows: • Single Vehicle—1 psi/min (7 kPa/min) per service reservoir • Tractor/Trailer—3 psi/min (21 kPa/min) per service reservoir
There is excessive leakage in the fittings, hoses, and tubing connected to the compressor, air dryer, and wet tank.	Using a soap solution, test for leakage at the fittings, drain valve, and safety valve in the wet tank. Repair or replace as needed.
Check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5 cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.
Governor is inoperative.	Test the governor for proper cut-in or cut-out pressures and excessive leakage in both positions.
Leaking purge-valve housing assembly or O-rings in the air dryer end cover.	With the supply port open to atmosphere, apply 120 psi (830 kPa) at the control port. Apply a soap solution to the supply port and exhaust port (purge valve seat area). Permissible leakage is a 1-inch (2.5 cm) bubble in 5 seconds. Repair or replace as needed.
Compressor unloader mechanism is leaking excessively.	Remove the air strainer or fitting from the compressor inlet cavity. With the compressor unloaded, check for unloader piston leakage. Slight leakage is allowed.
Holset "E" type compressor.	Test the air dryer system. For instructions, refer to Bendix Product Bulletin PRO-08-19 entitled *"Troubleshooting the Holset "E" Compressor System with Bendix Air Dryer."*
Lack of air at the governor RES port (rapid cycling of the governor).	Test the governor for proper pressure at the RES port. Pressure should not drop below cut-in pressure when the compressor begins the unloaded cycle. If the pressure does drop, check for kinks or restrictions in the line connected to the RES port. The line connected to the RES port on the governor must be the same diameter, or larger than the lines connected to the UNL ports on the governor.

Problem—Water in the Vehicle Reservoirs

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Desiccant cartridge assembly contains excessive contaminants.	Replace the desiccant cartridge.
Discharge line is of improper length or material.	Discharge line must consist of at least 6 ft. (1.8 m) of wire braid Teflon hose, copper tubing, or a combination of both between the discharge port of the compressor and the air dryer supply port. Discharge line lengths and inside diameter requirements are dependent on the vehicle application. Contact your local Bendix representative for further information.
Air system was charged from an outside air source that did not pass through an air dryer.	If the system must have an outside air fill provision, the outside air should pass through an air dryer. This practice should be minimized.
Air dryer is not purging.	See *"Problem—Air Dryer Does Not Purge or Exhaust Air."*

Troubleshooting

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Purge (air exhaust) is insufficient due to excessive system leakage.	See *"Problem—Air Dryer Is Constantly Cycling or Purging."*
Air bypasses the desiccant cartridge assembly.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed.
Purge (air exhaust) time is significantly less than the minimum allowable.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed. Replace the desiccant cartridge assembly.
Excessive air usage—air dryer not compatible with vehicle air system.	Install an accessory bypass system. Consult your Bendix representative for additional information.

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air	
Possible Cause	**Remedy**
Desiccant cartridge is plugged or saturated.	Check the compressor for excessive oil passing, or incorrect installation. Repair or replace as needed. Replace the desiccant cartridge.
Defective discharge check valve in end cover of the AD-IP.	Test to determine if air is passing through the check valve. Repair or replace as needed.
There is a problem in the fittings, hose, or tubing between the air dryer and the wet tank.	See if air is reaching the first reservoir. Inspect for kinked tubing or hose. Check for undrilled or restricted hose or tubing fittings.
Safety valve setting is lower than the maximum system pressure.	Reduce the system pressure, or install a safety valve with a higher pressure setting.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Air dryer purge valve is leaking excessively.	With the compressor loaded, apply a soap solution on the purge valve exhaust to test for excessive leakage. Repair the purge valve as needed.
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
Purge control line is connected to the reservoir or exhaust port of the governor.	Connect the purge control line to the unloader port of the governor.
Purge valve is frozen open due to an inoperative heater or thermostat, bad wiring, or a blown fuse.	Test the heater and thermostat, following instructions in this manual.
Inlet and outlet air connections are reversed—unable to build system pressure.	Reconnect the lines properly.
System is leaking excessively.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is as follows: • Single Vehicle—1 psi/min (7 kPa/min) per service reservoir • Tractor/Trailer—3 psi/min (21 kPa/min) per service reservoir

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Purge valve stays open; supply air leaks to control side.	Replace the purge valve and housing.

Problem—Unable to Build System Pressure

Problem—Unable to Build System Pressure	
Possible Cause	**Remedy**
Inlet and outlet air connections reversed.	Connect compressor discharge to air dryer supply port. Reconnect lines properly.
Check valve between air dryer and wet tank.	Test check valve for proper operation. Repair or replace as necessary.
Kinked or blocked (plugged) discharge line.	Check to determine if air passes through discharge line. Check for kinks, bends, excessive carbon deposits, or ice blockage.
Excessive bends in discharge line (water collects and freezes).	Discharge line should be constantly sloping from compressor to air dryer with as few bends as possible. See *Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure*

Problem—Air Dryer Does Not Purge or Exhaust Air

Problem—Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
Purge control line is broken, kinked, frozen, plugged, or disconnected.	See if air flows through the purge control line when the compressor is unloaded. The purge control line must be connected to the unloader port of the governor.
Air dryer purge valve isn't working.	See if air reaches the purge valve. If it does, repair the purge valve.
Also See - *Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure*	

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (May Look Like Whitish Liquid, Paste, or Small Beads); or, Unsatisfactory Desiccant Life

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (may look like whitish liquid, paste, or small beads) or Unsatisfactory Desiccant Life	
Possible Cause	**Remedy**
This problem usually occurs with one or more of the previous problems.	Refer to the appropriate corrections listed previously.
Air dryer is not securely mounted; there is excessive vibration.	Vibration should be held to a minimum. Tighten the mounting fasteners.
Malfunctioning or saturated desiccant cartridge.	Replace desiccant cartridge assembly.
Compressor is passing excessive oil.	Check for proper compressor installation; if symptoms persist, replace the compressor.
Desiccant cartridge not attached properly to the end cover.	Check the torque and tighten if necessary. Refer to **Subject 120** for instructions.

Troubleshooting

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle	
Possible Cause	**Remedy**
Pinging noise is due to a single cylinder compressor with high pulse cycles.	A slight pinging sound may be heard during system build-up when a single cylinder compressor is used. If this sound is deemed objectionable, it can be reduced substantially by increasing the discharge line volume. This is done by adding a 90 in^3 (1475 cm^3) reservoir between the compressor and the air dryer.

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)	
Possible Cause	**Remedy**
Leaking Turbo Cutoff valve.	Repair or replace purge valve assembly.
Check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5 cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.
Leaking purge valve control piston O-ring.	Repair or replace purge valve assembly.

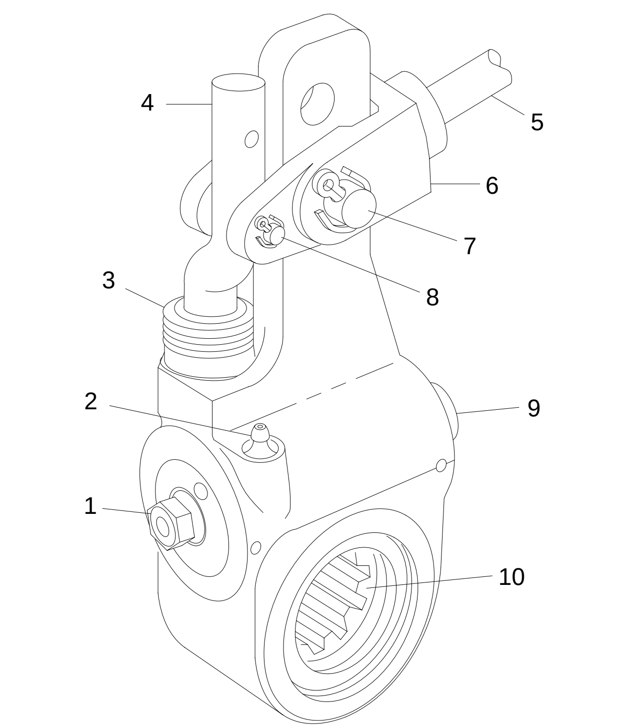
Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode	
Possible Cause	**Remedy**
Compressor does not "unload."	Check the governor installation: there is no air line from the governor to the compressor, or the line is restricted. Repair or replace as needed.

General Information

The Gunite automatic slack adjuster (**Fig. 1**) has two main functions:

- As a lever it converts the straight-line force of the brake chamber push rod to torque on the brake camshaft. Rotation of the camshaft forces the brake shoes against the drum.



1. 7/16-Inch Adjusting Hexnut
2. Grease Fitting
3. Boot
4. Link
5. Brake Chamber Push Rod
6. Clevis
7. 1/2-Inch Clevis Pin
8. 1/4-Inch Clevis Pin
9. Grease Relief Opening
10. Slack Adjuster Spline

Fig. 1, Gunite Slack Adjuster

- As an automatic slack adjuster, it maintains the lining-to-drum clearance needed for proper brake chamber push rod stroke.

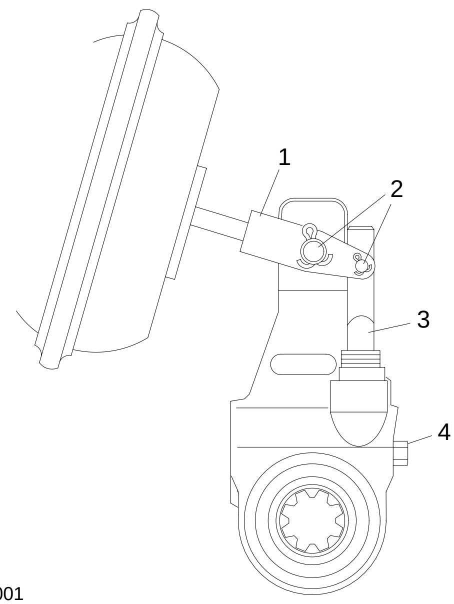
The slack adjuster is installed between the brake chamber push rod and the brake camshaft. A clevis is either welded to the brake chamber push rod or screwed on. The clevis is connected to the top of the slack adjuster. The bottom of the slack adjuster is splined to the brake camshaft. The splines hold the slack adjuster internal gear to the camshaft, so the camshaft turns when the slack adjuster moves. When the brakes are applied, the brake chamber push rod moves outward forcing the slack adjuster and camshaft to rotate. This movement forces the brake shoes against the drum.

The brakes are adjusted when the slack adjuster senses an increase in the lining-to-drum clearance. The slack adjuster's internal worm shaft and ratchet shorten excessive lining-to-drum clearance. This provides maximum leverage for the brake chamber push rod. The automatic slack adjuster adjusts the brakes at the beginning of the brake application.

Slack Adjuster Removal and Installation

IMPORTANT: This automatic slack adjuster cannot be rebuilt. If it is damaged or inoperative, replace the unit.

Each factory-installed brake chamber has a clevis welded onto the pushrod. See **Fig. 1**. On a replacement brake chamber, the clevis is threaded onto the pushrod, and has a jam nut installed. See **Fig. 2**.



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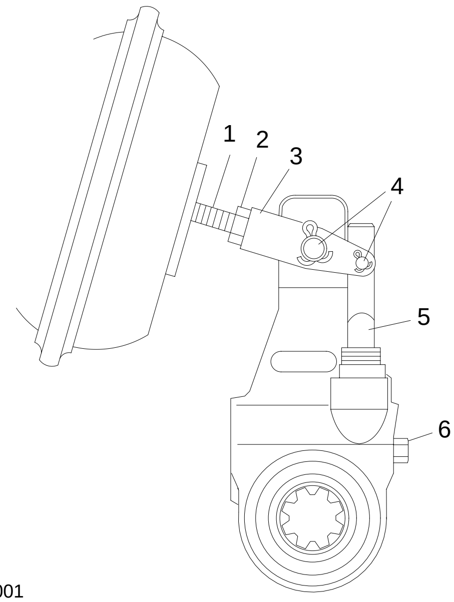
1. Brake Chamber Pushrod and Clevis Assembly
2. Cotter Pins and Clevis Pins
3. Link
4. Adjusting Hexnut

Fig. 1, Slack Adjuster (attached to welded clevis)

Removal

1. With the vehicle parked on a level surface, chock the tires. If you are removing a rear slack adjuster, cage the parking brake power spring. For instructions, refer to the applicable brake chamber section in this group.
2. Remove the cotter pins and clevis pins.
3. Rotate the adjusting hexnut counterclockwise until the slack adjuster clears the clevis.
4. Remove the snap ring from the brake camshaft, then slide the slack adjuster off the camshaft.



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1. Brake Chamber Pushrod (threaded)
2. Jam Nut
3. Threaded Clevis
4. Cotter Pins and Clevis Pins
5. Link
6. Adjusting Hexnut

Fig. 2, Slack Adjuster (attached to threaded clevis)

Installation

NOTE: For brake chambers that have pushrods with threaded clevises, measure the pushrod length before installing the new slack adjuster. With the brakes fully released, and no air pressure to the chamber, check the dimension between the chamber face and the centerline of the 1/2 inch clevis pin hole. It should be 2.25 inches (57 mm) for long stroke chambers, and 2.75 inches (70 mm) for standard stroke chambers.

1. Coat the camshaft splines, and the splines of the slack adjuster gear with an anticorrosion grease.
2. Using the old snap ring, install the automatic slack adjuster on the brake camshaft.
3. Turn the adjusting hexnut clockwise to rotate the slack adjuster toward the brake chamber until the holes line up.

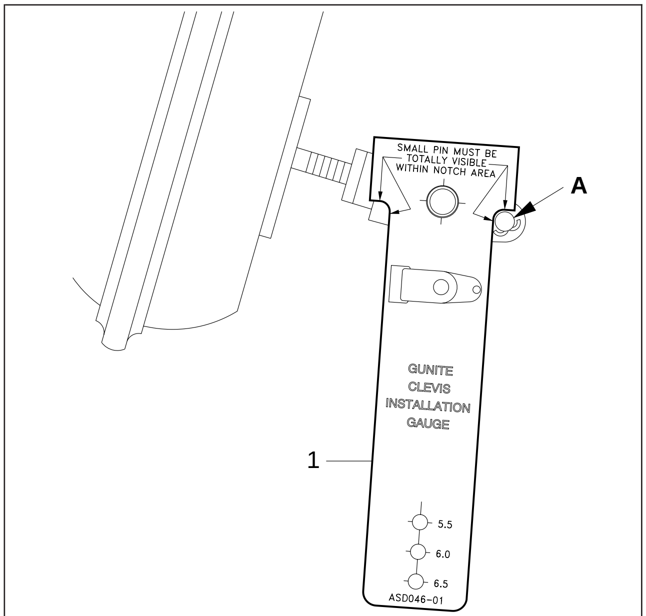
Slack Adjuster Removal and Installation

4. Install the clevis pins and cotter pins.

WARNING

Manually adjusting an automatic slack adjuster to bring the pushrod stroke within legal limits is likely masking a mechanical problem. Adjustment is not repairing. Before adjusting an automatic slack adjuster, troubleshoot the foundation brake system and inspect it for worn or damaged components. Improperly maintaining the vehicle braking system may lead to brake failure, resulting in property damage, personal injury, or death.

5. If the pushrod has a threaded clevis, use the gauge supplied with the new slack adjuster to check the adjustment of the clevis, as follows. See **Fig. 3**.



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A. Adjust the clevis in or out to position the 1/4-inch clevis pin within the notched area of the gauge.

1. Installation Gauge

Fig. 3, Checking the Clevis Adjustment

5.1 Position the 1/2-inch hole in the gauge over the end of the 1/2-inch clevis pin.

5.2 Align the applicable 1/4-inch hole in the bottom of the gauge over the center of the camshaft.

5.3 Check that the 1/4-inch pin is visible in the notched area of the gauge. If the pin is not in the right location, back off the slack adjuster and readjust the pushrod length, then repeat this step.

NOTE: Make sure there is clearance between the slack adjuster and other vehicle components when the brakes are applied and the pushrod travels its maximum stroke.

6. Set the initial free-stroke, as follows.

6.1 Turn the adjusting hexnut clockwise until the brake linings contact the drum.

6.2 Turn the adjusting hexnut counterclockwise one-half turn. There should be about 30 lbf·ft (41 N·m) resistance, and a ratcheting sound will be heard.

7. Measure the brake chamber applied stroke, as follows.

7.1 With the brakes fully released, use a ruler to measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 4**.

7.2 Build air pressure to at least 85 psi (586 kPa). Apply the brakes, then measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 4**. The difference between the measurements is the brake chamber stroke.

7.3 The brake chamber stroke must be within the range shown in **Table 1**. If it is not, check the foundation brakes for problems such as worn cams, bushings, pins and rollers, or broken springs. Repair or replace as needed. For instructions, refer to the applicable brake section in this group. Then, repeat the two previous steps.

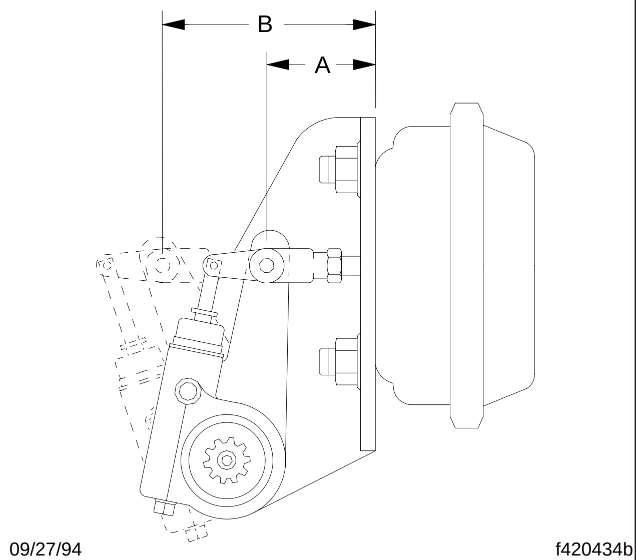
8. If a rear axle slack adjuster was installed, manually uncage the parking brake. Refer to the applicable brake chamber section in this group for instructions.

9. Apply the parking brakes.

10. Remove the chocks from the tires.

11. In a safe area, check for proper brake operation, as follows.

Slack Adjuster Removal and Installation



A. Brakes Released B. Brakes Applied

Fig. 4, Brake Stroke Measurements

11.1 Apply and release the brakes several times to check for correct operation of the slack adjusters.

11.2 Perform six low-speed stops to ensure correct parts replacement and full vehicle control.

11.3 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than the others show a lack of braking effort on those wheels.

Brake Chamber Stroke Specifications			
Chamber Type (Size)	Maximum Applied Stroke*: inch (mm)	Free-Stroke: inch (mm)	
		New Brake Installation	In-Service Brake
Long Stroke†			
16 and 20	2-1/2 (64)	5/8 to 3/4 (16 to 19)	1/2 to 5/8 (13 to 16)
24 and 30	3 (76)		

* Specifications are relative to a brake application with 80–90 psi (550–620 kPa) air pressure in the brake chambers.

† Long stroke design is indicated by a tag, or embossing, on the brake chamber.

Table 1, Brake Chamber Stroke Specifications

Specifications

Lubricant Type	Temperature
Lubriplate Aero	Above –40°F (–40°C)
Texaco Multifak EP–2 Mobil Grease 77	Above –20°F (–29°C)

Table 1, Approved Lubricants

Standard Clamp Type Brake Chamber Data			
Type	Outside Diameter: inches (cm)	Rated Stroke: inches (cm)	Maximum Stroke at Which Brakes Must be Readjusted: inches (cm)
9	5-1/4 (13.3)	1.75 (4.5)	1 3/8 (3.5)
12	5 11/16 (14.4)	1.75 (4.5)	1 3/8 (3.5)
16	6 3/8 (16)	2.25 (5.7)	1 3/4 (4.5)
20	6 25/32 (17)	2.25 (5.7)	1 3/4 (4.5)
24	7 7/32 (18.3)	2.25 (5.7)	1 3/4 (4.5)
30	8 3/32 (20.5)	2.50 (6.35)	2 (5)
36*	9 (22.8)	3.00 (7.6)	2 1/4 (5.7)

* If type 36 chamber is used, slack length should be less than 6 inches.

Table 2, Standard Clamp Type Brake Chamber Data

Long Stroke Clamp Type Brake Chamber Data			
Type	Outside Diameter: inches (cm)	Rated Stroke: inches (cm)	Maximum Stroke at Which Brakes Must be Readjusted: inches (cm)
16	6 3/8 (16)	2.50 (6.35)	2 (5)
20	6 25/32 (17)	2.50 (6.35)	2 (5)
24	7 7/32 (18.3)	2.50 (6.35)	2 (5)
24*	7 7/32 (18.3)	3.00 (7.6)	2 1/2 (6.35)
30*	8 3/32 (20.5)	3.00 (7.6)	2 1/2 (6.35)

* Identified by square air port bosses.

Table 3, Long Stroke Clamp Type Brake Chamber Data

General Information

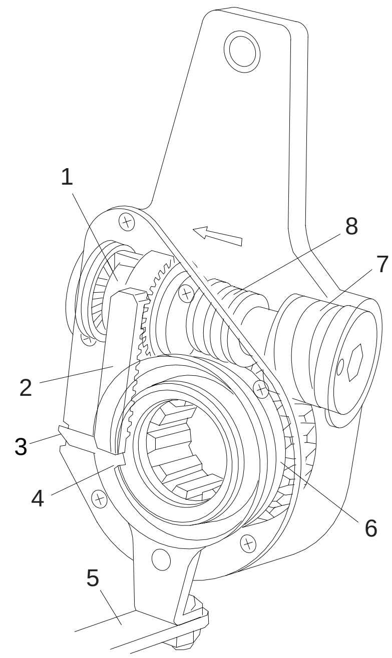
The Haldex automatic slack adjuster serves two main functions:

- As a lever, it converts the straight-line force of the air brake chamber pushrod to torque on the brake camshaft. Rotation of the camshaft spreads the brake shoes out against the brake drum, applying the brakes.
- As an adjuster, it maintains cam brake chamber pushrod stroke and lining-to-drum clearance automatically during normal use.

When the brakes are applied, the slack adjuster rotates and moves the shoes into contact with the drum. The clearance notch corresponds to the normal lining-to-drum clearance. See **Fig. 1**. Different notches are available to meet the requirements of various vehicles and brake duty cycles. As the brake application continues, the rack moves upward and rotates the one-way clutch which slips in this direction.

As the brake torque increases, the coil-spring load is overcome and the wormshaft is displaced axially, releasing the cone clutch.

When the brake begins its return stroke, the coil spring load returns to normal and the cone clutch is again engaged. The rack is pulled back to its original position in the notch. Any additional travel brought about by brake lining wear causes the rack to turn the locked one-way clutch and rotates the wormshaft through the locked cone clutch. The wormshaft then rotates the worm wheel and camshaft, adjusting the brakes.



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NOTE: Older slack adjusters may not have an installation indicator.

1. Clutch Assembly
2. Enclosed Rack
3. Installation Indicator (aligned with indicator notch)
4. Clearance Notch
5. Control Arm Anchor Bracket (design varies depending on the axle)
6. Worm Wheel
7. Coil Spring
8. Wormshaft

Fig. 1, Haldex Slack Adjuster

Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

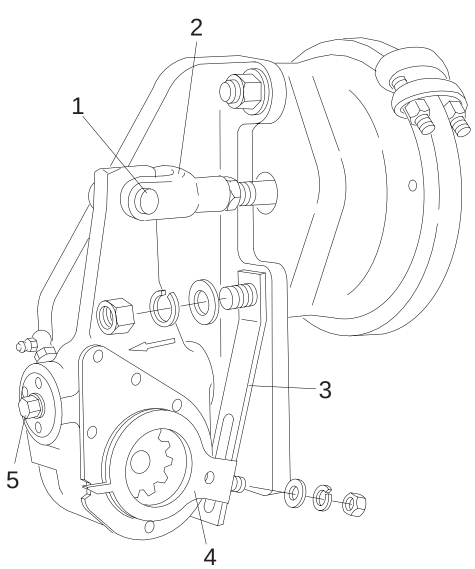
Slack Adjuster Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

1. With the vehicle parked on a level surface, set the parking brakes, and shut down the engine. Chock the tires.
2. If a rear-axle slack adjuster will be removed, release the parking brakes and cage the power spring of the parking brake chamber. For instructions, refer to the applicable brake chamber section in this group.
3. Remove the anchor bracket fasteners and the anchor bracket. See **Fig. 1**.



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1. Clevis Pin
2. Clevis
3. Anchor Bracket
4. Control Arm
5. Adjusting Hexnut

Fig. 1, Anchor Bracket Removal/Installation

4. Remove the cotter pin from the clevis pin. Remove the clevis pin.
5. Remove the snap ring that secures the slack adjuster on the camshaft.

CAUTION

Do not use an impact wrench on the adjusting hexnut. To do so may damage the slack adjuster or camshaft.

6. Using a 7/16-inch box wrench, turn the adjusting hexnut counterclockwise to move the adjuster arm out of the clevis. A minimum of 13 lbf·ft (18 N·m) is required to overcome the internal clutch. You will hear a ratcheting sound.
7. Remove the slack adjuster from the camshaft.

Installation

NOTE: For brake chambers that have pushrods with threaded clevises, measure the pushrod length before installing the new slack adjuster. With the brakes fully released, and no air pressure to the chamber, check the dimension between the chamber face and the centerline of the 1/2 inch clevis pin hole. It should be 2.25 inches (57 mm) for long stroke chambers, and 2.75 inches (70 mm) for standard stroke chambers.

1. Check that the brake-chamber pushrod is fully retracted.
2. Apply antiseize compound to the camshaft splines.

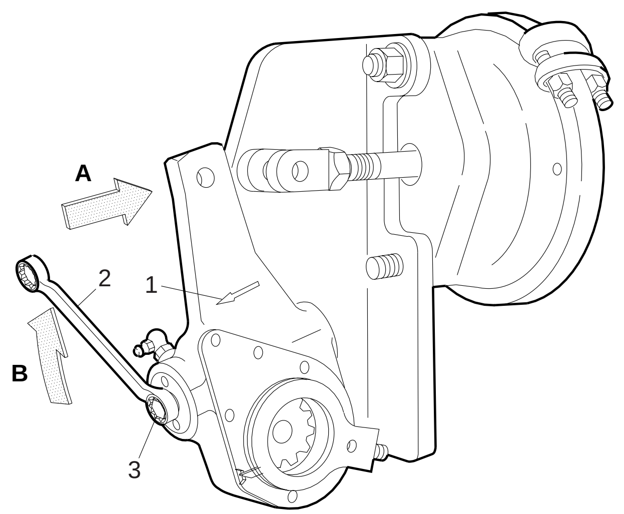
IMPORTANT: When correctly installed, the brake-chamber pushrod pushes in the direction of the arrow on the slack adjuster housing.

3. Install the slack adjuster on the camshaft, with the adjusting hexnut pointing away from the brake chamber. See **Fig. 2**.
4. Using a snap ring, secure the slack adjuster on the camshaft. Use at least one inner washer and enough outer washers to allow no more than 0.060-inch (1.52-mm) movement on the shaft.

IMPORTANT: Never pull the pushrod out to meet the slack adjuster or push the slack adjuster into position. Always turn the adjusting hexnut for positioning.

5. Using a 7/16-inch box wrench, turn the adjusting hexnut clockwise until the slack adjuster hole is aligned with the pushrod clevis hole. See **Fig. 2**.

Slack Adjuster Removal and Installation



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A. Use only the adjusting hexnut to align the slack adjuster with the pushrod clevis.
B. Turn the adjusting hexnut clockwise.

1. Direction of Applied Stroke
2. Box Wrench, 7/16 inch
3. Adjusting Hexnut

Fig. 2, Slack Adjuster Installation

6. Apply antiseize compound to the clevis pin, and insert the pin in the clevis hole. Do not install the cotter pin at this time.

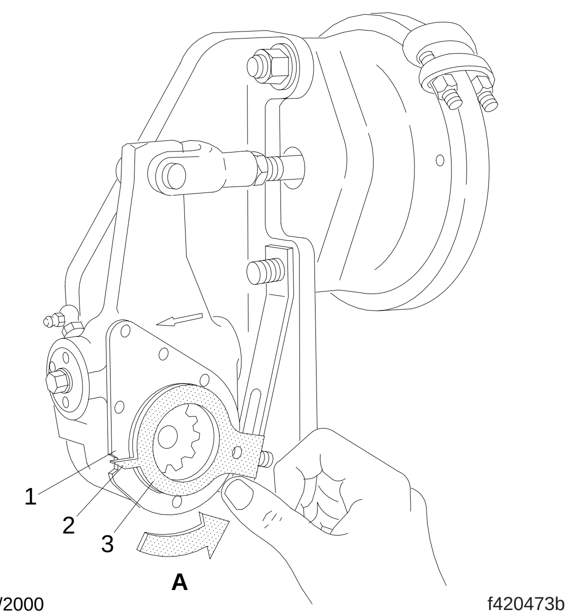
CAUTION

Never hammer the control arm. Hammering may damage the slack adjuster or camshaft splines.

7. Rotate the control arm away from the adjusting hexnut toward the brake chamber until it comes to a definite internal stop. Make sure the installation indicator is in the center of the indicator notch on the slack adjuster. See **Fig. 3**.

IMPORTANT: If the installation indicator is not aligned with the indicator notch, the brakes will be too tight.

NOTE: The anchor bracket and slack adjuster housing design will vary, depending on the axle. The anchor bracket mounting location is determined by the length of the control arm.



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NOTE: The installation indicator must be aligned with the indicator notch.

A. Rotate the control arm counterclockwise until it stops.

1. Indicator Notch
2. Installation Indicator
3. Control Arm

Fig. 3, Aligning the Control Arm

8. Install the control-arm anchor bracket, as follows. See **Fig. 1**.

   8.1 Tighten the anchor bracket fastener at the control arm 10 to 15 lbf·ft (14 to 20 N·m), making sure the control arm does not move from its position.

   8.2 Tighten the fastener at the brake chamber mounting stud according to the brake chamber manufacturer's specifications.

9. Adjust the brakes. See "Brake Adjustment".

Brake Adjustment

NOTE: A properly working self-adjusting slack adjuster does not require manual adjustment while in service.

Slack Adjuster Removal and Installation

WARNING

Manually adjusting an automatic slack adjuster to bring the pushrod stroke within legal limits is likely masking a mechanical problem. Adjustment is not repairing. Before adjusting an automatic slack adjuster, troubleshoot the foundation brake system and inspect it for worn or damaged components. Improperly maintaining the vehicle braking system may lead to brake failure, resulting in property damage, personal injury, or death.

1. Adjust the brake lining clearance by manually turning the adjusting hexnut clockwise until the brake lining contacts the brake drum, then back off the hexnut counterclockwise 1/2 turn. You will hear a ratcheting sound.

IMPORTANT: Incorrect installation can cause dragging brakes.

2. Make sure the brakes are still fully released, then check the position of the installation indicator on the control arm. It must be within the indicator notch on the slack adjuster.

   If the indicator is out of position, loosen the control arm fasteners and repeat the control-arm adjustment procedure. Then, tighten the bracket fasteners.

WARNING

Install and lock a new cotter pin in the clevis pin. Failure to do so could allow the pushrod to disengage from the slack adjuster, causing a loss of braking ability that could result in personal injury and property damage.

3. Install and lock a new cotter pin in the clevis pin.

IMPORTANT: Ensure that the air system has at least 100 psi prior to uncaging the brake chamber. This will aid in the uncaging of the parking brake since the parking brake should be fully released.

4. If a rear-axle slack adjuster was installed, manually uncage the parking brake. For instructions, refer to the applicable brake chamber section in this group.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

IMPORTANT: To check the brake adjustment, measure both the applied and free strokes.

NOTE: The location of the measurements is the same for both strokes but the applied stroke is measured with the brakes applied, while a lever is used to manually move the slack adjuster to measure the free stroke.

5. Measure the free stroke, as follows. The free stroke is the distance the slack adjuster has to travel to move the brake shoes against the drum.

   5.1 With the brakes released, measure the distance from the bottom of the brake chamber to the far side of the clevis-pin hole. Record the exact distance as measurement A.

   5.2 Using a lever, move the slack adjuster until the brake shoes contact the drum. Measure the distance from the bottom of the brake chamber to the far side of the clevis-pin hole. Record the exact distance as measurement B.

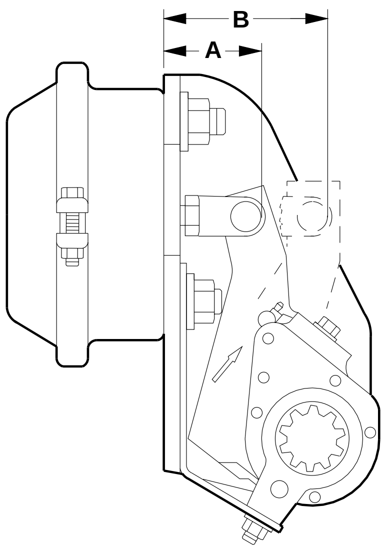
   5.3 Subtract measurement A from measurement B to determine the free stroke. For new brake installations, the free stroke should be 5/8 to 3/4 inch (16 to 19 mm). For in-service brakes, the free stroke should be 1/2 to 5/8 inch (13 to 16 mm). If it is not in this range, refer to **Troubleshooting 300**.

6. Measure the applied stroke, as follows.

   6.1 With the brakes released (pushrod fully retracted), measure the distance from the bottom of the brake chamber to the far side of the clevis-pin hole. See **Fig. 4**. Record the exact distance as measurement A.

   6.2 Apply and hold an 80 psi (551 kPa) brake application. Measure the distance from the bottom of the brake chamber to the far

Slack Adjuster Removal and Installation



NOTE: Measurements are from the bottom of the brake chamber to the far side of the clevis-pin hole.

A. Measurement with brakes released.
B. Measurement with brakes applied at 80 psi (551 kPa).

Fig. 4, Brake Applied Stroke Check

side of the clevis-pin hole. Record the exact distance as measurement B.

6.3 Subtract measurement A from measurement B to determine the applied stroke. Compare this value to the value in **Table 1**.

6.4 If the stroke varies or is greater than the maximum allowed length, refer to **Troubleshooting 300**.

7. Apply the parking brakes.
8. Remove the chocks from the tires.
9. In a safe area, check for proper brake operation, as follows.

9.1 Apply and release the brakes several times to check for correct operation of the slack adjusters.

9.2 Perform six low-speed stops to ensure correct parts replacement and full vehicle control.

9.3 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than the others show a lack of braking effort on those wheels.

Chamber Size	Maximum Applied Stroke: inch (mm)	Free Stroke: inch (mm)	
		New Brake Installation	In-Service Brake Installation
16	1-3/4 (44)	5/8–3/4 (16–19)	1/2–5/8 (13–16)
20			
24	1-7/8 (48)		
30	2 (51)		

Table 1, Brake Chamber Stroke Specifications

Troubleshooting Tables

Problem—Tight or Dragging Brakes

Problem—Tight or Dragging Brakes	
Possible Cause	**Remedy**
Improperly positioned control arm anchor bracket	See instructions in **Subject 110**.
System air pressure too low to fully release spring brake	Check that the air governor cuts out at the recommended setting.
Loose brake linings	Repair or replace the linings as required.
Pushrod binds on chamber housing	Check for correct alignment and correct chamber mounting bracket. Adjust or replace parts as needed.
Air supply does not exhaust completely	Test the air system valves for leakage and correct operation.
Out-of-round brake drums	Turn the brake drums, if possible. If the maximum allowable diameter of any brake drum has been exceeded, replace the drum. Also, turn or replace the other drum on the axle. For turning the drums, see the brake manufacturer's service manual.
Extreme differences in lining-to-drum clearances between shoes on same wheel	Check for proper operation of the brake mechanism. Lubricate or overhaul as needed.
Out-of-adjustment wheel bearings	Adjust the wheel bearings, or replace them if damaged. For instructions see **Section 33.01** for front axles and **Section 35.00** for rear axles.
Broken brake shoe return spring	Replace the brake shoe return spring.

Problem— Brake Chamber Pushrod Travel Is Excessive

Problem— Brake Chamber Pushrod Travel Is Excessive	
Possible Cause	**Remedy**
Loose, broken, or bent control arm anchor bracket	Tighten or replace the anchor bracket as required.
Worn camshaft bushings	Replace the worn camshaft bushings.
Camshaft binds	Lubricate the camshaft or overhaul the brake mechanism as needed.
Loose brake chamber mounting	Tighten the brake chamber mounting fasteners.
Worn slack adjuster clutch assembly	Replace the slack adjuster.

Specifications

Approved Lubricants	
Lubricants Type	**Lubricant Type**
Low Lube	SHC 460 Synthetic
Standard	Standard Chassis Grease

Table 1, Approved Lubricants

<table>
<tr><th colspan="3">Stroke Specifications</th></tr>
<tr><th>Chamber Size</th><th>Maximum Applied Stroke
Inch (mm)</th><th>Desired Free Stroke
Inch (mm)</th></tr>
<tr><td>12</td><td>1-3/8 (35)</td><td rowspan="2">3/8–1/2 (10–13)</td></tr>
<tr><td>16 and 20</td><td>1-3/4 (44)</td></tr>
<tr><td rowspan="3">24</td><td>1-3/4 (44)</td><td rowspan="5">3/8–5/8 (10–16) *</td></tr>
<tr><td>2 (51) — 2-1/2-Inch Extended Stroke</td></tr>
<tr><td>2.5 (64) — 3-Inch Extended Stroke</td></tr>
<tr><td rowspan="2">30</td><td>2 (51)</td></tr>
<tr><td>2.5 (64) — Long Stroke</td></tr>
</table>

* Without drag.

Table 2, Stroke Specifications

General Information

The Meritor automatic slack adjuster (**Fig. 1**) has two main functions:

- As a lever, it converts the straight-line force of the brake chamber pushrod to torque on the brake camshaft. Rotation of the camshaft forces the brake shoes against the brake drum.
- As an automatic adjuster, it automatically maintains brake chamber pushrod stroke, which controls lining-to-drum clearance during operation.

Meritor’s automatic slack adjuster automatically adjusts the clearance between the brake lining and the brake drum (rotor). When linings wear, this clearance increases and causes the chamber pushrod to move a greater distance to apply the brakes.

During operation, if the chamber stroke exceeds the design limit, the automatic slack adjuster will automatically adjust the pushrod’s return stroke to control clearance between the lining and the drum (rotor) and reset the stroke to the correct length.

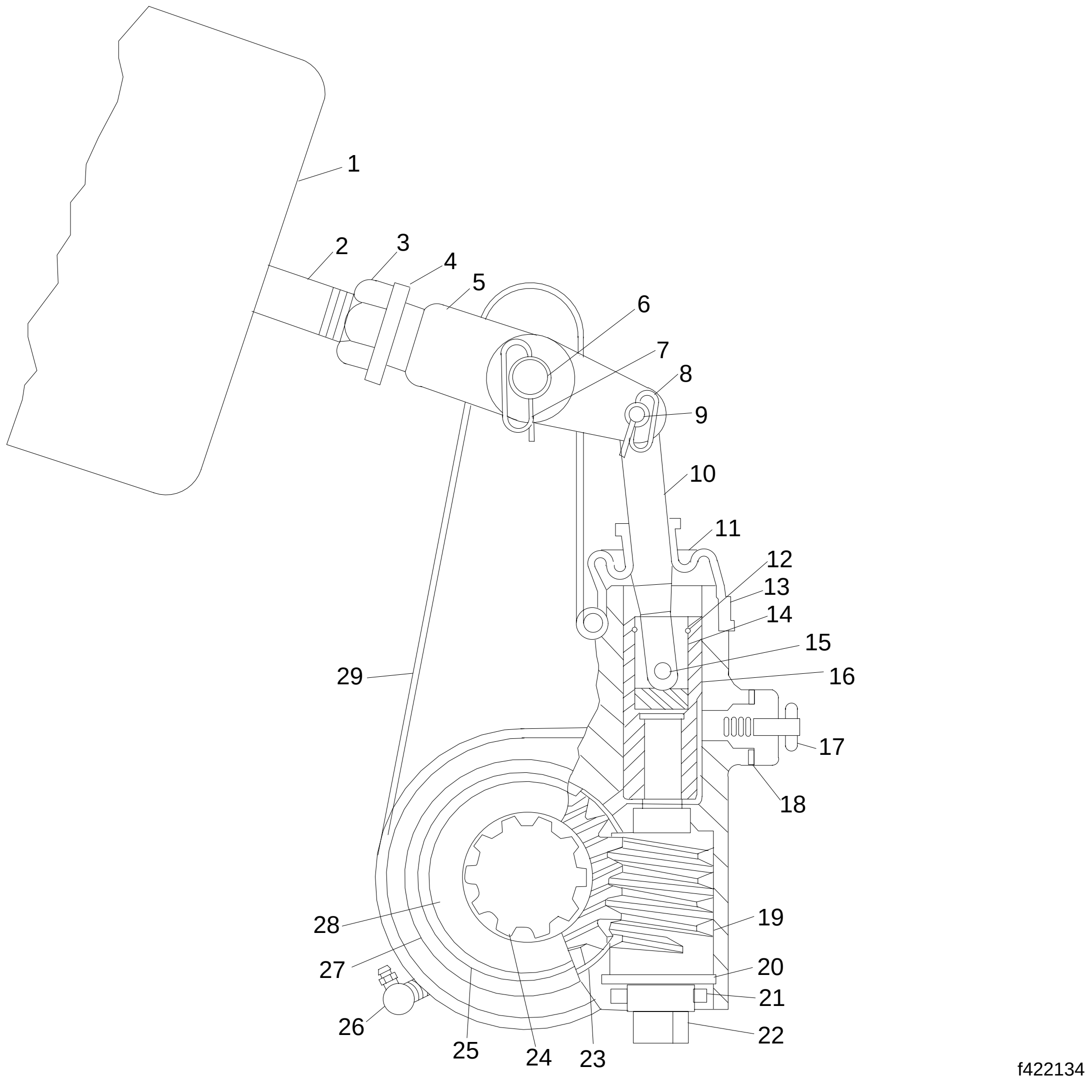
A pressed-in, sealed actuator boot is standard equipment on Meritor slack adjusters. The boot features a metal retaining ring with additional material that extends beyond the base of the retainer. The boot forms a seal once it is pressed into the slack adjuster body.

Meritor’s automatic slack adjusters, including the factory-installed slack adjusters on the Q Plus cam brakes, have a one-piece threaded clevis. See **Fig. 2**.

The one-piece threaded clevis:

- Has a threaded hole for the pushrod;
- Can be straight or offset;
- Is used on all service replacement automatic slack adjusters.

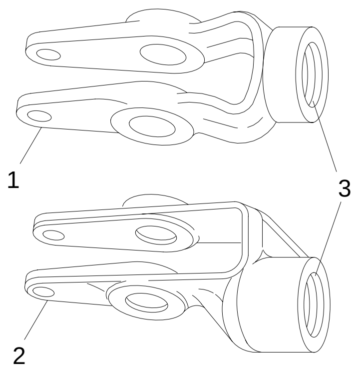
General Information



1. Brake Air Chamber
2. Brake Chamber Pushrod
3. Clevis Jam Nut
4. Collar
5. Clevis
6. Large Clevis Pin
7. Large Clevis Pin Retainer Clip
8. Small Clevis Pin Retainer Clip
9. Small Clevis Pin
10. Actuator Rod
11. Boot
12. Piston Retaining Ring
13. Boot Retaining Clamp
14. Actuator Piston
15. Roller (Pin)
16. Actuator (Adjusting Screw)
17. Pull-Pawl Assembly
18. Gasket
19. Worm
20. Worm Retaining Snap Ring
21. Worm Seal
22. Manual (Worm) Adjusting Nut
23. Gear-to-Body Seal
24. Camshaft Splines
25. Gear Retainer/Seal
26. Grease Fitting (if equipped)
27. Gear Thrustwasher
28. Gear
29. Slack Adjuster Arm

Fig. 1, Automatic Slack Adjuster (sectional view)

General Information



1. Straight Clevis
2. Offset Clevis
3. Threads

Fig. 2, One-Piece Threaded Clevis Configurations

Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

Slack Adjuster Removal and Installation

Removal

1. With the vehicle parked on a level surface, set the parking brakes, and shut down the engine. Chock the tires.

WARNING

Manually cage each parking brake chamber power spring in the release (no application) position before continuing. Loss of brake chamber air pressure will cause sudden application of the parking brakes, which could result in personal injury.

2. If the rear slack adjusters will be removed, release the parking brakes, then cage the power spring of the parking brake chamber.
3. Remove the retainer clips from the large and small clevis pins. Remove the clevis pins. See **Fig. 1**.

CAUTION

Disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

4. Using a screwdriver or an equivalent tool, pry the pawl button out about 1/32 inch (0.8 mm). See **Fig. 2**.

   Wedge the tool in place. Pull-pawls are spring-loaded; when the tool is removed, the pull-pawl will engage the teeth automatically.
5. Using a wrench, manually turn the square adjusting nut clockwise to move the slack adjuster away from the clevis. See **Fig. 3**.
6. Remove the snap ring, washer(s), and seal (if equipped) that secure the slack adjuster in place on the brake camshaft; save them for later installation.
7. Remove the slack adjuster from the camshaft.
8. Note the location and number of any remaining spacing washers on the camshaft. Remove the spacers and seal (LX500 and MX500 series only), and save them for later installation.

Installation

NOTE: For brake chambers that have pushrods with threaded clevises, measure the pushrod length before installing the new slack adjuster. With the brakes fully released, and no air pressure to the chamber, check the dimension between the chamber face and the centerline of the 1/2 inch clevis pin hole. It should be 2.25 inches (57 mm) for long stroke chambers, and 2.75 inches (70 mm) for standard stroke chambers.

1. Inspect the parts and prepare the slack adjuster for installation.
2. Check the brake camshaft splines for wear or corrosion.

IMPORTANT: The following lubricants provide corrosion protection. Do not mix them with other types of lubricants.

3. Coat the camshaft splines and the splines of the slack adjuster gear with Meritor 0-637, Meritor 0-695 (LX500 and MX500 only), Southwest SA 8249496, or an equivalent.
4. Apply the service brake several times. Make sure the return spring retracts the pushrod quickly and completely. Replace the return spring or brake chamber, if needed.
5. Slide the spacing washer(s) on the camshaft.

   On LX500 and MX500, install the slack adjuster seal with the lip facing the brake spider.
6. If reinstalling the same slack adjuster:

   6.1 Slide the slack adjuster on the camshaft, with the actuator rod on the side opposite the brake chamber.

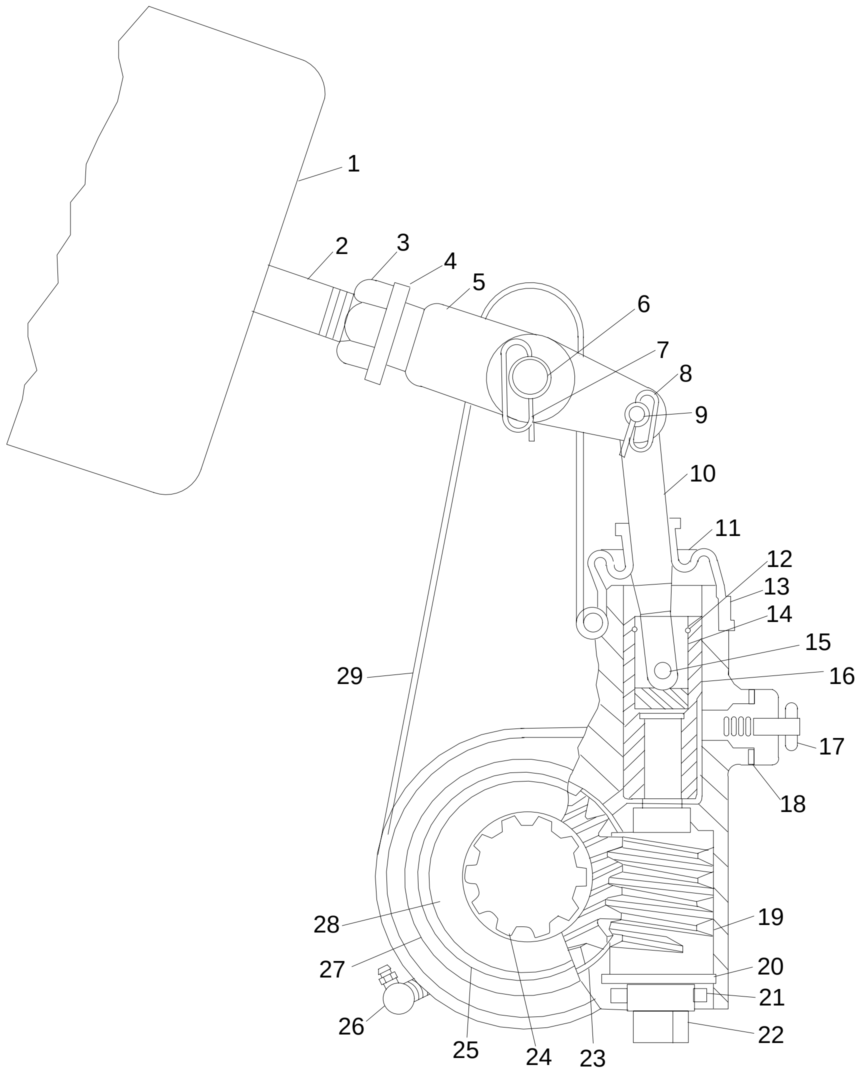
   6.2 On LX500 and MX500, install the orange slack adjuster seal on the camshaft. The lip on the seal must face the snap ring.

   6.3 Install the outer washer(s) and snap ring on the camshaft.

CAUTION

Disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could

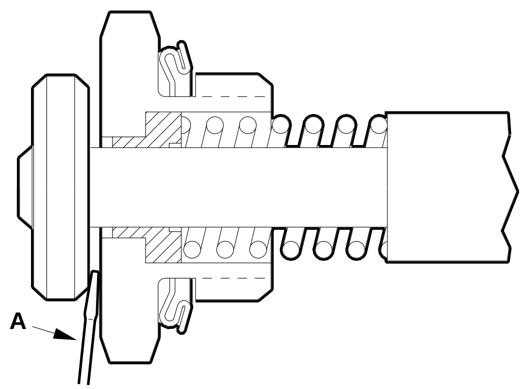
Slack Adjuster Removal and Installation



1. Brake Air Chamber
2. Brake Chamber Pushrod
3. Clevis Jam Nut
4. Quick-Connect Collar (if equipped)
5. Clevis
6. Clevis Pin (large)
7. Retainer Clip (large)
8. Retainer Clip (small)
9. Clevis Pin (small)
10. Actuator Rod
11. Boot
12. Piston Retaining Ring
13. Boot Retaining Clamp
14. Actuator Piston
15. Roller (Pin)
16. Actuator (Adjusting Sleeve)
17. Pull-Pawl Assembly (shown 90 degrees out of position)
18. Gasket
19. Worm
20. Worm Retaining Snap Ring
21. Worm Seal
22. Manual Adjusting Nut
23. Gear-to-Body Seal
24. Camshaft Splines
25. Gear Retaining Ring
26. Grease Fitting (if equipped)
27. Gear Thrustwasher
28. Gear
29. Slack Adjuster Housing

Fig. 1, Meritor Automatic Slack Adjuster

Slack Adjuster Removal and Installation



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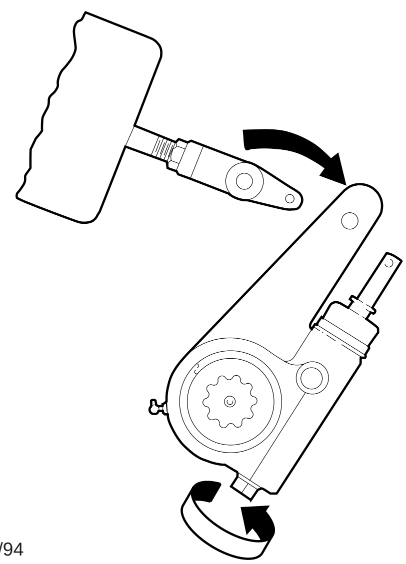
A. Insert a screwdriver here to pry the pull-pawl button out about 1/32 inch (0.8 mm).

Fig. 2, Pull-Pawl Assembly



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Turn the manual adjusting nut clockwise.

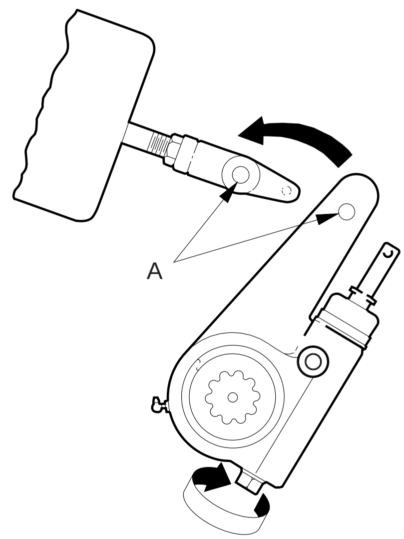
Fig. 3, Slack Adjuster Removal

damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

6.4 Using a screwdriver or an equivalent tool, pry the pawl button out at least 1/32 inch (0.8 mm). See **Fig. 2**. Wedge the tool in place.

IMPORTANT: Never pull the pushrod out to meet the slack adjuster or push the slack adjuster into position. Always turn the adjusting nut for positioning.

6.5 Using a wrench, turn the manual adjusting nut counterclockwise to align the hole in the slack adjuster housing with the large hole in the clevis. See **Fig. 4**.



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A. Turning the adjusting nut counterclockwise, align the large holes in the slack adjuster and clevis.

Fig. 4, Slack Adjuster Installation

7. If installing a new slack adjuster:

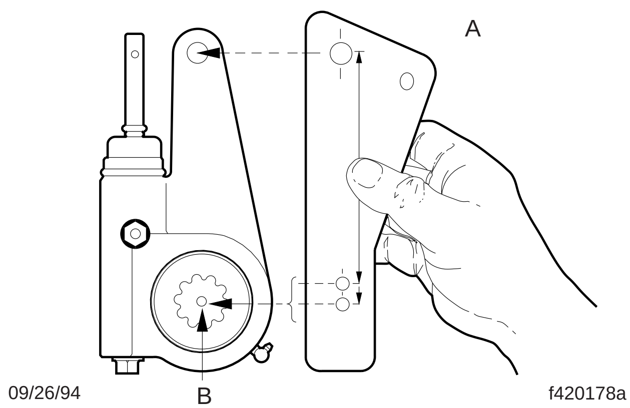
7.1 Using an installation template, measure the old and new slack adjusters. Measure from the center of the large clevis-pin hole to the center of the camshaft opening. See **Fig. 5**.

Make sure the old and new slack adjusters are the same length.

7.2 Slide the slack adjuster on the camshaft, with the actuator rod on the side opposite the brake chamber.

7.3 On LX500 and MX500 series, install the orange slack adjuster seal on the camshaft. The lip on the seal must face the snap ring.

Slack Adjuster Removal and Installation



A. Using a template, measure the slack adjuster arm length.
B. Camshaft Center

Fig. 5, Slack Adjuster Measurement

7.4 Install the outer washer(s) and snap ring on the camshaft.

7.5 Using a dial indicator, measure the in-and-out (axial) end play of the camshaft. If necessary, add the appropriate number of spacing washers to achieve the correct axial end play.

- For all Cam-Master brakes, except LX500 and MX500 series, there should be no more than 0.060 inch (1.52 mm) movement.
- For LX500 and MX500, the axial end play should be no more than 0.020 inch (0.51 mm).

CAUTION

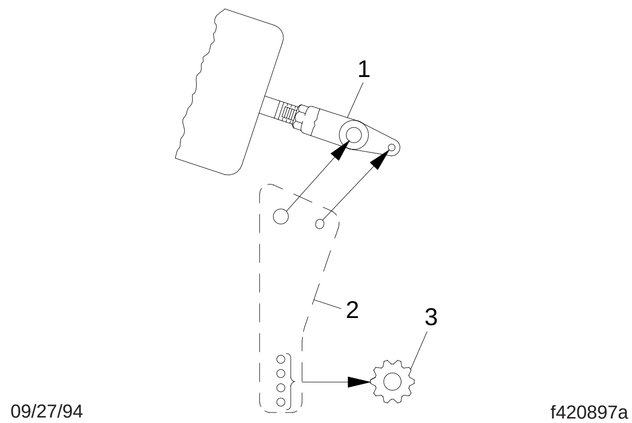
Disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

7.6 Using a screwdriver or an equivalent tool, pry the pawl button out about 1/32 inch (0.8 mm). See **Fig. 2**. Wedge the tool in place.

IMPORTANT: Never pull the pushrod out to meet the slack adjuster or push the slack adjuster into position. Always turn the adjusting nut for positioning.

7.7 Using a wrench, turn the manual adjusting nut counterclockwise to align the hole in the slack adjuster housing with the large hole in the clevis. See **Fig. 4**.

7.8 With the brakes fully released, place the installation template over the clevis and camshaft end. See **Fig. 6**.



Place the template over the clevis and camshaft end.

1. Clevis
2. Template
3. Camshaft End

Fig. 6, Template Placement

7.9 Temporarily insert the large clevis pin through the large holes in the template and the clevis.

7.10 Select the hole in the lower part of the template that matches the length of the slack adjuster. Hold the template in place on the center of the camshaft with a pencil.

7.11 Make sure the small hole in the clevis is completely visible through the 1/8-inch hole at the top of the template.

If it is not, loosen the clevis jam nut, and turn the clevis adjusting nut to adjust the position of the clevis on the pushrod until the small clevis hole is completely visible.

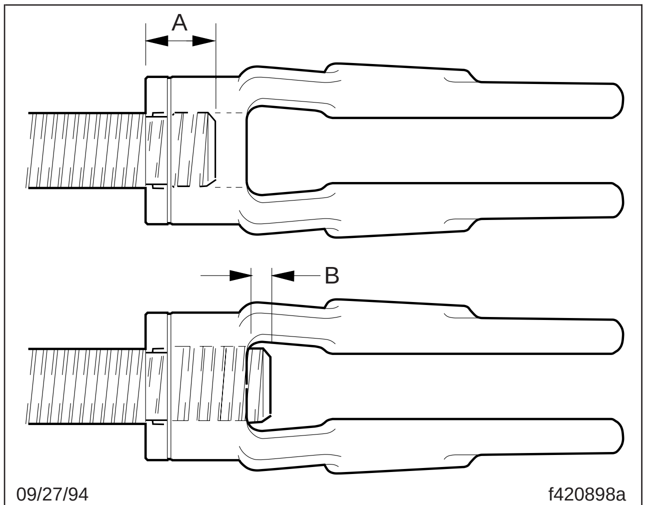
Slack Adjuster Removal and Installation

IMPORTANT: The pushrod must be installed in the clevis at least 1/2 inch (13 mm) and not extend beyond it more than 1/8-inch (3-mm).

7.12 Make sure there is at least 1/2 inch (13 mm) of thread engagement between the clevis and the pushrod. Also, check that the pushrod does not extend through the clevis more than 1/8-inch (3-mm). See **Fig. 7**.

If necessary, cut the pushrod, install a new pushrod, or install a new brake chamber.

7.13 Temporarily insert the small clevis pin through the template, clevis, and actuator rod to make sure the alignment is correct. Repeat the adjustment, if necessary. When the alignment is correct, remove both clevis pins and the template.



A. Minimum 1/2 inch (13 mm).
B. Maximum 1/8 inch (3 mm).

Fig. 7, Check Pushrod Engagement

8. Apply antiseize compound to the two clevis pins.
9. Insert both clevis pins with their pinheads on the inboard side of the slack adjuster. Be sure the small clevis pin is inserted through the hole in the actuator rod. Install new retaining clips to secure the clevis pins.
10. If it was loosened, tighten the clevis jam nut to the following values.
    - For 1/2–20 threads, tighten the clevis jam nut 20 to 30 lbf·ft (27 to 41 N·m).
    - For 5/8–18 threads, tighten the jam nut 25 to 50 lbf·ft (34 to 68 N·m).
11. Lube the slack adjuster through the grease fitting until the lubricant is forced out through the pawl slot or through the gear splines around the inboard snap ring.
12. Adjust the brakes. See "Brake Adjustment" below.

Brake Adjustment

NOTE: A properly working self-adjusting slack adjuster does not require manual adjustment while in service.

WARNING

Manually adjusting an automatic slack adjuster to bring the pushrod stroke within legal limits is likely masking a mechanical problem. Adjustment is not repairing. Before adjusting an automatic slack adjuster, troubleshoot the foundation brake system and inspect it for worn or damaged components. Improperly maintaining the vehicle braking system may lead to brake failure, resulting in property damage, personal injury, or death.

1. If a rear axle slack adjuster was installed, manually uncage the parking brake.
2. Fully release the brakes (the air chamber pushrod must be fully retracted).

CAUTION

Before turning the manual adjusting nut on the slack adjuster, disengage the pull-pawl. Failure to do so could damage the pull-pawl teeth. A damaged pull-pawl will not allow the slack adjuster to automatically adjust the brake clearance.

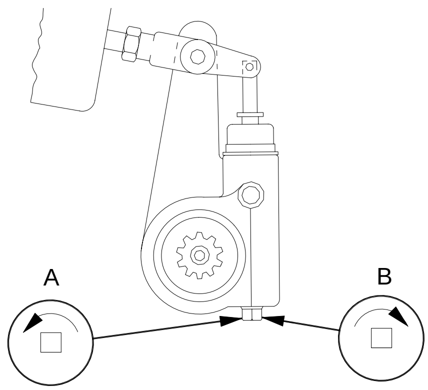
3. Using a screwdriver, pry the pull-pawl button out at least 1/32 inch (0.8 mm) to disengage the pull-pawl teeth from the slack adjuster actuator. See **Fig. 2**. Wedge the screwdriver in place. The pull-pawl will need to be disengaged until the brake adjustment is complete.

Slack Adjuster Removal and Installation

NOTE: When the screwdriver is removed, the pull-pawl will engage automatically.

4. Using the manual adjusting nut on the slack adjuster, adjust the brake chamber stroke (coarse adjustment), as follows. See **Fig. 8**.

    4.1 Turn the adjusting nut counterclockwise until the brake linings touch the brake drum.



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A. Shorten stroke. B. Lengthen stroke.

Fig. 8, Adjusting the Stroke

    4.2 Then, turn the adjusting nut clockwise 1/2 turn.

5. Measure and adjust the free-stroke, as follows.

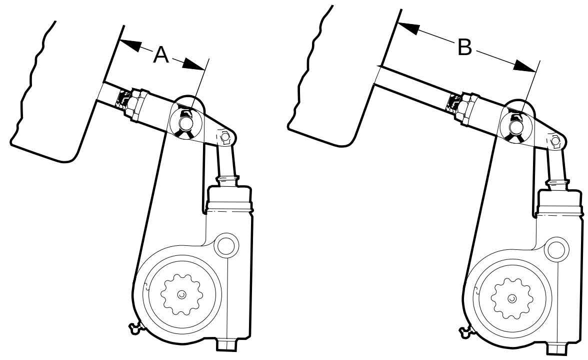
    5.1 With the brakes released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension A. See **Fig. 9**.

    5.2 Using a lever, move the slack adjuster until the brake linings contact the brake drum.

    Measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension B. See **Fig. 9**.

    5.3 Subtract dimension A from dimension B. The difference between these measurements is the free-stroke.

    5.4 The free-stroke for a new brake installation should be 5/8 to 3/4 inch (16 to 19 mm). For a brake that is in service, the free-stroke should be 1/2 to 5/8 inch (13 to 16 mm). If it is not, turn the adjusting nut 1/8 turn, as shown in **Fig. 8**. Then, measure the free-stroke again; readjust it until it is correct.



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NOTE: For either free-stroke or applied chamber stroke, subtract measurement A from B.

A. Measurement with the brakes released.
B. Measurement with the brakes applied by manual lever (free-stroke) or pressurized brake application (applied chamber stroke).

Fig. 9, Measuring the Stroke

6. Measure and adjust the applied chamber stroke (fine adjustment), as follows.

    6.1 If system pressure is not already at 100 psi (689 kPa), start the engine and build air pressure, then shut down the engine.

    6.2 With the brakes released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension A. See **Fig. 9**.

    6.3 Fully apply the brakes. Then, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 9**, Ref. B. Record this measurement as dimension B.

    6.4 Subtract dimension A from dimension B. The difference between these measurements is the true applied chamber stroke.

CAUTION

The adjusted applied chamber stroke should be as short as possible but not so short that the free-stroke is too short and the linings drag. If the linings drag, the brakes could be damaged.

6.5 The applied chamber stroke must not exceed the maximum value specified in **Table 1**.

If the applied chamber stroke is incorrect, turn the adjusting nut 1/8-turn counterclockwise to shorten the stroke, or 1/8-turn clockwise to lengthen it. See **Fig. 8**. Measure the applied stroke again and readjust it until it is correct.

6.6 If the slack adjuster is not maintaining the correct applied chamber stroke, check the condition of the foundation brakes. See **Section 42.01, Subject 150**.

7. Remove the screwdriver from the pull-pawl assembly. This will engage the pull-pawl with the actuator.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

8. In a safe area, check for proper brake operation before you put the vehicle in service, as follows.

8.1 Apply and release the brakes several times to check for air leaks and proper operation of the slack adjusters.

8.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.

8.3 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than others show a lack of braking effort on those wheels.

Brake Chamber Stroke Specifications			
Chamber Type (Size)	Maximum Applied Stroke*: inch (mm)	Free-Stroke: inch (mm)	
		New Brake Installation	In-Service Brake
Long Stroke†			
16 and 20	2-1/2 (64)	5/8–3/4 (16–19)	1/2–5/8 (13–16)
24 and 30	3 (76)		

* Specifications are relative to a brake application with 80–90 psi (550–620 kPa) air pressure in the brake chambers.

† Long stroke design is indicated by a tag, or embossing, on the brake chamber.

Table 1, Brake Chamber Stroke Specifications

Specifications

Lubricant Specifications	
Lubricant Type	**Temperature**
Amoco Super Permalube No. 2	–40°F (–40°C) or Above
Aralub 3837	
Citco Premium Lithium EP No. 2	
Exxon Ronex MP No. 2	
Kendall L–427 Super Blu No. 2	
Mobilith AW No. 1	
Meritor 0–616–A	
Meritor 0–692	
Shell Darina No. 1	
Sohio Factran EP No. 2	
Texaco Hytherm EP No. 1	
Texaco Thermotex EP No. 1	
Tribolube 12, Grade 1	
Mobil 28	Below –40°F (–40°C)
Meritor 0–645	

Table 1, Lubricant Specifications

Slack Adjuster Arm Lengths	
Slack Adjuster Arm Length inches (mm)	**Chamber Size**
5 (127)	9, 12, 16, 20, 24, 30
5-1/2 (140)	9, 12, 16, 20, 24, 30
6 (152)	24, 30
6-1/2 (165)	30

Table 2, Slack Adjuster Arm Lengths

Maximum Adjusted Brake Chamber Strokes	
Chamber Size	**Maximum Chamber Stroke for Cam Brake in inches (mm)**
9	Less than 1-1/2 (38)
12	Less than 1-1/2 (38)
16	Less than 1-3/4 (44)
20	Less than 1-3/4 (44)
24	Less than 1-7/8 (48)
24 *	Less than 2 (51)
30	Less than 2 (51)

* Long stroke.

Table 3, Maximum Adjusted Brake Chamber Strokes

Thread Sizes	
Chambers	**Thread Sizes inch**
9, 12,16	1/2–20
20, 24, 30, 36	5/8–18

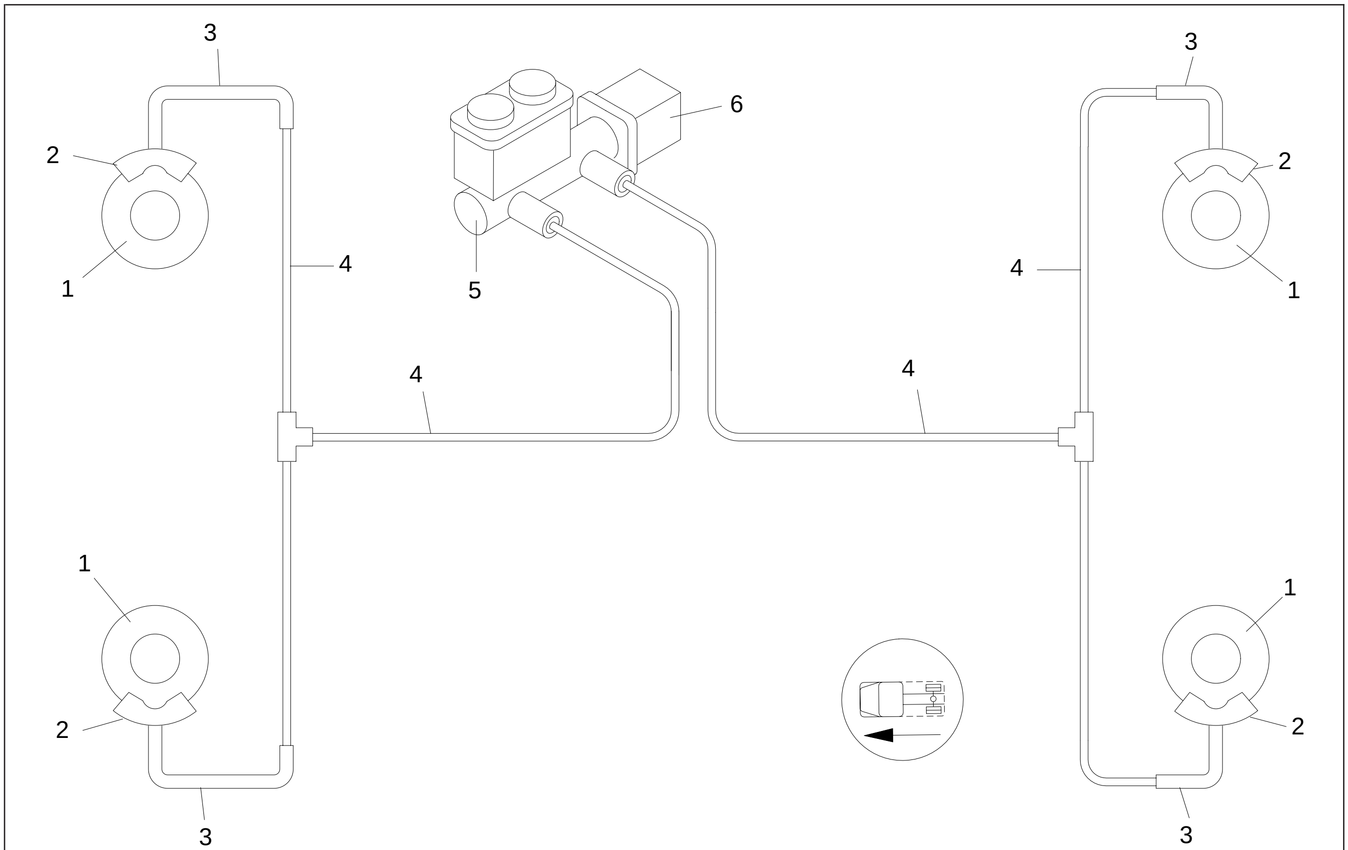
Table 4, Thread Sizes

General Information

The major parts of the hydraulic brake system are: the power brake booster, master cylinder, both rigid steel and flexible rubber hydraulic lines, and the brake caliper assembly at each rotor. See **Fig. 1**.

NOTE: On most vehicles in the field, the primary master cylinder piston controls the rear brakes, the secondary piston the front brakes. But on some vehicles the primary master cylinder piston controls the front brakes, the secondary master cylinder piston controls the rear brakes. Either configuration is considered normal and they are functionally identical. Technicians should check vehicle configuration for appropriate diagnosis and repair.

NOTE: This document deals with the hydraulic brake system. For antilock brake system (ABS) problems, see documentation specific to them.



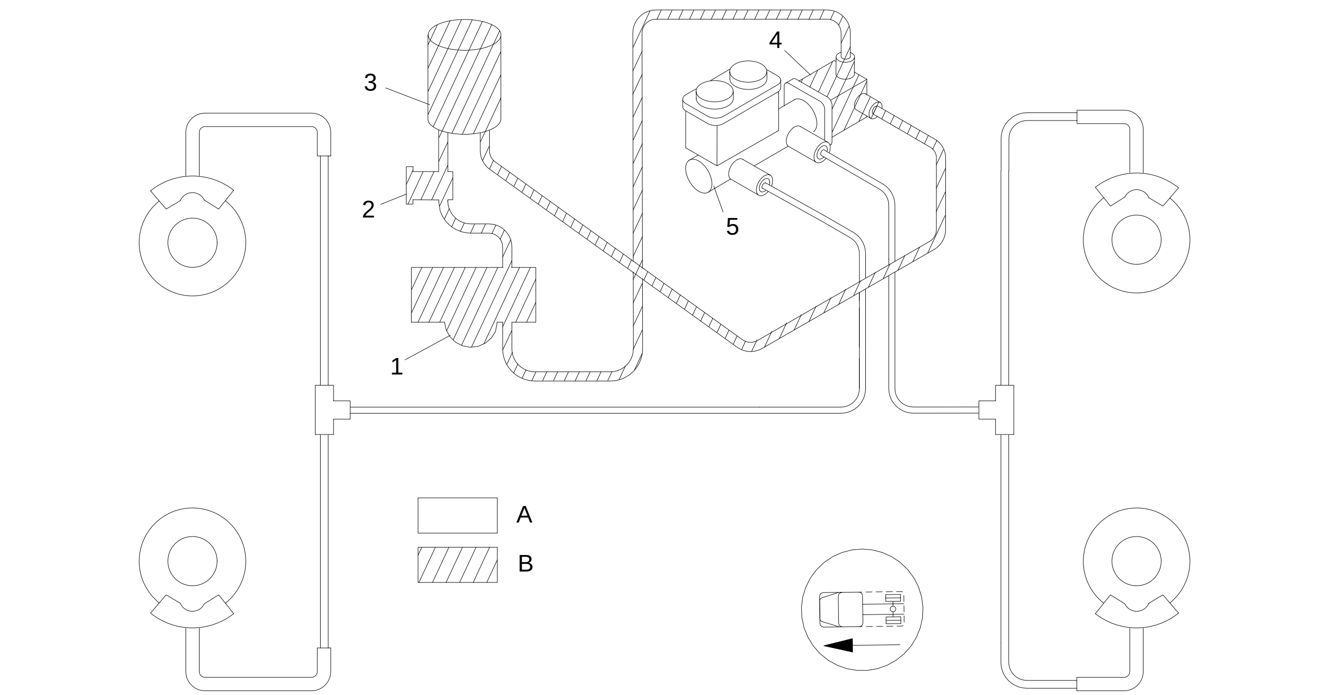
1. Rotor
2. Caliper and Pad Assembly
3. Flexible Brake Line
4. Rigid Brake Line
5. Master Cylinder
6. Power Brake Booster

Fig. 1, Brake System Major Parts

Illustrations in this document do not show ABS components.

The hydraulic brake components include two completely separate hydraulic systems that use different and unmixable hydraulic fluids, lines, and seals. **The components of each** *must* **be kept separate from the other.** See **Fig. 2**, which shows the separate systems.

General Information



A. Service Brake System (DOT 3 Brake Fluid)
B. Power Brake Booster and Power Steering System (ATF)

1. Power Steering Gear
2. Power Steering Pump
3. Power Steering Reservoir
4. Power Brake Booster
5. Brake Master Cylinder

Fig. 2, Brake System Major Parts

The power brake booster multiplies brake pedal effort to increase power to the brake master cylinder. The power increase comes from pressurized automatic transmission fluid (ATF) supplied by the power steering pump. **Note that the power steering system contains ATF, not "power steering fluid."**

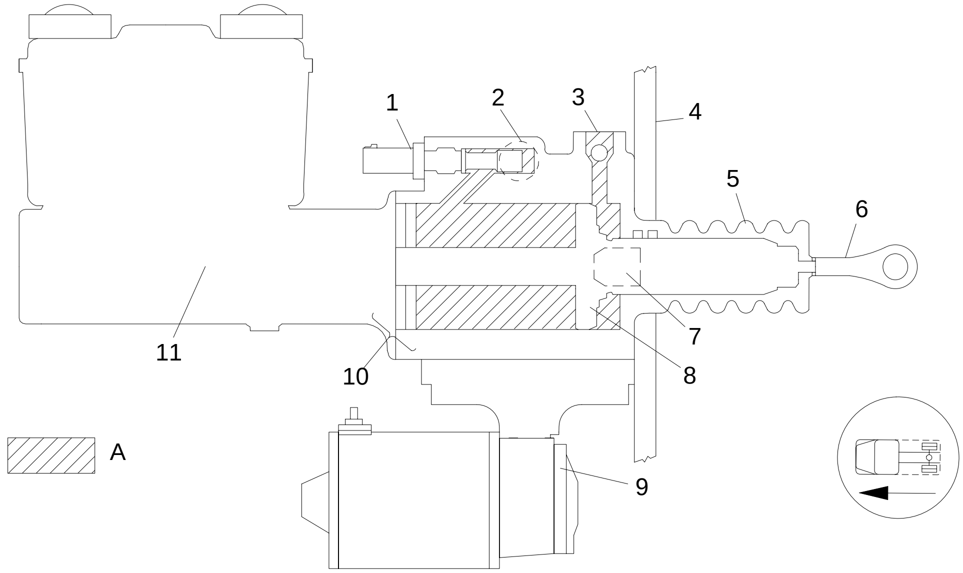
The service brake system, consisting of the master cylinder, the brake hydraulic lines and the brake calipers, uses only approved DOT 3 heavy duty brake fluid. **Serious damage will result from putting ATF in the brake master cylinder, or DOT 3 brake fluid in the power brake booster.**

Power Brake Booster

The major parts of the Hydro-Max® II power brake booster mounted on the frontwall are: a reaction piston, a power piston assembly, an end-cap assembly and an electric backup pump (Fig. 3). The brake master cylinder bolts to the front of the power brake booster.

The brake pedal rod connects the brake pedal to the power brake booster's power piston assembly. The reaction piston is inside the power piston. The forward end of the power piston fits through the booster end-cap assembly and rests against the brake master cylinder. The end-cap assembly keeps the ATF within the power brake booster.

The power brake booster gets pressurized ATF from the vehicle's power steering pump. The power steering pump sends the ATF through the steering gear to the power brake booster supply port, then the power brake booster return port sends the ATF back to the power steering reservoir. If the supply of pressurized ATF from the power steering pump to the power



NOTE: Not all parts are shown.

A. Automatic Transmission Fluid (ATF)

1. Flow Switch
2. Return Port (to steering reservoir)
3. Supply Port (from steering gear)
4. Firewall
5. Rubber Boot
6. Brake Pedal Rod
7. Reaction Piston
8. Power Piston Assembly
9. Electric Backup Pump
10. End-Cap
11. Master Cylinder (DOT 3 brake fluid only)

Fig. 3, Power Brake Booster

brake booster fails, a flow switch starts the electric backup pump to keep the power brakes working.

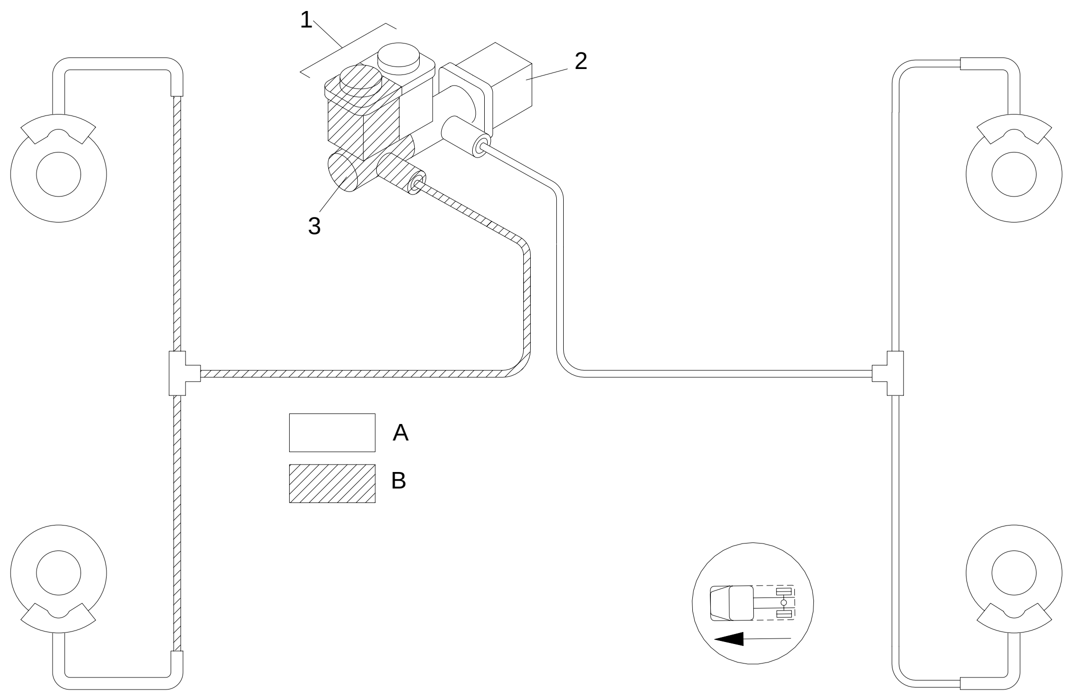
Master Cylinder

The brake master cylinder bolts to the power brake booster and functions as a dual supply system. In the most common configuration, the primary subsystem supplies pressurized DOT 3 brake fluid to the rear brakes, the secondary subsystem supplies it to the front brakes. See **Fig. 4**. For safety, each subsystem is independent so a problem with one will not affect the other.

The master cylinder is mounted on the front of the power brake booster. The main components of the master cylinder are the primary pressure chamber, the primary piston/actuator assembly and return spring, the primary reservoir section, and the secondary pressure chamber, secondary piston/actuator assembly, secondary return spring, and secondary reservoir section. See **Fig. 5**.

The pressure chambers connect to the front and rear brake caliper assemblies through hydraulic lines and hoses. There is a compensating valve at the bottom of each reservoir section that opens to connect it to its chamber in the master cylinder. When it is open, the compensation valve allows DOT 3 brake fluid in the reservoir to enter the brake lines to the calipers to take up for lining wear. When it is closed, the compensation valve allows pressure to build in its subsystem. A pressure differential valve operates a pressure differential switch (not shown), which sets off a dash warning light and buzzer if one of the subsystems does not build pressure.

General Information



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A. Rear Brake Lines
B. Front Brake Lines

1. Master Cylinder Reservoir
2. Power Brake Booster (ATF only)
3. Master Cylinder (DOT 3 brake fluid only)

Fig. 4, Dual Supply System

Non-ABS Brake Monitor Module

The brake monitor module, located behind the instrument control unit (ICU) on the driver side of the dash, monitors electrical signals from various sensors (but not ABS) in the service brake system and power brake booster system. If it detects a problem, the module activates the applicable warning light and buzzer on the dashboard.

The monitor module has nine input terminals and three output terminals, with one ground terminal. See **Fig. 6**. The output terminals connect to the brake system pressure and warning lights. The input terminals are connected to sensors in the brake system that detect improper operation.

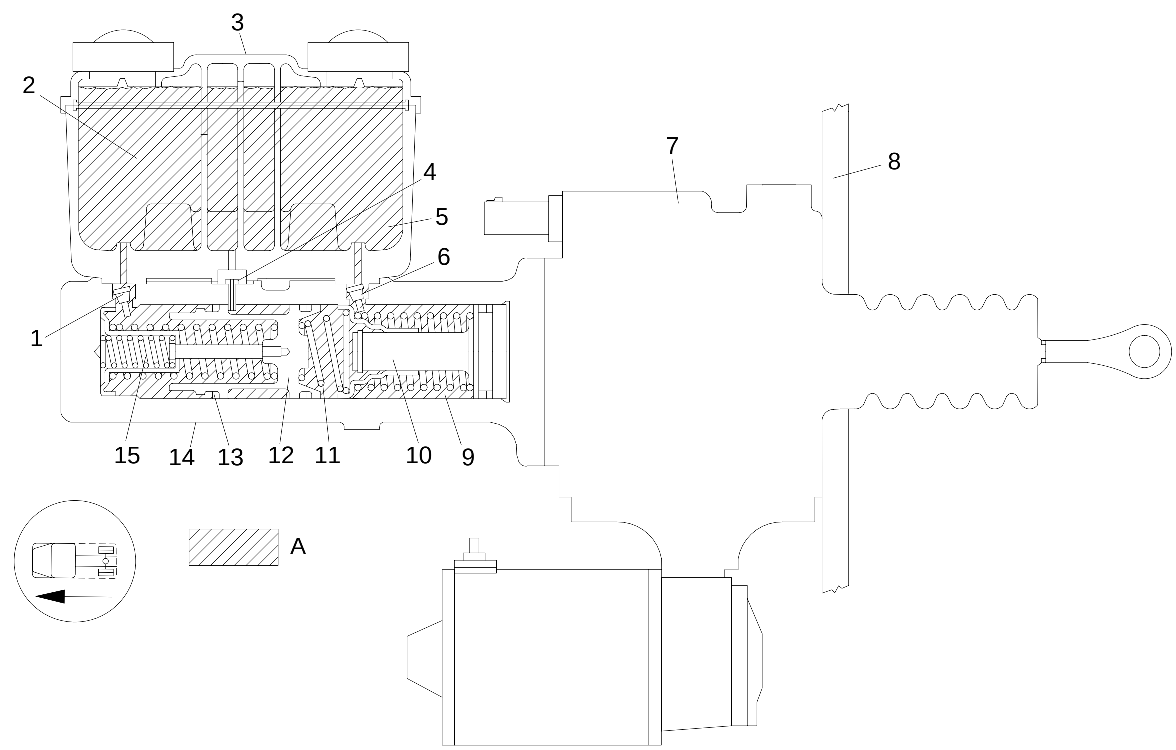
See **Table 1** for identification of the output and input terminals on the back of the module, and the circuits to which they are connected.

The monitor module, which operates on 9 to 16 volts DC, actively monitors the hydraulic brake system under any of the following conditions:

- When the ignition is on;
- When the brake pedal light switch is powered;
- If the ignition is off, but the driver's door is open and the parking brake is not applied.

When the ignition is turned on, the monitor module runs a self-test which lasts from 1 to 3 seconds. The warning light and buzzer come on, then go off if the system is working properly. The module then begins monitoring the hydraulic brake system. If it detects a problem, it turns on the brake warning light and buzzer.

NOTE: The buzzer is controlled by the instrument control unit (ICU).



NOTE: Not all parts are shown.

A. DOT 3 Brake Fluid

1. Secondary Compensating Valve (open)
2. Secondary Reservoir Section
3. DOT 3 Brake Fluid Reservoir
4. Piston Stop
5. Primary Reservoir Section
6. Primary Compensating Valve (open)
7. Power Brake Booster Assembly
8. Frontwall
9. Primary Pressure Chamber
10. Primary Piston/Actuator Assembly
11. Primary Piston Return Spring
12. Secondary Piston/Actuator Assembly
13. Secondary Pressure Chamber
14. Housing
15. Secondary Piston Return Spring

Fig. 5, Master Cylinder

The "R" light (brake pressure) output—terminal 3—is activated when any of the following conditions exist:

- The flow switch on the power brake booster closes due to reduced or lost flow of ATF to the power brake booster;
- The pressure differential switch on the master cylinder closes due to a pressure difference between the front and rear brake subsystems;
- The DOT 3 brake fluid level switch on the master cylinder reservoir closes due to a drop in the fluid level;
- Too much electrical resistance in the backup pump motor. This is often caused by a bad ground.

Monitor Module Terminal Identification		
Terminal Number	**Function**	**Circuit Number**
1	Not Used	—
2	Not Used	—
3	Light "R" (Brake System Pressure) Output	388H

General Information

Monitor Module Terminal Identification		
Terminal Number	Function	Circuit Number
4	Ground	GND
7	Ignition Input	81C
8	Not Used	—
9	Relay Input	388F
10	Not Used	—
11	Pressure Differential Switch Input	388A
12	Brake Pedal Input	388L
13	Backup Pump Motor Input	388C
14	Fluid Level Input	388B
15	Flow Switch Input	388G

Table 1, Monitor Module Terminal Identification

- No power to the backup pump at startup.

See **Table 2** for information on when the input terminals are activated.

Applying the Brakes

Pushing the brake pedal moves the brake pedal rod against the actuator pin in the power brake booster, moving the reaction piston forward inside the power piston. See **Fig. 7**. This moves the throttle valve, restricting the flow of ATF through the power piston, which increases pressure. The increased ATF pressure pushes the power piston forward through the end-cap assembly and into the master cylinder.

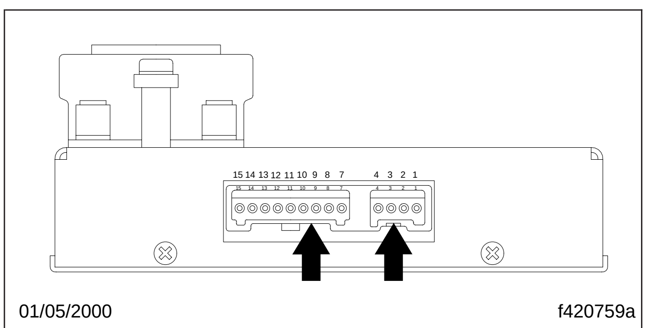


Fig. 6, Monitor Module Terminals

As the primary piston/actuator assembly is pushed forward in the master cylinder, the primary compensating valve closes. This shuts the outlet at the primary reservoir section and raises hydraulic pressure in the primary pressure chamber.

The primary piston/actuator assembly motion also moves the secondary piston/actuator assembly. This closes the secondary compensating valve, pressurizing the secondary pressure chamber.

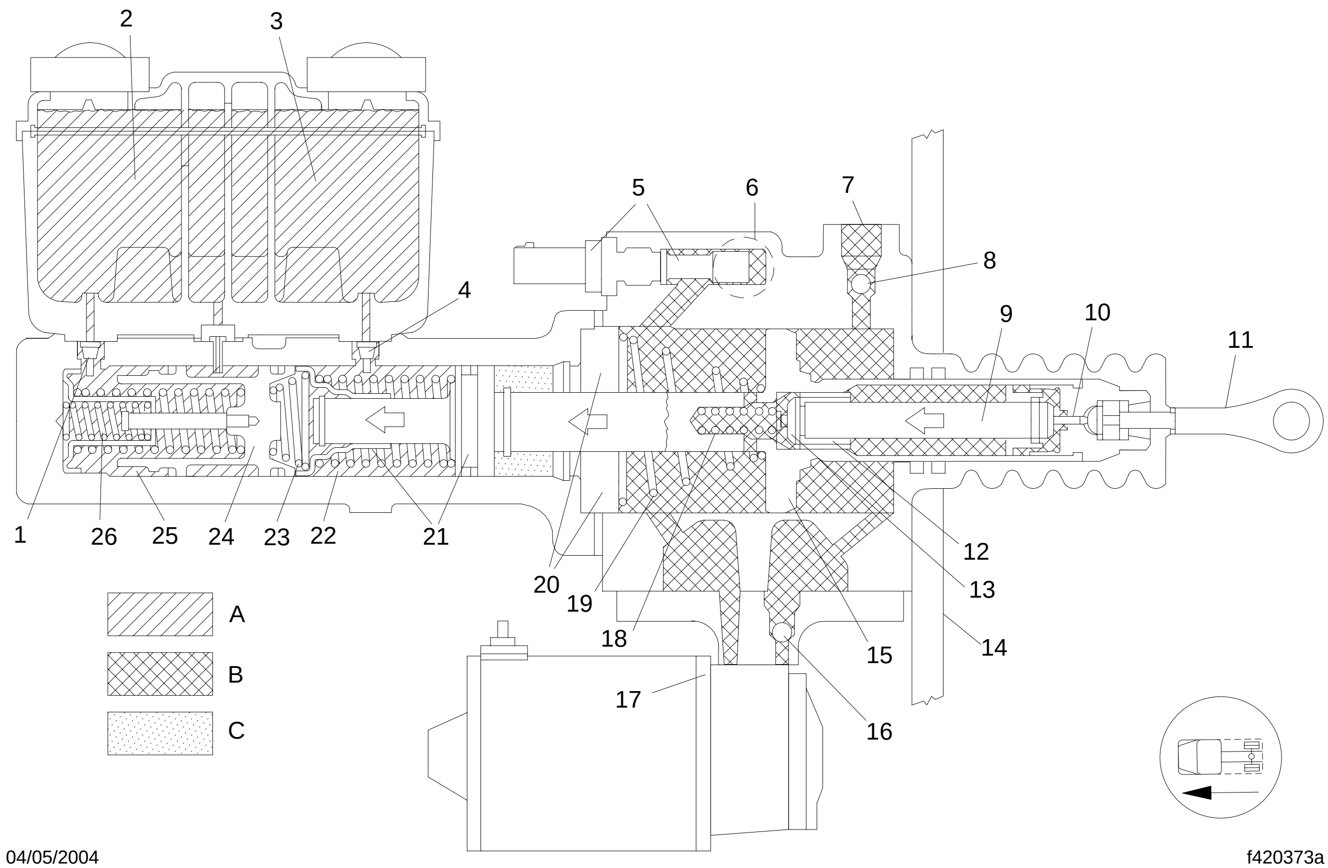
Both primary and secondary pressure chambers have outlet ports into individual brake lines leading to the brake calipers. The brake lines transmit the pressure through DOT 3 brake fluid to the calipers, moving the dual piston pads against the rotors. That pulls the caliper assemblies in, squeezing the rotors, slowing or stopping the wheels.

If the power brake booster loses pressure from the power steering pump, the flow switch turns on the backup pump, closing the main supply check valve and opening the backup pump check valve. The electric backup pump then takes over pressurizing the ATF in the power brake booster, providing enough pressure for the master cylinder to operate the brakes.

Releasing the Brakes

When the brake pedal is released, a return spring in the booster opens the throttle valve, reducing ATF pressure in the power brake booster. See **Fig. 7**. The reduced power brake booster pressure allows the master cylinder and piston return springs to move the booster power piston back toward the frontwall side of the power brake booster housing.

In the master cylinder, the return springs push back the primary and secondary pistons, opening their compensating valves. This lowers hydraulic pressure in the master cylinder and the brake lines, allowing the caliper pistons and their brake pads to back away from the brake rotors. With the brake pads no longer squeezing the rotors, the brakes let off and the rotors and wheel hubs can turn freely again.



NOTE: Not all parts are shown.

A. DOT 3 Brake Fluid
B. ATF
C. Air Space

1. Secondary Compensating Valve (closed)
2. Secondary Reservoir Section
3. Primary Reservoir Section
4. Primary Compensating Valve (closed)
5. Flow Switch Assembly
6. Return Port
7. Supply Port
8. Supply Check Valve (shown open)
9. Pressure Regulator Assembly
10. Actuator Pin
11. Brake Pedal Rod
12. Reaction Piston
13. Throttle Valve
14. Frontwall
15. Power Piston
16. Backup Pump Check Valve (shown closed)
17. Electric Backup Pump
18. Throttle Valve Return Spring
19. Piston Return Spring
20. End-Cap
21. Primary Piston/Actuator Assembly
22. Primary Pressure Chamber
23. Primary Piston Return Spring
24. Secondary Piston/Actuator Assembly
25. Secondary Pressure Chamber
26. Secondary Piston Return Spring

Fig. 7, Power Brake Booster and Master Cylinder

General Information

Input Terminal Activation			
Terminal Number	**Function**	**Circuit Number**	**Activated if**
7	Ignition Input	81C	The ignition is on.
8	Not Used	—	—
9	Relay Input	388F	The ignition is on or brake pedal is depressed.
10	Not Used	—	—
11	Pressure Differential Switch Input	388A	Pressure difference between front and rear systems becomes more than 483 kPa (70 psi).
12	Brake Pedal Input	388L	Brake pedal depressed.
13	Pump Motor Input	388C	Electrical resistance of backup pump motor too high.
14	Fluid Level Input	388B	Fluid level of master cylinder below 25 percent capacity.
15	Flow Switch Input	388G	No hydraulic flow through power brake booster.

Table 2, Input Terminal Activation

General Safety Precautions

WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- Disconnect the batteries.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

WARNING

Hydraulic brake fluid is hazardous, and can cause blindness if it gets in your eyes. Always wear safety glasses when handling brake fluid or bleeding brake components. Brake fluid may also be a skin irritant. If you get it on your skin, wash it off as soon as possible.

Special care must be taken when disposing of used brake fluid. Put the fluid in a sealed plastic container and label it "Used Brake Fluid." Then dispose of it in an approved manner. Check with local and state regulations as to the correct disposal procedure.

IMPORTANT: During service procedures, keep grease and other foreign material away from caliper assemblies, disc brake pads, brake rotors and external surfaces of the hub. Handle parts carefully to avoid damage to the caliper, rotor, disc brake pads or brake lines.

Asbestos and Non-Asbestos Safety

WARNING

Wear a respirator at all times when servicing the brakes, starting with the removal of the wheels and continuing through assembly. Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH.

Because some brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Exposure to airborne asbestos brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

Because medical experts believe that long-term exposure to some *non-asbestos* fibers could also be a health hazard, the following precautions should also be observed if servicing non-asbestos brake linings.

Areas where brake work is done should be separate from other operations, if possible. As required by OHSA regulations, the entrance to the areas should have a sign displayed indicating the health hazard.

During brake servicing, an air purifying respirator with high-efficiency filters must be worn. The respirator and filter must be approved by MSHA or NIOSH, and worn during all procedures.

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through

Safety Precautions

sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, the brake assembly must be cleaned in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with a HEPA filter system, remove dust from the brake drums, brake backing plates, and brake parts. After vacuuming, any remaining dust should be removed using a rag soaked in water and wrung until nearly dry. Do not use compressed air or dry brushing to clean the brake assembly.

If grinding or other machining of the brake linings is necessary, other precautions must be taken because exposure to asbestos dust is highest during such operations. In addition to the use of an approved respirator, there must be local exhaust ventilation such that worker exposure is kept as low as possible.

Work areas should be cleaned by industrial vacuums with HEPA filters or by wet wiping. Compressed air or dry sweeping should never be used for cleaning. Asbestos-containing waste, such as dirty rags, should be sealed, labeled, and disposed of as required by EPA and OSHA regulations. Respirators should be used when emptying vacuum cleaners and handling asbestos waste products.

Workers should wash before eating, drinking, or smoking, should shower after work, and should not wear work clothes home. Work clothes should be vacuumed after use and then laundered, without shaking, to prevent the release of asbestos fibers into the air.

WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to follow those safety precautions may result in personal injury.

Bleeding

WARNING

The hydraulic brake and power steering systems must be bled whenever any fitting has been loosened or disconnected. Failure to bleed the system will allow air to remain in it. That will decrease the vehicle's braking ability and can result in an accident, property damage, and serious personal injury.

Properly dispose of used hydraulic brake fluid. Used hydraulic brake fluid is often contaminated. Reusing it can cause brake system damage, loss of braking, property damage and serious personal injury.

Automatic transmission fluid (ATF) and brake fluid must not be mixed. Use only brake fluid for the master cylinder and brake lines. Use only ATF for the power brake booster. Mixing these two fluids will seriously damage the hydraulic system. ATF will damage the rubber parts of the ABS modulator, master cylinder, and brake calipers and can cause damage, loss of braking and serious personal injury.

Always use new clean DOT 3 brake fluid when bleeding the master cylinder and service brake system. Never reuse brake fluid, and do not use brake fluid containers for any other purpose. DOT 3 brake fluid exposed to the air absorbs water from it, so keep brake fluid containers tightly closed to keep new brake fluid clean and dry. Keeping the master cylinder reservoir properly filled to the bottom of the narrow filler neck helps reduce moisture absorption from the air.

IMPORTANT: Do not let DOT 3 brake fluid touch any painted surfaces. Brake fluid removes paint and may also damage other non-metallic surfaces. Do not let fluid get on brake pads or rotors.

Pressure Bleeding

Pressure bleeding is the preferred method for bleeding the service brake system. It requires the use of a special pressure bleeder kit consisting of a tank, pressure pump and valve, gauge, tubing and adapter. These are available from a number of manufacturers and include instructions for use. See Fig. 1.

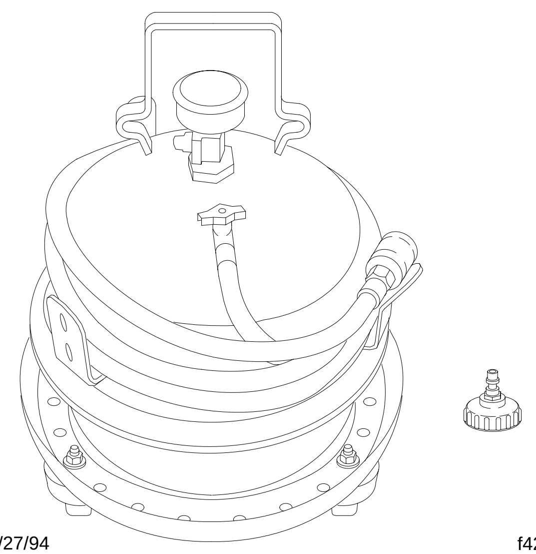


Fig. 1, Pressure Bleeder Kit

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the tires.
2. Open the hood.
3. Connect the pressure bleeder to the brake master cylinder reservoir following the manufacturer's instructions.

WARNING

Do not exceed 35 psi (241 kPa) at the master cylinder inlet. Exceeding this pressure could rupture the master cylinder assembly, spraying brake fluid around the area. This will almost certainly result in vehicle paint damage and may cause other damage or personal injury.

3.1 Fill the pressure bleeder with new DOT 3 approved brake fluid. Pressurize it according to the manufacturer's instructions.

Hydraulic System Bleeding

3.2 Using the supplied adapter, connect the pressure bleeder to either one of the fill ports on the master cylinder reservoir.

4. Bleed the hydraulic connections at the rear wheel calipers, starting on the right side.

   4.1 Put a wrench on the bleeder fitting at the caliper, then attach a length of clear tubing to the bleeder fitting. Make sure the tubing fits snugly. Submerge the other end of the tubing in a container of clean brake fluid. See **Fig. 2**.

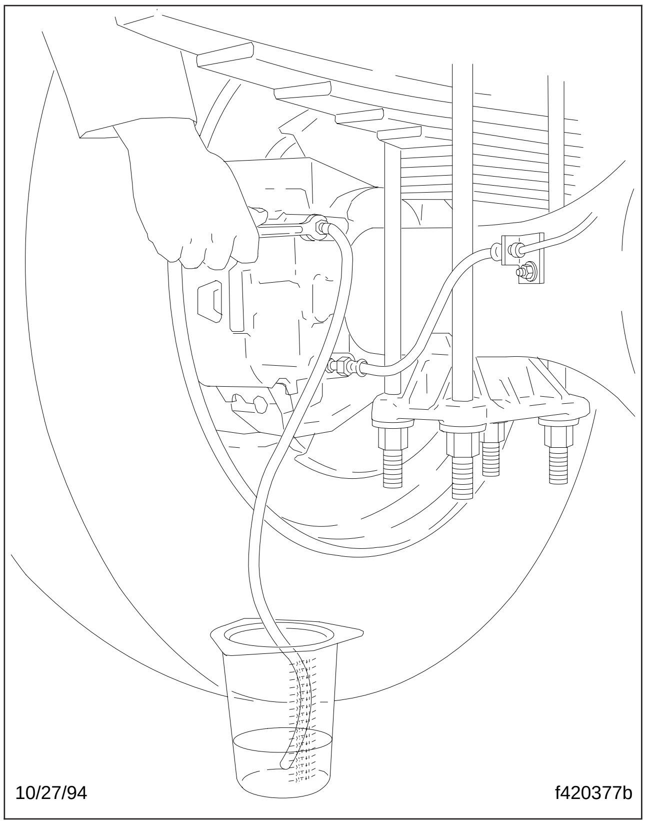


Fig. 2, Bleed the Connections at the Rear Wheel Calipers

   4.2 Loosen the bleeder fitting about 3/4-turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.

   4.3 Move to the left rear caliper and repeat steps for bleeding the caliper.

5. Add DOT 3 brake fluid to the master cylinder reservoir, if it is needed.

6. Bleed the front wheel brake calipers, right side first.

   6.1 Put a wrench on the bleeder fitting at the caliper, then attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the other end of the tubing in a container of clean brake fluid. See **Fig. 2**.

   6.2 Loosen the bleeder fitting by about 3/4-turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.

   6.3 Move to the left front wheel caliper and repeat steps for bleeding the caliper.

7. Check the brake fluid level in both compartments of the reservoir. Add new DOT 3 approved brake fluid if needed.

8. Check the operation of the brakes by pumping the brake pedal several times until it feels firm. The brake pedal should not go all the way down to the floor. If it does, see **Troubleshooting 300**.

9. Close and latch the hood.

10. Connect the batteries.

11. Remove the chocks from the rear tires.

12. Repeat step 8. Check for operation of the brakes.

Manual Bleeding

If you do not have pressure bleeding equipment, you can use the manual bleeding procedure.

IMPORTANT: Do not let the brake master cylinder fluid level get too low during manual bleeding operations. Keep the master cylinder reservoir filled with new DOT 3 approved brake fluid. Allowing the brake fluid reservoir to empty will force air into the system, the opposite of the desired result.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the tires.

2. Open the hood.

3. Disconnect the batteries. The ignition must remain off for the entire bleed procedure.
4. Bleed the master cylinder.

NOTE: It will not usually be necessary to bleed the master cylinder unless the brake fluid reservoir has run dry or master cylinder components have been replaced.

4.1 Using a wrench and holding a rag underneath to absorb leaking brake fluid, loosen the fitting at the rear outlet port on the master cylinder about one turn. See **Fig. 3**.

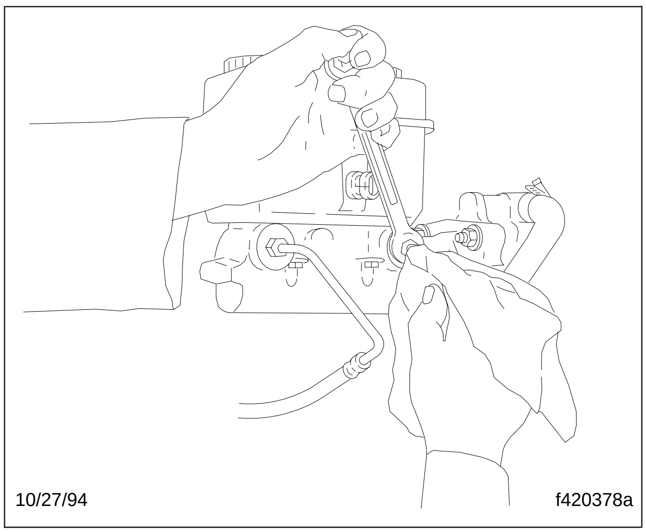


Fig. 3, Loosen the Fitting at the Rear Outlet Port

4.2 Have someone push the brake pedal down slowly to the floor and hold it there. Brake fluid and any air in the master cylinder will squirt from the fitting.

4.3 *With the brake pedal held down*, tighten the rear hydraulic line fitting firmly.

IMPORTANT: Do not release the brake pedal until the fitting is tightened, or more air will get into the system.

4.4 Release the brake pedal.

4.5 Loosen the fitting again and bleed the line until no air escapes from the fitting and the brake pedal feels firm.

4.6 Check the fluid level in the master cylinder reservoir. Add new DOT 3 approved brake fluid as needed to raise the level to the bottoms of the narrow filler necks.

4.7 Using a wrench and holding a rag under it to absorb leaking brake fluid, loosen the fitting at the front outlet port on the master cylinder. See **Fig. 4**. Loosen the fitting about one turn.

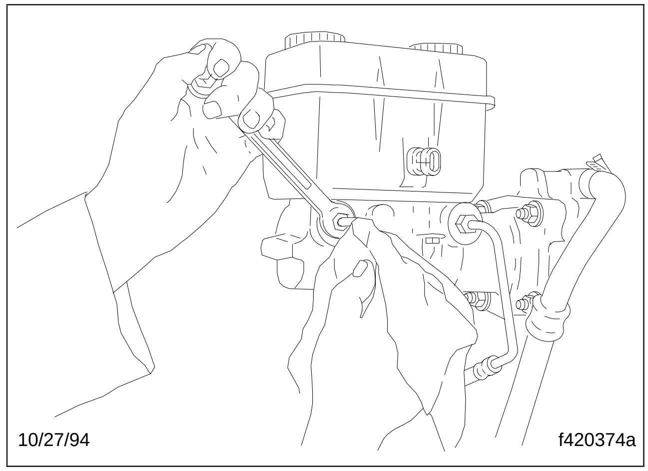


Fig. 4, Loosen the Fitting at the Front Outlet Port

4.8 Repeat steps as required for the front outlet port.

4.9 Check the brake fluid level in the master cylinder reservoir. Add new DOT 3 heavy duty brake fluid as needed.

5. Bleed the brake lines at the wheel calipers, starting at the right rear wheel caliper.

5.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tubing fits snugly. Submerge the other end of the tubing in a container of clean brake fluid. See **Fig. 2**.

5.2 Loosen the bleeder fitting by about 3/4-turn.

5.3 Have an assistant slowly push the brake pedal to the floor and hold it down. *Hold the brake pedal down* as you tighten the bleeder fitting.

IMPORTANT: Do not let off the brake pedal until the caliper fitting is tightened. Releasing

Hydraulic System Bleeding

the pedal before the fitting is tightened will suck air back into the system.

5.4 Release the brake pedal. Check the fluid in the tube. If there are air bubbles present, repeat bleeding as required until the fluid in the tube is completely free of air bubbles.

5.5 Check the brake fluid level in the reservoir. Add new DOT 3 heavy duty brake fluid as needed.

5.6 Repeat the steps for bleeding the left rear caliper, the right front caliper and the left front caliper. When finished, fill the reservoir to the bottoms of the narrow filler necks.

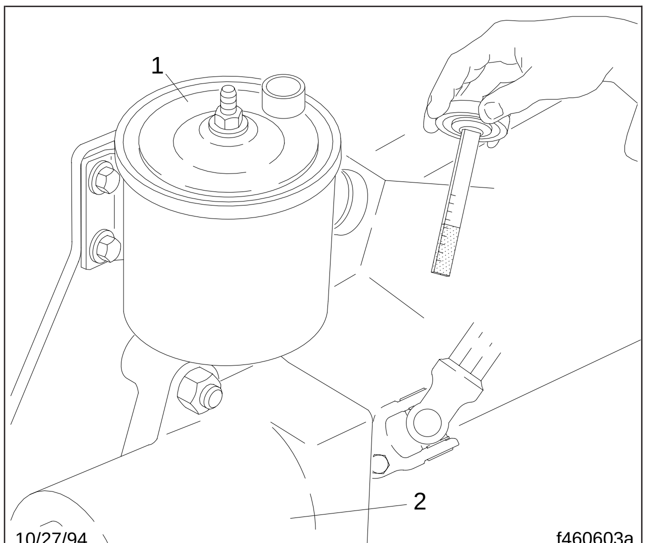
6. Close and latch the hood.
7. Connect the batteries.
8. Remove the chocks from the rear tires.
9. **Check the operation of the brakes by pumping the brake pedal several times until it feels firm.** The brake pedal should not go all the way down to the floor. If it does, see **Troubleshooting 300**.

Power Brake Booster Bleeding

WARNING

Use only clean, approved automatic transmission fluid (ATF) for the procedure below. Do not use DOT 3 brake fluid. Putting DOT 3 brake fluid in the power brake booster system will damage the seals and O-rings in the power brake booster, the power steering pump and the power steering gear. This could result in a loss of power steering and/or braking, which could possibly cause an accident resulting in property damage or serious personal injury.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Check the level of fluid in the power steering reservoir. See **Fig. 1**. Fill it with approved ATF as needed. See **Specifications 400** for approved ATF.



1. Power Steering Reservoir
2. Steering Gear

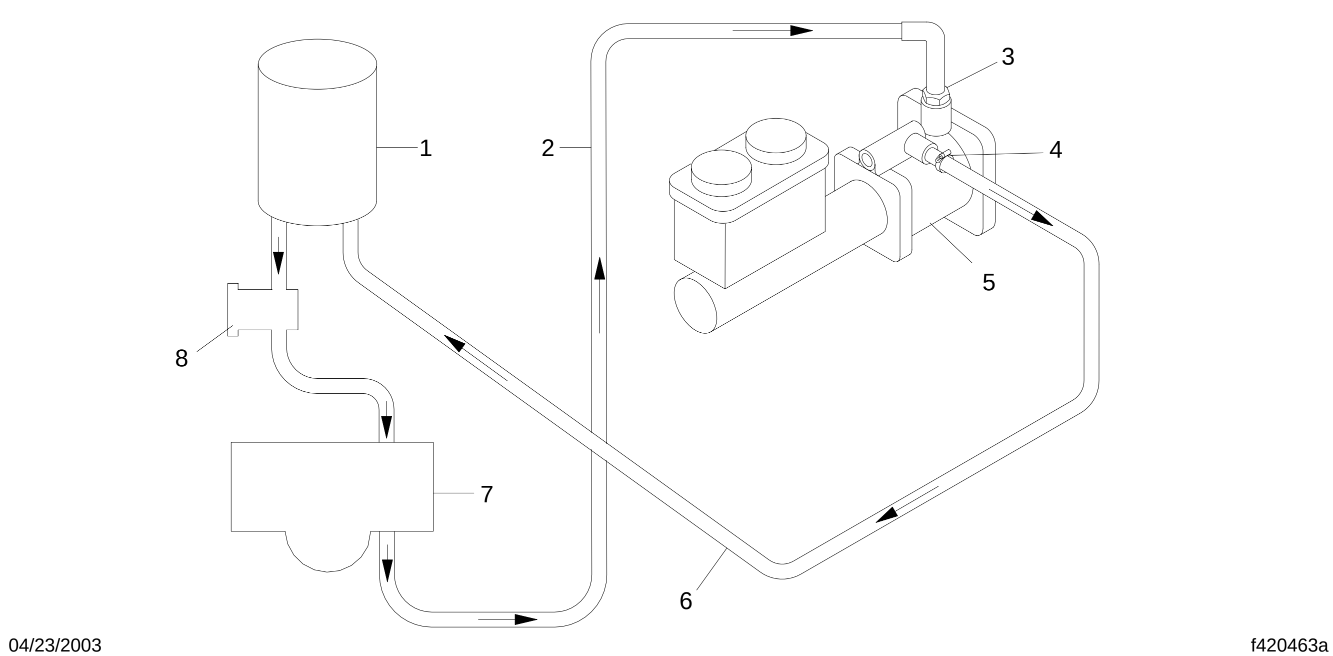
Fig. 1, ATF Level Check

4. Place the transmission in neutral and crank the starter several times, but do not start the engine.
5. Check the ATF level in the power steering reservoir. Fill, if needed.
6. Crank the starter and check the fluid level again.
7. Check the operation of the brakes.
   - 7.1 With the key off, push the brake pedal. The dash warning light and buzzer should come on and the backup pump should come on.
   - 7.2 Turn the key to the ON position, but do not start the engine. The dash warning light and buzzer should come on, and the backup pump should start to run.
   - 7.3 Start the engine. Depress the brake pedal. The dash warning light, buzzer and backup pump should stay off. If they come on, see **Troubleshooting 300** and find the problem.
   - 7.4 Shut down the engine. Check the ATF level in the power steering reservoir. Fill it as needed.
8. Close and latch the hood.
9. Remove the chocks from the rear tires.

Replacing Hydraulic Lines

Power Brake Booster System

The power brake booster gets pressurized ATF through its connection to the power steering gear and returns the ATF to the steering system into the power steering reservoir. See **Fig. 1**.



1. Power Steering Reservoir
2. Hydraulic Supply Line
3. Steel Fitting with O-Ring Seal
4. Hose Clamp
5. Power Brake Booster
6. Hydraulic Return Line
7. Power Steering Gear
8. Power Steering Pump

Fig. 1, Power Brake Booster System

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Replace all power steering hoses that are leaking or show signs of cracking, softening or bulging. Replace the entire hose; do not attempt to repair it.

3.1 Remove all hose clamps and tie straps used for routing the hose.

3.2 Using a shop towel over the fittings to catch dripping ATF power steering fluid, disconnect both ends of the hose being replaced.

3.3 Install the new hose.

If replacing the power brake booster supply hose, tighten the supply port connection to 21 ±5 lbf·ft (28 ±6 N·m), and the outlet connection on the power steering gear 41 lbf·ft (56 N·m).

If replacing the power brake booster return hose, tighten the hose clamps firmly at the booster return fitting and the power steering reservoir.

3.4 Install the hose clamps and replace any tie straps removed earlier.

Check the routing of the hose. Make sure it is away from heat sources and moving parts such as the steering and driveline. Make sure there are no kinks or sharp

Replacing Hydraulic Lines

bends in the hose, and that it can not be rubbed or pinched by other parts as they move.

4. Bleed the power brake booster system following the instructions in **Subject 120**.
5. Close and latch the hood.
6. Remove the chocks from the tires.

Service Brake System

The service brake system has two types of hydraulic brake lines, rigid steel tubing and flexible rubber hose.

The steel brake lines are 1/4-inch o.d. double-walled tubing, and run from the master cylinder to points on the chassis near each wheel. The rubber brake hoses are 1/8-inch i.d. low-expansion rubber; they connect the end of each rigid line to the caliper assembly at each wheel.

IMPORTANT: Use only lines or hoses approved for use in high pressure brake fluid applications.

Do not attempt to repair brake lines or hoses. Faulty lines or hoses must be replaced.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Locate the leak in the brake line. Determine the length and configuration (if a steel line) of the section involved.
4. If necessary, loosen and remove any brackets holding the brake line to the frame or axle so that you can remove the damaged section.
5. Put a container under the connection on one end of the leaking brake line. Disconnect the line. Plug both ends of the connection.

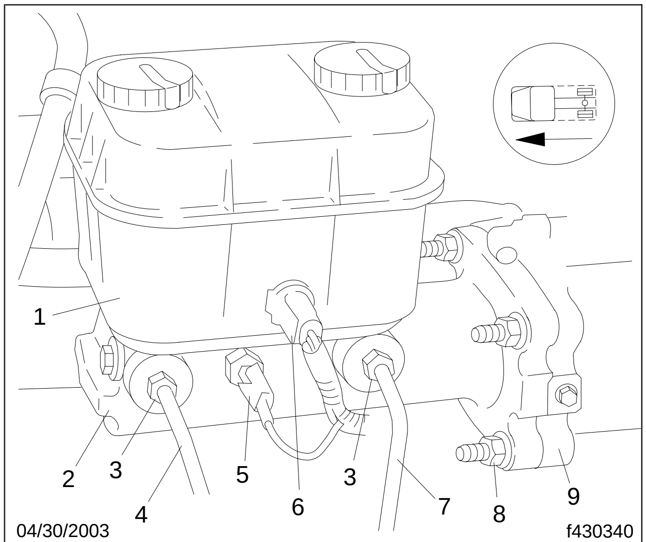
   Repeat at the connection on the other end of the leaking brake line, and remove it from the vehicle.
6. Remove the plugs installed earlier. Install the new section of brake line and tighten the connections.
7. Install any brackets that were removed.
8. Bleed the brake system following the procedure in **Subject 110**.
9. Close and latch the hood.
10. Remove the chocks from the rear tires.

Removal

WARNING

Before starting the procedure below, read the information in Safety Precautions 100. Exposure to brake fluid could cause serious, permanent health damage. Take precautions against exposing yourself to it.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Disconnect the wires from the pressure differential switch on the master cylinder body and the fluid level sensor on the reservoir. See Fig. 1.



1. Reservoir
2. Master Cylinder Housing
3. Brake Line Tube Nuts
4. Secondary Subsystem Brake Line
5. Pressure Differential Switch
6. Fluid Level Sensor
7. Primary Subsystem Brake Line
8. Flanged Hexnut
9. Power Brake Booster Mounting Flange

Fig. 1, Master Cylinder Assembly

CAUTION

Do not let the brake fluid get on any painted surface; it will quickly damage the paint. Wrap a rag around the fitting you are working on, or put a container underneath it to catch any fluid leaking as it is disconnected.

4. Disconnect the brake lines from the outlet ports of the master cylinder. See Fig. 2. Plug the brake lines to prevent contamination and leakage.
5. Remove the four flanged hexnuts that attach the master cylinder to the power brake booster unit. See Fig. 3.

   Remove the master cylinder from the vehicle. See Fig. 4. Keep it upright with a rag wrapped around it so you do not drip any brake fluid.

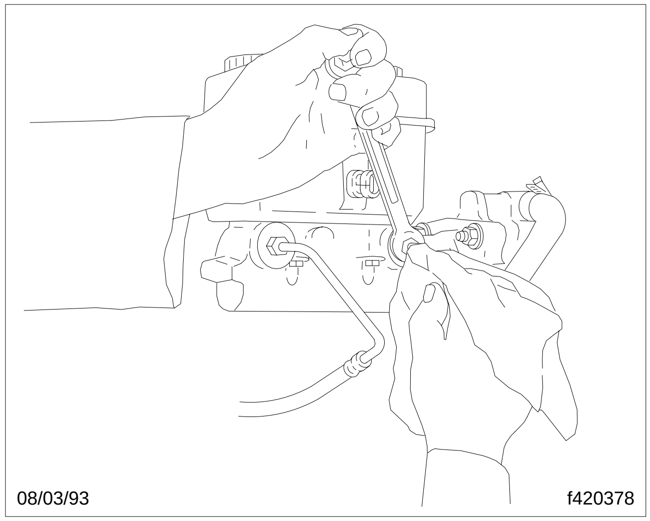


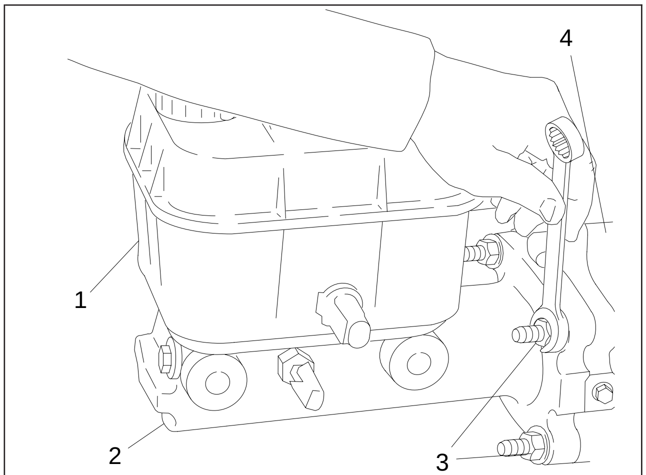
Fig. 2, Brake Lines

6. Remove the caps from the master cylinder reservoir, then carefully turn it over and dump the brake fluid into a container. Dispose of used brake fluid in a responsible and approved manner.

Installation

1. Bench bleed the master cylinder.
   - 1.1 Put the master cylinder and reservoir assembly in a vise.
   - 1.2 Install the plastic adapter and clear tubing on the master cylinder outlet ports, as shown in Fig. 5.

Master Cylinder Removal and Installation



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1. Reservoir
2. Master Cylinder
3. Flanged Hexnut
4. Power Brake Booster

Fig. 3, Remove Hexnuts

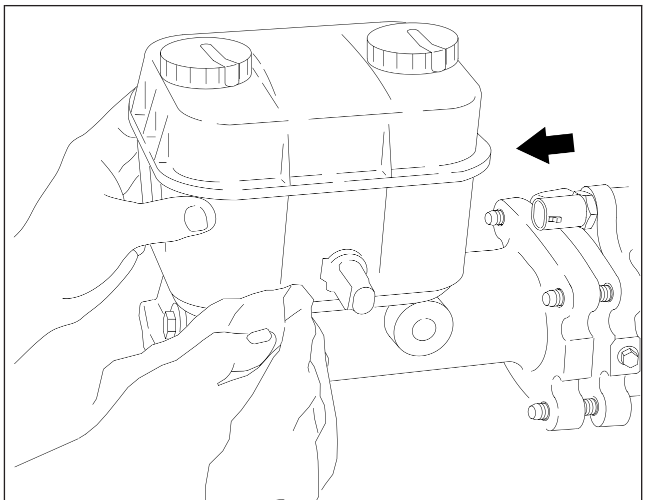

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Fig. 4, Remove the Master Cylinder

Put the other end of each tube up into the reservoir, as shown in **Fig. 6**.

1.3 Fill the reservoir about half-full with new DOT 3 heavy duty brake fluid.

1.4 Using a metal rod with a rounded end, push and release the primary piston several times. This purges air bubbles trapped in the master cylinder while returning fluid to the master cylinder reservoir.

The brake bleeder plastic adapters and tubing may be left in place to retain fluid until the master cylinder is in place and the vehicle brake lines are installed.

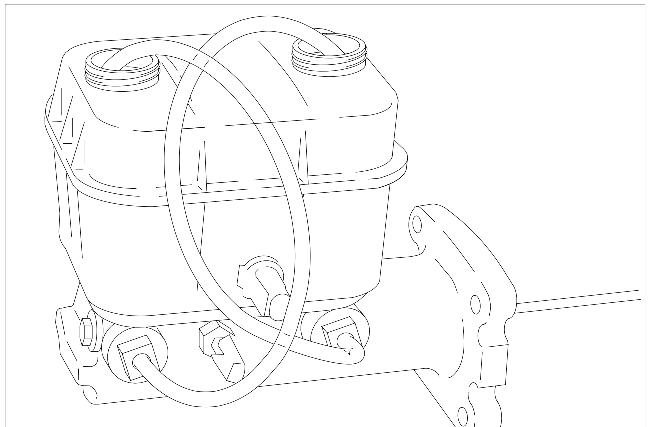

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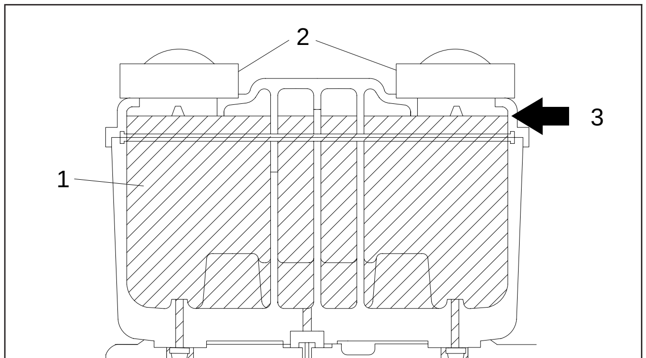
Fig. 5, Outlet Ports With Master Cylinder Bleeder Tubes



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1. DOT 3 brake fluid
2. Filler caps
3. Fill to bottom ring of filler neck

Fig. 6, Master cylinder fill level

2. Slip the master cylinder onto its studs on the front of the power brake booster, install the four flanged nuts on the studs of the power brake booster and tighten to 27 lbf·ft (37 N·m).
3. Remove the plastic bleeder tubes if they were left on after bench bleeding. Connect the secondary circuit line to the front outlet port on the

master cylinder, and the primary circuit line to the rear outlet port. Tighten the fittings to maximum 16 lbf·ft (22 N·m).

4. Connect the wires to the pressure differential switch and the fluid level sensor. See **Fig. 1**.
5. Fill the reservoir to the bottom of the narrow throat formed by the fill opening with new DOT 3 heavy duty brake fluid. See **Fig. 6**.
6. Bleed the entire brake system following the instructions in **Subject 110**.
7. Close and latch the hood.
8. Remove the chocks from the tires.

Hydro-Max® II Power Brake Booster Removal and Installation

Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Disconnect the batteries at the negative cable.
4. If the brake master cylinder is still mounted on the power booster, remove it following the instructions in **Subject 140**.
5. Inside the cab, disconnect the brake pedal rod from the brake pedal.
   - 5.1 Below the dash, find the clevis pin, washer, and cotter key that connect the power booster push rod to the brake pedal. See **Fig. 1**.

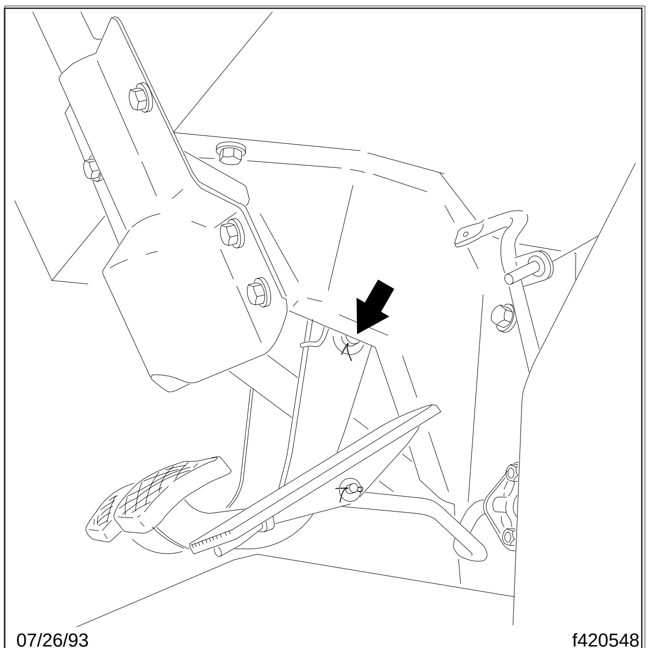
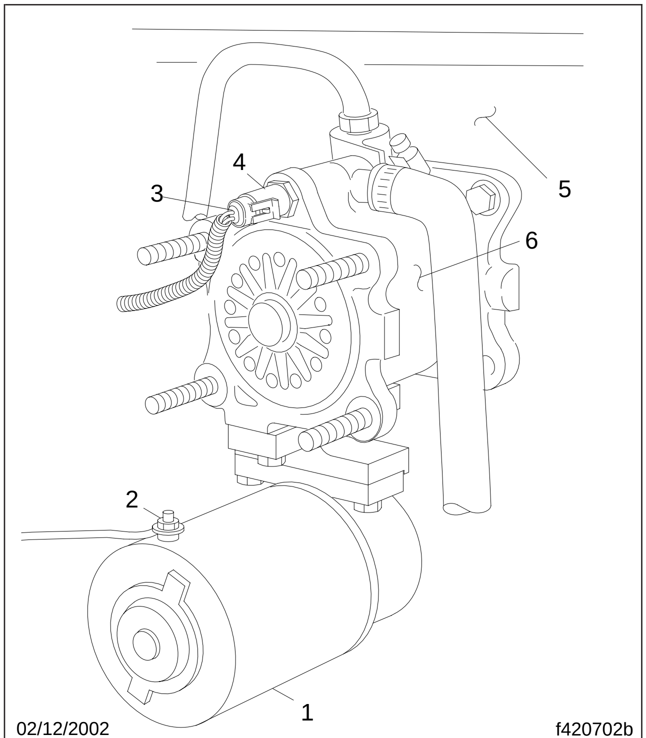


Fig. 1, Brake Pedal

   - 5.2 Remove the cotter key, washer and clevis pin.
6. Disconnect the wiring from the backup pump assembly. See **Fig. 2**.
7. Disconnect the wiring from the flow switch at the front of the power brake booster. See **Fig. 2**.



1. Backup Pump
2. Backup Pump Power Lead
3. Flow Switch Wiring
4. Flow Switch
5. Frontwall
6. Power Brake Booster Housing

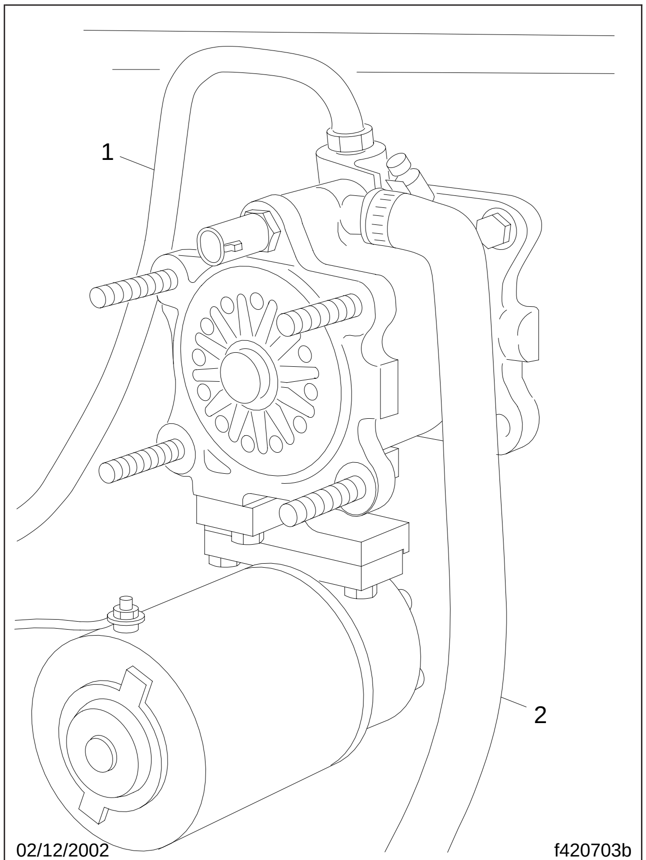
Fig. 2, Backup Pump Assembly (actual appearance may vary)

8. Using a shop towel or a container to catch any leaking automatic transmission fluid (ATF), disconnect the hydraulic supply and return lines from the power brake booster. See **Fig. 3**. Plug the lines.
9. Remove the four hexbolts and washers holding the power brake booster to the frontwall. See **Fig. 4**. Pull the power brake booster straight out from the frontwall. See **Fig. 5**.

Installation

1. Position the power brake booster on the frontwall so the brake pedal rod fits through the large hole and into the cab and the four holes in the power brake booster line up with those on the frontwall. See **Fig. 5**.

Hydro-Max® II Power Brake Booster Removal and Installation



1. Supply Line (steel)
2. Return Line (rubber)

Fig. 3, Power Brake Booster Lines (actual appearance may vary)

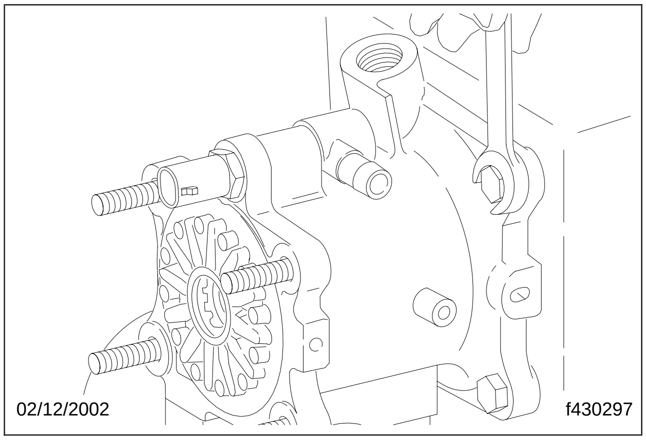


Fig. 4, Power Brake Booster Mounting (actual appearance may vary)

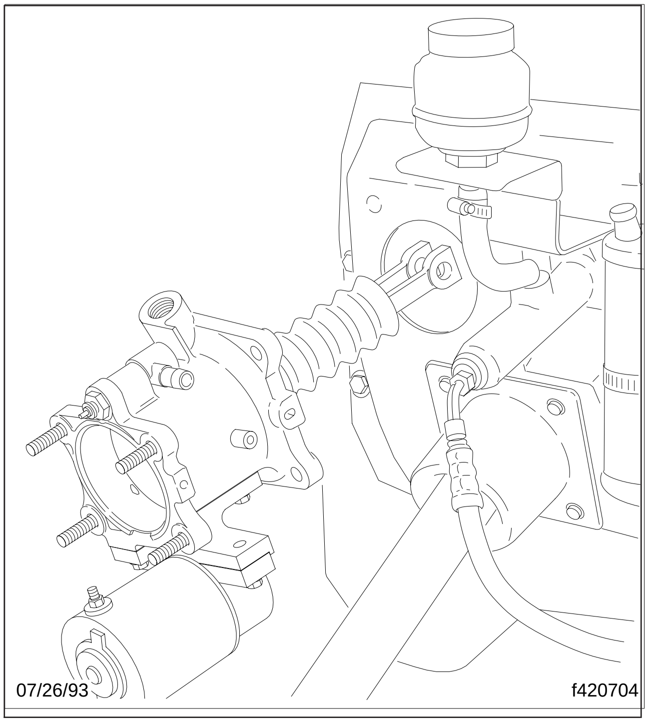
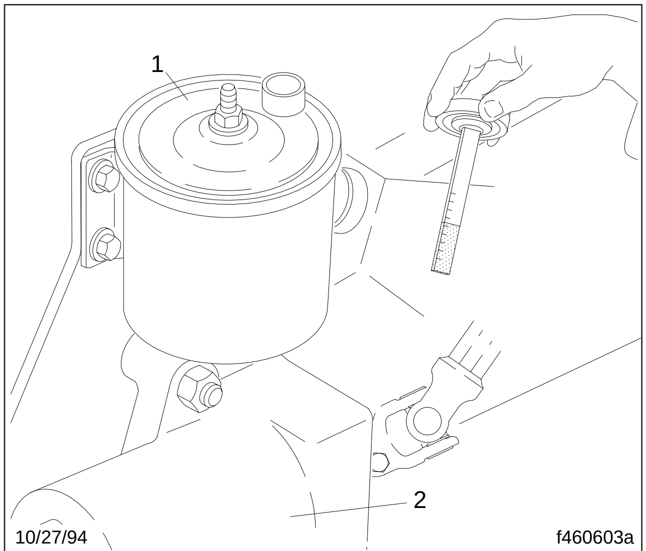


Fig. 5, Power Brake Booster Removal

2. Install the four mounting hexbolts and washers. See **Fig. 4**. Tighten to 27 lbf·ft (37 N·m).
3. Install the master cylinder on the power brake booster, following the instructions in **Subject 140**.
4. Connect the hydraulic supply and return lines See **Fig. 3**. Tighten the supply line to 21 lbf·ft (28 N·m). Tighten the hose clamp on the return line firmly.
5. Connect the wiring to the backup pump assembly and to the flow switch assembly. See **Fig. 2**.
6. Check the ATF level in the power steering reservoir See **Fig. 6**. Add approved ATF if needed. See **Specifications 400** for the approved ATF.
7. Connect the batteries.
8. Bleed the power brake booster following the instructions in **Subject 110**.
9. Close and latch the hood.
10. Remove the chocks from the rear tires.

Hydro-Max® II Power Brake Booster Removal and Installation



1. Power Steering Reservoir
2. Steering Gear

Fig. 6, Fluid Level Check

Hydraulic Brake Electronic Monitor Module Removal and Installation

NOTE: The monitor module is located on the driver side of the dash behind the instrument control unit (ICU).

Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries at the negative terminals.
3. Inside the cab, remove the dash trim panel. See **Fig. 1**.

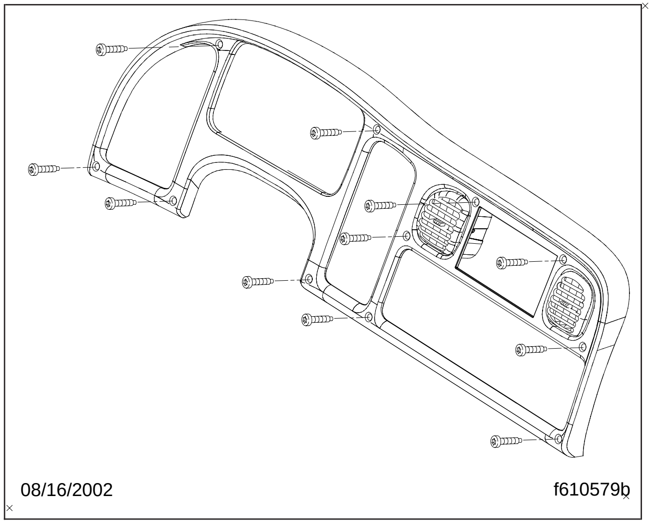


Fig. 1, Dash Trim Panel

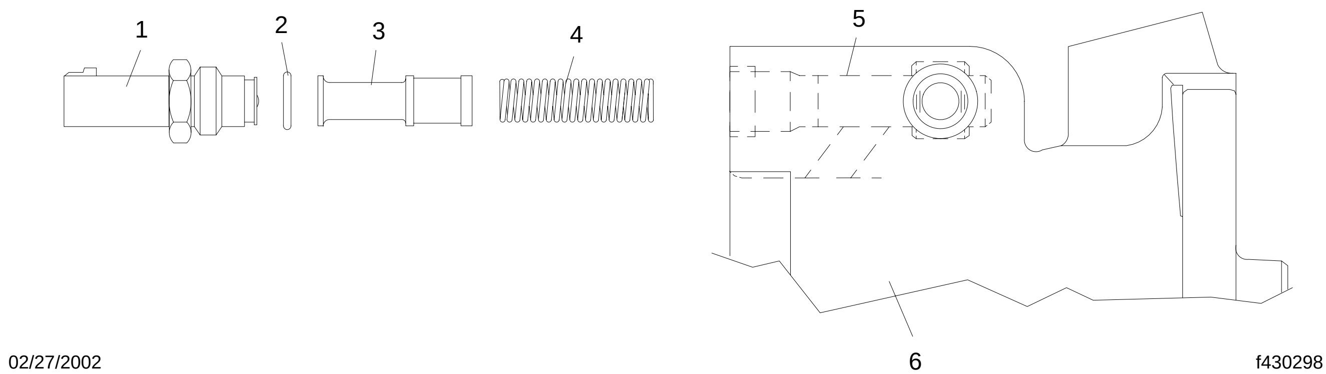
4. Locate the monitor module behind the instrumentation control unit (ICU-M2). Disconnect the 9-pin connector and the 4-pin connector from the module.
5. If necessary in order to remove the monitor module, remove the U-M2. For instructions, see **Section 54.04**, Subject 100.
6. Remove the monitor module.

Installation

1. Connect the 9-pin and the 4-pin connectors to the monitor module.
2. Install the monitor module on the mounting bracket.
3. If it was removed, install the ICU-M2. For instructions, see **Section 54.04**, Subject 100.
4. Install the dash trim panel. See **Fig. 1**.
5. Connect the batteries.
6. Remove the chocks from the rear tires.
7. Verify proper operation of the monitor module. See **Subject 120**.

Flow Switch Removal, Inspection and Installation

NOTE: Refer to **Fig. 1** when performing the following procedures.



1. Contact Assembly
2. O-Ring
3. Metering Piston
4. Spring
5. Flow Switch Bore
6. Booster

Fig. 1, Flow Switch Assembly (exploded view)

The most likely conditions requiring service of the flow switch are:

- Contamination of the metering piston.
- Damaged contact assembly.
- Leaking at the contact assembly.
- The backup pump running continuously when the engine is running.
- The backup pump not running when it should be.

Removal

1. Park the vehicle on a level surface, shut down the engine, apply the parking brakes and chock the tires.
2. Disconnect the batteries.
3. Place a suitable container under the booster to catch any automatic transmission fluid (ATF) that may drain out while removing the flow switch contact assembly.
4. Disconnect the wiring harness flow switch connector from the flow switch contact assembly.
5. Remove the contact assembly from the booster. Be prepared to catch the metering piston; it may be pushed out of the booster housing by the spring.
6. If the metering piston did not come out by itself, use a small magnet to extract the metering piston and spring from the bore.

Inspection

1. If the contact assembly is damaged, replace it.
2. If the O-ring seal is damaged, replace it.
3. Inspect the opening into the booster and inspect the flow switch bore. These surfaces must be clean and free of particles, chips or any other form of contaminant. Remove any contaminant.
4. Inspect the metering piston and spring for cleanliness. Remove any contaminants.

Installation

1. If a new contact assembly or O-ring is being used, install the O-ring onto the contact assembly.
2. Install the spring and metering piston into the flow switch bore.
3. Install the contact assembly and O-ring into the booster. Tighten 20 to 40 lbf·in (2 to 4 N·m).
4. Connect the wiring harness flow switch connector to the flow switch contact assembly.

Flow Switch Removal, Inspection and Installation

5. Fill the power steering pump reservoir to the proper level with ATF. Do not reuse old ATF from the booster.
6. Connect the battery ground cable.
7. Confirm proper installation of the switch.
   7.1 Start the engine. With the engine running, the power steering pump circulates ATF through the system. This automatically purges air from the booster.
   7.2 While the engine is running, press on the brake pedal several times to make sure the pedal feels normal.
8. Shut the engine off. Press on the brake pedal several times to make sure the pedal feels normal in the backup pump mode.
9. Check for leakage at the flow switch contact assembly.
10. Confirm that the backup pump does not run when the engine is running.
11. Confirm that the backup pump runs both when the engine is off and the ignition key is on, and when the ignition key and engine are off but the brake pedal is depressed.
12. Recheck the ATF level in the power steering pump reservoir. If necessary, add ATF.
13. Road test the vehicle to ensure proper steering and braking operation.

Hydraulic Brake Troubleshooting Index		
Common Categories	**Subject**	**Figure/Table**
Warning light and buzzer related to parking brake	Subject 300	**Fig. 1**
Warning light and buzzer related to service brake	Subject 300	**Fig. 2**
Backup pump runs continuously	Subject 300	**Fig. 3**, **Fig. 4**
Backup pump does not run	Subject 300	**Fig. 5**, **Fig. 4**
Abnormal brake pedal conditions	Subject 300	**Fig. 6**, **Fig. 8**
Hydraulic system leakage	Subject 300	**Fig. 9**, **Fig. 10**, **Fig. 11**, **Fig. 12**
Brakes are dragging	Subject 300	**Fig. 13**, **Fig. 14**
Short pad life, uneven pad wear, or overheated brakes	Subject 300	**Fig. 13**
Brake system pressure test	**Subject 310**	**Fig. 1**
Hydraulic brake system plumbing diagram	**Subject 400**	**Fig. 2**
Hydraulic system fluid specification	**Subject 400**	**Table 2** and **Table 3**
Fastener torque table	**Subject 400**	**Table 1**

Table 1, Hydraulic Brake Troubleshooting Index

Troubleshooting

This subject is designed to help service technicians do their own troubleshooting and to help them troubleshoot customer complaints. This guide covers most common problems encountered in the field, but some unusual problems may require approaches and remedies not covered here.

NOTE: This subject does not deal with pressure tests, they are covered in **Subject 310**.

Warning Light and Buzzer Related to Parking Brake

There may be two lights generally relating to brakes: the parking/service brake light, and an ABS light if the vehicle has ABS. This section refers only to the parking/service brake light, not ABS. There is one buzzer for all brake signals.

The brake light and buzzer come on together when triggered by one or more of the following:

- the parking brake switch
- the flow switch
- the fluid level indicator switch
- the differential pressure switch
- the electric backup pump

See **Fig. 1** for troubleshooting if the problem seems to be with the parking brake, or **Fig. 2** if the service brakes seem to be the problem.

Brake Warning Light and Buzzer Related to Service Brake

See **Fig. 2** for troubleshooting.

Backup Pump Runs Continuously

Normally, the backup pump will run only if the flow switch has activated its relay.

A good relay will run the backup pump only if it is triggered by the flow switch and there is power to the relay's coil. A bad relay can be stuck ON, making the backup pump run even though the relay coil is not triggered. A bad relay can also make the backup pump run although the flow switch has not triggered it.

See **Fig. 3** for troubleshooting and **Fig. 4** for electrical circuits of the master cylinder and power brake booster.

Backup Pump Does Not Run

The backup pump will not run if there is no voltage to the motor or if the motor is damaged — burnt out or

Troubleshooting

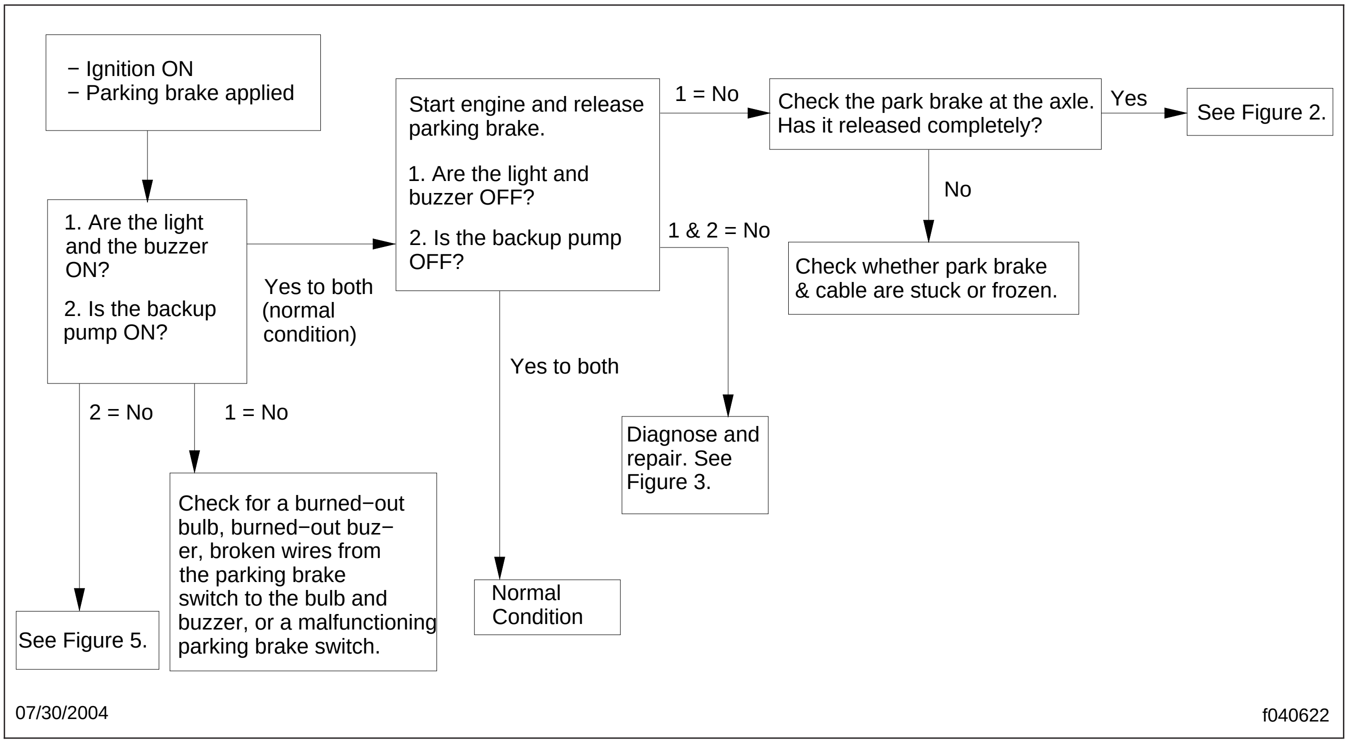


Fig. 1, Flow Chart: Brake Warning Light and Buzzer Relating to Parking Brake

jammed, for instance. Following are some of the possible reasons for the backup pump not running:

- a dead battery
- a broken relay
- a broken wire between the battery and pump motor
- a break in the circuit between the ignition switch/brake light switch and the flow switch
- a bad ground to the flow switch

See **Fig. 5** for troubleshooting and **Fig. 4** for electrical components of the master cylinder and power brake booster.

Abnormal Brake Pedal Conditions

Abnormal pedal conditions defined in this section include the following. See **Fig. 6** for flow chart diagnosis.

- Brake pedal dropping 1/2-inch when the engine is started.
- The brake pedal feels spongy, springy or soft.
- The brake pedal continues to fall with steady foot force.
- The brake pedal feels very hard.

Most common reasons for a very hard pedal—

- Insufficient flow or pressure from the power steering pump;
- ABS is blocking flow of brake fluid to the calipers.

Less likely causes include:

- contaminated power brake booster
- contaminated master cylinder
- binding pedal linkage
- binding power brake booster
- binding master cylinder
- blocked or kinked brake fluid tubes or hoses

With the engine OFF other causes are—

- Backup pump does not run;

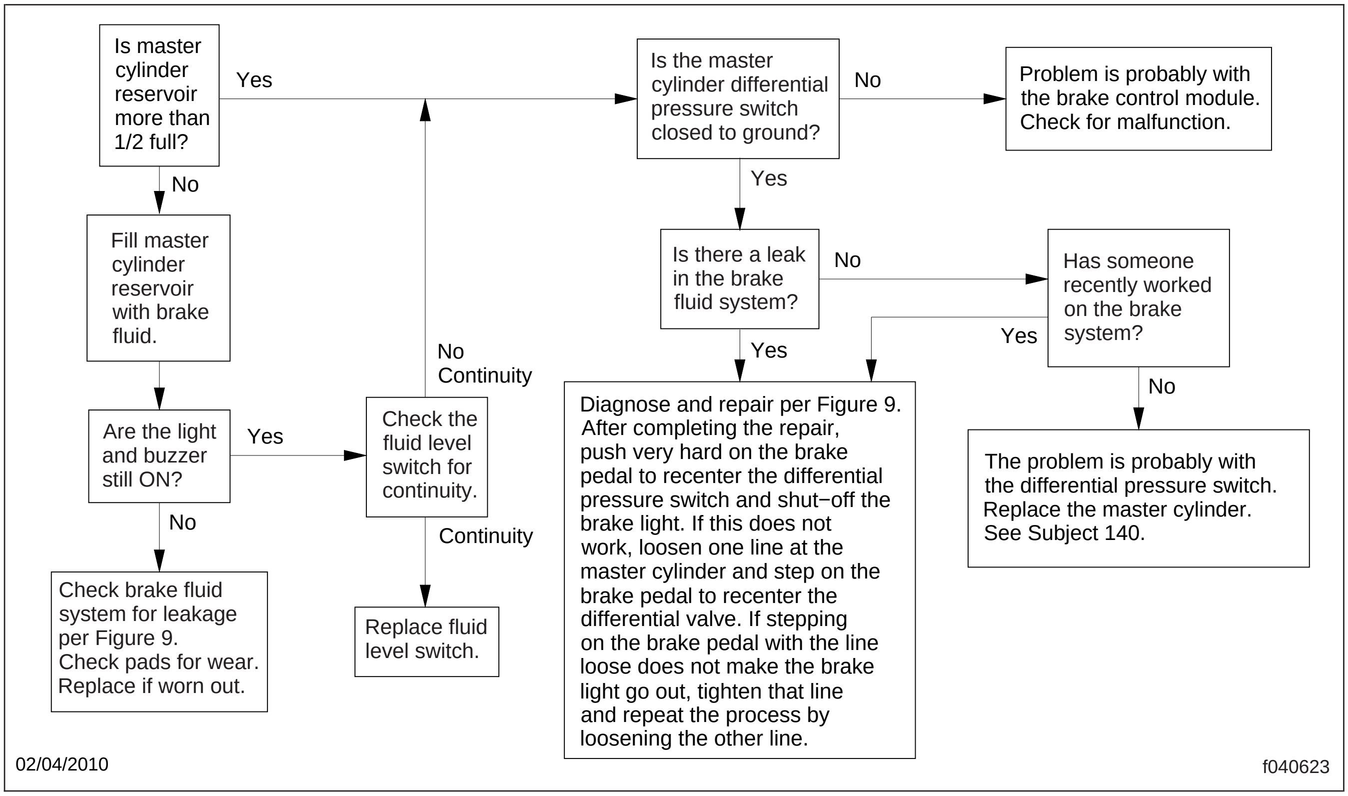


Fig. 2, Flow Chart: Brake Warning Light and Buzzer for Service Brake Problems

- The backup pump does not provide sufficient pressure.

See **Fig. 6** for abnormal brake conditions flow chart. **Fig. 7** illustrates how the rubber seals swell if ATF is put into the master cylinder.

See **Fig. 8** for flow chart regarding very hard brake pedal feel.

Hydraulic System Leakage

See **Fig. 9** and **Fig. 10** if hydraulic fluid leakage is detected.

See **Fig. 11** for the most frequent leak points at the power brake booster.

If fluid is leaking from any of the points listed in **Fig. 11**, see **Fig. 12**.

Brakes are Dragging

The following are possible causes for brake drag:

- The power brake booster does not return to the released position.
- The brake pedal linkage does not return to the released position.
- The master cylinder does not return to the re-leased position.
- The ABS system is trapping hydraulic pres-sure.
- The brake calipers don’t release.
- The brake lines or hoses are plugged, kinked, or collapsed.

NOTE: Some tests require doing things in the cab while at the same time, or within a few sec-onds, watching what happens elsewhere on the vehicle. These tests require two people.

See **Fig. 13** and **Fig. 14** for complete brake drag di-agnostics.

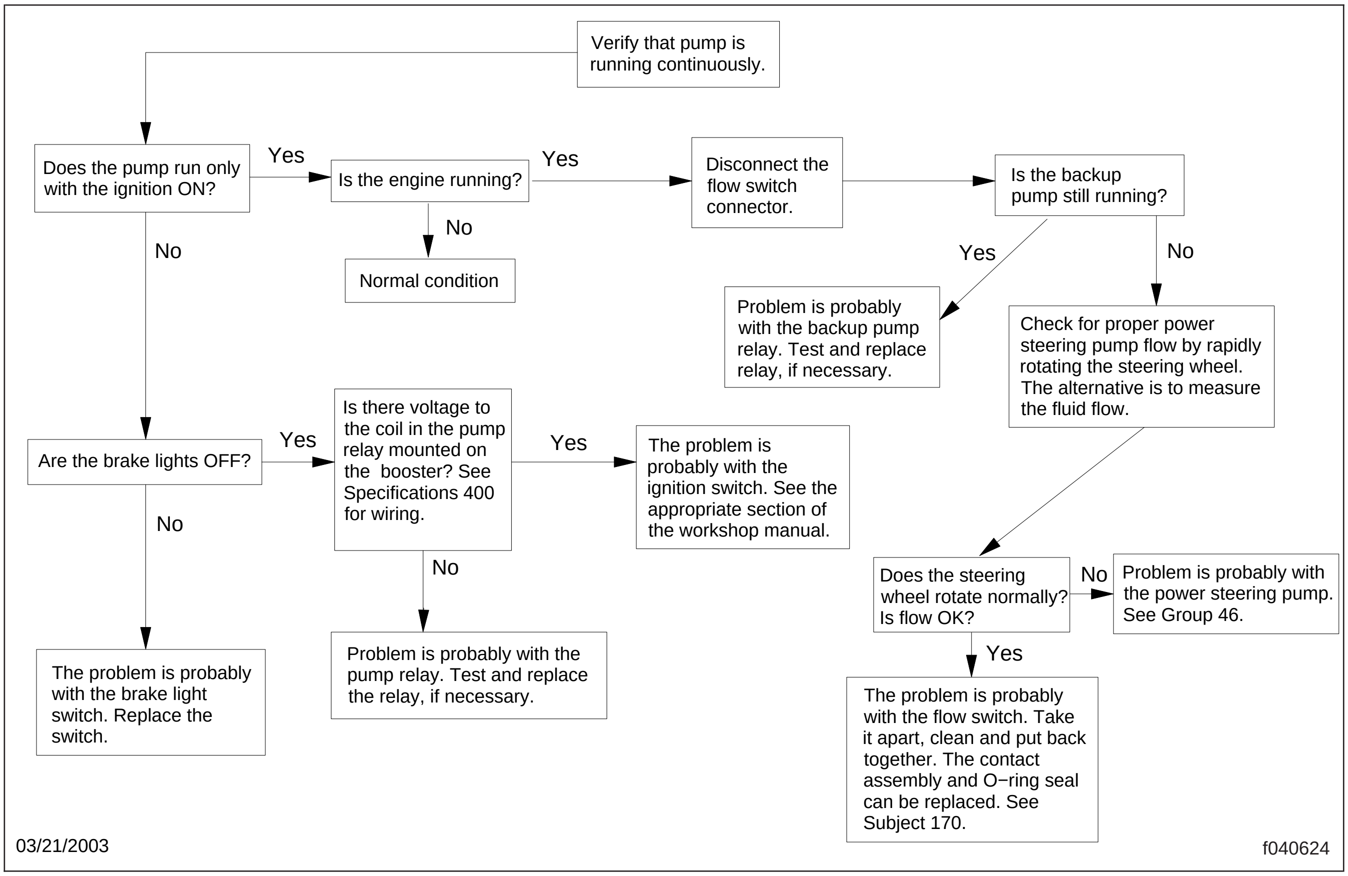


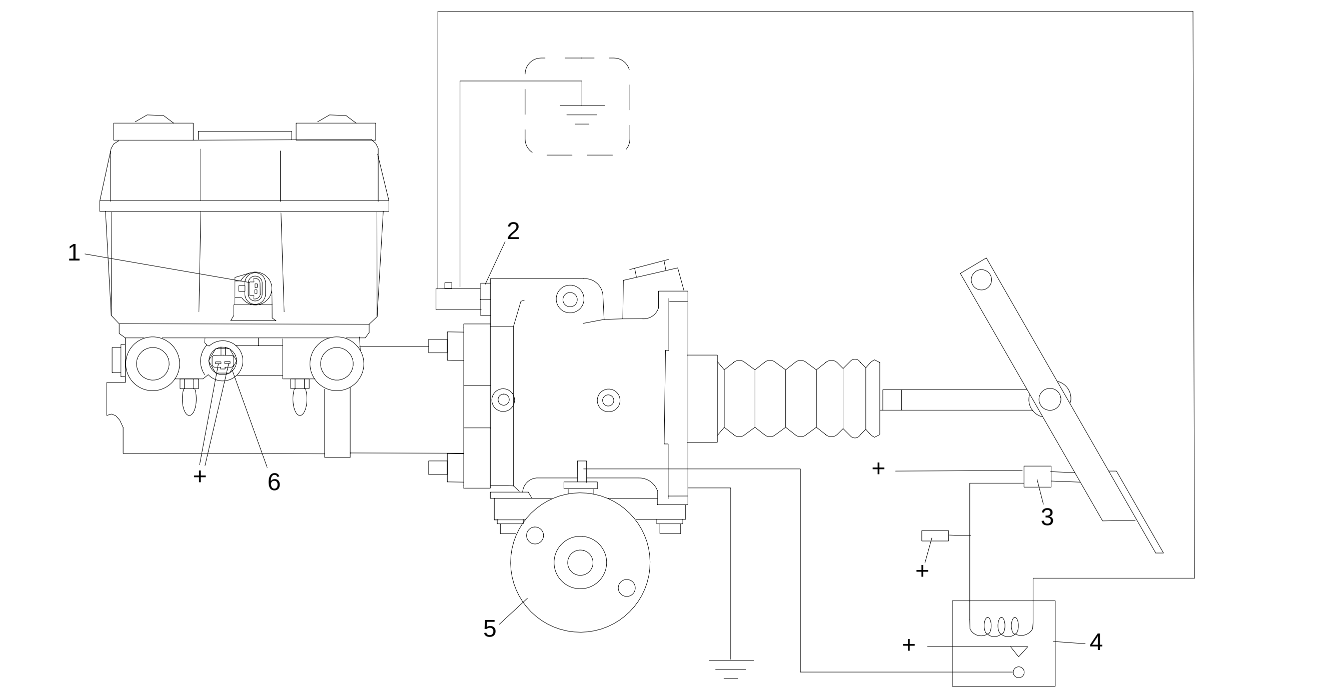
Fig. 3, Flow Chart: Backup Pump Runs Continuously

Short Pad Life, Uneven Pad Wear, or Overheated Brakes

NOTE: Because of vast differences in vehicle types, usage, terrain, driving style and many other factors, it is not possible to make a general prediction of brake lining life. In some cases of severe usage, short lining life is to be expected and does not indicate a problem in the brake system.

1. Check whether the brake pads are wearing abnormally. For instance, check whether the inner and outer pads are wearing unevenly.
2. If the brakes are dragging, smoking, overheating, smelling, pulling, or if there is poor acceleration, see **Fig. 13**.

   If the brake wear is not caused by one of these conditions, the problem is probably related to vehicle usage or the driver's braking habits. For low temperature or low duty conditions, consult the brake manufacturer for appropriate replacement linings.



1. Fluid Level Indicator Switch
2. Flow Switch
3. Brake Light Switch
4. Relay
5. Backup Pump
6. Differential Pressure Switch

Fig. 4, Electrical Components of the Master Cylinder and Power Brake Booster

Troubleshooting

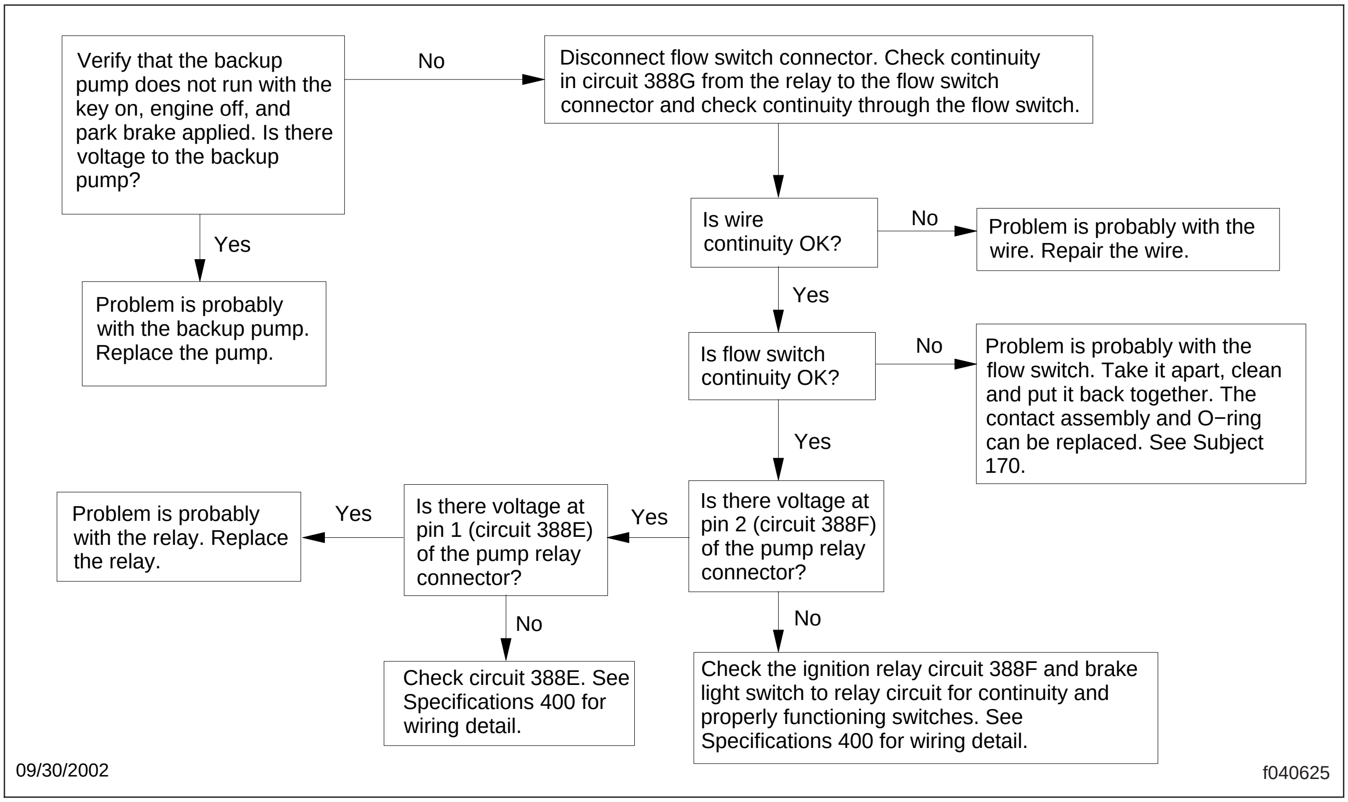


Fig. 5, Flow Chart: Backup Pump Does Not Run

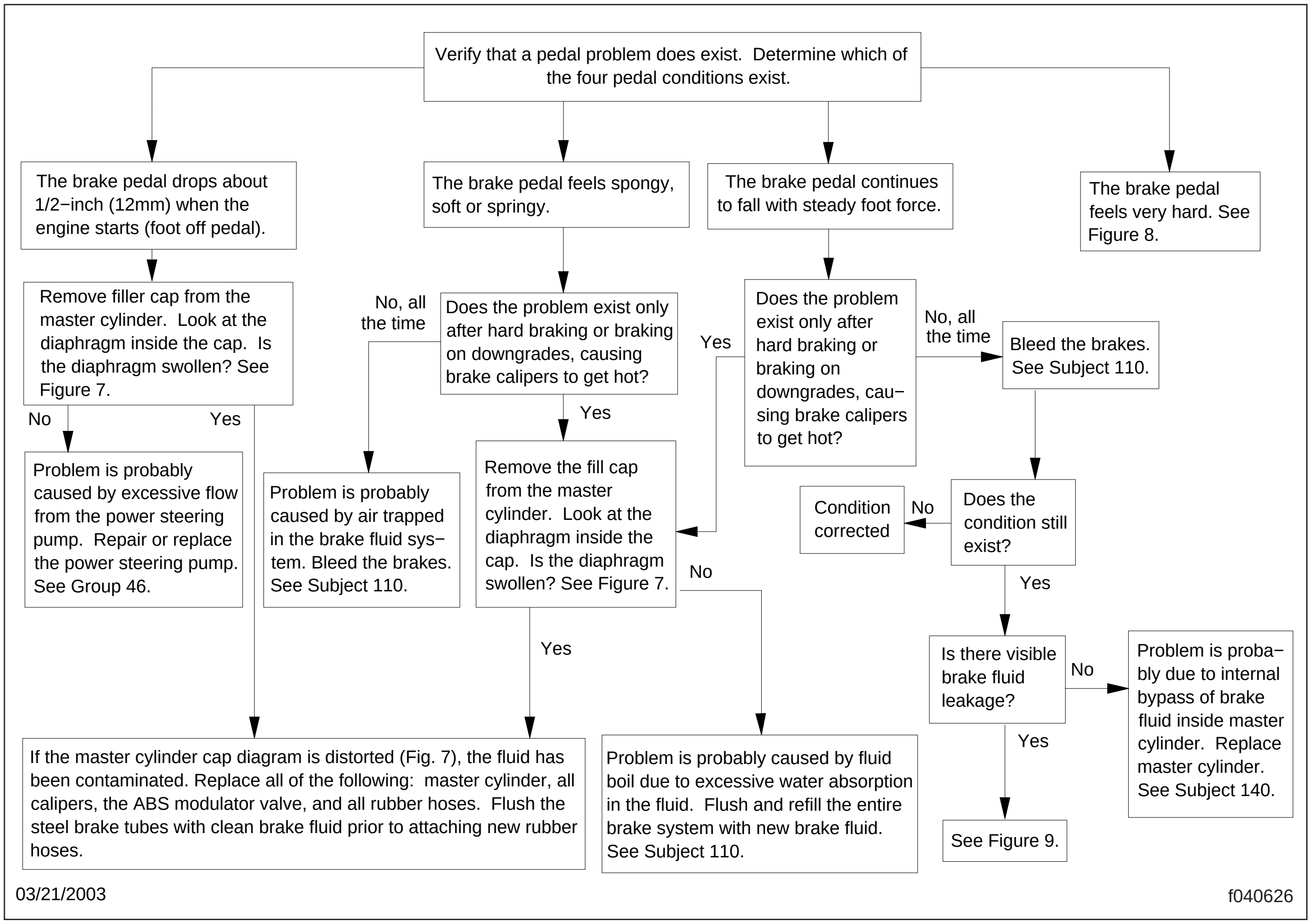
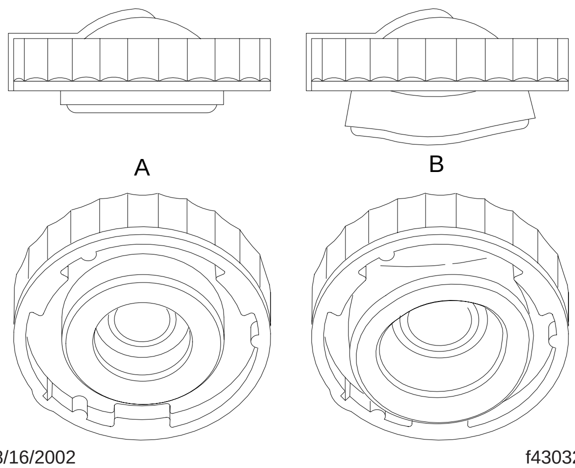


Fig. 6, Flow Chart: Abnormal Brake Pedal Conditions

Troubleshooting



A. Reservoir cap and diaphragm from uncontaminated system.
B. Reservoir cap and diaphragm from a system contaminated with power steering fluid, motor oil or ATF.

Fig. 7, Good and Bad Master Cylinder Fluid Reservoir Caps and Diaphragms

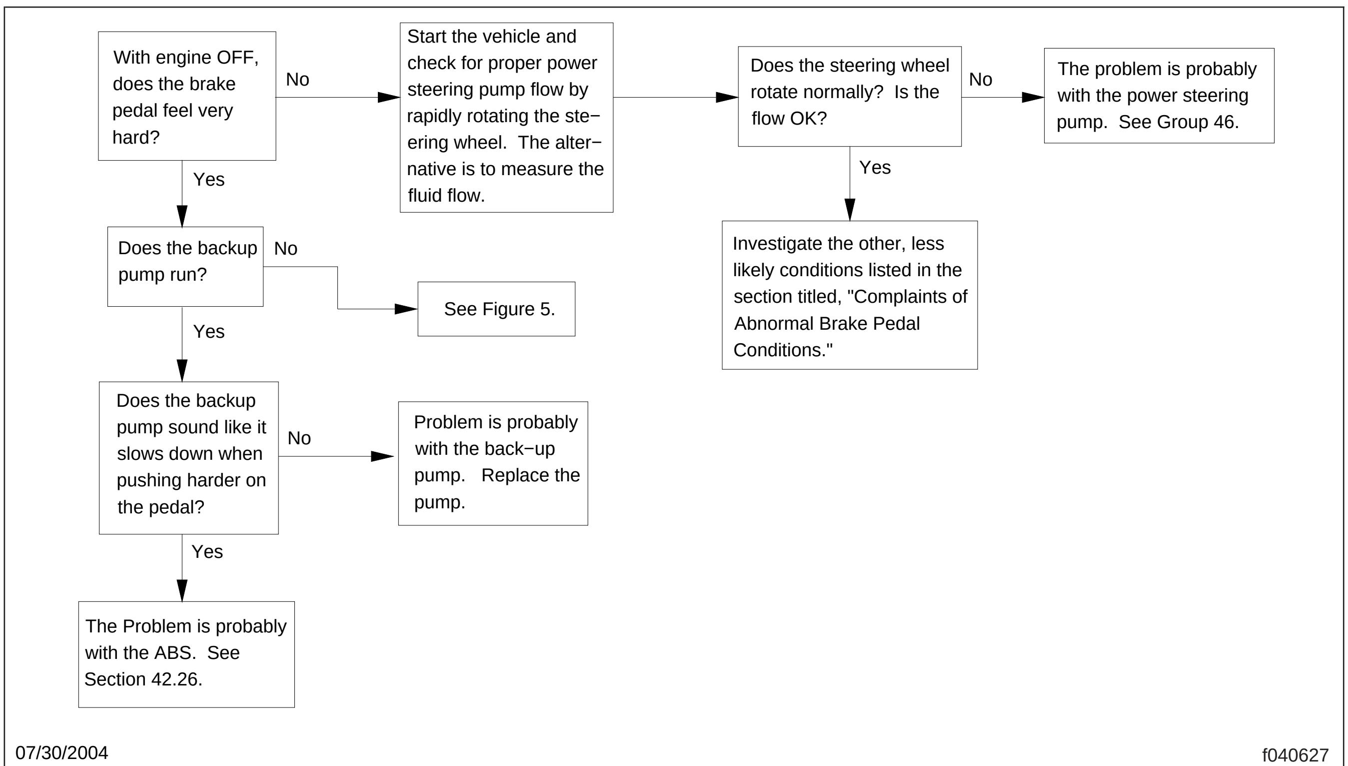


Fig. 8, Flow Chart: Brake Pedal Feels Very Hard

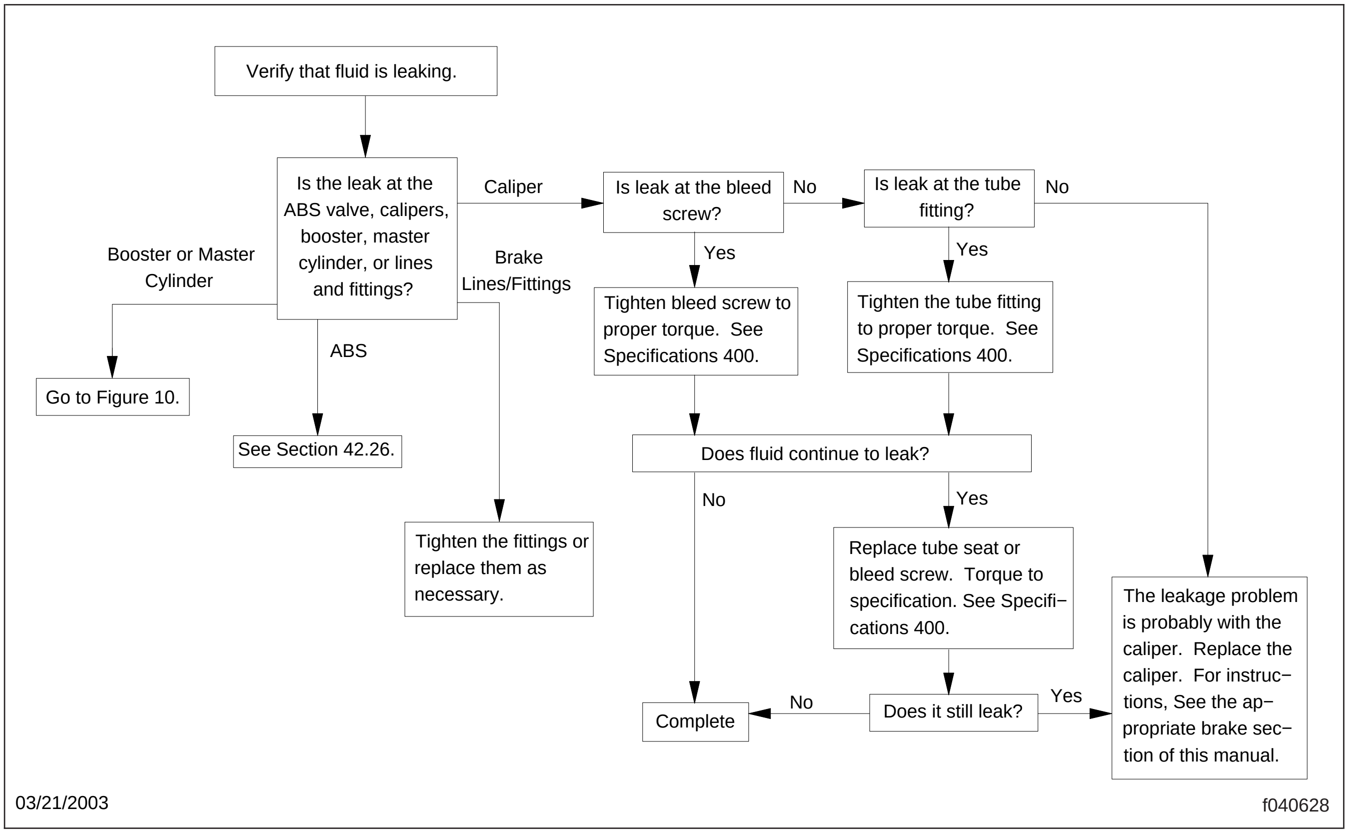


Fig. 9, Flow Chart: Hydraulic System Leakage

Troubleshooting

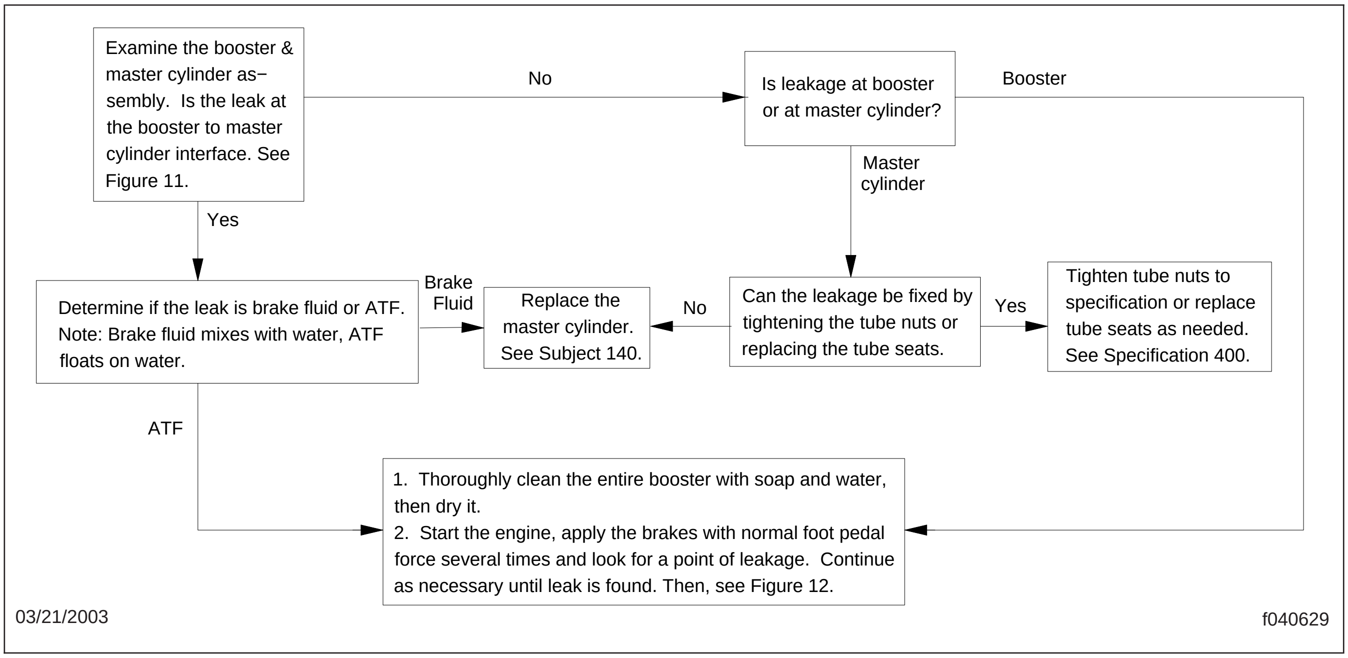
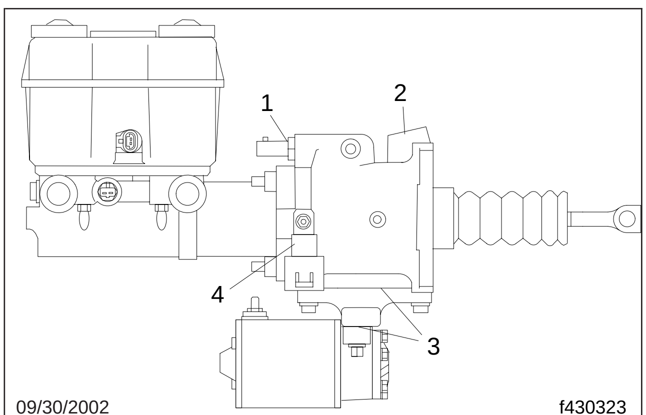


Fig. 10, Flow Chart: Hydraulic System Leakage (cont.)



1. Flow Switch and Power Brake Booster Interface
2. Inlet Port
3. Booster, Adapter and Pump Interface
4. Power Brake Booster and Master Cylinder Interface

Fig. 11, Potential Hydraulic Fluid Leak Points

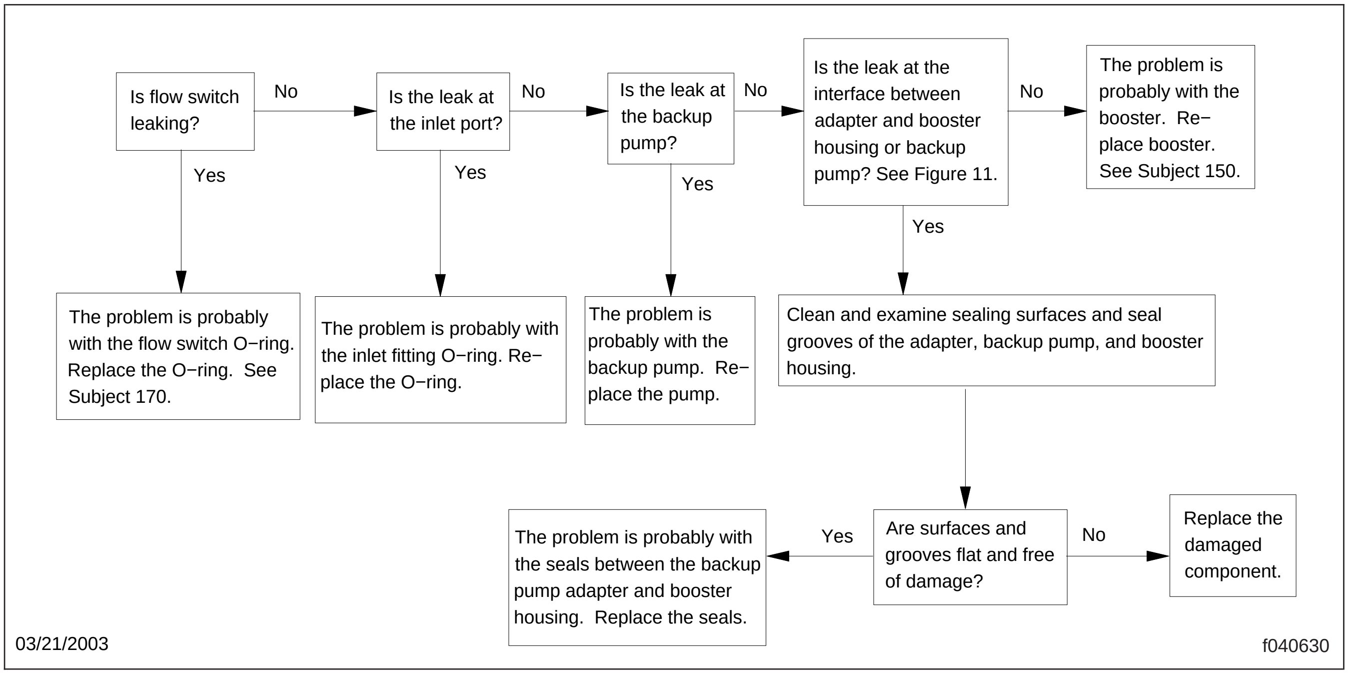


Fig. 12, Flow Chart: Hydraulic System Leakage (cont.)

Troubleshooting

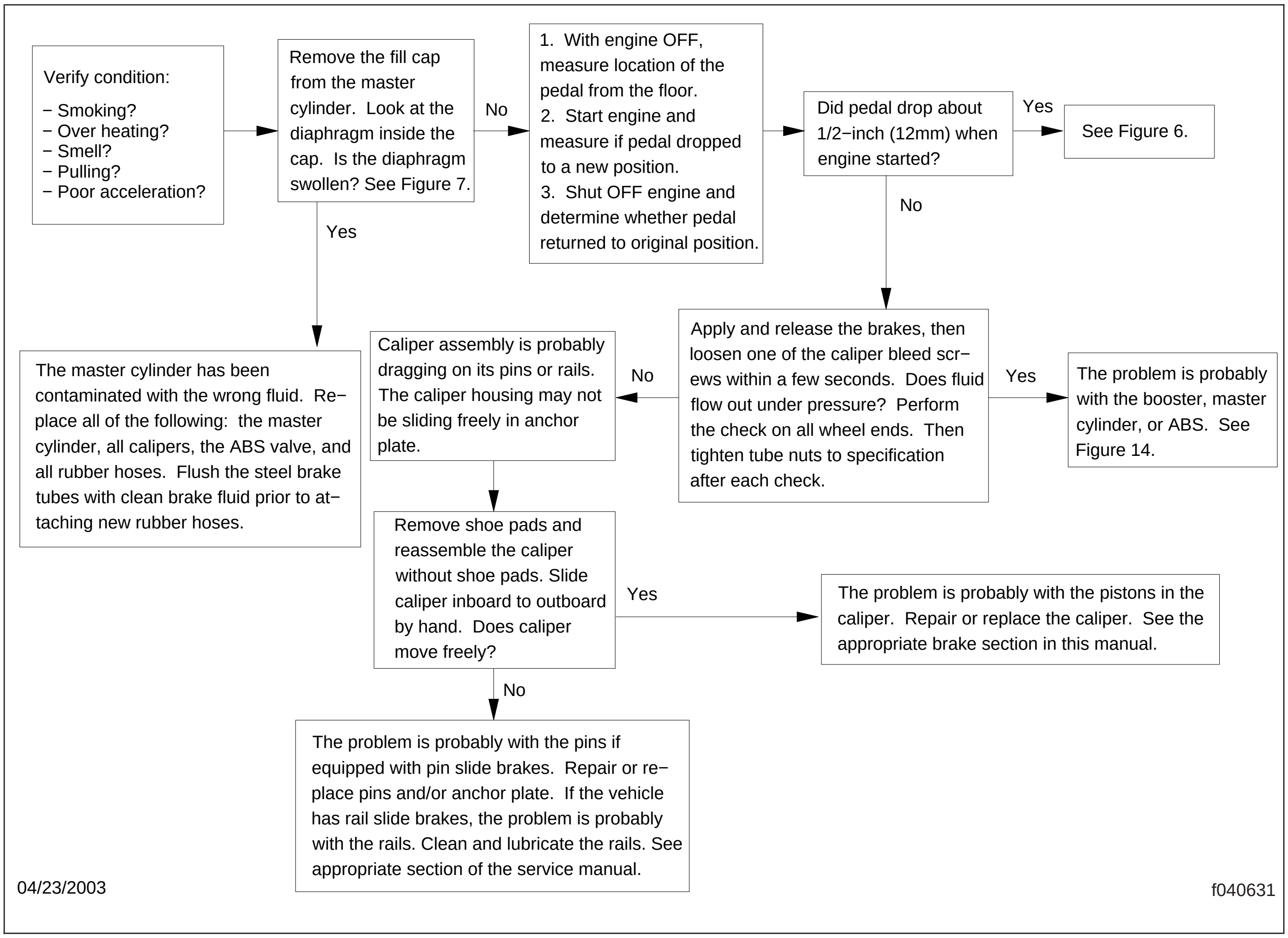


Fig. 13, Flow Chart: Brakes are Dragging

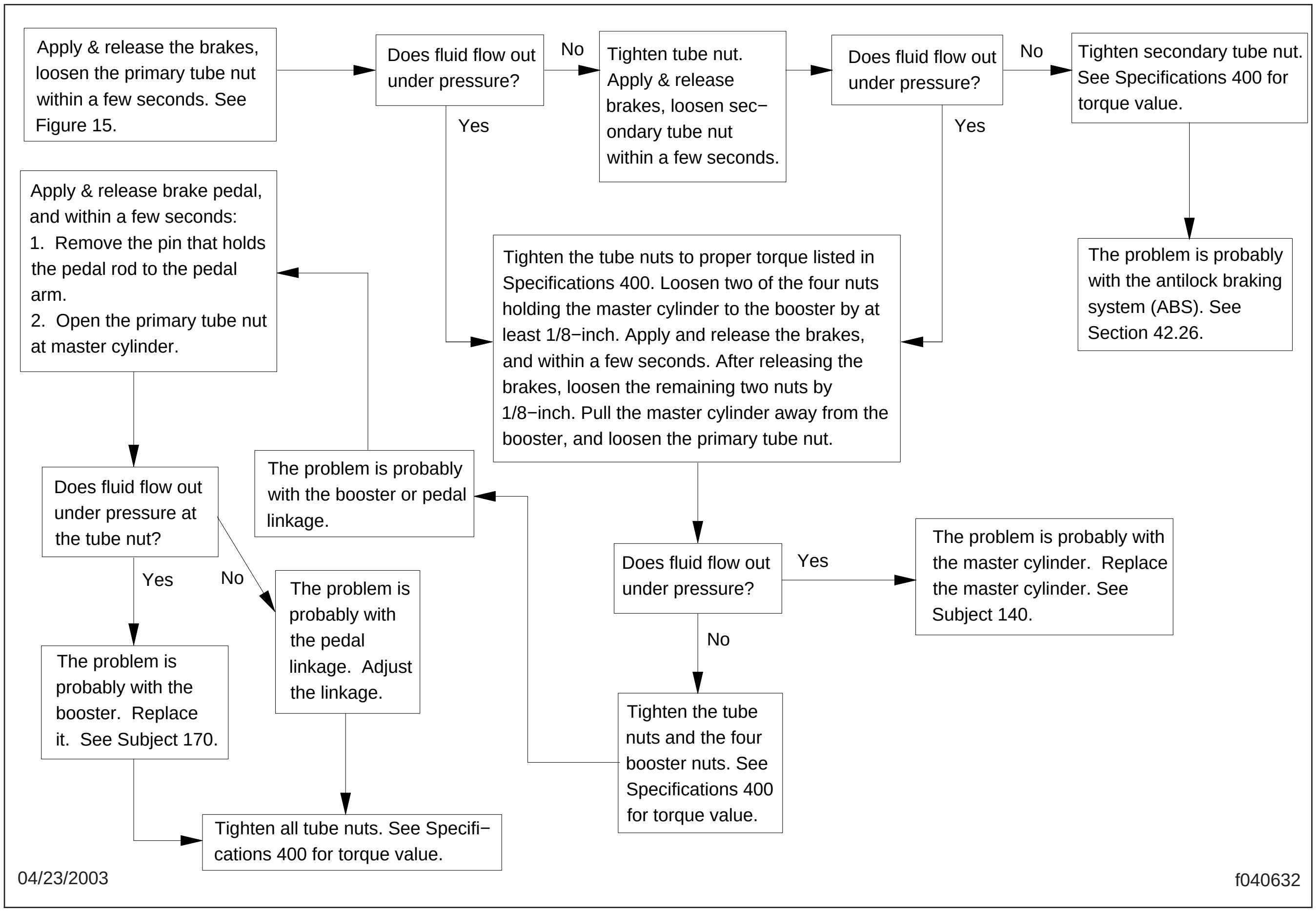
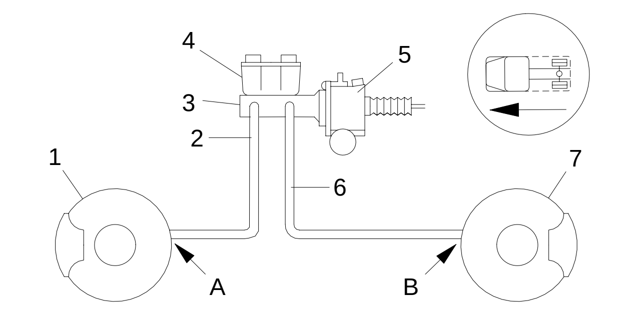


Fig. 14, Flow Chart: Brakes are Dragging (cont.)

Brake System Pressure Tests

NOTE: On most vehicles in the field, the primary master cylinder piston controls the rear brakes, the secondary piston, the front brakes. But on some vehicles the primary master cylinder piston controls the front brakes, the secondary master cylinder piston controls the rear brakes. Either configuration is considered normal and they are functionally identical. Technicians should check vehicle configuration for appropriate diagnosis and repair.

1. Install two low-pressure gauges with a range of 0 to 50 psi (345 kPa) — one at the rear wheels, and one at the front wheels. See **Fig. 1**.



A. Install gauge #2 here.
B. Install gauge #1 here.
1. Front Brake
2. Front Brake Lines
3. Master Cylinder
4. Reservoir
5. Power Brake Booster
6. Rear Brake Lines
7. Rear Brake

Fig. 1, Gauge Installation

2. Bleed the brakes following the procedure in **Subject 110**.
3. With the ignition off, lightly apply the brakes several times. Do not push hard on the brake pedal or you may damage the low-pressure gauges.
4. Release the brakes. Read the residual pressure on both gauges. Record the information.
5. If the residual pressure on either gauge is less than 2 psi (14 kPa), go to "System Pressure Test" below.

   If the residual pressure on one or both gauges is more than 2 psi (14 kPa), check the linkage between the brake pedal and the booster. Repair the linkage if needed. Repeat steps 3 and 4. If the problem is solved, go to "System Pressure Test" below. If the problem is not solved, continue these steps.
6. Check the hydraulic lines for internal blockage or kinking and replace them as needed. Repeat steps 3 and 4. If the problem is solved, go to "System Pressure Test" below. If the problem is not solved, continue with these steps.
7. Check for residual pressure at the master cylinder. Replace as needed. Go to "System Pressure Test" below.

System Pressure Test

1. Install two pressure gauges with a range of 0 to 2500 psi (17,250 kPa) — one at the rear wheels, and one at the front wheels. See **Fig. 1**.
2. Bleed the brakes following the procedure under **Subject 110**.
3. Make a copy of **Table 1**. Use this copy to record the results from the next step.

Test Results				
Pressure Test	**Gauge 1 (installed at rear wheel)**		**Gauge 2 (installed at front wheel)**	
Rapid Pressure Rise	Yes	No	Yes	No
Slow Pressure Rise	Yes	No	Yes	No
Highest Reading (psi)		psi		psi
Pressure Constant	Yes	No	Yes	No

Table 1, Test Results

4. Start the engine. Quickly apply the brakes using full pedal force. Hold the pedal down for 15 to 20 seconds. Record the speed of the pressure rise, the highest pressure registered on each gauge and whether the pressure stayed constant while the pedal was held down. Use a copy of **Table 1** to record your observations.
5. If the pressure reading on both gauges is not within 10 percent, the ABS may be affecting readings (**Section 42.26**). Replace the master cylinder if needed. Remove the pressure gauges.

Pressure Testing

Bleed the system following the instructions in **Subject 110**.

6. If the pressure reading on both gauges is within 10 percent but the gauges show less than 1770 psi (12 200 kPa), turn off the engine but leave the ignition on. Apply the brakes hard and hold the pedal down 15 to 20 seconds to test pressure from the backup pump.

   If both gauges show at least 860 psi (5930 kPa), replace the power steering pump. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

   If both gauges do not show at least 860 psi (5930 kPa), replace the power brake booster. Bleed the system following the instructions in **Subject 110**.

7. If the pressure reading on both gauges is within 10 percent and the gauges show at least 1770 psi (12 200 kPa), but the pressure came up slowly on both gauges, turn off the engine leaving the ignition on. Apply the brakes hard, hold down the pedal 15 to 20 seconds. If there was a rapid pressure rise on both gauges, repair or replace the power steering pump. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

   If the pressure rose slowly on both gauges, repair or replace the power brake booster. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

8. If the pressure reading on both gauges is within 10 percent and the gauges show at least 1770 psi (12 200 kPa), but the pressure comes up rapidly on one gauge and slowly on the other, there is probably a restriction in the brake system with the slow gauge. Remove the gauge and install it closer to the master cylinder until the pressure rises rapidly. The restriction is between that point and the point of previous installation. Repair or replace the brake line as needed. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

9. If the pressure reading on both gauges is within 10 percent, the gauges show at least 1770 psi (12 200 kPa) and the pressure came up rapidly on both gauges but the gauges do not hold constant pressure while the pedal is held down, turn off the engine. Leave the ignition on. Push hard on the brake pedal and hold it down for 15 to 20 seconds. If both gauges hold constant pressure while the pedal is down, repair or replace the power steering pump. Bleed the system following the instructions in **Subject 110**.

   If either gauge does not show constant pressure with the pedal held down, there is probably leakage between the master cylinder and the calipers.

10. If the pressure reading on both gauges is within 10 percent, the gauges show at least 1770 psi (12 200 kPa), the pressure comes up rapidly on both gauges and there is constant gauge pressure while the pedal is depressed but the brake pedal did not stay firm, there is probably leakage in the lines between the master cylinder and calipers.

11. If the pressure reading on both gauges is within 10 percent, the gauges show at least 1770 psi (12 200 kPa), the pressure comes up rapidly on both gauges, there is constant gauge pressure while the pedal is depressed and the brake pedal stays firm, the system is good. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**. If the problem still exists, check the foundation brakes.

See **Fig. 1** for a full view of the hydraulic brake system wiring.

See **Fig. 2** and **Fig. 3** for partial views of the hydraulic brake system wiring.

See **Fig. 4** for a full view of the monitor module wiring.

See **Fig. 5** and **Fig. 6** for partial views of the control module wiring.

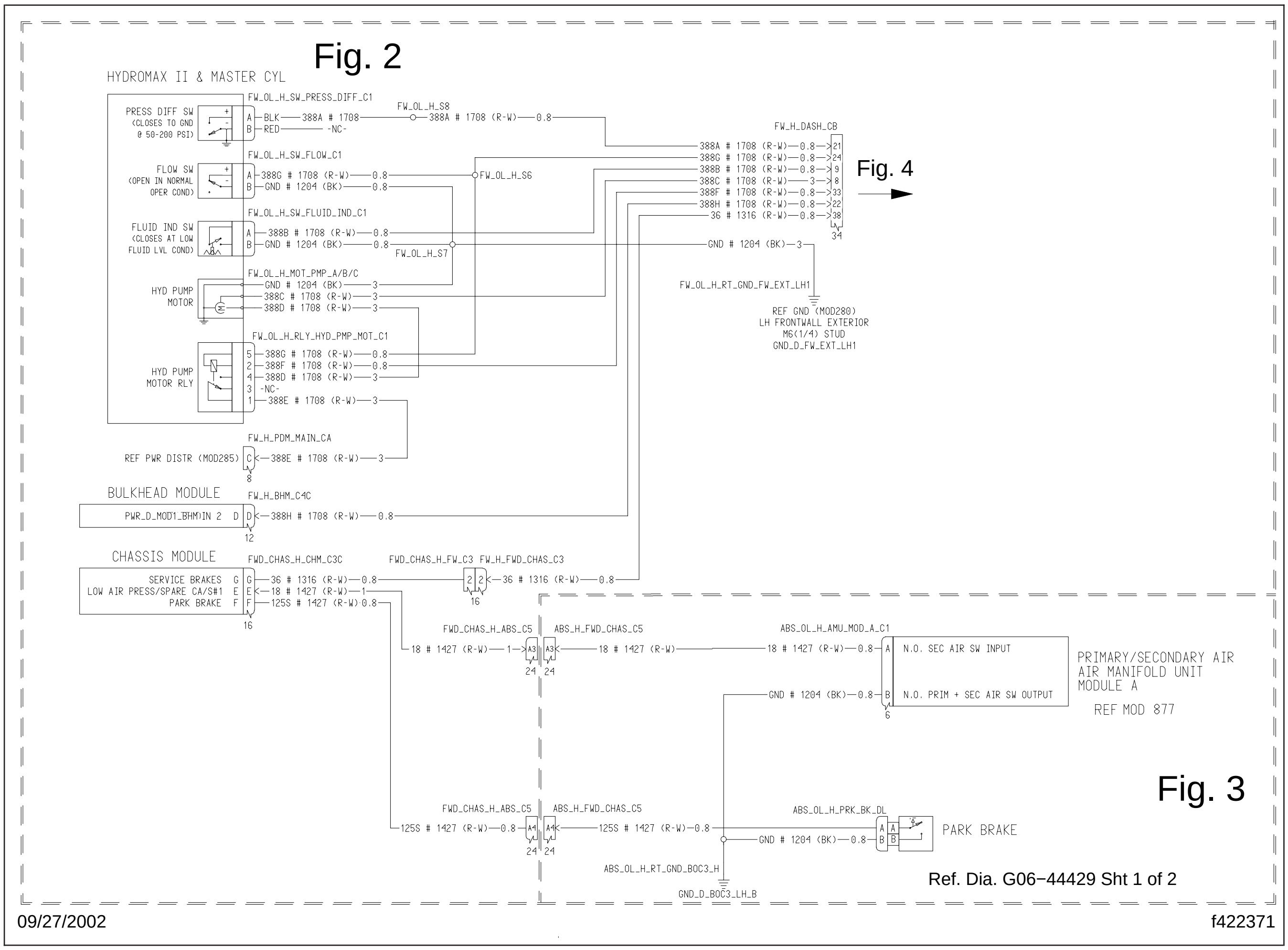


Fig. 1, Power Brake Booster and Master Cylinder Wiring (full view)

Specifications

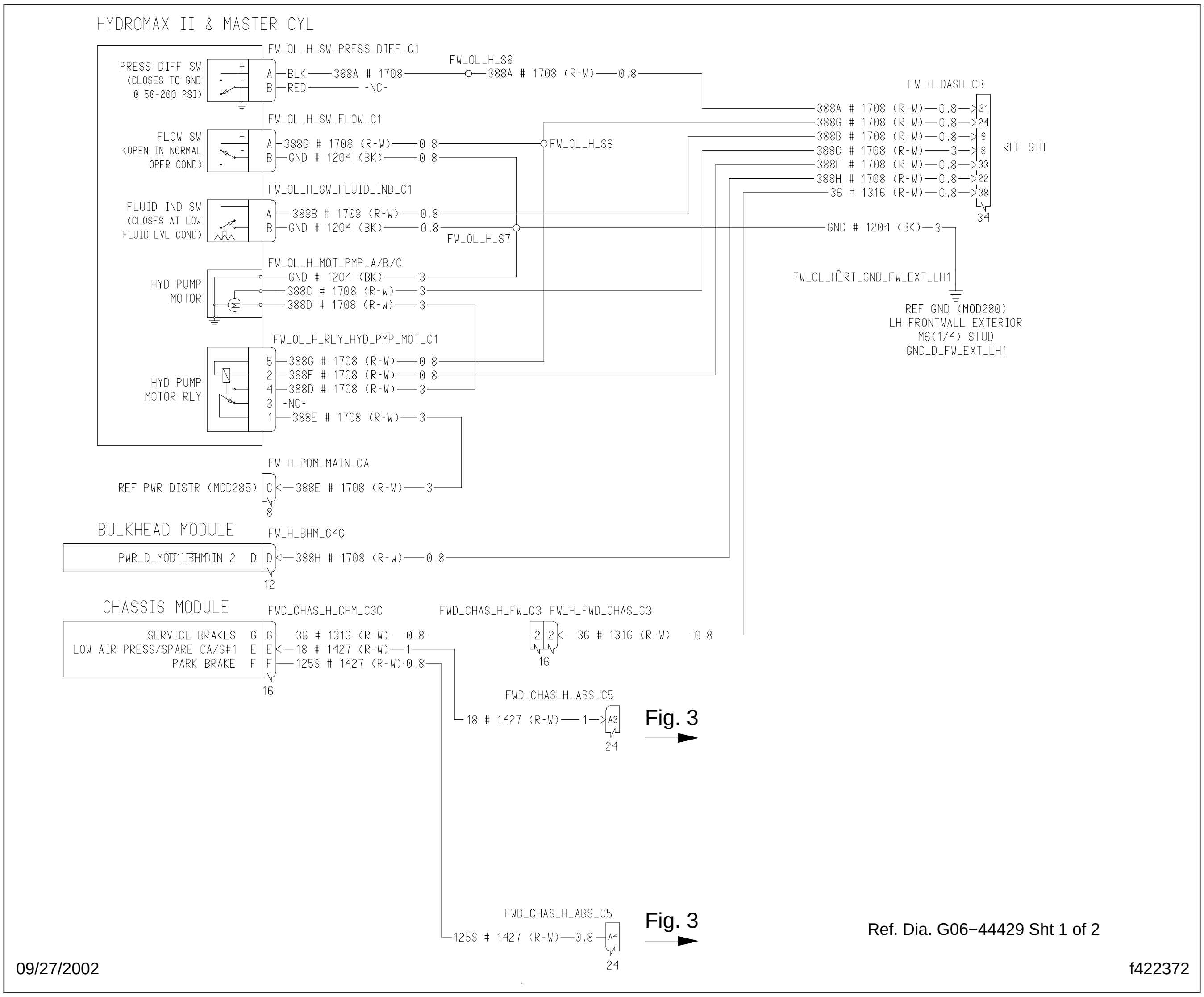


Fig. 2, Power Brake Booster and Master Cylinder Wiring (partial view)

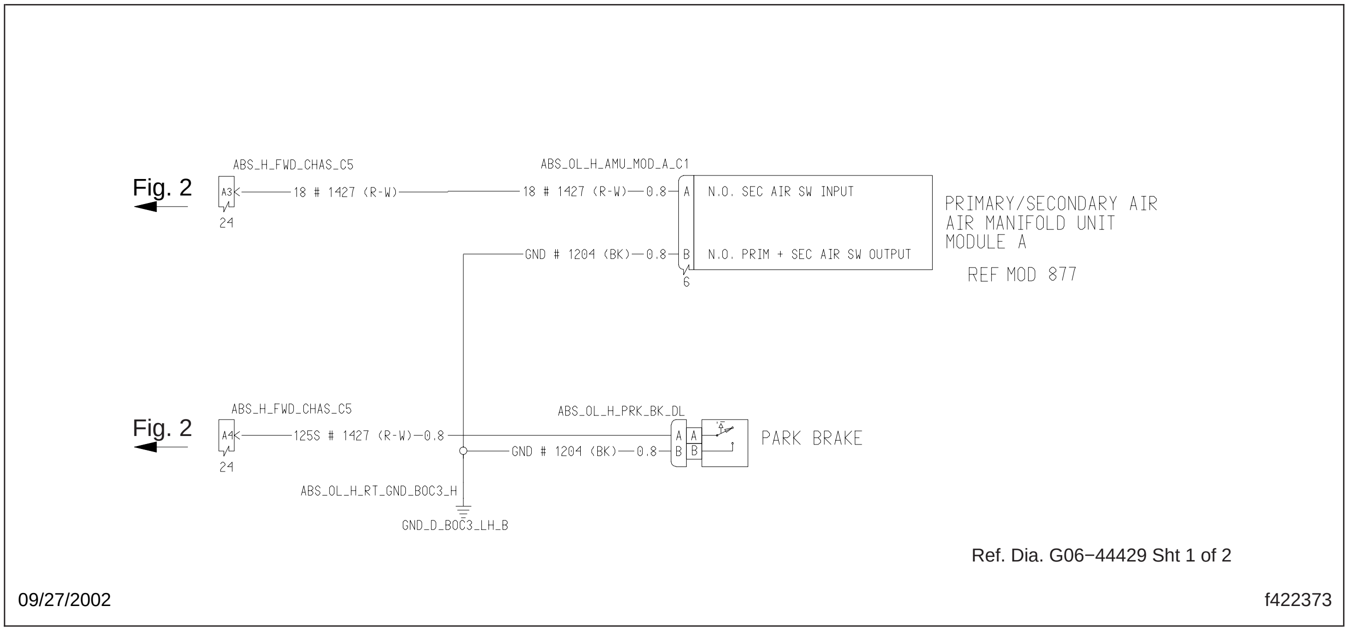


Fig. 3, Power Brake Booster and Master Cylinder Wiring (partial view)

Fastener Torques		
Description	**Torque: lbf·in (N·cm)**	**Torque: lbf·ft (N·m)**
Power Brake Booster Mounting Bolts	—	20 ±4 (28 ±6)
Master Cylinder Tube Nuts	–	Max.16.5 (22.6)
Master Cylinder Mounting Nuts	—	27 ±2 (37 ±3)
Power Brake Booster Supply Line Fitting	—	21 ±5 (27 ±7)
Backup Pump Mounting Screws	—	21.5 ±3.5 (29.2 ±4.7)
Relay Mount Screw	78 ±3 (77 ±7)	6.5 ±0.5 (8.75 ±0.85)
Flow Switch Contact Assembly	30 ±3 (30 ±0.10)	2.5 ±0.8 (3.4 ±1.1)
Differential Pressure Switch Contact Assembly	12 ±3(12 ±0.3)	1 ±0.25 (1.4 ±0.3)
Backup Pump Terminal Nut	17 ±4 (17 ±0.7)	1.4 ±0.5 (1.92 ±0.8)

Table 1, Fastener Torques

Approved Fluid for Power Brake Booster	
Fluid Type	**Recommended Fluid**
Automatic Transmission Fluid (ATF)	Dexron II®

Table 2, Approved Fluid for Power Brake Booster

Specifications

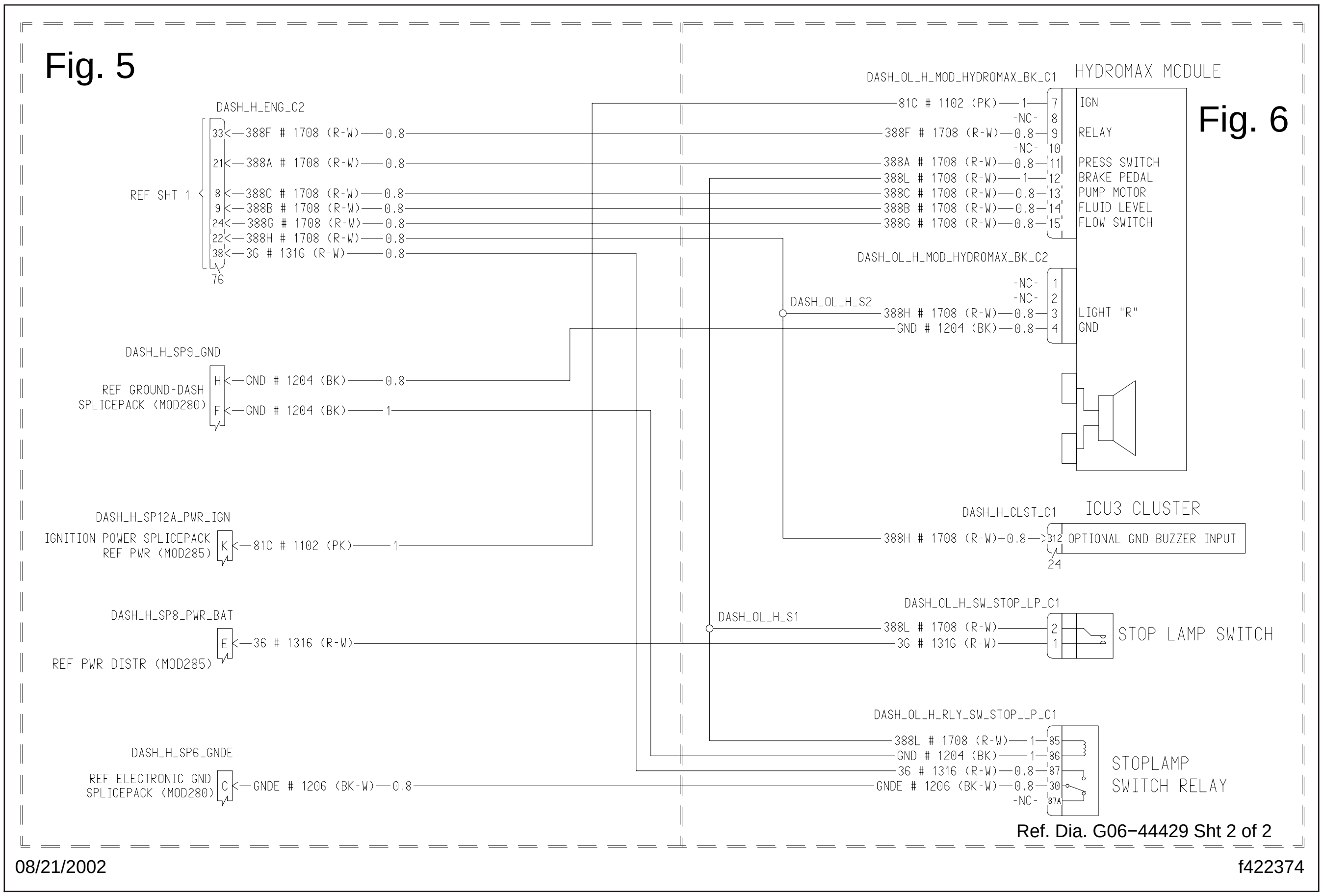


Fig. 4, Monitor Module System Wiring (full view)

Approved Brake Fluid for Brake System	
Fluid Type	**Recommended Fluid**
DOT 3 Brake Fluid	Wagner-Premium Plus Super HD Delco Supreme II Dow HD 50-4

Table 3, Approved Brake Fluid for Brake System

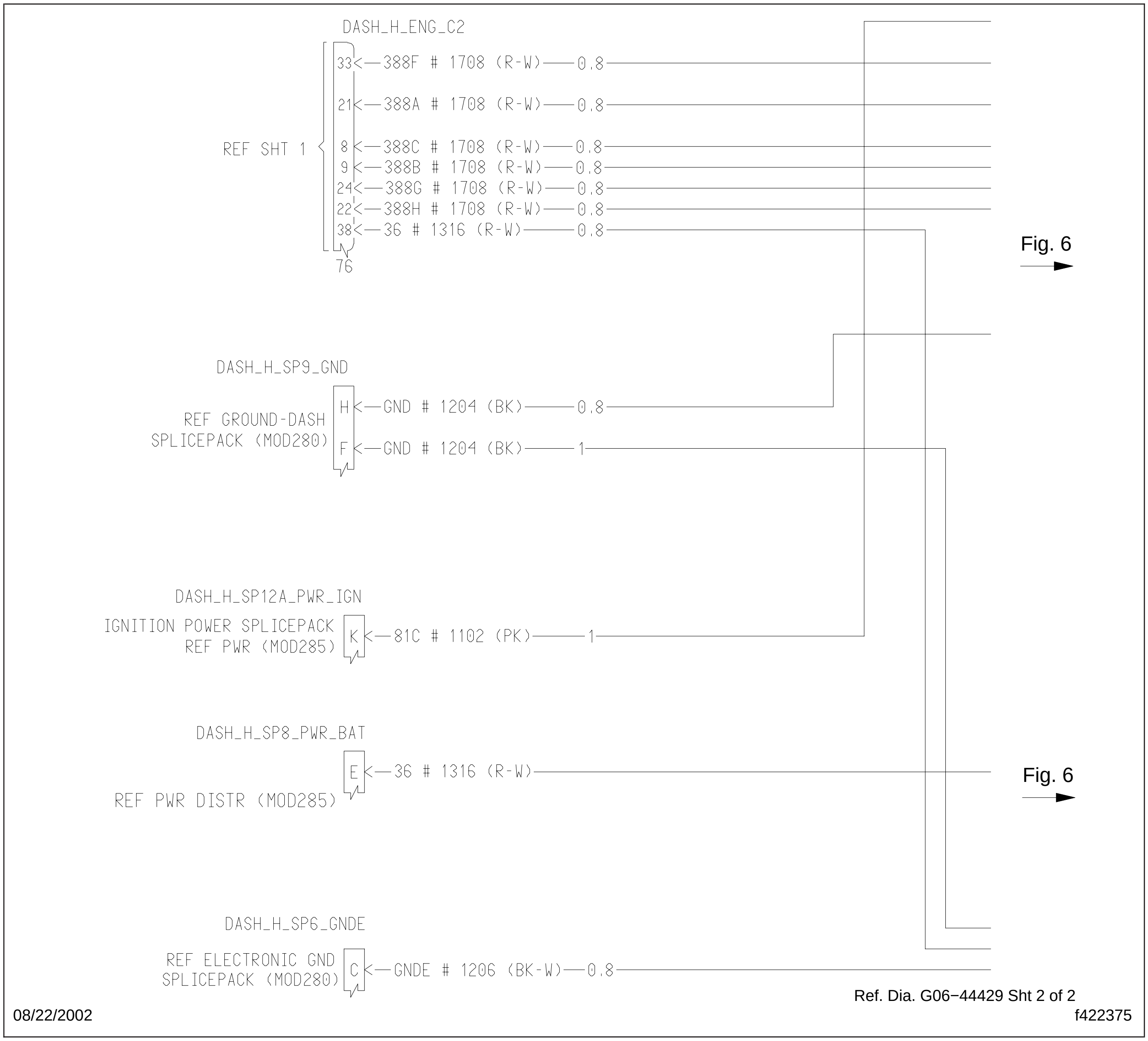


Fig. 5, Monitor Module System Wiring (partial view)

Specifications

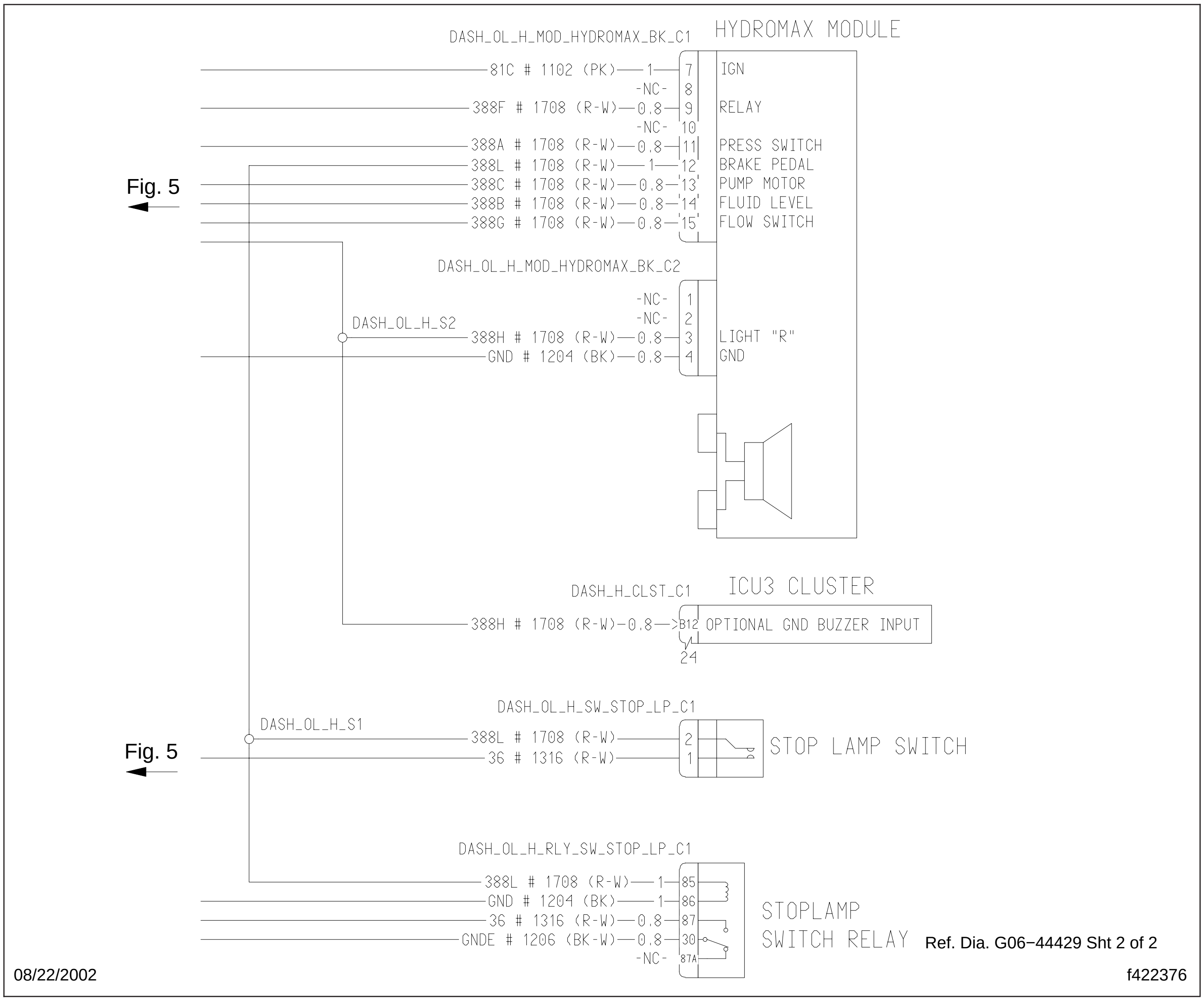
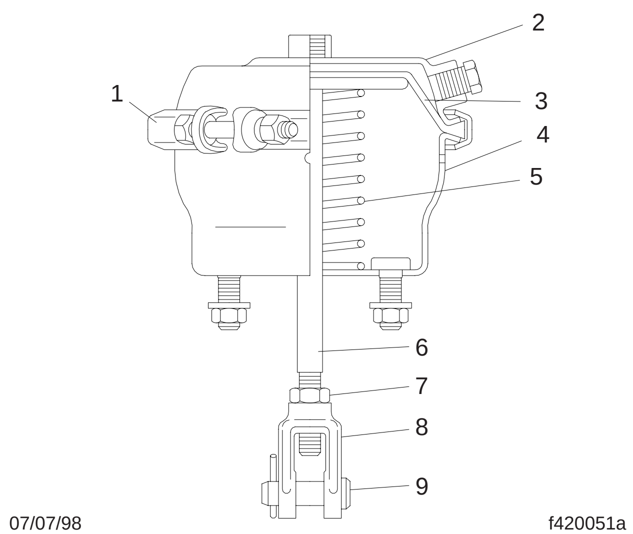


Fig. 6, Monitor Module System Wiring (partial view)

General Description

Brake chambers convert the energy of compressed air into the mechanical force and motion needed to apply the brakes. Two chambers operate the brakes, one on each side of the axle.

Each brake chamber consists of two dished metal sections: the cover assembly and the body assembly, which are separated by a nylon-neoprene diaphragm. A metal two-segment clamp ring holds the assemblies together. See **Fig. 1**.



1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
9. Clevis Pin

Fig. 1, Brake Chamber (sectional view)

In front of the diaphragm are the body, piston rod assembly, and a piston rod spring. The threaded piston rod assembly extends through the bottom of the body and connects to the clevis. See **Fig. 1**.

Different sized brake chambers are identified by numbers, which specify the effective area of the diaphragm. For example, a type 16 brake chamber has 16 square inches of effective area.

Principles of Operation

The greater the air pressure admitted to the brake chamber, the greater the force applied by the piston rod. Piston rod force is determined by multiplying the delivered air pressure by the effective diaphragm area. For example, if 60 psi (415 kPa) is admitted to a type 16 brake chamber, the force on the end of the piston rod is about 960 lb (436 kg).

When the brake pedal is depressed, air pressure from the brake valve passes through the port in the brake chamber cover to move the diaphragm and piston rod assembly forward. This compresses the spring, and applies a straight-line force to the slack adjuster, which converts it to a rotational force. This in turn rotates the camshaft and applies the brakes.

When the brake pedal is released, compressed air behind the diaphragm exhausts through the quick release valve. The spring then allows the piston rod assembly and diaphragm to return to their previous positions.

Operating and Leakage Tests

NOTE: For both of these tests, the air system must be pressurized to at least 80 psi (550 kPa).

Operating Test

1. Chock the tires.
2. Apply the brakes. Check that each piston rod moves out promptly, without binding.
3. Release the brakes. Check that each piston rod returns to the released position promptly, without binding.
4. Check the brake chamber stroke. It should be as short as possible without causing the brakes to drag. If needed, adjust the travel of the piston rod at the slack adjuster. For instructions, refer to the foundation brake section in this manual.

Leakage Test

1. Apply the brakes and hold them on full line pressure of at least 80 psi (550 kPa).
2. Using a soap solution, coat the clamp ring. Leakage is excessive if it produces a 1-inch (25-mm) bubble within five seconds.

CAUTION

Don't overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

3. If the leakage is excessive, tighten the clamp ring flange nuts evenly until the leakage is reduced. For acceptable torque ranges, see **Specifications 400**.
4. Using a soap solution, coat the area around the piston-rod hole. No leakage is permitted. If there is leakage, replace the diaphragm. For instructions, see **Subject 110**.

Diaphragm Replacement

Replacement

NOTE: This procedure is for service of a leaking brake chamber *diaphragm only*. If there are any other problems, refer to the applicable subjects elsewhere in this section.

1. Chock the tires.

WARNING

Wear safety goggles when draining the air system or loosening an air line because dirt or sludge could fly out at high speeds. Don't direct the airstreams at anyone. Don't disconnect pressurized hoses, since they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

Follow the manufacturer's recommendations when working on any air device so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or compressed-air propulsion.

2. Drain the air reservoirs and lines.
3. Back off the slack adjuster; for instructions, refer to the applicable slack adjuster section in this manual. Pull out the piston rod. See **Fig. 1**. Clamp the rod at the chamber body to protect it from damage.
4. Before disassembly, mark a reference line along the chamber to allow the parts to be reassembled later in their old positions. See **Fig. 2**.
5. Replace the diaphragm.

    5.1 Remove one clamp ring bolt and flange nut completely and loosen the other bolt and flange nut enough to remove the clamp ring.

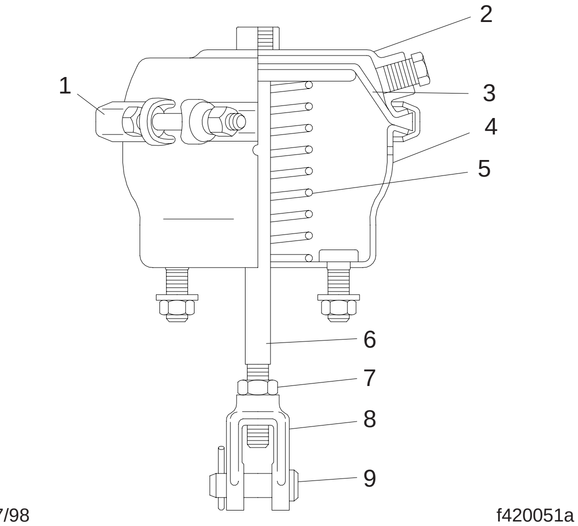
    5.2 Remove the cover assembly, and replace the diaphragm.

CAUTION

Don't overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

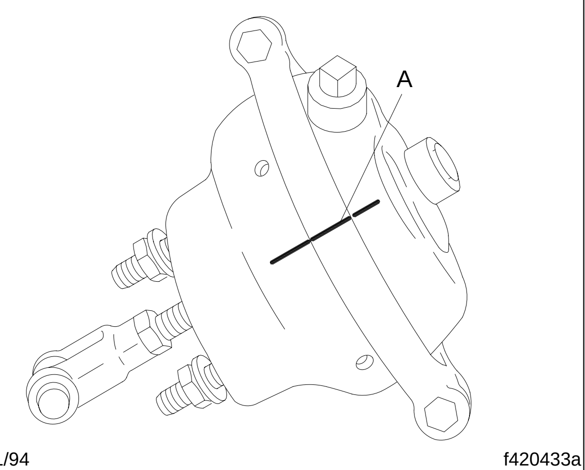
    5.3 Position the cover assembly and clamp ring (aligning the reference marks), and install the clamp ring bolt and flange nut. Tighten the flange nuts evenly to eliminate leakage. For acceptable torque ranges, see **Specifications 400**.

6. Release the clamp on the piston rod.



1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
9. Clevis Pin

Fig. 1, Brake Chamber (sectional view)



A. Reference Line

Fig. 2, Mark a Reference Line

Diaphragm Replacement

7. Do both of the tests in **Subject 100**.
8. Adjust the brakes at the slack adjuster. For instructions, refer to the applicable foundation brake section in this manual.
9. Remove the chocks from the tires.

Brake Chamber Removal and Installation

Removal

1. Chock the tires.

WARNING

Wear safety goggles when draining the air system or loosening an air line because dirt or sludge could fly out at high speeds. Do not direct the airstreams at other people. Do not disconnect pressurized hoses, since they may whip as air escapes. Failure to take all necessary precautions could result in severe personal injury.

Follow the manufacturer's recommendations when working on any air device so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or compressed-air propulsion.

2. Drain the air reservoirs and lines.
3. Carefully disconnect the air line from the brake chamber.
4. Remove the brake chamber. See **Fig. 1**.

    4.1 Remove the cotter pin(s) from the clevis pin(s).

    NOTE: Automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

    4.2 Remove the clevis pin(s) from the slack adjuster.

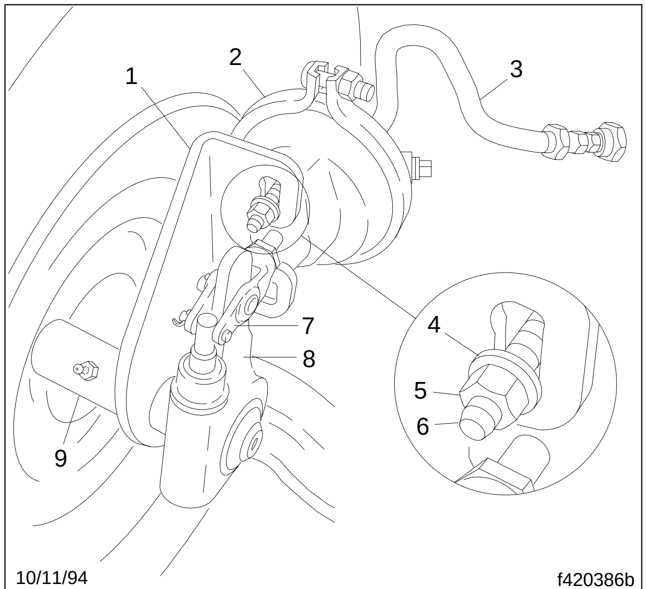
    4.3 From each mounting stud, remove any installed nuts and washers. Remove the brake chamber from the vehicle.

Installation

1. Before installing a new chamber, be sure the new chamber is the same size and make as the brake chamber on the other side of the axle.
2. Install the brake chamber. See **Fig. 1**.

    2.1 Attach the brake chamber to the mounting bracket using a hardened flatwasher and prevailing torque locknut. Install the flatwasher between the locknut and the mounting bracket.

    2.2 Tighten the locknuts. See **Specifications 400** for the correct torque value.



1. Chamber Mounting Bracket
2. Brake Chamber
3. Air Line
4. Hardened Flatwasher
5. Prevailing Torque Locknut
6. Chamber Mounting Stud
7. Clevis Assembly
8. Slack Adjuster (Automatic Type)
9. Camshaft Tube

Fig. 1, Brake Chamber Mounting

    2.3 Connect the clevis pins to the slack adjuster.

    2.4 Install and lock new cotter pin(s) to secure the clevis pin(s).

    NOTE: Automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

3. Adjust the brakes at the slack adjuster. For instructions, refer to the applicable foundation brake section in this manual.
4. Connect the air line to the brake chamber.

    4.1 Check that the hoses are properly supported and, if needed, clamped to provide good clearance.

    4.2 Before connecting the air line, make sure the fittings are clean and free of debris.

    4.3 Connect the air line as follows: tighten the nut finger-tight. Using a wrench, further

Brake Chamber Removal and Installation

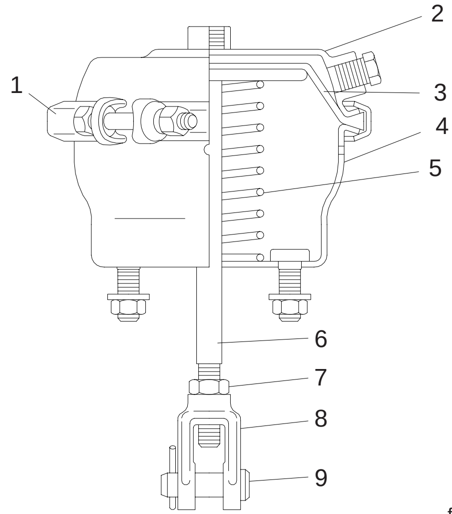
tighten the nut until there is resistance, then tighten one-sixth turn more.

5. Do both of the tests in **Subject 100**.
6. Remove the chocks from the tires.

Brake Chamber Disassembly, Inspection and Cleaning, and Assembly

Refer to **Fig. 1** during chamber disassembly and assembly.

Disassembly



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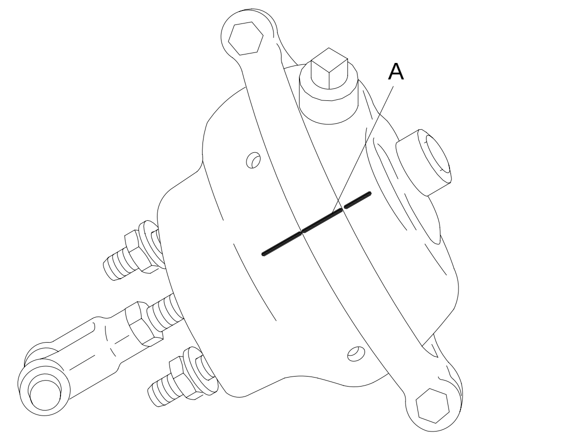
1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
9. Clevis Pin

Fig. 1, Brake Chamber (sectional view)

NOTE: If the brake chamber is to be disassembled without removing the body assembly from the vehicle, first back off the slack adjuster. For instructions, refer to the applicable slack adjuster section in this manual.

1. Before disassembly, mark a reference line along the chamber to allow the parts to be reassembled later in their old positions. See **Fig. 2**.
2. Pull out the piston rod. Clamp the rod at the chamber body to protect it from damage.
3. Disassemble the brake chamber.
   - 3.1 Remove one clamp ring bolt and flange nut completely and loosen the other bolt and flange nut enough to remove the clamp ring.
   - 3.2 Remove the cover assembly and the diaphragm.



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A. Reference Line

Fig. 2, Mark a Reference Line

   - 3.3 Remove the clevis locknut and clevis from the piston rod, and release the clamp on the piston rod, being careful to contain the piston rod assembly and body until the return spring is relaxed.
   - 3.4 Remove the piston rod assembly and spring.

Inspection and Cleaning

1. Clean all metal parts with cleaning solvent.
2. Inspect all parts for wear or damage; replace as needed.
   - 2.1 Check the cover and the body for dents. If any are too deep to be pounded out, replace as needed.
   - 2.2 Check the diaphragm for wear or deterioration and replace it if necessary. Haldex recommends replacement of the diaphragm whenever the service brake chamber is opened for inspection.
   - 2.3 Inspect all other parts not considered serviceable. Replace if necessary.

Brake Chamber Disassembly, Inspection and Cleaning, and Assembly

Assembly

1. Stand the piston rod assembly upright on a flat surface (if the chamber was removed from the vehicle).
2. Assemble the brake chamber.
   2.1 Place the return spring on the piston rod.
   2.2 Place the body on the piston rod assembly, and press the body down, working against the tension of the spring, until the body bottoms out on the flat surface. Clamp the rod at the body, making sure to protect the rod from damage. Insert the piston rod assembly through the body and clamp the rod (if the body wasn't removed from the vehicle).
   2.3 Place the diaphragm in the body.

CAUTION

Don't overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

   2.4 Position the cover assembly and clamp ring (aligning the reference marks), and install the clamp ring bolt and flange nut. Tighten the flange nuts evenly to eliminate leakage. For acceptable torque ranges, see **Specifications 400**.
3. Install the clevis locknut and clevis, and release the clamp on the piston rod.
4. If the brake chamber was removed from the vehicle, install it. For instructions, see **Subject 120**.
5. Do both of the tests found in **Subject 100**.

Specifications

Description	Chamber Size: in^2	Torque: lbf·ft (N·m)
Brake Chamber Mounting-Stud Locknuts	12	30 (41)
	16 (5/8-inch Stud)	100 (136)
	20	100 (136)
	24	100 (136)

Table 1, Mounting-Stud Locknut Torque Values

Description	Chamber Size: in^2	Torque: lbf·ft (N·m)
Clamp Ring Flange Nuts	12	16.5 to 21 (22 to 28)
	16	16.5 to 21 (22 to 28)
	20	9 to 18.75 (12 to 25.5)
	24	12.5 to 18.75 (17 to 25.5)

Table 2, Clamp Ring Torque Values

Description	Chamber Size: in^2	Torque: lbf·ft (N·m)
Piston Rod Nuts	12	20 to 30 (27 to 41)
	16 (5/8-inch Stud)	33 to 90 (45 to 122)
	20	33 to 90 (45 to 122)
	24	33 to 90 (45 to 122)

Table 3, Piston Rod Nut Torque Values

General Information

This troubleshooting guide is designed to help locate causes of problems originating in the air brake system. The corrective measures given are not intended to replace the detailed service information found in other sections of this manual or in the component manufacturer's service manuals. If the vehicle is equipped with ABS (antilock brake system), see **Section 42.00** for troubleshooting the ABS system.

IMPORTANT: Additional troubleshooting information is also available in **Section 42.19**, Air Manifold Unit (AMU).

Before attempting to isolate the causes of an air brake system problem, do the following:

1. Check the operation of the air compressor. Refer to the engine manufacturer's service manual.

   Check the pressure levels of the air reservoirs. See the pretrip inspection and daily maintenance chapter of the *Business Class M2 Driver's Manual*.
2. Be sure that all relay valves are operating. See Group 42 of the *Business Class M2 Maintenance Manual*.
3. Check the operation of the brake chambers as instructed in Group 42 of the *Business Class M2 Maintenance Manual*.
4. Examine all tubing for kinks, dents, and other damage. Replace damaged tubing.
5. Examine all hoses for cracks, drying out, overheating, and other damage. Replace damaged hoses.
6. Examine all air line fittings. Tighten loose connections; replace fittings that are damaged. For instructions, refer elsewhere in this group.
7. Examine leaking pipe connections for cracks or thread damage; replace as needed. If there is no damage, retighten the fitting. For instructions, refer elsewhere in this group.

Safety Precautions

WARNING

Follow the manufacturer's procedures while working on any air device. Some parts are subject to mechanical (spring) or pneumatic propulsion and may cause personal injury or property damage when released. Failure to take all necessary precautions during servicing of the air brake system can result in personal injury or property damage.

Compression and storage of air in the air brake system is comparable to the energy in a coiled spring: when released, it may present a hazard. Because of this, certain precautions are required.

1. Chock the tires. This will prevent accidental rolling of the vehicle when air is released from the brake system.
2. Don't disconnect pressurized hoses because they will whip as air escapes from the line. Drain the air system before disconnecting the air hoses.
3. When draining the air system, do not look into the air jets or direct them toward another person: dirt particles or sludge may be carried in the air stream.
4. As air pressure is drained and the parking/ emergency brakes apply, keep your hands away from the brake chamber push rods and parking brake chambers, which will activate automatically with the loss of pressure.

Troubleshooting

Troubleshooting Tables

Problem — Vehicle Does Not Slow Down Quickly Enough When Brakes Are Applied

Problem — Vehicle Does Not Slow Down Quickly Enough When Brakes Are Applied	
Possible Cause	**Remedy**
The vehicle is overloaded.	Observe the recommended maximum load limits.
There is low air pressure in the brake system, about 60 psi (413 kPa) or lower.	The drain cock on the air reservoir was left open; close the drain cock.
	Check the compressor output pressure; correct as necessary.
	Check the setting of the air governor with an accurate test gauge. Adjust the air governor to the recommended specification.
The application air lines are leaking excessively.	Check the application air lines, brake valve, and the service and parking brake chambers for air leaks. Repair or replace the damaged component(s).
Brake valve delivery pressure is below normal.	Lubricate the brake valve parts; overhaul the unit, if necessary.
Wear or glazing of the brake linings is present.	Install new brake linings on the brake shoes on both sides of the axle.
Adjustment or lubrication of the brakes is needed.	Adjust or lubricate the brakes.
The automatic slack adjusters are not operating.	Lubricate the automatic slack adjusters and check for binding, damaged, or inoperative slack adjuster parts. Replace damaged or inoperative parts, or eliminate the cause of the binding.
The cam has flipped over.	Replace the linings and the cam on each end of the axle.
One or more of the brake drums is broken or cracked.	Replace the brake drum(s).
Wrong size brake linings were installed.	Replace the brake linings with the recommended size.
Wrong size brake chambers were installed.	Replace the brake chambers with the recommended size.
A camshaft bracket or chamber mounting bracket is bent or broken.	Replace the camshaft bracket or chamber mounting bracket.
The brake chamber mounting stud nuts or brake chamber mounting bracket is loose.	Tighten the brake chamber to its mounting bracket or the mounting bracket to the foundation brake housing.
There is a ruptured diaphragm in the service brake.	Replace the diaphragm.

Problem — Service Brakes Release Too Slowly

Problem — Service Brakes Release Too Slowly	
Possible Cause	**Remedy**
The brake shoe anchor pins are frozen.	Inspect the anchor pins. If damaged, replace them; if not damaged, lubricate them.
Lubrication of the brake system components is inadequate.	Lubricate those components requiring periodic lubrication.
The brake foot valve is not returning to the fully released position.	Check for obstructions which might prevent the brake foot valve from returning to the fully released position. Remove any obstructions.

Troubleshooting

Problem — Service Brakes Release Too Slowly	
Possible Cause	**Remedy**
The exhaust port of the brake foot valve or quick-release valve is plugged.	Clear the exhaust port of obstructions.
The brake foot valve or quick-release valve is inoperative.	Overhaul or replace the inoperative valve, as needed.
The camshaft and bushings are binding.	Clean and lubricate the camshaft bushings.
The brake shoe return spring is weak or broken.	Replace the spring.

Problem — Service Brakes Do Not Apply or Apply Too Slowly

Problem — Service Brakes Do Not Apply or Apply Too Slowly	
Possible Cause	**Remedy**
Lubrication of the foundation brake assembly is needed.	Lubricate those components requiring periodic lubrication.
There is insufficient air pressure in the brake system.	Check all parts of the air pressure system for leaks or inoperative components.
The brake foot valve or relay valve is inoperative.	Repair or replace the brake foot valve or relay valve.
The camshaft bushings are binding.	Clean and lubricate the camshaft bushings.

Problem — Service Brakes Apply When the Parking Brakes Are Released With Air Pressure

Problem — Service Brakes Apply When the Parking Brakes Are Released With Air Pressure	
Possible Cause	**Remedy**
The air delivery lines to the brake chamber have been reversed.	Reverse the connections of the brake chamber air lines.

Problem — Service Brakes Do Not Release

Problem — Service Brakes Do Not Release	
Possible Cause	**Remedy**
The brake shoes are incorrectly adjusted.	Adjust the brakes. Also, make sure the slack adjuster is operating correctly. If not, overhaul or replace the slack adjuster.
The brake foot valve may not be in the fully released position.	Lubricate the brake foot valve if needed.
The brake foot valve is inoperative.	Overhaul or replace the brake foot valve.
There is restriction in the tubing, hose, or exhaust port of the brake foot valve or quick-release valve.	Check for bends or obstructions on the exhaust side of the service brakes. Remove any obstructions; plumb the air lines so that bends are minimal.
A broken power spring may be blocking the parking brake piston movement.	Replace the power spring or replace the parking brake assembly, whichever is recommended by the parking brake manufacturer.

Troubleshooting

Problem — Service Brakes Grab or Pull

Problem — Service Brakes Grab or Pull	
Possible Cause	**Remedy**
There is not enough weight on the vehicle (underloaded).	Add weight to the vehicle, reducing brake sensitivity.
Adjustment of the brakes on one axle is uneven.	Adjust the brakes.
Lubrication of the brake system components is inadequate.	Lubricate those components requiring periodic lubrication.
The brake mechanism is binding.	Lubricate the brake mechanism and make sure all parts are aligned with each other and are securely fastened.
The clevis pin or camshaft is binding at one or more wheels.	Clean and lubricate the camshaft bushings.
A brake spider is loose.	Tighten the mounting bolts or replace the brake spider.
A slack adjuster is damaged.	Replace the damaged component.
The air chamber push rods or slack adjusters are a different length.	Replace the components with the correct size and material.
The brake foot valve is inoperative.	Overhaul or replace the brake foot valve, as needed.
If equipped with cam brakes, there is a flat or dent on the S-head camshaft or on the cam roller(s).	Replace the damaged component(s).
Grease has saturated the brake linings or the linings are glazed.	Install a matched set of linings on both sets of brake shoes on that axle. Clean, turn, or replace both brake drums. For instructions on turning drums, refer to the brake manufacturer's service manual.
The brake linings are loose or broken.	Install a matched set of linings on both sets of brake shoes on that axle.
The brake linings are not a matched set. Different friction codes or different brands of brake linings are installed.	Install a new, matched set of brake linings. Clean, turn, or replace both brake drums on that axle. For instructions on turning drums, refer to the brake manufacturer's service manual.
A brake shoe is distorted or broken.	Replace the brake shoe. Install a new, matched set of linings on both sets of brake shoes on that axle.
The pilot pads are damaged, allowing the brake drum to be installed out-of-round.	Replace the wheel hub.
A brake drum is out-of-round to unacceptable limits.	Turn both the brake drums on that axle. If the maximum allowable diameter of either drum has been exceeded, replace that drum. For instructions on turning drums, refer to the brake manufacturer's service manual.
One or more brake drums is scored or broken.	Replace both of the drums on that axle.

Problem — Uneven Service Brakes

Problem — Uneven Service Brakes	
Possible Cause	**Remedy**
The wrong brake linings were installed, or the linings were not replaced in pairs.	Replace the brake linings with the recommended size. Install new linings on both sets of axle brake shoes.

Troubleshooting

Problem — Uneven Service Brakes	
Possible Cause	**Remedy**
Grease has saturated the brake linings or the linings are glazed.	Install new linings on both axle brake shoes. Clean the brake drums.
The return spring for the brake shoe release or the service brake has broken.	Replace all broken springs.
The brake drum is out-of-round to unacceptable limits.	Turn both the brake drums on that axle. If the maximum allowable diameter of either drum has been exceeded, replace that drum. For instructions on turning drums, refer to the brake manufacturer’s service manual.
A service brake chamber diaphragm is leaking.	Tighten the clamp ring. If leaks persist, replace the service brake diaphragm.
The wheel bearings are out of adjustment.	Adjust the wheel bearings, or replace them if damaged. For instructions, see **Group 33** or **Group 35**.
A brake spider is damaged.	Replace the brake spider.
The brake shoes are bent or stretched.	Replace the axle brake shoes on each wheel.
Grease, oil, or dirt is on the linings.	Replace the linings on each set of axle brake shoes. Clean the brake drums.

Problem — Dragging Service Brake

Problem — Dragging Service Brake	
Possible Cause	**Remedy**
The service brake return spring is broken.	Replace the service brake return spring.
The service-application air is not exhausting or not exhausting fast enough, due to blockage in the control valve, the quick-release valve, or the limiting and quick-release valve.	Test the air system valves for leakage and operation.
A brake shoe retracting spring is broken.	Replace the brake shoe retracting spring.
Binding is occurring in the camshaft linkage.	Lubricate the camshaft linkage. Replace bent or broken parts.

Problem — Insufficient Parking Brake Application When Dash Control Valve Is Activated

Problem — Insufficient Parking Brake Application When Dash Control Valve Is Activated	
Possible Cause	**Remedy**
The brakes are improperly adjusted.	Adjust the brakes.
A power spring is broken.	Replace the parking/emergency brake section.
A power spring in a parking brake is manually caged.	Release the power spring by screwing in the release bolt.

Troubleshooting

Problem — Dragging Brakes Due to Parking Brake Mechanism

Problem — Dragging Brakes Due to Parking Brake Mechanism	
Possible Cause	**Remedy**
The system air pressure is insufficient to fully release the parking brake.	Be sure that all air lines are clear. Check that the air governor cutout settings meet recommended specifications.
A parking brake diaphragm is ruptured or a piston seal is ineffective.	Replace the diaphragm or parking brake piston seal.

Problem — Air Pressure Will Not Rise to Normal

Problem — Air Pressure Will Not Rise to Normal	
Possible Cause	**Remedy**
The air pressure gauge(s) on the dash is (are) registering inaccurately.	Check the dash gauge(s) with an accurate test gauge. Replace the dash gauge(s) as needed.
There is excessive leakage (not including the air compressor).	Check all valves, air lines, and connections for leakage. Repair or replace valves and lines until leakage is eliminated.
The compressor is inoperative (including excessive leakage of the compressor).	Rebuild or replace the compressor.
The air reservoir drain cock has been left open.	Close the drain cock.
The air governor cutout setting is not adjusted correctly.	Check the setting with an accurate test gauge, then adjust the air governor to the recommended specification.
There is inadequate clearance at the compressor unloading valve.	Repair or adjust the compressor at the unloading valve.
If so equipped, the compressor drive belt is slipping.	Adjust or replace the compressor drive belt.
Carbon is building up in the compressor cylinder head or discharge line.	Remove the carbon. If disassembly is not recommended by the compressor manufacturer, replace the air compressor with a factory rebuilt or a new unit.
The driveshaft coupling is broken	Replace the coupling.

Problem — Air Pressure Rises Above Normal

Problem — Air Pressure Rises Above Normal	
Possible Cause	**Remedy**
The air reservoir pressure dash gauge is inaccurate.	Check the dash gauge with an accurate test gauge. Replace the dash gauge as needed.
The compressor air governor is out of adjustment.	Check the setting with an accurate test gauge, then adjust the air governor to the recommended specification.
The air governor is not operating.	Repair or replace the air governor.

Troubleshooting

Problem — Air Pressure Rises Above Normal	
Possible Cause	**Remedy**
There is too much clearance at the air compressor unloading valve.	Repair or adjust the compressor at the unloading valve.
The air compressor unloading valve is stuck closed.	
The air compressor unloading valve cavities or the unloading valve passage is blocked with carbon.	

Problem — Air Pressure Drops Quickly With the Engine Stopped and the Brakes Released

Problem — Air Pressure Drops Quickly With the Engine Stopped and the Brakes Released	
Possible Cause	**Remedy**
The brake foot valve is leaking.	Repair or replace the brake foot valve.
The air compressor discharge valve is leaking.	Repair or replace the discharge valve. If disassembly is not recommended by the compressor manufacturer, replace the air compressor with a factory-rebuilt or a new unit.
The air governor is leaking.	Repair or replace the air governor.

Problem — Air Pressure Drops Quickly With the Engine Stopped and the Brakes Fully Applied

Problem — Air Pressure Drops Quickly With the Engine Stopped and the Brakes Fully Applied	
Possible Cause	**Remedy**
A service or parking brake chamber is leaking.	Tighten the clamp ring(s). If leaks persist, replace the diaphragm(s) or assembly.
The brake foot valve or relay valve is leaking.	Repair or replace the component(s) or assembly.

Problem — Compressor Knocks (Continuously or Intermittently)

Problem — Compressor Knocks (Continuously or Intermittently)	
Possible Cause	**Remedy**
There is a loose drive pulley, belt, coupling, or gear (as indicated).	Tighten or replace the component. If applicable, inspect the pulley shaft for damage. Replace the shaft, if damaged.
Backlash is in the compressor drive gears on the drive coupling.	Repair or replace the compressor drive gears or drive coupling.
The air compressor bearings are damaged or worn.	Replace the bearings.
There are carbon deposits in the compressor cylinder head.	Remove the carbon deposits or replace the compressor.

Troubleshooting

Problem — Pressure Relief Valve Activates

Problem — Pressure Relief Valve Activates	
Possible Cause	**Remedy**
The pressure relief valve is out of adjustment.	Adjust the pressure relief valve, or install a new one.
There is excessive air pressure in the brake system.	Refer to the problem "Air Pressure Rises Above Normal."

Problem — Oil or Water in the Brake System

Problem — Oil or Water in the Brake System	
Possible Cause	**Remedy**
Excessive oil is passing through the air compressor.	Rebuild or replace the compressor.
If so equipped, the air compressor air strainer is dirty.	Clean the strainer or install a new one.
Draining of the air reservoirs needs to be performed more often.	Drain the air reservoirs daily.
If so equiped, the air dryer desiccant cartridge is oil saturated.	Install a new desiccant cartridge.

General Information

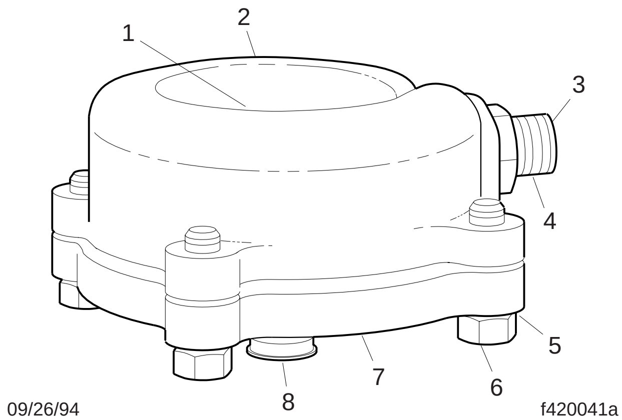
The DV-2 automatic reservoir drain valve automatically ejects moisture and contaminants from the reservoir in which it is connected. If operates automatically and requires no manual assistance or control lines from other sources.

The automatic reservoir drain valve (**Fig. 1**) has a die cast aluminum body and cover and is nomally mounted either in the bottom of the reservoir using the top port of the rain valve or in the end of an end drain reservoir using the side port of the valve.

The DV-2 is also available with a heater and thermostat (**Fig. 2**) cast into the cover for vehicles operated in subfreezing temberatures. A 1/4-inch male pipe adaptor is supplied with all DV-2 drain valves, end drain and bottom drain, both standard and heated. This adaptor should be installed directly into the valve.

With no pressure in the system, the drain valve's inlet and exhaust valves are closed. See **Fig. 3**. Upon charging the system, a slight pressure opens the inlet valve which permits air and contaminants to collect in the sump. See **Fig. 4**. The inlet valve remains open when pressure is rising in the system until the air compressor cuts off, allowing the spring action of the valve guide in the sump cavity to close the inlet valve. The inlet valve and the exhaust valve are now both closed. See **Fig. 5**. When the reservoir pressure drops approximately 2 psi (14 kPa), the air pressure in the sump cavity opens the exhaust valve and allows moisture and contaminants to be ejected from the sump cavity until pressure in the sump cavity drops sufficiently to close the exhaust valve. See **Fig. 6**.

The length of time the exhaust valve remains open and the amount of moisture and contaminants ejected depends upon the sump pressure and the wet tank pressure drop that occurs each time air is used from the system.



1. Top Reservoir Port
2. Valve Body
3. Hexhead Nipple
4. Side Reservoir Port
5. Lockwasher (4 qty.)
6. Capscrew (4 qty.)
7. Valve Cover
8. Exhaust Port

Fig. 1, Standard DV-2 Valve

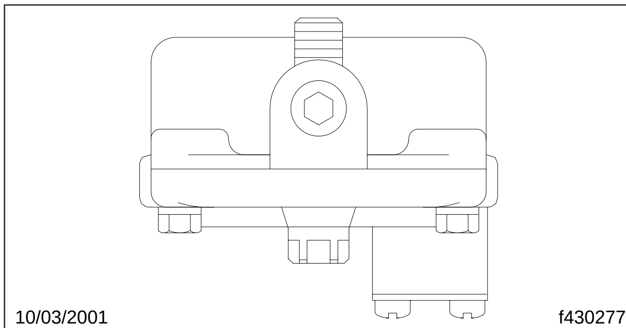


Fig. 2, DV-2 Valve with Heater/Thermostat

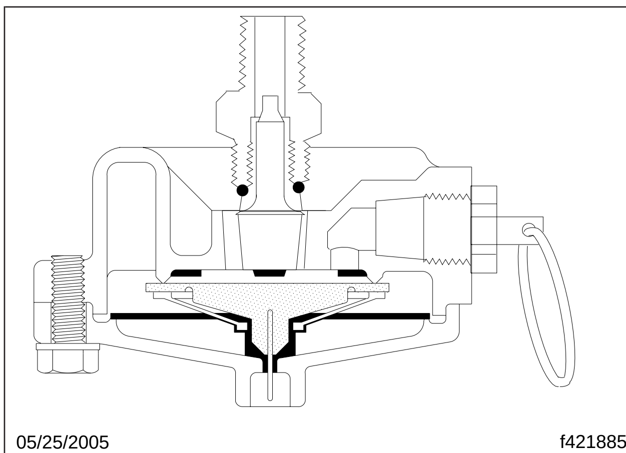


Fig. 3, No System Pressure

General Information

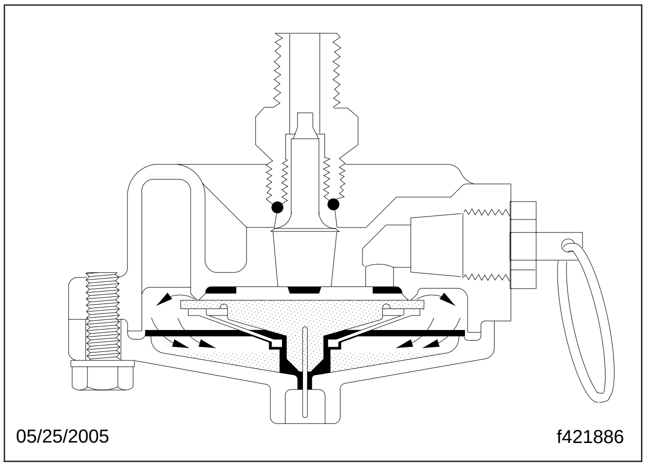


Fig. 4, Start of System Pressure Charging

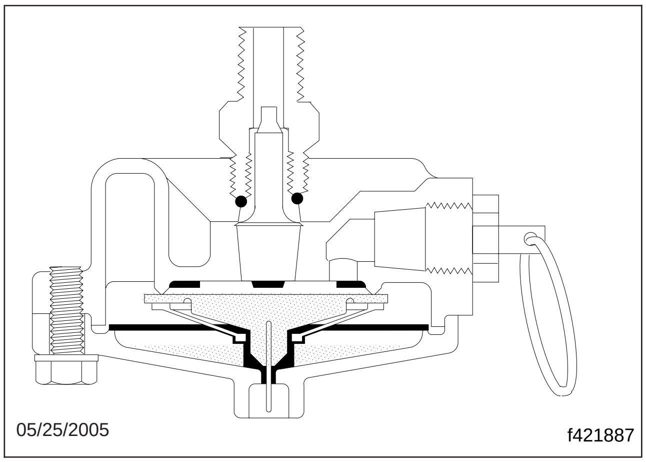


Fig. 5, System Pressure Rising

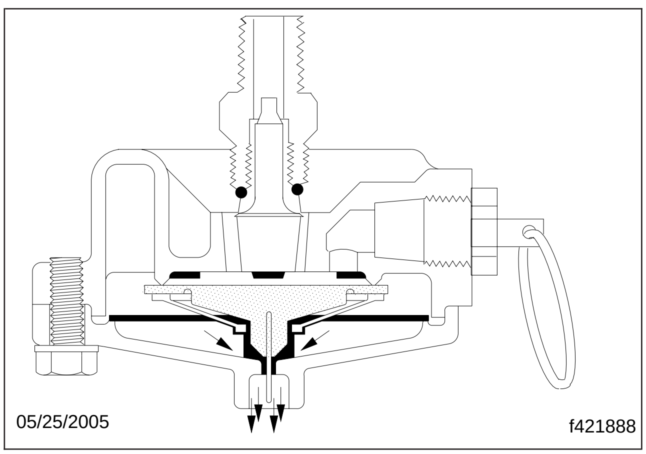


Fig. 6, Exhaust Cycle

Safety Precautions

Before attempting to work on the air brake system, observe the following precautions:

- Since the compression and storage of air can be compared to energy in a coiled spring, when released, it can present a hazard if not properly recognized. The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer's recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- Used reservoirs must not be used as replacements in order to eliminate the possibility of component failure.
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Operating Test

Perform the following test after repairing or replacing the DV-2 valve to ensure that the valve is functioning properly.

With the system charged, apply the brakes several times. Each time the brakes are applied, an exhaust of air should occur from the exhaust port of the drain valve. If no air comes out, push the wire stem located inside the exhaust port. If no air comes out after pushing the wire stem, there may be a plugged filter in the adapter which should be replaced.

If the drain valve does not function properly, replace it following the instructions in **Subject 120**.

Leakage Test

Perform the following test after repairing or replacing the DV-2 valve to ensure that the valve is functioning properly.

With the system charged and pressure stabilized in the system, there should be no leaks at the drain valve exhaust port. A constant slight exhaust of air at the drain valve exhaust port could be caused by excessive leakage in the air brake system.

If the drain valve is leaking excessively, repair it following the instructions in **Subject 120**.

Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. If the DV-2 with heater/thermostat is installed, disconnect heater wire from the valve.
4. Remove the drain valve assembly from the end of the wet tank air reservoir.

Installation

IMPORTANT: When installing a DV-2 drain valve equipped with a heater and thermostat, the #14 gauge lead wire on the valve should be connected to the ON position of the engine control or ignition switch. Use an 8 amp fuse for one valve, a 15 amp fuse for two valves, and a 20 amp fuse for three valves. All electrical connections must be waterproof.

1. Using a cleaning solvent, thoroughly flush and clean the wet tank reservoir to avoid early fouling at the drain valve. Aerate the wet tank thoroughly if solvents were used during cleaning.
2. Install the drain valve assembly on the wet tank by tightening the hexagonal nipple until the drain valve is positioned so that the valve body is parallel to the bottom of the wet tank with the exhaust port facing straight down. Make sure that the exhaust port is clear of any air, electric, or fuel lines. Make sure the drain valve is attached tight enough to prevent leakage.
3. If installing a DV-2 with heater/thermostat, connect heater wire.
4. Close the drain cocks to the supply and service reservoirs. Start the vehicle engine to pressurize the air system.
5. Leak test the drain valve following the instructions in **Subject 110**.
6. Remove the chocks from the tires.

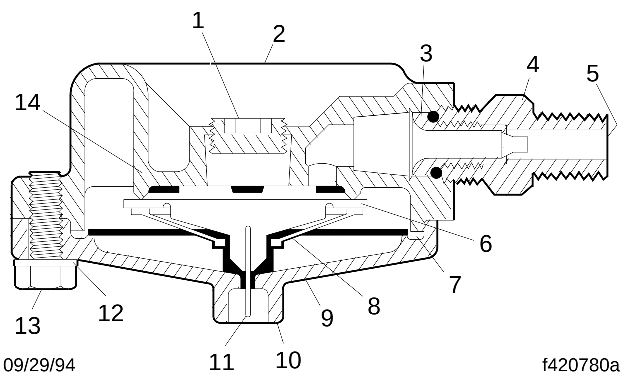
Disassembly, Cleaning and Inspection, and Assembly

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

NOTE: For a cutaway view of the standard DV–2 valve, see **Fig. 1**.

Disassembly



1. Top Reservoir Port
2. Valve Body
3. Filter Retainer
4. Hexhead Nipple
5. Side Reservoir Port
6. Inlet and Exhaust Valve
7. Valve Sealing Ring
8. Valve Guide
9. Valve Cover
10. Exhaust Port
11. Wire Stem
12. Lockwasher (4 qty.)
13. Capscrew (4 qty.)
14. Inlet Valve Seat

Fig. 1, Standard DV-2 Valve (cutaway view)

1. Remove the drain valve following the instructions in **Subject 120**.
2. Remove the four capscrews that hold the valve cover to the valve body.
3. Remove the valve cover and sealing ring.

NOTE: For vehicles equipped with the DV-2 with heater/thermostat (**Fig. 2**), the heater and thermostat are not serviceable. If the heater or thermostat has failed, the entire cover must be replaced. Do not remove the thermostat cover plate. It is moisture sealed and removal could result in early thermostat failure.

4. Remove the valve guide, and the inlet and exhaust valve from the valve body.

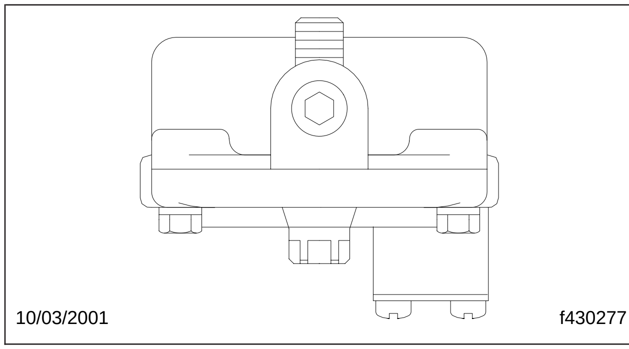


Fig. 2, DV-2 Valve with Heater/Thermostat

5. If equipped, remove the adaptor and filter assembly, filter retainer, and filter.
6. Remove the hexhead nipple from the valve body.

Cleaning and Inspection

WARNING

Use eye protection when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

1. Wash all metal parts of the drain valve in an approved cleaning solvent. Dry the metal parts of the disassembled moisture ejection valve with compressed air.
2. Wipe all rubber parts with a clean cloth. Examine all rubber parts for wear, cracks, tears, or other deterioration. If any rubber parts are worn, cracked, torn or otherwise deteriorated, replace them with new parts.
3. Examine all metal parts for wear, cracks, or other damage. If any metal parts are worn, cracked, or otherwise damaged, replace them with new parts. Discard filter screen, if present.

Assembly

Before assembling the drain valve, apply a light film of grease on the inlet valve seat.

CAUTION

Do not apply oil to the inlet and exhaust valve.

Disassembly, Cleaning and Inspection, and Assembly

1. Install the valve sealing ring into its groove in the valve cover.
2. Install the valve guide over the inlet and exhaust valve.
3. Install the valve guide, and the inlet and exhaust valve as an assembly into the valve cover. The wire stem will project through the exhaust port.
4. Install the valve body on the valve cover and install the lockwashers and capscrews. Tighten the capscrews 72 to 96 lbf·in (820 to 1080 N·cm).
5. Install the hexhead nipple onto the valve body, and tighten it 48 to 72 lbf·in (540 to 820 N·cm).
6. Install the drain valve on the wet tank following the instructions in **Subject 120**.

Specifications

Torque Values	
Description	**Torque lbf·in (N·cm)**
Valve Cover Capscrews	72–96 (820–1080)
Hexhead Nipple	48–72 (540–820)

Table 1, Torque Values

General Information

The air management unit (AMU) is a collection of pneumatic and electronic valves and pressure switches of modular form that fasten together in a row on a common rail. The AMU is usually located in the rear suspension area of the vehicle. However, it could be located anywhere on the vehicle chassis or body.

The AMU performs functions such as indicating various air pressure levels (switches), supplying either constant air or electrically controlled air to various chassis components (via an electric solenoid or pressure protected port). It also provides for pneumatic logic controls via double-check, inversion, relay and pressure regulation, therefore replacing double-check, inversion and relay valves on the vehicle.

The typical AMU layout (**Fig. 1**) contains one or more of the following:

- Pressure Switch
- Pressure Protection Module
- Solenoid Module
- Double-Check Valve Module
- Inversion Valve Module
- Relay Valve Module
- Regulator Module
- End Block Module

suspension, transmission, cab accessories, air to a truck body, and solenoid modules.

The solenoid modules control chassis components or systems such as fifth-wheel slide, rear suspension dump, inter-axle lock, diff-lock, end of frame air option, transfer case, and other ON-OFF air options.

The double check, inversion, and relay modules provide for air system logic used in various park brake interlocks, and other features. The regulator provides regulated air for lift axles, service brake check, work brake and other options.

Principles of Operation

Pressure Switch Module "A"

This pressure switch module (**Fig. 2**) receives three different air pressure inputs and closes or opens the appropriate switches when the pressures exceed the specified switch settings. There may be a total of 2, 3, or 4 separate switches in this module.

There are three application supply air ports and one primary air port.

The pressure switch is equipped with a shut-off valve, to shut off secondary air passing left to the pressure protection modules. This will allow air to the modules with constant air to be shut off when servicing. When the shut-off is operated, the air down stream will exhaust.

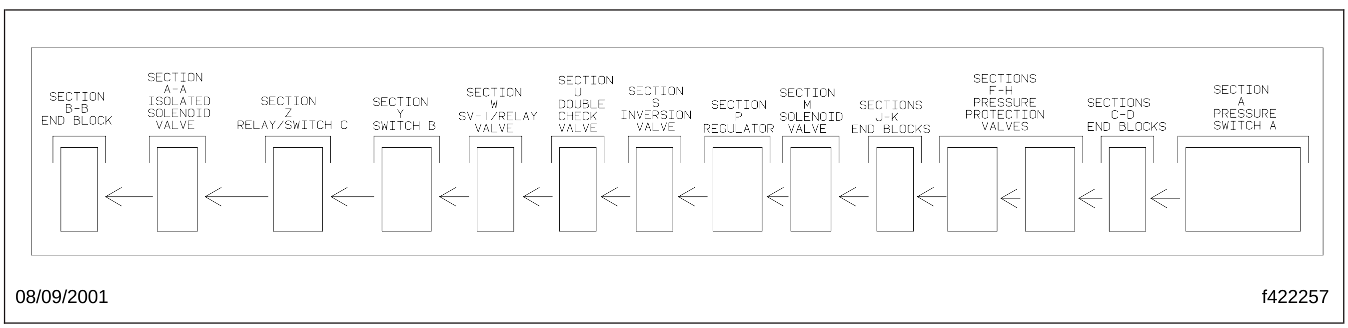


Fig. 1, Typical AMU Layout

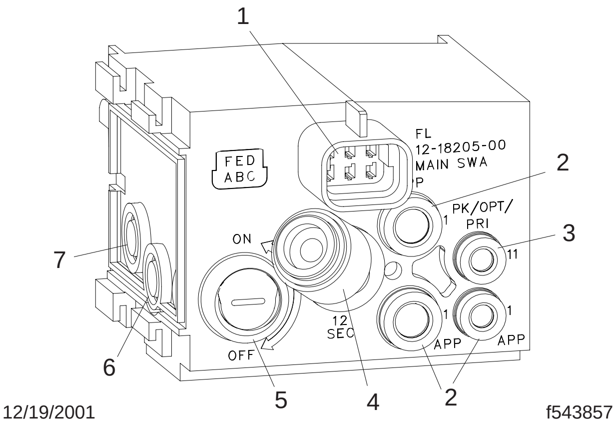
The switch modules will provide pressure level indication for low air tank pressure, brake application, park, and other optional pressures.

The pressure protection modules supply constant air to components such as chassis air suspension, cab

Pressure Switch Module "B" and "C"

Pressure Switch Module "B" (**Fig. 3**) receives one or two pressure inputs and opens or closes the

General Information



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1. Electrical Connector
2. Application Supply Air Ports
3. Primary Supply Air Port
4. Secondary Supply Air Port
5. Shut-off Valve
6. Secondary Air Internal Delivery Port
7. Non-Thru Port

Fig. 2, Pressure Switch Module "A"

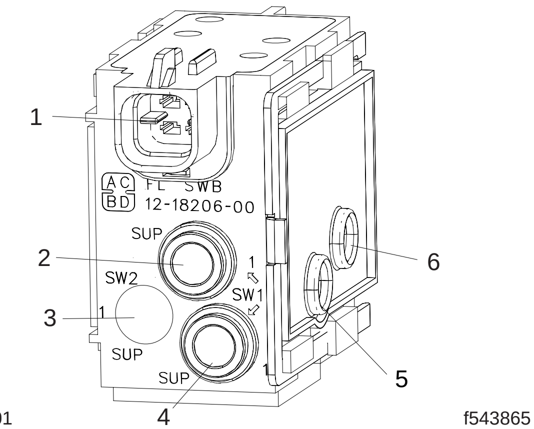
switch(es) when the pressure exceeds the specified switch setting.

Pressure switch module "C" contains a low current pressure switch, which receives a single pressure input and closes a switch when the pressure exceeds the specified switch setting. This module also contains a relay for delivering high current.

Pressure Protection Module

The pressure protection module (**Fig. 4**) shuts off all delivery air if the supply falls below the determined setting. It also shuts off the supply air to the valve if the delivery pressure fails below the determined setting.

The inlet to the pressure protection module is via an internal port on the right side that mates to the secondary air port on Switch Module "A" or the adjacent pressure protection module. This non-pressure protected air from Switch Module "A" will pass through the module from the internal supply port and out of the internal delivery port on the left side to supply the next valve (pressure protection, or solenoid). There is another delivery port on the left side that delivers pressure protected air to the adjacent module(s).



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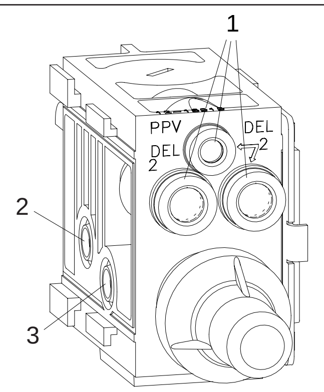
1. Electrical Connector
2. Switch 1 Supply Port
3 Switch 1 Supply Port
4. Switch 2 Supply Port
5. Non-Thru Port
6. Internal Delivery Port - RH side only (parking brake air)

Fig. 3, Pressure Switch Module "B"



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1. External Delivery Ports
2. Internal Delivery Port (LH side - delivery only)
3. Internal Supply Port (thru-port)

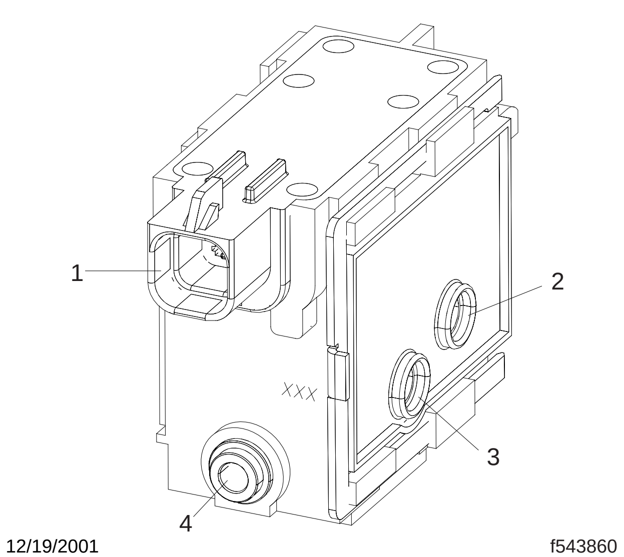
Fig. 4, Pressure Protection Module

Solenoid Module

There are two kinds of solenoid modules (**Fig. 5**): normally open (N.O.) and normally closed (N.C.). The solenoid module delivers air when electrically activated if N.C. It shuts off supply and exhausts delivery air when activated if N.O.

The inlet to the solenoid module mates to the port on the adjacent pressure protection module or another solenoid module. Pressure protected air will pass through the module from the internal supply port and out of the internal delivery port to supply the next solenoid module.

Each solenoid module is a three-way (supply, delivery and exhaust) on-off air valve. Every solenoid module has an internal pressure switch that monitors delivery pressure.



1. Electrical Connector
2. Internal Supply Port
3. Non-Thru Port
4. Delivery Port

Fig. 5, Solenoid Module

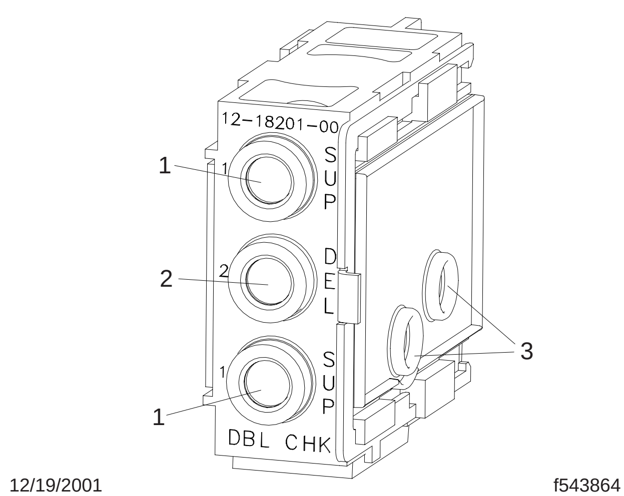
Double-Check Module

The double-check module (**Fig. 6**) delivers the higher air pressure of two separate input pressures. There are no internal air supply or delivery ports. There is one external outlet port on the face of the double check module.

Inversion Module

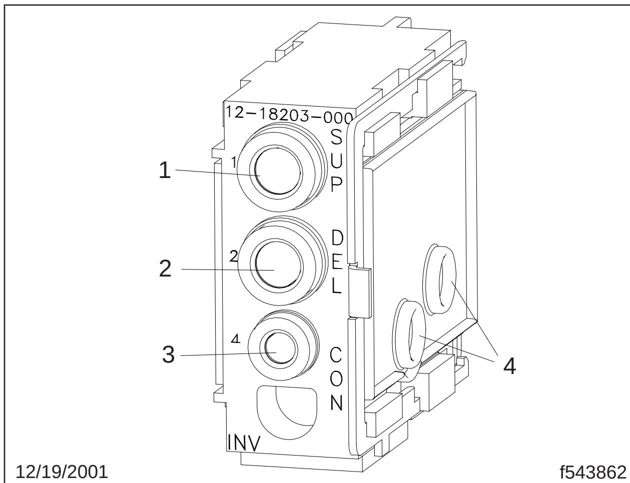
The inversion module (**Fig. 7**) is a normally open (N.O.) air valve that delivers system air pressure when the control pressure falls below the specified level. There are no internal supply, delivery, or control ports in this module.

The external supply, control, and delivery ports are on the face of the module.



1. External Supply Port
2. External Delivery Port
3. Non-Thru Ports

Fig. 6, Double-Check Module



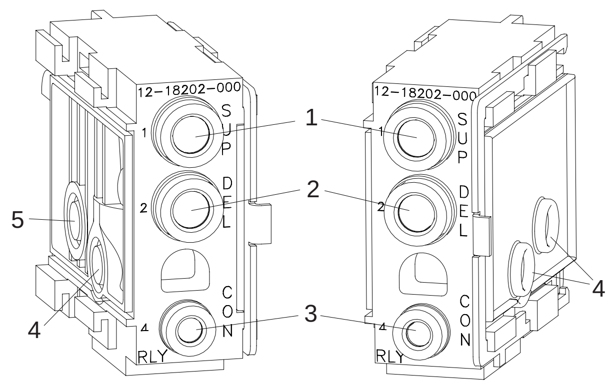
1. External Supply Port
2. External Delivery Port
3. External Control Port
4. Closed, Non-Thru Ports

Fig. 7, Inversion Module

General Information

Relay Valve

The relay valve (**Fig. 8**) is a normally closed air valve that delivers system air pressure when the control pressure exceeds the specified level. There is one internal control port on the left side of the module that will mate with pressure switch "B" module (**Fig. 3**) to receive parking brake air. The control, supply, and delivery ports are on the face of the module.



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1. External Supply Port.
2. External Delivery Port
3. External Control Port
4. Non-Thru Ports
5. Internal Control Port (Left-hand only)

Fig. 8, Relay Valve

Regulator Module

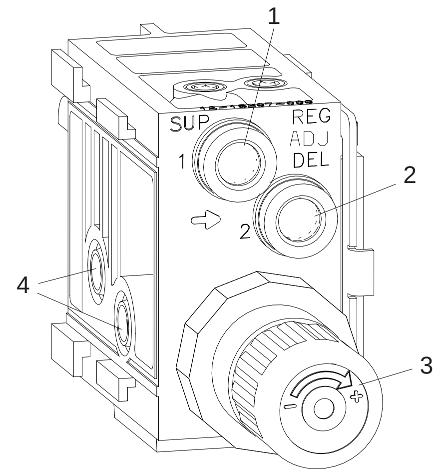
The adjustable regulator module (**Fig. 9**) limits the pressure delivered from the valve to a manually selected or adjusted level. Any pressure below this level will be approximatley equal to the supply pressure. The adjustment knob on the module allows for the delivery pressure to be set between 0 and 120 psi (827 kPa) at 180 psi (1240 kPa) supply pressure.

A non-adjustable regulator is also available. This module will have a pre-set pressure that will be printed on the module.

End Block

The ported end block module (**Fig. 10**) contains ports that are used to deliver air to another AMU on the vehicle or to modules at the other end of the AMU.

A non-ported end block is also available.



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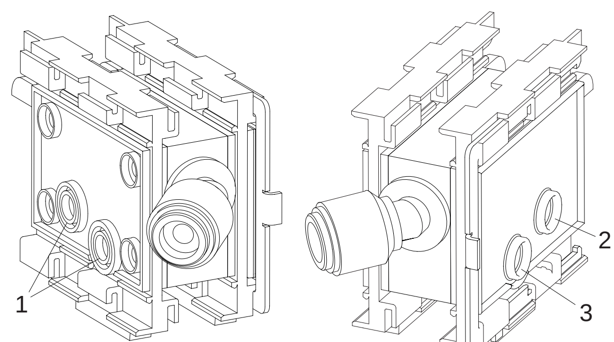
1. External Supply Port
2. External Delivery Port
3. Pressure Adjustment Knob
4. Closed, Non-Thru Ports

Fig. 9, Regulator Module



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1. Non-thru Ports
2. Internal Pressure Protected Port
3. Non-thru Port

Fig. 10, End Block

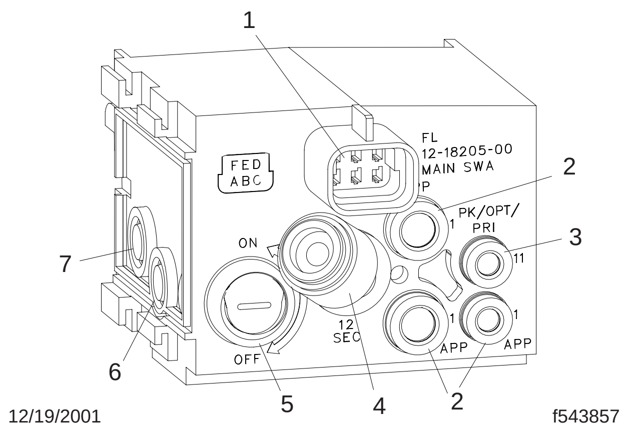
Replacement

Individual modules within the AMU can be replaced. The replacement may vary slightly for each module. The following is a general replacement procedure.

1. Park the vehicle on a level surface, shut down the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries.

NOTE: Pressure Switch "A" (**Fig. 1**) is equipped with a shut-off valve that will stop air from flowing to the modules to the left of the switch. This valve can be used to shut off air to the modules.

3. If replacing Pressure Switch "A", drain the air reservoirs. If replacing any other module, turn the shut-off valve on the pressure switch to the OFF position.

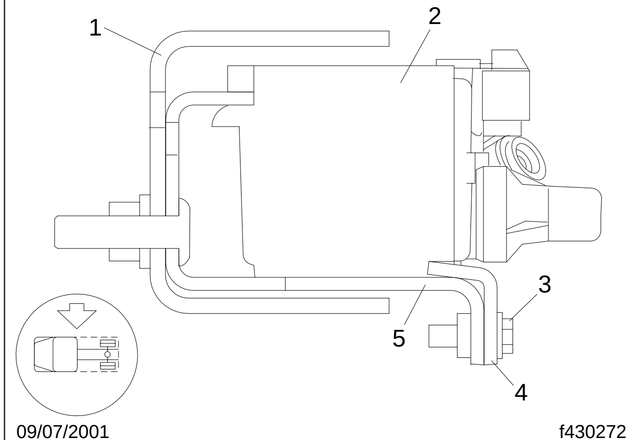


1. Electrical Connector
2. Application Supply Air Ports
3. Primary Supply Air Port
4. Secondary Supply Air Port
5. Shut-off Valve
6. Secondary Air Internal Delivery Port
7. Non-Thru Port

Fig. 1, Pressure Switch Module "A"

IMPORTANT: Clean the AMU and the area around it of all dirt and road debris before removing any modules. Failure do to so can result in dirt or road debris between the modules and their seals, causing air leakage.

4. Loosen the bolts on the L-bracket securing the air management unit (AMU) to the frame rail mounting bracket. See **Fig. 2**. This will allow the AMU to separate, allowing for easy removal of the module.



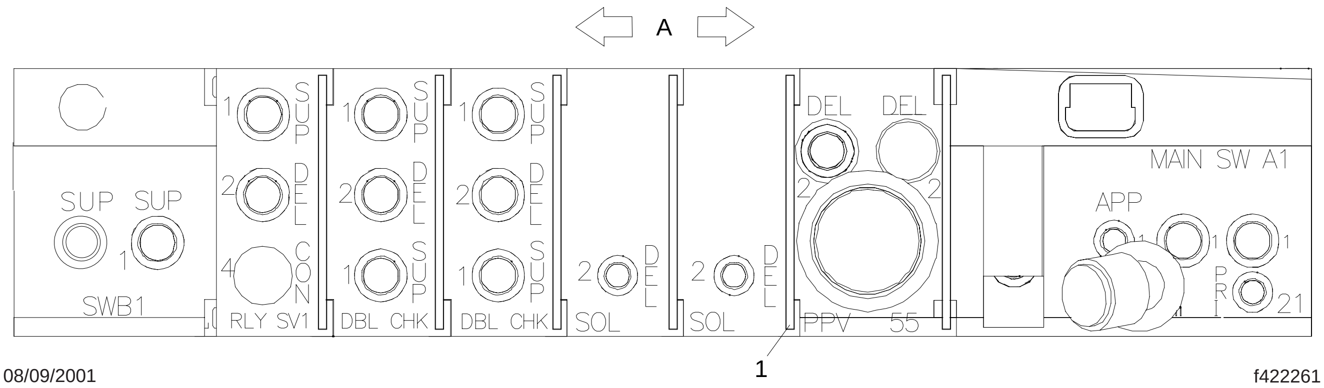
1. Crossmember
2. AMU
3. L-Bracket Bolt
4. L-Bracket
5. AMU Mounting Bracket

Fig. 2, Air Management Unit (AMU)

IMPORTANT: Be sure to mark all airlines before moving them from the modules.

5. Mark and disconnect the air lines (and electrical connectors, if applicable) from the module to be replaced.
6. Pull out the locking keys from both sides of the module to be removed and slide the AMU apart. See **Fig. 3**.
7. Remove the module.
8. Install the new seals on the sides of the module.
9. Place the new module in position and slide the module AMU together.
10. Push in the locking keys.
11. Install all air lines and electrical connectors as previously marked.
12. Firmly tighten the bolts on the L-bracket, securing the AMU in the mounting bracket. See **Fig. 2**.
13. If any other module besides Pressure Switch "A" was replaced, turn the shut-off valve on the pressure switch to the ON position.

AMU and AMU Module Replacement



A. Separate the AMU to remove the module.

1. Lock Key

Fig. 3, AMU Module Replacement

14. Connect the batteries.
15. Remove the chocks from the tires.

AMU Diagnostics

Pressure Switch "A" Testing

Pressure Switch Module "A" contains pressure switches and, on the 12-18205-XXX version only, a 3-way shut-off valve. The shutoff valve allows the rest of the AMU modules and downstream components to be serviced without having to drain the air tanks. Pressure Switch Module "A" comes in four different configurations (see **Table 1**) depending on whether the vehicle has air or hydraulic brakes and whether an air-horn/engine-fan pressure switch is needed. The internal pressure switches for part numbers 12-18205-XXX have a diode wired in parallel with the switch. Internal pressure switches for part numbers A12-19776-XXX do not have diodes wired in parallel with the internal pressure switches.

The low air pressure switches monitor the air pressure in the primary and secondary supply air systems. The pressure switches are internal to the Pressure Switch Module "A". The primary and secondary low air switches are wired in series. Each pressure switch closes when air pressure reaches approximately 70 ±5 psi (483 ±34 kPa). When both systems have reached 70 psi (483 kPa) and both switches are closed, a circuit to ground is completed to the Chassis Module (CHM). On the 12-18205-xxx valve, the low air pressure switch on the secondary side senses secondary air pressure downstream of the shutoff valve. If the shutoff valve is off, the pressure switch will be open regardless of pressure in the secondary air system. This will cause the vehicle's low air pressure warning lamp and buzzer to remain on even if both systems are fully charged.

The air-horn/engine-fan pressure switch monitors air pressure in the secondary air system. The purpose is to prevent the air-horn/engine-fan solenoid from activating when the system air pressure is too low. This switch closes at approximately 87 ±7 psi (600 ±48 kPa).

The stop lamp pressure switch monitors pressure in the service brake system. Its main purpose is to control the stop lamps. This switch closes at approximately 3.5 ±1.5 psi (24 ±10 kPa).

The park brake status pressure switch monitors air pressure in the park brake system. This switch opens at approximately 70 ±5 psi (483 ±34 kPa) for module part numbers 12-18205-002 and -003. This switch opens at 77 ±7 psi (531 ±48 kPa) for module part numbers A12-19776-002, -003, -012, and -013.

The optional pressure switch monitors air pressure in the secondary air system. This switch can be used to control optional accessories. This switch closes at approximately 70 ±5 psi (483 ±34 kPa).

For complete troubleshooting of a system (i.e. low air pressure warning lamp), refer to the appropriate coverage in this manual. The following tests are component tests only and do not troubleshoot an entire system.

Pressure Switch "A" Configurations				
Configuration	**Brake System Type**	**No. of Pressure Switches**	**Pressure Switch Function**	**Diagnostics Location**
1	Air Brake	3	Low Air Warning (Primary Air)	Pressure Switch "A" Tests (Air Brakes)
			Low Air Warning (Secondary Air)	
			Stop Lamp (Application Air)	
2	Air Brake	4	Low Air Warning (Primary Air)	
			Low Air Warning (Secondary Air)	
			Stop Lamp (Application Air)	
			Air Horn/Engine Fan	

Troubleshooting

Pressure Switch "A" Configurations				
Configuration	**Brake System Type**	**No. of Pressure Switches**	**Pressure Switch Function**	**Diagnostics Location**
3	Hydraulic Brake	2	Park Brake Status	Pressure Switch "A" Tests (Hydraulic Brakes)
			Optional Switch (Secondary Air)	
4	Hydraulic Brake	3	Park Brake Status	
			Optional Switch (Secondary Air)	
			Air Horn/Engine Fan	

Table 1, Pressure Switch "A" Configurations

Pressure Switch "A" Tests (Configurations 1 & 2 - Air Brakes)				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Low Air Pressure Switch Ground Circuit	·Key Off, Engine Off. ·Battery disconnected. ·Pressure Switch "A" 6-way connector disconnected.	Resistance Check: Measured between pin B (harness side) and the negative battery terminal.	Less than 1 ohm.	Check ground circuit wiring.
Low Air Pressure Switch Diode Applies to part numbers 12-18205-XXX: For all other part numbers: Skip this test.	·Key Off, Engine Off. ·Primary and Secondary air pressure under 10 psi (69 kPa). ·Pressure Switch "A" 6-way connector disconnected.	Resistance Check (or diode test if meter is capable): Measured between pin A and B (switch side). Then, reverse test leads and check again.	With the leads connected one way, the meter should read resistance (value not important), then when the leads are reversed, the reading should be infinite or 0 ohms.	Faulty Pressure Switch "A" (faulty diodes).
Low Air Pressure Switch	·Build system air to full pressure. ·Key Off, Engine Off. ·Pressure Switch "A" 6-way connector disconnected. ·Make sure Pressure Switch "A" shutoff valve is open.	Resistance Check: Measured between pin A and B (switch side). Then, reverse test leads and check again.	Less than 1 ohm (test leads both ways).	Faulty Pressure Switch "A".

Table 2, Pressure Switch "A" Tests (Configurations 1 & 2 - Air Brakes)

Stop Lamp Switch Tests (Configurations 1 & 2 - Air Brakes)				
NOTE: If any test fails, the Pressure Switch Module A is defective and must be replaced.				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Stop Lamp Ground Circuit	·Key OFF, Engine OFF. ·Battery disconnected. ·Pressure Switch "A" 6-way connector disconnected.	Resistance Check: Measured between pin C (harness side) and the negative battery terminal.	Less than 1 ohm.	Check ground circuit wiring.
Stop Lamp Switch Diode Applies to part numbers 12-18205-XXX: For all other part numbers: Skip this test.	·Key OFF, Engine OFF. ·Drain air tanks. ·Pressure Switch "A" 6-way connector disconnected.	Resistance Check (or diode test if meter is capable): Measured between pin C and D (switch side). Then, reverse test leads and check again.	With the leads connected one way, the meter should read resistance (value not important), then when the leads are reversed, the reading should be infinite or OL. NOTE: If the result is 0 ohms both ways, either the diode is shorted or the pressure switch is stuck closed. If the result was OL both ways, then the diode is open.	Faulty Pressure Switch "A".
Stop Lamp Switch	·Key OFF, Engine OFF. ·Pressure Switch "A" 6-way connector disconnected. ·Drain air tanks. ·Disconnect one of the APP ports on the face of the module and connect a regulated air supply setup as in **Fig. 1** to the port. ·Using the setup in **Fig. 1**, close Valve "A" and Valve "B". Back the regulator screw off so that the downstream pressure is zero. Connect shop air to the test apparatus. Open Valve "A". Apply 10 psi (69 kPa) to the APP port by adjusting the pressure regulator. This should cause the stop lamp pressure switch to close.	Resistance Check: Measured between pins C and D (switch side). Then, reverse test leads and check again.	Less than 1 ohm (test leads both ways). NOTE: If the resistance is more than 1 ohm either way, then the stop lamp switch is not closing between 2 and 5 psi (13 and 34 kPa).	Faulty Pressure Switch "A".

Table 3, Stop Lamp Switch Tests (Configurations 1 & 2 - Air Brakes)

Troubleshooting

Air-Horn/Engine-Fan Pressure Switch Tests (Configurations 1 & 2 - Air Brakes)				
NOTE: If any test fails, the Pressure Switch Module A is defective and must be replaced.				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Air-Horn/ Engine-Fan Pressure Switch Diode Applies to part numbers 12-18205-XXX. For all other part numbers: Skip this test.	·Drain air tanks. ·Key OFF, Engine OFF. ·Pressure Switch "A" 6-way connector disconnected.	Resistance Check (or diode test if meter is capable): Measured between pin E and F (switch side). Then, reverse test leads and check again.	With the leads connected one way, the meter should read resistance (value not important), then when the leads are reversed the reading should be infinite or 0 ohms. NOTE: If the result is 0 ohms both ways, either the diode is shorted or the pressure switch is stuck closed. If the result was 0L ohms both ways, then the diode is open.	Faulty Pressure Switch "A".
Air-Horn/ Engine-Fan Pressure Switch	·Key OFF, Engine OFF. ·Pressure Switch "A" 6-way connector disconnected. ·Drain air tanks. ·Close the 3-way shut-off valve on the module. ·Disconnect the SEC port on the face of the module and connect a regulated air supply setup as in **Fig. 1** to the port. ·Using the setup in **Fig. 1**, close Valve "A" and Valve "B". Back the regulator screw off so that the downstream pressure is zero. Connect shop air to the test apparatus. Open Valve "A". Apply 100 psi (689 kPa) to the SEC port by adjusting the pressure regulator. This should cause the air horn/engine fan pressure switch to close.	Resistance Check: Measured between pins E and F (switch side). Then, reverse test leads and check again.	Less than 1 ohm (test leads both ways). NOTE: If the resistance is more than 1 ohm either way, then the air horn/engine fan pressure switch is not closing between 80 and 94 psi (551 to 648 kPa).	Faulty Pressure Switch "A".

Table 4, Air-Horn/Engine-Fan Pressure Switch Tests (Configurations 1 & 2 - Air Brakes)

Park Brake Indicator Lamp Tests (configurations 3 & 4)				
NOTE: If any test fails, the Pressure Switch Module A is defective and must be replaced.				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Park Brake Indicator Lamp Ground Circuit	·Key Off, Engine Off. ·Battery disconnected. ·Pressure Switch "A" 6-way connector disconnected.	Resistance Check: Measured between pin C (harness side) and the negative battery terminal.	Less than 1 ohm.	Check ground circuit wiring.
Park Brake Indicator Lamp Switch Diode Applies to part numbers 12-18205-XXX For all other part numbers: Skip this step.	·Pressure Switch "A" 6-way connector disconnected. ·Drain air tanks. ·Disconnect the PK port on the face of the module and connect a regulated air supply setup as in **Fig. 1** to the port. ·Using the setup in **Fig. 1**, close Valve "A" and Valve "B". Back the regulator screw off so that the downstream pressure is zero. Connect shop air to the test apparatus. Open Valve "A". Apply 80 psi (551 kPa) to the PK port by adjusting the pressure regulator. This should cause the park brake pressure switch to open.	Resistance Check (or diode test if meter is capable): Measured between pin C and D (switch side). Then, reverse test leads and check again.	With the leads connected one way, the meter should read resistance (value not important), then when the leads are reversed, the reading should be infinite or OL. NOTE: If the result is 0 ohms both ways, either the diode is shorted or the pressure switch does not open at 65 to 75 psi (448 to 517 kPa). If the result was OL both ways, then the diode is open.	Faulty Pressure Switch "A" (faulty diodes).
Park Brake Indicator Lamp Switch	·Drain air tanks. ·Key OFF, Engine OFF. ·Pressure Switch "A" 6-way connector disconnected.	Resistance Check: Measured between pin C and D (switch side). Then, reverse test leads and check again.	Less than 1 ohm (test leads both ways) NOTE: If the resistance is more than 1 ohm either way then the park brake pressure switch is stuck open.	Faulty Pressure Switch "A"

Table 5, Park Brake Indicator Lamp Tests (configurations 3 & 4 - hydraulic brakes)

Troubleshooting

Optional Pressure Switch Ground Circuit Test (configurations 3 & 4 only - hydraulic brakes)				
NOTE: If any test fails, the Pressure Switch Module A is defective and must be replaced.				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Optional Pressure Switch Ground Circuit	·Key OFF, Engine OFF. ·Battery disconnected. ·Pressure Switch "A" 6-way connector disconnected.	Resistance Check: Measured between pin B (harness side) and the negative battery terminal.	Less than 1 ohm.	Check ground circuit wiring.
Optional Pressure Switch Diode Applies to part numbers 12-18205-XXX For all other part numbers: Skip this step.	·Key OFF, Engine OFF ·Pressure Switch "A" 6-way connector disconnected. ·Drain air tanks.	Resistance Check (or diode test if meter is capable): Measured between pins A and B (switch side). Then, reverse test leads and check again.	With the leads connected one way, the meter should read resistance (value not important), then when the leads are reversed, the reading should be infinite or OL. NOTE: If the result is 0 ohms both ways, either the diode is shorted or the pressure switch is stuck closed. If the result was OL both ways, then the diode is open.	Faulty Pressure Switch "A".
Optional Pressure Switch	·Key OFF, Engine OFF ·Pressure Switch "A" 6-way connector disconnected. ·Drain air tanks. ·Open the 3-way shut-off valve on the module. ·Disconnect the SEC port on the face of the module and connect a regulated air supply setup as in **Fig. 1** to the port. ·Using the setup in **Fig. 1**, close Valve "A" and Valve "B". Back the regulator screw off so that the downstream pressure is zero. Connect shop air to the test apparatus. Open Valve "A". Apply 80 psi (551 kPa) to the SEC port by adjusting the pressure regulator. This should cause the optional pressure switch to close.	Resistance Check: Measured between pins A and B (switch side). Then, reverse test leads and check again.	Less than 1 ohm (test leads both ways) If the resistance is more than 1 ohm either way, then the optional pressure switch is not closing between 65 and 75 psi (448 and 517 kPa).	Faulty Pressure Switch "A".

Table 6, Optional Pressure Switch Ground Circuit Test (configuration 3 and 4 only - hydraulic brakes)

Air-Horn/Engine-Fan Pressure Switch Diode Test (configurations 4 only)				
NOTE: If any test fails, the Pressure Switch Module A is defective and must be replaced.				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Air-Horn/ Engine-Fan Pressure Switch Diode Applies to part numbers 12-18205-XXX For all other part numbers: Skip this step.	·Drain air tanks. ·Key OFF, Engine OFF. ·Pressure Switch "A" 6-way connector disconnected.	Resistance Check (or diode test if meter is capable): Measured between pin E and F (switch side). Then, reverse test leads and check again.	With the leads connected one way, the meter should read resistance (value not important), then when the leads are reversed, the reading should be infinite or OL. NOTE: If the result is 0 ohms both ways, either the diode is shorted or the pressure switch is stuck closed. If the result was OL both ways, then the diode is open.	Faulty Pressure Switch "A".
Air Horn/ Engine Fan Pressure Switch	·Key OFF, Engine OFF ·Pressure Switch "A" 6-way connector disconnected. ·Drain air tanks. ·Close the 3-way shut-off valve on the module. ·Disconnect the SEC port on the face of the module and connect a regulated air supply setup as in **Fig. 1** to the port. ·Using the setup in **Fig. 1**, close Valve "A" and Valve "B". Back the regulator screw off so that the downstream pressure is zero. Connect shop air to the test apparatus. Open Valve "A". Apply 100 psi (689 kPa) to the SEC port by adjusting the pressure regulator. This should cause the air-horn/engine-fan pressure switch to close.	Resistance Check: Measured between pins E and F (switch side). Then, reverse test leads and check again.	Less than 1 ohm (test leads both ways) NOTE: If the resistance is more than 1 ohm either way then the air horn/engine fan pressure switch is not closing between 80 and 94 psi (551 and 648 kPa) .	Faulty Pressure Switch "A".

Table 7, Air Horn/Engine Fan Pressure Switch Diode Test (configurations 4 only)

Pressure Protection Valves

General Information

The pressure protection module shuts off all delivery air if the supply falls below the determined setting. It also shuts off the supply to the valve if the delivery pressure falls below the determined setting. Refer to **Table 8** for PPV open and closing pressures.

Troubleshooting

Pressure Protection Valve Specs			
Part Number	No. of Delivery Ports (External)	Open psi (kPa)	Closed psi (kPa)
12-18200-255	2	55 ±8 (379 ±55 kPa)	45 ±5 (310 ±34)
12-18200-285	2	85 ±8 (586 ±55 kPa)	67 ±5 (462 ±34)
12-18200-355	3	55 ±8 (379 ±55 kPa)	45 ±5 (310 ±34)
12-18200-385	3	85 ±8 (586 ±55 kPa)	67 ±5 (462 ±34)
A12-19772-255	2	55 ±8 (379 ±55 kPa)	45 ±5 (310 ±34)
A12-19772-285	3	85 ±8 (586 ±55 kPa)	67 ±5 (462 ±34)
A12-19772-355	2	55 ±8 (379 ±55 kPa)	45 ±5 (310 ±34)
A12-19772-385	3	85 ±8 (586 ±55 kPa)	67 ±5 (462 ±34)

Table 8, Pressure Protection Valve Specs

Test

Perform the followings pressure protection valve test to determine if the pressure protection valve module is functioning correctly. If any part of the test fails, replace the module.

1. Test for supply pressure drop protection.
   - 1.1 Drain the air tanks.
   - 1.2 Disconnect one of the delivery ports on the face of the module and connect an accurate pressure gauge.
   - 1.3 Connect an accurate pressure gauge to the secondary air tank.
   - 1.4 Start the engine and build air to maximum air pressure. Shut the engine off.
   - 1.5 Drain the secondary air tank while watching the gauges. The pressure on the delivery port of the pressure protection valve module should stop falling at approximately the closing pressure in **Table8**, while the pressure on the secondary tank gauge continues to fall to zero.
2. Test for delivery pressure drop protection.
   - 2.1 Drain the air tanks.
   - 2.2 Disconnect one of the delivery ports on the face of the module and connect a valve (use fittings and airline as necessary). Close the valve.
   - 2.3 Connect an accurate pressure gauge to the secondary air tank.

     Start the engine and build air to maximum air pressure. Shut the engine off.
   - 2.4 Open the valve installed on the delivery port of the module. When air stops flowing through the valve, observe the pressure gauge on the secondary air tank. The pressure should not fall below approximately the closing pressure listed in **Table8**.
3. Test for opening pressure.
   - 3.1 Drain the air tanks.
   - 3.2 Disconnect one of the delivery ports on the face of the module and connect an accurate pressure gauge.
   - 3.3 Connect an accurate pressure gauge to the secondary air tank.
   - 3.4 Start the engine and observe the gauges. The gauge on the delivery port of the module should remain at 0 psi (kPa) until the pressure in the secondary air tank pressure gauge reaches approximately the opening pressure listed in **Table8**.

Solenoid Valves

General Information

The solenoid valves control chassis components such as the fifth-wheel slide, rear suspension dump, inter-axle lock, diff-lock, end-of-frame air option, transfer case, and other ON-OFF air options. Solenoid valves are supplied with pressure protected secondary air. Therefore, they are always positioned to the left of the pressure protection valves on the air management unit (AMU). There are two variations of the solenoid valve, one is normally closed and the other is normally open. The normally closed solenoids come with various delivery port collar colors. This helps during manufacturing to match colored air lines to the correct solenoid valve. Other than that, they are functionally the same. Normally closed solenoid valves have a black cover, and normally open solenoid valves have a natural (light beige) colored cover. Each solenoid valve has an internal pressure switch that monitors delivery pressure. Solenoid valves with part numbers 12-18208-XXX have a diode wired in parallel with the pressure switch. All solenoid valves have a diode wired in parallel with the solenoid coil to prevent voltage spikes.

Solenoid Valve Electrical Pin and Functional Tests

Solenoid Coil Resistance and Diode Check *			
Conditions	Test Point	Good Result	If Test Fails:
·Key OFF, Engine OFF. ·Solenoid valve connector disconnected.	Coil Resistance and Diode Check: Measured between pin C and D (switch side). Then, reverse test leads and check again.	Approx. 16 ohms with leads both ways. NOTE: If result was much greater than 16 ohms one way and 0 ohms with the leads reversed, then the coil is open. If the result was 0 ohms both ways, then the diode or coil is shorted. There is no way to specifically check the internal diode.	Replace solenoid valve.

* NOTE: The solenoid has an internal diode wired in parallel with the coil.

Table 9, Solenoid Coil Resistance and Diode Check

Solenoid Valve Pressure Switch Diode Test			
Conditions	Test Point	Good Result	If Test Fails:
·Drain air tanks. ·Key OFF, Engine OFF. ·Solenoid valve connector disconnected. Applies to part numbers 12-18208-XXX: For all other part numbers: Skip this step.	Resistance Check (or diode test if meter is capable) Measured between pin A and B (switch side). Then, reverse test leads and check again.	With the leads connected one way the meter should read resistance (value not important), then when the leads are reversed the reading should be infinite or OL. NOTE: If the meter reads 0 ohms both ways, then either the switch is stuck closed or the diode is shorted. If the meter reads OL both ways, the diode is open.	Replace solenoid valve

Table 10, Solenoid Valve Pressure Switch Diode Test

Troubleshooting

Solenoid Valve Functional Test			
Conditions	**Test Point**	**Good Result**	**If Test Fails:**
·Drain the air tanks. ·Solenoid valve connector disconnected. ·Disconnect the air line to the external delivery port on the solenoid valve and connect an accurate pressure gauge in its place. ·Start the engine and build air to full pressure. Shut the engine OFF. ·Key OFF, Engine OFF	Solenoid Valve Functional Test: Using a fused jumper wire, connect solenoid pin C (solenoid valve side) to the positive battery post. Using another jumper wire, connect solenoid pin D (solenoid valve side) to ground. **Do not reverse the polarity of the solenoid coil, damage to the internal diode may result.**	For Normally Closed Valves: Before connecting the jumper wires, the pressure gauge should read zero pressure. The solenoid should switch on and deliver air to the external delivery port (pressure should read on the gauge). For Normally Open Valves: Before connecting the jumper wires, the pressure gauge should read pressure (55 or 85 psi [379 or 586 kPa] depending on upstream pressure protection valve). The solenoid should switch on and exhaust air from the external delivery port (pressure should read zero on the gauge).	Replace solenoid valve.

Table 11, Solenoid Valve Functional Test

Solenoid Valve Pressure Switch Functional Test (for normally closed valves only)			
Conditions	**Test Point**	**Good Result**	**If Test Fails:**
·Drain the air tanks. ·Solenoid valve connector disconnected. ·Disconnect the air line to the external delivery port on the solenoid valve and connect an accurate pressure gauge in its place. ·Start the engine and build air to full pressure. Shut the engine OFF. ·Key OFF, Engine OFF	Solenoid Valve Pressure Switch Functional Test: Using a fused jumper wire, connect solenoid pin C (solenoid valve side) to the positive battery post. Using another jumper wire, connect solenoid pin D (solenoid valve side) to ground. **Do not reverse the polarity of the solenoid coil, damage to the internal diode may result.** Once the solenoid has been energized, measure the resistance across pins A and B, then reverse the leads and check again.	With the Solenoid Energized: The resistance, with the leads both ways, should be less than 1 ohm, and the pressure gauge should read 55 psi (379 kPa) or 85 psi (586 kPa), depending on the upstream pressure protection valve. With the Solenoid De-energized: The resistance, with the leads both ways, should be more than 1 ohm, and the pressure gauge should read 0 psi. NOTE: Solenoid valves with a part number 12-18208-XXX have a diode wired in parallel with the pressure switch.	Replace solenoid valve.

Table 12, Solenoid Valve Pressure Switch Functional Test (for normally closed valves only)

Solenoid Valve Pressure Switch Functional Test (for normally open valves only)			
Conditions	**Test Point**	**Good Result**	**If Test Fails:**
·Drain the air tanks. ·Solenoid valve connector disconnected. ·Disconnect the air line to the external delivery port on the solenoid valve and connect an accurate pressure gauge in its place. ·Start the engine and build air to full pressure. Shut the engine OFF. ·Key OFF, Engine OFF	Solenoid Valve Pressure Switch Functional Test: Using a fused jumper wire, connect solenoid pin C (solenoid valve side) to the positive battery post. Using another jumper wire, connect solenoid pin D (solenoid valve side) to ground. **Do not reverse the polarity of the solenoid coil, damage to the internal diode may result.** Once the solenoid has been energized, measure the resistance across pins A and B, then reverse the leads and check again. Then disconnect the jumpers and measure the resistance across pins A and B again, then reverse the leads and check again.	With the Solenoid Energized: The resistance with the leads both ways should be more than 1 ohm and the pressure gauge should read 0 psi. With the solenoid De-energized: The resistance with the leads both ways should be less than 1 ohm and the pressure gauge should read 55 psi or 85 psi, depending on upstream pressure protection valve. Note: Solenoid valves with a part number 12-18208-XXX have a diode wired in parallel with the pressure switch.	Replace solenoid valve.

Table 13, Solenoid Valve Pressure Switch Functional Test (for normally open valves only)

Pressure Regulator Module

General Information

The pressure regulator module limits the pressure delivered from the valve to some level depending on its setting. Any pressure below this level will be nearly equal to the supply pressure. There are adjustable and non-adjustable pressure regulator valves. These valves do not have internal supply and delivery ports. The body color of all pressure regulators modules is natural (light beige). The delivery port collar colors vary depending on pressure setting. See **Table 14**.

Pressure Regulator Module Specs		
Part Number	**Regulated Pressure**	**Delivery Port Collar Color**
12-18207-000	0 to 150 psi (1034 kPa) - Adjustable	Violet
12-18207-030	30 psi (207 kPa) - Non-adjustable	Green
12-18207-060	60 psi (413 kPa) - Non-adjustable	Red
12-18207-080	80 psi (551 kPa) - Non-adjustable	Black

Table 14, Pressure Regulator Module Specs

Test

Perform the followings pressure regulator valve test to determine if the pressure valve module is functioning correctly. If the test fails, replace the module.

1. Drain the air tanks.
2. Disconnect the delivery port on the face of the module and connect an accurate pressure gauge.
3. Note the pressure setting of the regulator (see **Table 14**).
4. Connect an accurate pressure gauge to the secondary air tank.
5. Start the engine.
6. As pressure in the system is building, observe the pressure gauges. Until the pressure at the regulator valve equals its pressure setting, both gauges should read approximately the same. Once the pressure at the regulator reaches its setting it should remain at that pressure while the pressure in the secondary tank continues to rise to full pressure.

Inversion Valve Module (Normally Open Relay)

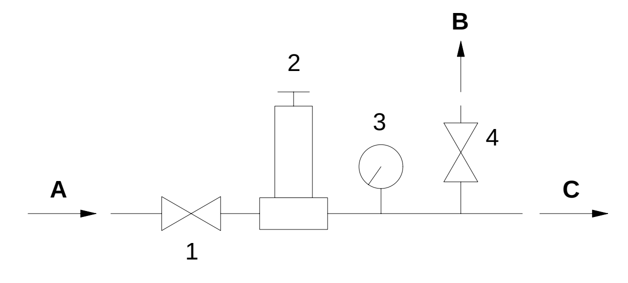
General Information

The inversion valve module is basically a normally open relay, meaning that when no pressure is applied to the control port, supply air is delivered to the delivery port. When pressure is applied to the control port, the supply air is cut off from the delivery port and the delivery air is exhausted to atmosphere. There are no internal supply, delivery, or control ports on this module.

When rising pressure applied to the control port reaches 45 ±5 psi (310 ±34 kPa), the delivery port is cut off from the supply port, and delivery port air is exhausted to atmosphere. When applied pressure to the control port releases and reaches 25 ±5 psi (172 ±34 kPa), the delivery port is no longer exhausted to atmosphere and supply air is delivered to the delivery port.

Test

To test the inversion valve, a simple tester can be constructed consisting of a regulator valve, two valves, a pressure gauge, and some air line. See **Fig. 1**.



A. Shop Air
B. Exhaust to Atmosphere
C. To Control Port

1. Valve "A"
2. Pressure Regulator
3. 0 to 150 psi gauge
4. Valve "B"

Fig. 1, Setup for Inversion and Relay Valve Testing

Perform the following test procedure to determine if the inversion valve module is functioning properly. If the module fails the test, replace it.

1. Drain the air tanks.
2. Disconnect the delivery port on the face of the module and connect an accurate pressure gauge.
3. Disconnect the control port on the face of the module and connect a regulated air supply setup as in **Fig.1** to the control port.
4. Start the engine, build system air to full pressure. Shut the engine off.
5. Using the setup in **Fig.1**, close Valve "A" and Valve "B". Back the regulator screw off so that the downstream pressure is zero. Connect shop air to the test apparatus. Open Valve "A". The gauge on the delivery port of the inversion module should read pressure.
6. Apply rising pressure to the control port by adjusting the pressure regulator. While increasing the pressure, observe the pressure gauges. When the control port pressure (regulated) reaches approximately 30 to 45 psi (207 to 310 kPa), the delivery port (on inversion module)

should exhaust (the delivery port gauge on the inversion valve module should drop to zero pressure).

7. Once the delivery port on the inversion valve module has exhausted (pressure goes to zero), close Valve "A" on the test apparatus. Next, open Valve "B" slightly so as to relieve the control port pressure very slowly while observing the pressure gauges. When the control port pressure drops (pressure gauge on the test apparatus) to approximately 20 to 30 psi (138 to 207 kPa), the pressure at the delivery port of the inversion valve should read pressure.

Double Check Valve Module

General Information

The double check valve module takes supply air from two sources and delivers the higher of the two to the delivery port. These modules do not have any internal through ports to other modules.

Test

Perform the following test procedure to determine if the double check valve module is functioning properly. If the module fails the test, replace it.

1. Drain the air tanks.
2. Disconnect the delivery port on the face of the module and connect an accurate pressure gauge.
3. Disconnect both supply ports.
4. Apply shop air to the upper supply port. The pressure gauge on the delivery port gauge should read shop air pressure. Check for leakage at the lower supply port, using a soapy water solution. There should be virtually no leakage (less than 3/8-inch bubble in 1 minute).
5. Next, apply shop air to the lower supply port. The pressure on the delivery port gauge should read shop air pressure. Check for leakage at the upper supply port, using a soapy water solution. There should be virtually no leakage (less than 3/8-inch bubble in 1 minute).

Relay Valve Module (normally closed)

General Information

The relay valve module delivers supply air to the delivery port when the air is applied to the control port. When air pressure is released from the control port, the delivery port is exhausted to atmosphere. This module comes in two versions. In one version, there is an internal control port in addition to the one on the face of the module. In the other version, there is an internal delivery port in addition to the one on the face of the module. In both versions, there are no other internal ports.

When rising pressure applied to the control port reaches 21 ±3 psi (144 ±20 kPa), the delivery port is cut off from the exhaust to atmosphere and the supply port delivers air to the delivery port. When applied pressure to the control port releases and reaches 11 ±3 psi (76 ±20 kPa), the delivery port is cut off from the supply air, and delivery port air is exhausted to atmosphere.

Test

Perform the following test procedure to determine if the relay valve module is functioning properly. If the module fails the test, replace it.

1. Drain the air tanks.
2. Disconnect the delivery port on the face of the module and connect an accurate pressure gauge.
3. Disconnect the control port on the face of the module and connect a regulated air supply setup as in **Fig.1** to the control port.
4. Start the engine, and build system air to full pressure. Shut the engine off.
5. Using the setup in **Fig.1**, close Valve "A" and Valve "B". Back the regulator screw off so that the downstream pressure is zero. Connect shop air to the test apparatus. Open Valve "A". The gauge on the delivery port of the inversion module should read zero pressure.
6. Apply rising pressure to the control port by adjusting the pressure regulator. While increasing the pressure, observe the pressure gauges. When the control port pressure (regulated) reaches approximately 18 to 24 psi (124 to 165

Troubleshooting

kPa), the delivery port (on relay module) should read pressure.

7. Once the delivery port gauge reads systems pressure, close Valve "A" on the test apparatus. Next, open Valve "B" slightly so as to relieve the control port pressure very slowly while observing the pressure gauges. When the control port pressure drops (pressure gauge on the test apparatus) to approximately 8 to 14 psi (55 to 96 kPa), the pressure at the delivery port of the relay valve should exhaust and read zero pressure.

Pressure Switch "B" Module

General Information

Pressure Switch "B" module comes in various configurations. All have at least one normally closed pressure switch. Differences between versions depend on an optional second normally open pressure switch. Some versions have internal ports, some do not. See **Table 15** for the variations of this module. Pressure switch "B" modules with P/Ns 12-18206-XXX have diodes wired in parallel with the internal pressure switches, all others do not.

Pressure Switch "B" Module									
Part Number	Switch 1		Switch 2		No. of Ports to SW 1		No. of Ports to SW 2		Module Cover Color (body always black)
	N.C.	Closes @ psi (kPa)	N.O.	Opens @ psi (kPa)	Int.	Ext.	Int.	Ext.	
12-18206-000	Yes	70±5 (483±34)	—	—	1	2	—	—	Natural (lt. beige)
12-18206-001	Yes	70±5 (483±34)	Yes	70±5 (483±34)	0	1	0	1	Black
12-18206-002	Yes	70±5 (483±34)	—	—	0	1	0	—	Black
12-18206-003	Yes	70±5 (483±34)	Yes	70±5 (483±34)	1	1	0	1	Natural (lt. beige)
12-18206-004	Yes	70±5 (483±34)	—	—	0	1	—	—	Natural (lt. beige)
12-18206-005	Yes	70±5 (483±34)	Yes	70±5 (483±34)	0	2	0	1	Black
12-18206-006	Yes	70±5 (483±34)	No	70±5 (483±34)	0	2	0	1	Black
12-18206-007	Yes	70±5 (483±34)	No	70±5 (483±34)	1	2	0	1	Natural (lt. beige)
12-18206-008	Yes	70±5 (483±34)	Yes	3.5±1.5 (24±10)	0	1	0	1	Black
12-18206-009	Yes	70±5 (483±34)	—	—	1	1	0	—	Natural (lt. beige)
12-18206-010	Yes	70±5 (483±34)	Yes	70±5 (483±34)	0	2	0	1	Black

Troubleshooting

Pressure Switch "B" Module									
Part Number	Switch 1		Switch 2		No. of Ports to SW 1		No. of Ports to SW 2		Module Cover Color (body always black)
	N.C.	Closes @ psi (kPa)	N.O.	Opens @ psi (kPa)	Int.	Ext.	Int.	Ext.	
12-18206-011	Yes	70±5 (483±34)	No	70±5 (483±34)	0	2	0	1	Black
12-18206-012	Yes	70±5 (483±34)	No	70±5 (483±34)	1	2	0	1	Natural (lt. beige)
12-18206-013	Yes	70±5 (483±34)	—	—	0	2	—	—	Black
12-18206-014	No	3.5±1.5 (24±10)	Yes	70±5 (483±34)	0	2	0	1	Black
12-18206-015	—	—	Yes	87±7 (600±48)	—	—	0	1	Black
12-18206-016	—	—	Yes	70±5 (483±34)	—	—	0	1	Black
A12-19777-001	Yes	77±7 (531±48)	—	—	1	2	—	—	Natural (lt. beige)
A12-19777-002	Yes	77±7 (531±48)	Yes	70±5 (483±34)	0	1	0	1	Black
A12-19777-003	Yes	77±7 (531±48)	—	—	0	1	—	—	Black
A12-19777-004	Yes	77±7 (531±48)	Yes	70±5 (483±34)	1	1	0	1	Natural (lt. beige)
A12-19777-005	Yes	77±7 (531±48)	Yes	70±5 (483±34)	0	2	0	1	Black
A12-19777-006	Yes	77±7 (531±48)	No	77±7 (531±48)	0	2	0	1	Black
A12-19777-007	Yes	77±7 (531±48)	No	77±7 (531±48)	1	2	0	1	Natural (lt. beige)
A12-19777-008/-108	Yes	77±7 (531±48)	Yes	3.5±1.5 (24±10)	0	1	0	1	Black
A12-19777-009	Yes	77±7 (531±48)	—	—	1	1	—	—	Natural (lt. beige)
A12-19777-010	Yes	77±7 (531±48)	Yes	70±5 (483±34)	0	2	0	1	Black
A12-19777-011	Yes	77±7 (531±48)	No	77±7 (531±48)	0	2	0	1	Black
A12-19777-012	Yes	77±7 (531±48)	No	77±7 (531±48)	1	2	0	1	Natural (lt. beige)
A12-19777-013	Yes	77±7 (531±48)	—	—	0	2	—	—	Black
A12-19777-014/-114	No	3.5±1.5 (24±10)	Yes	70±5 (483±34)	0	2	0	1	Black

Pressure Switch "B" Module									
Part Number	Switch 1		Switch 2		No. of Ports to SW 1		No. of Ports to SW 2		Module Cover Color (body always black)
	N.C.	Closes @ psi (kPa)	N.O.	Opens @ psi (kPa)	Int.	Ext.	Int.	Ext.	
A12-19777-015	—	—	Yes	87±7 (600±48)	—	—	0	1	Black
A12-19777-016	—	—	Yes	70±5 (483±34)	—	—	0	1	Black
A12-19777-017/-117	No	3.5±1.5 (24±10)	Yes	3.5±1.5 (24±10)	0	2	0	1	Black
A12-19777-018	Yes	77±7 (531±48)	Yes	70±5 (483±34)	1	2	0	1	Natural (lt. beige)
A12-19777-119	Yes	77±7 (531±48)	Yes	3.5±1.5 (24±10)	0	2	0	1	Black

Table 15, Pressure Switch "B" Module

Pressure Switch "B" Tests

For testing the pressure switches in pressure switch module “B”, first determine if the pressure switch to be tested is normally open or normally closed (see **Table 15**.) Then test the pressure switch using the appropriate tables that follow.

Troubleshooting

Testing Pressure Switch 1 — Switch "B" Module (all with normally closed pressure switch 1)				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Test if Switch Opens at Proper Pressure	Chock tires. Key OFF, engine OFF. Drain air tanks. Pressure switch "B" 4-way connector disconnected. Disconnect one of the SW1 ports on the face of the module and connect a regulated air supply setup as in **Fig. 1** to the SW1 port. Close valve "A" and valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A". Apply 5 psi (35 kPa) above the maximum opening pressure to the SW1 port by adjusting the pressure regulator. For example, if the opening pressure is 70–84 psi (483–579 kPa), then apply 89 psi (614 kPa) to the SW1 port. This should cause switch 1 to open.	Resistance Check: Measured between pin A and B (switch side).	Greater than 1 ohm. NOTE: If the meter reads less than 1 ohm, then the pressure switch is not opening within the proper pressure range, and is therefore faulty.	Faulty Pressure Switch "B". Replace it.
Test if Switch Closes at Proper Pressure	Using the same apparatus as used in the previous test, close valve "A", then back the regulator off and bleed off all pressure to the SW1 port using valve "B". Close valve "A" and valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A". Apply 5 psi (35 kPa) below the minimum opening pressure to the SW1 port by adjusting the pressure regulator. For example, if the opening pressure is 70–84 psi (483–579 kPa), then apply 65 psi (448 kPa) to the SW1 port. This should cause switch 1 to close.	Resistance Check: Measured between pin A and B (switch side).	Less than 1 ohm.	Faulty Pressure Switch "B". Replace it.

Table 16, Testing Pressure Switch 1 -- Switch "B" Module (all with normally closed pressure switch 1)

Troubleshooting

Testing Pressure Switch 1 – Switch "B" Module (All with normally open pressure switch 1)				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Test if Switch Opens at Proper Pressure	Chock tires. Key OFF, engine OFF. Drain air tanks. Pressure switch "B" 4-way connector disconnected.	Resistance Check: Measured between pin A and B (switch side).	Greater than 1 ohm. NOTE: If the meter reads less than 1 ohm, then the pressure switch is stuck closed, and is therefore faulty.	Faulty Pressure Switch "B". Replace it.
Test if Switch Closes at Proper Pressure	Disconnect one of the SW1 ports on the face of the module and connect a regulated air supply setup as in **Fig. 1** to the SW1 port. Close valve "A" and valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A". Apply 5 psi (35 kPa) above the maximum closing pressure to the SW1 port by adjusting the pressure regulator. For example, if the closing pressure is 2–5 psi (15–35 kPa) , then apply 10 psi (69 kPa) to the SW1 port. This should cause switch 1 to close.	Resistance Check: Measured between pin A and B (switch side).	Less than 1 ohm. NOTE: If the meter reads greater than 1 ohms, then the pressure switch is not closing within the proper pressure range, and is therefore faulty.	Faulty Pressure Switch "B". Replace it.

Table 17, Testing Pressure Switch 1 -- Switch "B" Module (all with normally open pressure switch 1)

Testing Pressure Switch 2 – Switch "B" Module (all with normally closed pressure switch 2)				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Test if Switch Opens at Proper Pressure	Chock tires. Key OFF, engine OFF. Drain air tanks. Pressure switch "B" 4-way connector disconnected. Disconnect one of the SW2 ports on the face of the module and connect a regulated air supply setup as in **Fig. 1** to the SW2 port. Close valve "A" and valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A". Apply 5 psi (35 kPa) above the maximum opening pressure to the SW2 port by adjusting the pressure regulator. For example, if the opening pressure is 70–84 psi (483–579 kPa), then apply 89 (614 kPa) psi to the SW2 port. This should cause switch 2 to open.	Resistance Check: Measured between pin C and D (switch side).	Greater than 1 ohm. NOTE: If the meter reads less than 1 ohm, then the pressure switch is not opening within the proper pressure range, and is therefore faulty.	Faulty Pressure Switch "B". Replace it.
Test if Switch Closes at Proper Pressure	Using the same apparatus as used in the previous test, close valve "A", then back the regulator off and bleed off all pressure to the SW2 port using valve "B". Close valve "A" and valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A". Apply 5 psi (35 kPa) below the minimum opening pressure to the SW2 port by adjusting the pressure regulator. For example, if the opening pressure is 70–84 psi (483–579 kPa), then apply 65 psi (448 kPa) to the SW2 port. This should cause switch 2 to close.	Resistance Check: Measured between pin C and D (switch side).	Less than 1 ohm. NOTE: If the meter reads greater than 1 ohm, then the pressure switch is not closing within the proper pressure range, and is therefore faulty.	Faulty Pressure Switch "B". Replace it.

Table 18, Testing Pressure Switch 2 -- Switch "B" Module (all with normally closed pressure switch 2)

Troubleshooting

Testing Pressure Switch 2 – Switch "B" Module (all with normally open pressure switch 2)				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Test if Switch Opens at Proper Pressure	Chock tires. Key OFF, engine OFF. Drain air tanks. Pressure switch "B" 4-way connector disconnected. Do the following for all N.O. SW2 modules except for modules where the SW2 closing pressure is 2–5 psi (15–35 kPa): Disconnect one of the SW2 ports on the face of the module and connect a regulated air supply setup as in **Fig.1** to the SW2 port. Close valve "A" and valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A". Apply 5 psi (35 kPa) below the minimum closing pressure to the SW2 port by adjusting the pressure regulator. For example, if the closing pressure is 65–75 psi (448–517 kPa), then apply 60 psi (414 kPa) to the SW2 port. This should cause switch 2 to be open.	Resistance Check: Measured between pin C and D (switch side).	Greater than 1 ohm. NOTE: If the meter reads less than 1 ohm, then the pressure switch is not open within the proper pressure range, and is therefore faulty.	Faulty Pessure Switch "B". Replace it.

Testing Pressure Switch 2 – Switch "B" Module (all with normally open pressure switch 2)				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Test if Switch Closes at Proper Pressure	Using the same apparatus as used in the previous test, close valve "A", then back the regulator off and bleed off all pressure to the SW2 port using valve "B". Close valve "A" and valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A". Apply 5 psi (35 kPa) above the maximum closing pressure to the SW2 port by adjusting the pressure regulator. For example, if the closing pressure is 65–75 psi (448–517 kPa), then apply 80 psi (552 kPa) to the SW2 port. This should cause switch 2 to close.	Resistance Check: Measured between pin C and D (switch side).	Less than 1 ohm. NOTE: If the meter reads greater than 1 ohms, then the pressure switch is not closing within the proper pressure range, and is therefore faulty.	Faulty Pressure Switch "B". Replace it.

Table 19, Testing Pressure Switch 2 -- Switch "B" Module (all with normally open pressure switch 2)

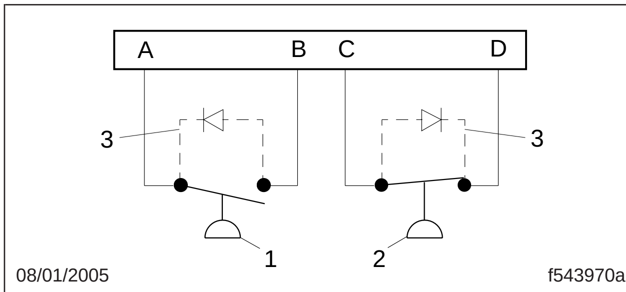
Specifications

Refer to the following figures and tables for electrical schematics and corresponding part numbers for internal components of individual air management unit (AMU) modules.

List of Figures and Tables

Schematics and Tables

See **Fig. 1** for pressure switch "A" with hydraulic brake systems and 4-pin connector wiring, and **Table 1** for corresponding part numbers.



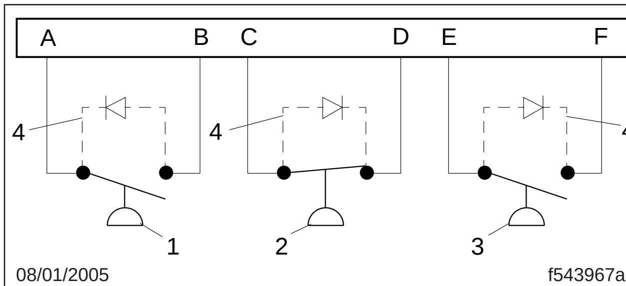
A–D are corresponding pins on electrical connector.
1. Optional Air Tank (secondary)
2. Park Brake
3. Diode (only on 12-18205-002)

Fig. 1, Pressure Switch "A" for Hydraulic Brake Systems

Pressure Switch "A" for Hydraulic Brake Systems Part Numbers	
With Diode	**Without Diode**
12-18205-002	A12-19776-002
—	A12-19776-012

Table 1, Pressure Switch "A" for Hydraulic Brake Systems Part Numbers

See **Fig. 2** for pressure switch "A" with hydraulic brake systems and 6-pin connector wiring, and **Table 2** for corresponding part numbers.



A–F are corresponding pins on electrical connector.
1. Optional Air Tank (secondary)
2. Park Brake
3. Engine Fan
4. Diode (only on 12-18205-003)

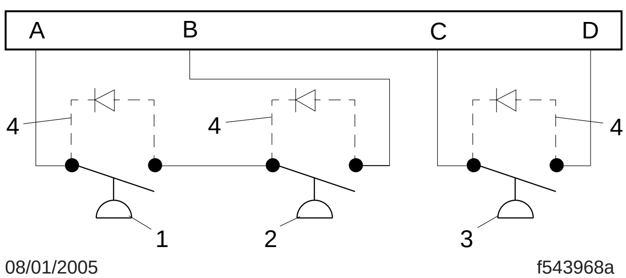
Fig. 2, Pressure Switch "A" for Hydraulic Brake Systems

Specifications

Pressure Switch "A" for Hydraulic Brake Systems Part Numbers	
With Diode	**Without Diode**
12-18205-003	A12-19776-003
—	A12-19776-013

Table 2, Pressure Switch "A" for Hydraulic Brake Systems Part Numbers

See **Fig. 3** for pressure switch "A" with air brake systems and 4-pin connector wiring, and **Table 3** for corresponding part numbers.



A–D are corresponding pins on electrical connector.

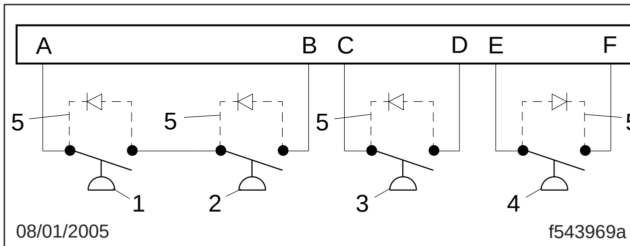
1. Low Air (secondary)
2. Low Air (primary)
3. Application Air
4. Diode (only on 12-18205-000)

Fig. 3, Pressure Switch "A" for Air Brake Systems

Pressure Switch "A" for Air Brake Systems Part Numbers	
With Diode	**Without Diode**
12-18205-000	A12-19776-000, -010
—	A12-19776-004, -014

Table 3, Pressure Switch "A" for Air Brake Systems Part Numbers

See **Fig. 4** for pressure switch "A" with air brake systems and 6-pin connector wiring, and **Table 4** for corresponding part numbers.



A–F are corresponding pins on electrical connector.

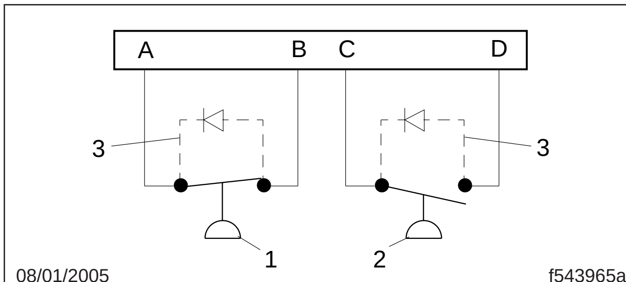
1. Low Air (secondary)
2. Low Air (primary)
3. Application Air
4. Engine Fan
5. Diode (only on 12-18205-001)

Fig. 4, Pressure Switch "A" for Air Brake Systems

Pressure Switch "A" for Air Brake Systems Part Numbers	
With Diode	**Without Diode**
12-18205-001, -011	A12-19776-001, -011
—	A12-19776-005, -015

Table 4, Pressure Switch "A" for Air Brake Systems Part Numbers

See **Fig. 5** for pressure switch "B" with SW 1 N.C. and SW 2 N.O. wiring, and **Table 5** for corresponding part numbers.



A–D are corresponding pins on electrical connector.

1. Switch 1
2. Switch 2
3. Diode (only on 12-18206-xxx)

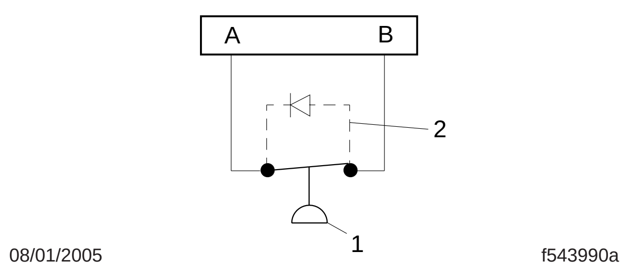
Fig. 5, Pressure Switch "B", 4-Pin Connector

Pressure Switch "B" Part Numbers	
With Diode	**Without Diode**
12-18206-001	A12-19777-002

Pressure Switch "B" Part Numbers	
With Diode	**Without Diode**
12-18206-003	A12-19777-004
12-18206-005	A12-19777-005
12-18206-008	A12-19777-008
12-18206-010	A12-19777-108
—	A12-19777-010
—	A12-19777-018
—	A12-19777-119

Table 5, Pressure Switch "B" Part Numbers

See **Fig. 6** for pressure switch "B" with SW 1 only wiring, and **Table 6** for corresponding part numbers.



A & B are corresponding pins on electrical connector.

1. Switch 1
2. Diode (only on 12-18206-xxx)

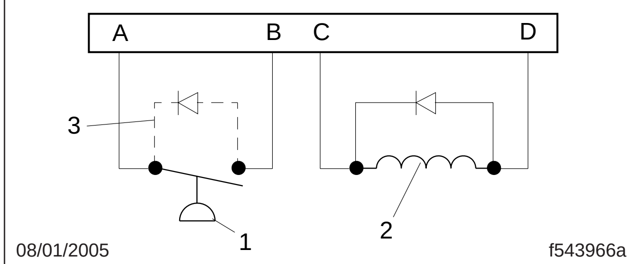
Fig. 6, Pressure Switch "B"

Pressure Switch "B" Part Numbers	
With Diode	**Without Diode**
12-18206-000	A12-19777-001
12-18206-002	A12-19777-003
12-18206-004	A12-19777-009
12-18206-009	A12-19777-013
12-18206-013	—

Table 6, Pressure Switch "B" Part Numbers

See **Fig. 7** for solenoid module wiring.

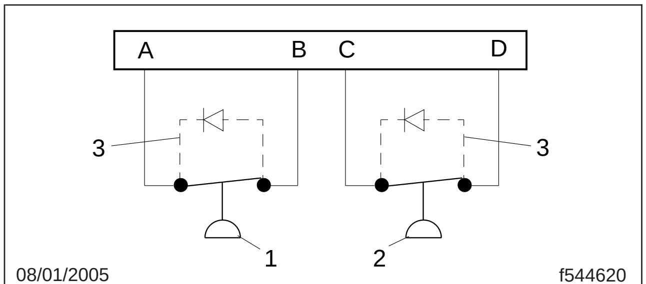
See **Fig. 8** for pressure switch "B" with SW 1 and SW 2 N.C. wiring, and **Table 7** for corresponding part numbers.



A–D are corresponding pins on electrical connector.

1. Pressure Switch (confirms solenoid activation)
2. Solenoid Coil
3. Diode (only on 12-18208-xxx)

Fig. 7, Solenoid



A–D are corresponding pins on electrical connector.

1. Switch 1
2. Switch 2
3. Diode (only on 12-18206-xxx)

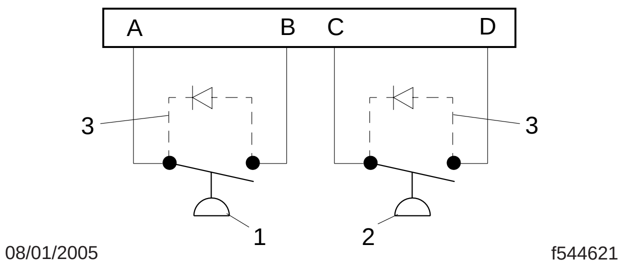
Fig. 8, Pressure Switch "B"

Pressure Switch "B" Part Numbers	
With Diode	**Without Diode**
12-18206-006	A12-19777-006
12-18206-007	A12-19777-007
12-18206-011	A12-19777-011
12-18206-012	A12-19777-012

Table 7, Pressure Switch "B" Part Numbers

See **Fig. 9** for pressure switch "B" with SW 1 and SW2 N.O. wiring, and **Table 8** for corresponding part numbers.

Specifications



A–D are corresponding pins on electrical connector.

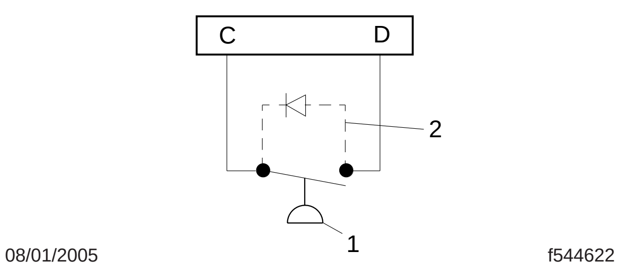
1. Switch 1
2. Switch 2
3. Diode (only on 12-18206-014)

Fig. 9, Pressure Switch "B", N.O.

Pressure Switch "B" Part Numbers	
With Diode	**Without Diode**
12-18206-014	A12-19776-014
—	A12-19776-114
—	A12-19776-017
—	A12-19777-117

Table 8, Pressure Switch "B" Part Numbers

See **Fig. 10** for pressure switch "B" with SW 2 only wiring, and **Table 9** for corresponding part numbers.



C & D are corresponding pins on electrical connector.

1. Switch 2
2. Diode (only on 12-18206-xxx)

Fig. 10, Pressure Switch "B", N.O.

Pressure Switch "B" Part Numbers	
With Diode	**Without Diode**
12-18206-015	A12-19776-015

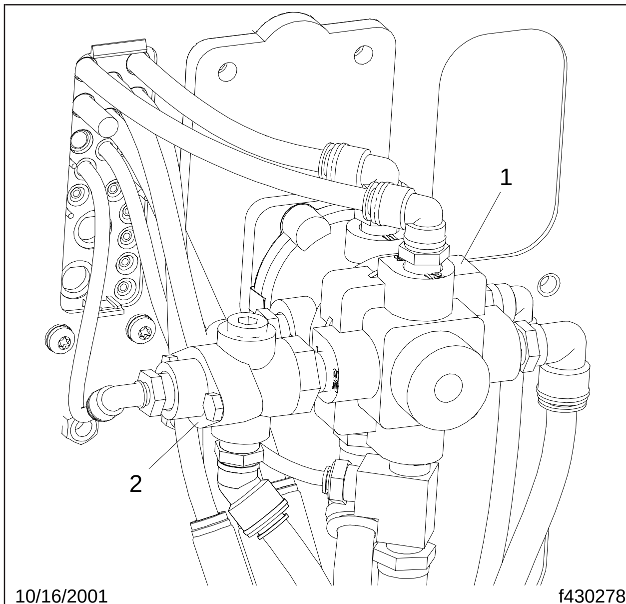
Pressure Switch "B" Part Numbers	
With Diode	**Without Diode**
12-18206-016	A12-19776-016

Table 9, Pressure Switch "B" Part Numbers

General Information

The Bendix DC–4 shuttle-type double check valve (**Fig. 1**) is normally used only when the vehicle is equipped with a trailer hand control valve. Double check valves are used in the air brake system to direct a flow of air into a common line from either of two sources, whichever is at the higher pressure. A shuttle type valve has a movable shuttle to seal off the lower pressure source and allow the air from the higher pressure source to flow.

In this case, the valve allows air to be supplied to the trailer brakes from either the hand control valve or the foot valve, whichever supplies the higher pressure. This allows the trailer brakes to be applied with either the hand valve or the foot valve. If both the foot and hand valves are applied simultaneously, the DC–4 valve will supply air to the trailer brakes from whichever valve is applying higher pressure.



1. Foot Brake Valve
2. Double Check Valve

Fig. 1, Brake Valve and Double Check Valve Plumbing

Principles of Operation

As pressurized air enters either end of the double check valve inlet port, the moving shuttle responds to the greater pressure source and seals the opposite port. The air flow continues out the delivery port of the valve. The position of the shuttle will reverse if the pressure levels are reversed. Double check valves are designed so the shuttle cannot interfere with the backflow of air in the exhaust mode.

Safety Precautions

When working on or around air brake systems and components, observe the following precautions:

1. Chock the tires and shut down the engine before working under a vehicle. Dropping air system pressure may cause the vehicle to roll. Keep hands away from brake chamber push rods and slack adjusters; they will apply as air pressure drops.
2. Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
3. Never exceed recommended air pressure and always wear safety glasses when working with compressed air. Never look into air jet or direct them at anyone.
4. Never attempt to disassemble a component until you have read and understood recommended procedures. Some components contain powerful springs, and injury can result if they are not correctly disassembled. Use only the correct tools, and observe all precautions regarding use of those tools.

Operating and Leakage Test

1. If testing the valve while in the vehicle, proceed as follows:

   1.1 Push in and release the foot brake pedal while checking that the brakes apply and release on both the tractor and trailer.

   1.2 Apply and release the trailer control valve while checking that only the trailer brakes apply and release.

   1.3 Apply the trailer control valve and check the exhaust port of the foot brake valve for leakage using a soap solution. A 1-inch (2.5-cm) bubble or less in 5 seconds is allowable. Release the valve.

   1.4 Disconnect the air line from the trailer control valve exhaust port. Push the foot brake pedal until it stops and hold it in place. Check the trailer control valve exhaust port for leakage using a soap solution. A 1-inch (2.5-cm) bubble or less in 5 seconds is allowable.

   1.5 Connect the air line to the trailer control valve exhaust port.

   1.6 If the double check valve does not function as described, or if the leakage is excessive, replace it. See **Subject 120** for instructions.

   If the valve cannot be replaced, repair it using Bendix parts. See **Subject 130** for instructions.

2. Connect two separately controlled air supplies to the inlet ports.

3. If bench testing the valve, proceed as follows.

   3.1 Apply and release air to one inlet port (foot brake pedal) while checking that the test gauge registers the application and release.

   3.2 Apply and release air to the other inlet port (trailer control valve) while checking that the gauge registers the application and release.

   3.3 Disconnect the line from one of the double check valve inlet ports. Apply air to the opposite inlet port while checking the first port for leakage using a soap solution. A 1-inch (2.5-cm) bubble or less in 5 seconds is allowable. Connect the line to the inlet port. Repeat this step, checking the opposite inlet port for leaks.

   3.4 If the double check valve does not function as described, or if the leakage is excessive, replace it. See **Subject 120** for instructions.

   If the valve cannot be replaced, repair it using Bendix parts. See **Subject 130** for instructions.

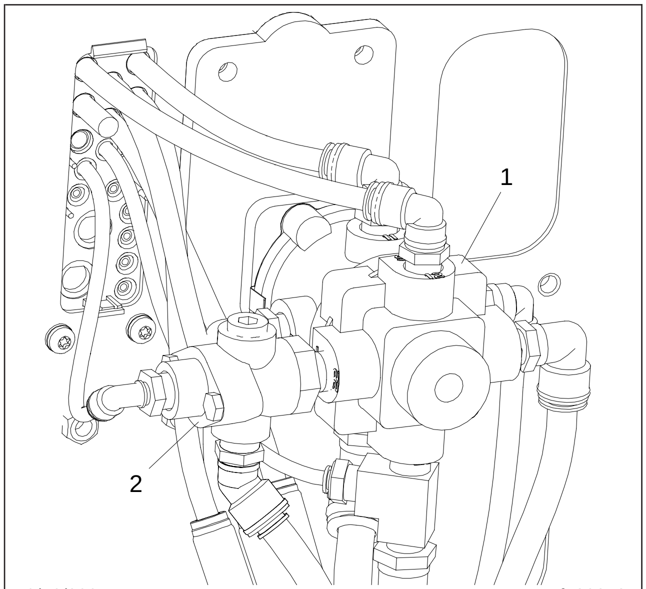
Double Check Valve Removal and Installation

Removal

WARNING

Wear safety goggles when draining the air system or disconnecting an air line because dirt or sludge particles could fly out at high speeds. Don't direct the air streams at other people. Don't disconnect pressurized hoses, since they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

1. Drain the air from the air reservoirs.
2. Disconnect the air lines from the double check valve. See **Fig. 1**.



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1. Foot Brake Valve
2. Double Check Valve

Fig. 1, Brake Valve and Double Check Valve Plumbing

3. Unscrew the double check valve from the foot brake valve.

Installation

1. Screw the double check valve into the foot brake valve. Tighten the valve firmly.
2. Connect the air lines to the double check valve as marked. Push the air lines firmly into the quick-connect fittings.

Double Check Valve Disassembly, Cleaning and Inspection, and Assembly

Disassembly

See Fig. 1 for a cross-sectional view of the check valve.

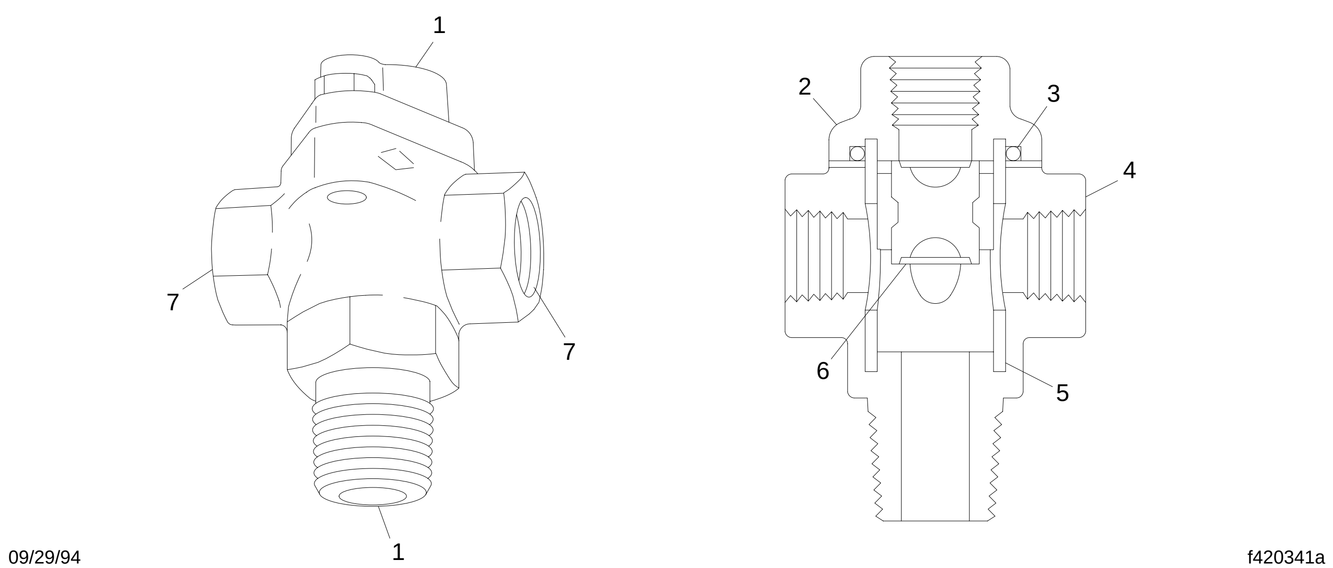
1. Remove the valve from the vehicle. For instructions, see Subject 120.
2. Remove the end cap from the valve.
3. Remove the O-ring.
4. Remove the shuttle valve and shuttle guide.

Cleaning and Inspection

1. Clean all metal parts in a cleaning solvent.
2. Inspect all metal parts for signs of cracks, wear, or deterioration. Replace all parts not considered serviceable.
3. Replace all rubber parts.

Assembly

1. Install the shuttle valve and shuttle guide in the valve body.
2. Coat the O-ring with BW 650M silicone lubricant (BW 291126). It is not necessary to lubricate the shuttle valve.
3. Install the O-ring.
4. Install the end cap on the valve body.
5. Install the valve on the vehicle. For instructions, see Subject 120.
6. Test the valve. For instructions, see Subject 110.



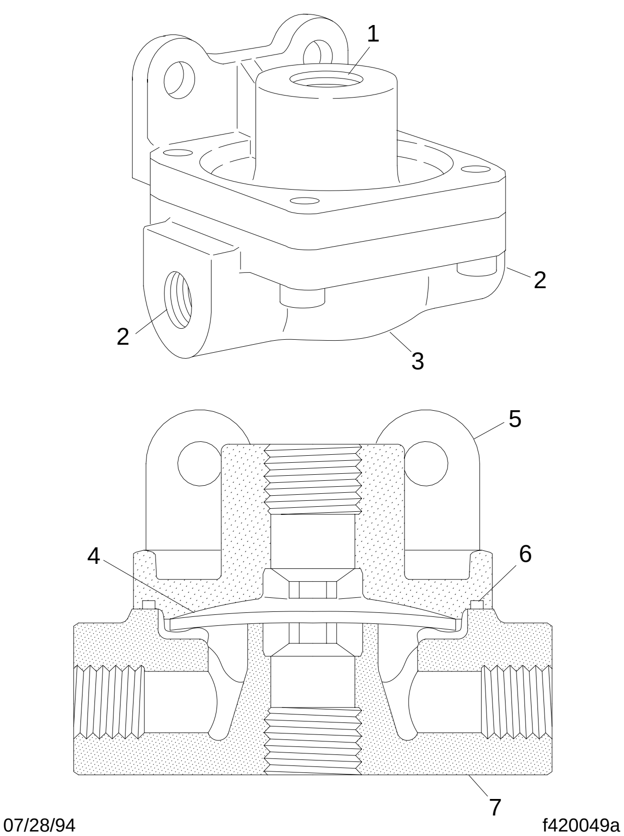
1. Supply Port
2. End Cap
3. O-Ring
4. Valve Body
5. Shuttle Guide
6. Shuttle Valve
7. Delivery Port

Fig. 1, Double Check Valve

General Information

QR-1 Valve

The function of the QR–1 quick release valve (Fig. 1) is to speed up the release of air pressure from the front service brake chambers. When the front brake chambers are equipped with a QR–1 valve, and a foot brake application is released, the exhaust port of the quick release valve opens and the air from the front brake chambers is exhausted through the quick release valve. This accelerates the release of the front brakes.



1. Supply Port
2. Delivery Port
3. Exhaust Port
4. Diaphragm
5. Cover
6. O-Ring
7. Body

Fig. 1, QR-1 Valve and Cross Section

When the front brake chambers are equipped with a QR–1 valve, it is located on the forward face of the crossmember just aft of the transmission. A delivery line from the foot valve is connected to the port on top of the QR–1 quick release valve; the two side ports are for brake chamber connections, and the exhaust port is located at the bottom of the valve.

QR-1C Valve

The QR–1C quick release valve (Fig. 2) is a dual function valve. Its primary function is to speed up the release of air pressure from the service brake chambers. Additionally, the valve works as an anti-compound device. The double check valve feature prevents a service and parking brake application from occurring at the same time.

The QR–1C valve is generally mounted on the axle and serves two spring brake actuators. A balance line from the relay valve delivery port is connected to the balance port on top of the QR–1C quick release valve. The two side ports are for brake chamber connections. The supply port is connected to the delivery port of the parking brake control valve, and the exhaust port is located at the bottom of the valve. The air connections to the QR–1C are as follows:

1. The QR–1C delivery port is connected to the emergency port of the spring brake.
2. The QR–1C balance port is connected to the delivery of the relay valve.

NOTE: The QR–1C valve should be connected to the delivery side (not to the service or signal side) of the relay valve.

3. The QR–1C supply port is connected to the delivery of the park control valve.

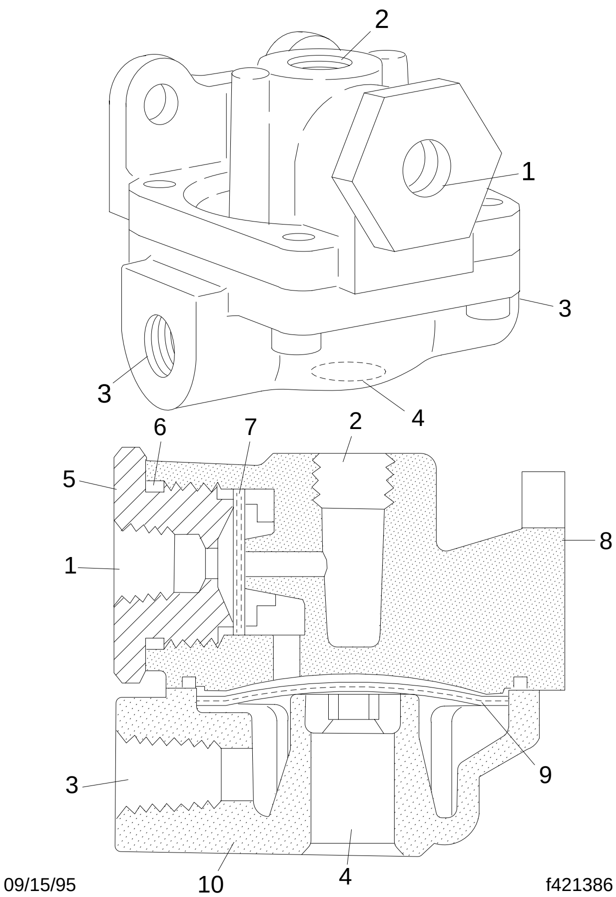
Principles of Operation

QR-1 Valve

When the foot brake control is applied, delivery air enters the brake valve port on the QR–1 quick release valve; the diaphragm moves down, sealing the exhaust port. At the same time, air pressure forces the edges of the diaphragm down, allowing air to flow out the brake chamber ports, filling the chambers and applying the front axle brakes.

When the brake chamber air pressure (beneath the diaphragm) equals the air pressure being delivered

General Information



1. Supply Port
2. Balance Port
3. Delivery Port
4. Exhaust
5. Cap Nut
6. Sealing Ring
7. Double Check Diaphragm
8. Body
9. Quick Release Diaphragm
10. Cover

Fig. 2, QR-1C Valve and Cross-Section

by the foot valve (above the diaphragm), the outer edge of the diaphragm will seal against the valve body seat. The exhaust port is still sealed by the center portion of the diaphragm. When the foot brake is released, the air above the diaphragm is released back through the foot brake valve exhaust, while the air beneath the diaphragm forces the diaphragm to rise, opening the exhaust port, and allowing air in the brake chambers to exhaust.

QR-1C Valve

Parking Brakes Released

When the parking brakes are released, air from the parking brake control valve flows through the QR–1C valve. This forces the double check diaphragm and the quick release diaphragm to flex and seal the balance and exhaust ports. Air flows into the inlet ports of the parking brake chambers from the QR–1C valve delivery ports.

Parking Brakes Applied

When the parking brakes are applied, supply line air pressure to the QR–1C valve is exhausted through the parking brake control valve. As air pressure is exhausted from one side of the double check diaphragm and the quick release diaphragm, both diaphragms flex in the opposite direction to open the balance and exhaust ports. Parking brake pressure is released at the exhaust port of the QR–1C valve while a small amount of air trapped between the two diaphragms is released through a relay valve or the foot valve exhaust port.

Anti-Compounding

When a service brake application is made with the parking brakes applied, service air enters the balance port and flows through the QR–1C valve into the inlet ports of the parking brake chambers. This prevents application of the service and parking brakes at the same time. Service air passing through the QR–1C valve flexes the double check and quick release diaphragms, sealing the supply and exhaust ports. When the service brake application is released, air is exhausted from the balance port allowing the supply port to seal the balance and exhaust ports and keep the spring brakes released.

Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

Operating and Leakage Tests

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

The following tests should be performed after repairing or replacing the quick-release valve to ensure that it is functioning properly.

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Release the parking brakes.
4. On QR-1C valves, remove the air line from the valve balance port. Build system air pressure to 120 psi (827 kPa). Coat the exhaust and balance ports with a soap solution; leakage of a 1-inch (2.5-cm) bubble in 5 seconds at either port is allowable. Install the air line at the balance port.
5. Apply the parking brakes. Step on the foot brake; the valve should exhaust air at the exhaust port when the foot brake is released.
6. Drain the air system.
7. Remove the air line from the valve supply port. Build system air pressure to 120 psi (827 kPa). With the foot valve depressed, coat the supply port and the seam between the body and cover with a soap solution; leakage of a 1-inch (2.5-cm) bubble in 5 seconds at the supply port is allowable. No leakage between the body and cover is permitted. Install the air line at the supply port.
8. If the valve does not function properly, or if leakage is excessive, repair or replace it following the instructions in this section.
9. Remove the chocks from the tires.

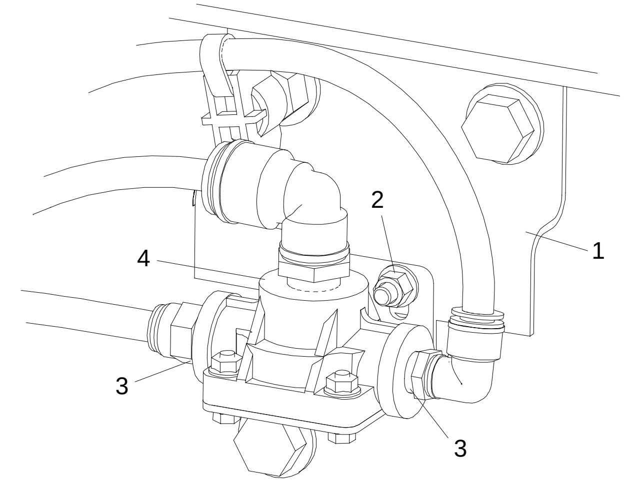
Removal and Installation

Removal

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so could result in personal injury.

1. Park the vehicle on a level surface and shut down the engine. Chock the tires or hold the vehicle by means other than air brakes.
2. Drain the air brake system.
3. Mark and disconnect the air lines from the quick release valve.
4. Remove the mounting bolts and the valve. See Fig. 1.



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1. Mounting Bracket
2. Mounting Nut and Bolt
3. Delivery Port
4. Supply Port

Fig. 1, Quick Release Valve Mounting (QR-1 valve shown)

Installation

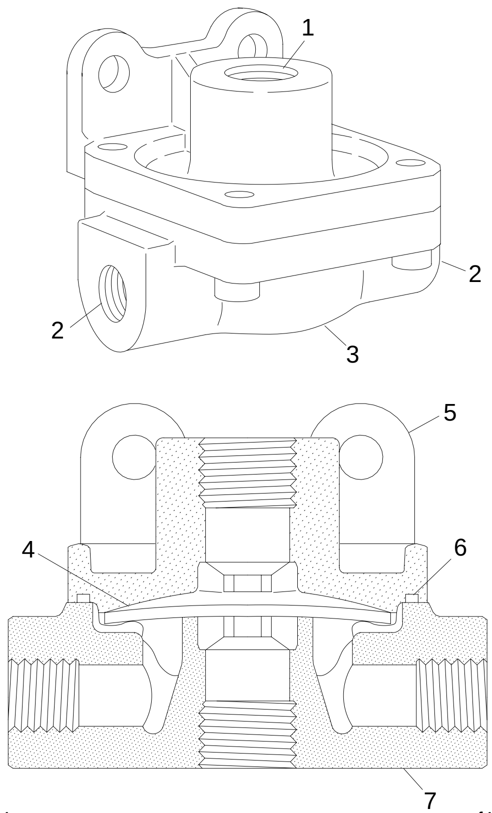
1. Install the quick release valve with the exhaust port facing down. Securely tighten the mounting bolts.
2. Install the air lines to the quick release valve in the locations previously marked.
3. Remove the chocks from the tires.
4. Perform the operating and leakage tests in Subject 110.

Disassembly, Cleaning and Inspection, and Assembly

Disassembly

Refer to the following figures during these procedures:

- QR-1 Valve - **Fig. 1**.
- QR-1C Valve - **Fig. 2**.



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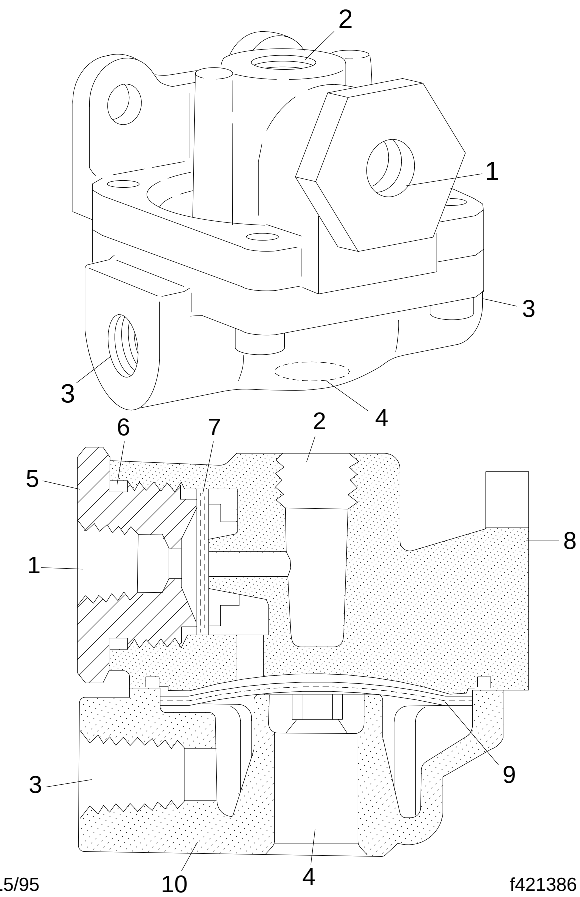
1. Supply Port
2. Delivery Port
3. Exhaust Port
4. Diaphragm
5. Cover
6. O-Ring
7. Body

Fig. 1, QR-1 Valve and Cross Section

1. Remove the quick release valve from the vehicle following the instructions in **Subject 120**.
2. Mark the valve body and cover for ease of installation.



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1. Supply Port
2. Balance Port
3. Delivery Port
4. Exhaust
5. Cap Nut
6. Sealing Ring
7. Double Check Diaphragm
8. Body
9. Quick Release Diaphragm
10. Cover

Fig. 2, QR-1C Valve and Cross-Section

3. Remove the cap nut at the supply port. Remove the sealing ring from the cap nut.
4. Remove the double check diaphragm.
5. Remove the four screws holding the valve cover on the valve body.
6. Separate the cover from the body and remove the sealing ring and the quick release diaphragm.

Disassembly, Cleaning and Inspection, and Assembly

Cleaning and Inspection

1. Clean all metal parts in mineral spirits. Wipe all rubber parts clean.
2. It is recommended that all rubber parts and any other part showing signs of wear or deterioration be replaced with genuine Bendix parts.

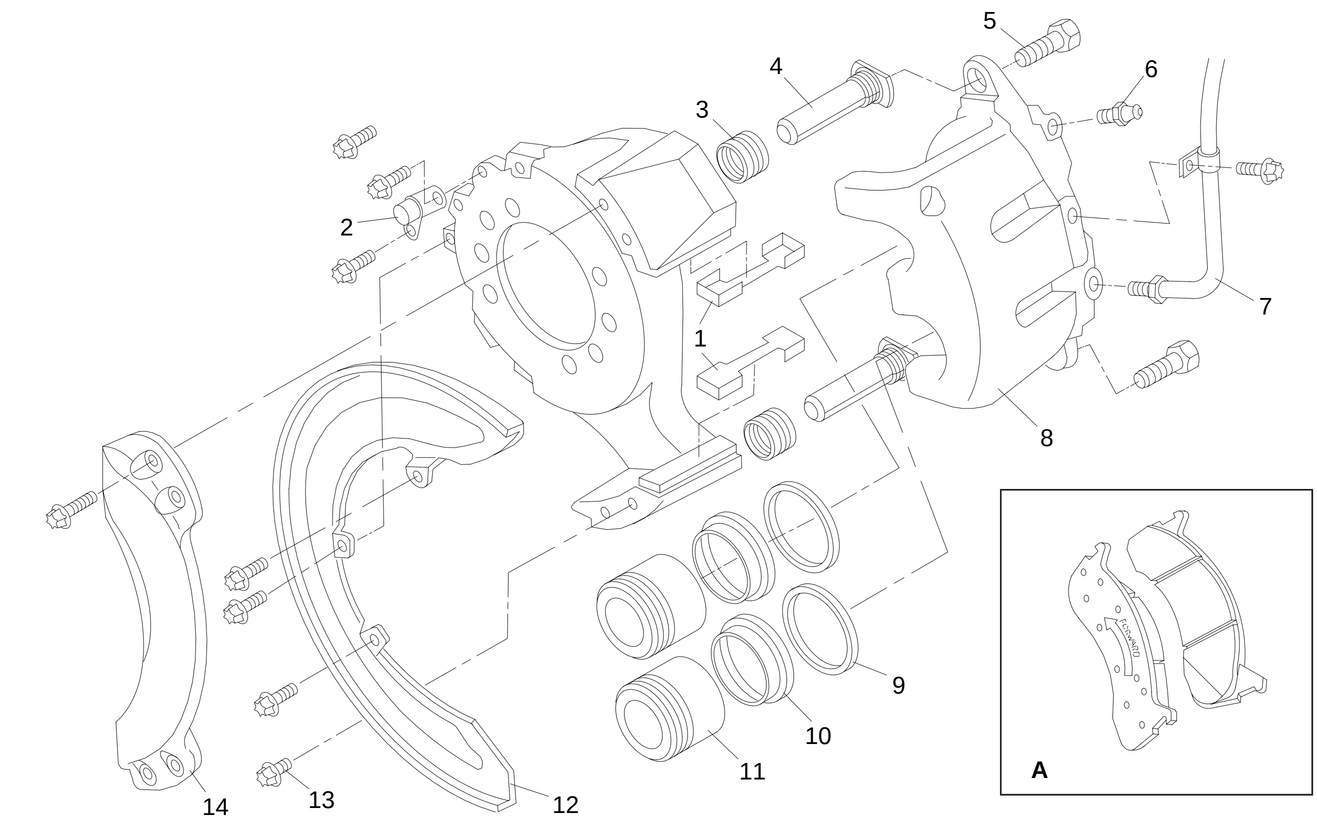
Assembly

1. Install the sealing ring on the cap nut.
2. Install the double check diaphragm in the valve body.
3. Install the cap nut. Tighten the nut 13 to 33 lbf·ft (142 to 376 N·m).
4. Install the quick release diaphragm in the cover.
5. Install the valve cover on the body. Tighten the screws 30 to 60 lbf·in (340 to 680 N·cm) evenly and securely.
6. Install the quick release valve, following the instructions in **Subject 120**.
7. Do the operating and leakage test as instructed in **Subject 110**.

General Information

Bosch® hydraulic pin slide disc brakes are two-piston sliding caliper brakes for use at both front and rear wheels. See **Fig. 1**. Each pin slide caliper disc brake wheel installation is comprised of three major components. See **Fig. 2**.

taches to and slides on sealed pins located in an anchor plate. The anchor plate is mounted on the steering knuckle flange on front axles or on the axle flange on rear axles. Two sizes of calipers are used: 66mm Twin (2 piston) and 73mm Twin (2 piston). See **Fig. 3**.



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A. Brake Pads
1. Slipper
2. Antilock Brakes Sensor Bracket
3. Guide Pin Boot
4. Guide Pin
5. Guide Pin Bolt
6. Bleed Screw
7. Brake Line
8. Caliper
9. Caliper Boot Seal
10. Piston Boot
11. Caliper Piston
12. Splash Shield
13. Plug (66mm only)
14. Tie Bar (73mm only)

Fig. 1, Pin Slide Brake (exploded view)

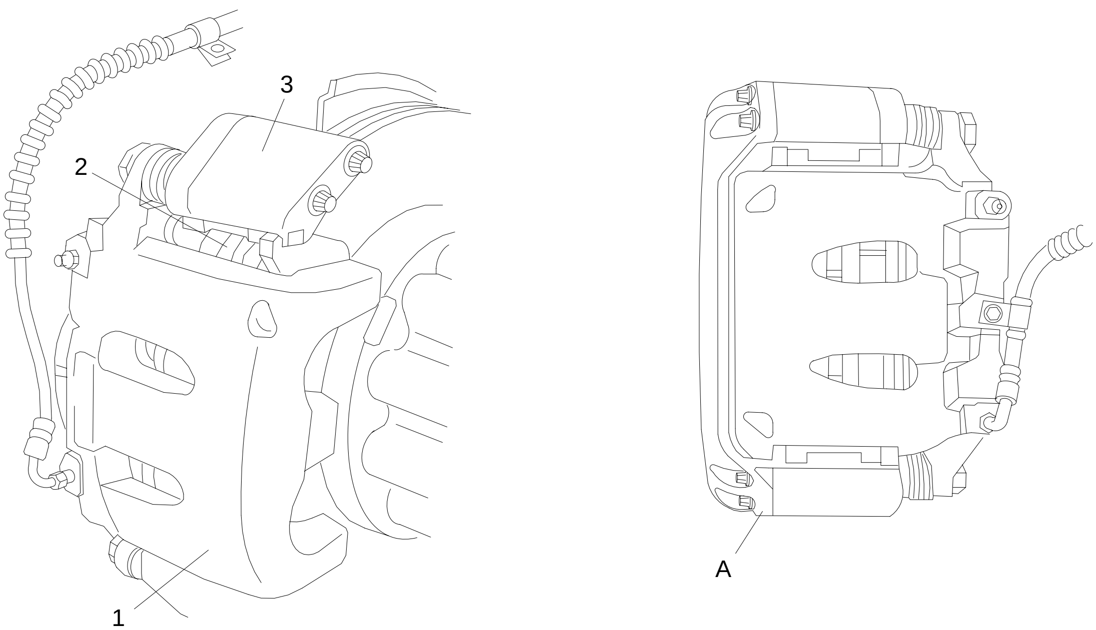
Caliper Assembly

The caliper assembly includes two hydraulic piston bores. The piston bores contain the pistons, piston seals and piston boots. The caliper assembly at-

Disc Brake Pads

The inboard and outboard disc brake pads are positioned with both ends mounted on the anchor plate pad abutments. The pads rest on stainless steel slip-

General Information



A. 73mm slider disc brakes incorporate a tie bar between the anchor plate abutment arms.
1. Caliper Assembly
2. Brake Pads
3. Anchor Plate Assembly

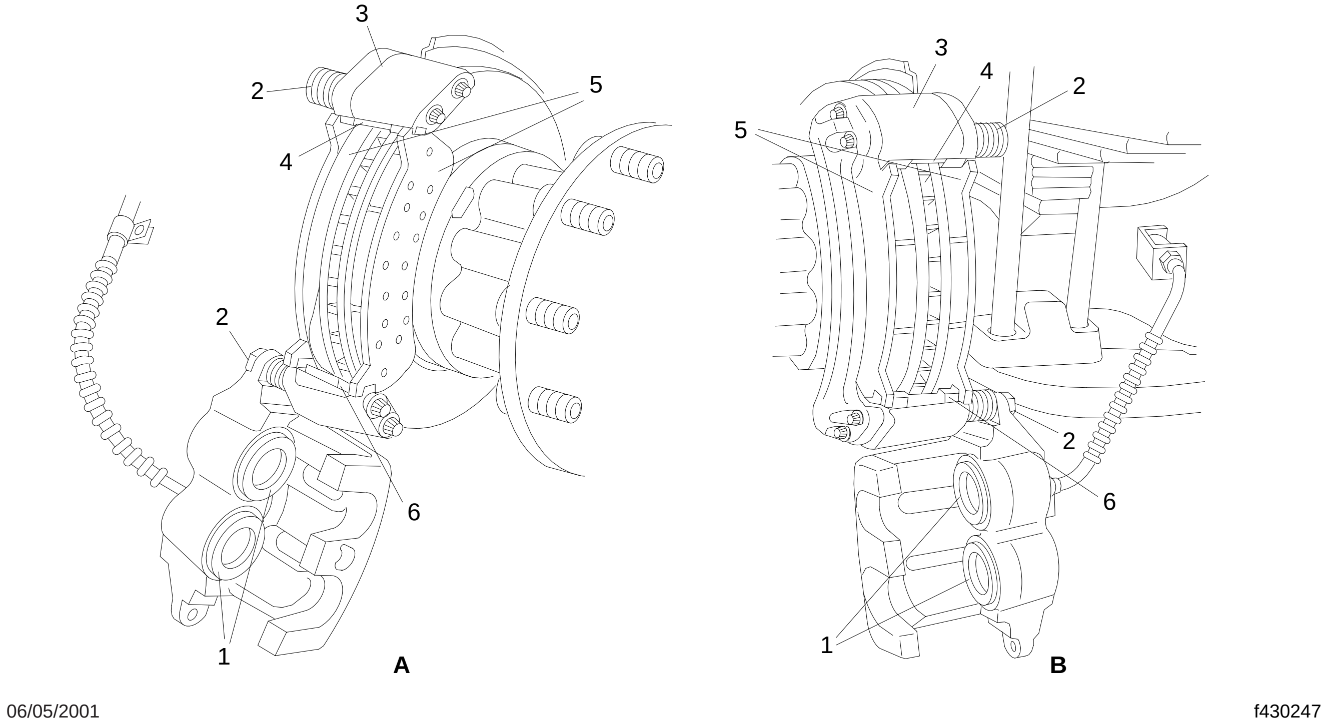
Fig. 2, Bosch Pin Slide Brakes Major Components

pers covering the anchor plate pad abutments. Inboard and outboard disc brake pads may be chamfered, and if so are marked with an arrow and the word "FORWARD" for proper installation. Brake pads may not be interchangeable inner to outer, so correct location is required during assembly.

Anchor Plate Assembly

The anchor plate includes lubricated floating guide pins sealed by rubber boots and anchor plate pad abutments protected by stainless steel slippers. A tie bar which spans the anchor plate abutment arms is used on 73mm pin slide disc brake installations only. A splash shield on the back of the rotor helps protect the brake assembly from road contamination. Bosses are provided for mounting an antilock brake system speed sensor. See **Fig. 4**.

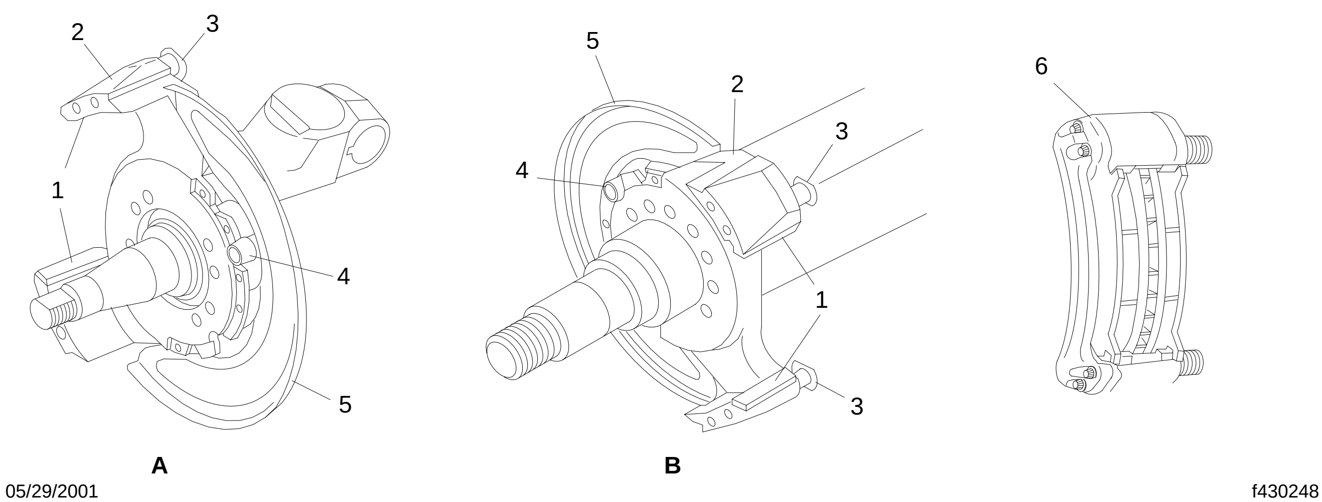
General Information



A. Front (66mm shown)	B. Rear (73mm shown)
1. Hydraulic Pistons with Seals and Boots	4. Upper Slipper
2. Sealed Pins	5. Brake Pads
3. Anchor Plate	6. Lower Slipper

Fig. 3, Bosch Pin Slide Brakes System Components

General Information



A. Front
1. Pad Abutment
2. Anchor Plate
3. Floating Guide Pin

B. Rear
4. Antilock Braking System Sensor Mounting
5. Splash Shield
6. Tie Bar (73mm brakes only)

Fig. 4, Anchor Plate and Splash Shield

General Safety Precautions

WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- Disconnect the batteries.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

WARNING

Hydraulic brake fluid is hazardous, and can cause blindness if it gets in your eyes. Always wear safety glasses when handling brake fluid or bleeding brake components. Brake fluid may also be a skin irritant. If you get it on your skin, wash it off as soon as possible.

Special care must be taken when disposing of used brake fluid. Put the fluid in a sealed plastic container and label it "Used Brake Fluid." Then dispose of it in an approved manner. Check with local and state regulations as to the correct disposal procedure.

IMPORTANT: During service procedures, keep grease and other foreign material away from caliper assemblies, disc brake pads, brake rotors and external surfaces of the hub. Handle parts carefully to avoid damage to the caliper, rotor, disc brake pads or brake lines.

Asbestos and Non-Asbestos Safety

WARNING

Wear a respirator at all times when servicing the brakes, starting with the removal of the wheels and continuing through assembly. Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH.

Because some brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Exposure to airborne asbestos brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

Because medical experts believe that long-term exposure to some *non-asbestos* fibers could also be a health hazard, the following precautions should also be observed if servicing non-asbestos brake linings.

Areas where brake work is done should be separate from other operations, if possible. As required by OHSA regulations, the entrance to the areas should have a sign displayed indicating the health hazard.

During brake servicing, an air purifying respirator with high-efficiency filters must be worn. The respirator and filter must be approved by MSHA or NIOSH, and worn during all procedures.

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through

Safety Precautions

sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, the brake assembly must be cleaned in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with a HEPA filter system, remove dust from the brake drums, brake backing plates, and brake parts. After vacuuming, any remaining dust should be removed using a rag soaked in water and wrung until nearly dry. Do not use compressed air or dry brushing to clean the brake assembly.

If grinding or other machining of the brake linings is necessary, other precautions must be taken because exposure to asbestos dust is highest during such operations. In addition to the use of an approved respirator, there must be local exhaust ventilation such that worker exposure is kept as low as possible.

Work areas should be cleaned by industrial vacuums with HEPA filters or by wet wiping. Compressed air or dry sweeping should never be used for cleaning. Asbestos-containing waste, such as dirty rags, should be sealed, labeled, and disposed of as required by EPA and OSHA regulations. Respirators should be used when emptying vacuum cleaners and handling asbestos waste products.

Workers should wash before eating, drinking, or smoking, should shower after work, and should not wear work clothes home. Work clothes should be vacuumed after use and then laundered, without shaking, to prevent the release of asbestos fibers into the air.

Brake Pad Removal, Inspection and Installation

WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

IMPORTANT: It is recommended that all disc brake pads on the vehicle be replaced at the same time. This will maintain balanced braking. If complete replacement is not desirable or necessary, make sure that at a minimum all disc brake pads on one axle (both ends) are replaced at the same time.

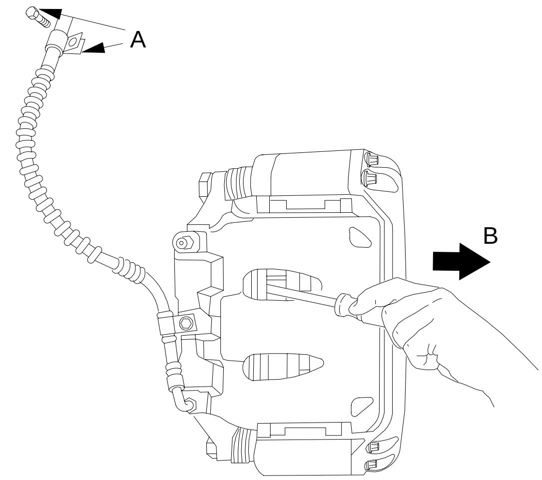
Removal

1. Park the vehicle on a level surface. Shut down the engine and apply the parking brake.
2. Open the hood.
3. If removing rear axle wheel pads, remove about half of the fluid from the rear section of the master cylinder reservoir. If removing front axle wheel pads, remove about half of the fluid from the front section. Removing the fluid from the reservoir keeps the reservoir from overflowing when retracting pistons into the caliper.
4. Chock the front or rear tires, depending on which axle is being worked on. Jack up the axle and support it with jackstands.
5. Remove the tires.
6. Visually inspect all brake pad linings. Lining pads should be replaced when the remaining lining reaches 3/16-inch (5-mm) thickness or less.

CAUTION

Care must be taken when positioning the pry bar. Incorrect positioning of the pry bar could result in damage to the caliper.

7. Insert a pry bar in one of the rotor cooling fin slots and pry the caliper outboard, pushing the caliper pistons into the piston bores. See Fig. 1.
8. On front axles only, remove the brake line retaining clip from its support mounting. This will allow the brake line hose to hang free. See Fig. 1.



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A. Remove this screw and clip on front axles only.
B. Move the caliper outboard to push the pistons in.

Fig. 1, Piston Retraction and Brake Line Clip Removal

IMPORTANT: When servicing disc brake pads only, loosen and remove the upper (top) caliper pin mounting bolt. Do not loosen the lower (bottom) pin mounting bolt.

9. Remove only the upper (top) pin mounting bolt. See Fig. 2.

CAUTION

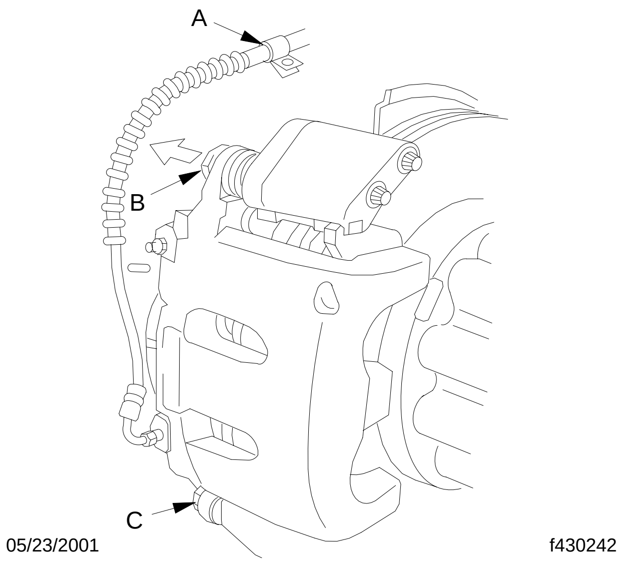
Do not pull on the guide pins. This may dislodge the guide pin boot from the guide pin or anchor plate grooves, which could damage the guide pin boot.

10. Swing the caliper assembly away from the rotor by carefully rotating the caliper on the lower pin mounting bolt and guide pin. See Fig. 3. Do not allow the brake line hose to become pinched or kinked.
11. Remove the inboard and outboard disc brake pads from the anchor plate pad abutment slippers.

IMPORTANT: Do not mark on the pad face.

12. If the original disc brake pads are to be reused, be sure to mark them in some manner so that they are installed in the same location.

Brake Pad Removal, Inspection and Installation



A. Make sure this clip is detached from the support bracket.
B. Loosen and remove the upper pin mounting bolt.
C. Do not loosen the lower pin mounting bolt.

Fig. 2, Remove Upper Pin Mounting Bolt

Inspection

IMPORTANT: Do not damage or dislodge the guide pin boots while cleaning the machined surfaces.

1. Inspect the machined surfaces of the caliper, guide pin mounting face, and anchor plate. If rust or corrosion is present, use a hand-held wire brush to clean the surfaces.
2. Inspect the caliper, piston seals, and pistons for leakage or damage. If leakage or damage is found, repair or replace the piston(s) as required.
3. Inspect the anchor plate for damage to the mating surfaces at the anchor plate pad abutment slippers and guide pin heads. If damage is found, repair or replace as required.
4. Inspect the rotor for scoring, warping, cracks bluing, heat spots or other damage. See **Fig. 4**. If any damage is found, repair or replace the rotor. For instructions, see **Subject 140**.

Installation

1. Position a metal plate across both caliper pistons. Use a C-clamp to push both pistons into the caliper to provide clearance for the new disc brake pads. See **Fig. 5**.

CAUTION

When replacing disc brake pads, make sure to use the same lining material on both axle ends. Mixing lining types can result in unbalanced braking, increased pad wear, or degraded stopping performance.

IMPORTANT: Inboard and outboard brake pads may not be interchangeable. The word "Forward" and a forward rotor rotation direction arrow may appear on each pad backing plate. Orient the pads as indicated by the arrow.

2. Position the inboard and outboard disc brake pads onto the anchor plate pad abutment slippers with the lining facing toward the rotor. See **Fig. 6**.

CAUTION

Use care when positioning the caliper over the disc brake pads, rotor, and upper guide pin head to avoid tearing, cutting, or dislodging the piston boots or guide pin boot.

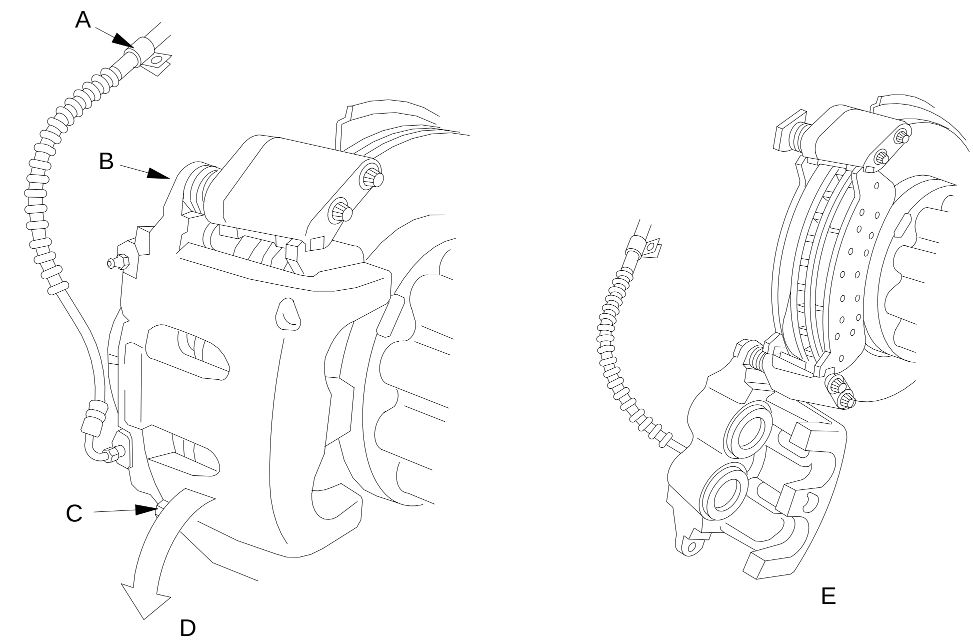
3. Carefully rotate the caliper closed about the lower pin mounting bolt and guide pin. Do not allow the brake line hose to become pinched or kinked. Align the flat on the upper guide pin head with the flat on the caliper upper guide pin boss. See **Fig. 7**.

CAUTION

Always tighten caliper pin mounting bolts in the proper sequence. Do not overtighten caliper pin mounting bolts. Increased brake drag may result from incorrect tightening.

IMPORTANT: If the lower mounting bolt was loosened, see **Fig. 8** before tightening either the upper or lower mounting bolt.

Brake Pad Removal, Inspection and Installation



A. Make sure this clip is detached from the support bracket.
B. Guide pin bolt has been removed.
C. Do not loosen the lower pin mounting bolt.
D. Swing the caliper down until it stops.
E. Caliper in the lowered position.

Fig. 3, Open Caliper to Access Brake Pads and Pistons

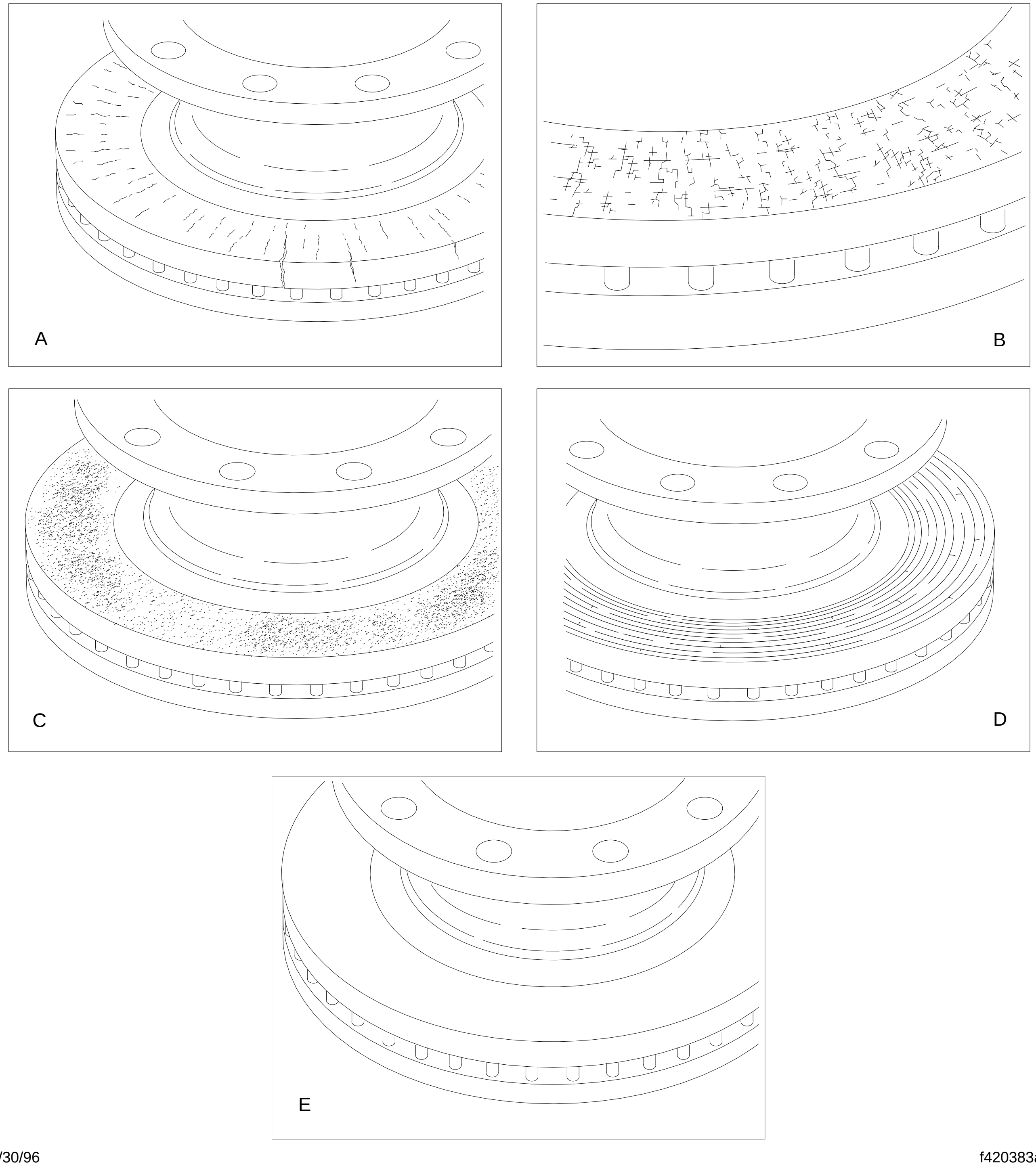
4. Hold the caliper in the closed position with the caliper upper guide pin boss hole aligned with the threaded hole in the upper guide pin head. Hand thread the pin mounting bolt. Tighten the bolt 93 to 107 lbf·ft (126 to 145 N·m). See **Fig. 8**.
5. On front axles only, install the previously removed brake line retaining clip. Make sure the brake line hose is not pinched or kinked.
6. Visually inspect all components serviced. Make sure the mounting pins are torqued according to the specifications in this procedure. Make sure the pads are seated and positioned to slide along the pad abutment slippers.
7. Install the tires, remove the jackstands and lower the vehicle.
8. Check the fluid level in the master cylinder reservoir and add the necessary amount of new DOT 3 approved brake fluid.
9. Pump the brake pedal until it feels firm. If it does not get firm, check for leaks or air in the brake system. Repair any leaks, if needed, then bleed the system, following the instructions in **Subject 160**.

WARNING

Do not move the vehicle until the brake pedal feels firm. To do otherwise could result in loss of vehicle control, causing an accident resulting in personal injury or property damage.

10. Close the hood and remove the chocks from the tires.
11. Road test the vehicle and seat the brake pads.
    - 11.1 Accelerate the vehicle to 30 mph (48 km/h), then brake to a stop, using medium brake pedal pressure. *Do not slam on the brakes.*
    - 11.2 Repeat this step between 4 and 5 times, allowing a 1-minute interval between brake applications.

Brake Pad Removal, Inspection and Installation



A. Cracking
B. Heat Checking
C. Discoloration
D. Scoring
E. Normal Finish

Fig. 4, Rotor Surface Check

Brake Pad Removal, Inspection and Installation

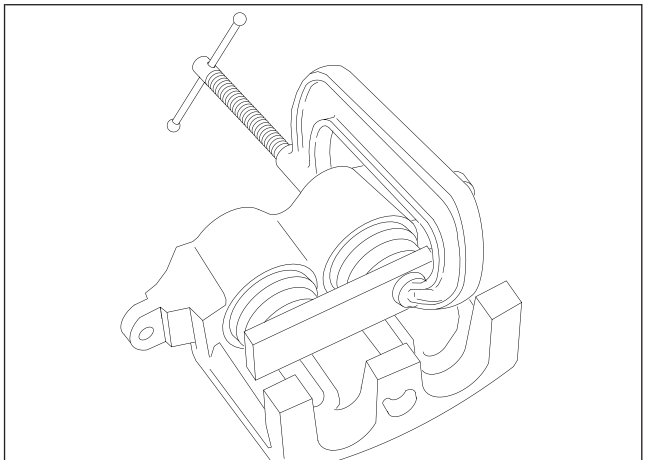
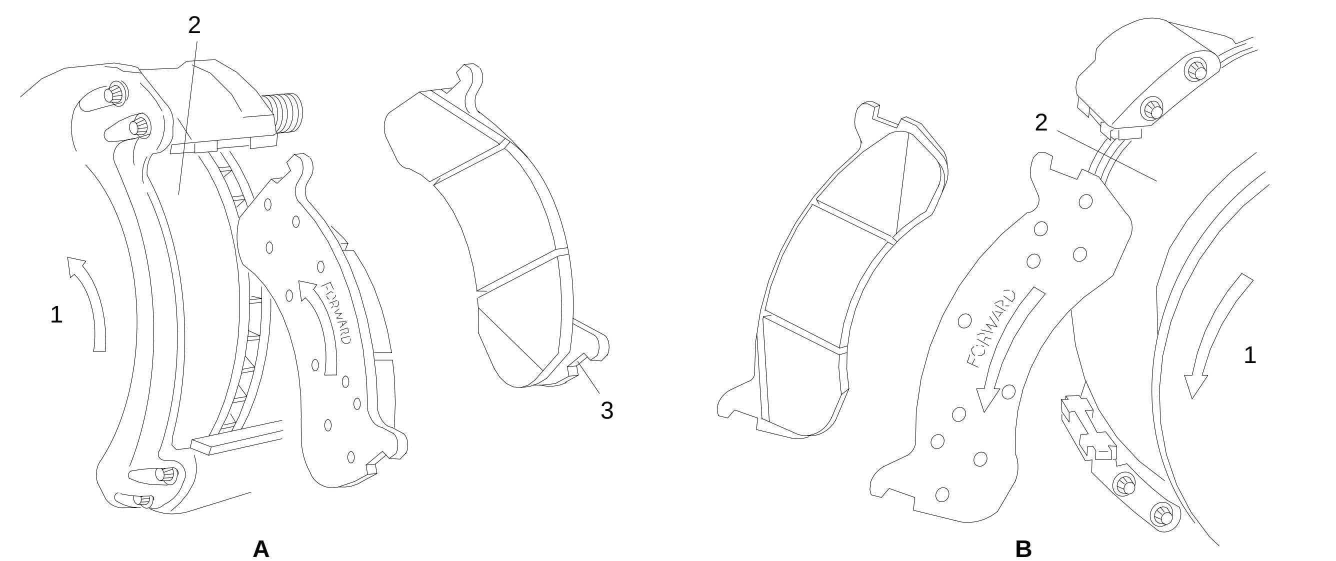


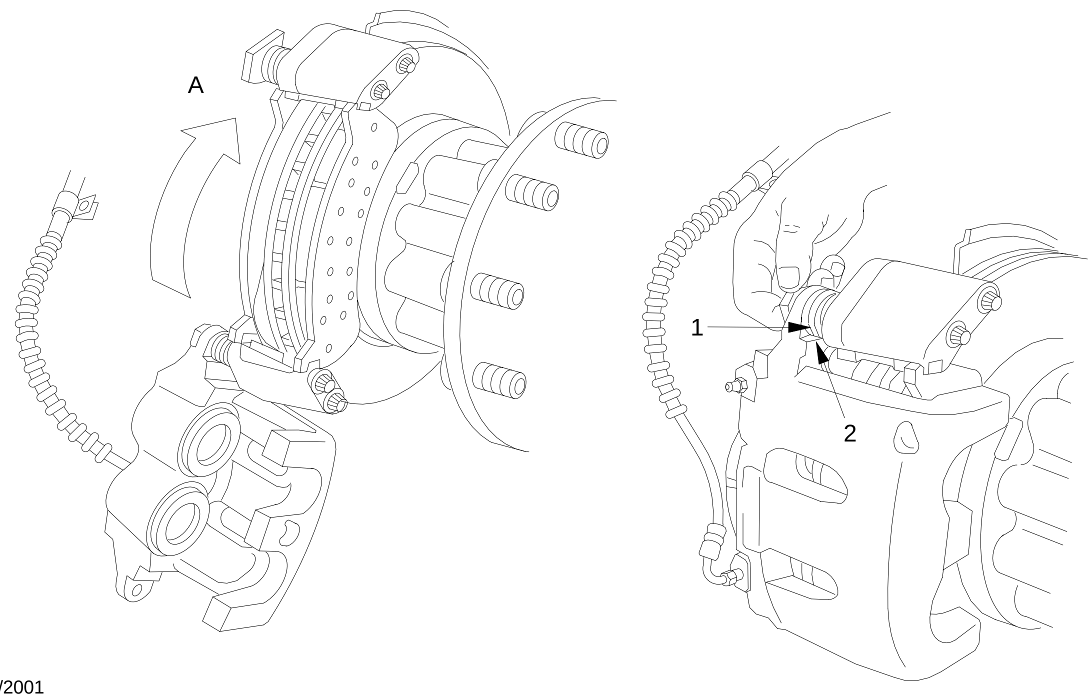
Fig. 5, Retract Pistons Into Caliper



A. Driver Side Rear
B. Driver Side Front and Forward-Mount Rear Brakes
1. Wheel Rotation
2. Rotor Face
3. Pad Notch

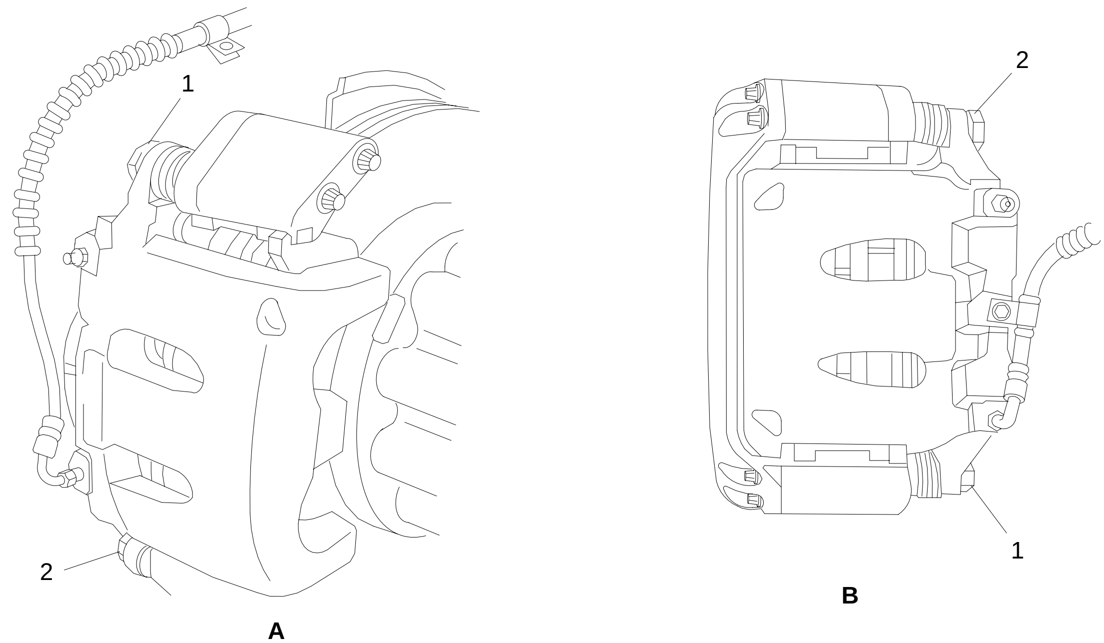
Fig. 6, Replacing Brake Pads on Front and Rear Brakes

Brake Pad Removal, Inspection and Installation



A. Swing the caliper up into position.
1. Flat on Guide Pin
2. Flat on Caliper

Fig. 7, Close Caliper Over Brake Pads and Rotor



A. Front Brakes and Forward-Mount Rear Brakes
1. Tighten First
B. Rear brakes
2. Tighten Second

Fig. 8, Tightening Sequence for Caliper Mounting Bolts

Brake Caliper Removal and Installation

WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

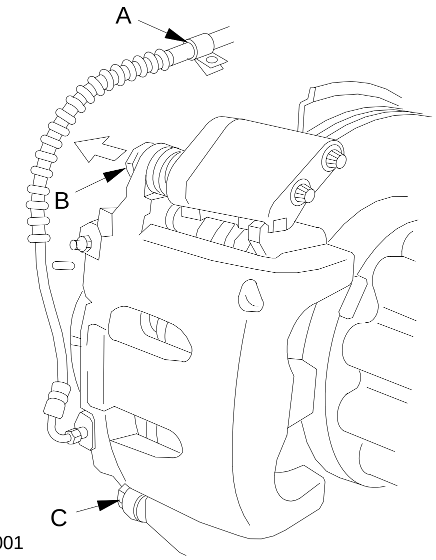
Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine.
2. Open the hood.
3. If removing the rear wheel caliper(s), remove half the fluid from the rear section of the master cylinder reservoir. If removing the front wheel caliper(s), remove half the fluid from the front section. Removing the fluid from the reservoir keeps the reservoir from overflowing when retracting pistons into the caliper.
4. Chock the front or rear tires, depending on which axle is being worked on. Jack up the axle and support it with jackstands.
5. Remove the tires.
6. On front axles only, remove the brake line retaining clip from its support mounting. This will allow the brake line hose to hang free. See **Fig. 1**.
7. Remove the upper (top) guide pin mounting bolt. See **Fig. 1**.

CAUTION

Do not pull on the guide pins. This may dislodge the guide pin boot from the guide pin or anchor plate grooves, which could damage the guide pin boot.

8. Swing the caliper assembly away from the rotor by carefully rotating the caliper on the lower pin mounting bolt and guide pin. See **Fig. 2**. Do not allow the brake line hose to become pinched or kinked.
9. Disconnect the brake fluid line from the caliper. See **Fig. 3**.
10. Remove the lower guide pin mounting bolt and remove the caliper from the anchor plate.



A. Make sure this clip is detached from the support bracket.
B. Remove the upper guide pin mounting bolt.
C. Do not loosen the lower guide pin mounting bolt.

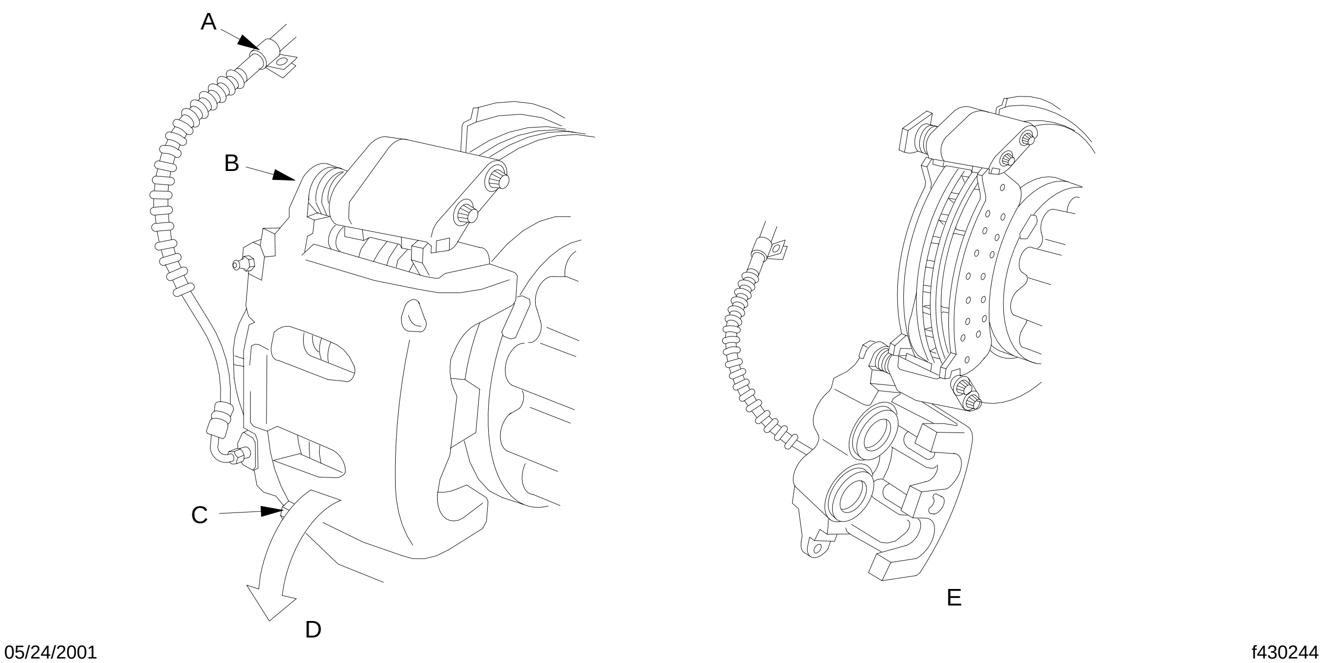
Fig. 1, Upper Pin Mounting Bolt Removal

Installation

NOTE: Use isopropyl alcohol to clean brake seals, boots, and pistons. Do not soak components for an extended period of time.

1. Clean contamination, dirt, and debris from the exterior of the caliper, machined faces, and around the caliper piston boots.
2. Visually inspect the caliper for brake fluid leakage or damage to pistons or piston boots. If there is leakage or damage, the caliper should be repaired or replaced. For repair instructions, see **Subject 130**.
3. Make sure the pistons are fully retracted into the caliper. Piston boots must be fully seated in the piston boot groove and the boot grooves in the caliper face.
4. Position the caliper on the anchor plate with the caliper lower guide pin boss hole aligned with the threaded hole in the lower guide pin head. Hand-thread the pin mounting bolt through the caliper and into the anchor plate.

Brake Caliper Removal and Installation



A. Make sure this clip is detached from the support bracket.
B. Guide pin bolt has been removed.
C. Lower Guide Pin Bolt
D. Swing the caliper down until it stops.
E. Caliper in the lowered position.

Fig. 2, Rotating the Caliper Away from the Rotor

CAUTION

Use care when positioning the caliper over the disc brake pads, rotor, and upper guide pin head to avoid tearing, cutting, or dislodging the piston boots or guide pin boot.

5. Carefully rotate the caliper closed about the lower pin mounting bolt and guide pin. Do not allow the brake line hose to become pinched or kinked. Align the flat on the upper guide pin head with the flat on the caliper upper guide pin boss. See **Fig. 4**.

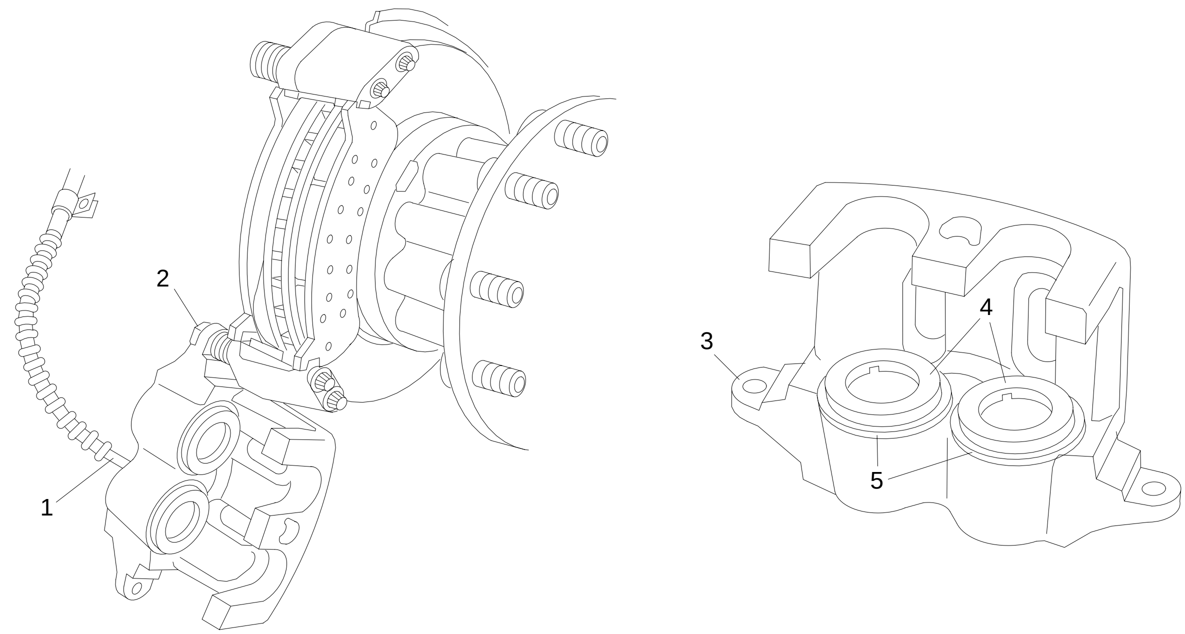
CAUTION

Always tighten caliper pin mounting bolts in the proper sequence. Do not overtighten caliper pin mounting bolts. Increased brake drag may result from incorrect tightening.

6. Hold the caliper in the closed position with the caliper upper guide pin boss hole aligned with the threaded hole in the upper guide pin head. Hand-thread the upper pin mounting bolt.

IMPORTANT: See **Fig. 5** and **Fig. 6** before tightening either the upper or lower mounting bolt.

7. Tighten the bolts 93 to 107 lbf·ft (126 to 145 N·m) in the sequence shown in **Fig. 5** and **Fig. 6**.
8. On front axles only, install the previously removed brake line retaining clip. Make sure the brake line hose is not pinched or kinked.
9. If the brake supply hose was disconnected, connect it.
   - 9.1 Tighten the brake supply hose fitting 15 lbf·ft (20 N·m).
   - 9.2 Bleed the brake supply line to the caliper, following the instructions in **Subject 160**. If you have removed more than one brake caliper, bleed the entire brake system.
10. Install the tires, remove the jackstands, and lower the vehicle.



1. Brake Line
2. Lower Guide Pin Bolt
3. Machined Face
4. Pistons
5. Piston Boots

Fig. 3, Caliper Removal from Anchor Plate

11. Check the fluid level in the master cylinder reservoir and add the necessary amount of new DOT 3 approved brake fluid.
12. Close and latch the hood.
13. Remove the chocks from the tires.

WARNING

Do not move the vehicle until the brake pedal feels firm. To do otherwise could result in loss of vehicle control, causing an accident resulting in personal injury or property damage.

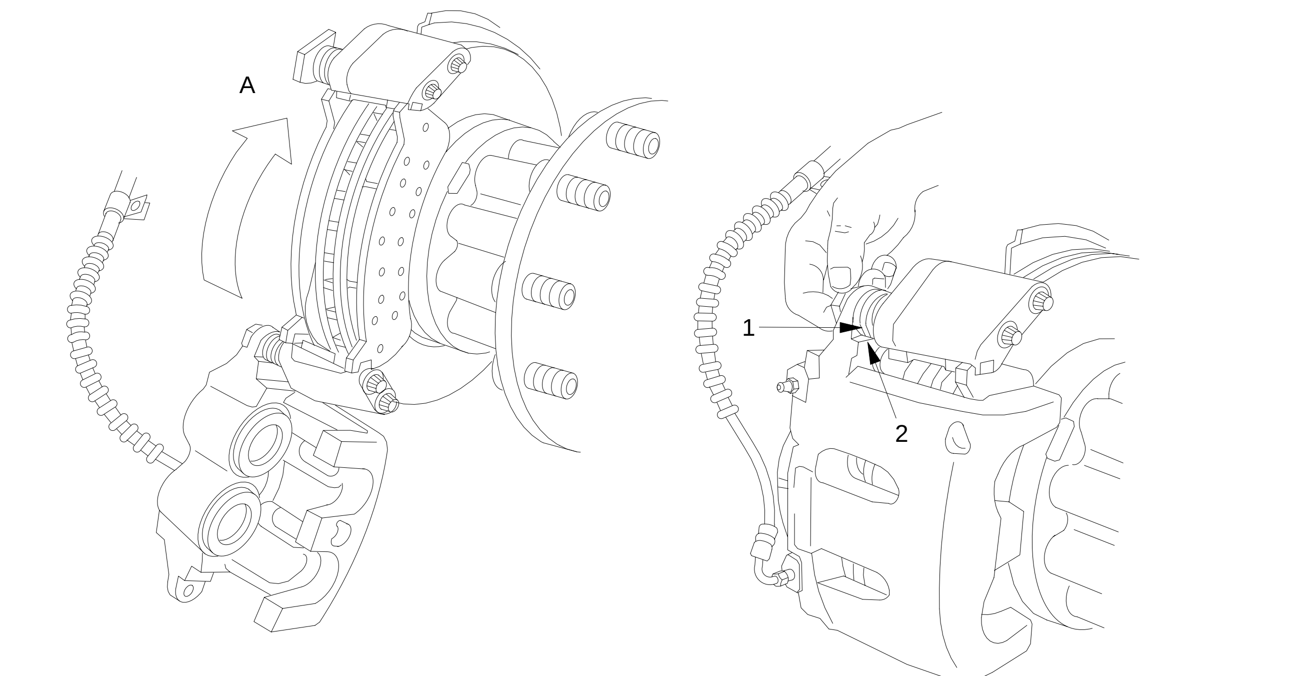
14. Seat the brake pads by pressing firmly on the brake pedal several times.

    If new brake pads were installed, road test the vehicle to seat the brake pads.

    14.1 Accelerate the vehicle to 30 mph (48 km/h), then brake to a stop, using medium brake pedal pressure. *Do not slam on the brakes.*

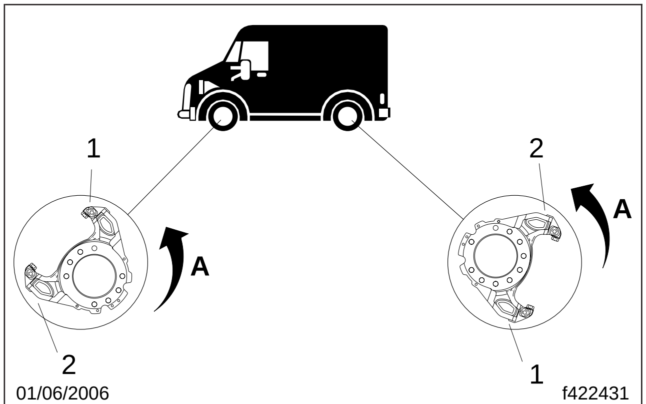
    14.2 Repeat this step 4 or 5 times, allowing a 1-minute interval between brake applications.

Brake Caliper Removal and Installation



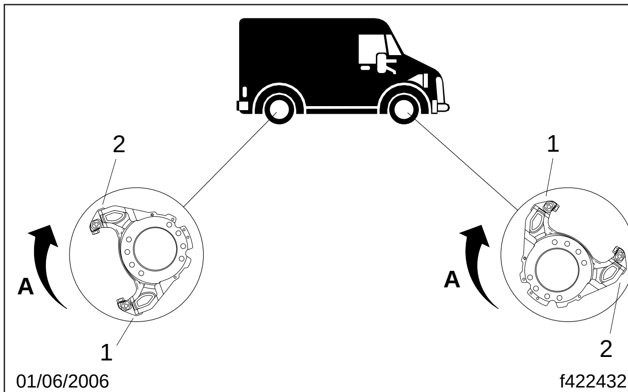
A. Swing the caliper up into position.
1. Flat on Guide Pin
2. Flat on Caliper

Fig. 4, Rotating the Caliper Over the Brake Pads and Rotor



A. Direction of Rotation (forward motion)
1. Tighten First
2. Tighten Second

Fig. 5, Tightening Sequence for Caliper Mounting Bolts, Left Side



A. Direction of Rotation (forward motion)
1. Tighten First
2. Tighten Second

Fig. 6, Tightening Sequence for Caliper Mounting Bolts, Right Side

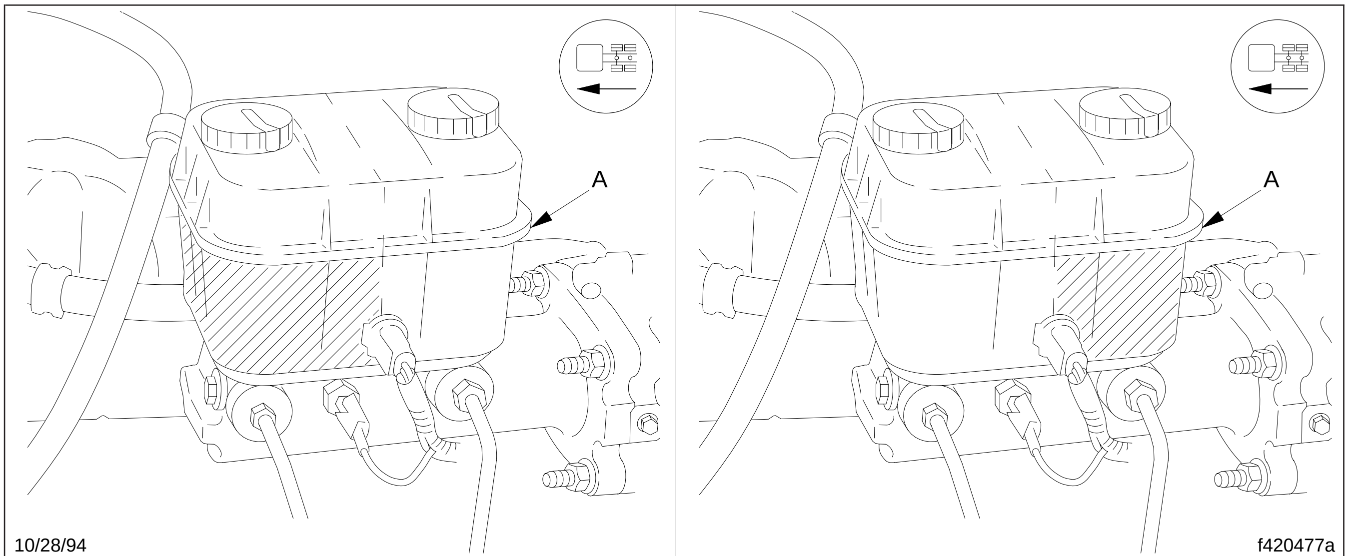
Brake Rotor Removal and Installation

WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the tires.
2. Open the hood.
3. Remove about half the brake fluid from the front section (if removing a front-axle rotor) or the rear section (rear-axle rotor) of the master cylinder reservoir. Removing the fluid from the reservoir keeps the reservoir from overflowing when retracting pistons into the caliper. See **Fig. 1**.



A. Fill level for brake fluid.

Fig. 1, Master Cylinder Reservoir

4. Chock the front or rear tires, as required.
5. Jack up the vehicle. Support the axle with jackstands.
6. Remove the tire.
7. Remove the brake caliper from the rotor, following the instructions in **Subject 120**.
8. Remove the hub and rotor assembly from the axle, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle. Put the hub on the floor so the rotor is facing up.
9. Remove the brake rotor from the wheel hub.
   9.1 Remove the hexbolts and washers that attach the rotor to the hub. See **Fig. 2**.
   9.2 Lift the brake rotor off the hub.

Installation

1. Visually inspect the rotors for scoring, warping, cracks, bluing or heat spots, or other damage. See **Fig. 3**. If signs of damage are found, the rotor should be resurfaced or replaced.
2. Install the rotor on the wheel hub.
   2.1 Position the rotor on the hub as shown in **Fig. 4**. Make sure the holes in the rotor are lined up with those of the hub.
   2.2 Install the mounting hexbolts and washers. Using a star pattern, tighten the hexbolts 130 lbf·ft (175 N·m). See **Fig. 5**.

Brake Rotor Removal and Installation

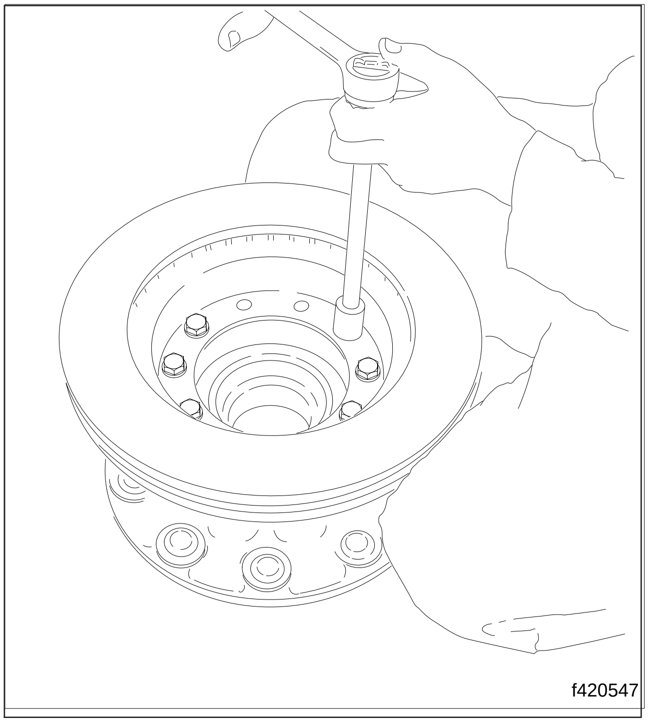
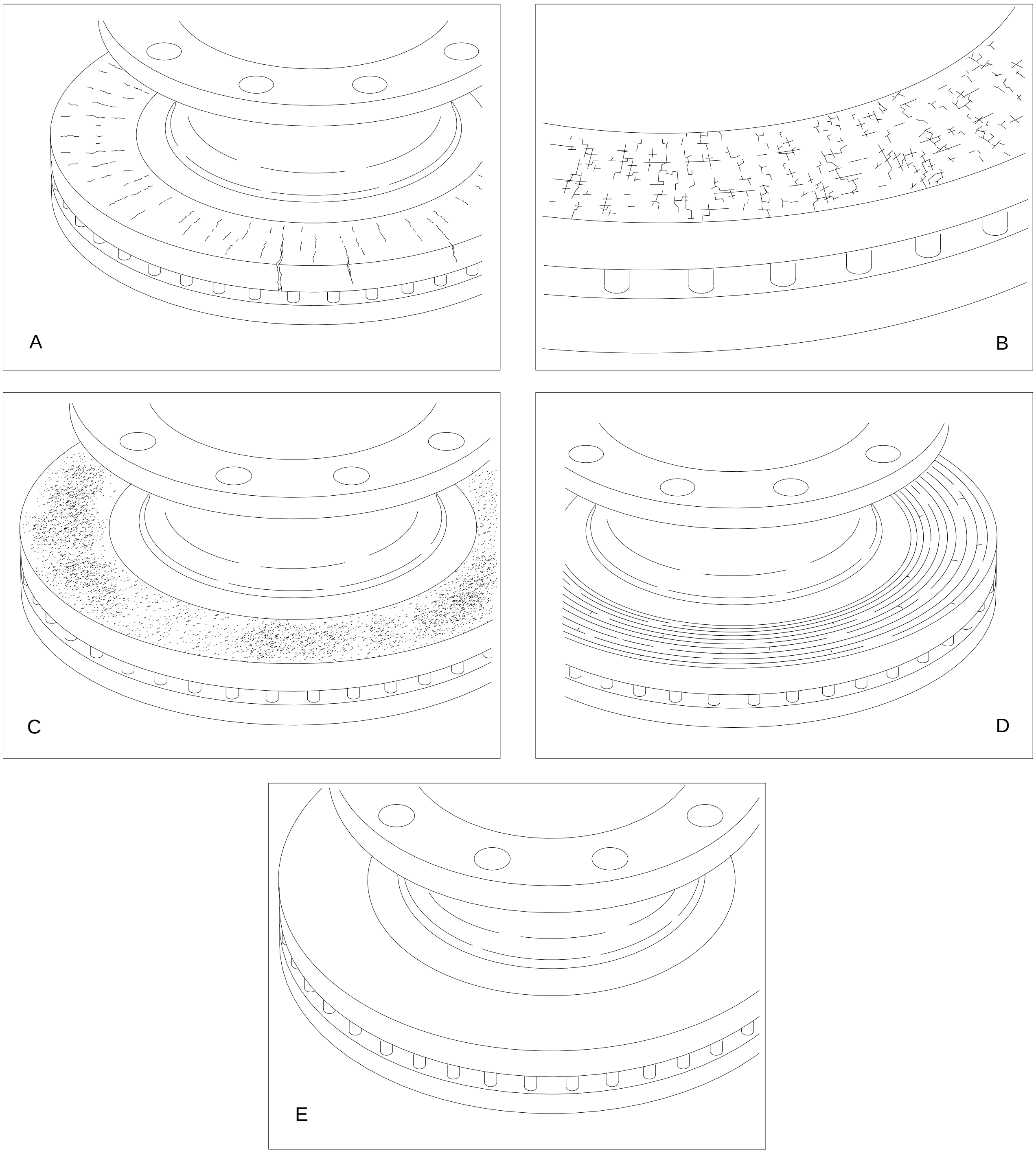


Fig. 2, Rotor-to-Hub Fasteners

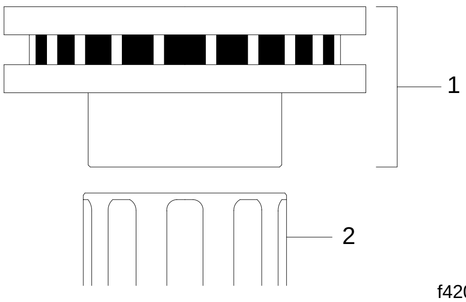
3. Install the hub and rotor assembly on the axle, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
4. Check rotor runout and parallelism. For instructions, see **Subject 140**.
5. Install the brake caliper on the rotor, following the instructions in **Subject 120**.
6. Install the tire.
7. Remove the jackstands. Lower the vehicle.
8. Fill the applicable section of the master cylinder reservoir with new DOT 3 approved brake fluid. The brake fluid level should be even with the raised seam on the outside circumference of the reservoir. See **Fig. 1**.
9. Close and latch the hood.
10. Remove the chocks from the tires.



A. Cracking
B. Heat Checking
C. Discoloration
D. Scoring
E. Normal Finish

Fig. 3, Rotor Surface Check

Brake Rotor Removal and Installation



1. Rotor
2. Wheel Hub

Fig. 4, Rotor-to-Hub Position

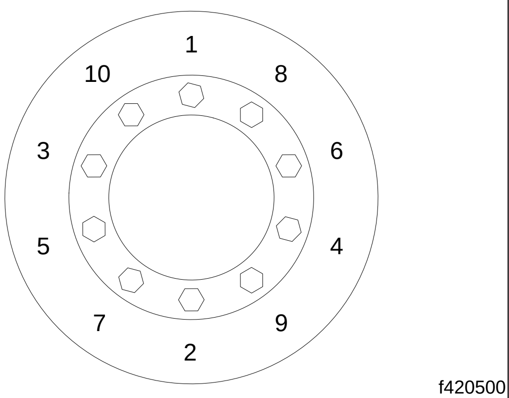


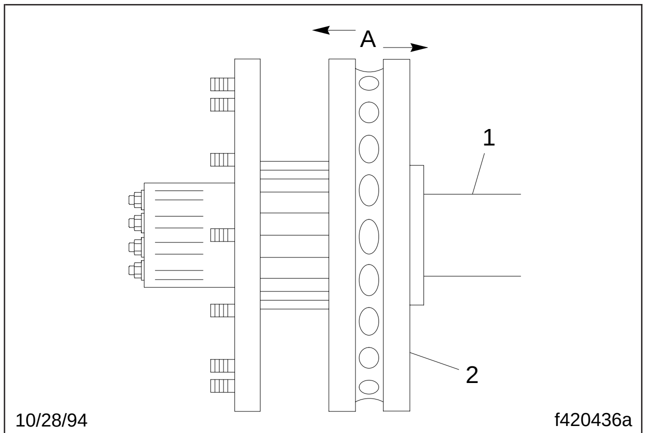
Fig. 5, Tightening Pattern

Brake Rotor Runout and Parallelism Check

Runout Check

Brake rotor runout refers to the amount of lateral wobble the rotor has when it is turning, with the wheel bearings correctly adjusted. See **Fig. 1**. Check the rotor runout whenever you replace the brake pads.

1. If not already done, chock the tires, jack up the axle you are working on and support it with jackstands. Remove the wheels and tires.
2. If working on the rear axle, put the transmission in neutral.
3. Using a dial indicator, measure the amount of runout while spinning the rotor, as shown in **Fig. 2**. Make sure the indicator is centered on the rotor face (between the outer and inner edges).
4. If the runout is more than 0.015 inch (0.38 mm), check that the rotor is securely mounted to the hub. Also check the wheel bearing end-play, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
5. Repeat the runout measurement. If the runout is still more than 0.015 inch (0.38 mm), replace the rotor.



A. Runout Dimensions
1. Axle
2. Rotor

Fig. 1, Brake Rotor Runout

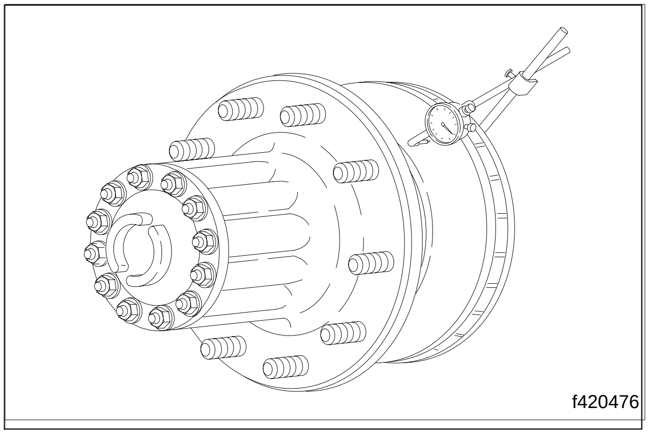


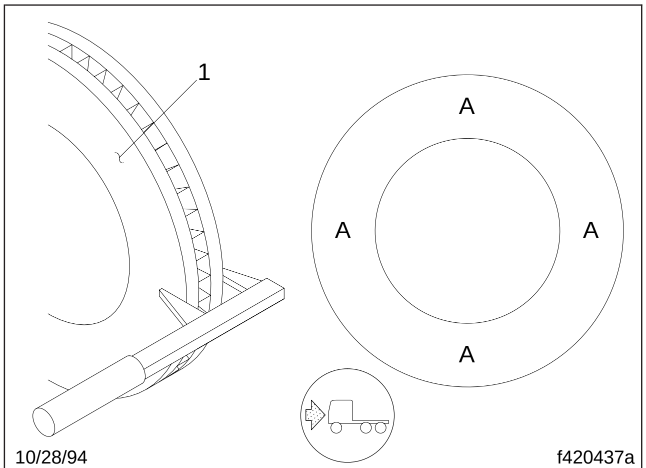
Fig. 2, Measure Runout

Parallelism Check

Parallelism is the difference in rotor thickness at different points around the rotor. It should be checked whenever the brake pads are replaced.

1. Using a micrometer, measure the thickness of the rotor (between the inboard and outboard faces) at four or more equally spaced points around the rotor. See **Fig. 3**.
2. If there is a difference of more than 0.005 inch (0.13 mm) between any two measurements, have the rotor resurfaced. If resurfacing will decrease the overall thickness of the rotor to 1.32 inches (33.5 mm) or less, replace the rotor.

Brake Rotor Runout and Parallelism Check



A. Measure thickness here.
1. Rotor Face

Fig. 3, Measure Rotor Thickness

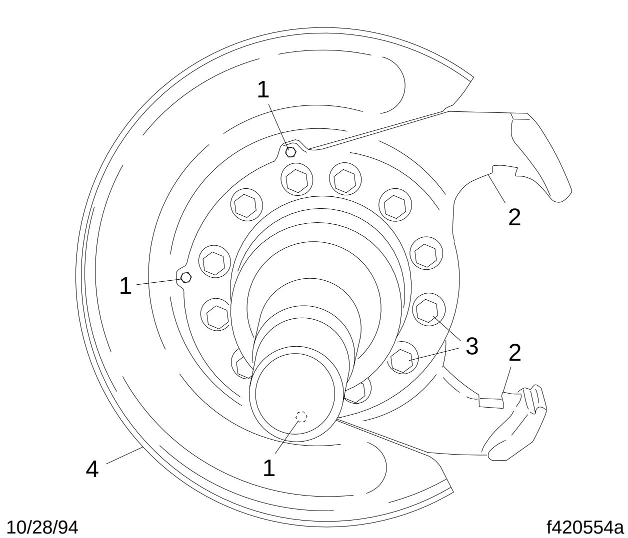
Anchor Plate Disassembly, Cleaning and Inspection, and Assembly

WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

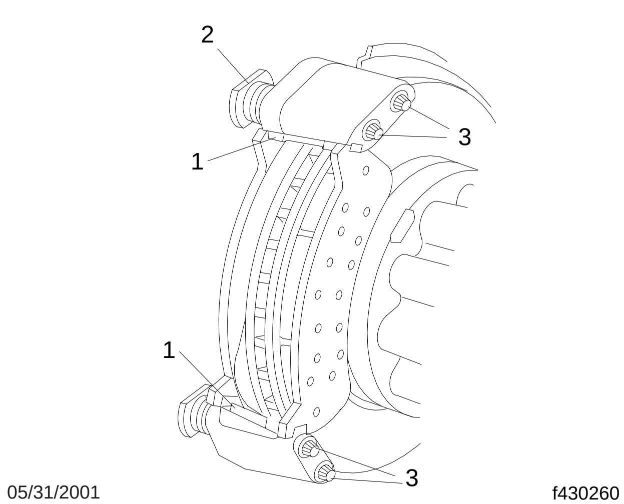
Disassembly

1. Park the vehicle on a level surface. Chock the rear or front tires, as required.
2. Jack up the vehicle. Support the axle with jack-stands.
3. Remove the tire.
4. Remove the brake caliper from the anchor plate following the instructions in **Subject 120**.
5. Remove the tie bar from the anchor plate on 73mm brakes, or remove the plugs from the anchor plate on 66mm brakes.
6. Remove the brake pads from the anchor plate. For instructions, see **Subject 110**.
7. Remove the wheel hub and rotor assembly from the axle, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
8. Remove the anchor plate from the axle.
   - 8.1 Remove the three screws holding the dust shield to the anchor plate and remove the dust shield.
   - 8.2 Remove the hexbolts, washers and nuts that hold the anchor plate to the axle. See **Fig. 1**.
   - 8.3 Remove the anchor plate from the axle.
9. Remove contamination, dirt and debris from the exterior of the anchor plate.
10. Remove the brake pad abutment slipper using a blunt nose drift pin or screwdriver and a light hammer. Avoid marring the anchor plate abutment surfaces. See **Fig. 2**.
11. Remove the guide pins and guide pin boots by pulling out the guide pin with a slight twisting motion.
12. Remove the splash shield and antilock braking system sensor bracket from the anchor plate. See **Fig. 3**.



1. Dust Shield Screw
2. Anchor Plate
3. Mounting Hexbolts
4. Dust Shield

Fig. 1, Axle End (typical)



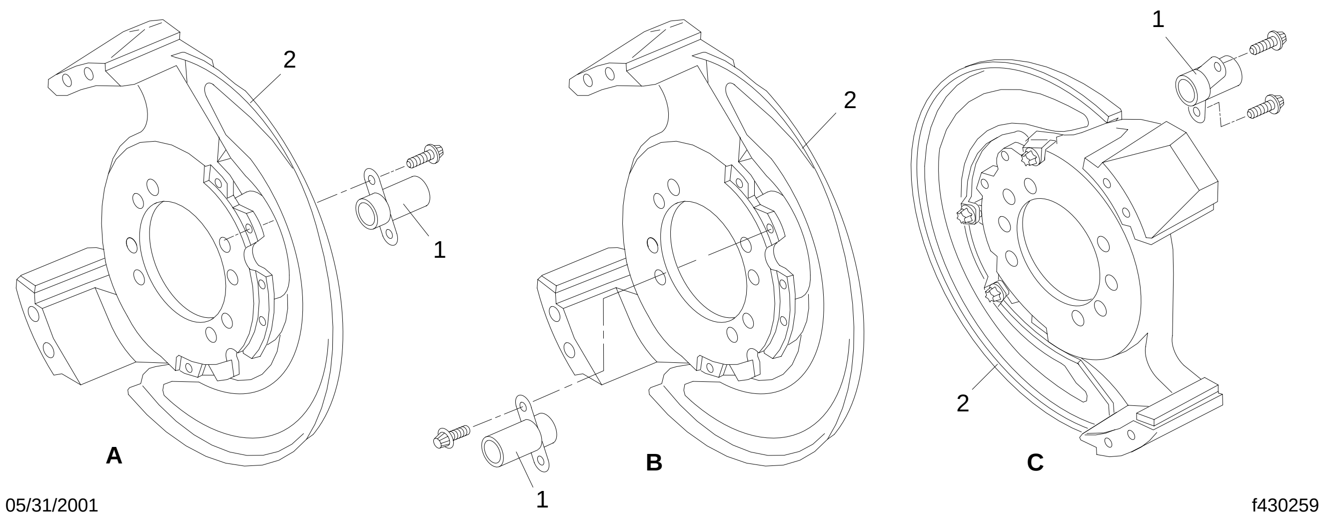
1. Pad Abutment Slipper
2. Guide Pin and Pin Boot
3. Plugs (66mm brakes only)

Fig. 2, Anchor Plate Components

Clean and Inspection

1. Clean the anchor plate with a brush and solvent. Make sure the anchor plate abutments, anchor plate tie bar mounting surfaces, axle flange

Anchor Plate Disassembly, Cleaning and Inspection, and Assembly



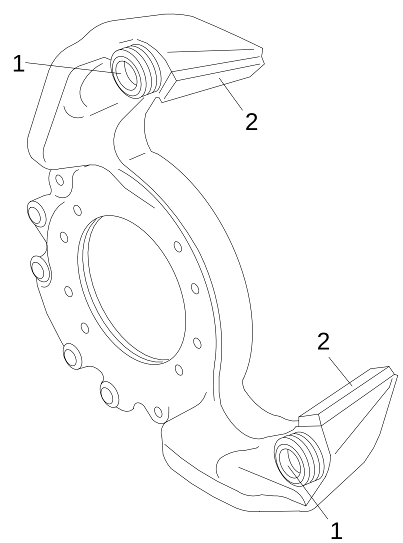
A. Driver Side Front Backing Plate Assembly (66mm brakes)
B. Driver Side Front Backing Plate Assembly (73mm brakes)
C. Driver Side Rear Backing Plate Assembly (typical)

1. Sensor Bracket
2. Anchor Plate

Fig. 3, Splash Shield and Sensor Mounting Bracket

mounting surface and anchor plate boot grooves are clean and free of any rust or corrosion. See **Fig. 4**. Use a hand-held wire brush to clean these surfaces. It is important to clean these areas of the anchor plate. Also make sure the tie bar bolt hole threads are clean and free of foreign matter.

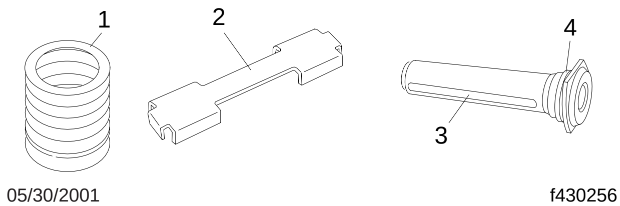
2. Clean the guide pin bores with a bore brush and solvent. Use compressed air to clean out and dry guide pin bores. Check the guide pin bores for excessive wear. Replace the anchor plate, if necessary.
3. Clean the guide pin boots with isopropyl alcohol. Do not use solvent to clean the boots. Inspect each guide pin boot for cracks, tears, holes and flexibility. If damage is found, the boot must be replaced. See **Fig. 5**.
4. Clean the guide pins with isopropyl alcohol. Make sure the guide pins, and the threads in the guide pins, are free of foreign matter and corrosion. Use compressed air to clean out and dry guide pins and bolt threads in the guide pins. Check the guide pins for wear. Replace them if excessive wear is detected.



1. Guide Pin Bore and Boot Groove
2. Pad Abutment Slipper Mounting

Fig. 4, Anchor Plate Machined Surfaces

Anchor Plate Disassembly, Cleaning and Inspection, and Assembly



1. Guide Pin Boot
2. Pad Abutment Slipper
3. Guide Pin
4. Boot Groove

Fig. 5, Loose Anchor Plate Components

5. Inspect the pad abutment slippers for damage or wear and clean them with solvent. Replace them if damaged or excessive wear is detected.
6. Visually inspect the anchor plate for worn or damaged slippers, and damaged or dislodged guide pin boots. If signs of wear or damage are found, the anchor plate should be repaired or replaced.

Assembly

NOTE: All brake parts must be clean and completely dry of cleaning fluids before assembly.

1. Uniformly apply Aeroshell Grade 5 grease to the entire guide pin bore and on the guide pin shaft. Use 1/8 ounce (3 grams) of grease to thoroughly lube each guide pin and guide pin bore set. See **Fig. 6**.
2. Apply a thin coat of Aeroshell Grade 5 grease to the inside opening at each end of the boot.
3. Slide the guide pin into the guide pin boot.
4. Insert the guide pin with the boot into the anchor plate guide pin bore until the boot is completely compressed.
5. Rotate the guide pin 1/4 to 1/2 turn back and forth in order to seat the guide pin boot.
6. Inspect the guide pin boot to make sure the boot is fully seated all around the guide pin and the anchor plate retaining grooves.
7. Install an anchor plate pad abutment slipper onto each anchor plate abutment. See **Fig. 7**. Use a soft brass or other light hammer to be sure the slipper is seated on the abutment. Avoid marring anchor plate abutment slipper surfaces.
8. Install the splash shield and antilock braking system sensor bracket to the anchor plate.

   When installing the splash shield and sensor bracket on the anchor plate for 66mm front and all rear brakes, the splash shield and sensor bracket are mounted on the inboard side of the anchor plate and the five bolts are installed from the inboard side. Tighten the bolts 12 to 16 lbf·ft (17 to 21 N·m).

   For 73mm front brakes, the splash shield and sensor bracket are mounted on the outboard side of the anchor plate and the five bolts are installed from the outboard side. Tighten the bolts 12 to 16 lbf·ft (17 to 21 N·m).
9. Remove all traces of dirt, grease and oil from the knuckle and axle brake flange.
10. Install the anchor plate on the axle.

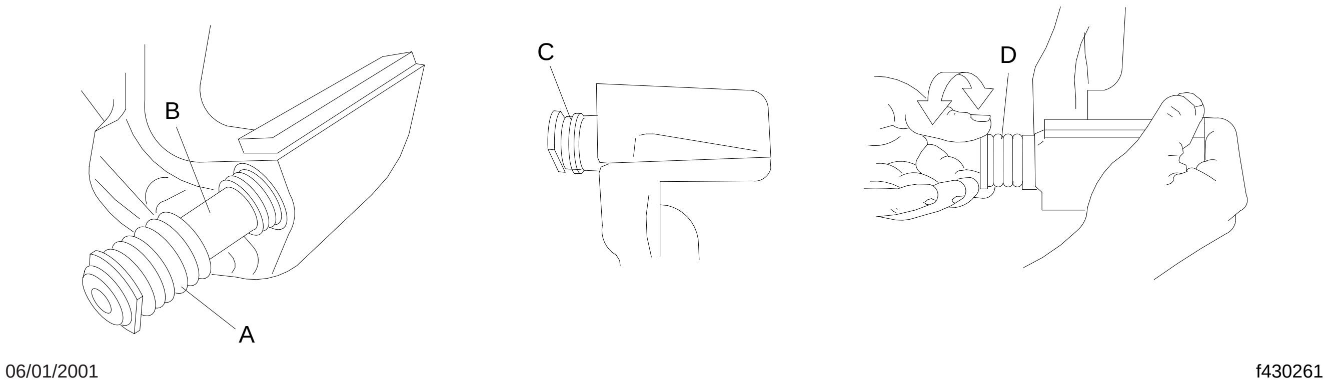
    10.1 Position the anchor plate against the outboard side of the axle flange, making sure the holes in both are lined up.

    10.2 From the outboard side of the anchor plate, install the hexbolts and washers. Install the nuts and remaining washers. See **Fig. 1**. Using a star pattern, tighten the hexnuts as follows:

    - Rear Axle; 97 to 123 lbf·ft (132 to 167 N·m)
    - Front Axle Type FC; 70 to 89 lbf·ft (95 to 121 N·m)
    - Front Axle Type FD/FF; 134 to 172 lbf·ft (182 to 233 N·m)
11. Install the dust shield on the anchor plate. See **Fig. 1**.
12. Install the wheel hub and rotor assembly onto the axle, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
13. On 66mm brakes, install the four bolt plugs into the anchor plate face. Tighten 16 to 27 lbf·ft (22 to 37 N·m). See **Fig. 8**.

    On 73mm brakes, install the anchor plate tie bar and the four tie bar bolts to the anchor plate face. Tighten 40 to 50 lbf·ft (54 to 68 N·m).
14. Install the brake caliper on the anchor plate following the instructions in **Subject 120**.

Anchor Plate Disassembly, Cleaning and Inspection, and Assembly



A. Lube the inside of the boot, both ends.
B. Apply Aeroshell Grade 5 grease to the bore and the pin.
C. Boot and pin in place.
D. Twist to seat in the groove.

Fig. 6, Install Guide Pins and Boots

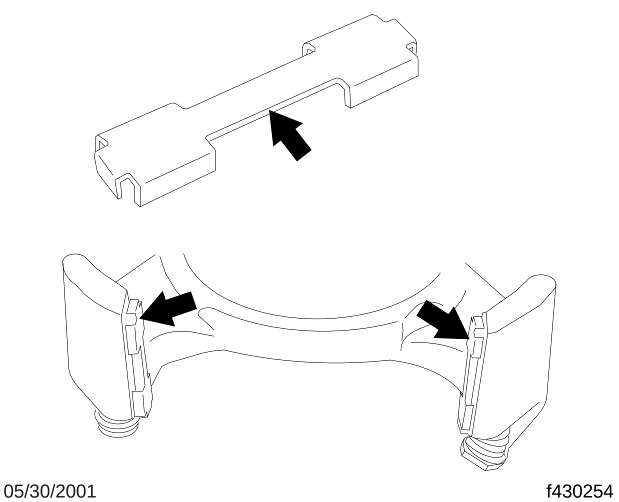
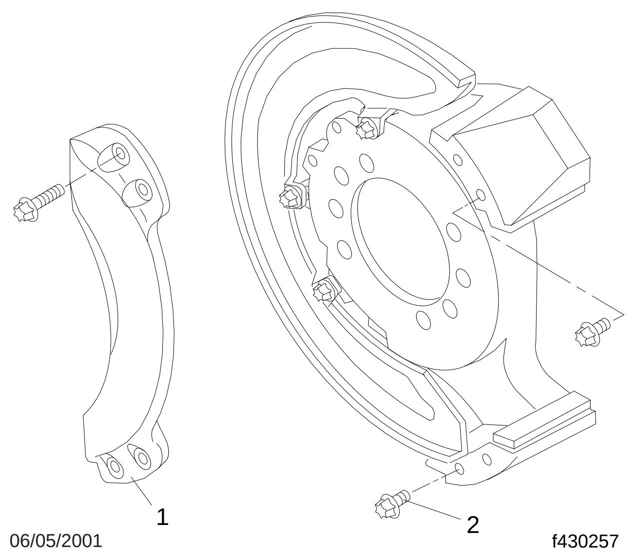


Fig. 7, Pad Abutment Slipper

15. Install the brake pads into the anchor plate. For instructions, see **Subject 110**.
16. Install the tire.
17. Remove the jackstands. Lower the vehicle.
18. Remove the chocks.



1. Tie Bar (73mm brakes only)
2. Plug (66mm brakes only)

Fig. 8, Plugs and Tie Bar

Bleeding

WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

Whenever any hydraulic system fitting is loosened or disconnected, the entire system must be bled to remove any air that may have entered it.

CAUTION

Power steering fluid and brake fluid are incompatible. Never mix these two fluids or serious damage to both hydraulic systems will result. Use only brake fluid for the master cylinder and brake lines. Use only power steering fluid for the power booster.

Always use new, clean brake fluid that meets DOT 3 specifications when bleeding the master cylinder and service brake system. Never reuse brake fluid and do not use brake fluid containers for any other purpose. Keep brake fluid containers tightly closed to keep new brake fluid clean and dry.

IMPORTANT: Do not let brake fluid touch any painted surfaces, as it will remove the paint. Brake fluid may also damage certain non-metal surfaces. Do not let it get on brake pads or rotors.

Pressure Bleeding

NOTE: Pressure bleeding is the preferred method for bleeding the service brake system. It requires the use of a special pressure bleeder kit, consisting of a tank, pressure pump and valve, gauge, tubing and adapter. These are available from a number of manufacturers and include instructions for use. See **Fig. 1**.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.

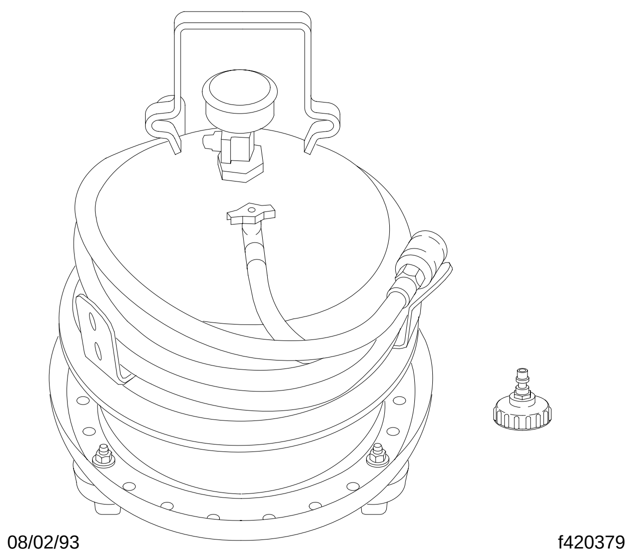


Fig. 1, Pressure Bleeder Kit

3. Connect the pressure bleeder to the brake master cylinder reservoir following the manufacturer's instructions.
   - 3.1 Fill the pressure bleeder with new DOT 3 approved brake fluid. Pressurize it according to the manufacturer's instructions.
   - 3.2 Using the supplied adapter, connect the pressure bleeder to the rear compartment of the master cylinder reservoir.
4. Bleed the hydraulic connections at the rear wheel calipers starting on the right side.
   - 4.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.
   - 4.2 Loosen the bleeder fitting about 3/4 turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.
   - 4.3 Move to the left rear caliper and repeat steps for bleeding the caliper.
5. Disconnect the pressure bleeder from the rear compartment of the master cylinder reservoir. Connect it to the front compartment of the reservoir.

System Bleeding

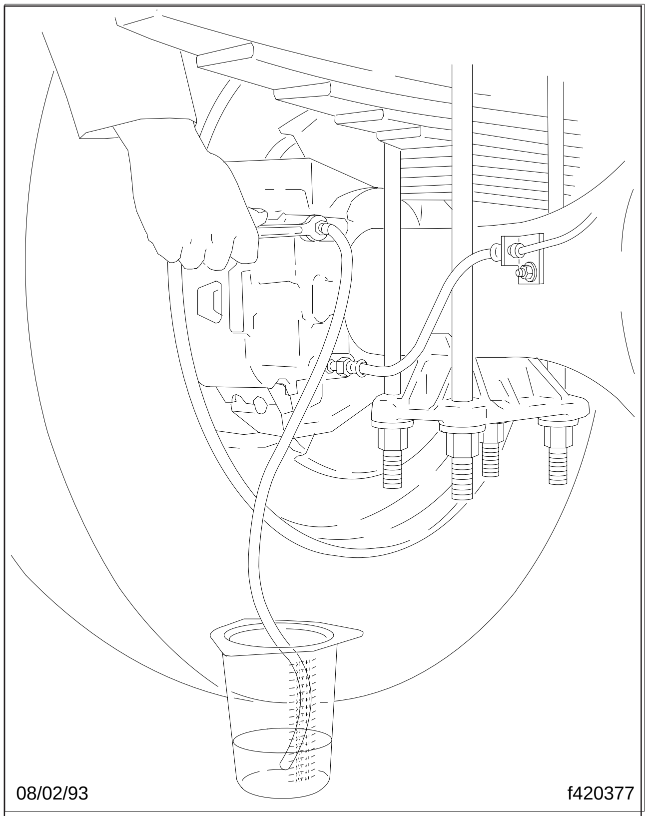


Fig. 2, Bleed the Hydraulic Connection

6. Bleed the front wheel brake calipers starting at the right side.

   6.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

   6.2 Loosen the bleeder fitting about 3/4 turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.

   6.3 Move to the left front wheel caliper and repeat steps for bleeding the caliper.

7. Check the brake fluid level in both compartments of the reservoir. Add new DOT 3 approved brake fluid if needed.

8. Check the operation of the brakes by depressing the brake pedal several times, until if feels firm. The brake pedal should not go all the way down to the floor. If it does, see **Troubleshooting, 300** and find the problem.

9. Close and latch the hood.

10. Remove the chocks from the rear tires.

Manual Bleeding

NOTE: If you do not have pressure bleeding equipment, you can use the manual bleeding procedure.

WARNING

Read over the information in Subject 100 before starting the procedure below. Failure to do so may result in either serious injury to yourself, or damage to the brake system, resulting in an accident causing serious personal injury or property damage.

IMPORTANT: Do not let the brake master cylinder run dry during manual bleeding operations. Keep the master cylinder reservoir filled with new, DOT 3 approved brake fluid. Failure to keep the brake reservoir filled could result in more air entering the system, making it impossible to effectively bleed the system.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.

2. Open the hood.

3. Bleed the master cylinder.

   3.1 Using a wrench (and a rag to absorb leaking brake fluid), loosen the fitting at the rear outlet port on the master cylinder. See **Fig. 3**. Loosen the fitting about one turn.

   3.2 Have someone push the brake pedal down slowly by hand to the floor. Brake fluid, and any air in the master cylinder, will squirt from the fitting.

   3.3 *With the brake pedal held down*, tighten the rear hydraulic line fitting firmly.

   IMPORTANT: Do not release the brake pedal until the fitting is tightened, or more air will get into the system.

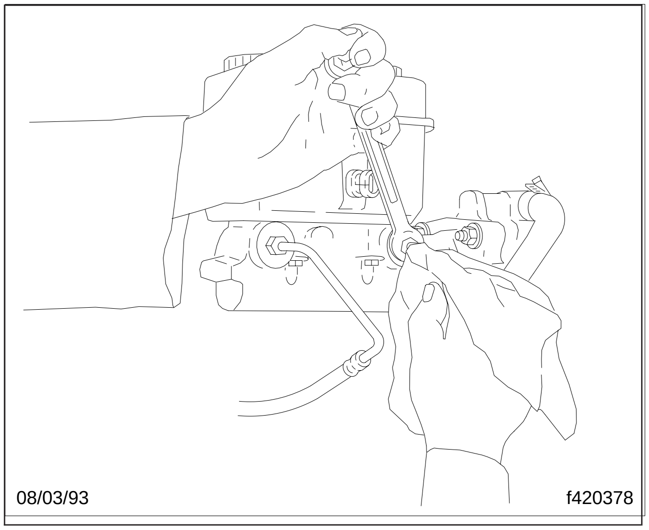


Fig. 3, Rear Outlet Port

3.4 Release the brake pedal.

3.5 Loosen the fitting again, and repeat steps for bleeding as required until no air escapes from the fitting, and the brake pedal feels firm.

3.6 Check the level of the rear compartment of the reservoir, then add new DOT 3 approved brake fluid if needed.

3.7 Using a wrench (and a rag to absorb leaking brake fluid), loosen the fitting at the front outlet port on the master cylinder. See **Fig. 4**. Loosen the fitting about one turn.

3.8 Repeat steps as required for the front outlet port.

3.9 Check the brake fluid level in the front compartment of the reservoir. Add new DOT 3 approved brake fluid if needed.

4. Bleed the hydraulic connections at the wheel calipers, starting at the right rear wheel caliper.

4.1 Put a wrench on the bleeder fitting at the caliper, then attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

4.2 Loosen the bleeder fitting about 3/4 turn.

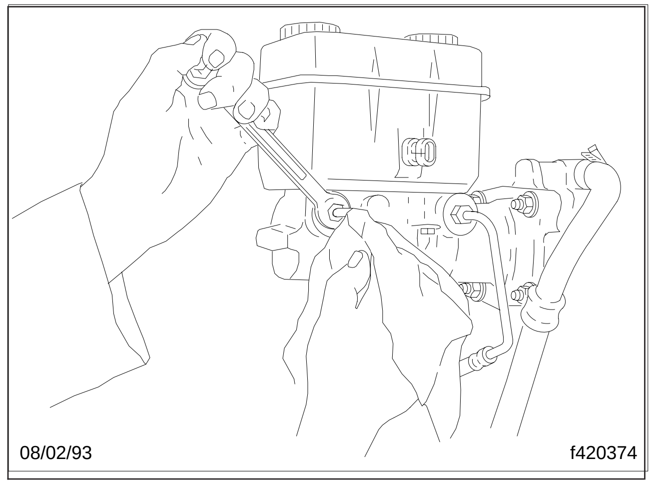


Fig. 4, Front Outlet Port

4.3 Have someone slowly push the brake pedal to the floor. *With the brake pedal depressed*, tighten the bleeder fitting.

IMPORTANT: Make sure the brake pedal stays depressed while you tighten the fitting. If it is released before you tighten the fitting, more air will get into the system.

4.4 Release the brake pedal. Check the fluid in the tube. If there are air bubbles present, repeat the steps as required until the fluid in the tube is completely free of air bubbles.

4.5 Check the brake fluid level in the reservoir. Add new DOT 3 approved brake fluid if needed.

4.6 Repeat the steps for bleeding the connections for the left rear caliper, the right front caliper and the left front caliper.

5. Close and latch the hood.

6. Remove the chocks from the rear tires.

Troubleshooting Tables

IMPORTANT: See **Section 42.15** for detailed hydraulic brake system troubleshooting procedures.

Problem—Noise and Chatter

Problem—Noise and Chatter	
Possible Cause	**Remedy**
Bent, damaged, or incorrect pads	Replace with the correct pads in axle sets.
Worn out lining plates (plates rubbing rotor)	Resurface or replace the rotor. Replace the pads in axle set.
Rotor polished or linings glazed	Remove the polish or glaze.
Foreign material embedded in linings	Replace the pads in axle sets.
Excessive rotor thickness variations or lateral runout	Resurface or replace the rotor.

Problem—Brakes Grab

Problem—Brakes Grab	
Possible Cause	**Remedy**
Incorrect pads or pads loose on plate	Replace with the correct pads in axle sets.
Grease or brake fluid on linings	Repair the grease seal or caliper. Replace the pads in axle sets.
Loose caliper at anchor plate pins	Tighten to specifications.
Excessive rotor lateral runout	Check the bearing adjustment. Resurface or replace the rotor.

Problem—Vehicle Pulls to One Side

Problem—Vehicle Pulls to One Side	
Possible Cause	**Remedy**
Incorrect pads or loose lining on plates	Replace with the correct pads in axle sets.
Grease or brake fluid on linings	Repair the grease seal or caliper. Replace the pads in axle sets.
Loose caliper or anchor plate	Tighten to specifications.
Caliper piston sticking	Repair or replace the piston or replace the caliper.
Caliper guide pins sticking	Repair or replace the guide pins and boots. Clean the pin bores and lubricate.
Excessive rotor lateral runout	Check the bearing adjustment. Resurface or replace the rotor.

Problem—Pulsating Brake Pedal

Problem—Pulsating Brake Pedal	
Possible Cause	**Remedy**
Worn or damaged front wheel bearings	Replace the wheel bearings.
Excessive variation in rotor thickness	Resurface or replace the rotor.

Troubleshooting

Problem—Springy or Spongy Pedal

Problem—Springy or Spongy Pedal	
Possible Cause	**Remedy**
Excessive rotor lateral runout	Resurface or replace the rotor.
Poor quality brake fluid (low boiling point)	Drain and clean the system. Refill with the approved brake fluid.
Weak brake hoses that expand under pressure	Replace the hoses.
Air in hydraulic system	Bleed the system. For instructions, see **Subject 170**.

Problem—All Brakes Drag (or Both Brakes on Same Axle)

Problem—All Brakes Drag (or Both Brakes on Same Axle)	
Possible Cause	**Remedy**
Binding brake pedal	Free-up and lubricate the pedal.
Soft or swollen rubber parts caused by incorrect or contaminated brake fluid	Replace rubber parts. Flush the system and refill with approved brake fluid. For instructions, see **Subject 160**.
Trapped pressure in brake lines caused by master cylinder and/or booster not fully releasing	Repair or replace the master cylinder and/or booster as necessary.

Problem—One Brake Drags

Problem—One Brake Drags	
Possible Cause	**Remedy**
Loose or worn front wheel bearings	Adjust to specifications or replace.
Defective brake hose or hydraulic tube (preventing return of fluid)	Replace the hose or tube.
Sticking caliper piston	Repair or replace the caliper.
Swollen caliper piston seal	Replace the seal. Drain and flush the system. Refill with the approved brake fluid.
Sticking caliper guide pin(s)	Repair or replace the pin(s). Lubricate the pins and boots.

Problem—Low Pedal

Problem—Low Pedal	
Possible Cause	**Remedy**
Leak in hydraulic brake system	Check the master cylinder, calipers, hoses and tubes. Replace as necessary.
Air in hydraulic brake system	Bleed the system. For instructions, see **Subject 160**.
Poor quality brake fluid (low boiling point)	Drain the system. Flush and refill with approved brake fluid.
Weak brake hoses that expand under pressure	Replace the defective hoses.
Pad and piston knockback caused by loose wheel bearings	Adjust or tighten parts or replace faulty parts as necessary.

Specifications

Kent-Moore Tools	
Kent-Moore Part Number	**Tool**
ZTSE4417	Seating Tool for 66 mm Caliper Pistons
ZTSE4418	Seating Tool for 73 mm Caliper Pistons

Table 1, Kent-Moore Tools

Fastener Torques			
Fastener Description	**Size**	**Grade**	**Torque: lbf·ft (N·m)**
Caliper Pin Mounting Bolts	M12 x 1.25	—	93 to 107 (126–145)
Brake Supply Hose Fitting	—	—	15 (20)
Tie Bar-to-Anchor Plate Mounting Bolt (73 mm only)	M10 x 1.5	—	40–50 (54–68)
Tie Bar-to-Anchor Plate Hole Plug (66 mm only)	M10 x 1.5	—	16–27 (22–37)
Dust Shield, ABS Sensor Mounting Bracket and Brake Line Clip Screw	5/16–18	—	12–16 (17–22)
Anchor Plate Mounting Hexnuts	—	—	Rear Axle: 97–123 (132–167) Front Axle Type FC: 70–89 (95–121) Front Axle Type FD/FF: 134–172 (182–233)
Caliper Bleed Screw	7/16–24	—	8–15 (10–20)
Rotor Mounting Hexbolts	9/16–12	8	130 (175)

Table 2, Fastener Torques

Approved Brake Fluid for Brake System	
Fluid Type	**Recommended Fluids**
DOT 3	Wagner-Premium Plus Super HD
	Delco Supreme II
	Dow HD 50-4

Table 3, Approved Brake Fluid for Brake System

Approved Brake System Grease	
Component	**Recommended Grease**
Anchor Plate Guide Pins, Guide Pin Boots, Guide Pin Bores	Aeroshell Grade 5 (ES-1246)
Caliper Piston Bores	Dow Corning DC-4

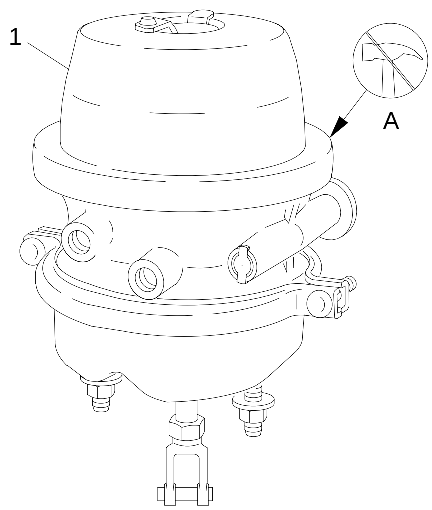
Table 4, Approved Brake System Grease

Rotor Specifications	
Outside Diameter	15.0 inch (381 mm)
Thickness, New	1.435 inch (36.45 mm)
Thickness, Discard	1.320 inch (33.53 mm)
Surface Finish	40–120 micro inch (40–100 micro inch preferred)

Table 5, Rotor Specifications

DANGER

Do not attempt to remove the factory-sealed clamp ring for any purpose at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



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A. Do not remove the factory-sealed clamp ring.
1. Model TR-T (TR Series) Brake Chamber

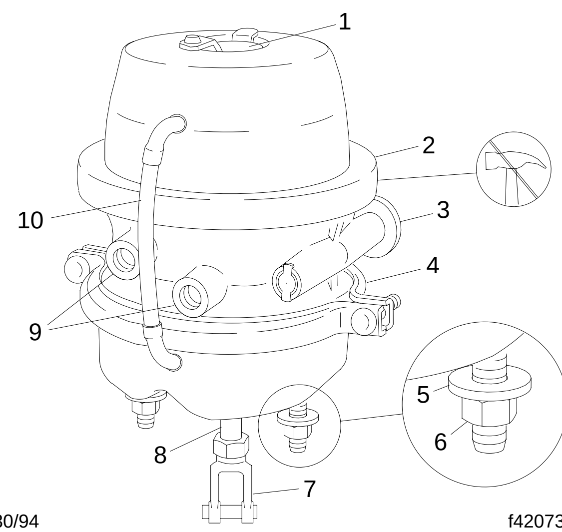
Fig. 1, Brake Chamber

IMPORTANT: On MGM TR series chambers, the parking/emergency brake section is factory sealed (no clamp ring) and is a *non-serviceable* unit.

General Information

MGM TR series tandem cam brake chambers consist of a service brake section and a parking/emergency spring brake section. See **Fig. 2**. The service brake section is the smaller section near the clevis assembly.

In the service brake section, the flange case and non-pressure chamber contain a service return spring, piston rod assembly, and service brake diaphragm.



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Do not remove the factory-sealed clamp ring.

1. End Cover Cap
2. Factory Sealed Parking Brake Clamp Ring
3. Release Bolt Storage Pocket
4. Service Brake Clamp Ring
5. Hardened Flatwasher
6. Prevailing Torque Locknut
7. Clevis Assembly
8. Piston Rod
9. Air Inlet Ports
10. External Breather Tube

Fig. 2, Model TR-T (TR Series) Brake Chamber

In the parking/emergency brake section, the flange case and the head contain a return spring, a pushrod assembly, a parking (spring) brake diaphragm, a piston, a power spring, and a detachable release bolt.

All MGM brake chambers are mounted to the frame using prevailing torque locknuts and hardened flatwashers.

MGM TR series chambers may be equipped with an external breather tube that protects the parking brake chamber from contaminants. These chambers are called Model TR-T chambers. See **Fig. 2**.

Periodic maintenance of the brake chambers is required. Also, whenever the service brake chamber is disassembled (*do not attempt to disassemble the parking brake chamber*), the parts should be inspected for damage. For maintenance schedules and procedures, and for inspection of brake chamber parts, see the *Acterra Maintenance Manual*.

General Information

Service Brakes

As the brake pedal is depressed, compressed air enters the service brake chamber through a port. Air pressure acts upon a diaphragm, which forces the piston rod toward the non-pressure chamber, applying a straight-line force to the slack adjuster, which converts it to a rotational force. This, in turn, rotates the camshaft and applies the brakes.

When the brake pedal is released, air is exhausted from the service brake chamber, and the return spring allows the diaphragm, piston rod, and slack adjuster to return to their normal positions, releasing the brakes.

Parking/Emergency Brakes

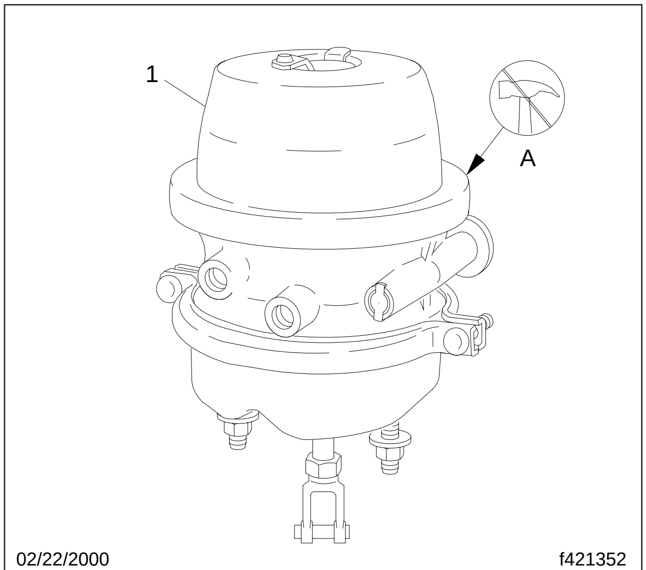
During parking brake release, compressed air enters the parking brake chamber and acts upon the diaphragm and piston, fully compressing the power spring. When the power spring is compressed, the parking brakes are released; the service brakes can then be operated at the brake pedal.

During parking brake application, air is exhausted from the parking brake chamber. The power spring releases, forcing the piston and parking brake diaphragm toward the flange case. The resulting motion on the pushrod forces the service brake diaphragm and piston rod outward, applying the brakes.

Power Spring Manual Compression and Reset

DANGER

Do not attempt to remove the factory-sealed clamp ring for any purpose at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



A. Do not remove the factory-sealed clamp ring.

1. Model TR-T (TR Series) Brake Chamber

Fig. 1, Brake Chamber

Manual Compression (Parking Brake Release)

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Remove the end cover cap from the center hole in the head of the chamber. See Fig. 2.

DANGER

Do not attempt to cage the power spring if the parking brake chamber is damaged severely enough to lose its structural integrity. If the power spring were to break loose, it could result in death, severe personal injury, or property damage.

A DAMAGED PARKING BRAKE CHAMBER IS EXTREMELY DANGEROUS! Only qualified service personnel should attempt to remove and disarm a damaged chamber. Using a torch, burn off the piston rod in the space between the clevis and the base of the service chamber.

Remove the chamber carefully from its bracket, and disarm it inside a suitable container. For disarming procedures, consult the MGM service manual.

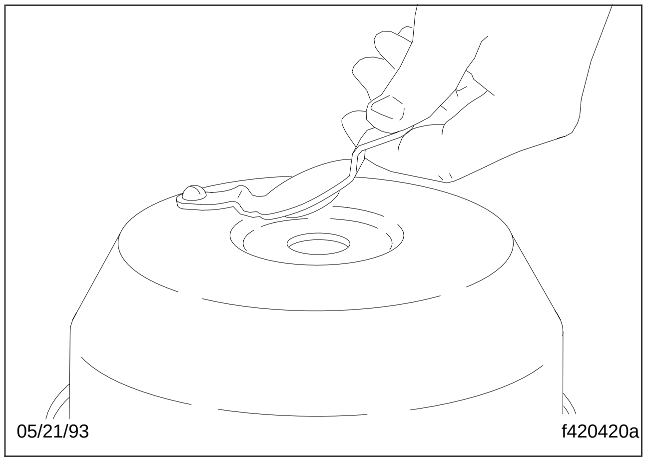


Fig. 2, Remove the End Cover Cap

3. Manually release the parking brake (cage the power spring).

   3.1 Using a hand wrench (*do not use an impact wrench*), unscrew the release nut, and remove the nut, flatwasher, and release bolt from the storage pocket on the side of the chamber. See Fig. 3.

   IMPORTANT: If these parts are not stored on the chamber, they must be otherwise obtained or purchased; the parking brake cannot be manually released without them.

   3.2 Apply at least 90 psi (620 kPa) air pressure to the parking brake inlet port (set the parking brake in the "release" position).

   3.3 Insert the release bolt into the center hole in the chamber head. See Fig. 4. Insert

Power Spring Manual Compression and Reset

the bolt until it bottoms out into the hole in the piston inside the chamber.

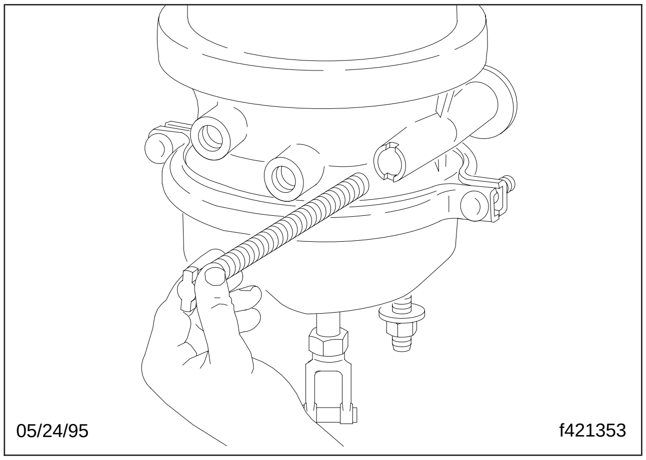


Fig. 3, Remove the Release Bolt

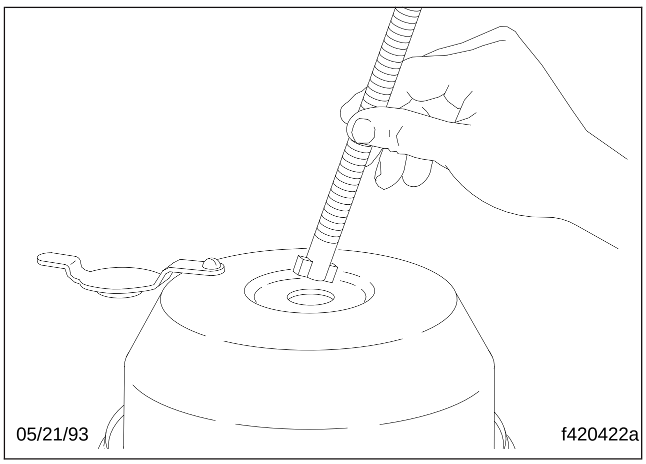


Fig. 4, Insert the Release Bolt

IMPORTANT: If you are not absolutely sure that the formed end of the bolt has engaged the piston correctly, repeat this step. Repeat it until you are absolutely sure.

3.4 Turn the release bolt one-quarter turn clockwise, and pull the bolt out to lock its formed end into the piston.

IMPORTANT: If the bolt does not lock into the piston in less than a 1/2 inch (13 mm) outward movement, repeat these steps until you are sure it does lock.

3.5 Holding the bolt locked into the piston, install the flatwasher and release nut on the end of the release bolt, and turn down the nut against the flatwasher until it is finger-tight. See **Fig. 5**.

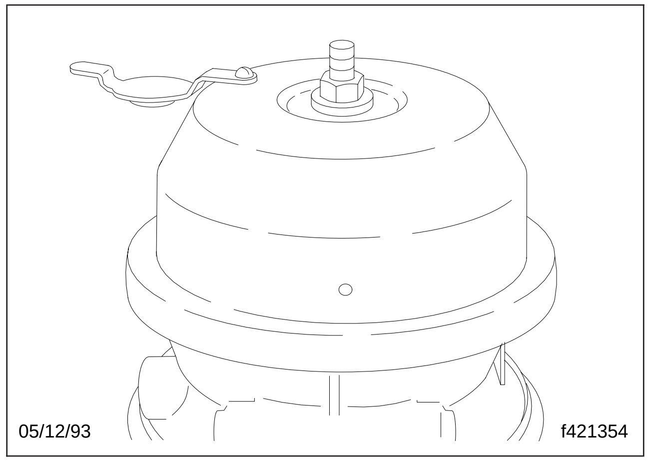


Fig. 5, Flatwasher and Release Nut Installed

CAUTION

Do not exceed 50 lbf·ft (68 N·m) torque on the release nut; and do not use an impact wrench on this nut. Too much torque could distort the head of the chamber and prevent manual release of the parking brake.

3.6 Using a hand wrench (*do not use an impact wrench*), turn the release nut clockwise until the bolt extends 3 inches (76 mm) above the nut. See **Fig. 6**.

IMPORTANT: Do not exceed the 3-inch (76-mm) length.

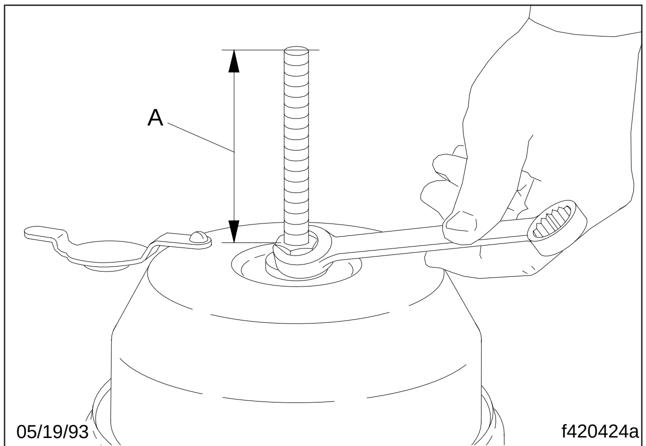
4. Once the power spring has been caged, exhaust the compressed air from the parking brake.

Manual Reset (Parking Brake Reset)

1. Uncage the power spring.

1.1 Apply at least 90 psi (620 kPa) air pressure to the parking brake inlet port (set parking brake in the "release" position).

Power Spring Manual Compression and Reset



Do not exceed the 3-inch (76-mm) length.

A. Measure this distance.

Fig. 6, Turn the Release Nut

CAUTION

Do not exceed 50 lbf·ft (68 N·m) torque on the release nut; and do not use an impact wrench on this nut. Too much torque could distort the head of the chamber and prevent manual release of the parking brake.

1.2 With air applied to the parking brake section (the parking brake control valve is in the "release" position), use a hand wrench to turn the release nut *counterclockwise* until the bolt bottoms out in the unit.

1.3 Remove the nut and flatwasher.

1.4 Push the release bolt into the piston and turn the release bolt one-quarter turn counterclockwise to unlock its formed end from the piston. Remove the release bolt from the center hole of the chamber.

2. Using a hand wrench (*do not use an impact wrench*), install the release bolt, flatwasher, and release nut in the storage pocket. MGM recommends 10 lbf·ft (14 N·m) torque on the nut against the flatwasher. See **Fig. 7**.
3. Snap the end cover cap in place over the center hole in the chamber head. See **Fig. 8**.

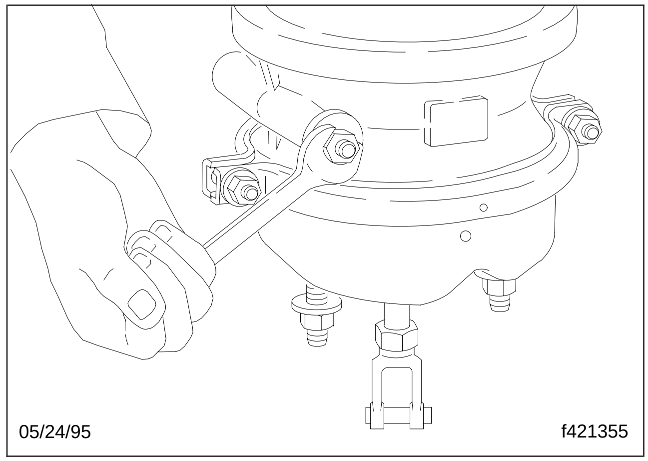


Fig. 7, Tighten the Release Nut

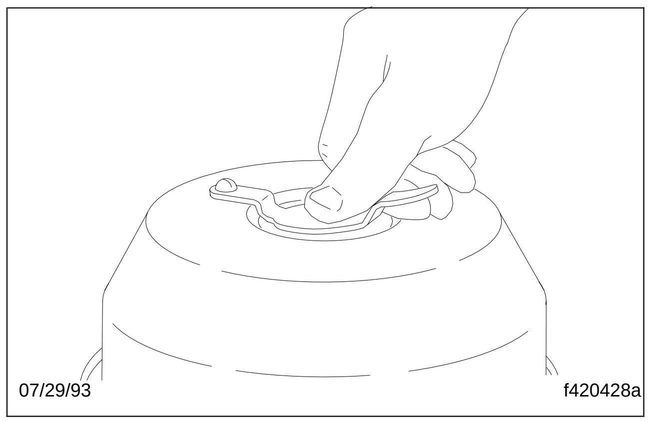


Fig. 8, Snap the End Cover Cap in Place

CAUTION

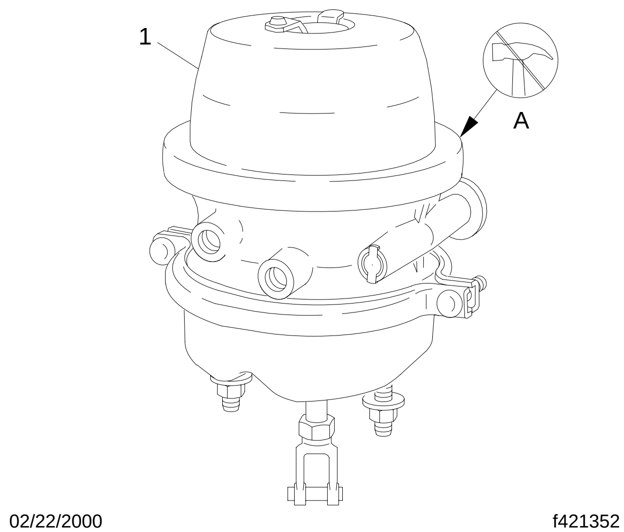
If the external breather tube or end cover cap is missing or incorrectly installed, road dirt and debris can adversely affect the operation of the brake chamber. Once inside the chamber, dirt and debris cause the internal parts to deteriorate and shorten their lives. Operating the unit without the external breather tube or end cover cap in place voids the MGM warranty.

4. Check the plastic end cover cap periodically. If it is damaged or missing, replace it with a new one at once. For intervals, see the *Business Class M2® Maintenance Manual*.
5. Remove the chocks from the tires.

Service Brake Diaphragm Removal and Installation

DANGER

Do not attempt to remove the factory-sealed clamp ring for any purpose at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



A. Do not remove the factory-sealed clamp ring.
1. Model TR-T (TR Series) Brake Chamber

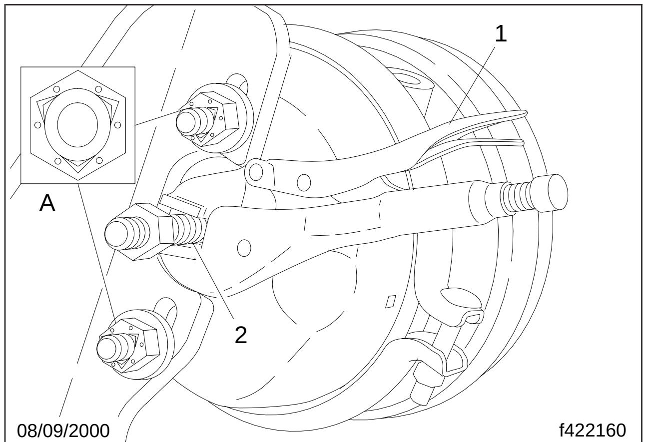
Fig. 1, Brake Chamber

Removal

1. To make removal and installation of the parking brake section easier (without removing the service brake chamber), lock off the service chamber piston rod.

   1.1 Apply the service brakes by actuating the driver's foot brake treadle valve.

   1.2 With the brakes applied, clamp a pair of locking-jaw pliers on the piston rod to lock the rod in place when the air pressure is released. See Fig. 2.



A. Prevailing Torque Locknut
1. Locking-Jaw Pliers
2. Piston Rod

Fig. 2, Lock the Piston Rod in Place

WARNING

Before caging (compressing) the power spring, chock the vehicle tires and read the warnings and instructions in Subject 100. When the power spring is caged, the vehicle may be without brakes, allowing it to roll out of control, possibly resulting in personal injury or property damage.

2. Manually release the parking brake (cage the power spring). For instructions, see Subject 100.

3. Mark the air lines for later reference. Carefully disconnect them from the brake chamber.

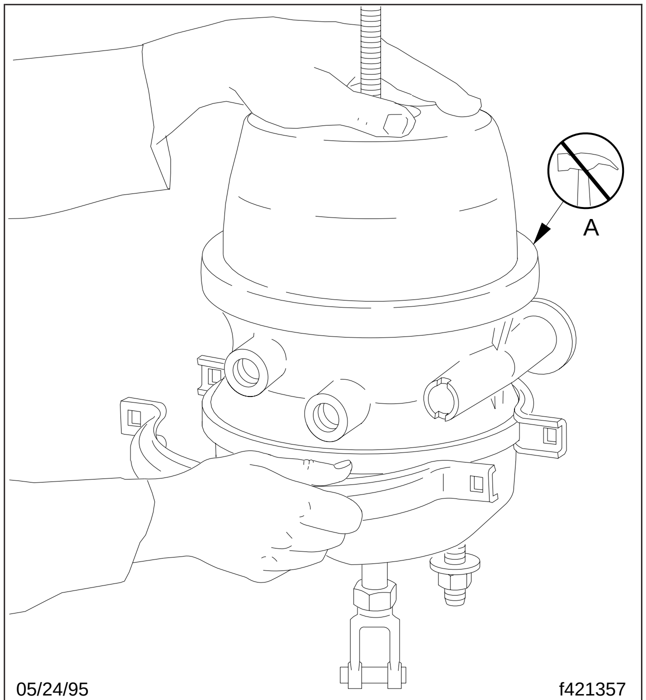
   On chambers equipped with an external breather tube, disconnect the tube and elbow from the service brake chamber.

4. Remove the parking brake section from the service brake section.

   4.1 Using a hand wrench (*do not use an impact wrench*), remove the clamp nuts on the *service* clamp ring (*do not disassemble the parking brake section*).

   4.2 While holding the parking brake section securely in place, remove the service clamp ring. Remove the parking brake section from the service brake non-pressure chamber. See Fig. 3.

Service Brake Diaphragm Removal and Installation



A. Do not remove the factory-sealed clamp ring.

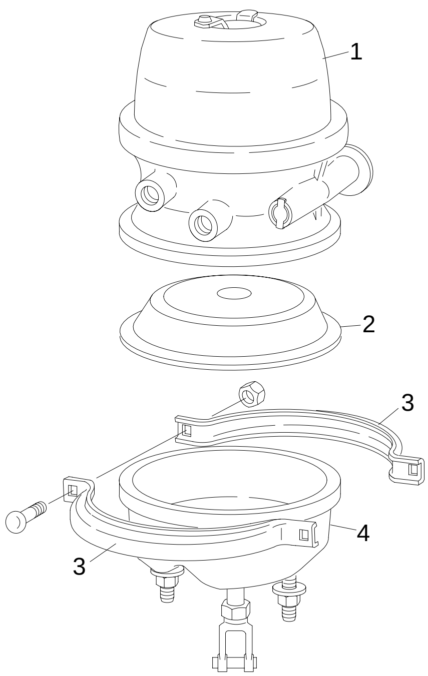
Fig. 3, Remove the Service Clamp Ring

5. Remove the service brake diaphragm from the bottom of the parking brake section.

Installation

IMPORTANT: At this time, take the opportunity to inspect the parking/emergency brake section, and replace it if it shows signs of damage, corrosion, or rust. Follow the detailed inspection instructions in the *Business Class M2® Maintenance Manual*.

1. Inspect all parts in the service (non-pressure) chamber. Replace any damaged or worn parts with genuine MGM-engineered replacement parts.
2. Place the new service brake diaphragm in the bottom recess of the parking brake section. See **Fig. 4**.
3. Install the (new, if needed) parking/emergency brake section.



1. Parking/Emergency Brake Section
2. Service Brake Diaphragm
3. Service Brake Clamp Ring
4. Service Brake (Non-Pressure) Chamber

Fig. 4, Brake Chamber Parts

3.1 If installing a new parking brake section, be sure it is the same size and make as the old one.

3.2 Check that the release bolt is fully extended outward. For instructions, see **Subject 100**.

3.3 Install the parking brake section on the service chamber so that all mating parts are aligned straight and the air lines are positioned to mate with the vehicle air supply lines.

4. Install the service brake clamp ring.

4.1 With the service brake clamp ring in place, install the clamp bolts and nuts.

4.2 Using a hand wrench (*do not use an impact wrench*), alternately tighten each clamp nut in increments of 60 to 120

Service Brake Diaphragm Removal and Installation

lbf·in (680 to 1360 N·cm) while constantly rechecking the alignment of mating parts.

If realignment is needed, loosen the nuts again, and repeat this substep.

4.3 Firmly tap around the circumference of the service clamp ring with a rubber mallet to ensure full seating of the clamp. Tighten the nuts to a final torque of 25 to 30 lbf·ft (34 to 41 N·m).

5. Make sure the air hose fittings are free of grease, dirt, and other debris. Apply Loctite® 242 sealant, or an equivalent, to the fittings, and install, as referenced earlier. Using a hand wrench (*do not use an impact wrench*), tighten the fittings 25 lbf·ft (34 N·m).

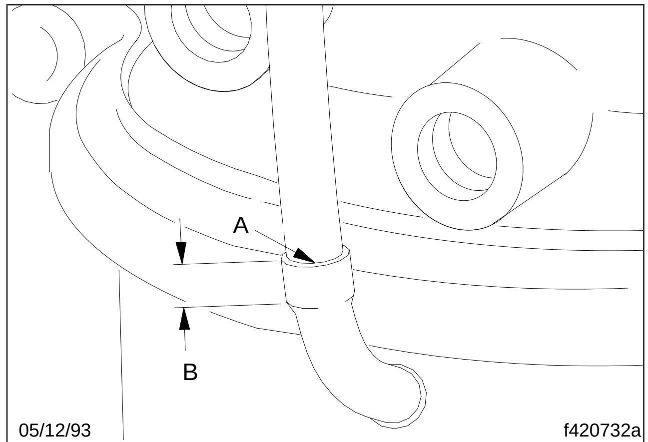
6. Using the vehicle system air, charge the parking brake with full line pressure—at least 100 psi (690 kPa). Using only soapy water (*never any type of oil,* which could deteriorate rubber parts), check for air leaks at the air lines and fittings. If bubbles or leaks appear, tighten the fittings slightly, but not over 25 lbf·ft (34 N·m).

7. With the parking brake still charged with full line pressure, apply and hold the foot brake treadle valve down to charge the service brake chamber. Remove the locking-jaw pliers from the service piston rod so that the piston returns to a normal position in the chamber.

8. Test for air leaks around the circumference of the *service* brake clamp ring. If bubbles or leaks appear, firmly tap the circumference of the clamp ring with a rubber mallet, and retighten the clamp nuts until leaks cease (*do not touch the parking brake section*). MGM recommends 25 to 30 lbf·ft (34 to 41 N·m) torque on the clamp hexnuts.

9. On chambers equipped with an external breather tube, make sure that the open end of the tube is free of grease, dirt, and other debris. Apply a high-quality rubber cement to the tube and insert it into the elbow at least a 1/2 inch (13 mm). See **Fig. 5**. Insert the tube into the service brake chamber.

10. With air pressure now exhausted from the service brake chamber, but held on the parking brake, reset the parking brakes by uncaging the power spring, and snap the end cover cap in place. For instructions, see **Subject 100**.



A. Apply adhesive here.
B. Check for 1/2 inch (13 mm) minimum engagement.

Fig. 5, Install the External Breather Tube

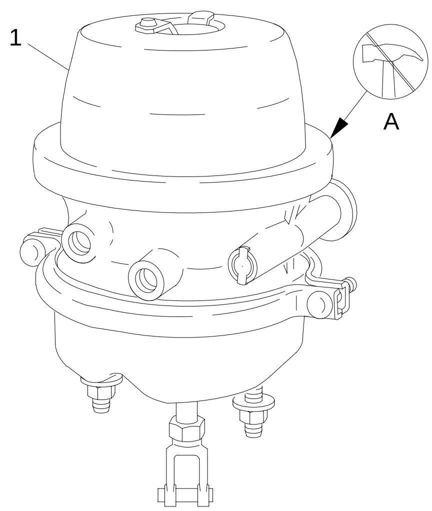
11. Adjust the brakes at the slack adjuster.

IMPORTANT: After replacing any brake chamber components, check the piston rod stroke and actuating alignment to ensure correct installation and foundation brake adjustment. No foundation brake adjustments, parking brake or service brake, can be made at the chamber and all "stroke" adjustments must be made at the slack adjuster. For instructions, see **Section 42.11** "Automatic Slack Adjusters, Meritor".

Replacement

DANGER

Do not attempt to remove the factory-sealed clamp ring for any purpose at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



A. Do not remove the factory-sealed clamp ring.
1. Model TR-T (TR Series) Brake Chamber

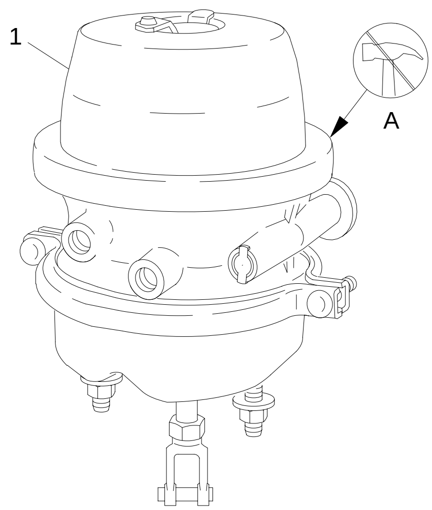
Fig. 1, Brake Chamber

IMPORTANT: The parking/emergency brake section can be replaced as a unit. For instructions, see **Subject 110**.

Combination Service and Parking Brake Chamber Removal and Installation

DANGER

Do not attempt to remove the factory-sealed parking brake clamp ring for any purpose at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



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A. Do not remove the factory-sealed clamp ring.
1. Model TR-T (TR Series) Brake Chamber

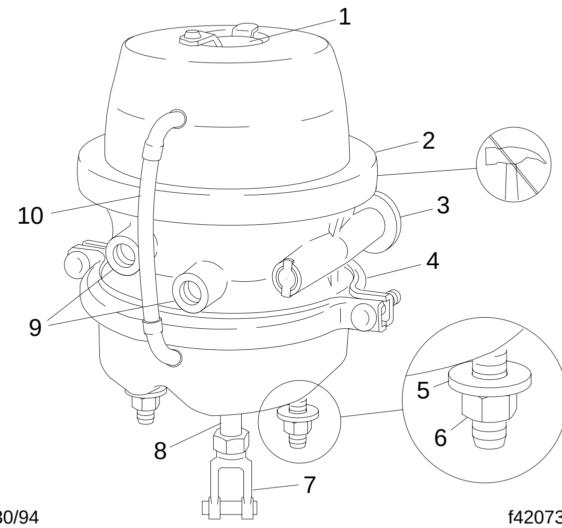
Fig. 1, Brake Chamber

Removal

WARNING

Before caging (compressing) the power spring, chock the vehicle tires and read the warnings and instructions in Subject 100. When the power spring is caged, the vehicle may be without brakes, allowing it to roll out of control, possibly resulting in personal injury or property damage.

1. Manually release the parking brake (cage the power spring). For instructions, see Subject 100.
2. Mark the air lines for later reference. Carefully disconnect the air lines from the brake chambers.



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Do not remove the factory-sealed clamp ring.

1. End Cover Cap
2. Factory Sealed Parking Brake Clamp Ring
3. Release Bolt Storage Pocket
4. Service Brake Clamp Ring
5. Hardened Flatwasher
6. Prevailing Torque Locknut
7. Clevis Assembly
8. Piston Rod
9. Air Inlet Ports
10. External Breather Tube

Fig. 2, Model TR-T (TR Series) Brake Chamber

3. Remove the brake chamber from the vehicle. See Fig. 2.

   3.1 Remove the cotter pin(s) from the clevis pin(s). Remove the clevis pin(s) from the clevis. Disconnect the clevis from the slack adjuster.

   NOTE: Meritor automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

   3.2 Make sure the parking brake has been released manually (the power spring has been caged). For instructions, see Subject 100. Also, make sure that the service brake piston is fully retracted (in the brakes "OFF" position). Record both of the following dimensions in either inches or mm, measuring outward from the base of the service brake chamber (Fig. 3):

Combination Service and Parking Brake Chamber Removal and Installation

- X dimension: to end of threaded piston rod
- Y dimension: to centerline of (large) clevis pin

IMPORTANT: If new chambers are to be attached to manual slack adjusters, the Y dimension is the most critical measurement. When installing the new assembly, its service piston rod must be cut to exactly duplicate this "rod-plus-clevis" length *after* the clevis assembly is installed on the piston rod. See **Fig. 4**.

If new chambers are to be attached to automatic slack adjusters, the X dimension is the most critical measurement. When installing the new assembly, its service piston rod must be cut to exactly duplicate the "rod only" length *before* the clevis assembly is installed on the piston rod. See **Fig. 4**.

3.3 From each mounting stud, remove any installed nuts and washers. Cautiously remove the brake chamber from the mounting bracket.

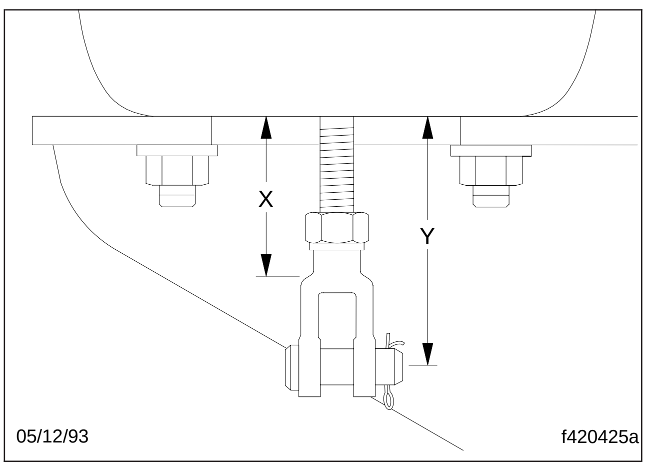


Fig. 3, Measure X and Y

Installation

1. If installing a new brake chamber unit (**Fig. 2**), perform the following steps:

   1.1 Make sure the power spring is caged (release bolt fully extended outward). If not, go to **Subject 100** and perform the applicable steps.

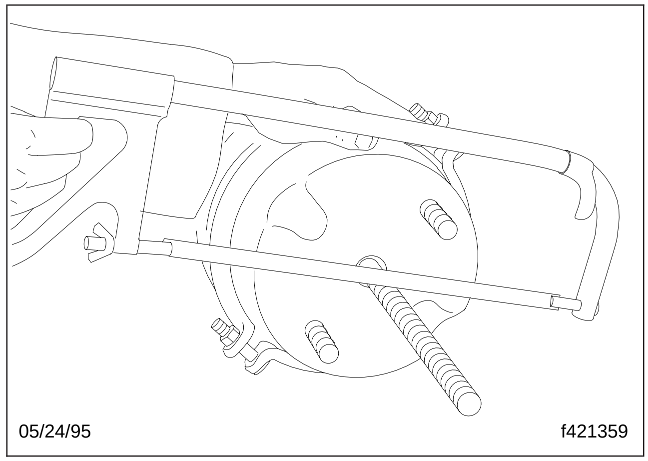


Fig. 4, Cut the Service Piston Rod

   1.2 Make sure that the piston rod is the same length as the rod on the old unit (measure the rods when *both* chambers are caged).

   1.3 Be sure the new chamber is the same size and make as the brake chamber installed on the other side of the axle.

   1.4 Remove the prevailing torque locknut and hardened flatwasher from each of the mounting studs on the chamber.

2. Clean the face of the mounting bracket, and install the chamber on the bracket, paying close attention to positioning the chamber air inlet ports for correct alignment to the vehicle air lines.

WARNING

Tighten the mounting nuts with a hand wrench, not an impact wrench. An impact wrench could damage the mounting fasteners, reducing the force of the brakes. This could result in personal injury or property damage.

3. Install one hardened flatwasher and prevailing torque locknut on each mounting stud. Using a hand wrench (*do not use an impact wrench*), tighten the nuts 100 to 115 lbf·ft (136 to 156 N·m). Make sure the flatwasher is installed between the locknut and the mounting bracket.

Combination Service and Parking Brake Chamber Removal and Installation

On chambers equipped with an external breather tube, make sure that the tube is installed in the side of the chamber that faces away from the road surface. An improperly installed breather tube voids the MGM warranty.

4. Check mating and alignment with the vehicle air lines.

   4.1 Using a hand wrench (*do not use an impact wrench*), loosen the clamp nuts on the *service* clamp ring (*do not disassemble the parking brake section*).

   4.2 Reposition the air inlet ports, as needed, to mate with vehicle air supply lines.

   Alternately tighten each clamp nut in increments of 60 to 120 lbf·in (680 to 1360 N·cm) while constantly rechecking the alignment of mating parts.

   If realignment is needed, loosen the nuts again and repeat this substep.

   4.3 Firmly tap around the circumference of the service clamp ring with a rubber mallet to ensure full seating of the clamp. Tighten the nuts to a final torque of 25 to 30 lbf·ft (34 to 41 N·m).

5. Install the slack adjuster. For instructions, see the appropriate slack adjuster section in this manual.

6. Inspect the piston rod to be sure it is working free, not binding, and is square with the chamber bottom within ±3 degrees in any direction from zero to full stroke. If there is misalignment, make corrections by loosening the locknuts and repositioning the chamber on the mounting bracket, or by shimming the slack adjuster to the right or left on the camshaft.

7. Make sure the air hose fittings are free of grease, dirt, and other debris. Apply Loctite® 242 sealant, or an equivalent, to the fittings, and install, as referenced earlier. Using a hand wrench (*do not use an impact wrench*), tighten the fittings 25 lbf·ft (34 N·m).

8. Using the vehicle system air, charge the parking brake with full line pressure, at least 100 psi (690 kPa). Using only soapy water (*never any type of oil,* which could deteriorate rubber parts), check for air leaks at the air lines and fittings. If bubbles or leaks appear, tighten the fittings slightly, but not over 25 lbf·ft (34 N·m).

IMPORTANT: If the service brake clamp ring was loosened to reposition the air inlet ports, apply air to the parking brake, and then apply and hold the foot brake treadle valve down to charge the service brake chamber. Now test for air leaks around the circumference of the *service* brake clamp ring. If bubbles or leaks appear, firmly tap the circumference of the clamp ring with a rubber mallet, and retighten the clamp nuts until leaks cease (*do not touch the parking brake section*). MGM recommends 25 to 30 lbf·ft (34 to 41 N·m) torque on the clamp hexnuts.

9. With air pressure now exhausted from the service brake chamber, but held on the parking brake, reset the parking brakes by uncaging the power spring and snap the end cover cap in place. For instructions, see **Subject 100**.

10. Adjust the brakes at the slack adjuster. For instructions, see the appropriate slack adjuster section in this manual.

IMPORTANT: After replacing any brake chamber, check the piston rod stroke and actuating alignment to ensure correct installation and foundation brake adjustment. No foundation brake adjustments, parking brake or service brake, can be made at the chamber and all "stroke" adjustments must be made at the slack adjuster. For instructions, see the appropriate slack adjuster section in this manual.

Specifications

Torque Values	
Description	Torque: lbf·ft (N·m)
Spring Brake Release Bolt Nut (in storage pocket)	10 (14)
Service Brake Clamp Ring Nut	25–30 (34–41)
Brake Chamber Mounting Stud Nut	100–115 (136–156)
Air Hose Fitting-to-Chamber	25 (34)

Table 1, Torque Values

General Information

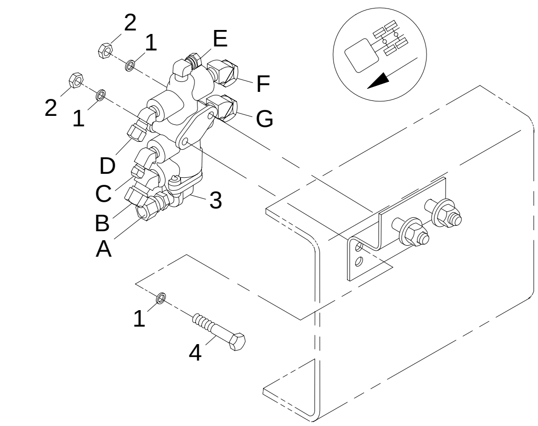
General Description

The Bendix TP–3DC is a tractor protection valve that includes an integral double check valve. The TP–3DC serves two purposes. First, as required by Federal law, the valve protects the tractor brakes in the event of trailer breakaway or a severe air system leak. Second, when used with a dash-mounted trailer supply control valve, the TP–3DC valve can be used to shut off the trailer control line before the trailer is disconnected.

The TP–3DC also includes an integral single check valve that prevents air from getting trapped in the trailer control line. Trapped air in this line could cause service/spring brake compounding and, if the trailer is parked with air applied, a trailer roll-away situation.

There are several different mounting locations for the TP–3DC tractor protection valve. A common mounting location is in the frame rail channel. See **Fig. 1**.

TP–3DC valve port designations and internal components are shown in **Fig. 2**.



A. From service brake foot valve, primary circuit
B. From service brake foot valve, secondary circuit
C. To air manifold (stop lamp switch)
D. From trailer supply valve
E. To proportioning relay (if installed)
F. To trailer emergency port
G. To trailer service port

1. 1/4" Flatwasher
2. 1/4–20 Locknut
3. TP–3DC Tractor Protection Valve
4. 1/4–20 Capscrew

Fig. 1, TP-3DC Mounting Location and Connections

Principles of Operation

Initial Charge

Pushing in the red trailer air supply knob on the instrument panel causes air to flow into the TP–3DC valve at the tractor supply port. See **Fig. 3**. Air flows through the valve housing, exiting via the auxiliary supply port (if used) and the trailer supply port, to pressurize the trailer brake system and release the trailer parking brakes.

As air pressure builds in the trailer supply circuit, the single check valve seats, and the valve plunger begins to move (against spring pressure) toward the guide. When pressure reaches about 45 psi (310 kPa), the inlet valve opens.

The TP–3DC valve is in the "run" mode, and ready to receive and deliver a service brake application from either the foot valve or the hand valve.

Service Brake Application

When the foot pedal is pressed, air flows to the TP–3DC valve tractor control primary and secondary ports. See **Fig. 4**. If the trailer control valve is also used, the external double check delivers the higher pressure (trailer control or foot valve secondary) to the TP–3DC Tractor Control secondary port.

Inside the TP–3DC valve, the higher pressure (primary or secondary) moves the diaphragm to seal off the port at the lower pressure.

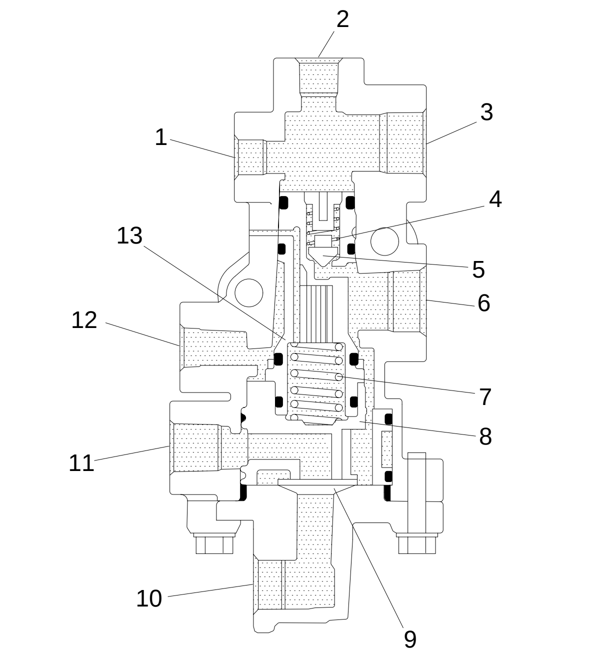
With the plunger bottomed against the guide and the inlet valve open (as described earlier), the higher pressure air flows through the valve to the trailer control port and the stop lamp switch, applying the trailer brakes and activating the tractor stop lamps.

NOTE: While air pressure also reaches the TP–3DC single check valve, the valve stays closed because supply pressure is acting on the other side.

Service Brake Release

When the foot pedal is released, air stops flowing into the TP–3DC valve at the tractor control primary or secondary port. At the same time, air in the trailer control line returns to the valve, flowing back through the open inlet valve. See **Fig. 5**.

General Information



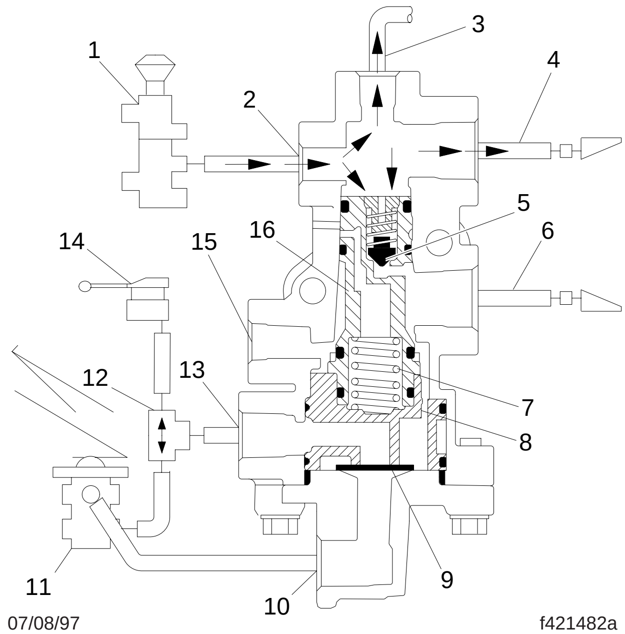
1. Tractor Supply Port
2. Auxiliary Supply Port
3. Trailer Supply Port
4. Check Valve Spring
5. Check Valve
6. Trailer Control Port
7. Valve Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Tractor Control Port(Secondary)
12. Stop Lamp Switch Port
13. Plunger

Fig. 2, TP-3DC, Sectional View

The air forces the diaphragm to seat, sealing off the tractor control primary port. The air then exits the valve at the tractor control (secondary) port and flows to the foot valve or hand valve where it is exhausted.

Tractor Protection

If the red trailer air supply knob on the instrument panel is pulled out (or if a large leak develops in the trailer supply circuit), pressure in the trailer supply circuit (and the auxiliary supply circuit, if used) is vented. See **Fig. 6**. When pressure drops to about 20 to 30 psi (138 to 207 kPa), the pressure can no longer overcome the spring force inside the TP–3DC valve and the inlet valve closes.



1. Trailer Air Supply Valve
2. Tractor Supply Port
3. Auxiliary Supply Port
4. Trailer Supply Port
5. Single Check Valve
6. Trailer Control Port
7. Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stop Lamp Switch Port
16. Plunger

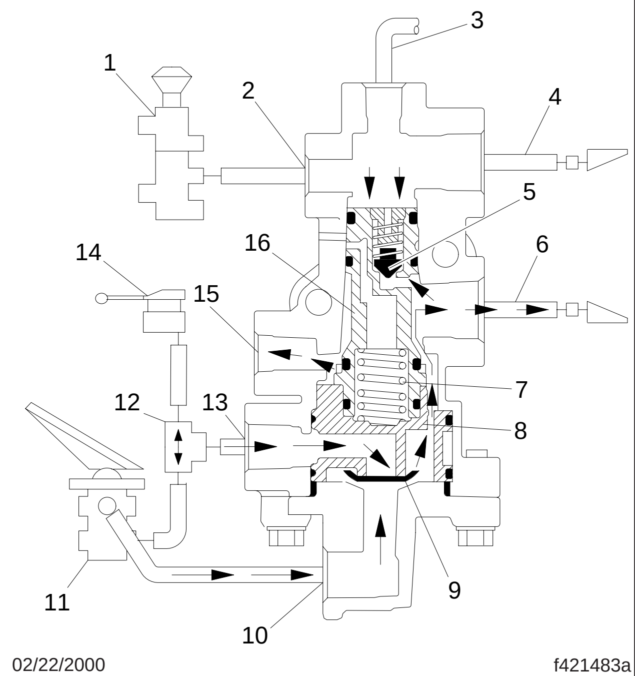
Fig. 3, Initial Charge

With the inlet valve closed, air pressure from the brake foot or hand control valves will not reach the trailer control circuit when the brakes are applied.

Anti-Compounding

If the red trailer air supply knob on the instrument panel is pulled out while the service brakes are applied, the single check valve in the TP–3DC prevents simultaneous spring and service brake application. As pressure in the trailer supply circuit drops, the spring in the TP–3DC valve forces the inlet valve closed (as described above in "Tractor Protection." Any pressure in the trailer control circuit is relieved by passing first through the single check valve and then exhausting at the trailer supply valve. See **Fig. 7**.

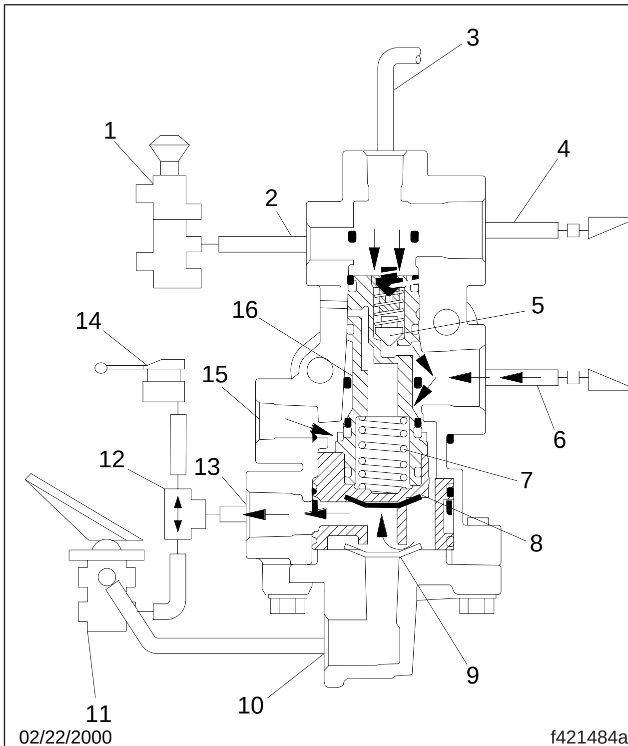
General Information



1. Trailer Air Supply Valve
2. Tractor Supply Port
3. Auxiliary Supply Port
4. Trailer Supply Port
5. Single Check Valve
6. Trailer Control Port
7. Valve Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stop Lamp Switch Port
16. Plunger

Fig. 4, Service Brake Application

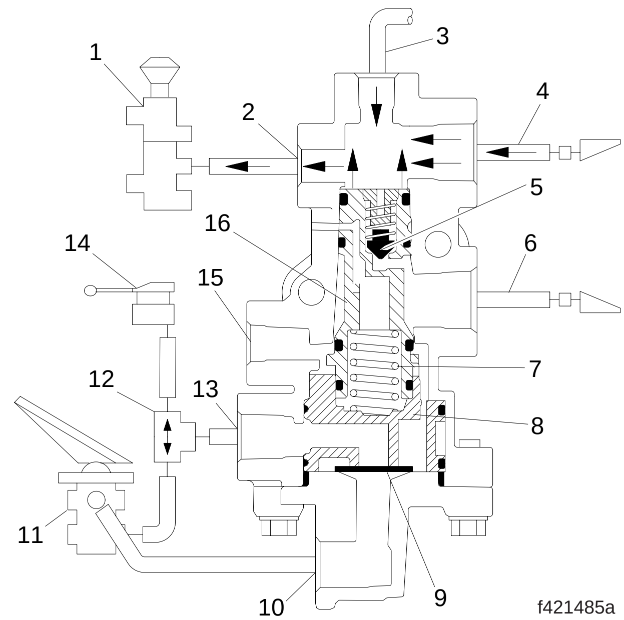
If the service brakes (hand or foot) are released and applied again, the closed inlet valve prevents air pressure from reaching the trailer control circuit.



1. Trailer Air Supply Valve
2. Tractor Supply Port
3. Auxiliary Supply Port
4. Trailer Supply Port
5. Single Check Valve
6. Trailer Control Port
7. Valve Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stop Lamp Switch Port
16. Plunger

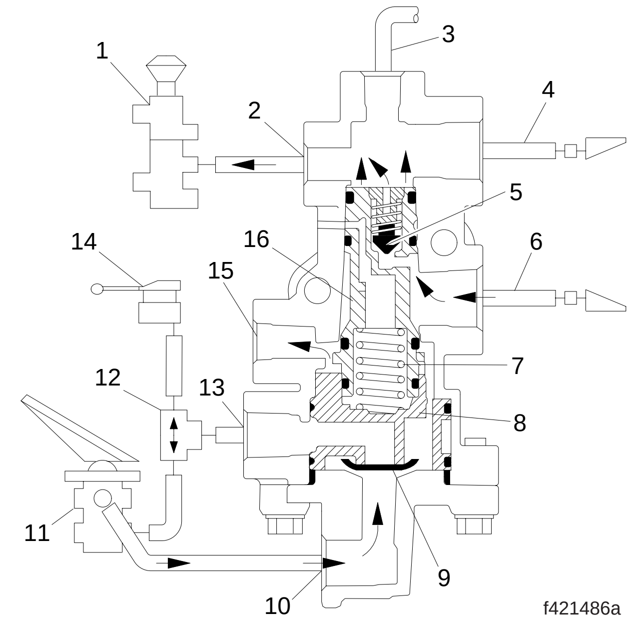
Fig. 5, Service Brake Release

General Information



1. Trailer Air Supply Valve
2. Tractor Supply Port
3. Auxiliary Supply Port
4. Trailer Supply Port
5. Single Check Valve
6. Trailer Control Port
7. Valve Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stop Lamp Switch Port
16. Plunger

Fig. 6, Tractor Protection



1. Trailer Air Supply Valve
2. Tractor Supply Port
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4. Trailer Supply Port
5. Single Check Valve
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7. Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stop Lamp Switch Port
16. Plunger

Fig. 7, Anti-Compounding

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

1. Chock the tires and shut down the engine before working under the vehicle. Releasing air from the system may cause the vehicle to roll. Keep hands away from brake chamber push rods and slack adjusters; they will apply as air pressure drops.
2. Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
3. Never exceed recommended air pressure and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
4. Never attempt to disassemble a component until you have read and understood recommended procedures. Some components contain powerful springs, and injury can result if not correctly disassembled. Use only correct tools and observe all precautions regarding use of those tools.

Leakage Test

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

1. Chock the tires, start the engine, and run it until the air system is fully charged.
2. Shut down the engine and place the trailer air supply valve in the emergency position (red knob pulled out).
3. Disconnect the trailer control line hose coupling. Then make a service application with either the foot valve or trailer control valve and check for leakage at the hose coupling with a soap and water solution. Leakage should not exceed a 1-inch (2.5-cm) bubble in 5 seconds.
4. Release the service brake application and place the trailer supply valve in the "run" position (red knob pushed in). Connect the trailer control coupling to a test gauge.
5. Make a service brake application and note that service air pressure is present at the trailer control line hose coupling.
6. With the ignition on, make and hold a service brake application and note that the stop lights function.
7. Disconnect the air line at the TP–3DC tractor control port (primary) and plug the line. Using a soap-and-water solution, make a service brake application and check for leakage at the open tractor control port. Leakage should not exceed a 1-inch (2.5-cm) bubble in 5 seconds.
8. Reconnect the air line to the tractor control port (primary) and disconnect the air line at the tractor control port (secondary). Then, plug the disconnected line. Make and service brake application and check for leakage at the open tractor control port using a soap-and-water solution. Leakage should not exceed a 1-inch (2.5-cm) bubble in 5 seconds.

IMPORTANT: If the valve does not function as described, or if leakage is excessive, repair or replace the valve.

9. Remove the chocks.

Removal

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

1. Chock the tires, and open the air reservoir drain cocks to bleed the air from the system.
2. Remove the trailer hose assemblies from the TP–3DC valve. Disconnect the tractor service and supply lines. Mark the lines for later assembly reference. Cap the air lines tightly to keep out contaminants.
3. Remove the fasteners attaching the TP–3DC valve to the vehicle, and remove the valve.

Installation

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

1. Place the TP–3DC valve on the vehicle, and attach it with bolts, washers, and nuts. Tighten the nuts 11 to 15 lbf·ft (15 to 20 N·m).

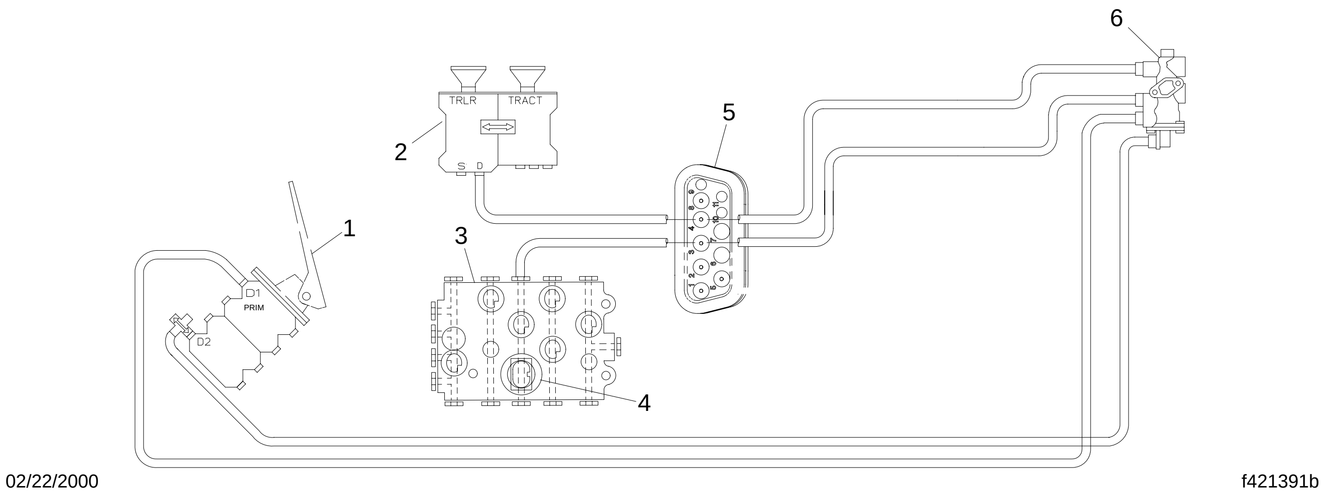
NOTE: The delivery line from the trailer air supply valve is connected to the tractor emergency port of the TP–3DC valve. See **Fig. 1**. The delivery line from the brake valve (double check valve) is connected to the tractor service port of the TP–3DC valve. Trailer hose assemblies are installed in the trailer emergency and trailer service ports of the TP–3DC valve.

2. Remove the caps from the air lines, and depending on the type of air hose, use the following instructions to connect the air hoses to the TP–3DC valve:

   If equipped with nylon tube air hoses, push the air lines into the quick-connect fittings on the valve.

   If equipped with wire braid hoses, connect the hose fittings to the valve ports, and hand-tighten the nuts. Using a wrench, tighten the nuts until there is resistance. Tighten one-sixth turn more. Do not overtighten.
3. Close the drain cocks to the air reservoirs. Start the vehicle engine to pressurize the air system.
4. Leak test the TP–3DC valve following the instructions in **Subject 110**.

Removal and Installation



1. Foot Valve
2. Dash Valves
3. Air Manifold and Pressure Switch
4. Stop Lamp Switch
5. Pass-Thru Grommet
6. TP–3DC Valve

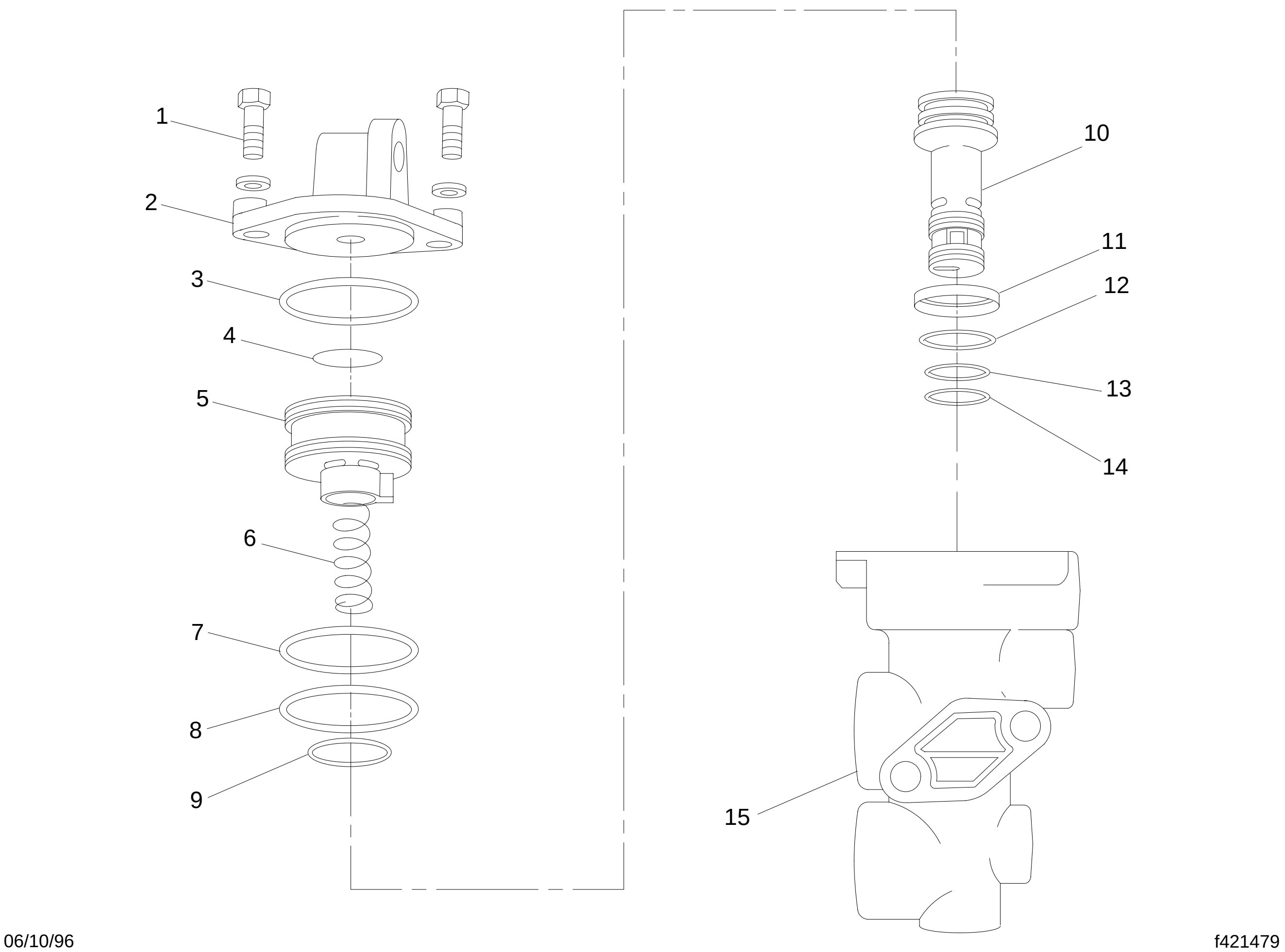
Fig. 1, TP-3DC Plumbing Diagram

Disassembly, Cleaning and Inspection, and Assembly

Disassembly

Refer to **Fig. 1** while performing the disassembly procedure.

1. Remove the valve from the vehicle, retaining the mounting hardware. For instructions, see **Subject 120**.



1. 1/4" Hex/Torx Screw
2. Valve Cover
3. O-Ring
4. Diaphragm
5. Guide
6. Valve Spring
7. O-Ring
8. O-Ring
9. O-Ring
10. Plunger
11. Collar
12. O-Ring
13. O-Ring
14. O-Ring
15. Valve Body

Fig. 1, TP-3DC Valve (exploded view)

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

2. Scribe a line across the valve cover and valve body to ensure proper alignment during assembly.

Disassembly, Cleaning and Inspection, and Assembly

3. Remove the two 1/4-inch screws which secure the valve cover to the valve body and allow the valve spring to expand until the valve cover can be removed.
4. Remove the cover O-ring and discard it.
5. Remove the diaphragm from the valve body and discard it.
6. Remove the guide from the valve body.
7. Remove the O-rings from the guide and discard them.
8. Remove the valve spring from the plunger, then the plunger from the valve body.
9. Remove the O-rings from the plunger and discard them.
10. Remove the collar and the O-ring from the plunger. Discard the O-ring, but keep the collar.

Cleaning and Inspection

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

WARNING

Wear goggles when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

1. Wash all metal parts of the TP–3DC valve in cleaning solvent, then dry them using compressed air.
2. Examine the cover, body, guide, and plunger for corrosion, excessive wear, cracks, or other damage. If any of these conditions are found on a part, replace the part with a new one.
3. Check the spring for distortion and corrosion. If the spring is distorted or corroded, replace it.
4. Check the valve body bores for deep scratches or gouging.

Assembly

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

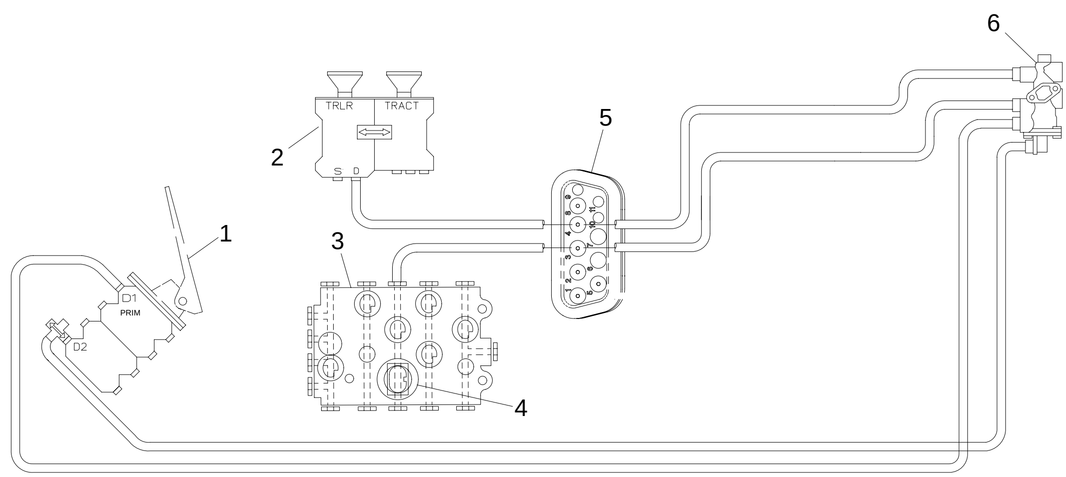
1. Lubricate the O-rings, O-ring grooves, body bores, and all sliding parts with the lubricant provided in the overhaul kit (Bendix silicone lubricant #291126 or equivalent).
2. Install the O-rings on the plunger.
3. Install the O-ring on the plunger and then the collar over the O-ring. Make sure that the collar is fully seated and firmly in place over the O-ring.
4. Install the plunger into the valve body and the spring into the plunger.
5. Install the O-rings in their grooves on the guide.
6. Align the indexing tab on the guide with the notch in the valve body and install the guide in the valve body.
7. Place the diaphragm in its recess on the guide.
8. Place the O-ring on the cover.
9. Place the cover on the guide and press them down, against spring pressure, until the cover is seated against the valve body.
10. Install the two 1/4-inch screws and tighten them 30 to 60 lbf·in (340 to 675 N·cm).
11. Install the TP–3DC valve on the vehicle following the instructions in **Subject 120**.

Specifications

See **Fig. 1** for a TP–3DC plumbing diagram.

Torque Values		
Description	**Torque lbf·in (N·cm)**	**Torque lbf·ft (N·m)**
Valve Cover Capscrews	30–60 (340–675)	—
Valve Mounting Capscrews	—	11–15 (15–20)

Table 1, Torque Values



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1. Foot Valve
2. Dash Valves
3. Air Manifold and Pressure Switch
4. Stop Lamp Switch
5. Pass-Thru Grommet
6. TP–3DC Valve

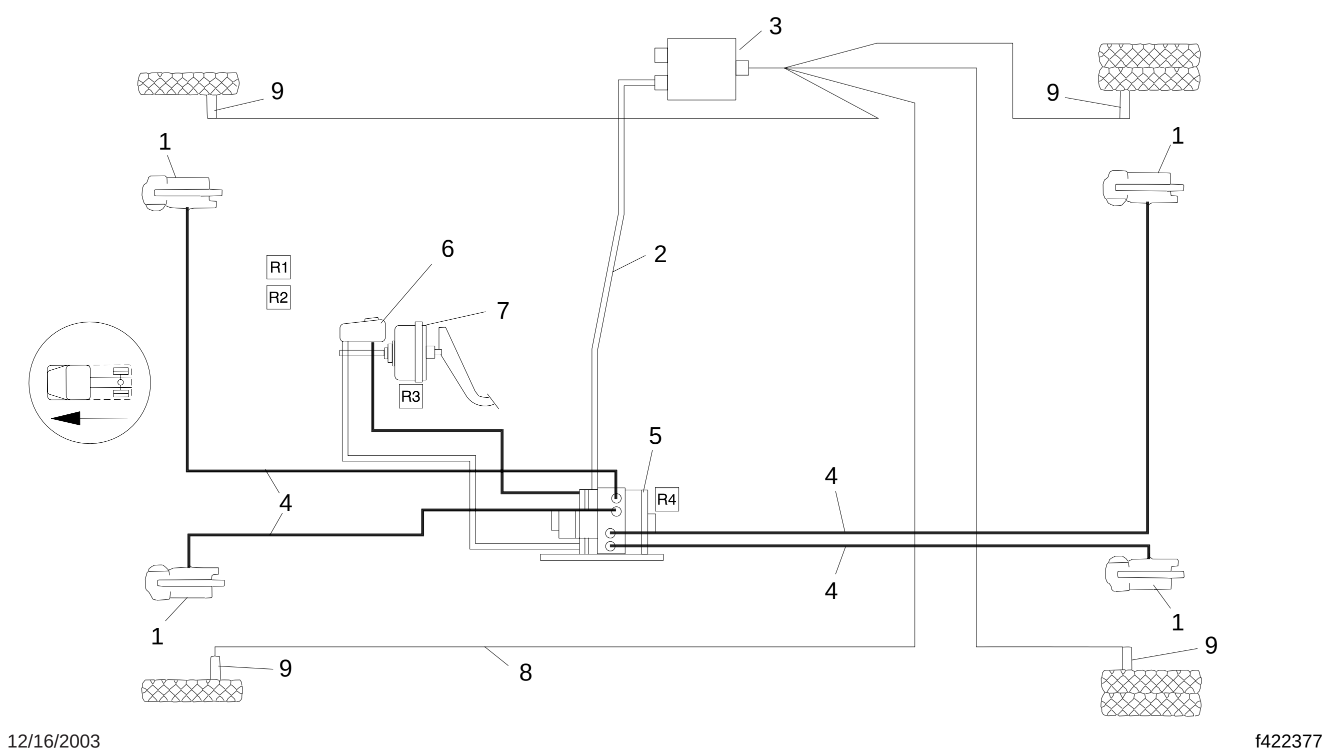
Fig. 1, TP-3DC Plumbing Diagram

General Information

The Meritor WABCO antilock braking system (ABS) is an electronic wheel speed monitoring and control system that works with the hydraulic brake system. See **Fig. 1**. ABS passively monitors vehicle wheel speed at all times and controls wheel speed during emergency stops. In normal braking applications, the hydraulic brake system is in effect.

wheel. The sensors transmit vehicle wheel speed information to an electronic control unit. During emergency braking, the control unit signals the ABS modulator assembly to reduce, maintain or increase hydraulic fluid pressure to the brake caliper. This prevents front and rear wheel lockup and enhances steering control during emergency braking situations.

The ABS electronic control unit is a digital microcomputer that serves as the information processing and



R1. Tractor ABS Lamp Relay (in dash)
R2. Stop Lamp Switch Relay (in dash)

1. Brake
2. ABS Warning Light
3. Electronic Control Unit (ECU)
4. Hydraulic Brake Line
5. ABS Modulator Assembly

R3. Back-Up Pump Relay (at hydraulic booster)
R4. ABS Modulator Pump Relay (on ABS modulator)

6. Master Cylinder
7. Hydraulic Booster
8. ABS Sensor Cable
9. Sensor Assembly

Fig. 1, Hydraulic ABS Components, Frame-Mounted ECU

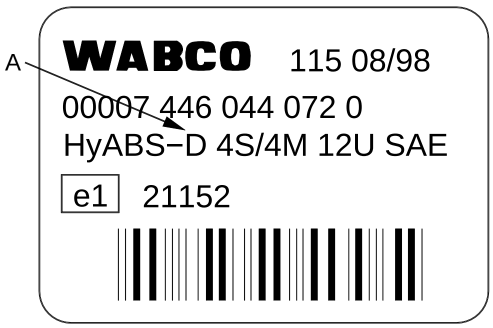
Business Class M2® vehicles use the "D" version of this system. The "D" version ECU has a "D" designation printed on the part number identification tag. See **Fig. 2**.

ABS includes signal-generating tone wheels and sensors located in the rotor assembly of each sensed

command center for the antilock braking system. See **Fig. 3**. The control unit receives and processes vehicle wheel speed information from the sensors. During emergency brake applications, the control unit regulates the braking force applied to each wheel by

General Information

sending control signals to the ABS modulator assembly. See **Fig. 4**.



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A. Version Designation

Fig. 2, ECU Identification Tag

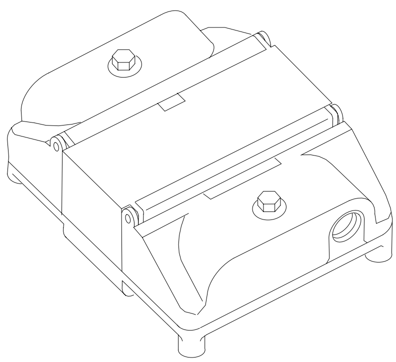

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Fig. 3, Frame-Mounted Electronic Control Unit, "D" Version

ABS Major Components

Wheel Speed Sensor

When the vehicle is moving, the teeth of the tone wheel cause changes in the magnetic field created by the sensor. The changes create an AC voltage signal that is generated by the sensor to the electronic control unit.

Electronic Control Unit

The electronic control unit (ECU) contains microcomputers to monitor the front and rear control channels. The ECU receives wheel speed signals and interprets these signals to calculate wheel speed and a vehicle reference speed. If the calculations indicate

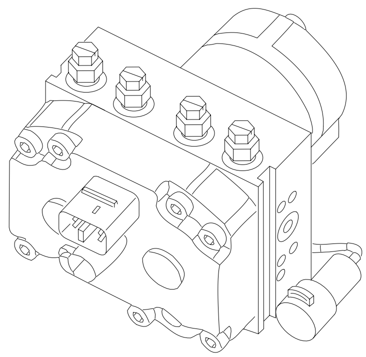

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Fig. 4, ABS Modulator Assembly, "D" Version

that a wheel is about to lock up, the ECU signals the ABS modulator assembly to adjust braking pressure. When this occurs, drivers may notice a pulsation of the brake pedal.

The ECU constantly monitors the wheel sensors, the ABS modulator assembly and the electrical circuitry.

IMPORTANT: After the ignition switch is turned on, the ABS warning light comes on for about 3 seconds. After about 3 seconds, the light goes out only if all of the ABS components are working correctly.

If, during vehicle operation, the ECU senses a failure in any part of the ABS system (a sensor, ABS modulator assembly, short circuit, etc.), the ABS warning light comes on and the circuit where the failure occurred is switched to normal braking action. Even if the ABS system is completely inoperative, normal braking is maintained. See Chapter 6 of the *Business Class M2® Driver's Manual* for complete operating instructions.

ABS Modulator Assembly

The ABS modulator assembly is attached to the left frame rail just aft of the back-of-cab crossmember. Depending on the signal received from the electronic control unit, the modulator prevents wheel lockup by adjusting the hydraulic fluid pressure. During normal braking applications, hydraulic fluid flows freely to the brake caliper housing through the modulator.

Within the modulator are an inlet and outlet control valve for each sensed wheel. If the electronic control unit signals indicate wheel lockup is close to occurring, fluid pressure to the brake caliper of the sensed wheel is reduced. The inlet valve of the sensed wheel closes, preventing fluid delivery to the brake caliper. At the same time, the outlet valve opens, allowing fluid to flow to an accumulator within the module. From the accumulator, a recirculation pump within the module delivers brake fluid back to the master cylinder.

As wheel speed increases, the ABS modulator assembly allows increases (inlet valve opens and outlet valve closes) or maintains brake pressure until the proper wheel speed is obtained or until wheel lockup occurs and the control cycle starts again.

If maintaining brake pressure, both valves are closed, preventing fluid delivery and maintaining fluid pressure.

Safety Precautions

WARNING

Breathing brake lining dust could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by NIOSH or MSHA. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

Because many brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Because medical experts believe that long-term exposure to some non-asbestos fibers could also be a health hazard, also observe the following precautions if servicing non-asbestos brake linings.

NOTE: The vehicle is originally equipped with non-asbestos brake linings.

Exposure to airborne brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

During brake servicing, wear an air purifying respirator with high-efficiency filters. The respirator and filter must be approved by NIOSH or MSHA, and worn during all procedures.

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency particulate air (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, or can’t be used, clean the brake assembly in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with an HEPA filter system, remove dust from the brake rotors, caliper assemblies, dust shields, and brake pads. After vacuuming, remove any remaining dust using a rag soaked in water and wrung until nearly dry.

WARNING

Hydraulic brake fluid is hazardous, and can cause blindness if it gets in your eyes. Always wear safety glasses when handling brake fluid or bleeding brake components. Brake fluid may also be a skin irritant. If you get it on your skin, wash it off as soon as possible.

Special care must be taken when disposing of used brake fluid. Put the fluid in a sealed plastic container and label it "Used Brake Fluid." Dispose of it in an approved manner. Check with local and state regulations as to the correct disposal procedure.

WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals.

Front Axle

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires to prevent vehicle movement.
2. Twist and pull the sensor to remove it from the sensor bracket. See **Fig. 1**.

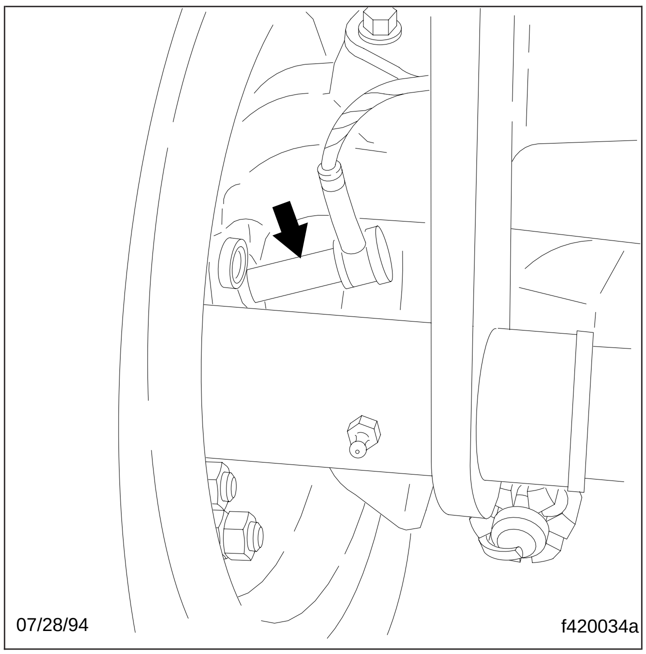


Fig. 1, Remove the Wheel Speed Sensor

3. Remove the sensor cable clip from the top cap.
4. Disconnect the sensor cable from the chassis harness.
5. Remove the sensor spring clip from the sensor bracket.
6. Connect the sensor cable to the chassis harness.
7. Attach the sensor cable to the steering knuckle top cap.
8. Coat the sensor spring clip and the sensor with Mobil HP, Valvoline EP 633, Penzoil 707L or an equivalent.
9. Press the sensor spring clip into the sensor bracket at the brake spider hole until it stops. Make sure the spring clip tabs are on the inboard side of the vehicle.
10. Press the sensor into the sensor spring clip until it is stopped by the tone wheel.
11. Remove the chocks from the rear tires.

Rear Axle

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the front tires to prevent vehicle movement.
2. Twist and pull the sensor to remove it from the mounting block in the axle housing.
3. Remove the sensor spring clip.
4. Remove the capscrew that attaches the sensor cable and the hose clamp to the axle tube.
5. Disconnect the sensor cable from the chassis harness.
6. Connect the new sensor cable to the chassis harness.
7. Attach the hose clamp and sensor cable to the axle tube located between the backing plate and the spring plate.
8. Press the sensor spring clip into the mounting block until it stops.
9. Coat the sensor with Mobil HP, Valvoline EP633, Penzoil 707L or an equivalent. Using your hand, push the sensor into the sensor spring clip until it is stopped by the tone wheel.
10. Remove the chocks from the front tires.

ABS Modulator Assembly Removal and Installation

WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

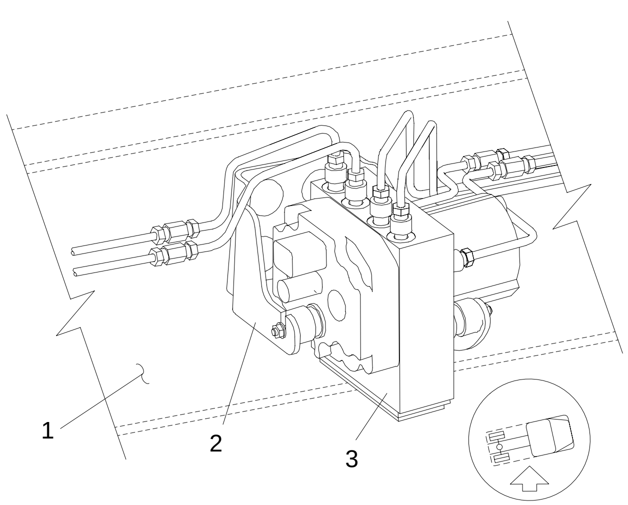
Removal

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. See **Group 54** for information on special terminals and connectors and on ordering tools for them.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the front and rear tires.

NOTE: The ABS modulator valve is located on the driver's-side frame rail directly behind the chassis module (CHM). See **Fig. 1**.

2. Put a container under the modulator to catch leaking brake fluid.



1. Driver's-side Frame Rail
2. Modulator Mounting Bracket
3. ABS Modulator Valve

Fig. 1, ABS Modulator Assembly Mounting, "D" Version

3. Disconnect the wiring from the modulator.

CAUTION

The modulator assembly contains hydraulic brake fluid, a caustic substance. Remove the brake lines and modulator carefully so that fluid does not leak and cause skin irritation or damage to components.

4. Mark the brake lines for ease of installation. Disconnect the lines.
5. Remove the mounting capscrews, washers and nuts that attach the modulator and bracket assembly to the bracket on the frame rail.
6. Remove the modulator and bracket assembly.

Installation

1. Install the modulator and bracket assembly. Install the mounting capscrews, washers and nuts that attach the modulator and bracket assembly to the bracket on the frame rail. Tighten the modulator and bracket assembly mounting nuts 132 lbf·in (1500 N·cm).
2. Connect the brake lines. Tighten the two small adapters (M10XI) 108 lbf·in (1200 N·cm). Tighten the four large adapters (M12XI) 132 lbf·in (1500 N·cm).
3. Connect the wiring to the modulator.
4. Bleed the brake system following the instructions in **Subject 130**.
5. Remove the chocks from the tires.

Hydraulic System Bleeding

WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Bleeding

WARNING

Failure to bleed the hydraulic brake system (including power steering system) whenever any hydraulic system fitting is loosened or disconnected will allow air to remain in the system. This will prevent the hydraulic pressure in the brake system from rising enough to apply the brakes properly. This will cause the stopping distance to increase and can result in serious personal injury.

Properly discard hydraulic brake fluid that is removed from the brake system. Hydraulic brake fluid that is removed can be contaminated and can cause damage, loss of braking and serious personal injury.

Automatic transmission fluid (ATF) and brake fluid are incompatible. Use only brake fluid for the master cylinder and brake lines. Use only ATF for the power booster. Never mix these two fluids or serious damage to both hydraulic systems will result. ATF will damage the rubber parts of the ABS modulator, master cylinder, and brake calipers and can cause damage, loss of braking and serious personal injury.

Always use new, clean brake fluid that meets DOT 3 specifications when bleeding the master cylinder and service brake system. Never reuse brake fluid, and don't use brake fluid containers for any other purpose. Keep brake fluid containers tightly closed to keep new brake fluid clean and dry.

IMPORTANT: Do not let brake fluid touch any painted surfaces, as it will remove the paint. Brake fluid may also damage certain non-metal surfaces. Do not let fluid get on brake pads or rotors.

Pressure Bleeding

Pressure bleeding is the preferred method for bleeding the service brake system. It requires the use of a special pressure bleeder kit, consisting of a tank, pressure pump and valve, gauge, tubing and adapter. These are available from a number of manufacturers and include instructions for use. See Fig. 1.

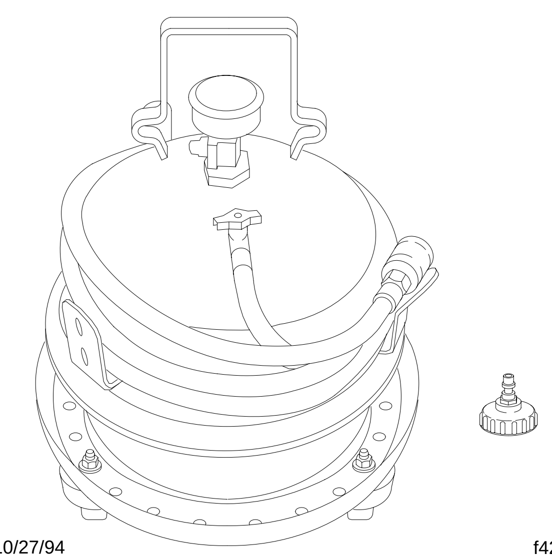


Fig. 1, Pressure Bleeder Kit

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Connect the pressure bleeder to the brake master cylinder reservoir following the manufacturer's instructions.

WARNING

Do not exceed 35 psi (241 kPa) at the master cylinder inlet. Exceeding this pressure could result in personal injury and/or vehicle damage.

3.1 Fill the pressure bleeder with new DOT 3 approved brake fluid. Pressurize it according to the manufacturer's instructions.

Hydraulic System Bleeding

3.2 Using the supplied adapter, connect the pressure bleeder to either fill port of the master cylinder reservoir.

4. Bleed the hydraulic connections at the rear wheel calipers, starting on the right side.

4.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

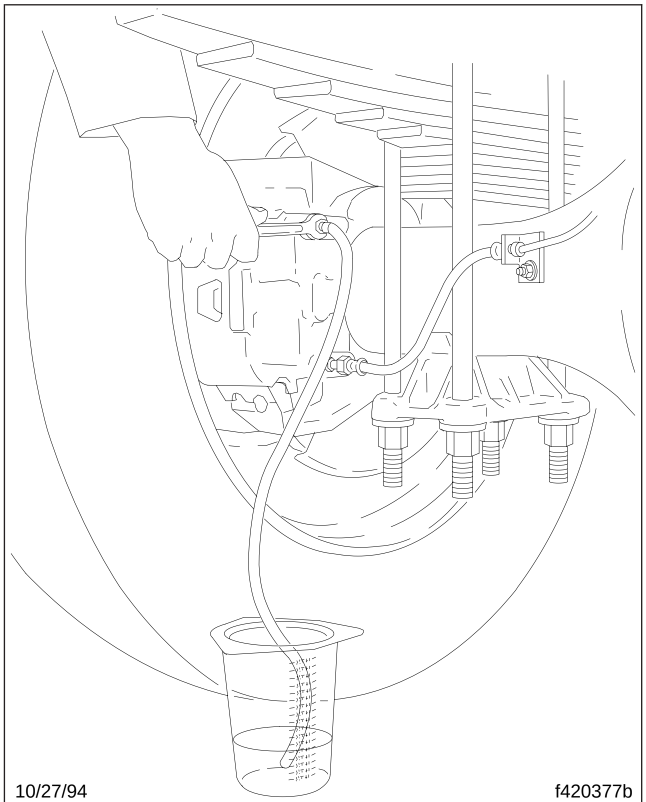


Fig. 2, Bleed the Connections at the Rear Wheel Calipers

4.2 Loosen the bleeder fitting by about a 3/4-turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.

4.3 Move to the left rear caliper and repeat steps for bleeding the caliper.

5. If needed, add brake fluid to the master cylinder reservoir.

WARNING

Do not exceed 35 psi (241 kPa) at the master cylinder inlet. Exceeding this pressure could result in personal injury and/or vehicle damage.

6. Bleed the front wheel brake calipers, starting at the right side.

6.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

6.2 Loosen the bleeder fitting by about a 3/4 turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.

6.3 Move to the left front wheel caliper and repeat steps for bleeding the caliper.

7. Check the brake fluid level in both compartments of the reservoir. Add new DOT 3 approved brake fluid if needed.

8. Check the operation of the brakes by depressing the brake pedal several times until if feels firm. The brake pedal should not go all the way down to the floor. If it does, see **Troubleshooting 300**.

9. Close and latch the hood.

10. Connect the batteries.

11. Remove the chocks from the rear tires.

12. Repeat step 8. Check for operation of the brakes.

Manual Bleeding

If you do not have pressure bleeding equipment, you can use the manual bleeding procedure.

IMPORTANT: Do not let the brake master cylinder fluid level get too low during manual bleeding operations. Keep the master cylinder reservoir filled with new, DOT 3 approved brake fluid. Failure to keep the brake reservoir filled could result in more air entering the system, making it impossible to effectively bleed the system.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.

2. Open the hood.
3. Disconnect the batteries. The ignition must remain off for the entire bleed procedure.
4. Bleed the master cylinder.

NOTE: In most cases, it will not be necessary to bleed the master cylinder unless the brake fluid reservoir is dry or after replacement of system components.

4.1 Using a wrench (and a rag to absorb leaking brake fluid), loosen the fitting at the rear outlet port on the master cylinder. See **Fig. 3**. Loosen the fitting about one turn.

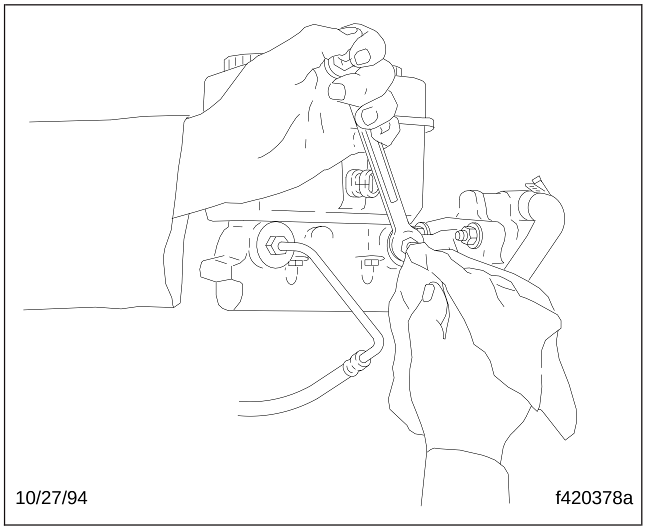


Fig. 3, Loosen the Fitting at the Rear Outlet Port

4.2 Have someone push the brake pedal down slowly by hand to the floor. Brake fluid and any air in the master cylinder will squirt from the fitting.

4.3 *With the brake pedal held down*, tighten the rear hydraulic line fitting firmly.

IMPORTANT: Do not release the brake pedal until the fitting is tightened or more air will get into the system.

4.4 Release the brake pedal.

4.5 Loosen the fitting again and repeat the steps for bleeding as required until no air escapes from the fitting and the brake pedal feels firm.

4.6 Check the fluid level in the master cylinder reservoir. Add new DOT 3 approved brake fluid if needed.

4.7 Using a wrench (and a rag to absorb leaking brake fluid), loosen the fitting at the front outlet port on the master cylinder. See **Fig. 4**. Loosen the fitting about one turn.

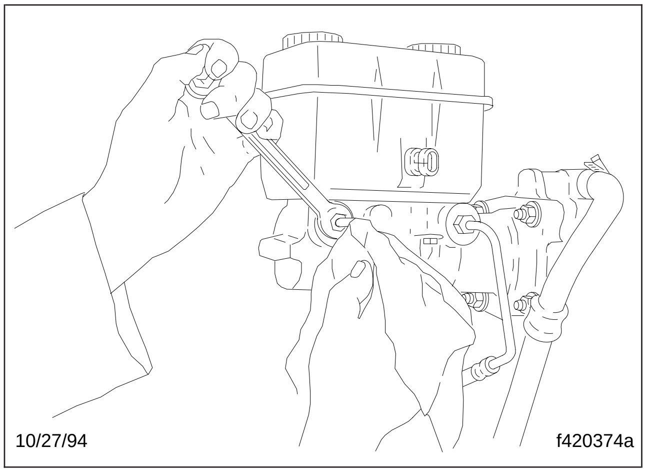


Fig. 4, Loosen the Fitting at the Front Outlet Port

4.8 Repeat steps as required for the front outlet port.

4.9 Check the brake fluid level in the master cylinder reservoir. Add new DOT 3 approved brake fluid if needed.

5. Bleed the hydraulic connections at the wheel calipers, starting at the right rear wheel caliper.

5.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

5.2 Loosen the bleeder fitting by about a three-quarter turn.

5.3 Have an assistant slowly push the brake pedal to the floor. *With the brake pedal depressed*, tighten the bleeder fitting.

IMPORTANT: Make sure the brake pedal stays depressed while you tighten the fitting. If it is released before you tighten the fitting, more air will get into the system.

Hydraulic System Bleeding

5.4 Release the brake pedal. Check the fluid in the tube. If there are air bubbles present, repeat steps as required until the fluid in the tube is completely free of air bubbles.

5.5 Check the brake fluid level in the reservoir. Add new DOT 3 approved brake fluid if needed.

5.6 Repeat the steps for bleeding the left rear caliper, the right front caliper and the left front caliper.

6. Close and latch the hood.
7. Connect the batteries.
8. Remove the chocks from the rear tires.
9. Check the operation of the brakes by depressing the brake pedal several times until if feels firm. The brake pedal should not go all the way down to the floor. If it does, see **Troubleshooting 300**.

WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Voltage Check

NOTE: Along with the following, the voltage can also be checked using the Meritor WABCO TOOLBOX Software.

IMPORTANT: Voltage must be between 9.5 and 14 volts for the 12-volt hydraulic ABS to function properly.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires to prevent vehicle movement.
2. Turn the ignition on.
3. Check the voltage between Pins 9 and 3, 9 and 2, and 9 and 11 on the black X2 ECU connector.
4. If voltage is not between 9.5 and 14 volts, verify proper wiring connections. Make corrections as required.
5. Remove the chocks from the rear tires.

ABS Indicator Light

IMPORTANT: If the ABS indicator light does not come on after the ignition is turned on, check all ABS fuses or circuit breakers and replace if necessary. Check the wiring to the ABS indicator light and repair or replace the wiring as required.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires to prevent vehicle movement.
2. Check the voltage potential at the light socket.
3. Check the continuity of the wires to the socket.
4. Replace the bulb.
5. Remove the chocks from the rear tires.

Sensor Voltage Output Test

IMPORTANT: Sensor output voltage must be at least 0.2 volts AC at 30 rpm.

WARNING

Block the wheels to prevent the vehicle from moving. Support the vehicle with safety stands. Do not work under a vehicle supported only by jacks. Jacks can slip and fall over. Serious personal injury can result.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the front and rear tires to prevent vehicle movement.
2. Turn the ignition off.
3. To measure voltage at the pins on the sensor connector, disconnect the sensor from the chassis harness.
4. Raise the vehicle off of the ground. Put safety stands under the axle.
5. Rotate the wheel by hand at 30 rpm (1/2 revolution per second).
6. Measure the voltage across the two pins at the sensor connector.
7. If the voltage is not greater than 0.2 volts AC, adjust the sensor and recheck. If the voltage is still not greater than 0.2 volts AC, replace the sensor.
8. Remove the safety stands and lower the vehicle.
9. Remove the chocks from the rear tires.

Sensor Resistance

IMPORTANT: The sensor resistance must be between 500 and 2000 ohms. Measure resistance at the sensor connector or at the pins on the ECU connector.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires to prevent vehicle movement.
2. Turn the ignition off.

Component Tests

3. Measure resistance at the sensor connector. Disconnect the sensor from the chassis harness.
4. Measure the resistance across the two pins at the sensor connector.
5. If the measurement is not between 500 and 2000 ohms, replace the sensor.
6. Remove the chocks from the rear tires.

Troubleshooting

Meritor WABCO TOOLBOX Software

The Meritor WABCO TOOLBOX Software can be used to diagnose hydraulic antilock brake system (ABS) faults. This software is packaged and launched from ServiceLink and provides J1587 fault codes and on-screen information to make the necessary repairs or replacements. TOOLBOX must be used to reset the ECU memory. See *Meritor WABCO Maintenance Manual No. 39, Rev. 1/00*.

ServiceLink

ServiceLink can be used to troubleshoot the Meritor WABCO hydraulic ABS. J1587 fault codes can be read by connecting the vehicle to the ServiceLink computer.

J1587 Fault Codes

The J1587 fault codes are a combination of the message identifier (MID), which indicates the ECU or system with the fault (136 for the hydraulic ABS ECU), and the system identifier (SID), which indicates the specific component within the system with the fault. The failure mode indicator (FMI) identifies a specific problem with the system component. See **Table 1** for a listing of J1587 fault codes. This table also lists the appropriate troubleshooting table to consult for fault code diagnosis.

ABS Warning Lamp Circuit

The ABS warning lamp circuit is controlled by wire alone. **It is NOT also controlled by the databus as with pneumatic ABS vehicles.** The ABS lamp circuit contains a relay located in the dash. The purpose of this relay is to turn on the ABS warning lamp in the instrument cluster should the ABS controller be disconnected from the vehicle harness.

When the ignition is turned on, the relay is energized. This causes the contact to open the circuit from ground to the instrument cluster (circuit 376L). If the ABS ECU becomes disconnected from the vehicles harness, the relay becomes de-energized (the ground provided by circuit 376L1 is now open), thus causing circuit 376L leading to the instrument cluster to be grounded through the relay. If a fault occurs in the ABS under normal operation, the ABS ECU will ground circuit 376L at pin 8 of the X2 connector, thus grounding the circuit leading to the instrument cluster and turning the ABS warning lamp on. See **Fig. 1** for ABS lamp relay wiring detail.

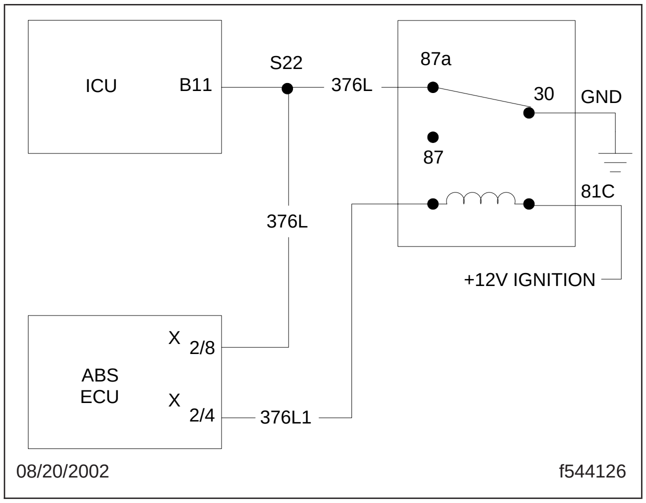


Fig. 1, ABS Lamp Relay Wiring

Refer to **Fig. 2** to identify a warning lamp condition, then **Fig. 3** to diagnose the condition.

Make the necessary repairs and clear the fault code from the ECU memory. If more than one fault exists, it will be displayed after the first one has been cleared from memory.

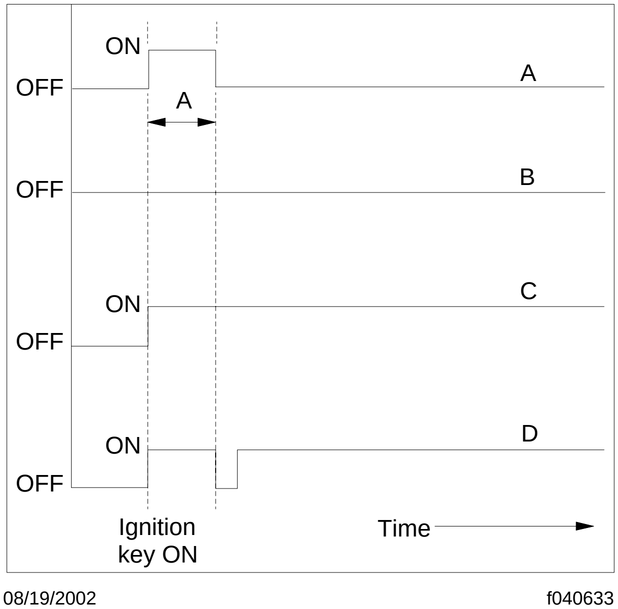
A volt ohmmeter (VOM) can determine the condition of the ABS valves, wheel end sensors and associated wiring. **Figure 4** displays pin locations at the ECU and **Fig. 5** displays pin locations at the ABS modulator valve. **Table 2** and **Table 3** display corresponding circuit to pin information.

IMPORTANT: The ignition switch must be off when connecting or disconnecting the ECU.

NOTE: The blink codes are erased from ECU memory as repairs are made. Once a repair has been made, cycle the ignition to ensure the blink code does not reappear. If there are any other outstanding faults, the next blink code will be displayed.

If the ABS light does not operate correctly after the ignition is turned on (the light does not come on at all or it does not go out after about 3 seconds), check all circuit breakers in the control unit panel and re-

Troubleshooting



A. Normal Condition
B. Bulb or Wiring Problem
C. Connector, Wiring or ECU (warning light circuit problem)
D. ABS Fault

Fig. 2, ABS Warning Lamp Conditions

place if necessary. Check the wiring to warning light and repair or replace the wiring as needed. When checking the warning light:

- Replace the bulb;
- Check for a fault in the warning lamp circuit, use ServiceLink or Meritor PC-based diagnostics;

The ABS system needs between 9.5 and 14 volts.

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. See **Group 54** for information on special terminals and connectors and ordering tools for them.

See the wiring diagrams in **Specifications 400** when troubleshooting the ABS system. If a fault cannot be repaired or erased from ECU memory, contact your District Service Manager or call Meritor WABCO at 1-800-535-5560.

Erasing a Fault from the ECU Memory

NOTE: An active fault cannot be erased until it has been corrected.

Meritor WABCO recommends that you erase all faults from the ECU memory after they have been noted and corrected.

Stored faults are erased from the ECU memory by clearing historic faults in ServiceLink or Meritor Toolbox.

Reset Memorized (Learned Components)

The ECU learns whether or not a retarder interrupt circuit is present. Once the ECU has detected a retarder circuit, it expects to see it every time the vehicle is powered up and will monitor the circuit for faults. If the ECU senses a resistance on the retarder circuit it will automatically learn that the retarder circuit exists. If an engine retarder circuit does not exist, but the ECU has detected one and is indicating faults, something may have been connected (a multimeter, etc.) to the retarder circuit during testing. Moisture, faulty circuit wiring, or moving an ECU from one vehicle to another can also cause the ECU to mistakenly detect a non-existent retarder circuit. If necessary, use the "Reset Memorized" command in the Meritor WABCO TOOLBOX Software to clear the ECU memory of this component. For instructions, see *Meritor WABCO Maintenance Manual No. 39, Rev. 1/00*.

Power Distribution Module

The main power distribution module (PDM) is mounted in the engine compartment on the left front quarter fender. See **Fig. 6** for the location of Fuse 16, ABS constant battery power. See **Group 54** for complete PDM information.

Bulk Head Module

The Bulkhead Module (BHM) is the primary module of the vehicle electrical system, and controls the operation of the other multiplex modules in the system and a variety of other vehicle components either directly or indirectly.

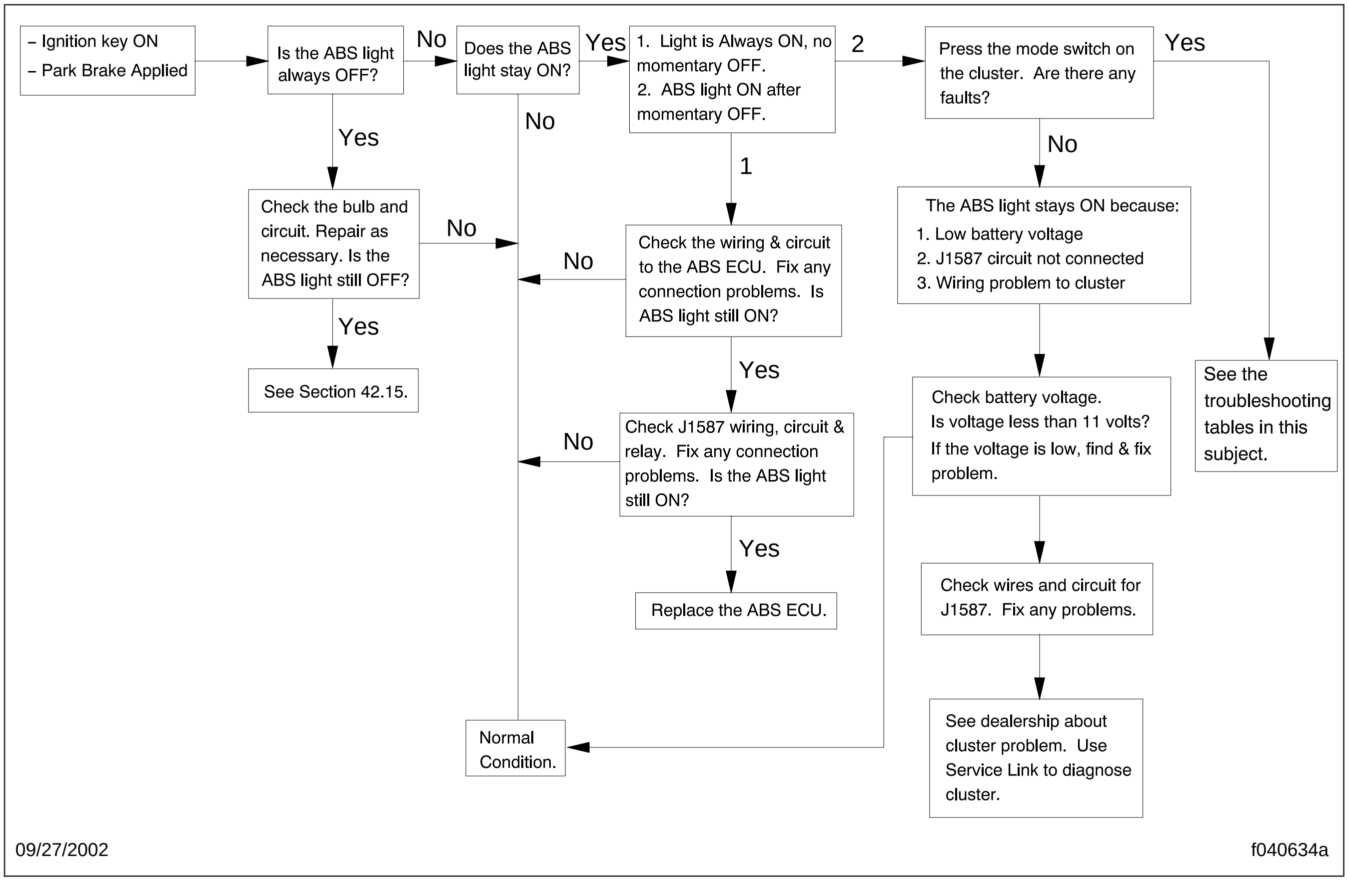
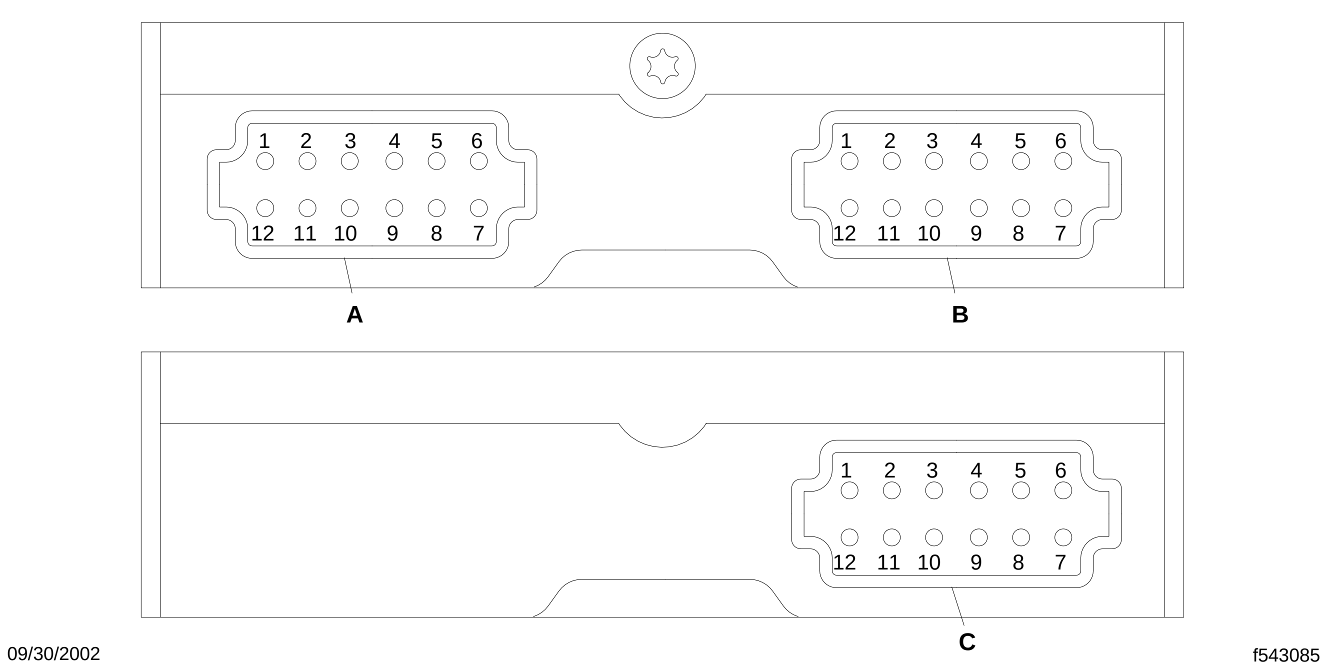


Fig. 3, Flow Chart: ABS Warning Lamp Troubleshooting

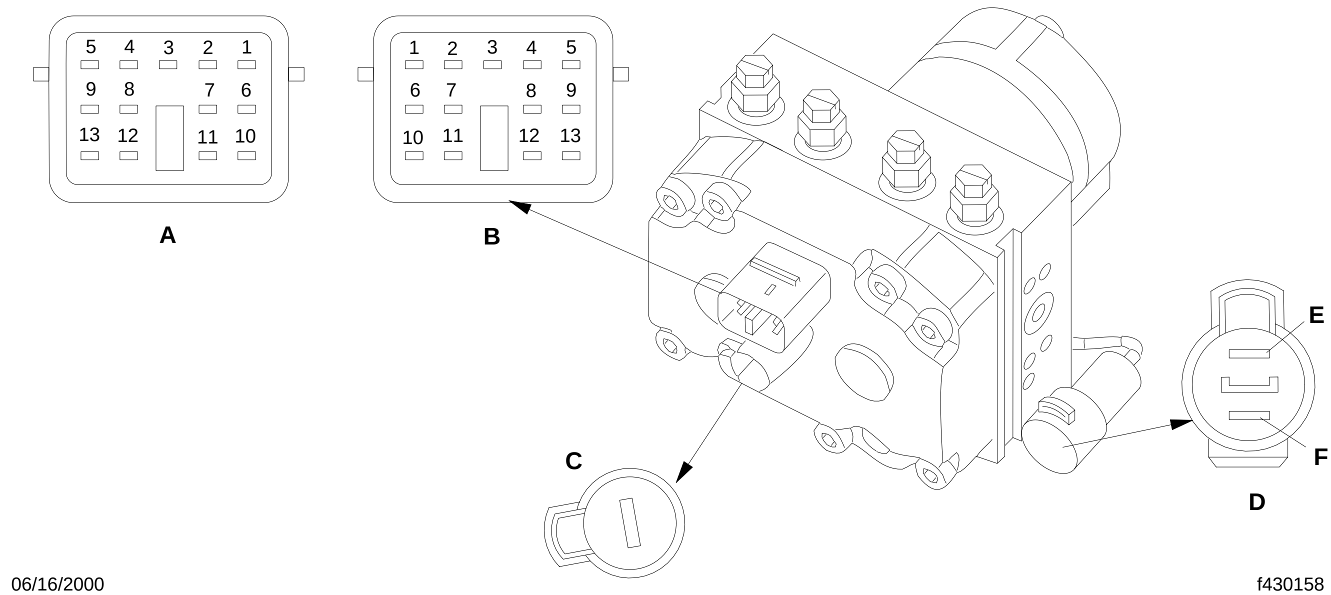
ABS ignition power is located at pin B1/P on the BHM (**Fig. 7**). For more information about the BHM, see **Section 54.12**.

Troubleshooting



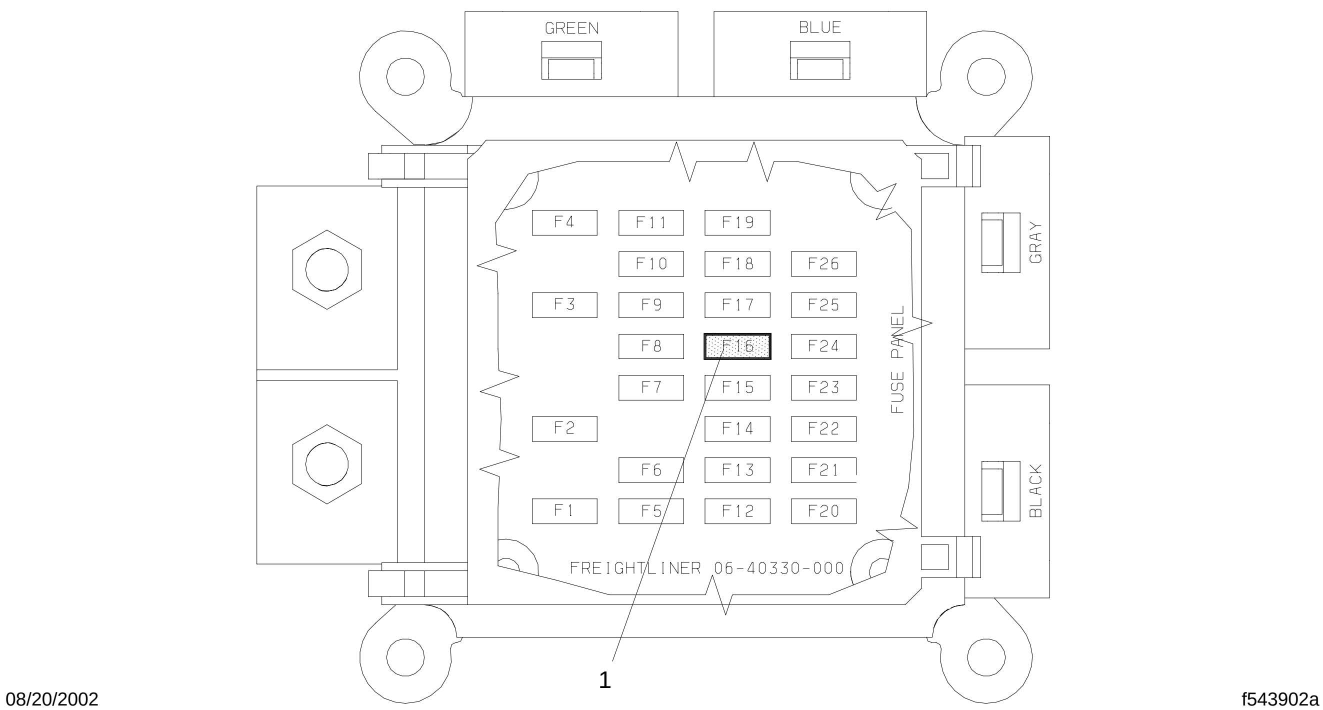
A. 12-Pin Black X2 Connector
B. 12-Pin Gray X1 Connector
C. 12-Pin Green X3 Connector

Fig. 4, ECU Connectors, D Version



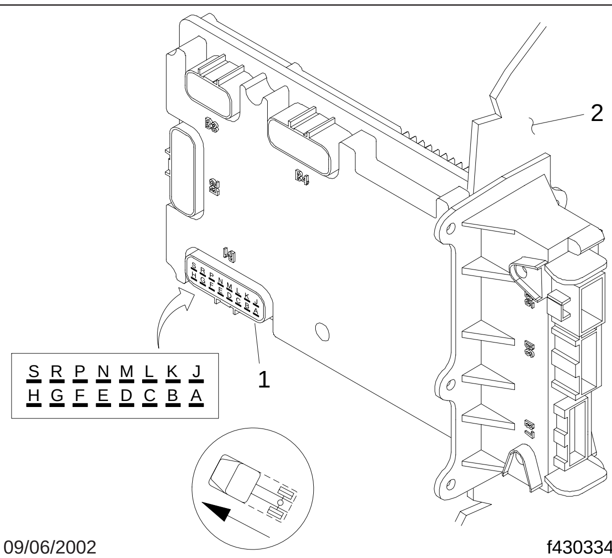
A. Harness Connector Pinout
B. Modulator Assembly Connector Pinout
C. Main Ground
D. Pump Connector
E. Pin 2, Pump Power
F. Pin 1, Pump Ground

Fig. 5, ABS Modulator Assembly Pin Connectors, D Version



1. Fuse 16, ABS Constant Battery Power

Fig. 6, Cab Power Distribution Module



1. B1 Connector
2. Frontwall

Fig. 7, Bulkhead Module (BHM)

Fault Codes		
J1587 Fault Code (MID-SID)	**Description**	**Troubleshooting Table**
136-001	Left Front Wheel Sensor *	Table 4
136-002	Right Front Wheel Sensor	Table 5
136-003	Left Rear Wheel Sensor	Table 6
136-004	Right Rear Wheel Sensor	Table 7
136-013	Retarder	Table 8
136-014	Power	Table 9
136-023	ABS Warning Light	Table 10
136-030	Recirculation Pump Relay	Table 11
136-042	Left Front Inlet Solenoid Valve	Table 12
136-043	Right Front Inlet Solenoid Valve	Table 13
136-044	Left Rear Inlet Solenoid Valve	Table 14
136-045	Right Rear Inlet Solenoid Valve	Table 15
136-048	Left Front Outlet Solenoid Valve	Table 16
136-049	Right Front Outlet Solenoid Valve	Table 17
136-050	Left Rear Outlet Solenoid Valve	Table 18
136-051	Right Rear Outlet Solenoid Valve	Table 19
136-054	Recirculation Pump	Table 20
136-055	ECU	Table 21
136-251	Low Voltage	Table 22
136-253	Internal Tire Parameter	Table 23
136-254	ECU Internal Fault	Table 24

* Blink codes 5-1, 5-3 and 5-4 indicate a fault with the right front, right rear and left rear wheel sensors respectively.

Table 1, Fault Codes

Troubleshooting

Circuit Wire Numbers and Descriptions, "D" Version			
Pin Connector	**Pin Number**	**Vehicle Wire Number**	**WABCO Circuit Description**
12-Pin Gray X1	1	—	Not Used
	2	GND	Ground
	3	378LFI	Left Front Inlet Valve
	4	378RFI	Right Front Inlet Valve
	5	378LRI	Left Rear Inlet Valve
	6	378RRI	Right Rear Inlet Valve
	7	378RRO	Right Rear Outlet Valve
	8	376LRO	Left Rear Outlet Valve
	9	378RFO	Right Front Outlet Valve
	10	378LFO	Left Front Outlet Valve
	11	—	Not Used
	12	—	Not Used
12-Pin Black X2	1	J1587–	SAE J1587 (–)
	2	376C	ECU Ignition Supply
	3	376A	ECU Supply/Battery
	4	376L1	Warning Light Relay
	5	—	Not Used
	6	376H	Pump Relay
	7	376R	Retarder Relay
	8	376L	ABS Indicator Light
	9	GND	Ground
	10	376B	Motor Monitor
	11	376A	ECU Supply/Battery
	12	J1587+	SAE J1587 (+)

Circuit Wire Numbers and Descriptions, "D" Version			
Pin Connector	Pin Number	Vehicle Wire Number	WABCO Circuit Description
12-Pin Green X3	1	—	Not Used
	2	—	Not Used
	3	377LR+	Left Rear Sensor
	4	377RF–	Right Front Sensor
	5	377LF+	Left Front Sensor
	6	377RR+	Right Rear Sensor
	7	377RR–	Right Rear Sensor
	8	377LF–	Left Front Sensor
	9	377RF+	Right Front Sensor
	10	377LR–	Left Rear Sensor
	11	—	Not Used
	12	—	Not Used

Table 2, Circuit Wire Numbers and Descriptions, "D" Version

ABS Modulator Assembly Pin Connectors		
Vehicle Wire Number	Pin Number	Circuit Description
1	376LRO	Left Rear Outlet Valve
2	378LRI	Left Rear Inlet Valve
3	—	Not Used
4	378RFI	Right Front Inlet Valve
5	378RFO	Right Front Outlet Valve
6	—	Not Used
7	—	Not Used
8	GNDE	Ground
9	—	Not Used

ABS Modulator Assembly Pin Connectors		
Vehicle Wire Number	Pin Number	Circuit Description
10	378RRO	Right Rear Outlet Valve
11	378RRI	Right Rear Inlet Valve
12	378LFI	Left Front Inlet Valve
13	378LFO	Left Front Outlet Valve
1	GND	Pump Ground
2	376A	Pump Power

Table 3, ABS Modulator Assembly Pin Connectors

Troubleshooting Tables

J1587 Fault 136-001 Left Front Wheel Sensor						
MID	SID	FMI	Problem	Test	Test Result	Action
136	001	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across Pins 5 and 8 of the green X3 ECU connector (Circuits 377LF+ and 377 LF–) while rotating the left front wheel 30 rpm.	Voltage greater than 0.2 VAC	Sensor adjustment solved the problem. Clear the stored faults and drive the vehicle 4 mph (6 km/h).
					Voltage less than 0.2 VAC	Check for excessive wheel bearing end play. Repair as necessary.

Troubleshooting

J1587 Fault 136-001 Left Front Wheel Sensor						
MID	SID	FMI	Problem	Test	Test Result	Action
136	001	02	Intermittent open circuit or incorrect sensor resistance NOTE: This SAE J1587 fault code can also be caused by incorrect or mixed tire size. Also see test 4.	2. Measure the resistance across Pins 5 and 8 of the green X3 ECU connector (Circuits 377LF– and 377 LF+).	Resistance reading between 500 and 2000 ohms	Check for intermittent, loose or poor connections in Circuits 377LF+ and 377LF– and repair as necessary. If the problem persists, suspect the ECU is at fault.
					Resistance reading below 500 or above 2000 ohms	Go to Test 3.
				3. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).	Resistance reading between 500 and 2000 ohms	Check the wiring between the ECU and the wheel sensor (Circuits 377LF+ and 377LF–). Repair as necessary. Go to Test 4.
					Resistance reading below 500 or above 2000 ohms	Replace the wheel sensor.
136	001	02	Incorrect or mixed tire size NOTE: This SAE J1587 fault code can also be caused by an intermittent open circuit or incorrect sensor resistance. Also, see tests 2 and 3.	4. Check for tire size deviation in excess of 16 percent. Mixed tire sizes can cause this fault.	Correct tire size and size variation does not exceed 16 percent	Perform Test 2 and Test 3 if not already done. If the problem is not found, verify the fault and check the ECU.
					Incorrect tire size or size variation exceeds 16 percent	Install the correct size tires.

J1587 Fault 136-001 Left Front Wheel Sensor						
MID	SID	FMI	Problem	Test	Test Result	Action
136	001	05	Open circuit	5. Measure the resistance across Pins 5 and 8 of the green X3 ECU connector (Circuits 377LF– and 377LF+).	Resistance reading between 500 and 2000 ohms	Check for intermittent, loose or poor connections in Circuits 377LF+ and 377LF– and repair as necessary. If the problem persists, suspect the ECU is at fault.
					Resistance reading below 500 or above 2000 ohms	Go to Test 6.
				6. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).	Resistance reading between 500 and 2000 ohms	Check the wiring between the ECU and the wheel sensor (Circuits 377LF+ and 377LF–). Repair as necessary.
					Resistance reading below 500 or above 2000 ohms	Replace the wheel sensor.

Table 4, J1587 Fault 136-001 Left Front Wheel Sensor

J1587 Fault 136-002 Right Front Wheel Sensor						
MID	SID	FMI	Problem	Test	Test Result	Action
136	002	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across Pins 4 and 9 of the green X3 ECU connector (Circuits 377RF+ and 377RF–) while rotating the right front wheel 30 rpm.	Voltage greater than 0.2 VAC	Sensor adjustment solved the problem. Clear the stored faults and drive the vehicle 4 mph (6 km/h).
					Voltage less than 0.2 VAC	Check for excessive wheel bearing end play. Repair as necessary.

Troubleshooting

J1587 Fault 136-002 Right Front Wheel Sensor						
MID	SID	FMI	Problem	Test	Test Result	Action
136	002	02	Intermittent open circuit or incorrect sensor resistance	2. Measure the resistance across Pins 4 and 9 of the green X3 ECU connector (Circuits 377RF– and 377RF+).	Resistance reading between 500 and 2000 ohms	Check for intermittent, loose or poor connections in Circuits 377RF+ and 377RF– and repair as necessary. If the problem persists, suspect the ECU is at fault.
					Resistance reading below 500 or above 2000 ohms	Go to Test 3.
				3. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).	Resistance reading between 500 and 2000 ohms	Check the wiring between the ECU and the wheel sensor (Circuits 377RF+ and 377RF–). Repair as necessary.
					Resistance reading below 500 or above 2000 ohms	Replace the wheel sensor.
136	002	05	Open circuit	4. Measure the resistance across Pins 4 and 9 of the green X3 ECU connector (Circuits 377RF– and 377RF+).	Resistance reading between 500 and 2000 ohms	Check for intermittent, loose or poor connections in Circuits 377RF+ and 377RF– and repair as necessary. If the problem persists, suspect the ECU is at fault.
					Resistance reading below 500 or above 2000 ohms	Go to Test 5.
				5. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).	Resistance reading between 500 and 2000 ohms	Check the wiring between the ECU and the wheel sensor (Circuits 377RF+ and 377RF–). Repair as necessary.
					Resistance reading below 500 or above 2000 ohms	Replace the wheel sensor.

Table 5, J1587 Fault 136-002 Right Front Wheel Sensor

J1587 Fault 136-003 Left Rear Wheel Sensor						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	003	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across Pins 3 and 10 of the green X3 ECU connector (Circuits 377LR+ and 377LR–) while rotating the left rear wheel 30 rpm.	Voltage greater than 0.2 VAC	Sensor adjustment solved the problem. Clear the stored faults and drive the vehicle 4 mph (6 km/h).
					Voltage less than 0.2 VAC	Check for excessive wheel bearing end play. Repair as necessary.
136	003	02	Intermittent open circuit or incorrect sensor resistance	2. Measure the resistance across Pins 3 and 10 of the green X3 ECU connector (Circuits 377LR– and 377LR+).	Resistance reading between 500 and 2000 ohms	Check for intermittent, loose or poor connections in Circuits 377LR+ and 377LR– and repair as necessary. If the problem persists, suspect the ECU is at fault.
					Resistance reading below 500 or above 2000 ohms	Go to Test 3.
				3. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).	Resistance reading between 500 and 2000 ohms	Check the wiring between the ECU and the wheel sensor (Circuits 377LR+ and 377LR–). Repair as necessary.
					Resistance reading below 500 or above 2000 ohms	Replace the wheel sensor.
136	003	05	Open circuit	4. Measure the resistance across Pins 3 and 10 of the green X3 ECU connector (Circuits 377LR– and 377LR+).	Resistance reading between 500 and 2000 ohms	Check for intermittent, loose or poor connections in Circuits 377LR+ and 377LR– and repair as necessary. If the problem persists, suspect the ECU is at fault.
					Resistance reading below 500 or above 2000 ohms	Go to Test 5.
				5. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).	Resistance reading between 500 and 2000 ohms	Check the wiring between the ECU and the wheel sensor (Circuits 377LR+ and 377LR–). Repair as necessary.
					Resistance reading below 500 or above 2000 ohms	Replace the wheel sensor.

Table 6, J1587 Fault 136-003 Left Rear Wheel Sensor

Troubleshooting

<table>
<tr><th colspan="7">J1587 Fault 136-004 Right Rear Wheel Sensor</th></tr>
<tr><th>MID</th><th>SID</th><th>FMI</th><th>Problem</th><th>Test</th><th>Test Result</th><th>Action</th></tr>
<tr><td rowspan="2">136</td><td rowspan="2">004</td><td rowspan="2">01</td><td rowspan="2">Incorrect sensor air gap</td><td rowspan="2">1. Adjust the sensor. Check the AC voltage across Pins 6 and 7 of the green X3 ECU connector (Circuits 377RR+ and 377RR–) while rotating the right rear wheel 30 rpm.</td><td>Voltage greater than 0.2 VAC</td><td>Sensor adjustment solved the problem. Clear the stored faults and drive the vehicle 4 mph (6 km/h).</td></tr>
<tr><td>Voltage less than 0.2 VAC</td><td>Check for excessive wheel bearing end play. Repair as necessary.</td></tr>
<tr><td rowspan="4">136</td><td rowspan="4">004</td><td rowspan="4">02</td><td rowspan="4">Intermittent open circuit or incorrect sensor resistance</td><td rowspan="2">2. Measure the resistance across Pins 6 and 7 of the green X3 ECU connector (Circuits 377RR– and 377RR+).</td><td>Resistance reading between 500 and 2000 ohms</td><td>Check for intermittent, loose or poor connections in Circuits 377RR+ and 377RR– and repair as necessary. If the problem persists, suspect the ECU is at fault.</td></tr>
<tr><td>Resistance reading below 500 or above 2000 ohms</td><td>Go to Test 3.</td></tr>
<tr><td rowspan="2">3. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).</td><td>Resistance reading between 500 and 2000 ohms</td><td>Check the wiring between the ECU and the wheel sensor (Circuits 377RR+ and 377RR–). Repair as necessary.</td></tr>
<tr><td>Resistance reading below 500 or above 2000 ohms</td><td>Replace the wheel sensor.</td></tr>
<tr><td rowspan="4">136</td><td rowspan="4">004</td><td rowspan="4">05</td><td rowspan="4">Open circuit</td><td rowspan="2">4. Measure the resistance across Pins 6 and 7 of the green X3 ECU connector (Circuits 377RR– and 377RR+).</td><td>Resistance reading between 500 and 2000 ohms</td><td>Check for intermittent, loose or poor connections in Circuits 377RR+ and 377RR– and repair as necessary. If the problem persists, suspect the ECU is at fault.</td></tr>
<tr><td>Resistance reading below 500 or above 2000 ohms</td><td>Go to Test 5.</td></tr>
<tr><td rowspan="2">5. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).</td><td>Resistance reading between 500 and 2000 ohms</td><td>Check the wiring between the ECU and the wheel sensor (Circuits 377RR+ and 377RR–). Repair as necessary.</td></tr>
<tr><td>Resistance reading below 500 or above 2000 ohms</td><td>Replace the wheel sensor.</td></tr>
</table>

Table 7, J1587 Fault 136-004 Right Rear Wheel Sensor

J1587 Fault 136-013 Retarder						
MID	SID	FMI	Problem	Test	Test Result	Action
136	013	03	Short to power	1. Disconnect the black X2 connector at the ECU. Disconnect the retarder relay. With the ignition ON, measure the voltage between Pin 7 of the black X2 ECU connector and a good chassis ground.	Voltage zero	Check for an intermittent short to power in Circuit 376R. If okay, ECU may be at fault.
					Voltage not zero	Check for a short to power in Circuit 376R. Repair as necessary.
136	013	05	Open circuit	2. Disconnect the black X2 connector at the ECU. Disconnect the retarder relay. Measure the resistance between Pin 7 of the black X2 ECU connector and relay connector cavity that corresponds to pin 85 of the relay.	Resistance less than 1 ohm	Check relay coil resistance (should be 60-85 Ohms). If okay, check circuit 81C (power to relay coil) for open. Repair as necessary.
					Resistance more than 1 ohm	Repair open in circuit 376R.
136	013	06	Short to ground	3. Disconnect the black X2 connector at the ECU. Disconnect the retarder relay. Measure the resistance between pin 7 of the X2 connector and a good chassis ground.	Resistance is less than 10 Ohms	Check circuit 376R for short to ground. Repair as necessary.
					Resistance is much greater than 10 Ohms	Check for intermittent short to ground in circuit 376R. If okay, ECU may be at fault.

Table 8, J1587 Fault 136-013 Retarder

J1587 Fault 136-014 Power						
MID	SID	FMI	Problem	Test	Test Result	Action
136	014	03	Voltage supplied to ECU with ignition OFF	1. Check for voltage backfeeding to ECU with the ignition off, especially to pins 7/X2 and 10/X2.	Voltage zero	Repair as necessary.
136	014	04	No voltage supplied to ECU with ignition ON	2. With the ignition ON, measure the voltage between Pin 3 of the black X2 ECU connector and a good chassis ground. Repeat between pin 11 and ground.	Voltage between 9.5 and 14 volts at both pins.	Check Circuit 376A for an intermittent open circuit. If the problem persists, suspect the ECU is at fault.
					Voltage below 9.5 volts at one or both pins.	Check Circuit 376A for an open circuit and check Fuse F16. Repair as necessary.

Table 9, J1587 Fault 136-014 Power

Troubleshooting

J1587 Fault 136-023 ABS Warning Light						
MID	SID	FMI	Problem	Test	Test Result	Action
136	023	05	Open circuit or low current	1. Disconnect the black X2 connector from the ECU. Turn the ignition ON.	ABS light illuminates	Check circuit 376L for open circuit between splice S22 and X2/8 at the ABS connector. Repair as necessary.
					ABS light does not illuminate	Check the bulb and wire (circuit 376L between splice S22 and ICU pin B11. If okay, replace the ICU.

Table 10, J1587 Fault 136-023 ABS Warning Light

J1587 Fault 136-030 Recirculation Pump Relay						
MID	SID	FMI	Problem	Test	Test Result	Action
136	030	03	Relay shorted to power	1. Disconnect the black X2 ECU connector. With the ignition ON, measure the voltage between Pin 6 and a good chassis ground.	Voltage zero	If the problem persists, suspect the ECU is at fault.
					Voltage not zero	Circuit 376H is shorted to power. Repair as necessary.
136	030	05	Relay open circuit	2. Disconnect the black X2 ECU connector. Measure the resistance between Pin 6 and a good chassis ground.	Resistance between 50 and 200 ohms	If the problem persists, suspect the ECU is at fault.
					Resistance below 50 or above 200 ohms	Check the relay coil, relay coil ground circuit, and Circuit 376H for an open circuit. Repair as necessary.
136	030	06	Relay short to ground	3. Disconnect the black X2 ECU connector. Measure the resistance between Pin 6 and a good chassis ground.	Resistance between 50 and 200 ohms	If the problem persists, suspect the ECU is at fault.
					Resistance below 50 or above 200 ohms	Check Circuit 376H for a short to ground. Repair as necessary.

<table>
<tr><th colspan="7">J1587 Fault 136-030 Recirculation Pump Relay</th></tr>
<tr><th>MID</th><th>SID</th><th>FMI</th><th>Problem</th><th>Test</th><th>Test Result</th><th>Action</th></tr>
<tr><td rowspan="2">136</td><td rowspan="2">030</td><td rowspan="2">07</td><td rowspan="2">Pump relay sticks, pump continues to run when ECU deactivates the relay
NOTE: The problem may be intermittent and a new relay may be required to correct the fault.</td><td rowspan="2">4. If the fault is active, disconnect the black X2 connector from the ECU. With the ignition ON, check to see if the recirculation pump is running.</td><td>Pump OFF</td><td>The ABS pump relay (located in the chassis harness, near the ABS valve) may be intermittently sticking. Try a new relay and verify that the problem is solved.</td></tr>
<tr><td>Pump ON</td><td>The ABS pump relay (located in the chassis harness, near the ABS valve) is sticking. Replace the relay.</td></tr>
</table>

Table 11, J1587 Fault 136-030 Recirculation Pump Relay

Troubleshooting

J1587 Fault 136-042 Left Front Inlet Solenoid Valve						
MID	SID	FMI	Problem	Test	Test Result	Action
136	042	03 05 06	Shorted to power (inlet valve) Open circuit (inlet valve) Shorted to ground (inlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 3 and 2 of the gray X1 ECU connector (Circuits 378LFI and GRDE).	Resistance reading 6.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.
					Resistance reading not 6.5±0.5 ohms	Go to Test 2.
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.
					Resistance reading not close to zero	Check and repair the ground circuit.
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.
				4. Measure the resistance in Circuit 378LFI between modulator connector Pin 12 and connector Pin 3 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.
					Resistance reading not close to zero	Repair Circuit 378LFI.
				5. With the modulator valve connector removed, measure the resistance across Pins 12 and 8 on the modulator connector.	Resistance reading 6.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.
					Resistance reading not 6.5±0.5 ohms	Replace the modulator valve.

Table 12, J1587 Fault 136-042 Left Front Inlet Solenoid Valve

J1587 Fault 136-043 Right Front Inlet Solenoid Valve						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	043	03 05 06	Shorted to power (inlet valve) Open circuit (inlet valve) Shorted to ground (inlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 4 and 2 of the gray X1 ECU connector (Circuits 378RFI and GRDE).	Resistance reading 6.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.
					Resistance reading not 6.5±0.5 ohms	Go to Test 2.
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.
					Resistance reading not close to zero	Check and repair the ground circuit.
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.
				4. Measure the resistance in Circuit 378RFI between modulator connector Pin 4 and connector Pin 4 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.
					Resistance reading not close to zero	Repair Circuit 378RFI.
				5. With the modulator valve connector removed, measure the resistance across Pins 4 and 8 on the modulator connector.	Resistance reading 6.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.
					Resistance reading not 6.5±0.5 ohms	Replace the modulator valve.

Table 13, J1587 Fault 136-043 Right Front Inlet Solenoid Valve

Troubleshooting

J1587 Fault 136-044 Left Rear Inlet Solenoid Valve						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	044	03 05 06	Shorted to power (inlet valve) Open circuit (inlet valve) Shorted to ground (inlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 5 and 2 of the gray X1 ECU connector (Circuits 378LRI and GRDE).	Resistance reading 6.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.
					Resistance reading not 6.5±0.5 ohms	Go to Test 2.
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.
					Resistance reading not close to zero	Check and repair the ground circuit.
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.
				4. Measure the resistance in Circuit 378LRI between modulator connector Pin 2 and connector Pin 5 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.
					Resistance reading not close to zero	Repair Circuit 378LRI.
				5. With the modulator valve connector removed, measure the resistance across Pins 2 and 8 on the modulator connector.	Resistance reading 6.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.
					Resistance reading not 6.5±0.5 ohms	Replace the modulator valve.

Table 14, J1587 Fault 136-044 Left Rear Inlet Solenoid Valve

<table>
<tr><th colspan="7">J1587 Fault 136-045 Right Rear Inlet Solenoid Valve</th></tr>
<tr><th>MID</th><th>SID</th><th>FMI</th><th>Problem</th><th>Test</th><th>Test Result</th><th>Action</th></tr>
<tr><td rowspan="10">136</td><td rowspan="10">045</td><td rowspan="10">03
05
06</td><td rowspan="10">Shorted to power (inlet valve)
Open circuit (inlet valve)
Shorted to ground (inlet valve)
NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.</td><td rowspan="2">1. Measure the resistance across Pins 6 and 2 of the gray X1 ECU connector (Circuits 378RRI and GRDE).</td><td>Resistance reading 6.5±0.5 ohms</td><td>Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.</td></tr>
<tr><td>Resistance reading not 6.5±0.5 ohms</td><td>Go to Test 2.</td></tr>
<tr><td rowspan="2">2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.</td><td>Resistance reading close to zero</td><td>Go to Test 3.</td></tr>
<tr><td>Resistance reading not close to zero</td><td>Check and repair the ground circuit.</td></tr>
<tr><td rowspan="2">3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.</td><td>Resistance reading close to zero</td><td>Go to Test 4.</td></tr>
<tr><td>Resistance reading not close to zero</td><td>Check the modulator ground circuit, repair as necessary.</td></tr>
<tr><td rowspan="2">4. Measure the resistance in Circuit 378RRI between modulator connector Pin 11 and connector Pin 6 on the gray X1 ECU connector.</td><td>Resistance reading close to zero</td><td>Go to Test 5.</td></tr>
<tr><td>Resistance reading not close to zero</td><td>Repair Circuit 378RRI.</td></tr>
<tr><td rowspan="2">5. With the modulator valve connector removed, measure the resistance across Pins 11 and 8 on the modulator connector.</td><td>Resistance reading 6.5±0.5 ohms</td><td>Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.</td></tr>
<tr><td>Resistance reading not 6.5±0.5 ohms</td><td>Replace the modulator valve.</td></tr>
</table>

Table 15, J1587 Fault 136-045 Right Rear Inlet Solenoid Valve

Troubleshooting

J1587 Fault 136-048 Left Front Outlet Solenoid Valve						
MID	SID	FMI	Problem	Test	Test Result	Action
136	048	03 05 06	Shorted to power (outlet valve) Open circuit (outlet valve) Shorted to ground (outlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 10 and 2 of the gray X1 ECU connector (Circuits 378LFO and GRDE).	Resistance reading 3.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.
					Resistance reading not 3.5±0.5 ohms	Go to Test 2.
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.
					Resistance reading not close to zero	Check and repair the ground circuit.
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.
				4. Measure the resistance in Circuit 378LFO between modulator connector Pin 13 and connector Pin 10 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.
					Resistance reading not close to zero	Repair Circuit 378LFO.
				5. With the modulator valve connector removed, measure the resistance across Pins 13 and 8 on the modulator connector.	Resistance reading 3.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.
					Resistance reading not 3.5±0.5 ohms	Replace the modulator valve.

Table 16, J1587 Fault 136-048 Left Front Outlet Solenoid Valve

J1587 Fault 136-049 Right Front Outlet Solenoid Valve						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	049	03 05 06	Shorted to power (outlet valve) Open circuit (outlet valve) Shorted to ground (outlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 9 and 2 of the gray X1 ECU connector (Circuits 378RFO and GRDE).	Resistance reading 3.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.
					Resistance reading not 3.5±0.5 ohms	Go to Test 2.
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.
					Resistance reading not close to zero	Check and repair the ground circuit.
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.
				4. Measure the resistance in Circuit 378RFO between modulator connector Pin 5 and connector Pin 9 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.
					Resistance reading not close to zero	Repair Circuit 378RFO.
				5. With the modulator valve connector removed, measure the resistance across Pins 5 and 8 on the modulator connector.	Resistance reading 3.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.
					Resistance reading not 3.5±0.5 ohms	Replace the modulator valve.

Table 17, J1587 Fault 136-049 Right Front Outlet Solenoid Valve

Troubleshooting

J1587 Fault 136-050 Left Rear Outlet Solenoid Valve						
MID	SID	FMI	Problem	Test	Test Result	Action
136	050	03 05 06	Shorted to power (outlet valve) Open circuit (outlet valve) Shorted to ground (outlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 8 and 2 of the gray X1 ECU connector (Circuits 378LRO and GRDE).	Resistance reading 3.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.
					Resistance reading not 3.5±0.5 ohms	Go to Test 2.
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.
					Resistance reading not close to zero	Check and repair the ground circuit.
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.
				4. Measure the resistance in Circuit 378LRO between modulator connector Pin 1 and connector Pin 8 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.
					Resistance reading not close to zero	Repair Circuit 378LRO.
				5. With the modulator valve connector removed, measure the resistance across Pins 1 and 8 on the modulator connector.	Resistance reading 3.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.
					Resistance reading not 3.5±0.5 ohms	Replace the modulator valve.

Table 18, J1587 Fault 136-050 Left Rear Outlet Solenoid Valve

J1587 Fault 136-051 Right Rear Outlet Solenoid Valve						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	051	03 05 06	Shorted to power (outlet valve) Open circuit (outlet valve) Shorted to ground (outlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 7 and 2 of the gray X1 ECU connector (Circuits 378RRO and GRDE).	Resistance reading 3.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.
					Resistance reading not 3.5±0.5 ohms	Go to Test 2.
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.
					Resistance reading not close to zero	Check and repair the ground circuit.
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.
				4. Measure the resistance in Circuit 378RRO between modulator connector Pin 10 and connector Pin 7 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.
					Resistance reading not close to zero	Repair Circuit 378RRO.
				5. With the modulator valve connector removed, measure the resistance across Pins 10 and 8 on the modulator connector.	Resistance reading 3.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.
					Resistance reading not 3.5±0.5 ohms	Replace the modulator valve.

Table 19, J1587 Fault 136-051 Right Rear Outlet Solenoid Valve

Troubleshooting

J1587 Fault 136-054 Recirculation Pump						
MID	SID	FMI	Problem	Test	Test Result	Action
136	054	03	Recirculation pump on without being activated by ECU NOTE: In this case the ECU is sensing voltage on the pump monitor circuit (Pin 10 of the black X2 connector) when the pump relay was not activated by the ECU (Pin 6 of the black X2 connector).	1. Remove the black X2 connector from the ECU. With the ignition ON, measure the voltage between Pin 10 and a good chassis ground.	Voltage zero	Check the ECU and verify the fault.
					Voltage not zero	Go to Test 2.
				2. Remove the ABS pump relay (R17) and repeat Test 1.	Voltage zero	Check the ABS pump relay R17; it may be sticking or shorted.
					Voltage not zero	Check for a short to power in Circuit 376B causing the pump to run when it should not be. Repair as necessary.
136	054	04	Recirculation pump does not switch on when activated by the ECU NOTE: In this case the ECU does not sense voltage on the pump monitor circuit (Pin 10 of the black X2 ECU connector) when the pump relay was activated by the ECU (Pin 6 of the black X2 ECU connector).	3. Remove the black X2 connector from the ECU. With the ignition ON, link Pins 6 and 3 while measuring the voltage between Pin 10 and a good chassis ground. The pump should run (do not hold for more than 1 minute).	Voltage between 9.5 and 14 volts	Check for intermittent connections in Circuit 376B and check the ABS pump relay for intermittent operation. Repair as necessary.
					Voltage below 9.5 or above 14 volts	Check Circuit 376A and check Relay R17. Repair as necessary.
136	054	07	Recirculation pump sticks or is locked NOTE: In this case, the ECU senses high current on the pump monitor circuit (Pin 10 of the black X2 ECU connector) indicating the pump motor is locked.	4. Remove the black X2 connector from the ECU. With the ignition ON, momentarily link Pins 6 and 3. The pump should run (do not hold for more than 1 minute).	Pump runs	Repeat the test to verify. If the fault persists, suspect a problem with the ECU.
					Pump does not run	Replace the recirculation pump.

Table 20, J1587 Fault 136-054 Recirculation Pump

J1587 Fault 136-055 ECU						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	055	02	Reference to ground interrupted	1. With the ignition OFF, measure the voltage between Pin 2 of the gray X1 ECU connector (Circuit GND) and a good chassis ground.	Voltage zero volts	Go to Test 2.
					Voltage not zero volts	Check the ground circuit for a short to positive voltage.
				2. Measure the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance near zero ohms	Check the ECU ground circuit (GND) for an intermittent or loose connection. Check ground Splice S10. If the problem persists, suspect the ECU is at fault.
					Resistance above zero ohms	Check the ECU ground circuit (GND). Repair as necessary.

Table 21, J1587 Fault 136-055 ECU

J1587 Fault 136-251 Low Voltage						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	251	03	Voltage too high NOTE: Voltage to the ABS ECU must be between 9.5 and 14 volts to function properly.	1. Disconnect the black X2 ECU connector. Start the engine and run it at governed speed while measuring the voltage between Pins 3 and 9.	Voltage between 9.5 and 14 volts	Check the electrical system. If the problem persists, suspect the ECU is at fault.
					Voltage below 9.5 or above 14 volts	Check the batteries and charging system for malfunction. Repair as necessary.
136	251	04	Low voltage to ABS solenoid valves NOTE: Voltage to the ABS ECU must be between 9.5 and 14 volts to function properly.	2. Disconnect the black X2 ECU connector. Start the engine and run it at idle while measuring the voltage between Pins 3 and 9 of the black X2 ECU connector.	Voltage between 9.5 and 14 volts	Verify that the batteries were not drained or the charging system was not overloaded when the fault occurred. If the problem persists, suspect the ECU is at fault.
					Voltage below 9.5 or above 14 volts	Check the batteries and charging system for malfunction. Repair as necessary.

Table 22, J1587 Fault 136-251 Low Voltage

Troubleshooting

J1587 Fault 136-253 Internal Tire Parameter						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	253	02	Incorrect internal tire parameter	—	—	Contact Meritor WABCO (1-800-535-5560).

Table 23, J1587 Fault 136-253 Internal Tire Parameter

J1587 Fault 136-254 ECU Internal Fault						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	254	12	Internal ECU Fault	—	—	Replace the ECU.

Table 24, J1587 Fault 136-254 ECU Internal Fault

Specifications

For a full view of the hydraulic ABS wheel sensor and modulator assembly (ECU green and gray connectors) wiring diagram, see **Fig. 1**.

For partial (detailed) views of the hydraulic ABS wheel sensor and modulator assembly (ECU green and gray connectors) wiring diagram, see **Fig. 2** and **Fig. 3**.

For hydraulic ABS pump and dash wiring (ECU black connector) wiring, see **Fig. 4**.

For partial (detailed) views of hydraulic ABS pump and dash wiring (ECU black connector) wiring, see **Fig. 5**, **Fig. 6**, and **Fig. 7**.

For retarder relay wiring, see **Fig. 8**.

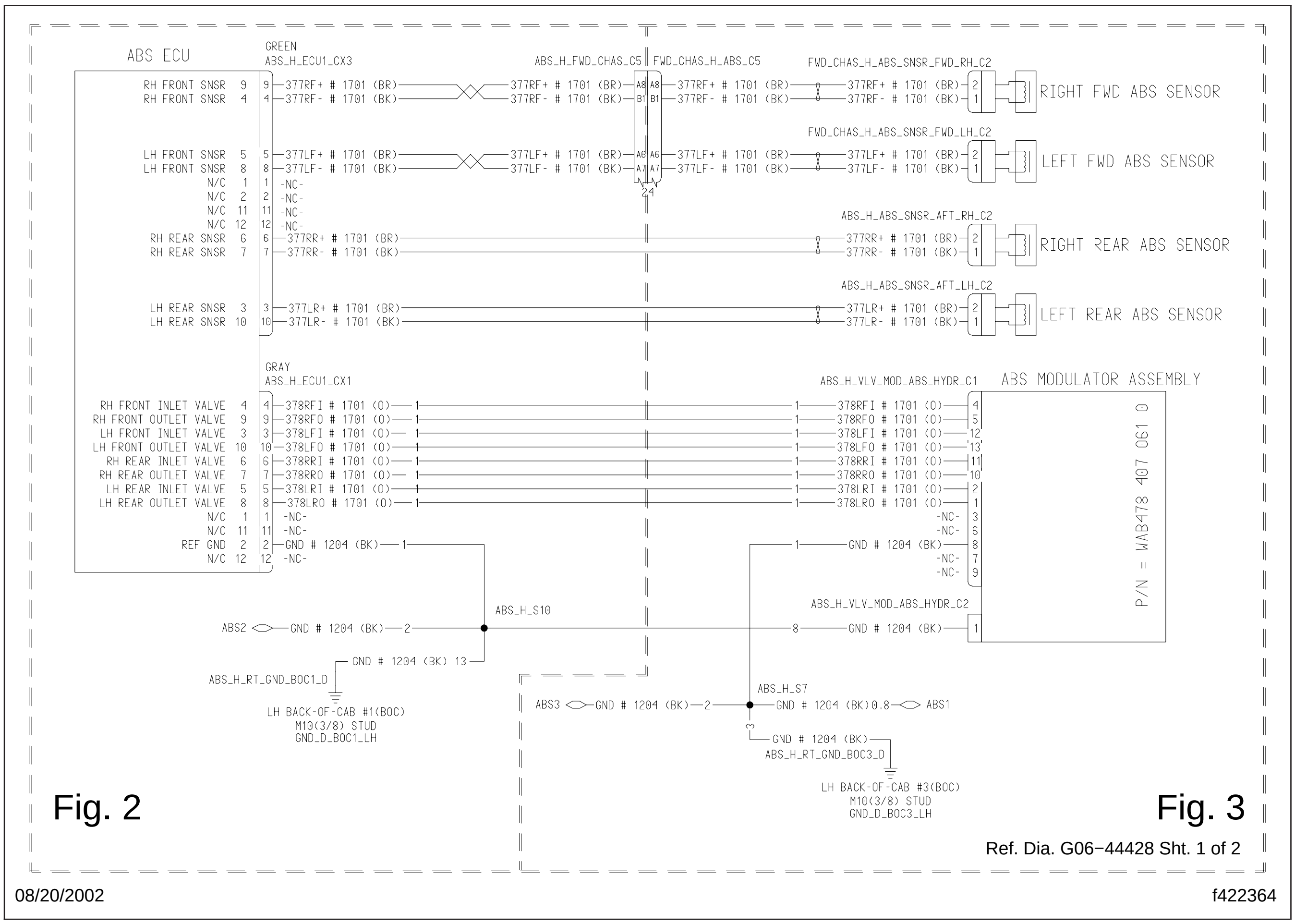


Fig. 1, Wiring Diagram, ABS Wheel Sensor and Modulator Assembly (full view)

Specifications

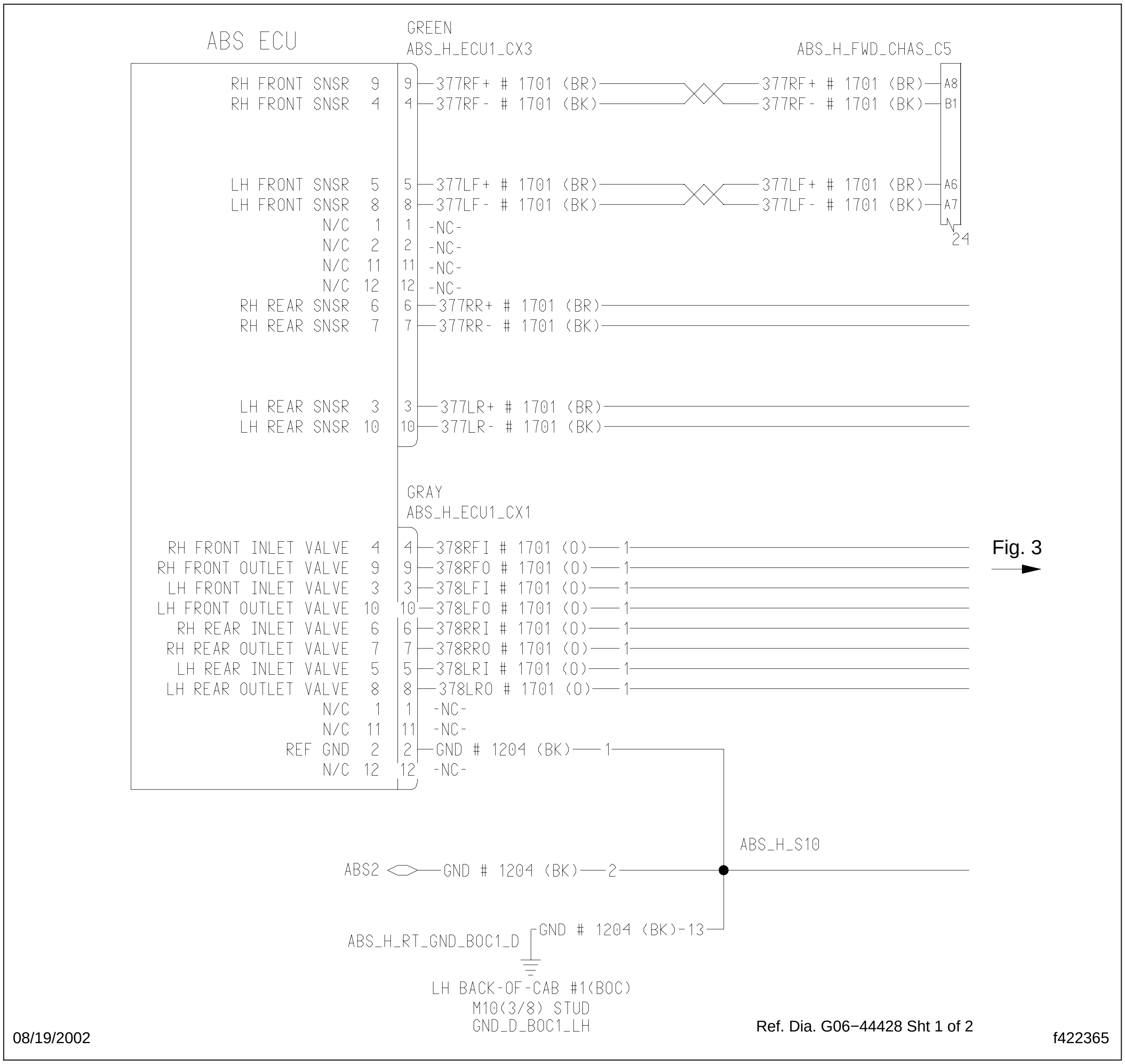


Fig. 2, Wiring Diagram, ABS Wheel Sensor and Modulator Assembly (partial view)

Specifications

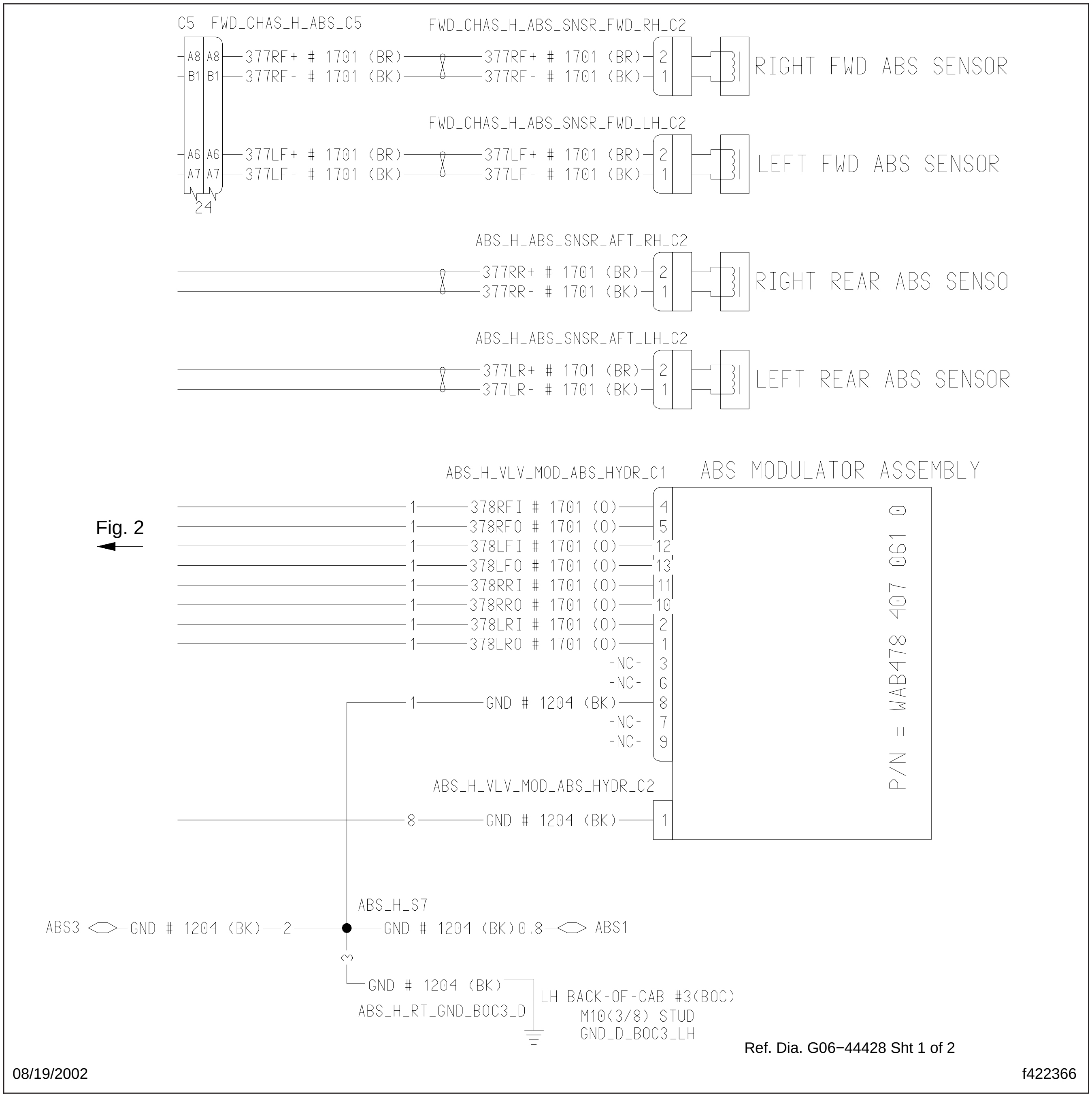


Fig. 3, Wiring Diagram, ABS Wheel Sensor and Modulator Assembly (partial view)

Specifications

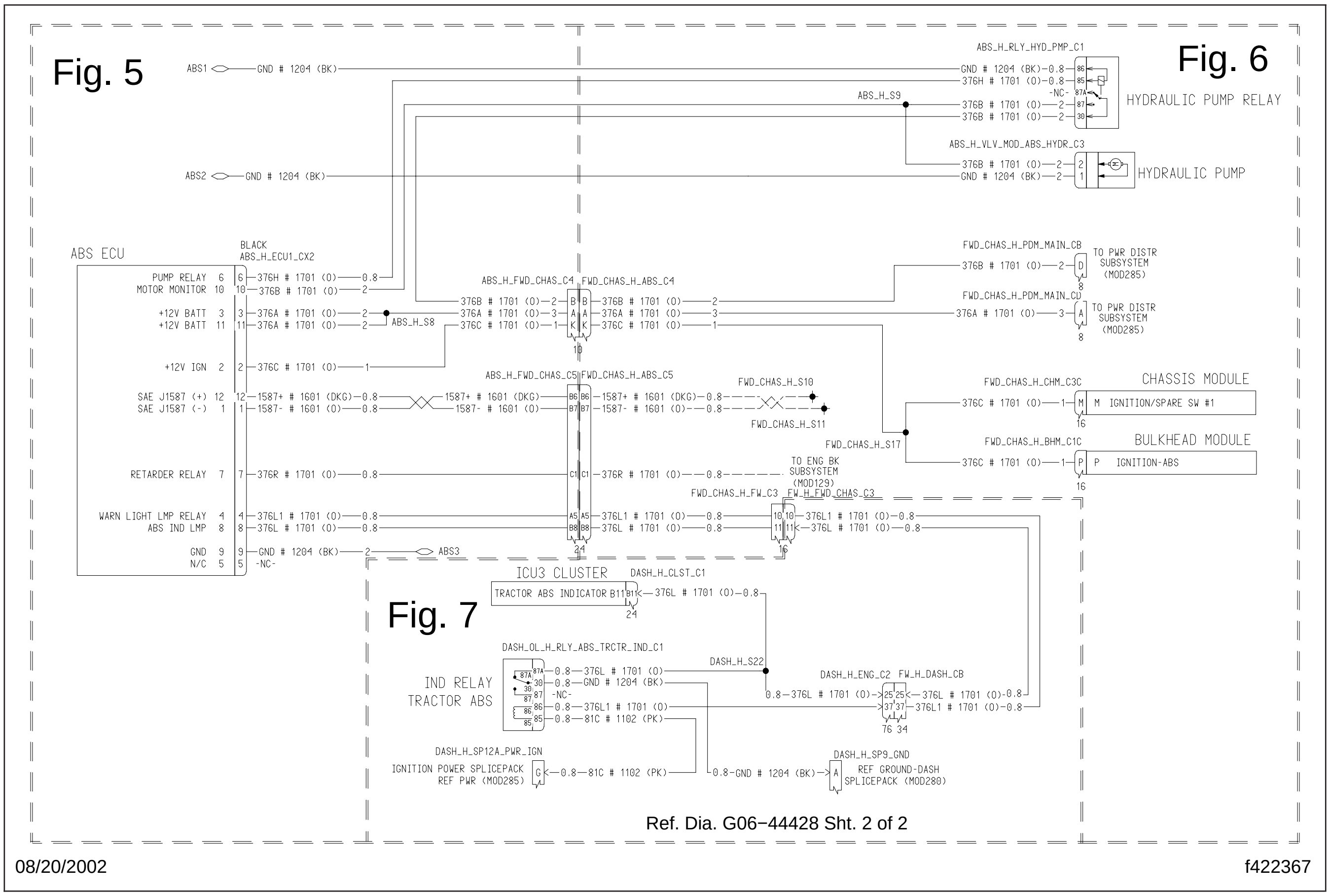


Fig. 4, Wiring Diagram, ABS Relays and Dash Wiring (full view)

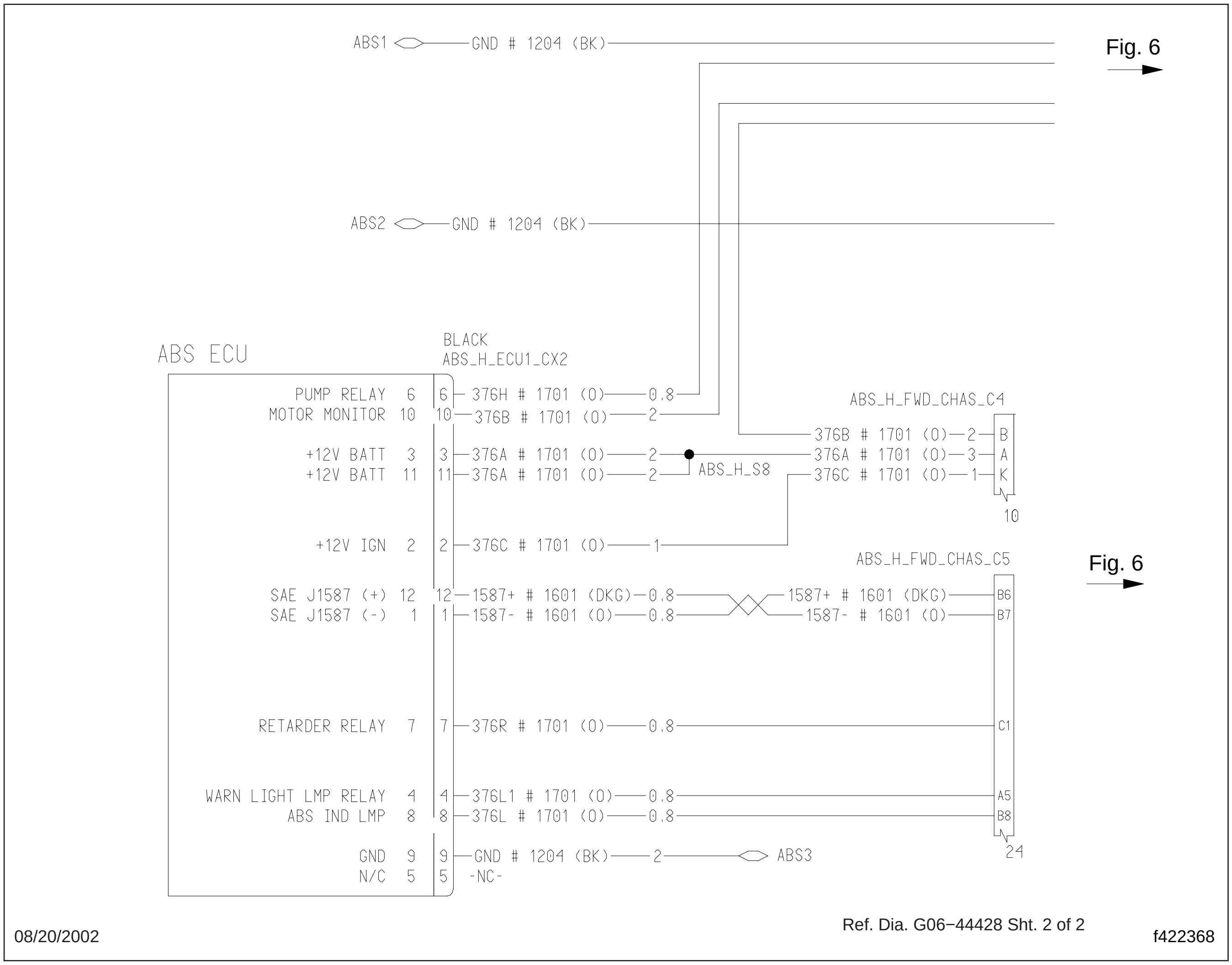


Fig. 5, Wiring Diagram, ABS Relays and Dash Wiring (partial view)

Specifications

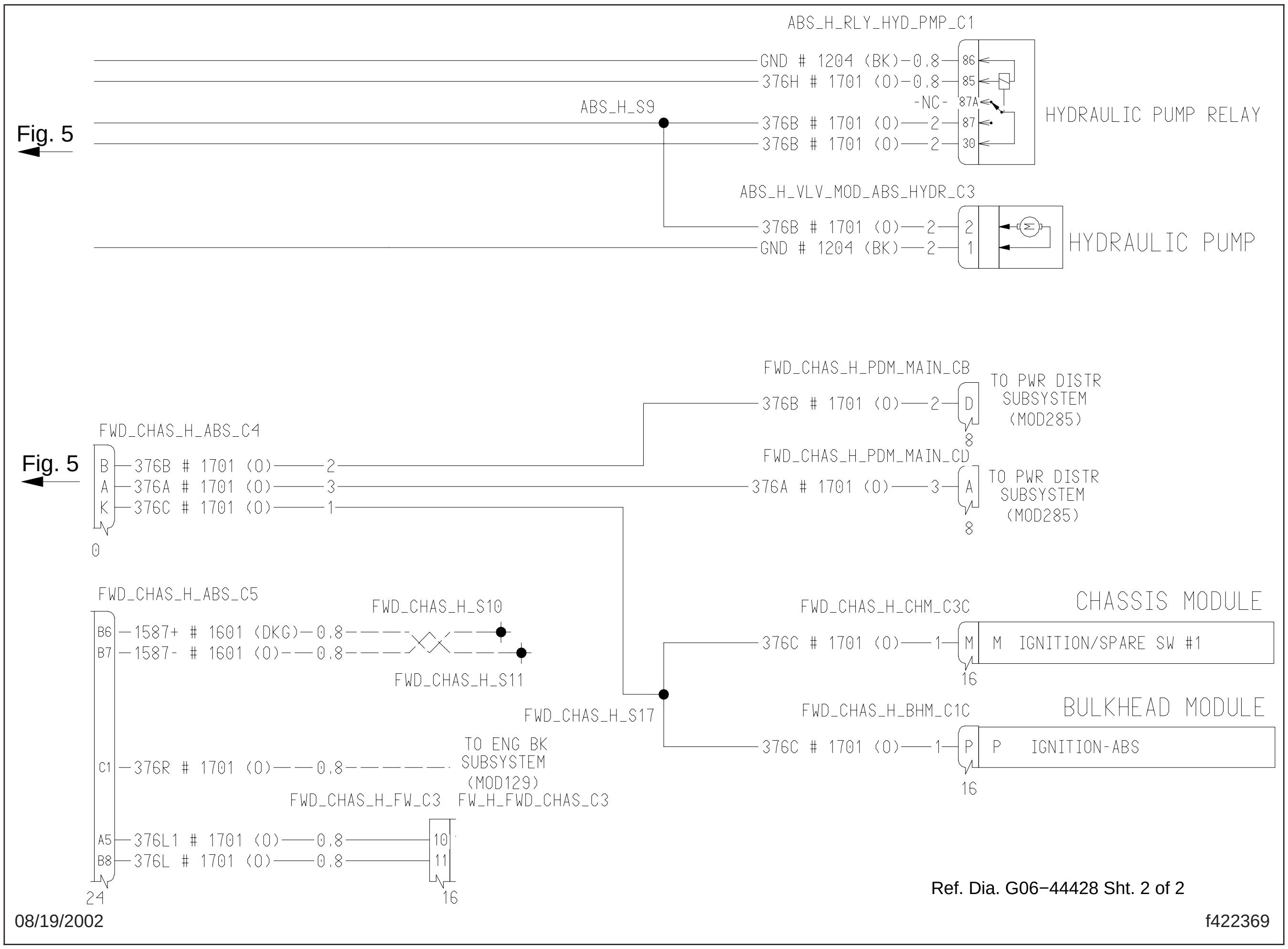


Fig. 6, Wiring Diagram, ABS Relays and Dash Wiring (partial view)

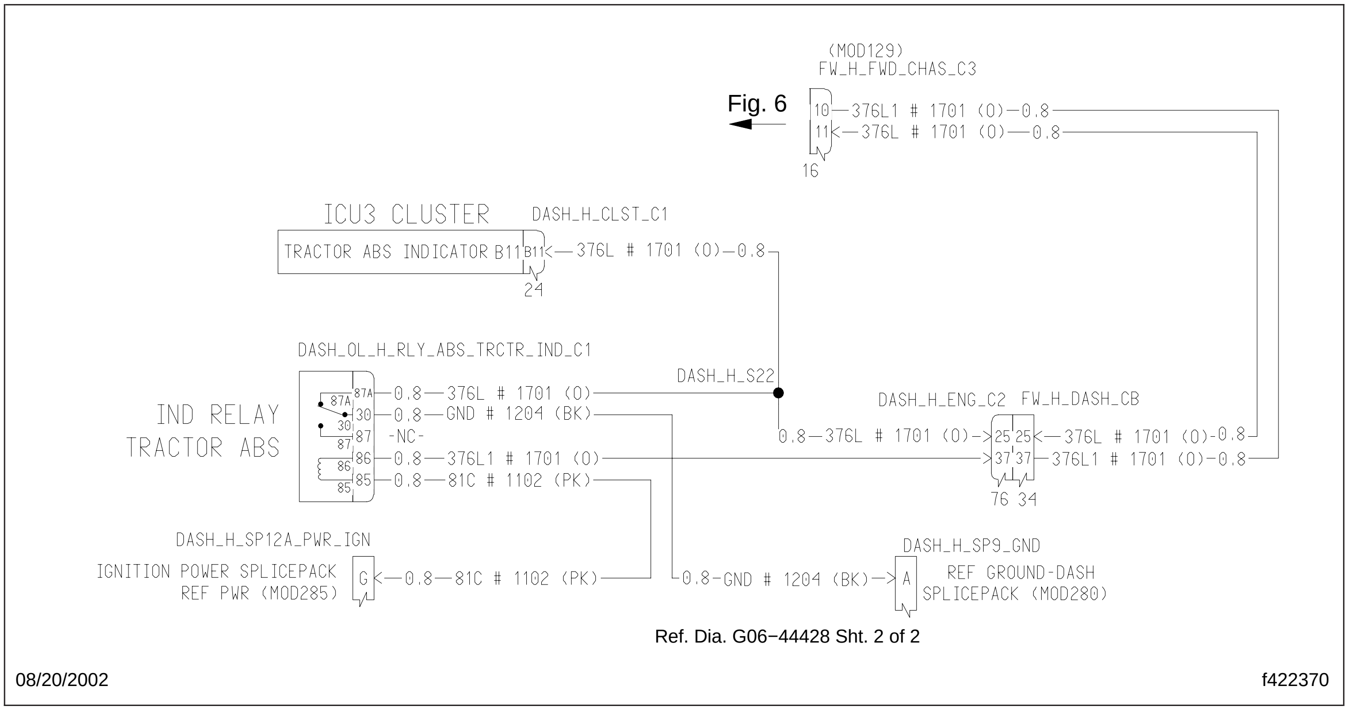


Fig. 7, Wiring Diagram, ABS Relays and Dash Wiring (partial view)

Specifications

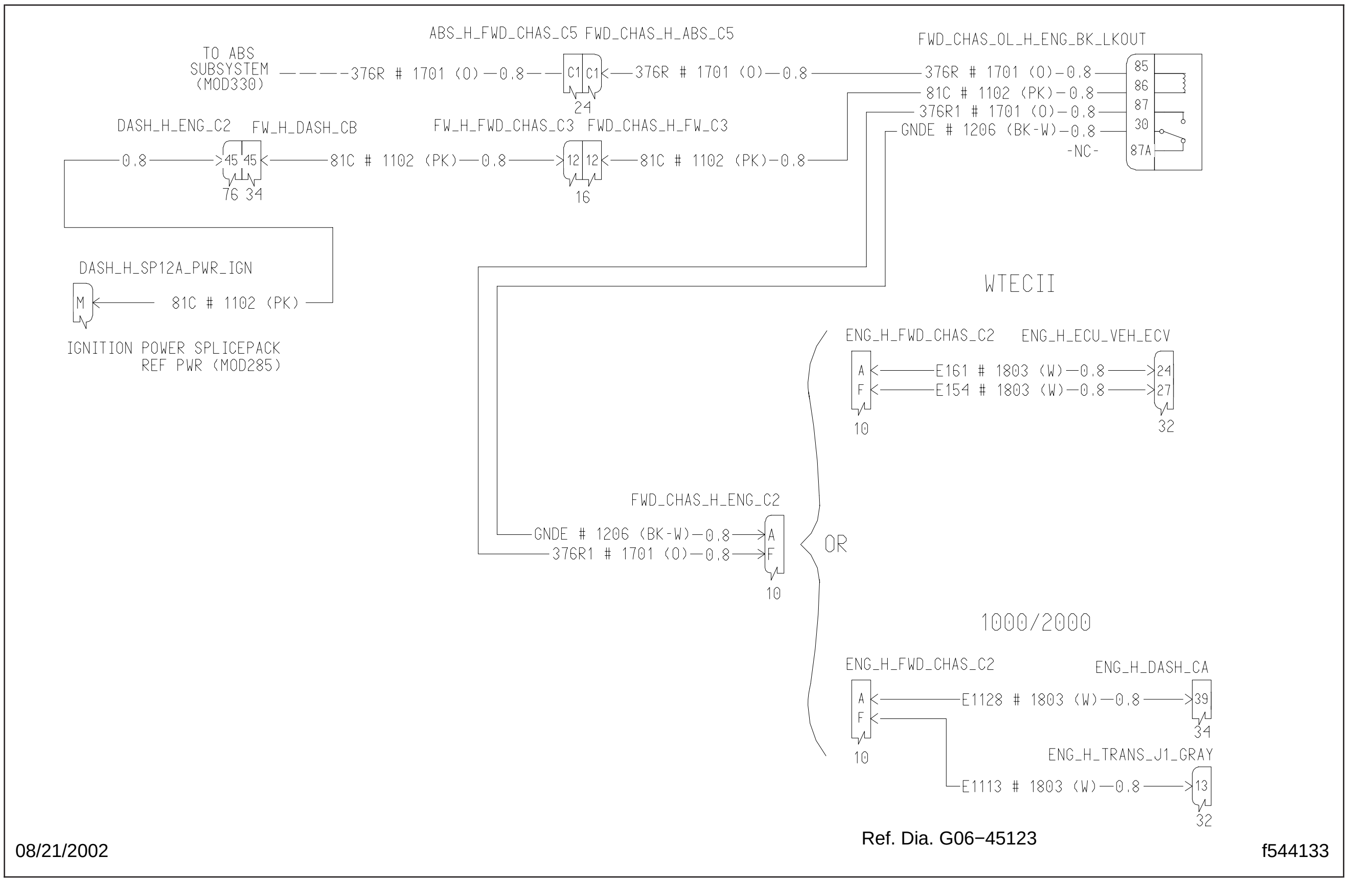


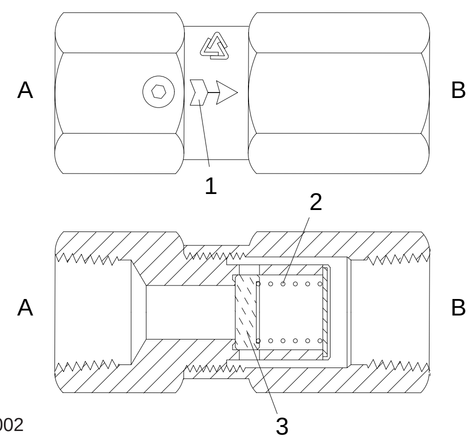
Fig. 8, Retarder Relay Wiring

General Information

The single check valve is installed in an air line to allow air flow in one direction and prevent air flow in the reverse direction. The check valve is installed in the upstream ends of the primary and secondary brake system air reservoirs to protect brake system air pressure in case the compressor, air pressure regulator or other air delivery component malfunctions.

The two types of SC-3 in-line single check valves are the wafer-style type (**Fig. 1**) and the ball type (**Fig. 2**).

NOTE: The SC-3 single check valve is NOT serviceable.



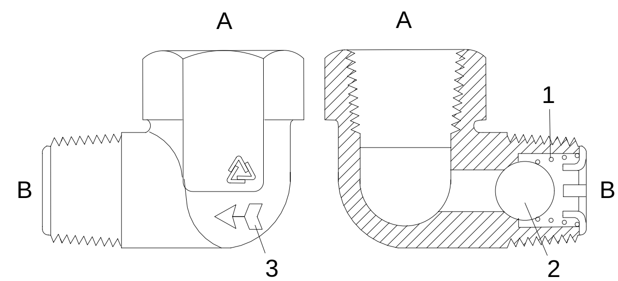
A. Supply Air
B. Delivery Air

1. Air-Flow Direction Arrow
2. Spring
3. Wafer-Type Check Valve

Fig. 1, Single Check Valve, Wafer-Type

Principle of Operation

Air flow in the normal direction moves the check valve from its seat, and the flow is unobstructed. Flow in the reverse direction is prevented by the seating of the ball or wafer-type disc, which is caused by a drop in up-stream air pressure and assisted by the spring.



A. Supply Air
B. Delivery Air

1. Spring
2. Ball-Type Check Valve
3. Air Flow Direction Arrow

Fig. 2, Single Check Valve, Ball-Type

Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Leakage Test

After repairing or replacing the single check valve, do the following test:

1. With the brake air system fully pressurized, drain the air from the supply reservoir (wet tank).
2. Remove the air line from the supply side of the check valve.
3. Coat the open end of the check valve with soap suds. A 1-inch (2.5-cm) or smaller bubble in 5 seconds is acceptable.
4. If the check valve is leaking too much, replace it.

Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air reservoirs.
3. Remove the supply line from the check valve.
4. Remove the check valve from the air reservoir.

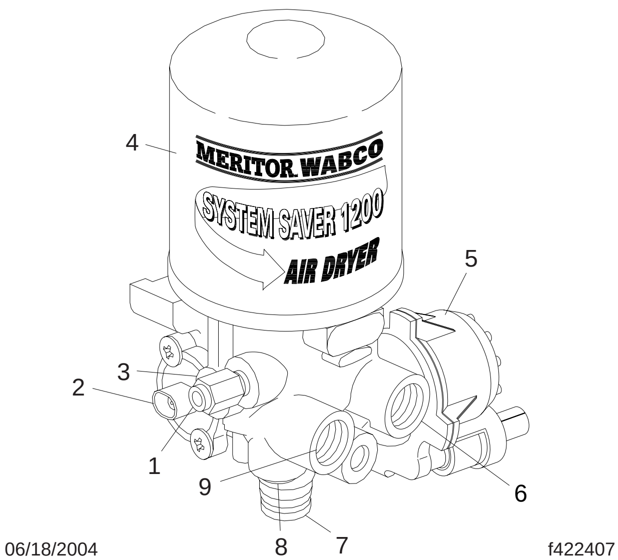
Installation

1. Screw the check valve into the supply end of the air reservoir. To ensure the valve is not reversed, the arrow marked on the valve body must point in the direction of air flow.
2. Leak test the check valve following the instructions under **Subject 110**.
3. Connect the supply line to the open end of the check valve.
4. Remove the chocks from the tires.

General Information and Principles of Operation

General Information

The System Saver 1200 air dryer (see Fig. 1) is a desiccant air dryer, mounted vertically between the air compressor and the supply reservoir. The air dryer receives hot compressed air, which it cools and filters before sending it to the supply reservoir, reducing the build-up of dirt and moisture in the vehicle air system.



1. Pressure Relief Valve
2. Heater/Thermostat Assembly
3. Governor Port (to air governor)
4. Desiccant Canister
5. Regeneration Valve Assembly
6. Outlet Port (to air supply reservoir)
7. Exhaust Port (Purge Valve Assembly)
8. Turbocharger Cutoff Valve
9. Inlet Port (from air compressor)

Fig. 1, WABCO System Saver 1200

The air dryer consists of a light-weight aluminum and steel body. The desiccant cartridge is contained in a spinoff canister at the top of the air dryer.

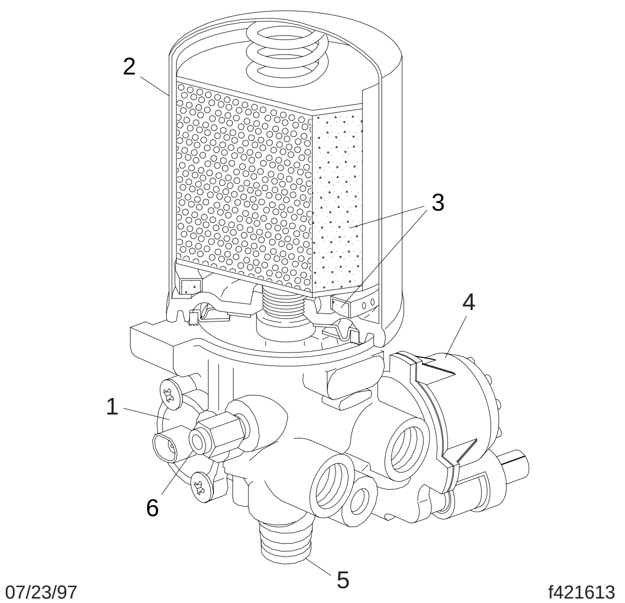
The following components attach to the body of the air dryer:

- Pressure Relief Valve—this valve protects the air dryer from over pressurization. The valve is attached directly to the air dryer.
- Desiccant Canister—a cylindrical steel housing that contains the filter elements and the desiccant needed to filter and dry the air that passes through it.
- Heater/Thermostat Assembly—located in the air dryer base, this assembly is designed to prevent the collected moisture from freezing.
- Outlet Check Valve—this valve prevents air in the system from flowing back through the air dryer and escaping out the purge valve during the compressor unload cycle.
- Pressure-Controlled Check Valve—this valve is separate from the air dryer and is installed on the system air tank. The valve allows air to back flow from the system tank to the supply tank as long as air system pressure remains between the normal cut-in and cut-out range of the air governor.
- Purge Valve—this valve allows the collected moisture and contaminants to be expelled from the air dryer during the purge cycle.
- Regeneration Valve—this valve allows air from the supply and system tanks to bypass the outlet check valve and flow into the regeneration valve. Air then flows through an orifice where the air expands and back flushes moisture off of the desiccant. The air is then exhausted through the purge valve.
- Silencer (Muffler)—an optional component that is attached to the purge valve and used to eliminate most of the noise during the air dryer purge cycle.
- Turbocharger Cut-Off Valve—this valve closes the path between the air compressor and the air dryer purge valve to help maintain boost pressure for maximum engine horsepower during the compressor unload cycle.

Principles of Operation

Hot, compressed air enters the air dryer through the inlet port. As the hot air is forced into the desiccant cartridge, the temperature of the compressed air falls to nearly ambient. Oil and water vapor condense and initially settle into the base of the dryer. The moisture-laden air also passes through the desiccant bed, where any remaining moisture is retained by the desiccant. The clean air then passes through the air dryer outlet port to the supply reservoir. See Fig. 2 .

General Information and Principles of Operation



1. Heater/Thermostat Assembly
2. Desiccant Canister
3. Filter
4. Regeneration Valve Assembly
5. Exhaust Port (Purge Valve Assembly)
6. Pressure Relief Valve

Fig. 2, Sectional View

When the compressor reaches about 125 psi (862 kPa), the purge valve opens, allowing the initial decompression of the dryer, and expelling the water and contaminants collected in the base of the dryer. The regeneration valve, along with the pressure-controlled check valve, allows the system air to flow back through the dryer. This back flow dries the desiccant for the next cycle.

Safety Precautions

WARNING

When draining the air system, do not look into the air jets or direct them toward another person, as dirt or sludge particles may be in the air-stream. Do not disconnect pressurized hoses because they may whip as air escapes from the line. Failure to take all necessary precautions during service operations of the air brake system can cause personal injury.

When working on or around air brake systems and components, observe the following precautions.

1. Apply the parking brake, chock the tires, and stop the engine when working under the vehicle. Draining the air system may cause the vehicle to roll. Keep hands away from the brake chamber push rods and slack adjusters, which may apply as air system pressure drops.
2. Wear safety goggles.
3. Never connect or disconnect a hose or line containing air under pressure; it may whip as air escapes. Never remove a component or pipe plug unless you are sure all system pressure has been depleted.
4. Don’t disassemble a component before reading and understanding recommended procedures. Use only the correct tools and follow basic tool safety.
5. Replacement hardware, tubing, hose, fittings, etc. should be the same size, type, length, and strength as the original equipment. When replacing tubing or hose, be sure that all of the original supports, clamps, or suspending devices are installed or replaced.
6. Replace any components that have stripped threads or damaged parts. Don’t attempt to repair parts by machining.
7. Never exceed recommended air pressure.

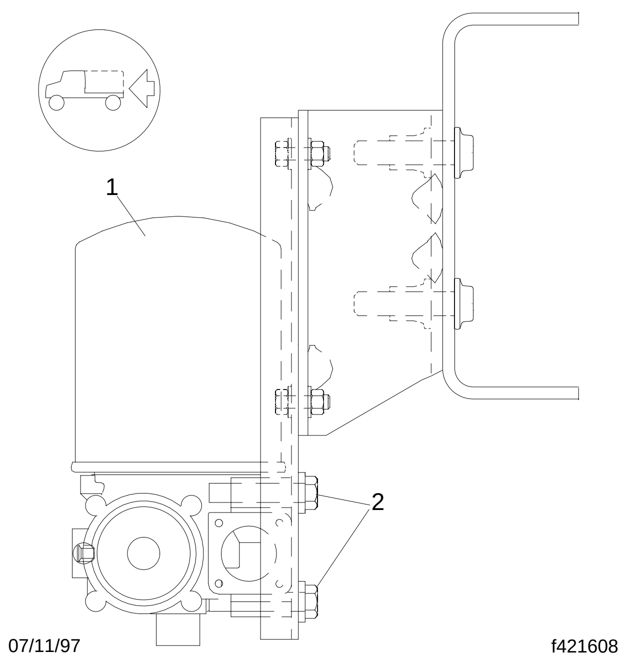
Air Dryer Removal and Installation

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

Removal

1. Drain the air system.
2. Disconnect the wiring harness from the air dryer.
3. Mark the air lines for later reference, then disconnect them from the air dryer.
4. Remove the capscrews, washers, and spacers that attach the air dryer to the mounting bracket.
5. Remove the air dryer. See **Fig. 1**.



1. Desiccant Canister
2. 1/2" Capscrew, Washer, and Spacer

Fig. 1, Air Dryer Installation (outboard rail mounting shown)

Installation

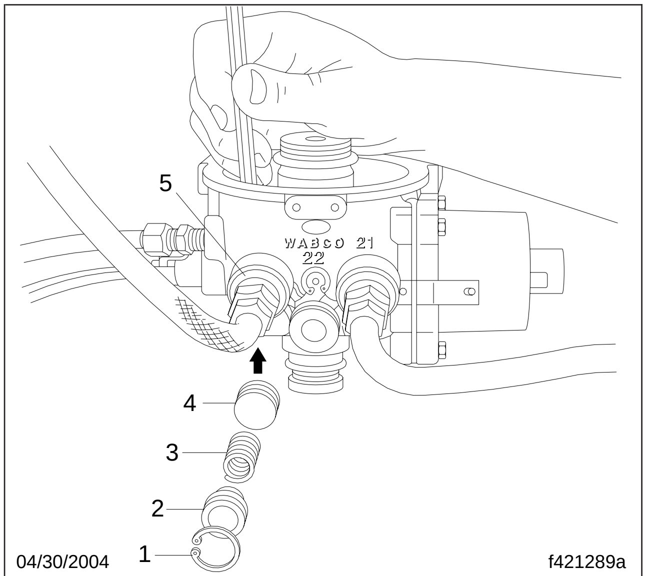
1. Position the air dryer on the mounting bracket. Install the spacers, washers, and capscrews. Tighten them 22 to 30 lbf·ft (30 to 41 N·m). See **Fig. 1** .
2. Make sure the air lines are clean. Replace any line or fitting that is crimped or damaged.
3. Connect the remaining air lines to the air dryer as previously marked. Tighten the nut on each fitting finger-tight. Then, using two wrenches to prevent twisting the hose, further tighten the nut until there is firm resistance.
4. Connect the air dryer wiring harness.
5. Pressurize the air system and check for leaks. Repair as necessary.

Replacement

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.
2. Remove the snap ring at the bottom of the valve assembly. The valve cover and spring may fall out of the cavity when the snap ring is removed. See **Fig. 1**.



1. Snap Ring
2. Cover
3. Spring
4. Piston
5. Inlet Port

Fig. 1, Push the Piston, Spring, and Cover out of the Valve Cavity

3. Using a strap wrench, turn the desiccant cartridge counterclockwise and remove it.
4. Using a wooden stick, push the piston, spring, and the cover out of the valve cavity.
5. Clean the valve cavity with a commercial cleaning solvent.
6. Install new O-rings on the piston and the cover.
7. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the new O-rings and the valve cavity.
8. Install the new piston with its hollow side facing out.

IMPORTANT: If the valve cavity is damaged, preventing a tight seal, replace the air dryer.

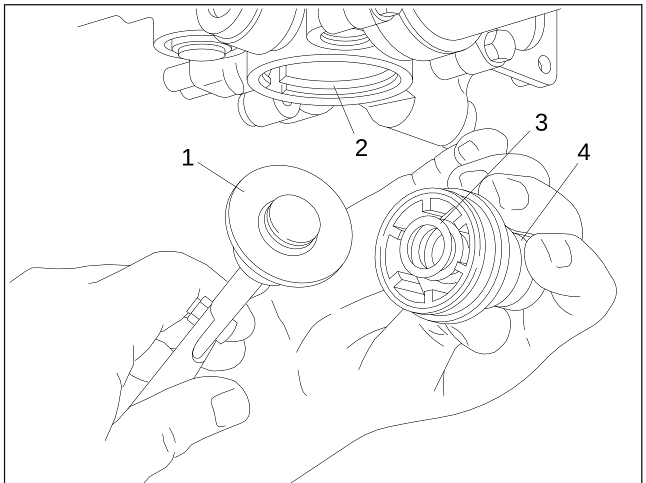
9. Install the new spring, cover, and snap ring to hold the components in place.
10. Thread the desiccant cartridge onto the dryer base (turn clockwise). When the seal contacts the base, tighten the cartridge one complete turn more. Do not over-tighten.

Replacement

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.
2. Remove the snap ring, valve head, and the spring from the exhaust port. See **Fig. 1**.



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1. Valve Assembly
2. Exhaust Port
3. Spring
4. Valve Head

Fig. 1, Remove the Valve Assembly

3. Pull the valve assembly out of the exhaust port.
4. Remove the O-ring from the base of the exhaust port.
5. Clean the purge valve cavity area with a commercial cleaning solvent.
6. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the O-rings and the valve cavity. Install the O-rings in the base of the exhaust port and on the valve head.
7. Position the new valve assembly in the valve cavity.

IMPORTANT: If the valve cavity is damaged, preventing a tight seal, replace the air dryer.

8. Install the spring in the valve head, and position them in the valve cavity.
9. Install the snap ring to secure the valve head in position.

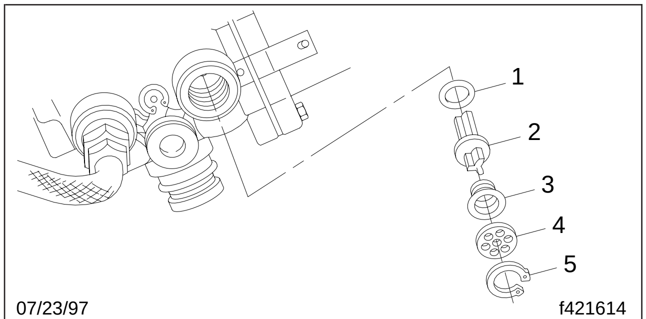
Outlet Check Valve Assembly Replacement

Replacement

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.
2. Disconnect the air line from the outlet port. See Fig. 1.



1. O-Ring
2. Valve Body
3. Spring
4. Washer
5. Snap Ring

Fig. 1, Outlet Check Valve Assembly

3. Remove the snap ring, washer, valve body, and the O-ring.
4. Clean the cavity area with a commercial cleaning solvent.
5. Install a new O-ring on the valve body.
6. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the new O-ring and the valve cavity.
7. Install the new valve body. Make sure that the long end of the body is inserted first into the valve cavity.
8. Install the new spring with its small end around the "Y" shaped fins on the valve body.

IMPORTANT: If the valve cavity is damaged, preventing a tight seal, replace the air dryer.

9. Install a new washer and snap ring to secure the assembly in the valve cavity.
10. Connect the air line to the outlet port. Tighten the nut on the fitting finger-tight. Then, using two wrenches to prevent twisting the hose, further tighten the nut until there is firm resistance. Tighten the nut one-sixth turn more.

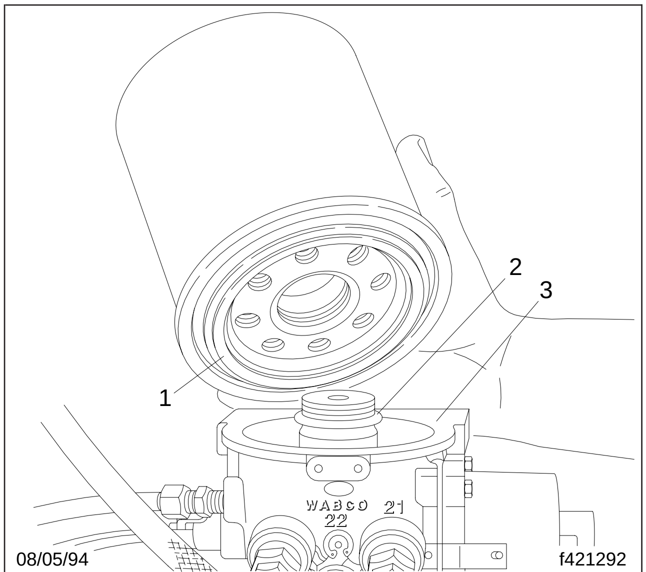
Desiccant Cartridge Replacement

Replacement

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.
2. Using a strap wrench, turn the desiccant cartridge counterclockwise and remove it. See **Fig. 1**.



1. Seal
2. O-Ring
3. Air Dryer Base

Fig. 1, Desicant Cartridge Replacement

3. Remove and discard the O-ring.
4. Clean the top surface of the dryer base with a commercial cleaning solvent.
5. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the new O-ring and the dryer base. Install the O-ring.
6. Thread the desiccant cartridge onto the dryer base (turn clockwise). When the seal contacts the base, tighten the cartridge one complete turn more. Do not over-tighten.

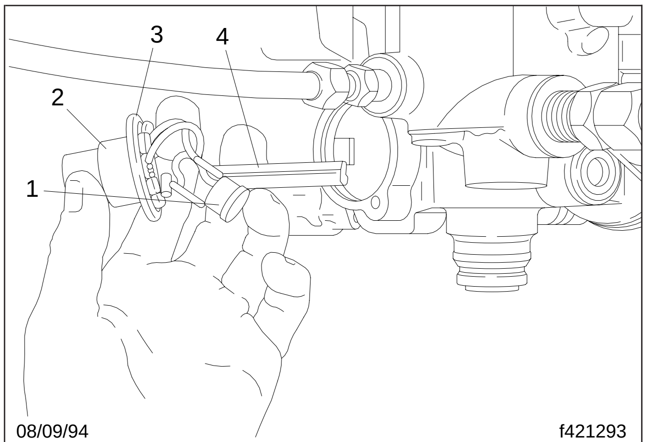
IMPORTANT: If the air dryer base is damaged, preventing a tight seal, replace the air dryer.

Replacement

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.
2. Disconnect the wiring harness.
3. Remove the screws that attach the heater/thermostat receptacle. Remove the receptacle and the O-ring.
4. Remove the retaining screw that holds the assembly in place. Remove and discard the heater/thermostat assembly. See **Fig. 1**.



1. Thermostat
2. Receptacle
3. O-Ring
4. Heater Element

Fig. 1, Heater/Thermostat Replacement

5. Clean the heater/thermostat assembly area with a commercial cleaning solvent.
6. Position the new heater/thermostat assembly in the cavity. Install the retaining screw.
7. Position the new receptacle and O-ring, and install the screws. Tighten the screws securely.
8. Connect the wiring harness.

Replacement

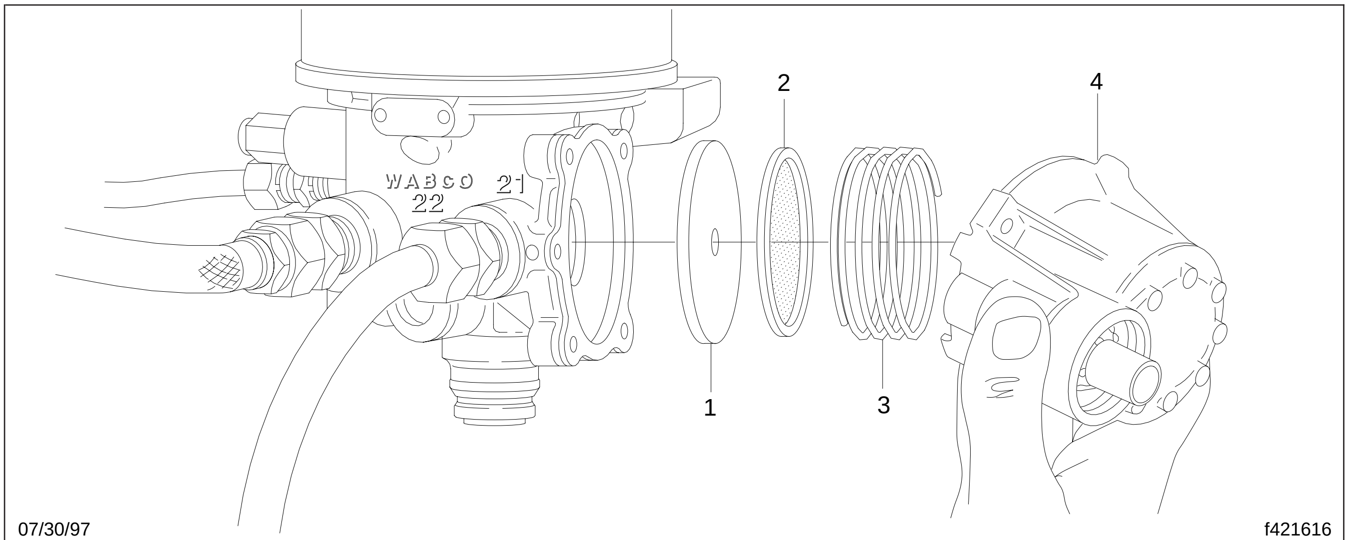
WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.

NOTE: When the valve housing is removed, the spring and the retainer will fall out of the housing. See **Fig. 1**.

2. Remove the four mounting bolts and remove the valve housing assembly.



1. Diaphragm
2. Retainer
3. Spring
4. Valve Housing Assembly

Fig. 1, Regeneration Valve Assembly

3. Remove the rubber diaphragm.
4. Using a commercial cleaning solvent, clean the groove where the diaphragm lip fits.
5. Install a new diaphragm with its lip in the groove.

IMPORTANT: If the groove is damaged, preventing a tight seal, replace the air dryer.

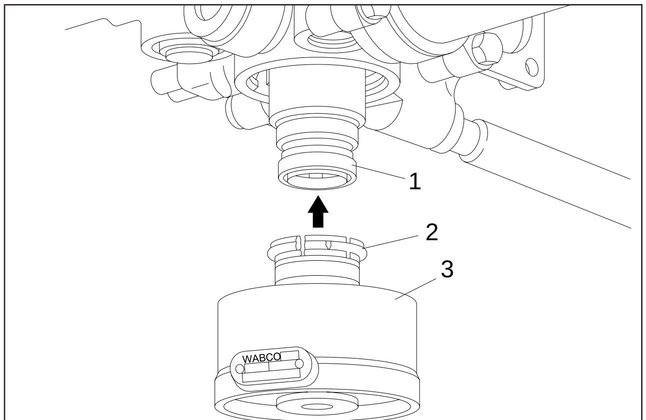
6. Install the new spring and retainer (with the retainer lip facing out).
7. Position the valve housing on the air dryer. Install the bolts and tighten them to 53 lbf·in (600 N·cm).

Replacement

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Using snap ring pliers, expand the snap ring and pull the silencer off of the purge valve head. See **Fig. 1**.



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1. Purge Valve Head
2. Snap Ring
3. Silencer

Fig. 1, Silencer Replacement

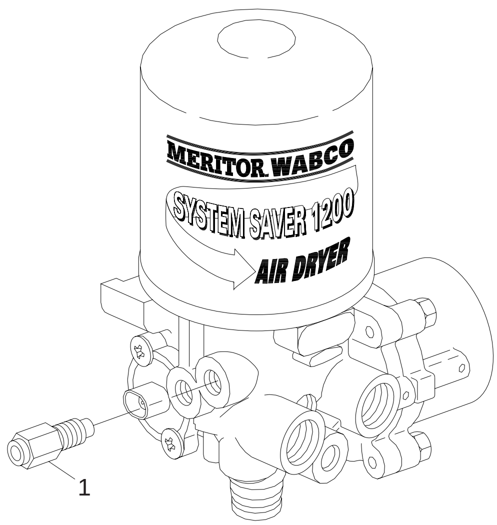
2. Push the new silencer onto the purge valve head until the silencer snaps into place.

Replacement

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.
2. Unscrew and remove the old valve from the dryer. See **Fig. 1**.



1. Pressure Relief Valve

Fig. 1, Pressure Relief Valve Replacement

3. Screw the replacement valve into the dryer base. Do not exceed a torque of 30 lbf·ft (41 N·m) for a 3/8-inch thread, or 65 lbf·ft (88 N·m) for a 1/2-inch thread.

NOTE: The threads on the replacement pressure relief valve provided by Meritor WABCO are coated with sealant. They do not require any additional sealant.

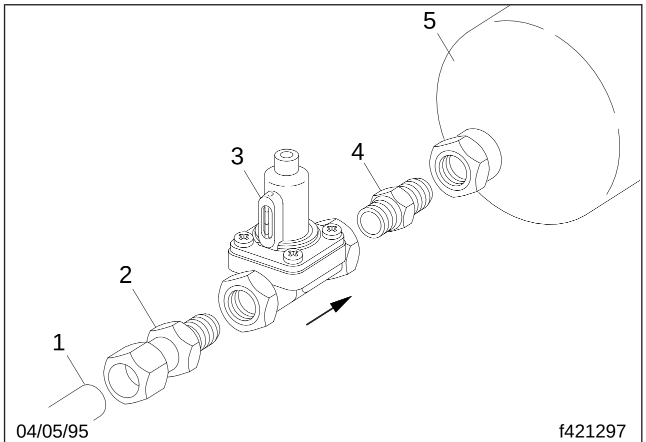
Pressure-Controlled Check Valve Replacement

Replacement

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.
2. Disconnect the air line from the fitting on the valve. See **Fig. 1**.



1. Air Line
2. Nylon Tube Connector
3. Pressure-Controlled Check Valve
4. Hex Nipple Pipe Fitting
5. Air Tank

Fig. 1, Check Valve Assembly Replacement

3. Remove the air-line fitting firm the valve.
4. Remove the valve and the hex nipple fitting from the air tank. Then remove the nipple from the valve.

NOTE: Apply liquid Loctite® Hydraulic Sealant (brown), or an equivalent, to the threads of all fittings before installing them. Always apply sealant to the external threads so that any excess will be scraped off externally rather than internally to the joint.

5. Install the pipe fittings on the new valve. Make sure that the arrow on the valve will be pointing towards the tank when installed.
6. Install the new valve on the air tank.
7. Connect the air line to the air-line fitting on the valve. Tighten the air line securely.

Operating Tests

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

Air Dryer Operating Check

1. Drain the air system.
2. Start the engine and build the air pressure to as close to cutout pressure as possible (about 125 psi [862 kPa]).
3. When the compressor reaches the unload cycle, the air dryer purges, beginning regeneration of the air dryer.
4. During the purge cycle, which lasts about 10 to 15 seconds, the wet tank and secondary system tank with pressure-controlled check valve will drop about 10 psi (69 kPa). Check the secondary system air gauge in the cab dash panel.
5. If the secondary gauge needle does not show a pressure drop of about 10 psi (69 kPa), one of the following problems may exist.
   - A pressure-controlled check valve is not installed.
   - The pressure-controlled check valve is installed in the wrong air tank.
   - The pressure-controlled check valve is installed on a one-way check valve, instead of in place of a one-way check valve.
   - There is an extra check valve located somewhere between the air dryer and the secondary air tank (usually at the wet tank).
   - The secondary air gauge is not plumbed to the secondary air system.
6. If system secondary air pressure drops 25 psi (172 kPa) or more during the purge cycle, and there are no other air-operated components in use, then there are air leaks or other system problems. Refer to **Troubleshooting, 300** for other possible causes.

Pressure-Control Check Valve Operating Check

1. Start the engine and build the air pressure to cutout pressure (about 125 psi [862 kPa]).
2. Stop the engine after the air compressor has unloaded.
3. Drain the supply system air tank down to about 80 psi (552 kPa) or lower.
4. Check the secondary air gauge. It should read 95 ±5 psi (655 ±34 kPa).

   If the gauge reading is less that 90 psi (621 kPa), either the pressure-control check valve is installed backwards, it is damaged, or there are air leaks in the secondary air system.

   If the secondary gauge reading does not change, or the reading does not fall below 100 psi (689 kPa):

   - There is no pressure-controlled check valve installed, or it is installed in the wrong tank.
   - The pressure-controlled check valve is installed into a one-way check valve, rather than in place of a one-way check valve.
   - There is another check valve located between the air dryer and the secondary air tank.
   - The secondary air gauge is not plumbed to the secondary air system.

Troubleshooting Table

Meritor WABCO System Saver 1200 Troubleshooting

Meritor WABCO System Saver 1200 Troubleshooting		
Condition	**Possible Cause**	**Solution**
Dryer leaks from purge valve during compressor-loaded cycle. The leak may cause excessive compressor cycling or prevent the system from building air pressure.	Purge valve frozen open (cold weather operation).	Check heater. Repair/replace if necessary. Make sure governor to dryer port 4 line is free of water/oil.
		Remove and inspect purge valve and clean water/oil from top of piston.
	Debris under purge valve seat, such as particles from fittings or air inlet line.	Disassemble and clean purge valve.
	Purge valve washer installed upside-down.	Remove cartridge and clean dryer sump area. Ensure lip on aluminum washer faces DOWN, away from dryer.
	Wrong air-line connected to dryer port 4 (unloader port).	Verify correct air-line installation and correct as needed.
	Purge valve snap-ring not fully seated in groove.	Seat snap-ring fully into groove.
Slight leak from purge valve. After several hours, the supply tank may be empty.	Outlet check valve not seating or regeneration valve not shutting off regeneration airflow.	Remove, inspect, and clean outlet check valve and regeneration valve diaphragms. Replace if worn or damaged.
Regeneration cycle too long (more than 30 seconds), accompanied by loss of pressure in the supply tank.	Outlet check valve not seating.	Inspect and replace outlet check valve as needed.
	Regeneration valve not shutting off regeneration airflow.	Replace regeneration valve.
Regeneration cycle too short (less than 10 seconds).	High air system demands during compressor unloaded cycle.	Increase air system capacity or reduce air demands.
	Pressure-controlled check valve not installed in system or not working properly.	Check and replace pressur-econtrolled check valve as needed.
	One-way check valve installed in system reservoir instead of, or with, pressure-controlled check valve.	Remove one-way check valve. Make sure pressure-controlled check valve is installed correctly.
	Regeneration valve not working.	Remove regeneration valve and clean oil from diaphragm.
		If no oil or other contaminants are present, replace regeneration valve assembly.
	Air governor not working properly.	Inspect per manufacturer’s instructions and repair/replace as needed.

Troubleshooting

Meritor WABCO System Saver 1200 Troubleshooting		
Condition	**Possible Cause**	**Solution**
No regeneration cycle. No airflow from purge valve after initial purge blast (dryer decompression).	Air dryer not connected to supply tank or connections reversed at dryer.	Verify proper dryer installation per system diagram.
	Regeneration valve not working.	Replace regeneration valve.
	One-way check valve installed in supply tank.	Remove one-way check valve.
	Alcohol evaporator installed between dryer and supply tank.	Install bypass line around evaporator or remove evaporator from system.
Air dryer does not purge when compressor unloads (no blast of air from purge valve).	Air line between governor and air dryer port 4 kinked or plugged.	Repair air line.
	Purge valve stuck closed.	Replace purge valve.
	Air governor not working properly.	Inspect air governor. Repair/replace per manufacturer's instructions.
	Cut-out pressure never achieved by air compressor.	Check for air leaks in system and repair as needed. If no leaks in system, check compressor output. Repair/replace per manufacturer's instructions.
Air dryer purges too often, perhaps as frequently as every 15 seconds, accompanied by excessive cycling of the compressor.	Leak in line between governor and dryer port 4.	Repair air line.
	Leak in line between supply tank and governor.	Repair air line.
	Excessive air system leaks.	Repair leaks.
	Excessive air system demands.	Increase air system capacity or reduce air demand.
	Outlet check valve not seating.	Inspect and replace outlet check valve as needed.
	Regeneration valve not shutting off properly.	Replace regeneration valve.
	Air governor has less than 16 psi range.	Replace air governor.
	Leaking air compressor unloader(s).	Inspect compressor. Repair/replace per manufacturer's instructions.
Air flows out of purge valve entire time compressor is unloaded.	Turbo cut-off valve not sealing.	Replace turbo cut-off valve.
	NOTE: With U Series air dryers the compressor unloads through the dryer, so a steady flow of air is normal.	
Rapid "spitting" of air from purge valve in small amounts. Frequency varies with engine speed.	Holset E-type compressor used, but no Econ valve installed.	Install Econ valve to provide make-up air to compressor.
	Compressor not completely unloading when cut-out pressure is reached.	Inspect compressor. Repair/replace per manufacturer's instructions.

Troubleshooting

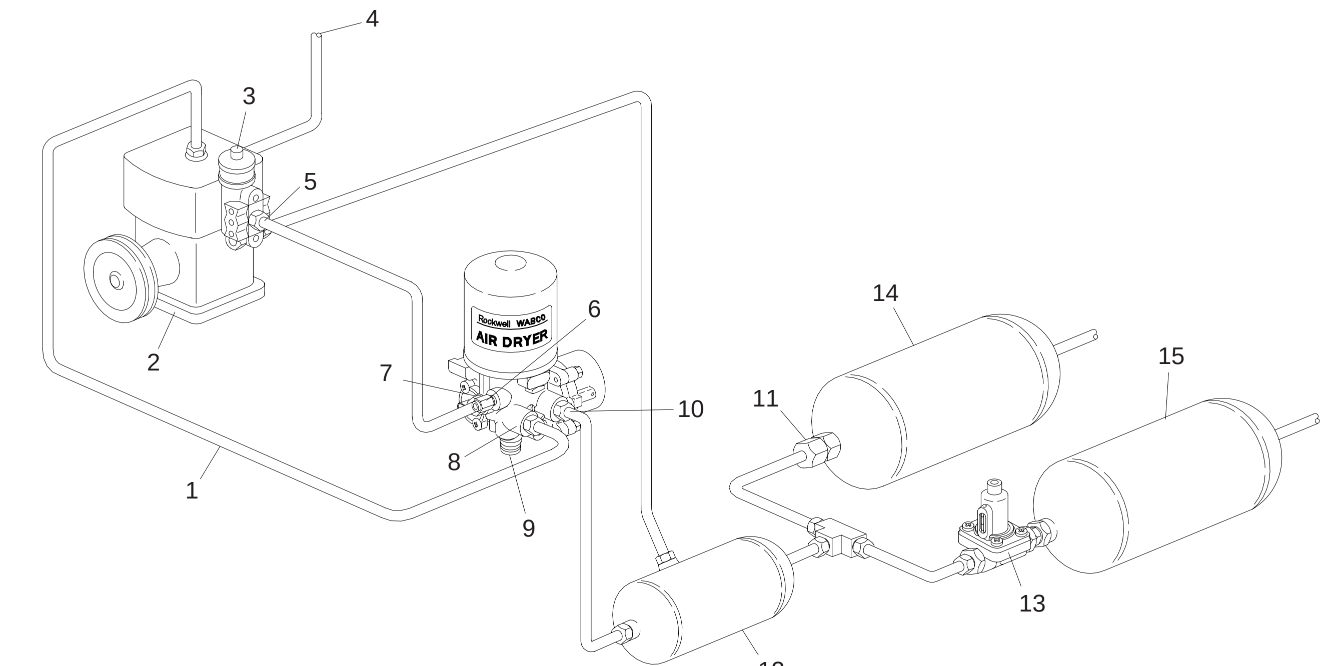
Meritor WABCO System Saver 1200 Troubleshooting		
Condition	**Possible Cause**	**Solution**
Air leak at turbo cut-off valve vent. Hole burned in piston.	Temperature of air coming into dryer is too high—not enough cooling takes place before dryer inlet.	Move dryer farther from compressor. Add additional compressor discharge line before air dryer. Add cooling coil or heat exchanger before air dryer. NOTE: Inlet air temperature must not exceed 175°F (80°C).
Air leak at turbo cut-off valve vent.	Lip seal installed upside-down on piston. Lip must face UP (towards dryer).	Install lip seal correctly.
	Valve bore worn excessively.	Inspect valve bore for wear. If a new turbo cut-off valve does not seal in a clean, lubricated bore, replace the air dryer.
Air dryer frozen (water collecting in base of dryer is freezing).	No electrical power to heater connector.	Check for a blown fuse. Repair heater circuit. NOTE: There must be power to the heater connector the entire time the vehicle's ignition is ON.
	Low voltage to heater connector.	Repair cause of low voltage, such as poor electrical ground, bad connections, corroded wire splices, etc.
	Heater assembly not working.	Replace heater assembly.
	Wrong voltage air dryer used; i.e., 12-volt air dryer used in a 24-volt system.	Replace with correct voltage air dryer.
No air pressure build-up in system.	Air dryer not plumbed correctly (connections reversed).	Ensure compressor discharge line is plumbed to air dryer port 1, and air dryer port 21 is connected to vehicle's supply tank.
	Wrong air line connected to dryer port 4.	Ensure dryer port 4 line is connected to the "UNL" port of the air governor.
	Air governor not working properly.	Inspect governor per manufacturer's instructions. Repair or replace as needed.
	Air system leaks, such as compressor discharge line, air dryer, reservoirs, brake or suspension valves, etc.	Locate leak(s) and repair.
	Air dryer leaks from purge valve.	Refer to purge valve conditions listed in this chart.
Water in tanks; often following aftermarket installation or when dryer is a replacement for a competitive brand.	Pressure-controlled check valve not installed in correct tank or not installed at all.	Install pressure-controlled check valve in secondary tank.
	Pressure-controlled check valve properly installed, but one-way check valve not removed.	Remove one-way check valve so that only the pressure-controlled check valve is installed between the secondary tank and supply tank.

Troubleshooting

Meritor WABCO System Saver 1200 Troubleshooting		
Condition	**Possible Cause**	**Solution**
Water, oil, or sludge in air system tanks.	Desiccant contaminated with oil.	Replace desiccant. Inspect compressor per manufacturer's instructions.
Water in system tanks, everything else checks out okay.	Dryer not suitable for application.	Review application guidelines. For assistance, call Arvin Meritor's Customer Service Center at 800-535-5560.

Specifications

See **Fig. 1** for the plumbing diagram.



1. Compressor Discharge Line
2. Air Compressor
3. Air Governor
4. Compressor Intake Line
5. Unloader Port
6. Pressure Relief Valve
7. Air Governor Port
8. Air Dryer Inlet
9. Purge Valve
10. Air Dryer Outlet
11. Check Valve
12. Supply Tank
13. Pressure-Controlled Check Valve
14. Primary Reservoir
15. Secondary Reservoir

Fig. 1, Air Dryer Plumbing Diagram

General Information

The Bendix PP–DC parking brake air valve is installed on trucks with air brakes, and is used to control the rear axle parking brakes. It is a push-pull type of valve, and is mounted on the right side of the dash.

Principles of Operation

When the valve knob is pulled out, air is exhausted from the parking brake chambers, releasing the springs, and applying the parking brakes. When the knob is pushed in, air flows into the parking brake chambers from the air reservoirs, and compresses the springs, releasing the parking brakes.

The PP–DC has a double check valve feature. The valve uses air pressure from the air system (primary or secondary) with the higher pressure for the parking brakes. If the pressure drops below 20 to 30 psi (138 to 207 kPa) in both air systems, the brakes will automatically apply. The parking brakes will not apply automatically unless pressure is lost from both systems.

Safety Precautions

When working on or around air brake systems and components, observe the following precautions:

- Chock the tires and stop the engine before working under a vehicle. Keep hands away from brake chamber push rods and slack adjusters; the brakes may apply as air system pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Never attempt to disassemble a component until you have read and understood recommended procedures. Some components contain powerful springs and injury can result if not properly disassembled. Use only proper tools and observe all precautions pertaining to use of those tools.

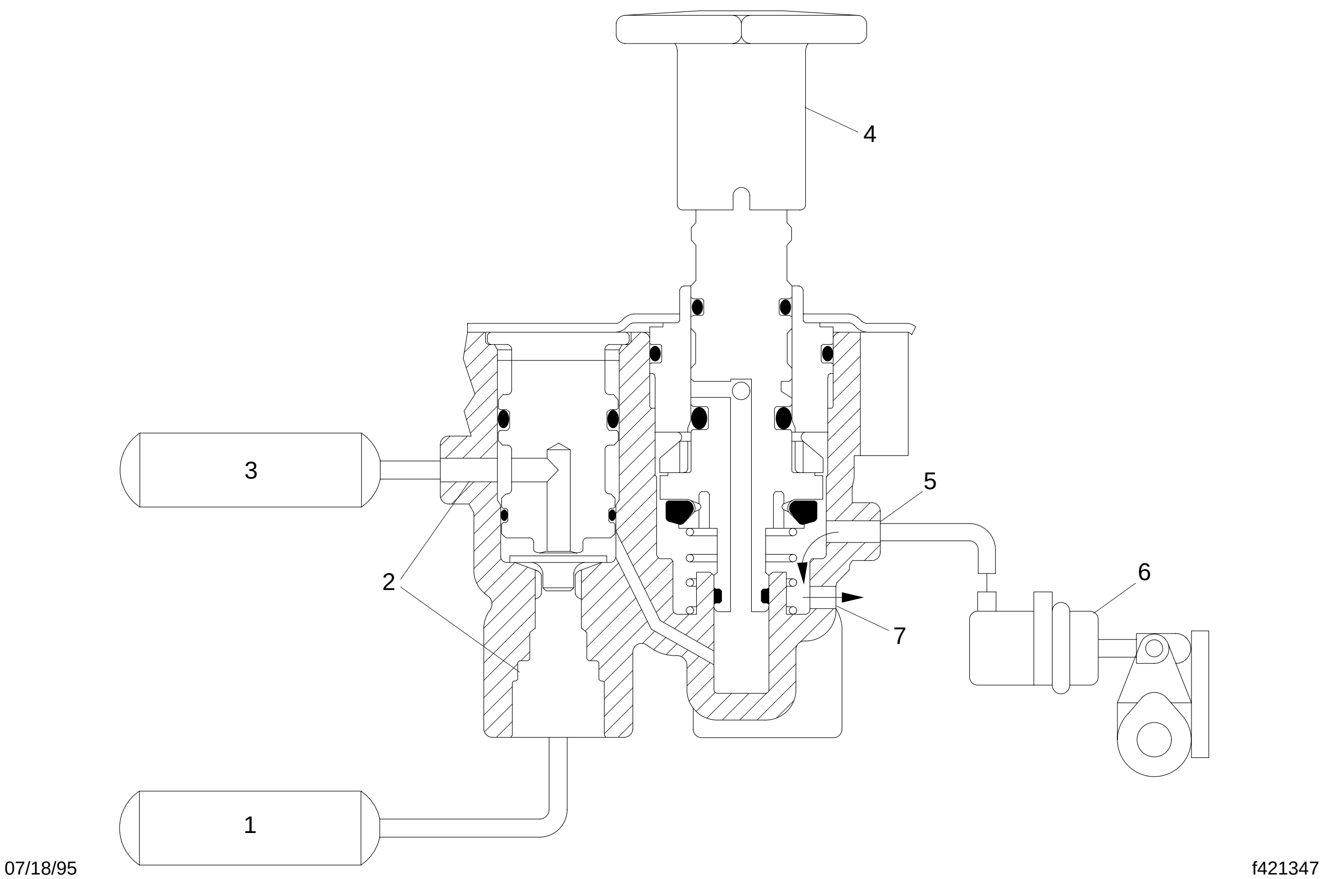
Parking Brake Hand Valve Tests

IMPORTANT: To do the following tests, ensure that two separate 120 psi (827 kPa) vehicle air sources are connected to the PP–DC supply ports. See **Fig. 1.** Tee an accurate test gauge into the supply lines, and provide for a means to control supply line pressure. Connect a small volume air source with a gauge to the delivery port.

Operating Test

1. Chock the tires.
2. Start the engine and build up the air pressure to the normal operating level.
3. With the valve knob pulled out, supply either supply port with 120 psi (827 kPa) of pressure. Push the valve knob in. Air pressure should rise in the delivery line and equal supply line pressure.

   Pull the valve knob out. Delivery pressure should exhaust to zero.
4. Build air pressure to each supply source to 120 psi (827 kPa). Decrease supply pressure at the secondary service reservoir supply port at a rate of 10 psi (69 kPa) per second.



1. Primary Service Reservoir
2. Supply Port
3. Secondary Service Reservoir
4. Valve Knob
5. Delivery Port
6. Brake Chamber
7. Exhaust Port

Fig. 1, Parking Brake Hand Valve (sectional view)

Parking Brake Hand Valve Tests

Primary supply pressure and delivery pressure should not drop below 100 psi (689 kPa). Repeat this step for decreasing primary service reservoir pressure.

5. Build air pressure to each supply source to 120 psi (827 kPa). Then, decrease both supply pressures to below 20 to 30 psi (138 to 207 kPa). The valve knob should automatically pop out when the pressure is within that range.

NOTE: Normally, the valve will pop out. In the event that it does not pop out, make sure that the brakes are applying as they are supposed to. If the brakes are working correctly, the valve is still functioning properly.

6. If the valve does not work as described, repair the valve or replace it following instructions under **Subject 130.**

Leak Testing

1. Chock the tires.
2. Supply the valve with 120 psi (827 kPa) from the primary reservoir supply port.
3. With the valve knob pulled out, coat the exhaust port and the plunger stem with a soapy solution. Leakage at either fitting should not exceed a 1-inch (2.5 cm) bubble every five seconds. There should be no leakage from the secondary reservoir supply port.
4. Supply the valve with 120 psi (827 kPa) from the secondary reservoir supply port. There should be no leakage from the primary reservoir supply port.
5. With the valve knob pushed in, coat the exhaust port and the plunger stem with a soapy solution. Leakage at the fittings should not exceed a 1-inch (2.5 cm) bubble every three seconds. If it does, replace or repair the valve, following instructions in **Subject 130.**

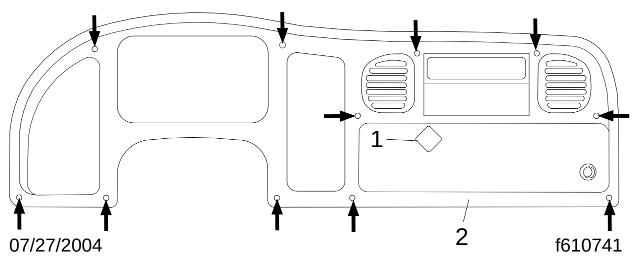
Parking Brake Hand Valve Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

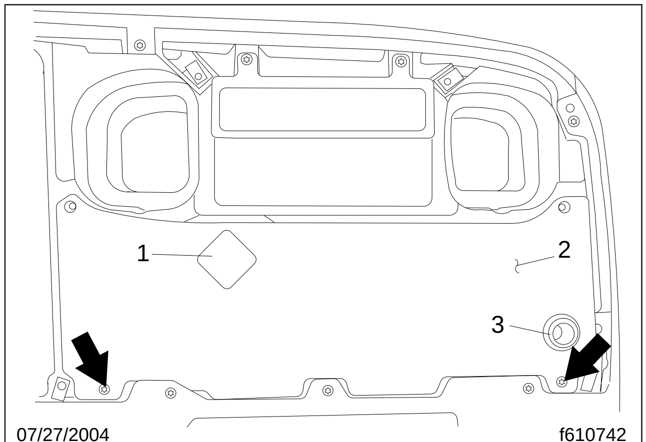
1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system and disconnect the batteries.
3. Remove the screws from the dash panel and remove the panel. See **Fig. 1**.



1. Park Brake Valve Knob
2. Dash Panel

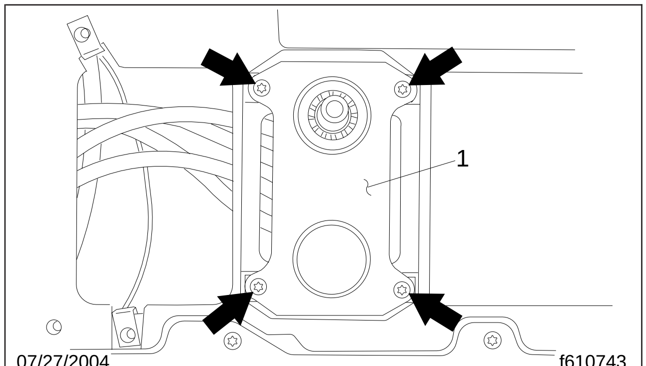
Fig. 1, Dash Panel Screws

4. Unscrew the knob from the stem of the spool on the PP-DC valve by turning it in a counterclockwise direction. Mark the knob in relation to the valve for later reference.
5. Remove the interior panel. See **Fig. 2**.
   - 5.1 Remove the two remaining screws securing the panel to the dash.
   - 5.2 Pull the panel out far enough to access the back of the cigarette lighter and mark and disconnect the two wires.
   - 5.3 Remove the panel.
6. Remove the four screws that attach the valve to the mounting panel. See **Fig. 3**. Remove the valve far enough to access the air line connections on the back.



1. Park Brake Valve Knob
2. Interior Dash Panel
3. Cigarette Lighter Receptacle

Fig. 2, Interior Dash Panel Screws



1. PP-DC Control Valve

Fig. 3, Valve Mounting Screws

7. Mark the air lines for later reference. Disconnect the lines from the module assembly and remove the module.

NOTE: The primary supply line is green. The exhaust line is yellow. The parking brake delivery line is black.

Installation

1. Position the valve and connect the air lines to the applicable fittings.
2. Install the valve and install the four mounting screws. See **Fig. 3**.

Parking Brake Hand Valve Removal and Installation

3. Install the interior panel.
    3.1 Position the interior panel and connect the cigarette lighter to the power connections previous removed.
    3.2 Secure the panel using the screws previously removed. See **Fig. 2**.
4. Attach the knob onto the threaded stem of the valve plunger, making sure it is correctly oriented as noted during removal.
5. Leak test the fittings following the instructions in **Subject 110**.
6. Install the dash panel and mounting screws. See **Fig. 1**.
7. Connect the batteries.
8. Remove the chocks from the tires.

Parking Brake Hand Valve Disassembly and Assembly

Disassembly

1. Remove the valve assembly from the dash, following the instructions in **Subject 120.**
2. Put the valve assembly in a soft-jawed or padded vise.
3. Remove the screws that attach the cover to the body. Remove the cover. See **Fig. 1.**
4. Pull the plunger stem and remove the plunger and guide spool from the body.
5. Remove and discard the plunger spring.
6. Using a screwdriver (if needed), carefully remove the check valve seat from the body. Use care not to damage either the check valve seat or the valve body.
7. Remove and discard the check valve seat O-rings.
8. Turn the body upside down and gently tap it on a flat surface to remove the check valve. Discard the check valve.
9. Remove the guide spool from the plunger. Remove and discard the O-ring.
10. Remove and discard the O-rings from the plunger. Also, remove and discard the exhaust seal.

Assembly

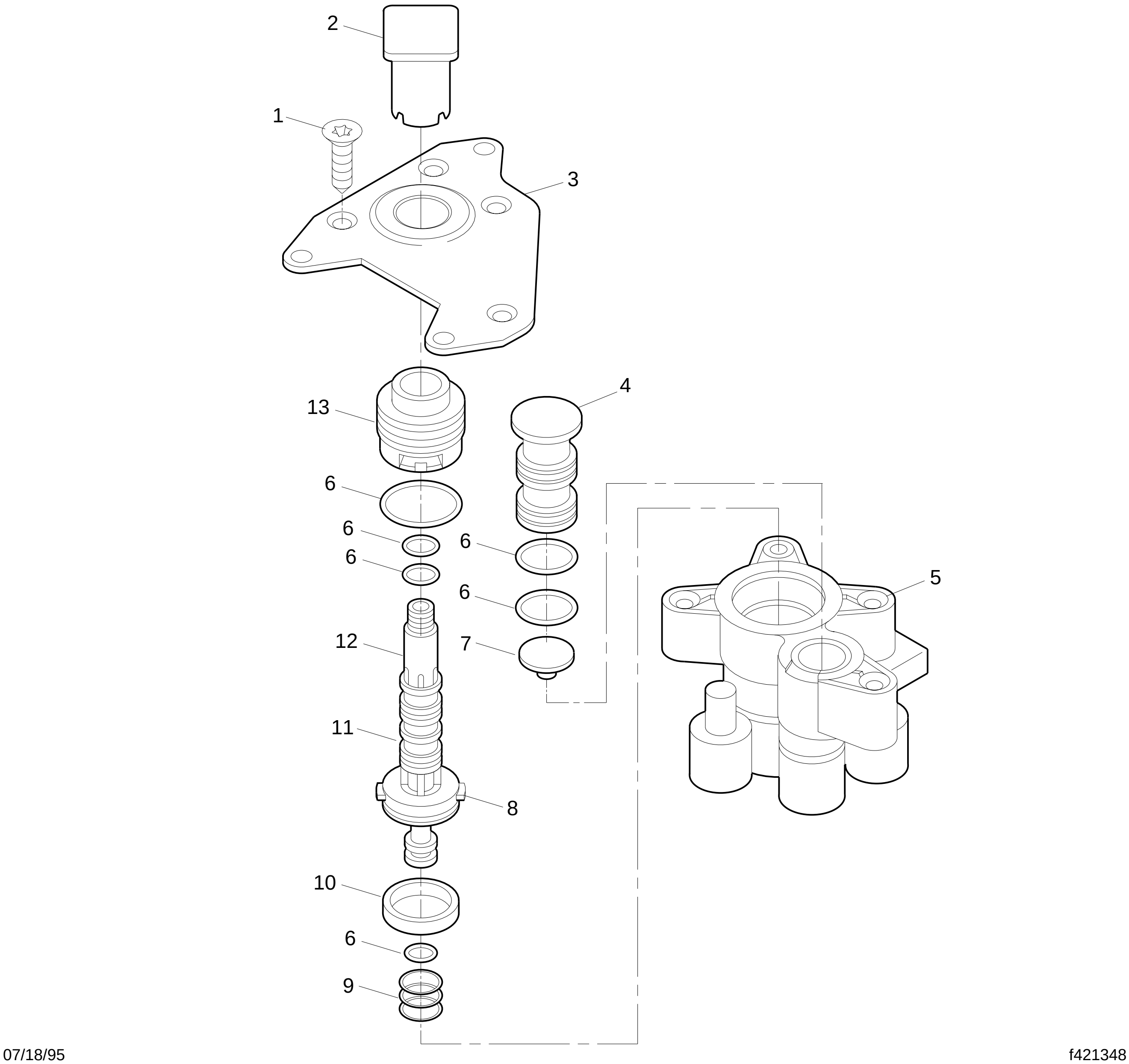
1. Clean and dry all the parts. **See Fig. 1.**
2. Check all the parts. Replace a part if any wear or damage is found.
3. Lightly grease all the parts—including the new parts from the maintenance kit—with Dow Corning 55 silicone pneumatic grease or equivalent.
4. Position the check valve in its seat in the body with the flat surface of the valve facing up. If needed, reach into the body to make sure that the valve is seated evenly in the bore.
5. Install the O-rings on the check valve seat and install the assembly into the body. Make sure that the check valve seat is even with the valve body surface.
6. Install the plunger spring into the body. Make sure that the spring is upright and seated properly in the body bore.

NOTE: The plunger spring should surround the protrusion or "lip" at the bottom of the body bore.

7. Install the O-rings onto the plunger, then install the plunger into the body.

   For ease of installation, line up the plunger's index tabs with the spaces in the body bore.
8. Install the O-ring on the guide spool. Install the spool over the plunger and into the body. Firmly press the guide spool into position.
9. Install the screws that attach the cover to the body. Tighten the screws 35 lbf·in (400 N·cm).
10. Install the valve in the dash, then leak test it. Follow the instructions in **Subject 120** for installation and **Subject 110** for leak testing.

Parking Brake Hand Valve Disassembly and Assembly



1. Screw
2. Valve Knob
3. Cover
4. Check Valve Seat
5. Valve Body
6. O-Ring
7. Check Valve
8. Index Tab
9. Plunger Spring
10. Exhaust Seal
11. Plunger
12. Plunger Stem
13. Guide Spool

Fig. 1, Exploded View

General Information

The Bosch parking brake is a lever-actuated, duo-servo, single-anchor drum brake. See **Fig. 1**. The brake is designed for driveline-mounted applications typically on the rear axle yoke. Its self-adjusting feature enables the brake to maintain a consistent functional clearance between the brake shoes and the drum as the shoe linings wear.

Major Components

The foundation of the brake is a ductile iron backing plate that mounts to the differential pinion housing with four capscrews. Major actuating components are a cam and a lever, which are fastened to the backing plate by an anchor screw. An anti-rattle spring under the head of this screw prevents clatter. The anchor point for brake actuation and shoe abutment is located at the 12 O'clock position when the assembly is properly mounted. See **Fig. 2**.

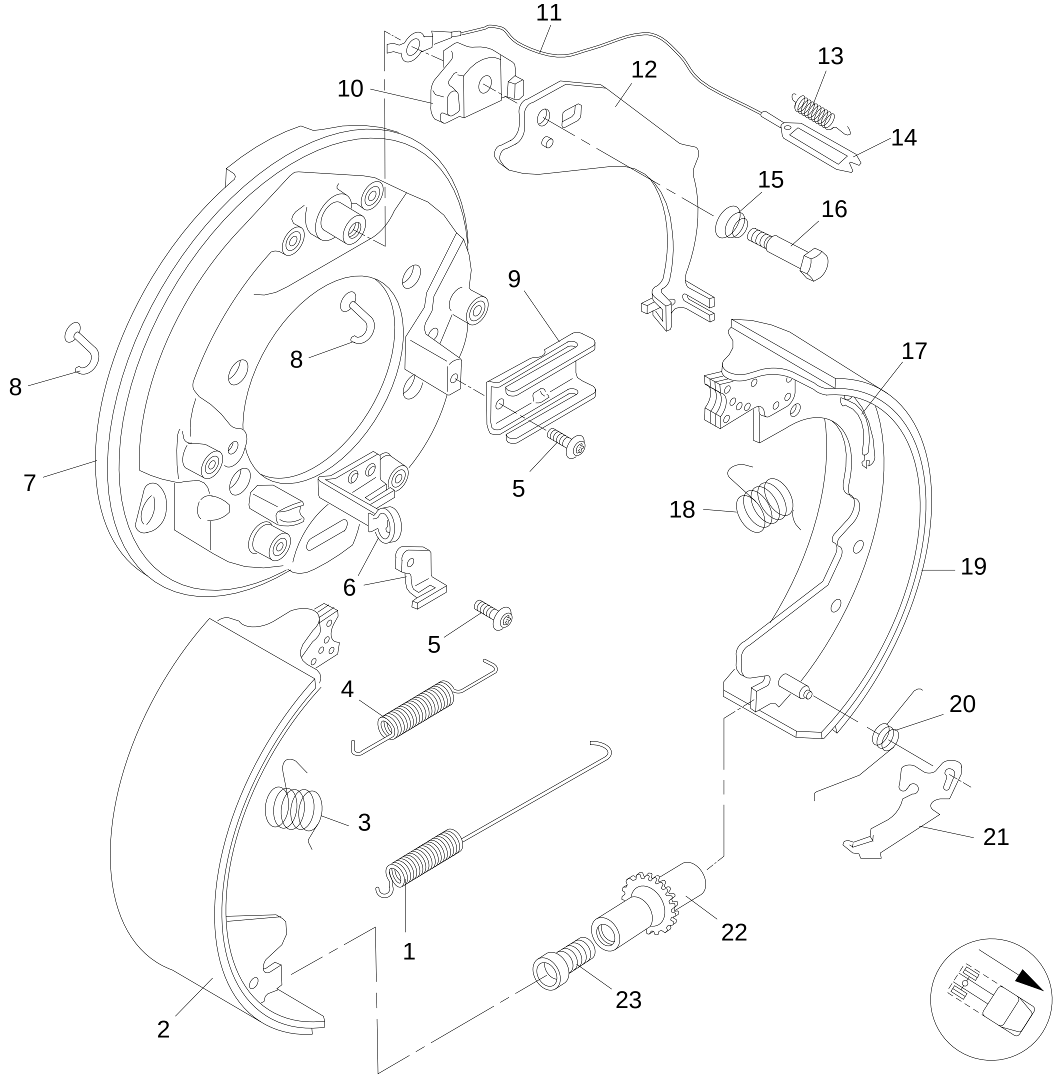
NOTE: The parking brake drum is not a Bosch part, it is a stamped steel drum supplied by Meritor.

Brake Shoes and Related Components

Brake shoes are attached to the backing plate by hold-down springs and pins. See **Fig. 2**. Both shoes seat against the backing plate anchor post at the top and are connected by the adjuster nut and screw assembly at the bottom. Shoe hold-down brackets are permanently mounted to the backing plate to assist in guiding the shoes. The shoes are pulled toward each other by two low-tension shoe-return springs. Proper orientation of the various springs, including their hook ends, must be maintained for the brake to function properly. The starwheel used for adjusting shoe clearance to the drum is on the adjuster nut. See **Fig. 3**.

The clearance between the shoe linings and the inside drum surface is adjusted in response to excessive movement of a given shoe when the brake is actuated. This excessive movement is typically due to normal wear of the lining during use. The adjuster cable is anchored at the top, by the anchor screw, routed along the side of the shoe by a cable guide, and attached to the auto-adjuster lever via a spring, assembled on the cable end-fitting, at the bottom of the brake. The adjuster lever seats against the starwheel on the adjuster nut and rotates the starwheel when adjustment is necessary. See **Fig. 4**.

General Information



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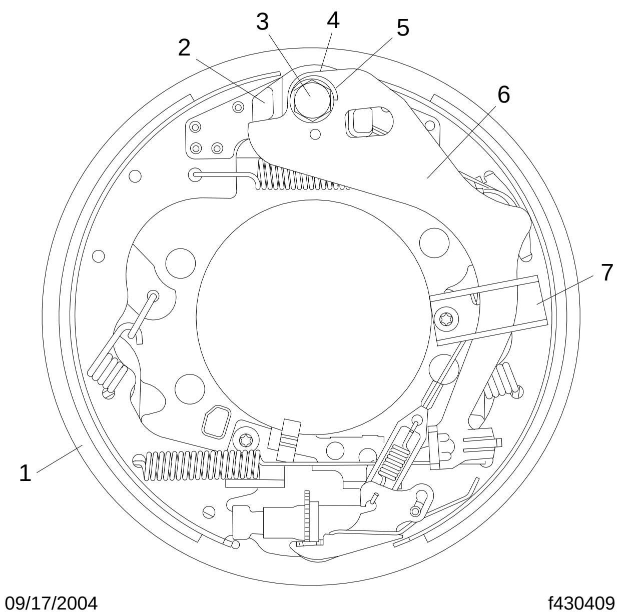
NOTE: The brake drum and brake mounting components are not shown.

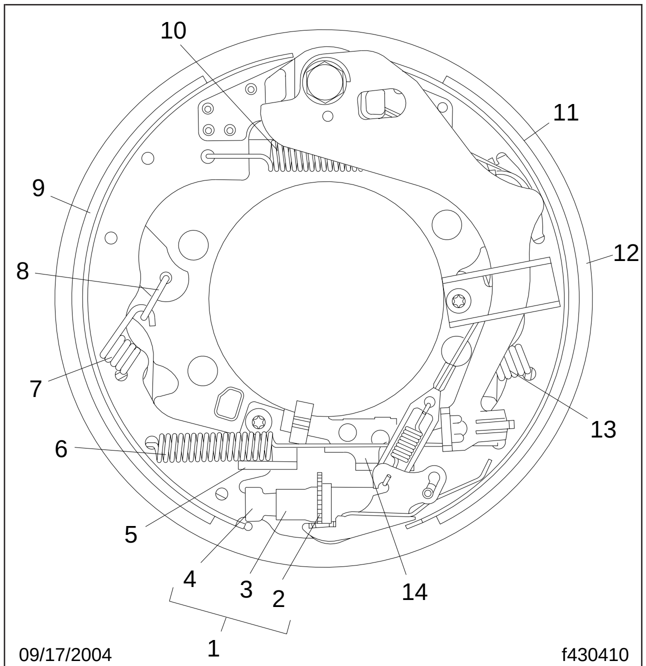
1. Lower Return Spring
2. Right Brake Shoe
3. Hold-Down Spring
4. Upper Return Spring
5. Screw
6. Hold-Down Bracket
7. Backing Plate
8. Hold-Down-Spring Pin
9. Lever Guide
10. Cam
11. Adjuster Cable
12. Lever
13. Adjuster Cable Spring
14. Spring End Fitting
15. Anti-Rattle Spring
16. Anchor Screw
17. Adjuster Cable Guide
18. Hold-Down Spring
19. Left Brake Shoe
20. Auto-Adjuster Spring
21. Auto-Adjuster Lever
22. Adjuster Nut
23. Adjuster Screw

Fig. 1, Bosch Parking Brake (exploded view)



1. Backing Plate
2. Cam
3. Anchor Screw
4. Anchor Point
5. Anti-Rattle Spring
6. Lever
7. Lever Guide

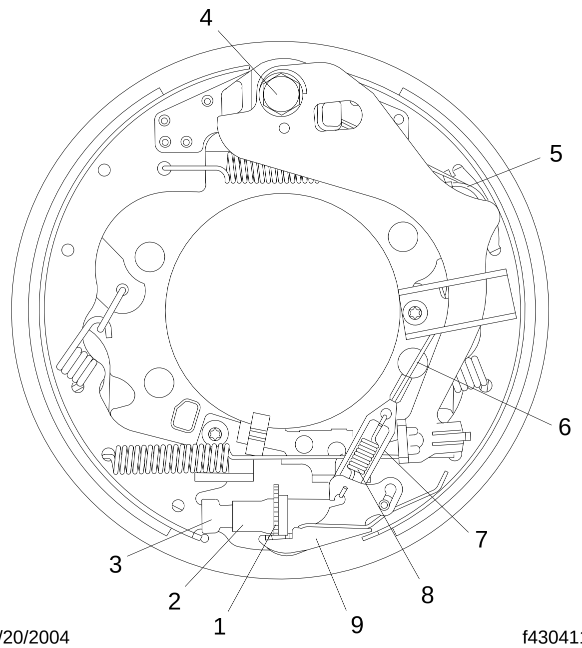
Fig. 2, Parking Brake Major Components



1. Adjuster Nut and Screw Assembly
2. Starwheel
3. Adjuster Nut
4. Adjuster Screw
5. Shoe Hold-Down Bracket
6. Lower Shoe Return Spring
7. Hold-Down Spring
8. Pin (opposite side not shown)
9. Brake Shoe
10. Upper Shoe Return Spring
11. Brake Shoe
12. Backing Plate
13. Hold-Down Spring
14. Shoe Hold-Down Bracket

Fig. 3, Brake Shoes and Related Components

General Information



1. Starwheel
2. Adjuster Nut
3. Adjuster Screw
4. Anchor Screw
5. Cable Guide
6. Adjuster Cable
7. Spring End Fitting
8. Adjuster-Cable Spring
9. Auto Adjust Lever

Fig. 4, Shoe Cage Adjusting Components

Safety Precautions

WARNING

Breathing brake lining dust could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by NIOSH or MSHA. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

During brake servicing, wear an air purifying respirator with high-efficiency filters. The respirator and filter must be approved by NIOSH or MSHA, and worn during all procedures.

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency particulate air (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, or can not be used, clean the brake assembly in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with an HEPA filter system, remove dust from the brake components. After vacuuming, remove any remaining dust using a rag soaked in water and wrung until nearly dry.

IMPORTANT: During service procedures, keep grease and other foreign material away from the drum and brake shoes. Handle parts carefully to avoid damage to brake components.

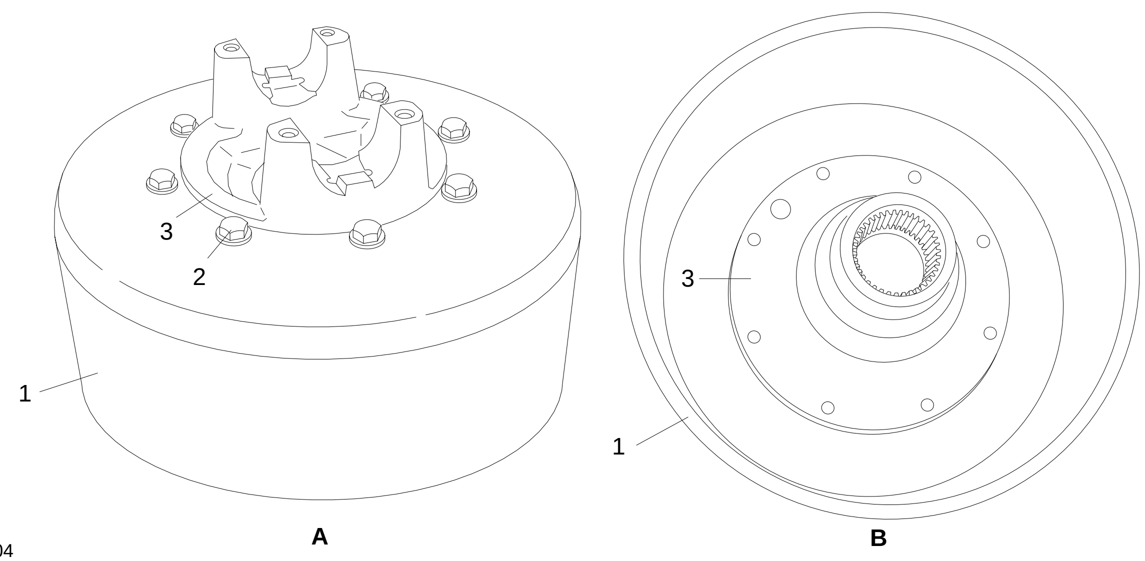
General Information

The driveline parking brake uses a stamped steel drum supplied by Meritor. See **Fig. 1**. The drum can be removed without removing the axle-input-flange-yoke from the pinion shaft. However, if you are going to work on the rest of the parking brake assembly, it is easier to remove the flange-yoke along with the drum.

1. Park the vehicle on a level surface, shut down the engine, and chock the front tires.
2. Raise the vehicle so that the axles can turn freely, and secure it on jack stands.

NOTE: Flange and driveshaft configurations will vary with the axle application.

3. Mark the position of the driveshaft in relation to the differential flange-yoke, then unbolt the driveline and secure it out of the way. See **Group 41**.



A. Outside View
B. Inside View
1. Drum
2. Capscrew and Washer
3. Flange-Yoke

Fig. 1, Drum and Flange Assembly (typical)

Removal

⚠ WARNING

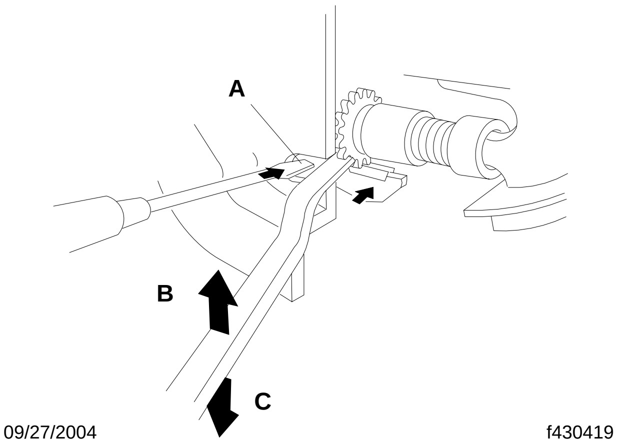
Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

IMPORTANT: Do not use a drum puller or a torch to remove a brake drum. Drum distortion may result.

4. If you are removing the drum only, mark the position of the drum on the flange-yoke, then remove the eight capscrews and washers that hold the drum to the yoke flange, then pull the drum off of the flange. If the drum is difficult to remove, insert a narrow screwdriver through the brake adjusting hole in the backing plate and disengage the adjuster lever from the adjuster nut teeth. With the adjuster lever disengaged (see **Fig. 2**), insert a brake adjusting tool through the adjusting hole to engage the adjusting nut teeth. Move the teeth upward enough times to retract the brake shoes to clear the drum. If the drum is

Drum Removal and Installation

rusted to the axle-input-flange-yoke pilot, tap the center of the brake drum with a non-metallic mallet to loosen it.



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Push the lever away from the starwheel to decrease the brake shoe spread.

A. Expand Shoe Spread
B. Decrease Shoe Spread

Fig. 2, Brake Adjustment

5. If you are removing the drum and flange, mark the position of the flange on the pinion shaft, then remove the flange nut and slide the drum and flange off of the pinion shaft spline as an assembly.

Installation

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

1. Clean the mounting surface of all dirt, drebris, grease, and oil.
2. If you removed the drum only, position the drum on the flange-yoke as marked during removal, then install the capscrews and washers. Tighten to 48 lbf·ft (65 N·m).
3. If you removed the drum and flange as an assembly, position the assembly on the pinion spline as marked during removal, then install the pinion nut. See **Group 35**.
4. Attach the driveline. See **Group 41**.
5. Adjust the brake shoes. See **Subject 140**.
6. Lower the vehicle.
7. Test the brake for proper operation before returning the vehicle to service.

Removal

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

1. Park the vehicle on a level surface, shut down the engine, and chock the front wheels.
2. Place the transmission in gear and release the parking brake.
3. Raise the rear of the vehicle so the wheels clear the floor, and install jack stands.
4. Mark the position of the driveshaft in relation to the differential, then unbolt the driveshaft from the differential and secure it out of the way. See **Group 41**.
5. Remove the drum. See **Subject 110**.
6. Inspect the brake. See **Subject 170**.

NOTE: Special tools are available for many of the steps in this procedure. See **Subject 400**.

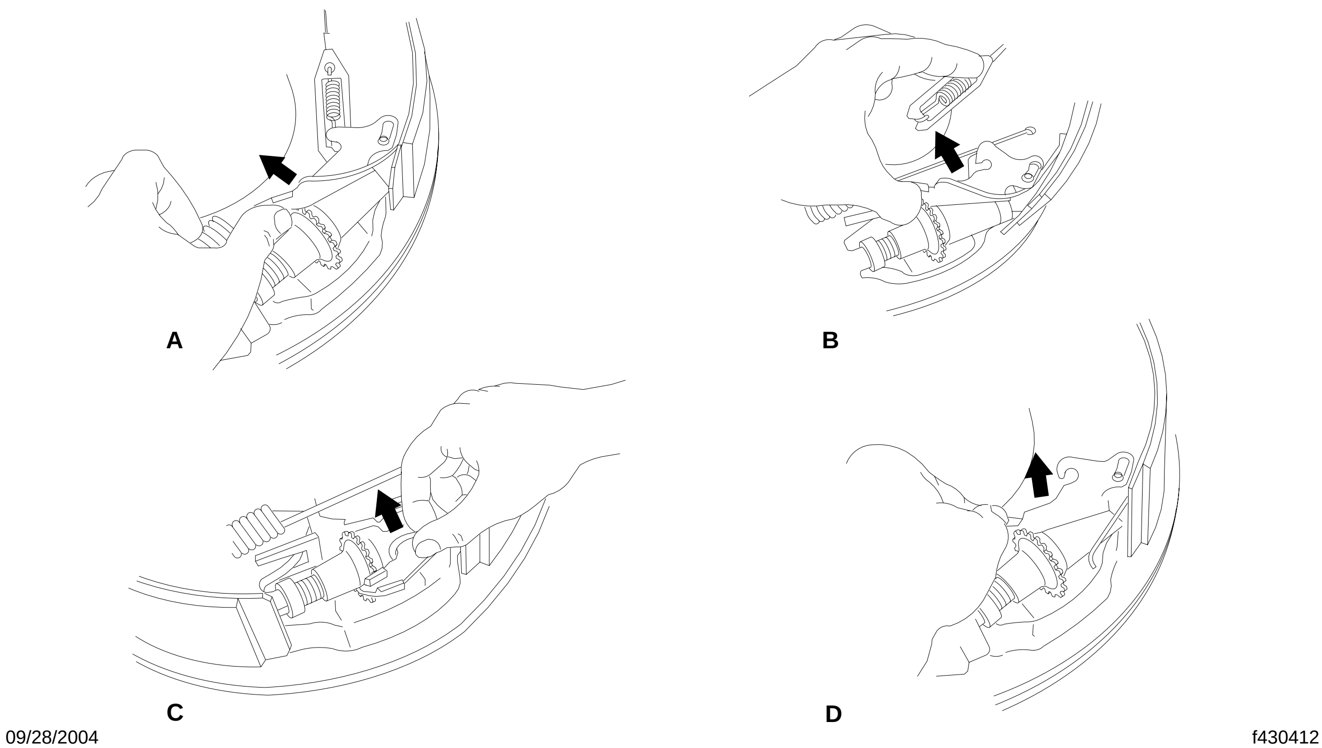
7. Detach the adjuster cable from the adjuster lever and slide the cable off of the adjuster cable guide. See **Fig. 1**.
8. Remove the adjuster lever and the adjuster spring. See **Fig. 1**. Save the parts for installation.
9. Using pliers, or a special tool, remove both shoe-return springs. See **Fig. 2**.
10. Detach the parking brake cable and the lever return spring from the lever.
11. Remove the anchor bolt and move the lever to provide access to the shoe hold-down spring. **Subject 130** for procedure.
12. Using a brake shoe spring tool or needlenose pliers, remove both of the shoe hold-down springs. See **Fig. 3**.
13. Remove the brake shoes from the backing plate.
14. Disassemble the adjuster nut and screw assembly for cleaning and inspection of the threads.

Installation

Proper orientation of all brake components, particularly the various springs, including their hook-ends must be maintained for proper brake function.

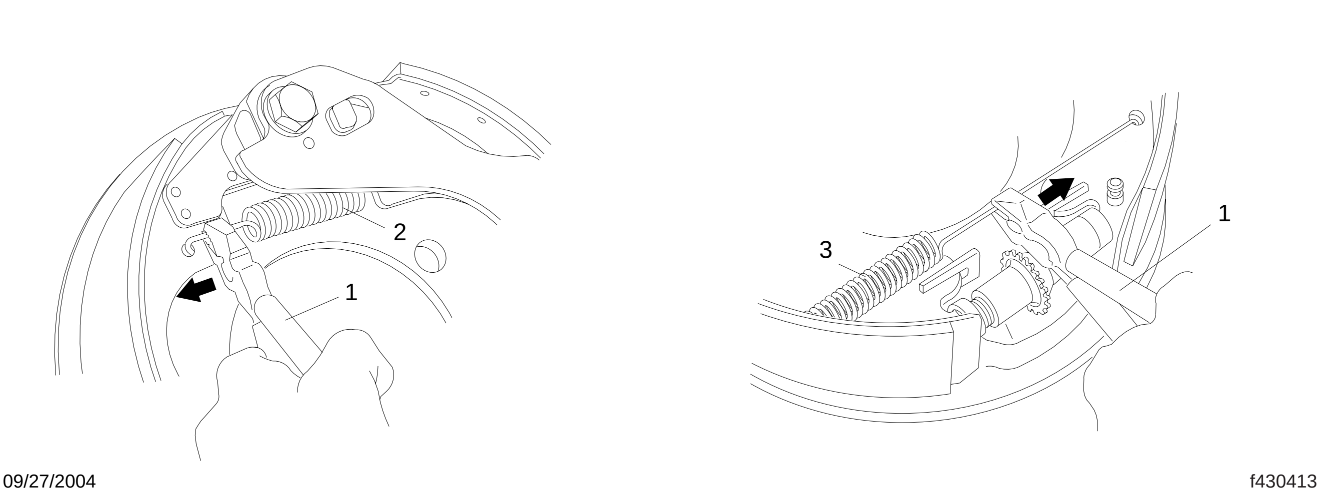
1. Clean the backing plate.
2. Apply a light film of Wolfrakote paste ledge grease, or an equivalent, to the six backing plate shoe ledges and the anchor post. See **Fig. 4**.
3. Apply a Chevron heavy-duty, lithium complex, extreme-pressure grease, or equivalent, to the cam plate lugs where they contact the shoe ends and the brake lever.
4. Apply a Chevron heavy-duty, lithium complex, extreme-pressure grease, or an equivalent, to the threads of the adjuster screw and the socket end of the adjuster nut. Install the screw fully into the adjuster nut. Ensure the screw moves in and out freely. If any damage to the threads prohibits free movement, or if the starwheel is damaged, replace the adjuster assembly.
5. Place one shoe in the installed position. See **Fig. 5**. Make sure the shoe with the adjuster cable guide and adjuster pin is installed on the correct side.
6. Install the shoe hold-down pin. See **Fig. 5**.
7. Position the second shoe and the adjuster nut and screw assembly. See **Fig. 3**. The adjuster nut should be seated against the shoe with the adjuster cable guide and pin. Attach the shoe hold-down spring to the shoe hold-down pin, using a brake spring tool. See **Fig. 3**.
8. Install both shoe-return springs. See **Fig. 5**.
9. Install the adjuster spring and the adjuster lever. Ensure that the adjuster lever is properly seated against the starwheel. See **Fig. 5**.
10. If the lever has been removed, install the lever and its associated components. See **Subject 130**.
11. Route the adjuster cable around the adjuster cable guide, under the shoe hold-down spring, and attach it to the adjuster lever.

Brake Shoe Removal and Installation



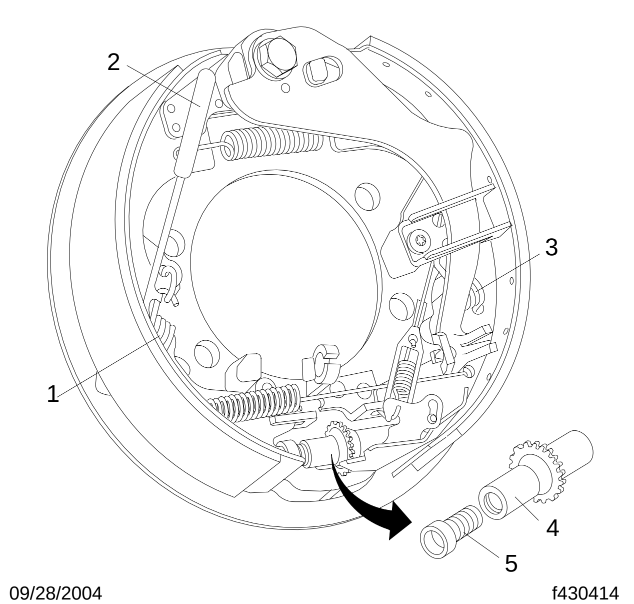
A. Raise the lever off the starwheel and push up.
B. Disengage the spring.
C. Disengage the lever spring.
D. Remove the lever and lever spring.

Fig. 1, Adjuster Lever and Adjuster Spring Removal



1. Pliers
2. Upper Return Spring
3. Lower Return Spring

Fig. 2, Shoe Return Spring Removal

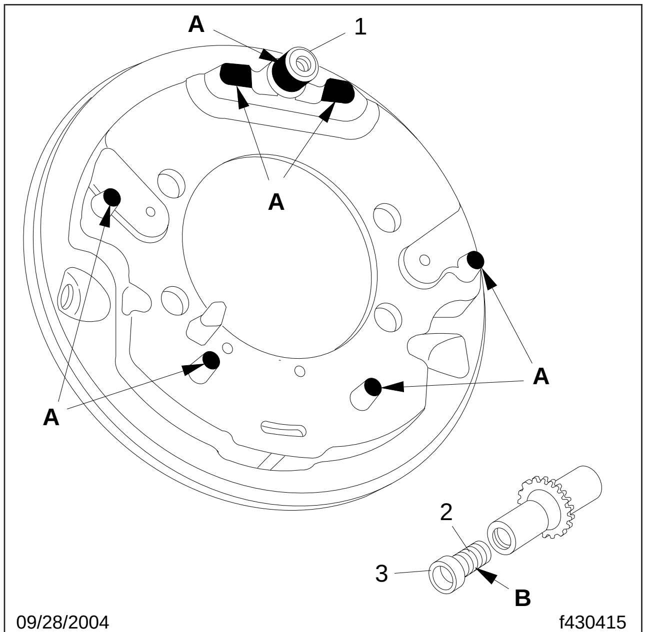


1. Hold-Down Spring
2. Hold-Down Spring Tool
3. Hold-Down Spring
4. Adjuster Nut
5. Adjuster Screw

Fig. 3, Shoe Hold-Down Spring Removal

Correctly assembled, the adjuster cable end-fitting is behind the adjuster lever, with the spring hook facing out. See **Fig. 6**.

12. Adjust the shoe cage. See **Subject 140**.
13. Inspect, service, and install the brake drum. See **Subject 110**.
14. Attach the driveshaft. See **Group 41**.
15. Lower the vehicle.
16. Test the brake for proper function before returning the vehicle to service.

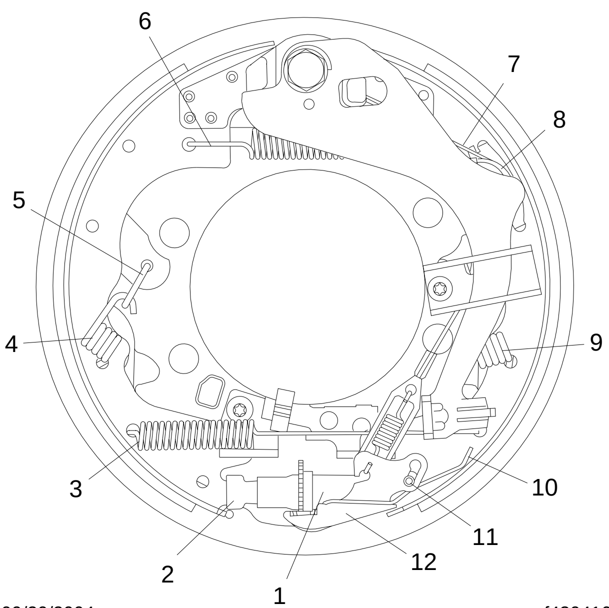


A. Apply Wolfrakote paste ledge grease.
B. Apply Chevron lithium grease.

1. Anchor Post
2. Threads
3. Socket

Fig. 4, Apply Grease to the Wear Points

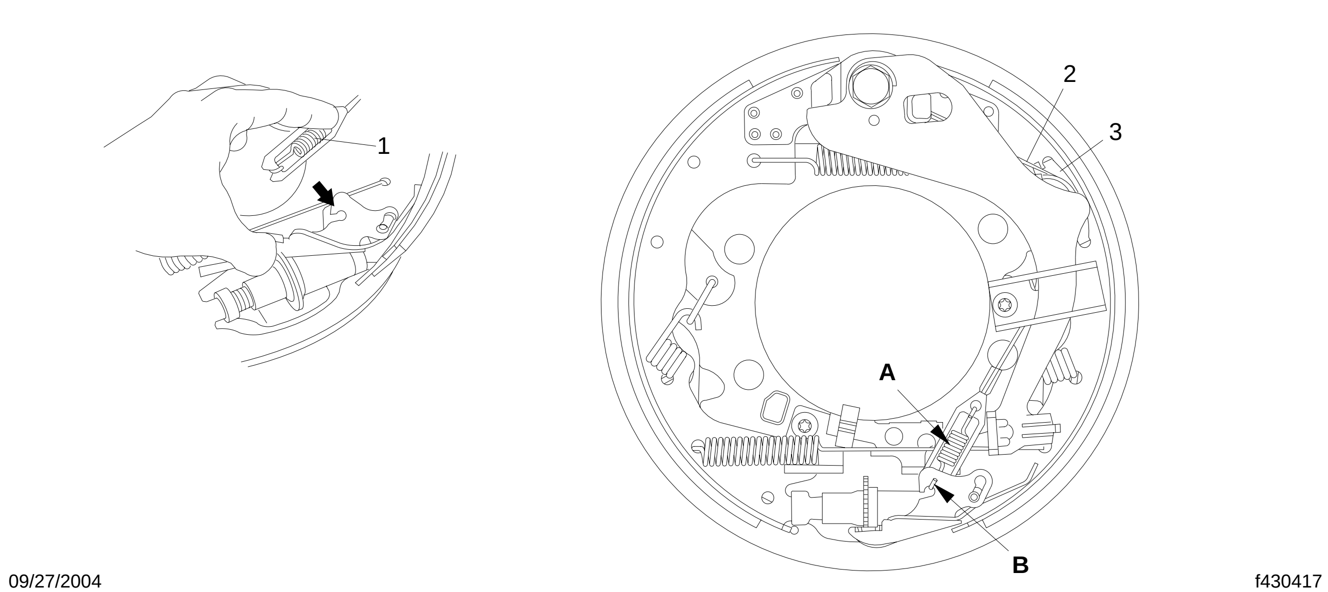
Brake Shoe Removal and Installation



1. Adjuster Nut
2. Adjuster Screw
3. Lower Shoe Return Spring
4. Hold-Down Spring
5. Hold-Down Pin (opposite side not shown)
6. Upper Shoe Return Spring
7. Adjuster Cable
8. Adjuster Cable Guide
9. Hold-Down Spring
10. Adjuster Spring
11. Adjuster Pin
12. Adjuster Lever

Fig. 5, Brake Shoe Installation

Brake Shoe Removal and Installation



A. Correct adjuster spring position.
B. Spring hook faces out when properly installed.
1. Adjuster Spring
2. Adjuster Cable
3. Adjuster Cable Guide

Fig. 6, Adjuster Cable Installation

Anchor Screw, Lever, and Cam Replacement

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

Replacement

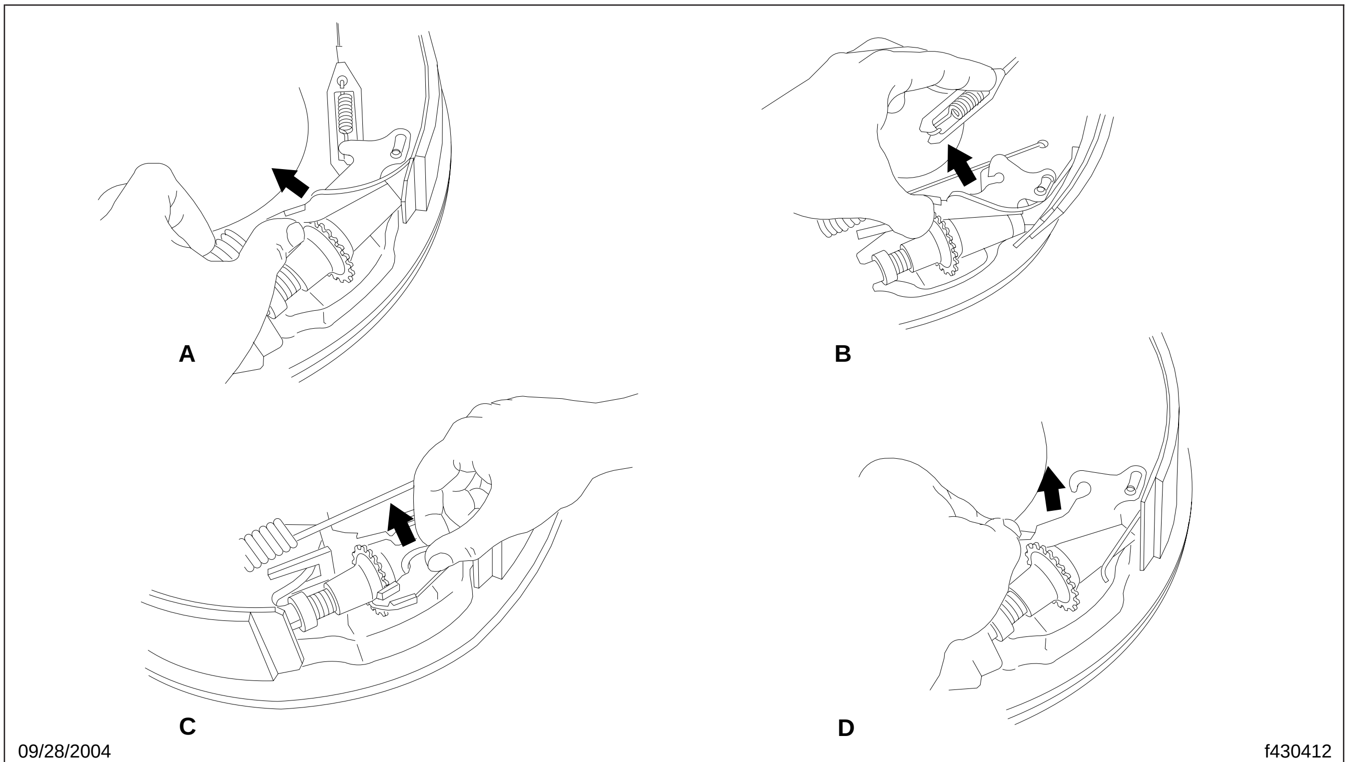
The anchor screw, lever, and cam should all be replaced at the same time. Do not replace just one or two of the three parts at any time. If for any reason the cam, lever, and anchor screw assembly is removed, a complete new set is recommended for service.

1. Park the vehicle on a level surface, shut down the engine, and chock the front tires.
2. Place the transmission in gear and fully release the parking brake.
3. Raise the rear of the vehicle so the wheels clear the floor, and install safety stands.
4. Disconnect the driveshaft and support it out of the way. See **Group 41**.
5. Remove the drum. See **Subject 110**.
6. Inspect the brake. See **Subject 170**.
7. Detach the parking brake cable and spring from the end of the brake lever.
8. Detach the adjuster cable from the adjuster lever and slide the cable off of the adjuster-cable guide. See **Fig. 1**.
9. Remove the anchor screw. See **Fig. 2**.
10. Remove the anti-rattle spring, lever, cam, and adjuster cable. See **Fig. 2**.
11. Remove the cured thread-locking compound from the anchor post threads. Run an M12 x 1.75 tap completely into the anchor post, and back it out. Blow out the hole with compressed air to remove any remaining debris.
12. Lubricate all parts with Chevron RPM high temperature grease or equivalant.
13. Install the adjuster cable, new cam, new lever, anti-rattle spring (small coil end toward screw head), and new anchor screw. See **Fig. 2**. Make sure the offset in the adjuster cable end is facing in the proper direction. Only thread the anchor screw into the anchor post one to two turns to temporarily hold the assembly together. Do not thread it in completely until you are ready to tighten it to specification. A faulty installation will result if the thread-locking compound is activated and begins to cure, prior to tightening the screw. When installing the anchor screw, care should be taken to ensure that the adjuster cable-end fitting is not clamped underneath the shoulder of the anchor screw. Clamping the adjuster cable may prevent proper functioning of the brake self-adjust feature.
14. Tighten the anchor screw to 74 lbf·ft (100 N·m).
15. Attach the lever return spring and the parking brake cable to the end of the brake lever.

IMPORTANT: When it is correctly assembled, the adjuster cable end-fitting is behind the adjuster lever with the spring hook facing out. See **Fig. 3**. Failure to do so may result in reduced brake operation.

16. Route the adjuster cable around the adjuster cable guide, under the shoe hold-down spring, and attach it to the adjuster lever. See **Fig. 3**.
17. Adjust the shoe cage. See **Subject 140**.
18. Make a final inspection of the shoe linings and the inside of the drum to ensure that no grease or other contamination is present.
19. Inspect, service, then install the drum. See **Subject 110**.
20. Attach the driveshaft. See **Group 41**.
21. Lower the vehicle.
22. Test the brake for proper function before returning the vehicle to service.

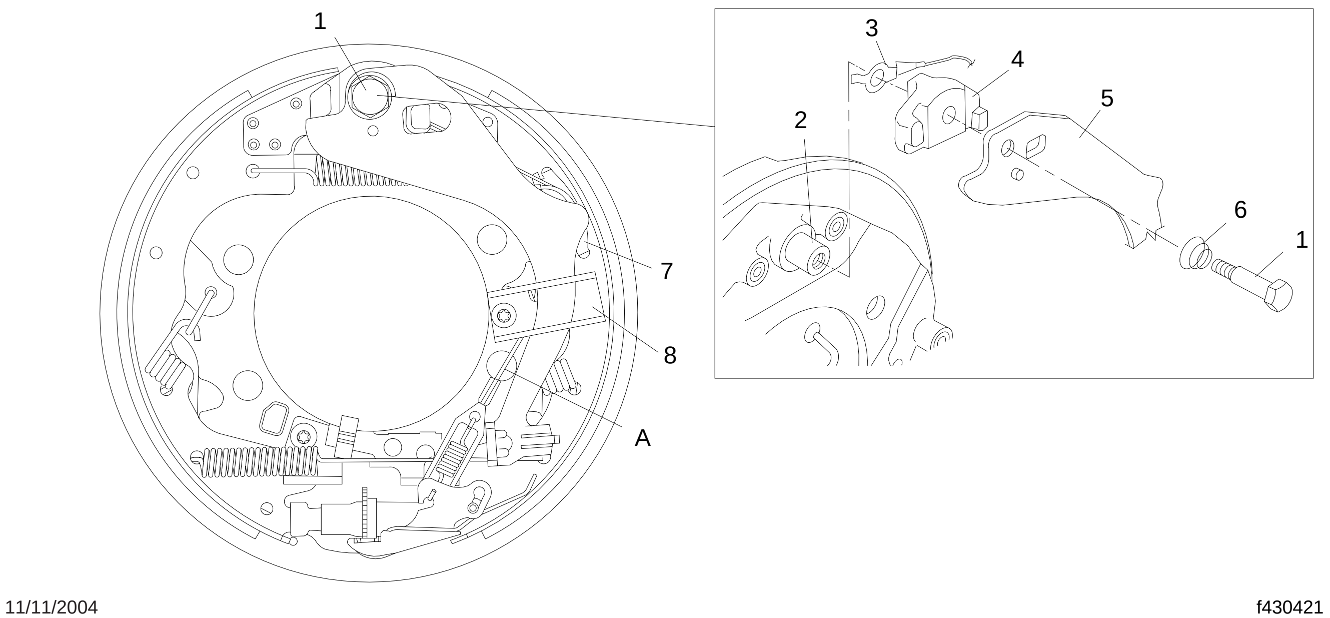
Anchor Screw, Lever, and Cam Replacement



A. Raise the lever off the starwheel and push up.
B. Disengage the spring.
C. Disengage the lever spring.
D. Remove the lever and lever spring.

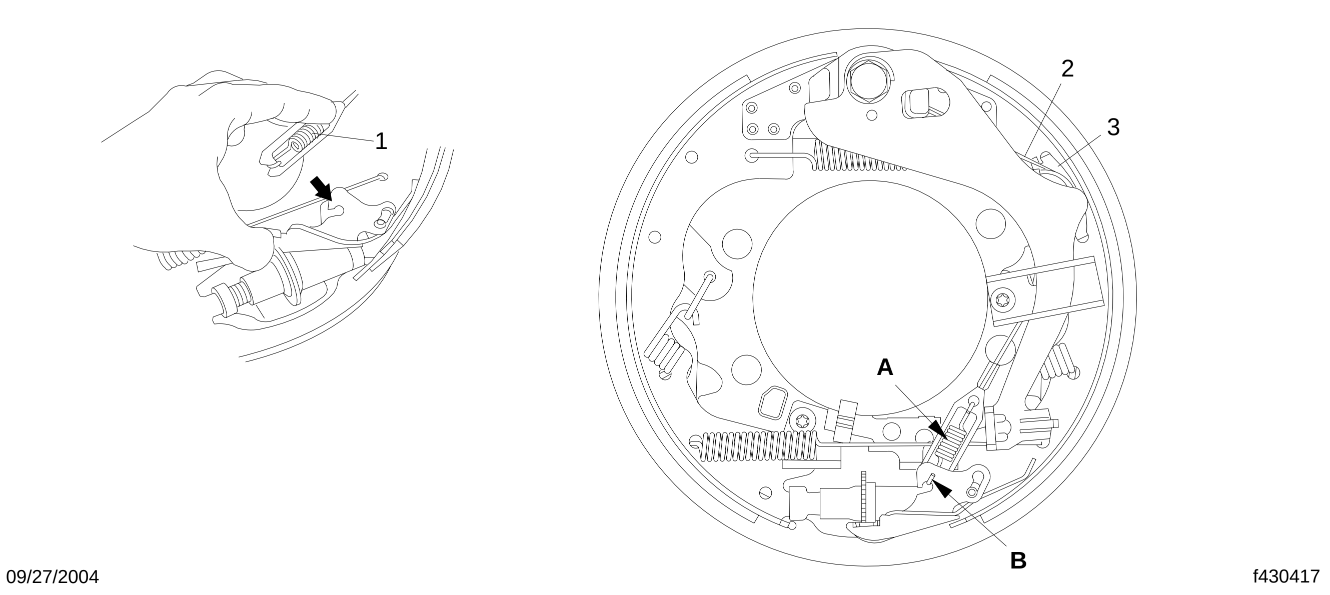
Fig. 1, Adjuster Lever and Adjuster Spring Removal

Anchor Screw, Lever, and Cam Replacement



A. Adjuster Cable Routing and Spring Attachment to Adjuster Lever
1. Anchor Screw
2. Anchor Post
3. Adjuster Cable
4. Cam
5. Lever
6. Anti-Rattle Spring
7. Adjuster Cable Guide
8. Lever Guide

Fig. 2, Adjuster Components Removal/Installation



A. Correct Spring Position
B. Spring Hook Facing Out
1. Adjuster Spring
2. Adjuster Cable
3. Adjuster Cable Guide

Fig. 3, Adjuster Cable Installation

⚠ WARNING

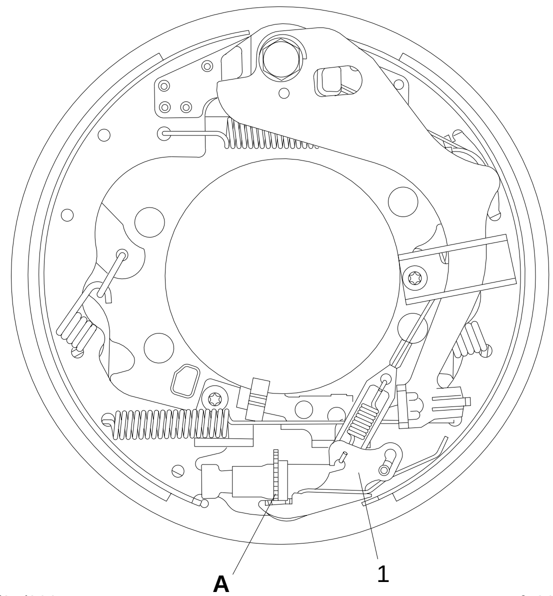
Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

Brake Shoe Adjustment with Drum Off

After replacing parking brake components, follow these instructions to properly adjust the parking brake. Once adjusted, the self-adjuster should keep the brake adjusted throughout the life of the brake shoes.

1. Using a 12-inch caliper, measure the inside diameter (i.d.) of the drum. Subtract 0.025 inches (0.6 mm) from the drum i.d. measurement. Set the measurement caliper to this value, and lock the setscrew.
2. Rotate the axle input yoke so the yoke is in the vertical position to provide clearance for the caliper.
3. Place the pre-adjusted caliper over the shoes at the center of the shoes.
4. To adjust the brake, move the adjuster lever away from the starwheel, and rotate the starwheel until the shoes touch the caliper jaws. See **Fig. 1**.

   During adjustment, move the calipers up and down around the shoe center points to ensure adjustment at the highest points on the shoes.



A. Rotate starwheel to adjust shoe spread.
1. Adjuster Lever

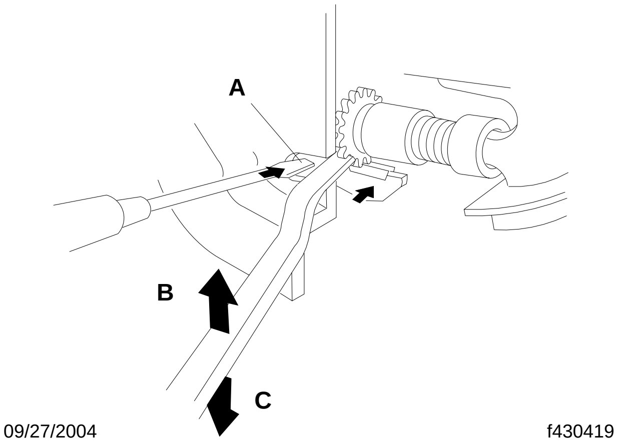
Fig. 1, Initial Brake Shoe Adjustment with Drum Off

Brake Shoe Adjustment with Drum Installed

The following procedure can be used to perform fine adjustments to the parking brake after the brake is assembled. If adjustment is necessary during the normal life of the brake, see **Subject 300** to determine if there is a problem with the parking brake.

1. Park the vehicle on a level surface, shut down the engine, chock the tires, place the transmission in gear, and fully release the parking brake.
2. Raise the rear wheels off the ground, and support the vehicle with jack stands.
3. Insert a brake adjusting tool through the adjusting slot and move the teeth downward to expand the brake shoes outward. See **Fig. 2**. Continue expanding the shoes until the drum can not be rotated.
4. Insert a thin screwdriver through the adjusting slot in the brake backing plate and push the adjusting lever away from the starwheel, then move the teeth upward to retract the shoes until the drum just begins to rotate without dragging.
5. Lower the vehicle.
6. Test the brake for proper operation before returning the vehicle to service.

Shoe Cage Adjustment Procedures



A. Push Lever Away From Starwheel to Decrease Shoe Spread
B. Expand Shoe Spread
C. Decrease Shoe Spread

Fig. 2, Brake Adjustment With Drum On

General Information

The Bosch driveline parking brake is self-adjusting and should not require adjustment of the cable under normal operating conditions.

NOTE: With time and use, all cables will stretch. The driveline parking brake actuation cable should be checked for proper adjustment whenever the brake is serviced.

There are three methods of actuation for the driveline parking brake. Depending on vehicle configuration, the brake is actuated by one of the following:

- A foot pedal under the dash
- A hand valve located on the dash
- The column-mounted shifter, when placed in "Park"

The hand-valve and the column-mounted shifter control an air-actuated spring chamber, mounted on the frame rail near the parking brake. Follow the appropriate procedure below when adjusting the brake cable after replacing the parking brake, parking brake components, or any of the parking brake actuation components.

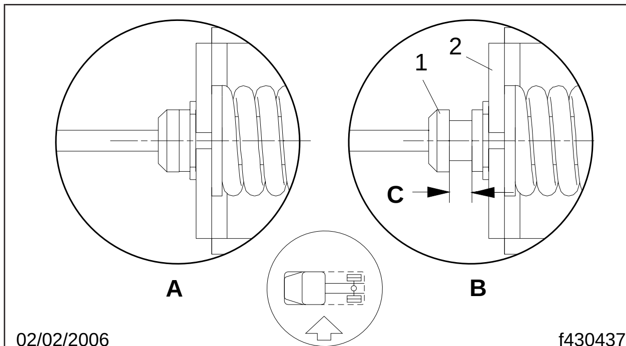
Cable Adjustment, Foot-Pedal-Actuated Parking Brake

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

1. Apply the parking-brake pedal until it bottoms out. Measure the sleeve extension at the bracket. See **Fig. 1**. If it is approximately 3/8 inch (9 mm), it is properly adjusted; no further work is needed. If not, release the parking-brake pedal and go to the next step.
2. At the right frame rail, forward of the parking brake, back off the jam nut a few turns, then thread the cable adjuster onto the cable end to the jam nut. See **Fig. 2**.

   Repeat Step 1. Continue tightening the adjuster until the sleeve extends from the bracket approximately 3/8 inch (9 mm).



A. Before adjustment
B. Sleeve extended
C. 3/8 inch (9 mm)
1. Sleeve
2. Bracket

Fig. 1, Cable Sleeve Extended

3. Release and apply the parking brake three times, assuring a solid application.
4. If needed, tighten the adjuster again until the sleeve again extends from the bracket approximately 3/8 inch (9 mm).
5. Tighten the jam nut.
6. Test the brake for proper operation before returning the vehicle to service.

Cable Adjustment, Air-Actuated Parking Brake

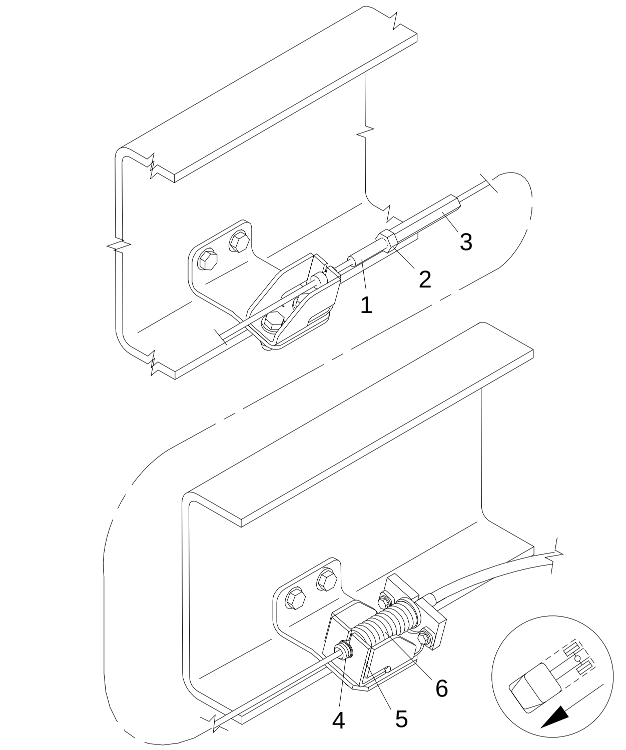
WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

CAUTION

The parking brake chamber is spring-loaded to the applied position and pressurized to the released position. This chamber can not be caged. Keep hands clear while working around the brake chamber. Loss of air pressure will cause the

Parking Brake Cable Adjustment



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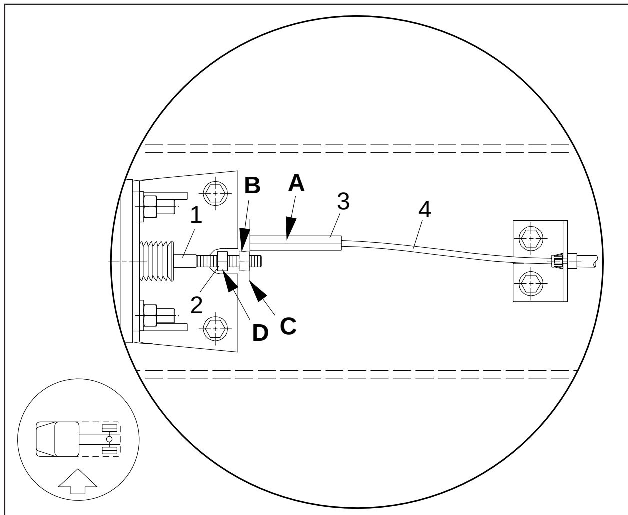
1. Cable End
2. Jam Nut
3. Adjuster Nut
4. Sleeve
5. Bracket
6. Spring

Fig. 2, Cable Adjustment, Foot-Pedal-Actuated Parking Brake

parking brake to apply, and may cause serious personal injury.

1. Release the parking brake.
2. If the cable is attached to the pushrod, loosen the jam nut and back off the adjuster nut to disconnect it from the pushrod.
3. Pull the adjuster nut forward until the cable slack is removed. See **Fig. 3**.
4. Reposition the jam nut to line up with the end of the adjuster nut.
5. Thread the adjuster nut onto the pushrod and against the jam nut. Tighten the jam nut. See **Fig. 4**.
6. Test the brake for proper operation before returning the vehicle to service.



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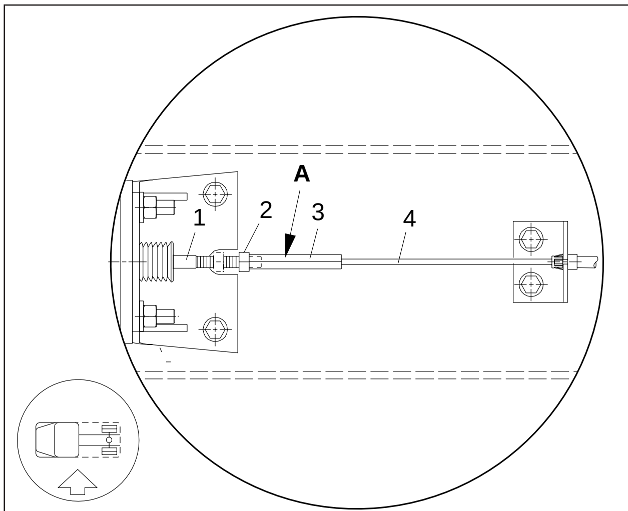
A. Pull adjuster nut forward until cable slack is removed.
B. Reposition jam nut to align with end of adjuster nut.
C. End of adjuster nut when pulled tight.
D. Jam nut before repositioning

1. Pushrod
2. Jam Nut
3. Adjuster Nut
4. Cable

Fig. 3, Cable Adjustment, Air-Actuated Parking Brake



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A. Thread adjuster nut onto pushrod and tighten jam nut.

1. Pushrod
2. Jam Nut
3. Adjuster Nut
4. Cable

Fig. 4, Air-Actuated Parking Brake Cable Adjustment

Driveline Parking Brake Assembly Removal and Installation

WARNING

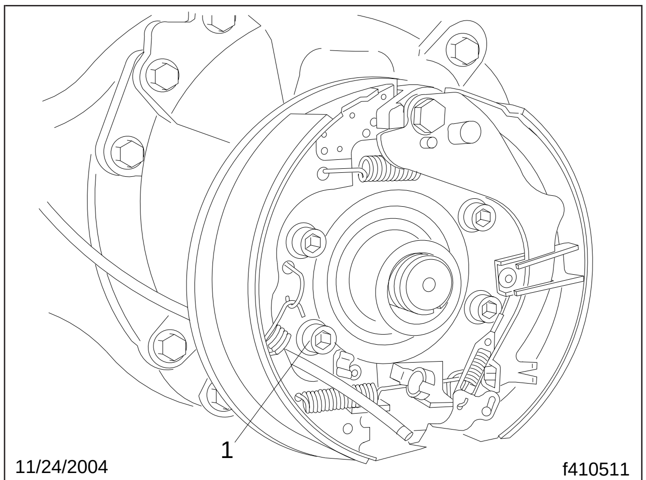
Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

Removal

1. Park the vehicle on a level surface, chock the front tires, and shut down the engine.
2. If necessary, raise the vehicle and set it on jack stands.

NOTE: The driveshaft and yoke-flange may vary depending on vehicle configuration.

3. Disconnect the driveshaft and secure it out of the way. See **Group 41**.
4. Remove the drum and axle-input flange as an assembly. See **Subject 110**.
5. Disconnect the actuation cable from the lever.
6. Compress the sheath prongs and pull the cable housing and the cable from the backing plate opening.
7. Remove the backing plate mounting fasteners. See **Fig. 1**.



1. Mounting Fasteners (4)

Fig. 1, Backing Plate Assembly (flange removed)

8. Remove the parking brake assembly.

Installation

1. Clean any dirt, debris, grease, or oil from the differential mounting surfaces.

NOTE: When properly installed, the anchor point for the actuation lever should be in the 12 o'clock position.

2. Position the parking brake assembly on the differential and install the backing plate mounting fasteners. Tighten to 236 lbf·ft (320 N·m).
3. Slide the actuation cable and housing into the opening in the backing plate and secure the cable housing in the backing plate. Make sure all the prongs are set.
4. Attach the actuation cable to the lever.
5. Adjust the shoes if needed. See **Subject 140**.
6. Install the drum and axle-input flange-yoke assembly. See **Subject 110**.
7. Attach the driveshaft. See **Group 41**.
8. Lower the vehicle.
9. Test the brake for proper operation before returning the vehicle to service.

Inspection

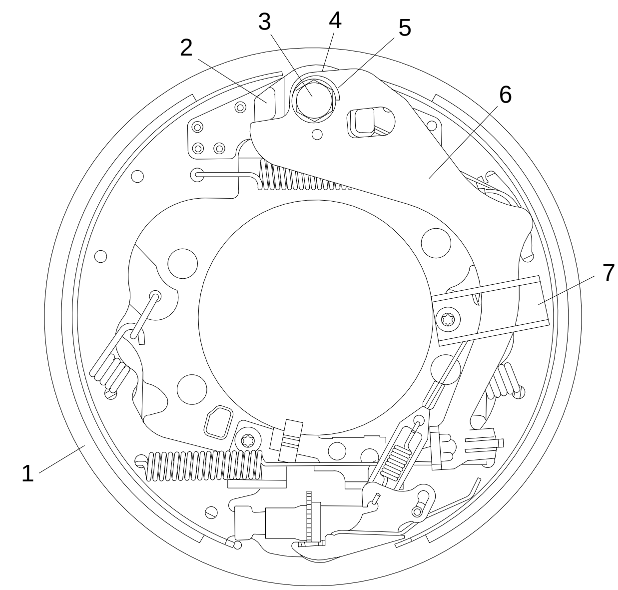
WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

NOTE: It is not necessary to raise the vehicle for inspection in most cases.

Anytime service is required, inspect all components in the parking brake assembly.

1. Park the vehicle on a level surface, shut down the engine, and chock the front tires.
2. Remove the drum. See **Subject 110**.
3. Clean the individual brake components, removing dust and grease to the extent reasonable.
4. Inspect the brake shoes. Shoes should be replaced if:
    - There is uneven lining wear, or when the remaining lining reaches approximately 1/32 inch (0.76 mm) thickness, or less, above the shoe;
    - Grease, automotive fluids, or other foreign material that would compromise operation is found on, soaked into, or embedded in the linings;
    - Cracks, excessive deformation, or wear at either end of the shoe is found.
5. Inspect the brake lever and cam. See **Fig. 1**. If cracks, excessive wear, or abnormal deformation are found in either part, replace as an assembly, the brake lever, cam, and anchor screw. Light wear, which typically shows up as polishing, or as shiny spots, is acceptable. If you are unsure, replace, as an assembly, the brake lever, cam, and anchor screw. See **Subject 130**.
6. Inspect the springs and hold down pins (see **Fig. 2**) for excessive wear, heat discoloration, heavy corrosion, or other damage. Replace damaged parts as necessary. See **Subject 120**.
7. Inspect the adjuster cable assembly for damage or wear. See **Fig. 2**. Replace as necessary. See **Subject 120**.

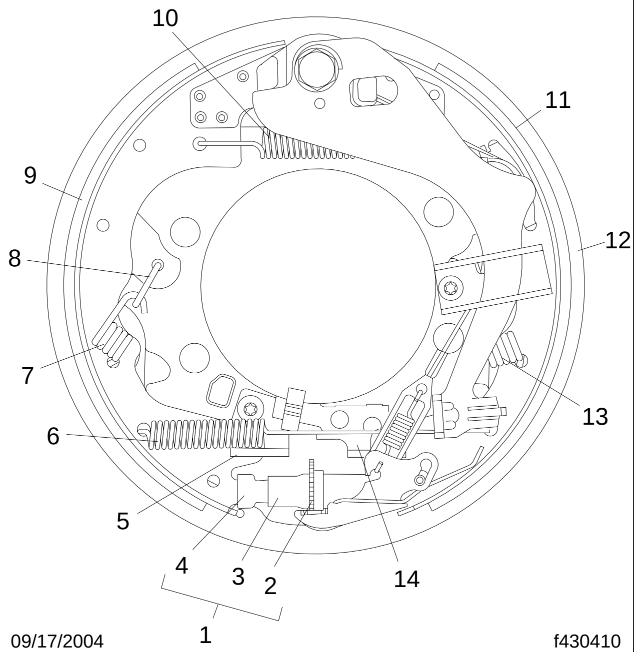


1. Backing Plate
2. Cam
3. Anchor Screw
4. Anchor Point
5. Anti-Rattle Spring
6. Lever
7. Lever Guide

Fig. 1, Parking Brake Major Components

8. Inspect the adjuster nut and screw (see **Fig. 2**) for any damage to the threads, or burrs, chips, or other damage to the teeth on the adjuster-nut starwheel. Damaged teeth or threads may prevent proper function of the brake self-adjusting function. Replace as necessary. See **Subject 120**.
9. Clean-out all dust or grease from the inside of the drum. Using a 12-inch caliper, or an inside-diameter micrometer, measure the inside diameter of the drum. Replace the drum if it exceeds the manufacturer's recommended maximum inside diameter (which typically is stamped on the inside of the drum near the mounting holes), if it is worn unevenly, has deep grooves, heavy corrosion, or excessive runout.
10. Inspect the parking-brake lever apply cable for excessive wear or damage. Replace it if necessary.
11. Inspect the differential pinion seal for evidence of leakage that can contaminate the parking brake system parts. Replace the seal as necessary.

Inspection



1. Adjuster Nut and Screw Assembly
2. Starwheel
3. Adjuster Nut
4. Adjuster Screw
5. Shoe Hold-Down Bracket
6. Lower Shoe Return Spring
7. Hold-Down Spring
8. Pin (opposite side not shown)
9. Brake Shoe
10. Upper Shoe Return Spring
11. Brake Shoe
12. Backing Plate
13. Hold-Down Spring
14. Shoe Hold-Down Bracket

Fig. 2, Brake Shoes and Related Components

See the differential manufacturer’s service literature for repair information.

Troubleshooting

Problem—Light Force or Lack of Resistance When Applying Brake Lever (on manual apply systems)

Problem—Light Force or Lack of Resistance When Applying Brake Lever (on manual apply systems)	
Cause	**Remedy**
Shoe cage under-adjusted	Adjust shoes; see **Subject 140**.
Worn or deformed actuation components (lever, cam lugs, shoe ends)	Inspect and replace damaged components; see **Subject 130** or **Subject 120**.
Apply system is not operating properly	Inspect application components and repair as necessary; see **Subject 130** or **Subject 120**.

Problem—Heavy Force or Excessive Resistance When Applying Brake Lever (on manual apply system)

Problem—Heavy Force or Excessive Resistance When Applying Brake Lever (on manual apply system)	
Cause	**Remedy**
Over-adjusted brake	Adjust shoes; see **Subject 140**.
Apply system is over-adjusted	Inspect application components and repair/adjust as necessary; see **Subject 150**.

Problem—Brake Does Not Release

Problem—Brake Does Not Release	
Cause	**Remedy**
Internal damage to brake	Inspect brake components and repair as necessary; see **Subject 170**.
Apply cable is bound up	Check cable for corrosion, binding, kinks, and damage. Adjust or repair as needed; see **Subject 150**.
Apply system is not operating properly	Inspect application components and repair as necessary; see **Subject 150**.

Problem—Brake Does Not Hold Vehicle On Hill

Problem—Brake Does Not Hold Vehicle On Hill	
Cause	**Remedy**
Grease, oil, or other foreign material on or embedded in shoe linings	Replace shoes and clean drum; see **Subject 120**. Inspect rear pinion seal for leakage that can contaminate park brake system parts, and repair as necessary.
Damaged or incorrect shoes	Replace with correct shoes; see **Subject 120**.
Worn out lining (metal shoe rim contacting drum)	Replace shoes; see **Subject 120**. Resurface or replace drum as necessary; see **Subject 110**.
Shoe cage is under-adjusted	Adjust shoes; see **Subject 140**.
Worn or deformed actuation components (lever, cam lugs, shoes)	Inspect and replace damaged components; see **Subject 130** or **Subject 120**.

Troubleshooting

Problem—Brake Does Not Hold Vehicle On Hill	
Cause	**Remedy**
Apply system is not operating properly	Inspect and replace damaged components and adjust as necessary; see **Subject 160**.

Specifications

Component Specifications		
Item	**Dimension**	**Specifications**
Shoe Lining:	thickness, new (above shoe)	0.277 inch (7 mm) (at center)
	thickness, replace (above shoe)	0.030 inch (0.76 mm)
	width	3 inch (75 mm)
Drum (typical): (non-Bosch part)	inside diameter	12.000 inch (304.8 mm)
	maximum inside diameter	12.035 inch (305.7 mm)
	thickness	0.315 inch (8 mm)
	surface finish	125 micro inch (3.2 micro m) or less

Table 1, Component Specifications

Fastener Torque Specifications		
Fastener	**Size**	**Torque**
Anchor Screw	M12 x 1.75	74 lbf·ft (100 N·m)

Table 2, Fastener Torque Specifications

Special Tools		
Tool	**Brand**	**Part Number**
Heavy Brake Spring Tool	KD	3499
	Matco	SP104
	BST	4480
	Lisle	44800
	SnapOn	BT 19A
Brake Shoe Retaining Spring Tool	Matco	RST10
	Vim Tools	B10
Parking Brake Cable Removal Tool	SnapOn	BT22A
	Lisle	40800

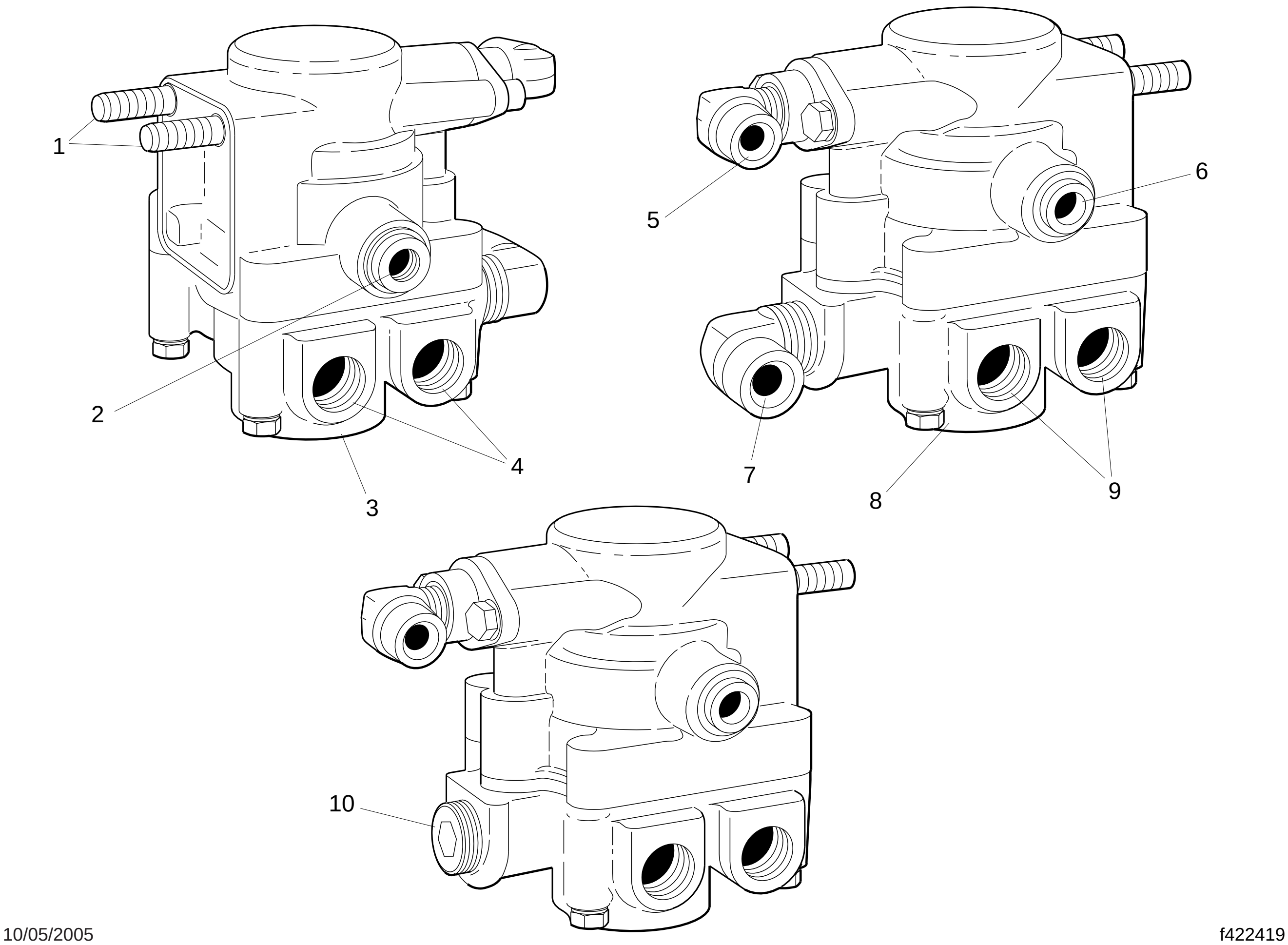
Table 3, Special Tools

Description

The Bendix SR-7™ spring brake modulating valve (see **Fig. 1** and **Fig. 2**) is used in conjunction with a dual air brake system and spring brake actuator, and performs the following functions:

- Provides a rapid application of the spring brake actuator when parking.
- Modulates the spring brake actuator application using the dual brake valve should a primary failure occur in the service brake system.
- Prevents compounding of service and spring brake forces.

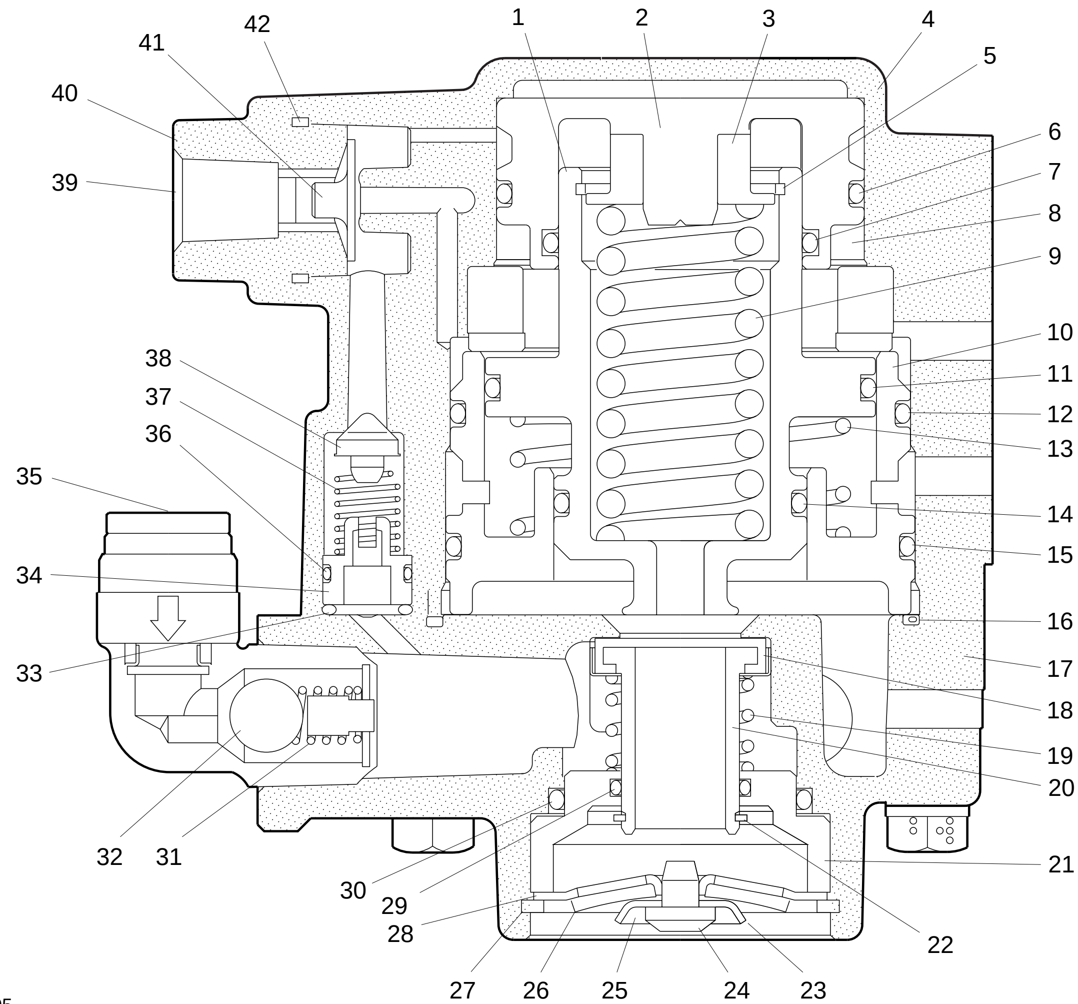
The SR-7 valve has one park control, one service control, one supply, one balance, four delivery NPT ports, and an exhaust port protected by an exhaust diaphragm. The valve incorporates two mounting studs for mounting the valve to the frame rail or crossmember.



1. Mounting Studs
2. 42 Control Port
3. Exhaust
4. Delivery
5. 41 Park Control (from dash valve)
6. 41 Balance Port
7. Supply Port
8. Exhaust
9. Delivery
10. Pipe Plug (QRV applications only)

Fig. 1, SR-7 Spring Brake Modulating Valve (exterior views)

General Information



1. Main Piston
2. Control Piston
3. Spring Guide
4. Upper Body
5. Retaining Ring
6. O-Ring
7. O-Ring
8. Spacer
9. Main Piston Spring
10. Static Piston
11. O-Ring
12. O-Ring
13. Static Piston Spring
14. O-Ring
15. O-Ring
16. O-Ring
17. Lower Body
18. Valve Retainer
19. Spring
20. Inlet/Exhaust Valve
21. Lower Valve Guide
22. Retaining Ring
23. Exhaust Port
24. #10 Torx Screw
25. Diaphragm Washer
26. Diaphragm
27. Retaining Ring
28. Valve Seat
29. O-Ring
30. O-Ring
31. Spring
32. Ball Check Valve
33. O-Ring
34. Check Valve Guide
35. Supply Port
36. O-Ring
37. Spring
38. Inline Single Check Valve
39. Park Control Port
40. Check Valve Cover
41. Double Check Valve
42. O-Ring

Fig. 2, SR-7 Spring Brake Modulating Valve (sectional view)

CAUTION

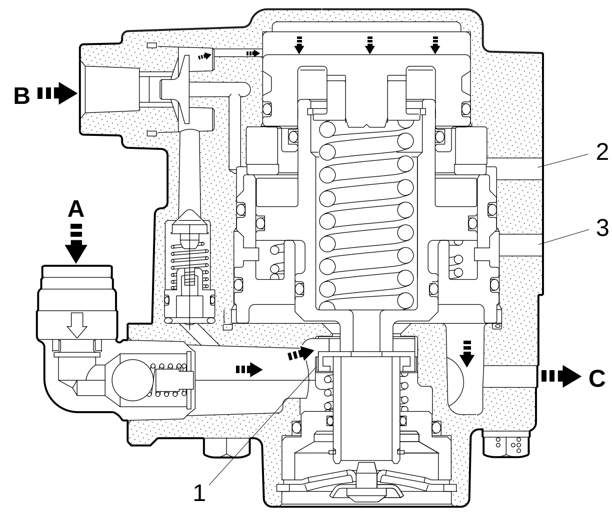
Do not attempt to disassemble the SR-7 valve. The valve contains high spring forces that could result in personal injury if disassembly is attempted.

Operation

The operation guidelines shown in this manual represent the relay valve based SR-7. A quick-release-based valve functions similarly to the relay-valve-based version with the exception that all air delivered to the spring brakes passes through the park control port through the in-line single check valve. The SR-7 quick release style can be easily identified by the pipe plug in the supply port of the valve. See **Fig. 1**. For vehicle-specific plumbing diagrams, go to **EZWiring**.

Charging the Spring Brake Actuators Below 107 PSI (737 kPa)

With the air brake system charged and the parking brakes released (by pushing in the dash valve button), air enters the park control port. This opens the SR-7 valve, to supply air pressure to the spring brake chambers. As illustrated, air pressure in the chambers is below 107 psi (737 kPa) (nominal). See **Fig. 3**.



A. Secondary reservoir constant pressure
B. Control line pressure
C. Delivery to spring brakes
1. Inlet/Exhaust Valve Open
2. Balance Port
3. Control Port

Fig. 3, Charging the Spring Brake Actuators Below 107 PSI (737 kPa)

Charging the Spring Brake Actuators Above 107 psi (737 kPa)

Once the SR-7 valve delivery pressure reaches 107 psi (nominal), the inlet and exhaust are closed (valve lap position). This maintains the spring brake hold-off pressure at 107 psi (nominal). See **Fig. 4**.

Normal Service Application

During a service brake application, the valve remains in the lap position. The SR-7 valve monitors the presence of air pressure in both primary and secondary delivery circuits. See **Fig. 5**.

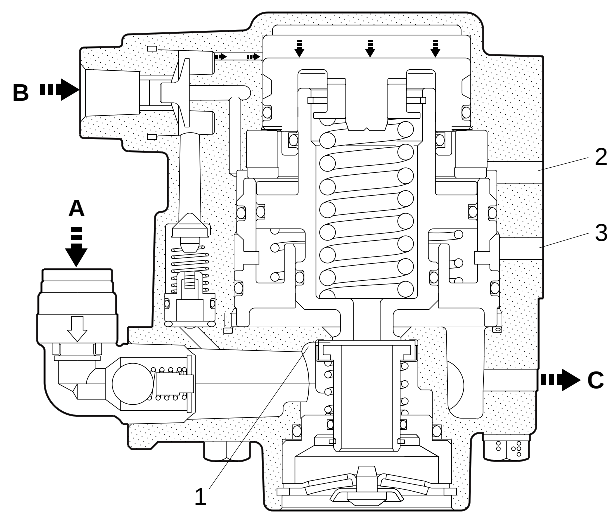
Parking

Actuating the park brakes (by pulling out the dash valve button) exhausts spring brake air pressure through the SR-7 valve exhaust port. See **Fig. 6**.

Service Application with Loss of Air in Primary Circuit

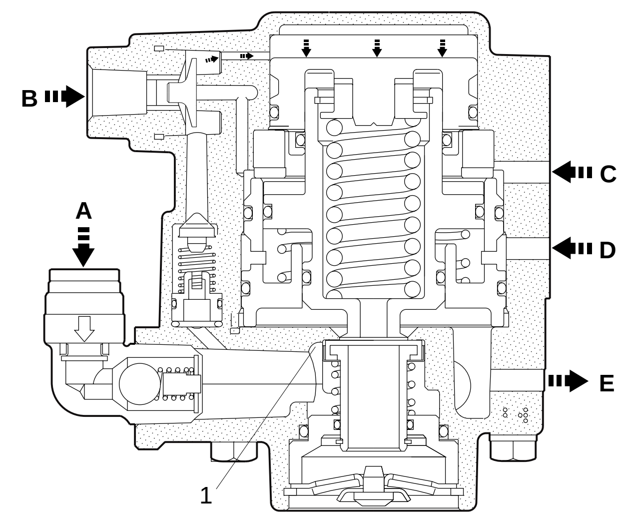
With the parking brakes released (dash valve button in) and the absence of air in the primary circuit delivery, a service brake application from the secondary circuit causes the pressure in the spring brakes to be exhausted proportionally to this application. This is known as spring brake modulation. A 30 psi (207 kPa) service brake application will exhaust the spring brake pressure to approximately 60 psi (414 kPa). See **Fig. 7**.

General Information



A. Secondary reservoir constant pressure
B. Control line pressure
C. Delivery to spring brakes
1. Inlet/Exhaust Valve Seated
2. Balance Port
3. Control Port

Fig. 4, Charging the Spring Brake Actuators Above 107 PSI



A. Secondary reservoir constant pressure
B. Control line pressure
C. Balance port—primary circuit pressure
D. Control port—secondary circuit pressure
E. Delivery to spring brakes
1. Inlet/Exhaust Valve Seated

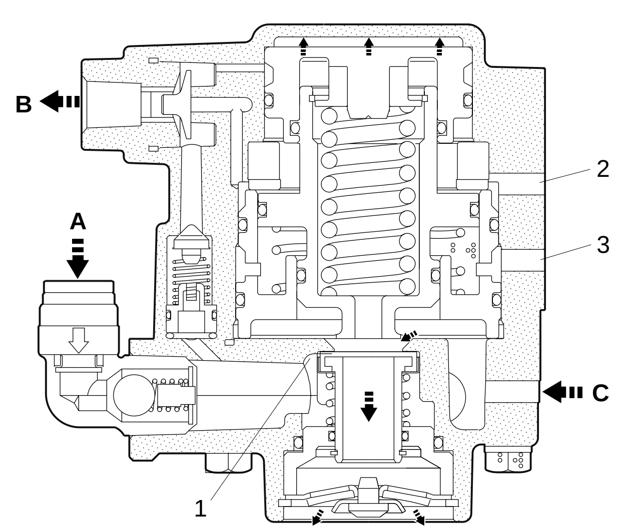
Fig. 5, Normal Service Application

Service Application with Loss of Air in Secondary Circuit

With the parking brakes released (dash valve button in) and the absence of air in the secondary circuit reservoir, the external single check valve in the supply port seals to prevent air leakage to atmosphere from the SR-7 valve. The dash valve delivery air flows through the inline single check valve and becomes SR-7 valve supply air. This air is delivered to maintain at least 107 psi (737 kPa) (nominal) in the spring brake chambers. See **Fig. 8**.

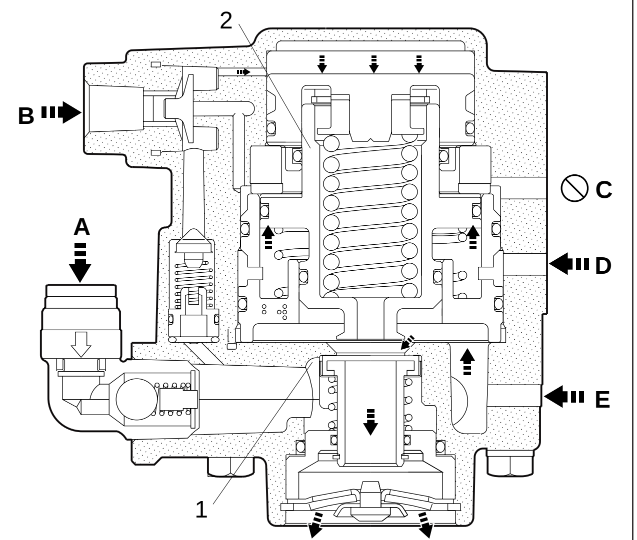
Anti-Compounding

The SR-7 valve provides anti-compounding of the service and spring brake forces. When the park brakes are actuated (by pulling out the dash valve button), a service brake application will cause the SR-7 valve to deliver air pressure to the spring brake chambers. Thus the vehicle is held stationary using a service brake application. When the service brake application is released, the delivery pressure is exhausted from the spring brake chambers and the vehicle remains parked using the spring brake actuators. See **Fig. 9**.



A. Secondary reservoir constant pressure
B. Control line pressure
C. Delivery to spring brakes
1. Inlet/Exhaust Valve Seated
2. Balance Port
3. Control Port

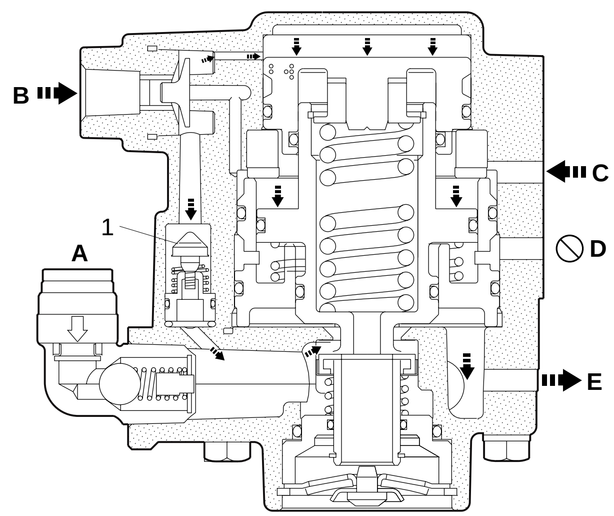
Fig. 6, Parking



A. Secondary reservoir constant pressure
B. Control line pressure
C. Balance port—loss of primary circuit pressure
D. Control port—secondary circuit pressure
E. Delivery to spring brakes
1. Inlet Valve Seated
2. Main Piston Moves Up

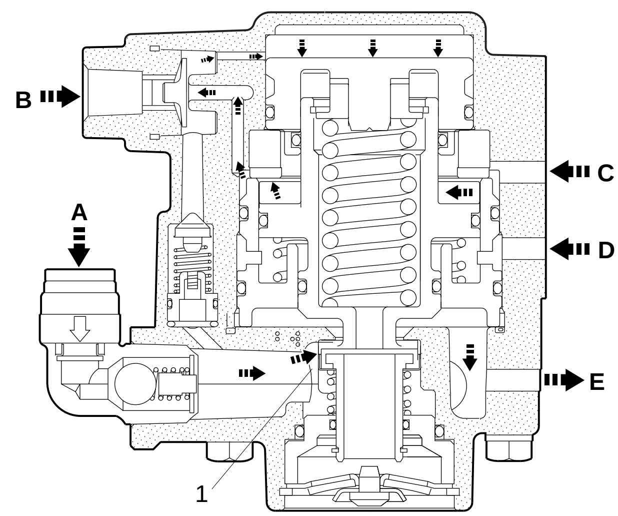
Fig. 7, Service Application with Loss of Air in Primary Circuit

General Information



A. Secondary reservoir no pressure
B. Control line pressure
C. Balance port—primary circuit pressure
D. Control port—loss of secondary circuit pressure
E. Delivery to spring brakes
1. Inline Single Check Valve

Fig. 8, Service Application with Loss of Air in Secondary Circuit



A. Secondary reservoir constant pressure
B. Control line pressure
C. Balance port—primary circuit pressure
D. Control port—secondary circuit pressure
E. Delivery to spring brakes
1. Inlet/Exhaust Valve Open

Fig. 9, Anti-Compounding

Safety Precautions

Before attempting to work on the air brake system, observe the following precautions:

- Since the compression and storage of air can be compared to energy in a coiled spring, when released, it can present a hazard if not properly recognized. The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer's recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- Used reservoirs must not be used as replacements, in order to eliminate the possibility of component failure.
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured, in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

Removal

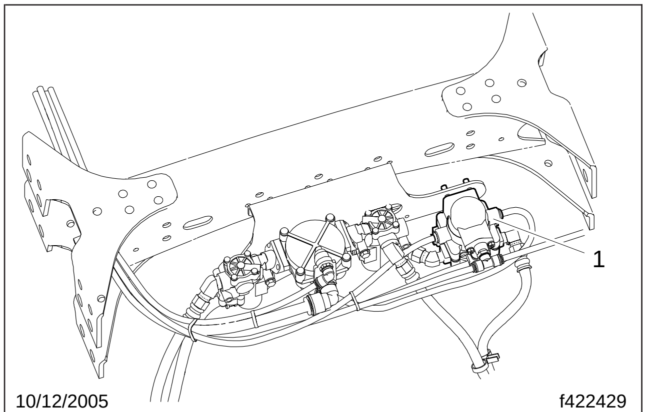
WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so could result in personal injury.

CAUTION

Do not attempt to disassemble the SR-7 valve. The valve contains high spring forces that could result in personal injury if disassembly is attempted.

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the tires.
2. Drain the air system.
3. Identify all the air lines attached to the valve, for reinstallation. See **Fig. 1** for a view of a typical installation, or access EZWiring for vehicle-specific plumbing diagrams.



1. SR-7 Valve

Fig. 1, SR-7 Spring Brake Modulating Valve Installation (typical)

4. Disconnect all the air lines from the valve.
5. Remove the two mounting nuts that secure the valve to the crossmember bracket, and remove the valve.
6. If the valve is being replaced, note the orientation of all fittings, then remove the fittings for use on the new valve.

Installation

1. If a new valve is being installed, install the fittings removed from the old valve.
2. Position the valve on the crossmember bracket and install the mounting nuts. Tighten to 15 to 18 lbf·ft (20 to 24 N·m).
3. Attach all the air lines as noted during removal.
4. Before returning the vehicle to service, perform the operating and leakage tests in **Subject 120**, *Tests*.

Operating Test

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so could result in personal injury.

CAUTION

Do not attempt to disassemble the SR-7 valve. The valve contains high spring forces that could result in personal injury if disassembly is attempted.

1. Chock the tires.
2. Charge the air brake system to governor cut-out pressure.
3. Place the parking control valve in the PARK position. Observe that the spring brake actuators apply promptly.
4. Remove one line from a delivery port of the SR-7 valve and install a test gauge that is known to be accurate. See **Fig. 1** for the port locations.
5. Place the parking control valve in the RELEASE position. Observe that the spring brake actuators fully release.
6. With the parking control valve still in the RELEASE position, note the gauge pressure reading. Correct spring brake actuator hold-off pressure is 107 psi (737 kPa) nominal.
7. Place the parking control valve in the PARK position. The gauge reading should drop to zero promptly. A lag (more than 3 seconds) in the drop of pressure would indicate faulty operation.
8. With the parking control valve still in the PARK position, gradually apply the foot brake valve and note a pressure reading increase on the gauge installed in the SR-7 valve delivery port.
9. Place the parking control valve in the RELEASE position.
10. Drain the reservoir that supplies the rear service brake circuit; apply the foot brake valve several times and note that the pressure reading on the gauge decreases each time the foot brake valve is applied (spring brake modulation). After the foot brake valve has been applied several times, the pressure reading on the gauge will drop to the point where release of the spring brake actuators will no longer occur.

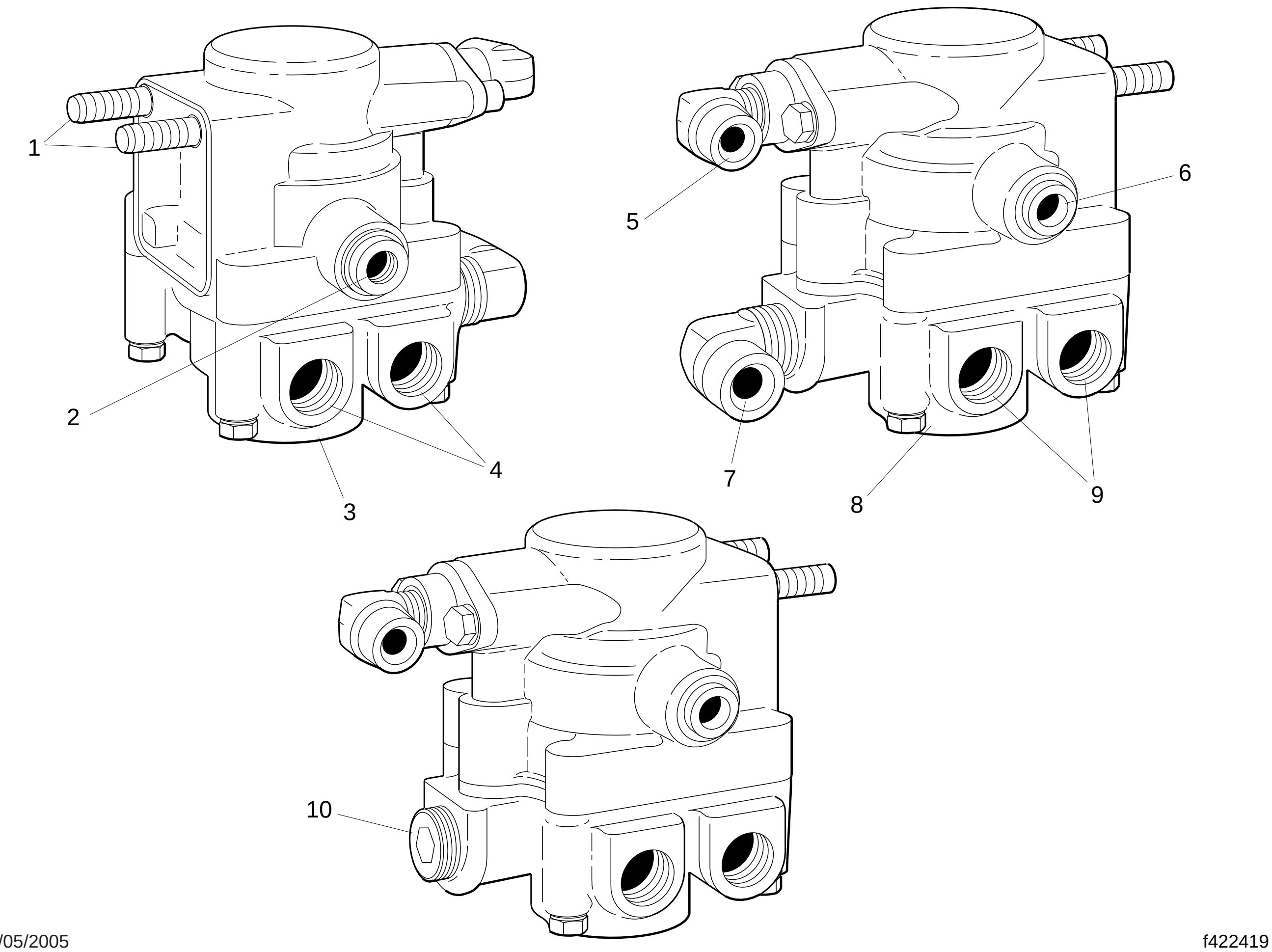
NOTE: The SR-7 valve is not servicable. If the valve does not function as described, replace it.

Leakage Test

Place the park control valve in the RELEASE position; using a soap solution, coat all ports including the exhaust port. A 1-inch (25-mm) bubble in three seconds is permitted.

NOTE: The SR-7 valve is not servicable. If the valve does not function as described, or if leakage is excessive, replace it.

Tests

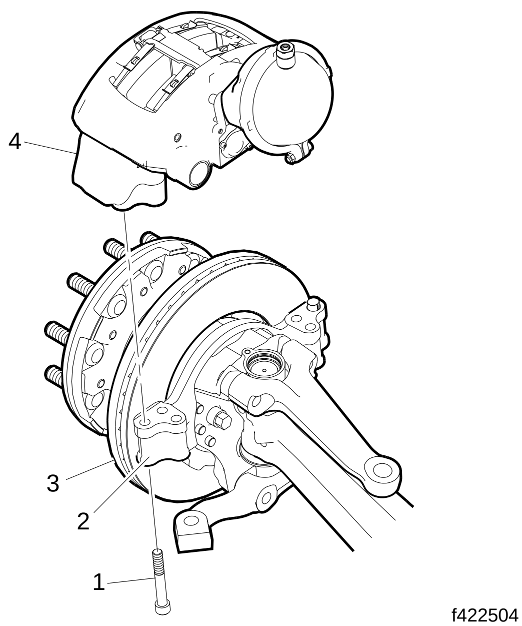


1. Mounting Studs
2. 42 Control Port
3. Exhaust
4. Delivery
5. 41 Park Control (from dash valve)
6. 41 Balance Port
7. Supply Port
8. Exhaust
9. Delivery
10. Pipe Plug (QRV applications only)

Fig. 1, SR-7 Spring Brake Modulating Valve (exterior views)

Description

Bendix air disc brakes use a floating caliper design to provide foundation braking on all axles. They are fitted with a standard brake chamber or a combination spring brake chamber, depending on the vehicle specification, and the position on the vehicle. The caliper-carrier and anchor plate are a proprietary design available only on Daimler vehicles. This design allows for easy removal and installation of the caliper/carrier assembly on all axles, without removing other major components. See **Fig. 1**.



1. Capscrew
2. Anchor Plate
3. Rotor
4. Caliper/Carrier

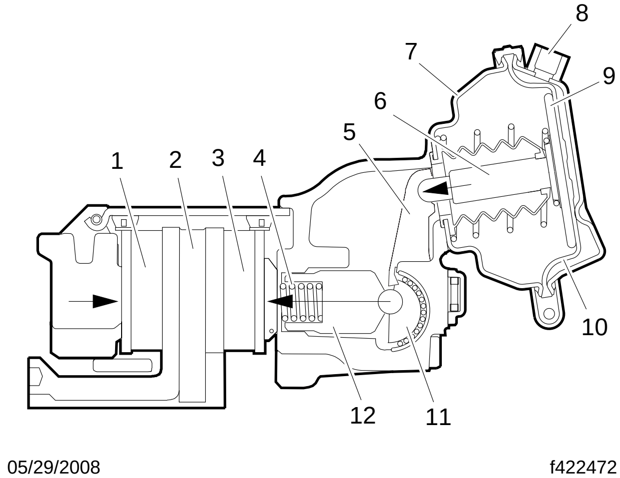
Fig. 1, Caliper/Carrier Installation

Operation

Bendix air disc brakes convert air pressure into braking force. See **Fig. 2**.

Brake Application

When the vehicle brakes are applied, air enters the service brake chamber through the supply port, applying pressure within the diaphragm. The pressure expands the diaphragm, applying force to the pressure plate and pushrod, and moving them forward.



1. Outer Brake Pad
2. Rotor
3. Inner Brake Pad
4. Return Spring
5. Lever
6. Pushrod
7. Brake Chamber
8. Supply Port
9. Pressure Plate
10. Diaphragm
11. Eccentric Bearing
12. Bridge

Fig. 2, Brake Operation

The pushrod presses against a cup in the internal lever, which pivots on an eccentric bearing, moving the bridge. Moving against a return spring, the bridge transfers the motion to two threaded tubes and tappets, which move the inner brake pad. The inner brake pad (from its normal position of having a running clearance between it and the rotor) moves into contact with the brake rotor. Further movement of the bridge forces the caliper, sliding on two stationary guide pins, away from the rotor, which pulls the outer brake pad into the rotor. The clamping action of the brake pads on the rotor applies braking force to the wheel.

Brake Release and Adjustment

When the vehicle brakes are released, the air pressure in the service brake chamber is exhausted, and the return springs in the chamber and the bridge return the caliper to a neutral, non-braked position. To maintain the running clearance gap between the rotor and the brake pads over time, the non-braked position is mechanically adjusted by a mechanism in the caliper. The adjustment mechanism operates automatically whenever the brakes are activated, to compensate for rotor and brake pad wear and to keep the running clearance constant. During pad or

General Information

rotor maintenance, the technician manually sets the system's initial non-braked position. The total running clearance (sum of clearances on both sides of the rotor) should be between 0.024 to 0.043 in. (0.6 and 1.1 mm).

General Safety Precautions

⚠ WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake calipers, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

Asbestos and Non-Asbestos Safety

⚠ WARNING

Wear a respirator at all times when servicing the brakes, starting with the removal of the wheels and continuing through assembly. Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH.

Because some brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Exposure to airborne asbestos brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

Because medical experts believe that long-term exposure to some *non-asbestos* fibers could also be a health hazard, the following precautions should also be observed if servicing non-asbestos brake linings.

Areas where brake work is done should be separate from other operations, if possible. As required by OHSA regulations, the entrance to the areas should have a sign displayed indicating the health hazard.

During brake servicing, an air purifying respirator with high-efficiency filters must be worn. The respirator and filter must be approved by MSHA or NIOSH, and worn during all procedures.

Safety Precautions

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency particulate air (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, the brake assembly must be cleaned in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with a HEPA filter system, remove dust from the brake drums, brake backing plates, and brake parts. After vacuuming, any remaining dust should be removed using a rag soaked in water and wrung until nearly dry. Do not use compressed air or dry brushing to clean the brake assembly.

If grinding or other machining of the brake linings is necessary, other precautions must be taken because exposure to asbestos dust is highest during such operations. In addition to the use of an approved respirator, there must be local exhaust ventilation such that worker exposure is kept as low as possible.

Work areas should be cleaned by industrial vacuums with HEPA filters or by wet wiping. Compressed air or dry sweeping should never be used for cleaning. Asbestos-containing waste, such as dirty rags, should be sealed, labeled, and disposed of as required by EPA and OSHA regulations. Respirators should be used when emptying vacuum cleaners and handling asbestos waste products.

Workers should wash before eating, drinking, or smoking, should shower after work, and should not wear work clothes home. Work clothes should be vacuumed after use and then laundered, without shaking, to prevent the release of asbestos fibers into the air.

Brake Pad Removal, Inspection, and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

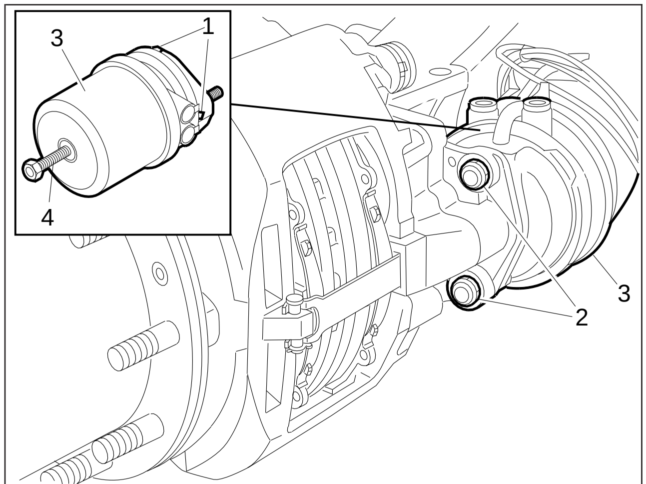
Removal

1. Shut down the engine. Chock the tires on the axle that is not being serviced.
2. If working on the drive axle, carefully cage and lock the spring brakes so that the springs cannot actuate during disassembly.

   Back out the release bolt using a maximum torque of 26 lbf·ft (35 N·m) to release spring force on the pushrod. See Fig. 1.
3. Drain the air from the air system.
4. Raise the front or rear axle and place safety stands under the frame or axle. Be sure the stands will support the weight of the vehicle.
5. Remove the wheel(s). See Group 40.

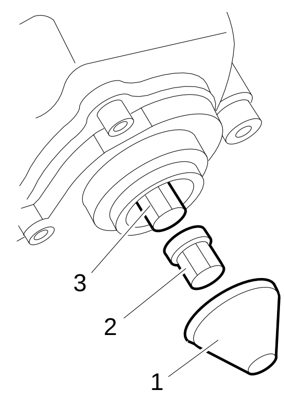
IMPORTANT: Before removing the brake pads, check the adjuster mechanism for proper operation.

6. Using the tab, pull off the adjuster cap, being sure to keep the shear adaptor in position on the adjuster. See Fig. 2.



1. Drain Plugs
2. Brake Chamber Nuts
3. Brake Chamber
4. Release Bolt

Fig. 1, Spring Brake Chamber Installation



1. Adjuster Cap
2. Shear Adaptor
3. Adjuster

Fig. 2, Shear Adaptor in Position

NOTICE

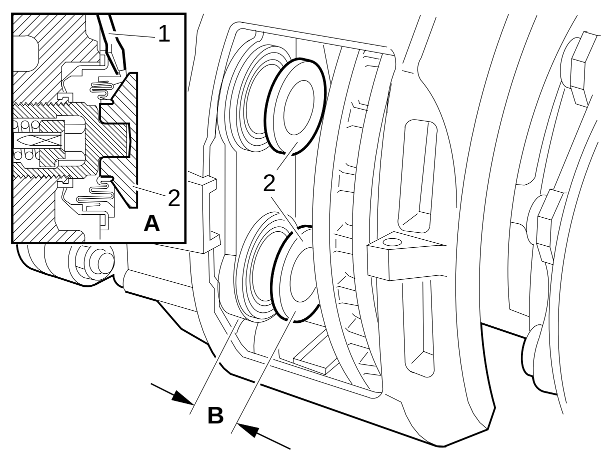
Do not use an open-ended wrench, as this may damage the adaptor.

IMPORTANT: Never turn the adjuster without the shear adaptor installed. The shear adaptor is a safety feature and is designed to prevent an excess of torque being applied to the adjuster. The shear adaptor will come loose if too much

Brake Pad Removal, Inspection, and Installation

torque is applied. If the shear adaptor fails, try again with a new adaptor. A second failure confirms that either the brake is applied or the adjustment mechanism is seized and the caliper/carrier assembly must be replaced.

7. Using a box-end wrench or socket, fully retract the tappet and boot assemblies by rotating the shear adaptor counterclockwise. See **Fig. 3**.



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A. Boot Location Ring
B. Extend less than 1.18 in (30 mm)

1. Boot Location Ring
2. Tappet and Boot Assembly

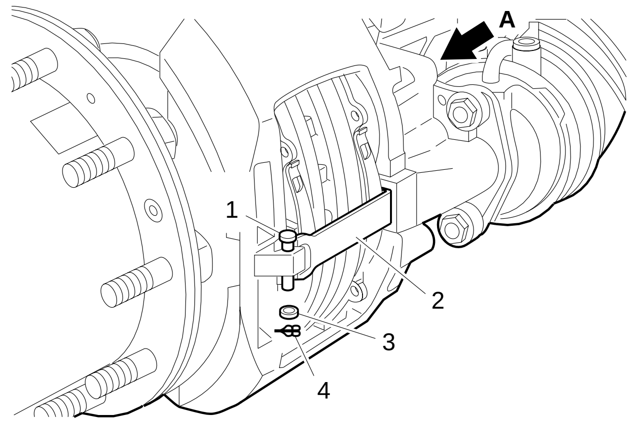
Fig. 3, Tappet and Boot Assembly

8. Remove the pad retainer clip and washer. See **Fig. 4**. Depress the pad retainer and remove the pad retainer pin. Discard all components that have been removed.
9. Slide the caliper to the outboard position. Remove the outer pad. See **Fig. 5**.
10. Slide the caliper to the inboard position. Remove the inner pad.

Inspection

Brake Pads

1. Measure the thickness of the friction material on the brake pad.



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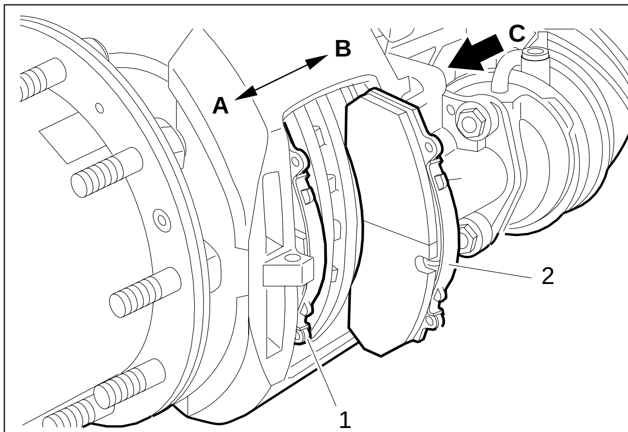
A. Shear Adjuster Location

1. Pad Retainer Pin
2. Pad Retainer
3. Washer
4. Clip

Fig. 4, Caliper Assembly



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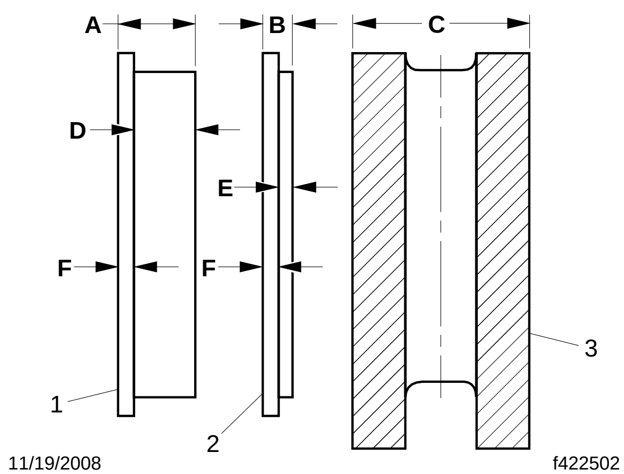
A. Outboard
B. Inboard
C. Area of Shear Adaptor

1. Outboard Brake Pad
2. Inboard Brake Pad

Fig. 5, Brake Pad Removal

If the thickness of the friction material is less than 0.079 in (2 mm) the pads must be replaced. See **Fig. 6**, Ref. E.

Most Bendix air disc brakes use 0.35 in (9 mm) backing plates. On a used brake pad, the combined pad and backing plate thickness should be no less than 0.43 in (11 mm).



1. New Pad
2. Used Pad
3. Rotor

A. New Pad Thickness 1.18 inch (30 mm)
B. Used Pad Thickness 0.43 inch (11 mm)
C. Rotor Thickness 1.77 to 1.46 inches (45 to 37 mm)
D. New Pad Friction Material Thickness
E. Used Pad Friction Material Thickness 0.079 inch (2 mm) minimum
F. Backing Plate Thickness 0.35 to 0.43 inch (9 mm to 11 mm)

Fig. 6, Brake Pad Inspection

2. If the pad thickness is within the acceptable range, inspect the pad surface.

   Minor damage (small amount of brake material chipped) at the edges is permitted, but replace the pads if major damage (section damaged or missing) is found on the surface.

Rotors

1. Examine the rotor and measure the thickness at the thinnest point. Avoid measuring near the edge of the rotor as minor burrs may be present. Replace the rotors when the minimum thickness is 1.46 in (37 mm), or when **one side** is greater than 0.15 inch (4 mm).

NOTE: It is recommended to replace the rotor with the same type that was originally installed on the vehicle and to replace the brake pads at the same time.

2. Inspect the rotor for grooves and cracks.

   Conventional rotors may be turned when changing pads, but is not normally necessary. In the case of severe grooving of the entire friction surface, then turning could be useful and may increase the load-bearing surface of the pads. To meet Bendix recommendations, the minimum rotor thickness after turning must be greater than 1.53 in (39 mm).

IMPORTANT: Always maintain air disc brake pads and rotors within specifications. Excessive pad or rotor wear will degrade optimum performance. When replacing rotors, be sure to adhere to Daimler Trucks North America (DTNA) recommended bolt tightening torques and sequence. See **Subject 130** for rotor replacement.

Installation

NOTE: When replacing brake pads, replace them as an axle set. Only use pads that have the same backing plate thickness as originally specified.

1. Install the outboard brake pad by sliding the caliper to the outboard position (be sure the brake lining material is facing the rotor).
2. Install the inboard pad by sliding the caliper to the inboard position.
3. Using a box-end wrench or socket, turn the shear adaptor clockwise until the pads come into contact with the rotor. Then turn the shear adaptor counterclockwise two clicks to set the initial running clearance.
4. Install the new pad retainer into the groove of the caliper. Depress the pad retainer, and install the new pad retainer pin so that it is pointing downward.
5. Install the new washer and spring clip to secure the pad retainer pin. See **Fig. 1**.

NOTE: The adjustment mechanism operates automatically whenever the brakes are activated, to compensate for rotor and brake pad wear and to keep the running clearance constant. During pad or rotor maintenance the technician is to manually set the systems' initial nonbraked position.

Brake Pad Removal, Inspection, and Installation

6. Set the total running clearance (sum of clearances on both sides of the rotor), between 0.024 to 0.043 in (0.6 to 1.1 mm). See **Fig. 7**.

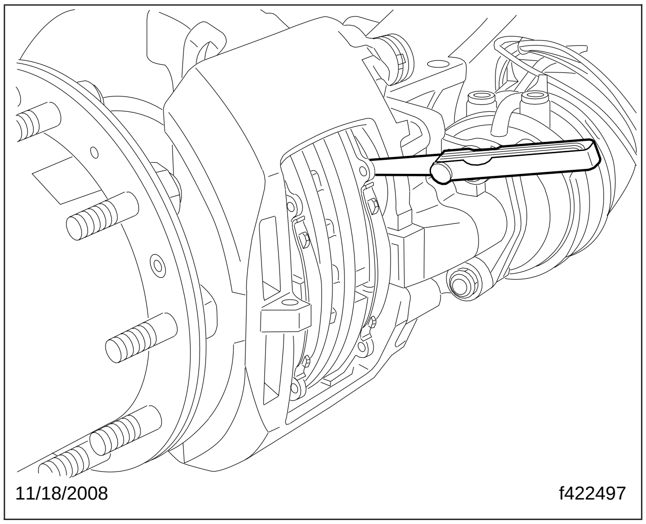


Fig. 7, Checking Brake Pad Running Clearance

7. Uncage the spring brake.
8. Apply and release the brake, then check that the hub turns easily by hand.
9. Using white lithium-based grease, lightly grease and install the adjuster cap.
10. Install the wheel(s). See **Group 40**.
11. Remove the safety stands and lower the vehicle.

Brake Caliper/Carrier Assembly Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

NOTE: Replacement bolts are not supplied with the caliper, use only bolts of a grade and type specified by Daimler Trucks North America (DTNA).

Replacement caliper/carrier assemblies may be delivered with a plastic cap, adhesive tape, or a breakthrough diaphragm in the area where the actuator is mounted. Remove the cap or tape only after installing the replacement caliper. If the replacement caliper has the breakthrough diaphragm, it should be left in place. Refer to **Fig. 1** for front caliper/carrier removal and installation.

Front Caliper/Carrier Assembly Removal

1. Apply the brakes and chock the tires.
2. Drain the air from the air system.
3. Raise the axle being serviced, and support it on a jackstand.
4. Remove the wheel. See **Group 40**.
5. Cut the zip ties holding the ABS harness to the brake hose as needed.

NOTE: If you are not replacing the caliper, it is not necessary to disconnect the air hose, if it can be safely supported out of the way while doing other work.

6. If replacing the caliper, disconnect the brake hose at the swivel connection at the frame rail, then remove the brake chamber from the caliper. See **Subject 150**.
7. With the caliper/carrier assembly securely supported, remove and discard the six bolts attaching the carrier to the anchor plate. Remove the caliper/carrier assembly.
8. Clean and inspect the anchor plate contact area. If damage is found, replace the anchor plate. See **Subject 140**.

Front Caliper/Carrier Assembly Installation

1. Position the carrier/caliper assembly, and attach it to the anchor plate with new bolts. Tighten 170 to 200 lbf·ft (230 to 271 N·m).
2. Install the brake pads, and brake pad shield, if equipped. See **Subject 110**.
3. Using new nuts, attach the brake chamber to the caliper/carrier assembly. Tighten 127 to 137 lbf·ft (172 to 186 N·m). See **Subject 150**.
4. Connect the brake hose.
5. Position the ABS harness, and install new zip ties to hold the harness to the brake hose. Leave room for movement.
6. Install the wheel. See **Group 40**.
7. Remove the jackstand, and lower the vehicle.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

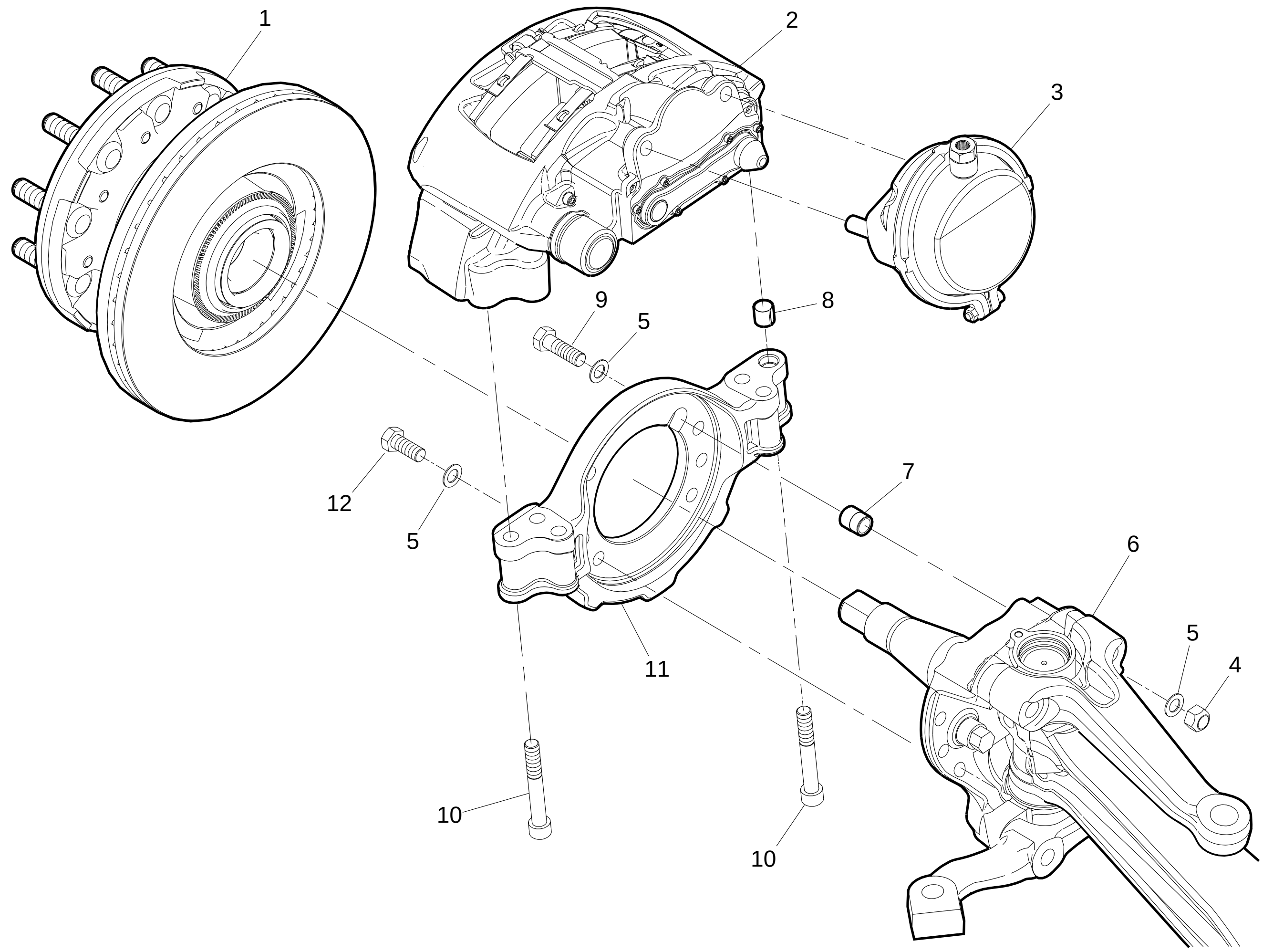
8. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
   - 8.1 Apply and release the brakes several times to check for air leaks and proper operation.
   - 8.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.
   - 8.3 Immediately after doing the above stops, check the rotor temperatures. Any rotors that are significantly cooler than others show a lack of braking effort on those wheels.

Rear Caliper/Carrier Assembly Removal

Refer to **Fig. 2** for rear caliper/carrier removal and installation.

1. Apply the brakes and chock the tires.

Brake Caliper/Carrier Assembly Removal and Installation



1. Hub and Disc Assembly
2. Caliper/Carrier Assembly
3. Brake Chamber
4. Nut
5. Washer
6. Spindle Assembly
7. ABS Sensor Bushing
8. Carrier Guide Bushing
9. Anchor Plate Bolt
10. Caliper Mounting Capscrew
11. Anchor Plate
12. Anchor Plate Capscrew

Fig. 1, Front Caliper and Carrier Assembly Installation

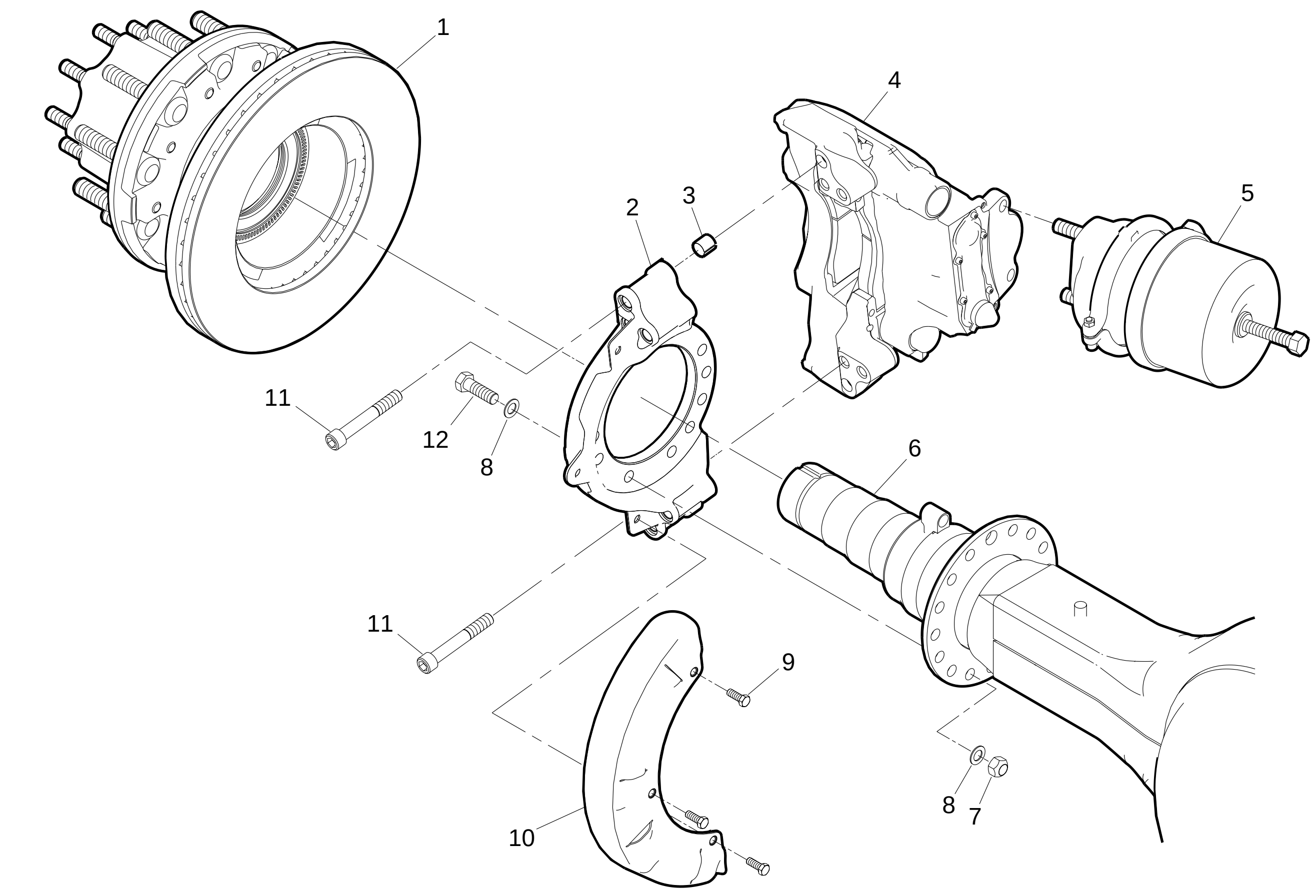
2. Raise the axle being serviced, and support it with an appropriate jackstand.
3. Remove the wheels. See **Group 40**.

⚠ WARNING

When work is being done on the spring chamber, carefully follow the service instructions of the chamber manufacturer. The sudden release of a compressed spring can cause serious personal injury or death.

4. Carefully cage and lock the spring brakes so that the springs cannot actuate during disassembly.

   Back out the release bolt using a maximum torque of 26 lbf·ft. (35 N·m) to release spring force on the pushrod. See **Fig. 3**.
5. Drain the air from the air system.



1. Hub and Rotor Assembly
2. Anchor Plate
3. Carrier Guide Bushing
4. Caliper/Carrier Assembly
5. Spring Brake Chamber
6. Axle End
7. Nut
8. Washer
9. Rotor Shield Capscrew
10. Rotor Shield
11. Caliper Mounting Capscrew
12. Bolt

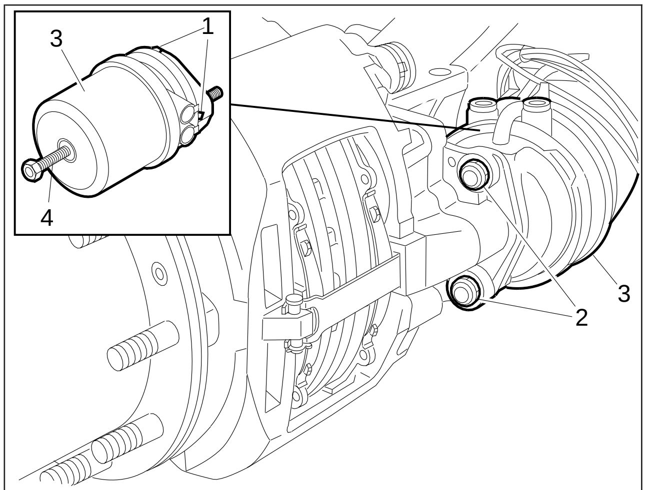
Fig. 2, Rear Caliper and Carrier Assembly Installation

6. Cut the zip ties holding the ABS harness to the brake hose as needed.
7. Remove the brake chamber from the caliper. See **Subject 150**.
8. Remove the rotor shield, if equipped.
9. With the caliper/carrier assembly securely supported, remove and discard the six bolts attaching the carrier to the anchor plate. Remove the caliper/carrier assembly.
10. Clean and inspect the anchor plate contact area. If damage is found, replace the anchor plate. See **Subject 140**.

Rear Caliper/Carrier Assembly Installation

1. Position the new carrier/caliper assembly, and attach it to the anchor plate with new bolts. Tighten 170 to 200 lbf·ft (230 to 271 N·m).

Brake Caliper/Carrier Assembly Removal and Installation



1. Drain Plugs
2. Brake Chamber Nuts
3. Brake Chamber
4. Release Bolt

Fig. 3, Spring Brake Chamber Installation

2. Install the brake pads, and brake pad shield, if equipped. See **Subject 110**.
3. Using new nuts, attach the brake chamber to the caliper/carrier assembly. Tighten 127 to 137 lbf·ft (172 to 186 N·m). See **Subject 150**.
4. Install the rotor shield, if equipped.
5. Uncage the spring brake chamber.
6. Install the wheels. See **Group 40**.
7. Remove the jackstand, and lower the vehicle.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

8. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
   8.1 Apply and release the brakes several times to check for air leaks and proper operation.
   8.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.
   8.3 Immediately after doing the above stops, check the rotor temperatures. Any rotors that are significantly cooler than others show a lack of braking effort on those wheels.

Brake Rotor Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

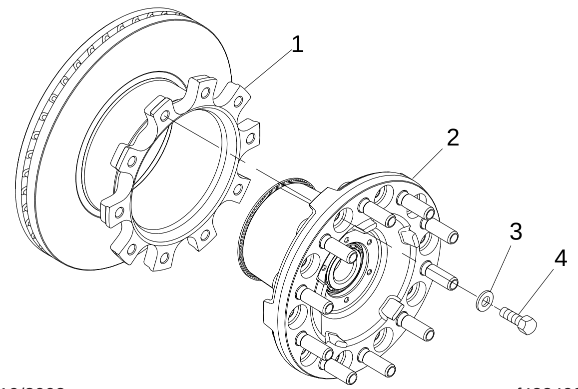
Brake Rotor Removal

1. Chock the wheels on an axle that is not being serviced.
2. Raise the axle end to be serviced, and secure it on a jackstand.
3. Remove the wheel(s). See **Group 40**.
4. Remove the brake caliper/carrier assembly. See **Subject 120**.
5. Remove the hub and rotor assembly. See **Group 33** for the front axle, or **Group 35** for the rear axle.

   If replacing the rotor, remove the capscrews from the hub, and remove the brake rotor. See **Fig. 1** for front axles, or **Fig. 2** for rear axles.

Brake Rotor Installation

1. If the rotor was removed from the hub, clean the mating surface of the hub and brake rotor as needed.



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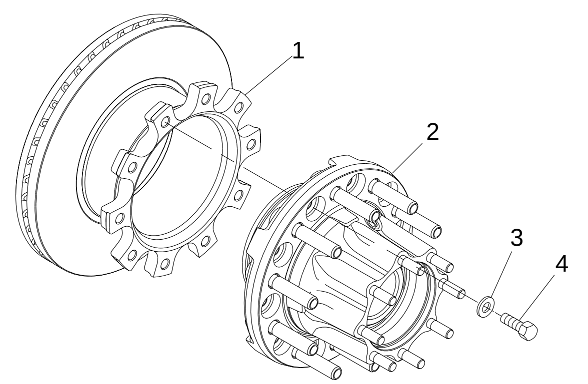
1. Rotor
2. Hub
3. Washer
4. Capscrew

Fig. 1, Front Rotor Installation



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1. Rotor
2. Hub
3. Washer
4. Capscrew

Fig. 2, Rear Rotor Installation

NOTE: It may be necessary to install the hub prior to tightening the hub-to-rotor capscrews to their final torque setting.

2. If replacing the rotor, position the new rotor on the hub, and install the capscrews. See **Fig. 1** for front axles, or **Fig. 2** for rear axles. Tighten 190 to 210 lbf·ft (258 to 285 N·m) using the sequence shown in **Fig. 3**.
3. Install the hub and rotor assembly. See **Group 33** for the front axle, or **Group 35** for the rear axle.

Brake Rotor Removal and Installation

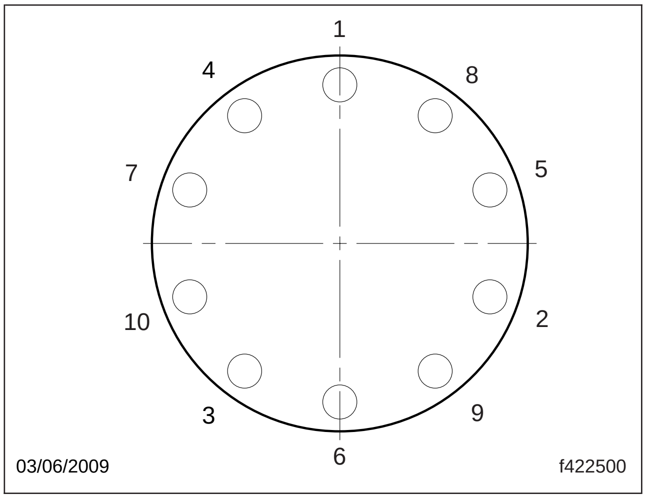


Fig. 3, Tightening Sequence

4. Install the brake caliper/carrier assembly. See **Subject 120**.
5. Install the wheel(s). See **Group 40**.
6. Remove the jackstand, and lower the vehicle.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

7. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
   7.1 Apply and release the brakes several times to check for air leaks and proper operation.
   7.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.
   7.3 Immediately after doing the above stops, check the rotor temperatures. Any rotors that are significantly cooler than others show a lack of braking effort on those wheels.

Anchor Plate Disassembly, Inspection, Cleaning, and Assembly

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Front Anchor Plate Removal

1. Apply the brakes and chock the tires.
2. Drain the air from the air system.
3. Raise the axle being serviced, and support it on a jackstand.
4. Remove the wheel. See **Group 40**.
5. Remove the caliper/carrier assembly. See **Subject 120**.
6. Remove the hub and disc assembly. See **Subject 130**.
7. Pull the ABS sensor from its hole in the axle flange, and secure it in a safe place.
8. Remove the fasteners and remove the anchor plate. See **Fig. 1**.

Rear Anchor Plate Removal

1. Apply the brakes and chock the tires.
2. Drain the air from the air system.
3. Raise the axle being serviced, and support it on a jackstand.
4. Remove the wheels. See **Group 40**.
5. Remove the rotor shield, if equipped. See **Fig. 2**.
6. Remove the caliper/carrier assembly. See **Subject 120**.
7. Remove the hub and disc assembly. See **Subject 130**.
8. Cut the zip ties holding the ABS sensor harness in place.
9. Disconnect the ABS sensor harness at its connection to the chassis harness, then feed it through the hole in the anchor plate and secure it in a safe manner.
10. Remove the fasteners and remove the anchor plate.

Anchor Plate Cleaning and Inspection

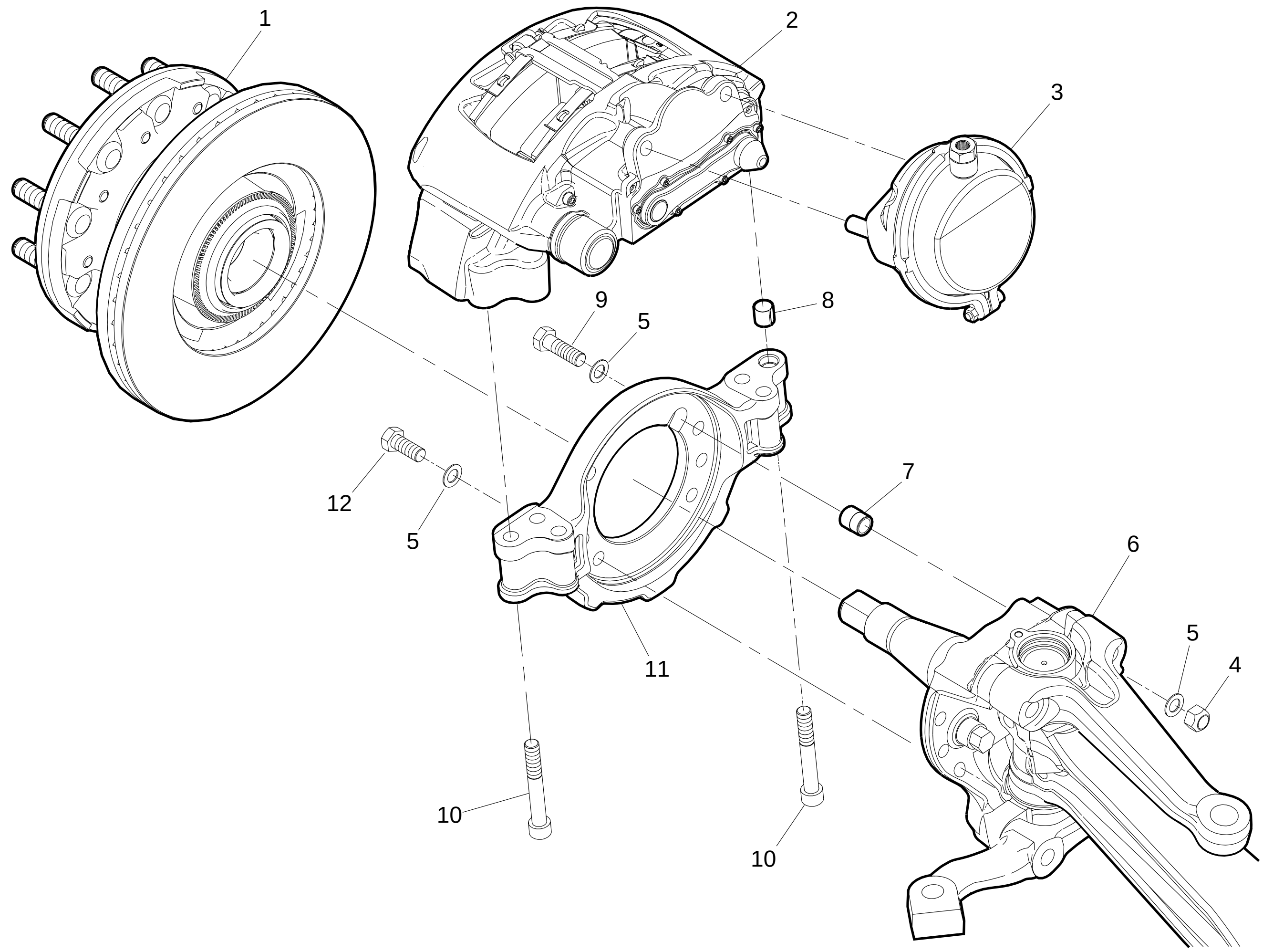
If replacing the anchor plate, it is not necessary to clean and inspect it. If the anchor plate will be reused, clean and inspect it as follows.

1. Clean the anchor plate with a brush and solvent.
2. Inspect the anchor plate for cracks or other damage. If damage is found, replace the anchor plate.
3. Inspect the carrier and axle flange mounting surface of the anchor plate. All surfaces must be clean and free of any rust or corrosion. Use a hand-held wire brush to clean these surfaces, if needed.
4. Check that the carrier bolt hole threads are clean and free of foreign matter, and that the carrier guide bushing is secure and properly seated.

Front Anchor Plate Installation

1. Position the anchor plate on the spindle flange with the caliper mounting bosses facing up, and the ABS sensor hole (larger) aligned with the uppermost forward hole on the axle flange.
2. Install the capscrews, washers, and nuts, as shown in **Fig. 1**.
   - 2.1 Install the 2-inch capscrew, washers, and nut, in the hole next to the ABS sensor hole.
   - 2.2 Then install the 1-1/2-inch capscrews that thread into the steering knuckle.
   - 2.3 Tighten the 2-inch capscrew 144 to 164 lbf·ft (195 to 222 N·m), and the 1-1/2-inch capscrews 168 to 188 lbf·ft (228 to 255 N·m) using the sequence shown in **Fig. 3**.
3. Install the hub and disc assembly. See **Subject 130**.
4. Install the ABS sensor. Push it in by hand, as far as it will go.
5. Install the caliper/carrier assembly. See **Subject 120**.
6. Install the wheel. See **Group 40**.
7. Remove the jackstand, and lower the vehicle.

Anchor Plate Disassembly, Inspection, Cleaning, and Assembly



1. Hub and Disc Assembly
2. Caliper/Carrier Assembly
3. Brake Chamber
4. Nut
5. Washer
6. Spindle Assembly
7. ABS Sensor Bushing
8. Carrier Guide Bushing
9. Anchor Plate Bolt
10. Caliper Mounting Capscrew
11. Anchor Plate
12. Anchor Plate Capscrew

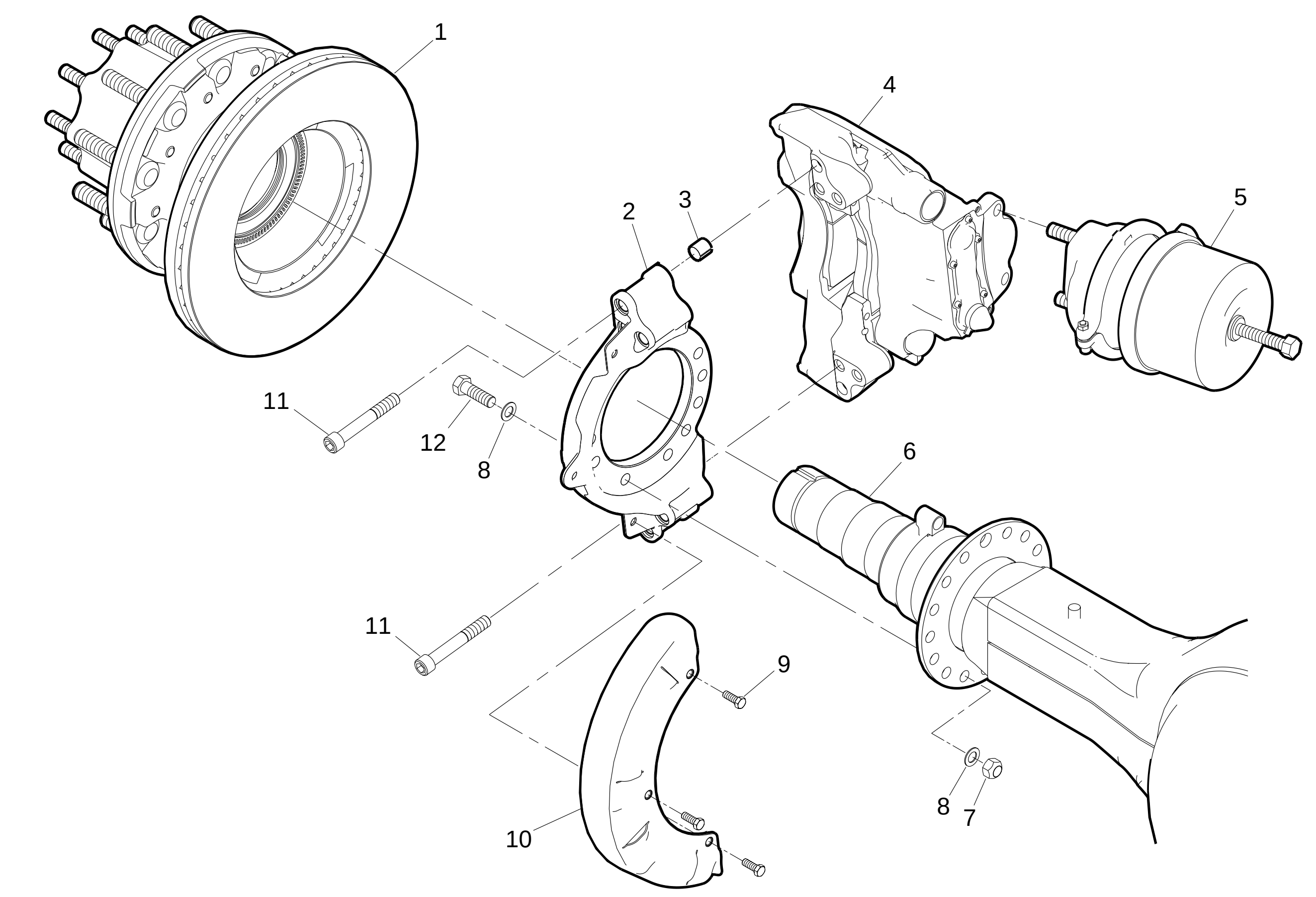
Fig. 1, Front Axle Anchor Plate Installation

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

8. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
   - 8.1 Apply and release the brakes several times to check for air leaks and proper operation.
   - 8.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.

Anchor Plate Disassembly, Inspection, Cleaning, and Assembly



1. Hub and Rotor Assembly
2. Anchor Plate
3. Carrier Guide Bushing
4. Caliper/Carrier Assembly
5. Spring Brake Chamber
6. Axle End
7. Nut
8. Washer
9. Rotor Shield Capscrew
10. Rotor Shield
11. Caliper Mounting Capscrew
12. Bolt

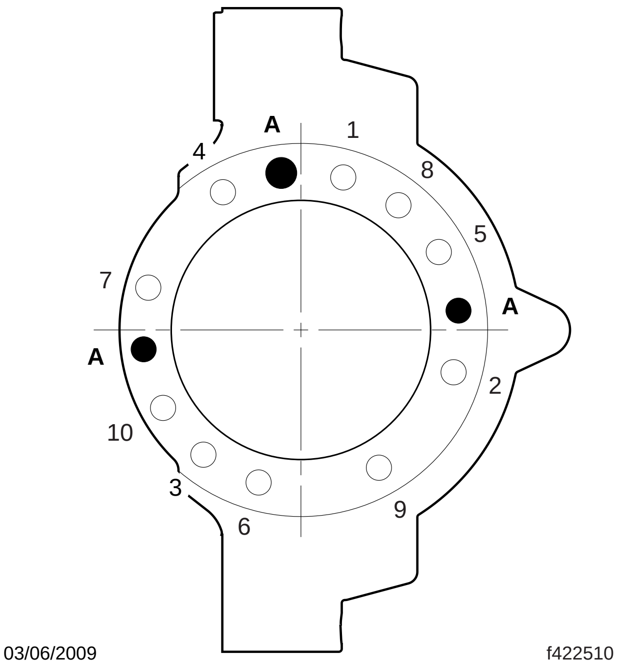
Fig. 2, Rear Axle Anchor Plate Installation

8.3 Immediately after doing the above stops, check the rotor temperatures. Any rotors that are significantly cooler than others show a lack of braking effort on those wheels.

Rear Anchor Plate Installation

1. Position the anchor plate on the axle flange with the ABS sensor hole at the 12 o'clock position on the axle flange. Install the ten capscrews, washers, and nuts, leaving the holes at 12, 3, and 9 o'clock positions empty. Tighten 144 to 164 lbf·ft (195 to 222 N·m), using the sequence shown in **Fig. 3**.
2. Feed the ABS sensor harness through the hole in the anchor plate, and connect it at the chassis harness. Secure it with zip ties as needed.
3. Install the hub and disc assembly. See **Subject 130**.
4. Install the caliper/carrier assembly. See **Subject 120**.
5. Install the rotor shield, if equipped.

Anchor Plate Disassembly, Inspection, Cleaning, and Assembly



A. Open Holes

Fig. 3, Tightening Sequence

6. Install the wheels. See **Group 40**.
7. Remove the jackstand, and lower the vehicle.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

8. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
   - 8.1 Apply and release the brakes several times to check for air leaks and proper operation.
   - 8.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.
   - 8.3 Immediately after doing the above stops, check the rotor temperatures. Any rotors that are significantly cooler than others show a lack of braking effort on those wheels.

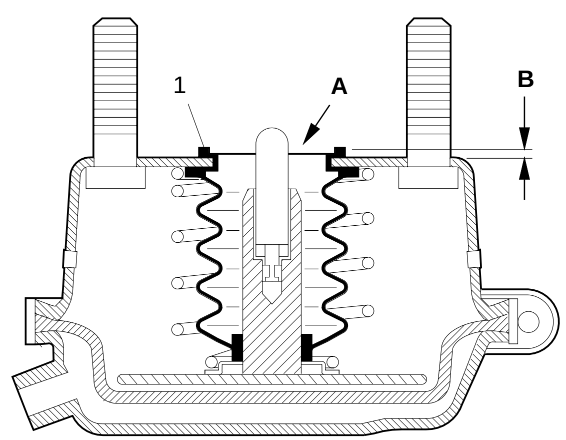
Brake Chamber, or Spring Brake Chamber, Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

IMPORTANT: Replace the brake chamber, or spring-brake chamber, only with units that are the same as originally installed on the vehicle. Replacement with alternate equipment could compromise brake performance and the vehicle warranty. Do not use brake chambers with seals with a thickness less than 0.12 in. (3 mm). See **Fig. 1**. Use only brake chambers which are recommended by Daimler Trucks North America (DTNA).

NOTE: New brake chambers have drain hole plugs installed in all positions. After installation, remove whichever plug is at the lowest position. Be sure that all other drain holes remain plugged.



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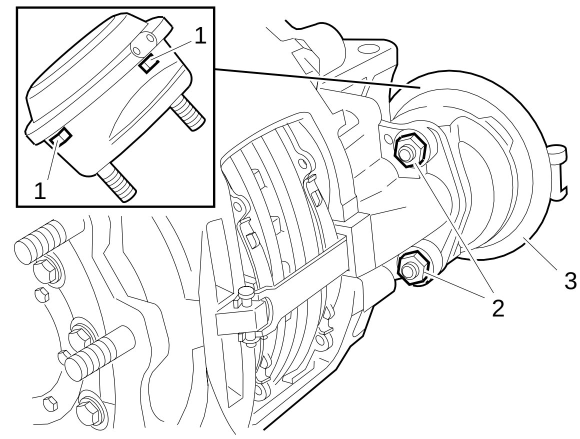
A. Pushrod Area
B. Do Not Use if Thickness is Less than 0.12 in (3 mm)
1. Seal

Fig. 1, Pushrod Area

Front Brake Chamber Removal

1. Apply the brakes and chock the tires.
2. Remove the wheels.
3. Drain the air from the air system.
4. Cut the zip ties holding the ABS wire to the air hose.
5. Disconnect the air hose at the frame rail connection.
6. Remove and discard the brake chamber mounting nuts. See **Fig. 2**.



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1. Drain Plugs
2. Brake Chamber Mounting Nuts
3. Brake Chamber

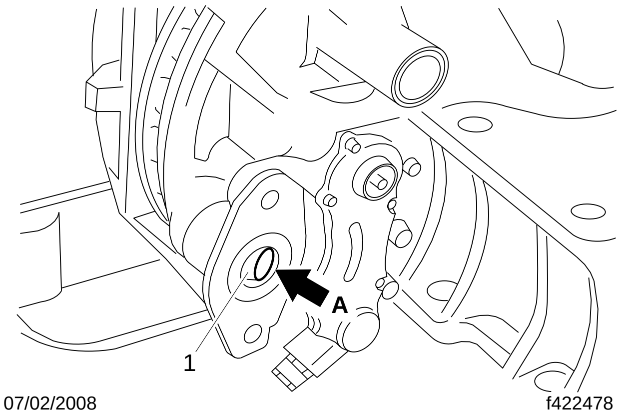
Fig. 2, Brake Chamber Installation

7. Remove the brake chamber.
8. If replacing the brake chamber, remove the air hose to use on the new one.

Front Brake Chamber Installation

1. If replacing the brake chamber, install the air hose from the old chamber.
2. Before installing the new brake chamber, clean and inspect the brake chamber flange for damage. See **Fig. 3**. The seal, as well as the pushrod area must be clean and dry. See **Fig. 1**.
3. Lubricate the spherical cup in the lever with white grease. Do not use grease containing molybdenum disulfate.

Brake Chamber, or Spring Brake Chamber, Removal and Installation



A. Actuator Flange

1. Spherical Cup in Lever

Fig. 3, Actuator Flange

4. Install the brake chamber using new self-locking nuts. Alternately tighten both nuts in increments to a final torque of 126 to 140 lbf·ft (170 to 190 N·m).
5. Connect the air hose. Be sure that the hose is not twisted, or in contact with moving vehicle components. The air hose routing must allow for full caliper travel.
6. Secure the ABS wire to the brake hose. Be sure to leave flex room.
7. Install the wheels.
8. Lower the vehicle.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

9. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
   - 9.1 Apply and release the brakes several times to check for air leaks and proper operation.
   - 9.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.
   - 9.3 Immediately after doing the above stops, check the rotor temperatures. Any rotors that are significantly cooler than others show a lack of braking effort on those wheels.

Spring Brake Chamber Removal

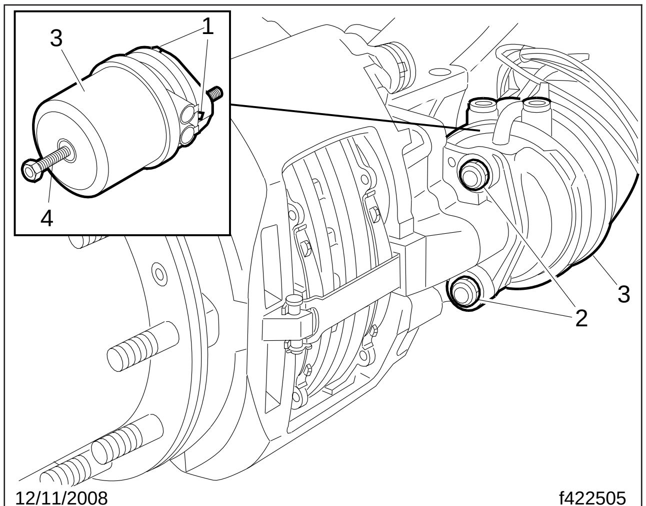
1. Set the brakes and chock the tires.
2. Remove the wheels.

WARNING

When work is being done on the spring chamber, carefully follow the service instructions of the chamber manufacturer. The sudden release of a compressed spring can cause serious personal injury or death.

3. Carefully cage and lock the spring brakes so that the springs cannot actuate during disassembly.

   Back out the release bolt using a maximum torque of 26 lbf·ft. (35 N·m) to release spring force on the pushrod. See **Fig. 4**.



1. Drain Plugs
2. Brake Chamber Nuts
3. Brake Chamber
4. Release Bolt

Fig. 4, Spring Brake Chamber Installation

4. Drain all the air pressure from the air brake system.

5. Cut the zip ties holding the ABS wire to the air hose.
6. Disconnect the air hose at the frame rail connection.
7. While supporting the spring brake chamber in position, remove and discard brake chamber mounting nuts. Remove the brake chamber.
8. If replacing the brake chamber, remove the air hose to use on the new one.

Spring Brake Chamber Installation

IMPORTANT: Replace the brake chamber, or spring-brake chamber, only with units that are the same as originally installed on the vehicle. Replacement with alternate equipment could compromise brake performance and the vehicle warranty. Do not use brake chambers with seals with a thickness less than 0.12 in. (3 mm). See **Fig. 1**. Use only brake chambers which are recommended by DTNA.

NOTE: New brake chambers have drain hole plugs installed in all positions. After installation, remove whichever plug is at the lowest position. Be sure that all other drain holes remain plugged.

1. If replacing the brake chamber, install the air hose from the old chamber.
2. Before installing the new brake chamber, clean and inspect the brake chamber flange for damage. The seal, as well as the pushrod area must be clean and dry. See **Fig. 3**.
3. Lubricate the spherical cup in the lever with white grease. Do not use grease containing molybdenum disulfate. See **Fig. 3**.
4. Install the brake chamber using new self-locking nuts. Alternately tighten both nuts in increments to a final torque of 126 to 140 lbf·ft (170 to 190 N·m).
5. Connect the air hose. Be sure that the hose is not twisted, or in contact with moving vehicle components. The air hose routing must allow for full caliper travel.
6. Secure the ABS wire to the brake hose. Be sure to leave flex room.
7. Uncage the spring brake.
8. Install the wheels.
9. Lower the vehicle.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

10. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
    - 10.1 Apply and release the brakes several times to check for air leaks and proper operation.
    - 10.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.
    - 10.3 Immediately after doing the above stops, check the rotor temperatures. Any rotors that are significantly cooler than others show a lack of braking effort on those wheels.

Specifications

Bendix Air Disc Brake Fastener Torque Specifications	
Installation	**Torque: lbf·ft (N·m)**
Hub to Rotor	190–210 (258–285)
Anchor Plate to Axle Flange: 2-inch (front)	144–164 (195–222)
Anchor Plate to Axle Flange: 1.5-inch (front)	168–188 (228–255)
Anchor Plate to Axle Flange (rear)	144–164 (195–222)
Caliper to Anchor Plate	170–200 (230–271)
Brake Chamber to Caliper	126–140 (170–190)
Rotor Shield to Anchor Plate	25–35 (34–47)

Table 1, Bendix Air Disc Brake Fastener Torque Specifications

General Information

The function of the Integrated Solution Air Dryer (AD-IS®) and reservoir system is to provide vehicles with an integrated air dryer, purge reservoir, governor, and a number of the charging valve components in a module. See **Fig. 1**.

The AD-IS® air dryer and reservoir system collects and removes air system contaminants in solid, liquid, and vapor form before they enter the brake system. It provides clean, dry air to the components of the brake system, which increases the life of the system.

Charge Cycle

Figure 2 shows the charge cycle.

When the compressor is loaded, compressed air, oil, oil vapor, water, and water vapor flow through the compressor discharge line to the inlet port of the air dryer body.

As air travels through the air dryer assembly, its temperature falls, causing some of the contaminants to condense and drop to the bottom of the air dryer assembly, ready to be expelled at the next purge cycle.

The air then flows into the desiccant cartridge. Once in the desiccant cartridge, air flows through an oil separator which removes oil and solid contaminants.

Air then flows into the desiccant drying bed. Air flowing through the desiccant becomes progressively dryer as water vapor adheres to the desiccant material.

Dry air exits the bottom of the desiccant cartridge and flows through the center of the base assembly. The air then flows to the delivery check valve, to the safety valve and also through an orifice plug into the purge reservoir. Air traveling through the delivery check valve flows to the governor and the four pressure protection valves.

As pressure builds during the initial charge, the purge reservoir fills. When the air pressure reaches 106 psi (731 kPa), the four pressure protection valves open and air is supplied to the primary reservoir, secondary reservoir, and accessories. If the pressure protection valves are preset to different values, the valves open in order of the lowest to the highest setting when charging a flat system.

The air dryer will remain in the charge cycle until the air brake system pressure builds to the governor cut-out setting of approximately 130 psi (896 kPa).

Purge Cycle

Figure 3 shows the purge cycle.

When air brake system pressure reaches the cutout setting of the governor, the governor unloads the compressor and the purge cycle begins. When the governor unloads the compressor, it pressurizes the compressor unloader mechanism and the dryer control port. The purge piston moves in response to air pressure, causing the purge valve to open and the turbo cutoff valve to close. When the purge valve opens, water and contaminants are expelled. Air flowing through the desiccant cartridge changes direction and begins to flow toward the open purge valve. Oil and solid contaminants collected in the oil separator are removed by air flowing from the purge reservoir, through the desiccant drying bed, and out through the open purge valve.

The purge cycle lasts only a few seconds and is detected by an audible burst of air at the air dryer exhaust.

The reactivation of the desiccant drying bed begins as dry air flows from the purge reservoir, through the purge orifice, and into the desiccant bed. Pressurized air from the purge reservoir expands after passing through the purge orifice; its pressure is lowered and its volume is increased. The flow of dry air through the drying bed reactivates the desiccant material by removing the water vapor adhering to it. Approximately 30 seconds is required for the entire purge reservoir of a standard air dryer to flow through the desiccant dryer bed.

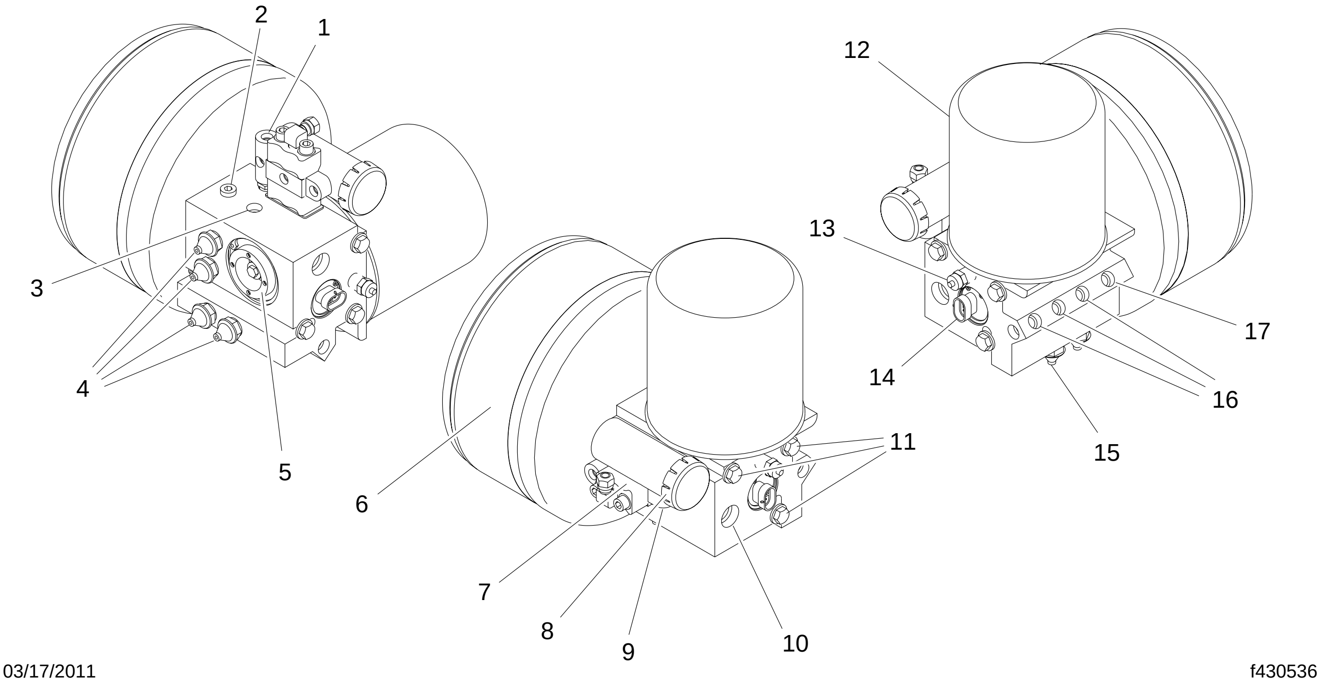
The delivery check valve assembly prevents air pressure in the brake system from returning to the air dryer during the purge cycle. After the purge cycle is complete, the air dryer is ready for the next charge cycle to begin.

Turbo Cutoff Feature

The primary function of the turbo cutoff valve is to prevent loss of turbocharger air pressure through the air dryer when the dryer is in the unloaded mode.

During the purge cycle, the downward travel of the purge piston is stopped when the turbo cutoff valve contacts its mating metal seat in the purge valve

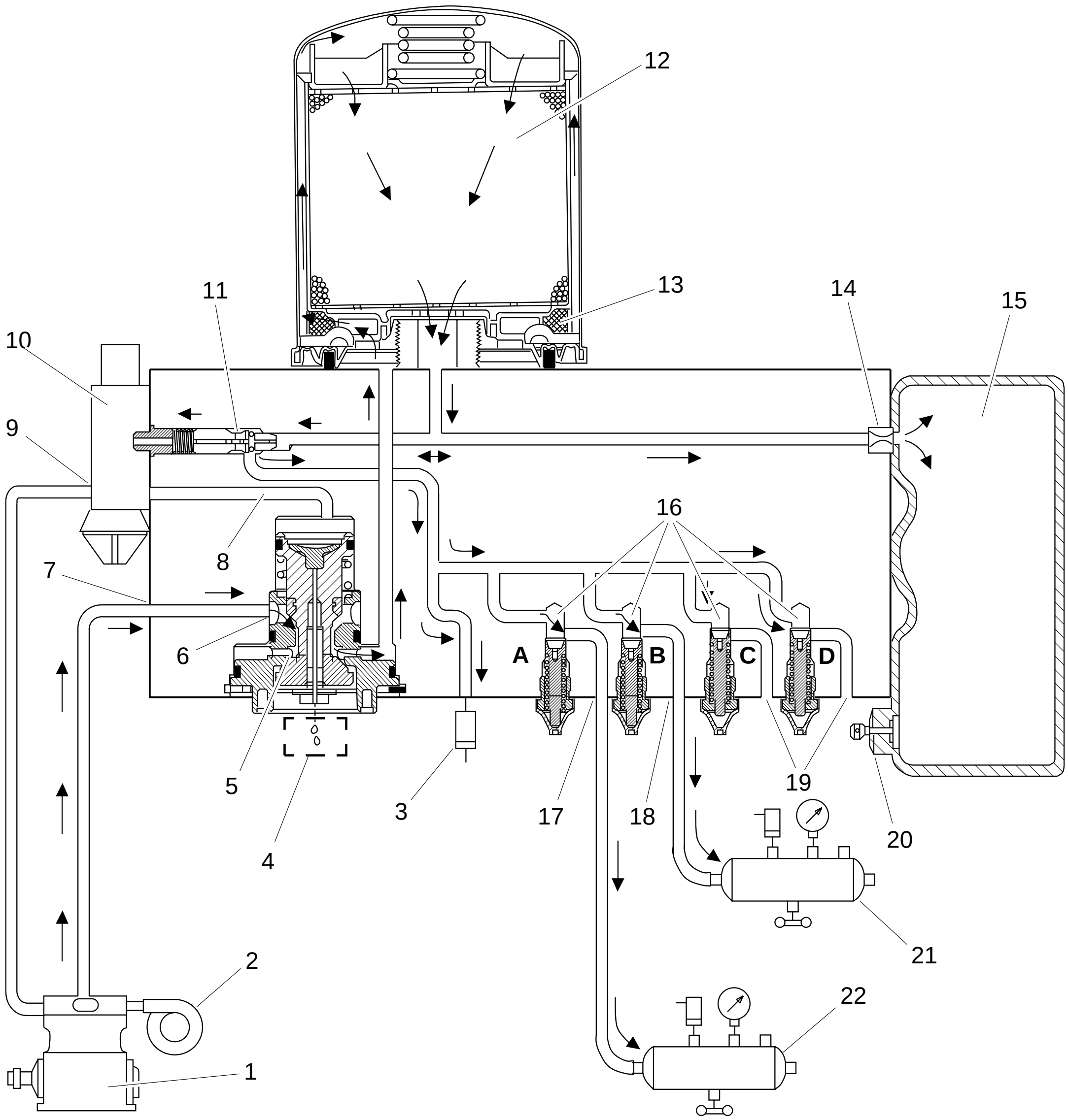
General Information



1. Governor Reservoir
2. Delivery to Secondary Reservoir
3. Delivery to Primary Reservoir
4. Pressure Protection Valves
5. Purge Valve
6. Purge Reservoir
7. Governor Unloader
8. Governor
9. Governor Exhaust
10. Supply from Compressor
11. Mounting Bolts (3)
12. Desiccant Cartridge
13. Safety Valve
14. Heater/Thermostat
15. Pressure Protection Valves (4)
16. Auxiliary Delivery Ports (4)
17. Auxiliary Delivery Ports (2)

Fig. 1, AD-IS Air Dryer

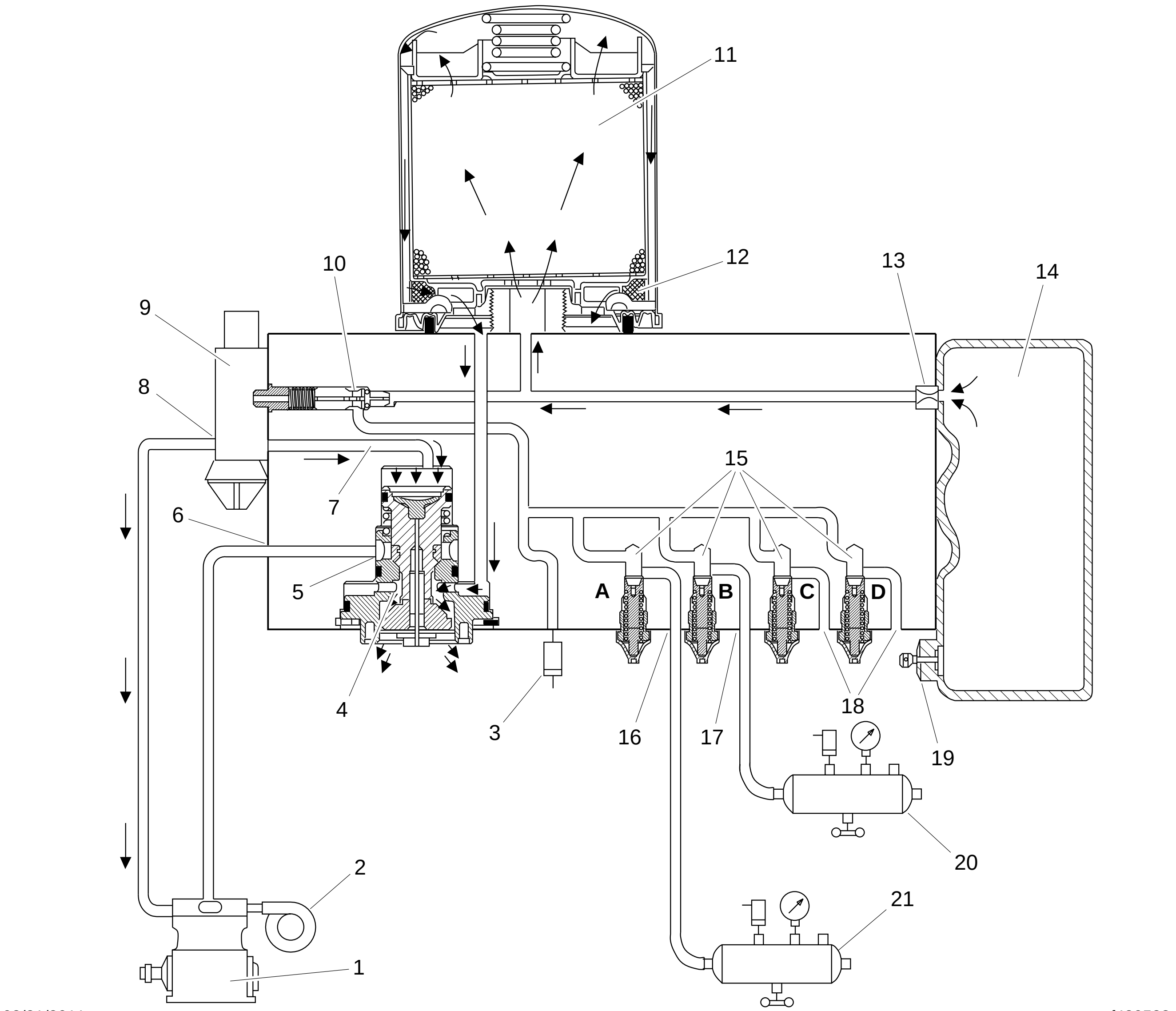
housing. With the turbo cutoff valve seated (closed position), air in the compressor discharge line and air dryer inlet port cannot enter the air dryer. This maintains turbocharger boost pressure to the engine.



1. Compressor
2. Engine Turbo
3. Safety Valve
4. Purge Control Channel Drain
5. Purge Valve (closed)
6. Turbo Cutoff Valve (open)
7. Inlet Port
8. Purge Control Channel
9. Unloader Port
10. Governor
11. Delivery Check Valve (open)
12. Desiccant Bed
13. Oil Separator
14. Purge Orifice
15. Purge Reservoir
16. Pressure Protection Valves
17. Primary Port
18. Secondary Port
19. Auxiliary Ports
20. Purge Reservoir Drain Valve
21. Secondary Reservoir
22. Primary Reservoir

Fig. 2, Air Dryer Charge Cycle

General Information



NOTE: All pressure protection valves are shown open.

1. Compressor
2. Engine Turbo
3. Safety Valve
4. Purge Valve (open)
5. Turbo Cutoff Valve (closed)
6. Inlet Port
7. Purge Control Channel
8. Unloader Port
9. Governor
10. Delivery Check Valve (closed)
11. Desiccant Bed
12. Oil Separator
13. Purge Orifice
14. Purge Reservoir
15. Pressure Protection Valves
16. Primary Port
17. Secondary Port
18. Auxiliary Ports
19. Purge Reservoir Drain Valve
20. Secondary Reservoir
21. Primary Reservoir

Fig. 3, Air Dryer Purge Cycle

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

- Chock the tires and shut down the engine before working under a vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Don’t disassemble a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools, and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.

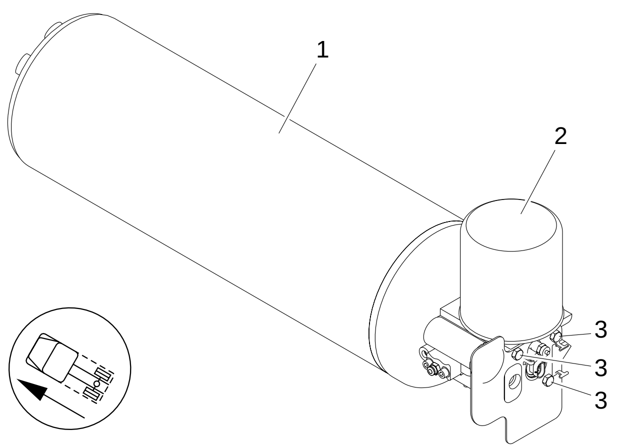
  Make sure that when replacing tubing or hose, all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs.
3. Mark and remove the air lines from the air reservoir.
4. Unplug the wiring harness from the heater/thermostat assembly.
5. Remove the three capscrews that fasten the air dryer to the air reservoir. See **Fig. 1**. Remove the air dryer.



1. Air Reservoir
2. Air Dryer
3. Capscrews

Fig. 1, AD-IS Air Dryer

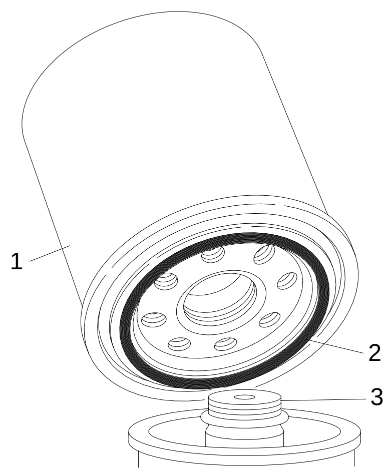
6. Remove the governor and delivery check valve from the air dryer. For instructions, see **Subject 130**.
7. Remove the desiccant cartridge. For instructions, see **Subject 120**.
8. Install the delivery check valve and governor onto the new air dryer. For instructions, see **Subject 130**.
9. If removed, install the desiccant cartridge. For instructions, see **Subject 120**.
10. Install the air dryer, making sure the two O-rings are installed between the air dryer and air reservoir. Use the three capscrews to fasten the air dryer to the reservoir. Tighten the capscrews 30 to 35 lbf·ft (41 to 47 N·m). See **Fig. 1**.
11. Connect the air lines and plug the wiring harness into the heater/thermostat assembly.
12. Perform the operational tests in **Subject 170**.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for desiccant cartridge replacement.



1. Desiccant Cartridge
2. Cartridge Sealing Ring
3. Threaded Base Post

Fig. 1, Desiccant Cartridge Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs.
3. Using a strap wrench or equivalent, loosen the desiccant cartridge. Spin the cartridge off by hand and discard it.
4. On the new desiccant cartridge, lubricate the sealing rings with silicone grease.

IMPORTANT: Only use the silicone grease supplied with AlliedSignal replacement kits.

5. Screw the desiccant cartridge onto the body, by hand, until the seal makes contact with the body. Rotate the cartridge clockwise about one full turn. If necessary, use a strap wrench to tighten the cartridge.

Delivery Check Valve and Governor Replacement

⚠ WARNING

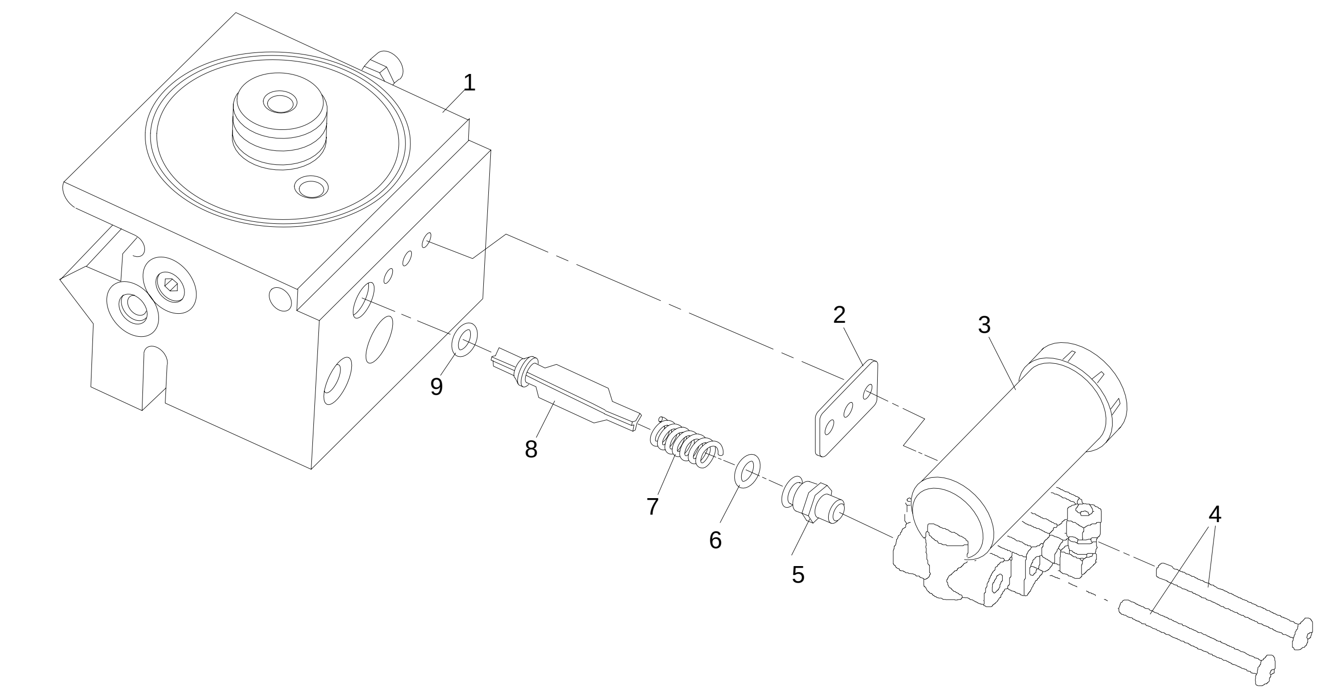
Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs.
3. Disconnect the air line from the governor and mark it for later reference. See **Fig. 1**. Remove the capscrews that attach the governor to the air dryer.
4. Remove the governor, adaptor fitting, and the adaptor O-ring. Remove the governor gasket and discard it.
5. Remove the spring and check valve.
6. Lubricate the new smaller O-ring and check valve body with silicone grease.

IMPORTANT: Only use the silicone grease supplied with AlliedSignal replacement kits.

7. Install the O-ring on the check valve body and push the O-ring down, over the longer set of three guide lands, until it is in the O-ring groove of the check valve body.
8. Install one end of the check valve spring over the check valve's shorter set of three guide lands. Turn the valve about 1/4 turn while holding the spring, if necessary, to secure the valve in place. Install the assembled check valve body, O-ring, and spring in the delivery port, so the O-ring rests on its seat and the free end of the spring is visible.



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1. Air Dryer Base
2. Gasket
3. Governor
4. Capscrews
5. Adaptor
6. O-Ring
7. Spring
8. Check Valve Body
9. O-Ring

Fig. 1, Delivery Check Valve Replacement

Delivery Check Valve and Governor Replacement

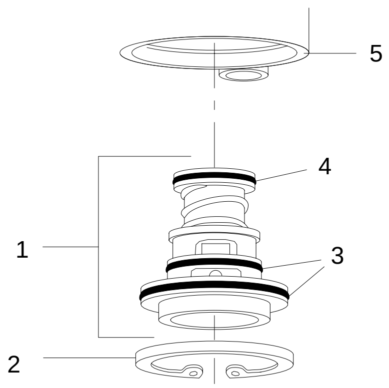
9. Install the adaptor fitting into the governor. Using the silicone grease, lubricate the remaining larger O-ring, and install it into the groove of the adaptor. Install the gasket supplied in the kit. Install the governor, and torque the capscrews 10 lbf·ft (14 N·m).
10. Perform the operational tests in **Subject 170**.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to Fig. 1 for purge valve replacement.



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1. Purge Valve Assembly
2. Retaining Ring
3. O-Rings
4. Quad-Ring
5. Air Dryer

Fig. 1, Purge Valve Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the vehicle air reservoirs.
3. Remove and discard the snap ring that secures the purge valve assembly in the end cover.
4. Remove the purge valve assembly from the air dryer end cover.
5. Lubricate the new O-rings, and O-ring grooves of the new purge valve assembly.
6. Lubricate the end cover bore of the new purge valve assembly.

IMPORTANT: Use only the silicone grease supplied with the AlliedSignal replacement kit.

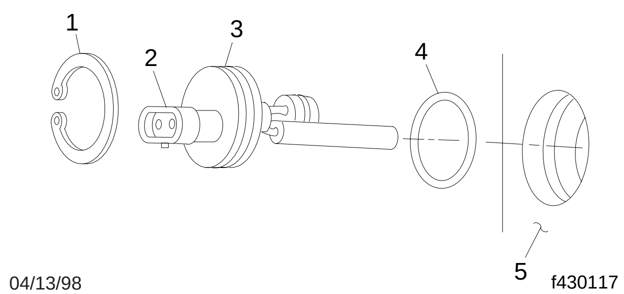
7. Install the two new O-rings on the purge valve housing cover, and the new quad-ring on the purge piston.
8. Install the new purge valve assembly in the end cover while making sure the purge valve housing is fully seated against the end cover.
9. Install the new retaining ring in its groove in the end cover.
10. Perform the operational tests in Subject 170.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Lift the lock tab on the vehicle wiring harness connector and disconnect it from the air dryer base. See **Fig. 1**.



1. Retaining Ring
2. Heater/Thermostat Connector Plug
3. Heater/Thermostat Assembly
4. O-Ring
5. Air Dryer Body

Fig. 1, Heater and Thermostat Assembly

3. Remove and discard the retaining ring that secures the heater and thermostat assembly in the air dryer body.
4. Carefully pull the heater and thermostat assembly straight out of the air dryer body and discard it.
5. Using the silicone grease provided with the AlliedSignal replacement kit, lubricate the O-ring groove and O-ring of the new assembly.

IMPORTANT: Do not lubricate the heater stick or thermostat.

6. Install the O-ring on the heater/thermostat assembly. Then, slide the assembly into the air dryer body, making sure not to scrape insulation from the wires.
7. Install the retaining ring in the groove of the air dryer body, making certain that it is fully seated in the groove.
8. Remove the protective cover from the assembly.
9. Turn the ignition on without starting the engine. Make sure vehicle power is present at the contacts of the vehicle wire harness.

WARNING

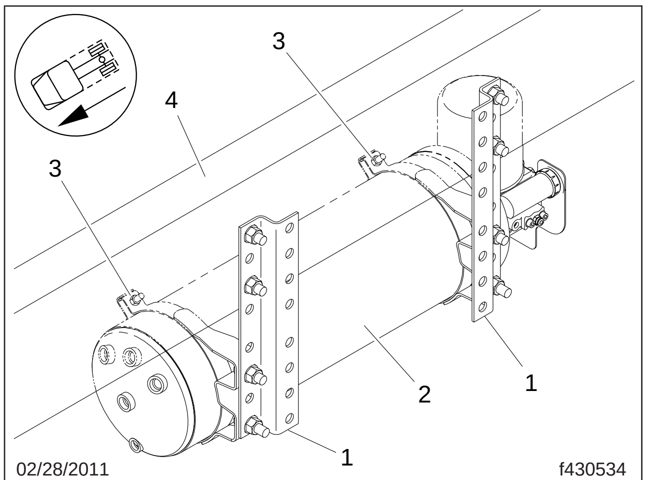
Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air system.
3. Mark and disconnect all reservoir air lines and couplers for later assembly. Cap the exposed ports tightly to keep out contaminants. If access is limited, remove the components after removing the reservoir from its mount.
4. Remove the air dryer. For instructions, see **Subject 110**.

NOTE: Loosen the bottom strap fastener first. See **Fig. 1**.

5. Remove the reservoir strap fasteners. Remove the reservoir.



1. Mounting Bracket
2. Air Reservoir
3. Strap Fastener
4. Frame Rail

Fig. 1, Air Reservoir, Frame Rail Mounting

6. If access is limited, do the next step first. If not, place a new reservoir in the mount, and install the strap fasteners. Tighten the fasteners 35 lbf·ft (47 N·m). Tighten the bottom strap fastener 136 lbf·ft (184 N·m).
7. As marked earlier, connect all air lines and couplers to the new reservoir, removing the caps as each component is installed. Tighten the connections as instructed elsewhere in this group.

   Install the air dryer. For instructions, see **Subject 110**.
8. Perform the operational test in **Subject 170**.

Operating and Leakage Tests

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Operational Tests

1. Shut down the engine, and chock the tires.
2. Install a pressure gauge in one of the spare governor ports labeled "RES."
3. Close all drain cocks and start the engine. Build the air system to governor cutout, then shut down the engine.
4. Check all air lines and fittings leading to and from the air dryer for leakage. Note the pressure on the air gauge after the governor cutout pressure is reached, a rapid loss of pressure could indicate a leaking delivery port check valve or turbo cut-off valve.
5. To check for delivery check valve leakage, allow the system air pressure to charge and listen for the air dryer to purge. The purge should last about 30 seconds.
6. Gradually open the drain cock on the purge tank and exhaust any residual pressure.
7. Coat the drain cock with a soap solution. If leakage does not exceed a 1-inch (25-mm) bubble in 1 second, go to step 9.

   If leakage does exceed a 1-inch (25-mm) bubble in one second, proceed with the following step.
8. Apply the brakes a few times, bring the air pressure to a point below governor cut-in (about 95 psi [655 kPa]). The governor will then signal the end of the purge cycle, closing the turbo cut-off valve. Allow any delivery line air pressure to drain, then check again for leakage at the purge tank drain cock. If excessive leakage has stopped, the turbo cut-off valve should be checked.

NOTE: If after replacing the delivery check valve, rapid loss of system air pressure continues, the delivery check valve and turbo cut-off valve are still leaking. Check the valves.

9. Check the operation of the end cover heater and thermostat assembly during cold-weather operation as follows:

   9.1 Check the electric power to the air dryer. With the ignition or engine kill switch in the ON position, check for voltage to the heater and thermostat assembly using a voltmeter or test-light. Unplug the electrical connector at the air dryer and place the test leads on each of the connections of the female connector on the vehicle power lead. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check to see if a good ground path exists.

   9.2 Test the thermostat and heater operation. Turn off the ignition switch and cool the thermostat and heater assembly to below 40°F (4°C). Using an ohmmeter, check the resistance between the electrical pins in the air dryer connector half. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly and 6 to 9 ohms for the 24-volt heater assembly.

   Warm the thermostat and heater assembly to about 90°F (32°C) and check the resistance again. The resistance should exceed 1000 ohms. If the resistance values obtained are within the stated limits, the thermostat and heater assembly is operating properly. If the resistance values obtained are outside the stated limits, replace the heater and thermostat assembly. For instructions, see **Subject 150**.
10. Check the pressure protection valves. Observe the pressure gauges of the vehicle as system pressure builds from zero. The primary gauge should rise until it reaches approximately 109 psi (752 kPa), then level off as the second pressure protection valve opens and allows the secondary volume to build. When the secondary pressure gauge passes through approximately 55 and 85 psi (379 and 586 kPa) there should be an associated leveling off of pressure as the third and fourth pressure protection valves open. Then, both the primary and secondary gauges should reach their full pressure of about 130 psi (896 kPa).

Troubleshooting

Problem—Air Dryer Is Constantly Cycling or Purging

Problem—Air Dryer Is Constantly Cycling or Purging	
Possible Cause	**Remedy**
Excessive system leakage.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is as follows: • Single Vehicle—1 psi/min (7 kPa/min) per service reservoir • Tractor/Trailer—3 psi/min (21 kPa/min) per service reservoir
There is excessive leakage in the fittings, hoses, and tubing connected to the compressor, air dryer, and wet tank.	Using a soap solution, test for leakage at the fittings, drain valve, and safety valve in the wet tank. Repair or replace as needed.
The check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at the opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.
Governor is inoperative.	Test the governor for proper cut-in or cut-out pressures and excessive leakage in both positions.
Compressor unloader mechanism is leaking excessively.	Remove the air strainer or fitting from the compressor inlet cavity. With the compressor unloaded, check for unloader piston leakage. Slight leakage is allowed.

Problem—Water in the Vehicle Reservoirs

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Desiccant cartridge assembly contains excessive contaminants.	Replace the desiccant cartridge.
Discharge line is of improper length or material.	Discharge line must consist of at least 6 ft (1.8 m) of wire braid Teflon hose, copper tubing, or a combination of both between the discharge port of the compressor and the air dryer supply port. Discharge line lengths and inside diameter requirements are dependent on the vehicle application. Contact your local Bendix representative for further information.
Air system was charged from an outside air source that did not pass through an air dryer.	If the system must have an outside air fill provision, the outside air should pass through an air dryer. This practice should be minimized.
The air dryer is not purging.	Refer to "Problem—Air Dryer Does Not Purge or Exhaust Air."
Purge (air exhaust) is insufficient due to excessive system leakage.	Refer to "Problem—Air Dryer Is Constantly Cycling or Purging."
Air bypasses the desiccant cartridge assembly.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed.
Purge (air exhaust) time is significantly less than the minimum allowable.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed. Replace the desiccant cartridge assembly.
Excessive air usage—air dryer not compatible with vehicle air system.	Install an accessory bypass system. Consult your Bendix representative for additional information.

Troubleshooting

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air	
Possible Cause	**Remedy**
The check valve is defective.	Test to determine if air is passing through the check valve. Repair or replace as needed.
Safety valve setting is lower than the maximum system pressure.	Reduce the system pressure, or install a safety valve with a higher pressure setting.
System pressure is too high.	Using an accurate gauge, test the system. Replace the governor if needed.
There are excessive pressure pulsations from the compressor.	Increase the volume in the discharge line. This can be done by adding a 90 in_3 (1475 $cm_{3)}$ [or larger] reservoir between the compressor and the air dryer and reservoir system.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Air dryer purge valve is leaking excessively.	With the compressor loaded, apply a soap solution on the purge valve exhaust to test for excessive leakage. Repair the purge valve as needed.
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
Purge valve is frozen open due to an inoperative heater or thermostat, bad wiring, or a blown fuse.	Test the heater and thermostat, following instructions in this manual.
The check valve is inoperative.	Refer to "Problem—Air Dryer Is Constantly Cycling or Purging."
The turbo cut-off valve is leaking.	Repair or replace the purge valve assembly.
The purge valve control piston quad-ring is leaking.	Repair or replace the purge valve assembly.
Discharge line is kinked or blocked.	See if air passes through the discharge line. Check for kinks, bends, or excessive carbon deposits.
There are excessive bends in the discharge line. Water is collecting and freezing.	Discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.
Pressure protection valves in the air dryer will not open.	Replace the air dryer; pressure protection valves are not serviceable.

Problem—Air Dryer Does Not Purge or Exhaust Air

Problem—Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
The air dryer purge valve is not working.	Make certain that air reaches the purge valve control port by installing a T-fitting with a pressure gauge into the governor unloader port. Repair the purge valve if needed.
Purge valve is frozen open due to an inoperative heater or thermostat, bad wiring, or a blown fuse.	Test the heater and thermostat. Refer to **Subject 170** for instructions.

Problem—Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
The purge valve control piston quad-ring is leaking.	Repair or replace the purge valve assembly.

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (may look like whitish liquid, paste, or small beads); or, Unsatisfactory Desiccant Life

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (may look like whitish liquid, paste, or small beads) or Unsatisfactory Desiccant Life	
Possible Cause	**Remedy**
This problem usually occurs with one or more of the previous problems.	Refer to the appropriate corrections listed previously.
The air dryer is not securely mounted; there is excessive vibration.	Vibration should be held to a minimum. Tighten the mounting fasteners.
Cloth-covered perforated plate in the air dryer desiccant cartridge is damaged, or the cartridge was rebuilt incorrectly.	Replace the plate or cartridge as needed. High operating temperatures may cause deterioration of filter cloth. Check the installation.
Compressor is passing excessive oil.	Check for proper compressor installation; if symptoms persist, replace the compressor.
Heater and thermostat, wiring, or a fuse is at fault, and isn't allowing the air dryer to purge during cold weather.	Test the heater and thermostat. Refer to **Subject 170** for instructions.
Desiccant cartridge is not attached properly to the end cover.	Check the torque and tighten if necessary. Refer to **Subject 120** for instructions.

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle

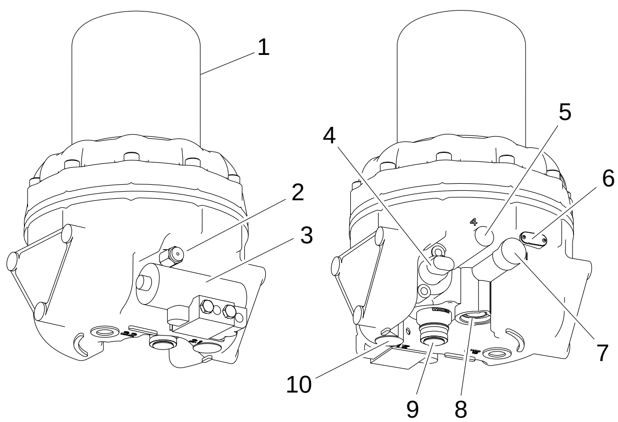
Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle	
Possible Cause	**Remedy**
Pinging noise is due to a single cylinder compressor with high pulse cycles.	A slight pinging sound may be heard during system build-up when a single cylinder compressor is used. If this sound is deemed objectionable, it can be reduced substantially by increasing the discharge line volume. This is done by adding a 90 in^3 (1475 cm^3) reservoir between the compressor and the air dryer.

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode	
Possible Cause	**Remedy**
Compressor does not "unload."	Check the air hose from the governor to the compressor for a missing, kinked, or restricted line. Repair or replace the air hose as needed. Repair or replace the compressor unloader.

General Information

The System Saver 1200 Plus air dryer, shown in **Fig. 1**, is a desiccant air dryer, mounted vertically between the air compressor and the supply reservoir. The air dryer receives hot compressed air, which it cools and filters before sending it to the supply reservoir, reducing the buildup of dirt and moisture in the vehicle air system.



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1. Desiccant Canister
2. Pressure Relief Valve
3. Governor
4. Heater/Thermostat Assembly
5. Control Port (to the air compressor unloader port)
6. Date Code Information (for the air dryer)
7. Air Dryer Inlet (from the air compressor discharge)
8. Turbocharger Cutoff Valve
9. Exhaust Port (Purge Valve Assembly)
10. Delivery/Outlet Port (to the air supply reservoir)

Fig. 1, WABCO System Saver 1200 Plus

The air dryer consists of a light weight aluminum and steel body. The desiccant cartridge is contained in a spinoff canister at the top of the air dryer.

The bottom half of the air dryer houses the following components.

- Pressure Relief Valve—this valve protects the air dryer from over pressurization. The valve is attached directly to the air dryer.
- Desiccant Canister—a cylindrical steel housing that contains the filter elements and the desiccant needed to filter and dry the air that passes through it.
- Heater/Thermostat Assembly—located in the air dryer base, this assembly is designed to prevent the collected moisture from freezing.
- Outlet Check Valve—this valve prevents air in the system from flowing back through the air dryer and escaping out the purge valve during the compressor unload cycle.
- Purge Valve—this valve allows the collected moisture and contaminants to be expelled from the air dryer during the purge cycle.
- Silencer (Muffler)—an optional component that is attached to the purge valve and used to eliminate most of the noise during the air dryer purge cycle.
- Turbocharger Cutoff Valve—this optional valve closes the path between the air compressor and the air dryer purge valve to help maintain boost pressure for maximum engine horsepower during the compressor unload cycle. A turbocharger cutoff valve is required with air compressors that use a turbocharged air intake.

NOTE: If the air compressor is naturally aspirated, the air passes from the vehicle air filter directly to the air compressor intake and **does not** require a turbocharger cutoff valve.

Principles of Operation

Hot, compressed air enters the air dryer through the inlet port. As the hot air is forced into the desiccant cartridge, the temperature of the compressed air falls to nearly ambient. Oil and water vapor condense and initially settle into the base of the dryer. The moisture-laden air also passes through the desiccant bed, where any remaining moisture is retained by the desiccant. The clean air then passes through the air dryer outlet port to the supply reservoir.

When the compressor reaches 125 psi (862 kPa), the purge valve opens, allowing the initial decompression of the dryer, and expelling the water and contaminants collected in the base of the dryer.

Safety Precautions

WARNING

When draining the air system, do not look into the air jets or direct them toward another person, as dirt or sludge particles may be in the air-stream. Do not disconnect pressurized hoses because they may whip as air escapes from the line. Failure to take all necessary precautions during service operations of the air brake system can cause personal injury.

When working on or around air brake systems and components, observe the following precautions.

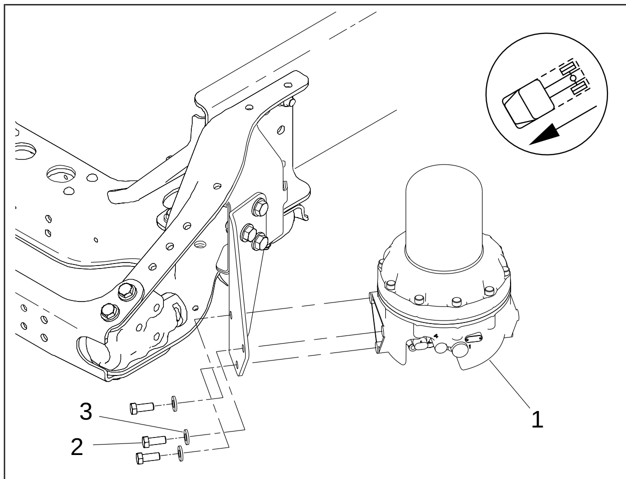
- Apply the parking brake, chock the tires, and stop the engine when working under the vehicle. Draining the air system may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air system pressure drops.
- Wear safety goggles.
- Never connect or disconnect a hose or line containing air under pressure; it may whip as air escapes. Never remove a component or pipe plug unless you are sure all system pressure has been depleted.
- Do not disassemble a component before reading and understanding recommended procedures. Use only the correct tools and follow basic tool safety.
- Replacement hardware, tubing, hose, fittings, etc., should be the same size, type, length, and strength as the original equipment. When replacing tubing or hose, be sure that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace any components that have stripped threads or damaged parts. Do not attempt to repair parts by machining.
- Never exceed recommended air pressure.

Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Refer to Fig. 1 for removal and installation of the air dryer.



1. Air Dryer
2. Mounting Screw
3. Washer

Fig. 1, Air Dryer Installation (left-hand forward frame mounting shown)

Removal

1. Drain the air system.
2. Disconnect the wiring harness from the air dryer.
3. Mark the air lines for later reference; then, disconnect them from the air dryer.
4. Remove the mounting screws and washers that attach the air dryer to the mounting bracket.
5. Remove the air dryer.

Installation

1. Position the air dryer on the mounting bracket. Install the washers and capscrews. Tighten them 52±4 lbf·ft (71±4 N·m).
2. Make sure the air lines are clean. Replace any line or fitting that is crimped or damaged.
3. Connect the remaining air lines to the air dryer as previously marked. Tighten the nut on each fitting finger-tight. Then, using two wrenches to prevent twisting the hose, further tighten the nut until there is firm resistance.
4. Connect the air dryer wiring harness.

Turbocharger Cutoff Valve Replacement

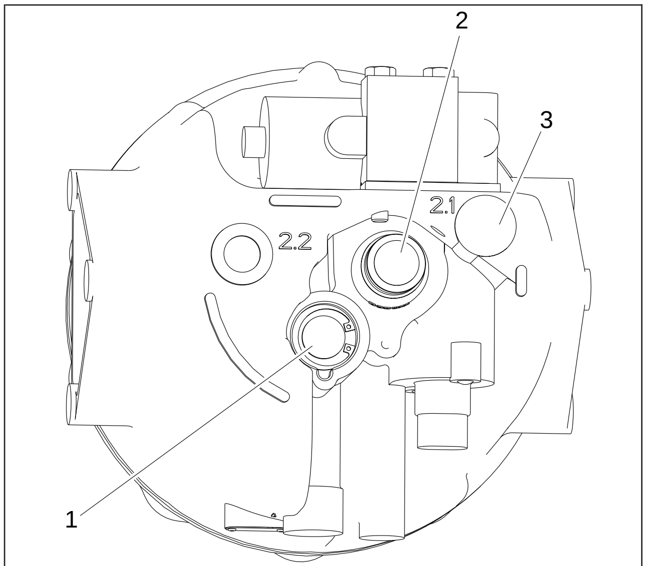
⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

IMPORTANT: The turbocharger cutoff valve is optional on the WABCO System Saver 1200 Plus air dryer.

Replacement

1. Drain the air system.
2. Remove the snap ring at the bottom of the valve assembly. See **Fig. 1** for the location of the turbocharger cutoff valve and **Fig. 2** for an example of the turbocharger cutoff valve assembly.



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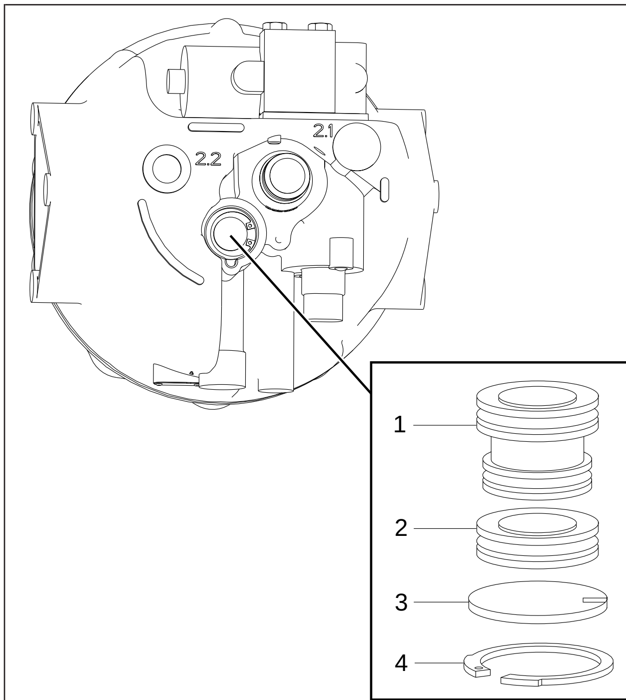
1. Turbocharger Cutoff Valve (has an orange cover)
2. Exhaust Port (Purge Valve Assembly)
3. Delivery/Outlet Port (to the air supply reservoir)

Fig. 1, Turbocharger Cutoff Valve

3. Clean the valve cavity with a commercial cleaning solvent.

IMPORTANT: If the valve cavity is damaged, preventing a tight seal, replace the air dryer. See **Subject 110** for instructions.

4. Install new O-rings on the piston and the sleeve.



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1. Piston
2. Sleeve
3. Cover
4. Snap Ring

Fig. 2, Turbocharger Piston and Sleeve Assembly

5. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the new O-rings and the valve cavity.
6. Press the piston into the sleeve.
7. Press the new piston and sleeve assembly into the air dryer.
8. Install the cover and snap ring to hold the components in place.

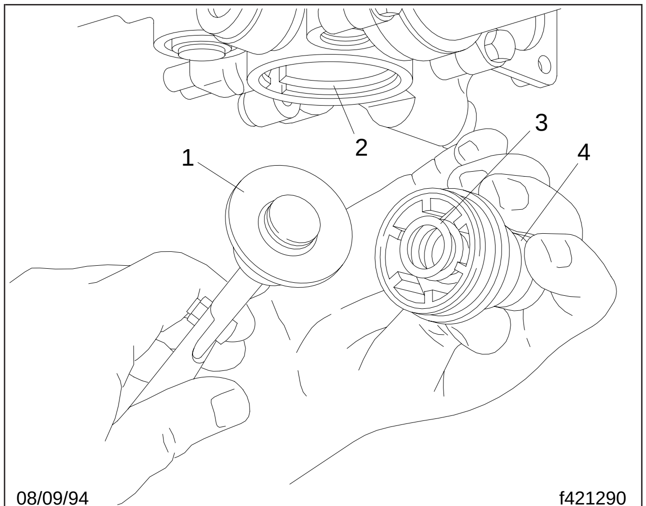
Purge Valve Replacement

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for purge valve replacement.



1. Valve Assembly
2. Exhaust Port
3. Spring
4. Valve Head

Fig. 1, Removing the Valve Assembly

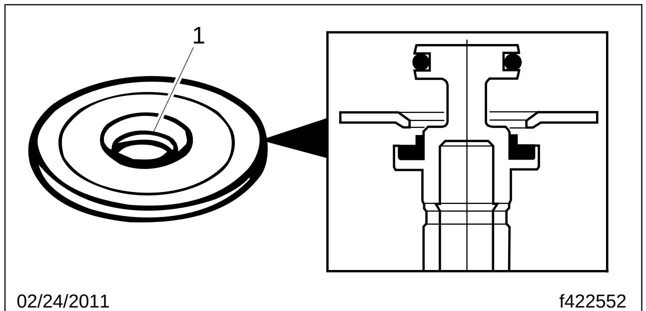
1. Drain the air system.
2. Remove the snap ring, valve head, and the spring from the exhaust port.
3. Pull the valve assembly out of the exhaust port.
4. Remove the O-ring from the base of the exhaust port.
5. Clean the purge valve cavity area with a commercial cleaning solvent.

IMPORTANT: If the valve cavity is damaged, preventing a tight seal, replace the air dryer.

6. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the valve cavity and all of the new O-rings. Install the O-rings in the base of the exhaust port and on the valve head.
7. Install the new washer and O-ring in the dryer base and on the valve head.

NOTE: The lip on the washer must face the piston seat as shown in **Fig. 2**.

8. Assemble the piston assembly.
   - 8.1 Install the O-ring in the groove on the piston head.
   - 8.2 Install the piston seat in the groove on the piston base.
   - 8.3 Install the washer on the piston.
9. Position the new valve assembly in the valve cavity.



1. Lip

Fig. 2, Washer Lip Facing Piston Seat

10. Install the spring in the valve head, and position them in the valve cavity.
11. Install the snap ring to secure the valve head in position.

NOTE: Make certain the snap ring is fully seated or the assembly will leak from the purge valve.

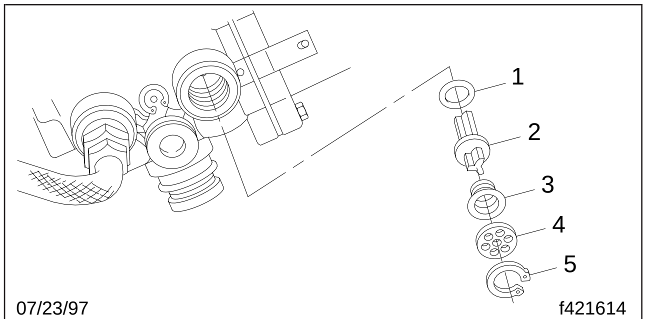
Outlet Check Valve Assembly Replacement

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for valve replacement.



1. O-Ring
2. Valve Body
3. Spring
4. Washer
5. Snap Ring

Fig. 1, Outlet Check Valve Assembly

1. Drain the air system.
2. Disconnect the air line from the outlet port.
3. Remove the snap ring, washer, valve body, and the O-ring.
4. Clean the cavity area with a commercial cleaning solvent.
5. Install a new O-ring on the valve body.
6. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the new O-ring and the valve cavity.
7. Install the new valve body. Make sure that the long end of the body is inserted first into the valve cavity.
8. Install the new spring with its small end around the Y-shaped fins on the valve body.

IMPORTANT: If the valve cavity is damaged, preventing a tight seal, replace the air dryer.

9. Install a new washer and snap ring to secure the assembly in the valve cavity.
10. Connect the air line to the outlet port. Tighten the nut on the fitting finger-tight. Then, using two wrenches to prevent twisting the hose, further tighten the nut until there is firm resistance. Tighten the nut one-sixth turn more.

Desiccant Cartridge Replacement

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

NOTICE

The WABCO System Saver 1200 Plus air dryer can use either a standard or oil coalescing desiccant cartridge. When replacing the desiccant cartridge, it is very important to use the same type of cartridge that was originally installed on the dryer. Oil coalescing cartridges can be used in any application, but require more frequent service intervals (every 1 to 2 years instead of every 2 to 3 years for a standard cartridge). Do not replace an oil coalescing cartridge with a standard cartridge, as this may result in contamination and malfunctioning of downstream air system components.

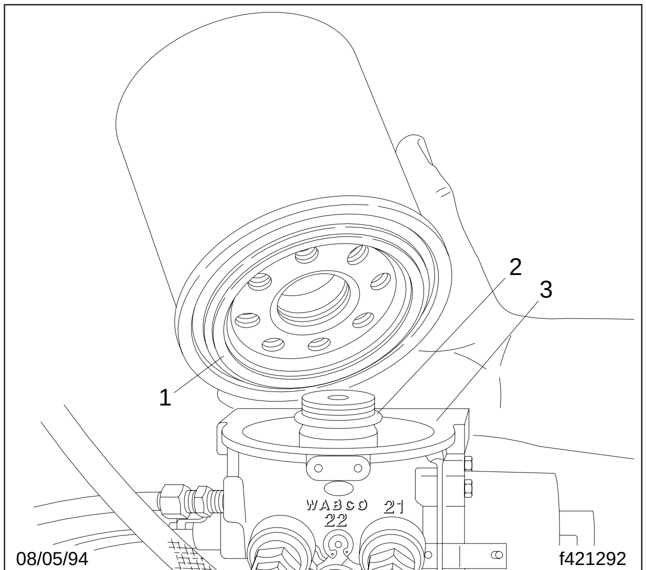
Replacement

Refer to **Fig. 1** for cartridge replacement.

1. Drain the air system.
2. Using a strap wrench, turn the desiccant cartridge counterclockwise and remove it.
3. Remove and discard the O-ring.
4. Clean the top surface of the dryer base with a commercial cleaning solvent.

IMPORTANT: If the air dryer base is damaged, preventing a tight seal, replace the air dryer.

5. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the new O-ring and the dryer base. Install the O-ring.
6. Thread the desiccant cartridge onto the dryer base (turn clockwise). When the seal contacts the base, tighten the cartridge one complete turn more. Do not overtighten.



1. Seal
2. O-Ring
3. Air Dryer Base

Fig. 1, Desiccant Cartridge Replacement

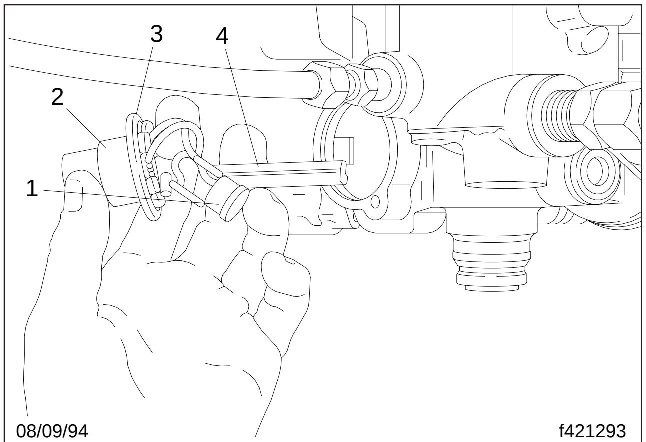
Heater/Thermostat Assembly Replacement

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for heater/thermostat assembly replacement.



1. Thermostat
2. Receptacle
3. O-Ring
4. Element

Fig. 1, Heater/Thermostat Replacement

1. Drain the air system.
2. Disconnect the wiring harness.
3. Remove the screws that attach the heater/thermostat receptacle. Remove the receptacle and the O-ring.
4. Remove the retaining screw that holds the assembly in place. Remove and discard the heater/thermostat assembly.
5. Clean the heater/thermostat assembly area with a commercial cleaning solvent.
6. Position the new heater/thermostat assembly in the cavity. Install the retaining screw.
7. Position the new receptacle and O-ring, and install the screws. Tighten the screws securely.
8. Connect the wiring harness.

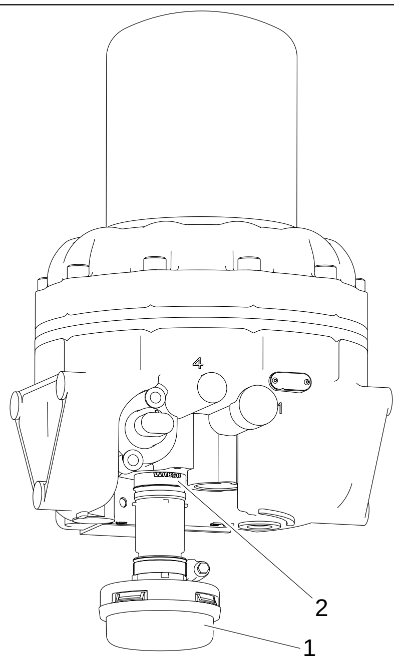
Silencer (Muffler) Replacement

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for silencer replacement.



1. Silencer
2. Purge Valve Head

Fig. 1, Silencer Replacement

1. Using snap ring pliers, expand the snap ring and pull the silencer off of the purge valve head.
2. Push the new silencer onto the purge valve head until the silencer snaps into place.

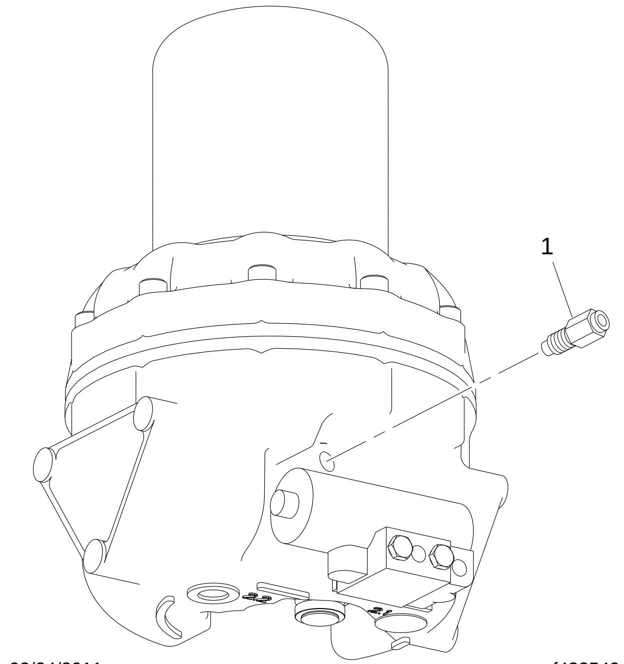
Pressure Relief Valve Replacement

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for valve replacement.



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1. Pressure Relief Valve

Fig. 1, Pressure Relief Valve Replacement

1. Drain the air system.
2. Unscrew and remove the old valve from the dryer.
3. Screw the replacement valve into the dryer base. Do not exceed a torque of 30 lbf·ft (41 N·m) for a 3/8-inch thread, or 65 lbf·ft (88 N·m) for a 1/2-inch thread.

NOTE: The threads on the replacement pressure relief valve provided by WABCO are coated with sealant. They do not require any additional sealant.

Governor Replacement

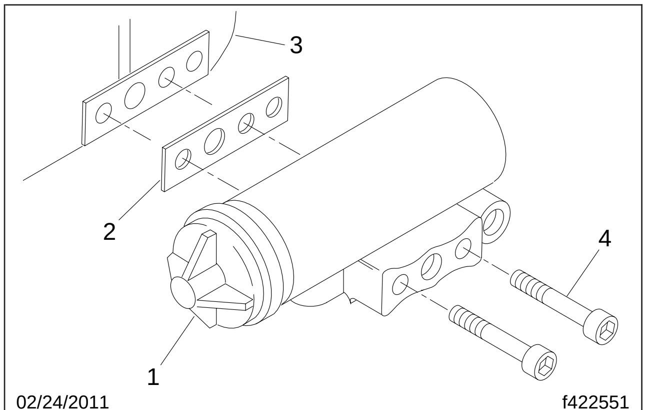
⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

IMPORTANT: When replacing the governor, use only the Meritor WABCO governor specified for use with the System Saver 1200 Plus air dryer.

Replacement

1. Remove the mounting bolts, governor and gasket as shown in **Fig. 1**. Discard the gasket.



1. Governor
2. Gasket
3. Air Dryer
4. Mounting Bolt

Fig. 1, Replacing the Governor

2. Place the new governor and gasket into position on the air dryer.
3. Using the mounting bolts, install the governor. Tighten the bolts 15 lbf·ft (20 N·m).

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Air Dryer Operating Tests

1. Drain the air system.
2. Start the engine and build the air pressure to as close to cutout pressure as possible (about 125 psi [862 kPa]).
3. When the compressor reaches the unload cycle, the air dryer purges, beginning regeneration of the air dryer.
4. There should be no visible pressure drop on the vehicle dash gauges during regeneration. If there is a visible pressure drop, and there are no other air-operated components in use, then there are air leaks or other system problems. Refer to **Troubleshooting 300** for other possible causes.

Troubleshooting

Problem—Air Dryer Purges Too Often and Is Accompanied by Excessive Cycling of the Compressor

Problem—Air Dryer Purges Too Often and Is Accompanied by Excessive Cycling of the Compressor	
Possible Cause	**Remedy**
There is a leak in the line between the unloader port of the air compressor and dryer port 4.	Repair the air line.
There is a leak in the line between the supply tank and the delivery/outlet port.	Repair the air line.
Excessive air system leaks.	Repair all leaks.
Excessive air system demands.	Increase the air system capacity or reduce air demand.
The outlet check valve does not seal.	Inspect and replace the outlet check valve as needed.
There is a leak at the air governor gasket.	Replace the gasket.
The air governor has less than 16 psi (110 kPa) range.	Replace the air governor.
The air compressor’s unloader(s) is leaking.	Inspect the air compressor and repair or replace it according to the manufacturer’s instructions.

Problem—The Air Dryer Does not Purge When the Compressor Unloads (No Blast of Air from the Purge Valve)

Problem—The Air Dryer Does not Purge When the Compressor Unloads (No Blast of Air from the Purge Valve)	
Possible Cause	**Remedy**
The air line between the unloader port of the air compressor and air dryer port 4 is kinked or plugged.	Repair the air line.
The purge valve is stuck closed.	Replace the purge valve.
The air governor is not working properly.	Inspect the air governor and repair or replace it according to the manufacturer’s instructions.
Cut-out pressure is never achieved by the air compressor.	Check for air leaks in the system and repair as needed. If no leaks are found, check the compressor output. Repair or replace the compressor according to the manufacturer’s instructions.

Problem—There Is Rapid "Spitting" of Air from the Purge Valve in Small Amounts; Frequency Varies With Engine Speed

Problem—There Is Rapid "Spitting" of Air from the Purge Valve in Small Amounts; Frequency Varies With Engine Speed	
Possible Cause	**Remedy**
A Holset E-type compressor is being used, but a non-1200E air dryer is installed.	Replace the air dryer with an SS1200E air dryer.
The compressor does not completely unload when cut-out pressure is reached.	Inspect the compressor and repair or replace it according to the manufacturer’s instructions.
This is normal for air dryers that are not equipped with an optional turbocharger cutoff valve.	Not applicable.

Troubleshooting

Problem—Air Leaks at the Turbo Cutoff Valve Vent; There Is a Hole Burned in the Piston

Problem—Air Leaks at the Turbo Cutoff Valve Vent; There Is a Hole Burned in the Piston	
Possible Cause	**Remedy**
The temperature of the air coming into the dryer is too high, and there is not enough cooling taking place before the air gets to the air dryer inlet.	Move the dryer farther from the compressor. Add additional compressor discharge line before the air dryer. Add a cooling coil or heat exchanger before the air dryer. NOTE: The inlet air temperature must not exceed 175°F (79°C).
The valve bore is worn excessively.	Inspect the valve bore for wear. If a new turbo cut-off valve does not seal in a clean, lubricated bore, replace the air dryer.
The piston is broken.	Replace the turbocharger cutoff valve. See **Subject 120**.

Problem—The Air Dryer Is Frozen (Water Collected in the Base of the Air Dryer Freezes)

Problem—The Air Dryer Is Frozen (Water Collected in the Base of the Air Dryer Freezes)	
Possible Cause	**Remedy**
There is no power to the heater connector.	Check for a blown fuse. Repair the heater circuit. NOTE: There must be power to the heater connector the entire time the vehicle's ignition is activated.
Low voltage to the heater connector.	Repair the cause of low voltage—poor electrical ground, bad connections, corroded wire splices, etc.
The heater assembly is not working.	Replace the heater assembly.
An incorrect voltage air dryer is being used (for example a 12V air dryer in a 24V system).	Replace with the correct voltage air dryer.

Problem—Air Pressure Will Not Build-Up in the System

Problem—Air Pressure Will Not Build-Up in the System	
Possible Cause	**Remedy**
The air dryer is not plumbed correctly.	Make certain the compressor discharge line is plumbed to air dryer port 1, and air dryer port 21 is connected to the vehicle's supply tank.
The wrong air line is connected to air dryer port 4.	Verify that the air dryer port 4 line is connected to the "UNL" port of the unloader port of the air compressor.
The air governor is not working properly.	Inspect the air governor and repair or replace it according to the manufacturer's instructions.
Air system components, such as the compressor discharge line, air dryer reservoirs, brake valves, or suspension valves leak.	Locate the leak(s) and repair as needed.
The air dryer leaks at the purge valve.	See *Air dryer purges too often and is accompanied by excessive cycling of the compressor* and *The air dryer leaks from the purge valve during a compressor loaded cycle (the leak may cause excessive compressor cycling or prevent the system from building air pressure).*

Troubleshooting

Problem—Water, Oil, or Sludge Is in the Air System Tanks

Problem—Water, Oil, or Sludge Is in the Air System Tanks	
Possible Cause	**Remedy**
Desiccant is contaminated with oil.	Replace desiccant. Inspect the compressor according to the manufacturer's instructions.

Problem—Water Is in the Air System Tanks

Problem—Water Is in the Air System Tanks	
Possible Cause	**Remedy**
The air dryer is not suitable for the vehicle.	Review the vehicle guidelines. Call the Meritor Customer Support Center for assistance at 1-800-535-5560.

Problem—The air dryer leaks from the purge valve during a compressor loaded cycle (the leak may cause excessive compressor cycling or prevent the system from building air pressure)

Problem—The air dryer leaks from the purge valve during a compressor loaded cycle. The leak may cause excessive compressor cycling or prevent the system from building air pressure.	
Possible Cause	**Remedy**
The purge valve is frozen open.	Check the heater, and repair or replace it if necessary. Make sure the air line between the unloader port of the air compressor and dryer port 4 is free of water and oil. Remove and inspect the purge valve, and clean any water or oil from the top of the piston.
Debris is under the purge valve seat.	Remove the purge valve and clean it. See **Subject 130** for instructions to remove the purge valve. Remove the desiccant cartridge and clean the dryer sump area. See **Subject 150** for instructions.
The purge valve washer is installed upside down.	Make certain the lip on the washer faces down, away from the air dryer.
The wrong air line is connected to air dryer port 4.	Verify that the dryer port 4 line is connected to the "UNL" port of the air compressor.
The purge valve snap ring is not fully seated in the groove.	Seat the snap ring fully into the groove.

Problem—The regeneration cycle is too long (more than 30 seconds), accompanied by loss of pressure in the supply tank

Problem—The regeneration cycle is too long (more than 30 seconds), accompanied by loss of pressure in the supply tank	
Possible Cause	**Remedy**
The outlet check valve is not seating.	Inspect the outlet check valve. Replace the valve if needed.

Problem—The regeneration cycle is too short (less than 20 seconds)

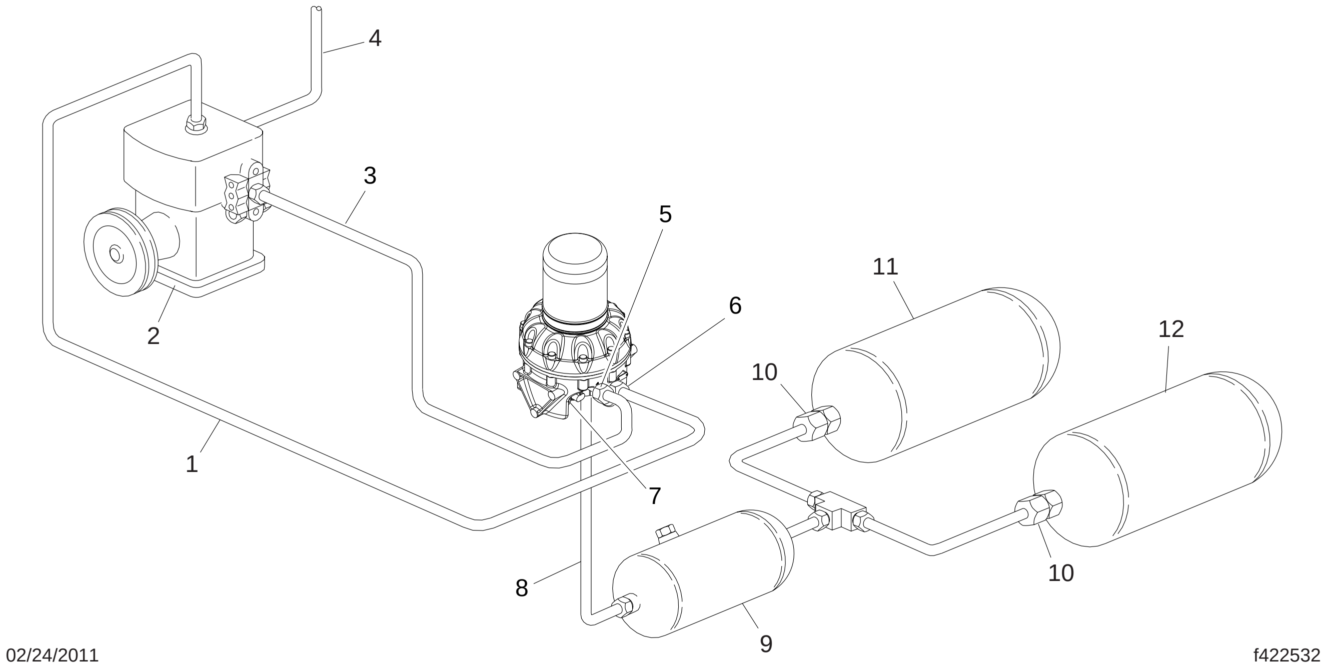
Problem—The regeneration cycle is too short (less than 20 seconds)	
Possible Cause	**Remedy**
There are high air system demands during a compressor unloaded cycle.	Increase the air system capacity or reduce air demands.

Troubleshooting

Problem—The regeneration cycle is too short (less than 20 seconds)	
Possible Cause	**Remedy**
The air governor is not working correctly.	Inspect the air governor and repair or replace it according to the manufacturer's instructions.

Specifications

See Fig. 1 for the plumbing diagram.



1. Compressor Discharge Line
2. Compressor
3. Signal Line
4. Compressor Intake Line (naturally aspirated or turbocharged)
5. Air Dryer Control Port
6. Air Dryer Inlet
7. Exhaust Port (Purge Valve Assembly)
8. Delivery Line (from the delivery/outlet port)
9. Supply Tank
10. Check Valve
11. System Reservoir
12. System Reservoir

Fig. 1, Air Dryer Plumbing Diagram

General Information

As of April 5, 2010, the auxiliary air valve assembly (AAVA) replaced the air management unit (AMU). The AAVA is a collection of electronic valves and pressure switches of modular form attached in a row on the frame rail. The AAVA is usually located in the rear suspension area of the vehicle. However, it could be located anywhere on the vehicle chassis or body.

The AAVA performs air-controlled functions such as axle differential locks, power takeoff (PTO), and fifth wheel slide. It also provides for pneumatic logic controls via double-check, inversion, relay, and pressure regulation, therefore replacing double-check, inversion, and relay valves on the vehicle.

The typical AAVA layout contains one or more of the following. See **Fig. 1** for a typical AAVA installation.

- AAVA Module
- Solenoid Valve Module

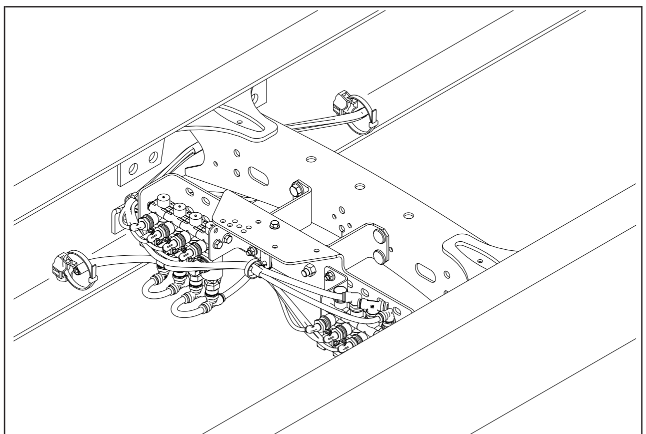


Fig. 1, Typical AAVA Installation

Principles of Operation

AAVA Module

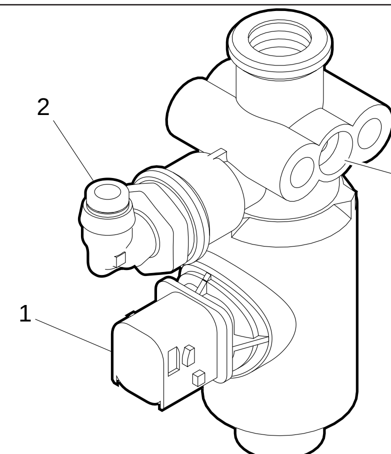
The AAVA is a solenoid-only assembly with a common air supply for the normally closed solenoids. The AAVA solenoids are located on the suspension crossmember, where the AMU was located on earlier vehicles. Pressure switches that were previously in the AMU are now located under the dash.

The AAVA solenoid current is about 1.5 amps. Vehicles built with chassis module (CHM) version 3.4 use a chassis power distribution module (PDM) with relays that switch power to the AAVA solenoids. Vehicles with CHM version 4.1 or later drive the AAVA solenoids directly with no need for relays in a chassis PDM. See **Specifications 400** for further information.

Solenoid Valve Module

The solenoid modules control ON-OFF air options. All solenoid valve modules are normally closed (NC). See **Fig. 2**. The solenoid valve module delivers air when electrically activated.

The inlet to the solenoid valve module mates to the port on the adjacent AAVA. Pressure protected air will pass through the AAVA from the internal supply port and out of the internal delivery port to supply the next solenoid to the next AAVA.



1. Electrical Connector
2. Delivery Port
3. Supply Port

Fig. 2, Solenoid Valve Module

Auxiliary Air Valve Assembly Module Replacement

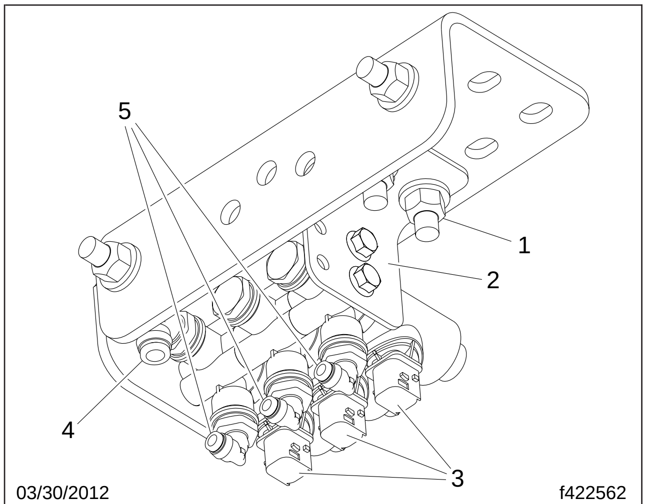
Replacement

Individual modules within the auxiliary air valve assembly (AAVA) can be replaced. The following is a general replacement procedure.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Disconnect the batteries.
3. Drain the air reservoirs.

IMPORTANT: Clean the AAVA and the area around it of all dirt and road debris before removing any modules. Failure to do so can result in dirt or road debris between the modules and their seals, causing air leakage.

4. Loosen the bolts on the L-bracket that secures the AAVA to the frame rail mounting bracket. See **Fig. 1**. This will allow the AAVA to separate, allowing for easy removal of the module.



1. L-Bracket Bolt
2. L-Bracket
3. Solenoid Valves
4. Air Supply Port
5. Delivery Ports

Fig. 1, Auxiliary Air Valve Assembly (AAVA)

IMPORTANT: Be sure to mark all air lines, the harness connector, and solenoid before removing them from the air valve.

5. Mark and disconnect the air lines, harness connector, and the solenoid from the air valve to be replaced. Refer to PartsPro® for harness and solenoid color coding.
6. Remove the bolts from the L-bracket and remove the AAVA.
7. Install the new seals on the AAVA module.
8. Place the new AAVA module on the L-bracket and install the bolts.
9. Install all air lines and electrical connectors as previously marked.
10. Firmly tighten the bolts on the L-bracket, securing the AAVA in the mounting bracket. See **Fig. 1**.
11. Connect the batteries.

Troubleshooting

To troubleshoot the auxiliary air valve assembly (AAVA) system, test the 12 V supply from the power distribution module (PDM) to the 12 V solenoid, and verify that the solenoid opens and closes. The fuses and relays for this functionality are located in the PDM. Refer to EZWiring™ for specific vehicle wiring information.

Figure 1 illustrates how AAVA works with a power distribution module (PDM). Refer to EZWiring™ for specific vehicle wiring information.

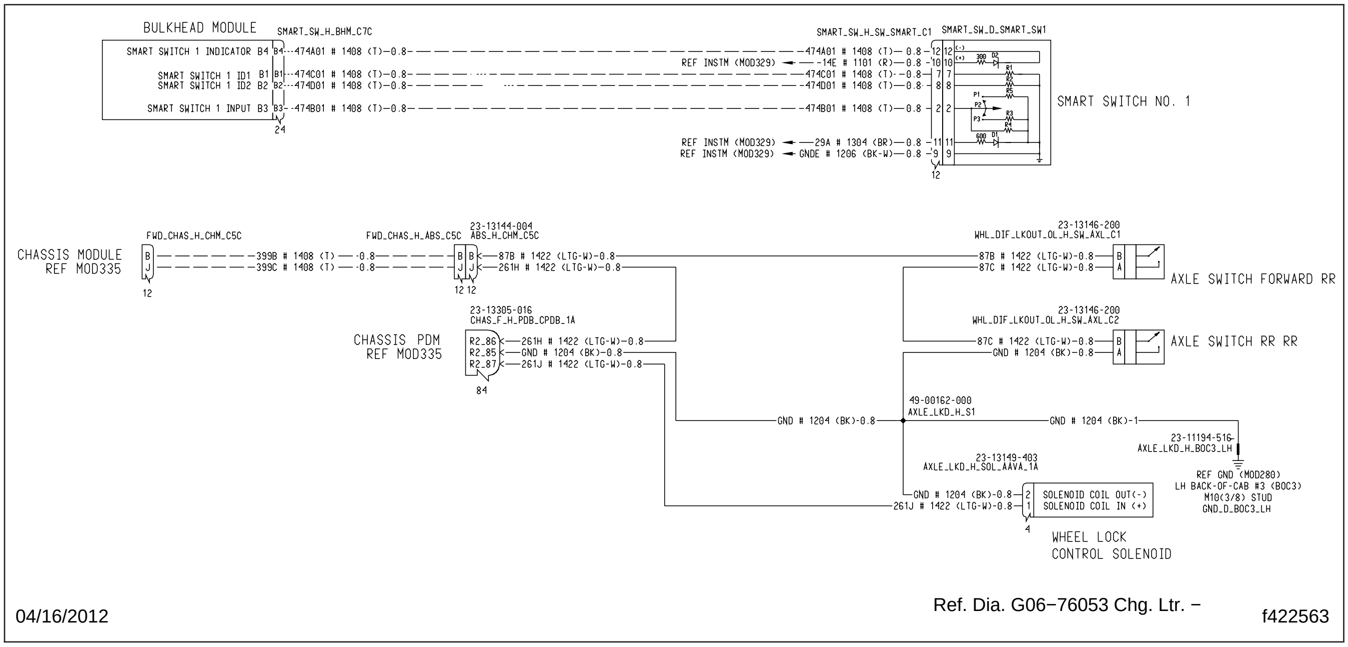
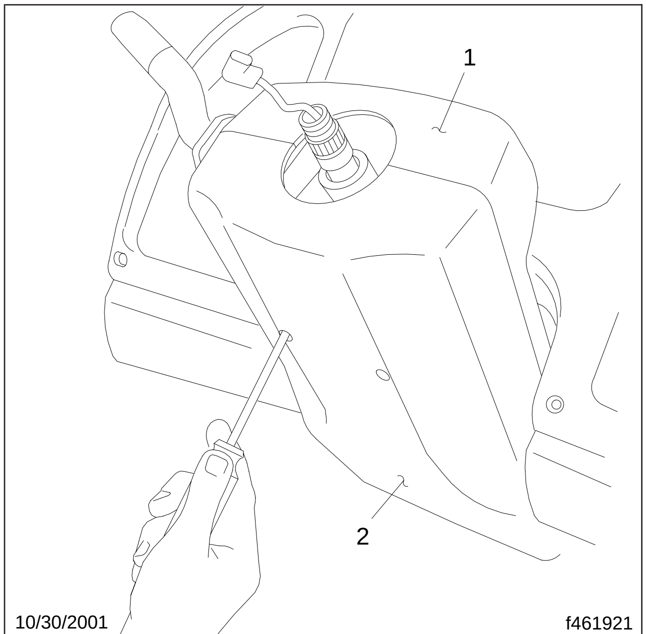


Fig. 1, AAVA Connected to a Chassis PDM (typical installation)

Replacement

1. Position the front tires straight ahead. If possible, drive the vehicle in a straight line for a short distance, stopping at the spot where service operations will be done.
2. Shut down the engine, apply the parking brakes, chock the tires, and open the hood.
3. Remove the steering column from the steering driveline.
   - 3.1 Remove the capscrews that attach the lower steering column cover to the steering column. Remove the lower and upper steering column covers. See **Fig. 1**.



1. Upper Steering Column Cover
2. Lower Steering Column Cover

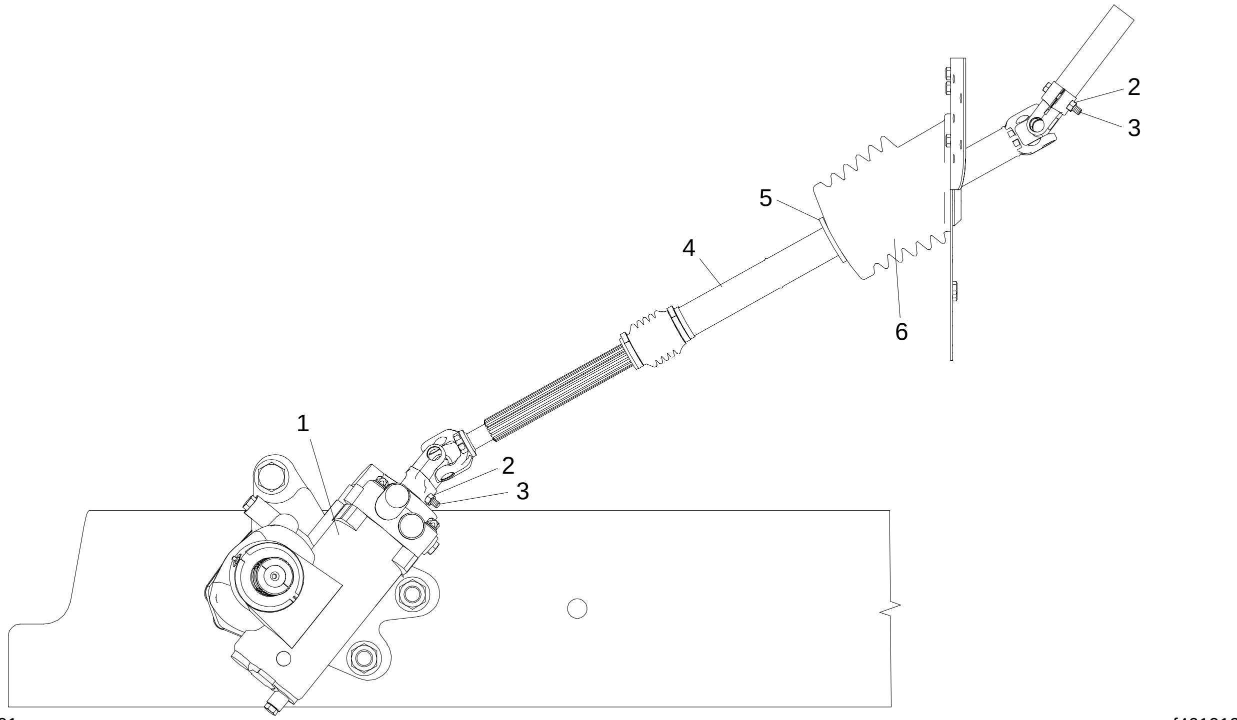
Fig. 1, Steering Column Covers

   - 3.2 Remove and discard the pinch bolt and nut that attach the steering column to the steering driveline.
4. Remove the boot bushing. See **Fig. 2**.
5. Remove and discard the pinch bolt and nut that attach the steering driveline to the steering gear. Then remove the steering driveline.
6. Place a new steering driveline through the boot and the frontwall.
7. Using a new pinch bolt and nut, attach the steering driveline to the steering gear input shaft. Torque the nut 30 to 35 lbf·ft (41 to 47 N·m).

   Apply torque seal, OGP F900WHITE, to the exposed threads of the pinch bolt and to the nut.
8. Install the boot clamp on the steering driveline.
9. Using a new pinch bolt and nut, attach the steering driveline to the steering column. Torque the nut 30 to 35 lbf·ft (41 to 47 N·m).

   Apply torque seal, OGP F900WHITE, to the exposed threads of the pinch bolt and to the nut.
10. Using capscrews, attach the upper and lower steering column covers to the steering column.
11. Lower the hood and remove the chocks from the tires.

Steering Driveline Replacement



1. Steering Gear
2. Nut
3. Pinch Bolt
4. Steering Driveline
5. Boot Bushing
6. Boot

Fig. 2, Steering Driveline Installation

Replacement

1. Position the tires straight ahead. If possible, drive the vehicle in a straight line for a short distance stopping at the spot where service operations are to be performed.

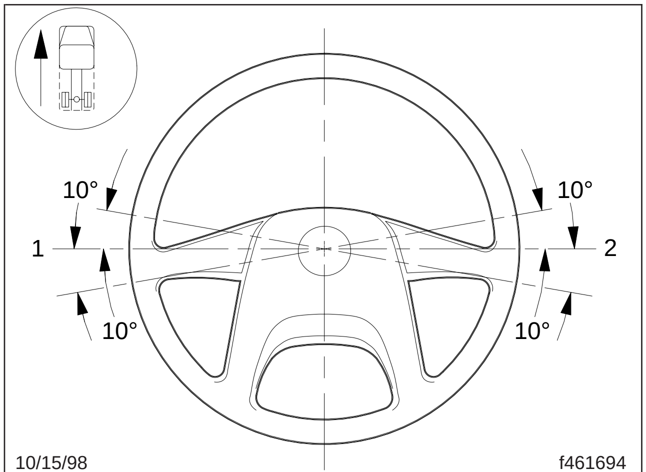
IMPORTANT: **Do not** turn the steering wheel at any time while the drag link is still attached to both the pitman arm and the axle steering arm. If the steering wheel is turned, the front tires will not be straight ahead.

2. Shut down the engine, apply the parking brakes, chock the rear tires, and open the hood.
3. Remove the cotter pin and castle nut that attach the drag link to the pitman arm.
4. Remove the cotter pin and castle nut that attach the drag link to the steering arm.
5. Remove the drag link.
6. Install a new drag link on the pitman arm and steering arm.

WARNING

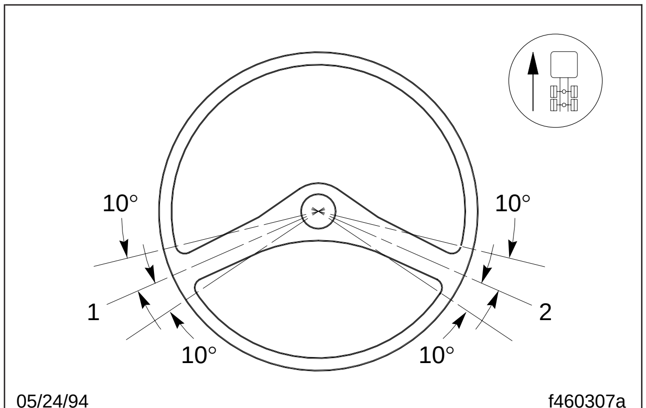
Failure to install and lock a new cotter pin in the ball stud and nut could result in disengagement of the parts and loss of steering control, which could result in personal injury or property damage.

7. Using castle nuts, secure the drag link to the pitman arm and steering arm. Torque the castle nuts using the appropriate torque value.
   - 3/4–16, 90 to 170 lbf·ft (122 to 230 N·m)
   - 7/8–14, 160 to 300 lbf·ft (217 to 407 N·m)
8. Continue to tighten each castle nut until a slot on the nut aligns with the hole in the ball stud. **Do not** back off the nut when locating the cotter pin hole.
9. Install new cotter pins in the ball studs and nuts. Lock the cotter pins in place.
10. Clean the grease fittings and apply chassis grease to the fittings until all the old grease is forced out.
11. Make sure that the steering wheel spokes are within 10 degrees of the 3 o’clock and 9 o’clock positions on a four-spoke steering wheel, or within 10 degrees of the 4 o’clock and 8 o’clock positions on a two-spoke steering wheel. See Fig. 1 or Fig. 2.
12. Lower the hood.



1. 9 o’Clock
2. 3 o’Clock

Fig. 1, Centered Four-Spoke Steering Wheel



1. 8 o’Clock
2. 4 o’Clock

Fig. 2, Centered Two-Spoke Steering Wheel

Testing

WARNING

All steering mechanisms are essential to the safe operation of the vehicle. Follow the instructions in this subject exactly. Failure to do so may result in loss of steering, which could cause personal injury or property damage.

1. Have someone gently turn the steering wheel back and forth. Check for looseness between the ball stud end and the pitman arm, and between the ball stud end and the steering arm. If the ball stud end is loose, replace the drag link. For instructions, see **Subject 100**.
2. Check for looseness of the ball stud nut. If the ball stud nut is loose, replace the nut and the cotter pin. Tighten the ball stud nut using the appropriate torque value.
    - 3/4–16, 90 to 170 lbf·ft (122 to 230 N·m)
    - 7/8–14, 160 to 300 lbf·ft (217 to 407 N·m)
3. Grasp the drag link near the pitman arm and move the drag link back and forth to check for axial movement in the ball stud end. If there is movement, replace the drag link. For instructions, see **Subject 100**. If there is movement of 1/8 inch (3 mm) or more, do not drive the vehicle until the drag link is replaced.
4. Grasp the drag link near the steering arm and move the drag link back and forth to check for axial movement in the ball stud end. If there is movement of 1/8 inch (3 mm) or more, replace the drag link. For instructions, see **Subject 100**.
5. Apply grease to the drag link until all the old grease is purged.

Steering Wheel Removal and Installation

Procedures under these headings apply to the following vehicle models, as specified:

- M2 models built before June 5, 2006.
- M2 models built on or after June 5, 2006.

M2 Built Before June 5, 2006

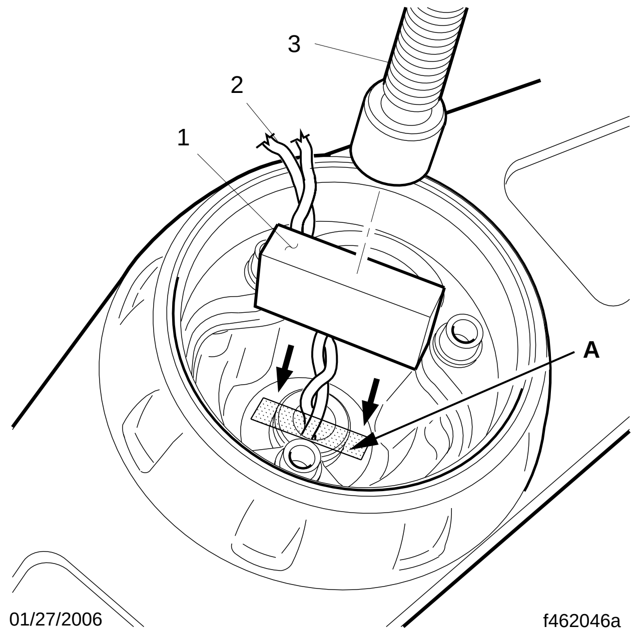
Steering wheels on vehicles built before June 5, 2006 have threaded holes and require the use of a steering wheel puller for removal.

Removal

1. Put the front wheels in the straight ahead position. If possible, drive the vehicle in a straight line for a short distance, stopping at the place where the work will be done. Don't turn the steering wheel at any time during the removal procedure.
2. Shut down the engine, apply the parking brakes, and chock the tires.
3. Using a small screwdriver, carefully pry out the horn button assembly and disconnect the two wires.
4. Using a deep socket to avoid damaging the wires, remove the steering wheel nut.

IMPORTANT: Be careful when removing the steering wheel, or the horn wires could be damaged. Use a steel block measuring approximately 1-5/8 x 5/8 x 1/4 inch (41 x 16 x 6.4 mm) as a spacer to protect the wires during steering wheel removal.

5. Using a steering wheel puller and a spacer on top of the steering shaft, remove the steering wheel from the steering column, see **Fig. 1**.



A. Place steel block on column to protect horn wires.

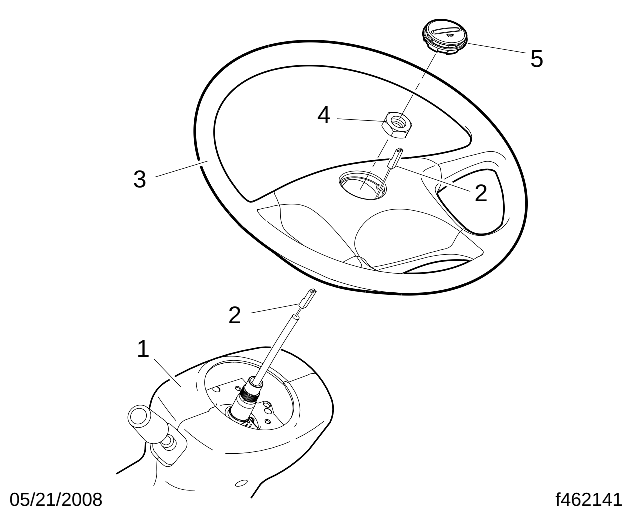
1. Steel Block
2. Horn Wires
3. Steering Wheel Puller

Fig. 1, Steering Wheel Removal

Installation

NOTE: Before installing the steering wheel, make sure the front tires are pointed straight ahead and that the steering gear is centered.

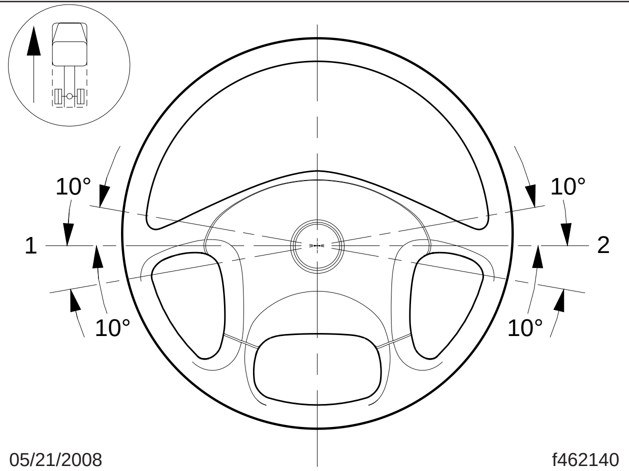
1. Thread the horn wiring harness through the steering wheel center hole and set the steering wheel on the steering column, see **Fig. 2**.
2. Make sure that the steering wheel is within ±10 degrees of center as shown in **Fig. 3**.



1. Steering Column
2. Horn Button Connectors
3. Steering Wheel
4. Steering Wheel Nut
5. Horn Button

Fig. 2, Steering Wheel and Connectors

Steering Wheel Removal and Installation



1. 9 o’clock position 2. 3 o’clock position

Fig. 3, Steering Wheel Position

3. Install a new steering wheel nut and tighten 55 to 65 lbf·ft (75 to 88 N·m).
4. Connect the wiring harness to the horn button.
5. Align the logo on the horn button assembly so that it is horizontal. Then press the horn button assembly into the steering wheel.

M2 Built On or After June 5, 2006

Steering wheels on vehicles built on or after June 5, 2006 do not have threaded holes. The tapered fit between the steering wheel and the column allows the steering wheel to be removed by hand.

Removal

1. Put the front wheels in the straight ahead position. If possible, drive the vehicle in a straight line for a short distance, stopping at the place where the work will be done. Don’t turn the steering wheel at any time during the removal procedure.
2. Shut down the engine, apply the parking brakes, and chock the tires.
3. Using a small screwdriver, carefully pry out the horn button assembly and disconnect the two wires.
4. Using a deep socket to avoid damaging the wires, loosen the nut that holds the steering wheel on the steering column. Leave the nut on the shaft.
5. Remove the wheel from the tapered fit by striking it from below, at the rim/spoke intersections, with both hands.
6. Remove the steering wheel nut and the wheel.

Installation

NOTE: Before installing the steering wheel, make sure the front tires are pointed straight ahead and that the steering gear is centered.

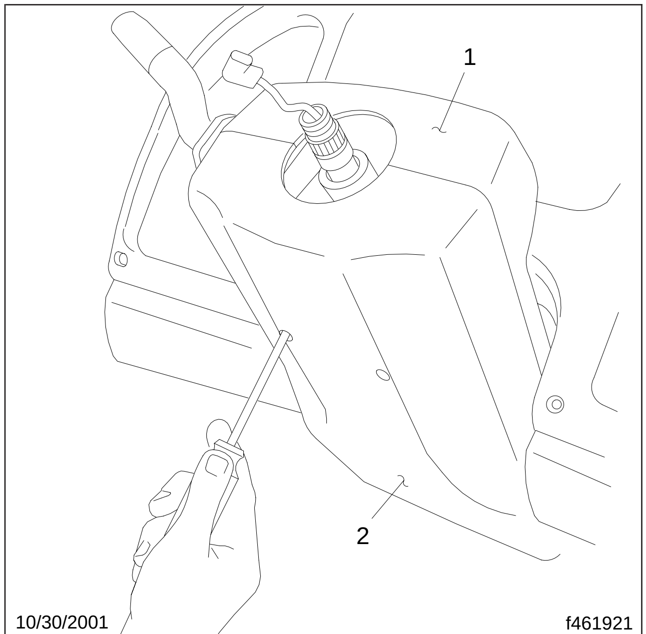
1. Thread the horn wiring harness through the steering wheel center hole and set the steering wheel on the steering column, see **Fig. 2**.
2. Make sure that the steering wheel is within ±10 degrees of center as shown in **Fig. 3**.
3. Install a new steering wheel nut and tighten the nut 33 to 41 lbf·ft (45 to 55 N·m).
4. Connect the wiring harness to the horn button.
5. Align the logo on the horn button assembly so that it is horizontal. Then press the horn button assembly into the steering wheel.

Steering Column Removal and Installation

Removal

1. Position the front tires straight ahead. If possible, drive the vehicle in a straight line for a short distance, stopping at the spot where service work will be done. Do not move the tires from the straight-ahead position during removal or at any time while the steering column is removed.
2. Shut down the engine, apply the parking brakes, and chock the tires.
3. Disconnect the batteries at the negative terminals or at the battery shutoff switch.
4. Remove the steering wheel. For instructions, see **Subject 100**.
5. On a vehicle with a fixed steering column, remove the screws that attach the lower and upper clamshell covers to the steering column and remove the covers. See **Fig. 1**.

   On a vehicle with an adjustable steering column, remove the screws that attach the lower and upper clamshell covers to the steering column and remove the covers. Remove the screws that attach the center and lower covers to the steering column and remove the covers. See **Fig. 2**.
6. Remove the self-canceling turn signal cam from the steering column.
7. Remove the turn signal lever.
   - 7.1 Disconnect the horn wire from the turn signal wiring harness.
   - 7.2 Remove the capscrews that attach the turn signal lever to the steering column.
8. Make a timing mark on the steering driveline yoke and the steering column spline.
9. Remove and discard the pinch bolt and nut from the steering driveline yoke. See **Fig. 3**.
10. Remove the capscrews that attach the steering column to the mounting bracket.
11. Remove the steering column from the steering driveline yoke.



1. Upper Clamshell Cover
2. Lower Clamshell Cover

Fig. 1, Fixed Steering Column Covers

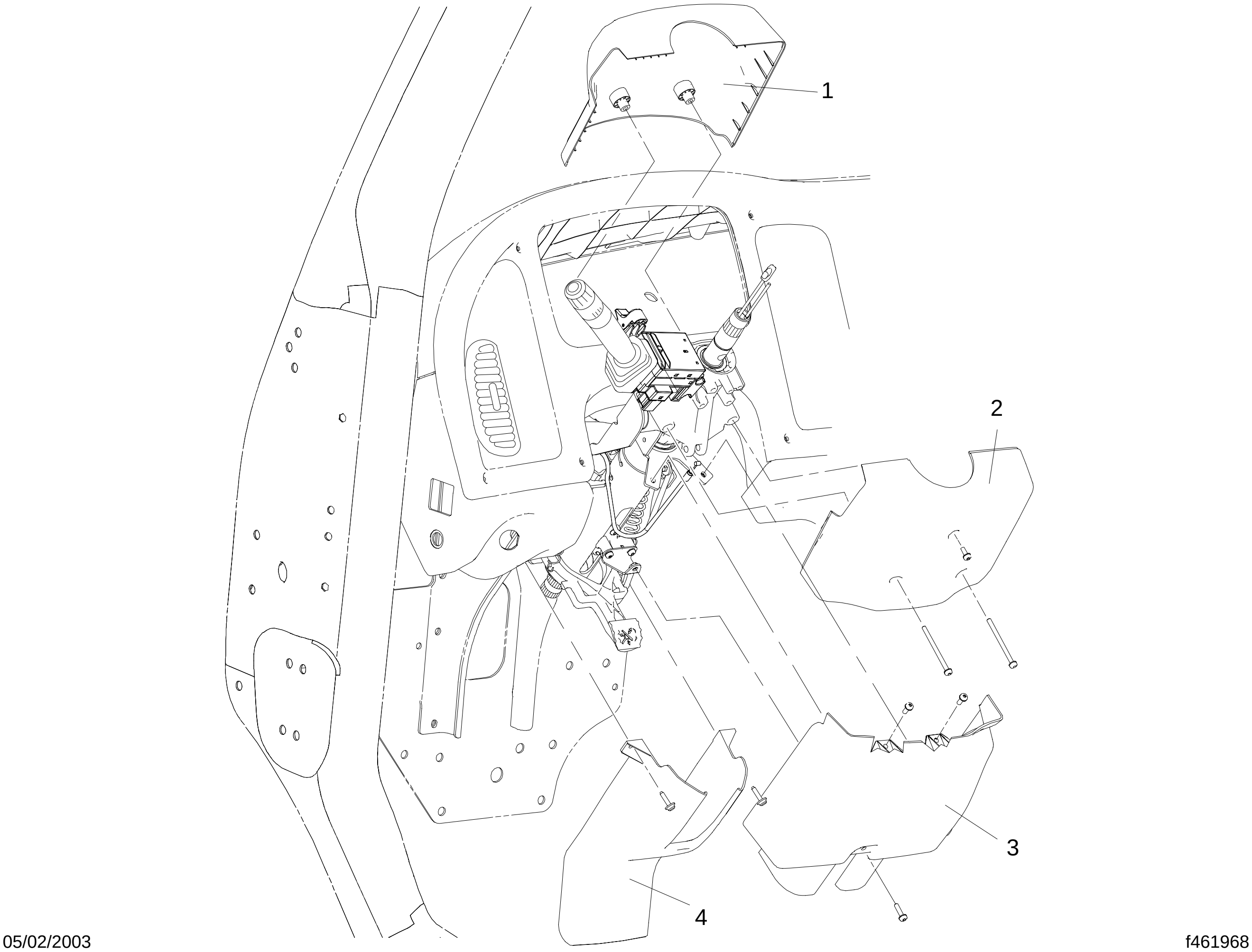
Installation

NOTE: The steering column yoke must be installed in the same orientation that it was in when it was removed.

1. Using a new pinch bolt and nut, attach the steering column to the steering driveline yoke. Torque the nut 30 to 35 lbf·ft (41 to 47 N·m).

   Apply torque seal, OGP F900WHITE, to the exposed threads of the pinch bolt and to the nut.
2. Using capscrews, attach the steering column to the mounting bracket. Torque the capscrews 24 to 30 lbf·ft (32 to 40 N·m).
3. Install the self-canceling turn signal cam on the steering column.
4. Using capscrews, attach the turn signal lever to the steering column.
5. Attach the horn wire to the turn signal wiring harness.

Steering Column Removal and Installation

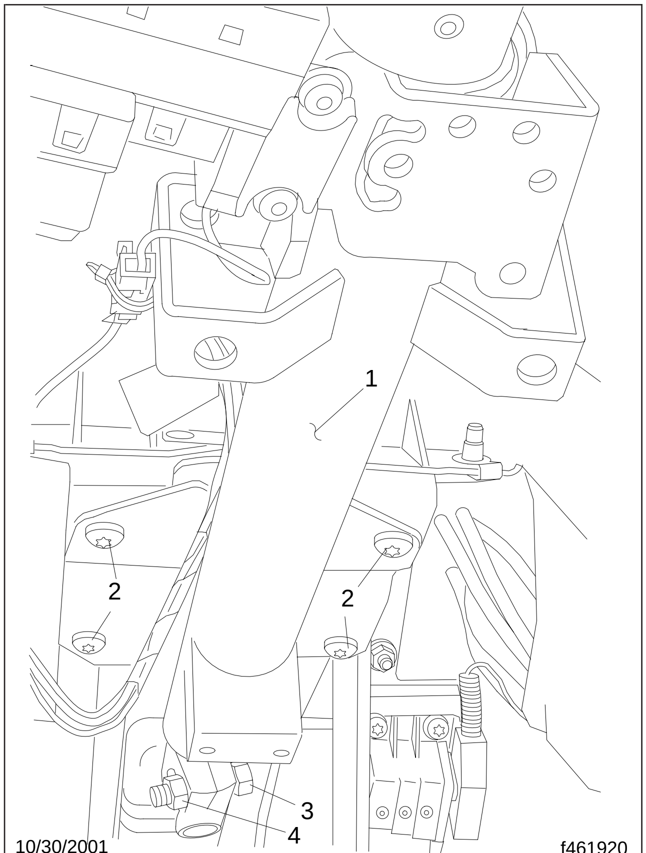


1. Upper Clamshell Cover
2. Lower Clamshell Cover
3. Center Cover
4. Lower Cover

Fig. 2, Adjustable Steering Column Covers

6. On a vehicle with an adjustable steering column, use screws to attach the lower and center steering column covers to the steering column.
7. Using screws, attach the upper and lower clamshell covers to the steering column.
8. Install the steering wheel. For instructions, see **Subject 100**.
9. Connect the batteries at the negative terminals or at the battery switch.
10. Remove the chocks from the tires.

Steering Column Removal and Installation

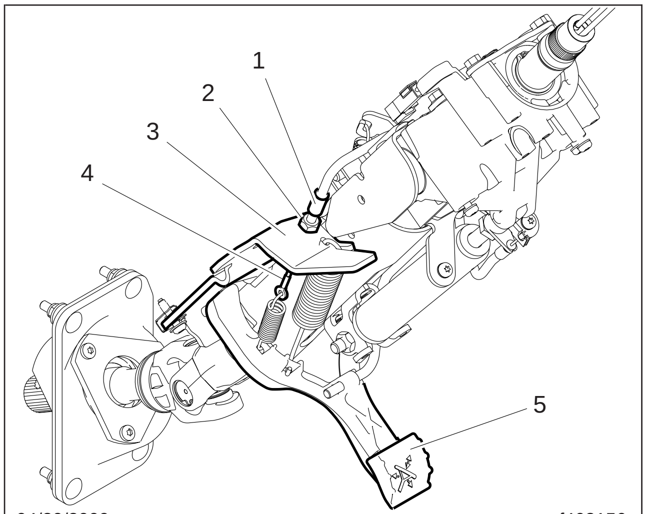


1. Steering Column
2. Capscrew
3. Pinch Bolt
4. Nut

Fig. 3, Fixed Steering Column

Tilt Lock Adjustment

1. Put the front wheels in the straight ahead position. If possible, drive the vehicle in a straight line for a short distance, stopping where the work will take place.
2. Shut down the engine, apply the parking brake, and chock the tires.
3. Remove the screws that attach the upper and lower clamshell covers to the steering column and remove the covers. Remove the screws that attach the center and lower covers to the steering column and remove the covers.
4. Loosen the cable jam nut located on the top side of the mounting bracket flange, see **Fig. 1**.



1. Cable Adjuster
2. Cable Jam Nut
3. Mounting Bracket Flange
4. Cable Slack
5. Steering Column Release Pedal

Fig. 1, Steering Column Tilt Lock Adjustment

5. Use the cable adjuster to remove all slack from the steering column release pedal.

NOTE: Removing too much cable slack can prevent the tilt lock mechanism from locking, regardless of the steering column release pedal position. Adding too much cable slack can prevent the tilt lock mechanism from unlocking when the pedal is fully depressed.

6. Test to verify proper steering column tilt function.
   - 6.1 Fully depress the steering column release pedal. The tilt mechanism should unlock.
   - 6.2 Release the pedal and let it revert to the standard position. The tilt mechanism should lock.
7. Readjust the cable slack if necessary.
8. Tighten the cable jam nut 25 to 30 lbf·in (282 to 340 N·cm).
9. Attach the lower and center steering column covers to the steering column first, then install the upper and lower clamshell covers.

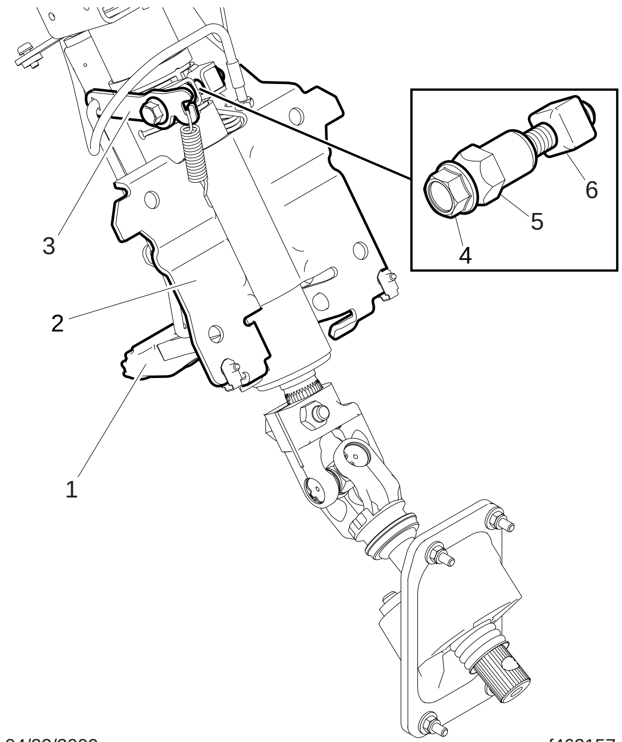
Telescope Lock Adjustment

1. Put the front wheels in the straight ahead position. If possible, drive the vehicle in a straight line for a short distance, stopping where the work will take place.
2. Shut down the engine, apply the parking brake, and chock the tires.
3. Remove the screws that attach the upper and lower clamshell covers to the steering column and remove the covers. Remove the screws that attach the center and lower covers to the steering column and remove the covers.
4. Loosen the telescope lock bolt, see **Fig. 2**.
5. While holding the telescope lock rod in place, rotate the telescope lock lever to adjust the telescope lock. Counterclockwise rotation will tighten the telescope lock, while clockwise rotation will loosen the telescope lock. The lever can be easily rotated by moving the steering column release pedal up or down.

NOTE: Rotating the lever too much can prevent the telescope lock mechanism from unlocking with the steering column release pedal depressed, or locking when the steering column release pedal is released.

6. Continue holding the telescope lock rod in place and tighten the lock bolt.
7. Test to verify proper steering column telescope function.

Adjustable Steering Column Lock Adjustments



1. Steering Column Release Pedal
2. Mounting Bracket
3. Telescope Lock Lever
4. Telescope Lock Bolt
5. Telescope Lock Rod
6. Telescope Lock Rod Nut

Fig. 2, Steering Column Telescope Lock Adjustment

7.1 Fully depress the steering column release pedal. The telescoping mechanism should unlock.

7.2 Release the pedal and let it revert to the standard position. The telescoping mechanism should lock.

8. Readjust the telescope lock lever if necessary. Once the telescope lock has been properly adjusted, tighten the lock bolt 145 to 150 lbf·in (1638 to 1695 N·cm).
9. Attach the lower and center steering column covers to the steering column first, then install the upper and lower clamshell covers.

General Description

NOTE: Procedures in this section have been slightly modified from the original component manufacturer's service manual. See the manufacturer's service literature (**trucksteering.trw.com**) for additional information.

The TRW THP and PCF power steering gears are integral hydraulic power steering gears that contain a manual steering mechanism, a hydraulic control valve, and a hydraulic power cylinder.

The pressure required for the steering gear to overcome resistance at the steered wheels is provided by the power steering pump. The rotary control valve directs the flow of hydraulic fluid to the appropriate cylinder cavity in the steering gear (and in the auxiliary cylinder in a dual steering gear system) at the proper flow rate and pressure. As the steering wheel is turned faster or slower, more or less fluid is required by the gear.

Principles of Operation

When the driver turns the steering wheel, that force travels from the steering wheel to the steering gear input shaft. A torsion bar, pinned at one end to the input shaft and at the other end to the worm shaft, turns with the input shaft and exerts a rotational force on the worm shaft. In response to the force exerted by the torsion bar, the worm shaft moves the rack piston forward or backward in the gear housing by means of a series of recirculating balls in the spiral channels of the worm shaft. As the rack piston slides back and forth, it turns the sector shaft. The sector shaft swings the pitman arm, which pulls or pushes the drag link. The drag link moves the axle steering arm, steering the vehicle.

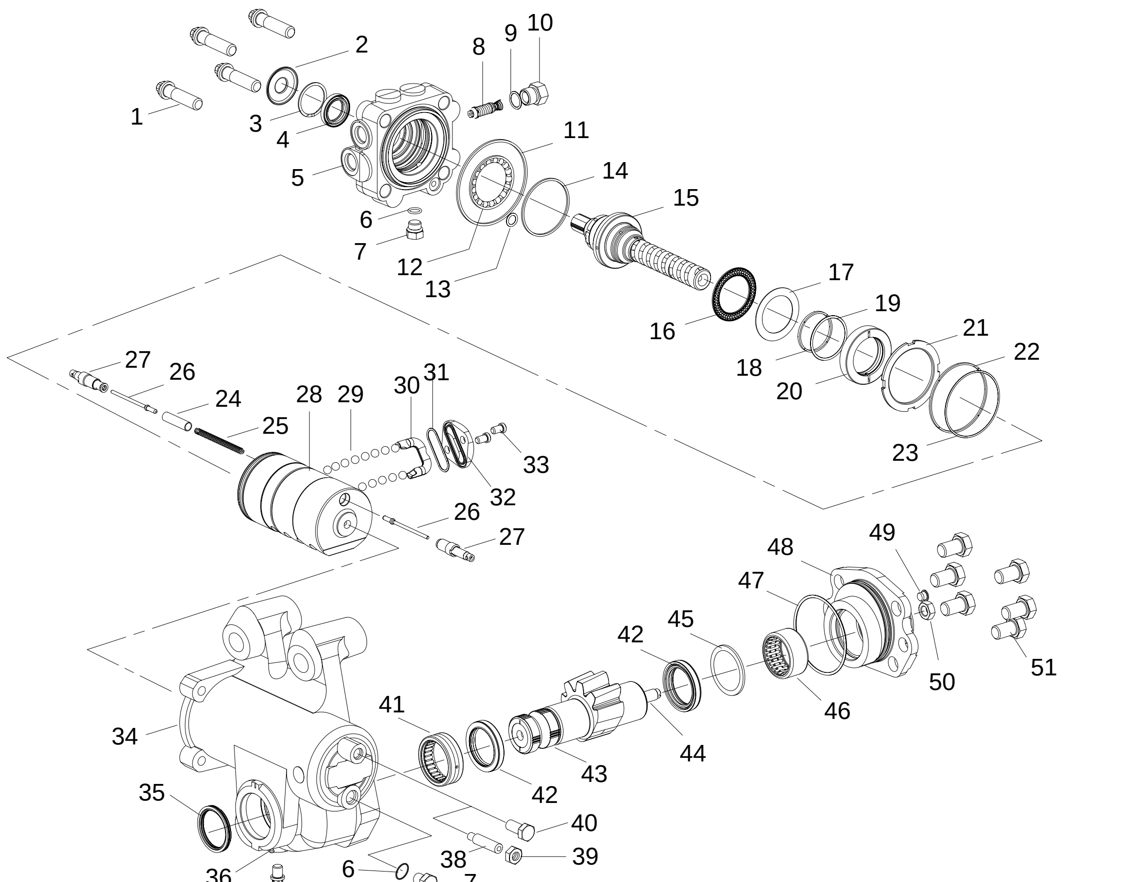
The rack piston's axial movement is resisted by its engagement to the sector shaft, which is linked to the steered wheels. Because of this resistance, the torsion bar activates the control valve, which directs pressurized fluid to the upper or lower cylinder cavity (depending on the direction of turn). The pressurized fluid assists in moving the rack piston up or down in the cylinder bore.

Most THP and PCF steering gears are equipped with two poppet (unloading) valves, one at each end of the rack piston. As the front wheels reach the axle stop—the farthest the wheels can turn in either direction—one poppet or the other, depending on the direction of the turn, will trip to prevent steering system damage. The tripped poppet reduces pressure in the gear, heat generated by the power steering pump, and outside forces acting on the steering linkage.

Some THP and PCF steering gears are also supplied with an internal pressure relief valve (PRV). The PRV limits maximum supply pressure to protect the power steering gear, but it does not reduce pressure as the steered wheels approach the axle stops.

See **Fig. 1** for an exploded view of the steering gear.

General Information



1. Valve Housing Capscrew
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Valve Housing
6. Auxiliary Port O-Ring (2)
7. Auxiliary Port Plug (2)
8. Relief Valve
9. O-Ring
10. Relief Valve Cap
11. Valve Housing O-Ring
12. Bearing Assembly
13. O-Ring
14. Seal Ring
15. Input Shaft Assembly
16. Thrust Bearing
17. Thrust Washer
18. Seal Ring
19. O-Ring
20. Bearing Adjuster
21. Adjuster Locknut
22. O-Ring
23. Seal Ring
24. Push Tube
25. Poppet Spring
26. Poppet
27. Poppet Seat and Sleeve Assembly
28. Rack Piston
29. Ball
30. Ball Return Guide
31. Cap Seal
32. Ball Return Guide Cap
33. Torx® Capscrew
34. Gear Housing
35. Dirt and Water Seal
36. Grease Fitting
37. Automatic Bleed Plug
38. Poppet Adjusting Screw
39. Poppet Adjusting Screw Nut
40. Poppet Fixed Stop Screw
41. Roller Bearing
42. Output Seal
43. Sector Shaft Assembly
44. Sector Shaft Adjusting Screw
45. Washer
46. Roller Bearing
47. Side Cover O-Ring
48. Side Cover Assembly
49. Vent Plug, Side Cover
50. Adjusting Screw Jam Nut
51. Capscrew

Fig. 1, TRW THP/PCF Steering Gear

Steering Gear Removal and Installation

Removal

1. Verify that the axle stops are adjusted correctly. Ensuring correct axle stop adjustment will eliminate the possibility of resetting steering gear poppet valves after the gear is installed. See **Group 33** for instructions.
2. Place the front tires in the straight-ahead position. If possible, drive the vehicle in a straight line for a short distance, stopping where the work is to be done.
3. Shut down the engine, apply the parking brakes, and chock the tires.
4. Disconnect the batteries and open the hood.
5. Clean all fittings and hose connections on the steering gear until they are free of dirt.
6. Drain the fluid from the power steering system. Disconnect the hydraulic lines from the steering gear, marking the lines for later reference. Plug the lines and the fittings to keep out dirt.
7. Remove the pitman arm. Refer to **Section 46.08** for instructions.
8. Disconnect the steering driveline from the steering gear input shaft.

   8.1 Remove and discard the pinch bolt and nut from the steering driveline lower end yoke.

NOTICE

Do not pound the U-joint or lower end yoke on or off the input shaft. Internal damage to the steering gear can result.

   8.2 Remove the end yoke from the input shaft.

WARNING

The steering gear is heavy. Use caution when removing, lifting, or carrying the steering gear. Failure to do so could cause personal injury.

9. Remove the fasteners that secure the steering gear to the frame rail. Remove the steering gear.

Installation

1. Mount the steering gear on the frame rail and install the mounting fasteners. Tighten the fasteners 342 to 434 lbf·ft (464 to 588 N·m).
2. Center the steering gear so that the timing mark on the sector shaft is aligned with the timing mark on the steering gear. Keep the steering gear centered as the installation continues.
3. Connect the steering driveline to the steering gear input shaft.

   3.1 Align the hole in the steering driveline lower end yoke with the indentation on the input shaft.

   3.2 Using a new pinch bolt and nut, attach the driveline lower end yoke to the input shaft. Tighten the nut 30 to 35 lbf·ft (41 to 47 N·m).

   3.3 Apply torque seal, OGP F900WHITE, to the exposed bolt threads and the nut to indicate the fasteners have been properly tightened.
4. Install the pitman arm. Refer to **Section 46.08** for instructions.
5. If the hydraulic line fittings were removed, attach them to the steering gear. Tighten the fittings 37 lbf·ft (50 N·m). Tighten the jam nut on the pressure line fitting to a maximum 41 lbf·ft (56 N·m).
6. Remove the plugs from the hydraulic lines. Connect the hydraulic lines to the steering gear. Tighten the nut on each fitting finger tight, then use a wrench to tighten the nut until there is firm resistance. Tighten one-sixth turn more.
7. Connect the batteries.
8. Fill and bleed the steering system. For instructions, refer to **Subject 110**.
9. Close the hood and perform the post-service checks in **Subject 150**.

Filling and Air Bleeding the System

WARNING

Fill the power steering system with only approved, clean hydraulic fluid. Mixing hydraulic fluids and using unapproved hydraulic fluid could lead to seal deterioration and leaks. Leaks could result in loss of power steering assist and spillage on the roadway, which could cause personal injury or property damage.

1. Fill the power steering reservoir nearly full with automatic transmission fluid. Do not turn the steering wheel.
2. Start the engine and let it idle for ten seconds, then shut it off. Check and fill the reservoir. Repeat this step at least three times, checking the fluid level in the reservoir each time.

IMPORTANT: Do not let the fluid level drop significantly or allow the reservoir to empty. Doing so may introduce air into the system.

3. Start the engine and let it idle for two minutes. Do not turn the steering wheel. Shut off the engine and check the fluid level in the reservoir. If needed, add more fluid.
4. Start the engine again. Turn the steering wheel from full-left to full-right several times. If needed, add more fluid to the reservoir.

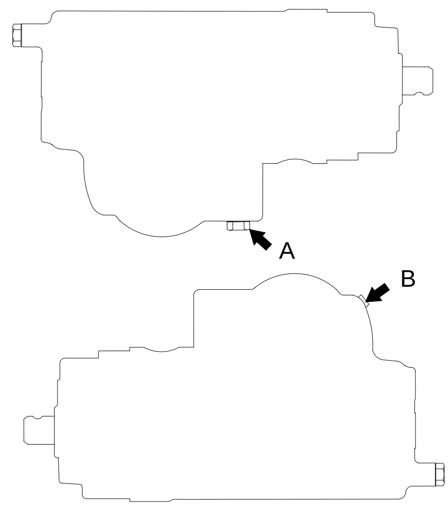
   Automatic bleed systems should now be free of trapped air.

   If the vehicle has a manual bleed system (**Fig. 1**), proceed to the next step.

IMPORTANT: Do not turn the steering wheel while the bleed screw is loosened.

5. With the wheels in the straight-ahead position, loosen the manual bleed screw two to three turns. Allow air and aerated fluid to bleed out until only clear fluid is seen. Close the bleed screw and add fluid to the reservoir if needed.

   Repeat this step until all air is out of the system.
6. Tighten the bleed screw 45 lbf·in (509 N·cm).



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A. Steering gear with automatic bleed plug. Do not remove the bleed plug.
B. Steering gear with manual bleed plug.

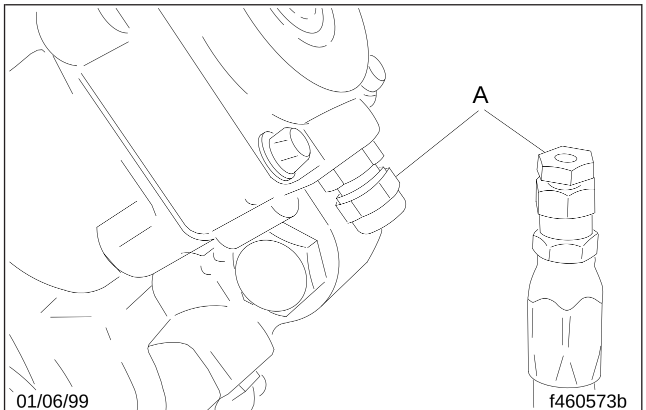
Fig. 1, Steering Gear Bleed Systems

Input Shaft Seal Replacement

Replacement

NOTE: The power steering pump is used in this procedure to force out the input shaft seal. To use this procedure, the power steering pump should have a minimum of 1500 psi (10 342 kPa) available.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Disconnect the return line from the steering gear and plug the line. See **Fig. 1**. Cap the return port of the steering gear with a high pressure fitting.



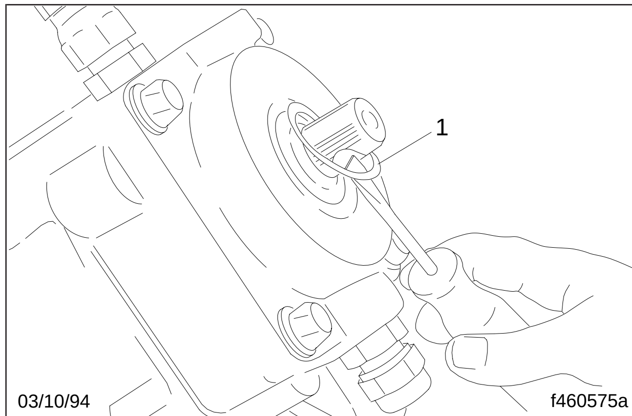
A. Cap the return line and the return port.

Fig. 1, Disconnected Return Line

NOTICE

Do not pound the U-joint or lower end yoke on or off the input shaft. Internal damage to the steering gear can result.

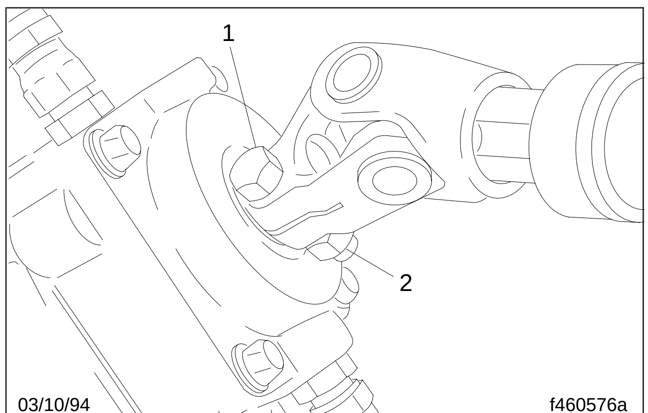
3. Disconnect the steering driveline from the steering gear input shaft.
4. Remove the dirt and water seal from the steering gear. Save this seal to determine the correct size of the new seal.
5. Using a clean cloth, remove all grease from around the input shaft.
6. Using a screwdriver inserted into the notch formed in the end of the retaining ring, remove the retaining ring. See **Fig. 2**. Be careful not to scratch the bore with the screwdriver.



1. Retaining Ring

Fig. 2, Retaining Ring Removal

7. Using a pinch bolt and nut, attach the steering driveline to the input shaft but do not tighten the nut. See **Fig. 3**.



1. Pinch Bolt
2. Pinch Bolt Nut

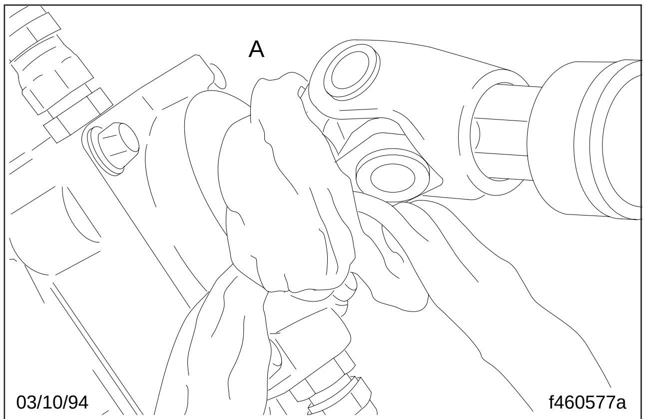
Fig. 3, Pinch Bolt Installation

8. Tie or wrap a shop towel around the input shaft and place a drain pan under the steering gear to catch the oil. See **Fig. 4**.

WARNING

Fill the power steering system with only approved, clean hydraulic fluid. Mixing hydraulic fluids and using unapproved hydraulic fluid could lead to seal deterioration and leaks. Leaks could result in loss of power steering assist and

Input Shaft Seal Replacement

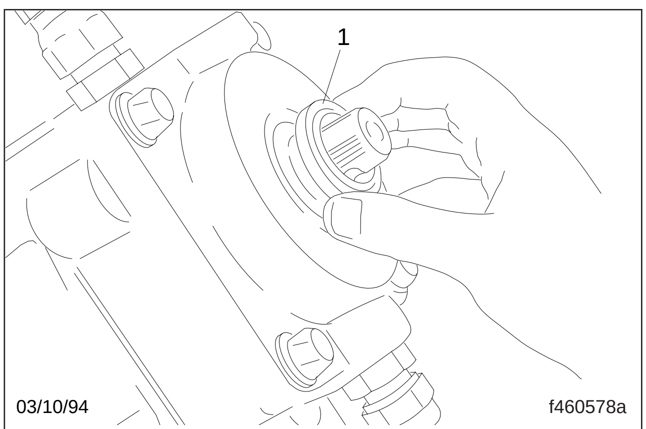


A. Cover the input shaft area.

Fig. 4, Shop Towel Covering the Input Shaft

spillage on the roadway, which could cause personal injury or property damage.

9. If needed, fill the power steering reservoir with automatic transmission fluid.
10. With the vehicle in neutral, momentarily turn the starter. If the engine starts, quickly turn it off. This should force out the input shaft seal.
11. Remove the shop towel, pinch bolt, and input yoke. Remove the input shaft seal. See **Fig. 5**.



1. Input Shaft Seal

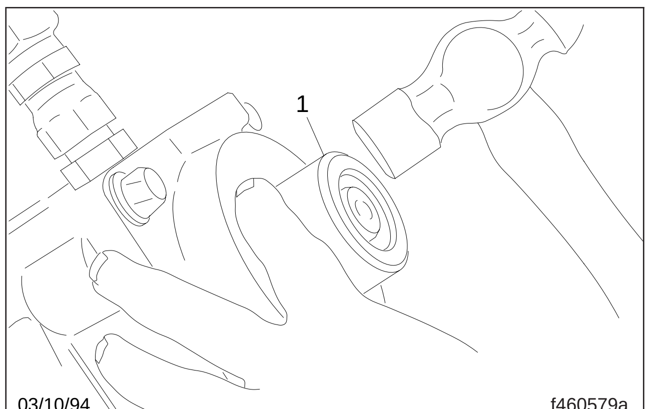
Fig. 5, Input Shaft Seal Removal

12. Inspect the seal area of the valve housing for seal fragments. Remove all seal fragments.
13. Check the input shaft seal for heat damage. If the seal is stiff and brittle, it is probably heat damaged. Determine and fix the cause of excessive heat in the vehicle.

WARNING

Do not use a socket to install the input shaft seal. You will not be able to control the seal installation depth with a socket and this could lead to leaks. Leaks could result in loss of steering assist and spillage on the roadway, which could result in personal injury or property damage.

14. Install a new input shaft seal.
    14.1 Using Exxon Polyrex® EP2 grease (045422), lubricate the inside diameter of the new input shaft seal and install it on the input shaft.
    14.2 Using a hammer and seal driver (J37073), tap the driver until the shoulder of the driver is square against the valve housing. See **Fig. 6**. Remove any seal material that may have sheared off in the seal bore or retaining ring groove.



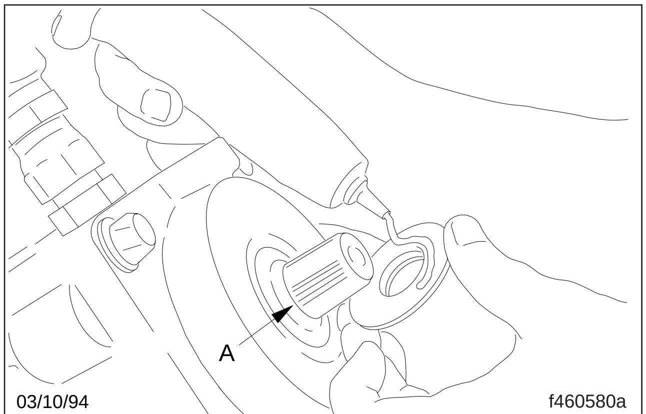
1. Seal Installer Tool

Fig. 6, Seal Installer Tool Position

15. Install a new retaining ring in the groove.
16. Using Exxon Polyrex EP2 grease (045422), pack the end of the valve housing bore.
17. Install a new dirt and water seal.
    17.1 Choose the correct size dirt and water seal by comparing the replacement seals to the old seal.

17.2 Apply Exxon Polyrex EP2 grease to the new dirt and water seal and install it on the input shaft. See **Fig. 7**. Seat it in the groove behind the serrations and against the valve housing.

Wipe any excess grease from the valve housing bore and input shaft once the seal has been installed.



A. Seat the seal here.

Fig. 7, Dirt and Water Seal Installation

18. Using a new pinch bolt and nut, attach the steering driveline to the input shaft. Tighten the nut 30 to 35 lbf·ft (41 to 47 N·m).
19. Apply torque seal, OGP F900WHITE, to the exposed bolt threads and the nut to indicate the fasteners have been properly tightened.
20. Connect the return line to the steering gear return port.
21. Bleed the air from the system. For instructions, see **Subject 110**.

Adjustment

NOTE: If the steering gear is installed on the frame rail, sector shaft adjustment can only be completed if the adjusting screw jam nut (located on the side cover) is accessible.

1. Apply the parking brakes and chock the rear tires.
2. With the engine on, turn the steering wheel until the timing mark on the sector shaft lines up with the timing mark on the housing. The sector shaft is now at its center of travel. Shut down the engine.
3. Remove the cotter pin and castle nut that attach the drag link to the pitman arm. Remove the drag link from the pitman arm.

IMPORTANT: To avoid resetting the poppets, do not turn the input shaft more than 1-1/2 turns from the center-of-travel position while the drag link is disconnected.

4. From the center-of-travel position, grasp the pitman arm at the lower end of the arm and gently try to move the arm back and forth. If the pitman arm is loose or lash (free play) is detected, the sector shaft is out of adjustment.
5. Loosen the adjusting screw jam nut.
6. If no lash was detected in step 4, use a screwdriver to turn the sector shaft adjusting screw counterclockwise until you feel lash at the sector shaft. See **Fig. 1**.

IMPORTANT: Do not use more than 10 lbf·ft (14 N·m) of force when tightening the adjusting screw.

7. Slowly turn the shaft adjusting screw clockwise until you feel no lash at the sector shaft. From this position, turn the screw clockwise 1/8 to 3/16 of a turn more. Hold the adjusting screw in place and tighten the jam nut 43 lbf·ft (58 N·m).
8. Turn the steering wheel 1/4 of a turn each side of center then back to center and check the pitman arm for lash. There should be no lash. If lash is detected, loosen the jam nut and repeat the previous step as well as this step.
9. Using a castle nut, attach the drag link to the pitman arm. Tighten the castle nut using the appropriate torque value:

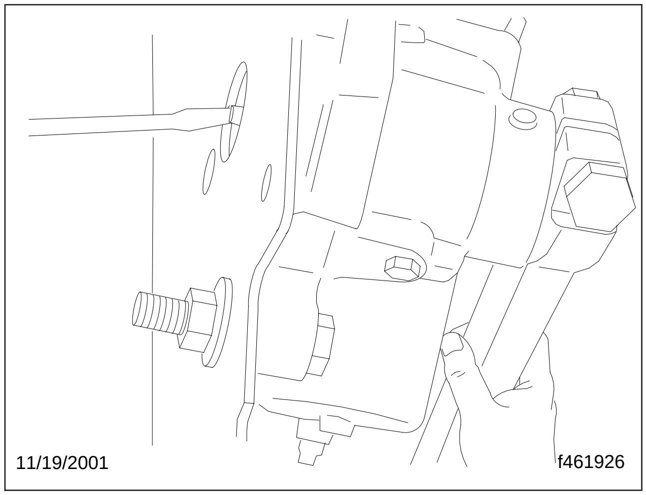


Fig. 1, Adjusting the Sector Shaft

- 3/4–16: 90 to 170 lbf·ft (122 to 230 N·m)
- 7/8–14: 160 to 300 lbf·ft (217 to 407 N·m)

WARNING

Failure to install and lock a new cotter pin in the ball stud and nut could result in disengagement of the parts and loss of steering control, which could result in personal injury or property damage.

10. Continue to tighten the castle nut until a slot on the nut aligns with the hole in the ball stud. Do **not** reverse the tightening direction of the nut when locating the cotter pin hole. Install a new cotter pin in the ball stud and nut, then lock the cotter pin in place.

NOTICE

Do not use a power grease gun to add grease to the sector shaft bearing. Doing so could damage the high-pressure seal and contaminate the hydraulic fluid.

11. Using only a hand-operated grease gun, add grease to the sector shaft bearing through the grease fitting in the housing until grease begins to extrude past the dirt and water seal.

Poppet Adjustment on a Single Gear

Resetting the Poppet Valves

1. Check that the axle stops are adjusted properly. See **Group 33** for instructions.
2. Start the engine and allow the vehicle to idle for 5 to 10 minutes to warm the hydraulic fluid.
3. Shut down the engine, apply the parking brakes, and chock the rear tires.
4. Hold the poppet screw with a wrench and turn the sealing nut back toward the wrench until the nut is flush with the base of the hex area of the poppet screw.
5. Make sure that the engine is off and the wheels are in the straight-ahead position.

NOTICE

Make sure the drive end of the adjusting screw is not below the face of the nut. If the drive end of the adjusting screw is below the face of the nut, the poppet seat flange will break when the upper poppet is prepared for setting.

6. Using a 7/32-inch Allen wrench, turn the adjusting screw and nut assembly (without turning the nut on the screw) into the housing until the nut is firmly against the housing. Tighten the nut against the housing. See **Fig. 1**.

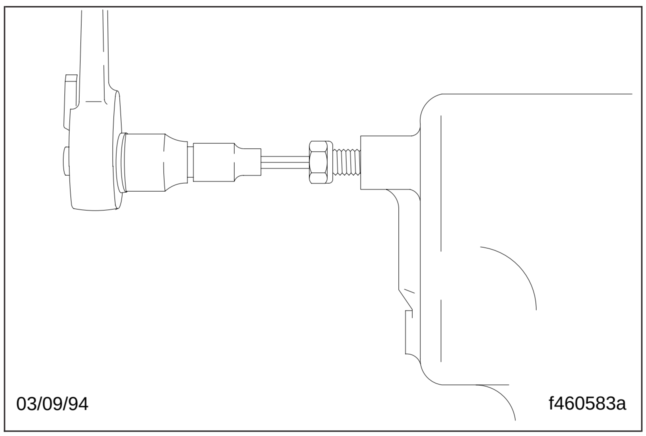


Fig. 1, Adjusting Screw and Nut Assembly

7. Place a jack under the center of the front axle and jack up the front of the vehicle so the steer axle tires are off the ground.
8. Push the upper poppet out to prepare it for setting.
   - 8.1 Start the engine and let it idle.
   - 8.2 Note which sector shaft timing mark is nearest the housing piston bore.

NOTICE

Do not hold the steering wheel at full turn for more than 10 seconds at a time. The heat buildup at pump relief pressure may damage components.

   - 8.3 Turn the steering wheel in the direction that makes this timing mark move toward the adjusting screw just installed. Turn the wheel in this direction until axle stop contact is made.
   - 8.4 Pull hard on the steering wheel. Put up to 30 lbf (133 N) pull on a 20-inch diameter steering wheel.
9. Set the upper poppet.
   - 9.1 Turn the steering wheel in the opposite direction (the timing mark will move away from the adjusting screw) until the other axle stop is contacted.
   - 9.2 Pull hard on the steering wheel. Put up to 30 lbf (133 N) pull on a 20-inch diameter steering wheel.
   - 9.3 Release the steering wheel and shut off the engine.
10. Loosen the sealing nut and back out the adjusting screw until the adjusting screw is one inch (2.5 cm) past the nut. See **Fig. 2**. Tighten the nut against the housing.
11. Set the lower poppet.
   - 11.1 Start the engine and let it idle.
   - 11.2 Turn the steering wheel in the original direction (the timing mark will move toward the adjusting screw) until axle stop contact is made.
   - 11.3 Hold the steering wheel in this position with up to 30 lbf (133 N) pull on a 20-inch diameter steering wheel for 10 seconds, then release. Repeat this hold-and-release process as many times as necessary while completing the next step.
12. Position the adjusting screw.

Poppet Adjustment on a Single Gear

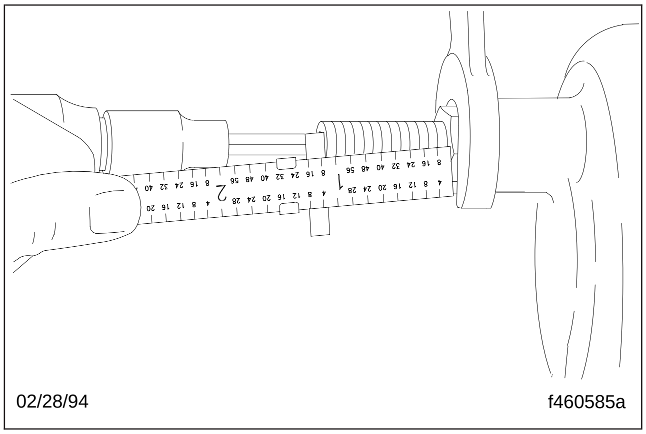


Fig. 2, Adjusting Screw Position

12.1 With the steering wheel held tightly at full turn, loosen the nut and hold it in place with a wrench.

12.2 Using an Allen wrench and finger pressure only, turn the adjusting screw clockwise until the Allen wrench stops. Do not attempt to turn the adjusting screw in any farther. Pause the turning-in process each time the driver releases the steering wheel. Continue turning only while the steering wheel is held at full turn.

12.3 Back off the adjusting screw 3-1/4 turns and tighten the nut 35 lbf·ft (47 N·m).

WARNING

If the adjusting screw protrudes more than 1-1/16 inches (27 mm) from the sealing nut, the screw could fall out of the steering gear, resulting in loss of power steering. This could cause an accident resulting in personal injury or property damage.

IMPORTANT: Once the poppet adjusting screw and sealing nut are in place, and the poppet valves have been manually adjusted, the adjustment procedure must be repeated if steering travel is either increased or decreased in the future.

WARNING

Fill the power steering system with only approved, clean hydraulic fluid. Mixing hydraulic fluids and using unapproved hydraulic fluid could lead to seal deterioration and leaks. Leaks could result in loss of power steering assist and spillage on the roadway, which could cause personal injury or property damage.

13. The poppets have now been completely reset. Check the power steering reservoir. The power steering fluid level should be between the MIN COLD mark and the middle mark just above it. If needed, add fluid.
14. Lower the vehicle.

Post-Service Checks

After power steering components have been worked on and before the vehicle is placed into service, the following items must be checked.

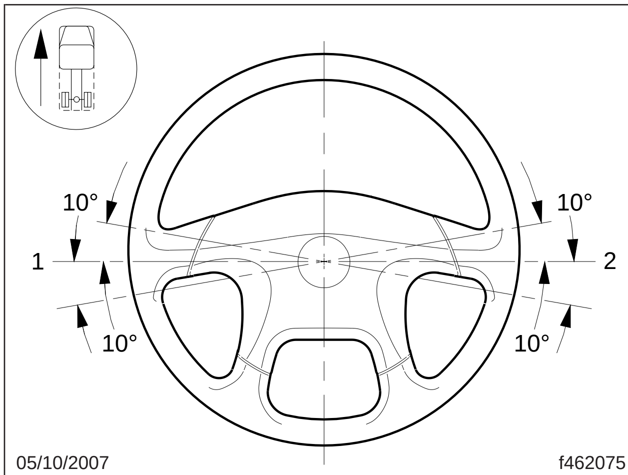
WARNING

Failure to check the following items could result in damage to the power steering system. This could cause loss of steering assist and spillage on the roadway, which could cause personal injury or property damage.

1. Operate the engine at idle while turning the steering wheel through several full-left and full-right turns. With the engine running and the power steering system at operating temperature, turn the steering wheel slowly from stop to stop while checking the power steering reservoir for frothing or a change in the fluid level (signs that air is trapped in the system).

   If air is present, inspect the system for leaking hoses or loose fittings. Replace the hoses or tighten the fittings as necessary. Bleed the air from the system. Refer to **Subject 110** for instructions.

2. With the engine turned off and warm, check the power steering reservoir fluid level. If needed, add power steering fluid.
3. At full-left and full-right turns, be sure the axle stops on the rear side of the spindle are set so there is at least 1/2 inch (13 mm) of clearance between the tires and any fixed components that are attached to the vehicle. Clearance between moving components should be at least 3/4 inch (19 mm). If clearance is less than the above, reset the axle stops.
4. Check that the poppets are set correctly. If needed, adjust them. For instructions, refer to **Subject 140**.
5. Test drive the vehicle. Check the steering wheel spoke position. If, during straight-ahead driving on a level road, the steering wheel spokes are not within ±10 degrees of the 9 o'clock and 3 o'clock positions, remove the steering wheel and reposition it. See **Fig. 1**.



1. 9 o'Clock Position
2. 3 o'Clock Position

Fig. 1, Steering Wheel Centered

Specifications

⚠ WARNING

Fill the power steering system with only approved, clean hydraulic fluid. Mixing hydraulic fluids and using unapproved hydraulic fluid could lead to seal deterioration and leaks. Leaks could result in loss of power steering assist and spillage on the roadway, which could cause personal injury or property damage.

THP and PCF power steering gears use automatic transmission fluid that meets Dexron II, Dexron III, Mercon, or ATF +4™ specifications.

Exxon Polyrex® EP2 Grease (045422) is approved for use on steering gear components.

Special tools can be ordered from:

SPX Kent-Moore
28635 Mound Road
Warren, Michigan 48092-3499
1-800-328-6657

SPX Kent-Moore Tools	
Tool Name	**Part Number**
Bearing and Seal Tool	J37071 and J37071–A
Special Tool	J36452–A
Bearing Adjuster Tool	J37070
Seal Driver Tool	J37073
Adjuster Locknut Tool	J37464

Table 1, SPX Kent-Moore Tools

General Information

The ZF FN4 power steering pump supplies power steering fluid for the operation of the power steering gear. The pump is a sliding-vane pump with an internal flow control and pressure relief valve. The primary parts of the pump include the input shaft, rotor, vanes, and cam ring; all contained in a lightweight alloy housing. The oval-shaped cam ring surrounds the cylindrical rotor, creating two pumping pockets positioned 180 degrees from each other. The position of the pumping pockets balances the internal forces within the pump. Flow rate and maximum pressure are not adjustable.

Principles of Operation

As the input shaft turns the rotor inside the cam ring, the centrifugal force pushes ten vanes out toward the surface of the cam ring. The pumping element has two pumping pockets opposed 180 degrees from each other that balance the internal forces using the pressure generated by the pumping action. Fluid entering via the inlet port is forced by the vanes through the pumping pockets in the cam ring, and out through the outlet port, to the steering gear. Once through the steering gear, the fluid returns to the power steering reservoir, then back to the power steering pump.

The pump outputs a fixed volume for each revolution of the input shaft. This volume is determined by the internal contour of the cam ring.

Power Steering Pump Removal and Installation

Removal

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries at the negative terminals, and open the hood.
3. Clean all the fittings and hose connections on the power steering reservoir, the power steering pump, and the pressure line on the power steering gear until they are free of dirt. See **Fig. 1**.

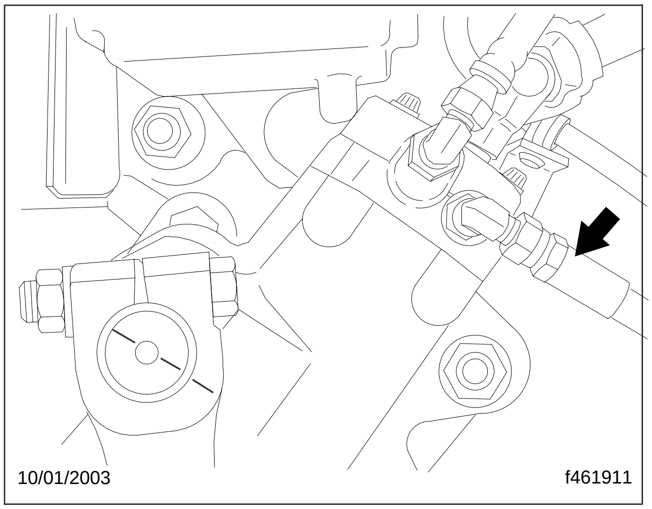


Fig. 1, Pressure Line on the Power Steering Gear

4. Drain the fluid from the power steering system. Disconnect the hydraulic lines from the power steering reservoir, marking the lines for later reference. Plug the lines and the fittings to keep out dirt.
5. Remove the bolts, nuts, and washers that attach the power steering reservoir to the mounting bracket. Remove the power steering reservoir.
6. Remove the pressure line at the power steering gear and plug the line.
7. On vehicles with a Caterpillar 3126 engine, the power steering pump may be mounted on the engine or the air compressor. If the power steering pump is mounted on the engine, remove the mounting bolts, nuts, and washers, then remove the pump. If the power steering pump is mounted on the air compressor, remove the mounting capscrews, then remove the pump.
8. On vehicles with an MBE900 engine, remove the capscrews that attach the power steering pump to the engine or to the air compressor.
9. Remove the power steering pump and discard the gasket or O-ring.
10. If the power steering pump is being replaced, remove the fittings on the pump and attach the fittings to the new pump.

Installation

1. On vehicles with a Caterpillar 3126 engine, install the power steering pump.
   - 1.1 Install a new gasket on the power steering pump.
   - 1.2 If the power steering pump is mounted on the air compressor, use capscrews to attach the steering pump to the air compressor and tighten the capscrews 27 to 32 lbf·ft (37 to 43 N·m).

     If the power steering pump is mounted on the engine, use bolts, nuts, and washers to attach the steering pump to the engine. Tighten the bolts 27 to 32 lbf·ft (37 to 43 N·m).
2. On vehicles with an MBE900 engine, install the power steering pump.
   - 2.1 Make sure the O-ring is in place on the power steering pump.
   - 2.2 Using capscrews, attach the power steering pump to the engine or the air compressor. Tighten the capscrews 27 to 32 lbf·ft (37 to 43 N·m).
3. Unplug the pressure line and attach it to the steering pump.
4. Unplug the remaining hydraulic lines and fittings and connect the lines.
5. Using bolts, nuts, and washers, attach the power steering reservoir to the mounting bracket.
6. Connect the batteries.
7. Fill the power steering reservoir to between the MAX HOT and MIN COLD lines. For approved power steering fluids, see **Specifications 400**.

Power Steering Pump Removal and Installation

8. Start the engine and turn the steering wheel from full right to full left two or three times to remove air from the lines.
9. Check the power steering reservoir again and add fluid if needed.
10. Check the hydraulic lines for leaks.
11. Turn off the engine, close the hood, and remove the chocks from the tires.

Specifications

Approved lubricants for the ZF FN4 power steering pump are:

- Automatic Transmission Fluid (ATF), Dexron® II or Dexron® III
- Engine Oil 15W40, 76 Lubricants or equivalent

IMPORTANT: Do not use engine oil in vehicles built from November 4, 2002.

General Description

NOTE: Procedures in this section have been slightly modified from the original component manufacturer's service manual. See the manufacturer's service literature (**trucksteering.trw-.com**) for additional information.

TRW TAS power steering gears are integral hydraulic power steering gears that contain a manual steering mechanism, a hydraulic control valve, and a hydraulic power cylinder.

The pressure required for the steering gear to overcome resistance at the steered wheels is provided by the power steering pump. The rotary control valve directs the flow of hydraulic fluid to the appropriate cylinder cavity in the steering gear (and in the auxiliary cylinder in a dual steering gear system) at the proper flow rate and pressure. As the steering wheel is turned faster or slower, more or less fluid is required by the gear.

Principles of Operation

When the driver turns the steering wheel, that force travels from the steering wheel to the steering gear input shaft. A torsion bar, pinned at one end to the input shaft and at the other end to the worm shaft, turns with the input shaft and exerts a rotational force on the worm shaft. In response to the force exerted by the torsion bar, the worm shaft moves the rack piston forward or backward in the gear housing by means of a series of recirculating balls in the spiral channels of the worm shaft. As the rack piston slides back and forth, it turns the sector shaft. The sector shaft swings the pitman arm, which pulls or pushes the drag link. The drag link moves the axle steering arm, steering the vehicle.

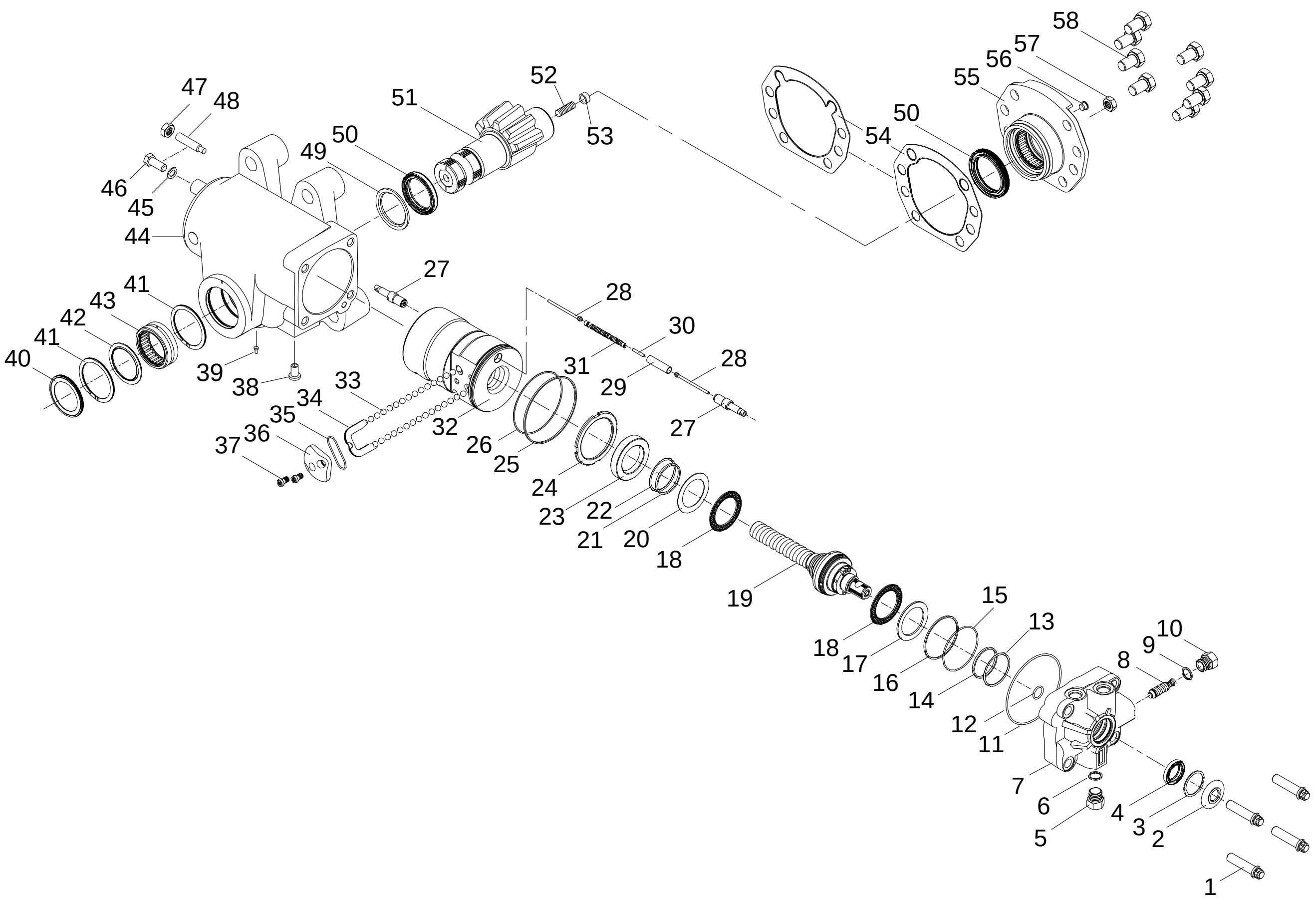
The rack piston's axial movement is resisted by its engagement to the sector shaft, which is linked to the steered wheels. Because of this resistance, the torsion bar activates the control valve, which directs pressurized fluid to the upper or lower cylinder cavity (depending on the direction of turn). The pressurized fluid assists in moving the rack piston up or down in the cylinder bore.

Most TAS steering gears are equipped with two poppet (unloading) valves, one at each end of the rack piston. As the front wheels reach the axle stop—the farthest the wheels can turn in either direction—one poppet or the other, depending on the direction of the turn, will trip to prevent steering system damage. The tripped poppet reduces pressure in the gear, heat generated by the power steering pump, and outside forces acting on the steering linkage.

Some TAS steering gears are also supplied with an internal pressure relief valve (PRV). The PRV limits maximum supply pressure to protect the power steering gear, but it does not reduce pressure as the steered wheels approach the axle stops.

See **Fig. 1** for an exploded diagram of a TRW TAS power steering gear.

General Information



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1. Bolts, Valve Housing
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Auxiliary Port Plug
6. O-Ring, Auxiliary Port Plug
7. Valve Housing
8. Relief Valve
9. O-Ring, Relief Valve
10. Relief Valve Cap
11. Seal Ring, Large
12. Seal Ring, Small
13. Seal Ring
14. O-Ring
15. Seal Ring
16. O-Ring, Valve Housing
17. Thrust Washer, Thick
18. Roller Thrust Bearing
19. Input Shaft/Valve/Worm Assembly
20. Thrust Washer, Thin
21. Seal Ring
22. O-Ring
23. Bearing Adjuster
24. Adjuster Locknut
25. Seal Ring, Rack Piston
26. O-Ring, Backup
27. Poppet Adjuster Seat and Sleeve Assembly
28. Poppet
29. Push Tube
30. Spacer Rod
31. Poppet Spring
32. Rack Piston
33. Steel Balls
34. Ball Return Guide Halves
35. Seal, Ball Return Guide Cap
36. Ball Return Guide Cap
37. Torx® Screws
38. Plug, Auto-Bleed
39. Grease Fitting
40. Dirt and Water Seal, Trunnion
41. Retaining Ring
42. Dirt Seal
43. Roller Bearing
44. Gear Housing
45. Washer, Stopscrew
46. Fixed Stop Screw, Poppet
47. Service Sealing Jam Nut
48. Service Poppet Adjusting Screw
49. Washer, Spacer
50. Output Seal
51. Sector Shaft
52. Adjusting Screw, Shaft
53. Retainer, Adjusting Screw
54. Gasket, Side Cover
55. Side Cover and Bushing/Bearing Assembly
56. Vent Plug, Side Cover
57. Jam Nut
58. Special Bolts, Side Cover

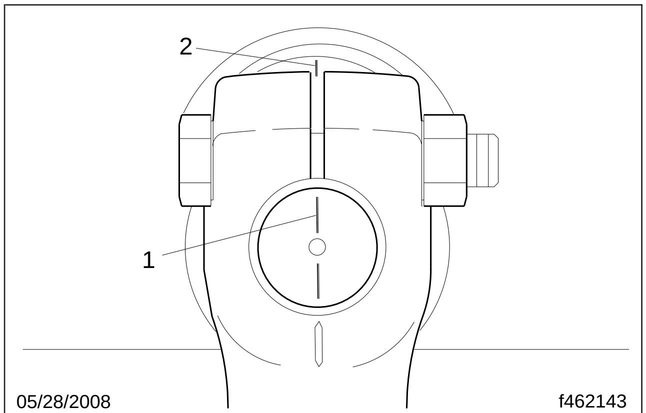
Fig. 1, TRW TAS85 Power Steering Gear Components

Steering Gear Adjustments

Sector Shaft Adjustment

NOTE: If the steering gear is installed on the frame rail, sector shaft adjustment can only be completed if the adjusting screw jam nut (located on the side cover) is accessible.

1. Apply the parking brakes and chock the rear tires.
2. With the engine on, turn the steering wheel until the timing mark on the sector shaft lines up with the timing mark on the housing. The sector shaft is now at its center of travel. See **Fig. 1**. Shut down the engine.



1. Housing Timing Mark
2. Sector Shaft Alignment Mark

Fig. 1, Timing Mark Placement

3. Remove the cotter pin and castle nut that attach the drag link to the pitman arm. Disconnect the drag link from the pitman arm.

IMPORTANT: To avoid resetting the poppets, do not turn the input shaft more than 1-1/2 turns from the center-of-travel position while the drag link is disconnected.

4. From the center-of-travel position, grasp the pitman arm at the lower end of the arm and gently try to move the arm back and forth. See **Fig. 2**. If the pitman arm is loose or lash (free play) is detected, the sector shaft is out of adjustment.
5. Loosen the adjusting screw jam nut.
6. If no lash was detected in step 4, use a screwdriver to turn the sector shaft adjusting screw counterclockwise until you feel lash at the sector shaft. See **Fig. 3**.

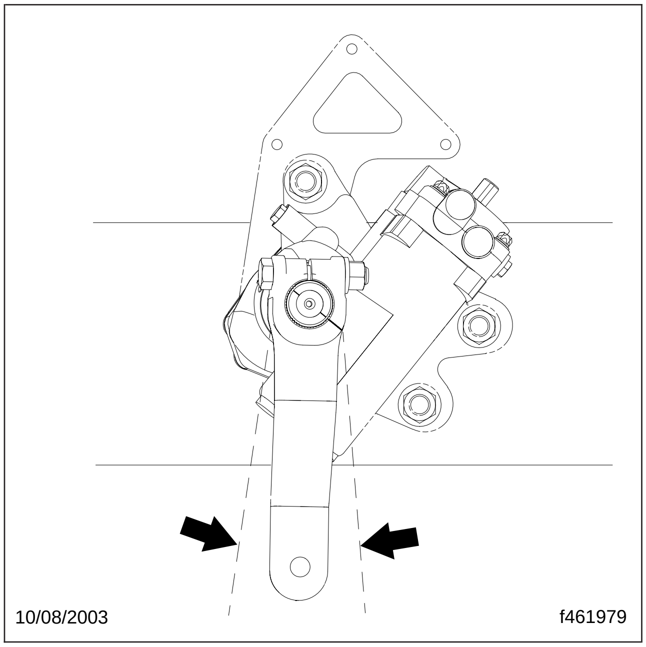


Fig. 2, Lash Check

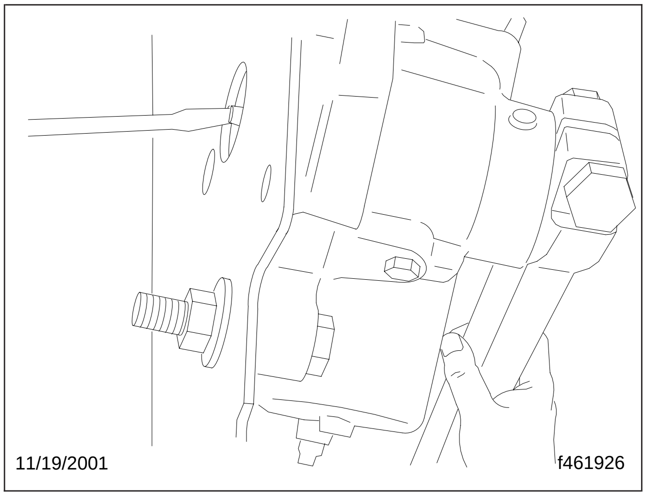


Fig. 3, Adjusting the Sector Shaft

IMPORTANT: Do not use more than 10 lbf·ft (14 N·m) of force when tightening the adjusting screw.

7. Slowly turn the adjusting screw clockwise until no lash is felt at the pitman arm. From this position, turn the adjusting screw clockwise 1/8 to 3/16 of

Steering Gear Adjustments

a turn more. Hold the adjusting screw in place and tighten the jam nut 43 lbf·ft (58 N·m).

8. Turn the steering wheel 1/4 of a turn to each side of center and recheck the pitman arm for lash. If lash is detected, adjust the sector shaft again.
9. Attach the drag link to the pitman arm. See **Section 46.08** for instructions.

WARNING

Failure to install and lock a new cotter pin in the ball stud and nut could result in disengagement of the parts and loss of steering control, which could result in personal injury or property damage.

10. Continue to tighten the castle nut until a slot on the nut aligns with the hole in the ball stud. Do **not** reverse the tightening direction of the nut when locating the cotter pin hole. Install a new cotter pin in the ball stud and nut, then lock the cotter pin in place.

NOTICE

Do not use a power grease gun to add grease to the sector shaft bearing. Doing so could damage the high-pressure seal and contaminate the hydraulic fluid.

11. Using only a hand-operated grease gun, add grease to the sector shaft bearing through the grease fitting in the housing until grease begins to extrude past the dirt and water seal.

Resetting the Poppet Valves

IMPORTANT: The axle stops must be set so that there are at least 1-3/4 steering wheel turns from a straight-ahead position to both a full-left and a full-right turn; otherwise the poppet valves will not work.

1. Verify that the axle stops are adjusted properly. See **Group 33** for instructions.
2. Start the engine and allow the vehicle to idle for 5 to 10 minutes to warm the hydraulic fluid.
3. Shut down the engine, apply the parking brakes, and chock the rear tires.
4. Hold the poppet screw with a wrench and turn the sealing nut back toward the wrench until the nut is flush with the base of the hex area of the poppet screw.
5. Make sure that the engine is off and the wheels are in the straight-ahead position.

NOTICE

Make sure the drive end of the adjusting screw is not below the face of the nut. If the drive end of the adjusting screw is below the face of the nut, the poppet seat flange will break when the upper poppet is prepared for setting.

6. Using a 7/32-inch Allen wrench, turn the adjusting screw and nut assembly (without turning the nut on the screw) into the housing until the nut is firmly against the housing. Tighten the nut against the housing. See **Fig. 4**.

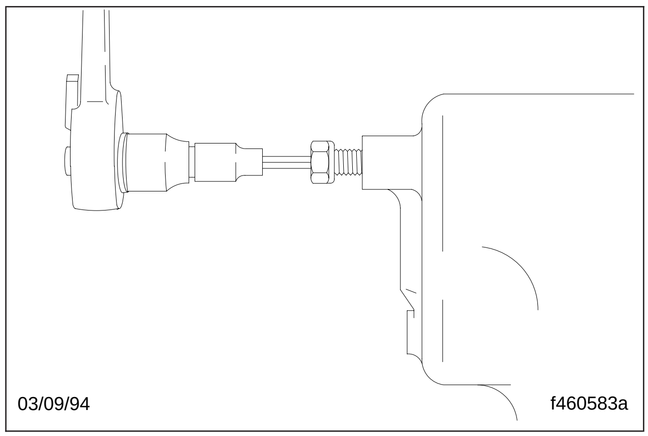


Fig. 4, Adjusting Screw and Nut Assembly

WARNING

Fill the power steering system with only approved, clean hydraulic fluid. Mixing hydraulic fluids and using unapproved hydraulic fluid could lead to seal deterioration and leaks. Leaks could result in loss of power steering assist and spillage on the roadway, which could cause personal injury or property damage.

7. Fill the power steering reservoir nearly full with automatic transmission fluid. Do not turn the steering wheel.

8. Place a jack under the center of the front axle and jack up the front of the vehicle so the steer axle tires are off the ground.
9. Push the upper poppet out to prepare it for setting.

    9.1 Start the engine and let it idle.

    9.2 Note which sector shaft timing mark is nearest the housing piston bore.

NOTICE

Do not hold the steering wheel at full turn for more than 10 seconds at a time. The heat buildup at pump relief pressure may damage components.

    9.3 Turn the steering wheel in the direction that makes this timing mark move toward the adjusting screw just installed. Turn the wheel in this direction until axle stop contact is made.

    9.4 Pull hard on the steering wheel. Put up to 40 lbf (178 N) pull on a 20-inch diameter steering wheel.

10. Set the upper poppet.

    10.1 Turn the steering wheel in the opposite direction (the timing mark will move away from the adjusting screw) until the other axle stop is contacted.

    10.2 Pull hard on the steering wheel. Put up to 40 lbf (178 N) pull on a 20-inch diameter steering wheel.

    10.3 Release the steering wheel and shut off the engine.

11. Loosen the sealing nut and back out the adjusting screw until the adjusting screw is 1 inch (2.5 cm) past the nut. See **Fig. 5**. Tighten the nut against the housing.
12. Set the lower poppet.

    12.1 Start the engine and let it idle.

    12.2 Turn the steering wheel in the original direction (the timing mark will move toward the adjusting screw) until axle stop contact is made.

    12.3 Hold the steering wheel in this position with up to 40 lbf (178 N) pull on a 20-inch diameter steering wheel for 10 seconds, then release. Repeat this hold-and-release process as many times as necessary while completing the next step.

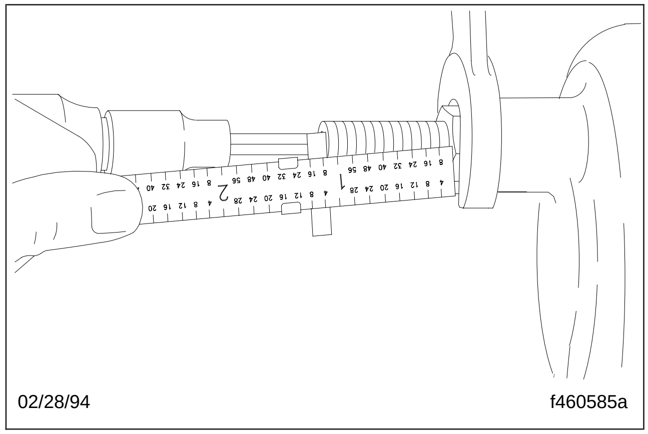


Fig. 5, Adjusting Screw Position

13. Position the adjusting screw.

    13.1 With the steering wheel held tightly at full turn, loosen the nut and hold it in place with a wrench.

IMPORTANT: Do not attempt to turn the adjusting screw in any farther. Pause the turning-in process each time the driver releases the steering wheel. Continue turning only while the steering wheel is held at full turn.

    13.2 Using an Allen wrench and finger pressure only, turn the adjusting screw clockwise until the Allen wrench stops.

WARNING

If the adjusting screw protrudes more than 1-1/16 inches (27 mm) from the sealing nut, the screw could fall out of the steering gear, resulting in loss of power steering. This could cause an accident resulting in personal injury or property damage.

    13.3 Back off the adjusting screw 3-1/4 turns and tighten the nut 35 lbf·ft (47 N·m).

Steering Gear Adjustments

WARNING

Fill the power steering system with only approved, clean hydraulic fluid. Mixing hydraulic fluids and using unapproved hydraulic fluid could lead to seal deterioration and leaks. Leaks could result in loss of power steering assist and spillage on the roadway, which could cause personal injury or property damage.

14. The poppets have now been completely reset. Check the power steering reservoir. If needed, add fluid.
15. Lower the vehicle.

Steering Gear Removal and Installation

Removal

1. Verify correct axle stop adjustment. Ensuring correct axle stop adjustment now will eliminate the need to reset the steering gear poppet valves after the gear is installed. For instructions, refer to **Group 33**.
2. Place the front tires in the straight-ahead position. If possible, drive the vehicle in a straight line for a short distance, stopping where the work is to be done.
3. Shut down the engine, apply the parking brakes, and chock the tires.
4. Remove the left bumper extension, if equipped.
5. Clean all fittings and hose connections on the steering gear until they are free of dirt.
6. Drain the fluid from the power steering system. Disconnect all hydraulic lines from the gear, marking the lines for later reference. Seal the lines and the fittings to keep out dirt.
7. Disconnect the pitman arm from the steering gear sector shaft. See **Section 46.08** for instructions.
8. Disconnect the steering driveline from the steering gear input shaft.
   - 8.1 Remove and discard the pinch bolt and nut from the steering driveline lower end yoke.

NOTICE

Do not pound the U-joint or lower end yoke on or off the input shaft. Internal damage to the steering gear can result.

   - 8.2 Remove the lower end yoke from the input shaft.

WARNING

The steering gear is heavy. Use caution when removing, lifting, or carrying the steering gear. Failure to do so could cause personal injury.

9. Remove the fasteners that attach the steering gear to the frame rail. Remove the steering gear.

Installation

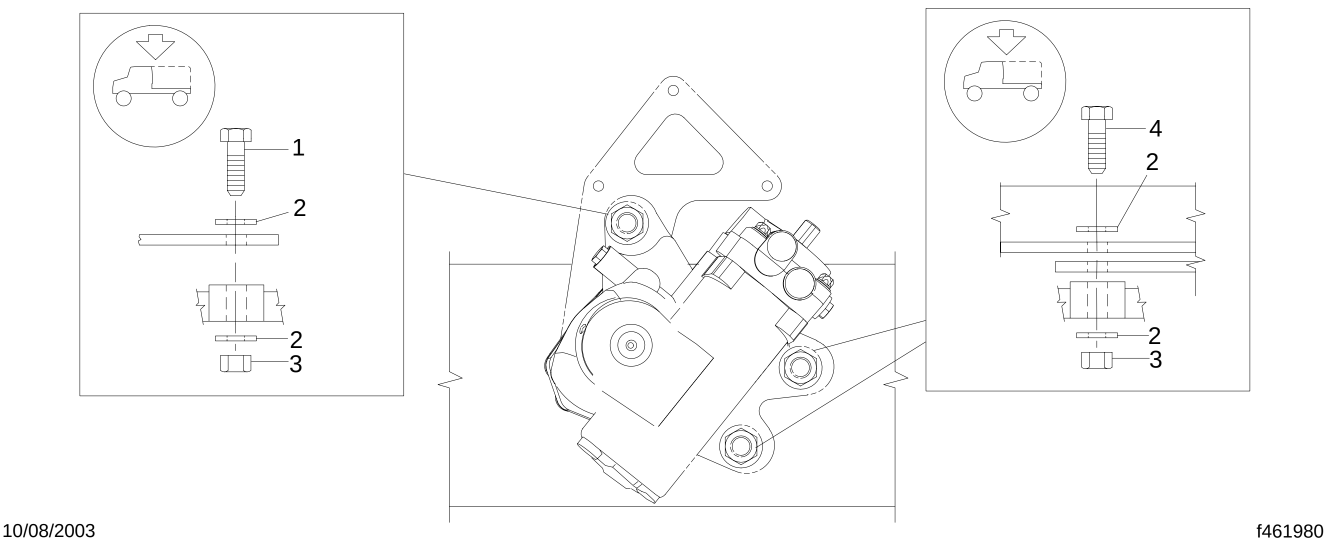
1. Install the steering gear and fasteners as shown in **Fig. 1**. Tighten the fasteners 278 to 352 lbf·ft (377 to 477 N·m).
2. Center the steering gear so that the timing mark on the sector shaft is aligned with the timing mark on the steering gear housing. See **Fig. 2**. Keep the steering gear centered as the installation continues.
3. Connect the steering driveline to the steering gear input shaft.
   - 3.1 Clean the steering gear input shaft and the inside of the driveline yoke.
   - 3.2 Apply a thin film of grease to the yoke spline.
   - 3.3 Slide the yoke on the input shaft and install a new pinch bolt and nut. Tighten the nut 30 to 35 lbf·ft (41 to 47 N·m).
   - 3.4 Apply torque seal, OGP F900WHITE, to the exposed bolt threads and the nut to indicate the fasteners have been properly tightened.

WARNING

Never leave a chisel wedged in the pitman arm slot. When using a chisel to spread the slot in the pitman arm, maintain a firm grip on the chisel at all times. Otherwise the chisel may fly loose, which could cause an injury.

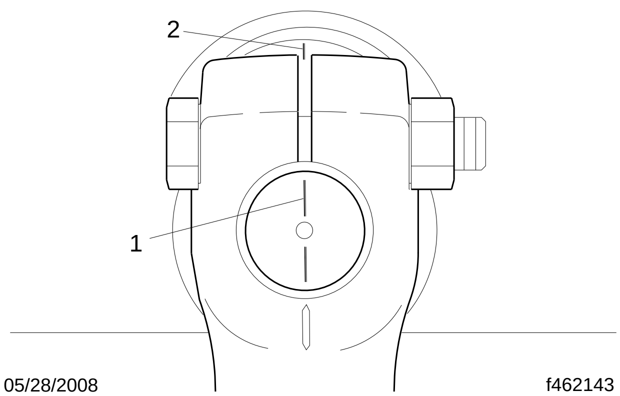
4. Install the pitman arm. See **Section 46.08** for instructions.
5. If they were removed, attach the hydraulic line fittings to the steering gear. Tighten the fittings 38 lbf·ft (52 N·m). Tighten the pressure line fitting jam nut 41 lbf·ft (56 N·m).
6. Remove the plugs from the hydraulic lines. Connect the lines to the steering gear as previously marked. Tighten the nut on each fitting finger tight. Then, use a wrench to tighten the nut until there is firm resistance. Tighten 1/6 of a turn more.
7. Connect the batteries.
8. Fill and bleed the steering system.

Steering Gear Removal and Installation



1. 7/8–14 x 4-1/2 Capscrew
2. 7/8" ID Washer
3. 7/8–14 Nut
4. 7/8–14 x 4 Capscrew

Fig. 1, Steering Gear Installation



1. Housing Timing Mark
2. Sector Shaft Alignment Mark

Fig. 2, Timing Mark Placement

WARNING

Fill the power steering system with only approved, clean hydraulic fluid. Mixing hydraulic fluids and using unapproved hydraulic fluid could lead to seal deterioration and leaks. Leaks could result in loss of power steering assist and spillage on the roadway, which could cause personal injury or property damage.

8.1 Fill the power steering reservoir nearly full with automatic transmission fluid. Do not turn the steering wheel.

8.2 Start the engine and let it idle for ten seconds, then shut it off. Check and fill the reservoir. Repeat this step at least three times, checking the fluid level in the reservoir each time.

IMPORTANT: Do not let the fluid level drop significantly or allow the reservoir to empty. Doing so may introduce air into the system.

8.3 Start the engine and let it idle for two minutes. Do not turn the steering wheel. Shut off the engine and check the fluid level in the reservoir. If needed, add more fluid.

8.4 Start the engine again. Steer the vehicle from full left to full right several times. Check and, if necessary, refill the reservoir.

Automatic bleed systems should now be free of trapped air. Skip to the last step in this procedure.

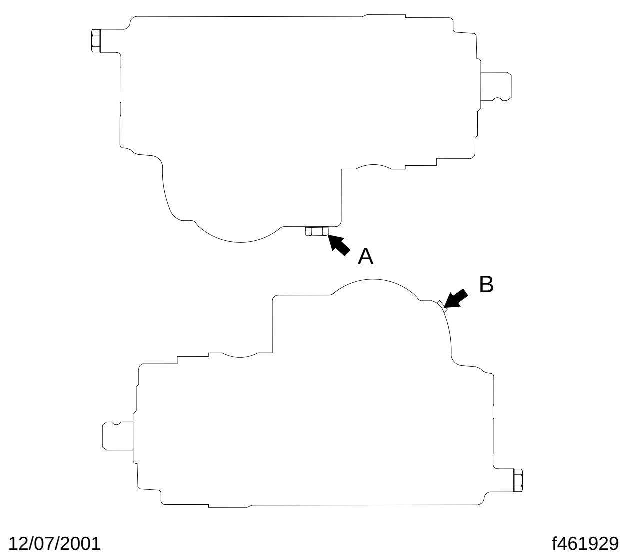
If the vehicle has a manual bleed system (**Fig. 3**), proceed to the next step.

IMPORTANT: Do not turn the steering wheel while the bleed screw is loosened.

8.5 With the wheels in the straight-ahead position, loosen the manual bleed screw two to three turns. Allow air and aerated fluid to bleed out until only clear fluid is seen. Close the bleed screw and add fluid to the reservoir if needed.

Repeat this step until all air is out of the system.

Tighten the bleed screw 45 lbf·in (509 N·cm).



A. Steering gear with automatic bleed plug. Do not remove the bleed plug.
B. Steering gear with manual bleed plug.

Fig. 3, Steering Gear Bleed Systems

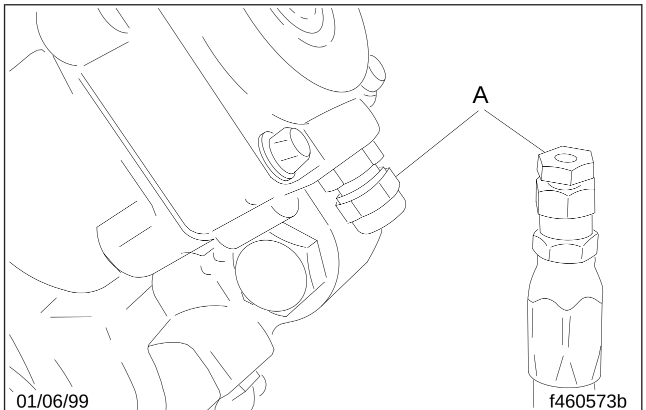
9. Close the hood, install the left bumper extension (if equipped), and perform the post-service checks in **Subject 130**.

Input Shaft Seal Replacement

Replacement

NOTE: The power steering pump is used in this procedure to force out the input shaft seal. To use this procedure, the power steering pump should have a minimum of 1500 psi (10 342 kPa) available.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Disconnect the return line from the steering gear and plug the line. See **Fig. 1**. Cap the return port of the gear with a high-pressure fitting.



A. Cap the return line and the return port.

Fig. 1, Disconnected Return Line

NOTICE

Do not pound the U-joint or lower end yoke on or off the input shaft. Internal damage to the steering gear can result.

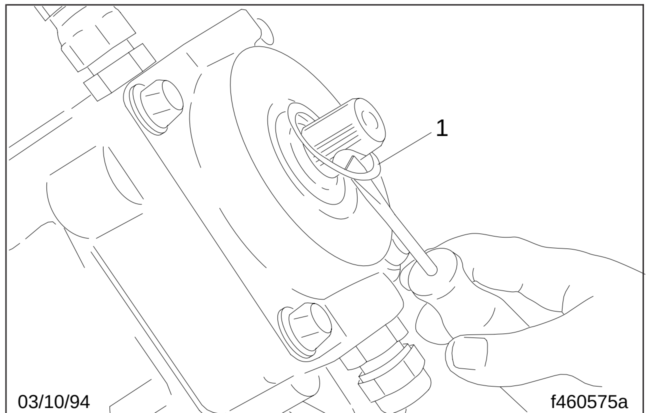
3. Disconnect the steering driveline from the steering gear input shaft.

   3.1 Remove and discard the pinch bolt and nut from the steering driveline lower end yoke.

   IMPORTANT: Do not turn the steering gear input shaft when removing the lower end yoke.

   3.2 Remove the lower end yoke from the input shaft. Push the driveline shaft into the driveline tube as you remove the lower end yoke.

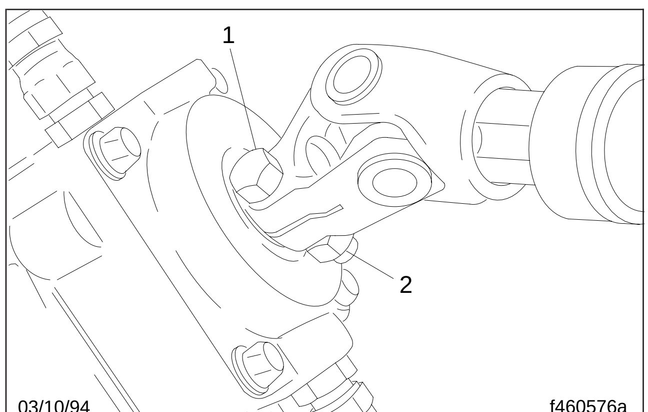
4. Remove the dirt and water seal from the steering gear. Save this seal to determine the correct size of the new seal.
5. Using a clean cloth, remove all grease from around the input shaft.
6. Using a screwdriver inserted into the notch formed in the end of the retaining ring, remove the retaining ring. See **Fig. 2**. Be careful not to scratch the bore with the screwdriver.



1. Retaining Ring

Fig. 2, Retaining Ring Removal

7. Slip the driveline lower end yoke back on the input shaft, then insert but do not tighten the pinch bolt. See **Fig. 3**.

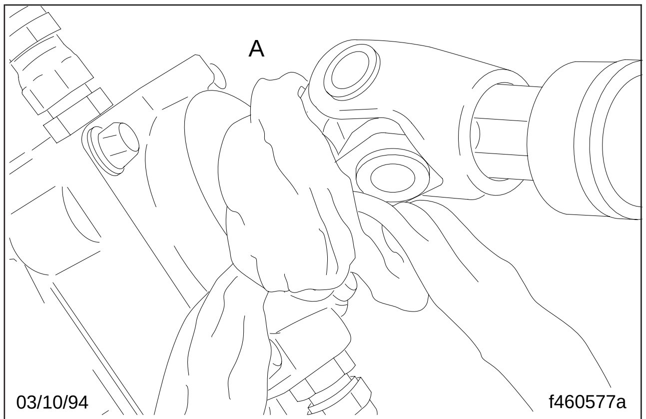


1. Pinch Bolt
2. Pinch Bolt Nut

Fig. 3, Pinch Bolt Installation

Input Shaft Seal Replacement

8. Tie or wrap a shop towel around the input shaft area and place a drip pan under the vehicle to catch the oil. See **Fig. 4**.



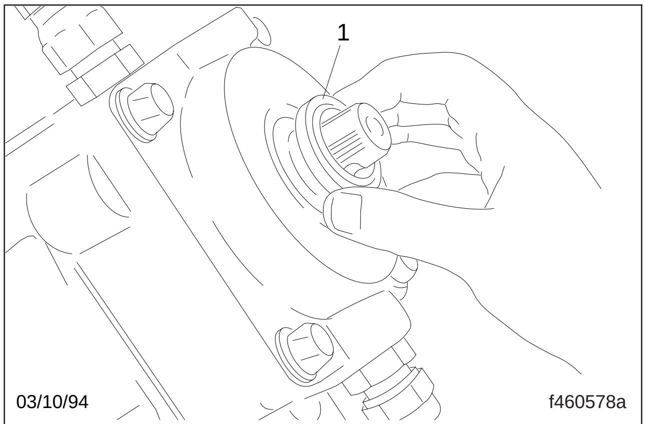
A. Cover the input shaft area.

Fig. 4, Shop Towel Covering the Input Shaft

WARNING

Fill the power steering system with only approved, clean hydraulic fluid. Mixing hydraulic fluids and using unapproved hydraulic fluid could lead to seal deterioration and leaks. Leaks could result in loss of power steering assist and spillage on the roadway, which could cause personal injury or property damage.

9. If needed, fill the power steering reservoir with automatic transmission fluid.
10. With the vehicle in neutral, momentarily turn the starter. If the engine starts, quickly turn it off. This should force out the input shaft seal.
11. Remove the shop towel, pinch bolt, and input yoke. Remove the input shaft seal. See **Fig. 5**.
12. Inspect the seal area of the valve housing for seal fragments. Remove any seal fragments.
13. Check the seal for heat damage. If the seal is stiff and brittle, and not pliable like the new seal, it is probably heat damaged. Determine and fix the cause of any excessive heat in the vehicle. Discard the old seal.



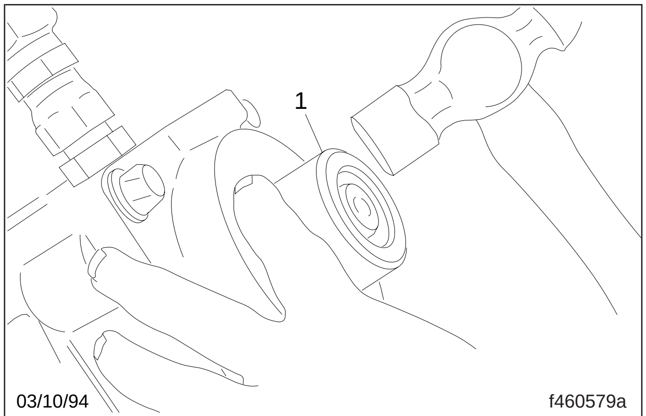
1. Input Shaft Seal

Fig. 5, Input Shaft Seal Removal

WARNING

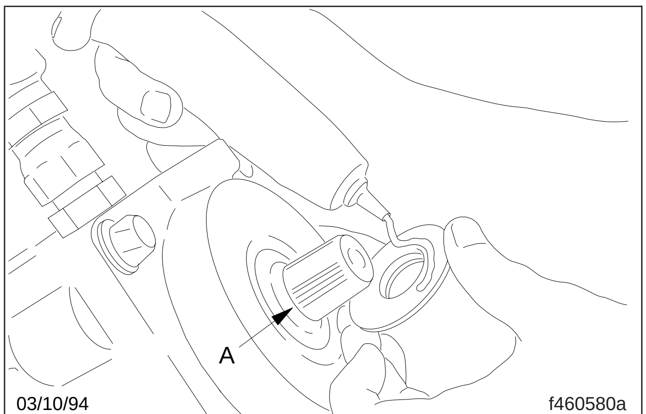
Do not use a socket to install the input shaft seal. You will not be able to control the seal installation depth with a socket and this could lead to leaks. Leaks could result in loss of steering assist and spillage on the roadway, which could result in personal injury or property damage.

14. Install a new input shaft seal.
    - 14.1 Using Exxon Polyrex® EP2 grease (045422), lubricate the inside diameter of the new input shaft seal and install it on the input shaft.
    - 14.2 Using a hammer and seal driver (J37073), tap the driver until the shoulder of the driver is square against the valve housing. See **Fig. 6**. Remove any seal material that may have sheared off in the seal bore or retaining ring groove.
15. Install a new retaining ring in the groove.
16. Using Exxon Polyrex EP2 grease, pack the end of the valve housing bore and around the input shaft with clean grease.
17. Install a new dirt and water seal.
    - 17.1 Choose the correct size dirt and water seal by comparing the replacement seals to the old seal.
    - 17.2 Apply Exxon Polyrex EP2 grease to the new dirt and water seal and install it on the input shaft. See **Fig. 7**. Seat it in the



1. Seal Installer Tool

Fig. 6, Seal Installer Tool Position



A. Seat the seal here.

Fig. 7, Dirt and Water Seal Installation

groove behind the serrations and against the valve housing.

Wipe any excess grease from the valve housing bore and input shaft once the seal has been installed.

18. Connect the steering driveline to the steering gear input shaft.

    18.1 Clean the input shaft and the inside of the driveline yoke.

    18.2 Apply a thin film of grease to the yoke splines.

    18.3 Slide the yoke on the input shaft and install a new pinch bolt and nut. Tighten the nut 30 to 35 lbf·ft (41 to 47 N·m).

    18.4 Apply torque seal, OGP F900WHITE, to the exposed bolt threads and the nut to indicate the fasteners have been properly tightened.

19. Connect the return line to the steering gear return port.

20. Fill and bleed the steering system.

WARNING

Fill the power steering system with only approved, clean hydraulic fluid. Mixing hydraulic fluids and using unapproved hydraulic fluid could lead to seal deterioration and leaks. Leaks could result in loss of power steering assist and spillage on the roadway, which could cause personal injury or property damage.

    20.1 Fill the power steering reservoir nearly full with automatic transmission fluid. Do not turn the steering wheel.

    20.2 Start the engine and let it idle for ten seconds, then shut it off. Check and fill the reservoir. Repeat this step at least three times, checking the fluid level in the reservoir each time.

IMPORTANT: Do not let the fluid level drop significantly or allow the reservoir to empty. Doing so may introduce air into the system.

    20.3 Start the engine and let it idle for two minutes. Do not turn the steering wheel. Shut off the engine and check the fluid level in the reservoir. If needed, add more fluid.

    20.4 Start the engine again. Steer the vehicle from full left to full right several times. Check and, if necessary, refill the reservoir.

    Automatic bleed systems should now be free from trapped air.

    If the vehicle has a manual bleed system (**Fig. 8**), proceed to the next step.

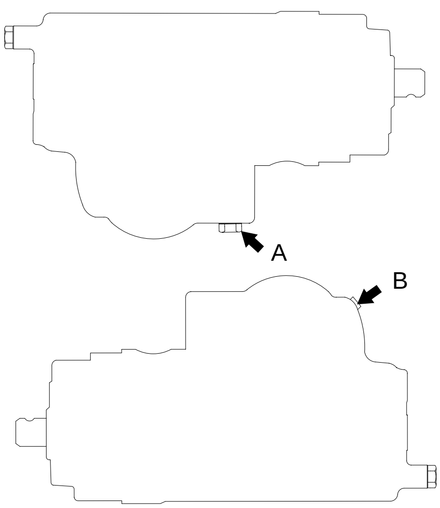
IMPORTANT: Do not turn the steering wheel while the bleed screw is loosened.

Input Shaft Seal Replacement

20.5 With the wheels in the straight-ahead position, loosen the manual bleed screw two to three turns. Allow air and aerated fluid to bleed out until only clear fluid is seen. Close the bleed screw and add fluid to the reservoir if needed.

Repeat this step until all air is out of the system.

Tighten the bleed screw 45 lbf·in (509 N·cm).



12/07/2001 f461929

A. Steering gear with automatic bleed plug. Do not remove the bleed plug.
B. Steering gear with manual bleed plug.

Fig. 8, Steering Gear Bleed Systems

21. Perform the post-service checks in **Subject 130**.

Post-Service Checks

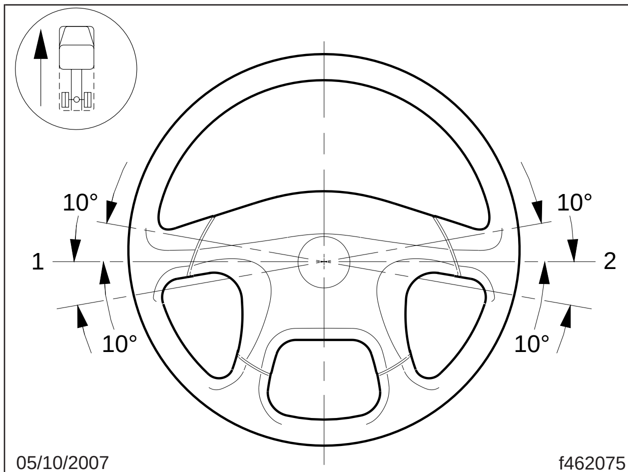
After power steering components have been worked on and before the vehicle is placed into service, the following items must be checked.

WARNING

Failure to check the following items could result in damage to the power steering system. This could cause loss of steering assist and spillage on the roadway, which could cause personal injury or property damage.

1. Operate the engine at low idle while turning the steering wheel through several full-left and full-right turns. With the engine running and the power steering system at operating temperature, turn the steering wheel slowly from stop to stop while checking the power steering reservoir for frothing or a change in the fluid level (signs that air is trapped in the system).

   If air is present, inspect the system for leaking hoses or loose fittings. Replace the hoses or tighten the fittings as necessary. Bleed the air from the system.
2. With the engine turned off and warm, check the power steering reservoir fluid level. If needed, add power steering fluid.
3. At full-left and full-right wheel cuts, be sure the axle stops (on the rear-side of the spindle) are set so there is at least 1/2-inch (13-mm) clearance between the tires and any fixed components that are attached to the vehicle. Clearance between moving components should be 3/4 of an inch (19 mm). If clearance is less than this, reset the axle stops.
4. Check that the poppets are set correctly. If necessary, adjust them. For instructions, see **Subject 100**.
5. If there are still problems with the power steering system, perform the troubleshooting procedures in **Section 46.09**. Otherwise, go to the next step.
6. Test drive the vehicle and check the steering wheel spoke position. With the front tires pointing straight ahead, check the position of the steering wheel spokes. They must be pointing within ±10 degrees of the 9 o'clock and 3 o'clock positions on a four-spoke steering wheel. If not, remove the steering wheel and install it in the correct position. See **Fig. 1**.



1. 9 o'Clock Position
2. 3 o'Clock Position

Fig. 1, Steering Wheel Centered

Specifications

⚠ WARNING

Fill the power steering system with only approved, clean hydraulic fluid. Mixing hydraulic fluids and using unapproved hydraulic fluid could lead to seal deterioration and leaks. Leaks could result in loss of power steering assist and spillage on the roadway, which could cause personal injury or property damage.

TRW TAS power steering gears use automatic transmission fluid that meets Dexron II, Dexron III, Mercon, or ATF +4™ specifications.

Exxon Polyrex® EP2 Grease (045422) is approved for use on steering gear components.

Special tools can be ordered from:

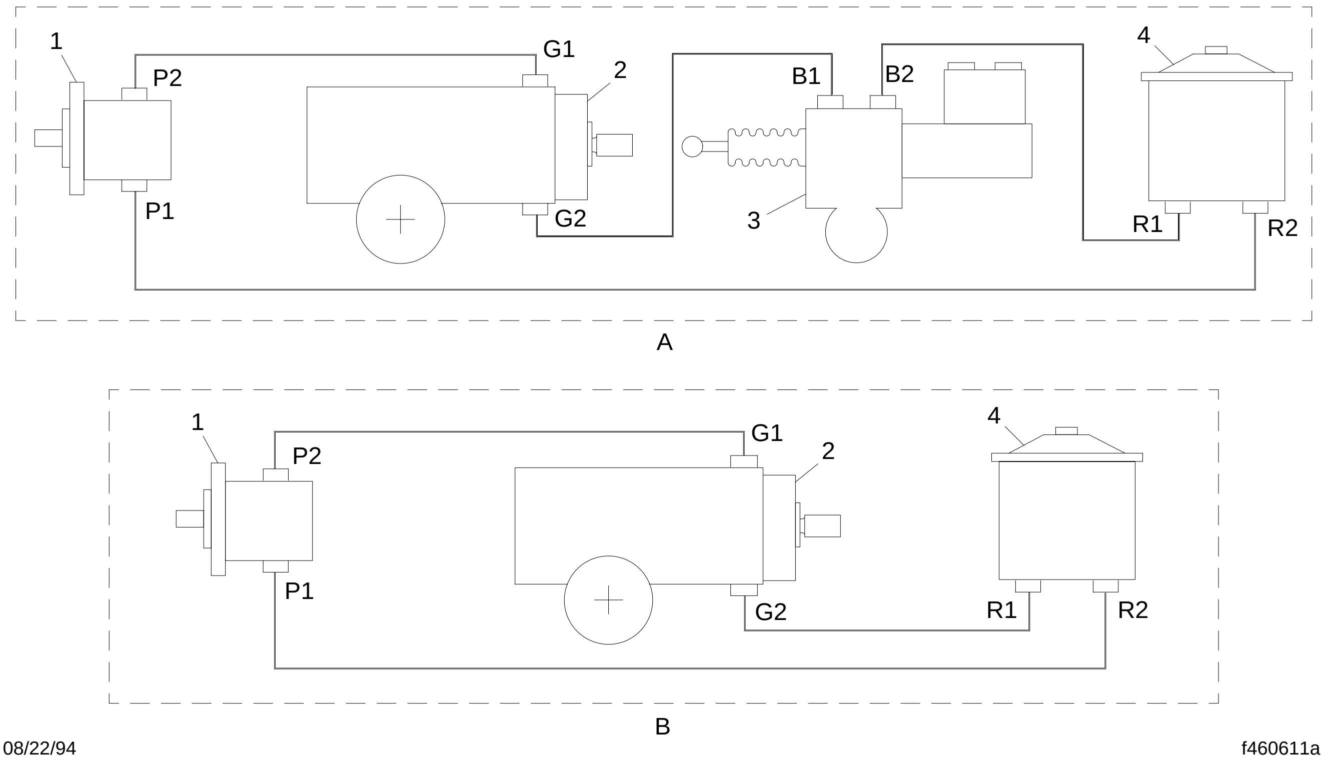
SPX Kent-Moore
28635 Mount Road
Warren, Michigan 48092-3499
1-800-328-6657

SPX Kent-Moore Part Numbers	
Part Number	**Tool**
J37070	Adjuster Tool
J37464	Adjuster Locknut Tool
J38779	Bearing and Seal Tool
J37073	Input Seal Installer
J38713	Poppet Adjuster Seat Tool, Heavy-Duty (preferred)
J36452	Poppet Adjuster Seat Tool
J37130	Relief Valve Plug
J8092	Tool Handle

Table 1, SPX Kent-Moore Part Numbers

See **Fig. 1** for a steering system plumbing diagram.

Specifications



A. Vehicles with Hydraulic Brakes

B. Vehicles with Air Brakes

1. Steering Pump
2. Steering Gear
3. Brake Booster
4. Reservoir

Fig. 1, Steering System Plumbing Diagram

Pitman Arm Removal and Installation

Removal

1. Identify the timing marks on the pitman arm and the steering gear sector shaft.
2. Remove the pinch bolt and nut that attach the pitman arm to the steering gear.
3. Remove the cotter pin from the castle nut that attaches the pitman arm to the drag link. Remove the castle nut.
4. Remove the pitman arm.

Installation

WARNING

Never leave a chisel wedged in the pitman arm slot. When using a chisel to spread the slot in the pitman arm, maintain a firm grip on the chisel at all times. Otherwise the chisel may fly loose, which could cause an injury.

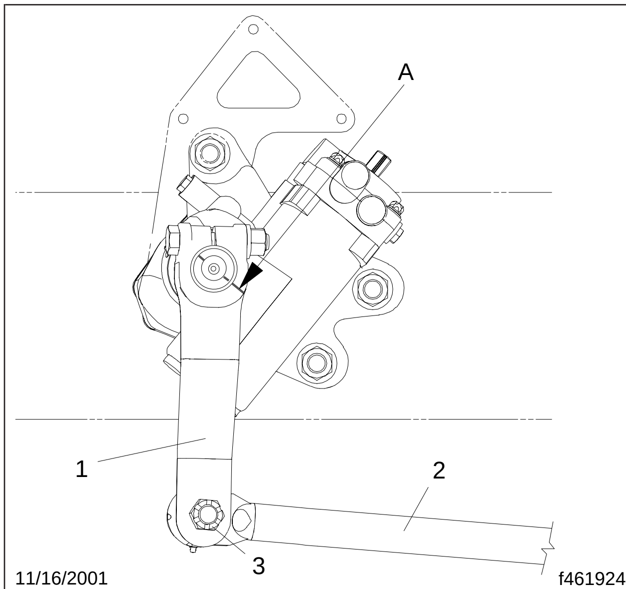
1. Install the pitman arm on the steering gear aligning the timing marks on the pitman arm with the timing marks on the sector shaft. See **Fig. 1**.

   The pitman arm may not fit over the splines on the sector shaft without spreading the slot in the pitman arm. To wedge the slot open, clamp the pitman arm in a vise with the slot at the top. Use a ball peen hammer to drive a chisel into the slot. Hold the chisel in place, remove the pitman arm from the vise, and install the pitman arm on the sector shaft. Remove the chisel from the slot.
2. Using a new pinch bolt and nut, attach the pitman arm to the steering gear. Torque the nut 130 to 155 lbf·ft (177 to 211 N·m).

WARNING

Failure to install and lock a new cotter pin in the ball stud and nut could result in disengagement of the parts and loss of steering control, which could result in serious personal injury or property damage.

3. Using a castle nut, attach the drag link to the pitman arm. Torque the castle nut 90 to 170 lbf·ft (122 to 230 N·m). If necessary, continue tightening the castle nut until a slot on the nut aligns with a hole in the ball stud. **Do not** back off the nut.



A. The timing mark on the pitman arm must line up with the timing mark on the sector shaft.

1. Pitman Arm
2. Drag Link
3. Castle Nut

Fig. 1, Pitman Arm

4. Install a new cotter pin through the ball stud and the castle nut and lock the cotter pin in place.
5. Apply torque seal, OGP F900WHITE, to the exposed bolt threads and the nut to indicate the fasteners have been properly tightened.
6. Wipe the grease fittings clean at both ball stud sockets. Using a pressure gun, fill the sockets with chassis grease.

General Information

A *Checklist for Troubleshooting Power Steering Problems*, form STI-492, has been developed to accompany the procedures below. Form STI-492 can be downloaded or printed **here** after logging into **www.AccessFreightliner.com**.

Each step and substep in these troubleshooting procedures corresponds to a step or substep on form STI-492. Use **Table 1** to determine which steps should be completed, based on the customer's complaint. It is very important that the information provided by the driver is communicated accurately to prevent wasting of diagnostic time. For example, if complaints include "Pulling to one side" and "Noisy steering," steps 1, 3, 4, 5, and 6 will be the tests for the most likely failure modes.

Start with the lowest test number and work up to the highest. For example, when completing steps 1, 3, and 6 to determine the cause of a vehicle pulling to one side, start with step 1 and finish with step 6.

Troubleshooting Steps

NOTE: Some of these inspections and procedures can be found in the Pretrip and Post-Trip Inspections and Maintenance chapter in the vehicle driver's/operator's manual.

Steps 1 through 4 may have been performed by the customer. Verify the vehicle service history with the customer to prevent redundant testing.

All measurements and readings must be recorded on STI-492.

Refer to the applicable section in this manual to repair or replace steering system components.

1. Check the tire pressure and load.

   1.1 Check the tires for damage.

   1.2 Check that the front tires are inflated to the correct pressure, and the tire pressure is equal on both sides. Correct the pressure if needed.

   Low pressure causes increased steering effort due to friction with the road surface. Unequal tire pressure causes unequal friction between the tire and the road. This can cause pulling to one side.

<table>
<tr><th colspan="13">Steering Complaint and Troubleshooting Steps Checklist</th></tr>
<tr><th rowspan="2">LH</th><th rowspan="2">RH</th><th rowspan="2">Both</th><th rowspan="2">Complaint</th><th colspan="9">Troubleshooting Steps</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th></tr>
<tr><td></td><td></td><td></td><td>Hard or heavy steering</td><td rowspan="5">•</td><td rowspan="5">•</td><td rowspan="5"></td><td rowspan="5">•</td><td rowspan="5">•</td><td rowspan="5">•</td><td rowspan="5">•</td><td rowspan="5">•</td><td rowspan="5">•</td></tr>
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<tr><td></td><td></td><td></td><td>Binding</td></tr>
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<tr><td></td><td></td><td></td><td>Pulling to one side*</td><td>•</td><td></td><td>•</td><td></td><td></td><td>•</td><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td><td>Excessive heat</td></tr>
</table>

* If there is consistent pull to one side, a braking issue could feel like a steering assist problem. Refer to **Group 42** in this manual to ensure the brake system is functioning properly.

Table 1, Steering Complaint and Troubleshooting Steps Checklist

Troubleshooting Procedures

1.3 Check that the rear tires are inflated to the correct pressure, and the tire pressure is equal on both sides. Correct the pressure if needed.

1.4 Check that the tire sizes are correctly matched, and whether duplex or oversized tires (that were not originally specified for the vehicle) have been installed.

Extra tire width causes increased steering effort due to extra friction with the road surface. If the axle stops were turned out to reduce wheel cut due to a change in tires, the power steering gear poppets may need to be adjusted.

1.5 Communicate with the driver or operator to determine whether the vehicle is operated at or over the rated load.

Increased load causes greater steering effort. Make sure the vehicle is being operated within rated capacities.

2. Check fifth wheel lubrication and condition.

   A dry fifth wheel plate makes it difficult to change direction. Check the plate surface for burrs, gouges, and irregularities.

3. Check vehicle alignment and wheel bearing adjustment.

   3.1 Check the vehicle service history for the last known alignment, and inspect tire wear for indications that an alignment needs to be completed.

   3.2 Check front axle caster and camber measurements.

   3.3 Ensure wheel bearings and rear axle are in good condition, and that toe is set correctly.

   3.4 Ensure the rear axle is properly aligned.

4. Check for loose and binding components. Check whether any steering components need maintenance or adjustment.

   4.1 Check for proper lubrication of the drag link, tie rods, and knuckle pins. Apply lubrication as needed.

   4.2 Check the COE steering column, if equipped. Chock the rearmost tires. With the engine shut down, turn the steering wheel and check for looseness or binding. Make sure all components are free to move, but are not excessively loose.

   4.3 Check the steering driveline U-joints for looseness or binding. Lubricate them if needed.

   4.4 Check the sector shaft adjustment.

   - With the vehicle on the ground, the engine idling, and the front tires pointed straight ahead, turn the steering wheel until slight motion is observed at the front wheels.
   - Align a reference mark on the steering wheel to a rule, then, with the engine running, slowly turn the steering wheel in the opposite direction until motion is again detected at the wheels.
   - Measure the lash (free play) at the rim of the steering wheel.

     Excessive lash exists if steering wheel movement exceeds 2-1/2 inches (64 mm) with a 20-inch (508-mm) steering wheel, or 2-1/4 inches (57 mm) with an 18-inch (457-mm) steering wheel.

   4.5 Check that the front wheels self-return without binding.

   - With the engine off, chock the rearmost tires and place the front tires on radius plates (turntables).
   - Disconnect the drag link from the steering arm.
   - By hand, pull one tire to the axle stop and release. The tire should self-return to almost straight ahead.
   - Repeat with the opposite tire.

     If a tire does not return to near straight ahead, check for binding or lack of lubrication in the steering axle kingpin bushings or tie rod linkage.
   - Connect the drag link and tighten the castle nut, then install a new cotter pin.

Troubleshooting Procedures

4.6 Inspect all suspension fasteners and components for wear or looseness.

5. Check the steering system for leaks and restrictions, and test the system back pressure.

5.1 Inspect hoses, fittings, and seals for damage or leaks.

- With the engine idling, inspect for kinked or collapsed hoses. Repair or replace any collapsed or kinked hoses. If collapsed hoses are found, ensure the steering system is filled with the correct automatic transmission fluid.
- Inspect fittings for leaks. Repair leaking fittings; replace parts as needed.
- Inspect all external seals. Replace leaking seals.

  Inspect the seal bores and sealing surfaces for scrapes or burrs. Make sure the seals are installed correctly using the recommended tools.
- If you replaced the steering gear input shaft seal and found it to be excessively hard, test the system operating temperature in step 6.

5.2 Inspect the steering gear for external leakage.

- Clean the area around the input shaft and inspect the input shaft for signs of leakage after operating the vehicle under normal conditions through steering maneuvers.
- Inspect the sector shaft for signs of leakage. A well greased or heavily used steering gear may weep oil from the grease seal, but a confirmed leak will be evidenced by fluid collecting while the vehicle is being operated under normal conditions.
- Inspect the vent plug in the trunnion housing for signs of leakage. Any fluid in or around the rubber vent plug indicates leakage from an internal steering gear seal.

NOTICE

Do not turn the steering wheel or allow system pressure to exceed the rating of the gauge during the following test. Damage to the gauge could occur.

5.3 Check total steering system back pressure.

- Install a low pressure gauge—300 psi (2068 kPa) maximum—between the steering pump and the steering gear.
- Check for correct fluid level. If necessary, add fluid. If bubbles or foam appear in the reservoir, check hose fittings for looseness or leaks.
- With the engine idling, read the total system back pressure on the pressure gauge.
- If the total system back pressure is greater than 100 psi (689 kPa), or 140 psi (965 kPa) for a vehicle with hydraulic brakes, replace the steering fluid filter and re-test the system. If the system back pressure is still excessive, go to the next substep.

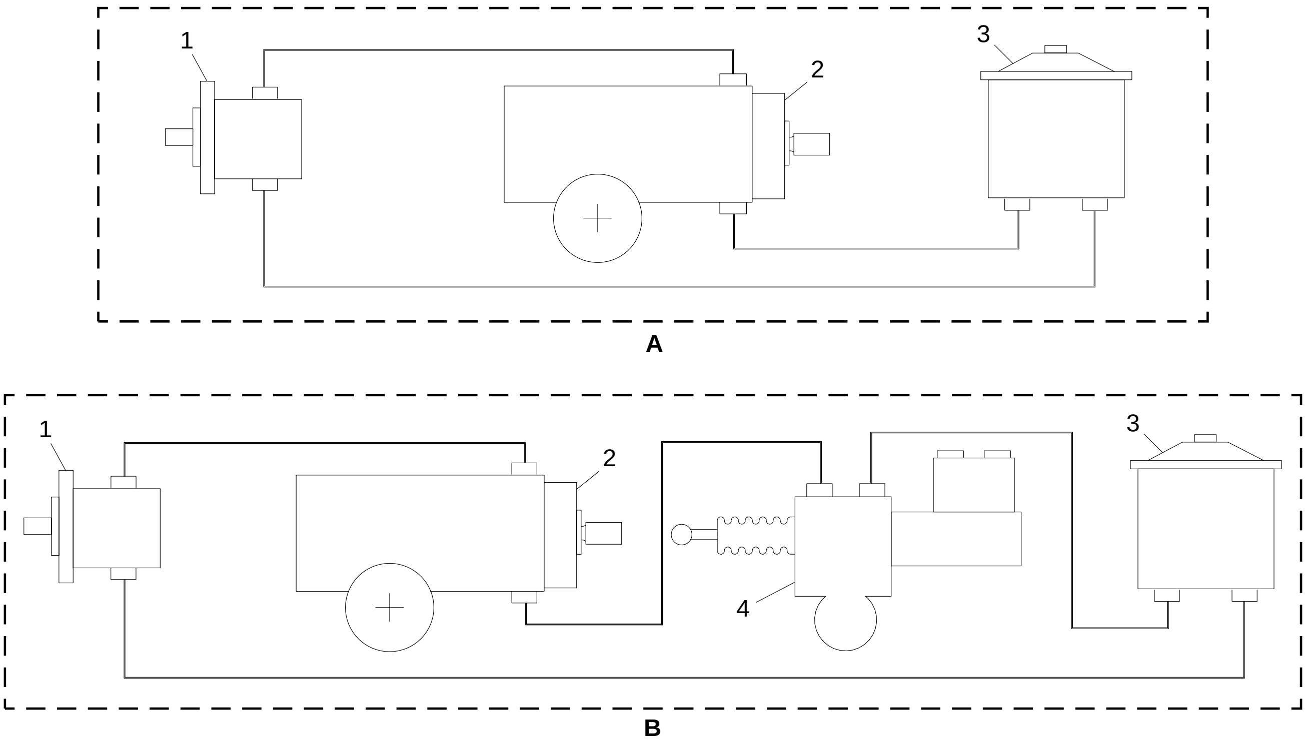
  If the total system back pressure is less than 100 psi (689 kPa), or 140 psi (965 kPa) for a vehicle with hydraulic brakes, restriction is not a problem—go to step 6.

5.4 Leave the low pressure gauge in place and check individual steering system components for excessive restriction. See **Fig. 1** for a plumbing diagram.

- Bypass the steering gear by disconnecting the steering gear input and output lines from the gear and coupling them together. See **Fig. 2** for an example.

  If the drop in system pressure from the value found in substep 5.3 is greater than 55 psi (379 kPa), the steering gear has excessive restriction. If the drop in pressure is less than 55 psi (379 kPa), reconnect the

Troubleshooting Procedures



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A. Vehicles With Air Brakes
B. Vehicles With Hydraulic Brakes

1. Steering Pump
2. Steering Gear
3. Reservoir
4. Brake Booster

Fig. 1, Plumbing Diagrams

gear input and output lines to the gear and continue with this substep.

- If the vehicle is equipped with hydraulic brakes, bypass the brake booster by disconnecting the booster input and output lines and coupling them together.

  If the drop in system pressure from the value found in substep 5.3 is greater than 40 psi (276 kPa), the brake booster has excessive restriction. If the drop in pressure is less than 40 psi (276 kPa), reconnect the booster input and output lines and continue with this substep.

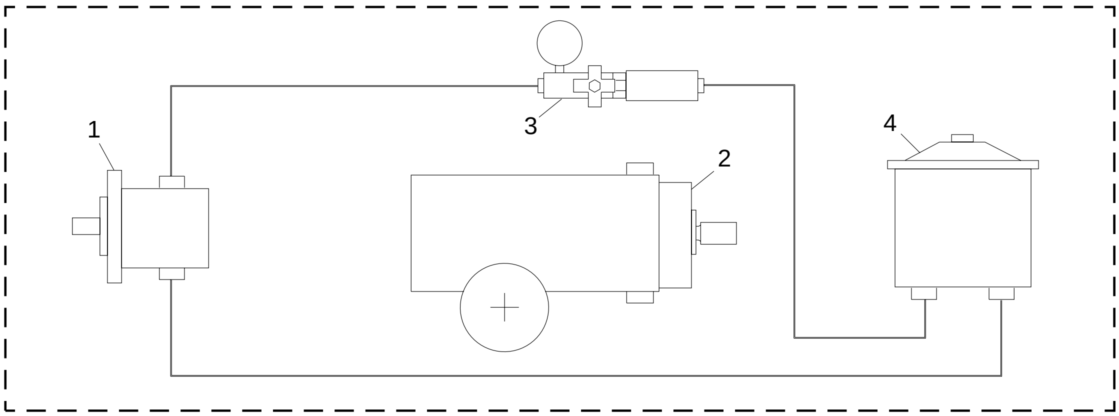
- Test each hydraulic line in the power steering system individually by bypassing them one at a time, as was done with the steering gear and brake booster, if equipped.

  If the drop in system pressure from the value found in substep 5.3 is greater than 12 psi (83 kPa) for any one line, replace the line and test total system back pressure again.

6. Check steering pump performance. Power steering fluid temperature should be approximately 180°F (82°C) to best replicate fluid temperatures under normal driving conditions.

   If the system fails the tests in the following substeps, replace the pressure relief valve (PRV) and complete the tests in the substeps below again. If the system fails again, replace the pump.

Troubleshooting Procedures



1. Steering Pump
2. Steering Gear
3. Low Pressure Gauge
4. Reservoir

Fig. 2, Testing Steering Gear Restriction

Install the PSSA between the steering pump and the gear for the following substeps. See the following heading, **Power Steering System Analyzer Setup**, for instructions on PSSA installation.

NOTICE

Do not leave the load valve closed for longer than five seconds during the following test. Doing so could damage the power steering system.

6.1 Check for erratic pump response.

- Slowly close the load valve and watch the pressure and flow readings as the valve closes, then open the valve immediately.
- If the pressure rises rapidly or appears uncontrolled, open the load valve immediately.
- If the response was erratic, replace the PRV or pump, as required. If the response was smooth and controlled, go to the next substep.

6.2 Check the pump relief pressure.

- Slowly close the load valve. When the valve is completely closed, read the pressure gauge, then open the valve.
- If the pump relief pressure does not exceed the relief pressure in **Table 2** or **Table 3**, refer to the pump manufacturer's service literature to verify the exact relief pressure for the pump.
- If the pump relief pressure does not exceed the relief pressure in **Table 2**, **Table 3**, or the pump manufacturer's specifications, replace the PRV or pump, as required.
- If the pump relief pressure exceeds the relief pressure in **Table 2** or **Table 3**, it is acceptable. Go to the next substep.

6.3 Test the pump relief valve reaction at idle.

- Run the engine at idle and note the flow rate with the load valve open.

Troubleshooting Procedures

<table>
<tr><th colspan="5">Minimum Measured Pump Flow and Relief Pressure at Engine Idle</th></tr>
<tr><th>Power Steering Gear</th><th>Flow at 1500 rpm, No Load: gpm (L/min)</th><th>Flow at 1000 psi (6900 kPa): gpm (L/min)</th><th>Flow at 1800 psi (12 400 kPa): gpm (L/min)</th><th>Typical Relief Pressure: psi (kPa)</th></tr>
<tr><td>Sheppard M100</td><td>3.7 (14.0)</td><td>2.8 (10.6)</td><td>2.3 (8.7)</td><td rowspan="9">2175 ± 100
(15 000 ± 700)*</td></tr>
<tr><td>TRW TAS40</td><td rowspan="4">3.7 (14.0)</td><td>2.1 (7.9)[†]</td><td>1.6 (6.1)</td></tr>
<tr><td>TRW TAS55</td><td>2.4 (9.1)[†]</td><td>1.9 (7.2)</td></tr>
<tr><td>TRW TAS65</td><td>2.8 (10.6)[†]</td><td>2.3 (8.7)</td></tr>
<tr><td>TRW TAS85</td><td>3.3 (12.5)</td><td>2.8 (10.6)</td></tr>
<tr><td>TRW TAS65 With C28 or C32 Linear Cylinder</td><td rowspan="4">5.8 (22.0)</td><td rowspan="2">4.9 (18.5)</td><td rowspan="2">4.4 (16.7)</td></tr>
<tr><td>TRW TAS65 With RCS65</td></tr>
<tr><td>TRW TAS85 With C28 or C32 Linear Cylinder</td><td rowspan="2">5.4 (20.4)[†]</td><td rowspan="2">4.9 (18.5)</td></tr>
<tr><td>TRW TAS85 With RCS65</td></tr>
<tr><td>ThyssenKrupp LZS5 Rack and Pinion</td><td>3.7 (14.0)</td><td>3.3 (12.5)</td><td>2.8 (10.6)</td><td>2300 ± 116
(15 500 ± 800)</td></tr>
</table>

* On vehicles with TRW TAS steering gears and hydraulic brakes, typical relief pressure is 2375 ± 100 psi (16 375 ± 690 kPa).

[†] Approximate value based on flow at 1800 psi (12 400 kPa).

Table 2, Minimum Measured Pump Flow and Relief Pressure at Engine Idle

<table>
<tr><th colspan="5">Minimum Measured Pump Flow and Relief Pressure for High-Pressure Gears at Engine Idle</th></tr>
<tr><th>Power Steering Gear</th><th>Flow at 1500 rpm, No Load: gpm (L/min)</th><th>Flow at 1000 psi (6900 kPa): gpm (L/min)</th><th>Flow at 2300 psi (15 860 kPa): gpm (L/min)</th><th>Typical Relief Pressure: psi (kPa)</th></tr>
<tr><td>Sheppard HD94</td><td rowspan="3">3.7 (14.0)</td><td>2.6 (9.8)</td><td>1.8 (6.8)</td><td rowspan="5">2683 ± 100
(18 500 ± 700)</td></tr>
<tr><td>TRW THP45</td><td>2.2 (8.3)</td><td>1.4 (5.3)</td></tr>
<tr><td>TRW THP60 or PCF60</td><td>2.6 (9.8)</td><td>1.8 (6.8)</td></tr>
<tr><td>TRW THP60 With Linear Cylinder</td><td rowspan="2">5.8 (22.0)</td><td rowspan="2">4.1 (15.5)</td><td rowspan="2">3.3 (12.5)</td></tr>
<tr><td>TRW THP60 With RCH45</td></tr>
</table>

Table 3, Minimum Measured Pump Flow and Relief Pressure for High-Pressure Gears at Engine Idle

- Close the load valve until the pump relief pressure is reached. Smoothly and quickly open the load valve and note the flow rate. Repeat this action three times. The flow rate should return to the flow rate first noted with the load valve open.
- If the flow rate does not return smoothly and quickly, the pump relief valve is not working correctly. Replace the replace the PRV or pump, as required.
- If the flow rate returns smoothly and quickly, the pump relief valve is acceptable. Go to the next substep.

6.4 Test the pump relief valve reaction at 1500 rpm.

- Run the engine at 1500 rpm and note the flow rate with the load valve open.
- Close the load valve until the pump relief pressure is reached. Smoothly and quickly open the load valve and note the flow rate. Repeat this ac-

tion three times. The flow rate should return to the flow rate first noted with the load valve open.

- If the flow rate does not return smoothly and quickly, replace the PRV or pump, as required.
- If the flow rate returns smoothly and quickly, the pump relief valve is acceptable. Go to the next substep.

6.5 Test the flow of the pump at idle with a load applied.

For vehicles with low-pressure steering gears, run the engine at idle and slowly close the load valve until the pressure gauge reads 1000 psi (6900 kPa). Read the flow rate on the gauge, then set the pressure to 1800 psi (12 400 kPa). Read the flow gauge, then open the load valve. Compare the values to those in **Table 2**.

For vehicles with high-pressure steering gears, use 1000 psi (6900 kPa) and 2300 psi (15 860 kPa) as the test load pressures. See **Table 3** for minimum flow rate.

6.6 Test the maximum flow of the pump with no load applied.

- Run the engine at 1500 rpm, make sure the load valve is completely open, and read the flow gauge.
- If the flow rate is below the minimum indicated in **Table 2** or **Table 3**, replace the PRV or pump, as required.
- If the flow rate is above 5.5 gpm (20.8 L/min) on a vehicle with a single steering gear, or 7.7 gpm (28.8 L/min) on a vehicle with an assist cylinder installed, replace the pump.

7. Test the steering gear internal leakage.

Select TRW integral steering gears and all ThyssenKrupp rack and pinion steering gears are equipped with an internal PRV that significantly limits maximum supply pressure to protect the steering gear. These gears, unlike gears on vehicles fitted with hydraulic brake boosters, cannot be tested for internal leakage by plugging the internal PRV in the gear. The pump output must be limited to prevent excessive pressure from damaging the gear, and the internal PRV passage must be blocked to direct oil flow through the gear.

Use PartsPro® for the specific VIN to determine if the steering gear is equipped with an internal PRV, which will be listed as a serviceable part under module 536.

If a TRW steering gear has an internal PRV but no hydraulic brake booster, see the following heading, **Internal Leakage Test Setup, TRW Steering Gears With an Internal PRV**, for instructions on setting up the necessary test components before proceeding with the following substeps.

ThyssenKrupp rack and pinion steering gears are also equipped with an internal PRV, but cannot be tested for internal leakage.

IMPORTANT: Make sure the fluid temperature is approximately 180°F (82°C) and the vehicle is stationary with the front wheels pointing forward.

7.1 Run the engine at idle with the load valve open.

WARNING

Keep fingers clear of the stop bolt and spacer block during the following test. Make sure that the spacer block contacts the axle stop squarely. Contact that is not square could break the stop bolts or eject the spacer block, which could cause serious personal injury.

7.2 Place an unhardened steel spacer, 1-inch (25-mm) thick, between the axle and the stop bolt on one side of the axle.

The spacer should have an extension or handle long enough to keep fingers clear of the axle stop area. A brazing rod or welding rod works well for this purpose.

NOTICE

While running the following test, do not hold the steering wheel in the full-turn position for more than five seconds. Doing so could damage the pump.

Troubleshooting Procedures

7.3 Have someone turn the steering wheel, applying enough force to completely close the rotary valve.

Complete closure of the rotary valve requires approximately 20 lbf (27 N) pull on the steering wheel, and will be indicated by a pressure reading nearly equal to the system relief pressure (tested in substep 6.2).

7.4 Hold the steering wheel in the full-turn position. Note the steering gear internal leakage on the PSSA.

7.5 Repeat the previous substeps for the opposite turn.

The maximum permissible internal leakage for a single gear is 1.0 gpm (3.8 L/min). If leakage is greater in either turning direction, replace the steering gear components as needed.

For systems with two or more steering gears and/or linear cylinders, the total acceptable internal leakage is 1.0 gpm (3.8 L/min) for each steering gear/ram in the system. Maximum internal leakage on a dual-gear system is 2.0 gpm (7.6 L/min). If the leakage is more than 2.0 gpm (7.6 L/min) on a dual-gear system, isolate the auxiliary cylinder from the system using the substeps that follow.

7.6 Disconnect the auxiliary cylinder hydraulic lines at the main gear auxiliary ports.

7.7 Plug the main steering gear ports with suitable steel or high-pressure plugs or caps.

7.8 Repeat the internal leakage test.

If the internal leakage is less than 1 gpm (3.8 L/min), repair or replace the auxiliary gear or linear cylinder. If the internal leakage is greater than 1 gpm (3.8 L/min), repair or replace the main gear.

8. Check the steering gear poppet relief valve and stop bolt adjustment.

NOTE: Poppets limit the steering assist when the front wheels approach the stop bolts. Improper adjustment can apply excessive force to the steering linkage, or cause loss of assist, as the steering wheel approaches either full-left or full-right turn.

8.1 Check the steering system for stop bolt adjustment.

Make sure the stop bolt settings limit the steering travel so there is ½-inch (13-mm) clearance from all stationary components, and 3/4-inch (19-mm) clearance from all moving components.

8.2 Make sure the pitman arm is situated on the steering gear sector shaft correctly. Check that the pitman arm and sector shaft timing marks are aligned.

NOTICE

If power steering pump relief pressure is reached while the steering wheel is at full lock, release the steering wheel from this position. Do not allow the pump relief pressure to be maintained for longer than five seconds or damage to the pump may result.

8.3 Check the poppet relief pressure.

- Install the PSSA between the steering pump and the steering gear. See the following heading, **Power Steering System Analyzer Setup**, for instructions on PSSA installation.
- Run the engine at idle with the load valve open. Turn the steering wheel to either full-lock position. Note the pressure gauge reading, then repeat for the opposite turn.
- The pressure should drop slightly before the stop bolts are contacted. If the pressure increases (from contact with the stop bolts), the poppets must be manually reset.

  If the pressure is relieved and assist is lost when the wheel is too far from the axle stop bolts, refer to the applicable section in this manual for gear-specific information.
- After poppet replacement or adjustment, test again for correct poppet relief function and record the new pressure.

8.4 Check for normal hissing sound at full turn.

NOTE: Noise from the power steering system does not necessarily mean there is a problem. Some noises are normal and are the result of proper operation.

See **Table 4** for possible causes and remedies for common noises associated with the power steering system and power steering pump.

8.5 Check for abnormal power steering noise.

Listen for a hissing sound at less than full turn. If a hissing sound is heard, check the steering gear poppet and the axle stop adjustment.

NOTICE

If the temperature exceeds 250°F (121°C), damage to hoses, seals, and other components may result if the vehicle continues to operate at excessive steering system temperatures. If this temperature is exceeded, stop the test and record the last noted temperature on STI-492.

9. Test the system operating temperature.

- Run the engine at governed speed.
- Observe the power steering fluid temperature until it stabilizes.
- Record the power steering fluid temperature in 10-minute intervals until 40 minutes have passed.
- If the temperature does not exceed 250°F (121°C) during the test, excessive heat due to system components is probably not the cause of the complaint. The system may still experience overheating due to driving and load conditions.

  If the temperature exceeds 250°F (121°C), excessive steering system back pressure or excessive pump flow may be the cause of the high temperature problem. If system back pressure or restriction values found in substeps 5.3 and 5.4 above were close to the maximum allowable, complete step 5 again. If steering pump flow and relief pressures found in step 6 above were close to the maximum allowable, complete step 6 again.
- If excessive heat continues to be a problem, a cooler may need to be added to the system.

Power Steering System Noise	
Noise	**Remedy**
Growling or other abnormal steering noise	Check the fluid level. Check for air bubbles and foam. Check for hose and fitting leaks. If there is air in the fluid, check for inlet tube and hose leaks. Correct all leaks.
A change from the usual pump sound	Check the steering fluid reservoir for air bubbles and foam. If there is air in the fluid, check for inlet tube and hose leaks. Correct all leaks.
Clicking noise during a turn	Check for loose steering components. Tighten any loose steering components. Check the front suspension for insufficient spring pin shims. Add front spring pin shims if needed.
Hissing when the steering wheel is at or near full turn	This is normal; no action is needed.
Steering Pump intake line is plugged	Drain the system. Clear the intake line if needed. Fill the system.
Air leak at the pump or reservoir connections, fittings, or shaft seal	Check all the connections by pouring power steering fluid over them, and listening for a reduction in sound. Tighten all connections as needed.
Pump input shaft is misaligned	Replace the pump.

Table 4, Power Steering System Noise

Troubleshooting Procedures

Power Steering System Analyzer Setup

The hydraulic power steering system is tested with a Power Steering System Analyzer (PSSA), and with the hydraulic fluid at operating temperature. The PSSA and adaptor kit are available from SPX Kent-Moore.

A PSSA is a combination of a flow meter, a shutoff valve, and a high-pressure gauge. See **Fig. 3**. The PSSA will allow you to measure flow and pressure, and provide a load on the pump in the hydraulic lines of the steering system.

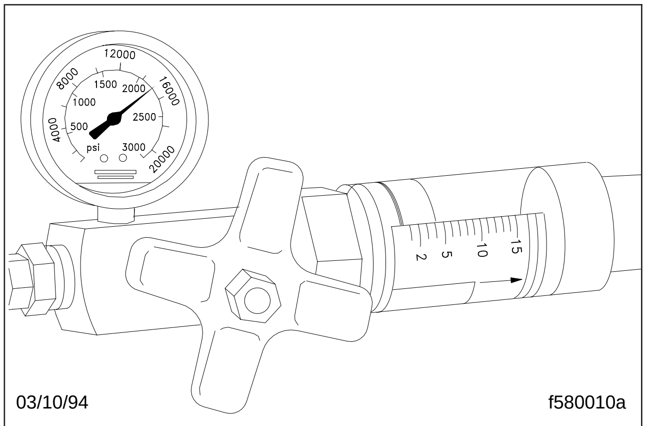


Fig. 3, Power Steering System Analyzer

1. Install a PSSA between the pump high-pressure line and the steering gear.
2. Fill and bleed the steering system as needed.

NOTICE

Do not leave the load valve fully closed for longer than five seconds. Doing so could damage the power steering system.

3. Run the engine at idle.
4. Partially close the load valve on the PSSA until the pressure gauge reads 1000 psi (6895 kPa).
5. Open the valve when the fluid temperature reaches about 180°F (82°C).

Internal Leakage Test Setup, TRW Steering Gears With an Internal PRV

Select TRW steering gears are equipped with an internal PRV that limits maximum supply pressure to protect the steering gear. These gears cannot be tested for internal leakage using the standard procedure. The pump output must be limited to prevent excessive pressure from damaging the gear, and the internal PRV passage must be blocked to direct oil flow through the gear.

Use PartsPro® to determine if a specific TRW steering gear is equipped with an internal PRV, which will be listed as a serviceable part under module 536.

If your TRW steering gear has an internal PRV, complete the following steps to set up the necessary internal leakage test components. See **Table 5** for a list of required leakage test components. The plumbing fittings and hose part numbers are recommended, but may be replaced with identical parts from other suppliers, if necessary.

The ThyssenKrupp rack and pinion steering gear is also equipped with an internal PRV, but cannot currently be tested for internal leakage.

IMPORTANT: The front wheels must be raised or on turnplates during this procedure.

1. Turn the engine off. Remove the relief valve cap, O-ring, and relief valve from the steering gear. See **Fig. 4**.
2. Install the relief valve plug, J-37130, in the internal PRV hole. Install the relief valve cap and O-ring over the plug.
3. Assemble the relief valve cartridge body, relief valve, and tee fittings as shown in **Fig. 4**.
4. Install the PSSA and other test components as shown in **Fig. 4**.
5. Open the external relief valve (**Fig. 4**, Item 15) on the relief valve cartridge. Ensure the PSSA shutoff valve is fully open.
6. Raise the front wheels off the ground and turn the steering wheel to the right and left full-lock positions five times to bleed air from the system.
7. Start the engine and bleed the remaining air out of the system by continuing to turn the wheel from side to side.

NOTICE

Do not leave the PSSA shutoff valve fully closed for longer than five seconds. Doing so could damage the power steering system.

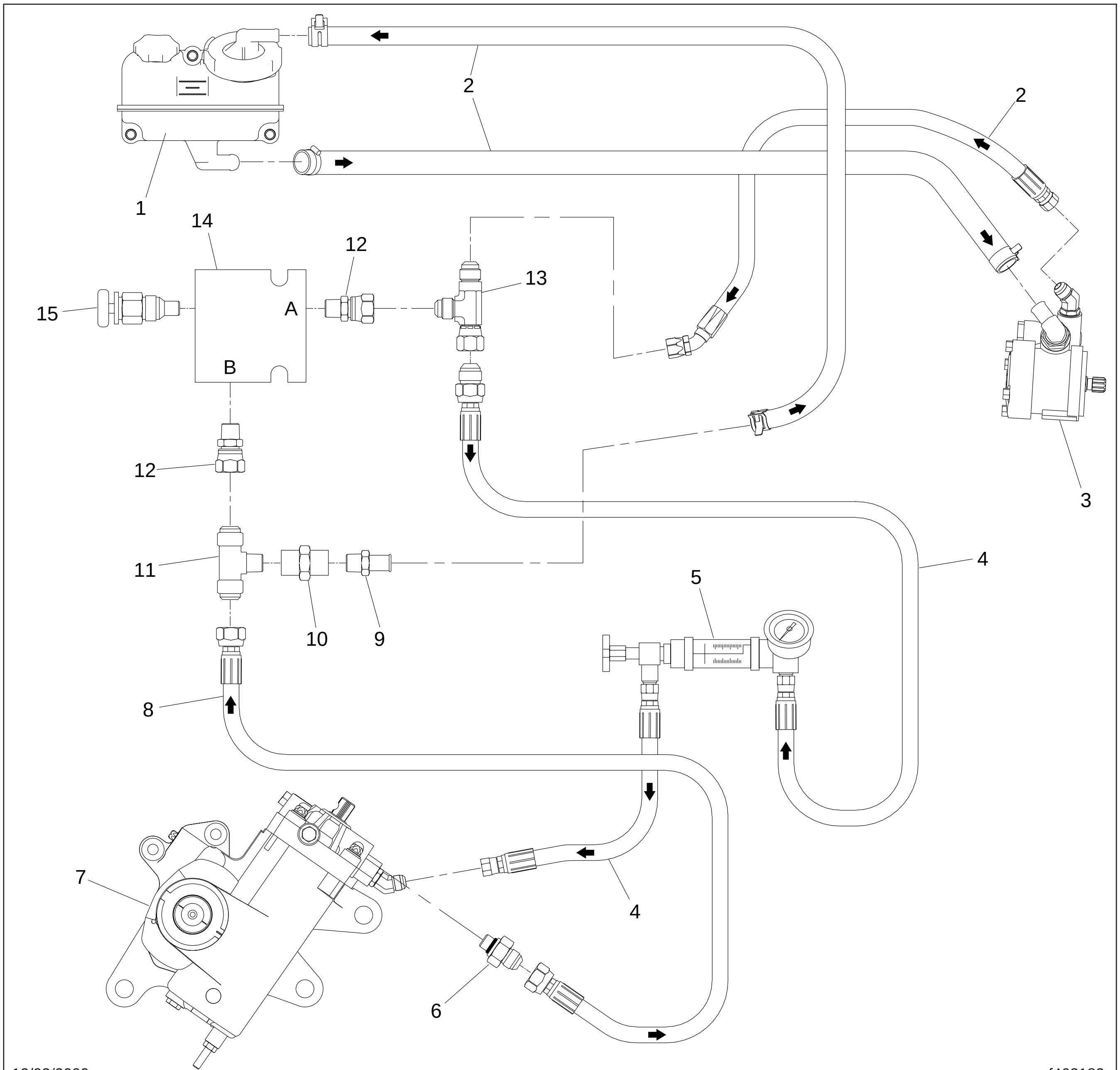
8. With the engine on, close the shutoff valve on the PSSA.
9. Set the system relief pressure by closing the external relief valve (**Fig. 4**, Item 15) until the gauge on the PSSA reaches 2,000 psi (13 790 kPa), then fully open the shutoff valve on the PSSA.
10. Continue with the steering gear internal leakage test (step 9 of the **Troubleshooting Steps** heading above).

Internal Leakage Test Components			
Part	**Available From**	**Part Number (Vendor P/N)**	**Item #, Fig. 4**
Power Steering System Analyzer (PSSA)	SPX Kent-Moore	J-26487	5
PSSA Adaptor Kit	SPX Kent-Moore	J-28593	—
Relief Valve Plug	SPX Kent-Moore	J-37130	—
Connector, Straight Thread with O-Ring	Daimler Trucks PDC	23-11470-088	6
Power Steering Hose, 42"	Daimler Trucks PDC	14-12694-042	8
Connector, 3/8" Male NPT to 5/8" Beaded Hose Barb	Daimler Trucks PDC	23-11321-001	9
Pipe Coupling, 3/8" NPT	Parker Hannifin	PH 3/8 GG S (3/8 GG-S)	10
Tee, Male JIC with Male NPT Branch*	Parker Hannifin	PH 8STXS (8 STX-S)	11
Swivel Adaptor, 3/8" Male NPT to Female 37 degree JIC (qty 2)	Weatherhead	WH 9100X8X6 (9100x8x6)	12
Swivel Nut Run Tee	Parker Hannifin	PH 8 R6X S (8 R6X-S)	13
3/8" Female NPT Aluminum Relief Valve Threaded Cartridge Body	Parker Hannifin	B10-2-A6P (PH B102A6P)	14
Aluminum Hydraulic Threaded Cartridge Relief Valve with Knob	Parker Hannifin	PH RAH101K30 (RAH101K30)	15

* Use steel 37 degree JIC fittings only.

Table 5, Internal Leakage Test Components

Troubleshooting Procedures



A. High-Pressure Input Port

B. Low-Pressure Output Port

1. Power Steering Fluid Reservoir
2. Existing Power Steering Fluid Lines (Qty 3)
3. Power Steering Pump
4. PSSA Fluid Lines (Qty 2)
5. PSSA
6. Connector, Straight Thread with O-Ring
7. Power Steering Gear (TAS85 shown)
8. Power Steering Hose, 42"
9. Connector, Male NPT to Beaded Hose Barb
10. Pipe Coupling
11. Tee, Male JIC with Male NPT Branch
12. Swivel Adaptor (Qty 2)
13. Swivel Nut Run Tee
14. Relief Valve Threaded Cartridge Body
15. External Relief Valve, Threaded Cartridge Type

Fig. 4, Internal Leakage Test Component Installation

General Information

The fuel system delivers fuel from the fuel tanks to the engine. It consists of the engine fuel system components, the fuel tank(s) and tank mounting components, the fuel lines, and (if so equipped) the shutoff valve. See **Fig. 1** for a schematic of the fuel system.

The engine fuel system components include fuel filters, injectors, fuel transfer pumps, and a fuel governor. For service and maintenance procedures, refer to the applicable engine manufacturer's service and maintenance manuals.

The fuel tanks are held in place by metal bands and brackets that transfer the load to the vehicle frame. On some installations, cab-access and chassis-access step assemblies attach to the fuel tank mountings.

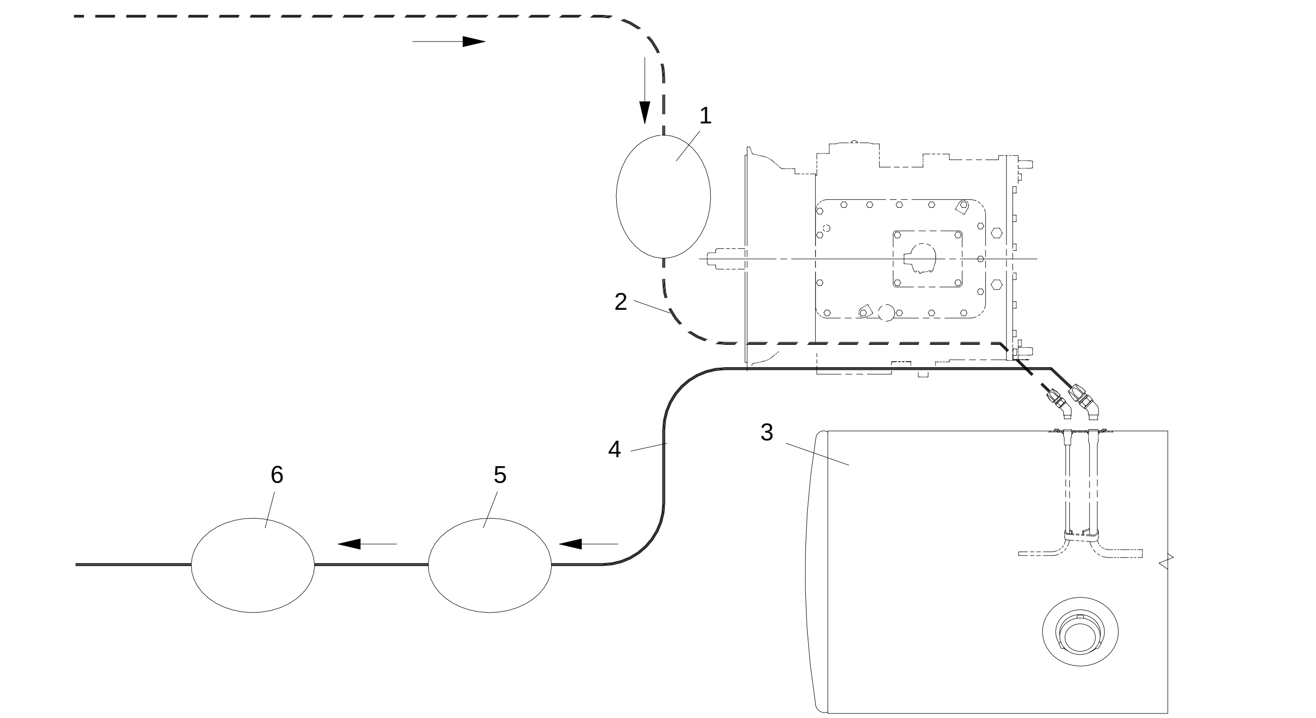
To ensure sufficient clearance between the fuel tanks and moving parts of the front suspension, fuel tank spacers are sometimes required on vehicles with flat leaf front suspensions or greaseable spring pins. On standard installations with frame outserts, spacers are not required.

Fuel suction and return lines made of nylon, or reinforced braided fabric, bring fuel from the tank to the engine, and return surplus fuel from the engine to the tank. A single right-side rectangular tank holding 30 gallons is standard. Tanks holding 40, 50, 60, 80 and 100 gallons are also available in both single- and dual-tank systems.

An EquiFlo® dual suction/dual return fuel system is standard on all vehicles with dual-tank systems. This system provides equal fuel levels in both fuel tanks without the need of a low crossover line.

Standard equipment also includes a fuel level sensor (in the primary tank in a dual-tank system), and an electronic fuel level gauge in the cab instrument cluster.

General Information



1. Fuel Cooler
2. Return Line
3. Fuel Tank
4. Suction Line
5. Fuel Heater
6. Fuel/Water Separator

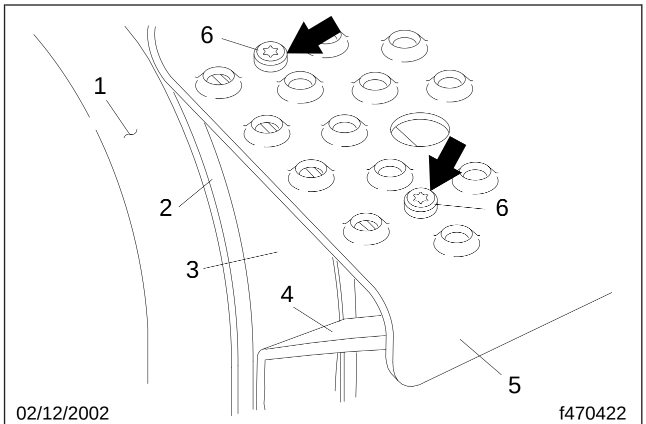
Fig. 1, Fuel System Schematic

Tank-Mounted Step Assembly Removal and Installation

Removal

NOTE: The procedure below describes a two-step installation. To remove a single step, follow the procedure for the bottom step of the two-step installation.

1. Remove the torx-head screws and washers that attach the top step to the braces welded to the fuel tank bands. See **Fig. 1**.



1. Fuel Tank
2. Band Isolator
3. Fuel Tank Band
4. Welded Brace (on band)
5. Top Step
6. Machine Screw, 1/4–20

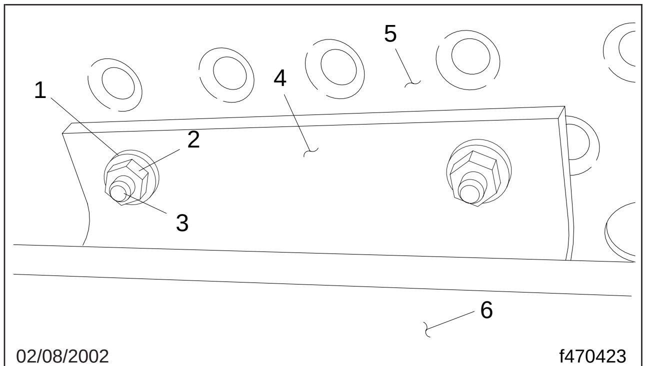
Fig. 1, Top Step Removal and Installation

IMPORTANT: Removing the bottom step from the riser is necessary only when the step itself needs replacement. If replacing the fuel tank, remove the step and risers as an assembly.

2. Remove the torx-head machine screws, locknuts and washers that attach the bottom step to the risers. See **Fig. 2**.
3. Remove the 3/8–16 mounting bolts, locknuts and washers that attach a step riser to each tank bracket. See **Fig. 3**.
4. Remove the step from the vehicle.

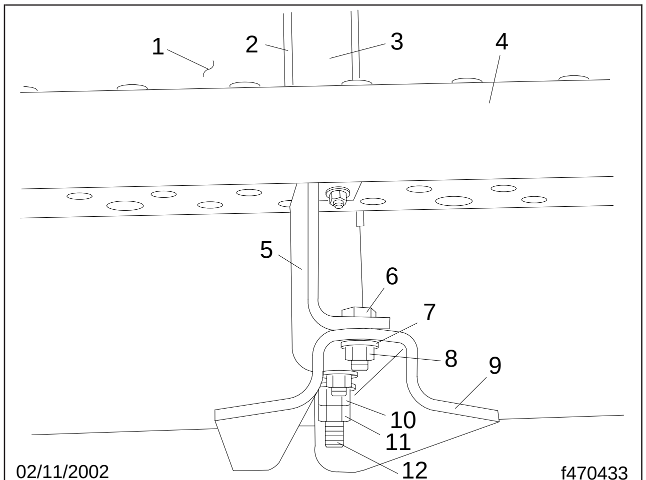
Installation

NOTE: The procedure below describes a two-step installation. To install a single step, follow



1. Washer
2. Locknut, 1/4–20
3. Machine Screw, 1/4–20
4. Step Riser
5. Bottom Step
6. Tank Bracket

Fig. 2, Bottom Step Removal and Installation



1. Fuel Tank
2. Band Isolator
3. Fuel Tank Band
4. Bottom Step
5. Step Riser
6. Riser Mounting Bolt, 3/8–16
7. Washer
8. Riser Locknut, 3/8–16
9. Tank Bracket
10. Mounting Nut, 1/2–13
11. Jam Nut, 1/2–13
12. T-Bolt

Fig. 3, Step Riser Removal and Installation

Tank-Mounted Step Assembly Removal and Installation

the procedure for the bottom step of the two-step installation.

1. Install a step riser on each tank bracket.
   1.1 Position a riser on each bracket, as shown in **Fig. 3**.
   1.2 Install the 3/8–16 mounting bolts, locknuts, and washers, as removed. Leave the fasteners finger-tight.
   1.3 When all the risers have been installed, tighten the locknuts 28 lbf·ft (38 N·m).
2. Install the bottom step on the risers, if removed.
   2.1 Position the bottom step on the risers, as shown in **Fig. 2**.
   2.2 Install the 1/4–20 machine screws, locknuts, and washers on the step, as removed. Leave the fasteners loose.
3. Install the top step on the fuel tank.
   3.1 Position the top step on the braces welded to the fuel tank bands, as shown in **Fig. 1**.
   3.2 Install the 1/4–20 machine screws, locknuts, and washers on the step, as removed. Leave the fasteners loose.
4. Tighten the step locknuts 72 lbf·in (800 N·cm).

Removal

WARNING

Damaged fuel tanks must be replaced. A repaired fuel tank may not meet U.S. Federal strength, leakage, and venting standards required for all fuel tanks. A repaired fuel tank may be more likely to spill fuel or be ruptured in a vehicle accident, which could lead to personal injury or property damage.

If a damaged tank is found, use the following procedure:

1. Park the vehicle on level ground. Apply the parking brakes and chock all the tires.
2. Remove the cab-access step(s). For instructions, see **Subject 100**.

WARNING

Do not drain fuel near, or allow fuel vapor near, open flame or intense heat. Doing so is a dangerous practice, and creates a severe fire hazard. This could lead to personal injury, or property damage.

3. Remove the fuel from the tank. See **Fig. 1** for location of the fuel drain plug.

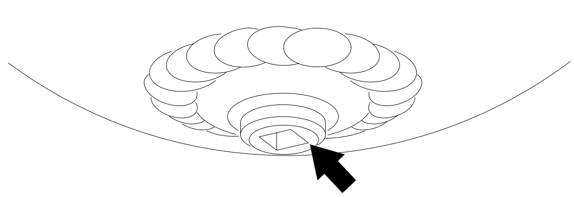


Fig. 1, Fuel Drain Plug

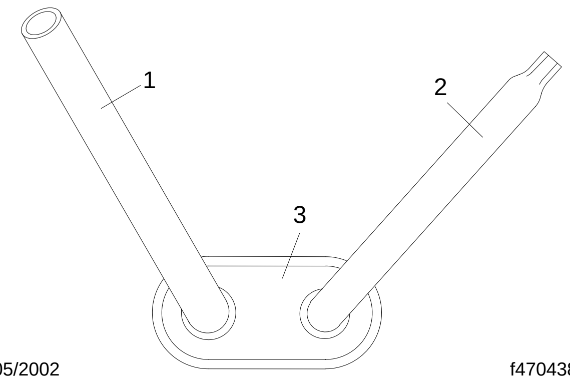
3.1 Place a suitable container under the fuel tank.

3.2 On a dual-tank installation, close the fuel shutoff valve (if equipped) located on the primary fuel tank.

3.3 Remove the drain plug.

3.4 Protect the fuel from contaminants. Store it in a clean container for later re-use.

4. Disconnect the fuel return and suction lines from the tank. Cap the lines to prevent fuel spillage. See **Fig. 2**.



1. Fuel Suction Line
2. Fuel Return Line
3. Mounting Plate

Fig. 2, Fuel Lines

5. Disconnect the electrical connector from the fuel level sensor harness and remove the cushioned clamp from the flange of the fuel level sensor. See **Fig. 3**.
6. Remove the fuel tank bands and isolators. See **Fig. 4**. For detailed procedures, see **Subject 120**.

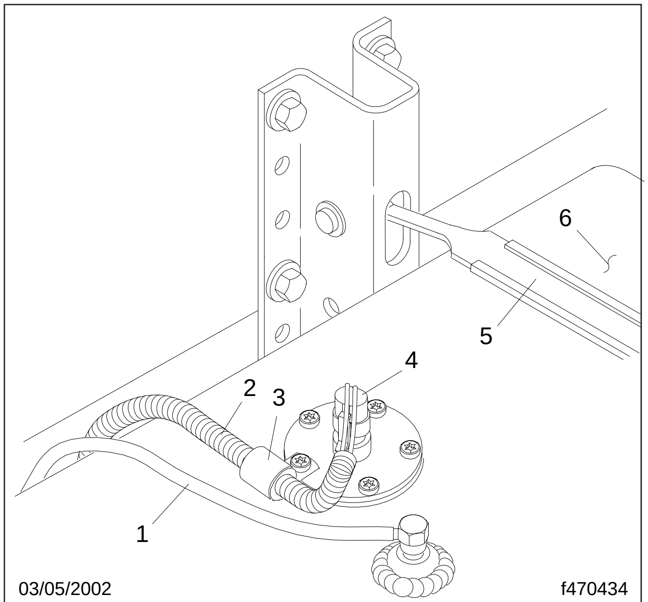
6.1 Remove the nuts and washers from the T-bolt at the lower (outboard) end of each tank bracket.

6.2 Remove the cotter pins and clevis pin from the upper (inboard) end of each tank bracket.

6.3 Remove the band and isolators from each tank bracket.

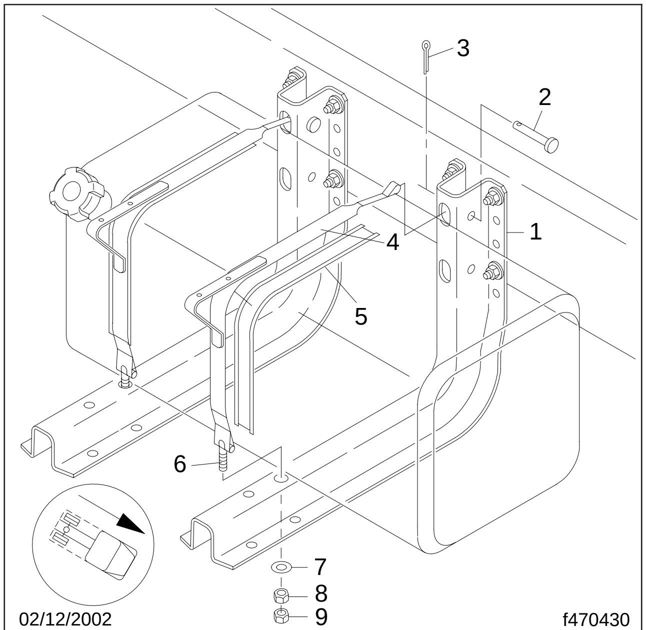
7. Using a fork lift, remove the fuel tank. Remove the tank bracket isolator from the fuel tank, if it adheres to the tank.
8. Inspect the bands, isolators, and brackets for wear and damage. Replace worn or damaged parts with new parts.

Fuel Tank Removal and Installation



1. Fuel Vent Line
2. Fuel Level Sensor Wiring Harness
3. Cushioned Clamp
4. Electrical Connector
5. Fuel Tank Band
6. Fuel Tank

Fig. 3, Electrical Connector, Fuel Level Sensor



1. Tank Bracket
2. Clevis Pin
3. Cotter Pin
4. Fuel Tank Band
5. Band Isolator
6. T-Bolt
7. Washer
8. Mounting Nut, 1/2–13
9. Jam Nut, 1/2–13

Fig. 4, Fuel Tank

WARNING

Failure to replace worn or damaged parts could result in loss of a fuel tank and spilling of fuel, which could cause property damage or personal injury.

9. When replacing a fuel tank, remove all parts necessary to install the new fuel tank. Inspect the parts, and replace them as needed.

   9.1 Remove and clean the pipe plugs and fittings for the fuel return and suction lines. Transfer them to the new fuel tank.

   9.2 Remove and clean the fuel vent line, pipe plug, and fitting. Transfer it as a unit to the new fuel tank.

   9.3 If a single or primary fuel tank is being replaced, transfer the fuel level sensor and gasket to the new fuel tank.

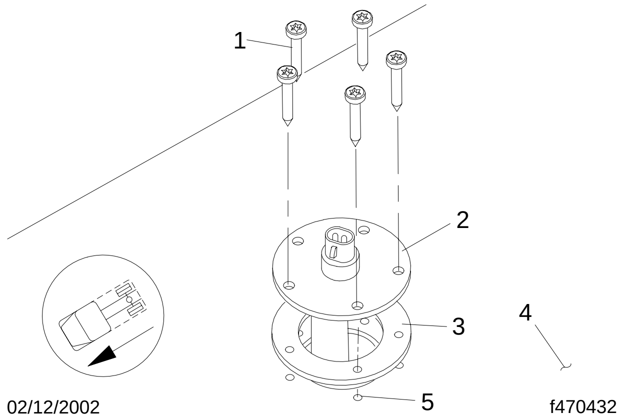
Installation

1. Install all necessary components on the new fuel tank before installation of the tank on the vehicle. See **Fig. 5** for fuel level sensor installation.

   1.1 If removed, install the fuel level sensor and gasket in the fuel tank. Install the self-tapping screws until contact is made with the sensor unit. Do not tighten the screws yet.

   1.2 Install all removed pipe plugs and fittings. Coat all tapered pipe plug and fitting threads with Loctite® 592, or an equivalent sealer. Install the vent line as a unit along with its pipe plug and fitting.

2. Make sure the tank bracket isolator is correctly positioned on the tank bracket.
3. Using a fork lift, or other approved lifting device, and place the fuel tank in its approximate installed position. Make sure the fuel filler neck is outboard.



1. Self-Tapping Screw, 10–24
2. Fuel Level Sensor
3. Gasket
4. Fuel Tank
5. Mounting Hole in Tank

Fig. 5, Fuel Level Sensor

On 106-inch cabs only, move the tank fore or aft until the distance from the front of the tank to the centerline of the forward tank bracket is 9.84 ± .20 inches (250 ± 5 mm).

4. Install the fuel tank bands and isolators.

 4.1 Position the closed (non-slotted) loop of a fuel tank band through the slot in the upper (inboard) end of each tank bracket.

 4.2 Install the clevis pin through the upper (inboard) end of each tank bracket and the loop of the fuel tank band. Install new cotter pins and bend back the ends to lock in the clevis pins.

CAUTION

Do not overtighten the fuel tank bands. To do so could damage the fuel tanks.

 4.3 Insert the T-bolt at the lower (slotted) end of each band into the tank bracket.

 4.4 Install a washer and two nuts on each T-bolt. Tighten the mounting nuts 15 lbf·ft (20 N·m).

 4.5 While holding the first nut stationary with a wrench, tighten each jam nut an additional 15 lbf·ft (20 N·m).

5. Attach the electrical connector to the fuel level sensor wiring harness. Attach the cushioned clamp to the flange of the sensor unit. Using a star pattern to distribute the torque evenly around the sensor unit, tighten the screws 15 to 30 lbf·in (160 to 340 N·cm).

6. Make certain the fuel lines are clean and install them on their fittings on the fuel tank. See **Subject 150** for general guidelines.

IMPORTANT: Install pipe plugs in any remaining open threaded holes. Coat all remaining tapered pipe plug and fitting threads with Loctite 592, or an equivalent sealer.

7. Install the cab-access step(s). For instructions, see **Subject 100**.

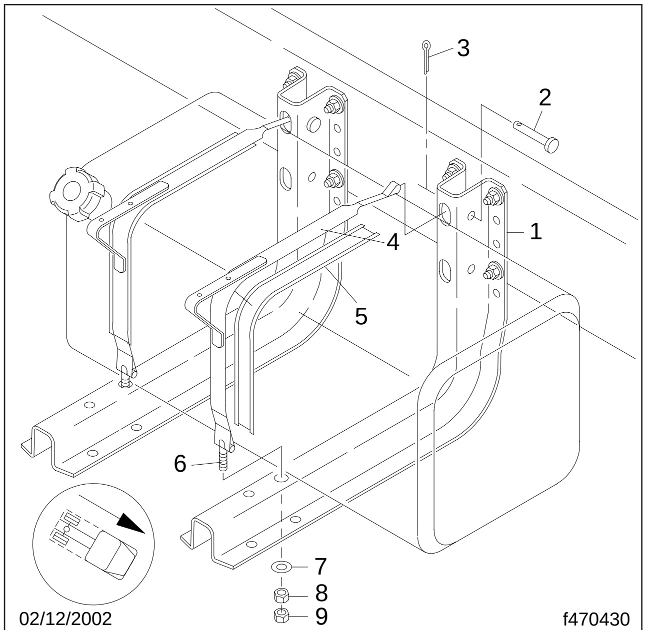
8. Add clean fuel to the fuel tank.

9. Prime the engine fuel system. For instructions, see **Subject 140**.

10. Remove the chocks from the tires.

Replacement

1. Apply the parking brakes and chock all the tires.
2. Remove the cab-access step(s). For instructions, see **Subject 100**.
3. Remove the fuel tank band and isolator. See **Fig. 1**.



1. Tank Bracket
2. Clevis
3. Cotter Pin
4. Fuel Tank Band
5. Band Isolator
6. T-Bolt
7. Washer
8. Mounting Nut, 1/2–13
9. Jam Nut, 1/2–13

Fig. 1, Fuel Tank Band Removal

3.1 Remove the two nuts and one washer from the T-bolt at the lower (outboard) end of the tank bracket.

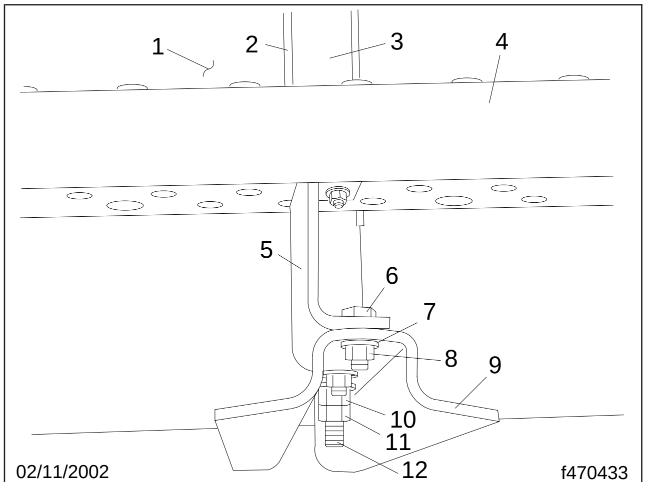
3.2 Remove the cotter pin and clevis pin from the eye at the upper (inboard) end of the tank bracket.

4. Inspect the isolator and clevis pin for wear or damage; replace if needed.

WARNING

Failure to replace worn or damaged parts could result in loss of a fuel tank and spilling of fuel, which could cause personal injury or property damage.

5. Install the isolator and the new tank band on the tank. See **Fig. 2**.



1. Fuel Tank
2. Band Isolator
3. Fuel Tank Band
4. Bottom Step
5. Step Riser
6. Riser Mounting Bolt, 3/8–16
7. Washer
8. Riser Locknut, 3/8–16
9. Tank Bracket
10. Mounting Nut, 1/2–13
11. Jam Nut, 1/2–13
12. T-Bolt

Fig. 2, Fuel Tank Band Installation

5.1 Install the clevis pin through the inboard end of the tank bracket and tank strap. Install and lock a new cotter pin in the clevis pin.

IMPORTANT: Fuel tanks can be damaged by overtightening the fuel tank straps.

5.2 Install a washer and two nuts on the tank strap T-bolt. Tighten the mounting nut 15 lbf·ft (20 N·m).

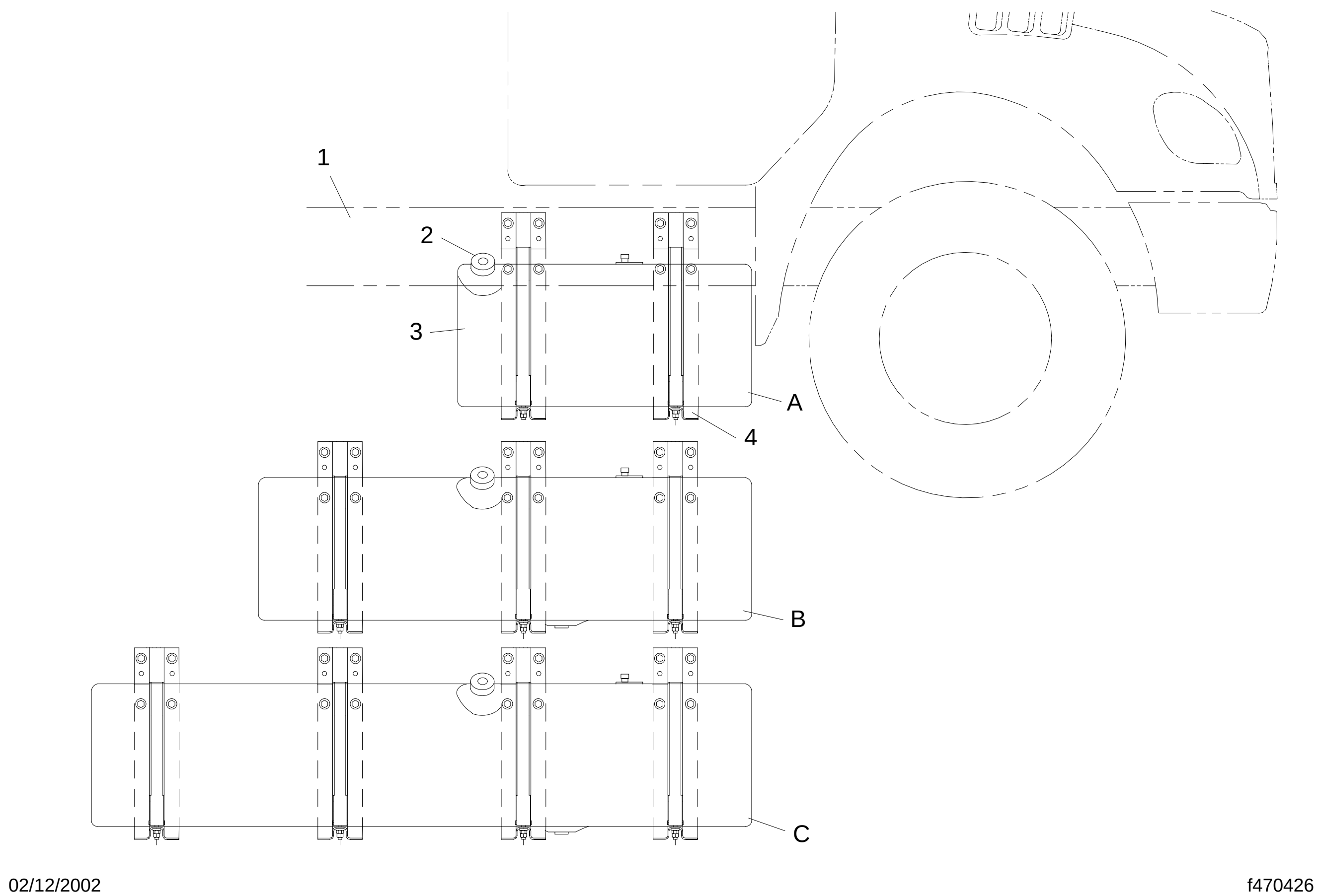
5.3 While holding the mounting nut stationary with a wrench, tighten the jam nut an additional 15 lbf·ft (20 N·m).

Fuel Tank Band Replacement

6. Install the cab-access step(s). For instructions, see **Subject 100**.
7. Remove the chocks from the tires.

Replacement

1. Remove the fuel tank. For instructions, see **Subject 110**.
2. Remove the locknut, washers, spacer (if installed), and capscrew that attach each bracket to the frame rail. See **Fig. 1** for bracket installation on different size fuel tanks and **Fig. 2** for fasteners.



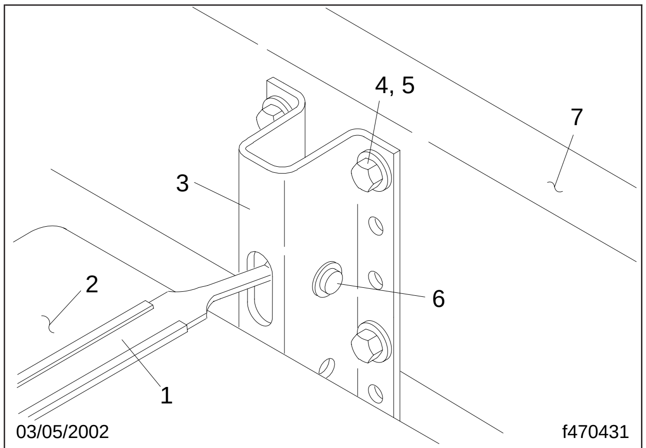
A. 30/40/50 Gallon Tanks
B. 60/80 Gallon Tanks
C. 100 Gallon Tank

1. Frame Rail
2. Filler Cap
3. Fuel Tank
4. Tank Bracket

Fig. 1, Fuel Tank Sizes

3. Remove the tank bracket from the vehicle.
4. From outside the frame rail, install the two upper capscrews and hardened washers. If so equipped, install the fuel tank bracket spacers onto the outboard ends of the capscrews. Position the new tank bracket on the capscrews, then install the two upper hardened washers and locknuts, finger-tight.
5. Install the two lower sets of fasteners. Tighten all of the 5/8–11 locknuts 136 lbf·ft (184 N·m).
6. Install the fuel tank. For instructions, see **Subject 110**.

Fuel Tank Bracket Replacement



1. Fuel Tank Band
2. Fuel Tank
3. Tank Bracket
4. Bracket Mounting Bolt, 5/8–11
5. Washer
6. Head of Clevis Pin
7. Frame Rail

Fig. 2, Fuel Tank Bracket

Priming

Before priming the system, make sure there is enough fuel in the tank(s). Don't fill them to more than 95 percent of capacity.

WARNING

Federal regulations prohibit filling a fuel tank to more than 95 percent of its capacity. A tank with air space is much less likely to rupture in an accident than one that has little or no air space. Fuel tank rupture could result in fuel spillage and a hazardous condition.

Don't crank the starter more than 30 seconds at a time during any of the following procedures; wait 2 minutes after each try to allow the starter to cool, or starter damage may occur.

1. On MBE900 engines, use the following procedure:

   1.1 Make sure that all high-pressure lines have been tightened to 18 lbf·ft (25 N·m) and all banjo bolts to 37 lbf·ft (50 N·m).

CAUTION

Correct torque on the high-pressure lines is critical. Incorrect torques could result in leaks or lack of power due to restricted fuel flow.

   1.2 If equipped with a hand pump on the fuel/water separator, work the hand pump 50 times.

   NOTE: There should be a strong resistance in the hand pump, caused by the pressure build-up within the fuel system.

   1.3 Crank the engine for 30 seconds at a time, but *no longer*. Before cranking the engine again, wait at least two minutes. The engine should start within four 30-second attempts.

   1.4 If the engine still does not start, open the high-pressure lines and bleed the air from the fuel system while cranking. Tighten the high-pressure lines and repeat the priming procedure.

2. On Caterpillar engines, if the engine is equipped with a priming pump, use it to prime the fuel transfer pump.

   2.1 Operate the priming pump plunger until there is resistance.

   2.2 Start the engine; if it doesn't start, more priming is needed. Once the engine has started, it may run rough; if so, run the engine at low idle until it runs smoothly.

3. On Caterpillar engines, if the engine isn't equipped with a priming pump, use the same procedure as for Mercedes-Benz engines.

Diesel Fuel Lines

If diesel fuel lines are worn, damaged, or deteriorated, replace them. Use the following guidelines for installing and routing them.

- Fuel lines must be free of droops, sharp bends, and kinks in the lines.
- Fuel lines must not extend below the fuel tank unless they are completely enclosed in a protective housing.
- Fuel lines must be routed in a continuous upward slope from the fuel tank to prevent high and low spots in the hoses.
- Fuel lines must be routed at least six inches (15 cm) from unshielded exhaust pipes and at least three inches (7.5 cm) from shielded exhaust pipes.
- Heat shields and/or hose insulation must be used to protect any section of fuel line that is less than six inches (15 cm) from a heat source.
- Fuel lines must be routed to allow routinely serviceable components such as dipsticks, filters, and water separators to be readily accessed without the need to disconnect the fuel lines.
- Fuel lines must be secured to prevent chafing, kinking, or other damage.
- Fuel lines must be long enough to allow movement of the parts to which they are attached.
- Coat all pipe threads (tapered threads) with Loctite® 592, or an equivalent.
- Finger-tighten pipe fittings; then tighten one and one half turns. Tighten more if necessary to seal.
- Fuel lines and fittings must be free of leaks, to prevent fuel loss or entry of air into the line, which may result in a loss of prime by the engine fuel system.
- Drains or other bottom fittings must not extend more than 3/4 inch (19 mm) below the lowest part of the fuel tank or sump.

Fuel Shutoff Valve Replacement, EPA10 Engines

Replacement

NOTE: Fuel shutoff valves are only installed on vehicles with dual tanks.

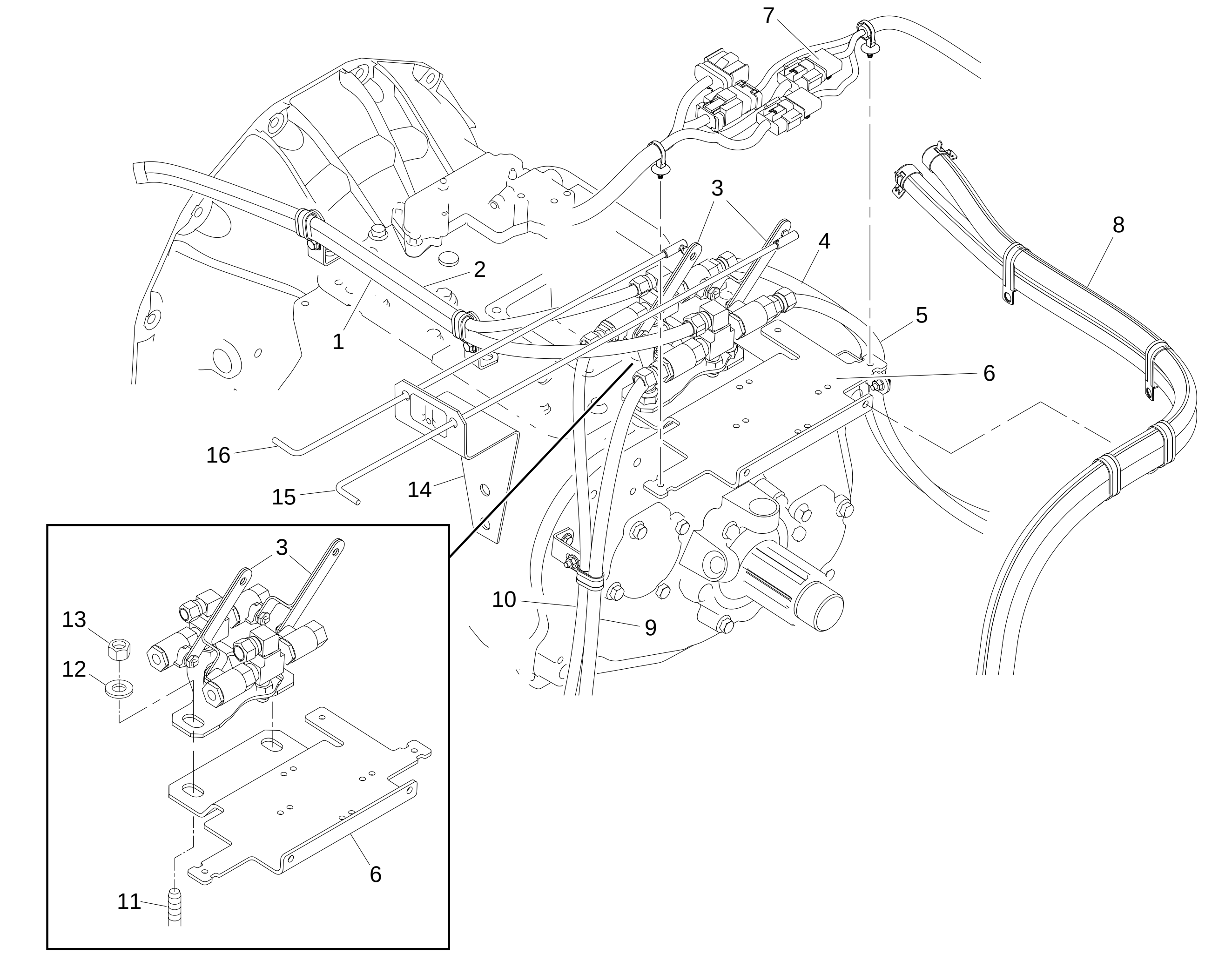
1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Put the transmission into high gear, chock the tires and open the hood.
2. Disconnect the fuel control rod(s) from the fuel shutoff valve lever(s). Swing the control rod(s) out of the way without removing them from the control rod mounting bracket. See **Fig. 1**.

WARNING

Aftertreatment device (ATD) internal temperatures can remain hot enough to cause personal injury or ignite combustible materials for hours after the engine is shut down, causing potentially serious burns or material damage. Wear appropriate protective gear when working around the ATD. Do not to let diesel from the fuel lines come into contact with the ATD.

3. Disconnect the driveline from the transmission output yoke. For instructions, see **Section 41.00, Subject 100** for uncoupling from a *half-round* end-yoke, or **Section 41.00, Subject 110** for uncoupling from a *full-round* end-yoke.
4. Disconnect the driveline midship bearing from the midship bearing bracket, and set the driveline out of the way.
5. Disconnect the aftertreatment device (ATD) wiring harnesses located on the EquiFlo bracket.
6. Disconnect the diesel exhaust fluid (DEF) coolant lines located on the EquiFlo bracket.
7. Disconnect the fuel lines from the tee fittings, then cap the lines.
8. In order to gain access to the fuel shutoff valves, it may be necessary to remove the standoff brackets that secure the DEF lines to the EquiFlo bracket, then move the lines aside. See **Fig. 1**.
9. Remove any remaining cables and brackets as needed to access the fuel shutoff valves.
10. Loosen the two jam nuts that secure the fuel shutoff valves and tee fittings to the EquiFlo bracket. Remove the tee fittings and valves as an assembly.
11. Remove the shutoff valves from the tee fittings, then install new shutoff valves.
12. Using two jam nuts, install the tee fitting and shutoff valve assembly on the EquiFlo bracket.
13. Install the fuel lines on the tee fittings and tighten the fittings.
14. If any ATD wiring harness standoff brackets were previously removed, install them on the EquiFlo bracket, then connect the wiring harnesses.
15. If any DEF line standoff brackets were previously removed, install them on the EquiFlo bracket.
16. Connect the DEF coolant lines.
17. Connect the ATD wiring harnesses.
18. Install any remaining cables and brackets that were previously removed.
19. Connect the driveline to the transmission output yoke. For instructions, see **Section 41.00, Subject 100** for coupling to a *half-round* end-yoke, or **Section 41.00, Subject 110** for coupling to a *full-round* end-yoke.
20. Connect the midship bearing to the midship bearing bracket.
21. Connect the control rod(s) to the fuel shutoff valve lever(s). Tighten the nuts 16 lbf·ft (22 N.m).
22. Start the engine and check for leaks.

Fuel Shutoff Valve Replacement, EPA10 Engines



1. Fuel Supply Line to Engine
2. Fuel Return Line from Engine
3. Fuel Shutoff Valves (qty 2)
4. Fuel Return Line to Right-Hand Fuel Tank
5. Fuel Supply Line from Right-Hand Tank
6. EquiFlo Bracket
7. ATD Wiring Harnesses
8. Coolant Lines (to and from DEF tank)
9. Fuel Supply Line from Left-Hand Tank
10. Fuel Return Line to Left-Hand Tank
11. EquiFlo Bracket Stud (qty 2)
12. Washer (qty 2)
13. Jam Nut (qty 2)
14. Control Rod Mounting Bracket
15. Right-Side Fuel Control Rod
16. Left-Side Fuel Control Rod

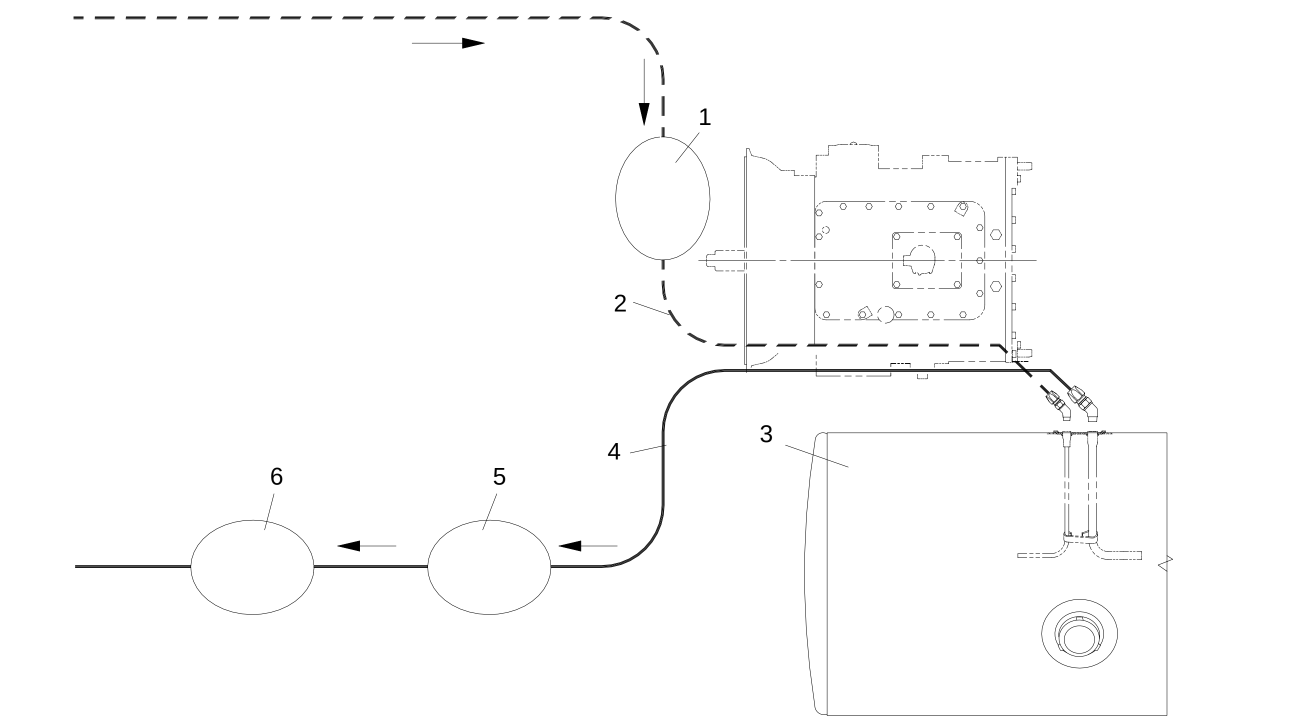
Fig. 1, Fuel Shutoff Valve Assembly, Dual-Tank Vehicle

Specifications

See **Fig. 1** for a schematic of the fuel system.

Fastener Torques			
Description	**Size**	**Grade**	**Torque**
Fuel Tank Band Mounting Nut and Jam Nut	1/2–13	B	15 lbf·ft (20 N·m)
Riser-to-Tank Bracket Locknut	3/8–16	C	28 lbf·ft (38 N·m)
Step-to-Riser Locknut	1/4–20	B	72 lbf·in (800 N·cm)
Tank Bracket Mounting Locknut	5/8–11	C	136 lbf·ft (184 N·m)

Table 1, Fastener Torques



1. Fuel Cooler
2. Return Line
3. Fuel Tank
4. Suction Line
5. Fuel Heater
6. Fuel/Water Separator

Fig. 1, Fuel System Schematic

General Description

Fuel/water separators are mounted between the fuel tank and the fuel pump. Fuel drawn to the engine travels through the fuel/water separator, which removes water and impurities. See **Fig. 1**, **Fig. 2**, or **Fig. 3** for DAVCO fuel/water separator configurations.

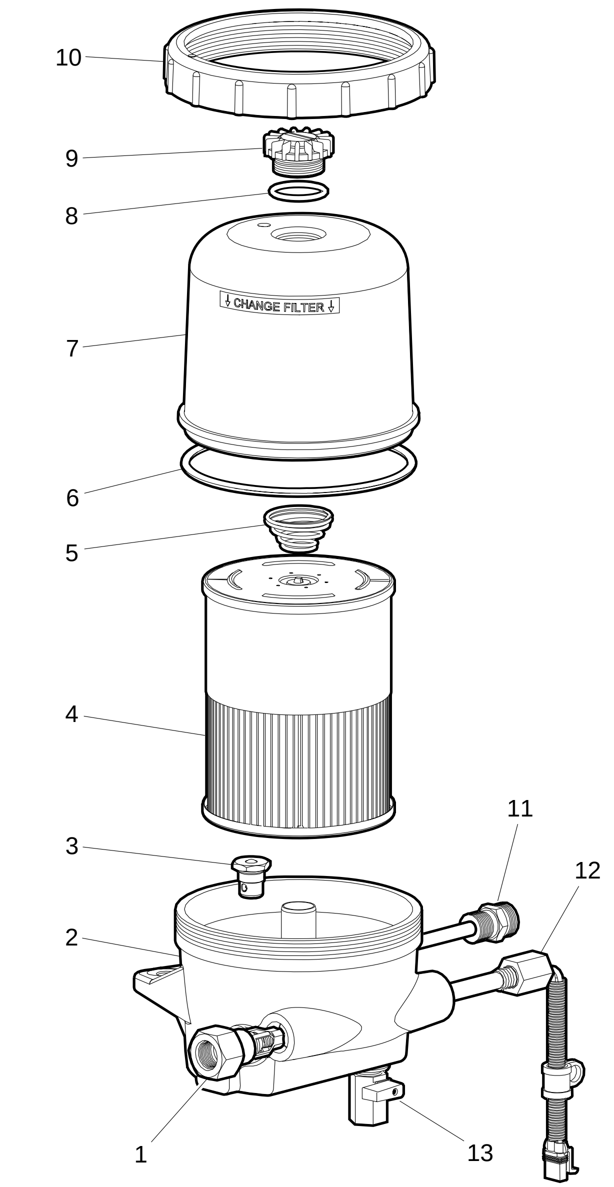
Heavier contaminants and water separate from the fuel in the lower housing of the fuel/water separator, and collect in the bottom to be drained out when the drain valve is opened. From the lower housing, the fuel level rises into the clear cover, which contains the replaceable filter element. The fuel passes through the filter element into the center of the filter, and on to the outlet port.

When the filter is new, the fuel is able to pass through the lower part of the filter element. As the element's lower portion clogs, the fuel level rises in order to pass through the filter. This process continues until the filter element is clogged all the way to the top.

For efficiency, the filter should be changed only when the fuel level has reached the top of the filter element. There is no significant restriction to fuel flow until the element is completely clogged.

DAVCO fuel/water separators come in a number of different configurations. There may be an electric heating element installed in the lower housing (**Fig. 1**, items 11 and 12) or there may be a fluid heat exchanger in the lower housing (**Fig. 2**, item 3). If there is fluid heat, the warming fluid may be fuel returning from the engine or engine coolant. **Fig. 4** shows the patterns that fuel and heating fluids follow in fluid-heated units.

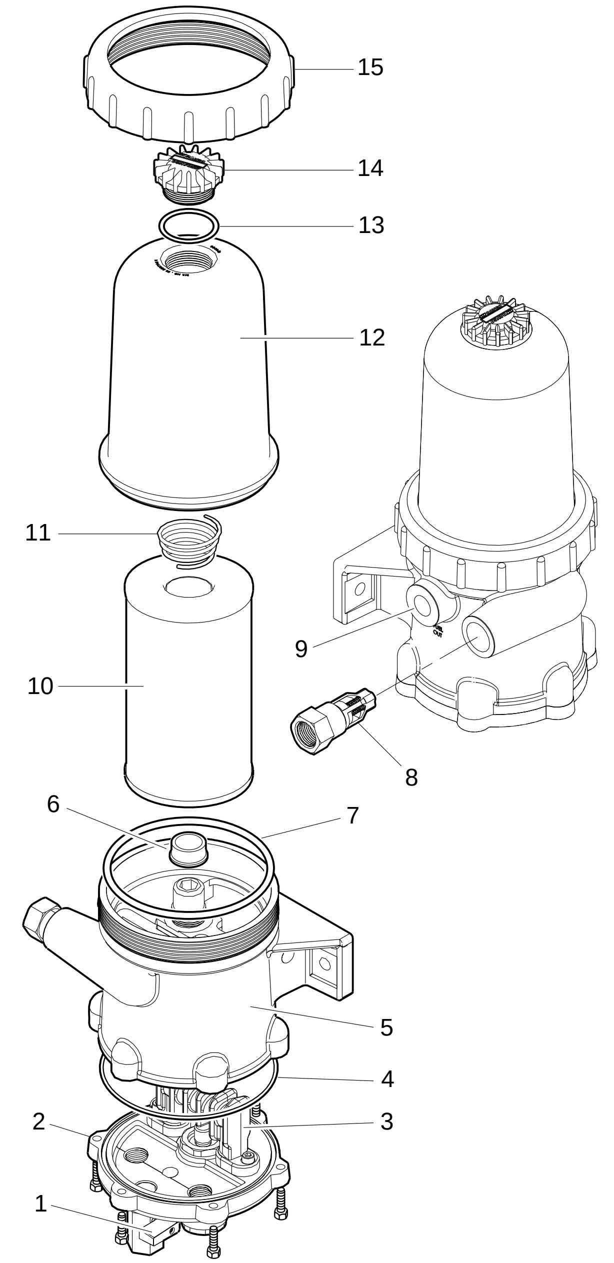
NOTE: The Daimler Trucks North America Learning Center (accessible through **www.AccessFreightliner.com**) and DAVCO (**www.DavcoTec.com**) offer excellent online resources for understanding, testing, and diagnosing fuel/water separator problems.



1. Inlet Port/Check Valve
2. Lower Housing
3. Bypass Valve
4. Filter Element
5. Spring
6. Cover O-Ring
7. Clear Cover
8. Vent Cap O-Ring
9. Vent Cap
10. Collar
11. 120VAC Pre-Heater
12. 12VDC Pre-Heater
13. Drain Valve

Fig. 1, DAVCO Fuel Pro 482

General Information



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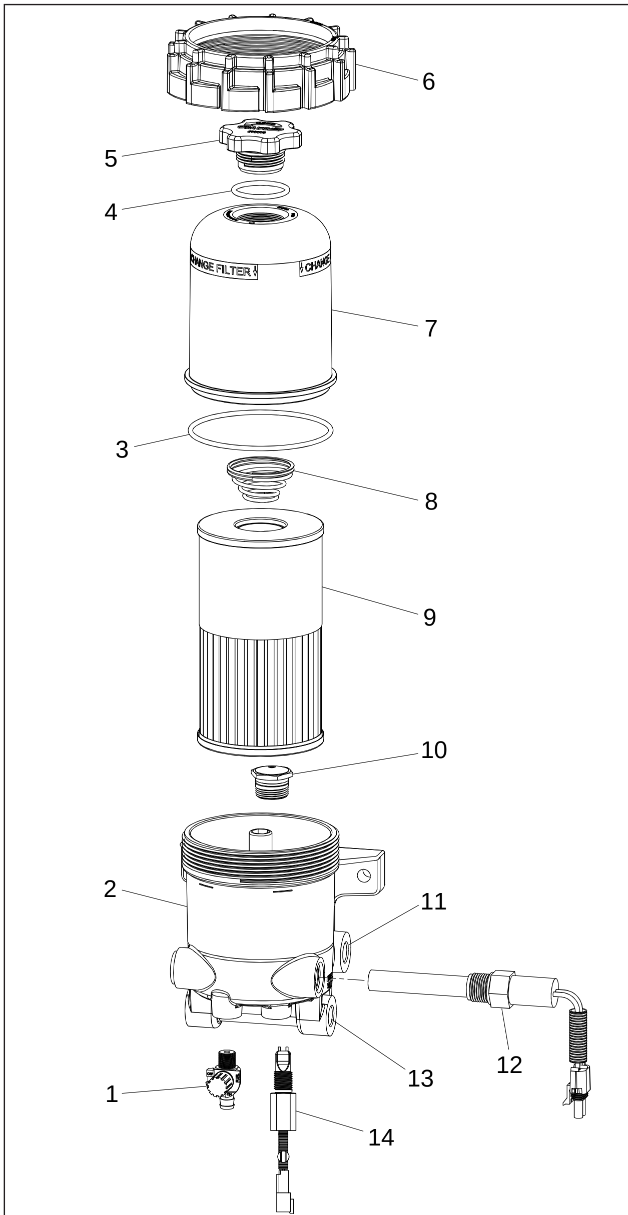
1. Drain Valve
2. Bottom Plate
3. Heat Exchanger
4. Bottom Plate O-Ring
5. Lower Housing
6. Grommet
7. Cover O-Ring
8. Inlet Port/Check Valve
9. Fuel Outlet Port
10. Filter Element
11. Spring
12. Clear Cover
13. Vent Cap O-Ring
14. Vent Cap
15. Collar

Fig. 2, DAVCO Fuel Pro 382



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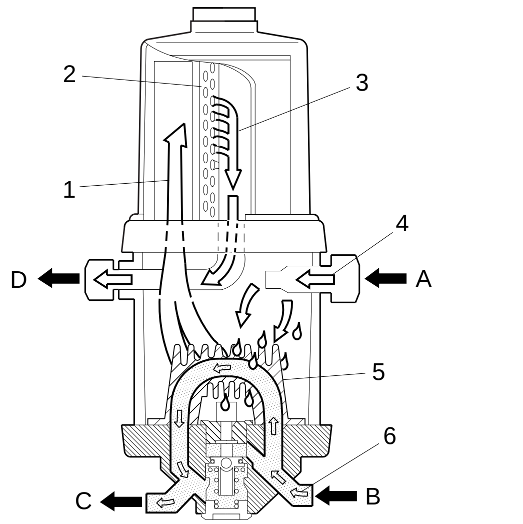
1. Drain Valve
2. Lower Housing
3. Cover O-Ring
4. Vent Cap O-Ring
5. Vent Cap
6. Collar
7. Clear Cover
8. Spring
9. Filter Element
10. Check Valve Assembly
11. Fuel Inlet Port
12. Pre-Heater
13. Fuel Outlet Port
14. Water-In-Fuel Sensor

Fig. 3, DAVCO Diesel Pro 243



A. Fuel Inlet Flow
B. Heating Fluid Inlet Flow
C. Heating Fluid Outlet Flow
D. Fuel Outlet Flow

1. Unfiltered, Heated Fuel
2. Filter Element
3. Filtered Fuel
4. Fuel From Fuel Tank
5. Heat Exchanger
6. Heating Fluid From Engine

Fig. 4, DAVCO Fluid Circulation, Fluid-Heated Units

Removal

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

Most service procedures are done with the fuel/water separator in place, but some procedures, such as pressure testing, require that the fuel/water separator be removed from the vehicle.

1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap (**Fig. 1**, Item 14) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Unplug the electric heating element, if equipped, or disconnect the heating fluid lines.
5. Disconnect the fuel outlet line.
6. Disconnect the fuel inlet line. If the inlet line is difficult to reach, loosen the connection, then fully disconnect it after the fuel/water separator is removed from the frame rail.
7. Remove the fuel/water separator mounting fasteners and remove the fuel/water separator from the frame rail. If the fuel inlet line was not completely disconnected in the previous step, disconnect it.

Installation

IMPORTANT: All fittings, including the locking collars, must be very clean as they are installed. A piece of grit or a damaged surface on a sealing face or in threads can cause air leaks.

Use paste sealer to ensure that the tapered thread fuel line fittings will not leak. Do not use sealer on compression fittings and do not seal the fittings with tape, which will eventually leak.

1. If the inlet fuel line is inaccessible when the fuel/water separator is mounted on the vehicle, loosely connect the inlet fuel line before mounting the fuel/water separator on the frame rail.

   To minimize restrictions, keep fuel line routing as smooth as possible, with no low-hanging loops that could trap water. If the fuel line is being made to length on the job, be sure that the inner liner of the hose is not cut by the fitting. Be certain the interior of all fuel lines is clean and free of debris before connecting them, and confirm that all fittings are clean.
2. Mount the fuel/water separator on the frame rail and install the mounting fasteners.

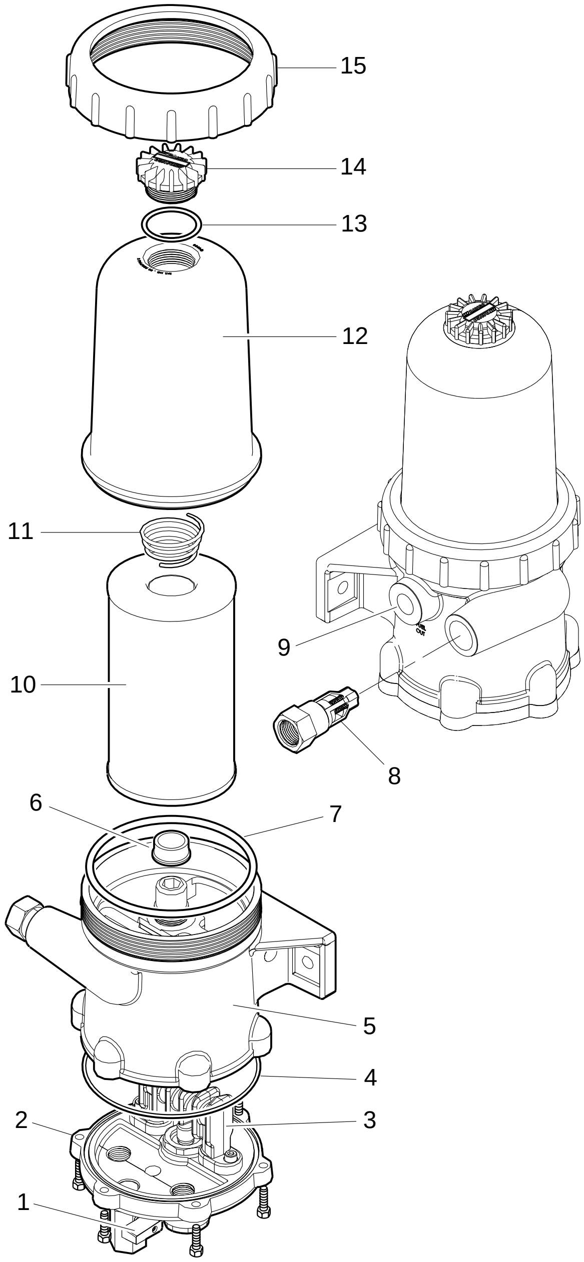
NOTICE

The lower housings on DAVCO fuel/water separators are made of aluminum. To avoid damaging threads, be careful not to overtighten fasteners or fittings on the fuel/water separator.

3. If the fuel inlet line was loosely connected previously, tighten it. If it was not connected, connect and tighten it.
4. Connect the fuel outlet line. Tighten the fitting 25 to 40 lbf·ft (34 to 54 N·m).
5. Install the electric heating element, if equipped, and connect the wiring harness, or connect the fluid heater lines. It does not matter which direction the heating fluid flows through the housing; the lines can be reversed.
6. Prime the system

   6.1 Ensure that the drain valve is closed.

Removal and Installation



1. Drain Valve
2. Bottom Plate
3. Heat Exchanger
4. Bottom Plate O-Ring
5. Lower Housing
6. Grommet
7. Cover O-Ring
8. Inlet Port/Check Valve
9. Fuel Outlet Port
10. Filter Element
11. Spring
12. Clear Cover
13. Vent Cap O-Ring
14. Vent Cap
15. Collar

Fig. 1, Fuel/Water Separator (Fuel Pro 382 shown)

6.2 Remove the vent cap from the cover, and fill the housing to the top with clean diesel fuel.

6.3 Install and hand-tighten the vent cap.

6.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.

6.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

6.6 Check for leaks and shut down the engine.

Filter Element Replacement

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap (**Fig. 1**, Item 14) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Using a DAVCO Collar Wrench (**Fig. 2**), remove the clear cover and collar.

NOTE: Broken vent cap and collar warranty claims will not be accepted if any tool other than a DAVCO Collar Wrench, p/n 380134 or 382002, is used for removal. During installation, the vent cap and collar are to be **hand-tightened only**, not tightened with a wrench.

5. Remove the filter, cover O-ring, and vent cap O-ring. Dispose of them in an environmentally acceptable manner.
6. Clean all threads and sealing surfaces very thoroughly. Even a small amount of dirt will prevent the fuel/water separator from sealing, and an air leak will result.
7. Install the grommet on the bottom of the new filter.
8. Install the new filter and grommet assembly and cover O-ring on the housing.
9. Install the clear cover and the collar. Hand-tighten the collar.
10. Prime the system
    - 10.1 Ensure that the drain valve is closed.
    - 10.2 Fill the housing to the top with clean diesel fuel.
    - 10.3 Install and hand-tighten the vent cap O-ring and vent cap.
    - 10.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
    - 10.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
    - 10.6 Check for leaks and shut down the engine.

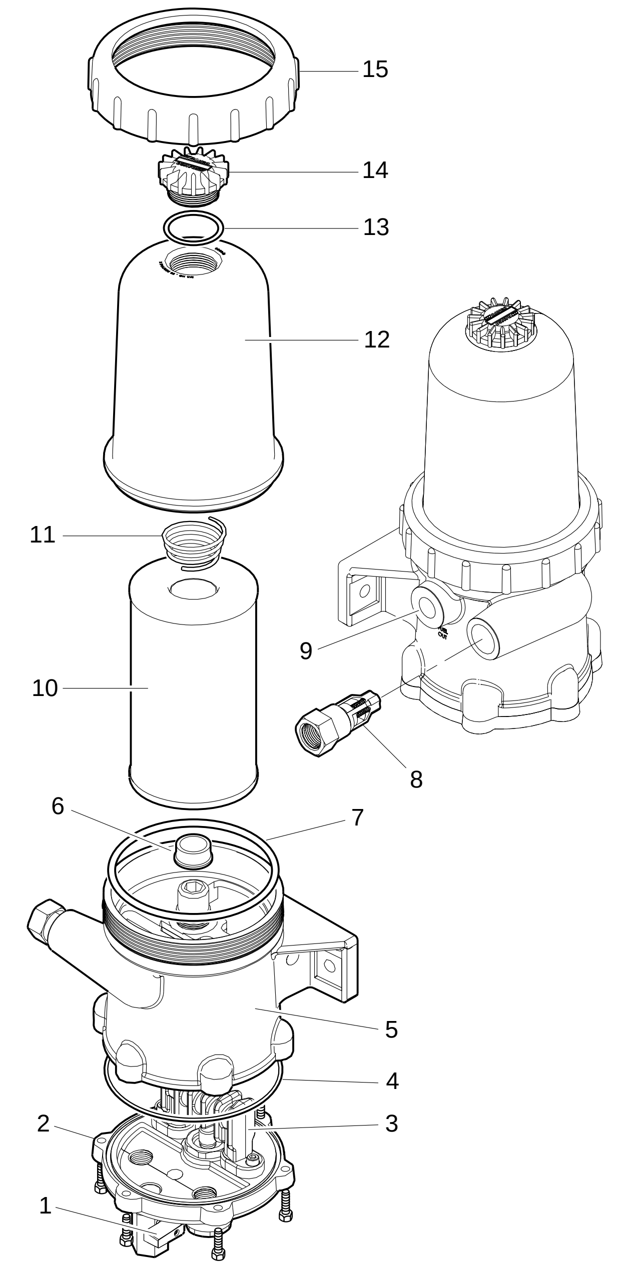
Emergency Temporary Filter Replacement

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

Filter and Check Valve Replacement



1. Drain Valve
2. Bottom Plate
3. Heat Exchanger
4. Bottom Plate O-Ring
5. Lower Housing
6. Grommet
7. Cover O-Ring
8. Inlet Port/Check Valve
9. Fuel Outlet Port
10. Filter Element
11. Spring
12. Clear Cover
13. Vent Cap O-Ring
14. Vent Cap
15. Collar

Fig. 1, Fuel/Water Separator (Fuel Pro 382 shown)

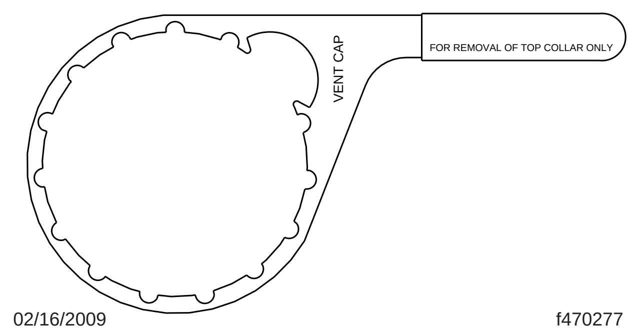


Fig. 2, DAVCO Collar Wrench

1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: When draining fluid from a fuel/ water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap (**Fig. 1**, Item 14) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Using a DAVCO Collar Wrench (**Fig. 2**), remove the clear cover and collar.

NOTE: Broken vent cap and collar warranty claims will not be accepted if any tool other than a DAVCO Collar Wrench, p/n 380134 or 382002, is used for removal. During installation, the vent cap and collar are to be **hand-tightened only**, not tightened with a wrench.

5. Remove the filter and dispose of it in an environmentally acceptable manner.
6. Clean all threads and sealing surfaces very thoroughly. Even a small amount of dirt will prevent the fuel/water separator from sealing, and an air leak will result.
7. Ensure that the drain valve is closed.

8. Remove the filter grommet from the filter stud, if equipped.
9. Fill the housing to the top with clean diesel fuel.
10. Install a standard engine spin-on filter (part number FF105 or equivalent) on the filter stud.
11. Install the cover O-ring, clear cover, and the collar. Hand-tighten the collar.
12. Install and hand-tighten the vent cap O-ring and vent cap.
13. Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
14. Check for leaks and shut down the engine.

Check Valve Replacement, Fuel Pro 382/482 and Diesel Pro 233 Configurations

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

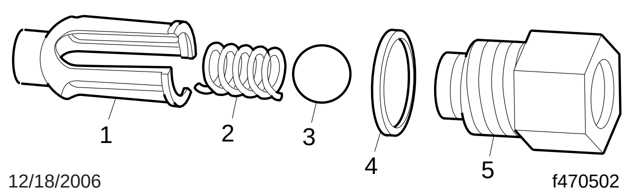
1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap (**Fig. 1**, Item 14) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Place a shop towel under the fuel inlet fitting. Hold the check valve body in place with an open-end wrench and, using a flare-nut wrench, carefully remove the fuel inlet fitting. Drain any residual fuel into the container.
5. Remove the check valve assembly from the fuel/water separator housing.
6. Remove and discard the check ball, spring, and plastic retainer. See **Fig. 3**.



1. Plastic Spring Retainer
2. Retaining Spring
3. Check Ball
4. Seal
5. Check Valve Body

Fig. 3, Check Valve Assembly

7. Carefully clean the threads on the check valve body. Install the new check ball, spring, and plastic retainer on the check valve body.
8. Clean the threads on the fuel inlet fitting and fuel/water separator housing. Apply a soft-set pipe thread sealant to the check valve body threads.
9. Install the check valve body in the fuel/water separator housing and tighten per the specifications in **Table 1**. Do not use tape to seal the fuel fittings; it will eventually leak.

Check Valve Assembly Torque Values	
Fuel/Water Separator	**Torque Value: lbf·ft (N·m)**
Fuel Pro 382	44–60 (60–81)
Fuel Pro 482	45 (61)

Filter and Check Valve Replacement

Check Valve Assembly Torque Values	
Fuel/Water Separator	Torque Value: lbf·ft (N·m)
Diesel Pro 233	25–40 (34–54)

Table 1, Check Valve Assembly Torque Values

10. Prime the system
    - 10.1 Ensure that the drain valve is closed.
    - 10.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
    - 10.3 Install and hand-tighten the vent cap.
    - 10.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
    - 10.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
    - 10.6 Check for leaks and shut down the engine.

Check Valve Replacement, Diesel Pro 243

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

1. Shut down the engine, apply the parking brake, and chock the tires.

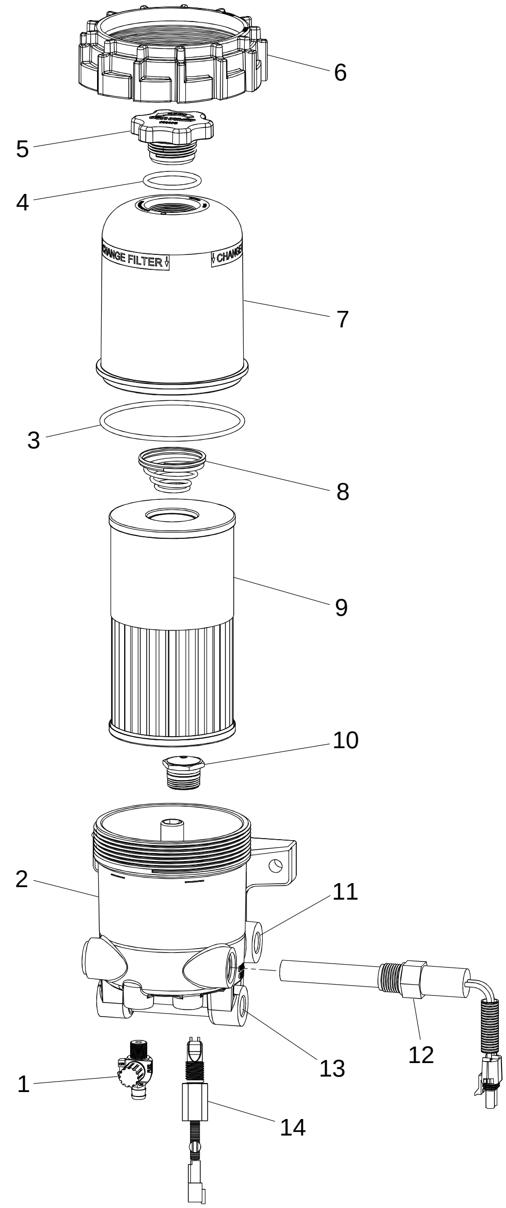
IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.
3. Remove the vent cap (**Fig. 4**, Item 5) and open the drain valve (**Fig. 4**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Using a DAVCO collar wrench (**Fig. 2**), remove the clear cover and collar.

NOTE: Broken vent cap and collar warranty claims will not be accepted if any tool other than a DAVCO collar wrench, p/n 380134 or 382002, is used for removal. During installation, the vent cap and collar are to be **hand-tightened only**, not tightened with a wrench.

5. Remove the filter and O-rings. Dispose of the filter and O-rings in an environmentally acceptable manner.
6. Remove the check valve from the lower housing.
7. Clean all threads and sealing surfaces very thoroughly. Even a small amount of dirt will prevent the fuel/water separator from sealing, and an air leak will result.
8. Install the new check valve body in the lower housing. Tighten the check valve 12 to 14 lbf·ft (16 to 19N·m).
9. Install the new filter and cover O-ring on the housing.
10. Install the clear cover and the collar. Hand-tighten the collar.
11. Prime the system
    - 11.1 Ensure that the drain valve is closed.
    - 11.2 Fill the housing to the top with clean diesel fuel.
    - 11.3 Install and hand-tighten the vent cap O-ring and vent cap.
    - 11.4 Start the engine. When the lubricating oil reaches its normal operating pressure,

Filter and Check Valve Replacement



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1. Drain Valve
2. Lower Housing
3. Cover O-Ring
4. Vent Cap O-Ring
5. Vent Cap
6. Collar
7. Clear Cover
8. Spring
9. Filter Element
10. Check Valve
11. Fuel Inlet Port
12. Pre-Heater
13. Fuel Outlet Port
14. Water-In-Fuel Sensor

Fig. 4, DAVCO Diesel Pro 243

increase engine speed to high idle for one to two minutes to purge air from the system.

11.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

11.6 Check for leaks and shut down the engine.

Electric Heater, Thermoswitch, and Fluid Heater Tests

Any one of several types of heaters and thermoswitches may be fitted to DAVCO fuel/water separators. They include 12 VDC heaters, 120 VAC heaters, combination heater thermoswitches, and fluid heaters. The voltage and wattage ratings are stamped on the hex or the sheath of each component.

Test procedures under these headings apply to the following heater types, as specified:

- Electric Heater
- 12 VDC Thermoswitch
- Combination Heater Thermoswitch
- Fluid Heat

The following equipment is recommended to test DAVCO heaters and thermoswitches:

- A precision low-resistance ohmmeter capable of measuring 0.1 ohm or less
- A clamp-on DC current-flow meter
- A means of chilling a thermoswitch, such as ice, dry ice, or compressed carbon dioxide
- A flameless source of heat, such as an infrared heat lamp
- A vortex tube to heat and cool a thermoswitch

Electric Heater

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Disconnect the heater from the wiring harness.
3. Connect the ohmmeter leads to the pins of the heater (for heaters with one pin, connect to the pin and the bushing).
4. Read the resistance and use **Table 1** to determine whether the heater is within the acceptable resistance range.
5. Connect the heater wiring harness.

Electric Heater Test Paramaters		
Electric Heater	**Watts**	**Resistance Range: Ohms**
12 VDC (two pin)	250	0.6–0.8
12 VDC (single pin)	250	0.4–0.5
12 VDC (single pin)	150	0.8–1.1
120 VAC	75	173–203
120 VAC	37	369–411

Table 1, Electric Heater Test Parameters

12 VDC Thermoswitch

1. Shut down the engine, apply the parking brake, and chock the tires.

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Disconnect the thermoswitch wiring harness, see **Fig. 1**. Remove the thermoswitch from the fuel/water separator.
5. Connect the ohmmeter leads to the pins of the thermoswitch.

Electric Heater, Thermoswitch, and Fluid Heater Tests

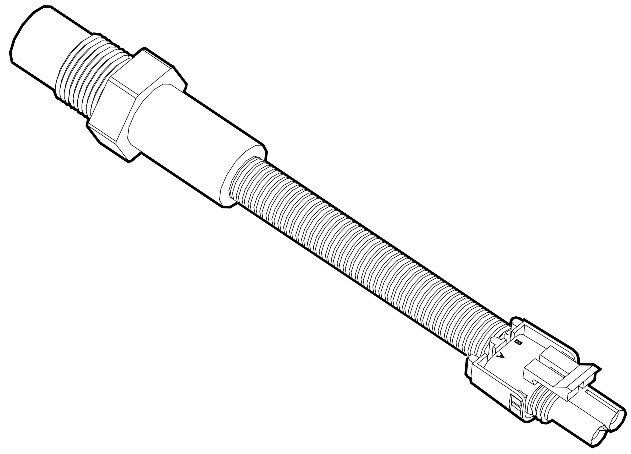


Fig. 1, 12 VDC Thermoswitch

6. Lower the thermoswitch temperature to below 40°F (4.4°C). The resistance shown on the ohmmeter should be less than 0.1 ohm.
7. Raise the thermoswitch temperature to above 60°F (15.5°C). The resistance should be more than 10 megohms.
8. Install the thermoswitch in the fuel/water separator. Connect the thermoswitch wiring harness.
9. Prime the system
   - 9.1 Ensure that the drain valve is closed.
   - 9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
   - 9.3 Install and hand-tighten the vent cap.
   - 9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   - 9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
   - 9.6 Shut down the engine; check for leaks.

Combination Heater Thermoswitch

1. Shut down the engine, apply the parking brake, and chock the tires.

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Disconnect the heater/thermoswitch unit from the wiring harness, see **Fig. 2**.
5. Connect the ohmmeter leads to the heater/thermoswitch pins.
6. Lower the heater/thermoswitch unit temperature to below 40°F (4.4°C).

   The resistance shown on the ohmmeter should be:

   - 0.8 to 1.1 ohms for a 12 VDC 150 W unit
   - 0.2 to 2.5 ohms for a 24 VDC 250 W unit

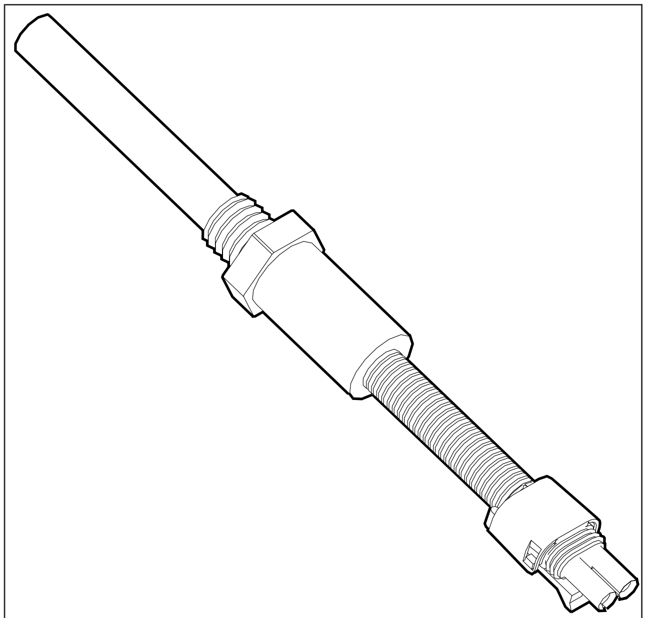


Fig. 2, Combination Heater Thermoswitch

7. Raise the heater/thermoswitch unit temperature to above 70°F (21°C). The heater/thermoswitch unit should show an open circuit.
8. Install the heater/thermoswitch in the fuel/water separator. Connect the heater/thermoswitch wiring harness.
9. Prime the system
   - 9.1 Ensure that the drain valve is closed.
   - 9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
   - 9.3 Install and hand-tighten the vent cap.
   - 9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   - 9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
   - 9.6 Shut down the engine; check for leaks.

Fluid Heat Exchanger

1. Shut down the engine, apply the parking brake, and chock the tires.

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

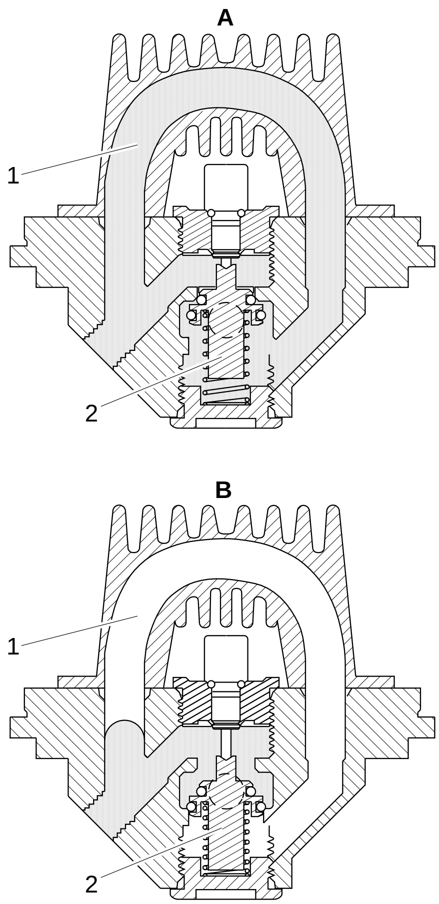
NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Disconnect the heating fluid lines from the bottom plate. These will be either engine coolant lines or return fuel lines. Plug engine coolant lines after removing them from the bottom plate of the housing.
5. Remove the bottom plate and lower housing O-ring.
6. When the fuel entering the fuel/water separator is cold, the thermovalve moves up, allowing warming fluid to enter the heater loop in the heat exchanger. When the fuel is warm, the thermovalve moves down, causing the warming fluid to bypass the heater loop and return directly to the tank. See **Fig. 3**.

Electric Heater, Thermoswitch, and Fluid Heater Tests

While looking into the fluid port of the bottom plate (Fig. 4), flow cold water over the thermovalve for 30 seconds, then run hot water over the thermovalve to determine whether the thermovalve spool is opening and closing.

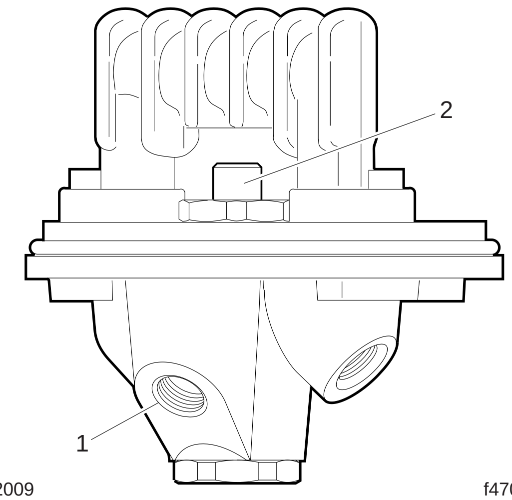
7. Replace the lower housing O-ring, and install the bottom plate on the fuel/water separator. There are two types of bottom plates: locking-collar-assembled and screw-assembled.



A. Fuel is Cold, Thermovalve Is Up
B. Fuel is Warm, Thermovalve is Down

1. Heater Loop
2. Thermovalve

Fig. 3, Heat Exchanger Fluid Flow



1. Fluid Port
2. Top of Thermovalve Spool

Fig. 4, Fluid Heater Thermovalve Test

- Locking-collar-assembled: Apply 2 to 3 drops of Loctite 406 to the bottom collar threads, then tighten 50 to 60 lbf·ft (68 to 81 N·m).
- Screw-assembled: Install the screws on the bottom plate and tighten them 8 to 10 lbf·ft (11 to 14 N·m).

8. Connect the heating fluid lines.
9. Prime the system
   - 9.1 Ensure that the drain valve is closed.
   - 9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
   - 9.3 Install and hand-tighten the vent cap.
   - 9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   - 9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
   - 9.6 Shut down the engine; check for leaks.

The Daimler Trucks North America Learning Center (accessible through **www.AccessFreightliner.com**) and DAVCO (**www.DavcoTec.com**) offer excellent online resources for understanding, testing, and diagnosing fuel/water separator problems.

Identifying Bubble Types

Vapor Bubbles

Vapor bubbles are harmless and are present in all diesel fuel systems. Vapor bubbles are often mistaken for air bubbles, but *do not affect engine performance.*

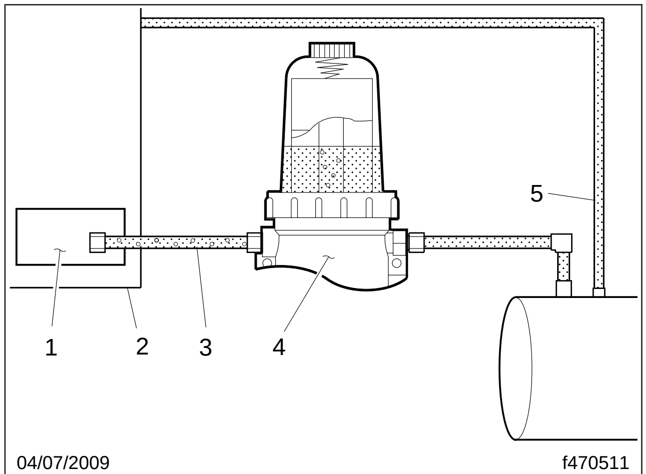
Vapor bubbles (see **Fig. 1**) may be visible in a diagnostic sight tube installed between the fuel/water separator and the fuel pump. They consist of harmless fuel vapor and trapped air, may vary from champagne-size to 1/4-inch (6-mm) diameter, and may increase in volume or size as the engine rpm increases. The lower pressure inside a fuel/water separator filter, caused by the suction of the fuel pump pulling fuel through the fuel/water separator, creates vapor bubbles. These vapor bubbles are normal and harmless to engine operation. In the fuel pump, the fuel is pressurized and the vapor bubbles dissolve. Vapor bubbles do not appear on the fuel return side of the system.

There is no troubleshooting or repair procedure required for vapor bubbles. Vapor bubbles do not cause performance issues and will not be present downstream of the fuel pump.

Air and Gas Bubbles

Air or gas bubbles indicate harmful leaks, and can cause hard starting and impaired engine performance. All diesel fuel holds some trapped air, caused by the natural splashing that occurs in the fuel tank. But excessive air bubbles, severe enough to degrade engine performance, indicate an air leak on the suction side of the fuel system, from the fuel tank into the fuel pump.

Air bubbles visible in the clear cover of a DAVCO fuel/water separator may indicate an air leak in the fuel system upstream of the bubbles, or in the fuel/water separator; see **Fig. 2**. If there are no bubbles visible in the clear cover but the engine runs rough, there may be an air leak at or between the fuel/water separator outlet port and the fuel pump inlet. These



1. Fuel Pump
2. Engine
3. Fuel Outlet Line, Vapor Bubbles Visible
4. Fuel/Water Separator, Vapor Bubbles Visible *Inside* Filter, *No* Bubbles Visible in Clear Cover
5. Fuel Return Line (no bubbles)

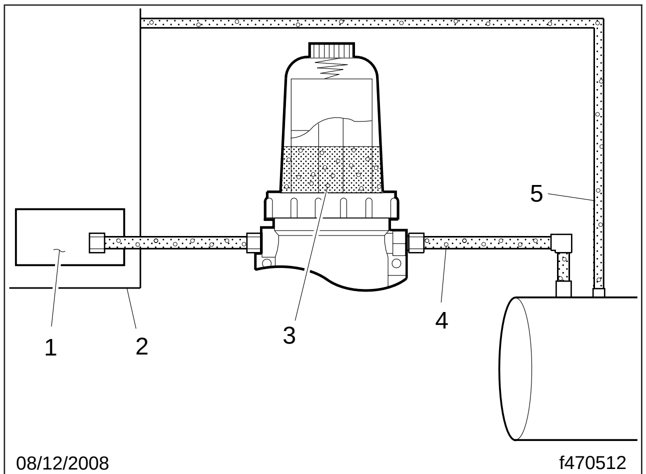
Fig. 1, Harmless Vapor Bubbles

bubbles will be visible in a diagnostic sight tube installed between the fuel pump and the fuel/water separator, and in a diagnostic sight tube installed in the fuel return hose.

Exhaust gas bubbles may also be visible in the clear filter cover. They are the result of leaking fuel injector seals, which can allow combustion gases to enter the fuel system, pass through the fuel return line into the fuel tank, and be drawn into the fuel/water separator. They may be visible in a diagnostic sight tube installed in the fuel return line. To test for combustion gas in the fuel, disconnect the return line at the tank, submerge the end in a bucket of fuel, run the engine, and watch for bubbles. As they pop, these bubbles may smell like exhaust fumes.

In extreme cases, these combustion gas bubbles cause enough aeration in the fuel tank to create visible bubbles in the clear cover of the fuel/water separator and impair engine performance. See the engine manufacturer's documentation for diagnosis and repair of injector seal leakage.

Use the following procedures to determine which bubbles are present in the fuel system, and whether repair is necessary.



1. Fuel Pump
2. Engine
3. Fuel/Water Separator, Bubbles Visible in Clear Cover
4. Fuel Inlet Line, Bubbles Visible
5. Fuel Return Line, Bubbles Visible

Fig. 2, Air Bubbles Indicating a Leak

Initial Diagnostic Procedure

1. Apply the parking brake, chock the tires, and turn on the engine.
2. Check for air bubbles in the fuel/water separator clear cover.
3. If no bubbles are visible in the clear cover, but the engine continues to run rough, lopes, or has loss of power, there may be an air leak between the fuel/water separator outlet and the fuel pump inlet.

   If so, bubbles should be visible in a diagnostic sight tube installed at the fuel pump inlet. Air bubbles may also be visible in a diagnostic sight tube installed in the fuel return line to the fuel tank.
4. Replace fuel lines and tighten fittings as needed.

Testing Procedures

Air Leak in the Fuel System

Air leaks are sometimes caused by:

- loose fittings;
- a faulty inlet check valve;
- faulty O-rings;
- leakage elsewhere in the fuel system;
- or dirt on threads and sealing surfaces.

Air leaks originating between the fuel tank and the fuel/water separator cause air bubbles visible in the clear cover, as shown in **Fig. 2**.

If there are symptoms of sucking air and there are no bubbles in the clear cover, look for the air leak at:

- the outlet fitting;
- the fuel pump inlet connection;
- the fuel hose connections;
- or at the vent cap O-ring.

1. Shut down the engine, apply the parking brake, and chock the tires.

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

2. Remove the fuel hose from the fuel pump inlet port.
3. Install a jumper hose from the inlet port into the fuel tank through the fill cap, or into a container of fuel.
4. Start the engine and look for bubbles in the clear filter cover. If the air bubbles are eliminated, the air source (and the leak) is at either the fuel tank fittings, or the hose connections.

   If air bubbles persist after the tank fittings and hose connections are secured, the leak may be in the fuel/water separator.
5. If the leak is suspected to be in the fuel/water separator, disconnect all fuel connections, coat

the threads with liquid or paste sealer, and reconnect the fuel connections and tighten them securely.

Air Pressure Testing

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.
3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Remove the fuel/water separator from the chassis. For instructions, see **Subject 100**.

WARNING

Wear goggles and skin protection when pressure-testing a fuel/water separator, and be careful not to perform this test near a source of possible ignition, such as an open flame. Never exceed the maximum pressure stipulated for the test, and do not perform this test if the clear cover appears to be damaged.

5. Plug the fuel outlet port. Do not remove the filter, filter cover, collar, vent cap, drain valve, or check valve. Do not remove the electric heating element (if equipped), and do not plug the fluid heat ports (if equipped).
6. Apply 15 psi (207 kPa) air pressure at the fuel inlet. Immerse the unit in a tank of water and look for air bubbles.
7. If no bubbles appear, the air leak is not in the fuel/water separator.
8. Install the fuel/water separator onto the chassis frame rail. For instructions, see **Subject 100**.
9. Prime the system

   9.1 Ensure that the drain valve is closed.

   9.2 Remove the vent cap from the cover, and fill the housing to the top with clean diesel fuel.

   9.3 Install and hand-tighten the vent cap.

   9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.

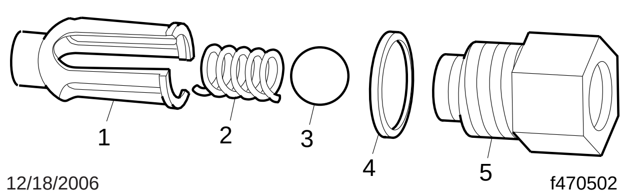
   9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

Filter Element Restriction Check

A DAVCO fuel/water separator, properly assembled with the rubber grommet in the bottom of the fuel filter, does not restrict fuel flow until the fuel level has risen to the top of the filter. If the fuel level has risen to the top of the filter, replace the filter.

Check Valve Operation Test, Fuel Pro 382/482 and Diesel Pro 243 Configurations

When air is introduced into the fuel system, (e.g. when draining fluid or when replacing the fuel filter), the check valve (**Fig. 3**) works to keep the fuel system primed from the fuel tank to the fuel/water separator.



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1. Plastic Spring Retainer
2. Retaining Spring
3. Check Ball
4. Seal
5. Check Valve Body

Fig. 3, Check Valve Assembly

To test for proper check valve operation, remove the fuel inlet line, then open the vent cap. Fuel should not flow out of the check valve, although a slight seepage of fuel is normal. If fuel drains back out of the check valve, complete the following procedure.

1. Shut down the engine, apply the parking brake, and chock the tires.

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Place a shop towel under the fuel inlet fitting. Hold the check valve body in place with an open-end wrench and, using a flare-nut wrench, carefully remove the fuel inlet fitting. Drain any residual fuel into the container.
5. Remove the check valve assembly from the fuel/water separator housing, see **Fig. 3**.
6. Clean and inspect the check valve body. If the valve body is damaged, or if the ball seat is not smooth, replace the valve. For instructions, see **Subject 110**.
7. If the valve body and ball seat are not damaged, clean the threads on the check valve body, fuel inlet fitting, and the water separator housing.
8. Apply a soft-set pipe thread sealant to the check valve body threads. Install the check valve body in the fuel/water separator housing. Do not use tape to seal the fuel fittings; it will eventually leak.

   Tighten the check valve body 44 to 60 lbf·ft (60 to 81 N·m) on a Fuel Pro 382, or 25 to 40 lbf·ft (34 to 54 N·m) on a Diesel Pro 232/233.
9. Prime the system
   - 9.1 Ensure that the drain valve is closed.
   - 9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
   - 9.3 Install and hand-tighten the vent cap O-ring and vent cap.
   - 9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   - 9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
   - 9.6 Check for leaks and shut down the engine.

Other Conditions Visible Inside the Cover

The clear filter covers fitted to DAVCO fuel/water separators provide the opportunity to monitor several aspects of fuel condition and engine status, as described in **Table 1**.

Conditions Visible Inside DAVCO Clear Filter Covers		
If You See:	**What to Do:**	**Comments:**
Amber-colored fuel below the top of the filter element	Nothing, the filter is doing its job	Do not change the filter.
Amber-colored fuel with dark patches in places on the filter element	Dark patches indicate bacteria or algae may be present. Use Fleetguard Monitor Kit CC2650 to test for microbiological activity.	It may be necessary to use a microbicide, and suggest vehicle operator carry extra filters.
Extremely dark or cloudy fuel with thick black film or sludge collecting on the filter element	Black film or sludge on the filter media indicates the presence of asphaltenes. It may be necessary to use an asphaltene conditioner.	Do not assume this is oil from the engine. Monitor the vehicle for oil consumption. Refer to engine manufacturer's service literature for more information.
Bubbles inside the clear cover	Check for air leaks anywhere in the fuel system. Any leak in any fitting will cause bubbles to appear in the clear cover.	This problem will lead to power complaints; it must be remedied.
No bubbles in the cover, but the engine is running rough	Check for air leaks between the fuel/water separtor outlet port and the fuel pump inlet. Check and tighten all fuel fittings in the area of the leak.	Do not replace the fuel/water separator.
Coolant in the fluid drained from the fuel/water separator	Check for leaks in the engine, where fuel and coolant are near each other. The most common problem place is the injector cup.	Do not allow the equipment to be operated until the problem is found and repaired.
Anything not listed here	Call DAVCO at 1-800-328-2611, or email: customerservice@DavcoTec.com	—

Table 1, Conditions Visible Inside DAVCO Clear Filter Covers

Specifications

Component	Fuel Pro 482	Fuel Pro 382		Diesel Pro 243		Diesel Pro 233	
	lbf·ft (N·m)	lbf·ft (N·m)	lbf·in (N·cm)	lbf·ft (N·m)	lbf·in (N·cm)	lbf·ft (N·m)	lbf·in (N·cm)
Inlet Port/Check Valve	45 (61)	44–60 (60–81)	—	12–14 (16–19)*	—	25–40 (34–54)	—
Water in Fuel Sensor	—	—	20–24 (226–271)	—	20–24 (226–271)	—	20–24 (226–271)
Electric Heating Element	15–30 (20–41)	15–30 (20–41)	—	25–40 (34–54)	—	15 (20)	—

* Check valve assembly not connected to inlet port on Diesel Pro 243 configurations.

Table 1, Torque Values

General Description

The fuel/water separator is mounted on the frame rail, between the fuel tank and the fuel pump. Fuel drawn to the engine travels through the fuel/water separator, which removes water and solid contaminants. The fuel/water separator includes a spin-on filter element and a sight bowl. See **Fig. 1**. The fuel/water separator may also be equipped with the following optional components:

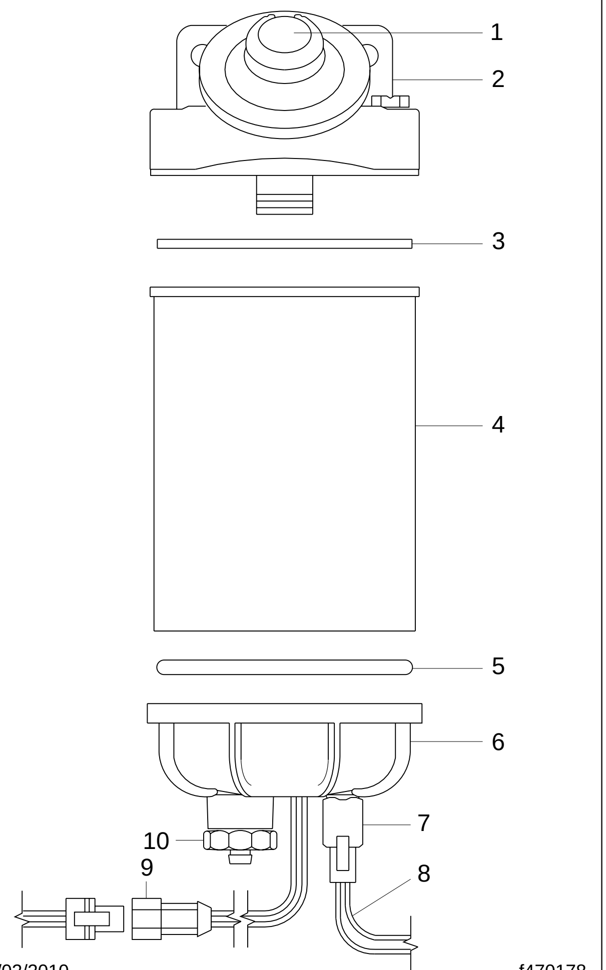
- Ignition-controlled heater to melt ice and wax in the fuel
- Water sensor probe to alert the operator to drain the sight bowl
- Manual priming pump to easily prime the fuel/water separator

Principles of Operation

Diesel fuel enters at the top of the separator and flows down past the heater element, if equipped, to the top of the filter element. As the fuel flows down the sides of the element, the heavier contaminants fall directly to the collection bowl. The filter element itself contains a resin that repels water and forces it to bead and fall to the collection bowl.

Filtered fuel is drawn out through the top of the separator, and the water and solid contaminants remain in the collection bowl. As water collects, it completes the circuit between the two prongs of the water sensor probe, if equipped, and a warning light on the dash alerts the operator to drain the bowl.

The heater is operated by turning on the ignition switch for 5 minutes before starting the engine.



1. Priming Pump
2. Mounting Head
3. Gasket
4. Filter Element
5. O-Ring
6. Sight Bowl
7. Water Sensor Probe
8. Water Sensor Probe Wiring Harness
9. Heater Wiring Harness
10. Drain Plug

Fig. 1, Fuel/Water Separator Assembly

Removal and Installation

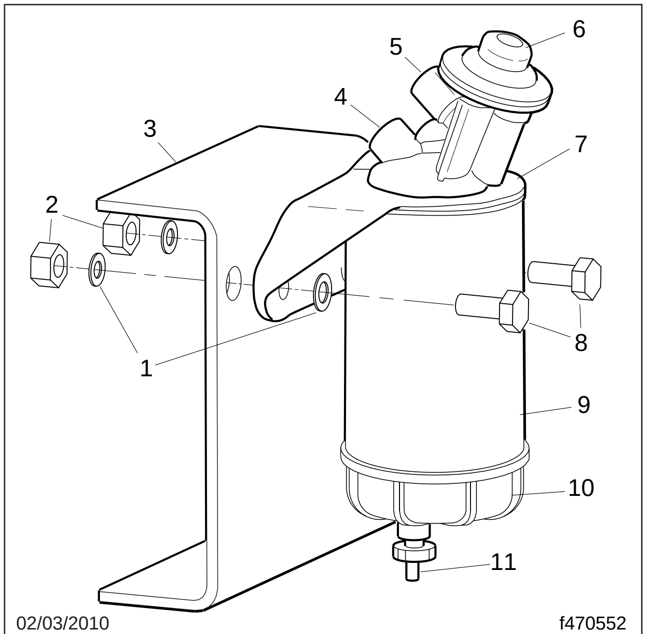
Removal

1. Shut down the engine, apply the parking brake, and chock the tires.

   Open the hood.
2. Place a suitable container under the fuel/water separator.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

3. Turn the drain plug counterclockwise to open it. If equipped, operate the priming pump. See **Fig. 1**.



1. Washers (qty 2)
2. Nuts (qty 2)
3. Frame Rail
4. Fuel Outlet Port
5. Fuel Inlet Port
6. Priming Pump
7. Mounting Head
8. Mounting Bolts (qty 2)
9. Filter Element
10. Sight Bowl
11. Drain Plug

Fig. 1, Fuel/Water Separator Assembly and Installation

4. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.

WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

5. Disconnect the fuel lines from the fuel/water separator.
6. If equipped, disconnect the wiring harnesses from the water sensor probe and the heater element.
7. Remove the fuel/water separator mounting bolts, and remove the fuel/water separator from its mounting bracket.

Installation

1. Mount the fuel/water separator on the frame rail mounting bracket, and install the mounting bolts. Tighten the bolts 40 lbf·ft (55 N·m).
2. Remove the sight bowl and the filter element as a unit from the new fuel/water separator.
3. Using clean motor oil or diesel fuel, lubricate the gasket in the top of the filter element.
4. Make sure the drain in the sight bowl is closed, then fill the filter element and bowl assembly with clean fuel.
5. Install the element and bowl assembly on the mounting head and hand-tighten it until snug.
6. If equipped, connect the wiring harnesses to the water sensor probe and the heater.
7. Connect the fuel lines to the fuel/water separator. Tighten all fittings finger-tight plus 1/4 turn.
8. Prime the fuel/water separator.

   If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.

   If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.
9. Start the engine and check for leaks.
10. Shut down the engine and repair any leaks.

Replacement

1. Shut down the engine, apply the parking brakes, and chock the tires.

   Open the hood.
2. Place a suitable container under the fuel/water separator.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

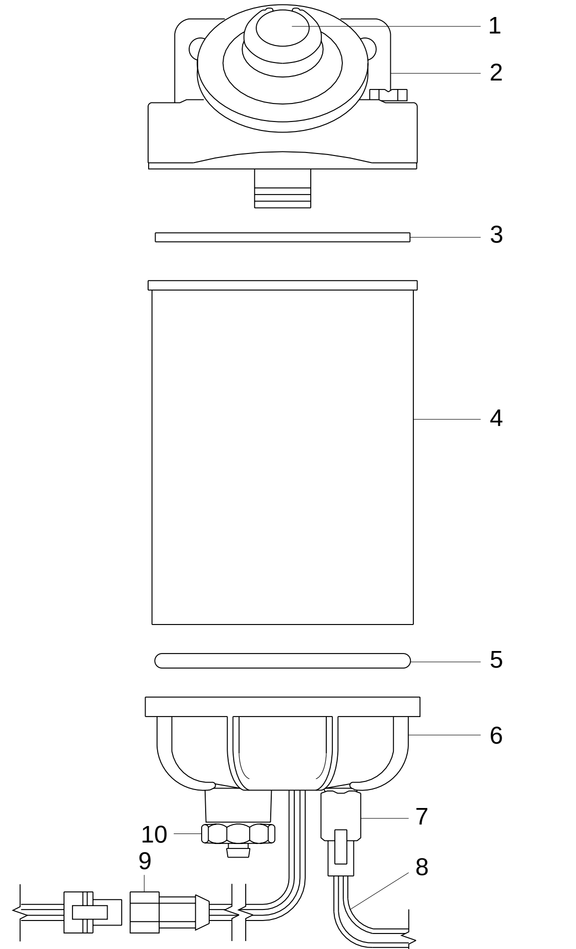
3. Turn the drain plug counterclockwise to open it. If equipped, operate the pump.
4. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.

WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

5. If equipped, disconnect the wiring harnesses from the water sensor probe and the heater. See **Fig. 1**.
6. Spin off the sight bowl and the filter element as a unit. Remove the gasket from the top of the filter element.
7. Remove the sight bowl from the filter element. Clean the O-ring seating surface.
8. Apply a thin coating of clean diesel fuel or engine oil to the O-ring and the new gasket.
9. Spin the sight bowl onto the new filter element and then fill the filter element and sight bowl assembly with clean diesel fuel.
10. Spin the entire assembly onto the mounting head and tighten by hand until snug.
11. Connect the heater and water sensor wiring harnesses, if equipped.
12. Prime the fuel/water separator.

    If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.



1. Priming Pump
2. Mounting Head
3. Gasket
4. Filter Element
5. O-Ring
6. Sight Bowl
7. Water Sensor Probe
8. Water Sensor Probe Wiring Harness
9. Heater Wiring Harness
10. Drain Plug

Fig. 1, Fuel/Water Separator Assembly

    If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.

13. Start the engine and check for leaks.
14. Shut down the engine and repair any leaks.

Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.

   Open the hood.
2. Place a suitable container under the fuel/water separator.

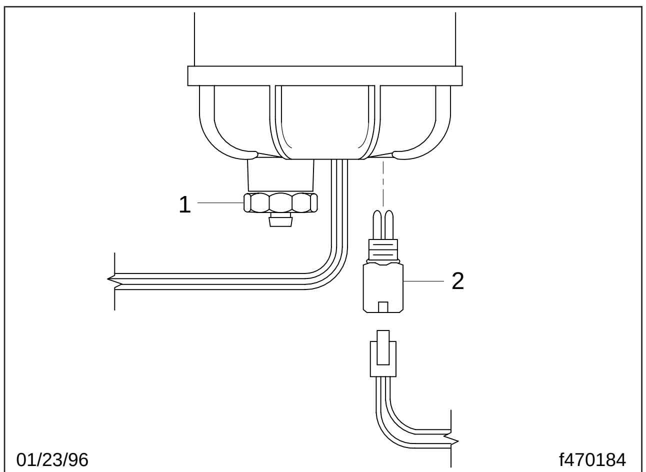
IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

3. Turn the drain plug counterclockwise to open it. If equipped, operate the priming pump.
4. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.

WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

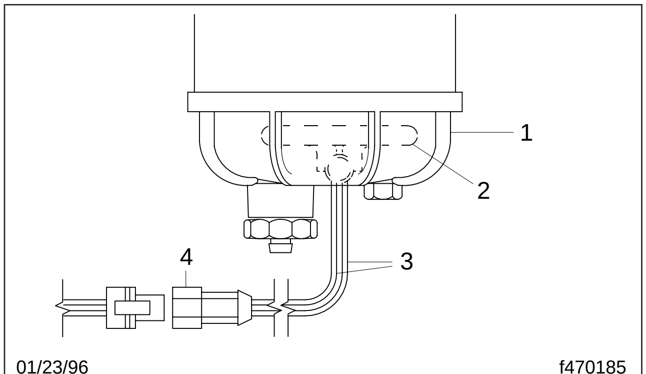
5. If equipped, disconnect the wiring harness from the water sensor probe. See **Fig. 1**.



1. Drain Plug
2. Water Sensor Probe

Fig. 1, Water Sensor Probe

6. Disconnect the heater wiring harness. See **Fig. 2**.



1. Sight Bowl
2. Heating Element
3. Heater Wires
4. Heater Wiring Harness

Fig. 2, In-Bowl Heater

7. Spin off the sight bowl and the filter element as a unit.
8. Remove the sight bowl from the filter element.
9. Remove the O-ring from the lip of the new sight bowl. Lubricate the O-ring with a thin film of clean engine oil or diesel fuel and put it back in the sight bowl.
10. Install the sight bowl on the bottom of the filter element and hand-tighten until it is snug.
11. Make sure the drain in the sight bowl is closed, then fill the filter element and bowl assembly with clean fuel.
12. Install the element and bowl assembly on the mounting head and hand-tighten it until snug.
13. Connect the heater wiring harness.

    If equipped, connect the water sensor wiring harness to the water sensor probe.
14. Prime the fuel/water separator.

    If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.

    If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.
15. Start the engine and check for leaks.
16. Shut down the engine and repair any leaks.

Water Sensor Probe Replacement

Replacement

1. Apply the parking brakes, shut down the engine, and chock the tires.

   Open the hood.
2. Place a suitable container under the fuel/water separator.

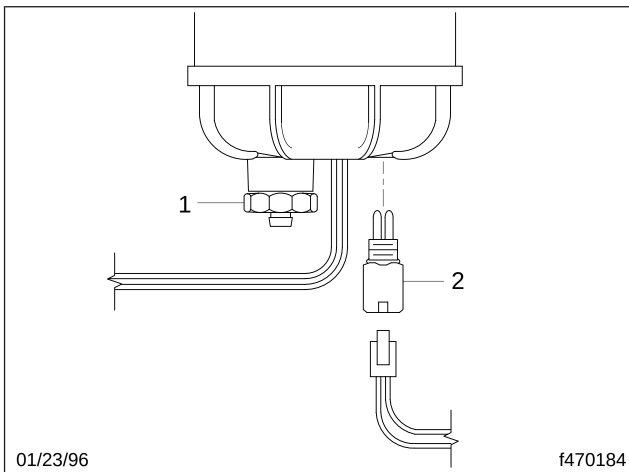
IMPORTANT: When draining fluid from a fuel/ water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

3. Turn the drain plug counterclockwise to open it. If equipped, operate the priming pump.
4. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.

WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

5. Disconnect the water sensor wiring harness from the water sensor probe. See **Fig. 1**.



1. Drain Plug
2. Water Sensor Probe

Fig. 1, Water Sensor Probe

6. Spin off the sight bowl and filter element as a unit.
7. Unscrew the water sensor probe from the base of the sight bowl.
8. Install a new water sensor probe in the base of the sight bowl.
9. Make sure the drain plug in the base of the sight bowl is closed snugly.
10. Fill the filter element and sight bowl assembly with clean diesel fuel.
11. Install the element and bowl assembly on the mounting head and hand-tighten it until snug.
12. Connect the water sensor wiring harness to the water sensor probe.
13. Prime the fuel/water separator.

    If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.

    If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.
14. Start the engine and check for leaks.
15. Shut down the engine and repair any leaks..

Troubleshooting

Problem—Air Leaking into the Fuel System

Problem—Air Leaking into the Fuel System	
Possible Cause	**Remedy**
The drain is not closed.	Tighten the drain valve.
The sight bowl or filter element is loose.	Hand-tighten the sight bowl or filter element until snug.
There are loose, broken, or clogged fuel fittings, valves, or filters.	Tighten, clean, or repair the fuel fittings, valves, or filters as needed.

Problem—High Water Light Does Not Illuminate For 2 to 5 Seconds When Ignition is Turned to ACCESSORY

Problem—High Water Light Does Not Illuminate For 2 to 5 Seconds When Ignition is Turned to ACCESSORY	
Possible Cause	**Remedy**
Wiring connections are loose.	Tighten connections as needed.
Fuel/water separator is not grounded.	Check that power is on, and the fuel/water separator is grounded.
Wiring is damaged.	Check for damaged wiring and replace as needed. See EZWiring for a diagram of the sensor circuit.
Water sensor probe is damaged.	Replace the water sensor probe. See **Subject 130** for instructions.

General Description

IMPORTANT: The liquefied natural gas (LNG) fuel system should be routinely inspected for gas leakage. Always use a natural gas detector to check the fuel tank, fuel filtering and regulating mechanisms, and fuel lines. Repair or replace any lines, devices, or connections that are leaking.

LNG is created by condensing natural gas into a liquid by cooling it to approximately -259°F (-162°C). When vaporized at ambient temperatures, natural gas is less dense than air, and it will rise and disperse. Cold atmospheric conditions may prevent natural gas from disbursing quickly when released in large amounts.

Natural gas is nontoxic, but can cause asphyxiation at high enough concentrations simply by excluding adequate oxygen to sustain life.

For natural gas to burn, it must first vaporize, then mix with air in the proper proportions (flammable range is 5 to 15% by volume in air), and then be ignited.

The LNG fuel system consists of:

- A fuel tank that stores LNG at an extremely low temperature
- Pressure relief and manual fuel shutoff valves
- A vaporizor or heat exchanging device that changes LNG to gaseous form
- A filling connection with a check valve that prevents the gas from flowing back out of the fuel filling line
- A pressure control regulator that reduces the high fuel tank pressure to the lower pressure needed for the engine
- A gas-air mixer to produce a flammable mixture for the engine
- An economizer, or pressure control regulator, that opens at pressures above 120 psi (827 kPa) to reduce pressure in the fuel tank
- A dash-mounted fuel contents gauge that indicates the fuel supply in the tank

If a natural-gas-fueled vehicle is involved in an accident and the fuel tank is damaged, remove the tank from service and have it inspected and repaired by the tank manufacturer. Repair or replace any damaged or leaking fuel lines, fittings, or other components. Install parts and components in accordance with the manufacturer's instructions.

Related Information and Websites

Detailed LNG fuel system component repair, replacement, and troubleshooting information can be obtained from the fuel system manufacturer's website: **www.nexgenfueling.com**.

Chart Inc.
1300 Airport Drive
Ball Ground, GA 30107
770-479-6531

The National Fire Protection Association website provides additional information about LNG and LNG fuel systems: **www.nfpa.org**.

Safety Precautions

DANGER

Natural gas vapors are highly flammable. Failure to observe the following safety precautions could lead to ignition of the natural gas, which could cause serious bodily injury or death.

Liquefied natural gas (LNG) vapors are highly flammable. Whenever a leak is suspected, immediately shut off all engines and ignition sources. Avoid causing sparks, and stay away from arcing switches and equipment. Extinguish cigarettes, pilot lights, flames, and other sources of ignition in the area and adjacent areas. Immediately provide extra ventilation to the area. Do not start any equipment until the gas leak is corrected and the area cleared of LNG.

Natural gas is nontoxic, but can cause asphyxiation at high enough concentrations simply by excluding adequate oxygen to sustain life.

Periodic inspections of the LNG tank are required by law to ensure continued safety. Each fuel tank should be visually inspected at specified intervals for external damage and deterioration. See the *Business Class M2® Maintenance Manual* for inspection schedule information.

If a tank receives an impact, or has deep scratches or gouges, it should be inspected before refilling. The inspection should be performed by a qualified person, in accordance with the tank manufacturer's established inspection criteria.

Always use a natural gas detector to test the system for leaks, whether an odor is present or not. A bubble solution can be used to pinpoint the exact location of leaks.

Servicing Precautions

Observe the following safety precautions when servicing LNG-powered vehicles:

- Always purge the fuel lines and tank before performing maintenance or repairs on the fuel system. This can be done by either transferring LNG in the fuel tank to an approved cryogenic-rated container, or by running the vehicle until the tank is empty and the engine stops.
- Close the fuel tank shutoff valves before performing maintenance and repairs. Open the valves only if LNG is needed to operate the engine or to check for leaks.
- Repair work on an LNG fuel system should be performed only by qualified technicians trained in automotive LNG system repair.
- Always tighten fasteners and fuel connections to the required torque specification. Overtightening or undertightening could cause leaks.
- Cover eyes and exposed skin with cryogenic-rated protective devices when working on the fuel system or fueling the vehicle.

Workshop Precautions

Do not store an LNG vehicle indoors for any extended period of time.

Observe the following safety precautions when LNG vehicles are inside a workshop:

- Use only safety fluorescent extension shop lights when working around LNG fuel systems.
- Ensure the shop ceiling is equipped with a vent system that will allow gas to escape and dissipate.
- Ensure the shop is equipped with an alarm system that activates when gas concentration in the air becomes dangerous.
- Have CO_2 fire extinguishers (ABC minimum) located in a highly visible and easily accessible location.
- Permit no smoking or other ignition sources within thirty feet of an LNG vehicle.
- Avoid open flames or sparks near an LNG vehicle.
- Check the fuel tank pressure gauge periodically to ensure that pressure is within the normal range of 120 to 150 psi (827 to 1034 kPa). In the unlikely event that tank pressure exceeds 230 psi (1586 kPa) and the pressure relief valve does not open automatically, vent the tank outdoors immediately.

Major Repair and Replacement of Parts

If a natural-gas-fueled vehicle is involved in an accident, remove the fuel tank from service and have them inspected by a qualified technician. Replace any leaking or damaged fuel tanks and fuel lines; repair or replace leaking or damaged fittings. Install parts and components in accordance with the manufacturer's instructions.

Any and all replacement parts (valves, fittings, tubing, etc.) of the LNG fuel system must be designed specifically for LNG use, and must be approved for use by the fuel system manufacturer.

Install parts and components in accordance with the fuel system manufacturer's instructions.

Gas Detection System

A gas detection system is used in all Daimler Trucks LNG-fueled vehicles. The system has a sensor in the engine compartment and one in the cab, both situated in high areas to detect natural gas buildup as a result of leaks. The system is meant to serve as a supplemental warning only. It is not intended to replace standard safety practices that should be conducted around flammable gases.

IMPORTANT: To function properly, the gas detection system must be powered at all times. The gas detection system is directly powered by the batteries, and can only be powered off by disconnecting the batteries. When servicing a natural-gas-fueled vehicle, disconnect the batteries only when necessary, and do not leave the batteries disconnected for extended periods of time.

De-Fueling

WARNING

Liquefied natural gas (LNG) vapors are highly flammable. Refer to the safety precautions listed in Subject 100 before servicing the vehicle. Failure to observe these precautions could lead to ignition of the natural gas, which could cause bodily injury, death, or severe property damage.

IMPORTANT: Follow all local, state, and federal guidelines regarding usage and venting of LNG.

Purging the fuel system and fuel tank can be done by either transferring LNG in the fuel tank to an approved cryogenic-rated container, or by running the vehicle until the tank is empty and the engine stops.

Detailed LNG tank de-fueling information and procedures can be obtained from the fuel system manufacturer: **www.nexgenfueling.com**.

Chart Inc.
1300 Airport Drive
Ball Ground, GA 30107
770-479-6531

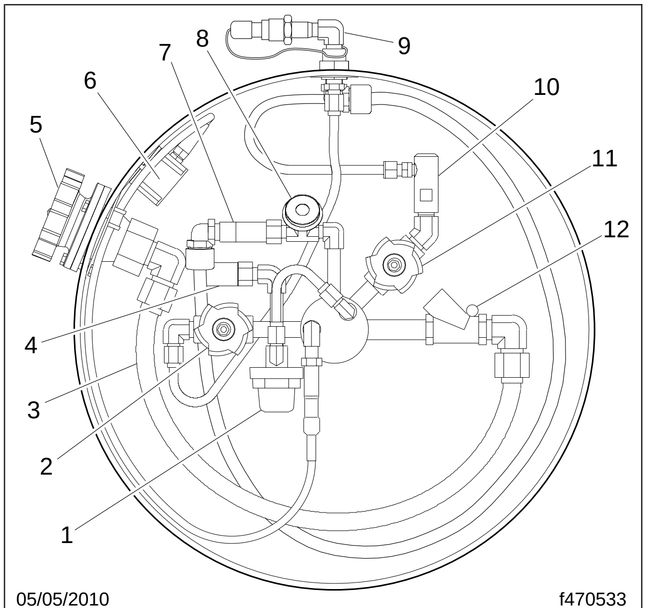
Replacement

⚠ WARNING

Liquefied natural gas (LNG) vapors are highly flammable. Refer to the safety precautions listed in Subject 100 before servicing the vehicle. Failure to observe these precautions could lead to ignition of the natural gas, which could cause bodily injury, death, or severe property damage.

Additional fuel system component repair, replacement, and troubleshooting information can be obtained from the fuel system manufacturer's website: **www.nexgenfueling.com**.

1. Shut down the engine and apply the parking brake.
2. De-fuel the LNG tank. See **Subject 110** for more information.
3. Once all fuel has been removed from the LNG tank, close the fuel shutoff and vapor shutoff valves.
4. Shut down all vehicle electrical systems.
5. Carefully remove the U-tube attached to the economizer and the tank knuckle. See **Fig. 1**.
6. Ensuring no threads are damaged, carefully remove the elbow fitting from the economizer.
7. Remove and discard the economizer.
8. When installing a new economizer, it is necessary to clean the internal economizer threads to prevent metal shavings and debris from collecting in the valve seat once installed.
   - 8.1 Counting each turn, thread the economizer onto the nipple fitting.
   - 8.2 Unscrew the economizer from the nipple fitting. Using compressed nitrogen or a wire brush, remove all metal shavings and debris from the external nipple threads and the internal economizer threads.
   - 8.3 Repeat the above two substeps until no shavings or debris are found in the economizer, always using the same number of full turns for each installation.



1. Economizer
2. Vapor Shutoff Valve
3. Fuel Fill Hose
4. Secondary Relief Valve (red cap)
5. Fuel Fill Fitting
6. Fuel Level Sender Box
7. Primary Relief Valve
8. Tank Pressure Gauge
9. Fill Vent Fitting
10. Excess Flow Valve
11. Fuel Shutoff Valve (liquid)
12. Fill Check Valve

Fig. 1, Fuel Tank Plumbing Components

9. Remove the economizer again, then thoroughly clean the threads on the nipple fitting and the economizer with compressed nitrogen or a wire brush.

IMPORTANT: Use nickel tape on all non-compression fittings. See the following section, **Nickel Tape Application**, for more information on using and applying nickel-impregnated or nickel-coated tape.

10. Apply nickel tape to the exposed nipple fitting threads, then install the economizer on the nipple fitting. Tighten the economizer one full turn beyond hand-tight.
11. Using compressed nitrogen or a wire brush, remove any dirt and debris from the elbow fitting threads, then apply nickel tape to the exposed fitting threads.
12. Install the elbow fitting on the economizer. Tighten the elbow fitting three turns beyond

Economizer Replacement

hand-tight. If necessary, use a backup wrench to hold the economizer in place while tightening the elbow fitting.

13. Install the U-tube on the economizer elbow fitting and the tank knuckle. Tighten the fittings one-quarter turn beyond hand-tight.
14. Using compressed nitrogen or a wire brush, remove any dirt and debris from the excess flow valve and fitting threads, then apply nickel tape to the exposed valve fitting threads.
15. Install the excess flow valve on the fitting. Tighten the excess flow valve one full turn beyond hand-tight. If necessary, use a backup wrench to hold the elbow fitting in place while tightening the valve.
16. Install the relief line on the excess flow valve. Tighten the fitting one-quarter turn beyond hand-tight.
17. Fill the LNG tank with fuel.

IMPORTANT: Close all windows and doors during the fueling process. Keeping windows and doors closed allows for easier leak detection inside the cab after fueling.

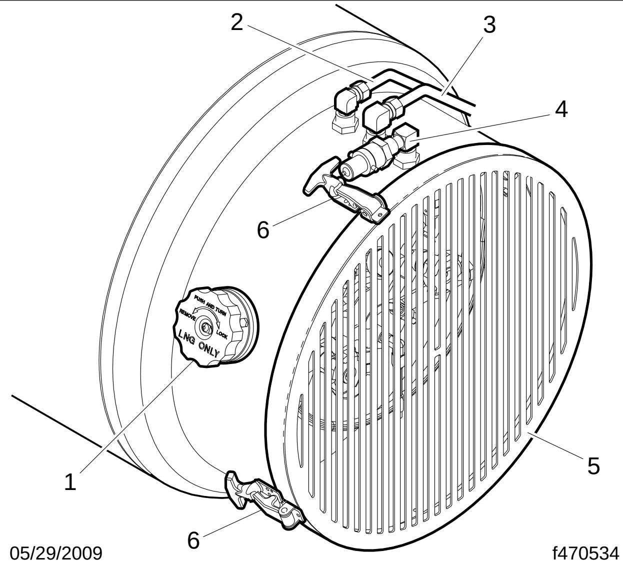
17.1 Remove the fuel fill fitting dust cap. See **Fig. 2**.

17.2 Using compressed nitrogen or a wire brush, remove any dirt, debris, or water that may have collected in the fuel fill fitting and the station dispensing nozzle.

17.3 Connect the station fueling nozzle to the tank fuel fill fitting.

17.4 Connect an electrical ground clamp and cable to the fuel tank.

IMPORTANT: An LNG tank on a vehicle that has not been operated in approximately ten days is considered to be a hot tank. When fueling a hot tank, LNG entering the tank will immediately vaporize, causing tank pressure to spike above 250 psi (1724 kPa) and automatically shutting down the station fuel pump. To prevent the pump from shutting down, connect a vent line to the fill vent fitting to capture escaping vapor, then open the shroud cover and open the vapor shutoff valve.



1. Fuel Fill Fitting
2. Fuel Outlet Line
3. Primary Relief Vent Line
4. Fill Vent Fitting
5. Shroud Cover
6. Shroud Cover Latches

Fig. 2, LNG Fuel Tank

17.5 Open the station's fill valve, if equipped, and start fueling. Monitor the flow or line pressure as filling progresses.

IMPORTANT: When fueling a hot tank, initially put 5 to 10 gallons (19 to 37 liters) of LNG in the tank and manually stop the fueling process. Drive the vehicle for 15 to 20 minutes to cool the tank and reduce tank pressure, then continue fueling the tank to full.

17.6 When a rapid pressure rise or flow rate drop is observed, close the station's fill valve, if equipped.

17.7 Disconnect the station hose from the tank fuel fill fitting.

17.8 Disconnect the electrical ground clamp and cable from the fuel tank.

17.9 Install the dust cap on the tank fuel fill fitting.

18. Start the engine and, using a methane detector, leak test all fuel system components. A bubble

solution can be used to pinpoint the exact location of leaks.

Repair or replace any leaking components.

Nickel Tape Application

Use nickel tape on all non-compression fittings. Do not use nickel tape on compression fittings.

Either nickel-coated or nickel-impregnated tape may be used to seal fittings.

1. Ensure that threads are close to ambient temperature and dry. Nickel tape applied to cold or wet threads can retain moisture, which can reduce sealing capabilities.

IMPORTANT: Wrap the tape in the direction of the threads.

2. Align the edge of the tape with the second thread so that the first thread is exposed.
3. Hold the end of the tape on the threaded surface and gently pull the tape down into the threads, keeping the tape under tension so the tape molds to the threads.
4. Wrap tape twice around pipes and fittings 1/2-inch (13 mm) or smaller in diameter.

   Wrap tape three times around pipes and fittings 5/8-inch to 1-inch (16 to 25 mm) in diameter.
5. Ensure the end of the tape is pulled down tight and no loose edges remain.
6. Hold the tape in place when installing components on nickel-wrapped threads.

Welding

WARNING

Liquefied natural gas (LNG) vapors are highly flammable. Refer to the safety precautions listed in Subject 100 before servicing the vehicle. Failure to observe these precautions could lead to ignition of the natural gas, which could cause severe bodily injury, death, or property damage.

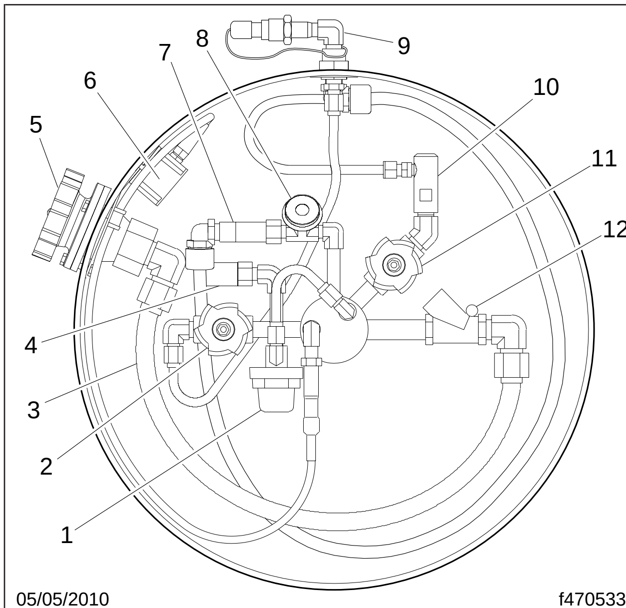
NOTICE

Welding an LNG fuel tank could damage the tank vacuum insulation and/or void the warranty. Consult the tank manufacturer (www.nexgenfueling.com or 770-479-6531) before welding an LNG tank.

IMPORTANT: Follow all local, state, and federal guidelines regarding usage and venting of LNG.

1. Park the vehicle on a level surface, shut down the engine and set the parking brake. Chock the tires.
2. Ensure the vehicle is parked in a well-ventilated area. Do not park the vehicle in an area where natural gas can accumulate.
3. De-fuel the LNG tank. See **Subject 110** for more information.
4. Close the fuel shutoff and vapor shutoff valves. See **Fig. 1**.
5. Use a natural gas detector to test the area around the vehicle for natural gas.
6. Shut down all vehicle electrical systems.
7. Cover the LNG tank and fuel lines with a metal shield or welding blankets to prevent sparks or residue from falling on LNG equipment.
8. Complete all necessary welding, then remove the protective welding blankets or metal shield.
9. Start up the vehicle electrical systems.
10. Fill the LNG tank with fuel.

    IMPORTANT: Close all windows and doors during the fueling process. Keeping windows and doors closed allows for easier leak detection inside the cab after fueling.



1. Economizer
2. Vapor Shutoff Valve
3. Fuel Fill Hose
4. Secondary Relief Valve (red cap)
5. Fuel Fill Fitting
6. Fuel Level Sender Box
7. Primary Relief Valve
8. Tank Pressure Gauge
9. Fill Vent Fitting
10. Excess Flow Valve
11. Fuel Shutoff Valve (liquid)
12. Fill Check Valve

Fig. 1, Fuel Tank Plumbing Components

10.1 Remove the fuel fill fitting dust cap. See **Fig. 2**.

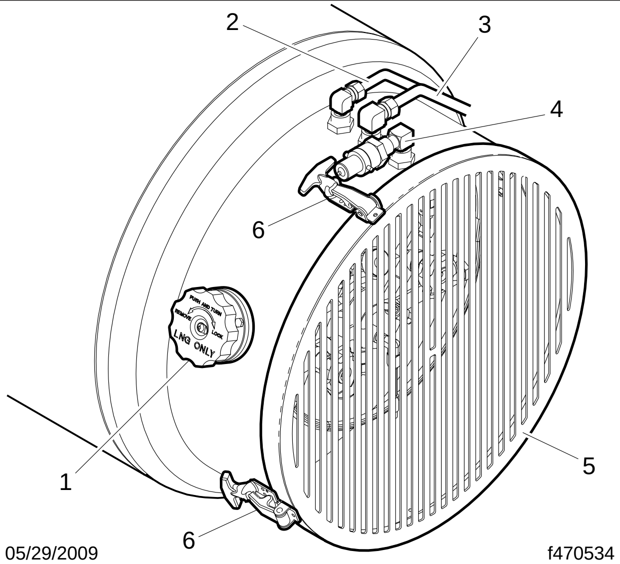
10.2 Using compressed nitrogen or a wire brush, remove any dirt, debris, or water that may have collected in the fuel fill fitting and the station dispensing nozzle.

10.3 Connect the station fueling nozzle to the tank fuel fill fitting.

10.4 Connect an electrical ground clamp and cable to the fuel tank.

IMPORTANT: An LNG tank on a vehicle that has not been operated in approximately ten days is considered to be a hot tank. When fueling a hot tank, LNG entering the tank will immediately vaporize, causing tank pressure to spike above 250 psi (1724 kPa) and automatically shutting down the station fuel pump. To prevent the pump from shutting

Welding an LNG Vehicle



1. Fuel Fill Fitting
2. Fuel Outlet Line
3. Primary Relief Vent Line
4. Fill Vent Fitting
5. Shroud Cover
6. Shroud Cover Latches

Fig. 2, LNG Fuel Tank

down, connect a vent line to the fill vent fitting to capture escaping vapor, then open the shroud cover and open the vapor shutoff valve.

10.5 Open the station's fill valve, if equipped, and start fueling. Monitor the flow or line pressure as filling progresses.

IMPORTANT: When fueling a hot tank, initially put 5 to 10 gallons (19 to 37 liters) of LNG in the tank and manually stop the fueling process. Drive the vehicle for 15 to 20 minutes to cool the tank and reduce tank pressure, then continue fueling the tank to full.

10.6 When a rapid pressure rise or flow rate drop is observed, close the station's fill valve, if equipped.

10.7 Disconnect the station hose from the tank fuel fill fitting.

10.8 Disconnect the electrical ground clamp and cable from the fuel tank.

10.9 Install the dust cap on the tank fuel fill fitting.

11. Open the fuel shutoff and vapor shutoff valves. See **Fig. 1**.

General Description

IMPORTANT: The compressed natural gas (CNG) fuel system should be routinely inspected for gas leakage. Use a natural gas detector to check fuel cylinders, fuel filtering and regulating mechanisms, and fuel lines. Replace leaking fuel cylinders; repair or replace any lines, devices, or connections that are leaking.

CNG is made by compressing natural gas to less than 1% of its volume at standard atmospheric pressure. When vaporized at ambient temperatures, natural gas is less dense than air, and it will rise and disperse. Cold atmospheric conditions may prevent natural gas from disbursing quickly when released in large amounts.

Natural gas is nontoxic, but can cause asphyxiation at high enough concentrations simply by excluding adequate oxygen to sustain life.

Commercial CNG normally contains an odor-producing chemical. However, a natural gas detector is recommended for leak checking; do not expect to detect natural gas leaks by scent.

For natural gas to burn, it must first vaporize, then mix with air in the proper proportions (flammable range is 5 to 15% by volume in air), and then be ignited.

The CNG fuel system consists of:

- Fuel cylinders that store CNG at high pressure
- Pressure relief and manual fuel shutoff valves
- A filling connection with a check valve that prevents the gas from flowing back out of the fuel filling line
- A high-pressure fuel filter
- A pressure control regulator that reduces the high fuel cylinder pressure to the lower pressure needed for the engine
- A gas-air mixer to produce a flammable mixture for the engine
- A dash-mounted fuel contents gauge that indicates the available fuel supply in the cylinders

Related Information and Websites

Detailed CNG fuel system repair, replacement, and troubleshooting information can be obtained from the fuel system manufacturer: **www.agilityfuelsystems.com**.

Agility Fuel Systems
5409 Maryland Way
Suite 215
Brentwood, TN 37027
951-244-5489

The following documents and websites provide additional information about CNG and CNG fuel systems:

- NFPA 52 *Vehicular Gaseous Fuel Systems Code, 2010*: **www.nfpa.org**
- Society of Automotive Engineers *Recommended Practice for Compressed Natural Gas Vehicle Fuel*: **standards.sae.org/j1616_199402/**
- Compressed Gas Association: **www.cganet.com**

Safety Precautions

WARNING

Compressed natural gas is highly flammable. Failure to observe the following precautions could lead to the ignition of the natural gas, which could cause severe property damage, bodily harm, or death.

Whenever gas is smelled, immediately shut off all engines and ignition sources. Avoid causing sparks, and stay away from arcing switches and equipment. Extinguish cigarettes, pilot lights, flames, and other sources of ignition in the area and adjacent areas. Immediately provide extra ventilation to the area. Do not start any equipment until the gas leak is corrected and the area cleared of natural gas.

Periodic inspections of the compressed natural gas (CNG) fuel cylinders are required by law to ensure continued safety. Each fuel cylinder should be visually inspected at specified intervals for external damage and deterioration. See the *Business Class M2 Maintenance Manual* for inspection schedule information.

If a cylinder receives an impact or has deep scratches or gouges, it should be inspected before refilling. The inspection should be performed by a qualified person, in accordance with the manufacturer's established inspection criteria and Compressed Gas Association procedures.

Always use a natural gas detector to check for leaks.

Servicing Precautions

Observe the following safety precautions when servicing CNG-powered vehicles:

- Always purge the fuel lines before performing maintenance or repairs on a CNG fuel system. Do not transfer CNG from one vehicle to another, as a buildup of static electricity could cause a spark and ignite the fuel.
- Only vent CNG outdoors in a safe location.
- Close the fuel cylinder shutoff valves before performing maintenance and repairs. Open the valves only if CNG is needed to operate the engine or to check for leaks.
- Repair work on a CNG fuel system should be performed only by qualified technicians trained in automotive CNG system repair.
- Always tighten fasteners and fuel connections to the required torque specification. Overtightening or undertightening could cause leaks.
- Cover eyes and exposed skin when working on a CNG fuel system or fueling a CNG vehicle.

Workshop Precautions

Do not store a CNG vehicle indoors for any extended period of time.

Observe the following safety precautions when CNG vehicles are inside a workshop:

- Use only safety fluorescent extension shop lights.
- Ensure the shop ceiling is equipped with a vent system that will allow gas to escape and dissipate.
- Ensure the shop is equipped with an alarm system that activates when gas concentration in the air becomes dangerous.
- Have CO_2 fire extinguishers (ABC minimum) located in a highly visible and easily accessible location.
- Permit no smoking or other ignition sources within thirty feet of a CNG vehicle.
- Avoid open flames or sparks near a CNG vehicle.
- Close the fuel cylinder shutoff valves when storing the vehicle inside. Open the valves only if CNG is needed to operate the engine or to check for leaks.

Major Repair and Replacement of Parts

Replace any leaking or damaged fuel cylinders and fuel lines; repair or replace leaking or damaged fittings. Install parts and components in accordance with the manufacturer's instructions.

Any and all replacement parts (valves, fittings, hoses, etc.) of the CNG fuel system must be designed specifically for CNG automotive use, and must be officially approved and rated for the pressures and conditions that pertain.

Gas Detection System

A gas detection system is used in all Daimler Trucks CNG-fueled vehicles. The system has a sensor in the engine compartment and one in the cab, both situated in high areas to detect natural gas buildup as a result of leaks. The system is meant to serve as a supplemental warning only. It is not intended to replace standard safety practices that should be conducted around flammable gases.

IMPORTANT: To function properly, the gas detection system must be powered at all times. The gas detection system is directly powered by the batteries, and can only be powered off by disconnecting the batteries. When servicing a natural-gas-fueled vehicle, disconnect the batteries only when necessary, and do not leave the batteries disconnected for extended periods of time.

Venting

WARNING

Compressed natural gas is highly flammable. Do not attempt to transfer compressed natural gas (CNG) from one vehicle to another, as a buildup of static electricity could cause a spark and ignite the fuel, which could cause bodily injury, death, or severe property damage.

IMPORTANT: Only vent compressed natural gas (CNG) outdoors in a safe location.

The fuel cylinder shutoff valves are installed in line from top to bottom. Closing a fuel cylinder shutoff valve will cut off the flow of CNG from that cylinder and all of the fuel cylinders positioned above it in the storage box.

Compressed natural gas can be vented from the fuel cylinders in two ways.

- Run the engine until it stops.
- Open the CNG bleed valve on the manifold.

If only one cylinder needs to be purged, close the fuel shutoff valves on the fuel cylinders positioned above it. Then, either run the engine until the cylinders are empty and the engine stops, or open the bleed valve and allow the CNG to vent. At this time, all CNG in the venting cylinder and the cylinders in line below it will have vented.

Pressure Regulator and Solenoid Valve Removal and Installation

Removal

WARNING

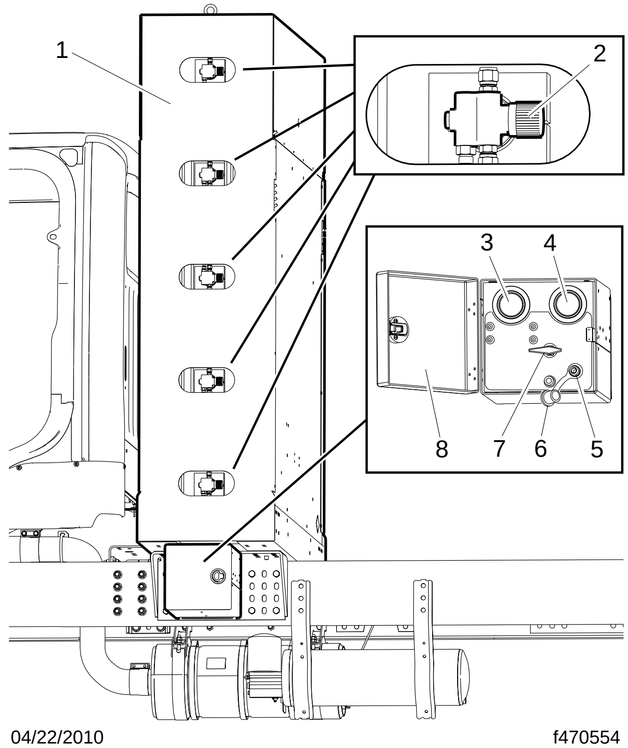
Compressed natural gas is highly flammable. Refer to the safety precautions listed in Subject 100 before servicing the vehicle. Failure to observe these precautions could lead to the ignition of the natural gas, which could cause bodily injury, death, or severe property damage.

NOTE: The pressure regulator and solenoid valve are located inside the fuel panel.

1. Shut down the engine and apply the parking brake.
2. Close the compressed natural gas (CNG) fuel cylinder shutoff valves. See **Fig. 1**.
3. Start the engine and let it idle until the fuel lines are empty and the engine stops. The gauges on the fuel panel should now read at or near 0 psi.
4. Close the manual fuel shutoff valve on the fuel panel.
5. Remove the two capscrews that secure the access cover to the fill panel, then remove the access cover. See **Fig. 2**. Save the capscrews.
6. Slowly open the bleed valve on the manifold to relieve remaining fuel pressure within the system. See **Fig. 3**.

IMPORTANT: Some pressure may remain in the fuel system between the solenoid valve and the engine. Use caution when loosening fittings, as a small amount of gas may leak out.

7. Drain the coolant from the cooling system. For instructions, see **Group 20**.
8. Remove the fitting that connects the manifold to the high-pressure fuel filter.
9. Disconnect the wiring harness from the solenoid valve.
10. Disconnect the coolant lines from the pressure regulator.
11. Unscrew and remove the coolant warming bowl from the pressure regulator.
12. Disconnect the fuel inlet, fuel outlet, and low pressure gauge lines from the pressure regulator.



1. Fuel Cylinder Storage Box
2. Fuel Cylinder Shutoff Valves (5 valves on a 5-tank system)
3. High-Pressure Gauge
4. Low-Pressure Gauge
5. Fuel Fill Port
6. Dust Cap
7. Manual Shutoff Valve
8. Fuel Panel Access Door

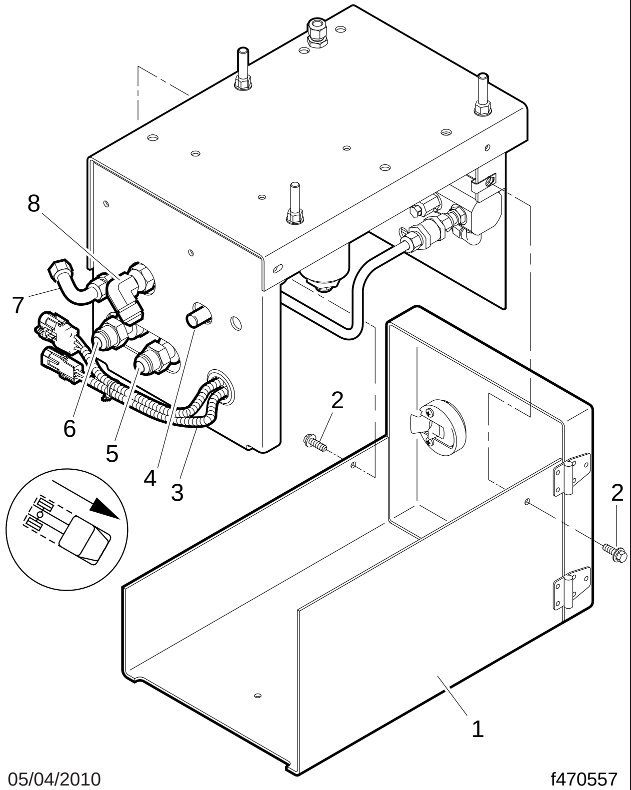
Fig. 1, CNG Fuel Cylinder Storage Box (5-cylinder system shown)

13. Remove the two capscrews that secure the pressure regulator to the CNG fuel panel, then remove the pressure regulator, solenoid valve, and fuel filter as an assembly. Save the capscrews.
14. Once the assembly has been removed from the fuel panel, each component can be disconnected as needed.

Installation

1. Connect the pressure regulator, solenoid valve, and fuel filter as an assembly.

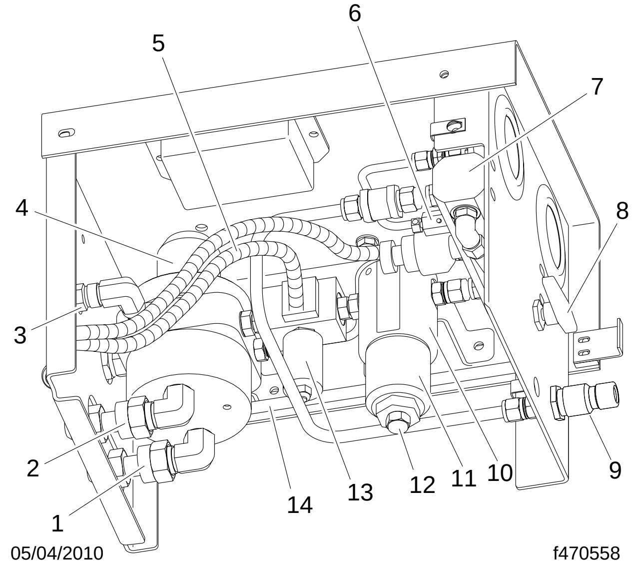
Pressure Regulator and Solenoid Valve Removal and Installation



1. Fuel Panel Access Cover
2. Capscrews (qty 2)
3. Wiring Harness
4. Pressure Relief Valve and Cap
5. Coolant Outlet Line
6. Coolant Inlet Line
7. Fuel Inlet Line (from fuel cylinders)
8. Fuel Outlet Line (to engine)

Fig. 2, CNG Fuel Panel Assembly

2. Secure the pressure regulator to the CNG fuel panel using the capscrews removed previously.
3. Connect the fuel inlet, fuel outlet, and low pressure gauge lines to the pressure regulator.
4. Connect the coolant lines to the pressure regulator.
5. Connect the wiring harness to the solenoid valve.
6. Install and tighten the fitting that connects the manifold to the high-pressure fuel filter.
7. Close the bleed valve on the manifold and open the manual fuel shutoff valve on the fuel panel.
8. Open the fuel cylinder shutoff valves.



1. Coolant Inlet Port
2. Coolant Outlet Port
3. Pressure Relief Valve
4. Pressure Regulator
5. Wiring Harness
6. Manifold Bleed Valve
7. Manifold
8. Manual Fuel Shutoff Valve
9. Fuel Fill Port
10. Filter Housing
11. Filter Bowl
12. Filter Drain Plug
13. Solenoid Valve
14. Fuel Line To Cylinders

Fig. 3, CNG Fuel Panel Components

9. If necessary, fill the cooling system and check for leaks. For instructions, see **Group 20**.
10. Start the engine and check for gas leaks in the fuel system.

    Using a methane detector, leak test all fuel system components. A bubble solution can be used to pinpoint the exact location of leaks.

    Repair or replace any leaking components.
11. Using the two capscrews removed previously, install the access cover on the fill panel.

Fuel Fill Port Removal and Installation

Removal

WARNING

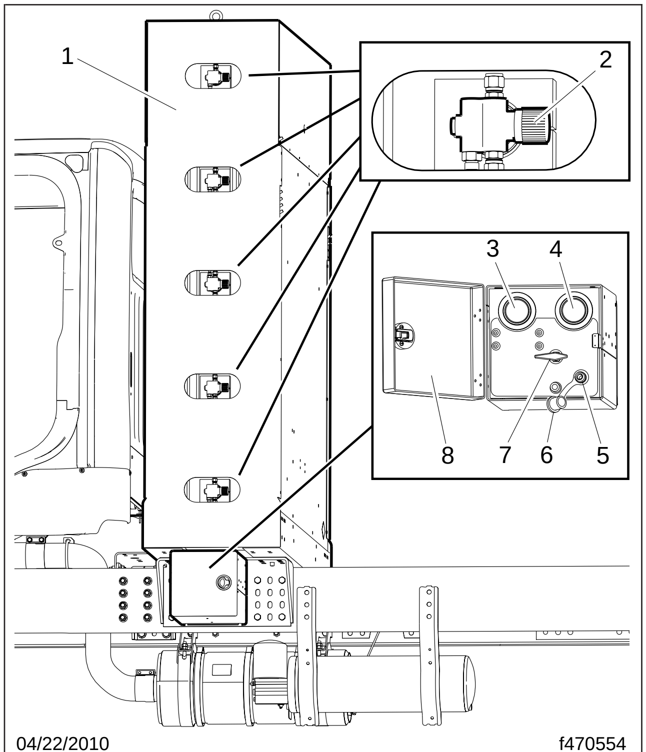
Compressed natural gas is highly flammable. Refer to the safety precautions listed in Subject 100 before servicing the vehicle. Failure to observe these precautions could lead to the ignition of the natural gas, which could cause bodily injury, death, or severe property damage.

NOTE: The fuel fill port is located on the fuel panel.

1. Shut down the engine and apply the parking brake.
2. Close the compressed natural gas (CNG) fuel cylinder shutoff valves. See **Fig. 1**.
3. Start the engine and let it idle until the fuel lines are empty and the engine stops. The gauges on the fuel panel should now read at or near 0 psi.
4. Close the manual fuel shutoff valve on the fuel panel.
5. Remove the two capscrews that secure the access cover to the fill panel, then remove the access cover. See **Fig. 2**. Save the capscrews.
6. Slowly open the bleed valve on the manifold to relieve remaining fuel pressure within the system. See **Fig. 3**.
7. Disconnect the fuel line from the fuel fill port.
8. Unscrew the mounting nut that secures the fill port to the fuel panel.
9. Slide the fuel fill port out of the access panel.

Installation

1. Install the fuel fill port in the access panel. Tighten the mounting nut.
2. Connect the fuel line to the fuel fill port.
3. Close the bleed valve on the manifold and open the manual fuel shutoff valve on the fuel panel.
4. Open the fuel cylinder shutoff valves.
5. Start the engine and check for gas leaks in the fuel system.



1. Fuel Cylinder Storage Box
2. Fuel Cylinder Shutoff Valves (5 valves on a 5-tank system)
3. High-Pressure Gauge
4. Low-Pressure Gauge
5. Fuel Fill Port
6. Dust Cap
7. Manual Shutoff Valve
8. Fuel Panel Access Door

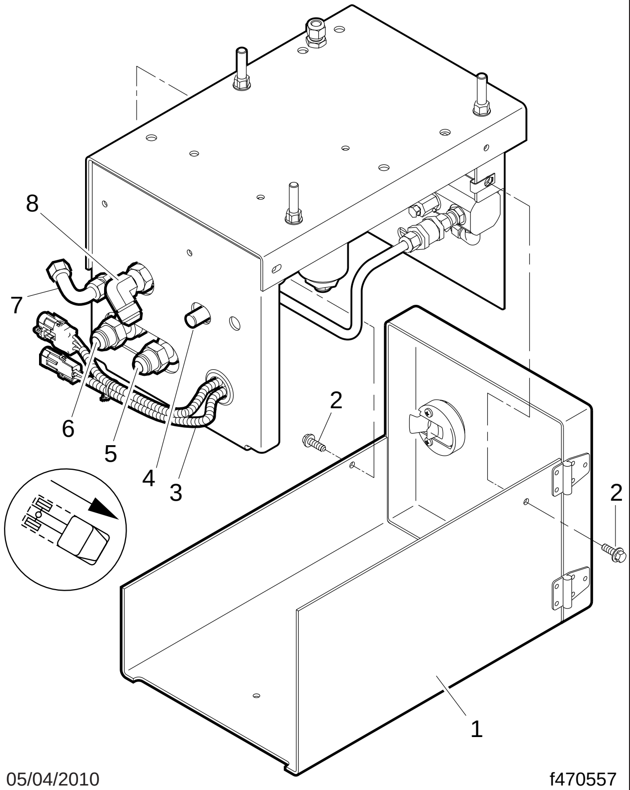
Fig. 1, CNG Fuel Cylinder Storage Box (5-cylinder system shown)

Using a methane detector, leak test all fuel system components. A bubble solution can be used to pinpoint the exact location of leaks.

Repair or replace any leaking components.

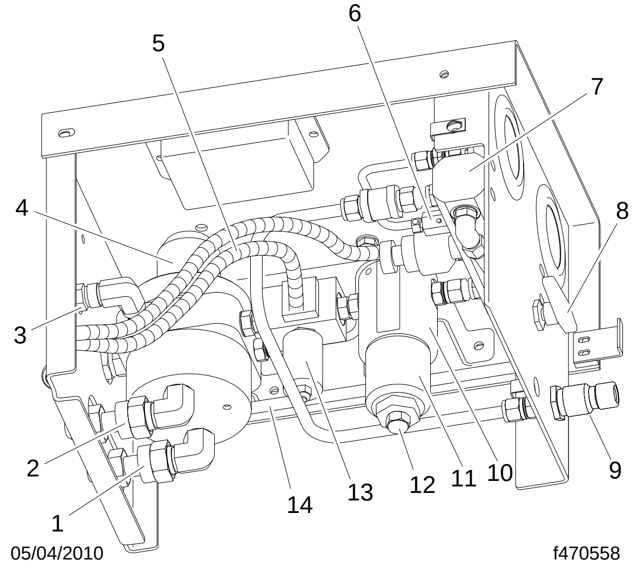
6. Using the two capscrews removed previously, install the access cover on the fill panel.

Fuel Fill Port Removal and Installation



1. Fuel Panel Access Cover
2. Capscrews (qty 2)
3. Wiring Harness
4. Pressure Relief Valve and Cap
5. Coolant Outlet Line
6. Coolant Inlet Line
7. Fuel Inlet Line (from fuel cylinders)
8. Fuel Outlet Line (to engine)

Fig. 2, CNG Fuel Panel Assembly



1. Coolant Inlet Port
2. Coolant Outlet Port
3. Pressure Relief Valve
4. Pressure Regulator
5. Wiring Harness
6. Manifold Bleed Valve
7. Manifold
8. Manual Fuel Shutoff Valve
9. Fuel Fill Port
10. Filter Housing
11. Filter Bowl
12. Filter Drain Plug
13. Solenoid Valve
14. Fuel Line To Cylinders

Fig. 3, CNG Fuel Panel Components

WARNING

Compressed natural gas is highly flammable. Refer to the safety precautions listed in Subject 100 before servicing the vehicle. Failure to observe these precautions could lead to the ignition of the natural gas, which could cause severe bodily injury, death, or property damage.

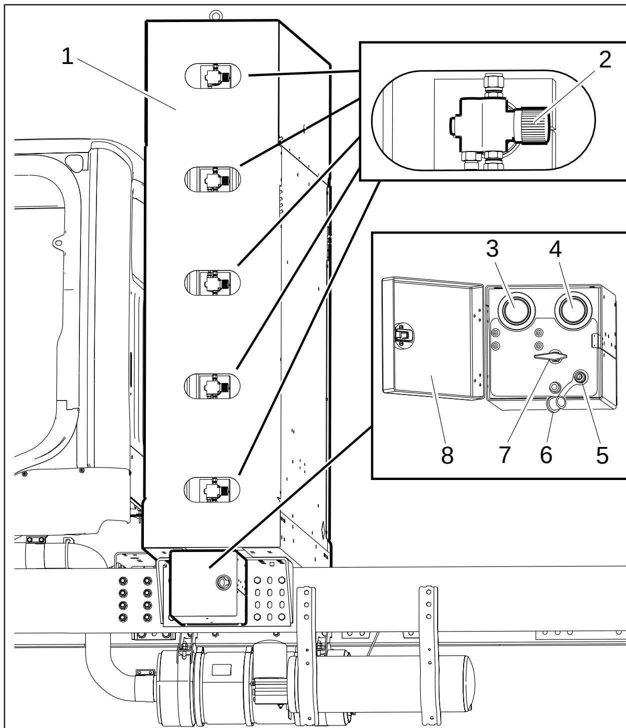
Welding

IMPORTANT: Follow all local, state, and federal guidelines regarding usage and venting of compressed natural gas (CNG).

1. Park the vehicle on a level surface, shut down the engine and set the parking brake. Chock the tires.
2. Close the CNG fuel cylinder shutoff valves. See **Fig. 1**.
3. Start the engine and let it idle until the fuel lines are empty and the engine stops. The gauges on the fuel panel should now read at or near 0 psi (0 kPa).
4. Close the manual fuel shutoff valve on the fuel panel.
5. Remove and save the two capscrews that secure the access cover to the fill panel, then remove the access cover. See **Fig. 2**.
6. Slowly open the bleed valve on the manifold to relieve remaining fuel pressure within the system. See **Fig. 3**.

IMPORTANT: Some pressure may remain in the fuel system between the solenoid valve and the engine. Use caution when loosening fittings, as a small amount of gas may leak out.

7. Disconnect the wiring harness from the solenoid valve.
8. Use a remote 12-volt power source to activate the solenoid valve to drain any compressed natural gas remaining in the fuel system between the solenoid valve and the engine.



1. Fuel Cylinder Storage Box
2. Fuel Cylinder Shutoff Valves (5 valves on a 5-tank system)
3. High-Pressure Gauge
4. Low-Pressure Gauge
5. Fuel Fill Port
6. Dust Cap
7. Manual Shutoff Valve
8. Fuel Panel Access Door

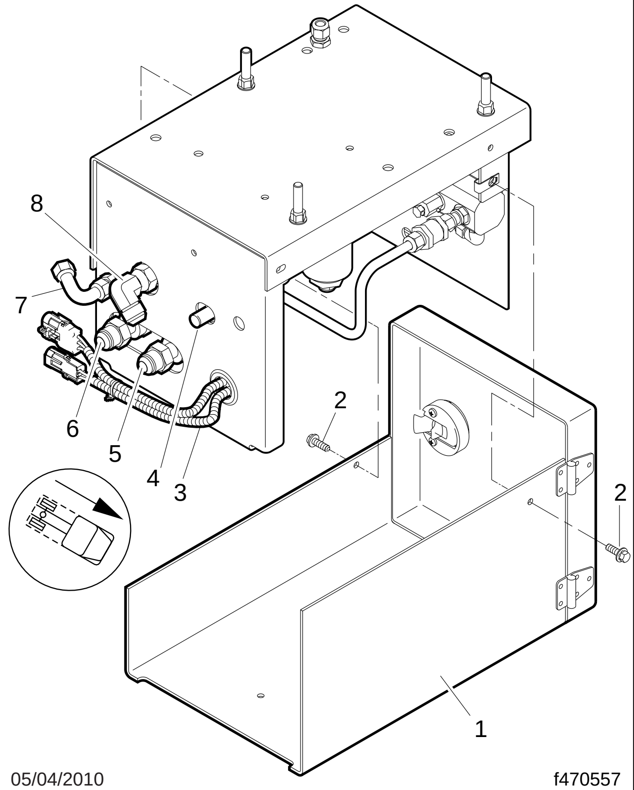
Fig. 1, CNG Fuel Cylinder Storage Box (5-cylinder system shown)

NOTICE

Disconnect the battery power and ground cables and any electronic control units (ECUs) installed on the vehicle. Electric currents produced during electric welding can damage various electrical components on the vehicle, such as alternator diodes and ECUs. Freightliner vehicle components that typically use ECUs include electronic engine, electronic automatic transmission, and antilock braking system (ABS).

For any ECU with a battery power harness, disconnect its ground terminal from the chassis ground, and disconnect its power terminal from

Welding a CNG Vehicle



NOTE: CNG fuel panel may be located on the right side of the vehicle.

1. Fuel Panel Access Cover
2. Capscrews (qty 2)
3. Wiring Harness
4. Pressure Relief Valve and Cap
5. Coolant Outlet Line
6. Coolant Inlet Line
7. Fuel Inlet Line (from fuel cylinders)
8. Fuel Outlet Line (to engine)

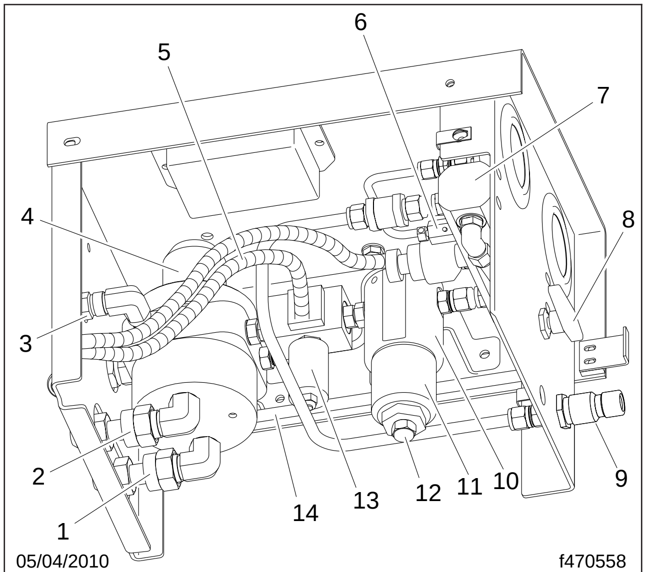
Fig. 2, CNG Fuel Panel Assembly

the battery positive post, or disconnect the main connection at the ECU.

9. Shut down all vehicle electrical systems and disconnect the battery.

10. Let the vehicle sit in a well-ventilated area for at least 10 minutes.

IMPORTANT: Do not weld in areas directly adjacent to CNG tanks. Avoid direct heat exposure on tanks.



1. Coolant Inlet Port
2. Coolant Outlet Port
3. Pressure Relief Valve
4. Pressure Regulator
5. Wiring Harness
6. Manifold Bleed Valve
7. Manifold
8. Manual Fuel Shutoff Valve
9. Fuel Fill Port
10. Filter Housing
11. Filter Bowl
12. Filter Drain Plug
13. Solenoid Valve
14. Fuel Line to Cylinders

Fig. 3, CNG Fuel Panel Components

11. Cover the CNG tanks and fuel lines with a metal shield or welding blankets to prevent sparks or residue from contacting CNG equipment.

12. Complete all necessary welding, then remove the protective welding blankets or metal shield.

13. Start up the vehicle electrical system and connect the battery.

14. Connect the electrical harness to the solenoid valve.

15. Close the bleed valve on the manifold and open the manual fuel shutoff valve on the fuel panel.

16. Open the fuel cylinder shutoff valves.

17. Start the engine and check for gas leaks in the fuel system.

Using a methane detector, leak test all fuel system components. A bubble solution can be used to pinpoint the exact location of leaks.

Repair or replace any leaking components.

18. Using the two capscrews removed previously, install the access cover on the fill panel.

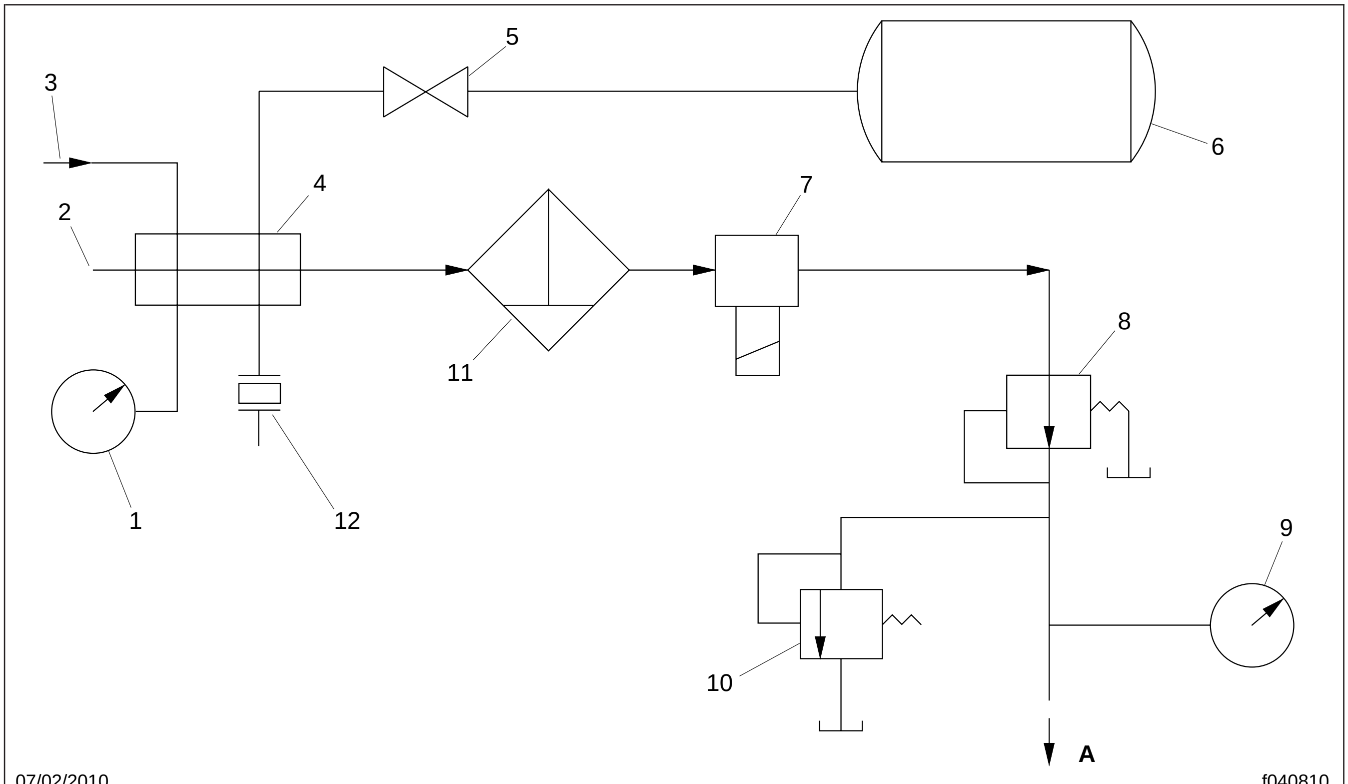
Troubleshooting

See **Fig. 1** for a schematic of all CNG fuel system components.

See **Fig. 2** for a flow chart to troubleshoot problems with an engine running lean.

See **Fig. 3** for a flow chart to troubleshoot a faulty dash-mounted fuel gauge reading.

See **Fig. 4** for a flow chart to troubleshoot a compressed natural gas leak in the fuel system.



A. Fuel flow to engine.

1. High-Pressure Gauge
2. Bleed Port
3. Fuel Fill Port
4. Manifold
5. Shutoff Valve
6. CNG Fuel Cylinder(s)
7. High-Pressure Solenoid Valve
8. Pressure Regulator
9. Low-Pressure Gauge
10. Pressure Relief Valve
11. High-Pressure Fuel Filter
12. Pressure Transducer

Fig. 1, CNG Fuel System Schematic

Troubleshooting

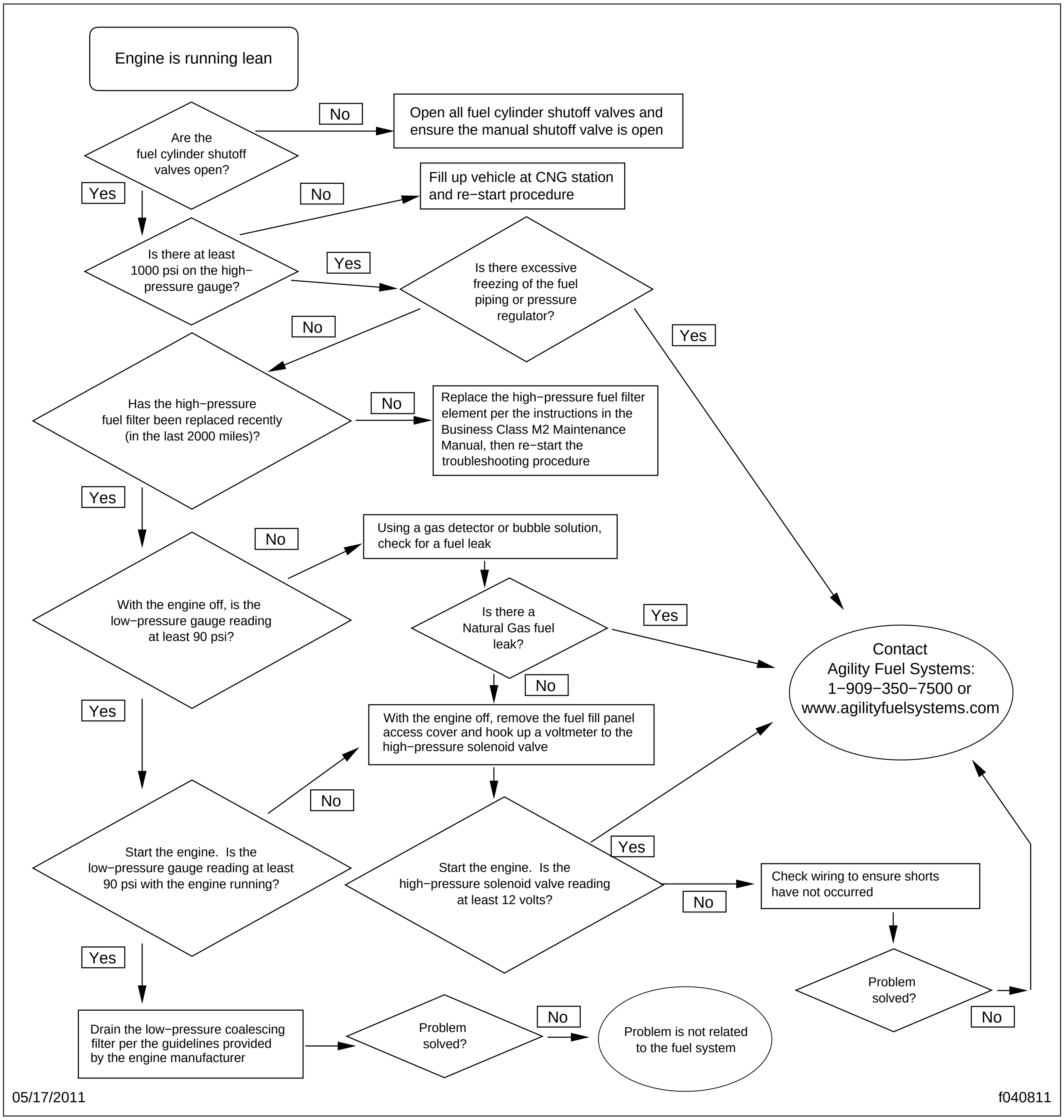


Fig. 2, Flow Chart: Engine Running Lean

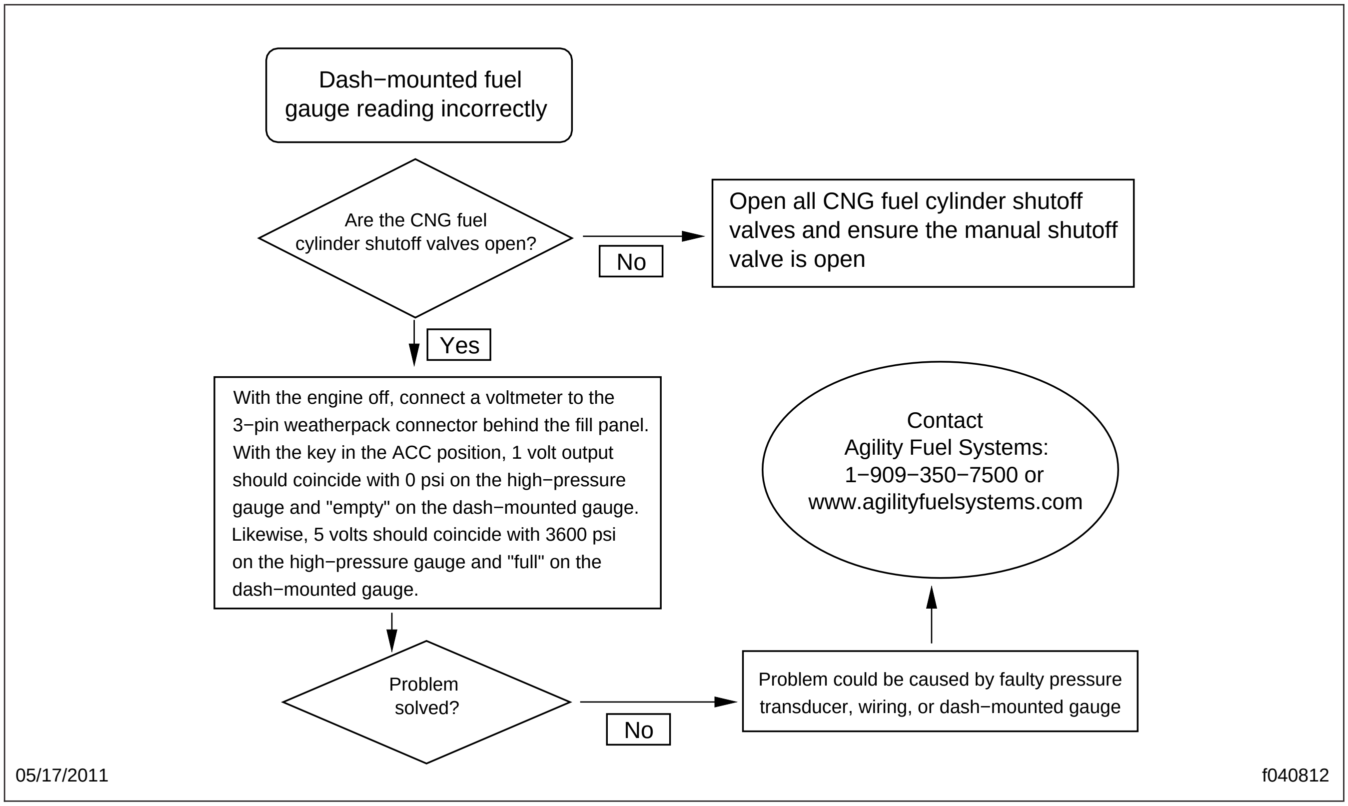


Fig. 3, Flow Chart: Faulty Dash Gauge

Troubleshooting

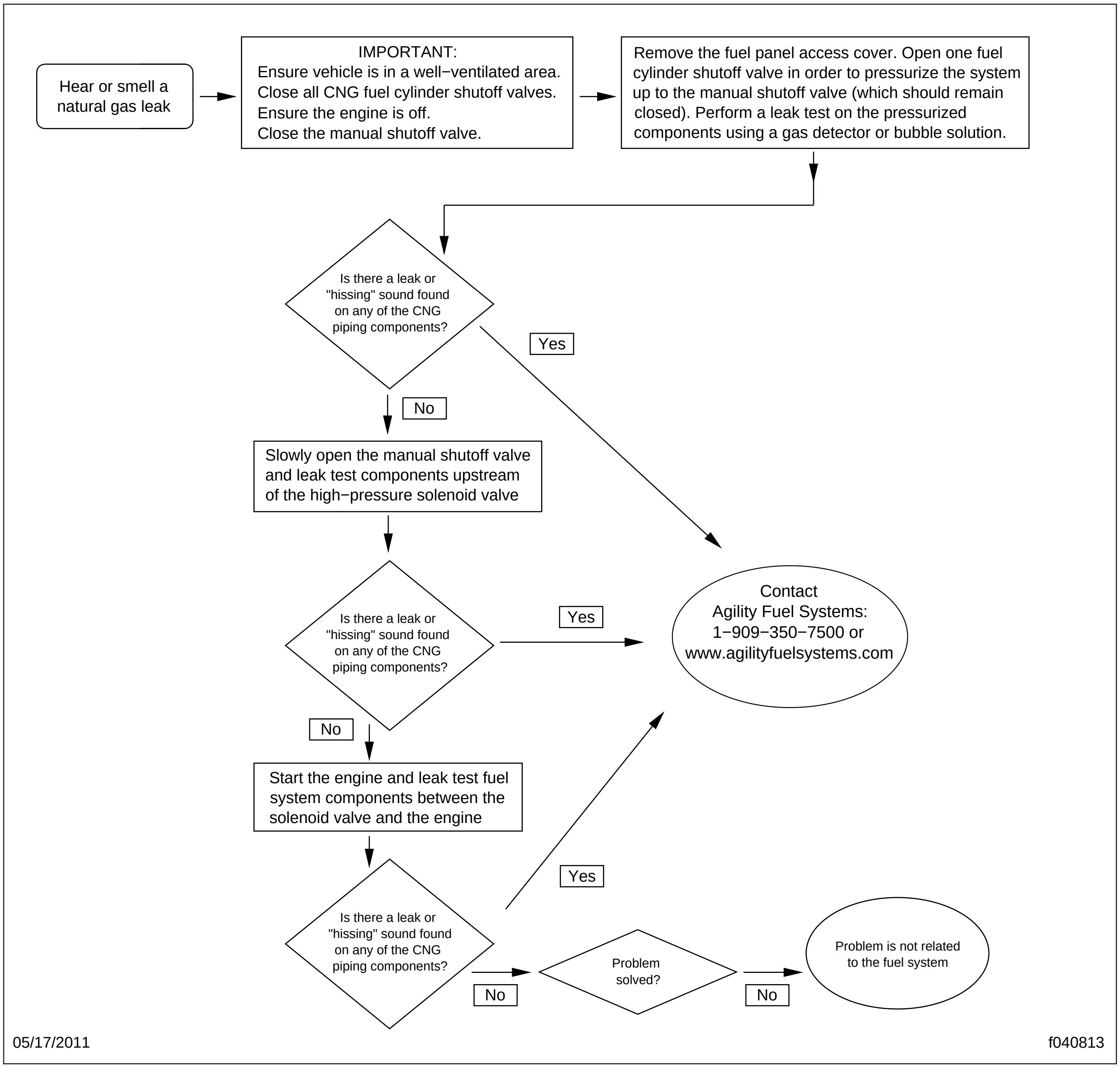


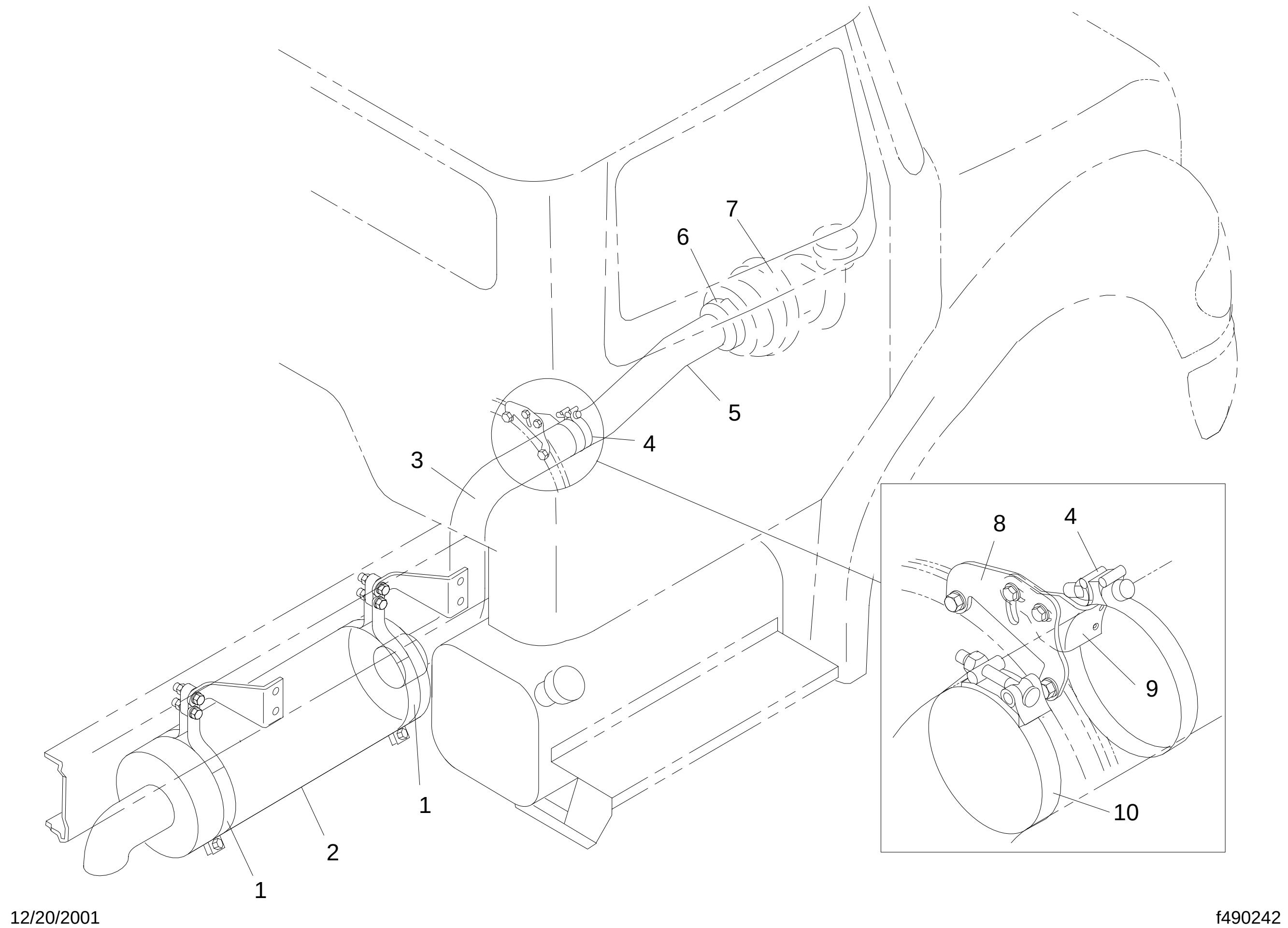
Fig. 4, Flow Chart: Gas Leak

General Information

The exhaust system routes hot exhaust gas away from the cab, and reduces engine exhaust noise. See **Fig. 1**. Business Class M2 vehicles have a horizontally mounted muffler on the right side of the vehicle and are available with a horizontal outlet.

Most exhaust installations consist of an engine exhaust pipe, sometimes called the turbo pipe, mounted to the rear of the turbocharger and secured with a V-clamp. A narrow-band clamp holds the exhaust pipe to the muffler.

A horizontal muffler hangs from brackets mounted inside the frame rail web. All exhaust components attach to either the engine or the chassis frame rails.



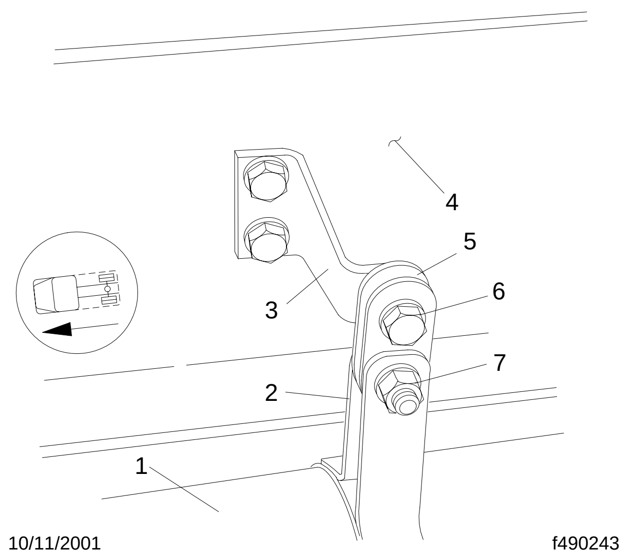
1. Muffler Mounting Band
2. Muffler
3. Exhaust Mid-Pipe
4. T-Bolt Clamp
5. Outlet Exhaust Pipe
6. V-Clamp Engine
7. Turbocharger
8. Exhaust Support Plate (attached to transmission)
9. Bracket
10. Narrow-Band Exhaust Clamp

Fig. 1, Horizontal Exhaust Mounting (Caterpillar 3126 engine)

System components include the engine outlet exhaust pipe, muffler, muffler mounting components, narrow-band exhaust clamps, and tail pipe.

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Loosen the clamp holding the muffler to the exhaust pipe.
3. Remove the fasteners holding the muffler mounting clamps to the rubber isolators. See **Fig. 1**.



1. Muffler
2. Muffler Mounting Band
3. Mounting Bracket
4. Frame Rail
5. Rubber Isolator
6. Hexbolt and Washer
7. Hexnut and Washer

Fig. 1, Muffler Mounting Components

4. Remove the muffler and tailpipe from the vehicle.

Installation

1. If installing a new muffler, loosely install the muffler mounting bands to the muffler. The bands should be loose enough so you can rotate and slide them. See **Fig. 2**.
2. Position the muffler, aligning the ears of the muffler bands with the rubber isolators attached to the frame.

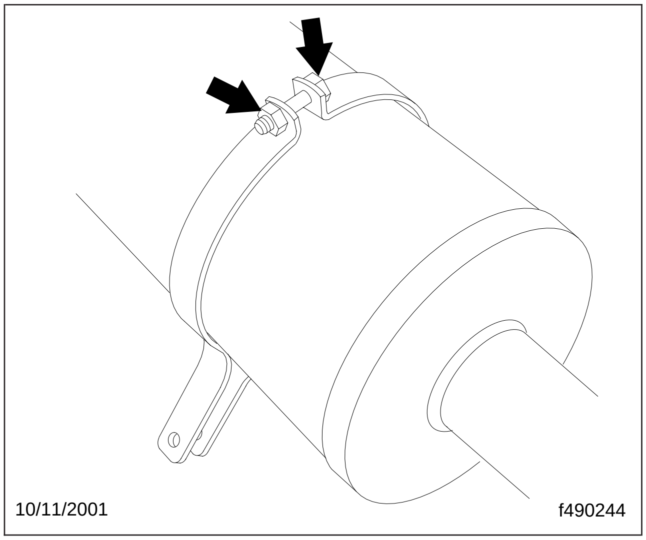
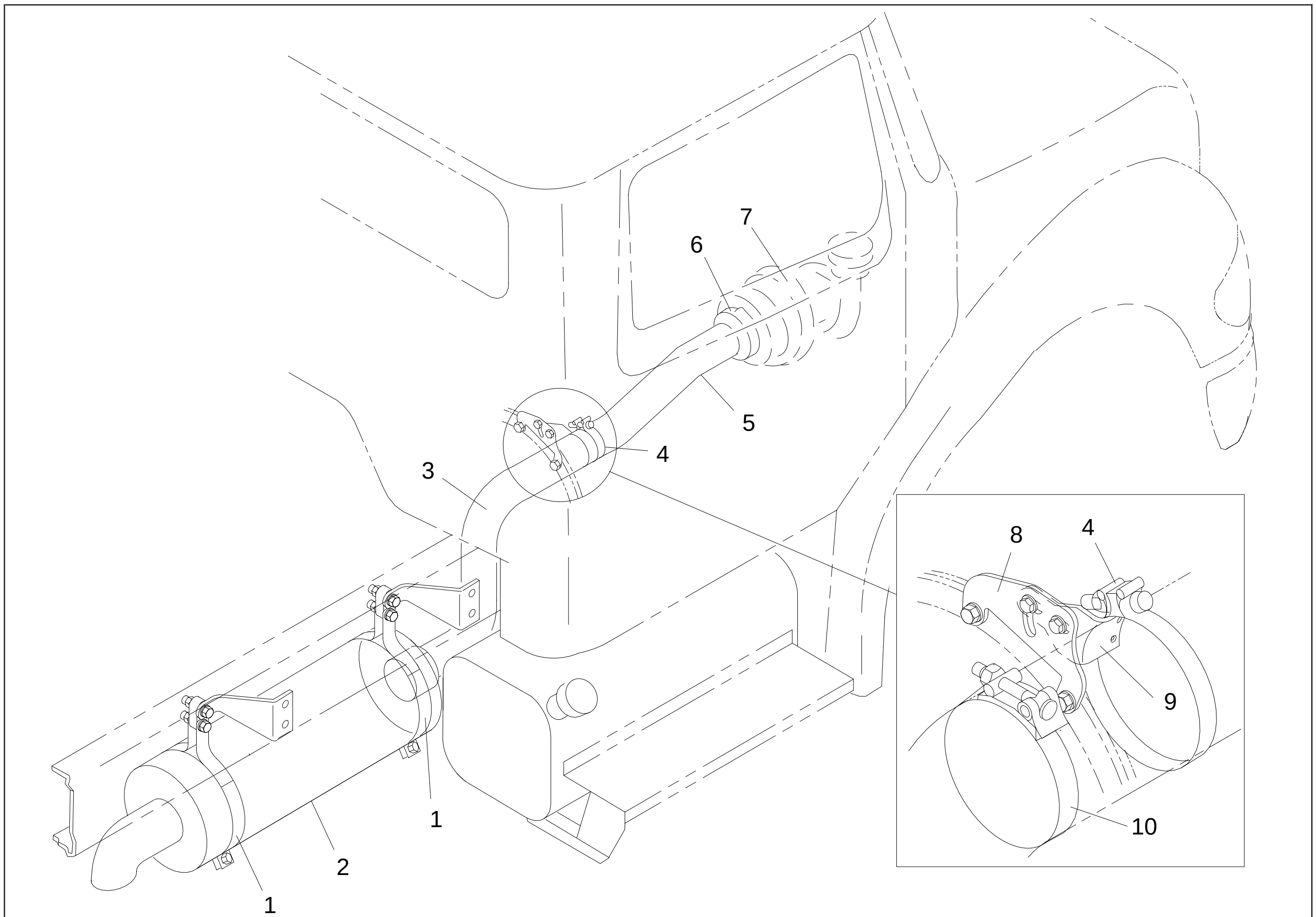


Fig. 2, Installing the Muffler Mounting Bands

3. Push the front of the muffler over the end of the exhaust pipe.
4. If needed, adjust the muffler mounting bands so the ears align with the rubber isolators.
5. Loosely attach the muffler bands to the isolators.
6. Make sure the muffler is pushed all the way onto the end of the exhaust pipe.
7. Install a narrow-band exhaust clamp onto the end of the muffler. Tighten it firmly.
8. Tighten the fasteners holding the muffler to the isolators.
9. If applicable, install the tail pipe to the end of the muffler, using a narrow-band exhaust clamp. Tighten the clamp firmly.
10. Start the engine and check for leaks. Tighten any fasteners as needed.
11. Remove the chocks from the tires.

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Remove the section of exhaust pipe between the muffer and the transmission. See **Fig. 1**.



1. Muffler Mounting Band
2. Muffler
3. Exhaust Mid-Pipe
4. T-Bolt Clamp
5. Outlet Exhaust Pipe
6. V-Clamp Engine
7. Turbocharger
8. Exhaust Support Plate (attached to transmission)
9. Bracket
10. Narrow-Band Exhaust Clamp

Fig. 1, Horizontal Exhaust Mounting (Caterpillar 3126 engine)

2.1 Loosen the narrow-band clamp holding the front and rear sections of the exhaust piping together.

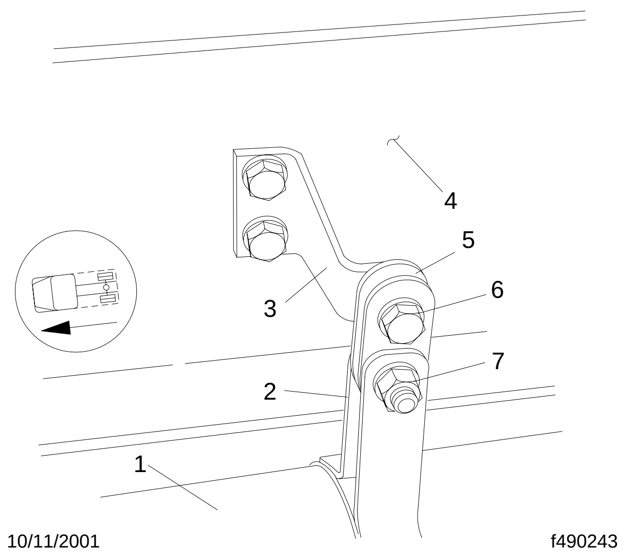
2.2 Remove the fasteners holding the muffler mounting clamps to the rubber isolators. See **Fig. 2**.

2.3 Remove the rear section of the exhaust pipe and the muffler together.

2.4 Loosen the clamp holding the exhaust pipe to the muffler and disconnect the pipe from the muffler.

3. Remove the forward section of the exhaust pipe.

Exhaust Piping Replacement



1. Muffler
2. Muffler Mounting Band
3. Mounting Bracket
4. Frame Rail
5. Rubber Isolator
6. Hexbolt and Washer
7. Hexnut and Washer

Fig. 2, Muffler Mounting Components

3.1 Loosen the V-clamp holding the exhaust pipe to the turbocharger.

3.2 Loosen the clamp holding the exhaust pipe to the bracket on the transmission.

3.3 Remove the exhaust pipe from the vehicle.

4. If applicable, remove the tailpipe.

Installation

1. Connect the forward section of the exhaust pipe to the turbocharger. Tighten the exhaust clamp just enough to hold it in place.
2. If it was removed, connect the muffler to the rear section of the exhaust pipe. Make sure the exhaust pipe is all the way inside the end of the muffler, then tighten the exhaust clamp snugly.
3. Place the rear section of the exhaust pipe and the muffler in position and push the rear exhaust pipe over the end of the front exhaust pipe.
4. Loosely connect the muffler to the frame mounted isolators.
5. Install the narrow band exhaust clamp.
6. As needed, adjust the pipes so that they are in a straight line.
7. Fully tighten the two exhaust clamps and the muffler mounting fasteners.
8. Start the engine and check for leaks. Tighten any connections as needed.
9. Remove the chocks from the tires.

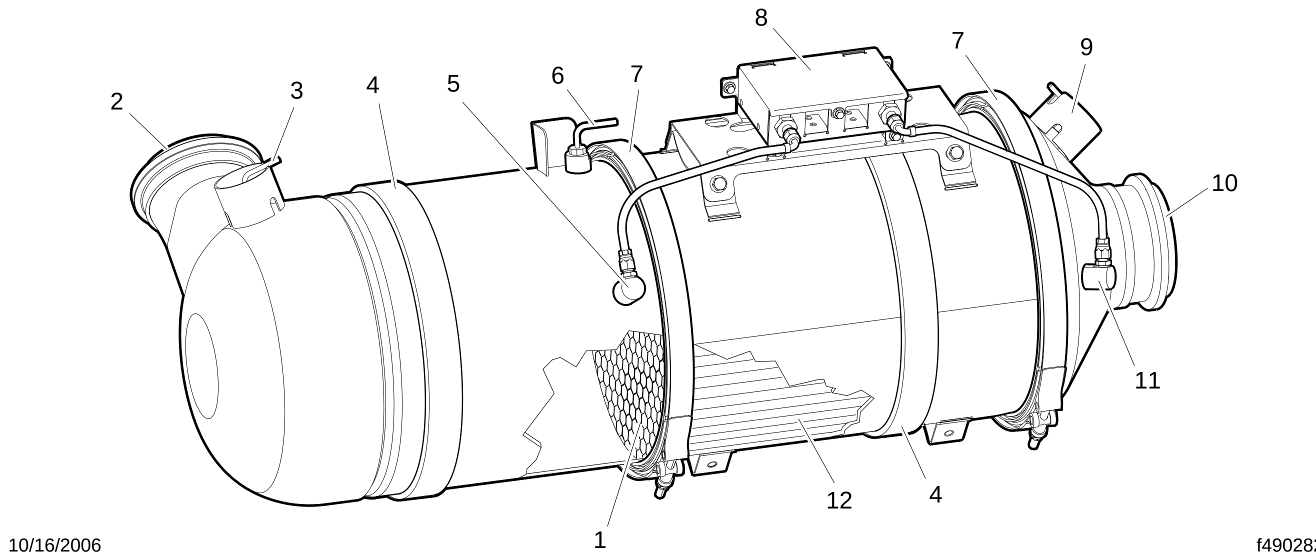
General Information

The aftertreatment system (ATS), introduced to meet the requirements of the EPA07 emission control regulations, includes all the piping and equipment between the turbocharger outlet and the tip of the exhaust pipe. It resembles the exhaust system on pre-EPA07 vehicles, but includes an aftertreatment device (ATD) instead of a muffler (see **Fig. 1**), and other equipment. Monitoring and operation of the ATS is controlled by an electronic control module (ECM).

EPA07 emissions regulations limit NOx to just over 1 gram per brake horsepower hour (g/bhp-hr) and particulate matter cannot exceed 0.01 g/bhp-hr. EPA07 engines require ultralow sulphur diesel (ULSD) fuel, for low emissions and long life of the diesel particulate filter (DPF), a honeycomb soot filter inside the ATD.

Engine manufacturers use different methods and equipment to reduce emissions from their engines, but an ATD is used on all of them. The ATD is always chassis-mounted, but can be mounted either vertically or horizontally. ATS exhaust piping is stainless steel.

Inside the ATD, the exhaust first passes through the diesel oxidation catalyst (DOC) where combustion gases are chemically broken down to water and carbon dioxide, then through the (DPF), where solid particles are trapped. The trapped particles are almost completely vaporized in the DPF in regeneration, sometimes shortened to the term, "regen." The soot from engine oil additives which cannot be vaporized is burned to ash and held in the DPF until it eventually builds up, and the DPF must be removed and physically cleaned.



1. Diesel Particulate Filter (DPF) Ceramic Honeycomb Substrate Openings
2. Marmon Fitting at Inlet from Turbocharger
3. Diesel Oxidation Catalyst (DOC) Intake Temperature Sensor
4. ATD Mounting Band
5. DPF Intake Pressure Sensor
6. DOC Outlet Temperature Sensor (connection to sensor housing not shown)
7. DPF V-Band Mounting Clamps
8. Sensor Housing
9. DPF Outlet Temperature Sensor (connection to sensor housing not shown)
10. Exhaust Outlet Marmon Fitting
11. DPF Outlet Pressure Sensor
12. DPF Substrate Tubes

Fig. 1, ATD Components (typical)

IMPORTANT: To minimize soot buildup on the DPF, low-ash oil is necessary for maximum service between physical cleanings. Only low-ash oil should be used in EPA07 engines.

NOTE: Freightliner documentation deals only with removal and installation of the components of the ATS. Refer to the engine manufacturer's

General Information

service literature for all testing, disassembly, cleaning, and repair of the ATD and other components.

IMPORTANT: The ATS is part of an integrated engine and emissions management system, controlled by the ECM. Follow the engine manufacturer's procedures, and use the correct equipment when diagnosing or working on any part of the ATS.

Regeneration

There are two types of regeneration; passive and active.

Passive regeneration happens whenever the ATD internal temperature is 572°F (300°C) or higher. This happens during normal loaded vehicle operation, and exhaust gas temperature is no higher than normal. Under load and at highway speeds, passive regeneration may be all that is necessary to keep the DPF clear. But running light loads, or at low speeds, does not generate enough heat in the ATD for passive regeneration, and soot builds up in the DPF.

As soot builds up in the DPF, it creates back pressure and decreases engine efficiency. So at intervals determined by the ECM, which keeps track of measurements such as engine hours, fuel consumed, and mileage, the ATS raises the temperature inside the ATD to burn the built-up soot to ash. This reduces the back pressure and allows the DPF to continue operating efficiently for tens of thousands of miles.

During active regeneration, engine rpm rise to fast-idle speed and extra fuel is injected into the ATD to raise its interior temperature very high, over 1112°F (600°C), and turn the trapped soot to harmless ash. There are two types of active regeneration; at-speed and parked.

- When conditions permit, the ECM automatically initiates at-speed regeneration. The exact conditions for regeneration vary, according to the engine manufacturer's design. Generally, it can happen only when the vehicle speed is above 7.5 mph, and active regeneration stops when the vehicle slows to 5 mph or below.
- Parked regeneration is initiated by a driver or technician when the vehicle is safely parked with the exhaust outlet well away from any flammable substance, a specific sequence of procedures is followed, and the driver pushes the regeneration button on the dashboard. The parked regeneration sequence varies according to engine and vehicle configuration, but it must be exactly followed or regeneration cannot happen. Follow the exact sequence prescribed for the vehicle, according to the engine manufacturer's literature.

EPA07 Aftertreatment Device Removal and Installation

Removal

These instructions are generalized, because vehicle configurations vary widely. The basic procedures apply to all aftertreatment systems. For service and repair beyond removal and installation, refer to the engine manufacturer's service literature.

NOTE: For test or service procedures on components of the ATS, consult the engine manufacturer's service literature.

NOTICE

The ATD assembly weighs from 125 to 150 pounds (57 to 68 kg) and must be protected from impact or sharp jolts. Dropping the ATD, or subjecting it to jarring impact can crack the diesel particulate filter (DPF) inside, which is built on a ceramic substrate. If that happens, the DPF is ruined and must be replaced.

A secure support is necessary to remove and install the ATD safely. The ATD must be held securely to protect it from falling, or hitting hard against something else.

The horizontal ATD lifting device (TLZ00785) is designed to handle a horizontal ATD. Vertical ATDs require a shop hoist secured to the lifting ears on top.

The aftertreatment device (ATD) is constructed so that its exterior operating temperature is comparable to that of a standard muffler, but during active regeneration, when a fuel mist is injected to raise its temperature and destroy soot deposits, its interior (see Fig. 1) and the outlet become hot enough to melt or ignite many common materials.

WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

1. Set the parking brake and chock the tires.

NOTE: Never attempt to start the vehicle with the ATD removed or with the ATD sensors disconnected, unless the engine manufacturer's documentation allows it for a diagnostic procedure.

2. Disconnect the connections at the sensor housing and the diesel oxidation catalyst (DOC) inlet temperature sensor. See Fig. 1.
3. Mark the Marmon fitting joints and mounting bracket orientation to the ATD, so that it can be installed exactly as it was removed. See Fig. 2.

NOTE: There are guide pins (see Fig. 3) to position the ATD during vehicle manufacture, but they are designed to break off if they are stressed. The most important thing about ATD mounting is that the other ATS components, particularly the bellows, must align correctly.

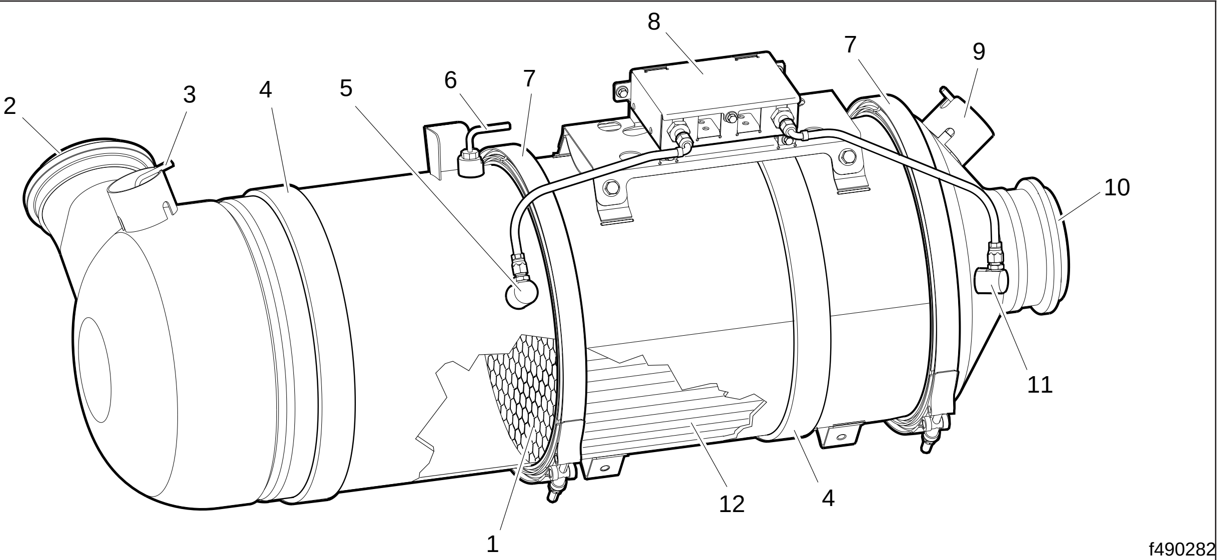
4. If the ATD is horizontally mounted, raise the ATD-handling device into place against it, so that the ATD is supported securely. If the ATD is vertically mounted, attach a shop crane or similar device to the lifting ears and take up the slack so that the lifting device is beginning to take the weight of the ATD.
5. The exhaust pipe may require support, such as a rope sling, to support it when the ATD is removed. If such support is required, install it now.

NOTICE

Be careful not to stress or twist the bellows as the ATD is manipulated. The bellows is not designed to support weight or withstand undue stress and can easily be damaged, requiring expensive replacement.

6. Remove the clamps from the Marmon fittings at the ATD inlet and outlet.
7. Remove the two mounting bands that hold the ATD to its mounting brackets, so that the ATD is held by the ATD handling device.

EPA07 Aftertreatment Device Removal and Installation



1. Diesel Particulate Filter (DPF) Front End Honeycomb
2. Marmon Fitting at Inlet from Turbocharger
3. Diesel Oxidation Catalyst (DOC) Intake Temperature Sensor
4. ATD Mounting Band
5. DPF Intake Pressure Sensor
6. DOC Outlet Temperature Sensor (connection to sensor housing not shown)
7. DPF V-Band Mounting Clamp
8. Sensor Housing
9. DPF Outlet Temperature Sensor (connection to sensor housing not shown)
10. Exhaust Outlet Marmon Fitting
11. DPF Outlet Pressure Sensor
12. DPF Ceramic Substrate

Fig. 1, Typical ATD

NOTE: It may be necessary to raise the vehicle, or remove heat shields or body panels, to remove the ATD.

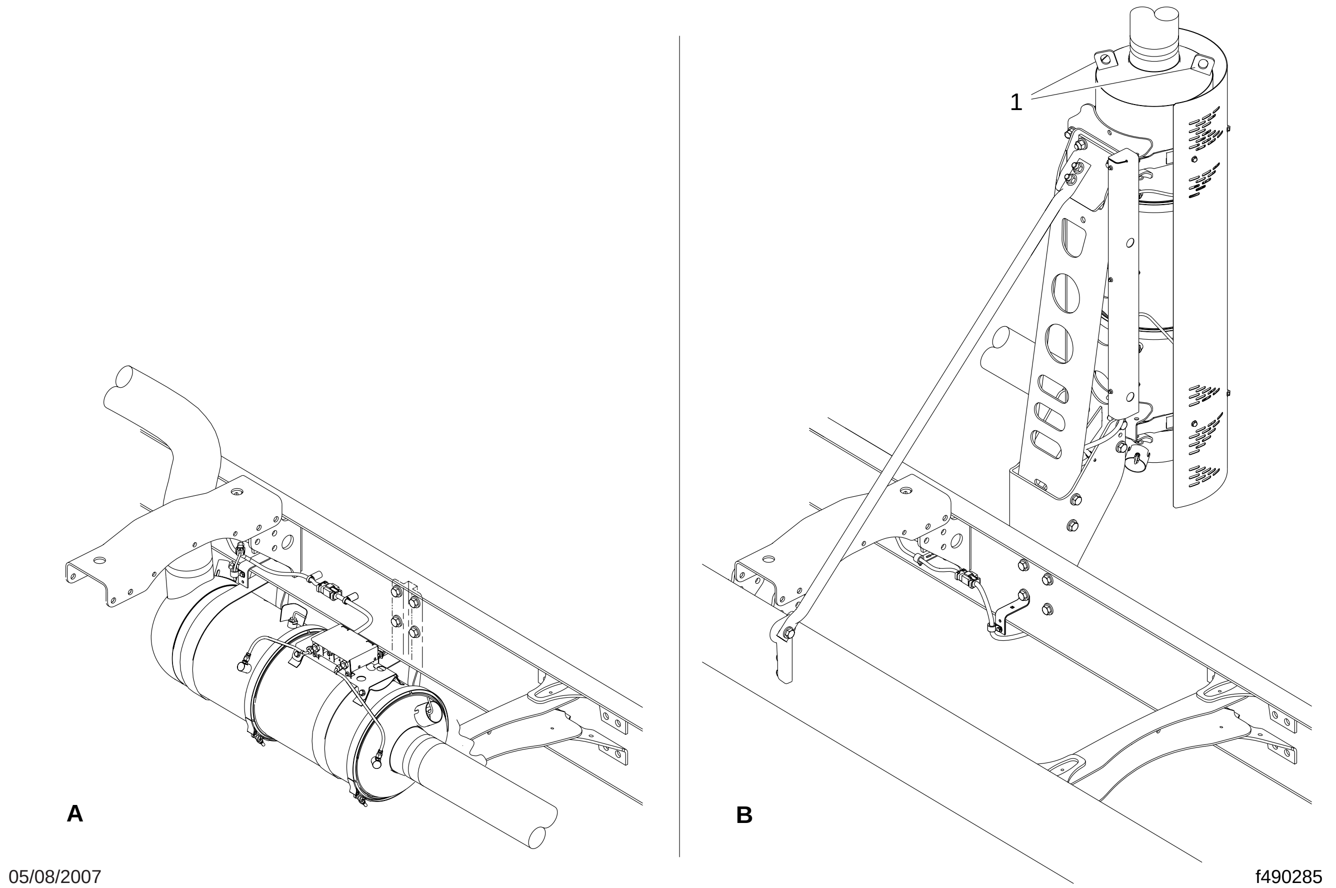
8. Move the ATD handling device slightly, so that the ATD positioning pin (see **Fig. 4**) clears its hole in the mounting bracket. Carefully remove the ATD from the vehicle.

NOTE: ATD component service procedures, such as cleaning the DPF or servicing the sensors, are documented in the engine manufacturers' service literature.

Installation

1. Use the ATD handling device to move the ATD into position, so the inlet and exhaust align with the inlet and exhaust piping. Be sure the ATD positioning pin engages its hole in the ATD mounting bracket, or that the positioning marks align.
2. Install the ATD mounting bands, but do not tighten them yet.
3. Position the V-band clamps on the Marmon fittings and tighten them to the value shown in **Table 1**.
4. Tighten the ATD mounting bands to the value shown in **Table 1**.
5. Connect the harness to the sensor housing and the front temperature sensor.
6. Remove the ATD handling device.
7. If a support was fastened around the exhaust pipe, remove it.
8. Operate the vehicle and check for leaks.

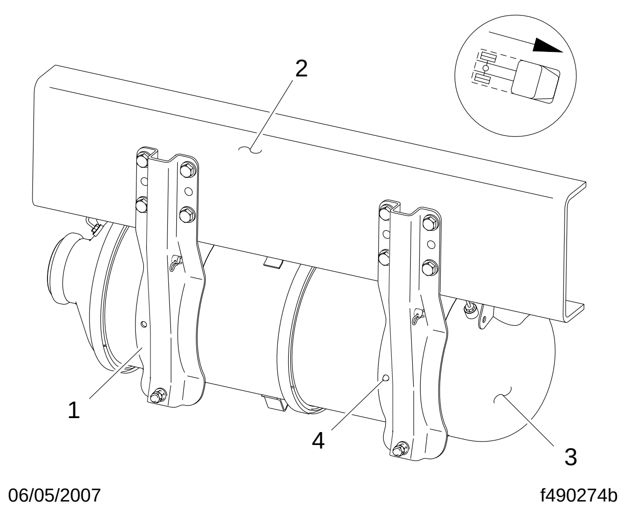
EPA07 Aftertreatment Device Removal and Installation



A. Typical Horizontal ATD Layout
B. Typical Vertical ATD Layout
1. Vertical ATD Lifting Ears

Fig. 2, ATD Mounting Options

EPA07 Aftertreatment Device Removal and Installation

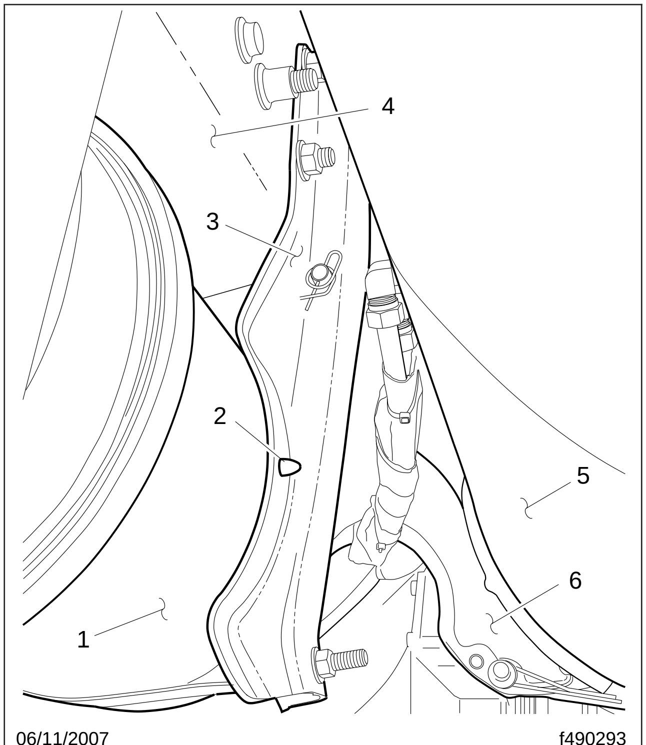


1. ATD Mounting Bracket
2. Chassis Frame Rail
3. ATD Inlet End
4. ATD Positioning Pin

Fig. 3, ATD Mounting on Frame Rail

ATD Torque Values	
Fitting	**Torque: lbf·ft (N·m)**
Mounting Bands	Initial: 15 (20) Final: 30 (41)
Temperature Sensor Nuts	26–29 (35–39)
Pressure Line Tube Nuts	11–13 (15–17)
Pressure Sensor Jam Nuts	15–18 (20–25)
Marmon V-Band Clamps	12–13 (16–17)
Compression Fittings	15–18 (20–25)
Bellows Torco Clamps	Target: 41 (56) Range: 35–48 (48–64)

Table 1, ATD Torque Values



1. ATD
2. ATD Positioning Pin
3. ATD Mounting Bracket
4. Chassis Frame Rail
5. Fuel Tank
6. Fuel Tank Mounting Bracket

Fig. 4, ATD Mounting Bracket

EPA07 Aftertreatment System Bellows Replacement

Replacement

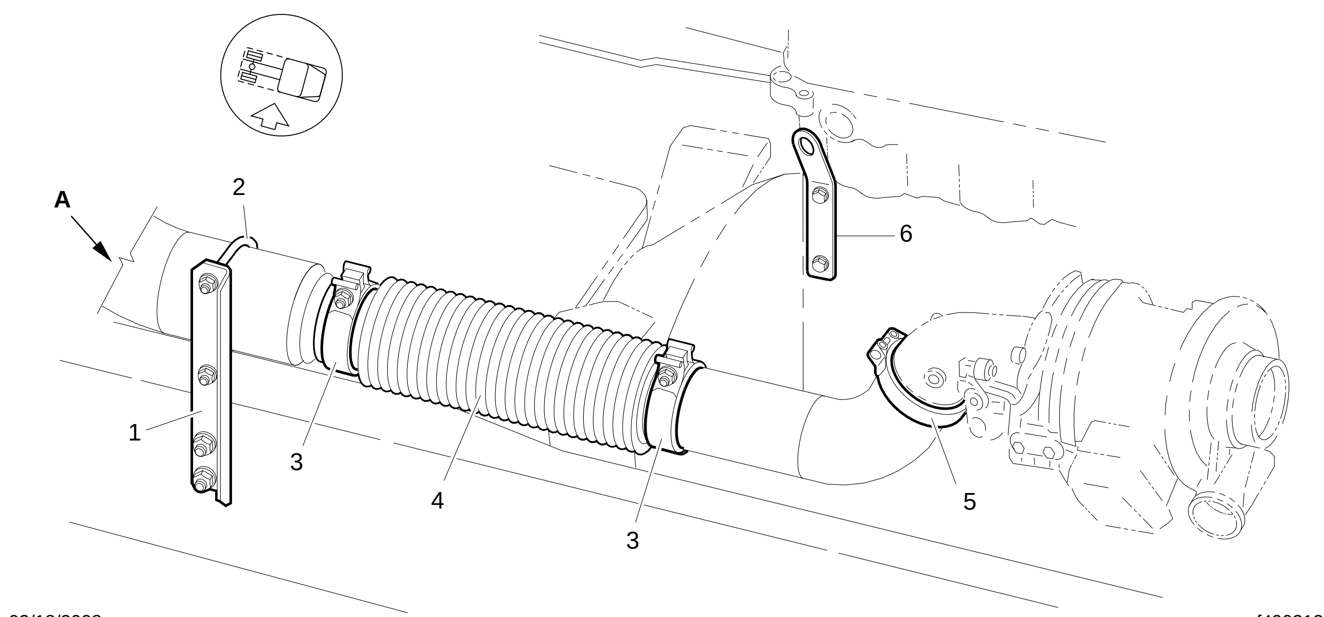
1. Open the hood.
2. Open the tool box under the passenger-side door, and remove the cover.
3. Remove the right quarter fender and mud flap. For instructions, see **Group 88**.
4. Remove the V-clamp (**Fig. 1**, Item 5) that holds the turbo outlet pipe to the turbocharger.
5. Remove the U-clamp that holds the aftertreatment device (ATD) inlet pipe to the support bracket on the frame rail (**Fig. 1**, Item 2).
6. Remove the clamp that holds the exhaust pipe to the front of the ATD, then disconnect the exhaust pipe from the ATD.
7. Remove the bellows and exhaust pipes as a unit from under the vehicle. If the vehicle is equipped with side fairings, remove the parts from the rear of the vehicle.
8. Place the assembly on a work bench. Loosen and spread the seal clamps on the ends of the bellows. Pry the ends of the bellows off the exhaust pipes, being careful not to damage the exhaust pipe ends. If it is not possible to remove the bellows this way, proceed as follows:

WARNING

Always wear a face shield and other appropriate protection when using a cutting wheel.

The cut edges of the bellows are extremely sharp, and can cause serious injury. Wear appropriate protective gear, including heavy gloves and a face shield, when removing the bellows from the exhaust pipes.

9. If you cannot remove the bellows by prying, use a cutoff wheel to cut through each end of the bellows between the exhaust pipe ends. Be careful not to cut the exhaust pipes. Discard the center section of the bellows when it is cut loose.



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A. To the Aftertreatment Device (ATD)

1. Frame-rail Support Bracket
2. U-Clamp
3. Seal Clamp
4. Bellows
5. V-Clamp
6. Bellows Support Bracket

Fig. 1, Bellows Installation

EPA07 Aftertreatment System Bellows Replacement

10. Carefully remove the bellows ends and clamps from the exhaust pipes, either by prying them off, or by driving them off with a soft drift. Be careful not to damage the exhaust pipes.

IMPORTANT: Take the following measurements *before* installing the bellows.

The main section of the ATD inlet pipe is a larger diameter than the turbo outlet pipe. Make sure you measure at the **end** of the pipe, where it inserts into the bellows. The two measurements should be identical. If they are not, loosen the U-clamp nuts that hold the ATD inlet pipe to the frame-rail support bracket, and move the pipe up or down as needed.

NOTICE

The ends of the ATD inlet pipe and the turbo outlet pipe must be in exact vertical and horizontal alignment before installing the new bellows. If they are not aligned the bellows will be twisted, and will fail after a short time.

11. Attach the turbo outlet pipe to the turbocharger, then to the bellows support bracket. Tighten the clamps enough to hold the pipe in place.
12. Attach the ATD inlet pipe to the ATD and the frame-rail support bracket. Tighten the clamps enough to hold the pipes in place.
13. Using a ruler or tape measure, measure the vertical distance between the end of the ATD inlet pipe and the frame rail. See **Fig. 2**. Do the same for the end of the turbo outlet pipe. The two measurements must be the same. If the measurements are different, loosen the U-clamp nuts on the frame-rail support bracket, and raise or lower the ATD inlet pipe as needed. Tighten the U-clamp nuts enough to hold the pipe in place.
14. Using a ruler (or a T-square) and a tape measure, measure the distance between each pipe end and the frame rail. See **Fig. 3**. If these two measurements are different, do one or more of the following adjustments (see **Fig. 4**):
    - Check that the U-clamp on the bellows support bracket is installed correctly, and is not crooked.
    - Rotate the turbo outlet pipe at the turbocharger.
    - Support the ATD with a suitable jack, then loosen the ATD straps and rotate the ATD.
    - Rotate the ATD inlet pipe at the Marmon flange on the ATD.
15. With the two pipe ends in horizontal and vertical alignment and the bellows not installed, measure the distance between them. See **Fig. 5**.

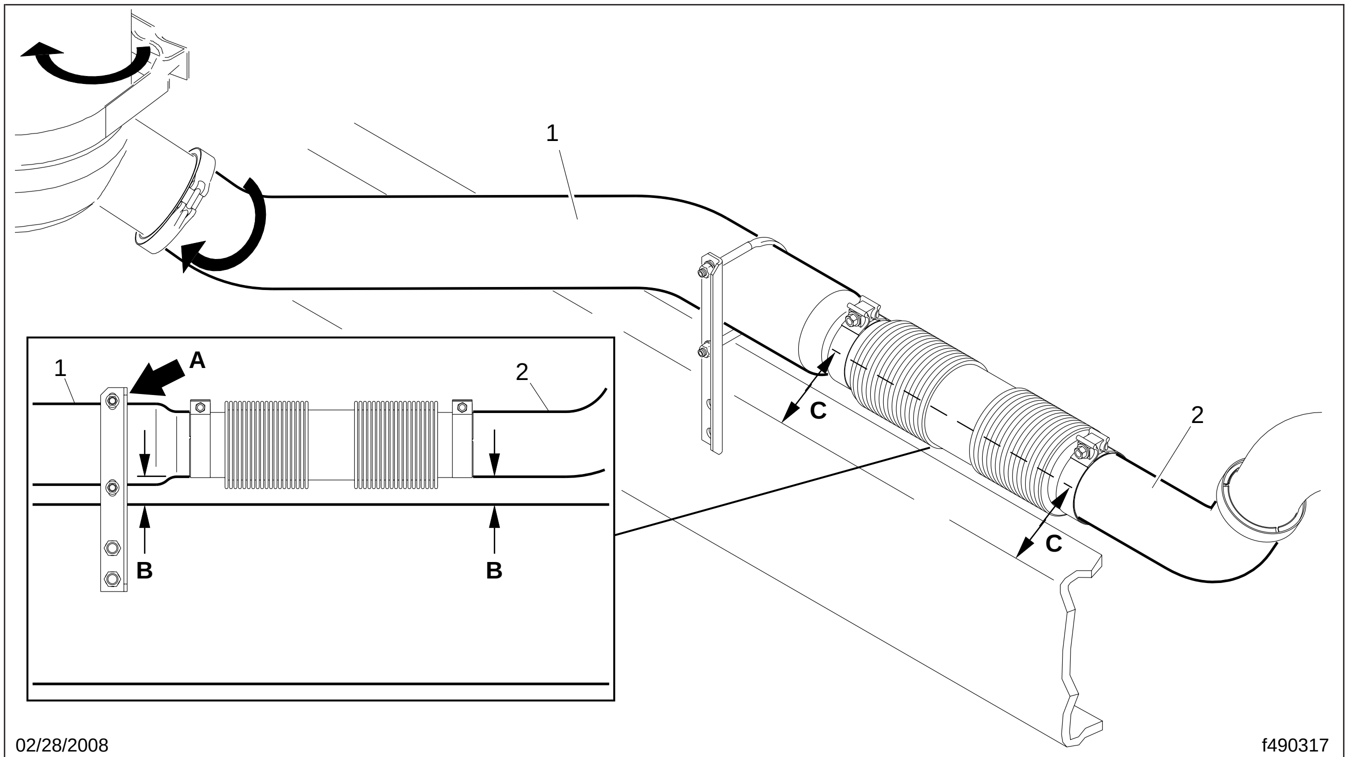
    The distance between the pipe ends is to be at least 14 inches (35.5 cm), but not more than 14-3/8 inches (36.5 cm).

    If the distance is less than the above, remove the turbo outlet pipe and the ATD inlet pipe, and cut off an equal amount from each pipe end, as needed; otherwise, go to the next step. Make sure you remove all burrs from the cut ends of the pipes.

IMPORTANT: If they were loosened, do not tighten the ATD mounting straps until the U-clamp nuts on the frame-rail support bracket are tightened to their final torque. To do otherwise will affect the alignment of the exhaust pipes.

16. When the horizontal and vertical alignment is the same for both exhaust pipes and the distances between the pipe ends is correct, tighten the U-clamp nuts on the frame-rail support bracket that holds the ATD inlet pipe in place. See **Subject 100** for torque values.
17. Tighten the V-clamp that holds the inlet pipe to the ATD. See **Subject 100** for torque values.
18. If applicable, tighten the mounting straps on the ATD, then remove the jack.
19. Remove the turbo outlet pipe from the turbocharger.
20. Remove any dirt or soot from the outer surface of the exhaust pipe ends to ease the installation of the new bellows.
21. Install the new bellows on the ATD inlet pipe, with the clamp nuts on top and facing outboard (**Fig. 2**).
22. Insert the end of the turbo outlet pipe into the bellows, then connect the pipe to the turbocharger and to the new bellows support bracket. See **Subject 100** for torque values.
23. Tighten the bellows seal clamps; see **Subject 100** for torque values.

EPA07 Aftertreatment System Bellows Replacement



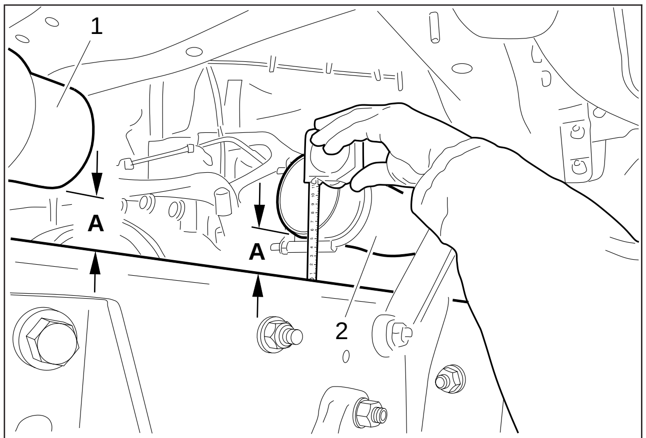
A. Up-and-down adjustment to be done at this bracket.
B. Vertical measurements to be the same.
C. Horizontal (in-and-out) measurements to be the same.

1. ATD Inlet Pipe
2. Turbo Outlet Pipe (support bracket not shown)

Fig. 2, Rotation and Adjustment Areas for Exhaust Pipe alignment (vertical ATD installation shown)

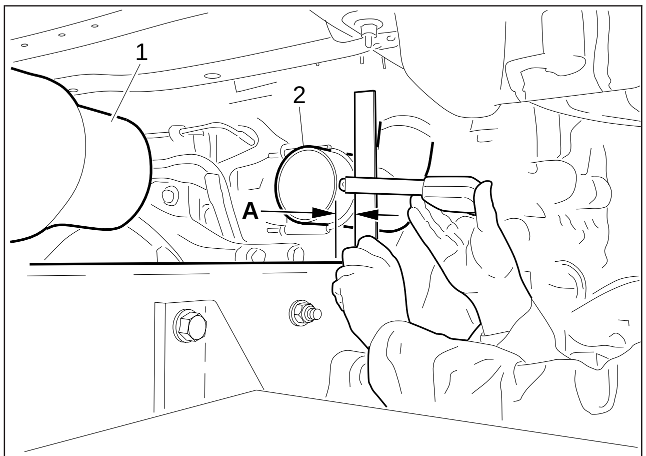
24. Start the engine and check for leaks. Shut down the engine, and tighten any clamps as needed.

EPA07 Aftertreatment System Bellows Replacement



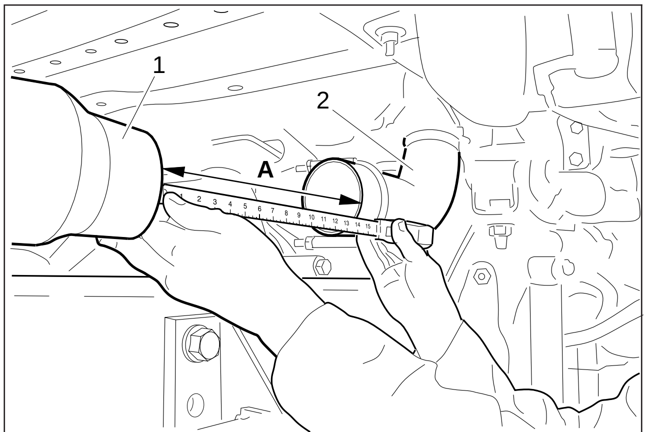
A. This distance must be the same at both exhaust-pipe ends.
1. ATD Inlet Pipe
2. Turbo Outlet Pipe

Fig. 3, Measuring the Vertical Distance



A. This distance must be the same at both exhaust-pipe ends.
1. ATD Inlet Pipe
2. Turbo Outlet Pipe

Fig. 4, Measuring the Horizontal Distance



A. This distance should be a minimum of 14 inches (35.5 cm) and a maximum of 14-3/8 inches (36.5 cm).
1. ATD Inlet Pipe
2. Turbo Outlet Pipe

Fig. 5, Measuring the Distance Between Pipe Ends

General Information

The Environmental Protection Agency (EPA) mandated that all engines built after December 31, 2009 must reduce the level of emissions exhausted by the engine to 0.2 grams per brake horsepower hour (g/bhp-hr) of nitrogen oxides (NOx).

To meet the EPA10 requirements, Daimler Trucks North America is using technology known as Selective Catalytic Reduction (SCR) in the exhaust aftertreatment system (ATS). The SCR process requires the introduction of diesel exhaust fluid (DEF) into the exhaust stream. DEF is colorless, non-toxic, and biodegradable.

IMPORTANT: The ATS is part of an integrated engine and emissions management system, controlled by the ACM. Follow the engine manufacturer's procedures, and use the correct equipment when diagnosing or working on any part of the ATS.

The ATS is always chassis-mounted, but there are several different installation options available to fit any needed vehicle configuration. ATS exhaust piping is stainless steel. The EPA10 aftertreatment system (ATS) includes all the piping and equipment between the turbocharger outlet and the tip of the exhaust pipe. It includes an aftertreatment device (ATD), an SCR catalyst, a DEF tank, tank header unit, pump, metering unit, DEF, aftertreatment control module (ACM), coolant, and air lines that run between each component. See **Fig. 1** for system components and function. Monitoring and operation of the ATS is controlled by an electronic control module (ACM).

EPA10 engines require ultralow sulfur diesel (ULSD) fuel, for low emissions and long life of the diesel particulate filter (DPF), a honeycomb soot filter inside the ATD. Inside the ATD, the exhaust first passes through the diesel oxidation catalyst (DOC) where combustion gasses are chemically broken down to water and carbon dioxide, then through the DPF, where solid particles are trapped. The soot is reduced to ash during regeneration, and the ash is collected in the DPF until the DPF is full, at which time the DPF must be removed and cleaned. The DPF needs to be removed and cleaned of ash at specific cleaning intervals. For DPF maintenance and repair information, see the specific engine manufacturer's service literature.

If the exhaust temperature is high enough, the trapped soot is reduced to ash in a process called passive regen, which occurs as the vehicle is driven normally. Passive regen, however, cannot always keep the DPF clean, so the ATD must also periodically undergo active regen. During active regen, extra fuel is injected into the exhaust stream to superheat and reduce the soot trapped in the DPF to ash. Active regen happens only when the vehicle is moving above a certain speed, as determined by the engine manufacturer.

Both active and passive regen happen automatically, without driver input. When operating conditions do not allow for active or passive regen, the vehicle may require a driver-activated parked regen which takes 20 to 60 minutes, depending on ambient conditions.

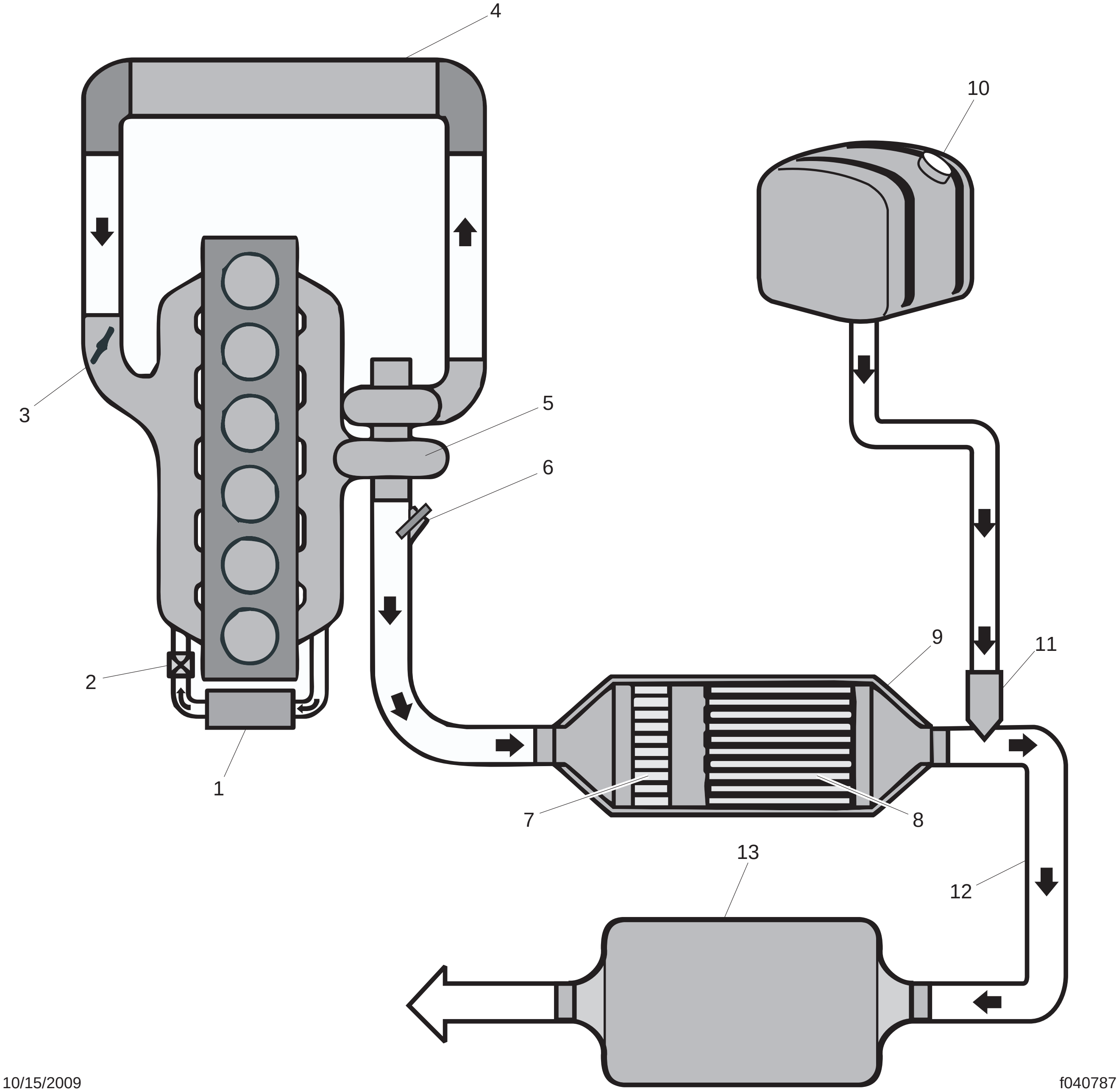
After exhaust gases leave the ATD, a controlled quantity of diesel exhaust fluid (DEF) is injected into the exhaust stream. DEF is colorless, non-toxic, and biodegradable. In the presence of heat, DEF is converted to ammonia gas, which reacts with NOx in the SCR chamber to yield nitrogen and water vapor, which exit through the tailpipe.

EPA10 compliant DTNA vehicles are equipped with an additional tank to carry the DEF necessary for the SCR process. The DEF tank will require filling a minimum of every second diesel refuel, dependant on the DEF tank capacity. DEF consumption will vary depending on ambient conditions and vehicle application.

IMPORTANT: All EPA10 compliant DTNA vehicles require the use of ULSD fuel with a maximum sulfur content of 15 parts per million (PPM). In addition, DTNA vehicles require the use of CJ-4 engine oils with less than 1% ash. See the specific engine manufacturer's literature for additional information.

NOTE: Freightliner documentation deals only with removal and installation of the components of the ATS. Refer to the engine manufacturer's service literature for all testing, disassembly, cleaning, and repair of the ATS components.

General Information

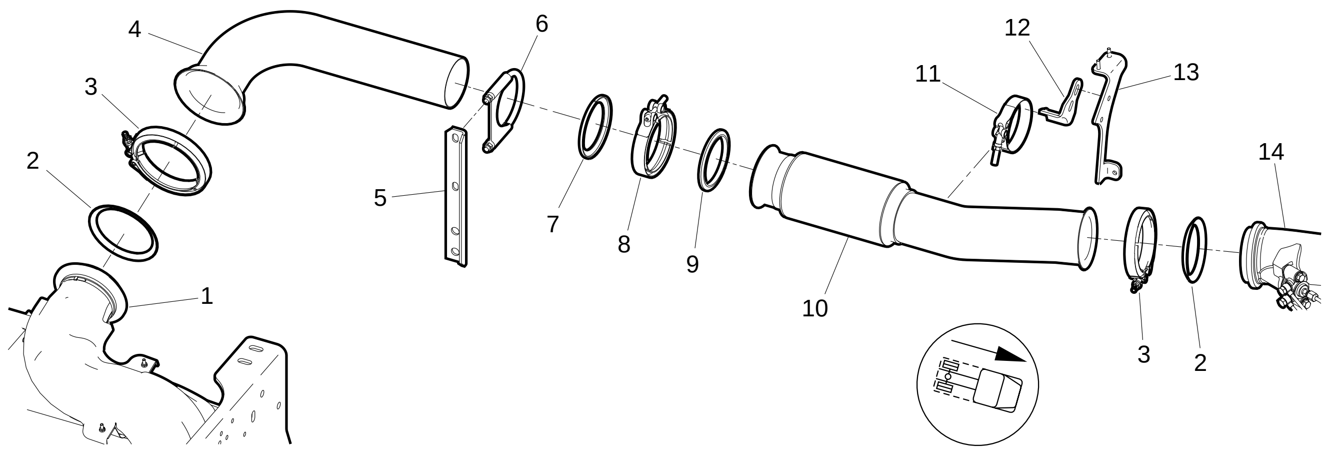


1. Exhaust Gas Recirculation (EGR) Cooler
2. EGR Valve
3. Intake Throttle Valve
4. Charge Air Cooler (CAC)
5. Turbocharger
6. Hydrocarbon Doser
7. Diesel Oxidation Catalyst (DOC)
8. Diesel Particulate Filter (DPF)
9. Aftertreatment Device (ATD)
10. Diesel Exhaust Fluid Tank
11. DEF Injector
12. Mixing Tube
13. SCR Catalyst Chamber

Fig. 1, Aftertreatment System (typical)

Bellows Replacement

Refer to **Fig. 1** for bellows replacement.



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1. ATD Inlet
2. Spherical Clamp Gasket
3. Spherical Clamp
4. ATD Inlet Pipe
5. Bracket
6. Clamp
7. Compression Gasket
8. Slip-Joint Clamp
9. Conical Gasket
10. Bellows
11. Bellows Pipe Support Clamp
12. L-Bracket
13. Bellows Pipe Support Bracket
14. Turbocharger Outlet Pipe

Fig. 1, Exhaust Bellows Installation (DD13 engine shown)

NOTE: Always use new exhaust pipe clamps and gaskets when installing exhaust system components.

1. Shut down the engine and chock the tires.

⚠ WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

2. Allow the exhaust system to cool before working on it.
3. Remove the inner fender/splash shield.
4. Remove the spherical clamp at the turbocharger outlet pipe. Discard the clamp and gasket.
5. Remove the spherical clamp at the ATD inlet. Discard the clamp and gasket.
6. Remove the turbocharger-outlet-pipe support bracket clamp. Save the clamp for reuse.
7. Remove the ATD-inlet-pipe support bracket clamp. Save the clamp for reuse.
8. If needed to make clearance, remove the ATD-inlet-pipe support bracket form the framerail.
9. Remove the bellows and ATD inlet pipe as an assembly.
10. On the workbench, replace the bellows as follows.

    10.1 Remove the bellows-to-ATD inlet-pipe slip-joint clamp and gaskets. Discard the clamp and gaskets.

    10.2 Slide the new slip-joint clamp, then the two new gaskets onto the ATD inlet pipe in the order shown in **Fig. 1**.

Bellows Replacement

    10.3 Slide the new bellows onto the ATD inlet pipe.

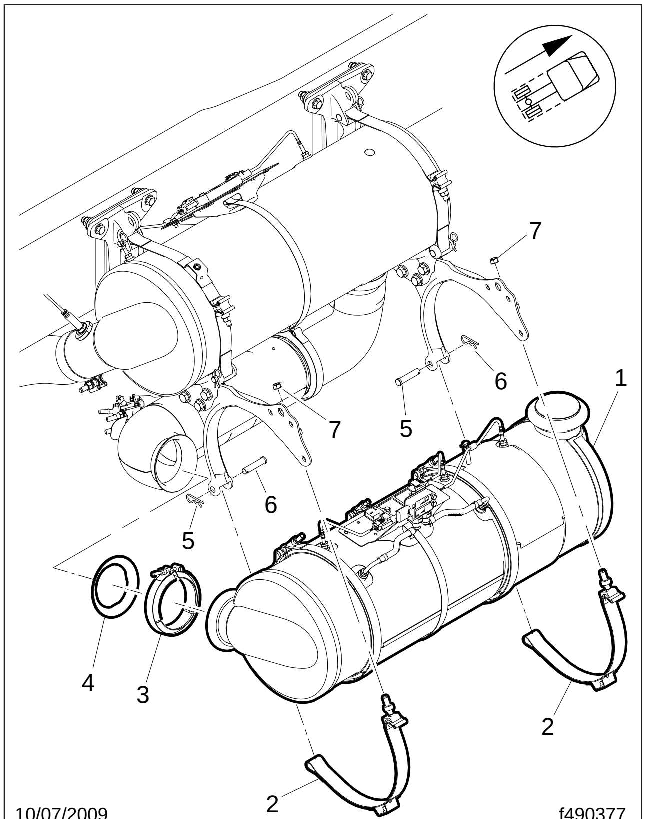
    10.4 Position the slip-joint clamp over the gaskets. Do not tighten at this time.

11. Position the bellows and ATD inlet pipe assembly on the vehicle.
12. Slide the ATD inlet pipe in or out of the bellows to align it with the ATD inlet.
13. Install the new spherical clamp and gasket at the ATD inlet. Do not tighten at this time.
14. Install the new spherical clamp and gasket at the bellows-to-the turbocharger outlet-pipe connection. Do not tighten at this time.
15. If removed, install the ATD-inlet-pipe support bracket on the framerail.
16. Install the turbocharger-outlet-pipe support bracket clamp. Do not tighten at this time.
17. Install ATD-inlet-pipe support bracket clamp. Do not tighten at this time.
18. Using a straight edge, align the bellows, the ATD inlet pipe, and the turbocharger outlet pipe. Check from at least two positions about 90 degrees apart. All three components should form a straight line through the connections.
19. Tighten the spherical clamp at the turbocharger outlet pipe connection 126 to 138 lbf·in (1425 to 1560 N·cm).
20. Tighten the spherical clamp at the ATD inlet connection 126 to 138 lbf·in (1425 to 1560 N·cm).
21. Tighten the slip-joint clamp at the ATD inlet to bellows connection 13 lbf·ft (18 N·m).
22. Tighten the turbocharger-outlet-pipe support bracket clamp 24 lbf·ft (30 N·m).
23. Tighten the ATD-inlet-pipe support bracket clamp 24 lbf·ft (30 N·m).
24. Start the engine and check for leaks. Further tighten the clamps on any leaking connections as needed.
25. Install the inner fender/splash shield.

Cummins ISB/ISC Under-Step Switchback ATD Removal and Installation

Removal

Refer to **Fig. 1** for removal and installation of the ATD components.



1. ATD
2. Clamping Straps
3. Spherical Clamp
4. Gasket
5. Retaining Pin
6. Clamping Strap Pin
7. Clamping Strap Nut

Fig. 1, Cummins ISB/ISC Under-Step Switchback ATS

NOTE: The ATD can be removed and installed without disturbing the SCR catalyst.

1. Set the parking brakes and chock the tires.

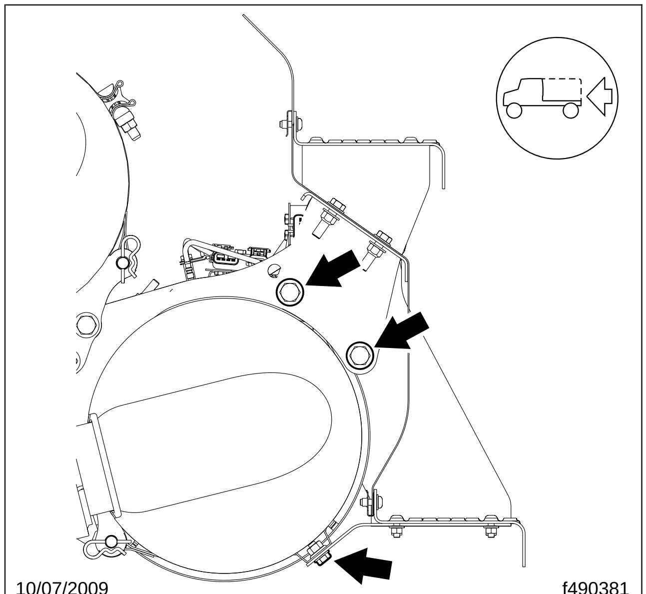
WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

2. Allow the ATS to completely cool before attempting to work on it.
3. Remove the right side inner fender. See **Group 60**.
4. Remove the upper step plate. See **Fig. 2**.



Remove these bolts.

Fig. 2, Step Removal

5. Remove the step unit from the ATS brackets.

NOTICE

Component alignment is critical to proper installation of ATS components. Before removing any components, put alignment marks (use both clocking and longitudinal marks where applicable) on all ATS components. This will aid in faster and more accurate alignment during as-

Cummins ISB/ISC Under-Step Switchback ATD Removal and Installation

sembly. Failure to accurately align all of the components of the ATS may result in component damage.

6. Make alignment marks on all of the components to be removed.
7. Disconnect the wiring harness at the control box on the ATD.

NOTICE

It is not necessary to disconnect the lines from the DEF metering unit to the DEF injector on the mixer tube unless one of these components is being replaced. However, it should be handled carefully to prevent damaging the hose connections.

8. Remove the mixer-tube clamp at the ATD and support the mixer tube as needed. Discard the clamp.
9. Remove the clamp, and disconnect the exhaust pipe from the engine at the ATD. Discard the clamp.
10. Position the ATD jack under the ATD.
11. Remove the nuts from the ATD clamping straps. Remove the straps, and discard the straps and hardware.

NOTICE

Be careful not to bump any of the sensors while removing the ATD. The sensors are easily damaged.

12. Carefully lower the ATD.
13. If replacing the ATD, transfer the control box from the old ATD to the new one.

Installation

IMPORTANT: Always use new gaskets when installing exhaust system components.

1. Using the jack, raise the ATD into position.

NOTICE

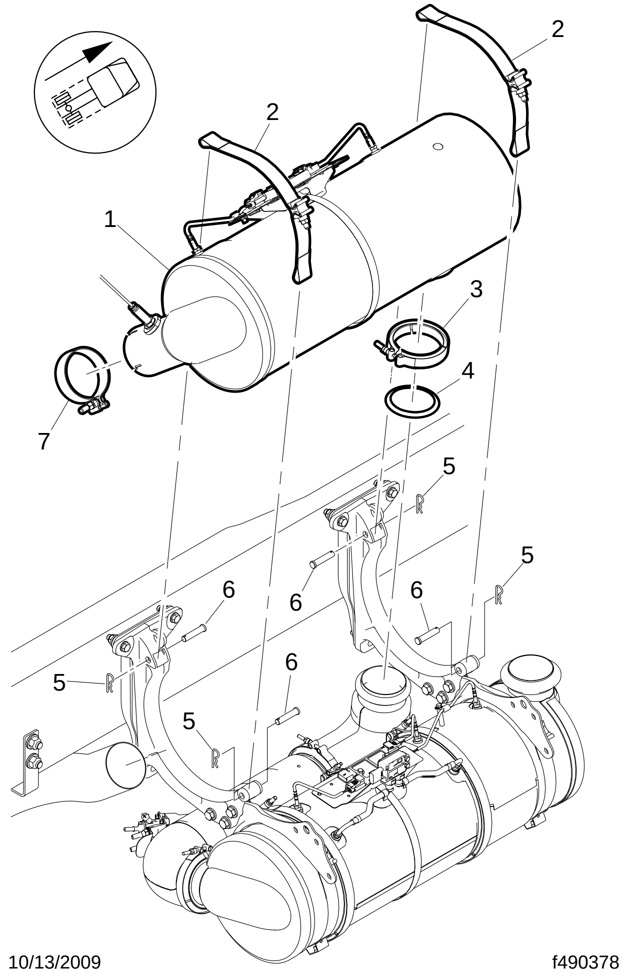
The ATD may rotate while tightening the clamps. It is important that this is prevented. Check the alignment during and after the clamping procedure and make adjustments as needed. Improper installation may lead to component failure.

2. Align the ATD, and install the new clamping straps. Do not tighten at this time.
3. Connect the exhaust pipe from the engine and install the new spherical clamp and gasket. Do not tighten at this time.
4. Position the mixer tube and install the new spherical clamp and gasket. Do not tighten at this time.
5. Check all alignment marks, and tighten the clamping strap nuts incrementally, first 15 lbf·ft (20 N·m), then 30 lbf·ft (40 N·m).
6. Check all alignment marks again. If not correct, loosen the clamp and repeat the previous step. Check the alignment on all connections. Make adjustments as needed.
7. Tighten the spherical clamps at the ATD inlet and the mixer tube connections 126 to 138 lbf·in (1425 to 1560 N·cm).
8. Connect the wiring harness to the control box on the ATD.
9. Start the engine and check for leaks. Further tighten the clamps on any leaking connections as needed.
10. Install the steps.
11. Install the inner fender.

Cummins ISB/ISC Under-Step Switchback SCR Catalyst Removal and Installation

Removal

Refer to **Fig. 1** for removal and installation of the SCR catalyst components.



1. SCR Catalyst
2. Clamping Strap
3. Spherical Clamp
4. Gasket
5. Retaining Pin
6. Clamping Strap Pin
7. Clamp, Exhaust Pipe

Fig. 1, Cummins ISB/ISC Under-Step Switchback SCR Catalyst Installation

NOTE: The SCR catalyst can be removed and installed without disturbing the ATD.

1. Set the parking brakes and chock the tires.

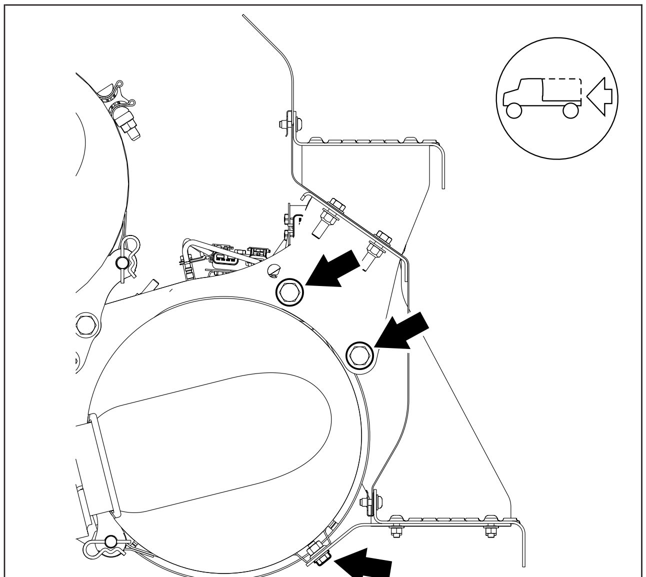
WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

2. Allow the ATS to completely cool before attempting to work on it.
3. Remove the right side inner fender. See **Group 60**.
4. Remove the upper step plate. See **Fig. 2**.

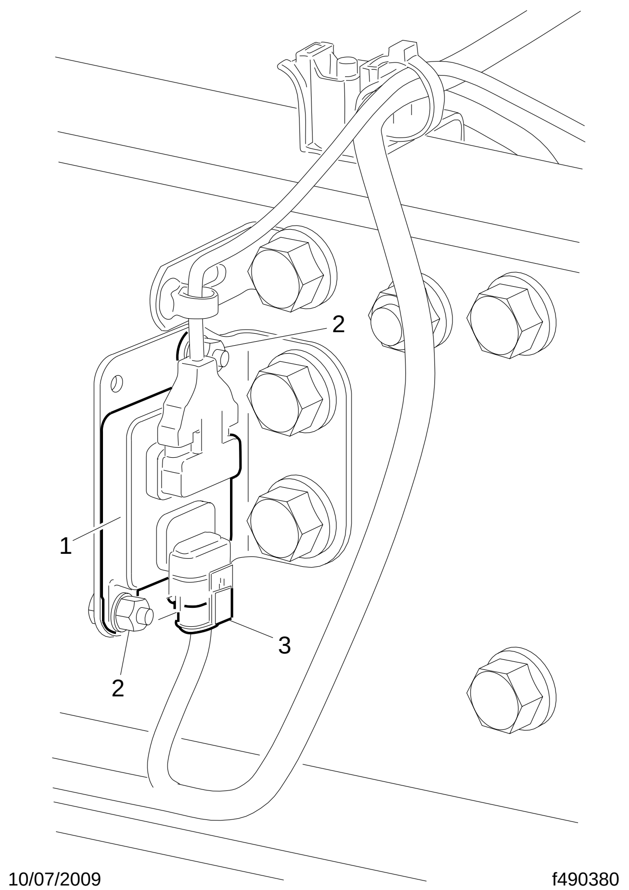


Remove these bolts.

Fig. 2, Upper Step Removal

5. Remove the step unit from the ATS brackets.
6. Disconnect the NOx sensor module from the main harness, and remove it from the frame rail bracket. See **Fig. 3**

Cummins ISB/ISC Under-Step Switchback SCR Catalyst Removal and Installation



1. NOx Sensor Module
2. Mounting Bolts and Nuts
3. Chassis Harness Connector

Fig. 3, NOx Sensor Module Installation

NOTICE

Component alignment is critical to proper installation of ATS components. Before removing any components, put alignment marks (use both clocking and longitudinal marks where applicable) on all ATS components. This will aid in faster and more accurate alignment during assembly. Failure to accurately align all of the components of the ATS may result in component damage.

7. Make alignment marks on all of the ATS components that will be removed.
8. Disconnect the exhaust outlet pipe at the SCR catalyst as needed.
9. Remove the clamp on the mixer tube. Discard the clamps.
10. Carefully let the mixer tube swing down, and support it as needed.

NOTICE

Do not bump any of the sensors while removing the SCR catalyst. The sensors are easily damaged.

11. Remove the nuts from the SCR catalyst clamping straps. Discard the straps and hardware.
12. With help from an assistant, lift the SCR catalyst out.

Installation

IMPORTANT: Always use new clamps and gaskets when installing exhaust system components.

1. With help from an assistant, position the SCR catalyst in the bracket, and align the alignment marks.
2. Install the new clamping straps. Do not tighten at this time.
3. Position the mixer tube and install the clamp. Do not tighten at this time.
4. If removed, connect the exhaust pipe to the SCR catalyst and install the clamp. Do not tighten at this time.

NOTICE

The SCR catalyst may rotate while tightening the clamps. It is important that this is prevented. Check the alignment during and after the clamping procedure and make adjustments as needed. Improper alignment may lead to component failure.

5. Check all alignment marks, and tighten the clamping strap nuts incrementally, first 15 lbf·ft (20 N·m) then 30 lbf·ft (41 N·m).
6. Check all alignment marks again. If not correct, loosen the clamp and repeat the previous step.

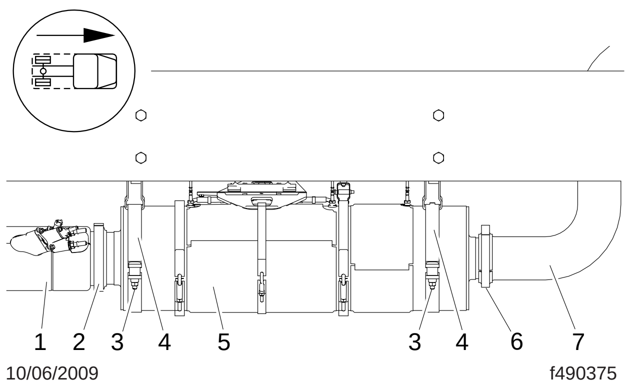
Cummins ISB/ISC Under-Step Switchback SCR Catalyst Removal and Installation

7. Tighten the spherical clamps at the SCR catalyst inlet and the mixer tube 126 to 138 lbf·in (1425 to 1560 N·cm).
8. Tighten the exhaust pipe clamp at the outlet of the SCR catalyst 45 to 60 lbf·ft (60 to 80 N·m).
9. Install the NOx sensor module on the bracket on the frame rail, then connect it to the chassis harness.
10. Connect the wiring harness to the control box on the SCR catalyst.
11. Start the engine and check for exhaust leaks. Further tighten the clamps on any leaking connections as needed.
12. Install the steps.
13. Install the inner fender.

Cummins 2HH ATD Removal and Installation

Removal

Refer to **Fig. 1** for removal and installation of the ATS components.



1. Mixer Tube
2. Spherical Clamp
3. Mounting-Strap Bolt and Nut
4. Mounting Strap
5. Aftertreatmment Device (ATD)
6. Spherical Clamp
7. ATD Inlet Pipe

Fig. 1, Cummins ISB/ISC 2HH ATD Installation

1. Shut down the engine and chock the tires.

WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

2. Allow the ATS to completely cool before working on it.

NOTICE

Component alignment is critical to proper installation of ATS components. Before removing any components, put alignment marks (use both clocking and longitudinal marks where applicable) on all ATS components. This will aid in faster and more accurate alignment during assembly. Failure to accurately align all of the components of the ATS may result in component damage.

3. Make alignment marks on all of the components to be removed.
4. Disconnect the wire harness to the control module on the ATD.
5. Remove the spherical clamp and gasket that connects the ATD inlet pipe to the ATD. Discard the clamp and gasket.
6. Remove the spherical clamp and gasket that connects the ATD to the mix-tube. Discard the clamp and gasket.
7. Position the jack and cradle under the assembly and secure it with straps.
8. Remove the bolts and nuts from the four mounting straps.
9. Lower the unit.
10. Remove and discard the mounting straps and hardware.

Installation

1. Position the assembly in the jack cradle and secure it with straps.
2. Slide the unit under the vehicle and raise it into position.
3. Install the new mounting straps.
4. Position the assembly in the mounting straps, then install the clamp bolts and nuts. Do not tighten at this time.

IMPORTANT: Always use new gaskets when installing exhaust system components.

5. Connect the ATD to the ATD inlet pipe and install the new spherical clamp and gasket. Do not tighten at this time.

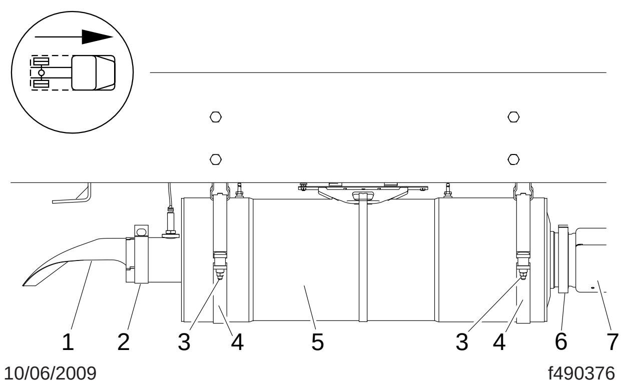
Cummins 2HH ATD Removal and Installation

6. Connect the ATD outlet to the mix tube and install the new spherical clamp and gasket. Do not tighten at this time.
7. Recheck the alignment of all components. Make adjustments to the mounting straps (and brackets) as needed then incrementally tighten the bolts 15 lbf·ft (20 N·m), them 30 lbf·ft (41 N·m).
8. Tighten the spherical clamps at the connections to the ATD inlet pipe and the mix tube 126 to 138 lbf·in (1425 to 1560 N·cm).
9. Connect the wiring harnesses to the control module on the ATD.
10. Remove the jack and cradle.
11. Start the engine and check for leaks. Further tighten the clamps on any leaking connections as needed.

Cummins 2HH SCR Catalyst Removal and Installation

Removal

Refer to Fig. 1 for removal and installation of the ATS components.



1. Exhaust Pipe Tip
2. Wide-Band Clamp
3. Mounting-Strap Bolt and Nut
4. Mounting Strap
5. SCR Catalyst
6. Spherical Clamp
7. Mixer Tube

Fig. 1, Aftertreatment System Installation

1. Shut down the engine and chock the tires.

WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

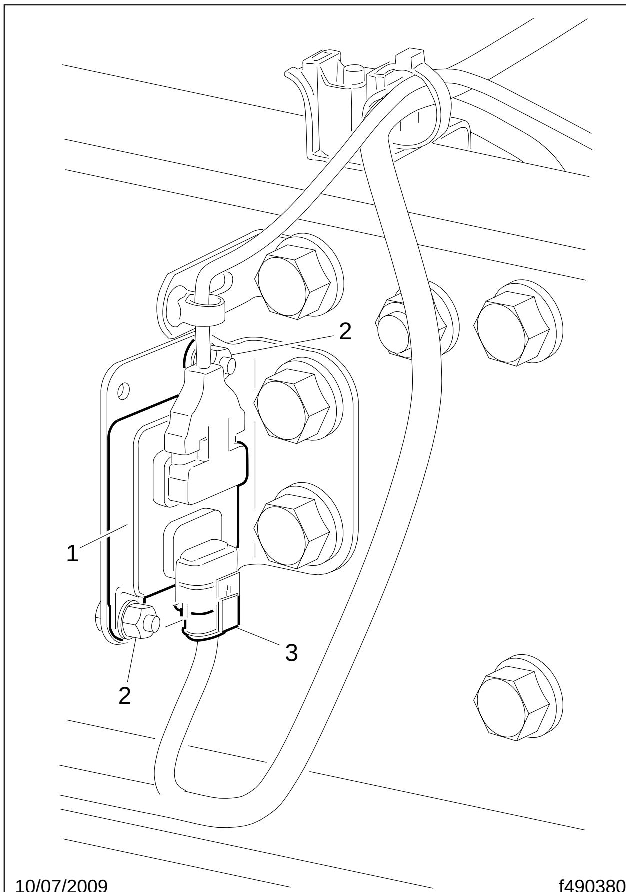
- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

2. Allow the ATS to completely cool before working on it.

NOTICE

Component alignment is critical to proper installation of ATS components. Before removing any components, put alignment marks (use both clocking and longitudinal marks where applicable) on all ATS components. This will aid in faster and more accurate alignment during assembly. Failure to accurately align all of the components of the ATS may result in component damage.

3. Make alignment marks on all components to be removed.
4. Disconnect the wire harness to the NOx sensor.
5. Remove the NOx sensor module from the frame rail bracket and secure it to the SCR catalyst. See Fig. 2.



1. NOx Sensor Module
2. Mounting Bolts and Nuts
3. Chassis Harness Connector

Fig. 2, NOx Sensor Module Installation

6. Disconnect the wire harness to the control module on the SCR catalyst.

Cummins 2HH SCR Catalyst Removal and Installation

7. Remove the spherical clamp that connects the SCR catalyst to the mixer tube. Discard the clamp.
8. Remove the wide-band clamp that connects the SCR catalyst to the exhaust pipe. Discard the clamp.
9. Position the jack and cradle under the assembly and secure it with straps.
10. Remove the bolts and nuts from the four mounting straps.
11. Remove and discard the mounting straps and hardware.
12. Lower the unit.

Installation

1. Position the assembly in the jack cradle and secure it with straps.
2. Install the new clamp straps.
3. Slide the unit under the vehicle and raise it into position.
4. Position the assembly in the mounting straps, and install the clamp bolts and nuts. Do not tighten at this time.

IMPORTANT: Always use new gaskets when installing exhaust system components.

5. Connect the SCR catalyst to the mixer tube and install the new spherical clamp and gasket. Do not tighten at this time.
6. Connect the SCR catalyst to the exhaust outlet pipe and install the new wide-band clamp. Do not tighten at this time.
7. Recheck the alignment of all components. Make adjustments to the mounting straps (and brackets) as needed then tighten the bolts 15 lbf·ft (20 N·m), then 30 lbf·ft (41 N·m).
8. Tighten the spherical clamp at the connection of the SCR catalyst and the mixer tube 126 to 138 lbf·in (1425 to 1560 N·cm).
9. Install the NOx sensor module on the bracket on the frame rail, then connect it to the chassis harness.
10. Connect the wiring harness to the control box on the SCR catalyst.
11. Remove the jack and cradle.
12. Start the engine and check for leaks. Further tighten the clamps on any leaking connections as needed.

DDC 2V2 ATD and SCR Catalyst Removal and Installation

General Information

Removing the DDC 2V2 ATD and SCR catalyst as a unit is the quickest, and easiest, way to remove it from the vehicle. The ATD or the SCR catalyst can be removed separately. When removing the components separately, mark all parts to assist in proper assembly. Daimler Trucks North America LLC does not recommend disassembling the ATD on the vehicle. Remove the component following the instructions below, and then disassemble it on a workbench following the instructions in the engine manufacturer's service literature.

WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

ATD and SCR Catalyst Removal and Installation

Removal

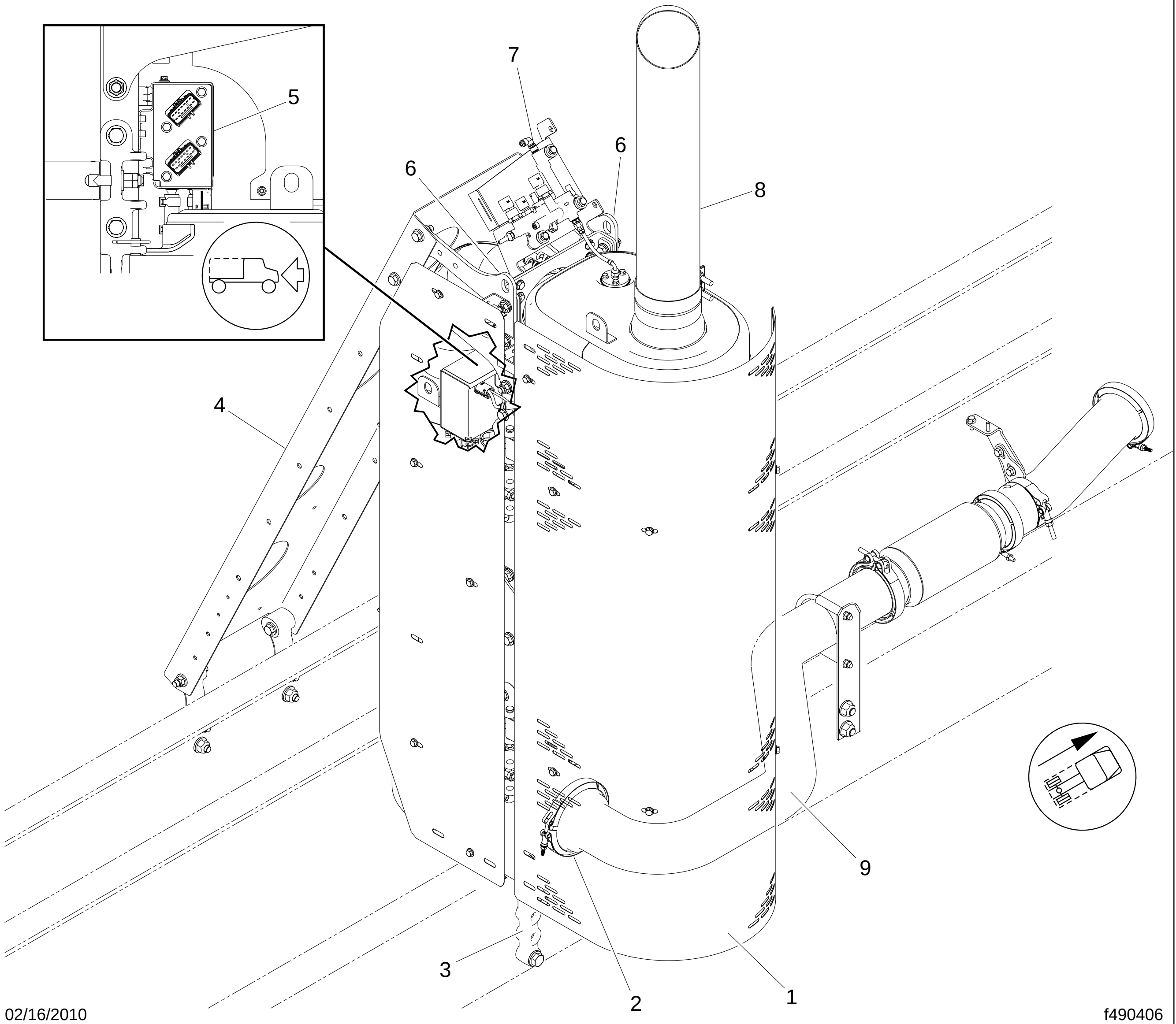
Refer to **Fig. 1** for the following procedure.

1. Shut down the engine and chock the tries.
2. Allow the ATS time to cool.
3. Remove the heat shield.
4. Remove the exhaust stack from the SCR catalyst.
5. Disconnect the two 14-pin connectors at the sensor box.
6. Disconnect the wiring connectors from the metering unit.
7. Disconnect the air lines from the metering unit.
8. Disconnect and cap/plug the DEF lines from the metering unit.
9. Remove the metering unit mounting plate with the metering unit attached.
10. Loosen the lower fasteners on the diagonal support brace. Disconnect the diagonal support brace from the lifting bracket that attaches to the vertical stanchion and swing it out of the way. Secure it as needed.
11. Disconnect the exhaust pipe at the intake to the ATD. Support it as needed so there is no stress on the bellows.
12. Position the overhead lifting device over the vertical stanchion and connect the hooks at the lifting points. Apply enough pressure to the lift points to prevent the unit from dropping when loosened.
13. Remove the four mounting fasteners that attach the vertical stanchion to the frame rail.
14. Lower the unit away from the vehicle.

Installation

1. Using the overhead lifting device, position the unit at the frame rail, and install the mounting fasteners. Tighten 159 to 201 lbf·ft (212 to 268 N·m).
2. Position the diagonal support brace and install the mounting fasteners. Tighten the upper and lower fasteners 49 to 63 lbf·ft (66 to 86 N·m).
3. Connect the two 14-pin connectors at the sensor box.
4. Install the metering unit and mounting plate.
5. Connect the wiring connectors to the metering unit.
6. Connect the air lines to the metering unit.
7. Connect the DEF lines to the metering unit.
8. Using a new seal, connect the exhaust pipe to the ATD. See **Fig. 2** for proper installation. Tighten the clamp 114 to 126 lbf·in (1290 to 1425 N·cm).
9. Install the exhaust stack. Tighten the clamp 27 to 37 lbf·ft (37 to 50 N·m).
10. Install the heat shield. Tighten 13 to 17 lbf·ft (18 to 22 N·m).

DDC 2V2 ATD and SCR Catalyst Removal and Installation



1. Heat Shield
2. Inlet Clamp
3. Vertical Stanchion
4. Diagonal Support Brace
5. Sensor Box
6. Lifting Points
7. Metering Unit and Mounting Plate
8. Exhaust Stack
9. Exhaust Pipe

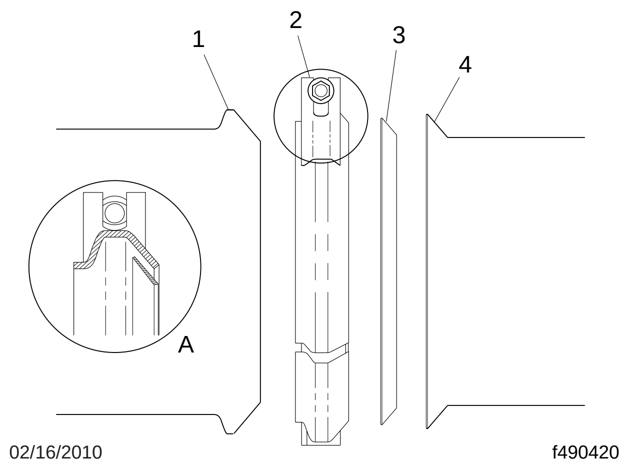
Fig. 1, 2V2 ATD and SCR Catalyst Installation

11. Start the engine and check for leaks. Tighten any connections as needed.

ATD Removal and Installation

Refer to **Fig. 3** for the following procedure.

DDC 2V2 ATD and SCR Catalyst Removal and Installation



NOTE: Clamp and seal are directional.
A. Correct Clamp and Seal Installation
1. ATD
2. Clamp
3. Gasket
4. Exhaust Pipe

Fig. 2, Spherical Clamp Installation

NOTICE

Alignment is essential. Mark every component's position prior to disassembling it on the truck. Improper assembly may result in leaks or damage to the ATS.

Removal

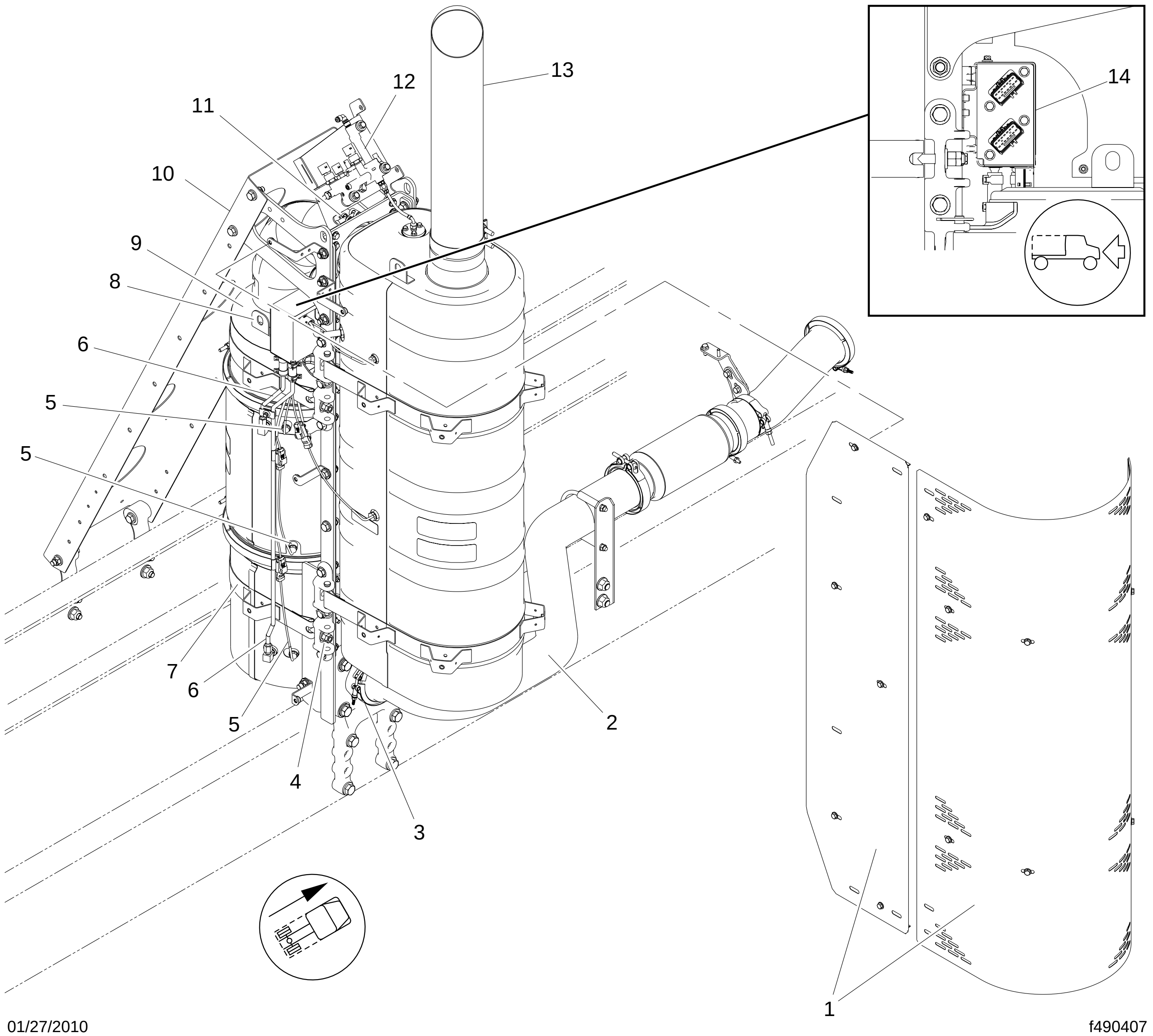
1. Shut down the engine and chock the tries.
2. Allow the ATS time to cool.
3. Remove the heat shield.
4. Disconnect the two pressure tubes at the connection to the ATD.
5. Disconnect the three temperature sensors on the ATD.
6. Disconnect the two 14-pin connectors at the sensor box.
7. Disconnect the wiring connectors from the metering unit.
8. Disconnect the air lines from the metering unit.
9. Disconnect and cap/plug the DEF lines from the metering unit.
10. Remove the metering unit mounting plate with the metering unit attached.
11. Loosen the lower fasteners on the diagonal support brace. Disconnect the diagonal support brace from the vertical stanchion, and swing it out of the way. Secure it as needed.
12. Remove the intake and outlet clamps from the ATD. Support the turbo outlet pipe as needed so there is no stress on the bellows.
13. Position the overhead lifting device over the ATD and connect the hooks at the lifting points. Apply enough pressure to the lift points to prevent the unit from dropping when loosened.
14. Remove the mounting clamps.
15. Lift the ATD away from the vehicle.

Installation

1. Using the overhead lifting device, position the ATD on the vertical stanchion, and secure it in position with the mounting clamps. Do not tighten the straps at this time.
2. Align the connection with the SCR catalyst, and using a new seal, install the clamp. See **Fig. 2** for proper installation. Tighten the clamp 114 to 126 lbf·in (1290 to 1425 N·cm).
3. Align the connection with the exhaust pipe from the turbocharger, and, using a new seal, install the clamp. See **Fig. 2** for proper installation. Tighten the clamp 114 to 126 lbf·in (1290 to 1425 N·cm).
4. Check all alignment marks, and tighten the clamping strap nuts incrementally, first 15 lbf·ft (20 N·m), then 30 lbf·ft (40 N·m).

   Install the jam nuts. Using a back-up wrench, tighten 30 lbf·ft (40 N·m).
5. Connect the two pressure tubes.
6. Connect the three temperature sensors.
7. Position the diagonal support brace and install the mounting fasteners. Tighten the upper and lower fasteners 49 to 63 lbf·ft (66 to 86 N·m).
8. Connect the two 14-pin connectors at the sensor box.
9. Install the metering unit and mounting plate.
10. Connect the wiring connectors to the metering unit.

DDC 2V2 ATD and SCR Catalyst Removal and Installation



1. Heat Shield
2. Exhaust Pipe
3. Intake Clamp
4. Clamping Strap Nuts
5. Temperature Sensor
6. Pressure Tube
7. Clamping Strap
8. Lifting Points
9. ATD
10. Diagonal Support Brace
11. Outlet Clamp
12. Metering Unit and Mounting Plate
13. Exhaust Stack
14. Sensor Box

Fig. 3, 2V2 ATD Installation

11. Connect the air lines to the metering unit.
12. Connect the DEF lines to the metering unit.
13. Install the heat shield.
14. Start the engine and check for leaks. Tighten any connections as needed.

SCR Catalyst Removal and Installation

Refer to **Fig. 4** for the following procedure.

Removal

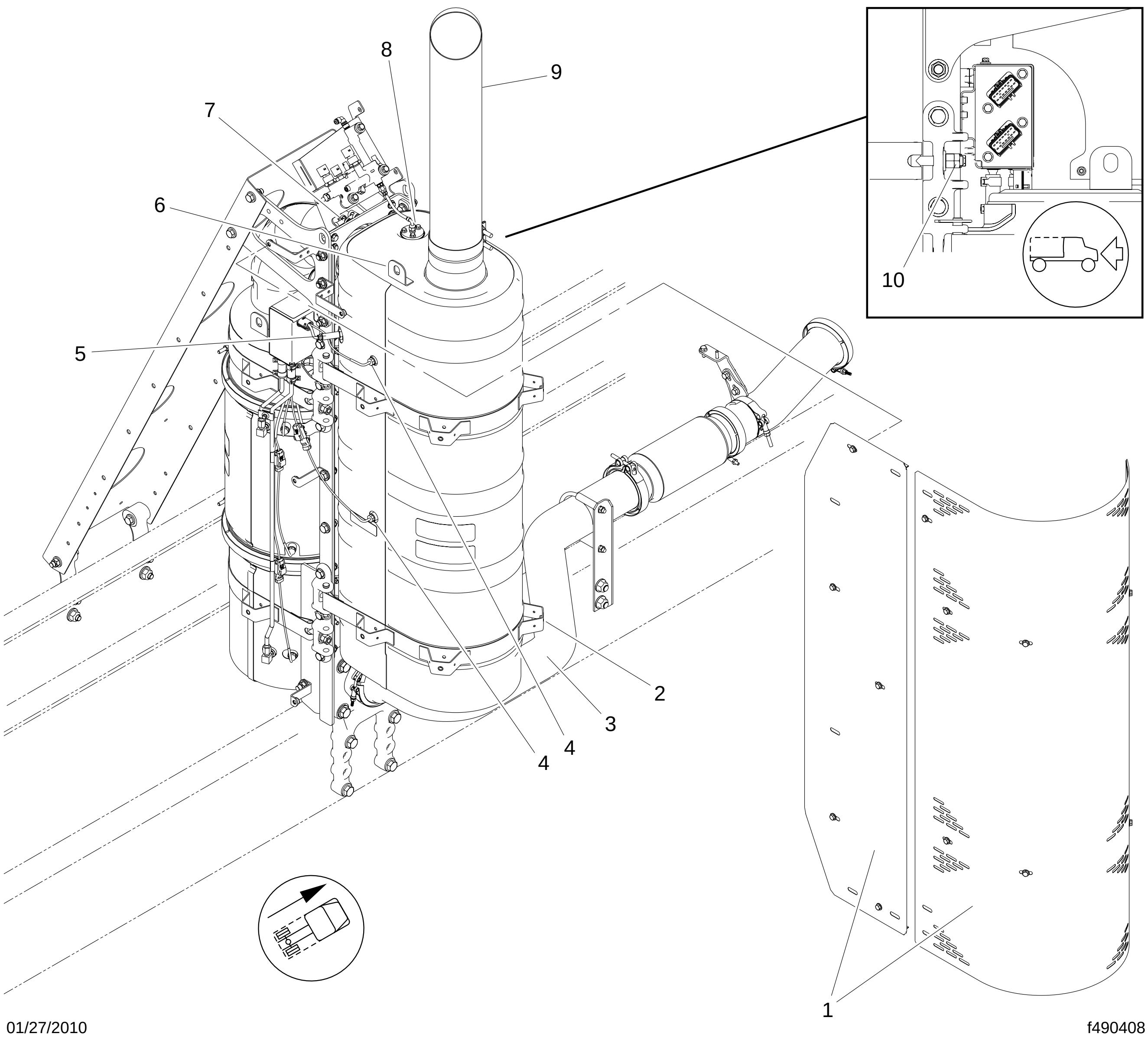
1. Shut down the engine and chock the tries.
2. Allow the ATS time to cool.
3. Remove the heat shield.
4. Remove the exhaust stack from the SCR catalyst.
5. Remove the SCR catalyst inlet clamp.
6. Disconnect the two temperature sensors and the NOx sensor.
7. Disconnect the DEF nozzle.
8. Position the overhead lifting device over the SCR catalyst and connect the hooks at the lifting points. Apply enough pressure to the lift points to prevent the unit from dropping when loosened.
9. Remove the clamping strap nuts.
10. Lift the SCR catalyst away from the vehicle.

Installation

1. Using the overhead lifting device, position the SCR catalyst on the vertical stanchion, and secure it in position with the mounting clamps. Do not tighten the straps at this time.
2. Align the connection with the ATD, and using a new seal, install the clamp. See **Fig. 2** for proper installation. Tighten the clamp 114 to 126 lbf·in (1290 to 1425 N·cm).
3. Check all alignment marks, and tighten the clamping strap nuts incrementally, first 15 lbf·ft (20 N·m), then 30 lbf·ft (40 N·m).

   Install the jam nuts. Using a back-up wrench, tighten 30 lbf·ft (40 N·m).
4. Connect the two temperature sensors and the NOx sensor.
5. Connect the DEF nozzle.
6. Install the exhaust stack. Tighten the clamp 27 to 37 lbf·ft (37 to 50 N·m).
7. Install the heat shield. Tighten 13 to 17 lbf·ft (18 to 22 N·m).
8. Start the engine and check for leaks. Tighten any connections as needed.

DDC 2V2 ATD and SCR Catalyst Removal and Installation



1. Heat Shield
2. Clamping Straps
3. Exhaust Pipe
4. Temperature Sensor
5. NOx Sensor
6. Lifting Points
7. SCR Catalyst Inlet Clamp
8. DEF Nozzle
9. Exhaust Stack
10. Clamping Strap Nuts

Fig. 4, 2V2 SCR Catalyst Installation

General Description

The Environmental Protection Agency (EPA) mandated that all engines built after December 31, 2009 must reduce the level of emissions exhausted by the engine to 0.2 grams per brake horsepower hour (g/bhp-hr) of nitrogen oxides (NOx).

To meet the EPA10 requirements, Daimler Trucks North America is using technology known as Selective Catalytic Reduction (SCR) in the exhaust aftertreatment system (ATS). See **Fig. 1**.

The SCR process requires the introduction of diesel exhaust fluid (DEF) into the exhaust stream. DEF is colorless, non-toxic, and biodegradable. In the ATS, the exhaust gases pass through the ATD, then are treated with precisely-controlled quantities of DEF, and then pass into the SCR catalyst. DEF consumption is dependent on ambient conditions and vehicle operation.

DEF is drawn from the tank by the DEF pump. The DEF is then filtered and, from the pump, transported through the DEF lines to the metering unit. The metering unit measures the correct amount of DEF, which is then injected into the hot exhaust flow after exhaust gases have passed through the ATD. In the presence of heat, DEF is converted to ammonia gas, which reacts with NOx in the selective catalyst chamber to yield harmless nitrogen and water vapor, which exit out the tailpipe.

DEF causes mild discoloration to aluminum, but will not affect its strength or structure. White crystals may be noticeable around components that come into contact with DEF. The crystals can be easily removed using water.

DEF freezes to a slush consistency at 12°F (-11°C). Because DEF can freeze, the DEF lines and metering unit are designed to purge whenever the engine is shut down to prevent damage. Complete purging of the DEF lines requires approximately five minutes after the engine is shut down.

DEF in the tank is allowed to freeze while the vehicle is non-operational. The DEF temperature sensor detects when the temperature of the DEF in the tank is approaching its freezing point. After the engine has been started and the engine coolant reaches a certain temperature, the coolant valve opens, allowing the coolant to flow through the coolant lines inside the DEF tank. The lines transfer heat, causing any frozen DEF in the tank to thaw and preventing liquid DEF from freezing during operation in cold weather. After flowing through the tank, the coolant is redirected back to the engine.

DEF will degrade over an extended period of time; shelf life is between twelve and eighteen months in standard operating conditions and temperatures. As DEF begins to degrade, it is usable but may be consumed at a slightly higher rate than normal.

A minor engine derate (approximately 25%) will occur when the DEF level registers below 5% on vehicles with Detroit Diesel engines, or 2.5% on vehicles with Cummins engines. If the DEF tank is empty, a major engine derate (vehicle speed is limited to 5 mph) will occur after an engine shut down and restart if the diesel tank has been refueled and the DEF tank is not refilled.

There are also safety controls that derate the engine if a contaminant has been introduced into the DEF tank. When a contaminant is detected, a minor engine derate will occur. When the vehicle has operated for 20 hours or 1000 miles with a contaminated tank, the vehicle will experience a major engine derate once the system determines that the vehicle is in a safe situation. Once the DEF tank has been filled with clean DEF, engine performance will return to normal.

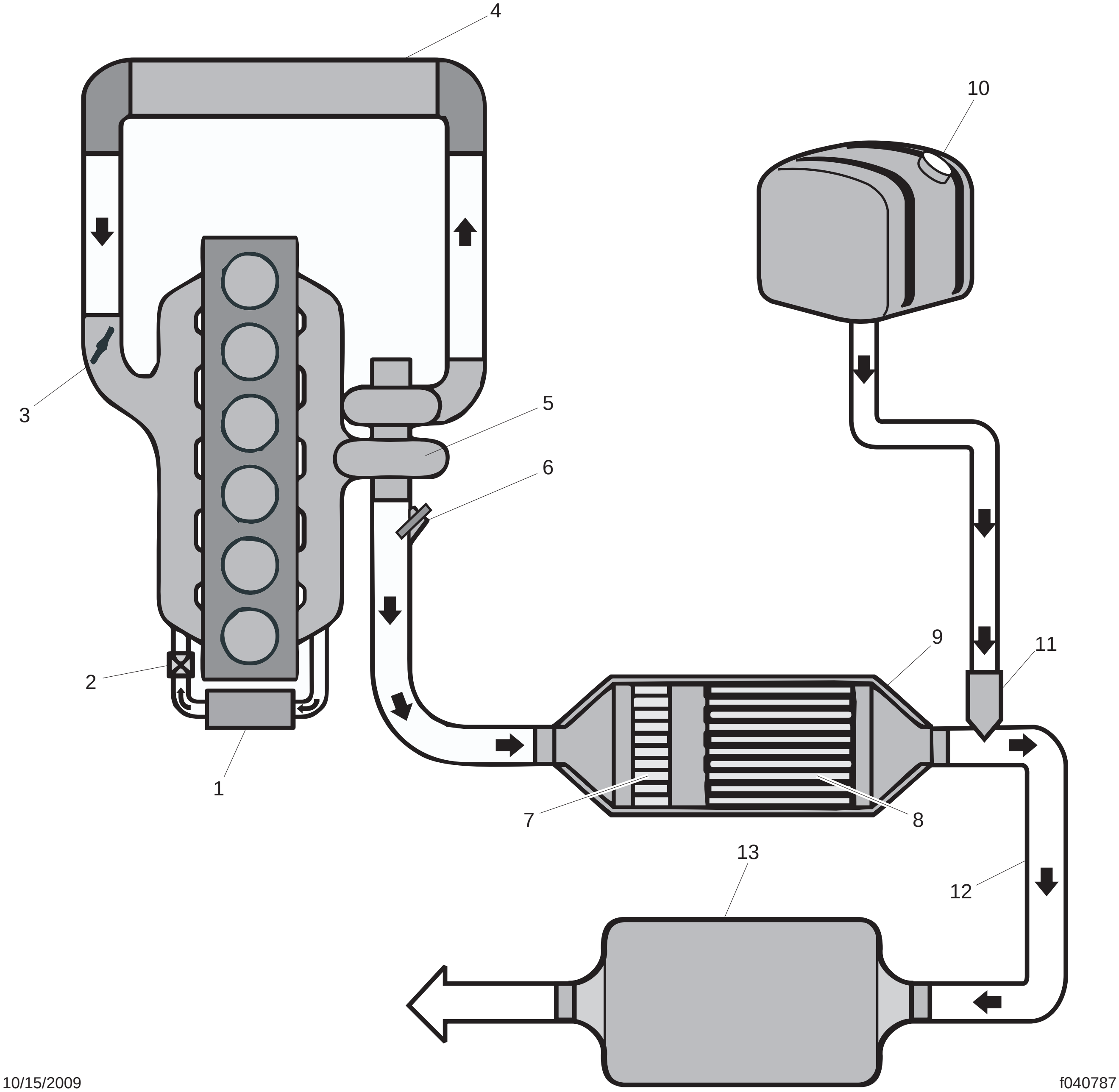
DTNA-covered components of the DEF system include the DEF tank, tank header unit, pump, and coolant, DEF, and air lines between these components. See the engine manufacturer's service literature for information regarding other DEF system components such as the metering unit and injector, and DEF system maintenance instructions and intervals.

For additional operating information, see the *Business Class M2 Driver's Manual*.

For additional information on and definitions for EPA10-compliant systems and components, see **Section 01.02**, EPA07/EPA10 Engine Information.

For additional information on the ATS, see **Section 49.02**, Aftertreatment System, EPA10.

General Information



1. Exhaust Gas Recirculation (EGR) Cooler
2. EGR Valve
3. Intake Throttle Valve
4. Charge Air Cooler (CAC)
5. Turbocharger
6. Hydrocarbon Doser
7. Diesel Oxidation Catalyst (DOC)
8. Diesel Particulate Filter (DPF)
9. Aftertreatment Device (ATD)
10. DEF Tank
11. DEF Injector
12. Mixing Tube
13. SCR Catalyst Chamber

Fig. 1, EPA10 Aftertreatment System

Daimler Trucks North America vehicles carry diesel exhaust fluid (DEF) tanks in three sizes: 6 gallons, 13 gallons, or 23 gallons.

NOTE: DEF creeps, causing white crystals to form around the line fittings. The presence of crystals does not mean the system has a leak. Replacing fittings or components is not necessary unless there is a system failure or a fault code.

6-Gallon Tank

Removal

IMPORTANT: Discard contaminated DEF or coolant in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Open the hood.
3. Drain the coolant from the cooling system. For instructions, see **Group 20**.
4. Place a clean drain pan underneath the tank to catch draining DEF. Uncontaminated DEF may be reused.

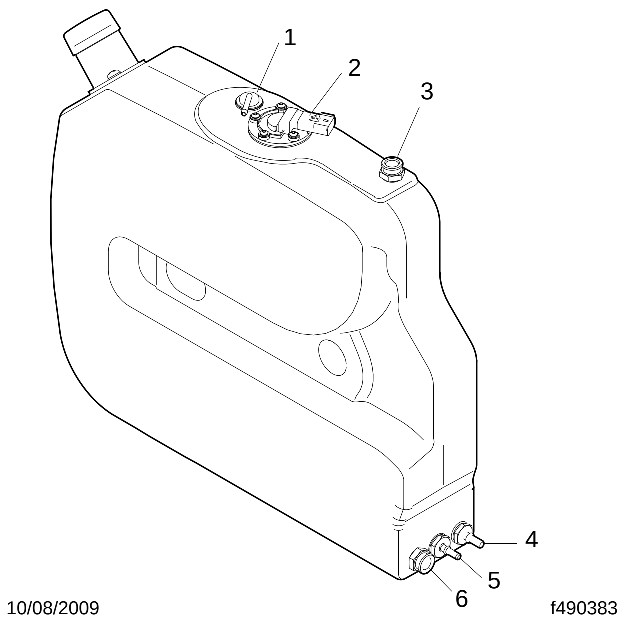
IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the DEF lines. Complete purging of the DEF lines requires approximately five minutes after the engine is shut down.

5. Disconnect the DEF line heater wiring harnesses from the DEF lines at the tank.

NOTICE

To disconnect a DEF line, push the line coupling in towards the male connector to move the holding clip to the unlocked position, then compress the prongs of the holding clip and pull the line off of the male connector. Failure to properly remove a DEF line can result in damage to a line coupling or DEF fitting.

6. Disconnect the DEF lines from the supply and return ports and let the DEF drain into the drain pan. See **Fig. 1** or **Fig. 2**.
7. Disconnect the wiring harness from the tank header unit.



1. Vent
2. DEF Level and Temperature Sensor Wiring Harness
3. Coolant Inlet
4. DEF Outlet
5. DEF Inlet
6. Coolant Outlet

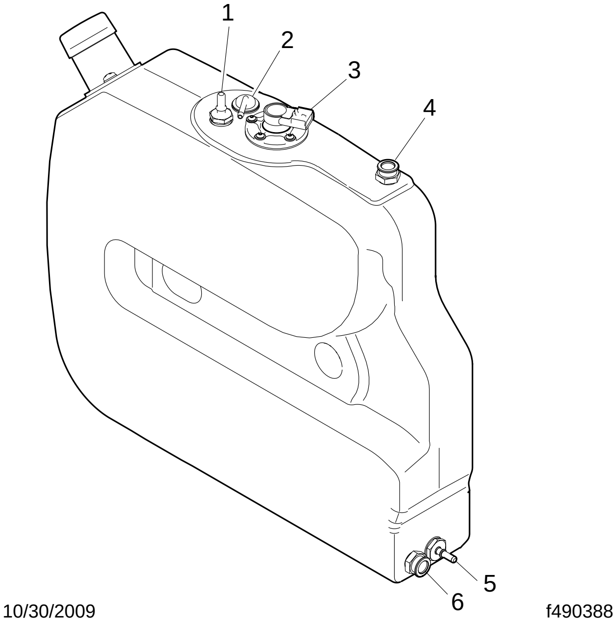
Fig. 1, 6-Gallon Tank Ports (Detroit Diesel shown)

8. Disconnect the coolant lines from the supply and return ports.
9. Disconnect the vent line.
10. If another chassis-mounted component is located directly aft of the DEF tank, check to see if the component is mounted close enough to prevent the tank from sliding off the mounting studs. If so, remove the nuts, bolts, and washers that secure the tank assembly to the frame casting, and remove the assembly from the frame casting.
11. Remove the two capscrews that secure the tank and retaining washers on the mounting studs. See **Fig. 3**.
12. Remove the two tank retaining washers from the tank mounting studs.
13. Slide the tank off of the mounting studs.

Installation

1. Slide the tank onto the mounting studs.

Tank Removal and Installation

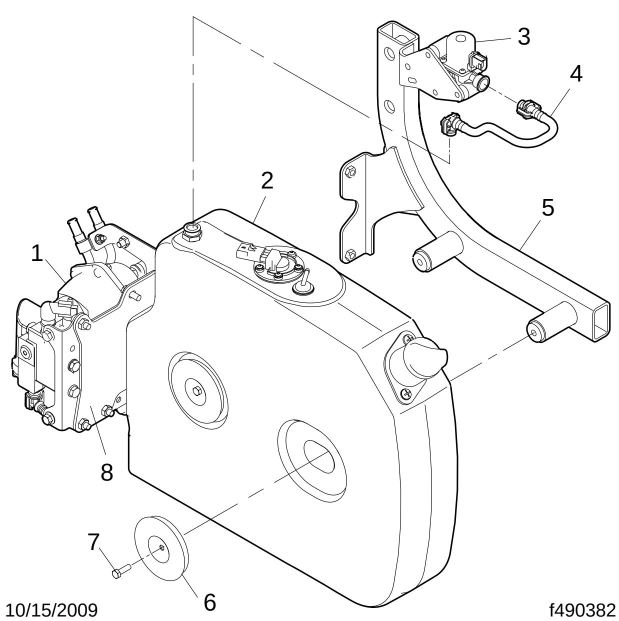


1. DEF Inlet
2. Vent
3. DEF Level and Temperature Sensor Wiring Harness
4. Coolant Inlet
5. DEF Outlet
6. Coolant Outlet

Fig. 2, 6-Gallon Tank Ports (Cummins shown)

2. Install two tank retaining washers on the tank mounting studs.
3. Install two capscrews onto the mounting studs, securing the tank and retaining washers on the tank mounting studs. Tighten the capscrews 11 to 18 lbf·ft (15 to 25 N·m).
4. If the tank assembly was previously removed from the frame casting, install the tank assembly on the frame casting. Tighten the four tank assembly mounting bolts 112 lbf·ft (152 N·m).
5. Connect the vent line.
6. Connect the coolant supply and return lines to the coolant ports on the tank.
7. Remove any white DEF crystals from the DEF ports on the tank and the DEF line couplings.

IMPORTANT: To connect a DEF line, push the line coupling onto the DEF port male connector, then pull back gently on the coupling to engage the holding clip in the locked position.



1. DEF Pump
2. DEF Tank
3. Coolant Valve
4. Coolant Supply Line
5. Tank Mounting Bracket
6. Tank Retaining Washer (Qty 2)
7. Capscrew (Qty 2)
8. Pump Mounting Bracket

Fig. 3, 6-Gallon Tank Mounting Assembly

8. Connect the DEF supply and return lines to the DEF ports on the back of the tank.
9. Connect the DEF line heater wiring harnesses to the DEF lines at the tank.
10. Connect the wiring harness to the tank header unit.
11. Fill the DEF tank.
12. Fill the cooling system and check for leaks. For instructions, see **Group 20**.
13. Close the hood.

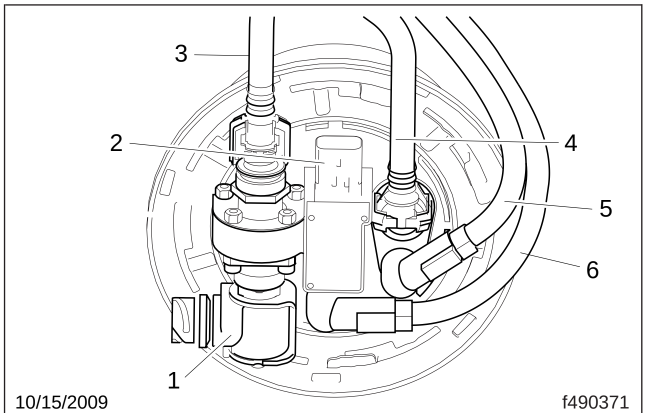
13- or 23-Gallon Tank

Removal

IMPORTANT: Discard contaminated DEF or coolant in accordance with EPA regulations.

Tank Removal and Installation

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Open the hood.
3. Drain the coolant from the cooling system. For instructions, see **Group 20**.
4. Remove the beauty cover, if equipped.
5. Using a siphon, empty the DEF from the tank into a clean container. Uncontaminated DEF may be reused.
6. Place a drain pan underneath the tank to catch any remaining DEF or coolant that drains out.
7. Disconnect the coolant valve and DEF level and temperature sensor wiring harnesses from the tank header unit. See **Fig. 4**.



1. Coolant Valve Wiring Harness
2. DEF Level and Temperature Sensor Wiring Harness
3. Coolant Return Line
4. Coolant Supply Line
5. DEF Return Line
6. DEF Supply Line

Fig. 4, DEF Tank Header Unit (Detroit Diesel shown)

8. Disconnect the coolant lines from the tank header unit.

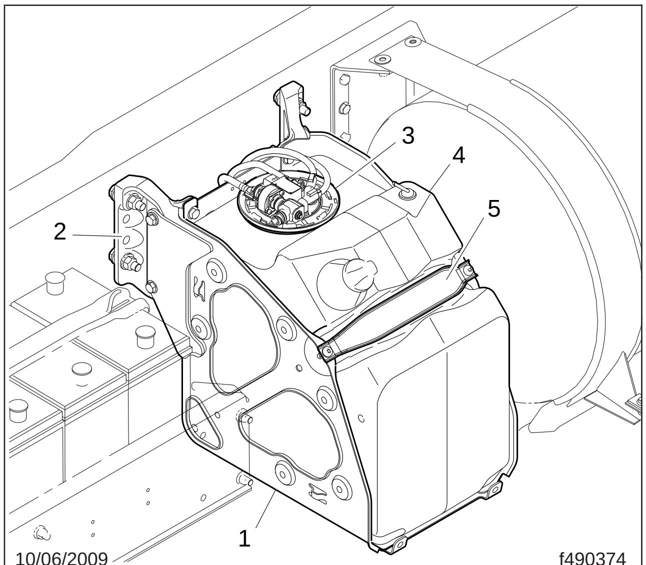
IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the DEF lines. Complete purging of the DEF lines requires approximately five minutes after the engine is shut down.

9. Disconnect the DEF line heater wiring harnesses from the DEF lines at the tank.

NOTICE

To disconnect a DEF line, push the line coupling in towards the male connector to move the holding clip to the unlocked position, then compress the prongs of the holding clip and pull the line off of the male connector. Failure to properly remove a DEF line can result in damage to a line coupling or DEF fitting.

10. Disconnect the DEF lines from the tank header unit.
11. Disconnect the vent line.
12. Remove the two nuts that secure the tank retaining bracket to the tank mounting cage and remove the retaining bracket. See **Fig. 5**.



1. Mounting Cage
2. Mounting Support Bracket
3. Tank Header Unit
4. Tank
5. Tank Retaining Bracket

Fig. 5, 13- or 23-Gallon DEF Tank Mounting Assembly

13. Remove the tank from the mounting cage.

Installation

1. Install the tank into the mounting cage.

Tank Removal and Installation

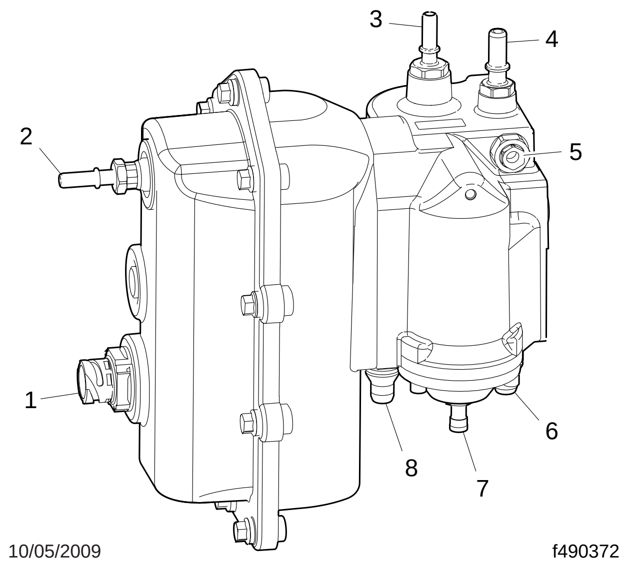
2. Install the tank retaining bracket on the tank mounting cage studs. Install two nuts on the tank retaining bracket and tighten the nuts 12 lbf·ft (16 N·m).
3. Connect the vent line.
4. Remove any white DEF crystals from the DEF ports on the header unit and the DEF line couplings.

IMPORTANT: To connect a DEF line, push the line coupling onto the DEF port male connector, then pull back gently on the coupling to engage the holding clip in the locked position.

5. Connect the DEF supply and return lines to the tank header unit.
6. Connect the DEF line heater wiring harnesses to the DEF lines at the tank.
7. Connect the coolant lines to the tank header unit.
8. Connect the coolant valve and DEF level and temperature sensor wiring harnesses to the tank header unit.
9. Fill the DEF tank.
10. Install the beauty cover, if equipped.
11. Fill the cooling system and check for leaks. For instructions, see **Group 20**.
12. Close the hood.

Pump Removal and Installation

EPA10-compliant vehicles have a diesel exhaust fluid (DEF) pump module (**Fig. 1**) mounted in a protective box to the back of the DEF tank.



1. Wiring Harness Connector
2. DEF Inlet Port
3. DEF Outlet Port (to metering unit)
4. DEF Outlet Port (to tank)
5. Compressed Air Port
6. Coolant Outlet Port
7. Air Bladder Fill Valve
8. Coolant Inlet Port

Fig. 1, DEF Pump (Detroit Diesel shown)

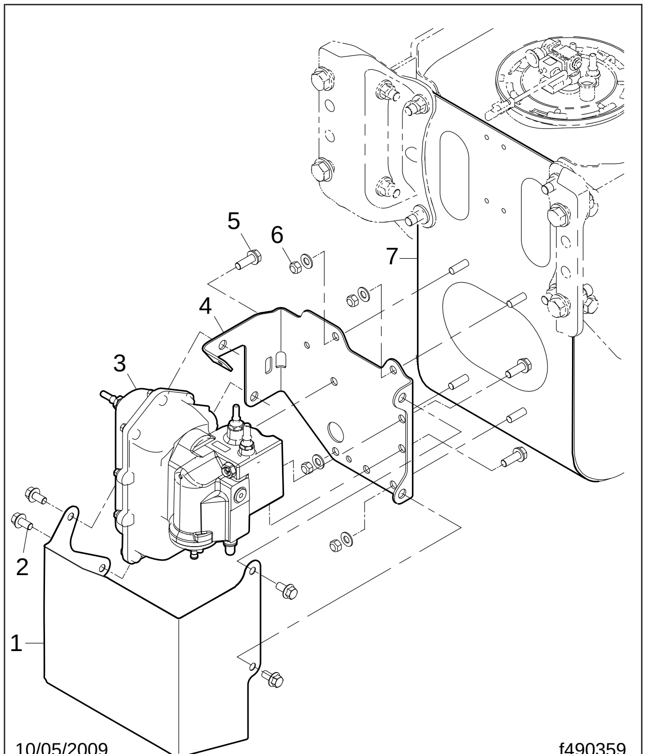
The DEF pump module filters and supplies DEF to the metering unit. The only serviceable components of the pump module are the air bladder and the filter. See the engine manufacturer's service literature for maintenance instructions and intervals.

NOTE: DEF creeps, causing white crystals to form around the line fittings. The presence of crystals does not mean the system has a leak. Replacing fittings or components is not necessary unless there is a system failure or a fault code.

Removal

IMPORTANT: Discard contaminated DEF or coolant in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Open the hood.
3. Drain the air system.
4. On a vehicle equipped with a Detroit Diesel engine, drain the coolant from the cooling system. For instructions, see **Group 20**.
5. Place a drain pan underneath the pump to catch any DEF or remaining coolant that drains out.
6. Remove the four mounting bolts that secure the protective cover over the pump. Remove the cover. See **Fig. 2**.



1. Protective Cover
2. Protective Cover Mounting Fasteners
3. DEF Pump
4. Pump Mounting Bracket
5. Pump Mounting Fasteners
6. Mounting Bracket Fasteners
7. DEF Tank Mounting Cage

Fig. 2, DEF Pump Removal and Installation

7. Disconnect the wiring harness from the pump.

Pump Removal and Installation

8. Disconnect the coolant lines and air line, if equipped, from the pump.

IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the DEF lines. Complete purging of the DEF lines requires approximately five minutes after the engine is shut down.

9. Disconnect the DEF line heater wiring harnesses from the DEF lines at the pump.

NOTICE

To disconnect a DEF line, push the line coupling in towards the male connector to move the holding clip to the unlocked position, then compress the prongs of the holding clip and pull the line off of the male connector. Failure to properly remove a DEF line can result in damage to a line coupling or DEF fitting.

10. Disconnect the DEF lines from the pump.
11. Loosen and remove the four nuts that secure the pump mounting bracket to the tank mounting cage.
12. Remove the DEF pump and mounting bracket.
13. Remove the three fasteners that secure the pump to the mounting bracket, and remove the pump from the bracket.

Installation

1. Using the three pump mounting fasteners, secure the pump to the pump mounting bracket. Tighten the fasteners 26 lbf·ft (35 N·m).
2. Install the four nuts that secure the pump mounting bracket to the DEF tank mounting bracket. Tighten the nuts 23 lbf·ft (31 N·m).
3. Remove any white DEF crystals from the DEF ports on the pump and the DEF line couplings.

IMPORTANT: To connect a DEF line, push the line coupling onto the DEF port male connector, then pull back gently on the coupling to engage the holding clip in the locked position.

4. Connect the DEF supply and return lines to the three DEF ports on the pump.
5. Connect the DEF line heater wiring harnesses to the DEF lines at the pump.
6. Connect the air line and coolant lines, if equipped, to the pump.
7. Connect the wiring harness to the pump.
8. Place the protective cover over the pump and install the four mounting bolts that secure the protective cover to the pump mounting bracket. Tighten the bolts 37 lbf·ft (50 N·m).
9. On a vehicle equipped with a Detroit Diesel engine, fill the cooling system and check for leaks. For instructions, see **Group 20**.
10. Fill the air system.
11. Close the hood.

Line Replacement

NOTE: Diesel exhaust fluid (DEF) creeps, causing white crystals to form around the line fittings. The presence of crystals does not mean the system has a leak. Replacing fittings or components is not necessary unless there is a system failure or a fault code.

Replacement

IMPORTANT: Discard contaminated DEF or coolant in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the battery ground cable. Disconnecting the battery ground cable too soon will prevent purging of the DEF lines after the engine is shut down.

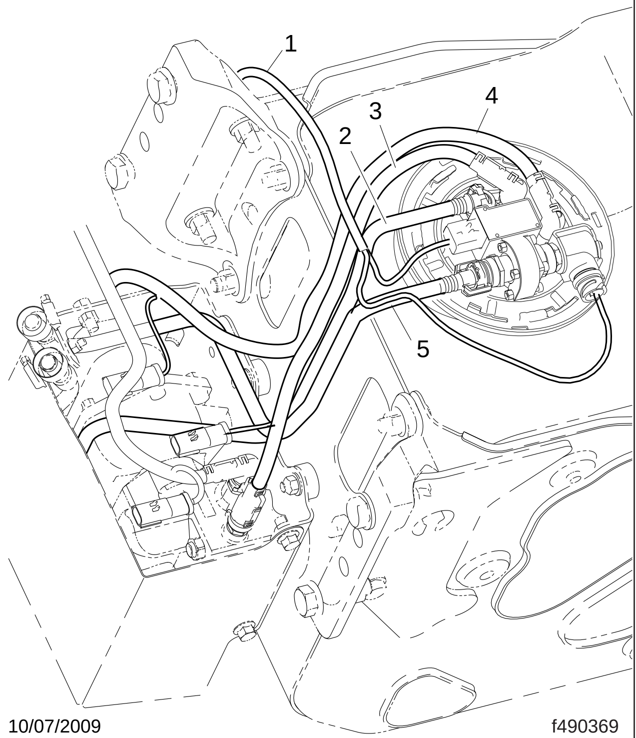
2. Disconnect the batteries.
3. Place drain pans underneath the DEF pump and the DEF metering unit to catch any draining DEF.
4. Disconnect the DEF line heater wiring harnesses from the DEF lines at the tank, pump, and metering unit.

NOTICE

To disconnect a DEF line, push the line coupling in towards the male connector to move the holding clip to the unlocked position, then compress the prongs of the holding clip and pull the line off of the male connector. Failure to properly remove a DEF line can result in damage to a line coupling or DEF fitting.

5. Disconnect the DEF lines between the DEF pump and the tank. See **Fig. 1**.
6. Disconnect the DEF lines between the pump and the metering unit.
7. Discard the lines.
8. Ensure the new DEF lines are undamaged and free of dirt or debris.
9. Remove any white DEF crystals from the DEF ports on the tank, pump, and metering unit.

IMPORTANT: To connect a DEF line, push the line coupling onto the DEF port male connector, then pull back gently on the coupling to engage the holding clip in the locked position.



1. Wiring Harness
2. Coolant Supply Line
3. DEF Return Line
4. DEF Supply Line
5. Coolant Return Line

Fig. 1, DEF Pump Line Connections

10. Install new DEF lines between the DEF pump and the tank.
11. Install new DEF lines between the DEF pump and the metering unit.
12. Connect the DEF line heater wiring harnesses to the DEF lines at the tank, pump, and metering unit.
13. Connect the batteries.

NOTE: DEF creeps, causing white crystals to form around the line fittings. The presence of crystals does not mean the system has a leak. Replacing fittings or components is not necessary unless there is a system failure or a fault code.

Replacement, 6-Gallon Tank

The DEF header unit on vehicles with a 6-gallon DEF tank is secured to the top of the tank, and contains the DEF level sensor and the DEF temperature sensor.

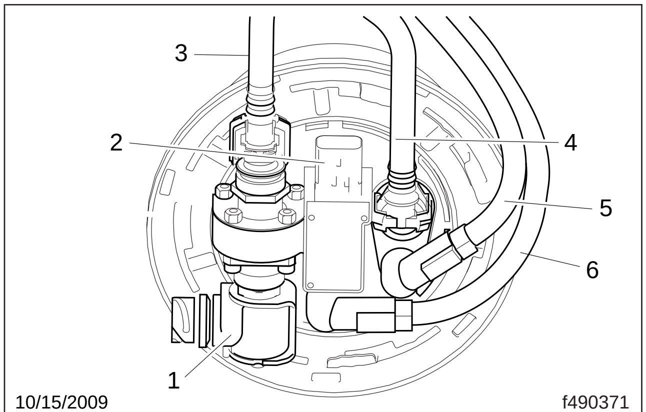
IMPORTANT: Discard contaminated DEF or coolant in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Remove the tank from the vehicle. See **Subject 100** for instructions.
3. Remove the header unit mounting capscrews and washers that secure the header to the tank.
4. Remove the header unit from the tank.
5. Install a new header unit into the tank.
6. Ensure that the header unit is situated securely on the raised lip of the tank, and is not tilted to the side.
7. Install the mounting capscrews and washers to secure the header unit to the tank. Tighten the capscrews 5 lbf·ft (7 N·m).
8. Connect the DEF level and temperature sensor wiring harness.
9. Install the DEF tank on the vehicle. See **Subject 100** for instructions.

Replacement, 13- or 23-Gallon Tank

The DEF header unit on vehicles with a 13- or 23-gallon DEF tank is secured to the top of the tank, and contains the engine coolant lines that run through the tank, the coolant valve, the DEF level sensor, and the DEF temperature sensor. See **Fig. 1**.

IMPORTANT: Discard contaminated DEF or coolant in accordance with EPA regulations.



1. Coolant Valve Wiring Harness
2. DEF Level and Temperature Sensor Wiring Harness
3. Coolant Return Line
4. Coolant Supply Line
5. DEF Return Line
6. DEF Supply Line

Fig. 1, DEF Tank Header Unit (Detroit Diesel shown)

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Remove the tank from the vehicle. See **Subject 100** for instructions.
3. Rotate the header lockring counter-clockwise to loosen it, then remove the lockring.
4. Remove the header unit from the tank by pulling the assembly straight up, then tilting it to pull the horizontal end clear of the tank; see **Fig. 2**.
5. Install a new header unit by tilting it to insert the horizontal end into the tank. Once the horizontal segment is inside the tank, tilt the header unit back to vertical to settle the bracket on top of the tank.
6. Ensure that the header unit is situated securely on the raised lip of the tank, and is not tilted to the side.
7. Install the header lockring and rotate it clockwise to secure it to the tank.
8. Remove any white DEF crystals from the DEF ports on the header unit and the DEF line couplings.
9. Install the DEF tank on the vehicle. See **Subject 100** for instructions.

Tank Header Unit Replacement

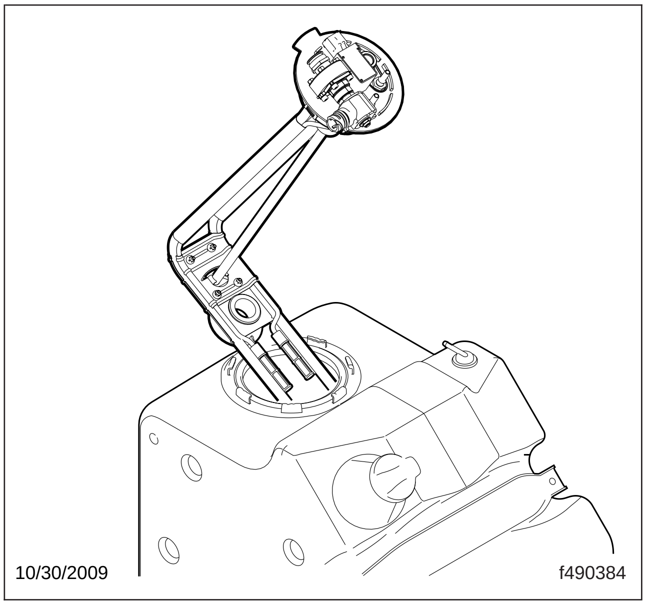


Fig. 2, Header Unit Tilt

NOTE: Diesel exhaust fluid (DEF) creeps, causing white crystals to form around the line fittings. The presence of crystals does not mean the system has a leak. Replacing fittings or components is not necessary unless there is a system failure or a fault code.

Periodic maintenance of the DEF pump filter is required. For instructions and intervals, see the engine manufacturer's service literature.

Replacement

Detroit Diesel

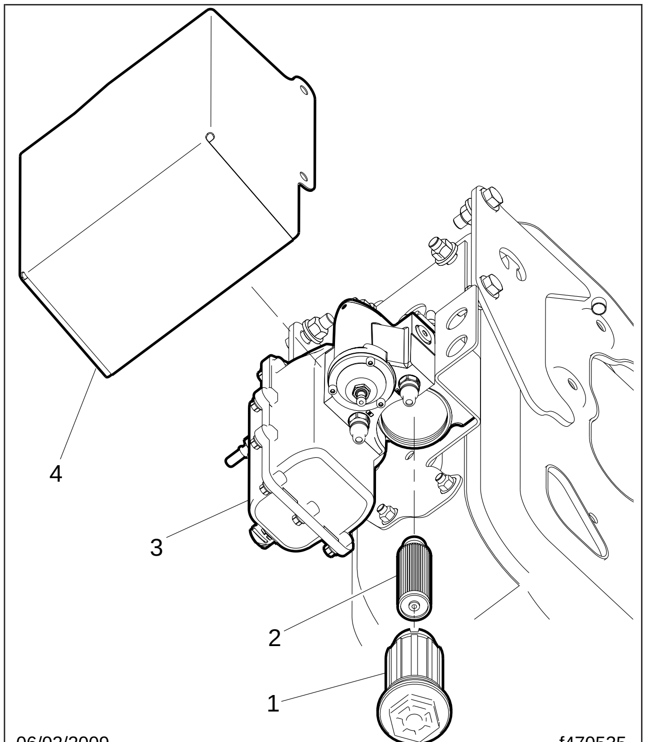
IMPORTANT: Discard contaminated DEF in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the battery ground cable. Disconnecting the battery ground cable too soon will prevent purging of the DEF lines after the engine is shut down.

2. Disconnect the batteries.
3. Remove the four mounting bolts that secure the protective cover over the pump. Remove the cover. The pump is located next to, or inboard of, the DEF tank.
4. Unscrew the filter cartridge; see **Fig. 1**. The cartridge includes both the filter case and the filter element, which are replaced as a unit. Verify that the filter element was removed with the case. If the filter element was not removed, use a suitable tool to remove it from the pump.

   Discard the filter element and case.
5. Lubricate the O-rings with clean DEF.
6. Check the new filter cartridge to ensure that the O-ring end of the filter element is facing out of the cartridge. Install the cartridge into the DEF pump. Tighten the filter cartridge 22 to 25 lbf·ft (30 to 34 N·m).
7. Place the protective cover over the pump and install the four mounting bolts that secure the protective cover to the pump mounting bracket. Tighten the bolts 37 lbf·ft (50 N·m).



1. Filter Case
2. Filter Element
3. DEF Pump
4. Cover

Fig. 1, DEF Filter Replacement, Detroit Diesel Engine

8. Connect the batteries.

Cummins

IMPORTANT: Discard contaminated DEF in accordance with EPA regulations.

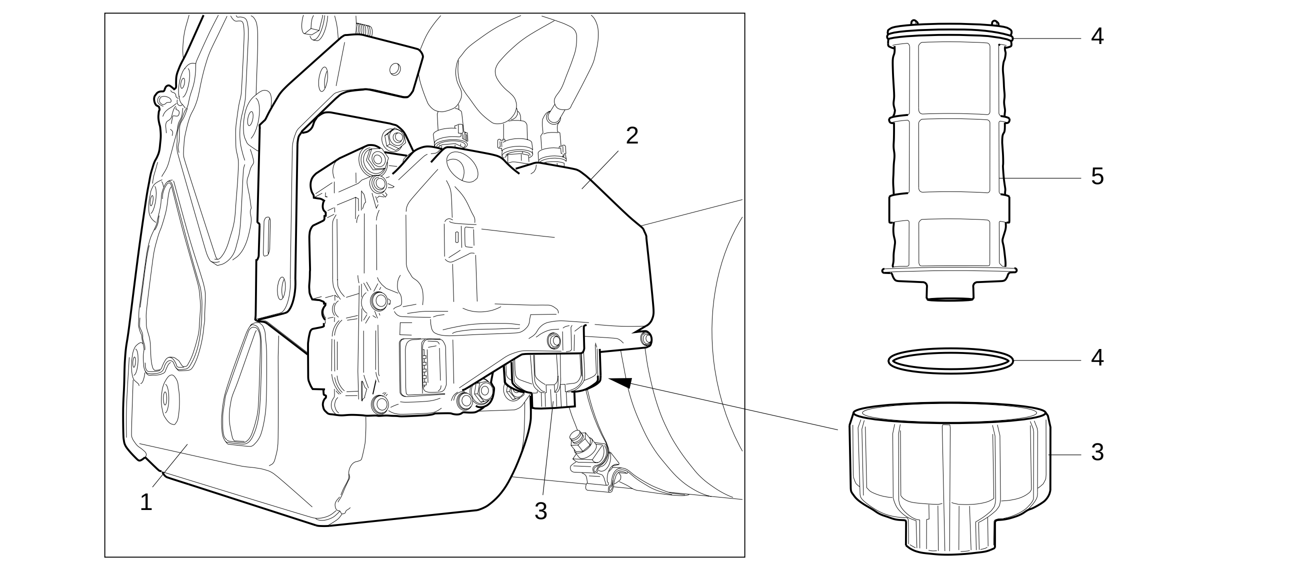
1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the battery ground cable. Disconnecting the battery ground cable too soon will prevent purging of the DEF lines after the engine is shut down.

2. Disconnect the batteries.
3. Remove the four mounting bolts that secure the protective cover over the pump. Remove the cover. The pump is located inboard of the DEF tank.

Pump Filter Replacement

4. Unscrew the filter cap, then remove and discard the filter element. See **Fig. 2**.
5. Install the new filter element into the DEF pump with the O-ring end facing into the pump.
6. Install the filter cap. Tighten the cap 15 to 18 lbf·ft (20 to 25 N·m).
7. Place the protective cover over the pump and install the four mounting bolts that secure the protective cover to the pump mounting bracket. Tighten the bolts 37 lbf·ft (50 N·m).
8. Connect the batteries.



1. DEF Tank
2. DEF Pump
3. Filter Cap
4. O-Ring
5. Filter Element

Fig. 2, DEF Filter Replacement, Cummins Engine

Tank Flushing

If a contaminant has been introduced into the diesel exhaust fluid (DEF) system and the engine has been started, the following DEF components must be replaced:

- Tank
- Pump
- Header unit
- Metering unit
- Injector

See the other subjects in this section for tank, pump, and header unit replacement.

See the engine manufacturer's service literature for other component replacement instructions.

Flushing

If a contaminant has been introduced to the DEF tank, but the engine has not been started, complete the following steps.

1. Apply the parking brake and chock the tires.
2. Place a suitable container underneath the DEF tank to catch any draining DEF.

IMPORTANT: Discard contaminated DEF or coolant in accordance with EPA regulations.

3. Remove the DEF and contaminant from the tank.

   On vehicles with a 6-gallon DEF tank, disconnect the DEF line from the DEF outlet port and let the DEF drain into the drain pan.

   On vehicles with a 13- or 23-gallon DEF tank, use a siphon to empty the DEF from the tank.
4. Remove the DEF tank. See **Subject 100** for instructions.
5. Thoroughly flush the tank with water until the tank is free of all contaminants.
6. Install the DEF tank. See **Subject 100** for instructions.

Introduction to Multiplexing

The term "multiplexing" describes how the Business Class® M2 electrical system works. Multiplexing is defined as sending multiple electronic messages through the same signal path at the same time—in this case, through the M2 wiring.

Multiplexing allows the M2 electrical system to simultaneously perform tasks and to monitor components. A multiplexed system uses electronic control units (ECUs) to operate the system. The electrical system components, such as switches and lamps, are connected to the ECUs, which collect and control all information about the components by communicating on the data bus.

A less formal description might be that multiplexing is much like the interstate highway system. Trucks and cars share the roadway, with each vehicle bound for a different destination. Every vehicle travels at different speeds, enters and exits at different places, and the occupants of every vehicle have different objectives. Whether it is a truckdriver hauling goods from a factory to a store or a saleswoman heading home from work, highway users are like the electronic signals flashing along the datalink.

Multiplexing was introduced in vehicles in the 1980's with the first electronically controlled engines and the initial use of the J1708/J1587 datalink. The concept was taken a step further in the early 1990's when transmissions were electronically connected to engines in order to control engine speed and torque output during shifting. Multiplexing has now been applied to the entire vehicle.

General Information

The multiplexed electrical system replaces traditional power distribution module (PDM) devices, such as relays and circuit breakers, with electronic devices that communicate over the vehicle datalinks. These electronic devices control power distribution to the electric loads on the vehicle. This is done by monitoring inputs (such as sensors and switches) and supplying power to outputs (such as lighting, displays, gauges, and indicators). This distributed approach to handling switch inputs and controlling electrical load outputs sharply reduces the number of wires on a vehicle. Rather than having individual wires transmitting voltage from switches to relays that then supply power to the components, the multiplexed system continuously monitors the status of all switches (input devices) and sends messages over the shared-wire J1939 datalink to control outputs.

The system communicates on two datalinks: the J1939 datalink and the J1708/J1587 datalink. J1939 is the primary datalink and is used for all control messaging and troubleshooting; J1708/J1587 is the secondary datalink and is used for limited troubleshooting. Fault codes are displayed on the instrument cluster display and they may also be viewed on ServiceLink®.

The multiplexed system uses the following controllers:

- Bulkhead Module (BHM)
- Chassis Module (CHM)
- optional Expansion Module (EXM)

The most important part of the multiplexed electrical system is the BHM. The BHM is the brain of the entire system, and controls all of the outputs in response to changes in any of the inputs. The CHM and EXM are slaves to the BHM and respond to commands from the BHM and broadcast the status of the inputs and outputs connected to them. See **Fig. 1**.

See **Fig. 2** for an example of how the headlamp signal inputs and outputs are handled in the multiplexed system. When the headlamp switch is turned on, the BHM senses the input. The BHM is programmed to know which outputs it should activate for each input signal and where those outputs are located (such as on the BHM, CHM, EXM, or other controller). In this example, the outputs for the left headlamp low beam are located on the BHM and the outputs for the right headlamp low beam are located on the CHM. The BHM can directly activate the left headlamp low beam. However, because the right headlamp low beam outputs are located on the CHM, the BHM must send a message over J1939 to the CHM to tell it to activate those outputs. Once the CHM receives the message, it activates the correct outputs and sends a message back to the BHM reporting the new status of the outputs. This fail-safe design allows at least one headlight to work even if the BHM or CHM should fail.

For an example of the flash-to-pass function, see **Fig. 3**. In this case, the input comes from the multifunction turn signal switch mounted on the steering column. It goes into the instrumentation control unit, or ICU3-M2, for processing. The instrumentation control unit (ICU) sends a message on J1939 to the BHM informing it of the multifunction turn signal switch status. The output for the right headlamp high beam is located on the BHM and the output for the left headlamp high beam is located on the CHM. The BHM directly flashes the right headlamp high beam and sends a message over J1939 to the CHM to tell it to flash the left headlamp high beam. Once the CHM receives the message, it flashes the headlamp high beam and sends a message back to the BHM reporting the new status of the output. To complete the loop, the BHM sends a message over J1939 to the ICU reporting that the command was completed. These messages are transmitted so quickly that the entire process takes only a fraction of a second.

The final example is the park brake telltale. See **Fig. 4**. To avoid driving away with the park brake set, the system is designed to warn the driver. When the driver pulls out the park brake switch on the dash to set the park brake, the CHM receives an electrical air pressure signal from either the air management unit (AMU), or a pressure switch on auxiliary air valve assembly (AAVA) vehicles. The CHM sends a J1939 message to the BHM, the BHM sends a J1939 message to the ICU, and the ICU turns on the park brake telltale dash light.

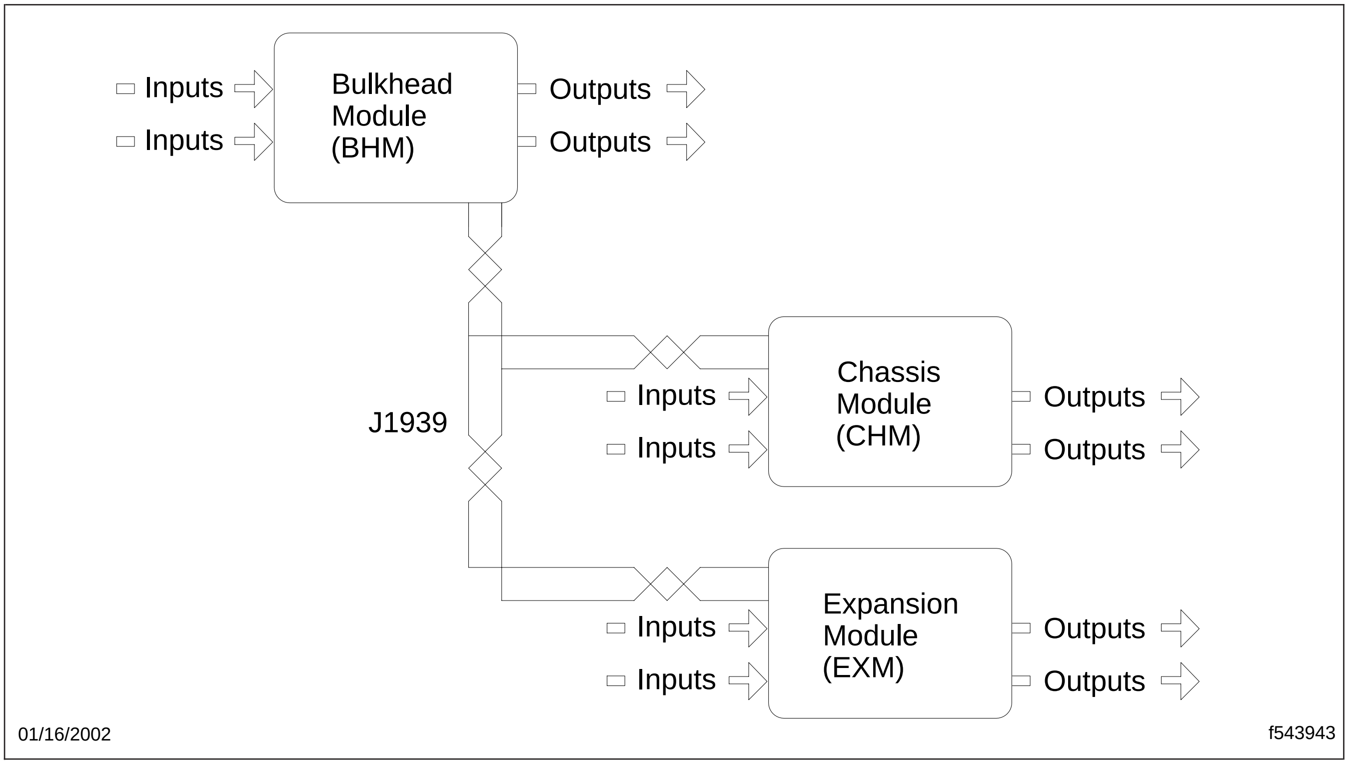


Fig. 1, Multiplexed System Controllers

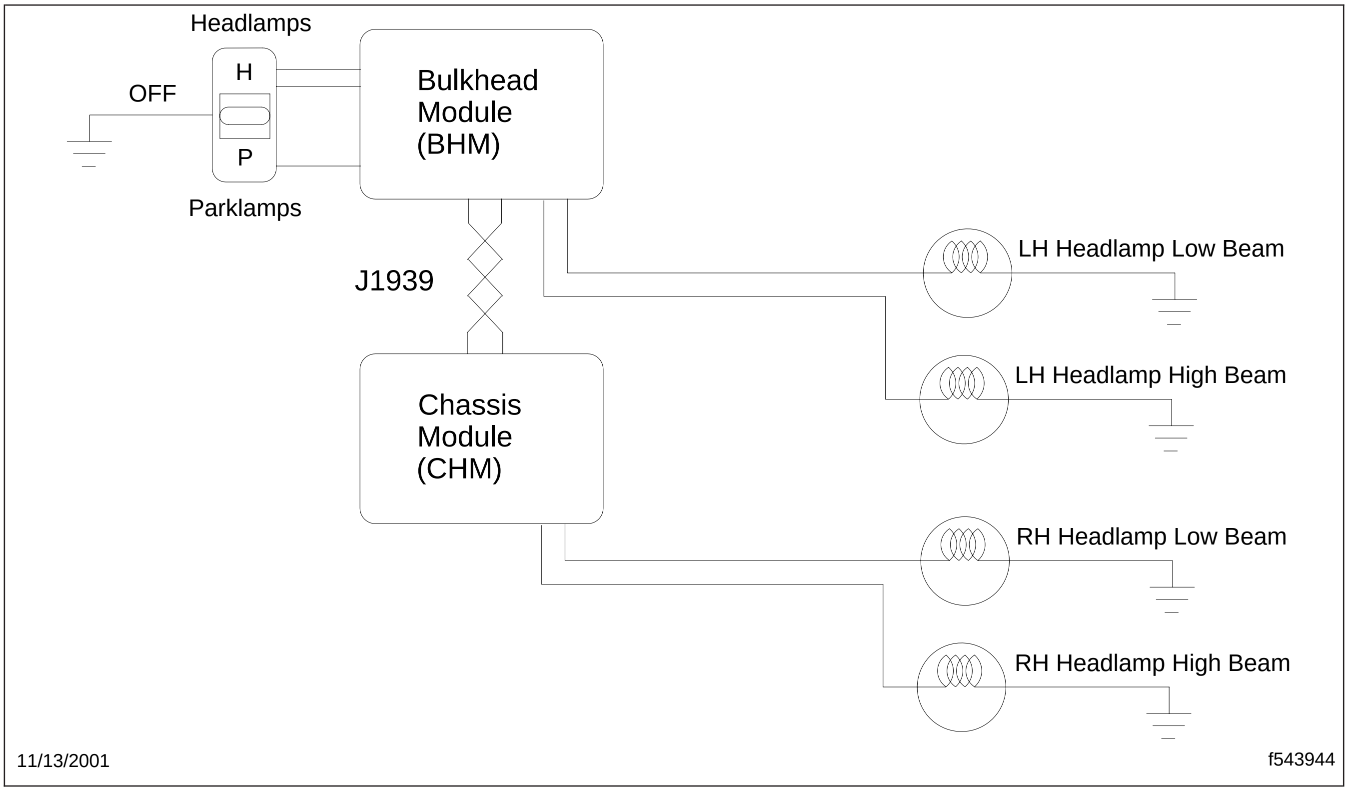


Fig. 2, Headlamp Switch Example

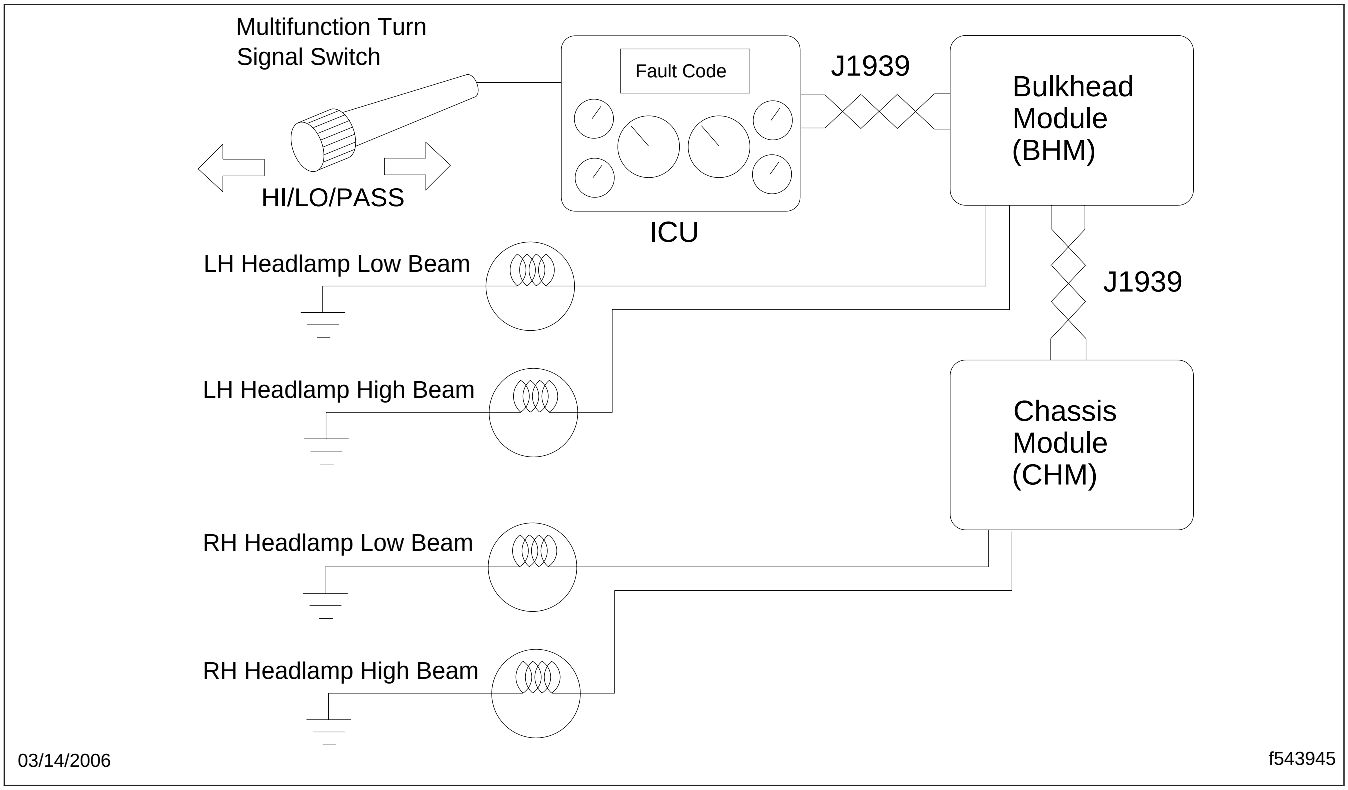


Fig. 3, Flash-To-Pass Example

General Information

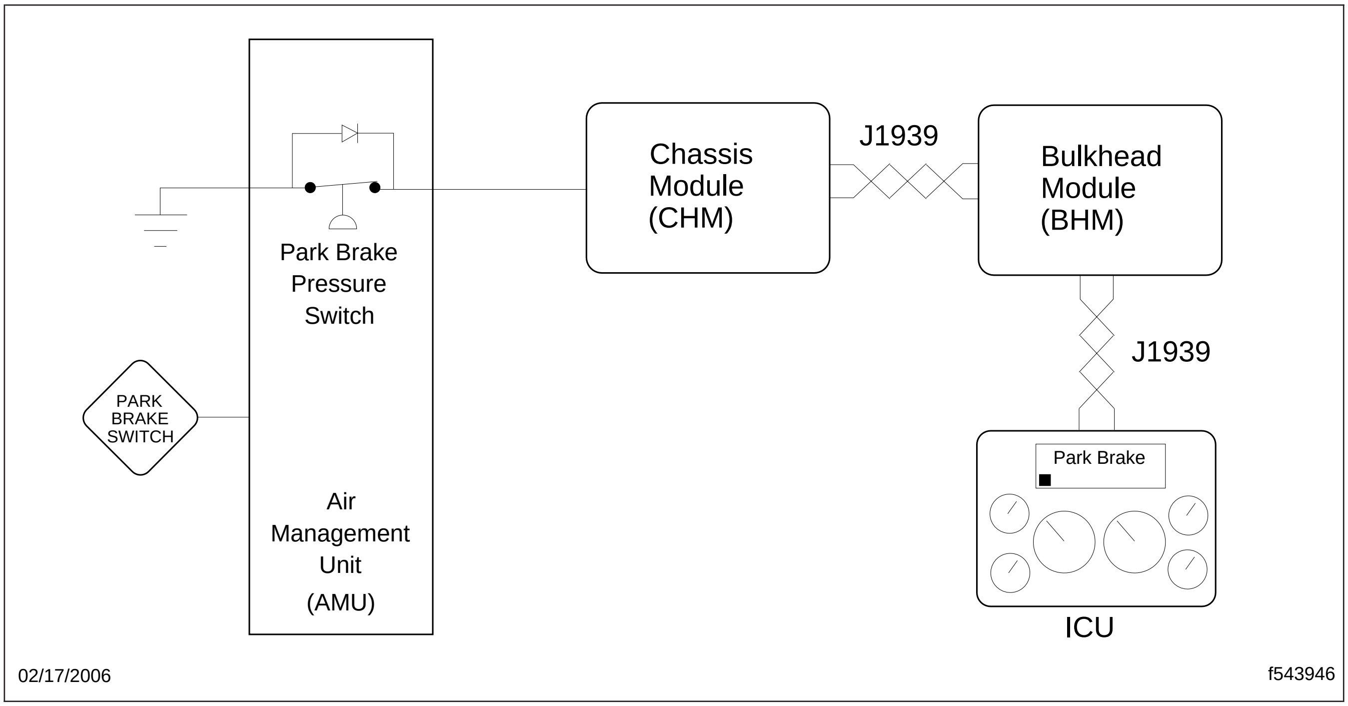


Fig. 4, Park Brake Telltale Example

Abbreviations and Terms

Use the following list to determine the meaning of the abbreviations and terms used in **Group 54**.

AAVA Auxiliary Air Valve Assembly

ABS Antilock Braking System

Activate To begin operating.

Address A unique location code for a device or data.

AMU Air Management Unit

API Application Programming Interface

ATC Automatic Traction Control

BHM Bulkhead Module

CAN Controller Area Network

CHM Chassis Module

Configure To set up a program or system for a particular device or set of devices.

Databus See datalink.

Datalink A collection of wires connecting system components through which data is transmitted.

DRL Daytime Running Lights

DTC Diagnostic Trouble Code

ECM Engine Control Module

ECU Electronic Control Unit, a device that communicates on a datalink.

EEPROM Electrically Erasable Programmable Read-Only Memory

EMC Electromagnetic Compatibility

EMI Electromagnetic Interference

EOL End of Line

ESD Electrostatic Discharge

EXM Expansion Module

Fault Code A limited set of alphanumeric characters representing a corresponding error message. Fault codes are limited to a maximum number of characters by the display output and cross-referenced to a more descriptive message. On J1939, fault codes are made up of a SA, SPN, and FMI. On J1708/J1587, fault codes are made up of an MID, PID/SID, and FMI.

FMEA Failure Mode Effects Analysis

FMI Failure Mode Indicator. The part of a J1708/J1587 or J1939 fault code that identifies how a part of or item on a device failed.

FMVSS Federal Motor Vehicle Safety Standard

HSD High Side Driver

HVAC Heating, Ventilating, and Air Conditioning

ICU Instrumentation Control Unit

Input A device that feeds a signal into the system, or signal that feeds a message into the system.

J1708/1587 An older vehicle communications network protocol intended to provide simple information exchange, including diagnostic data between electronic control devices.

J1939 A high speed vehicle communications network using the CAN protocol, which permits any device to transmit a message on the network when the datalink is idle. Each message includes an identifier that defines the message priority, who sent it, and what data is contained within it. Collisions are avoided due to the arbitration process that occurs while the identifier is transmitted, permitting high priority messages to get through with minimal delay.

LCD Liquid Crystal Display

LCL Low Coolant Level

LED Light-emitting Diode

Legend The icon, symbol or text on a warning light cover illuminated by a telltale lamp.

LSD Low Side Driver

MID Message Identifier. Identifies any device that communicates on J1708/J1587.

Multiplexing The process of combining several messages for transmission over the same signal path.

Output The signal or message that comes out of a system component or device.

Parameter A predetermined variable in a set, each of which restricts or defines the specific capabilities of the system as a whole. Used to customize the configuration of the system.

Pass-through Inputs and outputs on a device capable of allowing data to be transmitted through it without affecting the message or the device.

PCB Printed Circuit Board

Abbreviations and Terms

PID Parameter Identifier. The part of a J1708/J1587 fault code that identifies what part of or item on a device that failed. PIDs are not MID specific.

PLC Power Line Carrier

PRD Product Requirements Document

PWM Pulse Width Modulation

SA Source Address. Identifies any device that communicates on J1939.

SAE Society of Automotive Engineers

SID Subsystem Identifier. The part of a J1708/J1587 fault code that identifies what part of or item on a device that failed. SIDs are MID specific.

Smart Switch Configurable input device, called "smart" because it is recognized by the system not by its position or physical characteristics but by its resistance value.

SPN Suspect Parameter Number. The part of a J1939 fault code that identifies what part of or item on a device that failed.

Status Condition, position, or relative position of an input or output at a specific time.

TDS Technical Development Specifications

Telltale Any of a number of colored warning lights on the ICU instrument cluster that illuminates an icon, symbol, or text covering it.

UL Underwriters Laboratory

VCU Vehicle Control Unit

Reference Parameters

Reference parameters program the BHM to know which outputs to activate for each input and where those outputs are located. The two types of reference parameters are default and optional. Every vehicle has one default reference parameter and zero to any number of optional reference parameters.

The default reference parameter programs the BHM with features that come standard on each vehicle, such as headlights. Optional reference parameters program the BHM for vehicle-specific features, such as heated mirrors.

Each reference parameter is given a part number just like any other hardware part on the vehicle. A reference parameter only programs the parameters of the BHM.

Reflashing or reprogramming the software is separate from programming the parameters, just as it is in an engine controller.

Changing Features and Options

Features can be changed with ServiceLink® from the Features screen under the Bulkhead Module (BHM) icon. The Features screen displays the features that are installed in the BHM by listing the reference parameter numbers and their descriptions. From this screen, the user can reload all the currently installed features or make changes to the vehicle by entering new reference parameters.

General Information

When adding features to a Business Class® M2 vehicle, some important issues need to be considered. Read the information in this subject before adding features to the vehicle.

ServiceLink® must be used to add features to the unique multiplexed electrical system in the M2 vehicle.

1. To access ServiceLink training, go to **www.AccessFreightliner.com** and click on **Tools and Services**.
2. Click on **The Learning Center** and log on.
3. Select **More** from the software training icon.
4. From the **Web Based Training** course list, select **ServiceLink Web Based Training** (I.D. number WBTSLN-1).
5. Once you have started the training, click on **Features** to access the training that pertains to adding features.

If ServiceLink is not available, you will need to bypass the multiplexed electrical system and isolate circuits by connecting only to authorized vehicle interface points. The location of these interface points is explained in "Circuit Isolation."

Control Modules

The control modules of the multiplexed electrical system are the Bulkhead Module (BHM), Chassis Module (CHM), and any optional Expansion Module (EXM). While every vehicle will have a BHM and CHM, Expansion Modules will be added as needed to increase the capacity of the electrical system. The BHM is the main controller, or brain, of the system and is in constant communication with the CHM and any EXM over the J1939 datalink. Think of the CHM and any EXM as extensions of the BHM. The BHM uses the CHM and EXM as its arms and legs. The BHM controls inputs to and outputs from itself, the CHM, and any EXM based on the reference parameters that are programmed into it.

Reference Parameters

As with other electronic control units (ECU) on the vehicle, the BHM is programmed through the use of parameters. Reference parameters are used to add multiplexed features to the BHM. There is a reference parameter for each multiplexed feature, such as heated mirrors. It is these reference parameters that a technician will work with through ServiceLink. Each reference parameter has been given its own part number with the prefix 26-. Reference parameters can be found listed under their part number in bills of material (BOM) and in PartsPro®.

Floating Pins

Floating pins means that a pin in a connector is not necessarily always assigned to the same circuit on every vehicle. For that reason, you must use the Configuration screen in ServiceLink to verify pin assignment. G06 drawings are general guides and are not vehicle specific.

Adding a Feature

Use the following instructions to add features to the vehicle.

1. Using the *Freightliner Business Class® M2 Data Book*, select the applicable data code that applies to the requested add-on feature. For example, Daytime Running Lights, 311-001.
2. Contact Freightliner Parts Technical Support and provide the representative with the vehicle identification number (VIN) and the data code requested. The representative will advise of the availability of the feature.

NOTE: Reference parameters, such as 26-XXXXX-XXX, are needed to determine circuit availability for the desired feature.

NOTE: The following step should be done at the parts counter to ensure that all parts required for the job, including any EXM, are identified before a quote is given to the customer and the work begins. Since the Business Class M2 makes use of floating pins, it is possible that one truck may require an EXM to add a feature, and a seemingly identical vehicle will not.

3. Log on to the Freightliner mainframe. From the SOS/MAX menu, press F11, **Additional Features Multiplexing Inquiry**.

3.1 Key in the vehicle serial number, or the last six digits of the VIN.

3.2 Key in the reference parameter numbers from **all** the bills of material that are being added at that time.

The screen will indicate if the feature can be added with the existing control modules or if an additional EXM is needed. See **Fig. 1** for a view of the response screen. See **Table 1** for possible responses and necessary actions.

4. To add a reference parameter to the vehicle, use the Features screen in ServiceLink. It is best to have ServiceLink connected to the host and the vehicle at the same time. If this is not possible, connect ServiceLink to the host and add the reference parameter, then take the ServiceLink computer to the vehicle and update the vehicle.

device, connector, pin location, circuit number, and action. This table will be used to make circuit changes to the BHM, CHM, or EXM as necessary to add the features.

Circuit Isolation

If features must be added outside of the multiplexed electrical system, there are a few options for obtaining authorized interface points.

- Data code 353-XXX provides various options for vehicle wiring interfaces, including back of cab, frontwall, and end-of-frame locations. Data code 148-XXX provides options for engine wiring, and data code 34C-XXX provides options for transmission wiring. Go to **www.Access-Freightliner.com** for more information.
- Battery power connections must be made at

```
                      Vehicle Spec / Additional Feature Inquiry                           DSOVRI

   Serial Number :  J81277
   Lead Ser No. :   J81277           Built To-Date :      1             To Be Built:      0
   Customer :  TECHNICAL TR          Build Location :   MT. HOLLY       Fleet Size :      1

     Reference Parameter             Description
  Y  26-01005-000                    Engine Block Heater




  PF1=Help    PF3=Menu    PF12=Exit    PF20=Specs    PF21=BOMs    PF23=DBCode
  08:33:31 06/07/02 Features can be added to the existing devices
```

06/12/2002 f610616

Fig. 1, SOS/MAX Additional Feature Inquiry Response Screen

5. When the reference parameters are applied to the BHM, ServiceLink will provide any necessary wiring instructions via a table with columns for

the battery through one of the four available MEGA® Fuses.

- Inside the cab, there are splice packs behind the center dash that provide interface points for ignition voltage, ground, and panel lamp illumination.

IMPORTANT: When bypassing the multiplex electrical system, the interface points previously mentioned are the only authorized points. **Do not** splice in to any other electrical wiring.

SOS/MAX Additional Feature Inquiry Responses	
System Response	**Action Required**
Features can be added to the existing devices.	No other action is necessary to present a complete and accurate quote to the customer.
Features cannot be added to existing devices.	Expansion module required.
Feature requires additional engineering work.	Contact your District Service Manager (DSM).
Reference parameter not defined.	From the bill of material supplied, first verify and try re-entering the 26-XXXXX-XXX number(s) again. If this fails, contact Freightliner Parts Technical Support for further assistance.

Table 1, SOS/MAX Additional Feature Inquiry Responses

Troubleshooting

With the multiplexed electrical system, traditional multimeter-based current, voltage and resistance measurements are supplemented, or in some cases replaced, by software tools that can read and control the electronic signals and devices of the system. ServiceLink® is the tool that is used to troubleshoot the Business Class® M2 electrical system.

The modules of the multiplexed electrical system communicate on both J1939 and J1708/J1587. The primary datalink for the electrical system is J1939, and is used for all control messaging and troubleshooting. J1708/J1587 is the secondary datalink and is used for limited troubleshooting. Fault codes are displayed on the instrument cluster, and can also be viewed with ServiceLink.

Since the modules of the electrical system communicate on both J1939 and J1708/J1587, ServiceLink shows information for both datalinks. Although each module connected to the multiplexed electrical system is represented by an icon within ServiceLink, the Bulkhead Module (BHM) icon is the main icon for troubleshooting the system. This is because the Bulkhead Module is the main controller of the multiplexed system. The other icons are secondary and contain generic screens.

The following screens can be accessed under the Bulkhead Module icon:

- **General Info**—Displays information about the BHM such as make, model, hardware version, and software version.
- **Faults**—Displays the active and historic faults for all of the control modules on the multiplexed electrical system.
- **Configuration**—Displays the pinout for all of the control modules on the multiplexed electrical system compared to the host.
- **Features**—Displays the features that are installed in the BHM. From this screen the user can reload all the currently installed features, or make changes to the vehicle by entering new reference parameters.
- **Flashing**—Allows the user to update or reflash the software of the BHM.
- **Templates**—Gives a directory of Datalink Monitor Templates available for troubleshooting the multiplexed electrical system. These templates allow the user to monitor and manipulate the inputs and outputs of the electrical system.

The other control module icons, listed below, will have only a General Info screen, a Faults screen, and a Templates screen.

- Chassis Module (CHM)
- Expansion Module (EXM)

The General Info screen displays information about the particular module such as make, model, hardware version, and software version. The Faults screen displays the active and historic faults for the particular module on the particular datalink. The Templates screen gives a directory of Datalink Monitor Templates available for troubleshooting the particular module. These templates allow the user to monitor and manipulate the inputs and outputs of the electrical system.

NOTE: For more specific information about the Bulkhead Module see **Section 54.12**. For more specific troubleshooting information see **Section 54.12, Subject 300**.

Device Communications

For information on cross-referencing a J1587 Message Identifier (MID) and a J1939 Source Address (SA), see **Table 1**.

Device Communications on J1587 and J1939		
Device Description	**J1587 MID***	**J1939 SA†**
Engine	128	0
Transmission	130	3
Antilock Brakes	136	11
Instrument Cluster	140	23
Vehicle Security Unit (VSU)	163	—
Data Logging Unit (DLU)	179	251
Collision Avoidance System (Headway Controller)	219	42
Bulkhead Module	164	33
Chassis Module	249	71
Expansion Module #1	170	235
Expansion Module #2	187	236
Expansion Module #3	188	237
Expansion Module #4	178	238
Expansion Module #5	240	239

* Message Identifier

† Source Address

Table 1, Device Communications on J1587 and J1939

General Information

The on-highway environment places severe demands on a vehicles electrical system. The following material describes the methods for repairing and sealing electrical connections that will provide the durability necessary for the automotive environment.

There are four distinct components for making a wire repair that will withstand:

- the mechanical demands of vibration, strain, and thermal cycling
- the electrical requirement of oxidation free conductivity
- the insulating properties to resist shorting to adjacent objects
- the ability to seal for corrosion protection

When troubleshooting electrical systems, consider body height and suspension travel. Interference and strain may be caused by normal frame flexing and body accessories that are not apparent when a vehicle is stationary.

Wire Repair and Splicing

Disconnect the batteries at the negative terminals before performing any repairs to the electrical system.

IMPORTANT: Before repairing or replacing any damaged electrical system components, locate and correct the cause of the damage before continuing with the repair.

Wire that is discolored or melted due to an external heat source may need to be re-routed or installation of a heat shield may be necessary. If wire length permits, a splice may be made with a single connector. Often a length of wire will need to be added and two splices are made. Carefully check damaged wire for signs of corrosion that has wicked up into the insulation and through the wire. If the wire conductor has become green or black, cut off the discolored wire and replace it with a new section.

Corrosion on battery cable terminals may be cleaned with a mild solution of baking soda and water, and scrubbed with a wire brush.

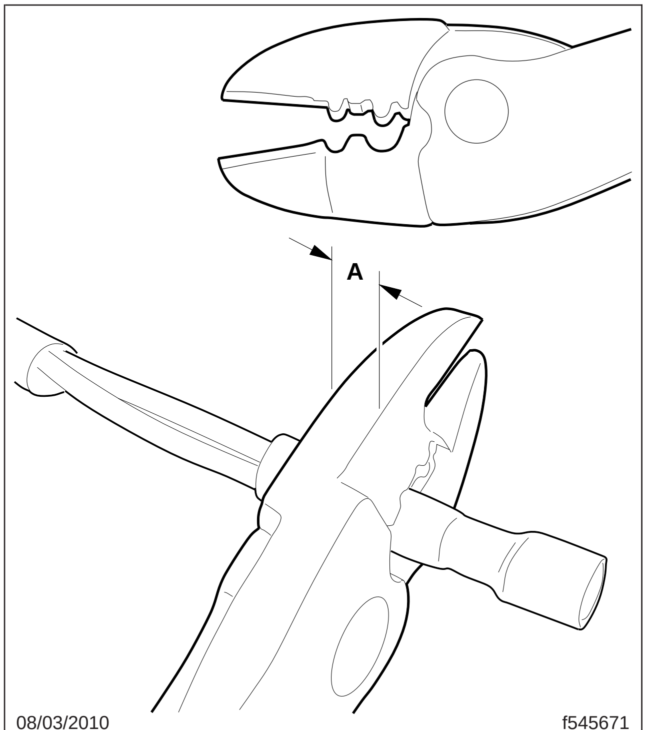
Wiring Repair Using Phillips STA-DRY® Solderless Connectors

Parts and Tools

Parts are available through the Parts Distribution Centers (PDCs) in packages of 25 connectors. Use the connectors and adhesive lined shrinkable tubing shown in **Table 1** when making a wiring splice.

Tools needed for wiring repair using solderless connectors include the following.

- A dimple-type crimp tool with a minimum 3/16 inch width. See **Fig. 1** for an example of a proper crimp tool. A typical manufacturer for this tool is Thomas & Betts.
- A heat gun rated at 1000°F (538°C).



A. Minimum 3/16 inch width.

Fig. 1, Dimple-Type Crimp Tool

Procedure

1. Dress the wires to be spliced by stripping the insulation to expose 1/4 inch of copper. Slide a 3-inch section of adhesive coated shrink tubing onto one of the wires.
2. Crimp the splice connector onto the wires. Use the type of crimp tool that makes a dimple in the connector. The dimple must be at least 3/16 inch wide or there will be too much space inside the connector and the solder will not flow into the wire. This crimp provides the mechanical retention needed. See **Fig. 2**.

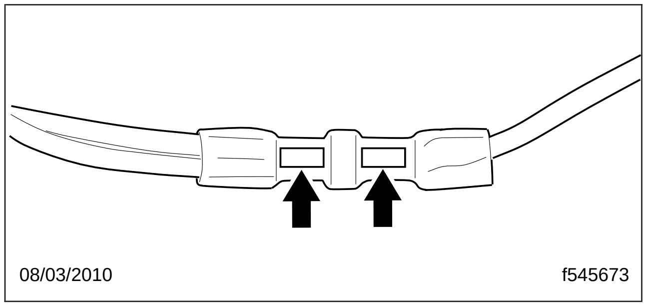


Fig. 2, Properly Crimped Splice

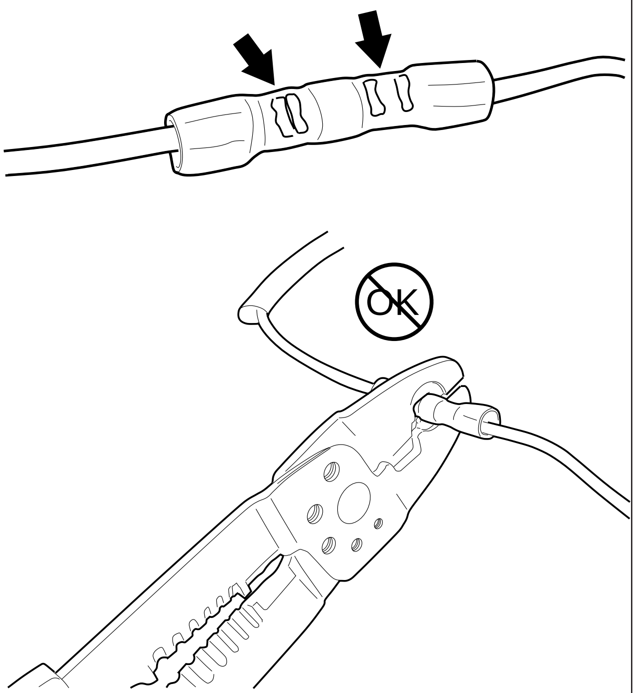
3. Pull test the wires by hand to ensure the crimp is mechanically solid.
4. A crimp tool that is too narrow will leave excessive air gaps in the crimp. The connection will not have the required amount of mechanical strength and the solder will not bond the wire to the connector. **Figure 3** shows an example of a bad crimp when the wrong tool is used.
5. Heat the properly crimped splice connector with the heat gun while slowly rotating the wire. The solder will take longer to flow than it will for the shrinkable insulation to contract. Heat until the solder band has completely melted into the connector. If the shrinkable insulation ruptures and a small amount of solder bubbles out, gently shake the splice to remove the solder. See **Fig. 4**.
6. When the connector has cooled, center the shrinkable tubing over the splice and heat the tubing until it has completely sealed the splice and a small fillet of adhesive is visible at the ends of the shrink tube. See **Fig. 4**.
7. A three-wire tap splice can be made following the same procedure. Use a connector that is large enough to fit all the strands of the wires. See **Fig. 5** for an example of the completed splice.

Wiring Repair Using Phillips STA-DRY® Solderless Connectors

Solderless Connector Parts		
Wire Size: gauge (mm)	**Connector Part Number***	**Shrinkable Tubing (Daimler Part Number)**
20 to 18 (0.5 to 0.8)	PHM 1 1863	1/4 inch with internal adhesive coating (48-02461-025)
16 10 14 (1 to 2)	PHM 1 1862	1/4 inch with internal adhesive coating (48-02461-025)
12 to 10 (3 to 5)	PHM 1 1861	3/8 inch with internal adhesive coating–4 foot length (48-02461-038)
8 or larger (5 or larger)	Replace the terminal or the entire cable	Use adhesive lined red for positive cables and black for negative cables.

* Twenty-five connectors per pack.

Table 1, Solderless Connector Parts



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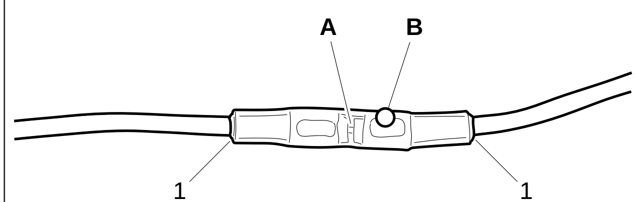
NOTE: Even with two crimps, there is too much air gap; the solder will not bond.

Fig. 3, Wrong Tool Being Used and a Crimp That Will Fail



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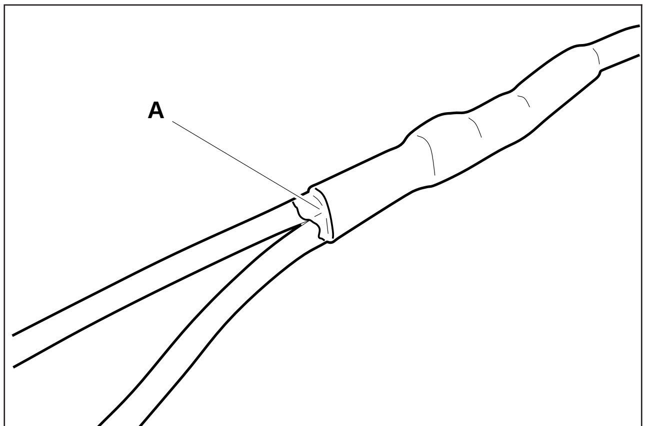
A. The solder band is completely melted.
B. Insulation rupture; gently shake off the solder bead.

1. Adhesive Fillet

Fig. 4, Solder Bead Rupture



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A. The fillet of adhesive at the ends of the shrink tube indicate a complete seal.

Fig. 5, Completed Three-Wire Tap Splice

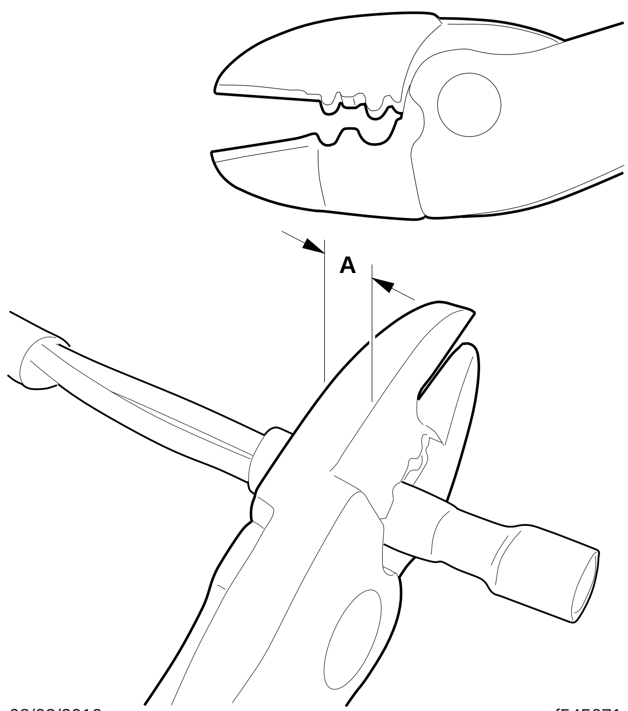
Wiring Repair Using Daimler Trucks North America (DTNA) Kit ESY ES66 404

Parts and Tools

Parts are available through the Parts Distribution Centers (PDCs) in kits with material for 50 splices. This kit may be used on 16 to 14 gauge (1 to 2 mm) wire.

Tools needed for wiring repair using solderless connectors include the following.

- A dimple-type crimp tool with a minimum 3/16 inch width. See **Fig. 1** for an example of a proper crimp tool. A typical manufacturer for this tool is Thomas & Betts.
- A heat gun rated at 250°F (121°C).



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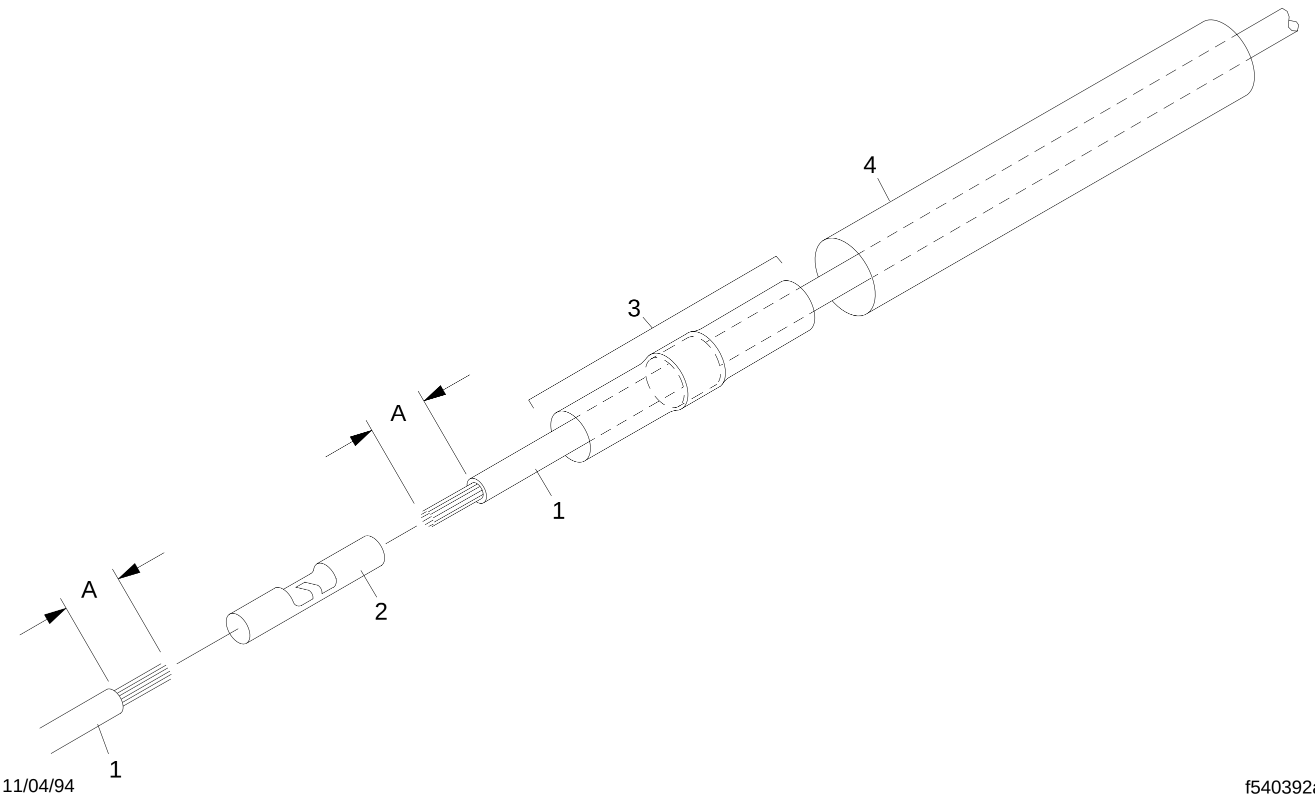
A. Minimum 3/16 inch width.

Fig. 1, Dimple-Type Crimp Tool

Procedure

1. Dress the wires to be spliced by stripping the insulation to expose 1/4 inch of copper. Slide a piece of the shrink tubing from the kit onto one of the wires.
2. Slide a shrinkable solder sleeve from the kit onto one of the wires.
3. Place the wires that will be spliced into each end of the barrel connector. See **Fig. 2** for an example of the splice.
4. Crimp each end of the barrel using a dimple-type crimp tool to secure the wires. See **Fig. 1** for an example of a proper crimp tool.
5. Pull test the wires by hand to ensure the crimp is mechanically solid.
6. Slide the shrinkable solder sleeve onto the barrel connector so the solder band is at the center of the barrel connector.
7. Heat the splice using a heat gun rated at 250°F (121°C) until the sleeve has completely shrunk against the wire and the solder flows into the barrel connector. A small fillet of adhesive may be visible at the ends of the connector. See **Fig. 3**.
8. Slide the shrinkable tubing over the splice and apply heat with a heat gun rated at 250°F (121°C) until it has completely shrunk against the wire insulation. A small fillet of adhesive should be visible at the ends of the shrinkable tubing.

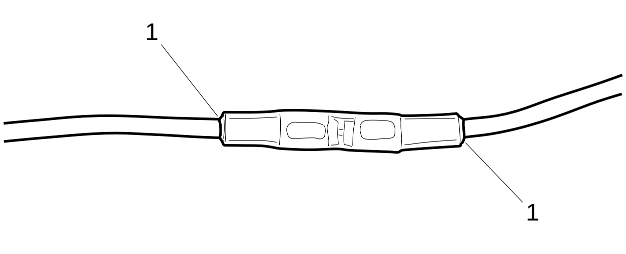
Wiring Repair Using Daimler Trucks North America (DTNA) Kit ESY ES66 404



A. 1/4 inch (6.4 mm)

1. Wire End
2. Barrel Connector
3. Solder Sleeve
4. Shrink Tube

Fig. 2, Splice Prepared with Parts in Kit ESY ES66 404



1. Adhesive Fillet

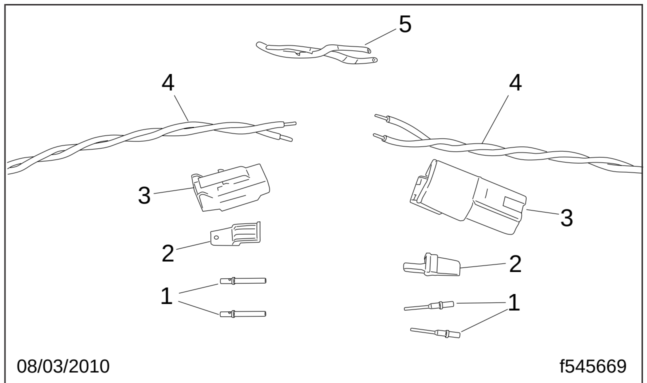
Fig. 3, Heated Solder Sleeve with Solder Band Melted into the Splice

Parts

Twisted-pair datalink wires may be spliced using a mating connector set. See **Table 1** for a typical set of datalink connector parts.

Procedure

1. Cut out any damaged section of datalink wire, keeping the lengths of the two wires equal. See **Fig. 1** for an example of a damaged section of datalink wire that has been removed and the datalink prepared for repair.
2. Crimp the terminals onto the wires using the proper crimp tool.
3. Pull test the terminals by hand to ensure the crimp is mechanically solid.
4. Insert the terminated wires into the connector body and install the terminal lock. The protocol for J1939 is for the yellow wire to be in cavity 1 and the green wire to be in cavity 2. Note that the lock is installed while holding the wires in position. Test the installation. If the wires slipped back during the lock installation, they will pull out of the connector.
5. Make certain the wires are twisted as close to the entry point of the connector as possible. Plug the two connector halves together. See **Fig. 2**.



1. Terminals
2. Terminal Lock
3. Connector
4. Twisted-Pair Datalink Wires
5. Damaged Section of Datalink Wires

Fig. 1, Datalink Splice Parts

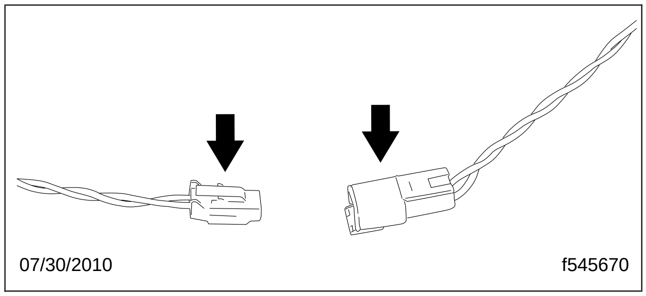


Fig. 2, Datalink Connectors

Datalink Connector Parts		
Description	**Part Number**	**Quantity**
Connector Body Plug	23-13148-204	1
Terminal Lock	23-13303-015	1
Terminals	23-13210-020	2
Connector Body Receptacle	23-13148-206	1
Terminal Lock	23-13303-013	1
Terminals	23-13210-030	2

Table 1, Datalink Connector Parts

Connection Protection

Use the dielectric protectants and procedures provided here to protect electrical connections from corrosion. A list of approved dielectric protectants is shown in **Table 1**.

The components listed in **Table 2** have electrical connections that need to be protected.

When disconnecting any of these circuits, clean the connection and remove the old dielectric material. Completely cover the exposed area after assembly using the product and procedure in this bulletin. Always follow the product manufacturers recommendations for work area ventilation.

Approved Dielectric Protectants			
Material	**Type**	**Manufacturer**	**Product**
Dielectric Red Enamel	Spray On	3M®	1602 IVI
		Glyptal	1201A
	Brush On	Glyptal	1201E 2100
Dielectric Grease	Lithium Base	Fiske Brothers Lubriplate® (FLP)	DS-ES
	Synthetic	Nye	Nyogel 760G

Table 1, Approved Dielectric Protectants

Electrical Component Protection and Procedure		
Protection	**Component**	**Procedure**
Dielectric Red Enamel	Starter - All Exposed Connections	Protect connections and cable terminals.
	Magnetic Switch	Protect connections and cable terminals.
	Alternator	Protect all connections. Do not allow dielectric material to enter the alternator.
	Bolt and Stud Ground Connections (outside cab)	Cover all terminals, studs, and nuts with dielectric enamel.
	Battery Cut-Off Switch Connections	Protect connections and cable terminals.
	Exposed Battery Cable Connections (located outside of the battery box)	Protect connections and cable terminals.
	Power Distribution Modules	Protect battery power studs on chassis mounted PDMs.
	Mega Fuses (when located outside of the battery box)	Place tape across the part of the fuse with the labeling, then apply the dielectric material. Remove the tape.

Electrical Connection Protection

Electrical Component Protection and Procedure		
Protection	**Component**	**Procedure**
Dielectric Grease, Lithium Base	Tail Lamp Bulb Sockets (non LED)	Remove the bulb, apply grease to the inside of socket. Replace the bulb.
	Battery Terminals	Apply grease to battery terminals before connecting interconnect cables.
	Battery Interconnect Cable Connections	Apply grease to connection studs and pads before connecting battery cables.
	Parked HVAC Power Connections	Disconnect the two power and one ground cable where they enter the basket on the underside of the cab. Apply grease, then connect.
	Inverter Power Connections	Disconnect the power and ground feeds at the cab pass through. Apply grease, then connect.
	Mega Fuses (if located in the battery box)	Apply grease to protect exposed terminals and connections.
Dielectric Grease, Synthetic	Connections with serial data circuits or with very low voltage signals.	Apply synthetic grease to the terminals inside the connector.

Table 2, Electrical Component Protection and Procedure

General Specifications

See **Table 1** for standard wiring color-coding.

See **Table 2** for standard wiring circuit numbers and descriptions.

Standard Wiring Color-Coding		
Color	**Abbr**	**Typical Usage**
Black	BK	Ground, General
Black-White	BK-W	Ground, Clean or Isolated
Blue DK	DKBL	Backup/Windshield Wiper/Trailer Auxiliary
Blue LT	LTBL	HVAC/Circulation Fans/1922+
Blue LT-White	LTBL-W	Water, Oil Gauge and Indicator (Engine and Transmission)
Brown	BR	Marker, Tail and Panel Lamps
Gray	GY	Electronic Engine (or TXL Insulation)
Green DK	DKG	Turn Signal, RH/Driver’s Display/Data Record/1587+/1939–
Green DK-White	DKG-W	Starting Aids/Fuel Heaters/Material Control/Winch/Tailgate
Green LT	LTG	Headlamp/Roadlamp/DRL
Green LT-White	LTG-W	Axle Controls and Indicators/Suspension/Fifth Wheel
Orange	O	ABS/EBS/1587–
Pink	PK	Start Control/Ignition/Charging/Volt and Ammeter/1922–
Pink-White	PK-W	Fuel Control and Indicators/Shutdown/Speed Limiter
Purple	PRP	Engine Fan/PTO/Auto Lube and Oil
Purple-White	PRP-W	Utility/Spot/Ad/Interior/Emergency Lighting
Red	R	Power Distribution, Constant
Red-White	R-W	Brake/Pneumatic/Hydraulic/Retarder/Stop
Tan	T	MPH, RPM Signals/Horn/Flasher/Pyro/Turbo
Tan-White	T-W	Audio/Video/Security/Window/Computer/Seat/Mirror/Cab-Tilt
White	W	Transmission (or SXL Insulation)
Yellow	Y	Turn Signal, LH/1939+ (or GXL Insulation)
Yellow-White	Y-W	Air Bag and SPACE

Table 1, Standard Wiring Color-Coding

Circuit Numbers		
Circuit Number	**Description**	**Modules**
1	Battery Cable, Ground	156 286 291
6	Battery Cable, Positive	224 281 291 292 293 295
14	Cab Power, Main	156 224 277 281 285 286 291 292 293 295 306 320 321
15	Starter, Crank Circuit	146 155 156 157 158 286 291 320 895
16	Alternator, Main Power	124 125 286 320 836 846

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
18	Air Pressure Warning	320 486 838 840 877 880 882
19	Voltmeter	286 320 836 846
20	Headlamp, Left	27D 288 304 312 320 659
21	Headlamp, Right	27D 288 304 312 320 659
22	Headlamp, Low and High Beam	27D 288 304 312 320 659
23	Tail Lamps	288 294 296 301 302 304 30A 320 335
24	Horn, Electric	288 320 321 726
25	Horn, Air	288 320 321 726
27	Road Lamp	288 313 314 320
28	Fog Lamp	288 313 314 320
29	Instrument Panel Lamps	27D 288 296 302 304 30A 312 320 335 659 732 811 81B
30	Transmission Temperature and Filter	286 320 343 345 34B 34C 353 355 863 864
31	Transmission Aux Controls and Temp	286 320 343 345 34B 34C 353 355 863 864
34	Engine Oil Pressure	165 286 320 852
35	Engine Oil Temperature	286 320 854
36	Stop Lamps	288 294 296 301 320 335 486 838 840 877 880 882
38	Turn Signal	288 294 296 298 299 300 301 320 335 811
39	Stop/Turn Combination Lamp	288 294 296 301 320 335 880
40	Fan, Windshield/Sleeper	287 320 716 718
41	Dome/Interior Lamp	271 287 294 300 302 305 311 312 314 316 318 319 31A 31B 31C 31D 31E 320 322 324 325 327 328 32B 32C 469 470
42	Axle Oil Temperature, Forward	288 320 865 866
43	Axle Oil Temperature, Rear	288 320 865 866
44	Axle Oil Temperature, Center	288 320 865 866
45	Receptacle, Trailer	173 285 296 297 303 306 307 308 309 310 320 321 331 334 335
46	Marker Lamps	288 296 302 304 30A 320 335
47	Fuel Level	288 320 844 847
48	Fuel Control and Level, Natural Gas	148 150 152 162 164 283 286 288 320 811 814 844 847 860
52	Ignition Switch	156 285 306 320 321
55	Data Recorder	283 286 320 343 810 817
57	12V Power Outlet/Lighter	284 287 320 785
58	Heater, Auxiliary	130 287 320 700 703 70A 70C 723
73	Utility Lamps	287 288 318 31J 320 327 329 57W
74	Starter Mag Switch, Solenoid	155 156 157 158 286 320 895

Circuit Numbers		
Circuit Number	Description	Modules
75	Starter Mag Switch, Ground	146 155 156 157 158 286 895
76	Mirror Heat	320 656 744 74E
78	Spot Lamp	316 320 57V
81	Ignition Switch Control Devices	156 285 304 306 320 811 814 860
82	Starter Mag Switch Power	155 156 157 158 286 320 895
86	Axle Lock Solenoid	288 320 452 874 878 87A 87B 87F 896 900
87	Axle Lock	288 320 452 865 866 874 878 87A 87B 87F 896 900
88	Lubrication System, Automatic	288 594
90	Sander, Road	288 320 329
91	Heater, Diesel Fired Auxiliary	130 132 138 140 141 154 166 286 287 288 320 467 700 703 70A 70C 723
94	Air Dryer, Heated	288 480 48A 880
95	Speaker, Radio	287 320 746 74D 750 751 753 75B 75C 79F 79G
97	Air Conditioner	130 287 320 700 703 70A 70B 723
98	Heater – A/C Motor, Blower	130 156 283 285 286 287 320 321 700 703 70A 70B 70C 723
99	Fuel Solenoid, Engine Run	148 150 152 162 164 283 286 320
102	Parking Lamps	288 296 302 304 30A 320 335
108	Door Activated Lamps Courtesy/ Footwell/Door	320 324 325 32B 675 676 677 67E 67F 811 814 860
113	Baggage Compartment Lamps	287 320 322 324 325 32C
117	Speed Sensor +	283 286 320 343 810 817
118	Speed Sensor –	283 286 320 343 810 817
119	Coolant Temperature, Engine	198 199 286 320 732 810 812 830 836 838 83A 840 841 842 843 844 845 846 847 852 854 856 858 862 864 865 866 867 868 869
120	Back-Up Lamps	288 294 320 471 721
121	Brake, Engine	128 129 164 283 286
122	Back-Up Alarm	288 294 320 471 721
123	Alternator, Voltage Regulation/ Rectifier	124 125 156 286 836
125	Park Brake Indicator/Warning	288 294 296 301 320 335 486 838 840 877 880 882
132	Alternator Charge Monitor	124 125 156 286 836
137	Alternator Indicator/Relay	124 125 156 286 836
140	Oil Pressure, Engine	286 320 852
149	Fan Manual Controls, Engine	273 276 286 320
154	Auxiliary Air Pressure	288 320 486 838 840 865 866 877 880 882
155	Axle Lift Controls	288 320 452 874 878 87A 87B 87F 896 900
157	Power Mirror Controls	320 656 744 74E

Specifications

Circuit Numbers		
Circuit Number	Description	Modules
162	Tachometer Sensor +	283 286 320 812 819
163	Tachometer Sensor –	283 286 320 812 819
166	Engine Starting Aid, Ether	132 154 286 320 467
168	Hour Meter, Engine	286 320 812 813 81A 837 852
170	Fifth Wheel Slide Lock and Controls	173 296 297 303 307 308 309 310 331 334 581 87E
171	Brakesaver, Cat	128 129 286 343 34B 34C 34W 353
172	Clock	287 320 687 738
173	Coolant Level, Engine	152 286 320 856
182	Fuel Pressure	320 841 843 845
183	Air Cleaner Restriction, Engine	329 472
193	Cab Tilt Pump	288 320 670
196	Fuel Water Separator Heater	110 127 220 288
200	PTO Controls	148 283 286 288 320 372
203	Exhaust Brake	128 129 164 283 286
204	Seat Belt Indicator/Warning	320 74F 756 760 763
208	Axle Control, Tri Axle, Steer Lock	288 320 376 452 865 866 874 876 878 87A 87B 87C 87F 896 898 900
209	Axle, Two Speed Shift Control	283 286 288 320 343 376 810 817 876 87C 898
210	Power Distribution Module, Outside Cab	224 281 285 286 291 292 293 295 306 320 321
211	Security System, Rockwell	287 320 656 787
214	Generator, Auxiliary	124 125 286 599
218	Pyrometer	286 320 858
219	Turbo Pressure	286 320 842
221	Suspension Dump Controls	288 320 87D 888 910
222	Headlamp Dimmer Controls	27D 288 304 312 320 659
223	Transmission Controls, Auto Shift	160 283 285 286 288 320 330 343 345 34B 34C 355 376 732 736 810 811 813 814 817 876 87C 898
224	Transmission Controls	286 288 320 343 345 34B 34C 353 355 376 876 87C 898
225	Air Pressure Gauge, Primary	320 486 838 840 877 880 882
226	Air Pressure Gauge, Secondary	320 486 838 840 877 880 882
227	Air Pressure Gauge, Application	320 486 838 840 877 880 882
232	Transmission Controls Power Supply	160 283 285 286 320 330 343 345 34B 34C 353 355 732 736 811 813 814
234	Engine Fan Controls	273 276 286 320
236	Transmission Neutral Indicator	286 320 343 345 34B 34C 353 355
242	Seat Controls	320 74F 756 760 763

Circuit Numbers		
Circuit Number	Description	Modules
243	Shore Power, Power Inverter	274 277 284 287 307 320 336 337 33C 785
244	Speed Limiter, Vehicle, Hewitt	150 164 283 286
246	Electric Fuel Pump	148 150 152 162 164 283 286 320
250	Predictive Cruise Control	149 283 286
253	Cab Tilt Indicator	288 320 670
254	Roof Mounted Emergency Lamp/ Strobe	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
255	Advertising/Identification Lamp	288 296 302 304 30A 319 320 335
256	Optional Power Wire	285 286 306 320 321
261	Axle Lock, Controlled Differential	288 320 865 866
262	Retarder, Allison Transmission	128 129 286 343 34B 34C 34W 353
281	Oil Filter Change Indicator	165 286 320 852
285	Suspension Electric and Air Controls	288 320 87D 888 910
286	Fuel Water Separator Indicator	122 127 288 320 80F 844 845 847
294	Air Tank Auto Drain Valve	288 480 48A 880
295	Radio, AM/FM/CB/Disc	287 320 746 748 74D 750 751 752 753 75B 75C 79F 79G
299	Air Temperature, Exterior	320 860 867
300	Radio, Audio Signal	287 320 746 74D 750 751 753 75B 75C 79F 79G
303	Low Air Pressure	322 486 838 840 877 880 882
315	Windshield Wipers and Controls	320 321 660 66B
320	Windshield Washer	320 321 660 66B
331	Diagnostic Connector Power/Tach Ext Test	160 283 286 320 32A 330 338 343 725 732 733 736 811 812 813 819 835 888
338	HVAC Controls	130 287 320 700 703 70A 70B 70C 723
339	LBCU/ICU/Gauge Power/Data	320 732 811 814 860
347	Shutter, Engine Fan	273 276 286 320
359	Headlamp On Signal, LBCU/ICU	27D 288 304 312 320 659
363	Power Windows	320 654 656 66A
364	Power Windows, Rear	320 654 656 66A
372	Receptacle # 2, Trailer 7-Way, ISO 3731	173 296 297 303 307 308 309 310 331 334 335
376	Antilock Brake Controls	160 283 285 286 296 308 320 330 331 332 333 335 343 34B 414 447 44G 44H 454 490 493 732 736 811 813 814
377	Antilock Brake Sensors	308 330 331 332 333 414 447 44G 44H 454 490 493
378	Antilock Brake Valves	160 283 285 286 308 320 330 331 332 333 343 34B 414 447 44G 44H 454 490 493 732 736 811 813 814

Specifications

Circuit Numbers		
Circuit Number	Description	Modules
379	Daytime Running Lamps (DRL)	271 27D 288 294 300 302 304 305 311 312 314 316 318 319 31A 31B 31C 31D 31E 31F 320 322 324 325 327 328 469 470 659
388	Hydraulic Brake Power/Controls	288 320 486 49A 880
399	Optional Circuit, Cab/Chassis, Customer Specified	160 283 285 286 306 320 321 329 330 343 34B 472 732 736 811 813 814 860
400	Optional Circuit, Cab/Chassis, Customer Specified	329 472
402	Engine Start/Stop System, TAS	152 156 162 283 285 286 287 320 321
406	Emergency Lamp, Alternating, Access	264 271 275 27A 27B 27C 27E 287 288 318 31A 31B 31C 31D 31G 31J 320 327 33A 57W
407	—	—
408	Emergency Vehicle Accessory and Warning Lights	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
410	Emergency Siren and Bells	288 320 321 726
416	Refrigerator/Video Power	284 287 320 737 75B 785
417	Mobile Phone Power	320 789 79C
424	Headlamp Wiper/Washer	288 304 312 320
425	PNDB/CLDS Controls	224 277 281 285 291 292 293 295 306
427	Satellite Tracking System	287 320 786 78A 79H 80D
428	Battery Isolator Protection System	124 125 156 224 277 281 285 286 291 292 293 295 306 836
430	Windshield Wiper Heater	320 321 660 66B
431	Starting Aid, Engine Preheater	132 154 286 320 467
432	Seat Controls	320 74F 756 760 763
433	Data Recorder	160 286 320 813
434	Suspension Controls, ECAS	283 286 288 320 343 810 817 87D 888 910
435	Seat Belt Indicator/Warning	320 74F 756 760 763
436	Camera, Rear and Side View	160 288 320 736
437	Instrument Control Unit/LBCU	320 486 732 811 814 838 840 860 877 880 882
439	Engine ECU and Controls	106 128 129 148 152 156 162 164 283 286 372
440	Engine ECU and Controls	106 128 129 148 149 152 156 160 162 164 273 276 283 285 286 301 320 330 343 34B 732 736 811 813 814 856 880
441	Engine ECU and Controls	106 148 164 165 283 286 320 852
442	Data Recorder/Data Logger	160 286 320 813
443	Door Locks	320 655 656 787
444	Obstacle Detection System/VORAD	160 288 320 736 73B 73C
445	Body Controls/Dump Lock	288 320 329
446	Tire Pressure Monitor System	288 320 489

Circuit Numbers		
Circuit Number	Description	Modules
447	Battery Cutoff Protection System	130 156 224 277 281 285 287 291 292 293 295 306 320 700 703 70A 70B 723
448	Tail Gate Controls	288 320 329
449	Fueling Data Recording and Transmitter	198 199 283 286 288 320 343 732 810 812 817 830 836 838 83A 840 841 842 843 844 845 846 847 852 854 856 858 862 864 865 866 867 868 869
450	Mirror Dimming Controls	320 656 744 74E
453	Optional Customer Specified Wiring	164 283 285 286 306 320 321 329 343 345 34B 34C 353 355 472
454	Inflatable Restraint and Seat Pretension	160 283 285 286 320 330 343 34B 725 732 736 811 813 814
455	Instrument Left/Right Side Selection	320
457	Dash Controls, Datalink, (BPU)	164 283 286
458	Step Deployment Unit, Passenger Side	320 675 676 677 67E 67F
459	Steering Pump Controls	539
460	Transmission-Automatic, Controls	286 320 343 345 34B 34C 353 355
461	Transmission-Automatic, Controls	286 320 343 345 34B 34C 353 355
462	Headlamps, Auxiliary	27D 288 304 312 313 314 320 659
463	Headlamps, Auxiliary Right	27D 288 304 312 313 314 320 659
464	Transmission, Smart Shift Control	286 320 343 345 34B 34C 353 355
465	Headlamp, Flashing Control	27D 288 304 312 320 659
466	Land Departure System	160 288 320 736
467	Engine Coolant Flow Systems	152 286 320 856
468	Obstacle Detection System/VORAD	160 288 320 736 73B 73C
469	Level Control, Body/Chassis	288 320 329
470	Datalink Transmit	287 320 786 78A 79H 80D
471	Datalink Receive	287 320 786 78A 79H 80D
472	Engine ECU and Controls	106 128 129 148 152 156 162 164 283 286 320 343 34B 34C 34W 353 856
473	Multifunction Stalk Switch	329 472
474	Smart Switch, Resistance Identified, MUX	329 472
475	Engine Idler Controls	152 156 162 283 286
476	Adjustable Pedal Controls	288 320 486 49A 880
477	Hazard Lights, USPS	320 327 329
478	E-Stroke Brake Monitoring System	320 486 838 840 877 880 882

Specifications

Circuit Numbers		
Circuit Number	Description	Modules
479	CB Radio Antenna Coaxial	320 748 751 752
480	Switched Auxiliary Air Pressure	288 320 486 49A 880
481	Chassis Expansion Module	160 283 285 286 320 329 330 343 34B 472 732 736 811 813 814
482	Firetruck Pump Controls	148 283 286 372
483	Engine ECU and Controls	106 148 152 156 160 162 164 283 285 286 320 330 343 34B 372 732 736 811 812 813 814 819
484	Tire Chains	288 320 452 874 878 87A 87B 87F 896 900
485	Public Address System	287 320 746 74D 750 751 753 75B 75C 79F 79G
486	Vehicle Information Center	283 286 288 320 732 74F 756 760 763 811 812 814 819 860 867 877 882
487	Engine Emissions Detection and Monitor	148 150 152 162 164 283 286 320 811 814 860
488	Brake Wear Indicator	320 486 838 840 877 880 882
490	Bus Door and Window Sensing and Warning	287 288 294 300 320 327 329 654 655 656 66A 675 676 677 67E 67F 700 703 723 787 811 814 860
491	Engine Compartment Lights/Buzzer	287 320 327 329 656 787 811 814 860
492	Engine ECU and Controls	148 150 152 162 164 283 286 320 372
493	All Wheel Drive Controls	288 320 452 874 878 87A 87B 87F 896 900
494	Transmission Shift Controls	286 320 343 345 34B 34C 353 355
495	Emergency Medical Service Accessories	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
496	Steering Wheel Controls	329 472
497	Transmission Controls	286 320 343 345 34B 34C 353 355
498	Transmission Controls	286 320 343 345 34B 34C 353 355
499	Engine ECU and Controls	164 283 286
504	Dome/Interior Lamp	287 320 322 324 325 32C
506	Aerial Equipment Systems	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
507	MUX Control, MSF/CGW	287 320 786 78A 79H 80D
508	CAN Datalink	287 320 786 78A 79H 80D
509	Firetruck Pump And Hose Controls	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
510	Firetruck Pump And Hose Controls	265 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
511	Bus Door and Window Sensing and Warning	146 155 156 157 158 286 895
512	Emergency Vehicle Auxilixry Switches	—
513	Emergency Vehicle Door Switches	—

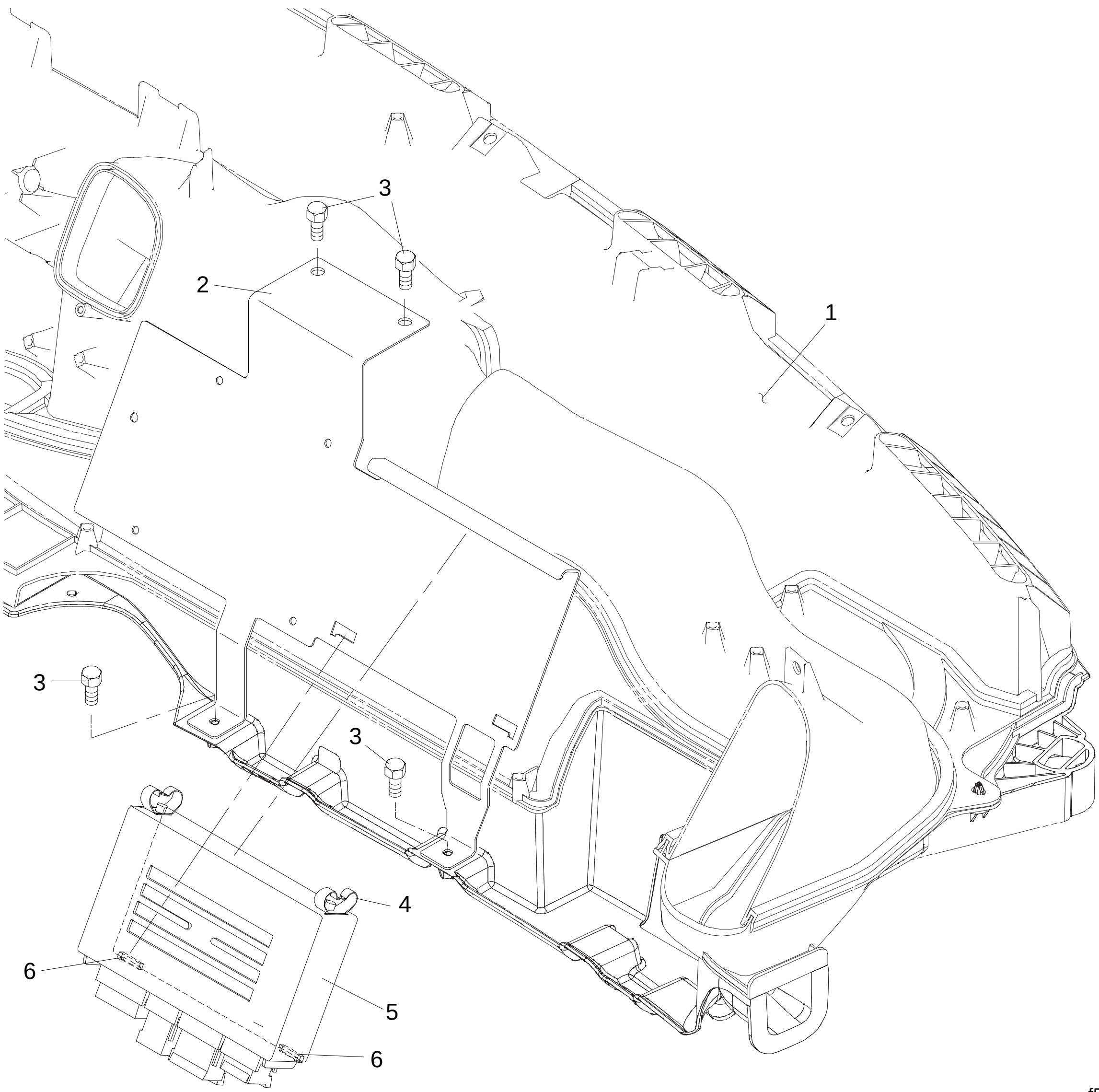
Circuit Numbers		
Circuit Number	Description	Modules
514	Emergency Vehicle Lights and Alarm	288 294 320 471 721
515	Emergency Vehicle Tank Level Systems	—
518	Emergency Vehicle Ladder and Rack Systems	—
519	Emergency Vehicle Body Lighting	—
520	Emergency Vehicle Body Lighting	—
521	Emergency Vehicle Body Lighting	—
522	Emergency Vehicle Body Lighting	—
523	Emergency Vehicle Body Lighting	—
524	Emergency Vehicle Power Source	—
525	Emergency Vehicle Warning Lights	—
526	Emergency Vehicle Body Lighting	—
527	Firetruck Pump And Hose Controls	—
528	Emergency Vehicle AC Power System	—
529	Windshield Defroster Grid	287 320 716 718
532	Aftertreatment Systems, Exhaust	160 164 283 285 286 320 330 343 34B 732 736 811 813 814
533	Engine ECU and Controls, Alternative Fuel	106 148 152 164 283 286 320 856
1587	J1587/J1708 Datalink	160 283 286 320 32A 330 338 343 725 732 733 736 811 812 813 819 835 888
1922	J1922 Datalink	160 283 286 330 343
1939	J1939 CAN Datalink	160 283 286 320 330 343 725 732 736 811 813 888

Table 2, Circuit Numbers

Vehicle Control Unit Removal and Installation

Removal

1. Disconnect the three electrical connectors (violet, gray, and brown) by pressing the release at the bottom of each connector.
2. Press up on the bottom of the vehicle control unit (VCU) to compress the mounting clips. See **Fig. 1**.
3. With the mounting clips compressed, pull outward on the VCU to clear the mounting tabs from the slots in the VCU bracket.



1. Dash
2. Vehicle Control Unit Bracket
3. 10–14 Capscrew
4. Mounting Clip
5. Vehicle Control Unit
6. Mounting Tab

Fig. 1, VCU Removal and Installation

Vehicle Control Unit Removal and Installation

4. Pull downward to release the mounting clips from the lip of the bracket and remove the VCU from the bracket.

NOTE: Do the following steps if it is also necessary to remove the VCU bracket.

5. Using a T25 Torx® screwdriver, remove the four capscrews that attach the bracket to the dash.
6. Remove the bracket from the dash.

Installation

1. If removed, position the VCU bracket on the dash. Install the four capscrews to hold it in place. Using a T25 Torx® screwdriver, tighten the screws until firm in the threaded inserts.
2. Insert the VCU into the lip of the VCU bracket and press upward to compress the mounting clips on top of the VCU.
3. When the mounting clips are compressed enough, slide the tabs on the back of the VCU into the slots in the VCU bracket. Make sure the VCU is secured in place.
4. Connect the violet, gray, and brown electrical connectors to the VCU as removed.

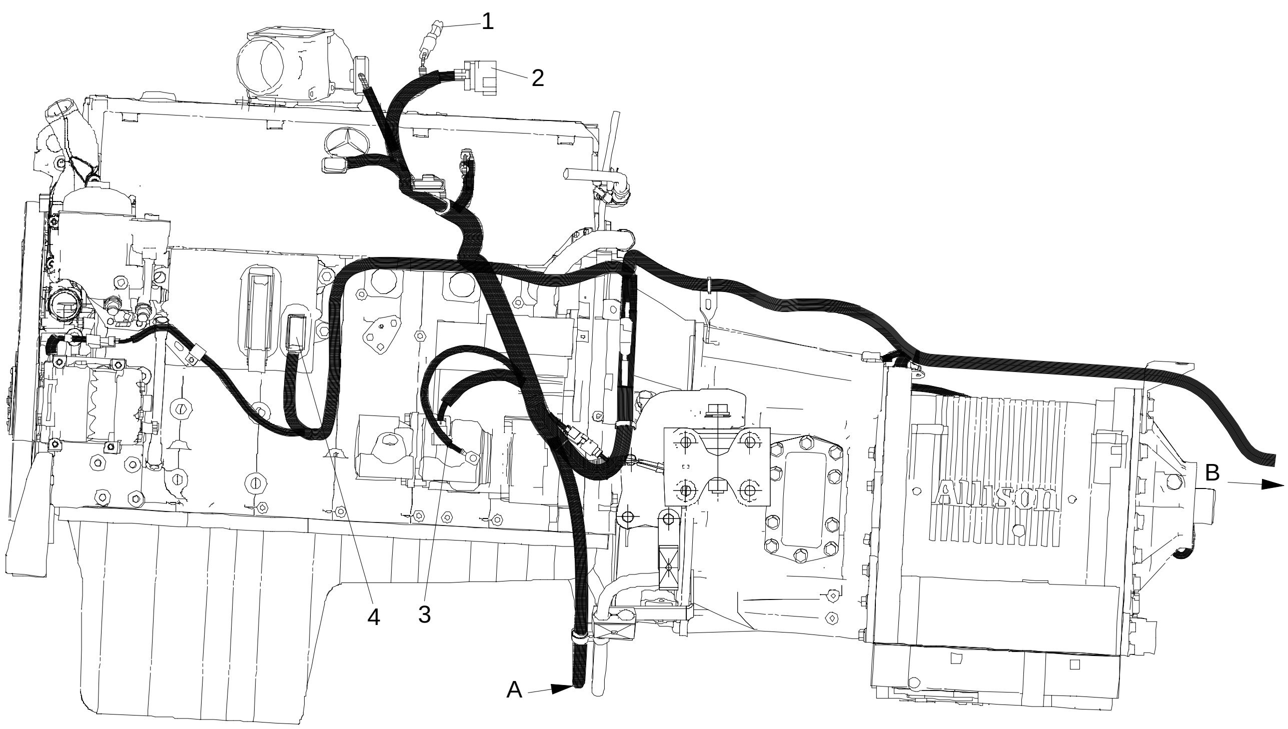
IMPORTANT: The connectors cannot be installed on the wrong plug location on the VCU because they each have different numbers of pins. Connector VC2 is not used at this time.

- Connector VC1 (brown) has 21 pins.
- Connector VC3 (gray) has 18 pins.
- Connector VC4 (violet) has 15 pins.

Harness Routing Diagrams

On a vehicle with an automatic transmission, see **Fig. 1** for a routing diagram of the engine wiring harnesses from the left side, and **Fig. 2** from the right side. **Fig. 3** shows the location of the transmission ECU (electronic control unit).

On a vehicle with a manual transmission, see **Fig. 4** for a routing diagram of the engine wiring harnesses from the left side, and **Fig. 5** from the right side.



01/17/2002 f012000

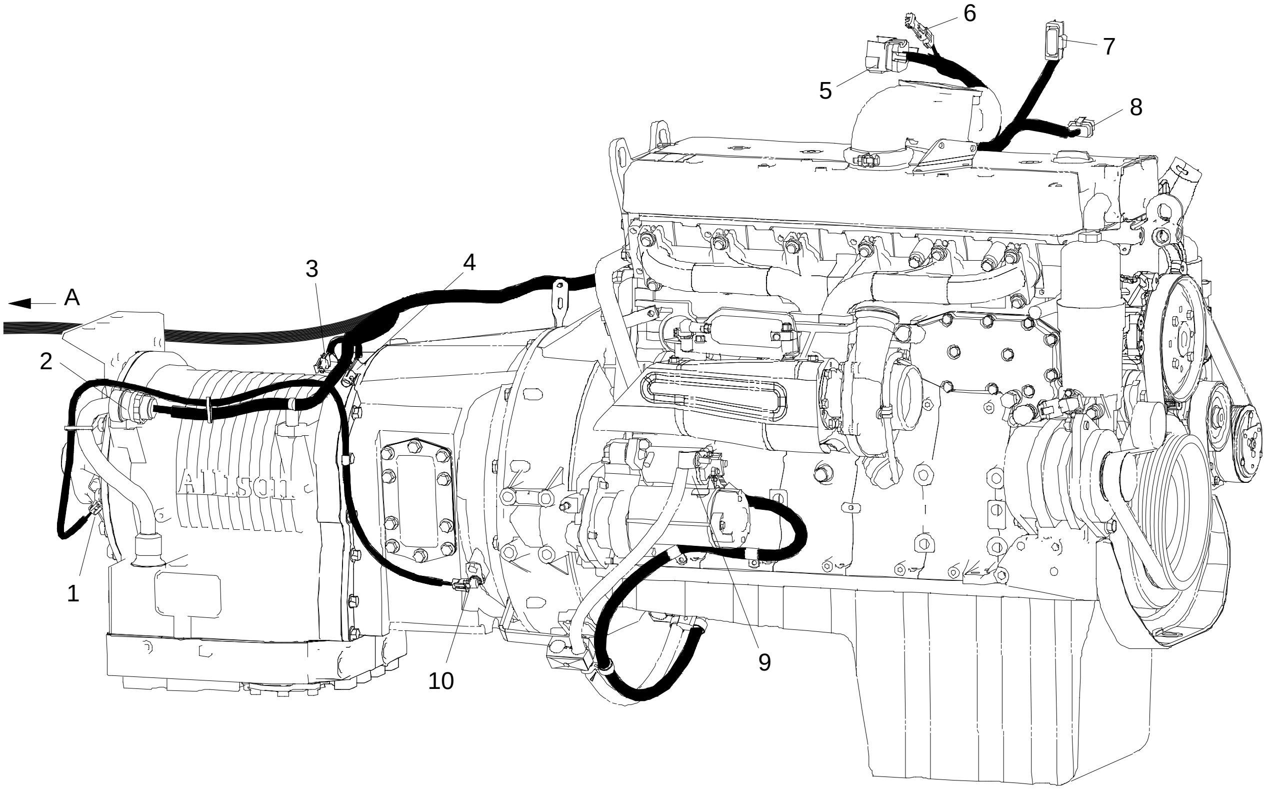
A. To Starter

B. To Transmission ECU

1. To Intake-air Heater (optional)
2. Bulkhead Connector
3. Engine Block Ground
4. PLD Vehicle Connector

Fig. 1, MBE900 Engine Harness Routing with Automatic Transmission, Left Side

Harness Routing Diagrams



01/17/2002 f011998

A. To Transmission ECU

1. Vehicle Speed Sensor
2. Transmission Harness Connector
3. Trans-chassis Harness Connector
4. To Retarder
5. Bulkhead Connector
6. Intake-air Heater Harness Connector (optional)
7. To Bulkhead Module
8. To Main Power Distribution Module (fuse box)
9. Starter Solenoid
10. Engine Speed Sensor

Fig. 2, MBE900 Engine Harness Routing with Automatic Transmission, Right Side

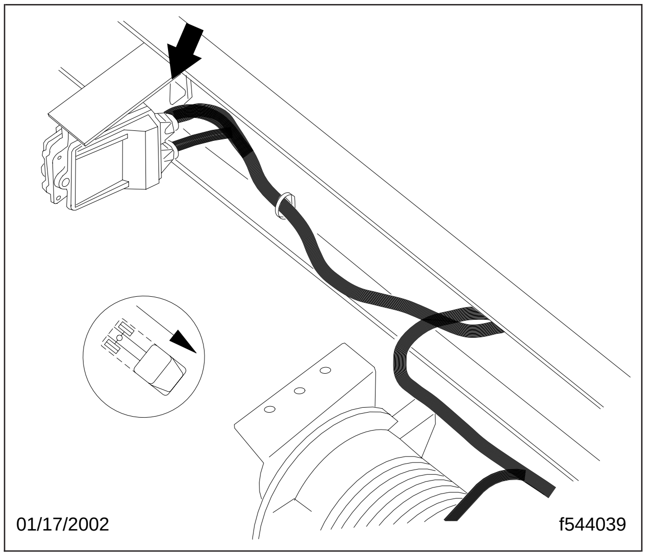
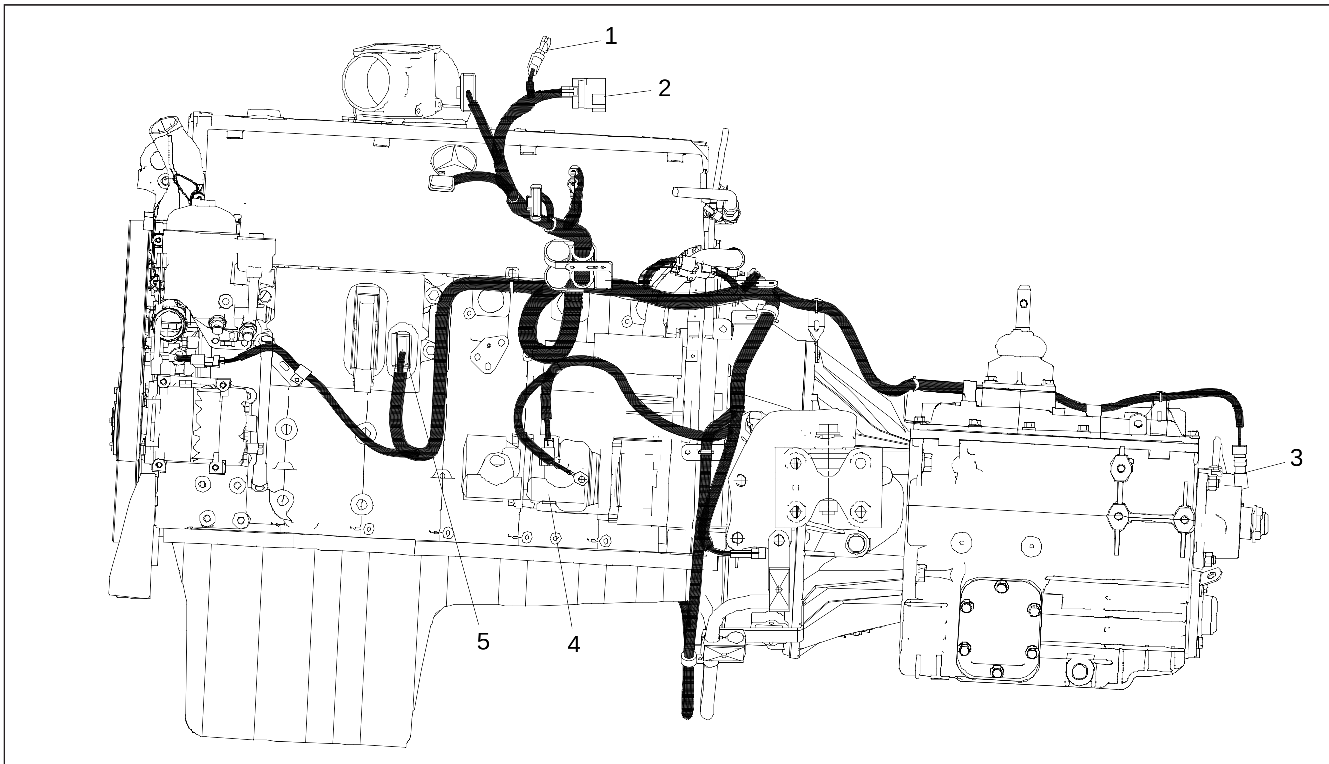


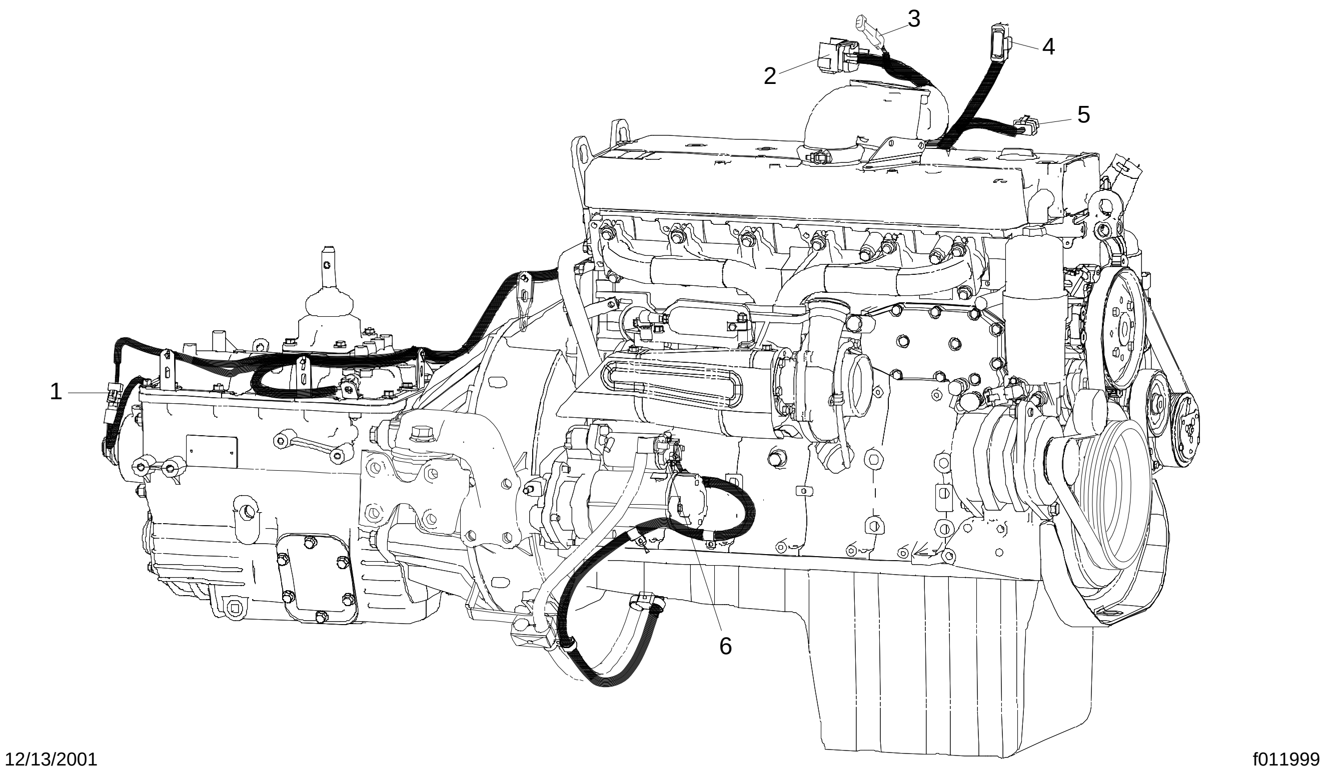
Fig. 3, Transmission Electronic Control Unit



1. To Intake-air Heater (optional)
2. Bulkhead Connector
3. Vehicle Speed Sensor
4. Engine Block Ground
5. PLD Vehicle Connector

Fig. 4, MBE900 Engine Harness Routing with Manual Transmission, Left Side

Harness Routing Diagrams



A. To Vehicle Control Unit (VCU)

1. Vehicle Speed Sensor
2. Bulkhead Connector
3. Intake-air Heater Harness Connector (optional)
4. To Bulkhead Module
5. To Main Power Distribution Module (fuse box)
6. Starter Solenoid

Fig. 5, MBE900 Engine Harness Routing with Manual Transmission, Right Side

Schematics

On a vehicle with an automatic transmission, see **Fig. 1** for a schematic of the engine wiring between the PLD control unit and the bulkhead connector. For a detailed (partial) schematic of the wiring to the transmission electronic control unit (ECU), main power distribution module (PDM), engine fan, low coolant probe, and intake-air heater (optional), see **Fig. 2**. For a detailed (partial) schematic of the wiring to the bulkhead module (BHM), see **Fig. 3**.

On a vehicle with an automatic transmission, see **Fig. 4** for a schematic of the cab wiring between the bulkhead connector and the vehicle control unit (VCU), including the devices attached to the dash harness. For a detailed (partial) schematic of the wiring for the engine protection system, see **Fig. 5**. For a detailed (partial) schematic of the wiring for the cruise control switches, panel lights, and engine fan switch, see **Fig. 6**.

On a vehicle with an automatic transmission, see **Fig. 7** for a schematic of the J1587 and J1939 datalink wiring.

On a vehicle with a manual transmission, see **Fig. 8** for a schematic of the engine wiring between the PLD control unit and the bulkhead connector.

On a vehicle with a manual transmission, see **Fig. 9** for a schematic of the cab wiring between the bulkhead connector and the vehicle control unit (VCU), including the devices attached to the dash harness. For a detailed (partial) schematic of the wiring for the engine protection system, see **Fig. 10**. For a detailed (partial) schematic of the wiring for the cruise control switches, panel lights, and engine fan switch, see **Fig. 11**.

On a vehicle with a manual transmission, see **Fig. 12** for a schematic of the J1587 and J1939 datalink wiring.

Wiring Schematics

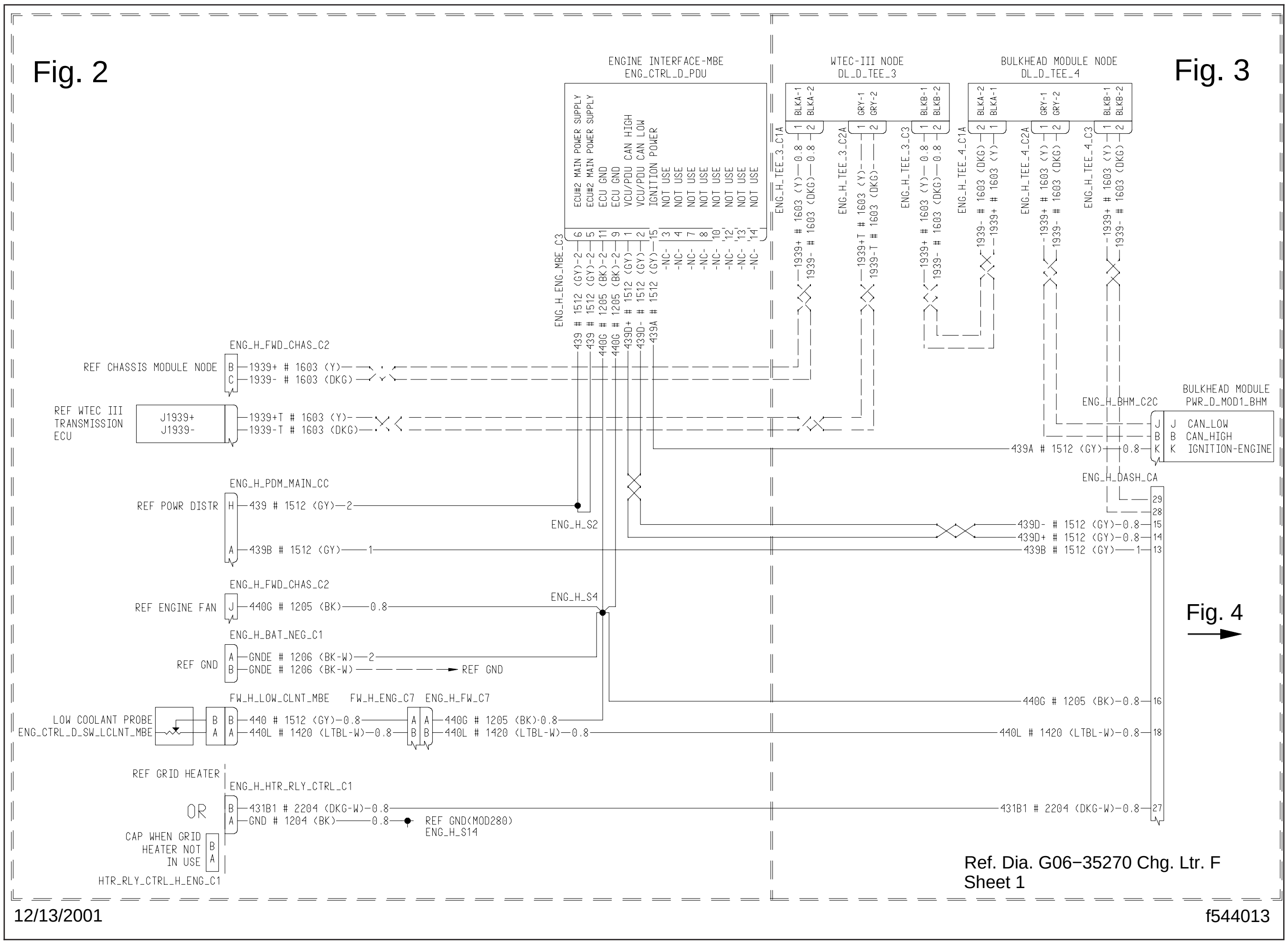


Fig. 1, MBE900 Engine Compartment Wiring Schematic, Automatic Transmission

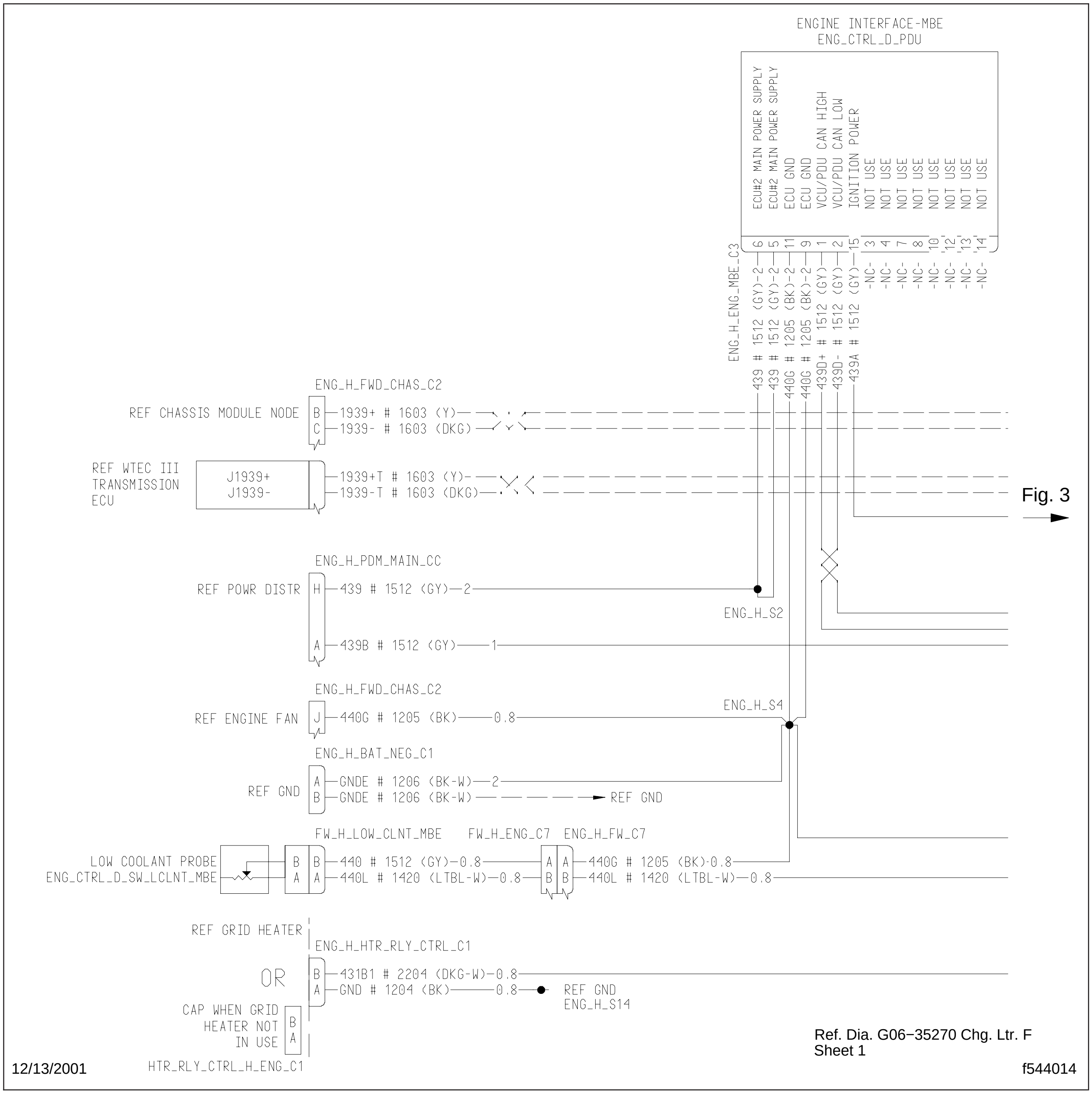


Fig. 2, MBE900 Engine Compartment Wiring Schematic, Automatic Transmission (detailed view, main PDM, trans ECU)

Wiring Schematics

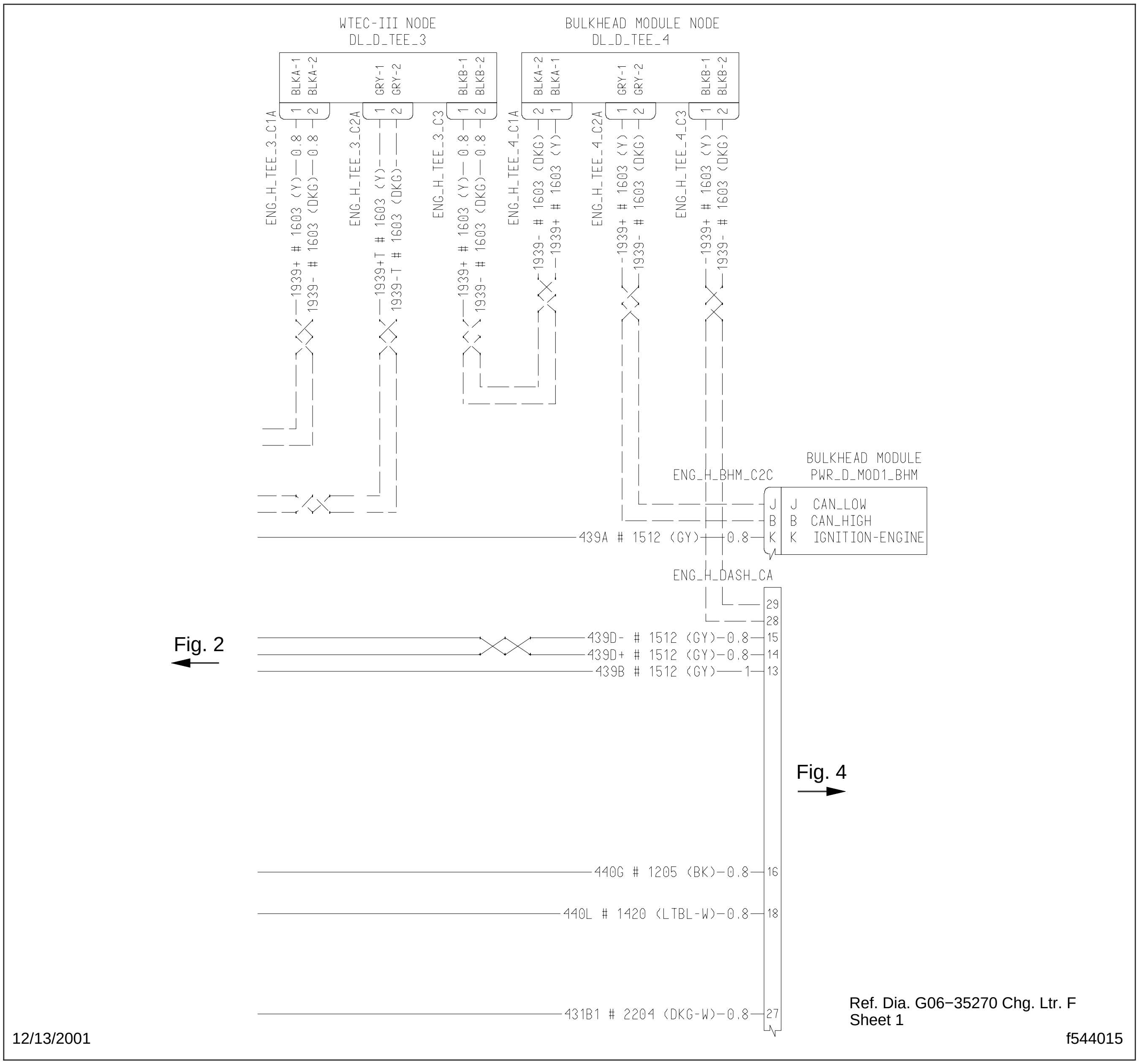


Fig. 3, MBE900 Engine Compartment Wiring Schematic, Automatic Transmission (detailed view, BHM)

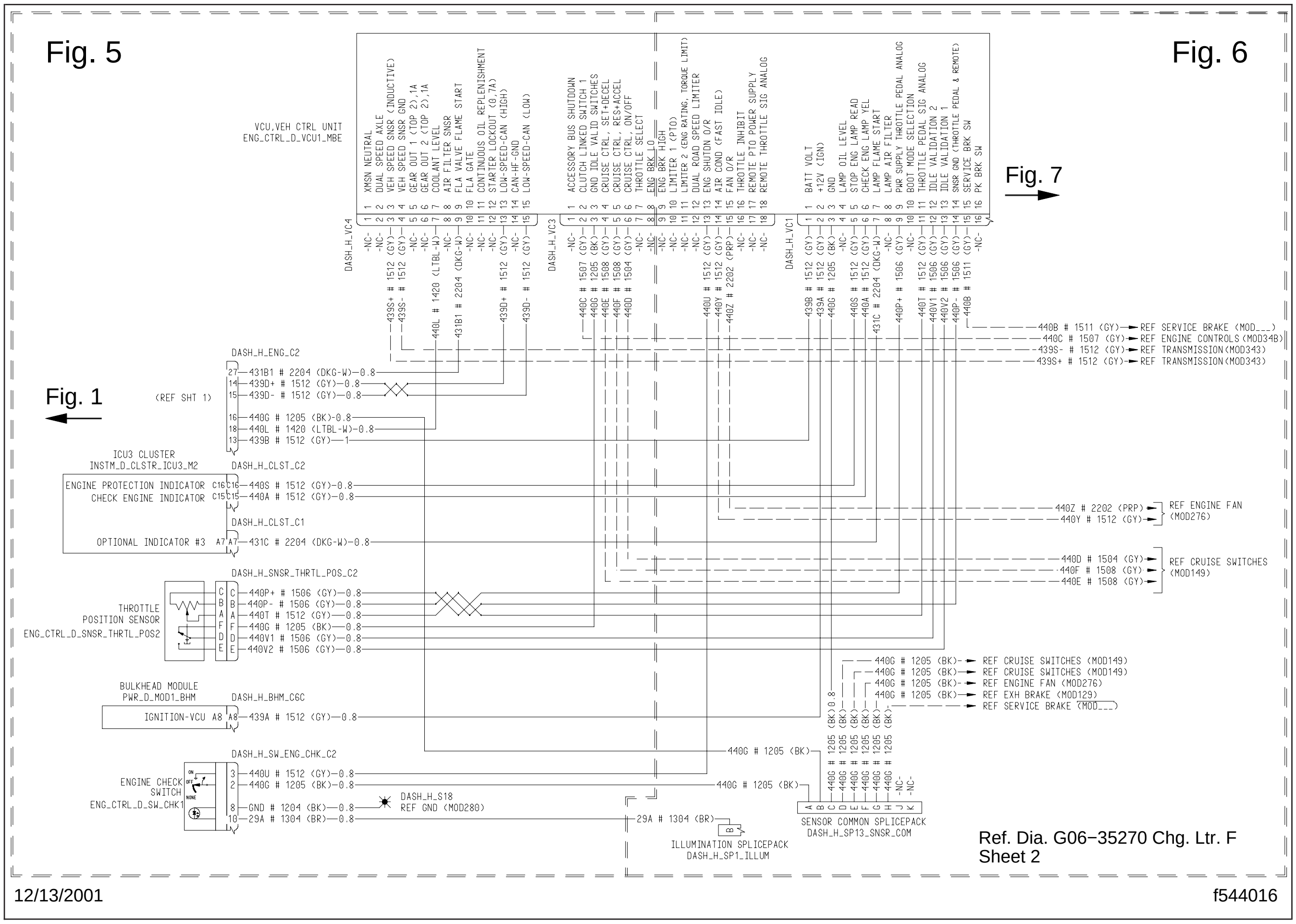


Fig. 4, MBE900 Cab Wiring Schematic, Automatic Transmission

Wiring Schematics

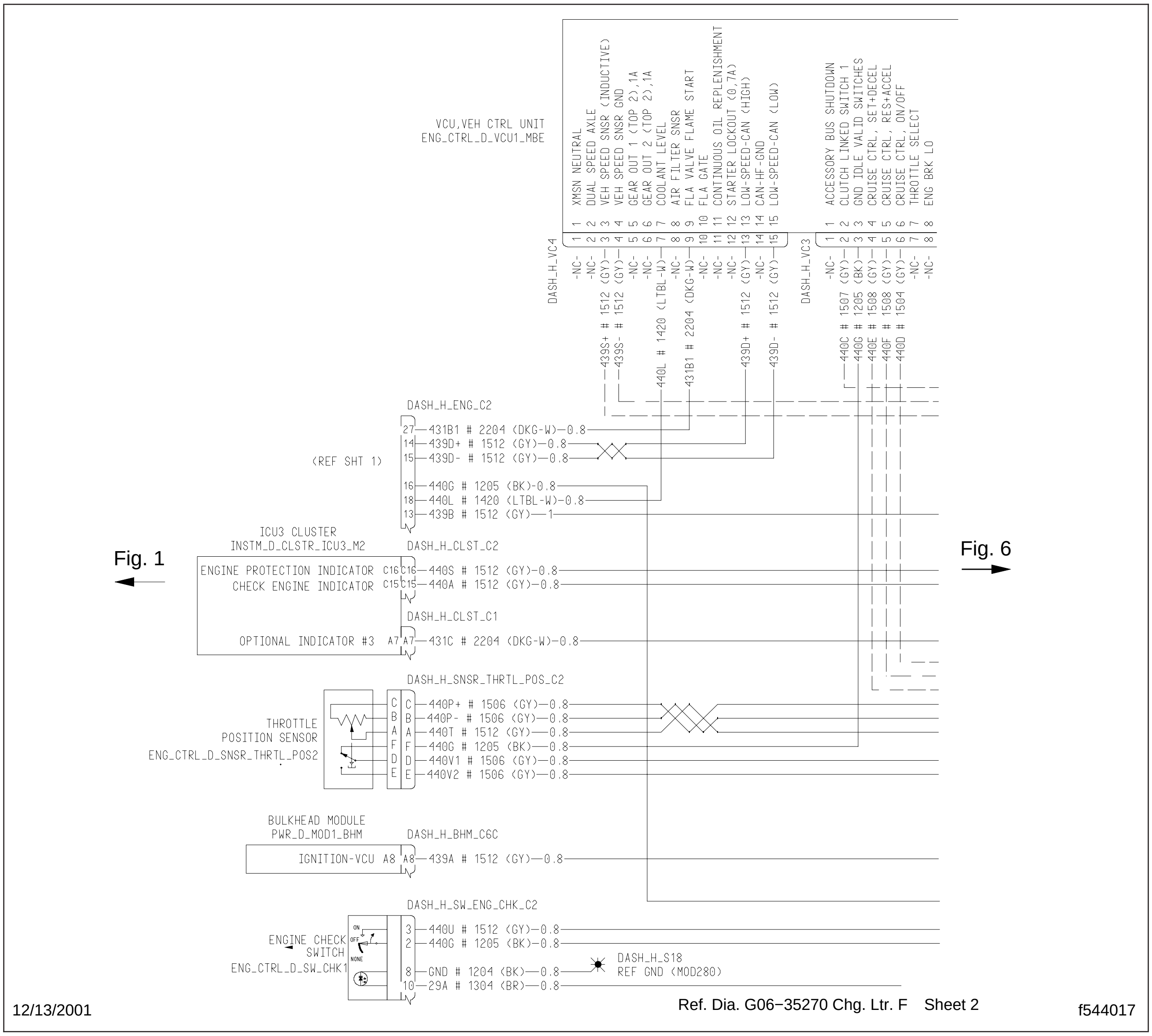


Fig. 5, MBE900 Cab Wiring Schematic, Automatic Transmission (detailed view, engine protection)

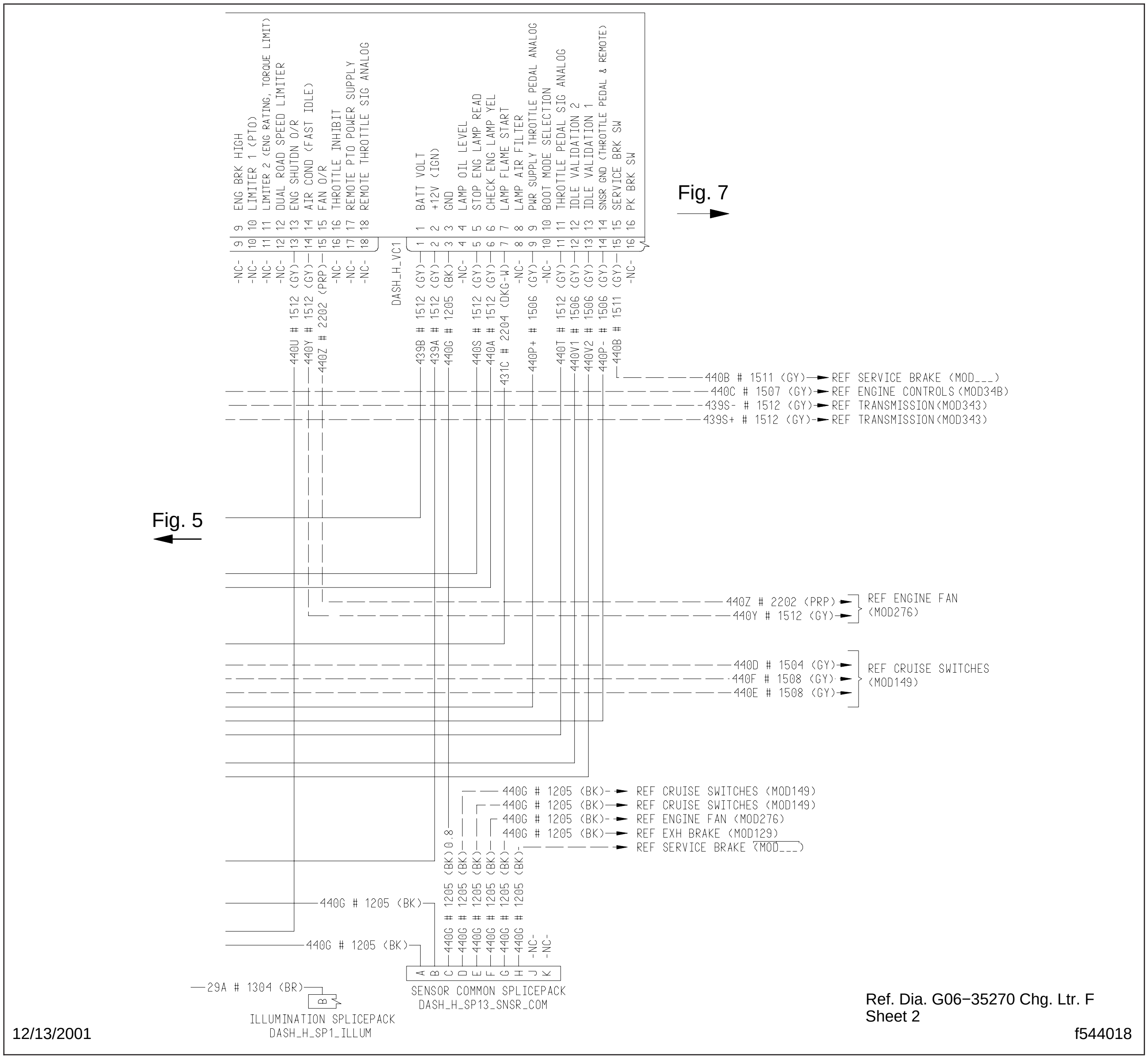


Fig. 6, MBE900 Cab Wiring Schematic, Automatic Transmission (detailed view, dash switches)

Wiring Schematics

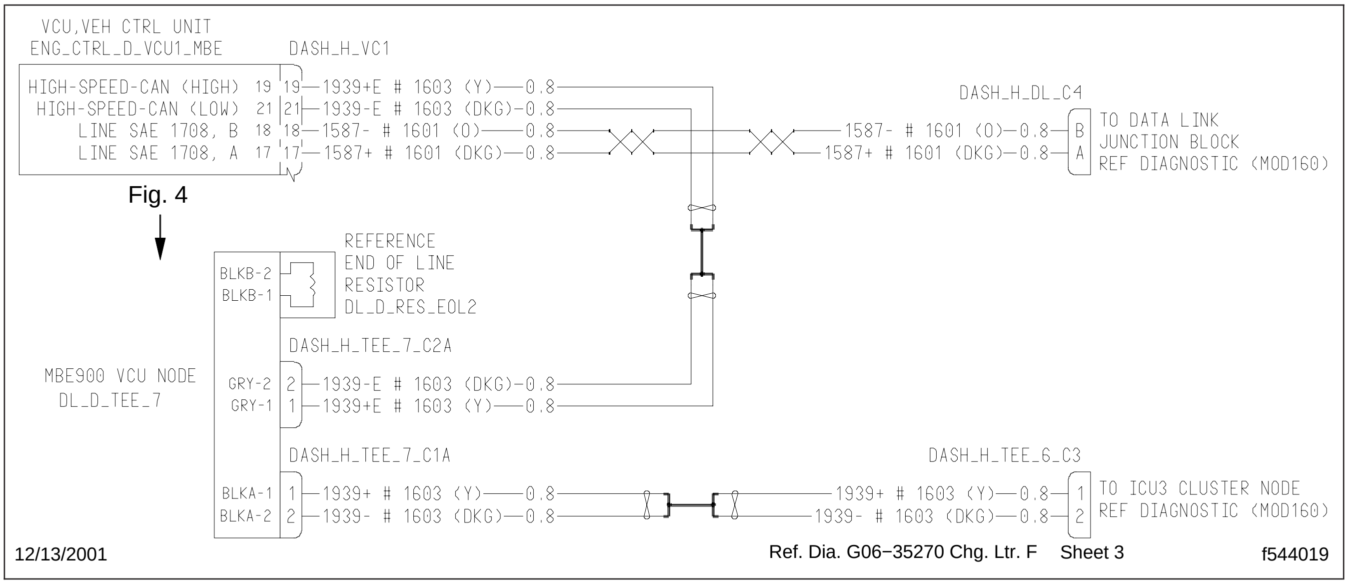


Fig. 7, MBE900 J1587 and J1939 Datalink Wiring Schematic, Automatic Transmission

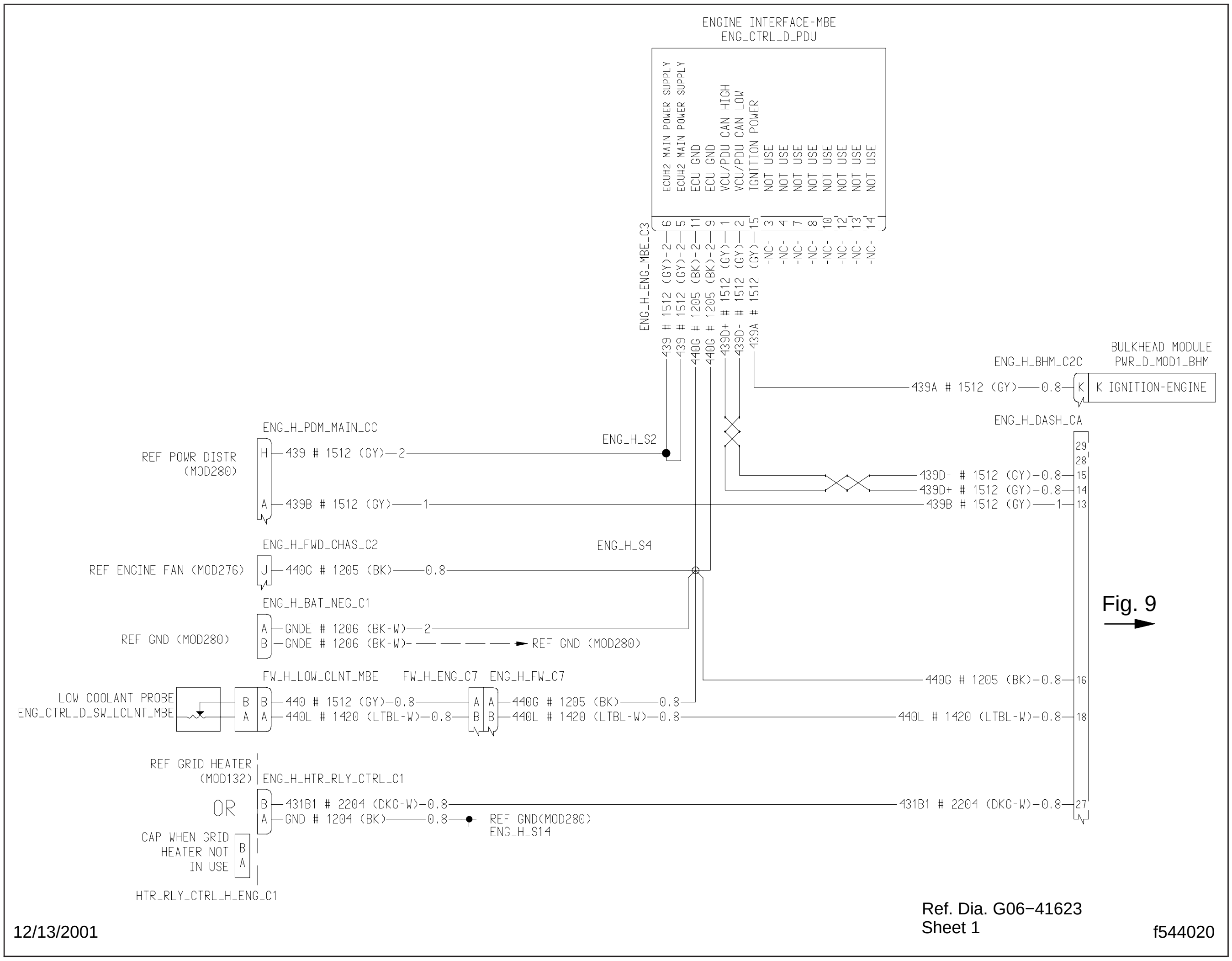


Fig. 8, MBE900 Engine Compartment Wiring Schematic, Manual Transmission

Wiring Schematics

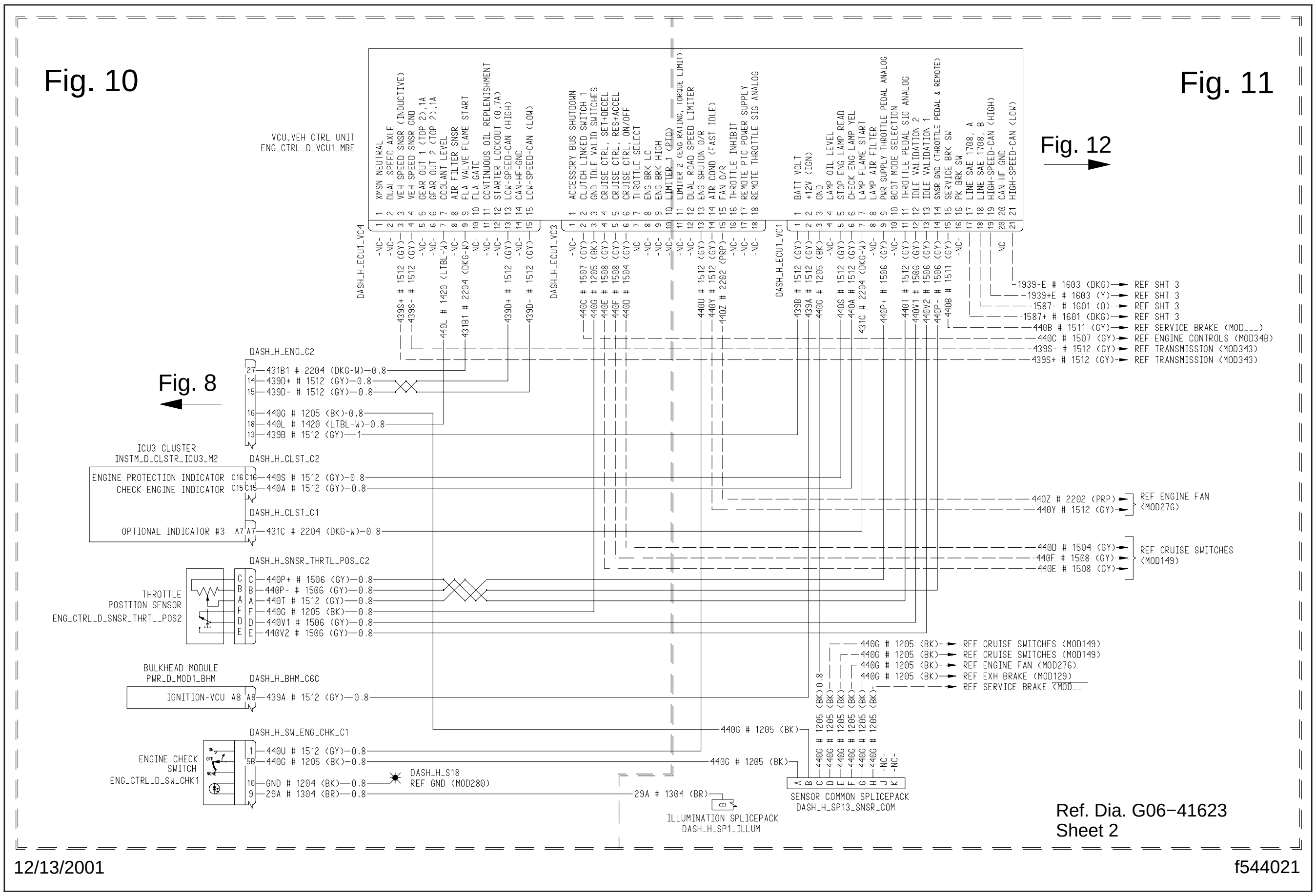


Fig. 9, MBE900 Cab Wiring Schematic, Manual Transmission

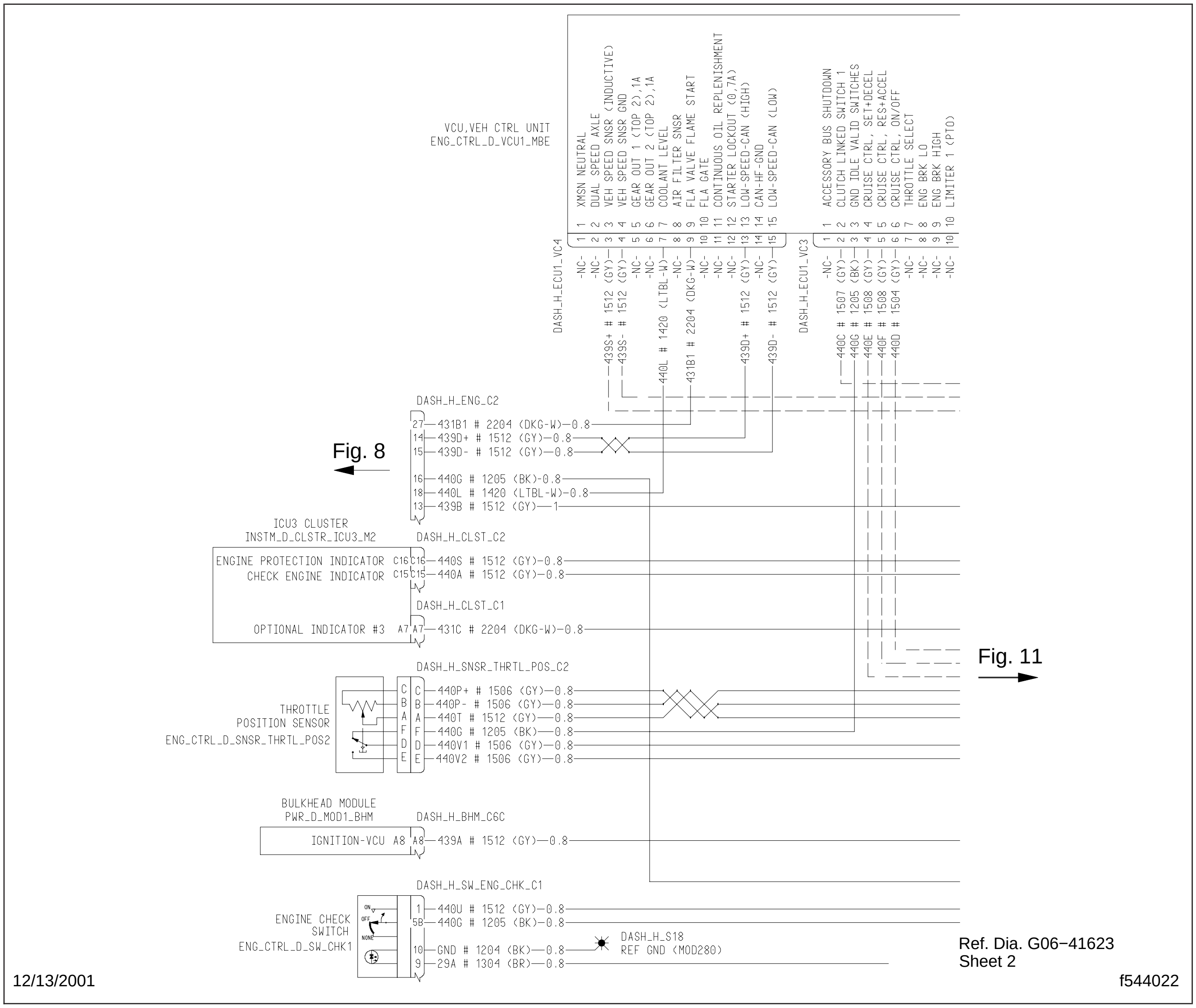


Fig. 10, MBE900 Cab Wiring Schematic, Manual Transmission (detailed view, engine protection)

Wiring Schematics

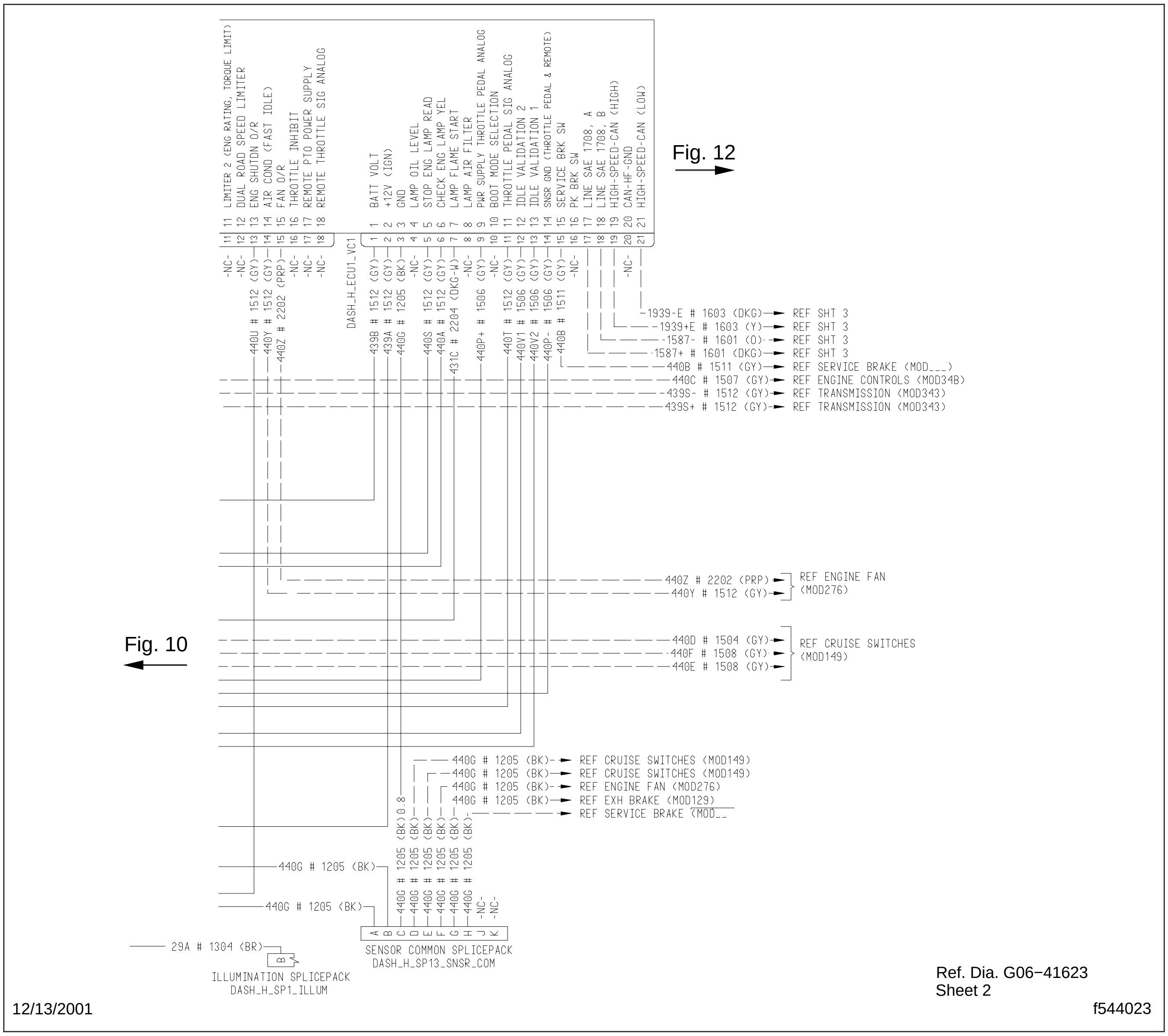


Fig. 11, MBE900 Cab Wiring Schematic, Manual Transmission (detailed view, dash switches)

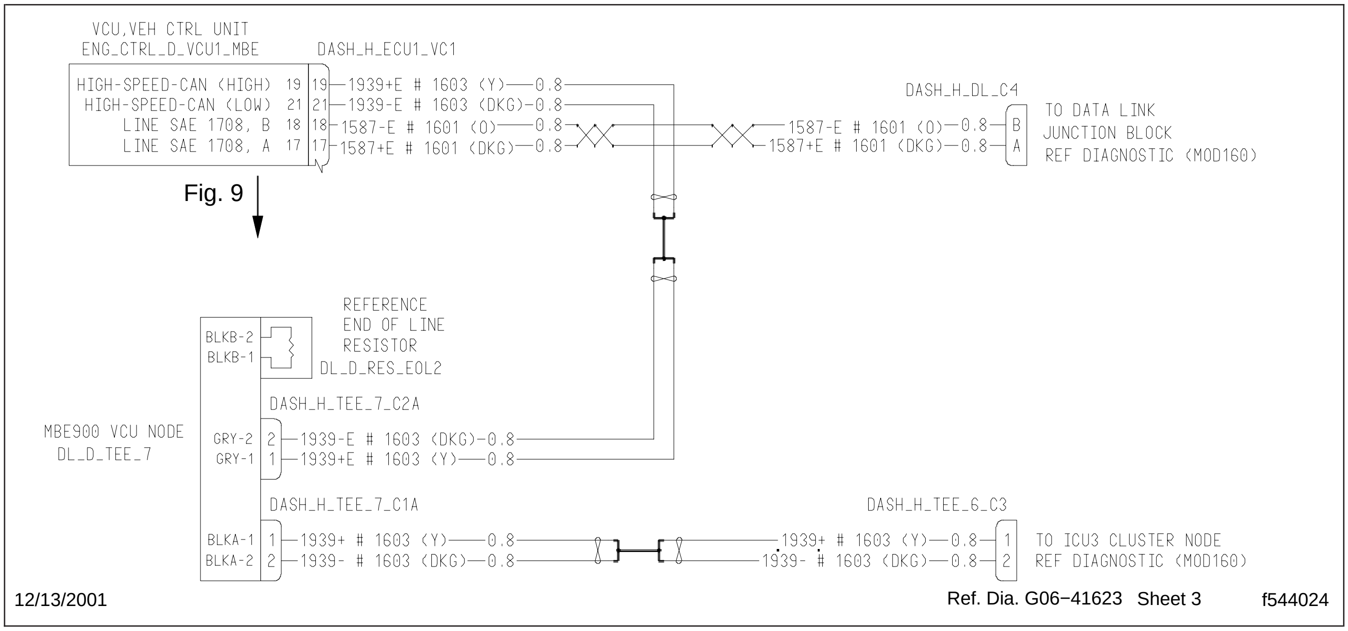


Fig. 12, MBE900 J1587 and J1939 Datalink Wiring Schematic, Manual Transmission

Harness Wiring

On a vehicle with an automatic transmission, see **Fig. 1** for a drawing of the engine harness.

For a detailed (partial) view of the bulkhead connector end, see **Fig. 2**. For a detailed (partial) view of the datalink connectors, see **Fig. 3**.

For a detailed (partial) view of the transmission and transchassis connectors, see **Fig. 4**.

For a detailed (partial) view of the engine connector end, see **Fig. 5**.

On a vehicle with a manual transmission, see **Fig. 6** for a drawing of the engine harness. For a detailed (partial) view of the engine connector end, see **Fig. 7**.

For a detailed (partial) view of the CAN datalink connector, see **Fig. 8**.

For a detailed (partial) view of the bulkhead connector end, see **Fig. 9**.

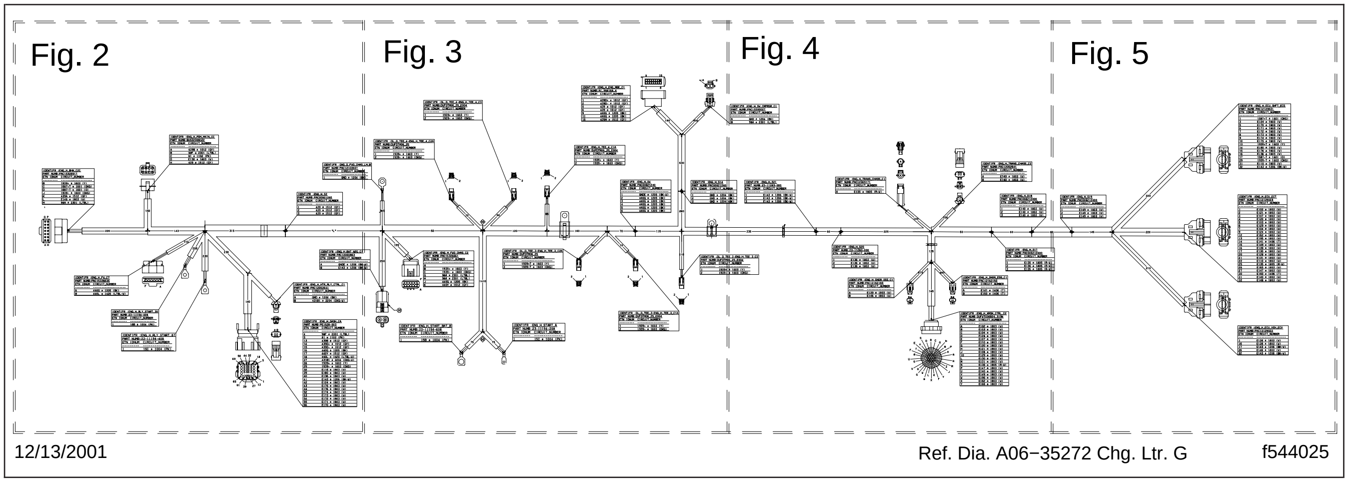


Fig. 1, MBE900 Engine Harness, Automatic Transmission

Harness Wiring

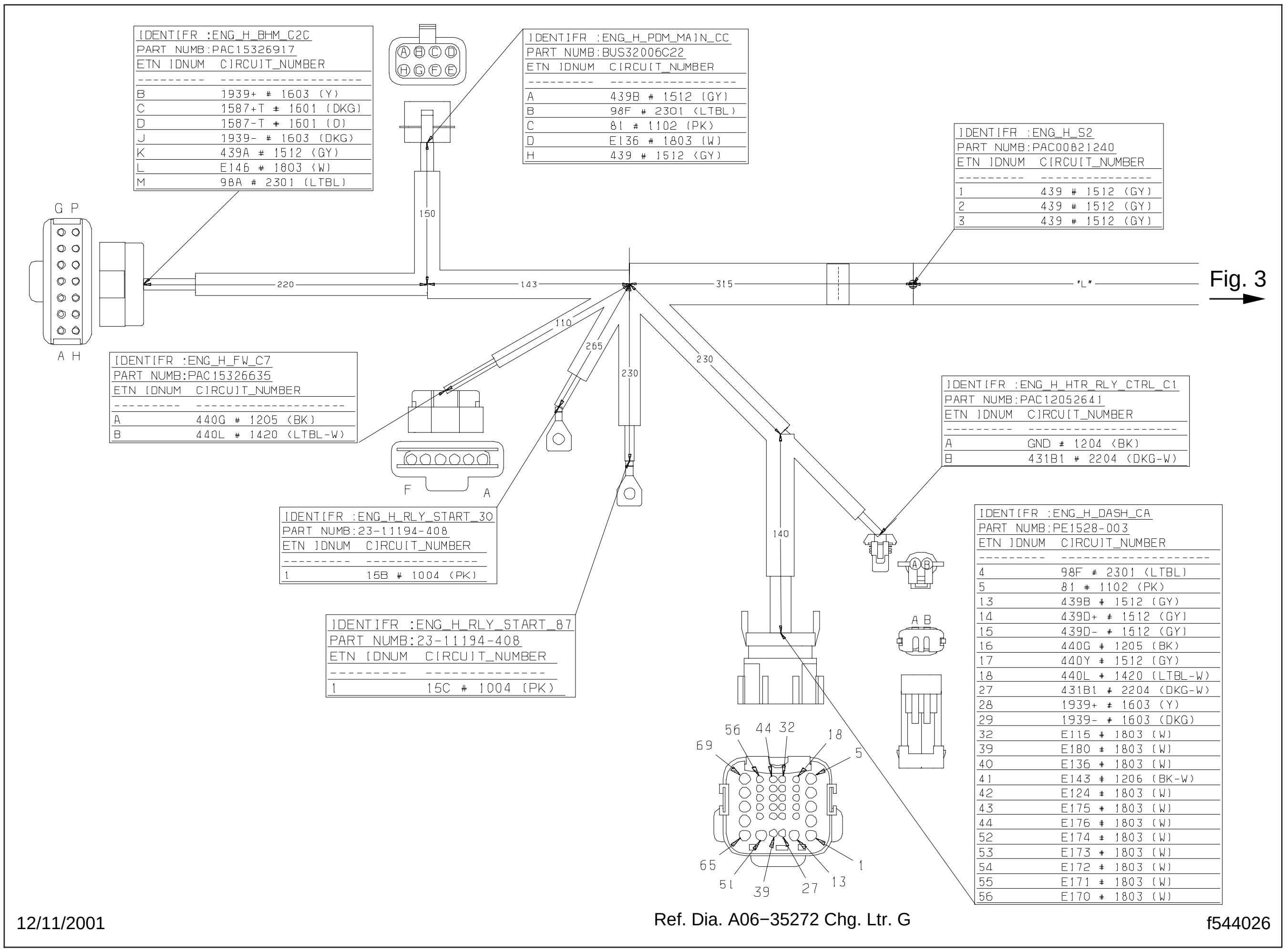


Fig. 2, MBE900 Engine Harness, Automatic Transmission (detailed view, bulkhead connector end)

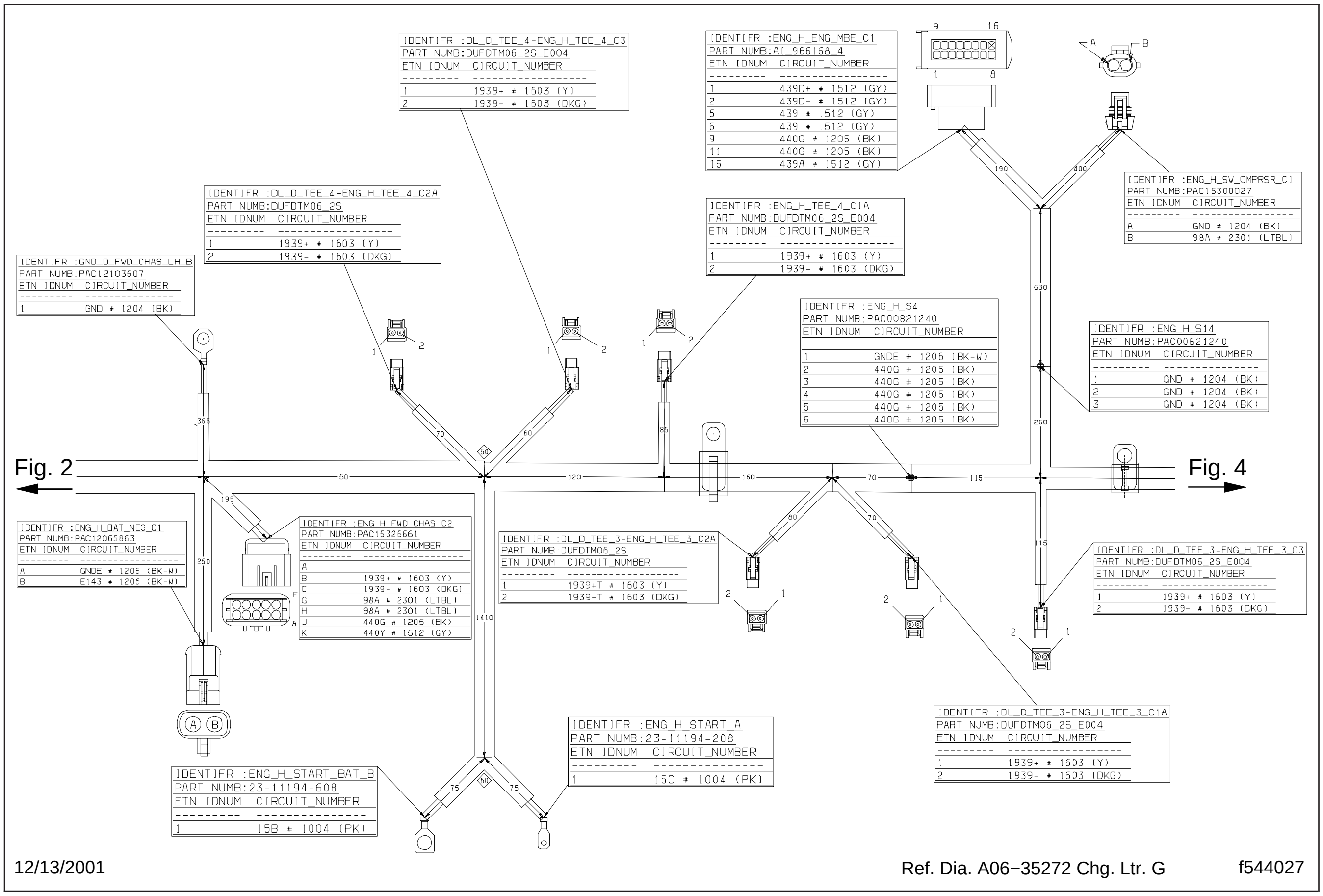


Fig. 3, MBE900 Engine Harness, Automatic Transmission (detailed view, datalink connectors)

Harness Wiring

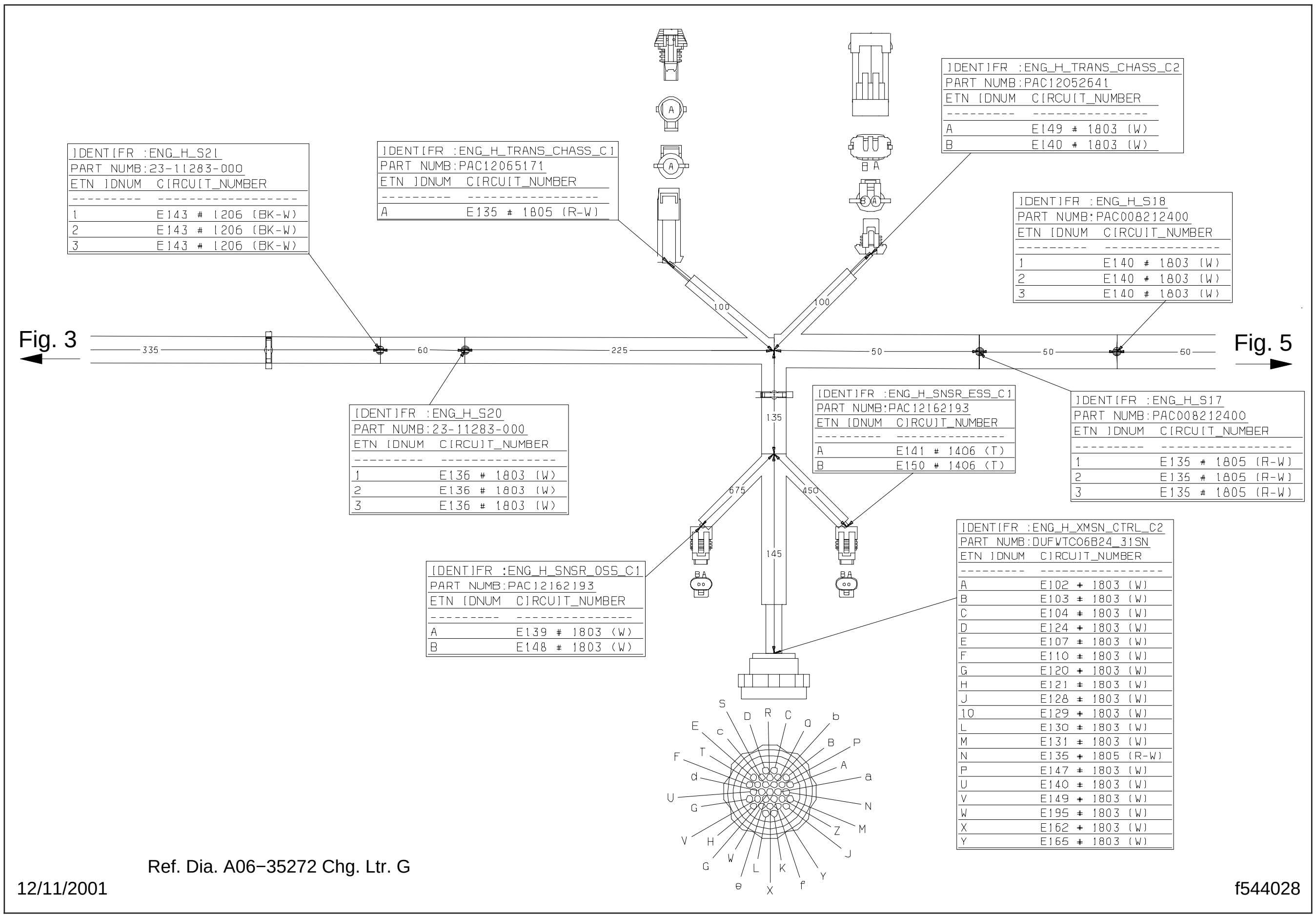


Fig. 4, MBE900 Engine Harness, Automatic Transmission (detailed view, transmission and transchassis connectors)

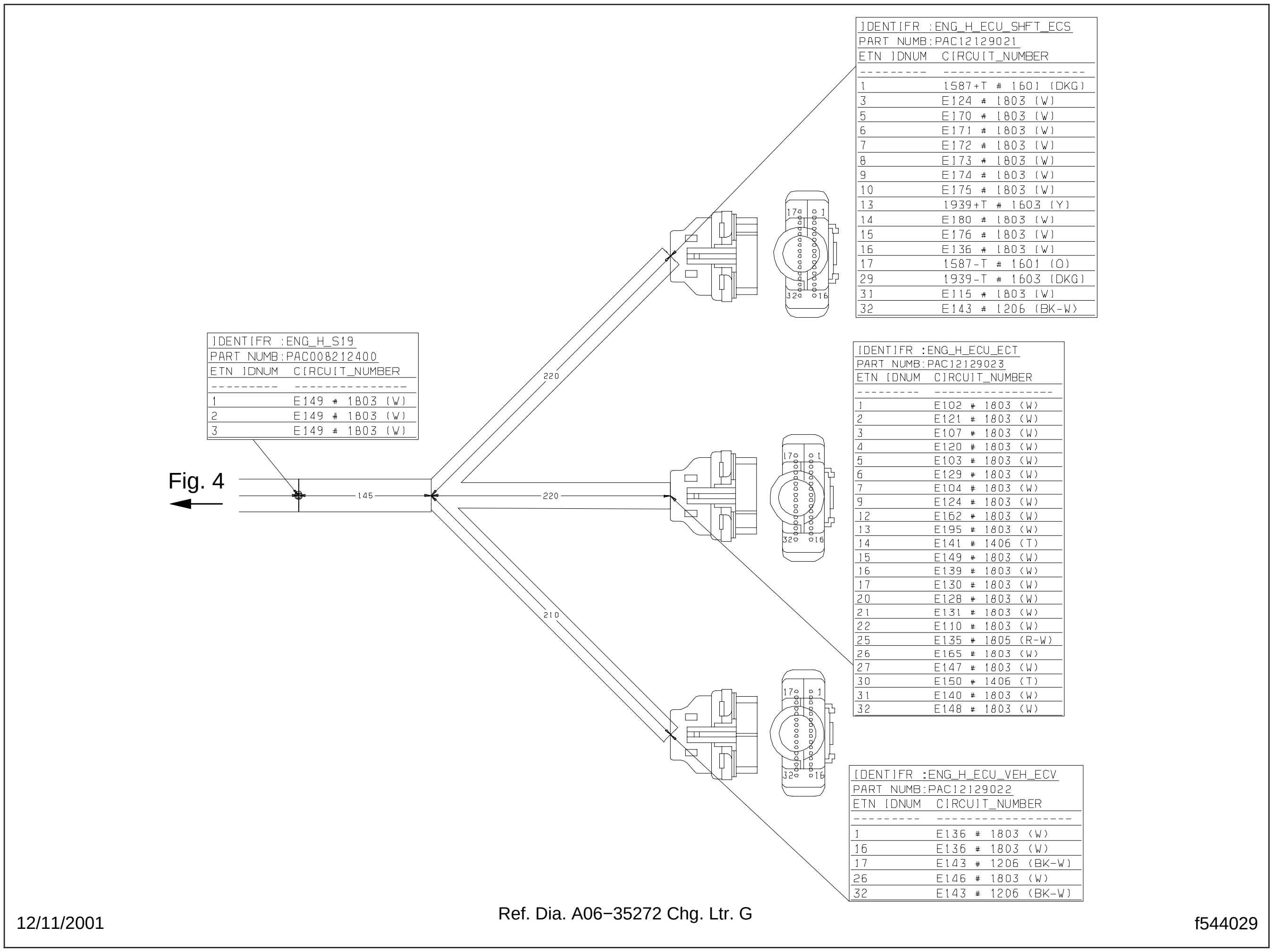


Fig. 5, MBE900 Engine Harness, Automatic Transmission (detailed view, engine connector end)

Harness Wiring

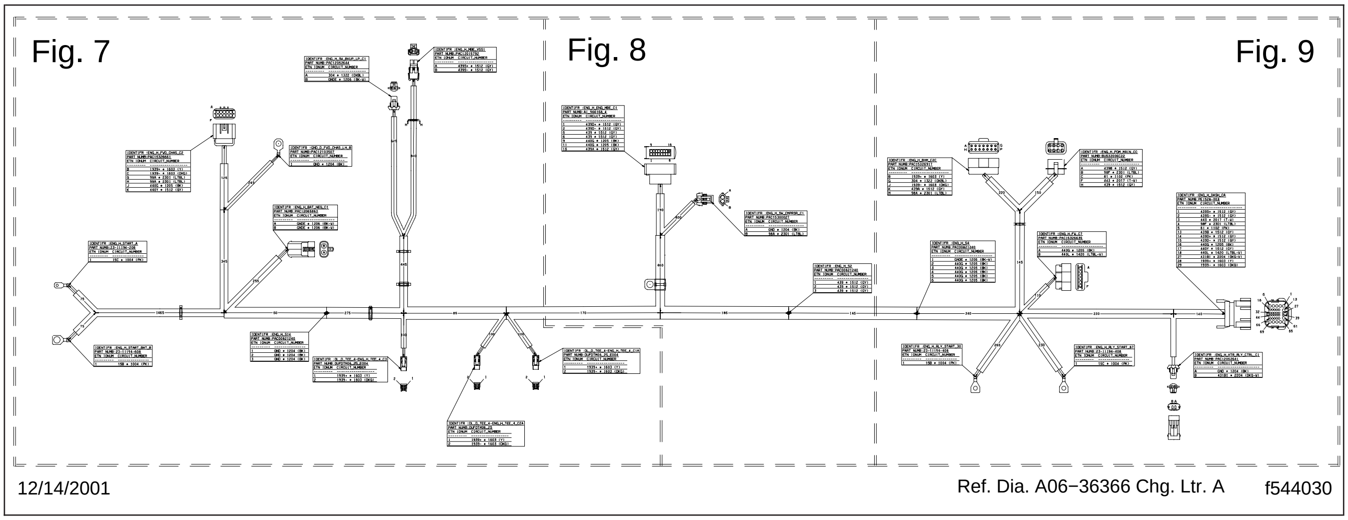


Fig. 6, MBE900 Engine Harness, Manual Transmission

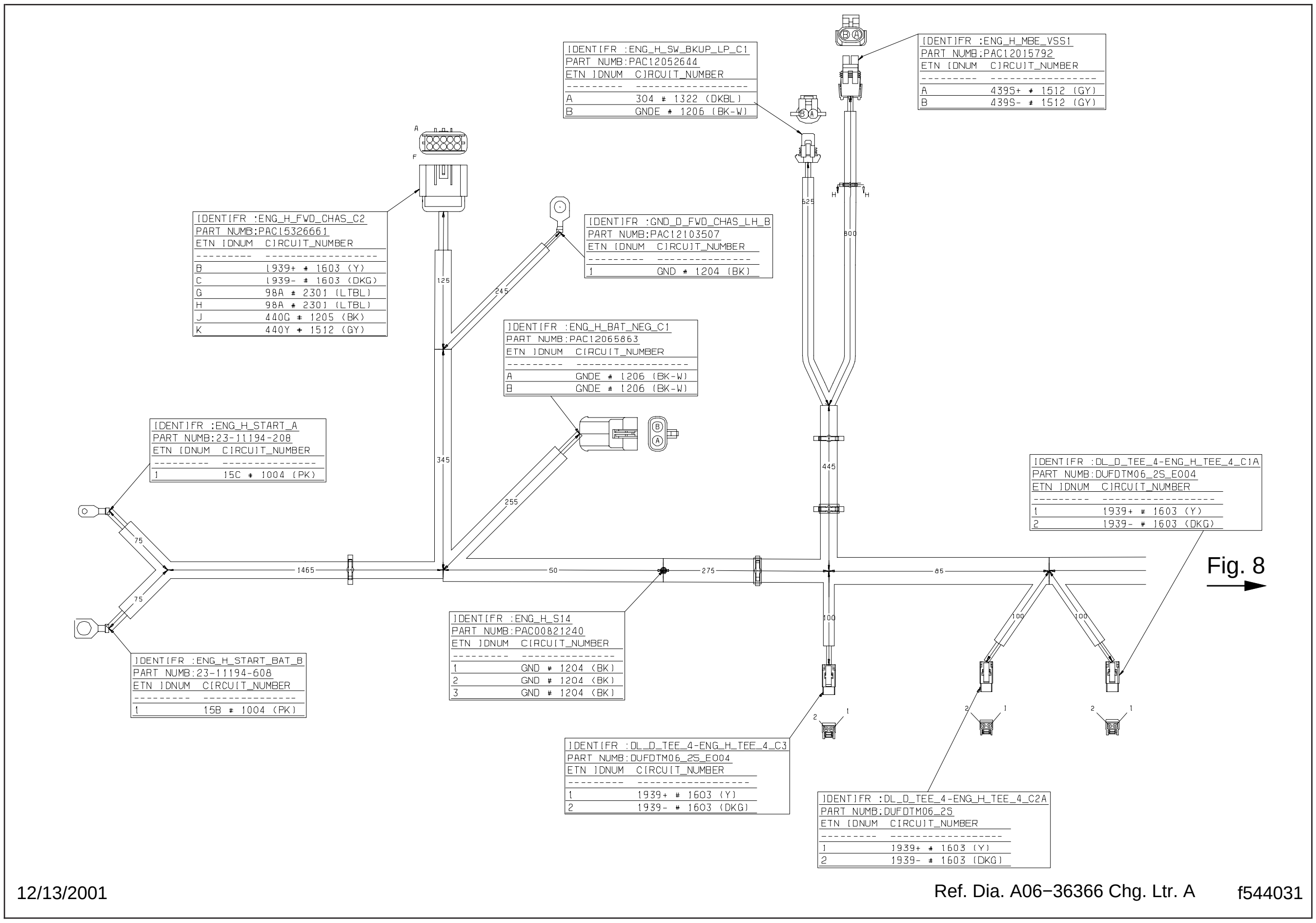


Fig. 7, MBE900 Engine Harness, Manual Transmission (detailed view, engine connector end)

Harness Wiring

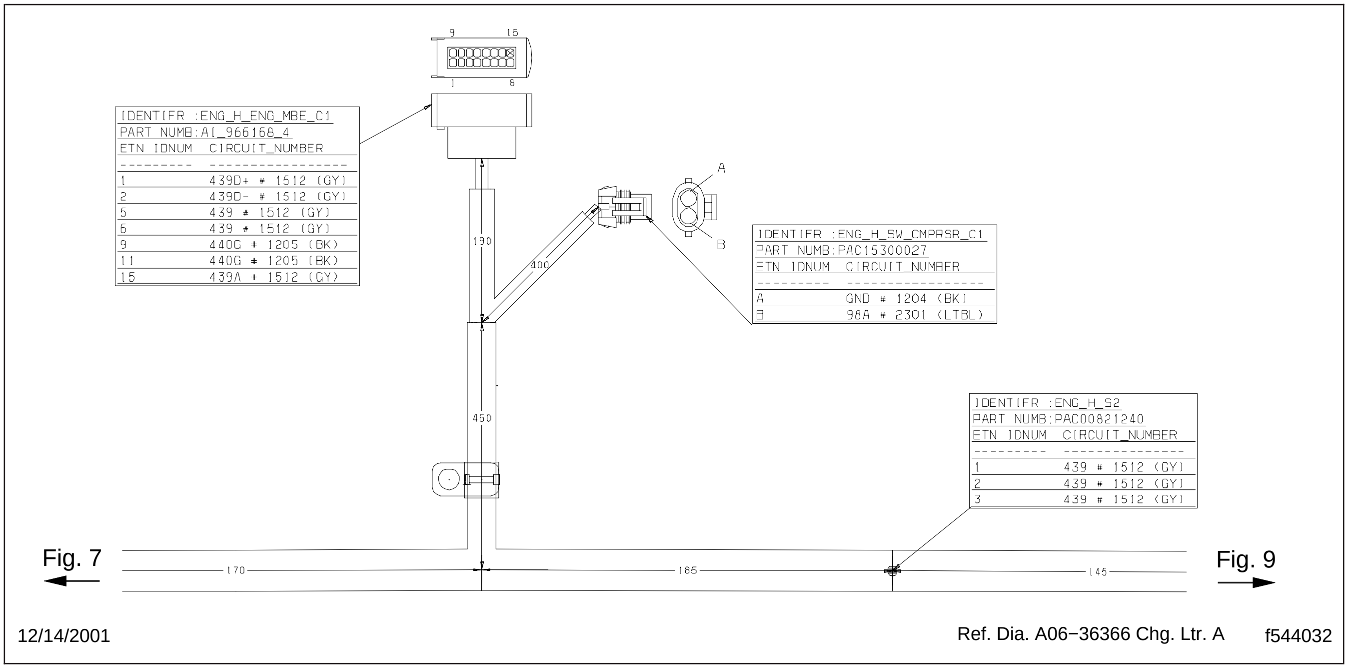


Fig. 8, MBE900 Engine Harness, Manual Transmission (detailed view, CAN datalink connector)

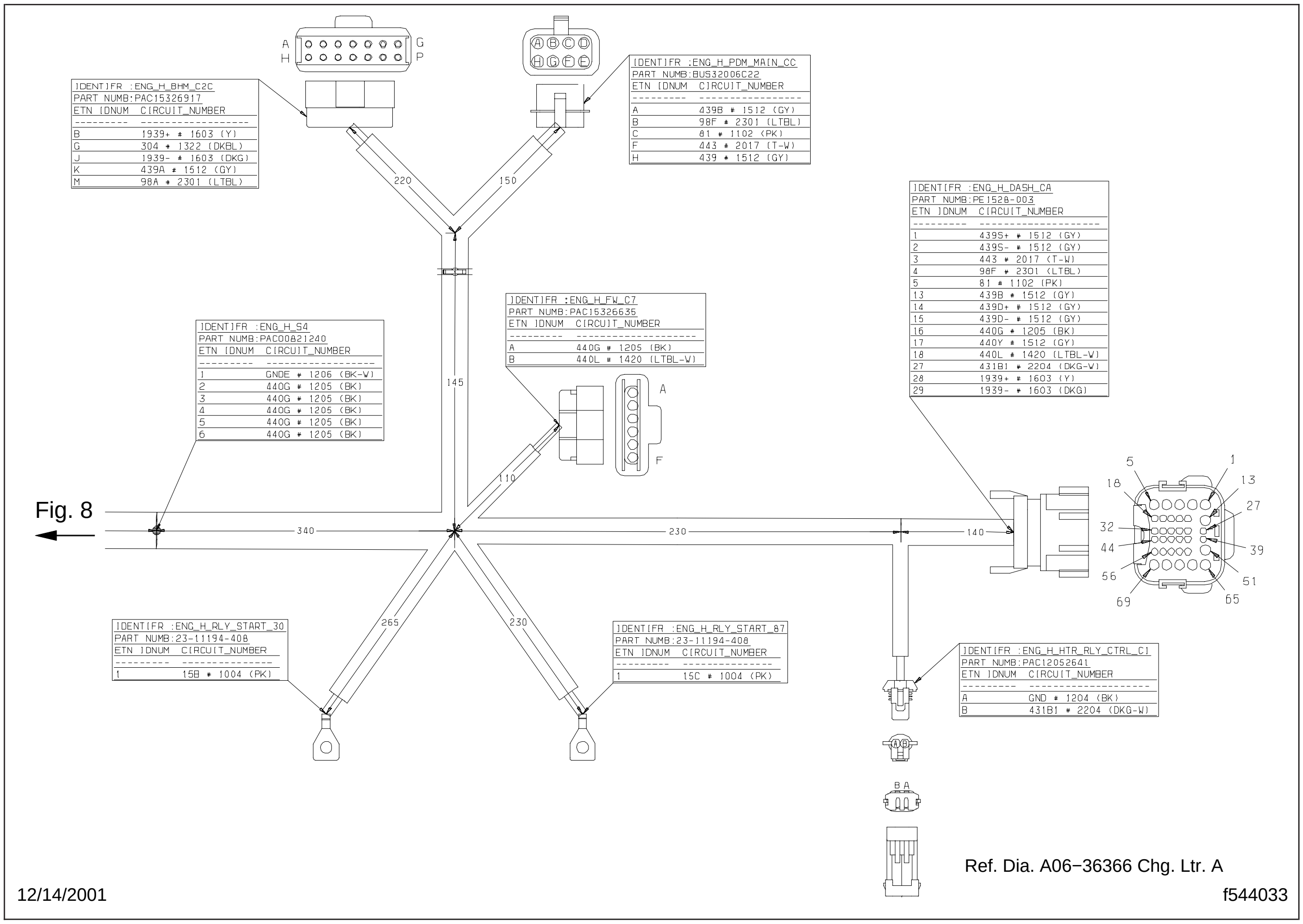


Fig. 9, MBE900 Engine Harness, Manual Transmission (detailed view, bulkhead connector end)

General Information

All Lead-Acid Batteries

Maintenance-free lead-acid batteries, both liquid-electrolyte batteries and gel cells, are electrochemical devices which store chemical energy. When the battery is connected to an external load, such as a starter, the chemical energy is converted into electrical energy and current flows through the circuit.

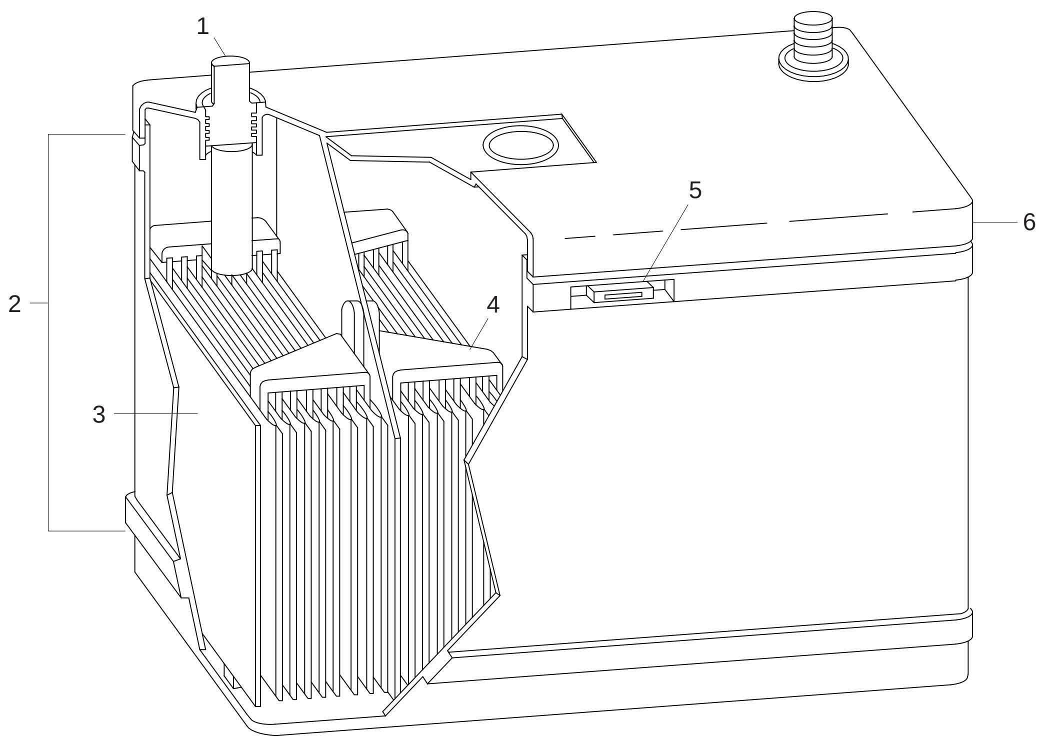
The automotive battery has three functions:

- To supply power to the starter and ignition system so the engine can be cranked and started.
- To stabilize the voltage in the electrical system by reducing temporary high voltages in the electrical system. These high transient voltages could damage other electrical components if they were not protected by the battery.
- To supply extra power when the electrical load requirements of the vehicle go beyond what the charging system can supply, or when the engine is not running.

All lead-acid batteries use plates made of two unlike metals held apart by separators. One of the metals becomes the positive plate, the other the negative plate. These plates are then grouped in pairs, alternating negative and positive. The groups are connected in series, and each plate group (cell) produces about two volts. Thus, a battery with six cells is a 12-volt battery. See **Fig. 1**.

In conventional liquid-electrolyte batteries (wet cells), each battery contains a group of plates immersed in a solution of electrolyte (dilute sulfuric acid). In a gel cell battery, the electrolyte is a solid gel, not a liquid.

Maintenance-free wet cells use calcium rather than antimony to improve grid strength. Calcium reduces



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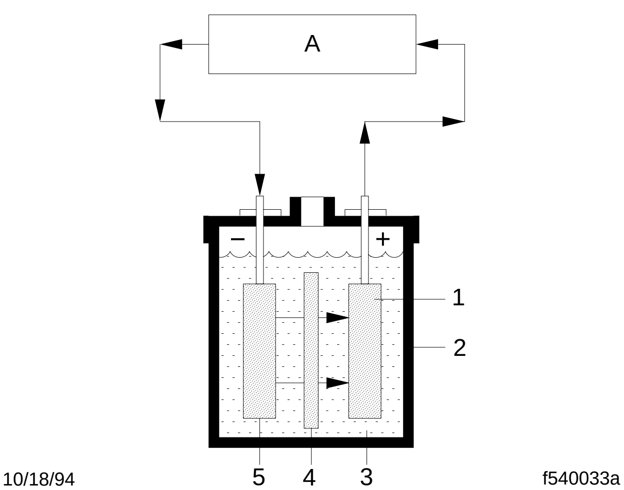
1. Terminal
2. Electrolyte Reservoir
3. Positive Plate Envelope
4. Intercell Connection
5. Vent Hole
6. Plastic Cover

Fig. 1, Typical Maintenance-Free 12-Volt Battery

General Information

the tendency for the battery to produce gas at normal charging voltages; therefore, little water is lost unless the battery has been charged at a very high rate. There are no filler caps in the cover. The battery is sealed except for small vent holes in the cover. The vents allow the escape of gases produced in the battery.

Electrical energy is produced in each cell by chemical changes in the plates and in the electrolyte whenever a battery is discharged. See **Fig. 2**. A battery produces maximum electrical energy only when the cells are fully charged. As the cells discharge, chemical changes in the plates gradually reduce the potential electrical energy available. Recharging the battery with an opposite flow of direct current reverses the chemical changes within the cells and restores them to their active state. See **Fig. 3**.



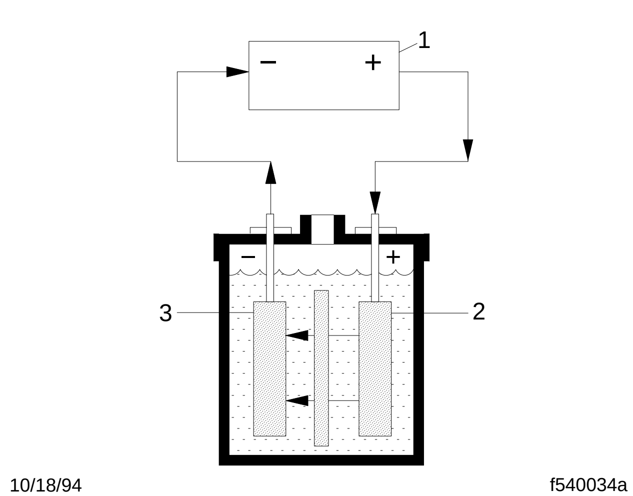
A. External Electrical Load (such as a starter)

1. Positive Plate
2. Battery Case
3. Electrolyte
4. Separator
5. Negative Plate

Fig. 2, Discharging the Battery

NOTE: Liquid-electrolyte batteries must be kept in an upright position to prevent electrolyte leakage. Tipping a wet cell beyond a 45-degree angle in any direction can allow a small amount of electrolyte to leak out the vent holes.

In standard installations, the batteries are mounted on the side of the frame rail.



1. Charger
2. Positive Plate
3. Negative Plate

Fig. 3, Charging the Battery

Only good care can ensure long battery life. Proper testing will indicate the battery condition. For more information, see **Subject 140**.

Selecting a Replacement

Long and trouble-free service is assured when the reserve capacity of the battery is equal to or exceeds 160 minutes and the cold cranking amp (CCA) rating of each replacement battery is at least 625 amperes. The CCA rating of the battery is a measure of its ability to supply high cranking power to the cranking motor at 0°F (–18°C).

The use of an undersized battery may cause poor performance and early failure. It may also cause damage to or reduced life of the starter. With falling temperatures, battery power decreases while the need for engine cranking power increases. Subzero temperatures reduce the capacity of a fully charged battery to 45 percent of the normal power, and at the same time, increase cranking load to 3-1/2 times the normal warm-weather load.

Batteries of a greater capacity should be considered if the electrical load has been increased through the addition of accessories, or if driving conditions are such that the charging system cannot keep the batteries charged.

IMPORTANT: Do not replace a battery on a medium-duty or heavy-duty tractor or truck with one designed for automobiles and light trucks. The cold cranking amp (CCA) rating may be the same or higher, but the plates are lighter, and the battery will not provide the reserve life that is needed. Also, these batteries do not have the extra vibration protection or temperature resistance required on a heavy-duty vehicle.

Storage

Always store batteries in an upright position. Do not store liquid-electrolyte type batteries on their sides as electrolyte may escape through the vent holes.

Maintain inventory levels in balance with demand and always rotate battery stock on a strict first-in, first-out basis. To protect against self-discharge, check the date codes stamped on the battery cartons and on the batteries themselves.

IMPORTANT: One of the major causes of problems with replacement batteries is failure to follow the first-in, first-out stock procedure.

Roller racks provide the best way to store batteries. If loaded properly from the back, racks insure that the oldest battery of a particular type will always appear in the front.

Mark the racks clearly, both front and back, to ensure that the same battery type will go in the same rack every time.

If roller racks are not available, use wooden shelving reachable from both the front and the back. Otherwise, old batteries must be removed to put new batteries in the back.

Never stack batteries on top of one another. If nothing else is available, simple battery storage racks can be made from loose, flat boards.

Maintenance-free batteries can have a shelf life of up to 12 months or more, depending upon storage temperatures, before charging is needed.

NOTE: Batteries in vehicles that are not in service are considered to be in storage. When a vehicle is to be out of service for 30 days or more, disconnect the negative ground terminal of each battery to prevent self-discharge caused by various components.

To minimize self-discharge, store batteries in as cool a place as possible, away from heat ducts in winter and shielded from direct sunlight in summer.

The best storage conditions are in clean, dry areas where ambient temperatures are stable between 32 and 80°F (0 and 27°C). Storage in temperatures above 80°F (27°C) is not recommended, as this increases the rate of self-discharge. Avoid temperatures below 32°F (0°C) to prevent freezing if a battery becomes discharged.

General Safety Precautions

WARNING

Keep sparks, flames, burning cigarettes, etc. away from batteries. Batteries generate explosive gases, which could cause a battery to explode, causing serious personal injury, including blindness.

When charging the batteries, gas forms in each cell and escapes through the vent holes. In poorly ventilated areas, the gas lingers around the battery several hours after it has been charged. The gas is explosive around sparks, flame, or other intense heat; if ignited, it could cause the battery to explode. Follow these precautions when charging the batteries.

- Wear safety glasses or a face shield when working with batteries. When many batteries are handled, wear rubber gloves and an apron to protect clothing.
- Make sure that the area is well ventilated.
- Do not install any lead-acid battery in a sealed container or enclosure. Allow hydrogen gas caused by overcharging to escape. Exploding hydrogen gas can cause blindness or other bodily injury.
- Make sure that the charger cable leads are clean and making good connections. A poor connection could cause an electrical arc which could ignite the gas mixture and explode the battery.
- Do not break live circuits at the terminals because a spark usually occurs at the point where a live circuit is broken. Use care when connecting or disconnecting booster leads or cable clamps on chargers.
- Do not smoke near batteries that are being charged or have recently been charged. Keep the batteries away from open flames or sparks.
- If the battery is frozen, let it reach room temperature before trying to charge it. Check for leaks and cracks before charging the battery. Replace the battery if leaks or cracks are seen.
- Take care that tools or metal objects do not fall across the battery terminals.

WARNING

Do not install any lead-acid battery in a sealed container or enclosure. Allow hydrogen gas caused by overcharging to escape. Exploding hydrogen gas can cause blindness or other bodily injury.

CAUTION

If a metal object connects an ungrounded battery terminal to a nearby metal part of the vehicle which is grounded, it could short out the batteries, causing sparks and possible property damage.

Battery Electrolyte Safety Precautions

WARNING

Protect skin and eyes from battery electrolyte (acid). Electrolyte is corrosive and could result in serious personal injury if splashed on your skin or in your eyes.

If electrolyte is splashed on your skin or in your eye, force the eye open, rinse it with cool, clean water for about five minutes and call a doctor immediately. Do not add eye drops or other medication unless advised by the doctor.

If electrolyte is swallowed, drink several large glasses of milk or water. Follow with milk of magnesia, a beaten raw egg, or vegetable oil. Call a doctor immediately.

Use extreme care to avoid spilling or splashing electrolyte. Electrolyte spilled or splashed on your body or clothing should be neutralized with baking soda or household ammonia, then rinsed with clean water.

Electrolyte can also damage painted or unpainted metal vehicle parts. If electrolyte is spilled or splashed on any metal surface, neutralize and rinse it with clean water.

To prevent possible skin burns, do not wear watches, rings, or other jewelry while performing maintenance work on the batteries.

Battery Safety Precautions

WARNING

Do not apply pressure to the end walls of a plastic-case battery. This could cause electrolyte to squirt from the vents, possibly resulting in serious injury to skin or eyes.

When handling plastic-case batteries, use a battery carrier. If one is not available, lift these batteries with your hands placed at opposite corners of the battery.

Emergency Starting of a Battery

WARNING

Before jump-starting a vehicle, read the instructions in Subject 120. Failure to follow the safety precautions could result in personal injury.

Handle both the charged and the discharged batteries carefully when using jumper cables. Follow the procedure below, being careful not to cause sparks.

CAUTION

Make sure the starting systems on both vehicles have the same voltage outputs, and make connections as described below. Otherwise, the starter or the charging system could be damaged.

IMPORTANT: At no time during this operation should the vehicles touch each other, as this could establish a ground connection and offset the benefits of this procedure.

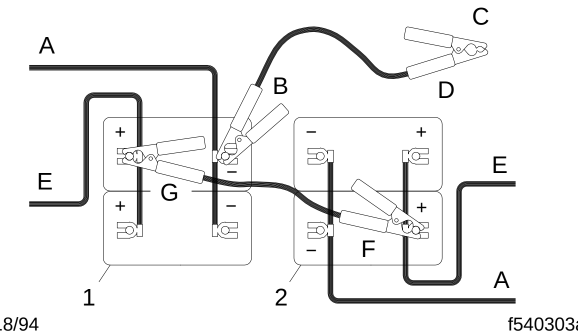
WARNING

Use the following procedure when jump-starting. Incorrect battery handling procedures could result in battery explosion and severe personal injury, including blindness.

1. Apply the parking brakes. Turn off the lights, heater, and all other electrical loads.

IMPORTANT: If the vehicles are exposed to traffic, activate the warning flashers on the booster vehicle.

2. For the first connection, attach one end of the jumper cable to the positive terminal of the booster battery. For the second connection, attach the opposite end of the same cable to the positive terminal of the discharged battery. See **Fig. 1** and **Fig. 2**.
3. For the third connection, attach one end of the other jumper cable to the negative terminal of the booster battery. For the fourth connection, attach the opposite end of that cable to a ground at least 12 inches (300 mm) from the battery of the vehicle being started. See **Fig. 1** and **Fig. 2**. The vehicle frame is usually a good ground.

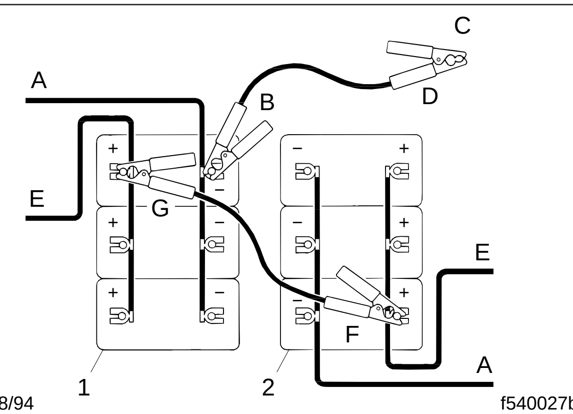


NOTE: This procedure is for negative-ground vehicles only.

A. To Ground
B. Third Connection
C. To Frame
D. Fourth Connection
E. To Starter
F. Second Connection
G. First Connection

1. Booster Battery
2. Discharged Starting Battery

Fig. 1, Jumper Connections, Two-Battery System



NOTE: This procedure is for negative-ground vehicles only.

A. To Ground
B. Third Connection
C. To Frame
D. Fourth Connection
E. To Starter
F. Second Connection
G. First Connection

1. Booster Battery
2. Discharged Starting Battery

Fig. 2, Jumper Connections, Three-Battery System

IMPORTANT: The final ground connection must provide good electrical conductivity and current-

Emergency Starting of a Battery

carrying capacity. To prevent sparks and explosions of hydrogen gas, do not connect directly to the negative post of the discharged battery.

4. Make sure that the clamps from one cable do not touch the clamps on the other cable. Do not lean over the batteries when making connections.
5. Make sure that everyone is standing away from the vehicles. Start the engine of the vehicle with the booster batteries. Wait a few minutes, then attempt to start the engine of the vehicle with the discharged batteries.

   Do not operate the starter longer than 30 seconds. Wait at least 2 minutes between starting attempts to allow the starter to cool. If the engine does not start after several attempts, check for the cause.
6. After starting, allow the engine to idle. Disconnect the ground connection from the vehicle with the discharged battery. Then disconnect the opposite end of the cable.
7. Disconnect the other cable from the discharged battery first, then disconnect the opposite end.

General Information

WARNING

Before testing a battery read the instructions in Subject 120. Failure to follow the safety precautions could result in personal injury.

Test any maintenance-free battery that does not hold a charge to see if it needs to be replaced, or if the problem lies elsewhere in the electrical system. Accuracy of the test depends on variables such as temperature and age of the battery. Follow the recommended testing instructions listed below.

IMPORTANT: Two types of battery tests are discussed in this subject. The first, Midtronics PowerSensor Micro740 Test, uses the Midtronics Micro740 battery tester and must be used by all U.S. and Canadian dealers for battery warranty claims. The second test is a load test using a carbon pile type tester and should **not** be used by U.S. or Canadian dealers for battery warranty claims.

Visual Inspection

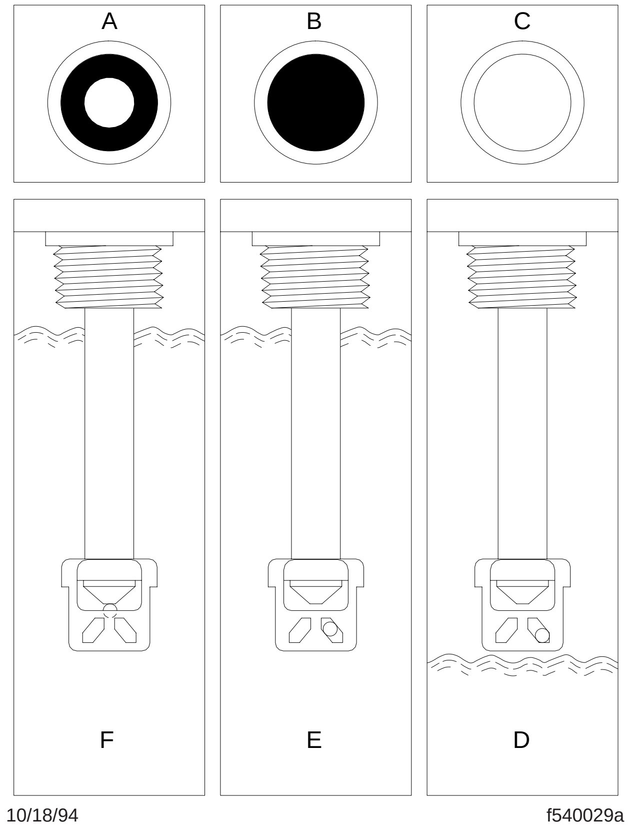
Check for obvious damage such as a cracked or broken case that could permit loss of electrolyte. If there is physical damage replace the battery. Find the cause of the damage and correct it as needed.

On maintenance-free batteries without a built-in hydrometer, perform the Midtronics PowerSensor Micro740 test or the load test.

On maintenance-free batteries with a built-in hydrometer, check the sight glass. If a green dot shows in the sight glass test the battery. If the sight glass is dark recharge the battery, then test it. See **Subject 150**. If the sight glass is clear replace the battery. See **Fig. 1**.

Prior to Testing

1. Clean the battery terminals with a soft wire brush before testing.
2. At the start of the test, make sure all vehicle accessory loads are off and the ignition is in the off position.



A. Green Dot
B. Dark
C. Clear
D. Dead Battery
E. 65 Percent or Less of Charge
F. 65 Percent or More of Charge

Fig. 1, Built-In Hydrometer or Charge Indicator (on optional batteries only)

Midtronics PowerSensor Micro740 Test

NOTE: This test must be used by all U.S. and Canadian dealers for battery warranty claims.

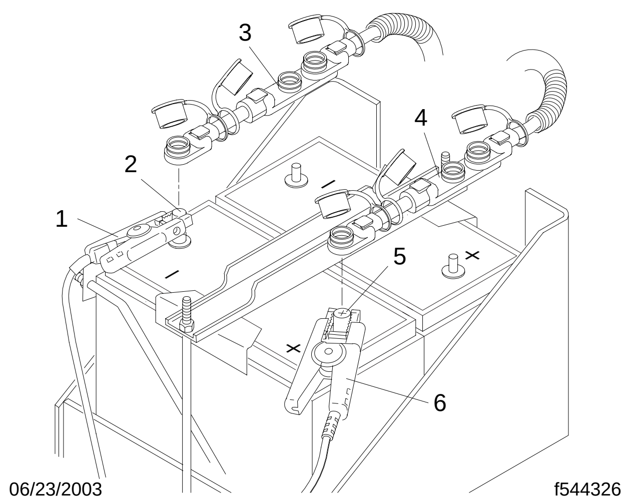
Every battery in a pack of two or more must be disconnected before testing. If more than one battery is selected to be tested, the analyzer will test the first battery, then prompt you to connect to the next battery after the test has been completed. If the ana-

Battery Testing

lyzer detects that the batteries are connected it will remind you to disconnect the pack before starting the test.

Connecting the Midtronics Tester

1. Screw an adapter onto the negative-terminal stud and one onto the positive-terminal stud. See **Fig. 2**.



1. Negative-Terminal Clamp
2. Negative-Terminal Adaptor
3. Negative-Terminal Battery Jumper
4. Positive-Terminal Jumper
5. Positive-Terminal Adaptor
6. Positive-Terminal Clamp

Fig. 2, Battery Connection

IMPORTANT: For accurate test results, connect the clamps to the lead adaptors or to the lead bases of threaded studs. Lead stud adaptors are included with the Micro740. Do not connect the clamps directly onto the threaded studs or an inaccurate test result may occur.

2. Connect the red clamp to the positive-terminal stud adaptor.
3. Connect the black clamp to the negative-terminal stud adaptor.
4. Rock the clamps back and forth to ensure a secure connection. Both sides of the clamp must be firmly connected to the adaptors before testing. If the test message CHECK CONNECTION appears, clean the terminals and/or reconnect the clamps.

Battery Test

NOTE: If the analyzer displays a test message after you start the test see "Test Messages" to determine the cause and remedy.

1. Use the arrow buttons at the top of the keypad to scroll to menu choices. Select BATTERY TEST. Press ENTER to select.
2. Enter the number of batteries being tested (1 to 6) and press ENTER to select.
3. Select the rating system CCA, SAE, EN, IEC, DIN, or JIS, then press ENTER.
4. Select the appropriate rating value (**Table 1**) then press ENTER.
5. If the analyzer detects that the temperature of the battery may make a difference in the results, it will ask you to select whether the battery temperature is above or below 32°F (0°C). It will resume the test after you make the selection and press ENTER.
6. At the end of the test, the Micro740 will display one of the following results from **Table 2** and the measured voltage and CCA, if applicable.

   If the result is REPLACE BATTERY or BAD CELL—REPLACE, the analyzer will prompt you to press ENTER to generate a battery code.

   When the prompt BAT.SERIAL # appears enter the battery serial number. Use the ARROW buttons to scroll to the correct digit, then press ENTER to select it and move to the next digit. Pressing the BACK button will move the cursor back one space. When finished, press ENTER.
7. Turn on the printer and align the analyzer transmitter with the printer receiver. Press and hold the MENU button. Select PRINT RESULTS from the option menu by using the arrow buttons and pressing ENTER. It will take about 30 seconds to print all test results, which are displayed simultaneously on the screen.

Battery Rating Systems		
Rating System	**Description**	**Value Range**
CCA	Cold Cranking Amps, as specified by SAE. The most common rating for cranking batteries at 0 F (-18 C)	100 to 1700 A
SAE	European labeling of CCA	100 to 1700 A
EN	Europa-Norm	100 to 1700 A
IEC	International Electrotechnical Commission	100 to 1000 A
DIN	Deutsche Industrie-Norm	100 to 1000 A
JIS	Japanese Industrial Standard: (shown on a battery as a combination of numbers and letters, for example: 80D26)	43 values from 26A17 to 245H52

Table 1, Battery Rating Systems

Battery Test Results	
Result	**Recommendation**
Good Battery	Return to service.
Good–Recharge	The battery is good, but has an insufficient state of charge. Fully charge the battery and return to service. See **Subject 150**.
Charge & Retest	The battery has a very low state of charge. Fully charge the battery and retest. Failure to fully charge the battery before retesting may cause false readings. See **Subject 150**.
Replace Battery	Replace the battery and generate a test code.
Bad Cell–Replace	Replace the battery and generate a test code.

Table 2, Battery Test Results

Test Messages

Test Message—SYSTEM NOISE

Test Message—SYSTEM NOISE	
Possible Cause	**Remedy**
The analyzer has detected computer or ignition noise and will attempt to retest.	Make sure all vehicle loads are off and the ignition is in the off position. The analyzer will automatically retest when it no longer detects system noise
You may be testing too close to a noise source.	Move away from any high-current device and retest.
Battery charge is too low to test properly.	Recharge the battery and retest. If the message reappears, replace the battery. See **Subject 150**.
Poor connection at battery terminal.	Connect the battery cables and retest.

Test Message—NON 12-VOLT BATTERY DETECTED

Test Message—NON 12-VOLT BATTERY DETECTED	
Possible Cause	**Remedy**
You are attempting to test both batteries in a 24-volt system at the same time.	Disconnect the batteries and test each one individually.

Battery Testing

Test Message—INTERNAL ERROR, SERVICE REQUIRED

Test Message—INTERNAL ERROR, SERVICE REQUIRED	
Possible Cause	**Remedy**
The analyzer has detected a hardware or software problem.	See the Midtronics Micro740 *Instruction Manual*.

Test Message—REVERSE CONNECTION

Test Message—REVERSE CONNECTION	
Possible Cause	**Remedy**
The clamps are connected in reverse polarity. IE: Red to negative(-) and black to positive (+).	Disconnect the clamps and reclamp to proper polarity.

Test Message—UNSTABLE BATTERY

Test Message—UNSTABLE BATTERY	
Possible Cause	**Remedy**
Batteries that are very weak or that have just been charged may have sufficient electrical activity to alter test results. The analyzer will automatically retest when the battery has stabilized. Fully charged batteries should stabilize quickly.	Charge weak batteries and then retest. See **Subject 150**.

Test Message—CHECK CONNECTION

Test Message—CHECK CONNECTION	
Possible Cause	**Remedy**
Poor connection. Both sides of the clamps must be firmly connected before testing.	Clean the battery terminals using a wire brush and a mixture of baking soda and water. Inspect and clean the clamps. Liberally apply baking soda and water with a clean cloth and thoroughly rub the jaw and spring. Use a soft wire brush to remove corrosion buildup. Rinse with water and let dry.

Load Test

NOTE: This test must **not** be used by U.S. and Canadian dealers for battery warranty claims.

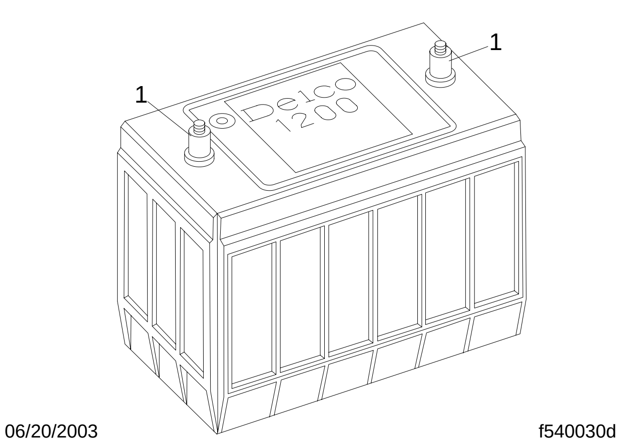
1. Before beginning the load test, make sure the battery to be tested is fully charged. See **Subject 150** for conventional battery and gel cell charging instructions.

WARNING

Before charging a battery, read the instructions in Subject 120. Failure to follow the safety precautions could result in personal injury.

When charging batteries, always wear eye protection. During charging, batteries give off explosive hydrogen gas. Exploding gas can cause blindness or other bodily injury.

2. Test each battery separately, either installed or removed. Disconnect the battery ground cable first.
3. Connect the tester leads to the battery terminals following the tester manufacturer's instructions. Batteries with sealed terminals require adaptors to provide a place for attaching the tester's leads. See **Fig. 3**.
4. Check the rated CCA of the battery. Apply a load equal to one-half the rated CCA across the terminals for 15 seconds to remove the surface



1. Terminal Adaptor

Fig. 3, Sealed Battery

charge from the battery. Remove the load and wait 15 seconds for the battery to recover.

For example, for a battery rated at 620 CCA, apply a load of 310 amperes across the terminals.

5. Estimate the battery temperature by touch and by the ambient temperature the battery was exposed to before this test, then find the voltage in the applicable table, **Specifications 400** that must be maintained while the battery supplies a specified electrical load.

   For example, at 70°F (21°C) the battery must supply 9.6V minimum.

6. Apply the specified test load to the battery for 15 seconds. The test load (amperes) is equal to one-half of the cold-cranking amperes of the 0°F (–18°C) rating of the battery.
7. Read the terminal voltage at the end of 15 seconds with the load still connected. Do not keep the load attached for a longer period of time before reading the voltage, as this would alter the test results.
8. Remove the load after 15 seconds and note the tester reading.

   If the voltage drops below the minimum listed in the table replace the battery.

   If the voltage is the same or greater than the minimum listed in the table the battery is capable of further service.

⚠ WARNING

Before charging a battery, read the instructions in Subject 120. Failure to follow the safety precautions could result in personal injury.

When charging batteries, always wear eye protection. During charging, batteries give off explosive hydrogen gas. Exploding gas can cause blindness or other bodily injury.

Charging a Conventional Battery

To ensure the general well being of the electrical system, the starting battery(s) should be kept at a high state of charge. In particular, if operating a vehicle with undercharged battery(s), the alternator can be overworked and may cause premature failure.

To charge a conventional liquid-electrolyte battery (wet cell), apply a charge rate in amperes for several hours. For example, a 10-ampere charge rate for five hours would produce a 50 ampere-hour charge to the battery.

General Guidelines for Charging Batteries

When charging multiple batteries on one charger, group batteries that have similar voltages and are of similar age. If not, the group will only charge as fast as the battery with the lowest state of charge. Batteries below 5 volts should be charged individually.

IMPORTANT: Do not overcharge maintenance-free batteries. Overcharging causes excessive loss of water from the electrolyte and eventual battery damage.

See **Table 1**, **Table 2**, **Table 3**, and **Table 4** to determine how long to charge the batteries.

Recharge Time Using Shop Charger for a Single Battery					
Voltage	State of Charge	Charger Maximum Rate			
		50 Amps	30 Amps	20 Amps	10 Amps
12.6	100%	Ready to Use			
12.4	75%	0.6 hours	0.9 hours	1.3 hours	2.5 hours
12.2	50%	1.2 hours	1.9 hours	2.7 hours	5.1 hours
12.0	25%	1.8 hours	2.9 hours	4.3 hours	7.8 hours
11.8	0%	2.5 hours	4.0 hours	5.7 hours	10.7 hours

Table 1, Recharge Time Using Shop Charger for a Single Battery

Recharge Time Using Shop Charger for a Two-Battery System					
Voltage	State of Charge	Charger Maximum Rate			
		50 Amps	30 Amps	20 Amps	10 Amps
12.6	100%	Ready to Use			
12.4	75%	1.2 hours	1.8 hours	2.6 hours	5.0 hours
12.2	50%	2.4 hours	3.8 hours	5.4 hours	10.2 hours
12.0	25%	3.6 hours	5.8 hours	8.6 hours	15.4 hours
11.8	0%	5.0 hours	8.0 hours	11.4 hours	21.4 hours

Table 2, Recharge Time Using Shop Charger for a Two-Battery System

Battery Charging

Recharge Time Using Shop Charger for a Three-Battery System					
Voltage	State of Charge	Charger Maximum Rate			
		50 Amps	30 Amps	20 Amps	10 Amps
12.6	100%	Ready to Use			
12.4	75%	1.8 hours	2.7 hours	3.9 hours	7.5 hours
12.2	50%	3.6 hours	5.7 hours	8.1 hours	15.3 hours
12.0	25%	5.4 hours	8.7 hours	12.9 hours	23.1 hours
11.8	0%	7.5 hours	12.0 hours	17.1 hours	32.1 hours

Table 3, Recharge Time Using Shop Charger for a Three-Battery System

Recharge Time Using Shop Charger for a Four-Battery System					
Voltage	State of Charge	Charger Maximum Rate			
		50 Amps	30 Amps	20 Amps	10 Amps
12.6	100%	Ready to Use			
12.4	75%	2.4 hours	3.6 hours	5.2 hours	10.0 hours
12.2	50%	4.8 hours	7.6 hours	10.8 hours	20.4 hours
12.0	25%	7.2 hours	11.6 hours	17.2 hours	31.2 hours
11.8	0%	10.0 hours	16.0 hours	22.8 hours	42.8 hours

Table 4, Recharge Time Using Shop Charger for a Four-Battery System

Batteries below 11.8 volts should be charged at no more than 10 amps for a minimum of 24 hours per battery. Check after the first hour and ensure that the battery is not getting hot.

If after using the above charging method you receive a charge and retest result from a Midtronics battery tester and the voltage is above 11.8 volts, continue to charge normally. If the battery voltage is below 11.8 volts, condemn the battery.

On optional batteries with built-in hydrometer (charge indicator), the battery is sufficiently charged when the green dot in the hydrometer is visible. Gently shake or tilt the battery at hourly intervals during charging to mix the electrolyte and check to see if the green dot appears. Do not tilt the battery beyond a 45-degree angle.

If the green dot does not appear after a 75 ampere-hour charge, continue charging for another 50 to 75 ampere-hours. If the green dot still does not appear, replace the battery.

NOTE: Batteries with built-in hydrometers (charge indicators) cannot be charged if the indicator color is clear or light yellow; this indicates low electrolyte level. Replace these batteries.

Refer to the following steps to charge a wet cell battery.

1. Clean the battery terminals.

NOTE: If the battery is cold, let it warm up. This will allow a normal charging rate.

2. Make sure that the charger is turned off.
3. Connect the charger to the battery following the manufacturer's instructions. Rock the charger lead clamps to make sure there is a good connection.
4. Turn on the charger and slowly increase the charging rate until the recommended ampere value is reached.

IMPORTANT: If the battery feels hotter than 125°F (52°C) or if rapid gassing or spewing of electrolyte occurs, lower the charging rate or stop charging the battery and allow it to cool.

5. After the battery(s) has charged for the recommended time, turn the charger off.

WARNING

Always turn the charger off before disconnecting it. Touching a charger lead when the circuit is live could create a spark and cause an explosion, resulting in personal injury.

6. Disconnect the charger cables from the battery.

NOTE: If the vehicle is equipped with an isolated battery system, be sure that both battery systems are charged.

7. If the engine does not crank satisfactorily when a charged battery is installed, test the battery using a Midtronics™ battery tester.

   If the battery passes the Midtronics test, check the fuel, ignition, cranking, and charging systems to find and correct the problem.

   If the battery does not pass the Midtronics test, replace it.

Gel Cell Charging

CAUTION

To avoid shortening the life of a gel cell, carefully regulate the charging voltage—between 13.8 and 14.1 volts.

It is hard to determine how long to charge a gel cell. Recharging time depends on the following factors:

- depth of discharge
- temperature
- size and efficiency of the charger
- age and condition of the battery

Because the chemical charging reaction slows down as it nears completion, about 60 percent of the total charging time will be spent bringing the battery from 10.5 volts under load (11.8 volts with no load) to 90 percent of full charge (12.92 volts, including surface charge). The other 40 percent of the time is required to charge the remaining 10 percent (full charge = 13.0 volts, including surface charge).

For example, if it takes 3-1/2 hours to charge a battery to 90 percent, it will take another 2-1/2 hours to bring it to full (100 percent) charge.

See **Table 5** for a list of estimated charging times to 90 percent of full charge. See **Table 6** for a list of estimated charging times to 100 percent of full charge. All charging times are based on the initial charge current accepted by the battery, using an automatic, temperature-sensing, voltage regulating charger set at 13.8 volts (2.30 to 2.35 volts per cell) on a totally discharged battery (at 11.80 to 12.00 volts, with no load).

Charging Time to 90 Percent of Full Charge			
Battery	Initial Amps Needed to Recharge In		
	13 Hours	6 Hours	3-1/2 Hours
G27	8	21	41
G31*	9	24	45

* Freightliner uses the G31 (Group 31) gel cell.

Table 5, Gel Cell Charging Guide (90 percent charge)

To use these tables, read the amps about one minute after the charger is first turned on. Use this initial reading to estimate the approximate charging time.

For example, if a G31 battery reads about 24 amps charge current when first turned on, the battery will be at 90 percent charge in about six hours and will be fully charged (100 percent) in about ten hours.

Charging Time to 100 Percent of Full Charge			
Battery	Initial Amps Needed to Recharge In		
	22 Hours	10 Hours	6 Hours
G27	8	21	41
G31*	9	24	45

* Freightliner uses the G31 (Group 31) gel cell.

Table 6, Gel Cell Charging Guide (100 percent charge)

To charge a gel cell, perform the following steps.

1. Remove the gel cell from the vehicle.
2. Clean the battery terminals.

NOTE: If the gel cell is cold, let it warm up to 68°F (20°C). This will allow a normal charging rate.

3. Make sure that the charger is turned off.

Battery Charging

CAUTION

Use a reliable, automatic, temperature-sensing, voltage-regulated charger to charge gel cells. Any other type of charger will damage the gel cell.

4. Connect the charger leads directly to the battery following the charger manufacturer's instructions. Rock the charger lead clamps to make sure there is a good connection.
5. Turn on the charger and set the charging rate between 13.8 and 14.1 volts (2.30 to 2.35 volts per cell).

CAUTION

To prevent damage, do not open a sealed gel cell or charge it in excess of 14.1 volts (2.35 volts per cell).

6. After about one minute, check the initial charge current. To charge to 90 percent of full charge, see **Table 5** to determine the approximate time of completion. To charge to 100 percent of full charge, see **Table 6** to determine the approximate time of completion.

IMPORTANT: If the battery feels hotter than 125°F (52°C) or if rapid gassing occurs, stop charging the battery and allow it to cool.

7. When finished, turn the charger off.

WARNING

Always turn the charger off before disconnecting it. Touching a charger lead when the circuit is live could create a spark and cause an explosion, resulting in personal injury.

8. Disconnect the charger cables from the battery.

Battery Removal, Cleaning and Inspection, and Installation

WARNING

Before doing any of the following procedures, read the instructions in Subject 120. Failure to follow the safety precautions could result in personal injury.

Removal

1. Before working on the battery, make sure all electrical loads such as lights, ignition, and accessories, are turned off.
2. Remove the battery box cover.
3. Disconnect the negative battery cable lead.
4. Disconnect the negative battery jumper post.
5. Disconnect the positive battery cable lead.
6. Disconnect the positive battery jumper post.
7. Remove the battery holddown and retainer if so equipped. Then remove the batteries from the carrier.

Cleaning and Inspection

1. Inspect all battery cables and interconnectors for wear, and replace them if necessary. Remove corrosion from cables, terminals, and battery posts with a wire brush and a solution of baking soda and water. Rinse thoroughly with clean water, and dry.
2. Clean and tighten the battery ground cable at the weld stud on the frame rail. There are two locations to service. First at the battery and, second at the engine behind the left wheel. Inspect and ensure that the nut is self-locking and that a flat washer is used. Do not use a split-lock washer or star washer. Torque the nut 15 to 18 lbf·ft (20 to 24 N·m). Seal the area with red dielectric spray enamel sealant.
3. Inspect the retainer assembly and battery box. Replace worn or damaged parts. Remove any corrosion with a wire brush and wash with a weak solution of baking soda and water. Rinse with clean water and dry. To prevent rusting, paint the retainer assembly if needed.
4. Be sure foreign objects, such as stones, bolts, and nuts, are removed from the battery box.

Installation

1. Be sure that the battery to be installed has a sufficient capacity to cover the electrical needs of the vehicle. For more information, see Subject 100.

CAUTION

Using an under-capacity battery will result in poor performance and premature battery failure, resulting in damage or reduced life of the starter.

2. Be sure the battery is at full charge when installed. If the battery has been in storage for some time, or if the installation is being made in subfreezing temperatures, give the battery a boost-charge before installing it. For instructions, see Subject 150.
3. Place the batteries in the carrier with the terminals in the proper position as referenced earlier. The batteries should rest level in the carrier.
4. Install the battery holddown and tighten it until the batteries are secure. See Fig. 1.

CAUTION

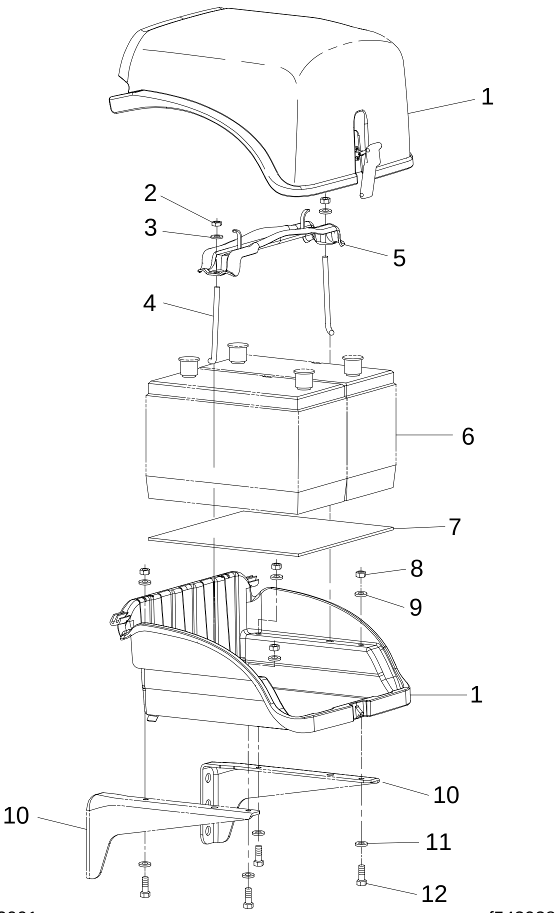
Do not overtighten the battery holddown. Overtightening could damage the batteries.

5. To provide corrosion protection, apply pumpable dielectric grease (48-02349-000) liberally to the terminal pads, then install the interconnectors. For a list of approved suppliers, see Specifications 400.

IMPORTANT: Many electrical components are located outside of the cab in areas subjected to harsh weather and road spray. Some components also have exposed metal electrical terminals, which, when subjected to harsh conditions, may suffer corrosion at the electrical connection. Spray dielectric sealant on all exposed electrical terminals and use dielectric grease on all covered terminals.

6. Connect the battery cables to the batteries and check for correct polarity with respect to the vehicle. Connect the ground cable last.
   - 6.1 Install the positive battery jumper post.
   - 6.2 Install the positive battery cable lead.

Battery Removal, Cleaning and Inspection, and Installation



1. Carrier and Cover
2. 3/8–16 Nut
3. Washer
4. Holddown Bolt
5. Battery Holddown
6. Battery
7. Liner
8. 5/16–18 Nut
9. Washer
10. Mounting Bracket
11. Washer
12. Capscrew

Fig. 1, Battery Box, Battery, and Battery Holddown

6.3 Install the negative battery jumper post.

6.4 Install the negative battery cable lead.

CAUTION

Reversed polarity may cause serious damage to the electrical system.

7. Tighten all battery connections to the torque specifications listed on the battery. Generally those are 10 to 15 lbf·ft (14 to 20 N·m). Proper torque is important for electrical system operation.
8. Start the engine and check the operation of the charging system. If needed, adjust or repair the charging system to obtain the correct charging output. For instructions, see the appropriate section in **Group 15**.

CAUTION

Make sure all battery posts are covered with protective caps. Failure to do so could cause the battery box cover to short across the posts.

⚠ WARNING

Before doing any of the following procedures, read the instructions in Subject 120. Failure to follow the safety precautions could result in personal injury.

Plastic Battery Box

Removal

1. Before working on the battery box, make sure all electrical loads such as lights, ignition, and accessories are turned off.
2. Pull down on the cover latch to release it from the catch, then remove the battery box cover.
3. See **Subject 160** for procedures to remove the batteries.
4. Remove the four sets of fasteners attaching the battery box to the mounting brackets. See **Fig. 1**.
5. Remove the battery box.

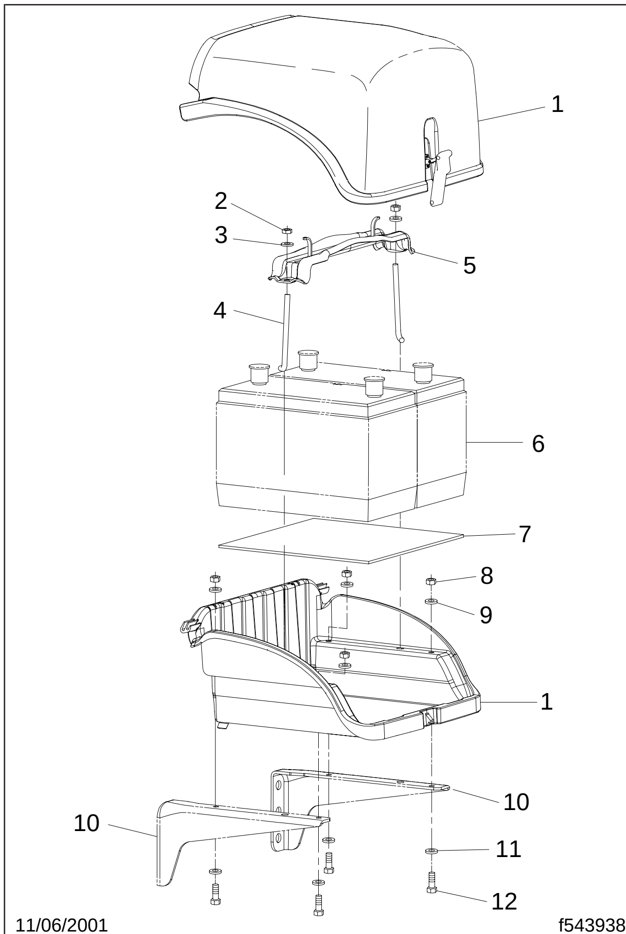
Installation

1. Line up the holes in the battery box with the holes in each mounting bracket.
2. Install the four sets of fasteners that attach the battery box to the mounting brackets. Tighten to 18 lbf·ft (24 N·m).
3. Place the batteries in the battery box with the terminals in the proper position. Make sure the batteries rest level in the box. See **Subject 160** for procedures to correctly install the batteries.
4. Install the battery holddowns. Tighten each nut to 10 lbf·ft (14 N·m).

⚠ CAUTION

Do not overtighten the battery holddowns. Overtightening could damage the batteries.

5. Place the battery box cover over the battery box and fasten the latch.



1. Cover
2. 3/8–16 Nut
3. Washer
4. Holddown Bolt
5. Battery Holddown
6. Battery
7. Liner
8. 5/16–18 Nut
9. Washer
10. Mounting Bracket
11. Washer
12. Capscrew

Fig. 1, M2 Frame-Mounted Plastic Battery Box

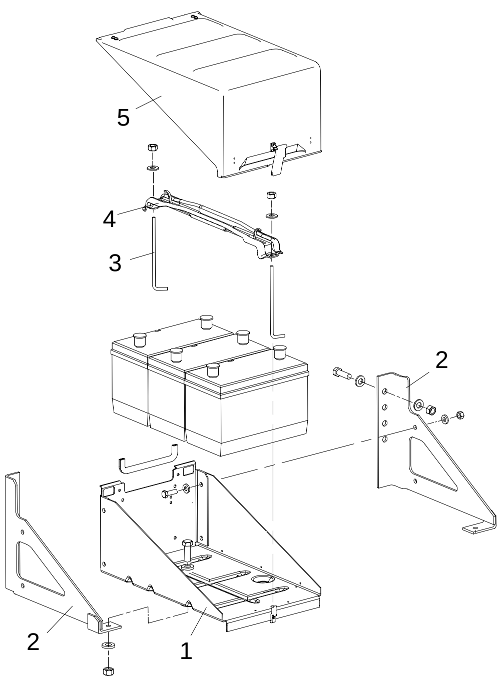
Steel Battery Box

Removal

1. Before working on the battery box, make sure all electrical loads such as lights, ignition, and accessories, are turned off.
2. See **Subject 160** for procedures to remove the batteries.

Battery Box Removal and Installation

3. Pull on the end of the holddown latch until the end clears the cover-mounted catch. Pivot the latch out of the way, then lift off the battery box cover. See **Fig. 2**.



1. Battery Box
2. Bracket, Battery Box
3. Holddown Bolt
4. Holddown
5. Battery Box Cover

Fig. 2, Steel Battery Box (typical)

4. Remove the fasteners that hold the battery box to the brackets.
5. Remove the battery box.

Installation

1. Line up the holes in the battery box with the holes in each mounting bracket.
2. Install the fasteners that attach the battery box to the mounting brackets. Tighten the fasteners to 18 lbf·ft (24 N·m).
3. Place the batteries in the battery box with the terminals in the proper position. Make sure the batteries rest level in the box. See **Subject 160** for procedures to correctly install the batteries.
4. Install the battery holddowns. Tighten each nut to 10 lbf·ft (14 N·m).

CAUTION

Do not overtighten the battery holddowns. Over-tightening could damage the batteries.

5. Place the battery box cover over the battery box and fasten the latch.

Troubleshooting

If the starting batteries test good but fail to perform satisfactorily in service, check for the following causes:

1. Accessories were left on overnight.
2. A slipping alternator belt, high resistance in the wiring, or an inoperative voltage regulator is causing the batteries to discharge.
3. The electrical load is exceeding the charging system capacity.
4. Wires in the electrical system are shorted or pinched.
5. There are loose or damaged battery cable-to-terminal connections.
6. The batteries are still connected in a vehicle that has been out of service. Small current drains of accessories that are connected all the time can discharge the batteries in six to eight weeks. Batteries left in a discharged condition for a prolonged period of time are subject to freezing and may become difficult to charge.

Problem—The Starting Batteries Are Undercharged

Problem—The Starting Batteries Are Undercharged	
Possible Cause	**Remedy**
The drive belt is loose.	Check the drive belt. Refer to the drive belt subject in the appropriate engine section in **Group 01** for instructions. If necessary, tighten to the manufacturer's specifications. Start the engine and check the alternator voltage and output. Refer to the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
The drive belt is damaged or missing.	Check the drive pulleys for locked bearings. Repair or replace any damaged components. Replace the drive belt and start the engine. Check the alternator voltage and output. Refer to the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
The batteries are undercharged.	Do a load test on the batteries. Refer to **Subject 140** for instructions. Charge or replace batteries as needed. If the batteries were discharged, start the engine and check the alternator voltage and output. Refer to the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
The cranking circuit is broken.	If the batteries were fully charged and passed the load test, check the cranking circuit. Make repairs as needed. Start the engine to verify the repair.
The control circuit is broken.	Check the starter wiring. Make repairs as needed. Start the engine to verify the repair.
The starter is cold.	Perform a cold weather starting test.
The battery cables do not deliver sufficient voltage to the starter.	Check the available cranking voltage.
The starter ring gear or pinion gear is damaged.	Visually check the ring and pinion gears.
The starter is damaged.	Replace the starter.
The alternator is malfunctioning.	Refer to the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
The isolator relay is not operating correctly (optional battery isolator system only).	Replace the isolator relay with an exact replacement continuous duty relay.

Troubleshooting

Problem—The Starting Batteries Are Overcharged

Problem—The Starting Batteries Are Undercharged	
Possible Cause	**Remedy**
The voltage regulator is damaged.	Run engine at approximately 2000 rpm. Using a digital voltmeter, check the voltage at the alternator. Refer to the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions. If the voltmeter reads 15.5V or above, replace the alternator.
The dash voltmeter is broken.	Run engine at approximately 2000 rpm. Using a digital voltmeter, check the voltage at the alternator. Refer to the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions. If the voltmeter reads below 15.5V, check and if necessary, replace the dash voltmeter.
The batteries are overheated.	Check battery temperatures. If 120°F (49°C) or above, connect cool, fully charged batteries and recheck the voltage at the alternator. Refer to the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions. If 119°F (48°C) or below, load test the batteries. Refer to **Subject 140** for instructions.
The batteries need replacing.	Check battery temperatures. If 119°F (48°C) or below, load test the batteries. Refer to **Subject 140** for instructions.

Electrical Drain and Parasitic Load Test

Batteries are replenished each time the vehicle is driven with normal vehicle use. In long-term parking situations, however, parasitic drains may discharge the batteries enough to cause a no-start condition.

A parasitic drain is an electrical load that draws current from the batteries when the ignition remains off. Some devices, such as the electronic control unit (ECU), the bulkhead module (BHM), the chassis module (CHM), the antilock braking system (ABS), and radio memory are intended to draw a very small current continuously. These draws are measured in milliamps (mA). Current draw should be less than 325 milliamps with no circuits active and the ECU, BHM, CHM, and ABS turned off.

Determining the Correct Parasitic Load

As more electronic content is installed, parasitic drain issues become more prevalent. The reserve capacity (RC) rating multiplied by 0.6 gives the approximate available ampere-hours (AH) from full charge to complete drain. Between full charge and complete battery drain there is a point where some of the electrical accessories still operate but the vehicle will not start.

NOTE: When there is bodybuilder-added equipment, contact the bodybuilder to get their specifications for parasitic draw and add it to the following numbers where appropriate.

Using up approximately 40 percent of the total available ampere-hours will usually take fully charged batteries to a no-start condition at moderate temperatures of 77°F (25°C). For typical batteries in a storage situation, depleting the available ampere-hours by 20 to 325 (depending on the number of batteries) will result in a no-start condition.

The recommendation for maximum parasitic drain is approximately 325 mA (0.325 amps). A typical drain falls into the 25 to 325 mA (0.025 to 0.325 amps) range. Multiply the drain (in amps) by the time (in hours) the batteries sit without being recharged. The result is the amount of ampere-hours consumed by the parasitic drain. The actual drain may be small, but over time the batteries grow steadily weaker.

A vehicle with a 325 mA drain and a fully charged 70 RC battery will last between five and six days. But if the batteries are at only 65 percent of full-charge, they are going to last only two days before causing a no-start condition.

Important: If the batteries begin storage at 90 percent of full charge, reduce the available ampere-hours accordingly.

Battery Electrical Drain and Parasitic Load Test

If the batteries in a vehicle become discharged in a shorter time than described earlier, the vehicle may have a parasitic load that is out of specification. Refer to the instructions in this subject to determine the source of parasitic loads.

A J38758 Parasitic Draw Test Switch (available from Kent-Moore) and a digital multimeter set to the 10A scale is required for this test.

Before performing the load test, ensure that the following conditions are met:

- the ignition key is out of the ignition;
- all doors are closed;
- the headlights and park lights are off;
- the courtesy lights are off;
- The batteries are fully charged.

1. With the vehicle parked, apply the parking brakes, and shut down the engine.
2. Disconnect the cable from the negative battery terminal.
3. Install the drain test tool, with the male end connected to the negative battery terminal.
4. Turn the draw test tool to the open position.
5. Attach the negative battery cable to the female end of the drain test tool.
6. Turn the drain test tool to the closed position.
7. Road test the vehicle while activating all accessories.
8. Shut down the engine and remove the ignition key.
9. Set the ammeter to the 10-amp scale and connect to the terminal on the drain test tool.
10. Turn the drain tool to the open position to allow current to flow thorough the ammeter.
11. Wait at least 60 seconds, then check the current reading. If the current reading is at or below 2 amps, close the drain tool (to maintain continuity in the electrical system) and switch down to the 2-amp scale for a more accurate reading when the drain tool is re-opened.
12. The ECU/BHM/CHM/ABS current draw should be less than 325 mA with no circuits active. The following measurement reflects the value of the current draw with all systems off.
    - A measurement below 325 mA indicates that the ECU/BHM/CHM/ABS is OK.
    - A measurement above 325 mA indicates a possible problem with the ECU/BHM/CHM/ABS. Disconnect each component and recheck the current draw as directed.
    - A measurement significantly over 325 mA indicates a problem unrelated to the ECU/BHM/CHM/ABS.
    - A measurement of approximately 0 amps indicates a faulty ECU, BHM, CHM, or ABS.
13. Repeat the parasitic current drain procedure after any repair is completed.
14. Remove the drain test tool and reconnect the negative battery cable.
15. Remove the chocks from the tires.

Specifications

Minimum Permissible Voltages	
Ambient Temperature °F (°C)	**Minimum Voltage (after 15 seconds at 300 amps)**
	12-Volt
70 (21) and Above	9.6
60 (16)	9.5
50 (10)	9.4
40 (4)	9.3
30 (–1)	9.1
20 (–7)	8.9
10 (–12)	8.7
0 (–18)	8.5

Table 1, Minimum Permissible Voltage at Various Ambient Temperatures

Charging Rates for Starting Batteries				
Rated Battery Capacity (reserve minutes)	**Slow Charge***		**Fast Charge†**	
	Hours @	**Amperes**	**Hours @**	**Amperes**
180	30	5	7-1/2	20
	15	10	5	30
			2-1/2	45

* Slow charging is recommended for completely charging the batteries.

† An emergency boost charge, which consists of a high charging rate, can be obtained by reducing the fast-charge time to half, while maintaining the same recommended ampere charge may be used to crank an engine.

Table 2, Charging Rates

Approved Electrical Lubricants	
Manufacturer	**Lubricant or Part Number**
Shell Oil Co.	No. 71032; No. 71306
Texaco, Inc.	No. 955
Quaker State	No. NYK–77

Table 3, Approved Electrical Lubricants

Standard Battery Specifications	
Reserve Capacity	**Cold Cranking Amps (CCA)**
180 minutes	750

Table 4, Standard Battery Specifications

General Information

The intake air restriction indicator indicates how much air filter capacity has been used and how much remains. The indicator registers the actual maximum restriction of the filter element when the engine is operating at full load. The indicator retains the reading so that the remaining capacity can be read after the engine is shut down.

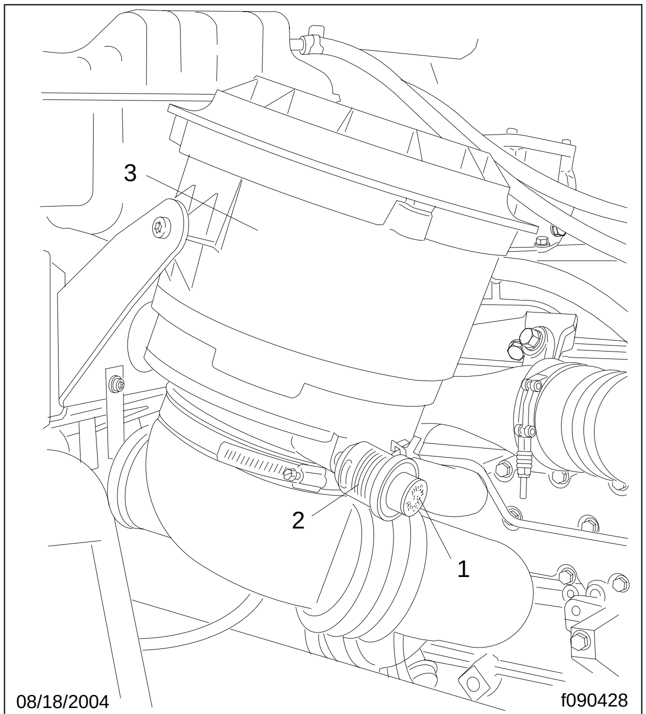
The intake air restriction indicator is mounted under the hood on the intake air piping, or in the cab on the dash panel. See **Fig. 1** and **Fig. 2**.

Do not open the air cleaner assembly until the indicator registers maximum restriction. When maximum restriction occurs, the air cleaner element needs to be serviced. For possible causes and corrective action, see **Troubleshooting 300**.

The intake air restriction indicator and the fitting may become plugged with moisture or engine vapors, possibly causing an incorrect reading. For troubleshooting procedures, see **Troubleshooting 300**.

An optional amber warning indicator is available and is displayed on the ICU3-M2, defined as "Air Filter Restriction."

NOTE: Most engine degreasers are harmful to the polycarbonate (Lexan) plastic that is used in the intake air restriction indicator. When cleaning the engine or other components, avoid getting degreaser on the indicator.



1. Reset Button
2. Intake Air Restriction Indicator
3. Air Cleaner Assembly

Fig. 1, Intake Air Restriction Indicator Mounted Under the Hood

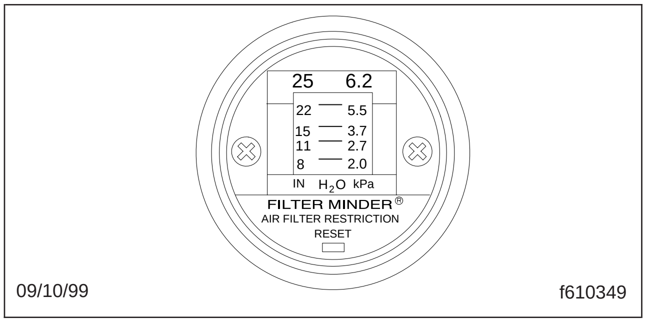


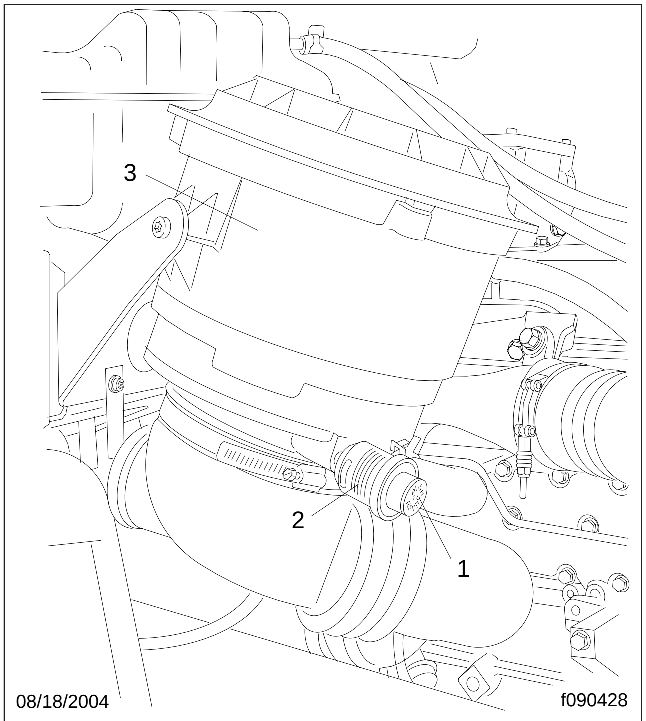
Fig. 2, Intake Air Restriction Indicator Mounted in the Cab

Air Restriction Indicator Removal and Installation

Intake Air Restriction Indicator Mounted Under the Hood

Removal

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Using a wrench, remove the intake air restriction indicator from the intake air piping. See **Fig. 1**.



1. Reset Button
2. Intake Air Restriction Indicator
3. Air Cleaner Assembly

Fig. 1, Intake Air Restriction Indicator Mounted Under the Hood

Installation

1. Install the indicator on the intake air piping.
2. Close the hood and remove the chocks from the tires.

Intake Air Restriction Indicator Mounted in the Cab

Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Remove the necessary dash panels to access the intake air restriction indicator. For instructions, see **Section 60.08**, Subject 100.
3. Remove the electrical connector from the indicator. See **Fig. 2**.

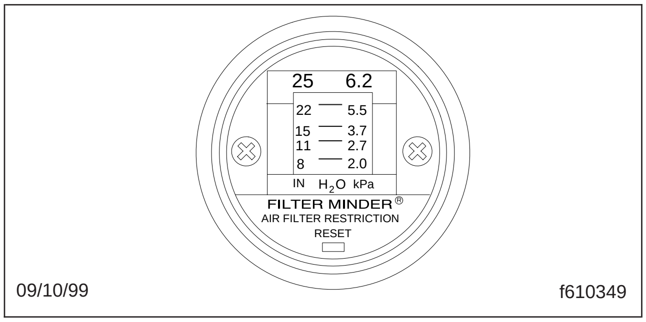


Fig. 2, Intake Air Restriction Indicator Mounted in the Cab

4. Remove the air line from the indicator.
5. Remove the screws that attach the indicator to the dash, and remove the indicator.
6. Using screws, attach a new indicator to the dash.
7. Attach the air line to the indicator.
8. Attach the electrical connector to the indicator.
9. Install the dash panels. For instructions, see **Section 60.08**, Subject 100.
10. Remove the chocks from the tires.

Troubleshooting Tables

Problem—No Restriction Reading

Problem—No Restriction Reading	
Possible Cause	**Remedy**
The gauge leaks.	Remove the air restriction gauge. Apply a vacuum to the gauge until the yellow indicator reaches the red line. With your thumb on the mounting fitting, close the end of the gauge airtight. Hold in the reset button. The yellow indicator will drop slightly and then not move unless the gauge has a leak. If the gauge is functioning properly, install it and press the reset button. If the yellow indicator continues to move, replace the air restriction gauge. Repeat the troubleshooting procedure to verify that the new gauge does not leak. When the gauge is functioning properly, install it and press the reset button.
The air cleaner or intake pipe fitting is plugged.	Remove the obstruction.
Engine airflow is too low to generate a reading.	Turbocharged engines must be at full load to pull full engine airflow. Restrictions can be simulated by gradually closing off air intake. If there is still no restriction reading, check for leaks in the gauge or vacuum hose, as appropriate, and take corrective action.
The safety filter, if equipped, is plugged.	Do not clean the safety filter. Replace it with a new one.

Problem—High Restriction Readings

Problem—High Restriction Readings	
Possible Cause	**Remedy**
The element is plugged.	Anytime a high restriction is noted, it should be verified by resetting the restriction indicator and checking it again after several hundred miles of normal operation. Install a new filter element.
The intake screens or ducts are plugged.	Check the system upstream from the air restriction gauge and remove any debris. Check for damage or improper installation, and take necessary corrective action.
Heavy snow or rain.	Temporary high restriction can occur during a rain or snow storm and disappear after drying out. Anytime a high restriction is noted, it should be verified by resetting the restriction indicator and checking it again after several hundred miles of normal operation.

Low Coolant Level Probe Replacement

Replacement

The low coolant level probe, which is located near the coolant reservoir, is only used on vehicles with a Caterpillar or Cummins engine.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Disconnect the electrical connector from the low coolant level probe. See **Fig. 1**.

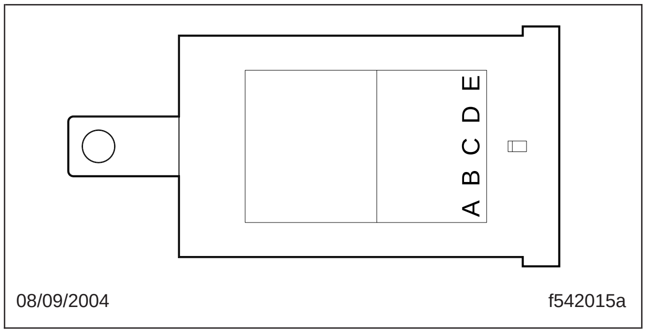


Fig. 1, Low Coolant Level Probe

4. Remove the probe from the mounting bracket.
5. Install a new probe on the mounting bracket.
6. Connect the electrical connector to the probe.
7. Run the engine and make sure there are no false indications of low coolant level.
8. Close the hood and remove the chocks from the tires.

J1587 Datalink

The J1587 datalink is a low-speed vehicle datalink that communicates information between the electronic control units (ECU) on the vehicle. The J1587 datalink is also referred to as J1708.

J1708 refers to the SAE standard for the physical part of the datalink, such as the wiring and electronic components. J1587 refers to the SAE standard for the messaging protocol that communicates on the J1708 network. In the context of vehicle repair, the terms J1708 and J1587 are used interchangeably.

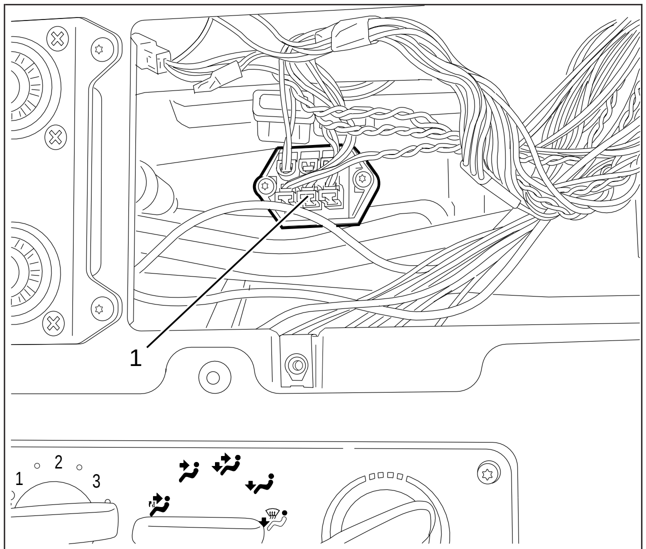
The J1587 datalink uses a twisted pair of wires to reduce interference from the digital messages being sent on the wires. Wire colors for the J1587 datalink are:

- **Orange** J1587–
- **Dark green** J1587+

See **Fig. 1** for a simplified schematic of the J1587 datalink, and to gain a basic understanding of how the J1587 datalink is laid out. G06-43822 is the drawing number of the J1587 wiring schematic. The wiring schematics for the J1587 datalink are found in module 160.

The dash J1587 junction block is located behind the center dash panel. See **Fig. 2**.

See **Table 1** for diagnostic connector pinouts.



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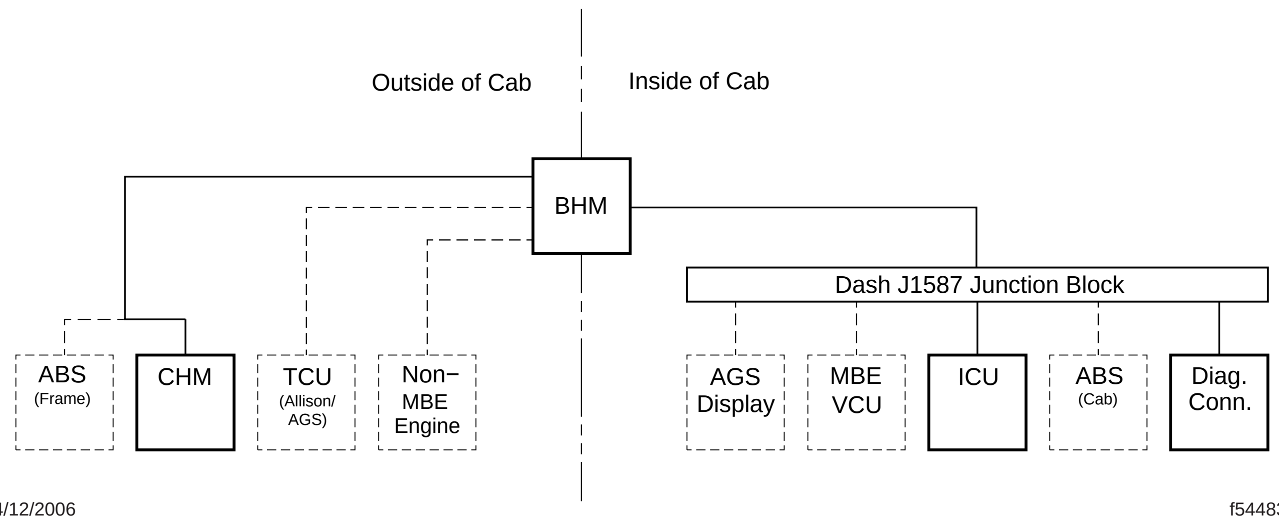
1. Junction Block

Fig. 2, Dashboard J1587 Junction Block



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NOTE: The solid lines represent required components and wiring. The dashed lines represent optional components and wiring.

Fig. 1, Simplified J1587 Schematic

General Information

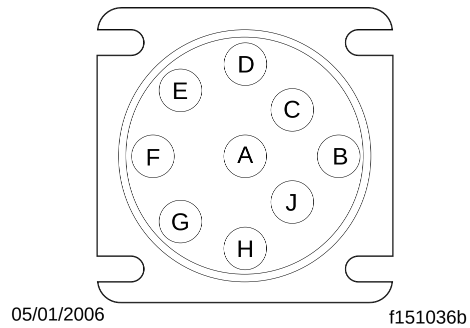
<table>
<tr><th colspan="3">J1587 and J1939 Diagnostic Connector Pinouts</th></tr>
<tr><th>Pin</th><th>Description</th><th>Diagnostic Connector</th></tr>
<tr><td>A</td><td>Ground</td><td rowspan="9">
NOTE: The connector is viewed looking toward the diagnostic connector.</td></tr>
<tr><td>B</td><td>Battery +12V</td></tr>
<tr><td>C</td><td>J1939+</td></tr>
<tr><td>D</td><td>J1939–</td></tr>
<tr><td>E</td><td>J1939 Shield (only if heavy cable is used)</td></tr>
<tr><td>F</td><td>J1587+</td></tr>
<tr><td>G</td><td>J1587–</td></tr>
<tr><td>H</td><td>Not Used</td></tr>
<tr><td>J</td><td>Not Used</td></tr>
</table>

Table 1, J1587 and J1939 Diagnostic Connector Pinouts

Symptoms of a Malfunctioning J1587 Datalink

Symptoms of a malfunctioning J1587 datalink may include:

- gauges not working
- ICU displays **no J1587**, **no EnG**, or **no AbS**
- cannot retrieve fault codes from an ECU
- ServiceLink® does not connect to vehicle
- one or more ECUs do not show up on the ServiceLink ECU list

J1939 Datalink

The J1939 datalink is a high-speed vehicle datalink that communicates information between electronic control units (ECU) on the vehicle. The J1939 communicates at 250,000 bits per second.

Unlike the J1587 datalink, the J1939 datalink allows an ECU to broadcast requests as well as information. Examples of information that can be communicated on the J1939 datalink are:

- engine rotational speed
- road speed
- transmission tailshaft speed
- engine retarder deactivation request
- engine torque reduction request
- communication between the Bulkhead Module, Chassis Module, and the instrumentation control unit

See **Fig. 3** for a simplified schematic of the J1939 datalink, and to get a basic understanding of how the J1939 is wired.

The backbone of the J1939 datalink is the section of the datalink that is between the two terminating resistors. Each ECU is connected to the backbone. The wiring between each ECU and the backbone is referred to as a branch.

See **Table 1** for diagnostic connector pinouts.

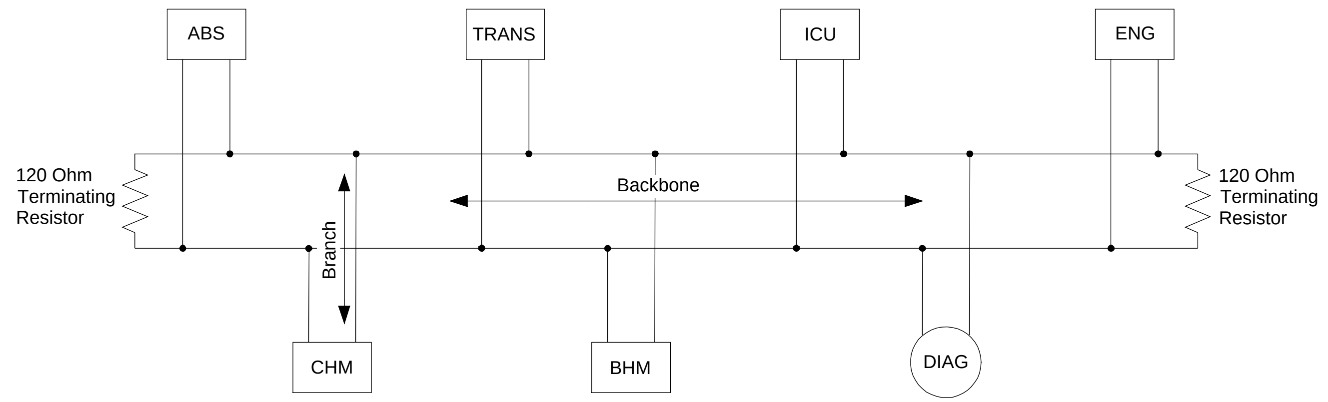
Terminology

Backbone The main J1939 datalink wiring that lies between the two terminating resistors. It does not include the branch circuits to each ECU or to the diagnostic connector. See **Fig. 3**.

Branch Circuit The section of J1939 datalink between the backbone and each ECU that has J1939, and between the backbone and the diagnostic connector.

Diagnostic Connector A 9-pin diagnostic connector is used for troubleshooting the electrical system.

ECU The electronic control unit connects to the J1939 datalink via a branch circuit.



NOTE: Some ECUs shown in this schematic may not be standard on all vehicles. The schematic does not show optional ECUs such as an Expansion Module or Switch Expansion Module.

Fig. 3, Simplified J1939 Schematic

J1939 Datalink Wiring

- **Yellow** J1939+
- **Green** J1939–

Tee Connector/Splice Junctions where branch circuits and terminating resistors connect to the backbone of the J1939 datalink.

Terminating Resistors The J1939 datalink has two 120Ω terminating resistors, one at each end of the backbone. The total datalink parallel resistance is 60Ω.

Symptoms of a Malfunctioning J1939

Symptoms of a malfunctioning J1939 include:

- J1587 fault code or blink code indicating a J1939 problem.
- AutoShift does not function correctly. It reverts to AutoSelect mode with a code 35 active.
- CHECK ENGINE or ENGINE WARNING indicator is lit.
- TRACTION, WHEEL SPIN, or ATC indicator is lit.
- Right headlamp and hazard lamps are on.
- ICU3-M2 displays **no Data** or **no J1939**.
- Harsh shifting with Allison 1000/2000/2400 transmissions with Allison code U2105. This code can only be viewed with Allison software. Since Allison 1000/2000/2400 transmissions use J1939 and not J1587, this fault will not show up in ServiceLink. Allison 1000/2000/2400 transmissions generally do well at estimating shift points without J1939; therefore this problem often goes unnoticed.

Terminating Resistors

The J1939 datalink consists of twisted yellow and green wires. The yellow wire is J1939+; the green wire is J1939–. The J1939 datalink has two terminating resistors, one at each end of the backbone.

The purpose of the terminating resistors is to minimize the reflection of data on the datalink. Collision of reflected data can cause J1939 messages to become partially or completely lost. Data collision can also cause the data to be erratic. Terminating resistors prevent this from occurring. Although the J1939 datalink may function with a missing or failed terminating resistor, data collision can occur and cause problems.

Each terminating resistor is 120Ω, but the equivalent of two 120Ω resistors in parallel is 60Ω.

Since the resistors are in parallel with one another, their total resistance equals 60Ω. If a terminating resistor is removed, the circuit resistance should be 120Ω. However, with both resistors installed in the circuit there should be 60Ω measured at any two points between J1939+ and J1939– in the circuit, such as between pins C and D of the diagnostic connector.

IMPORTANT: It is essential that two terminating resistors are installed in the J1939 datalink. Numerous J1939 problems have been attributed to missing terminating resistors.

See **Fig. 4** for an example of a wiring diagram that can be used when troubleshooting a J1939 datalink problem.

One terminating resistor is located in a tee along the left frame rail, usually behind the cab. See **Fig. 5**. A second terminating resistor is located in the dash. See **Fig. 6**.

Each ECU is generally connected to the J1939 backbone using a tee connector or splice. See **Fig. 7**.

Making the Pinout Measurements Easier to See

The pins on the diagnostic connector may be difficult to see when testing. If the pins are difficult to see, use a Y-cable as an extension to the diagnostic connector to make test measurements easier. See **Fig. 8** for a drawing of the connector at the end of the Y-cable and the corresponding 9-pin diagnostic connector pins.

Locating J1939 Wiring Diagrams

The J1939 wiring diagram can be found in module 160. Other modules may also contain datalink wiring information. See **Table 2**.

Use PartsPro® to obtain drawing numbers for installation drawings, harness assembly drawings, and wiring diagrams applicable to the vehicle being worked on.

Component Module Locations	
Component	**Module Number**
General J1939 harness drawings, schematics, and installation drawings	160
Engine harness and installation drawings	283 and 286
Transmission harness and installation drawings	34A and 343
ABS harness and installation drawings	330, 332, and 333

Table 2, Component Module Locations

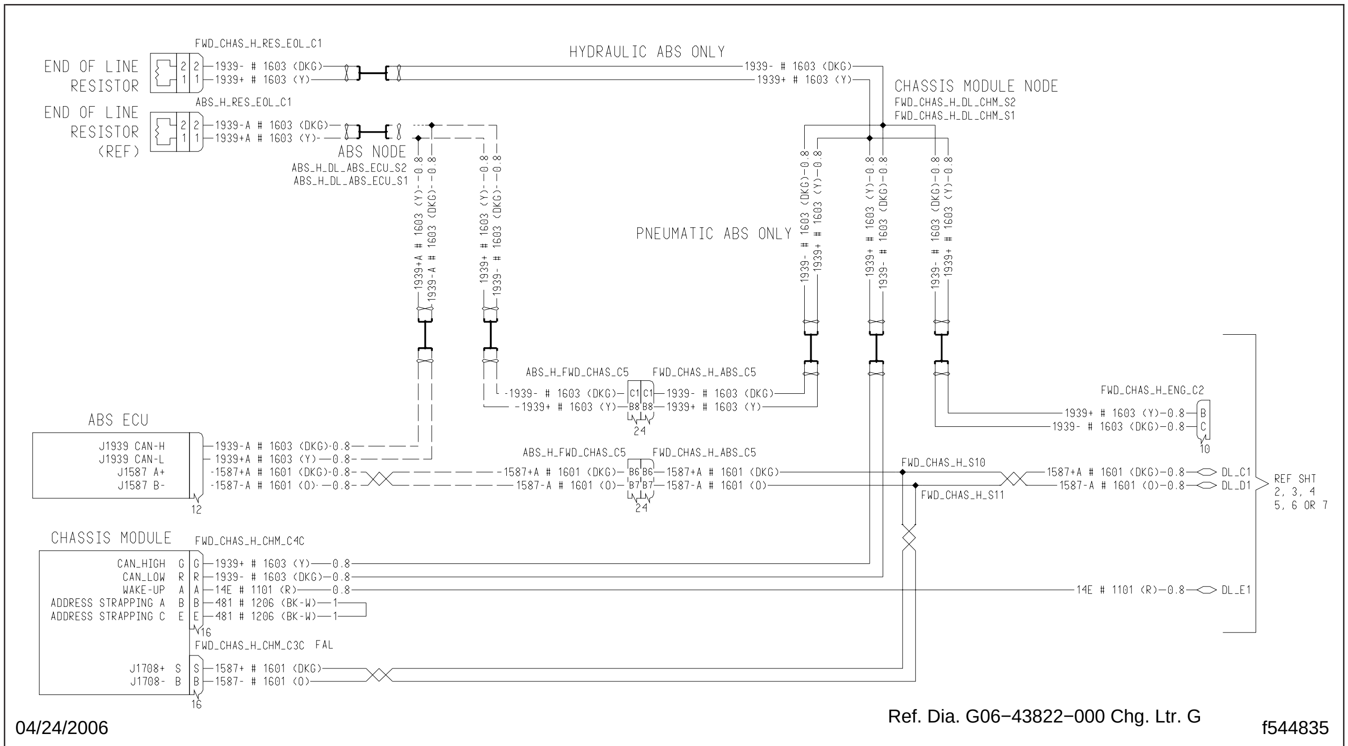
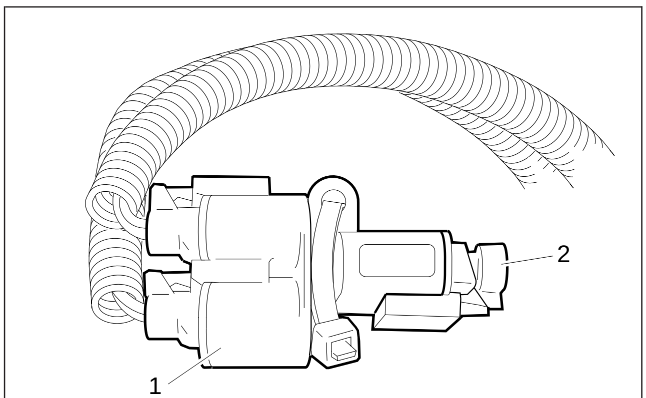
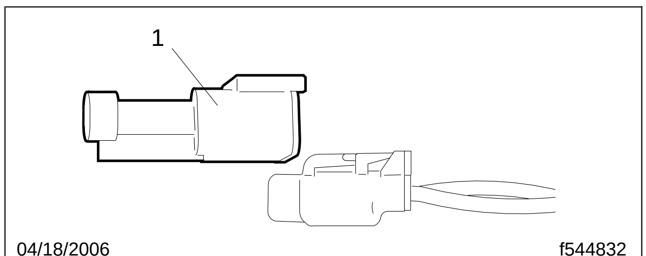


Fig. 4, Example of a J1939 Datalink Wiring Schematic



1. Connector Tee
2. Terminating Resistor

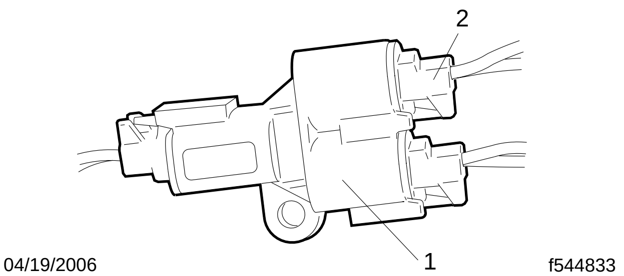
Fig. 5, Terminating Resistor Located in the Chassis



1. Terminating Resistor

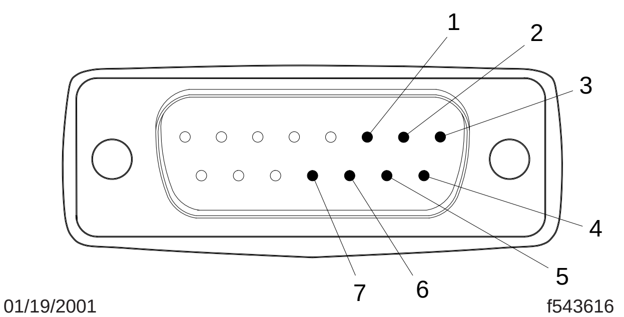
Fig. 6, Terminating Resistor Located in the Dash

General Information



1. Branch to Backbone
2. Branch to ECU

Fig. 7, J1939 Tee Connector



1. Pin A
2. Pin E
3. Pin B
4. Pin F
5. Pin G
6. Pin C (J1939+)
7. Pin D (J1939–)

Fig. 8, Y-Cable Pinouts

Background Information

Although the J1939 datalink backbone and branch circuits can be repaired, it is often preferable to replace the faulty section of datalink. The technician must determine whether the datalink should be repaired or replaced. If a repair to the backbone or a branch circuit will take more than 20 minutes to complete, Freightliner recommends that the faulty section of the datalink be replaced.

The length of the branch circuits can be as short as several inches to as long as 10 feet. The technician must decide whether to repair, replace, or overlay the faulty section of the datalink.

Repair Procedures

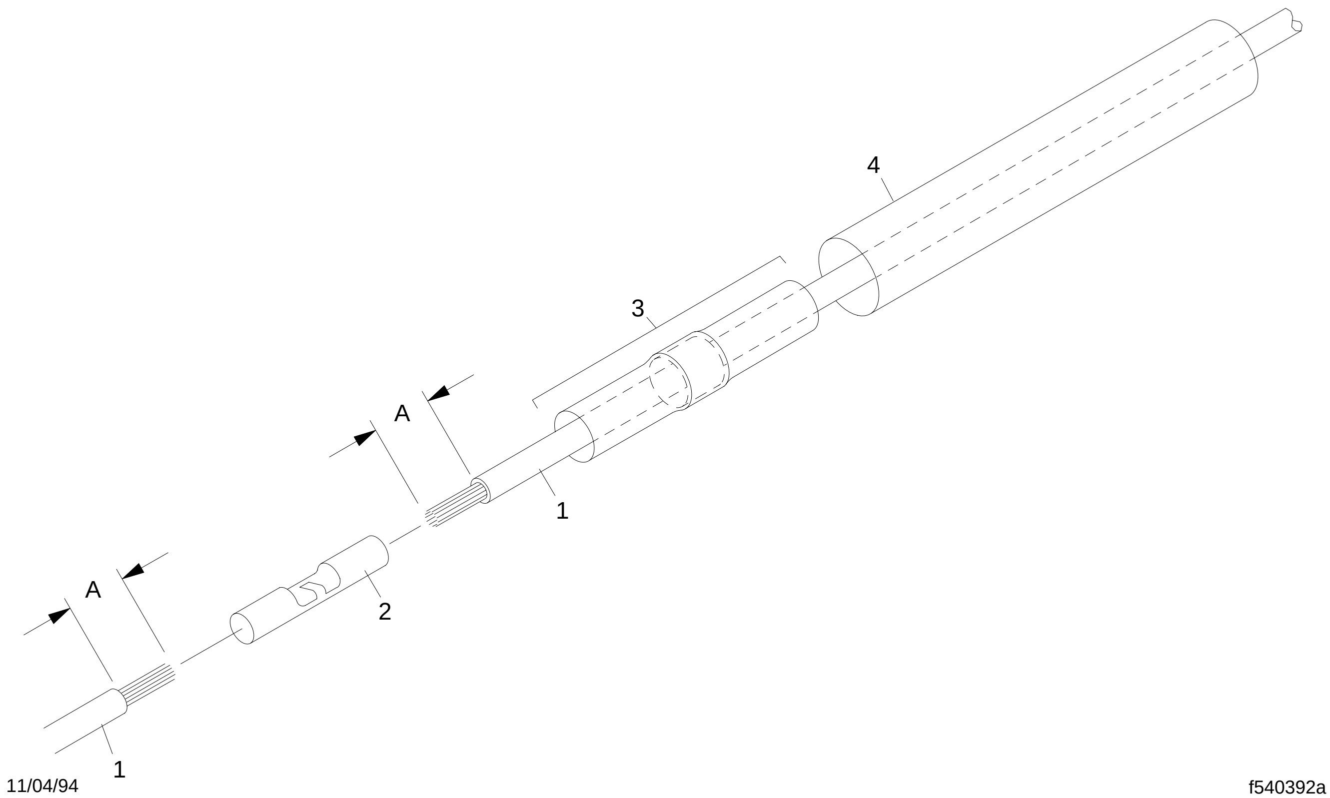
CAUTION

Use care when soldering connections inside the dash. Do not allow a hot soldering iron to contact other wires or components, as damage could occur. If you are unable to safely solder the connection, overlay the damaged datalink with a new datalink.

IMPORTANT: The following procedure is the only approved method of repairing broken wires on a Freightliner vehicle. This procedure (solder splicing) is done using solder repair kit ESYES66 404 and is for 14- or 16-gauge wire. Do not repair wire that is 12 gauge or larger. Replace it instead.

1. Strip the ends of the wire to be repaired. Make sure the stripped ends are 3/8- to 1/2-inch (10- to 13-mm) long.
2. If repairing an exterior wire, slip a 3-inch (75-mm) long piece of heat shrink over one end of the wire. See **Fig. 1**.
3. Slip a solder sleeve from kit ESYES66 404 over one end of the wire. See **Fig. 1**.
4. Using a suitable crimp tool and a crimp splice from the kit, crimp the ends of the wire as follows:
   - 4.1 Insert a stripped wire end into the crimp splice until it touches the wire stop in the middle of the crimp splice. See **Fig. 2**.
   - 4.2 Center the crimping tool between the wire stop and the end of the crimp splice, then crimp the wire.
   - 4.3 Repeat the previous substeps for the other end of the wire.
5. Check the crimp, making sure the crimping tool impression is on both ends of the crimp splice.
6. Slide the solder sleeve over the crimp splice so that the solder ring is over the center of the crimp splice. See **Fig. 3**. Then apply 250°F (121°C) heat until the solder flows into the splice crimp and the solder sleeve has shrunk completely against the wire.
7. Slide the heat shrink over the splice, then apply 250°F (121°C) heat to it until it is completely shrunk against the wire insulation. Some of the sealant material should be bubbling out of the ends of the heat shrink.

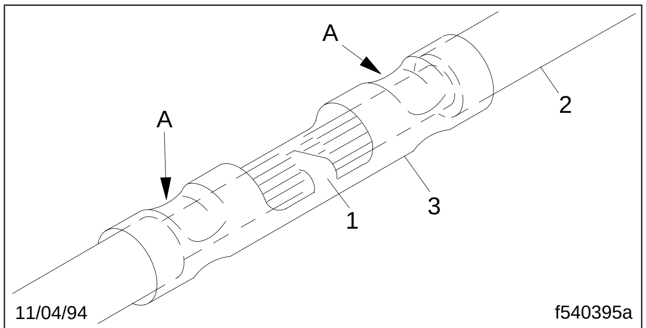
Repair Procedures



A. 3/8 to 1/2 Inch (10 to 13 mm)

1. Wire End
2. Crimp Splice
3. Solder Sleeve
4. Heat Shrink

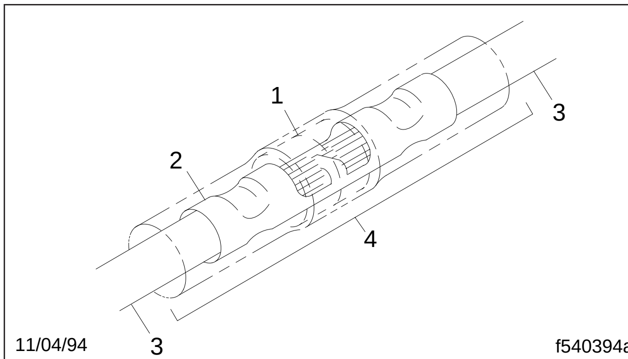
Fig. 1, Exterior Wire Repair



A. Center crimping tool here.

1. Wire Stop
2. Wire
3. Crimp Splice (shown crimped)

Fig. 2, Example of a Wire Crimp



1. Solder
2. Crimp Splice (shown crimped)
3. Wire
4. Solder Sleeve

Fig. 3, Wire Ready for Soldering

Troubleshooting the J1587 Datalink

Diagnosing the J1587 Datalink			
Test No.	**Test Description**	**Test Result**	**Action**
1	Determine if ServiceLink® connects to the vehicle J1587 datalink. Attempt to connect ServiceLink and refresh the ECU list. If ServiceLink connects to the J1587 datalink, the ECU list displays **J1708 - - Detected** and some or all ECUs display in white under the J1708 ECU list. Does ServiceLink connect to the J1587 datalink?	Yes	**Go to test no. 9.**
		No	**Go to test no. 2.**
2	Repeat test no. 1 on another vehicle with a known good J1587 datalink. Does ServiceLink connect to the vehicle?	Yes	**Go to test no. 3.**
		No	Check cables between PC and vehicle; check vehicle interface adaptor; check PC settings. Repair as necessary.
3	Make sure the park brake is set. Turn the ignition on. Does the ICU display **no J1587**?	Yes	**Go to test no. 5.**
		No	**Go to test no. 4.**
4	Is the power light illuminated on the vehicle interface adaptor?	Yes	Check the J1587 datalink wiring between the diagnostic connector and the dash junction block for shorts. Repair as necessary.
		No	Check power and ground supply to diagnostic connector. If OK, check PC cable and interface device. Repair as necessary.
5	Disconnect BHM connector B1. Attempt to connect ServiceLink and refresh the ECU list. If ServiceLink connects to the J1587 datalink, the ECU displays **J1708 - - Detected** and the ICU, BHM, and other ECUs (depending on vehicle configuration) display in white under the J1708 ECU list. Does ServiceLink connect to the J1587 datalink?	Yes	There is a problem in the J1587 wiring outside of the cab between the BHM connector B1 and the ABS and CHM. Locate source of trouble and repair as necessary.
		No	**Go to test no. 6.**
6	Check if the vehicle is equipped with any of the following: • non-MBE engine • Allison transmission • AGS transmission Does the vehicle have any of the above options?	Yes	**Go to test no. 7.**
		No	**Go to test no. 8.**

Troubleshooting the J1587 Datalink

<table>
<tr><th colspan="4">Diagnosing the J1587 Datalink</th></tr>
<tr><th>Test No.</th><th>Test Description</th><th>Test Result</th><th>Action</th></tr>
<tr><td rowspan="2">7</td><td rowspan="2">Disconnect the BHM connector C2.

Attempt to connect ServiceLink and refresh the ECU list.

If ServiceLink connects to the J1587 datalink, the ECU list displays J1708 - - Detected and the ICU, BHM, CHM, and other ECUs (depending on vehicle configuration) display in white under the J1708 ECU list.

Does ServiceLink connect to the J1587 datalink?</td><td>Yes</td><td>There is a problem between the BHM and non-MBE engine or between the BHM and the transmission control unit (Allison and AGS only).

Repair as necessary.</td></tr>
<tr><td>No</td><td>Go to test no. 8.</td></tr>
<tr><td rowspan="2">8</td><td rowspan="2">Locate the J1587 junction block behind the center dash panel.

Follow these steps:

1. Disconnect one of the J1587 connectors from the junction block.

2. Attempt to connect ServiceLink and refresh the ECU list. Does either the ICU or the BHM now display in white in the ECU list?

If yes, stop. Enter "yes" in the Test Result column to the right and follow the Action given.

If no, continue to step 3.

3. Plug the connector into the junction block.

4. Disconnect the next connector on the J1587 junction block that has not yet been disconnected.

5. Refresh the ServiceLink ECU list. Does either the ICU or the BHM now display in white in the ECU list?

If yes, stop. Enter "yes" in the Test Result column to the right and follow the Action given.

If no, continue to step 6.

6. Are there any remaining connectors on the junction block that have not yet been disconnected?

If yes, go to step 3.

If no, enter "no" in the Test Result column and follow the Action given.</td><td>Yes</td><td>The J1587 circuit that was just disconnected from the junction block is shorted or the ECU on the circuit is faulty.

Repair as necessary.</td></tr>
<tr><td>No</td><td>There is a short between the J1587 junction block and the diagnostic connector.</td></tr>
</table>

Troubleshooting the J1587 Datalink

Diagnosing the J1587 Datalink			
Test No.	**Test Description**	**Test Result**	**Action**
9	With ServiceLink connected, look at the ECU list and determine which ECU(s) **do not display in white**. Case 1: None (All ECUs display.) Case 2: The BHM, CHM, and all other outside-of-cab ECUs Case 3: The ICU or one of the other inside-of-cab ECUs Case 4: One of the outside-of-cab ECUs Case 5: All ECUs except the CHM	Case 1	There is no problem found.
		Case 2	Check the J1587 wiring between the BHM and the J1587 junction block for an open. Repair as necessary.
		Case 3	Check the J1587 wiring between the ECU that does not display and the J1587 junction block for an open. Check the power and ground circuits to the missing ECU and the ECU itself. Repair as necessary.
		Case 4	Check the J1587 wiring between the ECU that does not display and the BHM for an open. Check the power and ground circuits to the missing ECU and the ECU itself.
		Case 5	Check power and ground supply to BHM. Check BHM itself.

Table 1, Diagnosing the J1587 Datalink

Use the following test procedures in the order given to successfully locate J1939 datalink problems. Do not skip test procedures or steps unless directed to do so.

- Test 1: J1939 Resistance Test
- Test 2: ECU Communication Test Using Datalink Monitor Template
- Test 3: Testing J1939 for Circuit Faults (shorts to power and ground)
- Test 4: Pinpointing Short Circuits on the J1939 Datalink

Test 1: J1939 Resistance Test

The J1939 resistance test checks whether or not both terminating resistors are installed and ensures that there is at least a complete circuit from the diagnostic connector through the backbone loop. It does not ensure that branch circuits to each ECU are okay.

IMPORTANT: The batteries **must** be disconnected prior to any J1939 resistance tests being performed. Failure to do so may result in inconclusive resistance measurements.

1. Turn the ignition off.
2. Disconnect the negative leads from the batteries.
3. Connect the leads of a digital multimeter (DMM) to pins C and D of the 9-pin diagnostic connector. See **Table 1**. Set the DMM to ohms.
4. Measure the resistance.
5. After the test is complete, connect the batteries.
6. See **Table 2** for test results and possible causes.

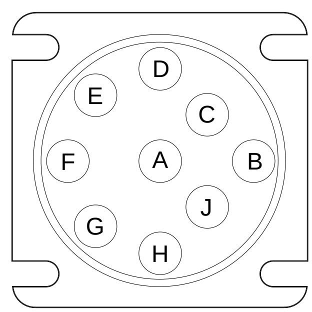
J1939 Diagnostic Connector Pinouts		
Pin	**Description**	**Diagnostic Connector**
A	Ground	 05/01/2006 f151036b
B	Battery +12V	
C	J1939+	
D	J1939–	
E	J1939 Shield (only if heavy cable is used)	
F	J1587+	
G	J1587–	
H	Not Used	
J	Not Used	NOTE: The connector is viewed looking toward the diagnostic connector.

Table 1, J1939 Diagnostic Connector Pinouts

Test 1: J1939 Resistance Test	
Result	**Possible Cause**
60Ω ±6Ω	The J1939 datalink backbone is intact and both terminating resistors are installed. Perform the procedures in **Test 2**.
120Ω ±12Ω	Either of the following: • One of the terminating resistors is missing. • One of the terminating resistors is open.
40Ω ±4Ω	Three terminating resistors have been installed; one must be removed. There must be one terminating resistor at each end of the backbone for a total of two.

Troubleshooting the J1939 Datalink

Test 1: J1939 Resistance Test	
Result	**Possible Cause**
0Ω to 5Ω	J1939+ and J1939– have shorted together somewhere in the datalink.
Greater than 1000Ω	Either of the following: • An open in the circuit between the diagnostic connector and the J1939 backbone. • Both terminating resistors are missing or open.
Any other readings	Any of the following: • Incorrect terminating resistor resistance. • Poor or corroded connections. • Short circuit to ground or an open circuit somewhere on the datalink. Go to **Test 2** to pinpoint the problem.

Table 2, Test 1: J1939 Resistance Test

Test 2: ECU Communication Test Using Datalink Monitor Template

The following test procedures check for communication with each ECU connected to the J1939 datalink. If one ECU fails to communicate, pinpoint whether the problem is with the wiring or an ECU. If all ECUs communicate as they should, the J1939 datalink is probably not the problem.

Test 2.1: Check Whether Each ECU Connected to the J1939 Datalink Responds

1. Connect ServiceLink® to the vehicle.
2. Open the **M2 J1939 Test** Datalink Monitor template.
3. Following the instructions in the template, check whether each ECU that is supposed to be connected to the datalink responds.
4. See **Table 3** for test results and possible causes.

Test 2.2: Check the J1939 Datalink Wiring to the ECU That Does Not Respond

IMPORTANT: The batteries **must** be disconnected prior to any J1939 resistance tests being performed. Failure to do so will result in incorrect resistance measurements.

1. Disconnect the negative leads from the batteries.
2. Locate the connector at the ECU that did not respond and disconnect it.
3. Locate the pins for J1939+ and J1939–. Refer to the appropriate wiring diagrams if necessary.
4. Make sure that J1939+ and J1939– polarity is correct at the component before proceeding. If reversed, correct the wiring and verify that this corrected the problem.
5. Using a digital multimeter set to read ohms, measure the resistance across the two J1939 datalink pins at the connector to the suspect ECU (harness side).
6. After the test is completed, connect the batteries.
7. See **Table 4** for test results and possible causes.

Test 2.3: Install a Test ECU to Confirm the Problem

1. Install a test ECU.
2. Connect ServiceLink to the vehicle.
3. Open the **M2 J1939 Test** Datalink Monitor template.
4. Following the instructions in the template, check whether each ECU that is supposed to be connected to the datalink responds.

Test 2.1: Check Whether Each ECU Connected to the J1939 Datalink Responds	
Result	**Possible Cause**
All ECUs respond.	The J1939 datalink is probably not the problem.
One ECU fails to respond.	Perform the procedures in **Test 2.2**.
No ECUs respond.	Any of the following: • The polarity of J1939+ and J1939– pinouts at the diagnostic connector may be reversed. • There may be a problem with the PC-to-vehicle communications adaptor or cables. • The entire datalink may be down due to a short to power or to ground. Go to **Test 3** to pinpoint the problem.

Table 3, Test 2.1: Check Whether Each ECU Connected to the J1939 Datalink Responds

Test 2.2: Check the J1939 Datalink Wiring to the ECU That Does Not Respond	
Result	**Possible Cause**
60Ω ±6Ω	The J1939 datalink itself is probably not the problem. Make sure that there is power and ground to the suspect ECU. Go to **Test 2.3** after ECU power and ground connections have been confirmed.
Not 60Ω ±6Ω	There is a problem with the J1939 wiring between the ECU connector and its connection to the J1939 backbone. Repair as necessary.

Table 4, Test 2.2: Check the J1939 Datalink Wiring to the ECU That Does Not Respond

5. See **Table 5** for test results and possible causes.

Test 3: Testing J1939 for Circuit Faults (shorts to power and ground)

The following test procedure checks for shorts to power and shorts to ground on the J1939 datalink.

NOTE: All test procedures are performed using a digital multimeter (DMM) set to read voltage.

Before proceeding, verify that battery voltage (approximately +12 VDC) is available at pin B of the diagnostic connector. With the ignition on, use a DMM to test for voltage at pin B by placing the positive (+) lead on pin B and the negative (–) lead on a good chassis ground.

Test 3.1: Test J1939+ for Shorts to Power and Ground

1. Turn the ignition on.
2. Touch the positive (+) lead to pin B (+12 VDC) and the negative (–) lead to pin C (J1939+) of the diagnostic connector.
3. See **Table 6** for test results and possible causes.

Test 3.2: Test J1939– for Shorts to Power and Ground

1. Turn the ignition on.
2. Touch the positive (+) lead to pin B (+12 VDC) and the negative (–) lead to pin D (J1939–) of the diagnostic connector.
3. See **Table 7** for test results and possible causes.

Troubleshooting the J1939 Datalink

Test 4: Pinpointing Short Circuits on the J1939 Datalink

The following test procedure pinpoints shorts to power and shorts to ground on the J1939 datalink. The tests will indicate which side of the cab/engine interface the problem exists. It will indicate whether the problem is in the wiring outside or inside the cab.

NOTE: All tests are performed using a DMM set to read voltage.

Before proceeding, verify that battery voltage (approximately +12 VDC) is available at pin B of the diagnostic connector. With the ignition on, use a DMM to test for voltage at pin B by placing the positive (+) lead on pin B and the negative (–) lead on a good chassis ground.

Test 4.1: Pinpoint J1939+ for Short to Power or Ground

Only perform this test procedure if directed here in **Test 3.1**.

1. Disconnect the 76-pin cab-to-engine bulkhead connector that contains J1939 wiring.
2. Turn the ignition on.
3. Touch the positive (+) lead to pin B (+12 VDC) and the negative (–) lead to pin C (J1939+) of the diagnostic connector.
4. See **Table 8** for test results and possible causes.

Test 4.2: Pinpoint J1939– for Short to Power or Ground

Only perform this test procedure if directed here in **Test 3.2**.

1. Disconnect the 76-pin cab-to-engine bulkhead connector that contains J1939 wiring.
2. Turn the ignition on.
3. Touch the positive (+) lead to pin B (+12 VDC) and the negative (–) lead to pin D (J1939–) of the diagnostic connector.
4. See **Table 9** for test results and possible causes.

Test 2.3: Install a Test ECU to Confirm the Problem	
Result	**Possible Cause**
All ECUs respond.	The ECU was faulty and the test ECU confirmed this. Replace the ECU.
The ECU still does not respond.	The problem has not been confirmed. Carefully repeat all the diagnostics. If the ECU still does not respond, contact Freightliner for assistance.

Table 5, Test 2.3: Install a Test ECU to Confirm the Problem

Test 3.1: Test J1939+ for Shorts to Power and Ground	
Result	**Possible Cause**
0 VDC	J1939+ is shorted to power. Go to **Test 4.1**.
12 VDC (battery voltage)	J1939+ is shorted to ground. Go to **Test 4.1**.
Any other reading	J1939+ is neither shorted to power or ground. Go to **Test 3.2**.

Table 6, Test 3.1: Test J1939+ for Shorts to Power and Ground

Test 3.2: Test J1939– for Shorts to Power and Ground	
Result	**Possible Cause**
0 VDC	J1939– is shorted to power. Go to **Test 4.2**.
12 VDC (battery voltage)	J1939– is shorted to ground. Go to **Test 4.2**.

Test 3.2: Test J1939– for Shorts to Power and Ground	
Result	**Possible Cause**
Any other reading	J1939– is neither shorted to power or ground. There may be a problem with the PC-to-vehicle communications adaptor or cables. The datalink itself appears to be okay.

Table 7, Test 3.2: Test J1939– for Shorts to Power and Ground

Test 4.1: Pinpoint J1939+ for Short to Power or Ground	
Result	**Possible Cause**
0 VDC	J1939+ is shorted to power inside the cab. Locate and repair the short.
12 VDC (battery voltage)	J1939+ is shorted to ground inside the cab. Locate and repair the short.
Any other reading	J1939+ is shorted to power or ground outside the cab. Locate and repair the short.

Table 8, Test 4.1: Pinpoint J1939+ for Short to Power or Ground

Test 4.2: Pinpoint J1939– for Short to Power or Ground	
Result	**Possible Cause**
0 VDC	J1939– is shorted to power inside the cab. Locate and repair the short.
12 VDC (battery voltage)	J1939– is shorted to ground inside the cab. Locate and repair the short.
Any other reading	J1939– is shorted to power or ground outside the cab. Locate and repair the short.

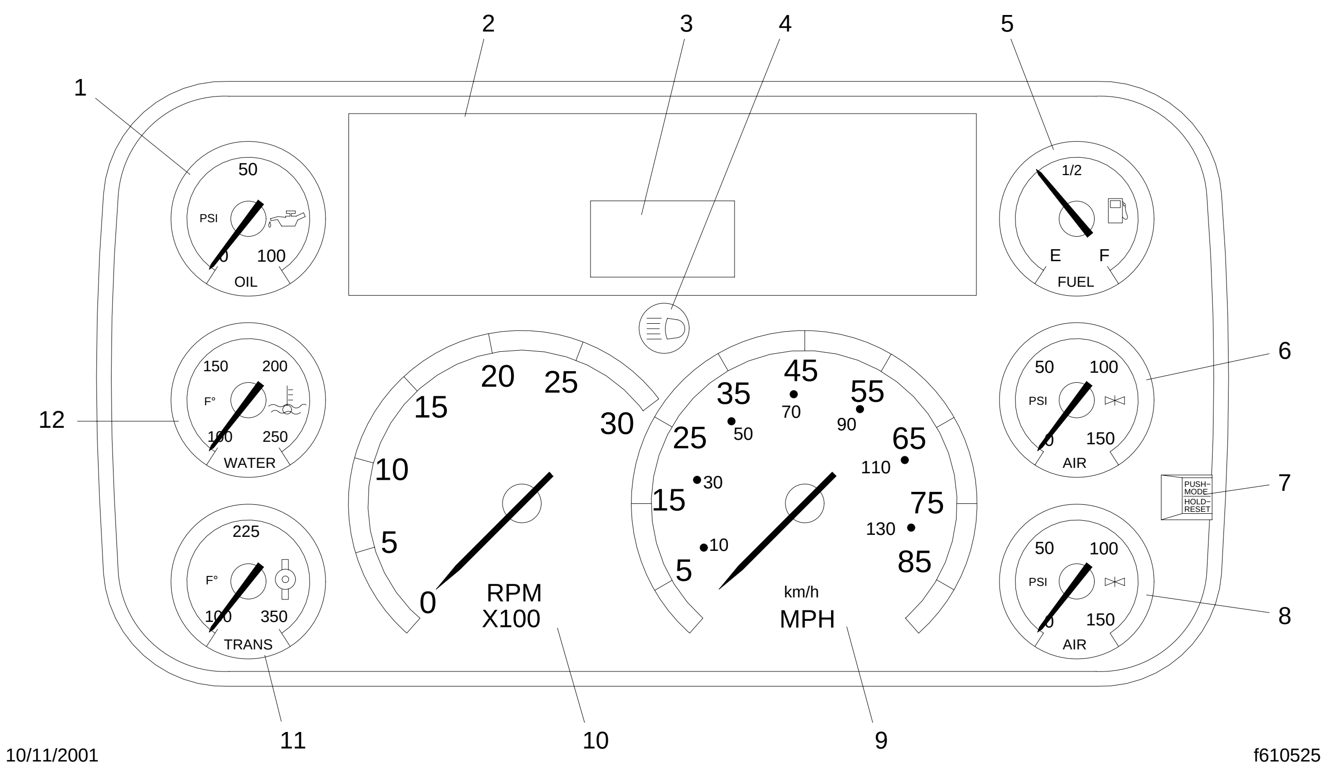
Table 9, Test 4.2: Pinpoint J1939– for Short to Power or Ground

General Description

The ICU3 instrument cluster is comprised of gauges, warning lights, indicator lights, a buzzer, and a driver display screen built into a single unit to provide the driver with engine and vehicle information. The ICU3 receives data through datalink messages, hardwire inputs, and air pressure inputs. The ICU3 contains up to eight individual gauges, and up to six additional satellite gauges. See **Fig. 1**. The ICU3 contains a message center with a liquid crystal display (LCD), driver display, and up to 28 warning and indicator lamps. The ICU3 has no field changeable parameters, with the exception of those functions that can be set using the Mode/Reset button, and the display menus such as service intervals and odometer units.

Main ICU Gauges

The speedometer, fuel level, engine coolant temperature, tachometer, primary and secondary air pressure, and engine oil pressure gauges are standard on all ICU3 configurations. Vehicles may have additional optional gauges depending on the configuration. The ICU3 receives data to drive most of the gauges from either J1587 datalink messages on vehicles built with EPA07 emissions and prior, and over J1939 on EPA10 and later vehicles. Data is received from the engine controller or transmission controller, or from sensors wired directly to the ICU3. Air pressure gauges are connected directly to the air system they monitor. They are not controlled by the ICU directly, except for backlighting. The ICU3 gauges



1. Engine Oil Pressure Gauge
2. Dash Message Center
3. Dash Driver Display Screen
4. Headlight High-Beam Indicator
5. Fuel Level Gauge
6. Primary Air Pressure Gauge (optional)
7. Mode/Reset Button
8. Secondary Air Pressure Gauge (optional)
9. Speedometer (U.S. version)
10. Tachometer (optional)
11. Transmission Fluid Temperature Gauge (optional)
12. Coolant Temperature Gauge

Fig. 1, ICU3 Gauge Layout (typical U.S.)

sweep 270 degrees, except for the tachometer, which sweeps 180 degrees. ICU3 gauge pointers and backlighting are lit by light emitting diodes (LEDs). The only serviceable parts on the ICU3 are the air pressure gauge module, the nine top center indicator lamps and lenses, and the Mode/Reset button.

Remote-Mounted (Satellite) Gauges

The ICU3 can drive external satellite gauges connected to the proprietary datalink between the ICU3 and the satellite gauges. Four pins are used for this function: gauge power, gauge ground, data, and backlighting. Optional satellite gauges include engine oil temperature, turbo boost, pyrometer, forward-rear axle temperature, rear-rear axle temperature, application air, axle lift, and suspension air pressure.

Awake State and Sleep State

The Bulkhead Module (BHM), Chassis Module (CHM), and instrumentation control unit (ICU) are, as a group, in an awake state or a sleep state depending on vehicle conditions. When any of these electronic components are awakened, the remaining components wake up if they are not already awake. When the BHM, CHM, and ICU are in an awake state, the odometer reading appears on the dash driver display screen.

One of the following actions will cause the BHM, CHM, or ICU to go into an awake state:

- opening the door
- turning on the hazard switch
- turning the ignition switch to any position other than OFF
- turning on the headlight/parking light switch
- depressing the service brake

The BHM, CHM, and ICU will enter a sleep state when they are no longer actively controlling any outputs or responding to any inputs and all other power down requirements are met.

To determine whether or not the electrical system is going into a sleep state, do the following.

1. Enter the vehicle.
2. Shut the doors.
3. Do not apply the service brakes.
4. Make sure the ignition switch and hazard switch are in the OFF position.

   One minute after these conditions are met, and provided that one of the parameters in **Table 1** has not been added to the BHM, the odometer reading should disappear. If the odometer reading does not disappear, the electrical system is not going to sleep.

Parameters		
Parameter Part Number	**Description**	**Hours**
26-01017-002	Switched Center Pin Power	24
26-01019-003	Exterior Lighting	16,667
26-01019-004	Exterior Lighting	16,667
26-01019-005	Exterior Lighting	16,667

Table 1, Parameters

Dash Message Center

The dash message center includes the warning and indicator lights and a liquid crystal display (LCD). The LCD is used to display the odometer, voltmeter, and service information.

Mode/Reset Button

The Mode/Reset button, located on the right side of the instrument cluster, is used to scroll through the message center displays, and to manage driver information settings. When the parking brake is applied, the message center presents additional displays that are not available when the parking brake is off. The following lists the displays that are available on an EPA10 vehicle when the parking brake is applied.

a. Trip distance

b. Trip hours

c. Temperature (EPA10 Only)

d. Select screen

e. Temperature alert screen

f. Diagnostic screen

g. Clear screen (with less than 254 miles)

h. Engine miles

i. Engine hours
j. Set Up
k. Back to odometer

Each press of the Mode/Reset button advances to the next display. Pressing and holding the Mode/ Reset button in each display advances to any additional functions it may have. See subject 410 for detailed operation of the message center display screens.

Trip Miles

To reset trip miles and/or trip hours to zero, press and hold the Mode/Reset button for 1 second or longer.

Miles or Kilometers

To toggle between MI (miles) or KM (kilometers), press the Mode/Reset button while in the SELECT screen.

Fault Codes

When a fault code exists and the parking brake is applied, the display shows the message identifier (MID) on EPA07 and earlier vehicles, and the source address (SA) on EPA10 vehicles, of the ECU with the fault. For example, if the antilock brake system has a fault, the MID **AbS136** displays. If more than one ECU is reporting an active fault, the display cycles through the MIDs or SAs for each ECU.

Use the following instructions to display the active fault codes.

1. Press the mode/reset button until **dIAG n** displays. The letter "n" represents the number of active faults.
2. Press and hold the mode/reset button once to display the MID/SA of the fault.
3. Press the mode/reset button again to display details of the fault. Pre EPA10 vehicles will show the subsystem identifier (SID) or parameter identifier (PID). EPA10 vehicles will show the suspect parameter number (SPN).
4. Press the mode/reset button again to display the failure mode indicator (FMI) of the fault.
5. Press the mode/reset button again to return to the first fault display.
6. If more than one fault code is active, press and hold the mode/reset button to proceed to the next fault, then follow the previous four steps to display the additional faults.

Warning and Indicator Lights

The ICU3 has spaces for 28 warning and indicator lights. See **Fig. 2** for pre-EPA07 configuration, **Fig. 3** for EPA07 configuration, and **Fig. 4** for EPA10 configuration.

There are four rows of warning and indicator lights. The lights, or telltales, in the top row are optional. The light in position 8 (counting left to right across the top row) is a permanently mounted amber LED. The remaining top row indicators use replaceable incandescent lamps.

NOTE: Positions 1 through 8 are ground and databus-activated circuits. Position 9 is power activated and databus activated.

The lights on the other three rows are installed at fixed positions that do not vary. Some lights are optional. If an optional light is not requested, the position is blank (does not light up).

The following fixed-position lights are standard:

- stop engine warning (red)
- check engine indicator (amber)
- engine protection warning (red)
- low air pressure warning (red)
- low engine oil pressure warning (red)
- high coolant temperature warning (red)
- fasten seat belt warning (red)
- low battery voltage warning (red)
- parking brake on warning (red)
- tractor ABS indicator (amber)
- left-turn signal (green)
- right-turn signal (green)
- high beams on indicator (blue)

The following fixed-position lights are optional:

- air filter restriction indicator (amber)
- alternator no charge indicator (amber)

General Information

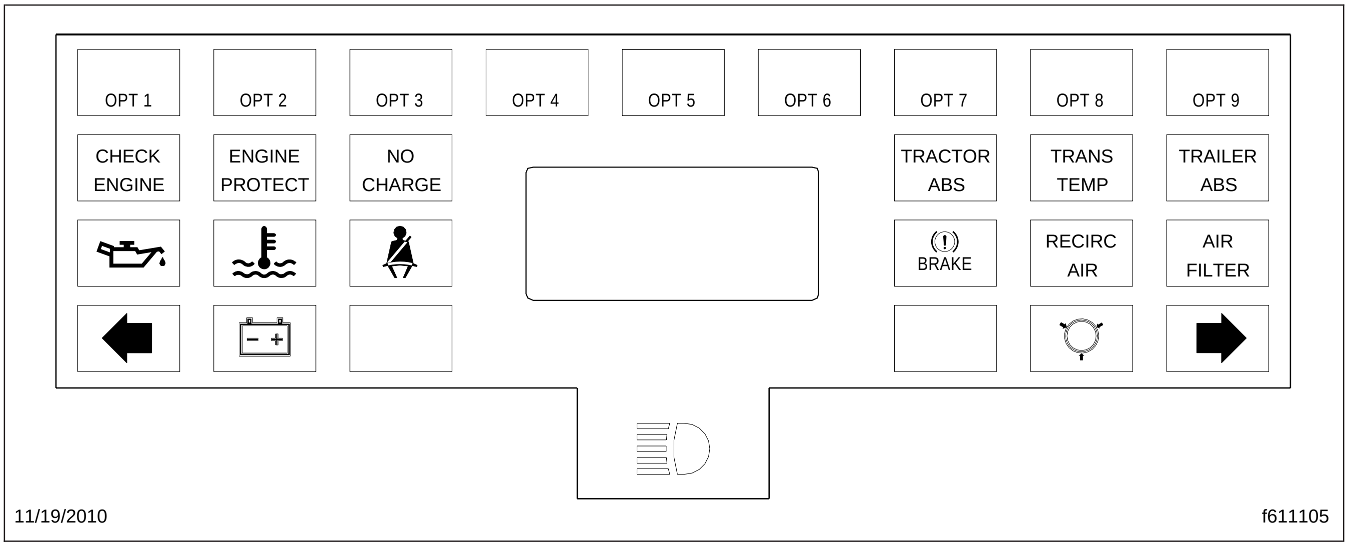


Fig. 2, Dash Message Center, ICU3 (pre-EPA07)

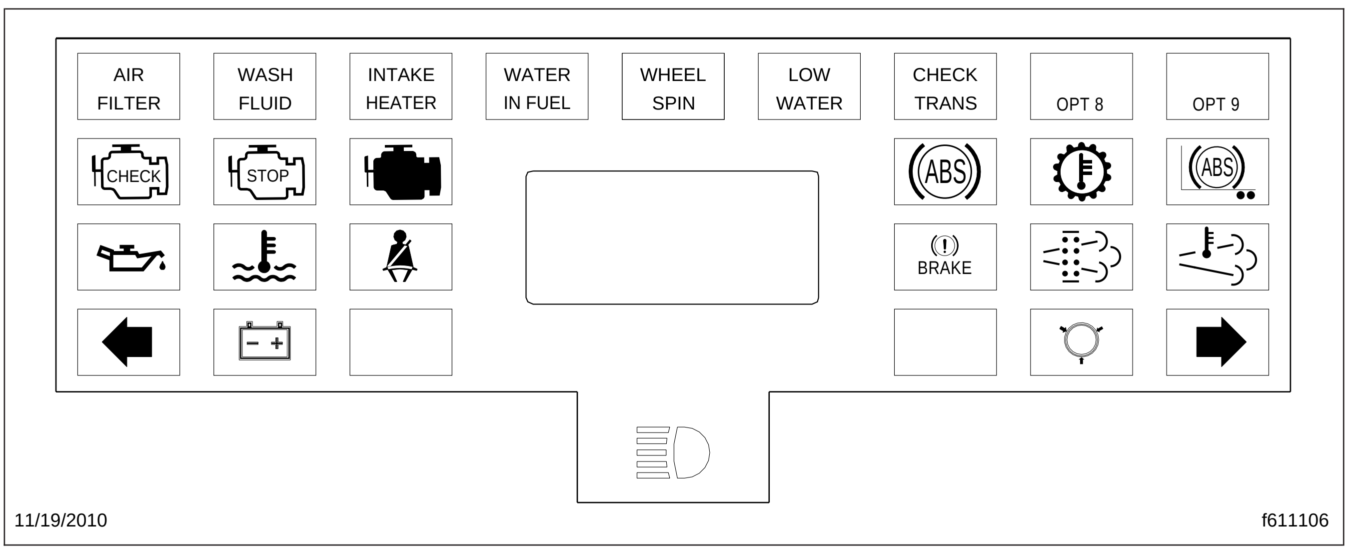


Fig. 3, Dash Message Center, ICU3 (EPA07)

- high transmission temperature warning (amber)–installed on vehicles with automatic transmissions
- recirculated air indicator (amber)
- trailer ABS indicator (amber)–installed on vehicles designed to be used with a trailer

The following lights are optional:

- low coolant level warning (red)
- electronic braking system (EBS) warning (red)
- check transmission indicator (amber)
- intake heater indicator (amber)
- low washer fluid indicator (amber)
- optimized idle indicator (amber)
- wait to start indicator (amber)
- water in fuel indicator (amber)
- wheel spin indicator (amber)

Other optional lights may be specified.

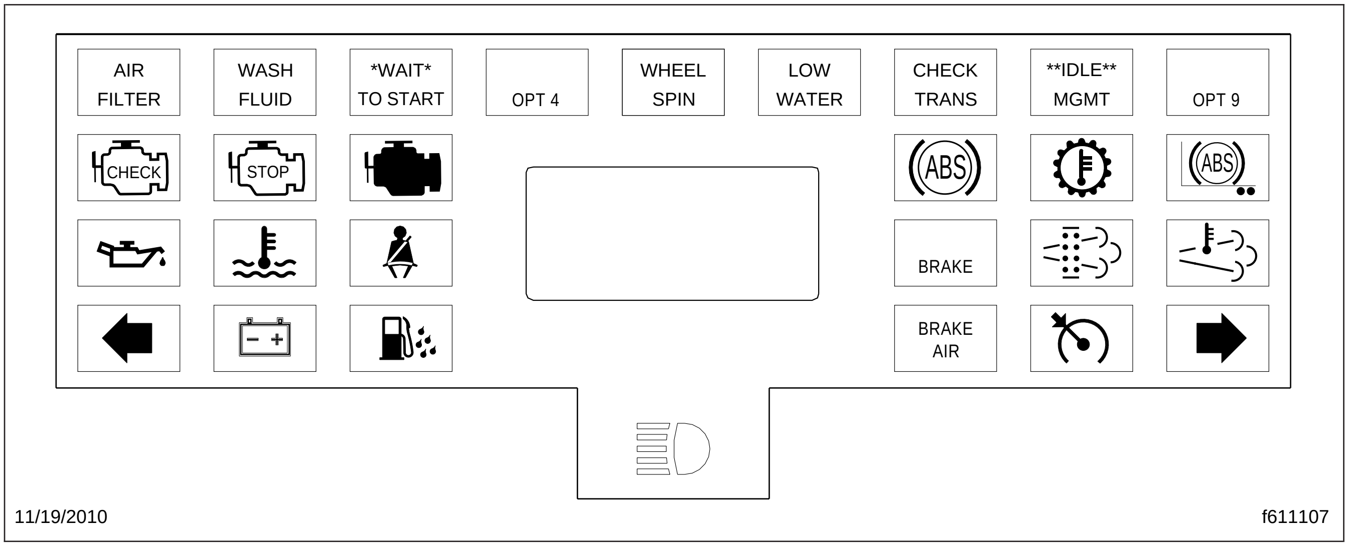


Fig. 4, Dash Message Center, ICU3 (EPA10)

Principles of Operation

Ignition Sequence

When the ignition is turned to ON, the ICU3 runs through the ignition sequence. See **Fig. 5**.

If only the headlights are turned on, the dash driver display screen displays the odometer.

IMPORTANT: When the ignition is first turned to ON, all the electronic gauges complete a full sweep of their dials, the warning and indicator lights light up, and the buzzer sounds for three seconds when the seat belt is latched.

The following warning and indicator lights go on during the ignition sequence.

- low engine oil pressure warning
- high coolant temperature warning
- low air pressure warning
- parking brake on warning
- low battery voltage indicator
- fasten seat belt warning illuminates for 15 seconds (unless pin D10 is hardwired on EPA10 ICUs. If pin D10 is hardwired, the light will remain on for only three seconds when the seat belt is latched.)
- all engine warning lights, including engine protection, check engine, and stop engine
- all ABS warning lights, including wheel spin, tractor ABS, and trailer ABS (if installed); and
- the DEF level indicator on EPA10 vehicles will illuminate all segments green, then turn them off one at a time before turning the left most segment amber then red.

NOTE: While the engine and ABS warning lights go on during the ignition sequence, they are not controlled by the ICU3, but by their own system ECU.

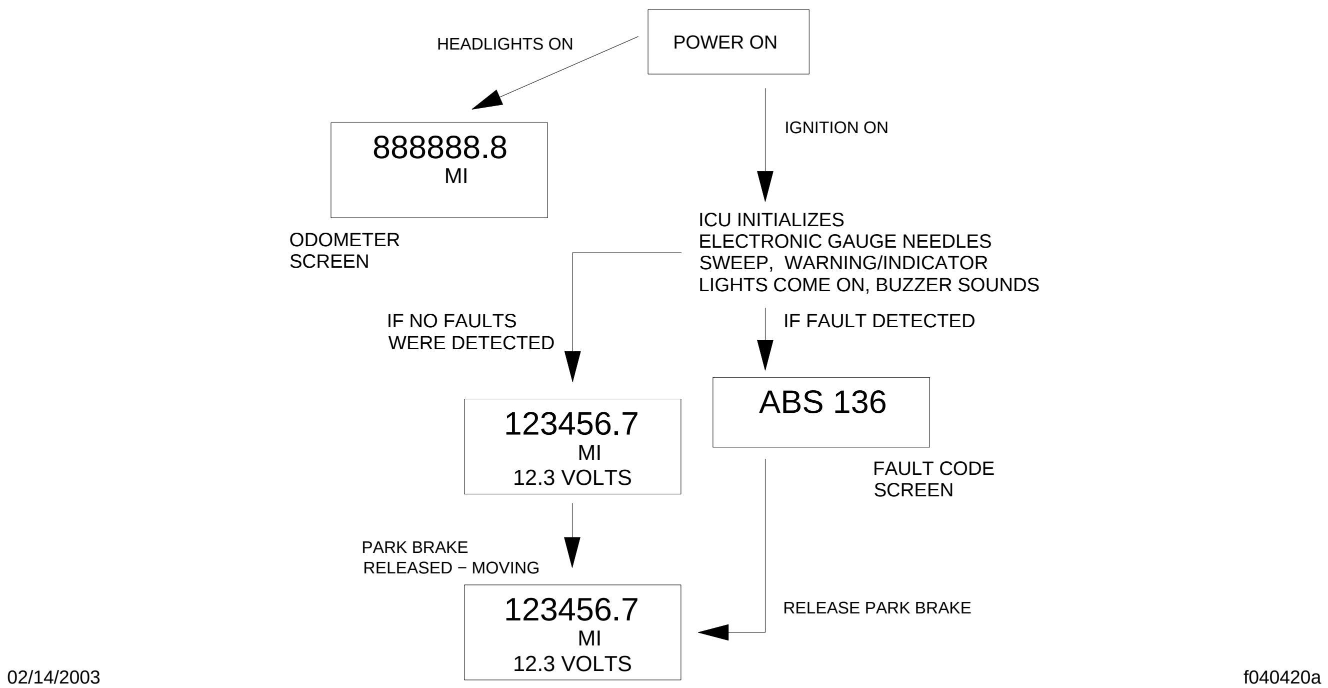
Once the ignition has been turned to ON, the ICU performs a self-test, and polls the databus for faults.

During the first half of the self-test, all segments of the dash driver display screen illuminate as "888888.8". During the second half of the self-test, the software revision level is displayed.

If there are no active faults, the screen then displays the odometer.

If the ICU3 has received active fault codes from other devices, it displays the three-letter acronym for the device broadcasting the fault. It also displays the MID or SA number for each for three seconds, one after the other, until the parking brake is released or the ignition is turned to OFF.

General Information



NOTES:

- During the first half of the self-test, all segments of the display illuminate. During the second half of the self-test, the software revision level is displayed.
- If there is more than one fault, the ICU3 displays them, one after another, changing every three seconds, until the park brake is released.

Fig. 5, ICU3 Ignition Sequence

The screen displays a code, called the message identifier (MID) for EPA07 and earlier vehicles, or source address (SA) for EPA10 and later vehicles. These identify the ECU or system that is broadcasting the fault code.

NOTE: If the ICU3 receives a message from an ECU that has not been preprogrammed into the memory of the ICU, it displays "SYS ###" instead, where ### is replaced by the MID/SA of the broadcasting device.

Once the parking brake is released, the ICU3 displays the odometer again.

Odometer

The odometer is set to display in either miles or kilometers, depending on the primary scale of the speedometer. The legend, either **MI** or **KM**, illuminates between the odometer and the volts display when the engine is running or the headlights are turned on.

To toggle between MI (miles) or KM (kilometers), press the Mode/Reset button while in the SELECT screen.

The odometer is a seven-digit display with a decimal point until the vehicle has traveled 999,999.9 miles or kilometers (km). At one million miles (km), the odometer rolls over to "1000000" without the decimal point, and can continue up to 9,999,999. The odometer only displays significant figures (no leading zeros).

The ICU compares odometer data received from the engine controller to its own stored value. It will only alter its stored value if the difference is less than two miles (three km). When the ICU is replaced, the odometer display will start from zero even though the engine controller odometer may be a much larger value.

IMPORTANT: Although the odometer uses data supplied by the engine control module (ECM) to update its count, it keeps its own mileage starting from zero, when it was first installed. The ICU odometer may not match the engine ECU odometer. This may occur if the engine has been operated with the ICU disconnected, as may occur during factory break-in or engine service, or if the ICU has been replaced.

Buzzer/Chime

The buzzer sounds during the ignition sequence and whenever one of the following conditions exists:

- The engine oil pressure falls below the preset level, which is 5 to 9 psi (35 to 62 kPa) on most engines.
- The coolant temperature rises above the preset level, which is 215°F (102°C) on Caterpillar and Detroit Diesel engines, and 189°F (87°C) on MBE900 engines, and 225 to 230°F (107 to 110°C) on Cummins engines.
- The air pressure falls below the preset level of approximately 70 psi (483 kPa).
- The parking brake is set with the vehicle moving at a speed greater than 2 mph (3 km/h).
- The J1939 brake failure message is received from the ABS.
- The J1939 heartbeat message is not received from the ABS.
- The system voltage falls below 11.9 volts.
- An optional circuit connected to pin B12 will activate the buzzer when it is connected to ground.
- The door is open and the parking brake is not set.

ICU3 Removal and Installation

Removal

The instrumentation control unit, ICU3, is a one-piece unit, including housing, fixed gauges, a removable air gauge module, and the dash message center. See **Fig. 1**.

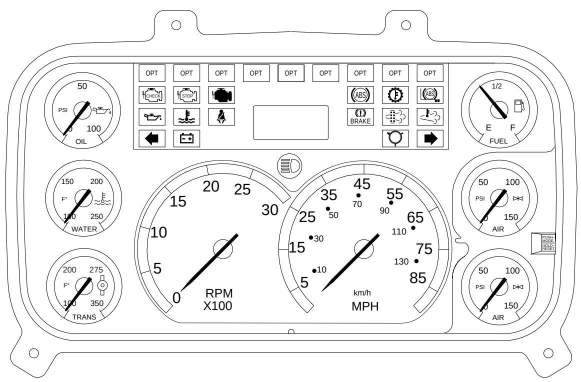


Fig. 1, ICU3, Front View

1. Disconnect all negative leads from the batteries.

⚠ WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

2. Discharge the air pressure from the primary and secondary air tanks.
3. Remove the dash trim piece by removing the 11 screws that secure it. All fasteners for this procedure are 10–16 Torx® capscrews. See **Fig. 2**.

NOTICE

Do not forcibly pull the ICU3 from the dash. This may dislodge electrical connections or air lines from the back of the ICU3, causing damage to connections, lines, or the dash.

4. Remove the four screws that secure the ICU. See **Fig. 3**.
5. Disconnect the two electrical connectors from the back of the ICU. See **Fig. 4**.

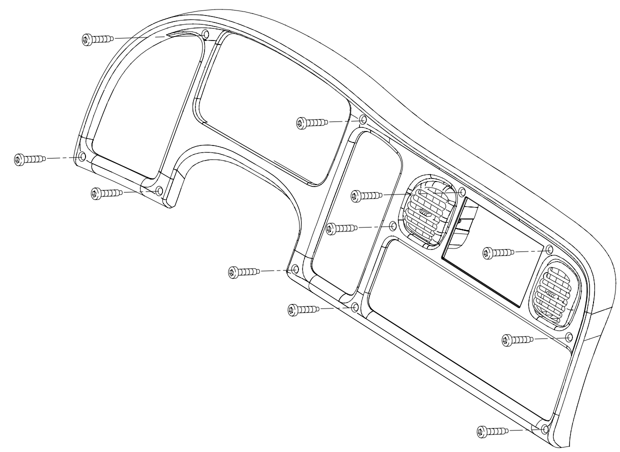
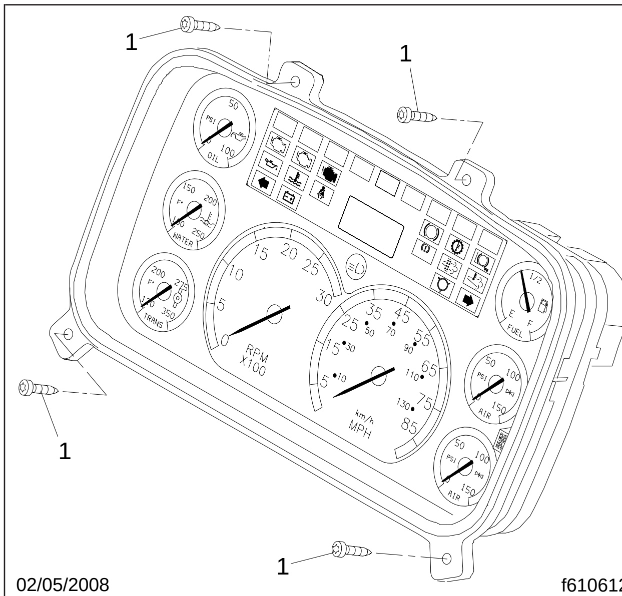


Fig. 2, Dash Trim Piece

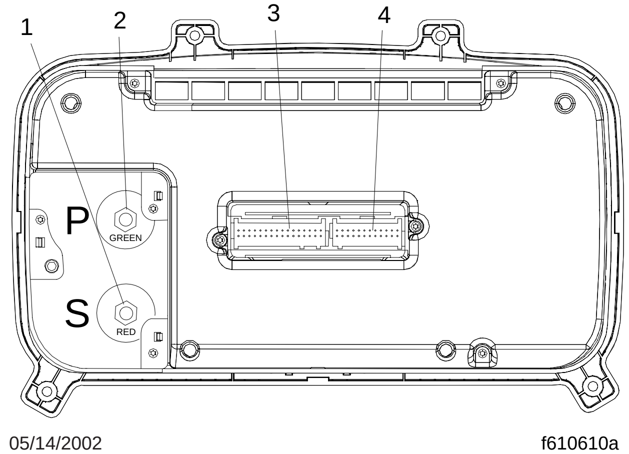


1. 10–16 Torx Capscrew

Fig. 3, ICU3 Installation

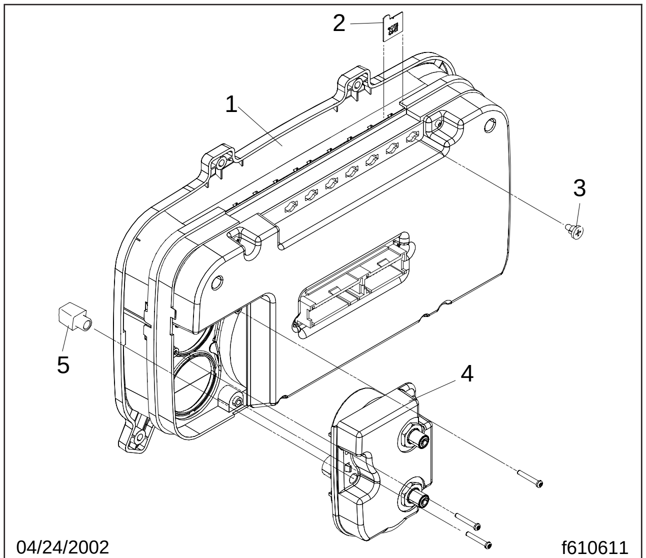
6. Remove the air lines by pressing the push-lock connectors, then pulling the air lines away from the gauges. The lines are color-coded for ease of installation. The primary air line is green and is connected to the upper gauge. The secondary air line is red and is connected to the lower gauge.

ICU3 Removal and Installation



1. Secondary Air Pressure Gauge
2. Primary Air Pressure Gauge
3. 32-Pin Electrical Connector
4. 24-Pin Electrical Connector

Fig. 4, ICU3, Rear View



1. ICU3
2. Telltale
3. Light Bulb
4. Air Gauge Module
5. Mode/Reset Button

Fig. 5, ICU3, Rear View

Air Pressure Gauge Module Replacement

The air pressure gauge mode/reset button module may be replaced as a sub-assembly. See **Fig. 5**. This avoids the need to replace the entire ICU3.

NOTICE

NOTICE: Be careful not to damage the ribbon electrical connector or the air gauge needles when removing the air gauge module. The gauge needles are exposed once the module is removed. A thin-ribbon electrical connector connects the air gauge module and the ICU3 housing. Once the fasteners that secure the air gauge module are removed, take care in separating the module from the ribbon electrical connector. Do not separate the air gauges from module cover.

NOTE: Placing the cluster on a clean towel or cloth will help keep the plastic face from getting scratched during this procedure.

1. Carefully place the ICU3 face down on a smooth surface and remove the three Torx® capscrews that secure the air gauge module to the ICU. See **Fig. 6**.

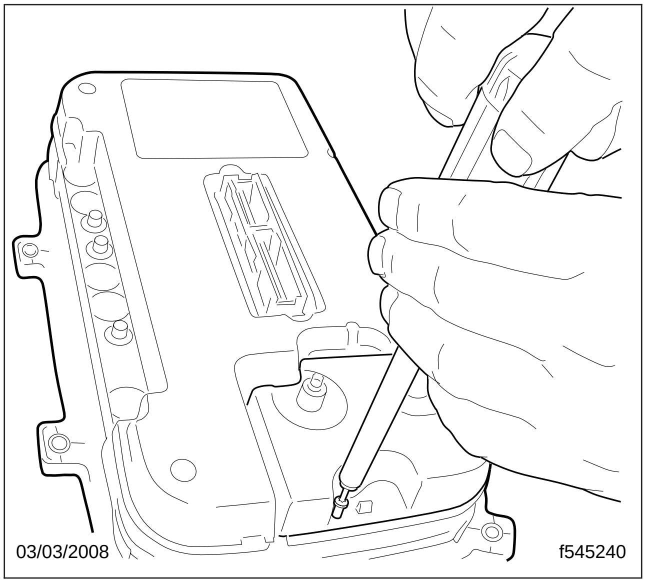


Fig. 6, Removing the T-8 Screws

2. Separate the air gauge module slightly from the ICU to allow access to the electrical ribbon that connects the module to the ICU. See **Fig. 7**.
3. Disconnect the electrical connection ribbon from the ICU, not from the air gauge module. Grip the

ribbon firmly on each side and lift out, then remove the air gauge module.

4. Position the air gauge module close to the opening it belongs in and connect the electrical ribbon connector in its slot. Gripping the ribbon end firmly, place the ribbon end into the slot and push it straight in until it stops.
5. Place the air gauge module into its opening in the ICU3. Make sure the electrical ribbon is inside the module, and that the mode/reset button shaft in the ICU cavity lines up with the receptacle in the air gauge module.
6. Install the three Torx capscrews and tighten them to secure the air gauge module.

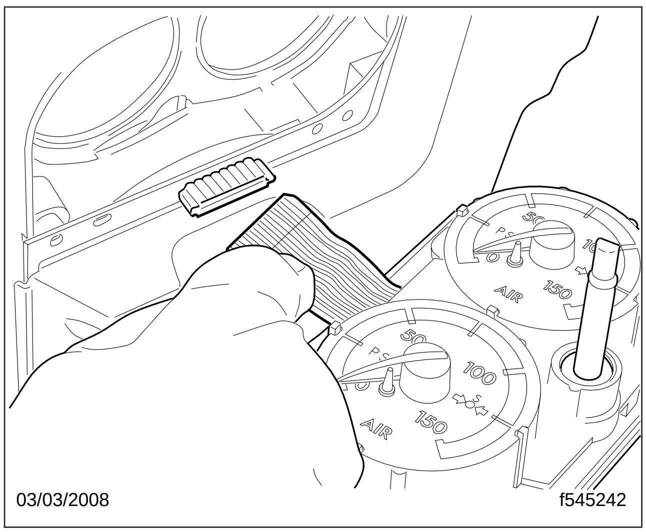


Fig. 7, Disconnecting the Ribbon Cable

Installation

1. Connect the air lines to the air gauges by pressing them firmly into the push-lock connector on the back of the gauge. The green air line connects to the primary (upper) gauge. The red air line connects to the secondary (lower) gauge. See **Fig. 4**.
2. Connect the electrical connectors to the back of the ICU3.
3. Place the ICU3 in the dash opening and secure it with the four capscrews. Tighten the capscrews 30 lbf·in (340 N·cm).
4. Install the dash trim piece and secure it with 11 capscrews. Tighten the capscrews 30 lbf·in (340 N·cm).
5. Connect the batteries.

NOTE: Mechanical (air) gauges do not make a sweep.

6. Turn on the ignition and test the operation of the cluster. All electronic gauges should make one complete sweep and return to their normal indicating positions. The warning and indicator lights should turn on, then off, as described is **Subject 050**.
7. Start the engine and verify proper operation of the air gauge module as the air pressure builds.

Background Information

The instrumentation control unit, ICU3, is a one-piece unit, including housing, fixed gauges, a removable air gauge module, and the dash message center. See **Fig. 1**.

NOTE: Since the top-row warning and indicator lamps are optional, some positions in the row may not have a lamp and telltale.

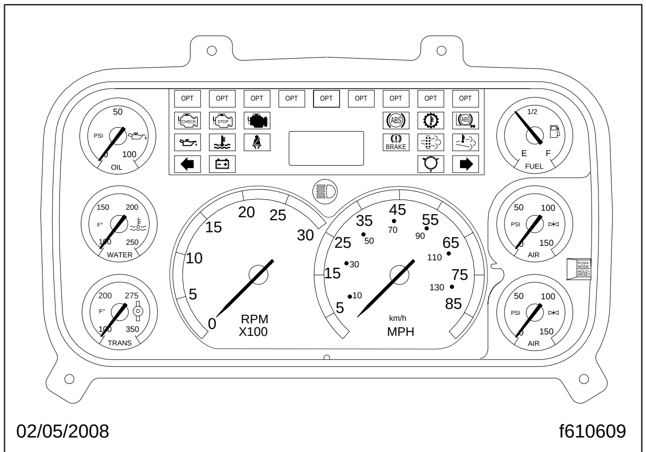


Fig. 1, ICU3

The nine top-row warning and indicator lamps are all replaceable except for the lamp in position 8, counting left to right. The lamp in that position is a permanent LED.

The term "telltale" refers to the small plastic bezel in the top row with a warning or indicator message printed on it. Telltales are replaceable.

IMPORTANT: If more extensive service work on the ICU3 is required, the electrical and air gauge connections must be disconnected. See **Subject 100** for instructions.

NOTICE

Do not forcibly pull the ICU3 from the dash. This may dislodge electrical connections or air hoses from the back of the ICU3, causing damage to the connections, the air hoses, or the dash.

Lamp Replacement

1. Disconnect the negative leads from the batteries and discharge the pressure from the air tanks.
2. Remove the dash trim piece by removing the 11 capscrews that secure it. All fasteners for this procedure are 10–16 Torx® capscrews. See **Fig. 2**.

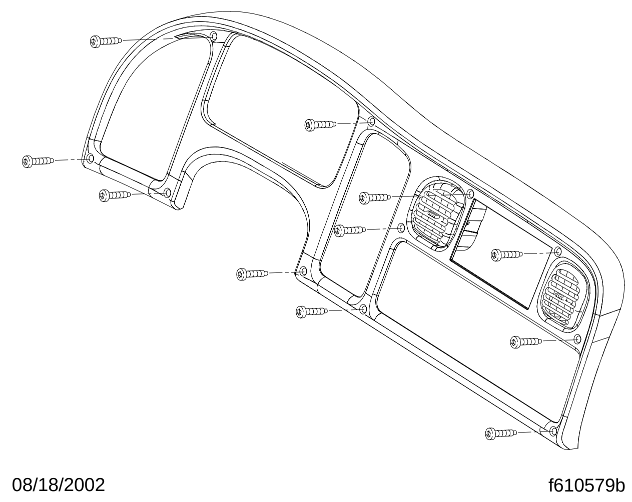


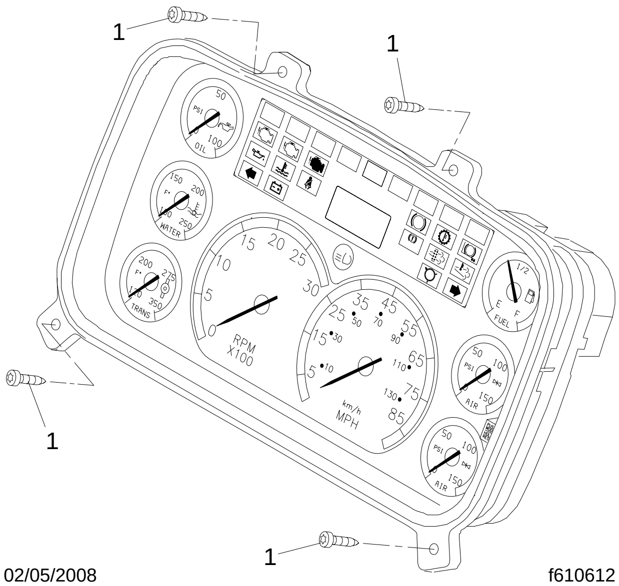
Fig. 2, Dash Trim Piece

3. Remove the four capscrews that secure the ICU3. See **Fig. 3**.
4. Place a clean towel over the front of the ICU3 before pulling it forward to prevent scratches. Carefully pull the ICU3 forward to access the top row of lamps and telltales.
5. Use a small screwdriver or flat blade to twist out the lamp by its base behind the telltale. Turn the lamp one-quarter turn and remove. See **Fig. 4**.
6. Place a new lamp in the opening and twist it one-quarter turn.
7. Using capscrews, install the ICU3.
8. Using capscrews, install the dash trim piece.
9. Connect the batteries.

Telltale Replacement

1. Disconnect the negative leads from the batteries and drain the air tanks.

Lamp and Telltale Replacement



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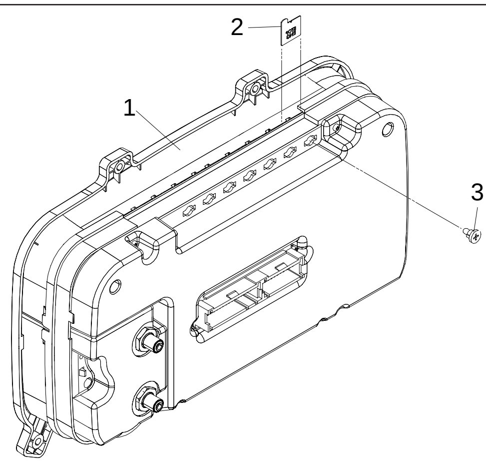
1. Torx Capscrew

Fig. 3, ICU3 Installation



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NOTE: Air gauge and electrical connections are shown removed for clarity.

1. ICU3
2. Telltale
3. Lamp

Fig. 4, ICU3, Rear View

2. Remove the dash trim piece by removing the 11 capscrews that secure it. All fasteners for this procedure are 10–16 Torx® capscrews. See **Fig. 2**.
3. Remove the four capscrews that secure the ICU3. See **Fig. 3**.
4. Place a clean towel over the front of the ICU3 before pulling it forward to prevent scratches. Carefully pull the ICU3 forward to access the top row of lamps and telltales.
5. Using a pair of needlenose pliers or a similar tool, grab the exposed tab at the top of the telltale slot and carefully pull the telltale out from the top of the ICU. See **Fig. 4**.
6. Place a new telltale in the slot the same way it was removed. Properly orient the telltale so the text is readable from the front, then grab the top tab of the telltale and slide it into the slot.
7. Using capscrews, install the ICU3.
8. Using capscrews, install the dash trim piece.
9. Connect the batteries.
10. Turn the ignition on. Check all lamps and telltales for correct operation.

Troubleshooting

IMPORTANT: Begin troubleshooting the ICU using **Table 1**.

ICU Instrumentation Troubleshooting – Start Here		
Problem Type	**Symptom**	**Procedure to Use**
Fault Code	A fault code is displayed on the ICU display	Table 13
	A Roll Call fault is present – Examples are "no ENG" or "no ABS"	Table 13
	"nO DATA" is displayed on the LCD	Table 13
	"nO J1939" is displayed on the LCD	Table 13
	"- - - - - - -" (seven dashes) is displayed on the LCD	Table 13
Gauges	Problem with a gauge in the ICU	Table 2
	Problem with a satellite gauge	Table 6
Backlighting	Problem with backlighting in the ICU	Table 18
	Problem with backlighting in a remote gauge	Table 18
Warning Indicators	Problem with an in-gauge indicator	Table 22
	Problem with an indicator in the ICU	Table 21
	Problem with the seat belt lamp	Table 23
	Problem with the DEF indicator	Table 12
LCD Display	A segment of the LCD does not work	Table 19
	The LCD is completely inoperative	Table 19
Mode/Reset Button	The mode/reset button is sticking or does not change the display	Table 20

Table 1, ICU Instrumentation Troubleshooting – Start Here

Gauge Diagnosis

ICU Gauge Diagnosis – Start Here			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition on without starting the engine. All the gauges, except air pressure gauges, should sweep full scale and back in unison. Do the gauges sweep correctly when the ignition is turned on, and does the DEF indicator cycle?	Yes	Go to Step 3.
		No	Go to Step 2.
2	Is the ICU completely nonresponsive?	Yes	Test for battery power-on pin D14, ignition power-on pin D15, and the ground on pin D13. Troubleshoot and repair any fault with these circuits as necessary. If these circuits are all working, replace the ICU.
		No	Replace the ICU.

Troubleshooting

ICU Gauge Diagnosis – Start Here			
Step	**Test Procedure**	**Test Result**	**Action**
3	Use Table 3 to determine the gauge input source. Use the troubleshooting action based on the gauge input.	Fuel Level	Go to Table 8.
		DEF Level	Go to Table 12.
		Air Pressure	Go to Table 7.
		Sensor Driven	Go to Table 9.
		Data Driven	Go to Table 10.

Table 2, ICU Gauge Diagnosis – Start Here

Table 3 defines where each gauge, standard or optional, receives its input signal. Some gauges are datalink-driven, meaning the information is sent to the instrument cluster from some other ECU. Other gauges are controlled by a sensor wired directly to the instrument cluster or an air line connected directly to the gauge.

Standard and Optional Gauges: Input Source to ICU		
Gauge	**EPA07 and Earlier Input**	**EPA10 J1939 Input**
Ammeter*	Not part of the ICU	Not part of the ICU
Application Air Pressure	Air line connected to gauge	Air line connected to gauge
DEF Level	N/A	J1939 from engine (SA 00 SPN 1761) or J1939 from aftertreatment control module (ACM) (SA 61 SPN 1761)
Engine Coolant Temperature	J1587—from engine (MID 128 PID 110)	J1939 from engine (SA 00 SPN 110)
Engine Oil Pressure	J1587—from engine (MID 128 PID 100)	J1939 from engine (SA 00 SPN 100)
Engine Oil Temperature	J1587—from engine (MID 128 PID 175)	J1939 from engine (SA 00 SPN 175)
Forward Rear-Axle Temperature	Sensor connected to ICU	Sensor connected to ICU
Fuel Level	Sensor connected to ICU	Sensor connected to ICU
Low DEF Indicator	N/A	J1939 from engine (SA 00 SPN 5245)
Primary Air System Pressure	Air line connected to gauge	Air line connected to gauge
Pyrometer	J1587—from engine (MID 128 PID 173)	J1939 from engine (SA 00 SPN 3241)
Rear Rear-Axle Temperature	Sensor connected to ICU	Sensor connected to ICU
Secondary Air System Pressure	Air line connected to gauge	Air line connected to gauge
Speedometer	J1587—from engine (MID 128 PID 84)	J1939 from engine (SA 00 SPN 84
Suspension Air Pressure	Air line connected to gauge	Air line connected to gauge
Tachometer	J1587—from engine (MID 128 PID 190)	J1939 from engine (SA 00 SPN 190)
Transmission Oil Temperature	Sensor connected to ICU	Sensor connected to ICU

Standard and Optional Gauges: Input Source to ICU		
Gauge	**EPA07 and Earlier Input**	**EPA10 J1939 Input**
Turbo Boost Pressure	J1587datalink—from engine (MID 128 PID 439)	J1939 from engine (SA 00 SPN 102)

* Ammeter is a stand-alone gauge that is not connected to the ICU.

Table 3, Standard and Optional Gauges: Input Source to ICU

Satellite Gauge Diagnosis

The ICU is capable of controlling up to eight additional gauges located in the dash panels. These gauges are controlled by a databus with backlighting, power, and ground sourced by the ICU. See **Table 4**.

Satellite gauges that are sensor or data driven will initialize at power-on with the same sequence as the gauges in the main ICU3. The air pressure gauges only use the backlighting power from the ICU3. If there is a short circuit in any of the satellite gauges or the interconnecting wiring harness, it is possible that none of the gauges will work.

Satellite Gauge Daisy Chain Circuits		
Connector/Pin	**Name**	**Function**
C6	Gauge Power	12 volt source for satellite gauges
C7	Gauge Ground	Ground supply for satellite gauges
D6	Illumination	Backlighting voltage source for satellite gauges
D7	Gauge Data	Databus to satellite gauges

Table 4, Satellite Gauge Daisy Chain Circuits

Table 5 identifies the satellite gauges that may be used with the ICU.

ICU Satellite Gauges	
Gauge	**Input Source**
Engine Oil Temperature	Data from the engine controller
Turbo Boost Pressure	Data from the engine controller
Pyrometer	Data from the engine controller
Forward Rear-Axle Temperature	Sensor connected to ICU
Rear Rear-Axle Temperature	Sensor connected to ICU
Application Air Pressure	Air line connected to gauge
Suspension Air Pressure	Air line connected to gauge
Lift Axle Air Pressure (up to 4)	Air line connected to gauge

Table 5, ICU Satellite Gauges

Troubleshooting

Satellite Gauge Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition to ON without starting the engine. All the satellite gauges, except air pressure gauges should sweep full scale and back in unison. Do the electrical satellite gauges sweep correctly when the ignition is turned to ON?	Yes	Go to Step 3.
		No	Go to Step 2.
2	Are all the electrical satellite gauges nonresponsive?	Yes	Troubleshoot for a short in the satellite gauge wiring by testing for ignition voltage on pin C6 and ground on pin C7. Disconnect the satellite gauges one at a time to troubleshoot for a short in a gauge that could be taking the databus down. Repair any wiring fault or replace any defective gauge. If no problem was found, replace the ICU.
		No	Troubleshoot for a fault in the connection to the inoperative gauge and repair as appropriate. Otherwise, replace the inoperative gauge.
3	Use **Table 5** to determine the gauge input source. Use the troubleshooting procedure based on the gauge input.	Air Pressure	Go to **Table 7**.
		Sensor Driven	Go to **Table 9**.
		Data Driven	Go to **Table 10**.

Table 6, Satellite Gauge Diagnosis

Air Pressure Gauge Diagnosis

Air Pressure Gauge Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
1	Which air pressure gauge is not functioning correctly?	Primary or Secondary	Go to Test 2.
		Application	Go to Test 3.
		Suspension	Go to Test 4.
		Lift Axle Pressure	Go to Test 5.
2	Drain the air tanks. Connect an accurate pressure gauge to the primary or secondary air tank depending on which gauge has a problem. Start the engine and build air pressure until the compressor cuts out. Is the air pressure gauge in the cluster within 11 psi (76 kPa) of the test gauge?	Yes	Gauge is OK. No problem found.
		No	Check air line to gauge for kinks, pinches, or wire ties that are crushing the air line feed. If OK, replace the air pressure gauge module.

Air Pressure Gauge Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
3	Connect an accurate pressure gauge to a delivery port on the foot valve. Make a 90 psi (621 kPa) brake application while observing the application air pressure gauge in the cluster and the test gauge. Is the air pressure gauge in the cluster within 11 psi (76 kPa) of the test gauge?	Yes	Gauge is OK. No problem found.
		No	Check air line to gauge for kinks, pinches, or wire ties that are crushing the air line feed. If OK, replace the air pressure gauge.
4	Connect an accurate pressure gauge to the air suspension. Is the air pressure gauge in the cluster within 11 psi (76 kPa) of the test gauge?	Yes	Gauge is OK. No problem found.
		No	Check air line to gauge for kinks, pinches, or wire ties that are crushing the air line feed. If OK, replace the air pressure gauge.
5	Raise the lift axle. Connect an accurate pressure gauge to the application side of the lift axle air system. Lower the axle and adjust the pressure. Is the axle pressure on the instrument panel gauge within 11 psi of the test gauge?	Yes	If the pressure cannot be controlled with the adjustment knob, check the reverse switch and pressure dump valve. Check the pressure adjustment regulator, replace if it is not controlling the pressure. Otherwise, there is no problem.
		No	Check air line to gauge for kinks, pinches, or wire ties that are crushing the air line feed. If OK, replace the air pressure gauge.

Table 7, Air Pressure Gauge Diagnosis

Fuel Level Gauge Diagnosis

The fuel level gauge is controlled by the ICU using a variable resistance input from the fuel level sending unit that is located in the fuel tank. The fuel level sending unit resistance varies linearly from 31±2Ω with a full tank to 247±3Ω when empty.

If the ICU3 is measuring a resistance greater than 284Ω between circuit 47 and ground, the EPA10 cluster will set a fault for fuel level circuit open. If the ICU3 is measuring less than 23.5Ω between circuit 47 and ground, the EPA10 cluster will set a fault for fuel level circuit shorted low. ServiceLink may be used to monitor for these faults on EPA10 J1939 clusters. On all model years of clusters, the gauge will read empty until the measurement from the sensor is between 284Ω and 23.5Ω. Refer to **Table 8** for the fuel level diagnostic procedure.

NOTE: If the fuel level sensor is below the minimum resistance (short to ground) or above the maximum (open), the fuel gauge will read empty. Shorting the fuel sensor wires will not drive the gauge to full scale.

Troubleshooting

Fuel Level Gauge Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
1	If a 100 ohm resistor is available, disconnect the fuel level sender connector and place the resistor across circuit 47 and ground in the wiring harness connector to simulate the fuel level sending unit. Turn the ignition to the run position and observe the fuel gauge. If, after gauge initialization, the gauge points very closely to the 1/2 tank mark, then the wiring and ICU are all operating correctly. If there is no problem with the wiring and ICU, go to Step 4. Does the fuel level gauge stay at empty even though there is fuel in the tank or is the complaint an inaccurate and intermittent reading? Note - turn the ignition to OFF and disconnect the batteries before continuing.	Stays at Empty	Go to Step 2.
		Inaccurate or Intermittent	Go to Step 4.
2	Disconnect the connector at the fuel level sender and measure the resistance of the sender. What is the resistance of the sender?	Greater Than 284Ω or Less Than 23.5Ω	Go to Step 4.
		Between 284Ω and 23.5Ω	Go to Step 3.
3	Connect the fuel level sender and disconnect the connectors on the back of the ICU. Measure the resistance in the vehicle wiring between circuit 47 in connector pin D1 and the ground circuit in connector pin D2. What is the resistance of the circuit?	Greater than 284Ω	Troubleshoot and repair an open circuit on either circuit 47 or the ground between the ICU connector and the fuel level sender.
		Between 284Ω and 23.5Ω	This is the valid resistance range. If the fuel tank is full and the resistance is close to 31Ω, replace the ICU. Otherwise, no problem is indicated.
		Less than 23.5Ω	Troubleshoot and repair a short to ground on circuit 47 between the ICU connector and the fuel level sender.
4	Remove the fuel level sending unit from the fuel tank. Connect an ohm meter to the pins at the fuel level sender connector. Slowly move the level of the float arm from full to empty. See **Fig. 2**. Does the resistance vary linearly from 31±2Ω to 247±3Ω?	Yes	Troubleshoot and repair for corrosion or an intermittent connection in the circuitry between the ICU and the fuel level sender.
		No	If it is a sealed unit, replace it. See **Fig. 1**. If it is an open unit, using electrical contact cleaner, clean the deposits from the wiper area and the shaft contact ring of the sender. See **Fig. 3**. Move the float arm from full to empty and back several times to work the deposits loose. Repeat this cleaning procedure, then allow it to air dry. Go to Step 5.

Fuel Level Gauge Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
5	Connect an ohm meter to the pins at the fuel level sender connector. Slowly move the level of the float arm from full to empty. Does the resistance vary linearly from 31±2Ω to 247±3Ω?	Yes	Install the repaired fuel level sender into the fuel tank.
		No	Replace the fuel level sender with a new unit.

Table 8, Fuel Level Gauge Diagnosis

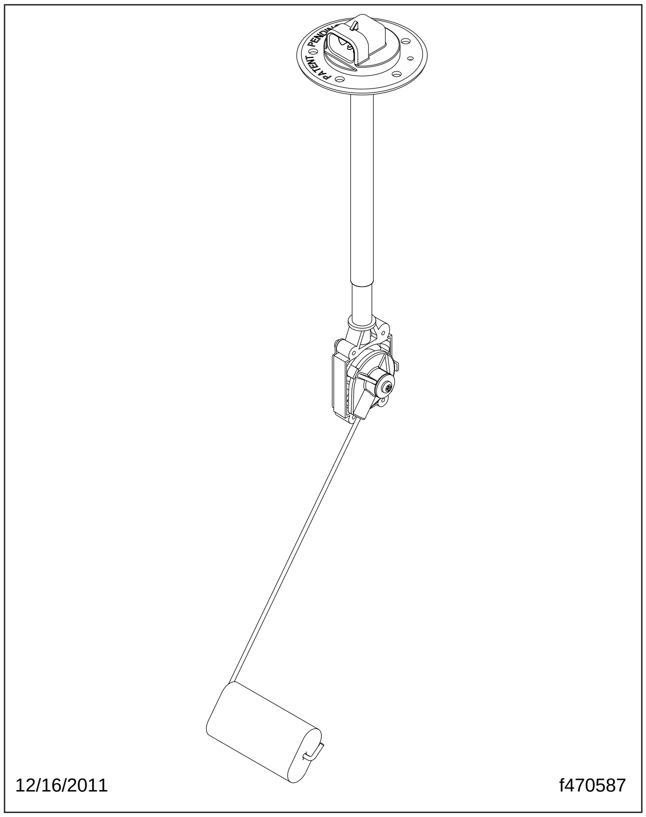
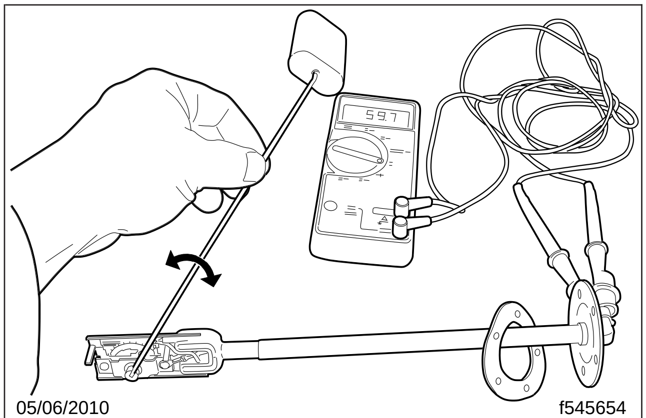
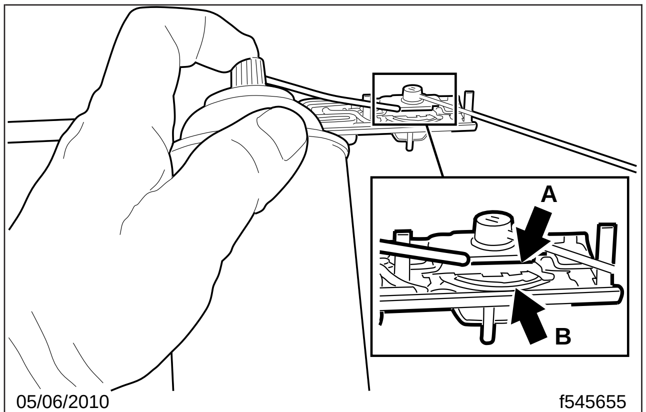


Fig. 1, Sealed Fuel Level Sending Unit



Slowly move the float arm from full to empty.

Fig. 2, Testing the Fuel Level Sending Unit



Spray cleaner on the wiper (A) and the shaft contact ring (B).

Fig. 3, Cleaning the Wiper Area

Troubleshooting

Sensor-Driven Gauge Diagnosis

Sensor-Driven Gauge Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
1	Does the gauge stay pegged at the full scale or the bottom of scale reading even though the temperature is at some mid-point or is the complaint an inaccurate reading? Note: Turn the ignition to OFF and disconnect the batteries before continuing.	Stays Pegged	Go to Step 2.
		Inaccurate	Go to Step 3.
2	Disconnect the connector at the sensor and measure the resistance of the sensor. Does the sensor measure open, shorted, or some mid-range resistance for that sensor, using the table in **Specifications 400**?	Open or Shorted	Replace the sensor.
		Mid-Range Resistance	Locate and repair the wiring fault for that sensor. Use the circuit and pin information tables in **Specifications 400** to identify the circuits to troubleshoot.
3	Remove the sensor and place it in a container of water with a thermometer and heat to a temperature where the resistance can be accurately measured with an ohm meter. Use the resistance table in **Specifications 400** for the sensor under test to determine if the measured resistance is appropriate for the temperature. Does the resistance value match the table value?	Yes	Measure the resistance of the wiring between the ICU and the sensor connector. Locate and repair a partially open or short circuit.
		No	Replace the sensor.

Table 9, Sensor-Driven Gauge Diagnosis

Data-Driven Gauge Diagnosis

Data-Driven Gauge Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
1	If the problem is with the DEF level indicator, use the procedure in **Table 12**. Connect ServiceLink and open the datalink monitor template for the instrument cluster. Start the engine and let it run until the operating condition should register on the gauge. For example, oil temperature must be above the minimum position on the gauge. Is the display on the computer within 5% of the position of the gauge in the ICU?	Yes	Use the troubleshooting procedure for the sensor giving incorrect data. For example, use the engine manufacturer's troubleshooting procedure for sensors connected to the engine controller.
		No	Replace the ICU.

Table 10, Data-Driven Gauge Diagnosis

DEF Level Indicator Diagnosis

The DEF level indicator is integrated into the fuel gauge, and uses J1939 data from the ACM. The DEF level is measured by a sealed non-contact variable-resistance sensing assembly located in the DEF tank. The DEF level sensor resistance can be measured at the tank connector. For Detroit Diesel engines, the level sensor signal uses pins 1 and 2. For Cummins engines, the level sensor uses pins 1 and 4. On Detroit Diesel engines, when the DEF tank is empty, the sensor will measure approximately 240Ω. When full, it will measure approximately 19.8KΩ. On Cummins engines, when the DEF tank is empty, the sensor will measure approximately 4.8KΩ. When full, it will measure approximately 68Ω. Use the resistance to float height table in **Specifications 400** to test the resistance for a specific float height. When there is no DEF in the tank or when there is a fault in the DEF level sensing circuit, the indicator will flash the red segment until the fault is corrected, or a sufficient amount of DEF is added to the tank. Perform the recommended action in **Table 11** to troubleshoot faults with the DEF level sensing circuitry indicated by fault codes with SPN 1761.

DEF Level Faults from SA 0 or SA 61				
SPN	**FMI**	**Description**	**Behavior**	**Action**
1761	1 17 18 31	DEF level low	The DEF level is low. MIL, CEL, STOP engine lamp, and engine derate may be active.	The DEF tank has run too low. Fill the DEF tank so that it is at least 25% full and idle the engine for 5 minutes. If the problem is still present use the DEF level diagnostic procedure in **Table 12**.
1761	3	DEF level circuit out of range high	The voltage on circuit 532F is greater than the ACM expects.	Troubleshoot circuits 532F and 532F- between the ACM and the temperature level sensor for a wiring fault and also for an open level sensor unit.
1761	4	DEF level circuit out of range low	The voltage on circuit 532F is close to 0 volts.	Troubleshoot circuit 532F between the ACM and the temperature level sensor for a wiring fault and also for a shorted level sensor unit.

Table 11, DEF Level Faults from SA 0 or SA 61

DEF Level Diagnostic Procedure			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition to ON but do not start the engine. Does the DEF level indicator illuminate all segments green, then turn them off beginning from the right, one at a time until the left one becomes amber then red, before either showing a mid-range level, or flashing the left segment red?	Yes	The DEF level indication display is working properly. Go to Step 2.
		No	Replace the ICU3.
2	Use Servicelink to check for any J1939 faults. Is there a fault for SPN 1761 with FMI 3 or 4 (DEF level sensor out of range) or are any J1939 communications fault codes active? NOTE: SPN 1761 FMI 1, 17, 18, or 31 indicate the DEF level is low. There is no wiring fault but there may be a problem with DEF level indication accuracy.	Yes	If the code is for a FMI 4, troubleshoot for a wiring fault in circuit 532F between the DEF level sensor and the ACM. If the code is FMI 3, go to Step 3. If there is a J1939 communications fault, use the troubleshooting information in this manual to locate and repair communications.
		No or Accuracy Problem	Go to Step 4.
3	Turn the ignition to OFF then disconnect the 4 wire connector at the DEF level sender. Use a short jumper wire to short pins 1 and 2 (for Detroit Diesel engine) or pins 1 and 4 (for Cummins engine) together in the vehicle harness side of the connector. Turn the ignition on without starting the engine. Allow the indicator initialization sequence to complete, then check for fault codes. Is there an active fault for SPN 1761 FMI 4?	Yes	The wiring indicates continuity. Go to Step 4.
		No	Troubleshoot and repair for an open in circuit 532F and/or circuit 532F- between the DEF level sensor and the ACM.

Troubleshooting

DEF Level Diagnostic Procedure			
Step	**Test Procedure**	**Test Result**	**Action**
4	Turn the ignition to OFF and disconnect the batteries. Remove the temperature/level sender unit from the DEF tank. Connect an ohm meter to pins 1 and 2 (for Detroit Diesel engine) or pins 1 and 4 (for Cummins engine) at the 4 pin connector. Slowly raise the level of the float from empty to full. Record the resistance range measured. Does the vehicle have a Cummins or a DD engine?	Cummins	If the resistance did not vary from approximately 4.8KΩ at empty to 68Ω at the full position, replace the temperature/level sender unit.
		Detroit Diesel	If the resistance did not vary from approximately 240Ω at empty to 19.68KΩ at the full position, replace the temperature/level sender unit.

Table 12, DEF Level Diagnostic Procedure

Fault Code Diagnosis

The ICU3 will display fault codes that are broadcast from other devices on the databus. Follow the procedure in **Table 13** to determine if there is a problem with the ICU3, another device on the databus, a sensor that is connected to the ICU, or with the databus itself. Fault codes that are generated by the ICU3 can be read using ServiceLink.

Some circuitry faults within the ICU3 will cause the LCD to display "- - - - - - -" (seven dashes). Replace the ICU3 when this is displayed.

Roll call faults occur when the ICU3 is not receiving data from a device that had been on the databus in the past. If a device has been removed from an EPA10 vehicle (Qualcomm for example), perform the resetEE procedure from the ICU3 setup menu. See **Subject 410** for details of this procedure. Roll call fault messages are originated by the ICU3 for display only. They are not broadcast over the databus and cannot be read by ServiceLink or any other data analysis tool.

Fault codes originated by other devices are echoed on the display when the ignition is first turned to ON and the parking brake is set. **Table 16** and **Table 17** identify the most common ECUs that would broadcast these faults.

Fault Code Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
1	Is the fault code from MID 140 on an EPA07 or earlier vehicle, or from SA 23 on an EPA10 vehicle, or some other fault?	MID 140	Use **Table 14** to identify the fault code and the troubleshooting procedure.
		SA 23	Use **Table 15** to identify the fault code and the troubleshooting procedure.
		Other	Go to Step 2.
2	Does the display only show seven dashes (- - - - - - -) or some other message?	Dashes	The ICU has an internal error. Replace the ICU.
		Other Message	Go to Step 3.

Fault Code Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
3	Is the message "nO dATA" or another message showing nO something?	Yes	If the message is "nO dATA" or "nO J1939", the ICU is unable to communicate with any other device on the vehicle. Troubleshoot the databus for loss of function. If the message is something with a 3-letter code, for example "no ENG" there is a roll call fault. A roll call fault will show SID 254 Fail 07 on J1587 systems and SPN 639 FMI 07 on J1939 vehicles. Use **Table 16** for EPA07 and earlier and **Table 17** for EPA10 vehicles to identify the device that is not communicating and causing a roll call fault.
		No	Go to Step 4.
4	Is the vehicle an EPA07 or earlier, or an EPA10?	EPA07 or Earlier	Use **Table 16** to identify the device broadcasting the fault code. Refer to the troubleshooting subject for that device to determine how to proceed for the fault it is broadcasting.
		EPA10	Use **Table 17** to identify the device broadcasting the fault code. Refer to the troubleshooting subject for that device to determine how to proceed for the fault it is broadcasting.

Table 13, Fault Code Diagnosis

EPA07 ICU J1587/J1708 Fault Codes MID 140 (ICU)			
SID/PID	**FMI**	**Description**	**Behavior**
P168	1	Low System Voltage	The vehicle voltage measured by the ICU is less than 10.5 volts.
ACTION: Troubleshoot the vehicle charging system. Test the alternator, and test for voltage drop in the alternator cables and battery cables. If the vehicle is equipped with a remote sense circuit to the alternator, check the fuse for circuit 123E.			
S240	12	EEPROM Memory Fault	The ICU has an internal memory fault. The display may show "- - - - - - -", (seven dashes).
ACTION: Replace the ICU.			
S254	12	Internal Electronics Fault	The ICU microprocessor or other internal critical electronics has a fault. The display may show "- - - - - - -", (seven dashes).
ACTION: Replace the ICU.			

Table 14, EPA07 ICU J1587/J1708 Fault Codes MID 140 (ICU)

ICU3 J1939 Fault Codes SA 23 (ICU)				
SPN	**FMI**	**Conn/Pin**	**Description**	**Behavior**
96	5	D1 (+) D2 (–)	Fuel Level Circuit Open	The resistance between pins D1 and D2 is greater than 298 ohms. The gauge will point to empty.
ACTION: Use the troubleshooting procedure in **Table 8** beginning at Step 4.				
96	6	D1 (+) D2 (–)	Fuel Level Circuit Short	The resistance between pins D1 and D2 is less than 23.5 ohms. The gauge will point to empty.
ACTION: Disconnect the fuel level sensor connector at the sending unit. Turn the ignition to ON and check the fault code display. If the fault code for fuel level circuit short (FMI 6) is still active, locate and repair the short in circuit 47 between the LBCU and the fuel level sender. Otherwise use the troubleshooting procedure in **Table 8** beginning at Step 5.				

Troubleshooting

ICU3 J1939 Fault Codes SA 23 (ICU)				
SPN	FMI	Conn/Pin	Description	Behavior
168	1	n/a	Low Voltage	The ICU is measuring a system voltage of less than 12.0 volts.
ACTION: Troubleshoot the charging system and test the battery cables for voltage drop.				
177	6	C12 (–) C13 (+)	Transmission Temp Sensor Short	The resistance between pins C12 and C13 is less than 70 ohms. The gauge will point full scale.
ACTION: Troubleshoot for a shorted transmission temperature sensor and for a short to ground in circuit 30.				
628	12	n/a	ICU Internal Memory Fault	The ICU has an internal memory fault. The display may show "- - - - - - -", (seven dashes).
ACTION: Replace the ICU.				
629	12	n/a	ICU Internal Electronics Fault	The ICU microprocessor or other internal critical electronics has a fault. The display may show "- - - - - - -", (seven dashes).
ACTION: Replace the ICU.				
639	7	n/a	Roll Call Fault	Any other J1939 device that the ICU expects on the network but is not broadcasting will generate a fault code. The source address will be of the device that the ICU is not receiving messages from. Note that this is actually an ICU-generated fault code.
ACTION: If a device has been removed from the vehicle or if a used ICU is installed, a roll call reset must be performed. Use the "rESEt EE" Screen in the setup menu. If a J1939 device is not broadcasting due to an error, use the troubleshooting procedure for that device to determine the cause of it going off-line.				
2567	0	n/a	Excessive Broadcast Announce Messages (BAM)	Another device on the J1939 databus is transmitting an excessive number of fault messages that are intended for the ICU.
ACTION: Use ServiceLink or scroll through the fault codes that the ICU3 displays to determine which controller has many fault codes. Use the appropriate troubleshooting procedures for that controller to repair its system.				

Table 15, ICU3 J1939 Fault Codes SA 23 (ICU)

EPA07 and Earlier Displayed Fault Messages			
Message	System With Active Fault	Message	System With Active Fault
ECU 128	Engine Control Unit (engine control module)	rAd 221	Radio
tCU 130	Transmission Control Unit	tSU 223	Transmission Shift Unit
AbS 136	Antilock Brake System	CEL 231	Cellular Phone
SAT 181	Satellite Communications (Qualcomm)	SbU 232	Seat Belt Unit (SPACE/Airbag system)
CdU 219	Collision Detection Unit (VORAD)	SYS ###	Generic—system not defined in this table

Table 16, EPA07 and Earlier Displayed Fault Messages

EPA10 Displayed Fault Messages			
Message	System With Active Fault	Message	System With Active Fault
EnG 0	Engine Controller – CPC	EEC 61	Aftertreatment Control Module (ACM)
EnG 1	Engine Controller – MCM	CEL 74	Cellular Phone
tCU 3	Transmission Control Unit	SAt 75	Satellite Communications
tSU 5	Transmission Shift Unit	rAd 76	Radio
AbS 11	Antilock Brake Controller	SbU 83	Seat Belt Unit – Space
CdU 42	Collision Detection Unit	SYS ###	Where ### is the source address of any other J1939 controller that is not in this list.

Table 17, EPA10 Displayed Fault Messages

Gauge Backlighting Diagnosis

Gauge Backlighting Diagnosis			
Test	Test Description	Test Result	Action
1	Is only the air pressure gauge module backlighting affected?	Yes	Go to Test 2.
		No	Go to Test 3.
2	Remove the three air gauge module screws and carefully lift the air gauge module off the back of the ICU while leaving the ribbon cable connected. Inspect the ribbon cable connection to the ICU PC board. Make sure that it is plugged in all the way. Is the ribbon cable connection OK?	Yes	Replace the air pressure gauge module.
		No	Repair the ribbon cable connection as necessary.
3	Turn the headlights on and press the dimmer switch to increase then decrease the backlighting. Is the backlighting inoperative for all of the HVAC, headlight switch, and ICU?	Yes	Use the troubleshooting procedures in **Section 54.30**.
		ICU only	Go to Test 4.
4	Access the back of the ICU and disconnect the two electrical connectors. Turn the headlights on. Measure voltage between pins A1(+) and D3(–) while increasing and decreasing the dimmer switch. The voltage should range between approximately 2.5V (dim) and 11.3V (full bright). Does the measured voltage change through this range?	Yes	Replace the ICU.
		No	Go to Test 4.

Gauge Backlighting Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
5	Measure voltage between pin A1(+) and a known good ground while increasing and decreasing the dimmer switch. The voltage should range between approximately 2.5V (dim) and 11.3V (full bright). Does the measured voltage change through this range?	Yes	Repair backlighting ground circuit to ICU pin D3 as necessary.
		No	Troubleshoot circuit 29A between BHM and ICU. Repair the wiring as appropriate.

Table 18, Gauge Backlighting Diagnosis

LCD Diagnosis

LCD Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the headlights ON with the ignition in the OFF position. Does the LCD light up and display mileage?	Yes	Go to Test 2.
		No	Turn the ignition to ON without starting the engine. If the LCD initializes all segments, then use the troubleshooting procedure in **Section 54.12** to troubleshoot the ICU wakeup feature. Otherwise go to Step 2.
2	Turn the ignition to ON without starting the engine. Do all the segments of the LCD turn on and initialize or is the LCD completely inactive?	Only some segments initialize	Replace the ICU.
		LCD completely inactive	Test for battery power-on pin D14, ignition power-on pin D15, and the ground-on pin D13. Troubleshoot and repair any fault with these circuits as necessary. If these circuits are all working, replace the ICU.
		All segments initialize	There is no problem with the LCD or there is a more appropriate symptom to troubleshoot such as backlighting.

Table 19, LCD Diagnosis

Mode/Reset Button Diagnosis

Mode/Reset Button Diagnosis			
Test No.	**Test Description**	**Test Result**	**Action**
1	Press the Mode/Reset button several times to determine if it is sticking or binding. Does the button move freely?	Yes	Go to Step 2
		No	Remove the button cap and inspect for foreign substance in the shaft area. Clean as necessary. It may be necessary to remove the air gauge module from the ICU to clean the shaft and grommet.

Mode/Reset Button Diagnosis			
Test No.	**Test Description**	**Test Result**	**Action**
2	Follow the procedure in **Subject 110** to remove the gauge module from the ICU. Note the ribbon cable connection when the gauge module is removed. Is the ribbon cable completely connected?	Yes	Replace the gauge module.
		No	Properly connect the ribbon cable and test the Mode/Reset button operation. Install the repaired ICU if it now works. Otherwise replace the gauge module.

Table 20, Mode/Reset Button Diagnosis

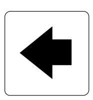
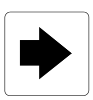
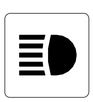
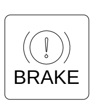
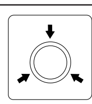
Warning and Indicator Lamps Diagnosis

Use **Table 21** to determine if an indicator lamp has a power-on bulb check and how it is activated.

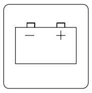
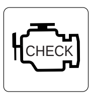
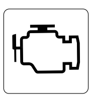
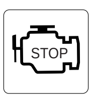
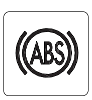
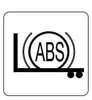
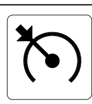
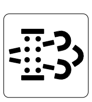
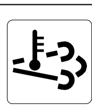
The ICU does not set fault codes for lamps that are inoperative. If an indicator does not illuminate, use the **Activation** and **Control Pin** information to determine if the problem is the signal that drives the lamp or if the lamp itself is inoperative.

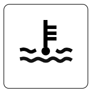
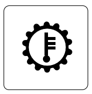
For data-driven indicators, use ServiceLink to monitor the data for the indicator. If the ICU does not illuminate an indicator when ServiceLink shows that it is on, there is a problem with the indicator. The top row lamps are replaceable, for the others, the ICU must be replaced.

For indicators that are hardwired, monitor the voltage at the ICU input pin. Use the **Activation** column information to determine when the indicator should illuminate. Troubleshoot the vehicle wiring harness or switch as necessary. Indicators with a power-on bulb check (even though they are LEDs) are confirmed to work.

ICU Warning and Indicator Lamps					
Lamp	**Symbol**	**Bulb Check**	**Activation**	**Control Pin**	**Buzzer Operation**
Left Turn Signal		NO	Lamp is ON when 12V is applied to the control pin or lamp is ON when commanded over J1939 from the BHM.	C8	Beep sound when control pin is at 12V or commanded from the BHM
Right Turn Signal		NO	Lamp is ON when 12V is applied to the control pin or lamp is ON when commanded over J1939 from the BHM.	D8	Beep sound when control pin is at 12V or commanded from the BHM
High Beam		NO	Lamp is ON when 12V is applied to the control pin or lamp is ON when commanded over J1939 from the BHM.	A12	None
Park Brake		YES	Lamp is ON when commanded over J1939 from the ABS Controller or from the BHM.	Data	Buzzer active when vehicle speed is greater than 2 MPH (3 km/h) (Uses speed data from ABS)
Low Air Pressure		YES	Lamp is ON when commanded over J1939 from the BHM.	Data	Buzzer active whenever lamp is ON

Troubleshooting

ICU Warning and Indicator Lamps					
Lamp	**Symbol**	**Bulb Check**	**Activation**	**Control Pin**	**Buzzer Operation**
Battery Voltage		YES	Lamp is ON when system voltage has been less than 12 volts for longer than 40 seconds. The message is broadcast by the engine controller.	Data	Buzzer active whenever lamp is ON
Fasten Seat Belt		YES	If pin D10 is not hardwired to seat belt buckle, lamp is ON for 15 seconds at power up only. If pin D10 is hardwired, the bulb check is 3 seconds long and the lamp is OFF when ground is applied to the control pin.	N/A or D10	Friendly chime for 10 seconds when pin D10 is hardwired if park brake is off and seat belt is not latched
Check Engine Lamp (CEL)		YES	Lamp is ON when ground is applied to the control pin or Lamp is ON/ FLASHING when commanded by the engine controller.	C15 and Data	None
Malfunction Indicator Lamp (MIL)		YES	Lamp is ON when ground is applied to the control pin.	A9	None
Stop Engine		YES	Lamp is ON when ground is applied to the control pin or Lamp is ON/ FLASHING when commanded by the engine controller.	C16 and Data	None
Tractor ABS		YES	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the tractor ABS controller. The lamp will also be ON when the ICU is not receiving data from the ABS controller.	B11 and Data	None
Trailer ABS		YES	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the trailer ABS controller.	D12 and Data	None
Cruise Control		YES	Lamp is ON when the cruise enable switch is in the ON position.	B9	None
DPF Regeneration (REGEN)		YES	Lamp is ON when ground is applied to the control pin or Lamp is ON/ FLASHING when commanded by the engine controller.	C10 and Data	None
High Exhaust Temperature		YES	Lamp is ON when ground is applied to the control pin or Lamp is ON/ FLASHING when commanded by the engine controller.	A5 and Data	None
Water In Fuel (EPA10)		NO	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the engine controller.	C9 and Data	None

ICU Warning and Indicator Lamps					
Lamp	**Symbol**	**Bulb Check**	**Activation**	**Control Pin**	**Buzzer Operation**
Low Oil Pressure		YES	Lamp is ON when commanded by the engine controller. The lamp will latch on for a minimum of 30 seconds.	Data	Buzzer is active when the lamp is ON
High Coolant Temperature		YES	Lamp is ON when commanded by the engine controller. The lamp will latch on for a minimum of 30 seconds.	Data	Buzzer is active when the lamp is ON
High Transmission Temperature		YES	Lamp is ON when ground is applied to the control pin or Lamp is ON/ FLASHING when commanded by the transmission controller or the retarder.	A4 and Data	None
Option 1 (Air Filter Restriction)	AIR FILTER	NO	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the BHM SA 33, SPN 5086.	C14 and Data	None
Option 2 (Washer Fluid Low)	WASH FLUID	NO	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the BHM SA 33, SPN 80.	A6 and Data	None
Option 3 (EPA07 and earlier - Intake Heater EPA10 - Wait to Start)	INTAKE HEATER WAIT TO START	NO	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the engine controller SA 0, SPN 1081.	A7 and Data	None
Option 4 (EPA07 and Earlier - Water In Fuel)	WATER IN FUEL	NO	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the BHM SA 33 SPN 5086.	A8 and Data	None
Option 5 (Wheel Spin)	WHEEL SPIN	NO	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the BHM SA 33.	B1 and Data	None
Option 6 (Low Water)	LOW WATER	NO	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the engine controller SA 0.	B8 and Data	None
Option 7 (Check Transmission)	CHECK TRANS	YES	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the transmission controller	C11 and Data	None
Option 8 (Idle Management)	IDLE MGMT	NO	Lamp is ON when ground is applied to the control pin.	C1 and Data	None

Troubleshooting

ICU Warning and Indicator Lamps					
Lamp	**Symbol**	**Bulb Check**	**Activation**	**Control Pin**	**Buzzer Operation**
Option 9	—	NO	—	D4 and Data	None

Table 21, ICU Warning and Indicator Lamps

In-gauge lamps illuminate during power-on initialization, and when the data to the gauge indicates a fault, or an out-of-normal-range condition. An illuminated in-gauge lamp indicates that immediate attention is necessary.

ICU In-Gauge Warning Lamps			
Lamp	**Bulb Check**	**Input Source**	**Activation**
Low Fuel Level	YES	Fuel Level Sensor	When the fuel level is less than 1/8th of a tank, the lamp will be ON. A 60-second delay applies to activation and deactivation unless ignition power is cycled and it will immediately indicate for the measured value.
Low DEF Level	YES	Data	When the DEF level is less than 15% of tank capacity, the low DEF light will be ON. When DEF level is less than 5% of tank capacity, the low DEF light will flash.

Table 22, ICU In-Gauge Warning Lamps

Seat Belt Lamp Troubleshooting			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition to OFF, then turn it to the ON position without starting the engine. Does the lamp always stay on, never illuminate, or only illuminate for 3 to 15 seconds at power-on?	Always ON	The ICU has learned that it is in a vehicle that has a seat belt buckle switch hardwired to ICU pin D10. Troubleshoot for an open seat belt buckle switch or open circuit between the seat belt buckle and the ICU. If the vehicle does not have a hardwired seat belt buckle switch, perform the ICU3 reset EE procedure as described in **Specifications 400**.
		Never ON	The lamp itself is open circuit, replace the ICU3.
		Only ON 3 to 15 seconds	A vehicle that does not have a hardwired seat belt buckle switch illuminates the lamp for 15 seconds at power-on. A vehicle that has a hardwired seat belt switch illuminates this lamp for 3 seconds at power-on and then will turn it off if the seat belt input is at ground (seat belt connected). There is no problem with the lamp circuit if it operates according to this description.

Table 23, Seat Belt Lamp Troubleshooting

[Figure 1](#) is an overview schematic of the ICU3 as it is connected to the vehicle.

The two ICU3 main cab harness connectors are pink and plug into pins located in the center of the unit on the back. Connector-1 has 24 cavities numbered A1 through A12 and B1 through B12. See Table 1.

Connector-2 has 32 cavities, numbered C1 through C16, and D1 through D16. See Table 2.

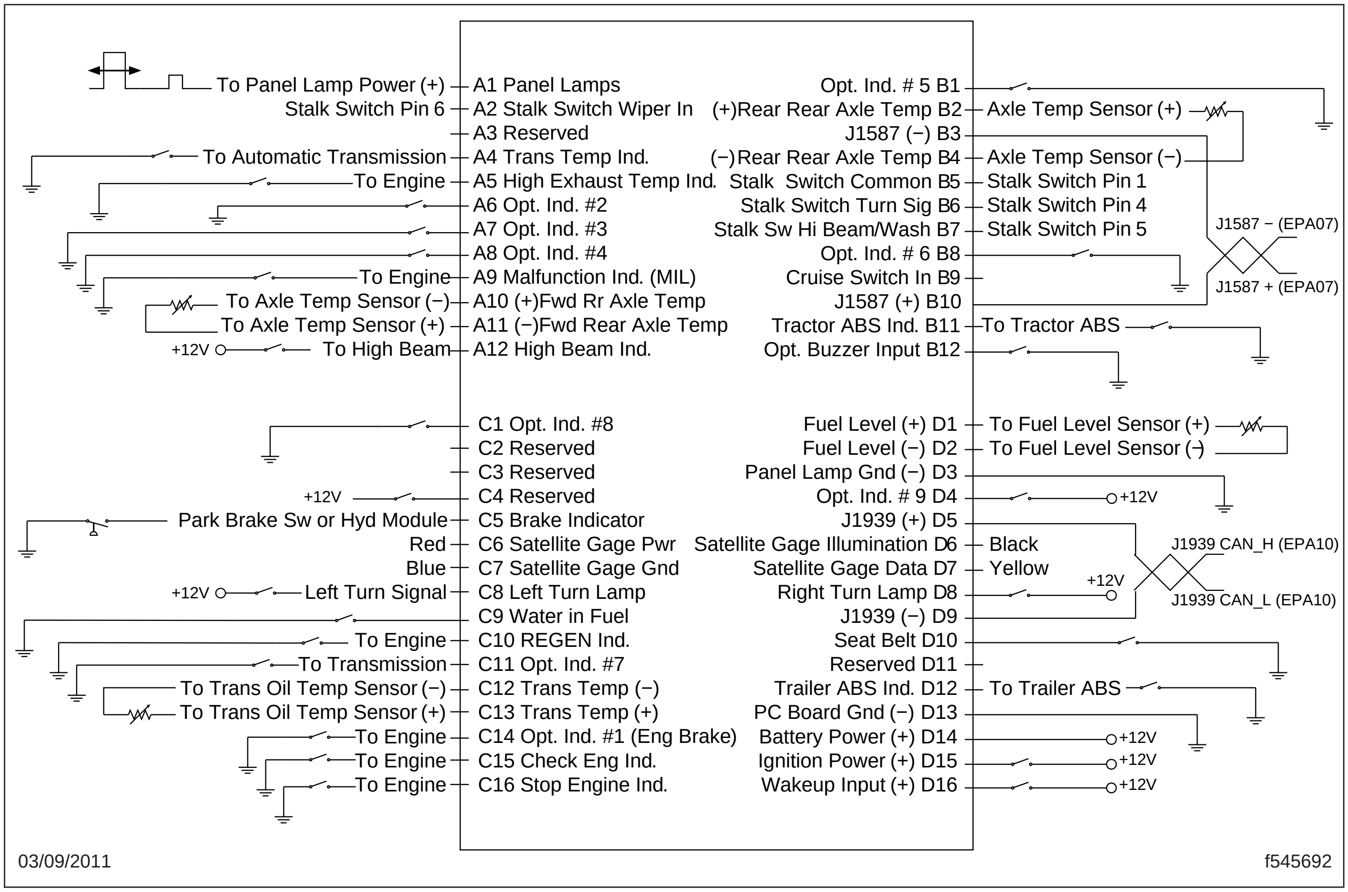


Fig. 1, ICU3 Overview Schematic

Specifications

ICU3 Connector-1 Pin Assignments, Pins A1 Through B12		
Pin	Description	Wire
A1	Panel Backlight Power (+)	29A
A2	Multifunction Turn Signal Switch Wiper Input	473C
A3	Reserved	18B
A4	Transmission High Temperature Indicator	30A
A5	High Exhaust Temperature Indicator	429L
A6	Optional Indicator 2	376T
A7	Preheater Relay 1 Coil Signal (optional indicator 3)	431B1
A8	Optional Indicator 4	—
A9	Malfunction Indicator Lamp (MIL)	400
A10	Fwd Rear-Axle Temperature (+)	42
A11	Fwd Rear-Axle Temperature (–)	42G
A12	High Beam Indicator	222A
B1	Wheel Spin Warning Lamp (optional indicator 5)	376S
B2	Rear Rear-Axle Temperature Sensor (–)	43
B3	J1708 Network (–)	—
B4	Rear Rear-Axle Temperature Sensor (+)	43G
B5	Multifunction Turn Signal Switch Common Input	473
B6	Multifunction Turn Signal Switch Turn Signal Input	473A
B7	Multifunction Turn Signal Switch High Beam/Washer Input	473B
B8	Optional Indicator 6	—
B9	Cruise Control Switch Input	440D
B10	J1708 Network (+)	—
B11	Tractor ABS Indicator	376L
B12	Optional Buzzer Input	29G

Table 1, ICU3 Connector-1 Pin Assignments, Pins A1 Through B12

ICU3 Connector-2 Pin Assignments, Pins C1 Through D16		
Pin	Description	Wire
C1	Optional Indicator 8	E115
C2	Reserved	—
C3	Reserved	—
C4	Reserved	—
C5	Park Brake Indicator	125S
C6	Satellite Gauge Drive Power	Red
C7	Satellite Gauge Drive Gnd	Blue

ICU3 Connector-2 Pin Assignments, Pins C1 Through D16		
Pin	Description	Wire
C8	Left Turn Indicator	38J
C9	Water In Fuel Indicator	286
C10	REGEN Indicator	492J
C11	Wheel Spin Warning Lamp (optional indicator 7)	376S
C12	Transmission Oil Temperature (–)	30G
C13	Transmission Oil Temperature (+)	30
C14	Optional Indicator 1	—
C15	Check Engine Warning Lamp	440A
C16	Stop Engine Warning Lamp	440S
D1	Fuel Level (+)	47
D2	Fuel Level (–)	47G
D3	Panel Backlight Ground (–)	GND
D4	Optional Indicator 9	—
D5	J1939 (+)	1939+
D6	Satellite Gauge Illumination	Black
D7	Satellite Gauge Data	Yellow
D8	Right Turn Indicator	38K
D9	J1939 (–)	1939–
D10	Optional Seat Belt (EPA10)	—
D11	Reserved	—
D12	Trailer ABS Warning Lamp	376F1
D13	ICU System Ground (–)	GND
D14	Battery Power (+)	437
D15	Ignition Power (+)	81C
D16	Headlamp Power (+)	81C

Table 2, ICU3 Connector-2 Pin Assignments, Pins C1 Through D16

Fuel Level Sensor Resistance		
Gauge Reading	Sensor Resistance in Ohms	
	Acceptable Range	Nominal
Empty Stop	244.0 to 249.0	246.5
Empty	232.0 to 239.2	235.6
1/8	190.8 to 196.9	193.8
1/4	149.6 to 154.5	152.1
3/8	126.1 to 129.0	127.5
1/2	102.5 to 103.5	103.0

Specifications

Fuel Level Sensor Resistance		
Gauge Reading	Sensor Resistance in Ohms	
	Acceptable Range	Nominal
5/8	84.4 to 85.7	85.0
3/4	66.2 to 67.8	67.0
7/8	47.8 to 49.2	48.5
Full	29.4 to 30.6	30.0

Table 3, Fuel Level Sensor Resistance

Transmission Oil Temperature Sensor Resistance			
Gauge Temperature in °F	Sensor Resistance in Ohms	Gauge Temperature in °C	Sensor Resistance in Ohms
125	3318	60	2490
163	1626	80	1255
200	837	100	680
238	460	120	390
275	267	140	234
313	162	160	145
350	102	180	95

Table 4, Transmission Oil Temperature Sensor Resistance

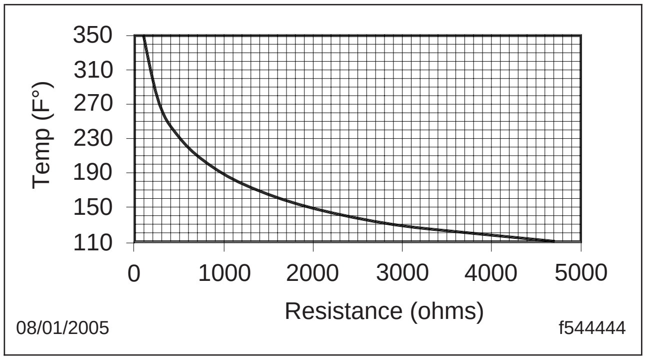


Fig. 2, Transmission Oil Temperature Sensor Resistance (°F)

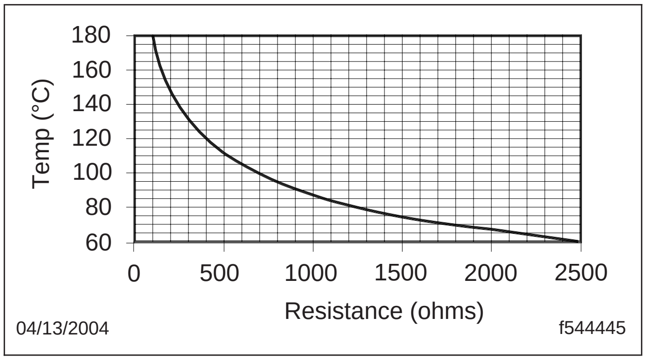


Fig. 3, Transmission Oil Temperature Sensor Resistance (°C)

Axle Oil Temperature Sensor Resistance, Standard Gauge	
Gauge Temperature	Sensor Resistance (ohms)
100°F	5933
125°F	3419
150°F	2079
175°F	1283
200°F	837
225°F	557
250°F	380
275°F	267
300°F	190

Table 5, Axle Oil Temperature Sensor Resistance, Standard Gauge

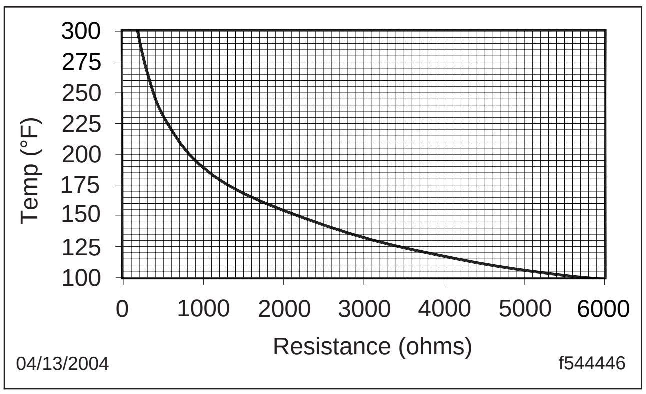


Fig. 4, Axle Oil Temperature Sensor Resistance (°F)

Axle Oil Temperature Sensor Resistance, Metric Gauge	
Gauge Temperature	Sensor Resistance (ohms)
30°C	8060
45°C	4465
60°C	2490
75°C	1503
90°C	915
105°C	595
120°C	390
135°C	267
150°C	185

Table 6, Axle Oil Temperature Sensor Resistance, Metric Gauge

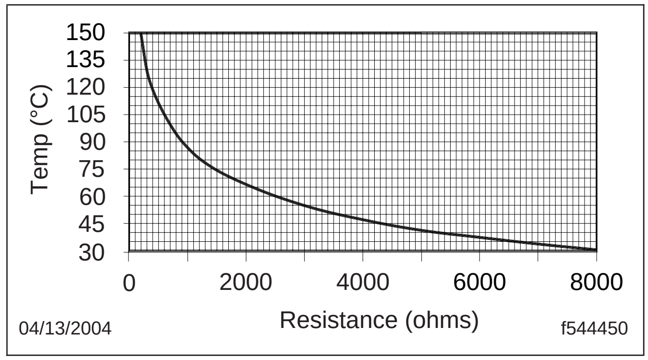


Fig. 5, Axle Oil Temperature Sensor Resistance (°C)

Cummins DEF Level Sensor Resistance	
Sensor Resistance (ohms)	Float Distance (mm) From Top Plate
68	<80
112	80
157	97.6
207	115.2
261	132.8
320	150.4
385	168
485	185.6
539	203.2
629	220.8
731	238.4
847	256
981	273.6
1135	291.2
1316	308.8
1532	326.4
1793	344

Specifications

Cummins DEF Level Sensor Resistance	
Sensor Resistance (ohms)	Float Distance (mm) From Top Plate
2114	361.6
2521	379.2
3052	396.8
3744	414.4
4812	433

Table 7, Cummins DEF Level Sensor Resistance

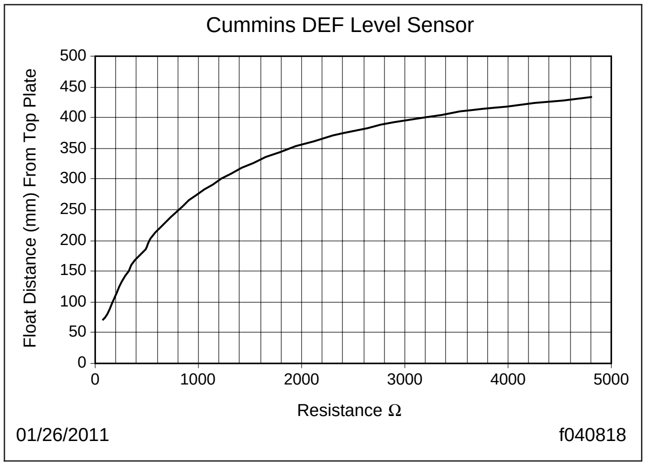


Fig. 6, Cummins DEF Level Sensor Resistance

DDC DEF Level Sensor Resistance	
Sensor Resistance (ohms)	Float Distance (mm) From Top Plate
19804	54
13764	74
10284	93
8074	113
6534	132
5384	152
4497	172
3799	191
3237	211
2762	230
2375	250
2035	270

DDC DEF Level Sensor Resistance	
Sensor Resistance (ohms)	Float Distance (mm) From Top Plate
1748	289
1493	309
1272	328
1076	348
902	368
744	387
601	407
471	426
353	446
240	<446

Table 8, DDC DEF Level Sensor Resistance

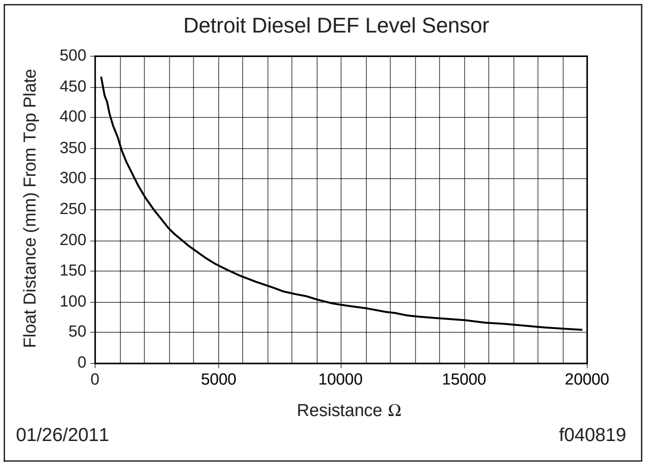


Fig. 7, DDC DEF Level Sensor Resistance

rESEt EE Procedure

To reset the EE memory in the ICU3, perform the following procedure. This will reset the memory to "forget" all the devices that have been learned.

1. Press the mode/reset button until the display shows SEt UP.
2. Hold the button until the display makes a beep and the word service appears. Depending on the options programmed, some other word may also appear.
3. Hold the button until the display shows rESEt.

4. Press the button once quickly so that EE is also displayed. This is the rESEt EE screen.
5. Hold the button until donE is displayed.

Mode/Reset Switch Functions

Use the following flow charts to cycle through the Mode/Reset switch functions and screens.

See **Fig. 1**, **Fig. 2**, **Fig. 3**, **Fig. 4**, **Fig. 5**, **Fig. 6**, and **Fig. 7**.

Mode/Reset Switch Functions

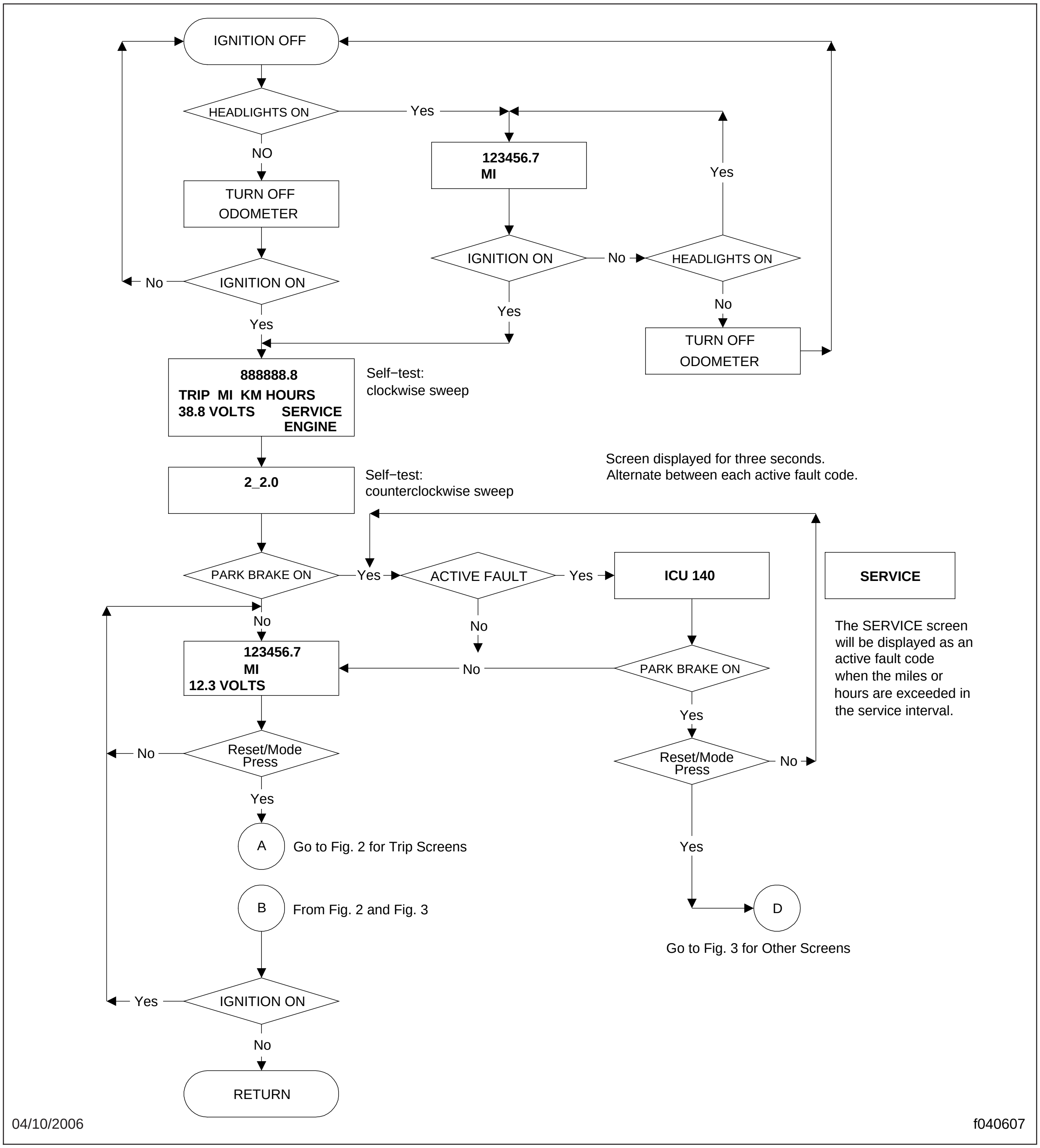


Fig. 1, Mode/Reset Switch Start Sequence

Mode/Reset Switch Functions

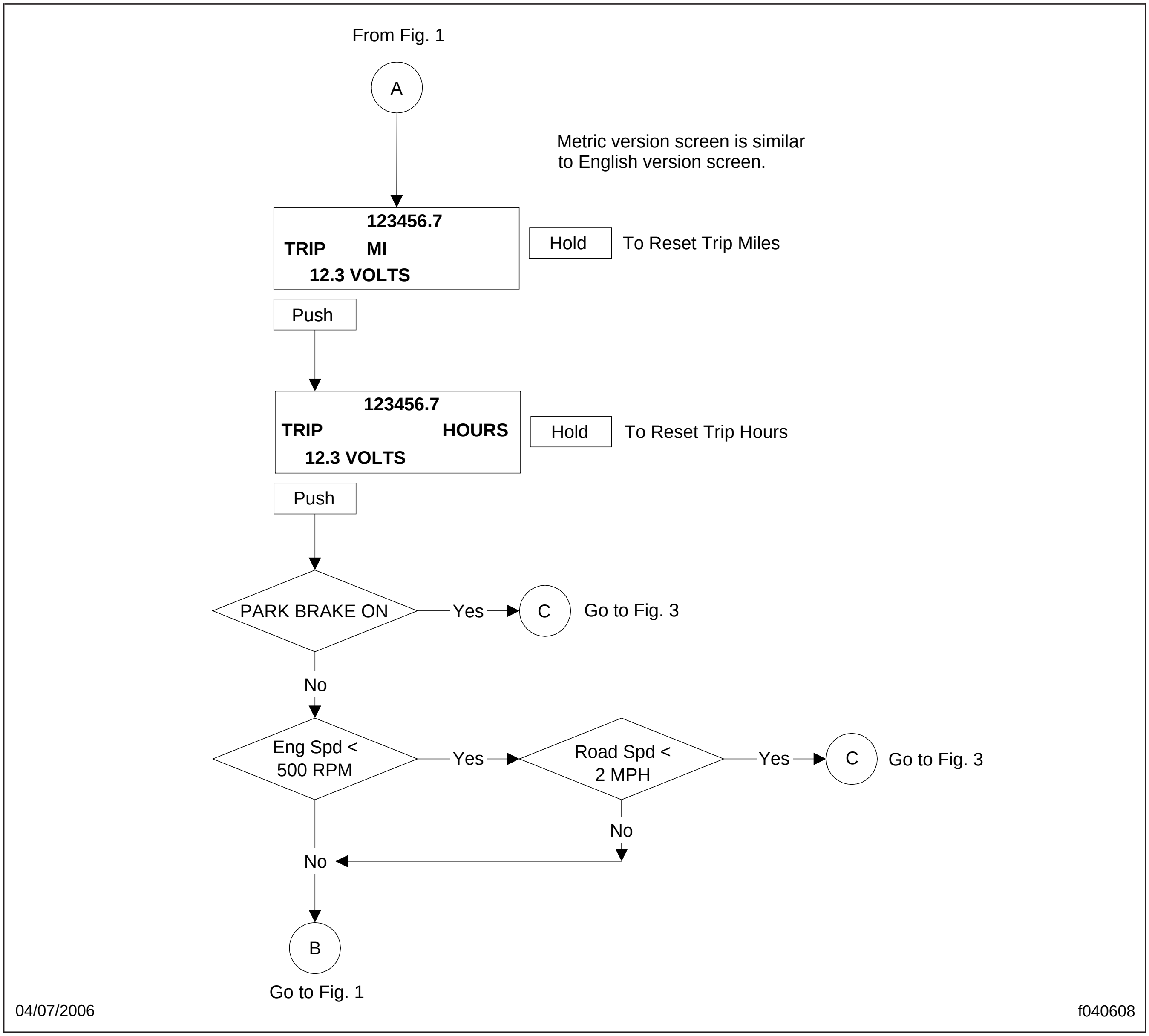


Fig. 2, Mode/Reset Switch Trip Screens

Mode/Reset Switch Functions

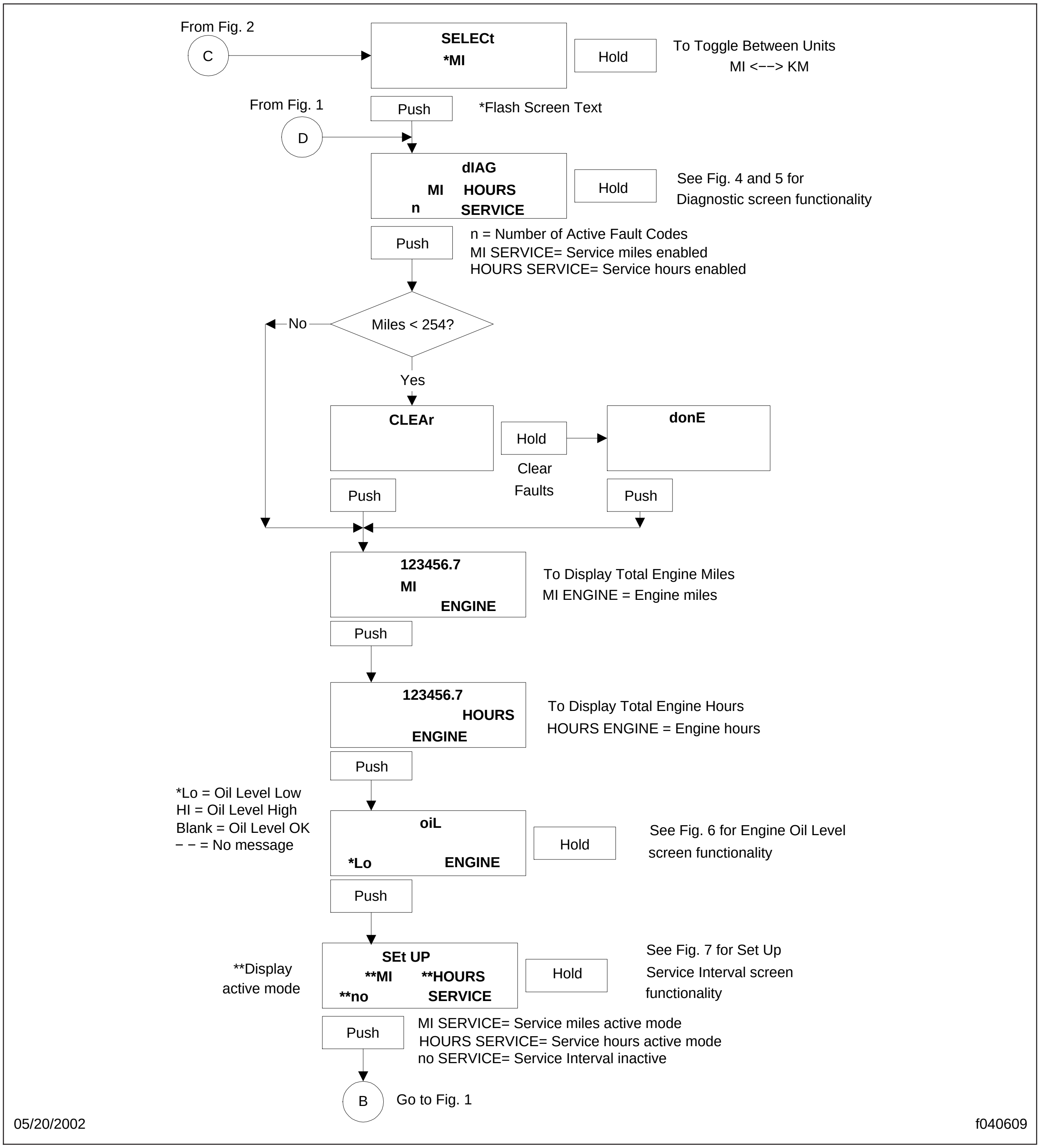


Fig. 3, Mode/Reset Switch Engine Miles and Service Screens

Mode/Reset Switch Functions

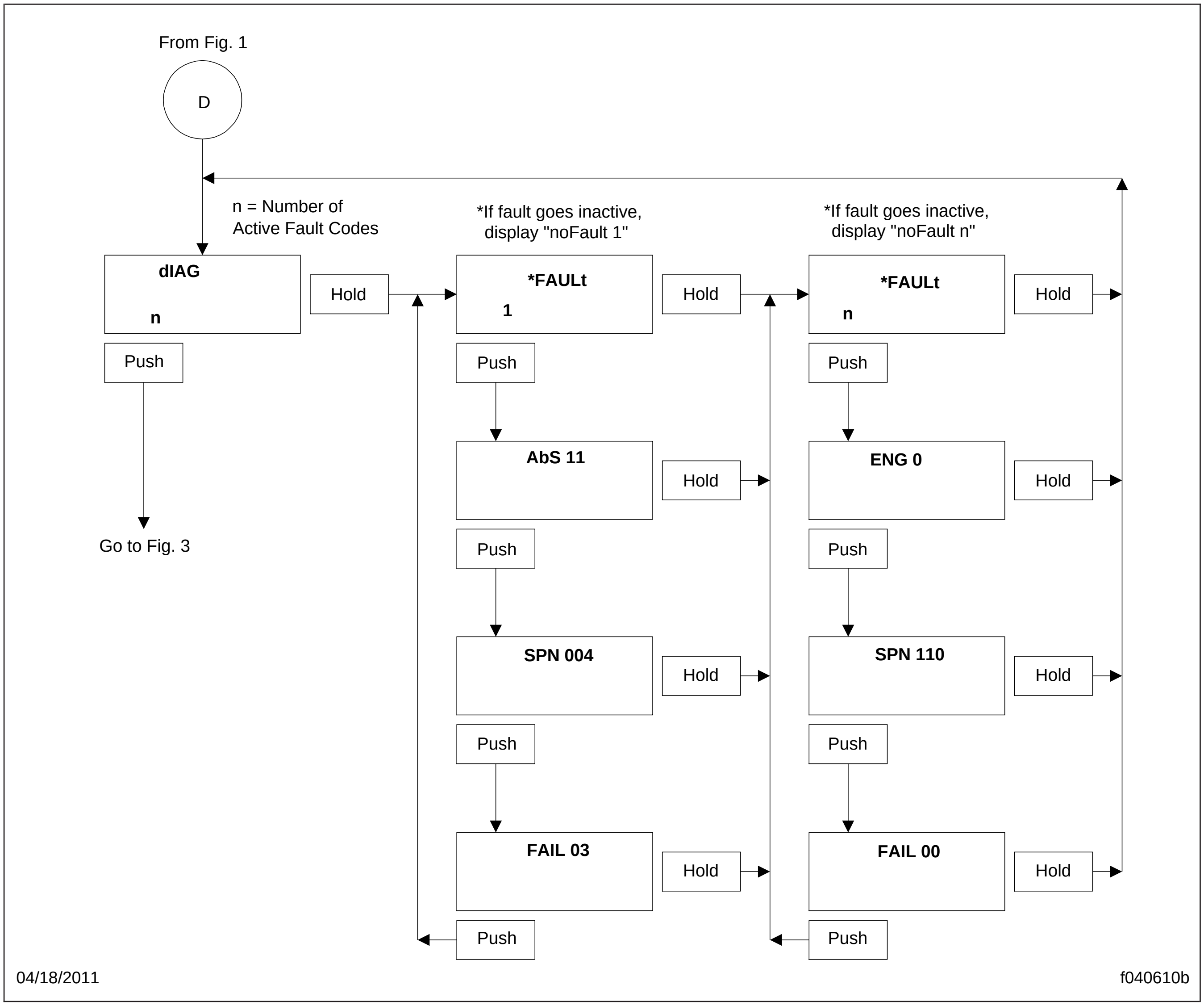


Fig. 4, Mode/Reset Switch Fault Screens

Mode/Reset Switch Functions

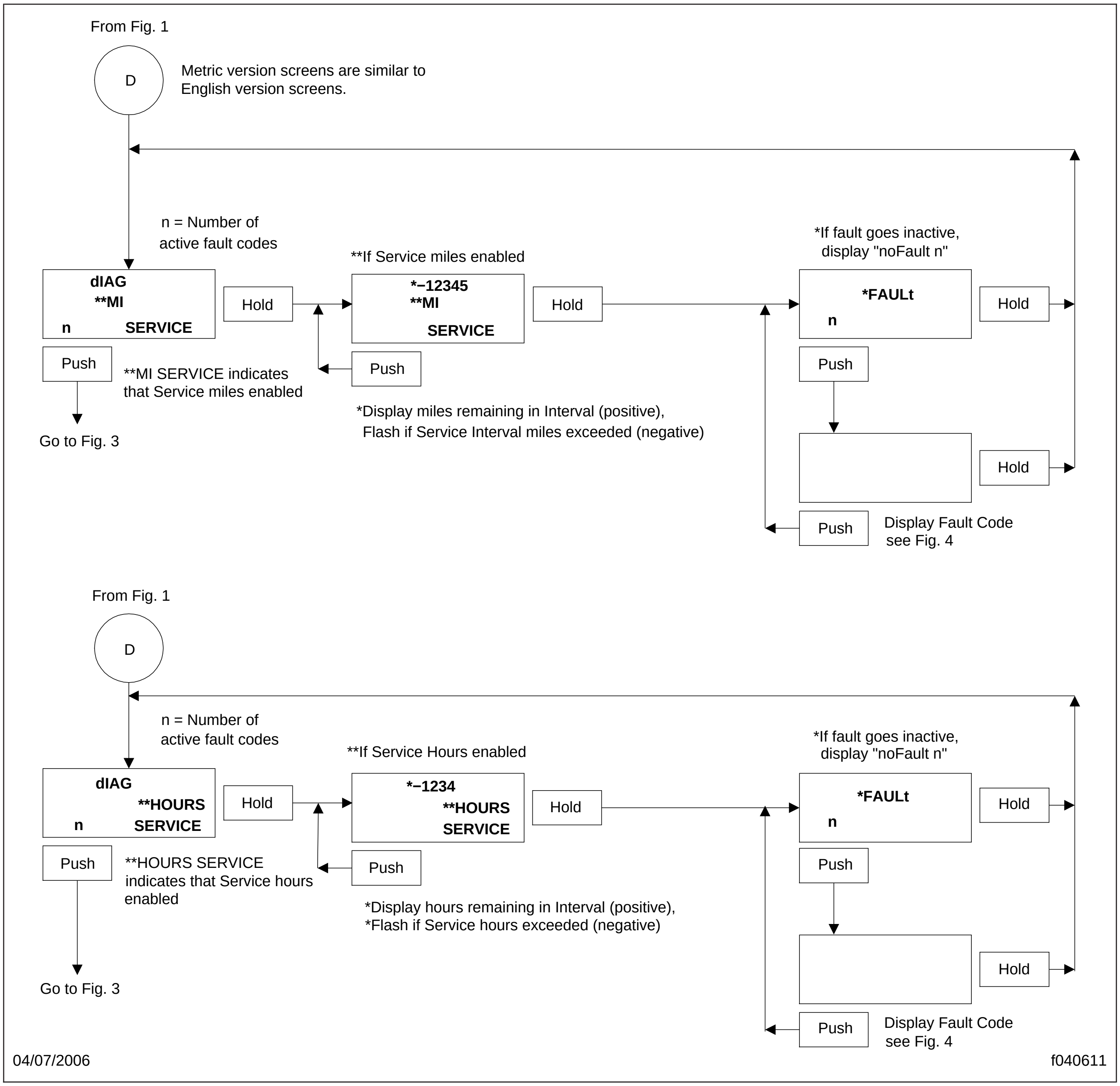


Fig. 5, Mode/Reset Switch Service Screens

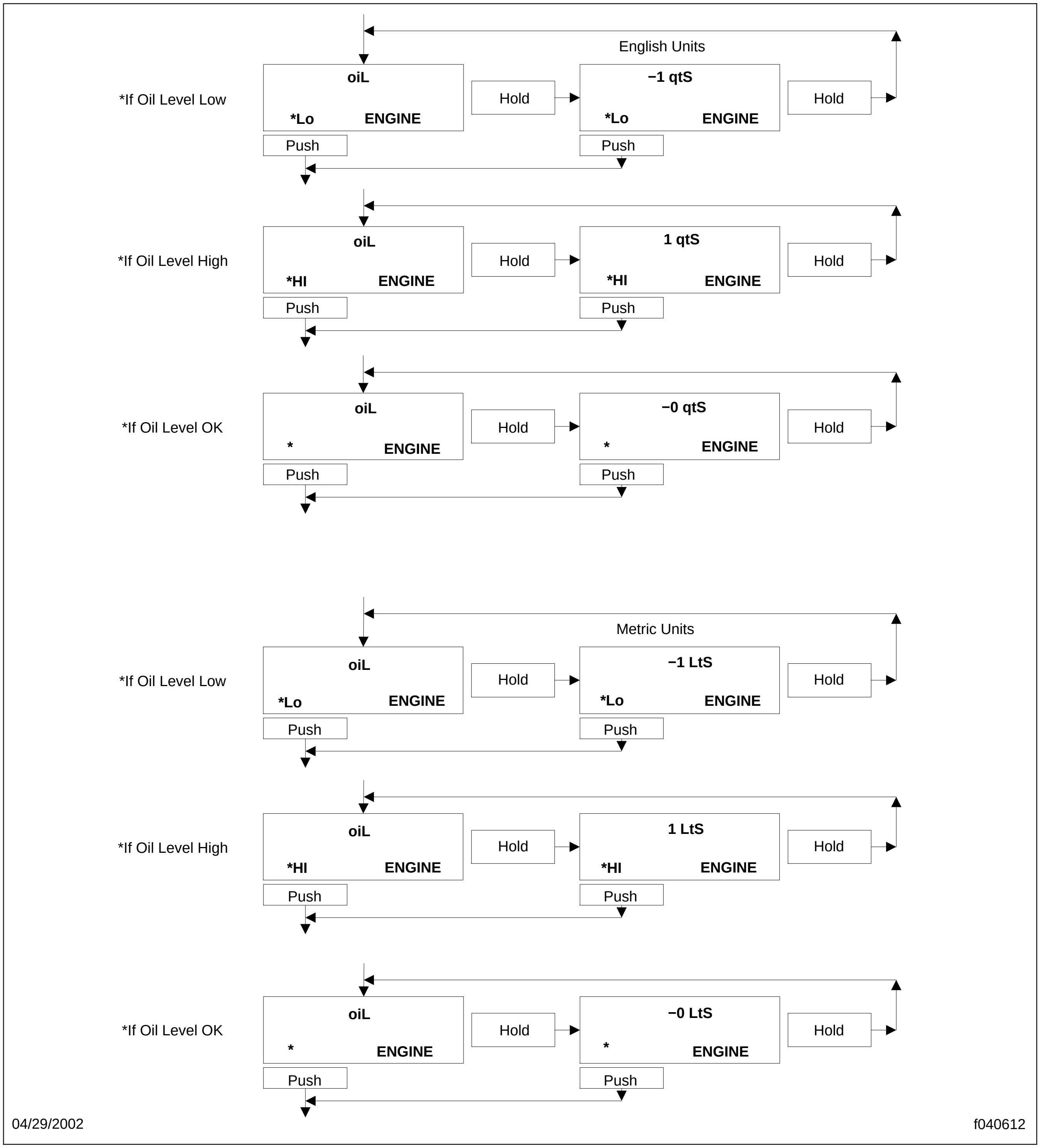


Fig. 6, Mode/Reset Switch Oil Level Screens

Mode/Reset Switch Functions

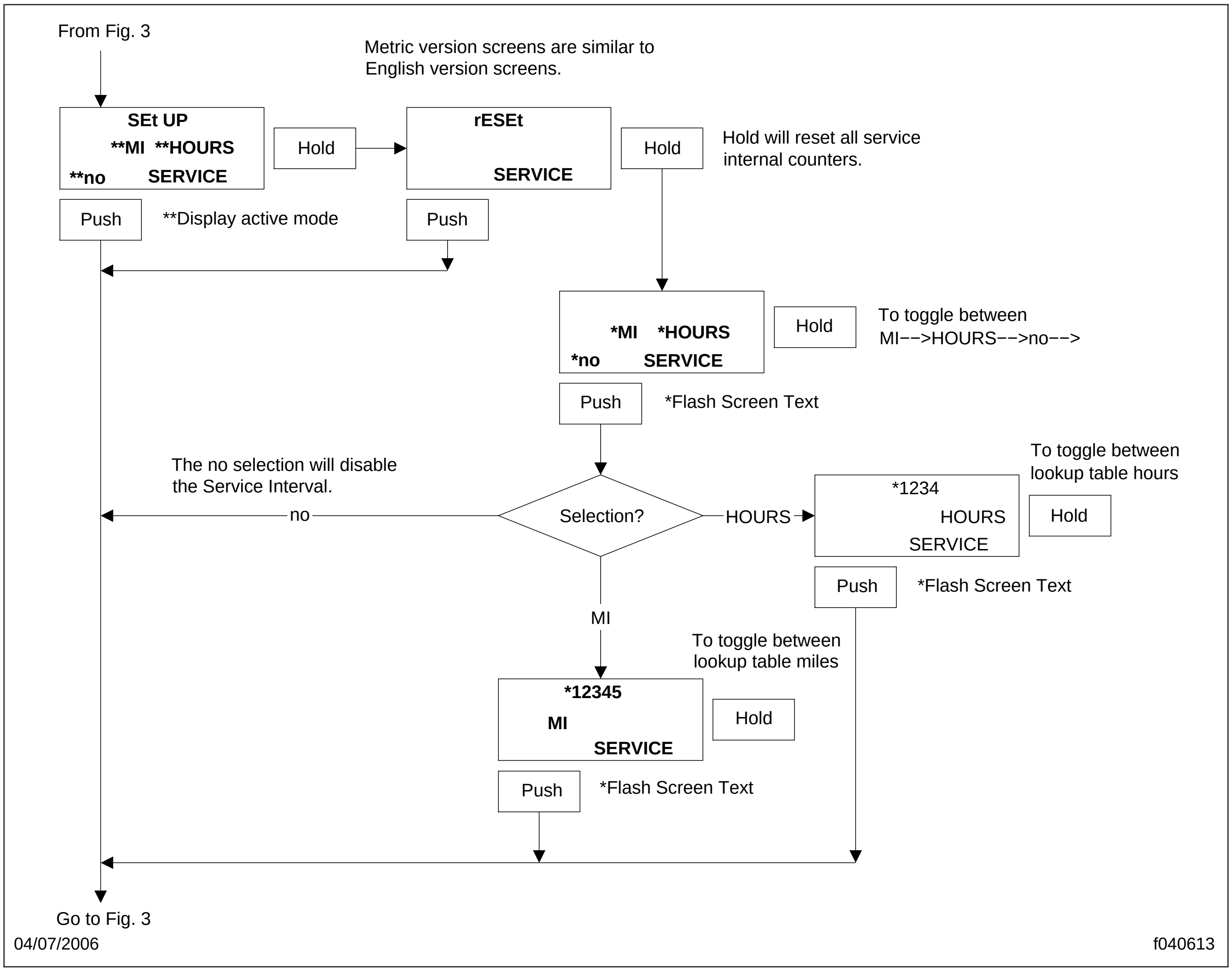


Fig. 7, Mode/Reset Switch Reset and Toggle Screens

General Information

The Bulkhead Module (BHM) is the primary module of the M2 electrical system. The BHM controls the operation of the other multiplex modules in the system along with a variety of other vehicle components either directly or indirectly.

The Bulkhead Module is mounted on the cab side of the frontwall and extends through an opening in the frontwall into the engine side of the frontwall. The BHM is located slightly below and outboard of the steering column.

The BHM has four harness connections on the engine side of the frontwall and three harness connections on the cab side. Connections on the engine side include:

- forward chassis harness
- engine harness
- two frontwall harnesses

Connections on the cab side include up to three dash harness connectors.

For more information about the M2 electrical system, see **Section 54.00** "Electrical System."

Awake State and Sleep State

The Bulkhead Module, Chassis Module (CHM), and instrumentation control unit (ICU) are, as a group, in an awake state or a sleep state depending on vehicle conditions. When any of these electronic components are awakened, the remaining components wake up if they are not already awake. When the BHM, CHM, and ICU are in an awake state, the odometer reading appears on the dash driver display screen.

One of the following actions will cause the BHM, CHM, or ICU to go into an awake state:

- opening the door switch
- turning on the hazard switch
- turning the ignition switch to any position other than off
- turning on the headlight/parking light switch
- depressing the service brake

The BHM, CHM, and ICU will enter a sleep state when they are no longer actively controlling any outputs or responding to any inputs and all other power down requirements are met.

To check whether or not the electrical system is going into a sleep state:

1. Enter the vehicle.
2. Shut the doors.
3. Remove your foot from the service brake.
4. Make sure the ignition switch and hazard switch are in the off position.

NOTE: One minute after these conditions are met, and provided that one of the parameters in **Table 1** has not been added to the BHM, the odometer reading should disappear. If the odometer reading does not disappear, the electrical system is not going to sleep.

Parameters		
Parameter Part Number	**Description**	**Hours**
26-01017-002	Switched Center Pin Power	24
26-01019-003	Exterior Lighting	16,667
26-01019-004	Exterior Lighting	16,667
26-01019-005	Exterior Lighting	16,667

Table 1, Parameters

Replacement

IMPORTANT: It is normally not necessary to replace the Bulkhead Module (BHM). Removing and installing the BHM should be a last resort to solving electrical problems, unless the unit needs replacing due to physical damage.

Follow troubleshooting procedures in this section to solve electrical problems before replacing the Bulkhead Module. If troubleshooting indicates a malfunction of the module, try flashing the parameters and the software before replacing the module. For flashing instructions, see **Subject 110**.

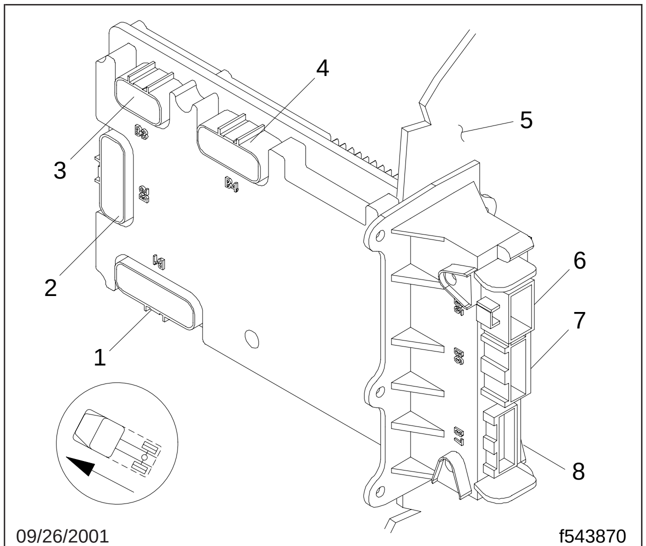
Also check the external wiring. See **Troubleshooting 300**.

See **Section 54.00, Subject 050**, for information about the M2 electrical system and **Section 54.00, Troubleshooting 300**, for information on troubleshooting the entire M2 electrical system.

1. Open the hood.
2. Disconnect the negative leads from the batteries.

NOTE: The bulkhead module is located on the frontwall slightly below and outboard of the steering column. See **Fig. 1**.

3. Disconnect bulkhead harnesses B1 through B4 from the engine side of the frontwall. See **Fig. 2**.
4. Disconnect bulkhead harnesses B5 through B7 from the bulkhead module on the cab side of the frontwall. See **Fig. 3**.
5. Remove the tread plate from the driver door entry.
6. Remove the kick panel from the left side of the driver footwell.
7. Remove the five Torx® capscrews that secure the BHM to the cab side of the frontwall, then remove the BHM by pulling it through the opening into the cab.
8. Place the BHM through the frontwall opening from the cab side, then secure it with five Torx capscrews and torque them 48 lbf·in (540 N·cm).
9. Install the kickpanel in the left side of the driver footwell and secure it with Torx capscrews.

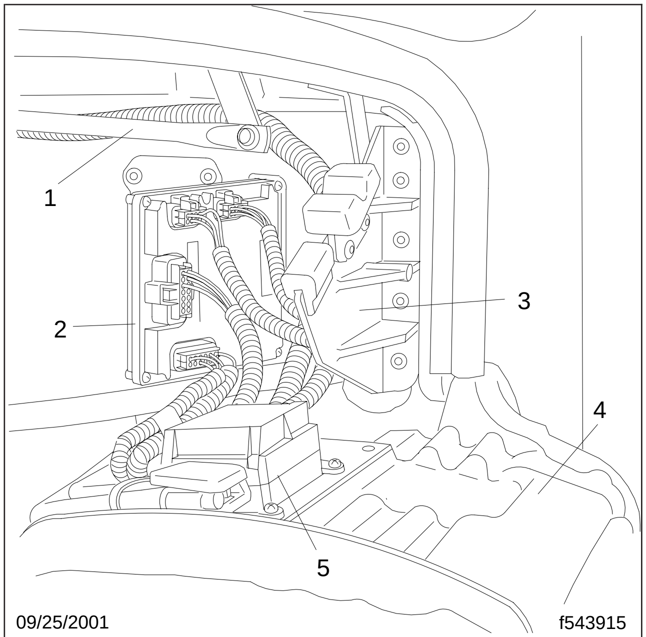


1. B1, Forward Chassis Harness
2. B2, Engine Harness
3. B3, Frontwall Harness
4. B4, Frontwall Harness
5. Frontwall
6. B5, Dash Harness
7. B6, Dash Harness
8. B7, Dash Harness

Fig. 1, Bulkhead Module Harness Connections

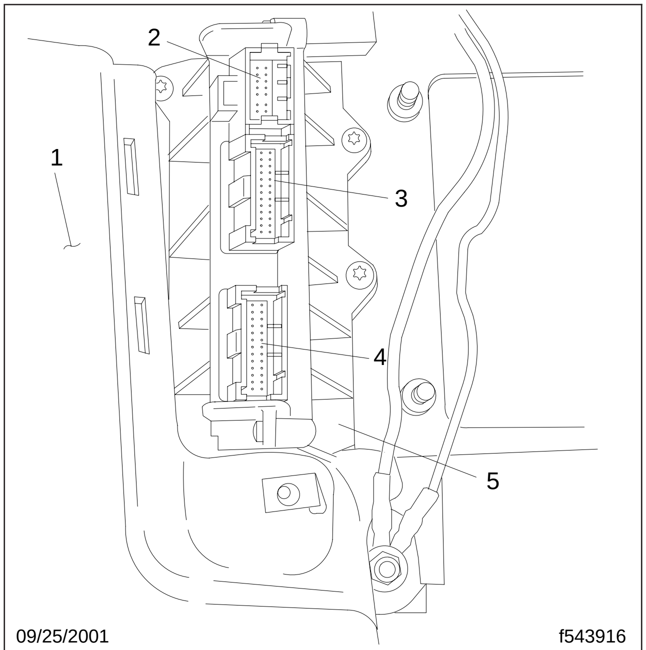
10. Install the tread plate at the driver door entry.
11. Connect the bulkhead harnesses B5 through B7 to the BHM on the cab side of the frontwall.
12. Connect the bulkhead harnesses B1 through B4 to the BHM on the engine side of the frontwall.
13. Connect the batteries.
14. Close the hood.
15. For instructions on flashing the BHM, see **Subject 110**.

Bulkhead Module Replacement



1. Wiper Linkage Arm
2. Bulkhead Module
3. Hood Support Bracket
4. Quarter Fender
5. Power Distribution Module

Fig. 2, Bulkhead Module from the Engine Side



1. Driver Footwell Kick Panel
2. B5, Dash Harness
3. B6, Dash Harness
4. B7, Dash Harness
5. Bulkhead Module

Fig. 3, Bulkhead Module from the Cab Side

Flashing the Bulkhead Module

When the Bulkhead (BHM) is flashed, both the application software and reference parameters are flashed to the BHM.

Flashing is done in ServiceLink® in the BHM "Flashing" screen. See the *ServiceLink User Guide* for more information on flashing.

Normally, it is only necessary to flash the BHM in one of the following situations:

- When, as a last resort in the troubleshooting process, the BHM is suspected of being faulty. This is to confirm that the problem is hardware related.
- When a replacement BHM is installed on a vehicle that originally had software version 6.1.

In all other situations, it is only necessary to perform the "Refresh Features List" in ServiceLink in the "Features" screen. This applies the appropriate reference parameters to the BHM specific to the vehicle. See the *ServiceLink User Guide* for more information on refreshing the features list.

NOTE: Pay particular attention to the first "NOTICES" screen when you open ServiceLink. This screen will contain timely details on matters pertaining to successfully flashing and applying reference parameters to the BHM.

IMPORTANT: The following is a general description of how the M2 electrical system works. ServiceLink® is the diagnostic tool for troubleshooting the M2 electrical system. For specific circuit and pin information for how the vehicle is wired, go to the Configuration screen in ServiceLink and select the specific function in which you are interested. To troubleshoot specific inputs and outputs of this system, go to the Templates screen in ServiceLink and select the template for the function in which you are interested.

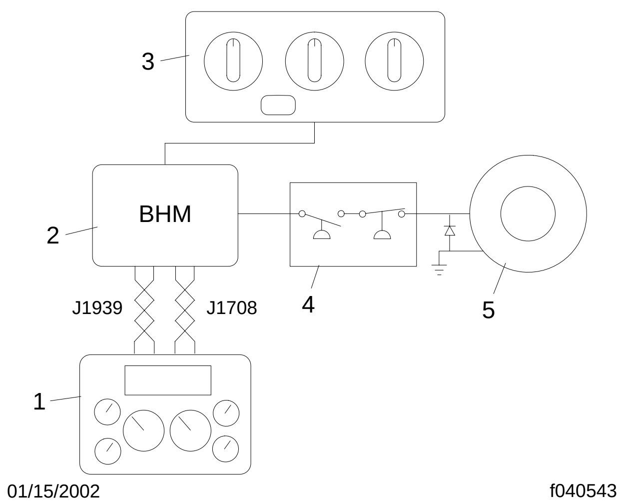
Contents of Subject 300

A/C Clutch Function

Description

The HVAC control panel does not directly control the clutch on the A/C compressor. When the driver selects the A/C button and other control conditions are met, the control panel sends an A/C clutch request signal to the Bulkhead Module (BHM). See **Group 83** for more information. Upon receiving this input, the BHM responds by activating the A/C compressor clutch. See **Fig. 1**.

Compressor cycling is handled in the same manner. When the control panel determines that the compressor needs to be cycled, it sends a signal to the BHM. The BHM reacts by cycling the compressor. The



1. Instrumentation Control Unit
2. Bulkhead Module
3. HVAC Control Panel
4. Binary Pressure Switch
5. A/C Compressor Clutch

Fig. 1, A/C Clutch Function

HVAC control panel contains the logic to prevent the compressor from cycling more than four times per minute.

The BHM monitors the A/C compressor clutch wiring and is capable of detecting a shorted circuit when the A/C clutch is being driven. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink.

Input and Output Conditions

Table 1 displays the A/C clutch system inputs to the BHM and how it will react to these inputs.

Fault Conditions

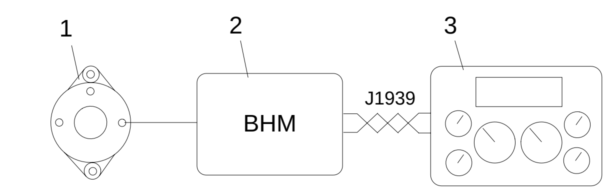
Table 2 displays how the BHM handles faults that it encounters in the A/C clutch system. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on either or both the J1939 and J1708 datalinks until the ignition switch is off.

Alternator Charging Function (optional)

Description

NOTE: Some vehicles will have the alternator "I" terminal hardwired directly to the NO CHARGE light on the ICU.

The NO CHARGE light on the Instrumentation Control Unit (ICU) is an optional indicator used to alert the operator to the presence of a problem with the alternator. The Bulkhead Module (BHM) monitors a voltage input from the "I" terminal on the alternator and sends a J1939 message to the ICU to report the status of the alternator. This message is used by the ICU to turn the NO CHARGE light on or off. The NO CHARGE light illuminates when the BHM does not detect voltage at the "I" terminal of the alternator. Once illuminated, the NO CHARGE light remains on until the BHM detects 14 volts at the alternator "I" terminal. Once off, the NO CHARGE light remains off until the BHM detects 0 volts at the alternator "I" terminal. See **Fig. 2**.



1. Alternator
2. Bulkhead Module
3. Instrumentation Control Unit

Fig. 2, Alternator Charging Function

Input and Output Conditions

Table 3 displays the charging system inputs to the BHM and how it will react to these inputs.

Backup Function

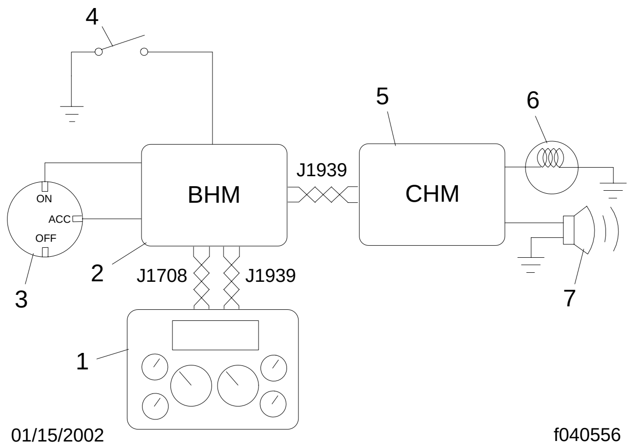
Description

The backup function provides a warning to anyone standing behind when the vehicle begins to back up. When the transmission is placed into reverse gear, the Bulkhead Module (BHM) sends a J1939 message to the Chassis Module (CHM) activating the backup lights and alarm.

The BHM is capable of detecting short circuits in the backup lights/alarm wiring on the CHM. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink.

Input and Output Conditions

Activation of the backup lights/alarm is different depending on the transmission type. A manual transmission uses a standard switch to tell the BHM when the transmission is in reverse. Automatic transmissions send a J1939 message to the BHM when they are placed into reverse gear. See **Fig. 3** and **Fig. 4**. Also see **Table 4**.



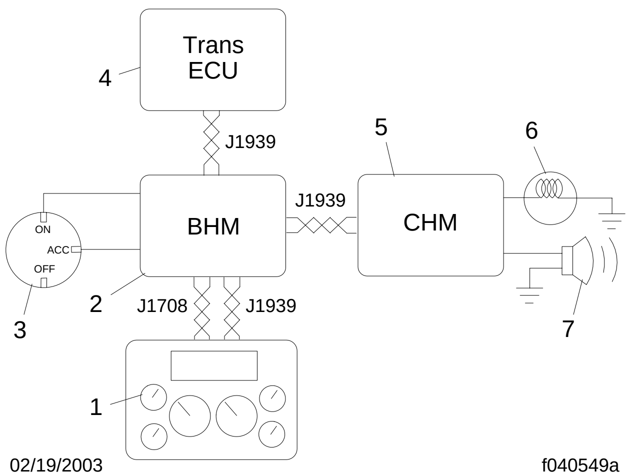
1. Instrumentation Control Unit
2. Bulkhead Module
3. Ignition Switch
4. Reverse Switch
5. Chassis Module
6. Backup Lights
7. Optional Backup Alarm

Fig. 3, Backup Function, Manual Transmission

Table 5 displays the backup lights and alarm system inputs to the BHM and how it will react to these inputs.

Fault Conditions

Table 6 displays how the BHM handles faults it encounters in the backup lights and alarm system. The reference parameters that program the BHM determine whether or not a fault code is broadcast. There-



1. Instrumentation Control Unit
2. Bulkhead Module
3. Ignition Switch
4. Transmission ECU
5. Chassis Module
6. Backup Lights
7. Optional Backup Alarm

Fig. 4, Backup Function, Automatic Transmission

fore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on either or both the J1939 and J1708 datalinks until the ignition switch is turned off.

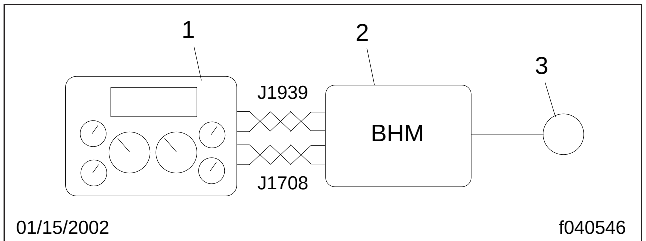
On vehicles with automatic transmissions, the BHM has the following **additional** J1939 fault messages. Any J1939 fault message may be transmitted until the ignition switch is turned off. See **Table 7**.

Cigar Lighter Function

Description

The cigar lighter provides 12 volt power (up to 15 amps) to any device plugged into it. The Bulkhead Module (BHM) supplies power at this port regardless of the position of the ignition switch.

The BHM is capable of detecting short circuits in the cigar lighter wiring. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 5**.



1. Instrumentation Control Unit
2. Bulkhead Module
3. Cigar Lighter

Fig. 5, Cigar Lighter Function

Fault Conditions

Table 8 displays how the BHM handles faults that it encounters in the cigar lighter system. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on either or both the J1939 and J1708 datalinks until the ignition switch is turned off.

Clutch Switch Function

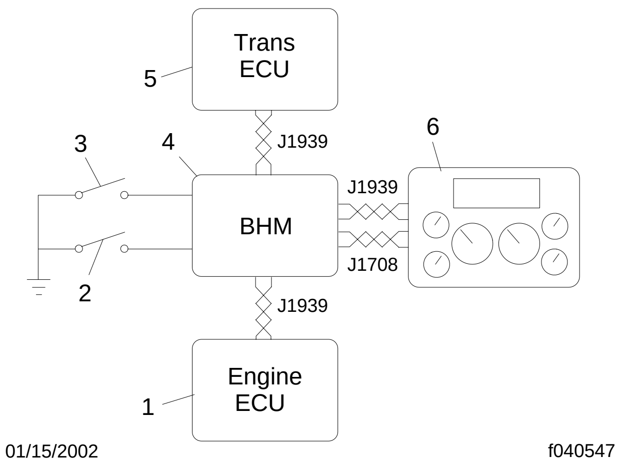
Description

NOTE: Only vehicles with a manual or three-pedal automated mechanical (AMT) transmission are equipped with a clutch pedal. The clutch switch is integrated into the clutch pedal assembly. See **Section 54.25** for information on the starter control system including the bottom-of-clutch switch input.

The Bulkhead Module (BHM) reads the position of the top-of-clutch and bottom-of-clutch switches. The top-of-clutch switch information is broadcast over J1939 datalink for use by the engine and, optionally, other ECUs. The bottom-of-clutch switch input is used for a starter system interlock; the switch position information is not broadcast for other ECUs. The BHM, engine ECU, and transmission ECU use the clutch position status information as inputs for systems such as starting and cruise control.

While both switches are mounted to the clutch pedal assembly, they are activated at different times during the operation of the clutch. As the clutch pedal is pressed towards the floor, the top-of-clutch switch changes from closed to open, and the BHM transmits this information over the J1939 datalink. Based on this information, if the cruise control is active the engine ECU will turn it off. As the clutch pedal reaches the floor, the bottom-of-clutch switch is activated. It will change from open to closed, as the pedal is fully depressed.

The BHM monitors the top- and bottom-of-clutch switch wiring and is capable of detecting error conditions. Faults discovered by the BHM will be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 6**.



1. Engine ECU
2. Bottom-of-Clutch Switch (normally open)
3. Top-of-Clutch Switch (normally closed)
4. Bulkhead Module
5. Transmission ECU
6. Instrumentation Control Unit

Fig. 6, Clutch Switch Function

Input and Output Conditions

Table 9 displays the clutch switch system inputs to the BHM and how it will react to these inputs.

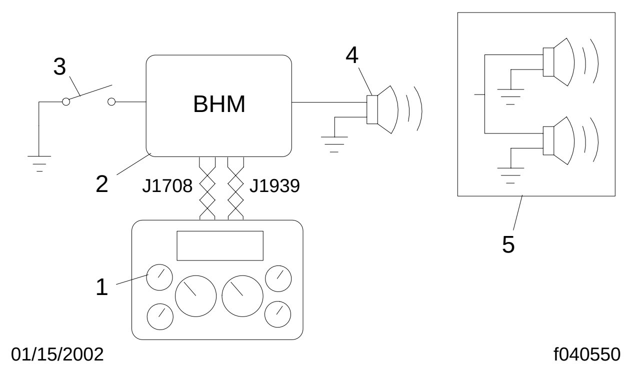
Fault Conditions

Table 10 displays how the BHM handles faults it encounters in the clutch switch system. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on either or both the J1939 and J1708 datalinks until the ignition switch is turned off.

Horn (electric) Function

Description

The Bulkhead Module (BHM) controls the horn. A single horn is standard; dual horns are optional. There is no change in functionality between single and dual horns. When the driver activates the horn switch, the circuit is completed and grounds the signal line to the BHM. The BHM activates the horn circuit as long as the signal line is grounded. The BHM is capable of detecting short conditions. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 7**.



1. Instrumentation Control Unit
2. Bulkhead Module
3. Horn Switch
4. Horn
5. Dual Horns (optional)

Fig. 7, Horn (electric) Function

Input and Output Conditions

Table 11 indicates how the horn should react based on the inputs from the signal line.

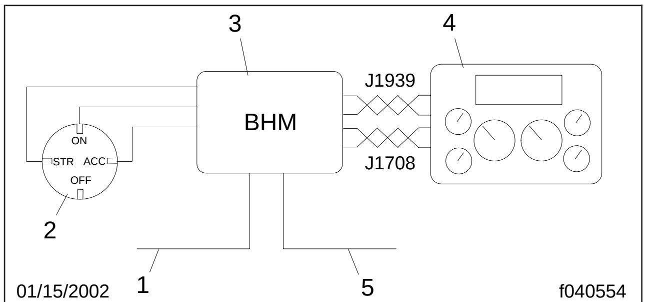
Fault Conditions

Table 12 displays how the BHM will handle faults that it encounters in the electric horn system. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on either or both the J1939 and J1708 datalinks until the horn switch is off.

Ignition System

Description

The ignition system is made up of multiple components. The Bulkhead Module (BHM) takes input from the ignition switch and uses the information to crank the starter and to supply ignition and accessory power to the vehicle. See **Fig. 8**.



1. Accessory Power (12V+)
2. Ignition Switch
3. Bulkhead Module
4. Instrumentation Control Unit
5. Ignition Power (12V+)

Fig. 8, Ignition System Function

Ignition System, Accessory Power Function

Description

The Bulkhead Module (BHM) continuously monitors the position of the ignition switch to determine if the accessory power outputs should be energized. Accessory power is provided to the HVAC control panel and the radio. Separate power feeds are used for each of the accessory outputs.

The BHM is capable of detecting shorted circuits in the accessory power outputs. Faults discovered by the BHM will be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 8**.

Input and Output Conditions

Table 13 displays the accessory power system inputs to the BHM and how it reacts to these inputs.

Fault Conditions

Table 14 displays how the BHM will handle faults it encounters in the accessory power system. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on either or both the J1939 and J1708 datalinks until the ignition switch is turned off.

Ignition System, Ignition Power Function

Description

The Bulkhead Module (BHM) continuously monitors the position of the ignition switch to determine if the ignition power outputs should be energized. Ignition power is provided to the following components:

- antilock brake system electronic control unit (ABS ECU)
- instrumentation control unit (ICU)
- engine ECU
- transmission ECU
- vehicle control unit (VCU), if equipped

Separate power feeds are used for each of the ignition outputs.

The BHM is capable of detecting shorted circuits in the ignition power outputs. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 8**.

Input and Output Conditions

Table 15 displays the ignition power system inputs to the BHM and how it will react to these inputs.

Fault Conditions

Table 16 displays how the BHM handles faults it encounters in the ignition power system. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on either or both the J1939 and J1708 datalinks until the ignition switch is turned off.

Ignition System, Ignition Switch Function

Description

The ignition switch has four positions: off, accessory, on, and start. The Bulkhead Module (BHM) continuously monitors the position of the ignition switch and broadcasts this information on the J1939 datalink. There are three circuits that run from the ignition switch to the BHM. One is for the accessory position, one is for the on position, and one is for the start position.

The BHM monitors the ignition switch wiring and is capable of detecting error conditions in the ignition switch circuits. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See Fig. 8.

Input and Output Conditions

Table 17 displays how the BHM reacts given the status of the ignition switch.

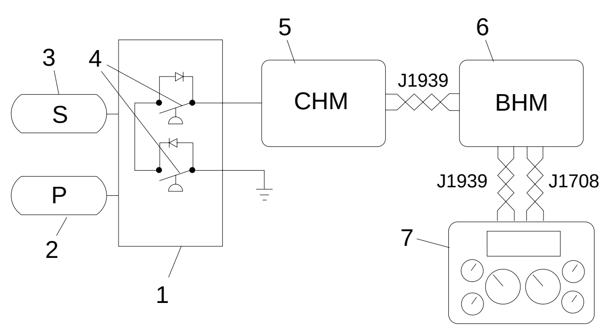
Fault Conditions

Table 18 displays ignition switch circuit conditions that will create a fault. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on either or both the J1939 and J1708 datalinks until a valid ignition switch status is detected.

Low Air Pressure Warning Function

Description

The Chassis Module (CHM) monitors the low air pressure switches and sends a J1939 message to the Bulkhead Module (BHM) indicating the switch status. The BHM sends a J1939 message to the instrumentation control unit (ICU) indicating whether the low air pressure warning light should be on or off. The ICU alerts the driver when the air pressure in the primary or secondary air systems is below 65 to 75 psi (450 to 520 kPa) by illuminating a telltale indicator. There are two normally open pressure switches wired in series in the air management unit (AMU) pressure switch module. On vehicles equipped with an auxiliary air valve assembly (AAVA), these switches are located in the air lines, inside the cab near the center of the dash. Both switches must close in order to complete the circuit to the CHM to change the low air pressure warning status from on to off. See Fig. 9. Faults detected by the BHM may be reported over J1939 and/or J1708 and may be viewed through ServiceLink.



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1. Air Management Unit (AMU) or Stand Alone Switches
2. Primary Air
3. Secondary Air
4. Low Air Pressure Switches
5. Chassis Module
6. Bulkhead Module
7. Instrumentation Control Unit

Fig. 9, Low Air Pressure Warning Function

Input and Output Conditions

Table 19 displays the low air pressure warning inputs to the BHM and how it will react to these inputs.

Fault Conditions

Table 20 displays how the BHM handles faults that it encounters in the low air pressure warning system. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on either or both the J1939 and J1708 datalinks.

NOTE: This fault also occurs when the CHM is unable to determine the switch status. This does not necessarily mean that the low air pressure switches are faulty.

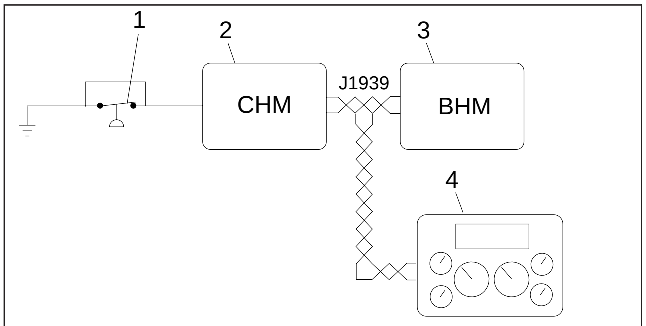
Park Brake (pneumatic) Function

Description

The Chassis Module (CHM) monitors the park brake switch and sends a J1939 message to the Bulkhead Module (BHM). The park brake switch is located in the air line, inside the cab near the center of the dash on vehicles equipped with an auxiliary air valve assembly (AAVA), and in the air management unit (AMU) valve on vehicles equipped with an AMU. The BHM sends the park brake status via a J1939 message to the instrumentation control unit (ICU). The park brake status is also broadcast over the J1939 datalink for other ECUs to use. The ICU alerts the operator when the parking brake is engaged. When the park brake is not set and the driver's door is open, the ICU will chime. See Fig. 10. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink.

Input and Output Conditions

Table 21 displays the park brake system inputs to the BHM and how it will react to these inputs.



1. Park Brake Pressure Switch
2. Chassis Module
3. Bulkhead Module
4. Instrumentation Control Unit

Fig. 10, Park Brake (pneumatic) Function

Fault Conditions

Table 22 displays how the BHM handles faults that it encounters in the park brake system. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 and/or J1708 datalinks.

NOTE: This fault also occurs when the CHM is unable to determine the switch status. This does not necessarily mean that the park brake pressure switch is faulty.

Wake Function

See Subject 050 for general information on the awake state and sleep state of the Bulkhead Module (BHM).

Wake-Up Initiation

The Bulkhead Module (BHM) wakes up the Chassis Module (CHM), Expansion Module (EXM), and Switch Expansion Module (SEM) by pulling the wake circuits from 12V down to approximately 4V. The EXM and SEM are optional.

The wake circuits remain active at 4V only as long as one or more of the inputs that initiate a wake remain active. See Fig. 11 for wake circuit connectivity and inputs that initiate a wake.

The BHM wakes up the instrumentation control unit (ICU) by applying 12V to its wake circuit.

The BHM initiates other modules to wake up when one or more of the following inputs to the BHM is active:

- driver door open
- passenger door open (optional input)
- headlight switch on
- hazard lights switch on
- ignition switch on

The CHM initiates a wake to the BHM, which in turn wakes all other modules when the:

- service brakes are applied.

When any of the above initiating inputs are inactive, the wake circuits float back to approximately 12V (except the wake circuit between the BHM and ICU). The ICU wake circuit remains active at 12V until the system goes to sleep.

Sleep Initiation

When the inputs that initiate a wake are inactive for 60 seconds, the BHM signals the modules to go to sleep by sending a message via J1939. The BHM also causes the ICU to go to sleep by removing power from its wake circuit.

NOTE: One minute after these conditions are met, and provided that one of the parameters in Table 23 has not been added to the BHM, the odometer reading should disappear. If the odometer reading does not disappear, the electrical system is not going to sleep.

Troubleshooting Quick Checks

If the ICU chimes when the door is opened, check for an open or short to power in the wake circuit between the BHM and CHM—the BHM cannot determine the park brake status and assumes it is not set while the door is open.

If the ICU does not display the odometer when the door is opened, check fuse 20 and check for an open in the BHM to ICU wake circuit.

To thoroughly check wake functionality, follow the troubleshooting procedures in Table 24.

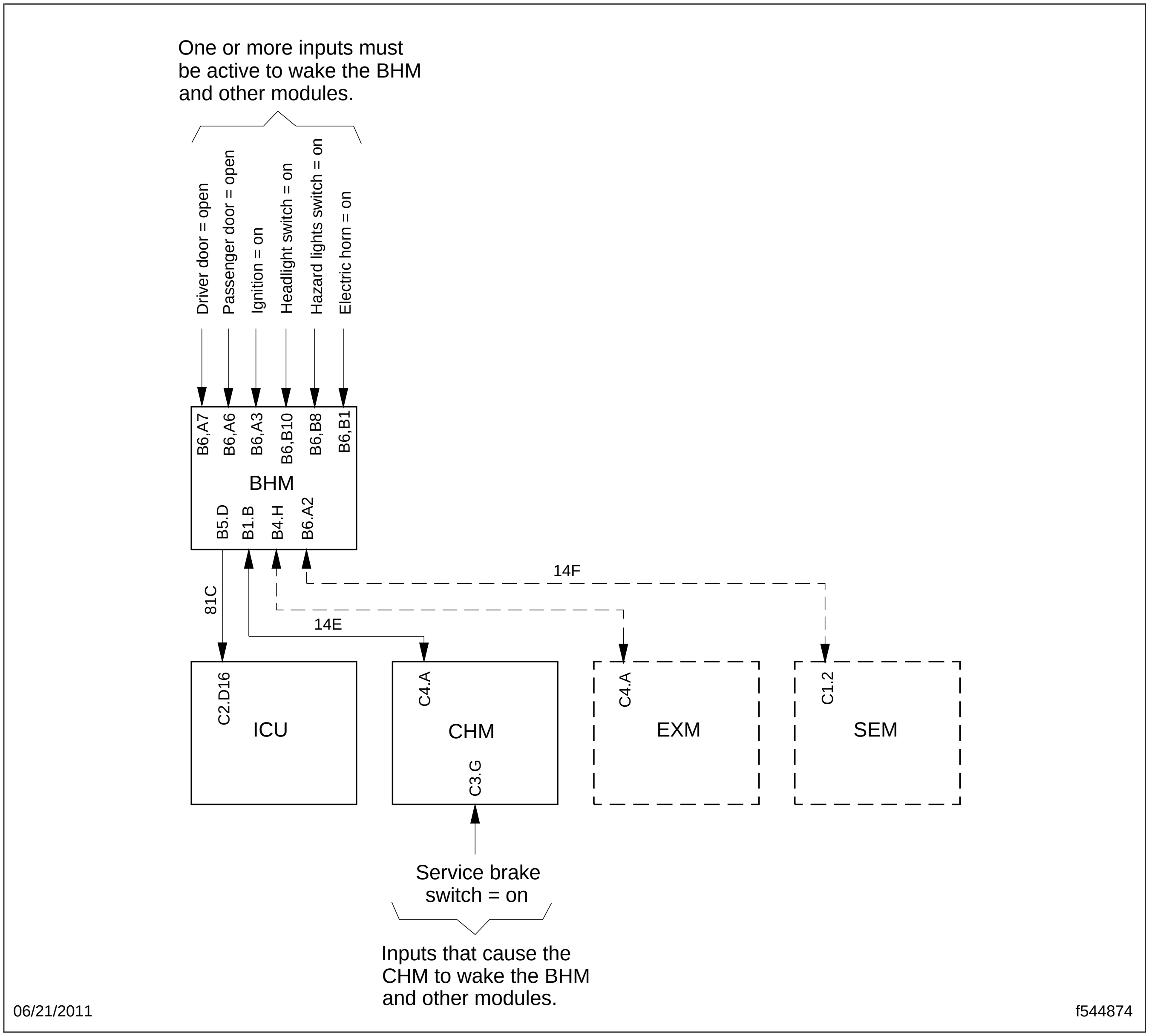


Fig. 11, Simplified Wake Schematic

Troubleshooting

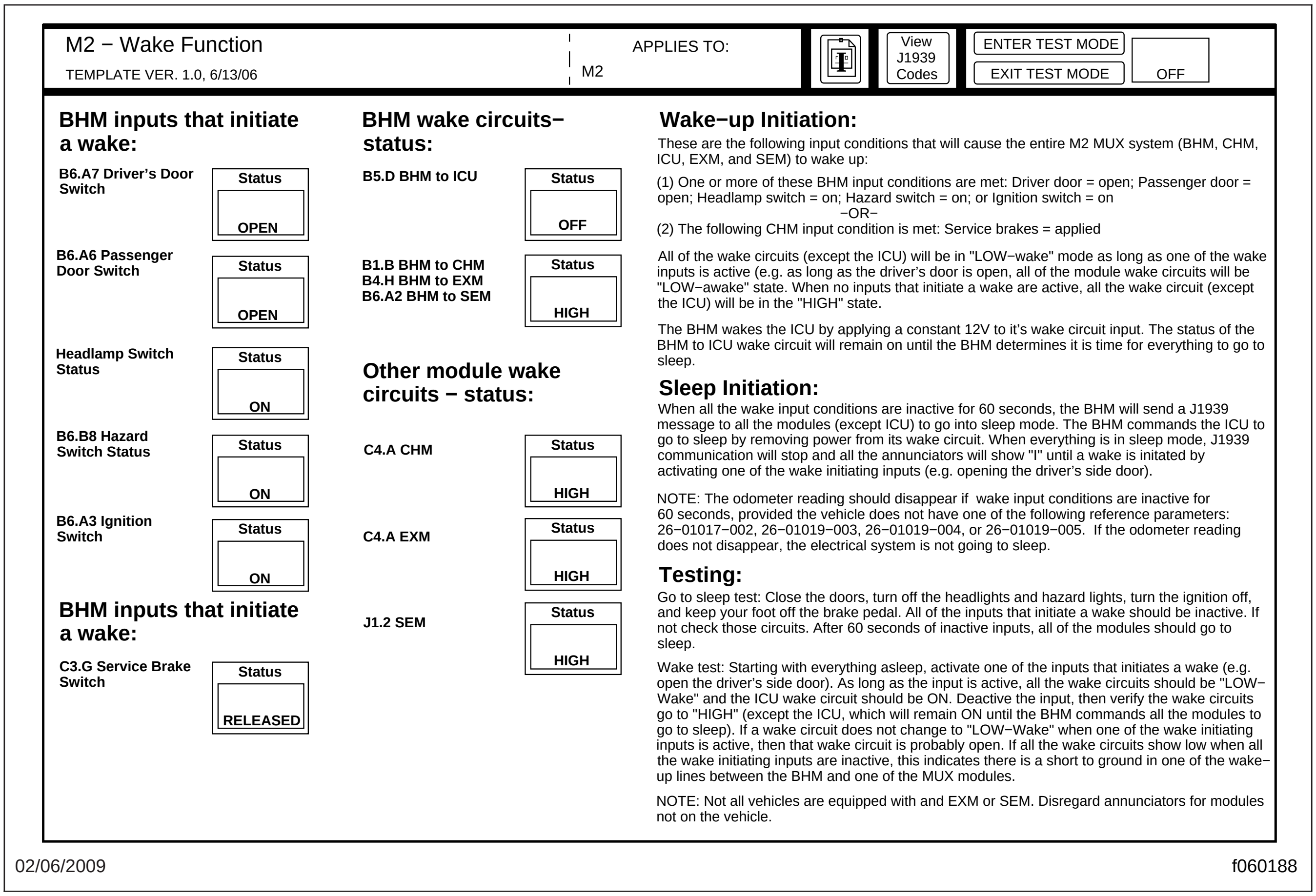


Fig. 12, Wake Function Datalink Monitor Template

A/C Clutch Function Input/Output Conditions		
Inputs to BHM		**Output from BHM**
Ignition Switch	**A/C Clutch Request**	**A/C Clutch**
On/Acc	On	Engaged
On/Acc	Off	Not Engaged
Off	On	Not Engaged

Table 1, A/C Clutch Function Input/Output Conditions

A/C Clutch Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
Status and or position of the ignition switch is in error.	BHM will assume the ignition switch is on.

A/C Clutch Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
A/C clutch wiring is shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 2, A/C Clutch Function Fault Conditions

Alternator Charging Function Input/Output Conditions		
Input to BHM from Alternator "I" Terminal	**Output from BHM via J1939 Message to ICU**	**Output from ICU**
14 volts	Charge status of J1939 message is high.	NO CHARGE light is off.
0 volts	Charge status of J1939 message is low.	NO CHARGE light is on.

Table 3, Alternator Charging Function Input/Output Conditions

Backup Function		
Transmission Type	**Input to BHM**	**BHM Conclusion**
Manual transmission	Backup switch is closed.	Transmission is in reverse.
Automatic transmissions	J1939 message from transmission indicates either: • Current Gear = Reverse • Selected Gear = Reverse • Gear Range = R	Transmission is in reverse.

Table 4, Backup Function

Backup Function Input/Output Conditions		
Inputs to BHM		**Output from BHM**
Ignition Switch	**Transmission Status**	**Backup Lights/Alarm***
On/Acc	Reverse	On
On/Acc	Not Reverse	Off
Off	Reverse	Off
Off	Not Reverse	Off

* Via J1939 message to the CHM

Table 5, Backup Function Input/Output Conditions

Backup Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
Ignition switch status is in error.	BHM will assume the ignition switch is in the on position and may transmit a fault message on the J1939 and/or J1708 datalinks.
Backup lights/alarm wiring shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 6, Backup Function Fault Conditions

Troubleshooting

Backup Function Fault Conditions, Automatic Transmissions	
Description of Fault	**Action Taken by BHM**
BHM fails to receive five consecutive J1939 messages from the transmission ECU.	BHM may transmit a J1939 fault message and assume the transmission is in reverse.
Transmission ECU sends an error indicator in the J1939 message to the BHM.	BHM may transmit a J1939 fault message and assume the transmission is in reverse.

Table 7, Backup Function Fault Conditions, Automatic Transmissions

Cigar Lighter Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
Cigar lighter wiring shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 8, Cigar Lighter Function Fault Conditions

Clutch Function Input/Output Conditions		
Inputs to BHM		**Output from BHM**
Top-of-Clutch Switch	**Bottom-of-Clutch Switch**	**J1939 Clutch Switch Message**
Closed	Open	Clutch pedal is released.
Open	Closed	Clutch pedal is depressed.
Open	Open	Clutch pedal is partially depressed.
Closed	Closed	Clutch pedal is released.*

* This is an error condition, see the Fault Conditions paragraph for more information.

Table 9, Clutch Function Input/Output Conditions

Clutch Function Fault Conditions		
Inputs to BHM		**Output from BHM**
Top-of-Clutch Switch	**Bottom-of-Clutch Switch**	
Closed	Closed	BHM transmits a J1939 and/or a J1708 fault message.

Table 10, Clutch Function Fault Conditions

Horn (electric) Function Input/Output Conditions	
Horn Switch	**Electric Horn**
Pressed	Activate (noise)
Released	Deactivate (silent)

Table 11, Horn (electric) Function Input/Output Conditions

Horn (electric) Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
Horn output shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 12, Horn (electric) Function Fault Conditions

Accessory Power Function Input/Output Conditions	
Input to BHM from Ignition Switch	**Output from BHM to Accessory Power Circuits**
Acc	On

Accessory Power Function Input/Output Conditions	
Input to BHM from Ignition Switch	**Output from BHM to Accessory Power Circuits**
Off	Off
On	On
Start	Off

Table 13, Accessory Power Function Input/Output Conditions

Accessory Power Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
Ignition switch is in error.	BHM will assume the ignition switch is on, and will transmit a fault message on the J1939 and/or J1708 datalinks.
The accessory power output wiring is shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 14, Accessory Power Function Fault Conditions

Ignition Power Function Input/Output Conditions	
Input to the BHM from the Ignition Switch	**Output from the BHM to the Ignition Power Circuits**
Acc	Off
Off	Off
On	On
Start	On

Table 15, Ignition Power Function Input/Output Conditions

Ignition Power Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
Ignition switch is in error.	BHM will assume the ignition switch is on, and may transmit a fault message on the J1939 and/or J1708 datalinks.
The ignition power output wiring is shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 16, Ignition Power Function Fault Conditions

Ignition Switch Function Input/Output Conditions			
Inputs to BHM			**Output from BHM**
Ignition Switch Accessory Circuit	**Ignition Switch On Circuit**	**Ignition Switch Start Circuit**	**J1939 Ignition Switch Position Message**
Open	Open	Open	Off
Closed	Open	Open	Acc
Closed	Closed	Open	On
Open	Closed	Closed	Start

Troubleshooting

Ignition Switch Function Input/Output Conditions			
Inputs to BHM			Output from BHM
Ignition Switch Accessory Circuit	Ignition Switch On Circuit	Ignition Switch Start Circuit	J1939 Ignition Switch Position Message
Open	Open	Closed	On*
Closed	Open	Closed	On*
Open	Closed	Open	On*

* These are error conditions. For more information see the "Fault Conditions" paragraph under the "Ignition System, Ignition Switch Function" heading.

Table 17, Ignition Switch Function Input/Output Conditions

Ignition Switch Function Fault Conditions			
Description of Fault			Action Taken by BHM
Ignition Switch Accessory Circuit	Ignition Switch On Circuit	Ignition Switch Start Circuit	
Open	Open	Closed	BHM transmits a J1939 and/or a J1708 fault message.
Closed	Open	Closed	BHM transmits a J1939 and/or a J1708 fault message.
Open	Closed	Open	BHM transmits a J1939 and/or a J1708 fault message.

Table 18, Ignition Switch Function Fault Conditions

Low Air Pressure Warning Function Input/Output Conditions				
Inputs to CHM		Input to BHM from CHM	Output from BHM to ICU	Input from ICU to BHM
Secondary Air Pressure Switch	Primary Air Pressure Switch	J1939 Low Air Pressure Switch Status Message	J1939 Low Air Pressure Warning Light Command Message	J1939 Low Air Pressure Warning Light Status Message
Open	Open	Open	Enabled	On
Open	Closed	Open	Enabled	On
Closed	Open	Open	Enabled	On
Closed	Closed	Closed	Disabled	Off

Table 19, Low Air Pressure Warning Function Input/Output Conditions

Low Air Pressure Warning Function Fault Conditions*	
Description of Fault	Action Taken by BHM
CHM transmits J1939 low air pressure status unavailable or in error to the BHM.	BHM may transmit J1939 low air pressure warning light status unavailable.

* This fault also occurs when the CHM is unable to determine the switch status. This does not necessarily mean that the low air pressure switches are faulty.

Table 20, Low Air Pressure Warning Function Fault Conditions

Park Brake (pneumatic) Function		
Input to CHM from Park Brake Pressure Switch	**Input to BHM from CHM via J1939 Park Brake Status**	**Output from BHM to ICU via J1939 Park Brake Light Status**
Closed	Engaged	On
Open	Disengaged	Off

Table 21, Park Brake (pneumatic) Function

Park Brake (pneumatic) Function Fault Conditions*	
Description of Fault	**Action Taken by BHM**
CHM transmits J1939 park brake switch status unavailable or in error to the BHM.	BHM may transmit J1939 message park brake light status unavailable.

* This fault also occurs when the CHM is unable to determine the switch status. This does not necessarily mean that the park brake pressure switch is faulty.

Table 22, Park Brake (pneumatic) Function Fault Conditions

Parameters		
Parameter Part Number	**Description**	**Hours**
26-01017-002	Switched Center Pin Power	24
26-01019-003	Exterior Lighting	16,667
26-01019-004	Exterior Lighting	16,667

Parameters		
Parameter Part Number	**Description**	**Hours**
26-01019-005	Exterior Lighting	16,667

Table 23, Parameters

Wake Circuits Troubleshooting Procedures			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Open the "Wake Function" Datalink Monitor template. See **Fig. 12**. Put the system into a sleep state by: • Closing the doors. • Turning off the headlight switch. • Turning off the hazard lights switch. • Turning off the ignition switch. • Removing your foot from the brake pedal. Are any of the BHM and CHM initiating inputs still in an active state on the template (yellow)?	Yes	Check the inputs that are remaining active. For example, if the driver door switch remains active (open) when the door is closed, check the door switch itself and the circuit wiring. Repair as necessary.
		No	**Go to test no. 2.**

Troubleshooting

Wake Circuits Troubleshooting Procedures

Test No.	Test Procedure	Test Result	Action
2	If everything works correctly after meeting the conditions in test no. 1, the system should go to sleep within 60 seconds. The template indicates this when all of the annunciators show an exclamation mark (!)*. NOTE: If the vehicle has one of the following reference parameters, the system will remain awake for 24 hours or longer: 26-01017-002, 26-01019-003, 26-01019-004, or 26-01019-005. NOTE: This troubleshooting step describes a special circumstance that is not typical of the majority of vehicles. If the system is not working correctly, one or more of the Wake Circuits in the right column of the "Wake Function" Datalink Monitor template remains active (yellow) after 60 seconds. Within 60 seconds of meeting the conditions in test no. 1, do all of the annunciators on the template show an exclamation mark (!)*?	Yes	**Go to test no. 6.**
		No	**Go to test no. 3.**
3	In the second column of the template under "Other Module Wake Circuits–Status" is the status of all the annunciators "LOW-Wake" (yellow)? NOTE: Disregard the annunciators for modules not on the vehicle; these will show an exclamation mark (!)*.	Yes	Check the wake circuits between the BHM and the following modules for a short to ground: • CHM • EXM • SEM Repair as necessary.
		No	**Go to test no. 4.**
4	If the B5.D BHM to ICU annunciator status is "ON" in the second column of the template under "BHM Wake Circuits–Status," continue with this test. If not, **go to test no. 5.** Disconnect BHM connector B5. Test for voltage on pin B5.D (harness side). Is voltage present?	Yes	The wake circuit between the BHM and ICU is shorted to power. Repair as necessary.
		No	**Go to test no. 5.**
5	In the second column of the template under "BHM Wake Circuits–Status," check the status of the annunciator labeled **B1.B BHM to CHM** **B4.H BHM to EXM** **B6.A2 BHM to SEM**. Is the annunciator status "LOW-Wake" (yellow)?	Yes	If this is the only active annunciator, replace the BHM.
		No	Check the multiplexed modules for ignition circuits that are shorted to power (not powering down when the ignition is off). If no problem is found, the system may not be going to sleep because the BHM is not sending the J1939 go-to-sleep message. Try a test BHM to confirm.

<table>
<tr><th colspan="4">Wake Circuits Troubleshooting Procedures</th></tr>
<tr><th>Test No.</th><th>Test Procedure</th><th>Test Result</th><th>Action</th></tr>
<tr><td rowspan="2">6</td><td rowspan="2">Starting with the system in the sleep state, activate one of the inputs that initiates a wake, such as opening the driver's door.
If the system is functioning properly, all of the annunciators on the template in the second column should be active (yellow) for ECUs equipped on the vehicle as long as the input remains active. For example, the door is open.
NOTE: If the vehicle is not equipped with an SEM or EXM, it is normal for the status of these annunciators to be "!"*.
Are all of the appropriate second column annunciators active?</td><td>Yes</td><td>Go to test no. 8.</td></tr>
<tr><td>No</td><td>Go to test no. 7.</td></tr>
<tr><td rowspan="3">7</td><td rowspan="3">Which annunciator is not active?</td><td>B5.D BHM to ICU</td><td>Replace the BHM.</td></tr>
<tr><td>B1.B BHM to CHM
B4.H BHM to EXM
B6.A2 BHM to SEM</td><td>Replace the BHM.</td></tr>
<tr><td>Any one of the "Other Module Wake Circuits–Status" for ECUs that are on the vehicle.</td><td>Check for an open in the wake circuit between the BHM and the module that is not showing active.
If OK, check power, ground, and the J1939 datalink to the ECU that is not responding.</td></tr>
<tr><td rowspan="2">8</td><td rowspan="2">Does the ICU wake up when the door is opened? This is indicated by the odometer being displayed.</td><td>Yes</td><td>No problem found.</td></tr>
<tr><td>No</td><td>Check the wake circuit between the BHM and ICU for open.
If OK, check fuse 20 and VBAT2 power supply to BHM B4.G.
If OK, ICU may be faulty.
Repair as necessary.</td></tr>
</table>

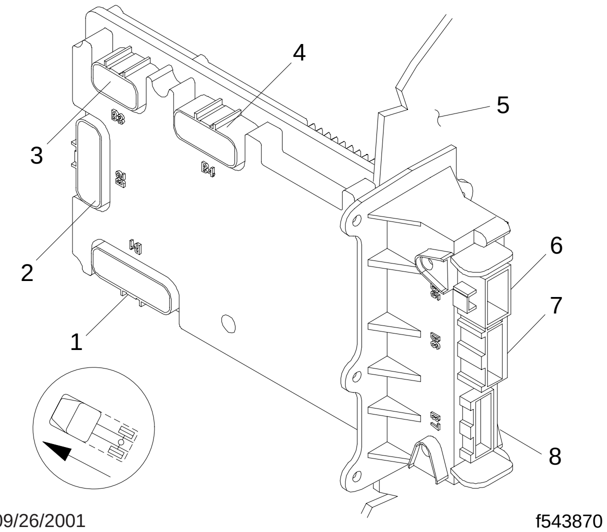
* The exclamation mark (!) will show on the versions of this template released with ServiceLink version 4.0 and higher. On templates released in ServiceLink versions prior to 4.0, if the annunciator is flashing, the flashing takes precedence over the status that it is displaying.

Table 24, Wake Circuits Troubleshooting Procedures

See **Fig. 1** for an illustration of the Bulkhead Module (BHM) Harness Connections.

See **Fig. 2** for maximum allowable current load for the full BHM output pins (part numbers A06-40959-000 and A06-40959-002).

See **Fig. 3** for an illustration of the BHM with pinout assignments and harness connections.



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1. B1, Forward Chassis Harness
2. B2, Engine Harness
3. B3, Frontwall Harness
4. B4, Frontwall Harness
5. Frontwall
6. B5, Dash Harness
7. B6, Dash Harness
8. B7, Dash Harness

Fig. 1, Bulkhead Module Harness Connections

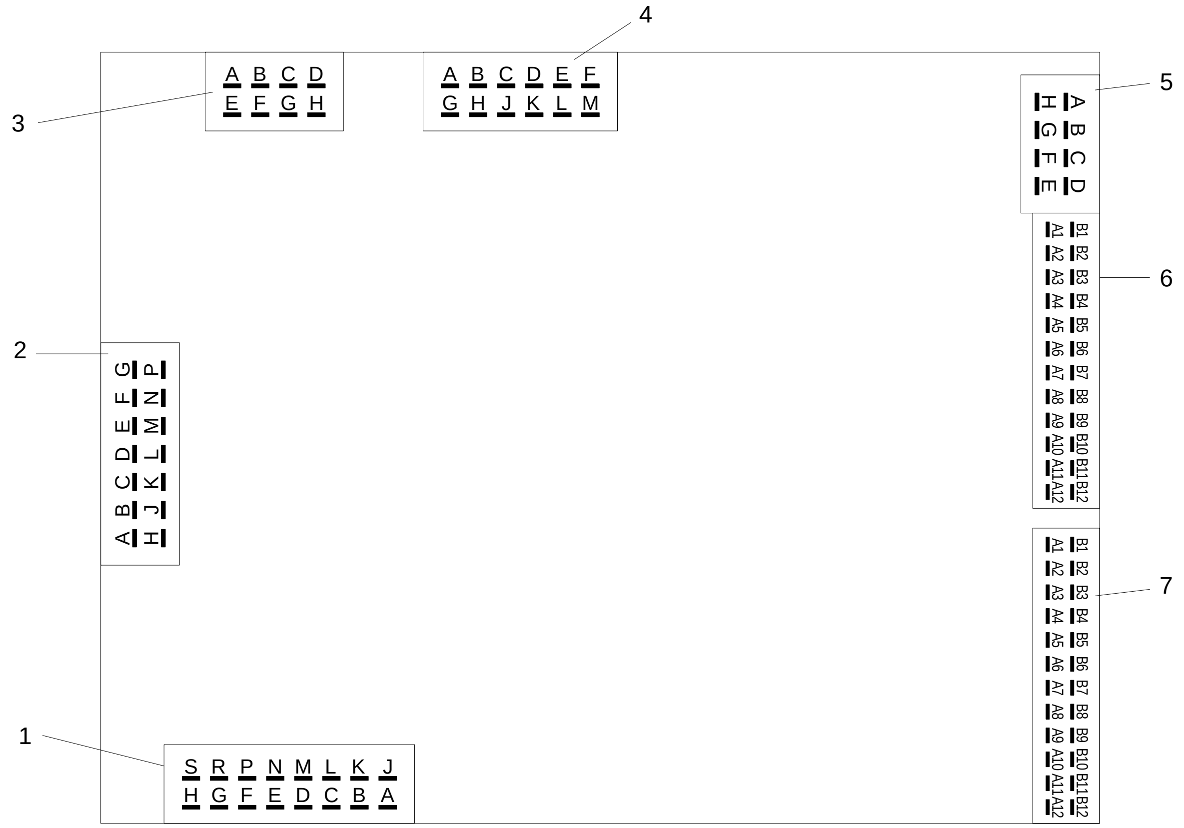
Maximum Current	Bulkhead Module Output
20A	B5.F − Cigar Lighter Output
12A	B3.E − Horn
12A Combined	B5.E − SPARE (Utility Light/Spotlight) B4.M − SPARE (Utility Light/Spotlight)
12A	B5.G − SPARE (Ignition)
12A * Combined	B5.H − Panel Lamps B7.A1 − Panel Lamps (Smart Switch)
12A Combined	B4.F − SPARE (Left Heated Mirror) B4.E − SPARE (Right Heated Mirror)
6.7A Combined	B6.A9 − Accessory (HVAC) B6.A10 − Accessory (Radio)
6.7A Combined	B5.A − Battery (Dome Lamps) B7.A12 − Battery (Smart Switch)
6.7A Combined	B6.A8 − Ignition (VCU) B2.K − Ignition (Engine) B1.P − Ignition (ABS) B2.L − Ignition (Trans) B1.F − Fuel Water Sensor Power
6.7A	B5.D − Wake Up (Instrument Cluster)
6.7A	B5.B − Dome Lamps Switched
6.7A	B1.L − Left High Beam
6.7A	B1.R − Left Low Beam
6.7A Combined	B5.C − Clearance Lamps B1.K − Tail/License Plate/Trailer Relay
6.7A	B3.F − Wiper High
6.7A	B3.H − Wiper Low
6.7A	B3.G − Washer Pump
6.7A	B2.M − AC Clutch
6.7A	B4.B − Starter Relay (Crank)

11/24/2004 * See Note A below. f544533

NOTE A: Pulse Width Modulated Output

Fig. 2, Maximum Allowable Current Load for the Full-Feature Bulkhead Module Output Pins (part numbers A06-40959-000 and A06-40959-002)

Specifications



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NOTE: Pins shown are viewed toward the BHM or wire insertion end of the harness connector.

1. B1, Forward Chassis Harness
2. B2, Engine Harness
3. B3, Frontwall Harness
4. B4, Frontwall Harness
5. B5, Dash Harness
6. B6, Dash Harness
7. B7, Dash Harness

Fig. 3, Bulkhead Module With Pinout Assignments and Harness Connections

Connector B1 Forward Chassis Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B1-A	—	—
B1-B	Module Wake-Up Signal	Digital Input/ Output
B1-C	Spare Digital Input 4	Digital Input
B1-D	—	—
B1-E	Ground	Power Ground
B1-F	Fuel/Water Sensor Ignition Power	Digital Output
B1-G	Ground	Signal Ground
B1-H	J1587+ Datalink	Datalink

Connector B1 Forward Chassis Harness Pinouts		
Connector Pin	Signal Name	Signal Type
B1-J	Battery Power (VBAT5)	Power
B1-K	Tail Lamps/License Plate Lamp/Trailer Tail Relay	Digital Output
B1-L	Left High Beam	Digital Output
B1-M	Fuel/Water Separator (spare digital input 5)	Digital Input
B1-N	Battery Power (VBAT3)	Power
B1-P	ABS Ignition Power	Digital Output
B1-R	Left Low Beam	Digital Output
B1-S	J1587– Datalink	Datalink

Table 1, Connector B1 Forward Chassis Harness Pinouts

Connector B2 Engine Harness Pinouts		
Connector Pin	Signal Name	Signal Type
B2-A	J1587+ Datalink	Datalink
B2-B	J1939+ Datalink	Datalink
B2-C	J1587+ Datalink	Datalink
B2-D	J1587– Datalink	Datalink
B2-E	—	—
B2-F	—	—
B2-G	Backup Switch (spare digital input 3)	Digital Input
B2-H	J1587– Datalink	Datalink
B2-J	J1939– Datalink	Datalink
B2-K	Engine ECU Ignition Power	Digital Output
B2-L	Transmission ECU Ignition Power	Digital Output
B2-M	A/C Clutch	Digital Output
B2-N	—	—
B2-P	Alternator Charging	Digital Input

Table 2, Connector B2 Engine Harness Pinouts

Connector B3 Frontwall Harness Pinouts		
Connector Pin	Signal Name	Signal Type
B3-A	J1939– Datalink	Datalink
B3-B	J1939+ Datalink	Datalink
B3-C	Wiper Parked Position	Digital Input
B3-D	Main Battery Power (VBAT1)	Power
B3-E	Horn	Digital Output
B3-F	Wiper Motor High Speed	Digital Output

Specifications

Connector B3 Frontwall Harness Pinouts		
Connector Pin	Signal Name	Signal Type
B3-G	Washer Pump	Digital Output
B3-H	Wiper Motor Low Speed	Digital Output

Table 3, Connector B3 Frontwall Harness Pinouts

Connector B4 Frontwall Harness Pinouts		
Connector Pin	Signal Name	Signal Type
B4-A	Air Filter Restriction/Spare #9	Digital Input
B4-B	Starter Relay	Digital Output
B4-C	Ground	Ground
B4-D	Spare Digital Input 2	Digital Input
B4-E	Right Heated Mirror (spare digital output)	Digital Output
B4-F	Left Heated Mirror (spare digital output)	Digital Output
B4-G	Main Battery Power (VBAT2)	Power
B4-H	Module Wake-Up Signal	Digital Input/Output
B4-J	—	—
B4-K	Main Battery Power (VBAT4)	Power
B4-L	Washer Fluid Level (spare digital input 8)	Digital Input
B4-M	Utility Light/Spotlight (spare digital output)	Digital Output

Table 4, Connector B4 Frontwall Harness Pinouts

Connector B5 Dash Harness Pinouts		
Connector Pin	Signal Name	Signal Type
B5-A	Dome Lamps Battery	Digital Output
B5-B	Dome Lamps Switched	Digital Output
B5-C	Clearance Lamps (cab)	Digital Output
B5-D	Instrument Cluster Wake-Up	Digital Output
B5-E	Utility Light/Spotlight (spare digital output)	Digital Output
B5-F	Cigar Lighter	Digital Output
B5-G	Ignition Power, Other (spare digital output)	Digital Output
B5-H	Panel Lamps	Digital Output

Table 5, Connector B5 Dash Harness Pinouts

Connector B6 Dash Harness Pinouts		
Connector Pin	Signal Name	Signal Type
B6-A1	Ignition Switch Accessory Position	Digital Input
B6-A2	Module Wake-Up Signal	Digital Input

Connector B6 Dash Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B6-A3	Ignition Switch On	Digital Input
B6-A4	—	—
B6-A5	Ignition Switch Start	Digital Input
B6-A6	Passenger Door Open (spare digital input 10)	Digital Input
B6-A7	Driver Door Open	Digital Input
B6-A8	VCU Ignition Power	Digital Output
B6-A9	HVAC Power	Digital Output
B6-A10	Radio Power	Digital Output
B6-A11	J1587– Datalink	Datalink
B6-A12	J1587+ Datalink	Datalink
B6-B1	Horn Switch	Digital Input
B6-B2	Top of Clutch Switch (spare digital input 7)	Digital Input
B6-B3	Bottom of Clutch Switch (spare digital input 6)	Digital Input
B6-B4	—	—
B6-B5	Panel Lamps Increase	Digital Input
B6-B6	Panel Lamps Decrease	Digital Input
B6-B7	A/C Clutch Request	Digital Input
B6-B8	Hazard Switch	Digital Input
B6-B9	Headlamp Switch PARK Position	Digital Input
B6-B10	Headlamp Switch On Position	Digital Input
B6-B11	Headlamp Switch On 2 Position	Digital Input
B6-B12	—	—

Table 6, Connector B6 Dash Harness Pinouts

Connector B7 Dash Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B7-A1	Panel Lamps (smart switch)	Digital Output
B7-A2	Smart Switch 3 ID 1	Analog Input
B7-A3	Smart Switch 3 ID 2	Analog Input
B7-A4	Smart Switch 3 Input	Analog Input
B7-A5	Smart Switch 3 Indicator	Digital Output
B7-A6	Smart Switch 4 ID 1	Analog Input
B7-A7	Smart Switch 4 ID 2	Analog Input
B7-A8	Smart Switch 4 Input	Analog Input
B7-A9	Smart Switch 4 Indicator	Digital Output
B7-A10	Smart Switch 5 ID 1	Analog Input

Specifications

Connector B7 Dash Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B7-A11	Smart Switch 5 ID 2	Analog Input
B7-A12	Smart Switch Battery Power	Digital Output
B7-B1	Smart Switch 1 ID 1	Analog Input
B7-B2	Smart Switch 1 ID 2	Analog Input
B7-B3	Smart Switch 1 Input	Analog Input
B7-B4	Smart Switch 1 Indicator	Digital Output
B7-B5	Smart Switch 2 ID 1	Analog Input
B7-B6	Smart Switch 2 ID 2	Analog Input
B7-B7	Smart Switch 2 Input	Analog Input
B7-B8	Smart Switch 2 Indicator	Digital Output
B7-B9	Ground	Signal Ground
B7-B10	Smart Switch 5 Indicator	Digital Output
B7-B11	Smart Switch 5 Input	Analog Input
B7-B12	—	—

Table 7, Connector B7 Dash Harness Pinouts

Power Supply Fuses and Associated Outputs for the Bulkhead Module				
BHM Power Input	**BHM Power Input Pin**	**Fuse Supplying BHM Power Input**	**BHM Outputs Supplied**	**BHM Output Pin**
Power In			**Power Out**	
VBAT1	B3.D	Fuse 22 (30A)	Battery (dome lamps)	B5.A
			Battery (smart switches)	B7.A12
			Ignition (VCU)	B6.A8
			Ignition (engine)	B2.K
			Ignition (ABS)	B1.P
			Ignition (trans)	B2.L
			Fuel Water Sensor Power	B1.F
			Dome Lamps Switched	B5.B
			Left Low Beam	B1.R
			A/C Clutch	B2.M
			Smart Switch 1 Indicator	B7.B4
			Smart Switch 2 Indicator	B7.B8
			Smart Switch 3 Indicator	B7.A5
			Smart Switch 4 Indicator	B7.A9
			Smart Switch 5 Indicator	B7.B10
			Battery (smart switch)	B7.A12

Power Supply Fuses and Associated Outputs for the Bulkhead Module				
BHM Power Input	BHM Power Input Pin	Fuse Supplying BHM Power Input	BHM Outputs Supplied	BHM Output Pin
Power In			Power Out	
VBAT2	B4.G	Fuse 20 (30A)	Accessory (HVAC)	B6.A9
			Accessory (radio)	B6.A10
			Wake Up (instrument cluster)	B5.D
			Left High Beam	B1.L
			Wiper High	B3.F
			Horn	B3.E
VBAT3	B1.N	Fuse 18 (30A)	Wiper Low	B3.H
			Spare 8.0A HSD (ignition)	B5.G
			Panel Lamps	B5.H
			Panel Lamps (smart switch)	B7.A1
VBAT4	B4.K	Fuse 15 (30A)	Clearance Lamps	B5.C
			Tail Lamps/License Plate Lamp/Trailer Tail Relay	B1.K*
			Washer Pump	B3.G
			12V Output (cigar lighter)	B5.F
VBAT5	B1.J	Fuse 7 (30A)	Spare 8.5A (utility light/spotlight)	B5.E / B4.M
			Left Heated Mirror	B4.F
			Right Heated Mirror	B4.E

* This output supplies power to the Chassis Module pass-through for the tail lamps, license plate lamp, and trailer tail lamp relay.

Table 8, Power Supply Fuses and Associated Outputs for the Bulkhead Module

NOTE: Currents listed are the maximum allowable combined current load for each output pin or group of pins. When maximum allowable current load is exceeded, the BHM software will shut off the output pin or group of pins.

In Test Mode, the outputs will deliver more current load than the maximum allowable current values shown. When testing, do not exceed the maximum combined values for more than a few minutes or the life of the output driver inside the BHM may be shortened.

Bulkhead Module Fault Code Information

General Information

Subject 410 contains information on all proprietary Bulkhead Module (BHM) fault codes for J1587 and J1939 datalink protocols, how to view these codes, and what the codes mean. Each fault code contains three distinct pieces of information.

J1587 fault codes consist of the following elements in the order listed:

- Module Identifier (MID) – Identifies which electronic control unit (ECU) the fault is coming from. The J1587 MID identifying all Bulkhead Module information faults is 164.
- Subsystem Identifier (SID) – Indicates what function on the ECU has failed. All J1587 SIDs for the BHM are listed in **Table 1**.
- Failure Mode Indicator (FMI) – Indicates in what way the function failed.

J1939 fault codes consist of the following elements in the order listed:

- Source Address (SA) – Identifies which ECU the fault is coming from. The J1939 SA identifying all Bulkhead Module faults is 33.
- Suspect Parameter Number (SPN) – Indicates what function on the ECU has failed. All J1939 SPNs for the BHM are listed in **Table 2**.
- Failure Mode Indicator (FMI) – Indicates in what way the function failed.

See **Table 3** for a list of all failure mode identifiers for both datalink protocols.

References such as BHM B1.A indicate that the fault is sensed to be coming from the Bulkhead Module, connector B1, pin A. Similarly, CHM indicates the Chassis Module on a vehicle.

J1587 fault codes are shown under J1708 in ServiceLink. J1587 and J1708 are essentially the same datalink protocol.

Because the SAE J1939 subcommittee approves new SPNs for use in J1939 messaging on a continual basis, J1939 SPNs used for diagnostic messages could change when the Bulkhead Module part changes. These changes could impact any diagnostic message with an SPN value of 6915 or higher.

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
000	Backlighting Dimmer Switch Fault	7
001	Clutch Switch Fault	7
002	Reserved for Future Use	—
003	Headlamp Switch Disagreement–Both park and on inputs are closed	7
004	Multifunction Turn Signal Switch High Beam Input Fault	2
005	Ignition Switch Fault	7
006	Marker Interrupt Switch Fault	7
007	Multifunction Turn Signal Switch Disagreement–Both wiper high and wiper low inputs are on.	2
008	Multifunction Turn Signal Switch Disagreement–Wiper on/off is off and wiper high or low input is on	2
009	Wiper Park Input Fault	7
010	ICU3-M2 Hazard Switch CAN Feedback Error	2
011	Multifunction Turn Signal Switch Left Turn Signal Input Fault	2
012	Multifunction Turn Signal Switch Right Turn Signal Input Fault	2
013	Multifunction Turn Signal Switch Washer Switch Input Fault	2
014	Multifunction Turn Signal Switch Wiper On/Off Input Fault	2

Bulkhead Module Fault Code Information

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
015	Multifunction Turn Signal Switch Wiper Low Input Fault	2
016	Multifunction Turn Signal Switch Wiper High Input Fault	2
017	Wheel-Based Vehicle Speed CAN Message Error	2
018	Wake-up Hardware Fault–Modules are kept awake	7
019	Unknown Keep Awake Fault–Modules are kept awake.	7
020	Extra Smart Switch	7
021	Duplicate Smart Switch	7
022	Missing Smart Switch	7
023	Fifth Wheel Solenoid Unexpected Pressure Feedback	7
024	Fifth Wheel Solenoid No Pressure Feedback	7
025	End of Frame Air Unexpected Pressure Feedback	7
026	End of Frame Air No Pressure Feedback	7
027	Axle Lift Unexpected Pressure Feedback	7
028	Axle Lift No Pressure Feedback	7
029	Suspension Dump Unexpected Pressure Feedback	7
030	Suspension Dump No Pressure Feedback	7
031	Suspension Proportioning Unexpected Pressure Feedback	7
032	Suspension Proportioning No Pressure Feedback	7
033	Cigar Lighter Output Fault	7
034	BHM/ICU3-M2 Ignition Mismatch	7
035	BHM/ICU3-M2 Hazard Switch Mismatch	2
036	BHM/ICU3-M2 Wiper Park Mismatch	2
037	Missing Transmission CAN Message	9
038	Missing Chassis Module CAN Message	9
039	Remote Bucket Switch Stuck Fault	7
040	Axle Lift 2 Unexpected Pressure Feedback	7
041	Axle Lift 2 No Pressure Feedback	7
042	PTO 1 Unexpected Pressure Feedback	7
043	PTO 1 No Pressure Feedback	7
044	PTO 2 Unexpected Pressure Feedback	7
045	PTO 2 No Pressure Feedback	7
046	CHM No PWM DRLs Fault	8
047–049	Reserved for Future Use	—
050	BHM B1.A—Fuel Level Input Fault (Not Used)	3, 4
051	BHM B1.F, B1.P, B2.K, B2.L, B6.A8—Ignition Power Output Fault	5, 6
052	BHM B1.J—Main BHM Power VBAT5 Input Fault	3, 4

Bulkhead Module Fault Code Information

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	Description	Possible FMI
053	BHM B1.K, B5.C—Tail/Clearance Lamp Output Fault	5, 6
054	BHM B1.L—Left High Beam Output Fault	5, 6
055	BHM B1.N—Main BHM Power VBAT3 Input Fault	3, 4
056	BHM B1.R—Left Low Beam Output Fault	5, 6
057	BHM B2.M—A/C Clutch Output Fault	5, 6
058	BHM B3.D—Main BHM Power VBAT1 Input Fault	3, 4
059	BHM B3.E—Horn Output Fault	3, 4, 5, 6
060	BHM B3.F—Wiper High Speed Output Fault	5, 6
061	BHM B3.G—Washer Pump Output Fault	5, 6
062	BHM B3.H—Wiper Low Speed Output Fault	5, 6
063	BHM B4.B—Starter Relay Output Fault	5, 6
064	BHM B4.E, B4.F—Spare Output Fault	3, 4, 5, 6
065	BHM B4.G—Main BHM Power VBAT2 Input Fault	3, 4
066	BHM B4.K—Main BHM Power VBAT4 Input Fault	3, 4
067	BHM B4.M, B5.E—Spare Output Fault	3, 4, 5, 6
068	BHM B5.A, B7.A12—Dome Lamp Battery Power Output Fault	5, 6
069	BHM B6.A9, B6.A10—HVAC/Radio Ignition Power Output Fault	5, 6
070	BHM B5.B—Dome Lamp Switched Power Output Fault	5, 6
071	BHM B5.D—ICU Wake Output Fault	5, 6
072	BHM B5.F—Cigar Light Output Fault	3, 4, 5, 6
073	BHM B5.G—Spare Ignition Power Output Fault	3, 4, 5, 6
074	BHM B5.H, B7.A1—Panel Lamps Output Fault	3, 4, 5, 6
075	CHM C1.A, C1.H, C1.J—Backup Lamps/Alarm Output Fault	5, 6
076	CHM C1.G, C2.H, C3.N—Left Turn Signal Output Fault	5, 6
077	CHM C1.L—Right Stop Lamp Output Fault	5, 6
078	CHM C1.N—Left Stop Lamp Output Fault	5, 6
079	CHM C1.P, C2.E, C3.R—Right Turn Signal Output Fault	5, 6
080	CHM C2.A—Trailer Power Relay Output Fault	3, 4
081	CHM C2.F, C4.C, C4.D, C4.L, C4.M—Park/Marker Lamp Output	3, 4, 5, 6
082	CHM C3.A—Spare Output Fault	3, 4, 5, 6
083	CHM C3.C, C3.D—Spare Output Fault	5, 6
084	CHM C3.E—Low Air Pressure Input Fault	3, 4
085	CHM C3.F—Park Brake Input Fault	3, 4
086	CHM C3.J—Main CHM Power VBAT2 Input Fault	3, 4
087	CHM C3.K—Right DRL Output Fault	5, 6
088	CHM C3.L—Right Low Beam Output	5, 6

Bulkhead Module Fault Code Information

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
089	CHM C4.F—Left DRL Output Fault	5, 6
090	CHM C4.J—Main CHM Power VBAT3 Input Fault	3, 4
091	CHM C4.K—Right High Beam Output	5, 6
092	CHM C4.P—Main CHM Power VBAT1 Input Fault	3, 4
093	CHM C5.A—Solenoid #0 Pressure Feedback Fault	3, 4
094	CHM C5.B—Solenoid #1 Pressure Feedback Fault	3, 4
095	CHM C5.F—Solenoid #2 Pressure Feedback Fault	3, 4
096	CHM C5.G—Solenoid #3 Pressure Feedback Fault	3, 4
097	CHM C5.H—Solenoid #0 Output Fault	3, 4
098	CHM C5.J—Solenoid #1 Output Fault	3, 4
099	CHM C5.L—Solenoid #2 Output Fault	3, 4
100	CHM C5.M—Solenoid #3 Output Fault	3, 4
101	EXM Fault (Fault in one of the EXM Outputs)	3, 4, 5, 6

Table 1, J1587 SIDs for Bulkhead Module (BHM) MID 164

J1939 SPNs for Bulkhead Module (BHM) SA 33		
SPN	**Description**	**Possible FMI**
70	Parking Brake Switch	2
80	Washer Fluid Level	2
84	Wheel-based Vehicle Speed	19
96	Fuel Level	19
97	Water In Fuel Indicator	19
163	Transmission Current Range	12, 19
177	Transmission Oil Temperature Sensor	3, 4
523	Transmission Current Gear	12, 19
524	Transmission Selected Gear	12, 19
597	ABS Service Brake Switch	2
598	Clutch Switch	7
879	Front Left Turn Signals Output Fault	5, 6
880	Trailer Stop Lamp Relay Output Fault	4
881	Front Right Turn Signals Output Fault	5, 6
882	Park/Marker Lights Output Fault	4, 5, 6
973	Engine Retarder Selection	19
1487	Backlighting Dimmer Switch Fault	7
1550	A/C Clutch Output Fault	5, 6
2003	Missing Transmission CAN Message	9

Bulkhead Module Fault Code Information

J1939 SPNs for Bulkhead Module (BHM) SA 33		
SPN	**Description**	**Possible FMI**
2071	Missing Chassis Module CAN Message	9
6890	CHM No PWM DRLs Fault	8
6897	Fuel Water Separator Heater Output Fault	6
6898	Brake Air Dryer Output Fault	6
6906	PTO 2 No Pressure Feedback	7
6907	PTO 2 Unexpected Pressure Feedback	7
6908	PTO 1 No Pressure Feedback	7
6909	PTO 1 Unexpected Pressure Feedback	7
6910	Axle Lift 2 No Pressure Feedback	7
6911	Axle Lift 2 Unexpected Pressure Feedback	7
6912	Remote Bucket Switch Stuck Fault	7
6915	Lamp and Gauge Ignition Output Fault	4, 5, 6
6916	BHM/ICU3-M2 Wiper Park CAN Message Mismatch	2
6917	BHM/ICU3-M2 Hazard Switch CAN Message Mismatch	2
6918	Missing Smart Switch	7
6919	Duplicate Smart Switch	7
6920	Extra Smart Switch	7
6921	Unknown Keep Awake Fault–Modules are kept awake	7
6922	Wake-up Hardware Fault–Modules are kept awake	7
6923	Wiper Parked Input Fault	7
6924	Multifunction Turn Signal Switch Disagreement–Wiper on/off input is off and wiper high or low input is on	2
6925	Multifunction Turn Signal Switch Disagreement–Both wiper high and wiper low inputs are on	2
6926	Marker Interrupt Switch Fault	7
6927	Utility Lamp Output Fault	3, 4, 5, 6
6928	Suspension Proportioning No Pressure Feedback	7
6929	Suspension Proportioning Unexpected Pressure Feedback	7
6930	Suspension Proportioning Solenoid Output Fault	3, 4, 5, 6
6931	Suspension Dump No Pressure Feedback	7
6932	Suspension Dump Unexpected Pressure Feedback	7
6933	Suspension Dump Solenoid Output Fault	3, 4, 5, 6
6934	Spotlights Output Fault	3, 4, 5, 6
6935	Snow Plow Relay Output Fault	3, 4, 5, 6
6936	Rear 2 Differential Lock Pressure Feedback Fault	7
6937	Rear 2 Differential Lock Solenoid Output Fault	3, 4, 5, 6
6938	Rear 1 Differential Lock Pressure Feedback Fault	7

Bulkhead Module Fault Code Information

J1939 SPNs for Bulkhead Module (BHM) SA 33		
SPN	Description	Possible FMI
6939	Rear 1 Differential Lock Solenoid Output Fault	3, 4, 5, 6
6940	Optional Feature Output Fault	3, 4, 5, 6
6941	Heated Mirrors Output Fault	3, 4, 5, 6
6942	Interaxle Pressure Feedback Fault	7
6943	Interaxle Solenoid Output Fault	3, 4, 5, 6
6944	Fuel Water Separator Heater Output Fault	4, 5, 6
6945	Front Differential Lock Pressure Feedback Fault	7
6946	Front Differential Lock Solenoid Output Fault	3, 4, 5, 6
6947	Fog Lamp Output Fault	5, 6
6949	Fire Pump Pressure Feedback Fault	7
6950	Fire Pump Solenoid Output Fault	3, 4, 5, 6
6951	Fifth Wheel Slide No Pressure Feedback	7
6952	Fifth Wheel Slide Unexpected Pressure Feedback	7
6953	Fifth Wheel Slide Solenoid Output Fault	3, 4, 5, 6
6954	End of Frame Air No Pressure Feedback	7
6955	End of Frame Air Unexpected Pressure Feedback	7
6956	End of Frame Air Solenoid Output Fault	3, 4, 5, 6
6957	Daytime Running Lights (DRL) Output Fault	5, 6
6958	Brake Line Air Dryer Output Fault	3, 4, 5, 6
6959	Axle Shift Pressure Feedback Fault	7
6960	Axle Shift Solenoid Output Fault	3, 4, 5, 6
6961	Axle Lift No Pressure Feedback	7
6962	Axle Lift Unexpected Pressure Feedback	7
6963	Axle Lift Solenoid Output Fault	3, 4, 5, 6
6964	Air Horn Solenoid Output Fault	5, 6
6965	BHM VBAT 5 Input Fault	3, 4
6966	BHM VBAT 4 Input Fault	3, 4
6967	BHM VBAT 3 Input Fault	3, 4
6968	BHM VBAT 2 Input Fault	3, 4
6969	BHM VBAT 1 Input Fault	3, 4
6970	Wiper High Output Fault	5, 6
6971	Wiper Low Output Fault	5, 6
6972	Multifunction Turn Signal Switch Wiper High Input Fault	2
6973	Multifunction Turn Signal Switch Wiper Low Input Fault	2
6974	Multifunction Turn Signal Switch Wiper On/Off Input Fault	2
6975	ICU3-M2 Wiper Park CAN Feedback Error	2

Bulkhead Module Fault Code Information

J1939 SPNs for Bulkhead Module (BHM) SA 33		
SPN	Description	Possible FMI
6976	Washer Pump Output Fault	5, 6
6977	Multifunction Turn Signal Switch Washer Switch Input Fault	2
6978	Multifunction Turn Signal Switch Right Turn Signal Input Fault	2
6979	Multifunction Turn Signal Switch Left Turn Signal Input Fault	2
6980	Right Stop Lamp Output Fault	5, 6
6981	Left Stop Lamp Output Fault	5, 6
6982	Wake Up Hardware Fault	5, 6
6983	Starter Relay (mag switch) Output Fault	5, 6
6984	Ignition System, Accessory Power Outputs Fault	5, 6
6985	Ignition System, Ignition Power Outputs Fault	2, 5, 6
6986	Ignition Switch Fault	7
6987	Taillights, Clearance Lights, License Plate Lights Output Fault	5, 6
6988	Left Low Beam Output Fault	5, 6
6989	Right Low Beam Output Fault	5, 6
6990	Left High Beam Output Fault	5, 6
6991	Right High Beam Output Fault	5, 6
6992	Multifunction Turn Signal Switch High Beam Input Fault	2
6993	Headlamp Switch Disagreement–Both park and on inputs are closed.	7
6994	ICU3-M2 Hazard Switch CAN Feedback Error	19
6995	Horn Output Fault	3, 4, 5, 6
6996	Dome Lamps Switched Power Output Fault	5, 6
6997	Cigar Lighter Output Fault	3, 4, 5, 6
6998	Dome Lamps Battery Power Output Fault	5, 6
6999	Backup Lamps/Alarm Output Fault	5, 6
7000	Panel Lamp Backlighting PWM Output Fault	3, 4, 5, 6
524280	Component ID Mismatch	31
524281	Application to Parameter Incompatibility	31
524282	Parameter Checksum Failure	12
524283	Application Checksum Failure	12
524284	Boot Block Checksum Failure	12
524285	Boot Hold Line is Active	4
524286	Ram Failure	12

Table 2, J1939 SPNs for Bulkhead Module (BHM) SA 33

Bulkhead Module Fault Code Information

Failure Mode Identifiers		
FMI	**J1939 Description**	**J1587 Description**
00	Data valid but above normal operational range–Most severe level	Data valid but above normal operational range (engine overheating)
01	Data valid but below normal operational range–Most severe level	Data valid but below normal operational range (engine oil pressure too low)
02	Data erratic, intermittent, or incorrect	Data erratic, intermittent, or incorrect
03	Voltage above normal or shorted high	Voltage above normal or shorted high
04	Voltage below normal or shorted low	Voltage below normal or shorted low
05	Current below normal or open circuit	Current below normal or open circuit
06	Current above normal or grounded circuit	Current above normal or grounded circuit
07	Mechanical system not responding or out of adjustment	Mechanical system not responding properly
08	Abnormal frequency, pulse width, or period	Abnormal frequency, pulse width, or period
09	Abnormal update rate	Abnormal update rate
10	Abnormal rate of change	Abnormal rate of change
11	Root cause not known	Failure mode not identifiable
12	Bad intelligent device or component	Bad intelligent device or component
13	Out of Calibration	Out of Calibration
14	Special Instructions	Special Instructions
15	Data valid but above normal operational range–Least severe level	Reserved for future assignment by the SAE Subcommittee
16	Data valid but above normal operational range–Moderately severe level	—
17	Data valid but below normal operational range–Least severe level	—
18	Data valid but below normal operational range–Moderately severe level	—
19	Received network data in error	—
31	Condition Exists	—

Table 3, Failure Mode Identifiers

General Information

The Chassis Module (CHM) and the Expansion Module (EXM) both serve the same function in the M2 electrical system by acting as slaves to the Bulkhead Module (BHM). The CHM and EXM respond to commands from the BHM and broadcast the status of the inputs and outputs that are sent to and delivered by the modules.

A Business Class M2 vehicle will always have a Chassis Module, but will only have an Expansion Module when optional features require it. The CHM and EXM both have five harness connectors, though they may not all be used.

Chassis Module

The CHM is usually mounted on the left frame rail, aft of the cab. See **Fig. 1**. The CHM is available in two configurations depending on the vehicle options:

- standard Chassis Module
- full Chassis Module

The vehicle will have either a standard CHM or a full CHM, but not both. The standard CHM uses only the C1, C3, and C4 harness connectors. The remaining harness connectors are sealed. See **Fig. 2**.

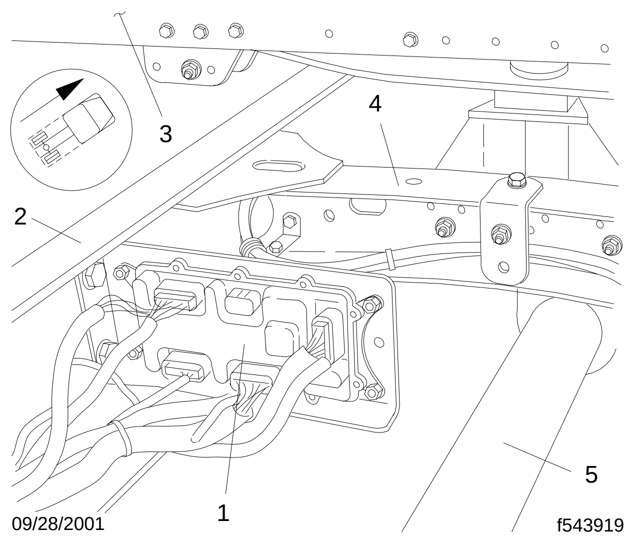
Both the standard CHM and full CHM are supported by one version of software.

Alternate Mounting Location of the CHM

On some M2 vehicles the CHM is factory installed under the cab instead of on the frame rail behind the cab. This alternate location affects the C5 connector on the CHM, which controls any air management unit (AMU) solenoid that the vehicle may be equipped with.

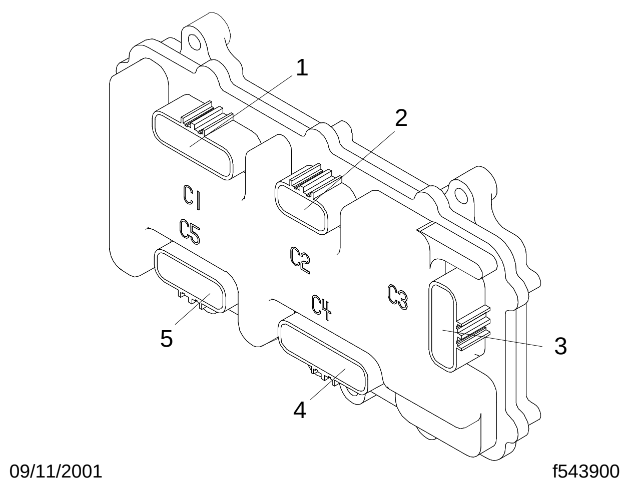
When the CHM is mounted on the frame rail behind the cab, the harness for the AMU solenoids plugs directly into the C5 connector on the CHM. When the CHM is factory installed under the cab, a jumper loom is required between the plug coming from the AMU solenoids and the C5 connector on the CHM.

The jumper loom is part of the forward chassis harness that is used with the CHM when it is factory installed under the cab. The jumper loom has generic circuit numbers and is present regardless of whether or not the AMU circuits are used on the vehicle.



1. Chassis Module
2. Left Frame Rail
3. Cab Backwall
4. Crossmember
5. Driveline

Fig. 1, Chassis Module Installation on Frame Rail



1. C1, Taillight Harness
2. C2, Trailer Module Harness, Full CHM Only
3. C3, Forward Chassis Harness
4. C4, Forward Chassis Harness
5. C5, Air Management Unit Harness, Full CHM Only

Fig. 2, Chassis Module Harness Connectors

NOTE: See **Specifications 400** for information on how a factory-installed CHM under the cab affects the wiring.

General Information

Awake State and Sleep State

The BHM, CHM, and instrumentation control unit (ICU) are, as a group, in an awake state or a sleep state depending on vehicle conditions. When any of these electronic components are awakened, the remaining components wake up if they are not already awake. When the BHM, CHM, and ICU are in an awake state, the odometer reading appears on the dash driver display screen.

One of the following actions will cause the BHM, CHM, or ICU to go into an awake state:

- opening the door switch
- turning on the hazard switch
- turning the ignition switch to any position other than off
- turning on the headlight/parking light switch
- depressing the service brake

The BHM, CHM, and ICU will enter a sleep state when they are no longer actively controlling any outputs or responding to any inputs and all other power down requirements are met.

To check whether or not the electrical system is going into a sleep state:

1. Enter the vehicle.
2. Shut the doors.
3. Remove your foot from the service brake.
4. Make sure the ignition switch and hazard switch are in the off position.

NOTE: One minute after these conditions are met, and provided that one of the parameters in **Table 1** has not been added to the BHM, the odometer reading should disappear. If the odometer reading does not disappear, the electrical system is not going to sleep.

Expansion Module

The EXM is mounted on the aft chassis. Only one Expansion Module is available on a vehicle. See **Fig. 3** for an illustration of the Expansion Module.

NOTE: The harness connector numbers on the CHM and EXM are the same since the hardware for the two modules is the same. However, the harness connector names for the CHM and EXM are not the same since the connectors on the EXM serve different functions than the connectors on the CHM.

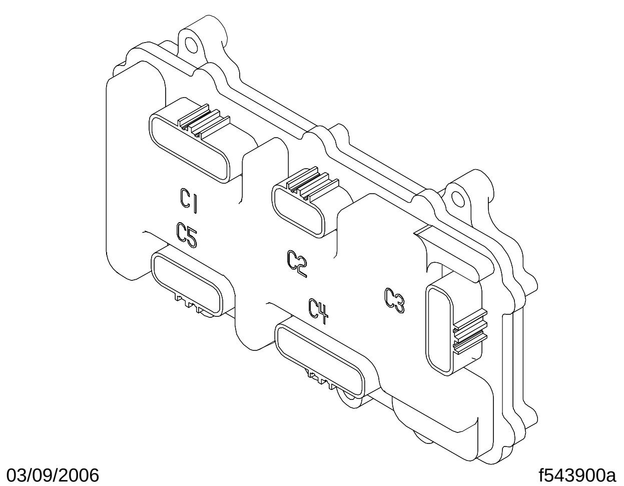


Fig. 3, Expansion Module Harness Connectors

The EXM configuration uses external strapping. External strapping is a process that assigns a unique, predefined J1939 Source Address and J1587 Message ID to the module, which is viewable in ServiceLink®.

Parameters		
Parameter Part Number	**Description**	**Hours**
26-01017-002	Switched Center Pin Power	24
26-01019-003	Exterior Lighting	16,667
26-01019-004	Exterior Lighting	16,667
26-01019-005	Exterior Lighting	16,667

Table 1, Parameters

External strapping is the interconnection of specific pins on the module in order to select a desired feature. In the external strapping of the Expansion Module, the J1939 source address and the J1587 message ID are used to identify the module on the vehicle datalinks. Pins on the C4 connector of the Expansion Module are connected as specified in **Table 2**. See the "Pinouts at Connector C4" table in **Specifications 400** to match the address ID to the actual pin locations.

Module Configuration and External Strapping IDs						
System Definition	Address ID Connections on Connector C4*				J1939 Source Address	J1587 MID
	A	B	C	D		
EXM	X	—	—	X	235	170
CHM	No Connections				71	249

* Connections are shown as address IDs, not as pin numbers.

Table 2, Module Configuration and External Strapping IDs

Chassis Module and Expansion Module Replacement

Replacement

IMPORTANT: It is rarely necessary to replace the Chassis Module (CHM) or the Expansion Module (EXM). Replacing the CHM or EXM should be the last resort to solving electrical problems, unless the module needs to be replaced due to physical damage. Follow troubleshooting procedures in **Section 54.12, Troubleshooting 300**, to solve electrical problems before replacing either the CHM or the EXM. If troubleshooting indicates a malfunction of either module, try reflashing the parameters and the software before replacing the module. Also check the external wiring.

See **Section 54.00, Subject 050**, for information about the M2 electrical system and **Section 54.00, Troubleshooting 300**, for information on troubleshooting the entire M2 electrical system.

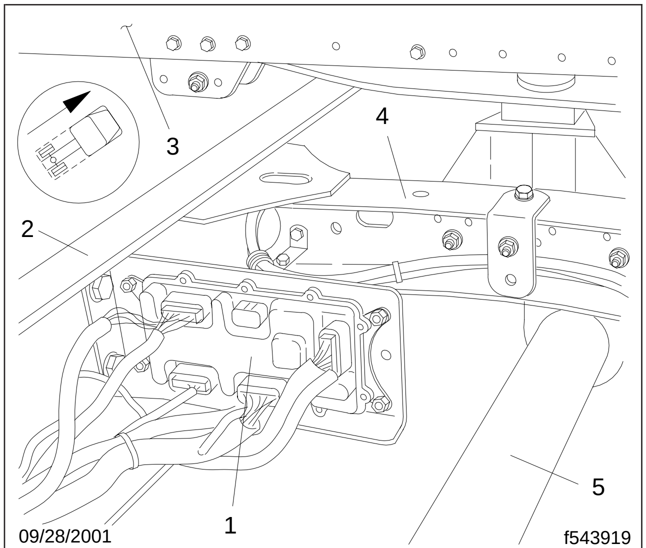
1. Disconnect the negative leads from the batteries or, if the vehicle is equipped with a battery disconnect switch, turn the switch to the off position.

NOTE: The Chassis Module is mounted on the left frame rail, aft of the cab. See **Fig. 1**. The EXM is mounted on the forward spring hanger bracket of the rear suspension.

2. Disconnect the harnesses at the harness connectors on the Chassis Module or Expansion Module. See **Fig. 2** or **Fig. 3**.

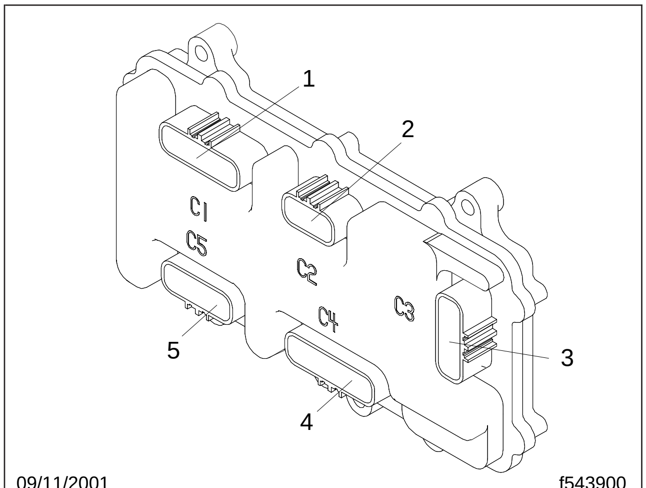
NOTE: The C2 and C5 connectors on the standard Chassis Module are sealed at the time of manufacture so that it is not possible to use these connectors. On a vehicle that has a full Chassis Module installed and no options on a particular connector (for example, a vehicle with air brakes but no trailer towing provision leaves the C2 connector empty), the connector will be installed and all the cavities on that connector will have sealing plugs.

NOTE: Before removing the Chassis Module from the mounting plate, note its orientation. Connector C3 is toward the center of the vehicle, and connectors C1 and C5 are toward the frame rail.



1. Chassis Module
2. Left Frame Rail
3. Cab Backwall
4. Crossmember
5. Driveline

Fig. 1, Chassis Module Installation



1. C1, Taillight Harness
2. C2, Trailer Module Harness, Full CHM Only
3. C3, Forward Chassis Harness
4. C4, Forward Chassis Harness
5. C5, Air Management Unit Harness, Full CHM Only

Fig. 2, Chassis Module Connectors

3. Remove the bolts and nuts that secure the Chassis Module or the Expansion Module, then remove the CHM or EXM.

Chassis Module and Expansion Module Replacement

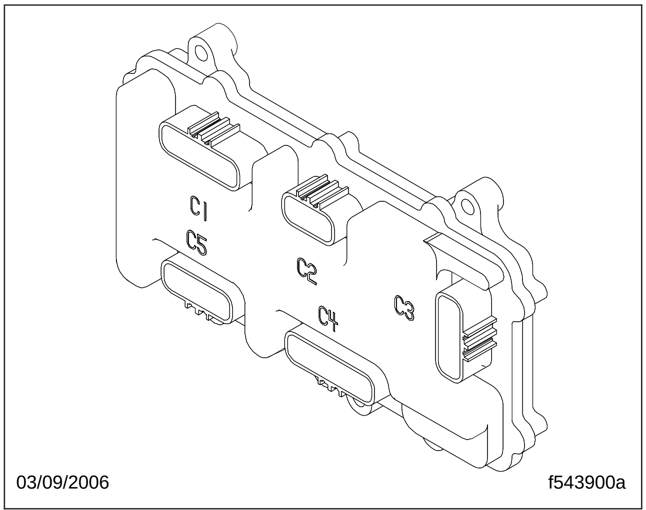


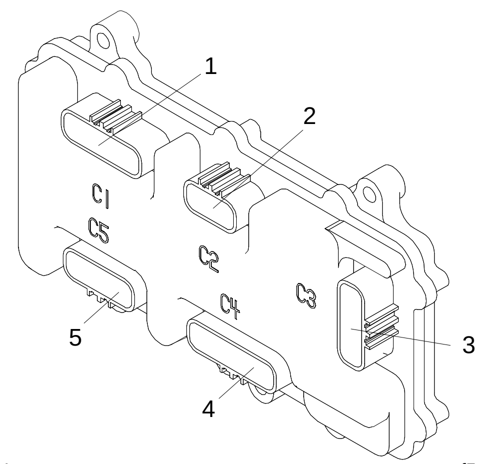
Fig. 3, Expansion Module Connectors

4. Properly orient the Chassis Module on its mounting plate. Using bolts and nuts, secure the CHM or EXM.
5. Connect the harnesses to the CHM or EXM.
6. Connect the batteries or turn the battery disconnect switch to on.
7. Check to make sure the electrical components work.

Chassis Module

See **Fig. 1** for an illustration of the Chassis Module (CHM).

See **Fig. 2** for an illustration of the CHM and EXM with pinout assignments and harness connectors.



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1. C1, Taillight Harness
2. C2, Trailer Module Harness, Full CHM Only
3. C3, Forward Chassis Harness
4. C4, Forward Chassis Harness
5. C5, Air Management Unit Harness, Full CHM Only

Fig. 1, Chassis Module Harness Connectors

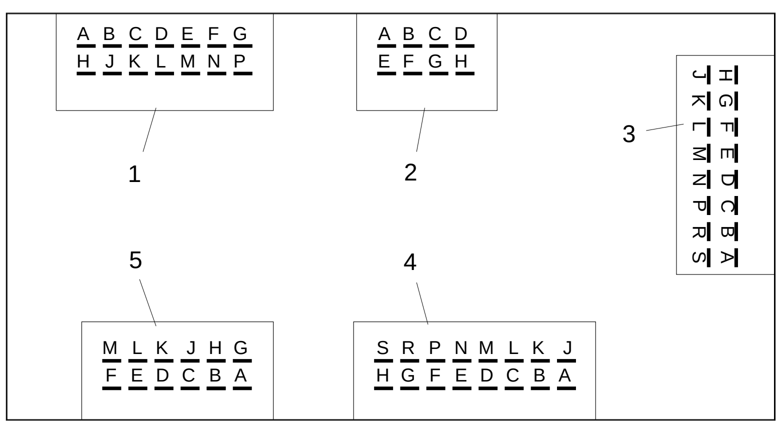
See **Fig. 3** for maximum allowable current load for the full Chassis Module output pins (part numbers 06-34530-XXX and 06-75158-000).

See **Fig. 4** for maximum allowable current load for the standard Chassis Module output pins (part number 06-42391-000).

NOTE: The power supply to the Bulkhead Module microprocessor is supplied from any of the five VBAT inputs (VBAT1, VBAT2, VBAT3, VBAT4, or VBAT5) through an internal diode network. The same is true for the Chassis Module with its input VBAT1, VBAT2, or VBAT3; VBAT4 on CHM 06-75158-000. In theory, if any one of the module's VBAT inputs is supplying power, the module will be functional.

Currents listed are the maximum allowable combined current load for each output pin or group of pins. When maximum allowable current load is exceeded, the CHM software will shut off the output pin or group of pins.

In Test Mode, the outputs will deliver more current load than the maximum allowable current values shown. When testing, do not exceed the maximum combined values for more than a few minutes or the life of the output driver inside the CHM may be shortened.



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1. C1
2. C2
3. C3
4. C4
5. C5

Fig. 2, Chassis Module and Expansion Module With Pinout Assignments and Harness Connectors

Specifications

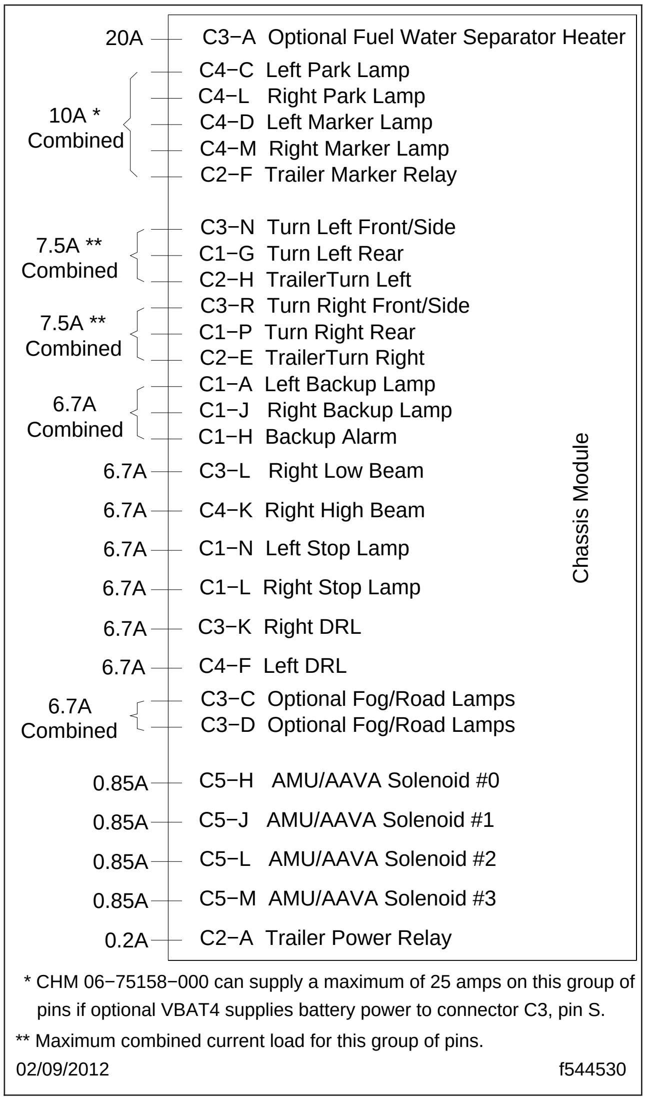


Fig. 3, Maximum Allowable Current Load for the Full Chassis Module Output Pins

Alternate Mounting Location of the CHM

On some M2 vehicles the CHM is factory installed under the cab instead of on the frame rail and behind the cab. This alternate location affects the wiring. See **Fig. 5**.

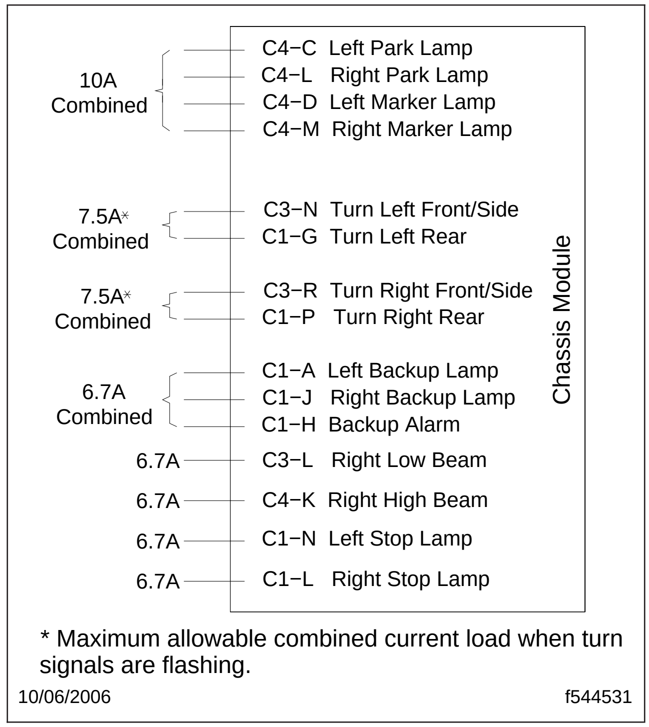
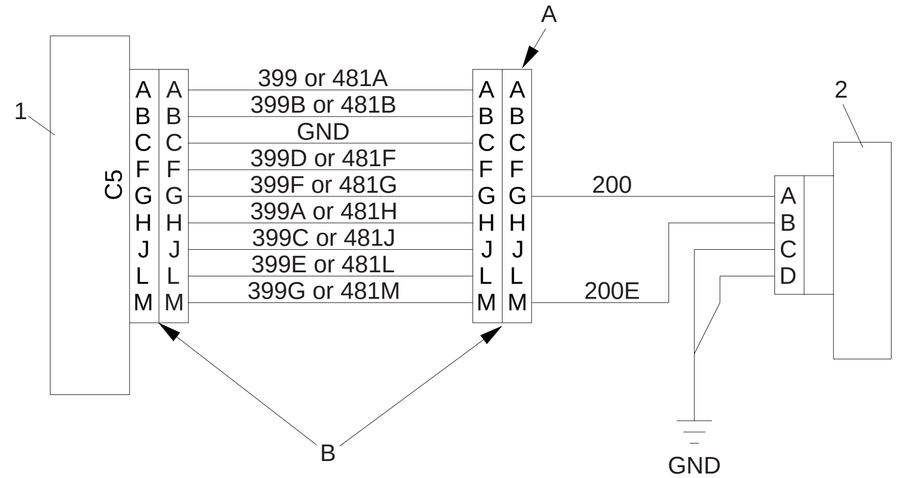


Fig. 4, Maximum Allowable Current Load for the Standard Chassis Module Output Pins (part number 06-42391-000)

Example of How a Factory-installed Under-the-cab CHM Affects the Wiring

A vehicle with a factory-installed under-the-cab CHM and power takeoff (PTO) controls with an AMU/AAVA solenoid may be wired with circuit numbers 200 and 200E for the PTO AMU/AAVA solenoid as shown in **Fig. 5**. When these circuits become part of the jumper harness in the forward chassis harness, the circuit numbers change to 399F (or 481G) and 399G (or 481M) respectively.

In this example the remaining circuits contained in the jumper harness are unused. This may cause confusion since the G06-XXXXX-XXX wiring diagram for each individual function does not depict the additional wiring in the forward chassis harness or the circuit numbers when the CHM is mounted under the cab.



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A. This connector connects directly to the CHM C5 connector when the CHM is mounted on the frame rail, behind the cab. Check this connector for actual circuits used on the vehicle.
B. The jumper harness, which is part of the forward chassis harness, is present only when the CHM is mounted under the cab. The wires are numbered in either 399 series or 481 series depending on the harness manufacturer.

1. Chassis Module
2. Power Takeoff Solenoid

Fig. 5, Wiring Diagram of CHM Connector 5

Expansion Module

See **Fig. 6** for an illustration of the Expansion Module (EXM).

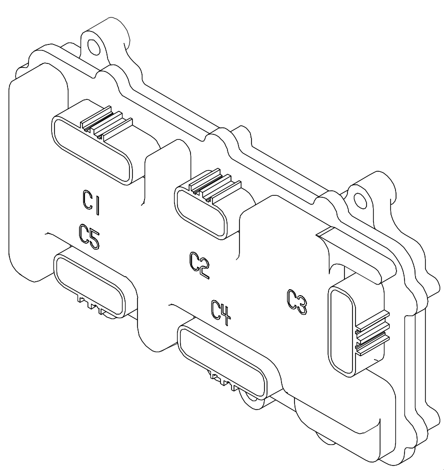

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Fig. 6, Expansion Module Harness Connectors

See **Fig. 2** for an illustration of the CHM and EXM with pinout assignments and harness connectors.

See **Fig. 7** for maximum allowable current load for the Expansion Module output pins (part number 06-42399-000).

NOTE: Amperage listed is the maximum allowable amperage for each output circuit. When maximum allowable amperage is exceeded, the CHM may turn off the output.

When using ServiceLink® in Test Mode, the outputs will deliver more current than the maximum allowable current values shown. When testing, do not exceed the maximum combined values for more than a few seconds or the life of the output driver inside the module may be shortened.

Specifications

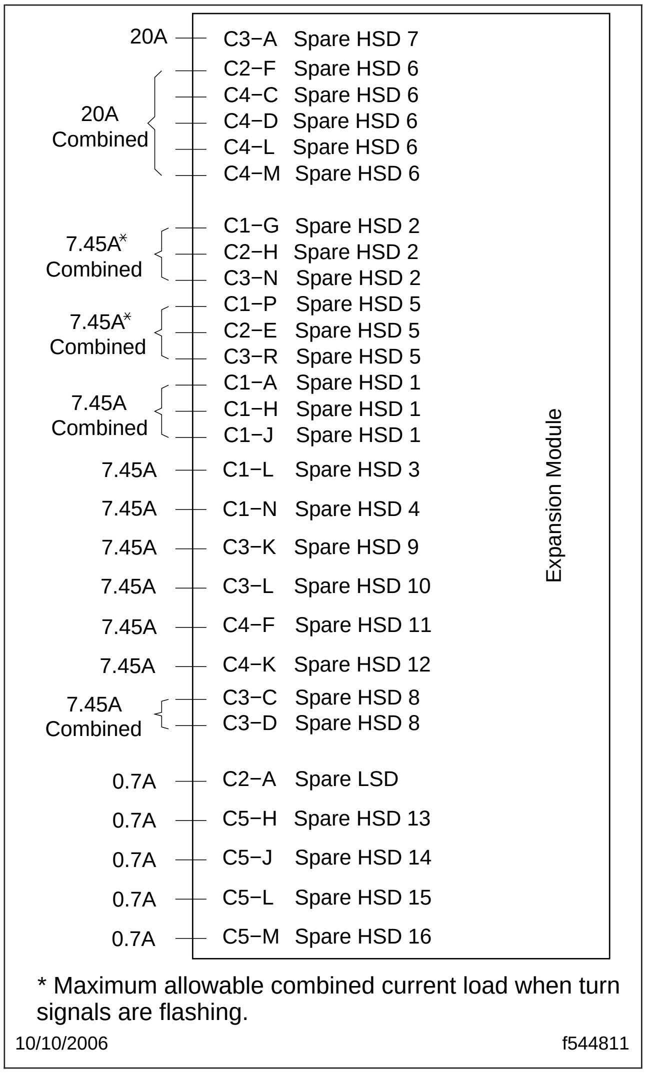


Fig. 7, Maximum Allowable Current Load for the Expansion Module Output Pins (part number 06-42399-000)

Taillight Harness Pinouts at Connector C1				
Connector and Pin Numbers	**Signal Name**	**Signal Type**	**Full**	**Standard**
C1-A	Left Backup Lamp	Digital Output	X	X
C1-D	Left Taillight Pass-Through	Pass-Through	X	X
C1-E	Right Taillight Pass-Through	Pass-Through	X	X
C1-F	License Plate Lamp	Digital Output	X	X

Taillight Harness Pinouts at Connector C1				
Connector and Pin Numbers	Signal Name	Signal Type	Full	Standard
C1-G	Left Rear Turn Lamp	Digital Output	X	X
C1-H	Backup Alarm	Digital Output	X	X
C1-J	Right Backup Lamp	Digital Output	X	X
C1-L	Right Stop Lamp	Digital Output	X	X
C1-N	Left Stop Lamp	Digital Output	X	X
C1-P	Right Rear Turn Lamp	Digital Output	X	X

Table 1, Taillight Harness Pinouts at Connector C1

Trailer Module Harness Pinouts at Connector C2				
Connector and Pin Numbers	Signal Name	Signal Type	Full	Standard
C2-A	Trailer Power Relay	Digital Output	X	—
C2-C	Ground	Power Ground	X	—
C2-D	Trailer Stop Lamp Relay Pass-Through	Pass-Through	X	—
C2-E	Trailer Right Turn Lamp	Digital Output	X	—
C2-F	Trailer Marker Lamps Relay	Digital Output	X	—
C2-G	Trailer Taillight Relay Pass-Through	Pass-Through	X	—
C2-H	Trailer Left Turn Lamp	Digital Output	X	—

Table 2, Trailer Module Harness Pinouts at Connector C2

Forward Chassis Harness Pinouts at Connector C3				
Connector and Pin Numbers	Signal Name	Signal Type	Full	Standard
C3-A	Fuel/Water Separator Heater	Digital Output	X	—
C3-B	J1587– Datalink (not used on CHM 06-75158-000)	Datalink	X	X
C3-C	Fog/Road Lamps	Digital Output	X	—
C3-D	Fog/Road Lamps	Digital Output	X	—
C3-E	Low Air Pressure	Digital Input (active low)	X	X
C3-F	Park Brake	Digital Input (active low)	X	X
C3-G	Service Brake	Digital Input (active low)	X	X
C3-H	Ground	Power Ground	X	X
C3-J	Main Battery Power (VBAT2)	Power	X	X
C3-K	Right DRL	Digital Output	X	—
C3-L	Right Low Beam	Digital Output	X	X
C3-M	Ignition	Digital Input (active high)	X	X

Specifications

Forward Chassis Harness Pinouts at Connector C3				
Connector and Pin Numbers	Signal Name	Signal Type	Full	Standard
C3-N	Left Front/Side Turn Lamp	Digital Output	X	X
C3-P	Taillight/License Plate Lamps Pass-Through	Pass-Through	X	X
C3-R	Right Front/Side Turn Lamp	Digital Output	X	X
C3-S	J1587+ Datalink or VBAT4 on CHM 06-75158-000	Datalink	X	X

Table 3, Forward Chassis Harness Pinouts at Connector C3

Forward Chassis Harness Pinouts at Connector C4				
Connector and Pin Numbers	Signal Name	Signal Type	Full	Standard
C4-A	Module Wake-Up Signal	Digital Input/Output	X	X
C4-B	Address Identification A	Analog Input	X	X
C4-C	Left Park Lamp	Digital Output	X	X
C4-D	Left Marker Lamp	Digital Output	X	X
C4-E	Address Identification C	Analog Input	X	X
C4-F	Left DRL	Digital Output	X	—
C4-G	J1939+ Datalink	Datalink	X	X
C4-H	Ground (address identification D)	Signal Ground	X	X
C4-J	Main Battery Power (VBAT3)	Power	X	—
C4-K	Right High Beam	Digital Output	X	X
C4-L	Right Park Lamp	Digital Output	X	X
C4-M	Right Marker Lamp	Digital Output	X	X
C4-N	Address Identification B	Analog Input	X	X
C4-P	Main Battery Power (VBAT1)	Power	X	X
C4-R	J1939– Datalink	Datalink	X	X
C4-S	Ground	Power Ground	X	X

Table 4, Forward Chassis Harness Pinouts at Connector C4

Connector C5 Air Controls				
Connector and Pin Numbers	Signal Name	Signal Type	Full	Standard
C5-A	Pressure Signal Analog Input 0	Digital Input (active low), Analog Input	X	—
C5-B	Pressure Signal Analog Input 1	Digital Input (active low), Analog Input	X	—
C5-C	Ground	Signal Ground	X	—
C5-F	Pressure Signal Analog Input 2	Digital Input (active low), Analog Input	X	—
C5-G	Pressure Signal Analog Input 3	Digital Input (active low), Analog Input	X	—

Connector C5 Air Controls				
Connector and Pin Numbers	Signal Name	Signal Type	Full	Standard
C5-H	Solenoid 0	Digital Output	X	—
C5-J	Solenoid 1	Digital Output	X	—
C5-L	Solenoid 2	Digital Output	X	—
C5-M	Solenoid 3	Digital Output	X	—

Table 5, Connector C5 Air Controls

Power Supply Fuses and Associated Outputs for the Chassis Module				
CHM Power Input	CHM Power Input Pin	Fuse Supplying CHM Power Input	CHM Outputs Supplied	CHM Output Pin
Power In			Power Out	
VBAT1	C4.P	Fuse 19 (30A)	Right Low Beam	C3.L
			Turn Right Front/Side	C3.R
			Turn Right Rear	C1.P
			Right Stop Lamp	C1.L
			Left Stop Lamp	C1.N
			Right DRL	C3.K
			Fog/Road Lamps	C3.C/C3.D
			Trailer Turn Right	C2.E
VBAT2	C3.J	Fuse 17 (30A)	Left Park Lamp	C4.C
VBAT4			Right Park Lamp	C4.L
			Left Marker Lamp	C4.D
			Right Marker Lamp	C4.M
			Trailer Marker Relay	C2.F
			Right High Beam	C4.K
			Left Backup Lamp	C1.A
			Right Backup Lamp	C1.J
			Backup Alarm	C1.H
			Turn Left Front/Side	C3.N
			Turn Left Rear	C1.G
			Left DRL	C4.F
			Trailer Turn Left	C2.H

Specifications

Power Supply Fuses and Associated Outputs for the Chassis Module				
CHM Power Input	CHM Power Input Pin	Fuse Supplying CHM Power Input	CHM Outputs Supplied	CHM Output Pin
Power In			Power Out	
VBAT3	C4.J	Fuse 13 (30A)	Fuel Water Separator Heater	C3.A
			Solenoid 0	C5.H
			Solenoid 1	C5.J
			Solenoid 2	C5.L
			Solenoid 3	C5.M

Table 6, Power Supply Fuses and Associated Outputs for the Chassis Module

Chassis Module Pass-Throughs		
CHM Input	CHM Outputs Supplied	CHM Output Pin
C3.P*	Left Taillight	C1.D
	Right Taillight	C1.E
	Trailer Taillight Relay	C2.G
	License Plate Lamp	C1.F

* CHM pin C3.P is supplied by BHM pin B1.K.

Table 7, Chassis Module Pass-Throughs

Pinouts at Connector C1		
Connector and Pin Numbers*	Signal Name	Signal Type
C1-A	Spare HSD 1†	7.45A Output (combined load, all pins)
C1-H		
C1-J		
C1-G	Spare HSD 2	
C2-H		
C3-N		
C1-L	Spare HSD 3	
C1-N	Spare HSD 4	
C1-P	Spare HSD 5	
C2-E		
C3-R		

***** Connector and pin numbers in bold are from another connector.

† High Side Driver

Table 8, Pinouts at Connector C1

Pinouts at Connector C2		
Connector and Pin Numbers	Signal Name	Signal Type
C2-A	Spare LSD*	Output
C2-C	Ground	Ground
C2-D	See C3-G	—
C2-E	See C1-P	—
C2-F	Spare HSD 6†	20A Output
C2-H	See C1-G	—

* Low Side Driver

† High Side Driver

Table 9, Pinouts at Connector C2

Pinouts at Connector C3		
Connector and Pin Numbers	Signal Name	Signal Type
C3-A	Spare HSD 7*	20A Output
C3-B	J1587–	Datalink
C3-C	Spare HSD 8	7.45A Output
C3-D	See C3-C	—
C3-E	Spare Input 1	Digital (active low) Input
C3-F	Spare Input 2	Digital (active low) Input
C3-G	Spare Input 3	Digital (active low) Input
C3-H	Ground	Ground
C3-J	VBAT 2	Power
C3-K	Spare HSD 9	7.45A Output
C3-L	Spare HSD 10	7.45A Output

Pinouts at Connector C3		
Connector and Pin Numbers	Signal Name	Signal Type
C3-M	Ignition	Digital (active high) Input
C3-N	See C1-G	—
C3-R	See C1-P	—
C3-S	J1587+	Datalink

* High Side Driver

Table 10, Pinouts at Connector C3

Pinouts at Connector C4		
Connector and Pin Numbers	Signal Name	Signal Type
C4-A	Module Wake-Up	Digital Input/Output
C4-B	Address Strapping A	Analog Input
C4-C	See C2-F	—
C4-D		
C4-E	Address Strapping C	Analog Input
C4-F	Spare HSD 11*	7.45A Output
C4-G	J1939+ Datalink	Datalink
C4-H	Address Strapping Ground	Signal Ground
C4-J	VBAT 3	Power
C4-K	Spare HSD 12	7.45A Output
C4-L	See C2-F	—
C4-M		
C4-N	Address Strapping B	Analog Input
C4-P	VBAT1	Power
C4-R	J1939– Datalink	Datalink
C4-S	Ground	Power Ground

* High Side Driver

Table 11, Pinouts at Connector C4

Pinouts at Connector C5		
Connector and Pin Numbers	Signal Name	Signal Type
C5-A	Spare Input 4	Digital (active low) Input
C5-B	Spare Input 5	
C5-F	Spare Input 6	
C5-G	Spare Input 7	
C5-H	Spare HSD 13*	0.7A Output
C5-J	Spare HSD 14	
C5-L	Spare HSD 15	
C5-M	Spare HSD 16	

* High Side Driver

Table 12, Pinouts at Connector C5

General Information

Smart switches are optional low-current switches that are connected to the Bulkhead Module (BHM) or to an optional Switch Expansion Module (SEM) on a Business Class® M2 vehicle. A smart switch is used to activate an optional feature on the vehicle. These features may include, but are not limited to:

- fog lights
- differential lock control
- interaxle lock control
- pusher and tag axle controls
- fifth wheel slide control
- PTO control
- split-shaft PTO and fire pump controls
- marker light interrupt control

A smart switch is similar in appearance to a high-current switch. A smart switch can be differentiated from a high-current switch by the part number that is marked on the side of the switch. Each smart switch has a base part number of A06-37217.

Another way to differentiate a smart switch from a high-current switch is to look at the electrical connector used on the switch. See **Fig. 1** and **Fig. 2** for illustrations of the connectors used on smart switches and high-current switches.

A smart switch is significantly different from a high-current switch. Unlike a high-current switch, the smart switch is designed to control very low currents, and will be damaged if it is connected to a high-current circuit. A smart switch has an internal printed circuit board which contains:

- A light-emitting diode (LED) for backlighting the switch when the headlights are turned on;
- A light-emitting diode (LED) that, when on solid, indicates the feature is activated and, when blinking, indicates an error condition.
- Two precision resistors that are used to create a unique switch identifier that allows the BHM to identify each switch that is connected;
- Three precision resistors that are used to indicate the position of the switch.

A small number of smart switches do not have an LED indicator. Instead, these switches have two LEDs for backlighting.

A smart switch does not function correctly without programming the BHM. Optional features are designed around specific smart switch part numbers, and a different smart switch number cannot be substituted.

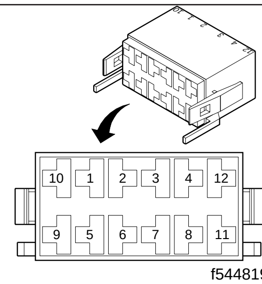


Fig. 1, Connector Used on a Smart Switch

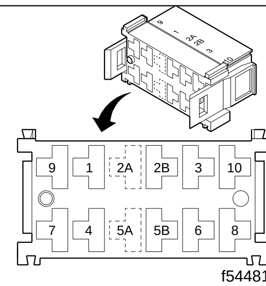


Fig. 2, Connector Used on a High-current Switch

Smart Switches Removal and Installation

Removal

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Remove the trim plate panel. For instructions, see **Section 60.08, Subject 100**.
3. Remove the gauge panel surrounding the smart switch you want to remove. For instructions, see **Section 60.08, Subject 100**.
4. Disconnect the electrical connector from the smart switch.
5. Remove the smart switch from the gauge panel.

Installation

1. Install a new smart switch in the gauge panel.
2. Connect the electrical connector to the smart switch.
3. Install the gauge panel. For instructions, see **Section 60.08, Subject 100**.
4. Install the trim plate panel. For instructions, see **Section 60.08, Subject 100**.
5. Remove the chocks from the tires.

Typical Smart Switch Faults

Smart switch faults must be diagnosed to determine if the smart switch itself is the cause of the problem. See **Table 1** for symptoms that might indicate a smart switch fault.

See **Table 2** for descriptions of smart switch faults.

Determining Which Smart Switches the Vehicle is Programmed to Use

Use the following instructions to determine which vehicle functions use a smart switch.

1. Log on to ServiceLink® and click on the BHM icon.
2. Click on the **Features** tab.
3. All of the reference parameters programmed into the Bulkhead Module (BHM) that use a smart switch have "(Smart Switch)" in the description of the reference parameter. See **Fig. 1**.

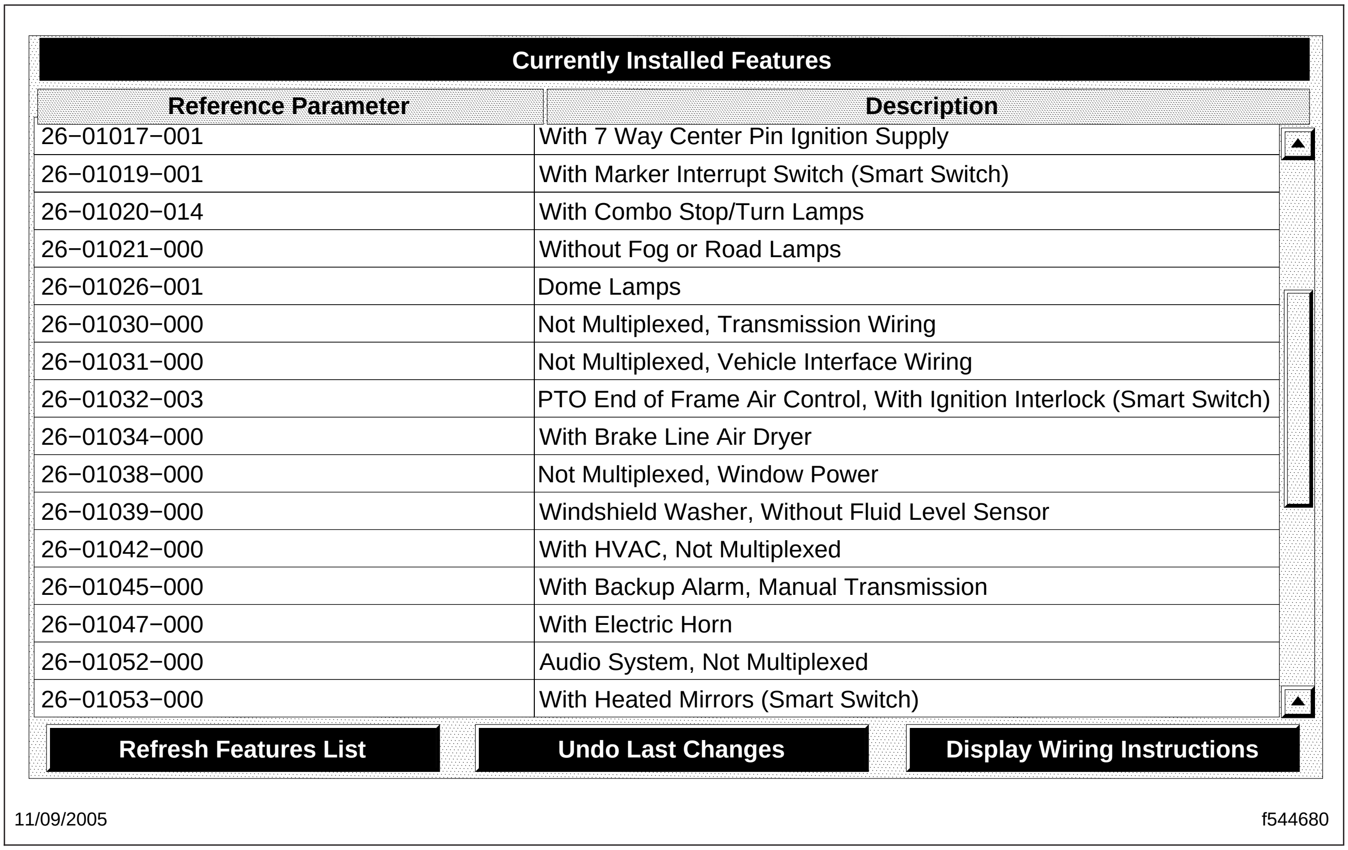
Smart Switch Faults						
J1587 Fault			J1939 Fault			Fault Description
MID	SID	FMI	SA	SPN	FMI	
164	022	07	33	6918	07	Missing Smart Switch
164	021	07	33	6919	07	Duplicate Smart Switch
164	020	07	33	6920	07	Extra Smart Switch
—	—	—	128	6914	04	Smart Switch VBAT Short to Ground
—	—	—	129	6914	04	Smart Switch VBAT Short to Ground
—	—	—	130	6914	04	Smart Switch VBAT Short to Ground
—	—	—	131	6914	04	Smart Switch VBAT Short to Ground

Table 1, Smart Switch Faults

Definition of Smart Switch Faults	
Problem	Description
Missing Smart Switch Fault	The BHM cannot detect a smart switch for a function that is programmed into the BHM by a reference parameter For example, no fog lamp switch, but a reference parameter for fog lamps is programmed into the BHM.
Duplicate Smart Switch Fault	The BHM has detected more than one smart switch for a particular function programmed into the BHM by a reference parameter. For example, two fog lamp smart switches are connected.
Extra Smart Switch Fault	The BHM detects a smart switch for a function that is not programmed into the BHM by a reference parameter. For example, a fog lamp switch is connected, but the vehicle is not programmed for fog lamps.
Smart Switch VBAT Short to Ground	The smart switch indicator and/or backlight drive circuit is overloaded. Only smart switches connected to a SEM report this fault.

Table 2, Definition of Smart Switch Faults

Troubleshooting



Currently Installed Features

Reference Parameter	Description
26−01017−001	With 7 Way Center Pin Ignition Supply
26−01019−001	With Marker Interrupt Switch (Smart Switch)
26−01020−014	With Combo Stop/Turn Lamps
26−01021−000	Without Fog or Road Lamps
26−01026−001	Dome Lamps
26−01030−000	Not Multiplexed, Transmission Wiring
26−01031−000	Not Multiplexed, Vehicle Interface Wiring
26−01032−003	PTO End of Frame Air Control, With Ignition Interlock (Smart Switch)
26−01034−000	With Brake Line Air Dryer
26−01038−000	Not Multiplexed, Window Power
26−01039−000	Windshield Washer, Without Fluid Level Sensor
26−01042−000	With HVAC, Not Multiplexed
26−01045−000	With Backup Alarm, Manual Transmission
26−01047−000	With Electric Horn
26−01052−000	Audio System, Not Multiplexed
26−01053−000	With Heated Mirrors (Smart Switch)

Fig. 1, Currently Installed Features Screen

NOTE: Some reference parameter descriptions may indicate there is a smart switch even if the description indicates the vehicle is not programmed with that feature. An example is 26-01019-000, "Without Marker Interrupt Switch (Smart Switch)." Since a vehicle with this reference parameter is not programmed with the marker interrupt switch, there is no marker interrupt smart switch.

4. If the vehicle is equipped with a Switch Expansion Module, there will be an icon on the left-side menu of ServiceLink for that ECU. Click on that icon to display a separate tab for smart switches. This screen lists all smart switches connected to the SEM.

NOTE: Smart switches connected to the Bulkhead Module are not listed in the Switch Expansion Module smart switch screen.

5. To verify which smart switches are connected to the SEM, click the **Identify SEM** button in ServiceLink on the SEM Smart Switch screen. See **Fig. 2**. The smart switch indicator lights will blink for the switches connected to the SEM.

Troubleshooting Smart Switch Faults

Use the following instructions to troubleshoot the smart switch faults described in **Table 2**.

Missing Smart Switch Fault

The Missing Smart Switch fault occurs when a smart switch that the BHM is programmed to use is not found connected to one of the five BHM ports or one of the six SEM ports. Use the following steps to troubleshoot this fault.

1. Access the Features screen in ServiceLink to determine which smart switches the vehicle is

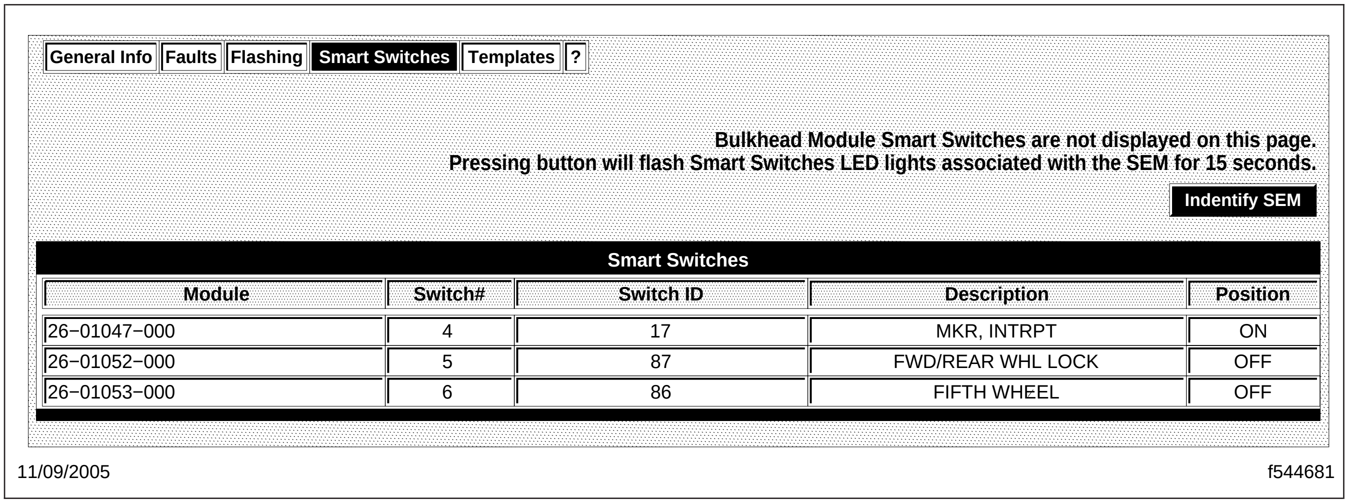


Fig. 2, SEM Smart Switch Screen

programmed to use. For instructions, see "Determining Which Smart Switches the Vehicle is Programmed to Use" in this subject.

2. Identify which smart switches the vehicle recognizes as being installed using one of the appropriate J1939 templates in ServiceLink (for either the BHM or the SEM).

NOTE: See the ServiceLink User’s Guide under "Templates" for instructions on using the DataLink monitor templates. These templates provide the unique smart switch decimal value that indicates what smart switches the Bulkhead Module is programmed to use.

3. See the "Smart Switch Part Number, Function, and ID Number" table in **Specifications 400** to cross-reference the smart switch decimal value with the smart switch function. Compare this with the smart switches that were expected based on what features the Bulkhead Module was programmed to use.

4. Determine which smart switch is missing or not being correctly identified.

   A missing smart switch fault may occur due to one of the following conditions:

   - The smart switch is physically not connected.
   - There is a switch ID circuit wiring problem.
   - J1939 communication problems exist between an optional SEM and the BHM.
   - The switch ID resistors in the smart switch itself are faulty.

5. Remove the smart switch from the dash. Using the "Smart Switch Part Number, Function, and ID Number" table in **Specifications 400**, determine the values of ID resistors R1 and R2. Add the R1 and R2 values. Measure the resistance between pins 7 and 8 of the smart switch. If the measurement is within 1 percent of the added resistance value, the switch is okay.

Extra Smart Switch Fault

The Extra Smart Switch fault indicates that a smart switch that the vehicle is not programmed to utilize is found connected to one of the five BHM or six SEM smart switch ports. Use the following steps to troubleshoot this fault.

1. Access the Features screen in ServiceLink to determine which smart switches the vehicle is programmed to use. For instructions, see "Determining Which Smart Switches the Vehicle is Programmed to Use" in this subject.

2. Identify which smart switches the vehicle recognizes as being installed using one of the appropriate J1939 templates in ServiceLink (for either the BHM or the SEM).

NOTE: See the ServiceLink User’s Guide under "Templates" for instructions on using DataLink monitor templates. These templates provide the unique smart switch ID number that indicates what smart switches the Bulkhead Module actually recognizes as being on the vehicle.

3. See the "Smart Switch Part Number, Function, and ID Number" table in **Specifications 400** to cross-reference the smart switch part number with the smart switch function. Compare this with the smart switches that were expected based on what features the Bulkhead Module was programmed to use.
4. Determine which smart switch is missing or not being correctly identified.

Duplicate Smart Switch Fault

The Duplicate Smart Switch fault indicates that there are two or more identical smart switches connected to either the BHM or SEM smart switch ports.

Determine which smart switches the vehicle is programmed to use. See the Features screen in ServiceLink to determine which smart switches the vehicle is programmed to use. For instructions, see "Determining Which Smart Switches the Vehicle is Programmed to Use" in this subject.

The switch function that is duplicated will be two or more smart switch ports that have the same smart switch ID number shown in the applicable template. The duplicate switch must be disconnected. See the ServiceLink User’s Guide under "Templates" for instructions on using DataLink monitor templates.

Smart Switch VBAT Short to Ground Fault

The Smart Switch VBAT Short to Ground fault indicates a smart switch indicator and/or backlight drive circuit is overloaded. Only smart switches connected to a SEM will report this fault. Use the following steps to troubleshoot this fault.

1. Access ServiceLink to determine which smart switches are connected specifically to the SEM.
2. Click on the **Switch Expansion Module** icon on the left-side list of the ECUs.
3. Click on the **Smart Switch** tab. A list of all smart switches that are connected to the SEM will be displayed.
4. Click on the **Identify SEM** button in ServiceLink. This causes the smart switch indicator lights to blink.
5. Based on the descriptions of the switches connected to the SEM, look for the smart switch that is connected to the SEM, but has an indicator light that is not blinking.
6. Once the affected smart switch is identified, troubleshoot the switch and check the wiring for a short circuit.

The Switch Controlled Option Does Not Work

When a smart switch controlled option does not work when the smart switch is activated, the problem is likely due to one of the conditions described in **Table 3**.

If a function does not work and there are no active smart switch fault codes, then the following procedure will help determine if the smart switch itself or its wiring is the cause of the problem. If smart switch fault code(s) are active, troubleshoot them first.

To determine if the smart switch or its wiring is the cause of the multiplexed function not working, see **Table 4**.

Smart Switch Controlled Option Faults	
Problem	**Description**
Hardware problems	Main VBAT fuse that supplies the output pin is open.
	BHM, CHM, or EXM output driver circuit is overloaded; too much current will cause the output to shut off.
	Faulty BHM, CHM, or EXM output driver (internal BHM, CHM, or EXM problem).
Output problems	The output device is faulty. For example, the suspension dump AMU/AAVA solenoid valve is faulty.
	The output device wiring is faulty.
	Output is not wired to the correct output pin.
	If the output is connected to the CHM, there are possible J1939 communication problems between the BHM and CHM.
	If the output is connected to an EXM, there are possible J1939 communication problems between the BHM and EXM.
Input problems	Faulty smart switch.
	Faulty smart switch wiring.
	Other input conditions for the function to activate are not met. For example, the BHM does not sense that the park brake is set in order to activate the suspension dump valve.
	J1939 communication problems exist between the optional SEM and the BHM.
Software problems	The reference parameter is not compatible with vehicle options.
	The reference parameter has errors.

Table 3, Smart Switch Controlled Option Faults

Smart Switch Troubleshooting			
Step	**Test Procedure**	**Test Result**	**Action**
1	Are any smart switch faults active?	Yes	Troubleshoot faults as outlined in this subject.
		No	Go to **step 2**.

Troubleshooting

Smart Switch Troubleshooting

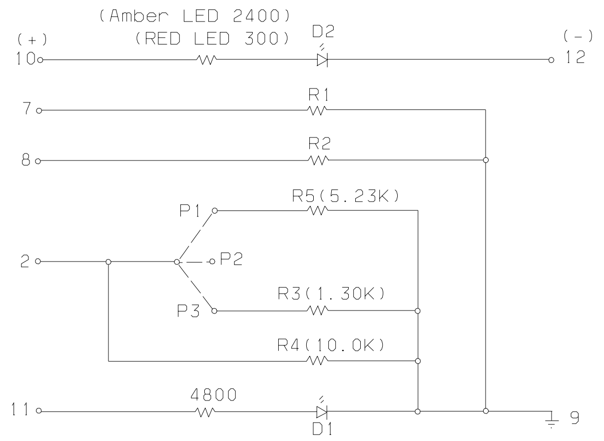
Step	Test Procedure	Test Result	Action
2	Observe the smart switch indicator (if equipped) while attempting to operate the function with the switch. NOTE: If the switch does not have an indicator light, go to **step 3**.	Blinks steady	The function interlocks were met, but the BHM does not sense that the function actually engaged. For example, if a function uses an AMU/AAVA solenoid, the BHM may not be sensing that the function engaged through the AMU or air pressure switch. This could be caused by the AMU/AAVA solenoid not switching, a defective pressure switch, or a wiring fault. This does not indicate a problem with the smart switch.
		On, then quickly off	Some other condition is not met in order for the function to work. For example, if the function requires that the park brake be set in order for the function to operate, and the park brake is not set, then the function will not work. This does not indicate a problem with the smart switch.
		Off	Go to **step 3**.
		Switch does not have indicator	Go to **step 3**.
3	Using ServiceLink, access the BHM Features screen. Is there a reference parameter listed for the function, and does it indicate the use of a smart switch?	Yes	Go to **step 4**.
		No	The reference parameter for the function is not loaded into the BHM. Load the correct reference parameter using ServiceLink.
4	Find the part number on the smart switch for the function that is not working. Using the "Smart Switch Part Number, Function, and ID Number" table in **Specifications 400**, find the ID Number that corresponds to the part number of the switch. In ServiceLink, open the applicable smart switch template (either for the BHM, or SEM). Locate the column that has the smart switch ID that matches the ID Number in "Smart Switch Part Number, Function, and ID Number" table in **Specifications 400**. While observing the input or position status on the template, operate the switch through each position. There should be a change in either the voltage input, or position (depending on the template). Is there a change in switch position reflected in the template?	Yes	The problem is not with the smart switch or its wiring. The problem is either with the output to the function, or possibly a reference parameter problem.
		No	Go to **step 5**.

Smart Switch Troubleshooting			
Step	**Test Procedure**	**Test Result**	**Action**
5	Remove the smart switch. Check resistance between pins 2 and 9 for each switch position. Compare readings with the values specified in the "Switch Position Input Resistance, Pin 2 to Pin 9" table in **Specifications 400**. Are the resistance values within specifications?	Yes	Check wiring (circuit 474B) between pin 2 of the smart switch and the BHM. Repair as necessary.
		No	Replace the smart switch.

Table 4, Smart Switch Troubleshooting

Specifications

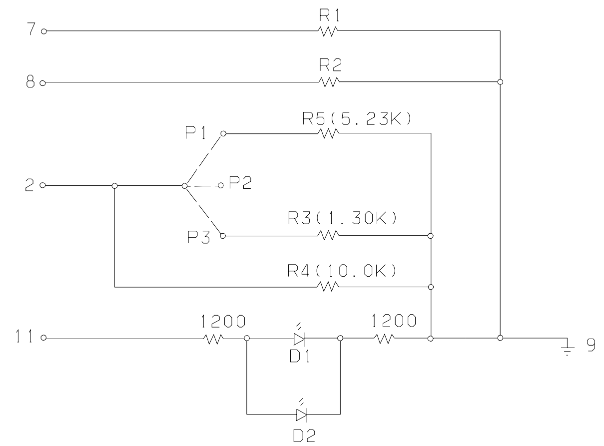
See **Fig. 1** for the wiring diagram of a two-position smart switch. See **Fig. 2** for the wiring diagram for a three-position smart switch.



08/27/2004 Ref. Dia. A06−37217 Chg. Ltr. K f544518

D2 Activation LED
R1 ID No. 1 Resistor
R2 ID No. 2 Resistor
R3 Switch Position No. 3 Resistor
R4 Switch Off Resistor (Same as switch position no. 2; only applies to switches with on/off/on pattern.)
R5 Switch Position No. 1 Resistor
D1 Backlighting LED

Fig. 1, Smart Switch Wiring, Circuit Diagram A



08/31/2004 Ref. Dia. A06−37217 Chg. Ltr. K f544519

R1 ID No. 1 Resistor
R2 ID No. 2 Resistor
R3 Switch Position No. 3 Resistor
R4 Switch Off Resistor (Same as switch position no. 2; only applies to switches with on/off/on pattern.)
R5 Switch Position No. 1 Resistor
D1 Backlighting LED
D2 Backlighting LED

Fig. 2, Smart Switch Wiring, Circuit Diagram B

Pinout for Circuit Diagram A Smart Switch		
Pin	**Circuit Number**	**Circuit Description**
2	474B	Switch Position Input
7	474C	Switch Function ID 1 Input
8	474D	Switch Function ID 2 Input
9	GND	Ground
10	14E	Indicator (+)
11	29A	Backlighting (+)
12	474A	Indicator (–)

Table 1, Pinout for Circuit Diagram A Smart Switch

Pinout for Circuit Diagram B Smart Switch		
Pin	**Circuit Number**	**Circuit Description**
2	474B	Switch Position Input

Specifications

Pinout for Circuit Diagram B Smart Switch		
Pin	Circuit Number	Circuit Description
7	474C	Switch Function ID 1 Input
8	474D	Switch Function ID 2 Input
9	GND	Ground
11	29A	Backlighting (+)

Table 2, Pinout for Circuit Diagram B Smart Switch

Switch Position Input Resistance, Pin 2 to Pin 9		
Lower Switch Position	Mid Switch Position	Upper Switch Position
1138 to 1162 ohms	9900 to 10,100 ohms	3400 to 3468 ohms

Table 3, Switch Position Input Resistance, Pin 2 to Pin 9

Smart Switch Part Number, Function, and ID Number					
Smart Switch Part Number	Smart Switch Function	Circuit Diagram	Smart Switch ID Number	R1 Value in Ohms	R2 Value in Ohms
A06-37217-000	Marker Interrupt	A	17	1020	1020
A06-37217-001	Engine Retarder	A	18	1020	1300
A06-37217-002	Mirror Heat	A	19	1020	1620
A06-37217-003	Utility Lamp	A	20	1020	2000
A06-37217-005	Fog Lamp	A	22	1020	2940
A06-37217-006	Rear Fog Lamp	A	23	1020	3570
A06-37217-007	Snowplow	A	24	1020	4320
A06-37217-008	Bunk Override	A	25	1020	5230
A06-37217-009	Engine Check	A	26	1020	6340
A06-37217-010	PTO	A	27	1020	7870
A06-37217-011	Transretarder	A	28	1020	10,000
A06-37217-012	Brake Check	A	33	1300	1020
A06-37217-013	Dome Lamp	A	34	1300	1300
A06-37217-014	Optional	A	35	1300	1620
A06-37217-015	Shutdown Override	A	36	1300	2000
A06-37217-016	Engine Fan	A	37	1300	2430
A06-37217-017	PTO	A	38	1300	2940
A06-37217-018	Transfer Case	A	39	1300	3570
A06-37217-019	Fuel Heater	A	40	1300	4320
A06-37217-020	Transfer Case	A	41	1300	5230
A06-37217-021	Spot Lamp	A	42	1300	6340
A06-37217-022	Advertising Light	A	43	1300	7870

Specifications

Smart Switch Part Number, Function, and ID Number					
Smart Switch Part Number	**Smart Switch Function**	**Circuit Diagram**	**Smart Switch ID Number**	**R1 Value in Ohms**	**R2 Value in Ohms**
A06-37217-023	Trailer Auxiliary	A	44	1300	10,000
A06-37217-024	Lift Axle	A	49	1620	1020
A06-37217-025	Air Unloader	A	50	1620	1300
A06-37217-026	Axle Shift	A	51	1620	1620
A06-37217-027	Beacon	A	52	1620	2000
A06-37217-028	Increment/Decrement	B	53	1620	2430
A06-37217-029	Bunk Control	A	54	1620	2940
A06-37217-030	Interaxle Lock	A	55	1620	3570
A06-37217-031	Forward Wheel Lock	A	56	1620	4320
A06-37217-032	Left Step	A	57	1620	5230
A06-37217-033	Right Step	A	58	1620	6340
A06-37217-034	Rear Wheel Lock	A	59	1620	7870
A06-37217-035	Auxiliary Transmission	A	60	1620	10,000
A06-37217-036	Suspension Dump	A	65	2000	1020
A06-37217-037	Fifth Wheel Slide	A	66	2000	1300
A06-37217-038	Alternate Flasher	A	67	2000	1620
A06-37217-039	DRL Override	A	68	2000	2000
A06-37217-040	Backup Alarm	A	69	2000	2430
A06-37217-041	Lift Axle 2	A	70	2000	2940
A06-37217-042	RPM Control	A	71	2000	3570
A06-37217-043	RPM+/RPM–	B	72	2000	4320
A06-37217-044	Center Wheel Lock	A	73	2000	5230
A06-37217-045	Interaxle Lock 2	A	74	2000	6340
A06-37217-046	Forward Wheel Lock	A	75	2000	7870
A06-37217-047	Transfer Case PTO	A	76	2000	10,000
A06-37217-048	Auxiliary Air	A	81	2430	1020
A06-37217-049	Auxiliary Air 2	A	82	2430	1300
A06-37217-050	Auxiliary Air 3	A	83	2430	1620
A06-37217-051	Auxiliary Air 4	A	84	2430	2000
A06-37217-052	Headlamp/Marker	B	—	—	—
A06-37217-053	Dimmer	B	—	—	—
A06-37217-056	Exhaust Brake	A	85	2430	2430
A06-37217-057	Electric/Air Horn	B	86	2430	2940
A06-37217-058	Front/Rear Wheel Lock	A	87	2430	3570
A06-37217-059	Interaxle Lock 1	A	88	2430	4320

Specifications

Smart Switch Part Number, Function, and ID Number					
Smart Switch Part Number	**Smart Switch Function**	**Circuit Diagram**	**Smart Switch ID Number**	**R1 Value in Ohms**	**R2 Value in Ohms**
A06-37217-060	Interaxle Lock 1 & 2	A	89	2430	6340
A06-37217-061	Forward Wheel Lock	A	90	2430	10,000
A06-37217-062	Rear Wheel Lock	A	91	2430	7870
A06-37217-063	Forward/Center Wheel Lock	A	92	2430	10,000
A06-37217-064	Center/Rear Wheel Lock	A	97	2940	1020
A06-37217-065	Rear Wheel Lock	A	98	2940	1300
A06-37217-066	Forward/Center/Rear Wheel Lock	A	99	2940	1620
A06-37217-067	All Wheel Drive	A	100	2940	2000
A06-37217-068	Lift Axle 1	A	101	2940	2430
A06-37217-069	Lift Axle 3	A	102	2940	2940
A06-37217-070	Auxiliary Axle 5	A	103	2940	3570
A06-37217-071	Fire Pump	A	104	2940	4320
A06-37217-073	Marker Interrupt	B	17	1020	1020
A06-37217-074	Engine Air Intake	A	105	2940	5230
A06-37217-077	Electric/Air Horn	A	86	2430	2940
A06-37217-078	Lift Axle	A	49	1620	1020
A06-37217-079	Lift Axle 1	A	101	2940	2430
A06-37217-080	Lift Axle 2	A	70	2000	2940
A06-37217-081	Lift Axle 3	A	102	2940	2940
A06-37217-084	Compartment Lamp	A	106	2940	6340
A06-37217-085	Right Compartment Lamp	A	107	2940	7870
A06-37217-086	Left Compartment Lamp	A	108	2940	10,000

Table 4, Smart Switch Part Number, Function, and ID Number

General Information

The multifunction turn signal switch is mounted on the left side of the steering column, just below the steering wheel. The switch controls the:

- turn signals
- windshield wipers and washers
- headlight dimmer/flash to pass
- hazard warning flasher

The switch uses a low-current resistive ladder network for the switch functions. Low-current switches allow the use of smaller diameter wires, while the resistive ladder network reduces the number of wires.

Each switch function corresponds to a resistive output. The resistive ladder output is connected to the instrumentation control unit (ICU3-M2) where the signals are processed and sent to the Bulkhead Module to actuate high-current devices such as the headlights, turn signals, and wiper motor.

The hazard switch is a traditional switch and is directly wired to the Bulkhead Module.

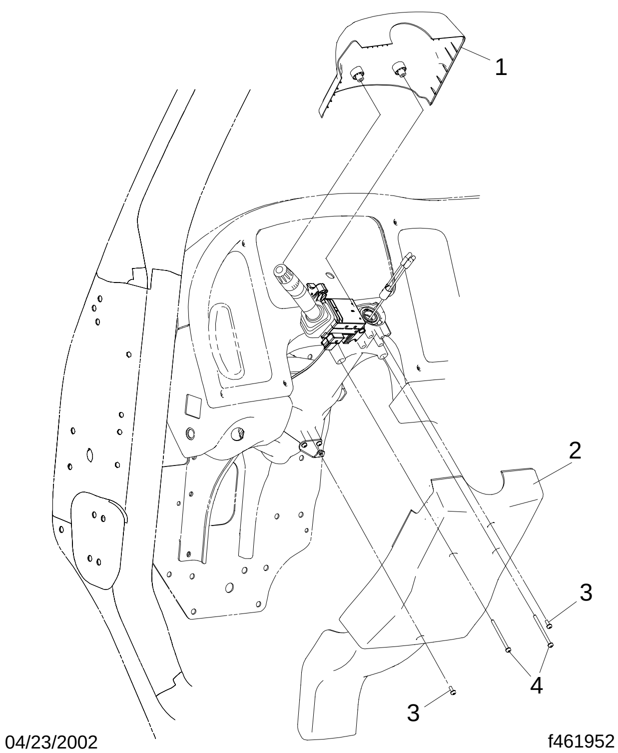
Multifunction Turn Signal Switch Removal and Installation

Removal

1. Disconnect the negative leads from the batteries.

NOTE: The multifunction turn signal switch is mounted on the left side of the steering column, just below the steering wheel.

2. Remove the capscrews that attach the upper and lower clamshell covers to the steering column cover. See **Fig. 1**.

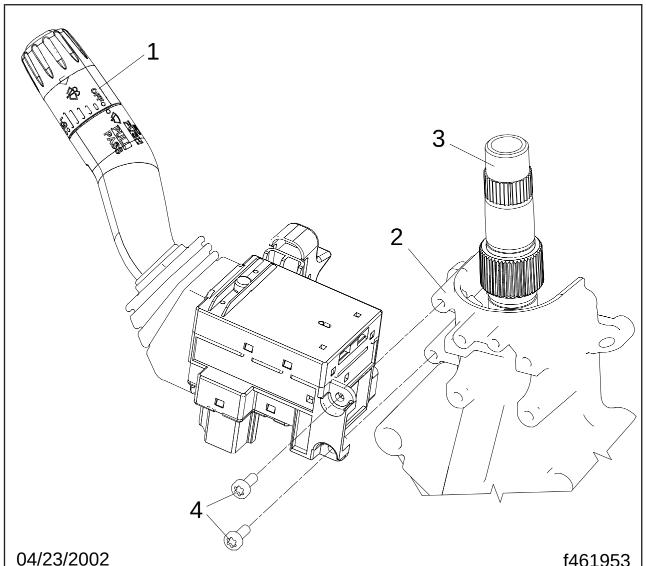


NOTE: Steering wheel shown removed for clarity.

1. Upper Clamshell Cover
2. Lower Clamshell Cover
3. 12-mm Long Capscrew
4. 70-mm Long Capscrew

Fig. 1, Clamshell Covers Installation

3. Remove the capscrews that attach the multifunction turn signal switch to the steering column cover. See **Fig. 2**.
4. Disconnect the two electrical harness connectors from the multifunction turn signal switch, then remove the switch.



1. Multifunction Turn Signal Switch
2. Steering Column Cover
3. Steering Column
4. 15-mm Long Capscrew

Fig. 2, Multifunction Turn Signal Switch Installation

Installation

1. Connect the two electrical harness connectors to the multifunction turn signal switch.
2. Properly orient the multifunction turn signal switch and use two capscrews to attach the switch to the steering column cover. Torque 7 lbf·ft (9 N·m).
3. Using four capscrews, attach the upper and lower clamshell covers to the steering column cover.
4. Connect the batteries.
5. Verify the operation of the switch functions.

Specifications

See Fig. 1 for a wiring diagram of the multifunction turn signal switch.

Multifunction Turn Signal Switch Resistor Values		
Description	**Resistor**	**Value in Ohms**
Pin 6 Wiper Off (normal position)	R1	24
Pin 6 Wiper Intermittent 1	R2	56
Pin 6 Wiper Intermittent 2	R3	100
Pin 6 Wiper Intermittent 3	R4	160
Pin 6 Wiper Intermittent 4	R5	240
Pin 6 Wiper Intermittent 5	R6	390
Pin 6 Wiper Low Speed	R7	680
Pin 6 Wiper High Speed	R8	1600
Pin 5 Normal Position	R9	1500
Pin 5 Windshield Washer	R10	300
Pin 5 High Beam/Flash High Beam	R11	180
Pin 4 Normal Position	R12	1500
Pin 4 Left Turn Signal	R13	300
Pin 4 Right Turn Signal	R14	180

Table 1, Multifunction Turn Signal Resistor Values

Multifunction Turn Signal Switch Resistance Range Values		
Description	**Resistor**	**Resistance Range in Ohms**
Pin 6 Wiper Off (normal position)	R1	23.8 – 24.2
Pin 6 Wiper Intermittent 1	R2	55.4 – 56.6
Pin 6 Wiper Intermittent 2	R3	99.0 – 101.0
Pin 6 Wiper Intermittent 3	R4	158.4 – 161.6
Pin 6 Wiper Intermittent 4	R5	237.6 – 242.4
Pin 6 Wiper Intermittent 5	R6	386.1 – 393.9
Pin 6 Wiper Low Speed	R7	673.2 – 686.8
Pin 6 Wiper High Speed	R8	1584.0 – 1616.0
Pin 5 Normal Position	R9	1485.0 – 1515.0
Pin 5 Windshield Washer	R9 and R10 in parallel	247.5 – 252.5
Pin 5 High Beam/Flash High Beam	R9 and R11 in parallel	159.1 – 162.3
Pin 5 Washer and High Beam	R9, R10 and R11 in parallel	103.6 – 105.7
Pin 4 Normal Position	R12	1485.0 – 1515.0
Pin 4 Left Turn Signal	R12 and R13 in parallel	247.5 – 252.5

Specifications

Multifunction Turn Signal Switch Resistance Range Values		
Description	Resistor	Resistance Range in Ohms
Pin 4 Right Turn Signal	R12 and R14 in parallel	159.1 – 162.3

Table 2, Multifunction Turn Signal Switch Resistance Range Values

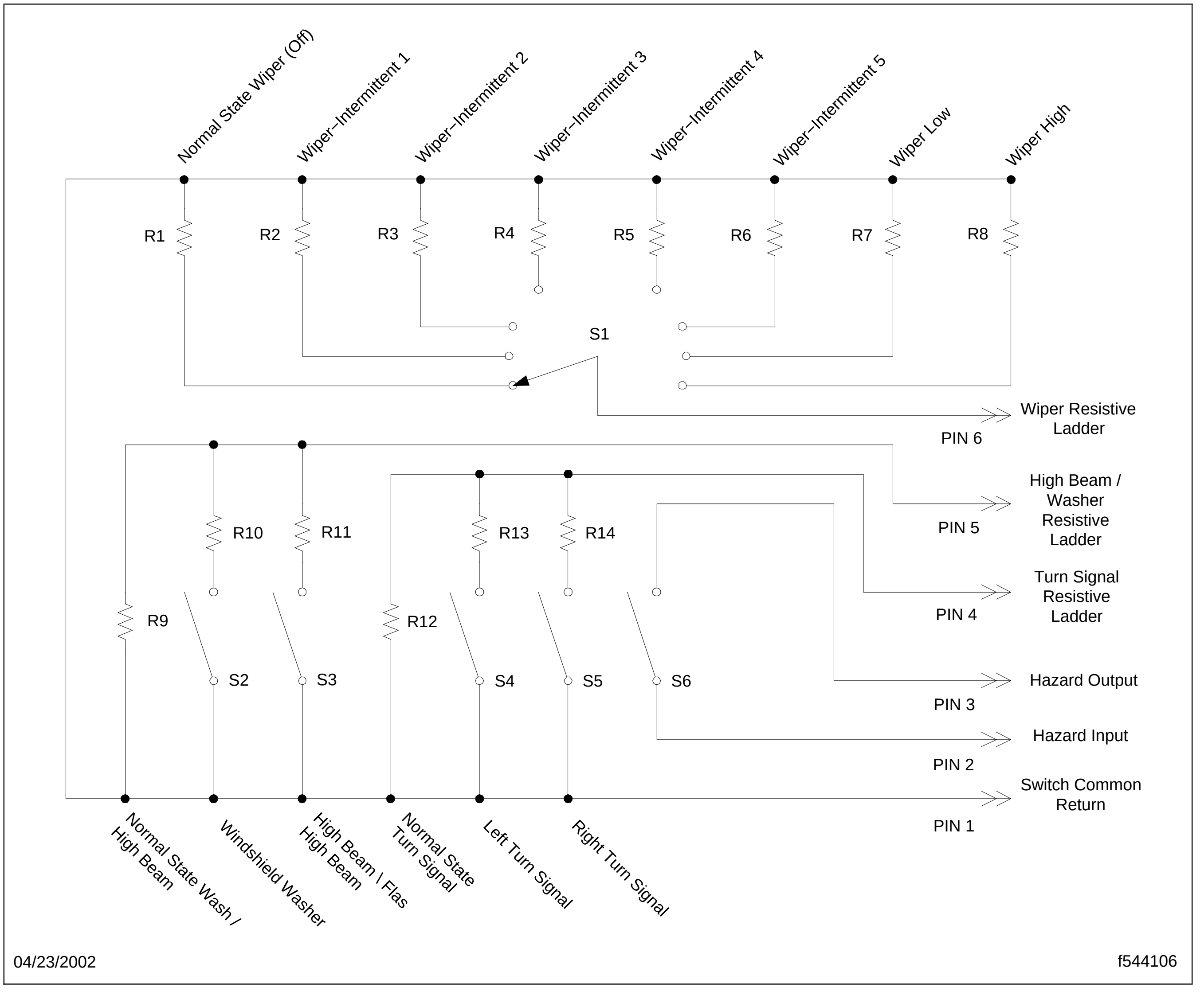


Fig. 1, Multifunction Turn Signal Switch Wiring Diagram

General Information

Background Information

A Switch Expansion Module (SEM) is used on a Business Class® M2 vehicle when more than five smart switches are installed on the vehicle. A Switch Expansion Module supports up to six smart switches.

The function of the SEM is to:

- Read all smart switch IDs and positions;
- Transmit the smart switch IDs and position data on the J1939 datalink;
- Turn on the smart switch indicator lights when commanded to do so by the Bulkhead Module (BHM).

The SEM is a remote-mounted device on the M2 chassis. The SEM mounts to a bracket that is installed behind the gauge panel that is below the radio. See **Fig. 1**.

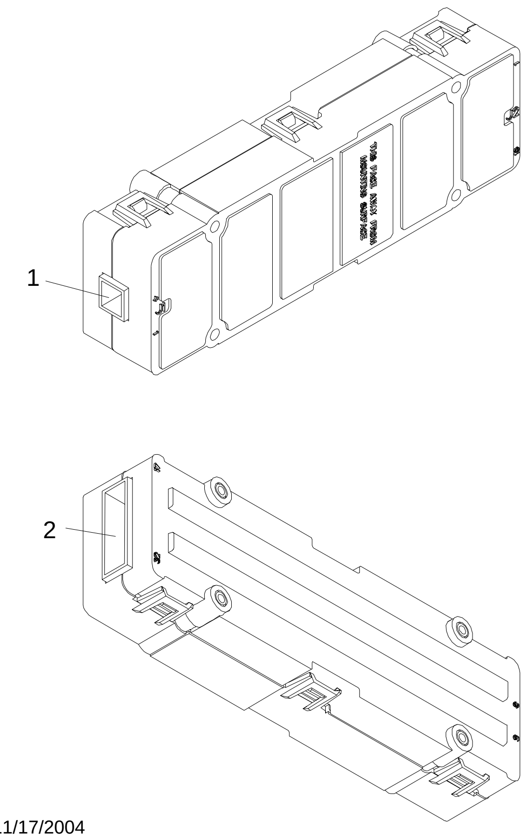
Smart switches are connected to the SEM using a harness connected to the J2 connector of the SEM.

The SEM communicates only over the J1939 datalink. It has no J1708/J1587 communication.

The SEM does not have any power output pins. Open power output pins must be available in a Chassis Module (CHM) or a Chassis Expansion Module (EXM) to control electrical devices, or another ECU that supports J1939 messages. This ECU must be able to receive J1939 commands in response to the activation of a smart switch.

If there are no open power output pins in the CHM or EXM, and there is no ECU that supports J1939 messages and receives commands in response to the activation of a smart switch, then the SEM is not required and it does not unlock any additional multiplexing capabilities.

In order to add an SEM, reference parameters must be available for programming the BHM.



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1. J1 Connector
2. J2 Connector

Fig. 1, Switch Expansion Module

Switch Expansion Module Replacement

Replacement

1. Using ServiceLink®, take note of the icons that appear for the Switch Expansion Modules (SEM) on the vehicle.
2. Turn off the engine, apply the parking brakes, and chock the tires.
3. Disconnect the negative leads from the batteries.
4. Remove the trim plate panel from the dashboard. See **Fig. 1**. For instructions, see **Section 60.08, Subject 100**.
5. Disconnect the dome light switch at the right dash panel, then remove the right dash panel.
6. Remove the top cover from the dashboard.
7. Disconnect the connectors from each end of the SEM. See **Fig. 2**.

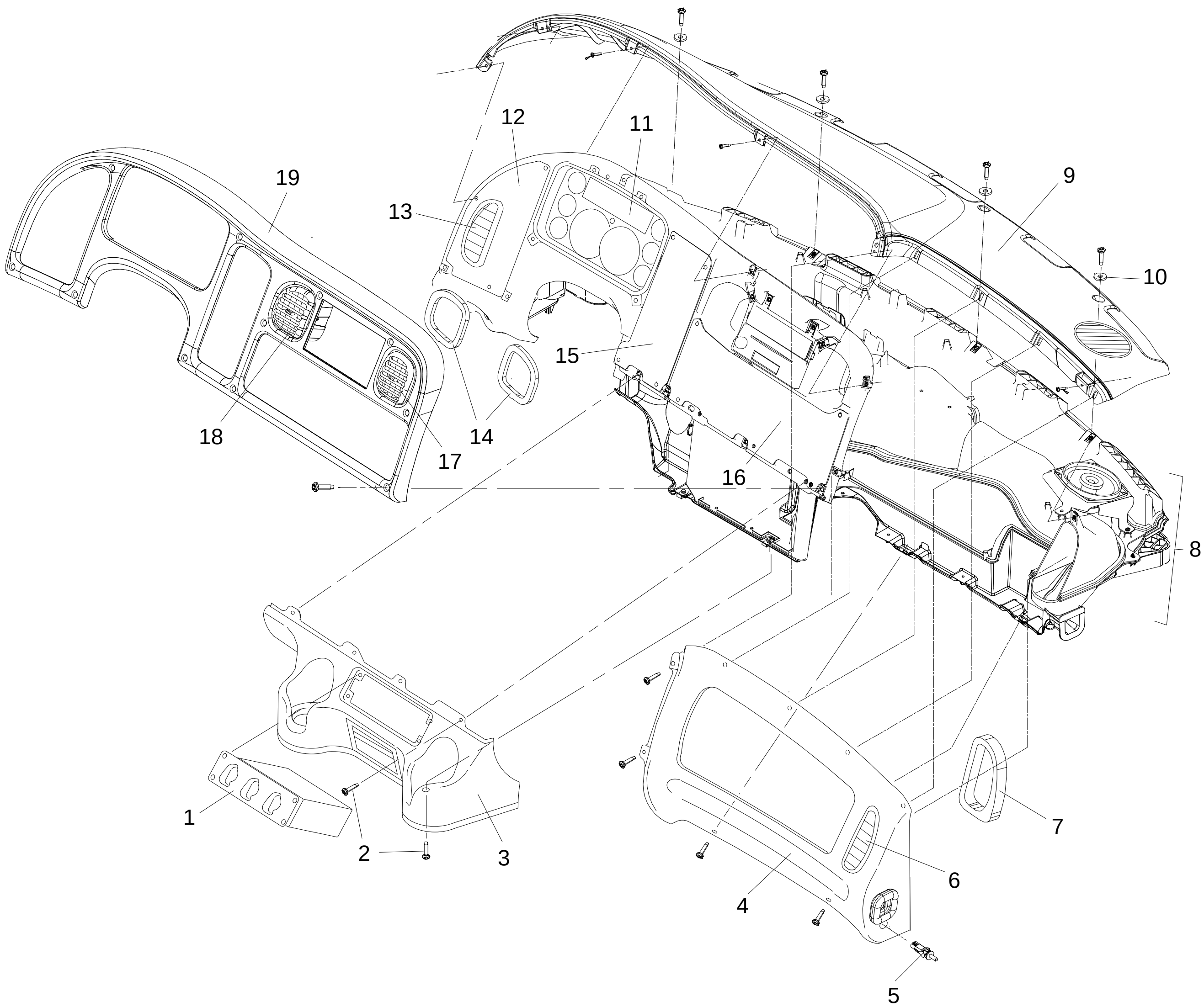
NOTE: If the vehicle has a Mercedes-Benz engine, a vehicle control unit (VCU) is mounted behind the right dash panel.

8. If the vehicle is equipped with a VCU, lift the VCU off the mounting bracket and set it down.
9. Remove the tie straps as necessary to remove the VCU wiring harness from the mounting clip, and to access the capscrews on the mounting bracket.
10. Remove the capscrews at the top and bottom of the mounting bracket, then remove the mounting bracket.
11. Remove the four capscrews that attach the SEM to the mounting bracket, and remove and discard the SEM.
12. Using four capscrews, attach a new SEM to the mounting bracket.
13. Using four capscrews, install the mounting bracket.
14. If the vehicle is equipped with a VCU, mount the VCU on the mounting bracket.
15. Use tie straps as necessary to secure the VCU wiring harness.
16. Connect the connectors to each end of the SEM.
17. Install the top cover on the dashboard. For instructions, see **Section 60.08, Subject 100**.
18. Install the right dash panel on the dashboard.
19. Install the trim plate panel on the dashboard.
20. Connect the batteries.
21. Using ServiceLink, take note of the icons that appear for the Switch Expansion Modules on the vehicle. If the SEM that was replaced did not appear in ServiceLink, then the new SEM will not appear in ServiceLink.

NOTE: To identify an SEM, go into the SEM icon in ServiceLink. Click on the **Smart Switches** tab and use the **Identify SEM** button to flash the indicator lights of the smart switches connected to that particular SEM. This makes it possible to locate the SEM and to see which smart switches are connected to which SEM.

22. Remove the chocks from the tires.

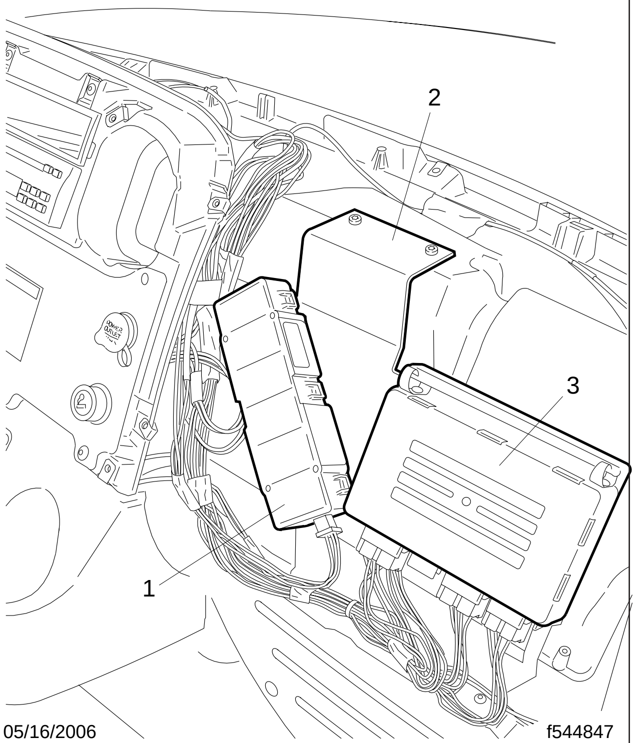
Switch Expansion Module Replacement



1. HVAC Control Panel
2. Torx® Capscrew
3. Cup Holder Panel
4. Right Dash Panel
5. Dome Light Switch
6. Right Window Outlet Louver
7. Duct Seal
8. Tray Assembly With HVAC Ducts
9. Top Cover
10. Washer
11. Instrument Cluster
12. Gauge Panel
13. Left Window Outlet Louver
14. Duct Seal
15. Switch Panel
16. Gauge Panel
17. Right Dash Outlet Louver
18. Left Dash Outlet Louver
19. Trim Plate Panel

Fig. 1, Dash Panels

Switch Expansion Module Replacement



1. Switch Expansion Module
2. Mounting Bracket
3. Vehicle Control Unit (vehicle with Mercedes-Benz engine only)

Fig. 2, Location of Switch Expansion Module

Installation

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the negative leads from the batteries.
3. Remove the trim plate panel from the dashboard. See **Fig. 1**. For instructions, see **Section 60.08, Subject 100**.
4. Disconnect the dome light switch at the right dash panel, then remove the right dash panel.
5. Remove the top cover from the dashboard.

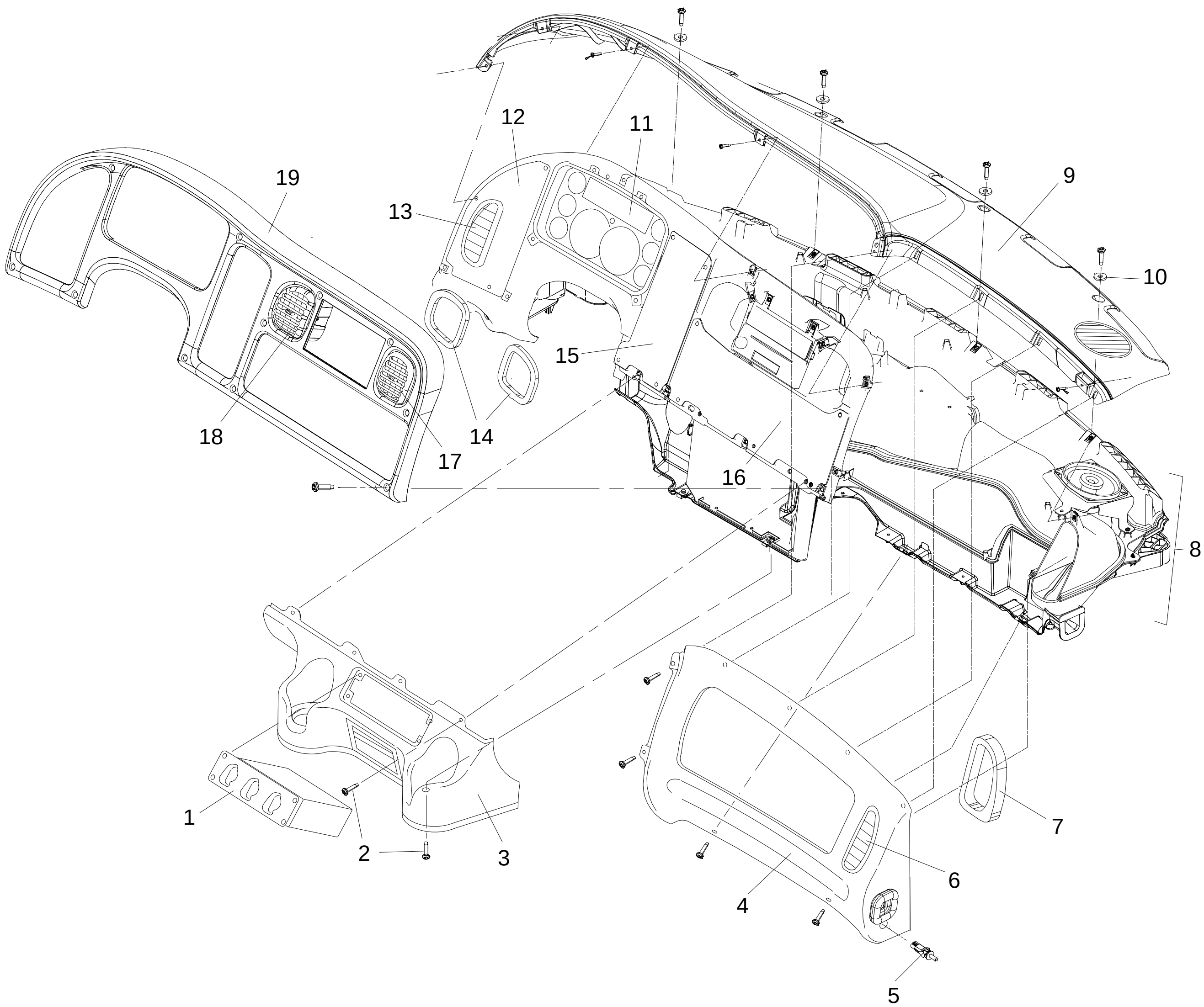
NOTE: If the vehicle has a Mercedes-Benz engine, a vehicle control unit (VCU) is mounted behind the right dash panel.

6. If the vehicle is equipped with a VCU, lift the VCU off the mounting bracket and set it down. See **Fig. 2**.
7. Remove the tie-straps as necessary to remove the VCU wiring harness from the mounting clip, and to access the capscrews on the mounting bracket.
8. Remove the capscrews at the top and bottom of the mounting bracket, then remove the mounting bracket.
9. For instructions on installing a smart switch, see **Section 54.14, Subject 100**.
10. Using four capscrews, install the Switch Expansion Module (SEM) to the mounting bracket.
11. Using four capscrews, install the mounting bracket.
12. If the vehicle is equipped with a VCU, mount the VCU on the mounting bracket.
13. Overlay the SEM wiring harness on the main cab harness. Connect one connector of the harness to the Bulkhead Module (BHM), one connector to the smart switch, and two connectors to the SEM.
14. Use tie-straps as necessary to secure the SEM harness to the main cab harness.
15. Use tie-straps as necessary to secure the VCU wiring harness.
16. Install the top cover on the dashboard. For instructions, see **Section 60.08, Subject 100**.
17. Install the right dash panel on the dashboard.
18. Install the trim plate panel on the dashboard.
19. Connect the batteries.
20. After installing an SEM, turn the ignition on and use ServiceLink® to connect to the vehicle. Notice that the newly installed SEM appears in ServiceLink as a new SEM icon in the left side bar. One of the following situations may be encountered.
    - If the serial number of the new SEM is lower than those already on the vehicle, it claims source address 128 and appears as SEM #1.
    - If the serial number of the new SEM is higher than those already on the vehicle, it appears as the next SEM in numeric order. For example, if there are two SEMs already on the vehicle appearing in ServiceLink as SEM #1 and SEM #2, the new SEM appears in ServiceLink as SEM #3.
    - If the serial number of the new SEM is between the serial numbers of SEMs already on the vehicle, the new SEM moves up the second SEM. The new SEM appears as SEM #2, and the SEM that was SEM #2 appears as SEM #3. Since SEM #1 still has the lowest serial number, it still appears as SEM #1.
    - If there are already three SEMs on the vehicle, the installation of a fourth SEM causes an **Invalid ECU (duplicate) – Unable to claim address** icon to appear in ServiceLink since no more than three SEMs can be installed on a vehicle. The fourth SEM should show a source address of 254.

NOTE: To identify an SEM, go into the SEM icon in ServiceLink. Click on the **Smart Switches** tab and use the **Identify SEM** button to flash the indicator lights of the smart switches connected to that particular SEM. This makes it possible to locate the SEM and to see which smart switches are connected to which SEM.

21. Remove the chocks from the tires.

Installation



1. HVAC Control Panel
2. Torx® Capscrew
3. Cup Holder Panel
4. Right Dash Panel
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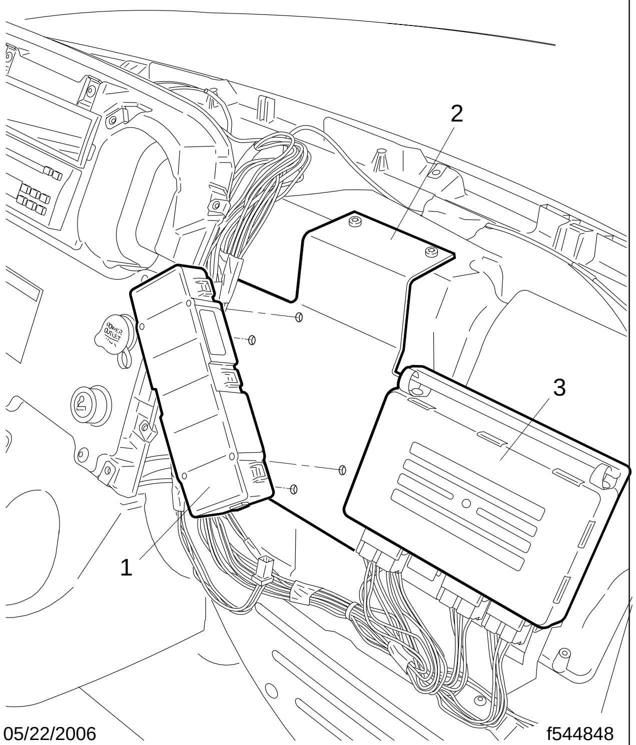
9. Top Cover
10. Washer
11. Instrument Cluster
12. Gauge Panel
13. Left Window Outlet Louver
14. Duct Seal
15. Switch Panel
16. Gauge Panel
17. Right Dash Outlet Louver
18. Left Dash Outlet Louver
19. Trim Plate Panel

Fig. 1, Dash Panels



1. Mounting Bracket
2. Vehicle Control Unit

Fig. 2, Location of Switch Expansion Module

SEM J1939 Source Address Claiming Scheme

A Switch Expansion Module (SEM) on the J1939 datalink claims a J1939 source address. The source address (SA) identifies the module and can be viewed using ServiceLink®. See **Table 1** for a list of the SEM source addresses.

SEM J1939 Source Addresses	
Source Address	**SEM Number**
128	SEM #1
129	SEM #2
130	SEM #3

Table 1, SEM J1939 Source Addresses

Switch Expansion Modules on a vehicle are numbered SEM #1 through SEM #3 depending on the serial number of the SEM. The SEM with the lowest serial number, which is printed on the SEM housing, attempts to claim the lowest SEM source address, 128. Each additional SEM then claims a source address in similar fashion from low to high. The SEM with the next-highest serial number claims the next-highest source address, 129, and so on until all SEMs have claimed a source address.

NOTE: Although the Bulkhead Module (BHM) supports up to three Switch Expansion Modules, the SEM mounting bracket on the Business Class® M2 vehicle is designed for mounting only one SEM.

Once an SEM is installed and claims an address, it stores that as a preferred source address. Every time the vehicle is turned on after that, the SEM will attempt to reuse that preferred source address. This way, each SEM should appear in ServiceLink as the same SEM number (SEM #1 through SEM #3) each time ServiceLink is connected, regardless of whether an SEM is removed or whether the physical locations of the SEMs on the vehicle have changed. The only exception is when an SEM with a lower serial number is added.

If a new SEM is installed that has a serial number lower than those already on the vehicle, the new SEM will claim the lowest source address, 128, and bump up the source addresses of the other SEMs. The SEM that used to claim the source address of 128 must now claim 129, the SEM that used to claim 129 must now claim 130.

Invalid SEM

If a problem occurs while flashing the application code on an SEM, the SEM may not be able to claim one of the source addresses in **Table 1**. The SEM will appear in ServiceLink screens at source address 133 and with an icon labeled **Invalid SEM (Unresponsive)**. It will not report any make, model, or software ID. In this case, the technician can still access the **Flashing** tab and attempt to flash the SEM to recover it.

Locating the Correct SEM to Troubleshoot

To assist the technician in determining the specific SEM a given smart switch is connected to, ServiceLink has a **Smart Switches** tab located under the SEM icon. There the technician will find an **Identify SEM** button that can be used to briefly flash the indicator lights of a bank of smart switches connected to a specific SEM. This allows the technician to locate the correct SEM for troubleshooting smart switches.

Removing an SEM

1. Connect to the vehicle in ServiceLink and take note of the icons that appear for the SEMs connected to the vehicle.
2. Remove the SEM.
3. Reconnect to the vehicle in ServiceLink and take note of the icons that appear for the SEMs connected to the vehicle.
4. The icon for the removed SEM should be gone and none of the other SEMs still on the vehicle should change their order. For example, if there are three SEMs on a vehicle, appearing in ServiceLink as SEM #1, SEM #2, and SEM #3 and the second SEM is removed, on reconnecting to the vehicle in ServiceLink the icons for SEM #1 and SEM #3 still appear and the icon for SEM #2 is gone.

Fault Code Information

Fault Codes

NOTE: For troubleshooting procedures, see **Section 54.14, Subject 300**.

See **Table 2** for J1939 suspect parameter numbers (SPN) for Switch Expansion Module source addresses (SA) 128 through 130.

See **Table 3** for the failure mode identifiers (FMI) for J1939 datalink protocols.

J1939 Suspect Parameter Numbers for Switch Expansion Module Source Addresses 128 Through 130		
SPN	**J1939 Description**	**Possible FMI**
2033	No CAN communication from BHM	19
6914	Smart Switch VBatt Short to Ground	04

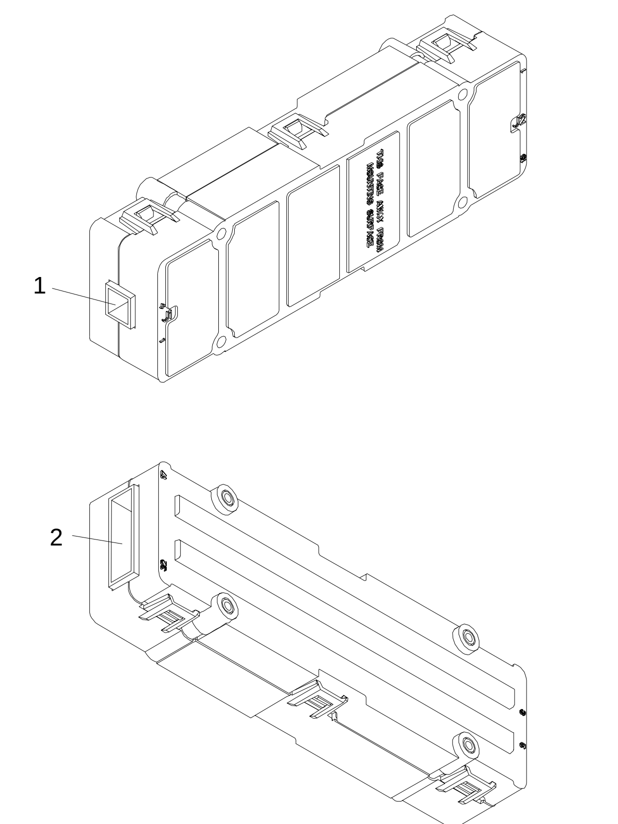
Table 2, J1939 Suspect Parameter Numbers for Switch Expansion Module Source Addresses 128 Through 130

Failure Mode Identifiers	
FMI	**J1939 Description**
19	Received network data in error
04	Voltage below normal or shorted low

Table 3, Failure Mode Identifiers

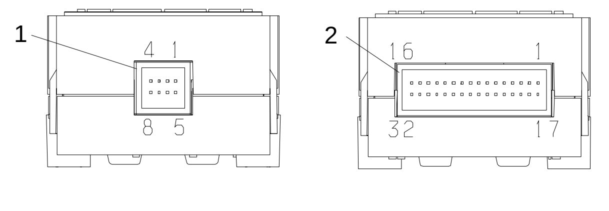
Specifications

For an illustration of the SEM, see **Fig. 1**. For an end view of the module connectors, see **Fig. 2**.



1. J1 Connector 2. J2 Connector

Fig. 1, Switch Expansion Module



1. J1 Connector 2. J2 Connector

Fig. 2, End Views of the Switch Expansion Module

SEM Pinouts at J1 Connector			
Pin	**Signal Name**	**Type**	**Amps**
1	VBAT1 (unswitched power)	Power	1
2	System Wakeup	Bidirectional	—
3	System Ignition	Input	—
4	J1939– Datalink	Comm	—
5	GND	Ground	—
6	GND	Ground	—
7	GND	Ground	—
8	J1939+ Datalink	Comm	—

Table 1, SEM Pinout Definitions at Connector J1

SEM Pinouts at J2 Connector			
Pin	**Signal Name**	**Type**	**Amps**
1	Smart Switch Ground	Signal Ground	—
2	SS5 Indicator	Smart Switch LED Drive	—
3	SS3 Indicator	Smart Switch LED Drive	—
4	SS1 Indicator	Smart Switch LED Drive	—
5	SS6 ID1	Smart Switch Analog Input	—
6	SS5 ID2	Smart Switch Analog Input	—
7	SS5 Switch Position	Smart Switch Analog Input	—
8	Smart Switch Backlight	Smart Switch Backlight	0.2

Specifications

SEM Pinouts at J2 Connector			
Pin	Signal Name	Type	Amps
9	Smart Switch Vbat	Smart Switch Vbat	0.2
10	SS4 ID2	Smart Switch Analog Input	—
11	SS4 Switch Position	Smart Switch Analog Input	—
12	SS3 ID1	Smart Switch Analog Input	—
13	SS2 ID2	Smart Switch Analog Input	—
14	SS2 Switch Position	Smart Switch Analog Input	—
15	SS1 ID1	Smart Switch Analog Input	—
16	Smart Switch Ground	Signal Ground	—
17	Smart Switch Ground	Signal Ground	—
18	SS6 Indicator	Smart Switch LED Drive	—
19	SS4 Indicator	Smart Switch LED Drive	—
20	SS2 Indicator	Smart Switch LED Drive	—
21	SS6 ID2	Smart Switch Analog Input	—
22	SS6 Switch Position	Smart Switch Analog Input	—
23	SS5 ID1	Smart Switch Analog Input	—
24	Smart Switch Ground	Signal Ground	—
25	Smart Switch Ground	Signal Ground	—
26	SS4 ID1	Smart Switch Analog Input	—
27	SS3 ID2	Smart Switch Analog Input	—
28	SS3 Switch Position	Smart Switch Analog Input	—
29	SS2 ID1	Smart Switch Analog Input	—
30	SS1 ID2	Smart Switch Analog Input	—
31	SS1 Switch Position	Smart Switch Analog Input	—
32	Smart Switch Ground	Signal Ground	—

Table 2, SEM Pinout Definitions at J2 Connector

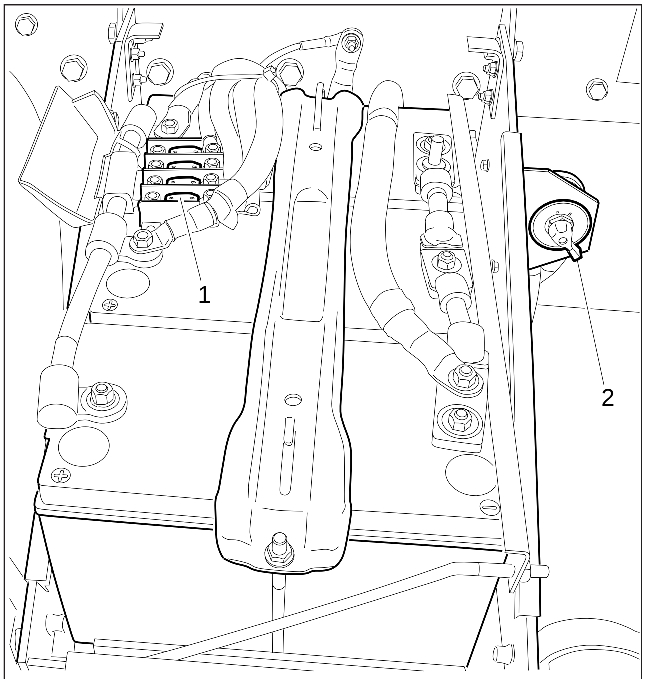
General Information

MEGA Fuse Junction Block

Vehicles have a MEGA fuse junction block (MFJB) inside the battery box to distribute and fuse some of the power circuits.

Typical circuits protected by the MEGA fuses in EPA07 and earlier vehicles are the main PDM, the powertrain PDM, and the trailer/chassis PDM. The alternator and starter are connected directly to the batteries. See **Fig. 1** for a typical battery box mounted MFJB.

EPA10 vehicles use the battery box mounted MFJB to protect the power circuits feeding the chassis PDM and other optional PDMs.



1. MEGA Fuses
2. Battery Cutoff Switch

Fig. 1, Typical EPA07 Battery Box

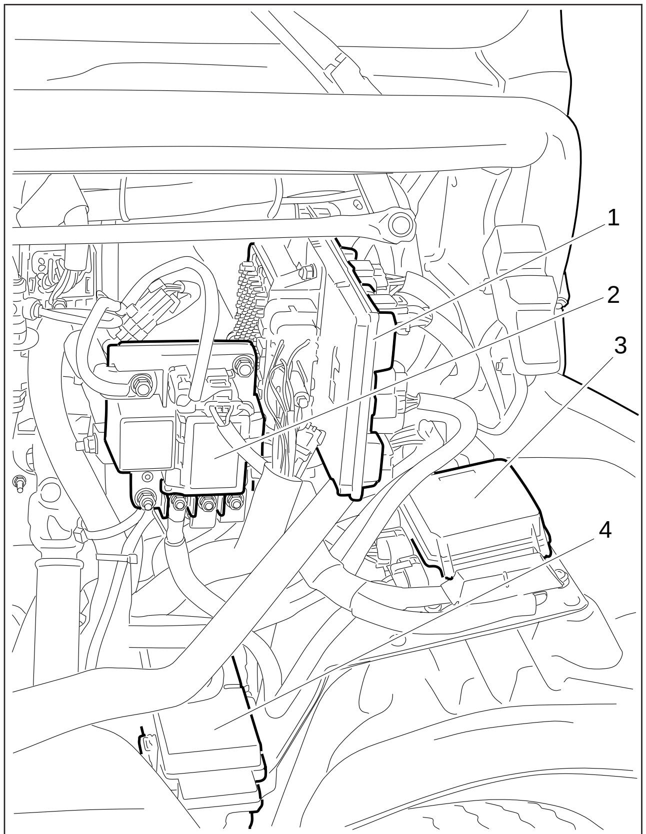
Powernet Distribution Box (PNDB)

EPA10 vehicles incorporate the powernet distribution box (PNDB) to distribute and fuse battery power to many of the vehicle loads. An optional cab load disconnect switch (CLDS) is available to disconnect selected circuits. The CLDS may be located on the chassis near the battery box or mounted so that it is operated from inside the cab. There is an LED in the CLDS that will illuminate when power is on. The LED will flash when certain faults are detected.

Some vehicles have an auxiliary PNDB in addition to the primary PNDB. If the vehicle is equipped with a CLDS, it controls both. An additional LED status indicator is in the CLDS on dual PNDB systems.

NOTE: See **Fig. 6** for the auxiliary PNDB.

The primary PNDB is located on the engine side of the front wall near the steering shaft. See **Fig. 2** for the location of the primary PNDB and other EPA10 engine compartment power distribution modules.



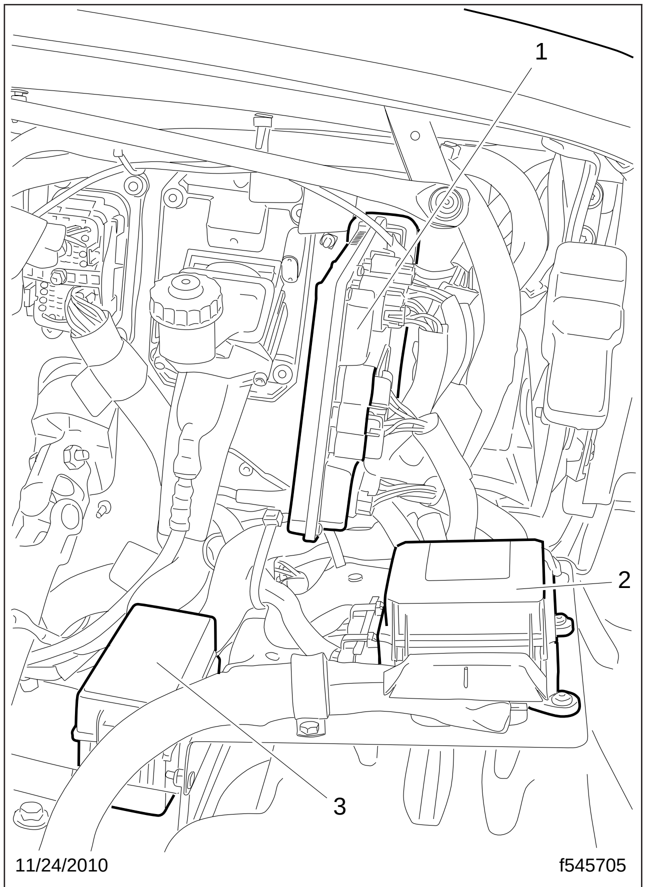
1. Bulkhead Module
2. PNDB
3. Main PDM
4. Powertrain PDM

Fig. 2, EPA10 Power Distribution Modules

General Information

Main Power Distribution Module

The main PDM is located on the driver side inner fender in the engine compartment. Power for most cab and many chassis functions are protected by fuses in the main PDM. Most vehicles have spare fuse circuits in the main PDM that can be used for customer installed options. A map of fuses to output connectors for the circuits in the main PDM is shown in **Subject 130**. See **Fig. 3** for EPA07 engine compartment power distribution modules.



1. Bulkhead Module
2. Main PDM
3. Powertrain PDM

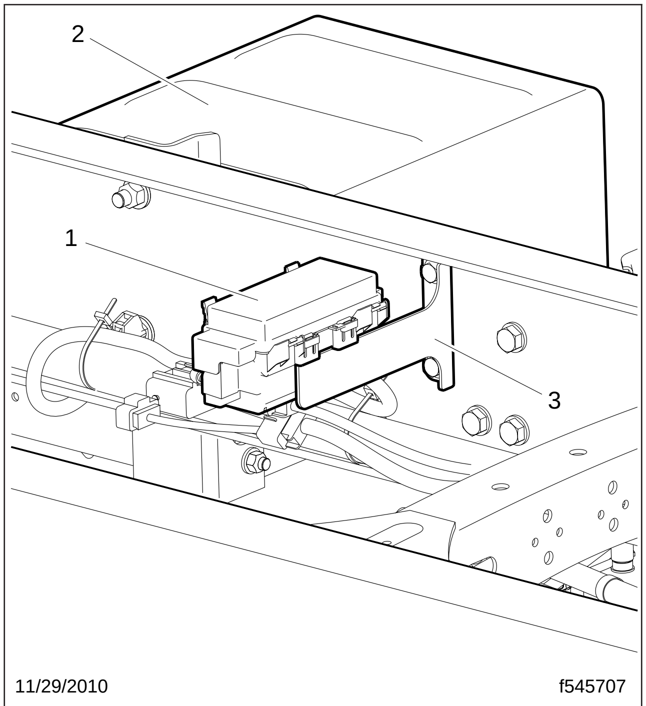
Fig. 3, Typical EPA07 Power Distribution Modules

Powertrain Power Distribution Module

Vehicles built for EPA07 and later use a powertrain PDM to protect circuits to the engine, transmission, and exhaust after treatment systems. The powertrain PDM is located inside the engine compartment on a bracket near the main PDM on the drivers side inner fender.

Chassis Power Distribution Module

The chassis power distribution module switches power to operate air valves for the axles, fifth wheel, suspension, PTO, and other air controlled devices on vehicles manufactured before chassis module 4.1 was released and with an auxiliary air valve assembly (AAVA). The chassis PDM is in an enclosed housing and located beneath or behind the cab on a bracket attached to the frame rails. See **Fig. 4**



1. Chassis PDM
2. Battery Box
3. Mounting Bracket

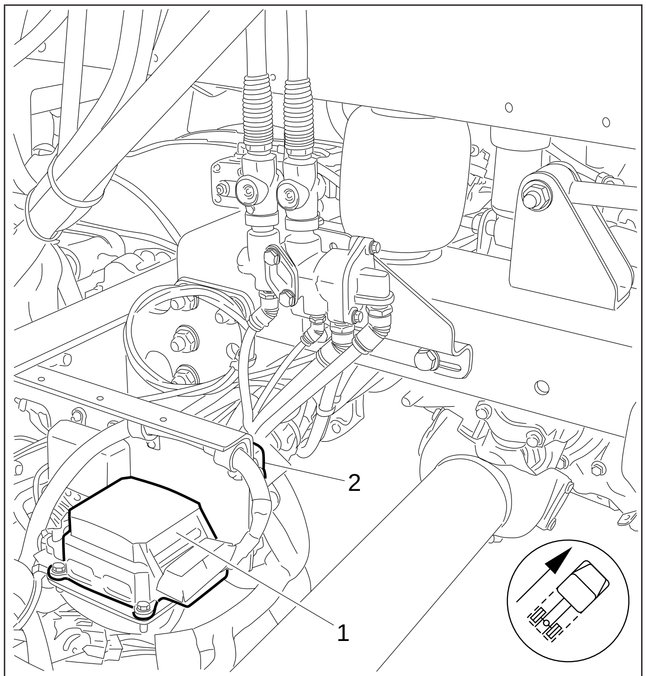
Fig. 4, Chassis PDM on Early AAVA Vehicle

Trailer Power Distribution Module

The trailer PDM fuses and supplies power for trailer lighting. The CHM controls the inputs to this PDM. The trailer PDM has traditionally been located on a bracket mounted to the frame below and behind the cab. In 2010, the trailer PDM has been relocated to inside the cab on the drivers side behind the seat. See **Fig. 5** for a typical EPA07 and earlier trailer PDM. See **Fig. 6** for a typical EPA10 in-cab trailer PDM.

Body Lighting Power Distribution Module

The body lighting PDM supplies higher amperage power for exterior lighting in addition to ignition and battery power for options installed by the truck equipment manufacturer. The body lighting PDM has traditionally been located on a bracket mounted to the frame below and behind the cab. In 2010, the body lighting PDM has been relocated to inside the cab on the drivers side behind the seat on the back wall or the floor. See **Fig. 6** for a typical EPA10 in-cab body lighting PDM installation.



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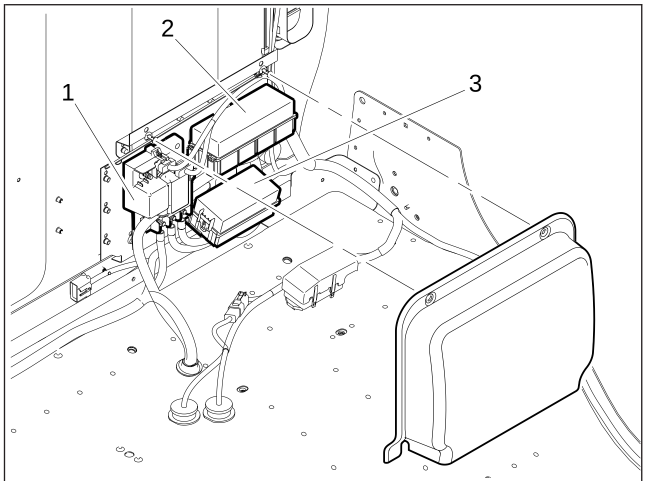
1. Trailer PDM
2. Chassis Module

Fig. 5, EPA07 Trailer PDM (deck plate removed)



12/15/2010 f545719

1. PNDB
2. Trailer PDM
3. Body Lighting PDM

Fig. 6, EPA10 In-Cab PDM Installation

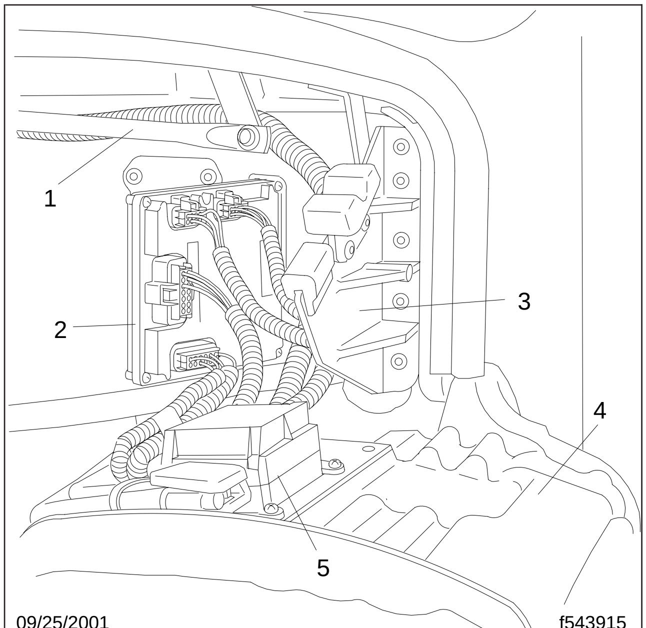
Main Power Distribution Module Removal and Installation

Removal

1. Disconnect the negative leads from the batteries.

NOTE: The main power distribution module (PDM) is mounted in the engine compartment on the left front inner fender. See **Fig. 1**.

2. Remove the nuts and washers that attach the battery cables to the power studs, then remove the battery power cables from the PDM. See **Fig. 2**.



1. Wiper Linkage
2. Bulkhead Module
3. Hood Support Bracket
4. Quarter Fender
5. Main Power Distribution Module

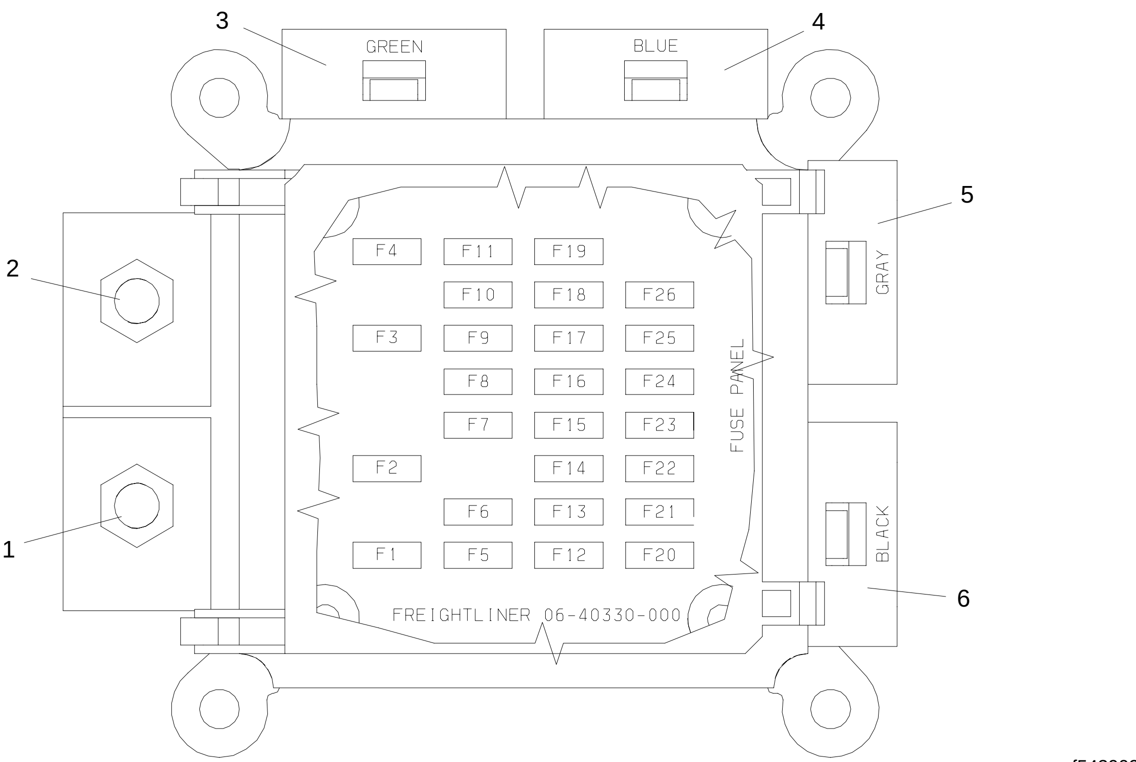
Fig. 1, Main Power Distribution Module Installation

3. Remove the four harness connectors (green, blue, gray, and black) from the PDM.
4. Remove the four Torx® capscrews that attach the PDM to the inner fender, then remove the PDM.

Installation

1. Properly orient the PDM and attach it to the quarter fender using four Torx capscrews.
2. Connect the four harness connectors to the PDM.
3. Using nuts and washers, attach the battery power ring connectors to the power studs.
4. Connect the batteries or tun the battery disconnect switch to on.
5. Verify operation of electrical components.

Main Power Distribution Module Removal and Installation



1. Battery Power to 125-Amp MEGA® Fuse 2
2. Battery Power to 125-Amp MEGA Fuse 1
3. Engine Harness Connector (green)
4. Forward Chassis Harness Connector (blue)
5. Forward Chassis Harness Connector (gray)
6. Frontwall Harness Connector (black)

Fig. 2, Main PDM Fuse Panel Layout and Connections

Powertrain PDM Removal and Installation

EPA07 Powertrain PDM

Removal

1. Disconnect the negative leads from the batteries.

NOTE: The powertrain power distribution module (PDM) is mounted in the engine compartment next to the left front inner fender. See **Fig. 1**.

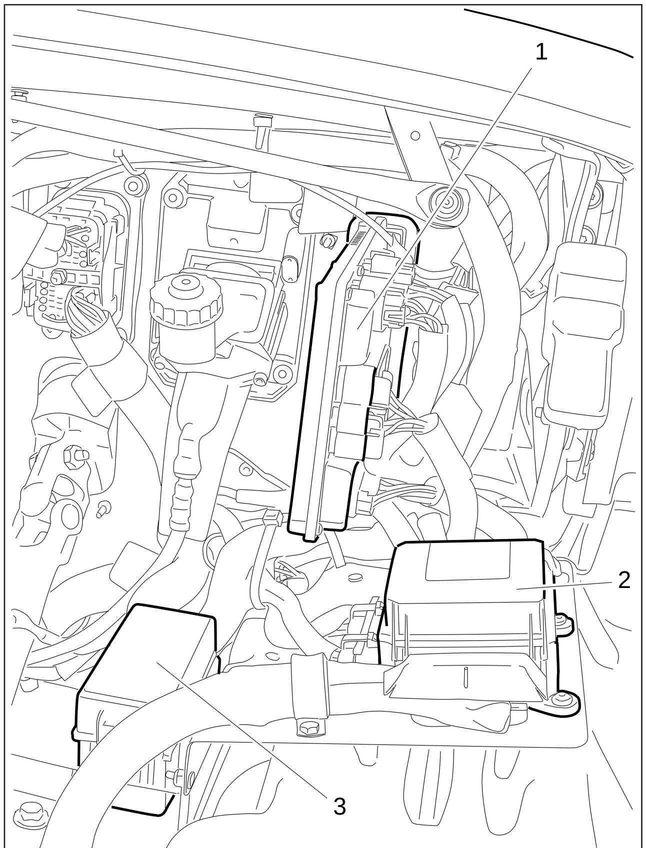
2. Using a screwdriver, release the support tabs that secure the PDM to the mounting bracket. See **Fig. 2**. Remove the PDM from the bracket.
3. Remove the top cover from the PDM.
4. Remove the fuses and relays from the top of the PDM, noting the location of each fuse and relay before removal.
5. Remove the terminal locks. See **Fig. 3**.
6. Release the bottom cover using the tab on the end of the PDM where the wires exit. The cover will hinge open.
7. Mark each wire for reassembly.
8. Remove the wires under the PDM by pressing each terminal lock with a pick tool. See **Fig. 4**.
9. Remove the PDM from the vehicle.

Installation

1. Attach all wires to the bottom of the PDM. The terminals will click into place when inserted correctly.

NOTE: If the terminals are inserted backward, the lock will not press into place.

2. Install the terminal locks.
3. Install the fuses and relays, using the locations noted earlier.
4. Install the bottom cover.
5. Position the PDM on the mounting bracket, and push down until the support tabs snap into place.
6. Install the PDM top cover. Use a wire tie to secure the cover, if necessary.
7. Connect the batteries.



11/24/2010 f545705

1. Bulkhead Module
2. Main PDM
3. Powertrain PDM

Fig. 1, Power Distribution Modules (EPA07 shown)

EPA10 Powertrain PDM

Removal

1. Disconnect the batteries at the negative terminals.
2. Insert a small flat screwdriver into the openings between the mounting bracket and the side of the PDM, then release the tabs. See **Fig. 2**.
3. Open the cover and remove the two retaining clips. See **Fig. 5**.
4. Lift the PDM block assembly out from the housing. The power feed circuits can be disconnected from the bus when the block assembly is about half way out of the housing.

Powertrain PDM Removal and Installation

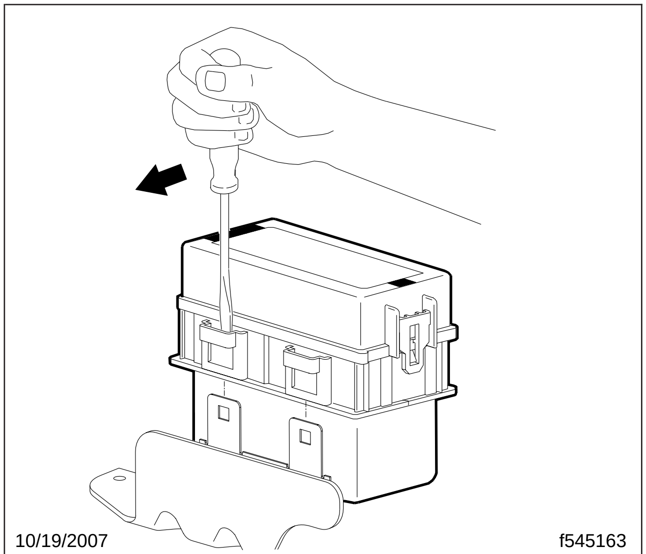
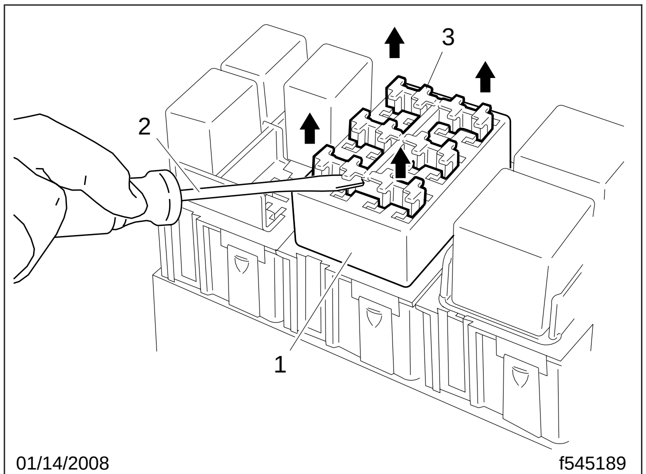


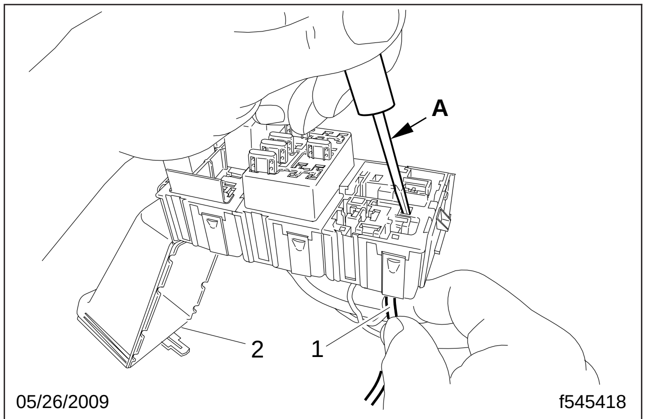
Fig. 2, PDM Removal



1. Terminal Housing
2. Flat-Tip Screwdriver
3. Terminal Locks

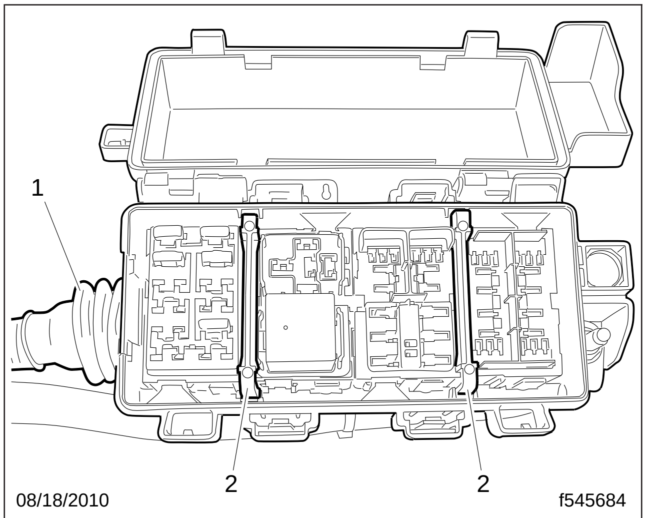
Fig. 3, Removing the Terminal Locks

5. Identify the positions and values of the fuses and relays, then remove them.
6. Lift the terminal locks up and out of the PDM. See **Fig. 3**.
7. Label all the wires before removing them from the PDM. Remove the wires.
8. Use a Delphi pick tool to release the tab on the terminal then remove it from the bottom side.



A. Press each terminal lock with the pick tool to remove.

Fig. 4, Removing the Wire with a Pick Tool



1. Connector Boot
2. Retaining Clips

Fig. 5, EPA10 PDM

9. Remove the PDM from the vehicle.

Installation

1. Insert each circuit into the bottom of the PDM block assembly. If the terminal is backward, the lock will not seat into place. See **Fig. 6**.
2. Install the terminal locks and the fuses and relays, as previously noted.

Powertrain PDM Removal and Installation

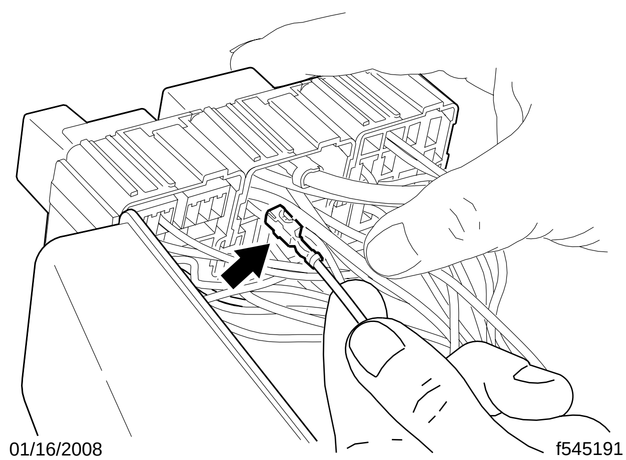
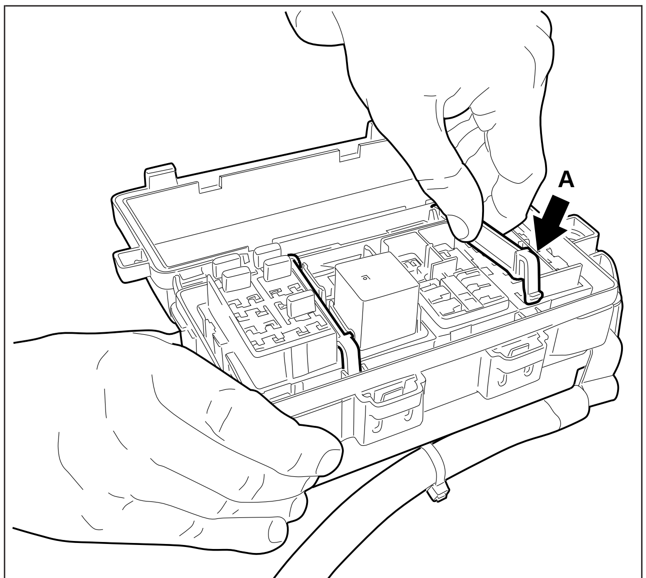


Fig. 6, Inserting Circuits in to the PDM

3. Place the PDM block assembly into the housing, and connect the power feed circuits to the buss bar.
4. Gently squeeze the PDM housing and install the two retaining clips. See **Fig. 7**.
5. Close the PDM cover.



A. Squeeze the housing of the PDM when installing the retaining clips.

Fig. 7, Installing the Retaining Clips

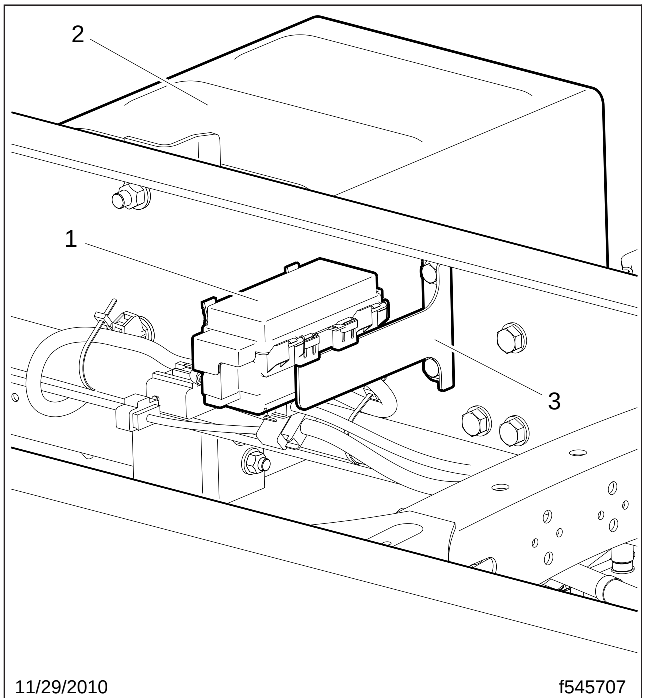
6. Install the PDM housing onto the bracket, if it was removed.
7. Connect the batteries and close the hood.

Chassis PDM Removal and Installation

Removal

The Chassis PDM is located underneath or behind the cab, near the battery box. See **Fig. 1**.

1. Disconnect the batteries at the negative terminals.
2. Open the cover and remove the two retaining clips. See **Fig. 1**.



1. Chassis PDM
2. Battery Box
3. Mounting Bracket

Fig. 1, Chassis PDM

3. Lift the PDM block assembly out from the housing. The power feed circuits can be disconnected from the bus when the block assembly is about half way out of the housing.
4. Identify the positions and values of the fuses and relays, then remove them.
5. Lift the terminal locks up and out of the PDM.
6. Label all the wires before removing them from the PDM. Remove the wires.
7. Remove the PDM from the vehicle.

Installation

1. Insert each circuit into the bottom of the PDM block assembly. If the terminal is backward, the lock will not seat into place.
2. Install the terminal locks and the fuses and relays, as previously noted.
3. Place the PDM block assembly into the housing, and connect the power feed circuits to the buss bar.
4. Gently squeeze the PDM housing and install the two retaining clips.
5. Close the PDM cover.
6. Install the PDM housing onto the bracket, if it was removed.
7. Connect the batteries.

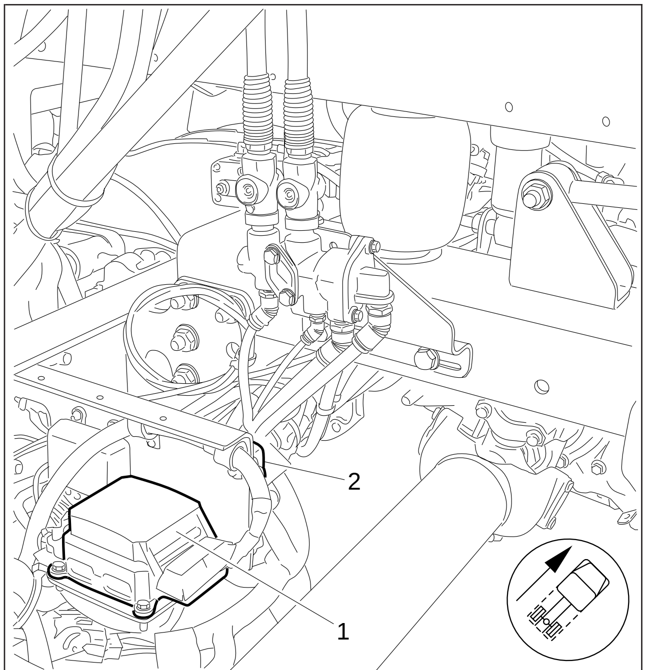
Trailer PDM Removal and Installation (EPA07 and earlier)

Removal

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the negative leads from the batteries.

NOTE: The trailer power distribution module is mounted in between the frame rails, on a bracket. See **Fig. 1**.

3. Remove the nut and washer that attach the positive lead to the trailer PDM battery power stud. Then remove the positive lead. See **Fig. 2**.
4. Disconnect the electrical connectors from the trailer PDM.
5. Remove the nuts and washers that attach the trailer PDM to the mounting bracket, then remove the PDM.



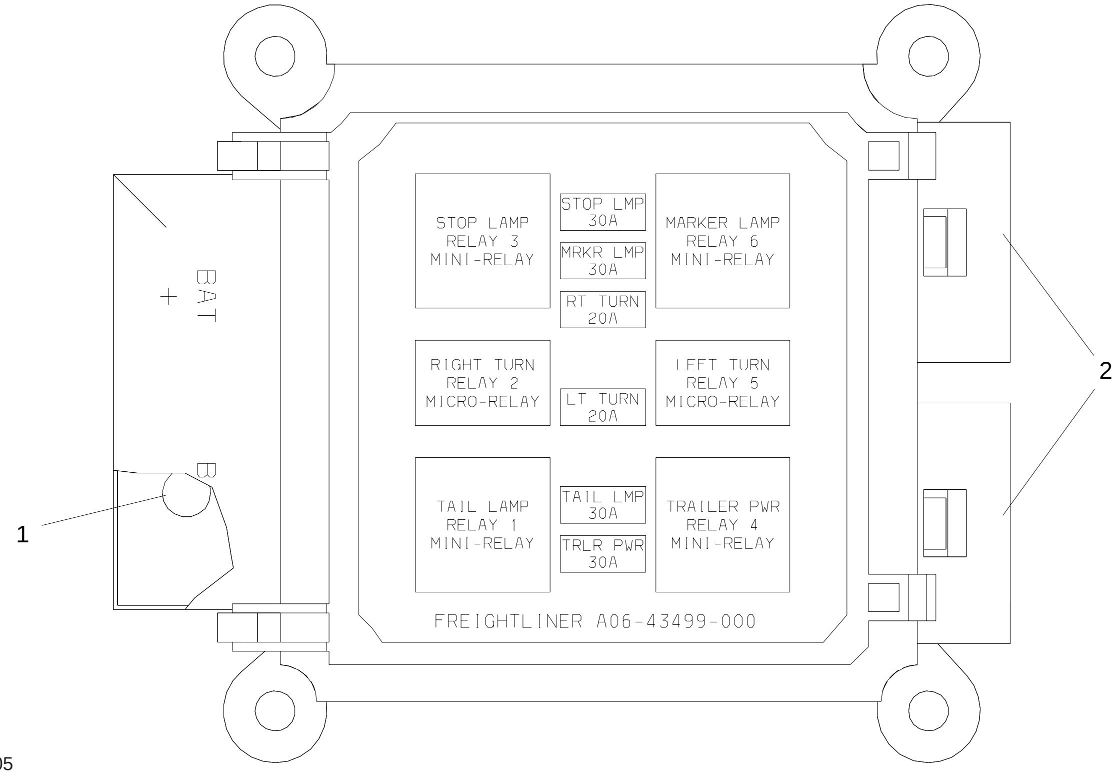
1. Trailer PDM
2. Chassis Module

Fig. 1, Typical EPA07 Trailer PDM (deck plate removed)

Installation

1. Using nuts and washers, attach the PDM to the mounting bracket.
2. Attach the electrical connectors to the trailer PDM.
3. Using a nut and washer, install the positive lead on the trailer PDM battery power stud. Torque the nut 11 to 13 lbf·ft (15 to 18 N·m). Apply dielectric red enamel to protect the power connection.
4. Connect the batteries.
5. Remove the chocks from the tires.

Trailer PDM Removal and Installation (EPA07 and earlier)



1. Battery Power Stud
2. Electrical Connector

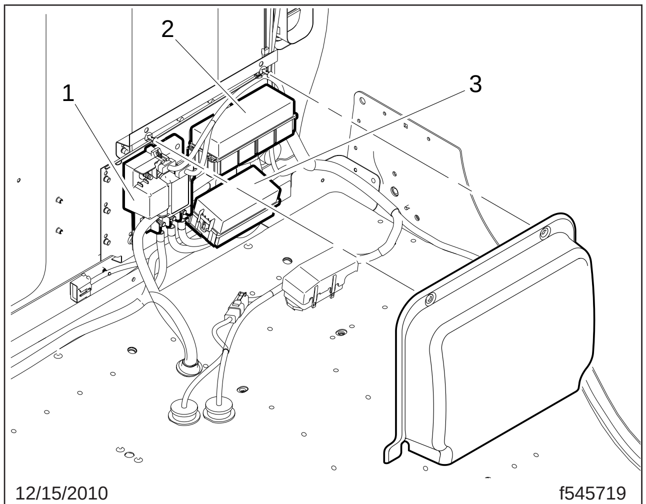
Fig. 2, Trailer PDM Fuse Panel Layout

EPA10 Body Lighting PDM Removal and Installation

The Body Lighting PDM is located behind the driver's seat.

Removal

1. Disconnect the batteries at the negative terminals.
2. Remove the cover of the PDM modules housing.
3. Open the cover of the Body Lighting PDM and remove the two retaining clips. See **Fig. 1**.



1. Auxiliary PNDB
2. Trailer PDM
3. Body Lighting PDM

Fig. 1, Power Distribution Modules (EPA10 shown)

4. Lift the PDM block assembly out from the housing. The power feed circuits can be disconnected from the bus when the block assembly is about half way out of the housing.
5. Identify the positions and values of the fuses and relays, then remove them.
6. Lift the terminal locks up and out of the PDM.
7. Label all the wires before removing them from the PDM. Remove the wires.
8. Remove the PDM from the vehicle.

Installation

1. Insert each circuit into the bottom of the PDM block assembly. If the terminal is backward, the lock will not seat into place.
2. Install the terminal locks and the fuses and relays, as previously noted.
3. Place the PDM block assembly into the housing, and connect the power feed circuits to the buss bar.
4. Gently squeeze the PDM housing and install the two retaining clips.
5. Close the PDM cover.
6. Install the PDM housing onto the bracket, if it was removed.
7. Connect the batteries.

Powernet Distribution Box Removal and Installation

Removal

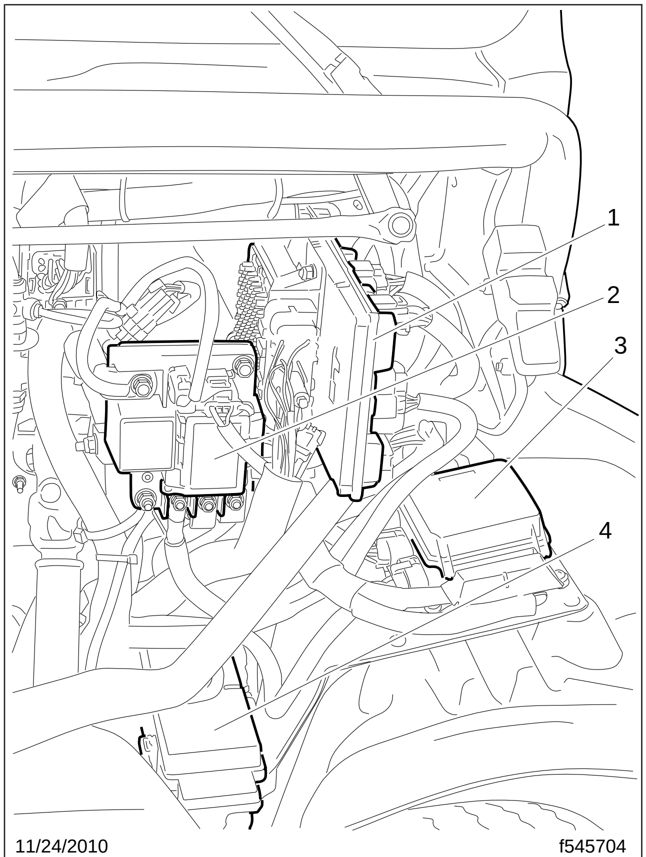
1. Disconnect all batteries. If the vehicle is equipped with an auxiliary battery bank, disconnect these batteries as well.
2. Open the hood.

NOTE: The powernet distribution box (PNDB) is located on the cab frontwall, next to the bulkhead module. See **Fig. 1**.

3. Disconnect the battery and power cables from the PNDB. See **Fig. 2**.
4. Disconnect the cab load disconnect switch (CLDS) connecter, if equipped.

IMPORTANT: Inspect the keep-alive and CLDS connectors and make sure that the plugs are in unused connector cavities. Install plugs to seal the connector if any are missing.

5. Disconnect the keep-alive circuit connector from the PNDB.
   - 5.1 Using a flat-head screwdriver, push the red locking tab up.
   - 5.2 Press and release the tab, then remove the connector.
6. Remove the two mounting nuts.
7. Remove the PNDB from the vehicle.



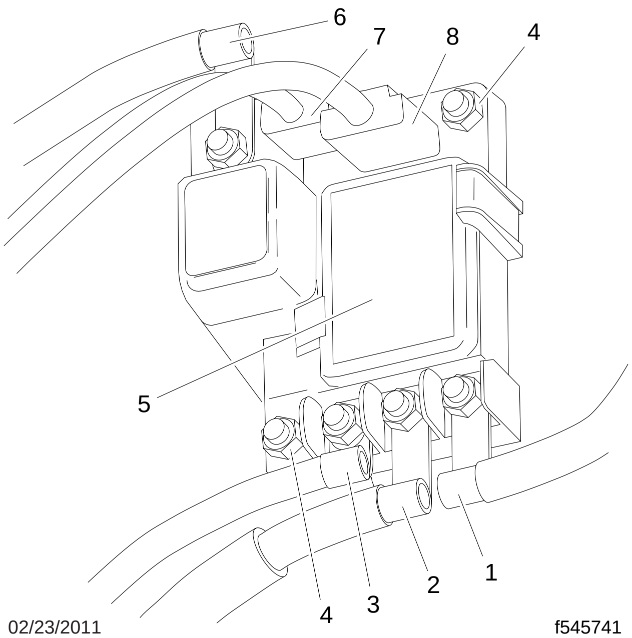
1. Bulkhead Module
2. PNDB
3. Main PDM
4. Powertrain PDM

Fig. 1, Power Distribution Modules (EPA10 shown)

Installation

1. Position the PNDB on the frontwall, and attach the two mounting nuts.
2. Connect the battery and power cables.
3. Attach the keep-alive circuit connector and the CLDS connector.
4. Connect the batteries.
5. Close the hood.

Powernet Distribution Box Removal and Installation



1. Main PDM Power (circuit 1)
2. Main PDM Power (circuit 2)
3. Powertrain PDM Power
4. Mounting Nut
5. Fuse Cover
6. Power (B+)
7. Disconnect Switch (CLDS) Connector
8. Keep-Alive Circuit Connector

Fig. 2, Powernet Distribution Box

Troubleshooting

MEGA Fuses

MEGA fuses must be measured using a voltmeter when in the circuit or with an ohm meter when out of the circuit to determine if they are open. There is no visual method of determining continuity. See **Fig. 1**.

In 2008, the type of MEGA fuses changed from Bussman to Littelfuse. The Littelfuse is staked and addresses the intermittently open circuit fault that may occur with the Bussman fuse. When MEGA fuses are replaced, be certain that stainless steel nuts and washers are used. Cover the connections in the battery box liberally with dielectric grease.

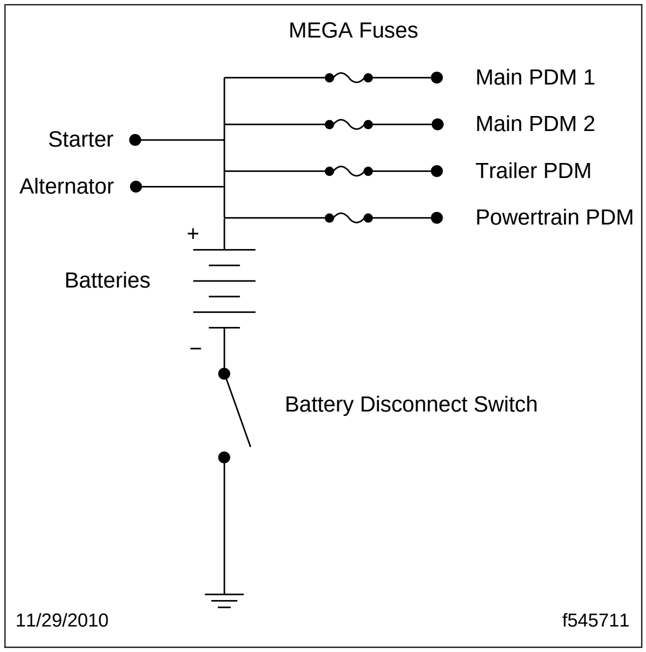


Fig. 1, Typical EPA07 and Earlier In-Battery Box MEGA Fuse Schematic

PNDB

Each powernet distribution box (PNDB) on the vehicle provides up to 4 low amperage circuits (30 amp and less), and up to three high amperage circuits through midi fuses. The fuses are located behind a cover on the face of the PNDB. On vehicles equipped with a cab load disconnect switch (CLDS), the high amperage circuits are switched on and off with the CLDS. The low amperage circuits are always live. Vehicles may have one or two PNDBs and both are connected to the same CLDS.

When the CLDS is in the on position, an LED on the switch, and another on the PNDB, will be illuminated. When there is an error condition with the PNDB system, the LED on the PNDB and CLDS may flash. A flashing LED indicates an error. An LED that remains on when the switch is off or no LED when the switch is on also indicates an error condition.

To test for open fuses, use conventional troubleshooting methods. The LED's in the PNDB and switch are not affected by open fuses or the circuits they connect.

NOTE: See **Table 1** to troubleshoot a switched PNDB system

PNDB and CLDS Troubleshooting			
Step	**Test Procedure**	**Test Result**	**Action**
1	Check the power cables on the PNDB for proper torque. Open the cover and inspect the MIDI fuse fastener torque and for discoloration caused by excessive heat.	Loose fasteners or heat discoloration.	Determine if the fasteners can be properly torqued or if the PNDB needs replacement. Repair or replace as required.
		All OK	Go to step 2.
2	Does the LED on the PNDB flash in a constant pattern when the CLDS is switched to the OFF or ON position or does the LED on the PNDB just randomly flicker?	Constant Repeating Flashing Pattern	Troubleshoot and repair any wiring faults on circuits 425D, 425F, or circuit 425G between the CLDS and the PNDB. If there is no wiring fault, replace the CLDS.
		Random flickering.	Replace the PNDB.
		No	Go to step 3.

Troubleshooting

PNDB and CLDS Troubleshooting			
Step	**Test Procedure**	**Test Result**	**Action**
3	Measure for ground on PNDB connector 1, pins 1 and 6. If either of these pins are not populated with a wire disregard measuring the unpopulated pin. Is ground present in the wiring harness supplying these pins?	Yes	Measure the voltage on PNDB connector X1, pin 4. If pin 4 is at about 11 volts then troubleshoot and repair for a wiring fault in circuits 425D, 425F, 425G between the CLDS and the PNDB and for a open or short circuit in the CLDS. If there is no wiring or switch fault, replace the PNDB.
		No	Repair an open ground circuit to the PNDB.

Table 1, PNDB and CLDS Troubleshooting

See **Fig. 2**, **Fig. 3**, **Fig. 4**, and **Fig. 5** for illustrations of the connectors with pin identification.

See **Table 2** for primary PNDB and CLDS connector and pin functions.

NOTE: PNDB connector X2 is not part of the switching and control system. See **Table 3** for information on the function of PNDB connector X2.

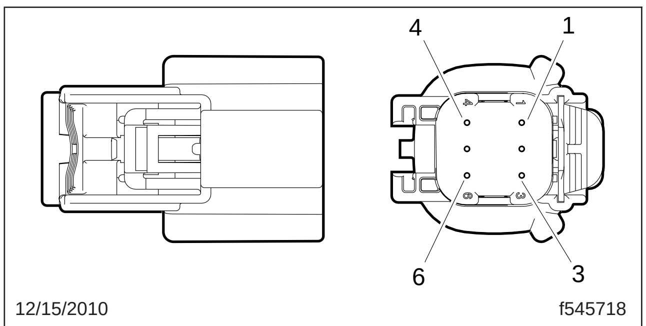


Fig. 2, Wire Insertion View of PNDB Connector X1

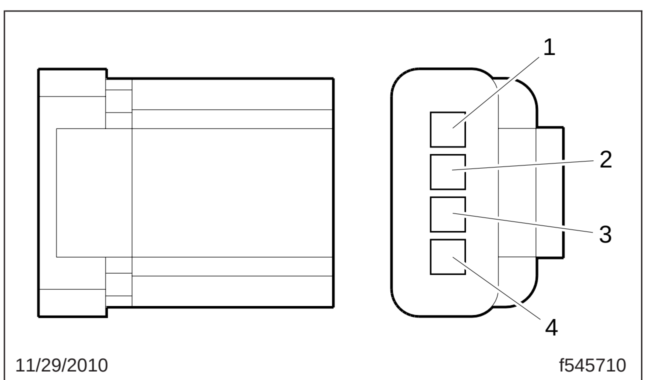


Fig. 3, Wire Insertion View of PNDB Connector X2

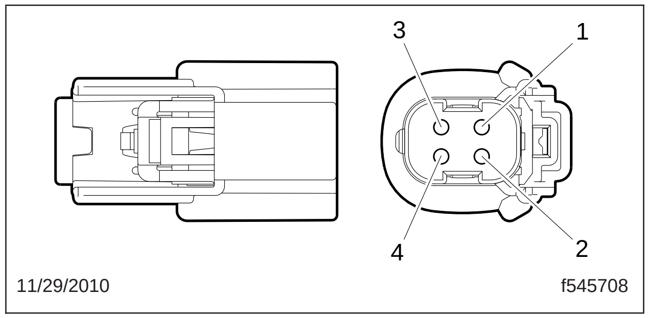


Fig. 4, Wire Insertion View of CLDS Connector X1

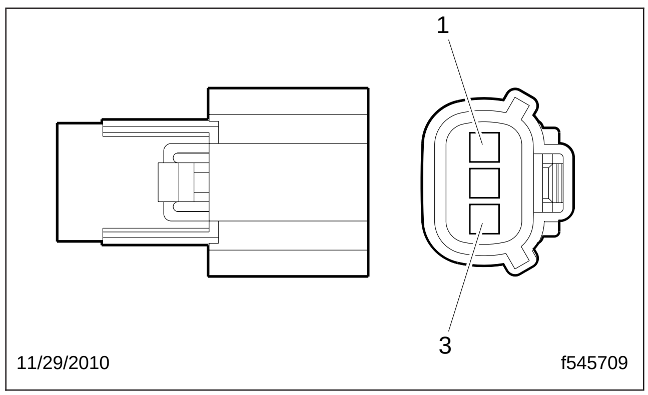


Fig. 5, Wire Insertion View of CLDS Connector X2

Primary PNDB and CLDS Connector and Pin Functions			
Device	**Connector, Pin**	**Voltage**	**Function**
Primary PNDB	X1, 1	0	Ground
	X1, 2	0	Off Signal – Always at ground.
	X1, 3	0 – ON	LED Indicator – PNDB drives this low when the switch is on.
	X1, 4	11	On Signal – Approximately 11 volts.
	X1, 5	11 – ON 0 – OFF	Control Signal – Approximately 11 volts when CLDS is on. At ground when off.
	X1, 6	0	Not used or ground circuit connecting to aux PNDB.
CLDS	X1, 1	11	On Signal – Approximately 11 volts.
	X1, 2	11 – ON 0 – OFF	Control Signal – Approximately 11 volts. when CLDS is on. At ground when off.
	X1, 3	0 – ON	LED Indicator – PNDB drives this low when switch is on.
	X1, 4	0	Off Signal – Always at ground.
	X2, 1	11 – ON 0 – OFF	Control Signal – Approximately 11 volts when CLDS is on. At ground when off.
	X2, 2	0	Off Signal – Always at ground.
	X2, 3	0 – ON	LED Indicator – PNDB drives this low when the switch is on.
Auxiliary PNDB	X1, 1	0	Ground
	X1, 2	0	Off Signal – Always at ground.
	X1, 3	0 – ON	LED Indicator – PNDB drives this low when the switch is on.
	X1, 4	X	Not used.
	X1, 5	11 – ON 0 – OFF	Control Signal – At approximately 11 volts when CLDS is on. At ground when off.
	X1, 6	0	Not used, or ground.

Table 2, PNDB and CLDS Connector and Pin Functions

See **Fig. 6** for a schematic of the dual PNDB system with the cab load disconnect switch option.

Troubleshooting

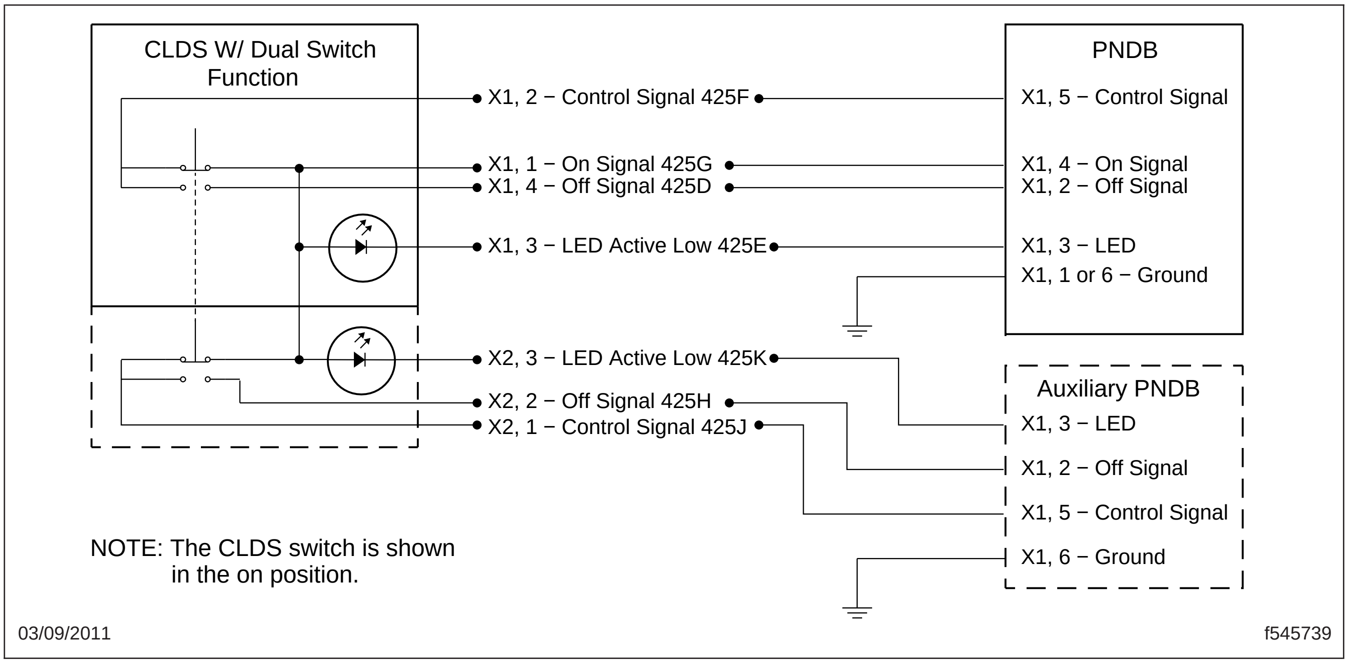


Fig. 6, Primary and Auxiliary PNDB with CLDS Option

Primary PNDB Fuses and Functions					
Fuse	**Amperage**	**Function**	**Circuit**	**Connector/Pin**	**Module**
ATC – A	30	ACM (After Treatment Module)	439	X2/1	28F
ATC – B	—	—	—	X2/2	—
ATC – C	5	Radio and Clock	295B	X2/3	74D
ATC – D	5	Alternator Remote Sense	125E	X2/4	12C
MIDI – 1	175	Powertrain PDM	439	1	283
MIDI – 2	125	Main PDM 1	14E	2	285
MIDI – 3	125	Main PDM 2	14E	3	285

Table 3, Primary PNDB Fuses and Functions

Main PDM

Main PDM Circuit Mapping		
Fuse	**Connector, Pin**	**Power Source**
F1	Green, A	1
F2	Green, B	1
F3	Green, H	2
F4	Green, G	2
F5	Black, D	1

Main PDM Circuit Mapping		
Fuse	**Connector, Pin**	**Power Source**
F6	Black, C	1
F7	Gray, F	1
F8	Green, C	2
F9	Green, D	2
F10	Blue, G Green, F	2
F11	Blue, H	2
F12	Black, H	1
F13	Gray, E	1
F14	Black, B	1
F15	Black, A	2
F16	Blue, A	2
F17	Blue, C	2
F18	Blue, B	2
F19	Gray, G	2
F20	Black, E	1
F21	Black, F	1
F22	Black, G	1
F23	Gray, H Blue, E	1
F24	Gray, D	1
F25	Gray, C	2
F26	Gray, A Gray, B Blue, D	2

Table 4, Main PDM Circuit Mapping

Powertrain PDM

Engine, transmission, and exhaust after treatment systems are powered through the powertrain PDM.

The circuits that populate this PDM will vary depending on vehicle option content.

EPA07 PTPDM			
Position	**Rating**	**Description**	**Module**
F1	10A	Electric Fan	283
F2	5A	Transmission ECU Ignition	34B
F3	20A	Fuel Heater/MAF Sensor	28F

Troubleshooting

EPA07 PTPDM			
Position	**Rating**	**Description**	**Module**
F4	20A	Fuel Heater/ICD Power	28F
F5	See Label	Engine Ignition	283
F6	See Label	VNT/ATD or Lockout Sol/Fuel Sender	—
F7	15A	LVD/Remote Sense	—
F8	See Label	Engine ECU Battery Power	283
F9	See Label	CPC/Engine ECU Battery Power	283
F10	See Label	Trans Batt Power	34B
F11	20A	Trans Batt Power	34B
F12	See Label	Trans Batt Power/EMP Air Pump	34B
R1	15A	START ENABLE	34B
R2	15A	MEIIR or Lockout Sol (Crank)	34B
R3	15A	CHECK TRANS/HYD BRAKES	34B/863
R4	See Label	Electric Fan/HEST Lamp or Lockout Sol (Run)	—
R5	See Label	STARTER/Electric Fan	156
R6	70A	Engine Ignition Power	283

Table 5, EPA07 PTPDM

EPA10 PTPDM			
Position	**Rating**	**Description**	**Module**
F1	30A	ECM/MCM, BAT	283
F2	10A	CPC, BAT	283
F3	10A or 30A	TCU, BAT	34B
F4	25A	COOLANT PUMP BAT	34B
F5	30A	BATTERY FAN, BAT	34B
F6	20A	DEF LINE HEATERS, BAT	28F
F7	10A	TCU/IGN or COOLANT PUMP, IGN	34B
F8	—	SPARE	—
F9	20A	ENG/SCR NOX SENSOR, IGN	28F
F10	5A or 15A	ECM, CPC, MCM, ACM – IGN	283
F11	10A	ELECTRIC FAN, IGN	276
F12	5A	DCU, IGN	28F
F13	50A	ECA/BAT	34B
F14	30A	HCM, BAT	34B
F15	25A	HEAT EXCHANGER FAN,BAT	34B
R1	MINI	PTO #2 or BATTERY FAN	885/34B

EPA10 PTPDM			
Position	Rating	Description	Module
R2	75A	IGN	283
R3	MICRO	AUTO NEUTRAL or COOLANT PUMP	877/34B
R4	MICRO	DEF LINE HEAT	28328F
R5	MICRO	PTO/MEIIR OR 12V CRANK	885/34B
R6	MICRO	ELECTRIC FAN	276
R7	MICRO	NEUTRAL INTERLOCK	87K
R8	MICRO	START ENABLE (TRANS)	34B

Table 6, EPA10 PTPDM

Chassis PDM

Vehicles with the AAVA have a chassis power distribution module. This PDM contains the fuses and relays that drive the air solenoids in the AAVA.

EPA10 Chassis PDM			
Position	Relay	Description	Module
F1, 5A	R1 Micro	Lift Axle #1	87F
F2, 5A	R2 Micro	Axle Lock #1	87B
F3, 5A	R3 Micro	Inter Axle Diff	87A
F4, 5A	R4 Micro	Axle Shift	87C
F5, 5A	R5 Micro	Fifth Wheel	87E
F6, 5A	R6 Micro	Optional Air Solenoid	87G
F7, 5A	R7 Micro	Air Horn	264
F8, 5A	R8 Micro	Air Suspension Dump	87D
F9, 5A	R9 Micro	Axle Lock #2	87B
F10, 5A	R10 Micro	Auto Park Brake	877
F11, 5A	R11 Micro	PTO Pump #1	885
F12, 5A	R12 Micro	PTO Pump #2	885

Table 7, EPA10 Chassis PDM

Troubleshooting

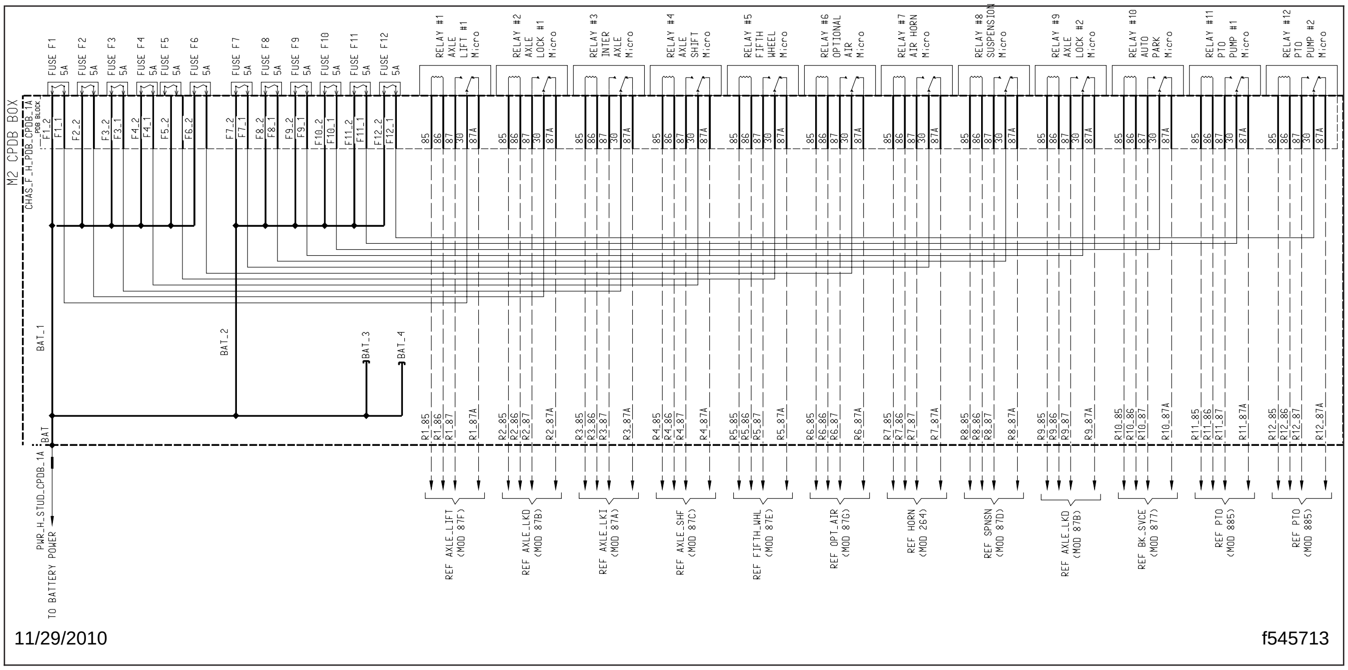
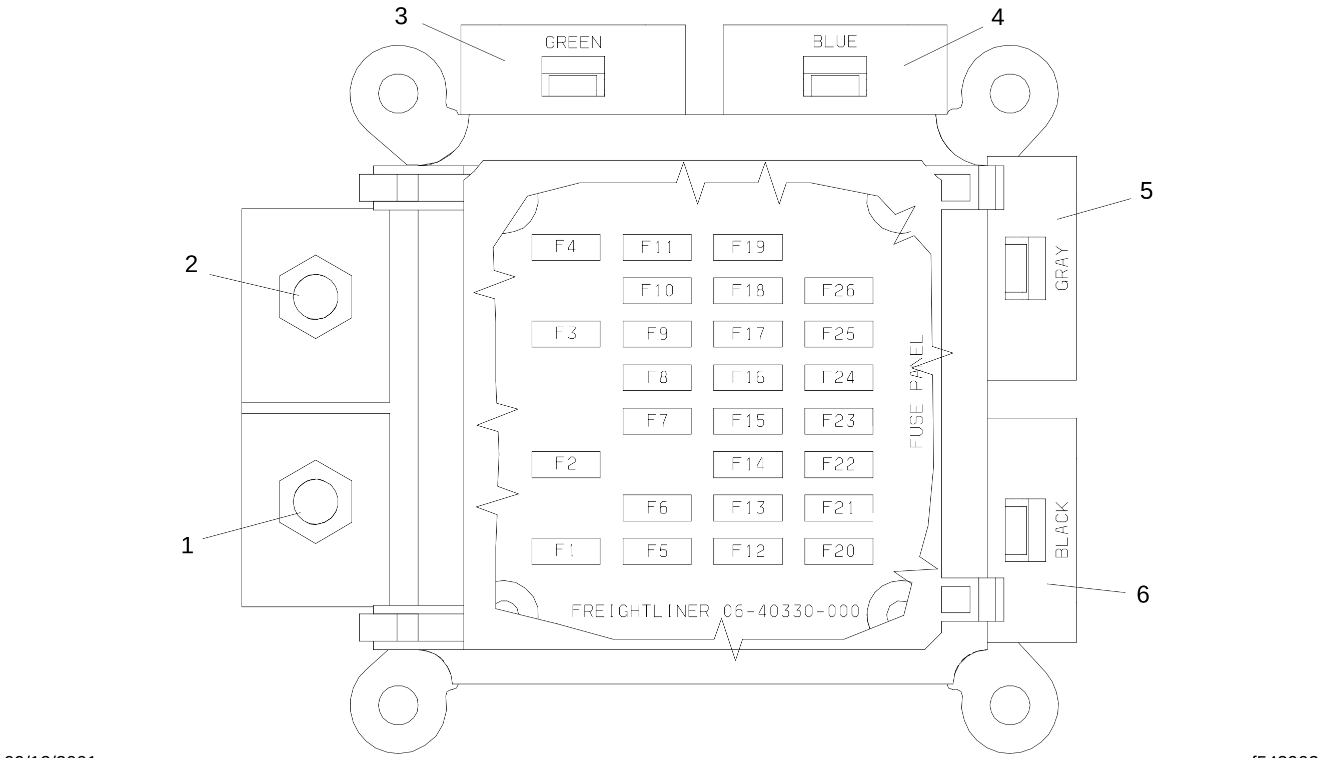


Fig. 7, Chassis PDM Schematic

Main PDM Specifications

See **Fig. 1** for an illustration of the main PDM fuse panel layout and connections.



1. Battery Power to 125-Amp MEGA Fuse 2
2. Battery Power to 125-Amp MEGA Fuse 1
3. Engine Harness Connector (green)
4. Forward Chassis Harness Connector (blue)
5. Forward Chassis Harness Connector (gray)
6. Frontwall Harness Connector (black)

Fig. 1, Main PDM Fuse Panel Layout and Connections

Fuse Specifications*				
Fuse Location	**Primary Function**	**Fuse Rating**	**Secondary Function**	**Fuse Rating**
F1	Vehicle Control Unit (MBE only)	10A	Spare	—
F2	Blower Motor	30A	—	—
F3	Engine ECU (MBE or Caterpillar C7 and C9)	20A	Engine ECU (Caterpillar 3126, C11, C13, C15 ACERT, and Cummins ISC)	30A
F4	Engine ECU (Caterpillar 2004 EPA)	20A	Transmission ECU	30A
F5	Ignition Switch	5A	—	—
F6	Hydromax Relay (hydraulic ABS)	30A	—	—

Specifications

Fuse Specifications*				
Fuse Location	Primary Function	Fuse Rating	Secondary Function	Fuse Rating
F7	Bulkhead Module	30A	—	—
F8	ICU3-M2	10A	—	—
F9	Automatic Transmission ECU	10A	Eaton AutoShift Transmission ECU	30A†
F10	Spare	—	—	—
F11	Spare	—	—	—
F12	Radio/Diagnostic	20A	—	—
F13	Chassis Module	30A	—	—
F14	Spare	—	—	—
F15	Bulkhead Module	30A	—	—
F16	ABS ECU (pneumatic)	15A	ABS ECU (hydraulic)	25A
F17	Chassis Module	30A	—	—
F18	Bulkhead Module	30A	—	—
F19	Chassis Module	30A	—	—
F20	Bulkhead Module	30A	—	—
F21	Spare	—	—	—
F22	Bulkhead Module	30A	—	—
F23	Spare	—	—	—
F24	Hydraulic Pump and Motor (hydraulic ABS)	25A	Spare	—
F25	Spare	—	—	—
F26	Spare	—	—	—

* Spare fuse locations may be used for additional options such as power windows and power door locks.

† The fuse rating for an AGS transmission is 20A.

Table 1, Fuse Specifications

Specifications

<table>
<tr><th colspan="2">MEGA® Fuse and the Corresponding PDM Fuses It Protects</th></tr>
<tr><th>MEGA Fuse</th><th>PDM Fuse</th></tr>
<tr><td rowspan="13">1</td><td>F1</td></tr>
<tr><td>F2</td></tr>
<tr><td>F5</td></tr>
<tr><td>F6</td></tr>
<tr><td>F7</td></tr>
<tr><td>F12</td></tr>
<tr><td>F13</td></tr>
<tr><td>F14</td></tr>
<tr><td>F20</td></tr>
<tr><td>F21</td></tr>
<tr><td>F22</td></tr>
<tr><td>F23</td></tr>
<tr><td>F24</td></tr>
<tr><td rowspan="13">2</td><td>F3</td></tr>
<tr><td>F4</td></tr>
<tr><td>F8</td></tr>
<tr><td>F9</td></tr>
<tr><td>F10</td></tr>
<tr><td>F11</td></tr>
<tr><td>F15</td></tr>
<tr><td>F16</td></tr>
<tr><td>F17</td></tr>
<tr><td>F18</td></tr>
<tr><td>F19</td></tr>
<tr><td>F25</td></tr>
<tr><td>F26</td></tr>
</table>

Table 2, MEGA Fuse and the Corresponding PDM Fuses It Protects

<table>
<tr><th colspan="2">PDM Fuses and the Corresponding PDM Output Pins</th></tr>
<tr><th>PDM Fuse</th><th>Output Connector and Terminal</th></tr>
<tr><td>F1</td><td>Green A</td></tr>
<tr><td>F2</td><td>Green B</td></tr>
<tr><td>F3</td><td>Green H</td></tr>
<tr><td>F4</td><td>Green G</td></tr>
<tr><td>F5</td><td>Black D</td></tr>
<tr><td>F6</td><td>Black C</td></tr>
<tr><td>F7</td><td>Gray F</td></tr>
<tr><td>F8</td><td>Green C</td></tr>
<tr><td>F9</td><td>Green D</td></tr>
<tr><td rowspan="2">F10</td><td>Blue G</td></tr>
<tr><td>Green F</td></tr>
<tr><td>F11</td><td>Blue H</td></tr>
<tr><td>F12</td><td>Black H</td></tr>
<tr><td>F13</td><td>Gray E</td></tr>
<tr><td>F14</td><td>Black B</td></tr>
<tr><td>F15</td><td>Black A</td></tr>
<tr><td>F16</td><td>Blue A</td></tr>
<tr><td>F17</td><td>Blue C</td></tr>
<tr><td>F18</td><td>Blue B</td></tr>
<tr><td>F19</td><td>Gray G</td></tr>
<tr><td>F20</td><td>Gray E</td></tr>
<tr><td>F21</td><td>Black F</td></tr>
<tr><td>F22</td><td>Black G</td></tr>
<tr><td rowspan="2">F23</td><td>Gray H</td></tr>
<tr><td>Blue E</td></tr>
<tr><td>F24</td><td>Gray D</td></tr>
<tr><td>F25</td><td>Gray C</td></tr>
<tr><td rowspan="3">F26</td><td>Gray A</td></tr>
<tr><td>Gray B</td></tr>
<tr><td>Blue D</td></tr>
</table>

Table 3, PDM Fuses and the Corresponding PDM Output Pins

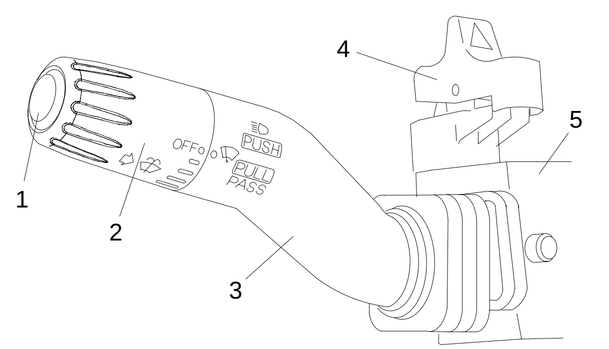
Description

The instrumentation control unit (ICU) monitors wiper control dial and washer switch position information from the multifunction turn signal switch and sends this information via J1939 messages to the Bulkhead Module (BHM). The BHM takes these messages from the ICU and uses the information to control the windshield wiper motor and the washer pump motor.

Wiper Control Dial

The wiper control dial at the end of the multifunction turn signal switch controls the operation of the wiper. See **Fig. 1**. There are two steady-speed settings, LO and HI, and five delay settings. The delay settings are indicated by five lines of various lengths on the wiper control dial. The longer the length of the line, the shorter the delay between wipes.

Rotate the wiper control dial away from you to turn the wipers on. When the wipers are on, rotate the wiper control dial toward you to turn the wipers off. See **Fig. 2**.

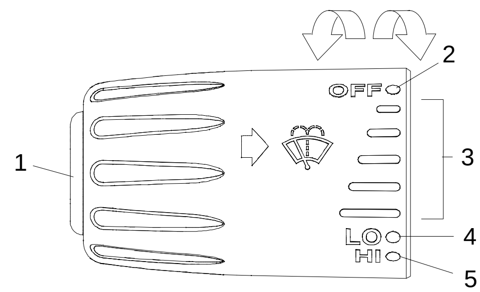


11/16/2001 f820386

1. Washer Button
2. Wiper Control Dial
3. Turn Signal Lever
4. Hazard Flasher
5. Multifunction Turn Signal Switch Module

Fig. 1, Multifunction Turn Signal Switch

See **Specifications 400** for wiper control dial input/output signals sent to the ICU.



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1. Washer Button
2. Wiper Off Position
3. Wiper Delay Positions
4. Low-Speed Wiper Position
5. High-Speed Wiper Position

Fig. 2, Wiper/Washer Controls

Wiper Motor

The wiper motor is a two-speed motor that runs the wipers at low speed or high speed. For the five intermittent positions, the wipers are pulsed at low speed. There is a short time delay between pulses that varies in duration according to the position of the wiper control dial.

The BHM controls the wiper motor speed by monitoring three J1939 messages that are received from the ICU. The three messages are:

- wiper on/off message
- wiper low message
- wiper high message

When one of the intermittent speeds is selected, the ICU controls the timing of the wipers by pulsing the wiper on/off and wiper low messages. See **Specifications 400** for the I/O conditions of the wiper motor operation.

The BHM also monitors the wiper motor wiring and is capable of detecting a short circuit. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and can be viewed through ServiceLink®. See **Troubleshooting 300** for possible wiper motor fault conditions.

General Information

Washer Pump

The washer pump is operated by a button at the end of the multifunction turn signal switch. To operate the washer, press the button in and hold it in for the length of wash you want. See **Table 1** for a description of the available wash cycles. Unless the wiper control dial is in the high position, wiping triggered by the wash button is done at low speed.

The BHM monitors the washer pump motor wiring and is capable of detecting a short circuit. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and can be viewed through ServiceLink. See **Troubleshooting 300** for possible washer pump fault conditions.

Washer Fluid Level

If the vehicle is equipped with an optional washer fluid level switch, the BHM will monitor the level of the washer fluid in the fluid reservoir and send this information to the ICU via a J1939 message. When the BHM sees ground at the washer fluid level input, it sends a J1939 message to the ICU indicating low washer fluid. The ICU then illuminates the low washer fluid indicator. If the washer fluid level input is unavailable or in error, the BHM will assume the washer fluid level is low.

Washer Cycles	
Cycle Activation Requirements	**Cycle Description**
Wash button is pressed less than 0.5 second.	Single dry wipe, commonly called a mist wipe.
Wash button is pressed from 0.5 to 1.0 second.	Short wash with three wipes.
Wash button is pressed more than 1.0 second.	Wash continues until the button is released.

Table 1, Washer Cycles

Fault Codes

The reference parameters that program the Bulkhead Module (BHM) determine whether a fault code will broadcast for any wiper/washer system fault. Even if the BHM detects a wiper/washer system fault, a fault code may not be transmitted. If the BHM is programmed to transmit wiper/washer system fault codes, they can be viewed through ServiceLink®. Fault messages may be transmitted on the J1939 datalink, the J1708 datalink, or both.

Wiper Control Dial

Table 1 displays wiper control dial message combinations that create a fault.

Wiper Motor

Table 2 displays how the BHM handles wiper motor faults.

Washer Pump

Table 3 displays how the BHM handles washer pump faults.

Wiper Control Dial Fault Conditions			
J1939 Wiper Control Dial Messages			Action Taken by the BHM
Wiper On/Off	Wiper Low	Wiper High	
Off	On	Off	BHM may transmit a J1939 and/or a J1708 fault message.
On	Off	Off	BHM may transmit a J1939 and/or a J1708 fault message.
On	On	On	BHM may transmit a J1939 and/or a J1708 fault message.
Off	On	On	BHM may transmit a J1939 and/or a J1708 fault message.
Off	Off	On	BHM may transmit a J1939 and/or a J1708 fault message.

Table 1, Wiper Control Dial Fault Conditions

Wiper Motor Fault Conditions	
Description of Fault	**Action Taken by the BHM**
Ignition switch is in error.	BHM will assume the ignition switch is on, and may transmit a fault message on the J1939 and/or J1708 datalinks.
Wiper commutator switch is unavailable or in error.	BHM will assume the wiper commutator switch is in the park position.
J1939 wiper on/off message from the instrumentation control unit (ICU) is unavailable or in error.	BHM may transmit a J1939 and/or a J1708 fault message.
J1939 wiper low message from the ICU is unavailable or in error.	BHM may transmit a J1939 and/or a J1708 fault message.
J1939 wiper high message from the ICU is unavailable or in error.	BHM may transmit a J1939 and/or a J1708 fault message.
Contradictory J1939 messaging between the ICU and BHM.	BHM may transmit a J1939 and/or a J1708 fault message.
ICU sends an error indicator in any of the J1939 wiper messages to the BHM.	BHM may transmit a J1939 and/or a J1708 fault message.
BHM fails to receive any five consecutive J1939 wiper messages from the ICU.	BHM may transmit a J1939 and/or a J1708 fault message.

Troubleshooting

Wiper Motor Fault Conditions	
Description of Fault	**Action Taken by the BHM**
Short in the wiper motor wiring.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 2, Wiper Motor Fault Conditions

Washer Pump Fault Conditions	
Description of Fault	**Action Taken by the BHM**
J1939 washer pump message from the ICU is unavailable or in error.	BHM assumes the J1939 washer pump message is off.
ICU sends an error indicator in the J1939 washer pump message to the BHM.	BHM may transmit a J1939 and/or a J1708 fault message.
BHM fails to receive five consecutive J1939 washer pump messages from the ICU.	BHM may transmit a J1939 and/or a J1708 fault message.
Short in the washer pump motor wiring.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 3, Washer Pump Fault Conditions

Description

The instrumentation control unit (ICU) monitors windshield wiper control dial and washer switch position information from the multifunction turn signal switch and sends this information via J1939 messages to the Bulkhead Module (BHM). The BHM takes these messages from the ICU and uses the information to control the windshield wiper motor and the washer pump motor. See **Fig. 1** for a diagram of the major components used in the operation of the wiper/washer system.

Input and Output Conditions

The wiper motor has a low speed, a high speed, and five intermittent speeds. The BHM controls the wiper motor speed by monitoring three J1939 messages that it receives from the ICU. The three messages are:

- wiper on/off message
- wiper low message
- wiper high message

When one of the intermittent speeds is selected at the multifunction turn signal switch, the ICU controls the timing of the wipers by pulsing the J1939 wiper on/off and the J1939 wiper low messages.

Table 1 displays the wiper control dial inputs to the ICU and the J1939 message outputs.

Table 2 displays the wiper motor inputs to the BHM and how the BHM reacts to these inputs.

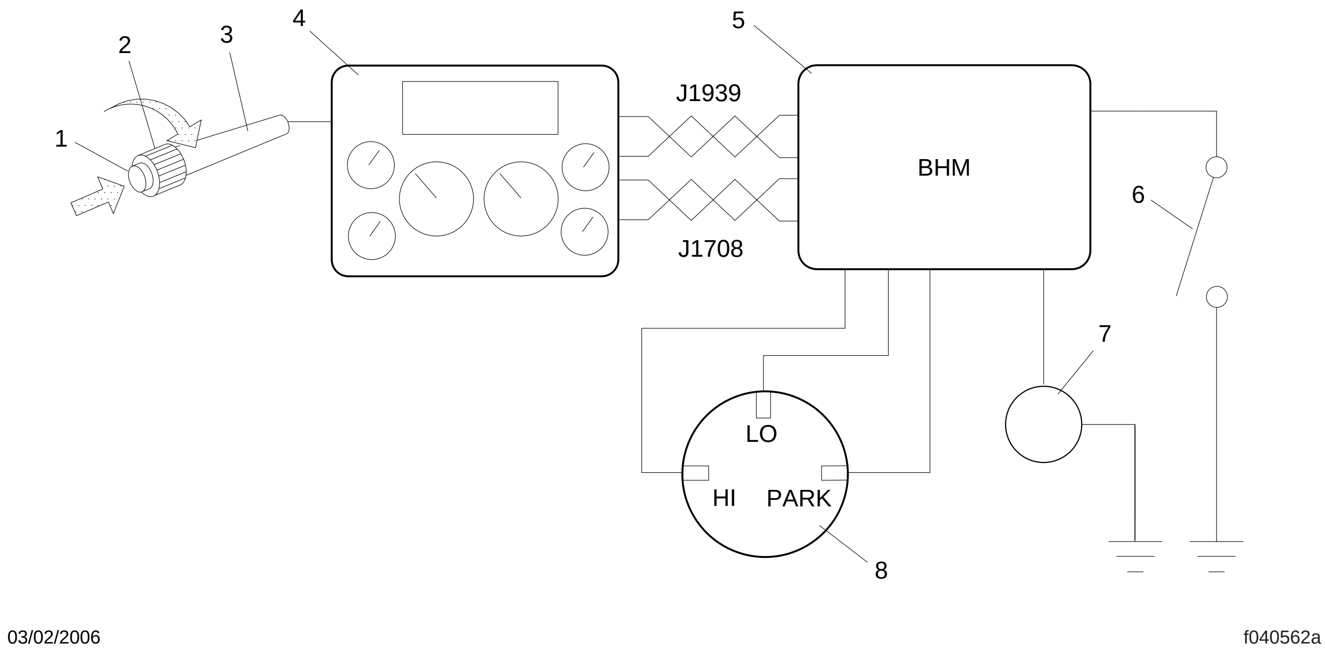
Wiring Diagram

Figure 2 shows a wiring diagram for a typical Business Class® M2 wiper/washer system. BHM pin identification and circuit colors shown on this diagram may not be representative of every vehicle.

Wiper Control Dial Input/Output Conditions				
Inputs to ICU		Outputs from ICU		
Wiper Control Dial Position	Wiper Operation Timing	J1939 Wiper On/Off Message	J1939 Wiper Low Message	J1939 Wiper High Message
OFF	Wiper off	Off	Off	Off
Intermittent 1	Wipe every 17 seconds	Pulsed on	Pulsed on	Off
Intermittent 2	Wipe every 12 seconds	Pulsed on	Pulsed on	Off
Intermittent 3	Wipe every 8 seconds	Pulsed on	Pulsed on	Off
Intermittent 4	Wipe every 5 seconds	Pulsed on	Pulsed on	Off
Intermittent 5	Wipe every 3 seconds	Pulsed on	Pulsed on	Off
LO	Wiper low speed	On	On	Off
HI	Wiper high speed	On	Off	On

Table 1, Wiper Control Dial Input/Output Conditions

Specifications



1. Washer Switch
2. Wiper Control Dial
3. Multifunction Turn Signal Switch
4. Instrumentation Control Unit
5. Bulkhead Module
6. Washer Fluid Level Sensor
7. Washer Pump
8. Wiper Motor

Fig. 1, Wiper/Washer System

Wiper Motor Input/Output Conditions				
Inputs to BHM				Output from BHM
Ignition Switch Position	J1939 Wiper On/Off Message	J1939 Wiper Low Message	J1939 Wiper High Message	Wiper Motor Speed
Start/Off	On/Off	On/Off	On/Off	Off
On/Acc	Off	Off	Off	Off
On/Acc	On	On	Off	Low
On/Acc	Off	On	Off	Low*
On/Acc	On	Off	Off	Low*
On/Acc	On	Off	On	High
On/Acc	On	On	On	High*
On/Acc	Off	On	On	High*
On/Acc	Off	Off	On	High*

* This is an error condition. See Specifications 300, for more information concerning fault conditions.

Table 2, Wiper Motor Input/Output Conditions

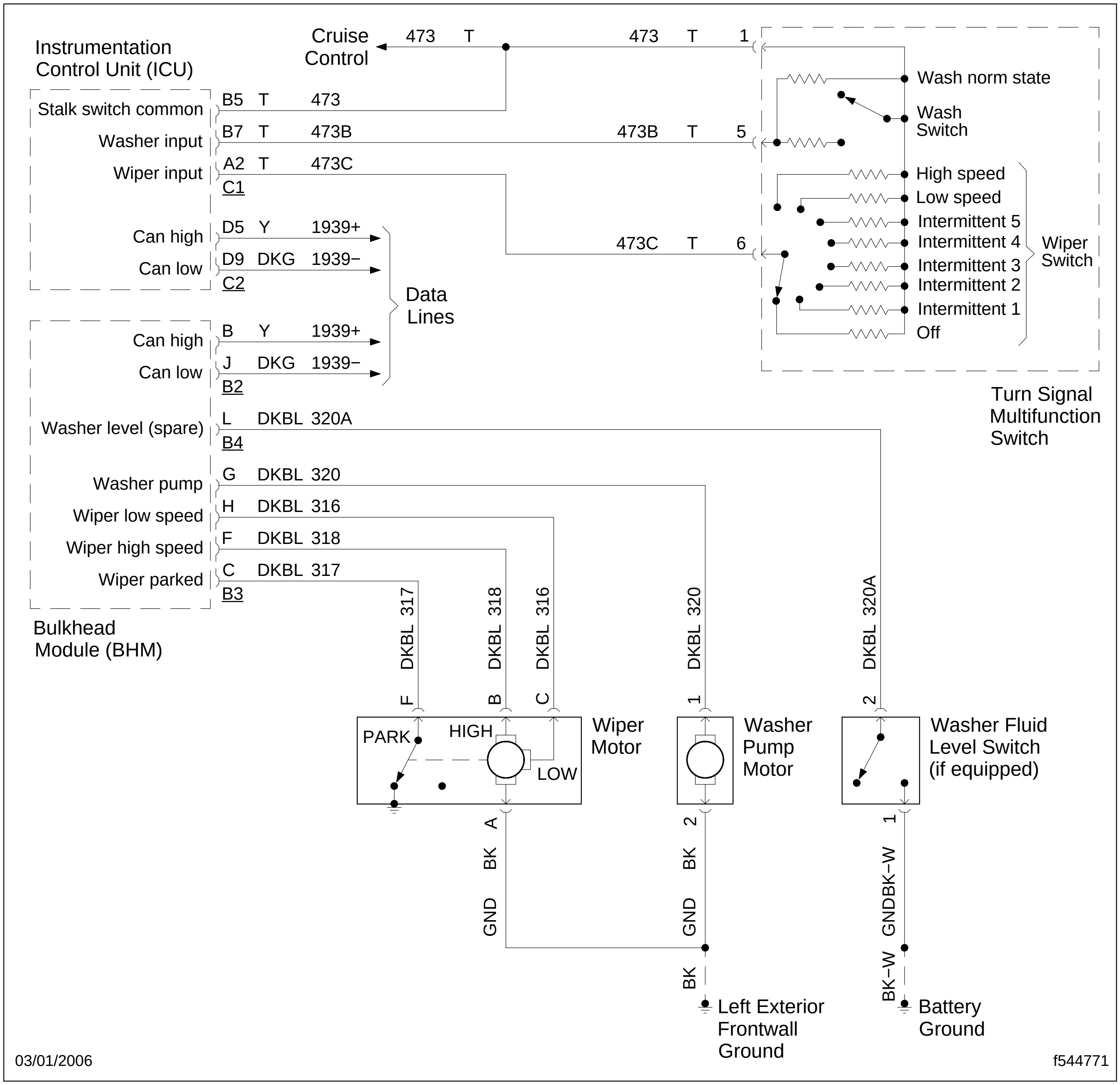
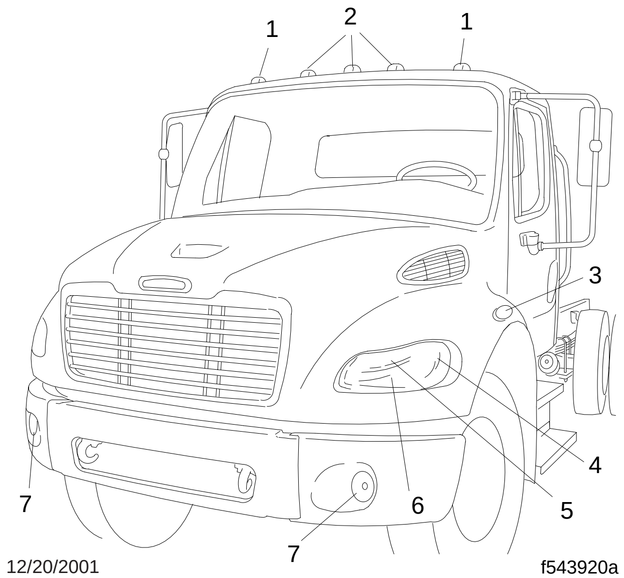


Fig. 2, Wiper/Washer Wiring Diagram

See **Fig. 1** for the locations of the forward exterior lights on a typical Business Class® M2 vehicle.



1. Clearance Light
2. Identification Light
3. Side Marker/Turn Signal Light
4. Park/Turn Signal Light
5. Headlight, Low Beam
6. Headlight, High Beam
7. Fog Light (optional)

Fig. 1, Forward Exterior Lights, All Models Except M2 106V

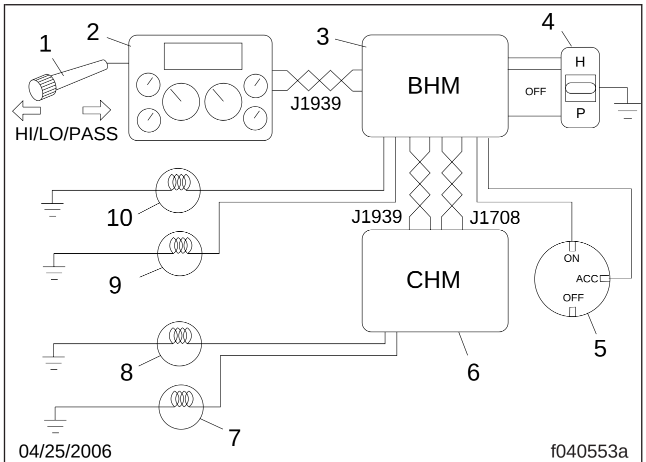
Headlight System

The Bulkhead Module (BHM) takes inputs from the multifunction turn signal switch via a J1939 message from the instrumentation control unit (ICU) as well as the combination headlight/parking light switch, and uses the information to control the headlights. See **Fig. 2**.

Headlight Switch Function

The headlight switch on the dash panel has three positions: off, park (parking lights), and on (headlights). The Bulkhead Module (BHM) continuously monitors the position of the headlight switch and broadcasts this information on the J1939 datalink.

There are three circuits that run from the headlight switch to the BHM. One is for the parking lights, the



1. Multifunction Turn Signal Switch
2. Instrumentation Control Unit
3. Bulkhead Module
4. Headlight Switch
5. Ignition Switch
6. Chassis Module
7. Right Headlight, Low Beam
8. Right Headlight, High Beam
9. Left Headlight, High Beam
10. Left Headlight, Low Beam

Fig. 2, Headlight System Function

other two are for the headlights. Either of the two headlight circuits running from the switch to the BHM can activate the headlights. The double circuits act as a fail-safe and allow the headlights to work even if one of the two wires is damaged or disconnected. See **Fig. 2**.

The BHM monitors the headlight switch wiring and is capable of detecting error conditions in the headlight switch circuits. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink®.

Headlight Assemblies

There are two headlight assemblies available for a Business Class M2 vehicle:

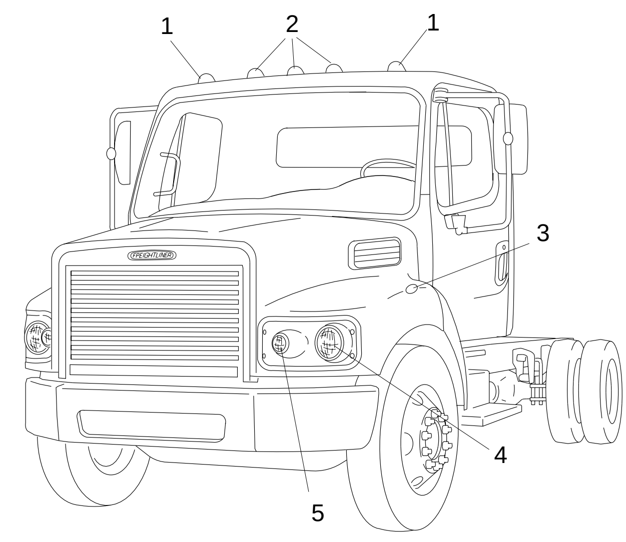
- composite headlights
- sealed-beam headlights

Composite headlights are installed on all models except M2 106V. Sealed-beam headlights are only installed on the M2 106V.

General Information

See **Fig. 1** for the locations of the forward exterior lights on a vehicle with composite headlights.

See **Fig. 3** for the locations of the forward exterior lights on a vehicle with sealed-beam headlights.



1. Clearance Light
2. Identification Light
3. Side Marker/Turn Signal Light
4. Headlight
5. Park/Turn Signal Light

Fig. 3, Forward Exterior Lights, M2 106V Only

A composite headlight assembly provides separate access to the low-beam bulb and high-beam bulb. The separate bulb connections of a composite headlight permit individual bulb replacement.

A sealed-beam headlight is an enclosed light assembly that is replaced as a single unit. The individual bulbs within the sealed-beam headlight are not replaceable.

The forward chassis harness supplies the headlights via an 8-pin connector. Depending on the type of headlight assembly, short wiring connections are made from the 8-pin connector to the headlight. A composite headlight has two separate electrical connections, one at each bulb of the headlight. A sealed-beam headlight has a single electrical connection at the rear of the headlight unit.

High Beams Function

The Bulkhead Module (BHM) continually monitors the position of the headlight switch and the position of the multifunction turn signal switch to determine if the headlights should be on low beams or high beams. The instrumentation control unit (ICU) transmits the multifunction turn signal switch position information to the BHM via a J1939 message. When the headlight switch is on and high beam or PASS is selected at the multifunction turn signal switch, the BHM activates the left high beam and sends a J1939 message to the Chassis Module (CHM) instructing it to activate the right high beam. High beams operate only with the ignition on.

The BHM is capable of detecting shorted circuits in the left high beam wiring and the right high beam wiring on the CHM. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 2**.

Low Beams Function

The Bulkhead Module (BHM) continually monitors the position of the headlight switch and the position of the multifunction turn signal switch to determine if the headlights should be on low beams or high beams. The instrumentation control unit (ICU) transmits the multifunction turn signal switch position information to the BHM via a J1939 message. When the headlight switch is on and low beam is selected at the multifunction turn signal switch, the BHM activates the left low beam and sends a J1939 message to the Chassis Module (CHM) instructing it to activate the right low beam.

NOTE: If the CHM does not see J1939 messages from the BHM, the right low beam is activated. If the BHM fails, the left low beam is activated.

The BHM is capable of detecting shorted circuits in the left low beam wiring and the right low beam wiring on the CHM. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 2**.

Daytime Running Lights

All Business Class M2 vehicles can be equipped with daytime running lights (DRL). Daytime running lights are required on vehicles domiciled in Canada. The customer can also request DRL.

IMPORTANT: When adding daytime running lights to a vehicle that was built without DRL, you must follow the "Adding a Feature" procedure in **Section 54.00, Subject 110**. Adding or changing a reference parameter without following this procedure may have legal consequences for the vehicle owner, which may include fines and having vehicles placed out of service. The regulations in the Federal Motor Vehicle Safety Standards (FMVSS) and Canadian Motor Vehicle Safety Standards (CMVSS) control the illumination intensity of daytime running lights and the required marking of lights used as DRL. Some jurisdictions enforce these regulations during vehicle inspections.

The daytime running lights use either the low-beam headlights or the front turn signal lights, depending on the type of vehicle. On an M2 106V vehicle, the low-beam headlights are used as the daytime running lights. On all other M2 vehicles, the front turn signal lights are used as the daytime running lights. DRL functionality is programmed to the BHM whether the low-beam headlights or the front turn signal lights are used.

See **Subject 500** for DRL reference parameters and descriptions.

NOTE: A vehicle that uses the low-beam headlights as the DRL cannot be converted to the front turn signal lights as the DRL. The front turn signal lights do not meet the legal requirements for lamp identification for use as DRL.

A vehicle that uses the front turn signal lights as the DRL cannot be converted to the low-beam headlights as the DRL. The headlights will not provide the legally-required illumination intensity.

DRL Using Low-beam Headlights

On an M2 106V vehicle with daytime running lights, the pulse-width-modulated (PWM) DRL is only supported by BHM part number 06-49824-002 (software version 6.40 or higher). Since the CHM controls the right low beam, the CHM must be part number 06-34530-004 to possess PWM capabilities. PMW low-beam DRL is used on an M2 106V vehicle.

Low-beam DRL is activated with the headlight switch off, the ignition on, and the park brake released. When these conditions are met, the BHM activates the left low beam and sends a J1939 message to the CHM instructing it to activate the right low beam.

When operating as daytime running lights, the low-beam headlights are pulse-width modulated at approximately 85 percent. This is recognized as a voltage supply to the low beams at a reading lower than battery voltage. If the headlight switch is turned on, full battery voltage is supplied to the low beams.

DRL Using Turn Signal Lights

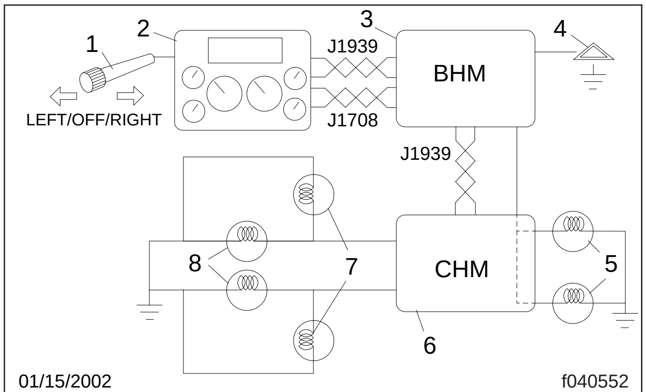
On a Business Class M2 vehicle with daytime running lights using turn signal lights, the front turn signals are powered by separate output pins on the CHM. A jumper harness must be installed to connect the DRL outputs directly to the front turn signal circuits. The DRL outputs of the CHM continuously illuminate the front turn signals when the ignition is on, the headlight switch is off, and the turn signals are not active. If the turn signal switch is activated when the DRL is on, the CHM turns on and off the DRL output to the appropriate turn signal.

Turn Signal Lights Function

The Bulkhead Module (BHM) uses J1939 message inputs from the instrumentation control unit (ICU) to instruct the Chassis Module (CHM) to activate the turn signals. The ICU monitors the position of the multifunction turn signal switch. When the ICU sees that the driver has activated this switch, it sends a J1939 message to the BHM. The BHM then checks whether the hazard switch has been activated. If the hazard switch has not been activated, the BHM sends a J1939 message to the CHM instructing it to illuminate the turn signal lights. See **Fig. 4**.

Exterior bulbs that provide turn signal identification often contain dual filaments in order to provide other vehicle lighting such as park lights or marker lights. Exterior turn signals on a typical M2 are:

- park/turn signal lights at the front of the vehicle
- side marker/turn signal lights on the front fenders
- taillights at the rear of the vehicle
- raised fender lights (optional) viewable from the front and side of the vehicle



1. Multifunction Turn Signal Switch
2. Instrumentation Control Unit
3. Bulkhead Module
4. Hazard Switch
5. Rear Turn Signal Lights
6. Chassis Module
7. Side Turn Signal Lights
8. Front Turn Signal Lights

Fig. 4, Turn Signal Lights Function

The CHM switches power on and off to all forward turn signals. The BHM operates the rear turn signals by sending pulsed power through the CHM to the taillights. The BHM is capable of detecting short circuits in the turn signal wiring. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink.

Hazard Lights Function

Hazard lights are used to warn other drivers of emergency situations. The same bulbs that are used for the turn signals are also used for the hazard lights. The BHM activates these lights based on the position of the hazard and multifunction turn signal switches. The BHM monitors the hazard switch directly. The instrumentation control unit (ICU) transmits the multifunction turn signal switch position information to the BHM via a J1939 message. When the hazard switch is on and neither the right-turn nor the left-turn signal is selected at the multifunction turn signal switch, the BHM sends a J1939 message to the CHM instructing it to activate all the forward lighting turn signals. The BHM activates the right-turn and left-turn signal lights at the rear of the vehicle by sending power through the CHM and to the lights.

NOTE: The CHM will activate the hazard lights in the event the BHM loses communication with the CHM on the J1939 datalink.

The BHM is capable of detecting short circuits in the right-turn and left-turn signal light wiring. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 4**.

Marker Lights Function

A marker light is any light that indicates the presence of the vehicle to other drivers. This includes parking lights, taillights, marker lights, identification lights, and clearance lights. See **Fig. 1** for forward maker light locations.

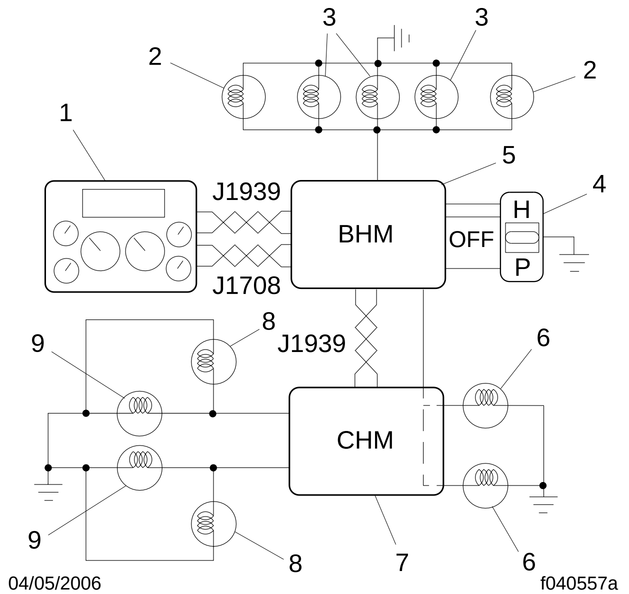
The Bulkhead Module (BHM) continually monitors the position of the headlight switch. When it sees that the operator has selected either headlights or parking lights, the BHM does several things. It sends power directly to the identification lights and clearance lights that are mounted on the cab roof. It also sends power through the Chassis Module (CHM) to the taillights. Finally, the BHM sends a J1939 message to the CHM instructing it to turn on the side marker lights and park lights.

The BHM is capable of detecting shorted wires in the marker light circuits. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 5**.

Variations on Marker Light Function

Marker lights may be programmed or adapted for functionality that differs from the headlight switch. Some common variations of marker light functionality are:

- battery-operated clearance lights
- clearance lights, identification lights, and taillights that are on at all times
- clearance lights and identification lights controlled by a marker interrupt switch
- marker lights turn off when the ignition is turned off



1. Instrumentation Control Unit
2. Clearance Light (top of cab)
3. Identification Lights (top of cab)
4. Headlight Switch
5. Bulkhead Module
6. Taillights
7. Chassis Module
8. Side Marker Lights (side of hood)
9. Park Lights (front of hood)

Fig. 5, Marker Lights Function

See **Subject 500** for the reference parameters required to program alternate marker light functionality. Some parameter programming requires no installation of additional features, while other parameters may require additional wiring.

When a customer requests battery-operated clearance lights, a different harness is used for the clearance and identification lights. The clearance lights are connected directly to the battery splice pack in the vehicle dash, while the identification lights are connected to the BHM.

Vehicles equipped with battery-operated clearance lights are equipped with a battery disconnect switch. The disconnect switch must be turned to the off position to turn off the clearance lights.

Vehicles equipped with marker lights that are programmed to be on at all times are equipped with a battery disconnect switch. These marker lights are turned off by placing the battery disconnect switch to the off position.

The marker interrupt switch turns on the identification lights, front park lights, side marker lights, and taillights when the headlight switch is in the off position. This switch turns off these lights when the headlight switch is in either the park or on positions. The interrupt switch can also be programmed for use with marker lights that are on with the ignition off.

Fog Lights Function

Fog lights are available as an optional feature on a Business Class M2 vehicle. Fog lights may only be activated if the ignition switch is on and the headlight high beams are off.

The BHM continually monitors the position of the ignition switch, multifunction turn signal switch, and the dash-mounted fog light switch. The fog light switch is a two-position latching smart switch that delivers signals directly to the BHM. If the fog light switch is on and the BHM has determined that the other requirements are met, the BHM sends a J1939 message to the CHM instructing it to turn on the fog lights. The CHM fog light outputs are at pins C and D of CHM connector C3.

The BHM is capable of detecting shorted wires in the fog lights circuits. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 6**.

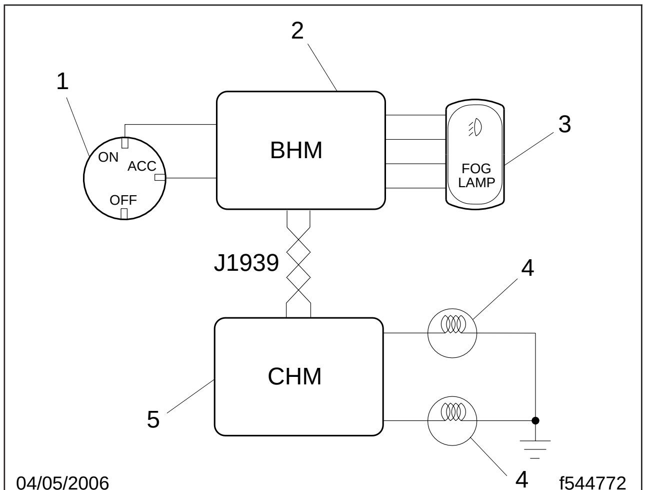
Snowplow Lights Provision

A provision for installation of snowplow lights is an optional feature on a Business Class M2 vehicle. Freightliner does not install snowplow lights or mounting hardware for the lights, only the provision for customer-installed snowplow lights.

A snowplow installed on a vehicle may block the standard vehicle headlights. When this situation occurs, the snowplow light provision allows the customer to install an auxiliary set of headlights and additional park/turn signal lights above the snowplow.

IMPORTANT: The customer installing the snowplow lights is responsible for complying with the regulations regarding snowplow lights and daytime running lights (DRL) functionality in the Federal Motor Vehicle Safety Standards

General Information



1. Ignition Switch
2. Bulkhead Module
3. Fog Light Switch
4. Fog Lights
5. Chassis Module

Fig. 6, Fog Lights Function

(FMVSS) and the Canadian Motor Vehicle Safety Standards (CMVSS).

When an M2 vehicle is equipped with the snowplow lights provision, the following electrical components are already installed on the vehicle:

- dash-mounted PLOW LAMP switch (snowplow light switch)
- snowplow light harness
- upper control module and lower control module mounted in the left, front wheel well

The snowplow lights can only be turned on when the ignition switch is on and the standard headlights are on.

WARNING

When a vehicle is equipped with snowplow light provision but snowplow lights are not installed, turning the PLOW LAMP switch on turns off both the standard headlights and the daytime running lights using low-beam headlights (M2 106V). Do not turn the PLOW LAMP switch on when snow-plow lights are not installed. Doing so could cause an accident resulting in serious personal injury or property damage.

Snowplow Lights Function

The Bulkhead Module (BHM) monitors the position of the snowplow light switch. The snowplow light switch is a two-position, latching smart switch that delivers signals directly to the BHM.

When the snowplow light switch is on and the BHM has determined that the other requirements are met, the BHM sends a message on the J1939 datalink to the Chassis Module (CHM) instructing it to signal the upper and lower control modules to switch the head-light output from the standard headlights to the auxil-iary headlight connector. The CHM snowplow lights control output is at pin C of the CHM C3 connector. See **Fig. 7**.

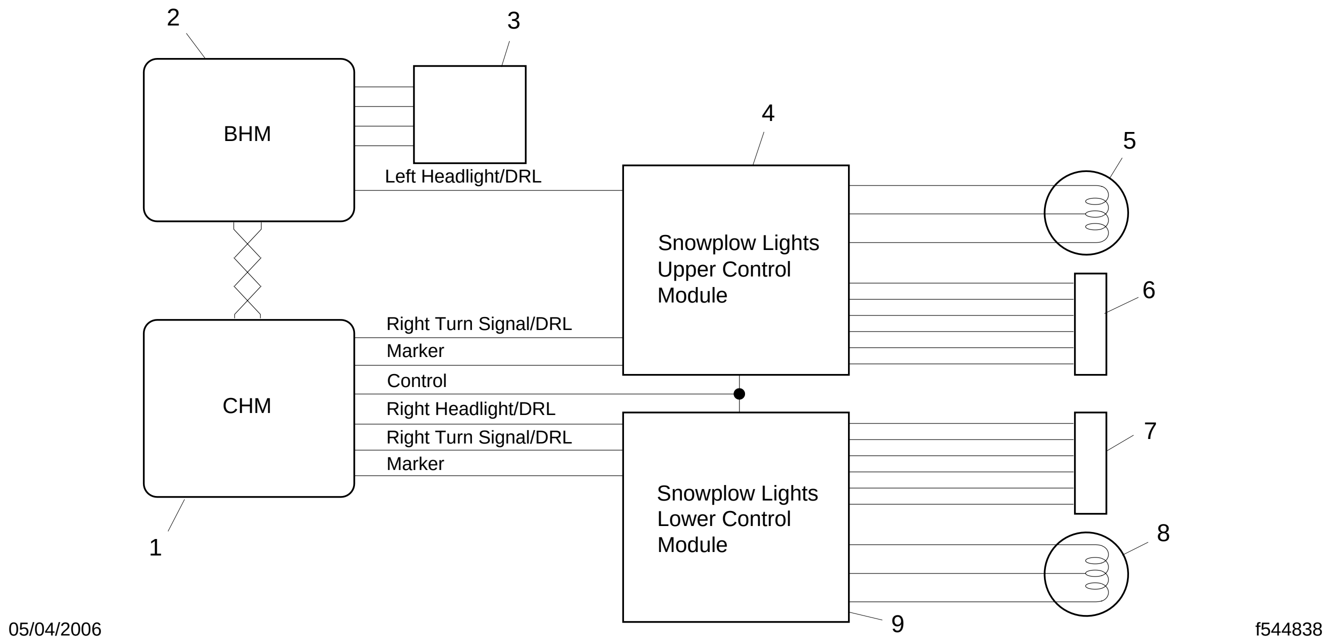
The low beams and high beams work with both the standard and auxiliary headlights. The same system of daytime running lights that is used on the standard headlights, whether using the turn signals or the low-beam headlights (M2 106V), is used on the snow-plow lights. The DRL system used on the M2 106V vehicle is also known as pulse-width-modulated DRL.

The snowplow light harness overlays the main chas-sis harness between the headlights and the CHM. The standard lighting circuits are intercepted at the connectors behind the headlights and rerouted through the upper and lower control modules, then back to the headlights.

A vehicle with a composite, standard headlight uses a different version of the snowplow light harness than a vehicle model M2 106V with a sealed-beam, standard headlight.

The two snowplow light connectors are located be-hind the headlights, one on each side. In addition to the switch headlight output, the snowplow light con-nectors provide the appropriate turn signal and marker lights, which are always active.

NOTE: The upper control module, which con-trols the right snowplow lights, and the lower control module, which controls the left snowplow lights, are identical. Both control modules have two 6-pin connectors—one black and one yel-low. Make sure that the connectors are paired correctly since the snowplow light harness is not color coded. The snowplow light harness has labels that indicate which connector each branch is intended to connect to. One branch is



1. Chassis Module
2. Bulkhead Module
3. Snowplow Lights Switch
4. Upper Control Module for Right Snowplow Lights
5. Right Low- and High-beam Headlights
6. Right Snowplow Light Connector
7. Left Snowplow Light Connector
8. Left Low- and High-beam Headlights
9. Lower Control Module for Left Snowplow Lights

Fig. 7, Snowplow Lights Function

longer that the other branch. The longer branch is connected to the upper control module.

Headlights, All Models

The headlight connectors on the main chassis harness are connected to the snowplow lights harness instead of the headlights. The low beam, high beam, and headlights common circuits are rerouted through the snowplow light harness to the upper and lower control modules. The control modules switch the signal between the standard headlights and the snowplow light connector, and all of these circuits route back to the appropriate connectors behind the headlights.

The headlight connectors on the snowplow light harness connect to the headlights while the snowplow lights circuits terminate at the snowplow light connector. Note that the snowplow headlight common circuits are switched by the upper and lower control modules, while the ground circuits at the snowplow connector are not.

Control, All Models

The control signal for the snowplow lights comes from the Chassis Module, normally from pin C of the C3 connector. This output is usually associated with fog lights; therefore, a vehicle cannot be equipped with both fog lights and a snowplow lights provision. The return for the upper and lower control module relays is spliced from the headlight common form the associated module.

Turn Signal Lights, All Models Except M2 106V

When the vehicle is equipped with daytime running lights, the DRL overlay connector connects to the turn signal connector on the snowplow light harness. When the vehicle is not equipped with DRL, the turn signal connector of the main harness connects to the turn signal connector on the snowplow light harness. The turn signal circuits are spliced to return to the DRL connectors on the main chassis harness and to

General Information

the upper and lower control modules for rerouting to the snowplow light connectors.

Park Lights, All Models Except M2 106V

The park lights circuit is picked up from the trailer output connection (C2) of the Chassis Module. Since this circuit is also required for trailer wiring when the vehicle has a towing provision, the circuit is spliced from a short jumper section in to which the trailer wiring can be connected. This circuit is provided to both the upper and lower control modules and from there to the snowplow light connectors.

Turn Signal and Park Lights, M2 106V Only

The turn signal/park light connectors on the main chassis harness are connected to the snowplow light harness instead of the turn signal/park lights. These circuits are spliced with one path continuing to the normal turn signal/park light connections, and the other path routed through the upper and lower control modules to the snowplow light connectors.

Before checking or adjusting the headlight aim, do the following:

- Remove any large amounts of mud or ice from the underside of the fenders.
- Check the springs for sagging or broken leaves.
- Check the suspension for proper function of the leveling mechanism. On cabs with air suspensions, make sure that the height is properly adjusted.
- Check for damage to the hood and hinge assembly. Repair as necessary.
- Clean the headlight lenses.
- With the vehicle unloaded, check that the tires are inflated to the recommended air pressure.

Headlight Aim Checking

1. Park the vehicle on a level surface 25 ft (7.6 m) from a screen or wall that can be used for aiming the headlights. Shut down the engine, apply the parking brakes, and chock the front tires. See **Fig. 1**.

NOTE: The low-beam headlight is the top bulb in the dual-beam assembly.

2. On each headlight, find the bulb center. See **Fig. 2**.
3. Measure the distance from the ground to the center of each low-beam bulb and note those distances.
4. On the screen or wall 25 ft (7.6 m) away, make the appropriate markings directly across from each headlight and at the same height as measured for the headlight.
5. Turn on the headlights to the low-beam setting. See **Fig. 3** for the ideal and acceptable patterns for both headlights.
    - If either or both headlights do not aim into the inner edges of the centerline, follow the adjusting procedure below.
    - If both headlights come close to the inside of each headlight centerline as shown, no further work is needed. Turn off the headlights and remove the chocks from the front tires.

Adjusting Composite Headlights

1. Lift the flap over the rear end of the headlight bucket to expose the two plastic adjusting knobs on each headlight. See **Fig. 4**.

NOTE: Horizontal aim should not be adjusted in the field.

2. With the vehicle parked 25 ft (7.6 m) from the screen or wall, put the headlights on low beams and turn both adjusting knobs the same amount as needed to adjust the lights until the beam pattern meets the acceptable standard in **Fig. 3**.

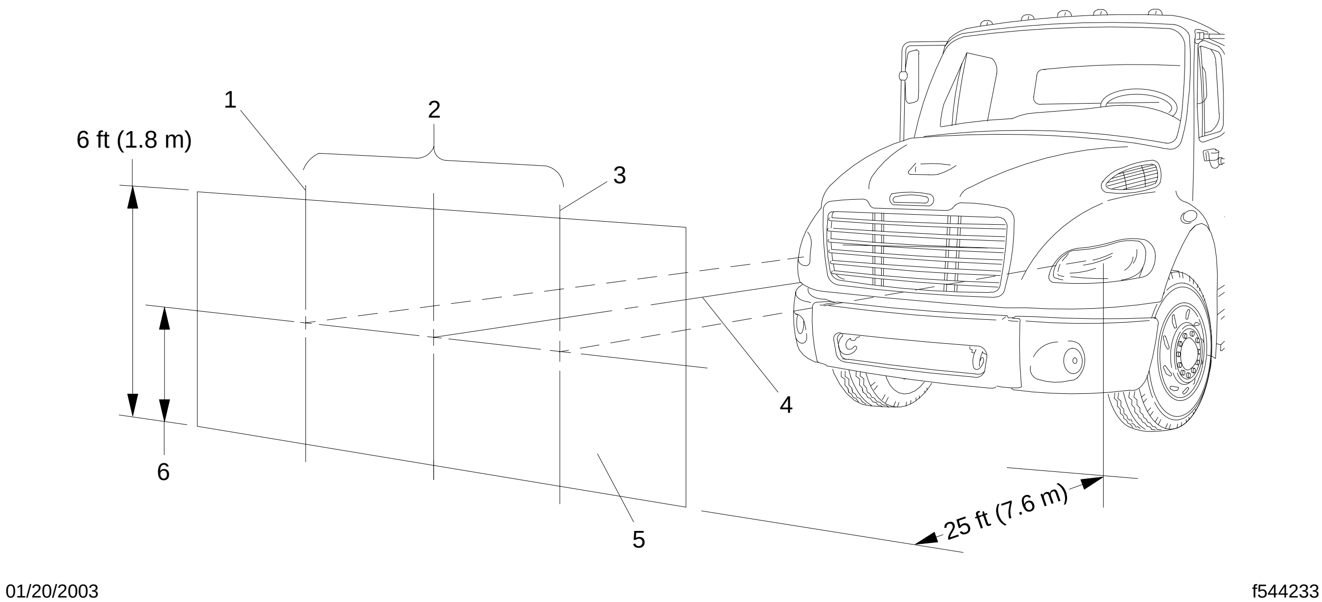
NOTE: Blocking off each light is not necessary, but it can help to present a clearer beam pattern.

3. Remove the chocks from the front tires.

Adjusting Sealed-beam Headlights

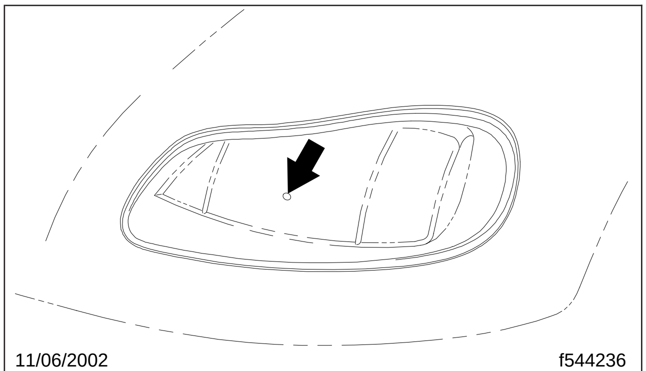
1. Park the vehicle on a level surface 25 ft (7.6 m) from a screen or wall that can be used for aiming the headlights. Shut down the engine, apply the parking brakes, turn on the headlight low beams, and chock the front tires
2. Locate the headlight adjusting screws that are accessible through the front of the headlight bezel. See **Fig. 5**.
3. Use a screwdriver to adjust the headlight beam position as necessary to achieve the acceptable standard shown in **Fig. 3**.
4. Remove the chocks from the front tires.

Headlight Aim Checking and Adjusting



1. Vertical Centerline of Right Headlight
2. Distance Between Headlights
3. Vertical Centerline of Left Headlight
4. Projected Vehicle Centerline
5. Screen or Wall
6. Height of Lamp Centers

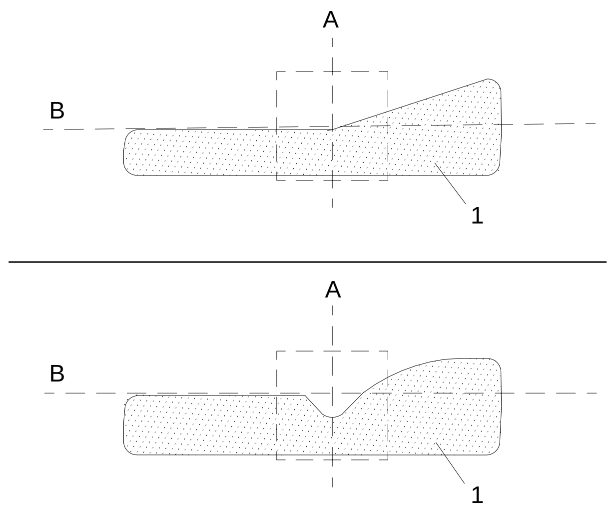
Fig. 1, Headlight Aiming Screen or Wall



NOTE: Measure beam height from the ground to the small dot roughly in the center of the headlight lens.

Fig. 2, Headlight Beam Height Adjusting Dot

Headlight Aim Checking and Adjusting



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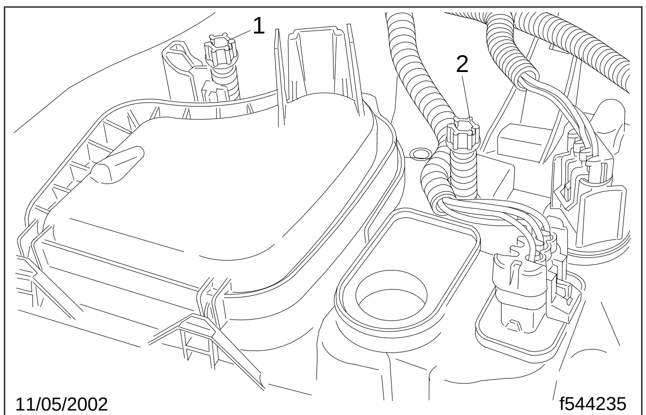
NOTE: The top view shows the ideal beam pattern; the bottom view shows an acceptable standard.

A. Vertical Centerline B. Horizontal Centerline

1. Bright Area

Fig. 3, Headlight Beam Pattern



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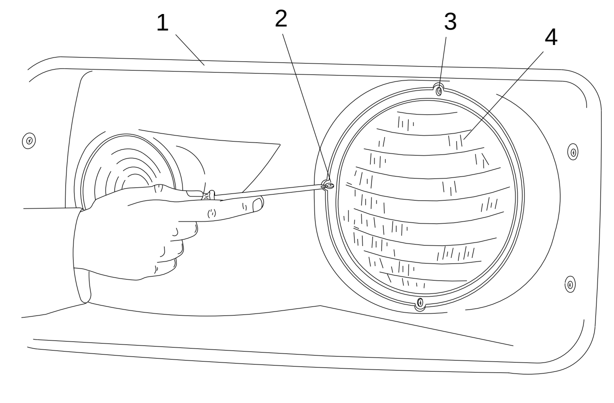
NOTE: The right side headlight bucket is shown. The left side is opposite.

1. Inboard Adjusting Knob
2. Outboard Adjusting Knob

Fig. 4, Headlight Adjusting Knobs



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1. Headlight Bezel
2. Horizontal Adjusting Screw
3. Vertical Adjusting Screw
4. Headlight

Fig. 5, Sealed-beam Headlight Adjusting

Exterior Lights Replacement

Before working on the vehicle, park it on a level surface and shut down the engine. Set the parking brake and chock the front and rear tires.

NOTE: Use gloves or a clean cloth or paper towel when handling halogen bulbs; do not handle them with bare hands. Oil from the skin causes overheating and rapid blowout. If bulbs are handled accidentally, use a cotton swab dipped in rubbing alcohol to remove oil.

NOTE: There are two types of headlights used on Business Class® M2 vehicles. Most M2 vehicles have composite headlights. The M2 106V vocational chassis has sealed-beam headlights. When replacing headlights and bulbs, use the correct replacement procedure for the type of headlight on the vehicle.

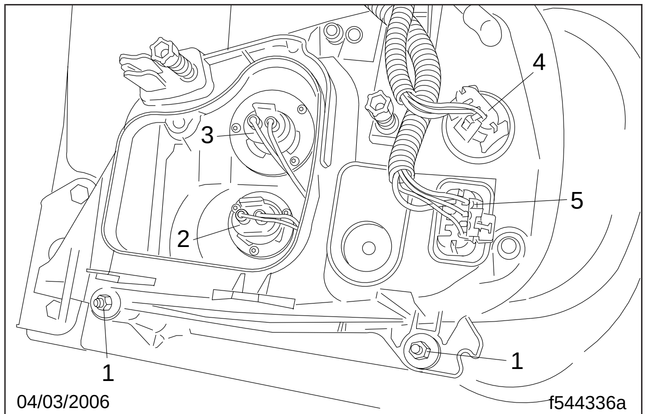
Composite Headlights

Headlight and Park/Turn Signal Light Assembly Replacement

1. Open the hood.
2. Secure the headlight splash guard out of the way.
3. Disconnect the headlight and park/turn signal light electrical connectors and cut any tie-straps that may be holding them to the headlight bucket assembly.
4. Remove the nuts from the two lower mounting adjustment studs. See **Fig. 1**.
5. Remove the Torx® capscrew from the upper mounting bracket.
6. Remove the headlight assembly.
7. Place a new assembly on the mounting studs and install the two nuts and washers.

NOTE: Before installing the new assembly, verify that the lower mounting adjustments on the new assembly are set the same as the old assembly.

8. Install the upper mounting capscrew.
9. Connect the two electrical connectors.
10. Verify the proper operation of the lights.



1. Lower Mounting Adjustment Nut
2. High Beam Socket
3. Low Beam Socket
4. Park/Turn Socket and Connector Assembly
5. Headlight Connector

Fig. 1, Headlight Bucket (rear view)

11. Return the headlight splash guard to its original operating position.

Headlight Bulb Replacement

1. Open the hood.
2. Remove the inner headlight cover by pressing the tab at the top and pulling out.
3. Disconnect the headlight connector. See **Fig. 1**.
4. Twist the high beam or low beam socket assembly 1/8 of a turn counterclockwise to remove it from the headlight bucket assembly and access the bulb.
5. Protecting the bulb with gloves or a cloth, unplug it from the socket. The bottom bulb in the assembly is the high beam lamp; the top bulb in the assembly is the low beam lamp.
6. Line up the bulb tabs and insert a new bulb into the socket then twist it 1/8 of a turn clockwise to secure it.
7. Connect the headlight connector.
8. Replace the inner headlight cover and snap it into place.
9. Close the hood.
10. Verify proper operation of the lights.

11. Check and adjust the headlight aim as described in Subject 100.

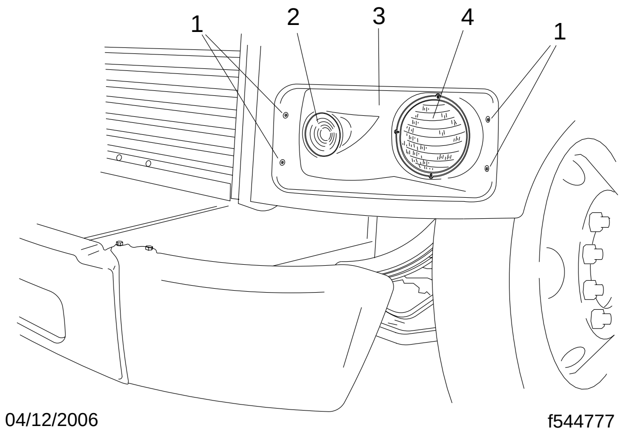
Front Park/Turn Bulb Replacement

1. Open the hood.
2. Twist the park/turn connector and socket assembly 1/8 turn counterclockwise and remove it from the headlight bucket. See Fig. 1.
3. Protecting the bulb with gloves or a cloth, pull the bulb straight out from the socket.
4. To provide corrosion protection, coat the base of the new bulb with dielectric grease. For approved lubricants, see Specifications 400.
5. Push the new bulb straight into the socket.
6. Place the connector and socket assembly in the headlight bucket and twist it 1/8 turn clockwise to lock it in place.
7. Verify proper operation of the lights.

Sealed-Beam Headlights

Headlight Replacement

1. Remove the four screws that attach the headlight bezel to the fender. See Fig. 2.



1. Bezel Retaining Screw
2. Park/Turn Signal Light
3. Headlight Bezel
4. Headlight

Fig. 2, Sealed-Beam Headlight Assembly

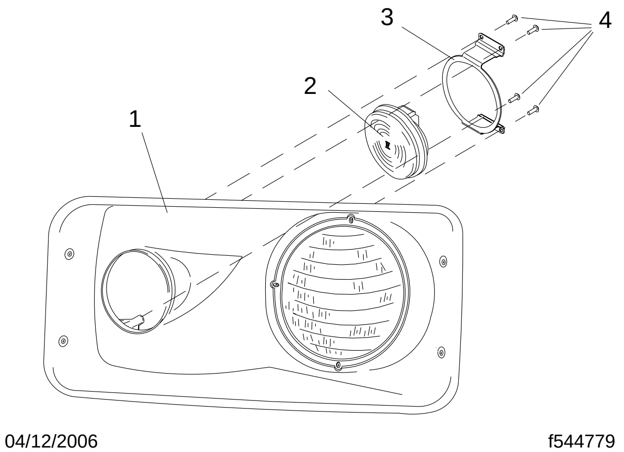
2. Remove the headlight bezel and disconnect the park/turn signal light electrical connector at the rear of the bezel.

NOTE: Do not turn the headlight adjustment screws. These screws are used for beam adjustment only; they do not secure the headlight retaining ring.

3. Remove the screws that secure the headlight retaining ring, then remove the retaining ring.
4. Ease the headlight from the housing to expose the electrical connector at the back of the light.
5. Disconnect the wiring connector from the headlight.
6. Check the wiring connector for corrosion and integrity. Clean and/or repair as needed.
7. Coat the prongs (connector terminals) of the new headlight with dielectric grease to help prevent corrosion. For approved lubricants, see Specifications 400.
8. Firmly seat the wiring connector onto the prongs of the new headlight.
9. Place the headlight in the headlight housing and position the light properly.
10. Place the retaining ring over the headlight and install the screws that secure the headlight.
11. Verify proper operation of the headlights.
12. Connect the park/turn signal light electrical connector.
13. Place the headlight bezel in the proper position and install the four screws.
14. Check and adjust the headlight aim as described in Subject 100.

Front Park/Turn Signal Light Replacement

1. Remove the four screws that attach the headlight bezel to the fender. See Fig. 2.
2. Disconnect the park/turn signal light electrical connector at the rear of the bezel.
3. Remove the four screws that attach the park/turn signal light retainer to the back of the headlight bezel. See Fig. 3.
4. Remove the park/turn signal light.



1. Headlight Bezel
2. Park/Turn Signal Light
3. Park/Turn Signal Light Retainer
4. Retainer Screw

Fig. 3, Sealed-Beam Park/Turn Signal Light

5. To provide corrosion protection, coat the electrical connection of the new light with dielectric grease. For approved lubricants, see **Specifications 400**.
6. Position the new park/turn signal light in the headlight bezel.
7. Place the retainer over the park/turn signal light and install the screws that secure the light to the bezel.
8. Connect the park/turn signal light electrical connector.
9. Verify proper operation of the lights.
10. Place the headlight bezel in the proper position and install the four screws.

Cab Clearance and Identification Light Assembly Replacement

1. Access the mounting nuts and electrical connections from inside the cab.
   1.1 Remove the left and right overhead map pockets to access the outer two lights.
   1.2 Remove the center console/dome light assembly or headliner to access the center three lights.
2. Disconnect the connector.
3. Remove the two mounting nuts and remove the light assembly.
4. Install a new clearance light. Tighten the two nuts to 60 lbf·in (677 N·cm).
5. Seal the hole with silicon sealant.
6. Connect the connector.
7. Replace the headliner or center console/dome lamp and/or map pockets.

Cab Clearance and Identification Light Bulb Replacement

1. From outside the cab, remove the capscrew that attaches the clearance light lens to the base.
2. Lift the lens cover at the rear with a screwdriver, and slide the cover forward off the locking tab.
3. Pull the bulb straight out to remove it.
4. To provide corrosion protection, coat the base of the new bulb with dielectric grease.

   For approved electrical terminal lubricants, see **Specifications 400**.
5. Plug in the new bulb and test for proper operation.
6. Install the lens on the base, making sure that it is fully seated.
7. Secure the clearance light in place with the capscrew.

IMPORTANT: Do not overtighten the capscrew or damage to the lens may occur.

Front Side Marker/Turn Signal Light Assembly Replacement

1. Open the hood.
2. If the harness is being replaced, cut the two tie-straps securing it at the molded splash guard.

3. Twist the marker/turn signal light connector 1/8 turn counterclockwise to disconnect the connector and harness.
4. Remove the two capscrews that attach the lens to the fender.
5. Remove the marker/turn signal light lens.
6. Using two capscrews, install a new marker/turn signal light lens on the fender.

IMPORTANT: Do not overtighten the capscrews or damage to the lens may occur.

7. Install a new harness, if required, and connect the electrical connector and bulb socket. Twist it clockwise 1/8 turn to secure.
8. If a new harness was installed, secure it to the molded plastic inner wheel well shroud using two tie-straps at the openings. Secure the tie-straps to the connector.

Front Side Marker/Turn Signal Light Bulb Replacement

1. Open the hood.
2. Twist the connector 1/8 turn counterclockwise to unplug the connector and bulb socket.
3. Pull the bulb straight out of the socket to remove it. Push a new bulb straight into the socket to replace it.
4. Insert the connector and bulbs into the lens assembly and turn 1/8 turn clockwise to secure.

Parameter Programming

When adding or changing a feature on a Business Class® M2 vehicle, you must use ServiceLink® to update the programming on the vehicle.

IMPORTANT: When adding daytime running lights (DRL) to an M2 vehicle that was built without DRL, you **must** follow the "Adding a Feature" procedure in **Section 54.00**. Adding or changing reference parameters without following this procedure may result in serious legal consequences for the vehicle owner, which may include fines and having the vehicle placed out of service. The regulations in the Federal Motor Vehicle Safety Standards (FMVSS) and Canadian Motor Vehicle Safety Standards (CMVSS) control the intensity of illumination of DRL lamps and the required marking of lamps used as DRL. Some jurisdictions enforce these regulations during vehicle inspections.

Version 6.10 Daytime Running Lights

For M2 vehicles with software version 6.10, the reference parameter programs both DRL and the stop/turn light functionality. The only DRL available for version 6.10 is turn signal DRL. Turn-signal DRL is available on all M2 chassis except the M2 106V vocational chassis.

Version 6.40 Daytime Running Lights

DRL for software versions 6.40 or higher may be turn-signal DRL or headlight low-beam DRL. Low-beam DRL is a pulse-width modulated (PWM) signal at 85 percent duty cycle. Low-beam DRL is used on the M2 106V vocational chassis. The reference parameters program only the DRL functionality.

Reference Parameters for Marker Lights

A marker light is any light that indicates the presence of the vehicle to other drivers. This includes parking lights, taillights, marker lights, identification lights, and clearance lights.

See **Table 1** for the reference parameters for marker light functionality.

Reference Parameters for Marker Lights		
Parameter	**Description**	**Functionality**
26-01019-000	Without marker interrupt switch	No marker interrupt switch, the marker lights turn on with the headlight switch.
26-01019-001	With marker interrupt switch	The marker lights turn on with the headlight switch, a momentary interrupt switch turns the marker lights off as long as the switch is held.
26-01019-003	Without marker interrupt switch, with constant on marker lights	No marker interrupt switch, the marker lights are on at all times. The battery disconnect switch is used to turn off the lights.
26-01019-004	With marker interrupt switch, marker lights on with ignition off	The marker lights are on when the ignition is off or when the headlight switch is turned on. A momentary interrupt switch turns off the marker lights when headlight switch is on.
26-01019-005	Without marker interrupt switch, with constant on marker lights	No marker interrupt switch, the marker lights are on at all times. The battery disconnect switch is used to turn off the lights.
26-01019-006	Without marker interrupt switch, marker lights off with ignition off	No marker interrupt switch, the marker lights are turned off when the ignition is turned off. The headlight switch controls the marker lights for all other conditions.

Table 1, Reference Parameters for Marker Lights

IMPORTANT: Use ServiceLink® to troubleshoot the M2 electrical system. For specific circuit and pin information for how the vehicle is wired, go to the Configuration screen in ServiceLink and select the specific function in which you are interested.

To troubleshoot specific inputs and outputs of this system, go to the Templates screen in ServiceLink and select the template for the function in which you are interested.

Headlight Switch Function

Input and Output Conditions

See **Table 1** for the Bulkhead Module (BHM) responses to the headlight switch input/output conditions.

Fault Conditions

See **Table 2** for the headlight switch circuit conditions that will create a fault. In these conditions, the BHM assumes the headlight switch status is on. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted.

If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 and/or the J1708 data links until the ignition switch is turned off.

Headlight Switch Input/Output Conditions					
Headlight Switch Inputs to BHM			Outputs from BHM		
Park Lights Signal	Headlight On 1 Signal	Headlight On 2 Signal	Headlight Switch Status	J1939 Headlight On/Off Message	J1939 Headlight Park Message
Open	Open	Open	Off	Off	Off
Closed	Open	Open	Park	Off	On
Open	Closed	Open	On	On	On
Open	Open	Closed	On	On	On
Open	Closed	Closed	On	On	On
Closed	Open	Closed	On*	On	On
Closed	Closed	Open	On*	On	On
Closed	Closed	Closed	On*	On	On

* These are error conditions. For more information see "Fault Conditions."

Table 1, Headlight Switch Input/Output Conditions

Headlight Switch Fault Conditions			
Description of Fault			Action Taken by BHM
Park Lights Signal	Headlight On 1 Signal	Headlight On 2 Signal	
Closed	Closed	Open	BHM may transmit a J1939 and/or a J1708 fault message.
Closed	Open	Closed	BHM may transmit a J1939 and/or a J1708 fault message.
Closed	Closed	Closed	BHM may transmit a J1939 and/or a J1708 fault message.

Table 2, Headlight Switch Fault Conditions

Headlight High Beams Function

Input and Output Conditions

See Table 3 for the Bulkhead Module (BHM) responses to the headlight high beams input/output conditions.

Fault Conditions

See Table 4 for the headlight high beams fault conditions and the resulting actions of the BHM. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted.

If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 and/or the J1708 data links until the ignition switch is turned off.

NOTE: The Flash-To-Pass function of the high beams only operates when the ignition is on and the high beam switch is in the low beam position.

Headlight High Beams Input/Output Conditions				
Inputs to BHM			Outputs from BHM	
Ignition Switch Position	Headlight Switch Position	High Beam Switch Position*	Left High Beam	Right High Beam†
On	On	High Beam/PASS	On	On
On	On	Low Beam	Off	Off
On	Off	High Beam/PASS	Off	Off
Off	On	High Beam/PASS	Off	Off

* Part of the multifunction turn signal switch

† Via J1939 message to the CHM

Table 3, Headlight High Beams Input/Output Conditions

Headlight High Beams Fault Conditions	
Description of Fault	Action Taken by BHM
Headlight switch is in error.	BHM will assume the headlight switch is on, and may transmit a fault message on the J1939 and/or J1708 data links.
Position of multifunction turn signal switch is unavailable or in error.	BHM will assume the multifunction turn signal switch position is low.
BHM fails to receive five consecutive J1939 multifunction turn signal switch position messages from the ICU.	BHM may transmit a J1939 and/or a J1708 fault message.
BHM receives a J1939 multifunction turn signal switch error message from the ICU.	BHM may transmit a J1939 and/or a J1708 fault message.
Left high beam wiring shorted.	BHM may transmit a J1939 and/or a J1708 fault message.
Right high beam wiring shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 4, Headlight High Beams Fault Conditions

Headlight Low Beams Function

Input and Output Conditions

See **Table 5** for the Bulkhead Module (BHM) responses to the headlight low beams input/output conditions.

Fault Conditions

See **Table 6** for the headlight low beams fault conditions and the resulting actions of the BHM. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted.

If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 and/or the J1708 data links until the ignition switch is turned off.

NOTE: If the CHM does not see J1939 messages from the BHM, the right low beam is activated. If the BHM fails, the left low beam is activated.

Headlight Low Beams Input/Output Conditions			
Inputs to BHM		Outputs from BHM	
Headlight Switch Position	High Beam Switch Position*	Left Low Beam	Right Low Beam†
On	Low Beam	On	On
On	High Beam/PASS	On	On
Off	High Beam/PASS	Off	Off

* Part of the multifunction turn signal switch

† Via J1939 message to the CHM

Table 5, Headlight Low Beams Input/Output Conditions

Headlight Low Beams Fault Conditions	
Description of Fault	Action Taken by BHM
Headlight switch is in error.	BHM will assume the headlight switch is on, and may transmit a fault message on the J1939 and/or J1708 data links.
Position of multifunction turn signal switch is unavailable or in error.	BHM will assume the multifunction turn signal switch position is low.
BHM fails to receive five consecutive J1939 multifunction turn signal switch position messages from the ICU.	BHM may transmit a J1939 and/or a J1708 fault message.
BHM receives a J1939 multifunction turn signal switch error message from the ICU.	BHM may transmit a J1939 and/or a J1708 fault message.
Left low beam wiring shorted.	BHM may transmit a J1939 and/or a J1708 fault message.
Right low beam wiring shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 6, Headlight Low Beams Fault Conditions

Turn Signal Lights Function

Input and Output Conditions

See **Table 7** for the Instrumentation Control Unit (ICU) turn signal lights input/output conditions.

See **Table 8** for the Bulkhead Module (BHM) responses to the turn signal lights system input/output conditions.

Fault Conditions

See Table 9 for the turn signal lights fault conditions and the resulting actions of the BHM. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted.

If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 and/or the J1708 data links until the ignition switch is turned off.

ICU Turn Signal Lights Input/Output Conditions		
Input to ICU	**Outputs from ICU**	
Multifunction Turn Signal Switch Position	**J1939 Right Turn Message**	**J1939 Left Turn Message**
Left Turn	Off	On
Right Turn	On	Off
Off	Off	Off

Table 7, ICU Turn Signal Lights Input/Output Conditions

Turn Signal Lights System Input/Output Conditions				
Inputs to BHM			**Outputs from BHM**	
J1939 Left Turn Message	**J1939 Right Turn Message**	**Hazard Switch Position**	**Left Turn and Stop Lights**	**Right Turn and Stop Lights**
Off	On	Off	Activated	Deactivated
On	Off	Off	Deactivated	Activated
Off	Off	On	Activated	Activated

Table 8, Turn Signal Lights System Input/Output Conditions

Turn Signal Lights Fault Conditions	
Description of Fault	**Action Taken by BHM**
Left turn switch position is unavailable or in error.	BHM will assume the J1939 left turn switch position is off.
Right turn switch position is unavailable or in error.	BHM will assume the J1939 right turn switch position is off.
Hazard switch position is unavailable or in error.	BHM will assume the hazard switch is on.
ICU sends an error indicator in the J1939 left turn switch position message.	BHM may transmit a J1939 and/or a J1708 fault message.
ICU sends an error indicator in the J1939 right turn switch position message.	BHM may transmit a J1939 and/or a J1708 fault message.
BHM fails to receive five consecutive left turn switch messages from the ICU.	BHM may transmit a J1939 and/or a J1708 fault message.
BHM fails to receive five consecutive right turn switch messages from the ICU.	BHM may transmit a J1939 and/or a J1708 fault message.
Left turn signal lights wiring shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Turn Signal Lights Fault Conditions	
Description of Fault	Action Taken by BHM
Right turn signal lights wiring shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 9, Turn Signal Lights Fault Conditions

Hazard Lights Function

Input and Output Conditions

See **Table 10** for the instrumentation control unit turn signal lights input/output conditions.

See **Table 11** for the BHM responses to the hazard lights system input/output conditions.

Fault Conditions

See **Table 12** for the hazard lights fault conditions and the resulting actions of the BHM. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted.

If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 and/or the J1708 data links until the ignition switch is turned off.

ICU Turn Signal Lights Input/Output Conditions		
Input to ICU	Outputs from ICU	
Multifunction Turn Signal Switch Position	J1939 Right-Turn Message	J1939 Left-Turn Message
Left Turn	Off	On
Right Turn	On	Off
Off	Off	Off

Table 10, ICU Turn Signal Lights Input/Output Conditions

Hazard Lights System Input/Output Conditions				
Inputs to BHM			Outputs from BHM	
Hazard Switch Position	J1939 Left Turn Message	J1939 Right Turn Message	Left-Turn and Stop Lights*	Right-Turn and Stop Lights*
Off	Off	On	Deactivated	Activated
Off	On	Off	Activated	Deactivated
On	Off	Off	Activated	Activated

* For combination stop/turn lamps. For separate stop and turn lamps, only the turn lamps will be activated.

Table 11, Hazard Lights System Input/Output Conditions

Hazard Lights Fault Conditions	
Description of Fault	Action Taken by BHM
Left turn switch position is unavailable or in error.	BHM will assume the left turn switch position is off, and may transmit a fault message on the J1939 and/or J1708 data links.

Hazard Lights Fault Conditions	
Description of Fault	**Action Taken by BHM**
Right turn switch position is unavailable or in error.	BHM will assume the right turn switch position is off, and may transmit a fault message on the J1939 and/or J1708 data links.
ICU sends a left turn switch error message to the BHM.	BHM may transmit a J1939 and/or a J1708 fault message.
ICU sends a right turn switch error message to the BHM.	BHM may transmit a J1939 and/or a J1708 fault message.
BHM fails to receive five consecutive left turn switch messages from the ICU.	BHM may transmit a J1939 and/or a J1708 fault message.
BHM fails to receive five consecutive right turn switch messages from the ICU.	BHM may transmit a J1939 and/or a J1708 fault message.
Left turn/stop lamp wiring shorted.	BHM may transmit a J1939 and/or a J1708 fault message.
Right turn/stop lamp wiring shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 12, Hazard Lights Fault Conditions

Marker Lights Function

Input and Output Conditions

See **Table 13** for the Bulkhead Module (BHM) responses to the marker lights input/output conditions. The marker interrupt switch is optional. If the vehicle does not have a marker interrupt switch, the BHM operates in the same way as if the vehicle has a marker switch that is open (off) all the time.

Fault Conditions

See **Table 14** for the marker lights fault conditions and the resulting actions of the Bulkhead Module (BHM). The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted.

If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 and/or the J1708 data links until the headlight switch is turned to off.

Marker Lights Input/Output Conditions			
Inputs to BHM		**Outputs from BHM**	
Headlight Switch	**Marker Interrupt Switch**	**Park, Marker, License Plate Lights**	**Taillights, Identification Lights**
Park	Off	Activated	Activated
Park	On	Deactivated	Deactivated
On	Off	Activated	Activated
On	On	Deactivated	Deactivated
Off	Off	Deactivated	Deactivated
Off	On	Activated	Activated

Table 13, Marker Lights Input/Output Conditions

Marker Lights Fault Conditions	
Description of Fault	**Action Taken by BHM**
Status or position of the headlight switch is in error.	BHM assumes the headlight switch is on, and may transmit a fault message on the J1939 and/or J1708 data links.
Status or position of the marker interrupt switch is unavailable or in error.	BHM assumes that the marker interrupt switch is off, and may transmit a fault message on the J1939 and/or J1708 data links.
Any marker light output wiring is shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 14, Marker Lights Fault Conditions

Fog Lights Function

Input and Output Conditions

See **Table 15** for the Bulkhead Module (BHM) responses to the fog lights input/output conditions.

Fog Lights Input/Output Conditions				
Inputs to BHM			**Outputs**	
Ignition Switch Position	**J1939 High Beam Status from ICU**	**Fog Light Switch**	**J1939 message from BHM to CHM**	**Fog Lights**
Off	Off	On	Deactivate	Off
On	On	On	Deactivate	Off
On	Off	On	Activate	On

Table 15, Fog Lights Input/Output Conditions

Snowplow Lights Provision

Input and Output Conditions

See **Table 16** for the Bulkhead (BHM) responses to the snowplow light input/output conditions.

Fault Conditions

See **Table 17** for the snowplow lights fault conditions and the resulting actions of the BHM. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted.

If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 and/or the J1708 datalinks until the ignition switch is turned off.

Effect of the Snowplow Lights Provision on Forward Lighting System Troubleshooting

Identification of faults in the forward lighting system can proceed normally when the snowplow lights provision is installed and operating correctly. However, problems with the snowplow light control modules and incorrect connections to the snowplow light harness cannot be identified through the J1939 or J1708 datalinks.

A bad snowplow light control module or improper connections can result in one or more lamps not illuminating when directed by the BHM, or in having one or more lamps driven by the incorrect signal. Other indications specifically associated with incorrect connections of the M2 106V snowplow light harness include relay chatter in one of the snowplow light control modules or a fault message indicating the park light and/or low-beam output is shorted.

Troubleshooting

Troubleshooting headlight, turn signal light, and park light operation when the snowplow light provision is present is facilitated by having snowplow lights installed; however, it is possible to do all checks with a digital multimeter to check the snowplow light connector pins instead.

Snowplow Lights Input/Output Conditions		
Inputs to BHM		Outputs from BHM
Snowplow Lights Signal	Headlight Switch Position	Snowplow Lights J1939 Message
Open	On	Off
Closed	On	On
Open	Off	Off
Closed	Off	Off

Table 16, Snowplow Lights Input/Output Conditions

Snowplow Lights Fault Conditions	
Description of Fault	Action Taken by BHM
Snowplow light switch is in error.	BHM will assume the snowplow light switch is off, and may transmit a fault message on the J1939 and/or J1708 datalinks.
Headlight switch is in error.	BHM will assume the headlight switch is on, and may transit a fault message on the J1939 and /or J1708 datalinks.

Table 17, Snowplow Lights Fault Conditions

Approved Electrical Lubricants	
Manufacturer	**Lubricant**
Standard Oil Co.	White Vaseline
Shell Oil Co.	No. 71032; No. 71306
Texaco, Inc.	No. 955
Quaker State	No. NYK-77

Table 1, Approved Electrical Lubricants

Replacement Bulb Part Numbers		
Description	**Part Number**	**Amps**
Composite Headlight, Low Beam	9006	4.30
Composite Headlight, High Beam	9005	5.08
Front Park/Turn Signal Light	3157	2.23
Clearance and Identification Lights	193	0.33 (14.0 design volts)
Front Side Marker/Turn Signal Light	194	0.27 (14.0 design volts)

Table 2, Replacement Bulb Part Numbers

Wiring Diagrams

IMPORTANT: The following wiring diagrams provide circuit details for the forward lighting electrical system of a typical Business Class® M2 vehicle. These details may not correspond to every vehicle.

See **Fig. 1** for wiring details of the control inputs for a typical M2 vehicle forward exterior lighting system.

See **Fig. 2** for wiring details of the control outputs for a typical M2 vehicle forward exterior lighting system.

See **Fig. 3** for a wiring diagram of the optional fog lights.

See **Fig. 4** for a wiring diagram of the optional snowplow lights provision.

Circuit Identification

See **Table 3** for a connector face view and pinout chart of the headlight connectors on the forward chassis harness for all models except the M2 106V.

See **Table 4** for a connector face view and pinout chart of the headlight connectors on the forward chassis harness for the M2 106V model only.

See **Table 5** for a connector face view and pinout chart of the park/turn signal light connectors on the forward chassis harness.

See **Table 6** for a connector face view and pinout chart of the side marker/turn signal light connectors on the forward chassis harness.

See **Table 7** for a connector face view and pinout chart of the snowplow light connectors on the snowplow light harness.

Specifications

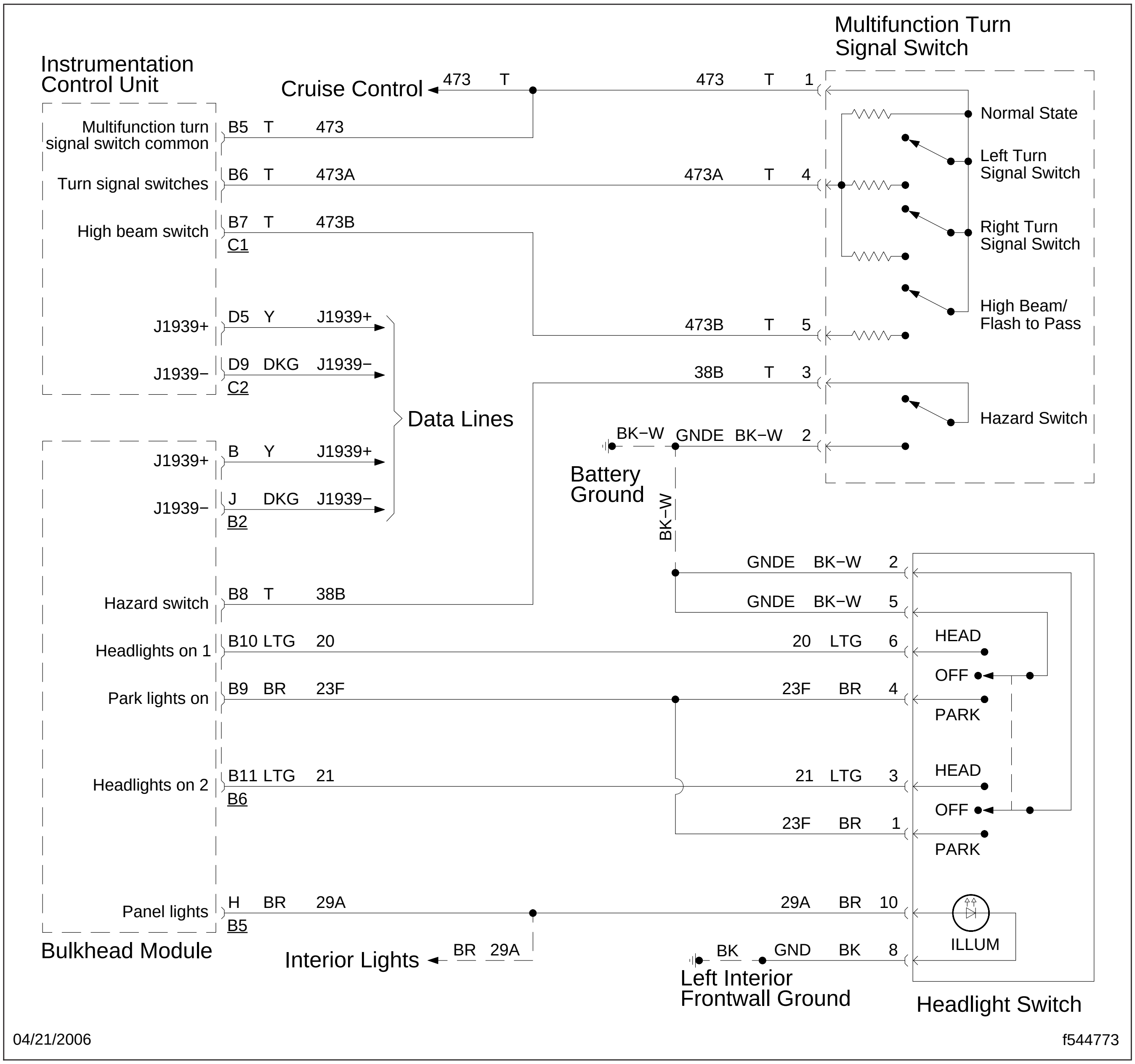


Fig. 1, Forward Exterior Lighting Inputs

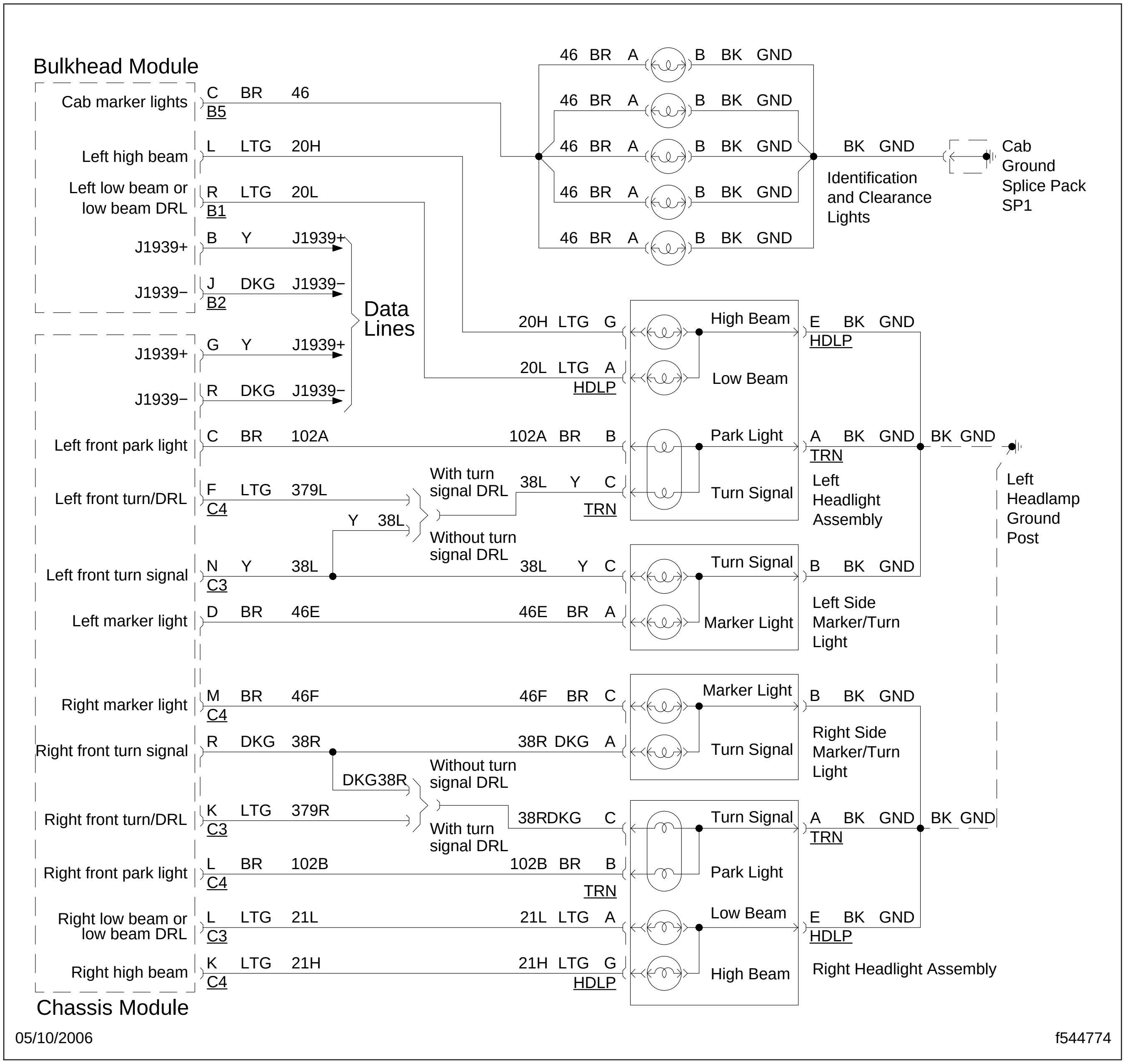


Fig. 2, Forward Exterior Lighting Outputs

Specifications

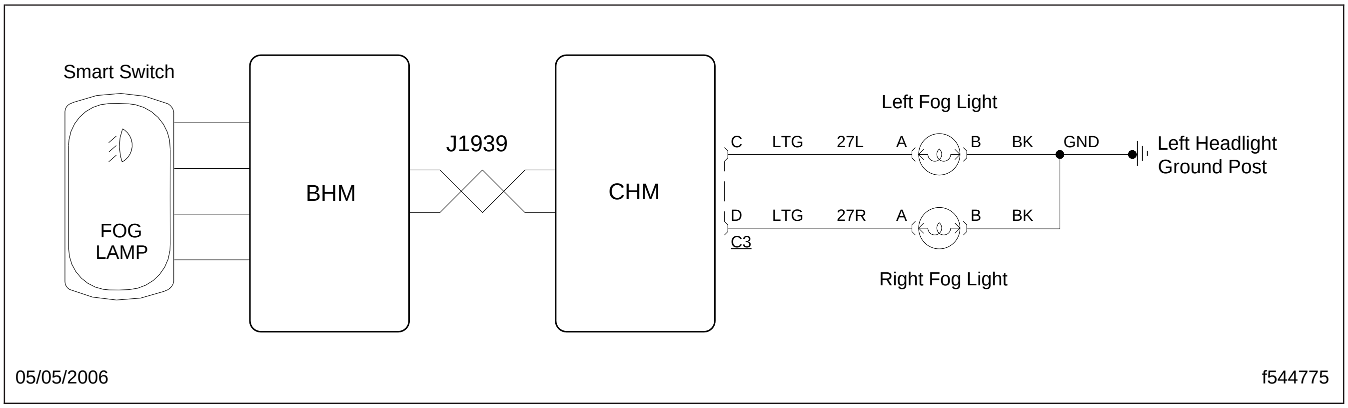


Fig. 3, Fog Lights Wiring Diagram

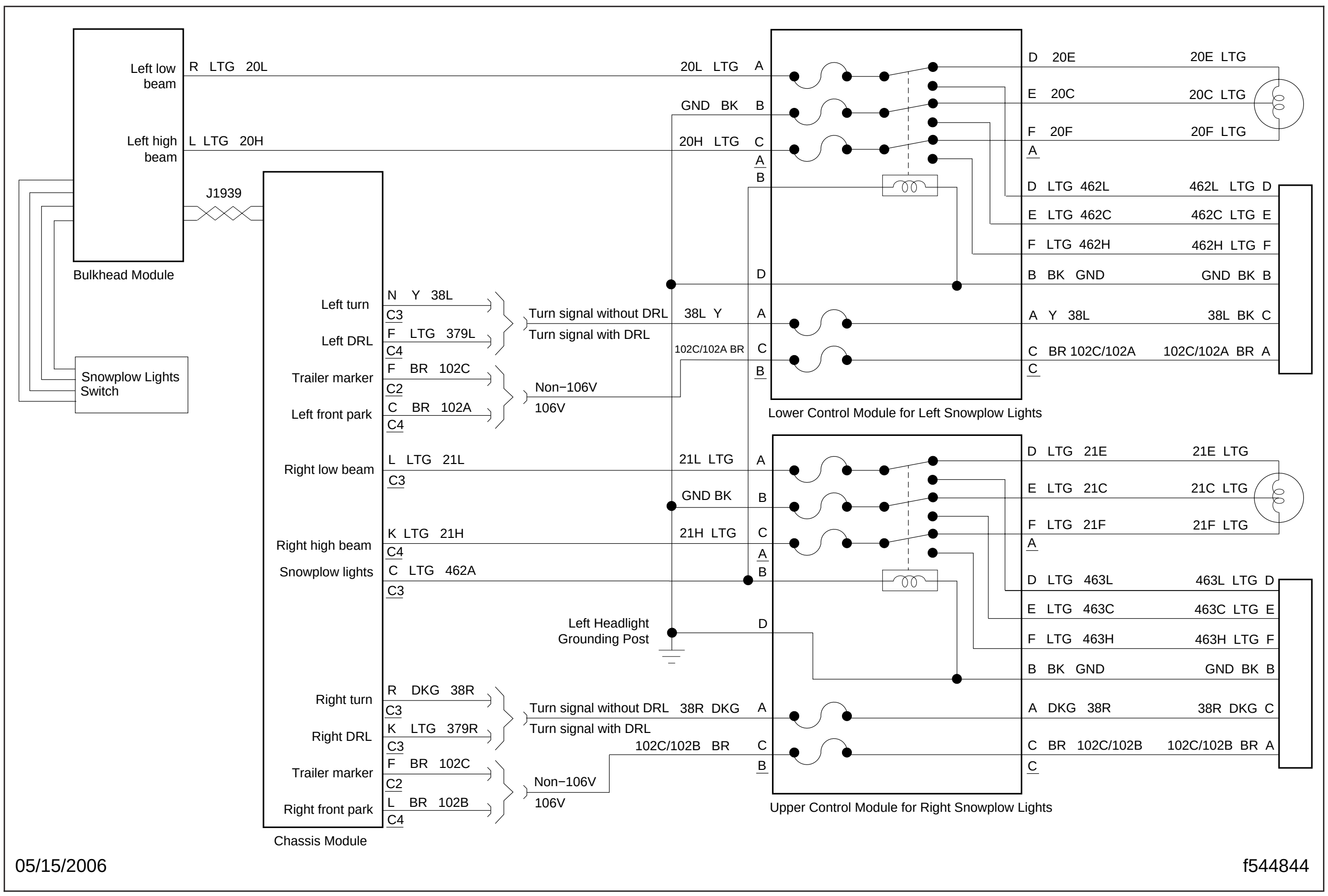


Fig. 4, Snowplow Lights Provision Wiring Diagram

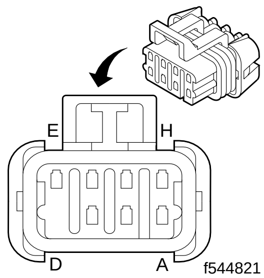
Forward Chassis Harness Headlight Connectors (all models except M2 106V)					
Connector Pin	Signal Name	Left Headlight		Right Headlight	
		Circuit Number	Circuit Color	Circuit Number	Circuit Color
 f544821					
A	Low Beam	20L	LTG	21L	LTG
B	—	—	—	—	—
C	—	—	—	—	—
D	—	—	—	—	—
E	Ground	GND	BK	GND	BK
F	—	—	—	—	—
G	High Beam	20H	LTG	21H	LTG
H	—	—	—	—	—

Table 3, Forward Chassis Harness Headlight Connectors (all models except M2 106V)

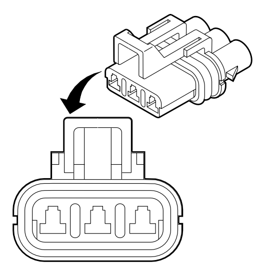
Forward Chassis Harness Headlight Connectors (M2 106V only)					
Connector Pin	Signal Name	Left Headlight		Right Headlight	
		Circuit Number	Circuit Color	Circuit Number	Circuit Color
 f544845					
A	Low Beam	20L	LTG	21L	LTG
B	Ground	GND	BK	GND	BK
C	High Beam	20H	LTG	21H	LTG

Table 4, Forward Chassis Harness Headlight Connectors (M2 106V only)

Specifications

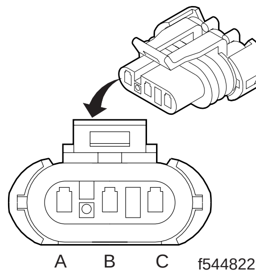
Forward Chassis Harness Park/Turn Signal Light Connectors					
Connector Pin	Signal Name	Left Park/Turn Signal Light		Right Park/Turn Signal Light	
		Circuit Number	Circuit Color	Circuit Number	Circuit Color
					
A	Ground	GND	BK	GND	BK
B	Park Light	102A	BR	102B	BR
C	Turn Signal	38L	Y	38R	DKG

Table 5, Forward Chassis Harness Park/Turn Signal Light Connectors

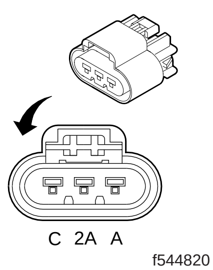
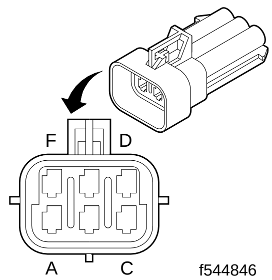
Forward Chassis Harness Side Marker/Turn Signal Light Connectors					
Connector Pin	Signal Name	Left Side Marker/Turn Signal Light		Right Side Marker/Turn Signal Light	
		Circuit Number	Circuit Color	Circuit Number	Circuit Color
					
A	Marker Light	46E	BR	46F	BR
B	Ground	GND	BK	GND	BK
C	Turn Signal	38L	Y	38R	DKG

Table 6, Forward Chassis Harness Side Marker/Turn Signal Light Connectors

Snowplow Light Connectors					
Connector Pin	Signal Name	Left Side Connector		Right Side Connector	
		Circuit Number	Circuit Color	Circuit Number	Circuit Color
					
A	Park Light	102C/102A*	BR	102C/102B*	BR
B	Ground	GND	BK	GND	BK
C	Turn Signal	38L	Y	38R	DKG
D	Auxiliary Low Beam	462L	LTG	463L	LTG
E	Auxiliary Headlight Ground	462C	LTG	463C	LTG
F	Auxiliary High Beam	462H	LTG	463H	LTG

* 102A and 102B are for model M2 106V only. 102C is for all other models.

Table 7, Snowplow Light Connectors

Rear Lighting

Typical rear lighting on a Business Class® M2 vehicle includes:

- stop lights
- turn signal lights
- license plate light
- backup light(s)
- taillights/park lights

All rear-lighting outputs come from the Chassis Module (CHM) via connector C1. The taillights and license lights are directly supplied by the Bulkhead Module (BHM) via a CHM pass-through; the same output controls the cab clearance and identification lights and the front park lights. See **Section 54.27** for more information on forward lighting.

All other rear lights are controlled by the CHM. An aft chassis harness normally connects at CHM connector C1 and routes the rear-lighting circuits along the frame rail toward the rear of the vehicle.

On an M2 vehicle there are two electrical designs for the stop and turn signal lights:

- combination stop/turn signal lights
- separate stop/turn signal lights

Combination Stop/Turn Signal Lights

Combination stop/turn signal lights use a single high-intensity filament of a taillight bulb for stop illumination and turn signal light indication. The CHM controls the high-intensity filament with a single output, making the output a combination of stop and turn signal lights functions.

When a vehicle is programmed for combination stop/turn signals, the circuit function operates so that the brake lights are overridden when the hazard lights and/or turn signal lights are on.

Factory-installed rear lights are only provided if a vehicle is ordered with combination stop/turn signal lights; however, the lights can be omitted by requesting a wiring-only provision. Rear lights are either integral taillights or individual light connections.

Integral taillights are enclosed lighting assemblies that contain all the rear lights and lighting circuitry.

The integral taillights mount on brackets at the rear of each frame rail. Positioning of the brackets can allow for taillight mounting inside the frame rail, outside the frame rail, or below the frame rail.

The aft chassis harness connects directly to the left integral taillight via a 5-pin connector. Inside the left taillight, circuits are wired to the individual bulbs, and circuits for the right taillight are wired to a second 5-pin connector on the left taillight housing. A taillight jumper harness that routes along the rear crossmember connects the left taillight to the right taillight and transfers the necessary right lighting signals. See **Fig. 1**.

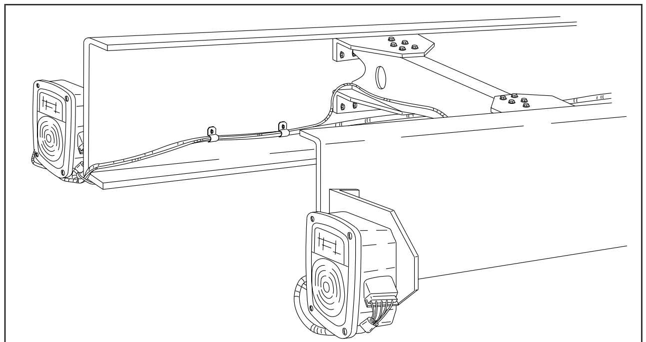


Fig. 1, Integral Taillights

Individual rear lights are usually mounted along the rear-closing crossmember. A rear-lighting harness connects to the 5-pin aft chassis connector. The rear-lighting harness routes circuits to all the individual rear-light connections. Some common harness configurations for individual rear lights are:

- rear lights with a center backup and license lights
- rear lights with dual backup lights
- rear lights that utilize the taillight jumper

Separate Stop/Turn Signal Lights

A vehicle may be ordered or reprogrammed for separate stop/turn signal light functionality. An M2 vehicle ordered with separate stop/turn signal light functionality is equipped with only a rear-lighting electrical harness; no rear lights are provided.

Separate stop/turn signal light functionality provides for individual stop and turn signal lights by programming the vehicle to use stop-only outputs and turn-signal-light-only outputs from the CHM. Each output is to feed the high-intensity filament of an individual rear light.

The harness that is included with separate stop/turn signal light programming connects to CHM connector C1 and routes along the frame rail toward the rear of the vehicle. The harness terminates with a sealed 7-pin connector that contains the rear-lighting outputs for customer adaptation.

Stop Lights

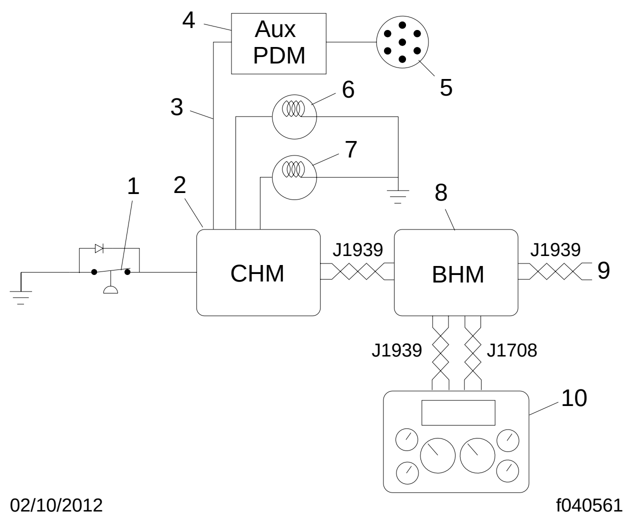
The M2 multiplexing system activates the stop lights when the service brake switch input on the CHM is grounded. The system also sends a J1939 cruise control/vehicle speed (CC/VS) message indicating that the driver is depressing the service brake. The CHM service brake switch input is connected to a switch or relay that is located in the service brake system.

When the service brake switch grounds the CHM input, the CHM immediately supplies power to the brake lights. This is a fail-safe feature that allows the stop lights to function even if the BHM or CHM microprocessors fail.

On a vehicle equipped with trailer electrical connections, the service brake switch also provides a fail-safe ground to the trailer stop light relay via a circuit board trace in the CHM.

With the service brake switch input grounded, the CHM sends a J1939 message to the BHM indicating that the stop lights are activated. If the BHM is not awake when this message is sent, the message wakes up the BHM. After receiving the CHM message, the BHM takes over the operation of the stop lights. The BHM communicates that the driver is depressing the service brake by broadcasting a service brake status message (part of the CC/VS message) over the J1939 datalink for other ECUs to use.

On AAVA vehicles, the stop light pressure switch is located in the application air line, in the center of the dash. On air management unit (AMU) vehicles, the stop light switch is integral to the AMU pressure switch "A." When the service brake is depressed, air pressure is applied at pressure switch "A." The stop light switch closes between 2 and 5 psi (13 and 34 kPa). See Fig. 2.

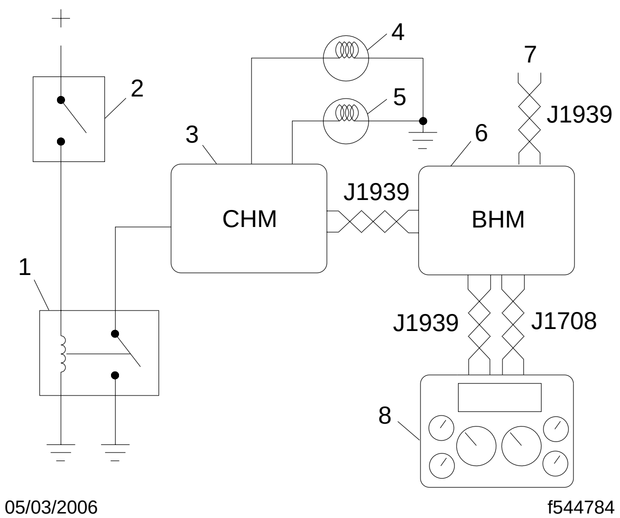


1. Stop Light Pressure Switch
2. Chassis Module
3. Trailer Stop Light Relay Signal
4. Auxiliary Power Distribution Module
5. 7-Way Trailer Receptacle
6. Right Stop Light
7. Left Stop Light
8. Bulkhead Module
9. General Datalink Broadcast
10. Instrumentation Control Unit

Fig. 2, Air Brakes Stop Lights Function

On vehicles equipped with hydraulic brakes, the service brake switch input on the CHM is connected to a relay instead of a switch. The relay is controlled by a switch that is mounted to the service brake arm. The stop light relay is mounted in the dash above the base of the steering column. Depressing the service brake closes the stop light switch. The closed stop light switch passes power from a battery-power dash splice pack to the coil of the stop light relay. The relay energizes and supplies a ground signal to the CHM service brake switch input through the closed contacts of the relay. See Fig. 3.

For combination and separate stop/turn signal light functionality, the CHM delivers the stop light outputs from pins L and N of CHM connector C1. With combination stop/turn signal lights, the factory-installed lighting draws 2.1 amps of current, leaving 5.35 amps available for additional lights. With separate stop/turn signal lights, the outputs at pin L and N are



1. Stop Light Relay
2. Stop Light Switch
3. Chassis Module
4. Right Stop Light
5. Left Stop Light
6. Bulkhead Module
7. General Datalink Broadcast
8. Instrumentation Control Unit

Fig. 3, Hydraulic Brakes Stop Lights Function

stop-only signals. Since no rear lighting is installed for separate stop/turn signal light functionality, 7.45 amps is available for the left and right stop-only outputs.

The BHM is capable of detecting short circuits in the stop light wiring to the CHM. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink®.

Backup Lights

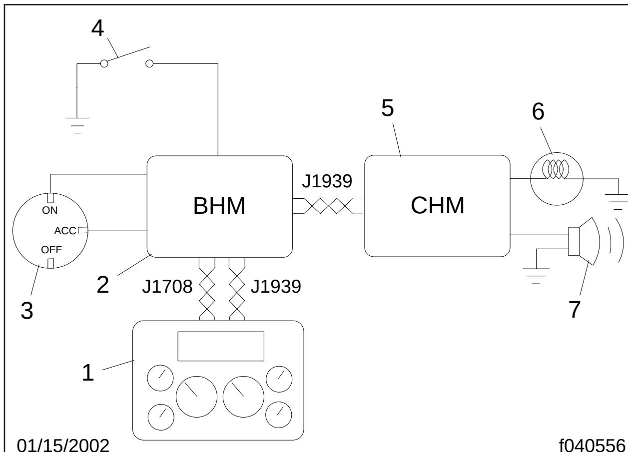
The backup function provides a visual and optional audio warning to anyone standing behind a vehicle that is backing up. When the transmission is placed into reverse gear, the BHM sends a J1939 message to the CHM activating the backup light(s) and optional audible backup alarm. The backup lights and optional audible backup alarm receive power from a single CHM electronic driver, but connect at three different pins on the CHM connector C1. The maximum combined current capacity for all three pins is 7.45A. See **Table 1**.

CHM Backup Lights Outputs	
Circuit Description	**Pin Location On CHM Connector C1**
Left Backup Light	A
Backup Alarm	H
Right Backup Light	J

Table 1, CHM Backup Lights Outputs

The BHM is capable of detecting short circuits in the backup lights/alarm wiring on the CHM. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink.

A vehicle with a manual transmission activates the backup lights/alarm differently than a vehicle with either an automatic or automated mechanical (AMT) transmission. A manual transmission uses a standard backup switch to tell the BHM when the transmission is in reverse. See **Fig. 4**.



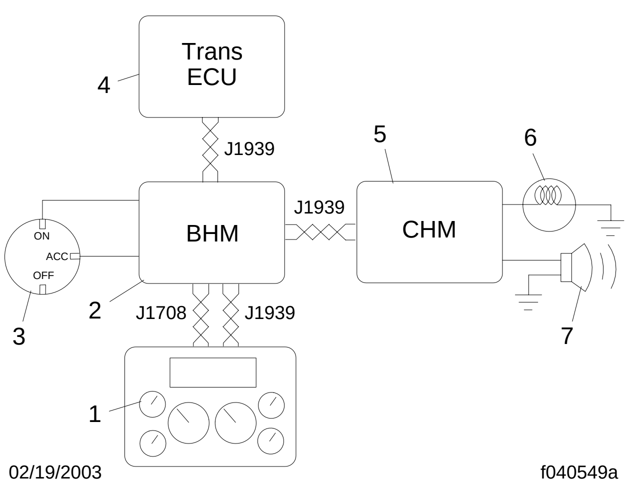
1. Instrumentation Control Unit
2. Bulkhead Module
3. Ignition Switch
4. Backup Switch
5. Chassis Module
6. Backup Lights
7. Optional Backup Alarm

Fig. 4, Backup Lights Function on a Vehicle With Manual Transmission

An automatic or AMT transmission sends a J1939 message to the BHM when the transmission is placed into reverse gear. See **Fig. 5**.

See **Table 2** for BHM backup function according to the type of transmission.

General Information



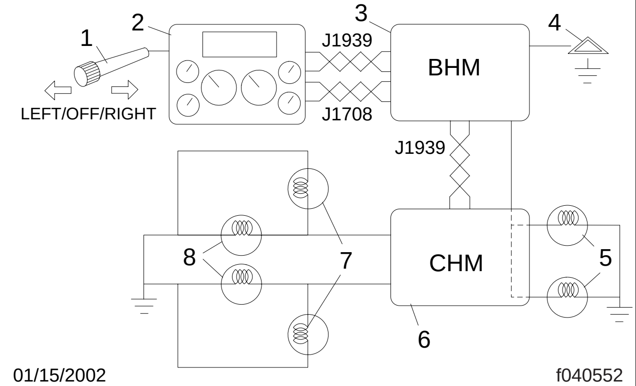
1. Instrumentation Control Unit
2. Bulkhead Module
3. Ignition Switch
4. Transmission ECU
5. Chassis Module
6. Backup Lights
7. Optional Backup Alarm

Fig. 5, Backup Lights Function on a Vehicle With Automatic or AMT Transmission

Turn Signal Lights

The BHM uses J1939 message inputs from the instrumentation control unit (ICU) to instruct the CHM to activate the turn signal lights. The ICU monitors the position of the multifunction turn signal switch. When the ICU senses that the driver has activated this switch, it sends a J1939 message to the BHM. The BHM then checks whether the hazard switch has been activated. If the hazard switch has not been activated, the BHM sends a J1939 message to the CHM instructing it to illuminate the turn signal lights. See **Fig. 6**.

The CHM operates the rear turn signal lights by pulsing the power to the taillights. With combination stop/turn signal lights, the CHM delivers power for the turn signal lights on the same outputs (pins L and N of CHM connector C1) as used for the the stop lights. The turn signal lights take priority over the stop lights. If a vehicle is braking while the multifunction turn signal switch is in a turn position, the appropriate stop/turn signal light pulses for turn signal lights while the opposing stop/turn signal light illuminates for braking.



1. Multifunction Turn Signal Switch
2. Instrumentation Control Unit
3. Bulkhead Module
4. Hazard Switch
5. Rear Turn Signal Lights
6. Chassis Module
7. Side Turn Signal Lights
8. Front Turn Signal Lights

Fig. 6, Turn Signal Lights Function

With separate stop/turn signal lights, the power for the stop lights is provided at pins L and N of CHM connector C1. The power for the separate turn signal lights is now provided at pins P and G of CHM connector C1.

With combination stop/turn signal lights, the factory-installed lighting draws 2.1 amps of current, leaving 5.35 amps available for additional lights. With separate stop/turn signal lights, the outputs at pins P and G are connected with several other possible turn signal light outputs, such as:

- front turn signal lights
- side turn signal lights
- trailer turn signal lights (if equipped)

The total current draw for all combined turn signal lighting can reach 4.1 amps. If a vehicle is not equipped with a high-current lighting interface option, this leaves only 3.35 amps for any additional turn signal lighting. Without the high-current lighting option, LED lights are recommended for any additional turn signal lights.

The BHM is capable of detecting short circuits in the turn signal wiring. Faults discovered by the BHM may be reported on the J1939 and/or J1708 data links and may be viewed through ServiceLink.

Turn Signal Daytime Running Lights

M2 chassis can be programmed to use the front turn signal lights as daytime running lights (DRL). The reference parameter used for programming the functionality of the rear stop/turn signal lights (combination or separate) also programs the DRL function of the front turn signal lights for chassis with BHM software version 6.10. See **Subject 120** for stop/turn signal light and turn DRL reference parameters and descriptions.

Hazard Lights

The operation, description, and function of the hazard lights are covered in "Forward Lighting Systems," **Section 54.27**.

Marker Lights

The operation, description, and function of the marker lights and taillights are covered in "Forward Lighting Systems," **Section 54.27**.

Backup Lights Function		
Transmission Type	**Input to BHM**	**BHM Conclusion**
Manual Transmission	Backup switch is closed.	Transmission is in reverse.
Automatic or AMT Transmissions	J1939 message from transmission indicates either: • Current Gear = Reverse • Selected Gear = Reverse • Gear Range = R	Transmission is in reverse.

Table 2, Backup Lights Function

Before working on the vehicle, park it on a level surface and shut down the engine. Set the parking brake and chock the front and rear tires.

Stop Light and Taillight Assembly Replacement

1. Disconnect the negative leads from the batteries or, if the vehicle is equipped with a battery disconnect switch, turn the switch to the off position.
2. Disconnect the electrical connectors to the taillight assembly.

NOTE: There are two connectors on the left taillight assembly and one connector on the right taillight assembly.

3. Remove the three nuts that attach the taillight assembly to the mounting bracket and remove the taillight assembly from the mounting bracket.
4. If the new taillight assembly did not come supplied with bulbs, follow the steps in "Stop Light and Taillight Bulb Replacement."
5. Place a new taillight assembly on the mounting bracket and secure the three nuts.
6. Connect the connectors.
7. Connect the negative leads to the batteries or, if the vehicle is equipped with a battery disconnect switch, turn the switch to the on position.
8. Verify the proper operation of the lights.
9. Remove the chocks from the tires.

Stop Light and Taillight Bulb Replacement

1. Remove the four capscrews that attach the lens to the housing.
2. Press the bulb in and turn it counterclockwise to release it from the socket.
3. To provide corrosion protection, coat the base of the new bulb with dielectric grease. For approved electrical terminal lubricants, see the applicable table in **Specifications 400**.
4. Install the new bulb, pressing and turning 1/8 turn clockwise to lock it. Test the bulb for proper operation.
5. Install the lens on the housing. Fasten it in place with capscrews.

IMPORTANT: Do not overtighten the capscrews or damage to the lens may occur.

6. Remove the chocks from the tires.

Separate Stop/Turn Signal Lights Conversion

The default rear lighting configuration for a Business Class® M2 vehicle is combination stop/turn signal lights. Combination stop/turn signal lights use the same bulb filament for stop light and turn signal light illumination.

ServiceLink® is required for conversion of combination stop/turn signal lights to separate stop/turn signal lights, and for conversion of separate stop/turn signal lights to combination stop/turn signal lights.

In a combination stop/turn signal lights to separate stop/turn signal lights conversion, the two existing Chassis Module (CHM) outputs for the combination stop/turn signal lights will become the stop light outputs. Two other outputs on the CHM will provide the signal for the new turn signal lights. The new turn signal light outputs will need circuits routed to the rear turn signal lights.

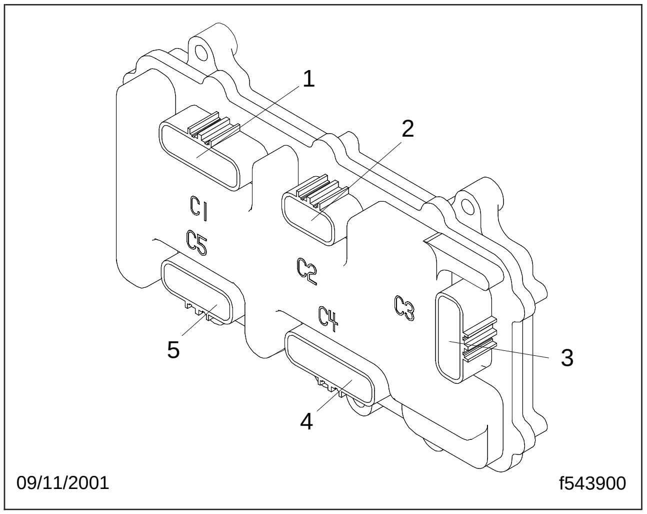


Fig. 1, Chassis Module Connector Identification

Converting Combination to Separate Stop/Turn Signal Lights

1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Gather the necessary parts:
   - 2 Packard GT280 female terminals (15304717, 15304720, or equivalent for 16/14 AWG)
   - 2 Packard GT280 cable seals (15366067 or equivalent)
   - Appropriate wiring for connecting additional lighting
3. Disconnect the negative leads from the batteries or, if the vehicle is equipped with a battery disconnect switch, turn the switch to the off position.
4. Cut new wires to the required length to reach the left- and right-rear turn signal lights. Be sure to have enough length for routing the wires and installing cable terminals.
5. Crimp a terminal and terminal seal to one end of each of the wires.
6. Locate and disconnect connector C1 of the CHM. See **Fig. 1**.
7. Remove the seals from cavities G and P of CHM connector C1.
8. Install the wire for the left turn signal light into cavity G. Make sure the terminal is fully seated.
9. Install the wire for the right turn signal light into cavity P. Make sure the terminal is fully seated.
10. Route the new turn signal light wires to the rear of the truck. Use a split loom to protect the wires and tie-strap the loom to the existing harness where appropriate.
11. Connect wires to the rear turn signal lights.
12. Connect the negative leads to the batteries or, if the vehicle is equipped with a battery disconnect switch, turn the switch to the on position.

IMPORTANT: When converting a vehicle from combination stop/turn signal lights to separate stop/turn signal lights, you must follow the conversion information in **Table 1** exactly. Using a different reference parameter may result in incorrect operation of either the rear lights or daytime running lights (DRL) and may have legal consequences for the vehicle owner, which may include fines and having vehicles placed out of service. The regulations in the Federal Motor Vehicle Safety Standards (FMVSS) and Canadian Motor Vehicle Safety Standards (CMVSS) control rear lighting and DRL functionality. Some jurisdictions enforce these regulations during vehicle inspections.

13. Using ServiceLink, apply the appropriate reference parameter to the vehicle. See **Table 1**.

Separate Stop/Turn Signal Lights Conversion

14. Verify the proper operation of the lights.
15. Remove the chocks from the tires.

Converting Separate to Combination Stop/Turn Signal Lights

1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Locate the existing turn signal wires where they terminate at the rear turn signal lights.
   - 2.1 Cut the wires.
   - 2.2 Apply heat shrink to the chassis side of the wires to seal the wire.
   - 2.3 Tuck the wires in to the harness loom.
3. Locate the existing stop light wires where they terminate at the stop lights.
   - 3.1 Route the wires as needed to the new combination stop/turn signal lights.
   - 3.2 Use convoluted tubing to protect the wires, and use tie-straps to secure the wires to the existing harness.

   NOTE: If the total current draw for the combination stop/turn signal light circuit on either side will exceed 6.7 amps, install relays.

IMPORTANT: When converting a vehicle from separate stop/turn signal lights to combination stop/turn signal lights, you must follow the conversion information in **Table 2** exactly. Using a different reference parameter may result in incorrect operation of either the rear lights or daytime running lights (DRL) and may have legal consequences for the vehicle owner, which may include fines and having vehicles placed out of service. The regulations in the Federal Motor Vehicle Safety Standards (FMVSS) and Canadian Motor Vehicle Safety Standards (CMVSS) control rear lighting and DRL functionality. Some jurisdictions enforce these regulations during vehicle inspections.

4. Using ServiceLink, apply the appropriate reference parameter to the vehicle. See **Table 2**.
5. Verify the correct operation of the lighting.
6. Remove the chocks from the tires.

Reference Parameters for a Conversion from Combination to Separate Stop/Turn Signal Lights	
Existing Parameter	**New Parameter**
26-01020-000 or 26-01020-010	26-01020-004 or 26-01020-009
26-01020-001	26-01020-003
26-01020-006	26-01020-007
26-01020-012	26-01020-013

Table 1, Reference Parameters for a Conversion from Combination to Separate Stop/Turn Signal Lights

Reference Parameters for a Conversion from Separate to Combination Stop/Turn Signal Lights	
Existing Parameter	**New Parameter**
26-01020-004 or 26-01020-009	26-01020-000 or 26-01020-010
26-01020-003	26-01020-001
26-01020-007	26-01020-006
26-01020-013	26-01020-012
26-01020-015	26-01020-014

Table 2, Reference Parameters for a Conversion from Separate to Combination Stop/Turn Signal Lights

Parameter Programming

When adding or changing a feature on a Business Class® M2 vehicle, you must use ServiceLink® to update the programming on the vehicle.

IMPORTANT: When converting a vehicle from combination stop/turn signal lights to separate stop/turn signal lights, or from separate stop/turn signal lights to combination stop/turn signal lights, you must follow the conversion information in **Subject 110** exactly. Using a different reference parameter may result in incorrect operation of either the rear lights or daytime running lights (DRL) and may have legal consequences for the vehicle owner, which may include fines and having vehicles placed out of service. The regulations in the Federal Motor Vehicle Safety Standards (FMVSS) and Canadian Motor Vehicle Safety Standards (CMVSS) control rear lighting and DRL functionality. Some jurisdictions enforce these regulations during vehicle inspections.

See **Table 1** for stop/turn signal light reference parameters. The turn signals of a vehicle may be programmed to provide DRL.

Stop/Turn Signal Light Reference Parameters	
Parameter	**Description**
26-01020-000	Combination stop/turn signal
26-01020-001	Combination stop/turn signal with DRL
26-01020-002	Combination stop/turn signal
26-01020-003	Separate stop/turn signal with DRL
26-01020-004	Separate stop/turn signal
26-01020-006	Combination stop/turn signal with DRL
26-01020-007	Separate stop/turn signal with DRL
26-01020-009	Separate stop/turn signal
26-01020-010	Combination stop/turn signal
26-01020-011	Combination stop/turn signal
26-01020-012	Combination stop/turn signal with DRL
26-01020-013	Separate stop/turn signal with DRL
26-01020-014	Combination stop
26-01020-015	Separate stop
26-01020-018	Combination stop/turn signal with DRL, front side marker and taillight on with DRL

Table 1, Stop/Turn Signal Light Reference Parameters

IMPORTANT: The following is a general description of how the rear lighting electrical system of a Business Class® M2 vehicle works. ServiceLink® is the diagnostic tool for troubleshooting the M2 electrical system. For specific circuit and pin information on how the vehicle is wired, go to the Configuration screen in ServiceLink and select the specific function in which you are interested. To troubleshoot specific inputs and outputs of this system, go to the Templates screen in ServiceLink and select the template for the function in which you are interested.

Turn Signal Lights

Input/output conditions and fault conditions for turn signal lights are covered in "Forward Lighting Systems," Section 54.27. For troubleshooting procedures, see **Section 54.27, Subject 300**.

Hazard Lights

Input/output conditions and fault conditions for hazard lights are covered in "Forward Lighting Systems," Section 54.27. For troubleshooting procedures, see **Section 54.27, Subject 300**.

Marker Lights

Input/output conditions and fault conditions for marker lights are covered in "Forward Lighting Systems," Section 54.27. For troubleshooting procedures, see **Section 54.27, Subject 300**.

Stop Lights

Input and Output Conditions

See **Table 1** for the Bulkhead Module (BHM) responses to the stop lights input/output conditions.

The service brake switch directly controls the trailer stop light relay. The stop light switch input pin is connected with a circuit board trace directly to the trailer stop light relay pin in the Chassis Module (CHM).

Fault Conditions

See **Table 2** for the stop lights fault conditions that create faults. The reference parameters that program the BHM determine whether a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 and/or the J1708 datalinks until the service brake switch is open.

Diagnostics for a Vehicle With Air Brakes

On air management unit (AMU) vehicles, pressure switch module "A" of the AMU contains internal pressure switches to monitor various functions. The internal pressure switches for part number 12-18205-XXX have a diode wired in parallel with each switch. Internal pressure switches for part number A12-19776-XXX do not have diodes in parallel with the switch.

One of the pressure switches of module "A" is the stop light switch. The stop light switch monitors pressure in the service brake system. Its main purpose is to control the stop lights. This switch closes at approximately 3.5 ±1.5 psi (24 ±10 kPa). See **Table 3** for testing of the stop light switch.

On auxiliary air valve assembly (AAVA) vehicles, there are two service brake pressure switches located in the center of the dash.

Stop Lights Input/Output Conditions			
Input to BHM from CHM	Outputs from BHM		
Service Brake Switch	J1939 Service Brake Message	Left Stop Light	Right Stop Light
Closed	Depressed	Activated	Activated
Open	Released	Deactivated	Deactivated

Table 1, Stop Lights Input/Output Conditions

Troubleshooting

Stop Lights Fault Conditions	
Description of Fault	**Action Taken by BHM**
Left stop light wiring is shorted.	BHM may transmit a J1939 and/or a J1708 fault message.
Right stop light wiring is shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 2, Stop Lights Fault Conditions

Stop Lights Switch Tests for a Vehicle With Air Brakes NOTE: If any test fails, the Pressure Switch Module A is defective and must be replaced.				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Stop Light Ground Circuit	Key off, engine off. Battery disconnected. Pressure switch "A" 6-way connector disconnected.	Resistance Check: Measured between pin D (harness side) and the negative battery terminal.	Less than 1 ohm.	Check ground circuit wiring.
Stop Light Switch Diode Applies to part number 12-18205-XXX. For all other part numbers, skip this test.	Key off, engine off. Drain air tanks. Pressure switch "A" 6-way connector disconnected.	Resistance Check (or diode test if meter is capable): Measured between pin C and D (switch side). Then reverse test leads and check again.	With the leads connected one way, the meter should read resistance (value not important). When the leads are reversed, the reading should be infinite or OL. NOTE: If the result is 0 ohms both ways, either the diode is shorted or the pressure switch is stuck closed. If the result was OL both ways, the diode is open.	Faulty Pressure Switch "A."

Stop Lights Switch Tests for a Vehicle With Air Brakes				
NOTE: If any test fails, the Pressure Switch Module A is defective and must be replaced.				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Stop Light Switch	Key off, engine off. Pressure switch "A" 6-way connector disconnected. Drain air tanks. Disconnect one of the APP ports on the face of the module and connect a regulated air supply setup to the port. Using the setup, close Valve "A" and Valve "B." Back the regulator screw off so that the downstream pressure is zero. Connect shop air to the test apparatus. Open Valve "A." Apply 10 psi (69 kPa) to the APP port by adjusting the pressure regulator. This should cause the stop light pressure switch to close.	Resistance Check: Measured between pins C and D (switch side). Then reverse test leads and check again.	Less than 1 ohm (test leads both ways). NOTE: If the resistance is more than 1 ohm either way, then the stop light switch is not closing between 2 and 5 psi (13 and 34 kPa).	Faulty Pressure Switch "A."

Table 3, Stop Lights Switch Tests for a Vehicle With Air Brakes

Backup Lights

Input and Output Conditions

See **Table 4** for the BHM responses to the backup lights input/output conditions.

Backup Lights Input/Output Conditions		
Inputs to BHM		**Output from BHM**
Ignition Switch	**Transmission Status**	**Backup Lights/Alarm***
On/Acc	Reverse	On
On/Acc	Not Reverse	Off
Off	Reverse	Off
Off	Not Reverse	Off

* Via J1939 message to the CHM

Table 4, Backup Lights Input/Output Conditions

Fault Conditions

See **Table 5** for the backup lights system conditions that will create a fault. The reference parameters that program the BHM determine whether a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 and/or the J1708 datalinks until the ignition switch is turned off.

On a vehicle with an automatic transmission, the BHM has **additional** J1939 fault messages that may be broadcast. Any J1939 fault message may be transmitted until the ignition switch is turned off. See **Table 6**.

Troubleshooting

Backup Lights System Fault Conditions	
Description of Fault	**Action Taken by BHM**
Ignition switch status is in error.	BHM will assume the ignition switch is in the on position and may transmit a fault message on the J1939 and/or J1708 datalinks.
Backup lights/alarm wiring shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 5, Backup Lights System Fault Conditions

Backup Lights System Fault Conditions for a Vehicle With an Automatic Transmission or Automated Mechanical Transmission (AMT)	
Description of Fault	**Action Taken by BHM**
BHM fails to receive five consecutive J1939 messages from the transmission ECU.	BHM may transmit a J1939 fault message and assume the transmission is in reverse.
Transmission ECU sends an error indicator in the J1939 message to the BHM.	BHM may transmit a J1939 fault message and assume the transmission is in reverse.

Table 6, Backup Lights System Fault Conditions for a Vehicle With an Automatic Transmission or Automated Mechanical Transmission (AMT)

Approved Electrical Lubricants	
Manufacturer	**Lubricant**
Standard Oil Co.	White Vaseline
Shell Oil Co.	No. 71032; No. 71306
Texaco, Inc.	No. 955
Quaker State	No. NYK-77

Table 1, Approved Electrical Lubricants

Replacement Bulb Part Numbers	
Description	**Part Number**
Stop/Turn Signal/Park Light	1157
Backup Light	1156

Table 2, Replacement Bulb Part Numbers

Wiring Diagrams

IMPORTANT: The following wiring diagrams provide circuit details for the rear lighting of a typical Business Class® M2 vehicle. These details may not correspond to every vehicle. ServiceLink® is the diagnostic tool for troubleshooting the M2 electrical system. For specific circuit and pin information on how the vehicle is wired, go to the Configuration screen in ServiceLink and select the specific function in which you are interested. To troubleshoot specific inputs and outputs of this system, go to the Templates screen in ServiceLink and select the template for the function in which you are interested.

See **Fig. 1** for wiring details of the control inputs for the rear lights of a typical M2 vehicle.

Combination Stop/Turn Signal Lights

See **Fig. 2** for wiring details of the control outputs for integrated rear lights.

See **Fig. 3** for wiring details of the control outputs for individual rear lights.

Separate Stop/Turn Signal Lights

If an order for a vehicle includes separate stop/turn signal lights functionality, the vehicle is not equipped with rear lights. Only a harness connection that supplies the lighting outputs is provided. See **Fig. 4** for wiring details of the control outputs at the rear lighting connection.

Circuit Identification

See **Table 3** for a connector face view and pinout chart of the CHM Connector C1.

See **Table 4** for a connector face view and pinout chart of the aft chassis harness rear light connector for vehicles with combination stop/turn signal lights.

See **Table 5** for a connector face view and pinout chart of the aft chassis harness rear light connector for vehicles with separate stop/turn signal lights.

Specifications

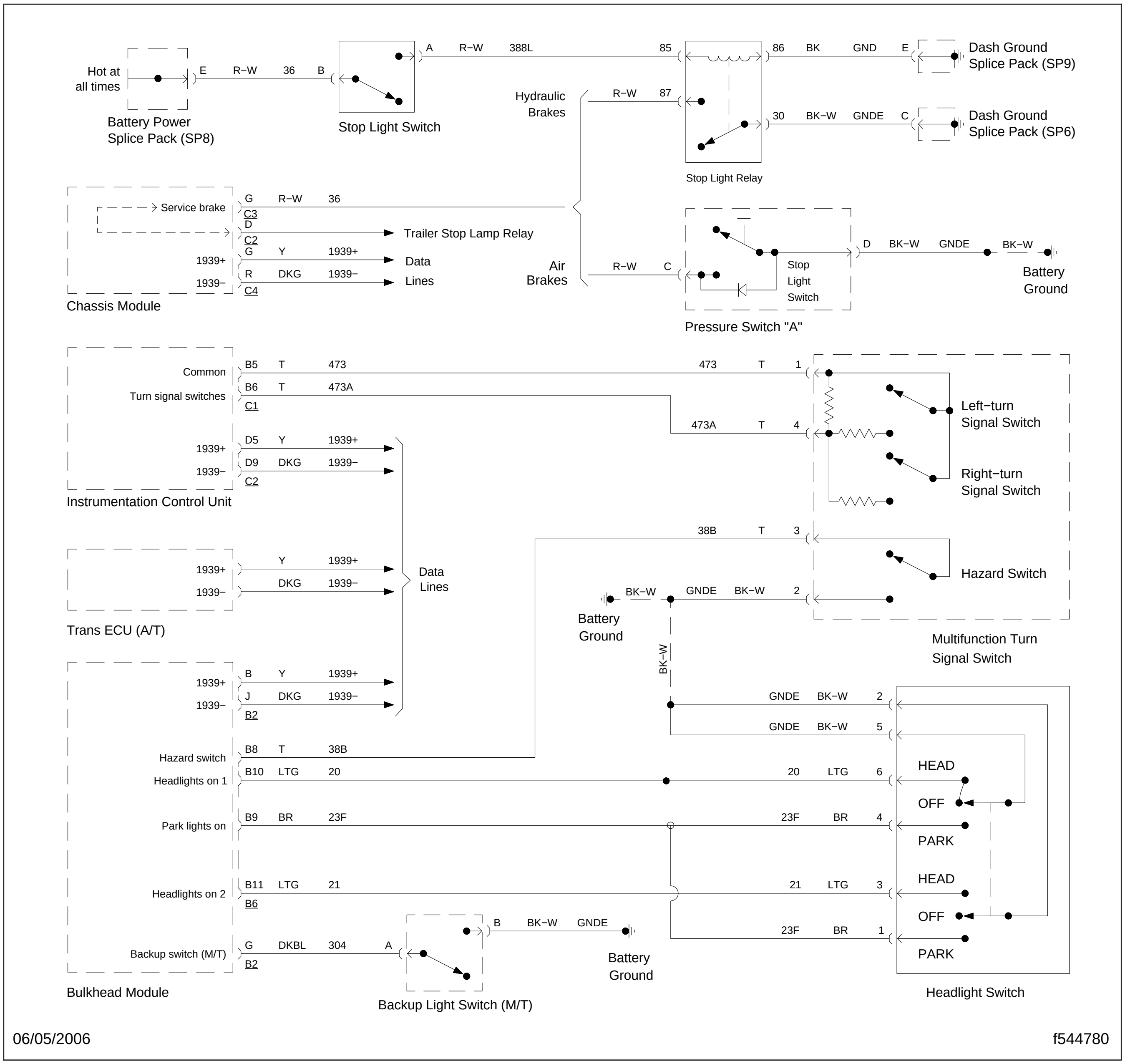


Fig. 1, Rear Exterior Lighting Inputs

Specifications

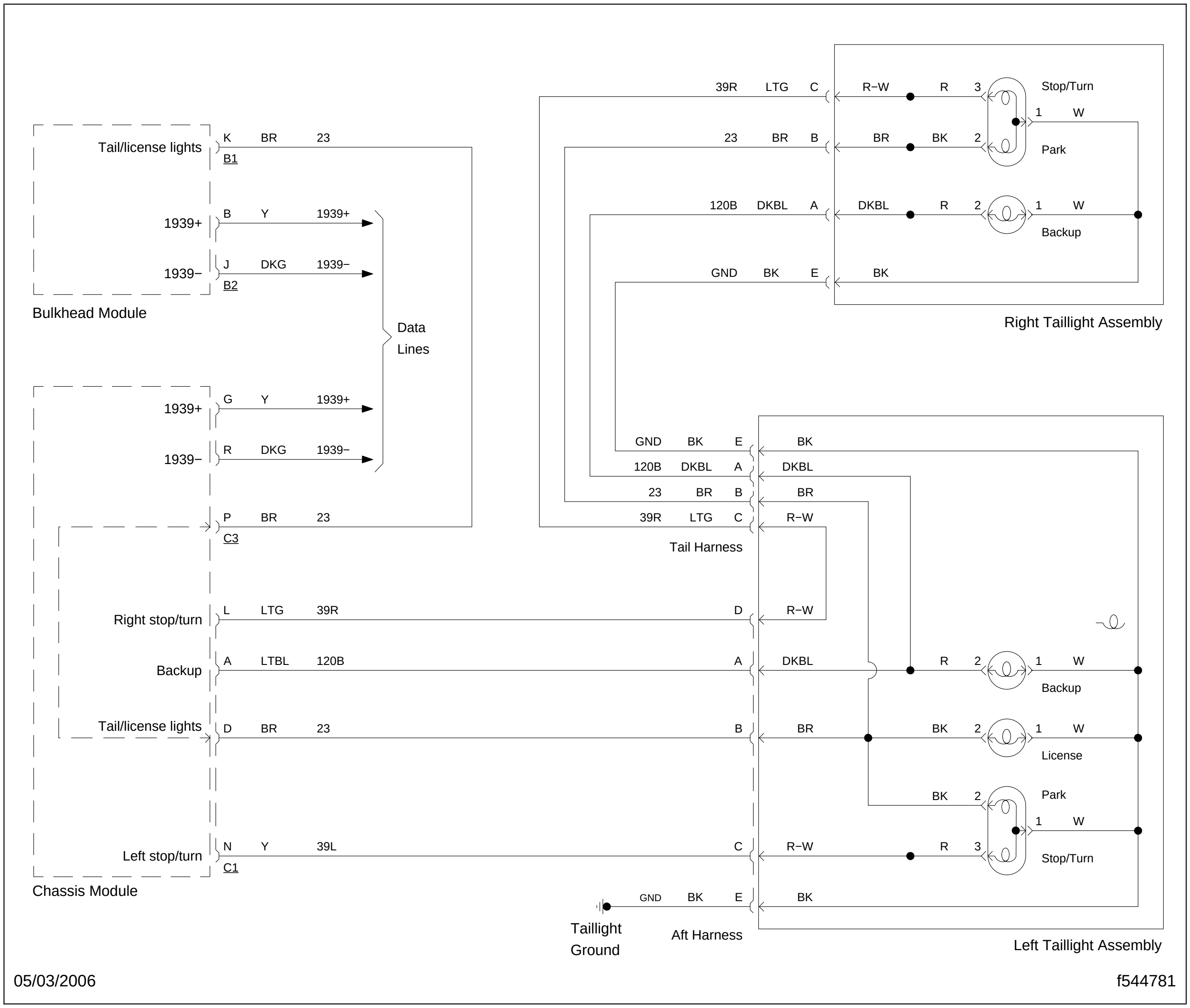


Fig. 2, Lighting Outputs for Integrated Rear Lights (combination stop/turn signal)

Specifications

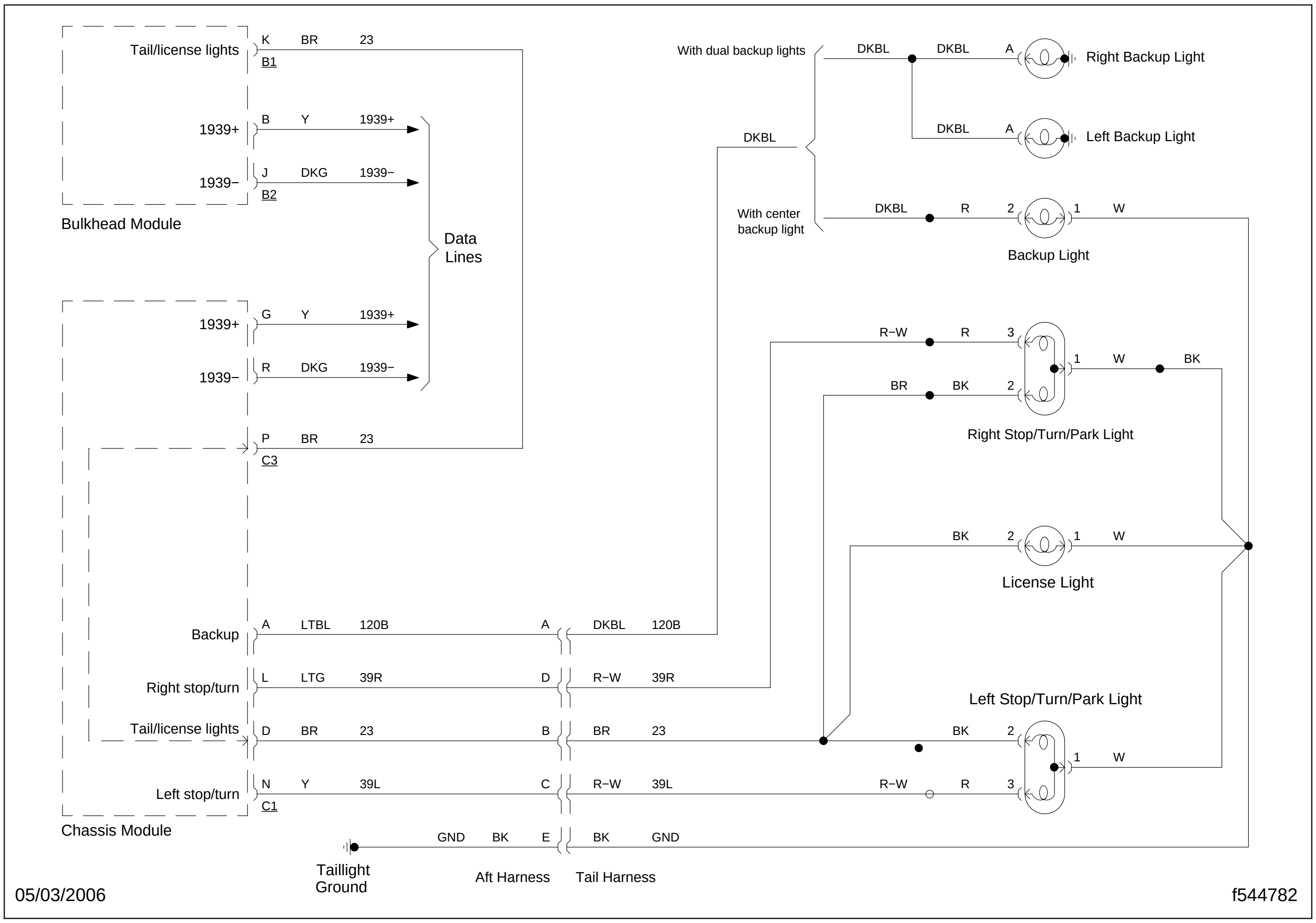


Fig. 3, Lighting Outputs for Individual Rear Lights (combination stop/turn signal)

Specifications

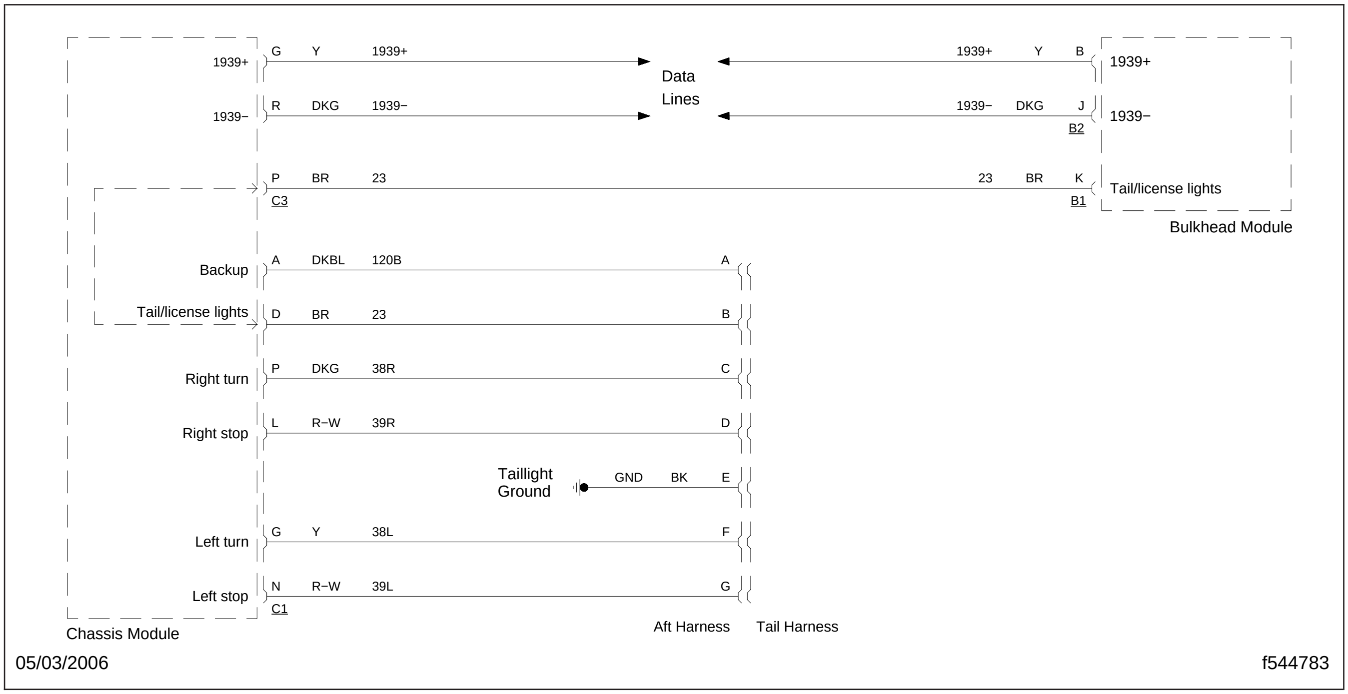
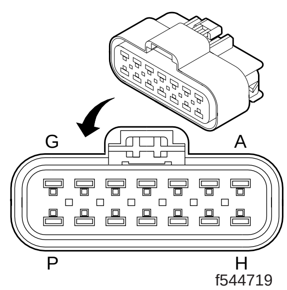


Fig. 4, Rear Lighting Connection (separate stop/turn signal)

Pinouts at CHM Connector C1					
Connector Pin	**Signal Name**	**Signal Type**	**Circuit Color**	**Circuit Number**	**Current Capacity**
					
C1-A	Left Backup Light (combination stop/turn signal)	Digital Output	LTBL	120B	7.45A*
C1-A	Left Backup Light (separate stop/turn signal)	Digital Output	DKBL	120B	7.45A*
C1-B	—	—	T	OPTA	—
C1-C	—	—	T	OPTB	—
C1-D	Left Taillight Pass-through	Pass-through	BR	23	1.0A†
C1-E	Right Taillight Pass-through	Pass-through	BR	23A	1.0A†
C1-F	License Plate Light	Digital Output	BR	23C	1.0A†
C1-G	Left Rear Turn Signal Light (separate stop/turn signal)	Digital Output	Y	38L	7.45A‡
C1-H	Backup Alarm	Digital Output	DKBL	120B	7.45A*

Specifications

Pinouts at CHM Connector C1					
Connector Pin	**Signal Name**	**Signal Type**	**Circuit Color**	**Circuit Number**	**Current Capacity**
C1-J	Right Backup Light	Digital Output	DKBL	120B	7.45A*
C1-K	—	—	T	OPTC	—
C1-L	Right Stop Light (combination stop/turn signal)	Digital Output	LTG	39R	7.45A
C1-L	Right Stop Light (separate stop/turn signal)	Digital Output	R-W	39R	7.45A
C1-M	—	—	T	OPTD	—
C1-N	Left Stop/Turn Signal Light (combination stop/turn signal)	Digital Output	Y	39L	7.45A
C1-N	Left Stop Light (separate stop/turn signal)	Digital Output	R-W	39L	7.45A
C1-P	Right Rear Turn Signal Light (separate stop/turn signal)	Digital Output	DKG	38R	7.45A§

* Pins C1-A, C1-H, and C1-J are fed from the same CHM circuit board trace. The maximum combined current capacity for all three pins is 7.45A.

† Pins C1-D, C1-E, and C1-F are fed from the same CHM circuit board trace. The maximum combined current capacity for all three pins is 1A.

‡ Pins C1-G, C2-H, and C3-N are fed by the same CHM circuit board trace. The maximum combined current capacity for all three pins is 7.45A.

§ Pins C1-P, C2-E, and C3-R are fed by the same CHM circuit board trace. The maximum combined current capacity for all three pins is 7.45A.

Table 3, Pinouts at CHM Connector C1

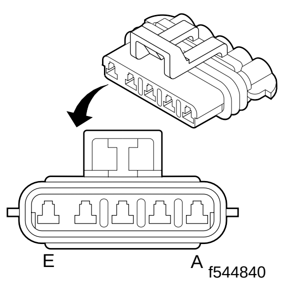
Rear Light Connector (combination stop/turn signal)				
Connector Pin	**Signal Name**	**Signal Type**	**Circuit Color**	**Circuit Number**
				
A	Backup Light	Output	LTBL	120B
B	Taillights and License Light	Output	BR	23
C	Left Stop/Turn Signal Light	Output	Y	39L
D	Right Stop/Turn Signal Light	Output	LTG	39R
E	Ground	Ground	BK	GND

Table 4, Rear Light Connector (combination stop/turn signal)

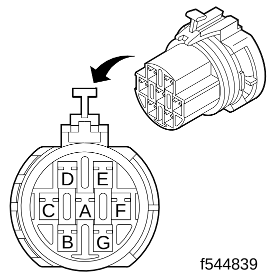
Rear Light Connector (separate stop/turn signal)				
Connector Pin	Signal Name	Signal Type	Circuit Color	Circuit Number
				
A	Backup Light	Output	DKBL	120B
B	Taillights and License Light	Output	BR	23
C	Right Turn Signal Light	Output	DKG	38R
D	Right Stop Light	Output	R-W	39R
E	Ground	Ground	BK	GND
F	Left Turn Signal Light	Output	Y	38L
G	Left Stop Light	Output	R-W	39L

Table 5, Rear Light Connector (separate stop/turn signal)

General Information

Introduction

The Business Class® M2 is available in several vehicle configurations. When an M2 vehicle is used as a tractor to pull a trailer, or as a truck to tow a piece of equipment, electrical connections are required between the vehicle and the trailer or the equipment.

Semitrailers and full trailers that are equipped with pneumatic brakes and used in North America or South America are generally equipped with an electrical cable that terminates in a 7-way connector that is defined in SAE J560 standard, *Primary and Auxiliary Seven Conductor Electrical Connector for Truck-Trailer Jumper Cable*. In some cases, a trailer used in North America is equipped with two electrical cables; one will be an SAE J560 connector and the other will be an ISO 3731 connector.

The harnesses and components that are used to provide an SAE J560 connector on a tractor or truck are nearly identical, regardless of the country of domicile of the vehicle. Most of the **component** variation is contained in the single-piece J560 connector, and if equipped, in the ISO 3731 connector that is installed on the tractor—the J560 connector and the ISO 3731 connector may be a straight connector or a 90-degree connector, and the cable may contain a signal filter that is related to the TRAILER ABS warning light. **Operational** variation is contained in the reference parameters that are used to control the functionality of the center pin of the J560 connector.

Overview

Trailer wiring requires the use of a full-feature Chassis Module (CHM). The CHM provides the necessary digital outputs, such as lighting and trailer power condition, via a wiring harness to the trailer power distribution module (PDM). The trailer PDM is usually mounted on the left frame rail aft of the cab, or on a rear crossmember at the end of the frame rail. Direct battery power is supplied to the trailer PDM via an independent connection to a 150 amp Battery MEGA® Fuse. The trailer PDM contains fuses and relays to enable high current outputs via a wiring harness to the trailer connector. It is possible to adapt trailer connector placement and mounting methods to better suit vehicle configuration or the preference of the body builder. Trailer PDM outputs include:

- taillights
- marker lights
- stop lights
- turn lights
- trailer power

If electrical trailer provisions are to include a trailer antilock braking system (ABS), the harness between the trailer PDM and trailer connector is adapted with a power line carrier (PLC) filter to permit communication of the trailer ABS warning signal on the trailer power circuit. The PLC filter is usually mounted alongside the trailer PDM.

Components

If electrical trailer provisions need to be added, visit a local Freightliner dealer to request a bill of material. Be prepared to provide the dealer with the vehicle identification number (VIN) and a sales option code (if known) for the desired feature. The bill of material provides a complete parts list that is tailored to the configuration and dimension of the vehicle.

The following is a list of some necessary components for establishing proper trailer electrical provisions:

- reference parameter (programs the new feature)
- upgraded CHM (full-feature Chassis Module required)
- trailer PDM with mounting hardware and bracket
- trailer connector J560 with mounting hardware and bracket
- harness between the CHM and the trailer PDM
- harness between the trailer PDM and the trailer connector
- power cable between the battery and the trailer PDM
- 150 amp Battery MEGA Fuse

The J560 center pin functionality must be programmed into the Bulkhead Module (BHM) of the truck. Use ServiceLink® to add the reference parameter if this feature is added to a vehicle that is already in service.

General Information

Installation or Replacement Guidelines

When installing or replacing any part of the electrical trailering system, follow these guidelines:

- Make ground connections at factory-provided ground stud locations whenever possible. If there is not a ground stud available, it will be necessary to add a bolt or self-threading fastener to connect the ground lugs to the frame rail.
- Route all wiring so that it will not be exposed to harmful conditions such as, moving parts, excessive heat, chafing, or saturation with oil or grease.
- Secure and protect all electrical components. Use appropriate mounting and installation techniques such as, retaining clips, harness protection, and correct hardware.
- Be sure to clean all paint, dielectric enamel, and road grime from the ground stud or frame before connecting the new ground leads. After the connections are secured, use a dielectric enamel on the ground connections to protect against corrosion.
- Removal of electrical components for an extended period of operation requires proper weatherproofing to avoid system damage and electrical faults.

Removal

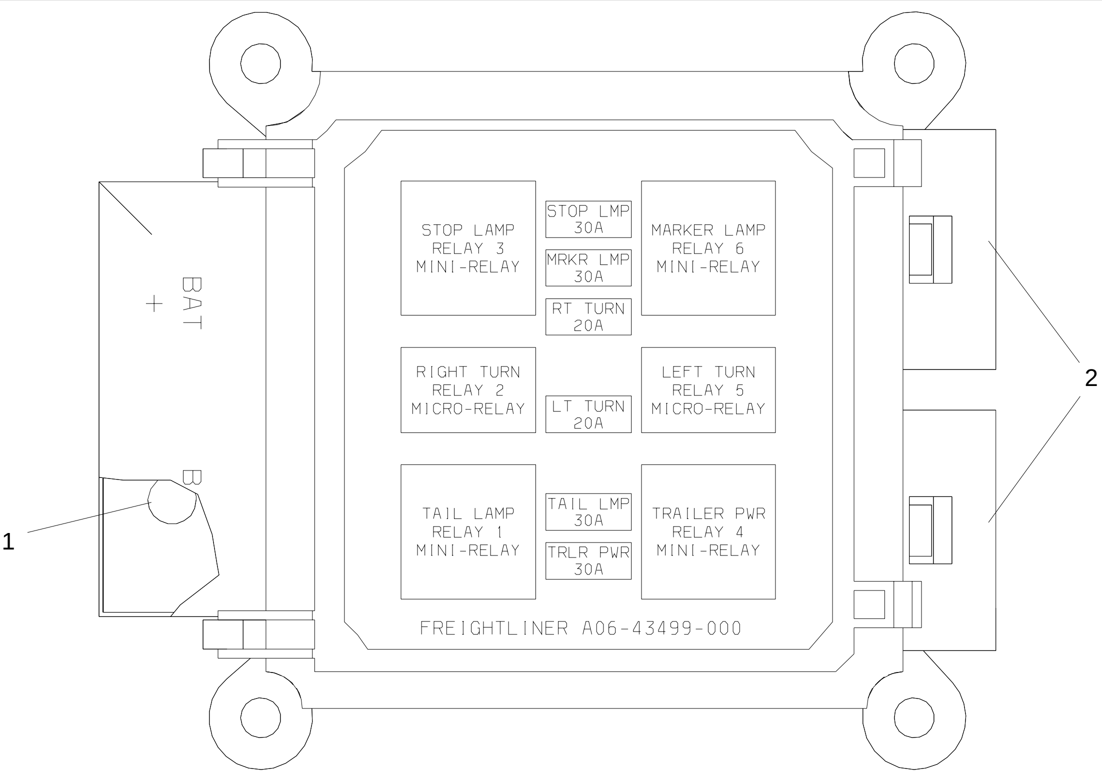
1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the negative leads from the batteries or, if the vehicle is equipped with a battery disconnect switch, turn the switch to the off position.

NOTE: The trailer power distribution module (PDM) is mounted on the left frame rail aft of the cab, or on a crossmember at the end of the frame rail.

3. Remove the capscrews that attach the metal cover on the PDM to the mounting plate, then remove the cover.
4. Remove the nut and washer that attach the positive lead to the trailer PDM battery power stud. Then remove the positive lead. See **Fig. 1**.
5. Disconnect the electrical connectors from the trailer PDM. See **Fig. 1**.
6. Remove the nuts and washers that attach the trailer PDM to the mounting bracket, then remove the PDM. See **Fig. 2** and **Fig. 3**.

Installation

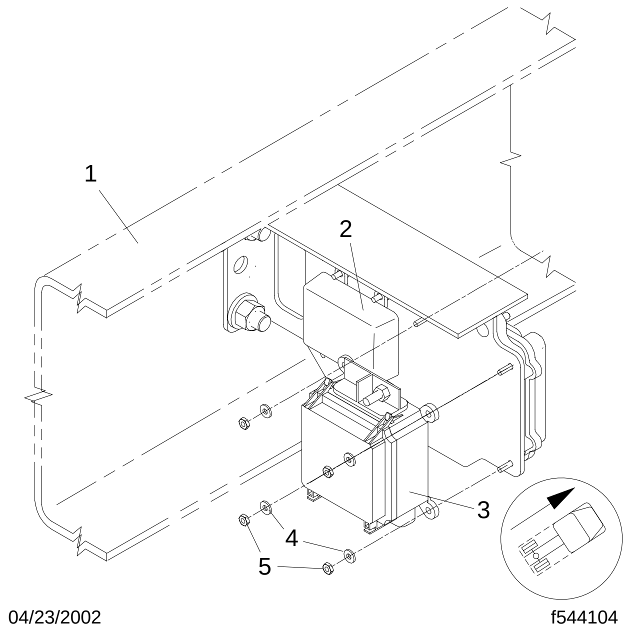
1. Using nuts and washers, attach the PDM to the mounting bracket.
2. Attach the electrical connectors to the trailer PDM.



1. Battery Power Stud
2. Electrical Connector

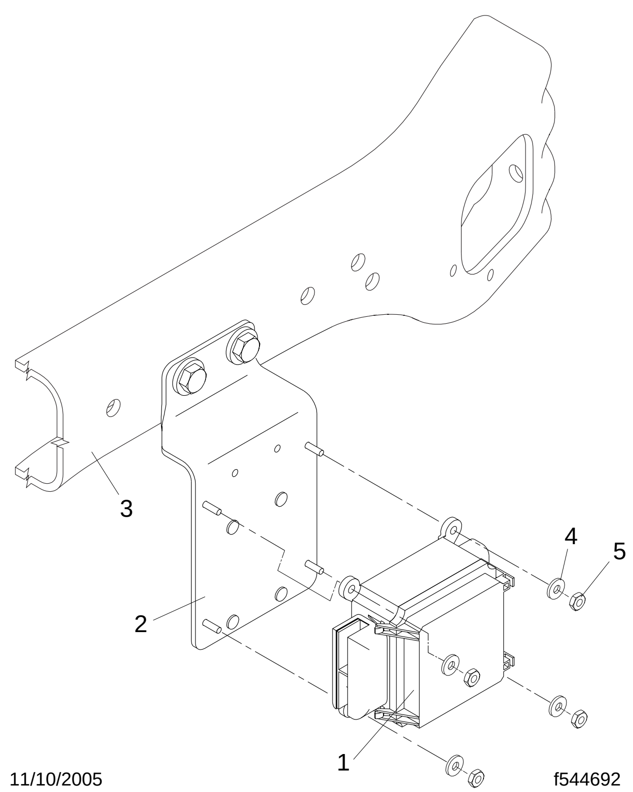
Fig. 1, Trailer PDM Fuse Panel Layout

PDM Removal and Installation



1. Left Frame Rail
2. PLC Filter
3. Trailer PDM
4. #10 Washer
5. 10-24 Nut

Fig. 2, Trailer PDM Aft-of-Cab Installation



1. Trailer PDM
2. Mounting Bracket
3. Crossmember
4. #10 Washer
5. 10-24 Nut

Fig. 3, Trailer PDM End-of-Frame Installation

3. Using a nut and washer, install the positive lead on the trailer PDM battery power stud. Torque the nut 11 to 13 lbf·ft (15 to 18 N·m).
4. Using capscrews, attach the metal cover (that protects the PDM) to the mounting plate.
5. Connect the batteries or turn the battery disconnect switch to on.
6. Verify the operation of the trailer electrical components.
7. Remove the chocks from the tires.

Parameter Programming

When adding or changing a trailer feature on the M2, you must use ServiceLink® to update the programming on the vehicle.

1. Establish a connection to ServiceLink.
2. Select the J1939 **Bulkhead Module** icon on the left side of the screen.
3. Select the **Features** menu.
4. Enter the appropriate reference parameter for the feature that is being programmed.
5. Click on **Add to List**.
6. Click on **Apply Changes**.

Troubleshooting

For electrical troubleshooting, see **Table 1**.

Electrical Troubleshooting	
Description of Fault	**Possible Cause**
Stop lights on at all times.	Battery MEGA® Fuse that supplies the trailer power distribution module (PDM) is open or missing.
Trailer connector center pin (pin 7) is not providing desired power condition.	Incorrect Reference Parameter.
Intermittent or no electrical trailer operation at all outputs.	Loss of connection. Check trailer PDM electrical connections and ground.
No operation on single output.	Trailer PDM components are inoperable. Check PDM fuse (blown) and relay (stuck) for that output.
Intermittent or no operation on single output.	Loose terminal connection(s), damaged wire. Trace the suspect circuit.

Table 1, Electrical Troubleshooting

Trailer Connector Testing

Make sure that the center pin is operating according to the programmed reference parameter. See **Specifications 400**.

Verify that all trailer lighting signals are operating properly. Test the taillights, marker lights, stop lights, parking lights, and turn lights.

Trailer Electrical System Wiring Diagram

See **Fig. 1** for a wiring diagram of the trailer electrical system with only a J560 connector.

See **Fig. 2** for a wiring diagram of the trailer electrical system with both J560 and ISO 3731 connectors.

Trailer Electrical System I/O Diagram

For an overview of the input and output signals of the trailer electrical system, see **Fig. 3**.

Reference Parameters

Several configurations of trailer wiring are available and are mainly defined by the function and use of the trailer connector center pin. Each configuration is provided a unique ServiceLink® reference parameter for programming the proper trailer wiring usage and center pin operation. For a list of possible trailer reference parameters and the corresponding descriptions, see **Table 1**.

Circuit Identification

Chassis Module

For Chassis Module (CHM) connector identification, see **Fig. 4**. For a connector face view and pinout chart of the CHM C2 connector, see **Table 2**.

Trailer PDM

For trailer power distribution module (PDM) layout and identification of electrical connections, see **Subject 100**. For a connector face view and pinout chart of the trailer module harness PDM connector, see **Table 3**. For a connector face view and pinout chart of the trailer connector harness PDM connector, see **Table 4**.

Trailer Connector

For a connector face view and pinout chart of the trailer connector harness at J560 connector, see **Table 5**. For a connector face view and pinout chart of the trailer connector harness at ISO 3731 connector, see **Table 6**.

Specifications

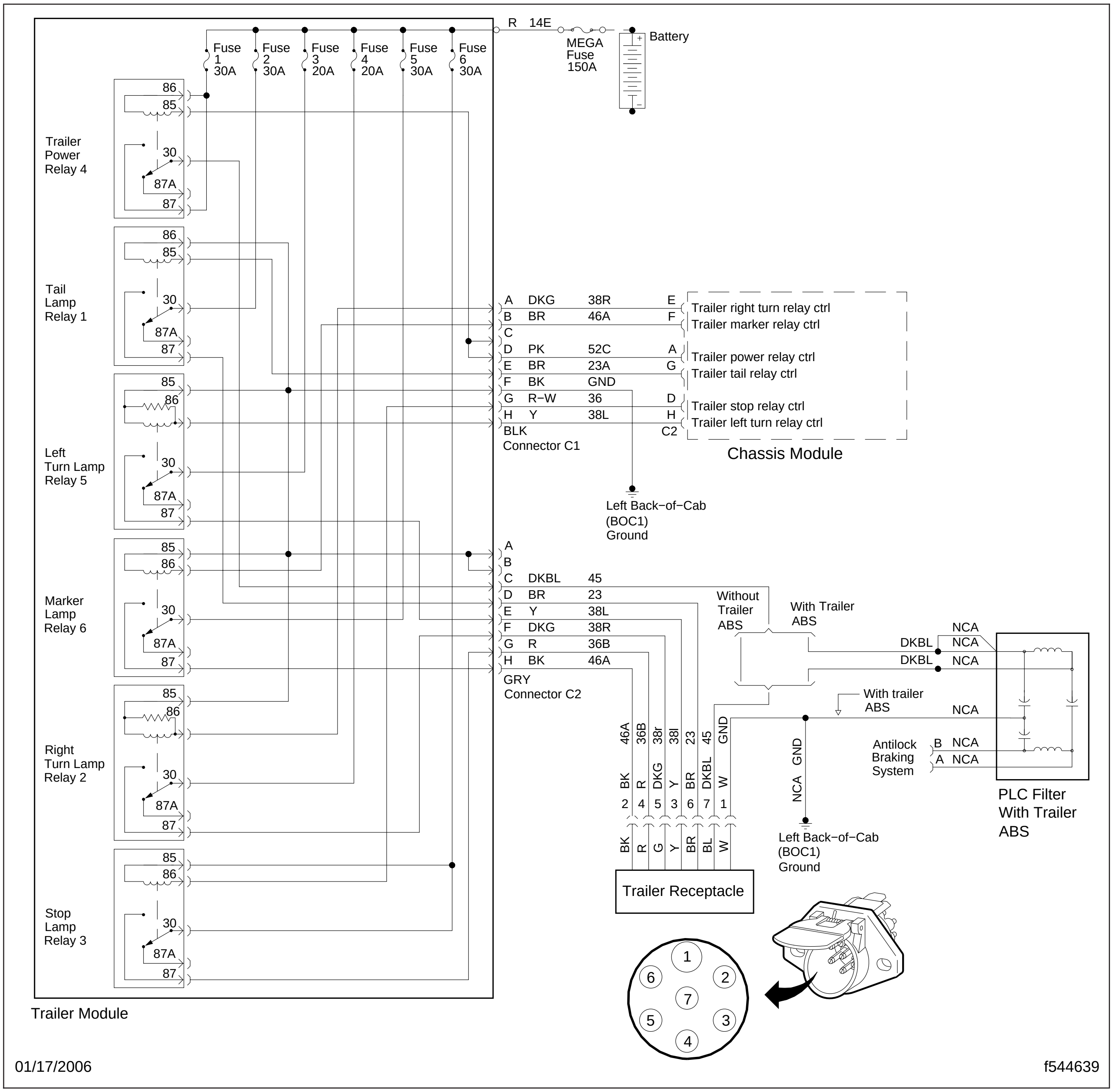


Fig. 1, Wiring Diagram of the Trailer Electrical System With Only a J560 Connector (primary receptacle)

Specifications

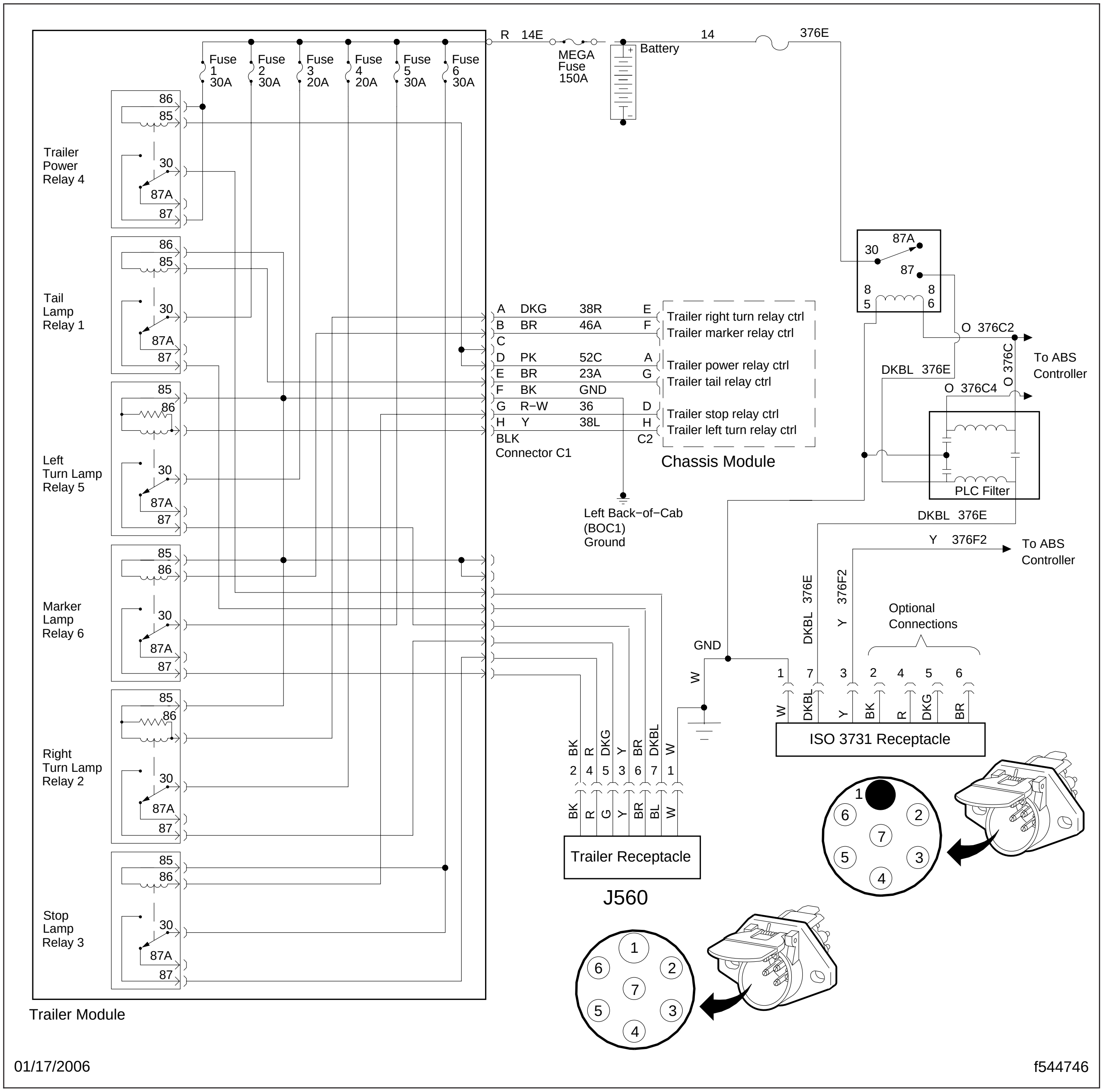
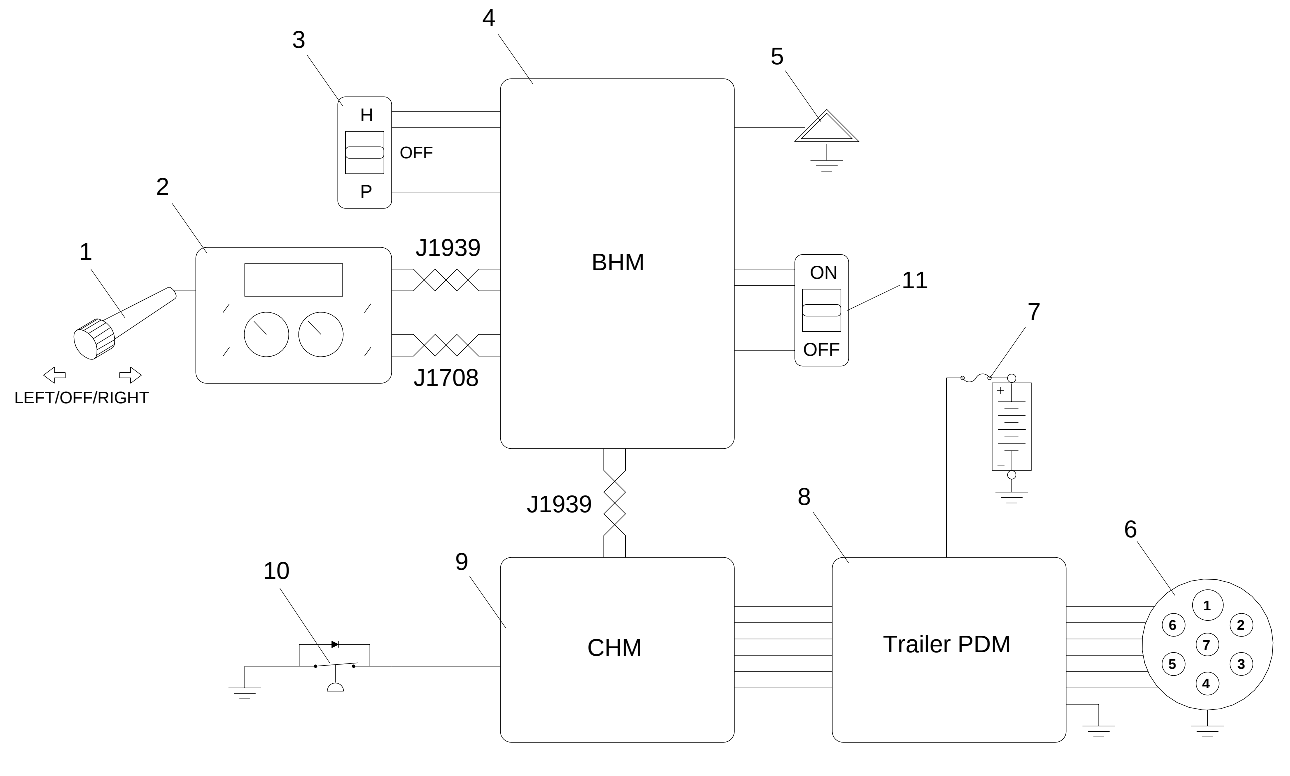


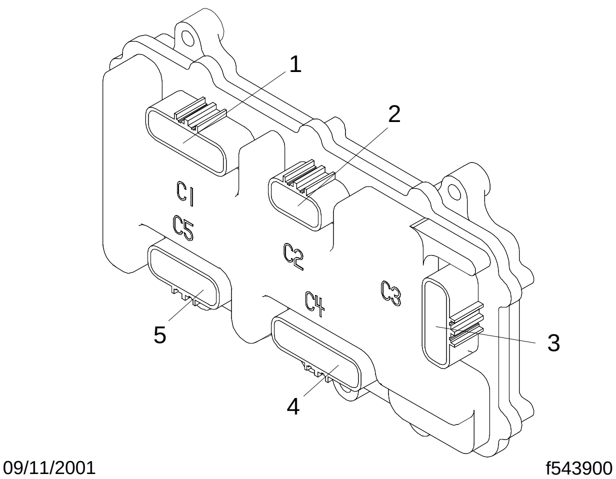
Fig. 2, Wiring Diagram of the Trailer Electrical System With Both J560 and ISO 3731 Connectors (primary and secondary receptacles)

Specifications



1. Multifunction Turn Signal Switch
2. Instrumentation Control Unit
3. Headlight Switch
4. Bulkhead Module
5. Hazard Switch
6. Trailer Connector
7. Battery MEGA® Fuse
8. Trailer Power Distribution Module
9. Full-feature Chassis Module
10. Brake Switch
11. Trailer Connector Center Pin Control Switch (optional parameter dependant)

Fig. 3, Trailer Electrical System I/O Diagram



1. C1, Tail Harness
2. C2, Trailer Module Harness
3. C3, Forward Chassis Harness
4. C4, Forward Chassis Harness
5. C5, Air Management Unit Harness

Fig. 4, Chassis Module Connector Identification

Trailer Reference Parameters		
Reference Parameter	**Description**	**Additional Information**
26-01017-000	Without 7-Way Center Pin Ignition Supply	No trailering
26-01017-001	With 7-Way Center Pin Ignition Supply	Provides +12 volts at the center pin (pin 7) of the trailer connector with ignition ON via PDM Fuse 1 (30A) with PDM relay 4 (trailer power) active.
26-01017-002	Switch-controlled 7-Way Center Pin (Smart Sw ID#44)	Provides for a dash switch that turns on/off the center pin power. +12 volts at the center pin (pin 7) of the trailer connector with dash switch ON via PDM Fuse 1 (30A) with PDM relay 4 (trailer power) active.
26-01017-004	Trailer Center Pin ON With Reverse Lights	Non-U.S. option, export feature. Provide reverse output at center pin.

Table 1, Trailer Reference Parameters

Specifications

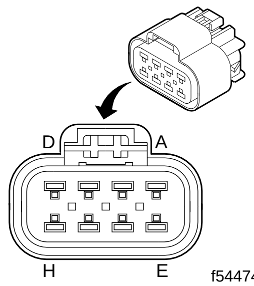
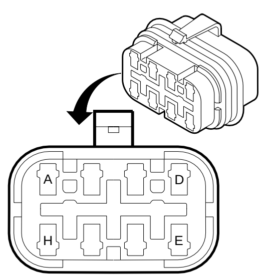
Trailer Module Harness Pinouts at CHM Connector C2				
Connector Pin	Signal Name	Signal Type	Circuit Color	Circuit Number
 f544741				
C2-A	Trailer Power Relay Control	Digital Output	PK	52C
C2-B	—	—	—	—
C2-C	—	—	—	—
C2-D	Trailer Stop Light Relay Control Pass-through	Pass-through	R-W	36
C2-E	Trailer Right Turn Light Relay Control	Digital Output	DKG	38RT
C2-F	Trailer Marker Light Relay Control	Digital Output	BR	46A
C2-G	Trailer Taillight Relay Control Pass-through	Pass-through	BR	23A
C2-H	Trailer Left Turn Light Relay Control	Digital Output	Y	38LT

Table 2, Trailer Module Harness Pinouts at CHM Connector C2

Trailer Module Harness Pinouts at PDM Connector C1				
Connector Pin	Signal Name	Signal Type	Circuit Color	Circuit Number
 f544740				
A	Trailer Right Turn Light Relay Control	Digital Input	DKG	38RT
B	Trailer Marker Light Relay Control	Digital Input	BR	46A
C	—	—	—	—
D	Trailer Power Relay Control	Digital Input	PK	52C
E	Trailer Taillight Relay Control	Digital Input	BR	23A
F	Ground	Ground	BK	GND

Trailer Module Harness Pinouts at PDM Connector C1				
Connector Pin	**Signal Name**	**Signal Type**	**Circuit Color**	**Circuit Number**
G	Trailer Stop Light Relay Control	Digital Input	R-W	36
H	Trailer Left Turn Light Relay Control	Digital Input	Y	38LT

Table 3, Trailer Module Harness Pinouts at PDM Connector C1

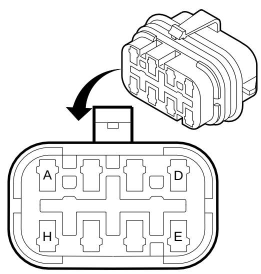
Trailer Connector Harness Pinouts at PDM Connector C2				
Connector Pin	**Signal Name**	**Signal Type**	**Circuit Color**	**Circuit Number**
 f544739				
A	—	—	—	—
B	—	—	—	—
C	Trailer Power Output	+12V via PDM Fuse 1 (30A) with PDM relay 4 (trailer power) active.	DKBL	45
D	Trailer Taillight Output	+12V via PDM Fuse 2 (30A) with PDM relay 1 (taillight) active.	BR	23
E	Trailer Left Turn Light Output	+12V via PDM Fuse 3 (20A) with PDM relay 5 (left turn) active.	Y	38L
F	Trailer Right Turn Light Output	+12V via PDM Fuse 4 (20A) with PDM relay 2 (right turn) active.	DKG	38R
G	Trailer Stop Light Output	+12V via PDM Fuse 6 (30A) with PDM relay 3 (stop light) active.	R	36B
H	Trailer Marker Light Output	+12V via PDM Fuse 5 (30A) with PDM relay 6 (marker light) active.	BK	46A

Table 4, Trailer Connector Harness Pinouts at PDM Connector C2

Specifications

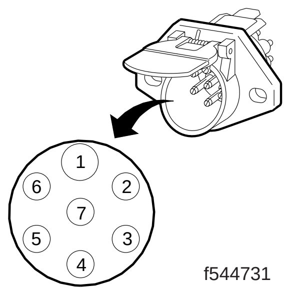
Trailer Connector Harness Pinouts at J560 Connector				
Connector Pin	Signal Name	Signal Type	Circuit Color	Current Capacity
 f544731				
1	Ground	Ground	W	20A
2	Trailer Marker Light	+12V via PDM Fuse 5 (30A) with PDM relay 6 (marker light) active.	BK	30A
3	Trailer Left Turn Light	+12V via PDM Fuse 3 (20A) with PDM relay 5 (left turn) active.	Y	20A
4	Trailer Stop Light	+12V via PDM Fuse 6 (30A) with PDM relay 3 (stop light) active.	R	30A
5	Trailer Right Turn Light	+12V via PDM Fuse 4 (20A) with PDM relay 2 (right turn) active.	G	20A
6	Trailer Taillight	+12V via PDM Fuse 2 (30A) with PDM relay 1 (taillight) active.	BR	30A
7	Trailer Power	+12V via PDM Fuse 1 (30A) with PDM relay 4 (trailer power) active.	BL	30A

Table 5, Trailer Connector Harness Pinouts at J560 Connector

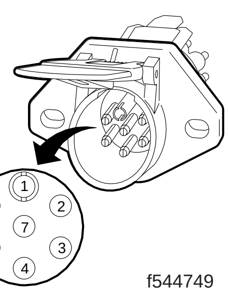
Trailer Connector Harness Pinouts at ISO 3731 Connector				
Connector Pin	Current	Signal Name	Signal Type	Color
 f544749				
1	30A	Ground	Ground	W
3	0.5A	Trailer ABS Lamp	+12V through relay controlled by tractor ABS	Y
7	20A	Trailer Power	+12V through relay controlled by tractor ABS	DKBL

Table 6, Trailer Connector Harness Pinouts at ISO 3731 Connector

Introduction

Interior lighting on a Business Class® M2 vehicle includes backlighting and courtesy lighting. Backlighting is the illumination of the instrumentation control unit and most of the switch legends.

The Bulkhead Module (BHM) controls the backlighting using a pulse-width modulated (PWM) signal. Pulse-width modulation is a method of controlling the percentage of time that the DC voltage is enabled. For example, a signal that is 80 percent modulated has the signal on 80 percent of the time, or 0.8 seconds for every second.

Courtesy lighting, or entrance lighting, is interior lighting that is turned on by opening a door on the vehicle. Most courtesy lights can also be turned on manually to provide dome/reading lights; however, there are optional door courtesy lights that only provide entrance lighting.

Backlighting

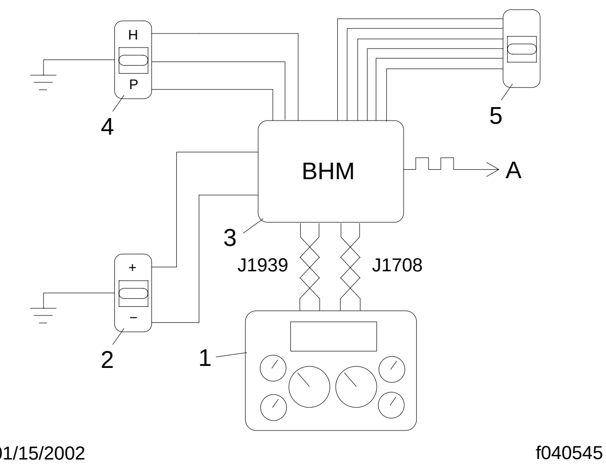
The backlighting function illuminates the dash display and numerous control switches throughout the vehicle cab. Backlighting power is provided to components that include, but are not limited to the:

- instrumentation control unit
- HVAC control panel
- headlight switch
- smart switches
- cruise control switches
- power door lock/window/mirror switches
- transmission dash shifter

Instead of controlling the level of backlighting with a rheostat (the common method for many Freightliner vehicles), the backlighting functionality in the Business Class M2 is controlled by a pulse-width modulated signal from the BHM. Backlighting voltage to the components can vary between 10 and 90 percent of battery voltage.

PWM does not adjust the voltage strength, it controls the percentage of time that the DC voltage is enabled. A multimeter capable of measuring duty cycle will read a voltage of 12 volts (nominal); a multimeter set to the DC range will read a voltage that is less than 12 volts.

The panel light increase/decrease switch is a two-position, momentary switch that controls the intensity of the backlighting. When the driver pushes the upper part of the switch, labeled INCR+, a ground circuit to the BHM is completed, indicating a request to increase the backlighting. When the driver pushes the lower part of the switch, labeled DECR–, a different pin at the BHM is grounded, indicating a request to decrease the backlighting. See **Fig. 1**.



A. Pulse-width Modulated Signal (illumination feed)

1. Instrumentation Control Unit
2. Dimmer Switch
3. Bulkhead Module
4. Headlight Switch
5. Marker Light Interrupt Switch

Fig. 1, Backlighting Function

Backlighting is active with the headlight switch in either the on or park positions, or if the marker interrupt switch is toggled while the headlight switch is in the off position.

The BHM monitors the backlighting voltage output and is capable of detecting a short circuit when the backlighting output is active. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink®.

Courtesy Lighting

Courtesy lights include:

- dome lights
- reading/map lights

General Information

- door entrance lights
- overhead console lights

The number and location of the courtesy lights varies depending on cab configuration and vehicle options. Courtesy lighting variations range from day cabs with one-switch activation (driver door) of a dome light assembly, to crew cabs with four-switch activation of the dome lights, reading lights, and optional door courtesy lights.

The BHM is capable of detecting shorted circuits in the courtesy lights wiring. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink.

Dome Lights

Dome lights are installed on all cabs. The basic dome light has a clear lens and is installed above the rear window. On cabs with an overhead console, there is an optional lighting assembly that contains two dome lights and two reading lights. Additional dome lights located in the headliner are available on crew cabs and extended cabs.

A dome light can be turned on by opening a door or pressing the switch on the dome light. There are two separate power circuits coming from the BHM to the dome light assembly. One circuit from pin A of BHM connector B5 has power at all times and is used to turn the light on when the driver presses the switch on the dome light. The other circuit from pin B of BHM connector B5 is powered when a door is opened. See **Fig. 2**.

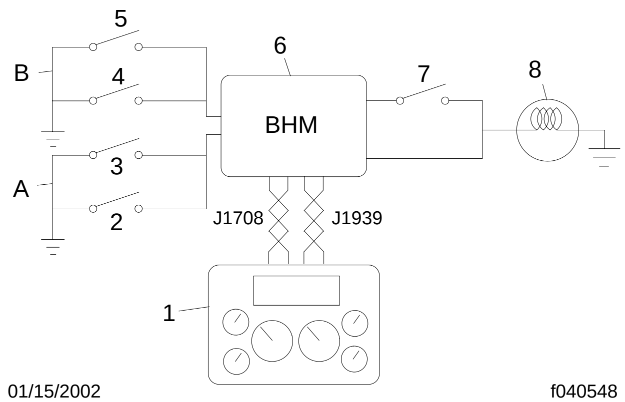
The number and location of door pin switches that activate the dome light(s) vary with cab configuration and vehicle options. On day cabs and extended cabs, the driver door switch is standard and the passenger side door switch is optional. On crew cabs, all four door switches are standard.

Reading/Map Lights

Reading lights are clear lights that are available with:

- The optional lighting assembly on a cab with an overhead console;
- A crew cab that has optional dome/reading light assemblies.

In the overhead console lighting assembly, the reading lights are located on either side of the overhead console next to the dome lights. The reading lights in this assembly are nonreplaceable light-emitting diode (LED) modules.



A. Passenger Side B. Driver Side

1. Instrumentation Control Unit
2. Rear Door Switch
3. Front Door Switch
4. Rear Door Switch
5. Front Door Switch
6. Bulkhead Module
7. Dome Light Switch
8. Dome Lamp Bulb

Fig. 2, Dome Light Function

Map lights are red lights that are available instead of the clear reading lights in the overhead console.

Door Entrance Lights

Door entrance lights are located on the inner door panels. These lights are only activated when a door is opened and can not be turned on manually. The door entrance lights provide additional interior lighting when getting in and out of the vehicle.

Most cab configurations utilize the dome light output at pin B of BHM connector B5 to activate the door courtesy lights; however, there are a few crew cab configurations where the Chassis Module (CHM) is used to activate the door entrance lights to remove some of the current load from the BHM output. For these configurations, the BHM sends datalink messages to the CHM requesting courtesy light activation. The CHM output at pin C of CHM connector C3 powers the door entrance lights.

Current Capacity

For cab configurations where the BHM powers many courtesy lights, it is necessary to be aware that exceeding the current capacity of a BHM output results in the BHM shutdown of that output. If adding additional interior lights to a vehicle, do not exceed the current capacity of control module output. See **Table 1** for identification of possible courtesy light outputs and the current capacity of those outputs.

Courtesy Light Outputs				
Module	**Pin**	**Connector**	**Function**	**Current Capacity**
BHM	A	B5	Dome lights battery power	6.7A*
BHM	B	B5	Dome lights and optional door courtesy lights switched power	6.7A
CHM	C	C3	Door courtesy lights (unused fog light output)	6.7A†

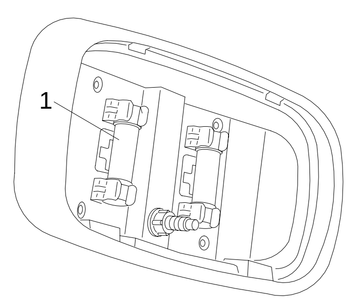
* Pins B5-A and B7-A12 (smart switch battery power) are fed from the same BHM circuit board trace. The maximum combined current capacity for both pins is 6.7A.

† Pins C3-C and C3-D (optional fog light) are fed from the same CHM circuit board trace. The maximum combined current capacity for both pins is 6.7A.

Table 1, Courtesy Light Outputs

Cab Rear Dome Light Bulb Replacement

1. Remove the lens using a flat-blade screwdriver to release the two tabs on the bottom of the lens. Then gently pry the lens from the bottom of the housing.
2. Remove the two bulbs from the lock clips by pulling them straight out. See **Fig. 1**.



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1. Bulb

Fig. 1, Cab Rear Dome Light

3. Press new bulbs into the lock clips.
4. Insert the two tabs on the lens into the slots in the top of the housing, then push the bottom of the lens into place, locking the tabs.

Cab Rear Dome Light Assembly Replacement

1. Remove the lens using a flat-blade screwdriver to release the two tabs on the bottom of the lens. Then gently pry the lens from the bottom of the housing.
2. Insert the screwdriver into the lower slots in the housing to release the two spring clips, then remove the assembly from the headliner.
3. Disconnect the electrical connector.
4. Connect the electrical connector of the new assembly.
5. Align the tabs on the top edge of the new assembly and press the lower edge of the assembly into place until the locking tabs click into place.

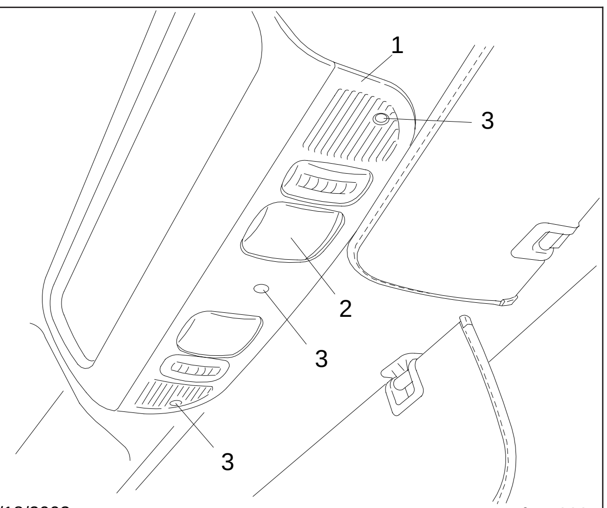
Overhead Console Map/ Reading Light Assembly Bulb Replacement

NOTE: The bulbs are replaceable in the inner larger lights only. The smaller lights use nonreplaceable LEDs.

1. Using a flat-blade screwdriver, release the tab by pushing on the edge of the lens that is indented. Then gently pry the lens from the housing.
2. Remove the bulb from the lock clip by pulling it straight out.
3. Press a new bulb into the lock clip.
4. Insert the tab on the lens into the slots in the housing, then push the lens into place, locking the tabs.

Overhead Console Map/ Reading Light Assembly Replacement

1. Remove the three Torx® capscrews that hold the center overhead panel in place. See **Fig. 2**.



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1. Center Overhead Panel
2. Reading Light With Replaceable Bulb
3. Torx Capscrew

Fig. 2, Overhead Panel With Map/Reading Lights

Interior Lights Replacement

2. Lower the assembly and disconnect the connector to the light assembly.
3. Remove the four capscrews that attach the light assembly to the panel, and remove the light assembly.
4. Using capscrews, install a new light assembly on the panel.
5. Connect the connector to the light assembly.
6. Using capscrews, install the center overhead panel.

IMPORTANT: ServiceLink® is the diagnostic tool for troubleshooting the M2 electrical system. For specific circuit and pin information on how the vehicle is wired, go to the Configuration screen in ServiceLink and select the specific function in which you are interested. To troubleshoot specific inputs and outputs of this system, go to the Templates screen in ServiceLink and select the template for the function in which you are interested.

Backlighting

Input and Output Conditions

See **Table 1** for the Bulkhead Module (BHM) responses to the backlighting input/output conditions.

Fault Conditions

See **Table 2** for the backlighting conditions that will create a fault. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 and/or the J1708 datalinks until both the headlight switch and the marker interrupt switch are turned off.

Dome Light Fault Conditions

See **Table 3** for the dome light conditions that will create a fault. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 and/or the J1708 datalinks until the ignition switch is turned off.

Backlighting Input/Output Conditions				
Inputs to BHM		Outputs from BHM		
Headlight Switch	Marker Interrupt Switch	Backlight Status	Illumination	Percent Battery Voltage Output
On/Park	Off	On	Dependent on dimmer switch position (range dim to bright).	Dependent on dimmer switch position (range 10 to 90%).
Off	On	On	Bright	100%
On/Park	On	Off	Off	0%
Off	Off	Off	Off	0%

Table 1, Backlighting Input/Output Conditions

Backlighting Fault Conditions		
Failed Component or Circuit	Description of Fault	Action Taken by BHM
Backlight dimmer switch	BHM sees panel light increase and panel light decrease simultaneously.	BHM may transmit a J1939 and/or a J1708 fault message.
Headlight switch	Headlight switch is in error.	BHM will assume the headlight switch is on.
Marker interrupt switch	Marker interrupt switch is in error.	BHM will assume the marker interrupt switch is off and may transmit a fault message on the J1939 and/or J1708 datalinks.

Troubleshooting

Backlighting Fault Conditions		
Failed Component or Circuit	**Description of Fault**	**Action Taken by BHM**
Backlighting power output	Backlighting power wiring is shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 2, Backlighting Fault Conditions

Dome Light Fault Conditions	
Description of Fault	**Action Taken by BHM**
Dome light power (hot at all times) wiring is shorted.	BHM may transmit a J1939 and/or a J1708 fault message.
Dome light switched (hot with door switch closed) wiring is shorted.	BHM may transmit a J1939 and/or a J1708 fault message.

Table 3, Dome Light Fault Conditions

Wiring Diagrams

IMPORTANT: The following wiring diagrams show typical interior lighting configurations available for a Business Class® M2 vehicle. The circuit details shown may not correspond to every vehicle. ServiceLink® is the diagnostic tool for troubleshooting the M2 electrical system. For specific circuit and pin information on how the vehicle is wired, go to the Configuration screen in ServiceLink and select the specific function in which you are interested. To troubleshoot specific inputs and outputs of this system, go to the Templates screen in ServiceLink and select the template for the function in which you are interested.

Backlighting

See **Fig. 1** and **Fig. 2** for backlighting wiring diagrams showing dimmer controls and instrument illumination.

Courtesy Lights

The number and location of courtesy lights are dependent on the vehicle configuration and vehicle options.

Day Cabs and Extended Cabs

See **Fig. 3** for a wiring diagram of the courtesy lights for a cab with a single rear dome light.

See **Fig. 4** for a wiring diagram of the courtesy lights for a cab with the optional lighting assembly in the overhead console.

Crew Cabs

Courtesy light door switches are standard on a crew cab. The courtesy lights are activated by opening any of the four vehicle doors. See **Fig. 5** for a wiring diagram of the door switches.

There are many interior lighting configurations available for crew cab vehicles. The Bulkhead Module (BHM) outputs that drive the interior lights have a limited load capacity. As supplied interior lighting increases, sometimes it is necessary to feed the door courtesy lights from an unused Chassis Module (CHM) output to prevent BHM output overload.

Typical examples of crew cab courtesy light configurations include:

- Two dome lights and optional door entrance lights. See **Fig. 6**.
- An overhead console, four dome lights, and optional front door entrance lights. See **Fig. 7**.
- An overhead console, four dome lights, and CHM-controlled door entrance lights. See **Fig. 8**.

Specifications

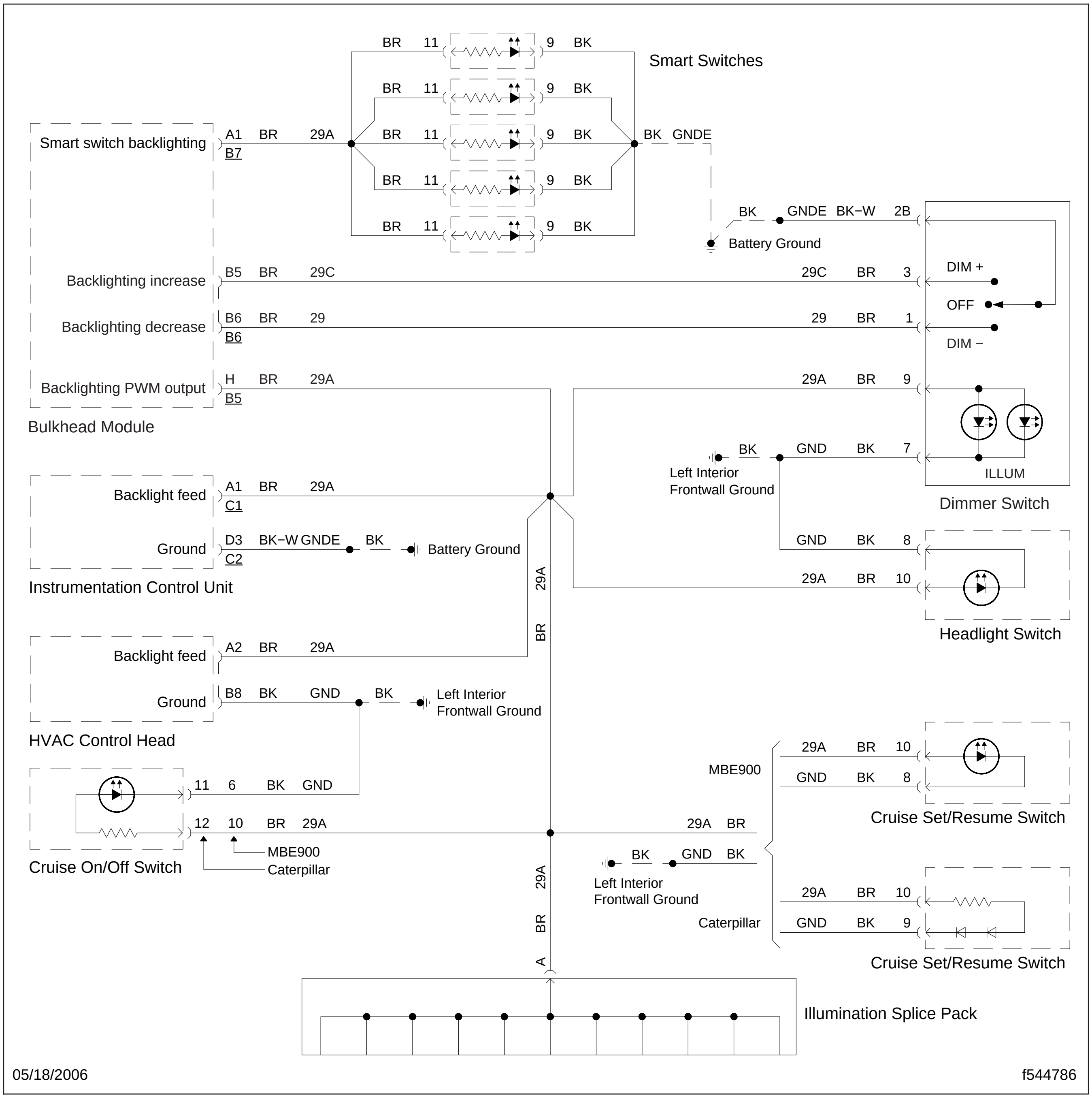


Fig. 1, Backlighting Dimmer Controls

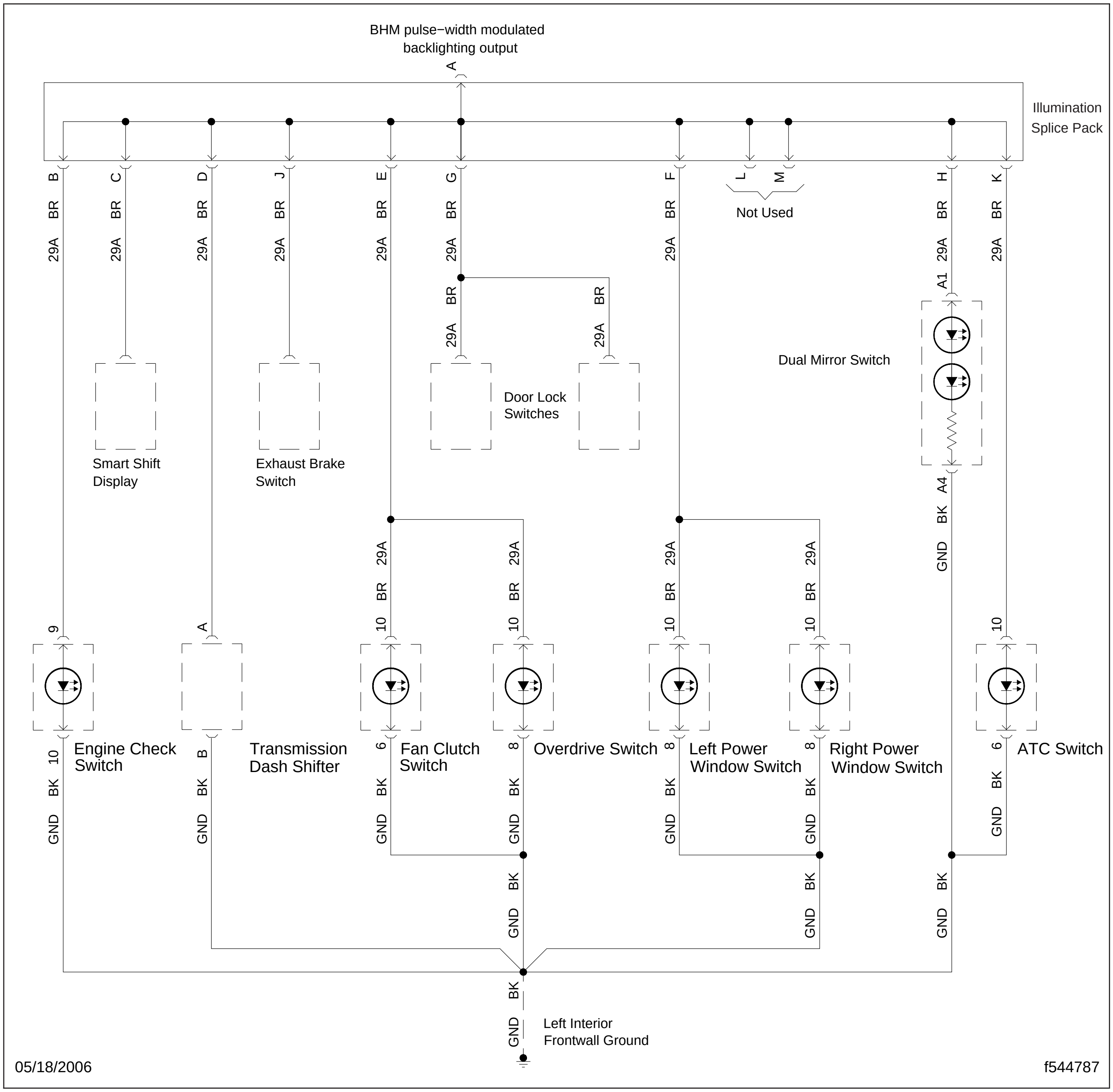


Fig. 2, Backlighting

Specifications

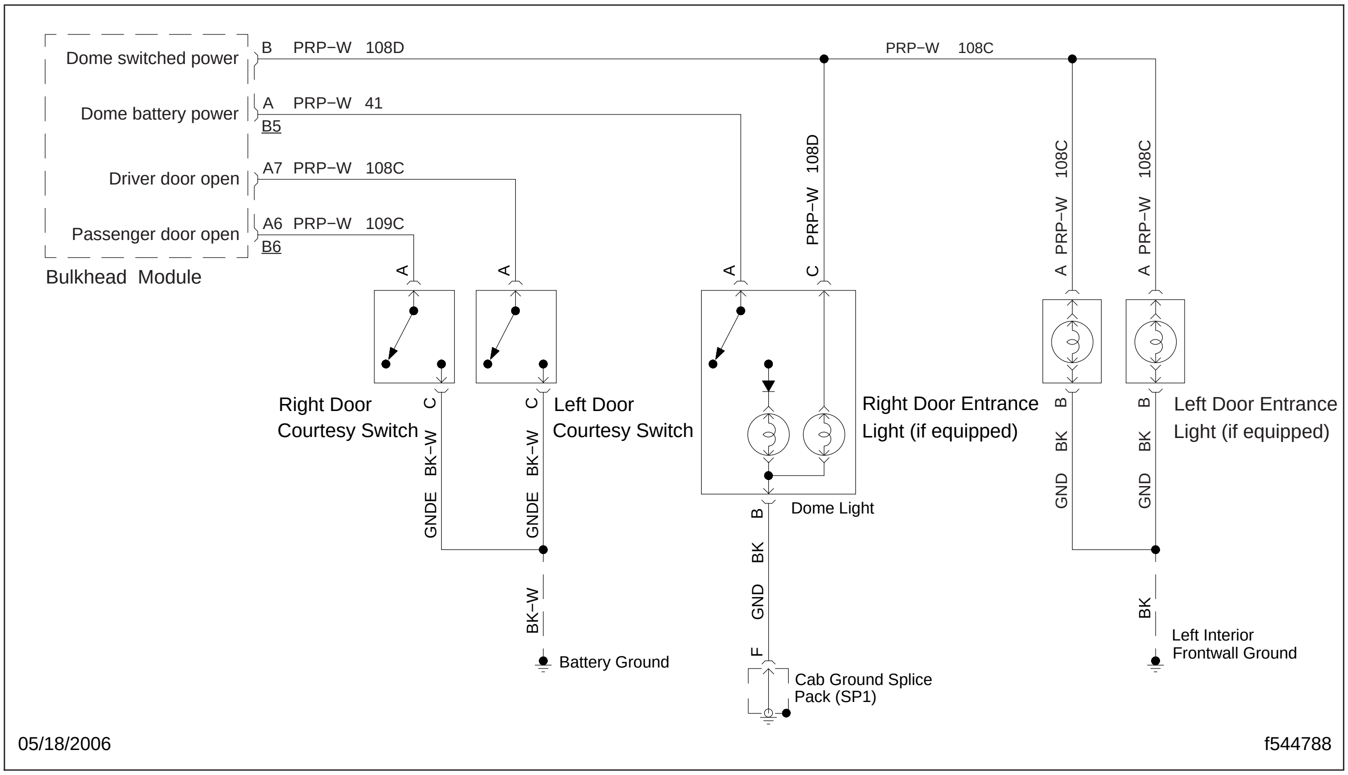


Fig. 3, Single Rear Dome Light

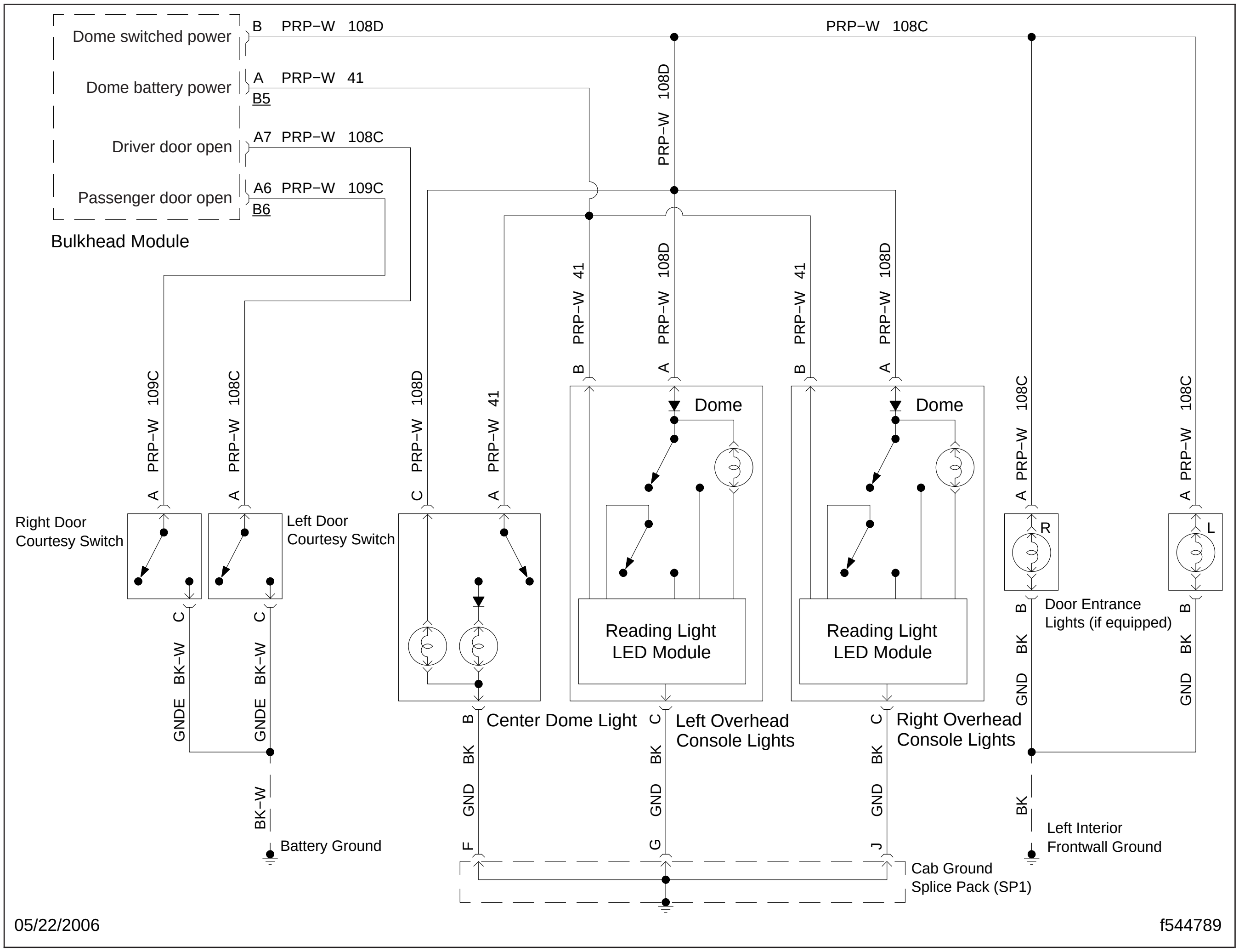


Fig. 4, Overhead Console

Specifications

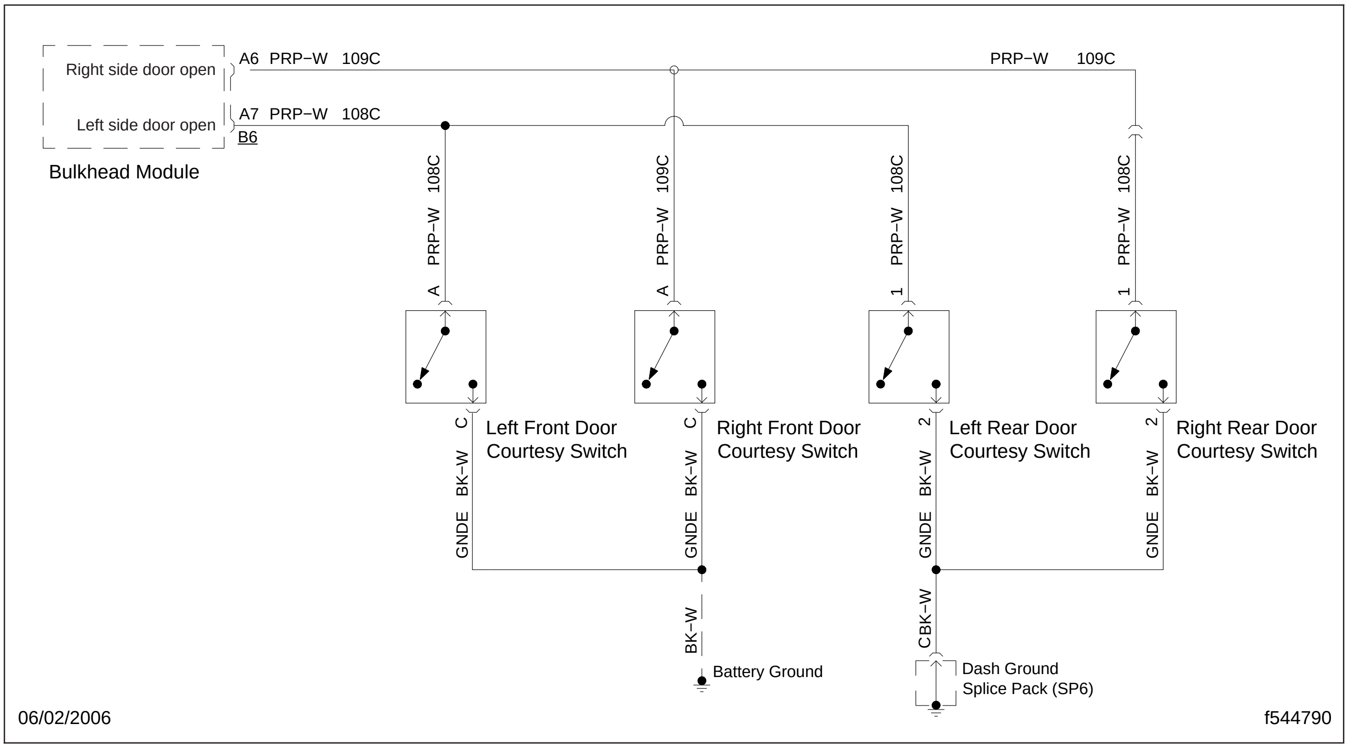


Fig. 5, Crew Cab Door Switches

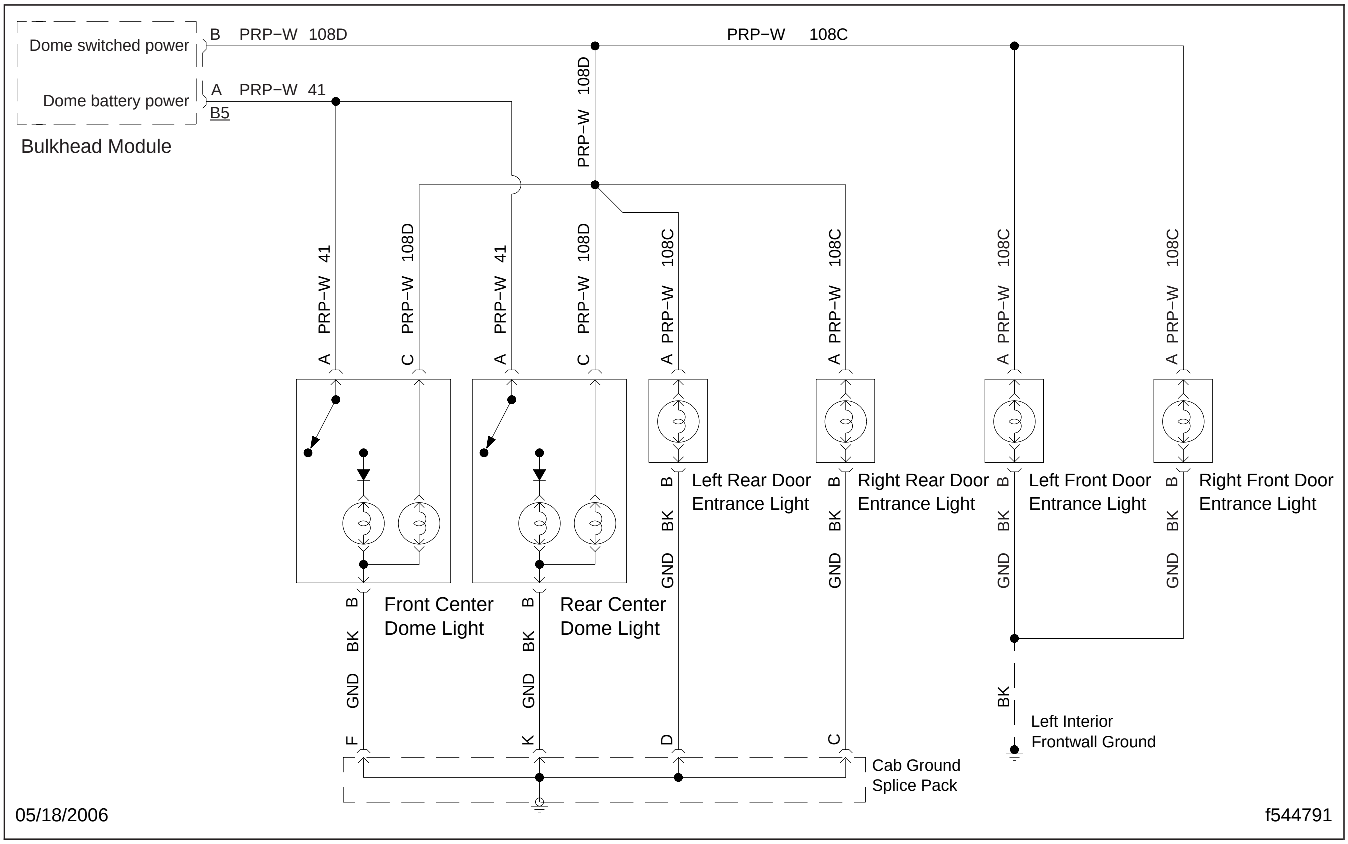


Fig. 6, Two Dome Lights

Specifications

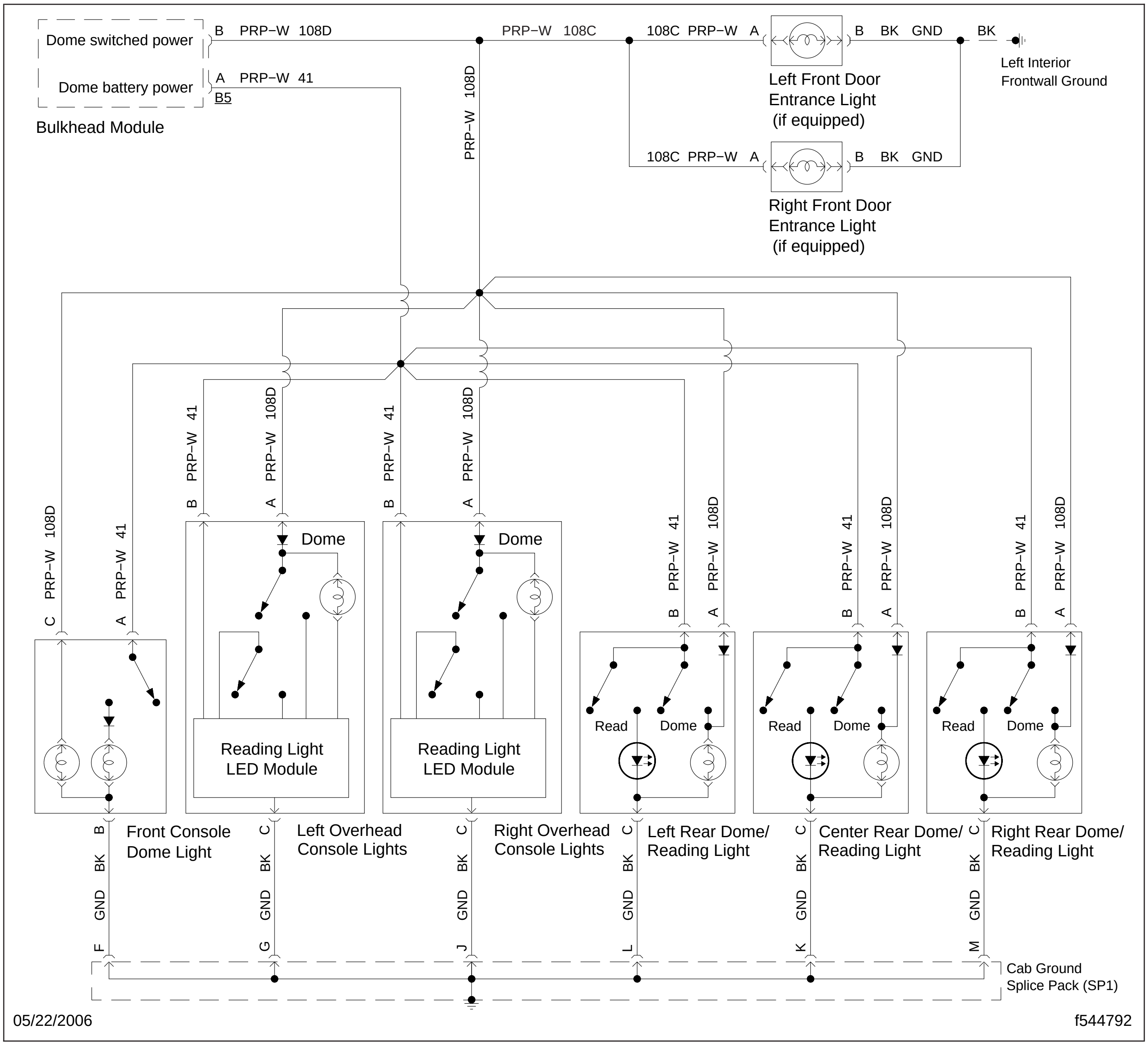


Fig. 7, Six Dome Lights with Optional Front Entrance Lights

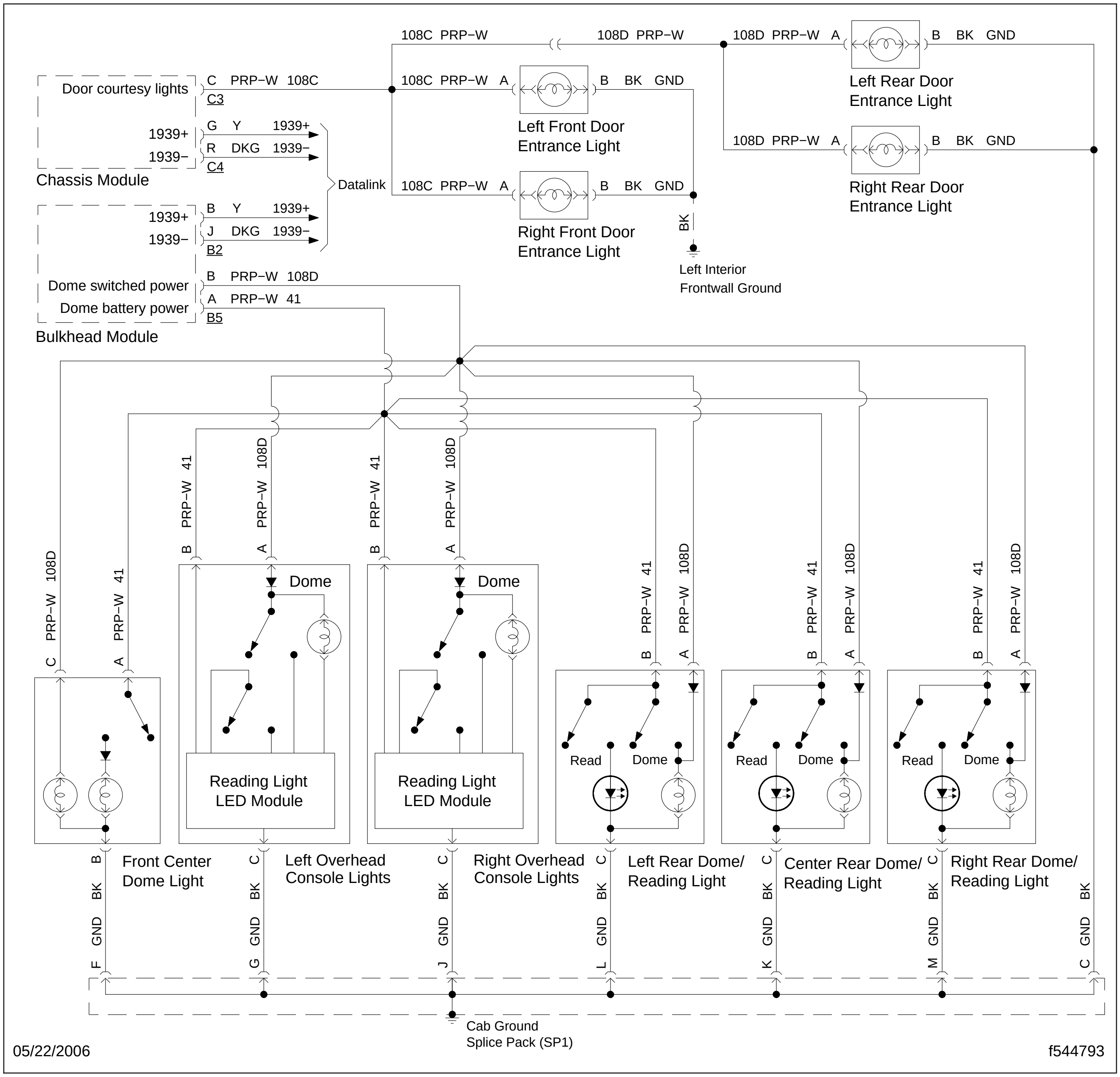


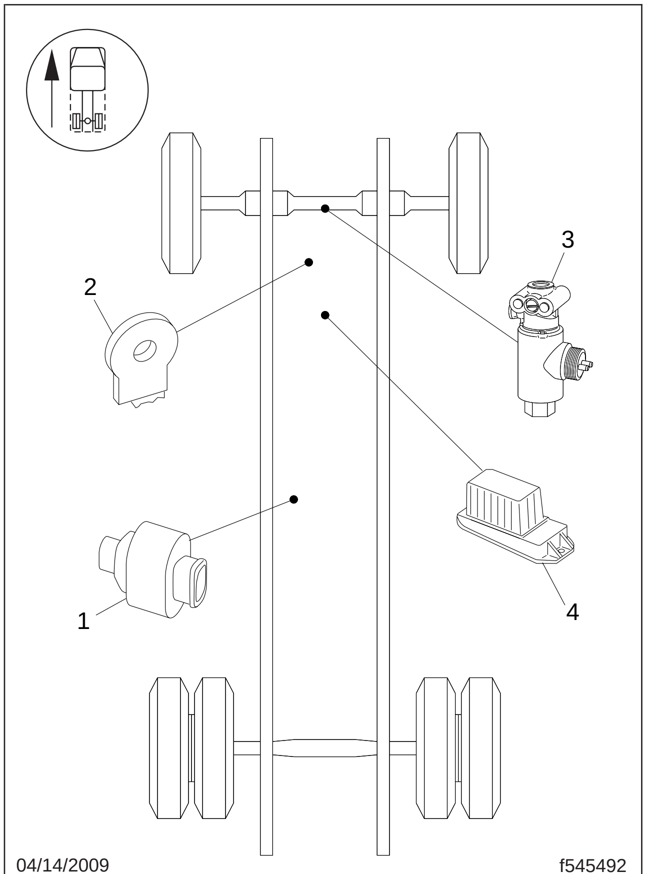
Fig. 8, Six Dome Lights with Four Entrance Lights

General Information

The Roll Stability Control (RSC) system is an electronic system that passively monitors wheel speed and lateral acceleration. The system controls drive axle and trailer axle braking while decreasing engine torque and applying engine retarder (if equipped) in emergency roll over situations. As a result, the driver has full control over the vehicle until the ABS Electronic Control Unit (ECU) detects a potential rollover, and intervenes accordingly.

When active, tractor rear brakes are applied using the ATC solenoid valve while the trailer brakes are applied by the RSC solenoid valve. This is the same process used for the ATC, that is connected between the pneumatic brake system foot valve and the rear relay brake valve. The RSC valve is connected between the foot valve and the tractor protection valve. In normal operation, the roll stability control valve is inactive and allows control of the trailer brakes from the foot valve. If a rollover is about to occur, the valve opens the air supply from the secondary air tank to the tractor protection valve, that activates the trailer brakes. See **Fig. 1**.

The Electronic Stability Control (ESC) system is an RSC system that offers the additional capability of complete directional stability (yaw control) in oversteer and understeer conditions, such as the ability to reduce the likelihood of drift-out or jackknife. The ESC system includes an additional solenoid valve for front axle braking, a brake pressure sensor, a Steering Angle Sensor (SAS), and an Electronic Stability Control ECU (ESC module) with an integrated yaw rate sensor. The additional sensors allow the ECU to determine where the driver is attempting to steer the vehicle and how much brake demand is required in order to more precisely control the vehicle in an emergency situation. The additional front solenoid valve allows for individual wheel braking on the steering axle to provide yaw control.



1. Brake Demand Pressure Sensor
2. Steering Angle Sensor
3. Front Axle Solenoid Valve
4. ESC Module

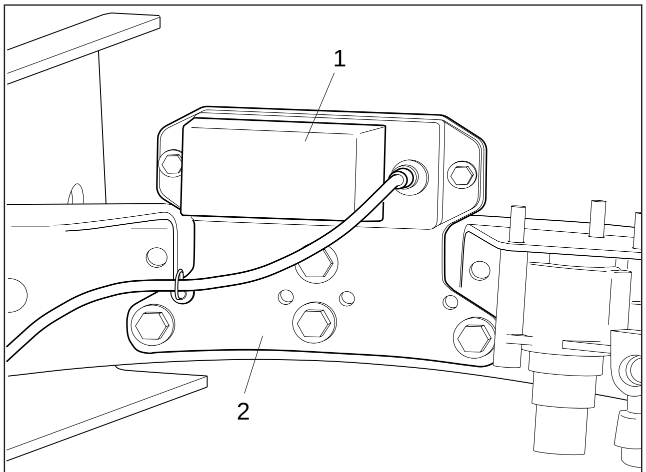
Fig. 1, Electronic Stability Control Components

Electronic Stability Control Module

The ECU is mounted under the cab on the crossmember located behind the transmission. See **Fig. 2** and **Fig. 3**.

The ESC module has two sensors: an accelerometer and a yaw rate sensor. An accelerometer is used to measure lateral acceleration. During cornering, lateral acceleration causes a force directed at the vehicles center of gravity, and if high enough, can cause a vehicle to roll. The yaw rate sensor provides rotational sensing that can be used to detect and help prevent vehicle spinout or jackknife. The ESC module has one 4-pin connector that is used to communicate with the ABS ECU.

General Information



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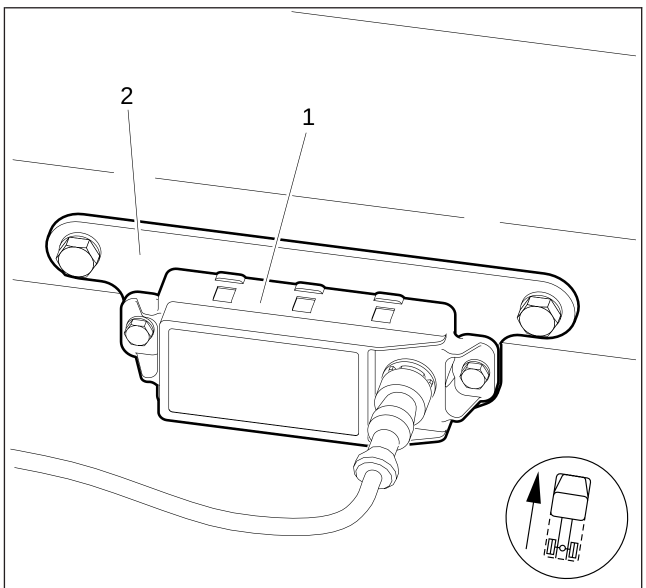
1. ESC Module
2. Mounting Bracket

Fig. 2, Electronic Stability Control Module, Extended Cab Mounting



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1. ESC Module
2. Mounting Bracket

Fig. 3, Electronic Stability Control Module, Day Cab Mounting

ESC Module Removal and Installation

Removal

1. Shut down the engine and chock the tires.
2. Disconnect the electrical connector.
   2.1 Turn the collar on the connector counter-clockwise until it stops.
   2.2 Disconnect the connector.
3. Remove the two screws from each side of the ESC module.
4. Remove the ESC module.

Installation

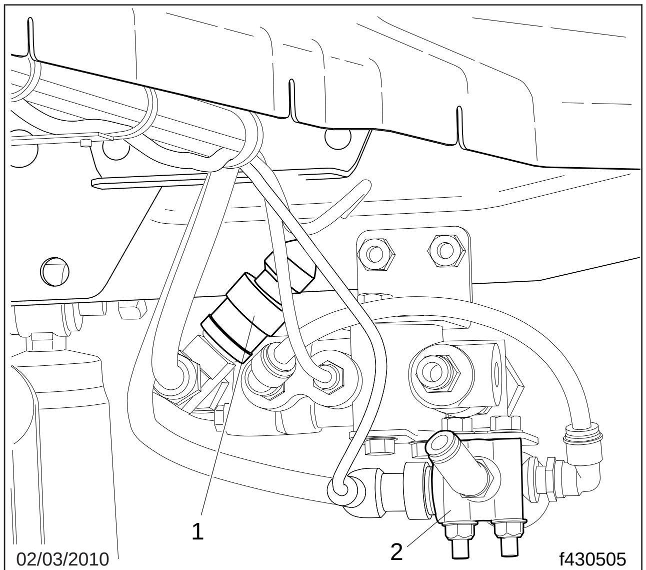
1. Position the ESC module on the crossmember and install two screws and nuts. Tighten the screws 16 lbf·ft (22 N·m).
2. Connect the electrical connector.
3. Initialize the new ESC module. Refer to the Meritor WABCO End of Line (EOL) procedure for the initialization process. The procedure can be found in the latest version of the Meritor WABCO Maintenance Manual (MM-0112). This document is available at the **Meritor WABCO website**.

NOTE: For complete instructions for using TOOLBOX software, refer to the ArvinMeritor "TOOLBOX User's Manual, TP-99102."

RSC Valve Removal and Installation

Removal

1. Shut down the engine and chock the tires.
2. Release the pressure from the air reservoirs.
3. Disconnect the electrical connector from the roll stability control (RSC) valve. See **Fig. 1**.



1. Brake Demand Pressure Sensor
2. Roll Stability Control Valve

Fig. 1, Pressure Sensor (mounted on trailer protection valve)

  3.1 Turn the collar on the connector counterclockwise until it stops.

  3.2 Disconnect the connector.

4. Disconnect the air lines.
5. Remove the two mounting screws and nuts.
6. Remove the RSC valve.

Installation

1. Position the RSC valve on the crossmember and install two mounting screws and nuts. Tighten the screws 13 lbf·ft (18 N·m).
2. Connect the air lines.
3. Connect the electrical connector to the RSC valve. Hand-tighten only.
4. Verify operation of the RSC valve.

  4.1 Connect the blue gladhand to a 50 cubic inch (819 cubic cm) air tank.

  4.2 Start the vehicle and allow the air reservoirs to fully charge.

  4.3 Shut down the engine.

  4.4 Turn the ignition to ON. Verify that the ATC/RSC/ESC indicator lamp operates correctly.

  4.5 Activate the RSC valve using the Meritor WABCO PC Diagnostics tool, TOOLBOX.

  4.6 Check for air leaks at the RSC valve. If the RSC valve leaks, make the necessary repairs.

  4.7 If the RSC valve fails to cycle, turn off the ignition and make sure the electrical connections are tight. Turn the ignition switch on and check the valve again. If the RSC valve still fails to cycle, check for fault codes.

Front Solenoid Valve Removal and Installation

Removal

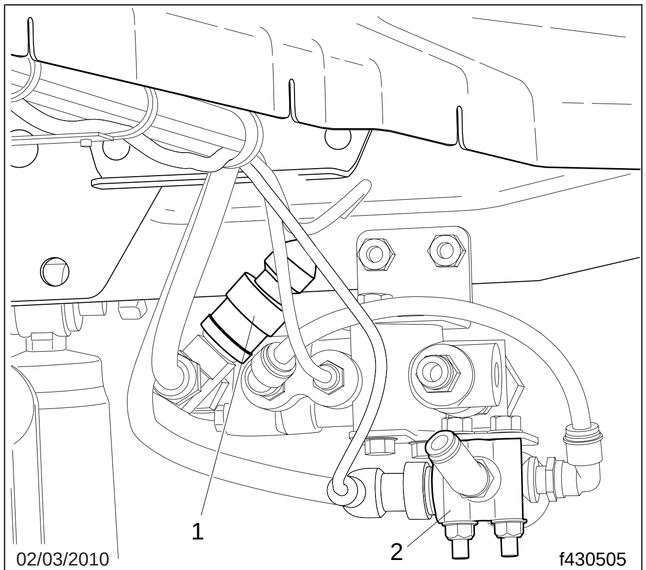
1. Shut down the engine and chock the tires.
2. Release the pressure from the air reservoirs.
3. Disconnect the electrical connector from the front solenoid valve.
   3.1 Turn the collar on the connector counter-clockwise until it stops.
   3.2 Disconnect the connector.
4. Disconnect the air lines.
5. Remove the two mounting screws and nuts.
6. Remove the front solenoid valve.

Installation

1. Mount the new solenoid valve and install the two screws and nuts. Tighten the nuts to 8 lbf·ft (11 N·m).
2. Connect the air lines to the front solenoid valve.
3. Connect the electrical connector to the front solenoid valve. Hand-tighten only.
4. Verify the operation of the solenoid valve.
   4.1 Start the vehicle and allow the air reservoirs to fully charge.
   4.2 Shut down the engine.
   4.3 Apply the brakes and check for air leaks at the front solenoid valve.
   4.4 Turn the ignition to ON. Verify that the ATC/RSC/ESC indicator lamp operates correctly.
   4.5 Activate the front solenoid valve using the Meritor WABCO PC Diagnostics tool, TOOLBOX.
   4.6 Check for air leaks at the front solenoid valve. If valve leaks, make necessary repairs.
   4.7 If front solenoid valve fails to cycle, turn off the ignition and make sure the electrical connections are tight. Then, turn the ignition switch on and check the valve again. If the front solenoid valve still fails to cycle, check for fault codes.

Removal

1. Shut down the engine and chock the tires.
2. Release the pressure from the air reservoirs.
3. Disconnect the wiring from the pressure sensor. See **Fig. 1**.



1. Brake Demand Pressure Sensor
2. Roll Stability Control Valve

Fig. 1, Pressure Sensor

    3.1 Turn the flange on the connector counterclockwise until it stops.

    3.2 Disconnect the connector.

4. Disconnect the pressure sensor.

Installation

1. Install the new air pressure sensor. Make sure that the pressure sensor is secured; the connector end should be higher than the threaded end to prevent freezing water from disabling the sensor.
2. Connect the electrical connector to the pressure sensor. Hand-tighten only.
3. Verify operation of the pressure sensor.

    3.1 Connect the blue gladhand to a 50 cubic inch (819 cubic cm) air tank.

    3.2 Start the engine and allow the air reservoirs to fully charge.

    3.3 Shut down the engine.

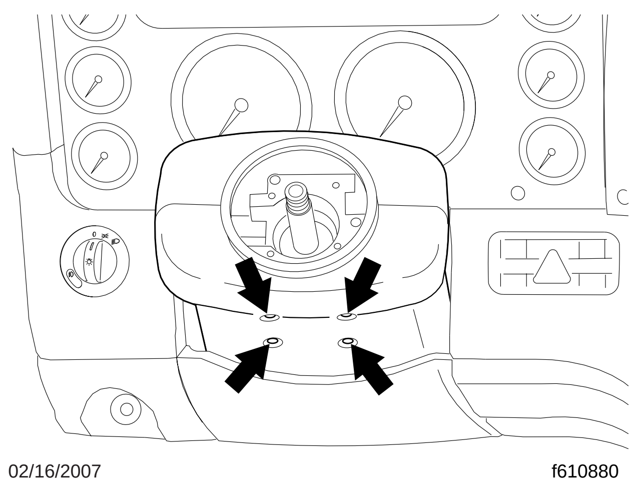
    3.4 Apply the brakes and check the pressure sensor fitting for leaks.

    3.5 Test drive the vehicle to verify that the ATC/RSC/ESC indicator lamp operates correctly.

Steering Angle Sensor Removal and Installation

Removal

1. Shut down the engine and chock the tires.
2. Remove the knee bolster panel, located below the steering column. Remove the four fasteners. See **Fig. 1**.



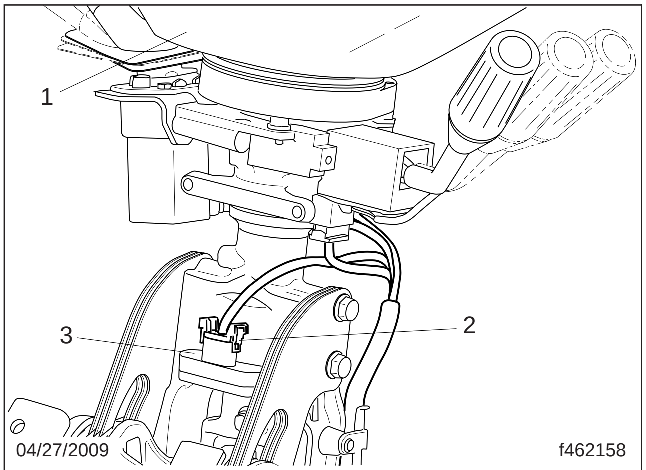
A. Steering wheel not shown for clarity.

Fig. 1, Lower Steering Column Cover Fasteners

3. Remove the steering column.
   - 3.1 Remove the pinch bolt and nut from the upper end yoke on the steering column shaft. Discard the pinch bolt and nut.
   - 3.2 Slide the upper-end yoke off the splines on steering column shaft.
4. Remove the 7-pin connector from the steering angle sensor. See **Fig. 2**.
5. Remove the 3 screws (two upper, one lower) holding the steering angle sensor to the steering column. See **Fig. 3**. Discard the 3 T20 screws and remove the steering angle sensor.

Installation

1. Apply a small amount of grease to the tab in the middle of the steering angle sensor opening, and to the groove of the steering shaft.
2. Place the new steering angle sensor on the steering shaft, making sure to align the guide pin on the steering angle sensor into the grooved slot on the steering shaft. Make sure the steering angle sensor is facing the same direction as originally installed.

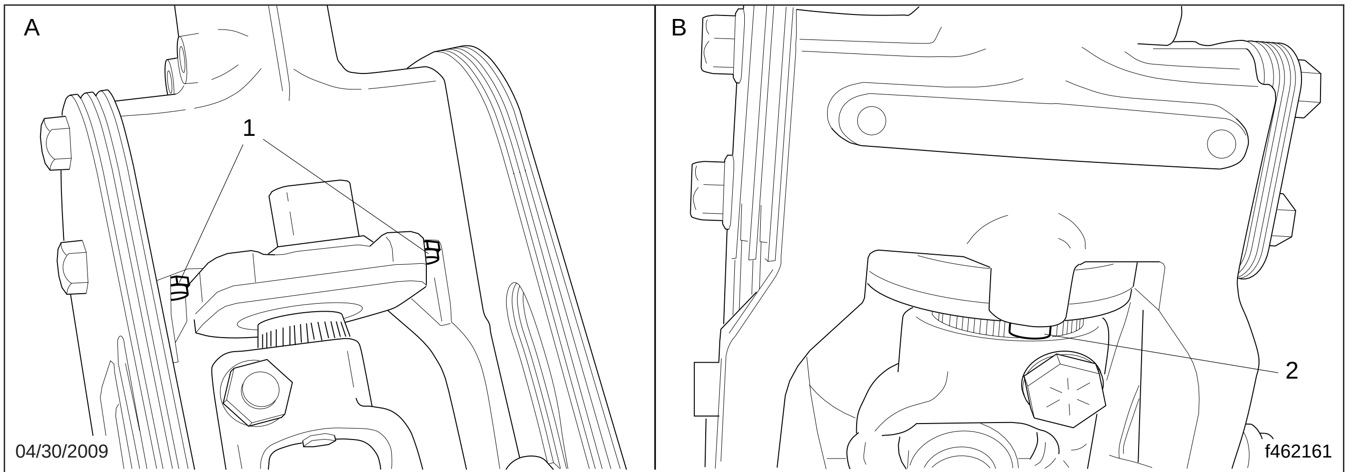


1. Steering Column
2. 7-Pin Connector
3. Steering Angle Sensor

Fig. 2, Steering Column Assenmbly

3. Secure the steering angle sensor onto the steering column using three new T20 screws.
4. Using a new pinch bolt and nut, attach the upper end yoke to the steering column shaft. Tighten the bolt 30 to 35 lbf·ft (41 to 47 N·m).
5. Connect the 7-pin connector onto the new steering angle sensor.
6. Install the steering column.
   - 6.1 Slide the upper-end yoke on to the splines on steering column shaft.
   - 6.2 Install the pinch bolt and nut on the upper end yoke on the steering column shaft.
7. Install the knee bolster. Tighten the four screws 26 to 34 lbf·in (295 to 385 N·cm).
8. Install the steering column upper and lower covers. Tighten the screws 26 to 34 lbf·in (295 to 385 N·cm).
9. Initialize the ESC module. Refer to the Meritor WABCO End of Line (EOL) procedure for the initialization process. In addition, when the steering angle sensor is replaced, it is important that the sensor is re-calibrated. These procedures can be found in the latest version of the Meritor

Steering Angle Sensor Removal and Installation



A. Steering Angle Sensor, Front
B. Steering Angle Sensor, Back

1. Upper Mounting Screws
2. Lower Mounting Screw

Fig. 3, Steering Angle Sensor

WABCO Maintenance Manual (MM-0112). This document is available at the **Meritor WABCO website**.

NOTE: For complete instructions for using TOOLBOX software, refer to the ArvinMeritor "TOOLBOX User's Manual, TP-99102."

Introduction

Lighting interface harnesses are used to provide a Business Class® M2 with additional lighting connections. Designed lighting interface harnesses discussed in this section include:

- high current
- low current
- additional marker lights

High-current and low-current interface harnesses provide multiple CHM-controlled lighting outputs such as taillights, stop lights, turn lights, and backup lights. Some vehicles that come equipped with additional marker light interface harnesses provide either a marker light 2-pin jumper harness or a customer access junction block with a marker light feed. When a vehicle is not equipped with a preinstalled marker light interface harness, additional marker lights can be supplied by a splice connection.

Overview

Many of the lighting interface harnesses provide signals that receive current protection from Chassis Module (CHM) outputs. The CHM will shut down outputs that exceed their maximum current capacity. When adding additional lighting to a vehicle, be sure to identify all loads of the same function that draw their current protection from the CHM. Make sure that the combined load from like sources does not exceed the maximum current capacity for any CHM output. Keep in mind that you need to consider the factory-installed lighting that remains on the vehicle. For circuit information, including current capabilities, see **Subject 400**.

If body marker lights are the only lights being added, tie the lights in to the vehicle electrical system using a jumper, a junction block, or a splice. See "Marker Light Jumper," "Marker Light Junction Block," and "Marker Light Splice" in this subject for more information.

Install an inline fuse to allow the technician to separate the marker lights when troubleshooting is required. To determine the fuse rating:

1. Add the steady-state current draw of the lighting load.
2. Select a standard fuse rating that is between 10 and 20 percent greater than the steady-state current draw. If there is not a standard fuse available in this range, use the next closest standard value up to the 10-amp limit.

High-Current Lighting Interface

The high-current interface harness is a 19-pin customer connector that provides 20-amp lighting outputs. The interface harness is located at the back of the cab or at the rear of the frame rail. High-current lighting is made possible by equipping the vehicle with a taillight power distribution module (PDM). The taillight PDM is usually mounted on the left frame rail aft of the cab, or on a rear crossmember at the end of the frame rail. The PDM contains relays and fuses for each lighting output. Direct battery power is supplied to the taillight PDM fuses via a cable connection to a 150-amp MEGA® Fuse. The CHM sends digital outputs to control the PDM lighting relays. The energized relays deliver 20-amp fuse-protected lighting outputs to the high-current interface harness. Taillight PDM outputs include:

- taillights
- backup lights
- stop lights
- turn lights

Low-Current Lighting Interface

The low-current interface harness terminates in a 12-pin connector that provides access to CHM-protected lighting outputs. The interface harness connector can be located in the engine compartment, at the back of the cab, or at the rear of the frame rail. The low-current interface harness provides the following lighting circuits:

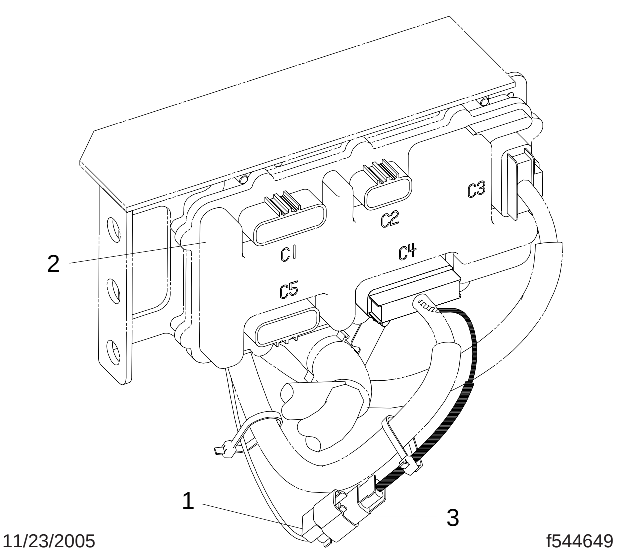
- taillights
- backup lights
- stop lights
- turn lights

The low-current interface harness is suitable for limited load applications such as additional LED lighting. Since the interface harness outputs are splices from existing circuits, CHM maximum current loads can not be exceeded. Most of the CHM lighting outputs provide a maximum current load of 6.7 amps, with the exception of the taillight outputs which provide a combined maximum current load of 1 amp. Current loads for each output include lighting connected to the interface harness plus all factory-installed lighting of the same function that is not permanently removed during body installation.

Marker Light Jumper Harness

The optional marker light jumper harness establishes a connection at pin M of the CHM connector C4. See **Fig. 1**. The harness provides additional marker light feeds via a 2-pin connector usually located near the CHM. The 2-pin connector supplies marker light outputs at both pins. The CHM output that provides the marker light feed to the junction block has a maximum combined current load of 10 amps. Marker lamp connections made to the the jumper harness should include an appropriately sized inline fuse for further circuit protection.

If the vehicle is not equipped with a marker light jumper harness, a harness can be installed by a Freightliner dealer.

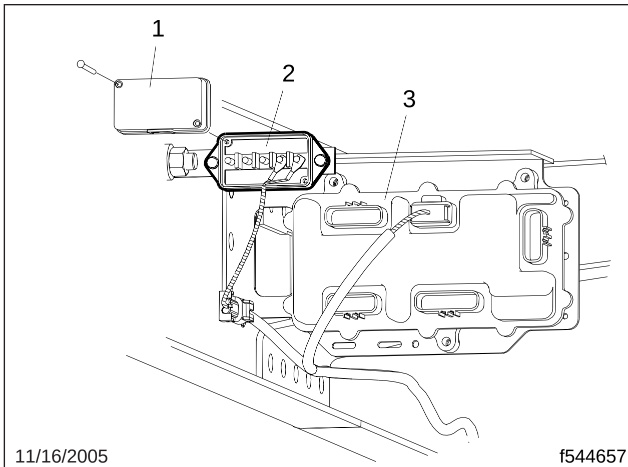


1. Body Builder Marker Light Connection
2. Chassis Module
3. Jumper Harness

Fig. 1, Marker Light Jumper Harness

Marker Light Junction Block

Some vehicles are equipped with a customer access junction block that is usually located on the frame rail near the CHM. See **Fig. 2**. This feature provides a 5-post quick connection point to support easy customer access. For one post, the junction block feed comes from a dash-mounted optional switch that provides 15-amp fused power. See **Section 54.40** for more information on connecting to the junction block. On another post, the junction block is provided a marker light feed from the CHM. The CHM output that provides the marker light feed to the junction block has a maximum combined current load of 10 amps. When establishing additional marker lamp connections to the the junction block, install an appropriately sized inline fuse for further circuit protection.



1. Junction Block Cover
2. Junction Block
3. Chassis Module

Fig. 2, Junction Block

Marker Light Splice

The marker light splice requires making a splice connection on the existing marker light circuit, located at pin M of the CHM connector C4. The new spliced feed should be equipped with an appropriately sized inline fuse. Do not exceed a combined load of 10 amps at pin M of CHM connector C4.

Components

If electrical lighting interface harnesses need to be added to a vehicle, visit a local Freightliner dealer to request a bill of material. Be prepared to provide the dealer with the vehicle identification number (VIN) and a sales option code (if known) for the desired feature. The bill of material provides a complete parts list that is tailored to the configuration and dimension of the vehicle.

The following components are necessary for creating a high-current lighting interface harness:

- taillight PDM with mounting hardware and bracket
- high-current interface harness
- harness between the CHM and the taillight PDM
- harness between the taillight PDM and the interface connector
- power cable between the battery and the taillight PDM
- 150-amp MEGA Fuse

Installation or Replacement Guidelines

When installing or replacing any part of an electrical system, follow these guidelines:

- Make ground connections at factory-provided ground stud locations whenever possible. If there is no ground stud available, it will be necessary to add a bolt or self-threading fastener to connect the ground lugs to the frame rail.
- Route all wiring so that it will not be exposed to harmful conditions such as moving parts, excessive heat, chafing, or saturation with oil or grease.
- Secure and protect all electrical components. Use appropriate mounting and installation techniques such as retaining clips, harness protection, and correct hardware.
- Be sure to clean all paint, dielectric enamel, and road grime from the ground stud or frame before connecting the new ground leads. After the connections are secured, use a dielectric enamel on the ground connections to protect against corrosion.
- Removal of electrical components for an extended period of operation requires proper weatherproofing to avoid system damage and electrical faults.

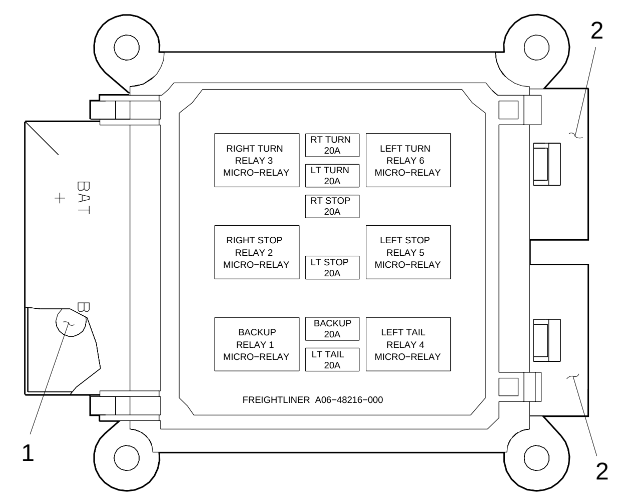
Taillight PDM Removal and Installation

Removal

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the negative leads from the batteries or, if the vehicle is equipped with a battery disconnect switch, turn the switch to the off position.

NOTE: The taillight power distribution module (PDM) can be mounted on the left frame rail aft of the cab, or on a crossmember at the end of the frame rail. If a vehicle is equipped with both a taillight PDM and trailer PDM, the taillight PDM is always mounted in the left frame rail aft of the cab.

3. Remove the nut and washer that attach the positive lead to the taillight PDM battery power stud, and remove the positive lead. See **Fig. 1**.
4. Disconnect the electrical connectors from the taillight PDM. See **Fig. 1**.
5. Remove the nuts and washers that attach the PDM to the mounting bracket, and remove the PDM. See **Fig. 2**.



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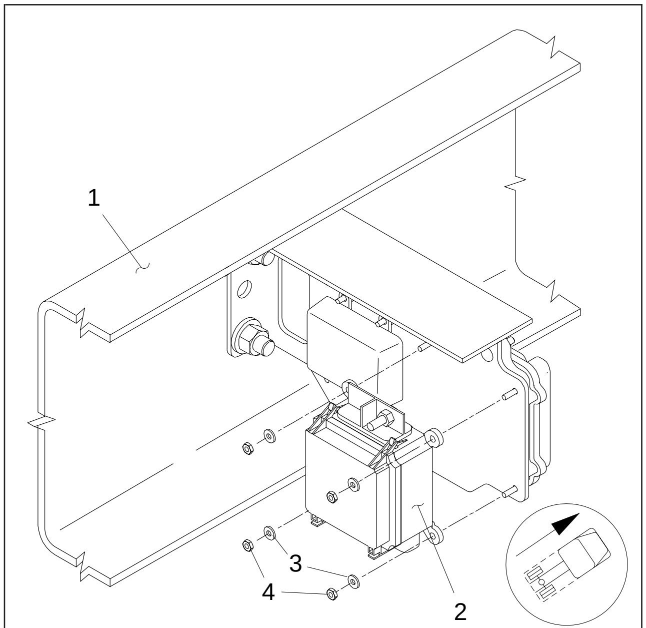
1. Battery Power Stud
2. Electrical Connector

Fig. 1, Taillight PDM Fuse Panel Layout



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1. Left Frame Rail
2. Taillight PDM
3. #10 Washer
4. 10-24 Nut

Fig. 2, Taillight PDM Installation

Installation

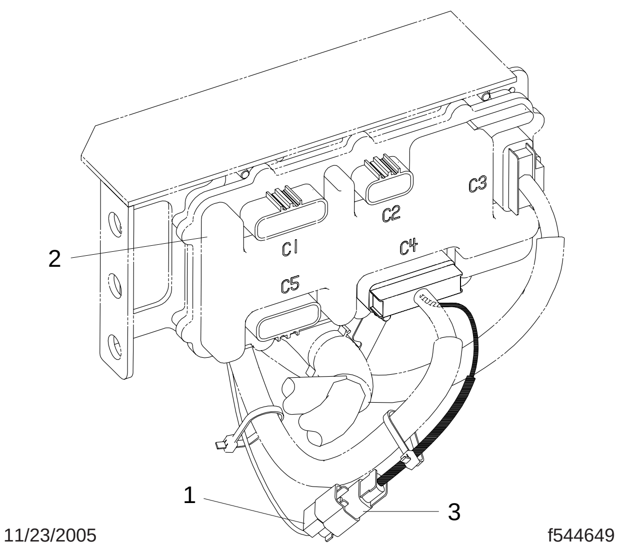
1. Using nuts and washers, install the taillight PDM on the mounting bracket.
2. Attach the electrical connectors to the taillight PDM.
3. Using a nut and washer, install the positive lead on the taillight PDM battery power stud. Torque the nut 11 to 13 lbf·ft (15 to 18 N·m).
4. Connect the batteries or turn the battery disconnect switch to on.
5. Verify the operation of the electrical components.
6. Remove the chocks from the tires.

Marker Light Jumper Harness for a Vehicle With an Optional Factory-Installed Harness

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the negative leads from the batteries.

NOTE: The Chassis Module (CHM) is located on a bracket behind the back-of-cab crossmember (standard location) or underneath the cab on the driver side. For CHM location and connector identification, see **Subject 400**.

3. Find marker light jumper harness A06-53321-000. See **Fig. 1**. The harness is inserted at pin M of the CHM electrical connector C4.



1. Body Builder Marker Light Connector
2. Chassis Module
3. Jumper Harness

Fig. 1, Marker Light Jumper Harness

4. Remove the seal plug from cavity B of the 2-pin connector of the marker light jumper harness and connect jumper harness A06-19868-074 to the cavity.
5. Splice additional marker lights to the blunt cut wire of harness A06-19868-074 using solder and heat shrink tubing.

IMPORTANT: The combined maximum allowable load at the chassis module **must not exceed 10 amps**. The A06-19868-074 harness includes a 7.5 amp inline fuse to ensure that the total load for the circuit does not exceed the maximum allowable 10 amps, including the existing connected load, which is normally 0.7 amps. If greater amperage is required, use the blunt-cut wire to trigger a relay with the power source coming from a separate fused battery supply.

6. Properly install and route the marker light circuit.
7. Connect the batteries.
8. Verify the operation of the marker lights.
9. Remove the chocks from the tires.

Marker Light Jumper Harness for a Vehicle Without an Optional Factory-Installed Harness

NOTE: When adding marker lights to a vehicle without a factory-installed optional harness, jumper harnesses A06-53321-000 and A06-19868-074 are required.

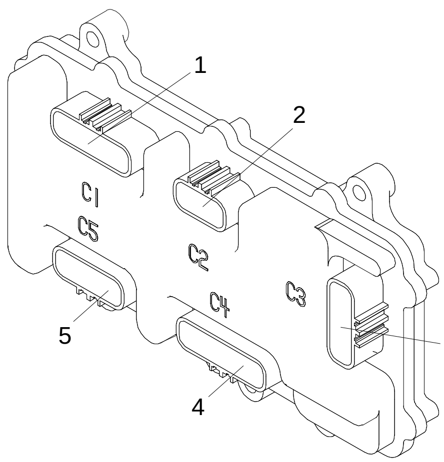
1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the negative leads from the batteries.

NOTE: The Chassis Module (CHM) is located on a bracket behind the back-of-cab crossmember (standard location) or underneath the cab on the driver side. For CHM location and connector identification, see **Subject 400**.

3. Disconnect the forward chassis harness from position C4 of the CHM. See **Fig. 2**.
4. Remove circuit 46F (BR, right marker lamp) from cavity M of the forward chassis harness. See **Fig. 3** and **Fig. 4**.
5. Connect the single connector end of jumper harness A06-19868-073 into cavity M of the forward chassis harness. See **Fig. 5**.
6. Connect the forward chassis harness to position C4 of the CHM.

Marker Light Connections

7. Connect circuit 46F to cavity A of the 2-pin connector of jumper harness A06-19868-073.
8. Remove the seal plug from cavity B of the 2-pin connector of jumper harness A06-19868-073, and connect jumper harness A06-19868-074 to the cavity. See **Fig. 5** and **Fig. 6**.
9. Splice additional marker lights to the blunt-cut wire of harness A06-19868-074 using solder and heat-shrink tubing.



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1. C1, Tail Harness
2. C2, Trailer Module Harness
3. C3, Forward Chassis Harness
4. C4, Forward Chassis Harness
5. C5, Air Management Unit

Fig. 2, Chassis Module Connections

IMPORTANT: The combined maximum allowable load at the chassis module must not exceed 10 amps. The A06-19868-074 harness includes an inline fuse to ensure that the total load for the circuit doesn't exceed the maximum allowable 10 amps including the existing connected load which is normally 0.7 amps. If greater amperage is required, use the blunt-cut wire to trigger a relay with the power source coming from a separate fused battery supply.

10. Properly install and route the marker light circuit.
11. Connect the batteries.
12. Verify the operation of the marker lights.
13. Remove the chocks from the tires.

Marker Light Junction Block

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the negative leads from the batteries.

NOTE: The Chassis Module (CHM) is located on a bracket behind the back-of-cab crossmember (standard location) or underneath the cab on the driver side. For CHM location and connector identification, see **Subject 400**.

3. Find the junction block attached to the frame rail near the CHM. See **Fig. 6**.
4. Remove the capscrews that attach the junction block cover to the junction block, and remove the cover. Then find the marker light feed at the yellow wire.
5. Using an appropriate ring terminal, connect the marker light circuit to the junction block.

IMPORTANT: The combined maximum allowable load at the chassis module **must not exceed 10 amps**.

6. Use an appropriately sized inline fuse to provide proper circuit protection to the marker light circuit.
7. Properly install and route the marker light circuit.
8. Using capscrews, attach the junction block cover to the junction block.
9. Connect the batteries.
10. Verify the operation of the marker lights.
11. Remove the chocks from the tires.

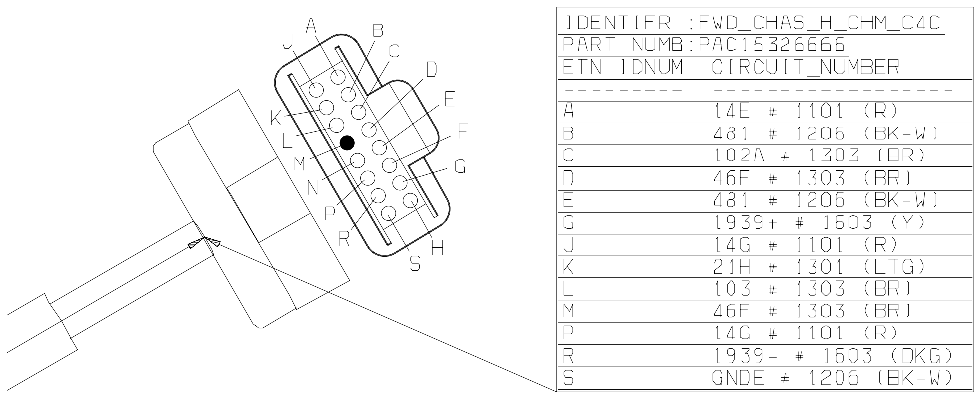
Marker Light Splice

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the negative leads from the batteries.

NOTE: The Chassis Module (CHM) is located on a bracket behind the back-of-cab crossmember (standard location) or underneath the cab on the driver side. For CHM location and connector identification, see **Subject 400**.

3. Find pin M of the CHM electrical connector C4.

Marker Light Connections



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NOTE: Cavities I, O, and Q are skipped to avoid confusion with the numbers 1 and 0. Connector end view is shown from the wire insertion end.

Fig. 3, Typical Forward Chassis Harness at Position C4

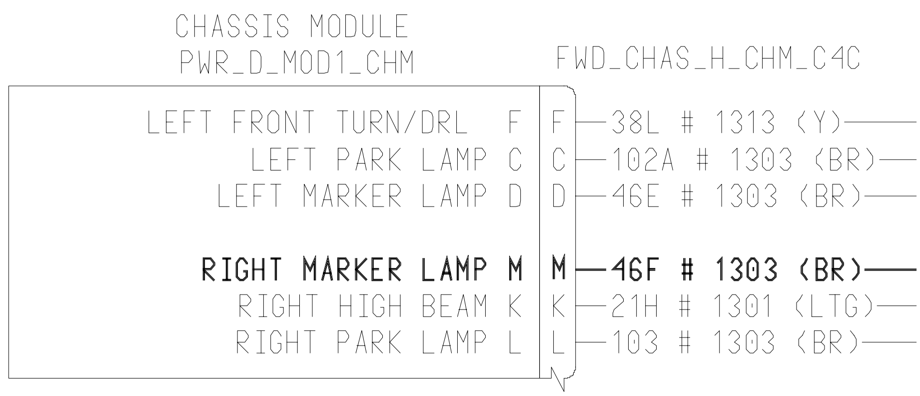

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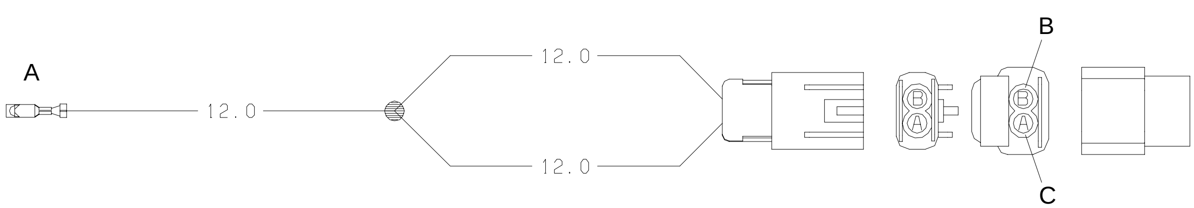
Fig. 4, Exterior Lighting Schematic at Chassis Module Connection C4



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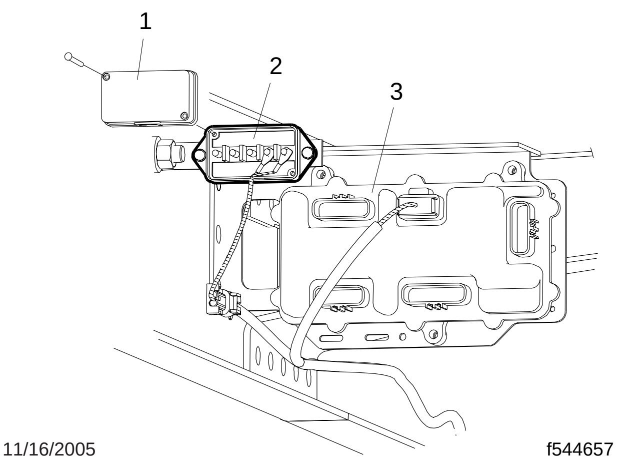
NOTE: Dimensions are in inches. Connector end view is shown from the wire insertion end.

A. Connect to cavity M of the forward chassis harness at position C4 of the Chassis Module.
B. Connect to harness A06-19868-074.
C. Connect to circuit 46F.

Fig. 5, Jumper Harness A06-19868-073

Marker Light Connections



1. Junction Block Cover
2. Junction Block
3. Chassis Module

Fig. 6, Junction Block Location

4. Pull back the wire loom to expose a sufficient length of circuit 46F to allow for splicing.
5. Splice within 6 to 8 inches (150 to 200 mm) of the CHM using appropriate waterproof methods.

IMPORTANT: The maximum allowable load from the vehicle chassis marker lights, combined with the added load of the body marker lights, **must not exceed 10 amps**.

6. Use an appropriately sized inline fuse to provide proper circuit protection to the marker light circuit.
7. Properly install and route the marker light circuit.

   Using electrical tape, wrap the harness bundle at least 2 inches (51 mm) on both sides of the splice connection, and wrap the added circuit at least 2 inches (51 mm) beyond the splice point to protect the marker light circuit. To reduce the chance of abrasion, cut a small notch in the wire loom where the added circuit leaves the loom. Install the wire loom over the harness bundle.
8. Connect the batteries.
9. Verify the operation of the marker lights.
10. Remove the chocks from the tires.

Stop Light Function

The stop light function of the high-current interface harness and the low-current lighting interface harness depends on the programming of the vehicle. Combination stop and turn lights are standard on M2 vehicles; however, it is possible to program the BHM (bulkhead module) for separate stop and turn lights. See **Table 1**.

To determine the stop lamp configuration presently programmed on a vehicle:

- Observe the lights in operation;
- Obtain the sales data-code description for the taillights from the dealer;
- Or use ServiceLink® to view the rear lighting reference parameter that begins with 26-01020.

When adding or changing a feature on the M2, you must use ServiceLink to update the programming on the vehicle. See **Section 54.28**, "Rear Lighting and Turn Signal Systems," for information on programming the functions of the stop and turn signal lights.

Stop Light Function			
Interface Type	**Pin Location**	**Programmed for Combination Stop and Turn Lights**	**Programmed for Separate Stop and Turn Lights**
Low Current	7	Right Stop/Turn Light	Right Stop Light
Low Current	8	Left Stop/Turn Light	Left Stop Light
High Current	10	Right Stop/Turn Light	Right Stop Light
High Current	18	Left Stop/Turn Light	Left Stop Light

Table 1, Stop Light Function

Troubleshooting

Electrical Troubleshooting		
Option	**Description of Fault**	**Possible Cause**
High Current	No outputs	MEGA® Fuse that supplies the PDM is open or missing.
High Current	No operation on a single output	PDM components are inoperable. Check the PDM fuse (blown) and relay (stuck) for that output.
Low Current, Additional Marker Lights	No operation on a single output	CHM may have disabled the output due to an overloaded circuit. Make sure that the collective load does not surpass the maximum current capacity for that circuit.
All	Intermittent or no operation at all outputs	Loss of connection. Check electrical connectors to make sure they are properly connected. For the high-current interface, check the ground connection.
All	Intermittent or no operation on a single output	Trace the suspect circuit and look for a loose terminal connection or damaged wire.
Additional Marker Lights	Intermittent or no operation	Check to see if the inline fuse is open (blown). Check the additional marker light connection point for proper installation.

Table 1, Electrical Troubleshooting

Current Capabilities

The high-current lighting interface harness supplies 20-amp circuit protection on all outputs. The Chassis Module (CHM) controls relays located in the taillight power distribution module (PDM). The PDM also contains fuses to provide the 20-amp circuit protection when the relays are activated. Battery power to the taillight PDM fuses is supplied from one of the MEGA® Fuses.

The low-current lighting interface harness provides outputs that are essentially splices from existing CHM lighting signals. The low-current interface harness provides for limited load applications such as additional LED (light-emitting diode) lighting. Since the interface outputs are splices from existing circuits, CHM maximum current loads can not be exceeded. Most of the CHM lighting outputs support a maximum current load of 7.45 amps, with the exception of the taillight outputs which support a combined maximum current load of 1 amp. When determining the total combined current load for any output, include the new lighting connected to the interface as well as all preexisting lighting of the same function that came factory-installed and is not permanently removed during body installation.

Additional marker light connections are powered by a CHM output. Do not exceed a maximum combined current load of 10 amps for a CHM marker lights output. When installing any additional marker lights, include an inline fuse with a rating equal to, or slightly higher than, the added lighting load. In no instance should the inline fuse exceed 10 amps.

Lighting Interface Wiring Diagrams

For a wiring diagram of the original design for the high-current interface harness A06-44608, see **Fig. 1**.

For a wiring diagram of the new design for the high-current interface harness A06-48218, see **Fig. 2**.

For a wiring diagram of the low-current interface harness A06-44388, see **Fig. 3**.

For a wiring diagram of the additional marker lights, see **Fig. 4**.

Circuit Identification

Chassis Module

The Chassis Module (CHM) may be located on a bracket behind the back-of-cab crossmember (standard location), or underneath the cab on the driver's side. For the back-of-cab CHM location, see **Fig. 5**. For CHM connector identification, see **Fig. 6**.

The high-current and low-current interface harnesses receive CHM lighting outputs via CHM connector C1. For a connector face view and pinout chart of the CHM C1 connector, see **Table 1**.

The marker light jumper harness is inserted at pin M of the CHM connector C4. For a connector face view of the CHM C4 connector and pin M identification, see **Table 2**.

The marker light junction block connection is made at pin F of the CHM connector C2. For a connector face view of the CHM C2 connector and pin F identification, see **Table 3**.

Taillight PDM

The taillight power distribution module (PDM) contains the necessary components to supply a high-current lighting interface harness. For taillight PDM layout and identification of electrical connections, see **Subject 100**.

For a connector face view and pinout chart of the taillight module harness PDM connector C2, see **Table 4**.

For a connector face view and pinout chart of the lighting interface harness PDM connector C8, see **Table 5**.

Lighting Interface

For a connector face view and pinout chart of the original design for the high-current lighting interface harness A06-44608, see **Table 6**.

For a connector face view and pinout chart of the new design for the high-current lighting interface harness A06-48218, see **Table 7**.

For a connector face view and pinout chart of the low-current lighting interface harness A06-44388, see **Table 8**.

Specifications

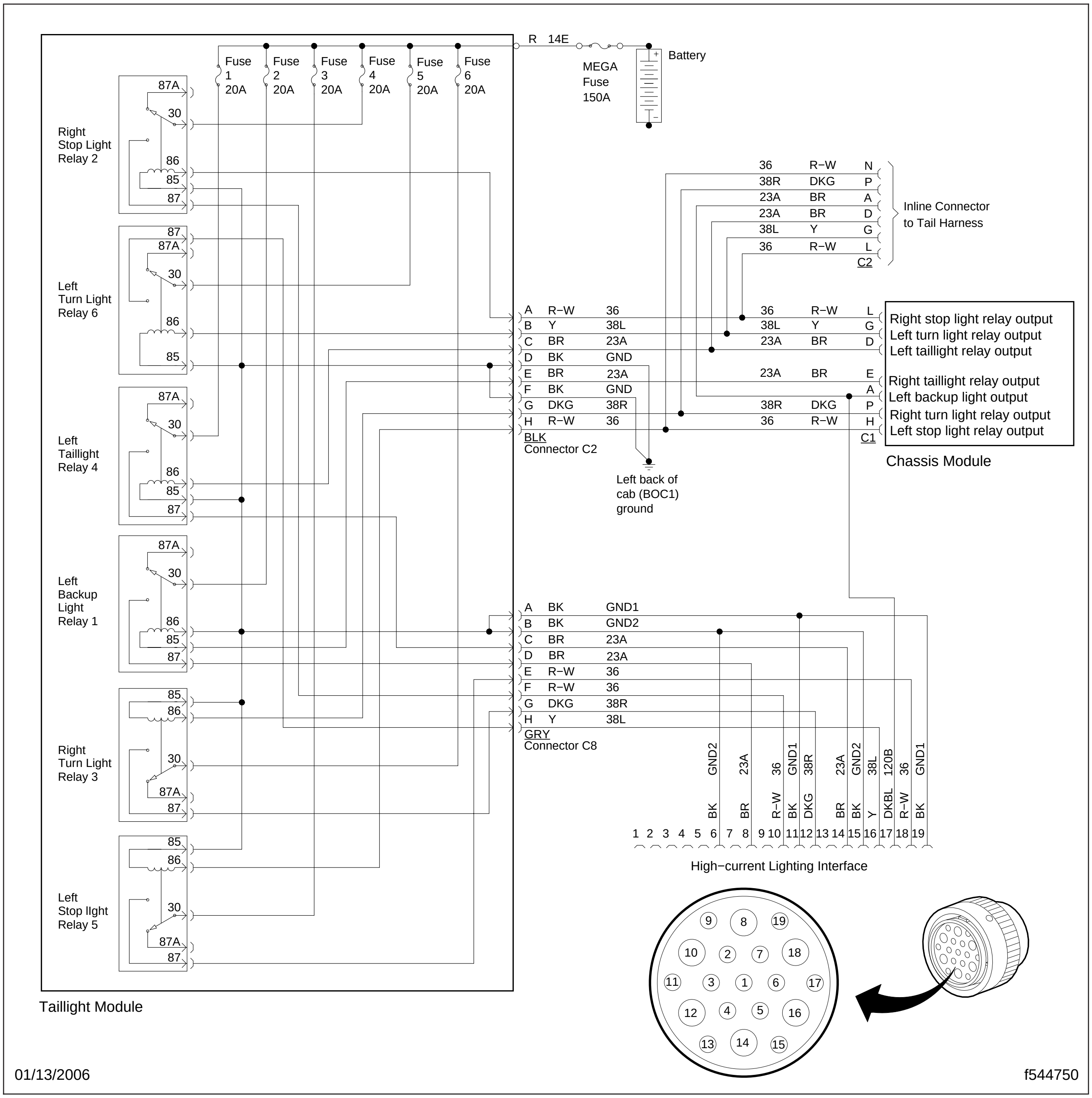


Fig. 1, Wiring Diagram of the Original Design for the High-Current Interface Harness A06-44608

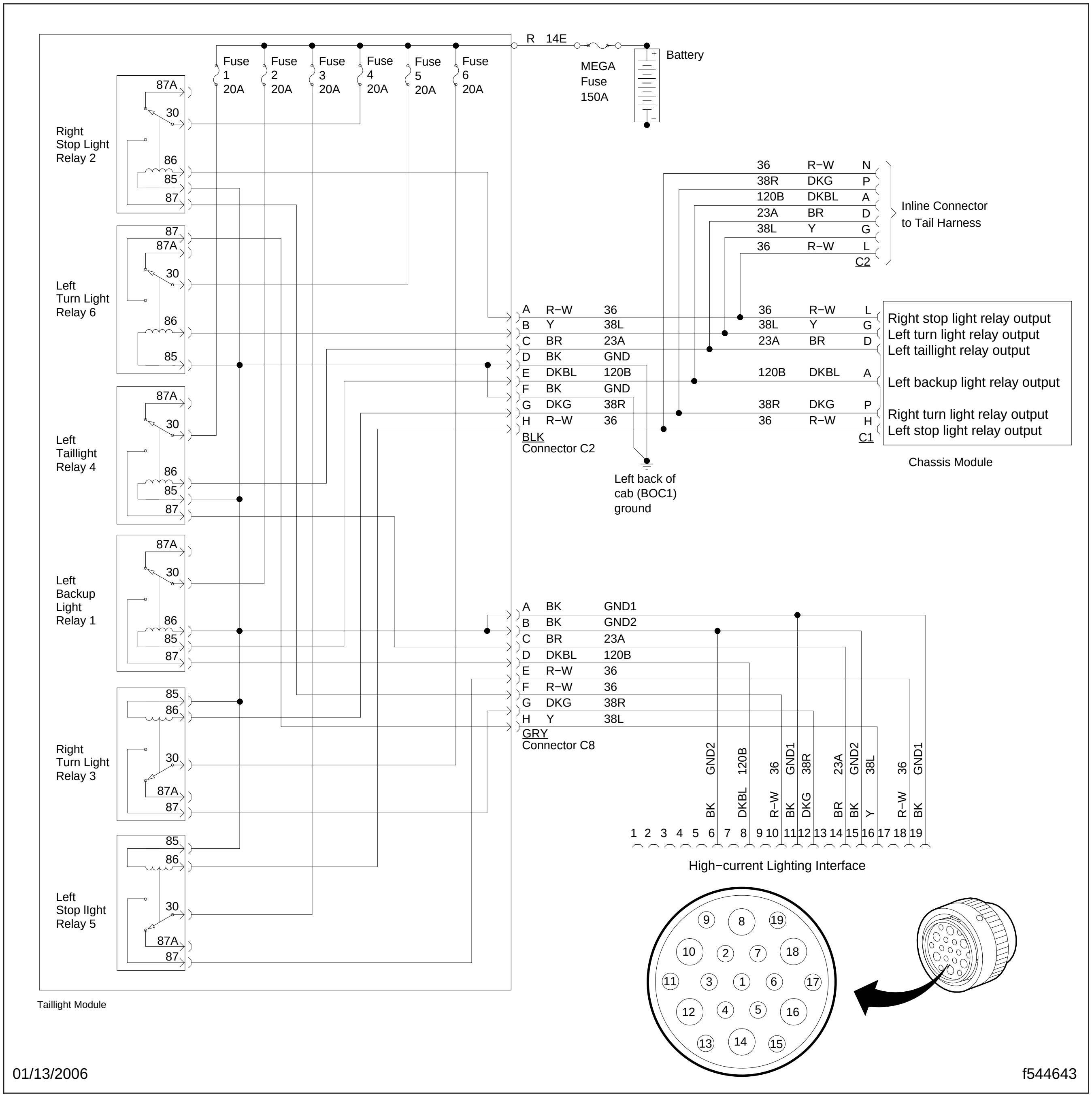


Fig. 2, Wiring Diagram of the New Design for the High-Current Interface Harness A06-48218

Specifications

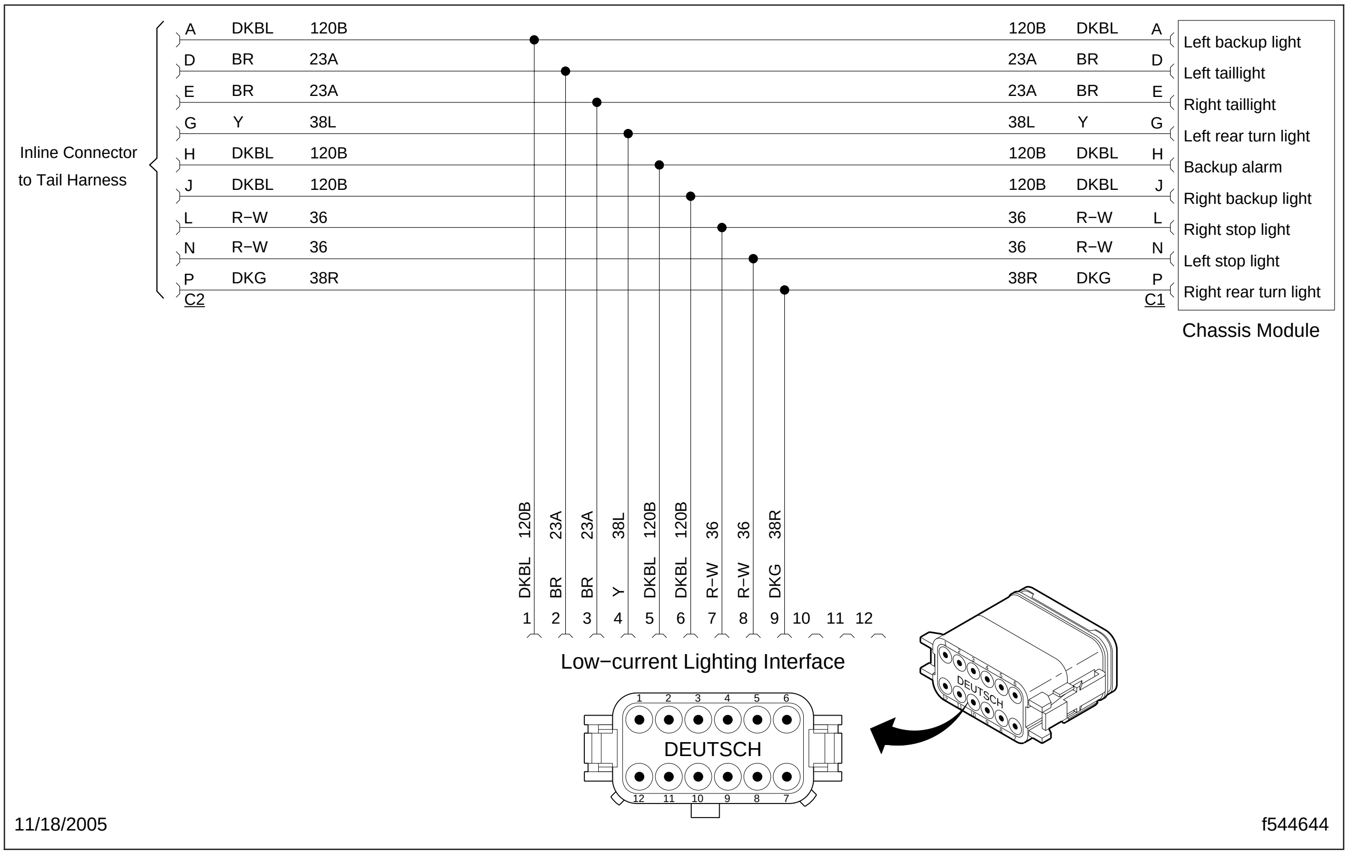


Fig. 3, Wiring Diagram of the Low-Current Interface Harness A06-44388

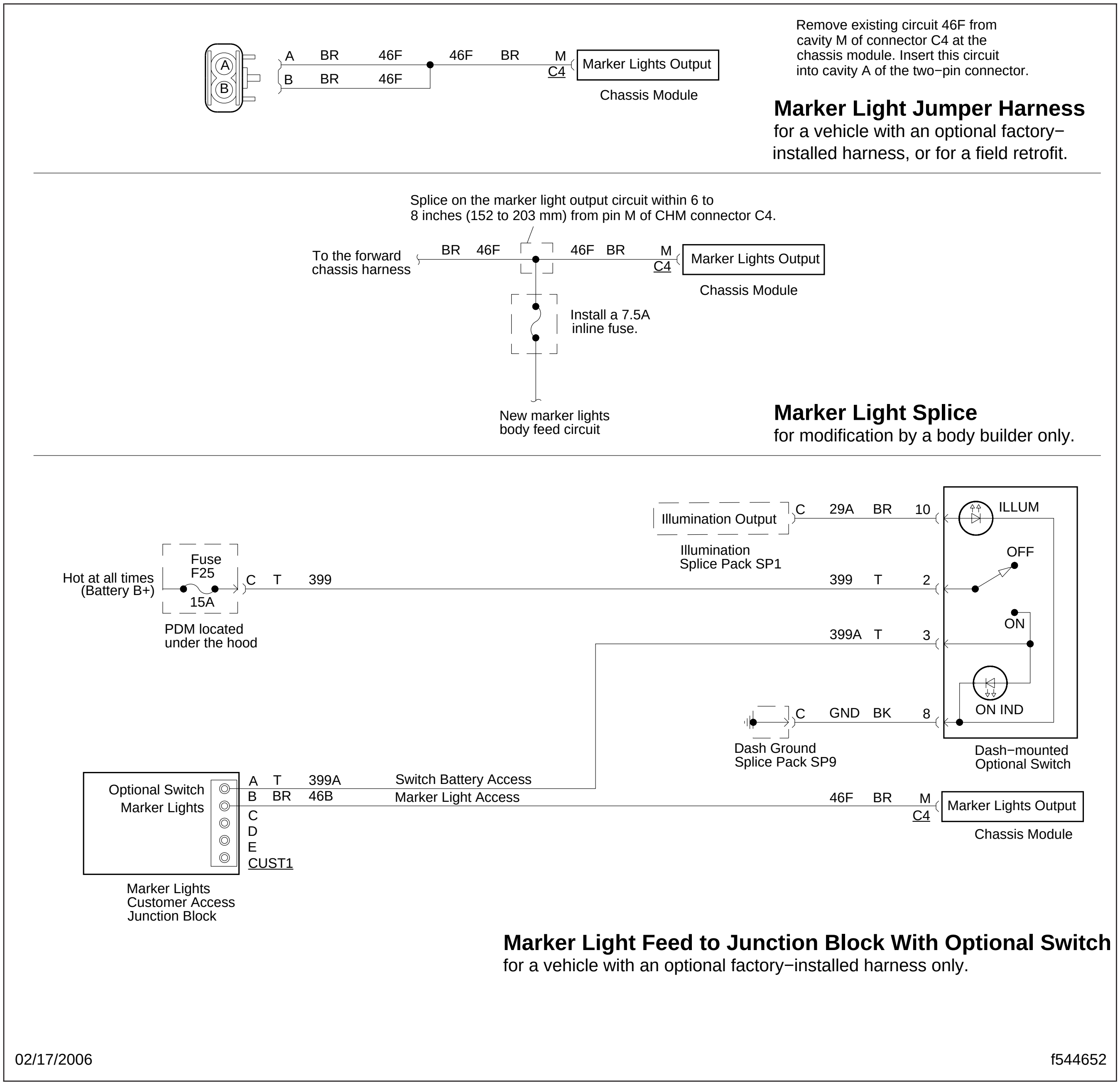
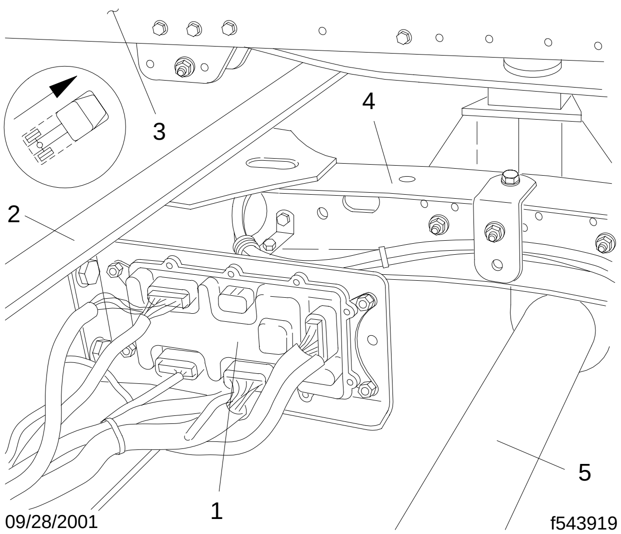


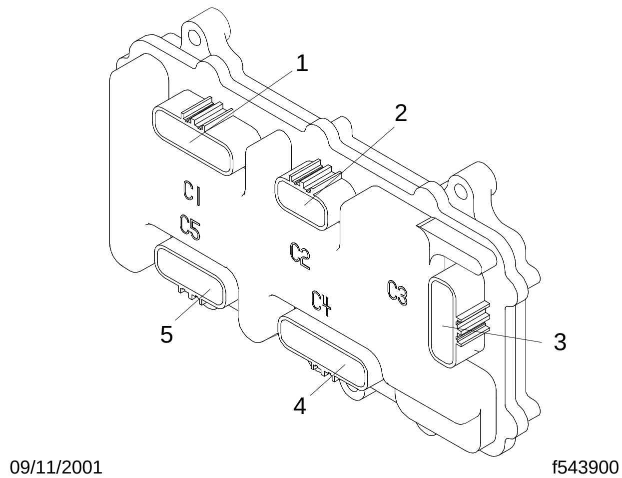
Fig. 4, Additional Marker Light Wiring Diagram

Specifications



1. Chassis Module
2. Left Frame Rail
3. Cab Backwall
4. Crossmember
5. Driveline

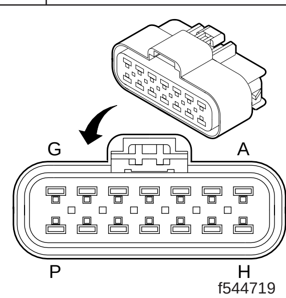
Fig. 5, Back-of-Cab Chassis Module Location



1. C1, Taillight Harness
2. C2, Trailer Module Harness
3. C3, Forward Chassis Harness
4. C4, Forward Chassis Harness
5. C5, Air Management Unit Harness

Fig. 6, Chassis Module Connector Identification

Lighting Interface Harness Pinouts at CHM Connector C1

Connector Pin	Signal Name	Signal Type	Circuit Color	Circuit Number	Current Capacity
					
C1-A	Left Backup Light	Digital Output	DKBL	120B	7.45A*
C1-B	—	—	T	OPTA	—
C1-C	—	—	T	OPTB	—
C1-D	Left Taillight Pass-Through	Pass-Through	BR	23A	1.0A†
C1-E	Right Taillight Pass-Through	Pass-Through	BR	23A	1.0A†
C1-F	License Plate Light	Digital Output	BR	23C	1.0A†
C1-G	Left Rear Turn Light	Digital Output	Y	38L	7.45A‡
C1-H	Backup Alarm	Digital Output	DKBL	120B	7.45A*

Specifications

Lighting Interface Harness Pinouts at CHM Connector C1					
Connector Pin	**Signal Name**	**Signal Type**	**Circuit Color**	**Circuit Number**	**Current Capacity**
C1-J	Right Backup Light	Digital Output	DKBL	120B	7.45A*
C1-K	—	—	T	OPTC	—
C1-L	Right Stop Light	Digital Output	R-W	36	7.45A
C1-M	—	—	T	OPTD	—
C1-N	Left Stop Light	Digital Output	R-W	36	7.45A
C1-P	Right Rear Turn Light	Digital Output	DKG	38R	7.45A§

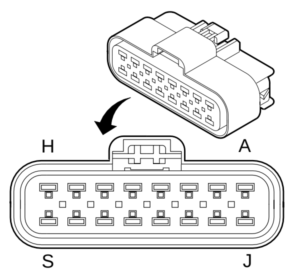
* Pins C1-A, C1-H, and C1-J are fed from the same CHM circuit board trace. The maximum combined current capacity for all three pins is 7.45A.

† Pins C1-D, C1-E, and C1-F are fed from the same CHM circuit board trace. The maximum combined current capacity for all three pins is 1A.

‡ Pins C1-G, C2-H, and C3-N are fed by the same CHM circuit board trace. The maximum combined current capacity for all three pins is 7.45A.

§ Pins C1-P, C2-E, and C3-R are fed by the same CHM circuit board trace. The maximum combined current capacity for all three pins is 7.45A.

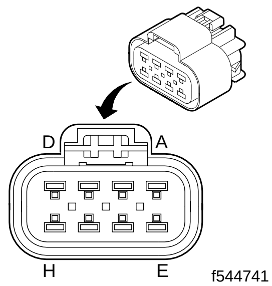
Table 1, Lighting Interface Harness Pinouts at CHM Connector C1

Marker Light Jumper Harness Connection at CHM C4					
Connector Pin	**Signal Name**	**Signal Type**	**Circuit Color**	**Circuit Number**	**Current Capacity**
 f544718					
C4-M	Right Marker Light	Digital Output	BR	46F	10A*

* Pins C4-M, C4-C, C4-D, C4-L, and C2-F are fed by the same CHM circuit board trace. The maximum combined current capacity for all five pins is 10A.

Table 2, Marker Light Jumper Harness Connection at CHM C4

Specifications

Marker Light Junction Block Connection at CHM C2					
Connector Pin	Signal Name	Signal Type	Circuit Color	Circuit Number	Current Capacity
					
C2-F	Trailer Marker Light Control	Digital Output	BR	46A	10A*

* Pins C2-F, C4-C, C4-D, C4-L, and C4-M are fed by the same CHM circuit board trace. The maximum combined current capacity for all five pins is 10A.

Table 3, Marker Light Junction Block Connection at CHM C2

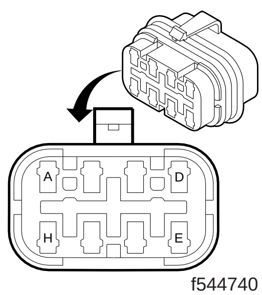
High-Current Taillight Module PDM Harness Connector C2				
Connector Pin	Signal Name	Signal Type	Circuit Color	Circuit Number
				
A	Right Stop Light Relay Control	Digital Input	R-W	36
B	Left Turn Light Relay Control	Digital Input	Y	38L
C	Left Taillight Relay Control	Digital Input	BR	23A
D	Ground	Ground	BK	GND
E	Backup Light Relay Control	Digital Input	DKBL	120B
F	Ground	Ground	BK	GND
G	Right Turn Light Relay Control	Digital Input	DKG	38R
H	Left Stop Light Relay Control	Digital Input	R-W	36

Table 4, High-Current Taillight Module PDM Harness Connector C2

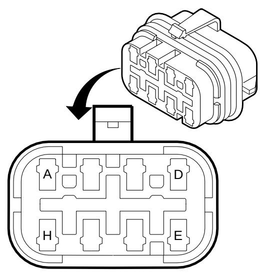
High-Current Lighting Interface PDM Harness Connector C8				
Connector Pin	Signal Name	Signal Type	Circuit Color	Circuit Number
f544739				
A	Ground	Ground	BK	GND 1
B	Ground	Ground	BK	GND 2
C	Left Taillight	+12V via PDM Fuse 1 (20A) with relay 4 (left taillight) active.	BR	23A
D	Backup Light	+12V via PDM Fuse 2 (20A) with relay 1 (backup light) active.	DKBL	120B
E	Left Stop Light	+12V via PDM Fuse 3 (20A) with relay 5 (left stop light) active.	R-W	36
F	Right Stop Light	+12V via PDM Fuse 4 (20A) with relay 2 (right stop light) active.	R-W	36
G	Right Turn Light	+12V via PDM Fuse 6 (20A) with relay 3 (right turn light) active.	DKG	38R
H	Left Turn Light	+12V via PDM Fuse 5 (20A) with relay 6 (left turn light) active.	Y	38L

Table 5, High-Current Lighting Interface PDM Harness Connector C8

Specifications

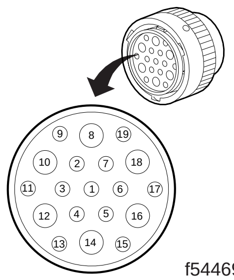
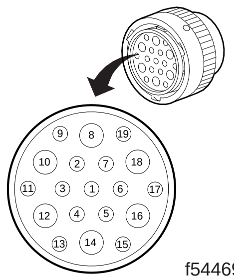
High-Current Lighting Interface Harness A06-44608					
Connector Pin	Signal Name	Signal Type	Circuit Color	Circuit Number	Current Capacity
 f544691					
1	—	—	—	—	—
2	—	—	—	—	—
3	—	—	—	—	—
4	—	—	—	—	—
5	—	—	—	—	—
6	Ground	Ground	BK	GND 2	—
7	—	—	—	—	—
8	Right Taillight	+12V via PDM Fuse 1 (20A) with relay 1 (right taillight) active.	BR	23A	20A
9	—	—	—	—	—
10	Right Stop Light	+12V via PDM Fuse 4 (20A) with relay 2 (right stop or stop/turn light) active.	R-W	36	20A
11	Ground	Ground	BK	GND 1	—
12	Right Stop Light or Right Stop/ Turn Light	+12V via PDM Fuse 6 (20A) with relay 3 (right turn light) active.	DKG	38R	20A
13	—	—	—	—	—
14	Left Taillight	+12V via PDM Fuse 1 (20A) with relay 4 (left taillight) active.	BR	23A	20A
15	Ground	Ground	BK	GND 2	—
16	Left Stop Light or Left Stop/ Turn Light	+12V via PDM Fuse 5 (20A) with relay 6 (left turn light) active.	Y	38L	20A
17	Backup Light	+12V via CHM.	DKBL	120B	7.45A
18	Left Stop Light	+12V via PDM Fuse 3 (20A) with relay 5 (left stop or stop/ turn light) active.	R-W	36	20A
19	Ground	Ground	BK	GND 1	—

Table 6, High-Current Lighting Interface Harness A06-44608

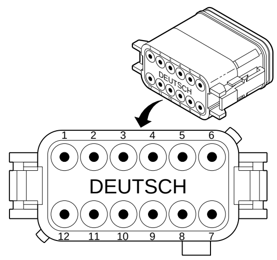
Specifications

High-Current Lighting Interface Harness A06-48218					
Connector Pin	**Signal Name**	**Signal Type**	**Circuit Color**	**Circuit Number**	**Current Capacity**
		 f544691			
1	—	—	—	—	—
2	—	—	—	—	—
3	—	—	—	—	—
4	—	—	—	—	—
5	—	—	—	—	—
6	Ground	Ground	BK	GND 2	—
7	—	—	—	—	—
8*	Backup Light	+12V via PDM Fuse 2 (20A) with relay 1 (backup light) active.	DKBL	120B	20A
9	—	—	—	—	—
10	Right Stop Light	+12V via PDM Fuse 4 (20A) with relay 2 (right stop light) active.	R-W	36	20A
11	Ground	Ground	BK	GND 1	—
12	Right Stop Light or Right Stop/ Turn Light	+12V via PDM Fuse 6 (20A) with relay 3 (right stop or stop/turn light) active.	DKG	38R	20A
13	—	—	—	—	—
14	Left Taillight	+12V via PDM Fuse 1 (20A) with relay 4 (left taillight) active.	BR	23A	20A
15	Ground	Ground	BK	GND 2	—
16	Left Stop Light or Left Stop/ Turn Light	+12V via PDM Fuse 5 (20A) with relay 6 (left turn light) active.	Y	38L	20A
17	—	—	—	—	—
18	Left Stop Light	+12V via PDM Fuse 3 (20A) with relay 5 (left stop or stop/ turn light) active.	R-W	36	20A
19	Ground	Ground	BK	GND 1	—

* Some early harnesses have pin 8 located in pin 17.

Table 7, High-Current Lighting Interface Harness A06-48218

Specifications

Low-Current Lighting Interface Harness A06-44388					
Connector Pin	Signal Name	Signal Type	Circuit Color	Circuit Number	Current Capacity
					
1	Left Backup Light	Digital Output	DKBL	120B	7.45A*
2	Left Taillight	Digital Output	BR	23A	1.0A
3	Right Taillight	Digital Output	BR	23A	1.0A
4	Left Turn Light	Digital Output	Y	38L	7.45A
5	Backup Alarm	Digital Output	DKBL	120B	7.45A*
6	Right Backup Light	Digital Output	DKBL	120B	7.45A*
7	Right Stop Light or Right Stop/Turn Light	Digital Output	R-W	36	6.7A
8	Left Stop Light or Left Stop/Turn Light	Digital Output	R-W	36	6.7A
9	Right Turn Light	Digital Output	DKG	38R	7.45A
10	—	—	—	—	—
11	—	—	—	—	—
12	—	—	—	—	—

* This pin is fed by CHM pins 1, 5, and 6. The maximum combined current capacity for all three pins is 7.45A.

Table 8, Low-Current Lighting Interface Harness A06-44388

Deutsch HDP Series Size 12 Terminals			
Terminal Type	AWG	Freightliner Part Number	Deutsch Part Number
Stamped and Formed	12/14	DUF1060120166	1060-12-0166
Solid	12/14	DUF046020412141	0460-204-12141

Table 9, Deutsch HDP Series Size 12 Terminals

Deutsch DT and HDP Series Size 16 Terminals			
Terminal Type	AWG	Freightliner Part Number	Deutsch Part Number
Stamped and Formed	16/18	DUF1060160122PS	1060-16-0122
	14/16	DUF1060140122PS	1060-14-0122
	14/16/18	DUF1060160722	1060-16-0722

Deutsch DT and HDP Series Size 16 Terminals			
Terminal Type	**AWG**	**Freightliner Part Number**	**Deutsch Part Number**
Solid	16/18	DUF046020216141	0460-202-16141
	14/16	DUF046021516141	0460-215-16141

Table 10, Deutsch DT and HDP Series Size 16 Terminals

Background Information

Freightliner provides an engine interface harness when an rpm control system is needed for optional body builder features and PTO (power takeoff) applications. The optional features provided by this harness include:

- fast idle
- increment/decrement
- multiple fixed speeds
- variable rpm

The body builder must install circuits and switches for the rpm control system that is required.

To determine if a vehicle is equipped with an engine interface harness, look for a black, 12-pin Deutsch DT Series connector located on the engine side of the frontwall, behind the cab inside the left frame rail, or at the rear of the vehicle inside the left frame rail.

Fast Idle

An on/off switch controls the fast idle.

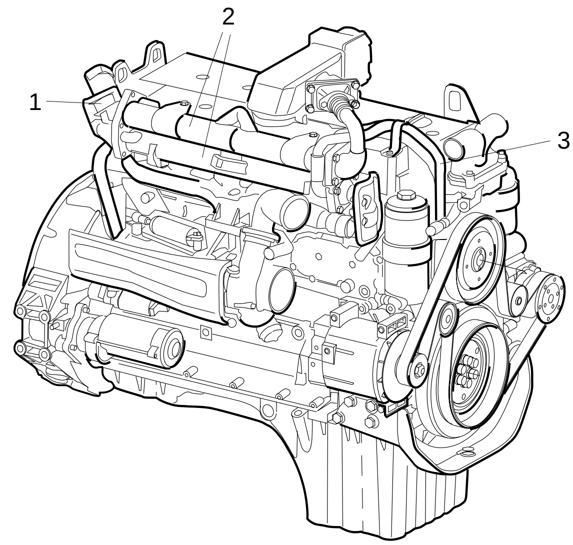
Increment/Decrement

The cruise control set and resume switches, or an increment/decrement switch located outside the cab, controls increment/decrement.

Although Cummins engines do not currently support the use of the cruise control set and resume switches for increment/decrement engine rpm control, they do support the use of an external increment/decrement switch.

On a vehicle with a Mercedes-Benz engine using multiplexed cruise control switches, an external increment/decrement switch cannot be added unless the cruise control switches are converted to wired switches. Vehicles with a 2004 EPA Mercedes-Benz engine have multiplexed cruise control switches. An engine with an EGR is a 2004 EPA engine. Check the engine to determine if it has exhaust gas recirculation (EGR). See **Fig. 1** and **Fig. 2** for some of the EGR components on an MBE900 and MBE4000 engine.

See **Subject 100** for instructions on how to hardwire the multiplexed cruise control switches in order to add an external increment/decrement switch.



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1. EGR Rotary Valve
2. EGR Cooler
3. EGR Cooler Coolant Supply

Fig. 1, MBE900 Engine With EGR

Multiple Fixed Speeds

On a vehicle with a Mercedes-Benz or Cummins engine, an on/off switch controls the multiple fixed speeds feature for PTO applications. When only one fixed speed is used, then the functionality is fast idle.

Press the on/off switch to the on position to attain fixed speed 1. Press the on/off switch on/off/on to attain fixed speed 2. Press the on/off switch on/off/on/off/on to attain fixed speed 3.

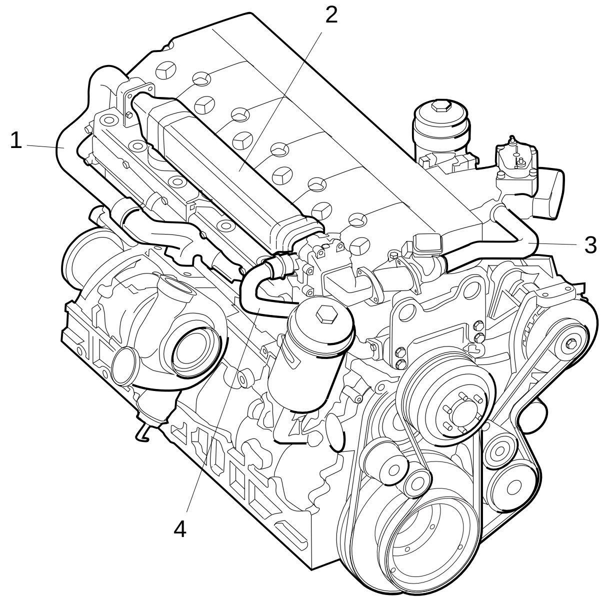
On a vehicle with a Caterpillar engine, one or two additional on/off switches control fixed speeds.

The rpm control switch must be in the on position before additional fixed speeds can be used. The rpm control switch can be programmed so that it controls a fixed speed when it is turned on. Refer to Caterpillar's service tools and documentation for more information.

Variable RPM

The remote throttle position sensor (TPS) controls the variable rpm through the use of a remote foot

General Information



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1. EGR Hot Pipe
2. EGR Cooler
3. EGR Delivery Pipe
4. EGR Cooler Coolant Return

Fig. 2, MBE4000 Engine With EGR

pedal, a rotary hand throttle, or an electronic rpm control system, such as a Class1 governor. All engines support the variable rpm feature. Variable rpm is typically used on fire trucks and vacuum trucks.

Refer to the engine manufacturer's technical documentation to determine the electrical characteristics and component specifications for a variable rpm control.

Installation of an Engine Interface

When an rpm control system is needed for optional body builder features and PTO (power takeoff) applications, order an engine interface harness from a Freightliner dealer. The Freightliner dealer can install the interface harness directly to the engine control module (ECM), and do the programming. For instructions on adding a feature, see **Section 54.00, Subject 110**.

The body builder has the option of using documentation available from the engine manufacturer to install the circuits needed for the rpm control system.

Programming the Engine

Use the engine manufacturer's service software to program the settings needed for rpm control.

Installation

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the negative leads from the batteries or, if the vehicle is equipped with a battery disconnect switch, turn the switch to the off position.
3. Remove the dash surround bezel, passenger-side dash cover, dash top cover, center dash panel, and left-side auxiliary control panel. See **Section 60.08** for removal instructions.
4. Disconnect the cruise control switches from the main dash electronic control unit (ECU) harness.
5. Remove the cruise control switches from the dash panel.
   5.1 From behind the dash panel, depress the clips that hold the switch in place.
   5.2 With the clips depressed, push the switch out through the front of the dash panel.
   5.3 Repeat these substeps for the other switch.
6. Tape the dash harness connectors so they do not rattle.

NOTE: The connectors will not be used again, but there is no need to remove them.

7. Install the new cruise control switches in the dash panel by pushing them in from the front of the dash panel until they click into place. See **Table 1** for part numbers of the cruise control switches and the engine cruise control harness.

Parts Required		
Description	**Part Number**	**Qty.**
On-Off Cruise Control Switch	A06-30769-011	1
Set-Resume Cruise Control Switch	A06-30769-012	1
Cruise Control Harness	A06-47841-000	1

Table 1, Parts Required

8. Connect the engine cruise control harness (A06-47841-000) to the cruise control switches, and route the harness over the main dash ECU harness. See **Fig. 1**.

IMPORTANT: Check the pin locations to verify the proper location.

9. Connect wires 440G to any open cavity on splice pack 13. See **Fig. 2** for a wiring diagram for a vehicle without an optional access connector for the engine control module (ECM); see **Fig. 3** for a wiring diagram for a vehicle with an optional access connector for the ECM (sales codes 148-014 through 148-046).

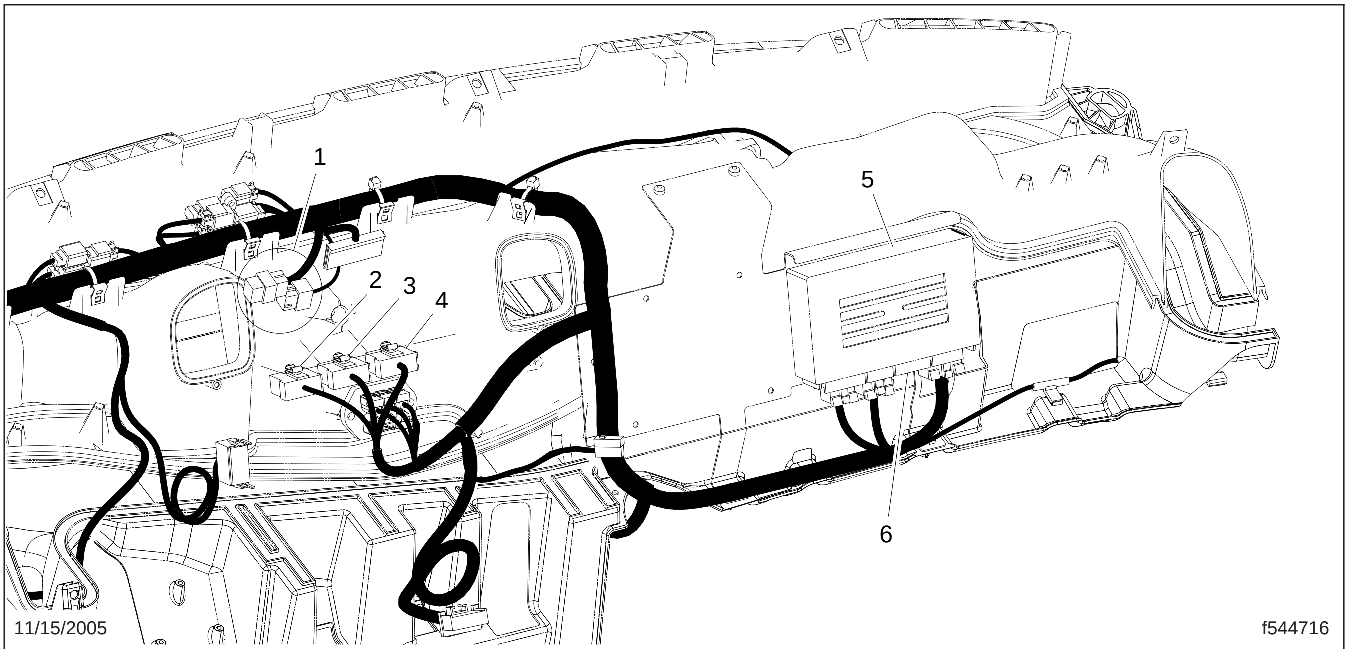
NOTE: The cavity locations may vary based on the vehicle configuration.

10. Connect wire 81C to any open cavity on splice pack 12A.
11. Connect wire 1204 GND to any open cavity on splice pack 9.
12. Connect wire 29A to any open cavity on splice pack 1.
13. On a vehicle without an optional access connector for the ECM, connect wire 440E to pin 4 of connector VC3 on the dash ECU harness. See **Fig. 2**.
    13.1 Connect wire 440F to pin 5 of connector VC3 on the dash ECU harness.
    13.2 Connect wire 440D to pin 6 of connector VC3 on the dash ECU harness.
14. On a vehicle with an optional access connector for the ECM, locate the 6-pin connector near the vehicle control unit (VCU). The 6-pin connector has an empty mating connector with wires 439U, 439A, and 439B. See **Fig. 3**.

    NOTE: There may be additional wires depending on the vehicle configuration.

    14.1 Unplug the mating connector and insert wire 440D in cavity 1, 440E in cavity 2, and 440F in cavity 3.
    14.2 Plug the mating connector into the vehicle-side 6-pin connector.
15. Install the dash panels. See **Section 60.08** for installation instructions.
16. Connect the batteries or turn the battery disconnect switch to on.
17. Using a Minidiag or DDDL, set the following parameters so that the cruise control switches will

Engine Cruise Control Harness Installation



1. Splice Pack 13
2. Splice Pack 1
3. Splice Pack 9
4. Splice Pack 12A
5. Dash Electronic Control Unit
6. VC3 18-pin Connector

Fig. 1, Main Dash ECU Harness Routing

work and to configure the rpm settings in power takeoff (PTO) mode.

17.1 Set parameter 11311 to zero (Cruise Switch On, Hardwired, or J1939 will be displayed).

17.2 Set parameter 11312 to zero (Set/Coast and Resume/Accel, Hardwired, or J1939 will be displayed).

17.3 Set parameter 11313 to zero (Cruise Pause, Hardwired, or J1939 will be displayed).

18. Set the following parameters as needed.

18.1 Program 10702 to the MAXIMUM RPM for PTO mode; this is the highest speed that the Cruise Control Resume input will reach.

18.2 Program 10703 to the MINIMUM RPM for PTO mode; this is the lowest speed that the Cruise Control Set input will reach.

18.3 Program 10709 to the speed desired (if different on initial startup) for the Cruise Control Set switch. The setting needs to be at least equal to or greater than 10703, and less than or equal to 10702.

18.4 Program 10712 to the speed desired (if different on initial startup) for the Cruise Control Resume switch input. The setting needs to be at least equal to or greater than 10703, and less than or equal to 10702.

18.5 10715 is the ramp rate and it should be adjusted to 250 rpm/second.

19. Verify that the cruise and engine PTO function correctly.

20. Remove the chocks from the tires.

Engine Cruise Control Harness Installation

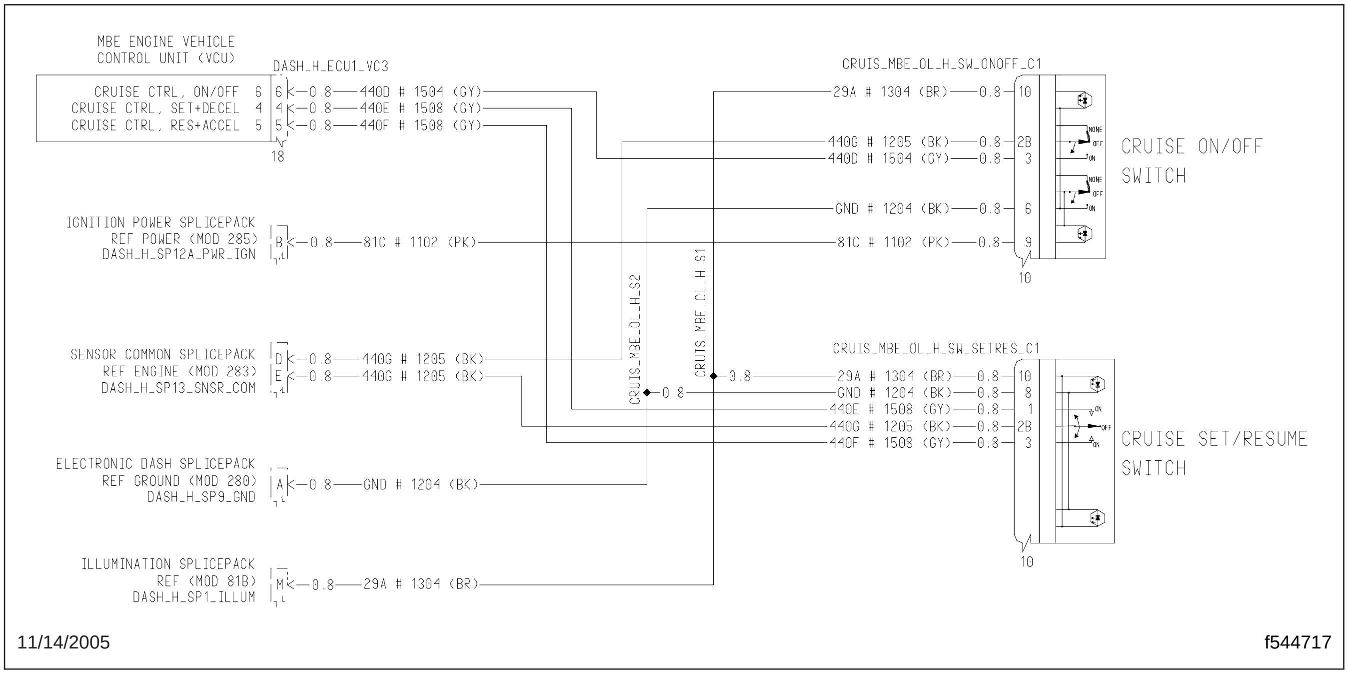


Fig. 2, Engine Cruise Control Harness Wiring Diagram for a Vehicle Without an Optional Access Connector for the ECM

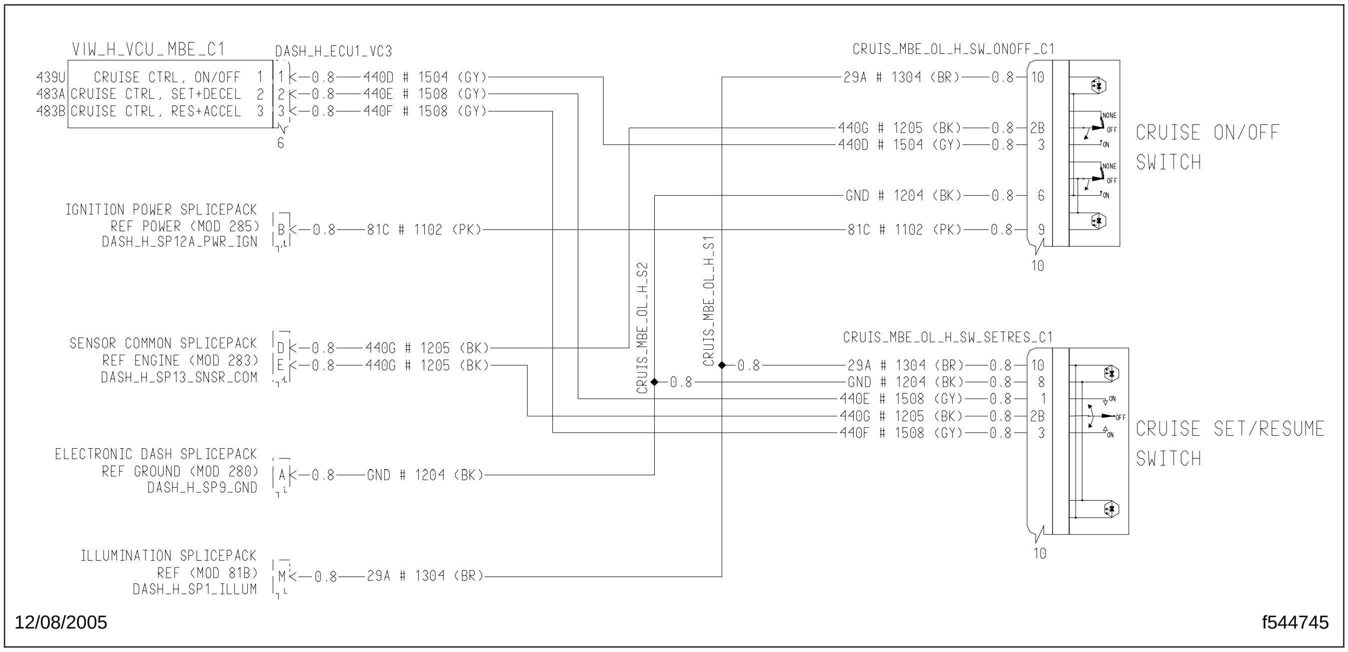


Fig. 3, Engine Cruise Control Harness Wiring Diagram for a Vehicle With an Optional Access Connector for the ECM

Troubleshooting

When troubleshooting the engine interface harness, use the engine manufacturer's diagnostic literature for problems that cannot be traced to the Freightliner engine interface harness or to the wiring installed by a body builder.

Engine Interface Harness Troubleshooting	
Symptom	**Diagnosis**
The remote PTO on/off circuit is not functioning.	Check that the pins are seated correctly in the Deutsch connector.
	Check the functionality of interlocks.
The remote increment/decrement feature is not functioning.	For a Mercedes-Benz engine with 2004 EPA specifications, perform the installation procedure in **Subject 100** if necessary.
	Check that the pins are seated correctly in the DT-series Deutsch connector.
	Make sure that all interlock conditions are met before operation.
	For a Caterpillar engine, check the engine programming.
The remote throttle system is not functioning.	Make sure that the engine has been programmed correctly for the remote throttle.
	Check that the pins are seated correctly in the DT-series Deutsch connector.
	Make sure all interlock conditions are met before operation.

Table 1, Engine Interface Harness Troubleshooting

Wiring Schematics

See **Fig. 1** for a typical wiring schematic for the engine interface harness for a vehicle with a Mercedes-Benz engine.

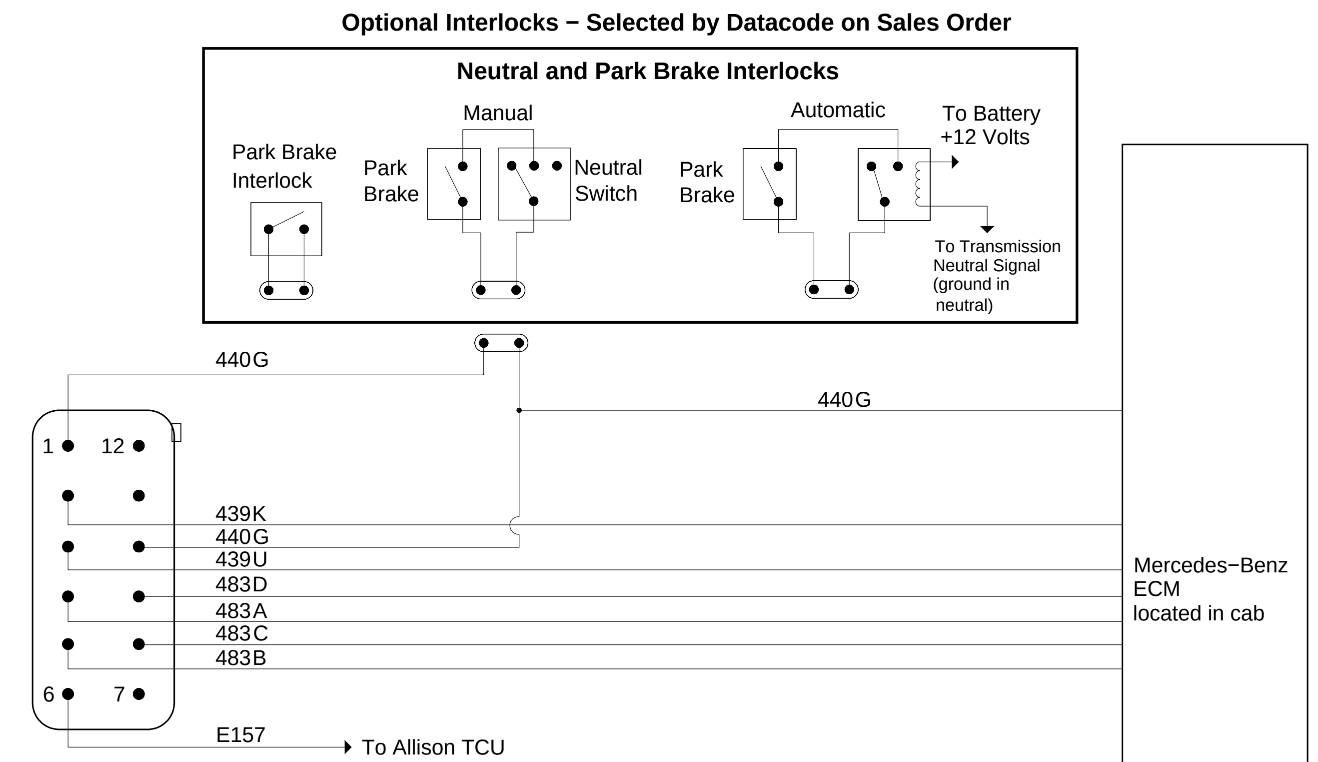
See **Fig. 2** for a typical wiring schematic for the engine interface harness for a vehicle with a Caterpillar engine.

See **Fig. 3** for a typical wiring schematic for the engine interface harness for a vehicle with a Cummins engine.

Deutsch DT Series Terminals			
Terminals	**Freightliner Part Number**	**Deutsch Part Number**	**AWG**
Stamped and Formed Terminals	DUF1060160122PS	1060-16-0122	16/18
	DUF1060140122PS	1060-14-0122	14/16
Solid Terminals	DUF046020216141	0460-202-16141	16/18
	DUF046021516141	0460-215-16141	14/16

Table 1, Deutsch DT Series Terminals

Specifications



Pin	Circuit	Function
1	440G	Sensor Common (interlocked)
2	439K	Fast Idle Enable Input
3	439U	RPM Mode On/Off Input
4	483A	RPM Mode Set Switch Input
5	483B	RPM Mode Resume Switch Input
6	E157	Allison Transmission Speedometer Signal
7	N/C	
8	483C	Remote TPS Input
9	483D	+5 Volt Supply for Remote TPS
10	440G	Sensor Common (non−interlocked)
11	N/C	
12	N/C	

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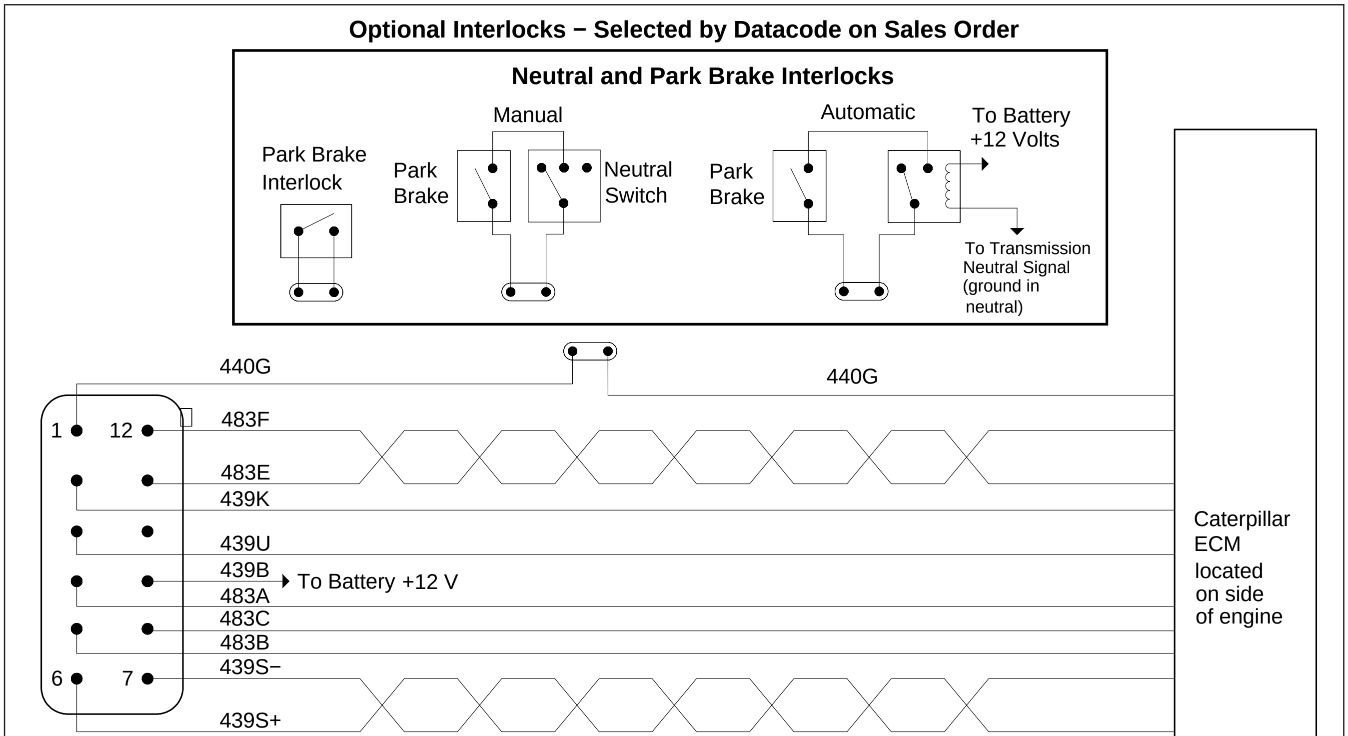
Fig. 1, Typical Wiring Schematic for the Engine Interface Harness for a Mercedes-Benz Engine



Pin	Circuit	Function
1	440G	Sensor Common
2	439K	Fast Idle Enable Input
3	439U	RPM Mode On/Off Input
4	483A	RPM Mode Set Switch Input
5	483B	RPM Mode Resume Switch Input
6	439S+	Speedometer + Signal
7	439S−	Speedometer − Signal
8	483C	Remote TPS Input
9	439B	+12 Volt Supply for Remote TPS
10	N/C	
11	483E	Tachometer + Signal
12	483F	Tachometer − Signal

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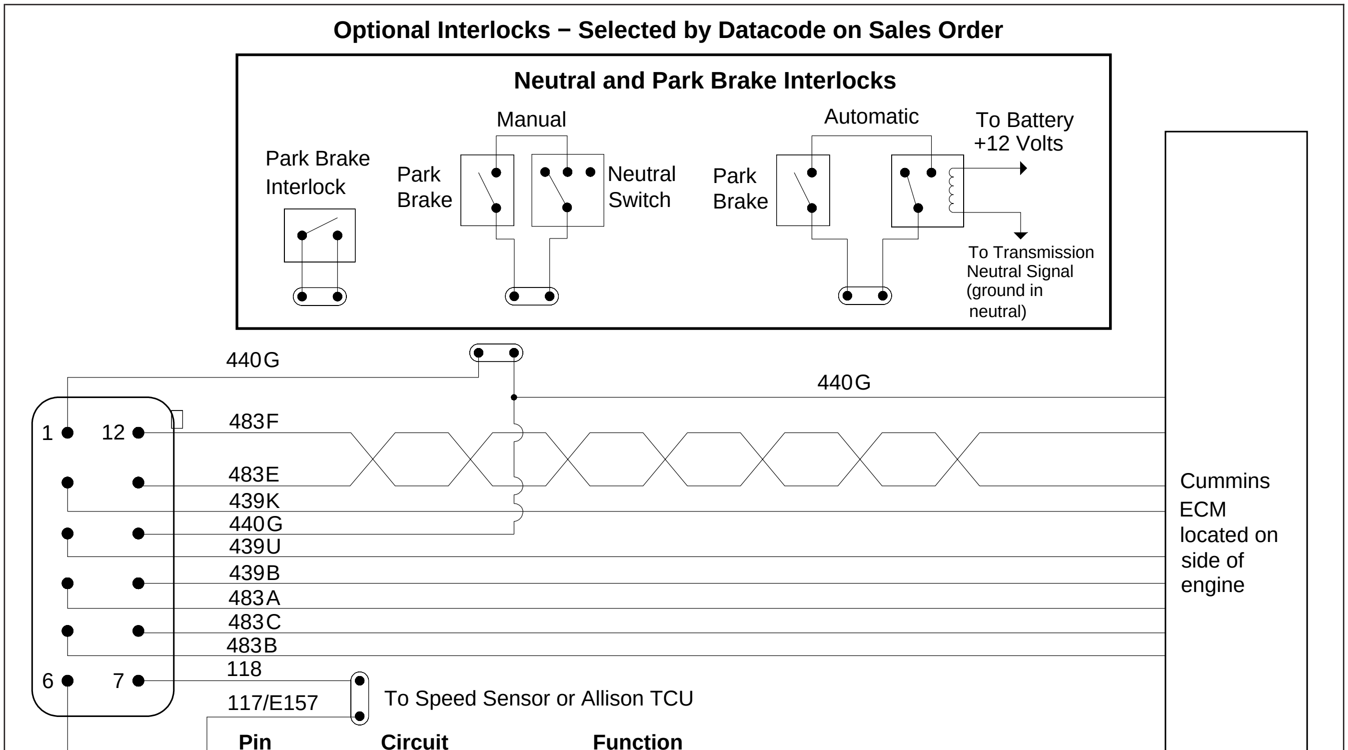
Fig. 2, Typical Wiring Schematic for the Engine Interface Harness for a Caterpillar Engine

Specifications



Pin	Circuit	Function
1	440G	Sensor Common
2	439K	Fast Idle Enable Input
3	439U	RPM Mode On/Off Input
4	483A	RPM Mode Set Switch Input
5	483B	RPM Mode Resume Switch Input
6	117/E157	Speedometer + Signal (manual/Allison)
7	118	Speedometer −˘Signal (manual only)
8	483C	Remote TPS Input
9	439B	+12 Volt Supply for Remote TPS
10	440G	Sensor Common (non−interlocked)
11	483E	Tachometer + Signal
12	483F	Tachometer Ground Signal

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Fig. 3, Typical Wiring Schematic for the Engine Interface Harness for a Cummins Engine

Background Information

Allison electronically controlled transmissions may be equipped with an optional transmission interface harness for customization by the body builder. The interface harness provides the vehicle interface wiring (VIW) connector to body builders for use in tying in to the transmission electronics for their specific application. The transmission interface harness provides for one type of VIW connector that is documented in the Allison transmission engineering documentation.

The transmission interface harness provides the VIW connection for the current generation of 1000/2000 Series or 3000/4000 Series electronic controls, depending on the transmission that is installed in the vehicle. The transmission interface harness provides most of the optional I/O circuits, and the speedometer signal, in a connector that can be used by the body builder.

See **Specifications 400** for wiring diagrams of the Allison Transmission® 1000/2000 Series and 3000/4000 Series VIW Connector.

Adding a Feature

Vehicle With a Transmission Interface Harness

On a vehicle equipped with a transmission interface harness, use the appropriate Deutsch DT Series pin terminal listed in **Table 1**. The terminal can be ordered from a Freightliner dealer. It may also be available through an Allison authorized service dealer.

Vehicle Without a Transmission Interface Harness

On a vehicle without a transmission interface harness, it is possible to wire in the individual circuits that are needed for a specific application. Currently, the Allison transmission control unit uses a Delphi Micro-Pack sealed, female terminal, part number PAC12084912. The terminal can be ordered from a Freightliner dealer. It may also be available through an Allison authorized service dealer.

CAUTION

Be extremely careful when installing the terminals in the connector. The terminals are very small and may get bent if not handled with care.

IMPORTANT: Before removing the cavity plugs from the connector, identify the cavities that will be used for the specific application.

It is highly recommended that you use Freightliner's wiring schematics when installing a feature on a vehicle without a transmission interface harness.

When adding a transmission interface harness to a vehicle, use the following instructions to add a feature to the vehicle.

1. Using the *Freightliner Business Class® M2 Data Book*, select the applicable data code that applies to the requested add-on feature.
2. Contact Freightliner Body Builder Technical Support at 503-745-6822 Monday through Friday, 6 A.M. to 3:30 P.M. Pacific time, and tell the representative the last six digits of the vehicle serial number and the data code requested. The representative will advise of the availability of the feature.

Deutsch DT Series Terminals			
Terminals	**Freightliner Part Number**	**Deutsch Part Number**	**AWG**
Stamped and Formed Terminals	DUF1060 16 0122	1060-16-0122	16/18
	DUF1060 14 0122	1060-14-0122	14/16
Solid Terminals	DUF046020216141	0460-202-16141	16/18
	DUF046021516141	0460-215-16141	14/16

Table 1, Deutsch DT Series Terminals

Troubleshooting

See the Allison *Troubleshooting Manual* for troubleshooting procedures.

Troubleshooting is dependent on the calibration that is programmed in to the transmission control unit (TCU). To determine the TCU calibration, obtain information from the 343 module data code on the vehicle sales order, or use Allison's diagnostic software, Allison DOC.

See **Fig. 1** for a wiring diagram of the Allison Transmission® 1000/2000 Series VIW Connector.

See **Fig. 2** for a wiring diagram of the Allison Transmission® 3000/4000 Series VIW Connector.

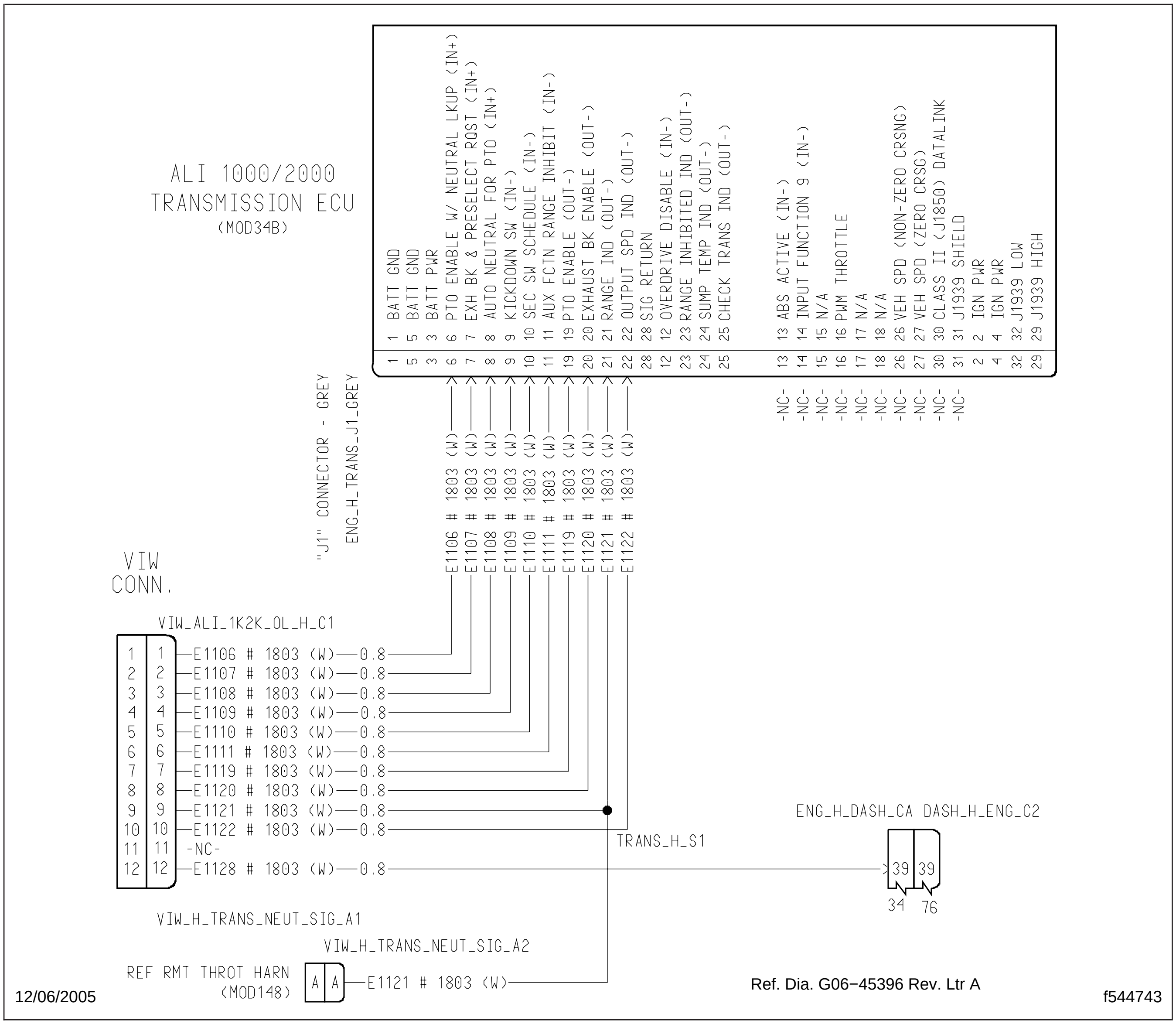

Fig. 1, Allison Transmission 1000/2000 Series VIW Connector Wiring Diagram

Specifications

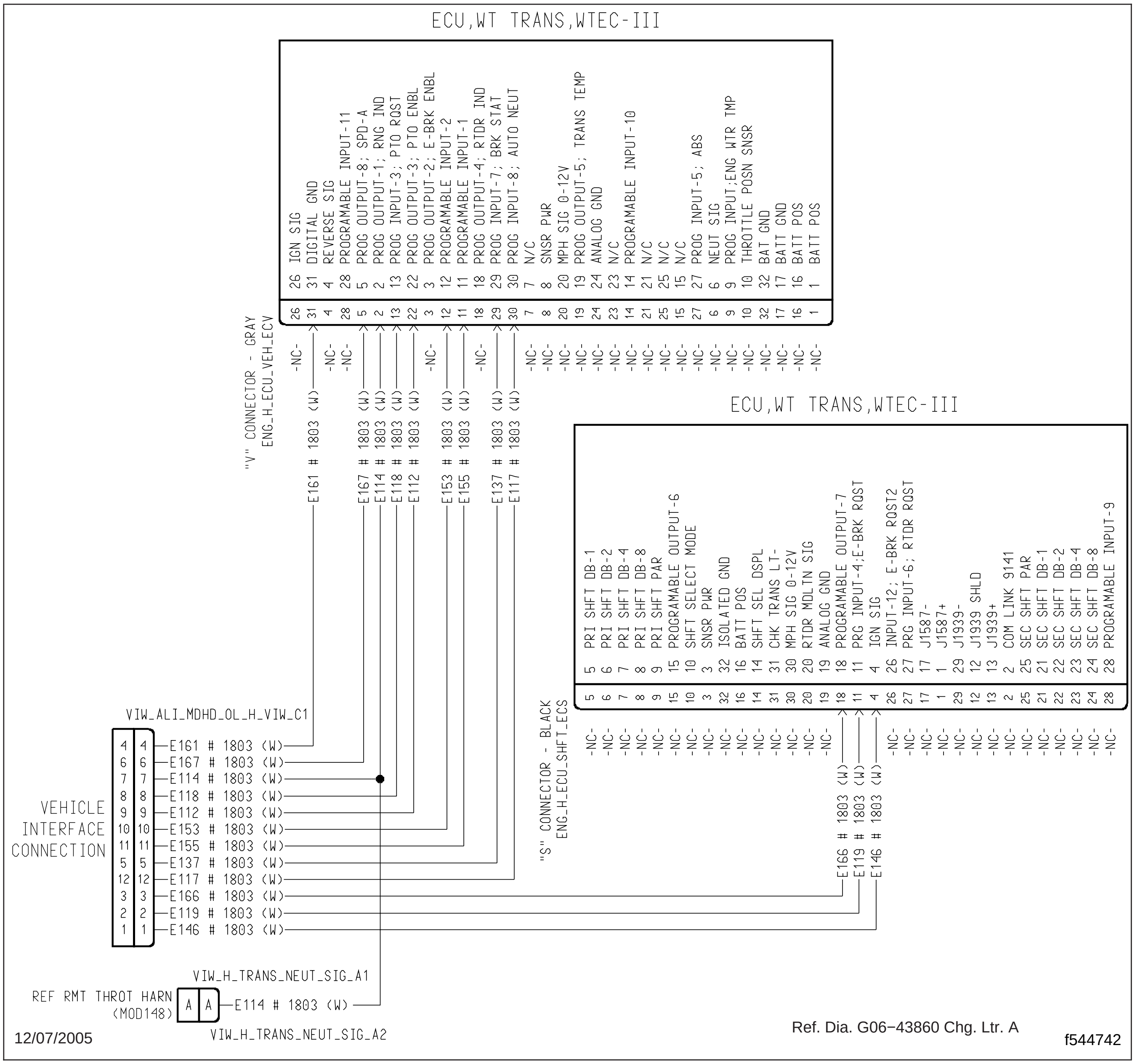

Fig. 2, Allison Transmission 3000/4000 Series VIW Connector Wiring Diagram

General Information

A PTO (power takeoff) and pump controls are options that can be ordered for a Business Class® M2 vehicle at the time the vehicle is ordered, after the vehicle is delivered, or when buying a used vehicle.

A vehicle with a Mercedes-Benz AGS[1] transmission must have PTO controls installed via the M2 electrical system. This is because the AGS electronics require some messages to be broadcast to disengage the clutch from the flywheel so that the PTO mechanism can be engaged, and then to engage the clutch on the flywheel after the PTO mechanism is engaged. If the vehicle has a Mercedes-Benz AGS transmission and is not equipped with PTO controls, see **Section 54.00, Subject 110**, for instructions on adding a feature.

A vehicle that is equipped with a transmission other than a Mercedes-Benz AGS is not required to use Freightliner PTO controls. PTO controls can be wired around the Business Class M2 electronic controls.

A vehicle with an Allison automatic transmission and body builder-installed PTO controls must have the transmission controller's PTO request input circuit connected to the activation switch.

PTO and pump controls use low-current outputs and digital inputs on the chassis module at the C5 electrical connector.

Feedback from the PTO or pump mechanism is required for correct operation of the PTO and pump controls. Feedback is provided by a ground input to the chassis module. A grounded feedback circuit indicates that the system is activated. An open feedback circuit indicates that either the system is not activated (PTO switch is not turned on), or there is a malfunction (PTO switch is turned on).

Definitions

Air shift PTO—Air pressure is used to shift the PTO mechanism.

Hydraulic shift PTO—Hydraulic pressure is used to shift the PTO mechanism. This is usually only available with an automatic transmission.

Normally closed AMU solenoid—Blocks the flow of air until power is applied to the solenoid coil.

Normally open AMU solenoid—Allows air to flow until power is applied to the solenoid coil.

Pump—Also called a split shaft PTO. The main driveshaft is "split" by the PTO. The PTO is actually a transfer case.

PTO Controls

The PTO controls include two types of electrical designs. The controls for air shift PTOs drive an AMU or AAVA solenoid. The controls for hydraulic shift PTOs drive a relay. Hydraulic solenoids require about 1.5 amps of current to engage a PTO mechanism.

Pump Controls

The pump controls comprise a single electrical design. Two solenoid outputs are used to shift the transfer case. One solenoid provides air when the feature is activated (normally closed). The other solenoid turns off the air supply when the feature is deactivated (normally open).

[1] The AGS and AGS2 designations refer to the same Mercedes-Benz transmission. References to AGS2 may be found in ServiceLink®.

PTO and Fire Pump Controls Electrical Troubleshooting

Use **Table 1** or **Table 2** to begin troubleshooting. For power takeoff (PTO) function electrical diagnosis, see **Table 1**. For fire pump controls function diagnosis, see **Table 2**.

Additional tables included in this subject are:

- **Table 3**: PTO and Fire Pump Control Switch and Interlocks Test
- **Table 4**: PTO Interlocks by Reference Parameter
- **Table 5**: Fire Pump Control Interlocks by Reference Parameter
- **Table 6**: PTO and Fire Pump Control J1587 Fault Codes
- **Table 7**: PTO and Fire Pump Control J1939 Fault Codes

PTO Function Electrical Diagnosis

Test No.	Test Procedure	Test Result	Action
1	In ServiceLink®, use the Chassis Module (CHM) Configuration screen to determine which CHM solenoid output number controls the solenoid for the PTO. Then open the "AMU Solenoids Circuits" or "AAVA Solenoids Circuits" in the appropriate Datalink Monitor template. Make sure the vehicle has full air pressure. Turn the ignition on. Attempt to engage the PTO using the smart switch in the dash while observing the status of the solenoid output under the "Outputs from BHM" heading for the solenoid number determined above. See **Fig. 1** and **Fig. 3.** Does the output status turn on at all? It may turn on, then drop out.	Yes	**Go to test no. 2.**
		No	Perform the PTO and Fire Pump Control Switch and Interlocks Test in **Table 3.**
2	Using the appropriate solenoids Datalink Monitor template, enter Test Mode. Attempt to turn the PTO solenoid on using the **ON** button on the template. NOTE: When done, exit Test Mode. When you attempt to turn on the PTO solenoid, can you hear it click?	Yes	**Go to test no. 3.**
		No	**Go to test no. 5.**
3	Make sure the vehicle has full air pressure. Turn the ignition on. Using the appropriate solenoids Datalink Monitor template, attempt to engage the PTO using the smart switch in the dash while observing the status of the pressure switch under the "Inputs to BHM" heading for the solenoid number that controls the PTO. See **Fig. 2** and **Fig. 3.** Does the status of the pressure switch say AIR ON at all, even if it comes on, then goes off?	Yes	**Go to test no. 4.**
		No	Check PTO solenoid pressure switch feedback circuit. Check the solenoid pressure switch. See **Section 42.19.** Check if air line is connected to solenoid. If the above items are OK, replace CHM.

Troubleshooting

PTO Function Electrical Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
4	In ServiceLink, open the "PTO Interlocks" Datalink Monitor template. Using **Table 4**, determine which PTO interlocks are used based on the PTO reference parameter programmed in to the BHM. Engage the PTO using the switch in the dash. Do any of the necessary interlocks drop out when the PTO solenoid drops out?	Yes	Determine the cause for interlock drop out and repair as necessary.
		No	Check PTO solenoid output circuit amperage. If it exceeds 0.85A, make necessary repair or modification. If amperage is OK, check for mechanical problem.
5	In ServiceLink, open the "Chassis Module Battery Inputs" Datalink Monitor template. Is Battery Power Feed No. 3 at approximately battery voltage?	Yes	The problem may be in the PTO solenoid output circuit. Make sure the PTO is wired to the correct CHM output pin per the ServiceLink CHM Configuration screen. Check PTO solenoid output circuit from the CHM to the solenoid, including the solenoid coil ground circuit, for opens. If CHM solenoid output circuit contains a relay, check the relay and the rest of its circuits to the solenoid. Check the solenoid output circuit between the CHM and solenoid (or relay if equipped) for short to ground. This will cause the CHM solenoid output to shut off due to high current. The current draw must not exceed 0.85A. Check the solenoid. See **Section 42.19.** If all of the above is OK, replace the CHM.
		No	Check fuse 13 in the power distribution module (PDM). If blown, locate and correct the source of high current. If fuse 13 is OK, check wiring between PDM fuse 13 and CHM pin C4-J for open circuit.

Table 1, PTO Function Electrical Diagnosis

Fire Pump Controls Function Electrical Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	In ServiceLink, use the Chassis Module (CHM) Configuration screen to determine which CHM solenoid output numbers control the two solenoids for the fire pump. Then open the "AMU Solenoids Circuits" or "AAVA Solenoids Circuits" in the appropriate Datalink Monitor template. Make sure the vehicle has full air pressure. Turn the ignition on. Attempt to engage the pump using the smart switch in the dash while observing the status of solenoid output under the "Outputs from BHM" heading for both of the solenoid numbers determined above. See **Fig. 1** and **Fig. 3.** Does the status of the solenoid output for both solenoids turn on at all? They may turn on, then drop out.	Yes	**Go to test no. 2.**
		No	Perform the PTO and Fire Pump Control Switch and Interlocks Test in **Table 3.**
2	Using the appropriate solenoids Datalink Monitor template, enter Test Mode. Attempt to turn the fire pump control solenoids on one at a time using the **ON** buttons on the template. NOTE: When done, exit Test Mode. NOTE: If operating normally, one solenoid should exhaust air when turned on, the other will exhaust air when turned off. What happens when the solenoids are turned on?	Both operate	**Go to test no. 3.**
		Neither operate	**Go to test no. 5.**
		Only one operates	Make sure one of the reference parameters in **Table 5** is applied to the vehicle. If not, correct as necessary. For the solenoid that is not working, make sure it is wired to the correct CHM output pins per the ServiceLink CHM Configuration screen. Check the solenoid output circuit from the CHM to the solenoid, including the solenoid coil ground circuit, for opens. Check the solenoid output circuit between the CHM and solenoid for short to ground. This will cause the CHM solenoid output to shut off due to high current. The current draw must not exceed 0.85A. Check the solenoid. See **Section 42.19.** If all of the above is OK, replace the CHM.

Troubleshooting

<table>
<tr><th colspan="4">Fire Pump Controls Function Electrical Diagnosis</th></tr>
<tr><th>Test No.</th><th>Test Procedure</th><th>Test Result</th><th>Action</th></tr>
<tr><td rowspan="2">3</td><td rowspan="2">Make sure the vehicle has full air pressure. Turn the ignition on.

Using the appropriate solenoids Datalink Monitor template, attempt to engage the fire pump using the smart switch in the dash while observing the status of the pressure switch under the "Inputs to BHM" heading for the two solenoids that control the fire pump. See Fig. 2 and Fig. 3.

NOTE: Under normal operation with the switch off, one solenoid should indicate air pressure, the other one should not. When the switch is turned on and the pump engages, the solenoid that indicated pressure should now be off, and the one that was off should now indicate pressure.

Does the status of the pressure switch change for both solenoids when the switch is turned on, even if it reverts back to its initial state?</td><td>Yes</td><td>Go to test no. 4.</td></tr>
<tr><td>No</td><td>For the solenoid that does not change pressure switch status:
• Check solenoid pressure switch feedback circuit.
• Check the solenoid pressure switch. See Section 42.19.
• Check the air lines.

If the above items are OK, replace CHM.</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">In ServiceLink, open the "Fire Pump Interlocks" Datalink Monitor template.

Using Table 5, determine which fire pump interlocks are used based on the reference parameter programmed into the BHM.

Engage the fire pump using the switch in the dash.

Do any of the necessary interlocks drop out when the fire pump solenoids drop out?</td><td>Yes</td><td>Determine the cause for interlock drop out and repair as necessary.</td></tr>
<tr><td>No</td><td>Check both fire pump solenoid output circuits for amperage. If either exceeds 0.85A, make necessary repair or modification.

If amperage is OK, check for mechanical problem.</td></tr>
</table>

Fire Pump Controls Function Electrical Diagnosis			
Test No.	Test Procedure	Test Result	Action
5	In ServiceLink, open the "Chassis Module Battery Inputs" Datalink Monitor template. Is Battery Power Feed No. 3 at approximately battery voltage?	Yes	The problem is in one or both of the fire pump solenoid output circuits. Make sure the fire pump solenoids are wired to the correct CHM output pins per the ServiceLink CHM Configuration screen. Check both fire pump solenoid output circuits from the CHM to the solenoids, including the solenoid coil ground circuit, for opens. Check both solenoid output circuits between the CHM and solenoids for short to ground. This will cause the CHM solenoid output to shut off due to high current. The current draw must not exceed 0.85A. Check the solenoid(s). See **Section 42.19.** If all of the above is OK, replace the CHM.
		No	Check fuse 13 in the PDM. If blown, locate and correct the source of high current. If fuse 13 is OK, check wiring between PDM fuse 13 and CHM pin C4-J for open circuit.

Table 2, Fire Pump Controls Function Electrical Diagnosis

PTO and Fire Pump Control Switch and Interlocks Test			
Test No.	Test Procedure	Test Result	Action
1	In ServiceLink, open the "Dash Smart Switches" Data Monitor template. NOTE: Be sure to open the correct template for the BHM software version on the vehicle. Look at each of the five BHM outputs: SS1 ID#, SS2 ID#, SS3 ID#, SS4 ID#, and SS5 ID#. If diagnosing the PTO, are any of the five SSn ID#s equal to 38? If diagnosing the fire pump controls, are any of the five SSn ID#s equal to 104?	Yes	**Go to test no. 6.**
		No	**Go to test no. 2.**

Troubleshooting

PTO and Fire Pump Control Switch and Interlocks Test			
Test No.	**Test Procedure**	**Test Result**	**Action**
2	Are any of the five SSn ID#s equal to 0?	Yes	**Go to test no. 5.**
		No	**Go to test no. 3.**
3	In ServiceLink, open the "Switch Expansion Module 1, Smart Switches" Datalink Monitor template. Look at each of the six SEM to BHM outputs: SS1 ID#, SS2 ID#, SS3 ID#, SS4 ID#, SS5 ID#, and SS6 ID#. If diagnosing the PTO, are any of the five SSn ID#s equal to 38? If diagnosing the fire pump controls, are any of the five SSn ID#s. equal to 104?	Yes	**Go to test no. 6.**
		No	**Go to test no. 4.**
4	Are any of the six SSn ID#s. equal to 0?	Yes	**Go to test no. 5.**
		No	Repeat test no. 3 using the next SEM template. For example, "Switch Expansion Module 2, Smart Switches."
5	Is fault code 164 s022 07 active?	Yes	Check the following and make the necessary repairs: • Check if PTO or PUMP smart switch is installed and connected. • Check smart switch wiring. • Check the smart switch. • If the smart switch is installed in SEM, check SEM.
		No	The PTO or fire pump controls smart switch is not programmed for the vehicle. Check and apply the proper 26-01032-xxx reference parameter.
6	Toggle the PTO smart switch on and off several times while observing the Datalink Monitor template which shows SSn ID# equal to 38 for PTO diagnosis, or 104 for fire pump controls diagnosis. If using the Smart Switches template, look for a change under the "BHM Inputs" heading in the input voltage for the smart switch. If using one of the Switch Expansion Modules templates under "SEM to BHM" heading, look for a change in the state of the "SSn Pos" annunciator for the smart switch. Is there a change in voltage or state when toggling the PTO switch?	Yes	**Go to test no. 7.**
		No	Check the following and make necessary repairs: • Check smart switch wiring. • Check the smart switch. • If the smart switch is installed in SEM, check SEM.

PTO and Fire Pump Control Switch and Interlocks Test			
Test No.	Test Procedure	Test Result	Action
7	In ServiceLink, open one of the following Datalink Monitor templates: • If testing the PTO controls, open the "PTO Interlocks" template. • If testing fire pump controls, open the "Fire Pump Interlocks" template. Using **Table 4** for PTO controls or **Table 5** for fire pump controls, determine which interlocks are used based on the reference parameter programmed into the BHM. While attempting to engage the PTO or fire pump using the switch in the dash, are all of the interlocks associated with the reference parameter met?	Yes	Reapply the PTO or fire pump control reference parameter. If the PTO or fire pump control continues to be inoperable, contact the Freightliner Customer Assistance Center at 1-800-FTL-HELP or 1-800-385-4357. There may be an error in the reference parameter.
		No	Determine the reason for the interlock not being met. Either repair the problem or advise the driver of proper operation.

Table 3, PTO and Fire Pump Control Switch and Interlocks Tests

PTO Interlocks by Reference Parameter					
Reference Parameter*	Description	Interlocks			
		Neutral (from transmission)		Ignition (BHM input)	Park Brake (from CHM)
		J1939 Current Gear	J1939 Selected Gear		
26-01032-003	PTO End of Frame Air Control, w/Ign Interlock (Smart Switch ID#38)	—	—	On	—
26-01032-005	PTO End of Frame Air Control, w/Neut & Ign Interlocks (Smart Switch ID#38)	Neutral	Neutral	On	—
26-01032-008	PTO End of Frame Air Control, AGS† Trans (Smart Switch ID#38)	—	—	On	Set
26-01032-014	PTO End of Frame Air Control, w/Neut Interlock (Smart Switch ID#38)	Neutral	Neutral	On	—
26-01032-019	PTO End of Frame Air Control, w/Park Brk Interlock (Smart Switch ID#38)	—	—	On	Set
26-01032-020	PTO End of Frame Air Cont,AGS Trans,Prk Brk & Neut Intlocks (Smart Switch ID#38)	Neutral	Neutral	On	Set

* For a given reference parameter, all the interlocks for that parameter must be in the state shown in order for the PTO solenoid to engage.

† The AGS and AGS2 designations refer to the same Mercedes-Benz transmission. References to AGS2 may be found in ServiceLink.

Table 4, PTO Interlocks by Reference Parameter

Troubleshooting

Fire Pump Control Interlocks by Reference Parameter				
Reference Parameter	Description	Interlocks		
		Indicated Vehicle Speed from Engine*	Ignition (BHM input)	Park Brake (from CHM)
26-01032-004	PTO Fire Pump Control (Smart Switch ID#104)	—	On	Set
26-01032-010	PTO Fire Pump Control, w/Park Brake & Veh Spd Interlocks (Smart Switch ID#104)	Approximately 5 mph (8 km/h)	On	Set

* The fire pump is driven by a transfer case. When the transfer case is shifted to deliver power to the fire pump, the transmission is put into gear to drive the transfer case (the vehicle will be stationary). Since the transmission drives the transfer case, an apparent output shaft speed will register indicating vehicle speed. In order to engage the fire pump, this apparent output shaft speed must be under 5 mph (8 km/h). Once the transfer case is engaged, it will remain engaged regardless of the apparent output shaft speed as long as the ignition is on, the park brake is set, and the pump smart switch remains on.

Table 5, Fire Pump Control Interlocks by Reference Parameter

PTO and Fire Pump Control J1587 Fault Codes				
MID	SID	FMI	Description	Action
164	025	07	End of Frame Air (PTO and fire pump control)–unexpected air pressure feedback	Solenoid is not activated, but CHM senses that the pressure switch is in an unexpected state. For example, a normally closed solenoid is off, but air pressure is detected. Check the following: • Air system • Pressure feedback circuit including the ground. • Solenoid–pressure switch may be stuck.
	026	07	End of Frame (PTO and fire pump control)–no air pressure feedback	Chassis Module engages solenoid, but the pressure switch does not change status indicating that the solenoid supplied, or exhausted, air downstream. Check the following: • Air system • Pressure feedback circuit including the ground. • Solenoid–pressure switch may be stuck.

Table 6, PTO and Fire Pump Control J1587 Fault Codes

PTO and Fire Pump Control J1939 Fault Codes				
SA	**SPN**	**FMI**	**Description**	**Action**
33	6954	07	End of Frame (PTO and fire pump control)–no air pressure feedback	Solenoid is not activated, but CHM senses that the pressure switch is in an unexpected state. For example, a normally closed solenoid is off, but air pressure is detected. Check the following: • Air system • Pressure feedback circuit including the ground. • Solenoid–pressure switch may be stuck.
	6955	07	End of Frame (PTO and fire pump control)–unexpected air pressure feedback	Chassis Module engages solenoid, but the pressure switch does not change status indicating that the solenoid supplied, or exhausted, air downstream. Check the following: • Air system • Pressure feedback circuit including the ground. • Solenoid–pressure switch may be stuck.

Table 7, PTO and Fire Pump Control J1939 Fault Codes

Troubleshooting

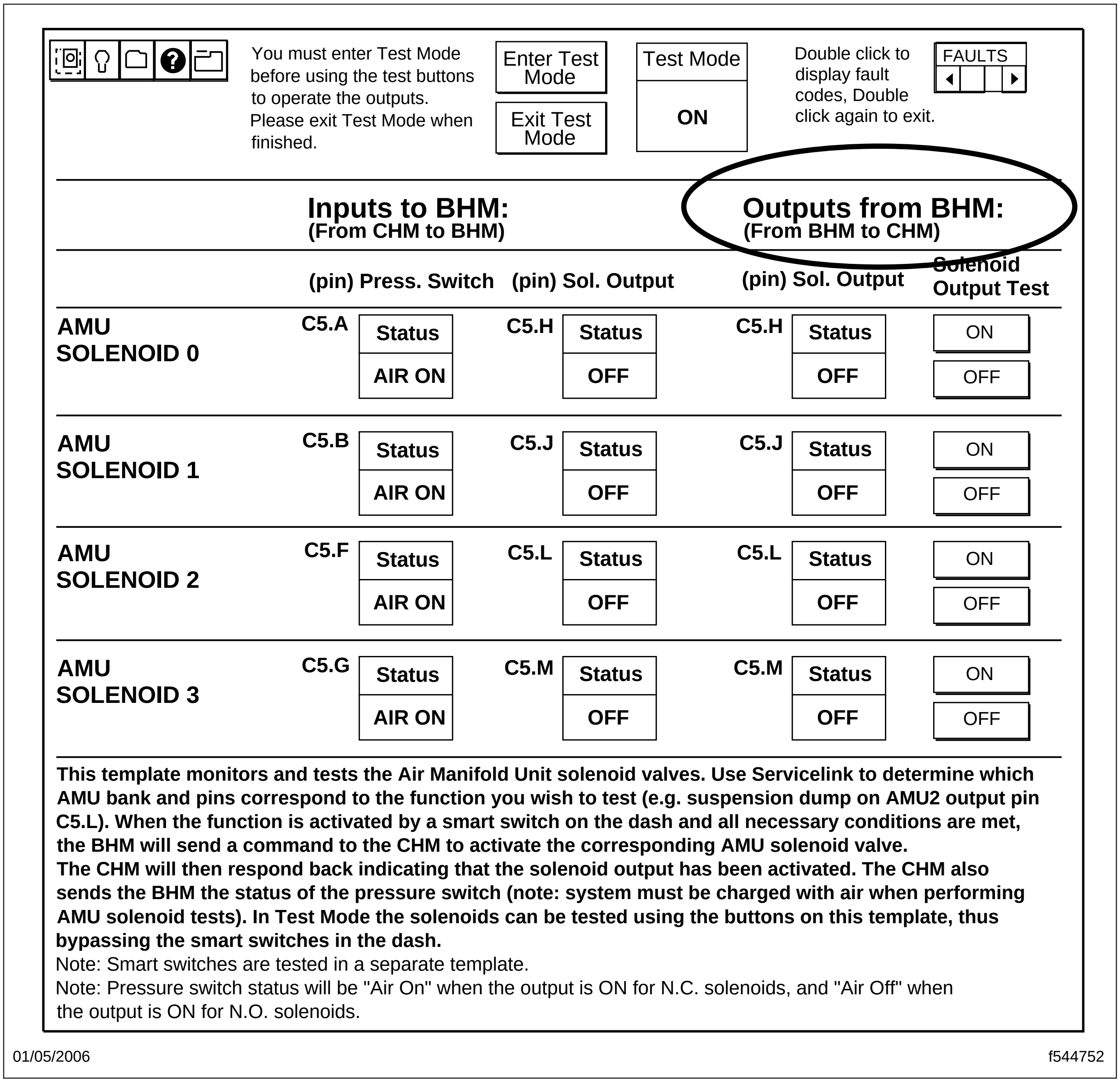

Fig. 1, AMU Solenoids Template, Outputs from BHM

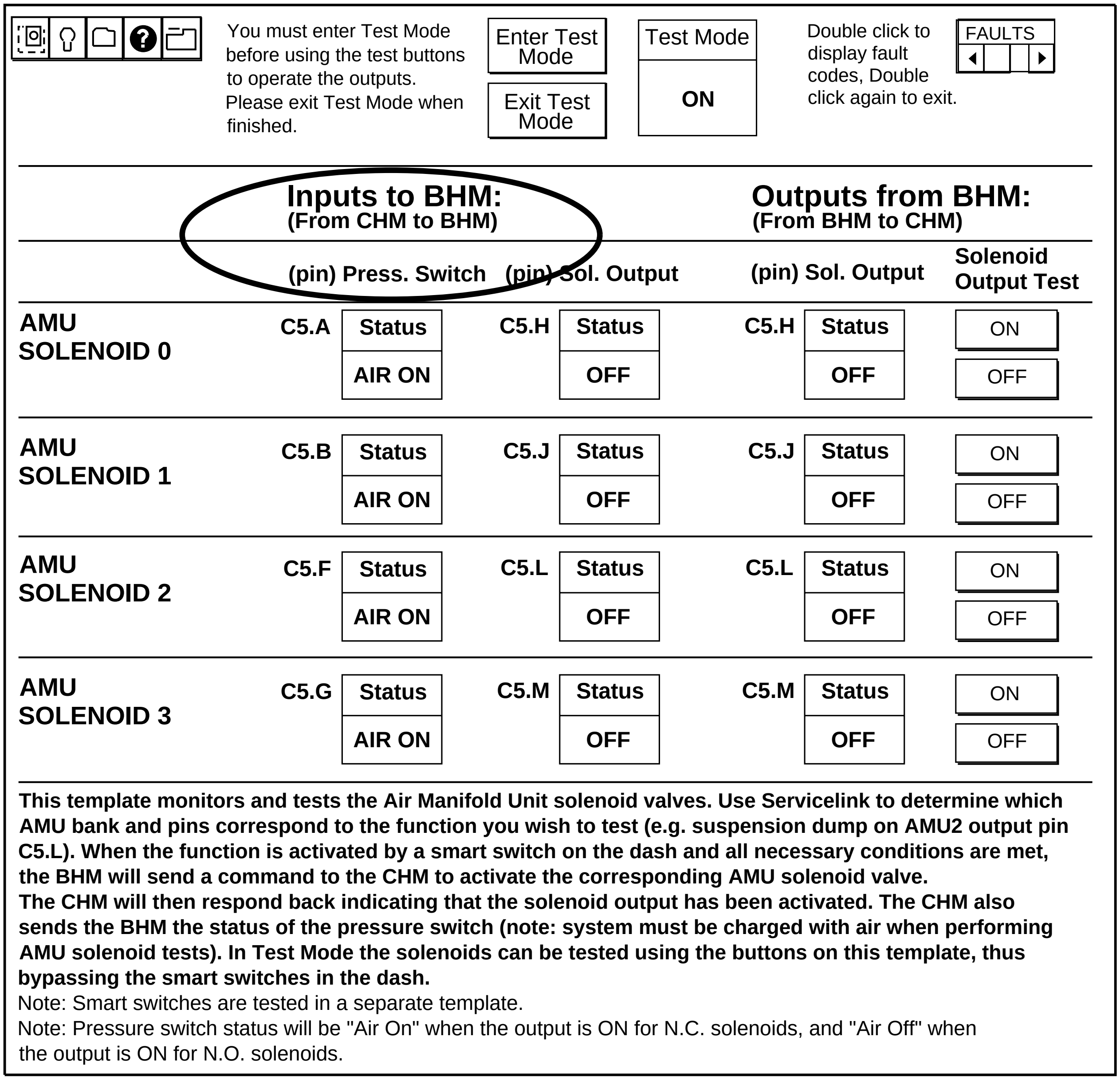

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Fig. 2, AMU Solenoids Template, Pressure Switch Status

Troubleshooting

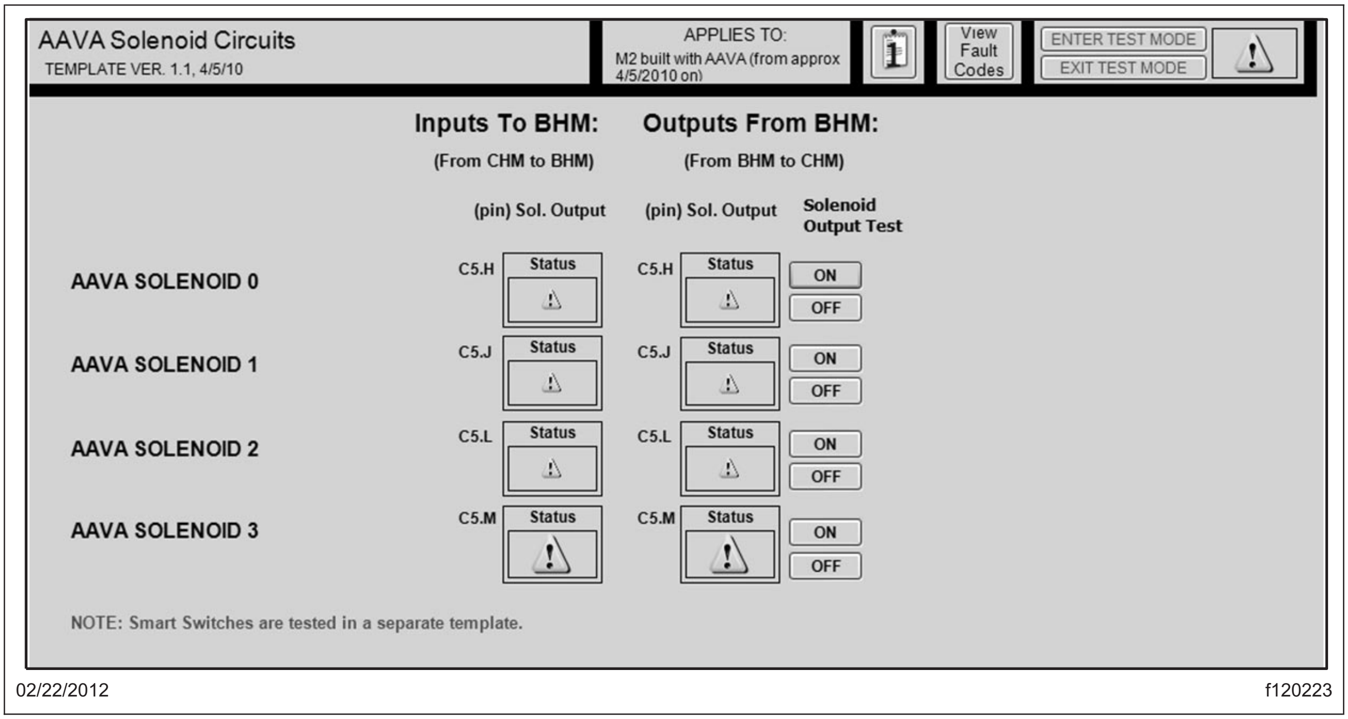


Fig. 3, AAVA Solenoids Template, Outputs from BHM

Specifications

See **Fig. 1** for a typical wiring diagram of an Allison hydraulic PTO.

See **Fig. 2** for a typical wiring diagram of an Allison hydraulic PTO with a 4th generation TCU.

See **Fig. 3** for a typical wiring diagram of a pneumatic PTO.

See **Fig. 4** for a typical wiring diagram of a split shaft PTO.

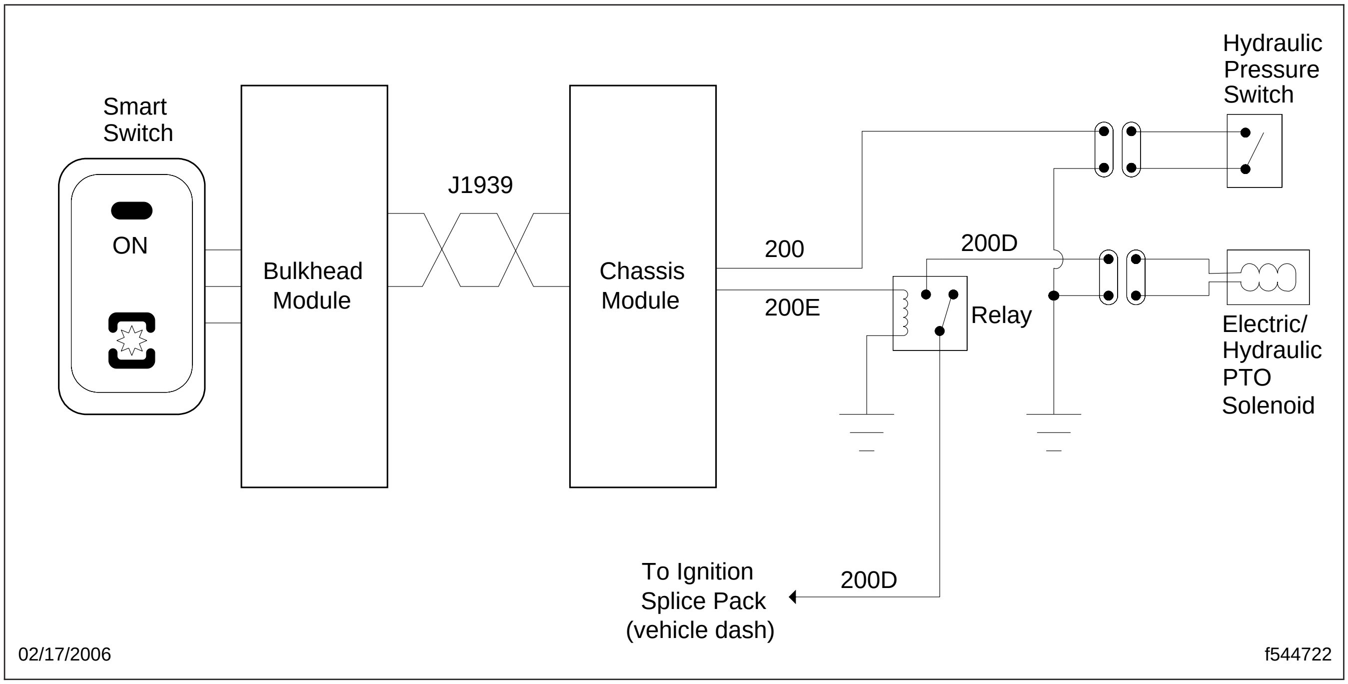
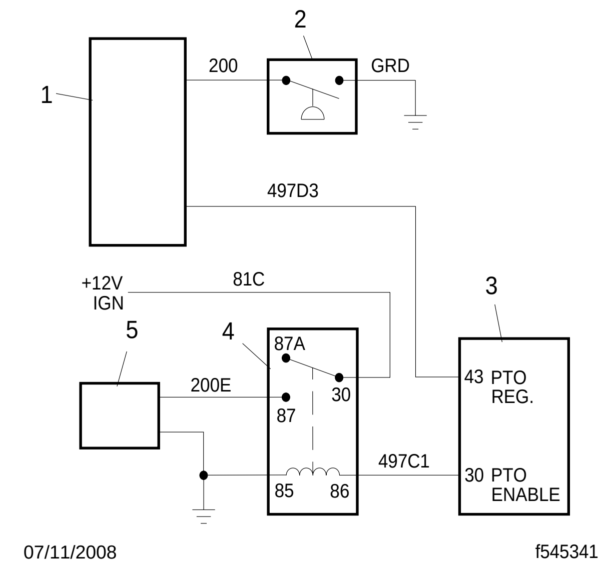


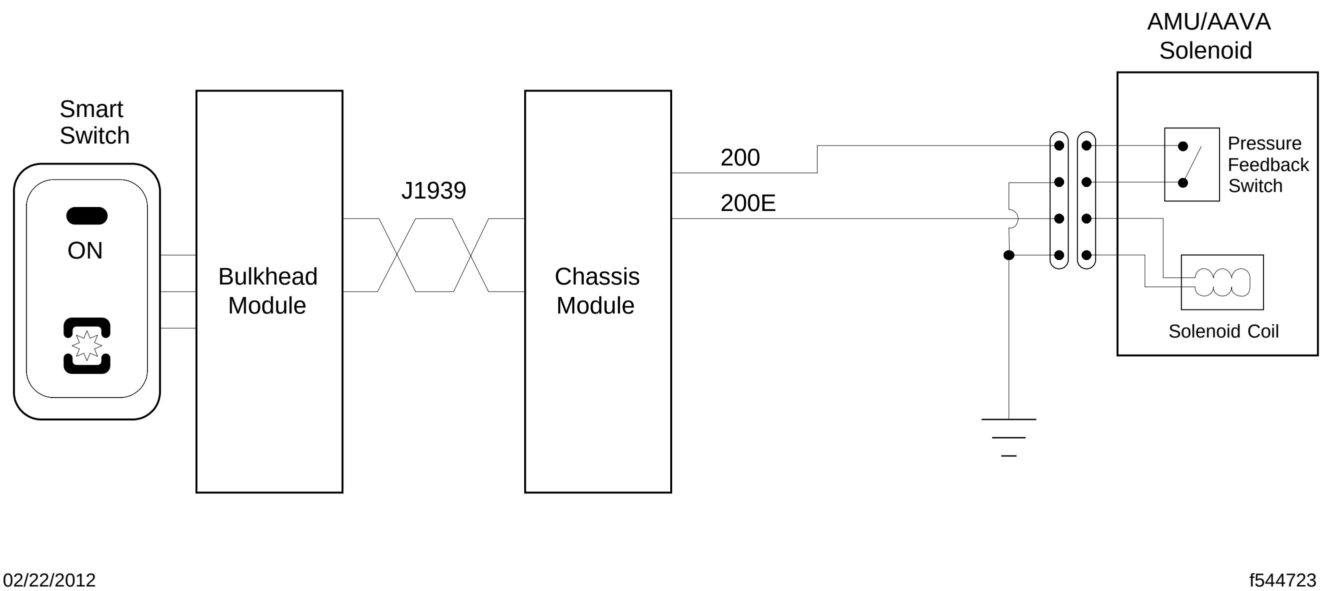
Fig. 1, Typical Wiring Diagram of an Allison Hydraulic PTO

Specifications



1. CHM
2. Hydraulic Pressure Switch
3. TCU
4. PTO Relay
5. PTO Solenoid

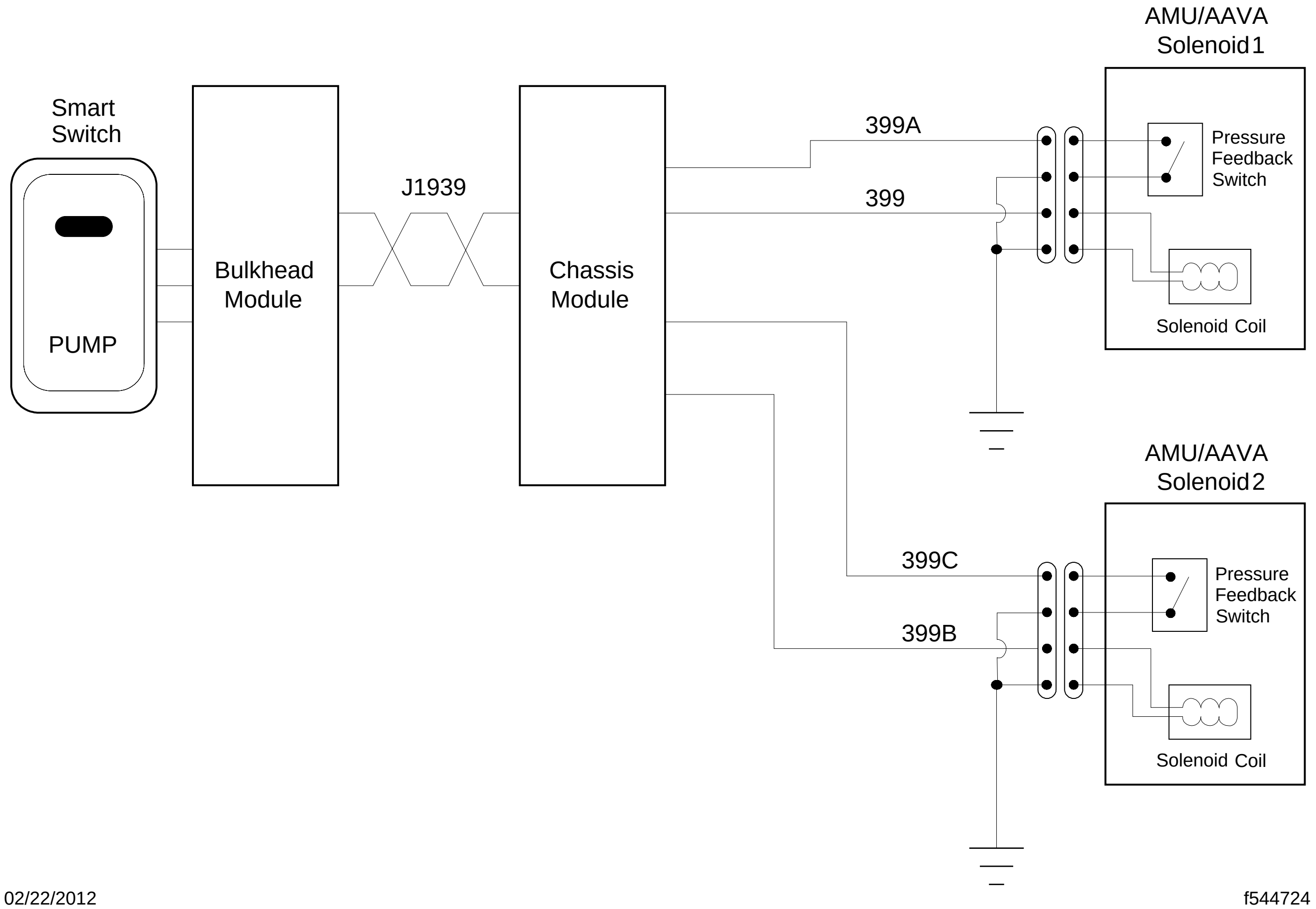
Fig. 2, Typical Wiring Diagram of an Allison Hydraulic PTO with 4th Generation TCU



NOTE: PTO functions use a solenoid that provides air when power is applied to the solenoid coil (normally closed). The pressure switch closes when air pressure reaches about 12 to 28 psi (83 to 193 kPa).

Fig. 3, Typical Wiring Diagram of a Pneumatic PTO

Specifications



NOTES:

- Pump functions require two solenoids to shift the transfer case. Solenoid 1 provides air when power is applied to the solenoid coil (normally closed). Solenoid 2 provides air when power is removed from the solenoid coil (normally open).
- The pressure switch closes when air pressure reaches about 12 to 28 psi (83 to 193 kPa).
- Only the feedback from the pressure switch in the normally closed solenoid is used by the pump control system. The other circuit is wired, but is not used.

Fig. 4, Typical Wiring Diagram of a Split Shaft PTO

General Information

Introduction

Optional power switches are factory-installed, switch-controlled power provisions that can be ordered for a Business Class® M2 vehicle. Optional switches can be ordered in a one-, two-, or four-switch configuration. All optional switches mount on the dash, provide fuse-protected battery power, and route to a customer access point. Optional switches are commonly used to provide battery-powered lighting, such as dome, spot, or beacon lights. Other applications include using the optional switch as a triggering mechanism to enable other features, such as hydraulic lift operations or access panel locks.

Overview

Available optional switch configurations include:

- one switch with a customer-access junction block
- one switch with a blunt-cut output
- two switches with blunt-cut outputs
- four switches with blunt-cut outputs

Optional power switches are mounted on the dash to the right of the steering column. Each switch is equipped with two LED lights; one LED provides switch illumination while the other indicates when the switch is in the on position. Battery-powered power distribution module (PDM) fuses, located under the hood, provide a constant power feed to each switch. When a switch is turned to the on position, the switch contacts close and supply battery power to an output circuit.

For vehicles with a single optional switch and junction block configuration, the output circuit from the optional switch is a red wire that connects to the 5-post junction block. The junction block is usually located on the frame rail near the Chassis Module (CHM) and provides a connection point that permits easy access. The red wire in the junction block is connected to the 15-amp optional switch output, while the yellow wire is connected to a marker light feed from the CHM. See **Section 54.35** for information on the junction block marker light feed.

For all other optional switch configurations, the output circuits from the optional switches route along the chassis toward the back of the cab where the circuits terminate inside the left frame rail near the standard location of the CHM on a vehicle with a day cab. On a vehicle with an extended cab or a crew cab, the circuits terminate under the cab.

Output circuits terminate as blunt-cut ends sealed in heat shrink. The blunt-cut ends extend a few inches out from the harness loom and are individually tagged with an identification label. The label identifies which switch is powering the circuit and also the current capacity of the circuit. See **Fig. 1**.

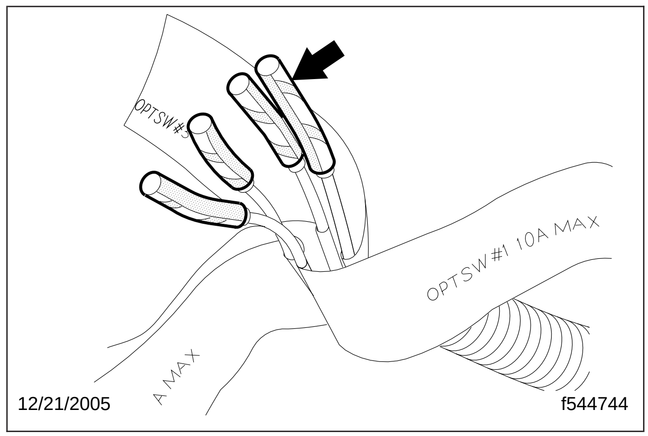


Fig. 1, Blunt-cut End

Current Capacity

It is important to note that the current capacities for optional switch outputs are not the same for all configurations. Current capacities differ according to the number of switches that come installed on a vehicle. For instance, for a two-switch configuration, the fused battery feed for both switches is supplied by one PDM fuse. This means that the total combined load from both switches cannot exceed the fuse rating. For optional-switch current capacities, see **Table 1**.

Optional-Switch Current Capacity

No. of Switches	PDM Fuse F25		PDM Fuse F26		Switch Output Current Capacity
	Rating	Switch Protected	Rating	Switch Protected	
1	15A	Switch 1	—	—	15A

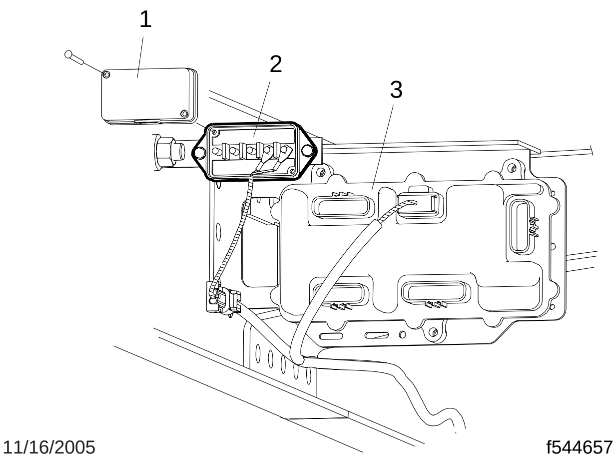
General Information

Optional-Switch Current Capacity					
No. of Switches	PDM Fuse F25		PDM Fuse F26		Switch Output Current Capacity
	Rating	Switch Protected	Rating	Switch Protected	
2	30A	Shared by switch 1 and 2	—	—	15A
4	20A	Shared by switch 1 and 2	20A	Shared by switch 3 and 4	10A

Table 1, Optional-Switch Current Capacity

Connecting to One Switch With a Junction Block

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the negative leads from the batteries or, if the vehicle is equipped with a battery disconnect switch, turn the switch to the off position.
3. Locate the junction block attached to the frame rail near the Chassis Module (CHM.) See **Fig. 1**.



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1. Junction Block Cover
2. Junction Block
3. Chassis Module

Fig. 1, Junction Block

4. Remove the capscrews that attach the junction block cover to the junction block, and remove the cover.
5. Locate the red wire in the junction block. The red wire receives power from the output circuit of the optional switch.

IMPORTANT: The power distribution module (PDM) fuse supplying power to the optional switch is rated for 15 amps. **Do not exceed a combined current load of 15 amps at the red wire in the junction block**.

6. Connect to the red wire in the junction block using a #10 ring terminal. The optional switch can provide 15 amps of fused battery power at the red wire.
7. Using capscrews, attach the junction block cover to the junction block.
8. Connect the batteries or turn the battery disconnect switch to the on position.
9. Verify the operation of the circuit(s) connected to the red wire in the junction block. The optional switch should control the electrical feature(s) connected to the red wire.
10. Remove the chocks from the tires.

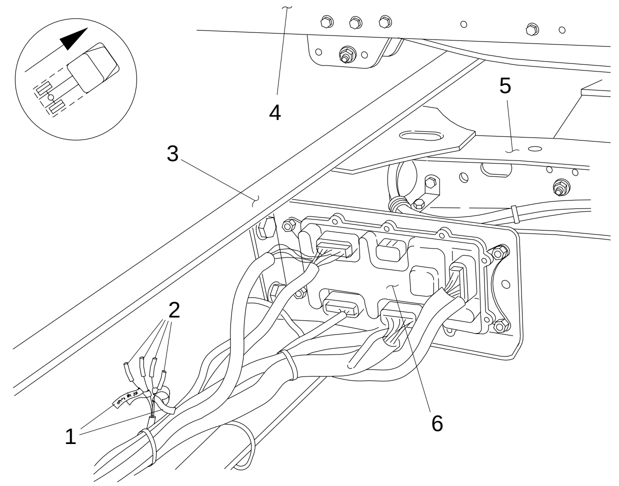
Connecting to One Switch Without a Junction Block or Multiple Switches

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the negative leads from the batteries or, if the vehicle is equipped with a battery disconnect switch, turn the switch to the off position.
3. Locate the customer connection end of the optional-switch output circuit. The connection end of the output circuit is located on the chassis behind the cab. The circuit end is an exposed blunt-cut wire sealed with heat shrink. There will be a blunt-cut circuit for each optional switch. See **Fig. 2**.
4. Use the identification label that is taped to the blunt-cut end to properly match the correct circuit with the corresponding optional switch.

NOTE: The following method of splicing the optional-switch circuits to load circuits is approved by Freightliner. Use solder splice repair kit ESY ES66 404, which works for 14 and 16 gauge wire.

5. Remove the heat shrink by cutting the optional-switch circuit wire near the end of the heat shrink.
6. Strip the insulation 3/8 to 1/2 inch (10 to 13 mm) from the ends of the optional-switch circuit wire and the wire for the load.
7. Place the three-inch (76-mm) length of heat shrink from the repair kit over the circuit that is being spliced to the optional-switch circuit.
8. Place the solder sleeve from the repair kit over one of the stripped wires.

Optional Switch Connections



1. Optional-switch Circuit Identification Label
2. Optional-switch Output Wire
3. Frame Rail
4. Back of Cab
5. Crossmember
6. Chassis Module

Fig. 2, Optional Switch Outputs

9. Use a suitable crimping tool and the crimp splice from the repair kit to crimp the wires together.
   - 9.1 Insert one of the stripped wire ends into the crimp splice until it touches the wire stop in the center of the crimp splice.
   - 9.2 Center the crimping tool between the wire stop and the end of the crimp splice over the wire.
   - 9.3 Crimp the splice on the wire.
   - 9.4 Check the crimp to be sure that the wire is held in place.
   - 9.5 Repeat the previous substeps for the other wire.
10. Place the solder sleeve over the crimp splice and center the solder ring over the crimp splice. Then apply 250°F (121°C) to the solder sleeve until the solder flows into the crimp splice and the plastic sleeve has shrunk against the wire and crimp splice. Be sure to keep the heat source well away from the heat shrink by sliding the heat shrink at least 4 inches (102 mm) from the splice joint.
11. Allow the solder sleeve to cool for a few minutes.
12. Place the heat shrink over the splice and center it as best you can. Then apply 250°F (121°C) to the heat shrink until it has shrunk completely over the wire insulation. Some of the sealant material should be bubbling out of the ends of the heat shrink.
13. When routing additional electrical wiring, make sure all circuits are properly protected and secured.
14. Connect the batteries or turn the battery disconnect switch to the on position.
15. Verify the operation of the electrical feature(s) connected to the optional switch output.
16. Remove the chocks from the tires.

Troubleshooting

For electrical troubleshooting, see **Table 1**.

Electrical Troubleshooting	
Description of Fault	**Possible Cause**
No power at an optional switch output. Switch is on.	Check appropriate power distribution module (PDM) fuse to see if it is open or missing. F25 supplies switches 1 and 2. F26 supplies switches 3 and 4.
No power at an optional switch output. Switch is on and power supply fuse is proven good.	Check the identification label on the output circuit. Make sure the output circuit is identified as belonging to the optional switch in use.
Intermittent or no operation.	Loss of connection. Could be caused by loose electrical connection(s), disengaged terminal connection(s), or damaged wire(s). Trace the suspect circuit.

Table 1, Electrical Troubleshooting

Wiring Diagrams

For a wiring diagram of the one-switch configuration, see **Fig. 1**.

For a wiring diagram of the two-switch configuration, see **Fig. 2**.

For a wiring diagram of the four-switch configuration, see **Fig. 3**.

Circuit Identification

For a pinout chart of a typical optional switch connector, see **Table 1**.

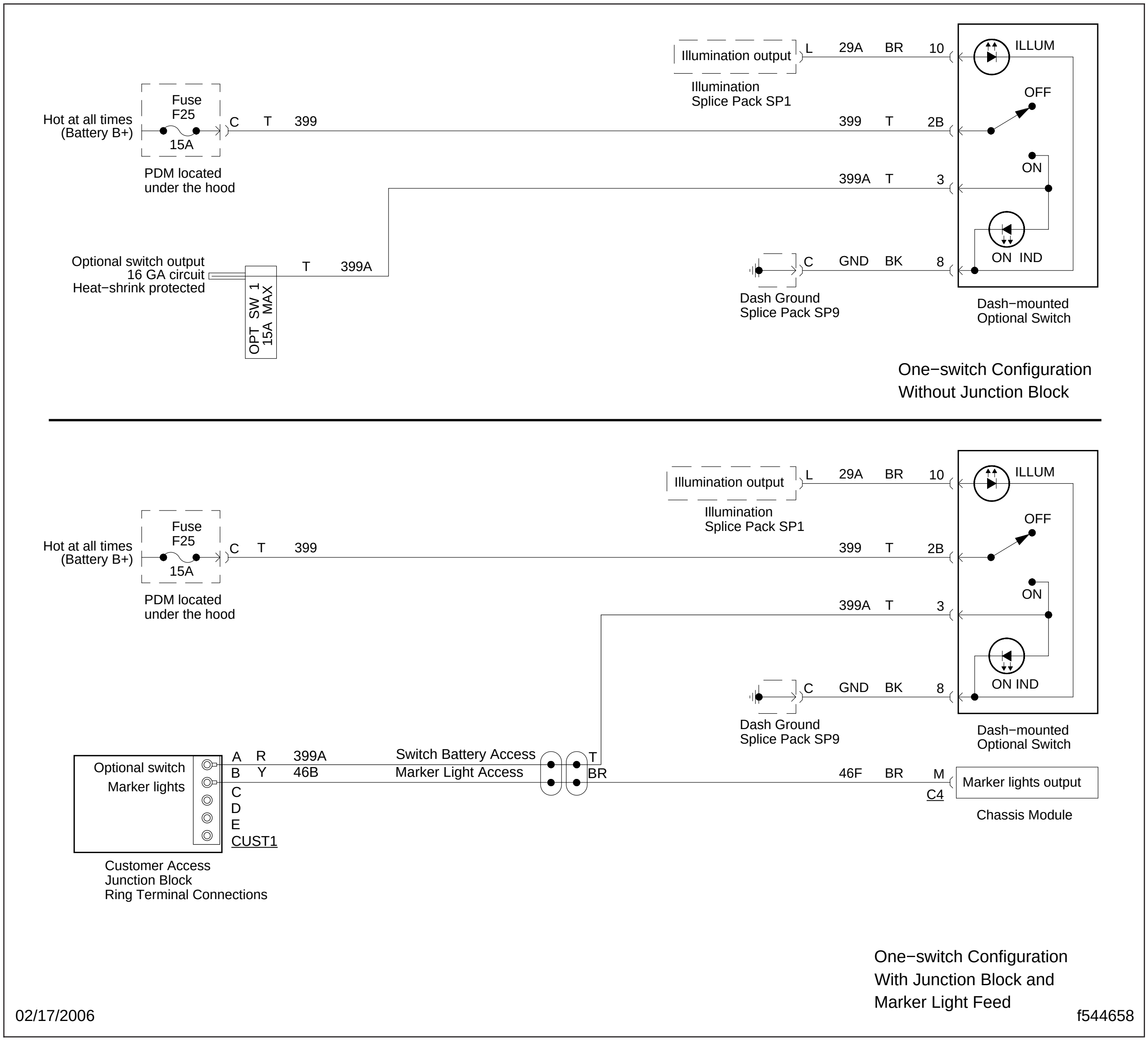


Fig. 1, One-Switch Configuration Wiring Diagram

Specifications

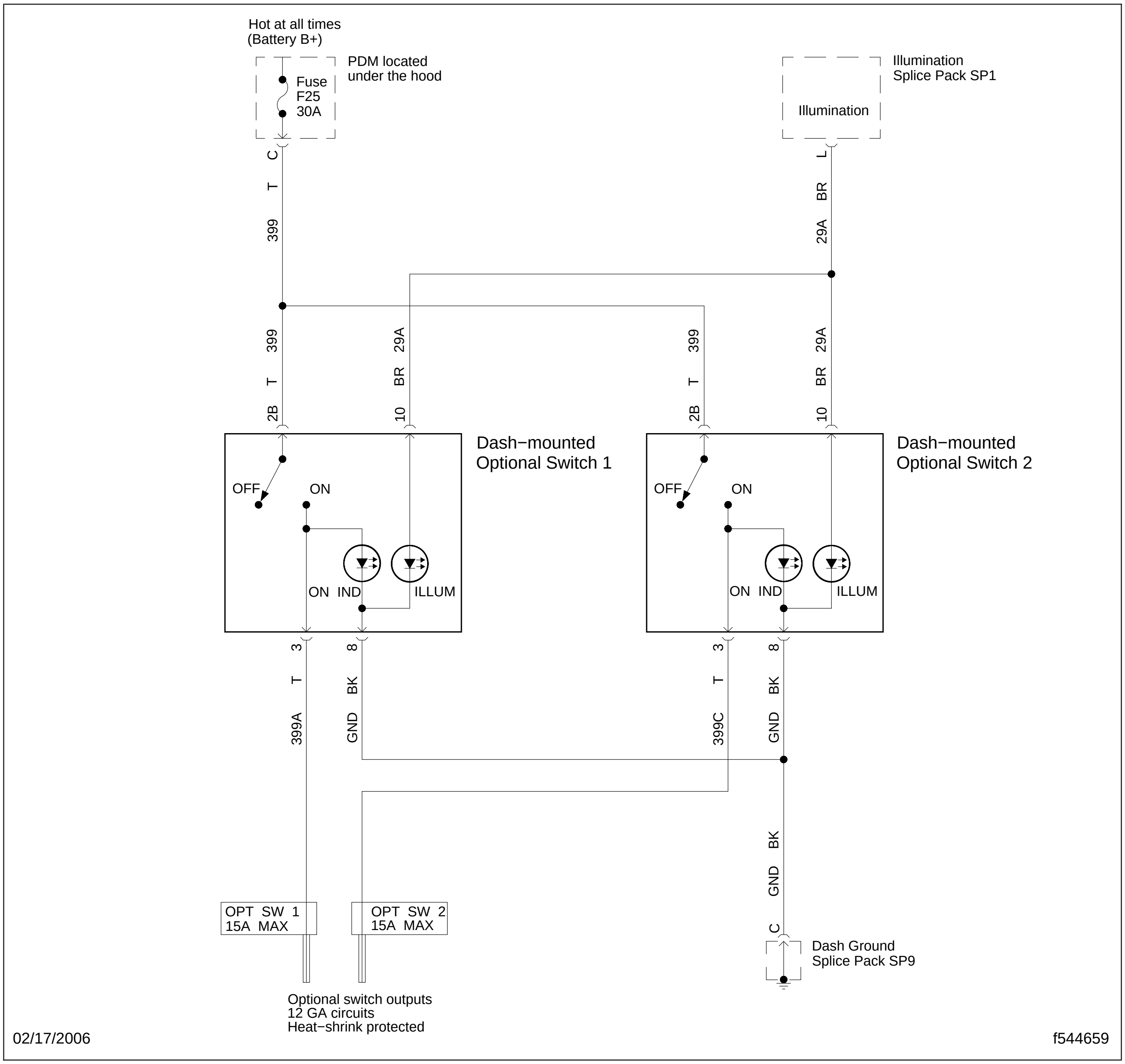


Fig. 2, Two-Switch Configuration Wiring Diagram

Specifications

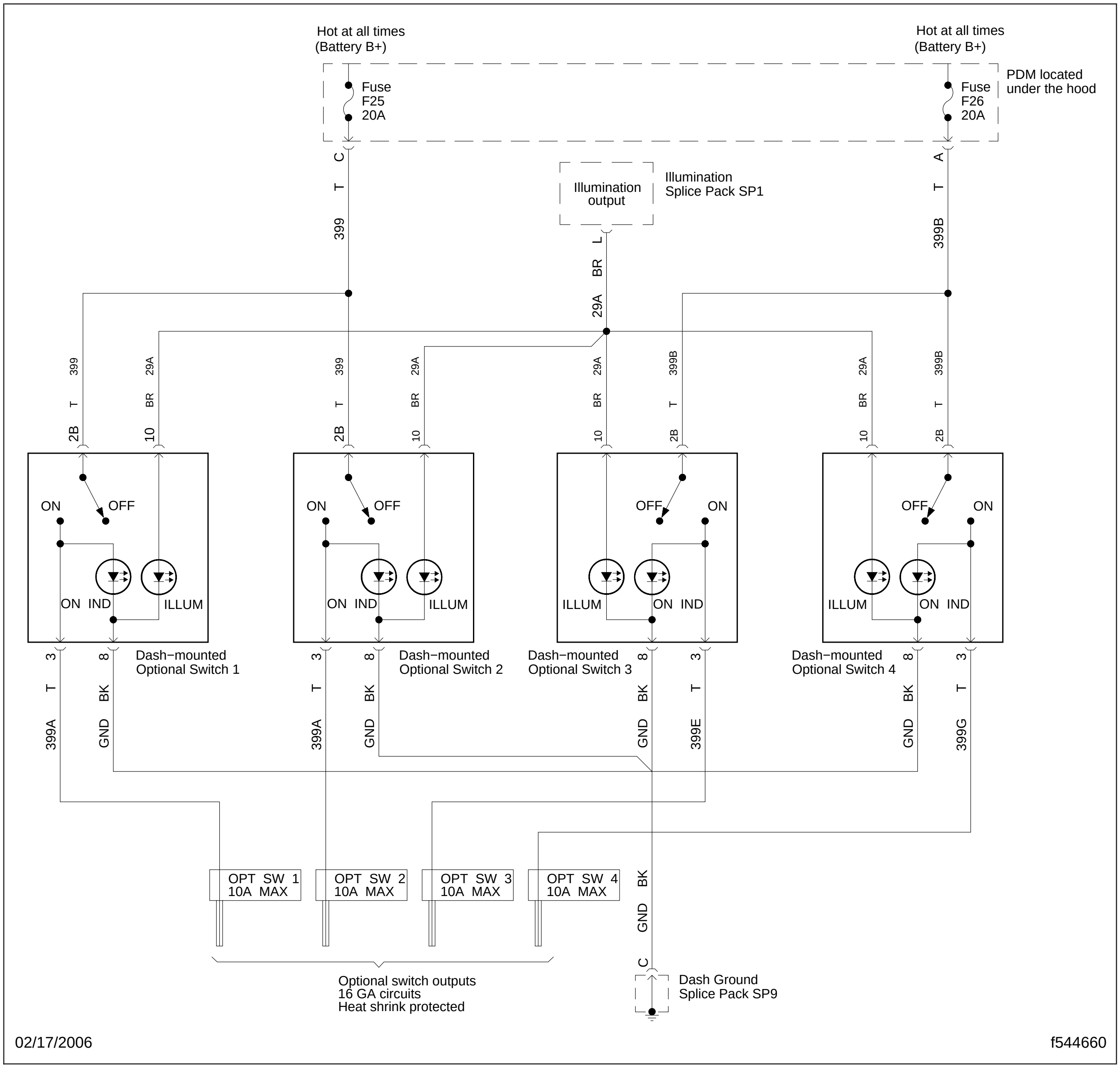


Fig. 3, Four-Switch Configuration Wiring Diagram

Specifications

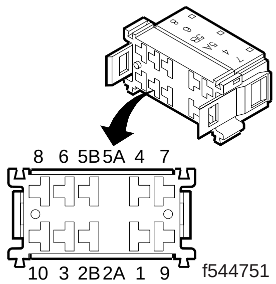
Optional Switch Connector				
Connector Pin	Signal Name	Signal Type	Circuit Color	Circuit Number
				
1	—	—	—	—
2B	Fused Battery Power	Input	T	399 for optional switches 1 and 2. 399B for optional switches 3 and 4.
3	Optional Switch Output	Output	T	399A for optional switch 1. 399C for optional switch 2. 399E for optional switch 3. 399G for optional switch 4.
4	—	—	—	—
5B	—	—	—	—
6	—	—	—	—
7	—	—	—	—
8	Ground	Ground	BK	GND
9	—	—	—	—
10	Illumination Feed	Input	BR	29A

Table 1, Optional Switch Connector

Replacement Parts		
Description	Freightliner Part Number	Vendor Part Number
Optional Switch	A06-03769-014	—
Eaton Connector	ETN285623	285623
Packard Metri-Pack 630 Terminal	PAC12015869	12015869

Table 2, Replacement Parts

Background Information

Chassis electrical control systems are optional features on a Business Class® M2 vehicle. These features include:

- interaxle lock
- axle shift
- suspension dump
- fifth wheel slide
- tag/pusher axle lift
- differential lock

The chassis electrical control systems are similar in their electronic operation and control. Most of these systems are activated by dash-mounted smart switches.

Smart switches contain internal resistors that communicate switch identification, location, function, and activation positions. Smart-switch signals are sent directly to the Bulkhead Module (BHM). The BHM reads the smart-switch resistor codes and communicates the necessary signals that request system operation.

Each smart switch is equipped with two light-emitting diodes (LED). One LED provides switch illumination while the other indicates when the switch is on and the system is activated. For more information concerning smart switches, see **Section 54.14**.

The BHM transmits system control requests via the J1939 data line to the Chassis Module (CHM). The CHM uses low-current outputs and digital inputs to control and monitor the different chassis electrical control systems.

Interaxle Lock

The interaxle lock is available on a vehicle with a tandem axle or a tri-drive axle. When activated, the interaxle differential is locked. This essentially makes the driveshaft a solid connection between the rear axles. Power entering the forward axle is transmitted straight through to the rear axle. Driveline torque is now delivered equally between the rear drive axles. In slippery conditions, without the interaxle lock activated, one drive axle receives the majority of the driveline torque when its wheels lose traction; however, with the interaxle lock activated, the rear drive axles spin equally and improve traction by turning all rear wheels at the same speed.

NOTE: Operating the vehicle with the interaxle lock activated under normal driving conditions increases driveline and tire wear. The interaxle lock should be used only when improved traction is needed.

Interaxle Lock Controls

With the engine running, the interaxle lock can be activated using a momentary, two-position smart switch. Press the upper half of the interaxle lock switch to activate the interaxle lock. Press the upper half of the interaxle lock switch again to deactivate the interaxle lock. See **Fig. 1**. If the interaxle lock is activated and the engine is then turned off, the system will deactivate the interaxle lock.

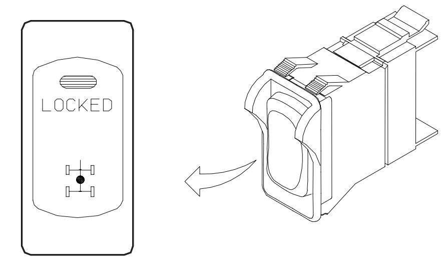


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Fig. 1, Interaxle Lock Switch

When the interaxle lock switch is activated, the CHM transmits a low-current output to a normally closed air management unit (AMU) solenoid. On auxiliary air valve assembly (AAVA) vehicles, the solenoid current is about 1.5 amps. The 2010 CHM does not have the current sourcing ability to drive these solenoids, so a relay in the chassis PDM is added to the circuit. The energized AMU/AAVA solenoid opens and supplies compressed air to the forward rear axle differential housing. The air sent to the housing applies a lock to the interaxle differential causing all driveline torque to be shared equally by the rear axles.

Feedback from the AMU/AAVA solenoid is required for correct operation of the interaxle lock controls. Feedback is provided by a ground input to the CHM. The ground input is delivered when the pressure switch closes. On AAVA-equipped vehicles, the pressure switch is in the air line. On AMU equipped vehicles, the pressure switch is in the AMU module. A grounded feedback circuit from the closed pressure switch indicates that the interaxle lock is activated and pressure is being supplied to the interaxle lock. An open feedback circuit indicates that the interaxle lock is not activated, or there is a malfunction; the interlock switch is turned on but the pressure switch is still open.

On a vehicle with a two-speed tandem axle, the electronic controls of the interaxle lock need to take into account the range position of the axles. Both axles must be in the same state (either high or low range) for the interaxle lock to be turned on or remain activated.

The electronic controls of the interaxle lock incorporate axle range position input as well as a second pressure-switch feedback to the CHM. Utilizing the feedback from the axle and pressure switches, the control logic provides a time delay to ensure proper function and to prevent damage. Once the interaxle lock is activated, any axle-range change may cause the interaxle lock to deactivate. A shift made from one range to another while the interaxle lock is activated requires that both axles reach the change state quickly before feedback indicates that the axles are not in the same drive range. For a description of the axle shift feature, see the information under the "Axle Shift" heading in this subject.

Axle Shift

Two-speed axle shift is an option available on a vehicle with a single or tandem axle. This option is available on a vehicle with a manual or automatic transmission; however, nonmultiplexed controls are only available on a vehicle with a manual transmission. A vehicle with a two-speed axle allows the operator to shift the drive axle between high and low gear ranges. At any time, the operator may change axle speeds to take mechanical advantage of different driving conditions.

NOTE: Since axle speed can be changed at any time, it is the driver's responsibility to ensure that axle speed selection is not done under harmful conditions, such as selecting low gear when the engine is at high rpm.

Multiplexed Controls

Multiplexed controls for the two-speed axle are available on a vehicle with a manual or automatic transmission. With the engine running, the two-speed axle is shifted between high and low ranges by a momentary, two-position smart switch. Press the upper half of the axle shift switch to change the axle speed. See **Fig. 2**. If the engine is turned off, then restarted, the two-speed axle will default to low range.

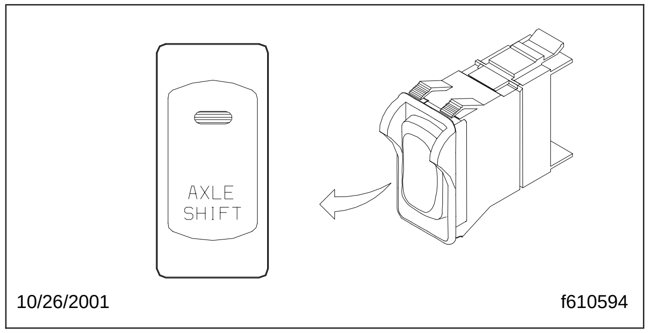

Fig. 2, Axle Shift Switch

When the axle shift switch is activated, the CHM transmits a low-current output to a normally closed air management unit (AMU) solenoid. On AAVA vehicles, the solenoid current is about 1.5 amps. The 2010 CHM does not have the current sourcing ability to drive these solenoids, so a relay in the chassis PDM is added to the circuit. The energized solenoid opens and supplies compressed air to the gear housing. The air sent to the housing shifts the axle into high gear. Pressing the axle shift switch again directs the CHM to remove the current supply to the AMU/AAVA solenoid, which stops the air supply to the gear housing. With a no-air condition at the housing, the axle shifts into low gear.

Feedback to the CHM is provided by switches located on each drive axle. When an axle shifts into the low-speed range, the axle switch closes and completes a ground signal to the CHM. The CHM uses the feedback signal(s) to determine if the system is functioning properly (axle shift switch confirms axle shift switch selection), or if there is a malfunction (axle shift switch does not confirm axle shift switch selection). Each rear axle of a tandem-axle vehicle has its own AMU/AAVA solenoid and axle switch. The CHM also monitors the feedback of both axle shift switches to make sure that the rear axles are in the same speed range.

Two-speed axle feedback is also provided to the Engine Control Module (ECM). For the MBE900 engine, the system provides axle position input via the J1939 data line messages between the CHM, BHM, and

ECM. For other engine configurations, the system controls a relay that provides a ground input as the ECM feedback. With the system set for low range, the relay coil receives no power and a ground input is provided to the ECM through the closed switch contacts of the relay. The operating power for this relay is provided by a splice connection into the CHM output that also controls the the AMU/AAVA solenoid. Pressing the axle shift switch shifts the axle to high range which causes the CHM to power both the the AMU/AAVA solenoid and the relay. The energized relay swings the switch contacts open and removes the ground signal from the ECM, thus communicating that the axle is in high range.

Nonmultiplexed Controls

On a vehicle with a manual transmission, the axle shift switch that activates the two-speed axle is built into the transmission shift knob. Because of the axle shift switch location, the controls are nonmultiplexed. The switch signals go directly to the AMU/AAVA solenoid that supplies the airflow to shift the two-speed axle. The axle shift switch operates as a two-position, latching switch with selections for low or high speed ranges. If the engine is turned off, then restarted, the two-speed axle defaults to low range.

With the engine running, selecting high range with the axle shift switch within the transmission shift knob closes the switch contacts and supplies power to a normally closed AMU/AAVA solenoid. The energized solenoid opens and supplies compressed air to the gear housing. The air sent to the housing shifts the axle into high gear. Selecting low range with the control switch opens the switch contacts and removes the power supply to the AMU/AAVA solenoid, stopping the air supply to the gear housing. With a no-air condition at the housing, the axle shifts into low gear.

For nonmultiplexed two-speed axle controls, axle range feedback is supplied to the ECM. An axle switch controls a relay that delivers a ground input to the ECM. The absence or presence of this ground signal indicates to the ECM what gear range the axle is in. In low range, the axle switch closes and completes a ground path for the relay. Since the relay receives power from a BHM-powered splice pack, the completed ground path through the axle switch allows the relay to energize. In high range, the relay is not energized because the axle shift switch is open and the relay is not grounded.

Suspension Dump

The suspension dump is available on a vehicle with rear air suspension. When activated, the suspension dump deflates the suspension air bags to lower the rear of the vehicle. Most vehicles with a suspension dump have an automatic refill that will inflate the rear suspension when the engine is turned off.

NOTE: To protect the chassis, the suspension dump is turned off when the vehicle speed reaches approximately 5 mph (8 km/h).

The suspension dump is available in two options. The first option has a lock solenoid that keeps the suspension in the last selected state when the engine is turned off. The second option does not have a lock solenoid; when the engine is turned off, the suspension inflates.

Suspension Dump Controls

With the engine running, the suspension dump can be activated using a momentary, two-position smart switch. Press the upper half of the suspension dump switch to deflate the suspension air bags and lower the rear of the vehicle. Press the upper half of the suspension dump switch again to raise the suspension to its normal height. See **Fig. 3**. The rear suspension also inflates when:

- Vehicle speed reaches approximately 5 mph (8 km/h);
- The engine is turned off and the autofill feature activates.

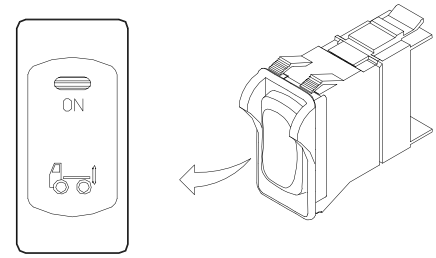

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Fig. 3, Suspension Dump Switch

When the suspension dump switch is activated, the CHM transmits a low-current output to a normally closed air management unit (AMU) solenoid. On AAVA vehicles, the solenoid current is about 1.5

amps. The 2010 CHM does not have the current sourcing ability to drive these solenoids, so a relay in the chassis PDM is added to the circuit. The energized solenoid opens and directs air flow by means of a three-port valve. An open solenoid removes the air supply to the rear suspension and vents the existing suspension pressure, allowing the rear of the vehicle to be lowered.

Feedback from the suspension dump solenoid air circuit is required for correct operation of the suspension dump controls. Feedback is provided by a ground input to the CHM. The input is at ground when a pressure switch within the AMU solenoid closes. On AAVA-equipped vehicles, the pressure switch is in the air line. A grounded feedback circuit from the closed pressure switch indicates that the system is activated. An open feedback circuit indicates that the suspension dump is not activated (suspension dump switch is not turned on), or there is a malfunction (suspension dump switch is turned on but the pressure switch is still open).

On a suspension dump with a lock solenoid, there is a second normally open AMU/AAVA solenoid that activates a double check valve in the rear suspension air supply. This valve keeps the rear suspension in the last selected state when the engine is turned off. This feature permits an override of the automatic refill, allowing the suspension to stay lowered. The lock solenoid receives power through a BHM-supplied splice pack.

A remote-activation switch is commonly installed in ambulances so that the suspension dump can be activated when the rear door opens. Freightliner provides a circuit that the body builder uses to install a remote-activation switch. The remote-activation switch is usually located at the rear of the ambulance. The remote-activation switch receives power through a direct wiring connection to the BHM.

Fifth Wheel Slide

A sliding fifth wheel is an option on an M2 vehicle. A sliding fifth wheel allows the weight of the trailer to be transferred between the tractor axles, thereby increasing or decreasing the distance between the front of the trailer and the back of the cab. A sliding fifth wheel can be adjusted to allow enough distance between the trailer and the cab to prevent the trailer from hitting the cab during a turn.

Fifth Wheel Slide Controls

With the engine running, the fifth wheel slide can be activated using a momentary, two-position smart switch. Pressing the upper half of the fifth wheel slide switch activates the fifth wheel slide. Pressing the upper half of the fifth wheel slide switch again deactivates the fifth wheel slide. See **Fig. 4**. If the fifth wheel slide is activated and the engine is turned off, the system will deactivate the fifth wheel slide. Drivers may activate the fifth wheel slide when vehicle speeds are below 8 mph (13 km/h). The fifth wheel slide automatically deactivates when the vehicle reaches speeds greater than 10 mph (16 km/h).

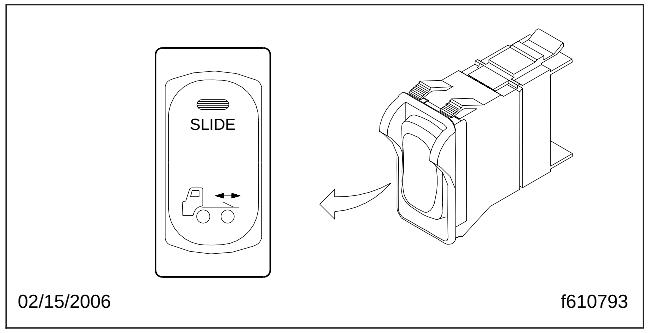
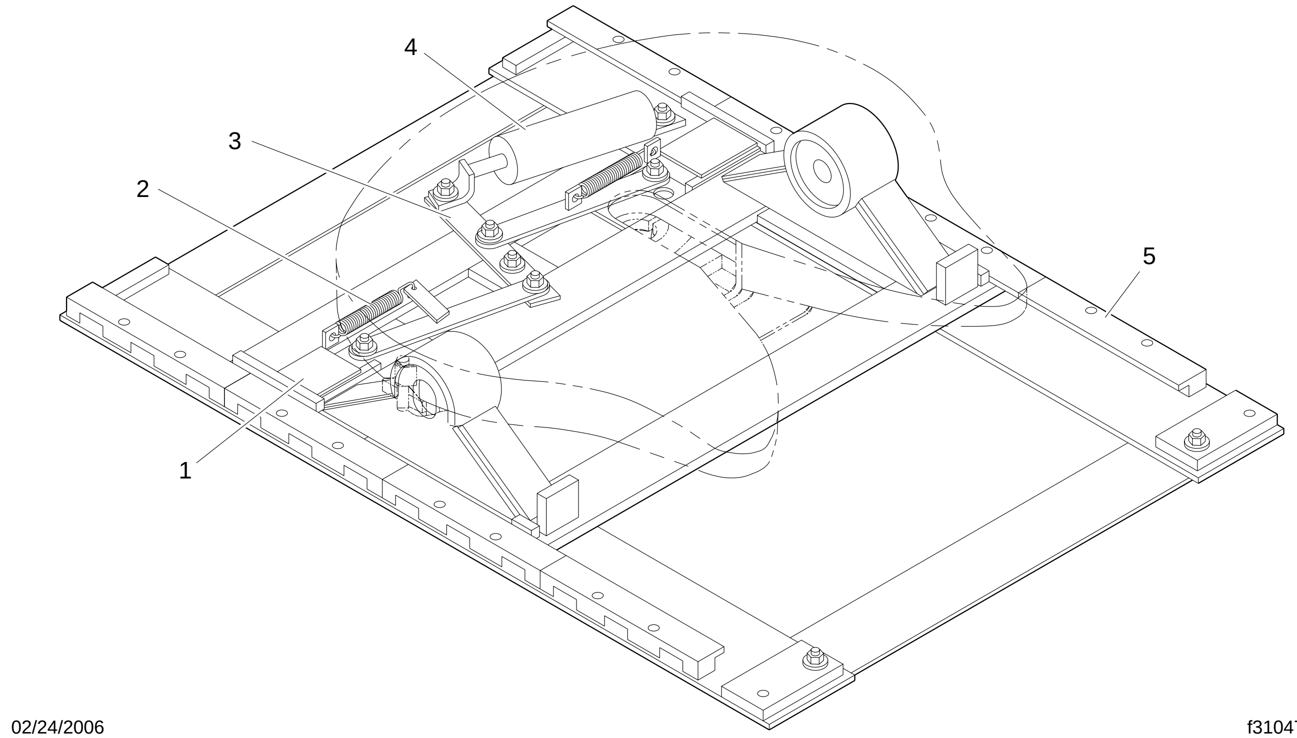


Fig. 4, Fifth Wheel Slide Switch

When the fifth wheel slide switch is activated, the CHM activates a low-current output to a normally closed air management unit (AMU) solenoid. On AAVA vehicles, the solenoid current is about 1.5 amps. The 2010 CHM does not have the current sourcing ability to drive these solenoids, so a relay in the chassis PDM is added to the circuit. The energized solenoid opens and supplies pressurized air to an air cylinder located on the fifth wheel. The cylinder operates a mechanical linkage that moves two plunger arms that are used to lock the fifth wheel in position. The spring return plungers are located on each rail of the fifth wheel mounting assembly. When the air cylinder is pressurized, the plungers withdraw and the fifth wheel is free to slide along the mounting rails. When the fifth wheel slide is deactivated, the springs on the linkage arms return the plungers to a lock position on the rails. See **Fig. 5**.

Feedback from the fifth wheel slide air cylinder circuit is required for correct operation of the fifth wheel slide controls. Feedback is provided by a ground input to the CHM. The ground input is delivered when a pressure switch within the AMU solenoid closes. On AAVA-equipped vehicles, the pressure



1. Lock Plunger
2. Return Spring
3. Control Linkage
4. Air Cylinder
5. Slide Rail

Fig. 5, Fifth Wheel Slide Assembly

switch is in the air line. A grounded feedback circuit from the closed pressure switch indicates that the fifth wheel slide is activated and pressure is being supplied to the fifth wheel slide air cylinder. An open feedback circuit indicates that the fifth wheel slide is not activated, or there is a malfunction; the fifth wheel slide is turned on but the pressure switch is still open.

Tag/Pusher Axle Lift

Tag and pusher axles are available on a variety of M2 vehicles. Tag and pusher axles are free-spinning axles that are not part of the vehicle drivetrain. Using air pressure, these axles are raised or lowered on the vehicle chassis.

When lowered, tag and pusher axles increase the weight capacity of a vehicle by distributing the vehicle load over more wheels. When increased weight capacity is not needed, the operator can raise the axle and save wear on the tires and axle. Tag axles are located behind the rear drive axles. Pusher axles are located in front of the rear drive axles. The control system for operating a tag or pusher axle is commonly referred to as axle lift.

Tag and pusher axles may only be lowered at vehicle speeds slower than 5 mph (8 km/h), but may be raised at any speed. To avoid damage to a tag or pusher axle, most axle lift controls automatically raise the axle when the vehicle is backing up. The tag or pusher axle returns to the lowered position when the vehicle is shifted out of reverse.

A vehicle with a reverse caster axle does not automatically raise the axle when backing up. These axles have air controls that change the caster angle of the axle to allow the axle to self-steer according to the direction of travel. Shifting the vehicle into reverse prompts the CHM to signal a caster angle change. With the axle's caster angle adjusted so that the axle is able to properly self-steer while reversing, the axle does not need to be raised.

Tag/Pusher Axle Lift Controls

There are many different control designs for tag and pusher axles. The tag or pusher axle type mainly determines the control design; however, other features on the vehicle may influence the design. Control similarities between all tag and pusher axles include:

- multiplexed electronics
- latching control switch
- reverse gear sense
- minimum of two AMU/AAVA solenoids
- four air bags (two at each axle end)

An M2 axle lift requires a minimum of two AMU/AAVA solenoids; some axle controls use three or four solenoids. Since the CHM has a limited number of designated AMU/AAVA outputs, the control design may use spare (unused) CHM outputs. If spare outputs are available, the CHM is programmed to use those outputs to power the necessary AMU/AAVA solenoids. Spare CHM outputs, often incorporated into axle lift controls, include: fog light outputs, backup light outputs, or daytime running lights (DRL) outputs on non-Canadian-domiciled vehicles.

Sometimes there are not enough spare CHM outputs to individually power each AMU/AAVA solenoid. For this circumstance, one of the Chassis Control Module's designated AMU outputs is wired so that the output controls a relay instead of a solenoid. This relay receives ignition power from a dash splice pack. The relay then supplies power to the AMU solenoids that operate the axle lift.

Tag and Pusher Axle Operation

With the engine running and the vehicle speed below 5 mph (8 km/h), a tag or pusher axle can be activated (lowered) using a latching, two-position smart switch. If the vehicle is turned off and restarted, a latching switch makes sure that the axle returns to the last selected position. Pressing the axle lift switch causes the CHM to send the appropriate signals to operate the AMU/AAVA controls. See **Fig. 6**.

Basic tag and pusher controls use two solenoids to supply air to the axle air bags. One solenoid is normally open, while the other is normally closed. At each end of the axle is a set of air bags. The sole-

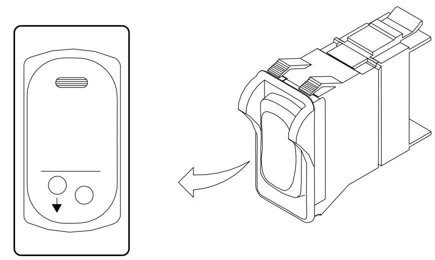


Fig. 6, Axle Lift Switch

noids fill one bag and vent the other to raise the axle. To lower the axle, the CHM sends signals to the AMU/AAVA solenoids and reverses the air flow.

Some axles use only a single solenoid to control the axle air bags. For this setup, the second solenoid is a normally open lock solenoid that operates a double check valve located in the air supply line to the tag or pusher axle. This valve keeps the axle lift in the last selected state when the engine is turned off. The lock solenoid receives power through a BHM-supplied splice pack.

Lock solenoids are present in many of the control designs. Without a lock solenoid, the axle lift controls send the tag or pusher axle into a nonpowered state whenever the engine is turned off. The nonpowered state is the position that the axle is in with the switch off, which is usually the raised position.

Reverse caster axles use four solenoids in their control setup. Two solenoids control the air supply to the axle air bags for raising or lowering. The third solenoid is a lock solenoid to keep the axle in position even if the engine is turned off. The fourth solenoid supplies air to a cylinder that controls the axle caster angle. The CHM receives transmission status signals via the J1939 data lines and uses this information to determine if the vehicle is traveling in a forward or reverse direction. Changes in vehicle direction result in corresponding changes in the caster angle of the axle.

Feedback from the tag/pusher axle air circuit is required for correct operation of tag and pusher axle controls. Feedback is provided by a ground input to the CHM. The ground input is delivered when a pressure switch is activated within the normally closed AMU solenoid. On AAVA-equipped vehicles, the pressure switch is in the air line. A grounded feedback circuit from the closed pressure switch indicates that air pressure is present in the lines feeding the air bags that lower the axle. A grounded feedback circuit means the tag or pusher axle is lowered.

Differential Lock

The differential lock is available on a vehicle with a single-drive axle or tandem axle. For a vehicle with a tandem axle, it is possible to have a differential lock for both axles or for only one axle. When the differential lock is activated, the clutch collar locks the axle differential case, gearing, and shafts together. A differential lock improves traction in slippery conditions by spinning the wheels of the axle at the same speed.

To prevent interaxle lock damage, the differential lock should only be activated when the vehicle is stopped or moving slowly at low throttle.

On some vehicles, differential lock activation is only possible when the vehicle is in the low speed range. On these vehicles, shifting out of the low speed range will deactivate the differential lock.

Differential Lock Controls

Differential lock controls discussed in this section describe multiplexed controls and do not cover nonmultiplexed factory-installed all-wheel drive.

With the engine running, the differential lock can be activated using a momentary, two-position smart switch. Press the upper half of the differential lock switch to activate the differential lock. Press the upper half of the differential lock switch again to deactivate the differential lock. See **Fig. 7**. If the differential lock is activated and the engine is then turned off, the differential lock will deactivate.

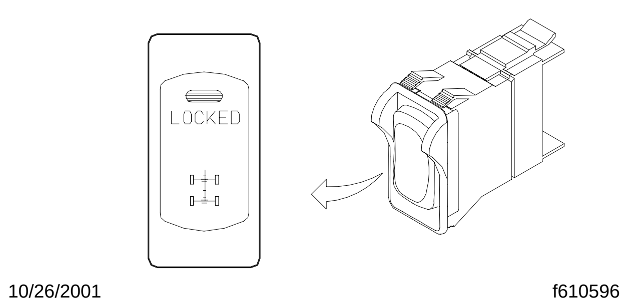


Fig. 7, Differential Lock Switch

When the differential lock switch is activated, the CHM transmits a low-current output to a normally closed air management unit (AMU) solenoid. On AAVA vehicles, the solenoid current is about 1.5 amps. The 2010 CHM does not have the current sourcing ability to drive these solenoids, so a relay in the chassis PDM is added to the circuit. The energized solenoid supplies pressurized air to the axle differential housing. The air sent to the housing applies a lock to the differential, causing all wheels on that axle to spin at the same speed.

Feedback to the CHM is required for correct operation of the differential lock. Each drive axle with a differential lock has an axle switch that provides CHM feedback. When an axle differential locks, the axle switch closes and completes a ground circuit to the CHM. The CHM uses the feedback signal(s) to determine if the differential lock is functioning properly or if there is a malfunction; the axle switch does not confirm the differential lock switch selection.

For a vehicle with a tandem axle, there are several differential lock control designs available:

- a differential lock on only one drive axle (**Fig. 8** or **Fig. 9**)
- one switch to control the differential locks on both axles (**Fig. 10**)
- two switches, each of which controls the differential lock for one axle (**Fig. 8** and **Fig. 10**)

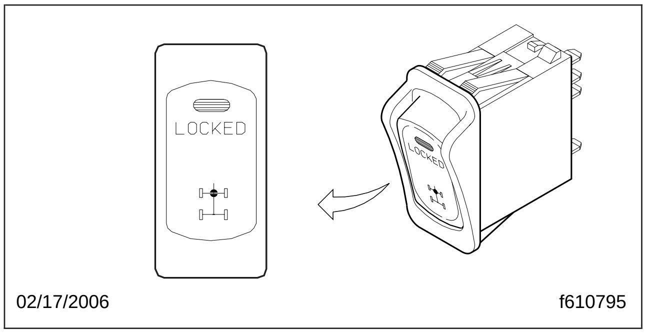


Fig. 8, Differential Lock on Forward-drive Axle of a Tandem Axle

General Information

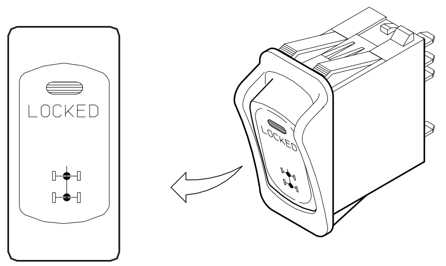


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Fig. 9, Differential Locks on Both Axles

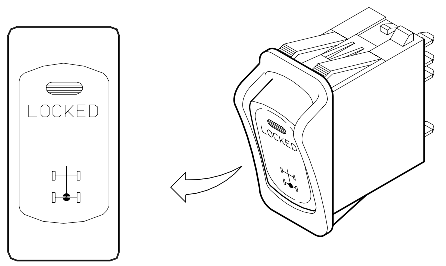

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Fig. 10, Differential Lock on Rear-drive Axle of a Tandem Axle or Single-drive Axle

Interaxle Lock

For electrical troubleshooting of the interaxle lock, see **Table 1**.

Interaxle Lock Troubleshooting		
Symptom	**Possible Cause**	**Check For**
Blinking indicator on the interaxle lock switch.	No feedback.	Damaged feedback circuit.
Interaxle lock may engage then drop out, or not engage at all.	Insufficient air pressure.	If air pressure gauge indicates sufficient pressure, there may be a kink or restriction in the air lines.
	Defective air management unit (AMU)/auxiliary air valve assembly (AAVA) solenoid.	Remove the air line from the forward rear axle differential and turn on the switch. If no air, replace the solenoid.
	Wiring fault in the circuit feedback switch.	Inspect grounds. Clean or repair as needed.
	Defective electrical connection to the AMU/AAVA solenoid.	Inspect connector and pins. Straighten bent pins and make sure that electrical connections are properly seated.

Table 1, Interaxle Lock Troubleshooting

Axle Shift

For electrical troubleshooting of the axle shift, see **Table 1**.

Axle Shift Troubleshooting		
Symptom	**Possible Cause**	**Check For**
Blinking indicator on the axle shift switch.	No feedback.	Damaged feedback circuit.
Axle high range may engage then drop out, or not engage at all.	Insufficient air pressure.	If air pressure gauge indicates sufficient pressure, there may be a kink or restriction in the air lines.
	Defective air management unit (AMU)/auxiliary air valve assembly (AAVA) solenoid.	Remove the air line from the gear housing and set switch to high range position. If air is not heard from the air line, replace the solenoid.
	The electrical connection to the AMU/AAVA solenoid is defective.	Inspect connector and pins. Straighten bent pins and make sure that electrical connections are properly seated.
	Wiring fault in the axle position feedback circuit.	For multiplexed controls, a ground signal from axle switch circuit indicates low gear range to the Chassis Module (CHM). Make sure that the axle switch circuit is not shorted to ground.
	Defective ground to solenoid or feedback switch.	Inspect grounds. Clean or repair as needed.

Table 1, Axle Shift Troubleshooting

Suspension Dump

For electrical troubleshooting of the suspension dump, see Table 1.

Suspension Dump Troubleshooting		
Symptom	**Possible Cause**	**Check For**
Blinking indicator on the suspension dump switch.	No feedback.	Damaged feedback circuit.
Suspension does not dump with ignition on.	Defective air management unit (AMU)/auxiliary air valve assembly (AAVA) solenoid.	Remove the air line from the rear air suspension and trigger suspension dump. If air still present, replace the solenoid.
	Wiring fault in the feedback switch circuit.	Inspect grounds. Clean or repair as needed.
	Defective electrical connection to the AMU/AAVA solenoid.	Inspect connector and pins. Straighten bent pins and make sure that electrical connections are properly seated.

Table 1, Suspension Dump Troubleshooting

Fifth Wheel Slide

For electrical troubleshooting of the fifth wheel slide, see **Table 1**.

Fifth Wheel Slide Troubleshooting		
Symptom	**Possible Cause**	**Check For**
Blinking indicator on the fifth wheel slide switch.	No feedback.	Damaged feedback circuit.
Fifth wheel slide may engage then drop out, or not engage at all.	Insufficient air pressure.	If air pressure gauge indicates sufficient pressure, there may be a kink or restriction in the air lines.
	Defective air management unit (AMU)/auxiliary air valve assembly (AAVA) solenoid.	Remove the air line from the fifth wheel slide release cylinder and turn on the switch. If no air, replace the solenoid.
	Wiring fault in the feedback switch circuit.	Inspect grounds. Clean or repair as needed.
	The electrical connection to the AMU/AAVA solenoid is defective.	Inspect connector and pins. Straighten bent pins and make sure that electrical connections are properly seated.

Table 1, Fifth Wheel Slide Troubleshooting

Tag/Pusher Axle Lift

For electrical troubleshooting of the tag/pusher axle lift, see **Table 1**.

Tag/Pusher Axle Lift Troubleshooting		
Symptom	**Possible Cause**	**Check For**
Blinking indicator on the axle lift switch.	No feedback.	Damaged feedback circuit.
Reverse caster axle not responding.	Insufficient air pressure.	If air pressure gauge indicates sufficient pressure, there may be a kink or restriction in the air line to the caster cylinder.
	Defective air management unit (AMU)/auxiliary air valve assembly (AAVA) solenoid.	Remove the air line from the caster angle cylinder. See if air is present when vehicle is placed in reverse. If no air, replace the suspect solenoid.
	Defective reverse caster air cylinder.	If the air supply at the reverse caster cylinder proves good, replace the cylinder.
Axle lift may engage then drop out, or not engage at all.	Insufficient air pressure.	If air pressure gauge indicates sufficient pressure, there may be a kink or restriction in the air lines.
	Defective AMU/AAVA solenoid.	Remove the air line from one of the axle lift air bags. Test that air supply is controlled by axle lift switch. Repeat for all axle air bags. If air supply at air bag is not properly responding to the switch requests, replace the suspect solenoid.
	Wiring fault to the pressure feedback switch circuit.	Inspect grounds. Clean or repair as needed.
	The electrical connection to the AMU/AAVA solenoid is defective.	Inspect connector and pins. Straighten bent pins and make sure that electrical connections are properly seated.
	Wiring fault in the ground to solenoid or pressure switch circuit.	Inspect grounds. Clean or repair as needed.

Table 1, Tag/Pusher Axle Lift Troubleshooting

Differential Lock

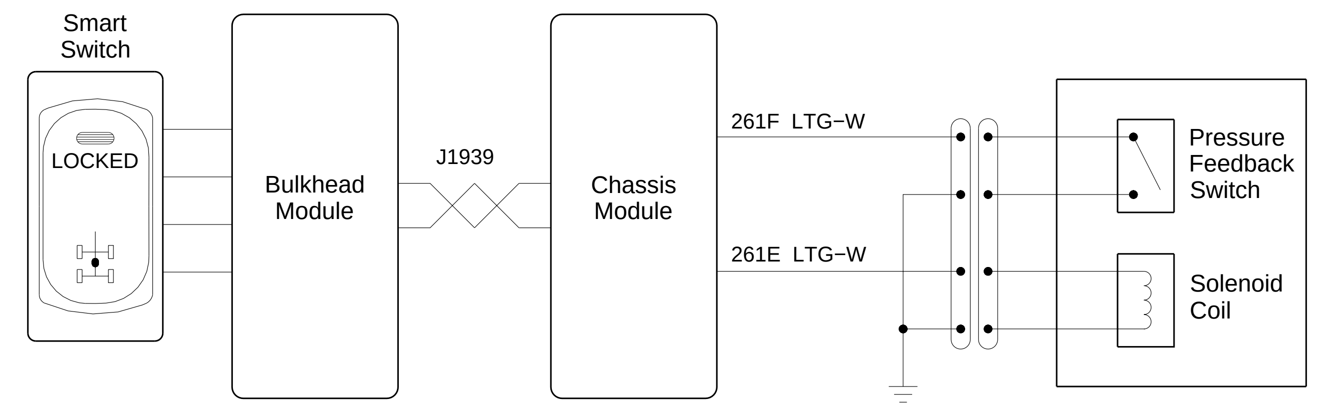
For electrical troubleshooting of the differential lock, see Table 1.

Differential Lock Troubleshooting		
Symptom	**Possible Cause**	**Check For**
Blinking indicator on the differential lock switch.	No feedback.	Damaged feedback circuit. Axle lock switch is not activated (closed) or is disconnected.
Differential lock may engage then drop out, or not engage at all.	Insufficient air pressure.	If air pressure gauge indicates sufficient pressure, there may be a kink or restriction in the air lines.
	Defective air management unit (AMU)/auxiliary air valve assembly (AAVA) solenoid.	Remove the air line from the differential housing and turn on the switch. If no air, replace the solenoid.
	Wiring fault in the axle position feedback circuit.	A ground signal from axle switch circuit indicates that the differential lock is activated. Make sure that the axle switch circuit is not shorted to ground.
	Defective electrical connection to the AMU/AAVA solenoid.	Inspect connector and pins. Straighten bent pins and make sure that electrical connections are properly seated.
	The ground to solenoid or pressure switch circuit is defective.	Inspect grounds. Clean or repair as needed.

Table 1, Differential Lock Troubleshooting

Interaxle Lock

For a wiring diagram of the interaxle lock, see Fig. 1.



NOTES:

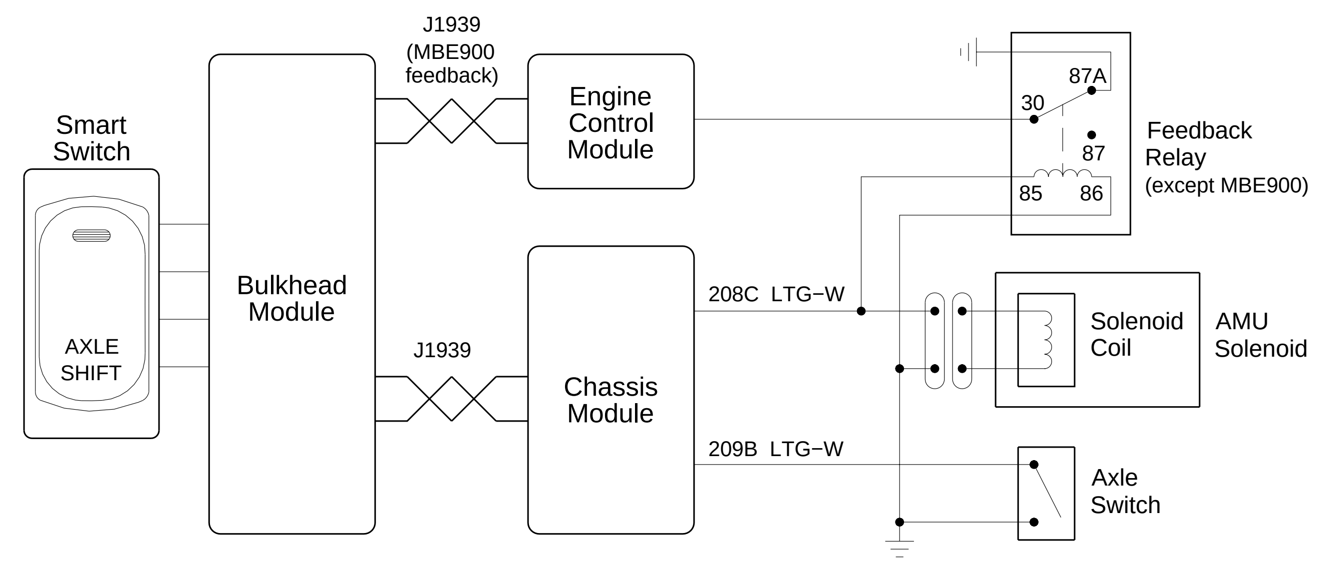
- Interaxle lock is active when the air solenoid is powered, allowing air to flow to the actuator.
- The pressure feedback switch closes when air pressure reaches about 12 to 28 psi (83 to 193 kPa).

Fig. 1, Interaxle Lock Wiring Diagram

Axle Shift

For a wiring diagram of the axle shift with multiplexed controls, see **Fig. 1**.

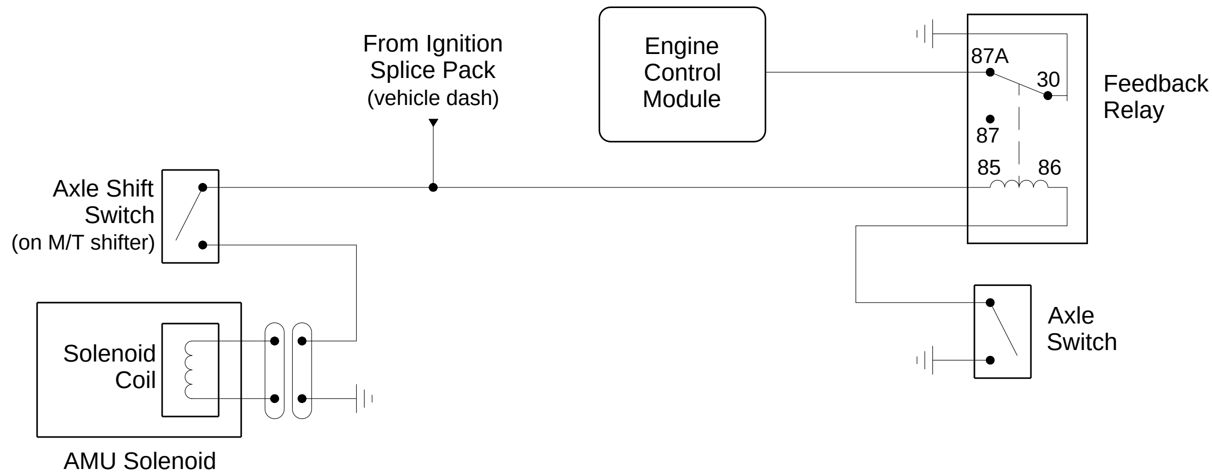
For a wiring diagram of the axle shift with nonmultiplexed controls, see **Fig. 2**.



NOTE: Multiplexed axle shift uses an air management unit (AMU) solenoid that provides air when power is applied by the CHM to the solenoid coil (normally closed).

Fig. 1, Wiring Diagram of Axle Shift With Multiplexed Controls

Axle Shift Specifications



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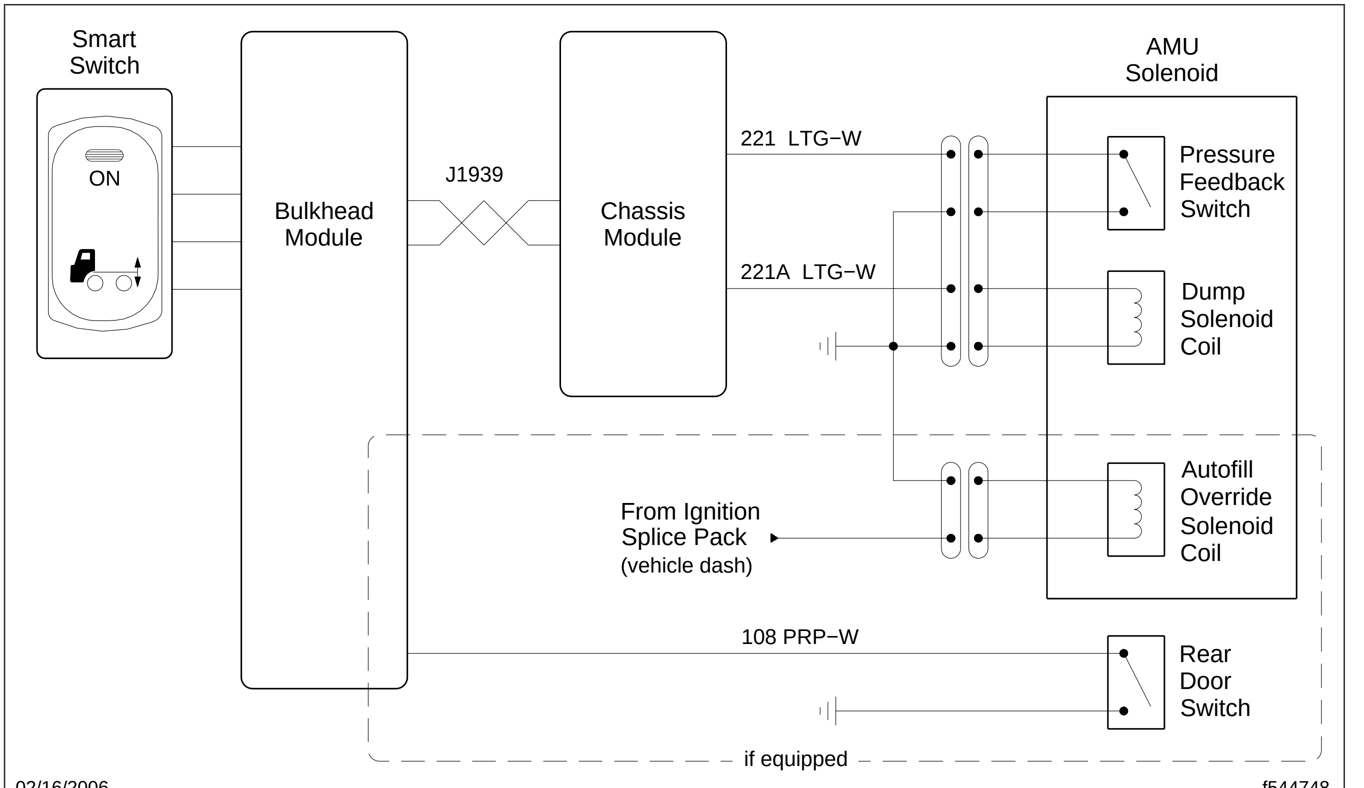
NOTE: Nonmultiplexed axle shift uses an air management unit solenoid that provides air when power is applied by the axle shift control switch to the solenoid coil (normally closed).

Fig. 2, Wiring Diagram of Axle Shift With Nonmultiplexed Controls (MT only)

Suspension Dump

For a wiring diagram of the suspension dump, see Fig. 1.



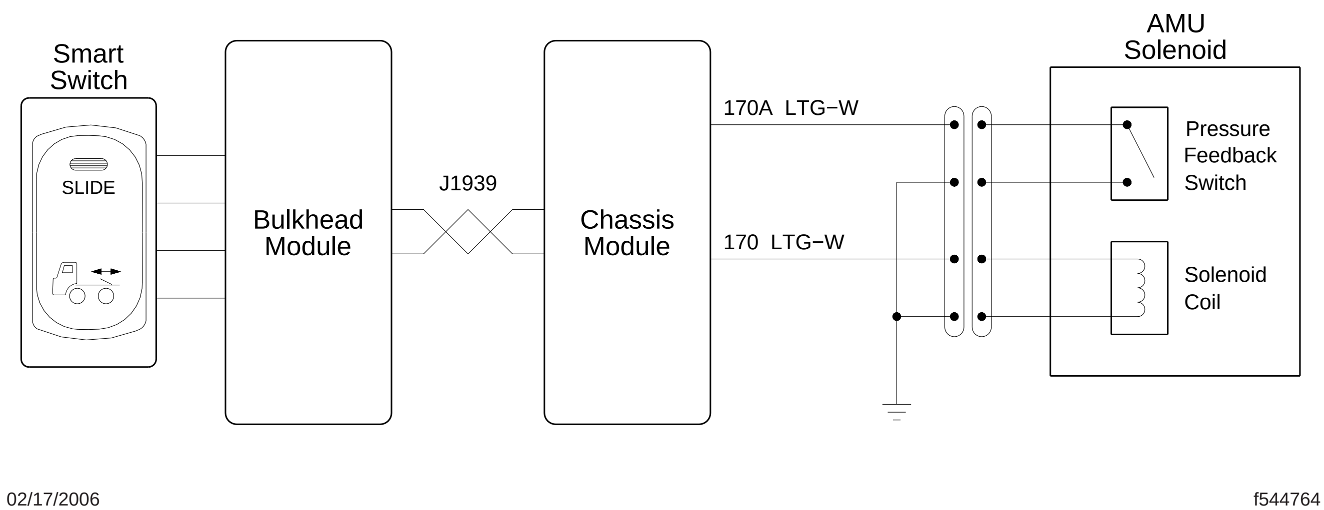
NOTES:

- Suspension dump uses an air management unit (AMU) solenoid that provides air when power is applied to the solenoid coil (normally closed).
- The pressure switch closes when air pressure reaches about 12 to 28 psi (83 to 193 kPa).
- The autofill override solenoid receives ignition power with the engine running and is normally open.

Fig. 1, Suspension Dump Wiring Diagram

Fifth Wheel Slide

For a wiring diagram of the fifth wheel slide, see **Fig. 1**.



NOTES:

- Fifth wheel slide uses an air management unit (AMU) solenoid that provides air when power is applied to the solenoid coil (normally closed).
- The pressure switch closes when air pressure reaches about 12 to 28 psi (83 to 193 kPa).

Fig. 1, Fifth Wheel Slide Wiring Diagram

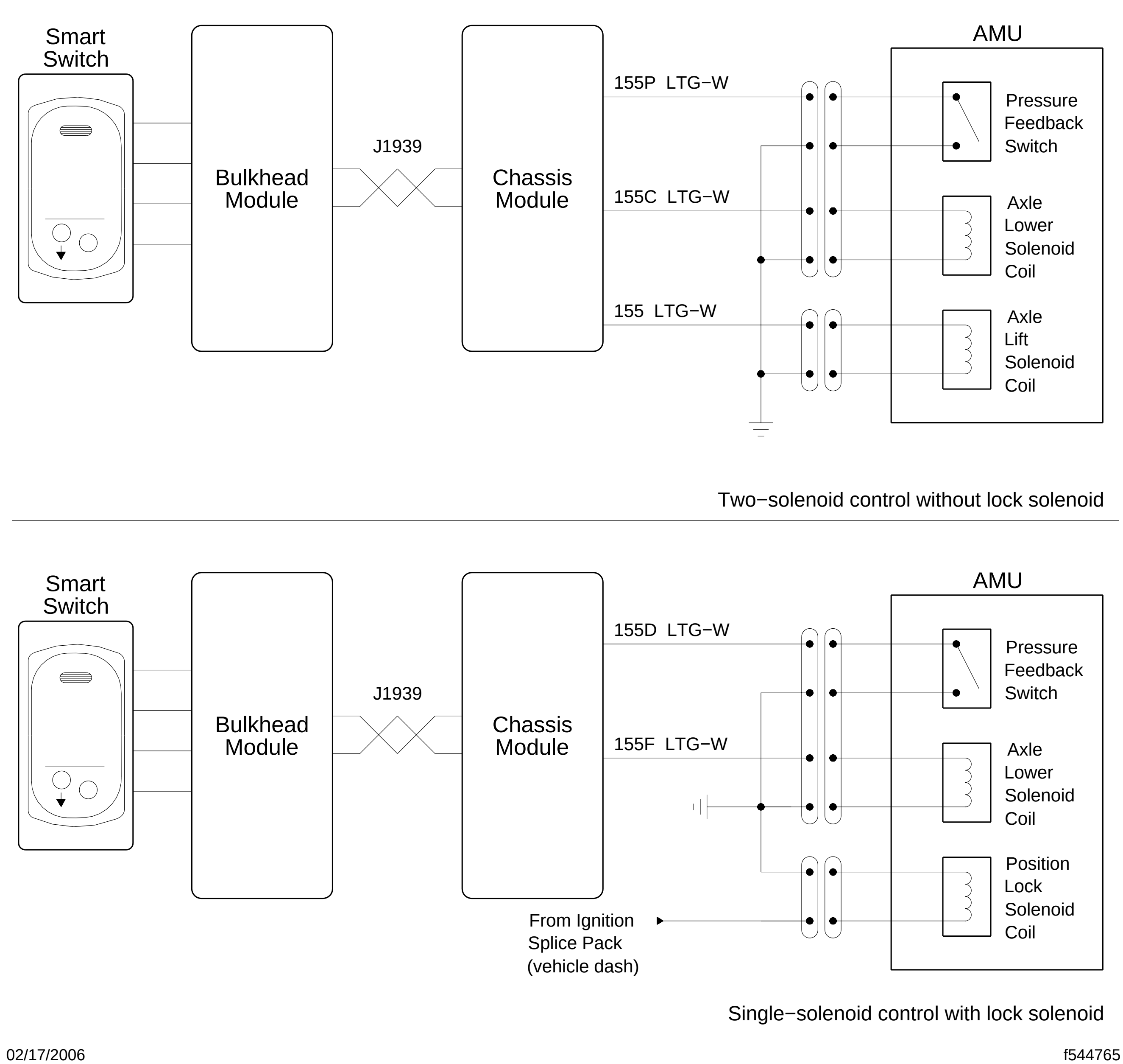
Tag/Pusher Axle Lift

For a wiring diagram of two-solenoid axle lift, see **Fig. 1**.

For a wiring diagram of a three-solenoid axle lift, see **Fig. 2**.

For a wiring diagram of a four-solenoid axle lift with reverse caster, see **Fig. 3**.

Tag/Pusher Axle Lift Specifications

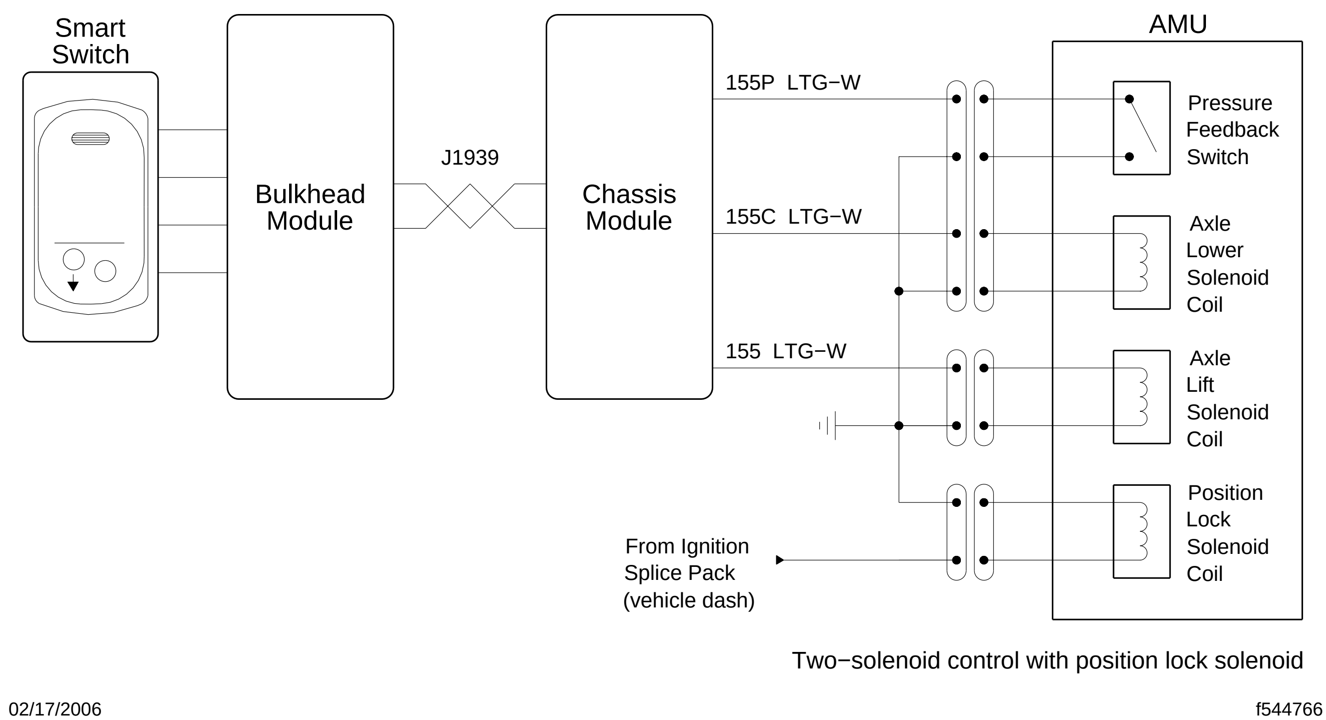


NOTES:

- The pressure switch is located in the normally closed axle lower solenoid and closes when the air pressure reaches about 12 to 28 psi (83 to 193 kPa).
- The lock solenoid receives ignition power with the engine running and is normally open.

Fig. 1, Two-Solenoid Axle Lift Wiring Diagram

Tag/Pusher Axle Lift Specifications

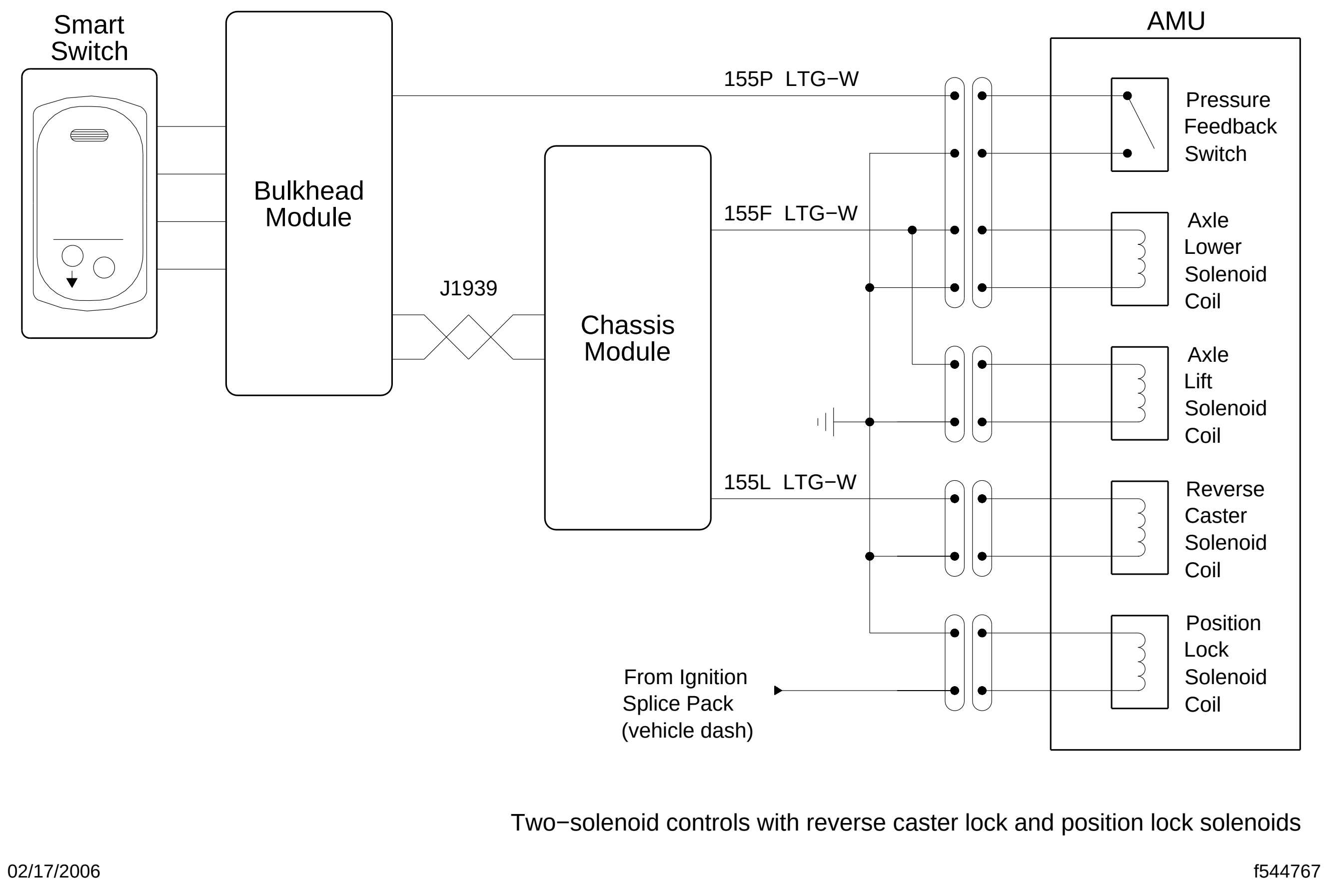


NOTES:

- The pressure switch is located in the normally closed axle lower solenoid and closes when the air pressure reaches about 12 to 28 psi (83 to 193 kPa).
- The lock solenoid receives ignition power with the engine running and is normally open.

Fig. 2, Three-Solenoid Axle Lift Wiring Diagram

Tag/Pusher Axle Lift Specifications



NOTES:

- The pressure switch is located in the normally closed axle lower solenoid and closes when the air pressure reaches about 12 to 28 psi (83 to 193 kPa).
- The lock solenoid receives ignition power with the engine running and is normally open.
- The reverse caster solenoid allows the axle to remain lowered when the vehicle is shifted into reverse.

Fig. 3, Four-Solenoid Axle Lift with Reverse Caster Wiring Diagram

Differential Lock

For a wiring diagram of single-drive axle differential lock, see **Fig. 1**.

For a wiring diagram of a one-switch tandem-axle differential lock, see **Fig. 2**.

For a wiring diagram of a two-switch tandem-axle differential lock, see **Fig. 3**.

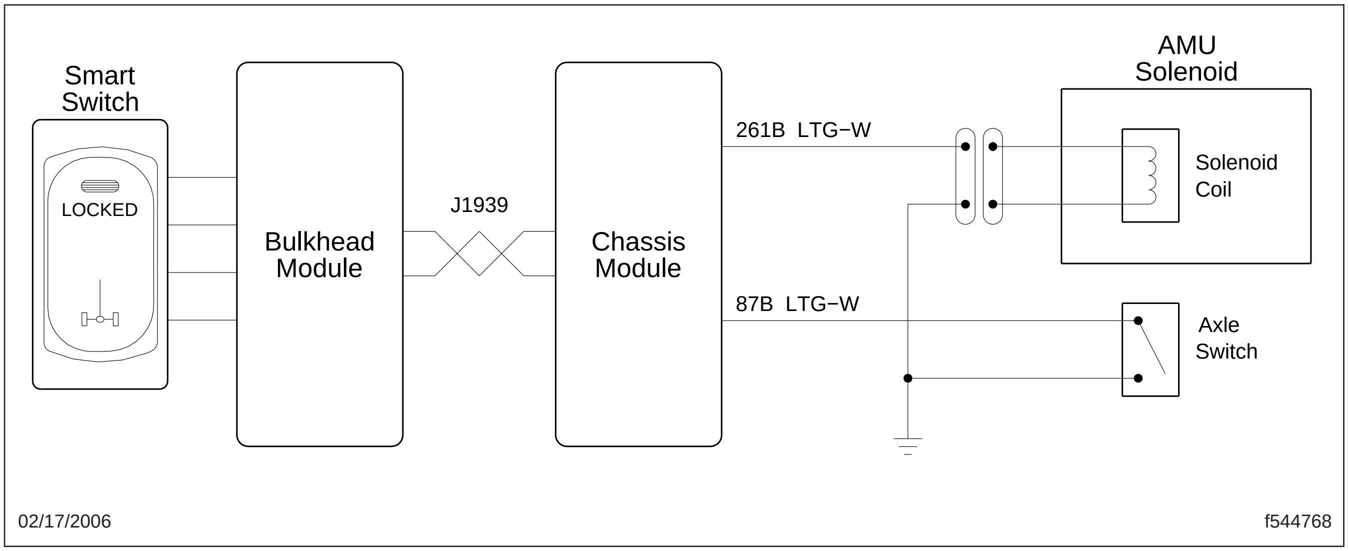


Fig. 1, Single-Drive Axle Differential Lock Wiring Diagram

Differential Lock Specifications

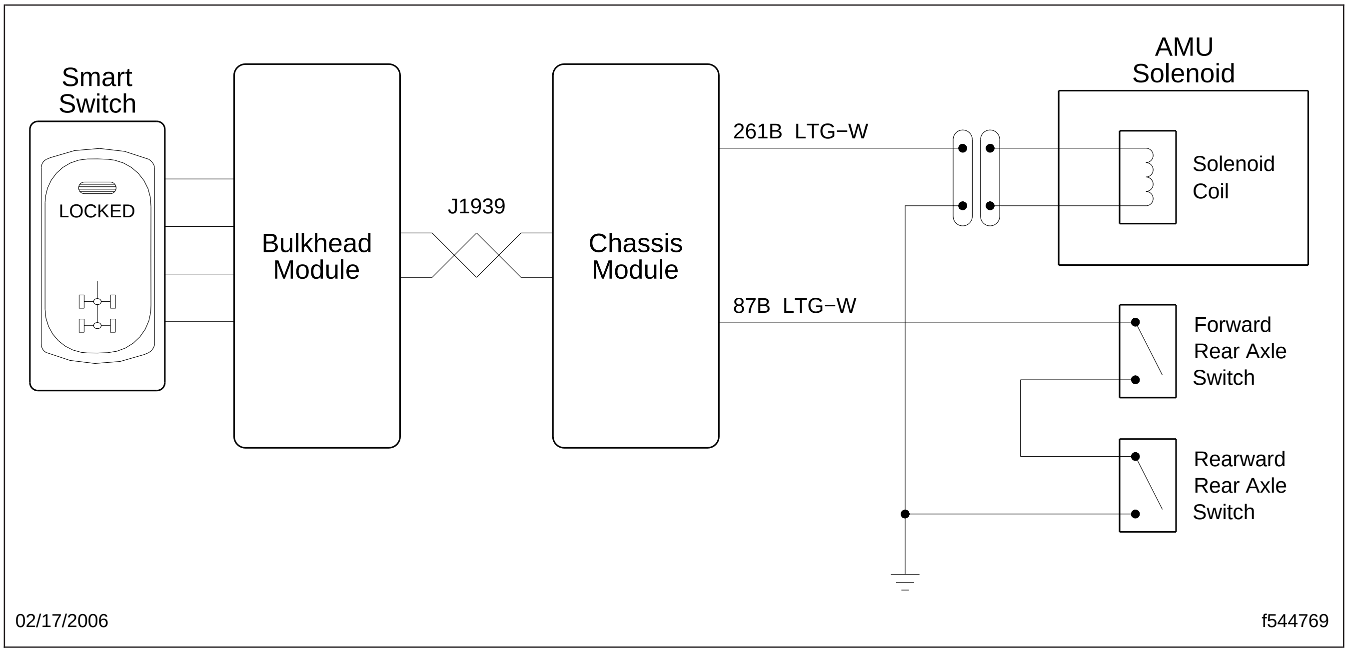


Fig. 2, One-Switch Tandem-Axle Differential Lock Wiring Diagram

Differential Lock Specifications

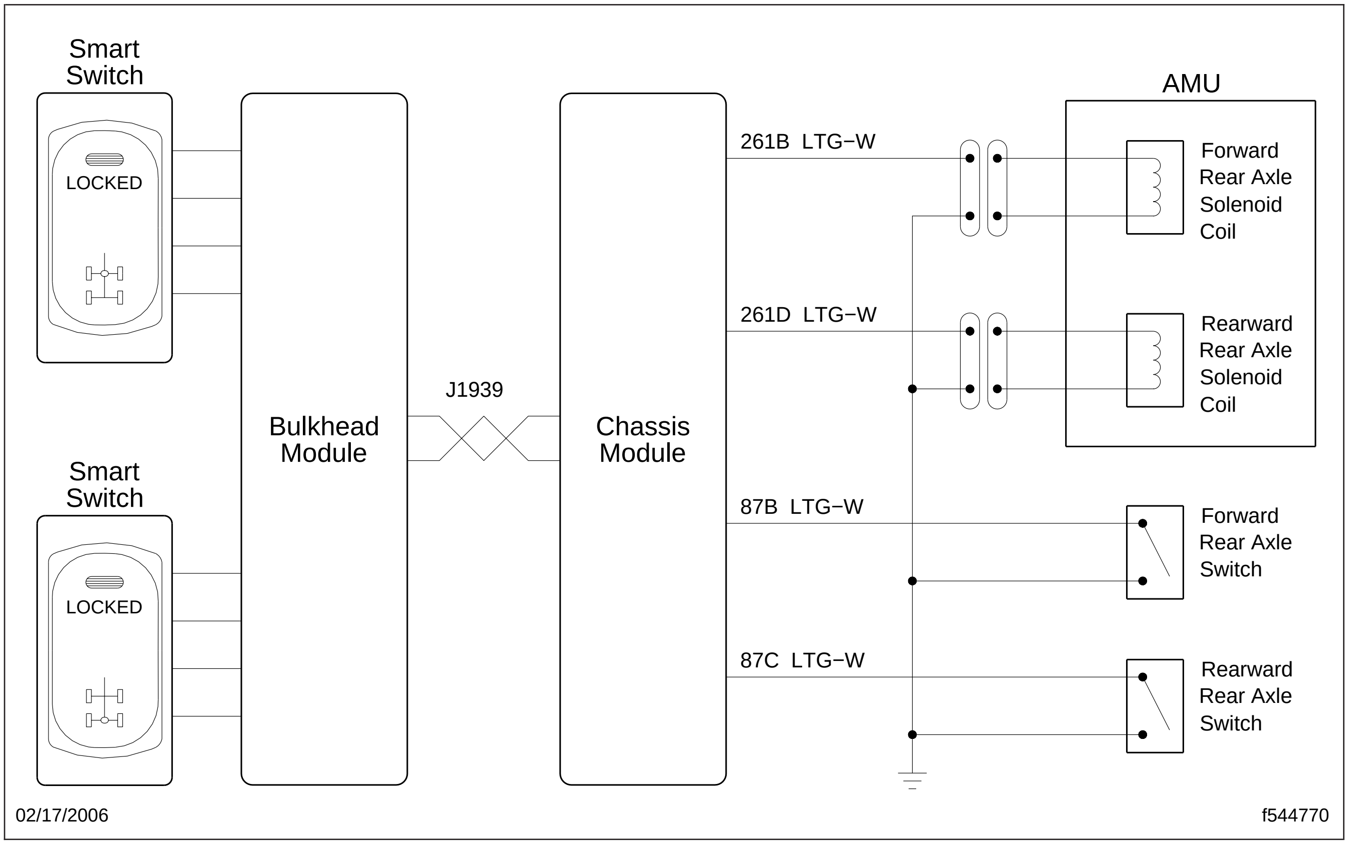


Fig. 3, Two-Switch Tandem-Axle Differential Lock Wiring Diagram

Introduction

A Business Class® M2 vehicle may be equipped with all-wheel drive (AWD). AWD delivers drive power to the front drive axle by engaging a front drive shaft that is connected to the transfer case. With AWD active, all front and rear wheels are used to provide drive power to the ground and greatly increase traction.

The electronic controls for AWD are not multiplexed. AWD is a stand-alone system that does not use datalink communications to operate and monitor the AWD system. The AWD system is engaged when an air solenoid is activated by the ABS controller. The air solenoid is a module of the AMU or a solenoid in the AAVA system.

The AWD controls may include:

- Activation of the transfer case ranges (low or high);
- Activation of the differential lock (with single rear axle);
- Activation of the interaxle lock (with tandem rear axles);
- Illumination of instrumentation control unit (ICU) indicators;
- Operational logic provided by the antilock brakes system ECU;
- Operation of AWD AMU/AAVA solenoids;
- Activation of AWD.

All-Wheel Drive

All-wheel drive engages the front drive shaft from the transfer case for all-wheel drive operation. With the engine running, AWD can be activated using a latching, two-position switch on the dash panel.

Pressing the upper half of the AWD switch engages the front drive axle. The switch LED illuminates when the switch is pressed for activation. Pressing the lower half of the AWD switch deactivates AWD.

NOTE: The controls are not multiplexed. If the AWD switch is left in the on position and the ignition key is turned off then back on, AWD will engage as long as all the interlock conditions are met.

AWD switch signals are wired directly to the antilock brakes system (ABS) ECU. Upon switch activation, the ABS ECU uses internal programmed logic to determine if AWD may be activated.

For AWD activation, the ABS ECU transmits a low-current output to a normally closed antilock brake AWD AMU or AAVA solenoid. The energized solenoid opens and supplies compressed air to the transfer case input port for the front driveshaft clutch. The air sent to the transfer case applies a lock to the forward drive shaft causing driveline power to be delivered to the front axle. With the forward axle engaged, a switch on the transfer case closes and sends a signal to the ICU to turn on the AWD indicator. See **Fig. 1**.

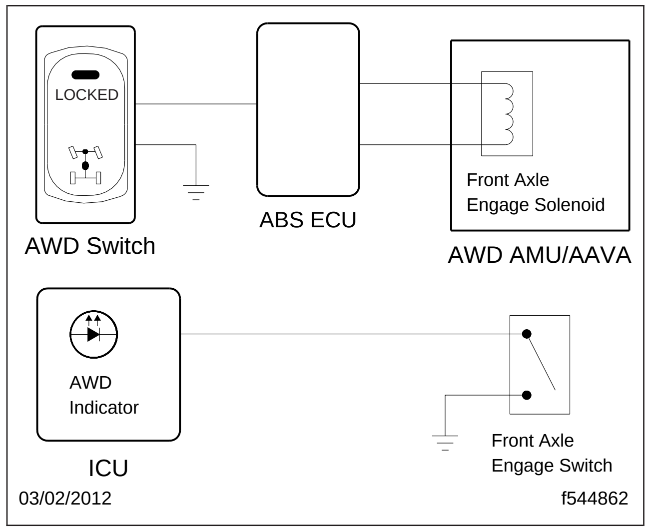


Fig. 1, AWD Function

The ABS ECU may restrict AWD activation to prevent excessive wear on the transfer case and other driveline components. Situations such as high engine speeds or variations between individual wheel speeds may prevent activation of AWD.

NOTE: Operating the vehicle with AWD activated under normal driving conditions increases driveline and tire wear. Use AWD when improved traction is needed.

Differential Lock

When a vehicle is equipped with a single rear drive axle, the differential lock controls are part of the AWD wiring. As part of the AWD wiring, the differential lock controls are not multiplexed.

When a vehicle is equipped with a tandem drive axle, the differential lock controls are multiplexed and therefore independent of the AWD wiring. See **Section 54.40** for information on multiplexed differential lock controls.

When the differential lock is activated using nonmultiplexed controls, the clutch collar locks the axle differential case, gearing, and shafts together. A differential lock improves traction in slippery conditions by spinning the wheels of the rear axle at the same speed.

With the engine running, the differential lock can be activated using a latching, two-position differential lock switch on the dash panel. When the upper half of the differential lock switch is pressed, a signal is sent from the switch to the ABS ECU requesting that the differential lock be activated. The switch LED illuminates when the switch is pressed for activation. When the lower half of the differential lock switch is pressed, the differential lock is deactivated.

NOTE: The controls are not multiplexed. If the differential lock switch is left in the on position and the ignition key is turned off then back on, the differential lock will engage as long as all the interlock conditions are met.

The differential lock switch is wired directly to the ABS ECU. Upon switch activation, the ABS ECU uses internal programmed logic to determine if the differential lock may be activated. For activation, the ABS ECU transmits a low-current output to a normally closed AWD AMU/AAVA solenoid. The energized solenoid opens and supplies compressed air to the differential housing. The air sent to the housing applies a lock to the differential, causing both axle shafts to spin at the same speed. With the differential lock engaged, a differential lock switch closes and sends a signal to the ICU to turn on the differential lock indicator. See **Fig. 2**.

Interaxle Lock

The interaxle lock is available with the AWD controls on a vehicle with tandem drive axles. When activated, the interaxle differential is locked. This essentially makes the driveshaft a solid connection between both the rear axles. Power entering the forward axle is transmitted straight through to the

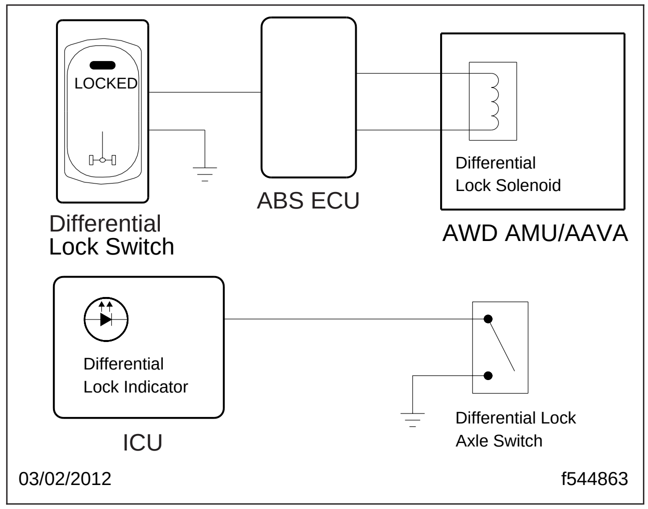


Fig. 2, Differential Lock Function

rear axle. Driveline torque is now delivered equally between the rear drive axles.

In slippery conditions without the interaxle lock activated, one drive axle receives the majority of the driveline torque when its wheels lose traction. With the interaxle lock activated, both rear drive axles spin equally and improve traction in slippery conditions by turning all the rear wheels at the same speed.

With the engine running, the interaxle lock can be activated using a latching, two-position interaxle lock switch on the dash panel. By pressing the upper half of the interaxle lock switch, a signal is sent from the switch to the ABS ECU requesting that the interaxle lock be activated. The switch LED and an ICU indicator illuminate when the switch is activated. Pressing the lower half of the interaxle lock switch deactivates the differential lock.

NOTE: The controls are not multiplexed. If the interaxle lock switch is left in the on position and the ignition key is turned off then back on, the interaxle lock will engage as long as all the interlock conditions are met.

The interaxle lock switch is wired directly to the ABS ECU. For activation, the ABS ECU transmits a low-current output to a normally closed AWD AMU/AAVA solenoid. The energized solenoid opens and supplies compressed air to the forward rear axle differential housing. The air sent to the housing applies a lock to the interaxle differential causing all driveline torque to be shared equally by the rear axles. See **Fig. 3**.

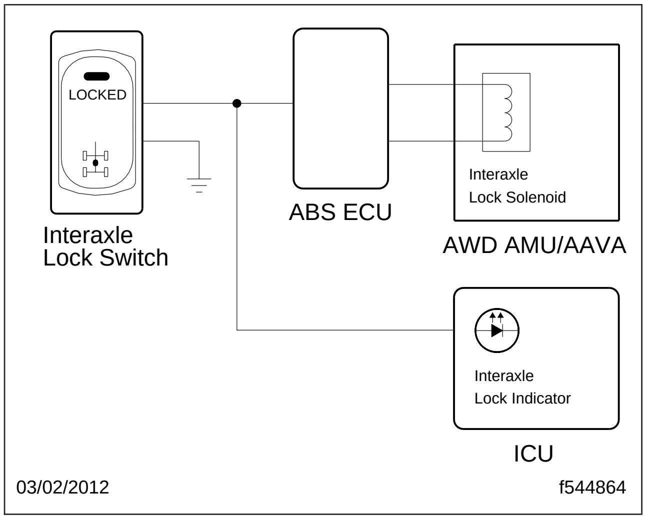


Fig. 3, Interaxle Lock Function

Transfer Case Range

The AWD system includes controls for the selection and activation of the transfer case speed range. These controls are not multiplexed. Electronic signals from the transfer case range switch activate relays in the auxiliary power distribution module (PDM). The relays control AWD AMU/AAVA solenoids that supply pressurized air to the transfer case to engage the selected range.

The auxiliary PDM is located under the top cover of the dashboard. On a vehicle with a winged dashboard, the auxiliary PDM is located in the center of the dashboard. On a vehicle with a flat dashboard, the auxiliary dashboard is located on the left side of the dashboard. The auxiliary PDM has a cover with a label on it. The part number of the label is 24-01410-003. See **Section 60.08, Subject 100** for dash panel removal and installation procedures.

The control relays in the auxiliary PDM include:

- ignition power supply relay
- low-range relay
- low-range interlock relay
- high-range relay
- high-range interlock relay

To prevent transfer case and driveline damage, range selection or range changes may only be made when the parking brake is applied. The controls for range selection use a dual contact parking brake pressure switch. The two sets of contacts within this pressure switch control activation of the transfer case range relays and transfer case range interlock relays.

Parking Brake Pressure Switch

On a Business Class M2 vehicle with AWD there is a parking brake pressure switch in the AWD AMU or in the park brake air line on AAVA equipped vehicles. The parking brake pressure switch has two sets of contacts that sense parking brake pressure as follows:

- Switch 1 is normally closed at 0 psi and opens when the air pressure reaches 70 to 84 psi (483 to 579 kPa).
- Switch 2 is normally open at 0 psi and closes when the air pressure reaches 2 to 5 psi (14 to 34 kPa).

NOTE: Air pressure of 0 psi at the parking brake AWD AMU/AAVA switch means that the parking brake is applied.

Parking Brake Applied

The circuits (493R and 493P) connected at switch 1 of the parking brake pressure switch control the transfer case range relays. When the parking brake is applied, there is 0 psi at switch 1 and the switch remains normally closed. With the engine on and switch 1 closed, all the coils of the transfer case relays are grounded, meaning the relays are energized. According to the selected position of the transfer case range switch, power is supplied from the range switch through the corresponding transfer case relay to the appropriate range solenoid. The activated solenoid supplies air to the transfer case to engage the selected range.

The circuits (GND and 493T) connected at switch 2 of the parking brake pressure switch control the transfer case range interlock relays. When the parking brake is applied, there is 0 psi at switch 2 and the switch remains normally open. With the engine on and switch 2 open, all the coils of the transfer case interlock relays are not grounded, meaning the relays are de-energized.

Parking Brake Released

When the parking brake is released, the pressure at the parking brake pressure switch will rise to the high pressure of the parking brake pneumatic circuit. The

General Information

two switch contacts of the parking brake pressure switch function independently from one another and are activated at different parking brake pressures. See **Table 1** for the circuit function of the parking brake pressure switches in the AMU/AAVA.

As parking brake pressure increases to 2 to 5 psi (14 to 34 kPa), the normally open switch 2 closes and connects circuits GND and 493T. With switch 2 closed, all the coils of the transfer case interlock relays are provided a ground, meaning the relays are energized. According to the selected position of the transfer case range switch, power is supplied from the range switch through the corresponding transfer case and transfer case interlock relays to the appropriate range solenoid. The interlock relays ensure that when there is active pressure in the parking brake pneumatic circuit, the transfer case cannot be shifted out of the selected range.

As parking brake pressure reaches 70 to 84 psi (483 to 579 kPa), the normally closed switch 1 opens and deactivates the transfer case relays. Above these pressures, power is still supplied to the selected AWD solenoid via the activated interlock relay. No transfer case range shifts are allowed until the interlock relays are deactivated. Deactivation of the interlock relays occurs only when the parking brake is applied and the pressure at the parking brake switch returns to 0 psi.

Transfer Case High Range

With the parking brake applied and 0 psi at the parking brake pressure switch, the normally closed switch 1 of the parking brake pressure switch energizes the high-range relay in the auxiliary PDM. Selecting the high-range position on the transfer case range switch sends power through the closed contacts of the high-range relay to the high-range solenoid and the high-range interlock relay. The powered high-range solenoid sends compressed air to the transfer case housing shifting the transfer case into high range. See **Fig. 4**.

When the parking brake is released, the pressure of the parking brake pneumatic circuit will rise. As parking brake pressure reaches 2 to 5 psi (14 to 34 kPa), the normally open switch 2 closes and energizes the transfer case high-range interlock relay. Now the high-range solenoid is receiving power from both the high-range relay and the high-range interlock relay. The high-range interlock relay prevents the transfer case from being shifted out of high-range while there is active pressure in the parking brake pneumatic circuit.

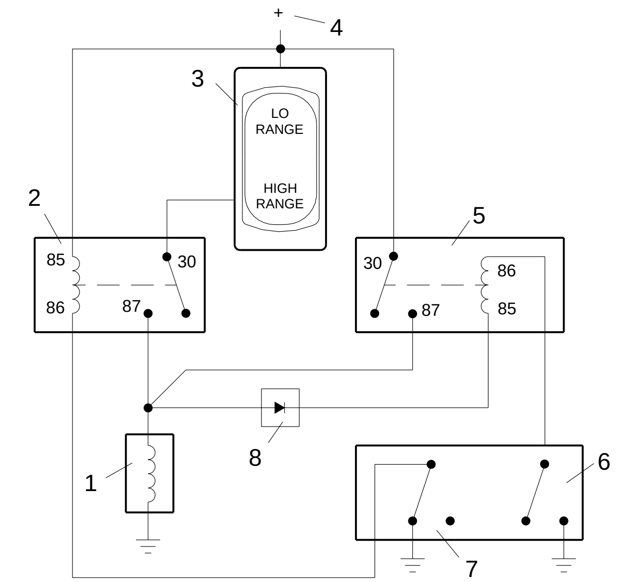
As parking brake pressure increases to 70 to 84 psi (483 to 579 kPa), the normally closed switch 1 opens and deactivates the transfer case high-range relay. At this pressure, the high-range solenoid is powered only by the high-range interlock relay. The transfer case will remain locked in high range until the parking brake is applied and the pressure at the parking brake switch returns to 0 psi.

Applying the parking brake decreases the pressure of the parking brake pneumatic circuit. As pressure falls to 70 to 84 psi (483 to 579 kPa), the high-range relay is energized. The high-range solenoid is now receiving power from both the high-range relay and the high-range interlock relay. When the pressure decreases to 2 to 5 psi (14 to 34 kPa), switch 2 will open and de-energize the high-range interlock relay.

Parking Brake Pressure Switch Circuit Function			
Pin	**Circuit**	**Switch Connection**	**Function**
A	493R	Switch 1 (normally closed)	Switch 1 is closed from 0 psi through approximately 70 to 84 psi (483 to 579 kPa). When closed, switch 1 connects circuits 493R and 493P. This activates all the coils of the transfer case range relays. Above 70 to 84 psi (483 to 579 kPa), switch 1 opens and the transfer case range relays are deactivated.
B	493P	Switch 1 (normally closed)	
C	GND	Switch 2 (normally open)	Switch 2 is open from 0 psi through approximately 2 to 5 psi (14 to 34 kPa). When open, switch 2 deactivates all the coils of the transfer case range interlock relays. Above 2 to 5 psi (14 to 34 kPa), switch 2 closes and connects circuits GND and 493T. This activates the transfer case range interlock relays and locks the transfer case into the selected range.
D	493T	Switch 2 (normally open)	

Table 1, Parking Brake Pressure Switch Circuit Function

After the high-range interlock relay is de-energized, the transfer case may be shifted to low range. Range changes can only occur when the parking brake is applied and the transmission is in neutral.



06/14/2006 f544865

1. High-Range Solenoid
2. High-Range Relay in Auxiliary PDM
3. Transfer Case Range Switch
4. Ignition Feed from Ignition Relay in Auxiliary PDM
5. High-Range Interlock Relay in Auxiliary PDM
6. Normally Open Switch 2 (part of the parking brake pressure switch)
7. Normally Closed Switch 1 (part of the parking brake pressure switch)
8. High-Range Interlock Diode

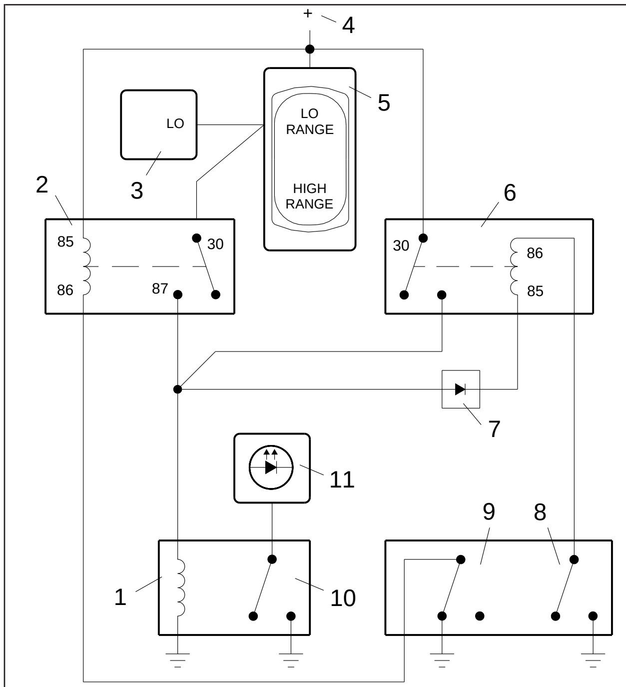
Fig. 4, High-Range Function

Transfer Case Low Range

With the parking brake applied and 0 psi at the parking brake pressure switch, the normally closed switch 1 of the parking brake pressure switch energizes the low-range relay in the auxiliary PDM. Selecting the low-range position on the transfer case range switch:

- Delivers a low-range signal to the engine ECU;
- Sends power to the low-range solenoid;
- Sends power to the low-range interlock relay in the auxiliary PDM.

The powered low-range solenoid sends compressed air to the transfer case housing shifting the transfer case into low range. A normally closed pressure switch inside the low-range solenoid opens when the solenoid is delivering air pressure. The solenoid pressure switch sends a signal that illuminates a low-range indicator on the ICU. See **Fig. 5**.



06/14/2006 f544866

1. Low-Range Solenoid
2. Low-Range Relay in Auxiliary PDM
3. Engine ECU (low-range notification)
4. Ignition Feed from Ignition Relay in Auxiliary PDM
5. Transfer Case Range Switch
6. Low-Range Interlock Relay in Auxiliary PDM
7. Low-Range Interlock Diode
8. Normally Open Switch 2 (part of the parking brake pressure switch)
9. Normally Closed Switch 1 (part of the parking brake pressure switch)
10. Low-Range Solenoid Pressure Switch
11. Low-Range Indicator in ICU

Fig. 5, Low-Range Function

The transfer case range switch provides the engine ECU notification that the transfer case is in low range. A low-range signal (ground input) is delivered via a circuit wired from the transfer case range switch directly to the engine ECU.

General Information

When the parking brake is released, the pressure of the parking brake pneumatic circuit will rise. As parking brake pressure reaches 2 to 5 psi (14 to 34 kPa), the normally open switch 2 closes and energizes the transfer case low-range interlock relay. Now the low-range solenoid is receiving power from both the low-range relay and the low-range interlock relay. The low-range interlock relay prevents the transfer case from being shifted out of low range while there is active pressure in the parking brake pneumatic circuit.

As increasing parking brake pressure reaches 70 to 84 psi (483 to 579 kPa), the normally closed switch 1 opens and deactivates the transfer case low-range relay. At this pressure, the low-range solenoid is powered only by the low-range interlock relay. The transfer case will remain locked in low range until the parking brake is applied and the pressure at the parking brake switch returns to 0 psi.

Applying the parking brake decreases the pressure of the parking brake pneumatic circuit. As pressure falls to 70 to 84 psi (483 to 579 kPa), the low-range relay is energized. The low-range solenoid is now receiving power from both the low-range relay and the low-range interlock relay. When the pressure decreases to 2 to 5 psi (14 to 34 kPa), switch 2 will open and de-energize the low-range interlock relay.

After the low-range interlock relay is de-energized, the transfer case may be shifted to high-range. Range changes can only occur when the parking brake is applied and the transmission is in neutral.

Troubleshooting

IMPORTANT: A Business Class® M2 vehicle with optional all-wheel drive (AWD) has nonmultiplexed electronic controls for the transfer case functions. The following troubleshooting procedures are for nonmultiplexed transfer case controls. These controls do not use datalink communications to operate and monitor the transfer case functions. Only use this troubleshooting section if your vehicle is equipped with AWD.

See **Table 1** for electrical troubleshooting of the all-wheel drive.

See **Table 2** for electrical troubleshooting of the driver-controlled differential lock on an AWD vehicle with a single rear axle.

See **Table 3** for electrical troubleshooting of the inter-axle lock on an AWD vehicle with dual rear axles.

See **Table 4** for electrical troubleshooting of the transfer case range.

All-Wheel-Drive Troubleshooting		
Symptom	**Possible Cause**	**Check For**
No illumination of the AWD indicator on the instrumentation control unit (ICU).	Bad feedback circuit	Check the front axle engage switch. If the switch is functioning properly, check the circuit from the switch to ground and the circuit from the switch to the ICU.
AWD may engage then drop out, or not engage at all.	Insufficient air pressure	If an air pressure gauge indicates sufficient pressure, there may be a kink or restriction in the air lines.
	Bad electrical connection to the AWD air management unit (AMU)	Inspect the connector and connector pins. Straighten bent pins and make sure that the electrical connections are properly seated.
	Bad solenoid in the AWD AMU	Remove the air line from the transfer case for the front drive shaft lock. If no air, replace the solenoid.
	No signal from the AWD switch	Check the circuits of the AWD switch. Check the circuit from the switch to ground and the circuit from the switch to the ABS ECU.
	Antilock brakes system (ABS) ECU malfunction	The front axle engage solenoid is controlled by the ABS ECU. Make sure that all criteria for AWD activation are met and that the ABS ECU is functioning properly.

Table 1, All-Wheel-Drive Troubleshooting

Driver-controlled Differential Lock Troubleshooting for an AWD Vehicle With a Single Rear Axle		
Symptom	**Possible Cause**	**Check For**
No illumination of the differential lock indicator on the ICU.	Bad feedback circuit	Check the differential lock axle switch. If the switch is functioning properly, check the circuit from the switch to ground and the circuit from the switch to the ICU.

Troubleshooting

Driver-controlled Differential Lock Troubleshooting for an AWD Vehicle With a Single Rear Axle		
Symptom	**Possible Cause**	**Check For**
Differential lock (nonmultiplexed) may engage then drop out, or not engage at all.	Insufficient air pressure	If an air pressure gauge indicates sufficient pressure, there may be a kink or restriction in the air lines.
	Bad electrical connection to the AWD AMU	Inspect the connector and connector pins. Straighten bent pins and make sure that the electrical connections are properly seated.
	Bad solenoid in the AWD AMU	Remove the air line from the differential housing and turn on the switch. If no air, replace the solenoid.
	No signal from the differential lock switch	Check the circuits of the differential lock switch. Check the circuit from the switch to ground and the circuit from the switch to the ABS ECU.
	ABS ECU malfunction	The differential lock solenoid is controlled by the ABS ECU. Make sure that the ABS ECU is functioning properly.

Table 2, Driver-controlled Differential Lock Troubleshooting for an AWD Vehicle With a Single Rear Axle

Interaxle Lock Troubleshooting for an AWD Vehicle With Dual Rear Axles		
Symptom	**Possible Cause**	**Check For**
No illumination of the interaxle lock indicator on the ICU.	Bad interaxle lock switch circuit	Check the ground circuit from the interaxle lock switch.
Interaxle lock (nonmultiplexed) may engage then drop out, or not engage at all.	Insufficient air pressure	If an air pressure gauge indicates sufficient pressure, there may be a kink or restriction in the air lines.
	Bad electrical connection to the AWD AMU	Inspect the connector and connector pins. Straighten bent pins and make sure that the electrical connections are properly seated.
	Bad solenoid in the AWD AMU	Remove the air line from the forward rear axle differential and turn on the switch. If no air, replace the solenoid.
	No signal from the interaxle lock switch	Check the circuits of the interaxle lock. Check the circuit from the switch to ground and the circuit from the switch to the ABS ECU.
	ABS ECU malfunction	The interaxle lock solenoid is controlled by the ABS ECU. Make sure that the ABS ECU is functioning properly.

Table 3, Interaxle Lock Troubleshooting for an AWD Vehicle With Dual Rear Axles

Transfer Case Range Troubleshooting		
Symptom	**Possible Cause**	**Check For**
No illumination of the low-range indicator on the ICU.	Bad feedback circuit	Make sure that the pressure switch inside the low-range solenoid is operating properly.

Troubleshooting

Transfer Case Range Troubleshooting		
Symptom	**Possible Cause**	**Check For**
Selected transfer case range (nonmultiplexed) may engage then drop out, or not engage at all.	Insufficient air pressure	If an air pressure gauge indicates sufficient pressure, there may be a kink or restriction in the air lines.
	Bad solenoid in the AWD AMU	Remove the air line of the suspect solenoid from the transfer case and turn on the switch. If no air, replace the solenoid.
	Bad relay in the auxiliary PDM	Check function of suspect relays. For each range there is a range relay and a range interlock relay. Make sure both relays are operational.
	Bad electrical connection(s)	Check the circuitry of the AWD system. Look for loose, damaged, or improperly seated components.
	Bad parking brake pressure switch in AWD AMU	Check the parking brake pressure switch for correct operation. Pins A and B are for the normally closed switch 1 that opens at 70 to 84 psi (483 to 579 kPa). Pins C and D are for the normally open switch 2 that closes at 2 to 5 psi (14 to 34 kPa).
Engine ECU not receiving low-range notification.	Bad feedback circuit	Check the feedback circuit. For vehicles without a transfer-case-mounted PTO, feedback is provided by a single circuit from the transfer case switch to the engine ECU. With a transfer-case-mounted PTO, feedback is provided by a low-range engine ECU relay in the auxiliary PDM.

Table 4, Transfer Case Range Troubleshooting

Wiring Diagrams

IMPORTANT: A Business Class® M2 vehicle with optional all-wheel drive (AWD) has nonmultiplexed electronic controls for the transfer case functions. The following wiring diagrams are for nonmultiplexed transfer case controls. These controls do not use datalink communications to operate and monitor the transfer case functions. Only use these wiring diagrams if your vehicle is equipped with AWD.

See **Fig. 1** for a wiring diagram of all-wheel drive.

See **Fig. 2** for a wiring diagram of the driver-controlled differential lock on an AWD vehicle with a single rear axle.

See **Fig. 3** for a wiring diagram of the interaxle lock on an AWD vehicle with dual rear axles.

See **Fig. 4** for a wiring diagram of the transfer case power.

See **Fig. 5** for a wiring diagram of the transfer case low range.

See **Fig. 6** for a wiring diagram of the transfer case high range.

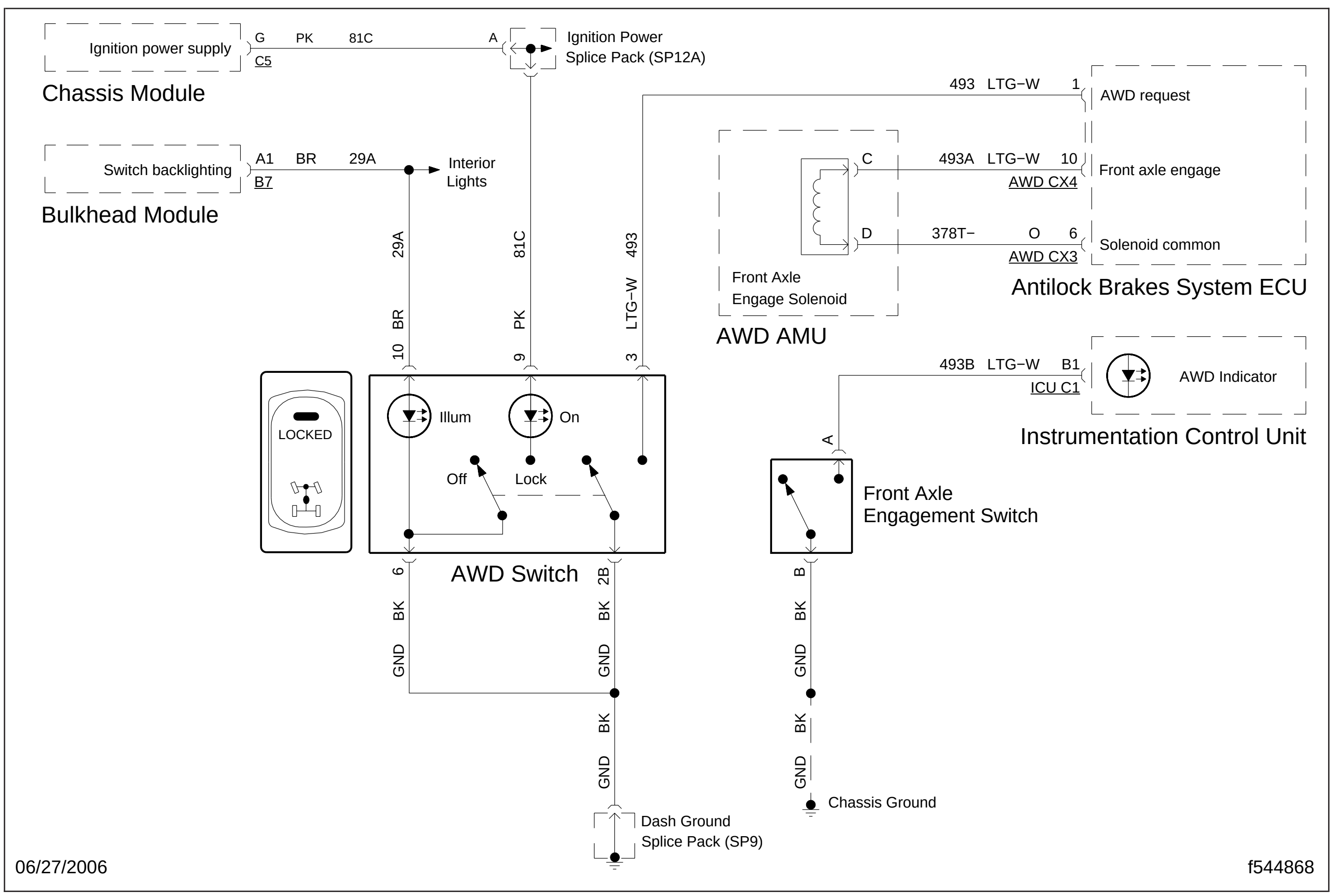


Fig. 1, AWD Wiring Diagram

Specifications

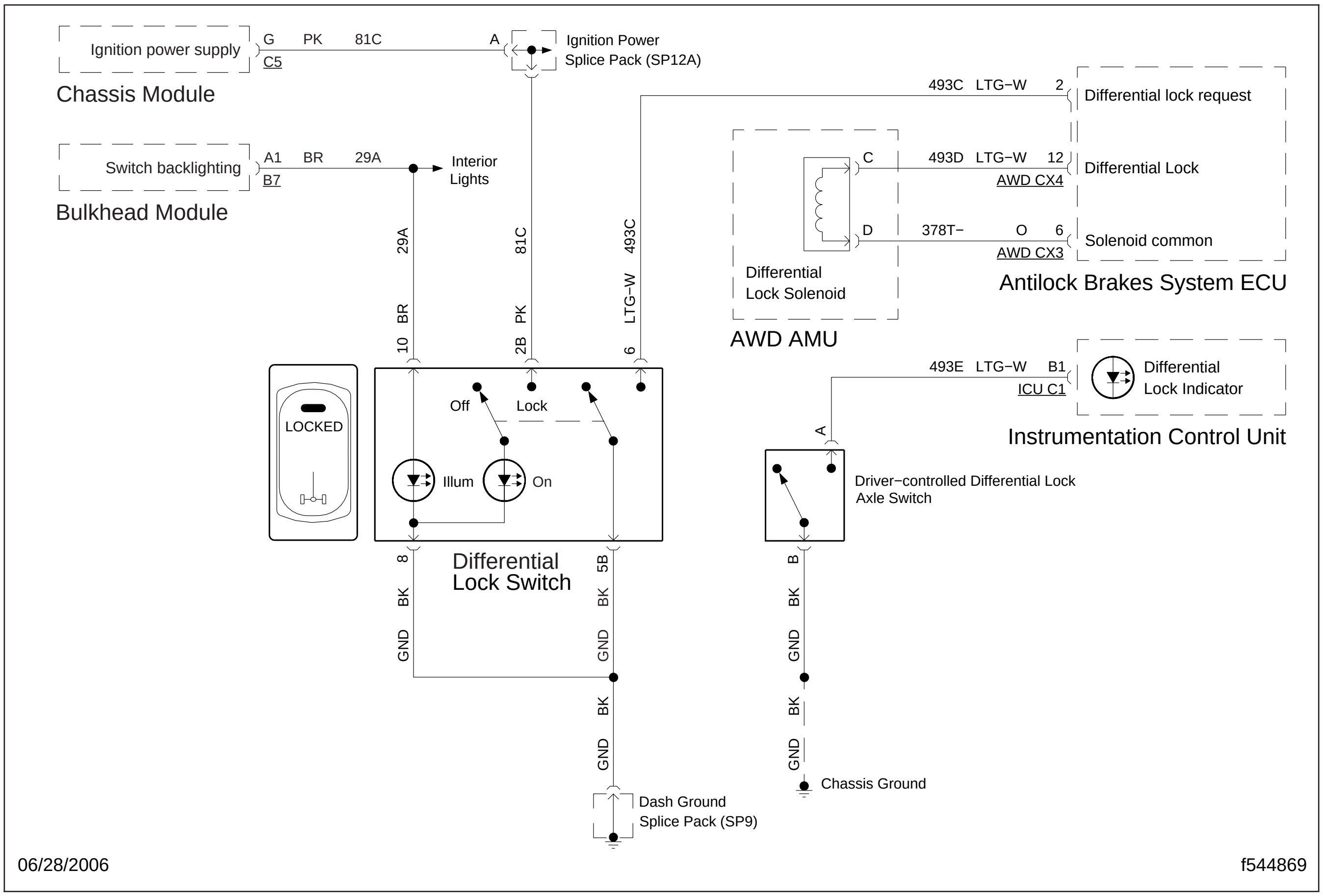


Fig. 2, Driver-Controlled Differential Lock Wiring Diagram for an AWD Vehicle With a Single Rear Axle

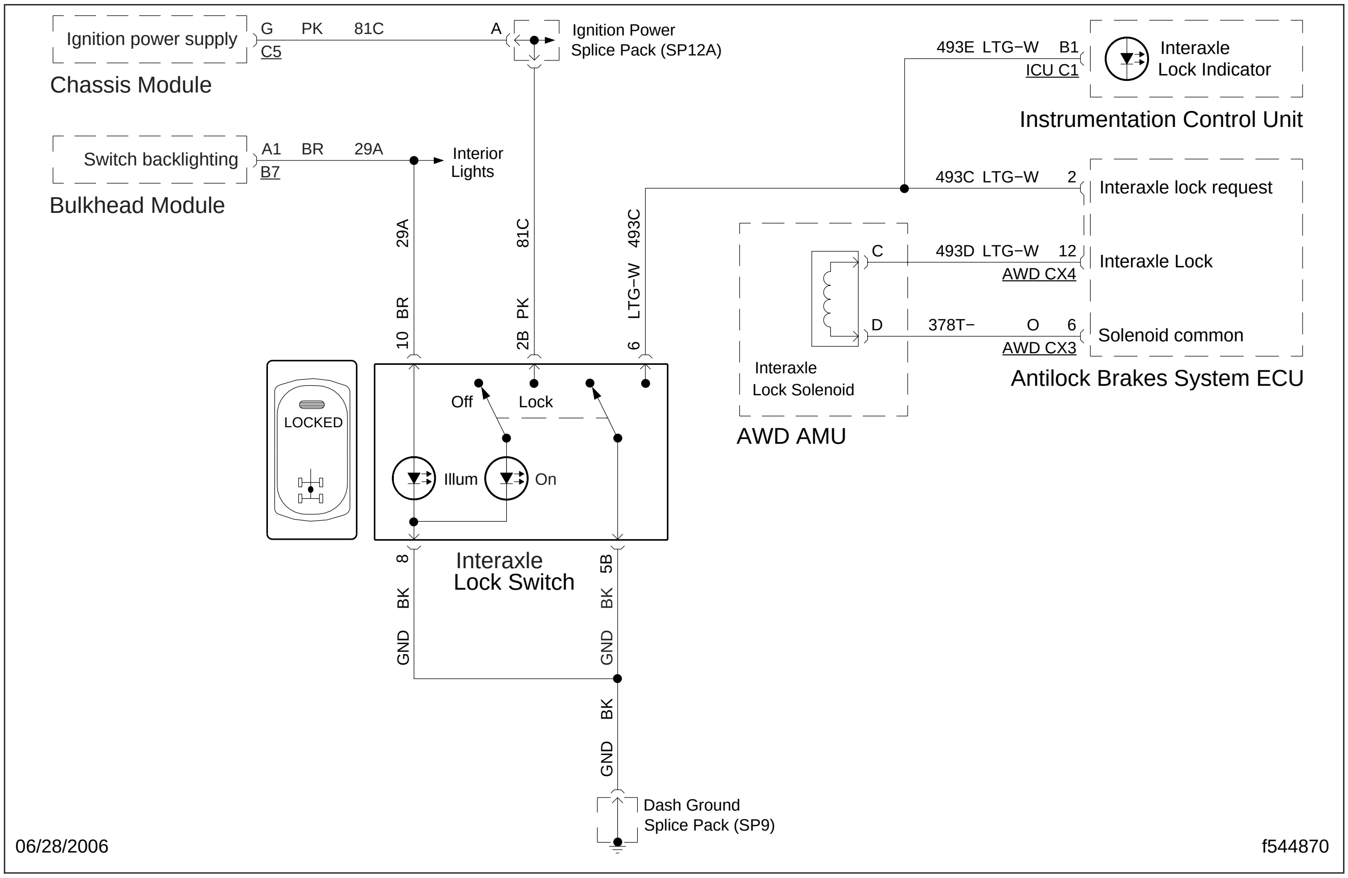


Fig. 3, Interaxle Lock Wiring Diagram for an AWD Vehicle With Dual Rear Axles

Specifications

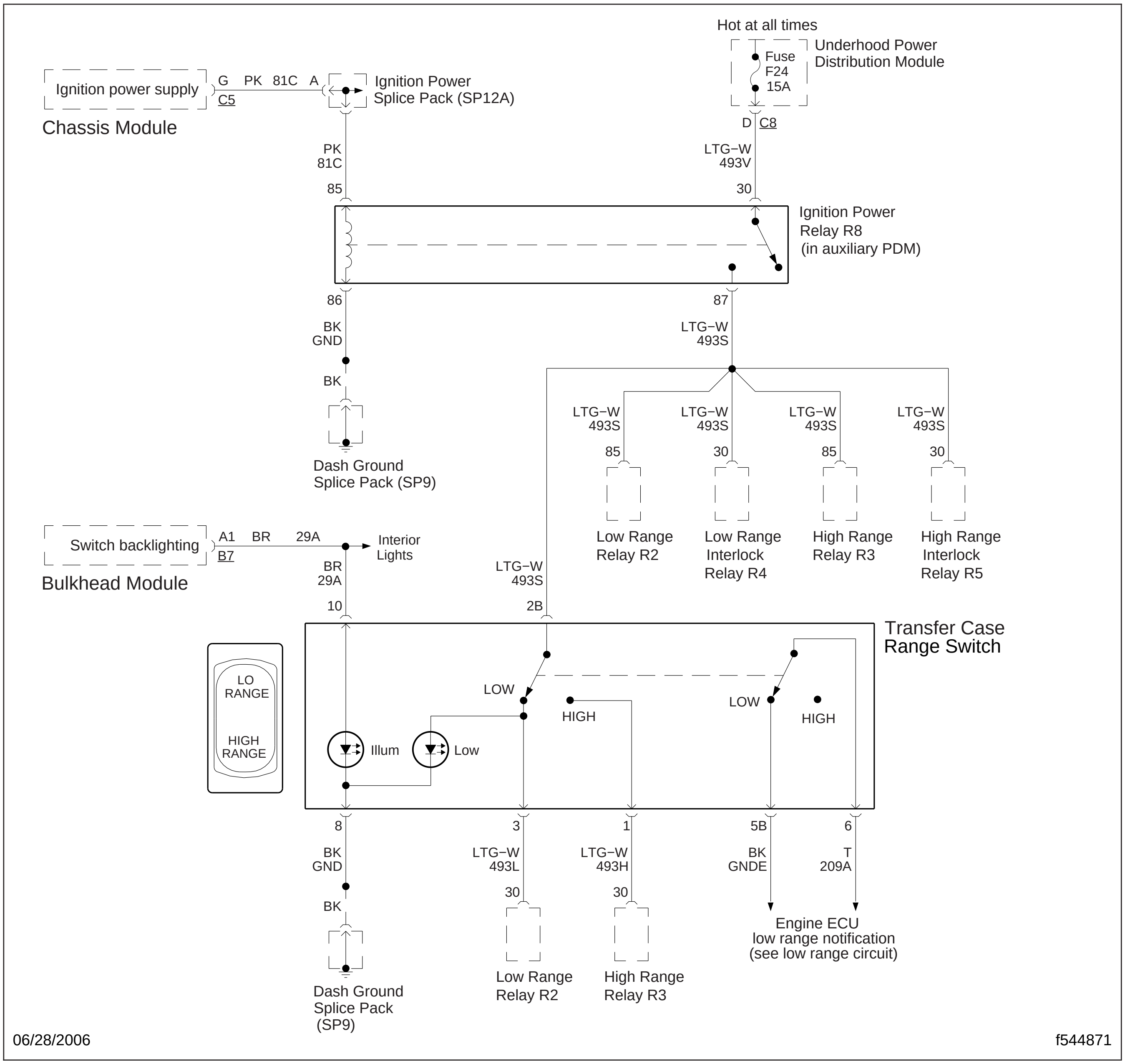


Fig. 4, Transfer Case Power Wiring Diagram

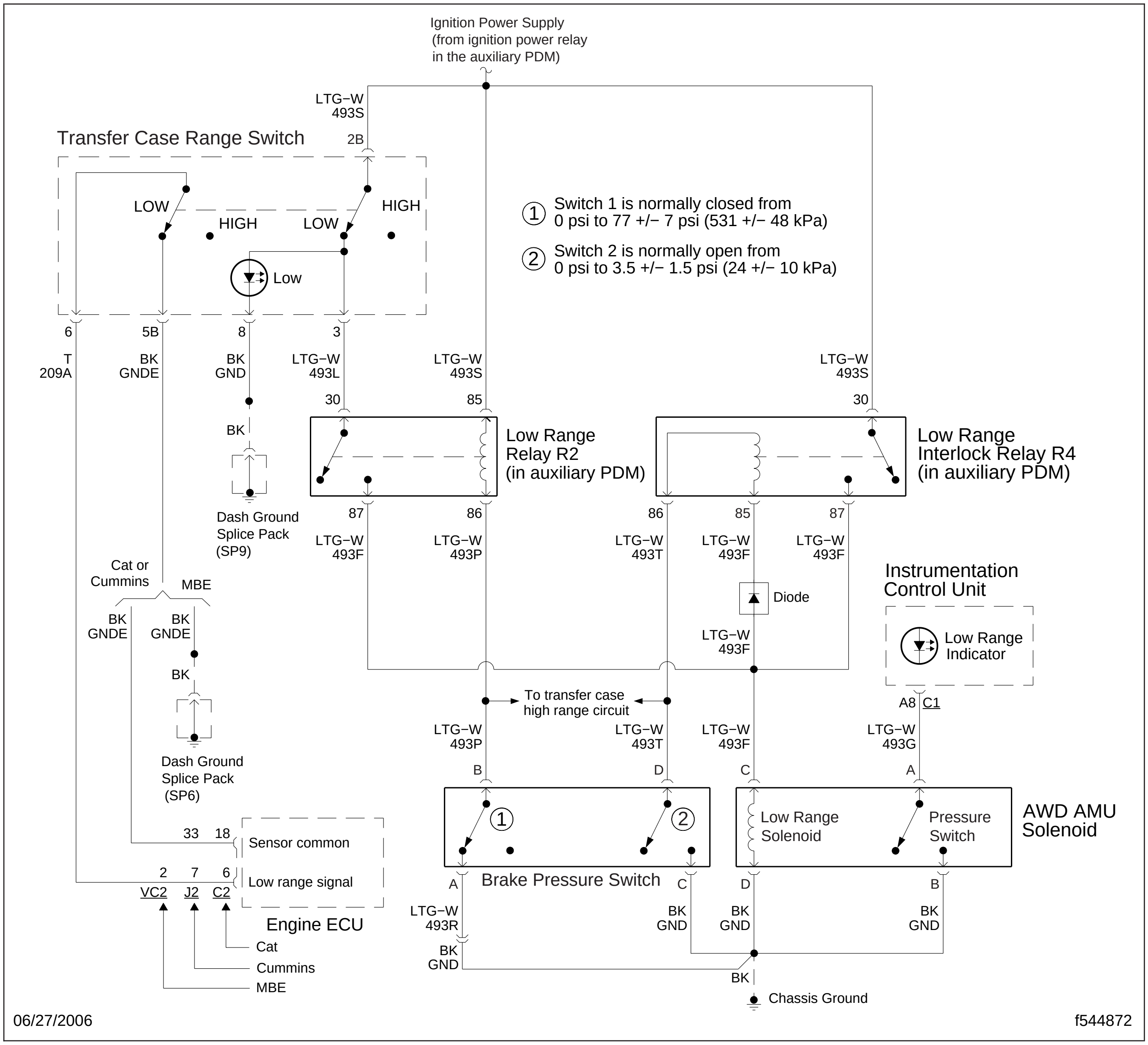


Fig. 5, Transfer Case Low-Range Wiring Diagram

Specifications

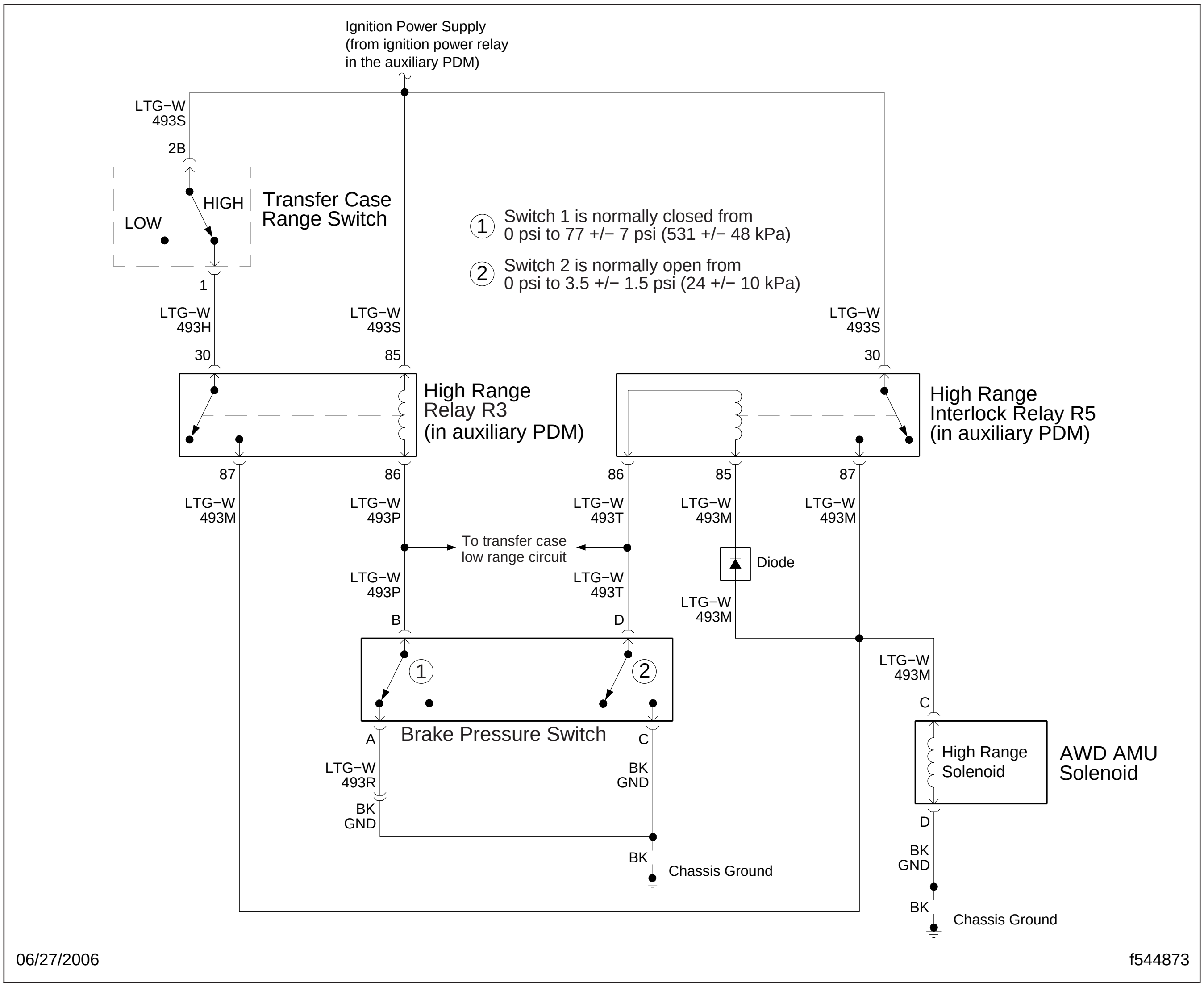
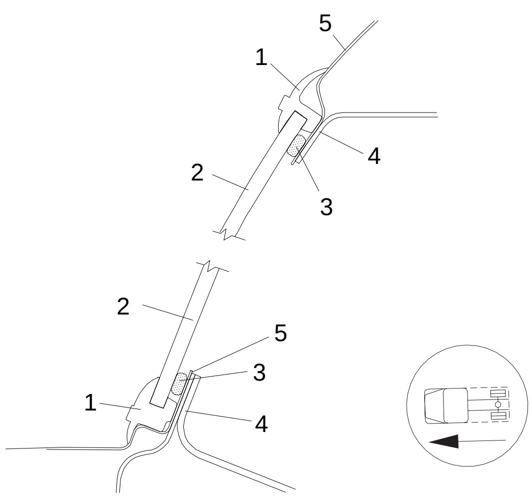


Fig. 6, Transfer Case High-Range Wiring Diagram

General Information

The one-piece windshield is available in two different styles: roped-in and encapsulated. The roped-in style is installed with a separate retainer that is not part of the windshield glass. The encapsulated style comes from the manufacturer with an injection-molded polyurethane seal and flange attached all the way around the edges of the windshield glass. There is no need for a separate retainer or moldings.

The encapsulated windshield is held in place on the windshield mask by a bead of urethane adhesive/sealant. The installation is similar to automobile windshields, where the urethane sealant holds the windshield in place and seals out moisture; see Fig. 1.



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1. Injection-Molded Polyurethane Seal and Flange
2. Windshield Glass
3. Urethane Adhesive/Sealant
4. Interior Trim
5. Windshield Mask

Fig. 1, Encapsulated Windshield Installation (cross-sectional view)

The information and procedure in this section applies only to the encapsulated style of windshield. This is the standard windshield installation for Business Class M2 vehicles.

See **Specifications 400** for special tools and materials needed to replace a windshield.

Replacement

NOTE: Freightliner recommends Sika Ultrafast, Dow U-400HV, or Bostik® 70-08A adhesive for windshield replacement.

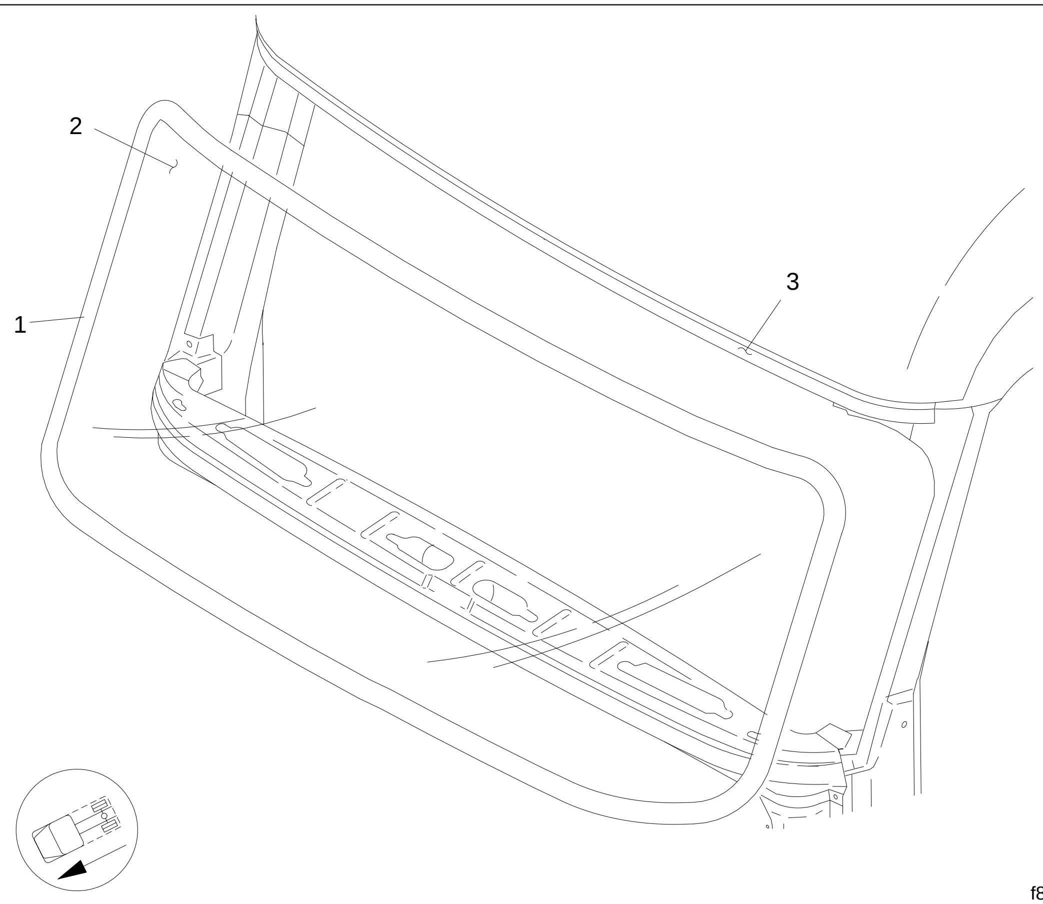
The procedure below specifies Dow adhesives and primers, though other manufacturers' systems can be used. Regardless of the system used, adhere to the adhesive manufacturer's instructions, and use that manufacturer's recommended primers and glass prep solutions for the entire procedure.

NOTE: The following procedure pertains to encapsulated windshields only; see **Fig. 1**.

If the windshield is cracked, carefully inspect the glass, urethane sealant, and the windshield mask to determine the cause. Correct the problem before installing a new windshield. If the underlying cause for the crack is not corrected, the replacement windshield may crack when exposed to high winds, pressure, temperature extremes, or vehicle motion.

NOTE: At least two people are needed to replace a windshield.

1. Apply the parking brakes and chock the tires.
2. Open the windows. Shutting the doors with the windows closed could pressurize the cab and create gaps in the uncured adhesive.
3. Open the hood.



11/09/2001 f820391

1. Polyurethane Flange and Seal
2. Windshield Glass
3. Windshield Mask

Fig. 1, Windshield Installation (encapsulated windshield)

4. Remove the windshield wiper arms; see **Group 82**.
5. Protect the paint finish and instrument panel by taping paper around the inside and outside of the windshield opening.
6. Lower the door windows, to prevent pressure build-up when closing the doors, which could damage the uncured adhesive seal.
7. Using a suitable knife, make a 90-degree cut into the polyurethane flange surrounding the windshield. Cut off the flange all the way around the windshield.
8. Using a pneumatic cutting tool (**Fig. 2**), a piano wire (**Fig. 3**), or a pull knife (**Fig. 4**), cut through the urethane sealant all around the edges of the windshield glass. See **Fig. 5** for a cross-sectional view.

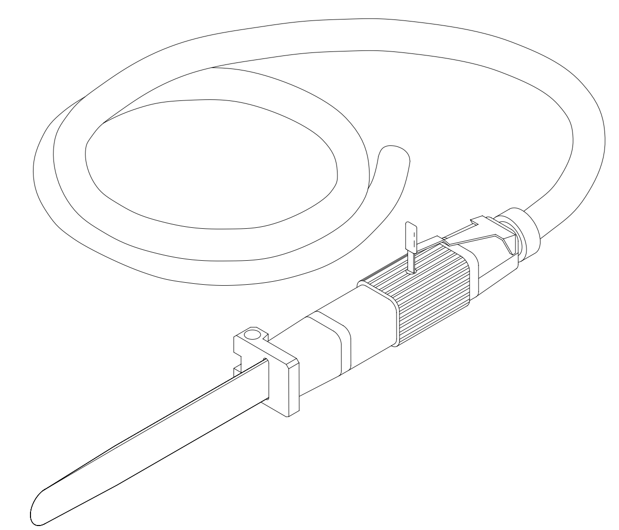
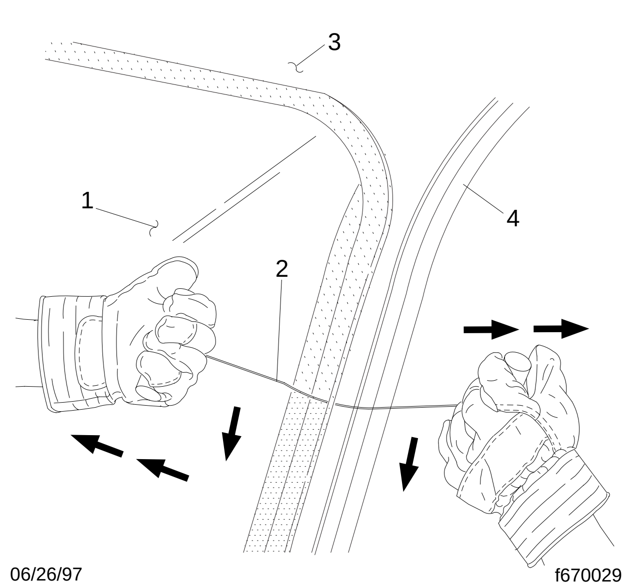


Fig. 2, BTB Pneumatic Cutting Tool

NOTE: To order a BTB pneumatic cutting tool, see **Specifications 400**.

WARNING

Wear protective gloves and safety glasses when replacing windshield glass. Gloves will protect your hands from sharp edges, and allow a better grip. Failure to wear gloves and safety glasses when handling glass could result in injury to hands or eyes.



1. Windshield Glass
2. Piano Wire
3. Roof
4. Door Frame

Fig. 3, Windshield Glass Removal with Piano Wire

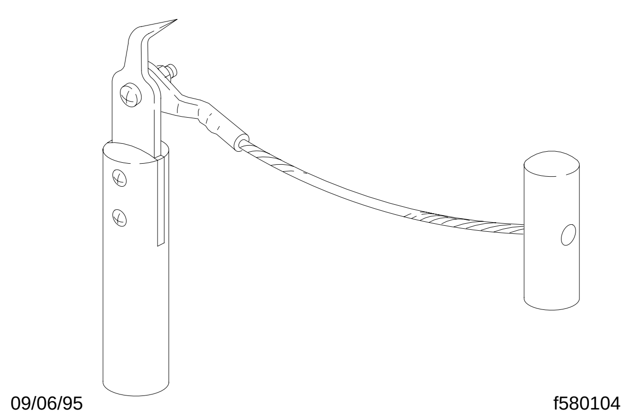
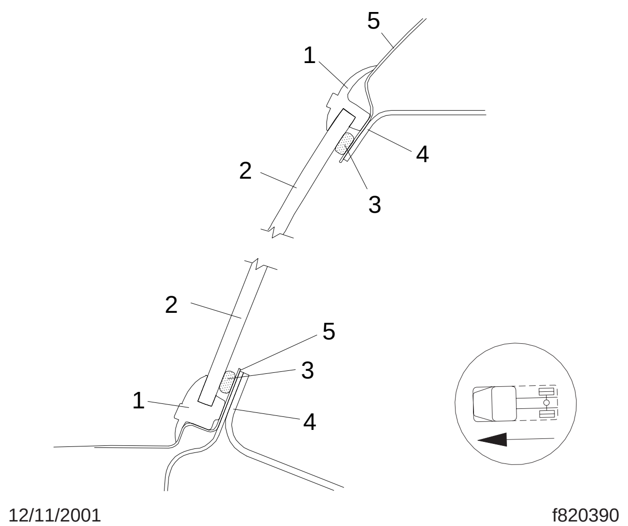


Fig. 4, Typical Pull Knife

9. Carefully remove the damaged windshield glass.
10. Using a BTB pneumatic cutting tool or a sharp knife, trim down the old urethane adhesive/sealant, leaving no more than 1/16 inch (1 to 2 mm) on the windshield mask. Make sure any remaining adhesive has a smooth and even surface.
11. Brush the remaining adhesive and debris from the windshield mask.



1. Injection-Molded Polyurethane Seal and Flange
2. Windshield Glass
3. Urethane Adhesive/Sealant
4. Interior Trim
5. Windshield Mask

Fig. 5, Encapsulated Windshield Installation (cross-sectional view)

12. Check the windshield mask. Apply Betaprime® 5404A Pinchweld and Encapsulation Primer to any bare metal. Allow to dry for a minimum of 6 minutes.

NOTE: Exposed bare metal areas larger than 1/2 inch x 1/2 inch (13 mm x 13 mm) require the use of Betaprime 5201TF Bare Metal Etch Primer.

13. Put the new encapsulated windshield glass on a suitable stand or fixture, with the inside surface of the glass facing up.
14. Clean the bonding surface of the glass with Betaclean GC-800.
15. Apply Betaprime 5500 1-Step Glass/Frit Primer all the way around the edge of the glass to a width of about 1 inch (25 mm). *Do not get any of the primer on the clear glass outside the black band.* Allow a minimum of six minutes for the primer to dry.
16. Holding the sealant applicator at a 90-degree angle to the windshield mask on the cab, apply a uniform and continuous bead of Betaseal U-400HV Adhesive all the way around the edges of the windshield mask. The bead should be a minimum of 3/8 inch (10 mm) thick.

    Keep the spiked edge of the applicator tip against the edge of the mask, and overlap the bead slightly.

IMPORTANT: Do not apply the urethane adhesive/sealant to the windshield glass. Aligning a windshield with adhesive on the glass is very difficult to do without getting the adhesive/sealant on the painted cab surface outside the windshield mask.

17. Attach a suction device to the outside of the windshield. Lift and install the windshield. Align the center of the windshield with the indexing point at the center of the windshield mask. Gently set the windshield in place, then adjust it side-to-side for the best fit. Make sure the lip of the polyurethane flange fits over the sheet metal of the A-pillars.
18. Gently press down on the glass all the way around the bead line to firmly seat the windshield.
19. With a spatula or a paddle, smooth the adhesive flat along the edge of the windshield and remove any excess.
20. Install the wiper arms; see **Group 82**.
21. Clean both sides of the new windshield glass.
22. Remove the protective coverings from the inside and outside of the windshield opening.
23. Close the hood.
24. See the adhesive manufacturer's documentation for cure and drive-away times.

Specifications

See Table 1 for the materials needed for windshield installation using Dow U-400HV urethane adhesive. The items in Table 1 are available from your local Dow/Essex dealer.

If using another adhesive, refer to the adhesive manufacturer's instructions for applicable cleaners and primers.

Materials and Tools Needed for Windshield Installation	
Material or Tool	**Part Number**
Betapclean® Glass Cleaner	GC-800
Betaprime® Glass Primer	5500
Betaprime Body Primer	5404A
Betaseal® Adhesive	U-400HV
Betaseal Primerless Auto Glass Adhesive	U-418

Table 1, Materials and Tools Needed for Windshield Installation

See Fig. 1 and Fig. 2 for the special tools needed for windshield removal.

To obtain the BTB pneumatic cutting tool (J–43029) contact:

SPX Kent-Moore
28635 Mound Road
Warren, Michigan 48092-3499
1-800-328-6657

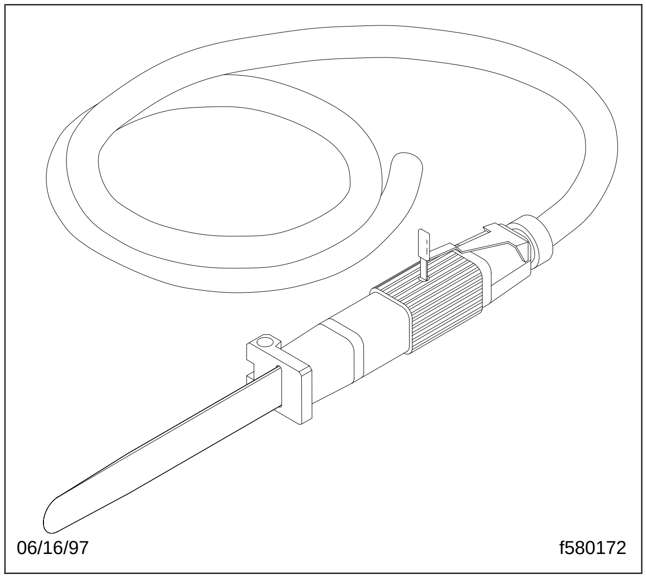


Fig. 1, BTB Pneumatic Cutting Tool (J-43029)

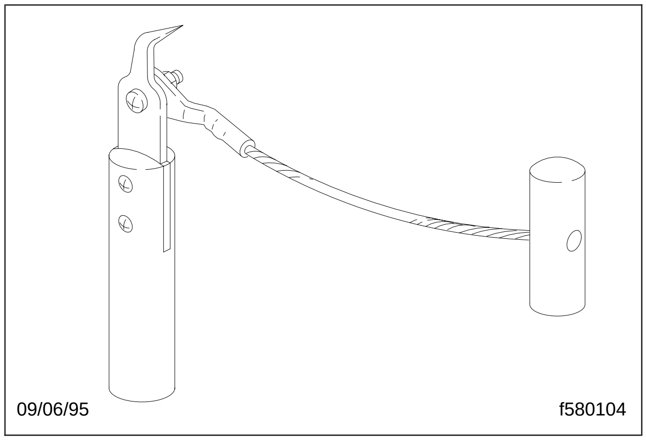


Fig. 2, Typical Pull Knife

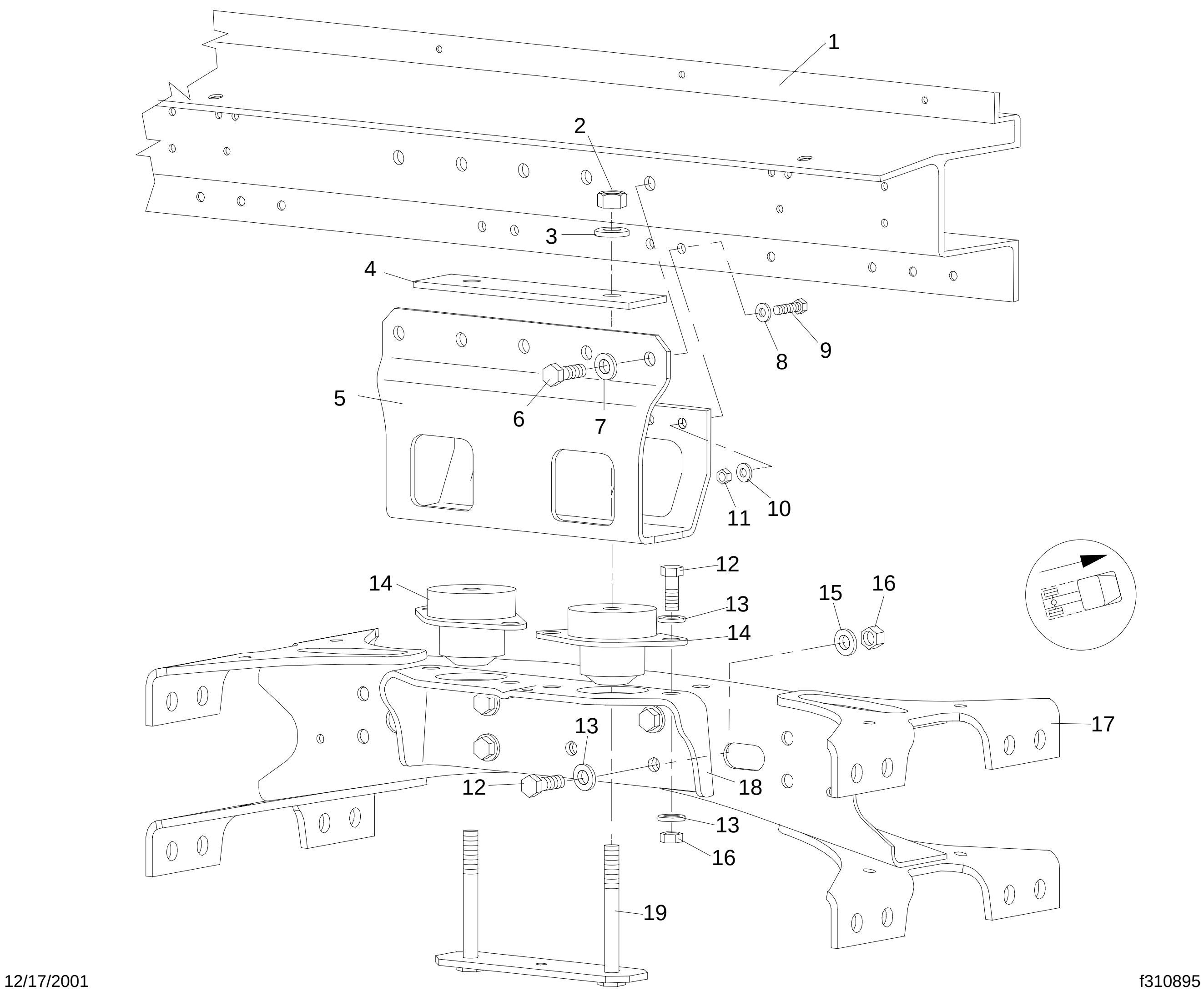
General Information

The solid rubber cab suspension consists of a pair of rubber isolators positioned between two mounting brackets. See **Fig. 1**.

The upper mounting bracket is attached to the cab rear sill, and the lower mounting bracket is attached to the frame rail crossmember.

The isolators are made of rubber with a steel mounting flange integral to each assembly. The isolators are not serviceable. Each is replaced as a complete assembly.

General Information



1. Cab Rear Sill
2. Hexnut, 5/8–11
3. Flatwasher
4. Upper Backing Plate
5. Upper Mounting Bracket
6. Hexbolt, M12 (5 qty.)
7. Flatwasher, M12 (5 qty.)
8. Flatwasher, M8
9. Hexbolt, M8
10. Flatwasher, M8
11. Hexnut, M8
12. Hexbolt, 1/2–13
13. Flatwasher
14. Isolator Assembly
15. Flatwasher
16. Hexnut, 1/2–13
17. Frame Rail Crossmember
18. Lower Mounting Bracket
19. Lower Backing Plate Assembly

Fig. 1, Cab Solid Rubber Suspension

Cab Suspension Components Replacement

Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Using a suitable jack, raise the cab enough to take the weight off the cab suspension.
3. Support the cab with safety stands, blocks of wood, or other suitable means.

WARNING

Do not work under the cab when it is supported only by a jack. Use safety stands or other suitable means to firmly support the cab. Jacks can slip, causing the cab to fall, which could result in serious injury or death.

4. Remove the hexnuts and washers from the lower backing plate studs. See **Fig. 1**.
5. If necessary, remove any fuel line, air line, or wiring standoff brackets from the frame rail crossmember. Move the lines/wiring out of the way.
6. Remove the fasteners holding the lower mounting bracket to the frame rail crossmember.
7. Remove the lower mounting bracket and the isolators from the vehicle and put them on a workbench.
8. Remove the fasteners that attach each isolator to the lower mounting bracket.

NOTE: The isolators are not serviceable. If they are damaged, replace the entire assembly.

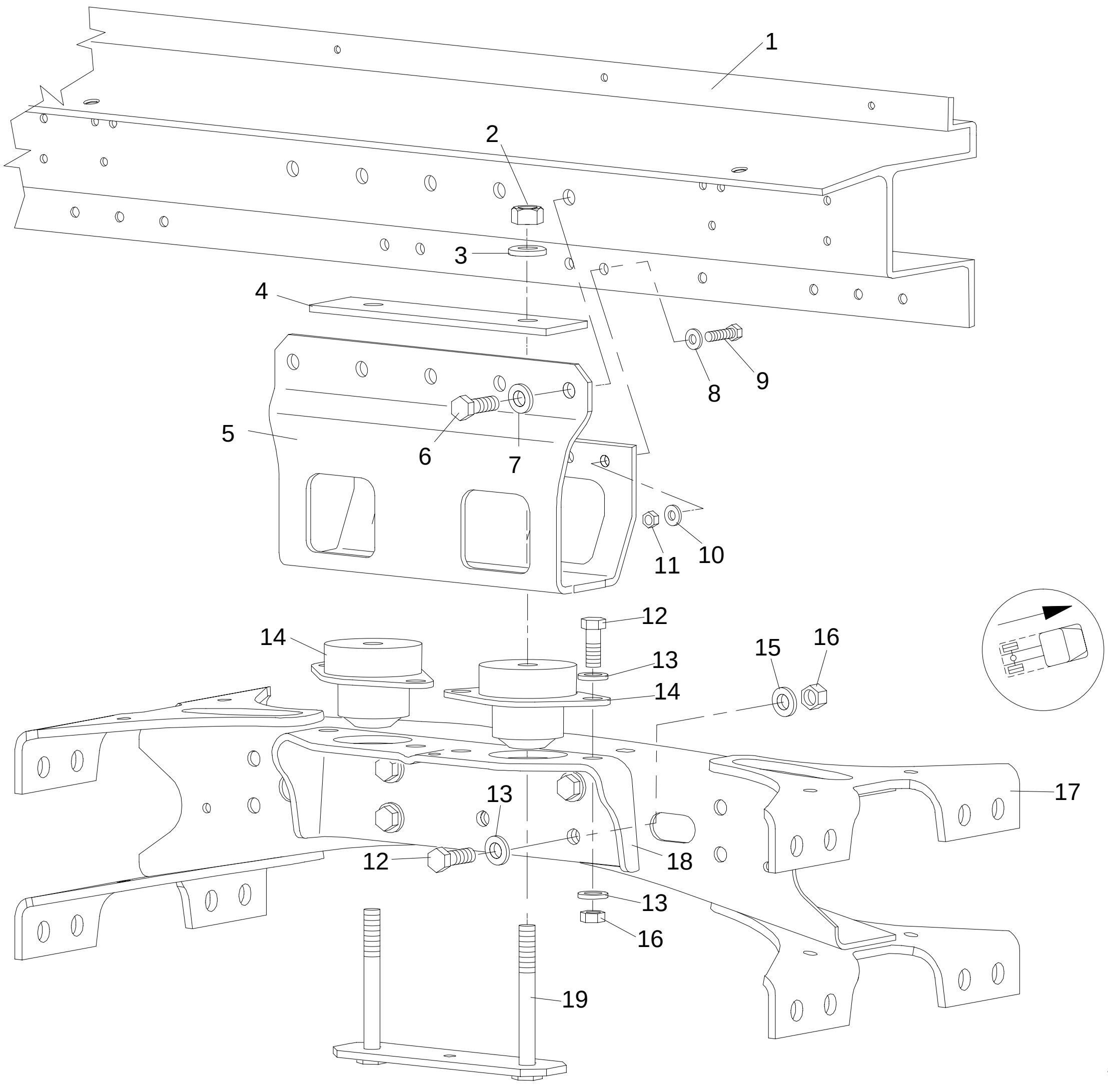
9. If replacing the upper mounting bracket, remove the five fasteners holding it to the outside of the cab rear sill, then the four fasteners holding it to the inside of the cab rear sill.
10. Remove the upper mounting bracket from the vehicle.
11. If it was removed, install the upper mounting bracket onto the cab rear sill. See **Fig. 1**.

    11.1 Position the upper mounting bracket in place on the rear sill and install the four M8 hexbolts, flatwashers, and hexnuts from the inside surface of the rear sill. Install the hexbolts with their heads inboard. See **Fig. 1**. Tighten 12 lbf·ft (19 N·m).

    11.2 On the outside surface of the rear sill, install the M12 hexbolts and washers. Tighten 60 lbf·ft (81 N·m).

12. Install the isolators onto the lower mounting bracket. Tighten the 1/2–13 fasteners 68 lbf·ft (92 N·m).
13. Install the studs of the lower backing plate through the isolators.
14. Install the lower bracket and the isolators onto the frame rail crossmember. Tighten the 1/2–13 fasteners 68 lbf·ft (92 N·m).
15. Raise the cab, remove the blocks or stands, and lower the cab.
16. Install the 5/8–11 hexnuts and washers onto the isolator center-bolts. Tighten 136 lbf·ft (184 N·m).
17. As applicable, attach any fuel line, air line or wiring standoff brackets that were removed earlier. Route the lines/wiring.
18. Remove the chocks from the tires.

Cab Suspension Components Replacement



1. Cab Rear Sill
2. Hexnut, 5/8–11
3. Flatwasher
4. Upper Backing Plate
5. Upper Mounting Bracket
6. Hexbolt, M12 (5 qty.)
7. Flatwasher, M12 (5 qty.)
8. Flatwasher, M8
9. Hexbolt, M8
10. Flatwasher, M8
11. Hexnut, M8
12. Hexbolt, 1/2–13
13. Flatwasher
14. Isolator Assembly
15. Flatwasher
16. Hexnut, 1/2–13
17. Frame Rail Crossmember
18. Lower Mounting Bracket
19. Lower Backing Plate Assembly

Fig. 1, Cab Solid Rubber Suspension

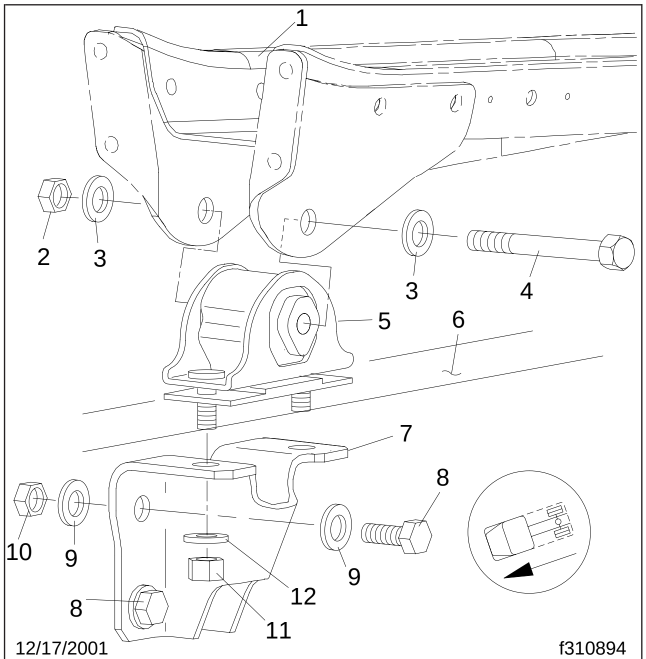
Specifications

Cab Suspension Fastener Torque Values		
Description	**Size**	**Torque: lbf·ft (N·m)**
Upper Mounting Bracket Rear Fasteners	M12	60 (81)
Upper Mounting Bracket Forward Fasteners	M8	12 (19)
Isolator Assembly Fasteners	1/2–13	68 (92)
Lower Mounting Bracket Assembly Fasteners	1/2–13	68 (92)
Lower Backing Plate Hexnuts	5/8–11	136 (184)

Table 1, Cab Suspension Fastener Torque Values

General Information

The forward part of the cab is attached to the frame rails with two cab mount assemblies. See **Fig. 1**. Each forward cab mount assembly consists of a hard rubber isolator surrounded by a steel bracket. The assembly is attached to a frame rail bracket and the cab underbody.



1. Cab Underbody Bracket
2. Hexnut, 5/8–11
3. Flatwasher
4. Isolator Hexbolt
5. Cab Mount Assembly
6. Left Frame Rail
7. Frame Rail Bracket
8. Hexbolt, 5/8–11
9. Flatwasher
10. Hexnut, 5/8–11
11. Hexnut, 5/8–11
12. Flatwasher

Fig. 1, Left Forward Cab Mount Installation

Forward Cab Mount Replacement

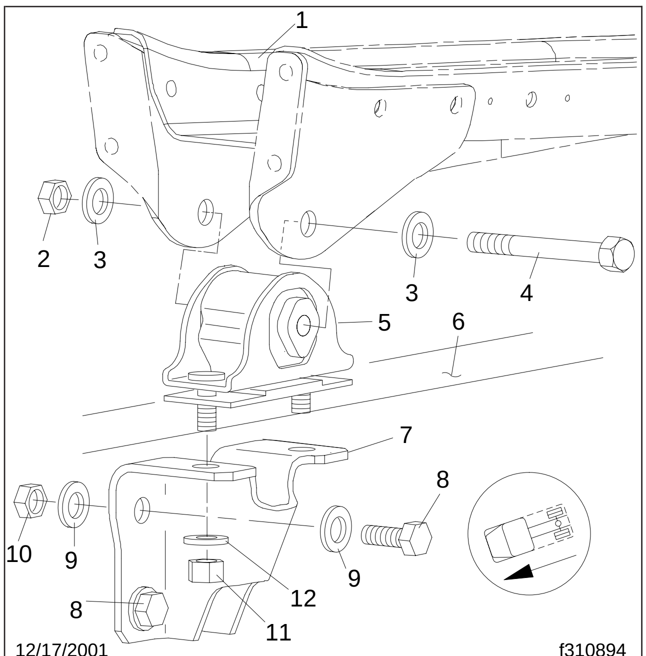
Replacement

1. Park the vehicle, apply the parking brakes, then chock the tires.
2. Jack up the front of the cab to take the weight off of the forward cab mount. Support the cab with jackstands.

WARNING

Do not work under the cab when it is supported only by a jack. Use safety stands or other suitable means to firmly support the cab. Jacks can slip, causing the cab to fall, which could result in serious injury or death.

3. Remove the 5/8–11 fasteners holding the cab mount assembly to the frame rail brackets. See **Fig. 1.**



1. Cab Underbody Bracket
2. Hexnut, 5/8–11
3. Flatwasher
4. Isolator Hexbolt
5. Cab Mount Assembly
6. Left Frame Rail
7. Frame Rail Bracket
8. Hexbolt, 5/8–11
9. Flatwasher
10. Hexnut, 5/8–11
11. Hexnut, 5/8–11
12. Flatwasher

Fig. 1, Left Forward Cab Mount Installation

4. Remove the 5/8–11 fasteners that hold the cab mount assembly to the cab underbody bracket.
5. If needed, raise the cab so the studs on the bottom of the cab mount assembly clear the holes on the frame rail bracket; then remove the cab mount assembly.
6. Install a new cab mount assembly.
   - 6.1 Place the cab mount assembly between the ears of the cab underbody bracket; then install the 5/8–11 isolator hexbolt, flatwashers and nut. Make sure the bolt head is facing outboard.
   - 6.2 Hand tighten the nut.
   - 6.3 Carefully lower the cab, making sure the studs at the bottom of the cab mount assembly line up with the holes in the frame rail bracket.

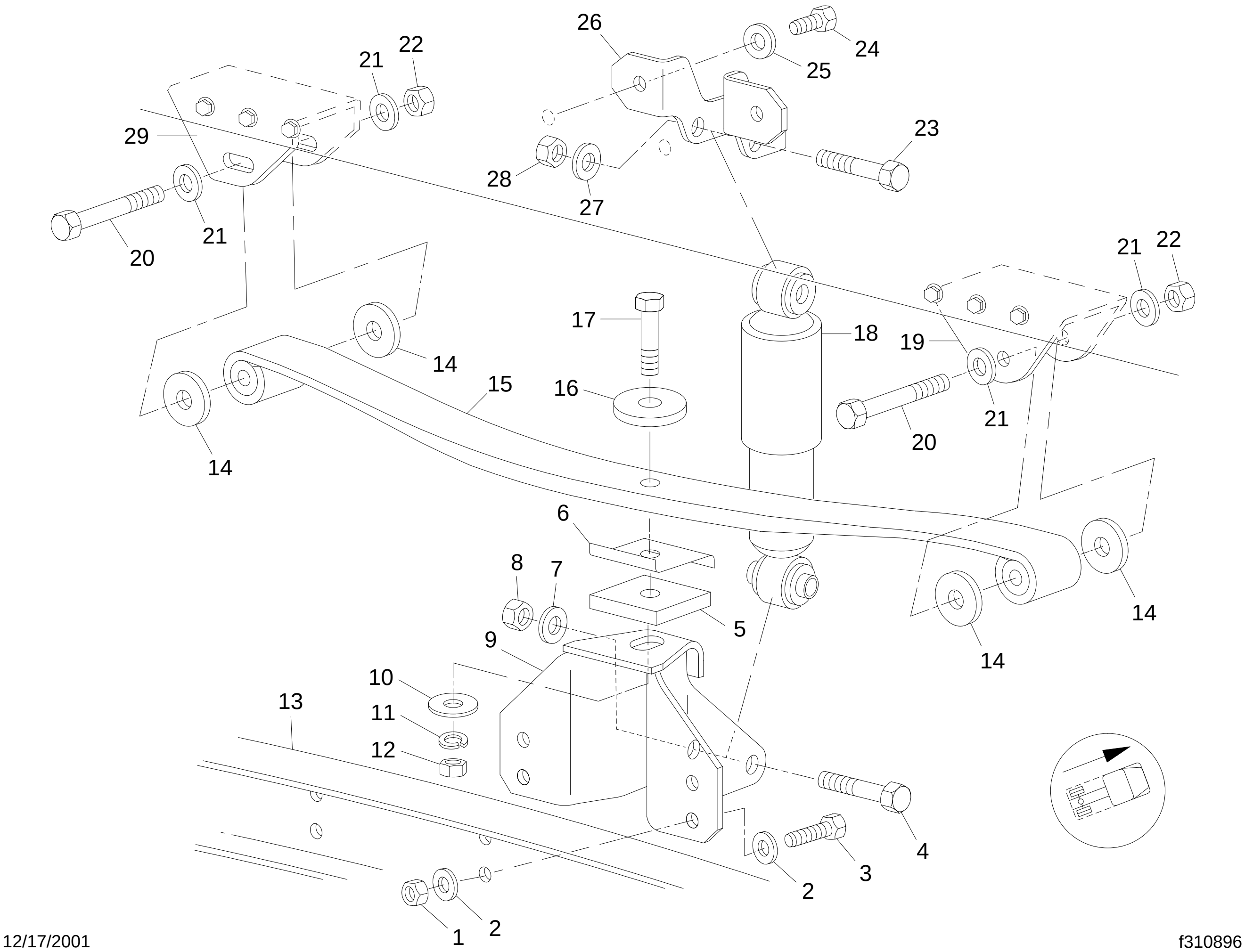
     Make sure the cab mount assembly is centered on the frame rail mounting bracket. Compare it with the cab mount assembly on the opposite side of the vehicle.
   - 6.4 Install the 5/8–11 nuts and washers onto the cab mount assembly studs. Tighten the nuts 136 lbf·ft (184 N·m).
   - 6.5 Tighten the nut on the isolator hexbolt 136 lbf·ft (184 N·m).
7. Raise the cab and remover the safety stands.
8. Lower the cab.
9. Remove the chocks from the tires.

General Information

The leaf spring cab suspension consists of a single leaf spring and a shock absorber mounted between the underside of the cab and the frame rail cross-member. See **Fig. 1**.

The leaf spring absorbs road shocks and vibration, and the shock absorber dampens the rebound of the leaf spring.

General Information



NOTE: The vertical fasteners for the spring-eye mounting brackets not shown.

1. Hexnut, 1/2–13 (4 qty.)
2. Flatwasher
3. Hexbolt, 1/2–13
4. Hexbolt, 1/2–13
5. Spacer Block
6. Shim
7. Flatwasher
8. Hexnut, 1/2–13
9. Lower Mounting Bracket Assembly
10. Flatwasher
11. Lockwasher
12. Hexnut, M12
13. Frame Rail Crossmember
14. Flatwasher
15. Leaf Spring
16. Flatwasher
17. Center-Bolt, M12 X 70
18. Shock Absorber
19. Spring-Eye Mounting Bracket (right-side)
20. Hexbolt, 1/2–13
21. Flatwasher
22. Hexnut, 1/2–13
23. Hexbolt, 1/2–13
24. Hexbolt, M12 X 45 (2 qty.)
25. Flatwasher (2 qty.)
26. Shock Absorber Upper Mounting Bracket
27. Flatwasher
28. Hexnut, 1/2–13
29. Spring-Eye Mounting Bracket (left-side)

Fig. 1, Cab Leaf Spring Suspension

Suspension Components Replacement

Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Remove upper and lower shock absorber fasteners, then remove the shock absorber. See **Fig. 1**.
3. Using a suitable jack, raise the cab enough to take the weight off the leaf spring.
4. Support the cab with safety stands, blocks of wood, or other suitable means.

WARNING

Do not work under the cab when it is supported only by a jack. Use safety stands or other suitable means to firmly support the cab. Jacks can slip, causing the cab to fall, which could result in serious injury or death.

5. Remove the leaf spring. See **Fig. 1**.

   5.1 Remove the M12 X 70 leaf spring centerbolt, hexnut and flatwashers.

   5.2 If needed, raise the cab slightly to remove the spacer and shim from the lower mounting bracket assembly.

   5.3 Remove the 1/2–13 spring eye fasteners.

   5.4 Remove the leaf spring from the vehicle.

6. If replacing them, remove the spring-eye mounting brackets from the underside of the cab.

   6.1 On one side of the cab, remove the M8 horizontal fasteners holding the spring-eye bracket to the cab backwall.

   IMPORTANT: Support the spring-eye bracket while removing the final vertical fastener from it.

   6.2 Remove the three M12 vertical fasteners that support the spring-eye bracket to the underside of the cab.

   6.3 Remove the spring-eye bracket.

   6.4 Repeat the procedure on the other side of the cab.

7. If replacing it, remove the lower mounting bracket assembly from the frame rail crossmember.

   7.1 Remove the four 1/2–13 fasteners holding the bracket to the crossmember.

   7.2 Remove lower mounting bracket assembly from the vehicle.

8. If replacing it, remove the upper shock absorber mounting bracket from the cab backwall.

   8.1 Remove the two M12 X 45 hexbolts and flatwashers.

   8.2 Remove the shock absorber upper mounting bracket.

9. If they were removed, install the right and left spring-eye brackets.

   IMPORTANT: The left-side spring-eye mounting bracket has an oblong mounting hole in it to allow for spring compression when the full weight of the cab is placed on the spring. See **Fig. 1**. Do not switch the right- and left-side brackets.

   9.1 On one side of the cab, place the applicable spring-eye bracket in position underneath the cab.

   9.2 Install the three vertical M12 X 45 hexbolts and flatwashers. Tighten *finger-tight*.

   9.3 Install the three M8 X 35 horizontal fasteners with the bolt heads outboard. Tighten finger-tight.

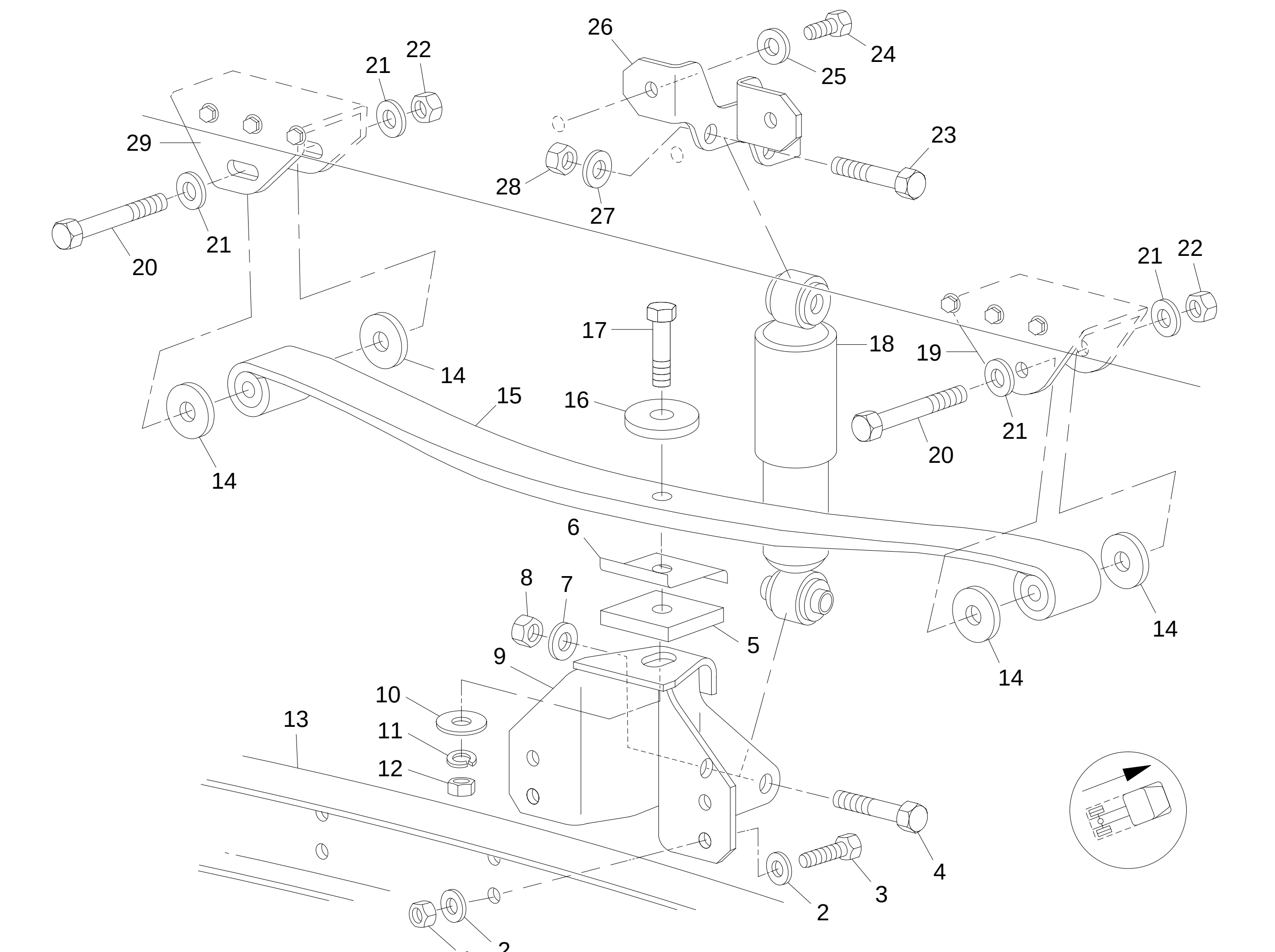
   9.4 Tighten the M12 vertical hexbolts 60 lbf·ft (81 N·m).

   Tighten the M8 horizontal fasteners 12 lbf·ft (16 N·m).

10. If it was removed, install the shock absorber upper mounting bracket. Tighten the fasteners 60 lbf·ft (81 N·m).
11. If it was removed, attach the lower mounting bracket assembly to the frame rail crossmember. See **Fig. 1**.

    Tighten the four 1/2–13 fasteners 68 lbf·ft (92 N·m).
12. Install the leaf spring. See **Fig. 1**.

Suspension Components Replacement



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NOTE: The vertical fasteners for the spring-eye mounting brackets not shown.

1. Hexnut, 1/2–13 (4 qty.)
2. Flatwasher
3. Hexbolt, 1/2–13
4. Hexbolt, 1/2–13
5. Spacer Block
6. Shim
7. Flatwasher
8. Hexnut, 1/2–13
9. Lower Mounting Bracket Assembly
10. Flatwasher
11. Lockwasher
12. Hexnut, M12
13. Frame Rail Crossmember
14. Flatwasher
15. Leaf Spring
16. Flatwasher
17. Center-Bolt, M12 X 70
18. Shock Absorber
19. Spring-Eye Mounting Bracket (right-side)
20. Hexbolt, 1/2–13
21. Flatwasher
22. Hexnut, 1/2–13
23. Hexbolt, 1/2–13
24. Hexbolt, M12 X 45 (2 qty.)
25. Flatwasher (2 qty.)
26. Shock Absorber Upper Mounting Bracket
27. Flatwasher
28. Hexnut, 1/2–13
29. Spring-Eye Mounting Bracket (left-side)

Fig. 1, Cab Leaf Spring Suspension

12.1 Position the right spring eye into the right spring-eye bracket and install the 1/2–13 fasteners. Use the outboard mounting holes in the spring-eye bracket. Tighten the fasteners just enough to hold them in place.

Suspension Components Replacement

12.2 Position the left spring eye into the left spring-eye bracket and install the 1/2–13 fasteners through the oblong hole in the spring-eye bracket.

12.3 If needed, raise the cab enough for clearance to install the spring shim and spacer block.

12.4 Install the shim and spacer block onto the top of the lower mounting bracket assembly.

12.5 Install the M12 X 70 center-bolt, flatwashers and hexnut. Tighten 60 lbf·ft (81 N·m).

13. Raise the cab, remove the blocks or safety stands, then lower the cab.
14. With the full weight of the cab on the leaf spring, tighten the left and right spring-eye fasteners 60 lbf·ft (81 N·m).
15. If it was removed, install the shock absorber.

    Tighten the upper and lower fasteners 45 lbf·ft (61 N·m).

IMPORTANT: Do not overtighten the shock absorber fasteners.

16. Remove the chocks from the tires.

Specifications

Cab Suspension Fastener Torque Values		
Description	**Size**	**Torque: lbf·ft (N·m)**
Leaf Spring Center-Bolt	M12 X 70	60 (81)
Spring-Eye Fasteners	1/2–13	60 (81)
Shock Absorber Upper and Lower Mounting Locknut	1/2–13	45 (61)
Lower Mounting Bracket Assembly Fasteners	1/2–13	68 (92)
Spring-Eye Bracket Horizontal Fasteners	M8 X 35	12 (16)
Spring-Eye Bracket Vertical Fasteners	M12 X 45	60 (81)
Shock Absorber Upper Mounting Bracket Hexbolts	M12 X 45	60 (81)

Table 1, Cab Suspension Fastener Torque Values

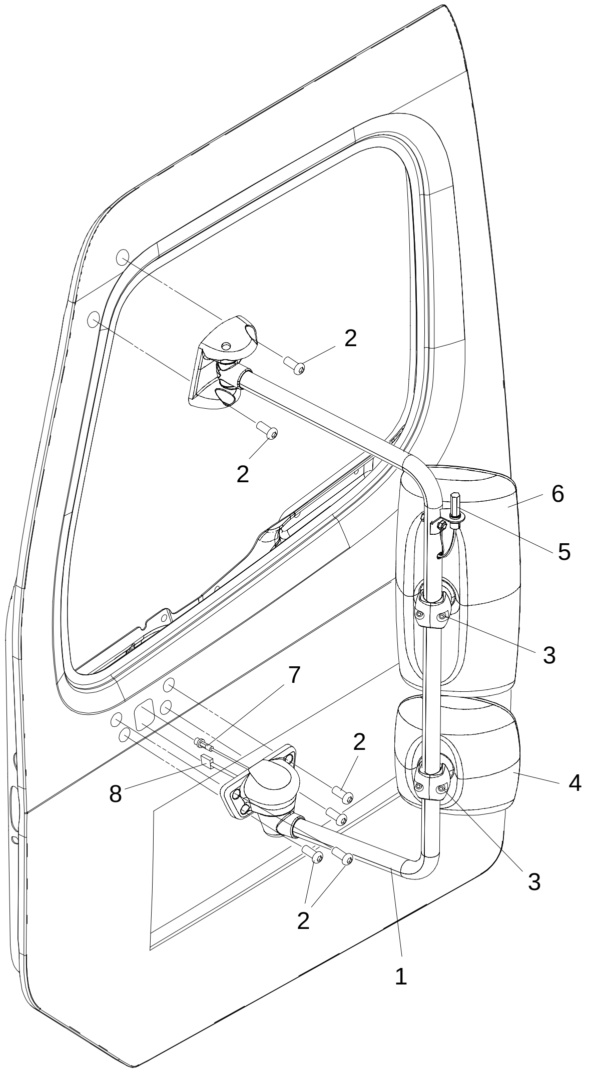
General Information

The Business Class M2 exterior mirror unit consists of a rectangular (flat) mirror mounted on a fold-away tubular support loop. An optional lower square (convex) mirror is mounted on the same support loop, below the main mirror. See **Fig. 1**.

Both mirrors are mounted in separate housings, and the housings are attached to the support loop, which is mounted to the door by brackets and Torx®-head screws.

Additional options include electrically powered and heated mirrors. In such cases, the wiring is hidden within the support loop and the mirror housings.

General Information



1. Fold-Away Tubular Support Loop
2. Torx-Head Screws, M8
3. Torx-Head Screws, Self-Tapping
4. Square, Convex Mirror Housing (optional)
5. CB Radio Antenna Lead (optional)
6. Rectangular, Flat Mirror Housing
7. CB Radio Antenna Cable (optional)
8. Electrical Wiring

Fig. 1, Exterior Mirror (manual, left side)

Exterior Mirror Removal and Installation

Mirror Assembly

Removal

1. Apply the parking brake and chock the tires.
2. Remove the two screws that attach the support loop upper bracket to the door; see **Fig. 1**.
3. While holding the support loop assembly, remove the four screws that attach the lower bracket to the door.
4. Disconnect any wiring or antenna cables, if present.

Installation

1. Connect any wiring and antenna cables, as applicable.
2. Holding the support loop in position, install the mounting screws finger-tight (two screws on the upper bracket, and four on the lower bracket). See **Fig. 1**.
3. Test the mirror function for movement and heating. If there are problems, check the wiring.
4. Tighten the mounting screws 10 lbf·ft (14 N·m) on both the upper and lower brackets.

Mirror Housing

NOTE: The procedure for removing and installing the convex and flat mirrors are identical.

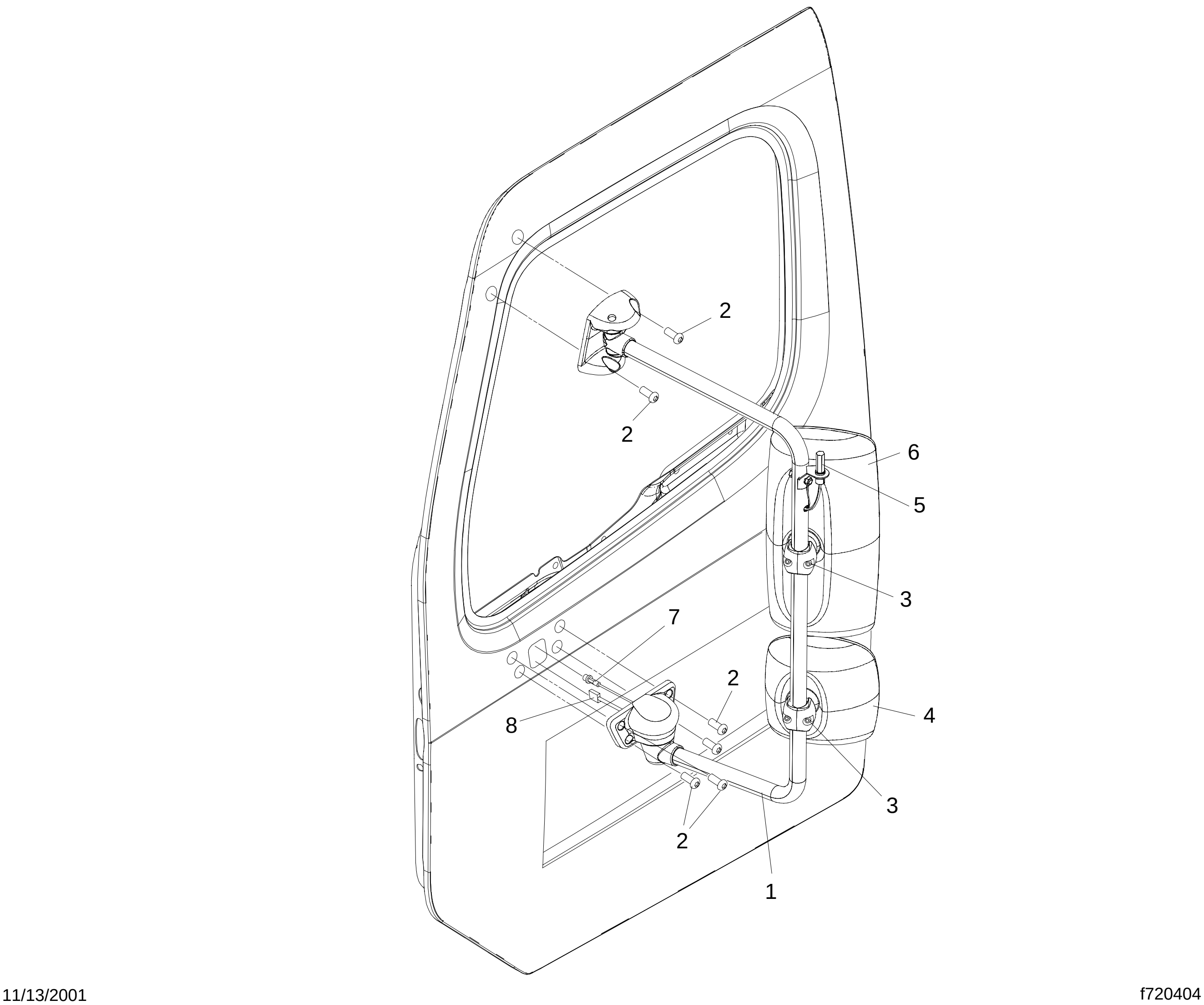
Removal

1. Apply the parking brake and chock the tires.
2. Mark the location of the mirror housing on the support loop; see **Fig. 1**.
3. If equipped with a heated/power mirror, remove the mirror bezel and glass, then disconnect the wiring.
4. Remove the two screws that attach the housing to the support loop. Disconnect any wiring, if present, and remove the housing assembly.

Installation

1. If equipped with a heated/powered mirror, connect the wiring to the mirror, then install the mirror glass and bezel into the mirror housing.
2. As previously marked, position the mirror housing onto the support loop. Install the self-tapping screws finger-tight; see **Fig. 1**.
3. Test the mirror function for movement and heating. If there are problems, check the wiring.
4. Tighten the self-tapping screws 96 lbf·in (1085 N·cm).

Exterior Mirror Removal and Installation



NOTE: LH shown.

1. Fold-Away Tubular Support Loop
2. Screws, M8
3. Screws, Self-Tapping
4. Square, Convex Mirror Housing
5. CB Radio Antenna Lead (optional)
6. Rectangular, Flat Mirror Housing
7. CB Radio Antenna Cable (optional)
8. Electrical Wiring

Fig. 1, Exterior Mirror Assembly

Specifications

Unless listed in **Table 1**, tighten all fasteners using the torque specifications found in **Section 00.04**.

Torque Specifications				
Fastener Description	**lbf·ft**	**N·m**	**lbf·in**	**N·cm**
Mirror Loop Assembly Mounting Screws, M8	10	14	—	—
Mirror Housing Mounting Screws	—	—	96	1085

Table 1, Torque Specifications

General Information

The aluminum cab is a semi-monocoque design, which means that the outer skin panels are load bearing as is the internal framework. This type of construction requires less framework than standard cab construction, and results in a very strong, yet lightweight cab. See **Fig. 1**.

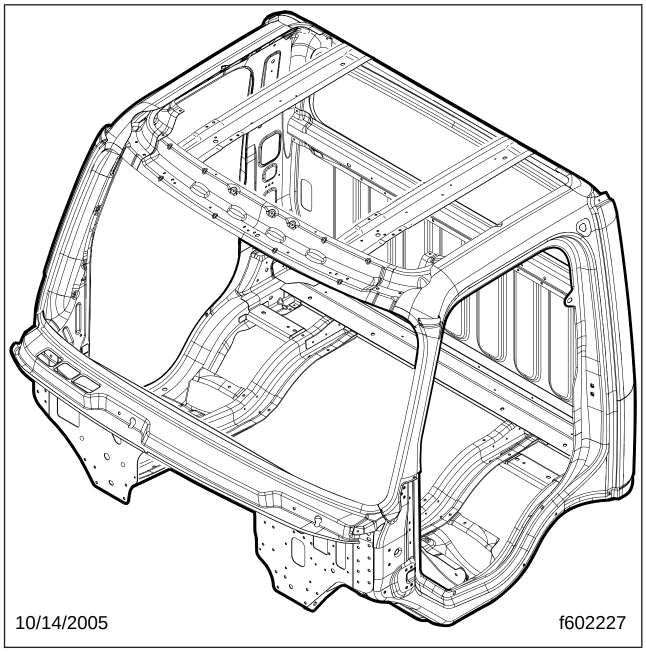


Fig. 1, Cab Structure (Day Cab Shown)

The three basic configurations of day cab, extended cab, and crew cab come in the following lengths:

- 106-inch flat-roof day cab
- 126-inch high-roof extended cab
- 132-inch high-roof extended cab
- 138-inch high-roof extended cab
- 148-inch high-roof crew cab
- 154-inch high-roof crew cab
- 160-inch high-roof crew cab

The major cab parts are the front-wall assembly, right and left door-frame (side-wall) assemblies, back-wall assembly, roof assembly, and the cab deck assembly. See **Fig. 2**.

The cab deck consists of a framework of longitudinal sills and transverse crossmembers, with a deck plate fastened to them. The cab deck is not available as an assembly; components must be ordered separately.

The door-frame assemblies consist of several panels that are riveted and glued together. In order to maintain structural integrity, the door-frame assemblies are available as complete units only.

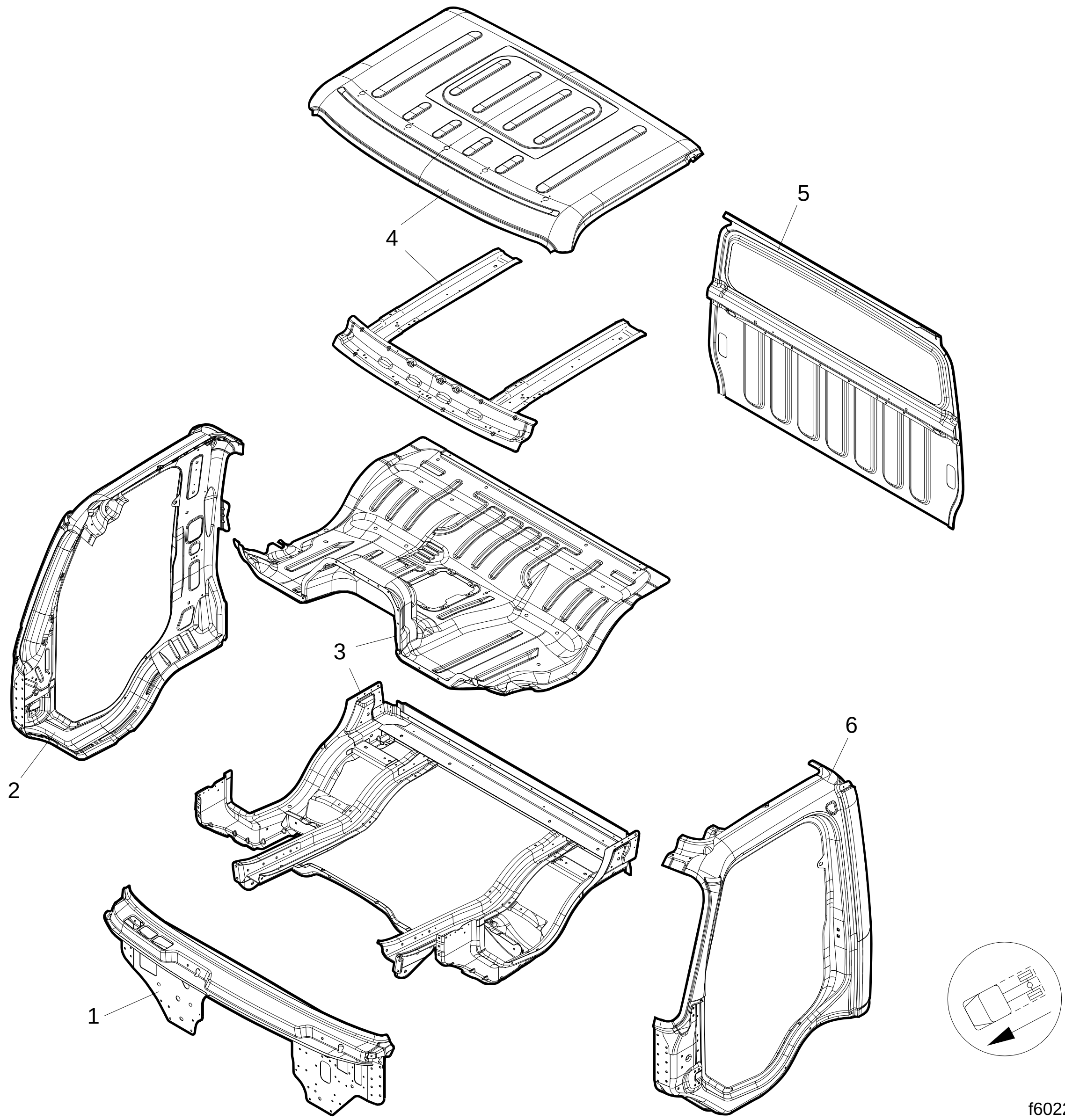
The cab back wall and cab roof components are available as individual pieces.

The cab front-wall assembly is a complete unit attached to the front of the door-frame assemblies, and must be replaced as an entire unit.

The cab parts are held together with a variety of fasteners, including Huck® bolts, blind rivets, and steel Henrob rivets. Structural foam or adhesive is used between the roof cap and roof bows to prevent flutter of the roof.

When any repairs are done to the cab, it is necessary to check the frame rails for correct alignment and squaring. The cab must be leveled and squared. If the cab is repaired without straightening the frame rails, undue stress could be put on the cab, which could weaken it. Also, it may be impossible then to square the cab.

General Information



1. Front-Wall Assembly
2. Right Door-Frame Assembly
3. Cab Deck Assembly
4. Cab Roof Assembly
5. Back-Wall Assembly
6. Left Door-Frame Assembly

Fig. 2, Major Cab Parts (Day Cab Shown)

Cab Water-Leak Detection

Use the following procedure to locate areas where water may intrude into the cab.

1. Park the vehicle, apply the parking brakes, and chock the front and rear tires.
2. Prepare a wash solution of at least one-quarter cup of soap to one gallon of water in a spray bottle.
3. Place tape over the cab exhausters.
4. Close all doors, windows, and vents.
5. With the HVAC system in "Fresh Air" mode, turn the fan blower motor on high.

NOTE: Perform the leak detection test with the HVAC system in the "Fresh Air" mode only. Do not set the system in the "Recirculation" mode.

6. Spray the cab with the wash solution and look for bubbles. See **Fig. 1**. Inspect all applicable areas listed below:
   - windshield perimeter
   - visor brackets (if so equipped)
   - air horns and marker lights (if so equipped)
   - roof deflector mounts (if so equipped)

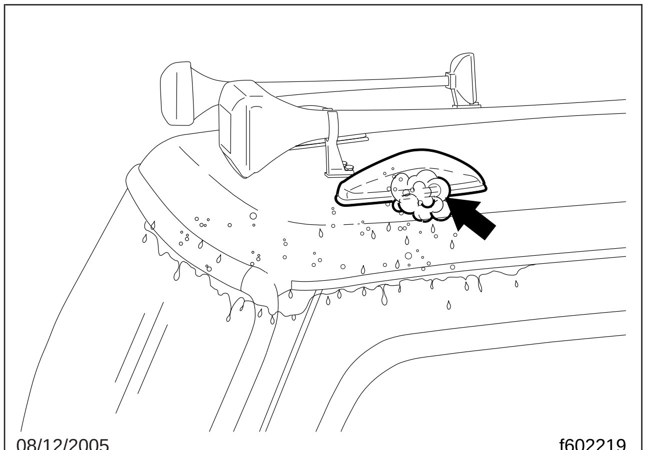


Fig. 1, Cab Water-Leak Detection with Wash Solution

7. Mark areas of suspected leaks.

NOTE: This method of leak detection may also identify areas that will not leak water, even though those areas produce bubbles. Bubbles around door seals and along the vehicle side walls will likely not cause water intrusion issues.

If small bubbles are found in an area that is not suspected to leak, a repair may not be necessary.

8. Rinse the wash solution off the vehicle with water.
9. Turn off the fan blower motor.
10. Remove the tape from the cab exhausters.
11. Remove the chocks from the tires.

Cab Water-Leak Repair

If a leak is found, the repair method will depend on the area and type of leak. It may be necessary to remove some components, though most leaks should be repairable by sealing the area of the leak with silicone sealant.

Repair leaks in the windshield using the approved method. See **Section 60.00, Subject 100**.

Upholstery Panels Replacement

NOTE: Interior components are varied and optional. The following generalized information is intended for broad use and should not be considered as a guide for a specific vehicle.

Headliner Replacement

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Drain the air tanks.
3. Disconnect the batteries at the negative terminals.
4. If applicable, remove all items from the overhead storage bins.
5. If so equipped, remove the front overhead storage bins by prying up around the edges of each bin.
6. Remove the sun visors.
   - 6.1 Remove the fasteners from the sun visor outboard brackets.
   - 6.2 Remove the sun visors.
7. Remove the inboard bracket for the sun visors.
8. Remove the dome light by prying it out from the upholstery panel, then disconnecting the wiring.
9. If so equipped, remove the center seat belt anchor.
10. Remove the small-head, Christmas-tree type fasteners attaching the headliner to the roof bows. See **Fig. 1**.
11. Remove the A-pillar covers and the passenger-side grab handle.
    - 11.1 Remove the Torx®-head screws holding the grab handle in place.
    - 11.2 Remove the Torx-head screws holding the A-pillar covers in place.
    - 11.3 Remove the driver's side A-pillar cover, then the passenger-side cover along with the grab handle.
12. If so equipped, disconnect the air horn lanyard from its anchor point on the roof structure, and pull it up and through the headliner.
13. Remove the remaining Christmas-tree type fasteners attaching the headliner to the rear wall upholstery panel.
14. Remove the headliner from the cab.

Installation

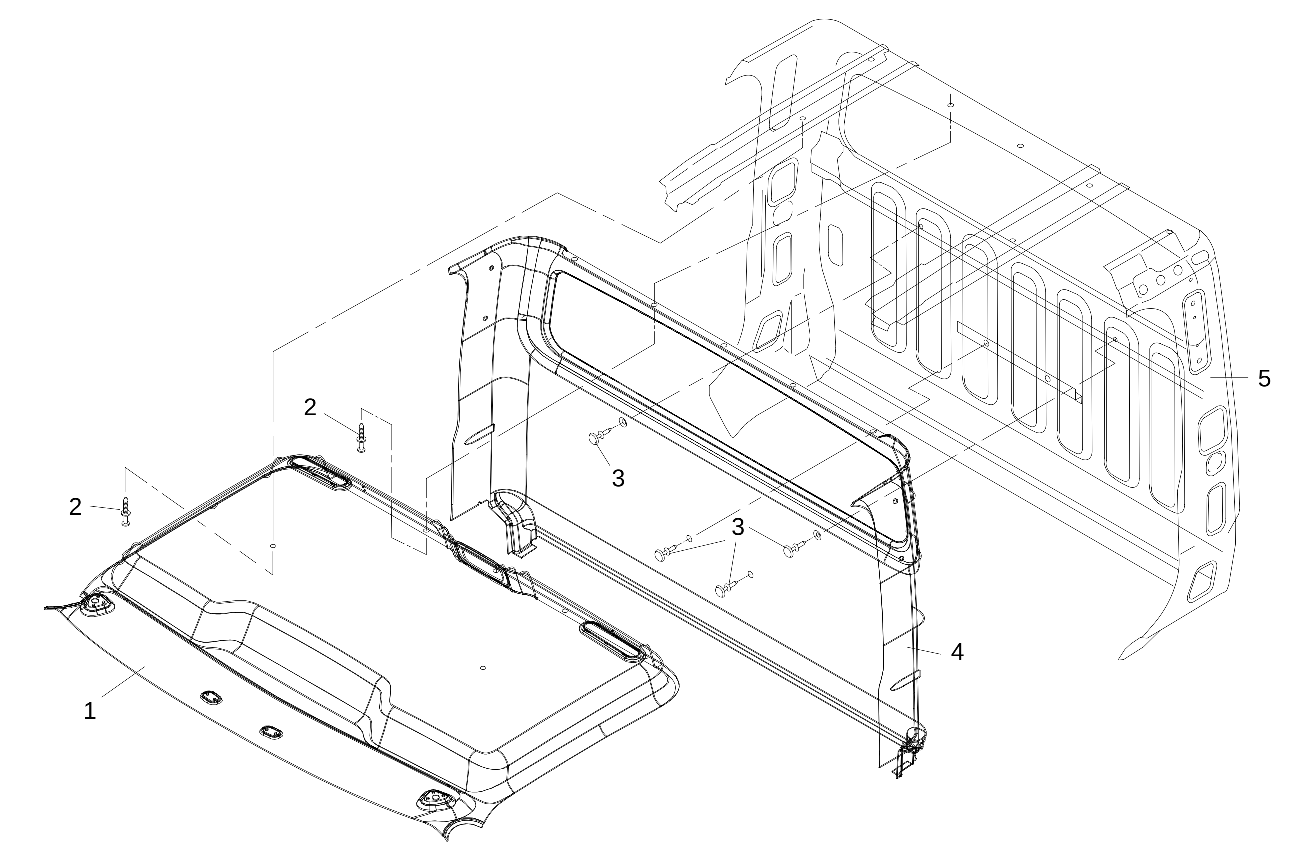
1. Put the headliner into the cab, using a helper to hold it in place.
2. Using new Christmas-tree type fasteners, attach the rear of the headliner to the rear wall upholstery panel and the cab structure.
3. Install the sun visors.
   - 3.1 Install the outboard brackets.
   - 3.2 Install the center bracket.
   - 3.3 Install the sun visors.
4. If so equipped, put the air horn lanyard through the opening in the headliner, then attach the lanyard to its anchor point on the cab roof structure.
5. If applicable, install the right- and left-side storage bins and the center bin.
6. Install the right- and left-side A-pillar covers.
7. Install the passenger-side grab handle.
8. Using new Christmas-tree type fasteners, attach the headliner to the roof bows.
9. Connect the wiring to the dome light, then install it into the headliner.
10. If so equipped, install the center seat belt anchor.
11. Connect the batteries.
12. Remove the chocks from the tires.

Rear Wall Upholstery Panel Replacement

Removal

NOTE: See **Fig. 1** for this procedure.

Upholstery Panels Replacement



1. Headliner
2. Christmas-Tree Type Fastener, small head (7 qty.)
3. Christmas-Tree Type Fastener, large head (4 qty.)
4. Rear Wall Upholstery Panel
5. Cab Structure

Fig. 1, Headliner and Rear Wall Upholstery Panels

1. If not already done, park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. If not already done, drain the air tanks.
3. If not already done, disconnect the batteries at the negative terminals.
4. Remove the seat(s). For instructions on removing a bench seat, see **Group 91** in this manual.
5. Remove the interior grab handles.
6. Remove the tread plates from the doorways.
7. Remove the upper anchors for the seat belts.
   7.1 On one side of the vehicle, pry off the plastic cover.
   7.2 Remove the hexnut, rubber washer, and bushing
   7.3 Remove the seat belt anchor.
   7.4 Repeat the procedure on the other side of the vehicle.
8. If so equipped, remove the driver’s and passenger’s seat-belt height adjusters.
9. Remove the lower outboard seat belt anchors.
10. Remove the seals from the rear edge of each door opening.
11. Remove the headliner. For instructions, see "Headliner Replacement" in this subject.

12. Remove the four Christmas-tree type fasteners holding the upholstery panel to the cab structure.
13. Pull up the bottom edge of the rear wall upholstery panel from behind the lip at the rear of the floor mat.
14. Remove the rear wall upholstery panel from the cab.

Installation

1. Put the rear wall upholstery panel in place in the cab.
2. Push the bottom rear edge of the panel down behind the lip on the floor mat.
3. Using new Christmas-tree type fasteners, attach the upholstery panel to the cab structure.
4. Install the headliner. For instructions, see "Headliner Replacement."
5. Install the door seals.
6. Connect the wiring and install the dome light.
7. Install the tread plates in the doorways.
8. Install the interior grab handles.
9. Install the upper center seat belt anchors.
10. If applicable, install the driver’s and passenger’s seat-belt height adjusters.
11. Remove the chocks from the tires.

Floor Mat Replacement

Removal

1. If not already done, park the vehicle on a level surface, shut down the engine, set the parking brakes, and chock the tires.
2. If not already done, disconnect the batteries at the negative terminals.
3. Remove the seat(s) and seat belts. For instructions on removing a bench seat, see **Group 91** in this manual.
4. Remove the kick panels forward of the doors.
5. Remove the tread plates from the doorways.
6. If equipped with a manual transmission, remove the shift lever boot, rubber mat, and metal cover plate.

   If equipped with an automatic transmission, remove the rubber mat and metal transmission cover plate. See **Fig. 2**.

NOTE: The transmission ECU is attached to the underside of the metal transmission cover plate. Disconnect the wiring from the ECU before removing the cover plate.

7. Push the bottom of the rear wall upholstery panel in, and lift the rear edge of the floor mat off the top of the metal lip at the rear of the cab deck. See **Fig. 2**. There is a plastic U-channel between the mat and the metal lip.

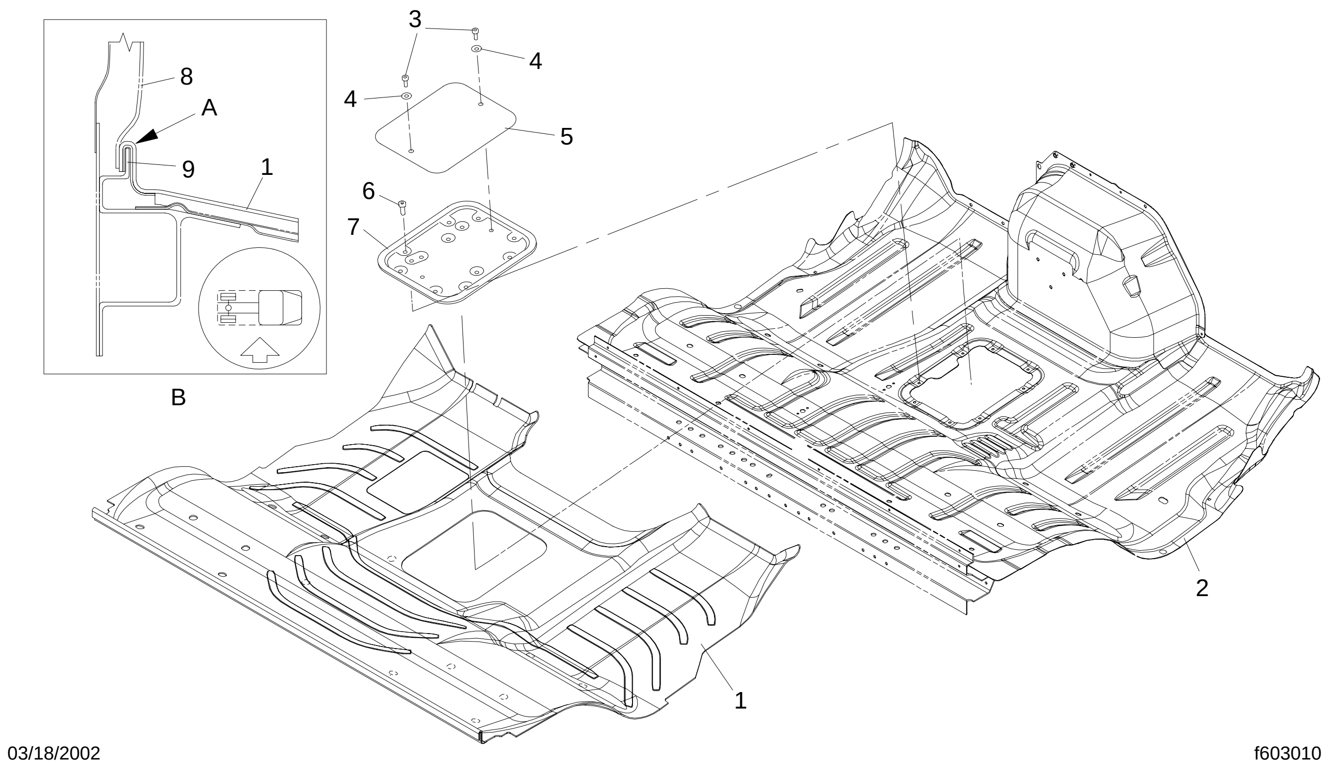
   Work your way across the width of the cab to remove both the U-channel and the floor mat.
8. Remove the floor mat and the attached insulation from the cab.

Installation

1. Put the floor mat and the attached insulation in place in the cab, then install it and the U-channel over the metal lip along the back wall.
2. If equipped with an automatic transmission, connect the wiring to the transmission ECU, then install the transmission cover plate and rubber mat. Tighten the fasteners firmly.

   If equipped with a standard transmission, install the metal cover plate, the rubber mat, and then the shift lever boot.
3. Install the kick panels forward of the doors.
4. Install the treadplates in the doorways.
5. Install the seat(s) and the seat belts. For instructions on installing a bench seat, see **Group 91** in this manual.
6. Connect the batteries.
7. Remove the chocks from the tires.

Upholstery Panels Replacement



A. Floor fits over this lip.
1. Floor Mat
2. Cab Deck Structure
3. Torx-head Screw, 1/4–20
4. Washer
5. Rubber Mat

B. Cross-Sectional View (rear of cab)
6. Torx-head Screw, M6 (8 qty.)
7. Cover Plate
8. Rear Wall Upholstery Panel
9. Steel Lip (plastic U-channel not shown)

Fig. 2, Floor Mat Installation (equipped with automatic transmission)

Dash Panels Removal and Installation

Removal

See Fig. 1 for the removal and installation procedures.

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Disconnect the batteries at the negative terminal.
3. Remove the HVAC lower cover by removing the three Torx-head screws holding it in place.
4. Remove the HVAC control head assembly by removing the Torx-head screws holding it in place.
5. Remove the trim plate panel.
6. Remove the right-hand dash panel assembly.
   6.1 Remove the Torx-head screws holding the panel in place.
   6.2 Disconnect the wiring for the dome light switch.

   NOTE: The dome light switch is on the side of the panel assembly and is activated by the door.

   6.3 Pry up the upper edge of the dash panel to release the clips from the slots.
   6.4 Remove the right-hand dash panel assembly.
7. Remove the top cover by removing the Torx-head screws holding it in place.
8. Remove the cup holder assembly.
   8.1 Remove the screws holding the assembly in place.
   8.2 Lift the assembly out and disconnect the wiring from the back of the HVAC controls.
   8.3 Remove the cup holder assembly.

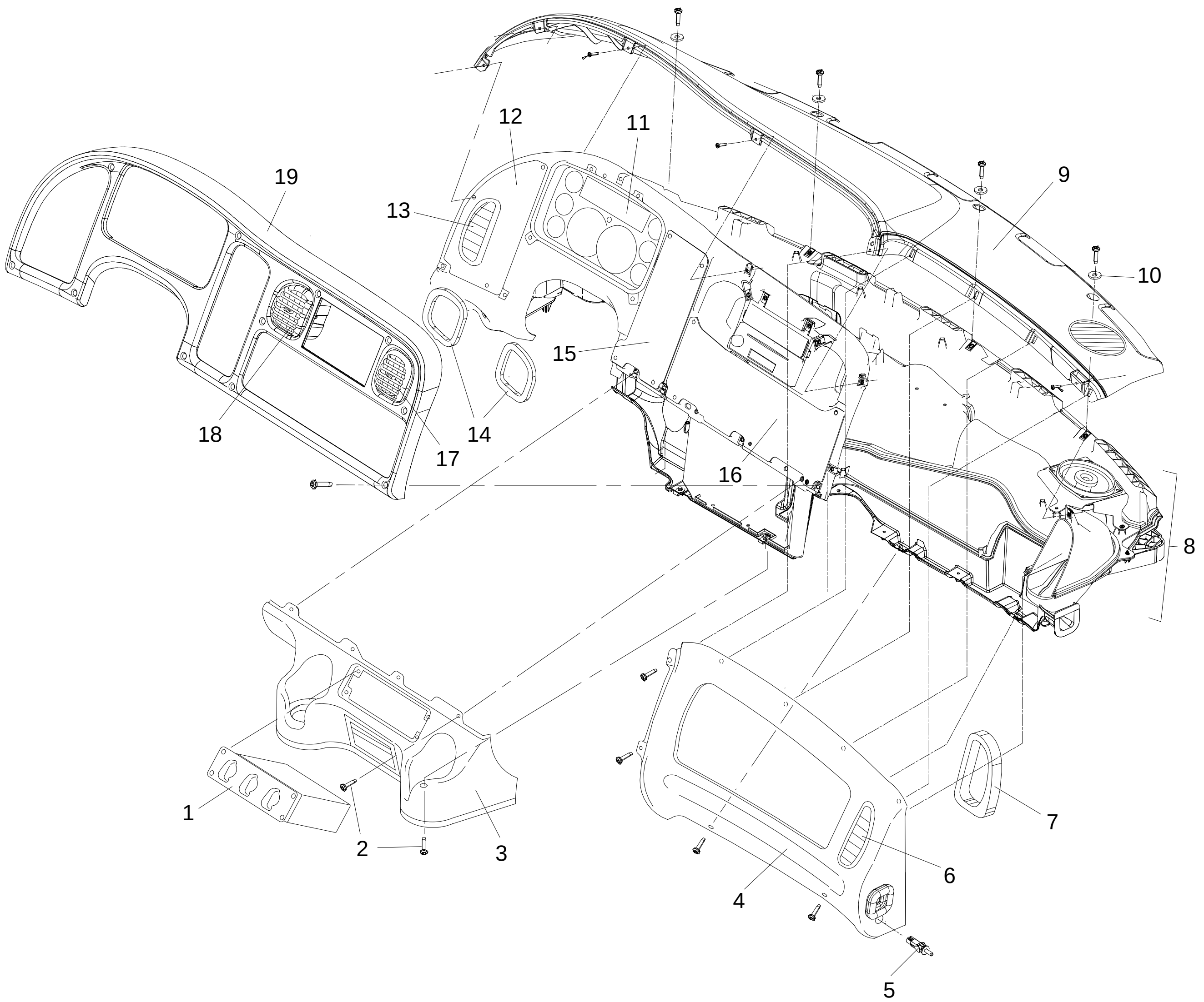
Installation

1. Install the cup holder assembly.
   1.1 Put the cup holder assembly in place and connect the wiring to the back of the HVAC controls.
   1.2 Install the Torx-head screws.
2. Install the top cover. Tighten the Torx-head screws firmly.
3. Install the right-hand dash panel assembly.
   3.1 Put the panel in place.
   3.2 Connect the wiring for the dome light switch on the side of the panel assembly.
   3.3 At the upper edge of the right-hand dash panel, push the clips into their slots.
   3.4 Install the Torx-head screws. Tighten firmly.

NOTE: The right-hand dash panel must be installed before you can install the trim plate panel.

4. Install the trim plate panel. Tighten the Torx-head screws firmly.
5. Install the lower HVAC panel. Tighten the Torx-head screws firmly.

Dash Panels Removal and Installation



NOTE: HVAC lower cover not shown.

1. HVAC Control Head Assembly
2. Torx®-Head Screw
3. Cup Holder Assembly
4. Right-Hand Dash Panel Assembly
5. Dome Light Switch
6. Right-Hand Window Outlet Louver
7. Duct Seal
8. Tray Assembly with HVAC Ducting
9. Top Cover
10. Washer
11. Instrument Cluster, ICU 3
12. Gauge Panel
13. Left-Hand Window Outlet Louver
14. Duct Seal
15. Gauge Panel
16. Gauge Panel
17. Right-Hand Dash Outlet Louver
18. Left-Hand Dash Outlet Louver
19. Trim Plate Panel

Fig. 1, Dash Panels

Tray Assembly Removal and Installation

Removal

The tray assembly functions as a dash support, wiring harness carrier, and as the ducting assembly for the heater/air conditioning system. It is attached to the cab frontwall.

1. Park the vehicle on a level surface, shut off the engine, set the parking brakes, and chock the tires.
2. Remove all the dash panels. See **Subject 100** for instructions.
3. As applicable, remove or disconnect the dash gauges, instruments, and controls.
4. Remove the upper dash panel assembly framework.

   4.1 Disconnect the ignition wiring.

   4.2 Disconnect and remove the dome light switch.
5. Tilt the hood.
6. Partially drain the radiator to below the level of the surge tank.
7. Remove the surge tank. See **Group 20** for instructions.
8. Separate the bulkhead electrical connector in the engine compartment by loosening the center-bolt. Push the cab end of the wiring harness through the frontwall and into the cab.
9. From inside the cab, mark, then disconnect all the wiring and air lines on the dash. Cut and remove any tie-straps holding the wiring or air lines in place.
10. Remove the left-hand kick panel and the tread plate, then mark and disconnect the ground wires to the left of, and below the steering column.
11. Remove the upper and lower steering column covers.
12. Disconnect the steering column by removing the four fasteners holding it to the mounting bracket. Do not disconnect the U-joint. Let the steering wheel and the column rest on the driver's seat.
13. Remove the two fasteners holding the tray assembly to the steering column mounting bracket.
14. Remove the one fastener attaching the tray assembly to the top of the HVAC unit.
15. Remove the Christmas tree-type fasteners holding the tray assembly to the wiring harness bracket.
16. Remove the two fasteners holding the tray assembly to the center bracket where the cup holder assembly was attached.
17. From the engine compartment, remove the four fasteners attaching the tray assembly to the frontwall.

    17.1 Remove the fasteners attaching the air cleaner to the mounting bracket and the rain tray. Remove the air cleaner.

    17.2 Remove the remaining fasteners attaching the tray assembly to the frontwall.
18. Remove the tray assembly from the cab.

Installation

1. Position the tray assembly in place in the cab, making sure the holes in the tray assembly line up with those in the frontwall.
2. Install the four fasteners attaching the assembly to the frontwall. Don't tighten them fully until they are all installed, then tighten them firmly.
3. Install the fasteners inside the cab (do not tighten fully until all are installed):
   - two at the steering column bracket
   - two at the edge of where the cup holder assembly was removed
   - one on top of the HVAC unit.
4. Install the bulkhead connector harness in the frontwall opening.

   As previously marked, connect the main harness plugs.
5. Attach the steering column to its bracket. Tighten the fasteners 25 lbf·ft (34 N·m).
6. Connect the ground wires to the stud below and to the left of the steering column.
7. Secure all the wiring with tie-straps.
8. Install the upper dash panel frame assembly.

   8.1 Connect the ignition wiring.

Tray Assembly Removal and Installation

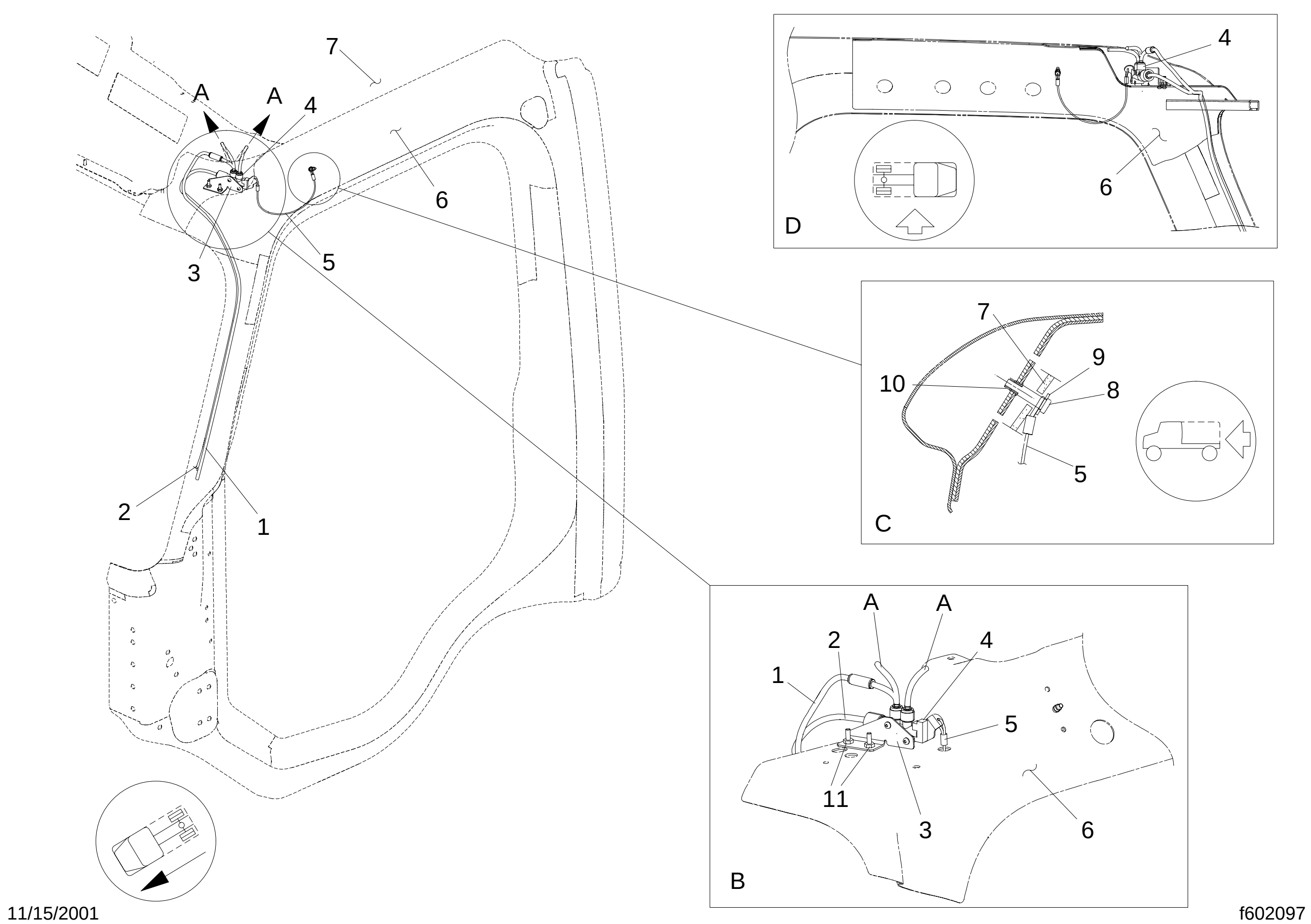
8.2 Install and connect the switch for the dome light.

9. As applicable, put all air lines and wiring through the openings in the dash panel frame assembly.
10. Install and connect the dash gauges, instruments, and controls.
11. Install the dash panels. See **Subject 100** for instructions.
12. Install the left-hand kick panel and tread plate.
13. Install the upper and lower steering column covers.
14. Install the cup holder assembly.
15. From outside the vehicle, install the air cleaner. See **Section 09.01**, Subject 110, for instructions.
16. Install the surge tank. See **Group 20** for instructions.
17. Fill the radiator through the surge tank.
18. Lower the hood.
19. Connect the batteries.
20. Remove the chocks from the tires.

Air Horn Valve Removal and Installation

Replacement

1. Apply the parking brake and chock the tires.
2. Drain the air supply, and disconnect the batteries.
3. Remove the screw and washer that hold the end of the control cable (lanyard) in place. See **Fig. 1**.
4. Remove the headliner.
5. Mark the air lines for later reference, then disconnect them from the air horn valve.
6. Remove the fasteners that attach the air horn valve to the mounting bracket. Remove the valve.
7. If necessary, disconnect the control cable (lanyard) from the air horn valve.
8. If applicable, connect the control cable (lanyard) to the new air horn valve.



A. To Air Horns on Roof
B. Top View
C. Control Cable (Lanyard) Attachment
D. Side View

1. Air Supply Line
2. To Under-Deck Air Horn (optional)
3. Mounting Bracket
4. Air Horn Valve
5. Control Cable (lanyard)
6. Side Header
7. Headliner
8. Screw
9. Washer
10. Threaded Hole
11. Bracket Fasteners

Fig. 1, Air Horn Valve Installation

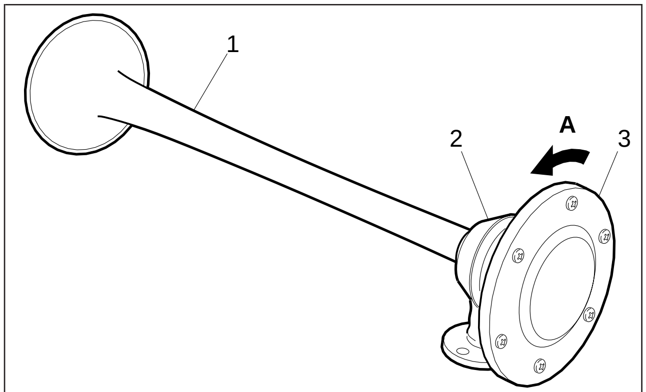
Air Horn Valve Removal and Installation

9. Attach the air horn valve to the mounting bracket.
10. As previously marked, connect the air lines to the air horn valve.
11. Install the headliner.
12. Using the screw and washer previously removed, attach the end of the control cable (lanyard) to the side header. Make sure the screw threads into the hole in the steel panel behind the headliner.
13. Connect the batteries.
14. Start the engine, and refill the air supply.
15. Test the horn.

Air Horn Adjustment, Grover Stuttertone

Adjustment

1. Apply the parking brake and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa), then shut off the engine, apply the parking brakes, and chock the tires.
3. Rotate the sound unit counterclockwise (as viewed from the back of the horn) to loosen the horn; see **Fig. 1**.



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A. Rotate the sound unit counterclockwise to loosen the horn.

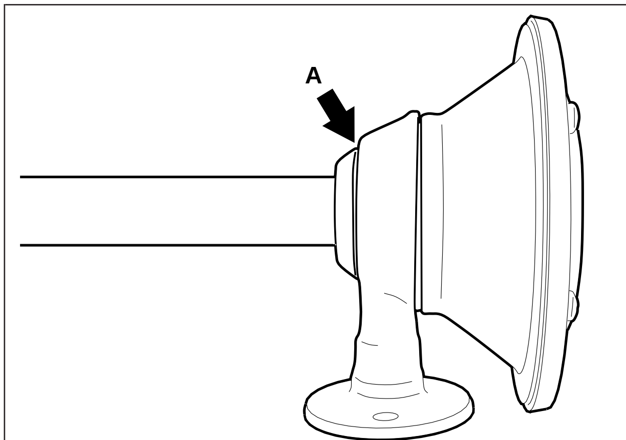
1. Bell
2. Mounting Ring
3. Sound Unit

Fig. 1, Loosening the Horn

4. Rotate the bell/bushing assembly until there is approximately one thread visible at the top front of the mounting ring. The bell/bushing assembly may need to be rotated in either direction. See **Fig. 2**.
5. Test the horn.

   If the horn sounds sounds "breathy" with a lot of air sound, the back of the bell is too far from the diaphragm. Loosen the sound unit, then rotate the bell 1/8 turn clockwise to make more of the bell stick out the back of the mounting ring. Tighten the sound unit and test the horn.

   If the horn sounds "pinched" or "squeaky," the bell is too close to the diaphragm. Loosen the sound unit, then rotate the bell 1/8 turn counter-clockwise to move it away from the diaphragm. Tighten the sound unit and test the horn.



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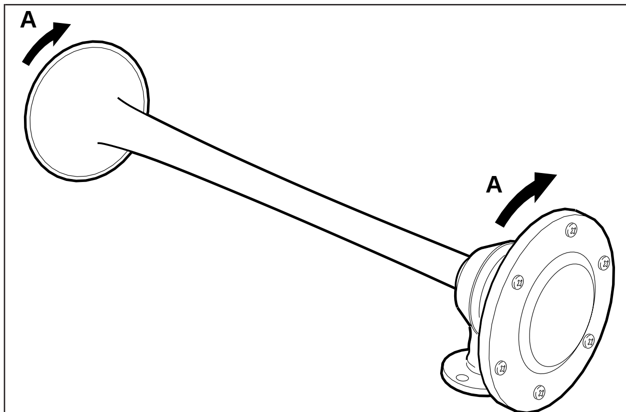
A. Rotate the bell/bushing assembly until there is approximately one thread visible at the top front of the mounting ring.

Fig. 2, Adjusting the Horn

NOTE: It may be necessary to loosen and adjust the horn several times to get desired results.

6. After the horn is adjusted to your satisfaction, tighten the horn by rotating the bell and the sound unit simultaneously in a clockwise direction (as viewed from the back of the horn); see **Fig. 3**.



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A. Rotate the bell and sound unit simultaneously in a clockwise direction, while the mounting ring is stationary.

Fig. 3, Tightening the Horn

Air Horn Adjustment, Grover Stuttertone

IMPORTANT: To preserve the desired gap between the bell and the diaphragm, the bell and the sound unit must be rotated together when tightening the air horn.

Safety Precautions

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake, and chock the front and rear tires.
2. Tilt the hood.
3. Disconnect the batteries. Attach the welding ground strap as close to the work being done as safely possible.

CAUTION

Before performing any electric welding on a vehicle, disconnect the battery power and ground cable, and disconnect all connectors from any electronic control units or similar devices installed on the vehicle. Electric currents produced during electric welding can damage various electrical components on the vehicle, which could result in malfunction of the components.

4. Disconnect all electronic control units and similar devices.

General Information

The cab rear air-suspension system absorbs road shocks better than a solid-mount system, and thus provides a smoother ride for cab occupants and cab-mounted equipment.

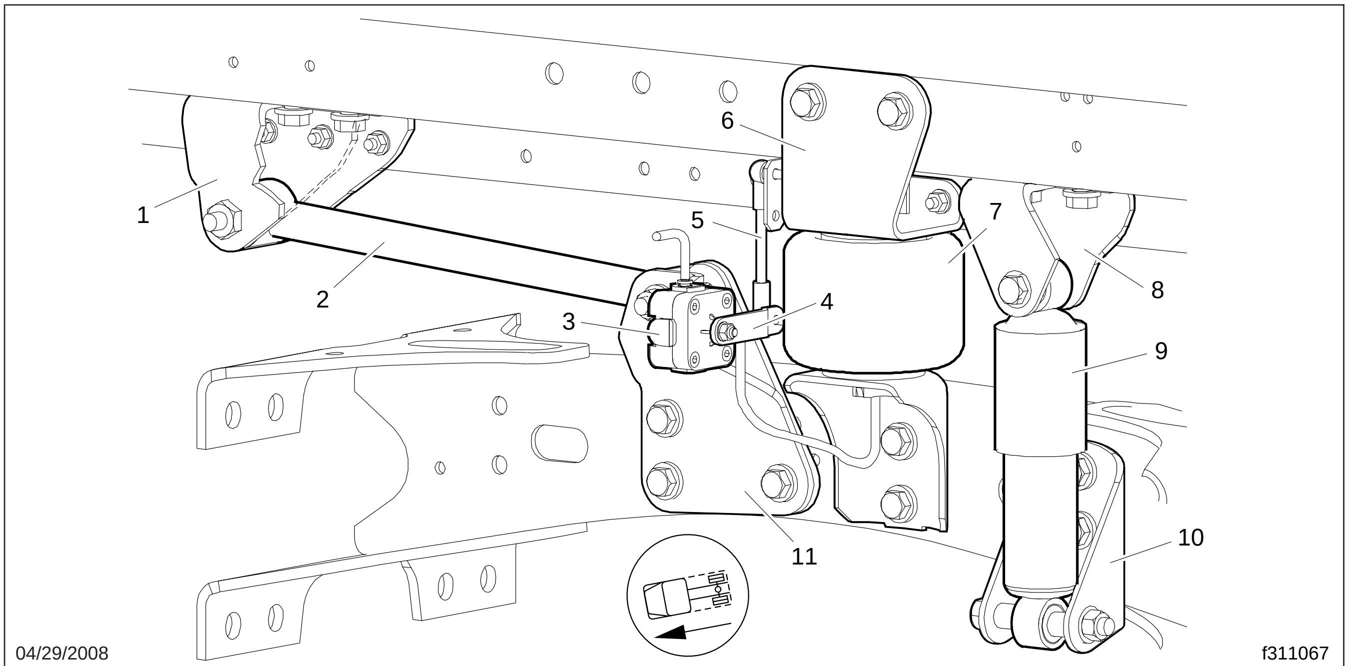
Several different cab air suspension installations are used on the M2, depending on the size of the cab. All installations consist of an air spring, a height-control valve, a lateral control rod, a shock absorber, and a vertical linkage; see **Fig. 1**.

Height-Control Valve

NOTE: If a leak occurs in the cab air-suspension system, a pressure protection valve (located at the secondary air tank, which supplies the air to the height-control valve) will maintain a minimum pressure of about 65 psi (450 kPa) in the vehicle secondary air system.

All of the air in the cab air-suspension system is admitted through or exhausted from the height-control valve. It mounts on the control rod bracket, which is attached to the frame rail crossmember. The height-control valve has a horizontal control lever, the outboard end of which is connected to the vertical linkage. The upper end of the vertical linkage is attached to a bracket on the cab underbody.

When the load on the cab increases, the dimension between the cab and the crossmember decreases, causing the vertical linkage to push downward on the end of the control lever. This turns the height-control



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1. Control Rod Cab Bracket
2. Lateral Control Rod
3. Height-Control Valve
4. Horizontal Control Lever
5. Vertical Linkage
6. Air Spring Upper Bracket
7. Air Spring
8. Shock Absorber Upper Bracket
9. Shock Absorber
10. Shock Absorber Lower Bracket
11. Control Rod Chassis Bracket

Fig. 1, Cab Rear Air Suspension Installation

Air Springs

The top of the air spring is mounted to a bracket on the cab underbody, and the bottom is mounted to a bracket on a frame rail crossmember. Together with the height-control valve, the air spring compensates for changes in cab load by maintaining the correct cab height at the rear of the cab.

valve shaft, which activates the height-control valve. Air flows through the valve and into the air springs until the pressure in the springs raises the cab to the correct height. At this height, the control lever and the control shaft are returned to their neutral positions, closing the intake air supply.

When the load on the cab decreases, the rear of the cab rises, causing the vertical linkage to pull up on the end of the horizontal linkage. Turning the height-control valve control shaft in this direction activates an exhaust port in the valve. This allows air pressure in the air springs to decrease until the cab is lowered to the correct height. Again, the control lever and control shaft are returned to their neutral positions, and air flow is stopped.

When the vehicle is in motion, small and abrupt movements of the cab will occur, resulting in small or abrupt movements of the control lever. These movements of the control lever do not activate the height-control valve because of a built-in free-travel range: a gap between the height-control valve control shaft and both of the valve cores (intake and exhaust).

Changes in load that result in larger movements of the control lever will activate the height-control valve. Such changes in load occur when occupants or heavy items are added to or removed from the cab. Also, when the vehicle is moving forward at high speed or in a high headwind, a major change in load occurs from the downforce applied to an optional air shield or air fairing. When these changes in load occur, the cab air-suspension system will adjust the height at the rear of the cab.

Lateral Control Rod

The lateral control rod limits the side-to-side motion of the rear of the cab. The inboard end of the control rod is mounted on the crossmember bracket.

Shock Absorbers

The shock absorbers control the air spring and cab suspension movement, and reduce the amount of oscillation in the cab suspension system.

Fitting Leakage Repair

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.

WARNING

Do not disconnect any air lines in the cab suspension system without first blocking the cab securely. If the cab isn't securely blocked, disconnecting an air line could cause the cab to fall abruptly, possibly resulting in serious injury.

2. Place blocks between the frame and the bottom of the cab to keep the cab in position when the air spring is deflated.
3. Drain all air from the air tanks.

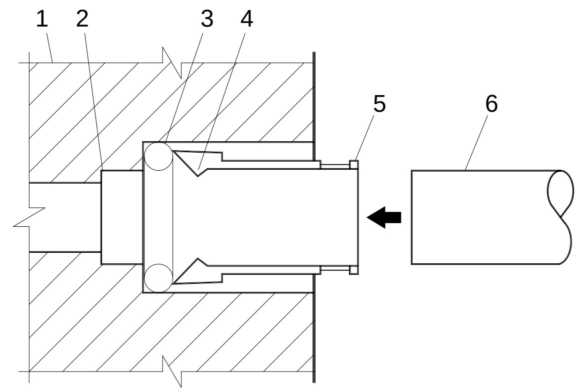
WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

4. Remove the nut and washer that attach the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the control lever.
5. Rotate and hold the control lever up until all air is exhausted from the air spring.
6. Push the collar of the quick-connect fitting into the fitting body with a 1/4-inch (7-mm) open-end wrench; see **Fig. 1**. With the collar pushed into the fitting, pull the tubing from the fitting. The fitting should easily release the tubing.

NOTE: Find the mark on the tubing, about 1/4 inch (7 mm) from the end, where the collar clamped the tubing; see **Fig. 2**. If this mark is less than 1/4 inch (7 mm) from the end of the tubing, the fitting was not assembled correctly and could have caused an air leak.

7. Inspect the end of the tubing for paint or debris that could prevent full insertion of the tubing into the fitting. Remove any dirt from the tubing and fitting.
8. Check that the end of the tubing is cut square. If the tubing is cut at an angle, the fitting will not seal correctly; cut the end of the tubing at an angle of 90 degrees.
9. Insert the squared-end of the tubing into the fitting. An initial resistance is felt when the tubing touches the clamping ring section of the collar. Push the tubing past this resistance another 1/4 inch (7 mm) or so until the tubing is fully against the shoulder.



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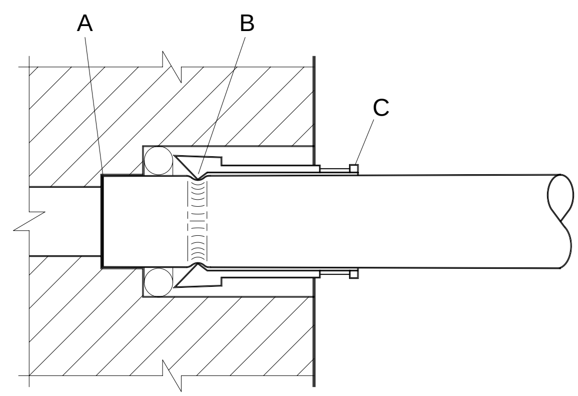
1. Fitting Body
2. Shoulder
3. Release Ring
4. Clamping Ring
5. Collar
6. Nylon Tube

Fig. 1, Parts of the Quick-Connect Fitting



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A. Square end of the tube against the shoulder.
B. The collar clamps the tube here.
C. Push the collar to release the tube.

Fig. 2, Correctly Installed Quick-Connect Fitting

Quick-Connect Fittings

10. Tug on the air tubing to ensure the tubing is clamped in the collar.
11. Align the vertical linkage with the control lever, and install the washer and nut.
12. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa). Check for air leaks.
13. Remove the blocks that were installed to support the cab.
14. Remove the chocks.

Height-Control Valve Checking

It is normal to hear air leaking from the height-control valve for as much as five minutes after getting out of the vehicle. This air leakage, due to a decreased load on the cab suspension, is just the height-control valve exhausting air from the air spring to reach the neutral position.

The height-control valves used on the M2 are Barksdale valves. Two methods are available to check the operation of the Barksdale height-control valves. A leak in the valve may be discovered without using a test kit, but a test kit is necessary to determine if the valve has an unacceptable rate of leakage.

Some Barksdale height-control valves have been returned for warranty because the four bolts in the valve housing were overtightened, often, enough to crack the valve housing. These bolts should not be loose, and should not normally require tightening, as there are no serviceable parts in the valve.

IMPORTANT: To prevent voiding the warranty on Barksdale height-control valves, note the following:

- Do not overtighten the bolts in the Barksdale height-control valve housing if you detect leaks in the housing. The bolts should not be loose, and should not require tightening. Only if necessary, tighten the valve housing bolts 45 lbf·in (500 N·cm). Any damage to the valve housing will void the warranty.
- If it is necessary to remove a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, crushing the valve body and damaging the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.
- Do not attempt to disassemble the Barksdale valve body or the control lever. There are no serviceable parts in the valve, and any disassembly will void the warranty.

Checking the Height-Control Valve Without Using a Test Kit

WARNING

Keep your hands and all objects away from the area under and around the cab when removing the pressure from the air system. Parts will move as the air is released and can cause personal injury or damage to any objects that are between the moving parts.

1. With the vehicle parked on a level surface, run the engine to build vehicle air pressure to at least 100 psi (690 kPa), then shut off the engine, apply the parking brakes, and chock the tires.
2. After shutting off the engine, wait 5 to 10 minutes for the air suspension system to equalize.

NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal, and does not indicate a defective valve.

3. Disconnect the vertical linkage from the horizontal control lever.
4. Pull the control lever up about 45 degrees for 6 to 8 seconds. If air passes through the valve, that section of the valve is okay.
5. Return the control lever to the neutral position.
6. Push the control lever down about 45 degrees for 6 to 8 seconds. If the air spring inflates, that section of the valve is okay.
7. Return the control lever to the neutral position. If the air stops again in the neutral position, the valve is working correctly.
8. If the valve works as stated in all of the above steps, no further checking is needed. Connect the vertical linkage to the control lever, then tighten the linkage nut.

NOTE: If a leak is detected, go to "Checking the Height-Control Valve Using a Test Kit." Barksdale valves have an acceptable leakage rate of 3 cubic inches (50 cc) per minute. You can determine if a leak is acceptable only by using the Barksdale test kit.

9. Remove the chocks.

Checking the Height-Control Valve Using a Test Kit

WARNING

Keep your hands and all objects away from the area under and around the cab when removing the pressure from the air system. Parts will move as the air is released and can cause personal injury or damage to any objects that are between the moving parts.

NOTE: The Barksdale field test kit is designed to be used with the height-control valve installed on the vehicle.

NOTE: Refer to **Specifications 400** for information on ordering this Barksdale height-control valve test kit.

1. If not already done, park the vehicle on a level surface, apply the parking brakes, and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa).
3. Shut off the engine and wait 5 to 10 minutes for the air suspension system to equalize.

NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal, and does not indicate a defective valve.

4. Check the rubber exhaust flapper at the back of the valve housing for leaks. Use a soapy solution.
5. Disconnect the vertical linkage from the control lever.
6. Rotate and hold the control lever up at about 45 degrees to exhaust air from the air springs.
7. Disconnect the air lines from the air spring ports on the height-control valve. Leave the elbow fittings (if equipped) in place. Install a Parker plug into each air spring port (or elbow fitting); see **Fig. 1**.
8. If a flapper is present on the exhaust port of the height-control valve, remove it using needlenose pliers.
9. Clean the surface around the exhaust port, then install the test fitting into the exhaust port. The centering pin on the fitting must align with the slot on the exhaust port. Rotate the test fitting 45 degrees clockwise to lock it in place; see **Fig. 1**.
10. Connect one end of the air hose from the kit to the test connector on the exhaust port, and the other end to the test gauge.
11. Check the height-control valve in the fill mode, as follows.

    11.1 Rotate the valve control lever down 45 degrees from the horizontal to the fill position.

    11.2 Press the reset button on the test gauge.

    11.3 Observe the test gauge for 30 seconds. Refer to **Fig. 2** for the maximum allowable exhaust pressure change versus inlet pressure.

    The valve is not working correctly if the gauge pressure reading exceeds the maximum allowable within 30 seconds.

    If the gauge reads less than the maximum allowable pressure change in 30 seconds, the valve is okay.

NOTE: The test gauge will register the exhausting air. *This does not indicate a defective valve.*

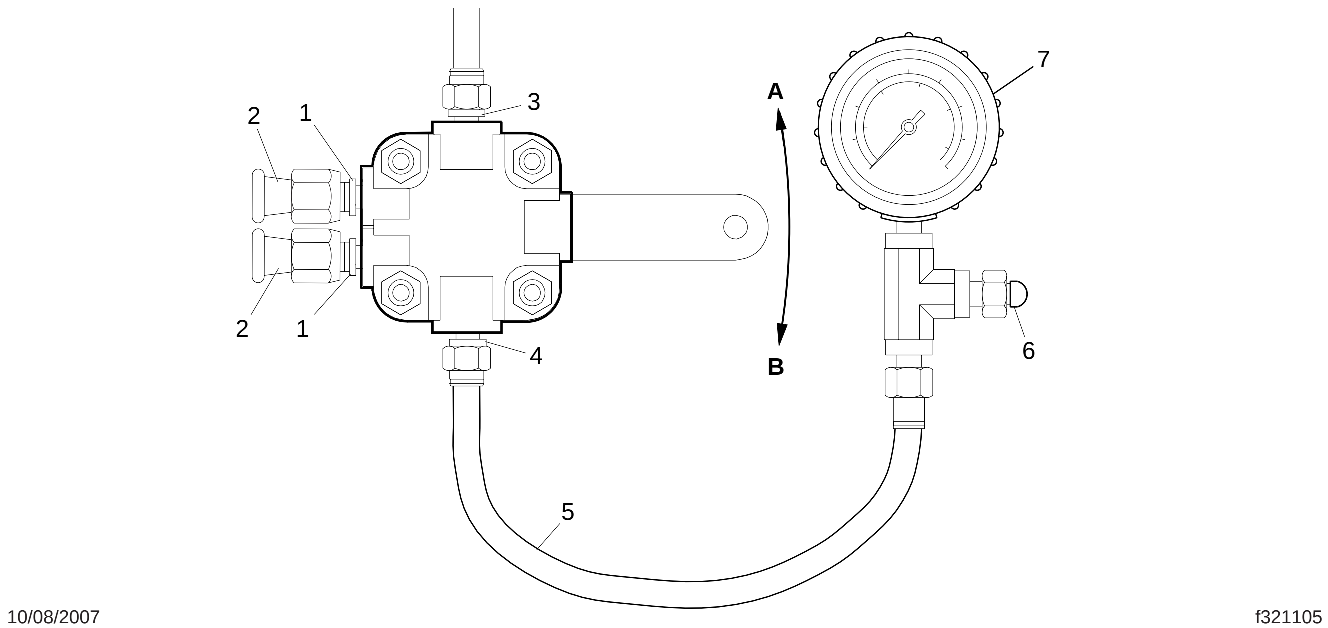
12. Check the height-control valve in the exhaust mode, as follows.

    12.1 Rotate the valve control lever up 45 degrees from the horizontal to the exhaust position.

    12.2 Press the reset button on the test gauge.

    12.3 Observe the test gauge for 30 seconds. Refer to **Fig. 2** for the maximum allowable exhaust pressure change versus inlet pressure.

    The valve is not working correctly if the gauge pressure reading exceeds the maximum allowable within 30 seconds.



A. Exhaust

1. Air Spring Port
2. Parker Plug
3. Air Intake Port
4. Exhaust Port Test Fitting

B. Fill

5. Air Line
6. Reset Button
7. Test Gauge Assembly

Fig. 1, Test Connections

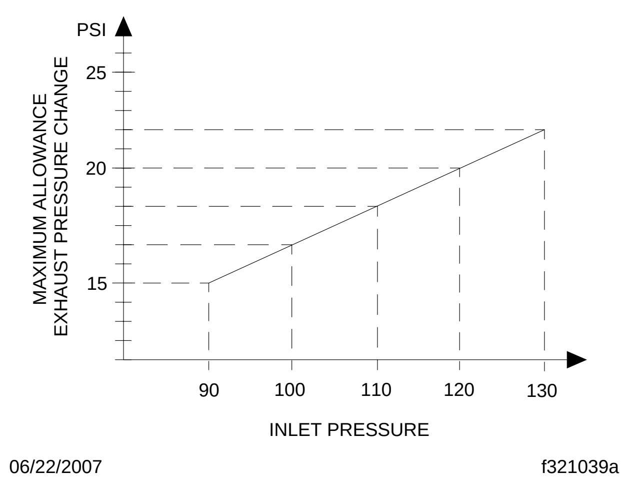


Fig. 2, Inlet Pressure vs. Exhaust Pressure Change in 30 Seconds

If the gauge reads less than the maximum allowable pressure change in 30 seconds, the valve is okay.

NOTE: The test gauge will register the exhausting air. *This does not indicate a defective valve.*

13. Disconnect the test gauge and connector from the valve exhaust port.
14. If the height-control valve is defective, replace it; see **Subject 120**.
15. Install the flapper on the exhaust port by pressing it into place.
16. Remove the two Parker plugs from the air spring ports, and connect the air lines to the air spring ports (or elbow fittings). Connect the vertical linkage to the height-control valve control lever. The ride height will automatically return to the correct position.
17. Remove the chocks.

Height-Control Valve Replacement

Replacement

IMPORTANT: Before replacing the height-control valve, perform the steps in **Subject 110** to see if the height-control valve is actually damaged or just out of adjustment.

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.

WARNING

Do not disconnect any air lines in the cab suspension system without first blocking the cab securely. If the cab isn't securely blocked, disconnecting an air line could cause the cab to fall abruptly, possibly resulting in serious injury.

2. Place blocks between the frame and the bottom of the cab, or use jack stands to keep the cab in position when the air spring is deflated.
3. Drain all air from the air tanks.

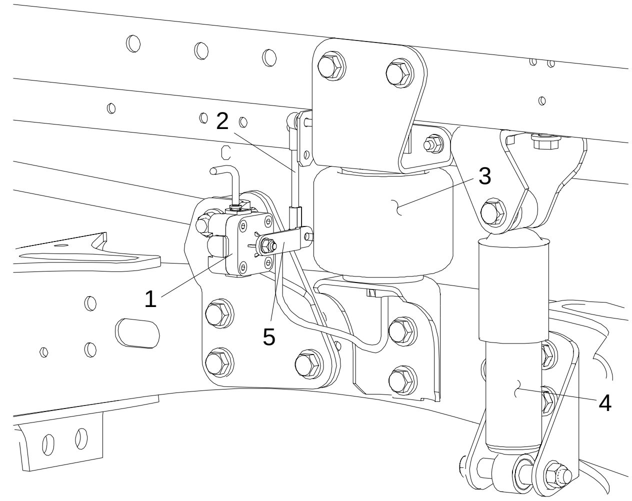
WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

4. Remove the nut and washer that attach the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the horizontal control lever; see **Fig. 1**.
5. Rotate and hold the horizontal-control lever up until all air is exhausted from the air spring.
6. Mark the air tubing to the height-control valve for later reference, then disconnect the tubing.

CAUTION

When removing or loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.



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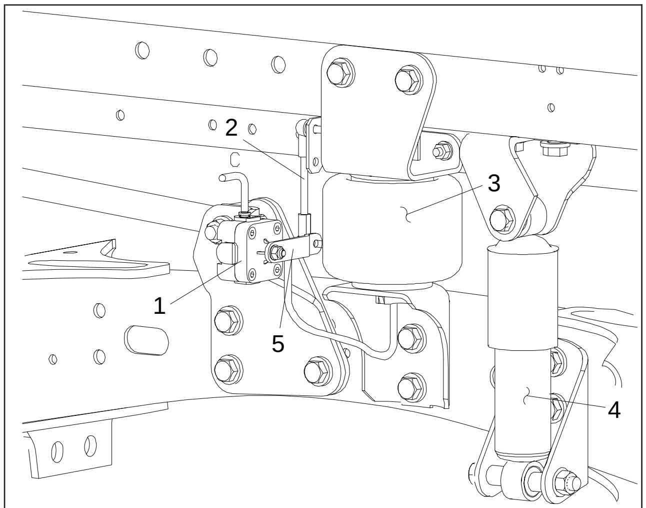
1. Height-Control Valve
2. Vertical Linkage
3. Air Spring
4. Shock Absorber
5. Horizontal Control Lever

Fig. 1, Cab Height-Control Valve

7. While holding the height-control valve mounting studs in place with an Allen wrench, remove the nuts and washers that attach the valve to the mounting bracket. Remove the height-control valve.
8. Position the new height-control valve on the height-control bracket. While holding the height-control valve mounting studs in place with an Allen wrench, install the nuts and washers, and tighten 45 lbf·in (500 N·cm). Do not overtighten.
9. Connect the air tubing to the height-control valve.
10. Align the vertical linkage with the horizontal control lever and install the washer and nut.
11. Start the engine and run it until air pressure builds to at least 100 psi (690 kPa).
12. Check all air tubing and fittings for leaks.
13. Remove the cab supports.
14. Remove the chocks.

Shock Absorber Replacement

1. Apply the parking brakes, shut down the engine, and chock the front and rear tires.
2. Place blocks between the frame and the bottom of the cab, or use jack stands to keep the cab in position when the shock is removed.
3. Remove the nut, washers, and bolt that attach the shock absorber to the mounting bracket on the cab. See **Fig. 1**.



1. Height-Control Valve
2. Vertical Linkage
3. Air Spring
4. Shock Absorber
5. Control Lever

Fig. 1, Cab Height-Control Valve

4. Remove the nut, washers, and bolt that attach the shock to the mounting bracket on the cross-member, then remove the shock.
5. Install the shock in the lower mounting bracket and install the bolt, washers, and nut.
6. Position the upper end of the shock in the mounting bracket and install the bolt, washers, and nut.
7. Tighten the upper and lower nuts 45 lbf·ft (61 N·m).
8. Remove the cab supports.
9. Remove the chocks.

Replacement

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.

WARNING

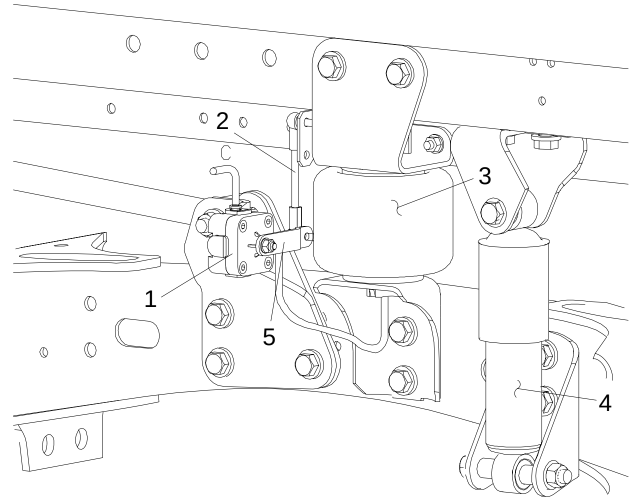
Do not disconnect any air lines in the cab suspension system without first blocking the cab securely. If the cab isn't securely blocked, disconnecting an air line could cause the cab to fall abruptly, possibly resulting in serious injury.

2. Place blocks between the frame and the bottom of the cab, or use jack stands to keep the cab in position when the air spring is deflated.
3. Drain all air from the air tanks.

WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

4. Remove the nut and washer that attach the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the control lever; see **Fig. 1**.
5. Rotate and hold the horizontal control lever up until all air is exhausted from the air spring.
6. Disconnect the supply air tubing from the bottom of the air spring. Push in the brass ring at the connection, then pull the air line straight out. If the new air spring will not be installed immediately, cover the open end of the air tubing to prevent dirt or other foreign material from entering.
7. Insert a screwdriver between the upper bracket and the air spring, and pry the air spring away from the bracket to pop the air spring tangs out of the bracket. Repeat the procedure for the bottom of the air spring, then pull the air spring out enough to access the supply air tubing.
8. Install the new air spring by snapping it into the bottom bracket first, then the top bracket.
9. Remove the cover from the air line, then connect it by pushing it into the fitting on the bottom of the air spring. Push the air line all the way in. If it is not pushed all the way in, the connection will leak air. Tug on the air line to seat it completely.
10. Align the vertical linkage with the control lever and install the washer and nut.
11. Start the engine, and run it until air pressure builds to at least 100 psi (690 kPa). Check for air leaks at the air spring.
12. Remove the cab supports.
13. Remove the chocks.



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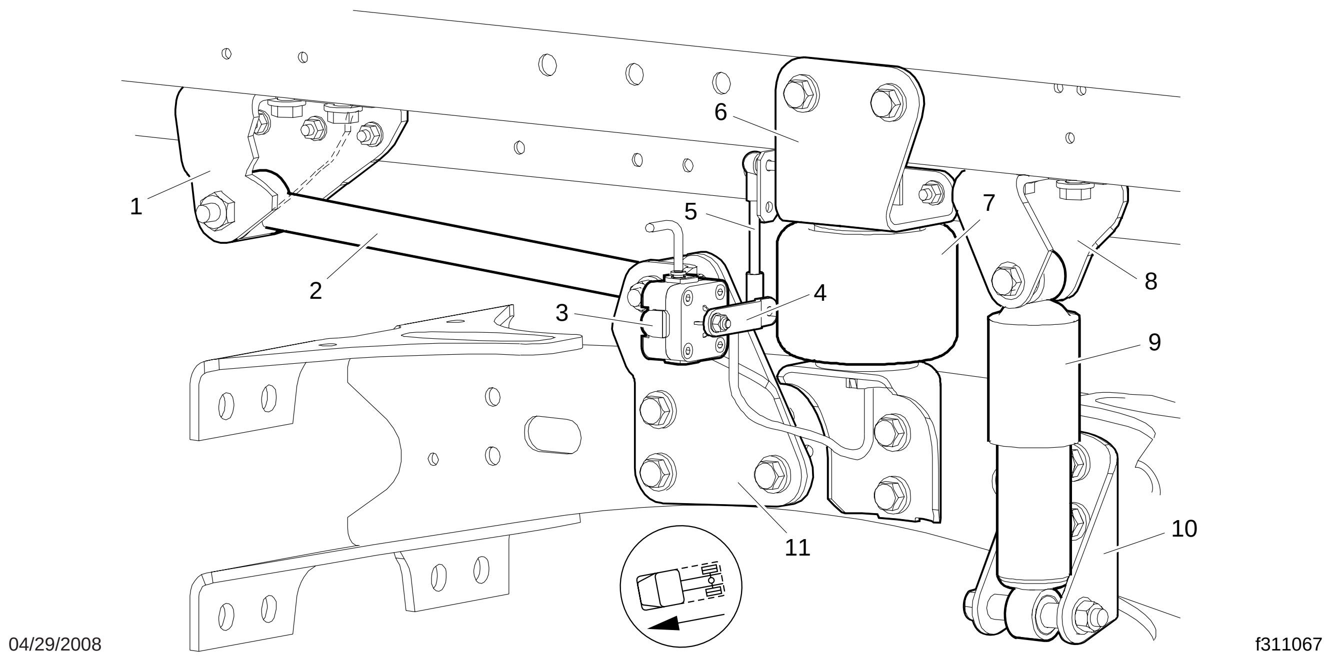
1. Height-Control Valve
2. Vertical Linkage
3. Air Spring
4. Shock Absorber
5. Horizontal Control Lever

Fig. 1, Cab Height-Control Valve

Lateral Control Rod Replacement

Replacement

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.
2. Place blocks between the frame and the bottom of the cab, or use jack stands to keep the cab in position when the lateral control rod is removed.
3. Remove the nut, washers, and bolt that attach the lateral control rod to the control rod cab bracket; see **Fig. 1**.



1. Control Rod Cab Bracket
2. Lateral Control Rod
3. Height-Control Valve
4. Horizontal Control Lever
5. Vertical Linkage
6. Air Spring Upper Bracket
7. Air Spring
8. Shock Absorber Upper Bracket
9. Shock Absorber
10. Shock Absorber Lower Bracket
11. Control Rod Chassis Bracket

Fig. 1, Cab Rear Air Suspension Installation

4. Remove the nut, washers, and bolt that attach the lateral control rod to the control rod chassis bracket, then remove the lateral control rod.
5. Attach the inboard end of the new lateral control rod in the chassis bracket, using the bolt, washers, and nut.
6. Position the outboard end of the lateral control rod in the cab bracket and install the bolt, washers, and nut.
7. Tighten the inboard and outboard nuts 45 lbf·ft (61 N·m).
8. Remove the cab supports.
9. Remove the chocks.

Vertical Linkage Replacement

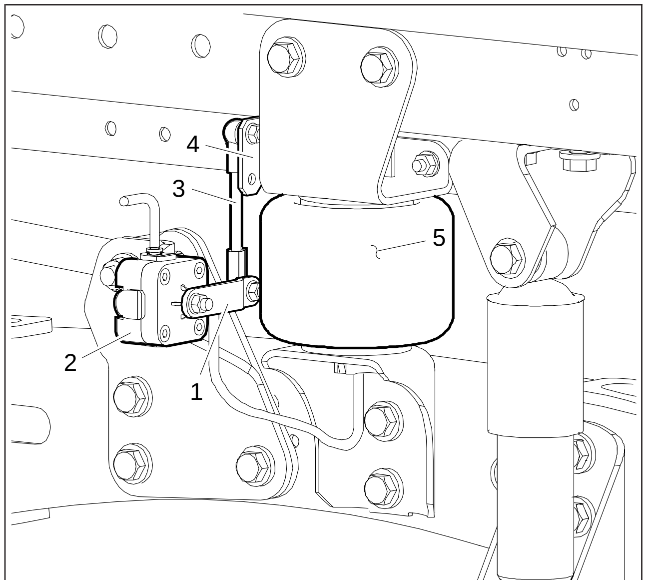
Replacement

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa), then shut off the engine.

WARNING

Do not disconnect the vertical linkage in the cab suspension system without first blocking the cab securely and inserting a pin in the neutral-position hole of the height-control valve and the horizontal control lever. If the cab is not securely blocked, dislodging the pin and moving the control lever could cause the cab to fall or rise abruptly, possibly resulting in serious injury.

3. Place blocks between the frame and the bottom of the cab or use jack stands to keep the cab in position when the air spring is deflated.
4. Insert a 5/32-inch (4-mm) drill bit into the neutral position hole of the height-control valve and horizontal control lever.
5. Disconnect the upper end of the vertical linkage. Depending on the vehicle configuration, it is attached to the cab underbody, or to a vertical linkage bracket on the cab underbody; see **Fig. 1**.
6. Remove the nut and washer that attach the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the control lever.
7. Align the new vertical linkage between the control lever and the bracket on the cab underbody. Attach the lower end of the linkage to the control lever, using the nut and washer.
8. Attach the upper end of the vertical linkage to the cab underbody, or to the vertical linkage bracket on the cab underbody.
9. Remove the drill bit or pin from the height-control valve.
10. Remove the cab supports.
11. Remove the chocks.



1. Horizontal Control Lever
2. Height-Control Valve
3. Vertical Linkage
4. Vertical Linkage Bracket
5. Air Spring

Fig. 1, Cab Height-Control Valve

Checking the Cab Height-Control System for Air Leaks

WARNING

Keep your hands and all objects away from the area under and around the cab when removing the pressure from the air system. Parts will move as the air is released and can cause personal injury or damage to any objects that are between the moving parts.

IMPORTANT: To prevent voiding the warranty on Barksdale height-control valves, note the following:

- Do not overtighten the bolts in the Barksdale height-control valve housing if you detect leaks in the housing. The bolts should not be loose, and should not require tightening. Only if necessary, tighten the valve housing bolts 45 lbf·in (500 N·cm). Any damage to the valve housing will void the warranty.
- If it is necessary to remove a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, crushing the valve body and damaging the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.
- Do not attempt to disassemble the Barksdale valve body or the control lever. There are no serviceable parts in the valve, and any disassembly will void the warranty.

1. Park the vehicle on a level surface, apply the parking brakes, and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa). Turn off the engine and wait 5 to 10 minutes for the system to equalize.

NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal and does not indicate a damaged valve.

3. Apply a soap-and-water solution to the outside of the air fittings on the height-control valve and on the suspension air springs. Look for bubbles indicating an air leak.
4. If bubbles are seen, check that the air tubing is installed correctly into the fitting; see **Subject 100**.

   If no bubbles are seen, check the height-control valve for air leaks; see **Subject 110**.

Diagnostics and Testing

Air Spring

Inspect the exterior surfaces of the air spring, looking for wear. With the air spring fully inflated, check to see if there is sufficient clearance around the air spring to prevent lines or objects from rubbing against the air spring. Air tubing or cab components that rub against the air spring will cause damage to the air spring. If the air spring is not capable of lifting the cab to its proper ride height, check to see if the shock absorber is damaged. A binding shock absorber will limit the air spring's ability to extend. To clean the air spring, use soap and water.

NOTE: Do not use organic solvents, abrasives, or pressurized steam cleaners to clean the air spring.

Shock Absorber

Inspect the shock body for damage such as bends or dents in the piston. Bends or dents in the shock body will negatively affect the operation of the shock. Inspect the shock body for signs of leaking fluid. Normal operation of the shock will result in some misting of the hydraulic fluid onto the exterior shock body. Large streams of fluid indicate a leak and the shock should be replaced; see **Fig. 1**.

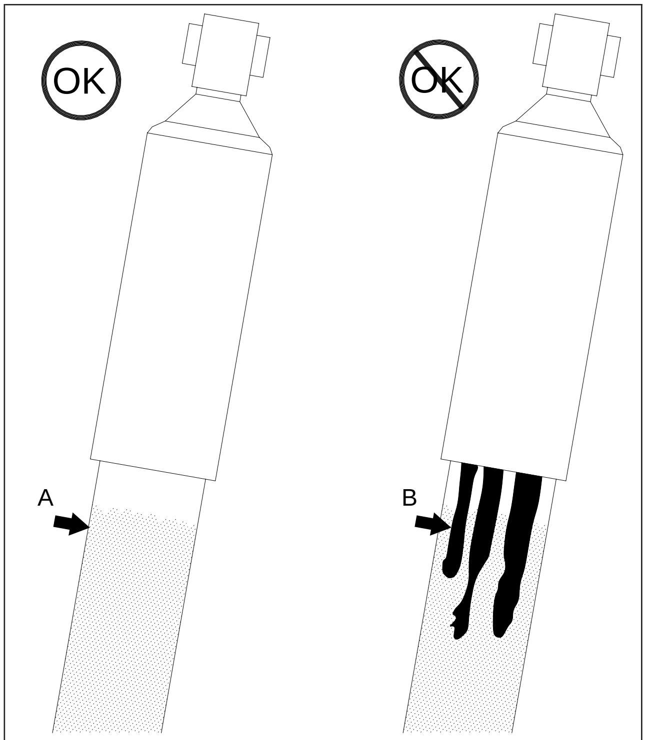
To test the operation of a shock absorber, hold the shock in an upright position and cycle the piston at least five times by pushing the piston up and down. The piston should move evenly throughout each section of the cycle. If the shock does not move evenly

Troubleshooting

when pushed down or pulled up, the shock should be replaced.

Noises such as squeaks, which may be intermittent, may be caused by the valves used to regulate the internal hydraulic fluid. This problem is not repairable and the shock will need to be replaced. Noises from the shock, such as knocking or rattling, may be due to movement between the bushings and mounting brackets. Inspect the bushings or mounting brackets for wear. Repair worn components as necessary. Check the torque of the shock absorber mounting nuts and tighten if necessary.

NOTE: The shock absorber bushings do not require any type of lubrication. Do not attempt to stop bushing noise by lubricating them; grease and mineral-oil-base lubricants will deteriorate the bushing rubber.



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A. Dust covered mist (normal).
B. Hydraulic fluid streaks indicating an actual leak.

Fig. 1, Differences Between Misting and Leaking

Torque Specifications

Unless listed in **Table 1**, tighten all fasteners using the torque specifications found in **Section 00.04**.

Torque Specifications				
Fastener Description	**lbf·ft**	**N·m**	**lbf·in**	**N·cm**
Lateral Control Rod Upper and Lower Nut	45	61	—	—
Shock Absorber Upper and Lower Nut	45	61	—	—
Height-Control Valve Mounting Nut	—	—	45	500

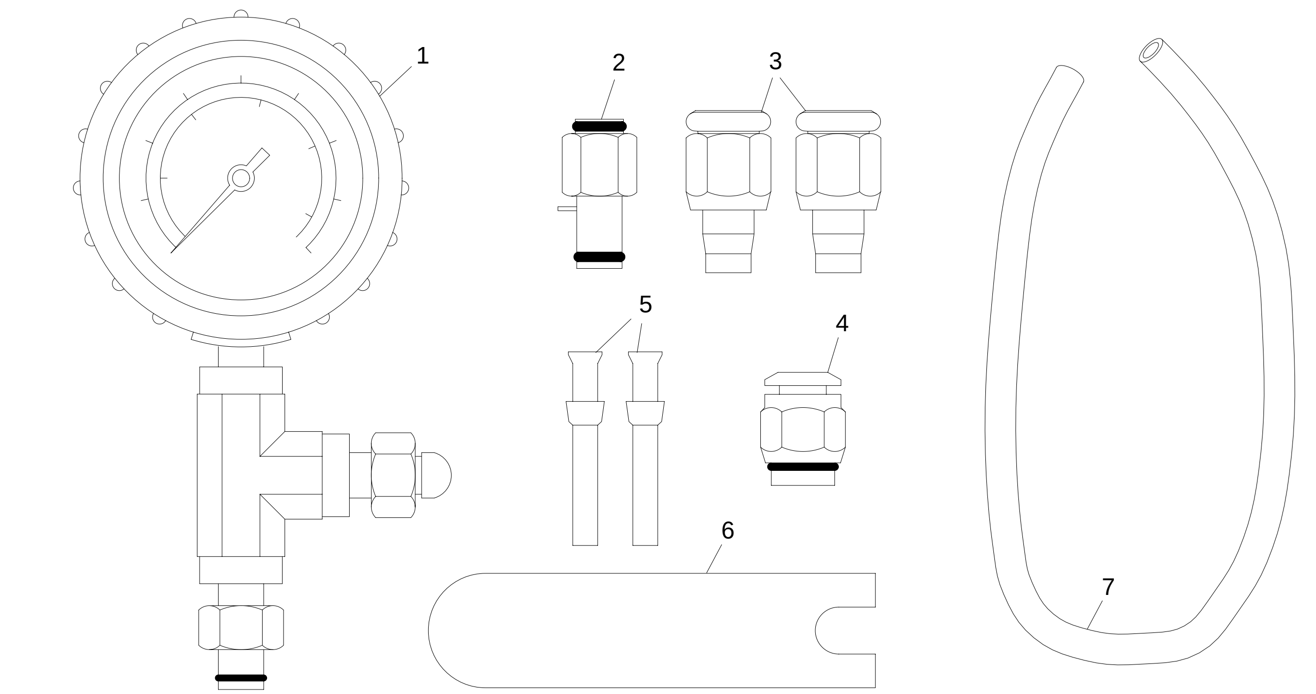
Table 1, Torque Specifications

Special Tools

Use the kit shown in **Fig. 1** to test a Barksdale height-control valve. Test kit BKS KD2264 is available via the Direct Ship program in paragon, or directly from Barksdale, at **www.barksdale.com**, or:

Barksdale, Inc.
3211 Fruitland Avenue
Los Angeles, California 90058
Telephone: 866-832-6278

Specifications



1. Test Gauge Assembly with Reset Button
2. Exhaust Port Test Connector for Cab Suspension Valve
3. Parker Plugs
4. Exhaust Port Test Connector for Chassis Suspension Valve
5. Test Plugs for Cab Suspension Valve
6. Special Tools for Disconnecting Air Line
7. Air Line

Fig. 1, Barksdale Height-Control Valve Test Kit BKS KD2264

General Information

The bulkhead-style cab door is composed of fully stamped steel inner and outer panels, with large internal steel reinforcements at the hinge/A-pillar, waist, and mirror mount. The primary door seal is mounted on the door assembly. A secondary seal is mounted on the cab around the door opening frame.

The “bulkhead” description refers to the manner in which the door, when closed, seats inside the door opening; the outer panel surface of the door is then flush with the outermost edge of the stamped door opening frame.

The door opens on two discreet, hidden hinges that require no maintenance. The door hinges allow a 65-degree opening. The primary mirror is mounted on the door, which is reinforced at the mount areas.

The wiring for the window, mirror, and courtesy light is routed through an opening on the hinge side of the door.

Most service operations can be done with the door attached to the vehicle. To reduce work time, do not remove the door unless necessary.

NOTICE

Do not attempt to disassemble the door shell. The door panels and reinforcements are assembled using a high-strength adhesive. The heat required to loosen the adhesive can compromise the structural integrity of the door assembly. If the door is structurally damaged, replace the entire door shell.

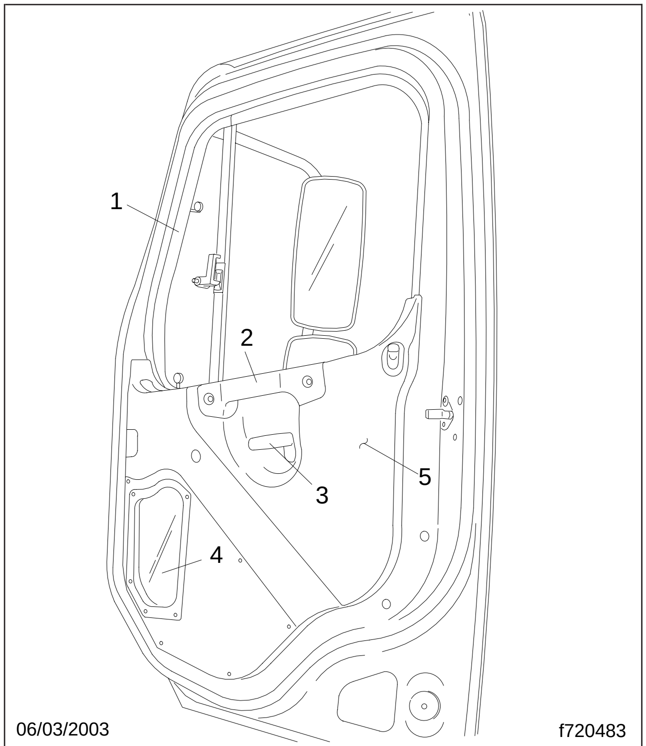
NOTICE

Before performing any electric welding on or near the door, read and comply with the welding precautions in Section 60.13, and disconnect the door wiring harness behind the inner trim panel. Electric currents produced during electric welding can damage various electronic components on the vehicle.

Door Trim Panel Removal and Installation

Removal

1. Apply the parking brake and chock the tires.
2. Using a T40 driver, remove the two mounting screws from the upper and/or lower door-pull handle. See **Fig. 1**.



1. Window Seal
2. Door Pull Handle
3. Interior Release Handle
4. View Window
5. Door Trim Panel

Fig. 1, Cab Door Trim

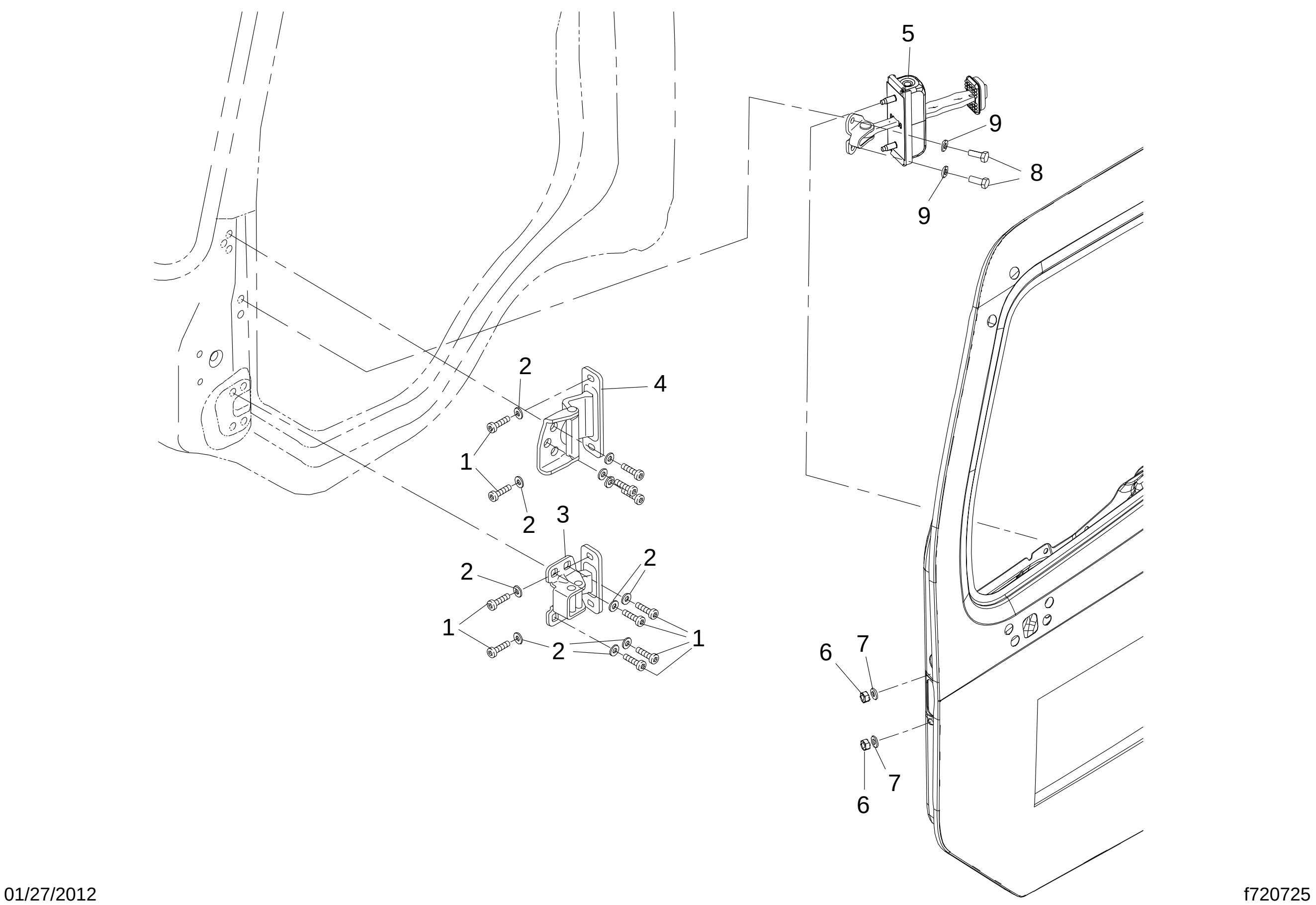
3. For vehicles with manual-crank windows, remove the window-regulator handle.
4. Using a T20 driver, remove the four attaching screws and the lower view-window trim ring, if so equipped.
5. Using a T40 driver, remove the interior release handle.
6. Using a T20 driver, remove the two screws from the forward flange.
7. Pull the trim panel outward from the door to release the snaps, then lift it up and over the lock knob.

Installation

1. Slide the trim panel over the door-lock knob.
2. Position the trim panel in place against the door, then press firmly at the location of each snap-in fastener to ensure that it engages completely.
3. Using a T20 driver, install the two screws in the forward flange of the trim panel.
4. Using a T20 driver, install the four screws and the lower view-window trim ring.
5. Using a T40 driver, install the upper and/or lower door-pull handle. Tighten the screws 11 to 13 lbf·ft (14 to 18 N·m).
6. Install the interior release handle. Tighten the screw 50 to 70 lbf·in (600 to 800 N·cm).
7. If the vehicle has manual-crank windows, install the window-regulator handle.

Removal

1. Apply the parking brake and chock the tires.
2. Lower the window.
3. Disconnect the batteries.
4. Remove the exterior side cowl panel.
5. Remove the door interior trim panel; see **Subject 100**.
6. Disconnect and remove the door wiring harness.
7. If replacing the door, remove any components (e.g. the regulator, latch, handles, connecting rods, or window glass) that will be installed on the replacement door; see the appropriate subjects in this section.
8. Remove the door check assembly as follows. See **Fig. 1**.
   - 8.1 Remove the two capscrews that attach the door check clevis bracket to the cab.
   - 8.2 Remove the two nuts that attach the door check to the edge of the door. Remove the door check assembly from the door.



1. Capscrews
2. Washers
3. Lower Door Hinge Assembly
4. Upper Door Hinge Assembly
5. Door Check Assembly
6. Hexnut
7. Washer
8. Hexbolts
9. Washer

Fig. 1, Door and Door Check Installation

Door Removal and Installation

CAUTION

Do not attempt to lift the door. The door weighs approximately 110 pounds (50 kg). Lifting or dropping the door could result in personal injury or damage to the door assembly and other components.

9. Using a door support or help from an assistant, support the door frame from its bottom to prevent it from falling or tipping during removal. With the door open and supported, loosen the capscrews that attach the the hinges to the door.

Installation

1. If the door seal has been damaged or is weathered, replace it. For instructions, refer to **Subject 120**.

CAUTION

Do not attempt to lift the door. The door weighs approximately 110 pounds (50 kg). Lifting or dropping the door could result in personal injury or damage to the door assembly and other components.

2. Using a door support or help from an assistant, support the door from its bottom to prevent it from falling or tipping during installation.
3. Install the hinge fasteners. Tighten the capscrews 11 to 13 lbf·ft (14 to 18 N·m).
4. Close the door and check for alignment. Adjust the door if needed; see **Subject 160**.
5. Install the door check assembly as follows.
   - 5.1 Attach the door check to the edge of the door. Tighten the nuts 50 to 70 lbf·in (600 to 800 N·cm).
   - 5.2 Attach the clevis bracket to the cab. Tighten the capscrews 50 to 70 lbf·in (600 to 800 N·cm).
6. If replacing the door, install all components on the door; see the appropriate subjects in this section.
7. Install and connect the door wiring harness.
8. Install the door interior trim panel; see **Subject 100**.
9. Install the exterior side cowl panel.
10. Connect the batteries.
11. If applicable, check that the door electrical components are operating correctly.

Replacement

There are four seals for the cab door (see **Fig. 1**):

- Primary seal
- Secondary seal
- Lower seal
- Rain gutter seal

Primary Seal

1. Apply the parking brake and chock the tires.
2. Open the door.
3. Remove the old seal from the door. It is held in place with double-sided tape and integral retainer clips.
4. Using alcohol, clean the surface of any old adhesive or dirt.
5. Install the new primary seal with the lip toward the edge of the door. Make sure the retainer clips are pushed all the way into their holes, and the seal is flat against the surface all the way around. Apply pressure to the areas of the seal that have adhesive tape to seat the seal firmly.
6. Close the door and check the seal. Adjust if necessary.

Secondary Seal

1. Apply the parking brake and chock the tires.
2. Open the door.
3. Remove the tread plate at the bottom of the doorway, then loosen up the upholstery panel.
4. Remove the old seal from the cab doorway. It fits over an edge.
5. Using alcohol, clean the surface of any old adhesive or dirt.
6. Install the new secondary seal. Start at the bottom and work your way around. Make sure it is pushed all the way on. Apply pressure to the areas of the seal that have adhesive tape to seat the seal firmly.
7. Put the upholstery in place, then install the tread plate.
8. Close the door and check the seal. Adjust if necessary.

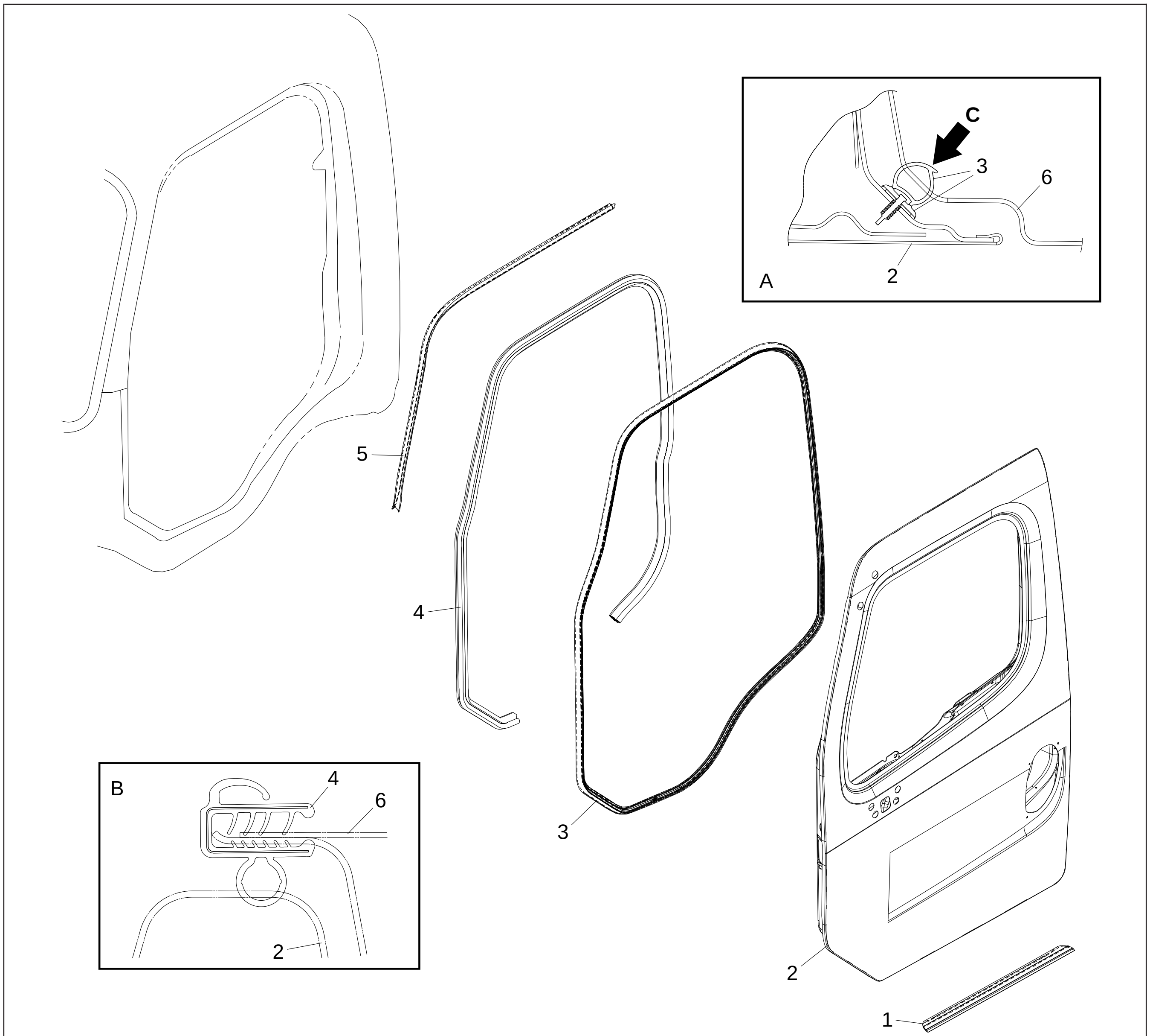
Lower Seal

1. Apply the parking brake and chock the tires.
2. Open the door.
3. Remove the old seal from the bottom of the cab doorway. It is held in place with double-sided tape.
4. Using alcohol, clean the surface of any old adhesive or dirt.
5. Install the new lower seal. Make sure it is completely seated. Apply pressure to the areas of the seal that have adhesive tape to seat the seal firmly.
6. Close the door and check the fit. Adjust if necessary.

Rain Gutter Seal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Open the door.
3. Remove the rain gutter seal from the cab doorway. It is held in place by double-sided tape.
4. Using alcohol, clean the surface of any old adhesive or dirt.
5. Install the rain gutter seal. Make sure it is pushed all the way on. Apply pressure to the areas of the gutter that have adhesive tape to seat the gutter firmly.
6. Close the door and check the fit. Adjust if necessary.

Door Seals Replacement



A. Cross-Sectional View of Primary Seal
B. Cross-Sectional View of Secondary Seal
C. Install the primary seal with the lip pointing toward the edge of the door.

1. Lower Seal (installed on the door)
2. Door
3. Primary Seal (installed on the door)
4. Secondary Seal (installed on the cab)
5. Rain Gutter Seal (installed on the cab)
6. Cab

Fig. 1, Door Seals

Replacement

NOTE: The door latches never require lubrication. They come from the manufacturer with lifetime lubrication.

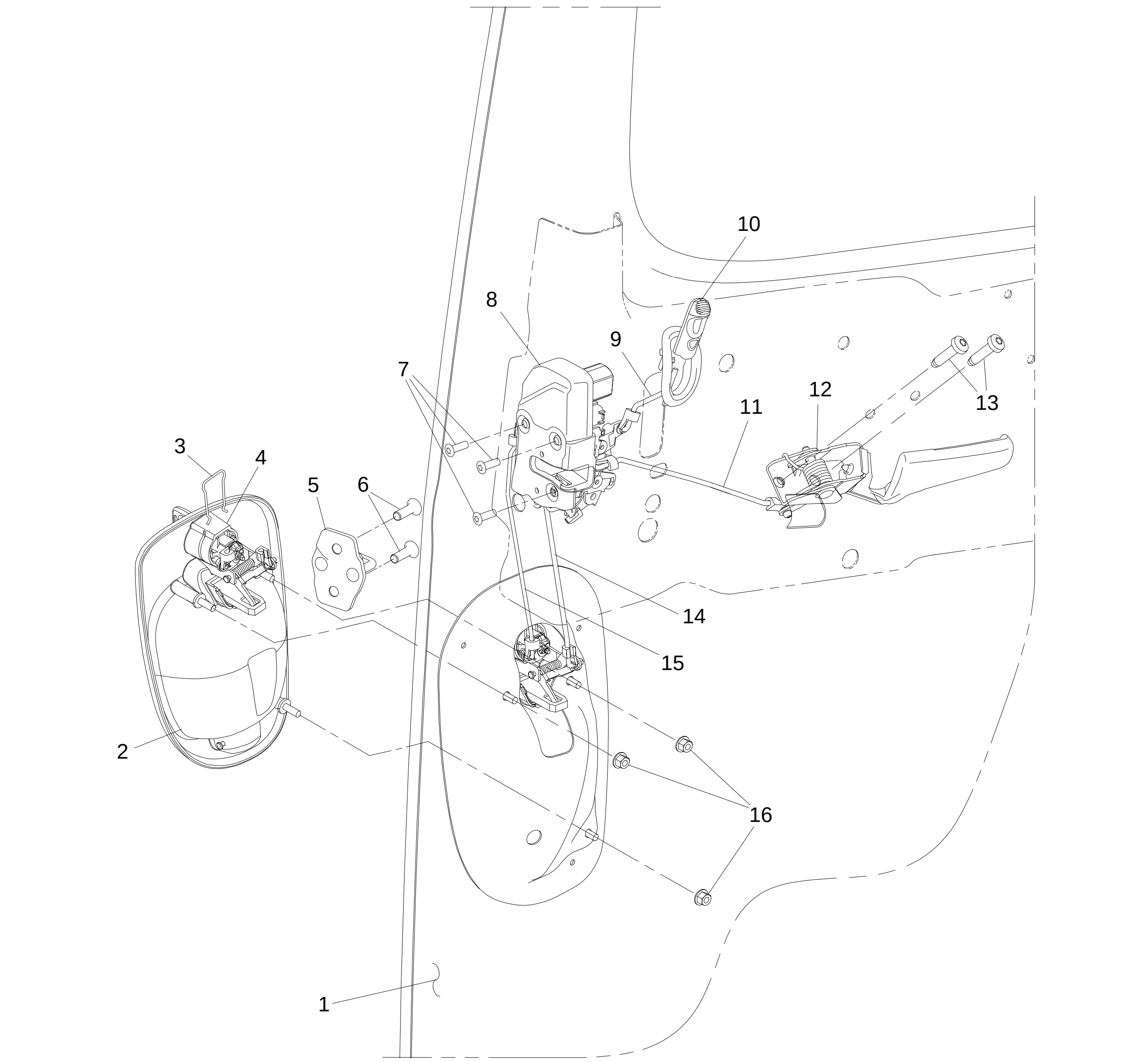
1. Apply the parking brake and chock the tires.
2. Remove the interior trim panel; see **Subject 100**.
3. Peel back the vapor barrier.
4. Disconnect the interior lock rod (**Fig. 1**, item 9) from the door latch assembly.
5. Disconnect and remove the exterior lock rod (item 15), the interior latch rod (item 11), and the exterior latch rod (item 14).
6. At the edge of the door, remove the three screws that attach the latch assembly to the door.
7. Move the latch assembly down to the interior door panel opening, then disconnect the dome light switch wiring from it.
8. Connect the dome light switch wiring to the new latch assembly.
9. Insert the latch assembly inside the door through the door panel opening, move it into position, then, using the three screws, attach it to the door edge. Tighten the screws 50 to 70 lbf·in (600 to 800 N·cm).
10. Connect the interior lock rod to the latch assembly.
11. Connect the exterior lock rod (item 15), and the interior and exterior latch rods (items 11 and 14).

    When connecting the exterior latch rod, make sure the rod length adjustment screw on the latch is loose. Connect the rod to the exterior door handle, then to the latch. When the latch is securely installed, tighten the rod length adjustment screw 15 to 25 lbf·in (170 to 280 N·cm).

NOTE: The colored end of each rod is attached to the latch assembly.

12. Check the rods for correct operation.
13. Install the vapor barrier.
14. Install the interior trim panel; see **Subject 100**.

Door Latch Replacement



1. Door Panel
2. Exterior Door Handle
3. Spring Clip
4. Exterior Lock Assembly
5. Striker Pin
6. Screws
7. Torx-Head Screws
8. Door Latch Assembly
9. Interior Lock Rod
10. Lock Button
11. Interior Latch Rod
12. Interior Door Handle
13. Torx-Head Screws
14. Exterior Latch Rod
15. Exterior Lock Rod
16. Hexnuts

Fig. 1, Door Components

Door Window Glass Replacement

Replacement

NOTE: This procedure is for manual window regulators.

1. Apply the parking brake and chock the tires.
2. Lower the window all the way.
3. Remove the interior trim panel; see **Subject 100**.
4. Peel back the vapor barrier.

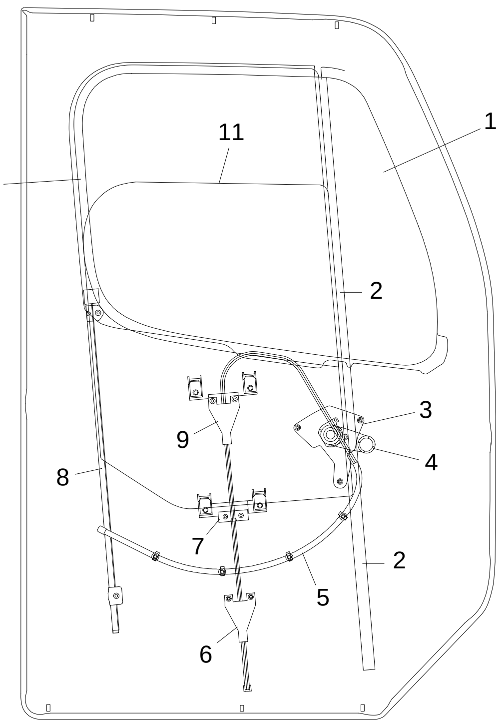
WARNING

Wear protective gloves and safety glasses when replacing window glass. Gloves will protect your hands from sharp edges, and allow a better grip. Failure to wear gloves and safety glasses when handling glass could result in injury to hands or eyes.

5. Remove the upper and lower screws that attach the glass rear channel to the interior door panel. Let the channel rest at the bottom of the door. See **Fig. 1**.
6. Remove the window seal from the door window opening, as follows.
   - 6.1 Peel back the vent-window seal where it overlaps the door-window seal.
   - 6.2 Pull the door-window seal down and back towards the rear of the cab to remove it. See **Fig. 2**.
7. Raise the window until the regulator-clamp screws can be accessed; see **Fig. 3**.
8. While supporting the glass, loosen the regulator clamps at the bottom edge of the window glass. See **Fig. 4**.
9. Remove the window glass by pulling it up and toward the inside of the door window opening.
10. Lower the new window glass through the inside of the window opening. Support the glass until it rests on the regulator-clamp pads.
11. Install the window seal into the window opening.

NOTE: If replacing the window seal, use 3M™ Strip-Calk 08578 at the joints with the vent window seal to prevent leakage.

12. Carefully raise up the window.



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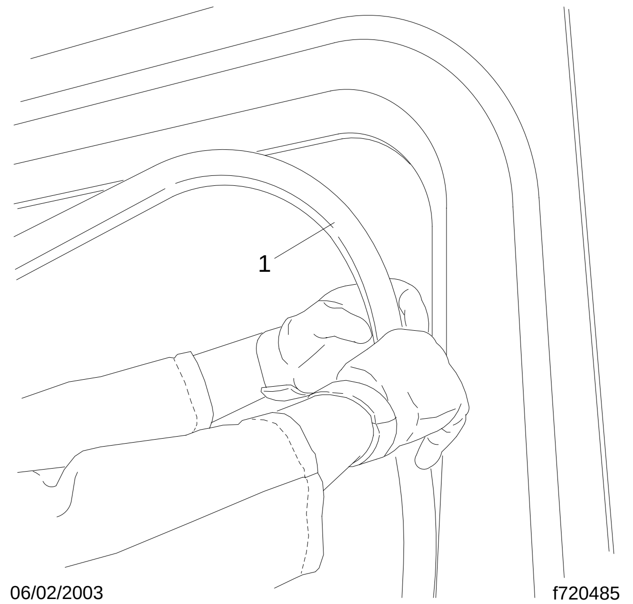
1. Vent Window
2. Window Division Bar
3. Crank Cover-Plate
4. Crank Handle
5. Window Regulator Assembly
6. Lower Run Bracket
7. Window Regulator Clamp Assembly
8. Glass Rear Channel
9. Upper Run Bracket
10. Window Seal
11. Window Glass

Fig. 1, Window Regulator Components

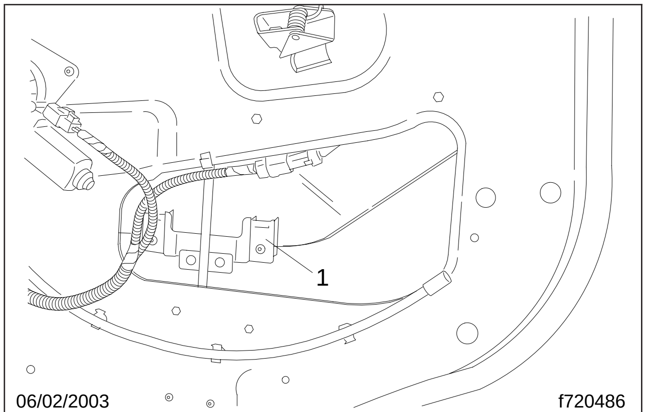
13. Pull up the glass rear channel, making sure the glass edge fits into it. Install the two screws that attach the channel to the door panel. Tighten the screws 60 lbf·in (700 N·cm).
14. Carefully tighten the regulator clamps at the bottom of the window glass. Tighten the clamps 55 to 64 lbf·in (625 to 725 N·cm). *Do not overtighten.*
15. Test the window regulator for smooth operation. The window should raise and lower with no binding.
16. Install the vapor barrier. Reuse the old adhesive to attach the vapor barrier to the door.

Door Window Glass Replacement



1. Window Seal

Fig. 2, Remove/Install the Window Seal

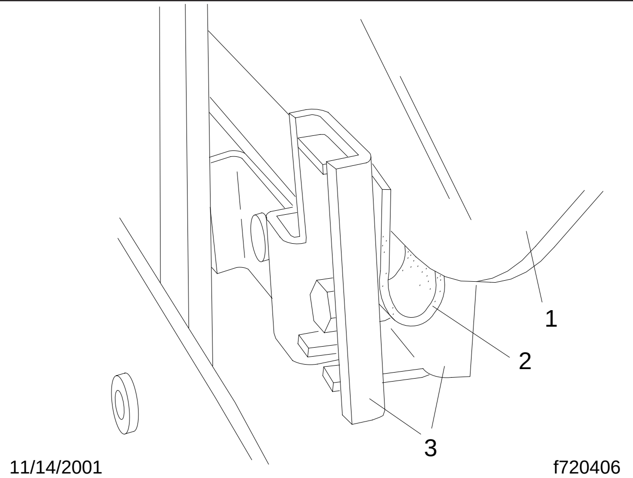


1. Regulator Clamp

Fig. 3, Regulator Clamp

NOTE: If the adhesive does not adhere, use 3M Strip-Calk 08578 as needed to affix the vapor barrier to the door.

17. Install the interior trim panel; see **Subject 100**.



1. Window Glass
2. Pad
3. Regulator Clamps

Fig. 4, Window Glass (bottom edge)

Replacement

1. Apply the parking brake and chock the tires.
2. Remove the manual window-regulator crank (if so equipped), the door latch handle, the pull handles, the lower view-window trim ring (if so equipped), and the door interior trim panel; see **Subject 100**.
3. Peel back the vapor barrier.
4. Remove the window seal and glass; see **Subject 140**.
5. Remove the vent-window glass.

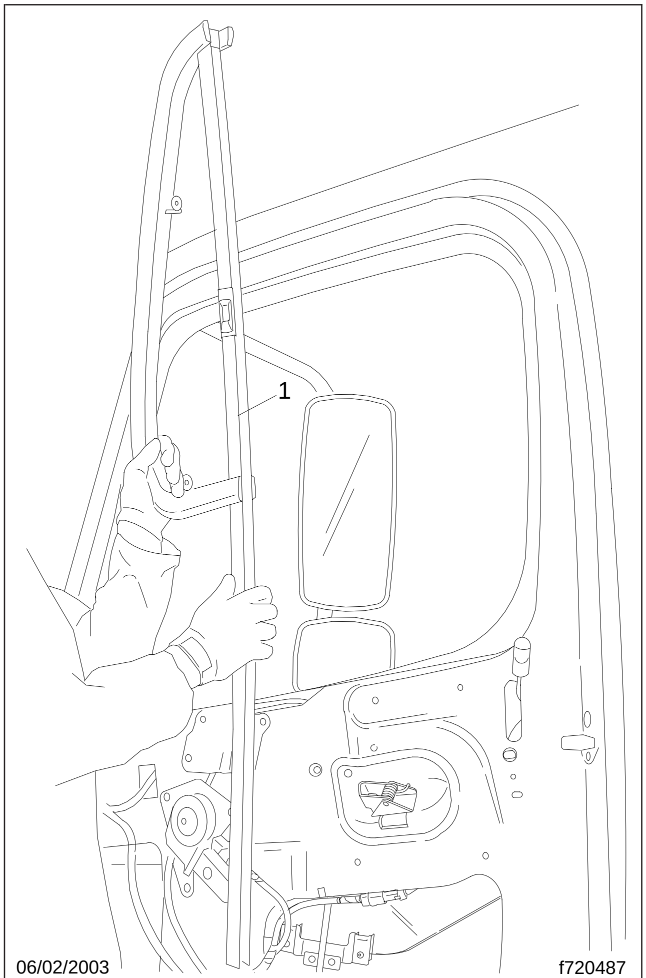
   For an operable vent window, loosen the latch and open the vent window. Remove the two screws that attach the glass to the vent-window frame, and remove the glass.

   For a fixed vent window, starting at the lower front corner apply light pressure against the inside of the glass while carefully prying the seal around the outside of the glass.
6. Remove the vent-window frame assembly as follows.

   6.1 Using a T20 driver, remove the three screws between the door and the front of the vent-window frame assembly.

   6.2 Using a T30 driver, remove the two screws that attach the run channel of the vent-window frame assembly to the door.

   6.3 Pull the vent-window frame assembly up and out of the window opening. See **Fig. 1**.
7. Stretch the top and bottom corners of the seal to release the locking tabs on the seal from the vent-window frame. See **Fig. 2**.
8. Remove the seal from the vent-window frame, carefully pulling it free from around the glass supports.
9. Stretch the new seal over the vent-window glass supports.
10. Apply soapy water to the window seal then press the top corner of the seal into the frame, locking the tabs on the seal into the frame. Work the seal around the frame, using the alignment tabs to position the seal properly. See **Fig. 3**.



1. Vent-Window Frame

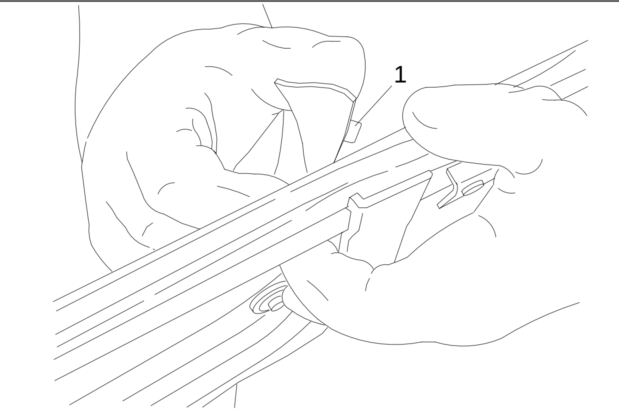
Fig. 1, Remove/Install the Vent-Window Frame Assembly

11. Stretch the bottom edge of the seal and push the locking tabs into the slot in the frame. See **Fig. 2**.
12. Install the vent-window assembly as follows.

    12.1 Slide the run channel through the window opening, then install the vent-window frame in the opening. See **Fig. 1**.

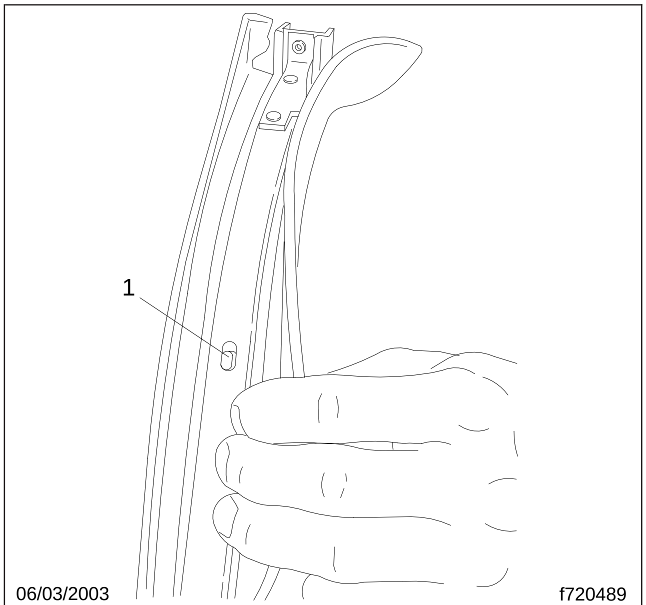
    Overlap the outside of the vent-window seal over the exterior edge of the door. Push the frame assembly forward in the window opening as far as possible.

Vent Window Seal Replacement



1. Tab

Fig. 2, Remove/Install the Vent-Window Seal



1. Alignment Tab

Fig. 3, Install the Vent-Window Seal

12.2 Install the three screws between the door and the vent-window frame. Tighten the screws 36 lbf·in (400 N·cm).

12.3 Using a T30 driver, install the two screws that attach the run channel to the door. Tighten the screws 60 lbf·in (700 N·cm).

12.4 *For an operable vent window,* use the two glass-mounting screws to install the glass in the frame assembly. Torque the screws to 50 to 70 lbf·in (600 to 800 N·cm).

For a fixed vent window, lubricate the inside of the seal with soapy water. From the outside, slide the upper corner of the glass into the seal, then while pushing in on the window, work the seal around the glass.

13. Install the window glass and seal; see **Subject 140**.

14. Install the vapor barrier. Reuse the old adhesive to attach the vapor barrier to the door.

NOTE: If the adhesive does not adhere, use 3M Strip-Calk 08578 as needed to affix the vapor barrier to the door.

15. Install the door interior trim panel, lower view-window trim ring (if so equipped), the pull handles, the door latch handle, and the manual window-regulator crank (if so equipped); see **Subject 100**.

General Information

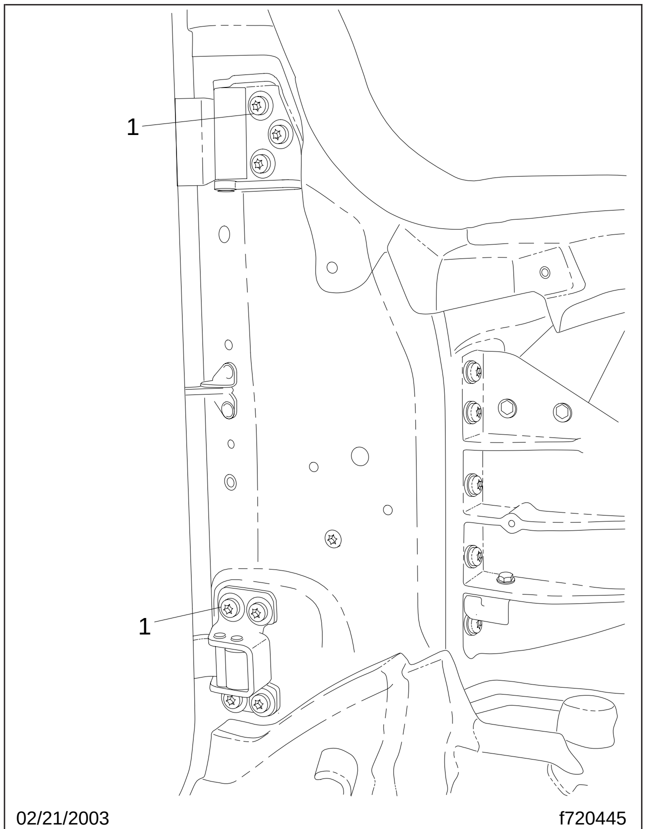
A newly installed door assembly must be adjusted for correct up-and-down, fore-and-aft, and in-and-out positioning relative to the door opening frame. The door assembly should also be adjusted whenever one or more of the following conditions exist (providing the door seal is correctly installed and is in good condition):

- wind or water leaks at the door opening frame
- premature wear of the door seal
- hard closing or opening of the door

The cab portion of the hinge has oversized holes, so that when the capscrews that attach the hinge to the cab (**Fig. 1**) are loosened, the door can be adjusted forward or aft, and up and down within the door opening frame. Slotted holes on the door portion of the hinge (**Fig. 2**) allow for in and out adjustment of the front of the door, and mounting slots for the striker (**Fig. 3**) allow for in and out adjustment of the rear of the door.

Up-and-Down, Fore-and-Aft Adjustment

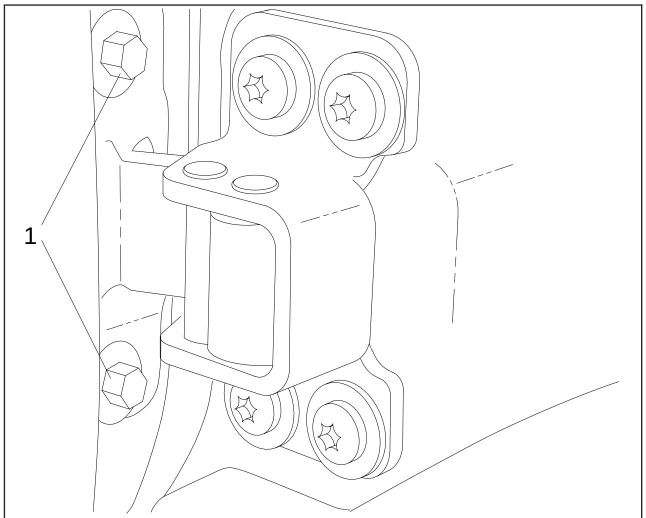
1. Apply the parking brakes and chock the tires.
2. From outside the cab, check the alignment of the door with the cab door-opening frame. Check that the spaces around the top of the door are uniform. If adjustment is needed, follow the steps below.
3. Remove the cowl side panel.
4. Mark both the vertical and horizontal positions of the latch striker and the hinge before loosening them for adjustment.
5. Loosen the striker, then tighten it just enough to prevent unintentional movement.
6. Loosen the capscrews that attach the hinges to the cab, but keep them tight enough to prevent unintentional movement. See **Fig. 1**.
7. Carefully close the door, then raise or lower it until the gap across the top of the door is about 5/16 inch (8 mm), and the gaps at the front and rear vertical edges of the door are about 3/8 inch (9 mm).



1. Adjusting Capscrews

Fig. 1, Fore-and-Aft and Up-and-Down Adjusting Capscrews on the Cab

8. Without disturbing the positions of the hinges or striker, carefully open and support the door, then tighten the hinge capscrews 11 to 13 lbf·ft (14 to 18 N·m).
9. Open the door and securely tighten the striker. From outside the cab, partially close the door until the latch jaws are about 1 to 2 inches (25 to 50 mm) from the striker. Be sure the striker is horizontal, and centered in the latch jaw when the door is closed. If needed, reposition the striker.
10. Tighten the striker screws 11 to 13 lbf·ft (14 to 18 N·m), then close the door and recheck the door alignment.
11. Install the cowl side panel.



1. Adjusting Capscrews

Fig. 2, In-and-Out Adjusting Capscrews on the Door

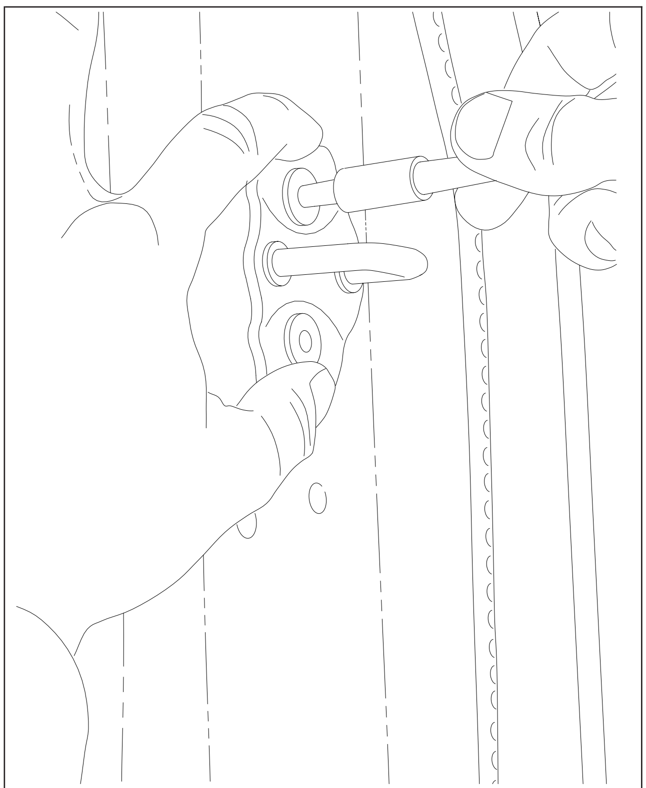


Fig. 3, Striker Adjustment

In-and-Out Adjustment

Poor in-and-out adjustment of the door is often indicated by hard closing of the door, wind and water leaks around the edge of the door, or premature wear of the door seal.

1. With the tires chocked, check the in-and-out adjustment of the door. The outer surface of the door should be flush, within ±3/64 inch (±1 mm), with the surface of the cab skin at *both* its front and rear edges. If adjustment is needed, follow the steps below.
2. If only the rear edge of the door needs adjusting, go to step 6.
3. If the front edge of the door needs adjusting, mark the vertical and horizontal positions of the hinge before loosening them for adjustment.
4. Loosen the capscrews that attach the hinges to the door frame, but keep them tight enough to prevent unintentional hinge movement. See **Fig. 2**.

NOTICE

Do not modify the holes in the hinge to allow for extra adjustment. This could affect the strength of the hinge and damage can result.

5. Carefully close the door, then move the front edge of the door in or out until the outer surface is flush, within ±3/64 inch (±1 mm), with the surface of the cab skin. Be careful not to disturb the up-and-down adjustment.

   If the door cannot be moved sufficiently to bring the upper corner into specified alignment, a shim(s) (part number 18-47661-000) may be added at the lower hinge on the cab side.
6. Without disturbing the positions of the hinges, carefully open and support the door, then tighten the hinge capscrews 11 to 13 lbf·ft (14 to 18 N·m).
7. If the rear edge of the door needs adjusting, mark the vertical and horizontal positions of the latch striker before loosening it for adjustment.
8. Loosen the striker (**Fig. 3**), then tighten it just enough to prevent unintentional movement.
9. Carefully close the door, then move the rear edge of the door in or out until the outer surface

is flush, within ±3/64 inch (±1 mm), with the surface of the cab skin. Be careful not to disturb the up-and-down adjustment.

10. Without disturbing the position of the striker, carefully open the door, then tighten the striker screws 11 to 13 lbf·ft (14 to 18 N·m).

NOTE: The striker must be horizontal when tightened.

11. Close the door and recheck the door alignment.

Striker Adjustment

For secure door closure, check the alignment of the latch and striker even if the striker was not loosened.

1. With the tires chocked, partially close the door and make sure that the striker is centered with the latch jaws. Only the center of the striker should contact the latch jaws.
2. Close the door. It should not move up or down as the latch jaws engage the striker.
3. Make sure that the latch jaws will just clear the striker head when the door is closed. If necessary, loosen the striker, then reposition it.
4. Repeat the previous two steps as needed, until the striker is correctly positioned. Tighten the striker screws 11 to 13 lbf·ft (14 to 18 N·m).

NOTE: The striker must be horizontal when tightened.

5. Carefully close the door to the fully latched position (second click). From outside the cab, check the in-and-out, fore-and-aft, and up-and-down positioning of the door.

Window Regulator

To field test a power window regulator, follow the procedure in **Table 1**.

NOTE: Power window regulators are equipped with automatic reset internal thermal protection to prevent motor damage from electrical failure or overuse. Depending on the air temperature, window load, and amount of use, the protection may trip after two or three window cycles. This is normal and is not considered to be a defect. Allow the motor to cool at least 10 minutes to reset the thermal protection before testing.

To field test a manual window regulator, follow the procedure in **Table 2**.

Power Window Regulator Not Working			
Step	**Test Procedure**	**Test Result**	**Action**
1	Check the fuse for the window regulators. Is it open?	Yes	Replace the fuse. Continue troubleshooting for a short in the system.
		No	Go to **step 2**.
2	Check the battery. Is it fully charged?	Yes	Go to **step 3**.
		No	Charge the battery.
3	Remove the interior door panel. Check for battery voltage at the window regulator terminals. With the window rocker switch in the neutral position, connect a voltmeter to the two terminals where the wiring harness connects to the window regulator motor. Is voltage present?	Yes	A shorted switch may have caused the internal circuit protection in the motor to trip. Correct the problem, allow the motor to cool for 10 minutes, then check for voltage again.
		No	Go to **step 4**.
4	With the window rocker switch pushed to the "DOWN" position, check the voltage at the regulator terminals. Also check the voltage with the rocker switch pushed to the "UP" position. What is the voltage reading?	11–15 volts	Go to **step 5**.
		Below 11 or above 15 volts	Check the battery for a full charge, then check the rocker switch for excessive resistance. Repair or replace the switch as needed.
		No voltage	Check the rocker switch for proper function. Replace as needed.
5	Remove the screws that attach the glass to the regulator. Is the glass free to move up and down within the run channels without binding?	Yes	Go to **step 6**.
		No	Adjust the glass run channels, or correct the binding condition. Go to **step 6**.
6	Attach the glass to the regulator, leaving the screws loose so that the glass is free to move slightly from side to side. Test the regulator. Does the regulator work properly with the glass mounting screws loosened?	Yes	Check the regulator mounting alignment, adjust if needed, then tighten the screws. Repeat as necessary.
		No	Go to **step 7**.
7	Test the regulator operation. Does it work properly?	Yes	Troubleshooting is completed.
		No	Replace the window regulator.

Table 1, Power Window Regulator Not Working

Troubleshooting

Manual Window Regulator Not Working or Noisy, Window Glass Binding			
Step	**Test Procedure**	**Test Result**	**Action**
1	Remove the interior door panel to gain access to the window regulator.	—	—
2	Are the regulator mounting screws tight, and is the glass secured to the regulator.	Yes	Go to **step 3**.
		No	Correct any problems and retest.
3	Disconnect the glass from the regulator. Is the glass free to move up and down within the run channels without binding?	Yes	Check that the glass attachment point of the regulator moves when the handle is cranked. If it does not, replace the regulator. Otherwise, go to **step 4**.
		No	Adjust the glass run channels, or correct the binding condition. Go to **step 4**.
4	Connect the glass to the regulator, leaving the screws loose so that the glass is free to move slightly from side to side. Crank the handle. Does the regulator work properly with the glass mounting screws loosened?	Yes	Raise and lower the glass completely, then tighten the glass mounting screws.
		No	Loosen the regulator mounting screws and try to adjust the regulator alignment for proper operation. The glass also may need to realigned after any adjustments to the regulator.
5	Test the regulator operation. Does it work properly?	Yes	Troubleshooting is completed.
		No	Replace the window regulator.

Table 2, Manual Window Regulator Not Working or Noisy, Window Glass Binding

Specifications

Unless listed in **Table 1**, tighten all fasteners using the torque specifications found in **Section 00.04**.

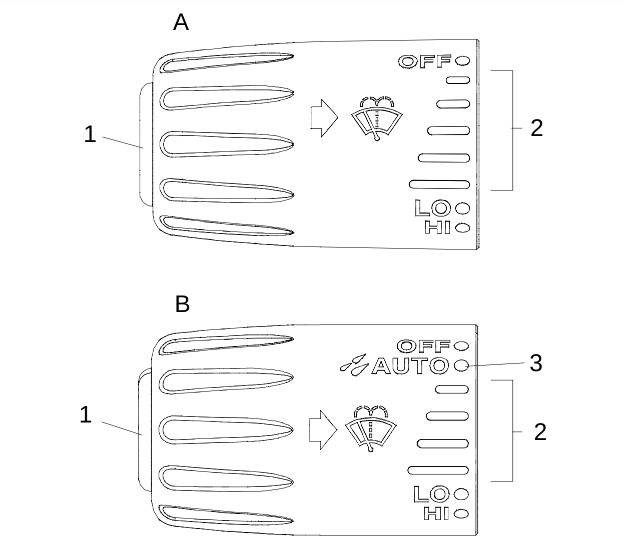
Torque Specifications				
Fastener Description	**lbf·ft**	**N·m**	**lbf·in**	**N·cm**
Interior Door-Pull Handle Screws	11–13	14–18	—	—
Interior Door-Latch Handle Screws	—	—	50–70	600–800
Door Hinge Capscrews, M8	11–13	14–18	—	—
Door Check-to-Door Nuts, M6	—	—	50–70	600–800
Door Check-to-Cab Screws, M6	—	—	50–70	600–800
Latch Assembly Mounting Screws	—	—	50–70	600–800
Exterior Latch Rod Adjustment Screw	—	—	15–25	170–280
Glass Channel Mounting Screws	—	—	60	700
Operable Vent Window Glass-Mounting Screws	—	—	50–70	600–800
Window Regulator Clamp	—	—	55–64	625–725
Vent-Window Frame Mounting Screws	—	—	36	400
Striker Screws	11–13	14–18	—	—

Table 1, Torque Specifications

General Information

The windshield wipers are operated by a switch at the end of the turn signal lever. See **Fig. 1**. To turn the windshield wipers on, turn the switch to the low speed, high speed, or any of the intermittent speeds. An optional automatic position will turn the windshield wipers on when rain is detected.

The windshield washer is operated by pressing the windshield washer button on the end of the windshield wiper switch. When the washer button is pressed less than 0.5 of a second, the wiper/washer provides one dry wipe or mist. When the washer button is pressed for 0.5 to 1.0 second, the wiper/washer provides three wipes and a wash. When the washer button is held in, the wash cycle will continue until the washer button is released.



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A. Standard Windshield Wiper Switch
B. Optional Windshield Wiper Switch
1. Windshield Washer Button
2. Intermittent Wiper Speeds
3. Automatic Wiper Position

Fig. 1, Windshield Wiper Switches

Replacement

1. Turn off the engine, apply the parking brakes, and chock the rear tires.
2. Make sure the wiper blades are parked. If necessary, park them by turning the wipers on and then off.

WARNING

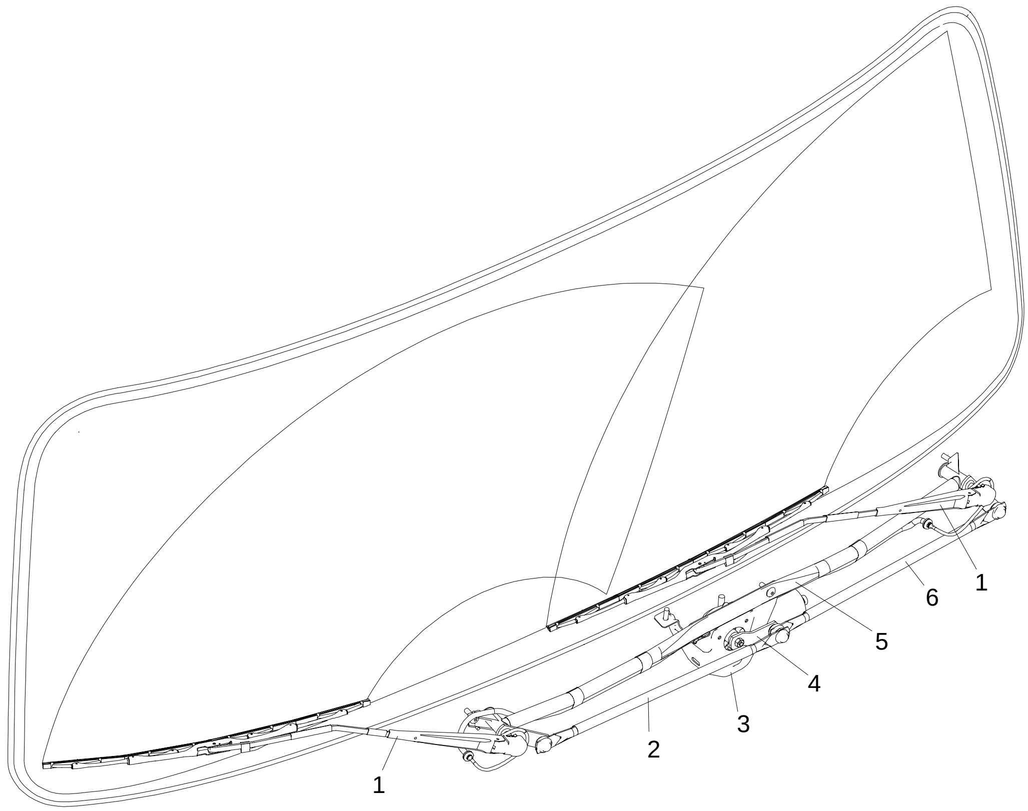
Disconnect the batteries before working on the wiper assembly. This will prevent the windshield wiper motor from cycling. The motor could cycle if the wiper linkage driveshaft is forced out of the parked position, which could result in personal injury.

3. Disconnect the batteries.
4. Open the hood.

NOTE: The wiper arms are different lengths. Note which wiper arm belongs on the right and left sides.

5. Remove the wiper arms and washer hoses.
6. Remove the fasteners that attach the unitizing tube to the cab. See **Fig. 1**.
7. Disconnect the wiring harness from the wiper motor.
8. Remove the unitizing tube.
9. Remove the nut and lockwasher that attach the motor lever to the wiper motor. Remove the motor lever.
10. Remove the seals and connecting arms from the pivot levers.
11. Remove the capscrews that attach the wiper motor to the wiper motor bracket. Remove the wiper motor.
12. Using capscrews, attach the wiper motor to the wiper motor bracket on the new unitizing tube.
13. Using a nut and lockwasher, attach the motor lever to the wiper motor. Torque the nut 9 to 12 lbf·ft (12 to 16 N·m).
14. Inspect the seals for wear and damage. Replace if necessary.
15. Attach the seals and connecting arms to the pivot levers.
16. Connect the wiring harness to the wiper motor.
17. Using fasteners, attach the unitizing tube to the cab.
18. Attach the wiper arms to the wiper pivot shafts.
19. Connect the batteries.
20. Lower the hood.
21. Remove the chocks from the tires.

Unitizing Tube Replacement



1. Wiper Arm
2. Right-Side Connecting Arm
3. Wiper Motor
4. Motor Lever
5. Unitizing Tube
6. Left-Side Connecting Arm

Fig. 1, Wiper Assembly

Replacement

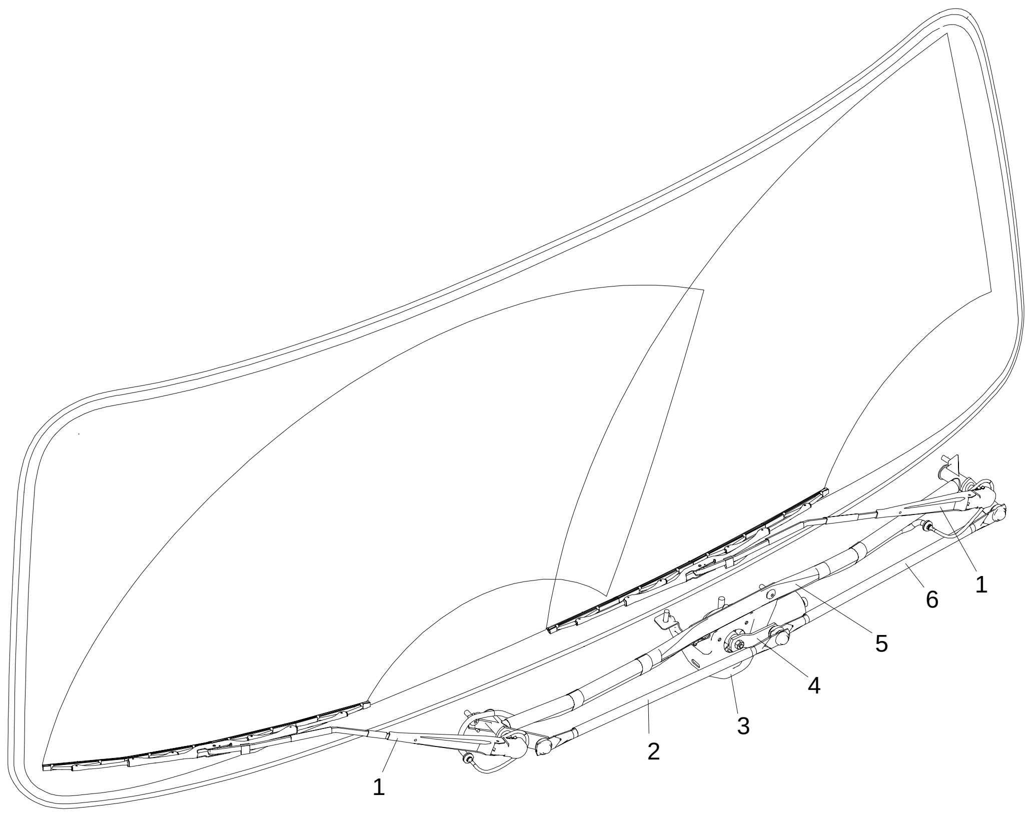
1. Turn off the engine, apply the parking brakes, and chock the rear tires.

WARNING

Disconnect the batteries before working on the wiper assembly. This will prevent the windshield wiper motor from cycling. The motor could cycle if the wiper linkage driveshaft is forced out of the parked position, which could result in personal injury.

2. Disconnect the batteries.
3. Open the hood.
4. Remove the seals and connecting arm from the pivot lever and motor lever. See **Fig. 1**.
5. Inspect the seals for wear and damage. Replace if necessary.
6. Use grease to lubricate the inner diameter of the open socket on the connecting arm. See **Fig. 2**.
7. Fill the ball stud and socket interface with grease.
8. Attach the connecting arm to the pivot lever and motor lever.
9. Lower the hood.
10. Connect the batteries.
11. Remove the chocks from the tires.

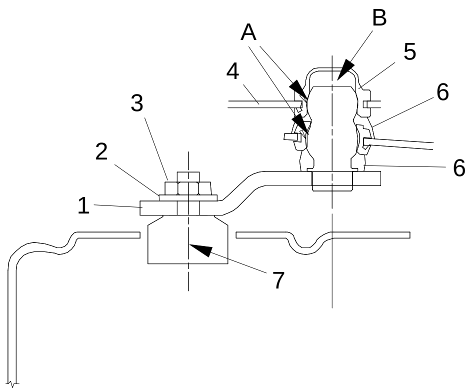
Connecting Arm Replacement



1. Wiper Arm
2. Right-Side Connecting Arm
3. Wiper Motor
4. Motor Lever
5. Unitizing Tube
6. Left-Side Connecting Arm

Fig. 1, Wiper Assembly

Connecting Arm Replacement



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A. Grease the inner diameter of the open socket before assembly.
B. Fill the ball stud and socket interface with grease.
1. Motor Lever
2. Lockwasher
3. Nut
4. Connecting Arm
5. Double Ball Stud
6. Seal
7. Centerline of Motor Output Shaft

Fig. 2, Wiper Motor Output Shaft Detail

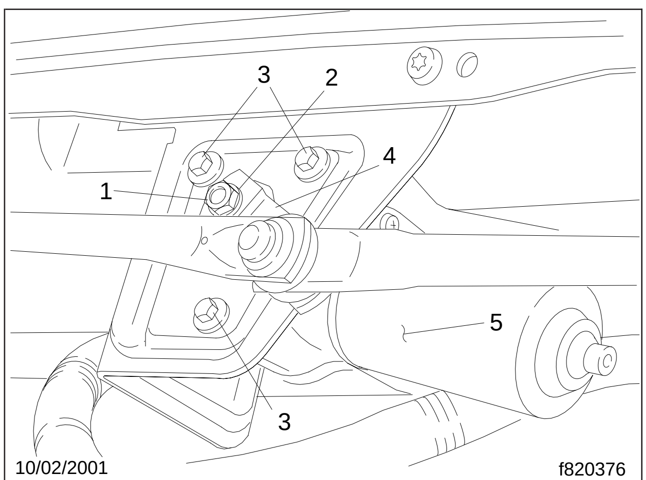
Replacement

1. Turn off the engine, apply the parking brakes, and chock the rear tires.
2. Make sure the wiper blades are parked. If necessary, park them by turning the wipers on and then off.

WARNING

Disconnect the batteries before working on the wiper assembly. This will prevent the windshield wiper motor from cycling. The motor could cycle if the wiper linkage driveshaft is forced out of the parked position, which could result in personal injury.

3. Disconnect the batteries.
4. Open the hood.
5. Remove the nut and lockwasher that attach the motor lever to the wiper motor. See **Fig. 1**. Remove the motor lever.



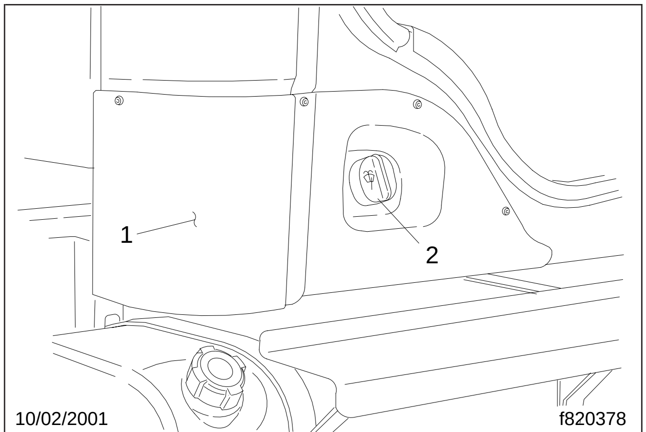
1. Nut
2. Lockwasher
3. Capscrew
4. Motor Lever
5. Wiper Motor

Fig. 1, Wiper Motor Assembly

6. Remove the capscrews that attach the wiper motor to the mounting bracket.
7. Disconnect the wiring harness from the wiper motor. Remove the wiper motor.
8. Connect the wiring harness to the new wiper motor.
9. Using capscrews, attach the wiper motor to the mounting bracket.
10. Using a nut and lockwasher, attach the motor lever to the wiper motor. Torque the nut 9 to 12 lbf·ft (12 to 16 N·m).
11. Connect the batteries.
12. Lower the hood.
13. Remove the chocks from the tires.

Replacement

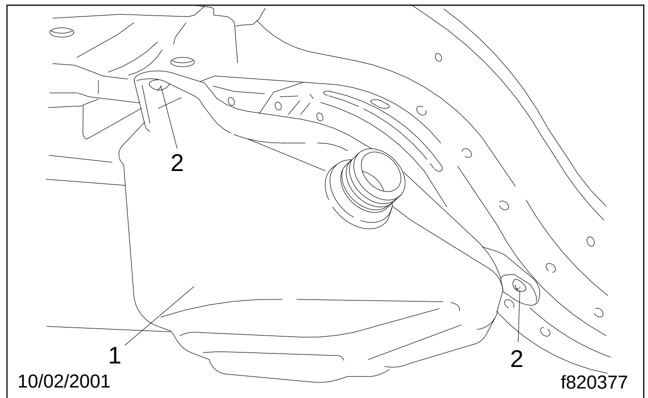
1. Turn off the engine, apply the parking brakes, and chock the rear tires.
2. Disconnect the batteries.
3. Open the hood.
4. Remove the washer reservoir cap.
5. Remove the Torx® fasteners that attach the washer reservoir cover to the right side of the cab. See **Fig. 1**. Remove the cover.



1. Washer Reservoir Cover
2. Washer Reservoir Cap

Fig. 1, Washer Reservoir Cover

6. Drain the washer reservoir if necessary.
   6.1 Place a container under the washer reservoir.
   6.2 Remove the washer hose from the pump and attach a hose long enough to reach the container.
7. Remove the wiring harness from the washer reservoir pump.
8. Remove the washer fluid line from the washer reservoir.
9. Remove the nut and Torx fasteners that attach the washer reservoir to the cab. See **Fig. 2**
10. Remove the pump from the washer reservoir.
11. Attach the pump to the new washer reservoir.



1. Washer Reservoir
2. Torx Fastener

Fig. 2, Washer Reservoir

12. Attach the washer fluid line to the washer reservoir.
13. Attach the wiring harness to the pump.
14. Using Torx fasteners and a nut, attach the washer reservoir to the cab.
15. Fill the washer reservoir with washer fluid if necessary. If the washer hose was removed, connect the short washer hose to the pump.
16. Using Torx fasteners, attach the washer reservoir cover to the right side of the cab.
17. Lower the hood.
18. Remove the chocks from the tires.

Thermodynamic Principles

Air conditioning works by removing heat and humidity from the air in the passenger compartment. This is accomplished through three thermodynamic principles; the principles and how they work in a vehicle are described below.

Heat Transfer

Heat always moves from warm areas to cold ones. Cold does not move from cold areas to warm ones. Air conditioners work by absorbing heat and carrying it away, not by generating cold air, although since the heat has been absorbed from it, the air coming from an air conditioner feels cold.

If two objects, one hot, one cold, are near each other, the heat energy in the warmer object will always travel to the lower heat energy area of the cooler object, until they are equal temperature. Higher energy flows to low energy; low energy never flows to high energy.

The British Thermal Unit (BTU) is used to determine the amount of heat transferred from one object to another. One BTU is the amount of heat energy required to raise the temperature of 1 pound (0.45 kg) of water 1°F (0.55°C).

For example, to raise the temperature of 1 pound (0.45 kg) of water from 32°F to 212°F (0°C to 100°C), one BTU must be added for 1°F (0.55°C) rise in temperature, a total of 180 BTUs. Conversely, in order to lower the temperature of 1 pound (0.45 kg) of water from 212°F to 32°F (100°C to 0°C), 180 BTUs must be removed from the water.

Latent Heat of Vaporization

As a liquid boils, it absorbs heat without raising the temperature of the resulting gas. When gas condenses, changing back to a liquid, it gives off heat without lowering the temperature of the resulting liquid.

For example, when a container holding 1 pound (0.45 kg) of water at 32°F (0°C) is heated, the temperature of the water rises 1°F (0.55°C) with each BTU energy that the water absorbs. After it absorbs 180 BTUs, raising its temperature 180°F (100°C), the water reaches a temperature of 212°F (100°C). This is the boiling point of water at standard sea level conditions.

Even though it continues absorbing more heat, the water temperature cannot go above 212°F (100°C) so that as it boils, it changes from liquid water to the vapor commonly called steam. It continues to absorb heat and boil until the entire pound of water has passed off into the atmosphere as steam. Under normal conditions the steam rapidly gives off its heat to the surrounding air, but it rises from the water at a temperature of 212°F (100°C).

In other words, the water and vapor temperatures can rise only 180°F (from 32°F to 212°F [0°C to 100°C]) at sea level pressure, even though many more than 180 BTUs are absorbed. The heat absorbed by the liquid in the process of boiling dissipates from the vapor into the cooler surrounding air, and the vapor condenses back to water.

The heat transferred as substances change their physical state, such as water boiling to vapor, and vapor condensing back to water, is called the latent (or hidden) heat of vaporization. Latent heat varies widely among various materials.

Water has a latent heat of vaporization of 970 BTUs and a boiling point of 212°F (100°C). This means that 1 pound (0.45 kg) of water at 212°F (100°C), will absorb 970 BTUs when changing completely to vapor at 212°F (100°C). Conversely, the vapor will give off 970 BTUs when condensing back to water at 212°F (100°C).

This heat energy transfer, occurring when a liquid boils or a vapor condenses, is a basic principle of all conventional refrigeration systems.

For a liquid to be a refrigerant, it must also have a low boiling point. That is, the temperature at which it boils must be lower than the temperature of the substance to be cooled.

R–134a is a TFT refrigerant, less damaging to the atmosphere than CFC refrigerants such as R12. R–134a has a temperature/pressure relationship which makes it suitable for vehicle air conditioning systems.

Effect of Pressure on Boiling or Condensation

Refrigerant circulates through part of the air conditioning system under high pressure. It expands to a lower pressure vapor in the evaporator, then flows to the refrigerant return port in the compressor. As pressures in the closed refrigerant circuit vary, the temperature of the refrigerant also varies: as pressure increases, temperatures increase; as the pressure decreases, temperatures decrease. In its low pressure gaseous state in the evaporator, a good refrigerant such as R–134a absorbs a large amount of heat from the cab, and carry the heat to the condenser where it transfers into the outside air.

Heating, Ventilation and Air Conditioning (HVAC) System General Description

Stated simply, the air conditioning system operates by circulating refrigerant between two heat transfer units. The unit in the cab absorbs heat from the air in the cab, and the one in front of the radiator gets rid of the heat from the cab, into the outside air. Both units consist of coiled tubing, covered with fins so they transfer heat most efficiently.

The heat transfer unit in the cab is called the evaporator. It is mounted in the dashboard, next to the blower fan. It absorbs heat out of the air in the cab and transfers it to the refrigerant, which carries the heat away. The other heat transfer unit, called the condenser, is usually mounted low in the front end of the vehicle. Hot refrigerant from the evaporator circulates to it, and gives off the stored heat to the air being pulled in by the engine cooling fan and the vehicle's forward movement.

Inside the cab, the blend air heating, ventilating, and air conditioning (HVAC) system uses a brushless blower motor to circulate temperature-controlled air through the cab. The rate of airflow is controlled by a multi-speed fan switch.

The temperature control switch on the climate control panel sets the desired temperature in the cab.

The air selection switch on the control panel controls ducting air from the blower through the cab. On vehicles with air conditioning, a recirculation button on the control panel allows the driver to recirculate the air in the cab and prevent fresh outside air from entering the system.

Recirculation mode helps to warm or cool the cab more quickly, but the cab tends to build more humidity and fog the windows in recirculation mode. Allowing fresh air to enter the system and circulate helps defog the cab.

On vehicles built prior to May 2, 2003, the system automatically returns to the fresh air mode and the recirculation light turns off, after being in the recirculation mode for 20 minutes. Pushing the recirculation button again returns the system to recirculation mode for another 20 minutes. If the recirculation button is pressed in recirculation mode before 20 minutes have passed, the system will switch to the fresh air mode.

On vehicles built from May 2, 2003, the system automatically enters partial recirculation mode for five minutes, to bring some fresh air into the cab. After five minutes in partial recirculation mode, the system will automatically resume full recirculation for another 20 minutes. The full and partial recirculation cycle will repeat as long as the system remains in recirculation mode. If the recirculation button is pressed when the system is in either recirculation mode, recirculation mode will be canceled. There may be a slight change in the sound within the cab as the system goes into, and out of, partial recirculation mode.

Description of Components

Actuator

The actuator is a combined motor and gearbox which drives the levers and doors within the HVAC assembly. Movement of the levers and doors is controlled by the settings on the climate control panel. A proportional feedback signal is returned from each actuator to the control panel to provide current position information. There are three actuators on the HVAC assembly: a temperature blend actuator, a recirculation actuator, and an air distribution actuator.

Binary Switch

A binary switch disengages the refrigerant compressor clutch, to protect the compressor from harmful operating conditions. It performs two functions.

- If refrigerant system pressure falls too low, the binary switch disengages the compressor clutch. This happens when falling pressure drops below 25.6 to 31.2 psig (177 to 215 kPa). Normal compressor operation resumes when the pressure rises to 25.7 to 34.3 psig (177 to 236 kPa).

- If the refrigerant system pressure rises above 426.5 to 483.5 psig (2941 to 3334 kPa), the binary switch shuts off the compressor clutch. When system pressure falls back to 313 to 426 psig (2158 to 2937 kPa), the compressor resumes operation.

Blower Motor

The brushless blower motor forces air through the HVAC evaporator, and through the duct work into the cab.

Climate Control Panel (control head)

The fan switch, air selection switch, and the temperature control switch are mounted on the climate control panel, which is also called the control head. On HVAC systems with air conditioning, the air recirculation button is mounted on the climate control panel.

The climate control panel is controlled by a microprocessor and backlit with LEDs (light-emitting diodes).

Condenser

In the condenser, the hot refrigerant gas coming from the compressor turns back into liquid. As it condenses to liquid, the refrigerant gives off the heat it has carried out of the cab. The heat goes out through the condenser tubing and cooling fins, to the air currents created by the engine fan and vehicle movement.

Evaporator

Because the evaporator is an area of low pressure in the system, the boiling point of the refrigerant falls, which helps it absorb heat from the tubing walls and fins of the coils. As it absorbs heat, liquid refrigerant quickly boils and turns into a gas.

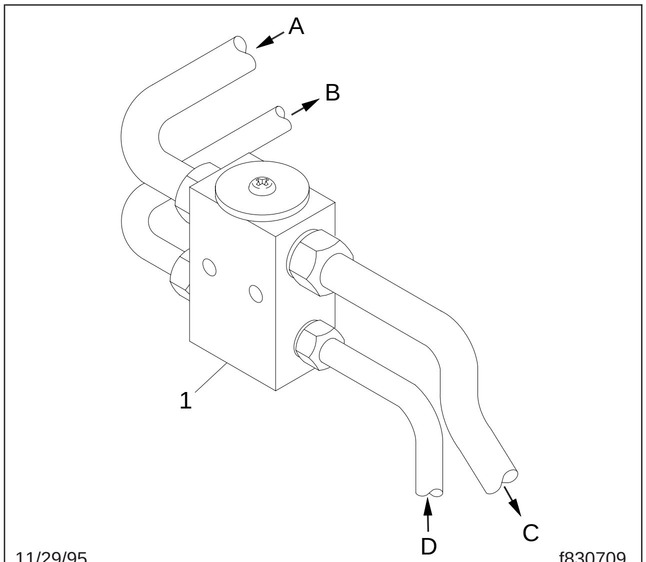
As heat is absorbed through the outside surfaces of the evaporator, air passing over the unit loses its heat to these cooler surfaces. Moisture in the air condenses on the outside of the evaporator and drains off as water, dehumidifying the air in the cab.

Evaporator Probe

The temperature of the evaporator is monitored by a variable resistance temperature probe. As the temperature of the evaporator increases, the temperature probe resistance decreases. The evaporator temperature probe is connected to the control head, which controls operation of the refrigerant compressor through the bulkhead module in order to prevent the evaporator core from freezing. When the evaporator temperature reaches 38.3°F (3.5°C), the control head sends a message to the bulkhead module to disengage the refrigerant compressor clutch. The refrigerant compressor will not resume operation until the temperature has risen above 40.1°F (4.5°C).

Expansion Valve

The expansion valve divides the high and low pressure areas of the refrigerant system. high pressure liquid refrigerant from the receiver-drier passes through the expansion valve, and moves into the low pressure area of the evaporator. See **Fig. 1** and **Fig. 2**.

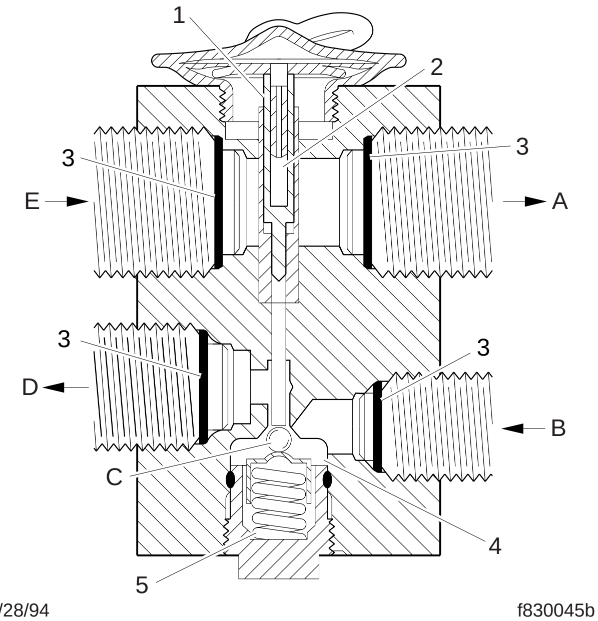


A. From the evaporator
B. To the evaporator
C. To the refrigerant compressor
D. From the receiver-drier

1. Expansion Valve

Fig. 1, Expansion Valve Refrigerant Lines

General Information



A. To the compressor
B. From the receiver-drier
C. Bleed at the ball seat
D. To the evaporator
E. From the evaporator

1. Internal Equalization Passage
2. Temperature Sensor
3. O-Ring
4. Metering Orifice
5. Ball and Spring

Fig. 2, Expansion Valve

The expansion valve proportions the flow rate of refrigerant according to the rate of evaporation in the evaporator. If the amount of liquid in the evaporator drops off, the temperature of the gas going to the compressor rises. This causes a sensor tube in the expansion valve to react to the temperature changes, which causes an orifice in the valve to open or close. Through the orifice, liquid refrigerant is metered into the evaporator.

Fan Cycling Switch

Located on the receiver-drier, the fan cycling switch sends a ground signal to the ECM (electronic control module) to keep the fan turned off, and takes away the ground to engage the fan. The fan will come on if the refrigerant pressure is greater than 300 ±10 psi (2070 kPa ±70 kPa). The fan turns off when the pressure drops below 250 ±10 psi (1725 kPa ±70 kPa).

Heater Core

The heater core is a convoluted tube covered with fins. When the water valve is open, warm engine coolant flows through the heater core tube, heating the tube and fins. The blower motor blows air through the finned tube and into the cab, to heat the cab.

Receiver-Drier

The receiver-drier is a reservoir and filter for liquid refrigerant. It also removes water and acids from the refrigerant. The water-absorbing material (desiccant) in the unit helps stop blockages caused by moisture forming in the expansion valve and other parts of the system.

Refrigerant

Refrigerant is the chemical that absorbs heat from the air in the cab and release it to the air outside the cab.

During compressor operation, refrigerant constantly changes from a gas to a liquid, then back to a gas, depending on whether it is absorbing heat (boiling) in the low pressure evaporator, or releasing absorbed heat in the high pressure condenser.

Refrigerant Compressor

"Heat" in the low pressure gas of the evaporator does not feel warm to the touch, because liquid refrigerant boils at a temperature much lower than the temperature at which water turns to ice. By touch, the "heated" gas in the coils is very cold. As a result, there is the problem of how to remove heat from subfreezing gas using outside air that may be higher than 100°F (38°C).

With a refrigerant compressor, low pressure gas from the evaporator can be squeezed into a much smaller space. When the gas is compressed, the heat it contains becomes concentrated. In this way, the gas is made hotter than the outside air without adding heat.

If the system pressure rises above 550 ± 50 psi (3792 ± 345 kPa), a pressure relief valve will vent, disengaging the compressor clutch until the pressure drops to 400 psi (2758 kPa).

A second purpose of the compressor is to move refrigerant through the system.

Definition of Terms

Refer to the following terms for a better understanding of the heater and air-conditioning system.

Air Conditioner A system used to control the temperature, humidity, and movement of air in the cab.

Air Cylinder Air-operated device used to open or close vents through which air is pushed into the cab by the blower.

Ambient Air Temperature The temperature of air around an object or the outside temperature.

Binary Switch This switch disengages the refrigerant compressor clutch to protect the compressor from harmful operating conditions.

Blower Motor A blower motor forces air through the HVAC assembly and through the duct work.

Blower Resistor Block Assembly Inline resistors that control the amount of voltage going to the blower motor. By controlling the voltage, you can control the fan speed.

Boiling Point The temperature at which a liquid changes to a gas. The boiling point varies with pressure.

Bulk Charging Use of large containers of refrigerant for charging a refrigerant system. Normally used for charging empty systems.

Charge A specific amount of refrigerant or oil by volume or weight. Also the act of placing an amount of refrigerant or oil into the air conditioning system.

Clutch Cycling Switch (Thermostatic Switch) Engages or disengages the compressor depending on changes in evaporator temperature.

Condensate Water taken from the air, which forms on the outer surface of the evaporator.

Condenser A heat exchanger that is used to remove heat from refrigerant, changing it from a high pressure hot gas to a high pressure warm liquid. Typically the condenser is mounted in front of the radiator.

Contaminants Anything other than refrigerant or refrigerant oil in the system. Usually means water, dirt, or air in the system.

Dehumidify To remove water from the air at the evaporator.

Dehydrate To remove all traces of moisture from the refrigerant system. This process occurs during evacuation.

Desiccant A drying agent used in the receiver-drier to remove moisture and maintain an extremely dry state.

Discharge Line Connects the refrigerant compressor outlet to the condenser inlet.

Discharge Pressure High-side pressure, or condensing pressure, of the refrigerant being discharged from the compressor.

Discharge Service Valve A device that allows high-side pressure to be checked and other service operations to be performed. This valve is located between the receiver-drier and the expansion valve.

Drive Pulley A pulley attached to the front of the engine crankshaft. It drives the compressor clutch pulley with a belt.

Duct A passageway for the transfer of air from one point to another.

Evacuate To place a high vacuum in the refrigeration system to remove air, and dehydrate, or remove traces of moisture.

Evaporate A change of state from a liquid to a gas.

Evaporator A component in which liquid refrigerant changes to a gas after it absorbs heat from the air. Also removes some moisture from the cab air.

Expansion Valve A device that causes a pressure-drop of the refrigerant and also regulates its flow.

Flooding A condition caused by too much liquid refrigerant going into the evaporator. Usually caused by an expansion valve that is stuck open.

Flushing A process of passing liquid refrigerant through an air conditioner component to remove dirt and water from the part. Liquid refrigerant removes heavy contamination, such as gritty dirt and large dirt buildup.

Freeze-Up Failure of a unit to operate properly because of ice forming at the expansion valve orifice or on the evaporator.

General Information

Heater Core A part of the heating system through which hot engine coolant flows to provide heat to the cab, or to adjust the temperature produced by the air conditioner.

Humidity The amount of water vapor in the air.

Hydraulic Lock The return of liquid refrigerant to the compressor, which could destroy the unit.

Leak Detector Any device used to detect refrigerant leaks in a refrigerant system.

Liquid Line high pressure liquid refrigerant is carried back to the evaporator from the condenser by the liquid line to repeat the evaporation/condensation cycle.

Liquid Pressure Pressure of refrigerant in the liquid line from the condenser to the expansion device.

Low Head Pressure High-side pressure that is lower than normal due to a system problem.

Low Suction Pressure Low-side pressure that is lower than normal due to a system problem.

Magnetic Clutch An electrical coupling device used to engage or disengage the compressor.

Manifold Designed to control refrigerant flow for system test purposes. It is used with manifold gauges.

Manifold Gauge A calibrated instrument used for measuring system pressures.

Manifold Gauge Set A manifold that is complete with gauges and charging hoses and is used to measure or test pressure.

Micron A metric unit of length equal to one-millionth of a meter. This unit of measure is used to measure vacuum drawn from a refrigerant system by a vacuum pump.

Nitrogen A colorless, odorless, dry, inert gas.

Opacity A measure of contamination of refrigerant oil in the compressor. Fresh refrigerant oil is clear; when contaminated, it appears cloudy or may have fine particles held in suspension.

Overcharge Too much refrigerant or oil in the system.

Polyalkylene Glycol (PAG) A highly refined synthetic oil used in R–134a air conditioning systems.

Polyol Ester (POE) A highly refined synthetic oil used in R–134a air conditioning systems.

PSIA Pounds per square inch, absolute pressure. Pressure exerted by the air at sea level. Atmospheric pressure is usually measured with a mercury barometer.

PSIG Gauge pressure, relative to the local atmosphere. At sea level, 0 PSIG is about 14.7 PSIA, which is standard atmospheric pressure. But in Denver, which is at about 5000 feet altitude, standard atmospheric pressure and PSIG are about 12.5 PSIA. It is possible to have a negative gauge pressure, indicating a vacuum.

Receiver-Drier A combination desiccant, filter, and storage container for liquid refrigerant.

Recovery Removal of the refrigerant from the air conditioning system.

Recycling Removal of contaminants and moisture from R–134a using a recovery and recycling station.

Refrigerant–134a (R–134a) The cooling agent used in automotive air conditioning systems. The chemical name for R–134a is tetrafluoroethane.

Refrigerant Compressor A device used to draw low pressure refrigerant gas from the evaporator and squeeze it into a high-temperature, high pressure gas. A second purpose of the compressor is to move refrigerant through the system.

Refrigeration Cycle The complete circulation of refrigerant through an air conditioning system, accompanied by changes in temperature and pressure.

Relative Humidity The actual water content of the air in relation to the total water the air can hold at a given temperature.

Resistor A voltage-dropping device, usually wire wound, for controlling fan speed.

Sensor A temperature- or pressure-sensing unit that is used to sense air temperatures or pressures, and provide a control voltage for operation of automatic temperature control units.

Suction Line The line connecting the evaporator outlet to the compressor inlet.

Suction Pressure Compressor inlet pressure or the system’s low-side pressure.

Suction Service Valve A device that allows low-side pressure to be checked and other service operations to be performed. This valve is located between the evaporator and the compressor.

Suction Side The low pressure area of the system, extending from the expansion valve to the compressor inlet.

Thermistor A vacuum pressure sensor that is used to measure, in microns of mercury, the internal system vacuum level after evacuation.

Thermostatic Vacuum Gauge A high-vacuum gauge sensitive to pressures ranging from atmospheric pressure to less than 1 micron of mercury, with scales reading from 25,000 microns to 1 micron of mercury.

Thermostatic Switch A temperature-sensitive switch used to control system temperature and prevent evaporator freeze-up. It does this by controlling the compressor's clutch operation.

Undercharge A system low on refrigerant resulting in lack of cooling and possible compressor damage.

Vacuum Refers to pressure that is less than atmospheric pressure.

Vacuum Pump A mechanical device used to evacuate and create a high vacuum in the refrigerant system.

Vacuum Pump Oil Water soluble oil used in some vacuum pumps to absorb moisture from the refrigerant system.

Vapor The gaseous state of a material.

Water Regulating Valve The mechanically or electronically controlled valve, used for controlling the flow of coolant to the heater core.

Principles of Operation

In a blend air system, the heater core is always filled with hot water. Air enters the HVAC assembly through the blower and blows through the evaporator. If the refrigerant compressor is engaged, the air is cooled by moving the heat from it into the evaporator, where the refrigerant absorbs the heat and carries it away. The temperature blend doors then direct the air through or around the heater core, depending on the climate control settings. The temperature blend doors are used to blend the correct amount of cold and hot air to reach the desired temperature. The temperature blend, air distribution, and recirculation levers and doors are controlled by actuators.

Air Conditioner

When the air conditioner is on, the compressor squeezes the refrigerant into a high-pressure, high-temperature gas. High pressure raises the condensation point of refrigerant gas, which allows the condenser to change it to a liquid. After it is compressed, refrigerant gas passes out of the discharge port of the compressor and on to the condenser.

At the condenser, air passing over the fins absorbs heat from the hot refrigerant gas. As the gas cools, it changes back to a liquid. The liquid moves to the receiver-drier, which filters it and removes traces of moisture and acids.

From the receiver-drier, liquid refrigerant moves to the expansion valve, which meters the flow into the evaporator and acts as a boundary between the high- and low-pressure sides of the system. The metered release of the expansion valve greatly drops the pressure of the liquid, causing it to expand. The pressure drop lowers the boiling point of the refrigerant and causes it to evaporate quickly, as it absorbs heat from air passing over the evaporator. The resulting cool air is forced into the cab by the blower. The heated refrigerant gas is drawn back into the compressor where the cycle is repeated.

Safety Precautions

Whenever repairs are made to any air conditioner parts that hold R–134a refrigerant, you must recover, flush (if contaminated), evacuate, charge, and leak test the system. In a good system, refrigerant lines are always under pressure and you should disconnect them only after the refrigerant charge has been recovered (discharged) at the service valves.

Refrigerant R–134a is safe when used under the right conditions. Always wear safety goggles and non-leather gloves while recovering, evacuating, charging, and leak testing the system. Do not wear leather gloves. When refrigerant gas or liquid contacts leather, the leather will stick to your skin.

WARNING

Use care to prevent refrigerant from touching your skin or eyes because liquid refrigerant, when exposed to the air, quickly evaporates and will freeze skin or eye tissue. Serious injury or blindness could result if you come in contact with liquid refrigerant.

Refrigerant splashed in the eyes should be rinsed with lukewarm water, not hot or cold. Do not rub the eyes. Apply a light bandage and contact a physician right away.

Refrigerant splashed on the skin should be rinsed with lukewarm water, not hot or cold. Do not rub the skin. Apply a light coat of a nonmedicated ointment, such as petroleum jelly. Contact a physician right away.

R–134a refrigerant does not burn at ambient temperatures and atmospheric pressure. However, it can be combustible at pressures as low as 5.5 psig (139 kPa absolute) at 350°F (177°C) when mixed with air concentrations that are greater than 60 percent.

WARNING

R–134a air conditioning systems should not be pressure tested or leak tested with compressed air. Combustible mixtures of air and R–134a may form, resulting in a fire or explosion that could cause personal injury or property damage.

Always work in an area where there is a constant flow of fresh air when the system is recovered, evacuated, charged, and leak tested. R–134a vapors have a slightly sweet odor that is difficult to detect. Frequent leak checks and air monitoring equipment are recommended to ensure a safe working environment.

IMPORTANT: When servicing an R–134a air conditioning system, use only service equipment certified to meet the requirements of SAE J2210 (R–134a recycling equipment). The equipment should be operated only by qualified personnel who are familiar with the recycling station manufacturer’s instructions.

Because of its very low boiling point, refrigerant must be stored under pressure. To prevent the refrigerant containers from exploding, never expose them to temperatures higher than 125°F (52°C).

On R–134a refrigerant systems, polyalkylene glycol (PAG) oil is used in the compressor. When handling PAG oil, observe the following guidelines:

- Keep the oil free of contaminants.
- Do not expose the air conditioning system or the PAG oil container to air for more than five minutes. PAG oil has a high moisture absorption capacity and the oil container should be immediately sealed after each use.
- Use care when handling. Spilled oil could damage painted surfaces, plastic parts, and other components such as drive belts.
- Never mix PAG oil with other types of refrigerant oil.

Replacement

IMPORTANT: Freightliner LLC does not recommend the use of any type of coolant system sealer or leak stop product.

1. Turn off the engine, apply the brakes, and chock the tires.
2. Disconnect the batteries at the negative terminals or at the battery shutoff switch.
3. Remove the air cleaner. For instructions, see **Section 09.01**, Subject 110.
4. Remove the surge tank. For instructions, see **Section 20.01**, Subject 130.
5. Remove the Torx® capscrew that attaches the coolant lines to the heater core. Remove the coolant lines from the heater core.
6. Remove the following dash panels inside the cab. See **Fig. 1**. For instructions, see **Section 60.08**.
   - lower HVAC cover
   - trim plate panel
   - cup holder panel
   - right-hand dash panel
7. Remove the capscrews that attach the temperature blend actuator to the HVAC assembly and remove the temperature blend actuator. See **Fig. 2**.
8. Remove the capscrews that attach the HVAC wiring harness to the HVAC assembly.
9. If the original heater core is being replaced, use a sharp utility knife to cut within the groove on the heater core access panel. Remove and discard the heater core access panel. See **Fig. 3**.

   If there is a heater core service cover in front of the heater core, remove the service cover.

WARNING

Failure to wear protective gloves could result in serious skin cuts due to the sharp edges on the heater core fins.

IMPORTANT: A small amount of antifreeze may be present in the heater core. Protect the interior of the vehicle to prevent any damage from an antifreeze spill.

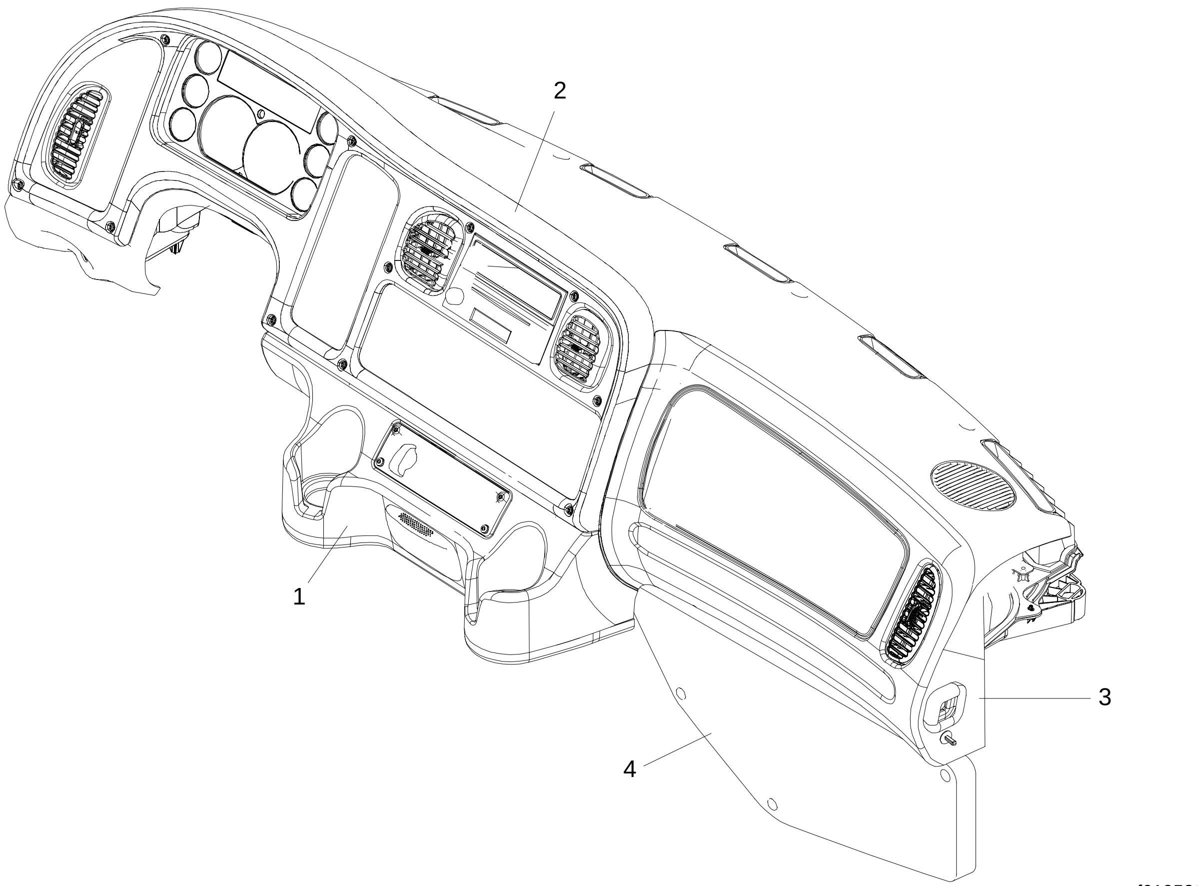
10. Wearing protective gloves, remove the heater core and drain any remaining coolant from the heater core.
11. Remove any debris or coolant that may be in the heater core housing.
12. Wearing protective gloves, install a new heater core in the HVAC assembly.

CAUTION

Do not overtorque the capscrew. Overtorquing the capscrew may crack the heater core.

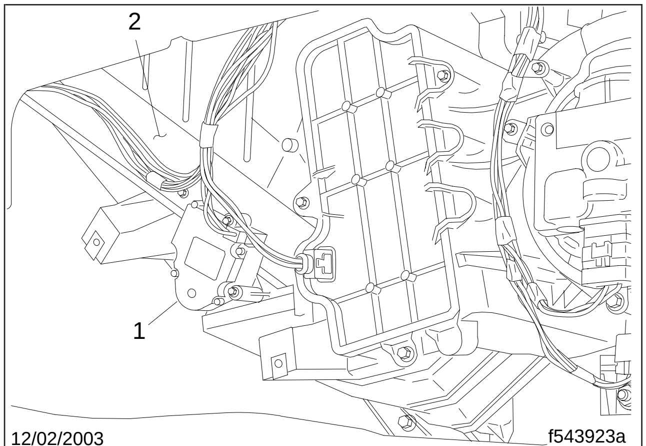
13. Using a Torx capscrew, attach the coolant lines to the heater core and torque the capscrew 30 lbf·in (340 N·cm).
14. Attach the heater core service cover to the HVAC assembly.
15. Using capscrews, attach the HVAC wiring harness to the heater core service cover, securing both the wiring harness and the cover.
16. Using capscrews, attach the actuator to the heater core service cover and the HVAC assembly.
17. Install the dash panels. For instructions, see **Section 60.08**.
18. Install the surge tank. For instructions, see **Section 20.01**, Subject 130.
19. Install the air cleaner. For instructions, see **Section 09.01**, Subject 110.
20. Connect the batteries at the negative terminals or at the battery shutoff switch.
21. Remove the chocks from the tires.

Heater Core Replacement



1. Cup Holder Panel
2. Trim Plate Panel
3. Right-Hand Dash Panel
4. Lower HVAC Cover

Fig. 1, Dash Panels



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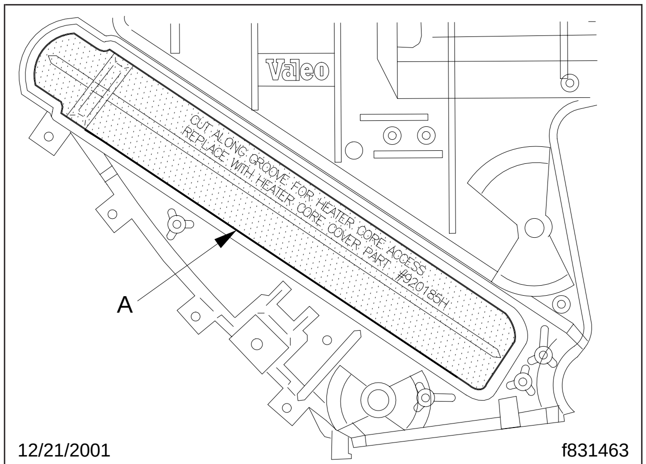
1. Temperature Blend Actuator
2. Heater Core Service Cover

Fig. 2, HVAC Assembly



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A. Cut within the groove on the heater core access panel.

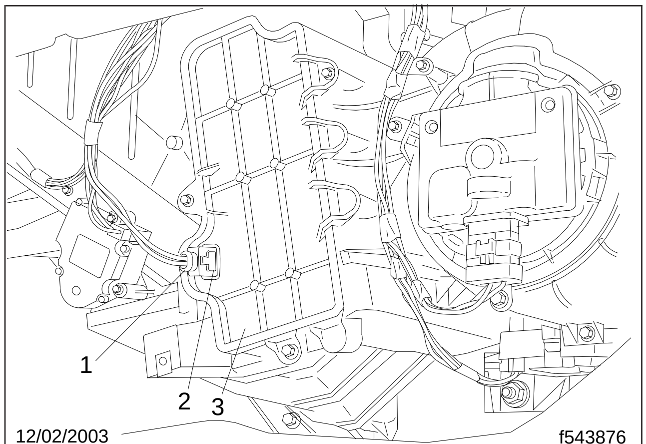
Fig. 3, Heater Core Access Panel

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Open the hood.
3. Recover the refrigerant from the air conditioning system. For instructions, see **Subject 220**.
4. Remove the air cleaner. For instructions, see **Section 09.01**, Subject 110.
5. Remove the surge tank. For instructions, see **Section 20.01**, Subject 130.
6. Remove the capscrew that attaches the refrigerant lines to the expansion valve and remove the refrigerant lines. Quickly cap the refrigerant lines.

IMPORTANT: Under no circumstances should the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

7. Remove the capscrews that attach the expansion valve to the evaporator lines.
8. Remove the lower HVAC cover inside the cab. For instructions, see **Group 60**.
9. Rotate the evaporator probe counterclockwise and pull the evaporator probe out of the evaporator service cover. See **Fig. 1**.
10. Remove the capscrews that attach the evaporator service cover to the HVAC assembly. Remove the evaporator service cover.
11. Remove the filter and the evaporator.
12. Remove the expansion valve from the evaporator.
13. Make sure the new evaporator is covered with the evaporator liner and the evaporator grommet is installed on the evaporator.
14. Uncap the evaporator lines.
15. Using only Mini Stat-O-Seals, replace the Mini Stat-O-Seals on the evaporator lines. Do not lubricate the Mini Stat-O-Seals prior to installation.
16. Using capscrews, install the expansion valve on the evaporator lines. Torque the capscrews 35 lbf·in (395 N·cm).



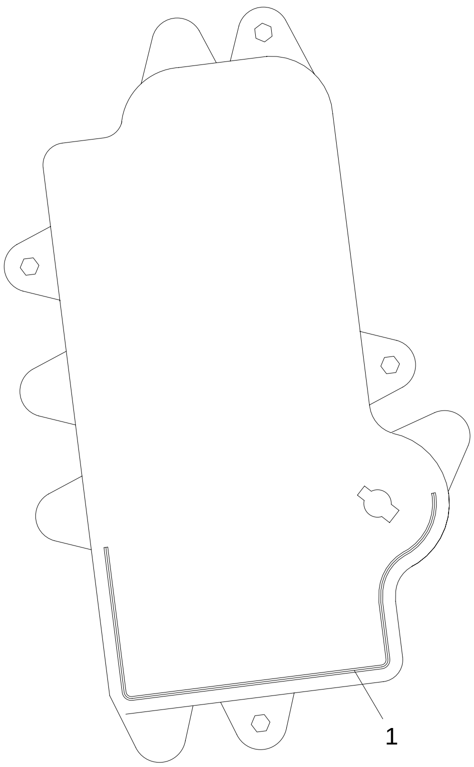
1. Evaporator Probe Wiring Harness
2. Evaporator Probe
3. Evaporator Service Cover

Fig. 1, Evaporator Probe and Service Cover

17. Install the evaporator in the HVAC assembly.
18. Uncap the refrigerant lines.
19. Using only Mini Stat-O-Seals, replace the Mini Stat-O-Seals on the refrigerant lines. Do not lubricate the Mini Stat-O-Seals prior to installation.
20. Connect the refrigerant lines to the expansion valve. Torque the capscrew on the retaining plate 11 to 15 lbf·ft (15 to 20 N·m).
21. Remove the condensate seal from the lower portion of the evaporator service cover, and install a new condensate seal in the same location on the service cover. See **Fig. 2**.
22. Using capscrews, attach the evaporator service cover to the HVAC assembly.

    If a tapped hole that is used to mount the evaporator service cover to the HVAC assembly becomes stripped, drill a new hole in one of the alternative mounting locations on the HVAC assembly. Use a 1/4-inch (6-mm) drill bit to make a new tapped hole. See **Fig. 3**.
23. Install the evaporator probe in the evaporator service cover.
24. Attach the lower HVAC cover to the dash panel. For instructions, see **Group 60**.
25. Install the surge tank. For instructions, see **Section 20.01**, Subject 130.

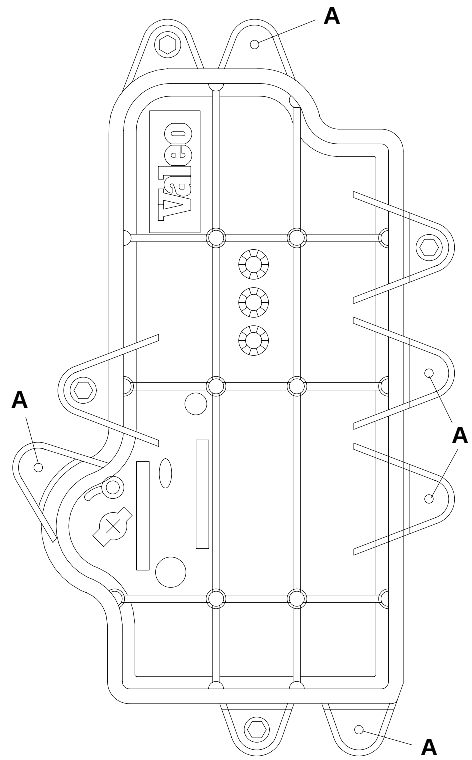
Evaporator Replacement



1. Condensate Seal

Fig. 2, Evaporator Service Cover

26. Install the air cleaner. For instructions, see **Section 09.01**, Subject 110.
27. Evacuate and charge the air conditioning system with refrigerant. For instructions, see **Subject 220** of this section. Be sure to add refrigerant oil to the compressor to replace that which is lost when the system is recovered. See **Section 83.01**, Subject 130.
28. Return the hood to the operating position.
29. Remove the chocks from the tires.



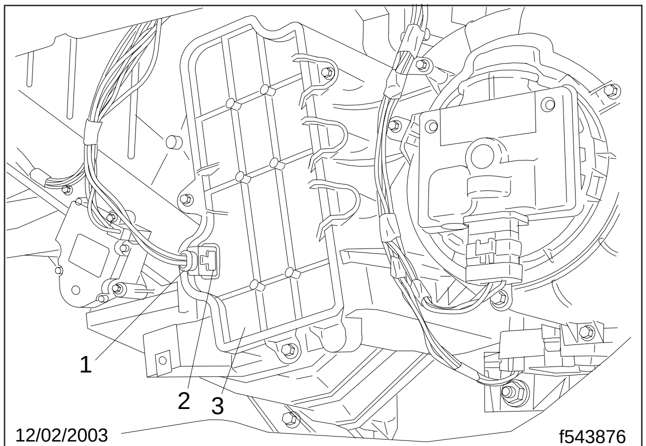
A. Drill a tapped hole in any of these alternative mounting locations.

Fig. 3, Evaporator Service Cover

Evaporator Probe Replacement

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Remove the lower HVAC cover. For instructions, see **Group 60**.
3. Press the metal retainer on the wiring harness connector to disconnect the wiring harness from the evaporator probe. See **Fig. 1**.



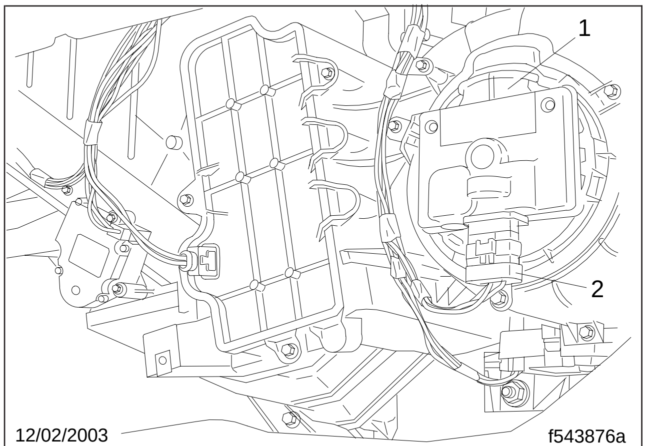
1. Evaporator Probe Wiring Harness Connector
2. Evaporator Probe
3. Evaporator Service Cover

Fig. 1, Evaporator Probe

4. Rotate the evaporator probe counterclockwise and pull the evaporator probe out of the evaporator service cover.
5. Install a new evaporator probe in the evaporator service cover.
6. Attach the wiring harness to the evaporator probe.
7. Attach the lower HVAC cover to the dash panel. For instructions, see **Group 60**.
8. Remove the chocks from the tires.

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Disconnect the batteries.
3. Remove the lower HVAC cover. For instructions, see **Group 60**.
4. Disconnect the wiring harness from the blower motor. See **Fig. 1**.



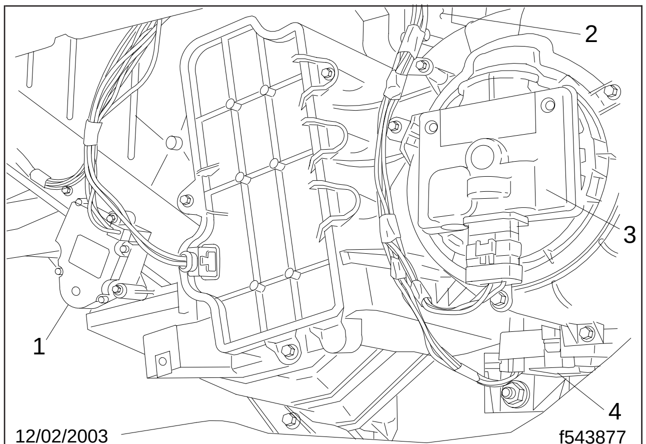
1. Blower Motor
2. Blower Motor Wiring Harness

Fig. 1, Blower Motor

5. Remove the capscrews that attach the blower motor to the HVAC assembly and remove the blower motor.
6. Using capscrews, install the new blower motor on the HVAC assembly.
7. Attach the wiring harness to the blower motor.
8. Attach the lower HVAC cover to the dash panel. For instructions, see **Group 60**.
9. Connect the batteries.
10. Remove the chocks from the tires.

Temperature Blend Actuator Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Remove the lower HVAC cover. For instructions, see **Group 60**.
3. Disconnect the wiring harness from the temperature blend actuator. See **Fig. 1**.



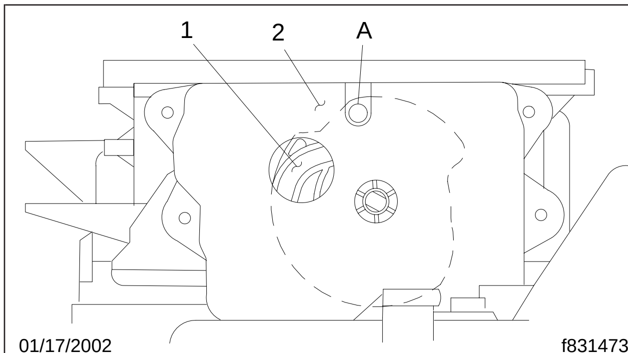
1. Temperature Blend Actuator
2. Air Distribution Actuator
3. Blower Motor
4. Recirculation Actuator

Fig. 1, Actuators

4. Remove the capscrews that attach the actuator to the HVAC assembly and remove the actuator.
5. Using capscrews, install the new actuator on the HVAC assembly. Make sure that the actuator is correctly aligned on the door extension.
6. Attach the wiring harness to the temperature blend actuator.
7. Attach the lower HVAC cover to the dash panel. For instructions, see **Group 60**.
8. Remove the chocks from the tires.

Air Distribution Actuator Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Remove the lower HVAC cover. For instructions, see **Group 60**.
3. Disconnect the wiring harness from the air distribution actuator. See **Fig. 1**.
4. Remove the capscrews that attach the actuator to the mounting plate and remove the actuator.
5. Before installing a new actuator, rotate the cam behind the mounting plate so that the alignment hole in the cam is aligned with the hole in the HVAC assembly. See **Fig. 2**.



A. Align the hole in the cam with the hole in the HVAC assembly.
1. Cam
2. Mounting Plate

Fig. 2, Cam Alignment for the Air Distribution Actuator

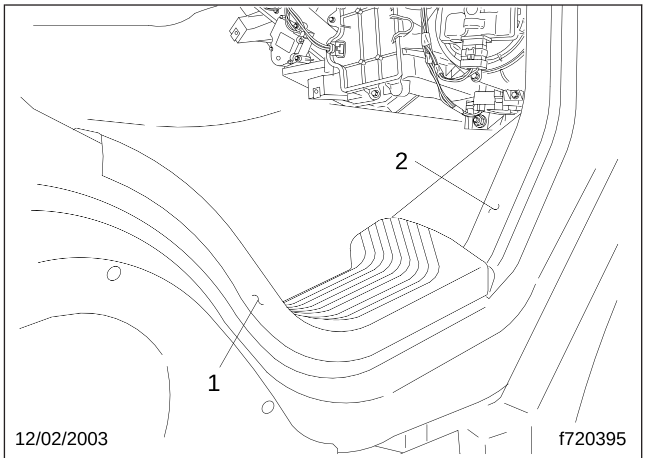
IMPORTANT: If the alignment hole in the cam is not aligned with the hole in the HVAC assembly, the actuator could be installed with the cam 180 degrees from the correct position. Incorrect alignment of the cam will prevent the air distribution doors from operating correctly.

6. Using capscrews, install the new actuator on the mounting plate. Make sure that the actuator is correctly aligned on the door extension.
7. Attach the wiring harness to the air distribution actuator.
8. Attach the lower HVAC cover to the dash panel. For instructions, see **Group 60**.
9. Remove the chocks from the tires.

Actuator Replacement

Recirculation Actuator Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Remove the lower HVAC cover. For instructions, see **Group 60**.
3. Disconnect the wiring harness from the recirculation actuator. See **Fig. 1**.
4. Remove the tread plate cover. See **Fig. 3**.



1. Tread Plate Cover 2. A-Pillar Cover

Fig. 3, A-Pillar and Tread Plate Covers

5. Remove the A-pillar cover.
6. Remove the capscrews that attach the actuator to the HVAC assembly and remove the actuator.
7. Using capscrews, install the actuator on the HVAC assembly. Make sure that the actuator is correctly aligned on the door extension.
8. Attach the wiring harness to the recirculation actuator.
9. Attach the A-pillar cover to the cab floor.
10. Attach the tread plate cover to the cab floor.
11. Attach the lower HVAC cover to the dash panel. For instructions, see **Group 60**.
12. Remove the chocks from the tires.

Heater and Air Conditioner Assembly or Heater Assembly Replacement

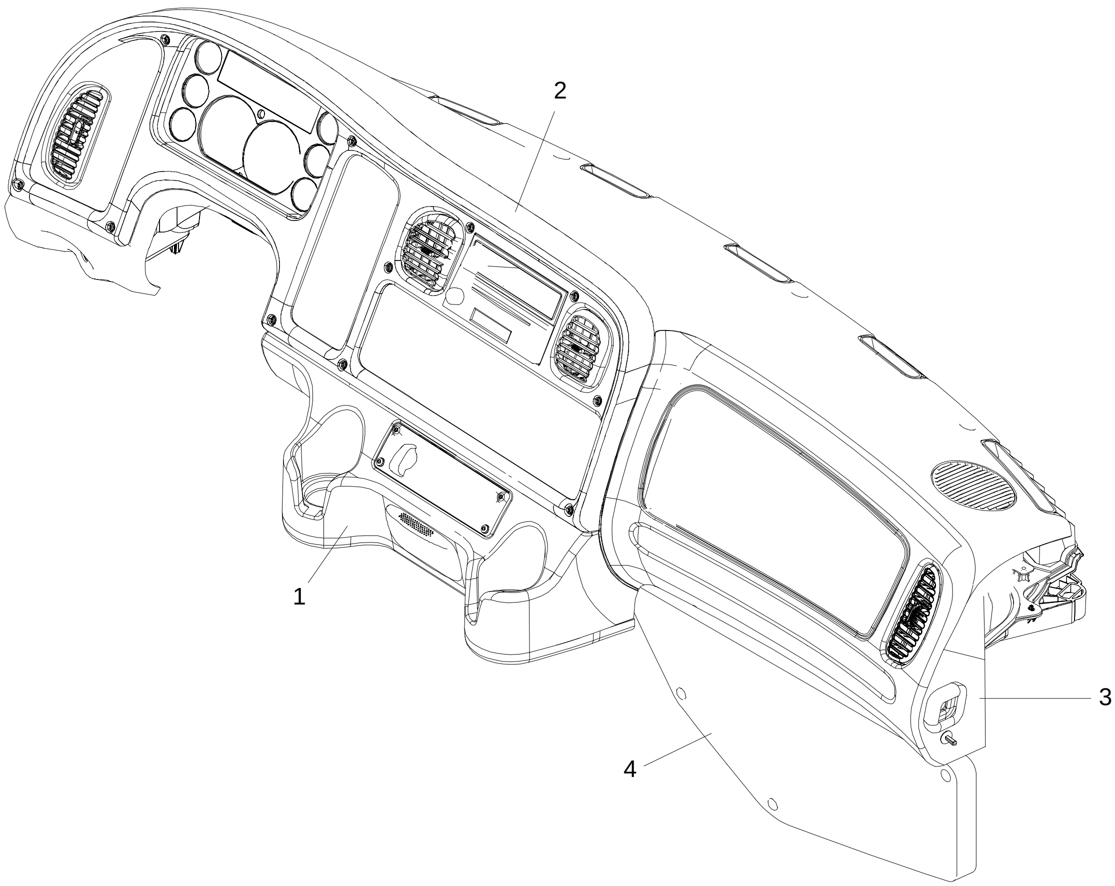
Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Disconnect the batteries.
3. Remove the surge tank. For instructions, see **Section 20.01**, Subject 130.
4. Remove the air cleaner. For instructions, see **Section 09.01**, Subject 110.
5. If equipped with an air conditioner, recover the refrigerant from the air conditioning system. For instructions, see **Section 83.00**, Subject 220.
6. Remove the Torx® capscrew that attaches the coolant lines to the heater core and remove the coolant lines.
7. Remove the capscrew that attaches the refrigerant lines to the expansion valve and remove the refrigerant lines. Quickly cap the refrigerant lines.

IMPORTANT: Under no circumstances should the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through the refrigerant lines since shop air is wet (humid).

8. Remove the following dash panels inside the cab. See **Fig. 1**. For instructions, see **Section 60.08**.
   - lower HVAC cover
   - trim plate panel
   - cup holder panel
   - right-hand dash panel
9. Disconnect the two HVAC wiring harnesses.
10. Remove the capscrews, nuts, and washers that attach the heater and air conditioner assembly or heater assembly to the dash and frontwall and remove the assembly.
11. Using capscrews, nuts, and washers, attach the new heater and air conditioner assembly or heater assembly to the dash and frontwall. Torque the capscrews 72 to 96 lbf·in (810 to 1080 N·cm). Torque the nuts 18 to 19 lbf·ft (24 to 26 N·m).
12. Connect the two HVAC wiring harnesses.
13. Using only Mini Stat-O-Seals, replace the Mini Stat-O-Seals on the refrigerant lines. Do not lubricate the Mini Stat-O-Seals prior to installation.
14. Using a capscrew, attach the refrigerant lines to the expansion valve. Torque the capscrew on the retaining plate 11 to 15 lbf·ft (15 to 20 N·m).
15. Using a Torx capscrew, attach the coolant lines to the heater core.
16. Install the dash panels. For instructions, see **Section 60.08**.
17. Install the surge tank. For instructions, see **Section 20.01**, Subject 130.
18. Install the air cleaner. For instructions, see **Section 09.01**, Subject 110.
19. Connect the batteries.
20. Remove the chocks from the tires.

Heater and Air Conditioner Assembly or Heater Assembly Replacement

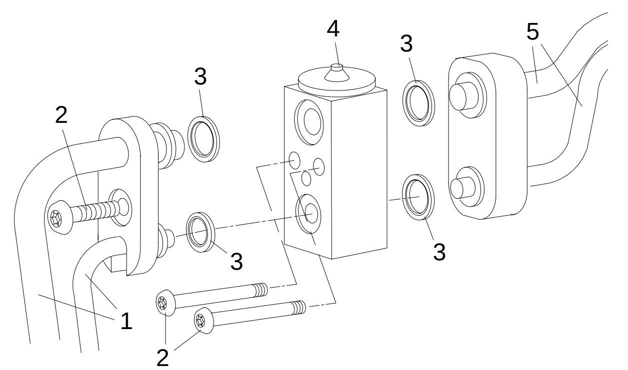


1. Cup Holder Panel
2. Trim Plate Panel
3. Right-Hand Dash Panel
4. Lower HVAC Cover

Fig. 1, Dash Panels

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Open the hood.
3. Recover the refrigerant from the air conditioning system. For instructions, see **Subject 220**.
4. Remove the air cleaner. For instructions, see **Section 09.01**, Subject 110.
5. Remove the surge tank. For instructions, see **Section 20.01**, Subject 130.
6. Remove the capscrew that attaches the refrigerant lines to the expansion valve and remove the refrigerant lines. Quickly cap the refrigerant lines. See **Fig. 1**.



1. Refrigerant Line
2. Capscrew
3. Mini Stat-O-Seal
4. Expansion Valve
5. Evaporator Line

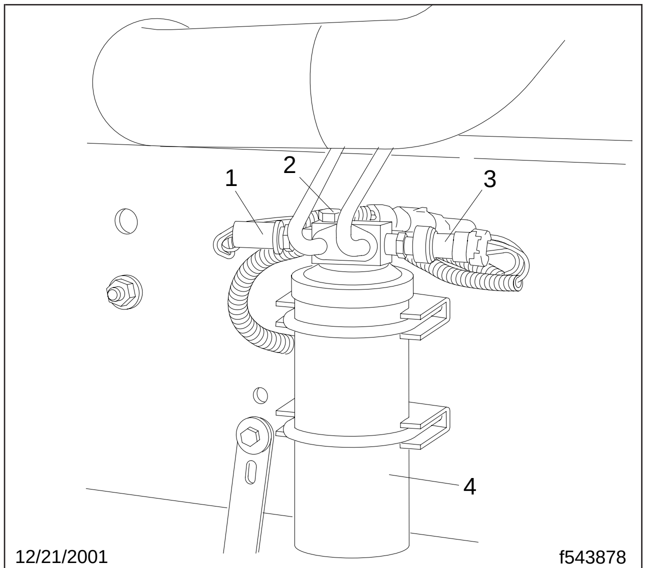
Fig. 1, Expansion Valve

IMPORTANT: Under no circumstances should the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

7. Remove the capscrews that attach the expansion valve to the evaporator lines and remove the expansion valve. If the evaporator lines will be exposed to air for more than five minutes, cap the evaporator lines.
8. If the evaporator lines were capped, uncap the lines.
9. Using only Mini Stat-O-Seals, replace the Mini Stat-O-Seals on the evaporator side of the expansion valve. Do not lubricate the Mini Stat-O-Seals prior to installation.
10. Using two capscrews, attach the expansion valve to the evaporator lines. Torque the capscrews 35 lbf·in (395 N·cm).
11. Using only Mini Stat-O-Seals, replace the Mini Stat-O-Seals on the refrigerant lines. Do not lubricate the Mini Stat-O-Seals prior to installation.
12. Attach the refrigerant lines to the expansion valve. Torque the capscrew on the retaining plate 11 to 15 lbf·ft (15 to 20 N·m).
13. Install the surge tank. For instructions, see **Section 20.01**, Subject 130.
14. Install the air cleaner. For instructions, see **Section 09.01**, Subject 110.
15. Evacuate and charge the air conditioning system with refrigerant. For instructions, see **Subject 220**of this section.
16. Be sure to add refrigerant oil to the compressor to replace that which is lost when the system is recovered. See **Section 83.01**, Subject 130.
17. Return the hood to the operating position.
18. Remove the chocks from the tires.

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Open the hood.
3. Recover the refrigerant from the air conditioning system. For instructions, see **Subject 220**.
4. Disconnect the wiring harness from the fan cycling switch and disconnect the wiring harness from the binary switch. See **Fig. 1**.



1. Fan Cycling Switch
2. Moisture Indicator
3. Binary Switch
4. Receiver-Drier

Fig. 1, Receiver-Drier

5. Remove the fan cycling switch and the binary switch from the receiver-drier.
6. Disconnect the refrigerant lines from the receiver-drier. Quickly cap the refrigerant lines.

IMPORTANT: Under no circumstances should the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

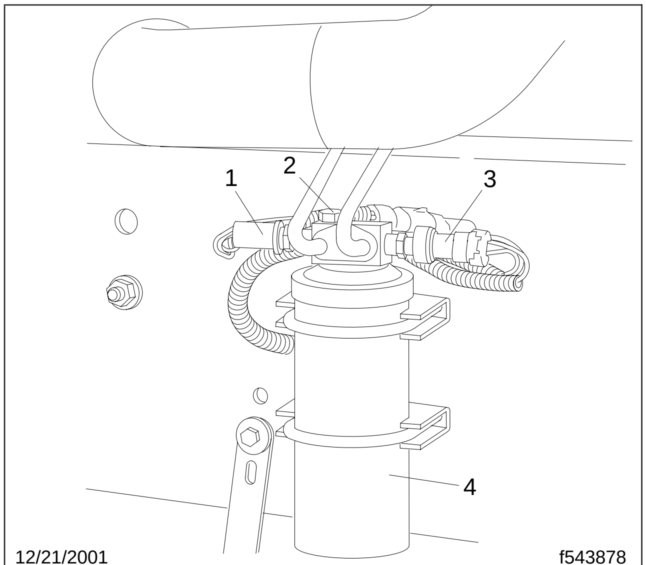
7. Remove the nuts and washers that attach the U-bolts and mounting brackets to the frame rail. Remove the receiver-drier.

IMPORTANT: If the desiccant cartridge inside the receiver-drier has fallen apart, flush the system and replace the expansion valve and the refrigerant compressor (desiccant matter can't be removed from these parts). A cartridge may fall apart from too much moisture in the system, because of poor evacuation of the system, or lack of maintenance.

8. Using U-bolts, mounting brackets, nuts, and washers, install a new receiver-drier on the frame rail.
9. Uncap the refrigerant lines.
10. Using only Mini Stat-O-Seals, replace the Mini Stat-O-Seals on the refrigerant lines. Do not lubricate Mini Stat-O-Seals prior to installation.
11. Connect the refrigerant lines to the receiver-drier. Torque the bolt on the retaining plate 11 to 15 lbf·ft (15 to 20 N·m).
12. Attach the fan cycling switch and the binary switch to the receiver-drier.
13. Attach the fan cycling wiring harness to the fan cycling switch and attach the binary switch wiring harness to the binary switch.
14. Evacuate and charge the air conditioning system with refrigerant. For instructions, see **Subject 220**.
15. Be sure to add refrigerant oil to the compressor to replace that which is lost when the system is recovered. See **Section 83.01**, Subject 130.
16. Return the hood to the operating position.
17. Remove the chocks from the tires.

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Open the hood.
3. Disconnect the wiring harness from the binary switch. See **Fig. 1**.



1. Fan Cycling Switch
2. Moisture Indicator
3. Binary Switch
4. Receiver-Drier

Fig. 1, Receiver-Drier

4. Remove the binary switch.
5. Install a new binary switch on the receiver-drier.
6. Connect the wiring harness to the binary switch.
7. Return the hood to the operating position.
8. Remove the chocks from the tires.

Condenser Removal and Installation

Removal

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Remove the capscrews that attach the grille to the hood. Remove the grille.
3. Open the hood.
4. Recover the refrigerant from the air conditioning system. For instructions, see **Subject 220**.
5. Disconnect the refrigerant lines from the condenser. Quickly cap the condenser inlet and outlet ports if the condenser will be reinstalled and cap the refrigerant lines.

IMPORTANT: Under no circumstances should the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

6. If the condenser is mounted below the charge air cooler, remove the charge air cooler. For instructions, see **Section 09.02**, Subject 100.
7. Remove the fasteners that attach the condenser to the charge air cooler or to the mounting brackets. Remove the condenser.

Installation

1. Using fasteners, install the condenser on the charge air cooler or the mounting brackets. Install and tighten the fasteners 84 to 108 lbf·in (950 to 1220 N·cm).
2. Uncap the inlet and outlet ports on the condenser and uncap the refrigerant lines.
3. Using only Mini Stat-O-Seals, replace the Mini Stat-O-Seals on the refrigerant lines. Do not lubricate Mini Stat-O-Seals prior to installation.
4. Connect the refrigerant lines to the condenser. Torque the bolt on the retaining plate 11 to 15 lbf·ft (15 to 20 N·m).
5. Evacuate and charge the air conditioning system with refrigerant. For instructions, see **Subject 220** of this section.
6. Add refrigerant oil to the compressor to replace that which is lost in the old condenser. For instructions, see **Section 83.01**, Subject 130.
7. Return the hood to the operating position.
8. Using capscrews, attach the grille to the hood.
9. Remove the chocks from the tires.

Climate Control Panel Replacement

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Remove the capscrews that attach the climate control panel to the cup holder panel. Pull the control panel away from the cup holder panel.
3. Disconnect the wiring harness from the control panel.
4. Connect the wiring harness to the new control panel.
5. Using capscrews, attach the control panel to the cup holder panel.
6. Remove the chocks from the tires.

Required Equipment

You will need a machine, or machines, to identify the refrigerant and to recover, evacuate, flush, and charge the refrigerant system. Ideally, it will be a single machine able to perform all the following functions:

- Identification—The machine must be able to verify the purity of the refrigerant in the air conditioning system, and should test for the presence of unapproved refrigerants.
- Recovery—The machine must be able to recover all traces of refrigerant from the air conditioning system.
- Evacuation—Ideally, the machine should have a vacuum pump rated at 6 cfm, and be maintenance free. A machine that requires maintenance is acceptable as long as it is properly maintained.
- Charging—The scale used in charging should be accurate to within ±1 ounce (30 mL).
- Flushing—Adaptors for the compressor(s), expansion device(s), and receiver-drier should be purchased or fabricated, to flush the system with refrigerant.

Refrigerant Identification

WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant, could lead to serious personal injury.

IMPORTANT: Identify the specific type of refrigerant in the air conditioning system, if you suspect one of the following possibilities:

- Excess noncondensable gas, such as nitrogen or air, is in the system.
- An unapproved refrigerant is in the system.
- The history of refrigerant system repairs is unknown.

1. Using a high-quality refrigerant identifier and the manufacturer’s instructions, attach the identifier to the vehicle and perform the test.
2. If the vehicle passes the test, it is safe to recover the refrigerant.
3. If the vehicle fails the test due to an excessive amount of noncondensable gas, recover the refrigerant system, then purge the recovery tank of the noncondensable gas.
4. If the test revealed the presence of a hydrocarbon-based refrigerant or a refrigerant other than R-134a, **do not recover the refrigerant into the general-use machine.** Recover non-R-134a refrigerant into a separate container specifically for refrigerant that must be recycled by a qualified recycling center. It is best to refer the customer to the place where the vehicle was last serviced, since properly disposing of non-134a refrigerants can be difficult and expensive.

Recovery

The recovery process removes most of the refrigerant charge in the system.

1. Turn off the engine, apply the parking brakes, chock the tires, and open the hood.
2. Remove the caps from the suction and discharge service valves.
3. If the history of refrigerant system repairs is unknown, or if you suspect that the system is charged with an unapproved refrigerant, identify the refrigerant using the "Refrigerant Identification" procedures.
4. Wearing protective goggles and nonleather gloves, attach the refrigerant recovery and charging machine hoses to the valves.

IMPORTANT: Push down firmly on the hose connectors, until they click into engagement. This ensures that the coupler is locked.

5. Follow the refrigerant recovery and charging machine manufacturer’s instructions, and recover all of the refrigerant from the refrigerant system.

IMPORTANT: Always comply with all federal and local regulations regarding refrigerant recovery and disposal. You may be subject to substantial penalties for improper procedures.

Refrigerant Service Operations

6. Measure the oil recovered during the recovery process. The refrigerant system will have to be filled with the same quantity of new refrigerant oil. If the system is contaminated with moisture, all of the compressor oil must be replaced with clean oil. If the system is heavily contaminated with desiccant or grit, replace the compressor, expansion valve, and receiver-drier, and flush the condenser and evaporator(s). After the system is charged, perform a performance check to ensure that the heat exchangers are not plugged.

Evacuating

The main purpose in evacuating the refrigerant system is to remove noncondensable gases (NCG), such as nitrogen and air. The secondary purpose is to boil off free water molecules.

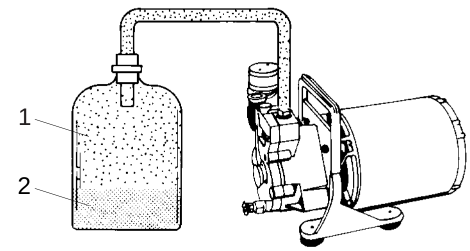
Water in the refrigerant can form ice crystals at the expansion valve. The ice crystals retard or stop the flow of refrigerant, causing a reduction or complete stoppage of cooling. As the expansion valve warms due to the lack of refrigerant, the ice melts and passes through the expansion valve. Then refrigerant will flow again, until the ice crystals re-form. The result is intermittent cooling.

Refrigerant oil has an extremely high moisture absorption capacity. Normally, the moisture picked up by the oil is passed off to the receiver-drier. If excessive moisture exists in the system, the lubricating ability of the oil is reduced, which could damage the compressor and other components.

Effects of Pressure on the Boiling Point of Water

Water boils at 212°F (100°C) at an atmospheric pressure of 14.7 psi (101 kPa), at sea level. At higher elevations the atmospheric pressure is lower, which allows water to boil at lower temperatures. See **Table 1** for boiling temperatures of water at converted pressures.

Another way to boil and remove water from the air conditioning system, is by lowering the system pressure to a vacuum, to cause the moisture to vaporize at normal ambient temperatures. A vacuum pump can reduce the pressure in the system. Since the pressure is lowest at the pump, NCG and water vapor are pulled out of the system. This process is called evacuation or dehydration. See **Fig. 1**.



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1. Vapor
2. Water

Fig. 1, Water to Vapor

Measuring Vacuum

Vacuum should be measured with an electronic thermistor vacuum gauge, which is designed for use with high vacuum pumps and can accurately read as low as 100 microns. This gauge can have an analog scale or a digital (LED or LCD) display.

The location of the vacuum gauge will affect the reading. The closer to the vacuum source, the lower the reading will be. Follow the manufacturer’s instructions for proper use of the vacuum gauge.

If the pressure will not stabilize, suspect a leak. If it does stabilize at a vacuum that is too high, for example 1500 microns Hg, it is an indication of moisture and more evacuation is required.

Holding a vacuum only means that there is no leak present under a vacuum. Other leaks may exist when the system is pressurized, so a proper leak test must be performed in conjunction with holding a vacuum.

Maintaining an Oil-Lubricated Vacuum Pump

Maintenance is important for a high-vacuum pump. The oil must be changed at regular intervals to prevent moisture buildup, which will cause decreased pump performance and eventual pump failure.

Pumping down for extremely wet air conditioning systems can completely saturate the pump oil, which will require the replacement of the vacuum pump oil.

Boiling Temperatures of Water at Converted Pressures		
Boiling Temperature of Water: °F (°C)	**Absolute Pressure: psi (microns Hg)**	**Vacuum: inHg (mmHg)**
212 (100)	14.696 (759993.4)	0 (0)
205 (96)	12.770 (660400.0)	3.92 (99.6)
194 (90)	10.169 (523881.6)	9.22 (234.2)
176 (80)	6.8699 (355269.8)	15.93 (404.6)
158 (70)	4.5207 (233786.7)	20.72 (526.3)
140 (60)	2.8900 (149580.7)	24.04 (610.6)
122 (50)	1.7987 (92555.1)	26.28 (667.5)
104 (40)	1.0700 (55336.4)	27.74 (704.6)
89 (30)	0.61540 (31826.2)	28.67 (728.2)
86 (27)	0.57010 (26220.4)	28.89 (733.8)
76 (24)	0.44435 (22979.9)	29.02 (737.1)
72 (22)	0.38856 (20094.7)	29.13 (739.9)
69 (21)	0.35084 (18143.7)	29.21 (741.9)
64 (18)	0.29505 (15258.5)	29.32 (744.7)
59 (15)	0.24720 (12783.8)	29.42 (747.3)
53 (12)	0.19888 (10285.0)	29.52 (749.8)
45 (7)	0.14746 (7625.8)	29.62 (752.3)
32 (0)	0.08858 (4579.6)	29.74 (755.4)
21 (–6)	0.05293 (2738.1)	29.81 (757.2)
6 (–14)	0.02521 (1304.0)	29.87 (758.7)
–24 (–31)	0.004905 (253.7)	29.911 (759.74)
–35 (–37)	0.002544 (131.6)	29.915 (759.84)
–60 (–51)	0.0004972 (25.7)	29.9200 (759.968)
–70 (–57)	0.0002443 (12.69)	29.92050 (759.9807)
–90 (–68)	0.0000526 (2.72)	29.92089 (759.9906)

Table 1, Boiling Temperatures of Water at Converted Pressures

CAUTION

Flush the vacuum pump every fourth time it is used, and before storing for long periods of time. Acid will form and corrode the pump, if water-laden oil remains in the pump for an extended period.

Vacuum pump oil is water soluble. This helps the pump create a high vacuum, by absorbing water and sealing the pump.

Use only vacuum pump oil as a lubricant. Do not use any solvent or any other oil. Clean oil should be run through the pump, until it runs out clear. Oil should be added to the fill level indicated on the pump. Check the oil level before each use.

Evacuation Procedure

1. The system must have been recovered and the refrigerant compressor filled with the correct

Refrigerant Service Operations

amount of refrigerant oil. Replace the receiver-drier if the system conditions require it.

2. Make sure the vacuum pump has been properly maintained.
3. Wearing protective goggles and nonleather gloves, attach the refrigerant recovery and charging machine hoses, or a vacuum pump, to the valves.

IMPORTANT: Push firmly on hose connectors until they click into engagement. This ensures that they are locked.

4. Follow the refrigerant recovery and charging machine manufacturer’s instructions, and evacuate the refrigerant system.
5. A minimum of 10 minutes with a 6-cfm pump should be used to evacuate the system, but a smaller pump requires a longer evacuation time. Make sure that the vacuum level reaches and maintains a point where water boils at your ambient temperature, then proceed with charging and leak testing the system.

Flushing

Flushing removes moisture-laden oil and some contamination, such as dirty oil and some particles. When a part is flushed, liquid refrigerant is forced through it. The liquid picks up the contaminants and flushes them out.

Whether to flush or replace a part depends on how much contamination there is as previously described.

Normally, the system always has pressure in it. Some loss of refrigerant from one season to the next is normal, and does not mean that the system is dirty. If refrigerant parts show signs of internal corrosion and grit, the system is contaminated.

If the system is contaminated with moisture, flush all sections of the system. Then change the oil in the compressor and replace the receiver-drier prior to evacuating and charging the system.

If the system is heavily contaminated or if desiccant has circulated through the system, replace the receiver-drier, expansion valve(s), and inspect the compressor.

Do not flush the receiver-drier or the compressor.

Flush the system in segments to lessen the chance of blowing deposits against a port.

Flush the system in the opposite direction of refrigerant flow. In other words, backflush the sections.

Flushing parts with refrigerant requires a refrigerant recovery and charging machine.

Flushing Procedure

Method 1

NOTE: Use this method when the recovery and charging machine is equipped with a flush cycle.

1. Recover the refrigerant from the air conditioning system.
2. Disconnect both ends of the line or part(s) being flushed. Tightly cap the lines to the rest of the system.

NOTE: You must remove the expansion device(s), receiver-drier, and compressor(s) when flushing. These components must be removed and bypassed when performing a system flush.

3. Install the flushing adaptors and an inline filter and follow the instructions from the manufacturer of the recovery and charging machine to perform the flush. When flushing the entire system, use an adaptor that fits where the compressor was located and backflush.
4. Remove the adaptors and bypass devices and install the expansion device(s), the compressor, and a new receiver-drier.
5. If installing the existing compressor, remove the oil in it and replace the oil with new oil. New compressors may or may not have a full charge of oil.
6. Charge the system with refrigerant and check the system performance.

Method 2

NOTE: Use this method when two recovery and charging machines are available.

1. Recover the refrigerant from the air conditioning system.
2. Disconnect both ends of the line or part(s) being flushed. Tightly cap the lines to the rest of the system.

NOTE: You must remove the expansion device(s), receiver-drier, and compressor(s) when flushing. These components must be removed and bypassed when performing a system flush.

3. Install the flushing adaptors and an inline filter. When flushing the entire system, use an adaptor that fits where the compressor was located and backflush.
4. Charge the part with 2 pounds (0.9 kg) of refrigerant or the system with 5 pounds (2.3 kg) of refrigerant, then recover the refrigerant with a second machine. It is desirable to start the recovery slightly before the charge cycle is done since this helps to push fluid through the system. Repeat the process several times until you think that all the oil has been removed.
5. Remove the adaptors and bypass devices and install the expansion device(s), the compressor(s), and a new receiver-drier.
6. If installing the existing compressor, remove the oil in it and replace the oil with new oil. New compressors may or may not have a full charge of oil.
7. Charge the system with refrigerant and check the system performance.

Oil Balancing

General Information

Compressors require refrigerant oil to function. When the air conditioning system is operating, some of the oil leaves the compressor and is circulated through the system with the refrigerant. The refrigerant oil cannot leave the system except when there is a leak, the refrigerant is recovered, or when a system part is replaced. It is important that the air conditioning system has the correct amount of refrigerant oil for proper operation. Too little oil will result in compressor failure. Too much oil will degrade the performance of the air conditioner, and cause damage to the compressor.

IMPORTANT: Whenever the air conditioning system is discharged or recovered, the recovered oil, from the charging machine, must be measured in order to know how much oil must be returned to the system. When a system component is replaced, a quantity of new oil equal to the recovered oil plus the oil coating the inside of the component must be returned to the system.

IMPORTANT: Refrigerant oil is hygroscopic (attracts moisture from its surroundings), and must not be exposed to the moisture that is present in the air. New oil must be from a container that has not been opened or that has been tightly sealed since its last use.

Tubing, funnels, or other equipment used to transfer the oil must be very clean and dry. When handling refrigerant oil:

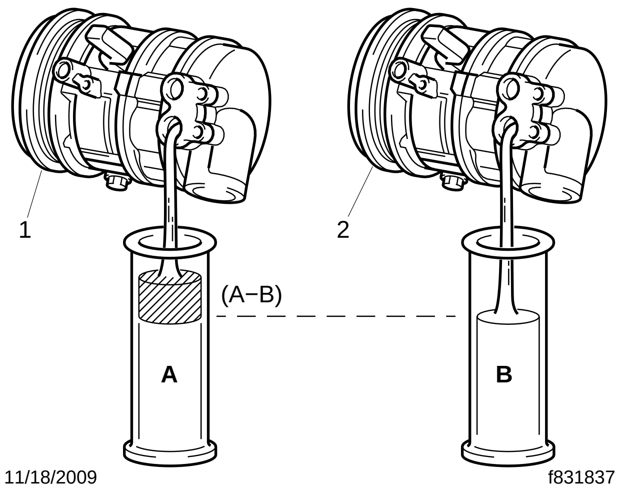
- Be sure that the oil is free of water, dust, metal powder, and other foreign substances;
- Do not mix the refrigerant oil with other types or viscosities of oil;
- Quickly seal the oil container after use. Refrigerant oil absorbs moisture when exposed to the air for any period of time.

Compressor Oil Balancing

Replacement refrigerant compressors are supplied with some refrigerant oil. If the air conditioning system has been flushed, the system will need a complete new charge of oil. If the system has not been flushed, use the following procedures to adjust the oil level, when a new compressor or other system component has been installed. The type of oil required depends on the brand of compressor used on the system. Refer to the workshop manual for the specific compressor on the vehicle being serviced for details about how the total system volume is determined. See PartsPro MOD 700 to determine the oil type and vehicle specific oil quantities.

1. Drain the remaining oil from the compressor into a clean graduated container, and note the amount. See **Fig. 2**.
2. Make note of the total volume of oil recovered.
3. Drain the oil from new compressor into a clean calibrated container, and compare the two quantities of oil.
4. Add only the amount of oil removed during recovery and from the old compressor to the system.

Refrigerant Service Operations



1. New Compressor 2 Old Compressor

Fig. 2, Oil Balancing

5. Add the new compressor oil as described in the supplier specific compressor service section of the workshop manual.

System Oil Balancing

After repairs are finished, refer to **Table 2** and use the following equation to determine the quantity of refrigerant oil that needs to be added to the system.

[Quantity Recovered] + [Quantity for All Replaced Components] = [Quantity Added to the System]

Table 2 provides the quantities of oil that need to be added to the system for each component that was replaced. Add the quantities listed in the table for each component that was replaced. Use the sum of the quantities or 6 fl oz (177 mL), whichever is less. Inject the calculated oil volume at the high-side pressure port during the refrigerant charging process.

Refrigerant Oil Quantities for Replaced Components

Add the quantities listed in this table for each component that was replaced. Use the sum of the quantities or 6 fl oz (177 mL), whichever is less.

Component	Quantity oz (mL)
High Pressure Line (main A/C)	1 (30)
Low Pressure Line (main A/C)	2 (59)
High Pressure Line (auxiliary A/C)	1 (30)
Low Pressure Line (auxiliary A/C)	3 (89)
Condenser	1 (30)
Evaporator (main A/C)	3 (89)
Evaporator (auxiliary A/C)	2 (59)
Receiver-Drier	3 (89)
Minor Leak at Connector Only	0.5 (15)
Major Leak at Connector Only	2 (59)

Table 2, Refrigerant Oil Quantities for Replaced Components

Charging

NOTE: Before charging, the system must be recovered and evacuated with the recovery and charging machine connected to the service and discharge port connections.

1. Obtain enough refrigerant to fully charge the system. To determine the amount of refrigerant needed to fully charge the system, read the Air Conditioner label on the vehicle or see **Specifications 400**.
2. Charge the system on the high side following the refrigerant recovery and charging machine manufacturer's instructions.
3. While the compressor is engaged, check the duct temperature and operating pressures at the suction and discharge ports. Compare the temperature and pressures to those in **Specifications 400**. If the operating pressures are not acceptable, see **Subject 300** for troubleshooting procedures.
4. Disconnect the hoses.
5. Shut down the engine.
6. Recover the refrigerant that is in the hoses.

Leak Testing Methods

General Information

Refrigerant is nearly odorless. As a result, all of it may leak away and not be noticed until the system stops cooling. All vehicle refrigerant systems lose some refrigerant. Higher loss rates signal a need to locate and repair the leaks.

Leaks are most often found at the compressor hose connections and at the various fittings and joints in the system. If unapproved replacement hoses are installed, refrigerant can be lost through hose permeation.

There are two leak testing methods to detect leaks in the refrigerant system: UV (ultraviolet) dye leak detection and electronic leak detection. Daimler Trucks North America LLC recommends using the UV dye leak detection whenever possible, even though there are some limitations to using this method. A leak on the front seal of the compressor **must** be verified using a heated diode leak detector method described under the heading "Electronic Leak Detection" in this subject. Visible dye on the front of the compressor clutch **does not** verify that there is a repairable leak at the front seal. Evaporator leaks may not show up with dye, and must be checked using a heated diode leak detector if dye is not present at the condensate drain.

UV Dye Leak Detection

WARNING

IMPORTANT: When using the UV dye leak detection method, always wear protective eyewear that blocks UV rays and enhances the visibility of the dye. Always wear nonleather gloves and protective eyewear when servicing the air conditioning system. Leather gloves do not adequately protect from freezing refrigerant.

1. Inspect the refrigerant system for leaks using a UV lamp.
   1.1 Inspect the entire refrigerant system under low lighting using a UV lamp. Low lighting will increase the apparent brightness of the UV dye at leak sights.
   1.2 Move the UV lamp along the entire refrigerant system, looking for signs of damage or corrosion on the fittings, hose-to-line crimps, switch ports, service ports with caps installed (dye inside the port is not an indication of a leak), brazed or welded areas, and around all connections. Check for evaporator leaks by illuminating the condensate drain tube or hole using the UV lamp.
   1.3 Move the UV lamp along the refrigerant system following a continuous path, so that no potential leak sites are missed. If a leak is found, continue to check the remainder of the system since other leaks may be present.
2. After repairing a leak, remove all UV dye residue remaining on the outside of the refrigerant system using the cleaner provided by the dye manufacturer, or a comparable cleaner. Use a spray bottle of cleaner, a toothbrush, and a spray bottle of clean water for hard-to-reach areas.

NOTE: Minor UV dye residue, or residue that is impossible to reach, will lose its fluorescence over time.

3. See **Table 3** for a list of products that have been tested and approved for use by Freightliner dealers.
4. Close the hood and remove the chocks from the tires.

Electronic Leak Detection

NOTE: Do not try to use a leak tester right after connecting or disconnecting service hoses. Traces of refrigerant at the fittings can falsely signal a leak. Always verify a leak by blowing shop air in to the area of the suspected leak and checking the area again.

When checking for leaks, move the probe all the way around the fitting or suspected leak.

Refrigerant Service Operations

Approved Products for UV Dye Leak Detection				
Type of Refrigerant Oil	Product Description	Vendor Part Number	Freightliner Part Number	Website Address
PAG	Tracerline BigEZ Kit—Can be injected without discharging the system. • Each kit includes one 4-oz (118-mL) cartridge and an injection tool.	TP-9741CS	ABP N83 327911	www.tracerli-ne.com
	• A 4-oz (118-mL) replacement car-tridge services 16 vehicles.	TP-9760-0004CS	ABP N83 327961	
	• An 8-oz (237-mL) replacement car-tridge services 32 vehicles.	TP-9760-0108	ABP N83 327951	
POE/ universal	Tracerline BigEZ Kit—Can be injected with-out discharging the system. • Each kit includes one 4-oz (118-mL) cartridge and an injection tool.	TP-9742CS	ABP N83 327910	www.tracerli-ne.com
	• A 4-oz (118-mL) replacement car-tridge services 16 vehicles.	TP-9770-0004CS	ABP N83 327950	
	• An 8-oz (237-mL) replacement car-tridge services 32 vehicles.	TP-9770-108	ABP N83 327960	
—	Tracerline Optimax UV Lamp	TP-8680	ABP N83 327985	www.tracerli-ne.com
—	Bright Solutions UV Lamp	BSL760	ABP N83 327967	www.brightsol.com
—	Service Valve Cap	—	PH 660412	—

Table 3, Approved Products for UV Dye Leak Detection

Daimler Trucks North America LLC recommends using only certain makes of the heated diode and infrared (IR) types of electronic leak detectors.

Recommended electronic heated diode type leak detectors are available from their manufacturers. See **Table 4**.

Another type of detector, the corona discharge type, is specifically **not recommended**.

Use the following procedures to locate refrigerant system refrigerant gas leaks using an electronic leak detector.

1. Operate the electronic leak detector in accordance with the manufacturer's instructions. Occasionally use a leak reference bottle of R-134a to ensure that the detector is working properly.
2. Leak test with the engine turned off.
3. Charge the air conditioning system with sufficient refrigerant to indicate a gauge pressure of at least 50 psi (345 kPa) with the system not operating. Typically, one-half pound (0.22 kg) of refrigerant is sufficient to create 50 psi (345 kPa) of pressure. It may not be possible to produce this pressure and perform a valid leakage test, if the ambient temperature is less than 59°F (15°C).
4. Be careful not to contaminate the detector probe tip if the part being tested is not clean. Wipe the part off with a dry shop towel or blow it off with shop air. Do not use cleaners or solvents, as many detectors are sensitive to their chemical ingredients.

Electronic Leak Detectors		
Designation	**Manufacturer**	**Comments**
D-TEK, D-Tek Select, and TekMate	Leybold Inficon 2 Technology Place East Syracuse NY 13057 (315) 434–1144	• Rechargeable battery • Hand-held design • Simple to operate
H–10 Professional	Bacharach Inc. c/o Yokogawa Corp. of America 2 Dart Road Newnan GA 30265 (800) 850–0044	• Rechargeable battery • Carrying case with strap • Calibration leak bottle • Manual sensitivity control • Most sensitive available
J 39400	SPX Kent-Moore 28635 Mound Road Warren MI 48092–3499 (800) 328–6657	• 12V DC or 120V AC • Carrying case with strap • Calibration leak bottle • Manual sensitivity control • Manual balance control

Table 4, Electronic Leak Detectors

5. Visually inspect the entire refrigerant system. Look for air conditioning lubricant leakage, and corrosion or damage to lines, hoses, and all other components. Inspect each questionable location carefully with the detector probe. Check all fittings, couplings, refrigerant controls, service ports (with caps installed), brazed or welded areas, and areas around attachment points and hold-downs.
6. Follow the path of the refrigerant system methodically, so that no leaks are missed. If a leak is found, continue to test the rest of the system.
7. Inspect an area of possible leakage slowly and close to the part, moving completely around the part. Move the probe no faster than one to two inches (25 to 50 mm) per second and no farther away than 1/4 inch (6.4 mm) from the part.
8. If a large leak is present in either the system being serviced or the service equipment, the surrounding air will be saturated with refrigerant gas. In this situation the leak detector gives erratic readings and will indicate leakage without being near a possible leak source. Place a large fan so that a light breeze blows through the work area. Verify a leak by blowing shop air into the area and repeating the inspection. Pinpoint a large leak by blowing out the area often.
9. You may test the evaporator core with it in its housing. Turn on the blower motor for a minimum of 15 seconds. Shut off the blower and wait for refrigerant gas to accumulate in the housing. Follow the detector instructions for the specific length of time to wait for the gas to accumulate. Insert the detector probe into the blower resistor block, or condensate drain tube if no water is present. If this is not possible, insert the probe into the closest opening to the evaporator, such as a heater or vent duct.

NOTE: Water inside the condensate drain tube can be removed by inserting a pencil-size rod into the drain tube. Inserting the rod will break the surface tension of any water near the opening of the drain tube, and allow the water to drain out so the probe tip can get an accurate reading. It is only necessary to break the plane of the drain tube with the probe tip, it does not need to be inserted far into the tube.

10. Leak test the front seal area of the compressor. Blow shop air into the cavities in and around the clutch, for at least 15 seconds. Let the compres-

Refrigerant Service Operations

sor stand for one minute, then test for leakage. Inspect axial-type compressors (Sanden or Sel-Tec) by placing the probe near the holes at the front of the clutch. See **Fig. 3**. Inspect two-cylinder reciprocating type compressors (Climate Control) by placing the probe between the clutch coil and the compressor. See **Fig. 4**.

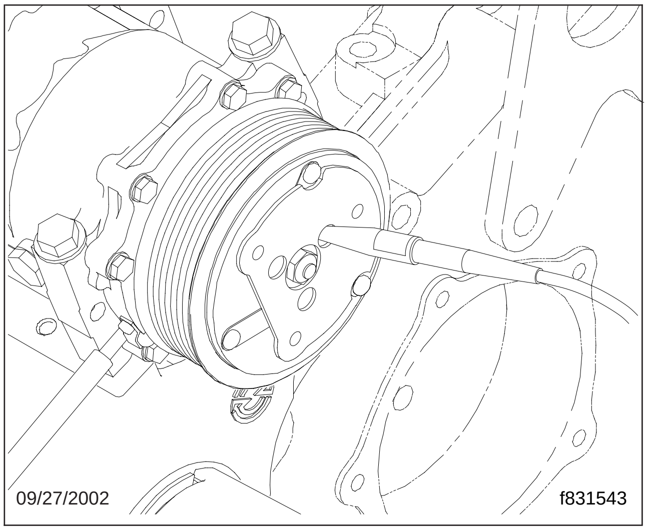


Fig. 3, Axial Type Compressor

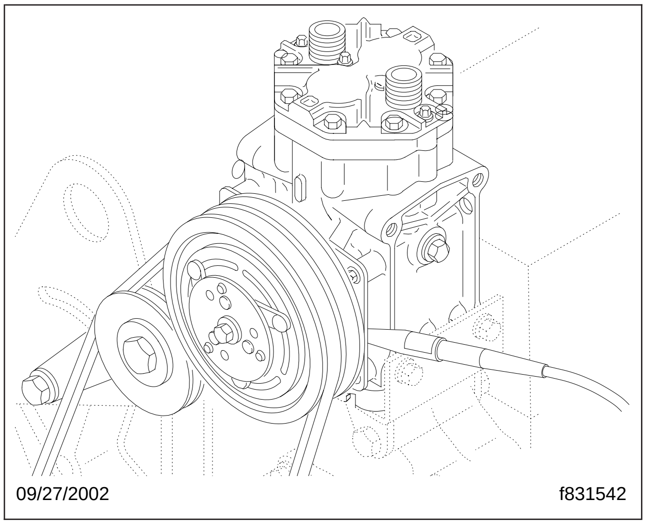


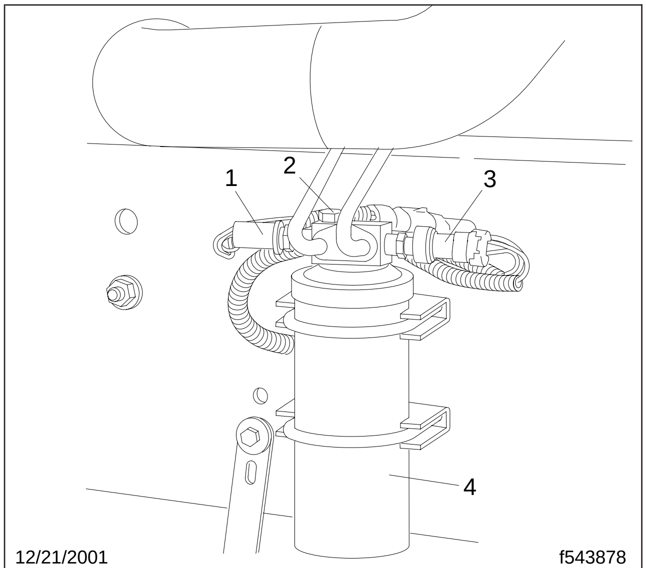
Fig. 4, Two-Cylinder Reciprocating Compressor

IMPORTANT: Be careful not to damage the clutch bearing seal with high pressure shop air.

11. Leak test repaired areas of the system after repairs have been performed. Leak test the service ports (with caps installed) after any service which disturbs the refrigerant system.

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Open the hood.
3. Disconnect the wiring harness from the fan cycling switch. See **Fig. 1**.



1. Fan Cycling Switch
2. Moisture Indicator
3. Binary Switch
4. Receiver-Drier

Fig. 1, Receiver-Drier

4. Remove the fan cycling switch.
5. Install a new fan cycling switch on the receiver-drier.
6. Connect the wiring harness to the fan cycling switch.
7. Return the hood to the operating position.
8. Remove the chocks from the tires.

Preliminary Checks

Before testing the operation of the air conditioning system, check the following items:

1. Make sure the drive belt on the refrigerant compressor is not damaged. Make sure the compressor mounting capscrews are tight. The capscrews should be torqued 15 to 19 lbf·ft (20 to 26 N·m).
2. Using a feeler gauge, check the refrigerant compressor for correct clutch clearance. See **Section 83.01, Subject 140** for instructions.
3. Check for broken or cut hoses. Check for loose fittings on all parts.
4. Check for road debris buildup on the condenser coil fins. Using air pressure and a whisk broom or a soapy spray of water, carefully clean off the condenser. Be careful not to bend the fins.
5. If there is not enough airflow, make sure that leaves or other debris have not entered the fresh air ports under the windshield. If debris is present, it could clog the air inlet and block airflow. Remove the debris carefully.

   Be sure that all ducts are connected to the dash outlets.

Air Conditioning System Performance Test

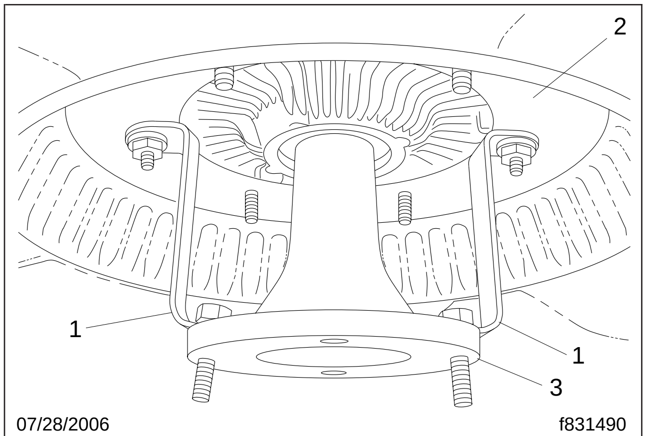
If the system does not operate within the following guidelines, further diagnosis and repair may be necessary.

1. Park the vehicle out of direct sunlight, shut down the engine, and chock the tires.
2. Open the hood.

NOTE: Make a printed copy of **Table 1** to use for recording the readings taken for this procedure.

3. Record the ambient temperature and the relative humidity in **Table 1**.
4. Make sure the engine fan is engaged. If equipped with a viscous fan, the fan must be manually locked before testing the A/C system.

   To lock the fan, make two Z-shaped brackets similar to those shown in **Fig. 1**. Mount the brackets to the fan and hub 180 degrees apart. It is important to use two brackets to prevent vibration when testing. The brackets can be made by drilling and bending 3/4-inch x 1/8-inch (19-mm x 3-mm) mild steel strap.



1. Z-Shaped Bracket
2. Fan
3. Hub

Fig. 1, Viscous Fan

WARNING

Use two brackets to lock the fan. If two brackets are not used, the bolts could shear or the fan could become unbalanced resulting in personal injury or damage to the fan.

5. Open the driver and passenger doors.
6. Connect the A/C test gauges to the refrigerant system service ports.
7. Place a thermometer in the center dash outlet.
8. Start the engine and warm it to operating temperature.
9. Set the engine speed to 1500 rpm.
10. Set the control panel to normal A/C, the recirculation to off, and the fan to the highest speed.
11. Allow time for the system to stabilize (at least 5 minutes or until the dash outlet temperature is at minimum) then record the values in **Table 1** under the "Actual Readings" heading.
12. Refer to the appropriate temperature/pressure table in **Subject 400**. Using the recorded ambient temperature and relative humidity readings, locate the values in the temperature/pressure

Troubleshooting

table and record them in **Table 1** under the "Published Readings" heading.

13. If the actual dash outlet temperature is within the range of the published values, then the system is performing satisfactorily. If the actual temperature is not within the published value, use the other readings such as high-side or low-side (suction or discharge) pressures and compressor cycling information to begin diagnosing the system.
14. If Z-shaped brackets were used to lock the viscous fan, remove the brackets.

Refrigerant Pressure Test Gauge Diagnosis

See **Table 2** for diagnosis of the system using refrigerant pressure test gauge readings. Check the specific component or condition mentioned in the Possible Cause column to help determine the cause of a problem with the system.

A/C Performance Test Data		
Test Data Item	**Published Readings (see step 12)**	**Actual Readings**
Ambient Temperature Relative Humidity (RH)		_____°F (°C) _____% RH
Center Dash Outlet Temperature	_____°F (°C) to _____°F (°C)	_____°F (°C)
High-Side Pressure	_____ psi (kPa) to _____ psi (kPa)	_____ psi (kPa)
Low-Side Pressure	_____ psi (kPa) to _____ psi (kPa)	_____ psi (kPa)
Compressor Cycling	yes/no	yes/no
Compressor On/Off Time (only if cycling)	on _____ sec off _____ sec	on _____ sec off _____ sec

Table 1, A/C Performance Test Data

System Diagnosis Using Refrigerant Pressure Readings			
Suction Pressure (low side)	**Discharge Pressure (high side)**	**Possible Cause**	**Remedy**
High	Low	Worn compressor.	Replace compressor. Be sure to identify and correct cause of failure (e.g. system contamination, incorrect oil charge, leaks, etc.)
High	Normal	Thermal expansion valve (TXV) stuck open.	Replace TXV.
High	High	Restricted condenser air flow.	Clean bugs, dirt, and any debris or obstructions blocking airflow through the condenser. Straighten condenser fins as necessary. Make sure engine fan is working properly and that fan shroud is in place.
		Air or moisture in the refrigerant.	Recover and evacuate the system, charge system with proper amount of pure R-134a refrigerant. Replace the R/D if moisture was determined to be an issue.
		System overcharged.	Recover and evacuate the system, charge system with proper amount of pure R-134a refrigerant.
		Blockage downstream of measurement point and before expansion valve.	Remove the blockage or replace the component with the blockage as necessary. Determine cause of blockage and make further repairs as required.

System Diagnosis Using Refrigerant Pressure Readings			
Suction Pressure (low side)	**Discharge Pressure (high side)**	**Possible Cause**	**Remedy**
Normal	Low	Improper belt tension.	Check belt tension, repair as necessary.
		Restricted suction line.	Remove the blockage or replace the component with the blockage as necessary. Determine cause of blockage and make further repairs as required.
		Worn compressor.	Replace compressor. Be sure to identify and correct cause of failure (e.g. system contamination, incorrect oil charge, leaks, etc.)
Normal	Normal	No problem found.	No action required.
Normal	High	Restricted condenser airflow.	Clean bugs, dirt, and any debris or obstructions blocking airflow through the condenser. Straighten condenser fins as necessary. Make sure engine fan is working properly and that fan shroud is in place.
		Slight over-charge.	Recover and evacuate the system, charge system with proper amount of pure R-134a refrigerant.
Low	Low	Blockage in system.	Remove the blockage or replace the component with the blockage as necessary. Determine cause of blockage and make further repairs as required.
		Low refrigerant charge.	Thoroughly leak test the system using approved UV dye and/or electronic detector. Repair all leaks as necessary. Charge system with proper amount of pure R-134a refrigerant.
		Frozen evaporator.	Check refrigerant charge, check evaporator probe, correct as necessary.
		Faulty thermal expansion valve (TXV).	Replace TXV.
		Faulty evaporator sensor.	Replace sensor.
Low	Normal	Blockage downstream of the measurement point and before the expansion valve.	Remove the blockage or replace the component with the blockage as necessary. Determine cause of blockage and make further repairs as required.
		Low refrigerant charge.	Thoroughly leak test the system using approved UV dye and/or electronic detector. Repair all leaks as necessary. Charge system with proper amount of pure R-134a refrigerant.
		Faulty evaporator sensor.	Replace sensor.
Low	High	Blockage downstream of the measurement point and before the expansion valve.	Remove the blockage or replace the component with the blockage as necessary. Determine cause of blockage and make further repairs as required.
		Low charge.	Thoroughly leak test the system using approved UV dye and/or electronic detector. Repair all leaks as necessary. Charge system with proper amount of pure R-134a refrigerant.
		Faulty evaporator sensor.	Replace sensor.

Table 2, System Diagnosis Using Refrigerant Pressure Readings

Troubleshooting

System Troubleshooting Tables

Problem — No Fresh Air (nonrecirculation mode)

Problem — No Fresh Air (nonrecirculation mode)	
Possible Cause	**Remedy**
Mechanical problem with the recirculation door actuator.	Inspect the recirculation door actuator for obstructions or mechanical damage. Correct as necessary.
Problem with the wiring.	Refer to "Recirculation Door Actuator Circuit Tests" for diagnosis.
The control head is not working.	
The blower motor is in protection mode.	Refer to "Blower Motor Circuit Tests" for diagnosis.

Problem — Warm Airflow When the Air Conditioner is On; A/C is Not Working; or Poor Performance of A/C

Problem — Warm Airflow When the Air Conditioner is On; A/C is Not Working; or Poor Performance of A/C	
Possible Cause	**Remedy**
Low refrigerant charge in the system.	Perform a leak test. Repair any leaks, evacuate the system, replace the receiver-drier, and add a full charge of refrigerant.
Too much refrigerant in the system.	Evacuate the system, then add a full charge of refrigerant.
Moisture in the system.	If moisture is in the system, ice crystals may form and block the flow of refrigerant at the expansion valve or other places in the system. Recover the refrigerant, replace the receiver-drier, evacuate the system, and add a full charge of refrigerant.
The refrigerant compressor is not working.	The refrigerant charge is low or high.
	The refrigerant compressor clutch or drive belt needs repair or replacement.
	Refer to "A/C Clutch Circuit Tests for Diagnosing No A/C Clutch Engagement" in this subject.
Ice has formed on the evaporator coil.	Defrost the evaporator coil before resuming operation of the air conditioner. Refer to "Evaporator Probe Circuit Tests" in this subject for diagnosis.
Temperature blend door actuator is not working.	Refer to "Temperature Blend Door Circuit Tests" in this subject for diagnosis.
	Mechanical problem with temperature blend door actuator.
Blockage in A/C system such as lines, evaporator, condenser, or expansion valve.	Remove the blockage.
The blower motor is in protection mode.	Refer to "Blower Motor Circuit Tests" for diagnosis.
The evaporator probe isn't working or is out of range.	Refer to "Evaporator Probe Circuit Tests" for diagnosis.

Problem — Low-Side Pressure Too Low

Problem — Low-Side Pressure Too Low	
Possible Cause	**Remedy**
The expansion valve is not working.	Check the expansion valve for blockage and function. Blockage may be due to moisture causing ice formation.

Problem — Low-Side Pressure Too Low	
Possible Cause	**Remedy**
There are line or component restrictions.	Remove the restrictions.
The refrigerant charge is low.	Perform a leak test. Repair any leaks, evacuate the system, replace the receiver-drier, and add a full refrigerant charge.

Problem — High-Side Pressure Too High

Problem — High-Side Pressure Too High	
Possible Cause	**Remedy**
Airflow through the condenser is restricted.	Check for and remove dirt or debris in front of the condenser and radiator.
	Check the engine fan operation.
There is an internal restriction in the condenser indicated by ice buildup on the condenser or a cool spot on the line from the condenser to the receiver-drier.	Replace the condenser. If compressor failure recently occurred, the blockage may be due to debris from a failed compressor.
Air is in the refrigerant.	Perform a leak test. Repair any leaks, evacuate the system, replace the receiver-drier if necessary, and add a full charge of refrigerant.
The engine is overheated.	Check the engine cooling system.
Restriction in the compressor discharge line.	Replace the line.

Problem — Compressor Runs Continuously

Problem — Compressor Runs Continuously	
Possible Cause	**Remedy**
Low refrigerant charge in the system.	Perform a leak test. Repair any leaks, evacuate the system, replace the receiver-drier, and add a full charge of refrigerant.
The evaporator probe isn’t working.	Refer to "Evaporator Probe Circuit Tests" for diagnosis.

Problem — Little or No Heat

Problem — Little or No Heat	
Possible Cause	**Remedy**
Low engine coolant.	Check coolant level. If low, check for source of leak and repair as necessary.
Plugged heater core.	Flush or replace the heater core as necessary.
Engine thermostat is not working.	Check to see if the engine thermostat is stuck open. Refer to **Section 20.00, Subject 300** for diagnosis.
Engine fan on all the time.	Refer to **Group 20** for diagnosis.
Mechanical problem with temperature blend door actuator.	Inspect the temperature blend door actuator for obstructions or mechanical damage. Correct as necessary.
Problem with the wiring.	Refer to "Temperature Blend Door Actuator Circuit Tests" for diagnosis.
The control head is not working.	

Troubleshooting

Problem — Water or Liquid Leaking from the Air Conditioner

Problem — Water or Liquid Leaking from the Air Conditioner	
Possible Cause	**Remedy**
The drain tubes are plugged.	Clean the drain tubes.
Heater core is leaking.	Leak test and replace the heater core if necessary.

Problem — Recirculation Mode Not Working

Problem — Recirculation Mode Not Working	
Possible Cause	**Remedy**
Air selection switch is set to full or partial defrost.	Recirculation mode is not available in any of the defrost settings. This is not a problem.
Mechanical problem with the recirculation door actuator.	Inspect the recirculation door actuator for obstructions or mechanical damage. Correct as necessary.
Problem with the wiring.	Refer to "Recirculation Door Actuator Circuit Tests" for diagnosis.
The recirculation door actuator is not working.	
The control head is not working.	

Problem — Air Selection Switch Not Working

Problem — Air Selection Switch Not Working*	
Possible Cause	**Remedy**
Mechanical problem with the air distribution door actuator.	Inspect the air distribution door actuator for obstructions or mechanical damage. Correct as necessary.
Problem with the wiring.	Refer to "Air Distribution Door Actuator Circuit Tests" for diagnosis.
The control head is not working.	

* Not able to control where the air is directed.

Problem — No Cool Vent Air on a Heater-Only System

Problem — No Cool Vent Air on a Heater-Only System	
Possible Cause	**Remedy**
Mechanical problem with the temperature blend door actuator.	Inspect the temperature blend door actuator for obstructions or mechanical damage. Correct as necessary.
Problem with the wiring.	Refer to "Temperature Blend Door Actuator Circuit Tests" for diagnosis.
The control head is not working.	

Problem — No Backlighting on the Control Head

Problem — No Backlighting on the Control Head	
Possible Cause	**Remedy**
Problem with the wiring.	Refer to "Backlighting Circuit Tests" for diagnosis.
The control head is not working.	

Problem — Blower Not Working

Problem — Blower Not Working	
Possible Cause	**Remedy**
Problem with the wiring.	Refer to "Blower Motor Circuit Tests" for diagnosis.
The control head is not working.	
A fuse is blown.	
The blower motor is not working.	

Component and System Tests

Use the following component and system tests to diagnose an HVAC problem.

Receiver-Drier

To the touch, the entire length of the receiver-drier should be the same temperature. If the receiver-drier is not the same temperature, it may indicate a blockage or low charge. Any blockage can cause high head pressures.

Cooling System

Although they are not physically connected, there is a close tie between the air conditioner and the cooling system. Poor air conditioner cooling can be the result of a problem in the cooling system.

If the cooling system does not work correctly, the heat of the engine will rise to abnormal levels. The added heat will transfer to the air conditioner, other underhood parts, and maybe make its way into the cab. The added heat makes it necessary for the air conditioner to work harder and reduces the ability of the air conditioner to cool the air in the cab.

See **Group 20** for cooling system troubleshooting, and see the engine manufacturer's service manual for other details about cooling system problems.

Expansion Valve

Problems with the expansion valve may be caused by the valve being stuck closed or open. When the valve is stuck closed, the evaporator coil and the expansion valve will be at outside temperature. When the valve is stuck open, both the coil and the valve will be extremely cold with frost or ice buildup.

Because the expansion valve channels are very small, blockages in the system tend to be found here. The valve is very sensitive to contamination. The contaminant is usually water. Less than a drop of water is all it takes to make the valve stop working. When water reaches the valve, the extreme cold that results from the pressure drop freezes the water, forming a block of ice in the valve. After the system shuts down and the valve warms, the ice melts and the valve operates again, only to be blocked again when the moisture returns and freezes.

On-and-off operation of the expansion valve means that the receiver-drier is not removing moisture from the system.

Refrigerant Compressor

Compressor problems usually show in one of four ways:

- abnormal noise
- seizure
- leakage
- low suction and discharge pressures

Resonant compressor noises are not causes for alarm. Irregular noise or rattles are likely to be caused by broken parts. To check for seizure, de-energize the magnetic clutch and see if the drive plate can be turned. If it won't turn, the compressor has seized.

Low discharge pressure may be caused by not enough refrigerant, not enough belt tension, or a blockage somewhere in the system. These things should be checked before servicing the compressor.

Evaporator

The evaporator coils are basically trouble-free when airflow over the fins is not blocked. The filter next to the evaporator removes debris. If the filter is installed, no blockage can occur.

If a leak exists in the system and it cannot be traced to other parts or fittings, suspect damage to one of the evaporator coils.

Condenser

The condenser is usually trouble-free. Normally, the temperature of the condenser outlet line is noticeably cooler than the inlet line. However, when road debris such as leaves or dirt build up, the airflow over the condenser fins is blocked. Air is not able to absorb enough heat to turn the hot refrigerant gas into a liquid. High head pressures will result. In these cases, carefully clean the outer surfaces of the condenser with compressed air or a soap and water solution. Be careful not to bend the fins.

High head pressures will also occur if the condenser tubing is abnormally bent, blocking the flow of refrigerant. Frost will appear at the point where the flow is restricted.

Less common internal blockages, such as bits of foreign material or metallic grit buildup, will stop the flow of refrigerant.

When troubleshooting a suspected condenser problem, remember that the problem may be caused by the radiator transferring high levels of heat to the condenser. See **Group 20** of this manual for cooling system troubleshooting, and see the engine manufacturer's service manual for other information about cooling system problems.

Line Restrictions

A restricted suction line causes low suction pressure at the compressor and little or no cooling. A restriction in a line between the compressor and the expansion valve can cause high discharge and low suction pressure, and insufficient cooling.

Areas of ice or frost buildup usually mean a blockage. Parts that often freeze are probably corroded or inoperative and should be replaced. Parts, such as the expansion valve, that freeze once in a while may do so because of moisture in the system. If this happens, recover the refrigerant charge, evacuate/recycle the system refrigerant, replace the receiver-drier, and recover, evacuate, and charge the system with refrigerant.

Temperature Blend Door Actuator Circuit Tests

The temperature blend door actuator controls the amount of air that is routed through the heater core. The temperature blend door actuator is controlled by the temperature control switch on the control head (climate control panel). The control head senses the door position by reading the feedback voltage from the actuator position sensor. The feedback voltage will be less than the 5V reference voltage sent by the control head to the sensor.

The target position is based on the temperature control switch setting and internal control head algorithms. The desired position is considered reached when one of the following conditions is true, although this does not necessarily mean that the position actually corresponds to the desired temperature setting (for example, if the actuator movement is limited due to an obstruction).

- The actuator feedback position has been reached.
- The actuator is stalled for more than 1 second; the actuator feedback position does not change for more than 1 second.
- The target position corresponds to an end stop and an additional 1 second extra drive in the same direction (to guarantee sealing) has been performed.

The temperature blend door should move from one extreme position to the other when turning the temperature control switch from cold to hot or from hot to cold.

Follow the tests in **Table 3** in the sequence presented. The directions under the column "What to Do if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the specified repair or check. If the temperature blend door actuator passes the tests in **Table 3** and the actuator still does not operate properly, check for mechanical problems with the actuator.

Temperature Blend Door Actuator Circuit Tests				
Test	**Conditions**	**Test Point**	**Good Result**	**What to Do if Test Fails**
actuator motor drive circuit	key on, engine off temperature blend door actuator connector removed fan (blower) switch on low change temperature setting while observing the digital multimeter (DMM)	Measure across pins 5 and 6 of the temperature blend door actuator connector.	9V+ for about 1 second*	Check wiring between control head and temperature blend door actuator. If wiring is okay, replace the control head.
actuator position sensor reference voltage circuit	key on, engine off temperature blend door actuator connector removed	Measure between pin 7 of the temperature blend door actuator connector and the battery negative post.	5V	
actuator position sensor reference ground circuit	key on, engine off temperature blend door actuator connector removed	Measure between pin 8 of the temperature blend door actuator connector and the battery positive post.	12V*	
actuator position sensor feedback signal circuit	key on, engine off all connectors connected	Backprobe pins B11 and B5 at control head connector.	0.50V (full hot) to 4.00V (full cold)†	Check wiring between control head and temperature blend door actuator.‡ If wiring is okay, replace the actuator.‡

* The voltage should be approximately the same as the battery voltage.

† Values are approximate.

‡ It is assumed that reference voltage and ground circuits are functioning.

Table 3, Temperature Blend Door Actuator Circuit Tests

Air Distribution Door Actuator Circuit Tests

The air distribution (mode) door actuator controls the direction the air is routed through the HVAC ducts in the cab. The air distribution door actuator is controlled by the air selection switch on the control head (climate control panel). The control head senses the air distribution door position by reading the feedback voltage from the actuator position sensor. The feedback voltage will be less than the 5V reference voltage sent by the control head to the sensor.

The target position is based on the air selection switch setting and internal control head algorithms. The desired position is considered reached when one of the following conditions is true, although this does not necessarily mean that the position actually corresponds to the desired air selection setting (for example, if the actuator movement is limited due to an obstruction).

- The actuator feedback position has been reached.
- The actuator is stalled for more than 1 second; the actuator feedback position does not change for more than 1 second.
- The target position corresponds to an end stop and an additional 1 second extra drive in the same direction (to guarantee sealing) has been performed.

The air distribution door should move from one extreme position to the other when turning the air selection switch from the far left to the far right or from the far right to the far left.

Follow the tests in **Table 4** in the sequence presented. The directions under the column "What to Do if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the specified repair or check. If the air distribution door actuator passes the tests in **Table 4** and the actuator still does not operate properly, check for mechanical problems with the actuator. To quickly check for normal operation, feel for air flowing from the correct outlet in each air selection setting.

Air Distribution Door Actuator Circuit Tests				
Test	**Conditions**	**Test Point**	**Good Result**	**What to Do if Test Fails**
actuator motor drive circuit	key on, engine off air distribution door actuator connector removed fan (blower) speed on low change the air selection setting while observing the digital multimeter (DMM)	Measure across pins 5 and 6 of the air distribution door actuator connector.	9V+ for about 1 second*	Check wiring between control head and air distribution door actuator. If wiring is okay, replace the control head.
actuator position sensor reference voltage circuit	key on, engine off air distribution door actuator connector removed	Measure between pin 10 of the air distribution door actuator connector and the battery negative post.	5V	
actuator position sensor reference ground circuit	key on, engine off air distribution door actuator connector removed	Measure between pin 8 of the air distribution door actuator connector and the battery positive post.	12V*	
actuator position sensor feedback signal circuit	key on, engine off all connectors connected	Backprobe pins B10 and B5 at control head connector.	0V (far right) to 5V (far left)	Check wiring between control head and air distribution door actuator.† If wiring is okay, replace the actuator.†

* The voltage should be approximately the same as the battery voltage.

† It is assumed that reference voltage and ground circuits are functioning.

Table 4, Air Distribution Door Actuator Circuit Tests

Recirculation Door Actuator Circuit Tests

The recirculation door actuator controls the source of the air, fresh or recirculated, that is routed through the HVAC ducts in the cab. The recirculation door actuator is controlled by the recirculation button on the control head (climate control panel).

Vehicles built from May 2, 2003, have partial recirculation. For information on this feature, see **Subject 050**.

The control rules for the recirculation mode are as follows:

- The recirculation mode is not available in the defrost settings.
- The default at power up is fresh air unless the fan switch is in the off position. When the fan switch is in the off position, the recirculation mode is the default mode, but the LED is not illuminated.
- When the recirculation mode is enabled, it will remain on until one of the following occurs:
  - the air selection switch is moved to a defrost mode;
  - the recirculation button is pressed;
  - the ignition is cycled;
  - 20 minutes have passed and the recirculation timer has expired.

NOTE: On vehicles built prior to May 2, 2003, the recirculation mode is canceled until the recirculation button is pressed again. On vehicles built from May 2, 2003, the system enters partial recirculation mode for five minutes, then resumes full recirculation mode for 20 minutes. This cycle repeats as long as the system remains in recirculation mode.

The control head senses the recirculation door position by reading the feedback voltage from the actuator position sensor. The feedback voltage will be less than the 5V reference voltage sent by the control head to the sensor.

The target position is based on the recirculation button setting and internal control head algorithms. The desired position is considered reached when one of the following conditions is true, although this does not necessarily mean that the position actually corresponds to the desired recirculation button setting (for example, if the actuator movement is limited due to an obstruction).

- The actuator feedback position has been reached.
- The actuator is stalled for more than 1 second; the actuator feedback position does not change for more than 1 second.
- The target position corresponds to an end stop and an additional 1 second extra drive in the same direction (to guarantee sealing) has been performed.

The recirculation door should move from one extreme position to the other when the recirculation button is pressed on and then pressed off.

Perform the tests in **Table 5** in the sequence presented. The directions under the column "What to Do if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the specified repair or check. If the recirculation door actuator passes the tests in **Table 5** and the actuator still does not operate properly, check for mechanical problems with the actuator. To quickly check for normal operation, set the fan switch to high and listen for a change in the sound of the blower near the HVAC unit while pressing the recirculation button on and off. The blower will be louder when recirculation is enabled.

Recirculation Door Actuator Circuit Tests

Test	Conditions	Test Point	Good Result	What to Do if Test Fails
actuator motor drive circuit	key on, engine off recirculation door actuator connector removed fan (blower) speed on low change the recirculation setting while observing the digital multimeter (DMM)	Measure across pins 5 and 6 of the recirculation door actuator connector.	9V+ for about 1 second*	Check wiring between control head and recirculation door actuator. If wiring is okay, replace the control head.
actuator position sensor reference voltage circuit	key on, engine off recirculation door actuator connector removed	Measure between pin 10 of the recirculation door actuator connector and the battery negative post.	5V	
actuator position sensor reference ground circuit	key on, engine off recirculation door actuator connector removed	Measure between pin 8 of the recirculation door actuator connector and the battery positive post.	12V*	

Recirculation Door Actuator Circuit Tests				
Test	Conditions	Test Point	Good Result	What to Do if Test Fails
actuator position sensor feedback signal circuit	key on, engine off all connectors connected	Backprobe pins A11 and B5 at control head connector.	0.8V (recirc. on) to 4.7V (recirc. off)	Check wiring between control head and recirculation door actuator.† If wiring is okay, replace the actuator.†

* The voltage should be approximately the same as the battery voltage.

† It is assumed that reference voltage and ground circuits are functioning.

Table 5, Recirculation Door Actuator Circuit Tests

Blower Motor Circuit Tests

The blower motor power and ground are supplied directly to the blower motor assembly. The blower speed is controlled by the fan switch on the control head (climate control panel). The control head sends a pulse width modulated (PWM) signal to the blower motor. The frequency of this signal is 2000 Hz. The pulse width varies with the fan switch selection.

The protection modes for the blower motor are as follows:

- Reverse Voltage Protection—The motor will not operate if the polarity of the motor leads, circuits 98F and ground, are reversed.
- Current Protection—If the motor exceeds the maximum limit, the speed will be reduced until the current is within the limits (23.5A maximum).
- Temperature Protection—If the motor's internal temperature sensor senses that the temperature is too high, the blower speed is reduced to 1000 rpm to reduce the load on the motor and a comparison is made between the sensor reading and the maximum limit. If the temperature is still too high, the blower speed is further reduced to the minimum value of approximately 500 rpm and a temperature comparison is made to the maximum. If, after the second comparison, the temperature is still too high, the motor will shut down until it has cooled sufficiently.

Perform the tests in **Table 6** in the sequence presented. The directions under the column "What to Do if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the specified repair or check. If the blower motor passes the tests in **Table 6** and the blower still does not operate properly, check the blower motor. To quickly check for normal operation, set the fan switch to high and listen for a change in the sound of the blower near the HVAC unit while pressing the recirculation button on and off. The blower will be louder when recirculation is enabled.

Blower Motor Circuit Tests				
Test	Conditions	Test Point	Good Result	What to Do if Test Fails
main power to blower motor	battery switch on (if equipped) key off blower motor connector removed	Measure between pin 4 of blower motor connector and negative battery post.	12V*	Check fuse F2 in the PDM under the hood. If the fuse is blown, check for shorted wiring or a damaged blower motor. Check for an open in circuit 98F.

Blower Motor Circuit Tests				
Test	**Conditions**	**Test Point**	**Good Result**	**What to Do if Test Fails**
blower motor ground circuit	battery switch on (if equipped) key off blower motor connector removed	Measure between pin 3 of blower motor connector and the positive battery post.	12V*	Check for an open in blower motor ground circuit.
PWM signal from control head	battery switch on (if equipped) key on, engine off blower motor connector disconnected change the fan (blower) speed setting on the control head and observe frequency using the digital multimeter (DMM)	Probe pins 4 and 5 of the blower motor connector, harness side (DMM set to measure frequency).	0 Hz fan off 0 Hz fan on high 2000 Hz all other speeds	Check circuit 338H. Check control head.
voltage drop (power circuit)	battery switch on (if equipped) key on, engine off all connectors connected fan (blower) speed on high	Backprobe pin 4 at the blower motor connector, other lead on positive battery post.	less than 0.5V	Locate high resistance or open in circuit 98F.
voltage drop (ground circuit)	battery switch on (if equipped) key on, engine off all connectors connected fan (blower) speed on high	Backprobe pin 3 at the blower motor connector, other lead on negative battery post.	less than 0.5V	Locate high resistance or open in blower motor ground circuit.
blower motor current draw	battery switch on (if equipped) key on, engine off all connectors connected fan (blower) speed on high	Use current clamp around circuit 98F or blower motor ground wire.	less than 23.5A	Check blower motor.

* The voltage should be approximately the same as the battery voltage.

Table 6, Blower Motor Circuit Tests

Evaporator Probe Circuit Tests

The evaporator temperature sensor is a resistive element, where the resistance increases as the temperature decreases. The control head (climate control panel) uses this sensor to determine the evaporator temperature. The control head uses the temperature information to determine if the A/C compressor should be engaged or not in order to prevent the evaporator core from freezing. As refrigerant flows through the evaporator, condensation will form on the surface of the evaporator. If this condensation freezes because the evaporator temperature is too low, airflow will be restricted through the core and poor cooling will result. The control head will shut off the compressor when the evaporator temperature is near the point where freezing may occur. See **Table 7** for evaporator probe temperature versus resistance values for units manufactured up to and including January 7, 2007. See **Table 8** for evaporator probe temperature versus resistance values for units manufactured on or after January 8, 2007.

Perform the tests in **Table 9** in the sequence presented. The directions under the column "What to Do if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the specified repair or check.

Troubleshooting

Evaporator Probe Temperature/Resistance (up to January 7, 2007)										
Temperature		Resistance: ohms		Temperature		Resistance: ohms		Temperature		Resistance: ohms
°F	°C			°F	°C			°F	°C	
5	–15	36,780		66	19	6500		84	29	4170
14	–10	27,830		68	20	6210		86	30	3995
23	–5	21,250		70	21	5935		88	31	3828
32	0	16,360		72	22	5673		90	32	3669
41	5	12,690		73	23	5426		91	33	3518
50	10	9927		75	24	5189		93	34	3373
59	15	7823		77	25	4964		95	35	3236
61	16	7466		79	26	4751		97	36	3104
63	17	7125		81	27	4548		99	37	2979
64	18	6805		82	28	4354		100	38	2860

Table 7, Evaporator Probe Temperature/Resistance (up to January 7, 2007)

Evaporator Probe Temperature/Resistance (from January 8, 2007)							
Temperature: °F (°C)	Resistance: ohms		Temperature: °F (°C)	Resistance: ohms		Temperature: °F (°C)	Resistance: ohms
-40 (-40)	92757		41 (5)	6998		122 (50)	993.2
-31 (-35)	66870		50 (10)	5485		131 (55)	823.2
-22 (-30)	48790		59 (59)	4330		140 (60)	685.8
-13 (-25)	35937		68 (20)	3443		149 (65)	574.2
-4 (-20)	26757		77 (25)	2757		158 70)	482.9
5 (-15)	20103		86 (30)	2221		167 (75)	408.3
14 (-10)	15252		95 (35)	1800		176 (80)	346.8
23 (-5)	11664		104 (40)	1468		185 (85)	295.6
32 (0)	9000		113 (45)	1204		—	—

Table 8, Evaporator Probe Temperature/Resistance (from January 8, 2007)

Evaporator Probe Circuit Tests				
Test	**Conditions**	**Test Point**	**Good Result**	**What to Do if Test Fails**
evaporator temperature probe	key off, engine off sensor probe removed and disconnected fill a cup with ice then add water to make an ice-water bath NOTE: use mostly ice and allow time for temperature to stabilize at 32°F (0°C) place the tip of the evaporator probe in the ice-water bath for 5 minutes before testing—leave the tip immersed while taking the resistance measurement—be sure the meter reading is stable before noting the final measurement	Measure across pins on the temperature probe.	for pre-1-8-07: 16,000 to 16,730Ω at 32°F (0°C) — for 1-8-07 on: 8910 to 9090Ω at 32°F (0°C)	Replace temperature probe.
evaporator temperature probe circuit test	battery switch on (if equipped) key on, engine off sensor probe installed, but connector is disconnected	Measure across temperature probe connector terminals.	5V	Check for an open in circuits 338K and 338GP. If wiring is okay, replace the control head.

Table 9, Evaporator Probe Circuit Tests

A/C Clutch Circuit Tests for Diagnosing No A/C Clutch Engagement

The A/C compressor clutch is controlled by the control head (climate control panel). When the control head determines that the A/C compressor is required, it grounds the A/C request input to the bulkhead module (BHM). When the BHM receives the A/C request signal from the climate control panel, it will apply power to the A/C clutch output when the following conditions are met—

- engine has been running more than 5 seconds;
- battery voltage is greater than 9.25V;
- low air pressure warning is not active on the ICU;
- A/C clutch has not been engaged in the previous 15 seconds.

NOTE: The **A/C clutch cycle timer strategy** is implemented differently, depending on BHM software versions. With BHM software version 6.1, the total A/C clutch cycle time (on + off time) is a minimum of 15 seconds. This ensures that the A/C compressor does not cycle more than 4 times per minute. With BHM software versions 6.4 and 6.5, the minimum compressor off time is 15 seconds. This means the total cycle time (on + off time) will always exceed 15 seconds. This too, ensures that the A/C compressor does not cycle more than 4 times per minute.

The BHM sends power to energize the A/C clutch. A binary switch is wired into this circuit, which will prevent the compressor clutch from engaging if the refrigerant pressure is too high or too low.

When **all** of the following conditions are met, the control head will send the A/C request signal to the bulkhead module:

- The air selection switch is in one of the A/C or defrost settings, or the recirculation mode is on.

- The fan switch is on any setting other than off.
- The evaporation sensor temperature is above 40.1°F (4.5°C).

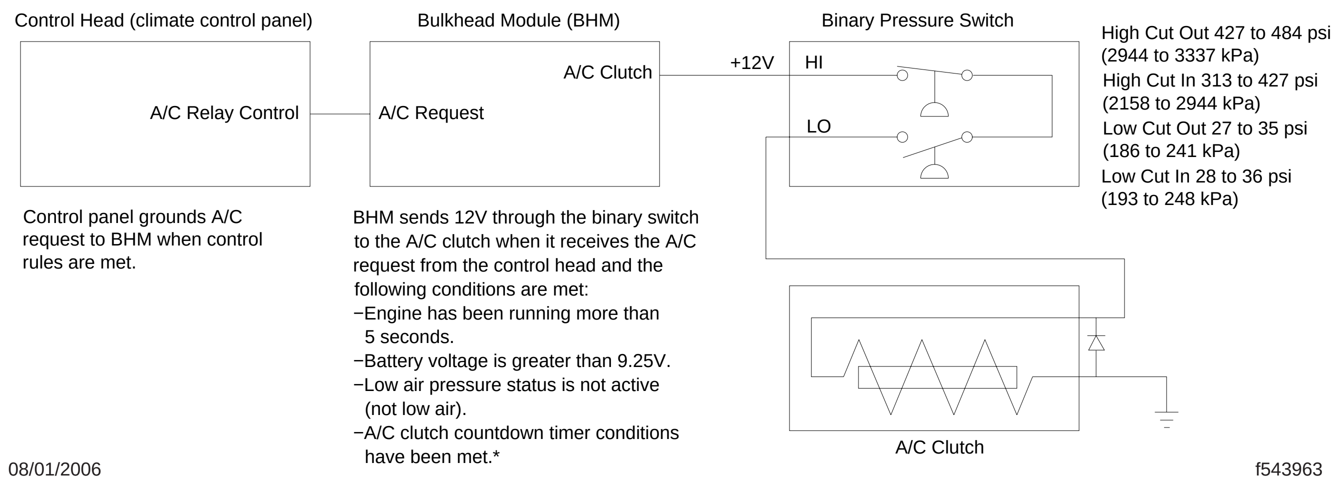
When these conditions exist, the control head sends the A/C request signal to the bulkhead module. See **Fig. 2**.

NOTE: The A/C signal will remain active until the evaporator sensor reaches 38.3°F (3.5°C), the fan is turned off, or the air selection switch is taken out of defrost or A/C mode.

- make sure that the engine speed is available (make sure it registers on the tachometer).

Backlighting Circuit Tests

See **Table 11** for the backlighting circuit tests. Perform the tests in **Table 11** in the sequence presented. The directions under the column "What to Do if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the specified repair or check. If all of the tests pass and the backlighting at the control head still does not operate properly, check the control head.



*See **A/C clutch cycle timer strategy** note above.
NOTE: Binary pressure switch positions indicate little or no system pressure.

Fig. 2, A/C Clutch Control Circuit

See **Table 10** for the A/C clutch circuit tests. Perform the tests in **Table 10** in the sequence presented. The directions under the column "What to Do if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the specified repair or check.

NOTE: If these tests pass and the A/C clutch still will not engage, check the following—

- make sure that the air system does not have an active low air pressure warning;
- make sure that the battery voltage to all BHM inputs is above 9.25V;

Fault Codes

If the A/C clutch is not working, use ServiceLink to check for fault codes. See **Table 12** and **Table 13** for a description of the fault codes.

A/C Clutch Circuit Tests for Diagnosing No A/C Clutch Engagement				
Test	**Conditions**	**Test Point/Method**	**Good Result**	**What to Do if Test Fails**
A/C request input	key on, engine on air selection switch in one of A/C settings fan (blower) speed on any setting but off connect ServiceLink and use the "A/C Clutch Function" Datalink Monitor template to see if the A/C request is seen by the BHM	ServiceLink/Datalink Monitor NOTE: Make sure the Datalink Monitor template is **not** in Test Mode. The control head should request A/C. This will cause the "A/C Request" annunciator on the template to indicate that the request is on. If the annunciator does not indicate that a request for A/C is received, check the settings on the control head before proceeding with "What to Do if Test Fails."	A/C request is received by the BHM	Perform the "Evaporator Probe Circuit Tests." Check wiring between the control head and the bulkhead module. Check for an open circuit. Check the control head. Check the bulkhead module. Try to manually ground the A/C request input while observing the template to confirm.
A/C clutch circuit*	key on, engine off connect ServiceLink and use the "A/C Clutch Function" Datalink Monitor template to manually actuate the A/C clutch output	ServiceLink/Datalink Monitor NOTE: Put the template in "Test Mode" and actuate the A/C clutch by selecting the button for "Clutch On." You should hear a distinct click when the clutch engages. The A/C clutch annunciator (BHM to clutch) should turn on when the output is energized. If this annunciator indicates that the output is on but the clutch does not engage, then the problem is in the A/C clutch circuit and not with the BHM. If the A/C clutch annunciator does not indicate that the output is energized when the output is turned on and the clutch does not engage, then the problem is with the BHM.	A/C clutch should engage	Check continuity across the binary switch. If the circuit is open, check if the refrigerant pressure is within operating range of the binary switch. (Refrigerant pressure may be very low or too high.) If pressures are okay, replace binary switch. Check for faulty wiring. Check for faulty A/C clutch ground circuit. Check for faulty A/C clutch coil (coil resistance should be $3\Omega \pm 0.5\Omega$). Check for faulty BHM (see note in Test Point/Method column).

* Circuit faults with the A/C clutch output may generate bulkhead module fault codes.

Table 10, A/C Clutch Circuit Tests for Diagnosing No A/C Clutch Engagement

Backlighting Circuit Tests				
Test	**Conditions**	**Test Point**	**Good Result**	**What to Do if Test Fails**
backlighting circuit ground test	battery switch on (if equipped) key off, engine off control head connector disconnected	Measure between pin B8 of the control head connector and the positive battery post.	12V*	Check for an open in the control head ground circuit.

Troubleshooting

Backlighting Circuit Tests				
Test	**Conditions**	**Test Point**	**Good Result**	**What to Do if Test Fails**
backlighting power test	battery switch on (if equipped) key off, engine off control head connector disconnected headlight switch on	Measure voltage between pins A2 (positive lead) and B8 (negative lead) on the control head connector while toggling the dimmer switch between full dim and full bright.	voltage should be about 1.2V at full dim and 10.8V at full bright	Check circuit 29A for an open/ short. If okay, refer to **Group 54** for further diagnosis.
backlighting pulse width modulated (PWM) signal test	battery switch on (if equipped) key off, engine off control head connector disconnected headlight switch on	Measure frequency between pins A2 and B8 on the control head connector.	400 Hz	Check circuit 29A for an open/ short. If okay, refer to **Group 54** for further diagnosis.

* The voltage should be approximately the same as the battery voltage.

Table 11, Backlighting Circuit Tests

J1587 Fault Codes, HVAC (bulkhead module related) MID 164				
MID	**SID**	**FMI**	**Fault Description**	**Action**
164	057	05	A/C clutch output open circuit (low current)	Check circuit 98A for an open circuit. Check binary switch; it may be open. If open, check for low or high refrigerant pressure. Also check the switch itself. Check A/C clutch coil for an open circuit.
		06	A/C clutch output shorted to ground (high current)	Check circuit 98A for a short to ground.

Table 12, J1587 Fault Codes, HVAC (bulkhead module related) MID 164

J1939 Fault Codes, HVAC (bulkhead module related) Source Address (SA) 33				
SA	**SPGN**	**FMI**	**Fault Description**	**Action**
33	1550	05	A/C clutch output open circuit (low current)	Check circuit 98A for an open circuit. Check binary switch; it may be open. If open, check for low or high refrigerant pressure. Also check the switch itself. Check A/C clutch coil for an open circuit.
		06	A/C clutch output shorted to ground (high current)	Check circuit 98A for a short to ground.

Table 13, J1939 Fault Codes, HVAC (bulkhead module related) Source Address (SA) 33

Refrigerant

WARNING

R–134a is the only refrigerant that is approved for use on Freightliner vehicles. Several companies offer less expensive, hydrocarbon-based refrigerant, such as propane and methane. Use of these refrigerants will void the warranty on the air conditioning system, cause damage to the air conditioning system, and possibly result in personal injury or property damage. Leaking air conditioning systems charged with hydrocarbon-based refrigerants pose a serious risk of fire or explosion under the hood, or inside the passenger compartment. No vehicle built by Freightliner Trucks can be safely charged with hydrocarbon-based refrigerants, regardless of what the refrigerant supplier states.

When servicing an air conditioning system, always use a refrigerant identifier to ensure that the system has not been charged with something other than R–134a. This should be standard practice since there is no way to tell what services have been previously performed. Identification by service technicians will help to avoid the risk of explosion and help to guard against contamination of equipment when refrigerant is recovered and recycled.

Refrigerant recovery/charge stations can be purchased from:

SPX Kent-Moore
28635 Mound Road
Warren, Michigan 48092-3499
1-800-328-6657

The vehicle's refrigerant charge level is printed on a sticker in the engine bay, on the right side of the vehicle. If the sticker is missing, check Group 83 in PartsPro (module/subgroup 700) for the proper sticker and charge information, using the vehicle's serial number.

Refrigerant Oil

IMPORTANT: Using the wrong refrigerant oil in the HVAC system will prevent proper lubrication, and may cause early failure of system components. Always verify that the correct oil is being used in the system. See **Table 1** for refrigerant oil specifications.

Refrigerant Oil Specification	
Refrigerant Oil	**Capacity**
Sanden PAG SP–20 or SP–15	10 fl oz (300 mL)

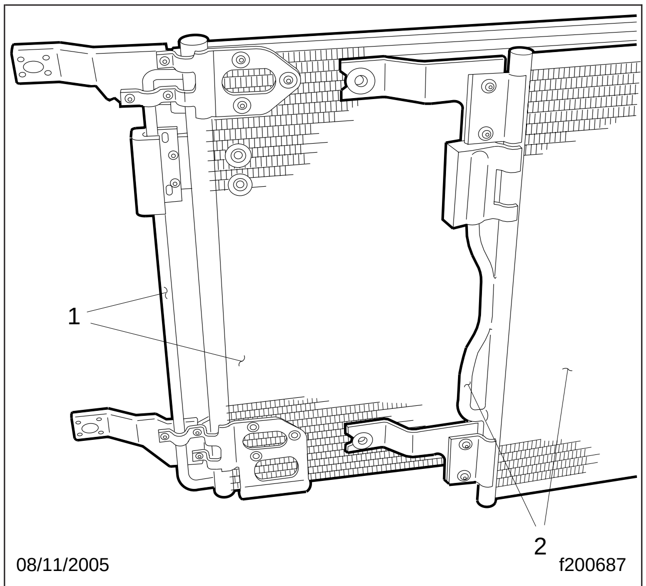
Table 1, Refrigerant Oil Specification

Temperature/Pressure Specification Tables (pre-EPA07 vehicles)

Determining Cooling Package Size

Before using the temperature/pressure specifications in **Table 2**, **Table 3**, **Table 4**, and **Table 5**, determine whether the vehicle has a small cooling package or a large cooling package, and what brand of condenser is installed. This can be done by looking at the condenser size and the condenser mounting location.

- See **Fig. 1** for an illustration that shows the difference between the Behr and Modine condensers.

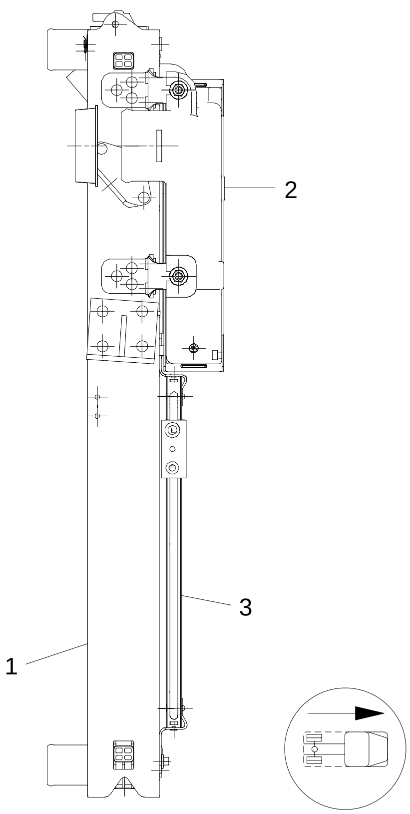


1. Behr Condenser
2. Modine Condenser

Fig. 1, Behr and Modine Condensers

Specifications

- Small Cooling Package: The condenser is mounted below the charge air cooler and does not cover the entire face of the radiator. See **Fig. 2**.



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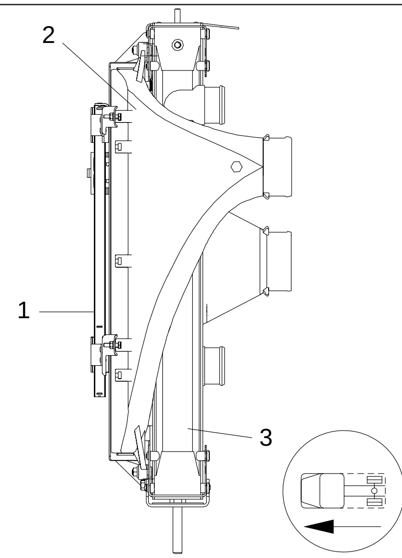
1. Radiator
2. Charge Air Cooler
3. Condenser

Fig. 2, Small Cooling Package

- Large Cooling Package: The condenser is mounted in front of the charge air cooler. See **Fig. 3**.

Determine Fins per Inch (fpi) of a Small Cooling Package Condenser

Early Business Class M2 vehicles with a small cooling package were equipped with a 14-fpi condenser. In October 2002, the 14-fpi condenser began being phased out and replaced with a 19-fpi condenser. The 14-fpi condenser may still be found on vehicles built through March 2003. For vehicles built from October 2002 through March 2003, it is necessary to determine whether the vehicle was built with a 14-fpi or 19-fpi condenser.



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1. Condenser
2. Charge Air Cooler
3. Radiator

Fig. 3, Large Cooling Package

If the vehicle has a large cooling package, it is not necessary to determine the number of fins per inch on the condenser to determine which temperature/pressure specification table to use. All Business Class M2 vehicles with a large cooling package use a 14-fpi condenser.

Use the following steps to determine whether the condenser has 14 fpi or 19 fpi.

1. Locate a section on the condenser face that is free of bent fins, and place a white sheet of paper over that area.
2. Using a soft-lead pencil, rub the lead lightly on the paper to transfer the impression of the fins to the sheet of paper. Transfer the impression to obtain an area about 1 inch by 3 inches (25 mm by 76 mm) on the paper.

IMPORTANT: Be careful not to bend the fins while transferring the impression.

3. Place the sheet of paper on a clean, flat surface and place a ruler on the impression. Line the ruler up with one of the fin marks.
4. Count the number of fin marks from the zero-inch (zero-mm) mark to the two-inch (51-mm) mark on the ruler. Divide the number of fins counted by 2 to obtain the approximate number of fins per inch. For example, 29 fins divided by 2 equals 14.5 or approximately 14 fins per inch.

Temperature/Pressure Specifications for a Vehicle With a Small Cooling Package* and a 14-fpi Condenser†

Ambient Air Temp.	Humidity (approximate)	Dash Outlet Temperature (approximate)	Service Port Pressures		A/C Compressor Status	A/C Compressor Status Comments
			High Side psi (kPa)	Low Side psi (kPa)		
70°F (21°C)	Low 25%	45–53°F (7–12°C)	77–142 (531–979)	8–31 (55–214)	Cycling	Off about 1 minute; On about 2 minutes
	High 55%	45–56°F (7–13°C)	82–181 (565–1248)	8–45 (55–310)	Cycling	Off about 1 minute; On about 4 minutes
80°F (27°C)	Low 25%	45–52°F (7–11°C)	103–176 (710–1213)	11–37 (76–255)	Cycling	Off about 1 minute; On about 5 minutes
	High 55%	50–59°F (10–15°C)	177–182 (1220–1255)	17–18 (117–124)	On	On steady
90°F (32°C)	Low 25%	51–53°F (11–12°C)	206–210 (1420–1448)	17–18 (117–124)	On	On steady
	High 55%	58–60°F (14–16°C)	225–231 (1551–1593)	23–24 (159–165)	On	On steady
100°F (38°C)	Low 25%	57–58°F (14°C)	256–258 (1765–1779)	22–23 (152–159)	On	On steady
	High 55%	67–69°F (19–21°C)	282–288 (1944–1986)	29–30 (200–207)	On	On steady

Test conditions:

- engine at 1500 rpm
- engine fan locked on (six-blade viscous with lock brackets)
- normal A/C mode, outside air
- blower speed on high, about 13.5 vdc
- cab doors open
- hood open
- parked out of direct sunlight
- no wind speed or less than 5 mph (8 km/h)
- stabilize at each point
- the condenser is mounted below the charge air cooler

* Refer to "Temperature/Pressure Specification Tables" to determine whether the vehicle has a small or large cooling package.

† Refer to "Temperature/Pressure Specification Tables" to determine the number of fins per inch on the condenser.

Table 2, Temperature/Pressure Specifications for a Vehicle With a Small Cooling Package and a 14-fpi Condenser

Specifications

Temperature/Pressure Specifications for a Vehicle With a Small Cooling Package* and a 19-fpi Condenser†						
Ambient Air Temp.	**Humidity (approximate)**	**Dash Outlet Temperature (approximate)**	**Service Port Pressures**		**A/C Compressor Status**	**A/C Compressor Status Comments**
			High Side psi (kPa)	**Low Side psi (kPa)**		
70°F (21°C)	Low 25%	43–52°F (6–11°C)	81–107 (558–738)	8–53 (55–365)	Cycling	On about 12 seconds; off about 12 seconds
	High 55%	48–55°F (9–13°C)	93–120 (641–827)	11–51 (76–352)	Cycling	On about 15 seconds; off about 8 seconds
80°F (27°C)	Low 25%	45–52°F (7–11°C)	108–144 (745–993)	9–44 (62–303)	Cycling	On about 20 seconds; off about 9 seconds
	High 55%	49–51°F (9–11°C)	140–149 (965–1027)	13–15 (90–103)	On	On steady
90°F (32°C)	Low 25%	49–50°F (9–10°C)	170–187 (1172–1289)	16–17 (110–117)	On	On steady
	High 55%	57–59°F (14–15°C)	185–191 (1276–1317)	23–24 (159–165)	On	On steady
100°F (38°C)	Low 25%	55–57°F (13–14°C)	210–220 (1448–1517)	22–23 (152–159)	On	On steady
	High 55%	66–68°F (19–20°C)	234–242 (1613–1669)	30–32 (207–221)	On	On steady

Test conditions:

- engine at 1500 rpm
- engine fan locked on (six-blade viscous with lock brackets)
- normal A/C mode, outside air
- blower speed on high
- cab doors open
- hood open
- parked out of direct sunlight
- no wind speed or less than 5 mph (8 km/h)
- stabilize at each point
- the condenser is mounted below the charge air cooler
- no wind speed or less than 5 mph (8 km/h)

* Refer to "Temperature/Pressure Specification Tables" to determine whether the vehicle has a small or large cooling package.

† Refer to "Temperature/Pressure Specification Tables" to determine the number of fins per inch on the condenser.

Table 3, Temperature/Pressure Specifications for a Vehicle With a Small Cooling Package and a 19-fpi Condenser

Temperature/Pressure Specifications for a Vehicle With a Large Cooling Package and a Behr Condenser but No Auxiliary HVAC Unit*						
Ambient Air Temp.	**Humidity (approximate)**	**Dash Outlet Temperature (approximate)**	**Service Port Pressures**		**A/C Compressor Status**	**A/C Compressor Status Comments**
			High Side psi (kPa)	**Low Side psi (kPa)**		
70°F (21°C)	Low 25%	44–53°F (7–12°C)	73–104 (503–717)	8–50 (55–345)	Cycling	On about 16 seconds; off about 32 seconds
	Medium 50%	44–52°F (7–11°C)	74–112 (510–772)	7–50 (48–345)	Cycling	On about 17 seconds; off about 19 seconds
	High 70%	46–54°F (8–12°C)	70–112 (483–772)	8–50 (55–345)	Cycling	On about 18 seconds; off about 17 seconds
80°F (27°C)	Low 25%	44–53°F (7–12°C)	87–127 (600–876)	8–47 (55–324)	Cycling	On about 24 seconds; off about 13 seconds
	Medium 50%	45–55°F (7–13°C)	90–135 (621–931)	10–49 (69–338)	Cycling	On about 40 seconds; off about 10 seconds
	High 70%	47–56°F (8–13°C)	128–134 (883–924)	14–20 (97–138)	On	On steady
90°F (32°C)	Low 25%	46–55°F (8–13°C)	110–162 (758–1117)	10–48 (69–331)	Cycling	On about 73 seconds; off about 9 seconds
	Medium 50%	48–52°F (9–11°C)	155–160 (1069–1103)	19–20 (131–138)	On	On steady
	High 70%	55–57°F (13–14°C)	167–170 (1151–1172)	22–23 (152–159)	On	On steady
100°F (38°C)	Low 25%	53–54°F (12°C)	192–196 (1324–1351)	22–23 (152–159)	On	On steady
	Medium 50%	60–62°F (16–17°C)	201–204 (1386–1407)	26–28 (179–193)	On	On steady
	High 70%	66–69°F (19–21°C)	211–214 (1455–1475)	29–30 (200–207)	On	On steady

Test conditions:

- engine at 1500 rpm
- engine fan locked on
- normal A/C mode, outside air
- blower speed on high
- cab doors open
- hood open
- parked out of direct sunlight

* Refer to "Temperature/Pressure Specification Tables" to determine whether the vehicle has a small or large cooling package.

Table 4, Temperature/Pressure Specifications for a Vehicle With a Large Cooling Package and a Behr Condenser but No Auxiliary HVAC Unit

Specifications

Temperature/Pressure Specifications for a Vehicle With a Large Cooling Package, a Behr Condenser, and an Auxiliary HVAC Unit*							
Ambient Air Temp.	**Humidity (approximate)**	**Dash Outlet Temperature (approximate)**	**Auxiliary Unit Lower Louver Temperature**	**Service Port Pressures**		**A/C Compressor Status**	**A/C Compressor Status Comments**
				High Side psi (kPa)	**Low Side psi (kPa)**		
70°F (21°C)	Low 25%	43–50°F (6–10°C)	45–53°F (7–12°C)	73–114 (503–786)	14–40 (97–276)	Cycling	On about 26 seconds; off about 15 seconds
	Medium 50%	44–53°F (7–12°C)	47–54°F (8–12°C)	74–119 (510–820)	16–42 (110–290)	Cycling	On about 35 seconds; off about 13 seconds
	High 70%	45–54°F (7–12°C)	49–58°F (9–14°C)	73–120 (503–827)	16–45 (110–310)	Cycling	On about 48 seconds; off about 10 seconds
80°F (27°C)	Low 25%	46–54°F (8–12°C)	49–56°F (9–13°C)	88–143 (607–986)	18–44 (124–303)	Cycling	On about 48 seconds; off about 11 seconds
	Medium 50%	48–50°F (9–10°C)	54–56°F (12–13°C)	145–150 (1000–1034)	24–26 (165–179)	On	On steady
	High 70%	54–55°F (12–13°C)	59–61°F (15–16°C)	158–164 (1089–1131)	28–29 (193–200)	On	On steady
90°F (32°C)	Low 25%	50–51°F (10–11°C)	56–57°F (13–14°C)	177–182 (1220–1255)	25–26 (172–179)	On	On steady
	Medium 50%	58–60°F (14–16°C)	64–66°F (18–19°C)	194–199 (1338–1372)	32–34 (221–234)	On	On steady
	High 70%	62–63°F (17°C)	68–69°F (20–21°C)	195–207 (1344–1427)	35–37 (241–255)	On	On steady
100°F (38°C)	Low 25%	58–59°F (14–15°C)	64–66°F (18–19°C)	227–235 (1565–1620)	31–33 (214–228)	On	On steady
	Medium 50%	67–68°F (19–20°C)	71–72°F (22°C)	242–247 (1669–1703)	40–41 (276–283)	On	On steady
	High 70%	74–75°F (23–24°C)	79–81°F (26–27°C)	261–265 (1800–1827)	49–50 (338–352)	On	On steady
Test conditions: • engine at 1500 rpm • engine fan locked on • normal A/C mode, outside air • blower speed on high • cab doors open • hood open • parked out of direct sunlight							

* Refer to "Temperature/Pressure Specification Tables" to determine whether the vehicle has a small or large cooling package.

Table 5, Temperature/Pressure Specifications for a Vehicle With a Large Cooling Package, a Behr Condenser, and an Auxiliary HVAC Unit

Temperature/Pressure Specification Tables (EPA07 compliant vehicles)

Before using the temperature/pressure specifications in **Table 7**, **Table 8**, **Table 9**, and **Table 10**, determine what condenser is installed on the vehicle. To do so, identify the vehicle rating, or measure the condenser. See **Table 6** for condenser identification.

Condenser Identification: EPA07 Compliant Vehicles			
Vehicle Rating	**Condenser**	**Width: in. (cm)**	**Height: in. (cm)**
M2 106 (MD)	Valeo MD-1	27 (69)	20 (52)
M2 112 (HD)	Valeo HD-1	33 (84)	19 (48)

Table 6, Condenser Identification: EPA07 Compliant Vehicles

Day Cab with Valeo MD–1 Condenser						
Ambient Air Temp.	**Humidity (approximate)**	**Dash Outlet Temperature (approximate)**	**Service Port Pressures**		**A/C Compressor Status**	**A/C Compressor Status Comments**
			High: psi (kPa)	**Low: psi (kPa)**		
70°F (21°C)	Low 25%	51–59°F (11–15°C)	70–130 (483–896)	10–60 (69–414)	Cycling	On 6 sec; Off 9 sec
	Med 50%	53–59°F (12–15°C)	74–130 (510–896)	10–52 (69–359)	Cycling	On 6 sec; Off 10 sec
	High 70%	55–62°F (13–17°C)	75–130 (517–896)	11–58 (76–400)	Cycling	On 7 sec; Off 8 sec
80°F (27°C)	Low 25%	53–60°F (12–16°C)	92–130 (634–896)	12–56 (83–386)	Cycling	On 7 sec; Off 8 sec
	Med 50%	55–61°F (13–16°C)	90–150 (621–1034)	13–60 (90–414)	Cycling	On 11 sec; Off 7 sec
	High 70%	52°F (11°C)	143 (986)	18 (124)	On	On steady
90°F (32°C)	Low 25%	52–58°F (11–14°C)	120–160 (827–1103)	15–50 (103–345)	Cycling	On 11 sec; Off 5 sec
	Med 50%	55°F (13°C)	169 (1165)	21 (145)	On	On steady
	High 70%	61°F (16°C)	177 (1220)	25 (172)	On	On steady
100°F (38°C)	Very Low 10%	51–56°F (11–13°C)	140–185 (965–1276)	16–55 (110–379)	Cycling	On 19 sec; Off 5 sec
	Low 25%	54°F (12°C)	187 (1289)	21 (145)	On	On steady
	Medium 40%	60°F (16°C)	196 (1351)	26 (179)	On	On steady

Test conditions:

- engine at 1500 rpm
- engine fan locked on
- normal A/C mode, outside air
- blower speed on high, about 13.5 vdc
- cab doors open
- hood open
- parked out of direct sunlight
- no wind speed or less than 5 mph (8 km/h)
- stabilize at each point

Table 7, Day Cab with Valeo MD–1 Condenser

Specifications

Crew Cab with Valeo MD-1 Condenser, Behr Aux HVAC							
Ambient Air Temp: °F (°C)	Humidity (approximate)	Dash Outlet Temperature (approximate)	Auxiliary Unit Lower Louver Temperature	Service Port Pressures		A/C Compressor Status	A/C Compressor Status Comments
				High: psi (kPa)	Low: psi (kPa)		
70 °F (21 °C)	Low 25%	50–56°F (10–13°C)	56–60°F (13–16°C)	90–110 (621–758)	20–53 (138–365)	Cycling	On 6 sec; Off 9 sec
	Med 50%	54–60°F (12–16°C)	57–60°F (14–16°C)	95–115 (655–793)	23–53 (159–365)	Cycling	On 9 sec; Off 8 sec
	High 70%	56–63°F (13–17°C)	57–62°F (14–17°C)	95–120 (655–827)	24–50 (165–345)	Cycling	On 14 sec; Off 5 sec
80 °F (27 °C)	Low 25%	55–60°F (13–16°C)	57–61°F (14–16°C)	120–135 (827–931)	22–52 (152–359)	Cycling	On 10 sec; Off 7 sec
	Med 50%	51°F (11°C)	58°F (14°C)	140 (965)	26 (179)	On	On steady
	High 65%	52°F (11°C)	60°F (16°C)	145 (1000)	28 (193)	On	On steady
90 °F (32 °C)	Low 25%	51°F (11°C)	58°F (14°C)	170 (1172)	26 (179)	On	On steady
	Med 40%	58°F (14°C)	65°F (18°C)	175 (1207)	32 (221)	On	On steady
100 °F (38 °C)	Very Low 10%	54°F (12°C)	62°F (17°C)	190 (1310)	28 (193)	On	On steady
	Low 25%	58°F (14°C)	66°F (19°C)	195 (1344)	32 (221)	On	On steady
	Med 35%	62°F (17°C)	69°F (21°C)	200 (1379)	36 (248)	On	On steady

Test conditions:

- engine at 1500 rpm
- engine fan locked on
- normal A/C mode, outside air
- blower speed on high, about 13.5 vdc
- cab doors open
- hood open
- parked out of direct sunlight
- no wind speed or less than 5 mph (8 km/h)
- stabilize at each point

Table 8, Crew Cab with Valeo MD-1 Condenser, Behr Aux HVAC

Day Cab with Valeo HD-1 Condenser						
Ambient Air Temp: °F (°C)	Humidity (approximate)	Dash Outlet Temperature (approximate)	Service Port Pressures		A/C Compressor Status	A/C Compressor Status Comments
			High: psi (kPa)	Low: psi (kPa)		
70 (21)	Low 25%	50–56°F (10–13°C)	80–100 (552–689)	12–53 (83–365)	Cycling	On 4 sec; Off 11 sec
	Med 50%	52–56°F (11–13°C)	80–95 (552–655)	13–52 (90–359)	Cycling	On 5 sec; Off 10 sec
	High 70%	53–58°F (12–14°C)	85–105 (586–724)	14–55 (97–379)	Cycling	On 6 sec; Off 6 sec
80 (27)	Low 25%	52–58°F (11–14°C)	120–125 (827–862)	16–58 (110–400)	Cycling	On 6 sec; Off 9 sec
	Med 50%	54–60°F (12–16°C)	120–125 (827–862)	18–60 (124–414)	Cycling	On 12 sec; Off 8 sec
	High 70%	53–61°F (12–16°C)	120–135 (827–931)	19–59 (131–407)	Cycling	On 26 sec; Off 4 sec
90 (32)	Low 25%	51–57°F (12–14°C)	125–150 (862–1034)	18–59 (124–407)	Cycling	On 7 sec; Off 5 sec
	Med 50%	51°F (12°C)	155 (1069)	21 (145)	On	On steady
100 (38)	Very Low 10%	52–63°F (11–17°C)	140–170 (965–1172)	18–60 (124–414)	Cycling	On 19 sec; Off 4 sec, then On 6 sec; Off 9 sec
	Low 25%	50°F (10°C)	175 (1207)	20 (138)	On	On steady
	Med 40%	54°F (12°C)	180 (1241)	23 (159)	On	On steady

Test conditions:

- engine at 1500 rpm
- engine fan locked on
- normal A/C mode, outside air
- blower speed on high, about 13.5 vdc
- cab doors open
- hood open
- parked out of direct sunlight
- no wind speed or less than 5 mph (8 km/h)
- stabilize at each point

Table 9, Day Cab with Valeo HD-1 Condenser

Specifications

Crew Cab with Valeo HD-1 Condenser and Behr Aux HVAC							
Ambient Air Temp: °F (°C)	Humidity (approximate)	Dash Outlet Temperature (approximate)	Auxiliary Unit Lower Louver Temperature	Service Port Pressures		A/C Compressor Status	A/C Compressor Status Comments
				High: psi (kPa)	Low: psi (kPa)		
70 (21)	Low 25%	52–56°F (11–13°C)	52–55°F (11–13°C)	85–105 (586–724)	19–48 (131–331)	Cycling	On 6 sec; Off 9 sec
	Med 50%	53–58°F (12–14°C)	53–55°F (12–14°C)	90–110 (621–758)	22–50 (152–345)	Cycling	On 7 sec; Off 9 sec
	High 70%	54–60°F (12–16°C)	56–61°F (13–16°C)	95–115 (655–793)	23–53 (159–365)	Cycling	On 7 sec; Off 7 sec
80 (27)	Low 25%	54–59°F (12–15°C)	56–58°F (13–14°C)	120–140 (827–965)	23–52 (159–359)	Cycling	On 6 sec; Off 11 sec
	Med 50%	53–58°F (12–14°C)	56–59°F (13–15°C)	120–140 (827–965)	26–40 (179–276)	Cycling	On 24 sec; Off 5 sec
	High 70%	55°F (13°C)	62°F (17°C)	145 (1000)	30 (207)	On	On steady
90 (32)	Low 25%	51–58°F (11–14°C)	57–60°F (14–16°C)	135–160 (931–1103)	25–48 (172–331)	Cycling	On 36 sec; Off 5 sec
	Med 50%	60°F (16°C)	67°F (19°C)	175 (1207)	35 (241)	On	On steady
100 (38)	Very Low 10%	52°F (11°C)	61°F (16°C)	185 ()1276	27 (186)	On	On steady
	Low 25%	56°F (13°C)	64°F (18°C)	190 (1310)	31 (214)	On	On steady
	Med 40%	62°F (17°C)	69°F (21°C)	195 (1344)	36 (248)	On	On steady

Test conditions:

- engine at 1500 rpm
- engine fan locked on
- normal A/C mode, outside air
- blower speed on high, about 13.5 vdc
- cab doors open
- hood open
- parked out of direct sunlight
- no wind speed or less than 5 mph (8 km/h)
- stabilize at each point

Table 10, Crew Cab with Valeo HD-1 Condenser and Behr Aux HVAC

Torque Specifications

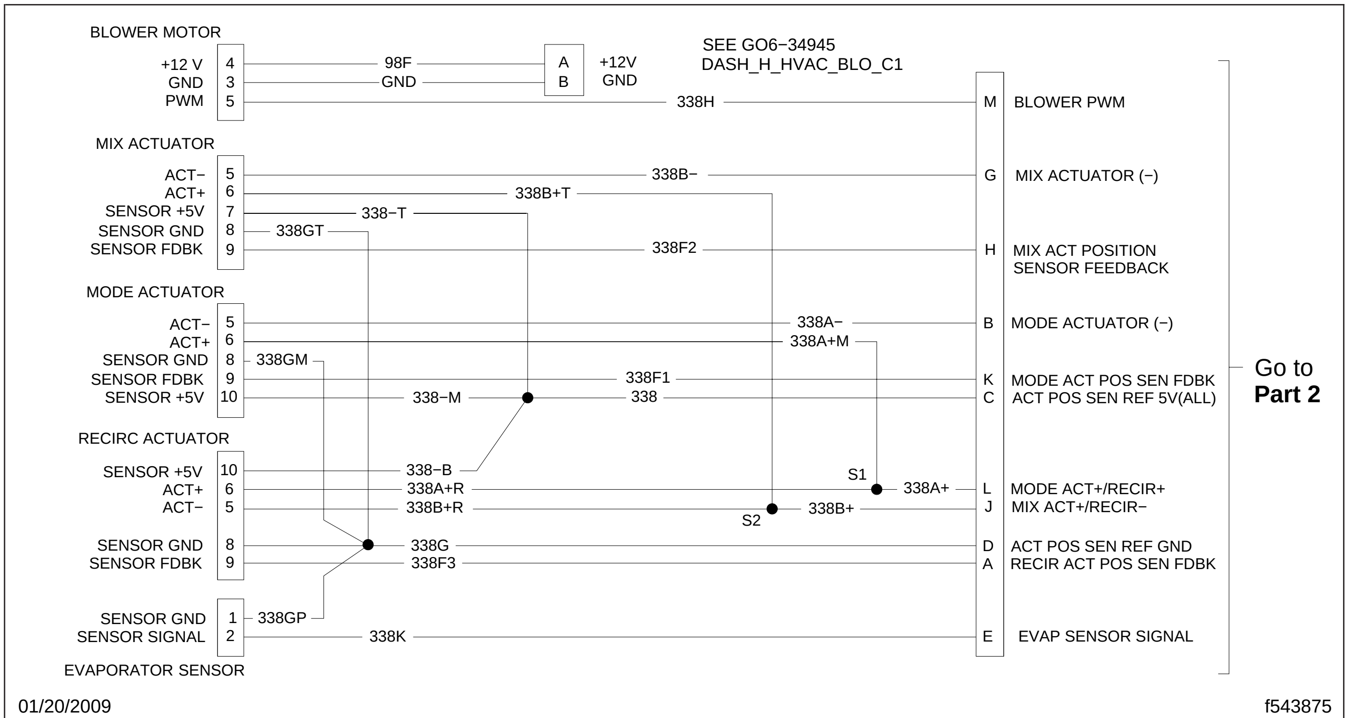
Table 11 shows torque specifications for Stat-O-Seal Assembly Bolts.

Stat-O-Seal Assembly Bolt Torque Specs	
HVAC Component	Torque: lbf·ft (N·m)
Refrigerant Compressor	11–15 (15–20)
Condenser	11–15 (15–20)
Receiver-Drier	11–15 (15–20)
Expansion Valve (to lines to receiver-drier)	11–15 (15–20)
Expansion Valve (small screws to evaporator lines)	35 lbf·in (395 N·cm)
Evaporator	11–15 (15–20)
Junction Block	11–15 (15–20)

Table 11, Stat-O-Seal Assembly Bolt Torque Specs

Wiring Diagrams

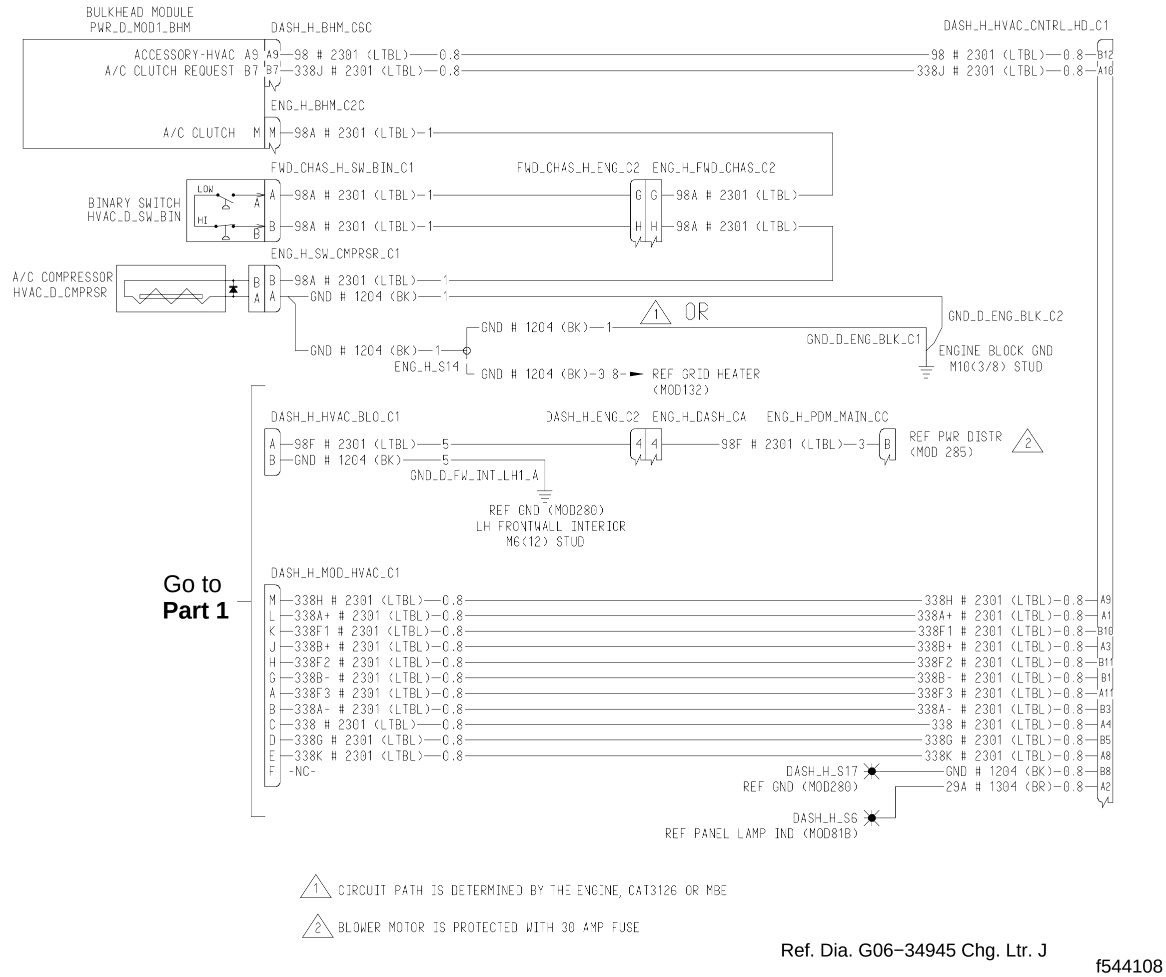
See Fig. 4 and Fig. 5 for the HVAC wiring diagram.



Go to **Part 2** in **Fig. 5**.

Fig. 4, HVAC Wiring Diagram, Part 1

Specifications



Go to **Part 1** in **Fig. 4**.

Fig. 5, HVAC Wiring Diagram, Part 2

General Information

The primary purpose of the refrigerant compressor is to draw refrigerant gas from the evaporator and compress it into high-pressure gas. High pressure raises the condensation point of refrigerant gas, which allows the condenser to change it to a liquid so that it can be used for cooling again. The secondary purpose of the compressor is to move refrigerant through the air conditioning system.

See **Fig. 1** for an illustration of the Sanden refrigerant compressor mounted on a Caterpillar 3126 engine.

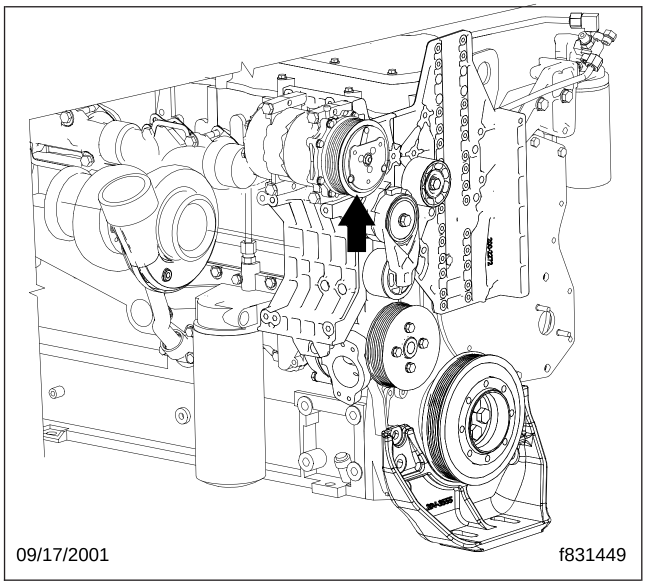


Fig. 1, Refrigerant Compressor on a Caterpillar 3126 Engine

Safety Precautions

Whenever repairs are made to any air conditioner parts that hold R–134a refrigerant, you must recover, purge or flush (if contaminated), evacuate, charge, and leak test the system. In a good system refrigerant lines are always under pressure and you should disconnect them only after the refrigerant charge has been recovered (discharged) at the service valves.

Refrigerant R–134a is safe when used under the right conditions. Always wear safety goggles and non-leather gloves while recovering, evacuating, charging, and leak testing the system. Do not wear leather gloves. When refrigerant gas or liquid contacts leather, the leather will stick to your skin.

WARNING

Use care to prevent refrigerant from touching your skin or eyes because liquid refrigerant, when exposed to the air, quickly evaporates and will freeze skin or eye tissue. Serious injury or blindness could result if you come into contact with liquid refrigerant.

Refrigerant splashed in the eyes should be rinsed with lukewarm water, not hot or cold. Do not rub the eyes. Apply a light bandage and contact a physician right away.

Refrigerant splashed on the skin should be rinsed with lukewarm water, not hot or cold. Do not rub the skin. Apply a light coat of a nonmedicated ointment, such as petroleum jelly. Contact a physician right away.

R–134a refrigerant does not burn at ambient temperatures and atmospheric pressure. However, it can be combustible at pressures as low as 5.5 psig (38 kPa absolute) at 350°F (177°C) when mixed with air concentrations that are greater than 60 percent.

WARNING

R–134a air conditioning systems should not be pressure tested or leak tested with compressed air. Combustible mixtures of air and R–134a may form, resulting in a fire or explosion that could cause personal injury or property damage.

Always work in an area where there is a constant flow of fresh air when the system is recovered, evacuated, charged, and leak tested. R–134a vapors have a slightly sweet odor that is difficult to detect. Frequent leak checks and air monitoring equipment are recommended to ensure a safe working environment.

IMPORTANT: When servicing an R–134a air conditioning system, use only service equipment certified to meet the requirements of SAE J2210 (R–134a recycling equipment). The equipment should be operated only by qualified personnel who are familiar with the recycling station manufacturer’s instructions.

Because of its very low boiling point, refrigerant must be stored under pressure. To prevent the refrigerant containers from exploding, never expose them to temperatures higher than 125°F (52°C).

On R–134a refrigerant systems, polyalkylene glycol (PAG) oil is used in the compressor. When handling PAG oil, observe the following:

- keep the oil free of contaminants
- do not expose the air conditioning system or the PAG oil container to air for long periods of time; PAG oil has a high moisture absorption capacity and the oil container should be immediately sealed after each use
- use care when handling; spilled oil could damage painted surfaces, plastic parts, and drive belts
- never mix PAG oil with other types of refrigerant oil

Preservice Checks

WARNING

Before doing any work, read the information in Safety Precautions 100. Failure to read the safety precautions and to be aware of the dangers involved when working with refrigerant could lead to serious personal injury.

Compressor problems usually show in one of four ways:

- abnormal noise
- seizure
- leakage
- low suction and discharge pressures

Resonant compressor noises are not causes for alarm. Irregular noise or rattles are likely to be caused by broken parts. To check for seizure, deenergize the magnetic clutch with the engine shut off and see if the drive plate can be turned. If it can't be turned, the compressor has seized.

Do the following checks whenever the air conditioner system is not cooling enough and the causes are unknown.

1. Be sure to check the moisture indicator to see if moisture is the cause of the problems. The air conditioner should be on when checking the indicator. It is better to check it at the end of the day.
2. Check the drive belt and mounting:
   2.1 On the drive belt look for wear, damage, or oil. If worn, oil-soaked, or damaged, remove it and install a new one. See **Group 01** of this manual for instructions.
   2.2 Check the compressor mounting parts for loose fasteners, cracks, or other damage. Tighten loose fasteners to the correct torque specification. Repair or replace cracked or damaged brackets.
3. Check the wiring and connections to the compressor clutch. Replace damaged wiring and tighten loose connections.
4. Check for road debris buildup on the condenser coil fins. Using air pressure and a whisk broom or a solution of soap and water, carefully clean the condenser. Be careful not to bend the fins.
5. Check the refrigerant charge in the air conditioner system. For instructions, see **Section 83.00**, Subject 220 of this manual.

NOTE: For other possible causes of air conditioner problems, see **Group 83** of this manual.

Refrigerant Compressor Removal and Installation

Removal

WARNING

Before doing any work, read the information in Safety Precautions 100. Failure to read the safety precautions and to be aware of the dangers involved when working with refrigerant could lead to serious personal injury.

1. Turn off the engine, apply the brakes, and chock the tires.
2. Recover the refrigerant from the air conditioning system. For instructions, see **Section 83.00**, Subject 220.
3. Remove the serpentine belt. Do not pry or roll the belt off the pulleys.
4. Disconnect the wiring harness from the compressor.
5. Disconnect the discharge and suction lines from the compressor. Quickly cap the discharge and suctions ports and the refrigerant lines.

IMPORTANT: Under no circumstances should the ports on the compressor or the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

6. Being careful not to spill any refrigerant oil, remove the capscrews and washers that attach the refrigerant compressor to the engine and remove the compressor.

Installation

IMPORTANT: A new compressor is filled with refrigerant oil and nitrogen gas. The quantity is printed on a label attached to the compressor. When installing a new compressor on the vehicle, do all of the steps below. If installing a used compressor, disregard the first step.

1. Prepare a new compressor.
   - 1.1 Gently release the nitrogen gas from the discharge side of the compressor. Be careful not to let the oil flow out.
   - 1.2 Turn the compressor shaft several times by hand to distribute oil which has settled in the cylinder.
2. If installing a new compressor, adjust the refrigerant oil level in the new compressor. For instructions see, **Subject 130**.
3. Using capscrews and washers, install the compressor on the mounting bracket. Torque the capscrews 15 to 19 lbf·ft (20 to 26 N·m).
4. Uncap the discharge and suction ports and the refrigerant lines. Check the refrigerant lines and the discharge and suction ports. They must be clean and free of nicks, gasket residue, and other foreign material.
5. Using only Mini Stat-O-Seals, replace the Mini Stat-O-Seals on the refrigerant lines. Do not lubricate the Mini Stat-O-Seals prior to installation.
6. Connect the refrigerant lines to the compressor. Torque the retaining plate 11 to 15 lbf·ft (15 to 20 N·m).
7. Connect the wiring harness to the compressor.
8. Install the serpentine belt.
9. If installing a new compressor or if the system was without any refrigerant pressure before repairs were started, replace the receiver-drier. For instructions, see **Section 83.00**, Subject 180.

   If the compressor is not being replaced, check the moisture indicator on the receiver-drier. If it is not cobalt blue, replace the receiver-drier. For instructions, see **Section 83.00**, Subject 180.
10. Evacuate, charge, and leak test the refrigerant system. For instructions, see **Section 83.00**, Subject 220.
11. Lower the hood.
12. Remove the chocks from the tires.

WARNING

Before doing any work, read the information in Safety Precautions 100. Failure to read the safety precautions and to be aware of the dangers involved when working with refrigerant could lead to serious personal injury.

General Information

Compressors are charged with 10 fl oz (296 mL) of refrigerant oil. When the air conditioning system is operating, some refrigerant oil leaves the compressor and is circulated through the system with the refrigerant, but the refrigerant oil cannot leave the system except when there is a leak, when the refrigerant is recovered, or when a system part is replaced.

It is important that the air conditioning system has the correct amount of refrigerant oil for proper operation. Too little oil will result in compressor failure. Too much oil will degrade the performance of the air conditioner and may cause damage to the compressor.

IMPORTANT: Whenever the air conditioning system is discharged or recovered, the recovered oil, from the charging machine, must be measured in order to know how much oil must be returned to the system. When a system component is replaced, a quantity of new oil equal to the recovered oil plus the oil coating the inside of the component must be returned to the system. New oil must be from a container that has not been opened or that has been tightly sealed since its last use.

Order Sanden PAG oil SKI 7803 1997 (type SP–20) for an 8.45-ounce (250-mL) can of refrigerant oil from your local Daimler parts distribution center. Tubing, funnels, or other equipment used to transfer the oil should be very clean and dry.

When handling refrigerant oil:

- Be sure that the oil is free of water, dust, metal powder, and other foreign substances;
- Do not mix the refrigerant oil with other types or viscosities of oil;
- Quickly seal the oil container after use. Refrigerant oil absorbs moisture when exposed to the air for any period of time.

Checking and Adding Refrigerant Oil

WARNING

Do not remove the oil fill plug on the refrigerant compressor without first recovering the system. Failure to recover the system could cause uncontrolled release of high-pressure refrigerant, which can freeze skin and eye tissue causing serious injury or blindness.

1. Before beginning the refrigerant recovery process, make sure that the oil accumulator and oil drain bottle on the recovery/recycle machine are emptied of oil from previous repairs.
2. Recover all of the refrigerant from the system. See **Section 83.00, Subject 220** for instructions.
3. Drain the recovered oil into the calibrated drain bottle of the recovery/recycle machine. Record the amount of oil recovered.
4. Inspect the refrigerant oil. If the oil has any of the following characteristics, flush and charge the system with 10 fl oz (296 mL) of oil.
    - silver or black oil—indicates metal in the air conditioning system due to compressor wear
    - milky oil—may indicate moisture in the system
    - grit or debris in the oil
5. Properly dispose of the recovered oil.
6. After repairs are finished, refer to **Table 1** and use the following equation to determine the quantity of refrigerant oil that needs to be added to the system.

    [Quantity Recovered] + [Quantity for All Replaced Components] = [Quantity to add to the System]

    Table 1 provides the quantities of oil that need to be added to the system for each component that was replaced. Add the quantities listed in the table for each component that was replaced. Use the sum of the quantities or 6 fl oz (177 mL), whichever is less.

Oil Check and Adding Oil to the Compressor

Refrigerant Oil Quantities for Replaced Components	
Add the quantities listed in this table for each component that was replaced. Use the sum of the quantities or 6 fl oz (177 mL), whichever is less.	
Component	**Quantity: oz (mL)**
High Pressure Line (main A/C)	1 (30)
Low Pressure Line (main A/C)	2 (59)
High Pressure Line (auxiliary A/C)	1 (30)
Low Pressure Line (auxiliary A/C)	3 (89)
Condenser	1 (30)
Evaporator (main A/C)	3 (89)
Evaporator (auxiliary A/C)	2 (59)
Receiver-Drier	3 (89)
Minor Leak at Connector Only	0.5 (15)
Major Leak at Connector Only	2 (59)

Table 1, Refrigerant Oil Quantities for Replaced Components

7. Remove the oil fill plug on the refrigerant compressor and add the refrigerant oil. Never add more than 8 fl oz (237 mL) to the system unless the system has been flushed.
8. Evacuate, charge, and leak test the refrigerant system. See **Section 83.00, Subject 220** for instructions.

Adjusting the Refrigerant Oil Level in a New Compressor

Sanden refrigerant compressors are charged with 10 fl oz (296 mL) of refrigerant oil. If the air conditioning system has been flushed, the compressor will need a 10-ounce charge. If the system has not been flushed, use the following procedure to adjust the oil level in the compressor.

Use the "Worksheet for Adjusting the Refrigerant Oil Level in a New Compressor" shown in **Fig. 1** to adjust the refrigerant oil level in a new compressor.

Oil Check and Adding Oil to the Compressor

Worksheet for Adjusting the Refrigerant Oil Level in a New Compressor

1. Drain the oil from the old compressor.
   - 1.1 Remove the oil plug and drain as much oil as possible into a clean, calibrated container.
   - 1.2 If there are caps on the suction and discharge ports, remove them.
   - 1.3 Drain the oil from the suction and discharge ports into the container while turning the shaft clockwise using a socket wrench on the armature retaining nut.
   - 1.4 Enter the amount of oil that was drained from the compressor. 1. ☐
2. See Table 1 of this subject to determine the total amount of refrigerant oil that is needed for each component that was replaced. Enter the amount, up to 6 fl oz (177 mL), here. 2. ☐
3. Add the amounts from steps 1 and 2 and enter the total. 3. ☐
4. Subtract the total in step 3 from 10 and enter that number. For example, if the total in line 3 was six, the calculation would be 10 − 6 = 4. 4. ☐
5. Refer to the table below for the amount of oil that must be drained from the new compressor.

If the number in step 4 is:	Drain this amount from the new compressor:
a negative number(−)	2 fl oz (59 mL)
0	2 fl oz (59 mL)
1	2 fl oz (59 mL)
2	2 fl oz (59 mL)
3	3 fl oz (89 mL)
4	4 fl oz (118 mL)
5	4 fl oz (118 mL)
6	4 fl oz (118 mL)
7	4 fl oz (118 mL)
8	4 fl oz (118 mL)
9	4 fl oz (118 mL)
10	4 fl oz (118 mL)

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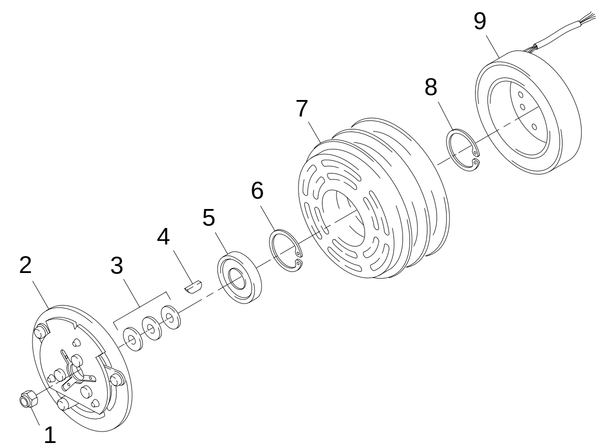
Fig. 1, Worksheet for Adjusting the Refrigerant Oil Level in a New Compressor

Clutch Assembly Removal, Inspection, and Installation

Removal

See Fig. 1 for an illustration of the clutch assembly components.



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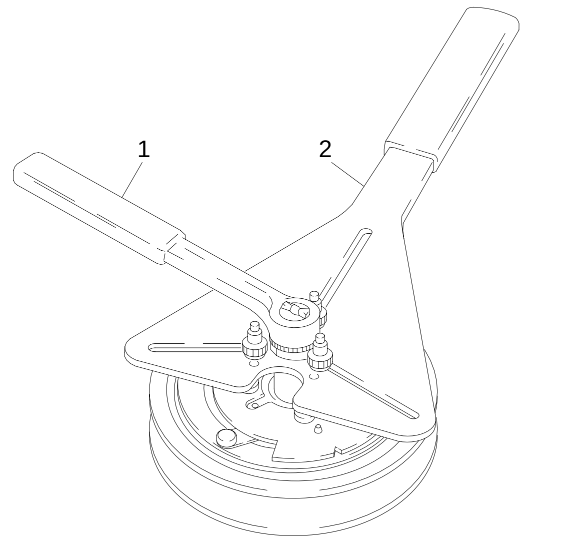
1. Shaft Nut
2. Drive Plate
3. Clutch Shims
4. Shaft Key
5. Rotor Bearing Dust Cover
6. Rotor Snap Ring
7. Rotor Assembly
8. Field Coil Assembly Snap Ring
9. Field Coil Assembly

Fig. 1, Clutch Assembly

1. Remove the compressor from the vehicle. For instructions, see **Subject 120**.
2. Insert the pins of the drive plate spanner into the threaded holes of the drive plate assembly. Hold the drive plate assembly securely while removing the retaining nut. See **Fig. 2**.
3. Using the drive plate puller, install the three puller bolts into the drive plate assembly. Turn the center screw clockwise to loosen and remove the drive plate. See **Fig. 3**.
4. If equipped with a rotor bearing dust cover, remove it. Be careful not to distort the cover when removing it.
5. Use a slotted screwdriver and hammer to remove the shaft key. See **Fig. 4**.



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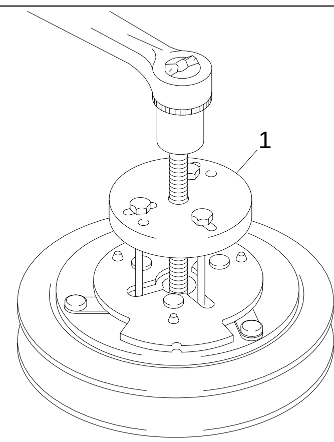
1. Socket Wrench 2. Drive Plate Spanner

Fig. 2, Remove the Retaining Nut



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1. Drive Plate Puller

Fig. 3, Remove the Drive Plate

6. Remove the clutch shims. Use a pointed tool and a small screwdriver to prevent the shims from binding on the shaft.
7. Using snap ring pliers, remove the rotor assembly snap ring.
8. Remove the rotor assembly.
   8.1 Insert the lip of the rotor puller jaws into the snap ring groove. See **Fig. 5**.

Clutch Assembly Removal, Inspection, and Installation

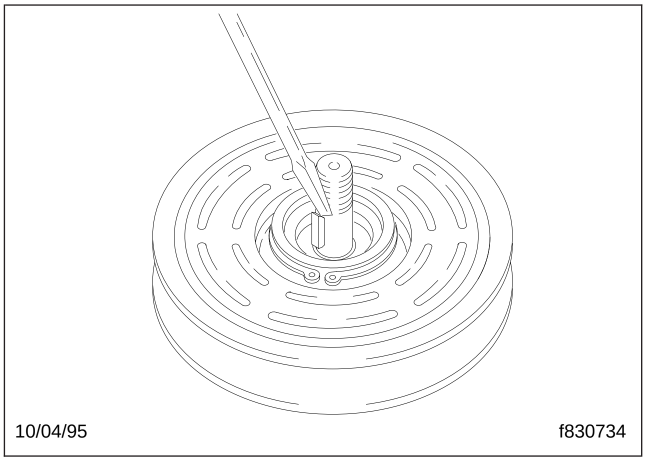


Fig. 4, Remove the Shaft Key

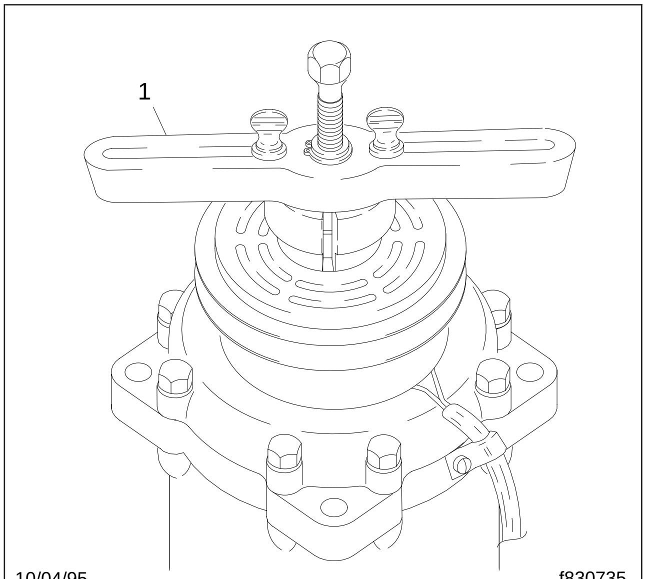


Fig. 5, Position the Rotor Puller Jaws

8.2 Place the rotor puller set over the exposed shaft.

8.3 Align the thumb screws to the puller jaws. Tighten the screws finger tight.

8.4 Using a socket wrench, turn the puller center bolt clockwise and remove the rotor assembly.

9. Remove the field coil assembly.

9.1 Remove the field coil assembly lead wire from the clamp on the compressor.

9.2 Disconnect the wiring harness.

9.3 Remove the snap ring. Then remove the field coil assembly.

Inspection

1. Inspect the drive plate assembly. If the frictional surface shows signs of damage due to too much heat, replace the drive plate assembly and the rotor assembly.
2. Check the appearance of the rotor assembly. If the frictional surface of the rotor shows signs of too much grooving due to slippage, replace both the rotor assembly and the drive plate assembly. Clean the frictional surfaces of the rotor assembly before installing it.
3. Check the field coil assembly for a loose connector and for cracked insulation. Replace it if necessary.

Installation

NOTE: When supporting the compressor in a vise, clamp only on the mounting ears, never on the body of the compressor.

1. Install the field coil assembly.

1.1 Position the coil assembly on the compressor.

1.2 Install the snap ring.

1.3 Attach the field coil assembly lead wire to the clamp on the compressor.

1.4 Connect the wiring harness.

2. Install the rotor assembly.

2.1 Position the rotor over the boss of the front housing.

2.2 Place the rotor installer ring into the bearing bore. Make sure that the edge rests only on the inner race of the bearing, not on the seal, rotor pulley, or outer race of the bearing.

2.3 Place the driver into the ring. Using a hammer or an arbor press, drive the rotor

Clutch Assembly Removal, Inspection, and Installation

pulley down against the front housing step. See **Fig. 6**.

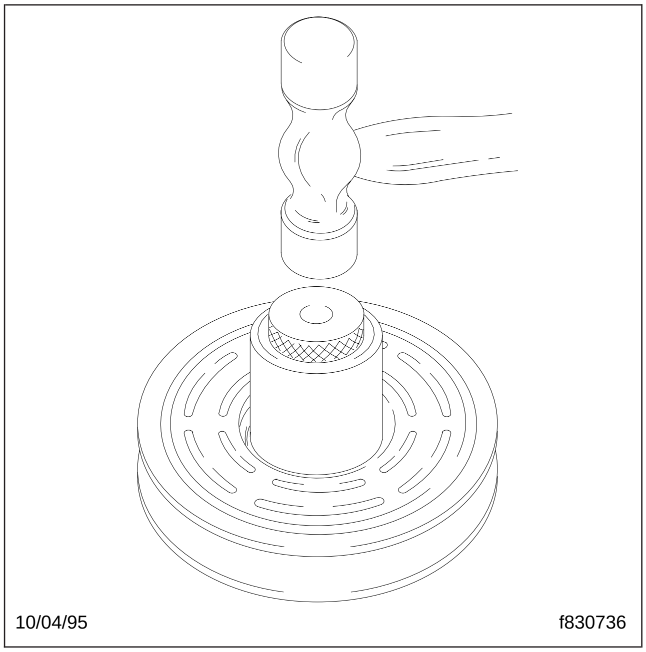


Fig. 6, Drive the Rotor Pulley Down Against the Front Housing Step

2.4 Using snap ring pliers, install the rotor bearing snap ring.

2.5 Using snap ring pliers, install the rotor retaining snap ring. If a bevel is present on the snap ring, make sure that it is facing away from the body of the compressor.

2.6 If equipped with a rotor bearing dust cover, install the cover by gently tapping it into place.

3. Install the drive plate assembly.

3.1 Using pliers, install the shaft key. See **Fig. 7**.

3.2 Install the shims.

3.3 Align the keyway in the drive plate assembly with the shaft key. Using a driver and a hammer or an arbor press, drive the assembly down over the shaft until it bottoms on the shims. See **Fig. 8**.

3.4 Install the retaining nut. If the nut is 1/2–20, tighten it 20 to 25 lbf·ft (27 to 34 N·m). If the nut is M8, tighten it 11 to 15 lbf·ft (15 to 21 N·m).

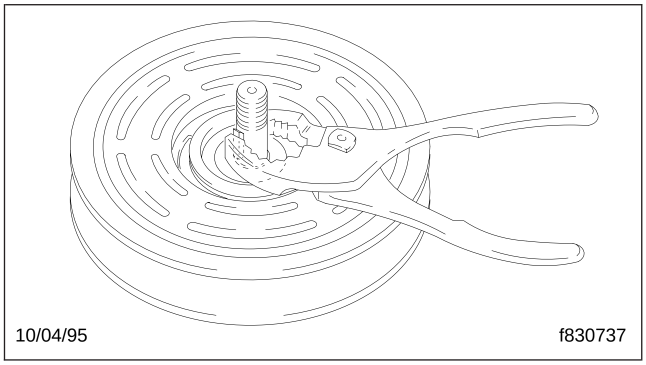


Fig. 7, Install the Shaft Key

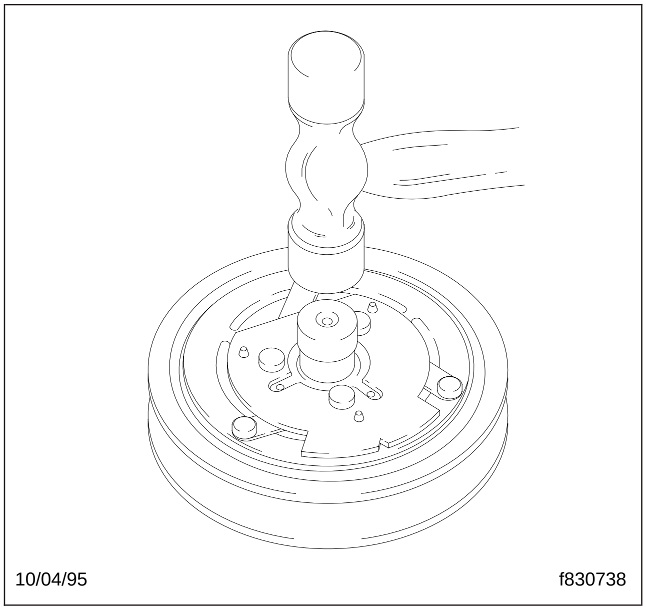


Fig. 8, Install the Drive Plate Assembly

4. Using a feeler gauge, check that the clutch clearance is 0.016 to 0.031 inch (0.4 to 0.8 mm). See **Fig. 9**. If the gap is not even around the clutch, gently tap down at the high areas. If the overall gap is out of spec, remove the drive plate assembly and change the shims as necessary.

5. Install the compressor on the vehicle. For instructions, see **Subject 120**.

Clutch Assembly Removal, Inspection, and Installation

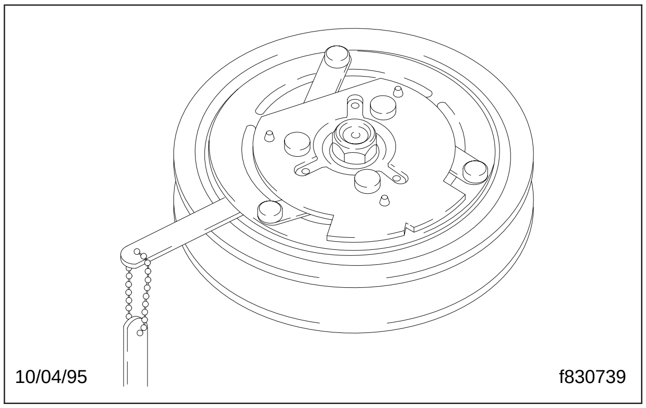


Fig. 9, Check the Clutch Clearance

Specifications

Special tools can be purchased from:

SPX Kent-Moore
28635 Mound Road
Warren, Michigan 48092-3499
800-328-6657

Mini Stat-O-Seal Assembly Bolt Torque Specs	
HVAC Component	**Torque: lbf·ft (N·m)**
Refrigerant Compressor	11–15 (15–20)
Condenser	11–15 (15–20)
Receiver-Drier	11–15 (15–20)
Expansion Valve*	11–15 (15–20)
Evaporator	11–15 (15–20)
Junction Block	11–15 (15–20)

* Torque the two small screws that attach the expansion valve–the evaporator lines at the frontwall 35 lbf·in (395 N·cm).

Table 1, Mini Stat-O-Seal Assembly Bolt Torque Specs

General Information

The compressor compresses low-temperature, low-pressure gas refrigerant gasified in the evaporator, into high-temperature, high-pressure gas refrigerant. The compressor then sends the refrigerant to the condenser.

The main purpose of the refrigerant compressor is to draw refrigerant gas from the evaporator and squeeze it into high-pressure gas. High pressure raises the condensation point of refrigerant gas, which allows the condenser to change it to a liquid so that it can be used for cooling again. A second purpose of the compressor is to move refrigerant through the air conditioning system.

Safety Precautions

Whenever repairs are made to any air conditioner parts that hold R–134a refrigerant, you must recover, purge or flush (if contaminated), evacuate, charge, and leak test the system. In a good system, refrigerant lines are always under pressure and you should disconnect them only after the refrigerant charge has been recovered (discharged) at the service valves.

Refrigerant R–134a is safe when used under the right conditions. Always wear safety goggles and non-leather gloves while recovering, evacuating, charging, and leak testing the system. Do not wear leather gloves; when refrigerant gas or liquid contacts leather, the leather will stick to your skin.

WARNING

Use care to prevent refrigerant from touching your skin or eyes, because liquid refrigerant, when exposed to the air, quickly evaporates and will freeze skin or eye tissue. Serious injury or blindness could result if you come into contact with liquid refrigerant.

Refrigerant splashed in the eyes should be rinsed with lukewarm water, not hot or cold. Do not rub the eyes. Apply a light bandage and contact a physician right away.

Refrigerant splashed on the skin should be rinsed with lukewarm water, not hot or cold. Do not rub the skin. Apply a light coat of a nonmedicated ointment, such as petroleum jelly. Contact a physician right away.

R–134a refrigerant does not burn at ambient temperatures and atmospheric pressure. However, it can be combustible at pressures as low as 5.5 psig (139 kPa absolute) at 350°F (177°C) when mixed with air concentrations that are greater than 60 percent.

WARNING

R–134a air conditioning systems should not be pressure tested or leak tested with compressed air. Combustible mixtures of air and R–134a may form, resulting in a fire or explosion, which could cause personal injury or property damage.

Always work in an area where there is a constant flow of fresh air when the system is recovered, evacuated, and charged. R–134a vapors have a slightly sweet odor that is difficult to detect. Frequent leak checks and air monitoring equipment are recommended to ensure a safe working environment.

IMPORTANT: When servicing an R–134a air conditioning system, use only service equipment certified to meet the requirements of SAE J2210 (R–134a recycling equipment). The equipment should be operated only by qualified personnel who are familiar with the recycling station manufacturer's instructions.

Because of its very low boiling point, refrigerant must be stored under pressure. To prevent the refrigerant containers from exploding, never expose them to temperatures higher than 125°F (52°C).

On R–134a refrigerant systems, polyalkylene glycol (PAG) oil is used in the compressor. When handling PAG oil, observe the following:

- keep the oil free of contaminants
- do not expose the air conditioning system or the PAG oil container to air for more than 30 minutes; PAG oil has a high moisture absorption capacity and the oil container should be immediately sealed after each use
- use care when handling: spilled oil could damage painted surfaces, plastic parts, and other components (drive belts)
- **never** mix PAG oil with other types of refrigerant oil

⚠ WARNING

Before doing any of the work below, read the information under Safety Precautions 100. Failure to read the safety precautions and to be aware of the dangers involved when working with refrigerant, could lead to serious personal injury.

Pre-Service Checks

NOTE: Compressor problems usually show in one of four ways: abnormal noise, seizure, leakage, or low discharge pressure. Resonant compressor noises are not causes for alarm; irregular noise or rattles are likely to be caused by broken parts. To check for seizure, de-energize the magnetic clutch and see if the drive plate can be turned. If it won't turn, the compressor has seized.

Make the following checks whenever the air conditioner system is not cooling enough and the causes are unknown.

1. Check the drive belt and mounting:

   1.1 On the drive belt, look for wear, damage, or oil. If worn, oil-soaked, or damaged, remove it and install a new one. See the drive belt section in **Group 01** for instructions.

   1.2 Check the compressor mounting parts for loose fasteners, cracks, or other damage. Tighten loose fasteners to the torque value in the torque specifications table under **Specifications 400**. Repair or replace cracked or damaged brackets.

   1.3 Check the tension of the compressor drive belt. See the drive belt section in **Group 01** for instructions.

2. Check the wiring and connections to the compressor clutch. Replace damaged wiring and tighten loose connections.

3. Check for road debris build-up on the condenser coil fins. Using air pressure and a whiskbroom or a solution of soap and water, carefully clean the condenser; be careful not to bend the fins.

NOTE: For other possible causes of air conditioner problems, see **Section 83.00, Subject 300**, and the applicable fan clutch section in **Group 20**.

Refrigerant Compressor Removal and Installation

WARNING

Before doing any of the work below, read the information under Safety Precautions 100. Failure to read the safety precautions and to be aware of the dangers involved when working with refrigerant, could lead to serious personal injury.

Removal

1. Apply the parking brakes, and chock the tires.
2. Raise the hood.
3. Begin recovery of the refrigerant from the air conditioning system; for instructions, see **Section 83.00, Subject 220**.
4. Turn off the engine.
5. Remove the drive belt. Do not pry or roll the belt off the pulleys. See the drive belt section in **Group 01** for instructions.
6. Disconnect the wiring harness from the compressor.

NOTICE

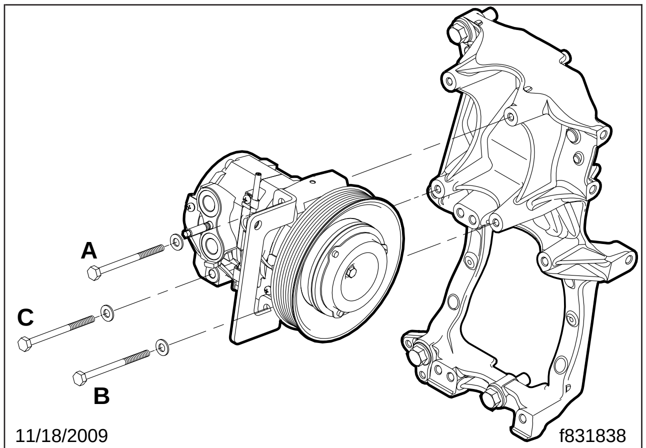
Under no circumstances should the ports on the compressor or the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

7. After the refrigerant has been fully recovered, remove the capscrews that attach the refrigerant lines and retaining plate(s) to the compressor. Remove the refrigerant lines and the retaining plates. Remove and discard the Mini Stat-O-Seals. Cap the discharge and suction ports and the refrigerant lines.
8. Being careful not to spill any refrigerant oil, remove the capscrews and washers that attach the refrigerant compressor to the engine, and remove the compressor.

Installation

IMPORTANT: A new compressor is filled with refrigerant oil and nitrogen gas. The oil quantity is printed on a label attached to the compressor. When installing a new compressor on the vehicle, gently release the nitrogen gas from the discharge side of the compressor.

1. Adjust the refrigerant oil level in the compressor; for instructions, see **Subject 130**.
2. Position the compressor on the mounting bracket and install the capscrews and washers. Tighten 15 to 19 lbf·ft (21 to 26 N·m) in the sequence shown in **Fig. 1**.



Tighten A, then B, then C.

A. Front Top
B. Front Bottom
C. Rear

Fig. 1, Tightening Sequence (typical installation shown)

3. Uncap the discharge and suction ports and the refrigerant lines. Check the refrigerant lines and the discharge and suction ports. They must be clean and free of nicks, gasket residue, and other foreign material.
4. Install new Mini Stat-O-Seals on the refrigerant lines.
5. Attach the refrigerant lines to the compressor. Tighten the capscrew 14 to 16 lbf·ft (19 to 22 N·m).
6. Connect the wiring harness to the compressor.
7. Install the drive belt.
8. If installing a new compressor, or if the system was without any refrigerant pressure before repairs were started, replace the receiver-drier; for instructions, see **Section 83.00, Subject 180**.

Refrigerant Compressor Removal and Installation

9. Evacuate, charge, and leak test the refrigerant system; for instructions, see **Section 83.00, Subject 220**.
10. Return the hood to the operating position.

⚠ WARNING

Before doing any of the work below, read the information under Safety Precautions 100. Failure to read the safety precautions and to be aware of the dangers involved when working with refrigerant, could lead to serious personal injury.

General Information

Denso compressors require ND-8 PAG refrigerant oil. When the air conditioning system is operating, refrigerant oil can leave the compressor and circulate through the system with the refrigerant, but the refrigerant oil cannot leave the system except when there is a leak, when the refrigerant is recovered, or when a system part is replaced.

It is important that the air conditioning system has the correct amount of refrigerant oil for proper operation. Too little oil will result in compressor failure. Too much oil will degrade the performance of the air conditioner, and cause damage to the compressor.

IMPORTANT: Whenever the air conditioning system is discharged or recovered, the recovered oil, from the charging machine, must be measured in order to know how much oil must be returned to the system. When a system component is replaced, a quantity of new oil equal to the recovered oil plus the oil coating the inside of the component must be returned to the system. New oil must be from a container that has not been opened or that has been tightly sealed since its last use. Tubing, funnels, or other equipment used to transfer the oil must be very clean and dry.

When handling refrigerant oil:

- Be sure that the oil is free of water, dust, metal powder, and other foreign substances;
- Do not mix the refrigerant oil with other types or viscosities of oil;
- Quickly seal the oil container after use. Refrigerant oil absorbs moisture when exposed to the air for any period of time.

Order Denso PAG oil (ND-8OIL, P/N DII LA446963 0040) from your local Freightliner parts distribution center, it is the only acceptable oil to use in a system with a Denso compressor.

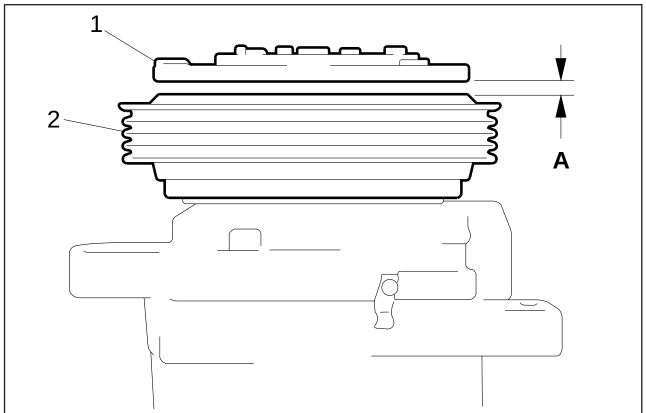
Denso Total System Oil Volume

Denso refrigerant compressors are supplied with approximately 4.5 oz. of ND-8 oil, but the vehicle configuration affects the total charge volume. If a complete new oil charge is required, the amount will be determined by the volume stated in the new compressor literature, and the volume listed in PartsPro. The two amounts will be combined to give the total oil charge required. If a complete new oil charge is not required, use the oil balancing info in **Section 83.00, Subject 220**.

Clutch Assembly Removal, Inspection, and Installation

IMPORTANT: The clutch should be replaced if it is worn.

Before replacing the clutch, check the air gap at three equally spaced points around the perimeter. The air gap should be at least 0.014 in (0.35 mm), and no greater than 0.024 inch (0.60 mm). The gap must be greater than 0.024 inch (0.60 mm) at all three points for the clutch to need replacing. See **Fig. 1**.



Check at three equally spaced points.
A. 0.014 to 0.024 in (0.35 to 0.60 mm)
1. Hub Sub-Assembly
2. Magnetic Clutch

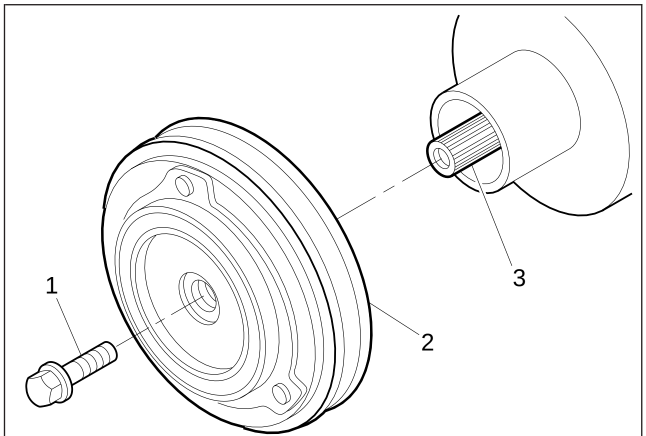
Fig. 1, Checking the Clutch Clearance

Removal

NOTE: The hub is secured with a bolt (splined shaft is used for connection with compressor).

1. Remove the compressor from the vehicle. For instructions, see **Subject 110**.
2. Remove the clutch retaining capscrew from the compressor shaft. See **Fig. 2**.
3. Remove the shims from the pressure plate. NOTE: Save the air gap shims for reassembly.

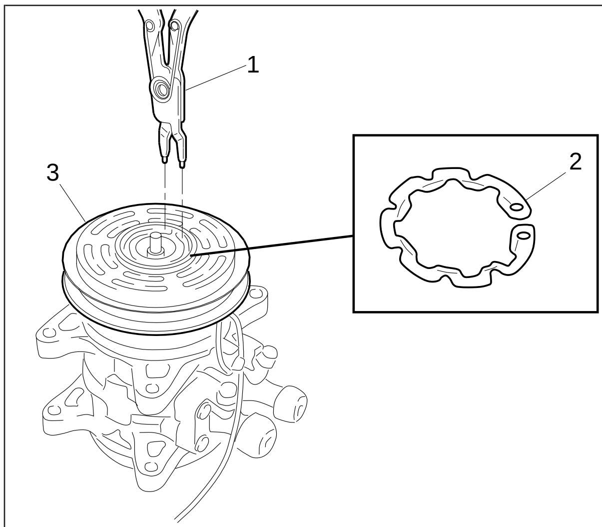
NOTE: If the rotor cannot be removed easily, tap the rotor lightly with a plastic hammer, then remove it from the compressor shaft being careful not to damage the pulley when tapping on the rotor.



1. Clutch Retaining Capscrew
2. Hub and Rotor Assembly
3. Splined Shaft

Fig. 2, Removing the Retaining Capscrew

4. Using snap ring pliers, remove the snap ring, then remove the rotor. Discard the snap ring. See **Fig. 3**.

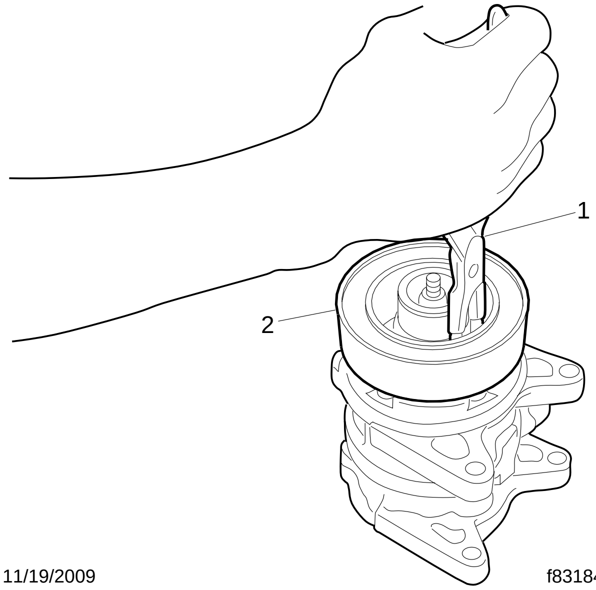


1. Snap Ring Pliers
2. Snap Ring
3. Rotor

Fig. 3, Rotor Removal

5. Using snap ring pliers, remove the snap ring, then remove the stator. Discard the snap ring. See **Fig. 4**.

Clutch Assembly Removal, Inspection, and Installation



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1. Snap Ring Pliers
2. Stator

Fig. 4, Stator Removal

Inspection

After the magnetic clutch is disassembled, inspect each component and decide whether they can be reused. Refer to **Table 1** for clutch inspection and recommended action.

<table>
<tr><th colspan="3">Magnetic Clutch Inspection</th></tr>
<tr><th>Part Name</th><th>Check Point and Expected Damage</th><th>Action</th></tr>
<tr><td rowspan="2">Hub</td><td>Dislocation or peeling of rubber.</td><td>Replace or Repair</td></tr>
<tr><td>Roughness, burn, rust, slip or extreme wear on mating surface.</td><td rowspan="5">Replace</td></tr>
<tr><td rowspan="2">Rotor</td><td>Play, unusual sound, rust, insufficient grease or seizure of bearing.</td></tr>
<tr><td>Roughness, burn, rust, slip or extreme wear on mating surface.</td></tr>
<tr><td rowspan="2">Stator</td><td>Burn, wire breakage or layer short circuit of stator coil. Resistance of stator coil at 68°F (20°C) should be 2.8 to 3.2 ohms.</td></tr>
<tr><td>Damage of deformation of rotor (pulley) groove(s).</td></tr>
</table>

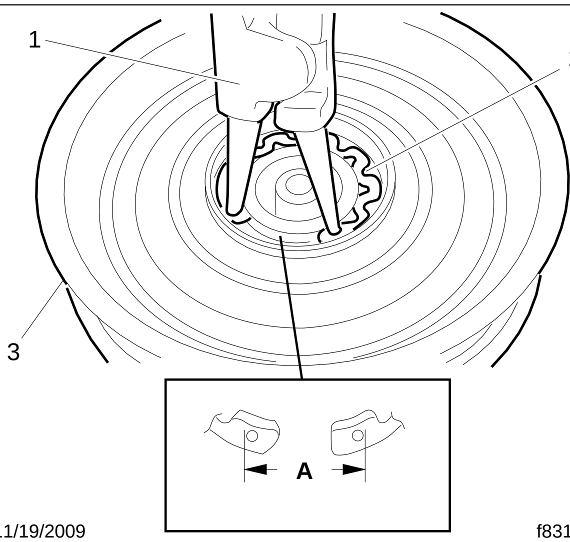
Table 1, Magnetic Clutch Inspection

Clutch Assembly Removal, Inspection, and Installation

Installation

NOTICE

Excessive opening of the snap rings may weaken the fixing force of the snap ring. Maximum allowed opening must not exceed 1.2 in (30.9 mm). See Fig. 5.



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A. Do not exceed 1.2 in (30.9 mm).

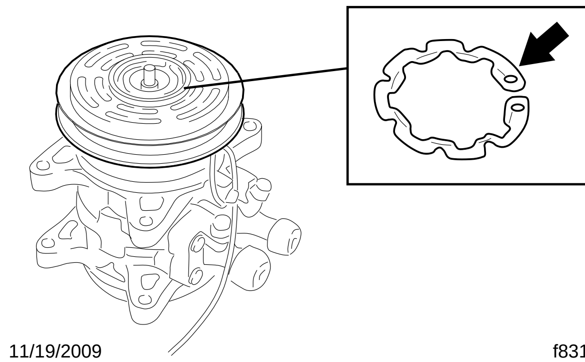
1. Snap Ring Pliers
2. Snap Ring
3. Rotor

Fig. 5, Snap Ring Installation

1. Align the stator to the compressor housing by positioning the index pin into its indexing hole/ slot.

IMPORTANT: The snap ring must be installed with the chamfered side facing up. See Fig. 6.

2. Secure the stator with a new snap ring. Make sure the snap ring is fully seated. See Fig. 7.
3. Install the rotor on the compressor and secure it with a new snap ring.
4. Temporarily install the hub to verify the gap clearance. See Fig. 1.
5. Check the air gap. The air gap between the hub and rotor should be 0.014 to 0.024 in (0.35 to 0.60 mm). Check the clearance at 3 locations.



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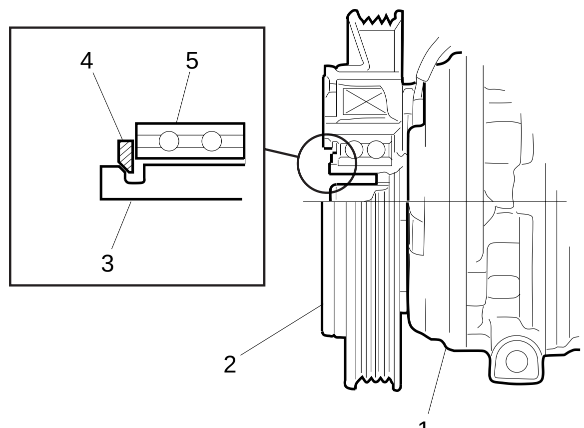
Chamfered side up.

Fig. 6, Snap Ring Installation



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1. Compressor
2. Clutch Assembly
3. Compressor Shaft
4. Snap Ring
5. Bearing

Fig. 7, Seating the Snap Ring

6. Set the air gap clearance between the pressure plate and rotor by adding or removing compressor shaft shims so that the air gap clearance is within the specified range and distance.
7. Install the clutch retaining capscrew in the compressor shaft. Tighten 15 to 19 lbf·ft (21 to 26 N·m).
8. After the clutch is assembled, turn the rotor by hand to verify it does not contact either the pressure plate or stator.

Specifications

Special tools can be purchased from the following independent suppliers:

Classic Tool Design
31 Walnut St.
New Windsor, NY 12553
845-562-8700

Mastercool USA Inc.
One Aspen Drive
Randolph, NJ 07869
(973) 252-9119

Torque Values		
Description	**Torque**	
	lbf·in (N·cm)	**lbf·ft (N·m)**
Compressor Mounting Fasteners	—	15–19 (21–26)
Clutch Retaining Capscrew	—	22 (30)
Clutch Lead Wire Clamp Screw	132 (1500)	—

Table 1, Torque Values

General Information

Business Class M2 vehicles have a molded, fiberglass-reinforced-plastic (FRP) hood panel, and sheet-molded compound (SMC) or reaction-injection-molded (RIM) polymer half-fenders that mount to the cab sides. Several reinforcing members (also made of SMC) are bonded to the engine side of the hood. The front grille is made of injection-molded plastic.

A recess in the hood, above the grille, provides the handle for hood tilting.

The hood panel is compression molded using the preform molding process. The first step in this process is to produce a preform by spraying chopped glass fibers and resin binder in a controlled manner onto a screen that's the same shape as the male molding die. The preform is then heated to cure the resin binder. Next, the preform is moved to a compression molding press. The preform is placed onto the male half of a matched metal mold. As the halves of the mold close, resin is distributed throughout the part, and is cured under heat and pressure.

After molding, the hood is trimmed. Then the fiberglass reinforcements and metal parts are bonded to the hood.

When in the operating position, the hood is supported at the front by the hood-hinge pivots and at the rear by hood support brackets which are attached to the cab. A groove in each bracket mates with pins attached to the inside of the hood, near each upper rear corner. The hood is held down with two rubber over-center latches, with part of the latch attached to the hood, and the other part attached to each half-fender. To prevent warm, under-hood air from entering the cab through the air conditioner/heater air-inlet, a hood seal attaches to the cowl panel, ahead of the windshield.

The front hood-hinge pivots are adjustable fore-and-aft and side-to-side. The rear hood support brackets are adjustable up-and-down only.

Two types of tilt-assist mechanisms are used on the Business Class M2. One type consists of two torsion bars, attached to a bracket bolted to the frame rail front closing crossmember. The outboard ends of the torsion bars fit into slots in the hood hinges. The other type consists of two spring struts, attached to the hood and brackets on the frame rail assemblies.

On vehicles with a torsion-bar tilt-assist mechanism, a damper prevents the hood from slamming when it is being closed. The damper is attached to the right-side upper hood hinge and the bumper.

Hood stop cables or straps, attached to the hood and the radiator, limit the tilt of the hood.

Splash shields under the hood extend to the inboard side of the tires.

On the underside of the hood are several 1-inch (25-mm) thick polyester polyurethane foam hood liners, with a polymer-film facing. The liners reduce engine noise emissions.

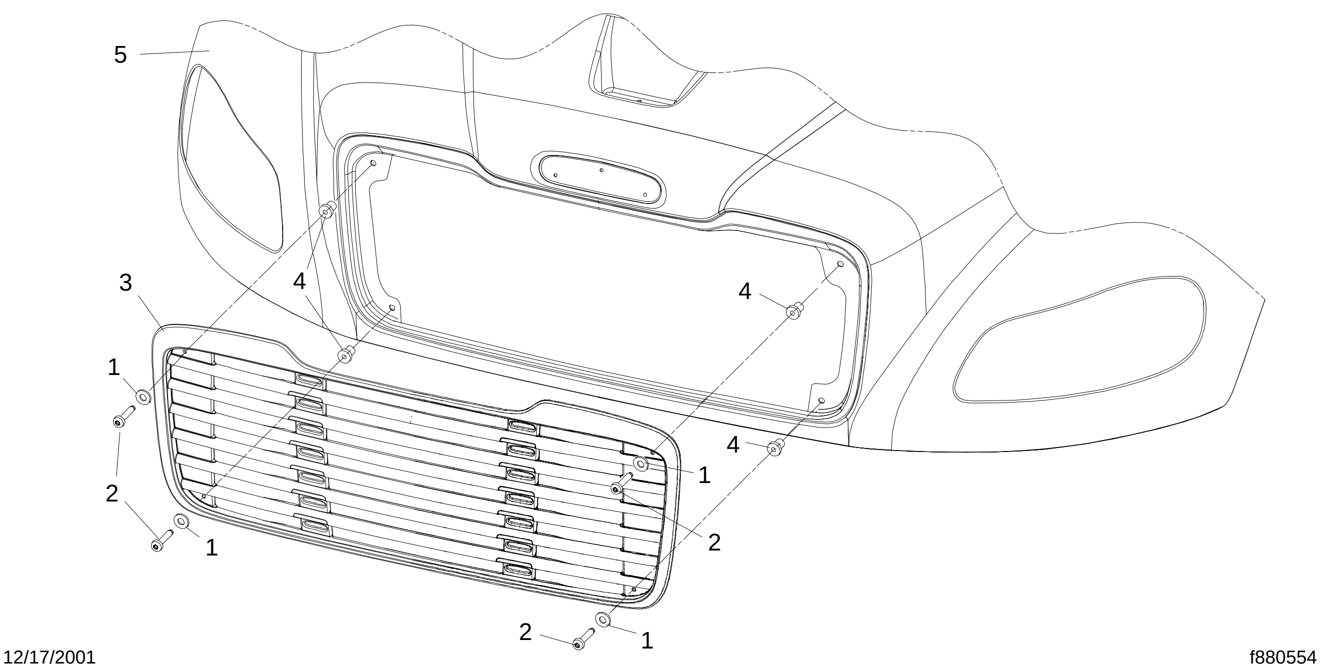
Grille Removal and Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, apply the parking brakes, and chock the rear tires.
2. With the hood in the operating position, use a Torx screwdriver (T30) to remove the grille-to-hood screws. See **Fig. 1**.
3. Remove the grille.

Installation

1. Place the grille in the hood opening and align the screw holes.
2. Using a Torx screwdriver (T30) install the screws and tighten them securely.



1. Washer
2. T30 Torx Screw
3. Grille
4. Well Nut
5. Hood

Fig. 1, Grille Installation

Hood Removal and Installation

Procedures under these headings apply to the following vehicles, as specified:

- vehicles with an engine manufactured through 2006
- vehicles with an EPA07 engine

WARNING

Do not try to lift the hood. Lifting the hood could result in personal injury or damage to the hood assembly and other components.

Vehicles With an Engine Manufactured Through 2006

Removal

1. With the vehicle parked, apply the parking brakes and chock the tires.
2. Remove the grille; see **Subject 100**.
3. Open the hood to the full-tilt position.
4. Remove the tilt-assist torsion bars, as follows; see **Fig. 1**.

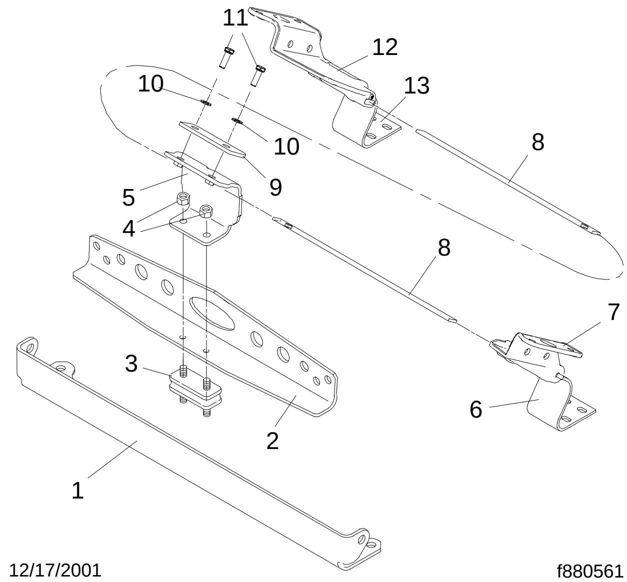
   4.1 Tilt the hood about 45-degrees to take the tension off the torsion bars of the tilt-assist assembly.

   4.2 Reach through the grille opening and remove the two hexbolts that secure the torsion bars to the center mounting bracket.

   4.3 Remove the outboard ends of the torsion bars from the slots in the upper hood hinges.
5. Place a support between the floor and the front of the hood; see **Fig. 2**.

   The support should be as wide and as long as the front of the hood, and should be the same height as the lowest edge of the hood. Place cardboard, carpet, rags, or other padding on top of the support to protect the hood.
6. Disconnect the hood damper from the hood; see **Fig. 3**.
7. Disconnect the wiring harness, as follows.

   7.1 Remove the standoff bracket located near the left hood hinge.



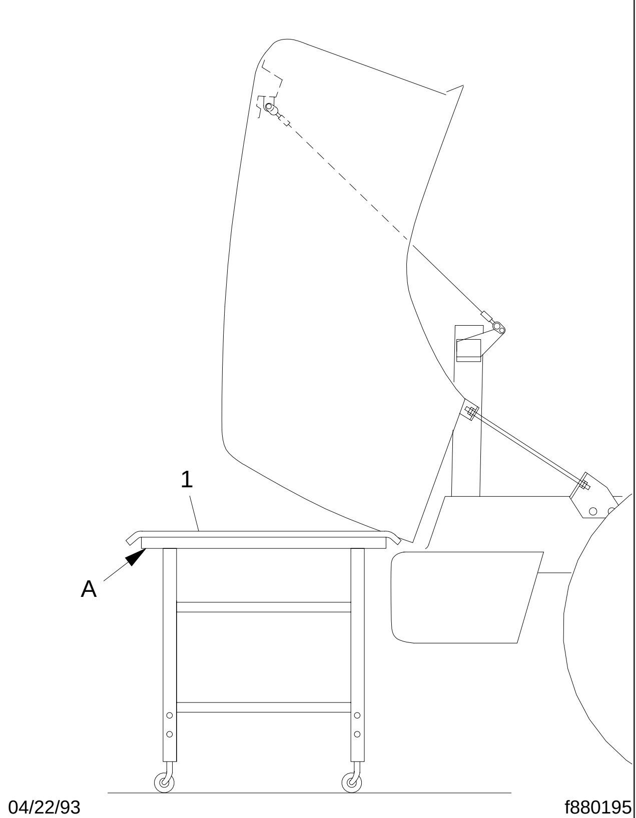
1. Crossmember Closing Bracket
2. Radiator Support Bracket
3. Radiator Isolator Assembly
4. Hexnuts
5. Center Mounting Bracket
6. Lower Hood Hinge, Left Side
7. Upper Hood Hinge, Left Side
8. Torsion Bar
9. Mounting Plate
10. Washer
11. Hexbolt, 3/8–16
12. Upper Hood Hinge, Right Side
13. Lower Hood Hinge, Right Side

Fig. 1, Torsion Bar Installation (vehicles with an engine manufactured through 2006)

   7.2 Disconnect the wiring harness that runs along the left-side frame rail.

8. Lower the hood until it is balanced over the pivots, to relieve tension on the stop cables. Have an assistant hold the hood in this position.
9. Disconnect the stop cables from the brackets on the radiator; see **Fig. 4**.
10. Carefully tilt the hood onto the support.
11. Using a T-40 Torx® screwdriver, remove the hood-hinge pivot bolts; see **Fig. 5**.
12. Remove the hood from the vehicle by carefully rolling or sliding the hood support away from the vehicle; do not try to lift the hood.

Hood Removal and Installation



A. The top of support should be at same height as the lowest edge of hood.

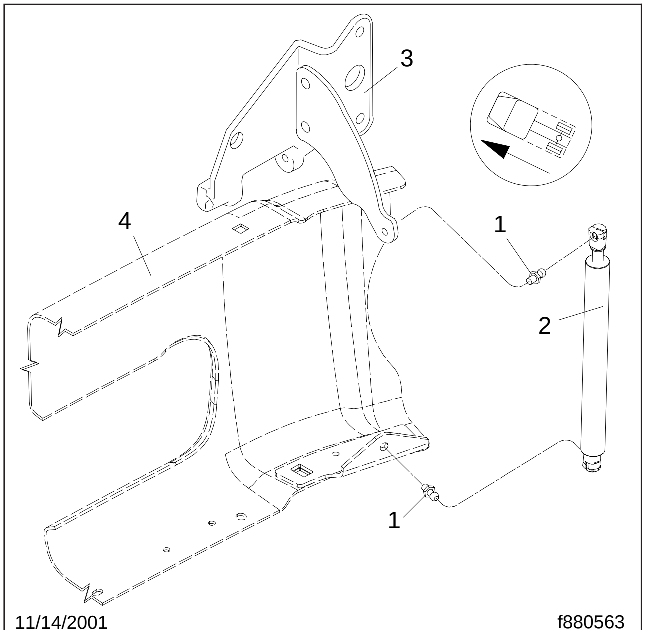
1. Cardboard, Carpet, or Furniture Pad

Fig. 2, Supporting the Hood (typical hood shown)

13. If it is necessary to remove the hood hinges, refer to **Fig. 6**.

Installation

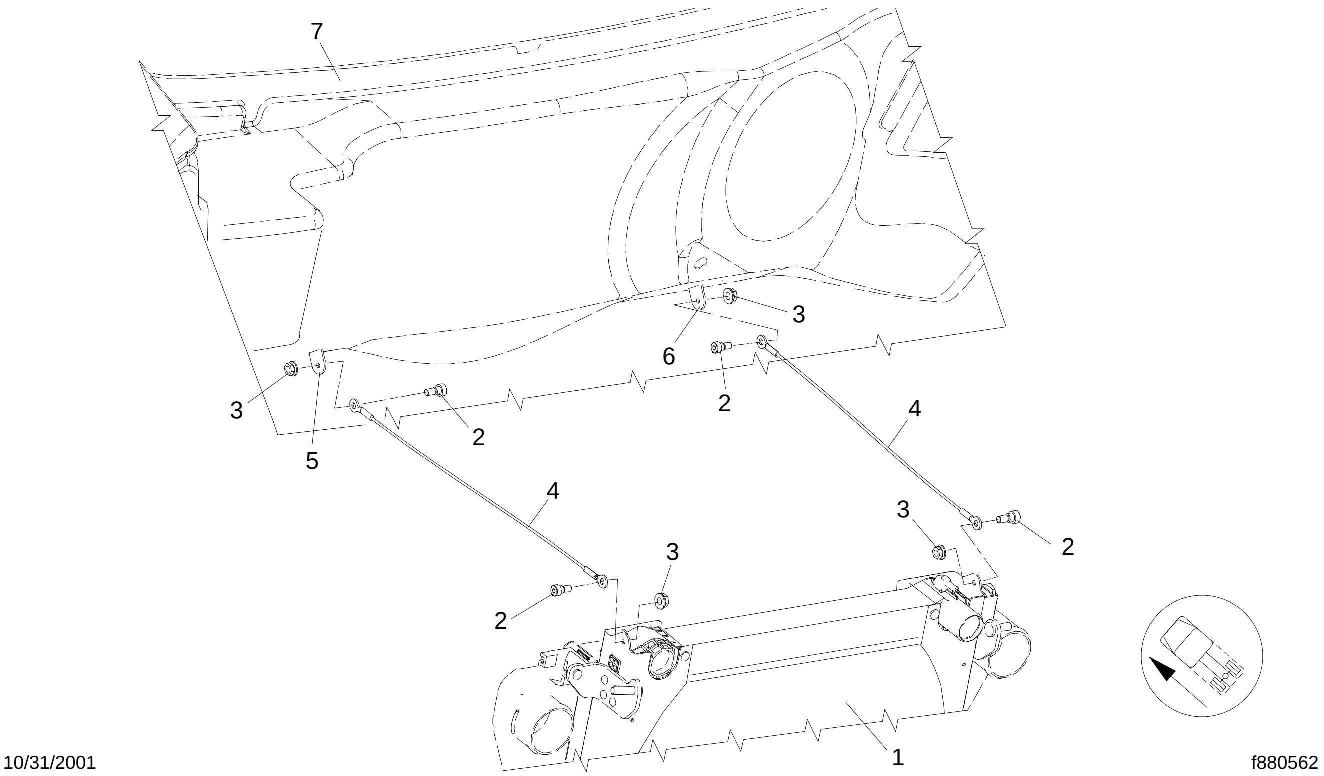
1. With the tires chocked, move the support and hood into alignment with the front of the vehicle. Do not try to lift the hood.
2. Align the holes of the hood hinge brackets with those in the lower hood hinges. Using a T-40 Torx screwdriver, install the hood-pivot bolts from the inboard side. Install the locknuts, and tighten them 25 lbf·ft (34 N·m); see **Fig. 5**.
3. Lower the hood until it is balanced over the pivots, then have an assistant hold the hood in this position.



1. Ball Stud
2. Damper
3. Right-Side Hood Hinge
4. Bumper

Fig. 3, Bumper-Mounted Hood Damper Installation

4. Connect the stop-cable assemblies to the brackets on top of the radiator. Tighten the flanged hexnuts firmly; see **Fig. 4**.
5. Remove the hood support from the front of the vehicle and lower the hood. Check the hood adjustment, and adjust the hood if needed; see **Subject 120**.
6. Open the hood to the full-tilt position.
7. Attach the hood damper to the hood bracket; see **Fig. 3**.
8. Install the torsion bars, as follows; see **Fig. 1**.
   - 8.1 With the hood tilted halfway, insert the outboard end of each torsion bar into the slot in the hood hinge.
   - 8.2 Place the inboard ends of the torsion bars on top of the mounting bracket. Install the mounting plate on top of the torsion bars.
   - 8.3 Secure the mounting plate and torsion bars to the mounting bracket with the



1. Radiator
2. Shoulder-Bolt, 3/8"
3. Flanged Hexnut
4. Hood Stop Cable
5. Left-Side Bracket
6. Right-Side Bracket
7. Hood

Fig. 4, Hood Stop Cables

3/8–16 hexbolts. Tighten the hexbolts 28 lbf·ft (38 N·m).

9. Connect the wiring harness on the left side of the vehicle, then attach it to the standoff bracket near the left hood hinge.
10. Install the grille; see **Subject 100**.
11. Remove the chocks.

Vehicles With an EPA07 Engine

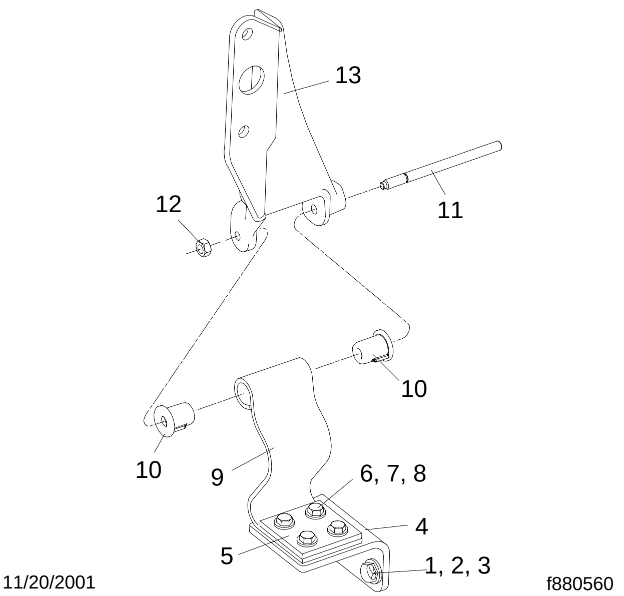
Removal

1. With the vehicle parked, apply the parking brakes and chock the tires.
2. Remove the grille; see **Subject 100**.
3. Open the hood to the full-tilt position.
4. Remove the tilt-assist spring struts by removing the fasteners that secure the struts to the frame assembly and the hood. For vehicles with a 106-inch BBC cab, see **Fig. 7**. For vehicles with a 112-inch BBC cab, see **Fig. 8**.
5. Place a support between the floor and the front of the hood; see **Fig. 2**.

   The support should be as wide and as long as the front of the hood, and should be the same height as the lowest edge of the hood. Place cardboard, carpet, rags, or other padding on top of the support to protect the hood.
6. Disconnect the wiring harness, as follows.

   6.1 Remove the standoff bracket located near the left hood hinge.

Hood Removal and Installation



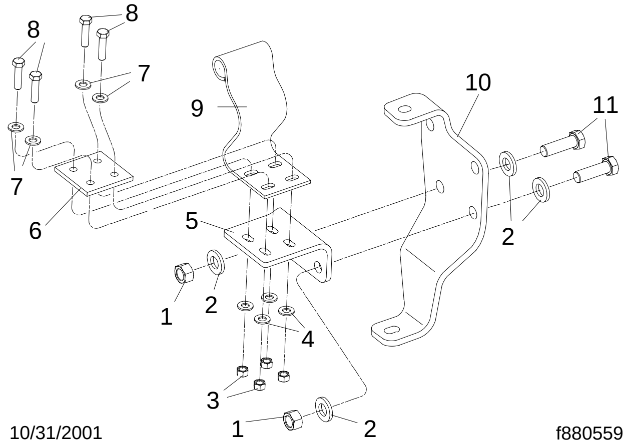
NOTE: Do not remove the bushings unless they are damaged.

1. Hexbolt, 5/8–11
2. Hexnut, 5/8–11
3. Washer
4. Mounting Bracket
5. Mounting Plate
6. Hexbolt, 3/8–16
7. Hexnut, 3/8–16
8. Washer
9. Lower Hood Hinge
10. Bushing
11. Hood Pivot Bolt
12. Locknut, M10
13. Upper Hood Hinge

Fig. 5, Hood Pivot Bolt Installation (vehicles with an engine manufactured through 2006)

6.2 Disconnect the wiring harness that runs along the left-side frame rail.

7. Lower the hood until it is balanced over the pivots, to relieve tension on the stop cables or straps. Have an assistant hold the hood in this position.
8. Disconnect the stop cables (**Fig. 4**), or stop straps (**Fig. 9**), from the brackets on the radiator.
9. Carefully tilt the hood onto the support.
10. Remove the hood-hinge pivot bolts. For a vehicle with a 106-inch BBC cab, see **Fig. 10**. For a vehicle with a 112-inch BBC cab, see **Fig. 11**.
11. Remove the hood from the vehicle by carefully rolling or sliding the hood support away from the vehicle; do not try to lift the hood.



1. Hexnut, 5/8–11
2. Washer
3. Hexnut, 3/8–16
4. Washer
5. Mounting Bracket
6. Mounting Plate
7. Washer
8. Hexbolt, 3/8–16
9. Lower Hood Hinge
10. Bumper Mounting Bracket
11. Hexbolt, 5/8–11

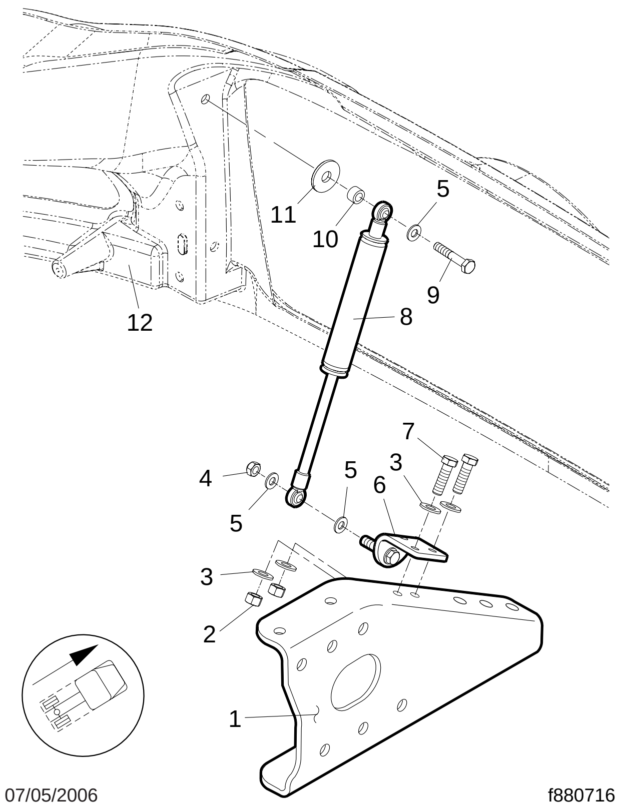
Fig. 6, Hood Hinge Installation (vehicles with an engine manufactured through 2006)

12. If it is necessary to remove the hood hinges, refer to **Fig. 10** (106-inch BBC), or **Fig. 11** (112-inch BBC).

Installation

1. With the tires chocked, move the support and hood into alignment with the front of the vehicle. Do not try to lift the hood.
2. Align the holes of the hood hinge brackets with those in the lower hood hinges. Install the hood-pivot bolts from the inboard side. Install the washers and locknuts. Tighten the locknuts 25 lbf·ft (34 N·m). For vehicles with a 106-inch BBC cab, see **Fig. 10**. For vehicles with a 112-inch BBC cab, see **Fig. 11**.
3. Lower the hood until it is balanced over the pivots, then have an assistant hold the hood in this position.
4. Connect the stop cables (**Fig. 4**) or stop straps (**Fig. 9**) to the brackets on top of the radiator. Tighten the fasteners firmly.
5. Remove the hood support from the front of the vehicle and lower the hood. Check the hood adjustment, and adjust the hood if needed; see **Subject 120**.

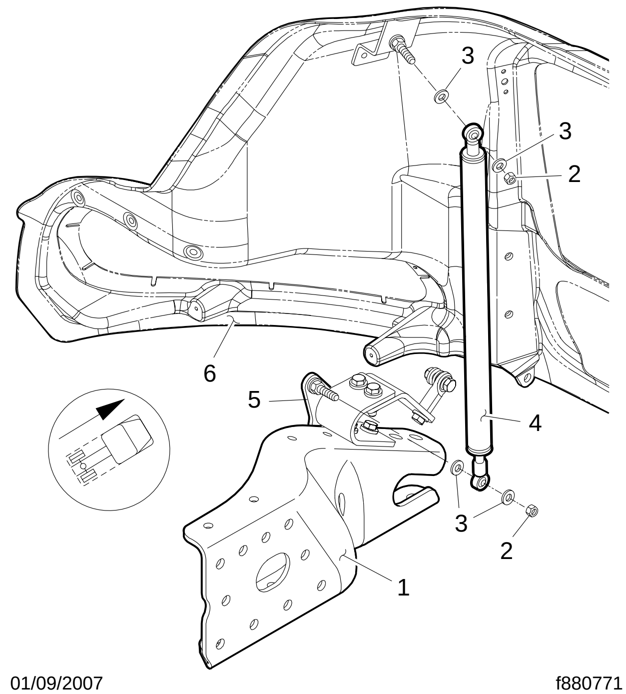
Hood Removal and Installation



NOTE: Left side shown; right side symmetrical.

1. Frame Rail Assembly
2. Nut
3. Flatwasher, Hardened
4. Locknut
5. Flatwasher
6. Strut Support Bracket
7. Bolt, 3/8–16
8. Tilt-Assist Strut
9. Capscrew, M8 x 45
10. Spacer
11. Washer
12. Hood

Fig. 7, Spring Strut Installation (vehicles with a 106-inch BBC cab)



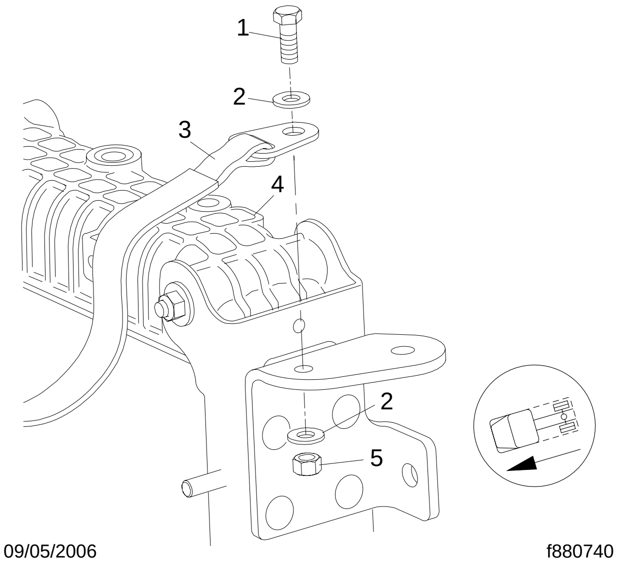
NOTE: Left side shown; right side symmetrical.

1. Frame Rail Assembly
2. Locknut
3. Washer
4. Tilt-Assist Strut
5. Strut Support Bracket
6. Hood

Fig. 8, Spring Strut Installation (vehicles with a 112-inch BBC cab)

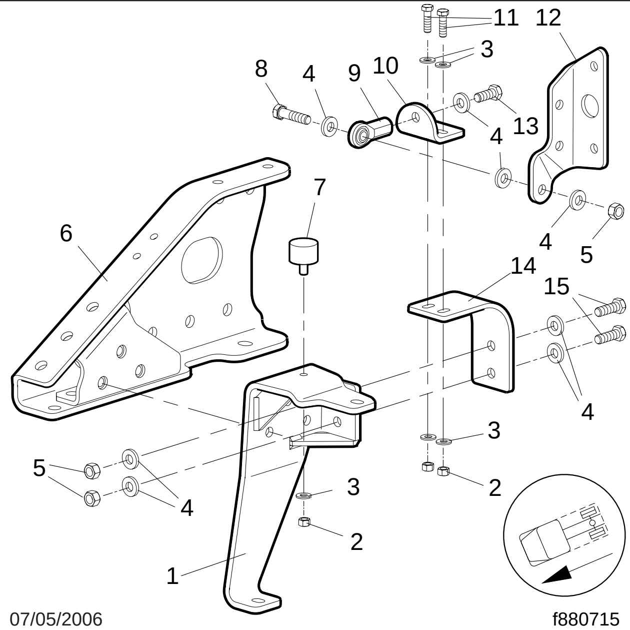
6. Open the hood to the full-tilt position.
7. Install the tilt-assist spring struts on the frame assembly and the hood. Tighten the fasteners 15 to 19 lbf·ft (20 to 26 N·m). For vehicles with a 106-inch BBC cab, see **Fig. 7**. For vehicles with a 112-inch BBC cab, see **Fig. 8**.
8. Connect the wiring harness on the left side of the vehicle. Then attach it to the standoff bracket.
9. Install the grille; see **Subject 100**.
10. Remove the chocks.

Hood Removal and Installation



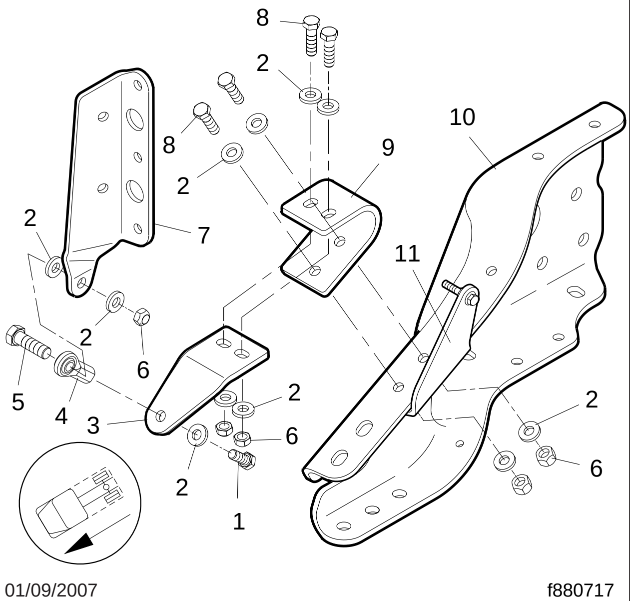
1. Bolt
2. Washer
3. Stop Strap
4. Radiator
5. Nut

Fig. 9, Hood Stop Strap Installation



1. Hood Pivot Bumper Mounting Bracket
2. Nut
3. Washer, Hardened
4. Washer, Hardened
5. Nut
6. Frame Rail Assembly, Left Side
7. Hood Pivot Bumper
8. Pivot Bolt
9. Rod-End Pivot
10. Pivot-Hinge Bracket
11. Bolt, 3/8–16 x 1.25
12. Pivot Bracket
13. Capscrew, 1/2–20 x 1.25
14. Pivot Hinge
15. Bolt, 1/2–13 x 1.5

Fig. 10, Hood Hinge Installation (vehicles with an EPA07 engine, and a 106-inch BBC cab)



1. Capscrew, 1/2–20 x 1.25
2. Washer, Hardened
3. Pivot-Hinge Bracket
4. Rod-End Pivot
5. Pivot Bolt
6. Nut
7. Pivot Bracket
8. Bolt, 1/2–13 x 1.75
9. Pivot Hinge
10. Frame Rail Assembly
11. Strut Support Bracket

Fig. 11, Hood Hinge Installation (vehicles with an EPA07 engine, and a 112-inch BBC cab)

Adjustment

1. Drive the vehicle back and forth to settle the frame and suspension. Park the vehicle on a flat, level surface. Shut down the engine, apply the parking brakes, and chock the tires.
2. With the hood in the operating position, and both hood latches latched, measure the gap between the rear vertical edge of the hood and the front outer vertical edge of the cowl at both sides of the vehicle. See **Fig. 1**. The gap should be between 1-3/8 and 1-5/8 inches (29 to 35 mm).

   If the gap on both sides is within specifications, go to the step for checking the alignment of the hood/cab character lines.

   If the gap is *not* within specifications on one or both sides, adjust the fore-and-aft position of the hood.

2.1 Determine the amount that the hood must be moved at one or both sides, to correct the gap.

2.2 Unlatch and tilt the hood.

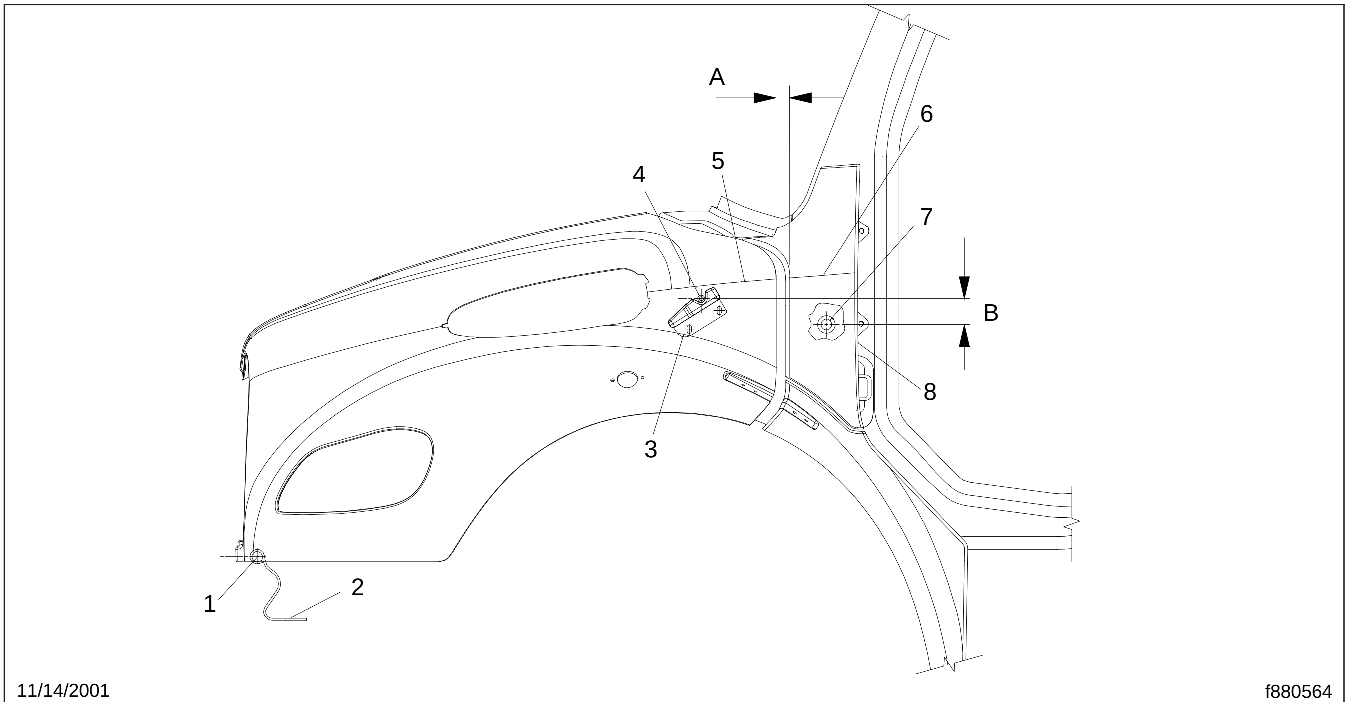
2.3 At the side(s) of the hood that must be moved, loosen the four fasteners that attach the hood hinge to the support bracket just enough to allow the hood to slide fore and aft for adjustment.

Slide that side(s) of the hood fore or aft the amount determined earlier.

Tighten the fasteners 28 lbf·ft (38 N·m).

2.4 Return the hood to the operating position, and fasten the latches.

2.5 Again, check the gap at both sides of the hood.



The tolerance between the hood and cab character lines is not to exceed 1/8 inch (3 mm).

A. Between 1-3/8 and 1-5/8 inches (29 to 35 mm)
B. Between 2-1/2 and 2-5/8 inches (58 to 62 mm)

1. Hood Pivot Bolt
2. Hood Lower Hinge
3. Hood Support Isolator
4. Hood Rear Locator Pin
5. Hood Character Line
6. Cab Character Line
7. Flanged Tooling Hole
8. Cowl

Fig. 1, Hood Fore-and-Aft and Rear Height Measurements

Hood Adjustment

If the gap is *not* within specifications, repeat the above procedure.

When the gap is within specifications at both sides of the hood, go to the next step.

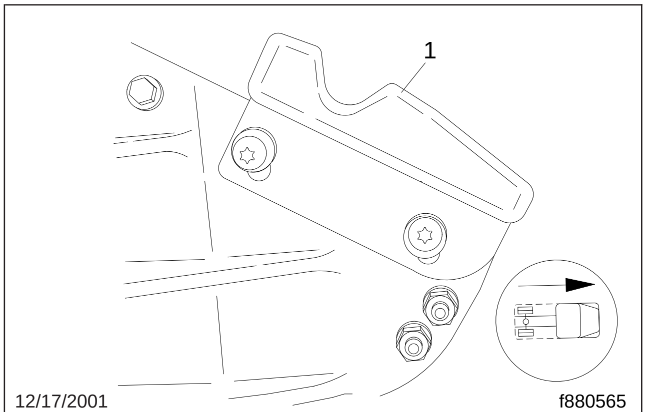
3. With the hood in the operating position, and both hood latches latched, check alignment of the cab and hood character lines. See **Fig. 2**.

   If the character lines are aligned, nothing more needs to be done.

   If the character lines are misaligned, adjust the up-and-down position of the rear of the hood.

   3.1 Unlatch and tilt the hood.

   3.2 If not already done, at the side(s) of the hood that must be moved, loosen the two fasteners that attach the rear hood support isolator assembly to the hood, just enough to allow the hood support assembly to move up or down for adjustment. See **Fig. 2**.



1. Rear Hood Support Isolator Assembly

Fig. 2, Rear Hood Support Isolator

NOTE: Complete the steps for up-and-down adjustment of one side, before doing the other side.

   3.3 Return the hood to the operating position, but latch only the side that is *not* being adjusted.

   3.4 At the side of the hood that's being adjusted, push down on the top of the hood until the character lines (or paint stripes) are aligned.

   3.5 Carefully tilt the hood, without changing the position of the hood support isolator assembly. Tighten the isolator fasteners firmly.

   If the other side of the hood needs to be adjusted, repeat the procedure.

4. Close the hood and latch it.
5. Remove the chocks from the tires.

Precautions

Before performing any fiberglass repairs, read the following precautions. Observe any additional precautions given by the manufacturers of the repair materials used.

1. All of the raw materials used in repairing fiberglass are harmful to the eyes and could cause blindness. Wear goggles or other protective eye shields to reduce the chances of splash contacting your eyes.
2. Wear protective gloves, as some people may have skin sensitivity to resin. Also, don’t allow the hardener to contact your skin. The hardener can be a skin irritant.

IMPORTANT: In case the hardener or resin contacts your skin, wash with soap and water. If the hardener or resin should contact your eyes, rinse with plenty of water (15 minutes), and call a doctor.

3. When working with fiberglass materials, wear old clothing, since the resin may damage garment material. Wash the clothing before wearing again.
4. Most of the liquids involved in fiberglass repair and cleanup (especially when using acetone as a solvent) are flammable; some are also toxic. Don’t perform repairs in areas where exposed (or stored) flammable liquids may contact an open flame or any burning material, such as a cigarette. Don’t perform repairs in areas that are not well-ventilated.

WARNING

Do fiberglass repairs in a safe workshop area to prevent severe personal injury due to explosion of flammable liquids or breathing of toxic fumes.

5. Do not use electric tools when the fumes of flammable solvents are present. The heat or sparks generated by the tools could create a fire hazard.
6. When grinding or sanding fiberglass surfaces, wear goggles or other protective eye shields, and also an air purifying respirator, either a throwaway type or one with a replaceable particulate filter(s). Don’t breath grinding dust or particles, otherwise irritation may occur. Also, during grinding and sanding operations, wear a disposable (paper) shop coat to keep dust and fiber slivers off your clothing.
7. Because fiberglass dust can shorten the life of electrical units, air-powered tools are preferred (for frequent use).
8. Unless fiberglass repairs are done on a regular (daily) basis, don’t save leftover liquids. If liquids must be saved, store them in cool, dark areas, away from direct sunlight.

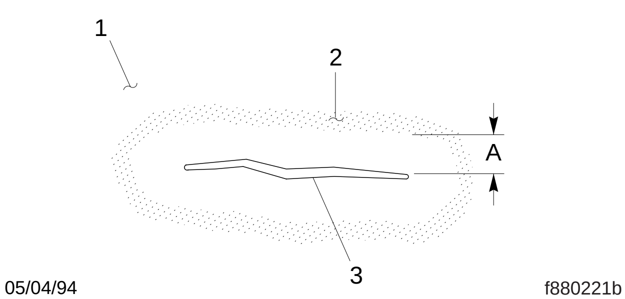
⚠ WARNING

Before starting any hood repair procedure, read the safety precautions in Subject 130. Failure to be aware of the hazards in using raw materials in working with fiberglass could result in serious and long-term health problems.

Surface Damage Repair

Surface damage refers to scratches, chips, or nicks on the outer surface of the hood. Use the following instructions to repair surface damage.

1. Examine the damaged area. If there are cracks, see if they go all the way through the hood. If they do, see "Structural Damage Repair" for instructions.
2. Clean the area with xylene, acetone, or an equivalent grease- and wax-removing solvent. Inspect the area closely.
3. Using 220-grit or finer sandpaper, remove all of the paint around the damaged area to a distance of about 1-1/2 inches (4 cm). See **Fig. 1**.



A. Remove paint and primer 1-1/2 inches (4 cm) around the damaged area. Use 220-grit or finer sandpaper.

1. Paint
2. Primer
3. Scratch

Fig. 1, Damaged Area with Paint and In-Mold Coating Removed

4. Using an air nozzle, blow off all dust.
5. Apply Ashland Pliogrip 7775L self-leveling urethane adhesive over the non-coated area and spread a thin layer using a squeegee applicator. Cover the entire damaged area, overlapping onto the painted surface. Leave a crowned excess of adhesive, slightly higher than the painted surface.

NOTE: When using Ashland Pliogrip 7775L, dispense the required adhesive from the cartridge in a continuous bead of uniform size and a uniform green color. Discard the initial few inches of discolored bead.

6. After the adhesive dries (about 50 minutes), sand it with a hand-held disc pad. Use 320-grit or finer sandpaper. Feather the edges of the fill so there are no visible sharp edges.
7. Clean the area with compressed air. Mask the area, then spot prime and paint it. Use Sherwin Williams BB–11 black conductive primer. See **Group 98** for spot-painting instructions.

Structural Damage Repair

The Preform FRP (fiberglass reinforced plastic) hood consists of a one-piece hood assembly. SMC (sheet molded compound) inner reinforcements are bonded to the engine-side of the hood with a structural adhesive. If the hood is damaged, determine which parts are affected.

If there is damage to any of the reinforcements, the damage is not repairable. For example, if the grille area of the hood is damaged so badly that the reinforcement bonded inside the grille area is also damaged, replace the entire hood assembly.

If a joint between two reinforcements, or between a reinforcement and the hood skin, has separated and there is no damage at the joint area, the parts can be rebonded. Or, if a part of the hood skin is damaged and its adjoining reinforcement(s) aren't damaged, the reinforcement can be separated from the damaged part, the damaged part can be patched, and the reinforcement(s) rebonded in place.

If a has a small crack or hole, it can be repaired; if it has a puncture or large fracture, it must be replaced.

For rebonding parts, see "Hood Reinforcement Rebonding."

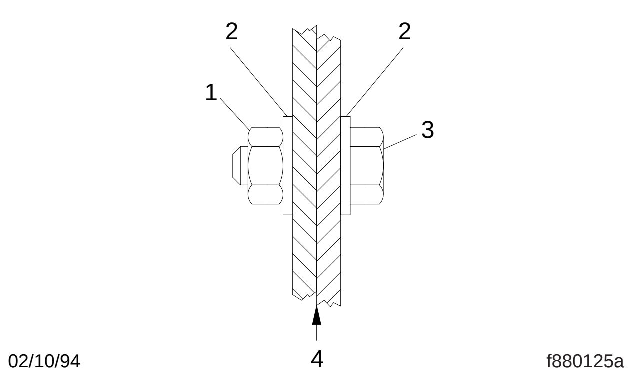
For damage in the form of a crack or small hole, see "Crack or Small Hole Repair."

For larger damaged areas, see "Puncture or Large Fracture Repair."

Hood Reinforcement Rebonding

1. If rebonding a joint that has partially separated, completely separate the reinforcement from the hood using a heat gun and putty knife. Remove as much of the old adhesive as possible. The heat gun will soften the adhesive and allow it to be peeled off the FRP.

   If the parts cannot be separated, work folded medium-grit sandpaper or a section of a steel hacksaw blade between the two surfaces to remove the old adhesive.
2. Scuff the surfaces with 80- to 220-grit sandpaper.
3. Clean the surfaces to be bonded with Ashland 6036 solvent or methylene chloride. Inspect the area closely to be sure all of the old adhesive, dirt, water, grease, and oils are removed.
4. If replacing a large part, align the part on the hood and clamp it in place. Drill holes through the bonding surfaces and install clamping bolts in the holes. Use two washers, one on each side of the joint. See **Fig. 2**. There should be enough clamping bolts to hold the hood in place and keep the bonding surfaces together, or at least one bolt every 12 to 18 inches (30 to 45 cm). Remove the part for application of adhesive.



1. Nut
2. Washers
3. Bolt
4. Bond Joint

Fig. 2, Clamping Bolt at Bond Joint

5. Following the manufacturer's instructions, use enough adhesive to bond the parts together. Use Ashland Pliogrip urethane cartridge materials 7773 or 7779.

NOTE: When using Ashland Pliogrip 7773 or 7779, insert the two tubes of adhesive into the applicator and dispense a 3/8-inch (10-mm) diameter bead of uniform green-colored adhesive at the bonding surface. Discard any adhesive that does not show this uniform green color.

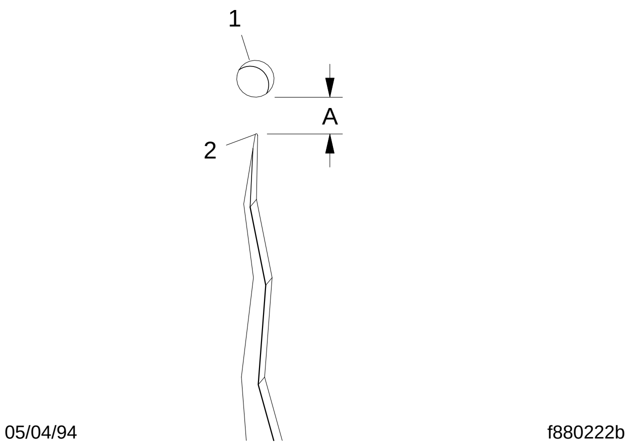
6. Within 3-1/2 minutes (7773) or within 10 minutes (7779) of applying the bead, align the part on the hood and clamp it firmly in place. If it is a large part, install the clamping bolts. Tighten the clamps or clamping bolts just enough to ensure that a uniform amount of pressure is applied along the seam. Ideally, the adhesive should be compressed to form a bondline 1-inch (25-mm) wide and 0.030-inch (0.76-mm) thick. This thickness can be ensured by sprinkling 0.030-inch (0.76-mm) glass beads into the adhesive before mating the parts.
7. Before it cures, remove any excess adhesive that squeezes out the edges of the bond.
8. Remove the clamps after the adhesive has cured for 30 minutes (7773) or for 60 minutes (7779).
9. If holes were drilled for clamping bolts, repair them using the instructions under "Crack or Small Hole Repair."
10. If necessary, prime and paint the repair area using the instructions under "Surface Damage Repair."

Crack or Small Hole Repair

A crack (fracture) or small hole through the laminate requires repair with a fiberglass-reinforced patch.

1. Examine the damage to the hood or apply hand pressure all around the damaged area to check for any concealed damage.
2. If a sound-absorbent liner is present on the underside of the damaged area, peel away the liner to provide an adequate working area.
3. Clean the damaged area on both sides of the hood or with xylene, acetone, or equivalent grease- and wax-removing solvent. Inspect the area closely. All dirt, water, grease, and oils must be removed.
4. If repairing a crack, use a 1/8-inch (3-mm) diameter bit to drill a hole completely through the uncracked laminate 1/8 inch (3 mm) from each end

of the crack, to prevent the crack from lengthening. See **Fig. 3**.



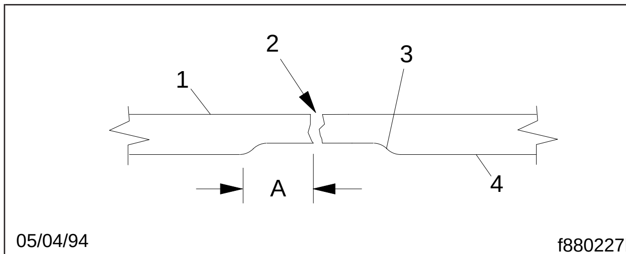
A. 1/8 inch (3 mm)

1. Drilled 1/8-inch (3-mm) Hole
2. End of Crack

Fig. 3, Drilling a Hole to Prevent the Crack From Lengthening

5. On the engine side of the hood (or underside of the), use a router bit (on a grinder or a drill) to grind away a shallow recess one-quarter the depth of the laminate and extending 1/2 inch (13 mm) outward from all sides of the damage. Taper the outside edge of the ground area. See **Fig. 4**.

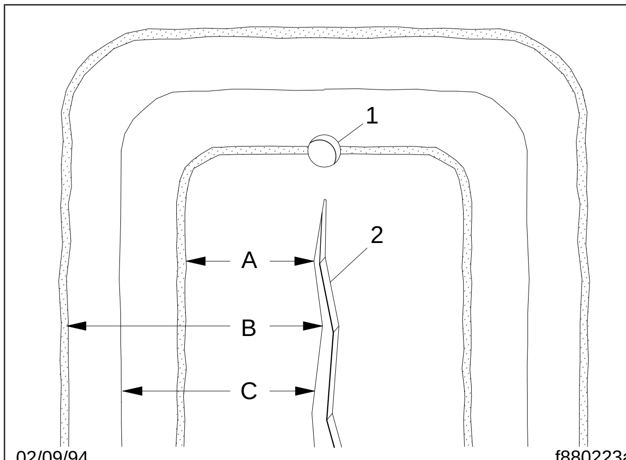
   If repairing a crack, grind outward to the drilled hole at the end of the crack, but not beyond. See **Fig. 5**, Ref. A.
6. Use 80- to 220-grit sandpaper to scuff an area at least 1 inch (25 mm) away from the fracture on all sides. Be sure to scuff thoroughly, since this will give the patch a surface to which it can stick. See **Fig. 5**, Ref. B.
7. Blow the dust away with compressed air and wipe the area with a clean cloth.
8. If necessary, align the panel sections on both sides of the crack, using weights or clamps to re-establish the original panel profile.
9. With a razor-blade knife, cut a section of woven fiberglass cloth to fully cover the crack and to overlay about 3/4 inch (20 mm). See **Fig. 5**, Ref. C.



A. Grind a shallow recess one-quarter the depth of the FRP and extending 1/2 inch (13 mm) outward in all directions from the damaged area.

1. FRP
2. Crack
3. Slight Taper
4. Engine Side of Hood (or underside of)

Fig. 4, Recessed Area (cross-sectional view)



A. Use a router to grind away a shallow recess one-quarter the depth of the FRP and extending 1/2 inch (13 mm) outward from the damage. If repairing a crack, don't grind past the hole drilled at the end of the crack.
B. Use 80- to 220-grit sandpaper to scuff the area 1 inch (25 mm) around the damage.
C. Cut the fiberglass cloth to fully cover the damage, and overlay about 3/4 inch (20 mm).

1. Hole
2. Crack

Fig. 5, Preparing the Damaged Area on the Engine Side of the Hood

10. To bond the fiberglass cloth to the damaged panel, use Ashland Pliogrip 7775L urethane adhesive.

NOTE: When using Ashland Pliogrip 7775L, dispense the required adhesive from the cartridge in a continuous bead of uniform size and a uniform green color. Discard the initial few inches of discolored bead.

11. Lay the cut section of fiberglass cloth on the repair area, centered over the damage. Using a fiberglass roller, press the cloth down firmly into the layer of adhesive to completely saturate the glass fibers.
12. Apply another layer of adhesive over the glass cloth. Spread the adhesive evenly using the fiberglass roller.
13. After 2 to 5 minutes, the adhesive will start to jell. It may take more time when cool, less when warm.

IMPORTANT: To avoid pre-jelling or skin-over, mate the FRP parts to be bonded within one to four minutes after dispensing the adhesive.

NOTE: To get a smoother surface, press a piece of masking tape, wider than the repair, directly over the wet adhesive and smooth it before it hardens. The tape can be removed after five minutes when the adhesive has set.

14. The patch should be hard enough in 50 minutes to allow sanding to a smooth flat surface if required.
15. Repair the damage on the outside surface of the hood, using the instructions in "Surface Damage Repair." Prime and paint both surfaces, using the instructions in **Group 98**.

Puncture and Large Fracture Repair (Section Replacement)

If a has a puncture or large fracture, replace the .

On very large damaged areas (for example, structural damage on the side surface of the hood covering an area of a square foot or more) it may be easier to do a section replacement rather than make a patch. Fenders and headlight reinforcements may be used in section replacements. Also, a second damaged hood with the needed section intact may be available as scrap.

IMPORTANT: A piece of Preform FRP from another vehicle hood must be used for section replacement. Use of any other material may not allow the necessary bonding for the repair.

1. Push in on the area immediately surrounding and underneath the damaged area to determine the extent of damage.
2. If a sound-absorbent liner is present on the underside of the damaged area, peel away the liner to provide an adequate working area.
3. Clean the damaged area on both sides of the hood with xylene, acetone, or an equivalent grease- and wax-removing solvent. Inspect the area closely. All dirt, water, grease, and oils must be removed.
4. Using a sabre saw, cut out a large, straight-sided panel containing the damaged area.

   If the damage extends to a joint where a reinforcement is bonded to the hood, completely separate the reinforcement with a heat gun and putty knife before cutting. See "Hood Reinforcement Rebonding" for instructions.

WARNING

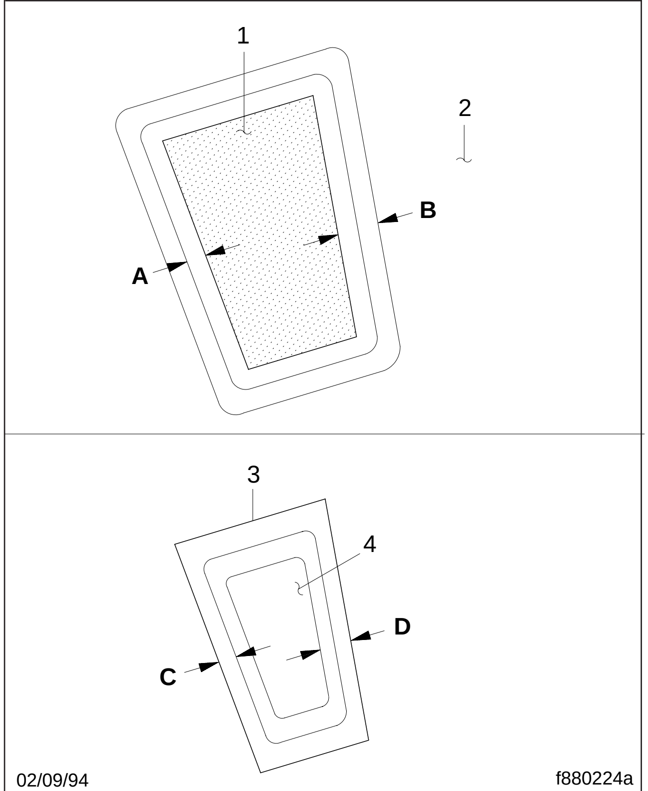
Wear goggles and an air purifying respirator when grinding, cutting, or sanding during all fiberglass repairs. The ground dust and particles could cause temporary or permanent damage to your eyes and, if inhaled, could cause throat or lung irritation.

5. From a scrap hood, cut a section replacement panel from the same area, only slightly larger than the cut-out in the damaged hood. Then, trim the section replacement to fit both the size and contour of the original cutout.

   If the damage is next to a headlight reinforcement, but doesn't include the reinforcement, remove the headlight reinforcement from the replacement section (scrap hood), not the damaged hood.
6. After the trimming is completed, sand the edges to allow a 1/16 to 1/8-inch (2 to 3-mm) gap around the cutout.
7. On the engine side of the hood, use a router bit (on a grinder or drill) to grind away a shallow recess one-quarter the depth of the laminate and extending 1/2 inch (13 mm) outward from all sides of the cutout area. See **Fig. 6**, Ref. A.

Also, grind 1/2 inch (13 mm) inward from all edges on the engine side of the section replacement. See Fig. 6, Ref. C.

Slightly taper the outside edge of the ground area on the hood and the inside edge of the ground area on the section replacement. See Fig. 7, Ref. 3.



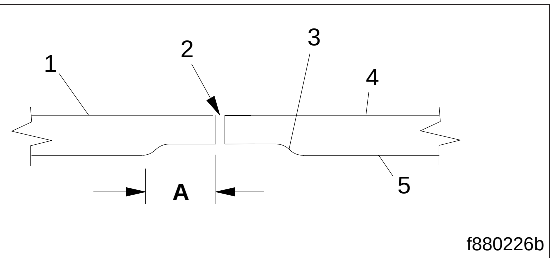
A and C: Use a router to grind away a shallow recess one-quarter the depth of the FRP and extending 1/2 inch (13 mm) away from the edge.

B and D: Use 80 to 220-grit sandpaper to scuff the area 1 inch (25 mm) around the damage.

1. Cutout Hole
2. Engine Side of Hood
3. Section Replacement
4. Engine Side of Section Replacement

Fig. 6, Preparing the Section Replacement and Hood Cutout on the Unexposed Side

8. Use 80 to 220-grit sandpaper to scuff an area at least 1 inch (25 mm) out from all sides of the cutout area. See Fig. 6, Ref. B.



A. Grind a shallow recess one-quarter the depth of the FRP and extending 1/2 inch (13 mm) outward in all directions from the damaged area.

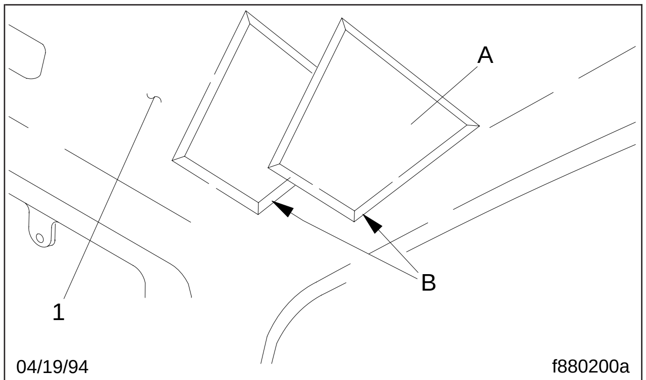
1. Section Replacement
2. Gap
3. Slight Taper
4. Hood
5. Engine Side of Hood

Fig. 7, Cutout Area (cross-sectional view)

Also, scuff at least 1 inch (25 mm) in from all sides of the section replacement. See Fig. 6, Ref. D.

Scuff thoroughly, since this will give the section replacement a surface to which it can stick. Be sure to completely sand off any undercoating sprayed on these areas.

9. On the outer sides of both the cutout and the section replacement, bevel the edges about 45 degrees. See Fig. 8.



A. Insert section replacement.
B. Bevel outer surface edges on all sides.

1. Exposed Side of Hood

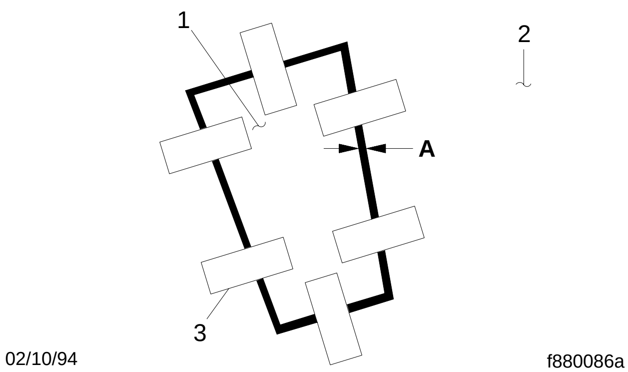
Fig. 8, Areas to be Beveled

10. Gently feather the outer painted surfaces back about 1/2 inch (13 mm) beyond the edges of the repair areas (on both the cutout and the section replacement), using 220-grit or finer sandpaper.

Hood Repair

11. Blow the dust away with compressed air, and wipe the area with a clean cloth.
12. If the section replacement is close enough to an edge, use clamps to temporarily secure it during the repair.

    If the replacement is too far from an edge to use clamps, use bond strips. See **Fig. 9**.



A. Gap of 1/16 to 1/8 inch (2 to 3 mm)

1. Section Replacement
2. Engine Side of Hood
3. Bond Strip

Fig. 9, Securing the Section Replacement to the Hood Using Bond Strips

12.1 Cut some scrap FRP into strips. Make enough strips to hold the section replacement in position; about one every 6 inches (15 cm). If the surface of the replacement panel is contoured or curved, use many small bond strips; larger strips could deform the curves.

12.2 On the engine side of the repair, use 220-grit sandpaper to scuff sand the areas on the hood and section replacement panels where you plan to bond the strips.

12.3 If a joint between the hood and a reinforcement was separated for the repair, rebond the joint. See "Hood Reinforcement Rebonding" for instructions.

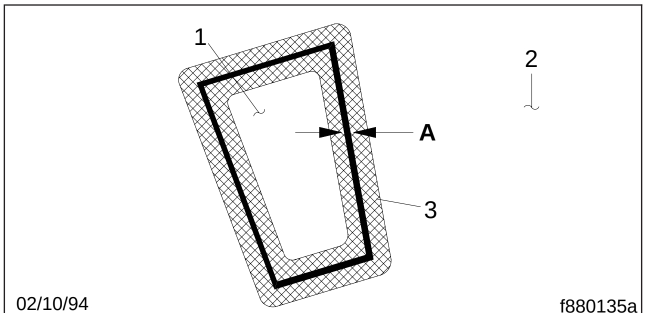
12.4 Holding the section replacement in position, bond the strips to both hood and replacement panels in the area already scuffed. Use Ashland Pliogrip 7773 to bond the strips.

NOTE: When using Ashland Pliogrip 7773, dispense the required adhesive from the cartridge in a continuous bead of uniform size and a uniform green color. Discard the initial few inches of discolored bead.

12.5 After the adhesive has hardened, use 80- to 220-grit sandpaper to scuff the bond strips.

12.6 Blow the dust away with compressed air, and wipe the area with a clean cloth.

13. With a razor-blade knife, cut sections of woven fiberglass cloth to fully cover the gap between the cutout and the section replacement, all the way around the damaged area. The cloth should overlay about 3/4 inch (20 mm) on both sides of the gap. See **Fig. 10**.



NOTE: The fiberglass cloth should overlay about 3/4 inch (20 mm) on both sides of the gap.

A. Gap of 1/16 inch to 1/8 inch (2 to 3 mm)

1. Section Replacement
2. Engine Side of Hood
3. Fiberglass Cloth

Fig. 10, Overlaying the Gap with Fiberglass Cloth

14. To bond the fiberglass cloth to the damaged panel, use Ashland Pliogrip 7775L urethane adhesive.

NOTE: When using Ashland Pliogrip 7775L, dispense the required adhesive from the cartridge in a continuous bead of uniform size and a uniform green color. Discard the initial few inches of discolored bead.

15. Use a plastic or metal device to spread a thin layer of adhesive over the scuffed area.
16. Lay the cut sections of fiberglass cloth on the repair area, centered over the damage. Using a

fiberglass roller, press the cloth down firmly into the layer of adhesive to completely saturate the glass fibers.

17. Apply another layer of adhesive over the glass cloth. Spread the adhesive evenly using the fiberglass roller.
18. After 2 to 5 minutes, the adhesive will start to jell. It may take more time when cool, less when warm.

IMPORTANT: To avoid pre-jelling or skin-over, the FRP parts to be bonded should be mated within 1 to 4 minutes after the adhesive is dispensed.

NOTE: To get a smoother surface, press a piece of masking tape, wider than the repair, directly over the wet adhesive and smooth it before it hardens. The tape can be removed after 5 minutes when the adhesive has set.

19. The patch should be hard enough in 50 minutes to allow sanding to a smooth flat surface, if desired.
20. Repair the damage on the outside surface of the hood and paint the surface on both sides, using the instructions in "Surface Damage Repair."

Specifications

Torque Specifications	
Fastener Description	**Torque Value**
Hood Pivot Bolt Locknuts	25 lbf·ft (34 N·m)
Torsion Bar Mounting Hexbolts	28 lbf·ft (38 N·m)
Tilt-Assist Spring Strut Fasteners	15 to 19 lbf·ft (20 to 26 N·m)

Table 1, Torque Specifications

General Description

The American LaFrance TwinFlow midship-mounted fire pump is a centrifugal pumping system designed to deliver large volumes of water under pressure. See **Fig. 1**.

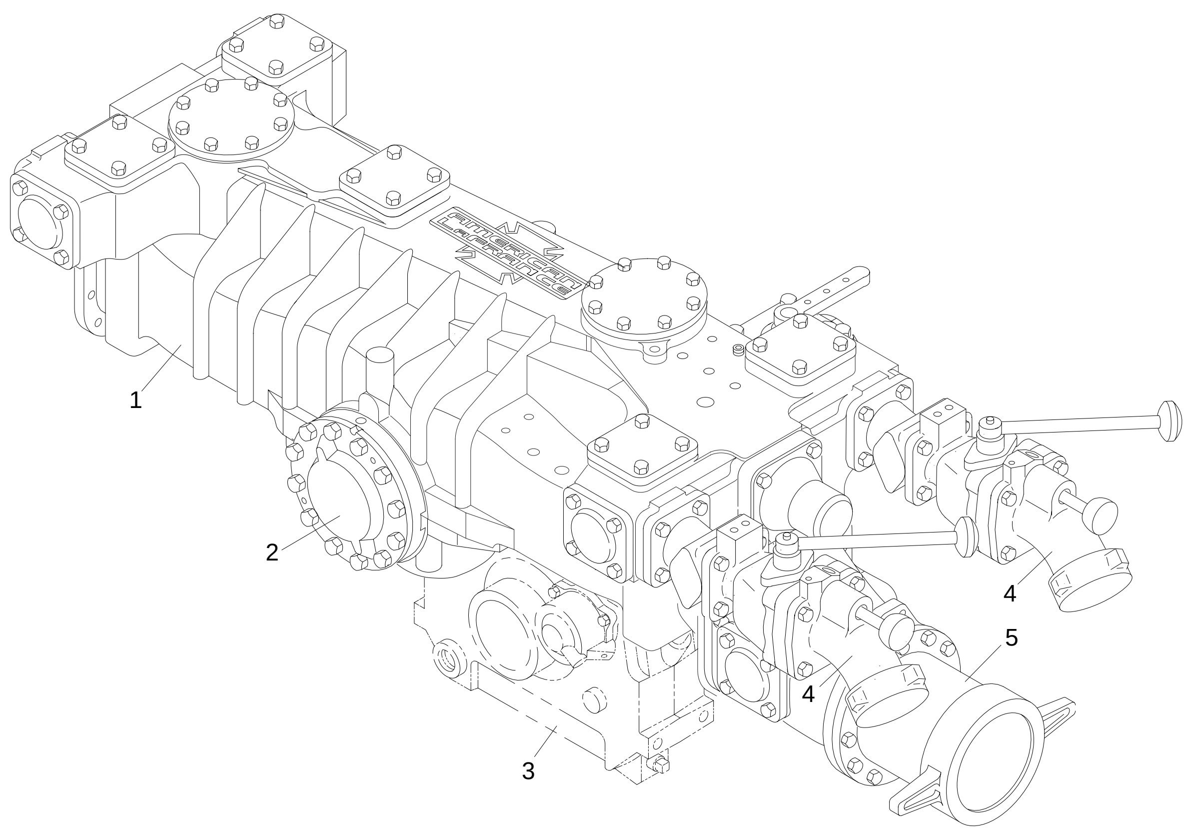
The TwinFlow fire pump consists of the following major components:

- A cast-iron pump body
- A bronze impeller(s) and a stainless steel shaft
- A pump gearbox (See **Fig. 2**)
- A priming system
- A pressure control device
- Valves

There are numerous other components, such as the AutoLube and the mechanical seal.

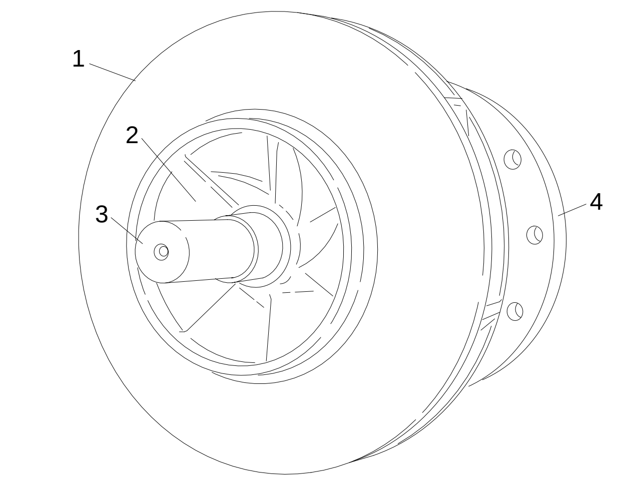
Pump type is determined by the number of impellers on a common shaft. The impeller, which is mounted on a shaft, rotated by the vehicle's engine, via the driveline, provides velocity to the water, causing it to build enough pressure and volume to be used for firefighting applications.

Bearings support and align the impeller shaft and other components. The bearings must be maintained on a scheduled basis. See **Group 90** of the *Business Class® M2 Maintenance Manual*.



1. Pump Body
2. AutoLube
3. Gearbox
4. Discharge
5. Intake

Fig. 1, American LaFrance TwinFlow Fire Pump (single-stage shown)



1. Shroud
2. Impeller Eye
3. Shaft
4. Mechanical Seal Housing

Fig. 2, Fire Pump Gearbox

The pump body is split horizontally in two sections for ease of removal of the impeller assembly, including the bearings and the clearance rings.

The pump gearbox and the impeller assembly are removable from the bottom of the vehicle in order to avoid interference with the pump plumbing and control mechanisms.

The pump has two large suction inlets, one on each side of the vehicle, though other inlets may be present. The inlets and the internal pump outlets are on opposite sides of the pump to balance forces caused by the intake and the discharge of water.

The AutoLube is built into the pump assembly to continuously force oil to the impeller shaft bushing to lubricate and cool the impeller bushing.

Principles of Operation

TwinFlow centrifugal pumps operate on the principle of centrifugal force, created by a rapidly spinning disk, (impeller). Water is routed to the center of the impeller, which throws the water outward. When water is confined in a closed container, in this instance, the pump body, the water pressure increases. The pressure level depends on how fast the impeller is rotating.

Water enters the spinning impeller at the intake and is confined by shrouds and vanes in the impeller, which, in turn, builds pressure. The vanes guide the water away from the inlet to the discharge to reduce the water's turbulence and to move the water toward the outer edge of the impeller. The shrouds serve as the sides of the impeller and confine the water to the centrifugal acceleration.

Single-stage pumps provide the same operating and rating-test pressures as a two-stage pump, but the two-stage pump offers additional operating (water) pressure.

The primary difference between a single-stage and a two-stage pump is that the single-stage has only one impeller and no transfer valve to switch between volume and pressure operation. A transfer valve is a two-position valve that permits the impellers in a two-stage pump to operate in parallel (volume) or series (pressure).

In two-stage pumps, the volume operation results in the pressure at the pump intake being added to the equal pressure developed by the impellers, and the amount of water sent to the discharge being the sum of the flows of the two impellers. The pressure operation features the impellers operating in series, or the output of the primary impeller supplied from the pump intake is supplied to the input of the secondary impeller. Thus, the pressure at the pump discharge is the sum of the pressures of the two impellers plus the pressure at the intake. The flow is then half of the volume operation.

In both types of pumps, the pressurized water is prevented from returning to the intake of the impeller(s) by clearance rings. Centrifugal pumps have clearance rings mounted between the spinning impeller and the pump body. Clearance rings, as well as the hubs of the impeller(s), will, over time, become worn or pitted and may need to be replaced, or machined to a smaller diameter.

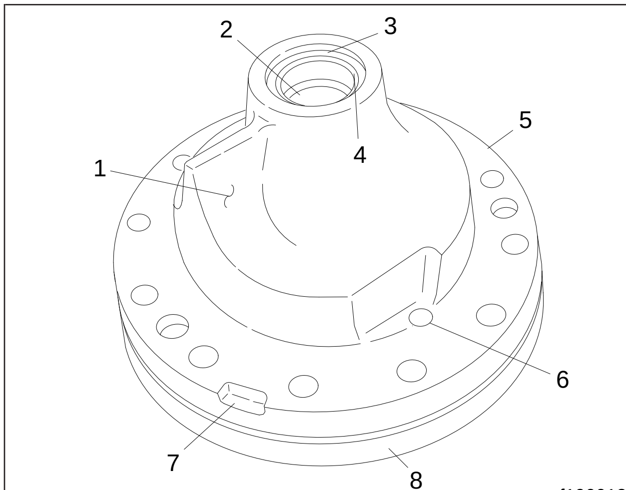
Replacement

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Drain the water from the pump.
3. Remove the fill and drain plugs from the AutoLube reservoir and drain the oil.
4. Use a center punch to mark the AutoLube cover and the front bearing housing (for proper alignment during assembly).

CAUTION

Do not use a chisel to separate the AutoLube from the pump body because the mating surfaces may be scratched or gouged, which could result in a leak. Also, the AutoLube is manufactured from cast metal, and if it becomes necessary to pry the AutoLube apart from the pump body, pry between the AutoLube and the pump body or at the AutoLube "notches." See Fig.1.

5. Remove the 1/2–13 x 2 capscrews that attach the AutoLube to the pump body, then gently pry the AutoLube from the pump body and impeller shaft.
6. Place the AutoLube face down on a workbench, then remove the two 3/8–16 x 3/4 Allen-head capscrews from the impeller side. Separate the two halves and remove the diaphragm.
7. Remove the seal lockring.
8. Remove the oil seal from the inner half of the AutoLube.
9. Check the impeller shaft bushing for wear.
10. Clean the inner and outer halves of the AutoLube.
11. Clean the gasket surfaces of the AutoLube and the pump body.
12. Check for restrictions in the water passages to the rear part of the AutoLube.
13. If it is necessary to replace the impeller shaft bushing, press the bushing from the inner side of the inner half of the AutoLube (side opposite the impeller). Install the bushing from the impeller side of the inner half of the AutoLube. See Fig. 1.



1. Cut Water
2. Impeller Shaft Bushing
3. Seal Lockring
4. Oil Seal
5. Front Bearing Housing
6. Water Passage
7. Pry Notch
8. AutoLube Cover

Fig. 1, Impeller Side of the AutoLube

CAUTION

The impeller shaft bushing seats against a shoulder in the inner half of the AutoLube and can only be removed and installed as described or the AutoLube may be damaged.

14. Install a new oil seal in the inner half of the AutoLube.
15. Install the seal lockring.
16. Position the diaphragm on the inner half of the AutoLube.
17. Line up the marks, and place the outer half of the AutoLube onto the inner half. Apply Loctite® 242 to the two 3/8–16 x 3/4 Allen-head capscrews. Tighten the capscrews 30 lbf·ft (41 N·m).
18. Install a new gasket on the AutoLube, and position the assembly (with the top up) onto the impeller shaft. Attach the AutoLube with 1/2–13 x 2 capscrews and tighten them to 80 lbf·ft (108 N·m).

AutoLube Seal Replacement

CAUTION

Do not damage the oil seal. A damaged oil seal could result in damage to the AutoLube assembly, as well as to the pump.

19. Fill the AutoLube with 90W oil, by pumping it in from the bottom plug opening until the oil spills from the top opening. This will eliminate air pockets and false readings.

CAUTION

Purge the air from the AutoLube while filling it with oil or a "false-fill" situation will develop, which could cause damage to the AutoLube and other components.

20. Add water to the pump.
21. Operate the fire pump and check the AutoLube for water or oil leaks.
22. Remove the tire chocks.

Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

Removal

NOTE: For an exploded view of the front gearbox assembly, see **Fig. 1**.

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Drain the water from the pump.
3. Drain the gearbox lubricant to prevent contamination.
4. Disconnect the pressure lubrication line to the gearbox cover. Plug the pressure lubrication line.
5. Disconnect the driveshafts from the gearbox.
6. Disconnect the electrical switches and the air lines. Mark the switches and air lines for assembly.
7. Disconnect the pump gearbox cooling lines.

WARNING

The gearbox is heavy. Support the gearbox with a lifting or supporting device while removing it from the pump body. Failure to do so could result in the gearbox falling, which could result in personal injury or property damage.

NOTE: Before removing the gearbox, use a center punch to mark the rear bearing housing, the mechanical seal housing, the oil pump cover, and the pump body, to ensure proper alignment during reassembly.

8. Support the gearbox with an appropriate device.
9. Remove the six 1/2–13 x 1-3/4 capscrews that attach the gearbox cover to the top of the gearbox.
10. Remove the 7/16–14 x 1-1/4 capscrews that attach the gearbox to the rear bearing housing.
11. Lower the gearbox. Be sure to balance the gearbox so that it does not tip from the lowering device. See **Fig. 2**.
12. Remove the gearbox cover.

NOTE: The threaded holes may need to be cleaned.

Disassembly

1. Remove and disassemble the intermediate shaft assembly. See **Fig. 3**.

   1.1 Disconnect the oil suction line from the lubrication pump.

   1.2 Remove the capscrews that attach the front bearing housing to the lubrication pump. Remove the housing and pump assembly.

   IMPORTANT: The rear bearing housing has threaded holes for 1/4–20 jackscrews to assist in removal. Hold the intermediate gear to prevent it from falling.

   1.3 Remove the capscrews that attach the rear bearing housing to the lubrication pump.

   1.4 Reach into the top of the gearbox housing and remove the intermediate gear and shaft assembly. The bearing inner cups are pressed onto the shaft, so care must be taken not to damage the cups during removal.

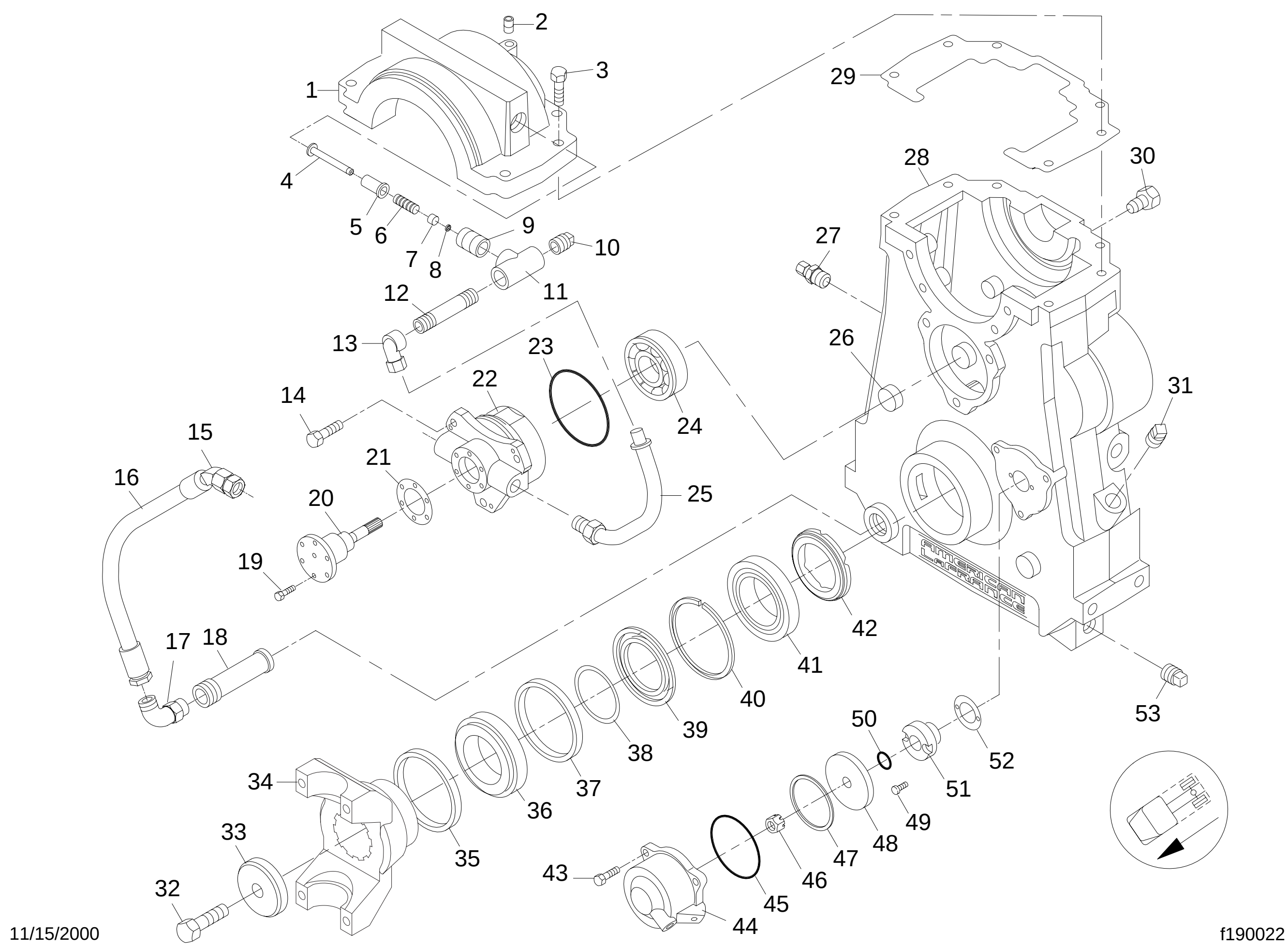
   1.5 Using a bearing splitter, clamp the halves of the splitter onto the back edge of the intermediate shaft bearing cup. Attach a crossbar puller to the bearing splitter halves and remove the cup. Care must be taken when removing the cup to not damage the lubrication pump spline in the center of the intermediate shaft. Repeat the procedure for the opposite-side bearing cup.

   1.6 Using a gear puller with reversed jaws, remove the intermediate shaft bearing cone from the intermediate shaft rear cover.

CAUTION

Lubrication pump impeller vanes are fragile, and may break or chip. Impeller vanes are installed only one way. If removal of the vanes is necessary, note the installation direction of the vanes (rounded edge). Failure to install the vanes properly will result in pump gearbox failure.

Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation



1. Gearbox Cover
2. Air Vent
3. Capscrew, 1/2–13 x 1-3/4
4. Oil Spray Valve
5. Bushing
6. Oil Spray Bar Spring
7. Retainer Spring
8. External Retaining Ring
9. Close Nipple, 3/4 NPT
10. Plug, 1/2 NPT
11. Branch Tee, 1/2 x 1/2 x 3/4
12. Nipple, 1/2 NPT x 3-1/2
13. Compression Elbow, 1/2 NPT x 1/2
14. Capscrew, 7/16–14 x 1-1/4
15. JIC 45 Elbow, 1/2 NPT x 1/2
16. Oil Suction Line
17. JIC 90 Elbow, 1/2 NPT x 1/2
18. Gearbox Lubrication Oil Filter
19. Capscrew, 1/4–20 x 5/8
20. Lubrication Oil Pump Cover
21. Lubrication Oil Pump Cover Gasket
22. Lubrication Oil Pump
23. Intermediate Ring and Oil Seal
24. Intermediate Bearing
25. Pressure Lubrication Hose, 1/2 ID
26. Plug, 1/2 NPT
27. Hard Copper Tube Fitting, 1/2 NPT x 3/8
28. Gearbox Assembly
29. Gearbox Cover Gasket
30. Gearbox Oil Level Indicator
31. Plug, 3/4 NPT
32. Capscrew, 3/4–10 x 1-1/2
33. Yoke Washer
34. Driveline Yoke
35. Oil Seal
36. Bearing and Race
37. Preload Spacer
38. Preload Shim
39. Snap Ring Lock
40. Snap Ring
41. Bearing and Race
42. Input Shaft Thrust Spacer
43. Capscrew, 5/16–18 x 1
44. Air Shift Cylinder
45. Shift Cylinder Seal
46. Hex Locking Nut, 1/2–13
47. Piston Seal Ring
48. Air Shift Piston
49. Capscrew, 1/4–20 x 1-5/8
50. Vee Block Seal
51. Air Cylinder Bushing
52. Shifter Bushing Gasket
53. Magnetic Plug, 3/4 NPT

Fig. 1, Front Gearbox Assembly (exploded view)

Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

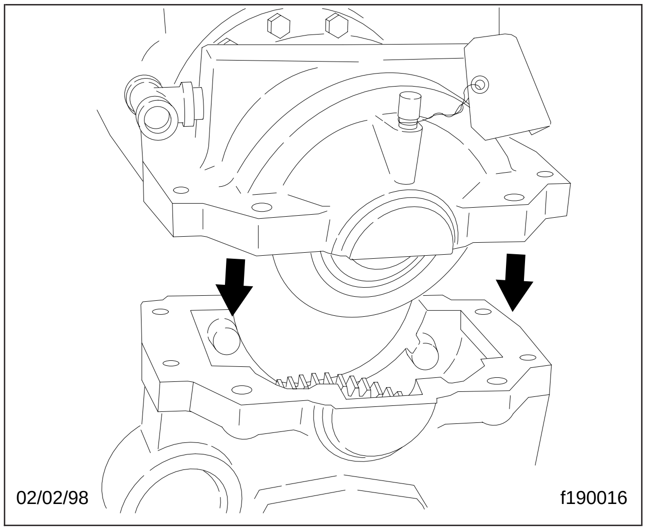


Fig. 2, Lowering the Fire Pump Gearbox

1.7 When disassembling the lubrication pump, be sure to note the number of gaskets and shims that are under the cover. Set these components aside for reassembly.

1.8 Using a centerpunch, mark the lubrication pump position, then remove the six 1/4–20 x 5/8 capscrews.

1.9 Remove the lubrication pump cover.

1.10 Remove the lubrication pump impeller and the shaft, being careful not to damage the impeller vanes.

1.11 Using a gear puller with reversed jaws, remove the intermediate shaft bearing cone from the intermediate shaft front cover. Care must be taken when removing the cup so as not to damage the lubrication pump spline in the center of the intermediate shaft cover.

2. Remove and disassemble the output shaft assembly. See Fig. 3.

2.1 Remove the manual shift eye from the rear of the shift yoke shaft.

2.2 Remove the detent Allen-head screw, spring, and detent ball from the top of the output shaft housing.

2.3 Remove the shift and interlock switches from the output shaft housing.

NOTE: Bolts may be different lengths.

2.4 Remove the 7/16–14 x 2-1/4 capscrews that retain the output shaft, then the housing to the gearbox housing. Carefully remove the output shaft housing by sliding the housing from the shift yoke shaft.

2.5 Remove the input shaft pilot bearing from the output shaft.

2.6 Remove the 3/4–10 x 1-1/2 capscrew that retains the rear driveline yoke to the output shaft, then remove the yoke.

2.7 Remove the output shaft seal.

2.8 Remove the output shaft by sliding it from the output shaft housing from the rear to the front. Use caution when sliding the output shaft through the bearing cones and spacer(s).

CAUTION

Bearing cups, cones, and spacers are factory pre-set for end play, and are only provided as a matched set. It is important that bearing cups, bearing cones, and spacers, when removed, be kept together in matched sets. Input and output shaft bearing and spacer sets are different. Failure to keep matched sets together or to not use factory pre-set and matched bearing and spacer sets will void the warranty and may result in gearbox failure.

IMPORTANT: Note the orientation of the bearings before disassembly.

2.9 Remove the inner and outer bearing cones.

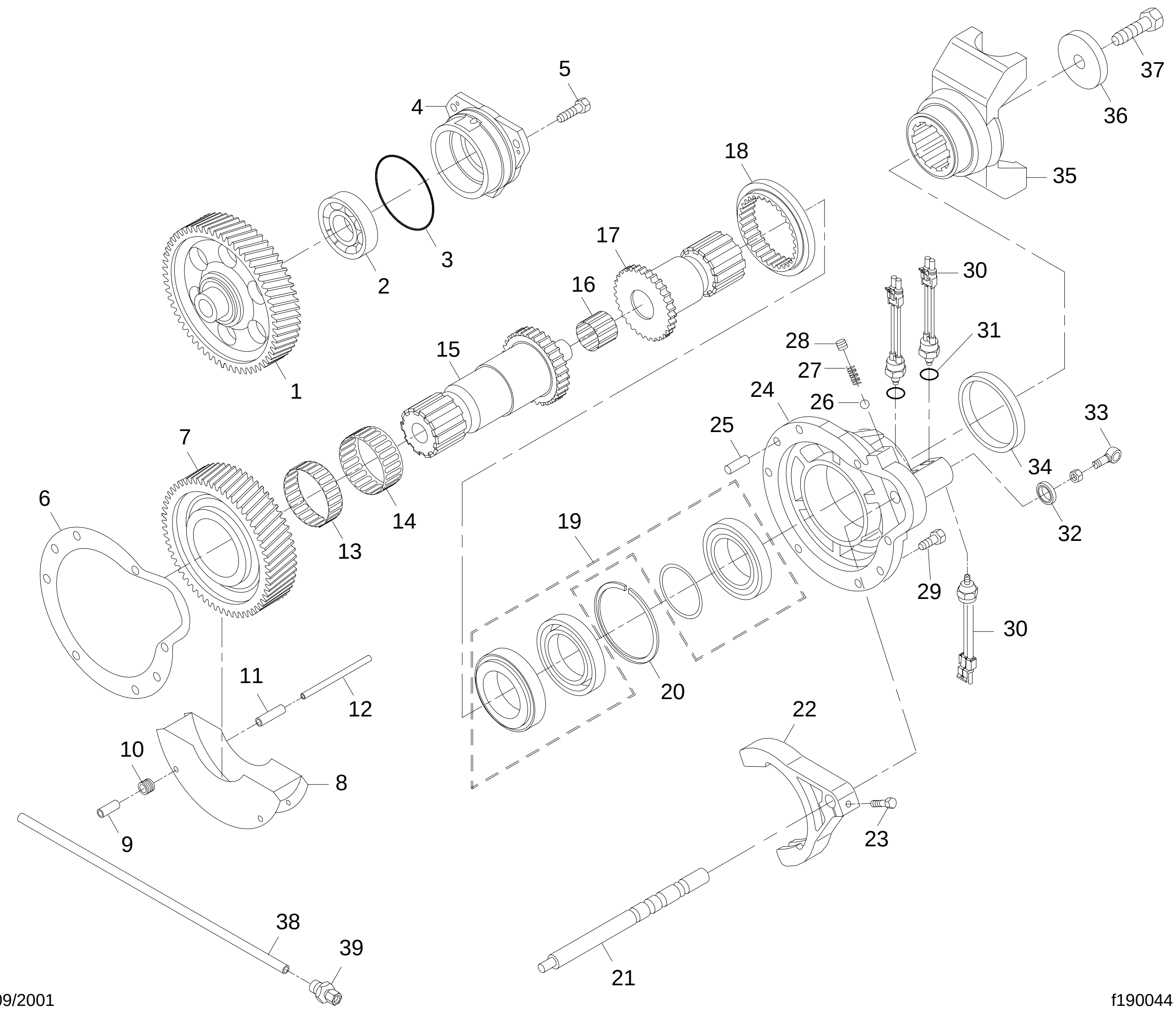
2.10 Using a brass drift, carefully drive out the outer bearing cup from the inside out. Remove the internal retaining ring, then the spacer(s).

2.11 Using a brass drift, carefully drive out the inner bearing cup from the outside in.

2.12 Remove the shaft seal from the output shaft housing.

3. Remove and disassemble the input shaft assembly. See Fig. 3.

Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation



1. Intermediate Gear Assembly
2. Intermediate Shaft Bearing
3. Intermediate Shaft Bearing Cover Oil Seal
4. Intermediate Shaft Bearing Cover
5. Screw, 7/16–14 x 1/8 Hex Nylock
6. Bearing Cover Gasket
7. Input Gear
8. Windage Tray
9. Spacer
10. Windage Tray Spring
11. Spacer
12. Windage Tray Rod
13. Short Caged Roller Bearing
14. Long Caged Roller Bearing
15. Input Shaft
16. Input Shaft Needle Bearing
17. Output Shaft
18. Shifting Collar
19. Rear Bearing Shims/Spacers Assembly
20. Internal Retaining Ring
21. Shifting Shaft
22. Shift Fork
23. Screw, 3/8–16 x 1-1/4 Hex Nylock G8
24. Output Shaft Housing
25. Gearbox Dowel Pin
26. Gearshift Shaft Ball
27. Compression Spring
28. Allen-Head Setscrew, HD, Self-Locking
29. Screw, 7/16–14 x 1-3/4 Hex Nylock
30. Gearshift Switch
31. Switch Seal Ring
32. Wiper/Scraper Seal
33. Manual Shift Eye
34. Lip Seal
35. Driveline Yoke
36. Yoke Washer
37. Capscrew, 3/4–10 x 1-1/2
38. Gearbox Cooling Tube
39. Cooling Tube Connector

Fig. 3, Rear Gearbox Assembly (exploded view)

Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

3.1 Remove the three 5/16–18 x 1 capscrews from the shift cylinder, then carefully slide the shift cylinder from the piston.

3.2 Remove the nut, then remove the piston from the shift shaft. Remove the seal ring from the piston.

CAUTION

Do not remove the piston from the shift yoke shaft unless it is damaged (and replacement is mandatory). When installing a new piston, install a new locknut and snugly tighten it, but do not overtighten as the nut can become distorted, which can cause shift failures.

3.3 Remove the shift shaft, the shift fork, and the shift ring assembly from the gearbox. Make sure the shift ring does not get dropped or damaged.

3.4 Note the location and orientation of the shift fork on the shaft, then remove the 3/8–16 x 1-1/4 screw from the shift fork, and remove the fork from the shift shaft.

3.5 Remove the shift shaft support block. Then remove the seal from the support block.

NOTE: One ear of the shift yoke is machined and will fit one way. Make a note of the location of the machined ear when removing the shift yoke.

3.6 Remove the 3/4–10 x 1-1/2 capscrew that attaches the front driveline yoke to the input shaft. Remove the yoke.

3.7 Remove the input shaft by sliding the input shaft from the output shaft housing opening at the rear of the gearbox. Use caution when sliding the input shaft through the bearing cones, the thrustwasher, and the drive gear. Place wooden blocks to support the drive gear and to protect the windage tray, and force the shaft loose.

CAUTION

Bearing cups, cones, and spacers are factory pre-set for end play, and are only provided as a matched set. It is important that bearing cups, bearing cones, and spacers, when removed, be kept together in matched sets. Input and output shaft bearing and spacer sets are different. Failure to keep matched sets together or to not use factory pre-set and matched bearing and spacer sets will void the warranty, and may result in gearbox failure.

There are two bearings of different widths supporting the drive gear on the input shaft. It is important that these bearings be installed in the drive gear in the proper location. Note the location of the bearings when removed. Failure to install the bearings properly can result in gearbox failure.

3.8 Reaching through the top of the gearbox housing, carefully remove the drive gear, the inner bearing cone, and thrustwasher. Remove the drive gear bearings.

3.9 Using a magnet, remove the positioning pins from the windage tray. Remove the windage tray and the positioning springs.

3.10 Remove the input shaft seal.

3.11 Remove the outer bearing cone.

3.12 Using a brass drift, carefully drive out the outer bearing cup from the inside out. Remove the internal retaining ring and the spacer(s).

3.13 Using a brass drift, carefully drive out the inner bearing cup from the outside in.

4. Inspect the cooling tube for damage and leaks.
5. Remove the gearbox oil filter from the suction inlet on the gearbox housing.
6. Clean and inspect each component of the gearbox assembly. Inspect the bearing cups and the cones for wear, pitting, and damage. Inspect the gear tooth surfaces for wear, damage, and pitting. Inspect the shift shaft block for wear. Inspect the gasket surfaces for nicks and gouges. Replace all components that are worn, damaged, or pitted.

Assembly

1. Install a new gearbox oil filter.
2. Assemble and install the input shaft assembly.

Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

CAUTION

Bearing cups, cones, and spacers are factory pre-set for end play, and are only provided as a matched set. It is important that bearing cups, bearing cones, and spacers, when removed, be kept together in matched sets. Input and output shaft bearing and spacer sets are different. Failure to keep matched sets together or to not use factory pre-set and matched bearing and spacer sets will void the warranty and may result in gearbox failure.

2.1 Using a brass drift or a bearing cup installation tool, install the inner bearing cup from the inside out. Then install the spacer(s) and insert the retaining ring.

2.2 Using a brass drift or a bearing cup installation tool, install the outer bearing cup from the outside in.

2.3 Coat the outer bearing cone with oil. Install the outer bearing cone.

2.4 Install the input shaft seal.

2.5 Install the windage tray positioning springs and windage tray. While holding the windage tray in place against the positioning springs, install the windage tray positioning pins.

CAUTION

There are two bearings of different widths supporting the drive gear on the input shaft. It is important that these bearings be installed in the drive gear in the proper location. The location of the bearings should have been noted when removed from the assembly. Make sure that the lubrication holes are aligned in the center of the larger bearing. Failure to install the bearings properly may result in gearbox failure.

2.6 Coat the new drive bearings with oil, then install the bearings in the drive gear.

2.7 Coat the inner bearing cone with oil, and install it. Then, install the thrustwasher.

2.8 Reaching through the top of the transmission housing, install the drive gear in position against the thrustwasher, being careful not to dislodge the windage tray.

2.9 Slide the input shaft through the output shaft housing opening at the rear of the transmission through the drive gear, the thrustwasher, the bearing cones, and spacer(s).

2.10 Install the front driveline yoke on the input shaft, being careful not to damage the input shaft seal. Apply Loctite® 242 to the 3/4–10 x 1-1/2 yoke capscrew. Install the capscrew and washer, then tighten them to 225 lbf·ft (305 N·m).

NOTE: Apply a coat of Loctite to all screws prior to reassembly.

NOTE: One ear of the shift yoke is machined, and it will only fit one way. Make sure the yoke is oriented on the shaft in the position noted during disassembly.

2.11 Make sure the shift fork is properly aligned (the machined side should be toward the threaded end of the shift shaft), then slide the new shift fork on the shift shaft. Align the shift fork with the groove in the shaft, then secure the shift fork in place with a 3/8–16 x 1-1/4 screw. Tighten the screw 33 lbf·ft (45 N·m).

2.12 Install a new seal on the shift shaft support block. Install a new gasket on the shift shaft support block. Install the shift shaft support block and gasket in the gearbox using two 1/4–20 x 5/8 capscrews. Tighten the capscrews to 96 lbf·in (1085 N·cm).

2.13 Place the shift ring into the shift fork grooves. While holding the shift ring in place, insert the shift shaft into the gearbox through the bushing. Make sure the teeth on the shift shaft ring line up with the teeth on the input shaft and gear.

2.14 Apply a light coating of grease to the new seal ring, then install the seal ring on the shift piston. Install the piston on the shift shaft end.

CAUTION

When installing the piston, use a new locknut and tighten snugly but do not overtighten. Over-

Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

tightening the locknut may distort the piston and cause shift failures.

2.15 Secure the piston in place with a new locknut.

2.16 Apply a light coating of grease to the shift cylinder seal, then install the seal in the groove on the shift cylinder.

2.17 Install the shift cylinder using three 5/16–18 x 1 screws. Tighten them to 17 lbf·ft (23 N·m).

3. Assemble and install the output shaft assembly.

3.1 Install a new shift shaft seal in the output shaft housing.

CAUTION

Bearing cups, cones, and spacers are factory pre-set for end play, and are only provided as a matched set. It is important that bearing cups, bearing cones, and spacers, when removed, be kept together in matched sets. Input and output shaft bearing and spacer sets are different. Failure to keep matched sets together or to not use factory pre-set and matched bearing and spacer sets will void the warranty and may result in gearbox failure.

3.2 Using a brass drift or a bearing cup installation tool, install the inner bearing cup from the inside out. Install the spacer(s). Then install the retaining ring.

3.3 Using a brass drift or a bearing cup installation tool, install the outer bearing cup from the outside in.

3.4 Coat the outer bearing cone with oil, then install it.

3.5 Install the output shaft seal.

3.6 Apply a coating of oil to the inner bearing cone, and install.

3.7 Apply a coating of oil to the input shaft pilot bearing, then install the bearing into the output shaft.

3.8 Install the output shaft by sliding the shaft in through the output shaft housing from the front to the rear. Be careful when sliding the output shaft through the bearing cones and spacer(s).

3.9 Install the rear driveline yoke on the output shaft, taking care not to damage the output shaft seal. Apply Loctite® 242 to the 3/4–10 x 1-1/2 capscrew. Install the capscrew and washer, then tighten to 225 lbf·ft (305 N·m).

3.10 Install a new gasket on the output shaft housing.

3.11 Apply Loctite® 242 to the two 7/16–14 x 2-1/4 and the four 7/16–14 x 1-3/4 capscrews. Install the output shaft and housing, sliding the housing onto the shift yoke shaft. Install the capscrews, then tighten the 2-1/4-inch capscrews 50 lbf·ft (68 N·m) and the 1-3/4-inch capscrews 53 lbf·ft (72 N·m).

3.12 Install the shift and interlock switches on the output shaft housing.

3.13 Apply Loctite® 242 to the detent Allen-head screw, and install the detent ball, spring, and Allen-head screw.

3.14 Install the manual shift eye from the rear of the shift yoke shaft.

3.15 Rotate the input shaft to check for proper movement.

4. Assemble and install the intermediate shaft assembly.

4.1 Press a new bearing cone into the intermediate shaft rear cover, coat the cone with oil, and install a new cover seal.

4.2 Press a new bearing cone into the intermediate shaft front cover, coat the cone with oil, and install a new cover seal.

CAUTION

Lubrication pump impeller vanes are fragile, and may break or chip. Impeller vanes are installed only one way. If removal of the vanes is necessary, note the installation of the vanes. Failure to install the vanes properly will result in transmission failure.

IMPORTANT: To ensure proper operation of the oil pump, use the same number of gaskets and shims that were removed when the oil pump was disassembled.

Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

4.3 Install the lubrication pump impeller assembly, vanes, and shaft into the front cover, aligning matchmarks. Apply Loctite® 242 to the six 1/4–20 x 5/8 capscrews and tighten them to 96 lbf·in (1085 N·cm).

4.4 Press the new bearing cups onto the intermediate shaft, one on each side of the intermediate gear.

4.5 Reaching through the top of the transmission housing, install the intermediate gear and shaft assembly, taking care not to damage the bearing cups.

4.6 Holding the intermediate gear assembly in place, install the rear intermediate shaft cover. Apply Loctite® 242 to the three 7/16–14 x 1-1/4 capscrews, and install but do not torque.

4.7 Install the front intermediate shaft cover, aligning the lubrication pump shaft spline with the intermediate shaft spline. Apply Loctite® 242 to the three 7/16–14 x 1-1/4 capscrews, and tighten all six capscrews to 53 lbf·ft (72 N·m)

4.8 Connect the oil suction line to the lubrication pump.

4.9 Rotate the input shaft and manually shift the transmission to check for proper movement and operation.

Installation

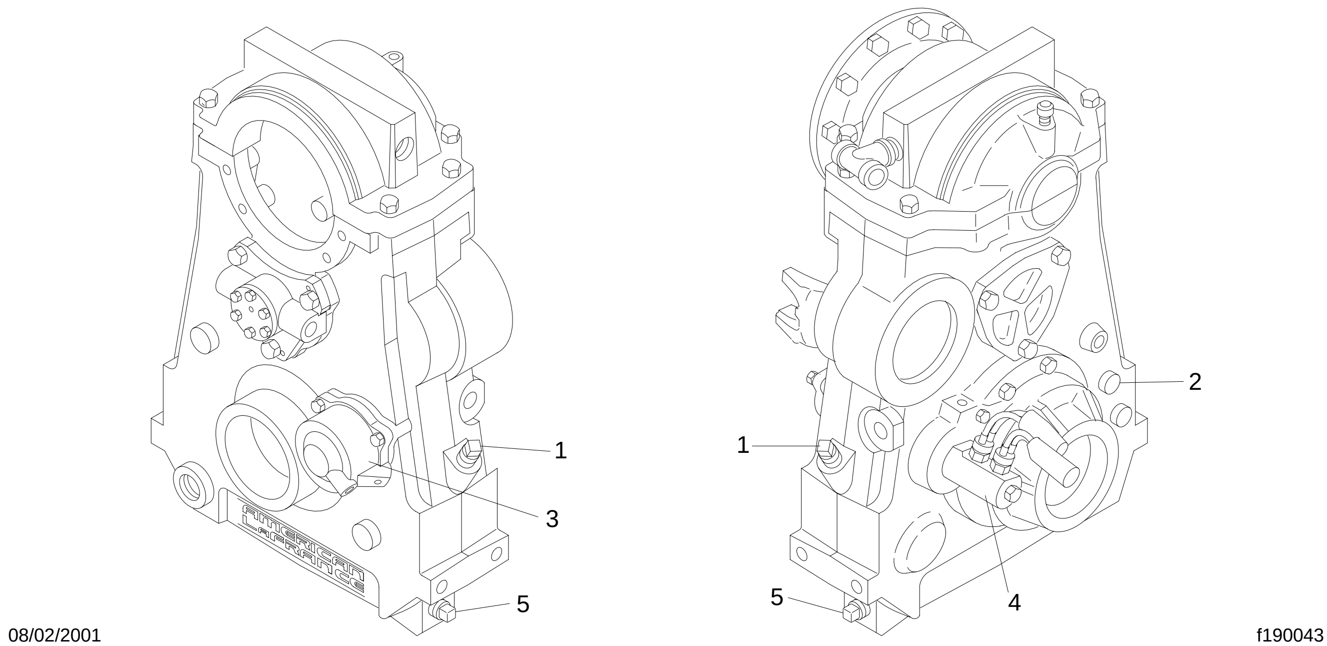
1. Install a new gasket on the seating surface of the rear bearing housing.

CAUTION

Properly align the rear bearing housing. If the rear bearing housing is not aligned with the matchmarks, the gear tooth mesh could be incorrect and may result in damage to the gearbox.

2. Using a lifting device, lift the gearbox into position (around the rear bearing housing). Apply Loctite® 242 to the six 1/2–13 x 1-3/4 capscrews, and attach the gearbox cover to the gearbox. Tighten finger-tight, but do not torque.
3. Apply Loctite® 242 to the twelve 7/16–14 x 1-1/4 capscrews, and insert the capscrews through the rear bearing housing cover and gasket into the gearbox. Tighten 53 lbf·ft (72 N·m).
4. Tighten the six 1/2–13 x 1-3/4 capscrews 65 lbf·ft (88 N·m).
5. Connect the pump gearbox cooling lines.
6. Connect the air lines and electrical switches.
7. Connect the driveshafts. Tighten the yoke fasteners 225 lbf·ft (305 N·m), and tighten the bearing retaining strap capscrews 40 to 48 lbf·ft (54 to 65 N·m).
8. Connect the lubrication line to the gearbox cover.
9. Fill the gearbox with the necessary lubricant. See **Fig. 4**.
10. Operate the pump and check for leaks. Verify the oil pressure at 25 to 35 psi (172 to 241 kPa) at the oil injection point.
11. Remove the chocks from the front and rear tires.

Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation



1. Fill Plug
2. Sight Glass
3. Power Shift Cylinder
4. Output Shaft Housing
5. Drain Plug

Fig. 4, Fire Pump Gearbox Lubrication and Fluid Change Locations

Replacement

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Drain the water from the pump.

WARNING

The gearbox assembly is heavy. Support the lower gearbox assembly with a lifting device. Failure to do so could result in the assembly falling, which could result in personal injury or property damage.

3. Remove the gearbox. See **Subject 110** for instructions.
4. Remove the 5/8–11 x 1-1/4 capscrew and bearing retaining washer from the end of the impeller shaft.
5. Remove the twelve 1/2–13 x 1-3/4 capscrews that attach the rear bearing housing to the pump body.
6. Use a centerpunch to mark the rear bearing housing, the mechanical seal housing, and the pump body so that the components are properly aligned during assembly.
7. Install two 1/2–13 x 3 jackscrews into the 1/2–13 threaded holes provided in the rear bearing housing. See **Fig. 1**, Ref. 15.
8. Turn the two jack screws evenly, clockwise, to push the rear bearing housing from the impeller shaft and pump body.

NOTE: To prevent damage to components as the rear bearing housing is pushed from the impeller shaft, place your hands under the gear opening to catch the gear, key, and bearings.

NOTE: It may be necessary to use pry bars to (gently) assist in removing the inner bearings and gear.

9. Remove the jack bolts.
10. Remove the slinger from the impeller shaft.
11. Remove the four 7/16–14 x 1-1/4 capscrews from the mechanical seal cover. See **Fig. 2**. Use a center punch to mark the seal cover for proper alignment during installation.
12. Use pry bars, if necessary, in the provided slots to loosen the mechanical seal cover from the impeller shaft and the pump body.
13. Remove the old mechanical seal, being careful not to damage the impeller shaft. Use two small hook-tools positioned about 180 degrees apart to pull the mechanical seal from the seal cavity, if necessary.
14. Clean the seal cavity and the impeller shaft.
15. Inspect the retaining ring on the shaft.
16. Remove the burrs at the gear key slot and the bearing lands, and remove the oil seal in the rear bearing housing. See **Fig. 3**.

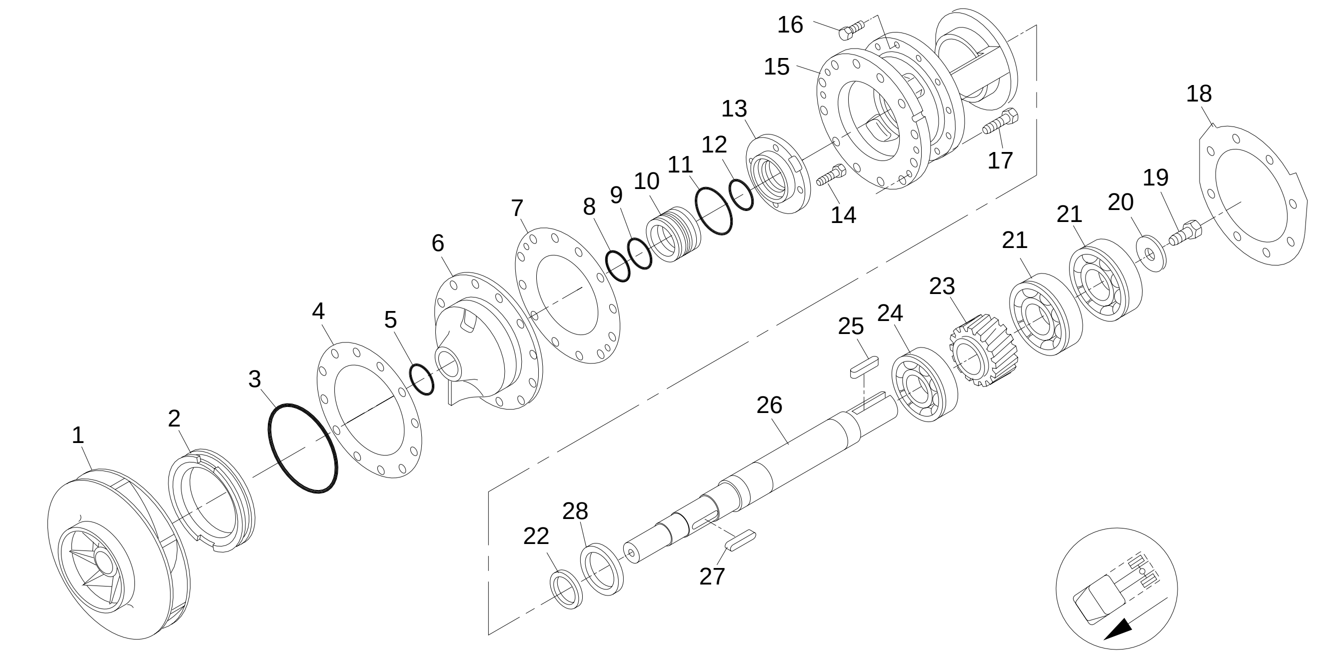
IMPORTANT: Always replace the entire mechanical seal with a new American LaFrance mechanical seal assembly.

CAUTION

When installing a new mechanical seal do not touch the sealing surface of the carbon seal ring or the metal seat while handling or installing. Oil and grease can damage the bellows of the mechanical seal. Use only a soap-and-water solution to lubricate the mechanical seal.

17. Clean the housing and the impeller shaft, and lubricate the impeller shaft and the new mechanical seal with a soap-and-water solution.
18. Install the new mechanical seal bellows over the end of the impeller shaft with the spring oriented toward the impeller. Using a soft pusher tube and keeping your fingers away from the carbon seal, carefully push the mechanical seal assembly into the mechanical seal cavity. If binding occurs, apply more soap-and-water solution to the impeller shaft and the bellows.
19. Install the steel cup, and seat it into the mechanical seal cover. Lubricate with a soap-and-water solution.
20. Remove and replace the seal rings in the mechanical seal cover. Apply the soap-and-water solution to the seal rings, then slide them over

Mechanical Seal Replacement



1. Impeller
2. Clearance Ring
3. Rear Bearing Housing Seal
4. Bearing/Seal Housing Gasket (impeller side)
5. Shaft Retaining Ring
6. Mechanical Seal Ring
7. Bearing/Seal Housing Gasket (mechanical seal side)
8. Shaft Seal Ring
9. Shaft Retaining Ring
10. Mechanical Seal and Steel Cup Assembly
11. Mechanical Seal Piston Ring
12. Shaft Seal Ring
13. Mechanical Seal Cover
14. Capscrew, 7/16–14 x 1-1/4
15. Rear Bearing Housing
16. Capscrew, 7/16–14 x 1-1/2
17. Capscrew, 1/2–13 x 1-3/4
18. Rear Bearing Housing Gasket
19. Capscrew, 5/8–11 x 1-1/4
20. Rear Bearing Washer
21. Bearing (aft)
22. Pump Shaft Slinger
23. Pump Shaft Gear
24. Bearing (forward)
25. Pump Shaft Gear Key
26. Pump Shaft
27. Impeller Key
28. Drive Unit Oil Seal

Fig. 1, Impeller Shaft Assembly (exploded view)

the end of the impeller shaft. Make sure the mechanical seal remains seated in the bore of the cover.

21. Insert the mechanical seal cover into the mechanical seal cavity, aligning it with the bolt holes and the orientation marks.
22. Insert the bolts in the mechanical seal housing to prevent the housing from rotating.
23. Install the four 7/16–14 x 1-1/4 capscrews. Tighten them to 53 lbf·ft (72 N·m).
24. Install the new slinger on the impeller shaft. Remove the retaining bolts.
25. Install the new gasket and oil seal in the rear bearing housing. Slide the housing and front bearing on the rear impeller shaft. The bearing is a press-fit on the impeller shaft, and slip-fit in the housing.

IMPORTANT: Do not allow the weight of the rear bearing housing to rest on the oil seal.

26. Insert the gear through the opening in the housing and align it with the impeller shaft. Slide the housing, front bearing, and gear on the shaft. The front bearing will stop when the inner race contacts the seat on the impeller shaft.
27. Line up the keyway in the gear and install the key into the keyway.

Mechanical Seal Replacement

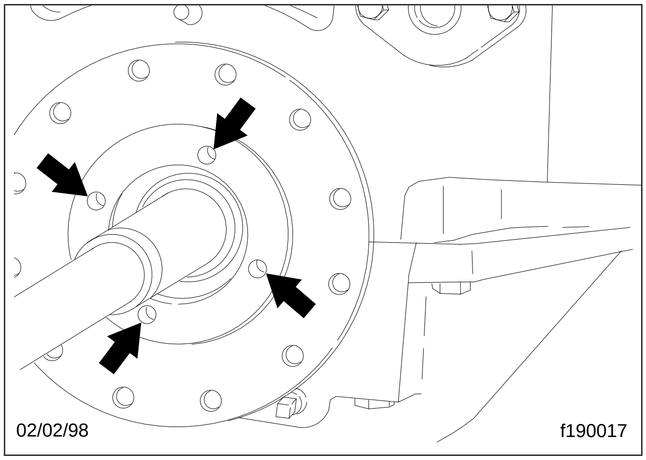
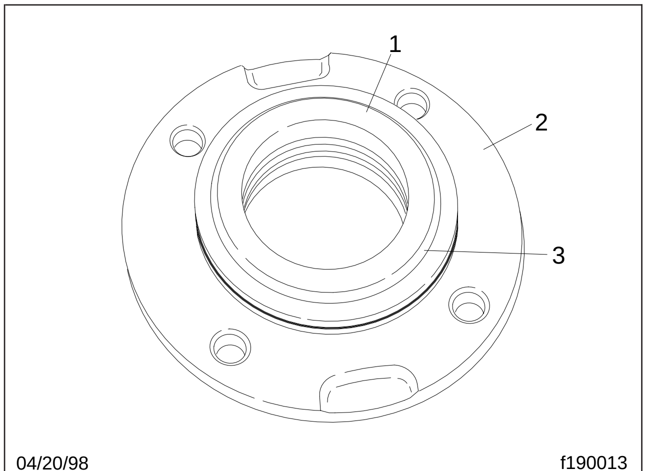


Fig. 2, Remove Four Capscrews



1. Steel Seat
2. Mechanical Seal Cover
3. Rubber Cup

Fig. 3, Mechanical Seal Assembly

28. Slide one of the two rear bearings onto the impeller shaft and into the housing. The rear bearings are a press-fit on the shaft and a slip-fit in the housing.
29. Using a series of different length capscrews, attach the rear bearing housing to the pump body. When it is possible, install the four capscrews (approximately 90 degrees apart). These bolts, in combination with the rear bearing, will center the housing. Double check to be sure the housing is centered and will clear the mechanical seal assembly.
30. Install the pusher bolt in the rear of the impeller shaft. Tighten the nut on the pusher bolt while holding the pusher bolt, pushing the rear bearing into the housing. Remove the pusher bolt, and install the second of the two rear bearings. Then, install the pusher bolt and tighten the nut while holding the pusher bolt to install the bearing.
31. Continue to tighten the nut on the pusher bolt while making sure the housing is aligned and centered. Once the pusher bolt is snug, the rear housing assembly, the gear, and the bearings should be in place. Remove the pusher bolt, and rotate the impeller assembly by placing a large screwdriver between the housing and the gear. The impeller assembly should rotate.

NOTE: A new impeller will have some resistance when the impeller shaft is rotated.

32. Apply Loctite® 242 to the 5/8–11 x 1-1/4 bearing retainer capscrew. Install and tighten it to 80 lbf·ft (108 N·m).
33. Apply Loctite® 242 to the twelve 1/2–13 x 1-3/4 capscrews. Install, and tighten them to 80 lbf·ft (108 N·m).
34. Install the gearbox. See Subject 110 for instructions.
35. Perform the annual service test on the pump. Check for leaks. Verify the oil pressure at 25 to 35 psi (172 to 241 kPa) at the oil injection point.
36. Remove the chocks from the front and rear tires.

Impeller Assembly Removal and Installation

Removal

NOTE: For an exploded view of the fire pump body assembly, see **Fig. 1**.

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Drain the water from the pump.

WARNING

The gearbox assembly is heavy. Support the lower gearbox assembly with a lifting device. Failure to do so could result in the assembly falling, which could result in personal injury or property damage.

3. Remove the gearbox. See **Subject 110** for instructions.
4. Remove the drain lines from the lower pump body.
5. Drain the oil from the AutoLube, and remove the 1/2–13 x 2 capscrews from the upper half of the AutoLube and pump body.
6. Remove the 7/16–14 x 1-1/2 capscrews from the upper half of the rear bearing housing and pump body.
7. Remove the 1/2–13 x 1-1/4 capscrews from the lower pump body.

WARNING

The lower pump body is heavy. Support the lower pump body and impeller assembly with a lifting device. Failure to do so could result in the lower pump body and impeller assembly falling, which could result in personal injury or property damage.

8. Position the lifting device with the lower pump body lifting adapter between the lifting device and the lower pump body.
9. Remove the 5/8–11 x 5 capscrews in each corner of the lower pump body.
10. Lower the lower pump body and impeller assembly. Be sure to balance the assembly so that it does not tip from the lifting device.
11. Remove the remaining capscrews from the lower half of the AutoLube, the rear bearing housing, and the lower pump body.

WARNING

The impeller assembly is heavy. Do not attempt to lift the assembly without the aid of another person or persons, or a lifting device. Failure to do so could result in the impeller assembly falling, which could result in personal injury or property damage.

12. Remove the remaining screws from the rear bearing housing, then from the lower pump body.
13. Lift the impeller assembly from the lower pump housing. See **Fig. 2**. Set the assembly aside.
14. Clean all gasket surfaces of the upper and lower pump bodies, as well as those on the AutoLube and the rear bearing housing face.
15. Clean the clearance ring and clearance ring seats in both the upper and lower pump body halves to remove all the "build up" material so that the new clearance ring will seat properly.

NOTE: Pitting of the clearance rings may occur from the "build up" material and the effects of corrosion. Once the seats are cleaned, any pitting on the clearance rings is considered normal.

Installation

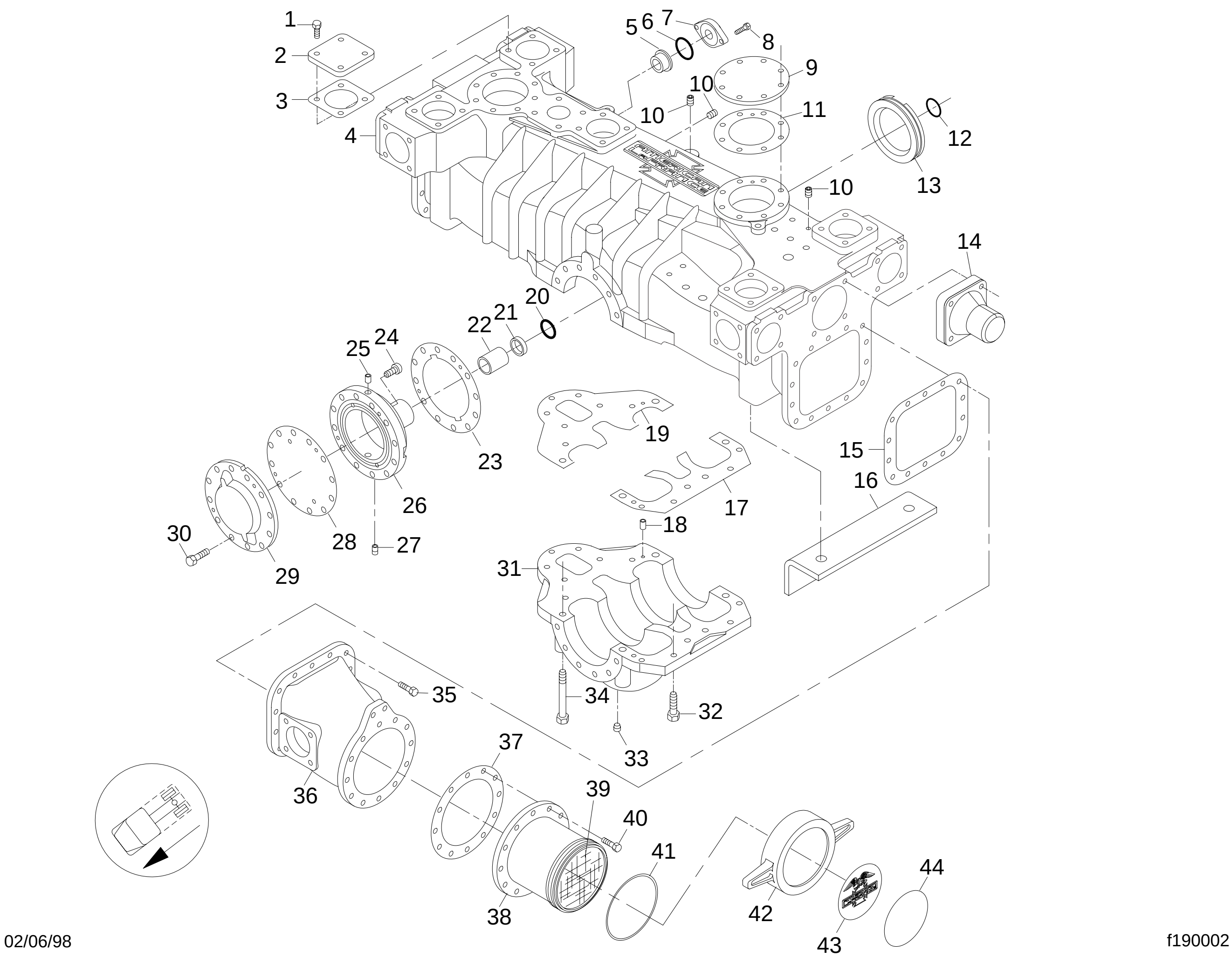
1. Install the pump body gaskets on the lower pump body, trimming as necessary to fit.

CAUTION

Failure to line up the clearance ring lock notches with the pump body tabs (as described in the next step) may result in pinched clearance rings, which could result in pump damage and pump failure.

2. Install the impeller assembly into the lower pump housing, carefully aligning the clearance ring lock-notch with the clearance ring lock tabs in the lower pump body. Then rotate the clearance rings to one side to open up lock notches to line

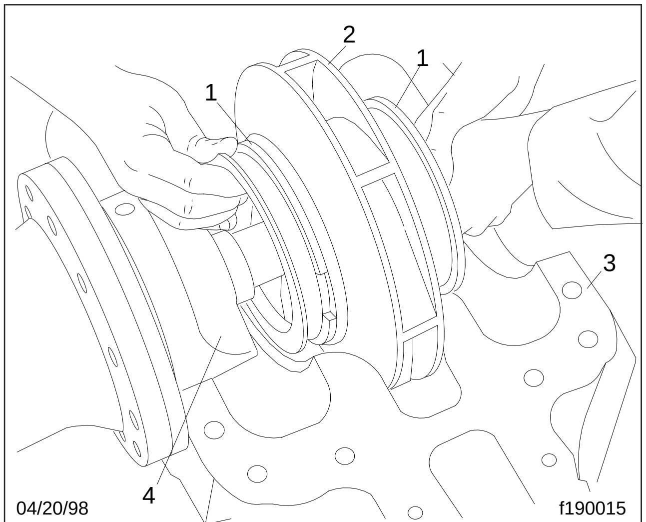
Impeller Assembly Removal and Installation



1. Hexhead Screw, 7/16–14 x 1-1/4
2. Flange Blank
3. Flange Gasket
4. Upper Pump Body
5. Priming Valve Strainer
6. Priming Valve Plate Seal Ring
7. Priming Valve Plate
8. Hexhead Screw, 7/16–14 x 1-1/4
9. Tank Connection Flange Blank
10. Plug, 1/4-inch
11. Tank Connection Gasket
12. Impeller Retaining Ring
13. Clearance Ring
14. QD Relief Valve Assembly
15. Suction Tube Extension Gasket
16. Pump Mounting Bracket
17. Pump Body Gasket (left side)
18. Dowel Pin
19. Pump Body Gasket (right side)
20. Oil Seal Retaining Ring
21. Front Bearing Housing Oil Seal
22. Front Bearing
23. Bearing/Seal Housing Gasket
24. Allen-Head Screw, 3/8–16 x 3/4
25. Brass Socket Plug, 1/4-Inch
26. Front Bearing Housing Assembly
27. Brass Socket Plug, 1/4-Inch
28. Front Bearing Diaphragm
29. Front Bearing Cover
30. Hexhead Screw, 1/2–13 x 2
31. Lower Pump Body
32. Hexhead Screw, 1/2–13 x 1-3/4
33. Plug, 1/2-Inch
34. Hexhead Screw, 5/8–11 x 5
35. Hexhead Screw, 1/2–13 x 1-1/4
36. Suction Tube Extension
37. Suction Tube Round Gasket
38. Suction Tube, 6-Inch
39. Suction Strainer, 6-Inch
40. Hexhead Screw, 7/16–14 x 1-1/4
41. Suction Cap Washer
42. Suction Cap
43. Medallion
44. Medallion O-Ring

Fig. 1, Fire Pump Body Assembly (exploded view)

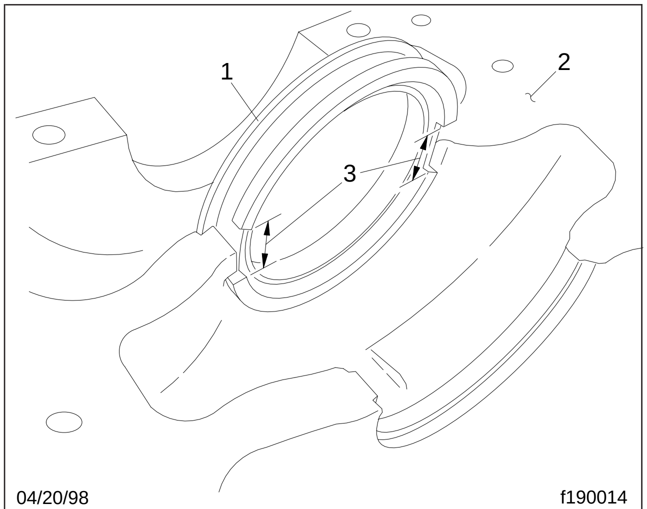
Impeller Assembly Removal and Installation



1. Clearance Ring
2. Impeller
3. Lower Pump Housing
4. Cut Water

Fig. 2, Lifting the Impeller Assembly from the Lower Pump Housing

up with the lock tabs in the upper pump body. See Fig. 3.



1. Clearance Ring
2. Lower Pump Housing
3. Clearance Ring Notches

Fig. 3, Clearance Ring Mounted in Pump Housing

3. Install the 1/2–13 x 1-3/4 capscrews through the rear bearing housing and the mechanical seal housing. Do not tighten.
4. Make sure the dowel pins are in the upper pump body to assist in aligning the lower pump body with the upper pump body.
5. Using a lifting device, slowly raise the lower pump body and the impeller assembly into place, making sure that the lower pump body aligns with the dowel pins, and that the clearance ring notches align with the clearance ring lock tabs in the upper pump body.
6. Rotate the impeller and check for freedom of movement when the lower pump body and the impeller assembly is in place.
7. Apply Loctite® 242 and install the four 5/8–11 x 5 capscrews (one at each corner of the lower pump body). Tighten snug but do not fully torque.
8. Install the 1/2–13 x 1-3/4 screws in the rear bearing housing and mechanical seal housing. Tighten them to 53 lbf·ft (72 N·m).
9. Remove the lifting device.
10. Apply Loctite® 242 to the 1/2–13 x 1-3/4 lower pump body capscrews and install them. Tighten snug but do not torque.
11. Torque the 5/8–11 x 5 capscrews 150 lbf·ft (203 N·m), then, starting from the center and moving outward, tighten the lower pump body capscrews 65 lbf·ft (88 N·m).
12. Install the AutoLube. See Subject 100 for instructions.
13. Install the gearbox. See Subject 110 for instructions.
14. Operate the pump and check for leaks. Verify the oil pressure at 25 to 35 psi (172 to 241 kPa) at the oil injection point.
15. Remove the chocks.

Impeller Shaft Disassembly and Assembly

Single-Stage Pump

Disassembly

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Remove the AutoLube. See **Subject 100** for instructions.
3. Remove the fire pump gearbox. See **Subject 110** for instructions.
4. Remove the impeller assembly. See **Subject 130** for instructions and see **Fig. 1** (for an exploded view of the assembly).
5. Place the impeller shaft on a work bench.
6. Note the orientation of the impeller vanes.
7. Remove the outer retaining ring.

WARNING

Wear protective, heat-resistant gloves while heating the impeller to remove it from the impeller shaft. Heated metal can cause injury to your hands.

CAUTION

Do not overheat the impeller. The impeller is constructed of bronze. If the impeller is overheated (and turns red or blue during removal from the shaft), it has been weakened and must be replaced.

8. Using an acetylene torch, carefully heat the "eye" of the impeller for approximately two minutes.
9. When heated properly, the impeller will slide free of the shaft. If the impeller moves but does not slide free, do not immediately reheat. Allow the complete assembly to cool to room temperature, then reheat and remove the impeller.
10. Allow the components to cool to room temperature.
11. Remove the inner clearance ring.
12. Remove the key.
13. Remove the inner retaining ring, and slide the mechanical seal housing from the impeller shaft.

Assembly

1. Clean the impeller shaft, the keyway, and the mechanical seal housing and face.
2. Check the waterway in the mechanical seal housing for restrictions.
3. Install the mechanical seal housing on the impeller shaft.
4. Install the inner retaining ring.
5. Install the new gasket on the mechanical seal housing face.
6. Install the key into the keyway.

CAUTION

If the impeller or clearance rings are dropped, damaged, or deformed, they will need to be replaced.

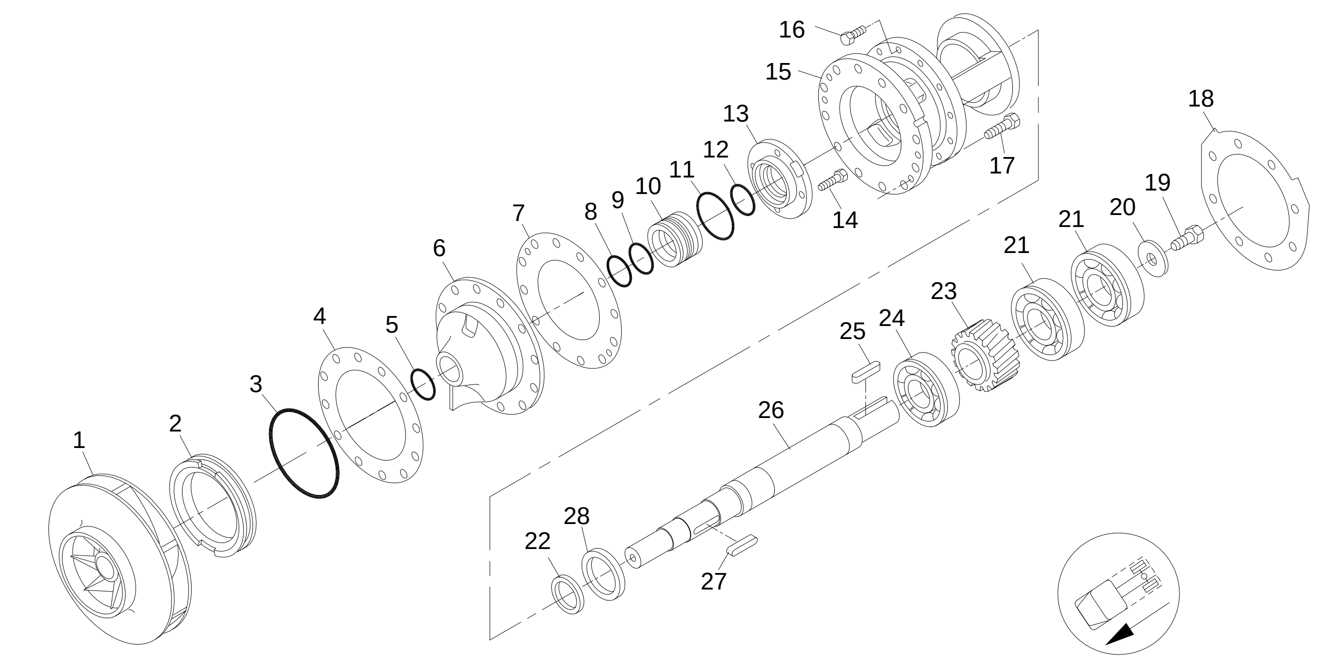
7. Install the inner clearance ring.

WARNING

Wear protective, heat-resistant gloves while heating the impeller to install it on the impeller shaft. Heated metal can cause injury to your hands.

8. Using the torch, heat the "eye" of the new impeller for approximately two minutes. Then, slide the impeller onto the shaft with vanes in proper orientation. If the impeller does not fully slide onto the shaft allow the assembly to cool to room temperature before reheating.
9. Install the outer retaining ring.
10. Install the impeller assembly. See **Subject 130** for instructions.
11. Install the outer clearance ring.
12. Install the impeller shaft assembly.
13. Install the fire pump gear box. See **Subject 110** for instructions.
14. Install the AutoLube. See **Subject 100** for instructions.
15. Remove the chocks from the front and rear tires.

Impeller Shaft Disassembly and Assembly



1. Impeller
2. Clearance Ring
3. Rear Bearing Housing Seal
4. Bearing/Seal Housing Gasket (impeller side)
5. Shaft Retaining Ring
6. Mechanical Seal Housing
7. Bearing/Seal Housing Gasket (mechanical seal side)
8. Shaft Seal Ring
9. Shaft Retaining Ring
10. Mechanical Seal And Steel Cup Assembly
11. Mechanical Seal Piston Ring
12. Shaft Seal Ring
13. Mechanical Seal Cover
14. Hexhead Screw, 7/16–14 x 1-1/4
15. Rear Bearing Housing
16. Hexhead Screw, 7/16–14 x 1-1/2
17. Hexhead Screw, 1/2–13 x 1-3/4
18. Rear Bearing Housing Gasket
19. Hexhead Screw, 5/8–11 x 1-1/4
20. Rear Bearing Washer
21. Bearing (aft)
22. Pump Shaft Slinger
23. Pump Shaft Gear
24. Bearing (forward)
25. Pump Shaft Gear Key
26. Pump Shaft
27. Impeller Key
28. Drive Unit Oil Seal

Fig. 1, Impeller Shaft Assembly (exploded view)

Two-Stage Pump

Disassembly

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Remove the AutoLube. See **Subject 100** for instructions.
3. Remove the fire pump gear box. See **Subject 110** for instructions.
4. Remove the impeller assembly. See **Subject 130** for instructions.
5. Place the impeller shaft assembly on a work bench.
6. Note the position of the impeller vanes.
7. Remove the inner and the outer retaining rings, then remove the mechanical seal housing.

WARNING

Wear protective, heat-resistant gloves while heating an impeller to remove it from the impeller shaft. Heated metal can cause injury to your hands.

CAUTION

Do not overheat the impeller. An impeller is constructed of bronze. If the impeller is overheated (and turns red or blue during removal from the shaft), it has been weakened and must be replaced.

8. With an acetylene torch, carefully heat the "eye" of the impellers for approximately two minutes.

IMPORTANT: Mark the impellers as to whether they are the primary or secondary impeller in relation to the AutoLube. Improper or backward installation of the impellers affects pump performance.

9. When heated properly, an impeller will slide free of the shaft. If the impeller moves but fails to slide free, do not immediately reheat. Allow the complete assembly to cool to room temperature, then reheat and remove the impellers. Heat the secondary impeller and remove. Then rotate the impeller shaft assembly end for end and heat and remove the primary impeller.

10. Remove the center support bearing.

11. Remove the mechanical seal housing, then the inner clearance ring.

12. Remove the key.

13. Remove the inner retaining ring, and slide the mechanical seal housing from the impeller shaft.

Assembly

1. Clean the impeller shaft, the keyway, the mechanical seal housing and face.

2. Check the waterway in the mechanical seal housing for restrictions.

3. Install the new gasket on the mechanical seal housing face.

4. Install the key into the keyway.

CAUTION

If the impellers or the clearance rings are dropped, damaged, or deformed, they require replacement.

5. Install the inner clearance ring.

WARNING

Wear protective, heat-resistant gloves while heating the impeller to install it on the impeller shaft. Heated metal can cause injury to your hands.

6. Using the torch, heat the "eye" of each impeller for approximately two minutes. Then slide the individual impellers on the shaft. If an impeller does not fully slide on the shaft, allow the assembly to cool to room temperature before reheating.

7. Install the outer retaining ring.

8. Install the outer clearance ring.

9. Install the impeller assembly. See **Subject 130** for instructions.

10. Install the mechanical seal housing on the impeller shaft.

11. Install the impeller shaft assembly.

12. Install the fire pump gearbox. See **Subject 110** for instructions.

13. Install the AutoLube. See **Subject 100** for instructions.

14. Remove the chocks from the front and rear tires.

Valve Removal, Disassembly, Assembly, and Installation

Pilot Valve

Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.

1. Drain the fire pump.
2. Rotate the adjustment handwheel counterclockwise to remove the spring tension.
3. Remove the capscrew and nut that attach the adjustment handwheel to the adjustment shaft. Then, remove the handwheel.

CAUTION

Identify and mark the line connections on the control body before removing. Improper connection of lines may result in the failure of the pilot valve, which could cause damage to the fire pump.

4. Remove the pump discharge pressure line and the relief valve line from the control body of the pilot valve.
5. While holding the pilot valve, remove the four 1/4–20 x 5/8 machine screws that attach the valve and cover plate to the Pump Operator's Panel, and separate the valve, plate, and the relief valve setting indicator (if equipped with PMD) from the panel.
6. Disassemble the pilot valve.
   6.1 Remove the four 5/16–18 x 1 Allen-head capscrews that secure the control body to the rear of the spring housing. Then, remove the control body.

CAUTION

Do not use pliers to unscrew the control valve from the diaphragm clamp. Damage to the control valve will render the pilot valve inoperative.

   6.2 Unscrew the control valve from the diaphragm clamp. Remove the diaphragm washer and the diaphragm.

   6.3 Remove the retaining ring, the seal and the bearing.

WARNING

Use a spring compressor to remove the pilot valve spring. The spring is under compression, and could become uncompressed, which could result in personal injury.

   6.4 Turn the adjustment handwheel clockwise to unscrew the adjustment shaft from the adjustment nut. From the handwheel end, remove the adjustment shaft from the spring housing.

   6.5 Remove both springs, the adjustment nut, and diaphragm clamp as an assembly from the spring housing, then separate them.

7. Clean all the pilot valve components. Inspect and lubricate with grease the threads on the adjustment shaft.
8. Assemble the pilot valve.

WARNING

Use a spring compressor to install the pilot valve spring. The spring is under compression, and could become uncompressed, which could result in personal injury.

CAUTION

Always remove the pilot valve discharge pressure inlet screen, which is located in the top of the discharge side of the pump. Clean or replace, as necessary. Failure to do so could render the pilot valve inoperative.

   8.1 Combine both springs, the adjustment nut, and the diaphragm clamp as an assembly, then install the assembly in the spring housing. Align the adjustment nut with the slot in the spring housing and the indicator plate on the PMD.

   8.2 Slide the adjustment shaft into the spring housing from the handwheel end. Turn the adjustment handwheel counterclockwise in order to screw the adjustment shaft into the adjustment nut until it bottoms in the diaphragm clamp. Do not put the springs under tension.

Valve Removal, Disassembly, Assembly, and Installation

8.3 Lubricate the new bearing, and slide the new bearing and bearing washer over the adjustment shaft into the spring body housing. Install the retaining ring. Then install the new seal washer and rotate the adjustment shaft in both directions to check for freedom of movement.

8.4 Install the new diaphragm washer and diaphragm. Screw the control valve into the diaphragm clamp.

8.5 Install the control body. Apply Loctite® 242 to the four 5/16–18 x 1 Allen-head capscrews that attach the control body to the rear of the spring housing.

9. Holding the pilot valve, align the cover plate, then install the four 1/4–20 x 5/8 machine screws that attach the pilot valve and cover plate to the Pump Operator's Panel.
10. Attach the pump discharge pressure line and relief valve line to the control body of the pilot valve.
11. Slide the adjustment handwheel on the adjustment shaft, then install the retaining capscrew and nut.
12. Fill the pump, then test the valve for proper operation and leaks.

Transfer Valve

NOTE: For an exploded view of the trasfer valve, see **Fig. 1**.

1. Drain the fire pump.

IMPORTANT: The transfer valve is a timed device. It is therefore important during disassembly to note the location of the transfer bracket locating pin, the transfer drum stop pin, the transfer drum sleeve locating pin, and the transfer drum stem key. It is not necessary to remove the transfer bracket locating pin, the transfer drum sleeve locating pin, or the transfer drum stop pin during disassembly.

2. Turn the adjustment handwheel clockwise until it stops. The transfer indicator should be at the top of the slotted guide in the cover plate.
3. Remove the two Allen-head setscrews from the transfer indicator guide. Slide the transfer indicator guide (on an adjustment stem) towards the transfer valve.
4. Remove the stem drive gear lock pin. Slide the adjustment stem from the stem drive, the support, and the transfer indicator guide, being careful not to drop or damage the transfer indicator guide and transfer indicator.
5. Remove the four 7/16–14 x 1-1/4 capscrews that retain the transfer bracket assembly to the pump body. Carefully remove the transfer bracket and the transfer valve drum.
6. Disassemble the valve.

6.1 Remove the locating pin that secures the countershaft in place.

6.2 Remove the countershaft from the countershaft gear.

6.3 Remove the countershaft gear and the countershaft gear spring from the transfer bracket assembly.

6.4 Remove the Allen-head set screw from the transfer drum gear. Slide the transfer drum gear from the drum stem. Remove the woodruff key from the transfer drum stem.

6.5 Separate the transfer bracket from the transfer drum by sliding it from the transfer drum stem.

6.6 Slide the transfer drum from the transfer sleeve.

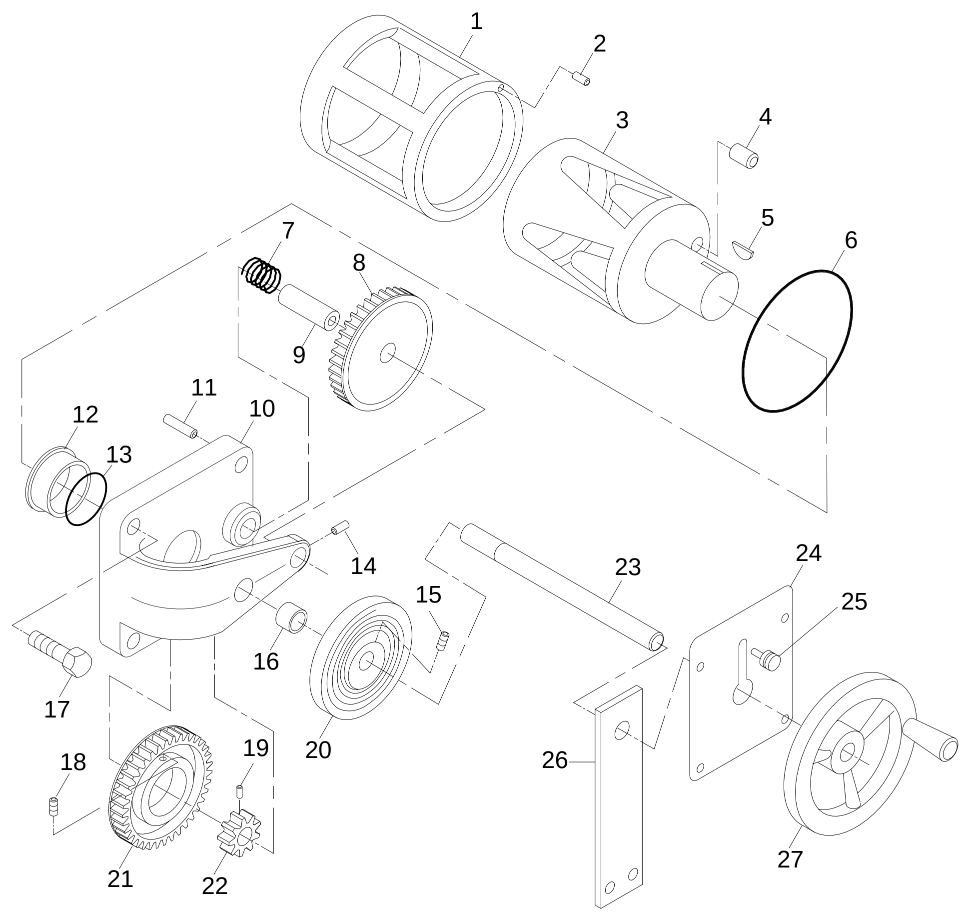
7. Assemble the valve.

7.1 Clean and inspect all sealing surfaces, and the mating surfaces of the transfer valve drum and sleeve. Clean and inspect the transfer bracket bushings, and the bushing surface on the transfer valve stem and the transfer valve adjustment stem.

7.2 Install new O-ring seals on the transfer valve drum stem and the transfer valve bracket.

7.3 Slide the transfer drum in the transfer bracket, being careful not to damage the bearing surfaces. Then, rotate the transfer drum until the drum stop pin is in the correct position.

Valve Removal, Disassembly, Assembly, and Installation



1. Transfer Drum Sleeve
2. Locating Pin
3. Transfer Drum
4. Transfer Drum Stop Pin
5. Woodruff Key
6. Transfer Bracket Seal Ring
7. Countershaft Gear Spring
8. Transfer Valve Countershaft Gear
9. Transfer Countershaft
10. Transfer Bracket Assembly (with bearings)
11. Bracket Locating Pin
12. Drum Bracket Bearing
13. Transfer Drum Seal Ring
14. Locating Pin
15. Allen-Head Screw, 1/4–20 x 3/8
16. Transfer Valve Stem Drive Gear
17. Hexhead Screw, 7/16–14 x 1-1/4
18. Sockethead Setscrew, #10–32 x 1/2
19. Gear Lock Pin
20. Transfer Indicator Guide
21. Transfer Valve Transfer Drum Gear
22. Transfer Stem Drive Gear
23. Transfer Stem
24. Instruction Plate
25. Transfer Indicator
26. Support Stem
27. Adjusting Wheel Assembly

Fig. 1, Transfer Valve (exploded view)

7.4 Install the woodruff key in the transfer drum stem. Install the transfer drum gear on the transfer drum stem. Apply Loctite® 242 to the Allen-head setscrew, then install the transfer drum gear.

7.5 Assemble the countershaft gear spring in the countershaft gear, and position the assembly in the transfer bracket. Then install the countershaft and the countershaft locating pin to lock the countershaft in place.

8. Install the transfer valve.

Valve Removal, Disassembly, Assembly, and Installation

8.1 Align the transfer drum stop pin, the transfer bracket locating pin, and the transfer drum sleeve locating pin into proper position.

8.2 Install the transfer valve drum and bracket assembly into the pump body.

8.3 Apply Loctite® 242 to the four 7/16–14 x 1-1/4 transfer bracket capscrews. Install and tighten 53 lbf·ft (72 N·m).

8.4 Slide the adjustment stem through the cover plate, the transfer indicator guide, and the support and transfer bracket.

8.5 Insert the stem drive gear in the transfer bracket, then slide the adjustment stem through the stem drive gear.

8.6 Insert the stem drive gear lock-pin into place, locking the stem drive gear onto the adjustment stem.

8.7 Apply Loctite® 242 to the transfer indicator guide setscrews. Install, but do not tighten them.

8.8 Turn the adjustment handwheel counterclockwise until it stops. Make sure the transfer indicator is at the top of the slotted guide toward the transfer indicator, making certain that the transfer indicator engages the transfer indicator guide in the top groove. Then tighten the inside set screw in the transfer guide indicator.

8.9 Rotate the adjustment handwheel from stop to stop. The transfer indicator should move freely from the top to the bottom of the slotted guide in the cover plate.

8.10 Tighten the outside setscrew in the transfer indicator guide, and recheck the movement of the transfer indicator.

9. Fill the pump, then test the valve for proper operation and leaks.

Back Flow Valve

1. Drain the water tank and the pump.
2. Disconnect the control linkage at the tank-to-pump valve.
3. Disconnect both ends of the flexible hose that connects the water tank to the tank-to-pump valve. Then slide the flexible hose toward the water tank outlet or the tank-to-pump valve plumbing.

NOTE: If the tank-to-pump valve is air-operated, drain the vehicles air system and disconnect the supply and the return line on the valve actuator, but do not remove the actuator from the valve. Also, the tank-to-pump valve may be connected to the pump body by capscrews or studs with nuts. If studs are used, it may be necessary to remove some or all of the studs to remove the valve. If so, remove only the studs necessary to remove the valve, as any studs left will assist in realigning the valve during installation.

4. Remove the eight 7/16–14 x 1-1/2 capscrews that retain the tank-to-pump valve to the pump body.
5. Remove the tank-to-pump valve and associated plumbing.

NOTE: The back flow valve is a flat butterfly plate with two pivots attached at the top. These pivots fit into two open pivot sockets in the pump body. When the gasket is removed, the back flow valve may fall out.

6. Remove the old gasket from the pump body.
7. Remove the back flow valve.
8. Clean all of the gasket surfaces on the pump body and the tank-to-pump flange.
9. Install the back flow valve. Using two fingers, hold the pivots in the pivot sockets and check the valve for freedom of movement.
10. Install a new gasket.
11. Apply Loctite® 242 to the eight 7/16–14 x 1-1/2 capscrews and attach the tank-to-pump valve to the pump body. Tighten the capscrews to 53 lbf·ft (72 N·m).
12. Slide the flexible connection hose so it is evenly spaced and secured on the water tank outlet and the tank-to-pump valve plumbing.
13. Attach the tank-to-pump valve controls and linkage.

14. Fill the pump, then test the valve for proper operation and leaks.

Sensing Valve

1. Disconnect the following lines at the sensing valve:
   - Pilot valve discharge line
   - QG relief valve line
   - PG relief valve line
   - Sensing valve pump suction line
   - Drain lines
2. Remove the 7/16–14 x 2 sensing valve mounting capscrew.
3. Remove the four 5/16–18 x 1 capscrews that attach the control body to the rear of the spring housing. Remove the control body, being careful not to lose the sensing valve spring.
4. Remove the control valve from the sensing valve body.
5. Unscrew the sensing valve from the diaphragm, being careful not to damage the control valve. Remove the diaphragm.
6. Before installing the sensing valve, clean all components.

CAUTION

Always remove the sensing valve suction inlet screen. Clean or replace as necessary. The screen is located in the suction side of the pump. Failure to do so may render components inoperative.

7. Install a new diaphragm on the diaphragm clamp. Apply Loctite 242 to the threads on the control valve, then install the control valve in the sensing valve body.
8. Install the sensing valve spring in the valve body cover.
9. Apply Loctite® 242 to the four 5/16–18 x 1 capscrews, then attach the control body to the rear of the spring housing. Make sure that the sensing valve spring properly aligns with the diaphragm clamp.
10. Make sure the "up" arrow is aligned properly.
11. Apply Loctite 242 to the 7/16–14 x 2 sensing valve mounting capscrew. Tighten 40 lbf·ft (54 N·m).
12. Connect all lines.
13. Fill the pump, then test the valve for proper operation and leaks.

TPM Relief Valve

1. Disconnect the line to the sensing valve and drain the fire pump. Make note of the wire connections.
2. Disconnect the indicator light switch.
3. Remove the four 7/16–14 x 1-1/4 capscrews that attach the relief valve assembly to the pump body.
4. Using a twisting motion, remove the relief valve assembly.
5. To disassemble the valve, remove the indicator light switch, remove the cover retaining ring then slide the cover out of the relief valve body.
6. Apply a small amount of pressure to the relief valve piston and remove the piston retaining ring. Carefully release the pressure held to the piston by the spring.
7. Remove the relief valve from the opposite end, sliding the relief valve stem out of the piston.
8. Reach through the center hole of the piston and pull the piston out of the indicator switch end of the relief valve body. Then, remove the piston spring.
9. To assemble and install the valve, first clean and inspect all components.
10. Clean all sealing surfaces and install new O-rings seals.
11. Install the relief valve in the relief valve body.
12. Install the piston spring by sliding the piston in the relief valve body while at the same time sliding the piston on the relief valve stem.
13. Apply light pressure to the piston to compress the piston spring, then install the piston retaining ring.

Valve Removal, Disassembly, Assembly, and Installation

14. Slide the cover into the relief valve body. Then install the cover retaining ring.
15. Using a powered test light, screw the indicator light switch in until the light goes out. Then turn an additional 3/4 to 1-1/4 turn. Apply Loctite 242 to the jamnut and tighten it.
16. Slide the relief valve assembly into the pump body with the side marked "top" up, being careful not to damage the O-rings.
17. Apply Loctite 242 to the four 7/16–14 x 1-1/4 capscrews, then install the assembly in the pump body. Tighten the capscrews to 53 lbf·ft (72 N·m).
18. Connect the indicator light switch.
19. Fill the pump, then test the valve for proper operation and leaks.

QD Relief Valve

NOTE: For an exploded view of the QD relief valve, see **Fig. 2**.

1. Drain the pump.
2. Note the location of the wires, then disconnect the indicator light switch.
3. Disconnect the relief valve supply line from the pilot valve and drain the line.
4. Remove the two 7/16–14 x 1-1/4 capscrews that attach the relief valve indicator light switch and the mounting bracket assembly to the relief valve cover. Remove the light switch and the bracket.
5. Compress the relief valve return spring (by hand), and remove the E-clip and washer. Then, remove the return spring.
6. Remove the two remaining 7/16–14 x 1-1/4 capscrews that retain the relief valve cover to the pump body. Using a twisting motion, carefully remove the relief valve cover.

CAUTION

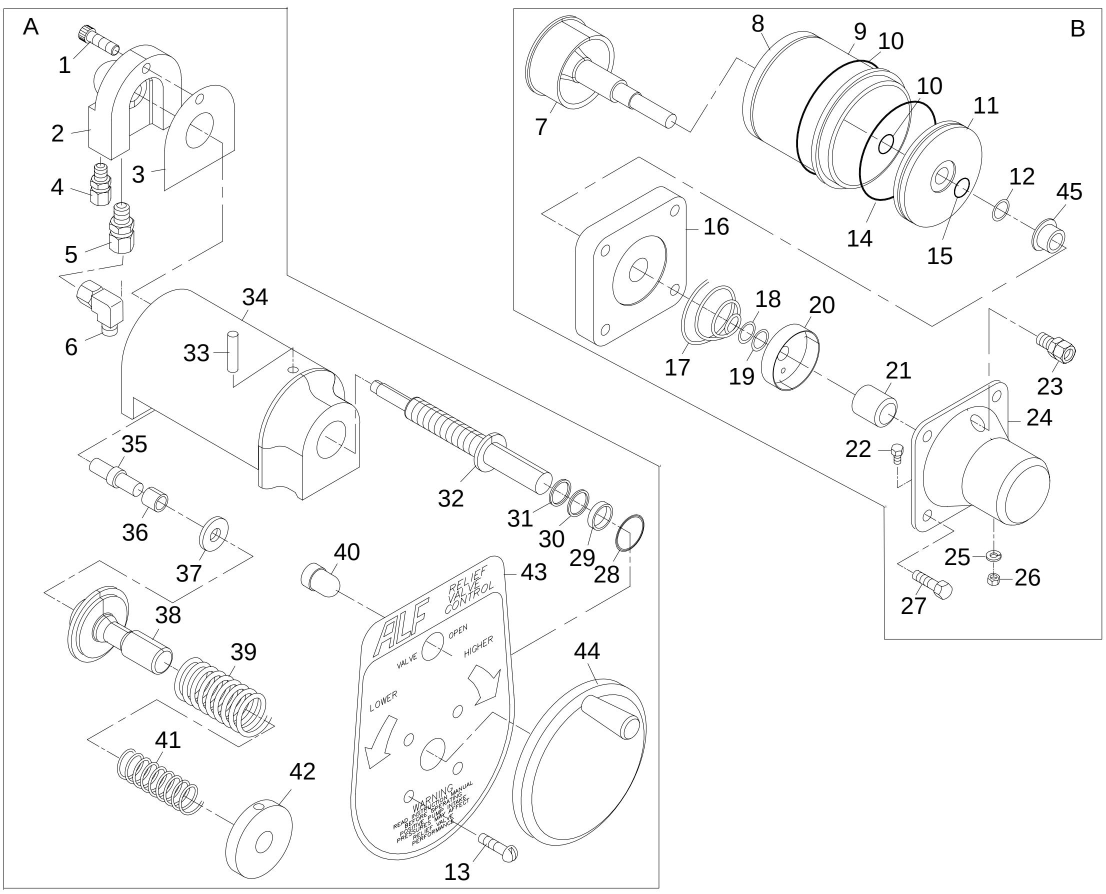
Do not push the relief valve too far into the pump body as it may fall into the pump body and become lodged or damaged. The relief valve is made of brass and is easily damaged by prying or hammering. Damaged valves must be replaced.

7. Remove the retaining ring that secures the relief valve piston to the relief valve. Gently push the relief valve into the pump body approximately 1 inch (25 mm), then pull it back out in a snap-motion. This should pop the relief valve piston out of the relief valve body. Repeat if necessary.

NOTE: It is not necessary to remove the relief valve unless it is damaged. To remove the relief valve, the relief valve body will have to be removed and the complete relief valve assembly will need to be replaced (as it will be necessary to pry the relief valve body from the pump body, which will likely damage it).

8. Clean and inspect all of the relief valve assembly components.
9. Clean all sealing surfaces and install new O-rings and Quad-ring seals.
10. Install the relief valve piston in the stem of the relief valve. Do not push the relief valve into the pump body. As it is necessary to start the piston on the relief valve stem, push the piston until you can grasp the relief valve stem. Then pull the relief valve stem outward while pushing on the relief valve piston. Once the relief valve piston is seated against the shoulder of the relief valve stem, install the retaining ring.
11. Operate the relief valve by hand to check for freedom of movement.
12. Slide the relief valve cover gasket and cover over the top of the relief valve stem to align the relief valve supply line from the pilot valve in the original position. Then, apply Loctite® 242 to two 7/16–14 x 1-1/4 capscrews and install them opposite of each other. Tighten, but do not torque them.
13. Compress and install the return spring, and secure it with a washer and E-clip.
14. Align the indicator light switch mounting bracket and switch with the two empty holes in the relief valve cover. Install the two remaining 7/16–14 x 1-1/4 capscrews. Tighten all capscrews 53 lbf·ft (72 N·m).
15. Connect the relief valve supply line from the pilot valve. Also, connect the drain line.
16. Connect the indicator light switch.

Valve Removal, Disassembly, Assembly, and Installation



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A. TPM Relief Valve Control Assembly

B. QD Relief Valve System Assembly

1. Allen-Head Screw, 5/16–18 x 1
2. Control Body Assembly
3. PM Control Valve Diaphragm
4. Connector Tube, 1/8" x 3/4"
5. Connector Tube, 1/4" x 3/8"
6. Connector Strainer
7. Relief Valve
8. Valve Body Seal Ring
9. Relief Valve Body
10. Piston Seal Ring
11. Transfer/Relief Valve Piston
12. Piston Retaining Ring
13. Screw, 1/4–20 x 5/8
14. Cover and Piston Seal Ring
15. Cover Seal Ring
16. Relief Valve Assembly Cover
17. Valve Spring
18. Washer
19. Spring Retaining Ring
20. Switch Strap
21. Indicator Light Switch
22. Hexhead Screw, #10–32 x 1/2
23. Connector Tube, 1/4" x 3/8"
24. Switch Bracket
25. Lockwasher, #10
26. Hexnut, #10–32
27. Hexhead Screw, 7/16–14 x 2-1/4
28. Sealing Washer
29. Bearing Washer Retaining Ring
30. Bearing Washer
31. Thrust Bearing
32. Adjusting Stem
33. Indicator Pin
34. Spring Housing
35. Control Valve
36. Control Valve Bearing
37. Diaphragm Support Bearing
38. Diaphragm Clamp
39. Outside Spring
40. Light Bulb
41. Inside Spring
42. Adjusting Nut
43. Instruction Plate
44. Adjusting Wheel Assembly
45. Piston Retaining Ring Cover

Fig. 2, TPM and QD Relief Valve (exploded view)

17. Fill the pump, then test the valve for proper operation and leaks.

Valve Removal, Disassembly, Assembly, and Installation

TPM Dump Valve

1. Drain the pump.
2. Disconnect the indicator light switch.
3. Disconnect the line to the sensing valve.
4. Remove one 7/16–14 x 2 sensing valve mounting capscrew.
5. Remove the four 7/16–14 x 1-3/4 capscrews that retain the relief valve assembly to the atmosphere dump.
6. Remove the four 7/16–14 x 1-1/2 relief valve mounting capscrews to remove the relief valve from the pump body.
7. Remove the relief valve assembly.
8. Remove the four 7/16–14 x 1-3/4 capscrews that retain the relief valve cover to the relief valve body.
9. Remove the indicator light switch assembly.
10. Apply a small amount of pressure to the relief valve spring, and remove the spring retaining ring and washer. Carefully release the pressure held on the spring and remove it.
11. Remove the relief valve cover.
12. Remove the piston retaining ring.
13. Remove the relief valve from the opposite end, sliding the relief valve stem out of the piston.
14. Reaching through the center hole of the piston, gently pull the piston from the indicator switch end of the relief valve body.
15. Before assembling and installing the valve, clean and inspect all components of the relief valve assembly.
16. Clean all sealing gasket surfaces and install new O-rings and gaskets.
17. Install the relief valve in the relief valve body.
18. Slide the piston into the relief valve body while at the same time sliding the piston onto the relief valve stem. Then install the piston retaining ring.
19. Install the new gasket, then install the cover on the relief valve body.
20. Install two 7/16–14 x 1-3/4 capscrews finger-tight (to keep the relief valve cover aligned with the valve body).
21. Install the valve spring over the relief valve stem. Then apply pressure to the valve spring to compress the spring.
22. Install the spring washer and the retaining ring.
23. Remove the two 7/16–14 x 1-3/4 capscrews that were installed to keep the relief valve cover aligned with the valve body. Place the indicator switch assembly into position on the relief valve cover. Apply Loctite® 242 to the four capscrews, install, and tighten 53 lbf·ft (72 N·m).
24. Apply Loctite® 242 to the four 7/16–14 x 1-1/2 capscrews to install the new gasket and the relief valve on the pump surface.
25. Apply Loctite® 242 to the four 7/16–14 x 1-1/2 capscrews, then install the new gasket and relief valve assembly on the atmosphere dump. Tighten 53 lbf·ft (72 N·m).
26. Apply Loctite® 242 to the 7/16–14 x 2 capscrew, install the sensing valve and tighten the capscrews 40 lbf·ft (54 N·m). Make sure the arrow points upward.
27. Connect the indicator light switch.
28. Connect the line to the sensing valve.
29. Fill the pump, then test the valve for proper operation and leaks.

Check Valves (two-stage only)

1. Drain the pump.

NOTE: There are two check valves (one on each side) in the suction side on the front of the two-stage pump body. The following procedure is used for both check valves.

2. Remove the four 1/2–13 x 1-1/4 capscrews from the check valve cover on the front side of the pump body.
3. Remove the check valve.
4. Clean the gasket surfaces, and inspect the check valve pivots and pivot sockets.
5. Install the check valve.

6. Install the new gasket in the pump body.
7. Apply Loctite® to the four capscrews, then secure the check valve cover to the pump body with the capscrews, being careful to align the check valve pivot with the pivot socket in the check valve cover. Tighten the capscrews to 53 lbf·ft (75 N·m).
8. Fill the pump, then test the valve for proper operation and leaks.

SPV Priming Valve

1. Drain the pump.
2. Disconnect the 3/4-inch (19-mm) vacuum hose that connects the priming valve to the primer.
3. Remove two 7/16–14 nuts that attach the priming valve to the studs in the pump body. If the studs are damaged, replace them with 7/16–14 x 1-3/4 zinc-plated studs.

NOTE: If the valve strainer and O-ring seal remains on the pump body, remove it carefully for cleaning and installation. If the valve strainer is removed as part of the priming valve, remove it from the body and set it aside. Use care as the valve strainer is easily damaged.

4. Note the location of the drain hole on the diaphragm cover, then remove the eight 5/16–18 x 3/4 capscrews that secure the diaphragm cover to the valve body. Remove the diaphragm cover and the diaphragm.
5. Hold pressure on the diaphragm washer to compress the valve spring, then remove the diaphragm washer retaining screw. Remove the diaphragm washer and valve spring. From the opposite side of the valve body, remove the valve.
6. Clean all the components of the priming valve and mating surfaces. Inspect the valve seat, and replace if worn or damaged.
7. Install the valve into the valve body from the pump side of the body.
8. Install the valve spring and diaphragm washer on the valve. Apply Loctite® 242 to the diaphragm washer retaining screw, compress the valve spring with the diaphragm washer, and install the valve.
9. Align the diaphragm holes with the capscrew holes in the diaphragm cover. Apply Loctite® 242 to the eight 5/16–18 x 3/4 capscrews, and install the diaphragm cover and diaphragm valve body. Tighten the capscrews 17 lbf·ft (23 N·m).
10. Install the valve strainer and O-ring seal on the pump side of the priming valve.
11. Apply Loctite® 242 on the two 7/16–14 priming valve mounting nuts and install the priming valve into the pump body. Tighten the mounting nuts 40 lbf·ft (54 N·m).
12. Connect the vacuum hose to the primer.
13. Fill the pump, then test the valve for proper operation and leaks.

Troubleshooting

Lack of use causes many problems for fire pumps and fire pump components.

IMPORTANT: The entire pumping system should be exercised on a regular basis, or, at least, weekly. This routine procedure should include all discharge valves and suction valves.

Abuse of the fire pump is rarely a problem. If the pump and pump components have been abused, indications of problems may be fairly obvious. For example, bent controls are a common indicator.

Simultaneous oil and water leaks are uncommon. Normally, a water leak indicates that a line has come loose or is broken. Gaskets are used between mating surfaces *without* sealant. If a leak is present at a gasket-mating surface, whether oil or water, the components should be disassembled and repaired.

Be certain when a device indicates it is not working that it is not a simple electrical problem, such as a burned-out indicator bulb.

Troubleshooting Tables

Problem—Pump Will Not Engage

Problem—Pump Will Not Engage	
Possible Cause	**Remedy**
Parking brake not set.	Set the parking brake.
Transmission not in neutral.	Shift transmission to neutral.
Insufficient air supply.	Repeat the recommended shift procedure: Check the air pressure gauges. This procedure requires at least 100 psi (689 kPa). Shut the engine down and check for air leaks.
Pump shift or application of parking brake attempted before apparatus was stopped.	Release the braking system momentarily and repeat the recommended shift procedure. *

* This condition is known as "Butt Tooth," which occurs when the transmission shifts and the shift gear-teeth and the teeth on the drive gear do not line up and "butt" up against each other. The American LaFrance fire pump transmission is designed with a sliding shift collar. Therefore, the occurrence of "Butt Tooth" will be rare.

Problem—Pump Will Not Shift

Problem—Pump Will Not Shift	
Possible Cause	**Remedy**
Battery voltage low.	Turn off accessories. Check the charging system of the apparatus. Inspect the batteries. If okay, recharge and try shift again.
Interface/Interlock module not receiving proper inputs.	Check the Officers Information Center output.
Transmission not receiving lock-up input.	Check output to transmission with Prolink.

Problem—Pump Will Not Prime

Problem—Pump Will Not Prime	
Possible Cause	**Remedy**
Low battery voltage.	Increase the engine speed 1000 to 1200 rpm for temporary support for electrical system requirements and primer operation. *
Worn or damaged priming system.	Perform the "Dry Vacuum Test," which follows the troubleshooting tables in this subject. If pump is tight but primer develops less than 22 inches of vacuum, the primer pump, motor, or priming valve may be worn or damaged.

Troubleshooting

Problem—Pump Will Not Prime	
Possible Cause	**Remedy**
Primer not operated long enough.	Operate for 30 seconds for pump up to 1250 gpm or for 45 seconds for 1500 and up gpm pump. Add 15 additional seconds if priming from front or rear suction. Do not run primer over 45 seconds. Stop and check for causes.
Suction lifts too high.	Do not attempt lifts exceeding 22 feet, except at low elevations.
Suction strainer blocked.	Check and clean.
Air pocket in suction hose or pump.	Place suction hose lower than suction intake. Slightly open a discharge valve momentarily to release trapped air.
Air leaks.	Perform the "Dry Vacuum Test," which follows the troubleshooting tables in this subject. Then, shut engine off and listen for air leaks. Pressurize the discharge side of the pump with approximately 100 psi (689 kPa) from the hydrant, and check for water leaks. Check connections and gaskets.

* Electric primer does not require engine speed to be increased for operation. A primer can and will draw in excess of 300 amps and primer operation can last 45 seconds.

Problem—Pump Loses Prime

Problem—Pump Loses Prime	
Possible Cause	**Remedy**
Suction lifts too high.	Do not attempt lifts exceeding 22 feet except at low elevations.
Suction strainer blocked.	Check and clean.
Air leaks.	Check all connections and gaskets. Perform the "Dry Vacuum Test," which follows the troubleshooting tables in this subject.
Pump pressure is too low when discharge appliance is opened.	Prime the pump again. Raise pump pressure higher and open the discharge appliance slowly.

Problem—Pump Primer Does Not Operate Properly

Problem—Pump Primer Does Not Operate Properly	
Possible Cause	**Remedy**
Does not operate electrically.	Check the batteries, connections, primer, and primer control. Check the control switch and solenoid on the primer. If the primer has not been used recently, it could be frozen. It should, if contact is still being made internally, show heavy current draw.
Primer is slow or lower than normal.	Check batteries, wiring, and connections. A large quantity of suction hoses or suction pipes can exceed primer capabilities. Too small diameter, or too long a length of piping between primer and pump can exceed primer capabilities. Lift not to exceed 20 feet (6 m), and 10 feet (3 m) for testing. The primer pump itself may be worn out.
Pulls some prime.	The primer pump could be in need of repairs or cleaning. Check for air leaks, and verify that the priming valve is not sticking.
Pulls full prime.	Check for air leaks. Check for clogged inlet strainer and screens. Check that the suction hose is submerged in adequate water supply. Check for air pockets and air accumulation in piping. Check for turbulence in piping. The pump impeller may be damaged or severely worn.

Problem—Insufficient Capacity or Pressure

Problem—Insufficient Capacity or Pressure	
Possible Cause	**Remedy**
Insufficient engine power.	Check engine performance.
Improperly set relief valve.	Readjust the relief valve to a higher pressure setting. If the relief valve is set too low it will open to relieve pressure and reduce capacity.
Transmission in incorrect range.	Check the transmission selector for correct range recommended for pumping procedure. Check that the fourth range lockup has occurred. If the transmission shifts while increasing engine speed, lock up has not occurred. Check engine speed or drive shaft speed for correct transmission range and inaccurate tachometer.
Air leaks.	Perform the "Dry Vacuum Test," which follows the troubleshooting tables in this subject.
Transfer valve in incorrect position.	Transfer valve must be in the "parallel or volume" setting for capacity or in the "series or pressure" setting for pressure. The transfer valve indicator may be out of adjustment. At idle, shift the transfer valve back and forth. You should hear the check valves close, and see a change in pressure on the master pressure gauge.
Tank fill valve leaking.	Repair the leak.

Problem—Engine Speed Too High for Capacity or Pressure

Problem—Engine Speed Too High for Capacity or Pressure	
Possible Cause	**Remedy**
Impeller blockage.	Check and clean. Backflushing through the discharge side of the pump may clear the obstruction. It may require disassembly of the pump.
Worn impeller or clearance rings.	Overhaul the pump. All other possibilities should be eliminated before overhauling the pump.
Suction strainer blocked.	Clean and check.
Lift too high.	Lifts over 10 feet will cause higher engine speeds and vacuum.
Transmission in incorrect range.	Check the transmission selector for correct range for recommended pumping procedure. Check that fourth range lockup has occurred. If the transmission shifts while increasing engine speed, lock up has not occurred. Check engine speed or driveshaft speed for correct transmission range and inaccurate tachometer.
Check valves damaged or missing.	At idle, shift the transfer valve back and forth. You should detect a change in the engine/pump sound, hear the check valves close, and see a change in the pressure on the master pressure gauge. If no apparent change occurs, remove the suction inlet cap and inspect the check valves. Insert a broom handle in the suction inlet and gently push each check valve open and let it close. Check valves should move freely.
Tank fill valve leaking.	Repair the leak.

Troubleshooting

Problem—Relief Valve Does Not Relieve When Valves are Closed

Problem—Relief Valve Does Not Relieve When Valves are Closed	
Possible Cause	**Remedy**
Incorrect pilot valve setting.	Repeat the proper procedure for setting the relief valve.
Pilot valve inoperative.	Disassemble, clean, and lubricate. Inspect the control valve diaphragm for wear or damage.
Relief valve inoperative.	Disassemble, clean, and lubricate.

Problem—Relief Valve Does Not Recover When Valves are Opened

Problem—Relief Valve Does Not Recover When Valves are Opened	
Possible Cause	**Remedy**
Dirt in system resulting in slow or sticky operation.	Disassemble, clean, and lubricate.

Problem—Unable to Attain Proper Setting

Problem—Unable to Attain Proper Setting	
Possible Cause	**Remedy**
Incorrect procedure.	Check procedure and reset.
Blocked strainer.	Disconnect the pilot valve supply line from the discharge side of pump. Remove the 90-degree fitting where the supply line connects to the pump. The strainer is attached to this fitting. Clean or replace the strainer and fitting assembly.
Dirt in pilot valve.	Disassemble, clean, and lubricate.
Hunting condition.	Insufficient water supply to the pilot valve. Check strainer and supply lines. If there is dirt in the pilot valve, disassemble, clean, and lubricate.

Problem—TPM Valve Does Not Relieve

Problem—TPM Valve Does Not Relieve	
Possible Cause	**Remedy**
Sensing valve inoperative.	Disassemble, clean, and lubricate. Inspect the control valve diaphragm for wear or damage.
PG relief valve inoperative.	Disassemble, clean, and lubricate.
PG relief valve sluggish.	Check and clean the discharge and suction strainers in the pump body.

Problem—TPM Valve Does Not Recover

Problem—TPM Valve Does Not Recover	
Possible Cause	**Remedy**
Dirt in system resulting in slow or sticky operation.	Disassemble, clean, and lubricate. Check and clean the discharge and suction strainers in the pump body.

Problem—AutoLube

Problem—AutoLube	
Possible Cause	**Remedy**
External leaks.	External leaks are the result of gasket failures. Disassemble and repair.
Internal leaks.	If water is leaking, replace the diaphragm. If oil is leaking, replace the AutoLube seal and the impeller bushing. Heavy oil usage by the AutoLube or oil present in the water when the pump master drain is opened indicates that the AutoLube seal and possibly the impeller bushing is damaged.

Problem—Mechanical Seal Leaks

Problem—Mechanical Seal Leaks	
Possible Cause	**Remedy**
Leak at mechanical seal.	If the mechanical seal is leaking it will have to be replaced. If properly cared for, the mechanical seal should be almost maintenance-free. Water quality will greatly affect seal life. The most common failure of the mechanical seal is from thermal-shock (running the pump dry, heating up the seal, then opening to a cool or cold water supply); the seal may shatter. Check the AutoLube. If the bushing is worn or missing, the impeller shaft will wobble and fracture the mechanical seal.

Problem—Pump Gear Box Does Not Function Properly

Problem—Pump Gear Box Does Not Function Properly	
Possible Cause	**Remedy**
Water in gear box.	Locate and repair the leak. Remove and clean the gear box filter. Replace the transmission oil. Water leaking onto the input drive shaft of the pump gear box will actually be screwed into the pump transmission past the oil seals. This is not a seal problem. Be certain the slinger(s) are in place. Check the pump gear box cooling line for internal fractures. Pump gear box will fill with water and overflow through breather.
Whine in gear box.	Check the oil level. If oil is low, helical gears and/or tapered bearings will whine. Check oil pressure. If the filter is clogged, oil pressure will be low. Drain oil and check for metal. Remove filter and check for metal. If metal is detected, pump gear box will have to be disassembled for complete inspection and repairs.
Knock or rattle in gear box.	Check for gears missing teeth. Check for damaged bearings. Disassemble and repair. *

* The cause may include foreign objects, low or contaminated oil, or low oil pressure. Low oil level or pressure will result in the transmission being damaged due to overheating.

Dry Vacuum Test

1. Open all the intake valves.
2. Cap all intakes. Close and uncap all discharge valves.

Troubleshooting

3. Using the pump's priming devices, develop a vacuum of at least 22 inHg (74.5 kPa) for 30 seconds for pumps up to 1250 gpm, or 45 seconds for pumps 1500 gpm or greater.
4. Reduce the maximum vacuum attained by 1 inHg (3.4 kPa) for each 1000 ft. (305 m) of elevation of the test site above 2000 ft (610 m).

NOTE: The vacuum should not drop more than 10 inHg (33.9 kPa) in 5 minutes. Do not operate the pump priming device once the five-minute test has begun.

See Table 1 for TwinFlow fire pump input and output shaft run-out specifications.

TwinFlow Fire Pump Input and Output Shaft Run-Out	
Description	**Allowable Range: inch (mm)**
Radial Run-Out	0.002–0.004 (0.0508–0.0102)
Axial Run-Out	0.000–0.020 (0.000–0.508)

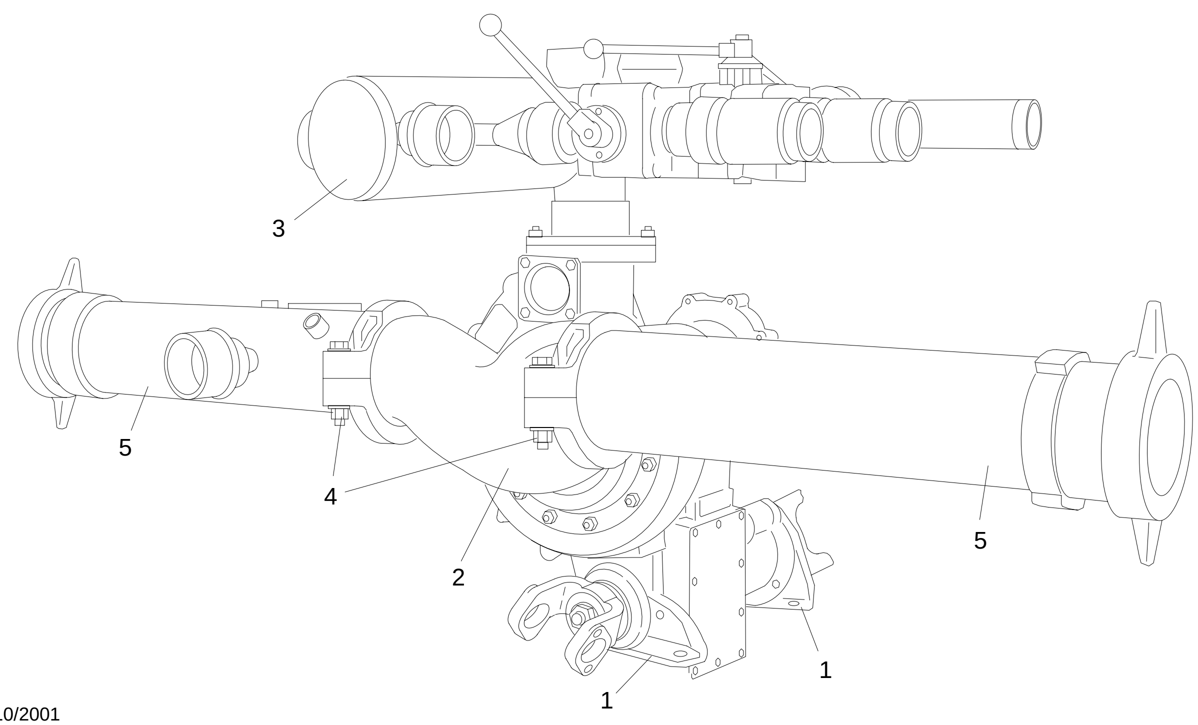
Table 1, TwinFlow Fire Pump Input and Output Shaft Run-Out

General Description

The American LaFrance midship-mounted PowerFlow fire pump (see **Fig. 1**) is a high-speed, single-stage, centrifugal pumping system designed to deliver large volumes of water under pressure.

The pump consists of the following major components:

- A cast-iron pump body
- A bronze impeller and a stainless steel shaft
- A pump gearbox
- A priming system
- A pressure-control device
- Valves
- Mechanical Seal



1. Mounting Brackets
2. Intake Y-Adapter
3. Discharge Manifold
4. Victaulic Couplings
5. Extension Tubes

Fig. 1, American LaFrance PowerFlow Fire Pump

The impeller, which is mounted on a shaft rotated by the vehicle's engine via the driveline, provides velocity to the water, causing it to build enough pressure and volume to be used for firefighting applications.

Bearings support and align the impeller shaft and other components inside the gearbox. The gearbox must be maintained on a scheduled basis.

The pump has two large suction inlets, one on each side of the vehicle, though other inlets may be present. The inlets and the internal pump outlets are on opposite sides of the pump to balance forces caused by the intake and the discharge of water.

Principles of Operation

The American LaFrance PowerFlow pump operates on the principle of centrifugal force. Water is routed to the center of the impeller, which throws the water outward from its center. Because the water is confined in a closed container, in this instance, the pump body, the shrouds, and the vane of the impeller, the

General Information

water pressure increases. The pressure level depends on how fast the impeller is rotating.

Water entering the pump intake is routed to the center of the rapidly spinning impeller, which is confined by the shrouds and vanes in the impeller, which builds pressure. The vanes guide the water away from the inlet to the discharge manifold to reduce the water's turbulence.

The pressurized water is prevented from returning to the intake of the impeller by clearance rings. Centrifugal pumps have clearance rings mounted between the spinning impeller and the pump body. Clearance rings, as well as the hubs of the impeller, will, over time, become worn or pitted and may need to be replaced, or machined to a smaller diameter.

Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

Removal

WARNING

Many of the components on the fire pump are heavy and awkward to handle. Always use the proper support equipment during removal and installation of the fire pump. Failure to do so could result in an assembly falling, which could result in personal injury or property damage.

NOTE: Due to the design of the PowerFlow fire pump, with the pump being supported by mounts located on the gearbox, the entire pump will have to be removed for complete gearbox disassembly and assembly. If repairs are only being made on the input/output shaft assembly, the pump and gearbox can be disassembled in the vehicle through the access cover on the side of the gearbox.

For a cross-section view of the gearbox, see **Fig. 1**.

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Drain the water from the pump.
3. Drain the gearbox lubricant to prevent contamination.

NOTE: Also check for water.

4. Disconnect the driveshafts from the gearbox.
5. Disconnect the air lines to the shift cylinder.
6. Label and disconnect the electrical switches from the pump.
7. Disconnect the pump master drain.
8. Disconnect the intake Y-adapter. Remove the eight 3/8–24 nuts that secure the intake Y-adapter to the suction head. See **Fig. 2**. Lay the Y-adapter aside.
9. Unbolt the discharge manifold from the top of the pump housing.
10. Remove both gearbox cooler lines.
11. Remove all eight bolts from the cooler, noting the different lengths, and remove the gearbox cooler.
12. Place a supporting device under the pump gearbox and secure the pump to it.
13. Remove the front and rear mounting bolts.
14. Due to the application and design of the pump mounting system, one or both crossmember supports for the pump may have to be removed. Remove one or both as needed.
15. Lower the pump, then move it to a work area.

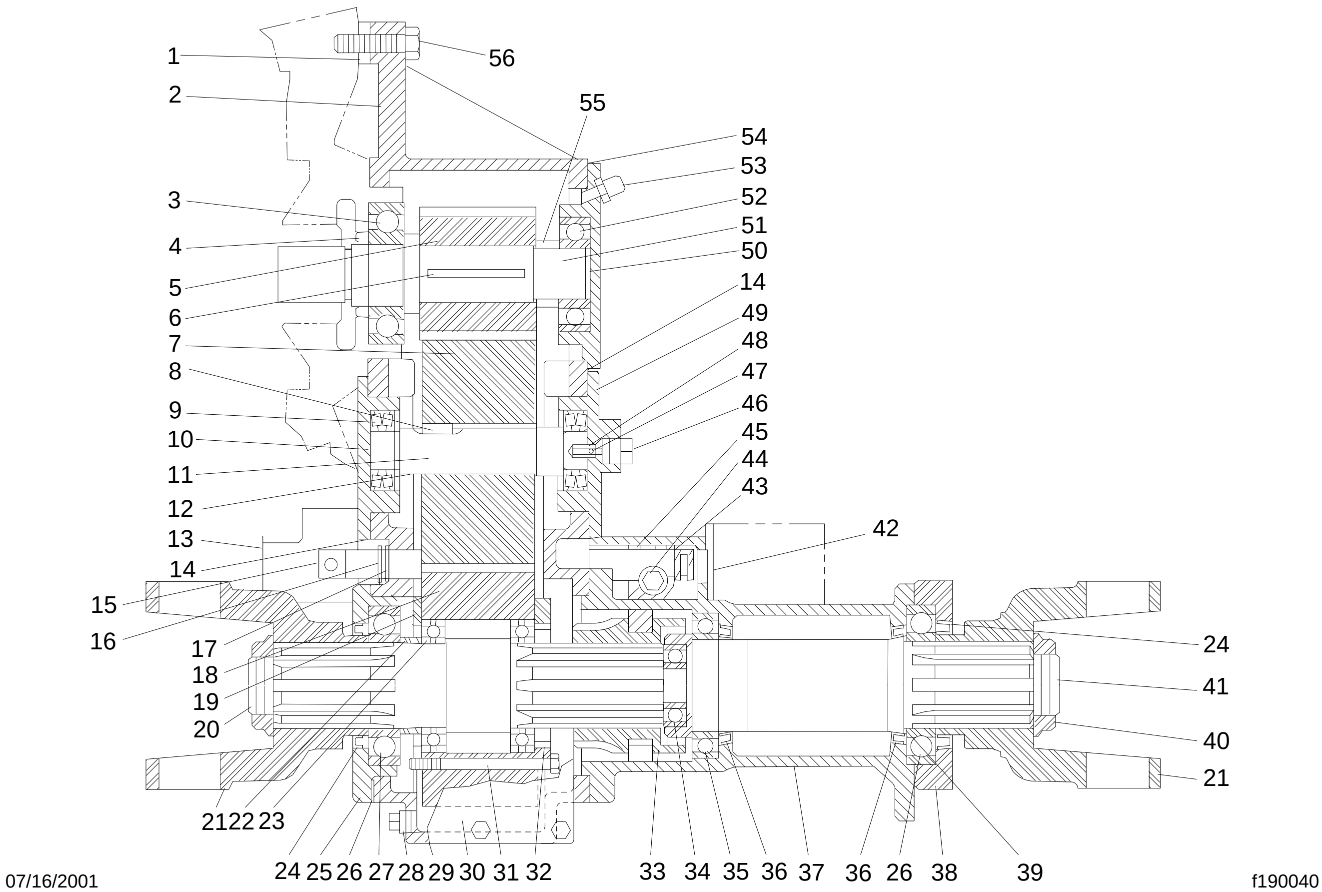
Disassembly

1. Disassemble the pump body (suction head, impeller, and seal). See **Subject 120**.

IMPORTANT: Once the three bolts that attach the volute housing to the gearbox have been removed, the volute housing is free and must be secured to prevent it from falling and being damaged.

2. Secure the pump gearbox to prevent the gearbox from shifting position, then remove the three 3/4–10 x 2 bolts that attach the volute housing to the pump gearbox. Separate the volute housing from the pump gearbox. Remove and discard the mechanical seal. Set it aside.
3. Remove the air shift cylinder and set it aside. See **Subject 130**.
4. Remove the shift switches and switch bracket from the input shaft bearing cover.
5. Remove both retaining rings from the front of the shift rod. See **Fig. 3**.
6. Remove all eight Allen-head bolts that secure the output shaft housing to the pump gearbox housing. Carefully separate the output shaft housing from the pump gearbox housing, taking care not to drop or damage the pilot bearing or the sliding shift gear.
7. Remove the locknut that secures the yoke to the output shaft then, remove the yoke. Remove the four 3/8–16 x 1-3/4 bolts that attach the rear bearing cover to the output shaft housing. Remove and set aside the cover. From the rear, press out the output shaft. Remove the bearings and bearing retaining ring. See **Fig. 4**.

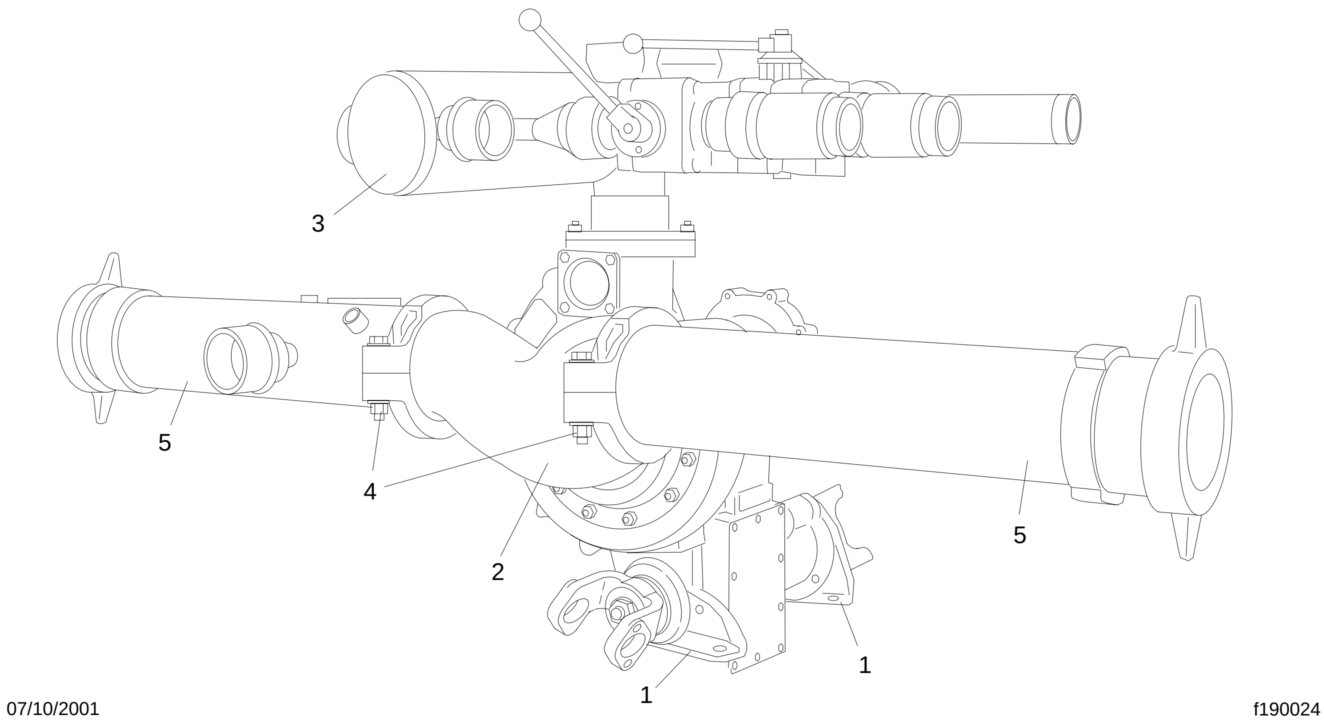
Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation



1. Gearbox Spacer
2. Gearbox
3. Impeller Shaft Bearing
4. Impeller Shaft Oil Seal
5. Input Shaft Gear
6. Input Shaft Gear Keyway
7. Intermediate Gear
8. Intermediate Gear Keyway
9. Intermediate Shaft Bearing
10. Intermediate Shaft Bearing Cap
11. Intermediate Shaft
12. Intermediate Gear Spacer
13. Water Shield
14. Intermediate Bearing Cap Gasket
15. Shift Shaft
16. Shift Shaft O-Ring
17. Shift Shaft Retaining Ring
18. Drive Gear
19. Bearing Retainer
20. Input Shaft
21. Drive Yoke
22. Input Shaft Seal
23. Input Shaft Bearing
24. Input Shaft Oil Seal
25. Input Shaft Bearing Bracket
26. Input Shaft Bearing Bracket Gasket
27. Input Shaft Bearing
28. Oil Drain Plug (magnetic)
29. Gearbox Cover Plate Gasket
30. Gearbox Cover Plate
31. Shift Gear Retaining Screws
32. Shift Gear
33. Sliding Shift Gear
34. Pilot Bearing
35. Output Shaft Bearing
36. Output Shaft Oil Seal
37. Output Shaft Bearing Housing
38. Output Shaft Bearing Cap
39. Output Shaft Bearing Backup Washer
40. Locknut
41. Output Shaft
42. Power Shift Opening Cover
43. Safety Wire
44. Lockbolt
45. Shift Fork
46. Tach Plug
47. Tach Cable Drive Nut
48. Tach Shaft Oil Seal
49. Idler Bearing Cap
50. Impeller Shaft Bearing Cap
51. Impeller Shaft
52. Impeller Shaft Rear Bearing
53. Gearbox Vent
54. Impeller Shaft Bearing Cap Gasket
55. Pump Shaft Gear Spacer
56. Volute Housing Bolts

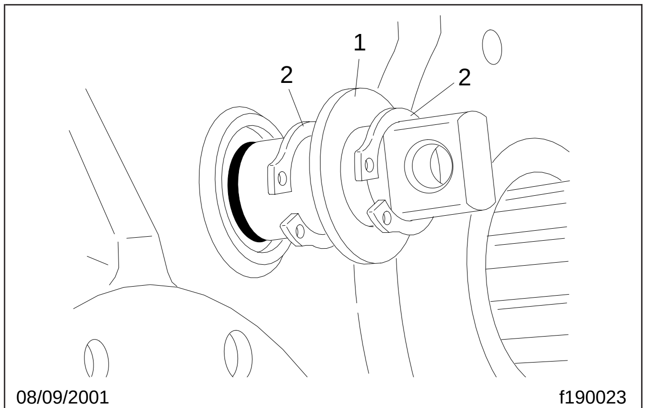
Fig. 1, Gearbox (cross-section view)

Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation



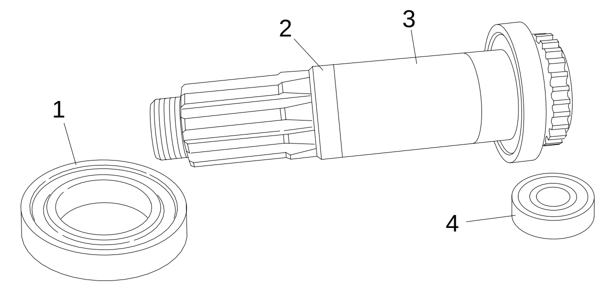
1. Mounting Brackets
2. Intake Y-Adapter
3. Discharge Manifold
4. Victaulic Couplings
5. Extension Tubes

Fig. 2, American LaFrance PowerFlow Fire Pump



1. O-Ring
2. Retaining Rings

Fig. 3, Pump Gearbox Shift Rod



1. Output Shaft Bearing
2. Bearing Retaining Ring
3. Output Shaft
4. Pilot Bearing

Fig. 4, Output Shaft

NOTE: The shift rod will slide out of the gearbox rearward as the output shaft housing is separated. See **Fig. 5**.

8. Remove shift shaft O-ring from case.
9. Remove the shift rod, fork, and sliding shift gear from the gearbox.

Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

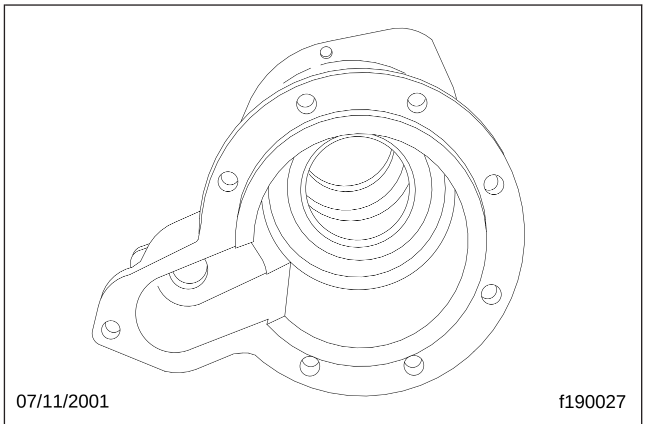
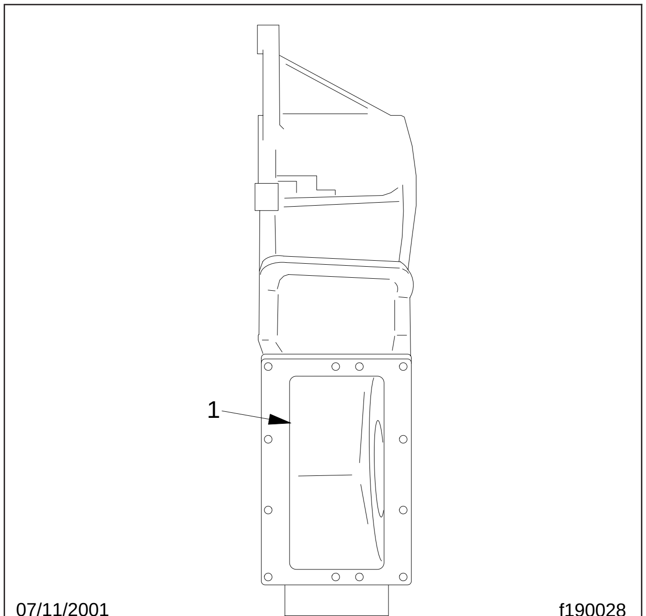


Fig. 5, Output Shaft Housing (rear view)

10. Remove the ten 5/16–18 x 1-3/4 bolts that secure the side cover to the gearbox. Remove the side cover and gasket. Discard the gasket.
11. Remove the locknut and yoke from the input shaft, and discard the locknut.
12. Through the rear opening in the pump gearbox (see **Fig. 6**), remove all six bolts that attach the shift gear to the main drive gear. Slide the input shaft off the main drive gear and remove it through the front of the pump gearbox. Remove the bearings and spacer from the input shaft. Through the side opening in the pump gearbox, remove the shift gear, shift gear bolts, main drive gear, and bearing retainer. See **Fig. 7**.
13. Remove the four bolts that secure the input shaft bearing cover to the gearbox. Install two jack bolts in the appropriate holes and remove the input shaft bearing cover.
14. Remove the four 3/8–16 x 1 bolts that secure the impeller shaft bearing cap to the pump gearbox. Insert jack bolts into the appropriate holes and remove the bearing cover.

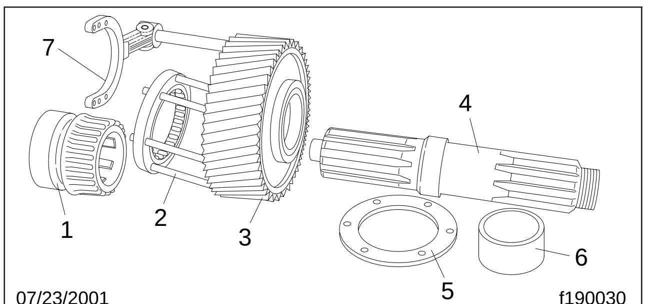
NOTE: Take note of the locations of the different sizes of spacers on the impeller shaft.

15. Press the impeller shaft out of the pump gearbox from the front to the rear. Take care not to damage the seal area. See **Fig. 8**.
16. Press the rear bearing from the impeller shaft.
17. Press the impeller shaft out of the impeller gear from the rear to the front. Remove the key and the spacer.



1. Access for Disassembly

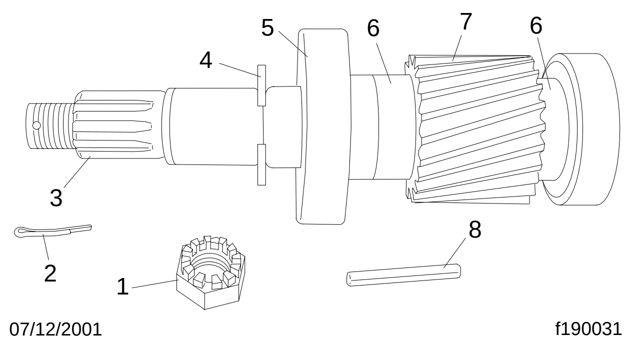
Fig. 6, Gearbox Side Access



1. Sliding Shift Gear
2. Shift Gear and Retaining Bolts
3. Drive Gear and Bearings
4. Input Shaft
5. Bearing Retainer
6. Spacer
7. Shift Fork

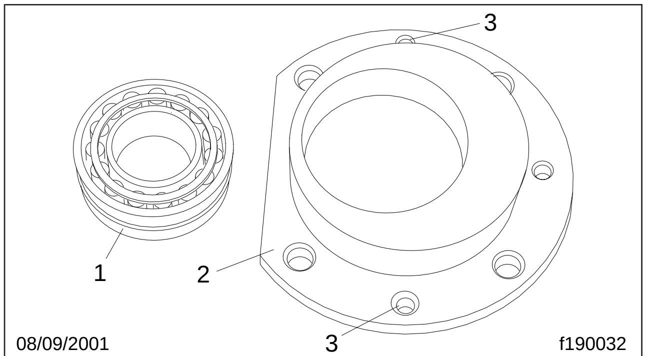
Fig. 7, Input Shaft and Related Components

18. Remove all four bolts from the rear intermediate shaft bearing cover. Insert jack bolts in the appropriate holes and remove the cover. Repeat the procedure to remove the front intermediate shaft bearing cover. See **Fig. 9**.
19. Remove the spacer from the front of the intermediate shaft. Press the intermediate shaft out of



1. Nut
2. Cotter Pin
3. Impeller Shaft
4. Slinger
5. Bearing
6. Spacer
7. Impeller Shaft Gear
8. Key

Fig. 8, Impeller Shaft and Related Components



1. Bearing
2. Intermediate Shaft End Cap
3. Jack Bolt Holes

Fig. 9, Intermediate Shaft Bearing Cover

the intermediate gear from the front to the rear. See **Fig. 10**.

NOTE: The intermediate gear is a tight pressed fit and is keyed to the shaft.

20. Press the front bearing off of the impeller shaft towards the seal area.
21. Clean all components, seal areas, and gasket surfaces. Check for wear or damage.

Assembly

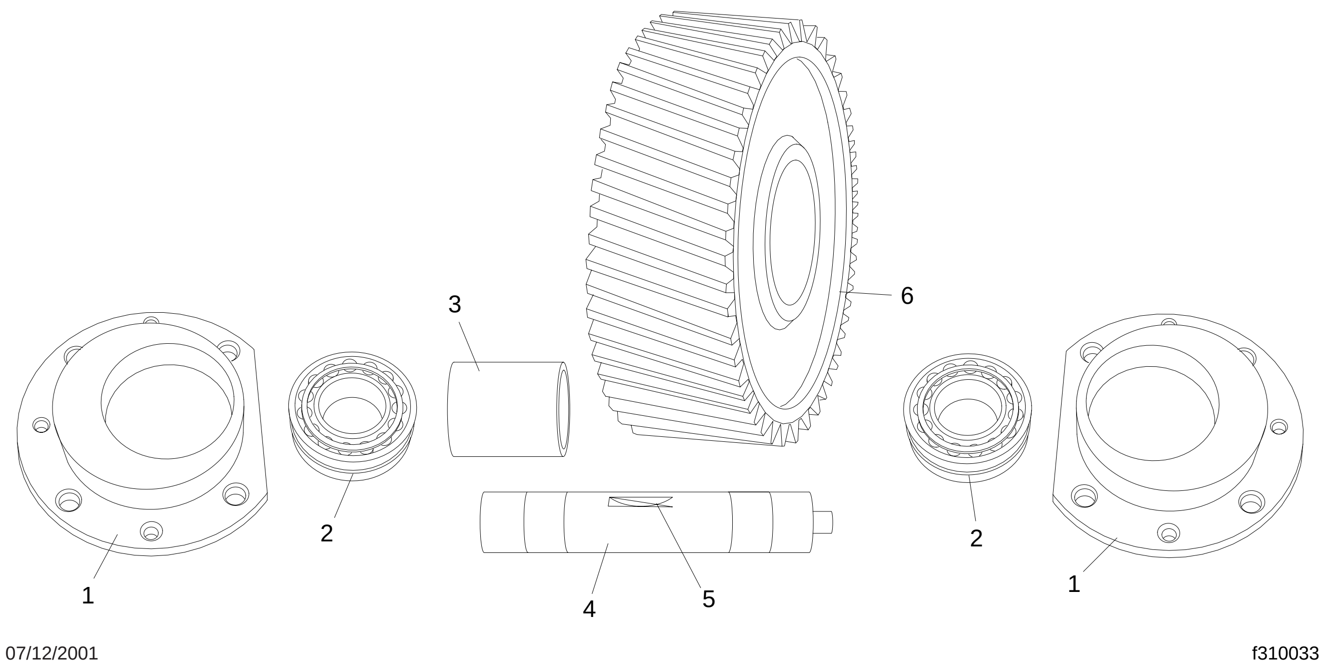
NOTE: When rebuilding the gearbox, replace all seals, bearings, and gaskets. Care must be taken, as most of the components of the gearbox use O-ring type seals (not gaskets) that can be easily damaged. Petroleum jelly can be used as a lubricant to ease the assembly process. Gasket cements or glues are not required.

1. Install the intermediate shaft. Place the intermediate gear in position. Install the key in the intermediate shaft and slide the intermediate shaft through the gear from the front of the gearbox. Install the spacer. Install the front bearing cover and tighten the bolts to 28 lbf·ft (38 N·m). Install the rear bearing cover and tighten the bolts. Check the intermediate shaft assembly for ease of rotation.
2. Install the main drive gear through the opening in the side of the gearbox. Install the drive gear bearings on the input shaft and slide the input shaft through the main drive gear from the rear to the front. Attach the bearing retainer and shift gear to the main drive gear and tighten the bolts. Slide the spacer on the input shaft from the front of the gearbox.
3. Install the front bearing retainer and tighten the bolts to 28 lbf·ft (38 N·m).
4. Install the input shaft yoke and tighten the new locknut 200 lbf·ft (271 N·m).
5. Install shift shaft O-ring into case.
6. Install the shift rod, shift fork, and sliding shift gear from the rear of the gearbox. See **Fig. 11**.
7. Install the retaining rings. Install the shift indicator switches.

NOTE: The output housing Allen-head attaching bolts are two different lengths. Be sure to install the short bolt in the correct location.

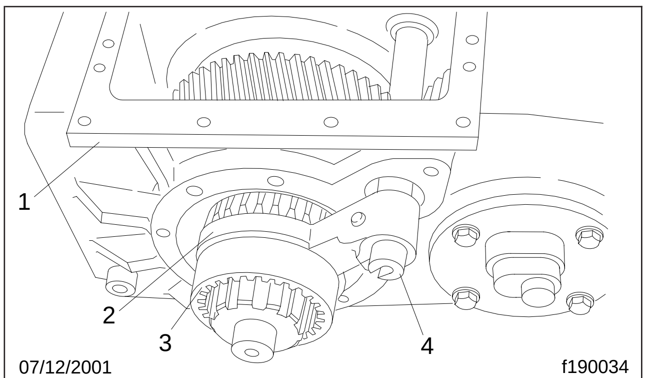
8. Install the output housing assembly. Slide the output housing assembly over the input shaft, being careful not to damage the pilot bearing. Install the attaching bolts and tighten them to 28 lbf·ft (38 N·m).
9. Install the air shift cylinder and tighten the bolts to 10 lbf·ft (13 N·m).
10. Install the rear bearing cover and bearing for the impeller shaft. Tighten the bolts to 28 lbf·ft (38 N·m).
11. Install the impeller shaft assembly from the front to the rear.

Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation



1. Intermediate Shaft End Cap
2. Bearing
3. Spacer
4. Intermediate Shaft
5. Keyway
6. Intermediate Gear

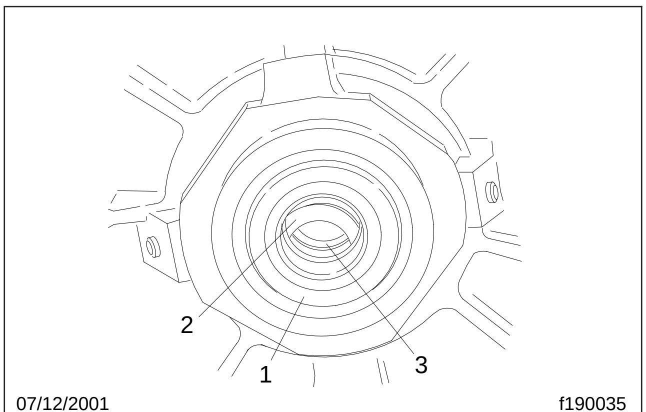
Fig. 10, Intermediate Shaft and Related Components



1. Gearbox
2. Shift Fork
3. Sliding Shift Gear
4. Shift Rod

Fig. 11, Sliding Gear Installation

12. Install the side cover on the gearbox with a new gasket and tighten the bolts to 22 lbf·ft (30 N·m).
13. Install the oil seal in the volute housing. If the slinger was removed, install a new slinger. See **Fig. 12**.



1. Front Impeller Bearing
2. Slinger
3. Oil Seal

Fig. 12, Volute Housing (rear view)

14. Carefully slide the volute housing over the impeller shaft. Align the slinger with the impeller shaft. Align the front impeller shaft bearing with the cavity in the rear of the volute housing and slide together. Install the attaching bolts with spacers and tighten the bolts to 70 lbf·ft (95 N·m).

Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

IMPORTANT: Extreme care MUST be taken when installing the volute housing on the impeller shaft to prevent damage to the oil seal.

15. Install the mechanical seal seat in the volute housing. See **Subject 110**.
16. Install the impeller, clearance rings, suction head, and Y-adapter. See **Subject 120**.
17. Install the gearbox cooler and connect the cooling lines.

Installation

1. Apply Loctite® 242 to the discharge manifold attaching bolts (3/8–16 bolts). Tighten them to 40 lbf·ft (54 N·m).
2. Clean the intake Y-adapter and install a new seal. The seal may be lubricated with petroleum jelly to ease installation.Install the intake Y-adapter.
3. Install the intake Y-adapter being careful not to damage the seal. Apply Loctite 242 to all studs and install the eight 3/8–24 nuts. Tighten them to 30 lbf·ft (41 N·m).
4. Connect the pump master drain.
5. Connect the electrical switches.
6. Connect the air lines to the shift cylinder.
7. Connect the driveshafts. Tighten the yoke fasteners to 225 lbf·ft (305 N·m). Tighten the bearing retaining strap capscrews to 40 to 48 lbf·ft (54 to 65 N·m).
8. Fill the gearbox with the necessary lubricant.
9. Fill the pump with water, test, and check for leaks.
10. Remove the chocks from the front and rear tires.

Replacement

CAUTION

DO NOT TOUCH the sealing surfaces of the seal as contamination will result in premature failure.

WARNING

Many of the components on the fire pump are heavy and awkward to handle. Always use the proper support equipment during removal and installation of the fire pump. Failure to do so could result in an assembly falling which could result in personal injury or property damage.

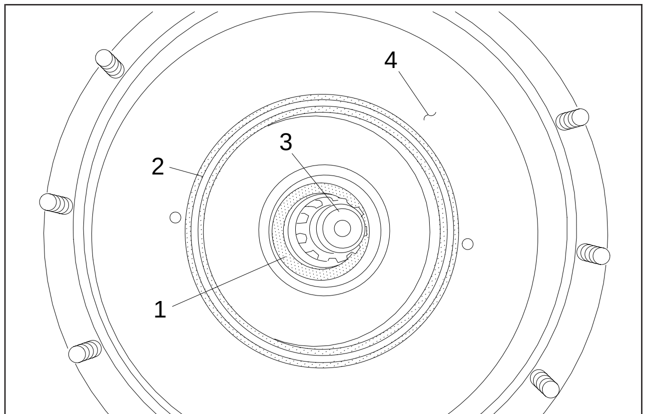
1. Drain the water from the pump.
2. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.

NOTE: If the clearance rings are not defective, they do not need to be replaced when replacing the mechanical seal.

3. Remove the pump impeller. See **Subject 120**.

NOTE: The mechanical seal is exposed once the impeller is removed.

4. Remove the mechanical seal from the impeller shaft, being careful not to damage the impeller shaft. See **Fig. 1**.
5. Remove the volute housing from the gearbox.
   - 5.1 Secure the pump gearbox to prevent it from shifting position.
   - 5.2 Remove the three 1/2–13 x 2 bolts that connect the volute housing to the pump gearbox.
   - 5.3 Separate the volute housing from the pump gearbox.
6. Lay the volute housing front side down. With a 1/4-inch diameter roll pin punch, push the mechanical seal seat out of the seal box.



1. Mechanical Seal
2. Rear Clearance Ring
3. Impeller Shaft
4. Volute Housing

Fig. 1, Volute Housing (impeller removed)

CAUTION

The use of any petroleum product to lubricate the mechanical seal will result in damage to the mechanical seal.

7. Clean the impeller shaft with a fine Scotchbrite pad. Wipe off the impeller shaft, then lubricate it with a mixture of water and liquid soap.

NOTE: If the oil seal in the volute housing is damaged in the process of removing the mechanical seal seat, install a new oil seal.

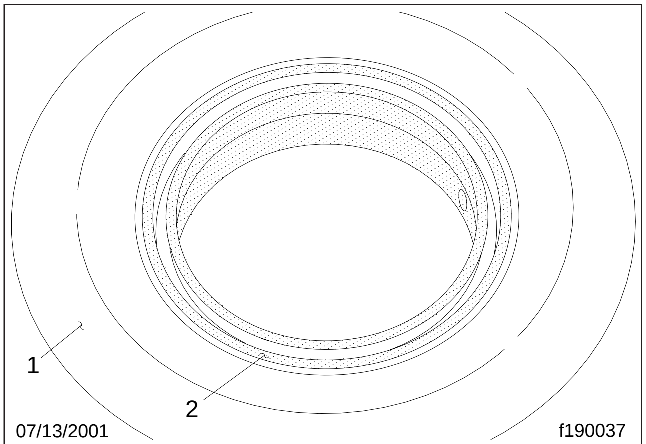
8. Install the volute housing.
   - 8.1 Carefully slide the volute housing over the impeller shaft.
   - 8.2 Align the slinger with the impeller shaft.
   - 8.3 Align the front impeller shaft bearing with the cavity in the rear of the volute housing, then slide them together.
   - 8.4 Install the attaching bolts, with spacers, then tighten the bolts to 70 lbf·ft (95 N·m).

CAUTION

The use of any petroleum product to lubricate the mechanical seal will result in damage to the mechanical seal.

Mechanical Seal Replacement

9. Lubricate the new seal seat with a mixture of water and liquid soap, then slide it on the impeller shaft and seat it in the mechanical seal box. See **Fig. 2**.



1. Oil Seal
2. Mechanical Seal Seat

Fig. 2, Volute Housing (rear view)

10. Lubricate the mechanical seal, then carefully slide it on the impeller shaft until it bottoms against the seal seat.
11. Install the pump impeller. See **Subject 120**.
12. Fill the pump with water, check the oil, and run the pump. Inspect it for leaks.

Impeller and Clearance Ring Removal and Installation

Removal

⚠ WARNING

Many of the components on the fire pump are heavy and awkward to handle. Always use the proper support equipment during removal and assembly of the fire pump. Failure to do so could result in an assembly falling which could result in personal injury or property damage.

For a cross-sectional view of the pump, see **Fig. 1**.

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Drain the water from the pump.
3. Disconnect the intake extension pipes by removing the bolts in both victaulic couplings, separating the halves of the victaulic couplings, then sliding the sealing donuts on the extension tubes.
4. Disconnect the gearbox cooler line from the suction head and the gearbox cooler.
5. Remove the intake Y-adapter by removing the eight 3/8– 24 nuts that secure it to the suction head. See **Fig. 2**.
6. Remove the suction head housing by removing the twelve 3/8 x 24 nuts. Carefully remove the suction head.
7. Remove the stainless steel cotter pin from the nut that secures the impeller on the impeller shaft. Remove the nut and impeller shaft washer. See **Fig. 3**.
8. Grasp the impeller and slide it off the impeller shaft. If the impeller is tight on the impeller shaft, install two bolts in the jack bolt holes, tighten the bolts evenly, and push the impeller off of the impeller shaft.
9. To remove the front clearance ring (located in the suction head) block the suction head up on two blocks of wood. Then using a small ball peen hammer and small diamond chisel, drive the clearance ring out. See **Fig. 4**.
10. To remove the rear clearance ring (located in the volute housing), use the same small ball peen hammer and small diamond chisel and drive the clearance ring out. See **Fig. 5**.

NOTE: When removing clearance rings be careful not to damage the clearance ring seating areas in both the suction head and volute housing.

11. Clean the seating areas for the clearance rings.

Installation

NOTE: Freezing the clearance rings prior to installation will greatly enhance installation and reduce the chances of damaging the clearance rings.

⚠ WARNING

The clearance ring is soft brass. Therefore, driving the clearance ring into place with a solid object will result in a damaged and distorted clearance ring that will damage the impeller.

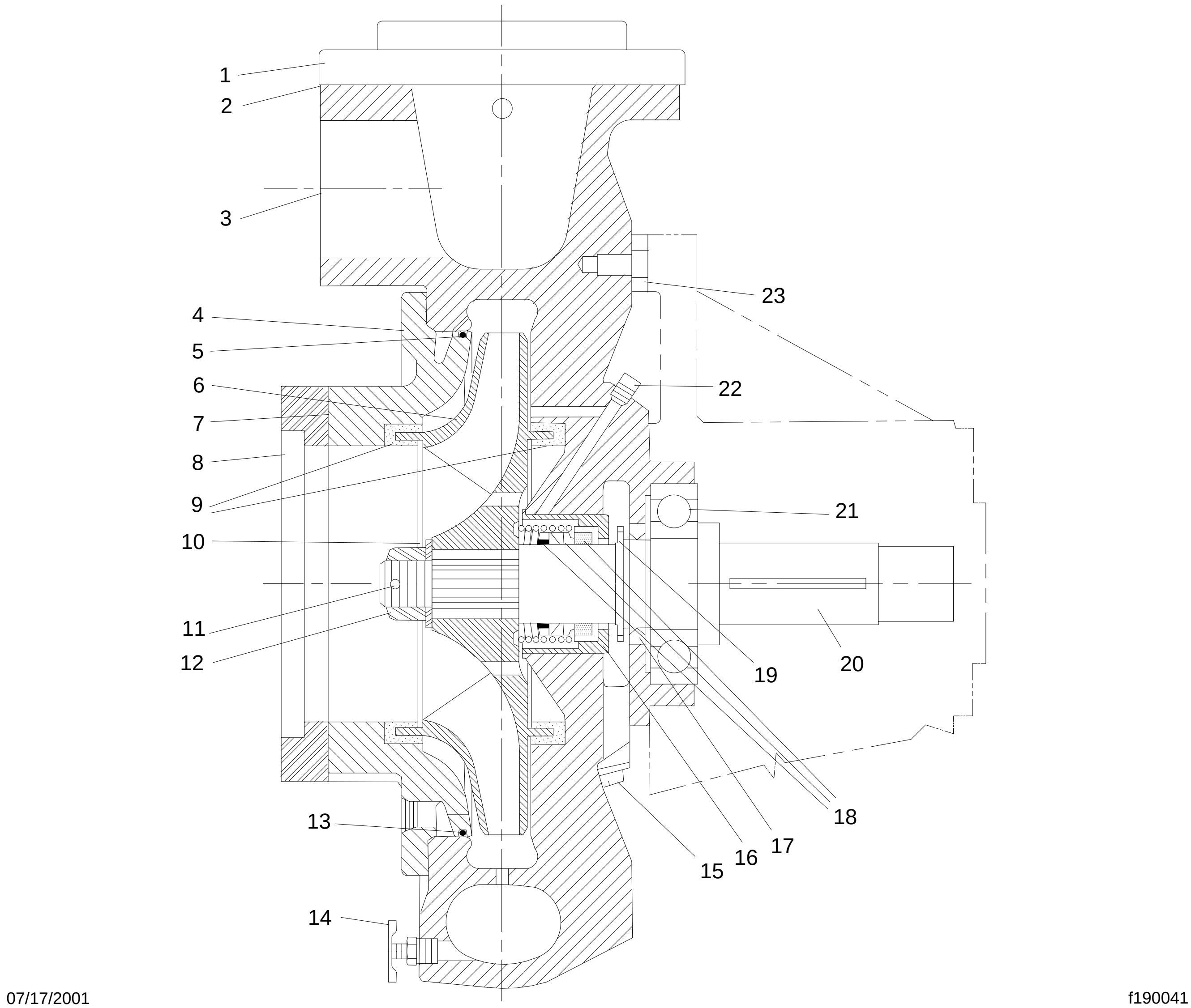
NOTE: When installing the clearance rings, be careful to install them square with the clearance ring seat.

1. Using a soft hammer, tap the clearance ring into place. Be sure the clearance ring seats fully and is square with the clearance ring seat.
2. Clean the impeller shaft.
3. Carefully side the impeller on the impeller shaft until it bottoms in the inner clearance ring.
4. Install the impeller shaft washer (bevel side out).
5. Install the impeller shaft nut. While tightening the impeller shaft nut, align the cotter pin hole. Tighten it to 50 lbf·ft (68 N·m).

IMPORTANT: You must use a stainless steel cotter pin to prevent electrolysis of fastening components, resulting in damage to pump components.

6. Install a new stainless steel cotter pin.
7. Clean the suction head, then install new seals, after lubricating the seals with petroleum jelly to ease installation.
8. Install the suction head, being careful not to damage the seals. Apply Loctite® 242 to all studs, then install the twelve 3/8–24 nuts. Tighten them to 30 lbf·ft (41 N·m).

Impeller and Clearance Ring Removal and Installation

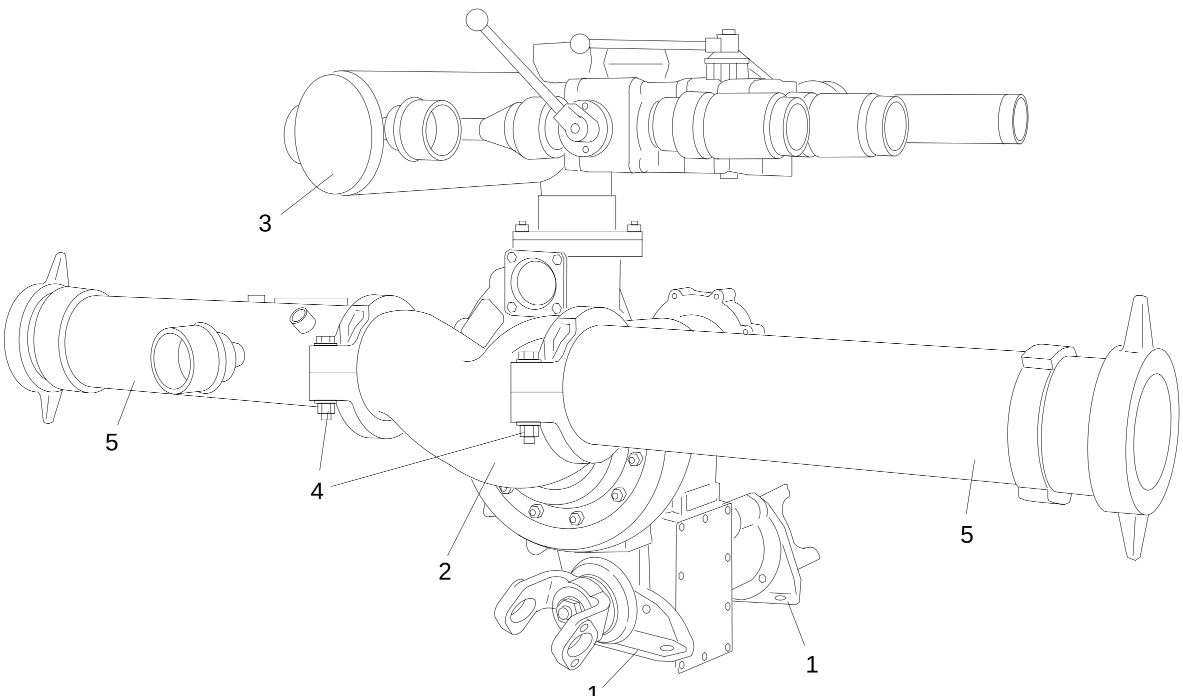


1. Discharge Flange
2. Discharge Gasket
3. Volute
4. Suction Head
5. Suction Head O-Ring
6. Impeller
7. Suction Flange Gasket
8. Suction Flange
9. Clearance Ring
10. Impeller Shaft Washer (beveled)
11. Cotter Pin
12. Impeller Nut
13. Heater Chamber O-Ring
14. Drain Cock
15. Packing Hole Plug
16. Mechanical Seal Box
17. Impeller Shaft Oil Seal
18. Mechanical Seal
19. Water Slinger
20. Impeller Shaft
21. Impeller Shaft Bearing
22. Plug, 1/8 NPT
23. Gearbox Spacer

Fig. 1, PowerFlow Fire Pump (cross-sectional view)

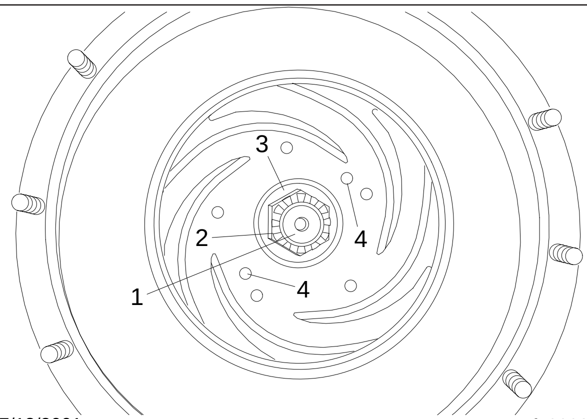
9. Clean the intake Y-adapter, then install a new seal after lubricating the seal with petroleum jelly to ease installation.

Impeller and Clearance Ring Removal and Installation



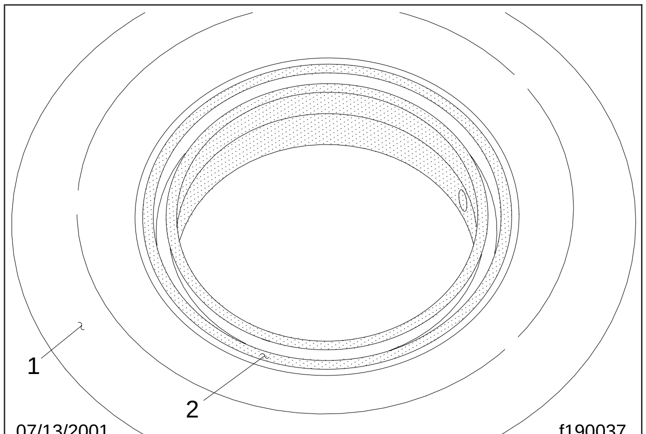
1. Mounting Brackets
2. Intake Y-Adapter
3. Discharge Manifold
4. Victaulic Couplings
5. Extension Tubes

Fig. 2, American LaFrance PowerFlow Fire Pump



1. Impeller Shaft
2. Impeller Retaining Nut
3. Beveled Washer
4. Jack Bolt Holes

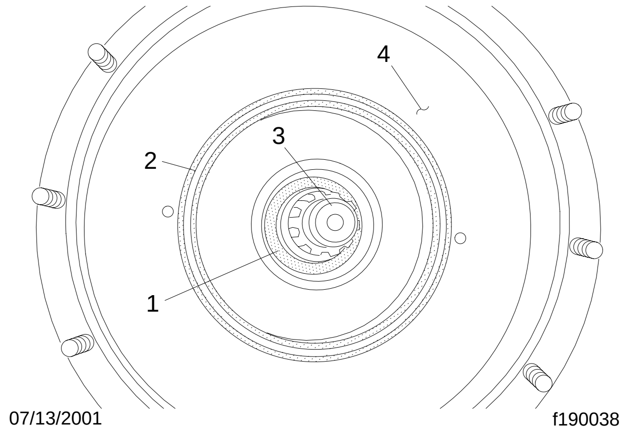
Fig. 3, Impeller and Related Components



1. Suction Head
2. Front Clearance Ring

Fig. 4, Suction Head (rear view)

Impeller and Clearance Ring Removal and Installation



1. Mechanical Seal
2. Rear Clearance Ring
3. Impeller Shaft
4. Volute Housing

Fig. 5, Volute Housing (impeller removed)

10. Install the intake Y-adapter, being careful not to damage the seal. Apply Loctite 242 to the eight 3/8–24 nuts. Install and tighten them to 30 lbf·ft (41 N·m).
11. Slide the extension tubes in until they meet the intake Y-adapter. Slide the sealing donuts on the intake Y-adapter until they are evenly spaced on both the extension tubes and the intake Y-adapter.
12. Install both halves of the victaulic coupling around the sealing donut. Install and tighten the clamping bolts. Repeat the procedure for the other side.

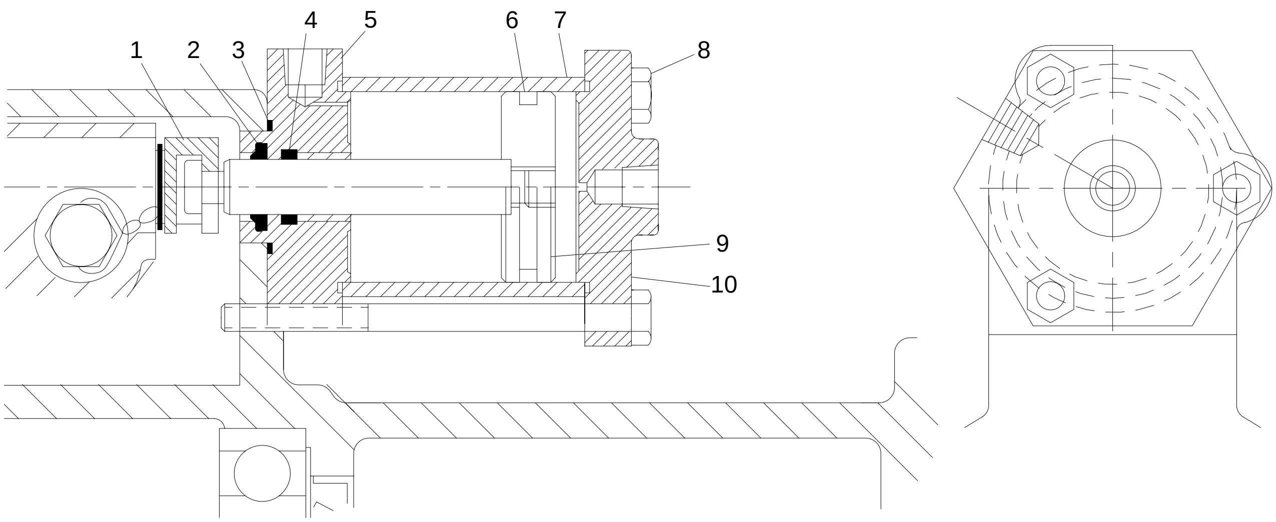
NOTE: Impeller and/or clearance ring replacement will necessitate a complete pump service test as detailed in NFPA 1911, Standard for Service Tests of Fire Pump Systems on Fire Apparatus.

13. Fill the pump with water, run it, and inspect it for leaks.
14. Remove the chocks.

Overhaul

NOTE: The air cylinder is three separate pieces; cylinder head, cylinder end, and cylinder. All of the separate pieces are held together by three bolts. During this procedure care must be taken as these components will separate when the bolts are removed. See **Fig. 1**.

5. Remove the air cylinder from the gearbox.
6. Check the cylinder and piston for damage, clean and replace all seals. Lubricate the seal with petroleum jelly for ease of assembly.
7. To reassemble the air cylinder, hold the cylinder head, cylinder end and cylinder together while sliding the piston rod into the shift rod yoke.



1. Yoke
2. Wiper Ring
3. O-Ring
4. Piston Rod O-Ring
5. Cylinder Head
6. Quad Ring Seal
7. Cylinder
8. Cylinder End Retaining Screw
9. Piston
10. Cylinder End

Fig. 1, Air Shift Cylinder (cut-away view)

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Drain the air from the air system.
3. Disconnect the air lines from the air shift cylinder. Mark the air lines for ease of reassembly.
4. Remove the three 5/16–18 bolts that secure the air cylinder to the gearbox.

NOTE: The piston rod in the air cylinder is notched and slides into a slotted yoke attached to the gearbox shift rod. The air cylinder must be shifted sideways to remove it from the shift rod yoke.

8. Apply Loctite® 242 to the three 5/16–18 screws and secure the air cylinder to the gearbox. Tighten them to 20 lbf·ft (27 N·m).
9. Reconnect the air lines to the air cylinder and test it.

Troubleshooting

Lack of use causes many problems for fire pumps and fire pump components.

IMPORTANT: The entire pumping system should be exercised weekly. This routine procedure should include all discharge valves and suction valves.

Abuse of the fire pump is rarely a problem. If the pump and pump components have been abused, indications of problems may be fairly obvious. For example, bent controls are a common indicator.

Simultaneous oil and water leaks are uncommon. Normally, a water leak indicates that a line has come loose or is broken. Gaskets are used between mating surfaces *without* sealant. If a leak is present at a gasket-mating surface, whether oil or water, the components should be disassembled and repaired.

Be certain when a device indicates it is not working that it is not a simple electrical problem, such as a burned-out indicator bulb.

Troubleshooting Tables

Problem—Pump Will Not Engage

Problem—Pump Will Not Engage	
Possible Cause	**Remedy**
Parking brake not set.	Set the parking brake.
Transmission not in neutral.	Shift transmission to neutral.
Insufficient air supply.	Repeat the recommended shift procedure: Check the air pressure gauges. This procedure requires at least 100 psi (689 kPa). Shut the engine down and check for air leaks.
Pump shift or application of parking brake attempted before apparatus was stopped.	Release the braking system momentarily and repeat the recommended shift procedure. *

* This condition is known as "Butt Tooth," which occurs when the transmission shifts and the shift gear-teeth and the teeth on the drive gear do not line up and "butt" up against each other. The American LaFrance fire pump transmission is designed with a sliding shift collar. Therefore, the occurrence of "Butt Tooth" will be rare.

Problem—Pump Will Not Shift

Problem—Pump Will Not Shift	
Possible Cause	**Remedy**
Battery voltage low.	Turn off accessories. Check the charging system of the apparatus. Inspect the batteries. If okay, recharge and try shift again.
Interface/Interlock module not receiving proper inputs.	Check the Officers Information Center output.
Transmission not receiving lock-up input.	Check output to transmission with Prolink.

Problem—Pump Will Not Prime

Problem—Pump Will Not Prime	
Possible Cause	**Remedy**
Low battery voltage.	Increase the engine speed 1000 to 1200 rpm for temporary support for electrical system requirements and primer operation. *
Worn or damaged priming system.	Perform the "Dry Vacuum Test," which follows the troubleshooting tables in this subject. If pump is tight but primer develops less than 22 inches of vacuum, the primer pump, motor, or priming valve may be worn or damaged.

Troubleshooting

Problem—Pump Will Not Prime	
Possible Cause	**Remedy**
Primer not operated long enough.	Operate for 30 seconds for pump up to 1250 gpm or for 45 seconds for 1500 and up gpm pump. Add 15 additional seconds if priming from front or rear suction. Do not run primer over 45 seconds. Stop and check for causes.
Suction lifts too high.	Do not attempt lifts exceeding 22 feet, except at low elevations.
Suction strainer blocked.	Check and clean.
Air pocket in suction hose or pump.	Place suction hose lower than suction intake. Slightly open a discharge valve momentarily to release trapped air.
Air leaks.	Perform the "Dry Vacuum Test," which follows the troubleshooting tables in this subject. Then, shut engine off and listen for air leaks. Pressurize the discharge side of the pump with approximately 100 psi (689 kPa) from the hydrant, and check for water leaks. Check connections and gaskets.

* Electric primer does not require engine speed to be increased for operation. A primer can and will draw in excess of 300 amps and primer operation can last 45 seconds.

Problem—Pump Loses Prime

Problem—Pump Loses Prime	
Possible Cause	**Remedy**
Suction lifts too high.	Do not attempt lifts exceeding 22 feet except at low elevations.
Suction strainer blocked.	Check and clean.
Air leaks.	Check all connections and gaskets. Perform the "Dry Vacuum Test," which follows the troubleshooting tables in this subject.
Pump pressure is too low when discharge appliance is opened.	Prime the pump again. Raise pump pressure higher and open the discharge appliance slowly.

Problem—Pump Primer Does Not Operate Properly

Problem—Pump Primer Does Not Operate Properly	
Possible Cause	**Remedy**
Does not operate electrically.	Check the batteries, connections, primer, and primer control. Check the control switch and solenoid on the primer. If the primer has not been used recently, it could be frozen. It should, if contact is still being made internally, show heavy current draw.
Primer is slow or lower than normal.	Check batteries, wiring, and connections. A large quantity of suction hoses or suction pipes can exceed primer capabilities. Too small diameter, or too long a length of piping between primer and pump can exceed primer capabilities. Lift not to exceed 20 feet (6 m), and 10 feet (3 m) for testing. The primer pump itself may be worn out.
Pulls some prime.	The primer pump could be in need of repairs or cleaning. Check for air leaks, and verify that the priming valve is not sticking.
Pulls full prime.	Check for air leaks. Check for clogged inlet strainer and screens. Check that the suction hose is submerged in adequate water supply. Check for air pockets and air accumulation in piping. Check for turbulence in piping. The pump impeller may be damaged or severely worn.

Problem—Insufficient Capacity or Pressure

Problem—Insufficient Capacity or Pressure	
Possible Cause	**Remedy**
Insufficient engine power.	Check engine performance.
Improperly set relief valve.	Readjust the relief valve to a higher pressure setting. If the relief valve is set too low it will open to relieve pressure and reduce capacity.
Transmission in incorrect range.	Check the transmission selector for correct range recommended for pumping procedure. Check that the fourth range lockup has occurred. If the transmission shifts while increasing engine speed, lock up has not occurred. Check engine speed or driveshaft speed for correct transmission range and inaccurate tachometer.
Air leaks.	Perform the "Dry Vacuum Test," which follows the troubleshooting tables in this subject.
Transfer valve in incorrect position.	Transfer valve must be in the "parallel or volume" setting for capacity, or in the "series or pressure" setting for pressure. The transfer valve indicator may be out of adjustment. At idle, shift the transfer valve back and forth. You should hear the check valves close, and see a change in pressure on the master pressure gauge.
Tank fill valve leaking.	Repair the leak.

Problem—Engine Speed Too High for Capacity or Pressure

Problem—Engine Speed Too High for Capacity or Pressure	
Possible Cause	**Remedy**
Impeller blockage.	Check and clean. Backflushing through the discharge side of the pump may clear the obstruction. It may require disassembly of the pump.
Worn impeller or clearance rings.	Overhaul the pump. All other possibilities should be eliminated before overhauling the pump.
Suction strainer blocked.	Clean and check.
Lift too high.	Lifts over 10 feet will cause higher engine speeds and vacuum.
Transmission in incorrect range.	Check the transmission selector for correct range for recommended pumping procedure. Check that fourth range lockup has occurred. If the transmission shifts while increasing engine speed, lock up has not occurred. Check engine speed or drive shaft speed for correct transmission range and inaccurate tachometer.
Check valves damaged or missing.	At idle, shift the transfer valve back and forth. You should detect a change in the engine/pump sound, hear the check valves close, and see a change in the pressure on the master pressure gauge. If no apparent change occurs, remove the suction inlet cap and inspect the check valves. Insert a broom handle in the suction inlet and gently push each check valve open and let it close. Check valves should move freely.
Tank fill valve leaking.	Repair the leak.

Troubleshooting

Problem—Relief Valve Does Not Relieve When Valves are Closed

Problem—Relief Valve Does Not Relieve When Valves are Closed	
Possible Cause	**Remedy**
Incorrect pilot valve setting.	Repeat the proper procedure for setting the relief valve.
Pilot valve inoperative.	Disassemble, clean, and lubricate. Inspect the control valve diaphragm for wear or damage.
Relief valve inoperative.	Disassemble, clean, and lubricate.

Problem—Relief Valve Does Not Recover When Valves are Opened

Problem—Relief Valve Does Not Recover When Valves are Opened	
Possible Cause	**Remedy**
Dirt in system resulting in slow or sticky operation.	Disassemble, clean, and lubricate.

Problem—Unable to Attain Proper Setting

Problem—Unable to Attain Proper Setting	
Possible Cause	**Remedy**
Incorrect procedure.	Check procedure and reset.
Blocked strainer.	Disconnect the pilot valve supply line from the discharge side of pump. Remove the 90-degree fitting where the supply line connects to the pump. The strainer is attached to this fitting. Clean or replace the strainer and fitting assembly.
Dirt in pilot valve.	Disassemble, clean, and lubricate.
Hunting condition.	Insufficient water supply to the pilot valve. Check strainer and supply lines. If there is dirt in the pilot valve, disassemble, clean, and lubricate.

Problem—TPM Valve Does Not Relieve

Problem—TPM Valve Does Not Relieve	
Possible Cause	**Remedy**
Sensing valve inoperative.	Disassemble, clean, and lubricate. Inspect the control valve diaphragm for wear or damage.
PG relief valve inoperative.	Disassemble, clean, and lubricate.
PG relief valve sluggish.	Check and clean the discharge and suction strainers in the pump body.

Problem—Mechanical Seal Leaks

Problem—Mechanical Seal Leaks	
Possible Cause	**Remedy**
Leak at mechanical seal.	If the mechanical seal is leaking it will have to be replaced. If properly cared for, the mechanical seal should be almost maintenance free. Water quality will greatly affect seal life. The most common failure of the mechanical seal is from thermal-shock (running the pump dry, heating up the seal, then opening to a cool or cold water supply); the seal may shatter.

Problem—Pump Gear Box Does Not Function Properly

Problem—Pump Gear Box Does Not Function Properly	
Possible Cause	**Remedy**
Water in gear box.	Locate and repair the leak. Remove and clean the gear box filter. Replace the transmission oil. Water leaking onto the input drive shaft of the pump gear box will actually be screwed into the pump transmission past the oil seals. This is not a seal problem. Be certain the slinger(s) are in place. Check the pump gear box cooling line for internal fractures. Pump gear box will fill with water and overflow through breather.
Whine in gear box.	Check the oil level. If oil is low, helical gears and/or tapered bearings will whine. Check oil pressure. If the filter is clogged, oil pressure will be low. Drain oil and check for metal. Remove filter and check for metal. If metal is detected, pump gear box will have to be disassembled for complete inspection and repairs.
Knock or rattle in gear box.	Check for gears missing teeth. Check for damaged bearings. Disassemble and repair. *

* The cause may include foreign objects, low or contaminated oil, or low oil pressure. Low oil level or pressure will result in the transmission being damaged due to overheating.

Dry Vacuum Test

1. Open all the intake valves.
2. Cap all intakes, and close and uncap all discharge valves.
3. Using the pump's priming devices, develop a vacuum of at least 22 inHg (74.5 kPa) for 30 seconds for pumps up to 1250 gpm, or 45 seconds for pumps 1500 gpm or greater.

NOTE: Reduce the maximum vacuum attained by 1 inHg (3.4 kPa) for each 1000 ft (305 m) of elevation of the test site above 2000 ft (610 m).

4. The vacuum should not drop more than 10 inHg (33.9 kPa) in 5 minutes. Do not operate the pump priming device once the 5-minute test has begun.

Seat Removal and Installation

Removal

1. Park the vehicle, apply the brakes, and chock the tires.
2. Push the seat belt buckles back behind the seat.
3. Remove the bolt and spacer from the center seat belt where it is attached to the cab floor.
4. Remove the center shoulder harness and lap belt from the bench seat.

NOTE: The far-right rear fastener that attaches the bench seat support to the cab floor is also used to secure the windshield washer reservoir to the cab.

5. From under the cab, remove the nut that attaches the windshield washer reservoir to the cab. Support the washer reservoir while the bench seat is being removed.
6. From inside the cab, remove the capscrews that attach the bench seat supports to the cab floor.
7. Remove the seat from the cab.

Installation

1. Using capscrews, install the bench seat in the cab. Torque the capscrews 12 to 14 lbf·ft (16 to 19 N·m).
2. Using a nut, attach the windshield washer reservoir to the cab.
3. Install the center shoulder harness and lap belt.
4. Using the same bolt and spacer that were removed from the seat belt, attach the center seat belt to the cab floor. Torque the bolt 35 to 45 lbf·ft (47 to 61 N·m).
5. Push the seat belt buckles forward to the front of the seat back.
6. Remove the chocks from the tires.

General Information

WARNING

Inspect and maintain seat belts. When any part of a seat belt system needs replacement, the entire seat belt must be replaced, both retractor and buckle side. Any time a vehicle is involved in an accident, and the seat belt system was in use, the entire vehicle seat belt system must be replaced before operating the vehicle. Do not attempt to modify the seat belt system; doing so could change the effectiveness of the system. Failure to replace worn or damaged seat belts, or making any modifications to the system, may result in personal injury or death.

Although the three-point seat belts installed in Freightliner vehicles appear similar to the seat belts used in passenger cars, there are some important differences that can affect service life:

- A heavy truck can travel more miles in a year than a car might go in its lifetime.
- There is more movement in a truck seat belt system, especially with air ride seats.
- Trucks often operate in more severe environments than cars, such as gravel pits, cement plants, and grain elevators, where the belts are exposed to abrasive dirt and dust.

Because of these factors, truck seat belt systems need to be inspected regularly to ensure that they are in proper condition; see **Subject 100**.

IMPORTANT: When any part of a seat-belt system needs replacement, the entire seat-belt system must be replaced—both the retractor side and the buckle side and, if equipped, both tether belts.

Seat Belt and Tether Belt Inspection

Inspection

WARNING

Inspect and maintain seat belts. When any part of a seat belt system needs replacement, the entire seat belt must be replaced, both retractor and buckle side. Any time a vehicle is involved in an accident, and the seat belt system was in use, the entire vehicle seat belt system must be replaced before operating the vehicle. Do not attempt to modify the seat belt system; doing so could change the effectiveness of the system. Failure to replace worn or damaged seat belts, or making any modifications to the system, may result in personal injury or death.

Seat belts and tether belts have a finite life which may be much shorter than the life of the vehicle. Regular inspections and replacement as needed are the only assurance of adequate seat belt security over the life of the vehicle.

1. Check the web for fraying, cuts, extreme dirt and dust, or for severe fading from exposure to sunlight, especially near the buckle latch plate and in the D-loop guide area.
2. Check operation of the buckle, latch, Komfort Latch or Sliding Komfort Latch (if equipped), web retractor, and upper seat belt mount on the door pillar. Check all visible components for wear or damage.
3. Check the seat belt and tether belt connection points, and tighten any that are loose.

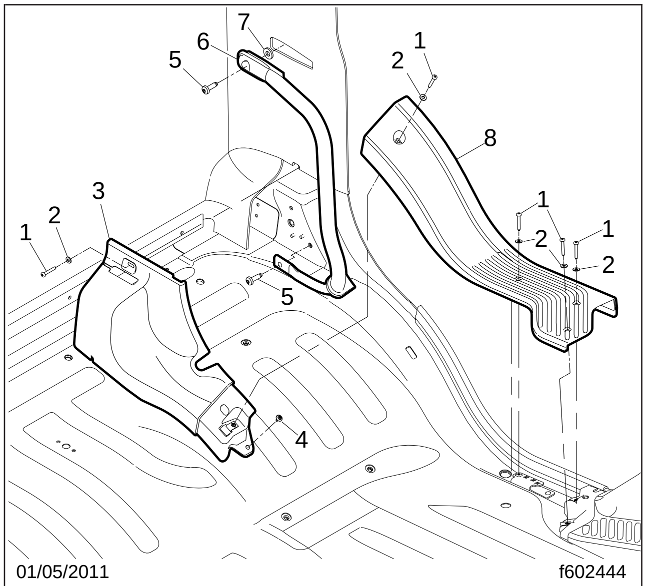
Seat Belt System Replacement

IMPORTANT: When any part of a seat-belt system needs replacement, the entire seat-belt system must be replaced—both the retractor side and the buckle side and, if equipped, both tether belts.

Any time a vehicle is involved in an accident, and the seat belt system was in use, the entire seat-belt system must be replaced before operating the vehicle.

Air Suspension Seat

1. Apply the parking brakes and chock the tires.
2. Remove the tread plate and the lower B-pillar cover, as follows.
   - 2.1 Remove the four screws and washers that attach the tread plate to the doorway and the lower B-pillar cover; see **Fig. 1**.
   - 2.2 Remove the screw that attaches the lower B-pillar cover to the doorway, and the screw and washer that attaches it to the B-pillar. Remove the B-pillar cover.
3. Disconnect the seat and tether belts from the seat by removing the capscrew from each end of the intermediate-connection-point (ICP) bar; see **Fig. 2**. Remove and discard the buckle side of the seat belt.
4. Remove the capscrews that attach the tether belts to the cab deck. Remove and discard the tether belts.
5. Remove the screw that attaches the seat-belt retractor to the lower B-pillar.
6. Remove the capscrews that attach the height adjuster to the upper B-pillar. Remove and discard the retractor side of the seat belt.
7. Install the height adjuster of the new seat belt on the upper B-pillar. Tighten the capscrews 35 to 45 lbf·ft (48 to 61 N·m).
8. Install the seat-belt retractor on the lower B-pillar. Tighten the screw 35 to 45 lbf·ft (48 to 61 N·m).
9. Attach the angle brackets of the new tether belts to the cab floor. Tighten the capscrews 35 to 45 lbf·ft (48 to 61 N·m).
10. On both sides of the seat, first place the tether bracket against the ICP bar, then place the seat-belt bracket on top of the tether bracket. Insert the capscrew through the brackets into the ICP bar. Tighten both capscrews 35 to 45 lbf·ft (48 to 61 N·m).
11. Install the lower B-pillar cover and the tread plate.



NOTE: LH shown.

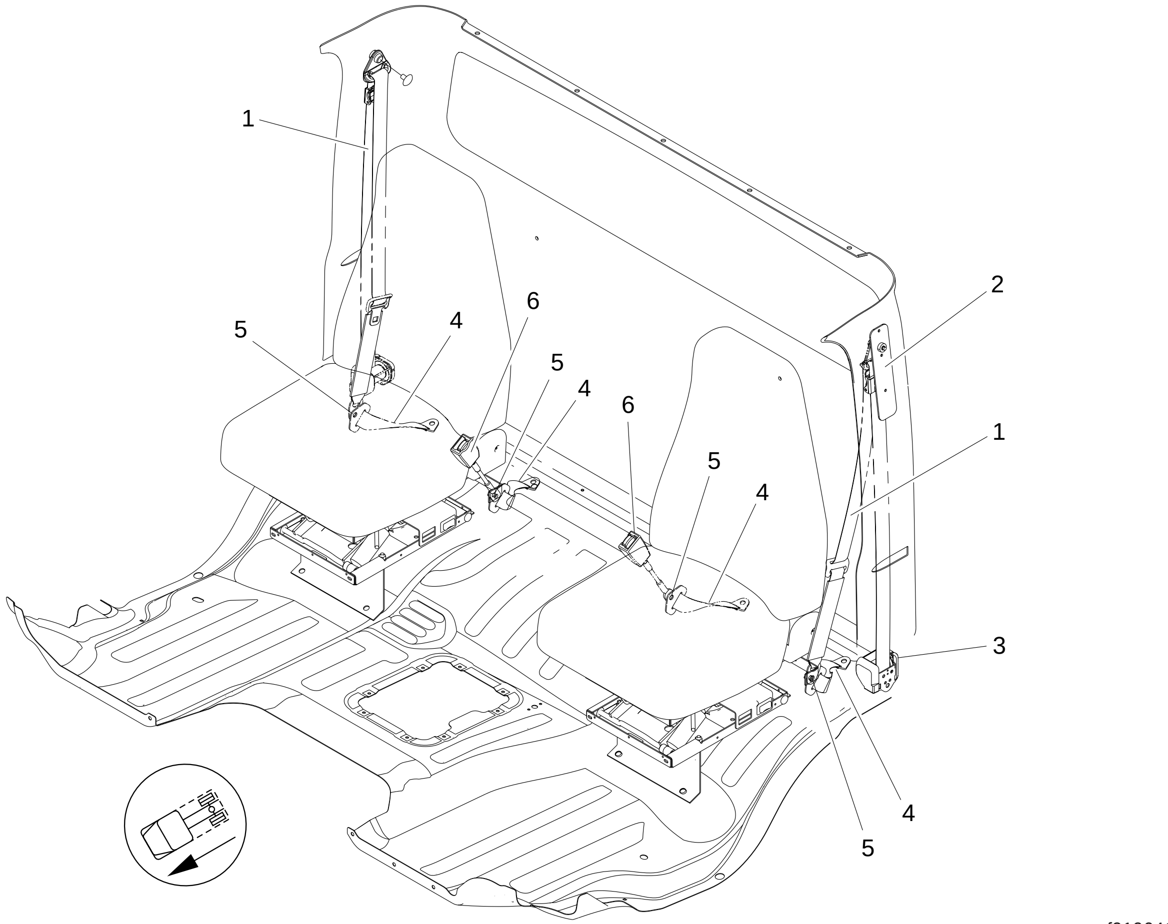
1. Dog Point Screw
2. Flatwasher
3. Lower B-Pillar Cover
4. Self-Tapping Screw
5. Capscrew, M8
6. Grab Handle
7. Washer
8. Tread Plate

Fig. 1, Tread Plate and Lower B-Pillar Cover Installation

Static Seat

1. Apply the parking brakes and chock the tires.
2. Remove the tread plate and the lower B-pillar cover, as follows.
   - 2.1 Remove the four screws and washers that attach the tread plate to the doorway and the lower B-pillar cover; see **Fig. 1**.
   - 2.2 Remove the screw that attaches the lower B-pillar cover to the doorway, and the screw and washer that attaches it to the B-pillar. Remove the B-pillar cover.

Seat Belt System Replacement



1. Seat Belt
2. Height Adjuster
3. Retractor
4. Tether Belt
5. Intermediate Connection Point (ICP)
6. Buckle

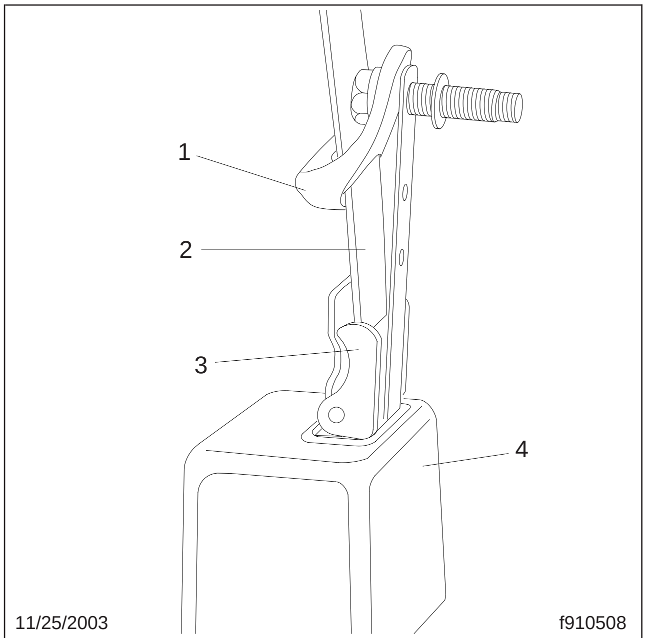
Fig. 2, Seat Belt Installation, Air Suspension Seats (typical)

3. Remove the capscrews that attach the seat-belt brackets to the cab deck. Remove and discard the buckle-side of the seat belt.
4. Remove the screw that attaches the seat-belt retractor to the lower B-pillar.
5. Remove the capscrews that attach the height adjuster to the upper B-pillar. Remove and discard the retractor side of the seat belt.
6. Install the height adjuster of the new seat belt on the upper B-pillar. Tighten the capscrews 35 to 45 lbf·ft (48 to 61 N·m).
7. Install the seat-belt retractor on the lower B-pillar. Tighten the screw 35 to 45 lbf·ft (48 to 61 N·m).
8. Attach both seat-belt brackets to the cab deck. Tighten the capscrews 35 to 45 lbf·ft (48 to 61 N·m).
9. Install the lower B-pillar cover and the tread plate.

Unlocking an Installed Retractor

Seat belt retractors are locking up and preventing the webbing from being extracted. This condition is known as reverse lock-up and is caused by excessive webbing spooling into the retractor before installation in the vehicle.

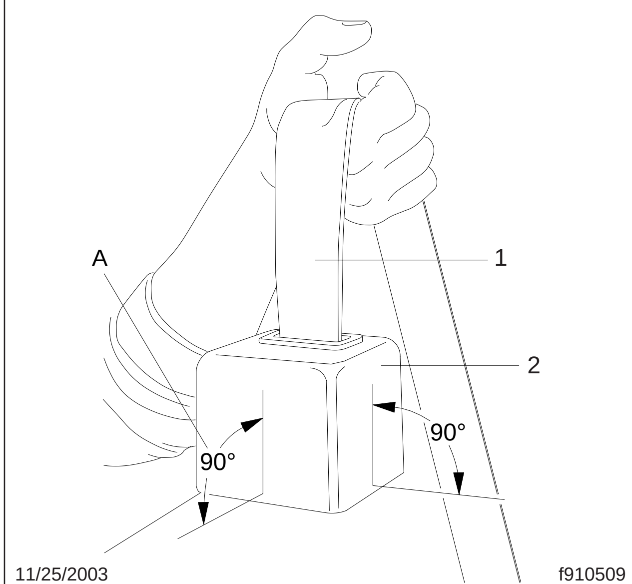
1. Park the vehicle, apply the parking brake, shut down the engine, and chock the front and rear tires.
2. Verify that the retractor is mounted in the 90-degree position. See **Fig. 1**.
3. Firmly grasp the web close to the retractor. See **Fig. 2**.



1. Web Guide Loop
2. Web
3. Komfort Latch®
4. Retractor Cover

Fig. 1, Retractor in the 90-Degree Position

4. Pull on the web with enough force to tighten the web onto the spool until the webbing locks back onto the retractor. The retractor should unlock when tension is released.
5. Remove the chocks from the tires.



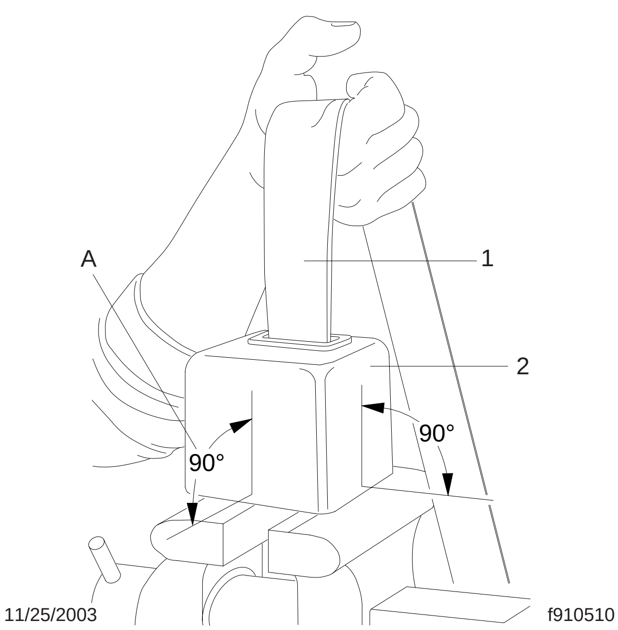
A. Orient the retractor at a 90-degree angle.
1. Web
2. Retractor Cover

Fig. 2, Firmly Grasp the Webbing

Unlocking an Uninstalled Retractor

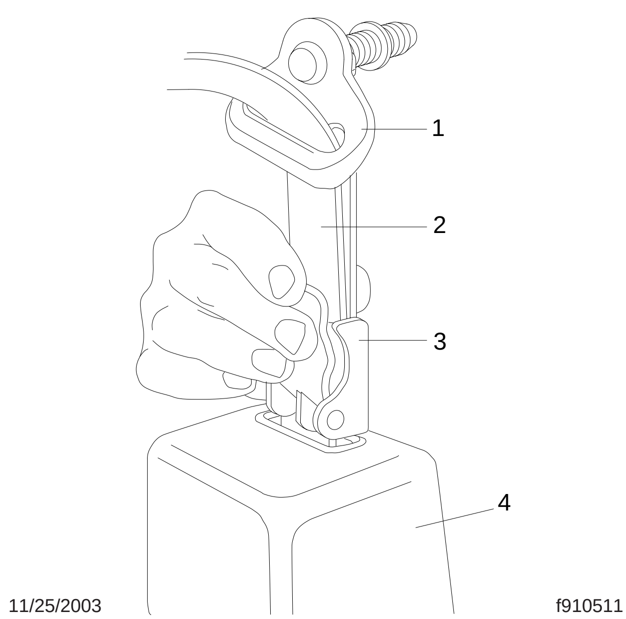
1. Clamp the retractor in a vice at a 90-degree angle. See **Fig. 3**.
2. Pull on the web with enough force to tighten the web onto the spool.
3. Release the web. This allows 1/2-inch (12.7-mm) of the webbing to feed back into the retractor storage housing and unlock the retractor.
4. Pull all the webbing out of the retractor, and allow only 12 to 15 inches (304 to 381 mm) to retract. Lock the Komfort Latch on the web. See **Fig. 4**.

Seat Belt Retractor Unlocking



A. Retractor oriented at a 90-degree angle.
1. Web
2. Retractor Cover

Fig. 3, Place the Retractor in a Vice



1. Web Guide Loop
2. Web
3. Komfort Latch
4. Retractor Cover

Fig. 4, Lock the Komfort Latch

Troubleshooting

WARNING

Inspect and maintain seat belts. When any part of a seat belt system needs replacement, the entire seat belt must be replaced, both retractor and buckle side. Any time a vehicle is involved in an accident, and the seat belt system was in use, the entire vehicle seat belt system must be replaced before operating the vehicle. Do not attempt to modify the seat belt system; doing so could change the effectiveness of the system. Failure to replace worn or damaged seat belts, or making any modifications to the system, may result in personal injury or death.

Replace the entire seat belt system if:

- the shoulder harness or lap belt is cut, frayed, or showing signs of extreme wear;
- the buckle and latch do not engage with a solid sounding click or do not release freely when the button is pressed;
- the retractor locks up at improper times or the lap belt or shoulder harness does not move freely to and from the retractor when the vehicle is not moving. Whether the seat belt is fastened or not, the retractor should not lock unless the seat belt is jerked;
- the shoulder harness or lap belt has been exposed to extreme sun light, dust, or dirt, causing the webbing color to fade and deteriorate the strength of the webbing;
- the plastic around the buckle is deformed, cracked, or broken exposing the internal mechanism;
- the retractor cover is cracked or broken exposing the internal mechanism or stored webbing;
- the metal or plastic area of the latch is deformed, cracked, corroded, or broken;
- the D-loop is deformed, cracked, or broken.

For seat belt replacement instructions, see **Subject 110**.

Replace, adjust, or tighten as necessary if:

- the tethers are missing, extremely loose, or are not attached to the seat;
- the D-loop webbing guide does not rotate freely;
- the hardware is missing, rusted, corroded, or damaged;
- the hardware is not tight.

Replace hardware with only Freightliner authorized parts.

Specifications

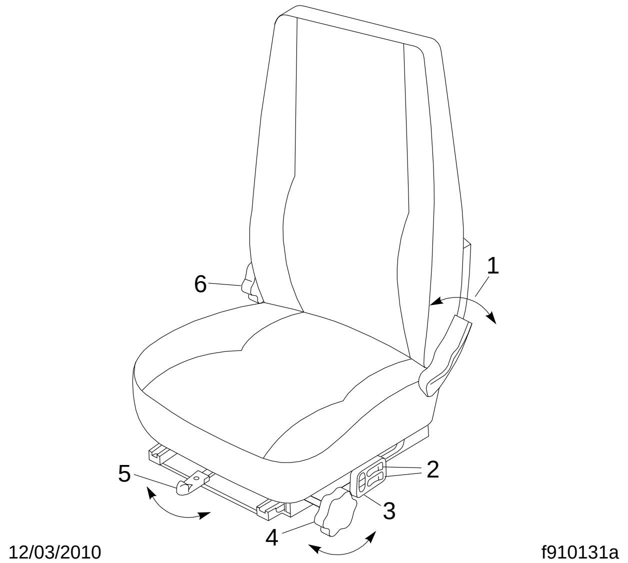
Unless listed in **Table 1**, tighten all fasteners using the torque specifications found in **Section 00.04**.

Torque Specifications		
Fastener Description	**lbf·ft**	**N·m**
Height Adjuster Mounting Screws	35–45	48–61
Seat Belt Retractor Mounting Screw		
Tether Belt Angle Bracket Screws		
Intermediate-Connecting-Point (ICP) Bar Screws		

Table 1, Torque Specifications

General Information

Bostrom T-Series air suspension seats offer weight/height adjustment, infinite adjustment Parabar II® lumbar support, and a fore-and-aft roller-track isolator system. See **Fig. 1**.



1. Back Rest Tilt Lever
2. Lumbar Support Switches (optional)
3. Height Adjustment Switch
4. Seat Cushion Tilt Knob
5. Fore-and-Aft Seat Adjustment and Isolator Lever
6. Lumbar Support Knob (optional)

Fig. 1, Bostrom T-Series Air Suspension Seat

For complete operating instructions, refer to **Chapter 5** in the *Business Class M2 Driver's Manual* or the seat manufacturer's operating manual.

Removal

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Adjust the seat to the maximum height.
3. Remove the suspension shroud (if equipped) from the seat base.
4. To secure the seat suspension in the extended position, bind the two cross-rods together with a large tie strap, at either the top or bottom of the fully extended scissor arms.

NOTE: If the seat is removed for a suspension rebuild (**Subject 150**), use a spacer block instead of tie straps to secure the seat in the extended position.

5. Release the air pressure from the seat air spring.

CAUTION

Do not remove the seat without first draining the seat air spring, and holding the seat suspension extended by securing the cross-rods together at either the top or bottom of the fully extended scissor arms. If the seat suspension is not properly secured, the seat could lower unexpectedly, pinching a hand or finger between the suspension parts, resulting in personal injury.

6. Drain the vehicle air reservoirs.

WARNING

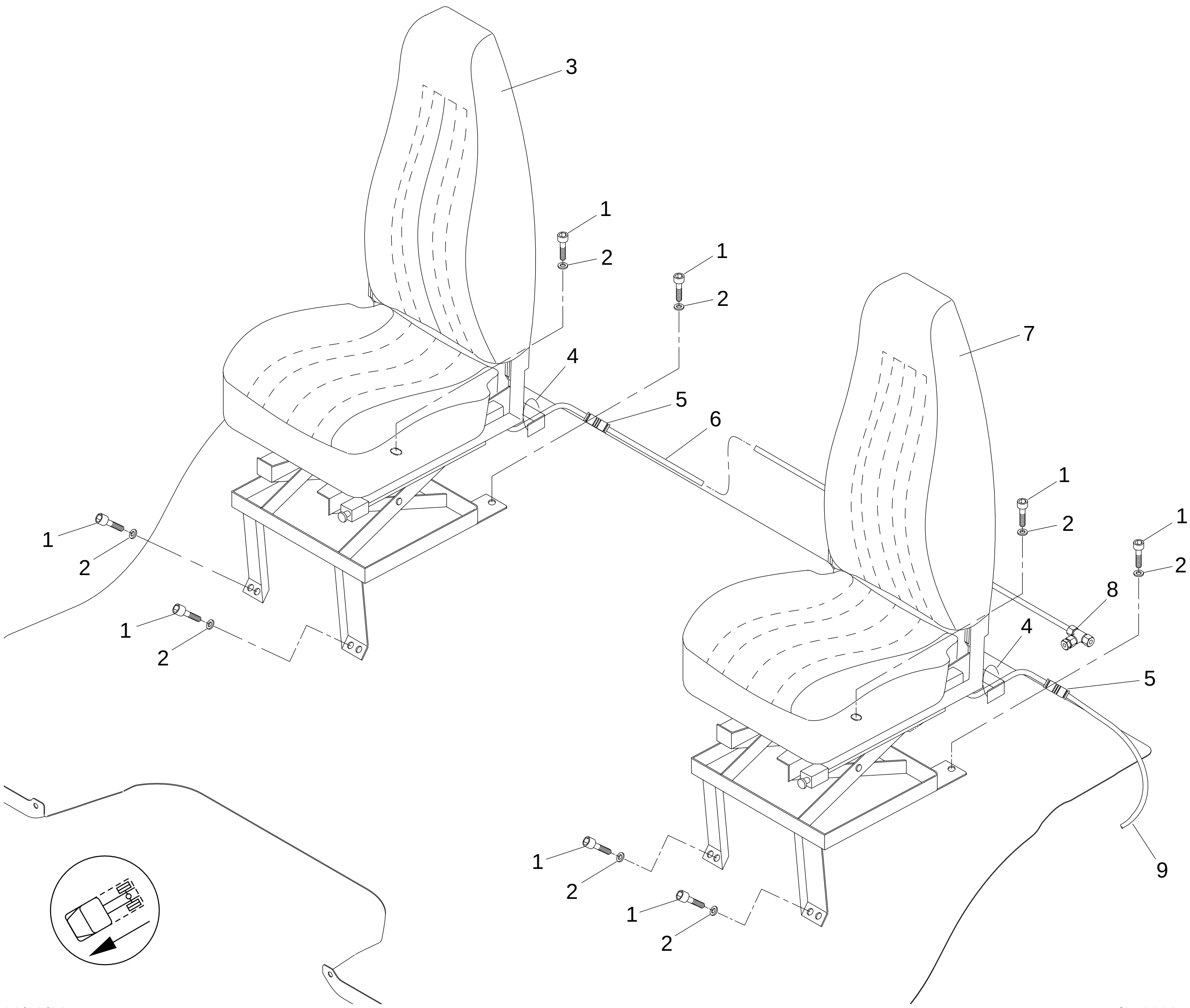
Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

7. If equipped with a seat heater, disconnect the power supply from the seat.
8. Disconnect the air valve air supply hose.
9. Remove the capscrews that attach the seat belt and tether belts to the intermediate-connection-point (ICP) bar.
10. Remove the capscrews and washers that attach the seat to the cab deck. Remove the seat from the cab. See **Fig. 1**.

Installation

1. Position the seat on the cab deck. Insert the capscrews through the washers and the seat base. See **Fig. 1**. Tighten the capscrews 25 to 29 lbf·ft (34 to 39 N·m).
2. Attach the seat belt and tether belts to the intermediate-connection-point (ICP) bar. Tighten the capscrews 35 to 45 lbf·ft (48 to 61 N·m).
3. Attach the air valve air supply hose.
4. If equipped with a seat heater, plug in the power supply to the seat.
5. Start the engine and allow the air reservoirs to fill. Adjust the seat to its maximum height, then remove the tie strap that binds either the top or bottom cross-rods together.
6. Install the suspension shroud (if equipped) on the seat base.

Seat Removal and Installation



1. Capscrew
2. Washer
3. Passenger Seat
4. Cable Tie
5. Union
6. Air Line (with passenger suspension seat only)
7. Driver Seat
8. Tee (with passenger suspension seat only)
9. Air Supply Line

Fig. 1, Seat Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Remove the seat from the vehicle; see **Subject 100**.
3. If not already done, secure the seat suspension in the extended position by binding the two cross-rods together with a large tie strap, at either the top or bottom of the fully extended scissor arms.

WARNING

Do not remove the seat without first draining the seat air spring, and holding the seat suspension extended by securing the cross-rods together at either the top or bottom of the fully extended scissor arms. If the seat suspension is not properly secured, the seat could lower unexpectedly, pinching a hand or finger between the suspension parts, resulting in personal injury.

4. Release the air pressure from the air spring.

WARNING

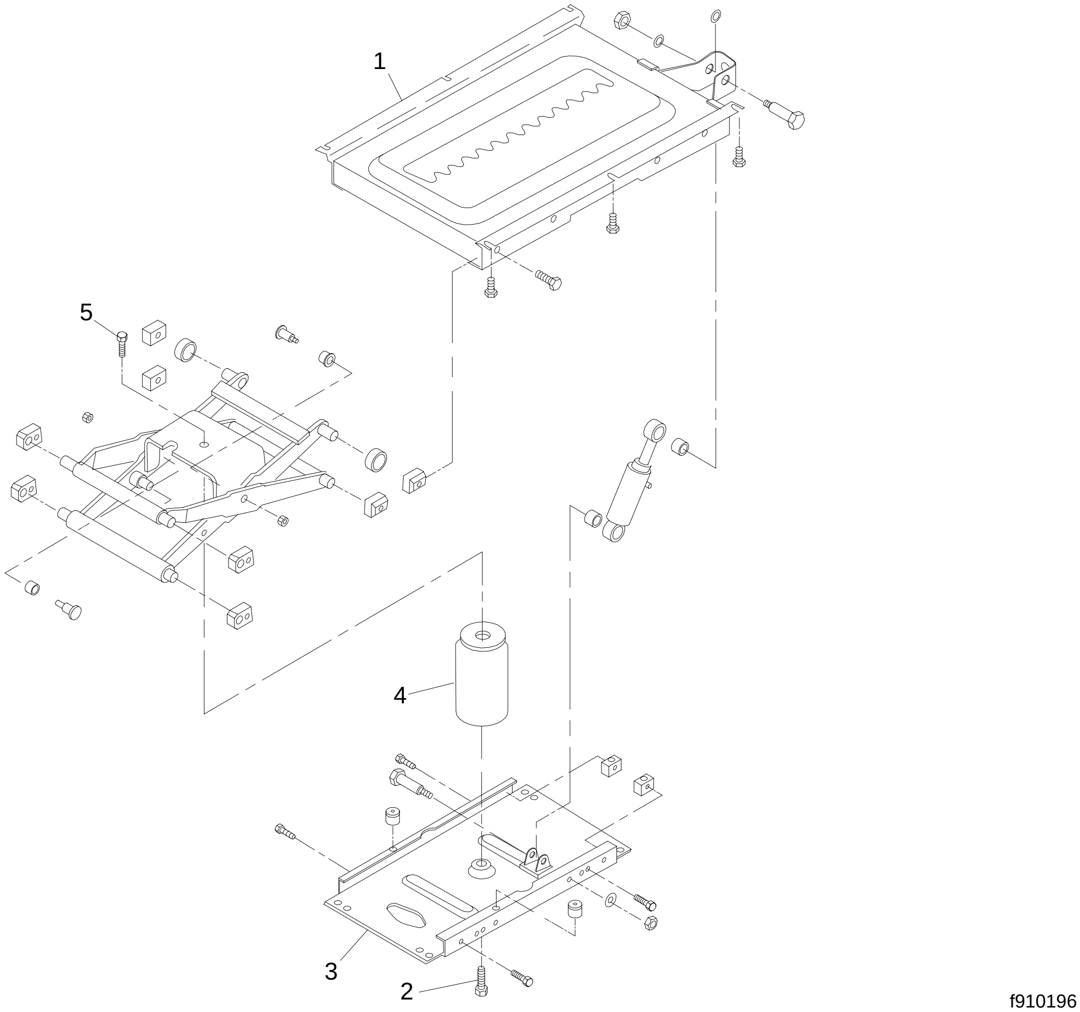
Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

5. Disconnect the air line from the air spring by loosening the air fitting while pulling the air line out of the fitting.
6. Remove the top and bottom capscrews from the air spring. Remove the air spring from the suspension. See **Fig. 1**.

Installation

1. Position the air spring in place so the fitting at the bottom of the air spring is toward the back of the seat. See **Fig. 1**.
2. Install the top capscrew. Tighten the capscrew 60 to 84 lbf·in (680 to 950 N·cm).
3. Install the bottom capscrew. Tighten the capscrew 24 to 48 lbf·in (270 to 540 N·cm).
4. Connect the air line to the fitting in the air spring by pushing the tube into the fitting.
5. Install the seat in the vehicle; see **Subject 100**.

Air Spring Removal and Installation



1. Upper Frame
2. Bottom Capscrew
3. Base
4. Air Spring
5. Top Capscrew

Fig. 1, Seat Air Spring Installation

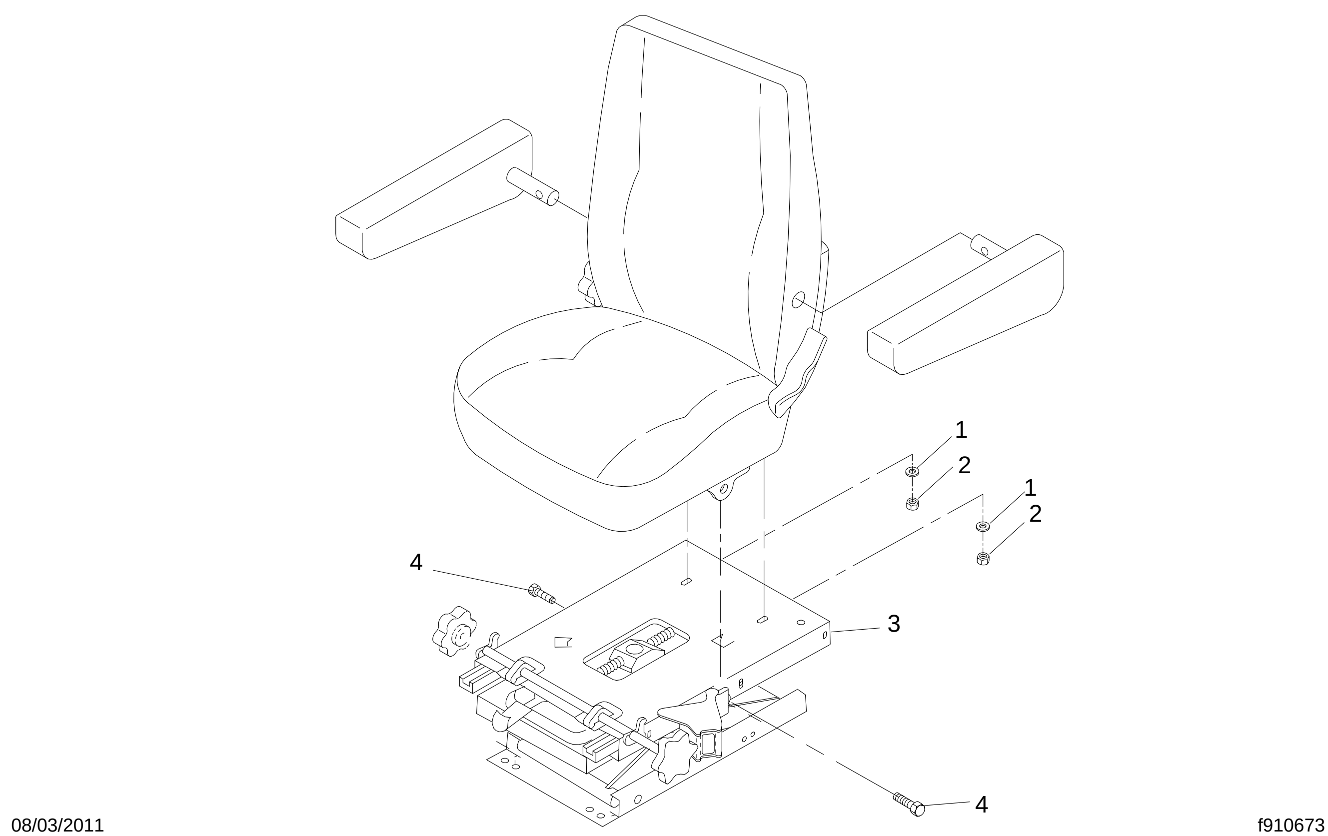
Seat/Back Assembly Removal and Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Adjust the seat/back assembly to the most rearward position
3. Remove the two nuts and flatwashers from the underside of the channel assembly. See **Fig. 1**.
4. Remove the two shoulder bolts from the channel assembly.
5. Disconnect the air lines to the lumbar supports.
6. Remove the seat/back assembly.

Installation

1. Place the seat/back assembly onto the channel assembly. See **Fig. 1**.
2. Connect the air lines to the lumbar supports.
3. Install the two shoulder bolts in the channel assembly.
4. Install the two nuts and flatwashers in the underside of the channel assembly.

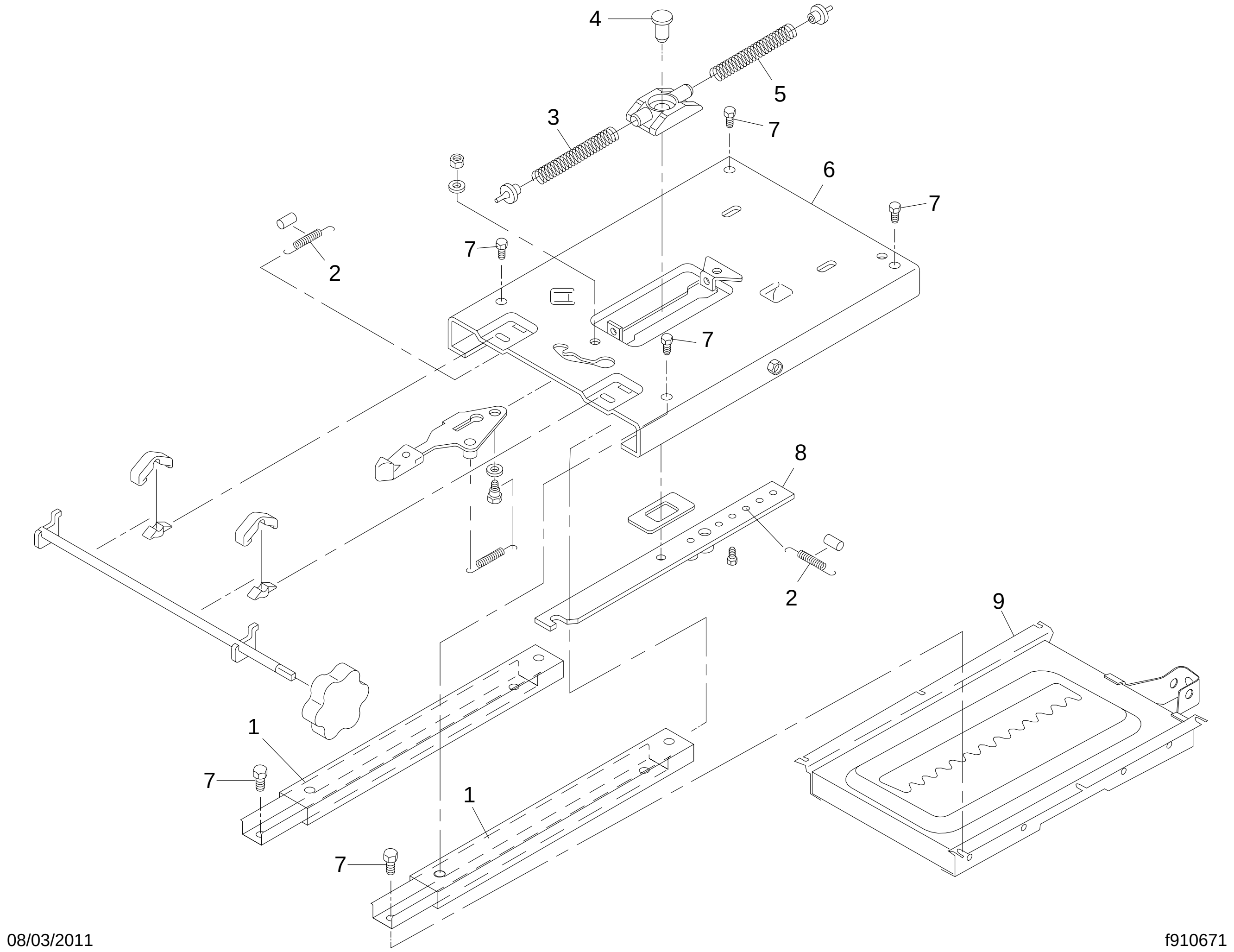


1. Flatwasher
2. Nut
3. Channel Assembly
4. Shoulder Bolt

Fig. 1, Seat/Back Assembly Installation

Replacement

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Remove the seat/back assembly; see **Subject 120**.
3. Move the isolator assembly to the rear. Remove the front screws and nuts that attach the rails to the upper frame. See **Fig. 1**.
4. Using care, move the isolator assembly to the front. Remove the rear screws and nuts that attach the rails to the upper frame.
5. Remove the screws that attach the rails to the isolator assembly.
6. Remove and install one slide rail at a time.
7. Using new screws, attach the slide rails to the isolator assembly.



1. Slide Rail
2. Spring
3. Front Isolator Spring
4. Pivot Bolt
5. Rear Isolator Spring
6. Isolator Assembly
7. Capscrew
8. Latch Bar
9. Upper Frame

Fig. 1, Slide Rail Installation

Slide Rail Replacement

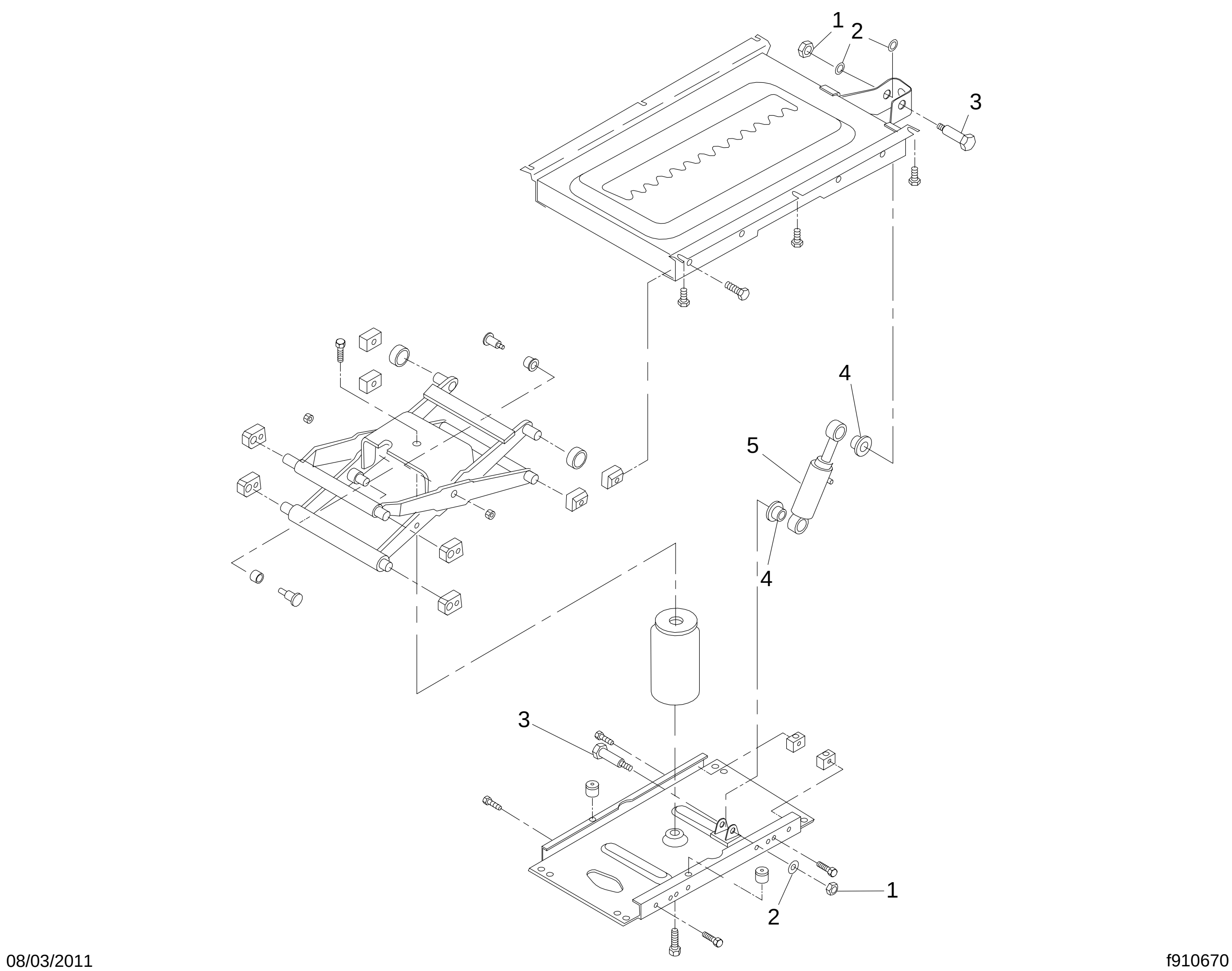
8. Using new screws and nuts, attach the slide rails to the upper frame.
9. Install the seat/back assembly; see **Subject 120**.

Damper Removal and Installation

Removal

NOTE: The seat/back assembly does not need to be removed.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Remove the suspension shroud (if equipped) from the seat base.
3. Adjust the seat to the maximum height.
4. Move the isolator assembly to the fully forward position to provide access to the damper assembly.
5. Remove the shoulder bolts, hexnuts and washers at the top and bottom of the damper. Remove the damper. See **Fig. 1**.



1. Hexnut
2. Washer
3. Shoulder Bolt
4. Bearing
5. Damper

Fig. 1, Damper Installation

Damper Removal and Installation

Installation

1. Install the new damper with the flanges of the bearings to the outside of the suspension. See **Fig. 1**.
2. Install the shoulder bolts, washers, and hexnuts at the top and bottom of the damper.
3. Install the suspension shroud (if equipped) on the seat base.

Suspension Rebuild—Bearing/Slide Block Removal and Installation

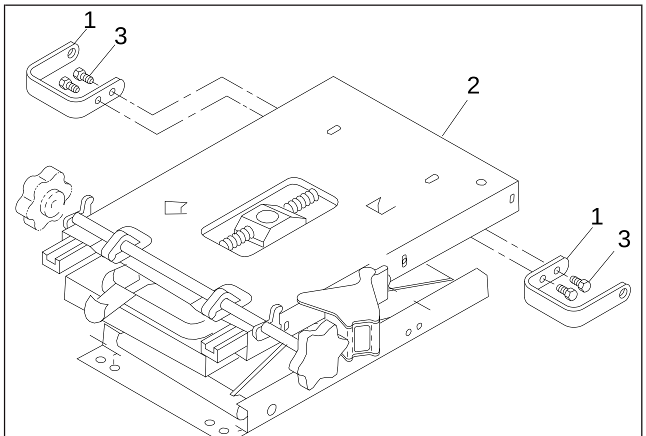
Removal

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.

WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

2. Bleed all air from the supply line. Disconnect the air supply line from the seat.
3. Remove the seat from the vehicle; see **Subject 100**.
4. With the seat suspension secured in the extended position with a spacer block, use the air valve to exhaust all air from the air spring.
5. Remove the seat/back assembly; see **Subject 120**.
6. Remove the ICP brackets. See **Fig. 1**.



1. ICP Bracket
2. Seat Suspension
3. Capscrew

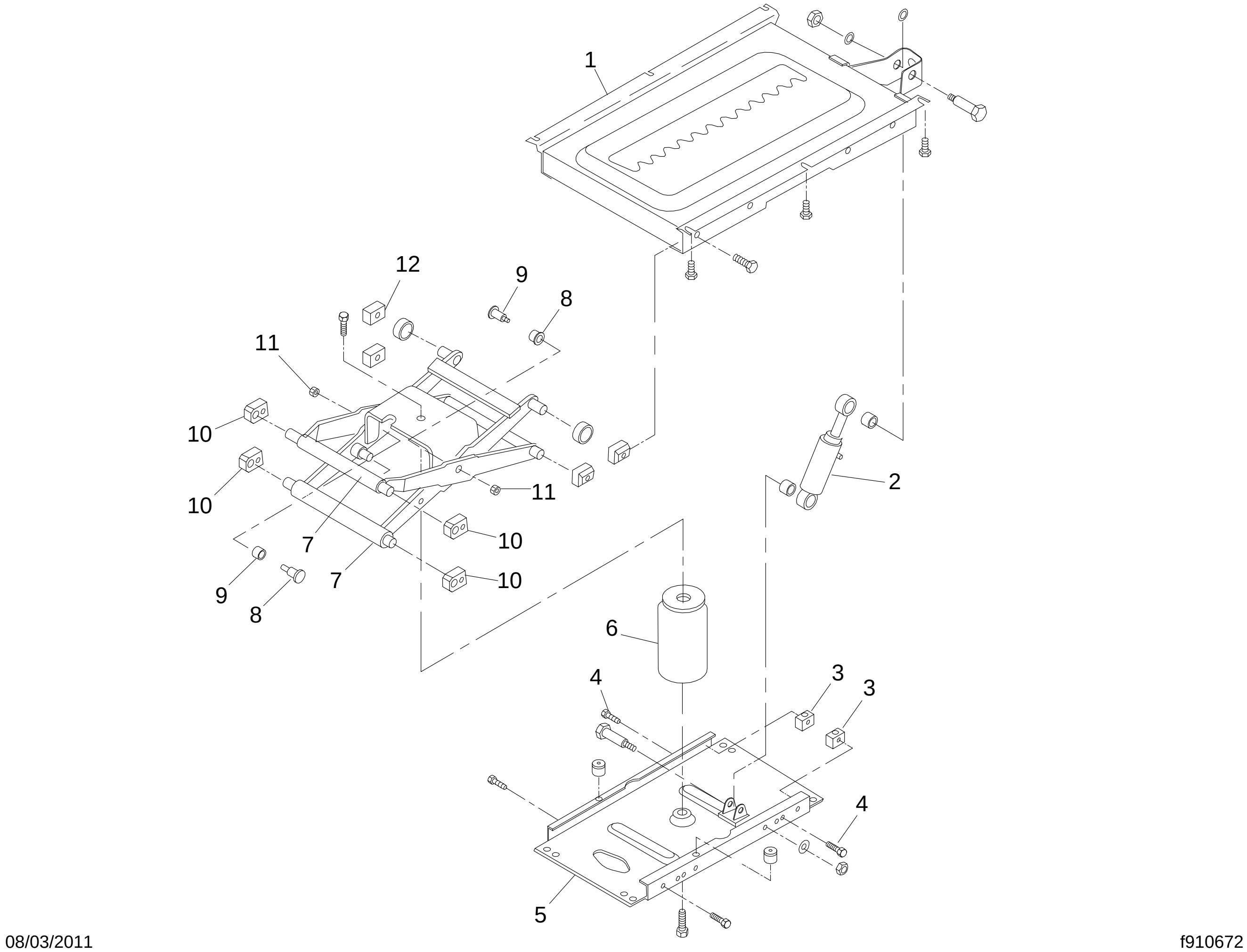
Fig. 1, ICP Brackets

7. Remove the air spring. See **Subject 110**.
8. Remove the damper. See **Subject 140**.
9. Remove the capscrews from the upper front bearing blocks. See **Fig. 2**.
10. Remove the capscrews from the lower rear stop blocks.
11. Remove the isolator assembly by lifting and sliding it forward until the bearing blocks can be removed from the cutouts in the channels on the upper frame. Then slide the channel rearward until the slide blocks can be removed.
12. Remove the capscrews from the lower front bearing blocks.
13. Slide the lever assemblies forward until the bearing blocks can be removed from the channels on the base. Then slide the lever assemblies rearward until the slide blocks can be removed from the channels.
14. Remove the shoulder bolts and nuts from the pivots of the lever assemblies and inspect the bolts. If the bolts are worn, replace them.

Installation

1. Replace the bearings at the pivots on the lever assembly by pushing out the old bearings and pressing in the new bearings. The flange of the bearings should be on the outside of the lever assembly. See **Fig. 2**.
2. Install the shoulder bolts and nuts into the pivots of the lever assemblies. Tighten the bolts 16 to 20 lbf·ft (22 to 27 N·m).
3. Install new bearing blocks, spacers and slide blocks on the levers with the beveled surfaces outward. Slide the levers with blocks into the channel on the base assembly. Tighten the capscrews 23 to 27 lbf·ft (30 to 37 N·m).
4. Slide the isolator assembly over the blocks. Line up the capscrews with the bearing blocks. Tighten the capscrews 23 to 27 lbf·ft (30 to 37 N·m).
5. Manually move the suspension up and down to make sure there are no clearance problems.
6. Block the suspension up with a spacer block placed between the base riser and the upper frame.
7. Install the air spring; see **Subject 110**.
8. Install the damper; see **Subject 140**.
9. Install the ICP brackets.
10. Install the seat/back assembly; see **Subject 120**.

Suspension Rebuild—Bearing/Slide Block Removal and Installation



1. Upper Frame
2. Damper
3. Stop Block
4. Capscrew
5. Base
6. Air Spring
7. Slide Lever Assembly
8. Shoulder Bolt
9. Bearing
10. Bearing Block
11. Nut
12. Slide Block

Fig. 2, Seat Suspension

11. Install the seat in the vehicle; see **Subject 100**.

Specifications

For fastener torque values, see Table 1.

Torque Values		
Description	Torque: lbf·in (N·cm)	Torque: lbf·ft (N·m)
Seat Mounting Capscrews	—	25–29 (34–39)
Seat/Tether Belt-to-ICP Bar Capscrews	—	35–45 (48–61)
Airspring Bottom Capscrew	60–84 (680–950)	—
Top Airspring Capscrew	24–48 (270–540)	—
Pivot Shoulder Bolt	—	17–19 (22–27)
Slide Block Capscrews	—	23–27 (30–37)
Bearing Block Capscrews	—	23–27 (30–37)

Table 1, Torque Values

General Information

Freightliner currently applies DuPont® single-stage Imron® 5000 or Imron Elite EA, or two-stage (base coat and clear coat) Imron 6000 or Imron Elite EB high-solids polyurethane enamel on the vehicle cab at the factory.

Black Standard Urethane or Imron 5000 is used on the vehicle chassis. The chassis includes the frame, spoke spider, running gear, and any components attached to the frame.

To meet the federal air quality regulations imposed by the EPA and local jurisdictions, these products contain lower levels of volatile organic compounds (VOCs) than earlier types (916Y, Centari®, and Imron), and are formulated free of lead and chrome.

The procedures in this section are for use with DuPont products. Unless otherwise noted, all products are manufactured by E. I. du Pont de Nemours and Company, Inc. Obtain approval from a Freightliner Regional Office for use of topcoats produced by other manufacturers.

Color-Matching

The recommended aftermarket paints for color-matching factory-applied paint are as follows:

- Cab—use Imron 5000, Imron 6000, Imron Elite EA, or Imron Elite EB
- Chassis—use only Imron 5000

To ensure proper gloss, durability, and color-matching of the enamel, repair panels with the same product originally applied to the vehicle. For example, use only Imron 6000 to repair panels previously painted with Imron 6000.

To determine the correct paint number for color-matching any original finish on a vehicle, refer to the paint specification on the vehicle specification decal. Refer to the vehicle driver's manual for the location of this decal.

NOTE: The high-solids Standard Urethane applied to the chassis at the factory is sold to original equipment manufacturers (OEMs) only, and is not available for aftermarket sale. Use Imron 5000, N0001 Black, for repainting.

General Guidelines

This section provides instructions for preparing large panels or the entire cab for topcoating with DuPont® products. For spot repairs or touch-ups, see Subject 120.

Before topcoating, the surface must be thoroughly cleaned and sanded. Any bare areas must also be conditioned and primed.

1. Preparation materials specified for one type of surface should not be used for any other type of surface.
2. Limit intermediate coatings, such as primers, to the brand and type specified by the finish-coat manufacturer.

CAUTION

Only experienced, qualified persons using proper equipment should attempt repainting or touch-up painting. Incorrect application of chemicals or paint could damage the surface or impair the finish.

Preparation for Prime Coat

Use the cleaners and conditioners specified in each step to prepare the surface for priming. See Specifications, 400 for a summary of the products used in this procedure.

WARNING

Do not use solvent-based cleaners on large areas of plastic or fiberglass such as the hood or air fairing. Wiping down these large areas may cause a buildup of static electricity. The resulting spark could cause a flash fire, which could result in personal injury or property damage.

1. Wash the entire vehicle with a mild detergent which does not contain lanolin or additives. Before the solution dries, rinse the vehicle with fresh water. Dry the vehicle.
2. Cover the area around the repair area to prevent damage to surrounding objects from solvent overspray or drips.

WARNING

Solvents are flammable. Keep the container closed. Use only with adequate ventilation. Keep solvents away from heat, sparks, and open flame. Breathing the vapor can cause headache, nausea, impaired reaction time, and impaired coordination.

3. Wipe all surfaces to be painted with a clean cloth soaked with solvent or cleaner. Remove all traces of wax, polish, grease, and silicones.
   - Metal—use DuPont Prep-Sol 3919 S.
   - Plastic—use DuPont Plastic Prep 2319 S.
   - Fiberglass—use DuPont Prep-N-Solv.

   3.1 Work on small areas at a time, wetting the surface liberally.

   3.2 Quickly wipe the surface with a clean cloth before the solvent or cleaner has a chance to dry. Change cloths frequently.
4. Feather the edge of all repaired areas, chipped surfaces, and scratches.

   4.1 Cut down the edges of broken spots with 220-grit sandpaper.

   4.2 Feather the edges by hand, using a sanding block with 400-grit sandpaper.
5. Sand the entire area to be painted. Using a sanding block and 400-grit sandpaper, or a DA sander and 240-grit sandpaper, remove the gloss to improve adhesion of the primer.
6. Using a clean cloth soaked with cleaner, remove any sanding dust.
   - Metal or plastic—use DuPont 3939 S lacquer and enamel cleaner.
   - Fiberglass—use a solution of one part water and one part isopropyl alcohol (IPA).
7. Treat bare metal and rusted areas.
   - Steel—use DuPont 5717 S metal conditioner.
   - Aluminum—use DuPont 225 S aluminum cleaner.

   7.1 Mix one part of the cleaner with two parts of water in a plastic bucket.

Preparing for Topcoating

7.2 Apply the cleaner with a cloth or sponge. If corrosion is present, work the surface with a stiff plastic brush or 3M Scotch-Brite® pad. Do not use any pads containing iron.

7.3 While the metal is still wet, wipe thoroughly with a clean, dry cloth. Allow the surface to dry before applying a conversion coating.

8. Apply a conversion coating to all bare metal.
   - Steel—use DuPont 5718 S metal conversion coating.
   - Zinc casings or galvanized surfaces (iron or steel)—use DuPont 5718 S metal conversion coating.
   - Aluminum—use DuPont 226 S aluminum conversion coating.

8.1 Pour the conversion coating into a plastic container (do not dilute). Using a 3M Scotch-Brite or similar non-iron abrasive pad, apply the conversion coating to the metal surface. Work only as much area as can be coated and rinsed before the solution dries.

8.2 Leave the coating on the surface for 2 to 5 minutes. Then, rinse off the solution with cold water, or mop with a sponge or cloth rinsed frequently in clean water.

If the metal surface dries before rinsing, reapply the conversion coating, then repeat the previous substep.

8.3 Wipe the surface dry with a clean cloth, or air dry.

9. With paper and tape, mask all areas that are not to be painted.

Prime Coat

IMPORTANT: The material, substrate or ambient temperature should be above 50°F (10°C) and below 110°F (44°C) for proper application of paint products.

Prime all bare and feathered areas before topcoating. The specified primers can be used on any surface.

1. Clean all cracks and surfaces with dry compressed air.
2. Using a tack cloth, wipe all surfaces to be painted.

WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying paint products, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

3. Prime all bare metal and feathered areas with DuPont primer.
   - Steel and aluminum—use Corlar 824 S epoxy primer.
   - Fiberglass—use Corlar 825 S epoxy primer.

3.1 Stir the primer thoroughly.

3.2 Mix two parts Corlar epoxy primer with one part DuPont 826 S activator.

3.3 Reduce three parts of this mixture with one part DuPont 3602 S lacquer thinner (viscosity reading is 18 to 22 seconds in a no. 2 Zahn cup). Stir thoroughly.

3.4 Wait 1 to 2 hours from time of mixing before using. This provides time for complete chemical induction.

3.5 Set the air pressure at the spray gun at 45 psi (310 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.

3.6 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.

3.7 Spray one full wet coat to give a dry film thickness of 0.7 to 1.0 mil (18 to 25 µm).

3.8 Clean the equipment immediately after use with DuPont 3602 S lacquer thinner.

3.9 Allow to dry for 2 to 4 hours before application of topcoat.

4. Wet sand the primer with 400-grit or finer sandpaper. Feather the edge into the surrounding area.

5. Dry the surface. Using a clean cloth soaked with cleaner, remove any sanding dust.
   - Metal or plastic—use DuPont 3939 S lacquer and enamel cleaner.
   - Fiberglass—use solution of 1 part water and 1 part isopropyl alcohol (IPA).

NOTE: See **Subject 110** for topcoating instructions.

General Guidelines

This subject provides instructions for applying a topcoat of DuPont® enamel to full panels or the entire cab. For spot repairs or touch-ups, see **Subject 120**.

CAUTION

Only experienced, qualified persons using proper equipment should attempt repainting or touch-up painting. Incorrect application of chemicals or paint could damage the surface or impair the finish.

Do not mix additives with the finish coats unless they are specified by the finish-coat manufacturer. See **Specifications, 400** for a summary of the products used in this procedure.

Do not apply if the paint temperature is less than 70°F (21°C). Use warm water or paint heaters to heat the paint to an optimum temperature of 85 to 95°F (29 to 35°C). The material, substrate or ambient temperature should be above 50°F (10°C) and below 110°F (43°C).

Before applying any topcoat:

1. Prepare the surface for topcoating. See **Subject 100** for instructions.
2. Clean all cracks and surfaces with dry compressed air.
3. Using a tack cloth, wipe all surfaces to be painted.

Imron 5000 Topcoating

Imron 5000 is a single-stage, low VOC, high-solids polyurethane enamel. It provides a durable, high-gloss surface with good chemical resistance. It requires the addition of an activator.

WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying paint products, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

Mixing

1. Stir the Imron 5000 enamel thoroughly.
2. Mix three parts Imron 5000 enamel with one part of DuPont 193 S or 194 S activator. No further reduction is necessary for application.

NOTE: The pot life of the mixture is about 2 to 4 hours at 70°F (21°C), unless an accelerator is added.

3. If faster curing time is desired, add DuPont 389 S fast-dry accelerator. Add up to 2 ounces (60 mL) to 1 gallon (3.8 L) of mixed material.
4. Mix thoroughly and strain.

NOTE: The viscosity of the mixture is about 10 to 19 seconds in a no. 3 Zahn cup, depending on the color. Adding reducer could affect the color match on some metallics.

Application

1. Set the air pressure at the spray gun to 60 to 65 psi (410 to 450 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.
2. Apply the topcoating.
   - 2.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.
   - 2.2 Using a cross-coat technique, spray one medium-wet coat in a north-to-south direction.
   - 2.3 Allow 5 to 10 minutes drying time between each application. Do not sand.
   - 2.4 Apply a second medium-wet coat in an east-to-west direction.
   - 2.5 A third medium-wet coat may be needed for good coverage of some colors.
3. To air dry, allow 2 to 4 hours with accelerator 389 S, and 6 to 8 hours without the accelerator.

   To force dry, wait 15 minutes following the application of the final coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).
4. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.

5. Clean the equipment immediately after use with DuPont 3602 S lacquer thinner or 8685 S reducer.

Recoating or Decorating

Two-toning, striping, or lettering may be applied in 4 to 6 hours if DuPont 389 S accelerator is used. Wait 10 to 12 hours if no accelerator is used.

Decals may be applied in 12 to 16 hours if 389 S accelerator is used. Wait 24 hours if no accelerator is used.

For topcoats cured over 72 hours, scuff-sand with 400-grit sandpaper and wipe with a clean tack cloth before recoating, striping, lettering, or applying decals.

Imron 6000 Topcoating

Imron 6000 is a two-stage, high-solids polyurethane enamel. It provides good cover with one cross-coat of the base color followed by one coat of Imron 6000 clear coat. Both the base color and clear coat require the addition of an activator.

WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying paint products, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

Mixing

1. Stir the Imron 6000 base color thoroughly.
2. Mix three parts Imron 6000 base color with one part DuPont 193 S or 194 S activator. No further reduction is necessary for application.

NOTE: The pot life of the mixture is about 2 to 4 hours at 70°F (21°C), unless an accelerator is added.

3. If faster curing time is desired, add DuPont 389 S fast-dry accelerator. Add up to 2 ounces (60 mL) to 1 gallon (3.8 L) of mixed material.
4. Mix thoroughly and strain.

NOTE: The viscosity of the mixture is about 10 to 19 seconds in a no. 3 Zahn cup, depending on the color. Adding reducer could affect the color match on some metallics.

Application

1. Set the air pressure at the spray gun to 60 to 65 psi (410 to 450 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.
2. Apply the topcoating.
   - 2.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.
   - 2.2 Apply one cross-coat of the Imron 6000 base color.
   - 2.3 Flash 10 minutes minimum. Do not sand.
   - 2.4 Purge the equipment with DuPont 3602 S lacquer thinner or 8685 S reducer.
3. Apply clearcoat.
   - 3.1 Mix three parts DuPont 3440 S or 3480 S clear with one part DuPont 193 S or 194 S activator.
   - 3.2 Apply one coat of the activated DuPont 3440 S or 3480 S clear. Some colors may require additional cross-coats.
4. To air dry, allow 2 to 4 hours if DuPont 389 S accelerator is used, and 6 to 8 hours if no accelerator is used.

   To force dry, wait 15 minutes following the application of the clear coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).
5. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.
6. Clean the equipment immediately after use with DuPont 3602 S lacquer thinner or 8685 S reducer.

Recoating or Decorating

Two-toning, striping, and lettering may be applied in 4 to 6 hours if DuPont 389 S accelerator is used. Wait 10 to 12 hours if no accelerator is used.

Decals may be applied in 12 to 16 hours if 389 S accelerator is used. Wait 24 hours if no accelerator is used.

Imron Elite EA Topcoating

Imron Elite EA is a single-stage, low VOC, high-solids polyurethane enamel. It provides a durable, high-gloss surface with good chemical resistance. It requires the addition of an activator.

WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying paint products, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

Mixing

1. Stir the Imron Elite EA enamel thoroughly.
2. Mix three parts Imron Elite EA enamel with one part of DuPont 194 S activator. No further reduction is necessary for application.

NOTE: The pot life of the mixture is about 2 to 4 hours at 70°F (21°C).

3. Mix thoroughly and strain.

NOTE: The viscosity of the mixture is about 10 to 19 seconds in a no. 3 Zahn cup, depending on the color. Adding reducer could affect the color match on some metallics.

Application

1. Set the air pressure at the spray gun to 60 to 65 psi (410 to 450 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.
2. Apply the topcoating.
   2.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.
   2.2 Using a cross-coat technique, spray one medium-wet coat in a north-to-south direction.
   2.3 Apply a second medium-wet coat in an east-to-west direction.
3. To air dry, allow 6 to 8 hours.

   To force dry, wait 7 minutes following the application of the final coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).
4. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.
5. Clean the equipment immediately after use with DuPont 3602 S lacquer thinner or 8685 S reducer.

Recoating or Decorating

Two-toning, striping, or lettering may be applied in 10 to 12 hours.

Decals may be applied in 24 hours.

For topcoats cured over 72 hours, scuff-sand with 400-grit sandpaper and wipe with a clean tack cloth before recoating, striping, lettering, or applying decals.

Imron Elite EB Topcoating

Imron Elite EB is a two-stage, high-solids polyurethane enamel. It provides good cover with one cross-coat of the base color followed by one coat of Imron Elite EB clear coat. Both the base color and clear coat require the addition of an activator.

WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying paint products, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

Mixing

1. Stir the Imron Elite EB base color thoroughly.
2. Mix three parts Imron Elite EB base color with one part 194 S activator. No further reduction is necessary for application.

Topcoating

NOTE: The pot life of the mixture is about 2 to 4 hours at 70°F (21°C).

3. Mix thoroughly and strain.

NOTE: The viscosity of the mixture is about 10 to 19 seconds in a no. 3 Zahn cup, depending on the color. Adding reducer could affect the color match on some metallics.

Application

1. Set the air pressure at the spray gun to 60 to 65 psi (410 to 450 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.
2. Apply the topcoating.
   - 2.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.
   - 2.2 Apply one cross-coat of the Imron 6000 base color.
   - 2.3 Purge the equipment with DuPont 3602 S lacquer thinner or 8685 S reducer.
3. Apply clearcoat.
   - 3.1 Mix three parts DuPont 8480 S Clear with one part DuPont 194 S activator.
   - 3.2 Apply one coat of the activated DuPont 8480 S.

   NOTE: Only DuPont 8480 S Clear may be used with Imron Elite EB. Other clear coats are not compatible with the Imron Elite EB basecoat.
4. To air dry, allow 6 to 8 hours.

   To force dry, wait 7 minutes following the application of the clear coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).
5. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.
6. Clean the equipment immediately after use with DuPont 3602 S lacquer thinner or 8685 S reducer.

Recoating or Decorating

Two-toning, striping, and lettering may be applied in 10 to 12 hours.

Decals may be applied in 24 hours.

General Guidelines

This subject provides instructions for making spot repairs or touch-ups with DuPont® enamels. Buffing may correct minor imperfections; more serious repairs require surface preparation before a topcoating can be applied. For striping, lettering, or decal application after the repair is complete, see **Subject 110**.

1. Preparation materials specified for one type of surface should not be used for any other type of surface. See **Specifications, 400** for a summary of the materials used in this section.
2. Limit intermediate coatings, such as primers, to the brand and type specified by the finish-coat manufacturer.
3. Do not mix additives with the finish coats unless they are specified by the finish-coat manufacturer.
4. Do not apply if the paint temperature is less than 70°F (21°C). Use warm water or paint heaters to heat the paint to an optimum temperature of 85 to 95°F (29 to 35°C). The material, substrate or ambient temperature should be above 50°F (10°C) and below 110°F (43°C).

CAUTION

Only experienced, qualified persons using proper equipment should attempt repainting or touch-up painting. Incorrect application of chemicals or paint could damage the surface or impair the finish.

Buffing Minor Imperfections

1. Clean the area carefully with a mild detergent, then rinse.
2. Remove imperfections using ultra-fine or micro-fine sandpaper (1500- or 2000-grit) and water. Rinse the area with clean water, then dry.
3. Buff the area.

   3.1 Use a clean foam pad at low speed (about 1600 rpm) with one of the following products:

   - DuPont 1500 S
   - Meguiar's No. 2 Fine-Cut Cleaner
   - 3M Finesse-it II 05928

   3.2 Using medium pressure, buff slowly in an overlapping pattern until the imperfection has been eliminated. Repeat as necessary.

   3.3 Rinse the area with clean water, then dry.
4. Polish the area.

   4.1 Apply one of the following products with a clean pad (3M Waffle Pad):

   - DuPont 3000 S
   - Meguiar's No. 9 Swirl Remover
   - 3M Perfect-it 05996

   4.2 Using medium pressure, work small areas using an even, overlapping pattern until the gloss is restored. As the polish dries and the gloss appears, ease the pressure on the polishing pad. Repeat as necessary.

Preparing for Topcoating

1. Wash the entire panel with mild detergent, containing no lanolin or additives. Before the solution dries, rinse with fresh water. Dry with a clean, lint-free cloth.
2. Cover areas around the repair area to prevent damage to surrounding objects from solvent overspray or drips.

WARNING

Solvents are flammable. Keep the container closed. Use only with adequate ventilation. Keep solvents away from heat, sparks, and open flame. Breathing the vapor can cause headache, nausea, impaired reaction time, and impaired coordination.

3. Clean the area to be repaired with DuPont 3939 S solvent and quickly wipe the surface with a clean, lint-free cloth before the solvent dries. Remove all traces of wax, polish, grease, and silicones.
4. Sand or grind all dents and scratches.

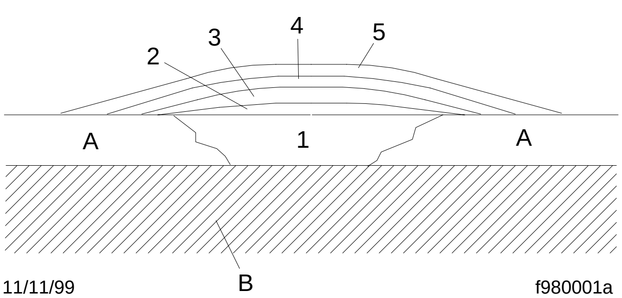
Spot Repair

5. Wet sand the area being repaired with 320-grit or finer sandpaper, or a 3M Scotch-Brite® or similar non-iron abrasive pad. Feather the edge.
6. Remove the sanding dust. Use the same solvent and wipe-on, wipe-off method used earlier to clean the area.
7. Mask all areas that will not be painted.
8. Clean all cracks and surfaces with dry compressed air.
9. Using a tack cloth, wipe all surfaces to be painted.

WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying paint products, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

10. Prime all bare metal and feathered areas with DuPont primer. See **Fig. 1**.
    - Steel and aluminum—use Corlar 824 S epoxy primer.
    - Fiberglass—use Corlar 825 S epoxy primer.



NOTE: Scale exaggerated for clarity. The number of layers depends on the specific application.

A. Existing Paint
B. Panel Material (substrate)

1. Primer
2. First Color Topcoat
3. Second Color Topcoat
4. Third Color Topcoat
5. Clear Coat

Fig. 1, Spot Repair Cross-Section

10.1 Stir primer thoroughly.

10.2 Mix two parts Corlar epoxy primer with one part DuPont 826 S activator.

10.3 Reduce three parts of this mixture with one part DuPont 3602 S lacquer thinner (viscosity reading is 18 to 22 seconds in a no. 2 Zahn cup). Stir thoroughly.

10.4 Wait 1 to 2 hours from time of mixing before using. This provides time for complete chemical induction.

10.5 Set the air pressure at the spray gun to 45 psi (310 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.

10.6 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.

10.7 Spray one wet coat to give a dry film thickness of 0.7 to 1.0 mil (18 to 25 µm).

10.8 Clean the equipment immediately after use with DuPont 3602 S lacquer thinner.

10.9 Air dry 2 to 4 hours or force dry 20 minutes.

11. Wet sand the primer with 400-grit or finer sandpaper. Feather the edge into the surrounding area.
12. If the original paint was Imron 6000, hand-rub the area around the spot repair with a medium grade compound to ensure a seamless finish.
13. Remove the sanding dust. Use the same solvent and wipe-on, wipe-off method used earlier to clean the area.
14. Wipe the repair area with a tack cloth.
15. If the finish is old, apply one coat of DuPont 222 S adhesion promoter over the entire repair area.

15.1 Set the air pressure to 35 psi (240 kPa) at the spray gun.

15.2 Flash for 5 to 10 minutes at 70°F (21°C) before topcoating.

Topcoating a Spot Repair

WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying paint products, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

Imron 5000 Topcoating

1. Mix the Imron 5000 polyurethane enamel.
   - 1.1 Stir the Imron 5000 enamel thoroughly.
   - 1.2 Mix three parts Imron 5000 base color with one part DuPont 193 S or 194 S activator. No further reduction is necessary for application.
   - 1.3 Mix thoroughly and strain.

   Note: The viscosity of the mixture is about 10 to 19 seconds in a no. 3 Zahn cup, depending on the color. Adding reducer could affect the color match on some metallics.
2. Set the air pressure at the spray gun at 60 to 65 psi (410 to 450 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.
3. For metallic topcoats only, apply one coat of DuPont 500 S urethane clear.
   - 3.1 Mix eight parts of 500 S urethane with one part 193 activator.
   - 3.2 Reduce the activated 500 S urethane mixture 50 percent with 8685 S reducer.
   - 3.3 Apply a medium-wet coat of the reduced 500 S urethane over the entire repair area, and well beyond where the color will be applied.
   - 3.4 Flash 3 minutes before applying the Imron 5000 topcoat.
4. Apply the solid color or metallic topcoating.
   - 4.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.
   - 4.2 Spray one medium-wet coat over the primed area.
   - 4.3 Flash 5 to 10 minutes.
   - 4.4 Apply a second medium-wet coat. Extend the spray area slightly to taper the edge and avoid a visible ring.
   - 4.5 A third medium-wet coat may be needed for good coverage of some colors. Allow each coat to flash before applying the next coat.

NOTE: A mist coat of five parts of color to three parts of 8022 S is recommended when applying metallics. Hold the gun about 18 inches (45 cm) from the surface.

5. Blend the repair area into the OEM finish.
   - 5.1 Lower the air pressure to 15 to 20 psi (100 to 140 kPa) at the spray gun.
   - 5.2 Empty the spray cup and refill it with DuPont 8022 S reducer or a blend of 8022 S and 8093 S.
   - 5.3 Carefully blend the edge of the repair with even coats to melt in the overspray.
   - 5.4 Spray one or two medium coats of the reducer over the entire area.
   - 5.5 If a haze appears around the edge after the reducer has dried, lightly rub the edge with DuPont 1500 S one-step polish.
6. To air dry, allow 2 to 4 hours if DuPont 389 S accelerator is used, and 6 to 8 hours if no accelerator is used.

   To force dry, wait 15 minutes following the application of the final coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).
7. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.
8. Clean the equipment immediately after use with DuPont 3602 S lacquer thinner or 8685 S reducer.

Imron 6000 Topcoating

1. Mix the Imron 6000 polyurethane enamel.

Spot Repair

1.1 Stir the Imron 6000 base color thoroughly.

1.2 Mix three parts Imron 6000 base color with one part DuPont 193 S or 194 S activator. No further reduction is necessary for application.

1.3 Mix thoroughly and strain.

Note: The viscosity of the mixture is about 10 to 19 seconds in a no. 3 Zahn cup, depending on the color. Adding reducer could affect the color match on some metallics.

2. Set the air pressure at the spray gun at 60 to 65 psi (410 to 450 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.
3. Apply the topcoating.

   3.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.

   3.2 Apply one cross-coat of the Imron 6000 base color over the primed area. No flash time is required before applying a clear coat.

   3.3 Purge the equipment with DuPont 3602 S lacquer thinner or 8685 S reducer.

   3.4 Mix three parts DuPont 3440 S or 3480 S clear with one part DuPont 193 S or 194 S activator.

   NOTE: For best results, apply the clear coat over the entire panel. If a blend of the repair area is attempted, apply the clear coat only over the repair area, overspraying the edge slightly.

   3.5 Apply one coat of the activated DuPont 3440 S or 3480 S clear.

4. Purge the equipment with DuPont 3602 S lacquer thinner or 8685 S reducer.
5. Blend the 3440 S or 3480 S clear into the surrounding topcoat.

   5.1 Set the air pressure to 25 psi (170 kPa) at the spray gun.

   5.2 Apply one coat of 3401 S blending clear over the repair area only to the overspray edge.

   5.3 Flash 2 minutes. Repeat if necessary.

6. To air dry, allow 2 to 4 hours if DuPont 389 S accelerator is used, and 6 to 8 hours if no accelerator is used.

   To force dry, wait 15 minutes following the application of the final coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).

7. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.
8. Clean the equipment immediately after use with DuPont 3602 S lacquer thinner or 8685 S reducer.

Imron Elite EA Topcoating

1. Mix the Imron Elite EA polyurethane enamel.

   1.1 Stir the Imron Elite EA enamel thoroughly.

   1.2 Mix three parts Imron Elite EA base color with one part DuPont 193 S or 194 S activator. No further reduction is necessary for application.

   1.3 Mix thoroughly and strain.

   Note: The viscosity of the mixture is about 10 to 19 seconds in a no. 3 Zahn cup, depending on the color. Adding reducer could affect the color match on some metallics.

2. Set the air pressure at the spray gun at 60 to 65 psi (410 to 450 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.
3. For metallic topcoats only, apply one coat of DuPont 500 S urethane clear.

   3.1 Mix eight parts of 500 S urethane with one part 193 S activator.

   3.2 Reduce the activated 500 S urethane mixture 50 percent with 8685 S reducer.

   3.3 Apply a medium-wet coat of the reduced 500 S urethane over the entire repair area, and well beyond where the color will be applied.

   3.4 Flash 3 minutes before applying the Imron Elite EA topcoat.

4. Apply the solid color or metallic topcoating.

4.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.

4.2 Spray one medium-wet coat over the primed area.

4.3 Flash 5 to 10 minutes.

4.4 Apply a second medium-wet coat. Extend the spray area slightly to taper the edge and avoid a visible ring.

4.5 A third medium-wet coat may be needed for good coverage of some colors. Allow each coat to flash before applying the next coat.

NOTE: A mist coat of five parts of color to three parts of 8022 S is recommended when applying metallics. Hold the gun about 18 inches (45 cm) from the surface.

5. Blend the repair area into the OEM finish.

   5.1 Lower the air pressure to 15 to 20 psi (100 to 140 kPa) at the spray gun.

   5.2 Empty the spray cup and refill it with DuPont 8022 S reducer or a blend of 8022 S and 8093 S.

   5.3 Carefully blend the edge of the repair with even coats to melt in the overspray.

   5.4 Spray one or two medium coats of the reducer over the entire area.

   5.5 If a haze appears around the edge after the reducer has dried, lightly rub the edge with DuPont 1500 S one-step polish.

6. To air dry, allow 2 to 4 hours if DuPont 389 S accelerator is used, and 6 to 8 hours if no accelerator is used.

   To force dry, wait 15 minutes following the application of the final coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).

7. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.

8. Clean the equipment immediately after use with DuPont 3602 S lacquer thinner or 8685 S reducer.

Imron Elite EB Topcoating

1. Mix the Imron Elite EB polyurethane enamel.

   1.1 Stir the Imron Elite EB base color thoroughly.

   1.2 Mix three parts Imron Elite EB base color with one part DuPont 193 S or 194 S activator. No further reduction is necessary for application.

   1.3 Mix thoroughly and strain.

Note: The viscosity of the mixture is about 10 to 19 seconds in a no. 3 Zahn cup, depending on the color. Adding reducer could affect the color match on some metallics.

2. Set the air pressure at the spray gun at 60 to 65 psi (410 to 450 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.

3. Apply the topcoating.

   3.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.

   3.2 Apply one cross-coat of the Imron Elite EB base color over the primed area. No flash time is required before applying a clear coat.

   3.3 Purge the equipment with DuPont 3602 S lacquer thinner or 8685 S reducer.

   3.4 Mix three parts DuPont 8480 S clear with one part DuPont 193 S or 194 S activator.

   NOTE: For best results, apply the clear coat over the entire panel. If a blend of the repair area is attempted, apply the clear coat only over the repair area, overspraying the edge slightly.

   3.5 Apply one coat of the activated DuPont 8480 S clear.

4. Purge the equipment with DuPont 3602 S lacquer thinner or 8685 S reducer.

5. Blend the 8480 S clear into the surrounding topcoat.

   5.1 Set the air pressure to 25 psi (170 kPa) at the spray gun.

Spot Repair

5.2 Apply one coat of 3401 S blending clear over the repair area only to the overspray edge.

5.3 Flash 2 minutes. Repeat if necessary.

6. To air dry, allow 2 to 4 hours if DuPont 389 S accelerator is used, and 6 to 8 hours if no accelerator is used.

   To force dry, wait 15 minutes following the application of the final coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).

7. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.

8. Clean the equipment immediately after use with DuPont 3602 S lacquer thinner or 8685 S reducer.

Specifications

See **Table 1** for Equipment Application Parameters.

See **Table 2** for DuPont Surface Preparation Materials.

See **Table 3** for DuPont Topcoating Materials.

See **Table 4** for DuPont Spot Repair Materials.

Equipment Application Parameters		
Parameter	**English Units**	**Metric Units**
Atomizing Air		
Primer	45 psi	310 kPa
Enamel	60–65 psi	410–450 kPa
Fluid Delivery	12–16 oz/min	350–470 mL/min
Booth Temperature	75°F	23°C
Spray Gun Distance	10–12 in	25–30 cm

Table 1, Equipment Application Parameters

DuPont Surface Preparation Materials				
Step	**Steel**	**Aluminum**	**Plastic**	**Fiberglass**
Wash and dry	Mild detergent (such as dish washing detergent)			
Wipe with cleaner	Prep-Sol 3919 S	Prep-Sol 3919 S	Plastic Prep 2319 S	Prep-N-Solv
Sand and feather	220-grit, then 400-grit			320 grit
Remove sanding dust	3939 S lacquer and enamel cleaner			Mix: - 1 part water - 1 part isopropyl alcohol
Treat bare metal	5717 S metal conditioner	225 S aluminum cleaner	—	—
Apply conversion coating to bare metal	5718 S metal conversion coating	226 S aluminum conversion coating	—	—
Apply sealer primer	Mix: - 2 parts Corlar 824 S primer with 1 part DuPont 826 S activator - reduce 3 parts of mixture with 1 part DuPont 3602 S lacquer thinner		Mix: - 2 parts Corlar 825 S primer with 1 part DuPont 826 S activator - reduce 3 parts of mixture with 1 part DuPont 3602 S lacquer thinner	

Table 2, DuPont Surface Preparation Materials

DuPont Topcoating Materials				
Step	**Imron 6000**	**Imron 5000**	**Imron Elite EA**	**Imron Elite EB**
Mix enamel	Mix: - 3 parts Imron 6000 - 1 part 193 S or 194 S activator	Mix: - 3 parts Imron 5000 - 1 part 193 S or 194 S activator	Mix: - 3 parts Imron Elite EA - 1 part 194 S activator	Mix: - 3 parts Imron Elite EB - 1 part 194 S activator

Specifications

DuPont Topcoating Materials				
Step	**Imron 6000**	**Imron 5000**	**Imron Elite EA**	**Imron Elite EB**
Add accelerator (optional)	389 S accelerator (up to 2 oz/gal of activated enamel)		None	None
Mix clear coat	Mix: - 3 parts 3440 S or 3480 S clear - 1 part 193 S or 194 S activator	—	—	Mix: - 3 parts 8480 - 1 part 194 S
Pressure at gun	60–65 psi (414–448 kPa)	60 psi (414 kPa)	60–65 psi (414–448 kPa)	60 psi (414 kPa)
Equipment cleanup	3939 S lacquer and enamel cleaner or 8685 S reducer			

Table 3, DuPont Topcoating Materials

DuPont Spot Repair Materials				
Step	**Imron 6000**	**Imron 5000**	**Imron Elite EA**	**Imron Elite EB**
Cleaning	3939 S lacquer and enamel cleaner		—	—
Sanding	320-grit or finer		—	—
Sealer primer	Mix: - 2 parts Corlar 824 S primer with 1 part DuPont 826 S activator - reduce 3 parts of mixture with 1 part DuPont 3602 S lacquer thinner		—	—
Compound	Medium grade compound	—	—	—
Adhesion promoter	222 S adhesion promoter		—	—
Topcoat	1 coat Imron 6000: - 3 parts base color - 1 part 193 S or 194 S activator	2 coats Imron 5000: - 3 parts enamel - 1 part 193 S or 194 S activator	Mix: - 3 parts Imron Elite EA - 1 part 194 S activator	Mix: - 3 parts Imron Elite EB - 1 part 194 S activator
Topcoat viscosity	10 to 19 sec (#3 Zahn cup)	10 to 19 sec (#3 Zahn cup)	—	—
Clear coat	Mix: - 3 parts 3440 S or 3480 S clear - 1 part 193 S or 194 S activator	—	—	Mix: - 3 parts 8480 - 1 part 194 S
Accelerator (optional)	389 S accelerator		None	None
Blending clear	1 coat 3401 S blending clear		—	—

DuPont Spot Repair Materials				
Step	**Imron 6000**	**Imron 5000**	**Imron Elite EA**	**Imron Elite EB**
Equipment cleanup	3939 S lacquer and enamel cleaner or 8685 S reducer			

Table 4, DuPont Spot Repair Materials

General Information

The procedures in **Subject 110** outlines body paint repair for the Business Class M2 vehicle that is equipped with an ambulance body. The procedures are to be used to eliminate galvanic and/or crevice corrosion and to prep the unit for repainting. These procedures are for use with PPG products. Unless otherwise noted, all products are manufactured by PPG. Obtain approval from Freightliner for use of topcoats produced by other manufacturers.

General Guidelines

These are instructions for making spot repairs or touch-ups with PPG Delfleet® Evolution urethane topcoat single stage or basecoat/clearcoat.

Buffing may correct minor imperfections; more serious repairs require surface preparation before a topcoating can be applied.

1. Preparation materials specified for one type of surface should not be used for any other type of surface.
2. Limit intermediate coatings, such as primers, to the brand and type specified by the paint manufacturer.
3. Do not use any products or additives that are not specifically recommended by the paint manufacturer in published literature.
4. Substrate and ambient temperature should be above 65°F (18°C) for optimum performance.

Buffing Minor Imperfections

1. Clean the area carefully with a mild detergent, then rinse.
2. Remove imperfections using ultra-fine or microfine sandpaper (1500- or 2000-grit) and water.
3. Rinse the area with clean water, then dry.
4. Buff the area, using a clean foam pad at low speed (about 1600 rpm) with one of the following products:
   - Meguiar's No. 2 Fine-Cut Cleaner
   - 3M Finesse-it II 05928

   Using medium pressure, buff slowly in an overlapping pattern until the imperfection has been eliminated. Repeat as necessary.
5. Rinse the area with clean water, then dry.
6. Polish the area with a clean pad, such as a 3M Waffle Pad, using either of the following products:
   - Meguiar's No. 9 Swirl Remover
   - 3M Perfect-It 05996

   Using medium pressure, work small areas using an even, overlapping pattern until the gloss is restored. As the polish dries and the gloss appears, ease the pressure on the polishing pad. Repeat as necessary

Preparing for Topcoating

1. Wash the entire panel in mild detergent, containing no lanolin or additives. Before the solution dries, rinse with fresh water. Dry with a clean, lint-free cloth.
2. Cover areas around the repair area to prevent damage to surrounding objects from solvent overspray or drips.

WARNING

Solvents are flammable. Keep the container closed. Use only with adequate ventilation. Keep solvents away from heat, sparks, and open flame. Breathing the vapor can cause headache, nausea, impaired reaction time, and impaired coordination.

3. Clean the area to be repaired with PPG D436/DX437/DX438 Substrate Cleaner. Choose the product depending on local regulations and degree of contamination. Quickly wipe the surface with a clean, lint-free cloth before the substrate cleaner dries.

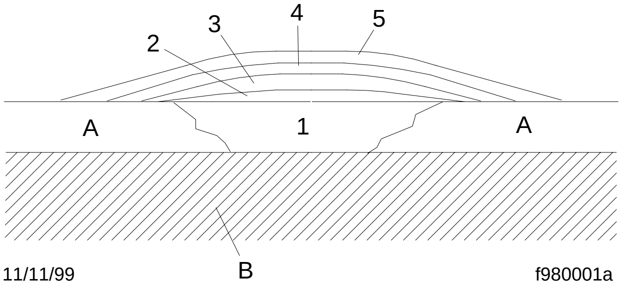
   Remove all traces of substrate contamination such as wax, polish, grease, diesel exhaust residue, and silicones. Do not allow substrate cleaners to air dry on the repair area.
4. Sand or grind all dents and scratches.
5. DA sand the area being repaired with 320- or 400-grit, or finer sandpaper, or a 3M Scotch-Brite® pad. Feather the edge.
6. Remove sanding dust using the method detailed in step 3 above.
7. Mask all areas not to be painted.
8. Clean all cracks and surfaces with dry compressed air.
9. Use a tack cloth to wipe all surfaces to be painted.

Spot Repair

⚠ WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying paint products, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

10. Prime all bare metal and feathered areas with PPG primer. Use F3995 primer for fiberglass, steel, and aluminum. See **Fig. 1**.



NOTE: The number of paint layers depends on the specific use.

A. Existing Paint
B. Panel Material (Substrate)
1. Primer
2. First Color Topcoat
3. Second Color Topcoat
4. Third Color Topcoat
5. Clearcoat

Fig. 1, Spot Repair Cross Section, Scale Exaggerated for Clarity.

10.1 Stir or shake primer thoroughly.

10.2 Mix three parts F3995 epoxy primer with one part F3996 activator and one-half part F–series reducer.

10.3 Set the air pressure at the spray gun to 55 psi (380 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 ml) per minute.

10.4 Spray one wet coat to yield a minimum dry film thickness of 0.7 mils (18µm).

10.5 Clean equipment immediately after use with PPG Gun Cleaning Solvent.

10.6 Air dry 1 hour or force dry 20 minutes at 120 to130°F (49 to 55°C).

11. If the original paint was a basecoat/clearcoat, hand rub the area around the spot repair with a medium grade compound to ensure a seamless finish. Use Scotch–Brite® 7448 or 2000-grit wet or dry sandpaper.

12. Remove the sanding dust. Use the same cleaner and wipe on, wipe off method used earlier to clean the area.

13. Wipe the repair area with a tack cloth.

Topcoating a Spot Repair

Delfleet® Evolution Single Stage Topcoating

1. Mix the Delfleet® Evolution Single Stage (FDGH) polyurethane enamel.

1.1 Stir the Delfleet® Evolution Single Stage (FDGH) polyurethane enamel thoroughly.

1.2 Mix three parts Delfleet® Evolution color (FDGH) with one part F3260 activator to 6 ounces additive F34XX per RTS gallon (44 ml per liter), to an optional 10 percent F33XX reducer. The pot life is 2 to 3 hours at 70°F (22°C). See **Table 1**.

PPG Additives and Reducers		
Speed Rating	**F34XX Additives**	**F33XX Reducers**
Fast Dry	F3400	F3320
Medium Dry	F3405	F3330
Slow Dry	F3410	F3340
Extra Slow Dry	—	F3350

Table 1, PPG Additives and Reducers

1.3 Mix thoroughly and strain.

NOTE: the viscosity of the mixture should be at 25 to 35 seconds in a No. 2 Zahn cup. Check the designated shelf life if using a product from a previously opened container.

2. Set the air pressure at 50 to 60 psi (345 to 415 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 ml) per minute. The fluid tip should be 1.3 to 1.5 mm.

3. Apply the solid or metallic color topcoat.

3.1 Spray one medium-wet coat over the primed area.

3.2 Flash 10 to 15 minutes.

3.3 Apply a second medium-wet coat. Extend the spray area slightly to taper the edge and avoid a visible ring.

4. FDGH dry film thickness must be a minimum of 1.5 mils (38μm).
5. To air dry, allow overnight cure at 65°F (19°C) minimum.
6. To force dry, flash 5 to 10 minutes, then cure 40 minutes at 140°F (60°C) metal temperature.
7. If taping, allow 3 hours at 68°F (20°C). To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied.
8. If decals are to be applied, let the paint cure at 70°F (21°C) for 3 days prior to putting them on.
9. Clean the equipment immediately after use with PPG Gun Cleaning Solvent.

Delfleet Evolution Basecoat/ Clearcoat Topcoating

1. **Option 1:** Mix the Delfleet Evolution Basecoat (FBCH) polyurethane enamel.

1.1 Stir/shake the Delfleet Evolution Basecoat (FBCH) thoroughly.

1.2 Mix three parts FBCH basecoat color with one part F3260 activator to one-half part F3440 converter. Pot life is 1 to 2 hours at 70°F (21°C) and 50 percent relative humidity.

1.3 Mix thoroughly and strain.

1.4 The viscosity of the mixture is 20 to 25 seconds in a No. 2 Zahn cup, depending on the color.

2. **Option 2:** Mix the Delfleet Evolution Basecoat-Fast (FBCS) polyurethane enamel.

2.1 Stir or shake the Delfleet Evolution Basecoat-Fast (FBCS) color thoroughly.

2.2 Mix three parts FBCS basecoat color with one part F3200. Ten percent F33XX Reducer is optional for this application. Pot life is 1 hour at 70°F (21°C) and 50 percent relative humidity.

2.3 Mix thoroughly and strain.

2.4 The viscosity of the mixture is 20 to 30 seconds in a No. 2 Zahn cup, depending on the color.

3. Set the air pressure at 50 to 60 psi (345 to 415 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 ml) per minute. The fluid tip should be 1.3 to 1.5 mm.
4. Apply the basecoat (FBCH or FBCS): Apply one or two coats of FBCH or FBCS basecoat color over the primed area until full hiding is achieved. Allow 5 to 10 minutes between coats.
5. If blending the repair area into the OEM finish, see instructions at the end of the top coat instructions.
6. Allow 30 minutes flash, prior to applying clearcoat.
7. If clearcoat is not applied within 8 hours, FBCH/ FBCS basecoat color must be sanded and recoated.
8. Mix the Delfleet Evolution High Build Clear

8.1 Mix three parts Delfleet Evolution Clearcoat F3905 with one part F3240 activator to one-half part reducer (F33XX) to 2 ounces accelerator per RTS gallon (16 ml per liter). Pot life is 1 hour to 1.5 hours at 70°F (21°C) and 50 percent relative humidity. See **Table 2**.

PPG Thinners	
Fast	F3320
Medium	F3330
Slow	F3340
Extra Slow	F3350

Table 2, F33XX Thinner Selection

8.2 Mix thoroughly and strain.

8.3 The viscosity of the mixture is 32 seconds in a No. 2 Zahn cup.

9. Set the clearcoat air pressure at the spray gun at 45 to 55 psi (310 to 380 kPa). For pressure feed

systems, set the fluid delivery at 12 to 16 ounces (350 to 470 ml) per minute. Use a 1.3 to 1.5 mm fluid tip.

10. Apply 2 coats of F3905 clearcoat with a 10 to 15 minute flash time between coats to reach 2.0 mils (50 µm) minimum dry film thickness.

NOTE: For best results, apply the clearcoat over the entire panel.

11. To blend the clearcoat:

    11.1 Apply one coat of the activated Delfleet Evolution F3905 Clearcoat.

    11.2 Mix one part DX840 to one part ready-to-spray F3905 clearcoat and apply this mixture to the blend edge. Additional DX840 may be added if a second coat to extend the blend edge is necessary or desired.

    11.3 Moving the gun from the outside in, mist a light coat onto the edge of the repair to melt in the dry overspray.

    11.4 To air dry, allow overnight cure at 65°F (18°C).

    11.5 If taping, allow 6 hours at 68°F (20°C). To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied.

    11.6 To force dry, flash off up to 5 minutes, then dry for 40 minutes at 150°F (65°C).

    11.7 If sanding or polishing are desired, allow the finish to sit 16 hours if air dried, and 4 to 8 hours after bake cool-down before polishing.

    11.8 Clean the equipment immediately after use with PPG Gun Cleaning Solvent.

Solid Color Blends in FBCH/FBCS/FDGH

1. Prepare the repair area as outlined above.
2. Spray color to full hiding in two or three coats, allowing specified flash time between coats.
3. Once hiding is achieved, pour out the remaining ready-to-spray (RTS) color from the gun.
4. Add several ounces of DX840 to the gun that still contains residual RTS color and lightly blend the outside edge.

NOTE: It is very important to add DX840 to the gun that still contains some residual RTS color. This keeps the outside edge from breaking or de-wetting.

5. For FBCH or FBCS repair jobs, apply clearcoat following a 30 minute flash time, or a similar force-dry.

Blending Metallic Colors in FDGH and Blending Metallic/Pearl Colors in FBCH/FBCS

NOTE: Spot repairs in high-solid colors often show a dark ring or halo around their edges. Spraying a wet bed helps prevent the ring or halo when repairing high-solid colors.

On very light colors, it may be necessary to spray the wet bed completely to the edge of the panel but not over the repair area, to prevent the halo effect.

1. Follow the steps outlined above to prepare the area for applying the wet bed.
2. Prior to applying the wet bed, the area that is to receive the wet bed should be scuffed with a gray scuff pad and cleaned with an appropriate substrate cleaner.
3. Mix F3905. Reduce the RTS F3905 1:1 by volume with DX840 and spray a wet bed on the outside of the spot.

    3.1 Spray one medium-wet coat to establish the wet bed. Keep the wet bed 4 to 6 inches outside the repair spot.

    3.2 Apply the color system mixed as detailed in previous headings, but do not add DX840 in this step. Spray from the repair spot into the wet bed, while the wet bed is still wet.

    NOTE: Do not apply DX840 to the edge of the color in this application. Doing so causes a halo effect.

    3.3 For basecoat repairs, allow the color to become tack-free before applying the final overall color. The overall clear (F3905) is not reduced with DX840. DX840 can be used to melt in the edges of the clearcoat, once this step is complete.

General Guidelines

In order to prepare the body for paint repair, a kit should be ordered from Ferguson Enterprises. It is identified as Fire Body Repair Kit #1. See **Specifications 400**.

Preparation

CAUTION

Only experienced, qualified persons using proper equipment should attempt repainting or touch-up painting. Incorrect application of chemicals or paint could damage the surface or impair the finish.

1. Wash the vehicle body to remove all dirt and contaminants.
2. Remove all hinges, fenderettes, diamondettes, and light fixtures.
3. Sand the body to remove all corrosion.
4. Remove all seam sealant around the extrusions. Clean out all residual debris from the extrusions.
5. Use compressed air to blow dirt and contaminants from all surfaces, especially in the extrusions.
6. Remove all stainless steel fasteners that are in the door extrusions and coat them with Dolphin 6075 Corrosion Bloc™ paste.

Surface Treatment and Conversion Coating

1. Wipe Parcosol® 263 Metal Cleaner on all bare metal surfaces, then wipe it off.
2. If the body is aluminum, wipe on Alodine® 5700 Conversion Coater, and let it dry in place.
3. Apply two-part polyester fillers or primer immediately after the pre-treatment is dry.

Priming

WARNING

Wear a positive-pressure, supplied-air vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying primer or topcoat, and until the work area has been exhausted of all vapor and spray mist. Breathing paint vapor or spray mist can cause personal injury.

1. Use a tack cloth on all surfaces.
2. Prime all surfaces with DP40LF (Gray) or DP90LF (Black) Epoxy mixed with DP401LF or DP402LF Catalyst (2 to 1 mix ratio) and 1/2 part DT Solvent. Cure for 30 to 60 minutes.
3. Prime all surfaces with Delfleet® Evolution F3983 mixed with F3984 (3 to 1 mix ratio). Cure for 30 minutes.

Caulking and Sealing Exterior Cosmetic Extrusion Joints

1. Sand all exterior cosmetic extrusion joints, then fill them using two-part polyester fillers.
2. Apply Royal Adhesive Solid Bond® caulking around the perimeter of the door extrusions. Seal all cosmetic surfaces. Cure for 2 to 3 hours.

Basecoat and Clearcoat Topcoat

1. Seal prime the body with DP40LF (Gray) or DP90LF (Black) Epoxy mixed with DP401LF or DP402LF Catalyst (2 to 1 mix ratio) and 1/2 part of an appropriate solvent. Cure for 30 minutes.
2. Apply Delfleet® Basecoat Urethane. Mix the materials using **Option 1 or Option 2:**
3. **Option 1:** Mix the Delfleet Evolution Basecoat (FBCH) polyurethane enamel.
   - 3.1 Stir/shake the Delfleet Evolution Basecoat (FBCH) thoroughly.
   - 3.2 Mix three parts FBCH basecoat color with one part F3260 activator to one-half part

Ambulance Body Paint Repair

F3440 converter. Pot life is 1 to 2 hours at 70°F (21°C) and 50 percent relative humidity.

3.3 Mix thoroughly and strain.

3.4 Using a No. 2 Zahn cup, the viscosity of the mixture is 20 to 25 seconds, depending on the color.

4. **Option 2 :** Mix the Delfleet Evolution Basecoat-Fast (FBCS) polyurethane enamel.

4.1 Stir or shake the Delfleet Evolution Basecoat-Fast (FBCS) color thoroughly.

4.2 Mix three parts FBCS basecoat color with one part F3200. Ten percent F33XX Reducer is optional for this application. Pot life is 1 hour at 70°F (21°C) and 50 percent relative humidity.

4.3 Mix thoroughly and strain.

4.4 Using a No. 2 Zahn cup, the viscosity of the mixture is 20 to 30 seconds depending on the color.

5. Set the air pressure. See **Specifications 400**.
6. Apply the basecoat (FBCH or FBCS): Apply one or two coats of FBCH or FBCS basecoat color over the primed area until full hiding is achieved. Allow 5 to 10 minutes between coats.
7. Allow 30 minutes flash, prior to applying clearcoat.
8. If clearcoat is not applied within 8 hours, FBCH/FBCS basecoat color must be sanded and recoated.
9. Apply clearcoat using DCU® 2002 Urethane:

9.1 Stir DCU 2002 clearcoat.

9.2 Mix four parts DCU 2002 with one part DCX 61 activator, and up to one part D871 or DT885 solvent depending on the temperature.

9.3 Mix thoroughly and strain.

9.4 Using a No. 2 Zahn cup, the viscosity of the mixture is 20 to 25 seconds.

10. Bake for 45 minutes at 140°F (60°C), or air dry overnight for 24 hours prior to installation of the hinges, fenderettes, and light fixtures.

Cut and Polish Finishing

Cut and polish the paint as needed to remove dirt, imperfections, and orange peel. See **Table 1** for the finishing materials list.

Compounding

1. Using a wool pad, apply a rubbing compound. Use approximately 1800 RPM on the buffer.
2. Buff the compound on the surface with a back and forth motion.

Cut and Polish Finishing Materials		
Steps	**Materials**	**Products**
Compound Operation	Wool Pad	3M® Wool Pad
	Rubbing Compound	3M PerfectIt III™or equivalent
Machine Glaze Operation	Machine Foam Pad	3M Foam Pad or equivalent
	Machine Glaze	3M FinesseIt™ or equivalent
Finish Glaze Operation	Glazing Pad	3M Foam Pad HookIt™ or equivalent
	Finish Glaze	3M PerfectIt™ Foam Pad Glaze or equivalent
Detailing Operation	Detail Cloth	3M or Norton Micro Fabric Buffing Cloth or equivalent

Table 1, Cut and Polish Finishing Materials

IMPORTANT: Be sure not to get the surface too hot, because this will soften the clearcoat and burn the finish.

NOTE: It may be necessary to use 3M PerfectIt III™ or an equivalent on older finishes, or finishes that have been cured for longer than seven days.

Machine Glazing

1. Using a machine glaze pad and a machine glaze product, add the glaze to the pad.
2. Start polishing using medium pressure. As the polish starts to work into the finish, lighten the pressure in order to remove swirl marks.

Finish Glaze

1. Using a glaze pad or an equivalent product, apply the finish glaze material to the pad.
2. Using a slow circular motion, work the glaze into the paint finish on an area about 3 ft (1 m) x 3 ft (1 m).

IMPORTANT: Do not polish with this glaze. It is to be applied only to the top of the finish.

Detailing

Using a detailing cloth, wipe the finish glaze off, being sure to shake the cloth and turn it over often. This will polish and fill any swirl marks that were left over from the glazing.

Exterior Underbody Sealing and Caulking

Apply Royal Adhesive Solid Bond around the underside perimeter of the body to seal all joints from moisture.

Hinge and Light Fixture Installation

1. Install the hinges using Mylar® film between all of the hinges to the frame and all of the hinges and the extrusions, to insulate from dissimilar corrosion.
2. Install the light fixtures using Dolphin 6075 Corrosion Bloc paste around all the openings and fasteners.

Fenderette Installation

1. Apply Mylar film to the perimeter of the wheel well openings.
2. Apply Dolphin 6075 Corrosion Bloc to all stainless steel fasteners used to secure the fenderette to the body.

Diamondette Installation

1. Apply 3M™ foam tape to the diamondette, vertically only. Do not apply horizontally.
2. Apply Dolphin 6075 Corrosion Bloc to all stainless steel fasteners used to secure the diamondette to the body.
3. After installation, apply Royal Adhesive Solid Bond caulk to the top and the sides of the installed diamondette. Do not apply caulk to the bottom.

Exterior Metal Grab Handles and Brackets Installation

1. Apply Mylar film between any metal exterior part and any painted surface.
2. Apply Dolphin 6075 Corrosion Bloc to all stainless steel fasteners used to secure metal parts.

Specifications

Material Safety Data Sheets are included with all materials. Order materials through Ferguson Enterprises at (843)-486-7722. See **Table 1** for the Fire Body Repair Kit # 1 list. See **Table 2** for the material selection list. See **Table 3** for the paint gun and paint booth setup list. See **Table 4** for the cut and polish finishing materials list.

Fire Body Repair Kit # 1				
Material	**Product Number or Size**	**Quantity Required**	**Part Number**	**Where Used**
Mylar® Tape	UHMW, 2-inch wide x 18 yards	4 Rolls (72 Yards)	710	All Hinges and Fenderettes
Dolphin Corrosion Bloc Paste™	6075, One-Pint Can with Dauber	1 One-Pint Can with Dauber	6075	Between All Joints and All Stainless Steel Fasteners
3M™ Foam Tape	VHB4646, 1-inch wide x 72 yards	2 Rolls	200-104	Diamondette Plate
Royal Adhesive Solid Bond®, Gray or White	20-Ounce Cartridge	4	200-286	Underbody and Diamondette Plate Cosmetic Seam Seal
Alodine® 5700	40 Wipes/Package	1	700-237	Aluminum Body Pretreatment
Parcosol® 263	40 Wipes/Package	1	700-218	Aluminum, Steel, and Stainless Steel Cleaner

Table 1, Fire Body Repair Kit #1

Material Selection	
Application Area	**Product**
Cleaning–Metal Substrate	Henkel Parcosol® 263 Wipes
Cleaning–Plastic or Fiberglass	PPG DX 103 (if needed)
Surface Treatment	Henkel Parcosol 263 Wipes for Aluminum, Galvanized, Galvaneal, and Stainless Steel
Conversion Coat	Henkel Alodine® 5700 Wipes for Aluminum
Seam Sealant (Underbody)	Royal Adhesive Solid Bond® DC 12250 (White or Gray)
Seam Sealant (Cosmetic)	Royal Adhesive Solid Bond DC 12250 (White or Gray)
Primer	DP40LF (Gray) or DP90LF (Black) Primer DP401LF or DP402LF Catalyst
Basecoat and Catalyst	Delta® or Delfleet® Color GXH 3640, DU 6, or DDH 526 Catalyst Global or DT Reducers
Clearcoat and Catalyst	DCU 2002 Clearcoat DCX 8 or DCX 61 Catalyst Global Reducers DX 830 Universal Blender
Accelerator	DX 84 for DCU 2002 Clearcoat

Table 2, Material Selection

Specifications

Paint Gun and Paint Booth Setup			
Parameter	**Primer**	**Delta® Basecoat**	**DCU 2002 Clearcoat**
Atomizing Air at Regulator	60–65 psi (415–448 kPa)	55–65 psi (379–448 kPa)	
Atomizing Air at Gun	40–45 psi (276–310 kPa)	45–50 psi (310–345 kPa)	
Fluid Delivery	13–15 oz/min (385–444 mL/min)	12–16 oz/min (355–473 mL/min)	
Booth Temperature	72–75°F (21–24°C)		

Table 3, Paint Gun and Paint Booth Setup

Cut and Polish Finishing Materials		
Steps	**Materials**	**Products**
Compound Operation	Wool Pad Rubbing Compound	3M® Wool Pad 3M PerfectIt III™or equivalent
Machine Glaze Operation	Machine Foam Pad Machine Glaze	3M Foam Pad or equivalent 3M FinesseIt™ or equivalent
Finish Glaze Operation	Glazing Pad Finish Glaze	3M Foam Pad HookIt™ or equivalent 3M PerfectIt™ Foam Pad Glaze or equivalent
Detailing Operation	Detail Cloth	3M or Norton Micro Fabric Buffing Cloth or equivalent

Table 4, Cut and Polish Finishing Materials