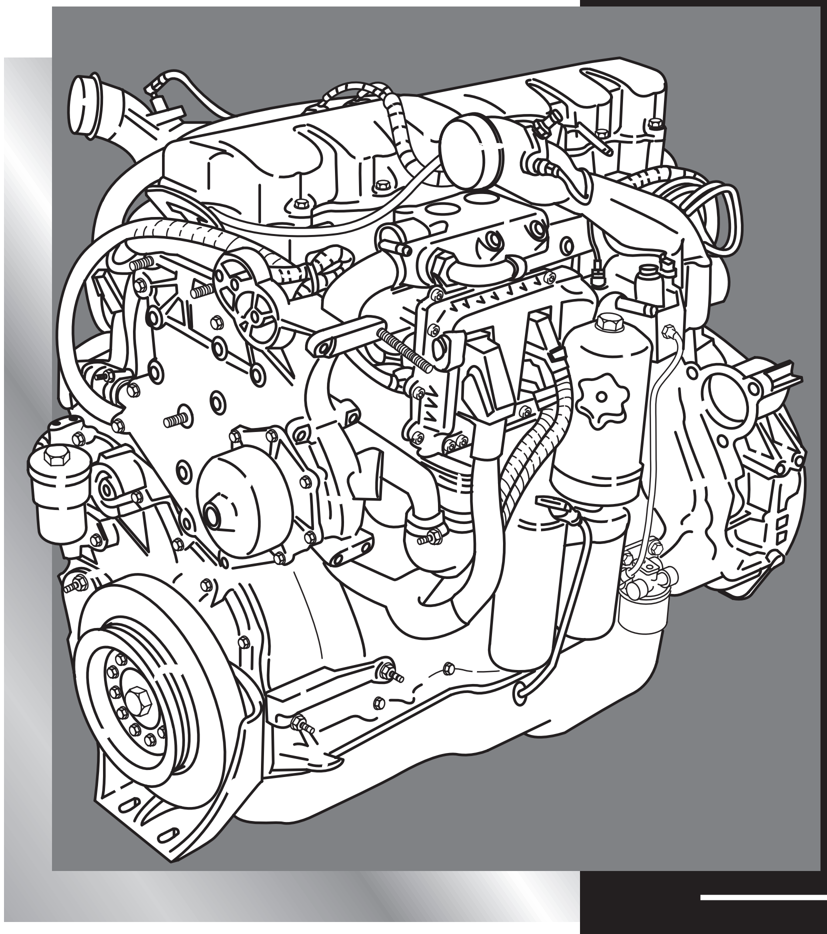

ASET

ASET™ AC DIESEL ENGINE

SERVICE MANUAL

for Engines with Exhaust Gas Recirculation (EGR)

Mack

OCTOBER 2006
(REVISED)
5-111

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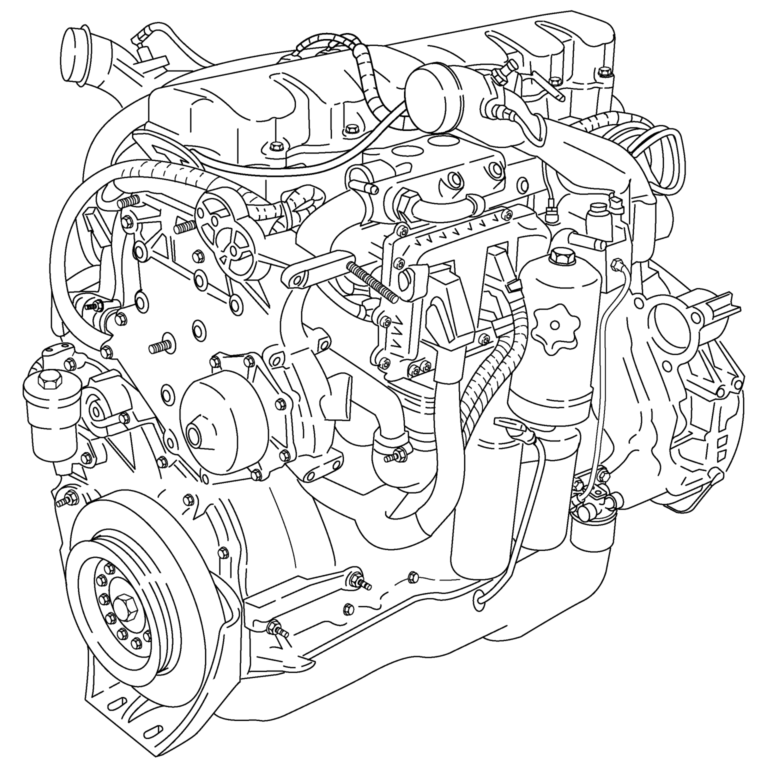
ASET™ AC ENGINE SERVICE MANUAL



View of ASET™ AC Engine

OCTOBER 2006

(REVISED — SUPERSEDES ISSUE DATED JANUARY 2005)
ENGINE 5-111

ATTENTION

The information in this manual is not all inclusive and cannot take into account all unique situations. Note that some illustrations are typical and may not reflect the exact arrangement of every component installed on a specific chassis.

The information, specifications, and illustrations in this publication are based on information that was current at the time of publication.

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INTRODUCTION

SAFETY INFORMATION

Advisory Labels

Cautionary *signal words* (Danger-Warning-Caution) may appear in various locations throughout this manual. Information accented by one of these signal words must be observed to minimize the risk of personal injury to service personnel, or the possibility of improper service methods which may damage the vehicle or cause it to be unsafe. Additional Notes and Service Hints are used to emphasize areas of procedural importance and provide suggestions for ease of repair. The following definitions indicate the use of these advisory labels as they appear throughout the manual:

⚠ *D A N G E R*

Danger *indicates an unsafe practice that could result in death or serious personal injury. Serious personal injury is considered to be permanent injury from which full recovery is NOT expected, resulting in a change in life style.*

⚠ *W A R N I N G*

***Warning* indicates an unsafe practice that could result in personal injury. Personal injury means that the injury is of a temporary nature and that full recovery is expected.**

⚠ *C A U T I O N*

***Caution** indicates an unsafe practice that could result in damage to the product.*

N O T E

Note indicates a procedure, practice, or condition that must be followed in order for the vehicle or component to function in the manner intended.

S E R V I C E H I N T

A helpful suggestion that will make it quicker and/or easier to perform a procedure, while possibly reducing service cost.

INTRODUCTION

Service Procedures and Tool Usage

Anyone using a service procedure or tool not recommended in this manual must first satisfy himself thoroughly that neither his safety nor vehicle safety will be jeopardized by the service method he selects. Individuals deviating in any manner from the instructions provided assume all risks of consequential personal injury or damage to equipment involved.

Also note that particular service procedures may require the use of a special tool(s) designed for a specific purpose. These special tools must be used in the manner described, whenever specified in the instructions.

DANGER

1. ***Before starting a vehicle, always be seated in the driver's seat, place the transmission in neutral, apply the parking brakes, and push in the clutch pedal. Failure to follow these instructions could produce unexpected vehicle movement, which can result in serious personal injury or death.***
2. ***Before working on a vehicle, place the transmission in neutral, set the parking brakes, and block the wheels. Failure to follow these instructions could produce unexpected vehicle movement, which can result in serious personal injury or death.***

DANGER

Engine-driven components such as Power Take-Off (PTO) units, fans and fan belts, driveshafts and other related rotating assemblies, can be very dangerous. Do not work on or service engine-driven components unless the engine is shut down. Always keep body parts and loose clothing out of range of these powerful components to prevent serious personal injury. Be aware of PTO engagement or nonengagement status. Always disengage the PTO when not in use.

DANGER

Do not work under a vehicle that is supported only by a hydraulic jack. The hydraulic jack could fail suddenly and unexpectedly, resulting in severe personal injury or death. Always use jackstands of adequate capacity to support the weight of the vehicle.

CAUTION

Before towing the vehicle, place the transmission in neutral and lift the rear wheels off the ground, or disconnect the driveline to avoid damage to the transmission during towing.

REMEMBER,
SAFETY . . . IS NO ACCIDENT!

INTRODUCTION

Mack Trucks, Inc. cannot anticipate every possible occurrence that may involve a potential hazard. Accidents can be avoided by recognizing potentially hazardous situations and taking necessary precautions. Performing service procedures correctly is critical to technician safety and safe, reliable vehicle operation.

The following list of general shop safety practices can help technicians avoid potentially hazardous situations and reduce the risk of personal injury. DO NOT perform any services, maintenance procedures or lubrications until this manual has been read and understood.

- Perform all service work on a flat, level surface. Block wheels to prevent vehicle from rolling.
- DO NOT wear loose-fitting or torn clothing. Remove any jewelry before servicing vehicle.
- ALWAYS wear safety glasses and protective shoes. Avoid injury by being aware of sharp corners and jagged edges.
- Use hoists or jacks to lift or move heavy objects.
- NEVER run engine indoors unless exhaust fumes are adequately vented to the outside.
- Be aware of hot surfaces. Allow engine to cool sufficiently before performing any service or tests in the vicinity of the engine.
- Keep work area clean and orderly. Clean up any spilled oil, grease, fuel, hydraulic fluid, etc.
- Only use tools that are in good condition, and always use accurately calibrated torque wrenches to tighten all fasteners to specified torques. In instances where procedures require the use of special tools which are designed for a specific purpose, use only in the manner described in the instructions.
- Do not store natural gas powered vehicles indoors for an extended period of time (overnight) without first removing the fuel.
- Never smoke around a natural gas powered vehicle.

EXPLANATION OF NUMERICAL CODE

The organization of MACK service manuals has been upgraded to standardize manual content according to a reference system based on component identification. The new reference system will help link the information contained in this publication with related information included in other MACK service/warranty publications, such as associated service bulletins, warranty manuals, and MACK Service Labor Time Standards.

The system is based on a numerical code, the first **digit** of which identifies the general component grouping as listed here:

GROUP **0**00 — GENERAL DATA

GROUP **1**00 — CHASSIS

GROUP **2**00 — ENGINE

GROUP **3**00 — CLUTCH, TRANSMISSION, TRANSFER CASE AND PTO

GROUP **4**00 — STEERING, AXLES, WHEELS AND TIRES, DRIVELINE

GROUP **5**00 — BRAKES, AUXILIARY SYSTEMS

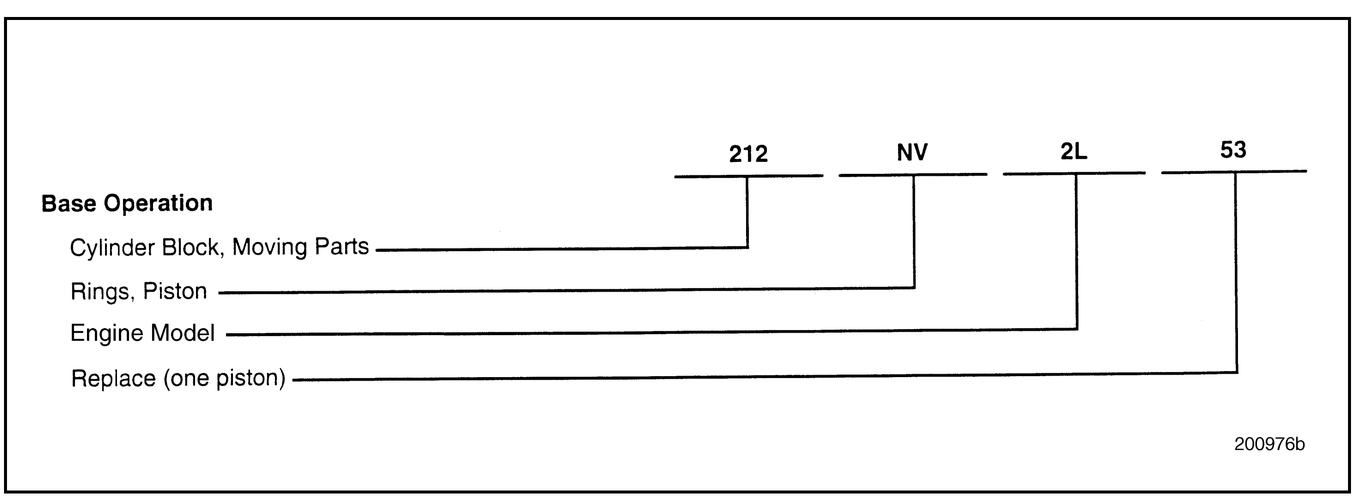
GROUP **6**00 — CAB, TRUCK BODY

GROUP **7**00 — ELECTRICAL

The second two digits of the three-digit code are used to identify the **system, assembly** or **subassembly**, as appropriate, within each of the groupings. The codes applicable to this publication are shown at the beginning of each procedure, as necessary, to guide you to specific component information.

Additionally, a two-character alpha code (i.e., [NV] RINGS, PISTON) may be referenced with each procedure. This alpha code, in combination with the three-digit Group number, identifies the specific assembly, sub-assembly or part, and directly relates to the first five positions of the operation code listed in MACK Service Labor Time Standards.

Example:



Numerical Code

CONVERSION CHART

Conversion Units			Multiply By:
Length Calculations			
Inches (in)	to	Millimeters (mm)	25.40
Inches (in)	to	Centimeters (cm)	2.540
Feet (ft)	to	Centimeters (cm)	30.48
Feet (ft)	to	Meters (m)	0.3048
Yards (yd)	to	Centimeters (cm)	91.44
Yards (yd)	to	Meters (m)	0.9144
Miles	to	Kilometers (km)	1.609
Millimeters (mm)	to	Inches (in)	0.03937
Centimeters (cm)	to	Inches (in)	0.3937
Centimeters (cm)	to	Feet (ft)	0.0328
Centimeters (cm)	to	Yards (yd)	0.0109
Meters (m)	to	Feet (ft)	3.281
Meters (m)	to	Yards (yd)	1.094
Kilometers (km)	to	Miles	0.6214
Area Calculations			
Square Inches (sq-in)	to	Square Millimeters (sq-mm)	645.2
Square Inches (sq-in)	to	Square Centimeters (sq-cm)	6.452
Square Feet (sq-ft)	to	Square Centimeters (sq-cm)	929.0
Square Feet (sq-ft)	to	Square Meters (sq-m)	0.0929
Square Yards (sq-yd)	to	Square Meters (sq-m)	0.8361
Square Miles (sq-miles)	to	Square Kilometers (sq-km)	2.590
Square Millimeters (sq-mm)	to	Square Inches (sq-in)	0.00155
Square Centimeters (sq-cm)	to	Square Inches (sq-in)	0.155
Square Centimeters (sq-cm)	to	Square Feet (sq-ft)	0.001076
Square Meters (sq-m)	to	Square Feet (sq-ft)	10.76
Square Meters (sq-m)	to	Square Yards (sq-yd)	1.196
Square Kilometers (sq-km)	to	Square Miles (sq-miles)	0.3861
Volume Calculations			
Cubic Inches (cu-in)	to	Cubic Centimeters (cu-cm)	16.387
Cubic Inches (cu-in)	to	Liters (L)	0.01639
Quarts (qt)	to	Liters (L)	0.9464
Gallons (gal)	to	Liters (L)	3.7854
Cubic Yards (cu-yd)	to	Cubic Meters (cu-m)	0.7646
Cubic Centimeters (cu-cm)	to	Cubic Inches (cu-in)	0.06102
Liters (L)	to	Cubic Inches (cu-in)	61.024
Liters (L)	to	Quarts (qt)	1.0567
Liters (L)	to	Gallons (gal)	0.2642
Cubic Meters (cu-m)	to	Cubic Yards (cu-yd)	1.308

Conversion Units			Multiply By:
Weight Calculations			
Ounces (oz)	to	Grams (g)	28.5714
Pounds (lb)	to	Kilograms (kg)	0.4536
Pounds (lb)	to	Short Tons (US tons)	0.0005
Pounds (lb)	to	Metric Tons (t)	0.00045
Short Tons (US tons)	to	Pounds (lb)	2000
Short Tons (US tons)	to	Kilograms (kg)	907.18486
Short Tons (US tons)	to	Metric Tons (t)	0.90718
Grams (g)	to	Ounces (oz)	0.035
Kilograms (kg)	to	Pounds (lb)	2.205
Kilograms (kg)	to	Short Tons (US tons)	0.001102
Kilograms (kg)	to	Metric Tons (t)	0.001
Metric Tons (t)	to	Pounds (lb)	2205
Metric Tons (t)	to	Short Tons (US tons)	1.1023
Metric Tons (t)	to	Kilograms (kg)	1000
Force Calculations			
Ounces Force (ozf)	to	Newtons (N)	0.2780
Pounds Force (lbf)	to	Newtons (N)	4.448
Pounds Force (lbf)	to	Kilograms Force (kgf)	0.456
Kilograms Force (kgf)	to	Pounds Force (lbf)	2.2046
Kilograms Force (kgf)	to	Newtons (N)	9.807
Newtons (N)	to	Kilograms Force (kgf)	0.10196
Newtons (N)	to	Ounces Force (ozf)	3.597
Newtons (N)	to	Pounds Force (lbf)	0.2248
Torque Calculations			
Pound Inches (lb-in)	to	Newton Meters (N•m)	0.11298
Pound Feet (lb-ft)	to	Newton Meters (N•m)	1.3558
Pound Feet (lb-ft)	to	Kilograms Force per Meter (kgfm)	0.13825
Newton Meters (N•m)	to	Pound Inches (lb-in)	8.851
Newton Meters (N•m)	to	Pound Feet (lb-ft)	0.7376
Newton Meters (N•m)	to	Kilograms Force per Meter (kgfm)	0.10197
Kilograms Force per Meter (kgfm)	to	Pound Feet (lb-ft)	7.233
Kilograms Force per Meter (kgfm)	to	Newton Meters (N•m)	9.807
Radiator Specific Heat Dissipation Calculations			
British Thermal Unit per Hour (BTU/hr)	to	Kilowatt per Degree Celsius (kW/°C)	0.000293
Kilowatt per Degree Celsius (kW/°C)	to	British Thermal Unit per Hour (BTU/hr)	3414.43
Temperature Calculations			
Degrees Fahrenheit (°F)	to	Degrees Celsius (°C)	(°F – 32) x 0.556
Degrees Celsius (°C)	to	Degrees Fahrenheit (°F)	(1.8 x °C) + 32

Conversion Units			Multiply By:
Pressure Calculations			
Atmospheres (atm)	to	Bars (bar)	1.01325
Atmospheres (atm)	to	Kilopascals (kPa)	101.325
Bars (bar)	to	Atmospheres (atm)	0.98692
Bars (bar)	to	Kilopascals (kPa)	100
Bar (bar)	to	Pounds per Square Inch (psi)	14.5037
Inches of Mercury (in Hg)	to	Kilopascals (kPa)	3.377
Inches of Water (in H_2O)	to	Kilopascals (kPa)	0.2491
Pounds per Square Inch (psi)	to	Kilopascals (kPa)	6.895
Pounds per Square Inch (psi)	to	Bar (bar)	0.06895
Kilopascals (kPa)	to	Atmospheres (atm)	0.00987
Kilopascals (kPa)	to	Inches of Mercury (in Hg)	0.29612
Kilopascals (kPa)	to	Inches of Water (in H_2O)	4.01445
Kilopascals (kPa)	to	Pounds per Square Inch (psi)	0.145
Power Calculations			
Horsepower (hp)	to	Kilowatts (kW)	0.74627
Kilowatts (kW)	to	Horsepower (hp)	1.34
Fuel Performance Calculations			
Miles per Gallon (mile/gal)	to	Kilometers per Liter (km/L)	0.4251
Kilometers per Liter (km/L)	to	Miles per Gallon (mile/gal)	2.352
Velocity Calculations			
Miles per Hour (mile/hr)	to	Kilometers per Hour (km/hr)	1.609
Kilometers per Hour (km/hr)	to	Miles per Hour (mile/hr)	0.6214
Volume Flow Calculations			
Cubic Feet per Minute (cu-ft/min)	to	Liters per Minute (L/min)	28.32
Liters per Minute (L/min)	to	Cubic Feet per Minute (cu-ft/min)	0.03531

ABOUT THE MACK ASET™ AC DIESEL ENGINE

This publication is intended to provide technicians with a working knowledge of the ASET™ AC diesel engine with cooled exhaust gas recirculation. MACK offers a similar engine to the AC which is more suited to the vocational applications called the AI/AMI. The AI/AMI engine is an internal exhaust gas recirculation design engine. For service and overhaul procedures for the ASET™ AI/AMI engine, refer to the 5-110 ASET™ AI/AMI Engines Service Manual. ASET™ is an acronym meaning Application Specific Engine Technology.

The ASET™ AC engine design is based on the E-Tech™ left-side redesign (LSR) with its plate-type oil cooler and oil filter mounting arrangement. A redesigned Centri-Max® ULTRA, and later ULTRA PLUS, centrifugal oil filter assembly and cover housing with an integral oil fill tube, is incorporated on all AC engines.

The ASET™ AC utilizes a new EECU with greater capacity which is relocated to the front left-side of the inlet manifold. The increased capacity of the EECU requires the addition of a cooling plate to help dissipate heat. The AC design also provides for cooling of the exhaust gases being recirculated through the combustion chambers.

Descriptions of these design changes and the other features are provided in detail in the DESCRIPTION & OPERATION section. Additionally, the service effects of these changes on removal, installation, disassembly, assembly, setup and adjustment procedures, etc., are included in the MAINTENANCE and REPAIR INSTRUCTIONS sections.

Development of the ASET™ AC engine has been driven by three basic requirements. It is designed to:

- Meet the year 2004 exhaust emission regulations.
- Meet customer demands for improved fuel economy, driveability and engine braking.
- Compete in a world market.

Although the drive to reduce emissions levels is primarily the result of government mandates, the ASET™AC engine is designed to be durable and easily maintained and to provide customers with good performance and fuel economy.

Mack Trucks, Inc. is looking beyond the borders of North America to increase its market and bring the quality, toughness and technology associated with the MACK name to a worldwide audience. The current environment of global regulations concerning exhaust emissions, noise and other factors has leveled the playing field on an international basis. This means that the improvements made to meet the North American environmental regulations are now applied worldwide.

Heater Core and Optional Fuel Heater Hose Connection Revisions

Beginning second quarter of 2004, a cooling system revision was phased into production that affects the ASET™ AC engines to move the heater core and optional fuel heater coolant return hose connection point. This change moves the heater core and optional fuel heater coolant return hoses from the thermostat housing bypass area to new locations on the lower radiator tube. This change is described in detail in the ENGINE DESIGN FEATURES section of this manual.

NOTES

VISUAL IDENTIFICATION

ENGINE MODEL IDENTIFICATION

(ASET™ AC ENGINE)

Engine Information Plate

The engine information plate is located on the top of the front cylinder head cover (back cover for LE and MR chassis). This plate includes information concerning:

- Engine model, serial number and 11GBA part number.
- Advertised horsepower at rated speed rpm.
- Emissions regulations to which the engine conforms and other pertinent information required by emissions regulations.
- Inlet and exhaust valve lash settings and engine brake slave piston lash setting.

The following explanations are provided to aid in interpreting some of the key information found on the engine information plate.

Item 1 — U.S. EPA Regulations

- An X in block 1 means the engine meets United States EPA regulations for the year stamped in block 4.

Item 2 — California Regulations

- An X in block 2 indicates the engine meets California emissions regulations for the year stamped in block 4. This engine is referred to as a 50-state engine and can be sold in any state throughout the United States.

Item 3 — ADR Regulations

- An X in block 3 means the engine has been certified to meet Australian emissions regulations.
- One dash in block 3 indicates that the engine is not to be operated in Australia.

Item 4 — Model Year

- The four-digit number stamped in block 4 represents the year in which the engine was certified.

Item 5 — Federal Family

- The 12-digit number stamped in block 5 denotes the Federal Family to which the engine belongs, for emissions certification purposes.
- All engines will have a 12-digit Federal Family number in block 5.
- The letter in the Federal Family number further identifies engine configuration as follows:

  V — Vocational ASET™ AI/AMI (IEGR)

  H — Highway ASET™ AC (CEGR)

  G — Natural gas engines

  P — (Pumper) non-road engine

Item 6 — California Family

- If the engine meets California emissions regulations, the same 12-digit number stamped in the Federal Family block will be stamped in the California block.
- If the engine does not meet California emissions regulations, there will be two dashes in block 6.

Item 7 — Exhaust Emission Control System

- These letters represent the basic engine systems that impact emissions and are defined as follows:

  EM — Engine Modification

  EC — Engine Control

  TC — Turbocharger

  CAC — Charge Air Cooler

  DI — Direct Injection

  SPL — Smoke Puff Limiter

  CEGR — Cooled Exhaust Gas Recirculation

Item 8 — Engine Brake

- This block is used only when the engine is equipped with an engine brake. The number stamped in this block indicates the brake lash setting as follows:
  - J-Tech™ Engine Brake — 0.021 inch (0.53 mm)
  - PowerLeash™ Engine Brake — 0.045 inch (1.143 mm)

Item 9 — PowerLeash™ Engine Brake

- An X in block 9 indicates the engine was built with a PowerLeash™ engine brake camshaft.

Figure 1 illustrates the location of the information plate and Figure 2 illustrates its content. Figure 3 illustrates a completed sample information plate to be used as an example.

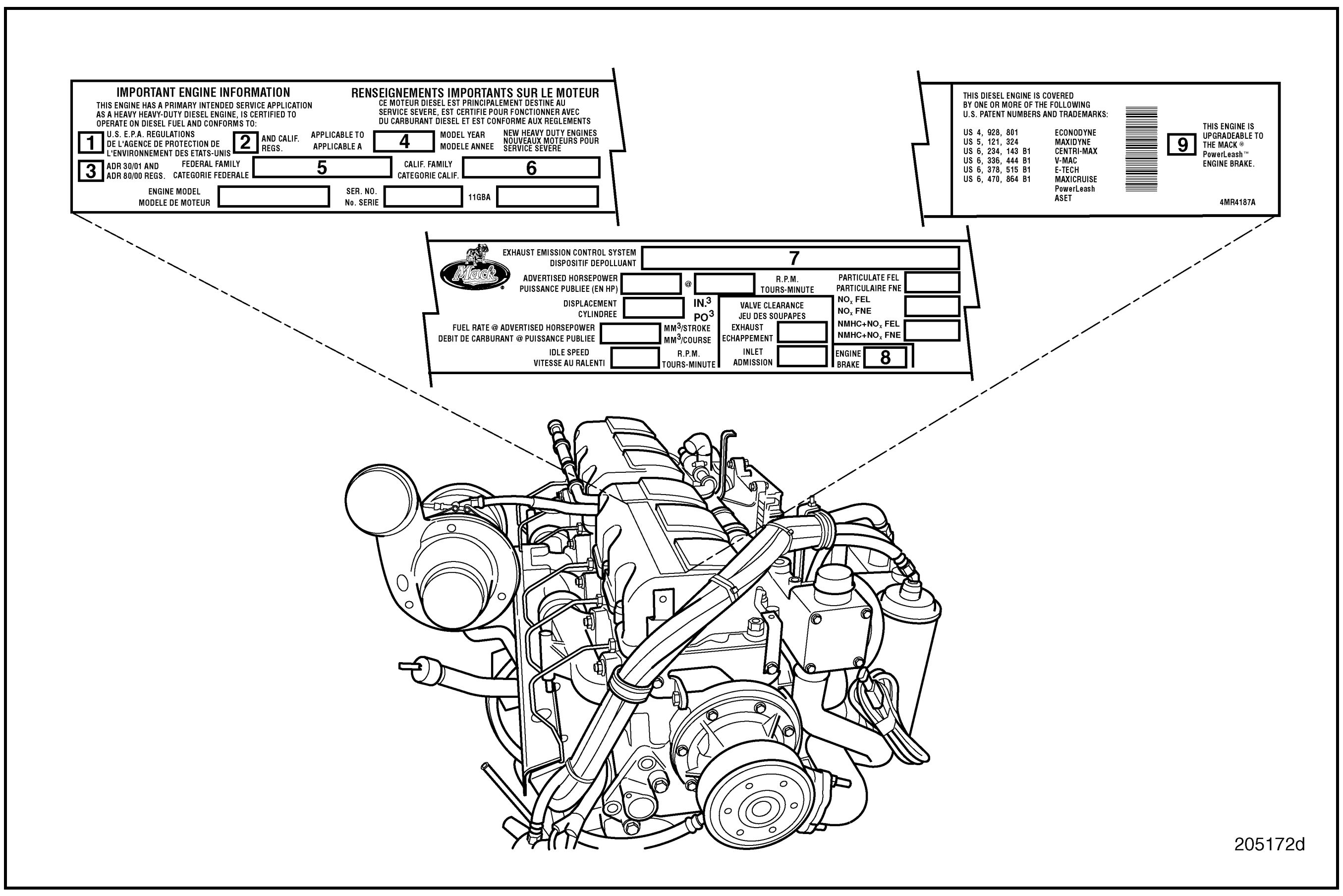


Figure 1 — Engine Information Plate Location (ASET™ AI Engine Shown, AC Same Location)

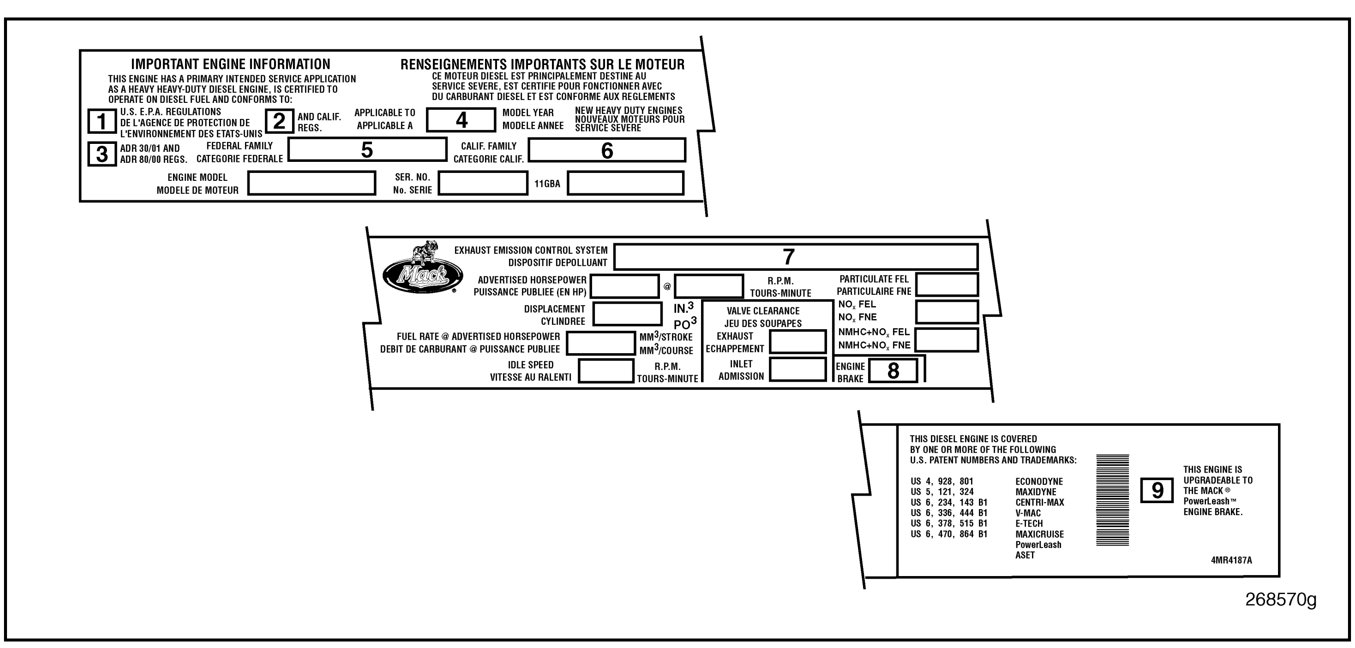


Figure 2 — Engine Information Plate

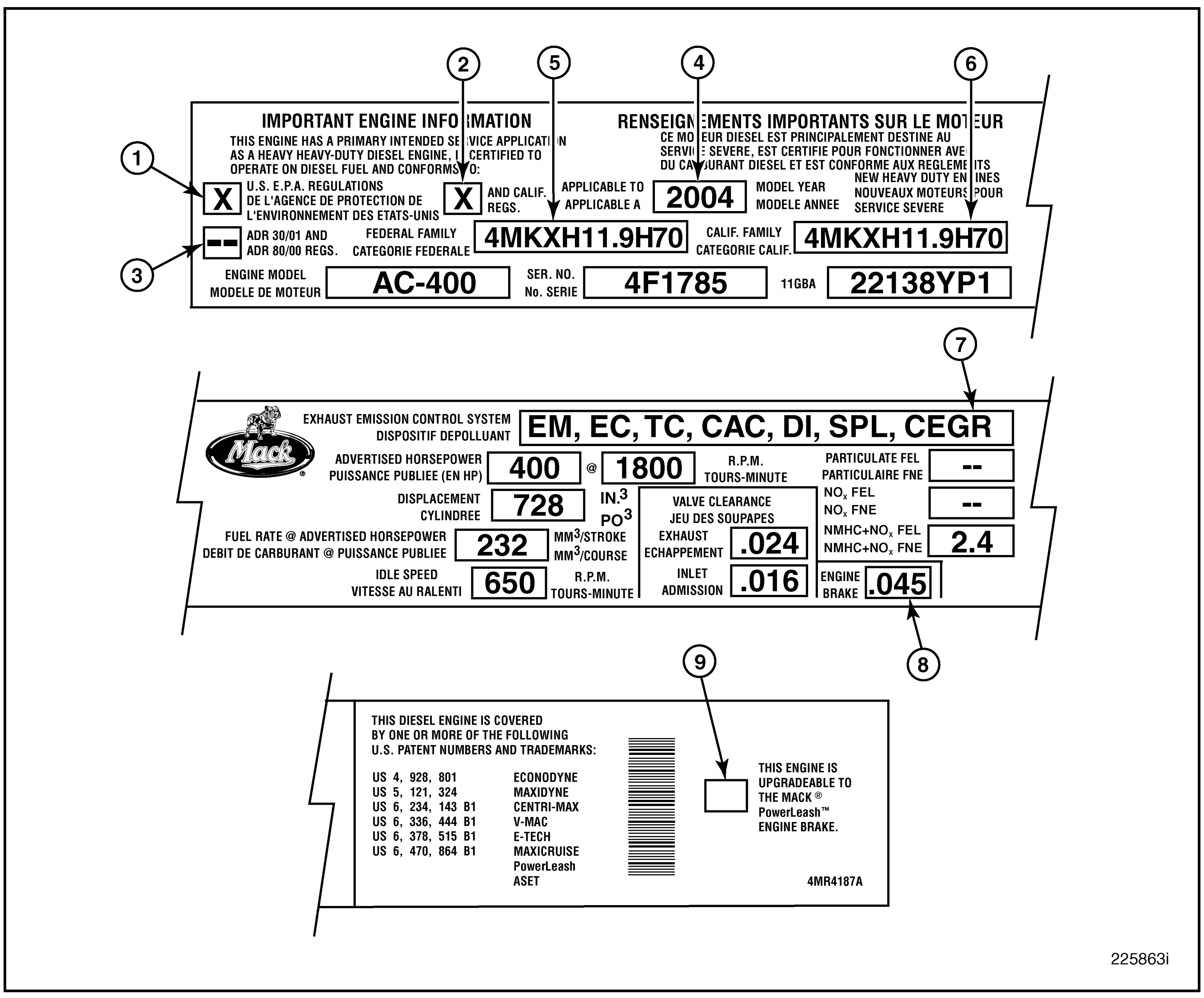


Figure 3 — Sample of Completed Plate

Engine Serial Number Identification

In addition to the engine information plate on the front cylinder head cover, the engine is also identified by the engine serial number stamped into the cylinder block. This serial number is located on the block right side just below the turbo oil drain tube flange as shown in Figure 4.

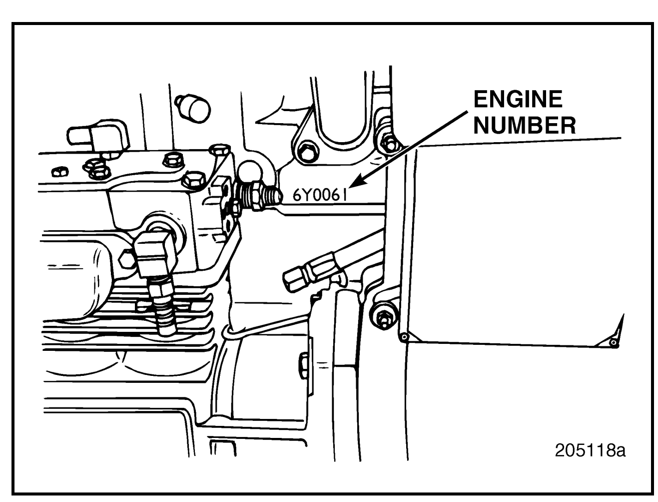


Figure 4 — Engine Serial Number

DESCRIPTION AND OPERATION

ENGINE DESIGN FEATURES

(ASET™ AC ENGINES)

In the fall of 2002, Mack Trucks introduced two new engines that comply with changes in governmental laws regulating engine emissions. Both engines evolved from the E7 E-Tech™ and continue with the electronic unit pump (EUP) fuel injection system and the V-MAC® III electronic control system. The core change in the design of the two new engines, however, is the use of exhaust gas recirculation to lower combustion temperatures for control of nitrogen oxides (NOx). Two different methods are used to accomplish this control. The methods are:

- Internal Exhaust Gas Recirculation (IEGR) — AI/AMI engine
- Cooled Exhaust Gas Recirculation (CEGR) — AC engine

This manual covers only the ASET™ AC engine's CEGR design, in which a portion of the exhaust gas is "cooled" externally before it is recirculated through the combustion chambers. The ASET™ AI engine's IEGR design receives complete service coverage in ASET™ AI/AMI Engines Service Manual 5-110. Regardless of the method used, CEGR or IEGR, both designs are improvements based on changes in several design features of the E7 E-Tech™ current controlled rate shaping (CCRS) engine. The changes are more extensive and visible for the AC engine which is used in linehaul applications at lower governed speeds, than the AI engine which is used in vocational applications at higher governed speeds.

For linehaul operations covered by the CH and CX models, the AC engine lineup provides the optimum in economy and performance with reduced NOx emissions. Included are both Econodyne® and Maxicruise®.

ASET™ AC ENGINE APPLICATIONS

Engine	Chassis
ASET™ AC MAXICRUISE®	
AC-310/330	CH, CX
AC-330/350	CH, CX
AC-355/380	CH, CX
AC-380/410	CH, CX
ASET™ AC ECONODYNE®	
AC-350	CH, CX
AC-400	CH, CX
AC-427	CH, CX
AC-460 (E)	CH, CX
AC-460 (P)	CH, CX

The MACK PowerLeash™ engine brake was introduced on ASET™ engines during mid-2003. The PowerLeash™ brake is integrated into the rocker shaft assemblies and uses the standard height cylinder head cover. Compared to add-on engine brakes, the PowerLeash™ brake has lighter weight, increased braking output, improved response and more consistent operation.

ASET™ AC Engine Technologies

The ASET™ AC engine uses current controlled rate shaping (CCRS) phased into production during 2001. Current controlled rate shaping provides a modulated two-phase injection of fuel into the cylinder. With the two-phase method, a small volume of fuel is injected into the cylinder prior to ignition followed immediately by the primary fuel charge after ignition (Figure 5). This phased injection of fuel effectively helps to lower NOx emissions and improve stability at idle.

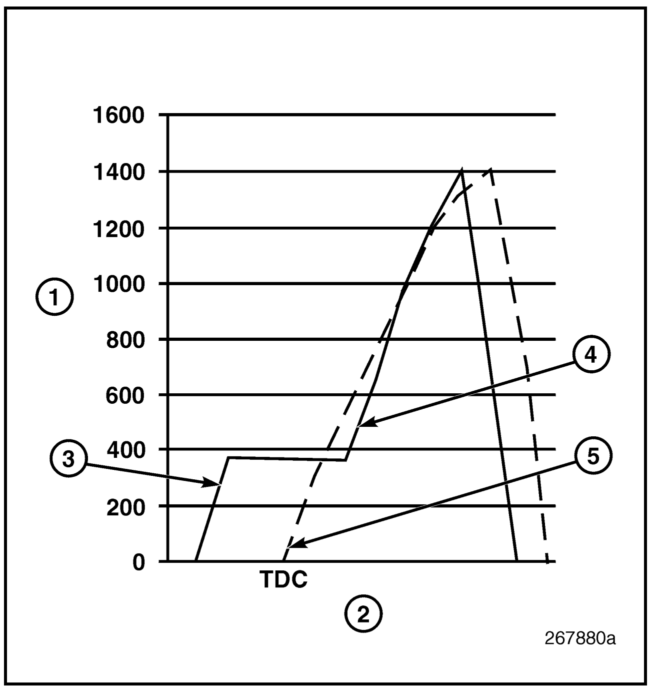


Figure 5 — CCRS "Phased" Fuel Injection

1. Pressure (bar) 2. Timing 3. CCRS Phase 1	4. CCRS Phase 2 5. Non-CCRS

The port design of the cylinder heads, the valve seat inserts and the piston crowns have been redesigned to change the swirl characteristics of the inlet charge. The redesigned piston is cast with a re-entrant bowl shape that is narrower at the top and widens as it curves deeper into the crown (Figure 6).

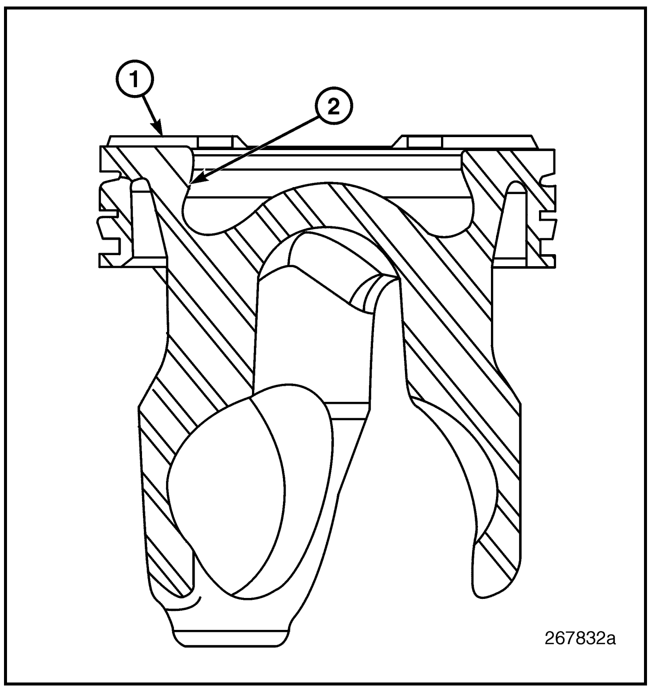


Figure 6 — Redesigned Piston Crown

1. Piston Crown	2. Re-Entrant Bowl

In addition, both the inlet and exhaust valve seat inserts are of a new design that has a smooth rounded radius (Figure 7) to achieve the optimum flow of air and exhaust gases in and out of the cylinders. With these changes, swirl is generated within the cylinder where it is needed to effectively mix inlet air, fuel and recirculated exhaust gas. Along with swirl characteristics, compression ratios have been changed for combustion efficiency, improved cold-start capability, faster warm-up and improved idle stability. Also, the top compression ring face coating has been revised to provide long life and less cylinder bore wear.

At the base of the valve seat insert radii, the contact surfaces with the valves are 30 degrees and 20 degrees, respectively, for exhaust and inlet valves. This is the same as current engines. However, the new design of the seat inserts prevents their removal in the traditional manner. A revised procedure for replacing the inserts is covered in the REPAIR INSTRUCTIONS section.

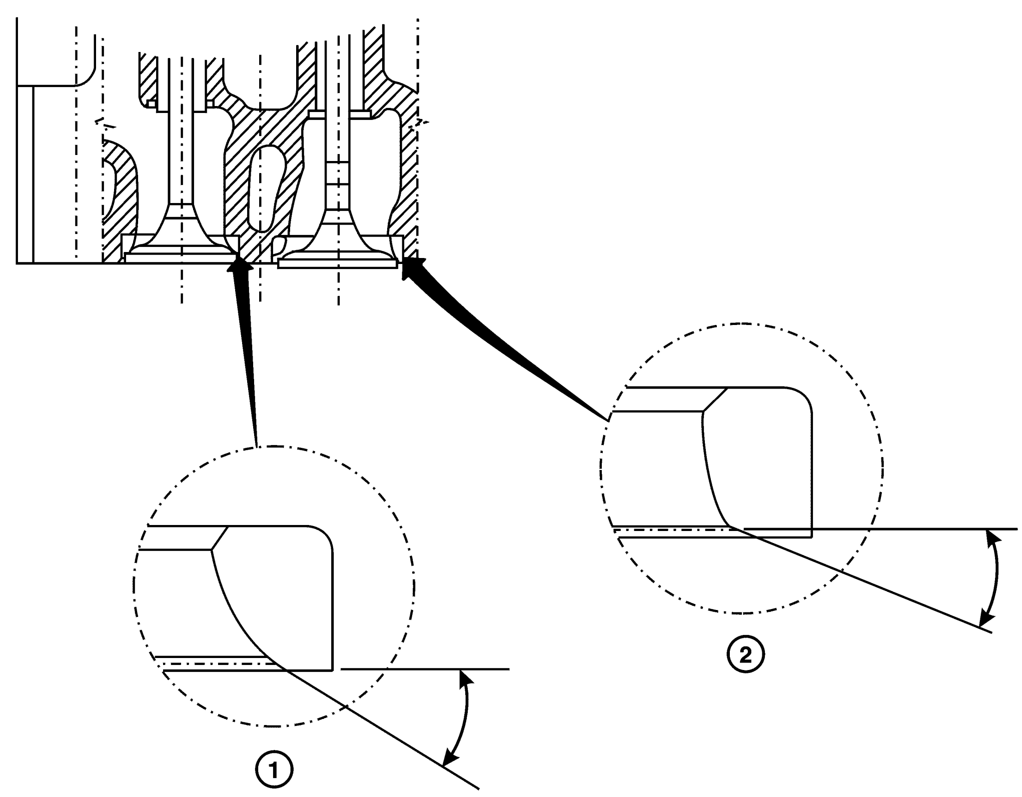


Figure 7 — Redesigned Valve Seat Inserts

1. Exhaust Valve Seat (with 30-Degree Contact Face)	2. Inlet Valve Seat (with 20-Degree Contact Face)

With the ASET™ AC (CEGR) engine technology, exhaust gas is recirculated by first being cooled and then mixed with the charged inlet air prior to entering the cylinder. While this leads to a more complex system with additional hardware, it works effectively to reduce NOx emissions and maintain fuel economy in linehaul applications with lower engine operating speed ranges.

The additional hardware required for the CEGR engine exhaust gas recirculation includes components to meter exhaust gases from the exhaust manifold for mixing with the charge air prior to entering the inlet manifold. An engine coolant cooled EGR cooler is used to reduce the exhaust gas temperature before it is released into the EGR mixing tube. The system also makes use of a variable geometry turbocharger and a more powerful engine electronic control unit (with additional sensor inputs) to provide the precision control required for the CEGR technology.

ASET™ AC (CEGR) Engine Features and Components

The primary external features that identify the AC (CEGR) engine include the following items:

- Cooled Exhaust Gas Recirculation (CEGR) system
- Variable Turbine Geometry (VTG) Turbocharger
- Modified cooling system with a redesigned water pump and housing
- Front fan and accessory drive arrangement with dual poly-V belts
- Increased capacity oil pan
- Relocation of the oil dipstick tube to the oil pan at the left side of the engine
- Enhanced engine electronic control unit (EECU) with increased capacity to measure and manage additional sensor inputs

COOLED EXHAUST GAS RECIRCULATION

The ASET™ AC engine with cooled exhaust gas recirculation (CEGR) incorporates an EGR valve and cooler along with the necessary piping and mixer tube (Figure 8). This hardware is controlled via an engine electronic control unit (EECU) that regulates the amount of exhaust gas recirculated into the engine air inlet. Before passing into the air inlet, the exhaust is cooled from 1200°F (649°C) to 350°F (178°C), enhancing the effectiveness of the recirculated gases in reducing the emission of nitrogen oxides (NOx).

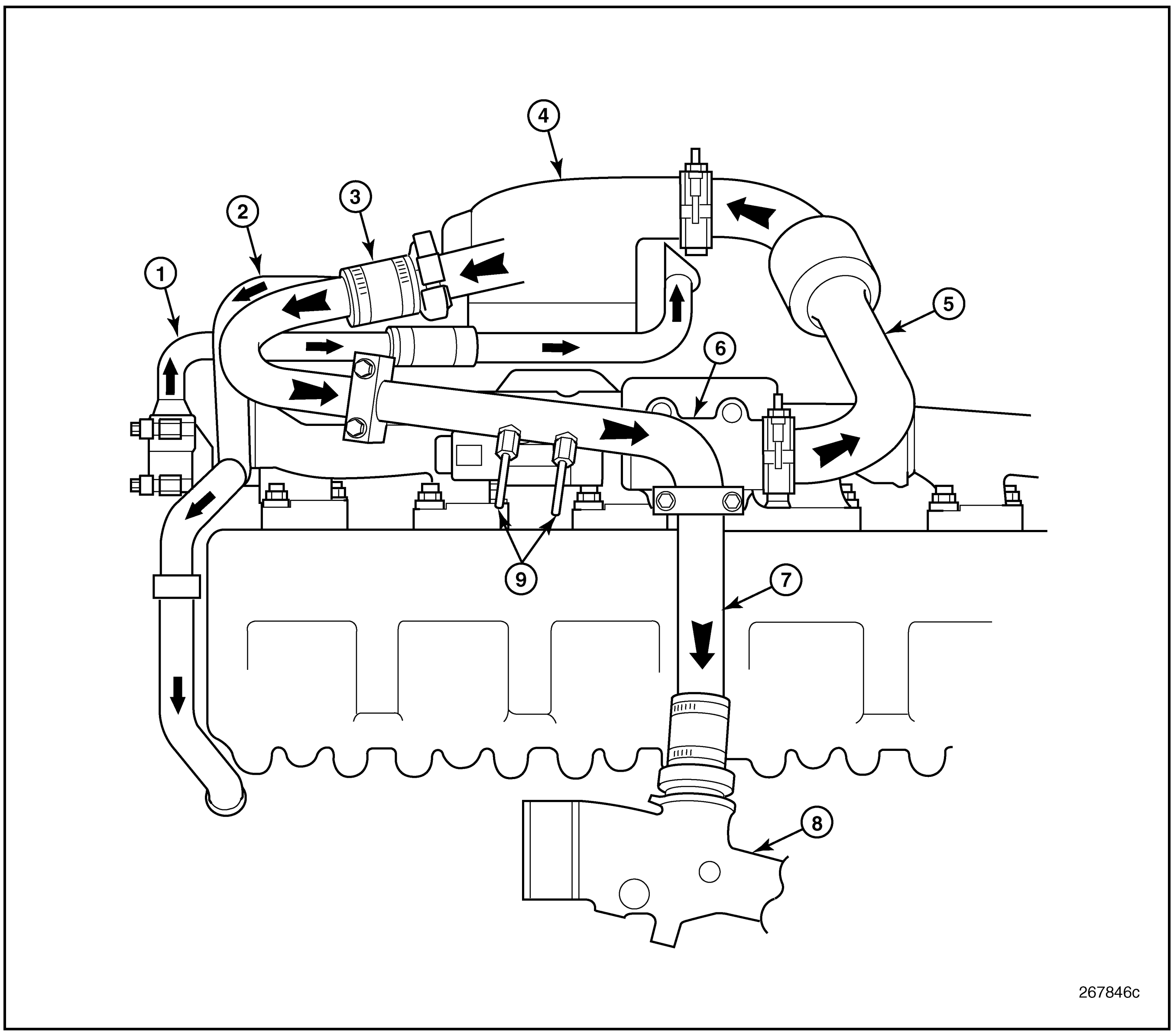


Figure 8 — Cooled Exhaust Gas Recirculation System (Engine Top View)

1. Water Pump-to-EGR Cooler Tube (Coolant Inlet) 2. EGR Cooler-to-Bypass Tube (EGR Cooler Coolant Outlet) 3. EGR Gas Tube "Cool-Side" 4. EGR Cooler 5. EGR Valve-to-Cooler "Hot-Side" Tube (EGR Gas Inlet)	6. EGR Valve 7. EGR Cooler-to-Mixer "Cool-Side" Tube (with EGR MASS Flow Sensors) 8. EGR Mixer Tube 9. EGR MASS Flow Sensors

EGR Valve — The poppet-type valve, operated by hydraulic pressure from the engine oil system, meters exhaust gas from the exhaust manifold into the EGR circuit (Figure 9). The hydraulic pressure is controlled by a solenoid within the valve assembly reacting to signals from the engine EECU. An internal spool valve diverts hydraulic fluid, applying pressure to precisely position the EGR poppet valve for control of exhaust gas circulated through the engine. The poppet valve has two sealing surfaces on a common shaft to draw gases from the front and rear sections of the manifold simultaneously.

The center section of the exhaust manifold (Figure 15) is redesigned with mounting surfaces for the EGR valve and turbocharger. The valve, which is mounted on top the center section of the manifold, is a non-serviceable unit. If a failure should occur in any part of the valve, the valve must be replaced as an assembly.

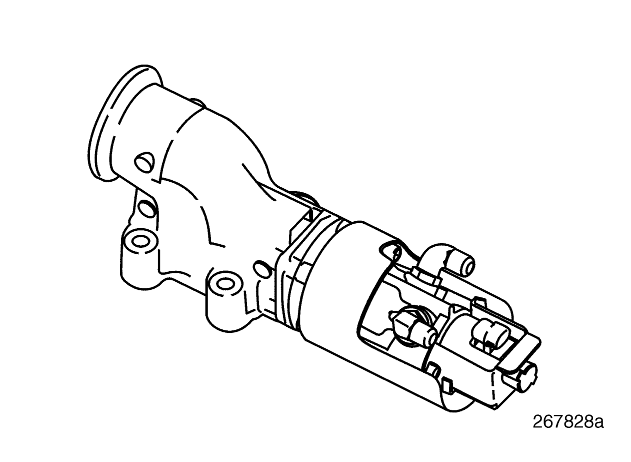


Figure 9 — EGR Valve

For current production (starting in March 2004), the design of the EGR control valve shaft seal has been changed to prevent contaminants from entering and damaging the oil seal. Additionally, a filter screen has been added to the oil inlet port (Figure 10). The screen and a wave washer are retained in the inlet port counterbore by the oil inlet fitting.

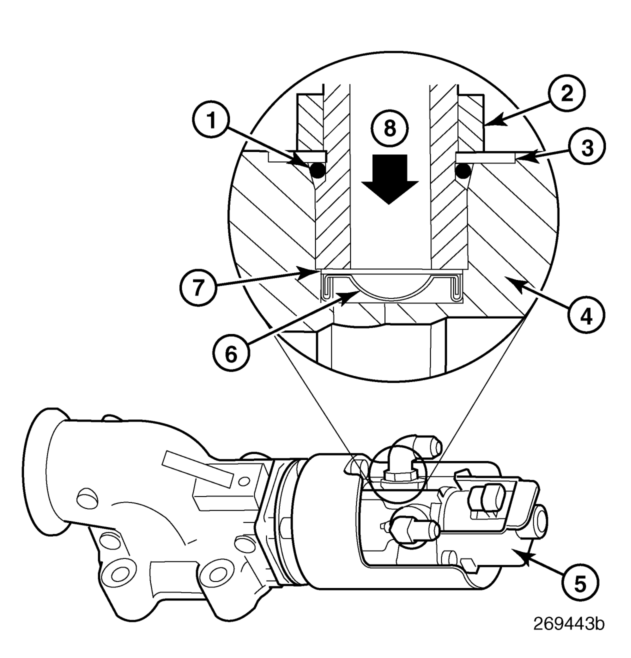


Figure 10 — EGR Valve Oil Inlet Filter Screen

1. O-Ring 2. Fitting Jam Nut 3. Integral Washer 4. Valve Body	5. Part Number Location 6. Filter Screen 7. Wave Washer 8. Oil Flow Direction

EGR Cooler — The cooler (Figure 11) is a stainless steel assembly mounted on the lower right side of the cylinder block. Hot exhaust gases enter the cooler making two passes through the core. Entering gases flow down through the outer core half and up through the inner half to exit at the top. Coolant flowing directly from the water pump makes three passes through the core. Entering at the rear, coolant is channelled forward through the top part of the core, then down and back through the bottom part, and finally up and forward for one more pass through the top before exiting at the front. This flow pattern achieves the greatest cooling effect while maintaining coolant temperatures below the boiling point.

A petcock is located at the bottom rear corner of the cooler for draining the cooler when it is to be removed for service. While there are no specific service requirements for the cooler, it is essential for coolant quality to be maintained to keep the core from becoming blocked. Also, prolonged idling can cause carbon buildup and blockage within the core and should be avoided.

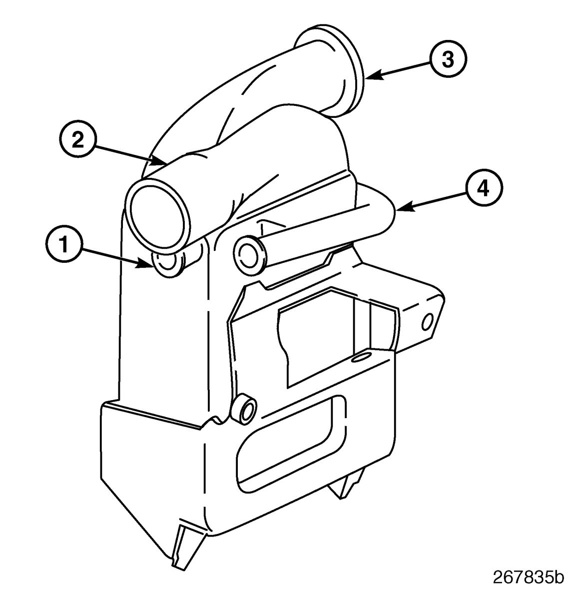


Figure 11 — EGR Cooler

1. Coolant Outlet 2. Gas Outlet	3. Gas Inlet 4. Coolant Inlet

EGR MASS Flow System Tubes and Clamps — A one-piece, 2-inch (51 mm) diameter tube is used to connect the EGR valve to the cooler on the hot side of the system. On the cool side of the system, a 1.5-inch (38 mm) diameter one-piece tube arrangement is used for routing the exhaust gases from the cooler to the mixer tube on the inlet manifold. The upper portion of the one-piece tube is fitted with the EGR MASS Flow sensors that provide system information to the EECU.

Current production now consists of a one-piece cool tube arrangement and a revised mounting system (Figure 12). Hose connections with constant tension-style clamps are used at both ends, eliminating the bellows sections as used with the two-piece arrangement. Coupling adapters are used in combination with the hoses to complete the connections on engines with flange-style cool tube ports on the mixer tube and EGR cooler. On later-production engines, the flange-style tube ports on the EGR cooler and mixer tube are redesigned to accept the hose connections directly, eliminating the need for the coupling adapters.

NOTE

The EGR MASS Flow sensors are an integral part of both EGR gas cool tube arrangements and cannot be removed. The sensors are calibrated specifically to the EGR cool tube and the EGR MASS Flow System module. If replacement is required, the entire cool tube assembly with its integral sensors and connecting harnesses MUST BE replaced along with the MASS Flow System module attached to the back of the EECU cooling plate.

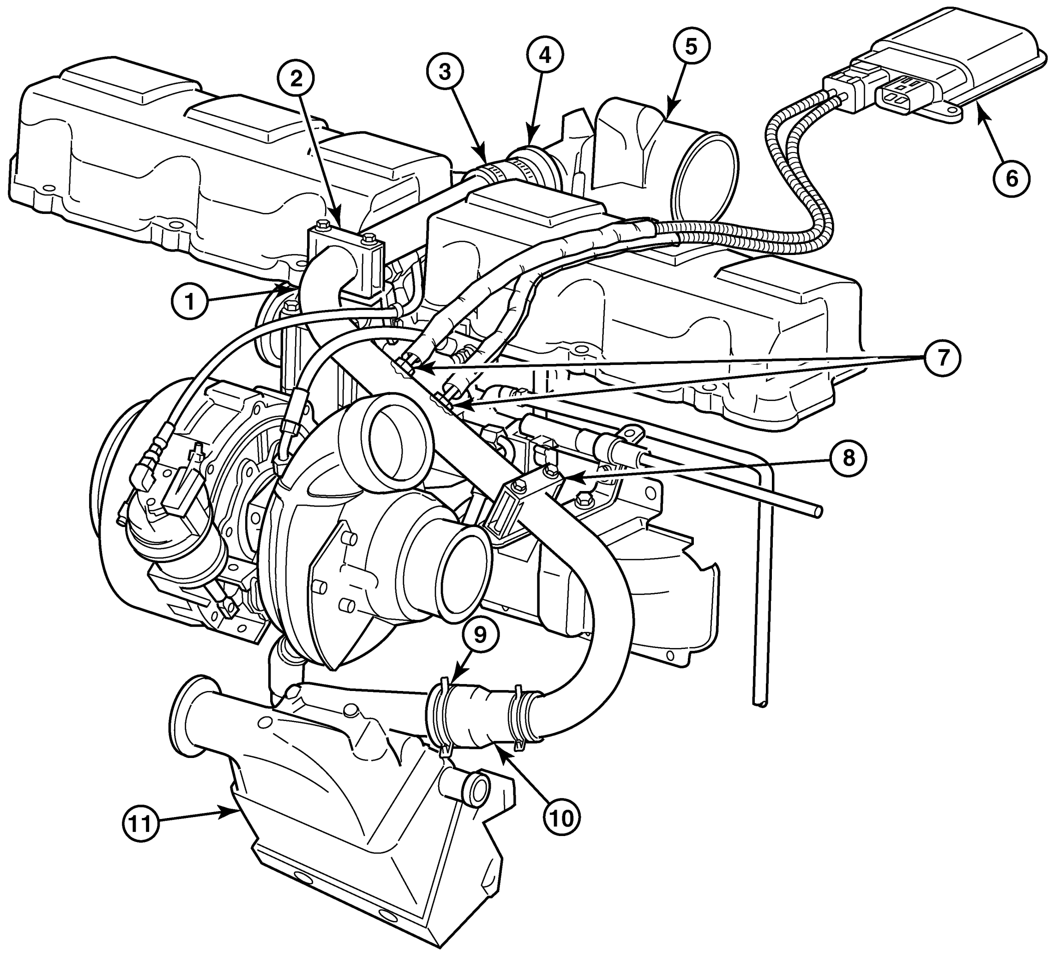


Figure 12 — MASS Flow System (with One-Piece Cool Tube Assembly)

1. EGR Cool Tube	7. MASS Flow Sensors
2. Upper Clamp	8. Lower Clamp
3. Coupling Hose and Clamps	9. Coupling Hose Clamp
4. Coupling Adapter	10. Coupling Hose
5. Mixer Tube	11. EGR Cooler
6. EGR MASS Flow Module (mounts on back of EECU cooling plate)	

Exhaust gases exiting the EGR valve are hot, near 1200°F (649°C). As such, the two tubes and four clamps are made of stainless steel to provide maximum service life. The hot tube section has an integral bellows that allows for expansion and contraction as engine temperatures change. Wire-mesh O-rings along with V-band clamps (Figure 13) are used for a gas-tight seal at the tube connections. The V-band clamps are different sizes depending on hot tube and cool tube use, with the cool tube being the smaller of the clamps. The seals are one-time use only and must be replaced anytime a tube is removed in service. Clamps used to connect the cool-side tubes generally can be reused. However, for the hot-side tube connections, the clamps can be reused, but the T-bolt and nut should not be reused. Threads of the clamp bolts used in the latter connections are prone to corrode in the hotter environment. When removed for service, the threads can be damaged making it impossible to properly torque and get a gas-tight seal with the new connection.

NOTE

The EGR hot tube clamp retaining nut may gall on the threads of the T-bolt at clamp removal. Whenever a hot tube clamp has been in-service and is removed, always install a **new** T-bolt and nut. The EGR hot tube clamps should not be replaced unless a clamp component, other than the T-bolt and nut, is damaged.

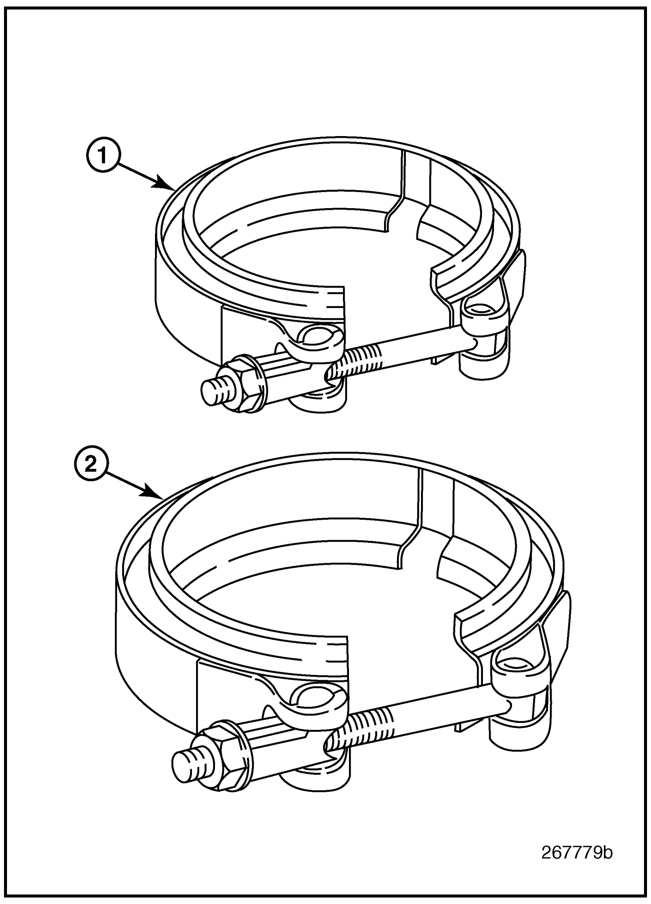


Figure 13 — EGR Tube Clamps

1. Cool Tube Clamp	2. Hot Tube Clamp

EGR MASS Flow System — As mentioned earlier, the EGR MASS Flow System (MFS) consists of a one-piece cool tube, two MASS flow sensors and the MFS electronic module. The MASS flow sensors are permanently mounted in the EGR tube bosses, and harnesses connect the sensors to the MFS electronic module.

When the MASS flow system is calibrated during the manufacturing process, one or both of the sensor retaining nuts are welded to the boss threads. Neither of the sensors is to be removed from the tube, or tampered with in any way. Additionally, the MASS flow system electronic module is calibrated to the tube and sensor assembly.

The entire cool tube with the EGR MASS Flow sensors must be replaced as an assembly along with replacement of the EGR MASS Flow control module should any part, tube, sensor or module fail.

EGR Mixer Tube — The EGR mixer tube is an assembly attached to a port at the top rear of the inlet manifold. Here, cooled exhaust gases are blended with the charged inlet air entering the inlet manifold and cylinders. The tube is a cast-aluminum assembly with ports for the CMCAC temperature and pressure sensors, and the boost air pressure relief valve (Figure 14).

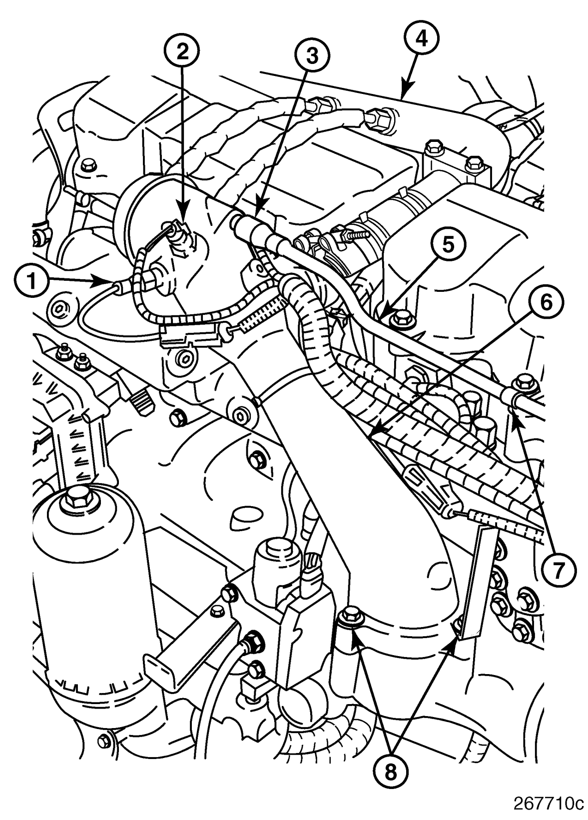


Figure 14 — EGR Mixer Tube

1. Temperature Sensor 2. Pressure Sensor 3. Boost Relief Valve 4. EGR Cool Tube	5. Boost Relief-to-Exhaust Tube 6. EGR Mixer Tube 7. Tube Clamp 8. Mixer Tube Capscrews

Boost Relief Valve (BRV) — Under certain operating conditions, high boost pressures and temperatures can be produced. To maintain boost pressures and temperatures within design limits, some AC engines have a boost relief valve located at the mixer tube venturi inlet with piping to the exhaust system.

CAUTION

No tampering with or removal of the boost air pressure relief valve is to be performed. Any such action will result in fault codes, power reduction and reduced life of CMCAC and engine components.

EGR Valve Heat Shield — To protect the EGR valve, its harness connection, oil supply and return lines from heat damage, an additional shield has been added at the right side of the engine. The additional shield surrounds the front section of the exhaust manifold and passes under the EGR valve to block heat radiating from the manifold and turbocharger.

CAUTION

All right-side heat shields, including EGR and EUP, are a mandatory part of the engine. The heat shields must be reinstalled if they are removed for maintenance or repair. Failure to do so will result in damage to the sensitive electronic and mechanical components.

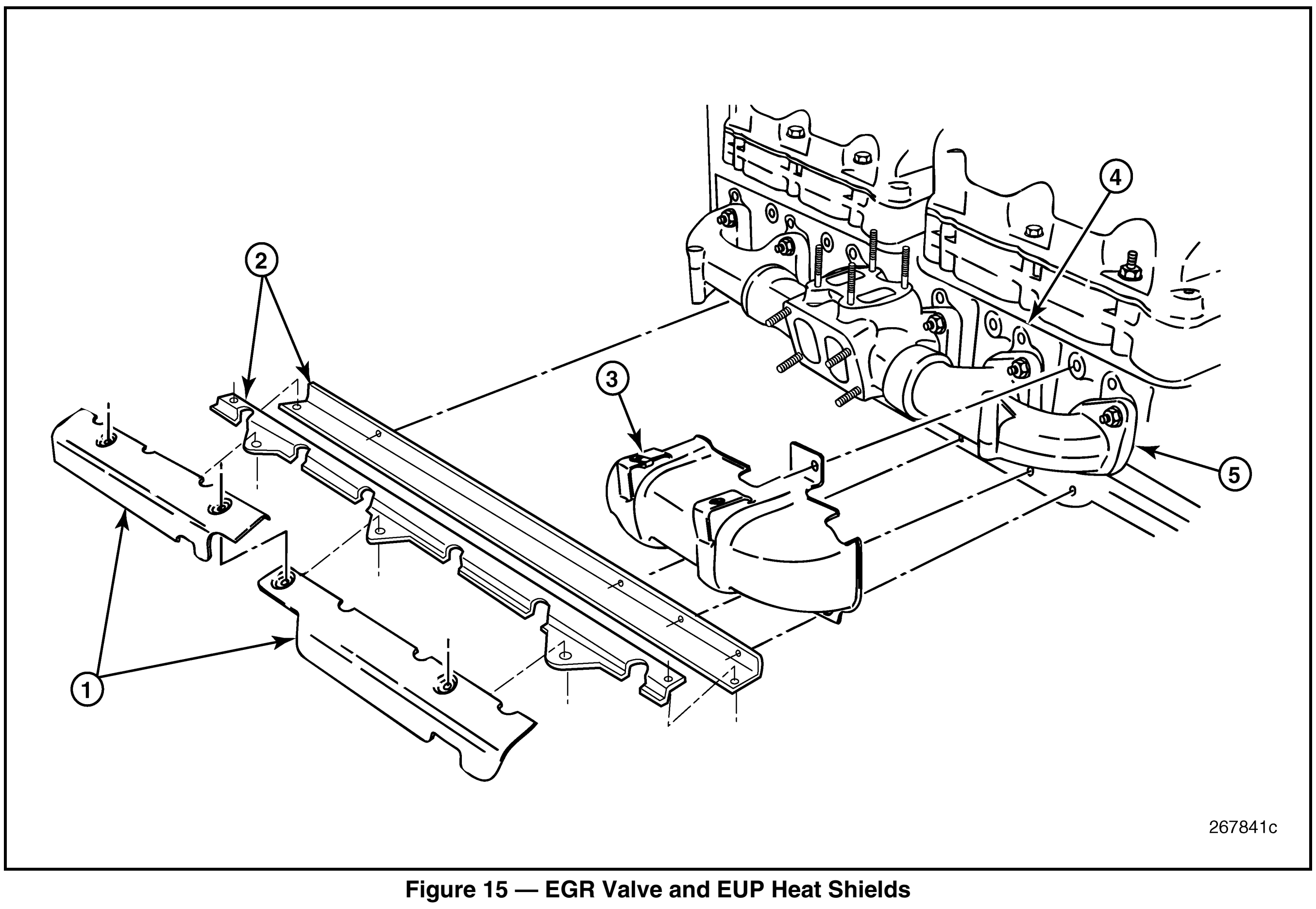


Figure 15 — EGR Valve and EUP Heat Shields

1. EUP Heat Shield (Outer) 2. EUP Heat Shield (Inner, Two Piece) 3. EGR Valve Heat Shield (Lower)	4. Cylinder Head 5. Exhaust Manifold

VARIABLE TURBINE GEOMETRY (VTG) TURBOCHARGER

The ASET™ AC (CEGR) engine is equipped with a variable geometry turbocharger. The assembly can be identified by the larger turbine housing and actuator assembly (Figure 16). The turbine housing has a set of variable position vanes that maintain sufficient back-pressure in the exhaust manifold for proper operation of the EGR system. A certain amount of back-pressure is required to push the exhaust gases into the pressurized intake air at the EGR mixer. A sensor on the actuator monitors vane position and provides input to the EECU for control of vane position and exhaust back-pressure.

There are several replacement parts available for the VTG turbocharger. Available service parts are as follows:

- VTG Actuator and Position Sensor Assembly
- Turbo Wheel Speed Sensor
- VTG Actuator Flange-to-Turbine Housing Allen-Head Bolts
- VTG Actuator Clevis Pin and Pin Retaining Clip

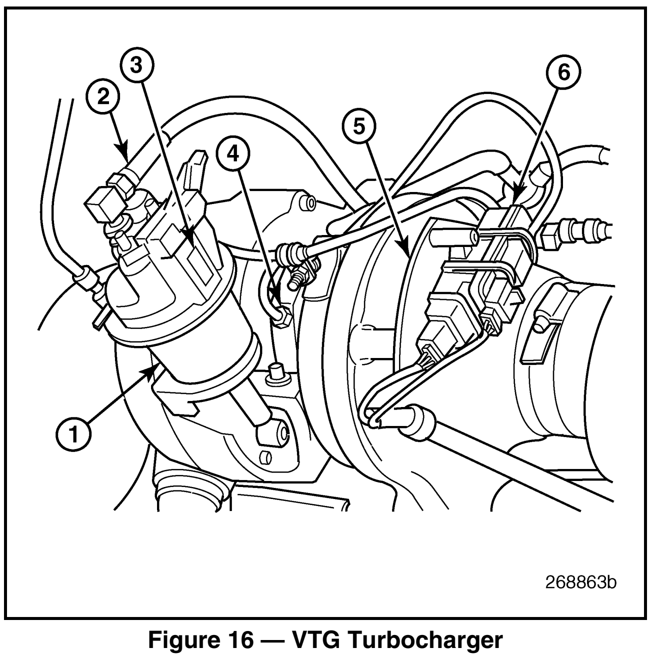


Figure 16 — VTG Turbocharger

1. VTG Vane Actuator 2. Actuator Air Line 3. Vane Position Sensor	4. Wheel Speed Sensor 5. Thermal Isolation Plate 6. Vane Position Sensor Module

In operation, modulated air pressure applied to the actuator closes the vanes. As the vanes close, the exhaust gases flow faster through a smaller opening to increase turbine shaft/wheel speed as well as increasing exhaust back-pressure. The EECU can then open the vanes as required to control back-pressure in the system.

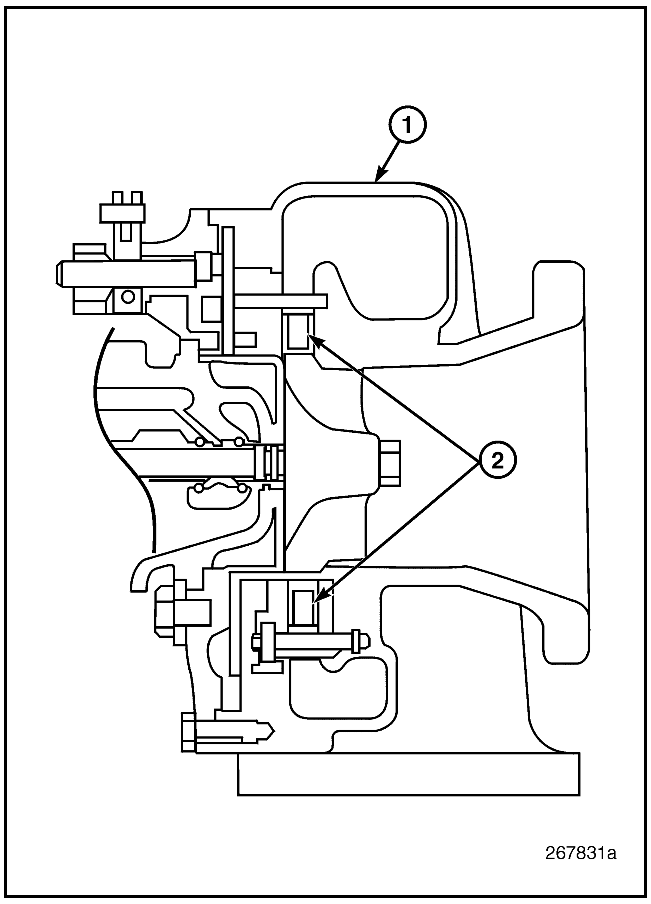


Figure 17 — Turbocharger Turbine Vanes

1. Turbine Housing	2. Turbine Vanes

The VTG Position Control Valve, which is located on the intake manifold at the No. 4 cylinder position, provides the modulated air pressure required for opening and closing the turbine vanes. The control valve is an electrically controlled pneumatic assembly (Figure 18) that either increases, decreases or maintains air pressure based on commands sent by the EECU. An air valve having this capability must constantly bleed air pressure. This bleed air is released directly to the atmosphere from a 1-inch diameter port on the lower front side of the valve assembly.

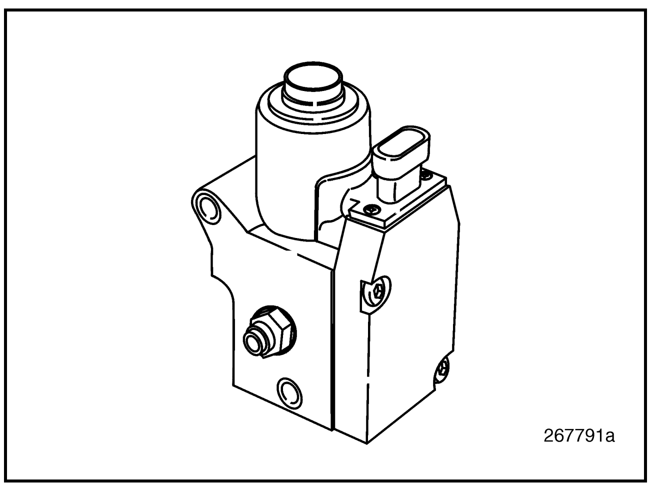


Figure 18 — VTG Position Control Valve

On early-production engines (prior to May 4, 2004), supply air enters the control valve directly from the chassis air system. As a result, small amounts of oil mist in the chassis air system can condense inside the valve. It is a normal condition to notice some oil seepage from the bleed port.

Engines produced after May 4, 2004 have an oil coalescing air filter (Figure 19) incorporated into the air line supplying the control valve to prevent oil condensation and possible “coking” inside the VTG position control valve. The filter is mounted on a bracket at the lower side of the cylinder block, to the rear of the oil filters. A service parts kit is available to retrofit early-production engines if conditions warrant it.

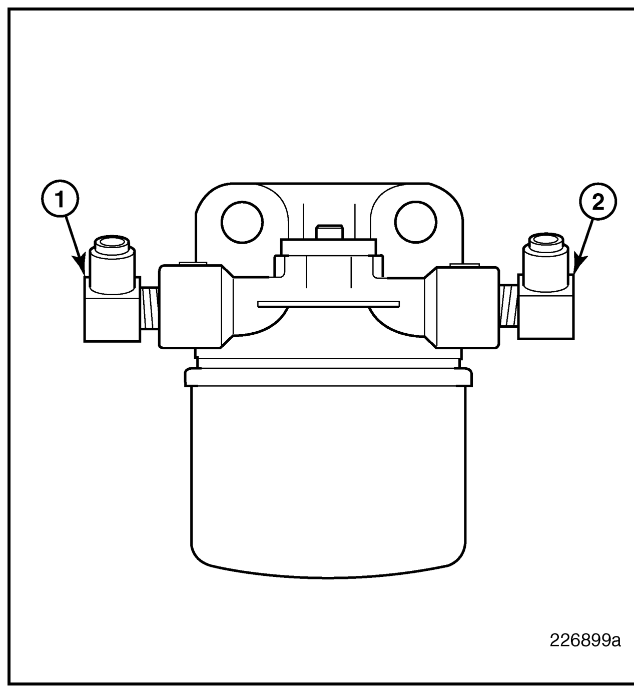


Figure 19 — Coalescing Air Filter

1. Outlet Port	2. Inlet Port

COOLING SYSTEM CHANGES

Redesigned Water Pump Housing Assembly — The water pump housing is a completely new assembly (Figure 20) covering the upper part of the cylinder block just above the front timing cover. With the new assembly, coolant flow is increased by 10 percent to meet the additional cooling capacity required by the EGR system. Coolant flows through the housing and into the cylinder block and EGR cooler circuits. These circuits run in parallel, circulating back to the inlet side of the oil cooler.

Mounted on the left side of the water pump housing is the separately serviceable pump cartridge with pulley and impeller. With the cartridge offset to the left side, the fan drive assembly and belt tensioners can be mounted directly at the center in one of several different vertical locations best suited for a vehicle configuration. Just behind the cartridge at the left rear side of the housing is a mounting pad for the coolant conditioner.

Sealing of the cartridge to the complete water pump housing is accomplished with an O-ring. The complete water pump housing assembly is bolted to the front of the cylinder block and cylinder head. Once in place, there are no service requirements for the assembly.

CAUTION

When replacing or reinstalling a removed assembly, it is critical that the setup procedures are followed to prevent the housing from being stressed and breaking.

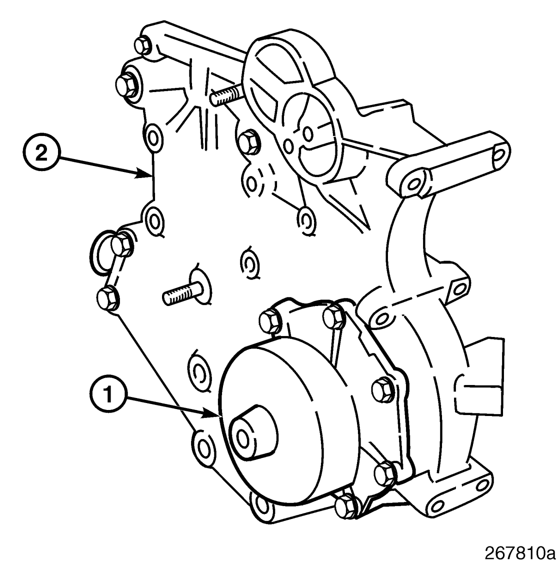


Figure 20 — Water Pump Housing Assembly

1. Water Pump Cartridge	2. Water Pump Housing

Dual Thermostat Housing — To get the additional cooling capacity and flow requirements for the EGR system, two thermostats are used. The thermostats are mounted in a new aluminum housing bolted to the top of the coolant (water) manifold (Figure 21). Sealing of the thermostat housing to the coolant manifold is accomplished by rubber seals attached to the bottom of each thermostat. No other gasket or sealant is required. A lip-type seal is pressed into the thermostat housing to prevent leakage past the thermostat barrel. Stainless steel inserts pressed into the housing eliminate any wear that otherwise would be caused by the thermostats as they open and close during operation.

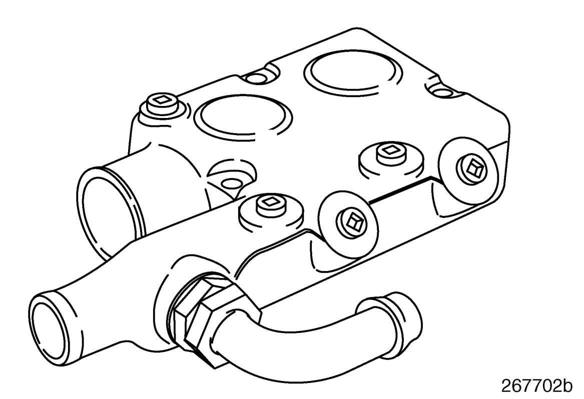


Figure 21 — Dual Thermostat Housing

Dual Thermostat Housing Revisions for 2004

The thermostat housing has an internal cast wall which divides the thermostat housing into two sections, the thermostat section and the bypass section.

The original thermostat housings had two 1/2-inch diameter holes cast into the wall between the two sections. The two 1/2-inch diameter holes restrict coolant flow so that a pressure differential is created between the two sections. This design allowed the cab heater coolant return lines to be connected to the thermostat housing bypass section.

Beginning second quarter of 2004, a thermostat housing having a larger opening in the divider wall was phased into production. This change reduces the pressure differential between the thermostat section and the bypass section, which provides improved water pump seal life and reduced cooling system noise and vibration.

With the thermostat housing positive differential reduced, the cab heater coolant return lines can no longer be connected to the revised thermostat housing or inadequate coolant flow through the heater would result. Therefore, the cab heater and optional fuel heater return lines have been moved to the radiator lower tube for highway chassis.

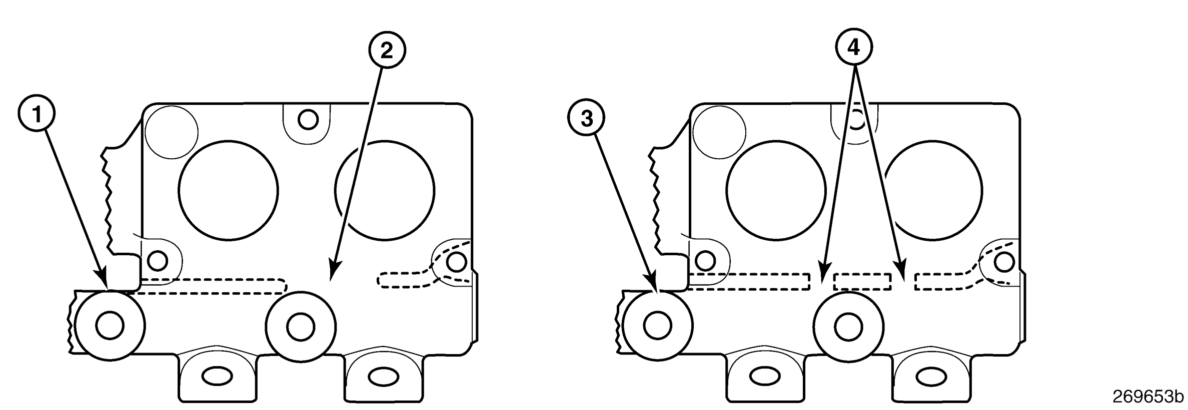


Figure 22 — Thermostat Housing Comparison

1. Thermostat Housing (2nd Quarter 04 and Later) 2. Enlarged Opening in Housing Divider Wall	3. Thermostat Housing (Prior to 2nd Quarter 04) 4. Two 1/2-Inch Holes in Housing Divider Wall

Heater Hose Connection Revisions — Beginning second quarter of 2004, a cooling system revision was phased into production that affects the ASET™ AC engine to move the cab heater and optional fuel heater coolant return hose connection point. This change relocates the heater coolant return hoses from the thermostat housing bypass area to a new location on the radiator lower tube.

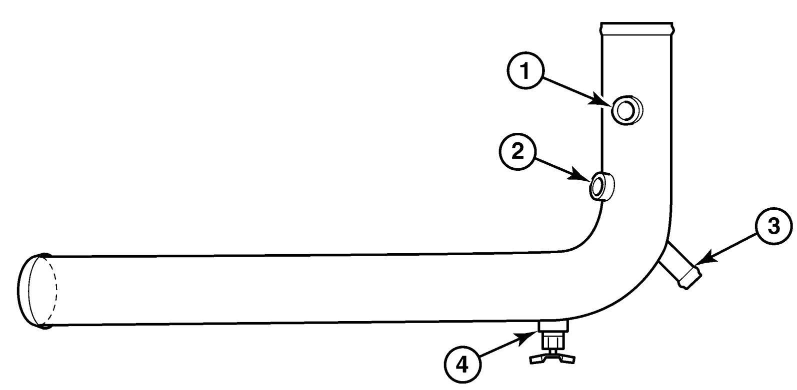


Figure 23 — Radiator Lower Tube with Welded Bosses (Spuds) for Heater Hose Connections

1. Fuel Heater Coolant Return 2. Cab/Sleeper Heater Coolant Return	3. Transmission Oil Cooler (If Equipped) 4. Draincock

Coolant and Inlet Manifolds — The coolant and inlet manifolds are both new designs changed to accommodate the dual thermostat housing and the EGR mixer tube (Figure 24). The coolant manifold, like the inlet manifold, is one-piece unit with a mounting pad on top for the thermostat housing. The manifold is attached to the cylinder heads with three bolts at each coolant port.

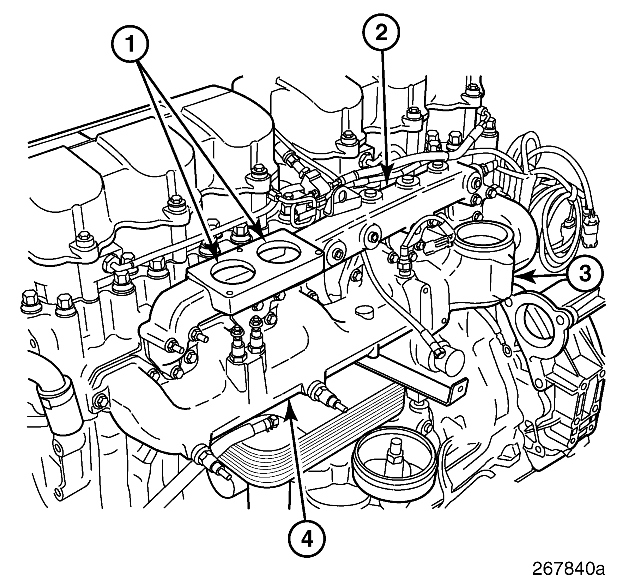


Figure 24 — Coolant and Inlet Manifolds

1. Thermostat Ports 2. Coolant Manifold	3. Mixer Tube Mounting 4. Inlet Manifold

Oil Cooler Filter Screen — A filter screen in the Y-shaped hose at the oil cooler inlet has been added to collect debris and particulates circulating in the cooling system. This prevents the oil and EGR cooler cores from becoming plugged.

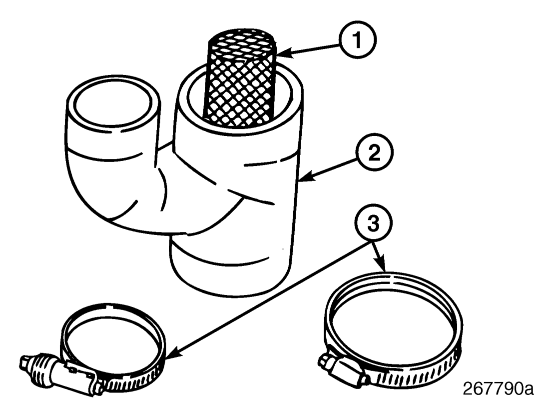


Figure 25 — Oil Cooler Filter Screen

1. Screen 2. Y-Shaped Hose	3. Hose Clamps

FRONT FAN AND ACCESSORY DRIVE ARRANGEMENT

In the dual poly-V drive belt arrangement, the fan drive is driven directly from the crankshaft pulley by a 10-rib poly-V belt. In turn, the water pump, alternator and the air conditioning compressor (if equipped) are driven off the fan-drive hub by a 6-rib poly-V belt (Figure 26). Two tensioners are used, one for the fan drive and one for the accessory drive.

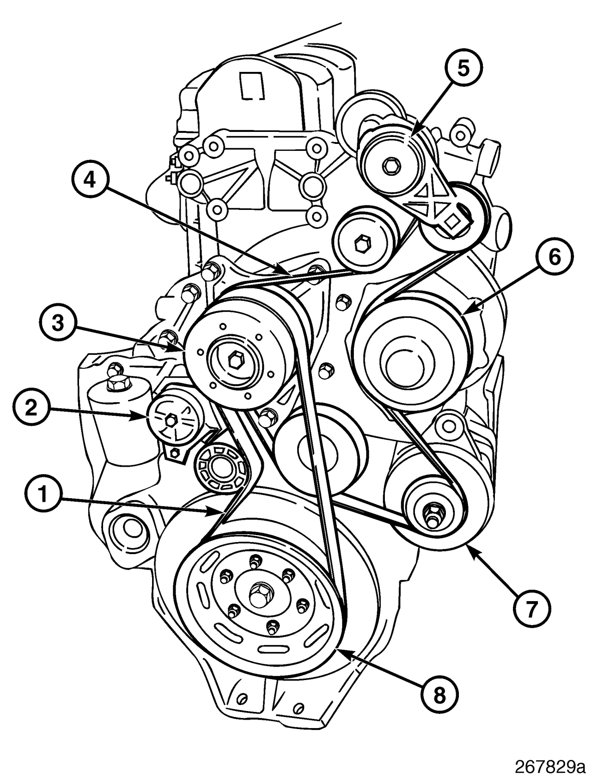


Figure 26 — Dual Poly-V Drive Belt Arrangement (Typical Non-AC Application)

1. 10-Rib Poly-V Belt	5. Tensioner
2. Tensioner	6. Water Pump
3. Fan-Drive Hub	7. Alternator
4. 6-Rib Poly-V Belt	8. Crankshaft Pulley

Both manually tensioned and automatically tensioned systems are used. Whether an engine has the manually tensioned or automatically tensioned system depends on the specific engine configuration and application. Service and adjustment is the same as current engines.

Specific accessory drive belt routing per chassis is included in the "SCHEMATIC & ROUTING DIAGRAMS" section of this manual.

VALVE SPRINGS, ROTATORS AND PUSH RODS

While valve design is unchanged, valve springs are of a new design. The progressive rate design is made from an improved material capable of working under the higher engine speeds. The AC engine is produced with a single-spring configuration at the inlet locations and a dual-spring configuration at the exhaust locations (Figure 27). The addition of an inner spring at the exhaust locations assists in seating the valves under the higher exhaust manifold back-pressures. The dual-spring configuration also requires a change in the design of the valve rotator, the exhaust valve guide and the valve stem seal.

SERVICE HINT

Current-production exhaust location inner springs are now being painted white. These springs are completely interchangeable with the former bare steel springs. The white paint was added to help verify that the inner spring is present after the cylinder head is built-up.

Valve Rotators

The dual-spring exhaust configuration changes the design of the valve rotator to include seating surfaces for both the inner and outer valve springs. This two stepped rotator is shown in Figure 29.

Early design configurations for both the single inlet and dual exhaust spring placed the rotators on the "tip-end" of the valve spring with a hardened washer at the valve spring seat. The hardened washers were added to prevent damage to the cylinder head that could be caused by the valve spring. Beginning June 2003, the valve spring configuration changed to a bottom rotator design, however, the single inlet and dual exhaust spring configuration remained. The bottom rotator design eliminated the need for the hardened washer spring seats. With both top and bottom designs, the rotator used with the dual springs is different from the rotator used with the single spring and the correct rotator must be used.

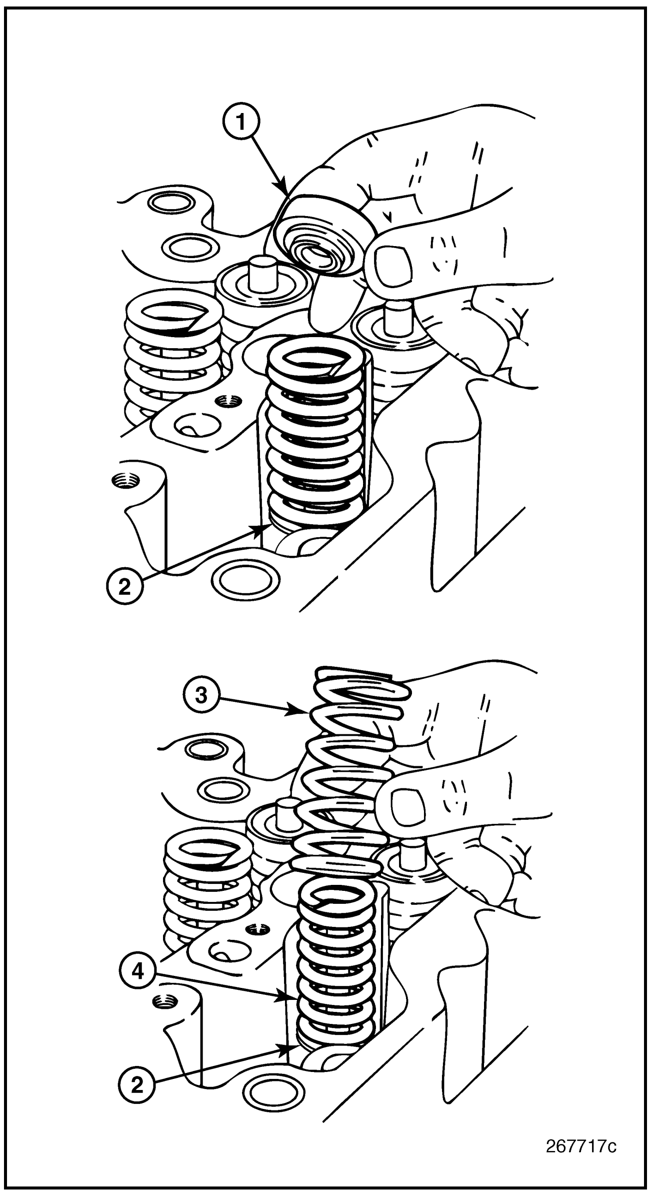


Figure 27 — Dual Exhaust Springs (to Mid-Year 2003)

1. Spring Rotator (Tip-End) 2. Hardened Spring Washer	3. Exhaust Spring (Outer) 4. Exhaust Spring (Inner)

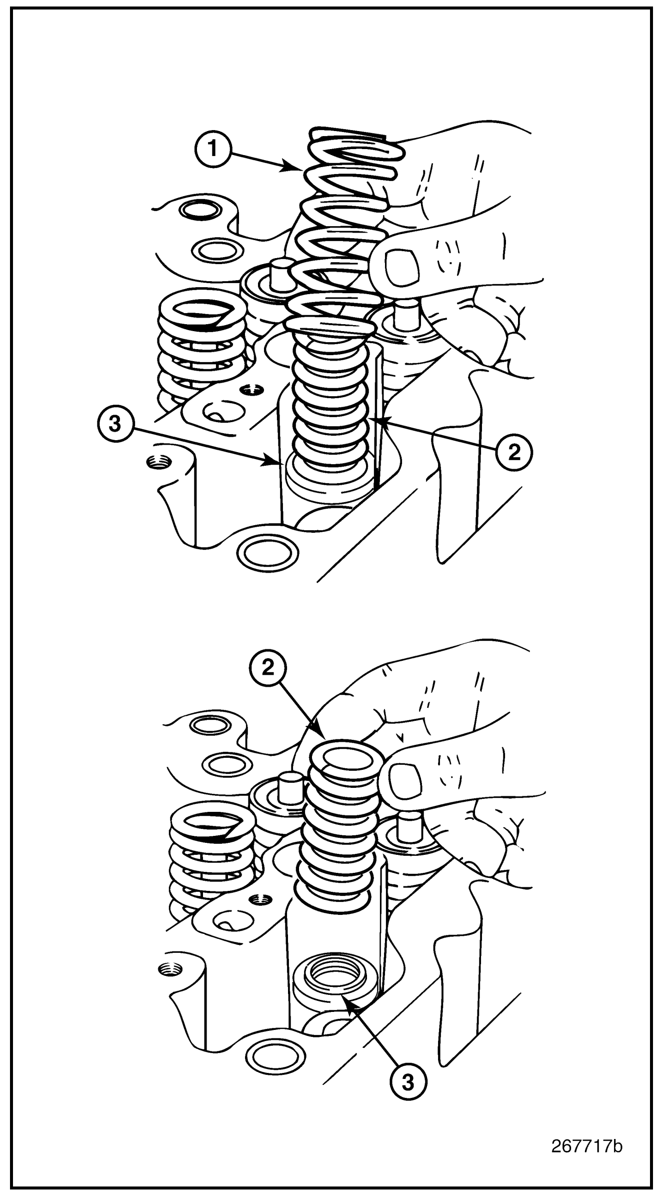


Figure 28 — Dual Exhaust Springs (Mid-Year 2003 and Later)

1. Exhaust Spring (Outer) 2. Exhaust Spring (Inner)	3. Valve Rotator (Bottom)

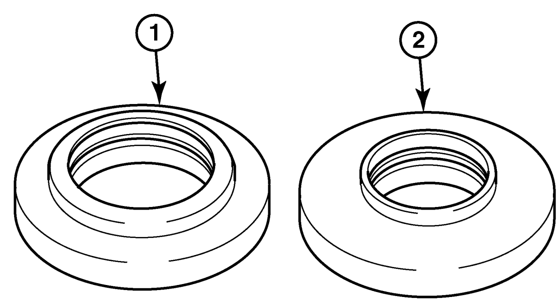


Figure 29 — Bottom Rotators

1. Rotator for Dual Springs (Exhaust Location)	2. Rotator for Single Valve Spring (Inlet Location)

Valve Stem Seals

The seal introduced with ASET™ engines is smaller than the previously used seal. This seal requires a new valve guide that is approximately 1/8 inch (6.35 mm) smaller than the previous guide and seal to allow clearance for the inner valve spring used on the exhaust locations. For standardization purposes, the new valve guide and seal are used at inlet locations as well.

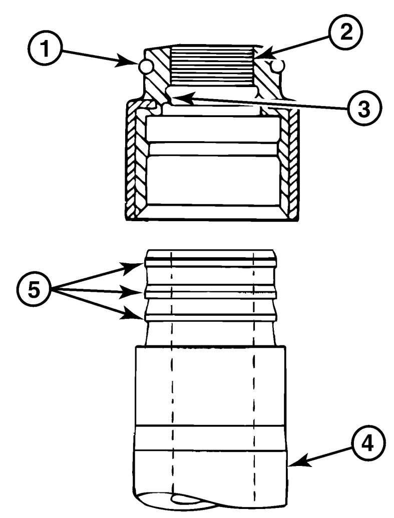


Figure 30 — Valve Stem Seal (Later Design)

1. Steel Retainer Band 2. Multi-Lip Section 3. Blowback Lip	4. Valve Guide 5. Three Sharp Ridges

Spring-Loaded Push Rods

All ASET™ engines are equipped with spring-loaded push rods at the exhaust locations, the same as those phased into production on the E-Tech™ engine. These push rod assemblies have a spring at the rocker arm end, and are designed to keep the roller lifter in constant contact with the cam. Additionally, this push rod design reduces valve clatter that results from the engine brake camshaft exhaust lobe clearances and operating dynamics of the exhaust valve train. The spring-loaded push rods are currently used at the exhaust valve locations only.

How Spring-Loaded Push Rods Operate

During the "valve opening" cycle, as the lifter roller rides up the ramp of the cam lobe, the push rod spring compresses, making the push rod a solid assembly that transmits the upward force of the lifter to the rocker arm. The push rod spring never becomes fully compressed; the push rod becomes solid when the internal stops of the upper and lower spring seats contact each other.

During the valve closing cycle, as the lifter roller travels down the ramp and into the cam lobe sub-base circle area, the push rod spring expands making the push rod longer, thus eliminating excessive lash from the valve train. Spring pressure keeps the roller contact with the cam and eliminates valve clatter.

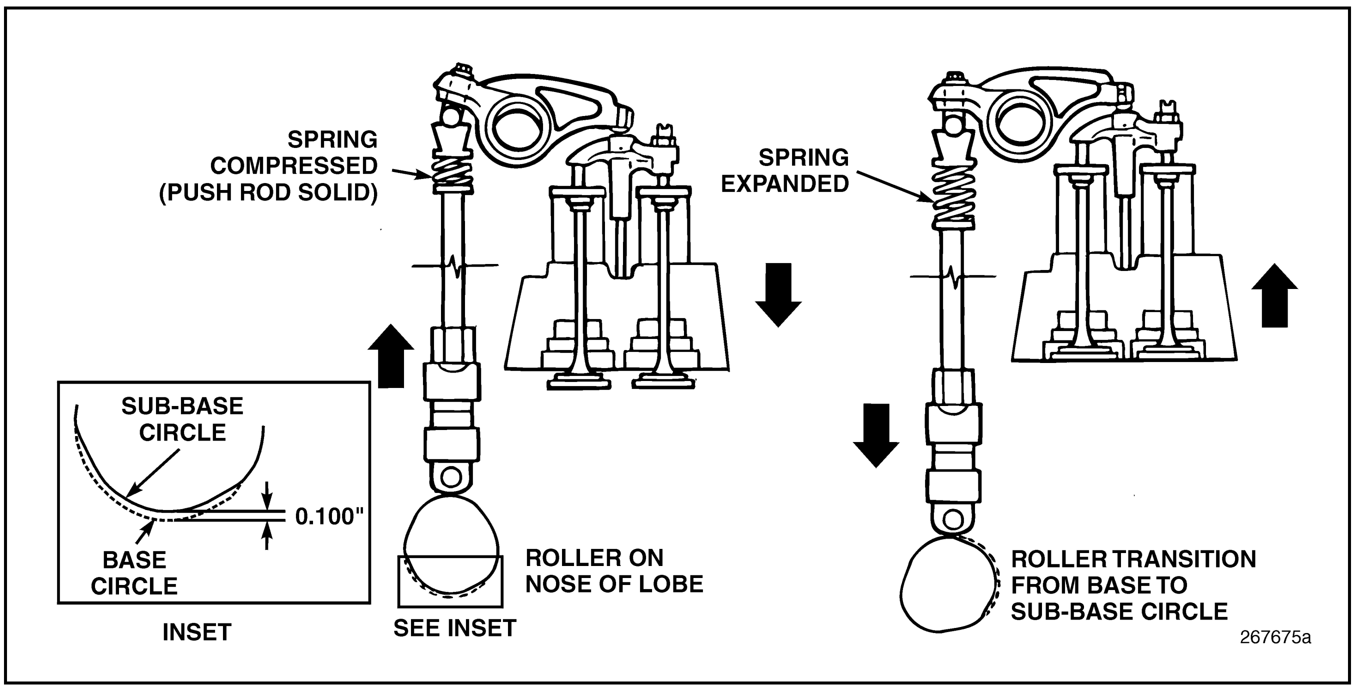


Figure 31 — Spring-Loaded Push Rod Operation

INCREASED CAPACITY OIL PAN AND IMPROVED FILTRATION

The capacity of the oil pan is 36 quarts (34.1 liters). The added volume, compared with that of earlier engine models, increases the soot retention levels to maximize oil drain intervals. In addition to the deeper sump, the oil pan also has a boss for mounting of the oil dipstick tube at the left side of the engine (Figure 32).

Oil filtration has also been improved for the ASET™ AC engine. The spin-on type full-flow oil filters have an improved filter media which gives a significant gain in efficiency. These filters are silver in color. The engines are also equipped with the new Centri-Max® ULTRA or ULTRA PLUS filter with its larger volume and improved filtration (0–5 microns).

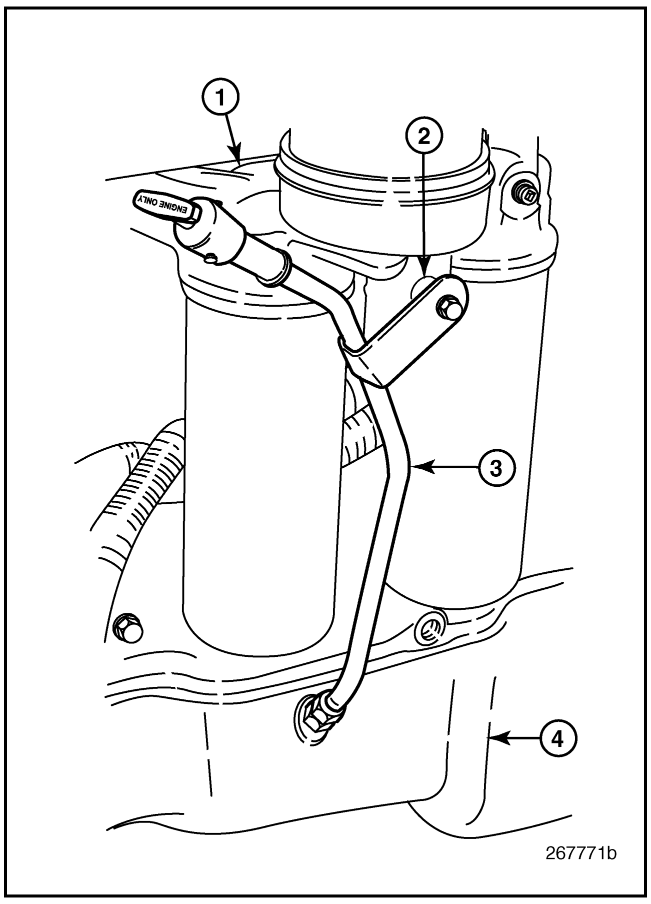


Figure 32 — Oil Dipstick Tube, Left Side Installation (AC Engine)

1. Oil Filter Adapter 2. Isolator	3. Dipstick Tube 4. Oil Pan

An improved centrifugal oil filter assembly was introduced in ASET™ AC engines in August 2003. This new centrifugal filter is called Centri-Max® ULTRA PLUS and contains new rotor and mating shaft journal diameters which are smaller than those used in previous centrifugal filter configurations. The smaller rotor bushing and shaft diameters provide a significant increase in rotor RPM and filtration efficiency.

CAUTION

The previous design rotor MUST NOT be used in the new Centri-Max® ULTRA PLUS filter. If the previous design rotor is used in a Centri-Max® ULTRA PLUS filter, the rotor bushings will be a very loose fit on the smaller shaft diameter. This will not allow the rotor to rotate, rendering the filter non-functional.

ENGINE ELECTRONIC CONTROL UNIT (EECU) AND SYSTEM SENSORS

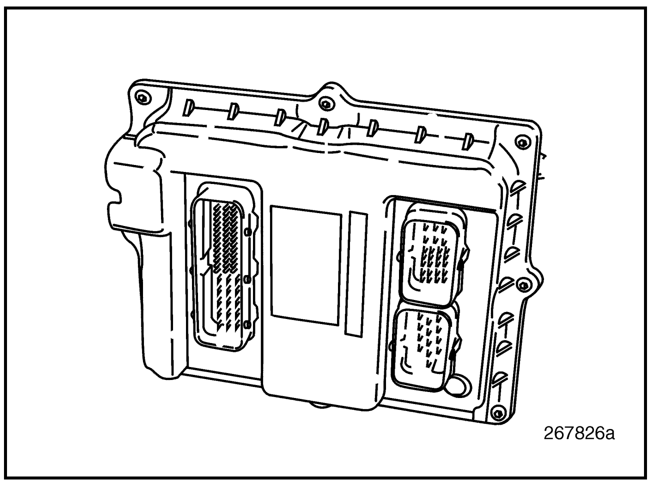


Figure 33 — Enhanced EECU (ASET™ Engines)

EECU — The EECU is a completely new unit (Figure 33). Because of its increased capacity and power, a cooling plate is required to maintain operating temperatures below the maximum 194°F (90°C). Both the control unit and its fuel-cooled mounting plate are located on the left side of the engine at the front of the coolant manifold. Rubber bushings isolate the EECU and cooling plate from engine vibration.

There are three sets of terminal connectors. All terminal pins are gold plated to provide low contact resistance, reduced fretting and corrosion for long service life. Circuits are routed through the three connectors, EJ1 (36 pin), EJ2 (89 pin) and EJ3 (16 pin), for control of:

- Engine fueling
- Variable geometry turbocharger
- Exhaust gas recirculation

Inputs for the three EECU control loops come from 16 sensors, six of which are new for the AC (CEGR) engine. These include chassis-mounted as well as engine-mounted sensors. Refer to Figure 34 and Figure 35 for location of the sensors described below.

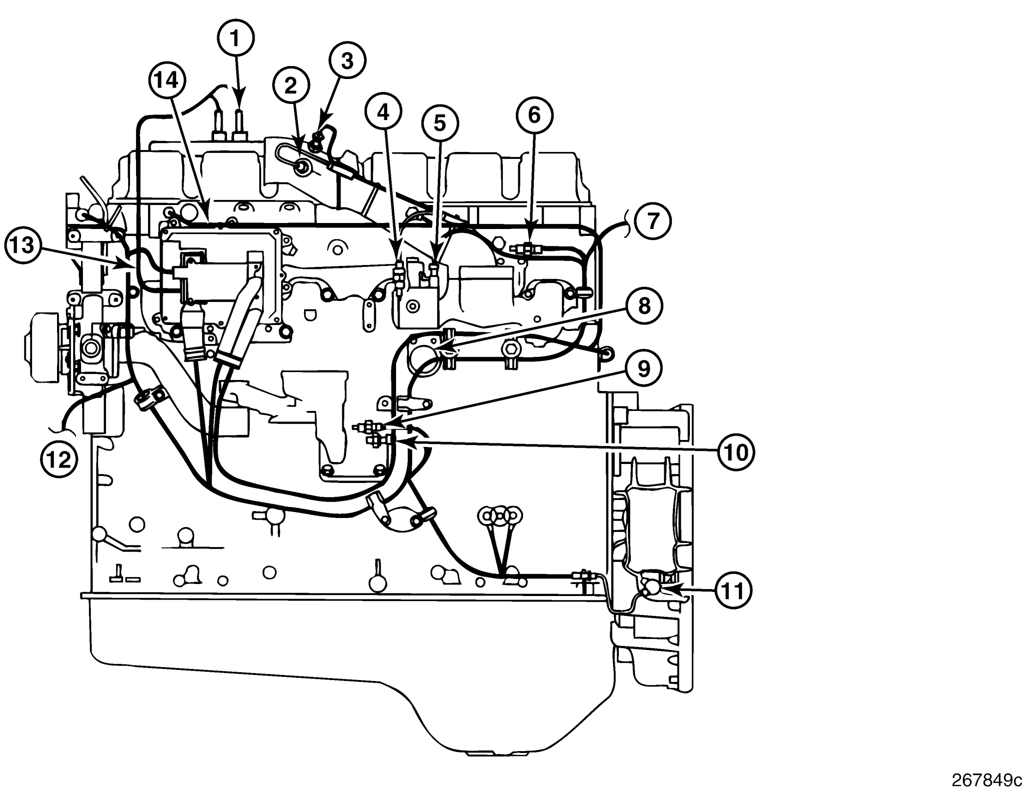


Figure 34 — ASET™ AC Engine Sensors (Left Side)

1. EGR MASS Flow Sensors	8. Deutsch Connector (V-MAC III Engine-to-Chassis Interface)
2. Boost Temperature Sensor	9. Oil Temperature Sensor
3. Boost Pressure Sensor	10. Oil Pressure Sensor
4. Inlet Manifold Temperature Sensor	11. Engine Speed Sensor (Speed and Position)
5. VTG Control Valve Connector	12. To Chassis-Mounted Ambient Air Temperature Sensor
6. To Chassis-Mounted Combustion Temperature/Humidity Sensor	13. Atmospheric Pressure Sensor (Integral to EECU)
7. Coolant Temperature Sensor	14. Engine Brake Harness Leads

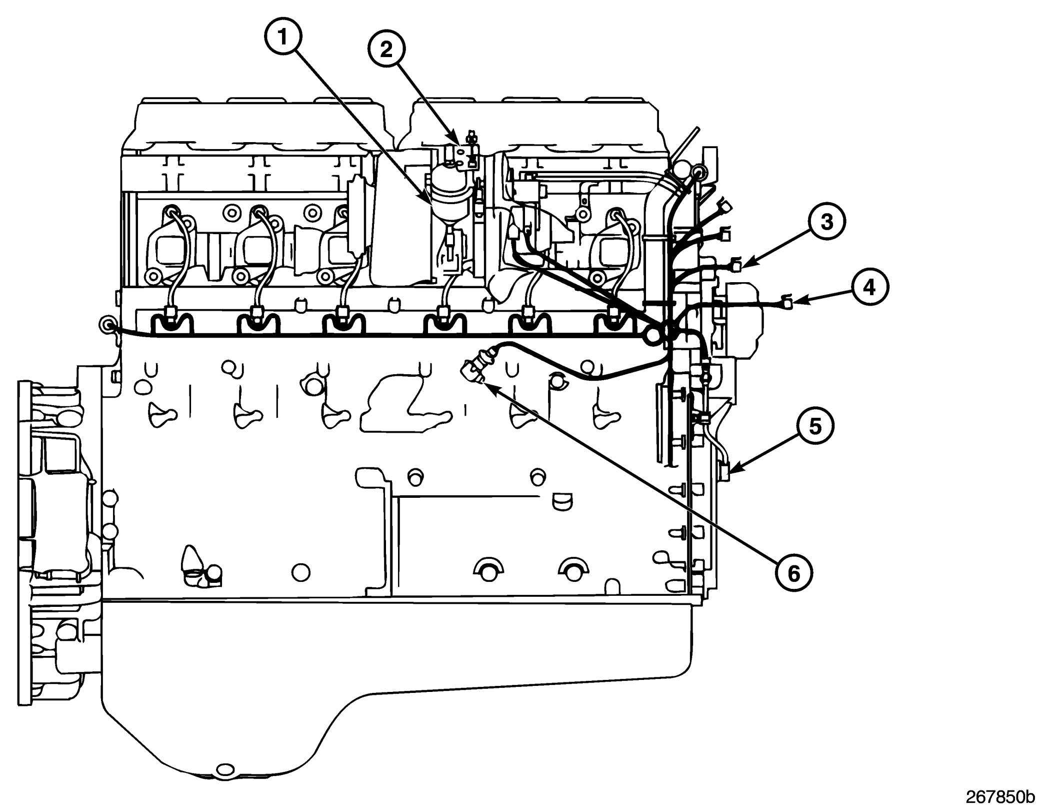


Figure 35 — ASET™ AC Engine Sensors (Right Side)

1. VTG Wheel-Speed Sensor (in Bearing Housing) 2. VTG Position Sensor 3. Connector-to-Fan Speed Sensor	4. To Chassis-Mounted Compressor Discharge Temperature Sensor 5. Engine Position Sensor 6. Fuel Temperature Sensor

Ambient Air Temperature Sensor — P/N 64MT2118

NOTE

The sensor is mounted off-engine and supplies temperature input to the engine electronic control unit (EECU). Location of the sensor depends upon chassis model. But in general, it is located at the front of the chassis mounted either on the front crossmember behind the bumper, on a hood hinge, hood hinge bracket, body, spring bracket or grille guard assembly.

Combustion Air Temperature/Humidity Sensor — P/N 64MT445, mounted in the air inlet tubing between the air cleaner and the turbocharger.

VTG Position Sensor (New) — P/N 64MT458, mounted on top of the turbocharger VTG actuator. It indicates the position of the vanes in the turbine housing inlet port.

VTG Wheel-Speed Sensor (New) — P/N 64MT457, mounted in the turbocharger bearing housing where it is used to indicate turbocharger wheel speed.

Compressor Discharge Temperature Sensor (New) — P/N 64MT450A, a wide-range fast-response type mounted in the charged-air tubing between the turbocharger and the CMCAC.

Boost Pressure Sensor (New) — P/N 64MT446, mounted in the EGR mixer tube.

CMCAC Outlet Temperature Sensor (New) — P/N 64MT450A, mounted in the EGR mixer tube.

EGR Temperature and MASS Flow Sensors (New) — Sensor pair mounted in the upper "cool-side" EGR tube between the EGR cooler and the mixer tube. The pair of sensors is calibrated specifically to the upper EGR tube and the EGR MASS Flow System module. If replacement is required, the entire tube assembly with its integral sensors must be replaced along with the MASS Flow System module attached to the back of the EECU cooling plate. Part numbers for the tube assembly are 206MS52 (with J-Tech™ engine brake) or P/N 206MS51 (without engine brake).

Atmospheric Pressure Sensor — Integral to the EECU module.

Inlet Manifold Temperature Sensor — P/N 64MT450A, mounted at a mid-point on the inlet manifold.

Oil Pressure Sensor — Mounted at the side of the oil filter adapter housing.

Oil Temperature Sensor — Mounted at the side of the oil filter adapter housing.

Coolant Temperature Sensor — Mounted at the rear of the coolant manifold.

Engine Speed Sensor — Mounted at the left side of the flywheel housing.

Engine Position Sensor — Mounted on the front timing cover beneath the crankcase breather housing.

Fan Speed Sensor — Mounted on the fan-drive hub support.

Fuel Temperature Sensor — V-MAC III monitors fuel temperature at the cylinder block fuel gallery inlet. This fuel temperature data is used by the system to adjust fuel delivery for optimized power and to provide accurate mpg fuel consumption information.

All of these sensors are connected via a reconfigured engine wiring harness. The harness incorporates three geared lock-down connectors at the EECU. The harness is also fitted with a new Deutsch vehicle interface connector located on the air inlet manifold below the VTG turbocharger position controller (Figure 36). This connector provides the connection for the interface between the engine control system and the chassis.

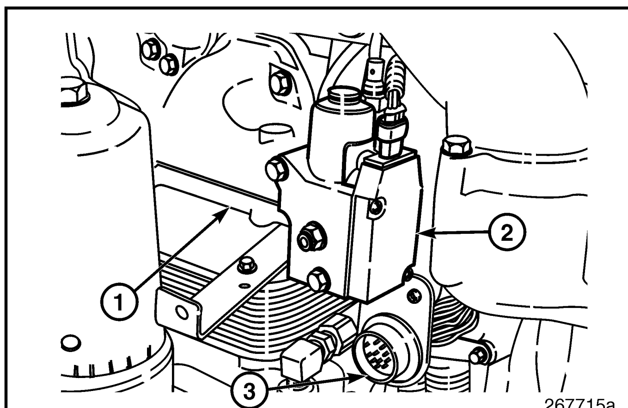


Figure 36 — Deutsch Connector

1. Inlet Manifold 2. VTG Position Controller	3. Vehicle Interface Connector

MACK Fuel Filtration System

On engines produced prior to December 22, 2003 and equipped with the MACK fuel filtration system, the filters are integrated into a compact unit with the fuel supply pump. This system is referred to as “SPIFF” for Supply Pump with Integrated Fuel Filters. Located on the right side of the engine, the integrated system consisting of a spin-on type fuel filter with improved efficiency (3–5 microns) and a pre-pump screen filter (Figure 37) replaces the traditional primary and secondary fuel filter system.

Current-production engines (December 22, 2003 and later) use a chassis-mounted primary filter in place of the pre-pump filter screen. The supply pump with integrated secondary filter is retained. However, the pre-pump filter screen is replaced by a plug.

NOTE

If the vehicle is equipped with the optional fuel filtration system, then the fuel supply pump is replaced with a traditional pump that does not have the integral pre-pump screen and primary filter.

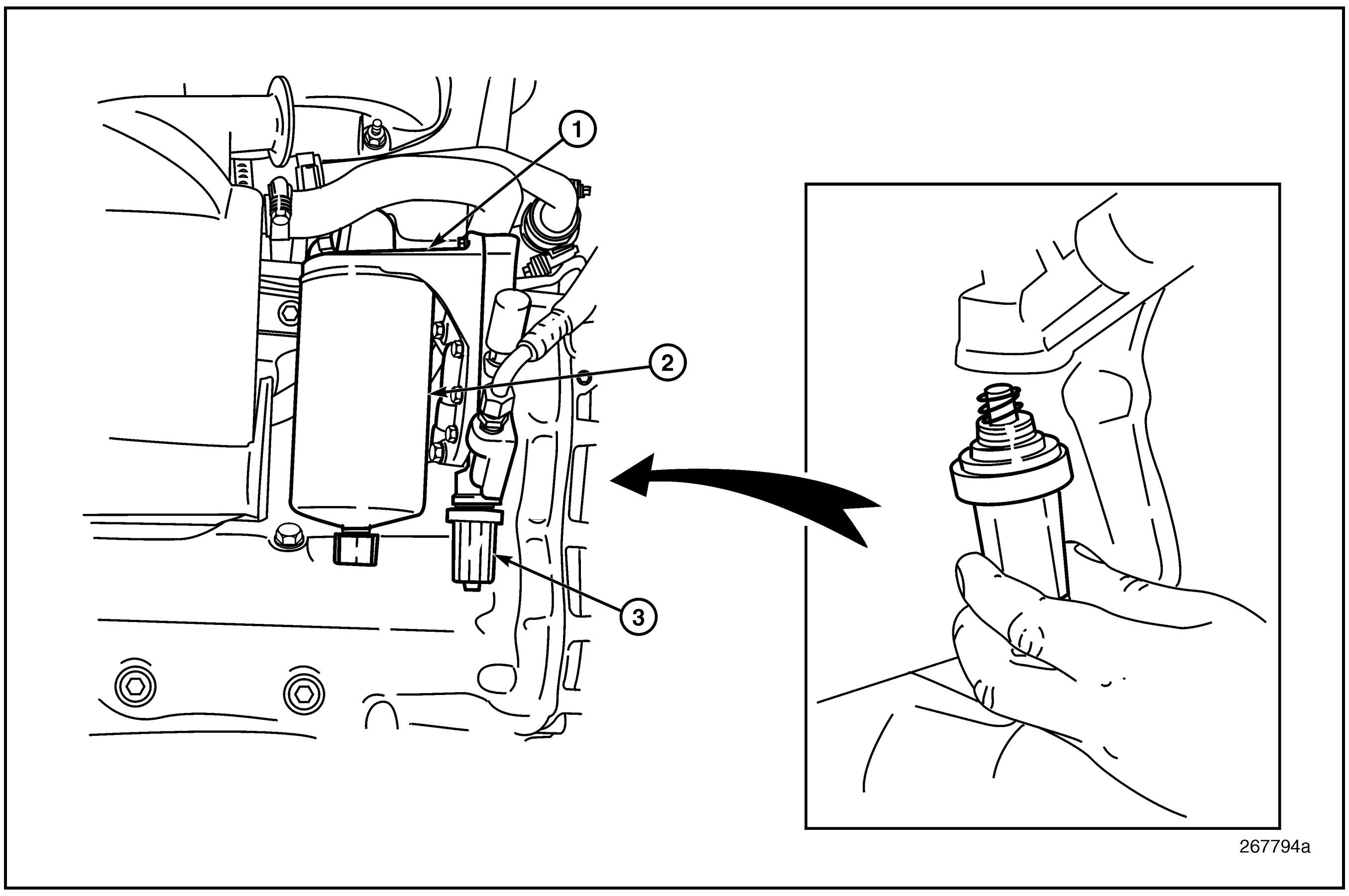


Figure 37 — MACK Fuel Filtration System (SPIFF)

1. Fuel Pump 2. Spin-On Type Filter (3–5 Microns)	3. Pre-Pump Filter (Used in production prior to December 22, 2003; replaced by a plug and O-ring in later production.)

Electronic Unit Pumps (EUP)

The fuel system is pressurized by six Electronic Unit Pumps (EUP), one per cylinder, driven by a third lobe on the engine camshaft. Each one of the single-plunger EUPs is actuated by a roller follower (tappet) in contact with the engine cam lobe.

The EUP is very similar to a unit injector. The primary difference is that the EUP delivers fuel through a fuel injection line to a conventional-style nozzle-holder assembly; whereas, a unit injector has a nozzle mounted directly on it.

The EUP is capable of providing very high fuel-injection pressures. The pump is controlled by a high-speed solenoid valve (see Figure 38) responding to electronic signals from the V-MAC III engine control module. This electronic control provides a greater timing range. The combination of higher pressures and greater timing control improves the combustion process and optimizes engine performance.

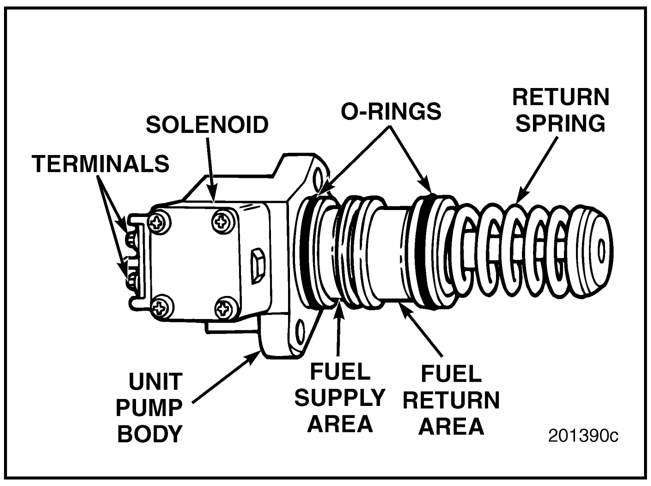


Figure 38 — EUP Components

NOTE

Although each EUP has three O-ring grooves on the pump housing, only the top and bottom grooves are fitted with O-rings. No O-ring is used in the center groove.

For the occasional instances where the standard lower O-ring fails to seal against fuel leakage into the crankcase, a service parts kit with a three-piece delta O-ring seal is available through the MACK Parts System. The delta seal, a triangular O-ring with two nylon support rings (Figure 39), is used at the lower O-ring location only.

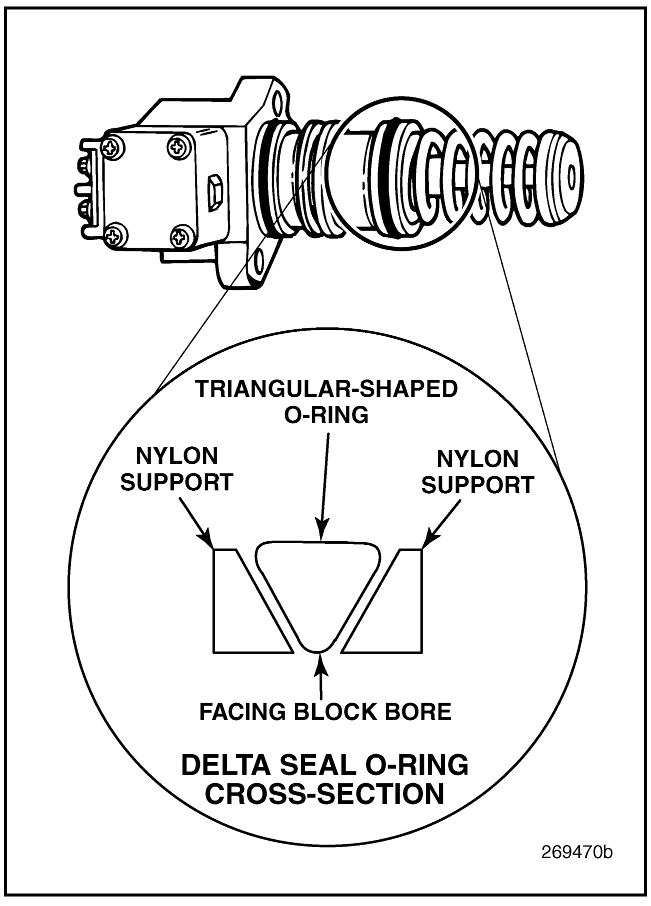


Figure 39 — Delta O-Ring Seal Cross Section

The EUP design does not include a helix on the pump plunger. Fuel delivery is controlled entirely by the solenoid valve. To start fuel delivery, the V-MAC III control system allows current to flow to the solenoid, closing the solenoid valve and trapping fuel in the pump. As the plunger moves upward, fuel is delivered through the high-pressure line to the fuel-injector nozzle assembly. When current flow to the solenoid is stopped, the solenoid valve opens and fuel in the pump then flows to the cylinder block fuel return gallery. Refer to Figure 40.

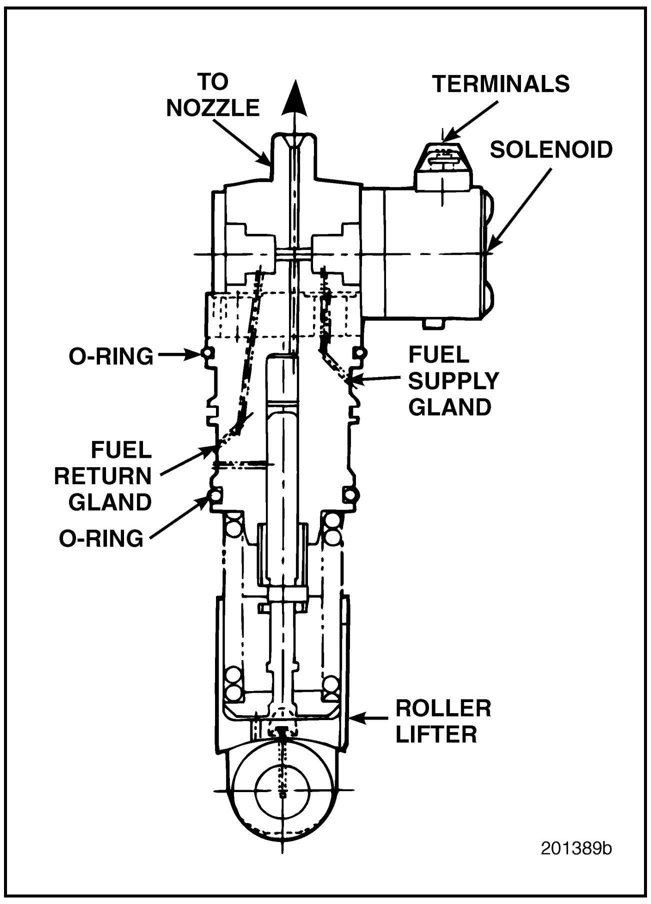


Figure 40 — Electronic Unit Pump

The EUP system, using proven industry technology, is well adapted to troubleshooting. When required, an individual EUP can be replaced with a minimum of downtime.

Because the unit pumps are located in close proximity to the exhaust manifold, heat shields (Figure 15) have been added to prevent excessive heat from reaching the EUP components. If removed during any maintenance or repair operations, the heat shields must be replaced to avoid damage to the sensitive electronic components.

Engine Brake

The optional MACK PowerLeash™ and J-Tech™ engine brakes are vehicle-slowing devices that allow the engine to act as an air compressor, producing retarding horsepower that helps slow the vehicle. The engine braking action is accomplished through hydraulics. When the engine brake is operated, a single exhaust valve opens near top dead center of the compression stroke, releasing high-pressure air out the exhaust. Opening one exhaust valve, instead of two, significantly reduces load to the engine brake and the valve train without adversely affecting braking power. Releasing compressed air to the exhaust prevents the return of energy to the engine piston on the expansion stroke. The result is a net power loss from the engine, or retarding horsepower, used to slow the vehicle.

MACK POWERLEASH™ ENGINE BRAKE FEATURES AND OPERATION

The MACK PowerLeash™ engine brake has the hydraulically controlled valve train components integrated into the exhaust rocker arms. During engine brake operation, one of the exhaust valves in each cylinder is opened just as the pistons approach top dead center of the compression stroke, allowing the compressed charge in each cylinder to be released and vented to the engine's exhaust system. The energy of compression is then lost. This loss of energy is what increases the braking effect of the engine and allows the vehicle to slow down while minimizing the need to use the service brakes to slow the vehicle. The service brakes must always be used to control the vehicle and bring the vehicle to a complete stop.

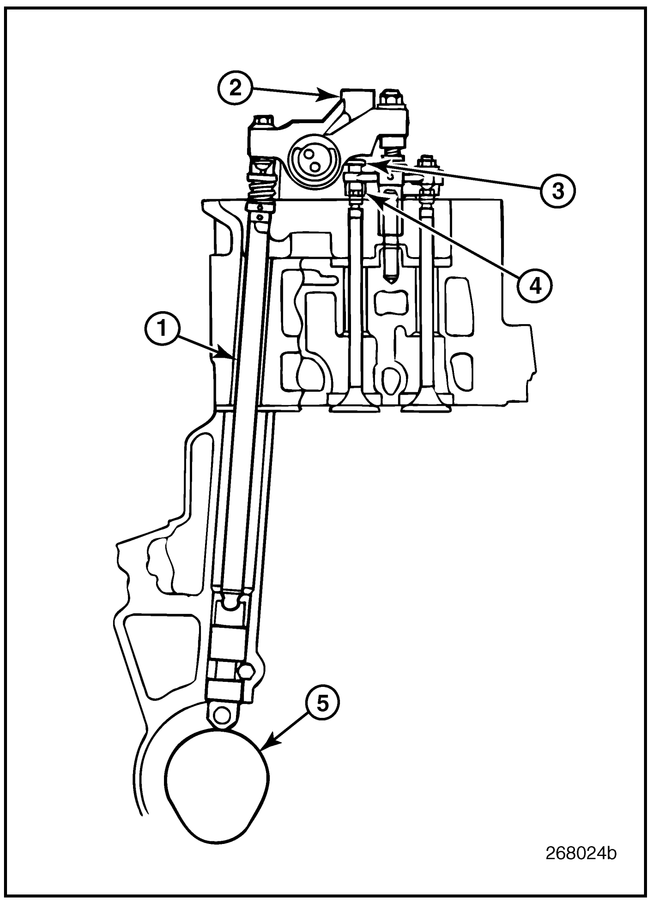


Figure 41 — MACK Engine Brake Cut-Away View

1. Spring-Loaded Push Rod 2. Engine Brake Hydraulic Actuator 3. Valve Actuating Pin	4. Valve Stem Tip Cap 5. Camshaft with Engine Brake Profile

Use of the MACK PowerLeash™ engine brake is controlled by a dash-mounted switch that has two power positions: a LOW position to apply approximately one-half (three cylinders) of the engine brake retarding capability, and a HIGH position to apply full retarding power (all six cylinders). The choice of LOW or HIGH operation depends on the driving situation, vehicle load and downhill percent grade. When the switch is in the OFF position, the engine brake is deactivated.

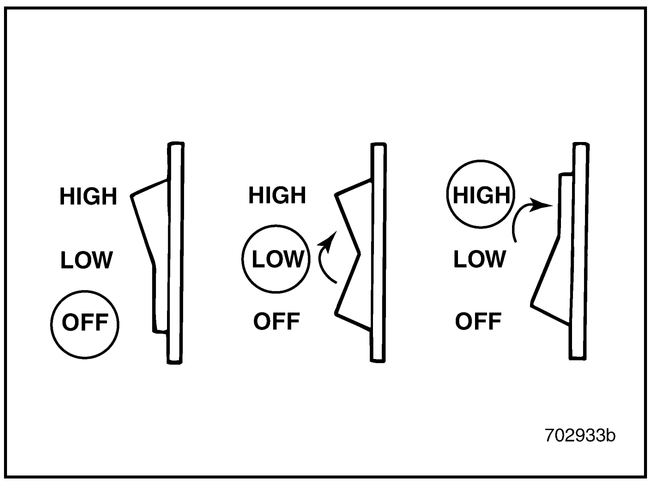


Figure 42 — Dash-Mounted Engine Brake Switch

Engine brake operation is controlled by the V-MAC® system. A constant 12 volts at a low current is supplied to the engine brake solenoids at all times. When the dashboard switch is turned ON and no fuel is requested (0% throttle), the engine electronic control unit (EECU) increases the current to the engine brake solenoids, causing the solenoid coils to energize.

When the engine brake is "enabled" (switch in either LOW or HIGH position), the V-MAC electronic control system commands engine brake power (engine brake "active") only when the following conditions are true:

- The foot-operated engine accelerator pedal is not depressed.
- The clutch pedal is not depressed (manual shift transmissions only).
- The engine speed is at least 900 rpm.
- Coolant temperature is above 125°F (52°C).

CAUTION

Engine stalling and potential engine damage can occur if the engine brake is operated at cold engine oil temperatures. The V-MAC engine control system includes a feature that prevents the engine brake from being activated until the engine coolant temperature reaches at least 125°F (52°C). The engine brake will not function until sufficient engine warm-up time has elapsed, regardless of the dashboard engine brake switch setting.

If the engine brake is active, it will automatically be deactivated by depressing either the accelerator or the clutch, or if the engine speed drops below 900 rpm. As soon as all of the engine brake “active” conditions are again true (foot off the accelerator, for example), the engine brake will again be activated. The engine brake can be deactivated simply by returning the dash-mounted control switch to the OFF position.

NOTE

The exception to this is if the vehicle has an automatic shifting manual transmission. In this application, the engine brake is automatically activated by the transmission even if the dash switch is turned OFF. This feature is needed to slow the engine RPM down rapidly, which allows this type of transmission to shift properly.

The engine brake may be used simultaneously with the vehicle service brakes to achieve the greatest vehicle slowing power. Releasing the vehicle service brake pedal does not deactivate the engine brake.

When the engine brake is enabled at the same time the V-MAC cruise control is in use, the engine brake automatically activates when necessary to slow the vehicle to the cruise set point speed. One of two possible options can be selected:

- The engine brake is activated 2 mph above the cruise set point (default mode).
- The engine brake is activated as soon as cruise control commands fueling to zero (vehicle has just reached cruise set point and fuel has been turned off).

The engine brake’s ability to control maximum vehicle speed under cruise control is limited to the selected retarding power of the engine brake. If the engine brake dash-mounted control switch is set to the LOW position, only half of the available braking power is used. If the dash-mounted control switch is set to the HIGH position, the cruise control invokes full engine brake power.

NOTE

Deactivating the cruise control function does not disable the engine brake.

The MACK PowerLeash™ engine brake may be activated or deactivated by other vehicle systems such as ABS and Headway control systems. Refer to the literature concerning these systems for additional information.

PowerLeash™ Mechanical System Operation

During an engine braking event, the inboard exhaust valve opens at the top of the compression stroke to provide engine braking. To accomplish this, hydraulic actuators are incorporated into the exhaust rocker arms, and a special “engine brake” profile is incorporated into the exhaust lobes of the camshaft.

The engine brake hydraulic actuator is controlled by engine oil pressure. Oil under pressure is supplied to the actuator through the “control” gallery, in the rocker shaft, and the flow of oil is controlled by the engine brake solenoid located on top of the shaft. A second gallery in the rocker shaft, the “constant” oil supply gallery, supplies a constant flow of oil to the inlet and exhaust rocker arms for lubrication.

When the engine brake is activated (dashboard control switch in either “low” or “high” positions, a no fuel [0% throttle] condition and the clutch pedal released), the engine brake solenoid energizes and directs the flow of “control” oil to the hydraulic actuators. When oil enters the actuator upper cavity, the actuator hydraulically locks with the plunger extended to take up the lash from the valve train. As cam rotation continues and the lifter roller reaches the transition point from sub-base to base circle, the upward movement of the push rod opens the inboard exhaust valve due to the hydraulically locked actuator plunger.

MACK PowerLeash™ Engine Brake Components

The MACK PowerLeash™ engine brake consists of the following primary components:

- **Camshaft** — The engine brake camshaft has a 0.125-inch engine brake lift profile (dimension from sub-base to base circle) on the exhaust lobes.

NOTE

The 0.125-inch brake-bump camshaft is mandatory for the PowerLeash™ engine brake.

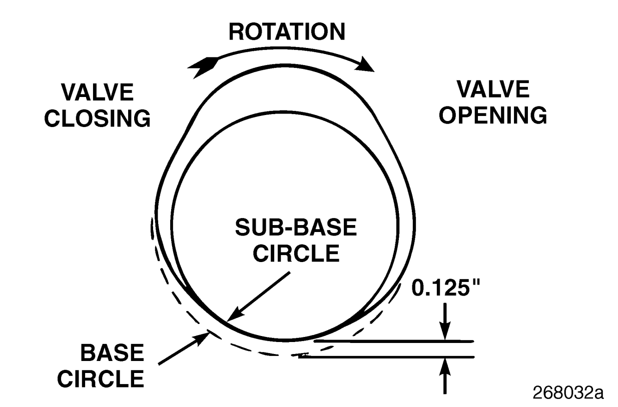


Figure 43 — MACK Engine Brake Exhaust Lobe Profile

- **Exhaust Rocker Arm/Hydraulic Actuator** — The exhaust rocker arm incorporates a hydraulic actuator that fills with oil and hydraulically locks to remove the clearance between the actuator plunger and the inboard exhaust valve. With clearance between the actuator and the actuating pin removed, the slight movement of the push rod created when the camshaft rotates to the area of transition from sub-base to base circle, pushes the rocker arm and opens the inboard exhaust valve before the piston reaches top dead center of the compression stroke.

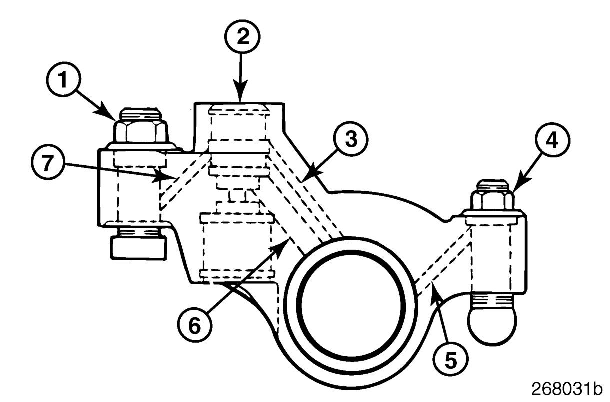


Figure 44 — MACK Engine Brake Exhaust Rocker Arm with Hydraulic Actuator

1. Valve Lash Adjusting Screw 2. Engine Brake Hydraulic Actuator 3. Constant (Lubrication) Oil Passage	4. Engine Brake Lash Adjusting Screw — This is NOT the valve lash adjusting screw. 5. Constant (Lubrication) Oil Passage 6. Control Oil Passage 7. Constant (Lubrication) Oil Passage

NOTE

The exhaust rocker arm has two adjusting screws. The adjusting screw located at the push rod end of the rocker arm adjusts engine brake plunger lash. The adjusting screw located at the valve end of the rocker arm adjusts exhaust valve lash.

The hydraulic actuator consists of the following:

— Plunger and spring located in the lower chamber

— Ball check valve located on top of the plunger and spring assembly

— Control piston and spring located in the upper chamber

Solenoid De-Energized — A constant supply of oil is fed to the actuator to fully lubricate all valve train components. Spring tension holds the control piston down to unseat the check valve ball. With the check valve ball unseated, oil flows freely into and out of the plunger chambers. When the engine brake solenoid is not energized, the plunger assembly can move up and down freely inside the actuator bore, but spring tension keeps the plunger seated against the lower snap ring. This free movement of the plunger provides the necessary clearance between the bottom face of the plunger and the exhaust valve actuating pin during normal engine operation.

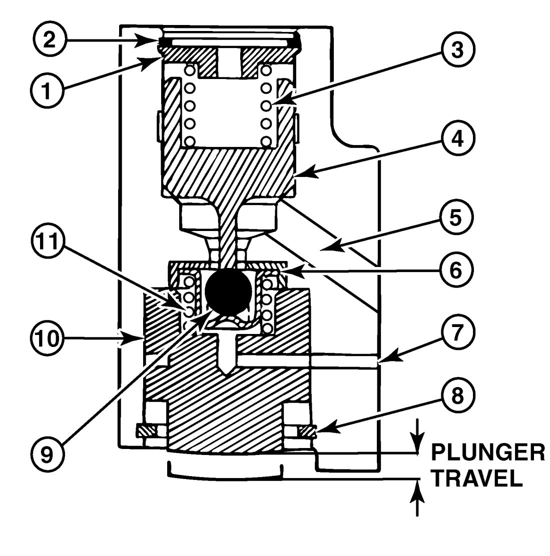


Figure 45 — Hydraulic Actuator Cut-Away View

1. Cover 2. Retaining Ring 3. Control Piston Spring 4. Control Piston 5. Control Oil Port (Reference Only, Not Actual Location)	6. Check Valve Assembly (Check Ball Seat at Top) 7. Leak Down Port 8. Retaining Ring 9. Check Valve Ball 10. Plunger 11. Plunger Spring

Solenoid Energized — When the engine brake solenoid energizes, oil flows into the rocker shaft “control” gallery, then from there into the actuator control piston cavity inside the rocker arm. The flow of oil moves the control piston upward off its seat and simultaneously fills the lower plunger cavity with oil. With the control piston off its seat, the check valve ball also moves upward. As the rocker begins to rotate and force the inboard exhaust valve open, oil pressure in the plunger cavity increases, forcing the check valve ball to seat and hydraulically lock the plunger in the extended position. With the plunger extended, lash between the plunger and the inboard exhaust valve is reduced. Continued rotation of the exhaust valve rocker arm opens the inboard exhaust valve, thus producing the braking event.

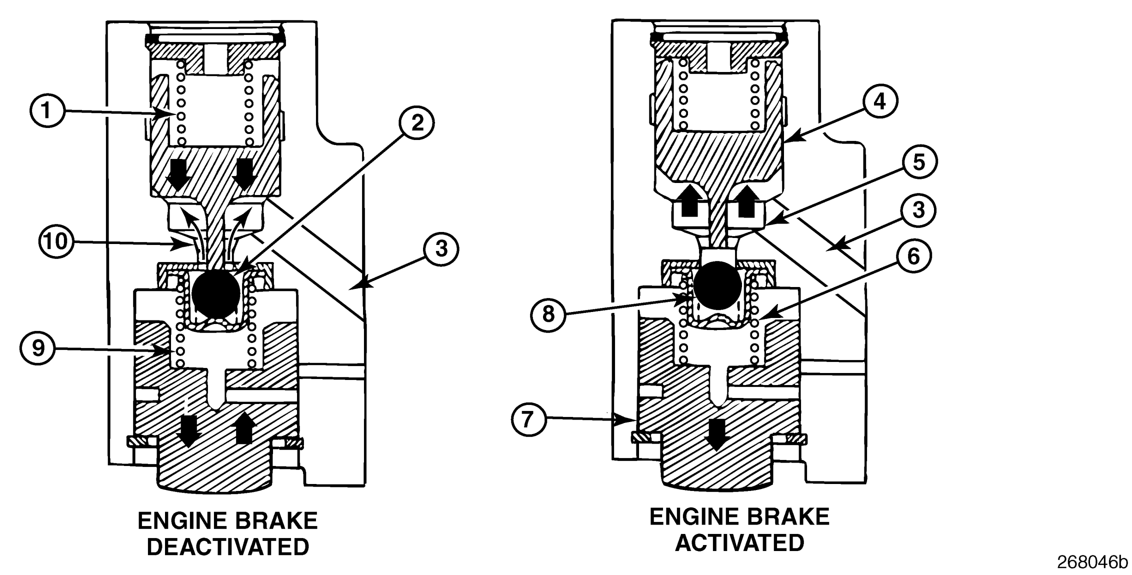


Figure 46 — Hydraulic Actuator Operation

1. Spring Tension Holds Control Piston Down	6. Oil Trapped in Plunger Bore
2. Control Piston Unseats Check Valve Ball	7. Plunger is Hydraulically Locked — Will Not Move Upward
3. Control Oil Port (Reference Only, Not Actual Position)	8. Spring Tension Pushes Check Valve Ball
4. Oil Pressure Pushes Control Piston Up Against Spring Tension	9. Spring Tension Holds Plunger Against Retaining Ring — Plunger Moves Freely in Bore
5. Oil Enters Upper Bore	10. Oil Flows Freely Past Check Valve Ball

When the engine brake solenoid is de-energized, the flow of oil to the actuator upper cavity is removed. Spring tension then pushes the control piston back down and unseats the check valve ball. With the check valve ball unseated, oil can again flow freely in and out of the plunger chamber, thus removing the hydraulic lock.

Rocker Shaft — The rocker shaft includes two oil galleries and a port for the solenoid. The upper gallery supplies “control” oil to the exhaust rocker arms, and the lower gallery provides a constant supply of oil to all the rocker arms. When the engine brake solenoid energizes, oil flows from the “constant supply” gallery to the “control” gallery, and in turn, control oil is then supplied to the hydraulic actuator upper (control piston) cavity.

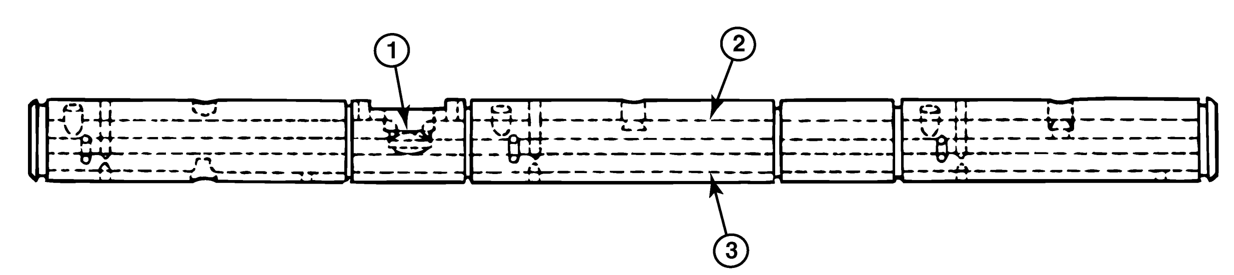


Figure 47 — Rocker Shaft

1. Engine Brake Solenoid Port 2. Control Oil Gallery	3. Constant Supply Oil Gallery

Oil is supplied to the rocker shaft through an oil supply passage in the front rocker shaft mounting bracket. This mounting bracket is "press-fit" on the rocker shaft, whereas the middle and rear mounting brackets are a new "slip-fit" design. An oil supply screen is located in the counterbore of the oil passage at the bottom of the rocker shaft mounting bracket.

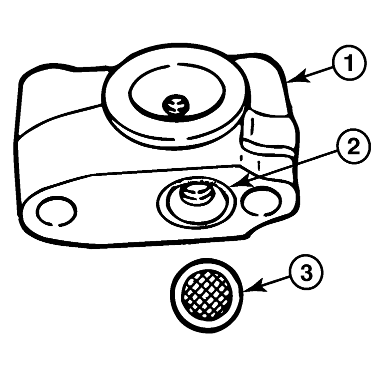


Figure 48 — Front Rocker Shaft Mounting Bracket

1. Front Mounting Bracket 2. Oil Supply Port	3. Oil Supply Screen

This screen is a relatively fine (100 x 100 mesh) stainless steel screen with a nominal rating of 40 microns. The purpose of this screen is to protect the engine brake hydraulic actuator against any initial debris that may be circulating with the oil at initial start-up following an engine rebuild or repair. Servicing the screen at any regular service interval is not required. The screen should be cleaned after any type of engine failure that has contaminated the lubrication system, if rocker shafts have been removed for any reason or after a major engine overhaul. Additionally, the screen should be inspected and cleaned if troubleshooting procedures for engine brake operation indicate a drop in oil pressure at the rocker shafts.

- **Exhaust Valve Yoke** — The inboard side of the exhaust yokes contains a hole for the exhaust valve actuating pin. The actuating pin rests on a cap that is installed over the tip of the valve stem on the inboard exhaust valve.

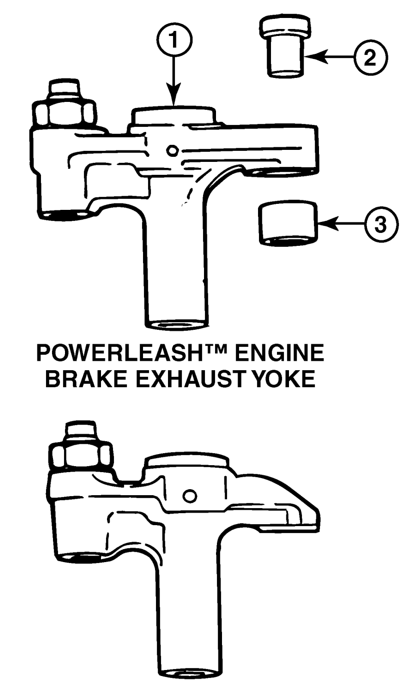


Figure 49 — Exhaust Yoke, Actuating Pin and Valve Stem Cap

1. Valve Yoke, Exhaust 2. Actuating Pin	3. Cap, Inboard Exhaust Valve Stem Tip

- **Spring-Loaded Push Rods** — To prevent excessive valve "clatter" created by the increased exhaust valve lash, and also keep the lifter roller in contact with the cam lobe, spring-loaded push rods are used. These push rod assemblies contain a spring on the rocker arm end. The spring allows the push rod to "expand" during the "valve closed" (or cam sub-base circle) cycle, thus eliminating excessive lash in the valve train and keeping the lifter roller in contact with the cam lobe. During the "valve opening" cycle, the spring compresses as the lifter roller travels up the ramp of the cam lobe. The push rod becomes a "solid assembly" when the internal stops of the upper and lower push rod seats make contact. When the push rod is "solid," the upward force of the valve lifter is transmitted to the rocker arm.

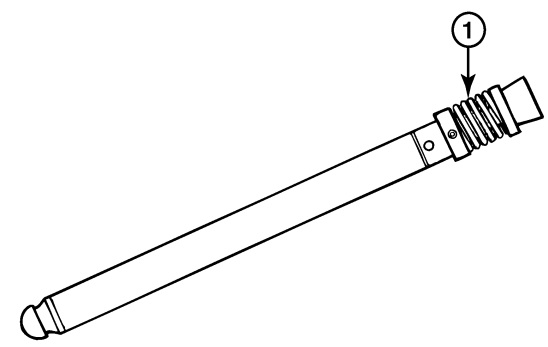


Figure 50 — Spring-Loaded Push Rod Assembly

1. Push Rod Spring

- **Cylinder Head Cover** — The MACK PowerLeash™ engine brake is completely integrated with the valve train; therefore, cylinder head cover spacers are not necessary. The cylinder head cover contains an electrical pass-through connection that connects the engine brake solenoid wire to the engine wiring harness.

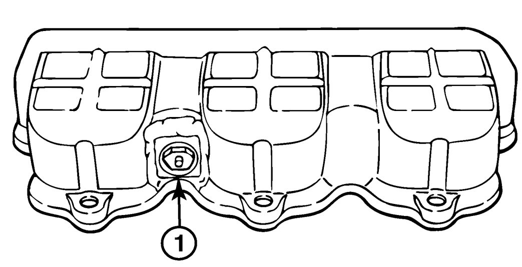


Figure 51 — Cylinder Head Cover with Electrical Pass-Through Connection

1. Electrical Pass-Through Connector

J-TECH™ ENGINE BRAKE FEATURES AND OPERATION

Refer to Figure 52.

The J-Tech™ brake functions in the following manner:

- Under powered operation, a large lash in the valve train “skips” the 0.100-inch brake bump on the camshaft.
- During engine brake operation, the solenoid valve is energized, allowing engine oil to fill the J-Tech™ brake housing oil passages.
- Oil overcomes the control valve spring and drives the control valve up in its bore. Oil passes through the ball check inside the control valve and exits through the port in the side, filling the master/slave piston circuit.
- Oil pressure causes the master piston and rocker arm to move down, removing the large lash from the cam side of the valve train. The result is a corresponding lash increase on the exhaust valve side.
- The brake bump on the exhaust cam forces the master piston upward and directs high-pressure oil to the slave piston. The check valve in the control valve prevents high-pressure oil from escaping.
- High-pressure oil causes the slave piston to move down, opening the outboard exhaust valve via a valve-actuating pin that passes through the center of the yoke adjusting screw. Activation occurs near top dead center and releases compressed air into the exhaust manifold.
- At stroke bottom, the slave piston separates from the reset valve, allowing oil to flow into the accumulator. This action reduces pressure in the high-pressure circuit, permitting the slave piston to retract and the exhaust valve to close in preparation for normal exhaust cycle. Oil in the accumulator ensures the hydraulic circuit is fully charged for the next cycle.

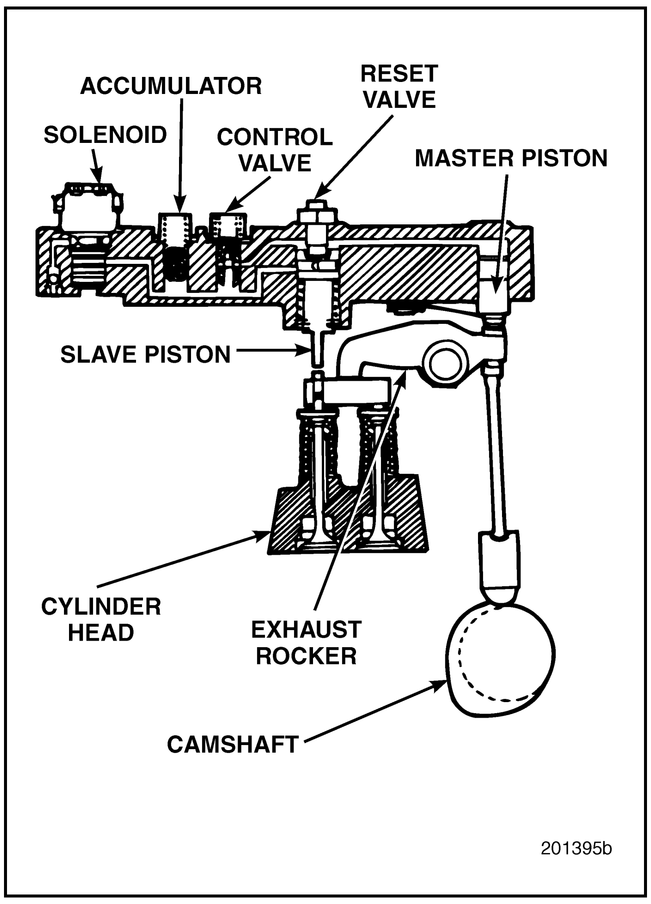


Figure 52 — J-Tech™ Brake

NOTE

Deactivating the cruise control function does not disable the engine brake.

The J-Tech™ engine brake may be activated or deactivated by other vehicle systems such as ABS and Headway control systems. Refer to the literature concerning these systems for additional information.

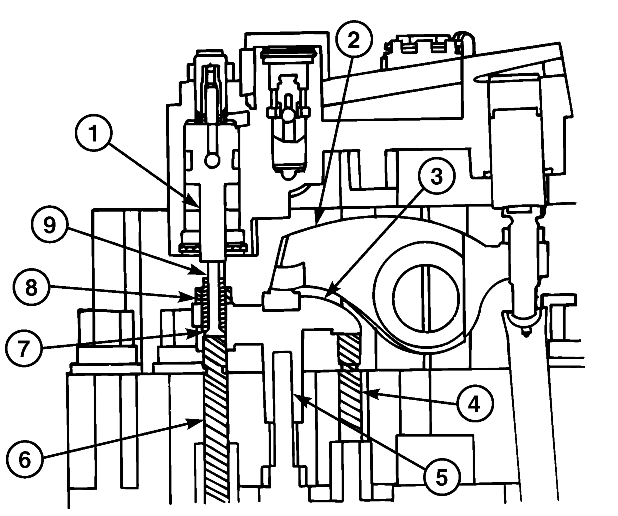


Figure 53 — J-Tech™ Brake Arrangement

Use of the J-Tech™ engine brake is controlled by a dash-mounted switch that has two power positions: a LOW position to apply approximately one-half (three cylinders) of the engine brake retarding capability, and a HIGH position to apply full retarding power (all six cylinders). The choice of LOW or HIGH operation depends on the driving situation, vehicle load and downhill percent grade. When the switch is in the OFF position, the engine brake is deactivated.

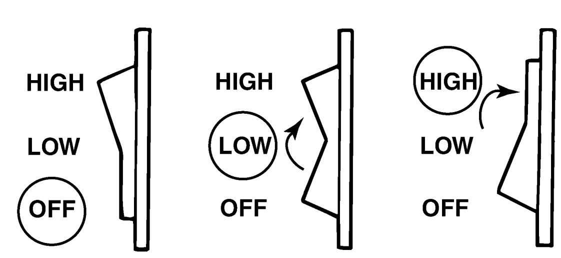


Figure 54 — Dash-Mounted Engine Brake Switch

With the J-Tech™ engine brake, the standard ASET™ engine valve yokes are used at both inlet and exhaust locations. However, a hollow yoke adjusting screw with a floating pin in the screw is used in the exhaust yokes (Figure 53). The screw opens only the exhaust valve directly beneath it when the engine brake is activated. In addition, the exhaust rocker arm adjusting screws and nuts (Figure 55) are unique for the J-Tech™ engine brake application.

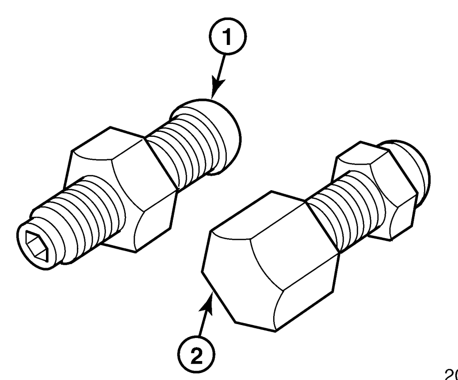


Figure 55 — Rocker Arm Adjusting Screws and Nuts

1. Standard Rocker Arm Adjustment Screw and Nut	2. Special Screw and Spherical Jam Nut (J-Tech™ Exhaust Position Only)

Camshaft

The camshaft (Figure 56) is machined with lobes for actuating the unit pumps and the inlet and exhaust valves. The large diameter of the camshaft provides the additional strength needed for operating the unit pumps as well as the valve train. Journals and lobes are induction-hardened by a process that produces a pronounced heat discoloration mark approximately 3/8-inch wide, around the front and rear faces of each journal and lobe.

Other notable features of the camshaft include a bump in the exhaust cam profile that provides timing for engine brake operation. There is also a groove in the No. 4 journal to aid in reducing cam bushing temperature.

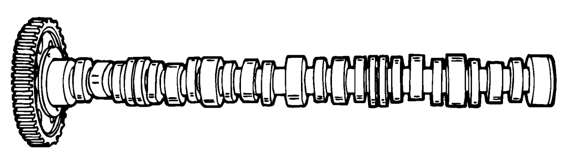


Figure 56 — Camshaft

Valve Train

ROLLER LIFTERS/FOLLOWERS

Roller lifters and roller followers or “tappets” are used to actuate the valves and unit pumps, respectively. The roller aspect of these assemblies handles aggressive cam profiles better and has increased load-carrying capability. The roller lifters are held in alignment by H-rings pressed into the lifter bores; whereas, the EUP roller followers are held in alignment by the tappet guide pins pressed into the cylinder block.

The current redesigned roller lifter has two longer lands that provide more bearing area than the previous design, and the lifter body is now made of hardened steel for greater scuff resistance (Figure 57). The bronze axle used in the previous design has been replaced with a steel axle having a smaller diameter for optimization of roller and axle sizes. The pressure oil feed hole to the axle has been eliminated and replaced with oil grooves on the inside of the lifter legs. The lifter roller is composed of a ceramic material specifically designed for use in engine components.

When handling ceramic roller lifter assemblies, care must be taken to avoid damage. If a lifter having a ceramic roller is dropped, cracks that are too small to detect may be present and result in failure of the ceramic roller. **DO NOT** use a ceramic roller lifter that has been dropped.

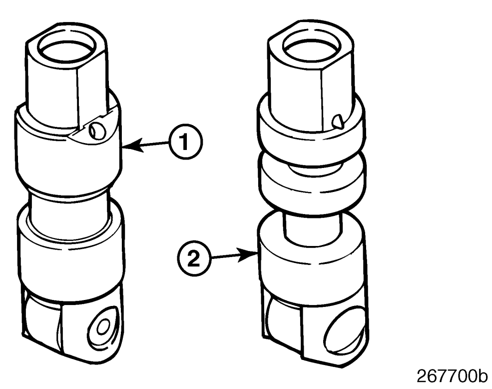


Figure 57 — Roller Lifters

1. Current Ceramic Roller Lifter	2. Non-Current Steel Roller Lifter

VALVES

The stem tip of the valve has grooves to identify the valve as intake or exhaust. The intake valve has one stem groove in addition to the valve spring keeper groove; the exhaust valve has two. Seat face angles are also different, 20 degrees for the intake and 30 degrees for the exhaust.

YOKES

Pinless valve yokes are used for the inlet valves (with standard push rods), and non-brake exhaust valves (with spring-loaded push rods). The spring-loaded push rods have made it possible to use pinless valve yokes at the exhaust locations on non-brake engines. As a result, valve yoke guide pins at the inlet and non-brake exhaust valve locations have been eliminated from the cylinder heads.

AC engines equipped with an engine brake have pin-type yokes at the exhaust valve locations and pinless yokes at the inlet valve locations. Both are made of ductile iron and have a button-style wear pin at the point of rocker arm engagement.

Significant dimensional changes and modifications have occurred in valve yoke design over the years. As a result, it is important that the correct valve yokes are used in all service work. The following will help in identifying the correct parts to use.

Pin-Type Yoke

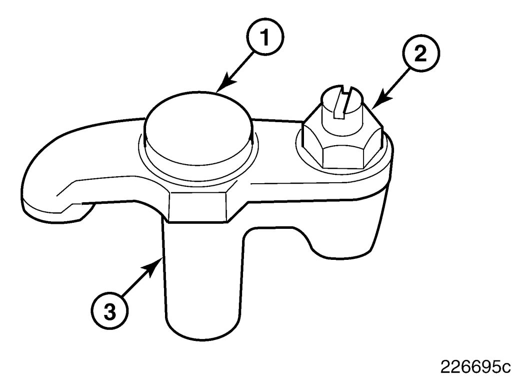


Figure 58 — Current Valve Yoke

1. Headed Pin 2. Adjusting Screw and Jam Nut	3. Valve Yoke

The most positive method of identification is to look at the nose of the valve yoke. ASET™/E-Tech™ valve yokes have the nose end of the slipper pad area ground flat as shown in Figure 59.

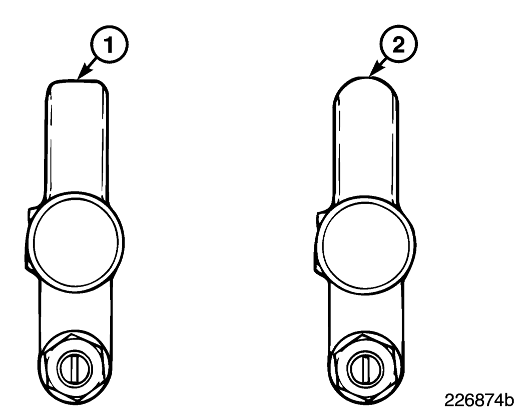


Figure 59 — ASET™/E-Tech™ and E7 Valve Yokes (Top View)

1. Flat Ground Nose (ASET™/E-Tech™)	2. Rounded Nose (E7 Only)

A second method of identifying the “button-head” yoke is to look at the side view. On the yoke design used for the ASET™ engines, the top surface of the adjusting screw end is on the same plane as the bottom surface of the “button-head.” On valve yokes used on engine models prior to ASET™ and E-Tech™, the top surface of the adjusting screw area is 0.145 inch below the bottom surface of the “button-head.” Refer to Figure 60 for an illustration of these differences.

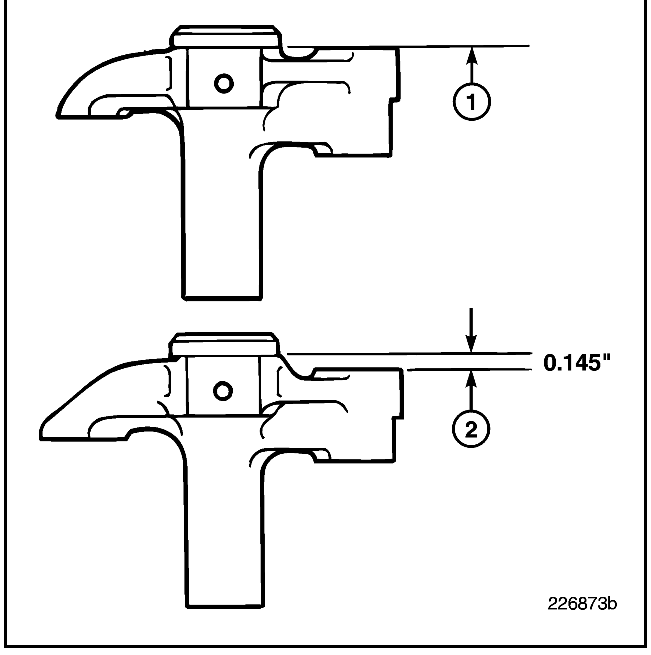


Figure 60 — Valve Yoke Side View

1. Same Plane (ASET™/E-Tech™)	2. Below (0.145″ for E6, E7 and E9 Only)

The valve yokes used on the ASET™/E-Tech™ engines have a deeper engagement at the yoke screw end than the yokes used on the E7-PLN engine, because of the longer valve (Figure 61). ASET™/E-Tech™ and E7-PLN yokes are very similar in appearance, but should not be interchanged.

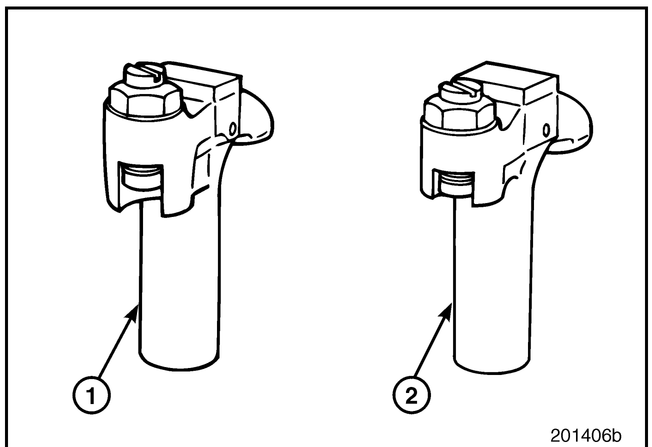


Figure 61 — Valve Yokes

1. Current	2. Non-Current

CAUTION

DO NOT interchange yokes. For example, if a current design yoke from an ASET™ engine is used on an earlier E7 engine, the valve keepers will become dislodged and cause a dropped valve. This will cause severe engine damage. If the non-current design yoke from an E7 engine is used on an exhaust location of a J-Tech™ brake-equipped ASET™ engine, the yoke will disengage from the valve stem tip during engine brake operation. See Figure 62.

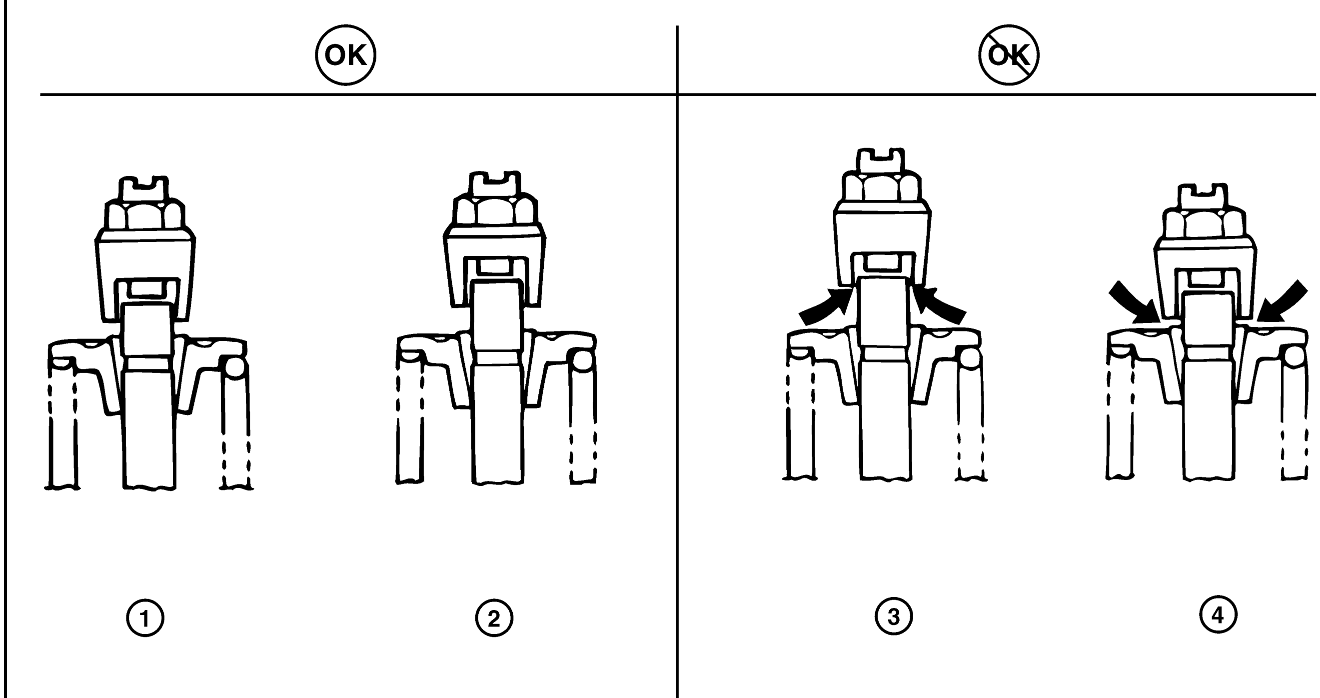


Figure 62 — Yoke/Valve Combinations

1. Correct E7 Yoke/Valve Combination 2. Correct ASET™/E-Tech™ Yoke/Valve Combination 3. E7 Yoke with ASET™/E-Tech™ Valve	4. ASET™/E-Tech™ Yoke with E7 Valve **Note:** Arrows identify problem areas.

Pinless Valve Yokes — Inlet and Non-Brake Exhaust Valve Locations

Approximately two years prior to ASET™ engine introduction, MACK standardized the use of pinless valve yokes at all inlet valve locations, together with standard push rods. Effective May, 2003, pinless yokes are also used at exhaust valve positions of non-brake engines with spring-loaded push rods. As a result, valve yoke guide pins at the inlet and non-brake exhaust valve locations have been eliminated from the cylinder heads.

NOTE

For pinless yokes at the exhaust positions of non-brake engines, the spring-loaded push rods are mandatory.

The pinless yoke is self-leveling in operation and does not have a yoke leveling adjustment screw. Inlet and non-brake exhaust valve lash adjustments are performed in the normal manner with the rocker arm adjusting screw. For the engine brake exhaust valves, it is still necessary to adjust the valve yoke first, then the rocker arm lash.

The bottom of the valve yoke that bridges the two valves has a round hole and an elongated hole that fit over the valve stems. The nose of the yoke with the elongated hole has two notches in the casting. When installing the pinless yokes, it is important that the end of the yoke with the two notches faces away from the valve rocker shaft. If the yoke is installed incorrectly, the yoke will contact the rocker arm.

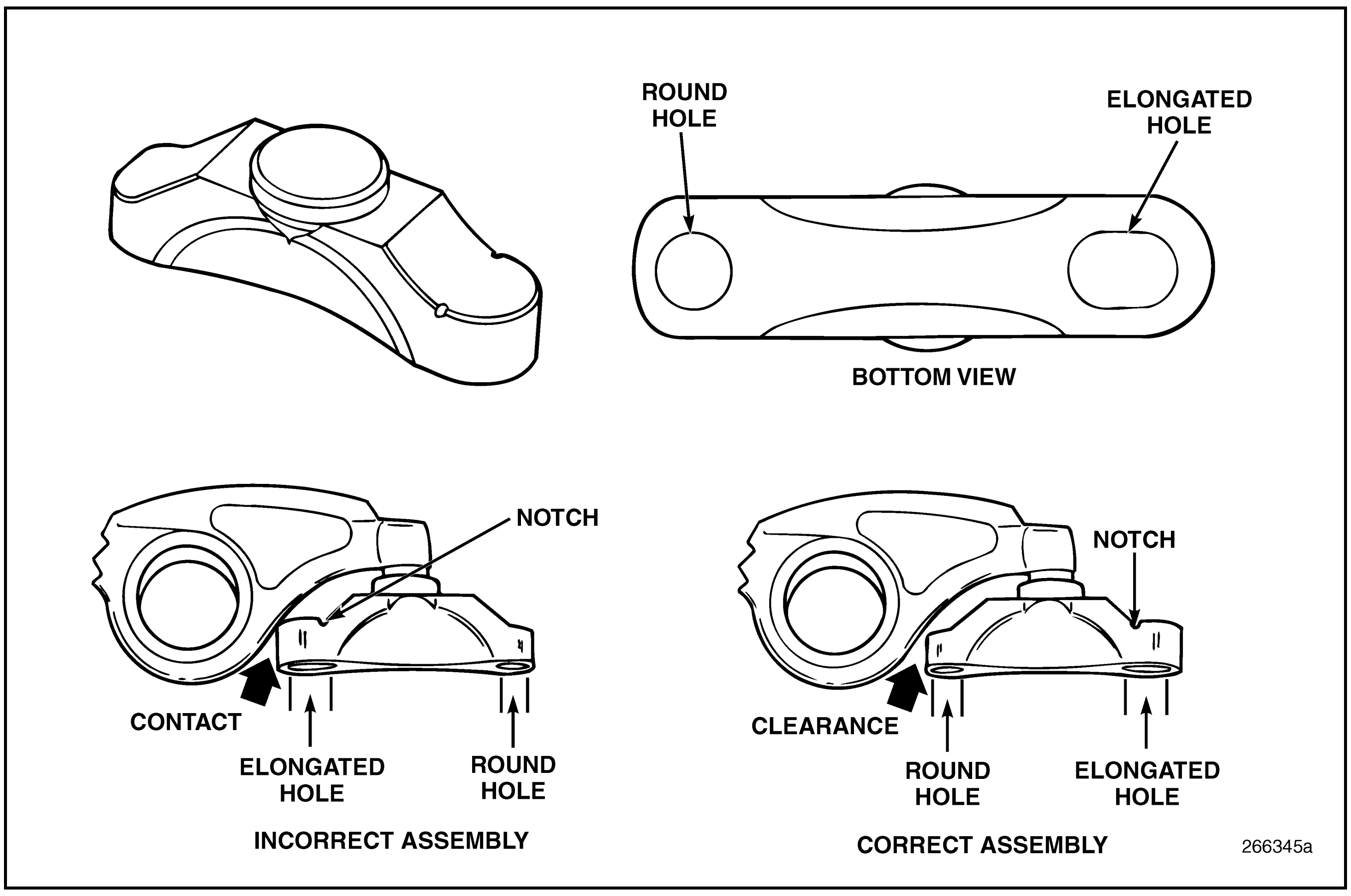


Figure 63 — Proper Assembly of the Pinless Valve Yoke

ROCKER ARM AND SHAFT ASSEMBLY

Rocker Arm Improvements Effective January 2002

Effective with the January 2002 introduction of the spring-loaded push rods, both inlet and exhaust both inlet and exhaust rocker arms have been revised to provide pressure oil feed to the valve adjusting screws. A vertical groove has been added to the inboard side of the adjusting screw bore, from the top of the bore to the oil supply hole that is just above the bottom of the bore. On the outboard side of the rocker arm adjusting screw boss, a closure plug has been installed into the drilled hole to eliminate the leak path for pressure oil and ensure sufficient oil to the adjusting screw.

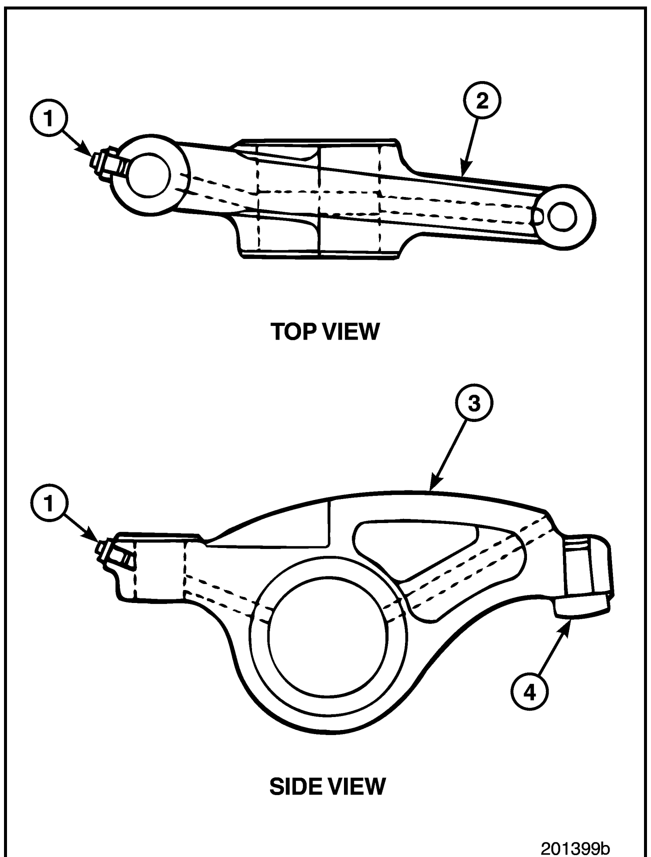


Figure 64 — Rocker Arm Effective January 2002

1. Plug 2. Rocker Arm (Top View)	3. Rocker Arm (Side View) 4. Hardened Pin

Further rocker arm improvements include adjusting screws that have a groove around the center of the screw, an oil passage cross-drilled through the shank of the screw and an oil passage drilled along the vertical center line of the screw. These oil passages provide lubrication to the ball end of the adjusting screw and the push rod cup. Additionally, to make it easier to hold the screw during valve adjustment, the new rocker arm adjusting screws have a 5 mm internal hex rather than a screwdriver slot as was used on previous adjusting screws.

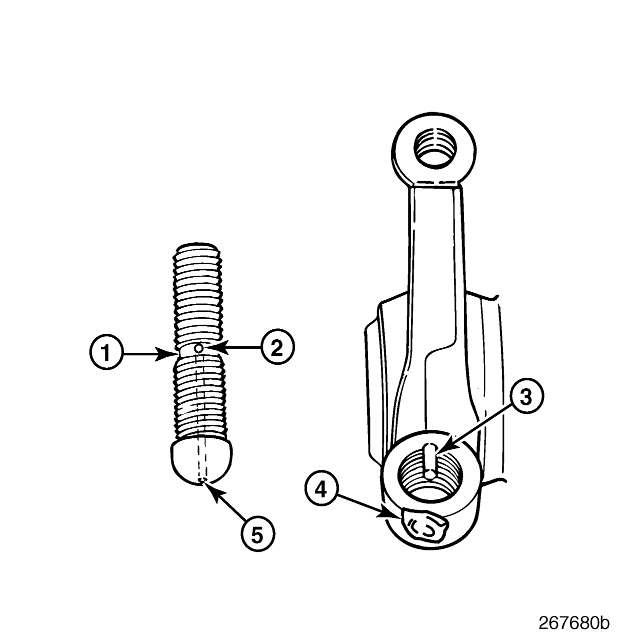


Figure 65 — Rocker Arm and Adjusting Screw with Oil Passages (Introduced January 2002)

1. Oil Supply Groove 2. Drilled Oil Passage 3. Oil Supply Groove	4. Outboard Oil Hole Plugged 5. Drilled Oil Hole Plugged

Rocker Arm Improvements Effective January 2003

Effective January 2003, the following new and improved components were introduced into production.

Rocker Arm Shaft

- Heavier wall thickness for added strength
- Increased radius in all retainer ring grooves, also for strength improvement
- Shaft end closure by pipe plugs, to provide a more secure closure than the previously used cup plugs
- The shaft has two additional oil supply holes to each rocker for directed lubrication to the rocker arm tip-end and adjusting screw

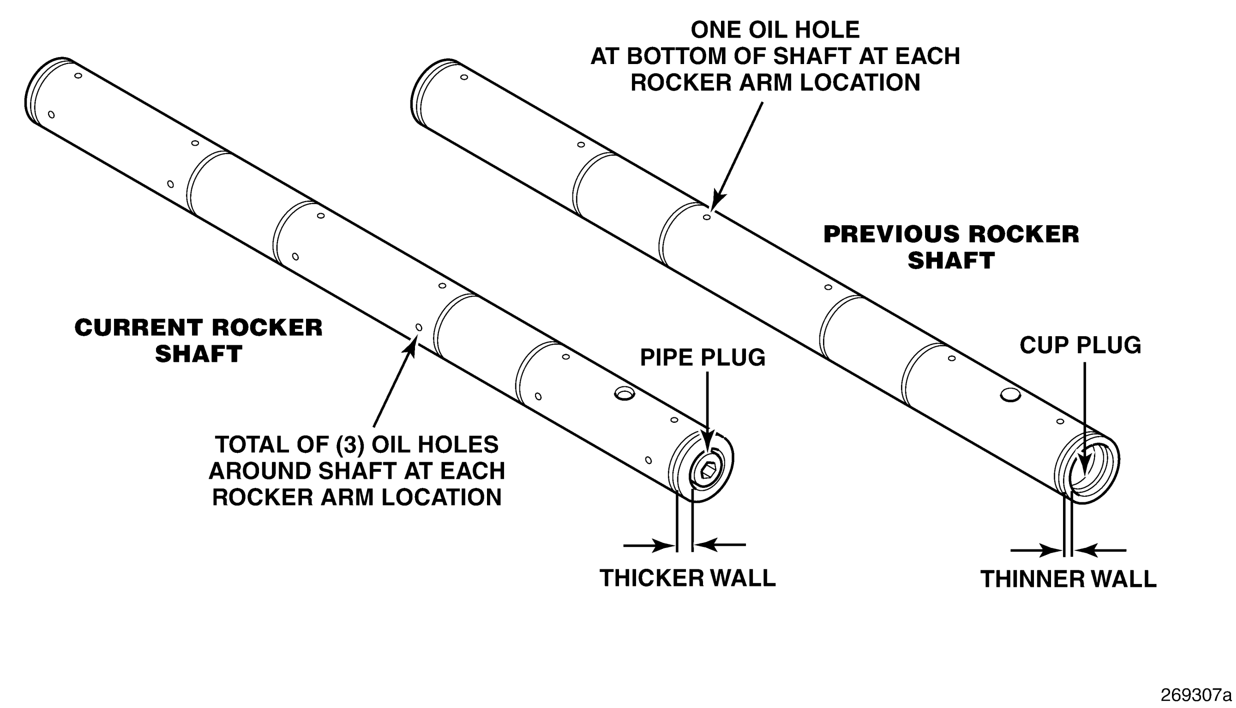


Figure 66 — Rocker Arm Shaft

Rocker Arms

- Increased casting thickness for added strength
- Carbonitrided steel bushing in shaft bore for wear resistance
- Revised oil passage drilling eliminates the adjusting screw bore closure plug

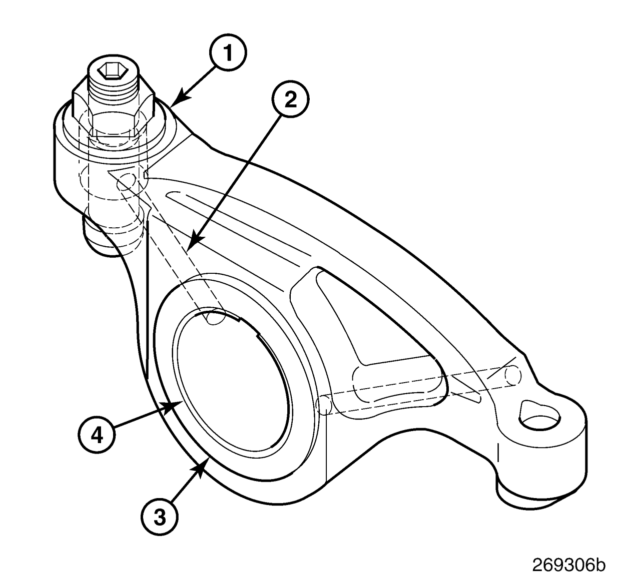


Figure 67 — Rocker Arms

1. Wider Casting at Nut Flange 2. Revised Oil Passage	3. Near-Full Width Casting 4. Steel Bushing

Rocker Arm Adjusting Screws

- The pressure oil fed adjusting screws are Armolloy coated for resistance to galling and wear

Pinless Valve Yoke

- The top inboard corner of yoke has been chamfered at a 45-degree angle, necessary to ensure clearance between yoke tip and the heavier rocker arm casting

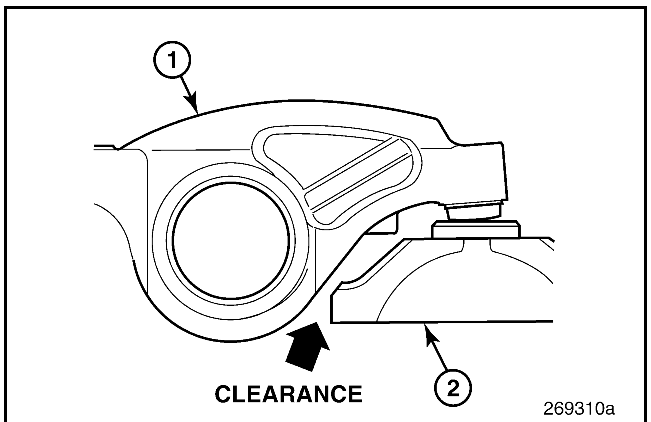


Figure 68 — Pinless Valve Yoke

1. Heavier Rocker Arm Casting	2. Yoke with Chamfered Tip

CAUTION

The revised rocker arm components described above cannot be intermixed with previous version components.

With the heavier rocker arms, it is mandatory to use the pinless valve yoke having the chamfered tip at the top of the inboard end.

Low-Pressure Fuel System

ASET™ AC engines have a cooling plate in the low pressure fuel circuit (Figure 69) to provide cooling for the higher capacity EECU. Fuel flows from the fuel tank to the EECU cooling plate, the pre-pump filter, the supply pump, the primary filter (combination primary and secondary) and then to the unit pumps.

In addition to the standard arrangement described above, Figure 70 illustrates a system equipped with the optional fuel filtration arrangement. With this arrangement, the supply pump is replaced with a traditional pump that does not have the integral pre-pump screen and spin-on filter.

To decrease restriction in the low-pressure fuel system, hoses and fittings with larger inside diameters are used for all suction lines in the system.

To meet unit pump demands, the supply pump provides a 100 gph fuel flow at 70 psi pressure. This high level of flow and pressure is needed to cool the unit pumps and EECU, and keep the fuel supply gallery filled. Pressure within the gallery is maintained by a pressure regulating valve with a 70 psi spring setting. A check valve fitting located at the fuel return gallery outlet on the cylinder block right side prevents the system from bleeding down when the engine is not operating.

The gear-type supply pump driven by the engine camshaft gear is located on the rear side of the right-front flange of the cylinder block. The pump is also fitted with a hand primer pump for all AC engine applications. In addition, the standard AC configuration also includes integral pre-pump and primary filters.

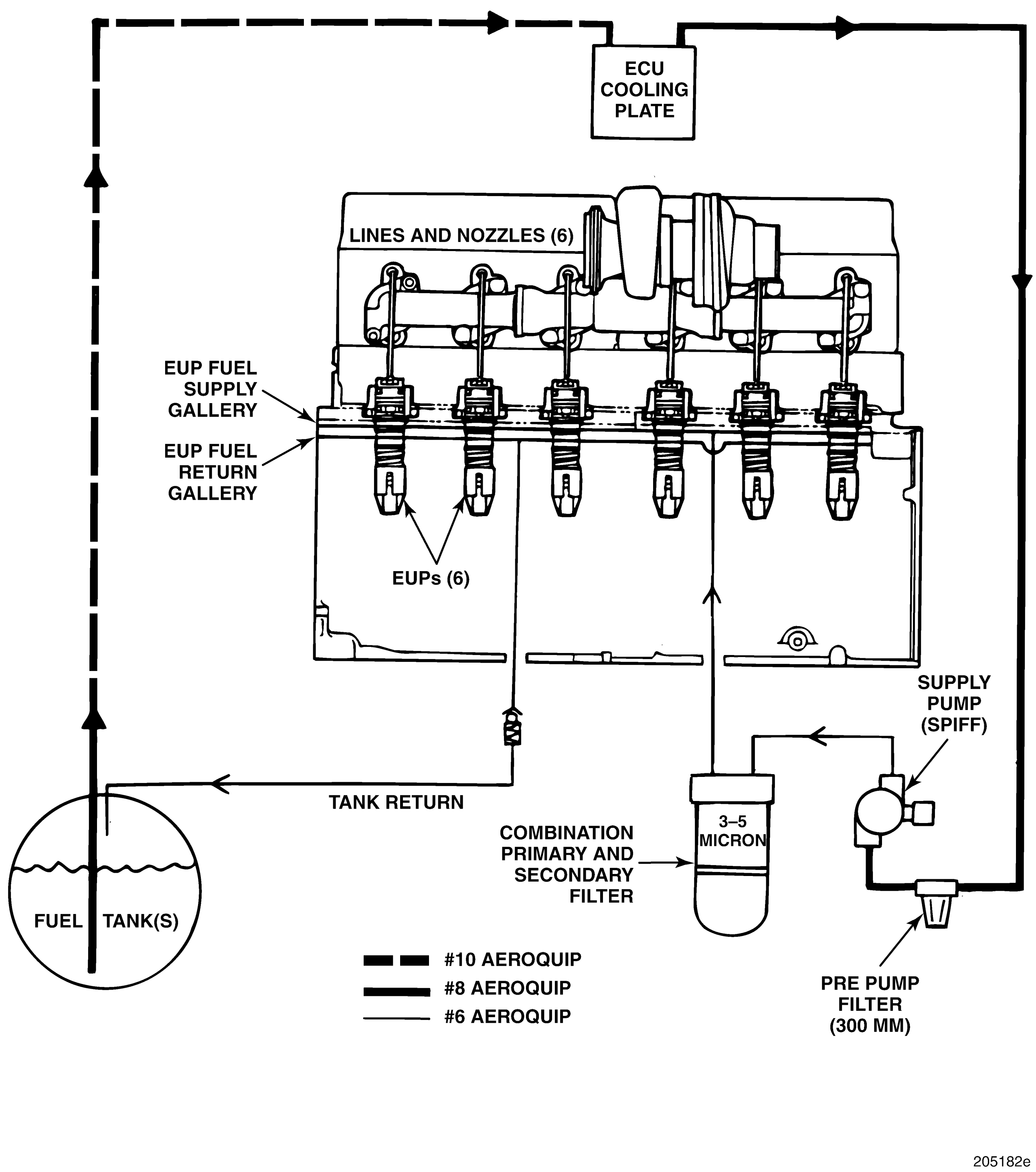


Figure 69 — Low-Pressure Fuel System for ASET™ AC Engine with SPIFF Filtration System

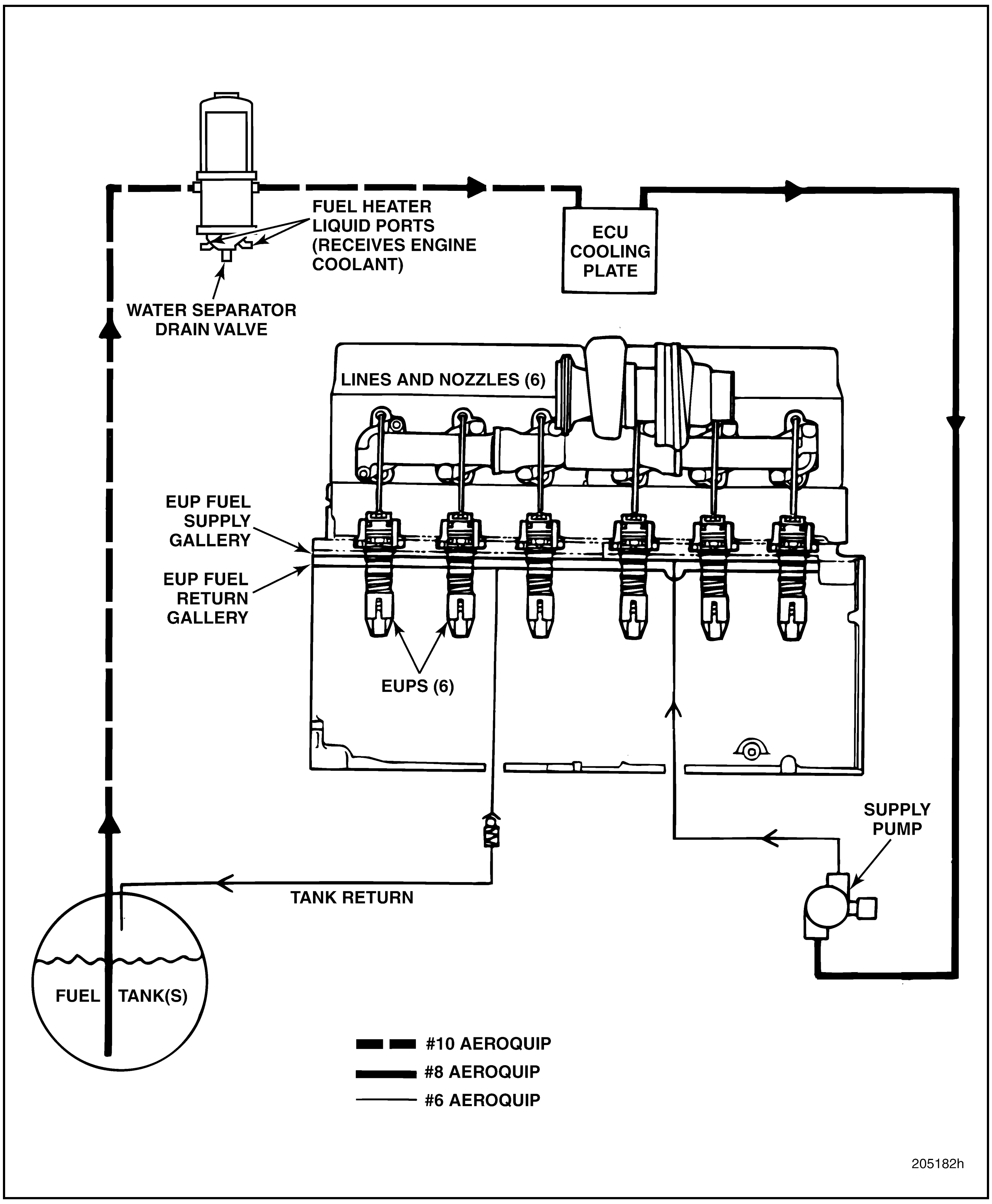


Figure 70 — Low-Pressure Fuel System for ASET™ AC Engine with Optional Fuel Filter Arrangement

High-Pressure Fuel System

The high-pressure fuel system (Figure 71) is designed to provide fuel to the combustion chamber under high pressure. In this system, unit pumps (one per cylinder) with operating pressures of 26,000 psi are used for this purpose. These high pressures, along with an extended timing range and optimized timing control, provide excellent performance.

Fuel is supplied to each of the unit pumps by the fuel supply gallery in the cylinder block. The high pressure required for fuel injection is generated by a pump plunger (10 mm diameter, 18 mm stroke), which is actuated by a roller cam follower (tappet) driven by the engine camshaft. The volume of fuel delivered to each cylinder is precisely metered by a solenoid mounted on each of the unit pumps, which responds to signals from the V-MAC III EECU. The pressurized fuel is delivered to the injector nozzles by individual external fuel injector lines.

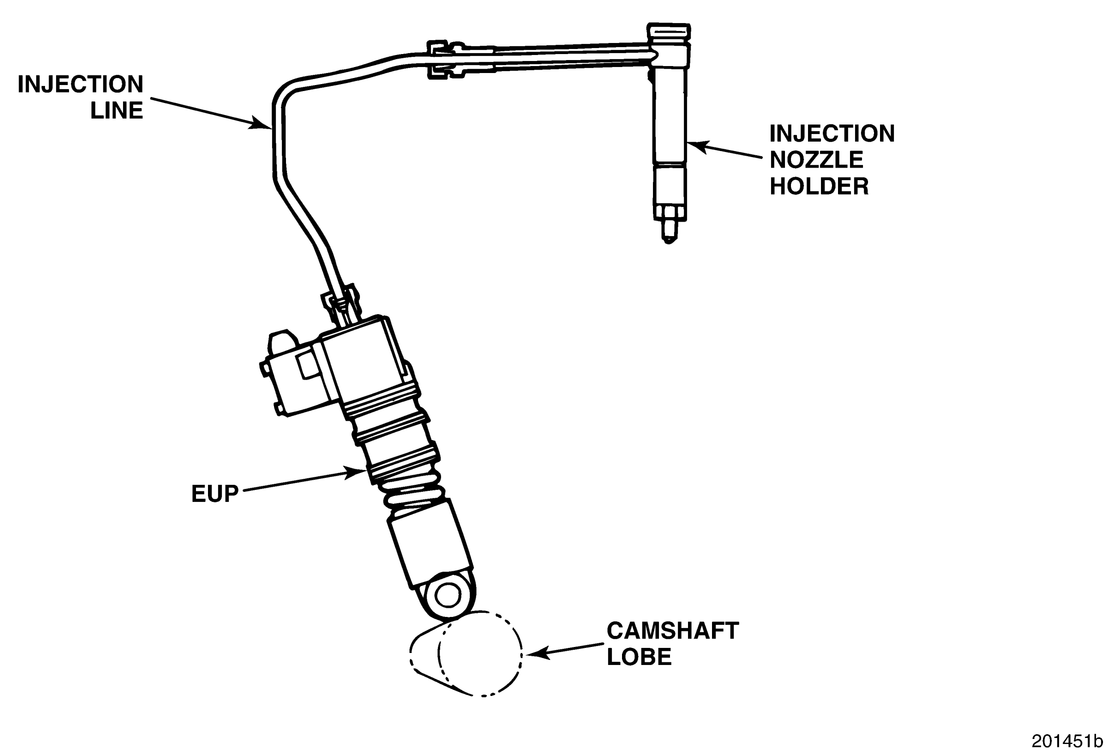


Figure 71 — High-Pressure Fuel System

High-Pressure Fuel Injection Lines

The high-pressure fuel lines for each cylinder (Figure 72) are short (17 inches) and have the strength to withstand the high fuel pressure generated by the electronic unit pumps. A standard configuration with the same part number is used for all cylinders and all engine models. Also, there are no clamps used on these lines.

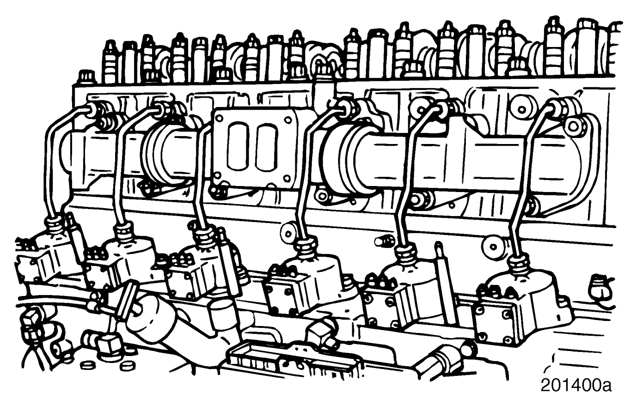
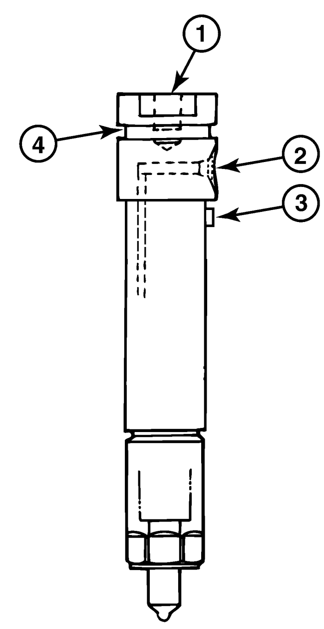


Figure 72 — Fuel Injection Lines

Fuel Injector Assemblies

Injector nozzles used with the ASET™ engines are 22 mm in diameter with the material strength to match the high operating pressures of the electronic unit pumps. The nozzle holder is also fitted with a locating pin to ensure proper alignment of the injector assembly in the cylinder head. The locating pin is on the same side as the nozzle holder fuel inlet port. Refer to Figure 73.



1. 5/16 INCH-24 THREADS FOR REMOVING NOZZLE FROM CYLINDER HEAD
2. NOZZLE FUEL INLET (HIGH PRESSURE FUEL LINE CONNECTION)
3. NOZZLE-TO-CYLINDER HEAD INDEXING PIN
4. O-RING GROOVE

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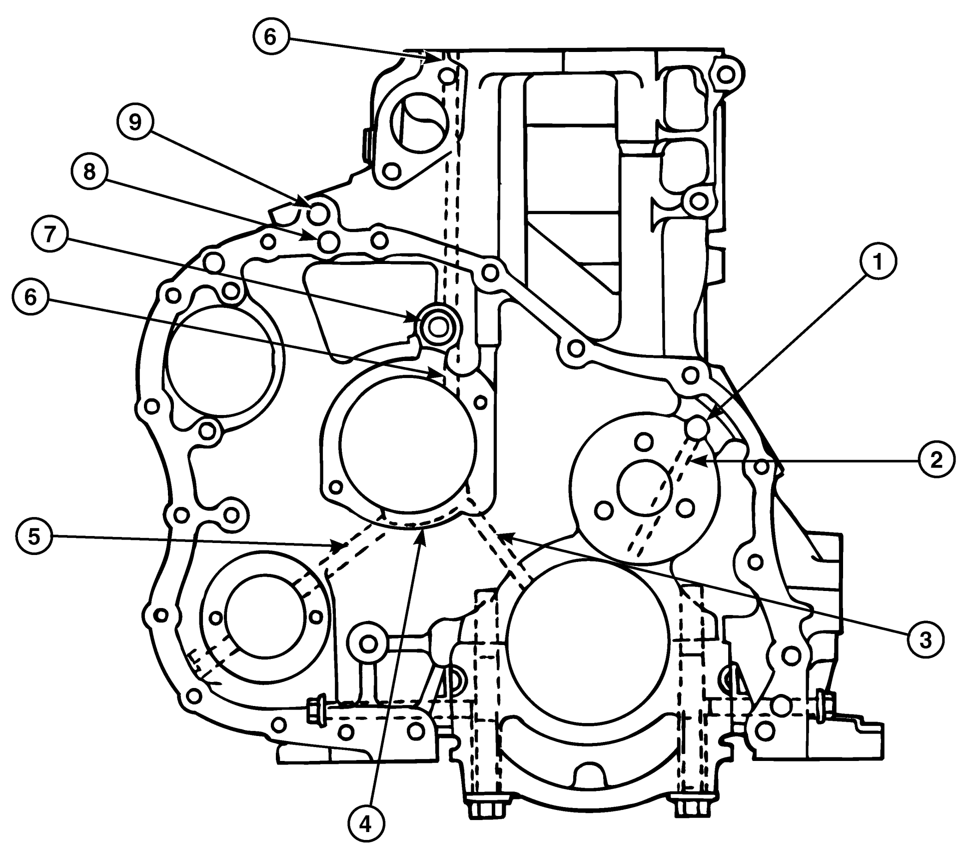
Figure 73 — Fuel Injector Nozzle Holder

Cylinder Block

The cylinder block is a single-piece design made of high-strength alloyed gray cast iron. The deep skirt extends well below the crankshaft center line and incorporates seven main bearings. The bearing caps are made of ductile iron and use buttress screws at the intermediate locations. Replaceable wet-dry sleeves line the cylinder bores.

Due to the large camshaft diameter, the cam bore position is shifted up and outboard to operate the unit pumps and provide cam-to-crank clearance (Figure 74). To accommodate this cam position, the push rod holes are angled four degrees and the air compressor angled outboard. The crank and cam timing gears do not mesh directly, but power transmission occurs through an idler gear mounted in an idler gear bore in the front face of the cylinder block. The right-front flange on the cylinder block provides a mounting surface for the fuel supply pump.



1. MAIN OIL GALLERIES (FRONT AND REAR)
2. MAIN GALLERY TO MAIN BEARING BORE OIL PASSAGE
3. MAIN BEARING BORE TO CAM BORE OIL PASSAGE
4. FRONT CAM BUSHING BORE TO FRONT AUX. BUSHING OIL SUPPLY ANNULUS
5. FRONT CAM BUSHING BORE TO FRONT AUXILIARY BUSHING OIL PASSAGE
6. NO. 2 AND NO. 5 CAM BUSHING BORE OIL SUPPLY TO VALVE LIFTER/EUP OIL GALLERIES (FRONT AND REAR) AND CYLINDER HEADS
7. VALVE LIFTER/EUP OIL GALLERIES (FRONT AND REAR)
8. FUEL RETURN GALLERY
9. FUEL SUPPLY GALLERY

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Figure 74 — Cylinder Block

The main oil gallery runs along the left side of the block. A second oil gallery — the valve lifter/EUP oil supply gallery — runs along the right side of the block. The valve lifter bores directly intersect this right-side gallery, while oil is supplied to the EUP by six passages drilled from the block's right side, through the EUP bore and into the adjacent valve lifter bore. The six holes along the block's right side are closed off with pipe plugs.

Both the left- and right-side oil galleries are drilled from the front and the rear, but do not meet at the center. Oil is supplied to the valve lifter/EUP oil gallery through drilled passages from the No. 2 and No. 5 cam bores. An annulus in both the No. 2 and No. 5 main bearing bores, as well as the groove in the upper bearing inserts and grooves around the No. 2 and No. 5 cam journals, ensure a high volume of oil to the valve lifter/EUP galleries.

Internal fuel supply and return galleries for the unit pumps are gun-drilled axially, the full length of the block's right side just below the unit pump mounting flange surface.

On the left-hand side of the cylinder block at the center is a four-bolt oil filter pedestal mounting pad (Figure 75). This pad is cast with two internal oil drain holes that allow the Centri-Max® ULTRA or ULTRA PLUS drain oil to pass directly into the crankcase. The two 3/4-inch "as-cast" holes are visible inside the crankcase on either side of the No. 4 main bearing bulkhead, between the Nos. 3 and 4 piston cooling nozzles. The external oil drain port in the cylinder block is no longer used and is covered with a block-off plate.

NOTE

The internally drained Centri-Max® ULTRA or ULTRA PLUS filter requires the two internal drain cavities in the cylinder block. The same cylinder blocks, however, are used to service engines having either the non-current externally drained Centri-Max®, or the internally drained Centri-Max® ULTRA or ULTRA PLUS filter assemblies. When a block is used for an engine equipped with the externally drained Centri-Max® filter, the oil drain cavities are not functional.

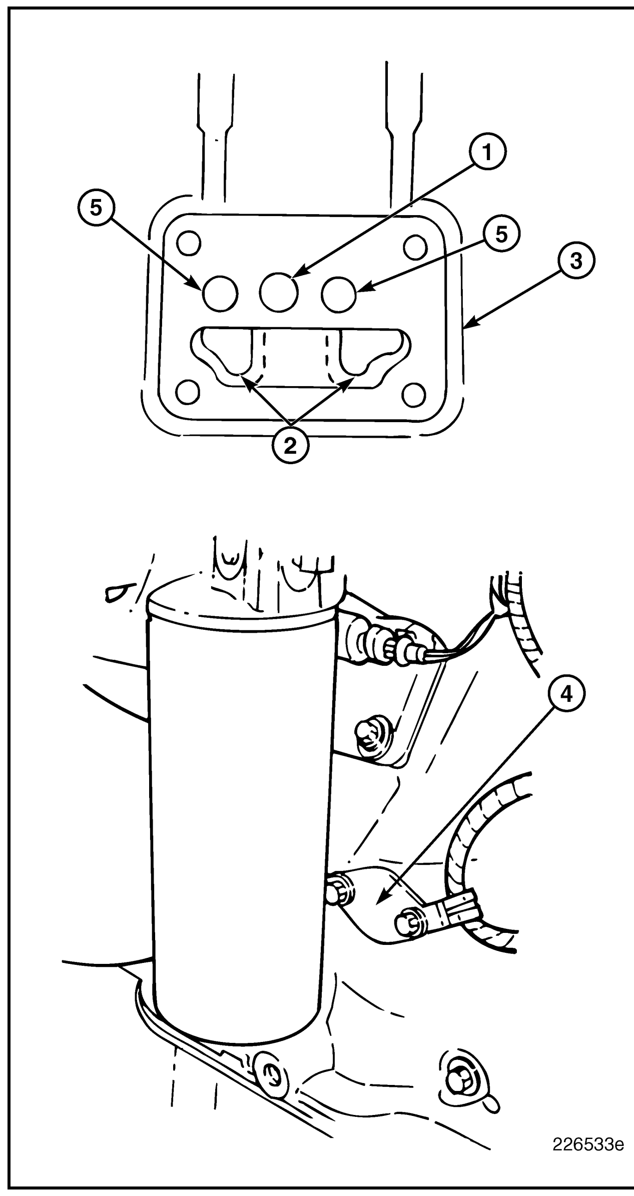

Figure 75 — Oil Filter Pedestal Mounting Pad

1. Oil Passage — Oil Pump-to-Oil Cooler and Filters 2. Internal Drain Holes 3. Mounting Pad (Block)	4. External Oil Drain Block-Off Plate 5. Oil Passage — Filtered Oil-to-Main Oil Galleries

Crankshaft

The crankshaft is fully counterbalanced and has induction-hardened journals. It is supported with main bearings at seven locations. Thrust washers are located at the center main bearing (position No. 4) to absorb fore and aft end thrust.

At the forward end of the crankshaft is an extension that carries the main drive gear, vibration damper and accessory drive pulleys. The main drive gear is keyed to the crankshaft, ensuring proper assembly and engine timing. At the rear of the crankshaft is a flange for mounting the flywheel. Two seals, one each at the front and rear journals of the crankshaft, prevent lubricating oil leaking from the engine.

Webs cast into the crankcase provide the upper main bearing supports for the crankshaft. Removable bearing caps retained with capscrews provide the lower bearing supports and proper alignment for the crankshaft. The bearing caps are not interchangeable and each has a number stamped on it which signifies its correct location and alignment in the crankcase. The caps are numbered 1 through 7, with the No. 1 main bearing cap at the front of the engine. The bearing inserts are precision-designed, and are positioned between the crankshaft and crankcase, and between the crankshaft and the bearing caps. Thrust flanges to support the thrust washers are located at the center main bearing (No. 4).

Block Heater

The engine accepts a straight element unit in the rear location. Effective with ASET™ engine introduction, all factory installations use the rear location only.

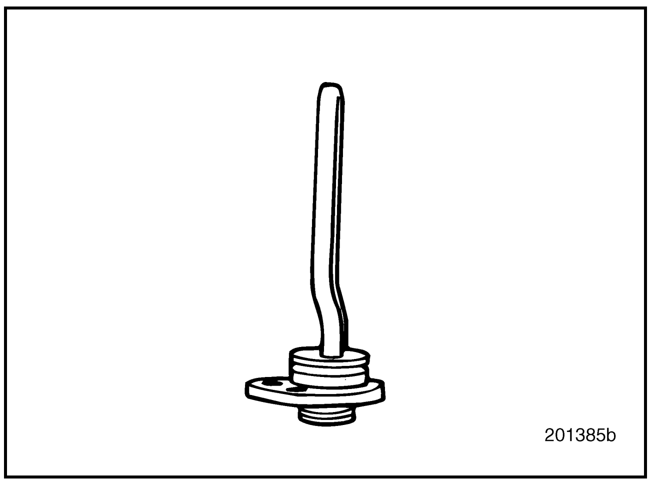

Figure 76 — Straight Block Heater

Cylinder Head

The cast-iron cylinder head (Figure 77) is constructed using a special iron alloy. The head contains cored inlet, exhaust and coolant passages, drilled oil passages, replaceable inlet and exhaust guides and seats, various drilled passages and tapped holes. Each cylinder head covers three cylinders and has two inlet and two exhaust valves per cylinder. Circular grooves in the deck surface correspond with the fire ring bead on the cylinder sleeves. This design sets the fire ring directly over the liner. With the cylinder head installed and the bolts tightened to specification, the liner coining bead extrudes the fire ring into the cylinder head groove, providing a positive combustion pressure seal.

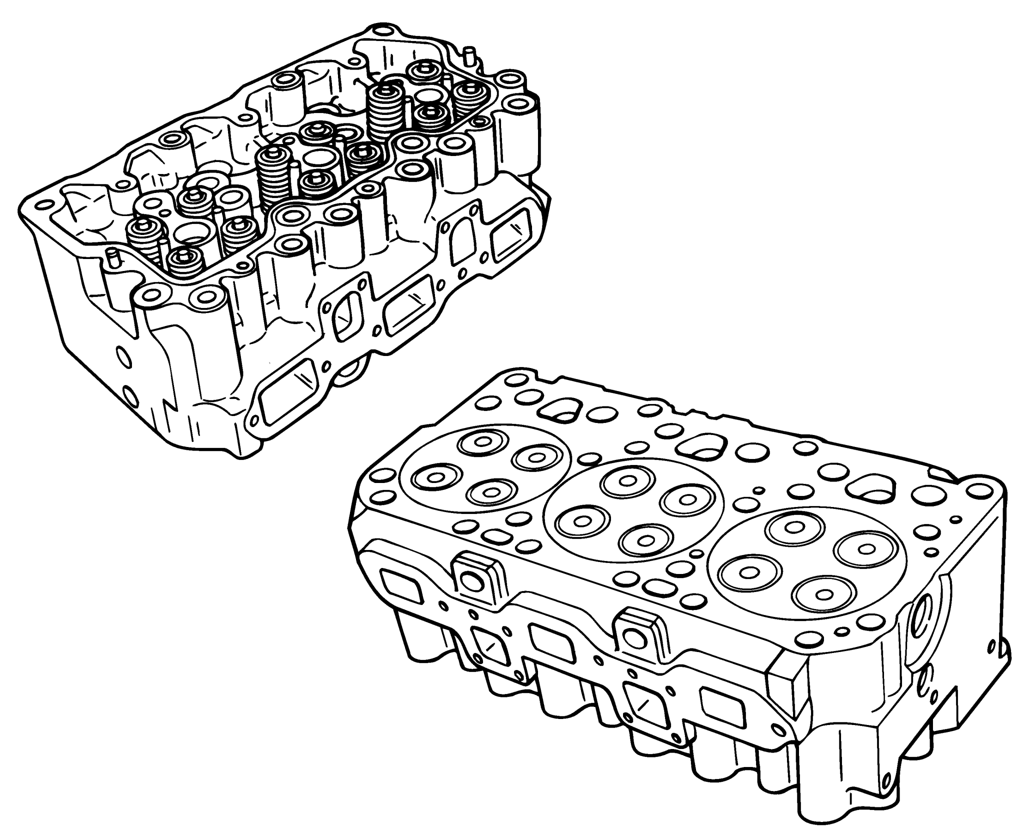

Figure 77 — Cylinder Head

Some characteristics of the cylinder head are not visually evident, but are still significant (Figure 78). They include the following listed items:

- Push rod holes are angled at four degrees due to outboard location of camshaft.
- Large nozzle sleeve diameter to accommodate 22 mm nozzle holder assembly with no leak off return.
- Water-jacket casting designed to improve coolant flow.
- Lower exhaust stud holes intersect with push rod holes; upper exhaust holes may intersect as well. This requires that all exhaust studs be sealed at installation to prevent oil weepage.

NOTE

ASET™ and E7 cylinder heads cannot be interchanged because of the differences in the machining.

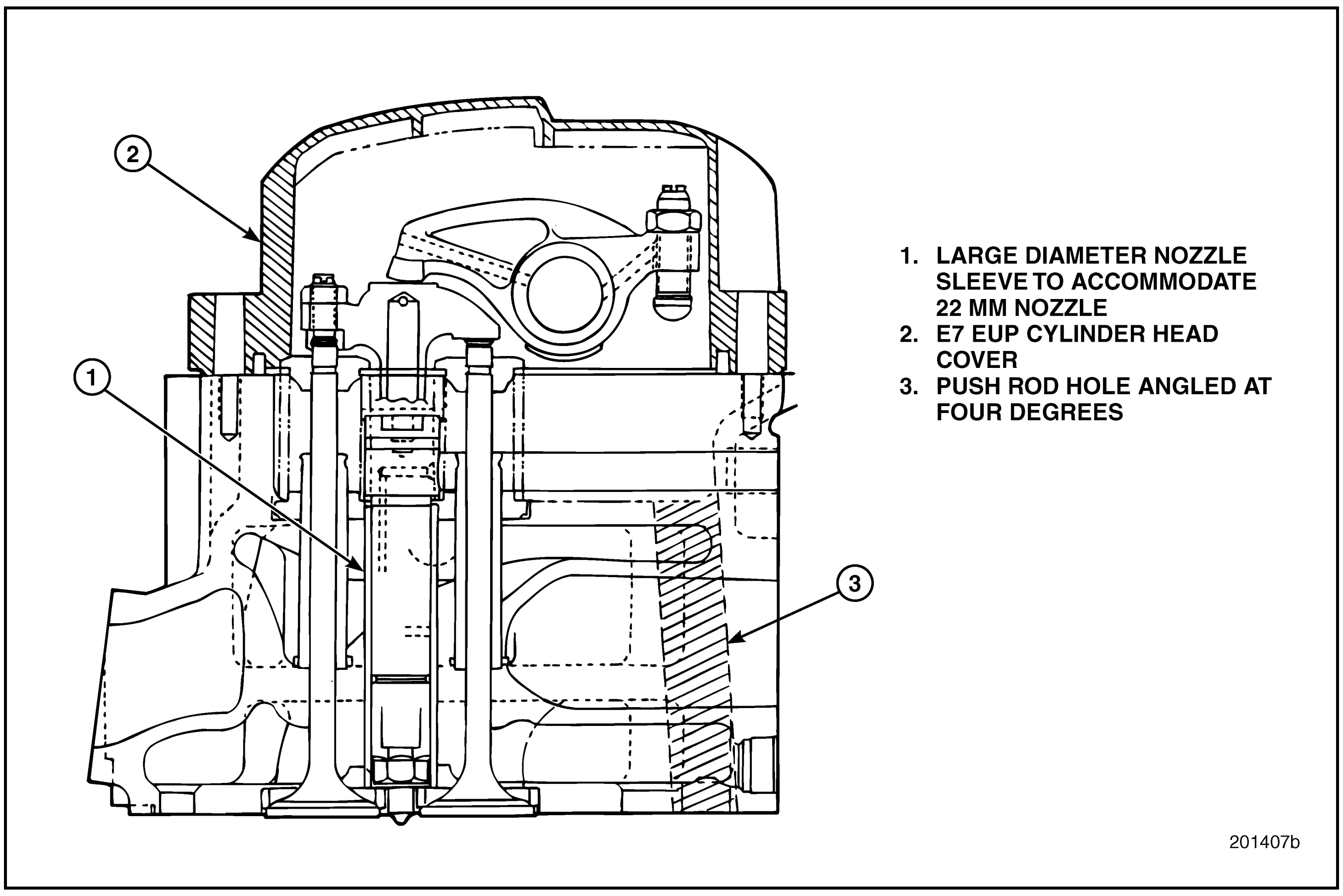

Figure 78 — Cylinder Head and Cover (ASET™ Engines)

Cylinder Head Gasket

ASET™ engines use the same fire ring as the E7 engine, but the cylinder head gaskets are different. The gaskets are identical except for obvious differences at the right-side push rod cutout areas. The right-side edge of the E7 gasket is straight, except for protrusions at the four right-side head bolt holes. The ASET™ gasket has these protruded areas as well, but also has six larger protrusions at the push rod hole cutouts (Figure 79). Care must be exercised to use the proper gasket only on the engine for which it is designed.

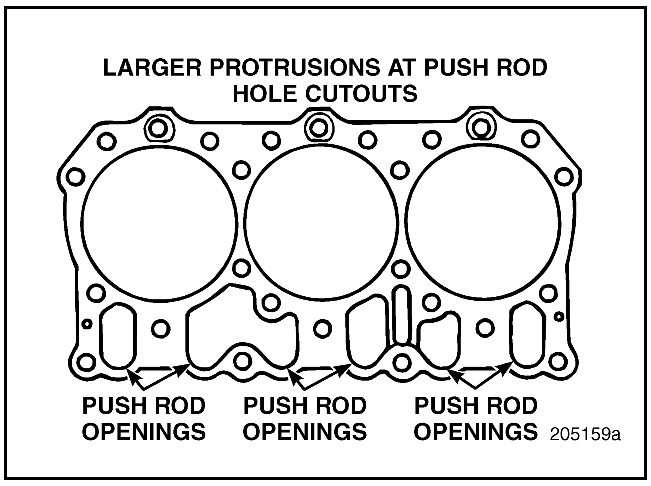

Figure 79 — ASET™ Head Gasket

Gear Train

The gear train (Figure 80) is designed to accommodate the large diameter camshaft and the addition of electronic unit pumps. An idler is positioned between the crankshaft and camshaft gears. As a result, the crankshaft and camshaft rotate in the same direction, unlike the E7 engine. In addition, the power steering pump and air compressor rotate in a direction opposite that of the E7. However, in order to maintain the same pumping direction and lubrication oil flow for both ASET™ and E7 engines, the oil pump drive gear helix is reversed on the ASET™ engines.

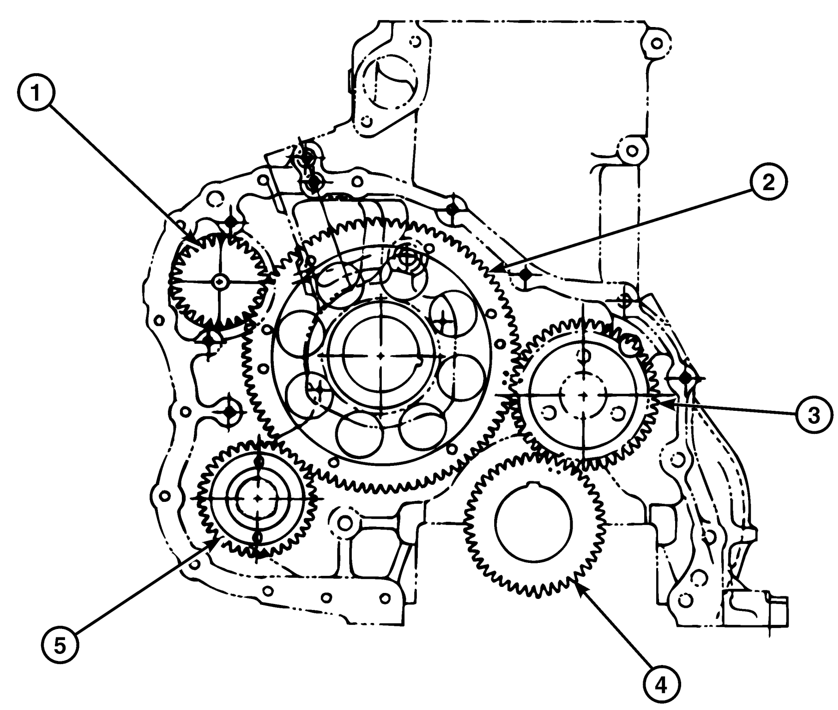

Figure 80 — Gear Train

1. Fuel Pump Gear 2. Camshaft Gear 3. Idler Gear	4. Crankshaft Gear 5. Auxiliary Shaft Gear

NOTE

There are 45 gear teeth on the crankshaft gear, 90 teeth on the camshaft gear and 48 on the idler gear. Because the idler gear has 3 more teeth than the crankshaft gear, the timing marks (Figure 81) align only once every 16 revolutions of the crankshaft. This is called a “hunting tooth” system.

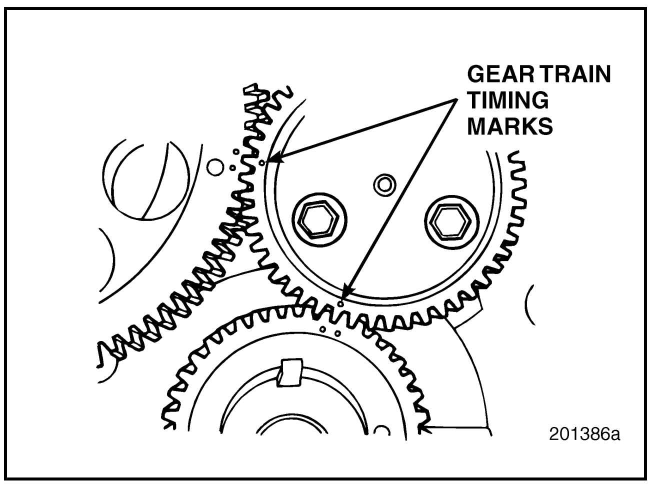

Figure 81 — Timing Marks

Air Compressor

E7, E-Tech™ and ASET™ air compressors have the same internal components, as the air compressor functions equally well with either direction of rotation. There are, however, some external differences between the engines and air compressors, which prevent the compressors from being interchangeable between the E7 and the E-Tech™ or ASET™ engines.

The air compressors used on all ASET™ AC engines utilize filtered air from the engine air intake system for their inlet air supply, not engine boost pressure. Previous engine designs used engine boost pressure.

Power Steering Pump

All ASET™ engines have the capability of driving a power steering pump from either the front or rear of the auxiliary shaft. Naturally, the direction of rotation of a front power steering pump is opposite that of a rear power steering pump.

CAUTION

Always refer to part number specification information when installing a power steering pump to ensure that the correct part with the correct direction of rotation is being used. Installing a power steering pump with the wrong direction of rotation will result in pump failure and inoperative power steering.

Vibration Damper Hub

Because of the wide timing gears used on ASET™ engines, it is essential that the correct vibration damper hub is used. The vibration damper hub is 3/8 inch shorter than the E7 hub (Figure 82) which is similar in appearance. Always make sure the correct vibration damper is used for the correct engine model.

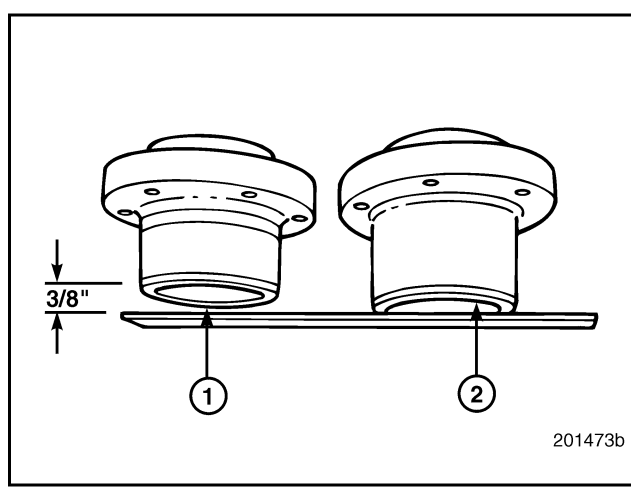

Figure 82 — Vibration Damper Hub

1. ASET™/E-Tech™ Hub	2. E7 Hub

Front Cover

The front cover (Figure 83) has been designed with a boss for the automatic belt tensioner, room for the idler gear, a mounting for the crankcase breather, and a boss for the engine position sensor.

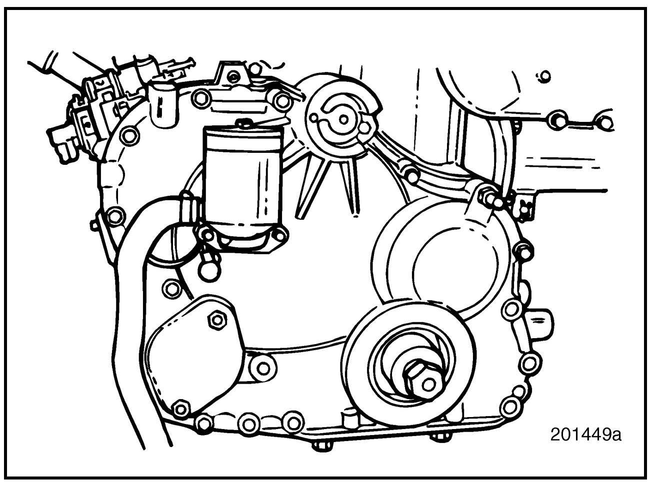

Figure 83 — Front Cover

CRANKCASE BREATHER

ASET™ engines have a crankcase breather filter assembly that mounts on the engine front timing gear cover. This system traps, collects and returns oil to the engine crankcase that would otherwise be lost with blow-by gases.

During operation, blow-by gases from the engine pass upward through the filter element, then down and out through the center standpipe, which exits from the canister lower-outboard side. When blow-by gases pass through the filter element, oil collects on element surfaces and then drains back into the crankcase.

NOTE

The ASET™ engines are equipped with a housing made of fiberglass-reinforced nylon (Figure 84). The breather element, housing mounting gasket and O-rings are NOT interchangeable with the non-current cast-aluminum housing design used on past model engines.

The canister lid and element are removable to allow element cleaning.

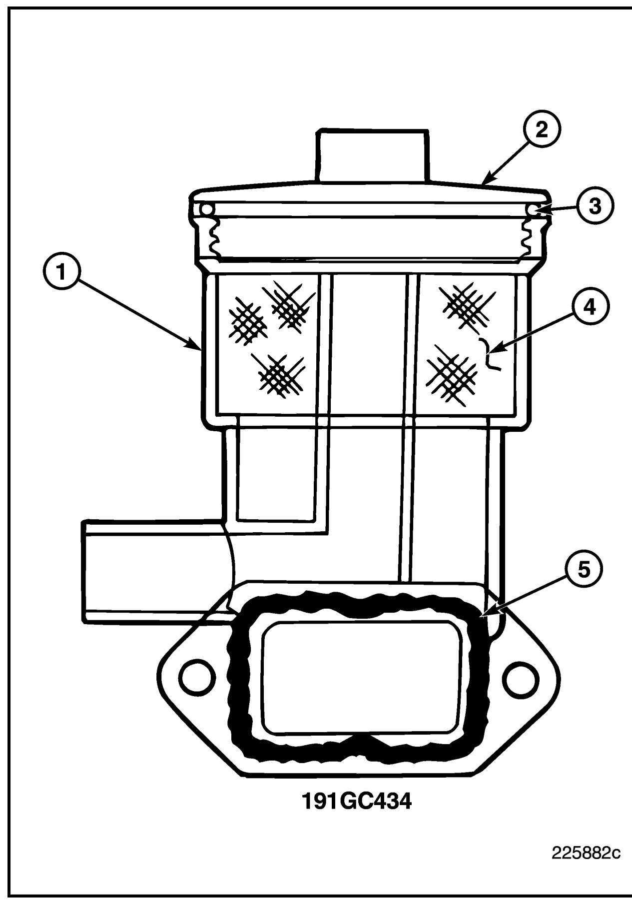

Figure 84 — Crankcase Breather

1. Fiberglass-Reinforced Nylon Housing 2. Cover 3. Cover O-Ring	4. Filter Element 5. Assembly Mounting O-Ring/Gasket

Lubrication System

ASET™ engines have oil galleries at both the left and right sides of the cylinder block. The galleries along with the corresponding passages supply lubricant oil to the moving components of the engine. Identification and description of both galleries and information for the oil pump, oil cooler and filters are included below.

MAIN OIL GALLERY

The main oil gallery on the left side of the engine is divided into two sections. The front section supplies oil through passages to the Nos. 1, 2 and 3 crankshaft journal bores and from there to the Nos. 1, 2 and 3 camshaft bores. Oil is also supplied to the idler gear bore and to the piston cooling nozzles of the Nos. 1, 2 and 3 cylinders. A 3/4-inch cup plug is used to close the passage at the front of the block (Figure 85).

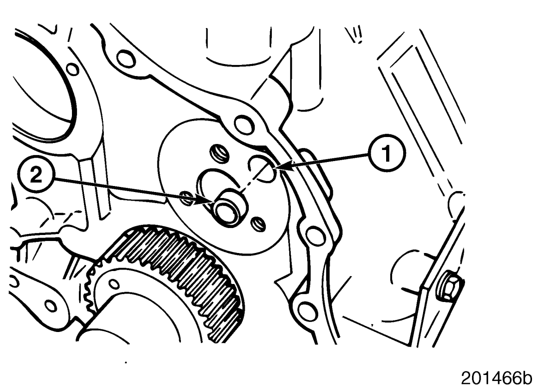

Figure 85 — Gallery Cup Plug

1. Main Oil Gallery	2. Cup Plug, 3/4-Inch

The rear section of the main oil gallery supplies oil through passages to the Nos. 4, 5, 6 and 7 crankshaft journal bores and from there to the Nos. 4, 5, 6 and 7 camshaft bores. Oil is also supplied to the piston cooling nozzles.

VALVE LIFTER/EUP OIL GALLERY

Refer to Figure 86.

A second oil gallery, located above the camshaft, supplies oil to the valve lifter bores and EUP bores. Oil is fed to the two sections of this gallery by drilled passages from the No. 2 and No. 5 cam bores which also feed oil to the cylinder head rocker arm shafts and engine brake assemblies. The No. 2 and No. 5 main bearing bores and the No. 2 and No. 5 cam journals are grooved to satisfy the additional oil flow required by this second oil gallery.

OIL PASSAGES

- The passage from the main oil gallery to the No. 1 main bearing bore intersects the idler gear hub bore to provide lubrication to the idler gear bushing.
- There are two oil annulus passages in the No. 2 and No. 5 main bearing bores. These passages, together with the groove in the upper bearing inserts and the groove around the No. 2 and No. 5 cam journals, ensure a high volume of oil to the right-side oil gallery.
- Valve lifter (roller follower) bores intersect the right-side oil gallery.
- Passages drilled through each EUP bore and into the adjacent valve lifter bore provide oil feed to each EUP.

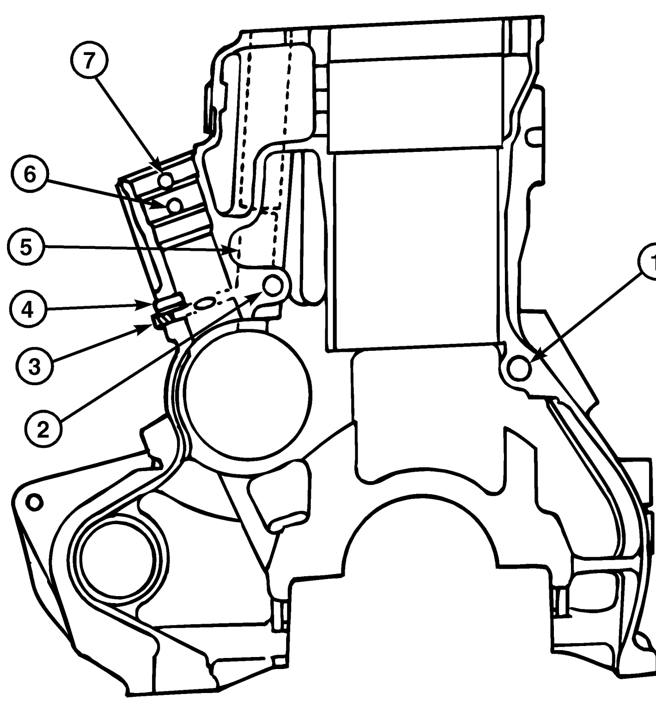

Figure 86 — Sectioned View, Front of ASET™ Engine Block

OIL PUMP

Due to the addition of an idler gear, the auxiliary shaft on the ASET™ and E-Tech™ engines rotates in the opposite direction of the E7 auxiliary shaft. However, in order to maintain the same pumping direction and lubrication oil flow for both ASET™/E-Tech™ and E7 engines, the oil pump drive gear helix is reversed on the ASET™ engines (Figure 87). With the reversed drive gear helix, the driving thrust load of the shaft pumping gears is toward the pump housing and not toward the pump cover, as with the E7 engine.

NOTE

- An improper drive gear on the oil pump will prevent oil pump installation, assuming a correct gear is on the auxiliary shaft.
- If an oil pump and an auxiliary shaft assembly were replaced, two improper gears could be installed, and engine failure would result.
- In replacing any of these critical parts, always refer to part number information in the MACK Parts System to ensure the correct component is being used.

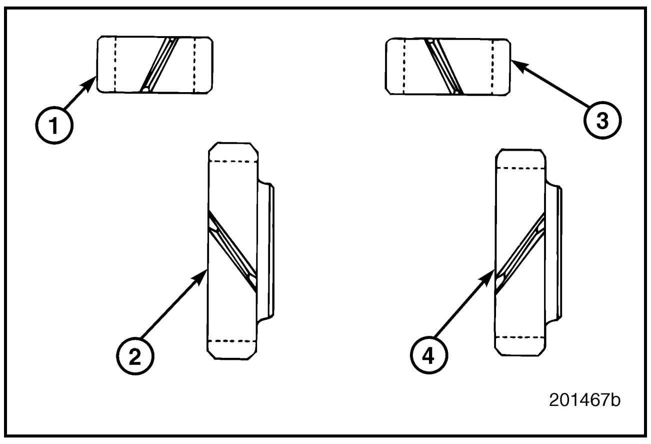

Figure 87 — Oil Pump Drive Gears

1. E7 Oil Pump Gear (12 Teeth) 2. E7 Aux. Pump Gear (18 Teeth)	3. ASET™ Oil Pump Gear (13 Teeth) 4. ASET™ Aux. Shaft Gear (17 Teeth)

The ASET™ oil pump also differs from the E7 oil pump in that it is designed to accommodate the faster auxiliary shaft speed. In addition, the auxiliary shaft used on the ASET™ engines (Figure 88) is through-drilled to carry oil to the rear auxiliary shaft bushing. This is different from the E7 engine, which provides oil to the rear bushing through a cylinder block oil passage. An E7 shaft CANNOT be used in an ASET™ engine. Doing so will result in failure of the auxiliary shaft rear bushing and the air compressor.

NOTE

The ASET™ auxiliary shaft is identified by three machined circumferential cuts in front of the stamped part number.

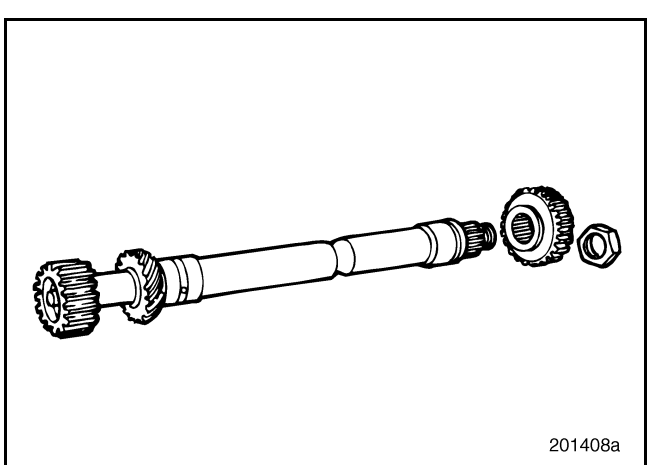

Figure 88 — Auxiliary Shaft

OIL COOLER AND FILTER MOUNTING BRACKET

The engines are equipped with a plate-type oil cooler and a centrifugal oil filter assembly, called Centri-Max® ULTRA or ULTRA PLUS, that is inverted and mounted on top of the bracket. With this arrangement, the filter housing includes the oil fill port.

The main member to which the oil cooler and oil filters are mounted is a one-piece aluminum casting which bolts to the four-bolt pad on the cylinder block. An oil drain passage within the casting allows the oil from the centrifugal filter to drain back to the crankcase.

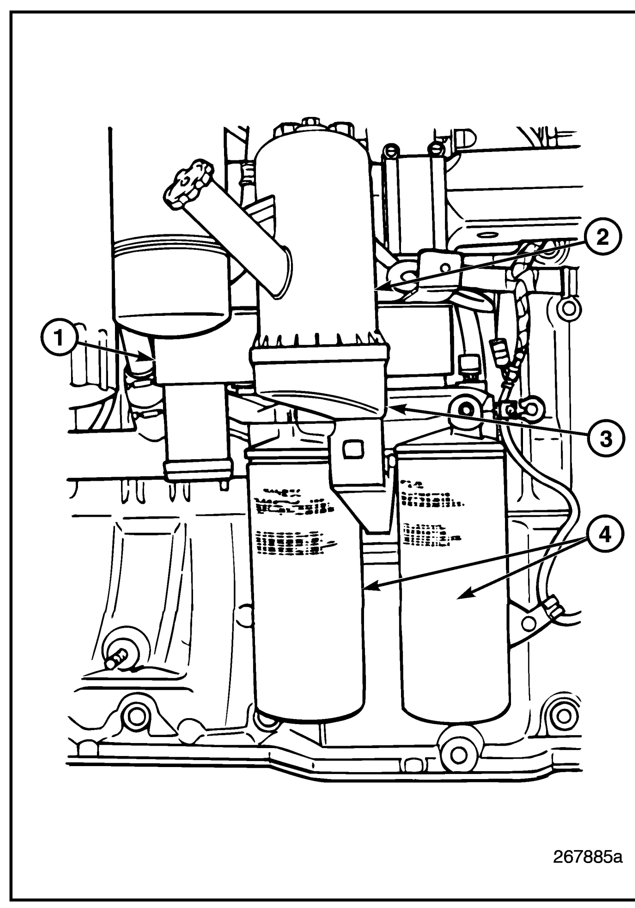

Figure 89 — Oil Cooler/Filter Mounting Bracket

1. Oil Cooler 2. Centri-Max® ULTRA or ULTRA PLUS Oil Filter	3. Oil Filter Mounting Bracket 4. Spin-On, Full-Flow Oil Filters

Ports for the V-MAC III oil pressure and oil temperature sensors are located on this mounting assembly. Remote oil supply ports are provided for the turbocharger, EGR valve, J-Tech™ engine brake, and also to supply oil pressure for other items such as a turbo unloader, REPTO, a mechanical oil pressure gauge or a remote-mounted centrifugal oil filter.

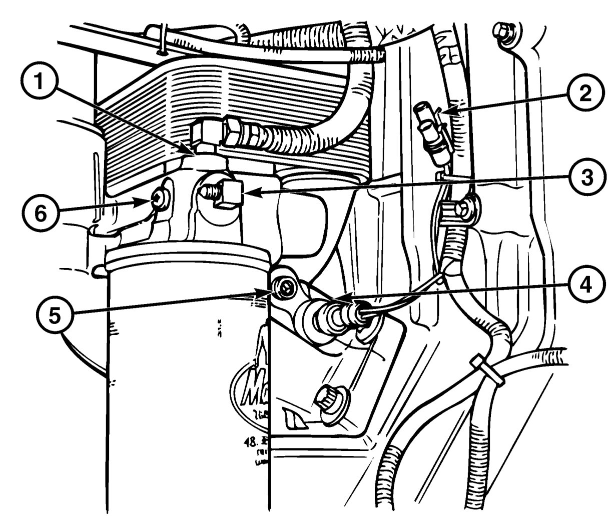

Figure 90 — Oil Supply Ports

1. Oil Supply Port for Turbocharger, EGR Valve and Engine Brake 2. Oil Temperature Sensor Harness Connectors 3. Oil Supply Port for REPTO, Turbo Unloader, Remote-Mounted Oil Filter	4. Oil Pressure Sensor 5. Oil Temperature Sensor Port 6. Oil Supply Port for Mechanical Oil Pressure Dashboard Gauge

OIL FILTERS

The lubrication system includes a centrifugal oil filter as well as primary and secondary full-flow filters (Figure 91). The centrifugal Centri-Max® ULTRA or ULTRA PLUS oil filter assembly, which also includes the oil fill port, is mounted at the top of the oil filter mounting bracket assembly. Its location is between and outboard of the two full-flow, spin-on filters, where it drains internally through the mounting bracket assembly into the crankcase.

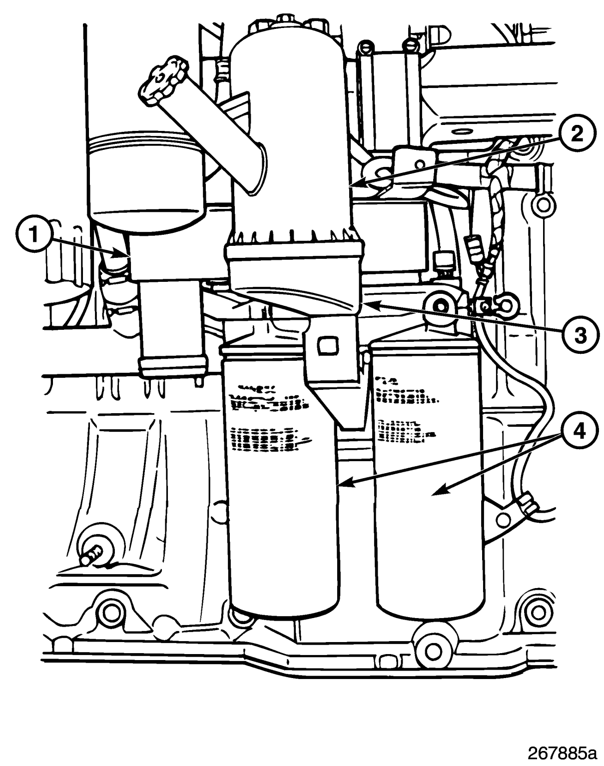

Figure 91 — Oil Filter Assembly

1. Oil Cooler 2. Centri-Max® ULTRA or ULTRA PLUS Filter	3. Oil Filter Mounting Bracket 4. Spin-On, Full-Flow Filters

The Centri-Max® ULTRA was used from the start of ASET™ engine production through mid-2003 and the Centri-Max® ULTRA PLUS from mid-2003 through present. The ULTRA PLUS unit has a smaller diameter spindle and redesigned rotor to provide a significant improvement in efficiency. For easy identification, the ULTRA PLUS rotor is black, whereas the ULTRA rotor is cream-colored.

The ULTRA PLUS filter was introduced in a one-piece spindle configuration and later in a two-piece configuration. The two-piece spindle configuration is the current standard. Both versions of the ULTRA PLUS, as well as the ULTRA configuration, are shown in Figure 92.

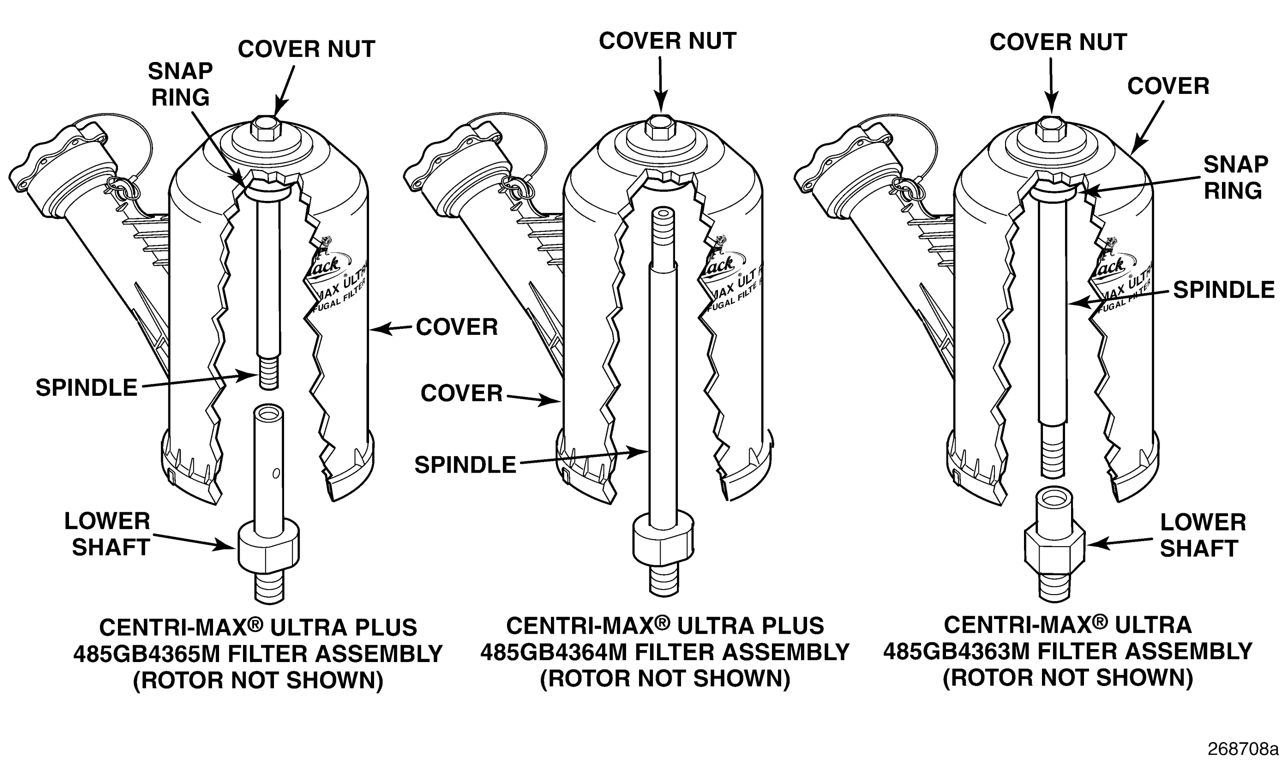

Figure 92 — Centri-Max® ULTRA and ULTRA PLUS Configurations

OIL COOLER

The oil cooler is a plate-type assembly that has a stainless steel housing and integral water inlet and outlet tubes. The cooler bolts directly to the aluminum oil filter mounting bracket with two bolts at each one of the oil ports.

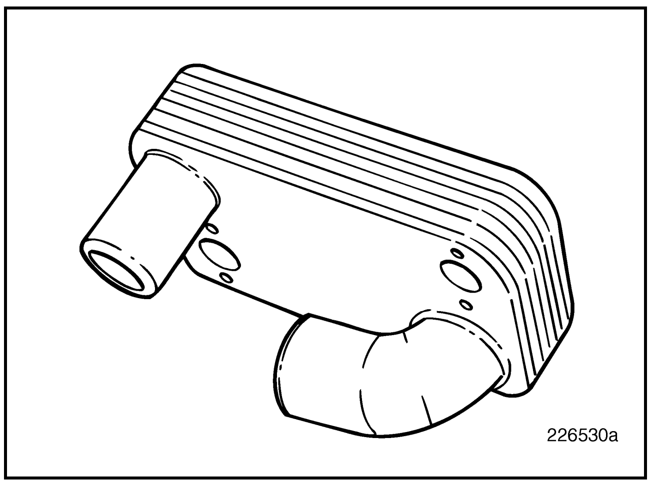

Figure 93 — Plate-Type Oil Cooler Assembly

A 2-1/4-inch diameter steel coolant tube connects the oil cooler water outlet to the water pump inlet (Figure 94). The flange end of the tube which bolts to the water pump inlet is sealed with an O-ring. A short section of hose and clamps is used to connect the tube to the oil cooler outlet. The most commonly used AC tube configuration has the water line to the surge tank coming off of a fitting on the thermostat housing. Other chassis models use variations of this configuration.

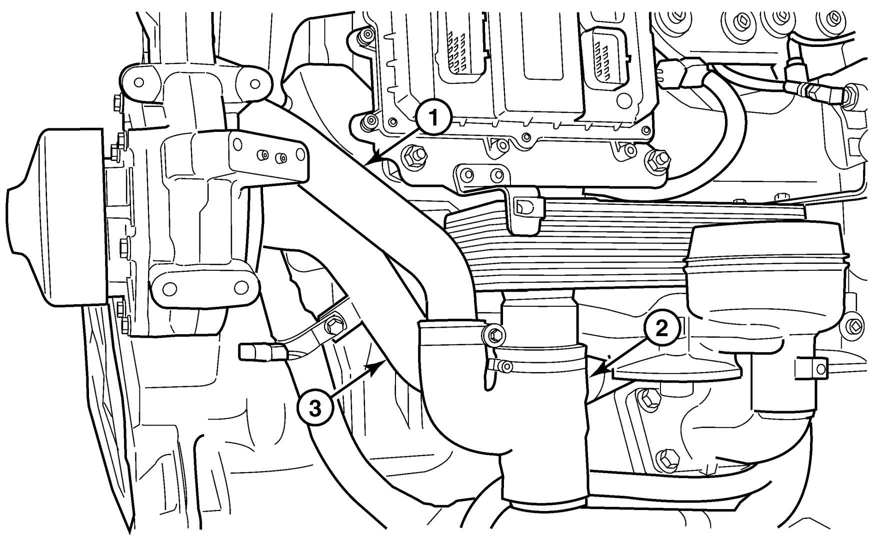

Figure 94 — Oil Cooler-to-Water Pump Inlet Line

1. Thermostat Bypass Tube 2. Oil Cooler-to-Radiator Tube Connection	3. Oil Cooler-to-Water Pump Coolant Tube

OIL COOLER DE-AERATION LINE

A de-aeration line is used to vent air which may otherwise become trapped in the plate-type oil cooler when filling the cooling system with coolant. On ASET™ AC engines the line is routed from the top of the oil cooler to a port on the side of the water manifold, just to the rear of the thermostat housing. The de-aeration line is made from 1/4-inch inside diameter (1/2-inch outside diameter) silicone heater hose, and is protected from rubbing and chafing by a length of convoluted tubing.

GLOSSARY OF TERMS (ASET™ ENGINES)

Air Pressure and Temperature Sensors at CMCAC

Sensors are mounted into the air intake between the CMCAC outlet and the EGR mixture tube. Sensors monitor CMCAC outlet air temperature and pressure.

Atmospheric Pressure Sensor

A sensor incorporated into the EECU that detects atmospheric (barometric) pressure. This pressure is affected by altitude.

Boost Pressure Relief Valve (BRV)

A valve which allows high turbocharger boost pressure to be released into the exhaust or intake air streams.

Breather Canister

A canister through which blow-by gases are filtered to remove engine oil for return of oil to the crankcase. The canister is mounted on the engine front cover.

Breather Filter

A meshed metal filtration element inside the breather canister. The element can be removed, cleaned and reinstalled in the canister.

Carbon Monoxide (CO)

An odorless, colorless gas resulting from incomplete combustion of hydrocarbons; found in diesel truck exhaust; poisonous to humans and animals.

Combustion Air Temperature and Humidity Sensor

Sensor is mounted in the air intake between the air cleaner and the turbo compressor housing which detects outside air temperature and humidity, and relays these values to the EECU.

Compressor Discharge Temperature Sensor

Sensor is mounted between the turbocharger compressor housing and CMCAC. Detects compressor discharge air temperatures.

Cooled Exhaust Gas Recirculation (CEGR)

A system whereby a pre-determined amount of exhaust gas is diverted through a heat exchanger, where it is cooled, and then routed to the inlet manifold for reintroduction into the combustion chambers. Adding the cooled exhaust gases to the combustible fuel and air mixture lowers the overall combustion temperatures for reduced formation of nitrogen oxides (NOx).

EGR MASS Flow System (EGR MFS)

The EGR MASS Flow System consists of the cool-side EGR tube with its two integral probes and associated wiring, and a control module. One probe is a combination flow sensor/heater and the other, a temperature sensor. Together, these components form a calibrated unit that measures the amount of exhaust gas being recirculated to the engine.

Electronic Unit Pump (EUP)

An electronically controlled fuel injection pump, one for each cylinder of an engine. The electronic unit pumps are actuated by roller followers and lobes on the engine camshaft.

Engine Electronic Control Unit (EECU)

A microprocessor-based controller, sometimes referred to as a module, mounted to the inlet manifold on the left side of the engine. For ASET™ AC (CEGR) engines, it is mounted to a cooling plate near the front of the manifold. For ASET™ AI (IEGR) engines, it is mounted near the rear of the manifold. With the MACK V-MAC III system, the EECU controls fuel timing and delivery, exhaust gas recirculation, fan operation, engine protection functions and engine brake operation.

Hydrocarbons (HC)

Gasoline, diesel fuel and motor oil are all hydrocarbons. These are all examples of a very large group of chemical compounds composed only of carbon and hydrogen; the largest source of hydrocarbons is from petroleum crude oil.

Internal Exhaust Gas Recirculation (IEGR)

A system whereby the exhaust gas is drawn from the exhaust manifold back into the combustion chamber during the intake stroke to control the formation of nitrogen oxides (NOx). This is accomplished with a special cam designed to hold the exhaust partially open during the intake stroke.

Exhaust Gas Recirculation (EGR)

A system whereby a pre-determined amount of exhaust gas is reintroduced into the combustion chambers. Adding a small percentage of the noncombustible exhaust gases to the combustible fuel and air mixture lowers the overall combustion temperatures reducing the formation of nitrogen oxides (NOx).

H-Ring

A type of guide ring used to prevent axial rotation of the valve roller follower. On the E-Tech™ engine, a ring is press-fit into each valve lifter bore.

Idler Gear

A timing gear positioned between the crankshaft and camshaft gears in the front gear train of the ASET™ engine.

Idler Tensioner

An automatic belt tensioning device designed to maintain optimum tension under varying engine speeds and load. The idler tensioner is optional on the ASET™ engine.

Oxides of Nitrogen (NOx)

High temperatures and pressures of combustion are what produce oxides of nitrogen (NOx). When combustion temperature exceeds 2,500°F (1370°C), oxygen and nitrogen combine in large quantities to form NOx. By themselves, NOx emissions are no great hazard; however, when mixed with the right amounts of HC in the air, NOx will combine in the presence of sunlight to form smog. The ASET™ AC/AI engines use EGR to cool the combustion process to lower emissions of NOx.

Poly-V Belt

A multi-ribbed belt design which is incorporated into the accessory drive belt and pulley arrangement at the front of the engine. ASET™ AI/AMI (IEGR) engines use a single poly-V belt and pulley arrangement; the ASET™ AC (CEGR) engines use a dual drive belt and pulley arrangement.

Rexroth Valve

See VTG Position Controller.

Roller Follower

A type of lifter with an axle-mounted roller that rides on (or follows) a camshaft lobe. The rolling motion of this design provides increased load capacity with less friction than the flat-faced lifter design. Roller followers are used to provide the lifting action for the electronic unit pumps and the intake and exhaust valves on the ASET™ engine.

Supply Pump with Integrated Fuel Filters (SPIFF)

The fuel supply pump contains both a pre-pump filter and a primary filter contained on one integrated housing.

Tappet Guide Pin

A pin used to prevent axial rotation of an EUP tappet. The pin is pressed into the cylinder block EUP tappet bore wall and fits into a slot in the tappet.

Variable Turbine Geometry (VTG) Turbocharger

Turbo turbine housing has moving components to control flow of exhaust gas and build back-pressure in the exhaust system for EGR flow.

VTG Position Controller

Mounted to rear of intake manifold, regulates air pressure to control the VTG.

VTG Position Sensor

A sensor mounted on the VTG actuator that determines the actuator's true position.

VTG Wheel Speed

A sensor mounted in the turbo bearing housing that detects turbine and compressor wheel speed.

Vehicle Electronic Control Unit (VECU)

A microprocessor-based controller, sometimes referred to as a module, mounted in the cab, inside the passenger-side dash panel. With the MACK V-MAC III system, the VECU controls engine speed, cruise control, accessory relay controls, idle shutdown and trip recorder functions.

COMPONENT LOCATOR

COMPONENT LOCATION VIEWS

The locations of primary component assemblies of the ASET™ AC engine are identified in the illustrations contained in this section. These views, however, do not include sensor locations. Sensor locations are identified under “Engine Electronic Control Unit (EECU) and System Sensors” in the DESCRIPTION & OPERATION section.

ASET™ AC Engine

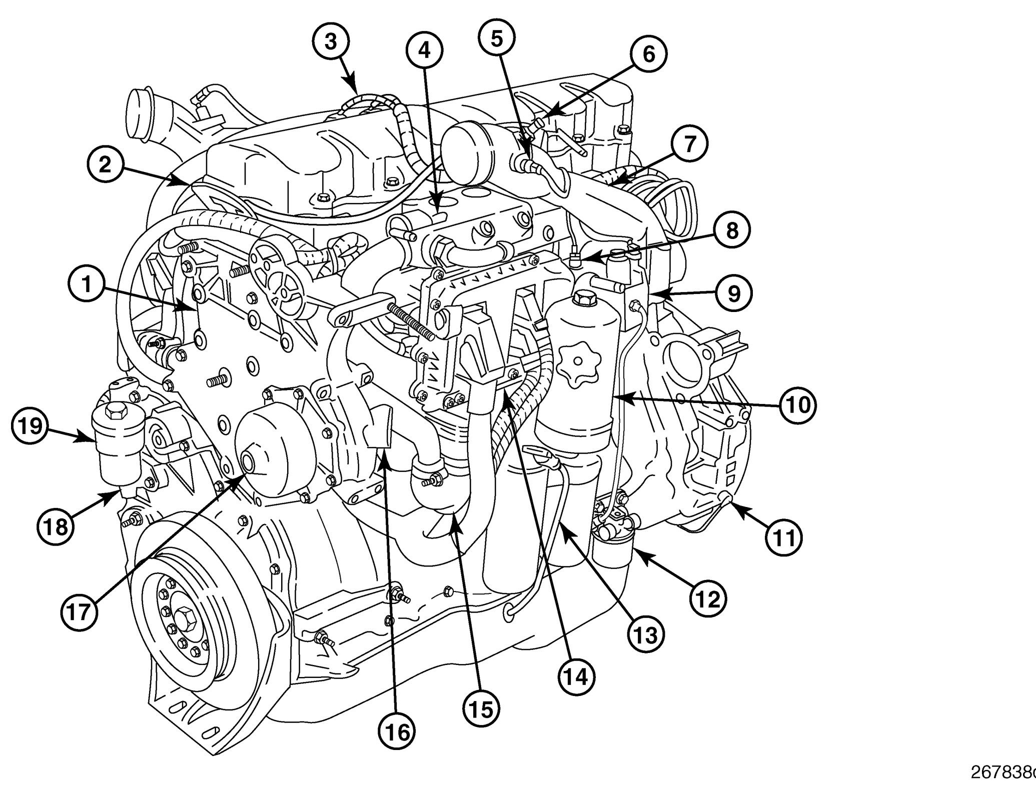

Figure 95 — ASET™ AC Engine, Front and Left Side

1. Water Pump Housing 2. Front Lifting Bracket 3. EGR MASS Flow Sensors 4. Dual-Thermostat Housing 5. Boost Temperature Sensor 6. Boost Pressure Sensor 7. EGR Gas Mixer Tube 8. Inlet Manifold Temperature Sensor 9. VTG Position Control Valve 10. Centri-Max® Filter Housing with Integral Oil Fill Port	11. Engine Speed Sensor 12. VTG Control Valve Oil Coalescing Air Filter 13. Oil Dipstick Tube 14. Engine Electronic Control Unit (EECU) 15. Y-Hose with Coolant Screen 16. Coolant Conditioner Mounting Pad 17. Water Pump Impeller Assembly 18. Engine Position Sensor 19. Crankcase Breather

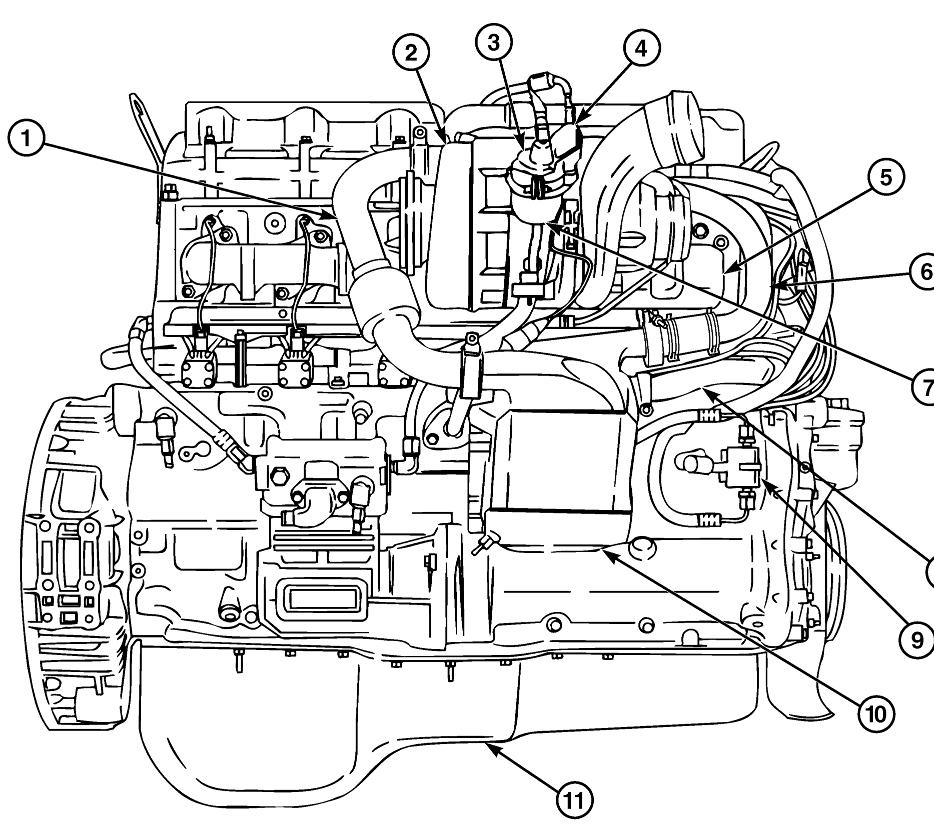

Figure 96 — ASET™ AC Engine, Right Side

1. EGR Gas Tube (Hot Side)	7. Turbo Wheel Speed Sensor (behind Actuator)
2. Variable Turbine Geometry (VTG) Turbocharger	8. EGR Coolant Return Hose
3. VTG Actuator Assembly	9. Fuel Supply Pump (Optional without Integral Filter Shown)
4. VTG Position Sensor	10. EGR Cooler Assembly
5. EGR Valve Heat Shield	11. Oil Pan, 36 Quart Capacity
6. EGR Gas Tube (Cool Side)	

NOTES

TROUBLESHOOTING

ENGINE SYMPTOM DIAGNOSIS FOR MACK ASET™ ENGINES

V-MAC III Diagnostics

NOTE

When operating in cold weather, fuel waxing can cause many of the problems described below. Also, water in the fuel can damage unit pumps and nozzles. Be sure to check for water in the fuel and/or fuel congealing before proceeding to troubleshoot a problem.

Also refer to the V-MAC III Service Manual, 8-211, for applicable blink code information.

ENGINE WILL NOT CRANK

Possible Cause	Correction
1. Batteries have low output.	1. Check the batteries. Charge or replace as required.
2. Loose or corroded battery or ground connections.	2. Clean and tighten battery and ground connections.
3. Broken or corroded wires.	3. Check voltage at the following connections: — Switch to starter — Battery to starter Replace as required.
4. Faulty starter or starter solenoid.	4. Check operation of starter and solenoid. Repair as required.
5. Faulty key switch.	5. Replace key switch.
6. Internal seizure.	6. Bar the engine over one complete revolution. If the engine cannot be turned, internal damage is indicated. Disassemble engine and repair as required.

ENGINE CRANKS — WILL NOT START

Possible Cause	Correction
1. Slow cranking speed.	1. Check corrections listed in preceding chart, ENGINE WILL NOT CRANK.
2. Code(s) present.	2. Correct cause of code(s). Refer to ENGINE MISFIRES — CODE(S) PRESENT chart.
3. No fuel to engine.	3. Check for fuel in the fuel tank. Check for plugged fuel tank connections, restricted or kinked fuel suction lines, fuel transfer pump failure or clogged fuel filters (including the pre-pump filter screen).
4. Defective fuel transfer pump.	4. Check transfer pump for minimum output pressure. Change fuel filters if low. Look for air leaks and recheck pressure. If still below minimum, replace transfer pump.
5. Poor quality fuel, or water in fuel.	5. Drain fuel from tank. Replace fuel filters and fill fuel tank with MACK-specified diesel fuel.
6. Incorrect engine oil viscosity.	6. Drain oil. Replace oil filters and fill crankcase with recommended grade oil.
7. Low compression.	7. Check cylinder compression. If low, refer to LOW COMPRESSION chart.
8. Faulty EUP fuel-return check valve.	8. Check for free poppet movement.
9. Faulty electrical connections.	9. Check electrical connections at ECU, engine position and engine-speed sensor connections.

ENGINE MISFIRES — CODE(S) PRESENT

Possible Cause	Correction
1. Code(s) present.	1. Correct cause of code(s). Check harness, battery and ground connections. If code(s) remains, replace ECU. If code is still present after replacing ECU, reinstall original ECU and refer to item 7 in ENGINE MISFIRES — NO CODE(S) chart.

ENGINE MISFIRES — NO CODE(S)

Possible Cause	Correction
1. Broken or leaking high-pressure fuel lines.	1. Check for fuel leaks. Repair as necessary.
2. Poor quality fuel, or water or dirt in fuel.	2. Drain fuel from tanks. Replace fuel filters and fill tank with MACK-specified diesel fuel.
3. Air in fuel system.	3. Check fuel system for air leaks. Repair as necessary. (Air generally gets into the fuel system on suction side of the fuel pump.)
4. Low fuel supply pressure.	4. Check to be sure there is fuel in the fuel tank. Check for sharp bends or kinks in the fuel line between the fuel tank and the fuel transfer pump. Also, check for clogged suction pipe (in the fuel tank) or a plugged fuel suction hose. Check for air in the fuel system, and check the fuel pressure. If the pressure is lower than specified, replace the fuel filters. Inspect fuel return check valve for free-moving poppet. If still low, replace the transfer pump.
5. Improper valve lash adjustment.	5. Check adjustment. Correct as necessary.
6. Worn camshaft lobe.	6. With valve lash properly adjusted, check rocker arm movement. If not within specifications, replace worn parts.
7. Valves not seating properly.	7. Remove heads, recondition valves as required, and reinstall heads.
8. Defective fuel injection nozzles or unit pump.	8. **Note:** The following test will register a fault in the ECU which may be cleared after test is completed. Make sure all EUP terminal wires are connected and tight. With the engine operating at low idle (625–675 rpm) and using V-MAC Support Software connected to the chassis, perform the cylinder cut-out test as outlined in the Support Software Manual, 8-333. If the cylinder is firing correctly, the engine sound will change. If a cylinder does not change the engine sound, that cylinder is not firing correctly. **Note:** With step 5 software, shorting out the terminals is the only way to determine if a cylinder is not firing correctly. However, starting with step 7 software, you must **not** short out the terminals on the EUPs. The use of the cylinder cut-out test is the only **recommended** procedure for determining if a cylinder is not firing correctly. With step 8 software, you can stop the engine by shorting out the terminals on an EUP. If a cylinder is not firing correctly, determine if a fuel pulse is present in the high-pressure injection line by touching the line firmly with a screwdriver about one inch from the EUP. **Note:** When it is difficult to determine if the problem is the EUP or the nozzle, first switch the EUP with that of an adjacent cylinder and recheck for a pulse in both affected cylinders. If the problem follows with the EUP, then the EUP is at fault. If the problem remains with the original cylinder, then the nozzle may be at fault. Compare the pulse felt with the EUP shorted vs. not shorted. If a normal pulse is detected when the EUP is not shorted, the problem may be in the injection nozzle or the engine valve adjustment. First check engine valve adjustment. If OK, repair or replace the nozzle. If no pulse is detected, replace the unit pump for that cylinder. **Note:** A tachometer that senses injection-line pressure can also be used to check if pulse is present (use J 39638 Tech Tach or equivalent). If an engine rpm is recorded on the tachometer, the problem may be in the injection nozzle or the engine valve adjustment. If no reading is obtained, replace the unit pump for that cylinder.
9. Cylinder head gasket leakage.	9. Check for visible signs of leakage, coolant in the oil, or traces of oil in the coolant. Use a compression tester to check each cylinder. Replace cylinder head gasket if necessary.
10. EGR valve stuck open.	10. With the engine running and EGR gases flowing, unplug the EGR valve. The valve should close. If not, replace the valve.

ENGINE STALLS AT LOW SPEEDS

Possible Cause	Correction
1. Code(s) present.	1. Correct cause of code(s).
2. Cylinder cutting out.	2. Isolate cylinder and determine cause of cutting out. Refer to item 8 in ENGINE MISFIRES — NO CODE(S) chart.
3. Idle speed set too low.	3. Check idle setting. Adjust as necessary.
4. High parasitic load.	4. Check for excessive loading due to engaged auxiliary attachments.
5. Fuel tank vent clogged or partially clogged.	5. Check fuel tank vents. Repair as necessary.
6. Low fuel supply.	6. Check for sufficient fuel in the fuel tank. Check fuel filters (including the pre-pump filter screen), replace if necessary. Check fuel supply lines for restrictions or air in the system. Check fuel return check valve for free-moving poppet. Check fuel pressure and repair or replace supply pump as required.
7. Defective fuel injection nozzle.	7. Isolate defective nozzle and replace. Refer to item 8 in ENGINE MISFIRES — NO CODE(S) chart.
8. Defective unit pump.	8. Refer to item 8 in ENGINE MISFIRES — NO CODE(S) chart.
9. EGR valve stuck open.	9. With the engine running and EGR gases flowing, unplug the EGR valve. The valve should close. If not, replace the valve.

ERRATIC ENGINE SPEED

Possible Cause	Correction
1. Air leaks in fuel suction line.	1. Check for air leaks. Repair as necessary.

LOW POWER

Possible Cause	Correction
1. Code(s) present.	1. Correct cause of code(s).
2. EGR valve-to-cooler pipe cracked or bellows leaking. Causes low boost pressure.	2. Inspect EGR valve-to-cooler pipe and correct or replace leaking component(s).
3. EGR valve sticking open. Causes low boost pressure, poor performance.	3. Inspect EGR valve components for carbon fouled, soot buildup or corrosion. Replace valve to correct.
4. Intercooler cracked or leaking.	4. Inspect intercooler, pressure-test, and repair or replace as required.
5. Plugged fuel tank vents.	5. Clean the fuel tank vents.
6. Restrictions in the air intake system such as clogged air filter(s).	6. Check for restrictions in the air intake system. Check the air pressure in the air intake manifold. Replace the air filter and make necessary repairs to the air intake system.
7. Poor quality fuel.	7. Drain fuel tank(s), clean system and replace fuel filters. Fill tank with MACK-specified diesel fuel. Bleed system.
8. Low fuel pressure.	8. Check for sufficient fuel in the fuel tank. Check fuel filters (including the pre-pump filter screen, if so equipped), replace if necessary. Check fuel supply lines for restrictions or air in the system. Check fuel return check valve for free-moving poppet. Check fuel pressure and repair or replace supply pump as required.
9. Improper valve lash adjustment.	9. Adjust valve lash to specified clearance.
10. Fuel-injection nozzle failure.	10. Repair or replace defective nozzle. Refer to item 8 in ENGINE MISFIRES — NO CODE(S) chart.
11. Turbocharger dirty or malfunctioning.	11. Inspect turbocharger. Clean, repair or replace as required.
12. Exhaust restriction.	12. Check for restrictions in the exhaust system.
13. Low compression.	13. Check items listed under LOW COMPRESSION.
14. Restrictions in intercooler.	14. Perform restriction pressure test. Clean any restrictions.
15. Restrictions in intercooler inlet/outlet tubes.	15. Disconnect tubing and clean restrictions.
16. Air cleaner-to-hood boot.	16. Check that the boot clamp on the air cleaner housing is tight, and that the boot is making full contact with the hood and has not collapsed.

NOTE

Low power complaints may result from many factors other than an engine problem. Be sure to check the chassis and trailer for dragging brakes and assess the drivetrain combination for driveability and application (engine-rated bhp, transmission and rear-axle ratios, tire sizes, etc.).

ENGINE WILL NOT ACHIEVE NO-LOAD GOVERNED RPM

Possible Cause	Correction
1. Code(s) present.	1. Correct cause of code(s).

NOTE

There are some operating conditions where the engine will not achieve no-load governed RPM by design. These conditions are:

- Customer data
- High vehicle acceleration at light load

EXCESSIVE BLACK OR GRAY SMOKE

Possible Cause	Correction
1. Intercooler core leakage.	1. Pressure-test intercooler. If test results are unsatisfactory, remove, repair or replace intercooler as needed.
2. Intercooler core fin obstructions.	2. Clean intercooler fins.
3. Insufficient air for combustion.	3. Check air cleaner for restrictions. Check inlet manifold pressure, and inspect the turbocharger for proper operation. Repair or replace as required.
4. Excessive exhaust back-pressure.	4. Check for faulty exhaust piping or restrictions in the muffler. Repair or replace as required.
5. Improper grade of fuel.	5. Drain fuel from tank(s). Replace fuel filters and fill tank(s) with MACK-specified diesel fuel.
6. Defective fuel injection nozzle or unit pump.	6. Isolate defective nozzle and replace. Refer to item 8 under ENGINE MISFIRES — NO CODE(S) chart.
7. Improper engine valve adjustment.	7. Reset valve adjustment.
8. Malfunctioning exhaust/intake valve.	8. Repair cylinder head/valve train.
9. EGR valve stuck open.	9. Inspect EGR valve components for carbon fouled, soot buildup or corrosion. Replace the valve to correct. To test: With the engine running and EGR gases flowing, unplug the EGR valve. The valve should close. If not, replace the valve.
10. EGR MFS sensor malfunctioning.	10. Replace EGR MASS Flow System.

NOTE

Black smoke is primarily a mechanical problem. The electronic V-MAC III system does not contribute to black smoke. Instead, the system derates engine power by reducing the amount of fuel supplied, for example, in response to a malfunctioning sensor.

Routine EGR service or wiring inspection IS NOT required in response to a black smoke condition.

EXCESSIVE BLUE OR WHITE SMOKE

Possible Cause	Correction
1. Code(s) present.	1. Correct cause of code(s).
2. No code(s) present, faulty cylinder.	2. Isolate faulty cylinder and repair as required.
3. EGR cooler leaking coolant into air/EGR inlet tubes.	3. Pressure-test coolant side of EGR cooler by submersion using low air pressure. Replace any coolers which produce bubbles through EGR passages.
4. Low fuel pressure.	4. Check fuel lines and filters for blockage.
5. Engine lubricating oil level too high.	5. Drain excess lubricating oil. If the oil is contaminated with either fuel or coolant, completely drain the oil pan. Change the oil filters. Locate the source of the leak and correct. Fill with MACK-specified engine oil. Check the oil level with the dipstick. DO NOT overfill.
6. Turbocharger passing oil.	6. Check for oil in the inlet manifold. Check for air inlet restriction (clogged air filter). Repair or replace turbocharger as required.
7. Worn piston rings.	7. Determine and correct the root cause, and repair engine as required.
8. Engine misfiring or running rough.	8. Check items as outlined in ENGINE MISFIRES — NO CODE(S) chart.

EXHAUST GAS SEEPING INTO CAB

Possible Cause	Correction
1. Cracked EGR valve housing.	1. Replace EGR valve.
2. Cracked EGR valve-to-cooler pipe including expansion joint (bellows).	2. Inspect EGR valve-to-cooler pipe and correct or replace leaking component(s).
3. Exhaust leak at EGR poppet valve.	3. Exhaust leak past EGR valve poppet stem and support bushing. Replace EGR valve.
4. Exhaust leak at turbocharger inlet or exhaust pipe.	4. Inspect, locate and repair exhaust leak.

EXCESSIVE FUEL CONSUMPTION

Possible Cause	Correction
1. Code(s) present.	1. Correct cause of code(s).
2. Restrictions in the air induction system.	2. Inspect system. Remove restrictions and replace defective parts as required.
3. External fuel system leakage.	3. Check external piping on fuel system for signs of fuel leakage. Repair as required.
4. Defective injection nozzle assembly.	4. Isolate defective nozzle assembly. Repair and replace as required. Refer to item 8 in ENGINE MISFIRES — NO CODE(S) chart.
5. Internal engine wear.	5. Determine and correct the root cause, and repair engine as required.
6. Air conditioning system commanding the engine cooling fan to be operating at all times.	6. If the engine fan is operating constantly, change the EECU customer data to indicate that no A/C is installed. Check the operation of the fan. If the fan disengages, restore the original settings in the EECU and repair the A/C system.

EXCESSIVE OIL CONSUMPTION

Possible Cause	Correction
1. External oil leaks.	1. Check engine for visible signs of oil leakage. Look for loose or stripped oil drain plugs, broken gaskets (cylinder head cover, etc.), and front and rear oil seal leakage.
2. Seal leak past EGR valve piston shaft.	2. Inspect EGR valve for oil loss over exhaust manifold. Replace EGR valve to correct.
3. External oil line leakage (J-Tech™, turbo, EGR feeds, etc.).	3. Check lines, hoses and connections for leaks. Ensure connections are at proper torque specifications. Replace any hoses or lines found to be leaking. Replenish oil.
4. Turbocharger passing oil.	4. Check for oil in the inlet manifold. Check for excessive inlet restriction (such as a dirty air filter). Repair/replace air filter or turbocharger as required.
5. Air compressor passing oil.	5. Repair or replace air compressor.
6. Clogged crankcase breather pipe.	6. Remove obstructions.
7. Excessive exhaust back-pressure.	7. Check exhaust pressure. Repair as required.
8. Worn valve stem seals.	8. Replace valve stem seals.
9. Worn valve guides.	9. Check for valve guide wear and replace guides as required.
10. Internal engine wear.	10. Determine and correct the root cause, and repair engine as required.

ENGINE OVERHEATS

Possible Cause	Correction
1. Coolant level low.	1. Locate cause. Look for leaking gaskets or loose or leaking hoses. Repair, replace or tighten as required. Replenish coolant.
2. EGR cooler coolant leak.	2. Replacement of the EGR cooler is required as no weld repairs are allowed to this stainless steel unit.
3. Loose or worn fan belts.	3. Adjust belt tension or replace belts as required.
4. Restricted airflow through radiator.	4. Remove any restrictions from the outer surface of the radiator.
5. Plugged radiator core.	5. Remove, repair or replace radiator as required.
6. Defective radiator pressure cap.	6. Test pressure of the radiator cap. Replace cap if required.
7. Defective coolant thermostat or temperature gauge.	7. Check opening temperature of thermostat. Check for correct installation. Check temperature gauge and sending unit. Replace if defective.
8. Viscous (or ON/OFF) fan drive not operating properly, or fan improperly positioned.	8. Check fan operation. Repair as required.
9. Combustion gases in coolant.	9. Determine point where gases are entering the cooling system. Repair or replace parts as required.
10. Defective water pump.	10. Remove, repair and reinstall water pump as required.
11. Plugged oil cooler.	11. Remove oil cooler. Disassemble, remove restrictions/replace parts as required. Reinstall.
12. Plugged oil cooler filter screen.	12. Remove the Y-shaped hose at the oil cooler inlet. Remove and clean the filter screen or replace parts as required. Reinstall.
13. Winterfront (if equipped) not opened.	13. Open or remove winterfront at specified ambient temperatures.
14. Shutters not opening properly (for chassis equipped with shutters).	14. Check shutter operation. Repair as required.

HIGH EXHAUST TEMPERATURE

Possible Cause	Correction
1. Operating chassis in wrong gear ratio for load, grade and/or altitude.	1. Instruct operator on correct gear selection for load and grade conditions.
2. EGR gas too hot.	2. EGR gas flow rate too high or poor heat transfer due to EGR cooler fouling. Check EGR cooler to ensure debris in the coolant has not become lodged in the cooler fins, restricting coolant flow. Check EGR valve operation to ensure full operation.
3. Restrictions in the air induction system.	3. Inspect air induction system. Remove restrictions and/or replace defective parts.
4. Air leaks in the air induction system.	4. Check pressure in the air intake manifold. Look for leaking piping and/or loose clamps. Make necessary repairs.
5. Leaks in the exhaust system (before the turbocharger).	5. Check exhaust system for leaks. Make necessary repairs.
6. Restrictions in the exhaust system.	6. Inspect system. Make necessary repairs.
7. Improper valve lash adjustment.	7. Adjust valve lash setting to specified clearance.
8. Defective fuel injection nozzle assembly.	8. Isolate defective nozzle. Refer to item 8 in ENGINE MISFIRES — NO CODE(S) chart.
High Pyrometer — Normal Boost	
9. Loose ducting.	9. Repair loose connections.
10. Intercooler core fin obstructions.	10. Clean intercooler fins.
High Pyrometer — Low Boost	
11. Intercooler core leakage.	11. Pressure-test intercooler. Remove, repair or replace intercooler if test results are unsatisfactory.
12. Dirty turbocharger.	12. Remove turbocharger and clean.
13. Leaks in the pressurized side of the air induction system.	13. Check for leaks. Repair as required.
14. Blockage in ducting between the air cleaner and the turbocharger.	14. Check for blockage and repair.
If VTG turbocharger vans are open more than desired, pre-turbine temperatures increase:	
15. Leaking actuator diaphragm.	15. Replace actuator.
16. Chassis air supply leaks causing low pressure.	16. Repair air leak.
17. Seized vane assembly.	17. Free up vane assembly.

LOW ENGINE OIL PRESSURE

Possible Cause	Correction
1. Oil level insufficient. Oil leaking from oil line, oil distribution block, gasket, etc.	1. Check engine oil level. Add oil if necessary. Check for oil leaks. Repair as required.
2. Incorrect oil viscosity.	2. Drain oil, change oil filters, and fill with the proper grade oil meeting MACK specifications.
3. Defective oil pressure gauge.	3. Check the operation of the oil pressure gauge. If defective, replace.
4. Clogged oil filter(s).	4. Replace oil filters. Clean or replace oil cooler. Drain oil and refill with oil meeting MACK specifications.
5. Engine oil diluted with diesel fuel.	5. Check fuel system for leaks. Make necessary repairs. Drain diluted oil, change oil filters, and refill with oil meeting MACK specifications.
6. Defective oil pump.	6. Remove oil pressure relief valve and check condition of seat. Check that relief valve spring is not sticking, and check for proper spring tension. Check internal thrust washer. Check cap. Check assembly parts. Using the incorrect parts will result in incorrect oil pressure. Make any necessary repairs or install a new relief valve.
7. Oil pump gears not meshing properly.	7. Check mounting arrangement. If the engine has been rebuilt, check that the gear ratio of the oil pump drive and driven gears are correct. Incorrect gear combinations will result in immediate gear failure and possible engine damage.
8. Incorrect oil filter mounting pad gasket.	8. Check for correct oil pad gasket.
9. Excessive clearance between crankshaft and bearings.	9. Overhaul the engine. Replace any worn/defective parts.
10. EGR valve not functioning properly due to low oil pressure.	10. Determine reason for low oil pressure. Refer to LOW ENGINE OIL PRESSURE chart.

OIL IN THE COOLING SYSTEM

Possible Cause	Correction
1. Defective oil cooler core.	1. Disassemble and repair or replace oil cooler core.
2. Blown head gasket.	2. Replace head gasket.
3. Cylinder head porosity.	3. Replace cylinder head.

COOLANT IN ENGINE OIL

Possible Cause	Correction
1. Defective oil cooler core.	1. Disassemble and repair or replace oil cooler core.
2. Cylinder head pipe plug leaking.	2. Repair leak.
3. Cylinder head gasket failure.	3. Pressure-test cooling system and repair as required.
4. Cylinder sleeve seat leaking.	4. Pressure-test cooling system and repair as required.
5. Cracked cylinder head.	5. Pressure-test cooling system and repair as required.

LOW COMPRESSION

Possible Cause	Correction
1. Improper valve lash adjustment.	1. Adjust valve lash to specified clearance.
2. Blown head gasket.	2. Replace head gasket.
3. Broken or weak valve springs.	3. Check and replace defective parts as required.
4. Valves not seating properly.	4. Remove, recondition and reinstall heads.
5. Piston rings stuck, worn, broken or improperly seated.	5. Determine and correct root cause and repair engine as required.
6. Camshaft or valve lifters worn.	6. Replace camshaft and/or valve lifters and perform any other necessary repairs as required.

FUEL IN LUBE OIL

Possible Cause	Correction
1. Excessive idling, especially in cold weather.	1. Minimize idling time and use all recommended cold weather accessories.
2. Injector nozzle malfunctioning.	2. Remove and pop-test nozzles. Clean or replace nozzles as required.
3. Unit pump O-ring leaking.	3. Replace O-rings. Inspect cylinder block bores for wear or damage.
4. Front fuel gallery plug.	4. Check for leakage of plug through supply pump mounting bore.

EGR SYSTEM MALFUNCTION (WITH COOLER AND VTG TURBOCHARGER)

Possible Cause	Correction
1. Excessive idling, especially in cold weather causing carbon buildup in the EGR cooler that blocks the flow of exhaust gas.	1. Minimize idling time and use all recommended cold weather accessories.
2. High EGR temperature out of the cooler indicates a failed cooler or coolant block.	2. Replace EGR cooler or correct coolant block.
3. EGR valve not working or sticking.	3. Check for correct oil supply to valve. Check for oil coking or corrosion at the actuator bushing area. Also check for wire harness failure including connectors.
4. EGR valve housing cracked.	4. Inspect EGR housing and replace as necessary.
5. EGR valve not functioning properly due to low oil pressure.	5. Determine reason for low oil pressure. Refer to LOW ENGINE OIL PRESSURE chart.
6. Turbocharger position does not follow the command.	6. This could be caused by mechanical or electrical problems with the VTG. Check codes related to VTG and check for mechanical problems at the turbo. Replace as necessary. **Note:** Verify that chassis air supplied to the VTG position controller (Rexroth® valve) is at least 95 psi.

CAMSHAFT TIMING AND LOBE LIFT CHECKS [213 CH]

Camshaft Timing Check

Correct camshaft timing is essential for proper engine performance. Incorrect camshaft timing may be suspected if soon after engine overhaul, lack of performance, unusual noise or excessive smoke is reported.

NOTE

While timing marks are stamped on the flywheel, current engines do not have a timing pointer since setting injection pump-to-engine timing is not necessary. However, the flywheel timing marks can be used to check the camshaft-to-crankshaft timing by looking up through the hole where the timing pointer would be located and viewing the timing marks. A pencil point may be inserted through the timing pointer hole to easily pinpoint the timing marks on the scale.

Camshaft timing can be checked using either the cylinder No. 3 or No. 4 inlet valve. For example purposes, the No. 3 cylinder is used in the following procedure.

1. Remove the cylinder head cover over cylinder No. 3.
2. Locate the inlet valves for No. 3 cylinder (the sixth valve set from the front of engine). Bar the engine to position the No. 3 piston at top dead center (TDC) of the compression stroke.
3. Loosen (back off) the inlet valve rocker adjusting screw jam nut. Ensure that the valve yoke is correctly adjusted. Adjust the inlet valve to zero lash.
4. Position a dial indicator (magnetic-base type) probe on the valve spring retainer. Preload the indicator to 1/2 indicator plunger travel.
5. Bar the engine in the direction of normal rotation and carefully observe the direction in which the indicator needle travels. Use the dial indicator to determine when the inlet valve is fully open.
6. Stop rotating the engine when travel of the dial indicator needle stops. If the dial indicator needle reverses direction, the full-open position is passed. Repeat the procedure if this occurs.
7. Remove the timing hole cover from the flywheel housing so that the flywheel timing marks can be viewed. Engine timing should be approximately 26 degrees. A difference of approximately 10 degrees indicates that the crankshaft-to-camshaft timing gears may be mismatched one tooth.

Camshaft Lobe Lift Check

When diagnosing potential lifter or camshaft failures, 0.030 inch (0.76 mm) less than the lift of a new camshaft is considered the minimum acceptable camshaft lobe lift for used components. Intake lobe lift differs depending on the camshaft part number. Camshaft lobe lift is measured by using a dial indicator at the push rod with the rocker arm adjusted to zero lash.

CHASSIS-MOUNTED CHARGE AIR COOLING TESTS [233 FA]

General Information

The Chassis-Mounted Charge Air Cooling (CMCAC) system cools hot turbocharged air before it enters the engine intake manifold. The CMCAC system uses ambient air as a cooling medium by allowing it to pass through a core equipped with heat-exchanging fins.

Hot turbocharged air, varying in pressure from 0.0–25 psi (0.0–172 kPa), passes through core tubes where heat is transferred to the ambient air by heat-exchanging fins.

Front-section core construction consists of a series of cold bars, cold fins and tube plates. Side-section core construction consists of a series of hot bars and hot fins.

Special Tool Required

- Charge Air Cooler Pressure Fixture J 41473

CMCAC Troubleshooting

Symptom	Probable Cause	Remedy
Normal Boost — High Pyrometer	1. Core fin obstructions.	1. Clean core fins.
Low Boost — High Pyrometer	1. Restriction in ducting between air cleaner and turbo.	1. Check for blockage and clean.
	2. Dirty turbocharger.	2. Clean turbocharger.
	3. Leaks in the pressurized side of the induction system.	3. Check for and repair leaks.
	4. Inlet manifold leak.	4. Check for loose or missing fittings, plugs, and/or damaged manifold-to-cylinder head gaskets. Replace missing parts, and repair loose connections.
	5. Open petcock (if equipped).	5. Close petcock.
	6. Core leakage.	6. Pressure-test core. Remove, repair or replace core if test results are not satisfactory.
Low Power	1. Restrictions in cooler.	1. Perform restriction pressure test. Clean out restriction.
	2. Restrictions in cooler inlet and outlet tubes.	2. Disconnect and clean obstructions.

CMCAC Pressure Test

Refer to Figure 97.

1. Remove the air ducting from core.
2. Plug the core inlet opening.
3. Insert a plug with an air line adapter in the core outlet opening.

N O T E

Charged air cooler pressure fixture J 41473 can be used on coolers with the flange connections.

4. Connect a safety chain or cable to both plugs.

W A R N I N G

Stand clear of the plug area when system is pressurized.

5. When plugs are secured, attach an air line (fitted to a pressure regulator and gauge) to the air line adapter in the core outlet opening.
6. Pressurize the system to 30 psi (207 kPa).
7. Shut off the air source. Pressure should not drop more than 5 psi (35 kPa) within 15 seconds. Repair or replace the core if pressure drop exceeds specification.
8. Carefully release pressure from the system.
9. After repairing or replacing the core, reconnect ducting. Tighten clamp nuts until clamp spring is fully compressed.

N O T E

When the spring is fully compressed, the torque applied on the nut is generally between 40–55 lb-in (4.5–6.2 N•m).

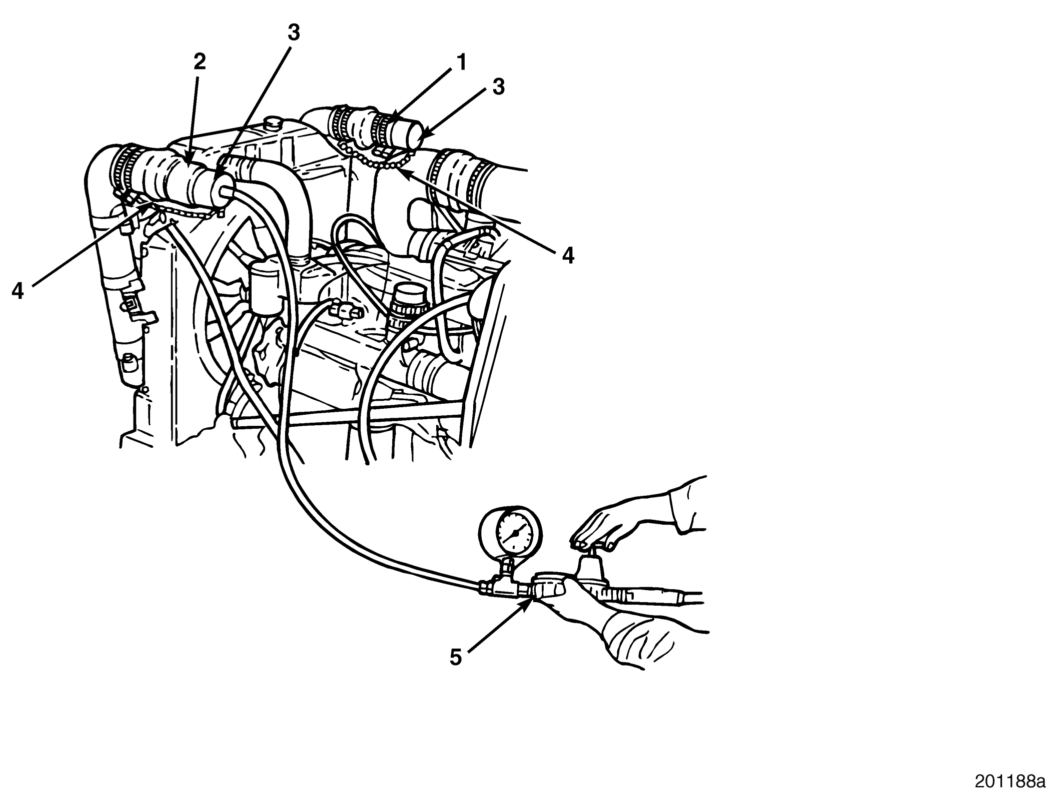

Figure 97 — CMCAC Pressure Test

1. Core Inlet 2. Core Outlet 3. Plug (Part of J 41473)	4. Safety Chain 5. Air Pressure Regulator and Gauge (J 41473)

Restriction Pressure Test

SERVICE HINT

Perform the restriction pressure test at maximum full-load condition.

A restriction in the internal portion of the cooler may interfere with proper airflow and can result in excessively high pyrometer readings. To perform a restriction pressure test, use the following procedure:

1. Install pressure gauge lines at both the inlet and outlet tubes of the charge air cooler.

NOTE

Some units are equipped with connection ports on the inward sides of the inlet and outlet charge cooler tubes. If so equipped, the plugs can be removed from these ports and the gauge lines connected. If not, adapters with gauge ports must be installed in the cooler inlet and outlet tubes.

2. Install the appropriate pressure gauge(s) to the cooler inlet and outlet tubes.
3. Start the engine and while operating it at full-load condition, read the pressure drop across the cooler.
   - If the pressure drop is higher than 2 psi (13.79 kPa) at full-load condition, the cooler has internal restrictions.
   - If the pressure drop is lower than 2 psi (13.79 kPa), the cooler is OK and can remain in service.

NOTE

If using manometers for this test, the difference between readings should not exceed 4 in-Hg (13.5 kPa).

4. Stop the engine.
5. If the pressure drop is higher than the specified amount, remove the cooler from the vehicle and flush the inside. Follow the procedure covered under CMCAC Preventive Maintenance to remove any deposits that may be present. Reinstall the cooler and then pressure-test the cooler.
6. If the cooler passes the restriction and pressure tests, remove the test equipment, reinstall inlet and outlet tubes, hoses and clamps. Reinstall the gauge-port plugs on systems so equipped. Tighten the clamps to 38 lb-in (4.3 N•m).

CAUTION

The clamp springs must always be located on the underside of the tube to avoid damaging the hood when closed.

Core Inspection

GUIDELINES

With the exception of straightening minor bends in the cold fins, the CMCAC core is not repairable and should be replaced when more extensive damage is encountered. To ensure that the CMCAC system will function properly after repair or replacement, a pressure/leak test is recommended.

Damage	Core Failures	Recommended Repair Procedure	System Check
Repairable	Bent cold fins	Straighten with small screwdriver or pair of small needlenose pliers.	Perform pressure/leak test.
Nonrepairable	All header tank-to-core separations	No repair procedure is recommended — replace unit.	Perform pressure/leak test.
	All header tank cracks	No repair procedure is recommended — replace unit.	Perform pressure/leak test.
	Internal fins damaged and separated from tube plate	No repair procedure is recommended — replace unit.	Perform pressure/leak test.
	Tube blockage	No repair procedure is recommended — replace unit.	Perform pressure/leak test.
	Tube/plate cracks or welds, cold bar separations or openings	No repair procedure is recommended — replace unit.	Perform pressure/leak test.
	Excessive cold fin damage (original shape of fins distorted beyond repair)	No repair procedure is recommended — replace unit.	Perform pressure/leak test.

INSPECTION

1. Carefully inspect the entire system to determine the exact location and extent of damage.
2. Inspect the cold fins and cold bars that run horizontally in the cooler.
3. Inspect all brazed or welded joints in the header tank.

CMCAC Preventive Maintenance

In case of engine and/or turbocharger failure, the charge air cooler should be flushed to make sure the cooler is free of debris.

FLUSHING PROCEDURE

1. Remove the chassis-mounted cooler and flush the inside with a safety solvent to remove oil and other foreign debris.
2. Shake cooler to remove large pieces.
3. Wash with hot, soapy water. Rinse with clean water and blow dry with compressed air in the reverse direction of flow.
4. Carefully inspect cooler to ensure cleanliness.

CAUTION

Do not use caustic cleaners when flushing the cooler. Be extremely careful when handling the cooler so as not to damage the core.

CYLINDER HEAD AND CYLINDER BLOCK LEAK TEST PROCEDURE

Verify suspected leaks in the cylinder heads or cylinder block by pressure testing before deciding to replace the cylinder head or block. Do not use magnaflux inspections alone as replacement criteria.

Before proceeding with the tests, look for coolant stains around the 3/4-inch NPT plugs on the tops of the cylinder heads. Check that the plugs are torqued to 55 lb-ft (75 N•m).

NOTE

Cylinder head pipe plugs used on engines manufactured April 1, 1999 or later (beginning with engine serial number series 9F) have encapsulated epoxy sealant applied to the threads. These pipe plugs are tightened to 55 lb-ft (75 N•m) at assembly, and the epoxy locks them in place. These plugs will not turn when an attempt is made to tighten them. If a coolant leak at an epoxy-sealed pipe plug is suspected, the plug may be removed by heating it to 400°F (205°C) with a torch. Before reinstalling the plug, the epoxy sealant must be thoroughly cleaned from the pipe plug threads, and the threads in the cylinder head. The plug and the cylinder head threads must then be cleaned with Loctite® Primer T and resealed with Loctite® 277. Reinstall the plug and torque to 55 lb-ft (75 N•m).

Also, make sure leakage is not caused by the oil cooler or air compressor. Perform the simpler checks first to prevent unnecessary engine disassembly. While performing the following tests, watch for indications of minor leaks, such as small bubbles, that can develop into more severe leaks during engine operation.

Cylinder Head and Head Gasket Check — In Chassis

1. Look for coolant stains around the 3/4-inch NPT pipe plugs on top of the cylinder heads. Check plug torque. The plug torque specification is 55 lb-ft (75 N•m). Refer to Figure 98.

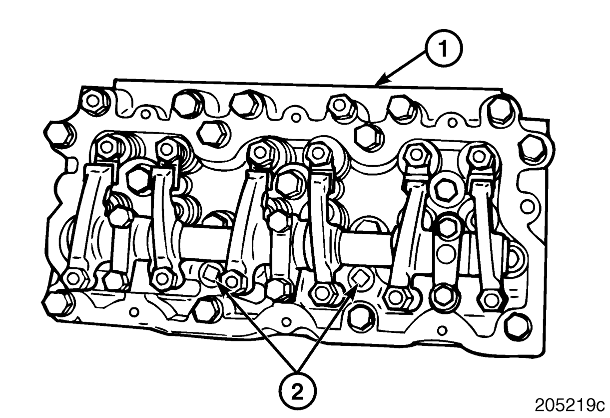

Figure 98 — Cylinder Head Pipe Plugs (3/4-Inch NPT)

1. Cylinder Head	2. Pipe Plugs

2. Before removing the thermostat(s), drain coolant from the cooling system until the coolant level is below the thermostat housing.
3. Remove the thermostat(s) and leave the thermostat housing open. Install a short section of hose, approximately 6–8 inches (152–203 mm) long, on the thermostat housing and add enough coolant to fill the housing.
4. Remove the fan belt from the water pump.
5. Start the engine and run at 1,000 rpm.
6. Observe coolant in the thermostat housing for air bubbles. This can indicate combustion pressurization of the cooling system and possible cylinder head gasket failure. Also, watch for traces of oil which would indicate possible cylinder head gasket or oil passage leakage.

NOTE

It is normal for some air bubbles to form in the cooling system as a result of the engine warming up to operating temperature.

7. Apply a soap-and-water solution between two cylinder heads to check for external combustion leakage.

Cylinder Head Fuel Passages Leak Check — In Chassis

NOTE

The symptoms of coolant-in-fuel are a loss of coolant with no apparent external leak, together with one or more of the following: coolant in fuel tank, coolant in fuel filter or yellow fuel out of fuel return line.

1. Remove the nozzles from both cylinder heads and pressurize the cooling system with a maximum of 15 psi (103 kPa) air pressure and look for coolant coming out around the nozzle sleeves.
2. Look into each nozzle sleeve bore for signs of coolant leakage.
3. A cracked or leaking nozzle sleeve should be replaced as an on-engine repair using the procedures described under “ENGINE DISASSEMBLY” procedures in the REPAIR INSTRUCTIONS section. If after replacing the nozzle sleeve(s) the re-pressure test shows that the problem still exists, the cylinder head(s) should be replaced.

Cylinder Block/Cylinder Head Coolant Passages Leak Check — In Chassis

Refer to Figure 99.

1. Drain coolant from the engine.
2. Remove the engine oil pan and cylinder head valve covers.
3. Remove the water pump assembly and use a suitable plate and gasket to seal the opening.
4. Remove the upper and lower hoses from the thermostat housing. Remove the thermostat housing and thermostat(s).
5. Secure a suitable plate and gasket over the thermostat housing opening in the coolant manifold.
6. Install an air fitting into one of the pipe plug holes in the coolant manifold.
7. Reinforce the hose connecting the coolant manifold sections by installing a hose clamp around the center of the hose to prevent the hose from rupturing during testing.
8. Remove one of the large pipe plugs from the water manifold and add hot water to fill the cooling system. Increase cylinder block temperature to 150°F (66°C). Loosen one of the pipe plugs near the top of the cylinder block to bleed air from the water jacket while filling. Also open the block drain to allow water to flow out. This will help warm the cylinder block. Tighten the loosened pipe plug after all of the trapped air has escaped.
9. After the cylinder block is sufficiently heated, close the block drain and apply approximately 50 psi (345 kPa) air pressure to the air connection.

⚠ CAUTION

Do not exceed 50 psi (345 kPa) air pressure. Damage to seals or cup plugs may result.

10. Check for coolant leaks at the bottom of each cylinder bore.
    - Coolant leaking between the cylinder sleeve outside diameter and cylinder block indicates a leaking cylinder sleeve seat.
    - Coolant leaking down the inside diameter of the cylinder sleeve indicates a leaking head gasket.

NOTE

Water leaking from the No. 2 or No. 5 cam bushings or from the No. 2 or No. 5 main bearings can indicate a breakthrough between the rocker arm feed passage and the water jacket (cylinder head).

Refer to the repair procedures in this manual to correct leaks.

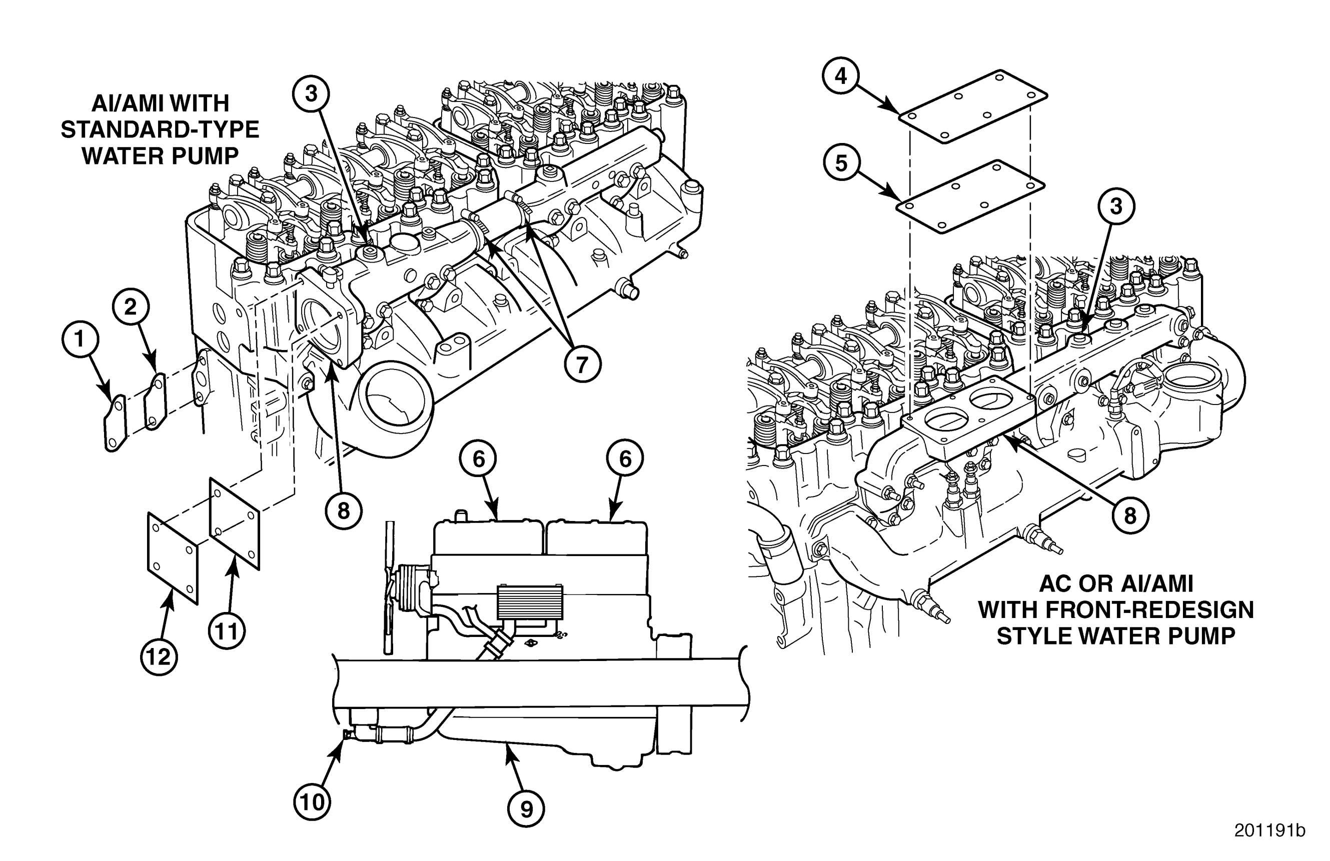

Figure 99 — Cylinder Block/Cylinder Head Leak Check (In Chassis)

1. Water Pump Inlet Cover Plate 2. Gasket 3. Remove pipe plug and install air inlet fitting on water manifold. 4. Dual Thermostat Cover Plate 5. Gasket 6. Remove valve covers.	7. Install additional hose clamp. 8. Remove housing and thermostat. 9. Remove oil pan. 10. Drain coolant. 11. Gasket 12. Water Manifold Cover Plate

Cylinder Head Oil Passage Leak Check — Out of Chassis

Refer to Figure 100.

1. Remove the cylinder head from the engine.
2. Install a suitable plug to seal the rocker arm oil passage at deck side of the head. There are two ways to plug the hole:
   - Drill and tap the oil passage to accept a pipe plug.
   - Insert a suitable rubber plug and clamp the plug in position with a C-clamp.
3. Install an air fitting in the rocker arm passage in the top of the head. Use a discarded rocker arm bracket with an oil feed passage. Cut the bracket through the rocker arm shaft bore parallel to the mounting base surface. Drill and tap the oil supply passage to accept an air fitting.
4. Bolt the modified bracket with air fitting to the cylinder head over the oil supply passage.
5. Immerse the cylinder head in water. Heat the water and cylinder head to 150°F (66°C).
6. Apply up to 50 psi (345 kPa) air pressure to the air fitting adapter installed in the rocker arm oil passage. Check for air bubbles. The formation of air bubbles indicates internal leakage between the cylinder head oil passage and the water jacket.

CAUTION

Do not exceed 50 psi (345 kPa). Damage to seals or cup plugs may result.

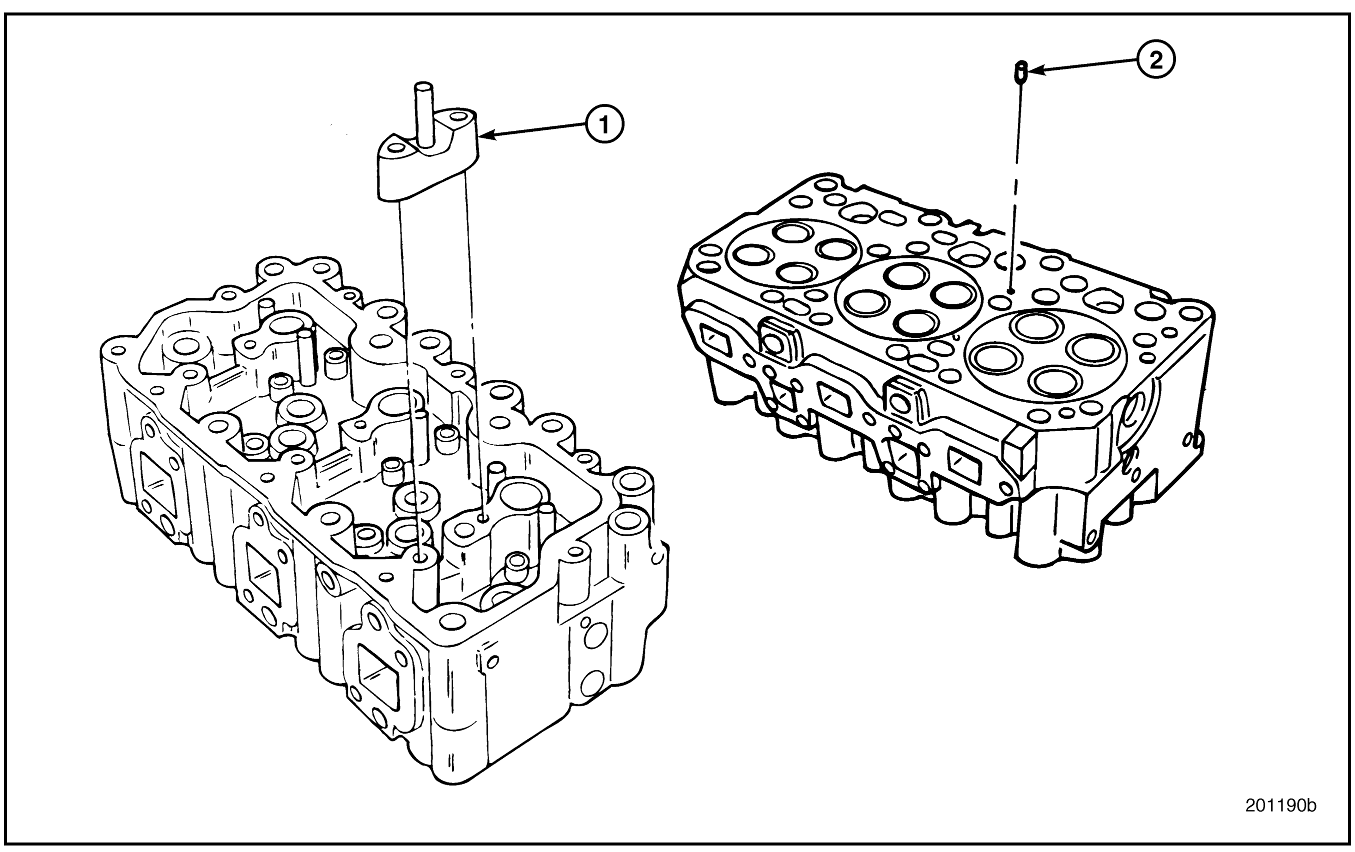

Figure 100 — Cylinder Head Oil Passage Leak Check (Out of Chassis)

1. Modified Bracket with Air Fitting	2. Plug (Pipe or Rubber)

Cylinder Head Coolant Passage Leak Check — Out of Chassis

Refer to Figure 101.

1. Remove cylinder head from the engine.
2. Fabricate a suitable 3/4-inch thick (19.1 mm) steel plate and a 1/4-inch (6.4 mm) rubber gasket. The plate must have cutouts for the entire combustion chamber. Position plate and gasket assembly on the underside of the head and secure with C-clamps, or with head bolts if the plate has been drilled for bolts.
3. Use suitable plate and gasket to seal the water manifold openings. Install an air fitting onto the plate.
4. Immerse the cylinder head in water. Heat the water and head to 150°F (66°C).
5. Apply up to 50 psi (345 kPa) air pressure to the fitting installed in the plate covering the water manifold opening. Check for air bubbles. The formation of air bubbles indicates that the cylinder head coolant passages may be leaking.

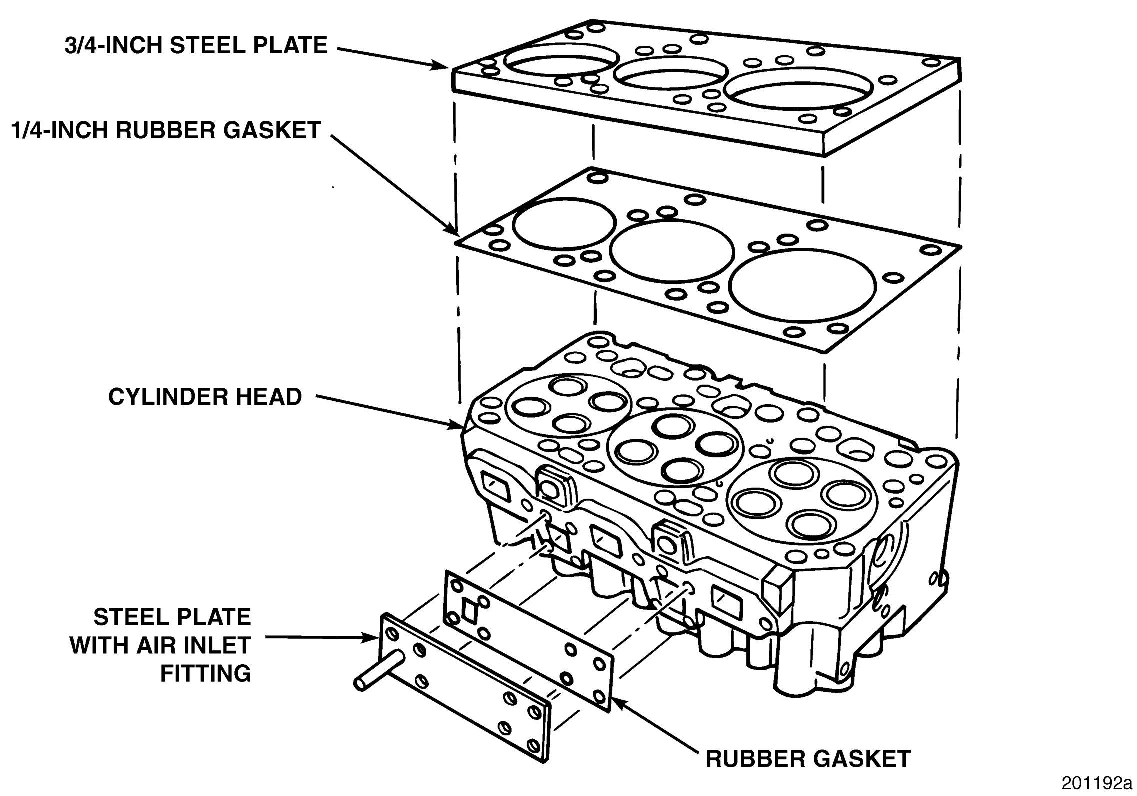

Figure 101 — Cylinder Head Coolant Passage Leak Check (Out of Chassis)

Cylinder Block Coolant Passage Leak Check — Out of Chassis

Refer to Figure 102.

1. Fabricate two 3/4-inch (19.1 mm) thick steel plates to simulate cylinder heads. The plates must have cutouts for the head capscrews and liners. Use a 1/4-inch (6.4 mm) thick rubber gasket as a seal. Install the plates onto the cylinder block.

NOTE

As an alternative to step 1, conduct the test using two known leak-free cylinder heads complete with gaskets and fire rings in place of the steel plates. With this alternative, a water manifold (with the outlet end sealed) can be used to seal off the cylinder head coolant ports. Fittings can be installed on the water manifold to introduce the heated water and air pressure needed for the test.

2. Remove the water pump assembly and seal the opening with a suitable plate and rubber gasket. The plate must be fabricated with adapters so that water heated to 150°F (66°C) and pressurized to 50 psi (345 kPa) can be introduced into the system.
3. Apply approximately 50 psi (345 kPa) air pressure into the cooling system. Visually inspect the cylinder block for signs of air and water leaks.

CAUTION

Do not exceed 50 psi (345 kPa). Damage to seals or cup plugs may result.

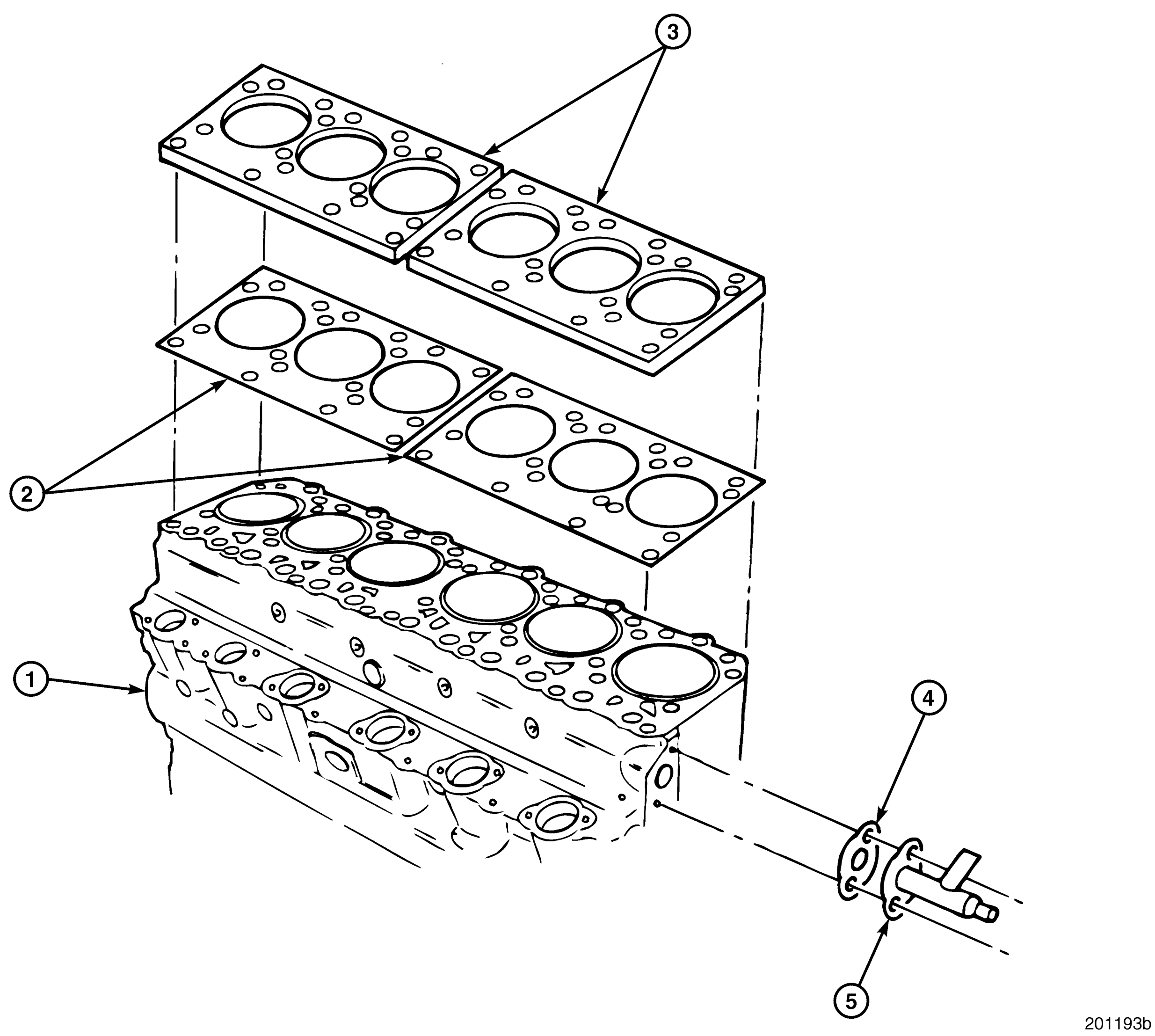

Figure 102 — Cylinder Block Coolant Passage Leak Check (Out of Chassis)

1. Cylinder Block 2. 1/4-inch Rubber Gaskets 3. 3/4-inch Steel Plates	4. Rubber Gasket 5. Plate with Air/Water Inlet Fittings

ENGINE BRAKE TESTS (MACK POWERLEASH™)

The ASET™ engines may be equipped with either a MACK PowerLeash™ engine brake or a J-Tech™ engine brake. The test procedures in this section apply only to the MACK PowerLeash™ engine brake.

Operational Tests

Before beginning the troubleshooting procedures, try to determine the exact nature of the problem. Talk to the driver, owner and/or mechanic to pinpoint the complaint or problem. The following checks may be helpful in trying to determine the nature of the problem.

BEFORE STARTING THE ENGINE

If there is a report of engine or engine brake noise, remove the cylinder head covers to determine the cause. Check the following items:

1. Check for loose or broken components.
2. Check and verify valve and engine brake plunger lash settings.
3. Check for bent push rods. If bent push rods are found, check for possible bent valves, and if the engine is equipped with ceramic roller lifters, check for broken ceramic rollers. Possible causes of bent valves or push rods could be:

   Engine overspeeding — Usually several valves are affected.

   One bent exhaust valve or push rod at a single cylinder — This indicates the possibility of incorrect valve adjustment. A bent exhaust valve can also be caused by the valve stem stuck in the guide, incorrect valve, brake or yoke adjustment, or broken or weak valve springs.

TEST DRIVE

NOTE

Engine brake will not engage until coolant temperature has reached 125°F (52°C).

1. Test drive the vehicle and measure intake manifold boost pressure while operating the engine brake. It is best to conduct the test with a loaded vehicle, engine at maximum-rated RPM and the engine brake ON. Downhill operation is desirable to stabilize RPM. Refer to the table on page 111 for boost pressures.

RETARDING BOOST PRESSURES (PSI) WITH MACK POWERLEASH™ ENGINE BRAKE

Engine Models: All AC Power Ratings
2100 rpm — 27 psi Boost
1900 rpm — 27 psi Boost
1700 rpm — 25 psi Boost
1500 rpm — 19 psi Boost
1300 rpm — 11 psi Boost
1100 rpm — 6 psi Boost
Note: Boost pressures may be less at high altitudes.

NOTE

If the vehicle does not have a boost pressure gauge, one must be installed. A pipe plug is located in the air inlet manifold for this purpose.

2. Record the maximum boost pressure with the engine brake switch in the HIGH position.
3. Record the boost pressure with the engine brake switch in the LOW position.

NOTE

LOW position may be either front or rear unit.

4. Disconnect the wire lead from the LOW position terminal of the engine brake switch and rerun the test with the switch in the HIGH position. Record the results.

NOTE

The individual boost pressure readings should be approximately the same as recorded in steps 3 and 4.

5. Compare the maximum boost pressure with the boost pressures in the table on page 111. A low reading indicates a possible problem. Readings at sea level should be within 3 psi of the values shown (at higher altitudes, slightly lower boost pressure readings are normal). Readings within 3 psi of the values shown indicate proper operation of the engine brake.

Electrical Troubleshooting

ASET™ engines have been equipped with a V-MAC® control feature that automatically provides a level of protection by activating the engine brake only after the recommended minimum oil temperature has been reached. Be sure that the engine is sufficiently warmed before conducting tests.

The MACK PowerLeash™ engine brake is activated by the V-MAC system. When the ignition switch is turned ON, the engine brake solenoids are supplied a constant 12-volt direct current with current flow increasing whenever the engine brake is activated. To properly diagnose electrical problems with the brake, an ammeter may be required.

NOTE

Some automated manual transmissions prevent engine brake operation when the transmission is in neutral.

If insufficient electrical power is reaching the engine brake, perform the preliminary checks outlined below. For more information, see the V-MAC® III Service Manual, 8-211.

NO ENGINE BRAKE OPERATION

1. Verify that the clutch pedal is not depressed and that the clutch switch is working properly.
2. Check for a blown fuse or circuit breaker.
3. With electrical power OFF, check the control system for a short to ground. Check systems separately to isolate where the short is occurring. If the control system is OK up to the engine brake valve cover/spacer connection, measure the resistance to the solenoid valve. High resistance means an open circuit in the solenoid or solenoid wire.

ONLY ONE ROCKER SHAFT OPERATING

1. Determine which rocker shaft is not operating by closing all the switches and checking the power at the wires leading to the solenoid valves (front and rear).
2. Remove the wire to the solenoid valve at the cylinder head cover/spacer and check for resistance (refer to the table on page 113). No reading indicates an open circuit in the wire or solenoid coil. A low resistance reading indicates a short to ground in the solenoid wire or solenoid coil.

SERVICE HINT

A constant 12-volt low amperage signal is supplied to the engine brake solenoids by the V-MAC III module when the ignition switch is turned on. During an engine braking event, V-MAC increases the current to the solenoids to activate the engine brake. The most accurate method of checking electrical function of the engine brake solenoid circuits is by using an ammeter to measure current at the solenoids when the engine brake is activated. When the engine brake is activated, current should be approximately 1.59 amps. For additional information, consult the V-MAC® III Service Manual, 8-211.

3. Test the solenoid by checking for current draw and pull-in voltage per specifications listed in the table on page 113.

MACK POWERLEASH™ SOLENOID SPECIFICATIONS

12-Volt Solenoid (P/N 805GC54)	
Resistance:	
—	9.62 to 10.75 ohms (cold)
—	11.8 to 14.3 ohms (hot)
Current Draw:	
—	0.84 to 1.66 amps (cold)
—	0.63 to 1.36 amps (hot)
Pull In Voltage:	
—	9 volts DC minimum

INTERMITTENT BRAKING

Inspect all wiring for loose connections and all switches for proper adjustment.

POOR PERFORMANCE

Connect a volt/ohmmeter (multimeter) to the electrical connector on the valve cover/spacer. Verify that a steady voltage signal is present when the engine brake is active. If not, check for loose connections or faulty switches. Repeat for all valve cover/spacer terminals.

MACK PowerLeash™ Checks (Hydraulic/Mechanical)

Remove the covers to begin inspecting the brake components, including housings and attendant hardware.

GENERAL INSPECTION AND ADJUSTMENT VERIFICATION

1. Inspect for missing or loose mounting bracket-to-rocker shaft bolts. The center and rear rocker shaft mounting brackets contain retaining bolts which intersect with the rocker shaft "control" oil gallery. If the center or rear rocker mounting bracket-to-rocker shaft bolts are loose or missing, a loss of control oil pressure and loss of brake function will occur.
2. Visually inspect the rocker shaft, exhaust rocker arms, hydraulic actuators, solenoid valve, etc., for obvious signs of damage or missing components. Repair or replace as necessary.
3. Check solenoid operation. The solenoid used with the MACK PowerLeash™ has a 0.200 inch diameter hole in the top that provides a means of troubleshooting solenoid operation. To check solenoid operation, insert a pin (having a diameter less than 0.200 inch) into the hole, then activate the engine brake. The pin should rise approximately 0.100 inch (2.54 mm) when the solenoid turns ON.
4. Check the valve yoke clearance, brake lash and valve lash adjustments. Readjust if necessary.

NOTE

Valve clearance must be checked with the timing pointer hole on the flywheel housing aligned with the proper valve setting mark on the flywheel for the cylinder being checked. This ensures that the valve lifter is on the camshaft base circle and not on the brake ramp portion of the lobe.

WARNING

Wear eye protection and do not expose your face over the engine area. Keep hands away from moving parts. Take precautions to prevent oil leakage down onto the engine.

Whenever engine is running and the valve covers are removed, oil splashing in the engine brake area could cause personal injury.

Never remove any engine brake component with the engine running. Personal injury may result.

NOTE

Brake lash settings must be made with the engine stopped and cold and with the exhaust valves closed.

BRAKE LASH SETTING

MACK PowerLeash™ Engine Brake	
—	Adjustment: 0.045 inch (1.14 mm)
—	Brake lash adjusting tool: standard feeler gauge and lb-in torque wrench
—	Adjust following the firing order: 1, 5, 3, 6, 2, 4

DETERMINING ENGINE OIL PRESSURE AND OIL PRESSURE AT THE ENGINE BRAKE UNITS

The engine brake requires a minimum oil pressure to operate. The oil pressure reading on the dash gauge is approximately the same as oil pressure at the engine brake.

NOTE

When determining minimum oil pressure, the oil temperature must be at least 200°F (93°C) when the test is performed. The pressure reading from the dashboard oil pressure gauge is sufficient.

OIL PRESSURE REQUIREMENTS

MACK PowerLeash™ Engine Brake	
—	Engine rpm 2100: 35 psi (2.4 bar)
—	Engine rpm 1100: 25 psi (1.7 bar)

If the oil pressure remains low, correct the engine problem as described under “OIL PRESSURE DROPPING BELOW MINIMUM REQUIRED FOR ENGINE BRAKE OPERATION” in the MACK PowerLeash™ Troubleshooting Guide included in this section.

MACK PowerLeash™ Troubleshooting Guide

Following is a list of problem conditions showing the probable causes and subsequent corrections.

ENGINE FAILS TO START OR STARTS AND RUNS ONLY ON THREE CYLINDERS

- **Solenoid valve stuck in ON position** — Ensure that electrical current is off to the engine brake units. If the solenoid valve remains on (cap down) with current off, replace the solenoid valve.
- **Solenoid valve O-ring missing or damaged** — Replace as necessary.
- **Solenoid not fully seated in rocker shaft bore** — Remove the solenoid, inspect and replace the O-rings as required. Reinstall the solenoid to its full seated position before snapping the retaining spring clips in place. The clips must require a moderate force to snap them around the rocker shaft and must provide enough spring tension to prevent any free movement of the solenoid or spring clips. If spring clip tension cannot be maintained, replace the clips.

ENGINE BRAKE WILL NOT OPERATE

- **Blown fuse, open electrical leads** — Look for a short circuit in the wiring. Replace any broken, brittle or chafed wires. Check solenoid tab for signs of shorting and replace if necessary. Replace 10 amp fuse.
- **On/Off switch, clutch switch or multi-position switch out of adjustment or defective** — Use a volt/ohmmeter to make certain that there is electrical voltage available at both terminals of each switch. Readjust if needed or replace if voltage will not pass through switch.

⚠ *WARNING*

Do not touch electrical connection when system is energized.

- **Mounting bracket-to-rocker shaft mounting screws loose or missing** — Inspect for missing or loose mounting bracket-to-rocker shaft screws. Repair as required.
- **Blocked oil supply screen at front rocker shaft mounting bracket** — Remove rocker shaft assemblies and clean oil supply screens.
- **Incorrect electrical power source** — Check that the supply voltage is the appropriate voltage. Recommended power source is from the key switch ON position. Ensure that power is not taken from a source with an additional on/off switch, i.e., light switch. See solenoid specifications in the table on page 113. Make sure wiring is in accordance with MACK wiring instructions.
- **Low engine oil pressure** — Determine oil pressure at engine brakes (solenoid valve and control valve). If oil pressure is below specification, the engine should be repaired in accordance with MACK procedures.
- **Brake lash not properly adjusted** — The engine brake units are very sensitive to adjustment. Incorrect adjustment may hold the valves open during positive power, leading to engine failure, or may cause the engine brake to work poorly or not at all. Confirm that the engine brake is properly adjusted in accordance with the table on page 114.

ENGINE BRAKE ACTIVATES WITH SWITCHES OPEN (OFF)

- **Solenoid valve lower seal ring damaged/missing** — Remove solenoid and inspect lower O-ring for damage. Replace as required.
- **Engine brake improperly wired** — Check wiring in accordance with MACK wiring diagrams.
- **Control pistons binding in bore** — Remove control piston. If body is scored, replace the control piston. Check for contaminants in lube oil. Clean bore and control piston. If binding continues, replace rocker arm.

- **Solenoid not fully seated in rocker shaft bore** — Remove the solenoid, inspect and replace the O-rings as required. Reinstall the solenoid to its full seated position before snapping the retaining spring clips in place. The clips must require a moderate force to snap them around the rocker shaft and must provide enough spring tension to prevent any free movement of the solenoid or spring clips. If spring clip tension cannot be maintained, replace the clips.

ENGINE BRAKE SLOW TO OPERATE OR WEAK IN EFFECT

- **Improper brake piston adjustment** — Readjust in accordance with the table on page 114.
- **Hydraulic lash adjuster plunger not moving in bore** — Inspect engine brake hydraulic actuator plunger for freedom of movement in the bore. Spring pressure should keep the plunger seated against the lower snap ring. If plunger does not move freely, replace the rocker arm assembly.
- **Control piston binding in rocker arm bores** — Remove control piston. Make sure check ball is seated in bore and can be moved off seat. Make sure there is spring pressure against the ball. Flush the ball check valve in a suitable, non-flammable cleaning solvent. If the ball check valve does not function properly, replace the rocker assembly.
- **Switch operation sluggish** — Check dash switches, clutch switch or other control switches. Readjust or replace as required. Check clutch return springs for proper operation. Check all controls for correct operation and replace as required.
- **Solenoid valve operation erratic** — Check solenoid valve using electrical specifications presented in the table on page 113. Disconnect the solenoid lead and provide 12 volts directly to the solenoid.

⚠ WARNING

Do not touch electrical connection when system is energized.

OIL PRESSURE DROPPING BELOW MINIMUM REQUIRED FOR ENGINE BRAKE OPERATION

- **Upper solenoid O-ring/seal ring damaged or missing** — Remove solenoid and inspect O-ring; replace if missing or damaged.
- **Plugged or damaged oil supply screen** — Remove the rocker shaft assembly and inspect the oil supply screen located in the oil supply port of the number one and four rocker shaft mounting brackets. Clean and replace as required.
- **Aeration of lubricating oil** — Check for aeration of the oil. Activate, then deactivate engine brake and observe escape oil coming from control valve cover. If oil has bubbles or is foamy, air is present in system. Aeration can be caused by an overfilled or underfilled crankcase, or a crack or other leak in the oil pickup tube. Correct in accordance with MACK procedures.
- **Lubricating oil being diluted by fuel oil** — Have an oil analysis of lube oil to determine if fuel is present. Correct per MACK procedures.
- **Low engine oil level** — Consult engine manual for specifications. Add oil or recalibrate dipstick as required.
- **Worn rocker arm shaft bores or rocker shaft** — Inspect rocker arm shaft bores and rocker shaft for wear. Repair as required.
- **Worn main and/or rod bearings or camshaft bushings** — Inspect/measure main bearings, rod bearings and cam bushings in accordance with MACK overhaul procedures. Replace as required.

ONE OR MORE CYLINDERS FAIL TO STOP BRAKING OR ENGINE STALLS

- **Control piston spring/valve inner spring broken** — Replace piston spring.
- **One or more control pistons/valves stuck in ON or UP position** — Check control pistons/valves for binding. Remove and clean, or replace if necessary. Inspect lube oil for contaminants.
- **Lower solenoid O-ring damaged (allows oil to enter brake with solenoid valve closed)** — Remove solenoid and replace all O-rings.
- **Solenoid valve exhaust plugged** — Remove any restrictions at exhaust (bottom) of solenoid valve.
- **Clutch switch stuck in ON position or out of adjustment** — Check for proper operation. Readjust or replace as needed.

ENGINE MISSES OR LOSES POWER

- **Hydraulic actuator adjustment too tight** — Readjust engine brake lash in accordance with the table on page 114.

SUDDEN DROP IN ENGINE LUBE OIL PRESSURE

- **Upper solenoid valve seal missing or damaged** — Remove solenoid and replace upper seal ring.

Removal and Inspection of MACK PowerLeash™ Engine Brake Components

INSPECTION

If oil pressure to the rocker shaft is not sufficient for engine brake operation, inspect the oil supply screen in the bottom of the front rocker shaft mounting bracket for debris, and clean or replace as necessary.

If oil pressure at the rocker shafts is sufficient for engine brake operation, then inspect the engine brake hydraulic actuator components for excess wear or damage.

1. Remove the retaining ring that holds the control piston cap in place on top of the actuator. Remove and inspect the control piston and spring. Free length of the spring should be 0.955 inch (24.3 mm). If the spring is broken or the free length is not within specifications, replace the spring.
2. Check the control piston for freedom of movement in the actuator bore. The control piston must move freely. If the piston binds or sticks, or if there are burrs on the piston or in the bore or if there is evidence of scuffing, replace the piston. Check the pintle on the end of the piston and replace if broken or showing evidence of wear.

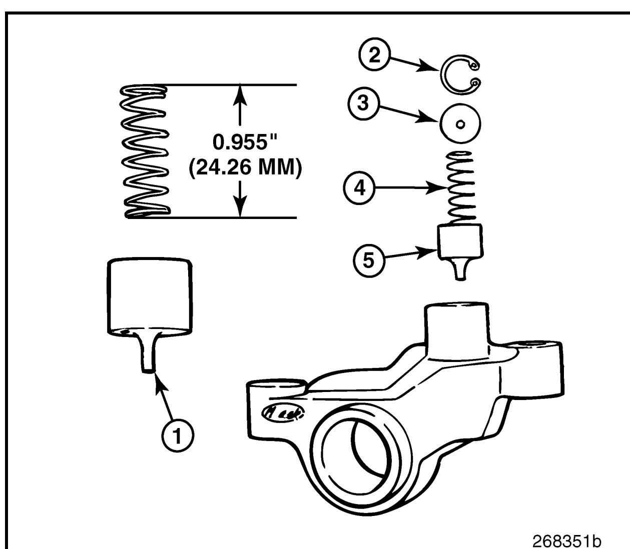

Figure 103 — Check Control Piston Spring Free-Length and Pintle Wear

1. Inspect Pintle for Wear or Damage 2. Snap Ring	3. Cover 4. Spring 5. Control Piston

3. Verify check valve function by carefully inserting a small screwdriver, drift pin or similar type of tool into the control piston bore and pushing on the check valve ball. There should be spring tension against the check ball, and the ball travel should be approximately 3/16 inch (4.763 mm). If the check ball does not move down freely, and if spring tension does not return the check ball to its seat, replace the rocker arm assembly.

NOTE

Check valve must not be over stroked. This could damage the valve and/or rocker arm.

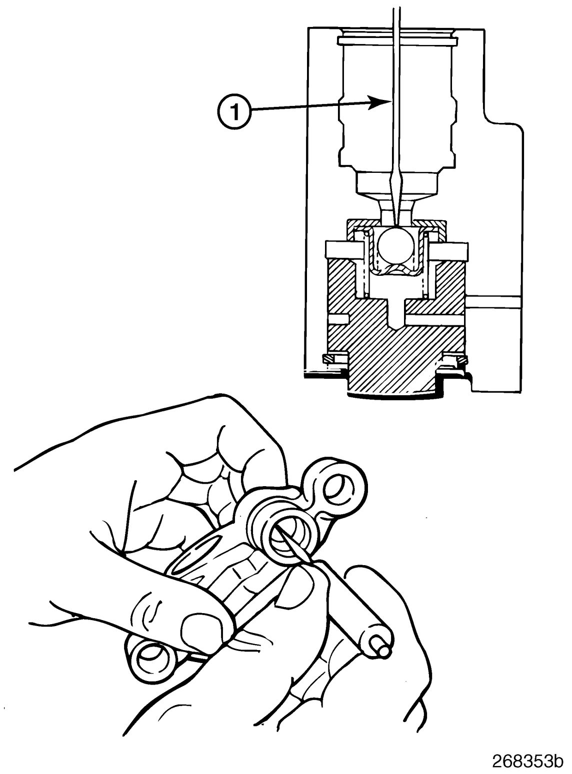

Figure 104 — Verifying Check Valve Function

1. Small Screwdriver or Drift

NOTE

The check valve is not replaceable. Any problems found with the check valve require that the complete rocker arm assembly be replaced.

4. If the check valve, control piston and control piston spring are OK, remove the rocker arm and check the hydraulic actuator plunger as follows:
   a. Make sure the plunger retaining ring is in place.
   b. Spring tension holds the plunger down against the retaining ring. Check for a broken spring by making sure the plunger is seated against the retaining ring.
   c. Push the plunger to make sure it moves freely in the bore and that spring tension seats the plunger against the retaining ring. If the plunger sticks or binds in the bore, or if spring tension does not keep the plunger seated against the retaining ring, replace the rocker arm.

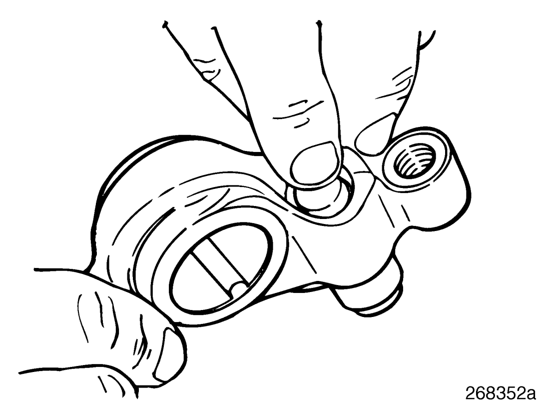

Figure 105 — Check Plunger Movement and Plunger Spring Tension

NOTE

The plunger is not serviceable. Any problems found with the plunger or plunger spring require that the complete rocker arm assembly be replaced. DO NOT attempt to remove any components from the rocker arm with the exception of those shown in Figure 103.

5. Check the valve actuator pin located in the valve yoke to ensure that the pin is not bent or damaged. The pin should not stick in the yoke at any point in its travel. There should be no signs of "mushrooming" or other damage where the plunger contacts the head of the actuating pin.

FINAL TEST

1. Install the engine brake components on the engine and adjust the brake piston and valve lash to the proper settings shown in the table on page 114.

   After installing the rocker assemblies and adjusting engine brake and exhaust valve lash, start the engine and run at an idle for several minutes.

NOTE

The engine brake requires a minimum oil pressure of 25 psi. When troubleshooting engine brake operation, it is desirable to do any test procedures with the engine operating at idle. Make sure engine oil pressure at idle is sufficient to support the engine brake minimum oil pressure requirement. If engine oil pressure is not sufficient at idle, increase engine speed until the minimum oil pressure requirement is obtained.

2. Check for oil leaks at the oil supply screen and solenoid valve. If leakage is noticed, shut the engine down and repair the leaks.

NOTE

Some leakage will be seen at the hydraulic actuator plunger and the control piston cap. This leakage is normal. Excessive leakage, however, must be investigated.

3. After these final inspections and necessary repairs, install the cylinder head covers.
4. Test drive the vehicle to verify any problems have been corrected.

ENGINE BRAKE TESTS (J-TECH™)

The ASET™ engines may be equipped with either a MACK PowerLeash™ engine brake or a J-Tech™ engine brake. The test procedures in this section apply only to the J-Tech™ engine brake.

Operational Tests

Before beginning the troubleshooting procedures, try to determine the exact nature of the problem. Talk to the driver, owner and/or mechanic to pinpoint the complaint or problem. The following checks may be helpful in trying to determine the nature of the problem.

BEFORE STARTING THE ENGINE

If there is a report of engine or engine brake noise, remove the cylinder head covers to determine the cause. Check the following items:

1. Check for loose or broken components.
2. Check and verify valve and engine brake plunger lash settings.
3. Check for bent push rods. If bent push rods are found, check for possible bent valves, and if the engine is equipped with ceramic roller lifters, check for broken ceramic rollers. Possible causes of bent valves or push rods could be:

   Engine overspeeding — Usually several valves are affected.

   One bent exhaust valve or push rod at a single cylinder — The problem may be a stuck master or slave piston, damaged slave piston adjusting screw (reset screw) or excessive oil pressure.

TEST DRIVE

NOTE

Engine brake will not engage until coolant temperature has reached 125°F (52°C).

1. Test drive the vehicle and measure intake manifold boost pressure while operating the engine brake (refer to table on page 120 for boost pressures). It is best to conduct the test with a loaded vehicle, engine at maximum-rated RPM and the engine brake ON. Downhill operation is desirable to stabilize RPM.

RETARDING BOOST PRESSURES (PSI) WITH J-TECH™ ENGINE BRAKE

Retarding boost pressures for MACK ASET™ engines equipped with J-Tech™ engine brakes were not available at time of publication.

NOTE

If the vehicle does not have a boost pressure gauge, one must be installed. A pipe plug is located in the air inlet manifold for this purpose.

2. Record the maximum boost pressure with the engine brake switch in the HIGH position.
3. Record the boost pressure with the engine brake switch in the LOW position.

NOTE

LOW position may be either front or rear unit.

4. Disconnect the wire lead from the LOW position terminal of the engine brake switch and rerun the test with the switch in the HIGH position. Record the results.

NOTE

The individual boost pressure readings should be approximately the same as recorded in steps 3 and 4.

5. Compare the maximum boost pressure with the specified boost pressures. A low reading indicates a possible problem. Readings at sea level should be within 3 psi of the values shown (at higher altitudes, slightly lower boost pressure readings are normal). Readings within 3 psi of the values shown indicate proper operation of the engine brake.

   With the J-Tech™ engine brake, a significantly lower reading in one housing indicates a possible problem with the housing.

Electrical Troubleshooting

ASET™ engines have been equipped with a V-MAC® control feature that automatically provides a level of protection by activating the engine brake only after the recommended minimum oil temperature has been reached. Be sure that the engine is sufficiently warmed before conducting tests.

NOTE

Some automated manual transmissions prevent engine brake operation when the transmission is in neutral.

NO ENGINE BRAKE OPERATION

1. Verify that the clutch pedal is not depressed and that the clutch switch is working properly.
2. Check for a blown fuse or circuit breaker.
3. With electrical power OFF, check the control system for a short to ground. Check systems separately to isolate where the short is occurring. If the control system is OK up to the engine brake valve cover/spacer connection, measure the resistance to the solenoid valve. High resistance means an open circuit in the solenoid or solenoid wire.

ONLY ONE HOUSING OPERATING

1. Determine which housing is not operating by closing all the switches and checking the power at the wires leading to the solenoid valves (front and rear).
2. Remove the wire to the solenoid valve at the cylinder head cover/spacer and check for resistance (refer to the table on page 121). No reading indicates an open circuit in the wire or solenoid coil. A low resistance reading indicates a short to ground in the solenoid wire or solenoid coil.

SERVICE HINT

A constant 12-volt low amperage signal is supplied to the engine brake solenoids by the V-MAC III module when the ignition switch is turned on. During an engine braking event, V-MAC increases the current to the solenoids to activate the engine brake. The most accurate method of checking electrical function of the engine brake solenoid circuits is by using an ammeter to measure current at the solenoids when the engine brake is activated. When the engine brake is activated, current should be approximately 1.59 amps. For additional information, consult the V-MAC® III Service Manual, 8-211.

3. Test the solenoid by checking for current draw and pull-in voltage per specifications listed in the table on page 121.

J-TECH™ SOLENOID SPECIFICATIONS

12-Volt Solenoid	
—	Resistance: 8.7 to 10.0 ohms
—	Current Draw: 0.9 to 1.6 amps
—	Pull In Voltage: 9 volts DC minimum
24-Volt Solenoid	
—	Resistance: 32.6 to 39.8 ohms
—	Current Draw: 0.46 to 0.75 amps
—	Pull In Voltage: 18 volts DC minimum

INTERMITTENT BRAKING

Inspect all wiring for loose connections and all switches for proper adjustment.

POOR PERFORMANCE

Connect a volt/ohmmeter (multimeter) to the electrical connector on the valve cover/spacer. Verify that a steady voltage signal is present when the engine brake is active. If not, check for loose connections or faulty switches. Repeat for all valve cover/spacer terminals.

J-Tech™ Checks (Hydraulic/Mechanical)

SPECIAL TOOL REQUIRED

- Jacobs Oil Pressure Test Kit 4559-18280

Remove the covers to begin inspecting the brake components, including housings and attendant hardware.

GENERAL INSPECTION AND ADJUSTMENT VERIFICATION

1. Visually inspect the brake units for obvious damage or missing parts. Replace as necessary.
2. Check the slave piston-to-actuator pin for proper clearance as shown in the table on page 122. Also check the intake and exhaust valve clearance. Readjust if necessary.

NOTE

Valve clearance must be checked with the timing pointer hole on the flywheel housing aligned with the proper valve setting mark on the flywheel for the cylinder being checked. This ensures that the valve lifter is on the camshaft base circle and not on the brake ramp portion of the lobe.

⚠ WARNING

Wear eye protection and do not expose your face over the engine area. Keep hands away from moving parts. Take precautions to prevent oil leakage down onto the engine.

Whenever engine is running and the valve covers are removed, oil splashing in the engine brake area could cause personal injury.

Never remove any engine brake component with the engine running. Personal injury may result.

NOTE

Brake slave piston clearance settings must be made with the engine stopped and cold and with the exhaust valves closed.

BRAKE SLAVE PISTON CLEARANCE SETTING

J-Tech™ Engine Brake	
—	Adjustment: 0.021 inches (0.533 mm)
—	Slave piston adjusting tool: standard feeler gauge
—	Adjust following the firing order: 1, 5, 3, 6, 2, 4

DETERMINING ENGINE OIL PRESSURE AND OIL PRESSURE AT THE ENGINE BRAKE UNITS

The engine brake requires a minimum oil pressure to operate. The oil pressure reading on the dash gauge is approximately the same as oil pressure at the engine brake. The exception to this is pre-2002 engines with Jake™ brake and without external oil supply lines to the Jake brakes. On these engines the oil pressure at the Jake brake is approximately 15 psi less than the dash gauge.

NOTE

When determining minimum oil pressure, the oil temperature must be at least 200°F (93°C) when the test is performed. The pressure reading from the dashboard oil pressure gauge is sufficient.

OIL PRESSURE REQUIREMENTS

J-Tech™ Engine Brake	
—	Engine rpm 2100: 40 psi (2.8 bar)
—	Engine rpm 1700: 35 psi (2.4 bar)*
—	Engine rpm 1500: 30 psi (2.0 bar)*
—	Engine rpm 1300: 30 psi (2.0 bar)*
—	Engine rpm 1100: 30 psi (2.0 bar)*

* Specified pressures with engine at 200°F (93°C) minimum oil temperature.

If the oil pressure remains low, correct the engine problem as described under "OIL PRESSURE DROPPING BELOW MINIMUM REQUIRED FOR ENGINE BRAKE OPERATION" in the Troubleshooting Guide included in this section.

INSPECTION OF J-TECH™ ENGINE BRAKE COMPONENTS

If oil pressure at the brake housings is sufficient for brake operation, then inspect the engine brake components for excess wear, damage or malfunctioning conditions described in this section.

1. Start the engine and allow it to idle for a few minutes. Check for oil leakage at the oil supply screw, solenoid valve and housing pipe plugs. Oil leakage can result in weak, intermittent or no braking. If leakage is found, shut down the engine and replace seals or repair as needed.

   When the engine is shut down for several minutes, the oil in the brake housings will bleed down. To refill the brake housings for immediate operation, depress the solenoid cap (pin) several times to fill the housing with engine oil.

2. With the engine brake on, observe that the master pistons are moving out of the housing and making contact with the exhaust rocker spherical nuts. They should move in and out freely. If they do not, shut down the engine and check the control valves and control valve springs for those cylinders.

WARNING

Remove control valve retaining components carefully to avoid personal injury. Control valve retaining components are under load from the control valve springs.

3. The control valve must move freely in the bore. If not, remove it and replace with a **new** control valve.

NOTE

If the bore is damaged (scored), use a light crocus cloth to smooth the bore. Clean the bore and install a **new** control valve. If severe damage to the bore is found, replace the housing.

4. Replace any broken springs.

5. If the control valves and springs are OK and the master and slave pistons were observed not to be operating, remove the housings for inspection.

   Visually inspect the following:

   Master piston springs — If broken or worn, replace the springs.

   Master pistons — Pistons must move freely in the bore. Check the hard facing on the master piston for damage; this is the area that contacts the spherical nut.

   Spherical nut rocker adjusting screw — Check the spherical nut for excessive wear. If a depression of 0.005 inch or deeper is found in the top of the spherical nut or if the pattern of wipe extends beyond the edge of the nut, replace the spherical nut. Also, replace the companion master piston. The spherical end of the rocker adjusting screw should be checked for proper contour and smooth appearance. Replace if necessary.

   Internal check valve components — If the housing contains internal check valve components and a hollow oil supply screw, remove the check valve components (ball, spring, retaining ring and washer) from the housing and replace the hollow oil supply screw with the current-production screw containing an integral check valve.

   Oil supply screws — Check for damage and replace if necessary.

6. Check the screw and pin assembly to ensure that the pin is not bent or damaged. The pin should not stick in the screw at any point in its travel. There should be no signs of mushrooming or other damage where the slave piston contacts the screw. Check to ensure that the retainer is in place on the top of the pin, making the pin captive in the screw. Replace the screw and pin assembly as a unit if necessary.
7. Remove and inspect the reset screw. A spring-loaded plunger located at the bottom of the screw seals the hole in the slave piston to provide proper master/slave operation. A stuck plunger or any debris will cause the hole in the slave piston to be uncovered prematurely, dumping oil pressure and shutting down the circuit. The reset screw prevents overtravel of the slave piston and exhaust valve to engine piston contact.

NOTE

Reset screw assemblies are not field serviceable.

8. Remove the slave pistons, using the following procedure.

WARNING

Wear safety glasses.

The slave piston is retained by springs that are under heavy compression. If the following instructions are not followed and proper tools not used, the springs will be discharged with enough force to cause personal injury.

J-TECH™ SLAVE PISTON REMOVAL

1. Remove the locknut on the slave piston adjusting screw. Back out the adjusting screw until the slave piston is fully retracted (screw is loose).
2. Place the hole in the slave piston clamp fixture over the slave piston adjusting screw. Replace locknut. Finger-tighten to hold fixture securely.
3. While holding the fixture in position, screw the holder down over the slave piston until the spring retainer is contacted.
4. Turn the handle slowly until the retainer is depressed to about 1/32 inch (1 mm), relieving pressure against the retaining ring.
5. Remove the retaining ring using retaining ring pliers. Back out the holder until the springs are loose, and remove the fixture. Remove all components, ensuring that there is no binding or burrs. Clean in an approved cleaning solvent. Inspect parts and replace as necessary.
6. A shiny, smooth contact surface on the reset screw plunger and slave piston is normal. If a rough surface exists on the plunger and/or slave piston, replace the parts. There should be a light spring force on the plunger and it should move freely. If not, replace the reset screw assembly.
7. Use the clamp fixture to reinstall the piston and springs. Be sure the retaining rings are placed on the retainer before screwing the clamp holder down.

8. Compress the slave piston springs down until the retainer is about 1/32 inch (1 mm) below the retaining ring groove. Reinstall the retaining ring. Be sure the retaining ring is fully seated in the groove.
9. Remove the clamp fixture slowly to ensure proper seating of the retaining ring.

FINAL TEST

Follow the instructions in the installation manual to reassemble the J-Tech™ housings. Install a **new** oil supply seal ring.

1. Install the housings on the engine. Check the valve yoke clearance and valve lash for proper adjustment and then adjust the slave piston clearance to the proper settings shown in the table on page 122.
2. Before installing the engine covers, start the engine and allow it to warm up for a few minutes.
3. Depress the solenoid valve several times to fill the housing with engine oil.

NOTE

Engine brakes require a minimum oil pressure for operation. If there is less than minimum at idle, run the engine at higher RPM (800–900) when making checks.

4. Check for oil leaks at the oil supply screw, solenoid valve and housing pipe plugs. If leakage is noticed, shut down the engine and repair the leaks.

NOTE

Some leakage will be seen at the master piston, slave piston and control valves. This is normal. Excessive leakage must be investigated (see "J-Tech™ Checks (Hydraulic/Mechanical)").

5. After final inspection and necessary repair, shut down the engine and replace the gaskets and covers.
6. Test drive the vehicle following the Test Drive procedures (covered earlier) to verify corrective action.

J-Tech™ Troubleshooting Guide

Following is a list of problem conditions showing the probable causes and subsequent corrections.

ENGINE FAILS TO START OR STARTS AND RUNS ONLY ON THREE (3) CYLINDERS

- **Solenoid valve stuck in ON position** — Ensure that electrical current is off to the engine brake units. If the solenoid valve remains on (cap down) with current off, replace the solenoid valve.

ENGINE BRAKE WILL NOT OPERATE

- **Blown fuse, open electrical leads** — Look for a short circuit in the wiring. Replace any broken, brittle or chafed wires. Check solenoid tab for signs of shorting and replace if necessary. Replace 10 amp fuse.
- **On/Off switch, clutch switch or multi-position switch out of adjustment or defective** — Use a volt/ohmmeter to make certain that there is electrical voltage available at both terminals of each switch. Readjust if needed or replace if voltage will not pass through switch.

WARNING

Do not touch electrical connection when system is energized.

- **Mounting bracket-to-rocker shaft mounting screws loose or missing** — Inspect for missing or loose mounting bracket-to-rocker shaft screws. Repair as required.
- **Incorrect electrical power source** — Check that the supply voltage is the appropriate voltage. Recommended power source is from the key switch ON position. Ensure that power is not taken from a source with an additional on/off switch, i.e., light switch. See solenoid specifications in the table on page 121. Make sure wiring is in accordance with MACK wiring instructions.
- **Low engine oil pressure** — Determine oil pressure at engine brakes (solenoid valve and control valve). If oil pressure is below specification, the engine should be repaired in accordance with MACK procedures.

- **Brake slave piston lash not properly adjusted** — The J-Tech™ model 690 engine brake units are very sensitive to adjustment. Incorrect adjustment may hold the valves open during positive power, leading to engine failure, or may cause the engine brake to work poorly or not at all. Confirm that the engine brake is properly adjusted in accordance with the table on page 122.

ENGINE BRAKE DOES NOT OPERATE AT LOW ENGINE RPM

- **Inlet check valve leaking** — Early production engine brake housings contained a check valve (with ball, spring, retaining ring and washer) assembled into the housing. In June 2000, the housing's internal check valve components and hollow oil supply screw were replaced by a new oil supply screw containing an integral check valve. If the housing contains the early production internal check valve components and a hollow oil supply screw, remove the check valve components (ball, spring, retaining ring and washer) from the housing and replace the hollow oil supply screw with the current-production screw containing an integral check valve.

ENGINE BRAKE ACTIVATES WITH SWITCHES OPEN (OFF)

- **Solenoid valve seal center ring damaged** — Remove solenoid and replace seal rings.
- **Engine brake improperly wired** — Check wiring in accordance with MACK wiring diagrams.
- **Solenoid not fully seated in rocker shaft bore** — Remove the solenoid, inspect and replace the O-rings as required. Reinstall the solenoid to its full seated position before snapping the retaining spring clips in place. The clips must require a moderate force to snap them around the rocker shaft and must provide enough spring tension to prevent any free movement of the solenoid or spring clips. If spring clip tension cannot be maintained, replace the clips.

ENGINE BRAKE SLOW TO OPERATE OR WEAK IN EFFECT

- **Lube oil cold and thick** — Allow engine to warm before operating engine brake.
- **Improper slave piston adjustment or slave piston sticking in bore** — Readjust in accordance with the table on page 122. Ensure that the slave piston responds smoothly to the reset screw by loosening the jam nut and turning the screw through its full travel for full slave piston motion. Make sure piston travels the full range without binding or sticking.

WARNING

Remove the slave piston carefully when disassembly is necessary. Use Jacobs slave piston tool part No. 4559-25084. Slave piston springs are under heavy compression.

- **Reset screw not properly sealing** — Remove reset screw and check for debris on the plunger or surface of the slave piston. Check to ensure that plunger moves freely with light pressure. Tip of plunger should be smooth and free of nicks or scratches. Replace reset screw if necessary.
- **Solenoid screen clogged stopping supply of oil to brake** — Remove solenoid valve and clean screen.
- **Master piston not moving in bore** — Inspect master piston and bore for scoring or burrs. If any are present, clean the surface with crocus cloth. If unable to remove burrs, replace piston or housing. Inspect lube oil for signs of contaminants. If any are present, replace oil and filter and correct cause of contamination.
- **Control valves binding in housing bore** — Remove control valve. If body is scored, replace the control valve. Check for contaminants in lube oil. Clean housing and control valve. If binding continues, replace housing.
- **Control valve defective** — Remove control valve. Make sure check ball is seated in bore and can be moved off the seat. Make sure there is spring pressure against the ball. Flush in cleaning solvent. Replace if necessary.

- **Switch operation sluggish** — Check dash switches, clutch switch or other control switches. Readjust or replace as required. Check clutch return springs for proper operation. Check all controls for correct operation and replace as required.
- **Solenoid valve operation erratic** — Check solenoid valve using electrical specifications presented in the table on page 121. Disconnect the solenoid lead and provide 12 volts directly to the solenoid. Ensure that the solenoid cap depresses.

⚠ WARNING

Do not touch electrical connection when system is energized.

OIL PRESSURE DROPPING BELOW MINIMUM REQUIRED FOR ENGINE BRAKE OPERATION

- **Upper solenoid O-ring/seal ring damaged or missing** — Remove the solenoid and inspect the upper seal ring; if damaged, replace all seal rings.
- **Aeration of lubricating oil** — Check for aeration of the oil. Activate, then deactivate engine brake and observe escape oil coming from control valve cover. If oil has bubbles or is foamy, air is present in system. Aeration can be caused by an overfilled or underfilled crankcase, or a crack or other leak in the oil pickup tube. Correct in accordance with MACK procedures.
- **Lubricating oil being diluted by fuel oil** — Have an oil analysis of lube oil to determine if fuel is present. Correct per MACK procedures.
- **Low engine oil level** — Consult engine manual for specifications. Add oil or recalibrate dipstick as required.
- **Worn rocker arm shaft bores or rocker shaft** — Inspect rocker arm shaft bores and rocker shaft for wear. Repair as required.
- **Worn main and/or rod bearings or camshaft bushings** — Inspect/measure main bearings, rod bearings and cam bushings in accordance with MACK overhaul procedures. Replace as required.

ONE OR MORE CYLINDERS FAIL TO STOP BRAKING OR ENGINE STALLS

- **Control piston spring/valve inner spring broken** — Replace inner spring.
- **One or more control pistons/valves stuck in ON or UP position** — Check control pistons/valves for binding. Remove and clean, or replace if necessary. Inspect lube oil for contaminants.
- **Solenoid valve sticking in ON position** — If solenoid valve cap remains down with no electric current being supplied, replace the solenoid valve.
- **Center solenoid seal ring damaged (allows oil to enter brake with solenoid valve closed)** — Remove solenoid and replace all seal rings.
- **Solenoid valve exhaust plugged** — Remove any restrictions at exhaust (bottom) of solenoid valve.
- **Clutch switch stuck in ON position or out of adjustment** — Check for proper operation. Readjust or replace as needed.

ENGINE MISSES OR LOSES POWER

- **Brake slave piston adjustment too tight** — Readjust brake slave piston clearance in accordance with the table on page 122.

SUDDEN DROP IN ENGINE LUBE OIL PRESSURE

- **Upper solenoid valve seal missing or damaged** — Remove solenoid and replace upper seal ring.

MAINTENANCE

LUBRICATION SYSTEM MAINTENANCE FOR ASET™ ENGINES

Crankcase Breather Element Cleaning

[219 ER]

All ASET™ engines are equipped with a fiberglass-reinforced nylon crankcase breather element canister. The procedure for cleaning the element is as follows:

1. Remove the canister cover by unthreading it from the housing.
2. Place a thin-blade screwdriver between the outside diameter of the element and the canister housing. Then, remove the element by rotating the screwdriver and element while exerting upward pressure.
3. Wash the element in shop solvent and blow dry with shop air.
4. Reinstall the element in the canister housing.

NOTE

A socket with the same diameter as the center tube in the breather housing will ease installation of the filter element. Insert the socket in the filter element and place the element and socket over the center tube. Then, slide the element onto the tube and remove the socket (Figure 106).

5. Install and tighten the canister cover.

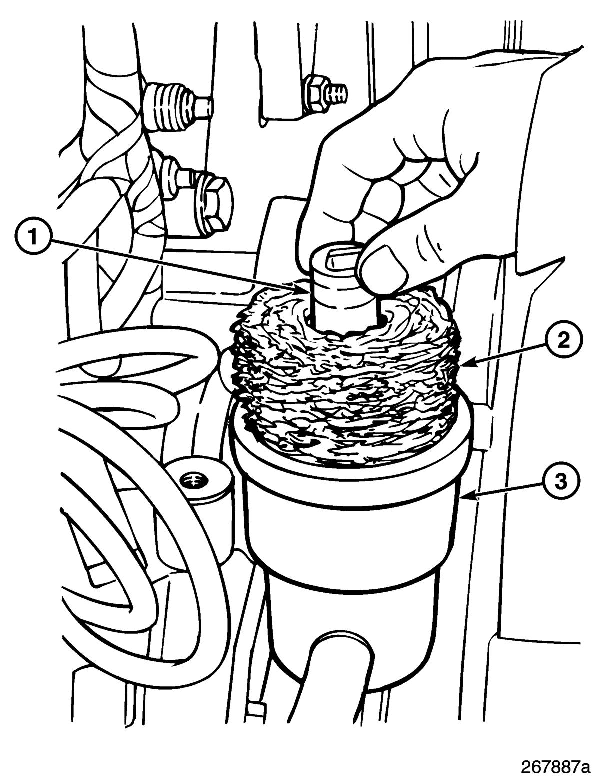

Figure 106 — Breather Element Installation

1. Socket 2. Element	3. Housing

Oil Level Check

When checking oil levels, the vehicle must be parked on level ground and the units at normal operating temperature. Components must be filled to the correct level. DO NOT OVERFILL.

The left-side dipstick location shown in Figure 107 applies to most ASET™ engines. Early production AI/AMI engines and AI engines built with the traditional front water pump configuration still utilize the right-side dipstick location.

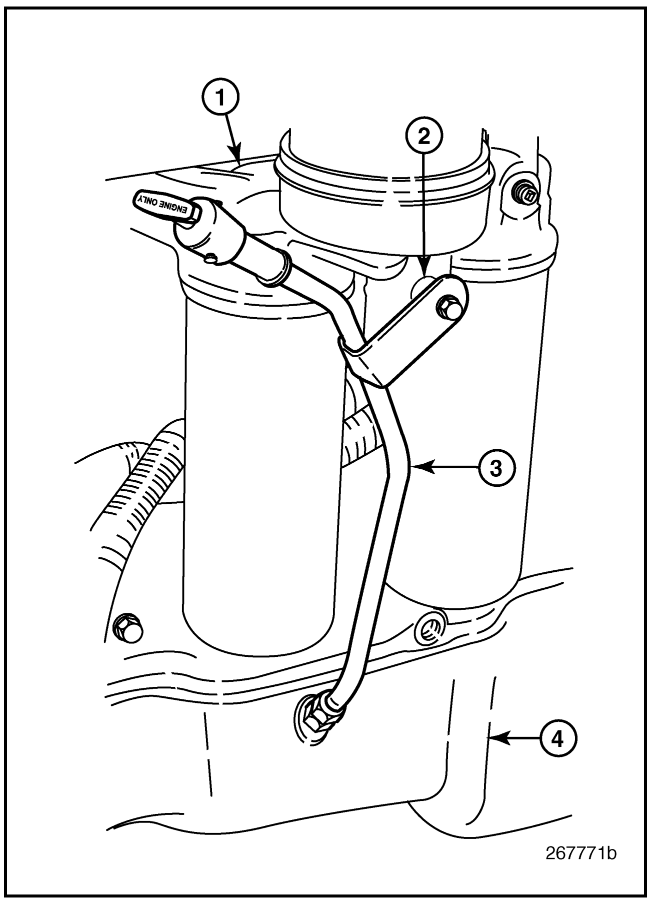

Figure 107 — Dipstick, Left-Side Installation (Most ASET™ Engine Applications)

1. Filter Mounting Bracket 2. Isolator	3. Dipstick Tube 4. Oil Pan

For accurate oil level readings, the dipstick must be inserted into the dipstick tube with the "L" and "F" markings facing upward. On conventional cabs, this will be with the finger-loop facing outboard, or away from the engine. On LE and MR models, the "F" and "L" marks must be facing up as the dipstick is inserted into the dipstick tube.

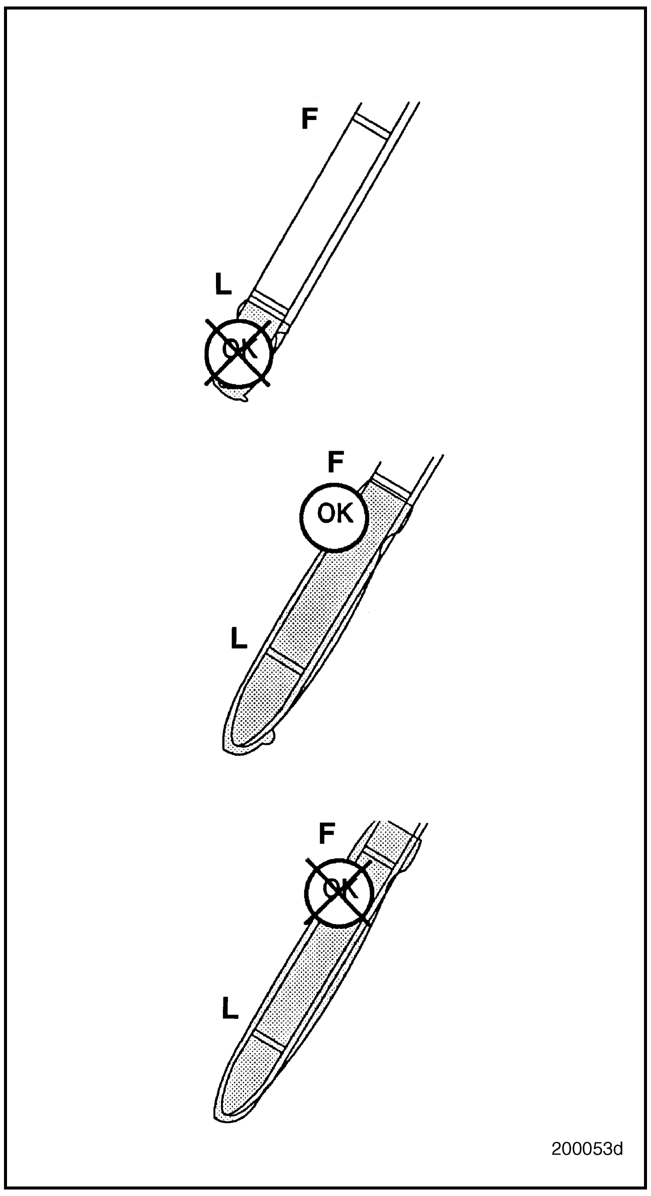

Figure 108 — Oil Level Check

Oil and Filter Change Procedure

[219 EV]

The ASET™ engines are equipped with improved spin-on type oil filters. The Centri-Max® ULTRA or ULTRA PLUS internally drained and vented filter design is taller and set in a cover housing with an integral oil fill port (Figure 109).

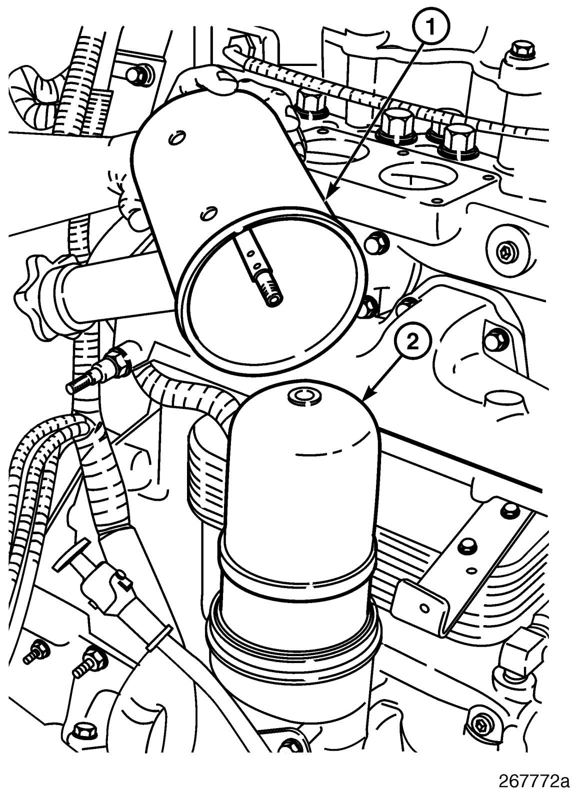

Figure 109 — Centri-Max® ULTRA Filter

1. Cover	2. Rotor

SPECIAL TOOLS REQUIRED

- Fuel and Oil Filter Wrench J 24783
- Oil Filter Wrench J 29927

DISPOSABLE SPIN-ON OIL FILTER REPLACEMENT

Change oil and replace oil filters using the following procedure:

1. Run the engine until normal operating temperature is reached. Then, shut off the engine and drain the oil before the engine cools.
2. Thoroughly clean the area around the filters before removing.
3. Using tool J 24783, remove both spin-on filters and wipe the filter mounting base clean.
4. Prefill each filter with 2 quarts (1.9 liters) of the specified engine oil. DO NOT allow any contaminants to enter the filters while prefilling.
5. Apply a film of clean engine oil to the sealing gasket on each new filter.
6. Install the filters and tighten 3/4 to 1 turn after the gasket contacts the base.
7. Fill the crankcase with the recommended engine oil. If the engine is equipped with a REPTO unit, add one additional quart.
8. Start the engine and check for leaks. Run the engine for approximately five minutes, then shut it off and recheck the oil level. Add oil if necessary.

NOTE

Use of anything other than genuine MACK filters may cause damage and void the engine warranty. Change filters according to the recommended maintenance schedule.

CENTRI-MAX® ULTRA OR ULTRA PLUS OIL FILTER

[219 EV]

The following procedure applies for both the ULTRA and ULTRA PLUS filters. However, the ULTRA PLUS rotor bushing hole sizes and the mating shaft journals are smaller than those of the ULTRA filter. As such, the rotors are not interchangeable.

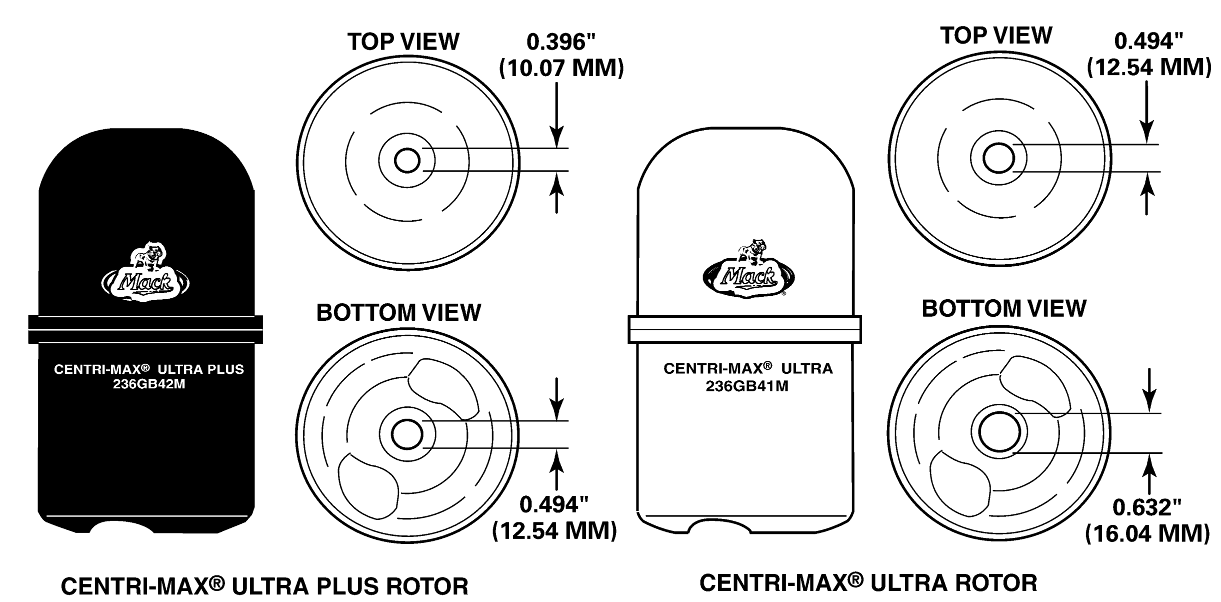

Figure 110 — Centri-Max® ULTRA PLUS and ULTRA Rotors

NOTE

Centri-Max® ULTRA PLUS filter assemblies may have a one-piece (early production) or two-piece (current production) spindle configuration. Both configurations, however, use the same ULTRA PLUS rotor.

1. To prevent contamination from entering the engine, thoroughly clean the area around the centrifugal oil filter before removing the cover assembly.
2. Loosen the nut at the top of the cover assembly, then remove the cover and rotor together.
3. Discard the rotor.
4. Clean the inside of the cover assembly.
5. Remove and discard the old O-ring seal from the filter housing base.
6. Install a **new** O-ring on the filter housing base (Figure 111). The O-ring should be installed dry, non-lubricated.

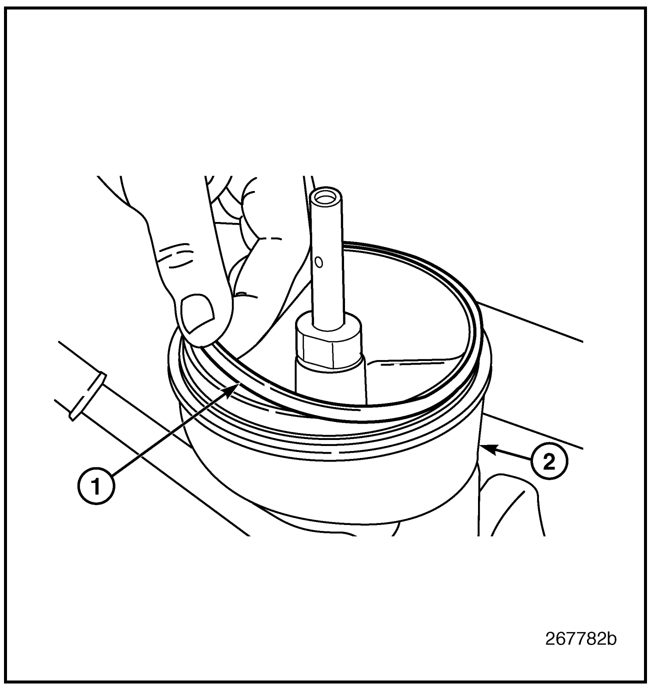

Figure 111 — O-Ring Installation

1. O-Ring	2. Filter Base

7. Install a **new** rotor over the spindle.

CAUTION

Use the correct rotor kit for the centrifugal filter assembly application, 57GC2206 for Centri-Max® ULTRA and 57GC2231 for Centri-Max® ULTRA PLUS. For easy identification, the ULTRA PLUS rotor is black, whereas the ULTRA rotor is cream color. If the ULTRA rotor is used in an ULTRA PLUS application, the rotor bushings will be a very loose fit on the smaller diameter shaft and the rotor will not rotate, resulting in a non-functioning centrifugal filter.

8. Install the cover assembly and tighten the retaining nut to 19 lb-ft (26 N•m).
9. Start the engine and check for leaks.

Centri-Max® ULTRA PLUS Spindle Replacement (If Required)

The Centri-Max® ULTRA PLUS with the two-piece spindle and new smaller diameter shaft became the standard for all ASET™ engines in the fourth quarter of 2003. This procedure covers only this latest style filter arrangement.

1. Remove the cover assembly, rotor and O-ring following the steps in the preceding oil filter replacement procedure.
2. Using an open end wrench, remove the lower shaft from the oil filter mounting adapter.

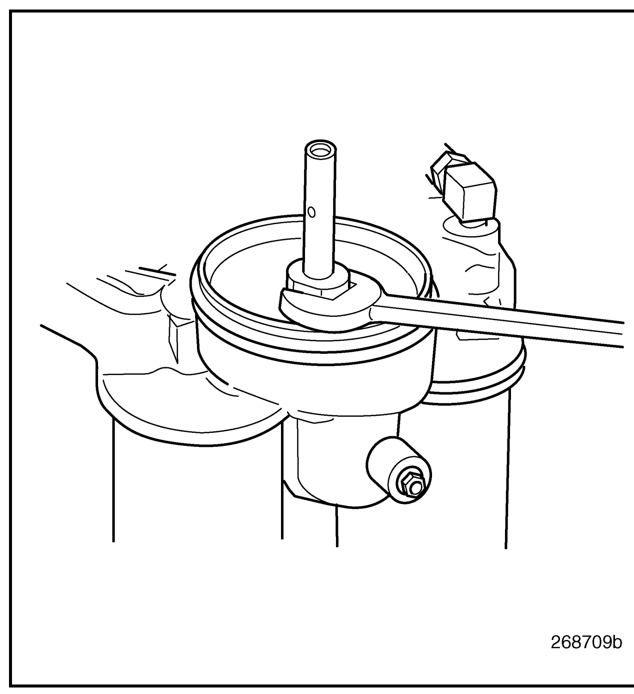

Figure 112 — Removing Lower Spindle from Oil Filter Mounting Adapter

3. Clean the spindle mating threads in the oil filter mounting adapter with Loctite® Non-Chlorinated Parts Cleaner (or similar type of safety solvent) and blow the area dry with clean shop air.
4. Apply Loctite® 271 to the threads on the lower end of the **new** spindle.

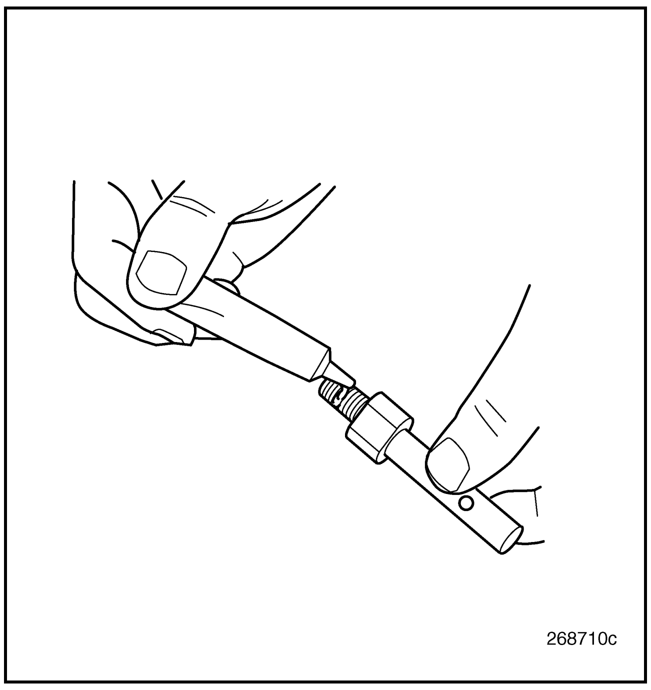

Figure 113 — Apply Loctite® 271 to Spindle Threads

5. Assemble the **new** spindle to the oil filter mounting adapter. Use an accurately calibrated torque wrench with a 5/8″ crow's foot to tighten the spindle to 26 lb-ft (35 N•m).

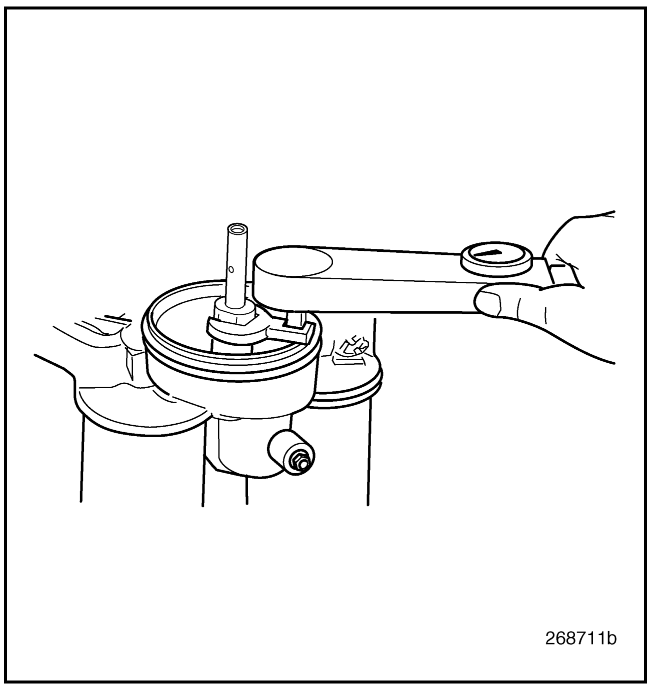

Figure 114 — Tightening Spindle

6. Install a **new** O-ring on the filter housing base (Figure 115). The O-ring should be installed dry, non-lubricated.

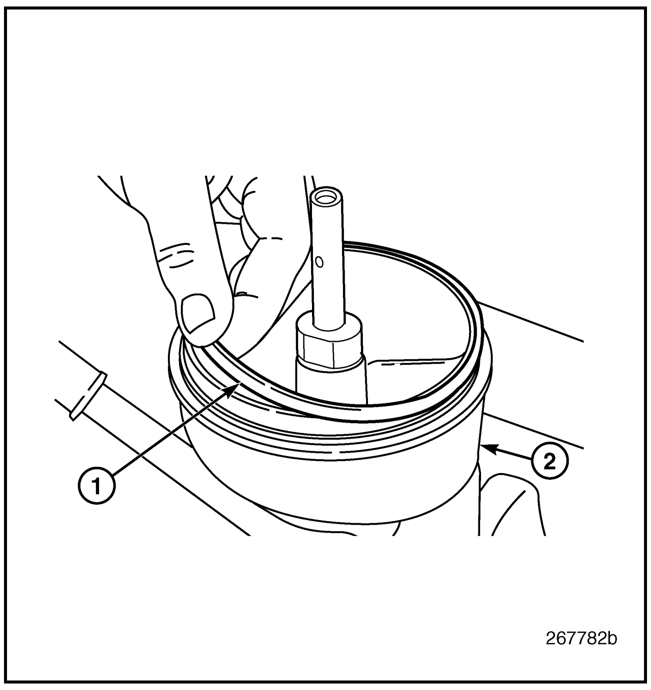

Figure 115 — O-Ring Installation

1. O-Ring	2. Filter Base

7. Install a **new** ULTRA PLUS rotor over the spindle.
8. Install the cover assembly and tighten the retaining nut to 19 lb-ft (26 N•m).
9. After one hour, start the engine and check for leaks.

NOTE

Allow the Loctite® to cure for a minimum of one hour before starting and running the engine.

FUEL FILTER ELEMENT REPLACEMENT FOR ASET™ AC ENGINES

Primary/Secondary Fuel Filter Change

[231 BA]

SPECIAL TOOL REQUIRED

- Fuel and Oil Filter Wrench J 24783

For engines produced before December 22, 2003, clean or replace the pre-pump filter screen and change the secondary fuel filter at each specified oil and filter change interval.

For current-production engines (December 22, 2003 and later production), change the chassis-mounted primary filter and replace the secondary filter on the supply pump at each specified oil and filter change interval. The pre-pump filter is no longer used and the port is plugged on current-production engines.

ASET™ AC FILTER DESCRIPTION

The pre-pump filter on the ASET™ AC engine, located at the bottom of the fuel supply pump, uses a screen cartridge to remove particulates that would damage the pump gears (Figure 116). The cartridge is fitted into a transparent housing that allows visual inspection for sediment in the trap. The cartridge housing is threaded onto the pump housing for easy removal for cleaning or replacement of the cartridge.

The high filtration primary spin-on fuel filter element (3–5 microns) used on CEGR engines is also located on the supply pump (Figure 117). It is mounted to a metric-threaded spud at the pump's pressure outlet. The filter element is fitted with a fuel-drain port at the bottom.

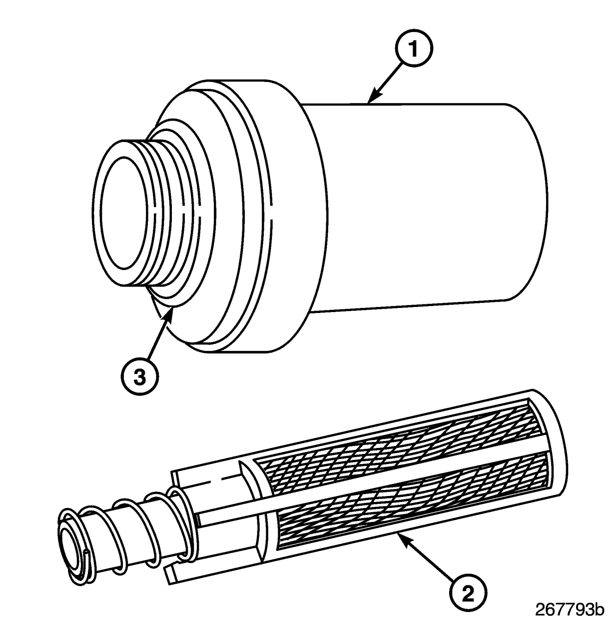

Figure 116 — Pre-Pump Filter

1. Screen Housing 2. Screen Cartridge	3. O-Ring

NOTE

Because of ice buildup in the fuel system or fuel waxing which can clog fuel filters, it may be necessary to reduce the time or mileage interval between fuel filter changes during extremely cold weather.

NOTE

General field practice is to prime the fuel filters before installation. This practice can allow dirt to enter the outlet port of the filter if caution is not used. Use filtered fuel only when priming the filter. Prime through the series of small holes on the top of the filter. DO NOT prime the filter through the center hole.

PRE-PUMP FILTER CARTRIDGE CLEANING OR REPLACEMENT

To remove, clean or replace the pre-pump filter cartridge (if so equipped):

1. Thoroughly wash the area around the filter housing and pump base with a suitable solvent and blow dry with compressed air.
2. Remove the filter housing from the pump base and remove the cartridge from the housing.
3. Empty accumulated sediment, then clean and dry the housing.
4. Clean the cartridge screen and check it for tears or other damage. Replace the cartridge if necessary.
5. Fill the housing with clean filtered fuel and insert the cartridge into the housing. Make sure the spring is in place at the top of the cartridge.
6. With the O-ring in place, install the housing to the pump base and tighten to 6–7 lb-ft (8–10 N•m).

SPIN-ON FUEL FILTER REPLACEMENT

To replace the spin-on fuel filter on the pressure side of the pump and the chassis-mounted primary fuel filter (if so equipped):

1. Again, make sure the filter element and pump mounting adapter is cleaned thoroughly. If not already done, wash the area around the filter element and pump mounting adapter with a suitable solvent and blow dry with compressed air.
2. With a suitable container in place under the filter element, open the drain fitting to remove residual fuel from the element. This step is necessary to avoid fuel spillage as the filter is tilted to move it out from between the engine and chassis frame.
3. Using tool J 24783, remove the old filter from the pump mounting.
4. Apply a thin film of clean engine oil to the sealing gasket of the new filter.
5. Using clean filtered fuel, prime the filter by filling it through the series of small holes at the top. DO NOT prime the filter through the center hole. Use care to avoid dirt entering the outlet port of the filter.
6. Install the **new** filter and tighten an additional 3/4 to 1 turn by hand after the gasket contacts the base.

⚠ CAUTION

If priming the fuel system on an ASET™ AC engine becomes necessary, the only acceptable method is to use the hand primer pump located on the supply pump. DO NOT attempt to prime the fuel system by applying air pressure to the fuel tank or by using an auxiliary pump, as these methods may result in severe engine damage caused by fuel that leaked past the supply pump seal into the crankcase.

7. Start the engine and check for leaks.

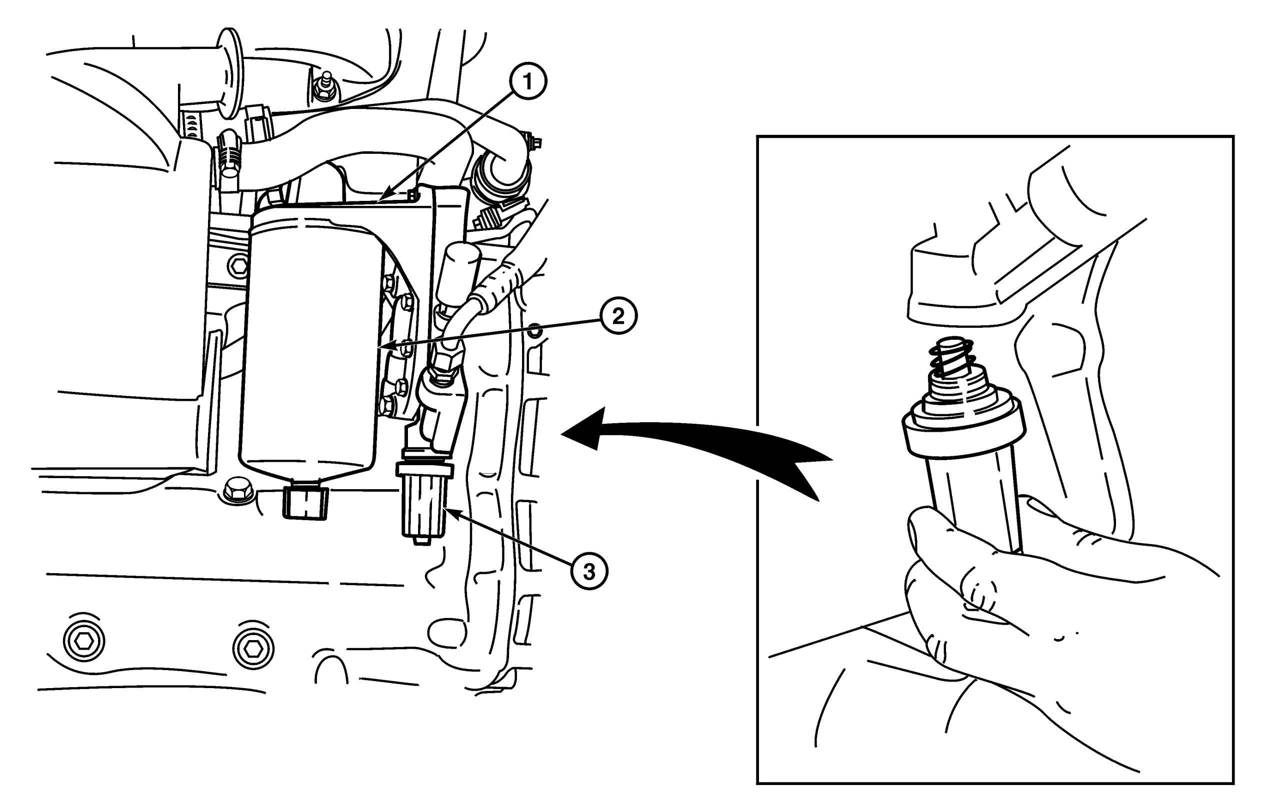

Figure 117 — MACK Fuel Filtration System (AC Engine)

1. Fuel Supply Pump with Filter Mounting Provision 2. Fuel Filter Element	3. Pre-Pump Filter (Used in production prior to December 22, 2003; replaced by a plug and O-ring in later production.)

COOLANT CONDITIONER ELEMENT REPLACEMENT FOR ASET™ ENGINES

Coolant Conditioner Replacement

[215 LD]

The location of the coolant conditioner on the ASET™ engines with traditional front configuration is on the thermostat housing at the front of the coolant manifold. ASET™ engine models with front-redesign and all ASET™ AC models, place the coolant conditioner at the back of the water pump housing at the lower left side.

SPECIAL TOOLS REQUIRED

- Fuel and Oil Filter Wrench J 24783
- Oil Filter Wrench J 29927

The conditioner element is replaced as follows:

All ASET™ ENGINES

1. Place a suitable container below the coolant filter area to catch any spilled coolant.
2. Using a suitable filter wrench (J 29927, or equivalent), remove the coolant conditioner filter element and discard.
3. Apply a light film of oil on the face of the new filter element gasket seal.
4. Install the filter element on the coolant conditioner base assembly. Using tool J 24783, tighten the filter element one full turn after the gasket contacts the base.

OIL COALESCING AIR FILTER REPLACEMENT

Engines produced after May 4, 2004 have an oil coalescing air filter incorporated into the air line supplying the control valve to prevent oil condensation and possible “coking” inside the VTG position control valve. This filter is mounted on a bracket at the lower side of the cylinder block, to the rear of the oil filters (Figure 118). The filter must be changed at each B, C and D inspection interval (every other engine oil change interval). Procedures for replacing the spin-on filter are as follows:

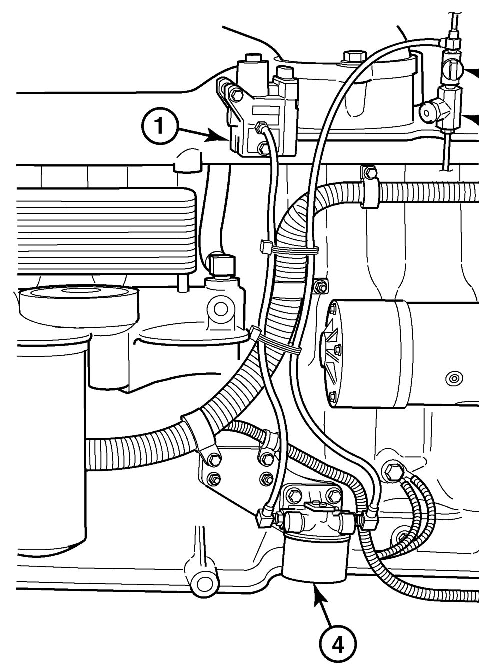

Figure 118 — Oil Coalescing Air Filter

1. VTG Position Control Valve	3. Pressure Protection Valve
2. Shut-Off Valve	4. Oil Coalescing Air Filter

1. Rotate the knob on the air line shut-off valve to the horizontal (off) position. When the valve is closed, residual pressure in the filter and lines is bled to the atmosphere.
2. Turn the filter counterclockwise to loosen and remove it from the adapter.
3. Apply a thin film of clean engine oil to the gasket of the **new** filter.
4. Install the filter to the adapter and hand-tighten until the gasket contacts the base. Tighten the filter one additional turn.
5. Rotate the shut-off valve knob to the vertical (on) position.

DRIVE BELT REPLACEMENT AND TENSIONING FOR ASET™ AC ENGINES [216 AA]

General Information

The service life of the poly-V belts is considerably improved over other systems and allows the use of higher horsepower cooling fans. All ASET™ engines are equipped with poly-V belt systems.

ASET™ AC ENGINES

In the AC dual poly-V drive belt arrangement, the fan drive is driven directly from the crankshaft pulley by a 10-rib poly-V belt. In turn, the water pump, alternator and the air conditioning compressor (if equipped) are driven off the fan-drive hub by a 6-rib poly-V belt (Figure 119). Two automatic tensioners are used, one for the fan drive and one for the accessory drive.

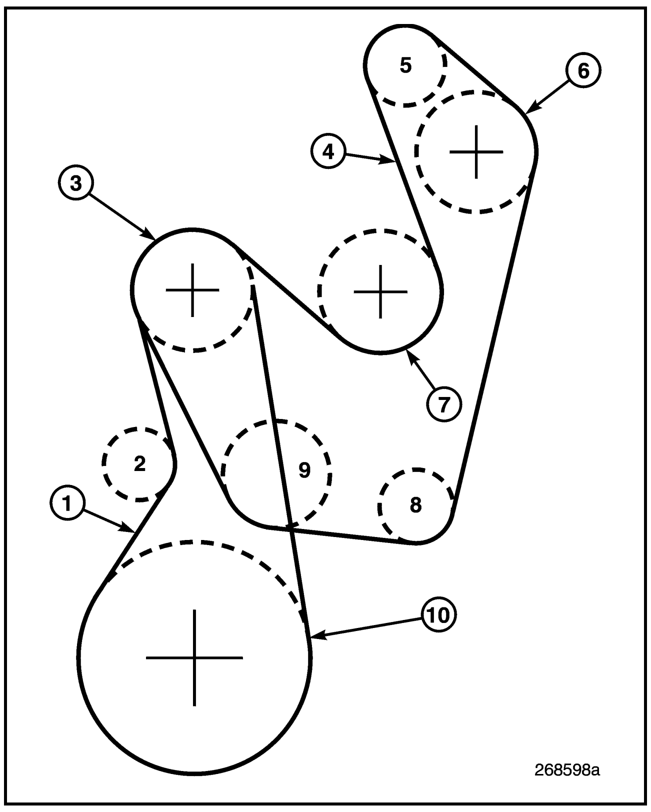

Figure 119 — AC Belt-Drive Arrangement

1. 10-Rib Poly-V Belt	6. A/C Compressor
2. Tensioner	7. Water Pump
3. Fan-Drive Hub	8. Alternator
4. 6-Rib Poly-V Belt	9. Idler Pulley
5. Tensioner	10. Crankshaft Pulley

NOTE

Refer to ASET™ AC ENGINE DRIVE BELT SPECIFICATIONS section for belt sizing and part numbers.

NOTE

Refer to ASET™ AC SCHEMATIC and ROUTING DIAGRAMS section for accessory drive belt routings.

The tensioner for the crankshaft-to-fan drive hub is mounted to the timing gear cover. This tensioner spring loads in a *counterclockwise* direction to apply load to the belt. The accessory drive belt tensioner is mounted on the new water pump assembly. There are two possible mounting locations for this tensioner depending on the chassis model and if equipped with an air conditioner. The tensioner spring-loading direction (*clockwise with A/C* or *counterclockwise non-A/C*) for applying load to the belt is determined by the mounting location.

Automatically Tensioned System

INSTALLATION

Swing the tensioner to the fully sprung position and, without force, place the belt over the pulleys. Do not allow the tensioner to snap against its stops. Do not pry the belt over a pulley.

TENSIONING

No tensioning adjustment is required. Once the tensioner is released against the belt, the belt is tightened to optimum tension automatically at all speeds and loads.

MAINTENANCE

The condition of the belt and tensioner should be checked when performing preventive maintenance inspections A, B, C and D as outlined in the *Maintenance and Lubrication* manual, TS494. Belt tension levels need not be checked as long as the tensioner is in good condition and there is no evidence of a loose belt.

NOTES

REPAIR INSTRUCTIONS, PART 1

ENGINE REMOVAL

General Instructions

Details of the engine removal procedure vary from one vehicle to another. This section provides general guidelines for removing the engine from the vehicle.

NOTE

Before beginning engine removal, make sure all equipment is available for use and has been inspected for safety.

NOTE

It is good practice to steam clean the engine to remove road grime, grease and oil before starting work. Steam cleaning the engine and engine area allows more detailed inspection and improved workmanship.

Care must be used to keep moisture from entering the air intake system. If moisture does enter the system, make sure it is removed (dried out) before the engine is reinstalled.

1. Position the vehicle on a flat and level surface in an area with ample work space in and around the vehicle. Ensure that a suitable lifting device is available.
2. Apply the parking brake and block the vehicle wheels to prevent the vehicle from moving. Observe all safety precautions.
3. Disconnect the battery negative (ground) cable.
4. Drain the air tanks.

Removal from Vehicle

1. Remove the hood (if so equipped) and position it away from the work area to prevent accidents or hood damage to conventional models. On cab over engine models, tilt the cab forward.
2. Place a suitable container beneath the engine and drain the engine oil and coolant. Open the coolant drain valves in the block and the EGR cooler.
3. Using an appropriated filter wrench, remove the oil filters, fuel filter(s) and coolant conditioner.
4. If the vehicle is equipped with air conditioning:
   a. Recover the refrigerant using A/C refrigerant recovery and recycling equipment.
   b. Disconnect the A/C compressor discharge hose at the connection near the radiator support.
   c. Disconnect the A/C line at the receiver/dryer.
   d. Locate and disengage the electrical connector from the binary pressure switch on the receiver/dryer.
   e. Locate and disengage the electrical connector from the low-pressure cutout switch in the A/C refrigerant line.
5. Disconnect and remove the upper radiator tube from the engine.
6. Disconnect the cab heater and fuel heater coolant return lines from the radiator lower tube (if applicable). The cab heater and optional fuel heater coolant return hoses were relocated from the thermostat housing to the radiator lower tube during mid-2004.
7. Disconnect the lower radiator tube from the Y-hose at the oil cooler coolant inlet on the engine and from the radiator outlet. Remove the tube from the engine.
8. Remove the clamps that retain the coolant overflow tank and then remove the tank.
9. Disconnect and remove the chassis-mounted charge air cooler inlet tube and hoses.
10. Disconnect and remove the chassis-mounted charge air cooler outlet tube and hoses.
11. Locate the engine coolant temperature sensor and disengage the electrical connector, if applicable. Remove the sensor harness from the radiator support.
12. Remove the fastener from the bracket that secures the radiator fan clutch air solenoid valve to the radiator support, if so equipped. Set the solenoid valve aside.

13. Remove the fan assembly as follows:
    a. Loosen the eight fan assembly mounting nuts and capscrews. Refer to Figure 120.
    b. While supporting the fan assembly, remove the nuts from the capscrews and remove the assembly.
    c. If the fan assembly is equipped with a viscous drive, be sure to store the assembly either horizontally, with the fan face down (hub flange up), or vertically, as shown in Figure 121. This will prevent fluid leaking from the assembly.

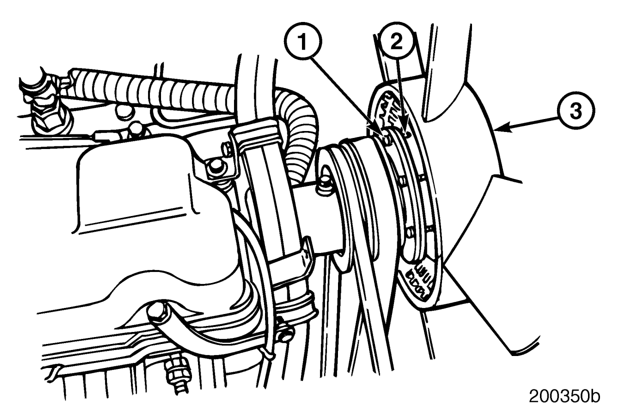

Figure 120 — Fan Assembly Removal

1. Capscrew 2. Nut	3. Fan Assembly

CAUTION

Do not store the assembly horizontally with the fan face up (hub flange down). Fluid in the viscous drive reservoir can leak out.

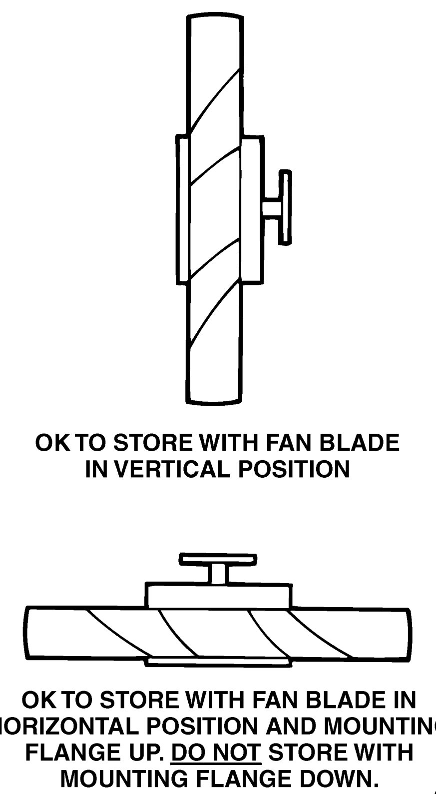

Figure 121 — Viscous Fan Drive Assembly Storage

14. Obtain a lifting device (chain fall or engine hoist) and support the radiator.
15. Remove the retaining bolts from the radiator support mounts.
16. Remove the radiator from the vehicle, using the lifting device and an assistant, if required.
17. Disconnect the heater hoses and A/C refrigerant lines, if applicable, from connections at the lower dash panel behind the engine.

18. Loosen clamps that secure the air intake tube to the turbocharger and air filter. Remove the intake tube.
19. Remove the air cleaner assembly, if required.
20. Remove all coolant tubes, ground straps, air lines, fuel lines, hydraulic hoses or tubes, throttle linkage and electrical wiring harnesses that are attached to the engine and would prevent its removal.
21. Disconnect the boost pressure relief valve tube at the exhaust pipe connection. Tube must be removed completely by disconnecting it from the boost pressure relief valve.

CAUTION

Use care when removing the boost pressure relief valve tube. The tube can be damaged if bent excessively at the bellows.

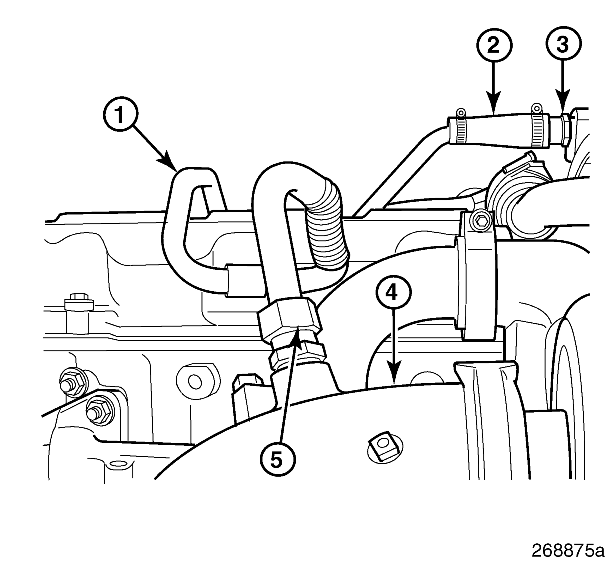

Figure 122 — Boost Pressure Relief Valve Tube

1. Relief Valve Tube-to-Exhaust 2. Valve-to-Tube Coupling 3. Boost Pressure Relief Valve (Turbo By-Pass)	4. Exhaust Pipe 5. Relief Valve Tube-to-Exhaust Pipe Connection

22. Remove the exhaust bracket from the clutch, torque converter or flywheel housing. Support the pipe so that it does not drop onto the EGR hot tube bellows and remove the exhaust clamp at the turbocharger.

CAUTION

DO NOT let the exhaust pipe drop onto the bellows of the EGR hot tube as the exhaust pipe clamp is being removed at the turbocharger. The bellows could be damaged requiring replacement of the hot tube.

23. Remove the power steering hoses and the reservoir, if applicable.
24. Disconnect any electrical cables or wires still connected to the starter (Figure 123). Remove the three capscrews from the mounting flange and remove the starter.

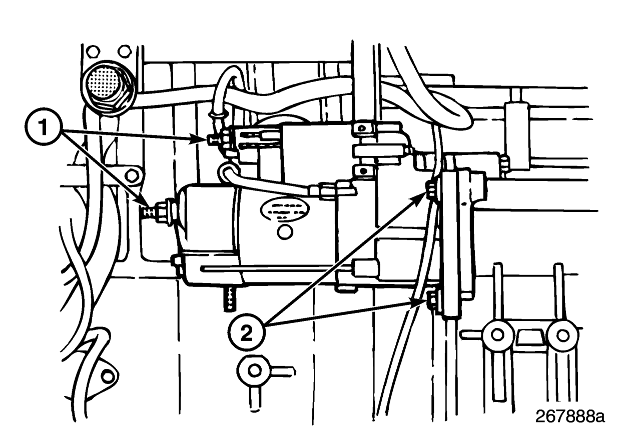

Figure 123 — Starter Removal

1. Electrical Terminals	2. Mounting Capscrews

25. Support the transmission with an appropriate transmission jack.
26. Remove the retaining bolts that secure the transmission bell housing to the flywheel housing.

NOTE

A new flywheel housing initiated into production in mid-2004, introduced a larger transmission-to-flywheel housing connection bolt. The bolt size increases from 10 mm to 7/16-inch. This should be noted if the flywheel housing is to be replaced during overhaul.

27. Remove the hood rest crossmember(s), if applicable.
28. Obtain the appropriate lifting equipment (bar or chain) and attach to the proper lift points on the engine.
29. Position and attach the engine hoist to the lift bar or chain and, using the hoist, place tension on the bar or chain.
30. If the vehicle is equipped with a manual transmission, remove the clutch linkage and bracket retaining bolts.
31. If the vehicle is equipped with an automatic transmission, remove the torque converter access panel and remove the capscrews that secure the torque converter to the flywheel.
32. Remove the retaining bolts that secure the engine mounts to the engine.
33. With the help of an assistant, remove the engine from the vehicle. Watch for obstructions that may interfere with its removal such as engine or chassis components, brackets, clamps or other parts still attached to the engine.
34. Refer to Engine Disassembly procedures for mounting the engine on an engine stand.

ENGINE DISASSEMBLY

General Instructions

This section includes step-by-step procedures for the complete disassembly of the engine upon removal from the vehicle. Major components are removed as assemblies and overhauled in the respective bench procedures sections.

CAUTION

Failure to follow the sequence of operations listed in this section may result in damage to the components or personal injury.

Filter Element Removal

[219 EV]

The oil filter elements and mounting adapter assembly, including the Centri-Max® ULTRA or ULTRA PLUS, must be removed before mounting the adapter plate to the engine. If not already removed, remove the filters following the procedure below.

Refer to Figure 124.

1. Place a suitable container below the filter element area to catch any spilled fluids.
2. Using a suitable filter wrench, remove the fuel and oil filter elements. Do not reuse filter elements. Discard used elements in a responsible, environmentally safe manner.
3. Remove the top-mounted Centri-Max® ULTRA or ULTRA PLUS oil filter.
    a. Loosen and remove the retaining bolt at the top of the filter cover.
    b. Remove the cover, element and rotor. Discard the seal.

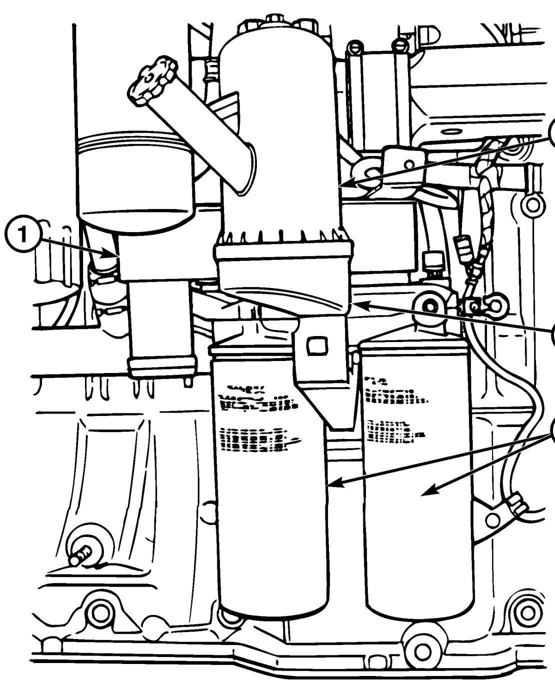

Figure 124 — Centri-Max® ULTRA Housing

1. Oil Cooler 2. Centri-Max® ULTRA Filter	3. Oil Filter Mounting Bracket 4. Spin-On Full-Flow Oil Filters

Dipstick Tube Removal

ASET™ AC engines are all built with the dipstick tube mounted on the left side of the engine which extends into the oil pan. This tube must be removed after all the oil has been drained, but before the oil filter mounting bracket assembly can be removed.

Oil Cooler and Oil Filter Mounting Bracket Assembly Removal

[215 DW, 219 EP]

The plate-type oil cooler and oil filter mounting bracket must be removed before mounting the engine in the stand. The configuration of the housing assembly protrudes into the area required for the engine mounting adapter plate. Refer to Figure 125 and remove the assembly as follows:

1. Disconnect the harness from the oil pressure and oil temperature sensors on the filter mounting bracket.
2. Disconnect the turbocharger lubrication supply line from the mounting bracket.
3. Loosen the clamps and remove the Y-hose and screen from the by-pass tube and oil cooler inlet.
4. Loosen the hose clamps at the cooler-to-water pump pipe connection, and slide the hose away from the cooler and further onto the pipe.
5. While supporting the oil cooler and oil filter mounting bracket assembly with one hand, remove the four capscrews attaching the oil cooler and oil filter mounting bracket to the cylinder block.
6. Lift the oil cooler and oil filter mounting bracket assembly off the block surface and place on a clean work surface.

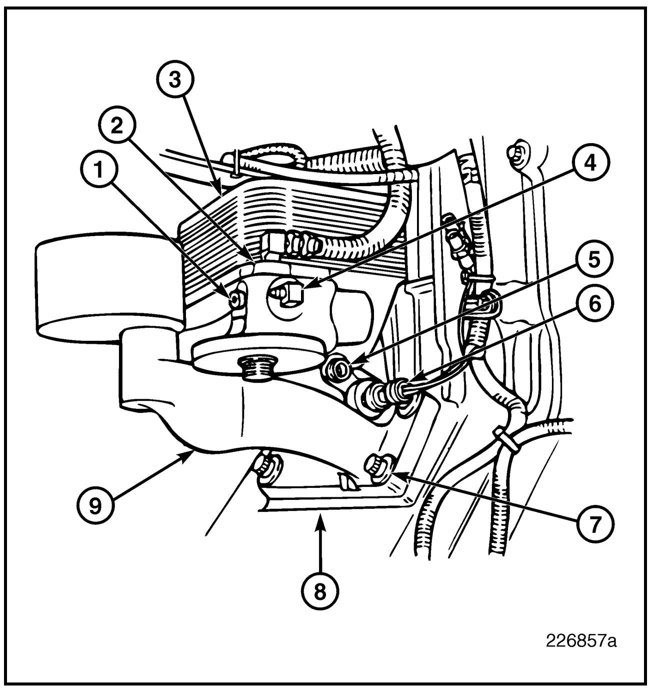

Figure 125 — Plate-Type Oil Cooler and Oil Filter Mounting Bracket Removal

1. Oil Supply Port (for Mechanical Dashboard Gauge) 2. Turbocharger Lubrication Supply Line 3. Oil Cooler 4. Oil Supply Port (for REPTO), Turbo Unloader and Remote-Mounted Oil Filter	5. Oil Temperature Sensor Port 6. Oil Pressure Sensor 7. Mounting Bracket Capscrews (Four) 8. Cylinder Block 9. Oil Filter Mounting Bracket

Oil Coalescing Air Filter Removal

If so equipped, the oil coalescing air filter assembly and bracket must also be removed before mounting the engine in a stand. Refer to Figure 126 and remove the assembly as follows:

1. Disconnect and remove the outlet air line from the air filter to the VTG position control valve.
2. If not already done, disconnect and remove the inlet air line from the filter assembly.
3. Remove and discard the filter element.
4. Remove the bolts securing the harness clamps to the mounting bracket.
5. Remove the retaining nuts securing the mounting bracket to the engine block and remove the filter adapter and mounting bracket as an assembly.

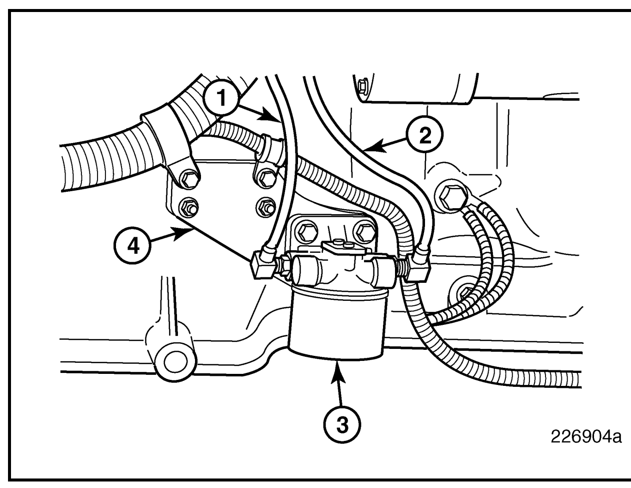

Figure 126 — Oil Coalescing Air Filter Assembly Removal

1. Outlet Air Line 2. Inlet Air Line	3. Oil Coalescing Air Filter 4. Mounting Bracket

Mounting Engine in Stand

W A R N I N G

The engine weighs approximately 2,300 lbs. (1043 kg) wet. Stay out from under the engine when it is being lifted. Failure of the lifting device could result in serious injury or death. Make sure to use lifting equipment that is rated at a capacity greater than the weight of the engine.

C A U T I O N

Engine stand, Kent-Moore tool number J 29109, and adapter plate J 38048, are recommended to safely support the engine during disassembly and reassembly procedures.

Avoid using an engine stand that supports the engine on the oil pan rail while the oil pan is still installed. Damage to the oil pan, pan gasket or the isolators may result. If this type of stand must be used and the oil pan is to remain installed, support the engine on the pads provided at each corner of the cylinder block as shown in Figure 127.

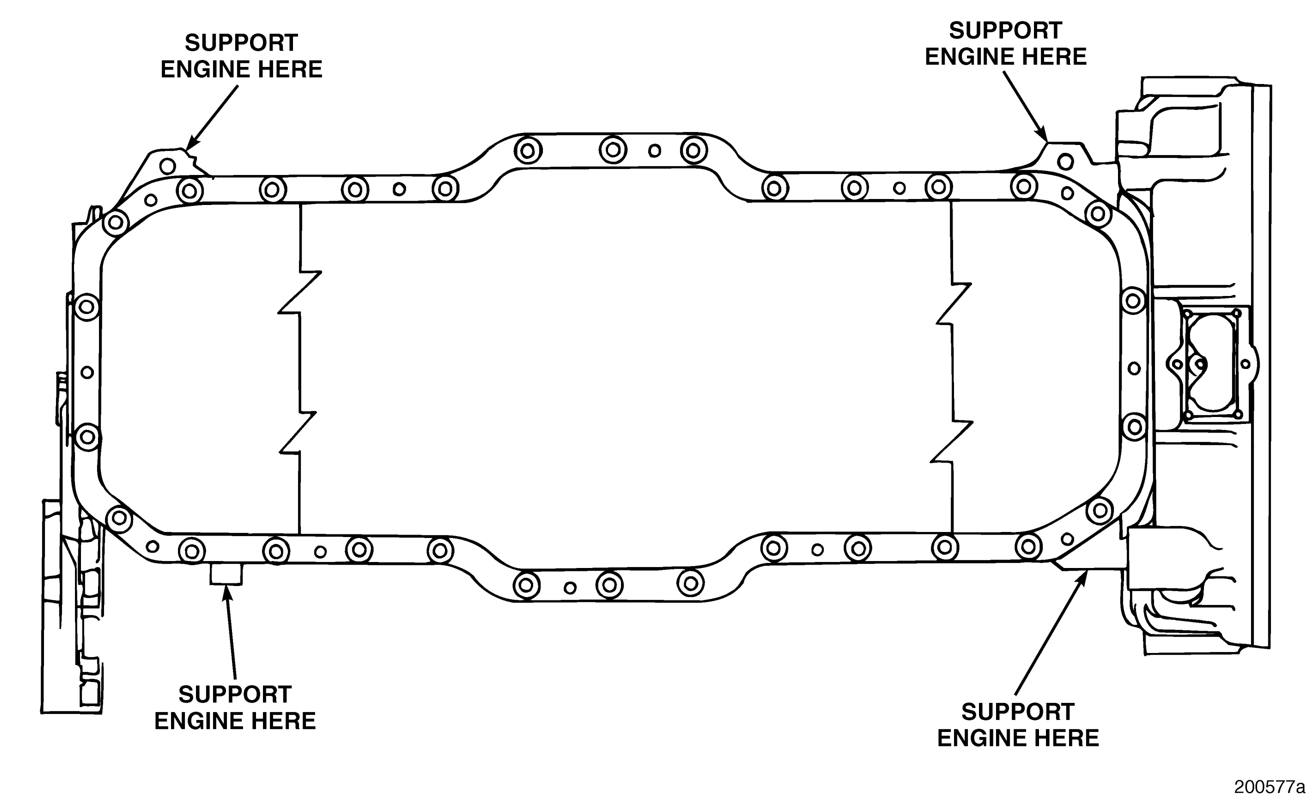

Figure 127 — Engine Support Pads

SPECIAL TOOLS REQUIRED

- Engine Stand J 29109
- Adapter Plate J 38048

PROCEDURE

Refer to Figure 128.

1. Using three mounting capscrews, secure the adapter plate J 38048 to the left side of the engine.
2. Secure the adapter plate to engine stand J 29109 with six mounting capscrews.
3. Remove the lifting device from the engine.

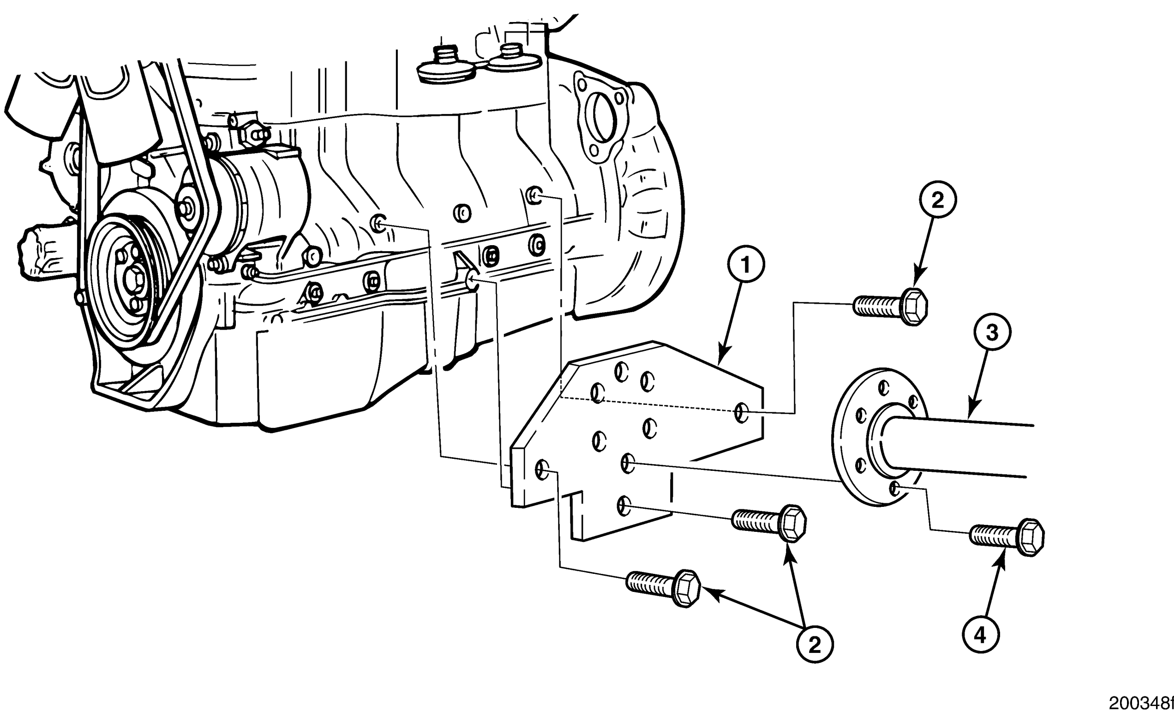

Figure 128 — Mounting Engine in Stand

1. Adapter Plate J 38048 2. Capscrews	3. Engine Stand J 29109 4. Capscrew

Alternator Removal

[271 CB]

Refer to Figure 129.

1. Loosen the adjusting capscrew and mounting capscrews.
2. Remove the poly-V drive belt(s).
3. Disconnect and tag the electrical wires.
4. Remove the mounting nuts, washers and capscrews, and remove the alternator.
5. Remove the mounting hardware and alternator plate.

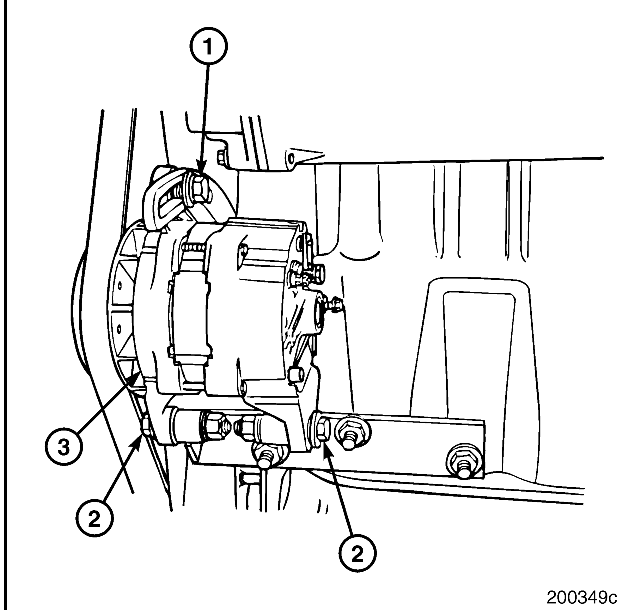

Figure 129 — Alternator Removal

1. Adjusting Capscrew 2. Mounting Capscrews	3. Alternator

Engine Electronic Control Unit (EECU) and Cooling Plate Removal

[230 EA]

NOTE

The following procedure applies for an EECU mounted to the cooling plate at the front left side of the engine.

1. Thoroughly clean and dry the area around the EECU harness connector to make sure the terminals remain clean and dry for reassembly.
2. Remove the harness retaining screw.
3. Disconnect the wiring harness connectors from the EECU (Figure 130).

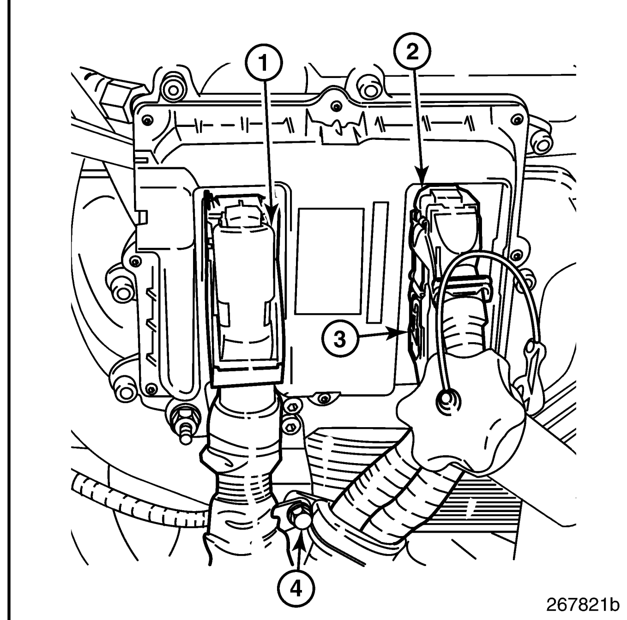

Figure 130 — EECU Connectors

1. Connector EJ2 (89 Pin) 2. Connector EJ1 (36 Pin)	3. Connector EJ3 (16 Pin) 4. Harness Retaining Screw

4. Remove the eight bolts, two each at the top, bottom and sides, that secure the EECU to the cooling plate.
5. Carefully remove the EECU from the cooling plate (Figure 131).

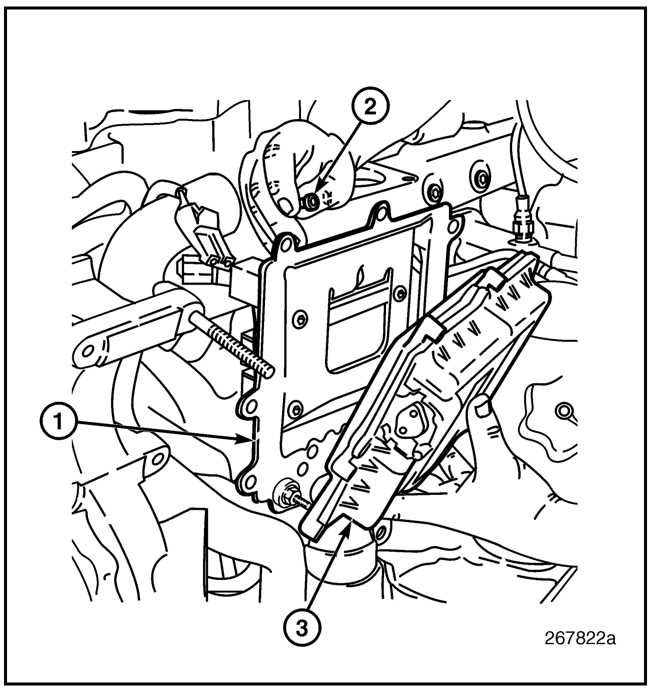

Figure 131 — EECU Removal (ASET™ AC Engine)

1. Cooling Plate 2. Retaining Bolt	3. EECU

6. Disconnect the two harness leads from the EGR MASS Flow module mounted to the back side of the cooling plate (Figure 132).

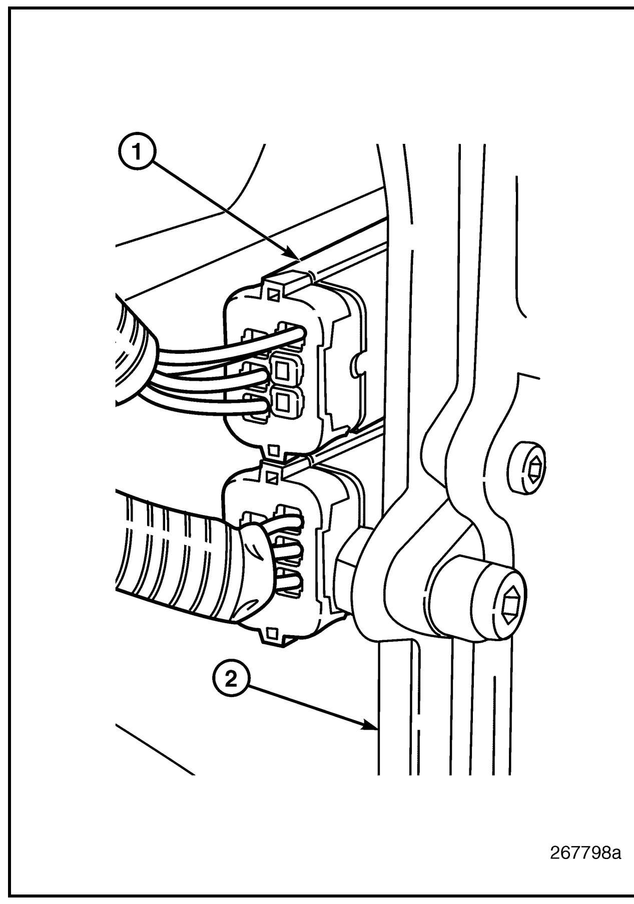

Figure 132 — EGR MASS Flow Module Connections

1. Module Connections	2. Cooling Plate

7. Disconnect the fuel lines at the inlet and outlet ports at the top of the cooling plate (Figure 133) and position the lines out-of-way.

CAUTION

Use care when disconnecting the fuel lines to avoid putting stress on the plate fittings and damaging the plate. Use two wrenches, one to support the plate fitting and the second to disconnect the line.

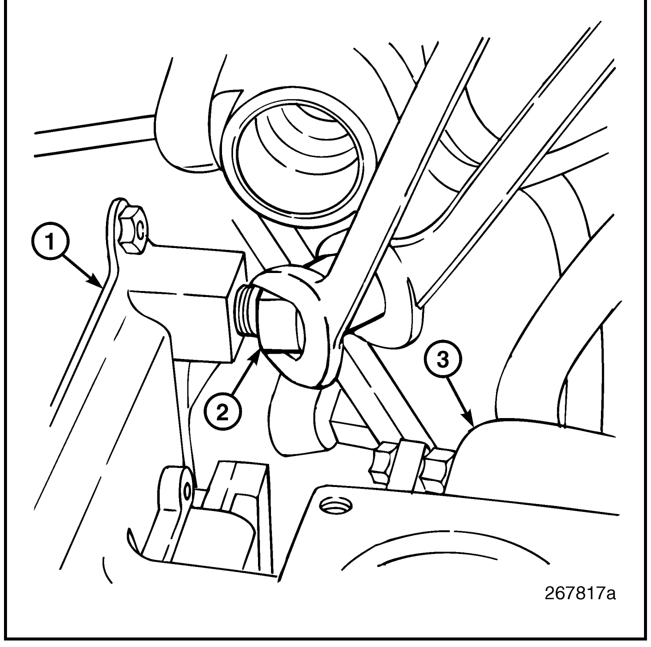

Figure 133 — Cooling Plate Fuel Lines

1. Cooling Plate 2. Fuel Line	3. Thermostat Housing

8. Loosen the two retaining nuts securing the plate support bracket to the mounting studs on top of the coolant manifold. The bracket has slotted attachment points so the retaining nuts need only to be loosened and not removed.
9. Remove the two retaining nuts from the mounting studs at the bottom of the cooling plate and remove cooling plate assembly.

EGR Gas Tube Removal

[214 HN, HP & HR]

NOTE

Effective 1st quarter 2004, the EGR cool tube is no longer a two-piece unit. The center coupling has been eliminated and the couplings at the mixer tube and EGR cooler are hose connections held in place by clamps.

The following procedure covers the removal of the EGR gas tubes in order of:

- Cool tube, one-piece assembly
- Hot tube

COOL TUBE REMOVAL (ONE-PIECE ASSEMBLY)

1. Disconnect the turbocharger oil supply line and the air line to the VTG actuator at the turbocharger (Figure 134). Plug the fittings to keep dirt and debris out.

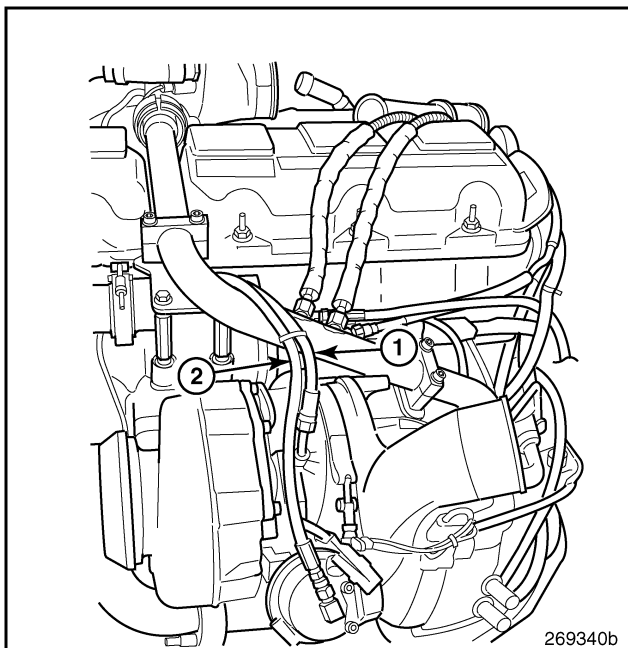

Figure 134 — Oil Supply and Air Lines

1. Turbocharger Oil Supply Line	2. VTG Actuator Air Line

2. Loosen and remove the clamps securing the cool tube to the brackets at the EGR valve and the front section of the exhaust manifold (Figure 135).

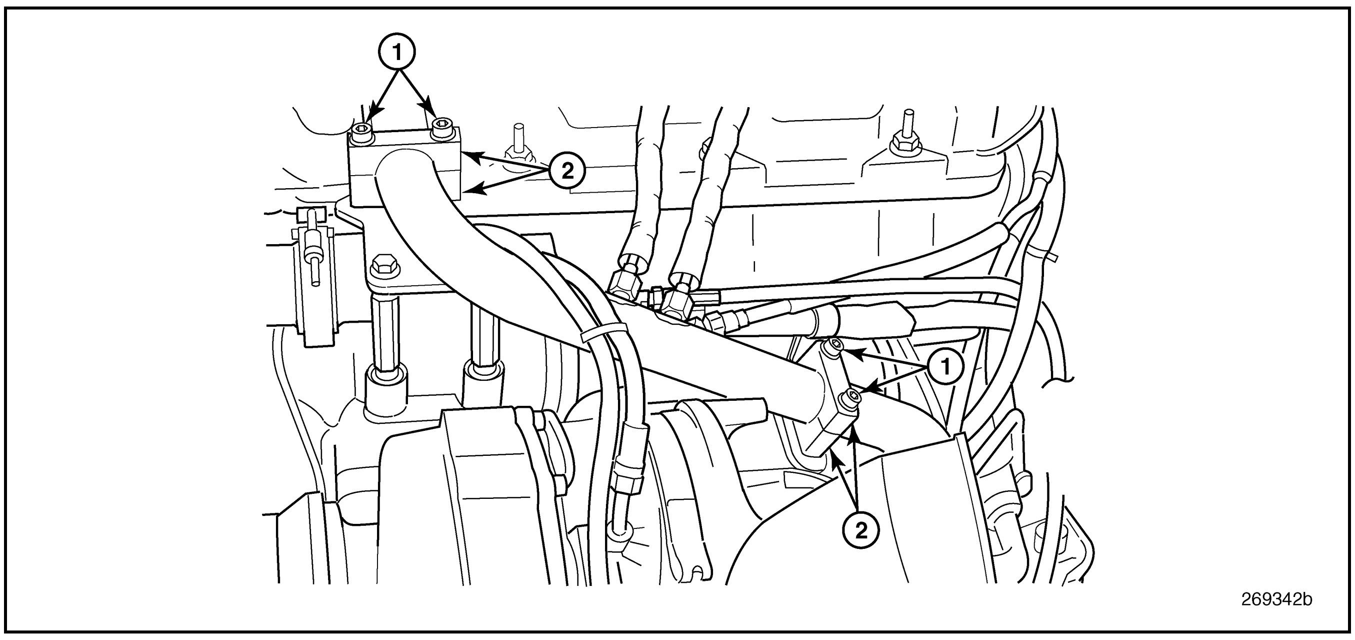

Figure 135 — Cool Tube Clamps

1. Clamp Bolts	2. Clamp, Upper and Lower Sections

3. Loosen and remove the clamps from the coupling hose at each end of the cool tube (Figure 136).

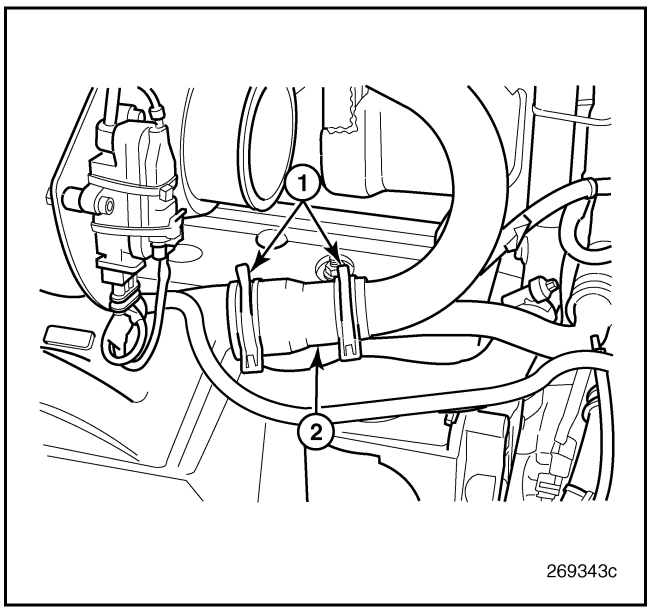

Figure 136 — Coupling Hose Clamps

1. Hose Clamps	2. Coupling Hose

4. Remove the cool tube and coupling hoses from the engine (Figure 137). Inspect the tube for corrosion or damage and the hoses for deterioration. Replace as required.

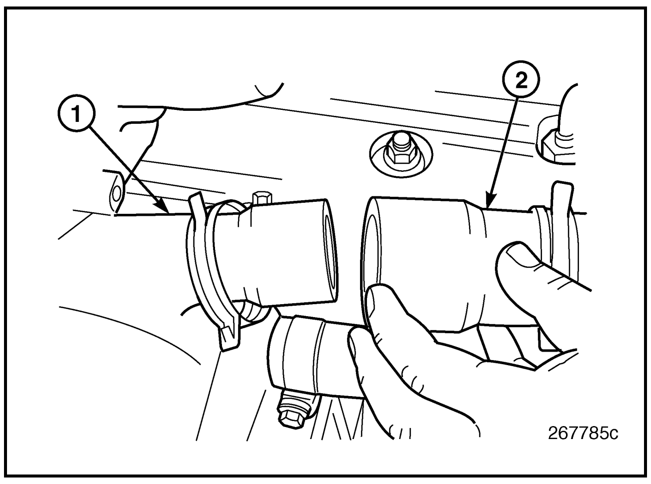

Figure 137 — Cool Tube Coupling Hose Removal

1. EGR Cooler	2. Coupling Hose

NOTE

Early-production engines will use coupling adapters in combination with the one-piece cool tube assembly. On vehicles so equipped:

- Loosen and remove the clamp from the cool tube coupling hose adapter at the EGR cooler tube mounting flange. Remove and discard the wire-mesh seal. Inspect the adapter for corrosion or damage and replace as required.
- Loosen and remove the clamp from the cool tube coupling hose adapter at the EGR mixer tube. Remove and discard the wire-mesh seal. Inspect the adapter and replace as required.

CAUTION

Do not attempt to remove the EGR MASS Flow sensors from the tube. The sensors are an integral part of the tube and must be replaced as an assembly.

HOT TUBE REMOVAL

1. Loosen and remove the clamp connecting the hot tube-to-EGR cooler inlet flange (Figure 138).

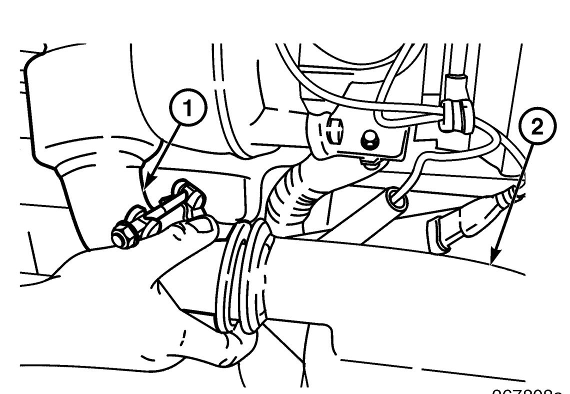

Figure 138 — Hot Tube-to-Cooler Connection

1. EGR Gas Hot Tube	2. EGR Cooler

2. Loosen and remove the clamp connecting the hot tube-to-EGR valve outlet flange. The hot tube also is fitted with wire-mesh seals in the flanges at both ends. Remove and discard the seals. Inspect the tube for corrosion or damage and replace as required.

EGR Cooler Removal

[214 HM]

1. Check to make sure that any residual coolant has been drained from the cooler. A petcock is located at the lower rear corner of the cooler to drain coolant.
2. Remove the four retaining nuts, two at each side, attaching the cooler assembly to the cylinder block and remove the assembly (Figure 139). Inspect the cooler assembly for damage and test for leaks as required.

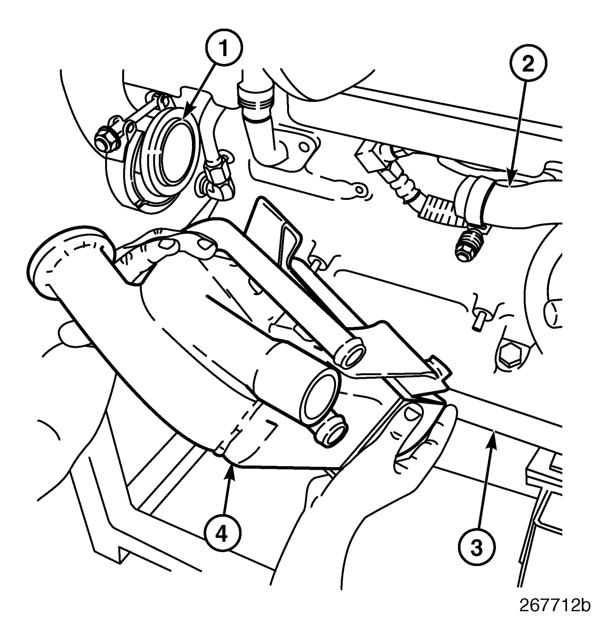

Figure 139 — EGR Cooler Removal

1. EGR Hot Tube 2. Coolant Return Hose	3. Cylinder Block 4. EGR Cooler

EGR Mixer Tube Removal

[214 HL]

1. Disconnect the electrical leads to the CMCAC outlet pressure and temperature sensors.
2. Remove the capscrew from the support bracket at the side of the EGR gas mixer tube. The bracket is attached between the mixer tube and the coolant manifold (Figure 140).

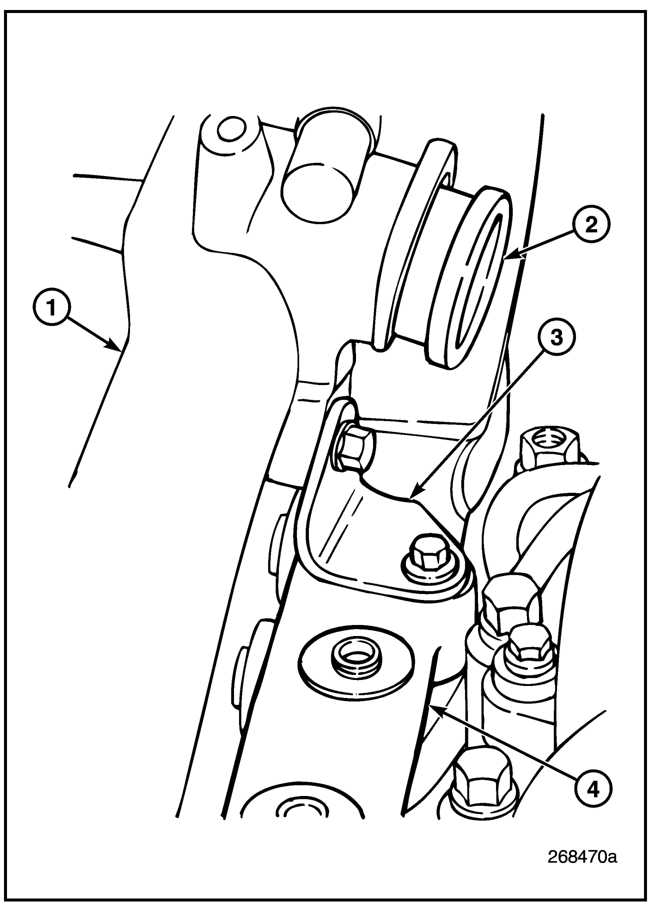

Figure 140 — Support Bracket

1. Mixer Tube 2. Cool Tube Port	3. Support Bracket 4. Coolant Manifold

3. Remove the capscrews attaching the mixer tube to the inlet manifold (Figure 141) and remove the tube.

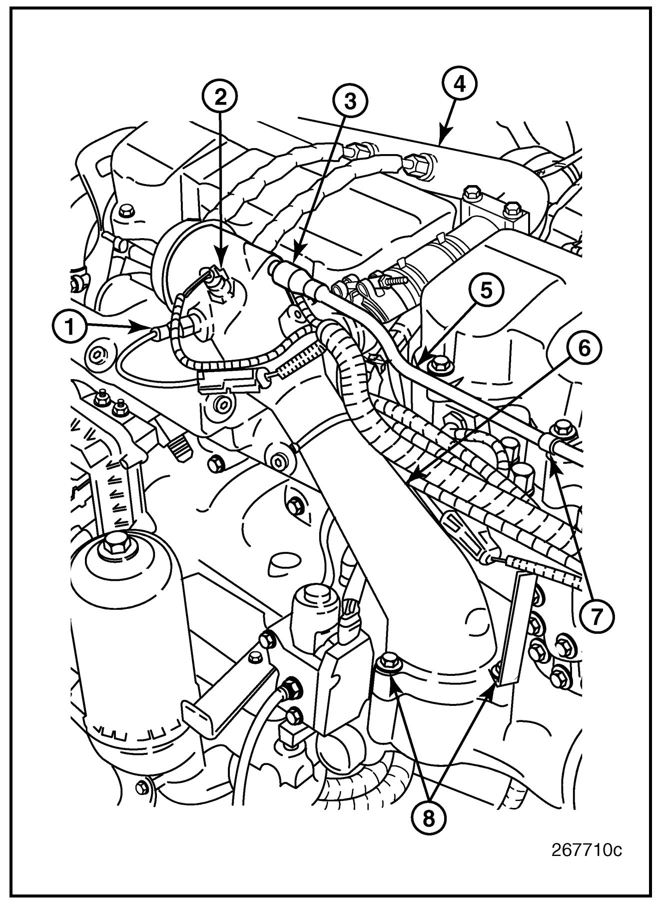

Figure 141 — EGR Gas Mixer Tube, Installed

1. CMCAC Pressure Sensor 2. CMCAC Temperature Sensor 3. Pressure Release Valve 4. EGR Cool Tube	5. Mixer Tube 6. Capscrews 7. Boost Pressure Relief Outlet Tube Clamp 8. Mixer Tube Capscrews

Thermostat Housing Removal

[215 NG]

1. Loosen the hose clamp and disconnect the by-pass hose at the front of the thermostat housing and remove the by-pass tube from the engine (Figure 142). The radiator hose and hose from the surge tank should already have been removed when removing the engine from the vehicle.

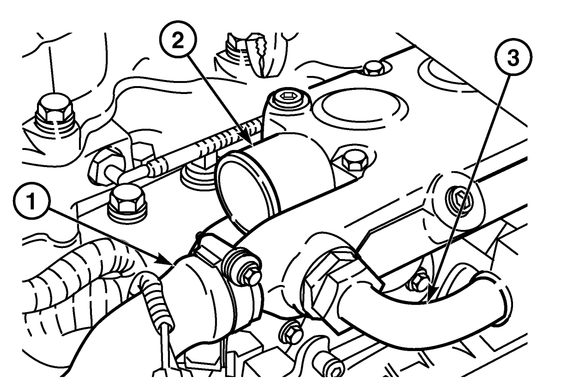

Figure 142 — Thermostat Housing Hose Connections

1. By-Pass Hose 2. Radiator Hose Port	3. Surge Tank Port

2. Remove the cab heater coolant return hose from the thermostat housing (if applicable). Also remove the optional fuel heater coolant return hose from the thermostat housing (if equipped). The cab heater and optional fuel heater coolant return hoses were relocated from the thermostat housing to the radiator lower tube during mid-2004.
3. Loosen and remove the three mounting capscrews from the thermostat housing.
4. Remove the thermostat housing assembly (Figure 143).

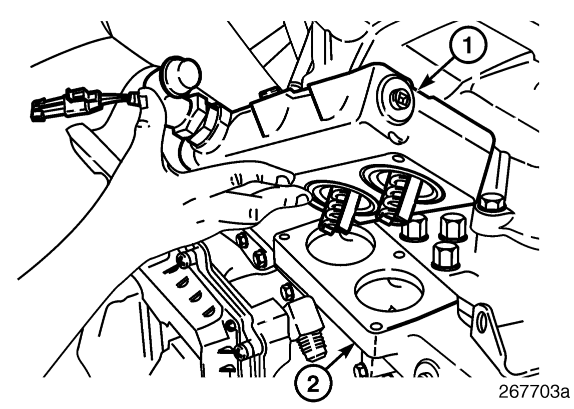

Figure 143 — Thermostat Housing

1. Thermostat Housing	2. Coolant Manifold

5. Remove the thermostats from the housing. Remove and discard the seals/O-rings.
6. Examine the surface of the thermostat sleeves and the housing bore area. Using crocus cloth, remove any surface nicks, burrs, sharp edges and tool marks from the sleeves and bore area to prevent premature failure of the seals.

Oil Supply Lines Removal

[214 HS, HT & RN]

EXTERNAL OIL SUPPLY ARRANGEMENT ASET™ AC ENGINES BUILT DECEMBER 2003 AND PRIOR

For all ASET™ AC engines produced before December 2003, the oil supply source for the EGR valve, J-Tech™ engine brake assemblies and VTG turbocharger is from the supply port on top of the oil filter mounting bracket as illustrated in Figure 144.

To remove the oil lines, first cut the stainless steel straps (if so equipped) that secure the lines together and to any support brackets. Then, disconnect the oil supply lines from the fittings at the EGR valve, junction blocks and oil filter adapter housing. Remove the lines from the engine.

NOTE

Avoid contaminating loose oil lines and fittings when disconnected. Fitting and oil line cleanliness is very important.

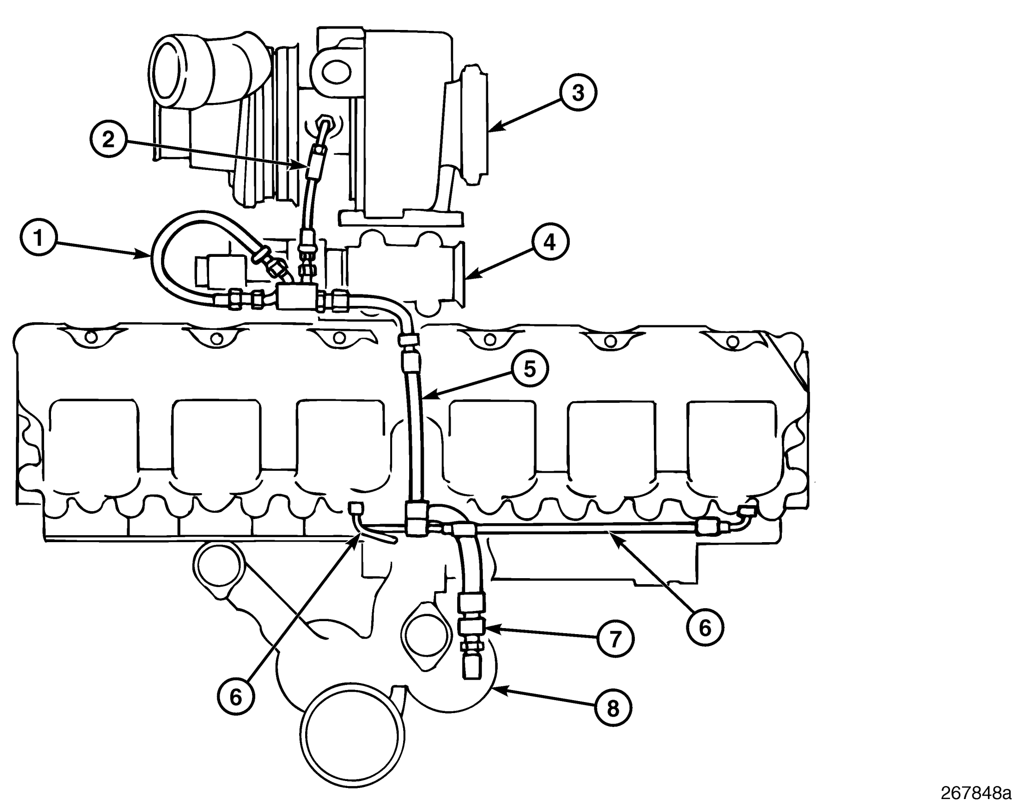

Figure 144 — EGR and VTG Oil Supply Lines (AC Engines Built December 2003 and Prior)

1. EGR Valve Supply Line, No. 6 Size 2. Turbocharger Supply Line, No. 6 Size 3. Turbocharger 4. EGR Valve 5. Supply Line, No. 8 Size (LH Junction-to-RH Junction)	6. J-Tech™ Engine Brake Supply Lines 7. Oil Supply Line, No. 10 Size J-Tech™ or No. 8 Non-J-Tech™ (Filter Bracket Oil Port-to-LH Junction) 8. Filter Mounting Bracket

EXTERNAL OIL SUPPLY ARRANGEMENT ASET™ AC ENGINES BUILT AFTER DECEMBER 2003

For all ASET™ AC engines produced after December 2003, the oil supply source for the VTG turbocharger is from the supply port on top of the oil filter mounting bracket. The oil supply for the EGR valve is now a separate oil supply line from the cylinder block oil supply port as illustrated in Figure 145. These are both direct oil lines without the use of any junction blocks or F-fitting. For J-Tech™-equipped engines, a No. 10 size line is connected between the oil filter mounting bracket and a junction block at the left side of the cylinder heads. Oil is supplied to the J-Tech™ engine brake assemblies (if equipped) from this block. A No. 6 size line passes between the cylinder heads directly to the turbocharger.

NOTE

Avoid contaminating loose oil lines and fittings when disconnected. Fitting and oil line cleanliness is very important.

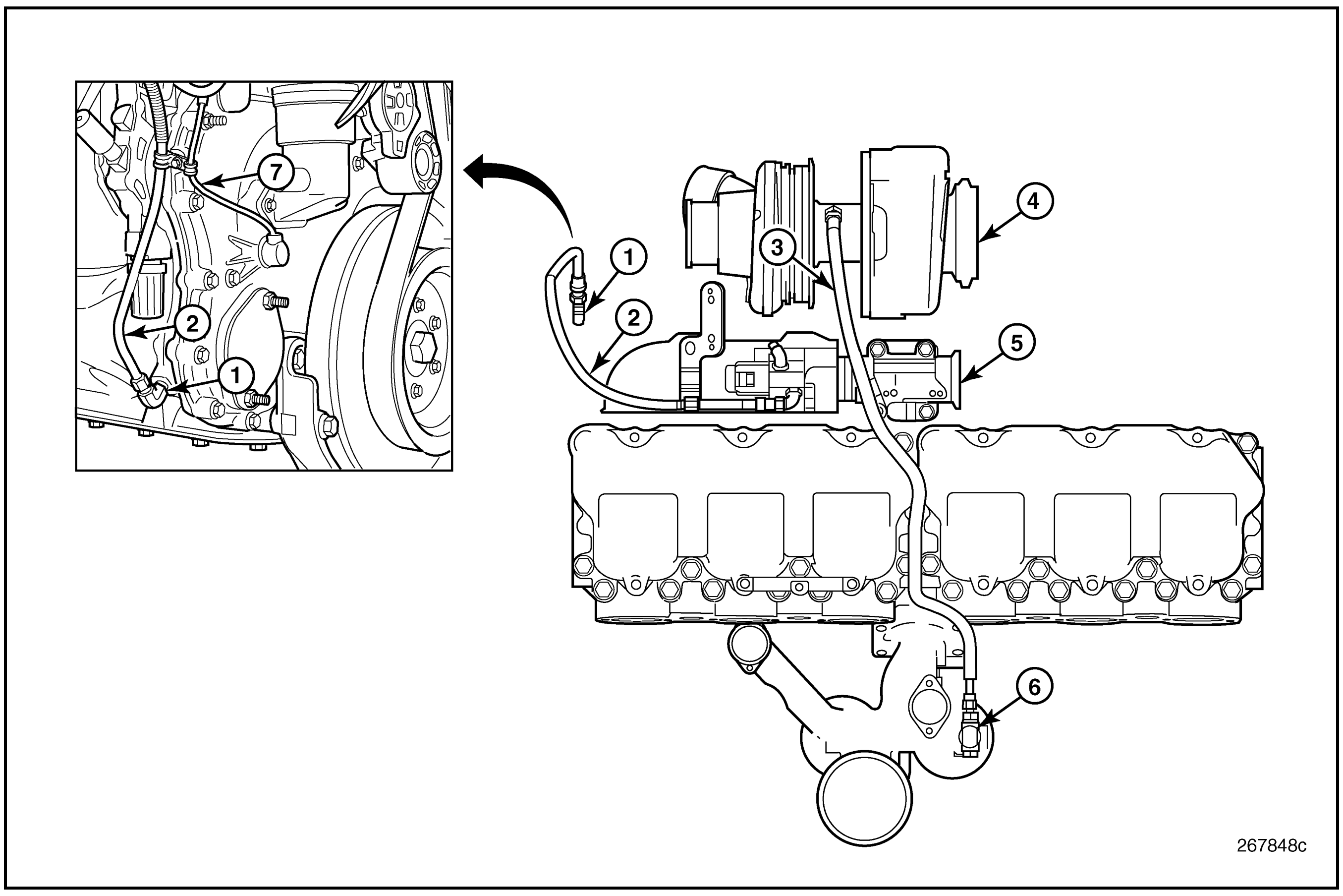

Figure 145 — EGR and VTG Oil Supply Lines (AC Engines Built After December 2003)

1. EGR Valve Oil Supply Line Fitting at Cylinder Block 2. EGR Valve Oil Supply Line, No. 6 Size 3. Turbocharger Supply Line, No. 6 Size 4. Turbocharger (VTG)	5. EGR Valve 6. Oil Supply Fitting at Filter Bracket 7. Harness (Ref.)

EGR Valve Removal

[214 QE]

1. Disconnect the electrical lead from the terminal on the EGR valve.

NOTE

Current-production engines are equipped with the one-piece cool tube assembly arrangement which utilizes spacer studs and a cool tube mounting bracket installed above the EGR valve mounting block (Figure 146. The bracket and spacers are removed before removing the valve.

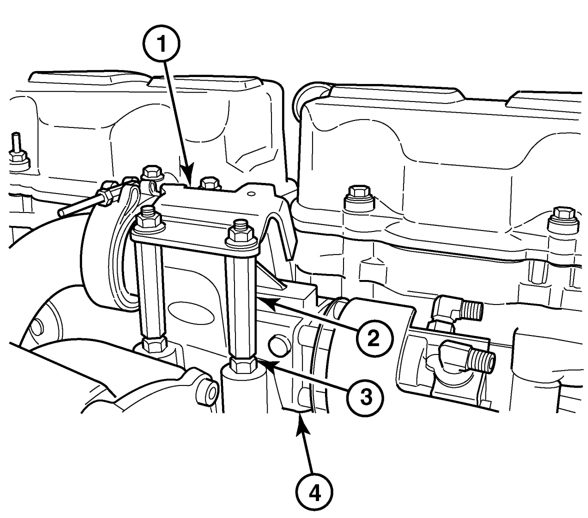

Figure 146 — EGR Valve (Shown with One-Piece Cool Tube Mounting Bracket)

1. EGR Cool Tube Upper Mounting Bracket 2. Spacer Studs	3. EGR Valve Mounting Nuts 4. EGR Valve

2. Remove the three nuts retaining the EGR valve upper mounting bracket to the spacer studs and remove the bracket and washers.
3. Remove the three spacer studs supporting the cool tube upper mounting bracket from the EGR valve mounting studs.
4. Remove the four nuts retaining the EGR valve assembly to the exhaust manifold and remove the valve assembly (Figure 147). Remove and discard the metal gasket from the manifold.

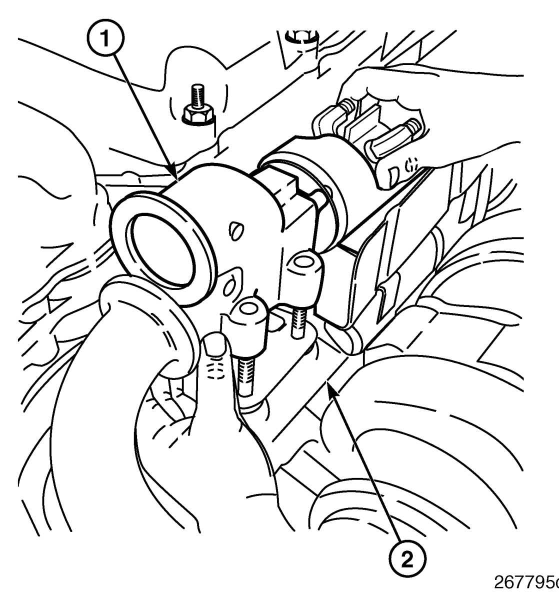

Figure 147 — EGR Valve Removal

1. EGR Valve Assembly	2. Exhaust Manifold

5. Inspect the valve assembly for damage and test as required. Replace the assembly if necessary.

Water Pump Housing Removal

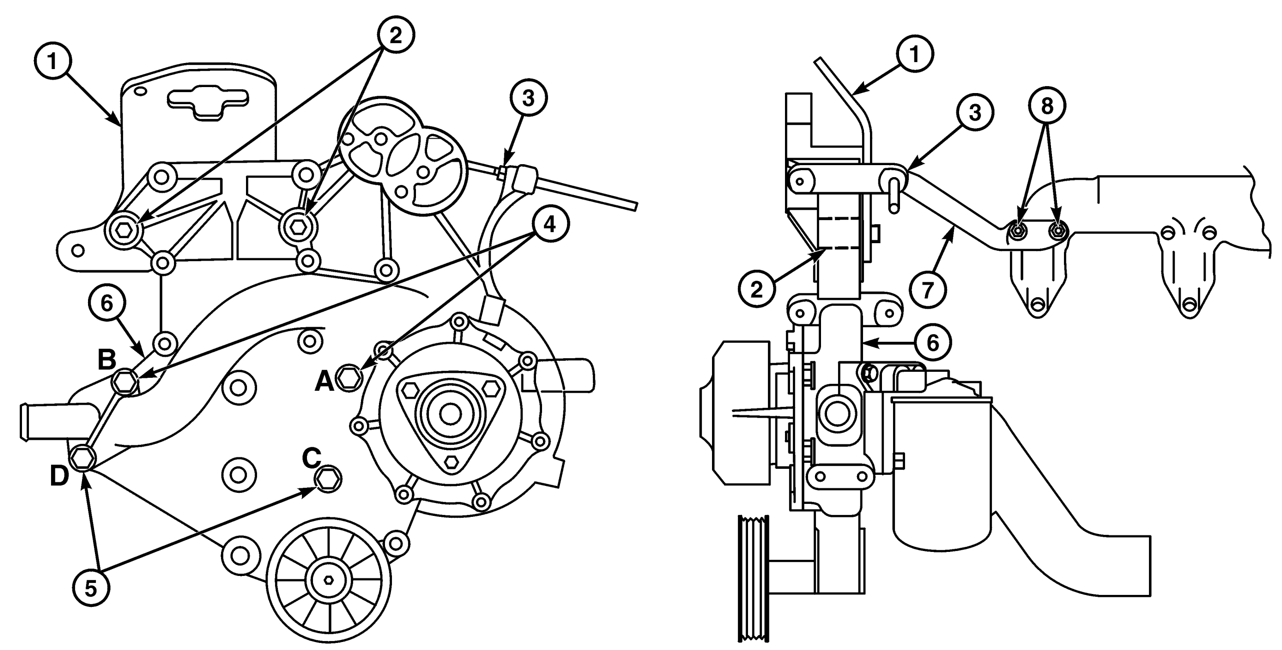

Figure 148 — Water Pump Assembly

1. Engine Lifting Bracket	5. Low-Position Mounting Capscrews
2. Threaded Inserts and Upper Mounting Capscrews	6. Water Pump Assembly
3. Stiffening Bracket Forward Mount	7. Water Pump Stiffening Bracket
4. Mid-Position Mounting Capscrews	8. Stiffening Bracket Rear Mount

If not already removed, first remove the coolant conditioner as follows:

1. Place a suitable container below the coolant filter area to catch any spilled coolant.
2. Using a suitable filter wrench, J 29927, or equivalent, remove the coolant conditioner filter element. Discard the element.
3. Remove the coolant conditioner head assembly from the pump housing by removing the mounting capscrews.
4. Remove and discard the O-rings.
5. Carefully remove and examine each check valve assembly. Depress the check ball. If the ball resists movement and does not return to its seat freely, the check valve assembly must be replaced.

To remove the pump housing, refer to Figure 149 as required to identify parts referenced in the steps below.

1. Remove the three mounting capscrews and remove the fan drive hub from the water pump housing (Figure 149).

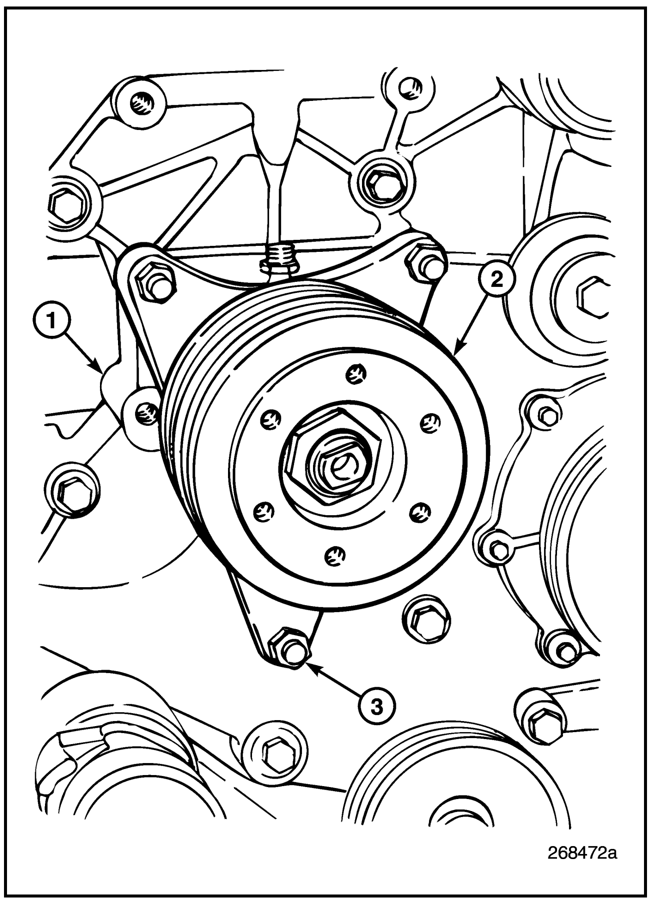

Figure 149 — Fan Drive Hub

1. Water Pump Housing 2. Fan Drive Hub	3. Mounting Bolts

2. Remove the seven mounting capscrews and remove the pump cartridge assembly from the water pump housing (Figure 150). Discard the O-ring.

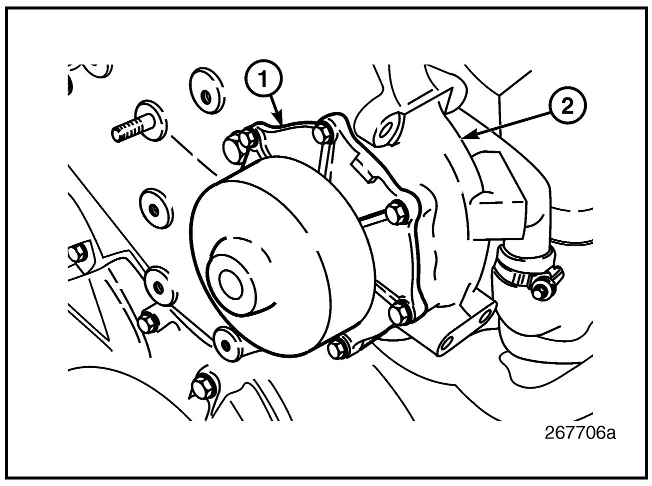

Figure 150 — Pump Cartridge Assembly

1. Cartridge Assembly	2. Pump Housing

3. Disconnect the coolant supply hose to the EGR cooler from the fitting on the water pump. Remove the hose from the engine.
4. Remove the three capscrews attaching the coolant inlet tube (from the oil cooler) to the inlet port at the back of the water pump at the left side of the engine. Remove the tube from the engine.
5. Remove the two mounting bolts from the threaded inserts at the top of the pump housing.
6. Using a suitable slotted-socket tool, remove the two inserts from the housing and remove the engine lifting bracket from between the housing and the cylinder head.

7. Remove the water pump stiffening bracket by first removing the two M8 flanged nuts from the studs at the forward position of the coolant manifold. Then remove the M8 flanged nut from the backside of the A/C compressor upper mounting stud to release the water pump stiffening bracket. Refer to Figure 148.
8. Support the pump housing and remove the two bottom mounting and two mid-position mounting bolts.
9. Remove the housing from the cylinder block (Figure 151).

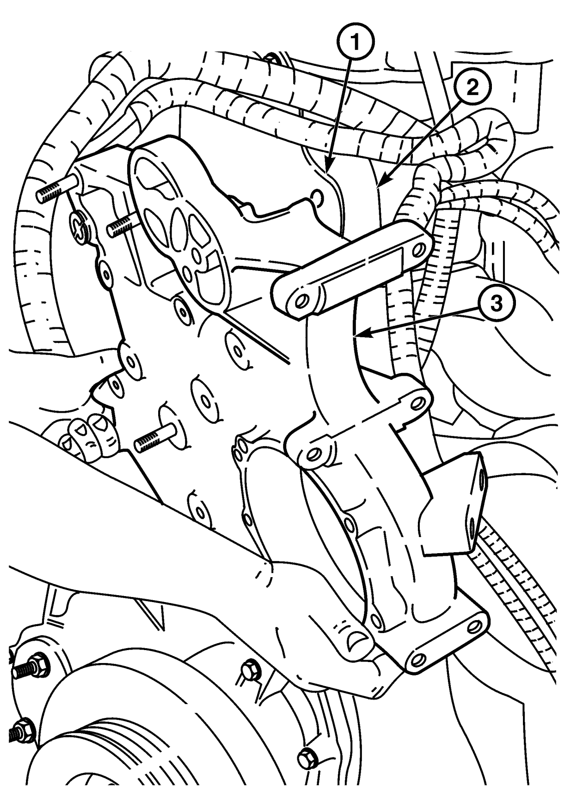

Figure 151 — Water Pump Housing Removal

1. Lifting Bracket 2. Cylinder Head	3. Water Pump Housing

VTG Position Control Valve Removal

[214 QB]

Refer to Figure 152 for reference in removing and installing the VTG position control valve.

1. Disconnect the harness electrical lead from the terminal on the control valve assembly.
2. Disconnect the VTG position actuator air line from the valve.
3. Loosen and remove the two capscrews attaching the valve to the inlet manifold. Remove the valve from the manifold.
4. Check the valve for proper operation. Replace as required.

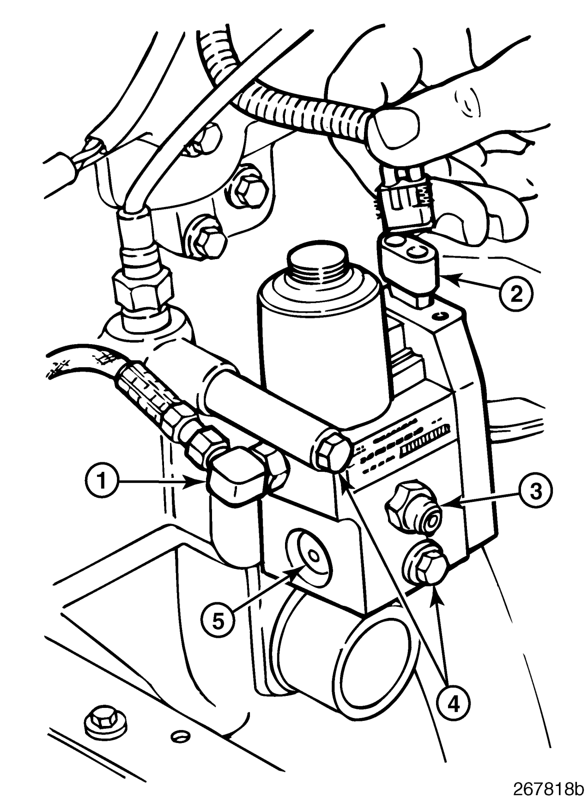

Figure 152 — VTG Position Control Valve

1. Outlet Port 2. Electrical Connector	3. Air Inlet Port 4. Mounting Capscrews 5. Air Bleed Port

Coolant Manifold Removal

[215 NK]

Refer to Figure 153.

1. Disconnect the wires to the dash gauge and V-MAC III coolant temperature sensors, and boost air temperature sensor as applicable. Position the wires out-of-way.
2. Support the coolant manifold assembly and remove the 12 flangehead capscrews retaining the assembly to the cylinder heads.
3. Remove the manifold assembly. It may be necessary to pry or tap lightly with a soft mallet on the housing to break the seal.
4. If the coolant manifold is to be replaced, remove the sensor(s) located on the manifold.

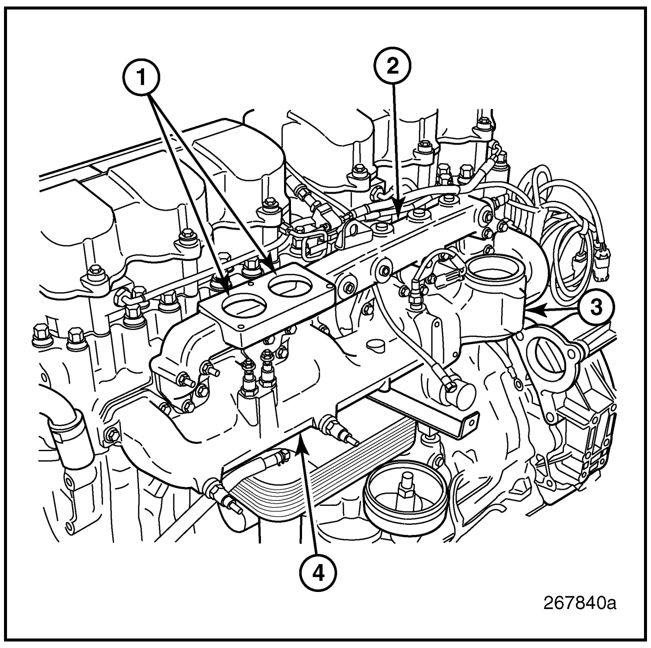

Figure 153 — Coolant and Inlet Manifolds

1. Thermostat Ports	3. Mixer Tube Mounting
2. Coolant Manifold	4. Inlet Manifold

Air Inlet Manifold Removal

[214 HD]

Refer to Figure 153.

1. Support the air inlet manifold and remove the 12 capscrews that secure the manifold to the cylinder heads.
2. Remove the air inlet manifold. It may be necessary to gently pry or tap the manifold lightly with a soft mallet to break the seal.
3. If the air inlet manifold is to be replaced, remove the inlet manifold temperature sensor located on the inlet manifold, if installed.

Turbocharger Removal

[214 SD]

Refer to Figure 154.

1. Remove the two capscrews securing the lubrication drain tube to the turbocharger.
2. Remove the two capscrews securing the drain tube to the cylinder block and remove the tube.

CAUTION

The turbocharger is heavy, weighing approximately 76 lbs. DO NOT attempt to remove or install the turbocharger without the help of an assistant or the use of a suitable lifting device.

3. Loosen the four nuts from the turbocharger mounting studs and remove the turbocharger from the exhaust manifold.

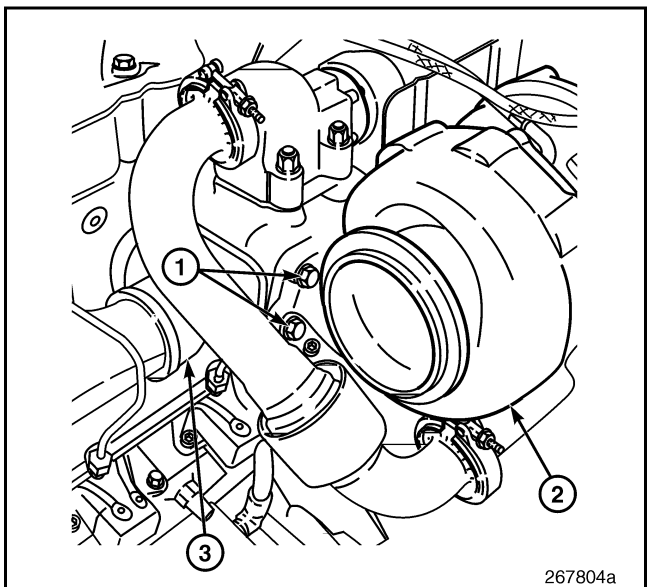

Figure 154 — Turbocharger Mounting

1. Retaining Nuts (4)	3. Exhaust Manifold (Center Section)
2. Turbocharger Assembly	

Fuel Nozzle Inlet Tube Assembly Removal

[222 KD]

1. Remove the three retaining nuts and remove the two outer EUP heat shields (Figure 155).
2. Remove the four retaining nuts securing the inner heat shield to the cylinder block and remove the shield.

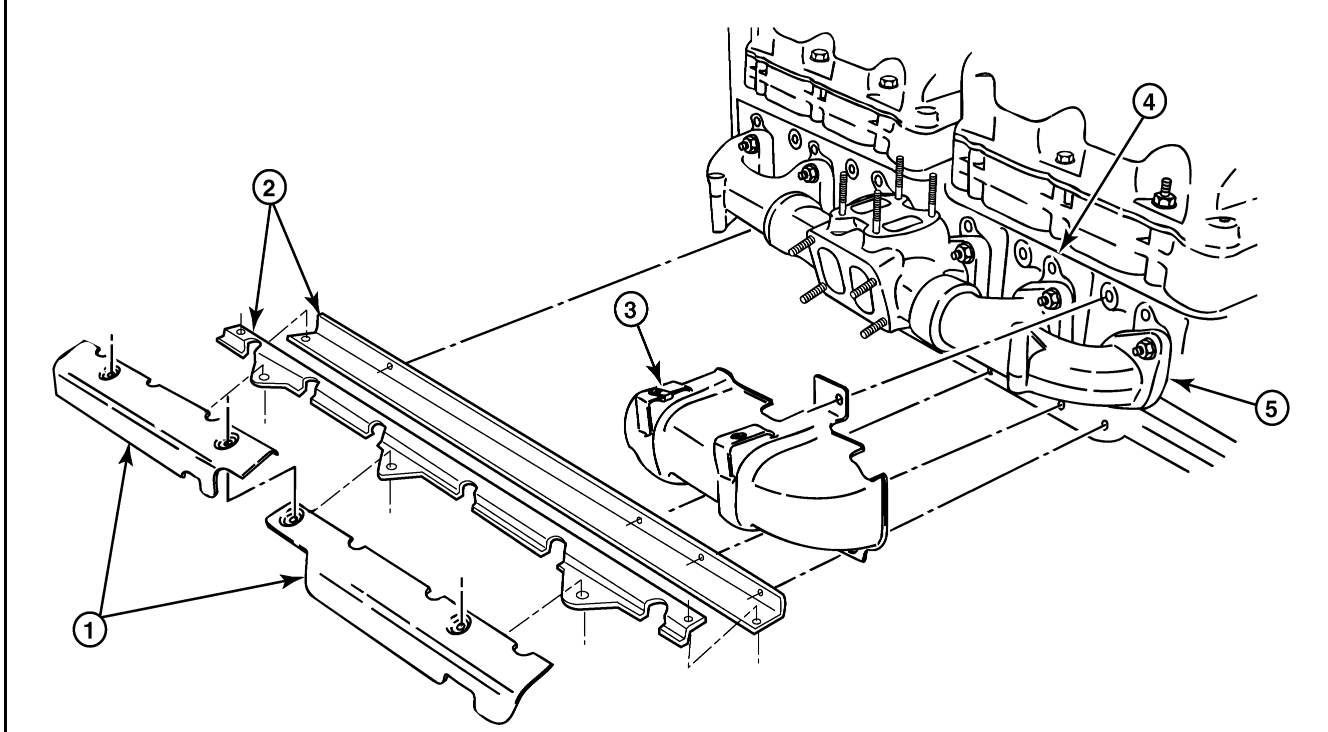

Figure 155 — EGR Valve and EUP Heat Shields

1. EUP Heat Shield (Outer) 2. EUP Heat Shield (Inner, Two Piece) 3. EGR Valve Heat Shield (Lower)	4. Cylinder Head 5. Exhaust Manifold

3. Loosen the tube line nut at the unit pump for the No. 1 cylinder (Figure 156). Be careful to avoid twisting the line while loosening the nut.

CAUTION

Fuel lines should not be bent at anytime during the removal process. Bending may result in damage to the fuel line(s). Even bending the line slightly and then bending it back to its original shape can damage the line.

4. Loosen tube line nut at the cylinder head and remove the tube assembly. Cap the line and fittings to prevent contaminants from entering the system.

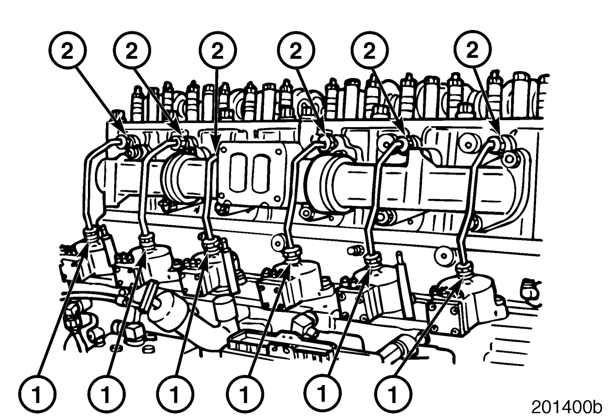

Figure 156 — Fuel Inlet Tube Assembly Removal

1. EUP Line Nut	2. Fuel Inlet Tube Line Nut

5. Repeat this procedure for the five remaining cylinders.
6. Remove the capscrew attaching the top of the EGR heat shield to the cylinder head. Remove the heat shield.

Exhaust Manifold Removal

[214 EG]

1. Support the exhaust manifold and remove the 12 mounting nuts (Figure 157) securing the manifold to cylinder heads.
2. Remove the exhaust manifold and gaskets. Discard the gaskets.

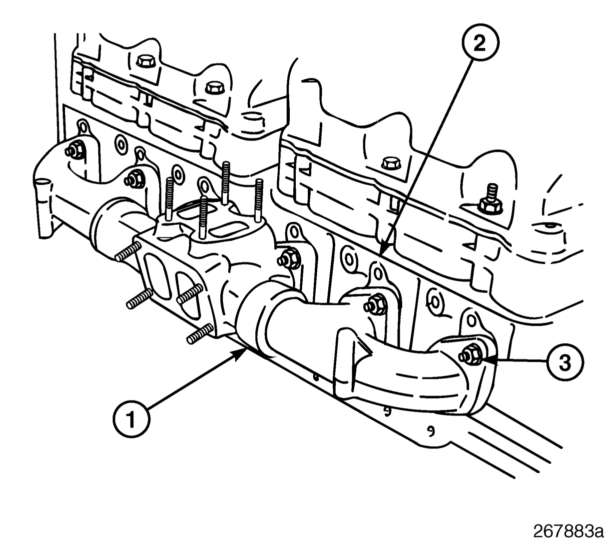

Figure 157 — Exhaust Manifold Removal

1. Exhaust Manifold 2. Cylinder Head	3. Manifold Stud/Nut

Engine Wiring Harness Removal

1. Disconnect the harness at each of the EUP terminals.
2. Disconnect the harness at the engine speed and position sensors and any remaining sensor locations not previously disconnected.
3. Remove the harness attaching hardware and remove the harness from the engine.

Electronic Unit Pump (EUP) Removal

[221 GP]

NOTE

EUPs must be paint marked with the cylinder number, and reinstalled at their original locations. This will eliminate any need to reprogram EUP information. If a **new** EUP is installed, reprogramming must be performed.

1. Place a drain pan beneath the right side of the engine. Remove the fuel-outlet fitting from the cylinder block fuel-return gallery above the air compressor. This allows fuel to drain from the internal passages.

WARNING

The EUP spring may be preloaded with significant spring tension, depending upon cam lobe position. To avoid injury from the EUP springing outward, steps 2 through 4 must be followed.

2. Remove the inboard EUP screw completely.
3. Loosen the outboard EUP screw and back it out 1/2 inch (12.7 mm).
4. Insert screwdrivers under the bolt bosses (front and rear) and pry until the EUP comes out against the screw head. (The EUP may spring out against the screw head.)

NOTE

The rapid upward movement of the EUP may result in the tappet spring retainer becoming dislodged from the plunger foot. If this occurs, simply reinstall the retainer. Refer to “Installation of Electronic Unit Pump Plunger Spring and Seat” on page 280 for installation instructions. This situation does not indicate any problem with the parts and should not occur if the above procedures are followed.

5. Remove the outboard EUP screw completely and remove the EUP from the cylinder block. Refer to Figure 158. Place the EUP in a clean area and cover it to prevent entry of dirt and other contaminants.

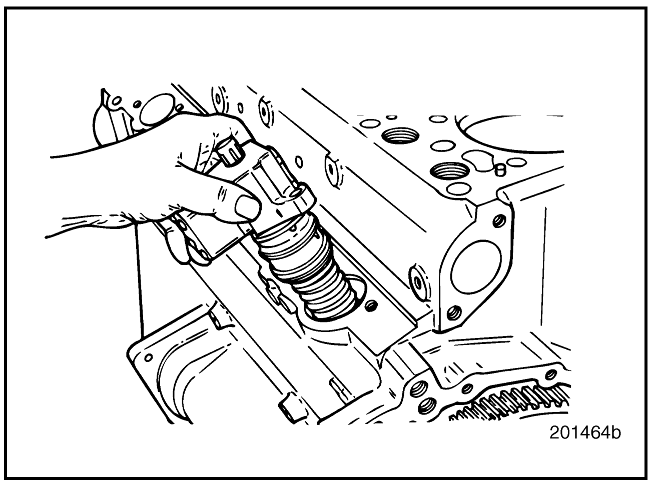

Figure 158 — EUP Removal

6. Remove the roller tappet from the EUP bore by hand (Figure 159). Do not use a tool, as it could damage the bore. Place the roller tappet in a clean area and cover it to prevent the entry of dirt and other contaminants.

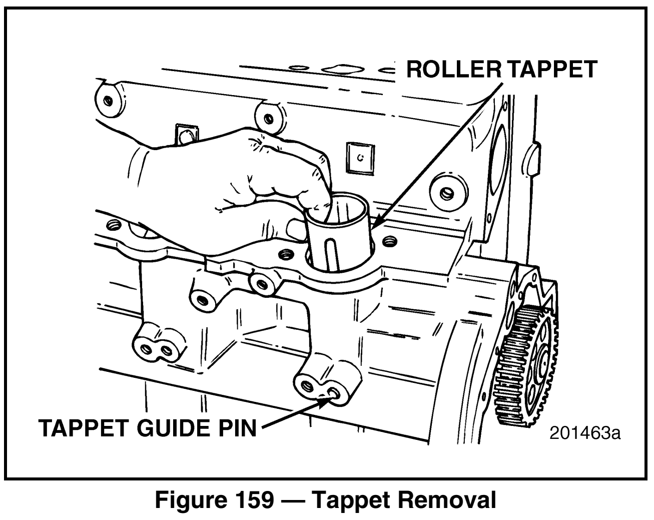

Figure 159 — Tappet Removal

Air Compressor Removal

[261 CK]

Refer to Figure 160.

Disconnect the coolant supply and return lines at the fittings on the air compressor cylinder head. Tag and cap the lines.

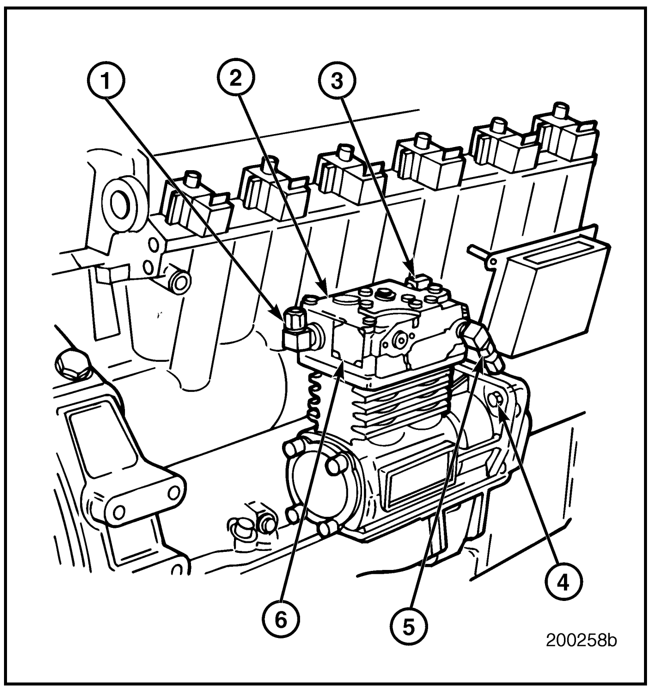

Figure 160 — Air Compressor Connections

1. Coolant Supply Line 2. Air Compressor Head 3. Coolant Return Line 4. Capscrew	5. Drain Fitting 6. Air Governor Mounting Flange

WARNING

The air compressor is heavy. Lifting the air compressor may require the help of an assistant or suitable lifting device. Attempting to lift the compressor without such assistance may result in severe personal injury.

Refer to Figure 161.

1. Remove the three mounting capscrews securing the air compressor to the auxiliary shaft housing.
2. Taking care not to damage or lose the lubrication oil supply tube, remove the air compressor by pulling it rearward out of the mounting flange. Remove and discard the gasket.

NOTE

If the oil supply tube is lost and not reinstalled, the air compressor will fail from lack of lubrication.

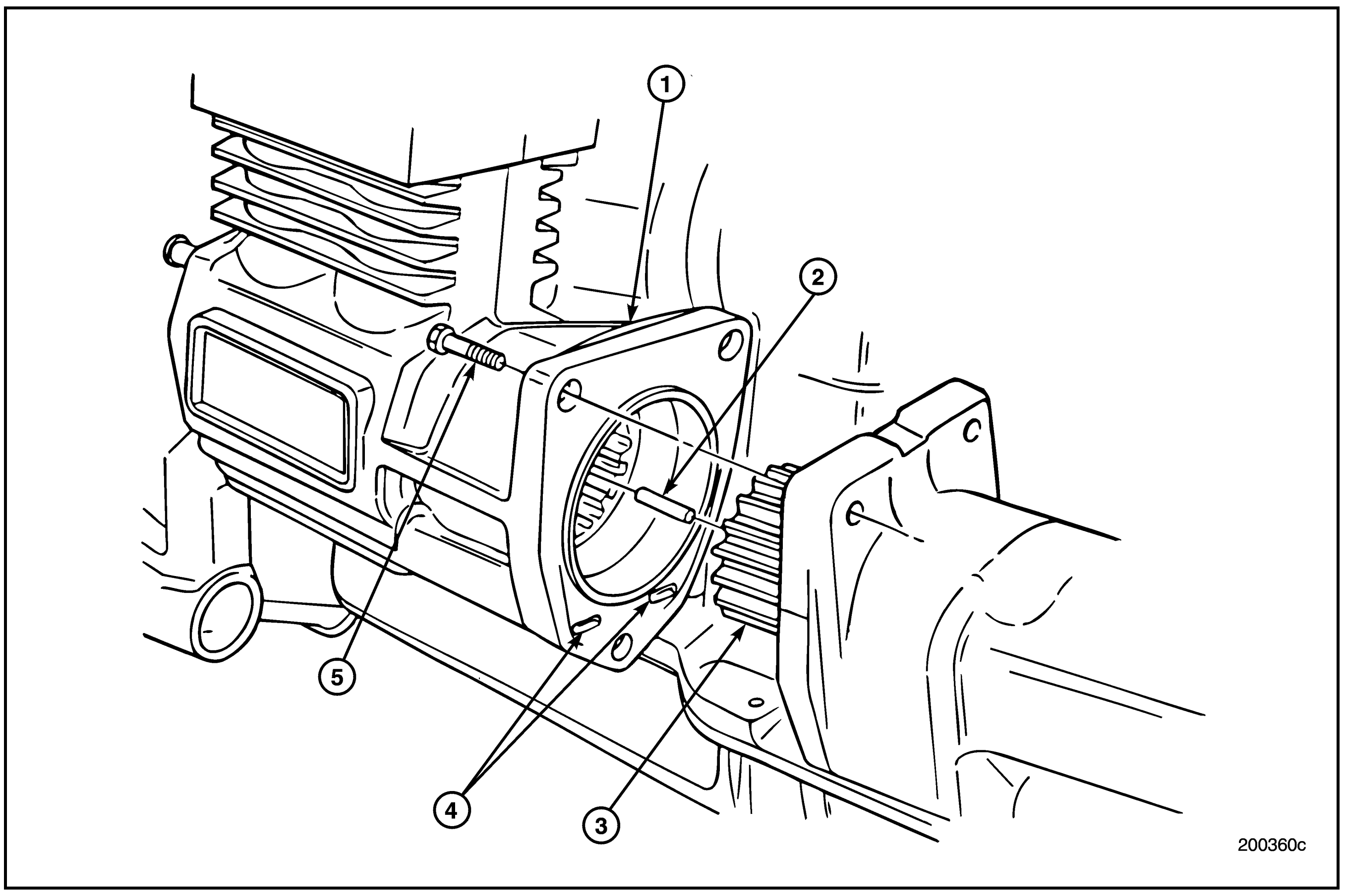

Figure 161 — Air Compressor Removal

1. Air Compressor 2. Oil Supply Tube 3. Auxiliary Shaft	4. Oil Drain Openings 5. Capscrew

Cylinder Head Cover and Spacer Removal

[213 JB]

NOTE

If the engine is equipped with a J-Tech™ engine brake, a spacer is installed under the cylinder head cover. Longer capscrews are used to secure the cylinder head cover and spacer to the cylinder head.

Engines equipped with the MACK PowerLeash™ engine brake do not have the spacer installed.

WITHOUT ENGINE BRAKE

1. Remove the cylinder head covers by removing the six retaining capscrews and isolators from each cover. Remove and discard the cover seals.

WITH MACK POWERLEASH™ ENGINE BRAKE

1. For the MACK PowerLeash™-equipped engines, unplug the wire connector from the outboard end of the cylinder head cover pass-through connector.

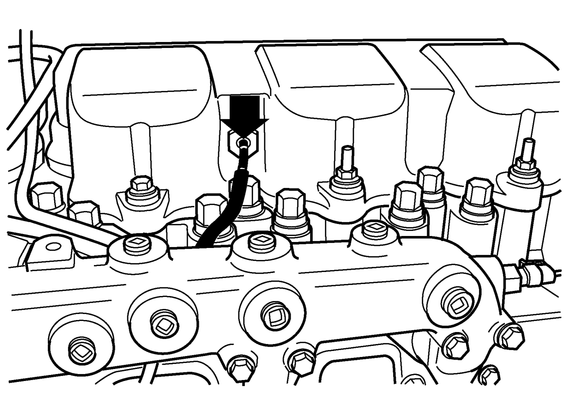

Figure 162 — PowerLeash™ Control Wire Removal

2. Remove the cylinder head covers by removing the six retaining capscrews from each cover. Also recover the cylinder cover isolators from each capscrew location.
3. For each cylinder head cover, carefully lift and tilt the cylinder head cover onto the cover's side as shown in Figure 163, being careful not to pull on the solenoid wire as the cover is being lifted. Unplug the 90-degree connector from the inside end of the cylinder head cover pass-through connector. Then, complete the removal of the cylinder head cover.

NOTE

If the solenoid wire is damaged from failure to disconnect the wire as described above, the solenoid assembly will need to be replaced.

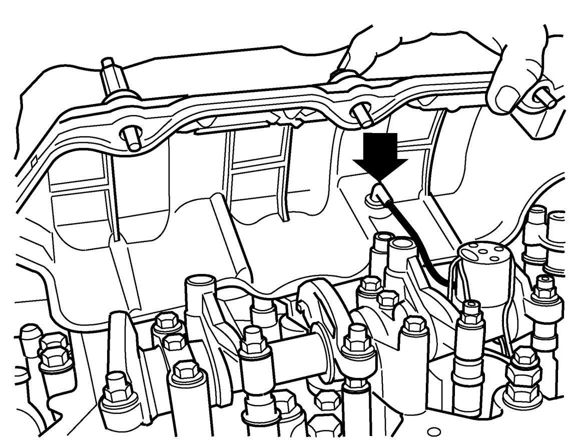

Figure 163 — PowerLeash™ Internal Control Wire Removal

SERVICE HINT

Should the cylinder head cover be removed without first disconnecting the solenoid wire from the connector on the inside of the cover, the wire can easily be damaged. Failure of the engine brake to operate (on one or both cylinder heads), or intermittent operation following removal and reinstallation of the cylinder head cover(s) is most likely caused by a damaged engine brake solenoid lead. In most cases, fault code 3-5 or 3-6 will be logged.

WITH J-TECH™ ENGINE BRAKE

1. Remove the cylinder head covers by removing the six retaining capscrews and isolators from each cover. Remove the cover and discard the cover seals.
2. Remove the control wire from the left side of each cylinder head cover or spacer housing.
3. Disconnect the wires at the actuator solenoid connector.
4. Remove the spacer housings and spacer seals.

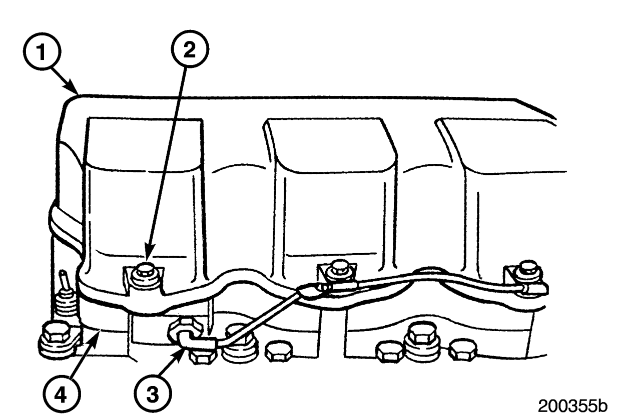

Figure 164 — J-Tech™ Cylinder Head Cover and Spacer

1. Cylinder Head Cover 2. Capscrew	3. Control Wire 4. Spacer Housing

Rocker Arm, Valve Yoke and Push Rod Removal

[213 LP, NV & LH]

ENGINES WITH J-TECH™ ENGINE BRAKE

Refer to Figure 165.

1. If the engine is equipped with a J-Tech™ engine brake, remove the six capscrews and washers retaining the brake actuator assembly and rocker arm assembly to each cylinder head.
2. Remove and mark the J-Tech™ control wire.
3. Remove the brake actuator and rocker arm assemblies from each cylinder head (one actuator and rocker arm assembly per head).
4. Remove the valve yokes from each pair of valves by lifting straight up on each yoke. Tag the yokes for reassembly in the same location.
5. Remove the valve push rods and tag the rods for reassembly.

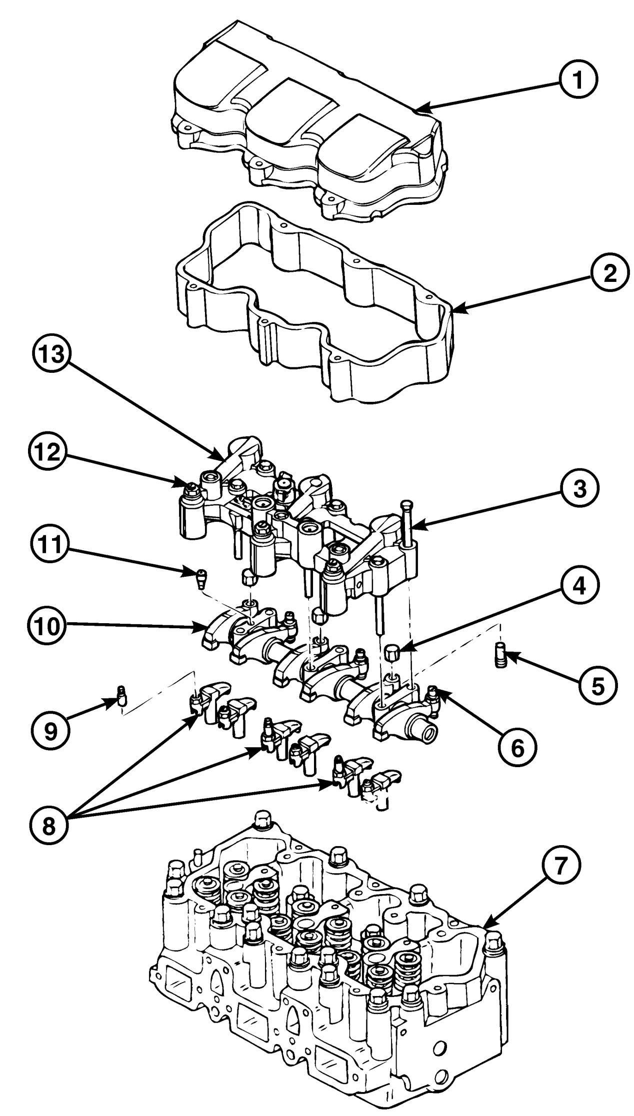

Figure 165 — Rocker Arm Shaft Assembly with J-Tech™ Engine Brake

1. Cylinder Head Cover 2. Spacer 3. Capscrew 4. Spherical Jam Nut 5. Exhaust Adjusting Screw 6. Standard Adjusting Screw and Jam Nut (Inlet Valves) 7. Cylinder Head	8. Exhaust Valve Yokes 9. Actuator Pin Assembly 10. Rocker Arm Shaft Assembly 11. Engine Brake Oil Supply Screw 12. Slave Piston Adjusting Screw 13. Engine Brake Assembly

ENGINES WITHOUT ENGINE BRAKE OR WITH MACK POWERLEASH™ ENGINE BRAKE

For engines without an engine brake and those equipped with the MACK PowerLeash™ engine brake, remove the rocker arms, valve yokes and push rods as follows:

1. Remove the six capscrews and washers retaining the rocker arm assembly to each cylinder head.
2. If the engine is equipped with a MACK PowerLeash™ engine brake, disconnect the ground and power wires.

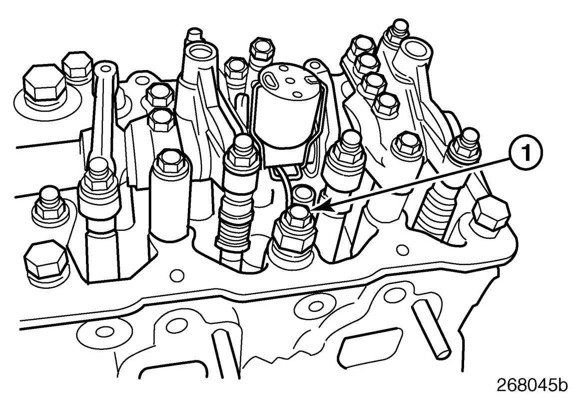

Figure 166 — Engine Brake Solenoid Ground Wire Secured to Cylinder Head Bolt

1. Ground Wire Location

3. Remove the rocker arm assemblies from each cylinder head.
4. Remove the valve yokes from each pair of valves by lifting straight up on each yoke. Tag the yokes for reassembly in the same location.
5. Remove the valve push rods and tag the rods for reassembly.

Revised Rocker Arm Shift Mounting Bolts

Effective November 16, 2005, a revised rocker shaft mounting bolt (part No. 416GC23M) was implemented into production on all ASET™ engines, replacing the previously used bolt (part No. 65AM5010). These bolts are available through the MACK Parts System, and should be used for any replacement needs for ASET™ engines.

NOTE

If any rocker shaft mounting bolts are found to be broken, all 12 mounting bolts MUST be replaced.

If loose or broken rocker shaft mounting bolts are encountered at disassembly, or if the rocker shaft is bent, contingent damage must be inspected and repaired as follows:

- Any type of valve train failure that results in excessive valve lash will generally result in a cracked or broken ceramic roller lifter. At any cylinder where the rocker shaft mounting bolts are loose or broken, or if the rocker shaft is bent, the oil pan must be removed and the engine rotated so that the cam lobe at the affected cylinder is pointed down. Inspect the lifter rollers at that location for obvious signs of roller damage. Also inspect the cam lobe for damage. Replace components as required. Additionally, if replacement of any of the lifters is required, the H-rings at the replaced lifter locations must be inspected for partial or full dislodgement and replaced as required.

  If obvious signs of damage to ceramic rollers are not evident and the lifters were not replaced, the vehicle must be driven on a short road test (for at least 1/2 hour) before being returned to service.
- Loose or broken rocker shaft mounting bolts will allow the rocker shaft to flex and eventually break. The rocker shaft may be cracked and must be replaced if the mounting bolts are loose or broken.
- If the rocker shaft is broken, the lifters must be replaced at the affected cylinder(s), and the H-rings must be inspected for partial or full dislodgement and replaced as required.

NOTE

Do not replace an entire rocker shaft assembly (which includes the rocker arms, mounting brackets, etc.) if only replacement of the shaft is required. Reuse components which are not damaged.

Nozzle Holder Removal

[222 KG]

SPECIAL TOOL REQUIRED

- Injection Nozzle Puller J 37093

SERVICE HINT

After removing the nozzles, it is a good practice to label or tag them for reinstallation into the same cylinders. After removal, place nozzles on a clean surface.

Refer to Figure 167.

1. Remove the nozzle holder retainer.
2. Assemble the injection nozzle puller J 37093 as follows:
   a. Attach the nut, bearing, spacer and rubber washer to the tool handle.
   b. Install the handle in the threaded hole of the nozzle holder until the rubber washer is slightly compressed.
3. With the tool in position, turn the nut clockwise to draw the nozzle holder from the insert in the cylinder head.
4. Continue turning the nut until the nozzle holder is free of the insert. Remove the nozzle holder and puller tool as an assembly.
5. Remove the nozzle holder gasket. The gasket is manufactured from a special iron material 0.060-inch (1.524 mm) thick.
6. Remove the remaining nozzle holders in the same manner.

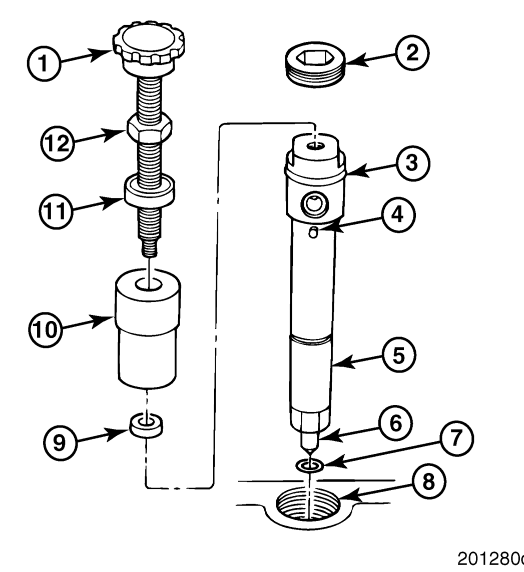

Figure 167 — Nozzle Holder Removal

1. Handle	7. Gasket
2. Nozzle Holder Retainer	8. Nozzle Mounting Hole
3. O-Rings	9. Rubber Washer
4. Alignment Pin	10. Spacer
5. Nozzle Holder	11. Bearing
6. Nozzle	12. Nut

Cylinder Head Assembly Removal

[213 EV]

Refer to Figure 168.

1. Remove the 20 mounting bolts from each cylinder head.

WARNING

Cylinder head assemblies are heavy. Lifting a cylinder head requires the help of an assistant or suitable lifting device. Attempting to lift a cylinder head without assistance may result in severe personal injury.

2. Using a suitable lifting device, remove the heads from the cylinder block.
3. Remove the gaskets and six fire rings. Discard the gaskets and fire rings.

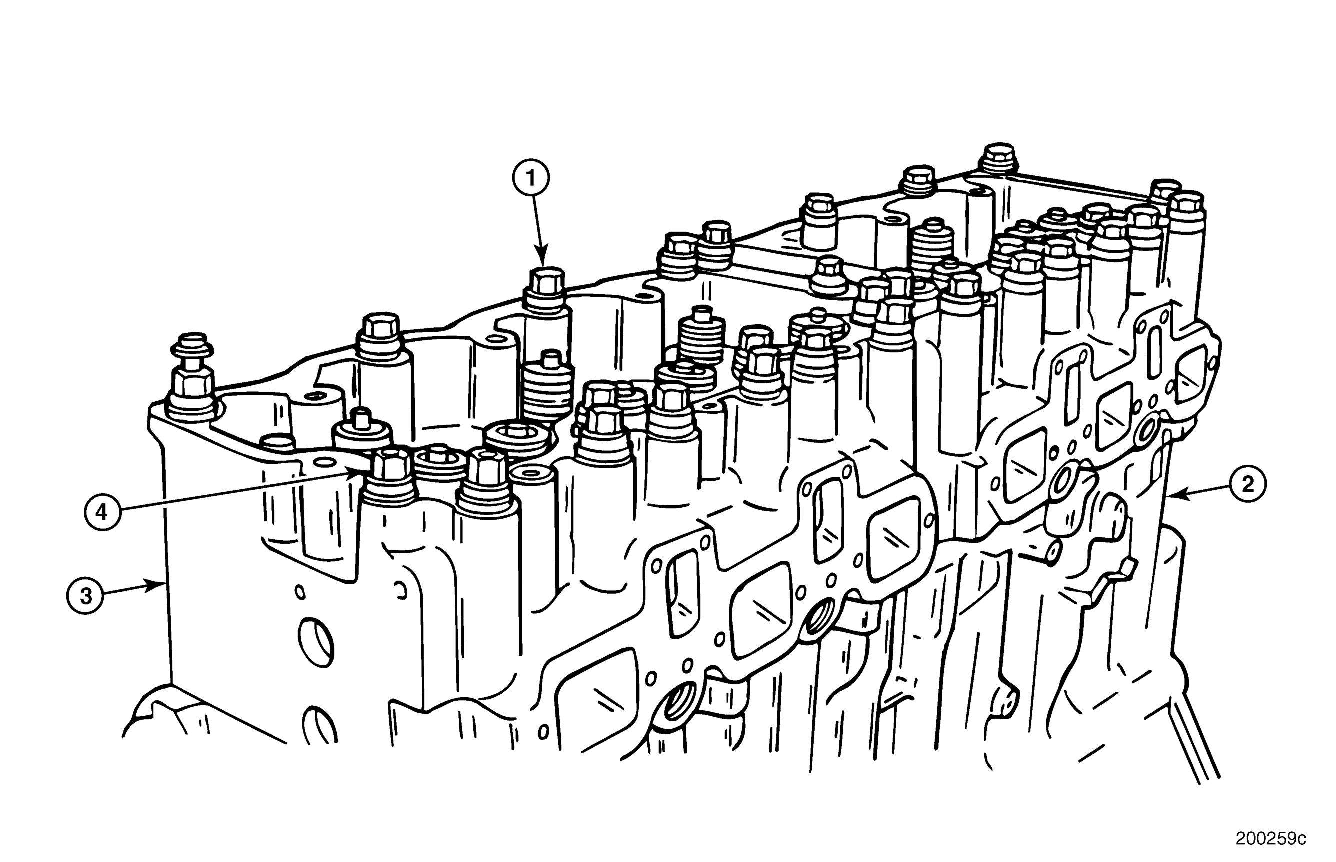

Figure 168 — Cylinder Heads

1. Bolt 2. Cylinder Block	3. Cylinder Head 4. Bolt (with Bracket Mounting Capscrew Hole in Head)

Vibration Damper and Crankshaft Hub Removal

[212 RB, RH]

1. Remove the capscrews attaching the vibration damper to the crankshaft hub (Figure 169). Six or 12 capscrews may be used to mount the damper to the hub depending on date of production.

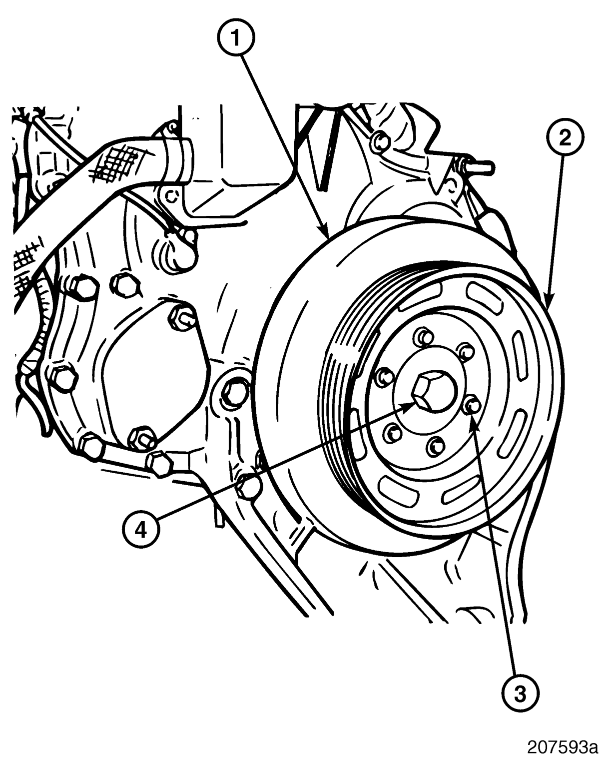

Figure 169 — Vibration Damper Removal

1. Vibration Damper 2. Pulley	3. Mounting Capscrews 4. Hub Capscrew

2. Remove the vibration damper and fan belt drive pulley together.
3. Using a suitable wrench, remove the crankshaft hub capscrew.
4. Using a suitable puller such as J 24420-C, remove the crankshaft hub (Figure 170).

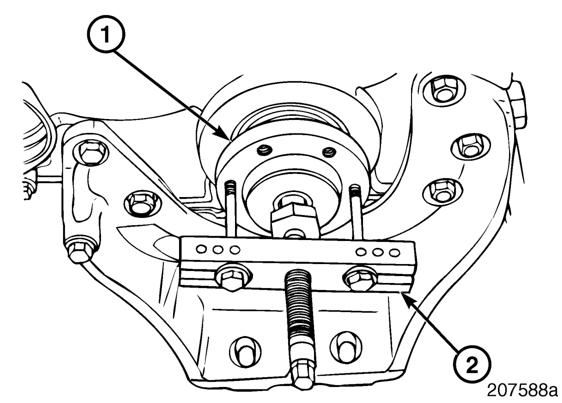

Figure 170 — Crankshaft Hub Removal

1. Crankshaft Hub	2. Puller

Oil Pan Removal

[211 NB]

WARNING

Make sure all loose components are secured to, or removed from, the engine before rotating the engine on the stand. Failure to do so may result in damage to components or severe personal injury.

Refer to Figure 171.

1. Rotate the engine so that the oil pan rail is upward (engine inverted).
2. Remove the two shouldered bolts securing the oil pan to the front cover.
3. Remove the two shouldered bolts securing the oil pan to the flywheel housing.
4. Remove the remaining integral hex-head shouldered studs and shouldered bolts securing the oil pan to the pan rails. Remove the oil pan.

NOTE

The oil pans are secured with shouldered bolts at the timing cover and flywheel housing and a combination of shouldered bolts and integral hex-head shoulder studs (one piece) along the pan rails.

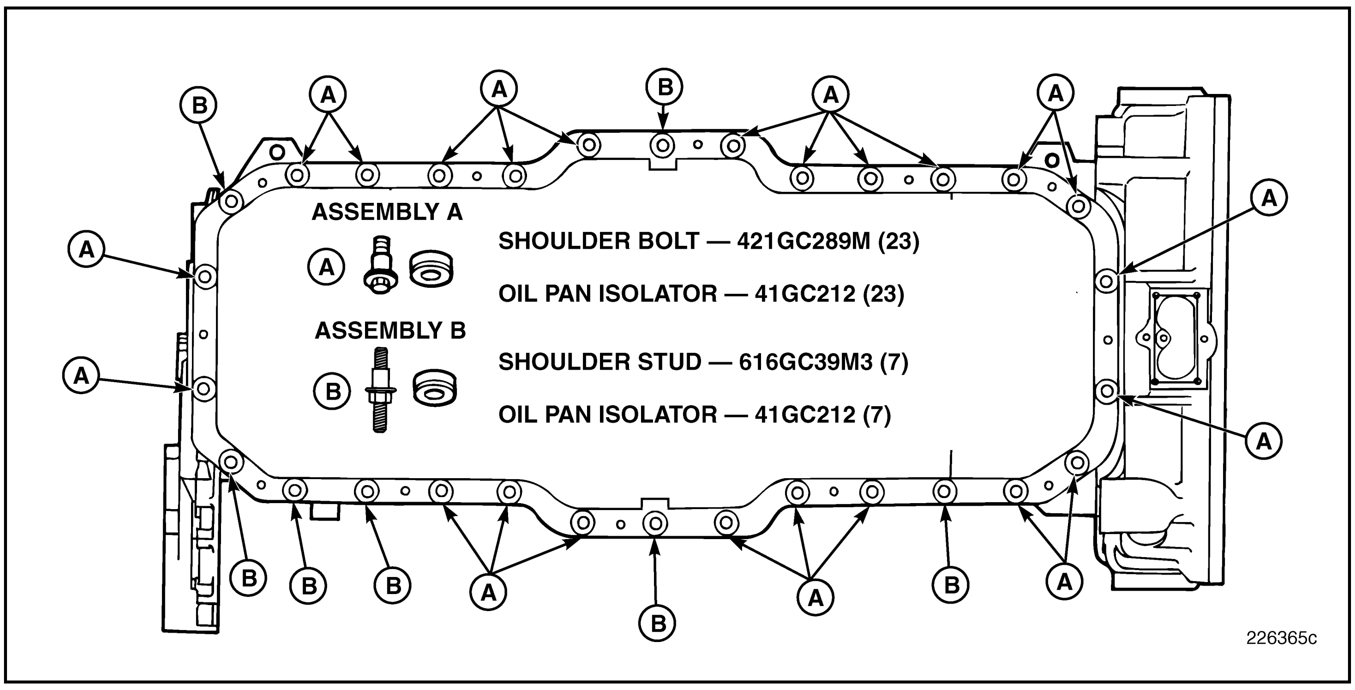

Figure 171 — Isolating Oil Pan Hex-Head Shoulder Bolt (A) and Shoulder Stud (B) Locations

Oil Pump Removal

[219 MU]

Refer to Figure 172.

SERVICE HINT

If the oil pump must be disassembled for any reason, it will be easier to loosen the housing cover retaining capscrews, the screen, the oil inlet tube capscrews, the cover plate capscrews, and the relief valve cap while the pump is still secured in position. Do so before loosening the three retaining capscrews.

The screen for the oil inlet tube is held in place by a steel retainer ring.

Remove the oil pump as a unit by removing the three retaining capscrews.

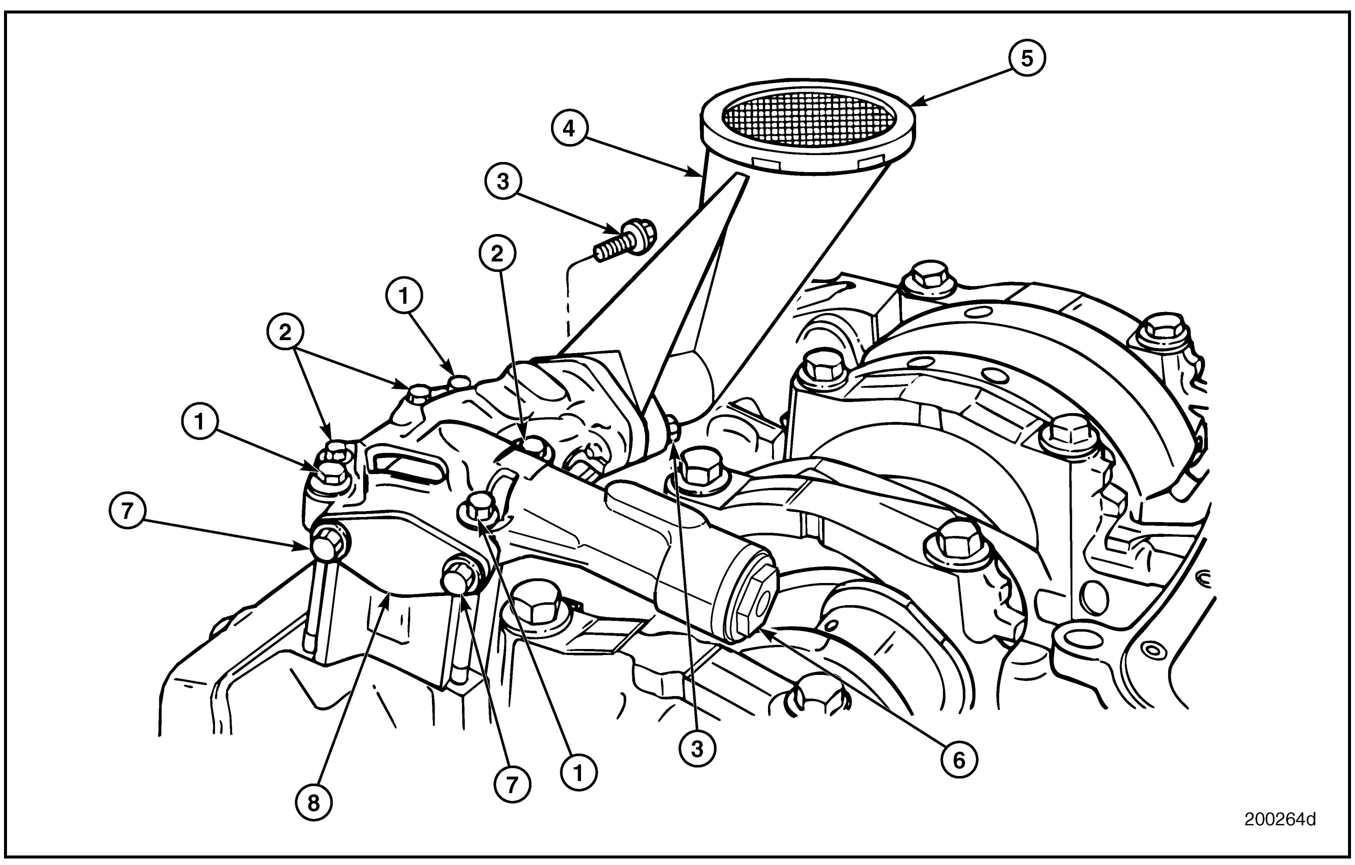

Figure 172 — Lubrication System Oil Pump

1. Pump Mounting Capscrews	5. Screen
2. Capscrews	6. Relief Valve Cap
3. Capscrews, 12-Point	7. Capscrews
4. Oil Inlet (Pickup) Tube	8. Plate

Front Cover Removal

[211 RP]

The engine can remain inverted on the stand or rotated with the cylinder deck up for removal of the front cover and auxiliary shaft if preferred.

1. Remove the front engine mount pedestal by removing the six retaining capscrews. Refer to Figure 173.
2. Remove the remaining mounting capscrews from the front cover.
3. Remove the front cover. It will be necessary to pry the cover from the engine block. Be careful not to damage the cover or block while using sharp tools around the machined surfaces.
4. Remove the crankshaft seal from the cover and discard the seal.

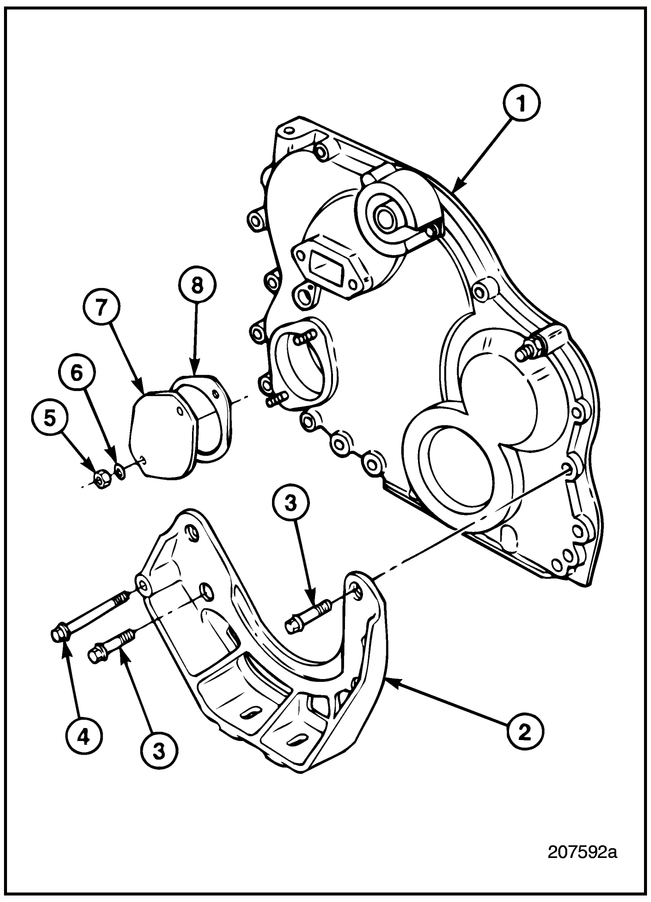

Figure 173 — Front Cover Removal

1. Front Cover 2. Pedestal 3. Capscrew (Short) 4. Capscrew (Long)	5. Nut 6. Washer 7. Cover 8. Gasket

Auxiliary Shaft Removal

[212 CV]

Refer to Figure 174.

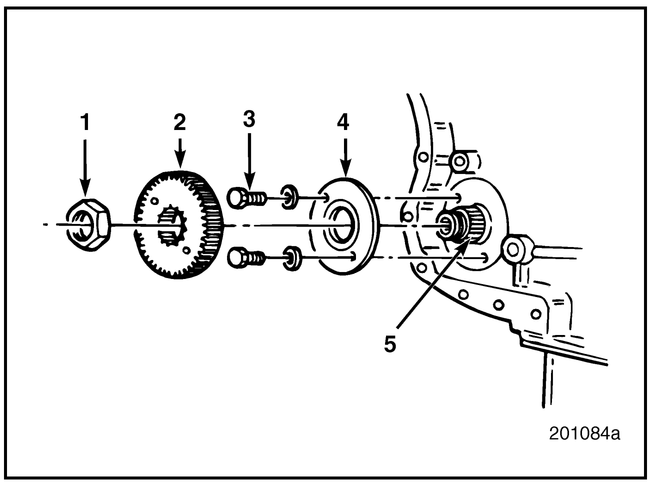

Figure 174 — Auxiliary Shaft Gear

1. Nut 2. Auxiliary Shaft Gear 3. Capscrew	4. Captured Thrust Washer 5. Shaft Splines

1. Remove the auxiliary shaft gear retaining nut.
2. Using a suitable puller such as J 4558-01, remove the auxiliary shaft gear from the splines on the end of shaft (Figure 175).

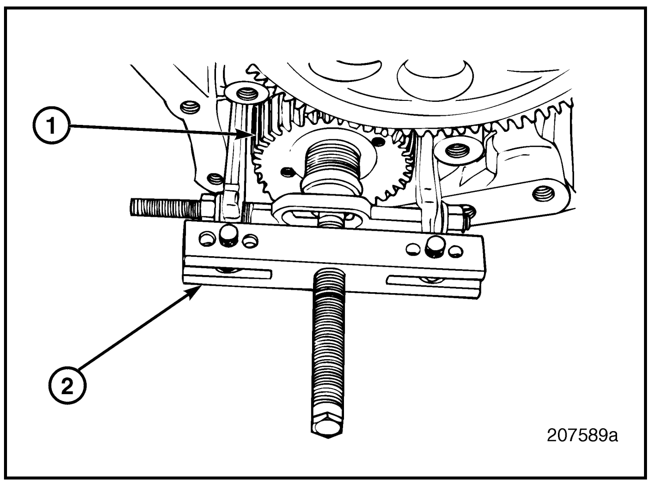

Figure 175 — Auxiliary Shaft Gear Removal

1. Auxiliary Shaft Gear	2. Puller

3. Remove the two retaining capscrews from the auxiliary shaft captured thrust washer. Remove the thrust washer.

CAUTION

Be very careful to avoid damaging the auxiliary shaft bushings or journals (Figure 176) while removing the shaft.

4. Remove the auxiliary shaft by pulling it rearward out of the air compressor mounting flange opening. If the engine oil pump is not removed, a rotating motion may be necessary to clear the engine oil pump drive gear.

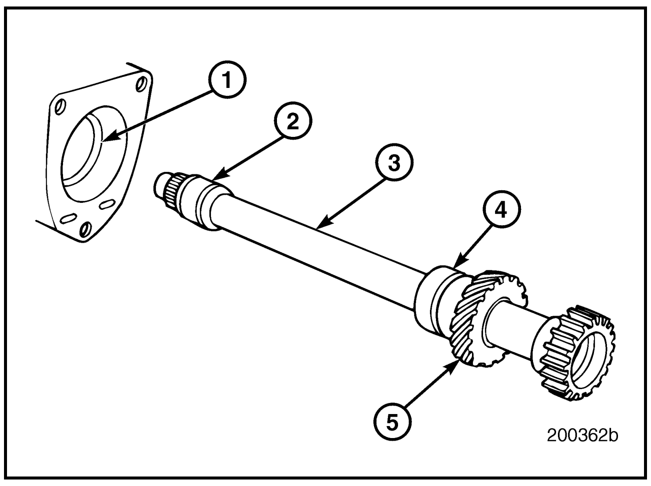

Figure 176 — Auxiliary Shaft Removal

1. Rear Bushing 2. Front Journal 3. Auxiliary Shaft	4. Rear Journal 5. Oil Pump Drive Gear

Camshaft Removal

[213 CH]

WARNING

Make sure all loose components are secured to, or removed from, the engine before rotating the engine on the stand. Failure to do so may result in damage to components or severe personal injury.

1. If not already done, rotate the engine so that the oil pan rail is upward (engine inverted).

NOTE

When the engine is rotated, the roller valve lifters will fall downward into the push rod holes and rest against the H-rings. They will be out of the way for removal of the camshaft.

2. Remove the three bolts retaining the idler gear hub to the cylinder block and remove the gear and hub.
3. Remove the two 12-point capscrews that retain the camshaft thrust washer. The camshaft may have to be rotated slightly to make the capscrews accessible through openings in the camshaft drive gear (Figure 177).

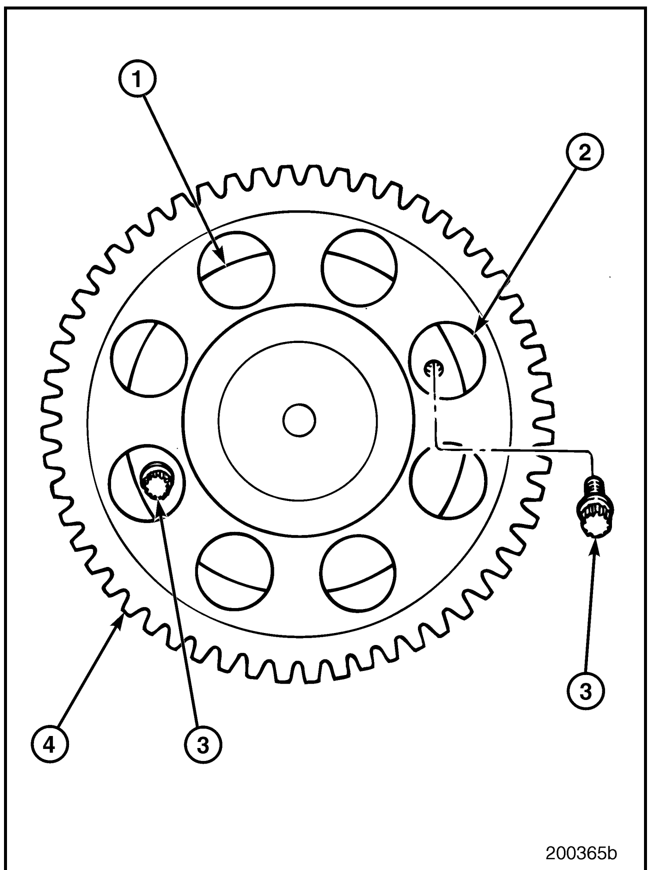

Figure 177 — Camshaft Thrust Washer Capscrews

1. Thrust Washer 2. Openings	3. Capscrew, 12-Point 4. Camshaft Drive Gear

4. Install the camshaft removal/installation tool J 41682 (Figure 178) in position on the rear segment of the camshaft, securing it to the shaft with the clip.

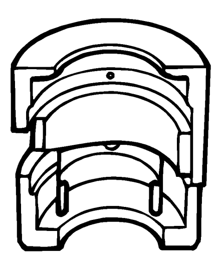

Figure 178 — Camshaft Installation Guide

5. Taking care not to damage the camshaft or bushings, pull the camshaft out from the front of the engine (Figure 179). Carefully guide the rear of shaft through the journals. If the shaft does not come out freely, ensure that all valve lifters are clear of camshaft lobes and journals.

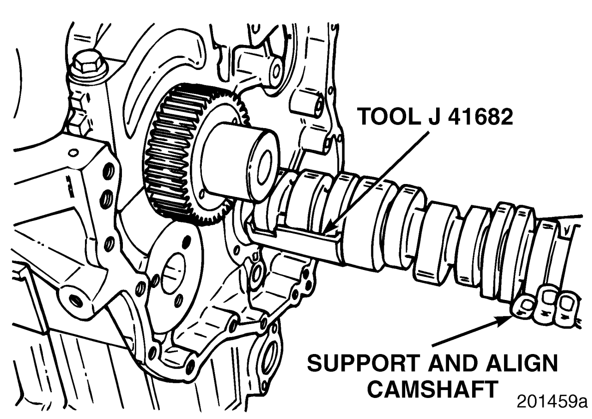

Figure 179 — Camshaft Removal

6. Remove the valve lifters.

SERVICE HINT

Valve lifters have established wear patterns and should be reinstalled in the same locations. Label each valve lifter upon removal and place on a clean work surface.

Piston and Connecting Rod Assembly Removal

[212 NP, LQ]

WARNING

The crankshaft and related components are heavy, have sharp edges and many possible pinch points. Always be careful while working in this area to avoid serious personal injury.

NOTE

Before removing the pistons, connecting rods and rod caps, ensure that they are tagged for reinstallation in the same cylinders from which removed.

Remove the connecting rod and piston assemblies in companion cylinder sets: 1 and 6, 2 and 5, and 3 and 4.

CAUTION

Do not stamp or engrave on the TOP of the piston. Doing so will reduce piston life.

1. Rotate the engine 90 degrees on the stand so that the pistons lie horizontally in the block with the top of the pistons and connecting rods accessible from the sides.
2. Rotate the crankshaft so that pistons 1 and 6 are lowered in the cylinder at least 2 inches (51 mm) to allow adequate room to remove carbon from the upper edge of the sleeves.
3. Using a sharp knife, carefully remove any carbon at the top of the sleeves (Figure 180). Remove any remaining carbon using crocus cloth or fine sandpaper. Then wipe the inside of the sleeves with a clean cloth.

CAUTION

Use care not to damage the cylinder sleeve when removing the carbon buildup.

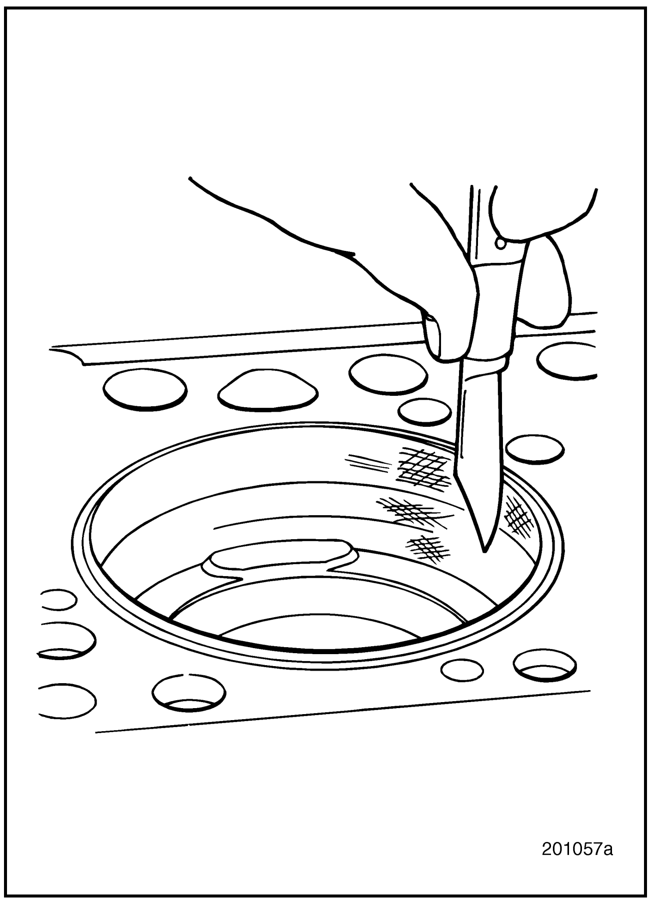

Figure 180 — Carbon Removal from Cylinder Sleeves

4. Rotate the crankshaft so that pistons 1 and 6 are at bottom dead center. Remove the connecting rod capscrews and the rod bearing caps. Refer to Figure 181.

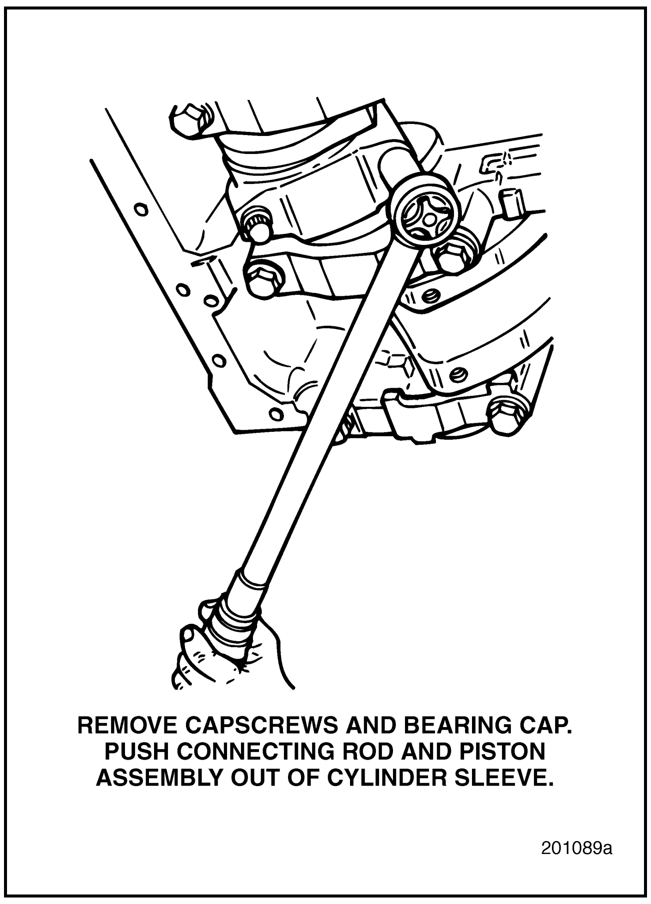

Figure 181 — Piston and Connecting Rod Assembly Removal

5. Using a hammer handle, push piston 1 from the cylinder bore. Remove piston 6 in the same manner.
6. After removing pistons 1 and 6, rotate the crankshaft so that the next set of pistons (2 and 5) is at bottom dead center.
7. Repeat steps 2 through 6 to remove piston sets 2 and 5, and 3 and 4.

Flywheel Removal

[212 UC]

1. With the engine stand rotated so that the engine is inverted (crankshaft horizontal), loosen all six flywheel retaining capscrews.

NOTE

On vehicles equipped with an automatic transmission, it may be necessary to remove additional components to gain access to the flywheel retaining capscrews. Refer to the Automatic Transmission Drive Arrangement Assembly Instructions, 5-902, for instructions regarding these arrangements.

2. Remove two of the flywheel retaining capscrews that are opposite each other (Figure 182). Then, install two longer capscrews or studs to allow the flywheel to be safely removed from the crankshaft.
3. Remove the remaining capscrews.
4. Carefully tap the flywheel, alternating from side to side, to work it off the aligning dowel pins.

WARNING

The flywheel is heavy. Lifting the flywheel will require the help of an assistant or the use of a suitable lifting device (J 25026-A or equivalent). Attempting to lift the flywheel without such assistance may result in severe personal injury.

NOTE

Remove the flywheel timing pointer, if present, to avoid damaging the pointer during flywheel removal.

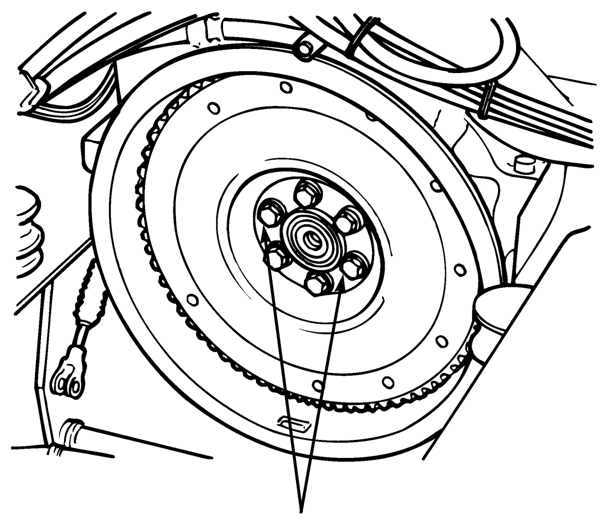

Figure 182 — Flywheel Removal

5. Support the flywheel and remove the two guide capscrews.
6. Using a suitable lifting device such as J 25026-A, or adequate assistance, remove the flywheel.

Flywheel Housing Removal

[211 HD]

1. Support the flywheel housing and remove the eight mounting capscrews (Figure 183).
2. Remove the flywheel housing. It may be necessary to tap lightly on the housing with a soft mallet to separate the housing from the engine block.
3. Remove the crankshaft rear seal from the housing and discard the seal.

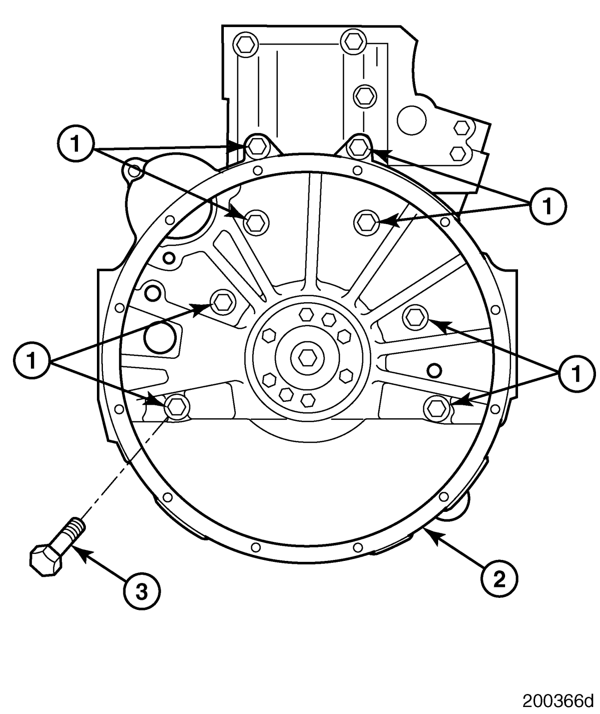

Figure 183 — Flywheel Housing Removal

1. Capscrew Locations 2. Flywheel Housing	3. Capscrew

Main Bearing Cap Removal

[211 JA]

NOTE

Before removing the main bearing caps, ensure that they are marked for reinstallation on the same journals. Keep the bearings with the same cap and tag, or mark them to identify the respective cap.

Refer to Figure 184.

1. Remove the eight buttress capscrews.
2. Remove the capscrews from each of the seven main bearing caps. The center main bearing cap houses the thrust washers.
3. Position a lady-foot pry bar under the tabs provided on the bearing caps and pry the caps upward. To work them loose, it may be necessary to tap the bearing caps, alternately from side to side, with a soft mallet.

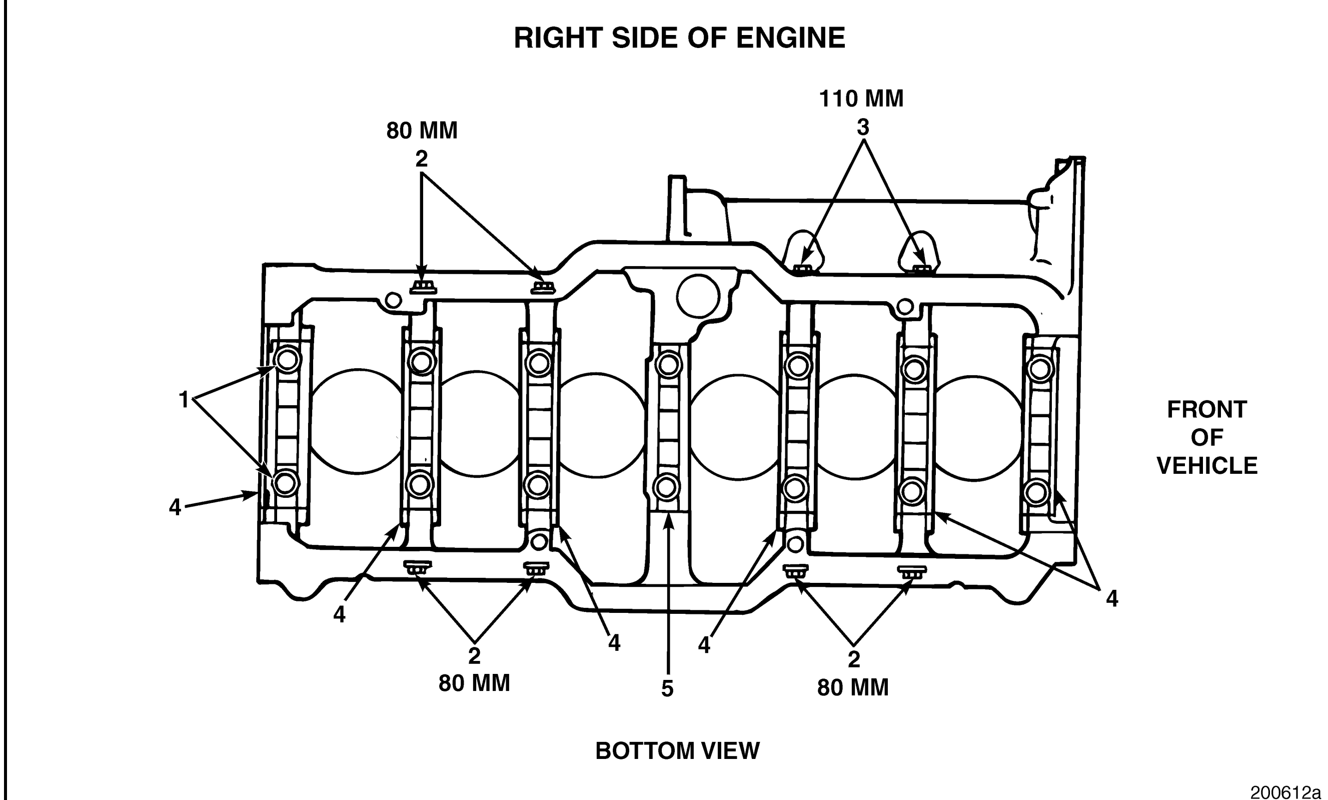

Figure 184 — Buttress Capscrew Installation

1. Main Bearing Cap Capscrews 2. Buttress Capscrews, 80 mm 3. Buttress Capscrews, 110 mm	4. Main Bearing Caps 5. Center Main Bearing Cap

Crankshaft Removal

[212 HP]

Refer to Figure 185.

1. Using a suitable lifting device, secure a sling or crankshaft support tool around the crankshaft and lifting device hook. Ensure that the crankshaft is evenly balanced when lifted from the engine block.
2. Lift the crankshaft from the engine block and store it in a secured stand, or horizontally on V-blocks.

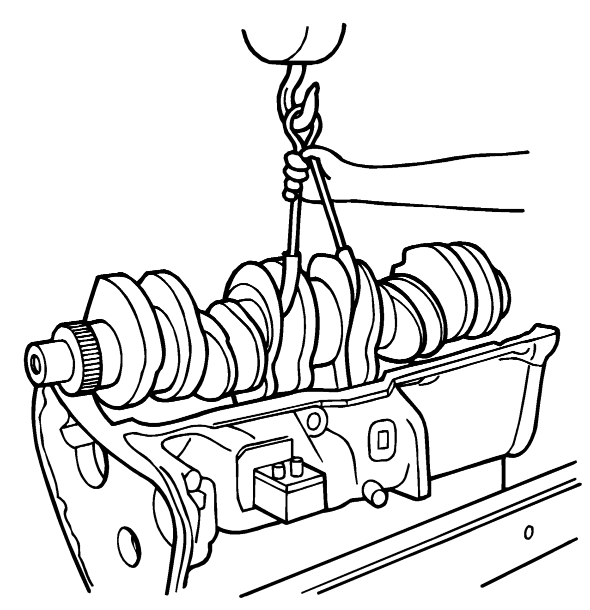

Figure 185 — Crankshaft Removal

3. Remove the main journal bearing inserts from the cylinder block and tag them for inspection.

CYLINDER BLOCK RECONDITIONING [211 DB]

Special Tools Required

- Camshaft Bushing Installation/Removal Kit J 42377
- Camshaft Bushing Remover/Installer J 21428-01
- Counterbore Tool PT2210
- Counterbore Cutter Plate PT2210-3A
- Hex Key Wrench PT2210-14
- Universal Dial Depth Gauge PT5025
- 3-Inch Stylus Extension PT5025-11

Piston Cooling Spray Nozzle Removal

[219 RV]

CAUTION

To avoid damaging the spray nozzles, remove them before removing the sleeves.

SERVICE HINT

It is best to use a 10 mm, 6-point socket on a 12-inch extension to remove the nozzle retaining capscrews.

Refer to Figure 186.

1. Remove the piston cooling spray nozzle by removing the retaining capscrew.
2. Carefully pull outward on the spray nozzle to remove it from the cylinder block.
3. Remove and discard the elastomer seal.
4. Repeat steps 1 through 3 to remove the remaining spray nozzles.

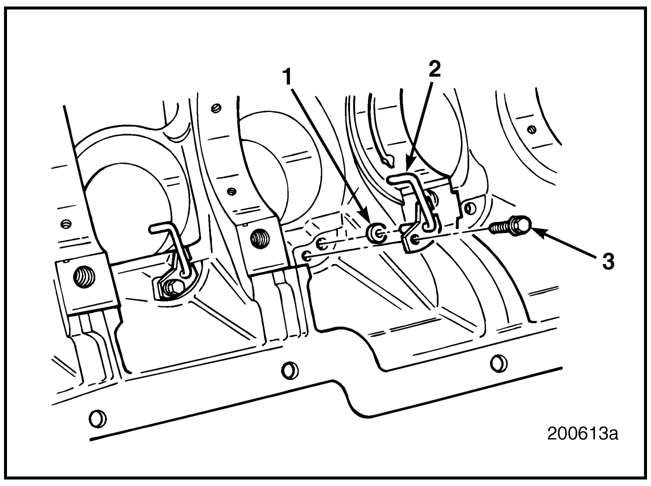

Figure 186 — Spray Nozzle Removal

1. Elastomer Seal 2. Spray Nozzle	3. Capscrew

Cylinder Sleeve Removal

[212 NC]

SPECIAL TOOL REQUIRED

- Cylinder Liner/Sleeve Puller PT6435

NOTE

Cylinder sleeve part Nos. 509GC463 and 509GC466 for service use do not have a crevice seal groove. It is recommended that use of the crevice seal be discontinued in all engine repairs or rebuilds, whether or not the liner has a crevice seal groove.

Refer to Figure 187 and Figure 188.

1. Rotate the engine in the stand so that it is upright (deck surface upward).
2. Use puller PT6435, or equivalent, to remove the cylinder sleeve from the cylinder block.
3. Place the puller in position above the sleeve with the puller shaft extending through the sleeve.

CAUTION

Extreme care must be taken to make sure the puller shoe is properly aligned in the bottom of the sleeve to prevent damage to the block.

4. Position the puller shoe so that it catches the lower lip of the sleeve. Ensure that it does not extend beyond the outside edges of the sleeve so that it will not come into contact with the cylinder block as the sleeve is removed.
5. Tighten the screw on the puller until the sleeve comes free from the cylinder block bore.
6. Remove the puller and sleeve from the engine. Then, remove the puller from the sleeve.
7. Remove any shims from the block counterbore ledge that may be installed.

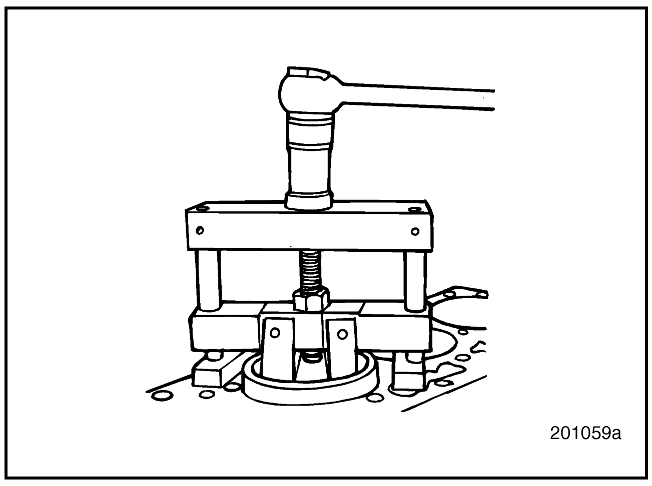

Figure 187 — Cylinder Liner/Sleeve Puller PT6435

8. Repeat steps 2 through 7 to remove the remaining cylinder sleeves.

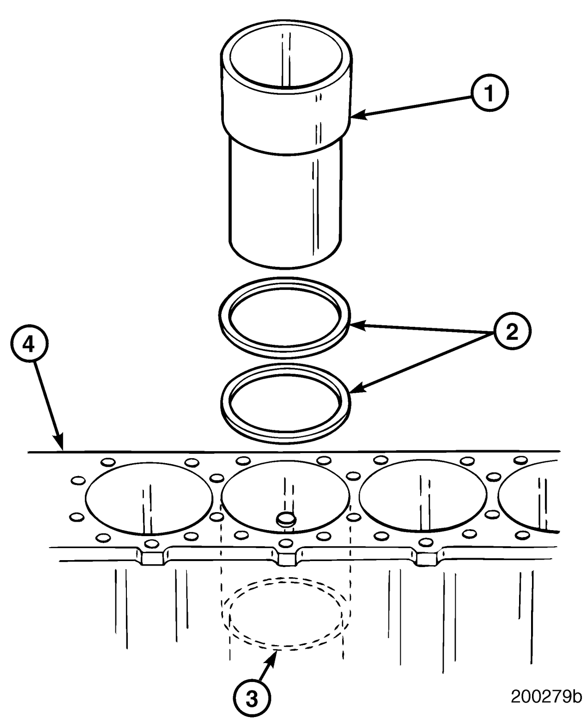

Figure 188 — Cylinder Sleeve Removal

1. Cylinder Sleeve 2. Shims	3. Counterbore Ledge 4. Cylinder Block

Cleaning and Inspection

The engine should have been thoroughly steam cleaned prior to component removal. If heavy accumulations of dirt and grease are still present, steam clean the block as thoroughly as possible before attempting to clean with solvents.

W A R N I N G

Cleaning solvent is flammable and toxic to the eyes, skin and respiratory tract. Skin and eye protection is required. Avoid repeated or prolonged contact. Use only in a well-ventilated area.

W A R N I N G

Compressed air used for cleaning can create airborne particles that may enter the eyes or irritate the skin. Pressure must not exceed 30 psi (207 kPa). Eye protection is required. Use only with effective chip guarding and personal protective equipment (goggles/shield, gloves, etc.).

N O T E

Cleaning the cylinder block is important. While cleaning the cylinder block, carefully inspect the areas around the cup plugs and the coolant jacket. If cup plugs or pipe plugs show signs of leaking, they should be replaced.

Cleaning the cylinder block is a good time to inspect it for cracks or other possible defects that may be reason for rejection. Refer to the TROUBLESHOOTING section for information on testing for leaks in the cylinder head and cylinder block. If damage is not found until after the engine is assembled, the engine must be disassembled and rebuilt again.

SOLVENT TANK CLEANING

NOTE

Use a cleaning tank large enough to accommodate the largest component to be cleaned. Fill the tank with a suitable solvent and always use caution while cleaning parts. Parts may be dried with compressed air.

1. Scrape any remaining gasket material from the block.
2. Using a wire brush or rotary wheel, remove any rust, corrosion or other debris from the block.
3. Clean all other block surfaces with mineral spirits or other suitable solvent.
4. Using due care and caution, clean and dry the block with compressed air.

INSPECTION

NOTE

A complete discussion of the proper methods for precision measuring and inspection is outside the scope of this procedure. However, every shop should be equipped with standard gauges, such as bore gauges, dial indicators, outside and inside micrometers, thickness gauges and straightedges.

Check the cylinder block for indications of cracking or coolant leakage. If any damage is suspected, use a standard dye penetrant or magnaflux procedure to determine if cracks exist. A cracked engine block must be replaced and never reused.

Refer to Figure 189.

Using a straightedge (PT5027 or equivalent) and thickness gauges, check the cylinder head mounting surfaces for flatness. The cylinder block mounting surface on a service block should be flat within 0.004 inch (0.102 mm) and flat within 0.002 inch (0.051 mm) over the area of each cylinder head mounting.

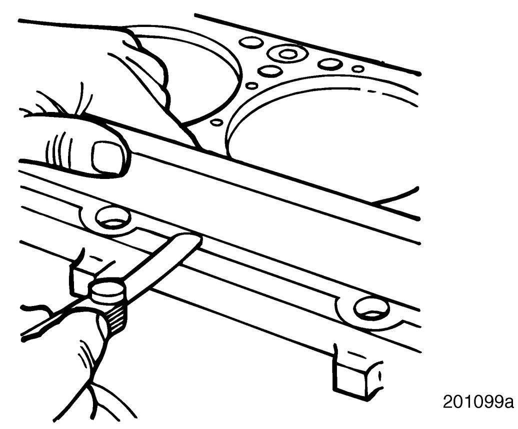

Figure 189 — Checking Flatness of Cylinder Block Deck

SERVICE HINT

If the cylinder block is determined to be serviceable after thorough cleaning and inspection, reassemble the engine. Use replacement or original parts, as determined during component inspection.

SALVAGING A DAMAGED EUP TAPPET BORE

Occasionally, severe failure of an EUP tappet roller and axle will result in parts of the tappet being driven up against the bottom of the tappet bore, causing damage to the bottom of the bore. This damage must be repaired. Depending upon the extent of the damage, it may be necessary to begin with a small die grinder to remove the displaced material, removing only the high spots to bring them down to the remaining bore surface, then finishing with a fine file, stone or emery paper. The bore and adjacent areas must be thoroughly cleaned to remove all metal particles and abrasive material. Perform a trial-fit of the EUP tappet and check for freedom of movement in the bore.

NOTE

Whenever a lifter bore is reworked or honed, be sure that all the metal and honing debris is cleaned from all affected areas by flushing with a fresh supply of suitable brake/parts cleaner.

SALVAGING A DAMAGED VALVE LIFTER BORE

Occasionally, a failure will result in severe wear and breakage of the roller and roller axle. These parts will then separate from the lifter body. Subsequently, the lifter legs (which had retained the axle in the lifter body) become bent-outward and are driven up into the lifter bore by the cam lobe. This action damages the bottom 1/4 to 3/8 inch (6.35 to 9.52 mm) of the bore and will prevent installation of the new lifter. It is necessary to clean up the damaged bore area with a file, stone or emery paper using care to remove **all** high spots from the bore. The goal is to clean up the areas of raised metal, but not to enlarge the bore diameter. Any remaining nicks or scores (low spots) do not inhibit proper function of the parts and will cause no problem. After removing any raised metal, use a flex-hone to lightly hone the bore.

Another condition sometimes encountered is a small amount of scuffing or foreign particle scoring in a lifter bore. This condition can inhibit static-free movement of a lifter. This will not cause a lifter hang-up in engine operation, but is sometimes noticed during lifter removal or installation. If this condition is encountered, use a flex-hone to lightly hone the bottom area of the lifter bore, trial-fitting the lifter until the high spots have been removed and free movement is re-established.

NOTE

Whenever a lifter bore is reworked or honed, be sure that all the metal and honing debris is cleaned from all affected areas by flushing with a fresh supply of suitable brake/parts cleaner.

LIFTER BORE CLEANING AND LIFTER CHECKS

While the camshaft is removed and lifter bores are relatively accessible, it is a good practice to clean all the lifter bores and then trial-fit all the lifters into their respective bores and H-rings. Clean and trial-fit lifters as follows:

1. Clean all lifter bores with a fresh supply of suitable brake/parts cleaner. Ensure all Loctite® residue and dried contamination has been removed from the lifter bore and H-ring area.
2. Trial-fit a lifter back into its original lifter bore by aligning the lifter flats with the H-ring flats. Use only light finger pressure when installing the lifters. Verify that the lifter has complete freedom of movement in the bore and H-ring in both the upward and downward directions. When the lifter is seated, it should be possible to rotate it slightly from left to right. If the lifter is sticky or tight, or if additional force was required to install the lifter, proceed as follows:
    a. Try the lifter in another lifter bore. A stack-up of component tolerances can result in a lifter being free in another bore. This is acceptable.
    b. If the problem persists when the lifter is tried in another bore, replace the lifter.
    c. If the problem is confined to a particular bore, determine if the lifter tightness is due to the lifter or the H-ring. If the bore is the problem, perform a bore clean up and hone as described in “SALVAGING A DAMAGED VALVE LIFTER BORE” on page 189. If the lifter is tight in the H-ring, replace the lifter or H-ring as determined by a trial-fit of another lifter.
3. Once all lifters have been trial-fit to their respective bores and H-rings, label each valve lifter and place on a clean work surface until reassembly.

Cylinder Sleeve Counterbore

[211 DB]

INSPECTION AND REPAIR

If the cylinder block deck is resurfaced, the cylinder sleeve counterbore depth must be recut to specification. If the cylinder block deck was not resurfaced but cylinder sleeve counterbore surface shows excessive pitting or erosion, recut the counterbore as required.

Use shims to re-establish the correct liner flange height. Shims are available in the following thicknesses: 0.002, 0.003, 0.004, 0.010, 0.012, 0.014, 0.020, 0.031 and 0.042 inch thicknesses, and are to be used as a single shim repair whenever possible.

If it is necessary to use more than a single shim, use the fewest shims possible. Also because very thin shims can be displaced, avoid the use of 0.002, 0.003 and 0.004 shim sizes whenever possible.

NOTE

Due to manufacturing tolerance differences, all shims should be measured to determine their actual shim thickness dimension before recutting the sleeve seat.

To resurface the cylinder sleeve counterbore area of the cylinder block, use counterbore tool PT2210 with counterbore cutter plate PT2210-3A.

NOTE

This procedure can be performed either in or out of the chassis. If performing the procedure in the chassis, be sure to cover the crankshaft and any holes in the cylinder block to prevent contamination from machining chips.

1. Thoroughly clean and inspect the sleeve seating surface on the cylinder block counterbore flange. Visually identify the counterbore flange that has the most severe pitting and recut it first to determine if the block will be within the specified recut limits.

⚠ CAUTION

Do not cut seats deeper than 4.040 inches (102.616 mm). If the maximum recut dimension is reached and visible pitting remains, the pitting is acceptable as long as there is not a complete leak path all the way across the cylinder block sleeve seat surface.

2. Make sure that the top of the deck is clean and free of burrs. Use a finish mill file and crocus cloth, if necessary, to create a smooth, flat surface for positioning the tool.
3. Using compressed air, thoroughly remove all debris.

NOTE

Universal dial depth gauge PT5025, with a three-inch stylus extension PT5025-11, is recommended for measuring the counterbore.

4. Measure and record the counterbore in four places, 90 degrees apart. Using a depth gauge with a three-inch extension, mark the shallowest point. Subtract the lowest number from the highest number. This is the minimum amount to be machined for cleanup. Additional machining may be required depending on the size of any remaining pits.

SETTING UP COUNTERBORE TOOL PT2210 WITH CUTTER PLATE PT2210-3A

Refer to Figure 190.

1. Loosen the two cutter bit hold-down capscrews. Install the cutter bit into the cutter plate PT2210-3A by turning the cutter bit adjuster counterclockwise. The cutter bit face must be positioned for a clockwise rotation cut.

⚠ CAUTION

Do not tighten the cutter bit hold-down cap.

The cutter point should not extend beyond the outer edge of the cutter plate. If the cutter bit does stick out, damage to the bit will occur when installing the counterbore tool on the cylinder block.

2. Install the cutter plate on the main shaft. Use the large end of hex key wrench PT2210-14 to hold the cutter plate and tighten securely. The hole in the side of the cutter plate accepts the large end of the tool.

CAUTION

Do not allow the cutter bit to touch the cylinder sleeve bore wall.

3. Position the tool in the cylinder bore by backing off the depth-set collars and lowering the cutter plate into the counterbore to center the tool.
4. Secure the cutter plate to the cylinder block with four M16 x 2 x 90 hex-head capscrews and special washers from the counterbore tool kit PT2210.
5. Cross-torque the capscrews to 30 lb-ft (41 N•m) using torque wrench J 24406 or equivalent.

NOTE

Lift the T-handle slightly (so cutter plate is not in contact with the counterbore) and rotate the main shaft counterclockwise to ensure that the cutter plate turns freely without binding. If necessary, loosen the capscrews and relocate the tool.

6. Using the counterbore tool T-handle, raise the cutter plate approximately 1/2 inch (12.7 mm) from the counterbore ledge.
7. Using hex key wrench PT2210-14, turn the cutter bit adjusting screw clockwise until the cutter bit contacts the counterbore ledge. Do not touch the counterbore wall.
8. Back off the lower depth-set collar and lower the cutter plate until the cutter rests on the ledge.
9. Rotate the lower depth-set collar down until the collar contacts the main housing.
10. Rotate the collar an additional five increments totaling 0.005 inch (0.127 mm). Each graduation of the collar is 0.001 inch (0.025 mm). This will lift the cutter bit 0.005 inch (0.127 mm) off the counterbore ledge, allowing an accurate setting of the cutter bit.

NOTE

It may be necessary to use a flashlight to see the cutter bit adjusting screw.

11. Using hex key wrench PT2210-14, turn the cutter bit adjusting screw clockwise until the cutter bit rests on the counterbore ledge.
12. If the cutter bit will not adjust, adjust the lower depth-set collar 0.005 inch (0.127 mm) more and recheck the cutter bit hold-down screws for looseness.
13. Zero the depth-set collars:
    a. Back off the lower depth-set collar and carefully lower the cutter plate into the bore and allow the cutter to rest on the counterbore ledge.
    b. Rotate both the upper and lower depth-set collars down until the bottom collar contacts the main housing.

CAUTION

Do not force the collar beyond this point, as it will lift the cutter plate and prevent an accurate zero reading.

14. Set the depth of the cut. Determine the final depth of the cut and back off the upper depth-set collar accordingly. Each increment on the depth-set collar increases the depth of the cut by 0.001 inch (0.025 mm). Tighten the thumbscrew on the upper collar securely.

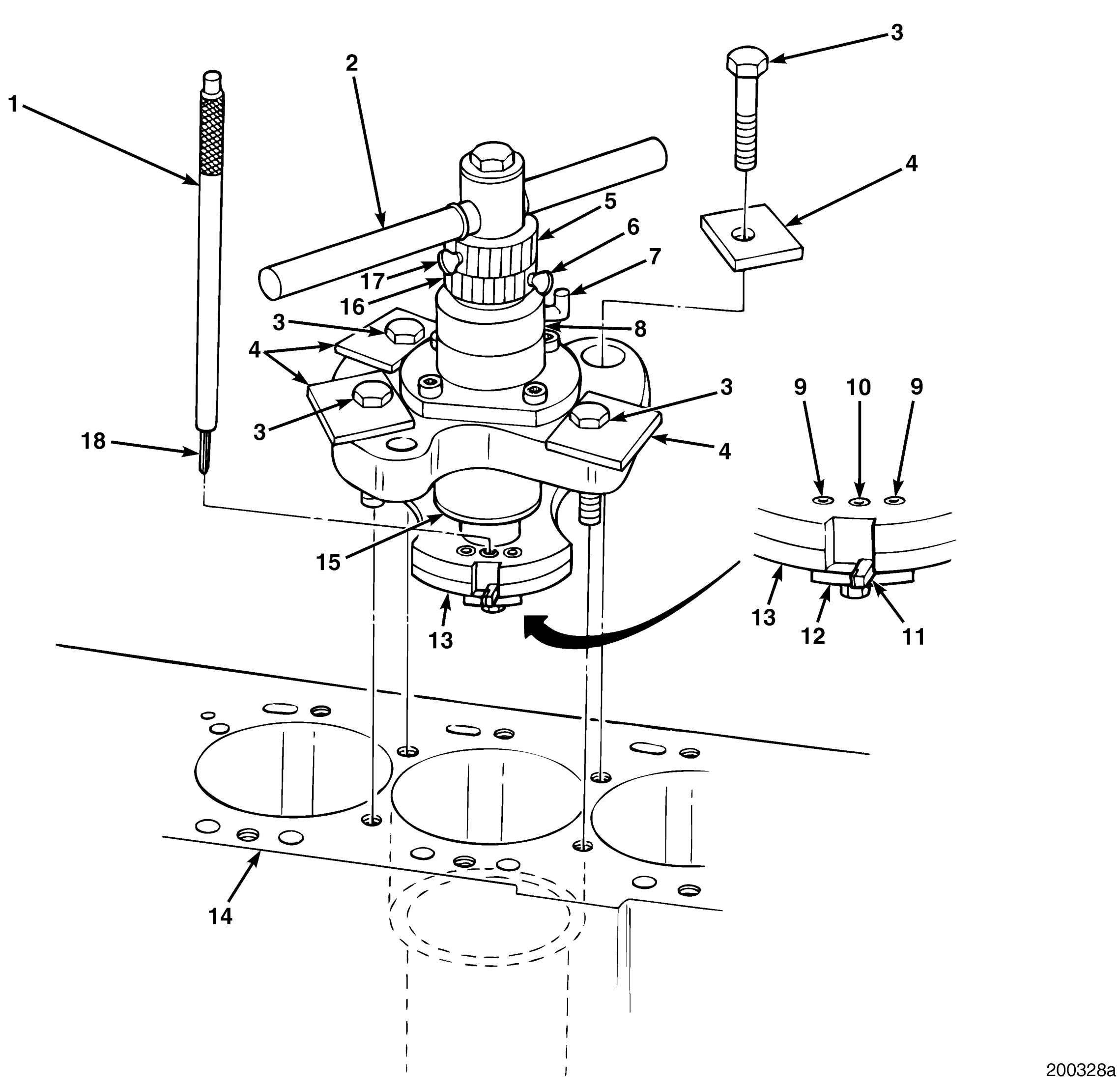

Figure 190 — Counterbore Ledge Tool Installation

1. Cutter Plate Holder	10. Cutter Bit Adjuster
2. T-Handle	11. Cutter Bit
3. Capscrews, M16 x 2 x 90	12. Hold-Down Cap
4. Special Washers	13. Cutter Plate
5. Upper Depth-Set Collar	14. Cylinder Block
6. Lower Thumbscrew	15. Main Shaft
7. Oil Fill Tube	16. Lower Depth-Set Collar
8. Main Housing	17. Upper Thumbscrew
9. Hold-Down Capscrews	18. Hex Key Wrench

CUTTING THE COUNTERBORE

Refer back to Figure 190.

Measure each counterbore depth as the recut is being performed. The goal is to provide a depth where only a single shim is necessary to obtain the proper cylinder sleeve stand-up height.

1. Fill the oil fill tube with 30W nondetergent oil to maintain lubrication during use.
2. Back off the lower depth-set collar two increments or less, and tighten the thumbscrew securely.
3. Cut the counterbore by turning the T-handle clockwise while maintaining constant downward pressure on the tool. Stop the handle in a different position to avoid creating a ridge in the counterbore.
4. Continue backing off the lower depth-set collar, no more than two graduations per cut. Check the depth measurement between each adjustment. Plan to remove 0.001 inch (0.025 mm) on the final cut to meet the final predetermined counterbore depth. This ensures achieving a very fine machined finish.
5. Remove the tool from the cylinder bore.
   a. Loosen the two cutter bit hold-down capscrews and rotate the cutter bit adjusting screw counterclockwise until the cutter bit is retracted into the cutter plate.
   b. Remove the four machine hold-down bolts and special washers.
   c. Remove the tool from the cylinder bore.
6. Follow steps 1 through 5 for the remaining cylinders.

COUNTERBORE DEPTH MEASUREMENT

Measure the counterbore depth (Figure 191) and calculate the shims needed to obtain proper cylinder sleeve stand-up height. Single shim repairs should be performed whenever possible.

Shims can be ordered through the MACK Parts System using part Nos. 505GC26P2, P3 ,P4, P10, P12, P14, P20, P31 and P42. The shim “P” number signifies shim thickness, i.e., P14 is 0.014-inch thick. The only exceptions to this are the P30 which is 0.031″ and P40 which is actually 0.042″. When installing shims, always use the thickest shims and the least amount of shims as possible to obtain the proper sleeve stand-up height. Use a single shim whenever possible, and if it is necessary to use more than a single shim, use the fewest shims possible. Also because very thin shims can be displaced, avoid the use of the 0.002, 0.003 and 0.004 shim sizes whenever possible.

NOTE

The current standard production counterbore depth is 3.998–4.002 inches.

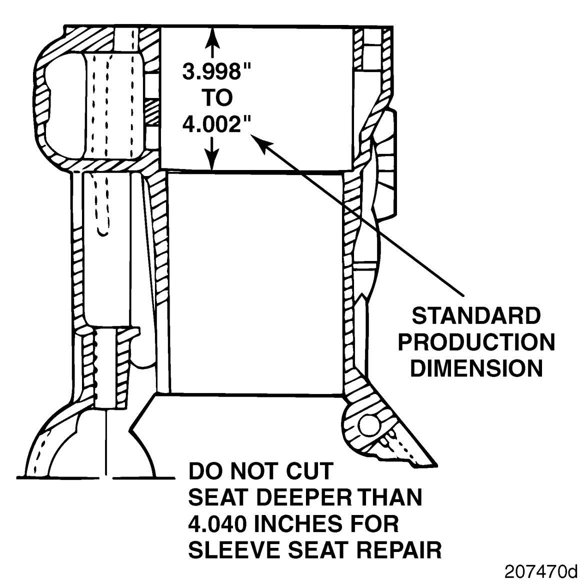

Figure 191 — Counterbore Depth Measurement

Effective March 2004, the nominal inside diameter of all the shims was reduced by 0.064″ (1.625 mm) (from 5.225″ [132.715 mm] to 5.161″ [131.089 mm]). This change allows for a better fit between the shim and the liner.

NOTE

If necessary, it is acceptable to use a combination of shims having the 5.225″ (132.715 mm) and the 5.161″ (131.089 mm) inside diameters on the same sleeve seat.

Cup Plug Replacement

REMOVAL

Refer to Figure 192.

1. Using a hammer and punch, drive one edge of the plug inward. The plug should rotate causing the opposite edge to move outward. When the edge moves out far enough, grab it with a pair of pliers and pull it out.

CAUTION

If, after several taps with a hammer, the plug does not rotate and is being driven inward, stop tapping. Drill a hole approximately 1/8 inch (3.2 mm) in diameter in the center of the plug. Insert a sheet-metal screw in the hole. Leave enough of the screw protruding from the plug to allow a pry bar to be inserted under the head of the screw and pry the plug out.

2. Clean the plug hole(s) with a wire brush or wire wheel. After cleaning, visually check the surface for cracks.

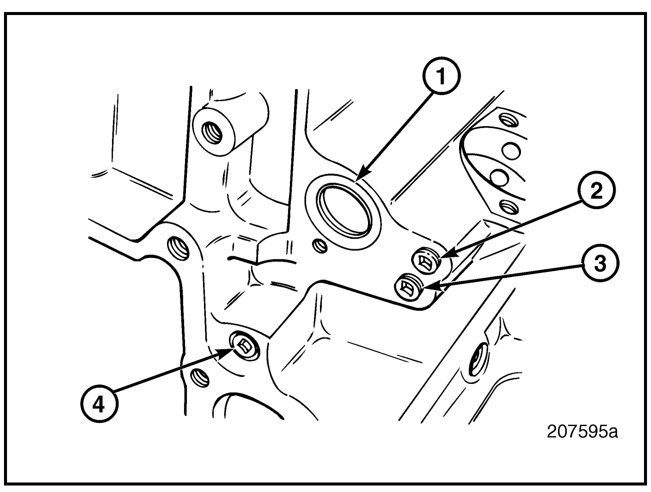

Figure 192 — Cylinder Block Plugs

1. Coolant Passage Cup Plug	3. Lower Fuel Gallery Pipe Plug
2. Upper Fuel Gallery Pipe Plug	4. Oil Gallery Pipe Plug

INSTALLATION

1. After cleaning the plug hole, apply a thin coat of Loctite® 277 to both the surface of the hole and the outer edge of the plug.
2. Using a proper driver, align the plug in the hole and drive it inward until the outer lip of the plug is 0.090 ± 0.040 inch (2.286 ± 1.016 mm) below the machined counterbore. Refer to Figure 193.

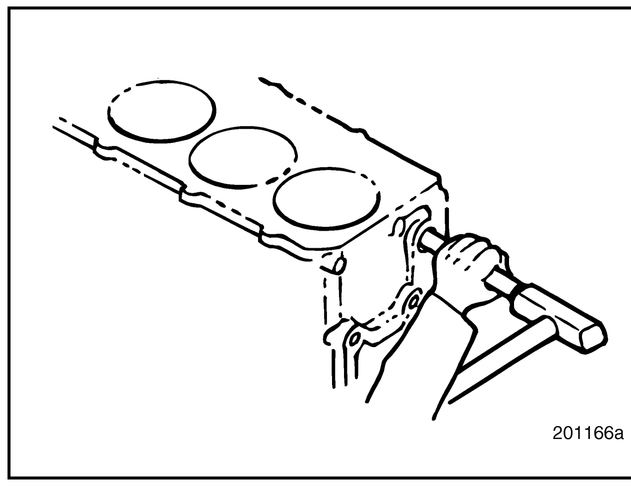

Figure 193 — Cylinder Block Cup Plug Installation

Pipe Plug Replacement

NOTE

Any rust around a pipe plug is an indication of a leak and the plug should be replaced.

REMOVAL

1. Using an appropriate wrench, remove the plug.
2. Clean the threads in the cylinder block by running a tap into the hole, just far enough to remove any rust on the threads without expanding the diameter of the hole. Use compressed air to remove any chips from the block.

NOTE

It is best to replace a leaking pipe plug. However, if reusing the same plug, clean it thoroughly, paying special attention to the threads.

3. Using a wire wheel, clean the threads of the plug. Visually check the thread surfaces for burrs or damage. Then clean and check the remaining surfaces.

INSTALLATION

Apply an appropriate Teflon® thread sealant to the threads and install the plug. Tighten the plug to specification. Refer to the torque chart in the SPECIFICATIONS section.

N O T E

New plugs may already have a sealer applied to the threads. Applying a Teflon® sealer to the threads will not adversely affect the precoating.

H-Ring Replacement

[213 LD]

H-rings are placed in the lifter bores to prevent the lifters from turning, and performing the same function as the roller tappet guide pins used with electronic unit pumps. The H-rings have an interference fit with the lifter bores in which they are installed and, under normal circumstances, are never removed.

If an unusual failure situation results in an H-ring being dislodged, it can be reinstalled or replaced with a **new** part, as required, using the following procedure:

1. Remove the affected H-ring, using remover tool J 42426 in combination with slide hammer J 6125-1B. Refer to Figure 194.

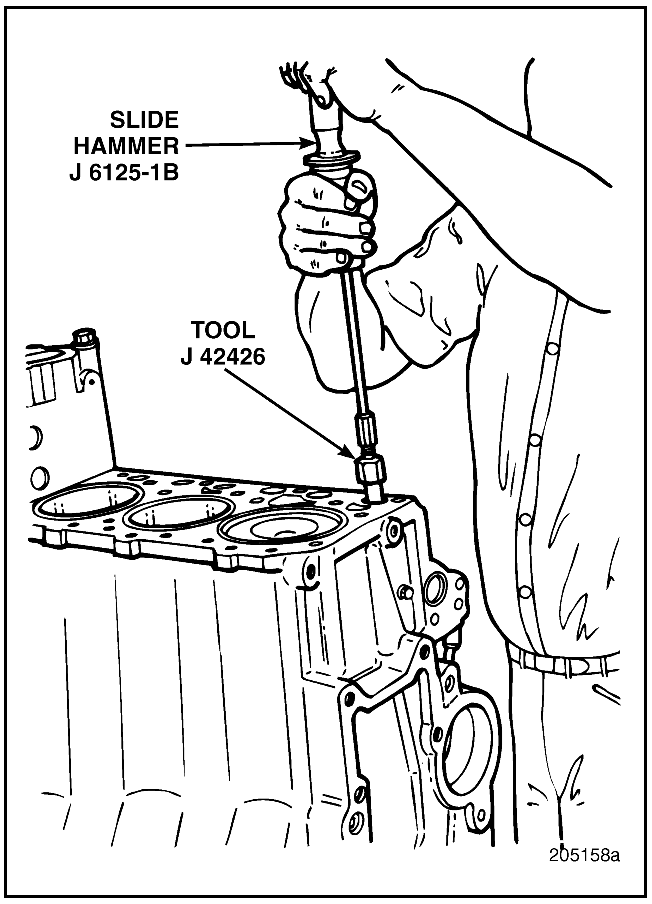

Figure 194 — H-Ring Removal

NOTE

In some cases, the H-ring remover tool may not position the collet far enough into the H-ring to provide proper engagement for removal. If this situation occurs, remove 0.375 inch (9.5 mm) of the threads by grinding or cutting them down; remove any burrs. This will allow the tool to be positioned further into the lifter bore.

2. Inspect the cylinder block lifter bore and place a **new** standard size H-ring onto the top of the bore. The H-ring should be a press-fit. If it is a slip-fit, an oversize H-ring is required. Determine the oversize as follows:
   - Check the fit of a **new** “P2” H-ring (+0.0015 inch [+0.0038 mm] oversize). If it is a press-fit, install it. The P2 can be identified by a single dot formed into the bottom surface next to the flat as shown in Figure 195.
   - If the P2 is slip-fit, install a **new** “P3” H-ring (+0.0030 inch [+0.076 mm] oversize). The P3 can be identified by two dots formed into the bottom surface.

CAUTION

An oversized H-ring is to be used only when the bore in the cylinder block is oversize. To use an oversize H-ring in an undamaged standard size bore will result in a press-fit that is too tight, causing the H-ring to collapse. A collapsed H-ring will eliminate free movement of the valve lifter or prevent it from being installed. For a proper press-fit, the H-ring-to-bore interference fit should be within the range of 0.0006–0.0020 inch (0.015–0.051 mm). An interference fit less than the 0.0006-inch minimum will result in the H-ring dislodging or turning in the block bore.

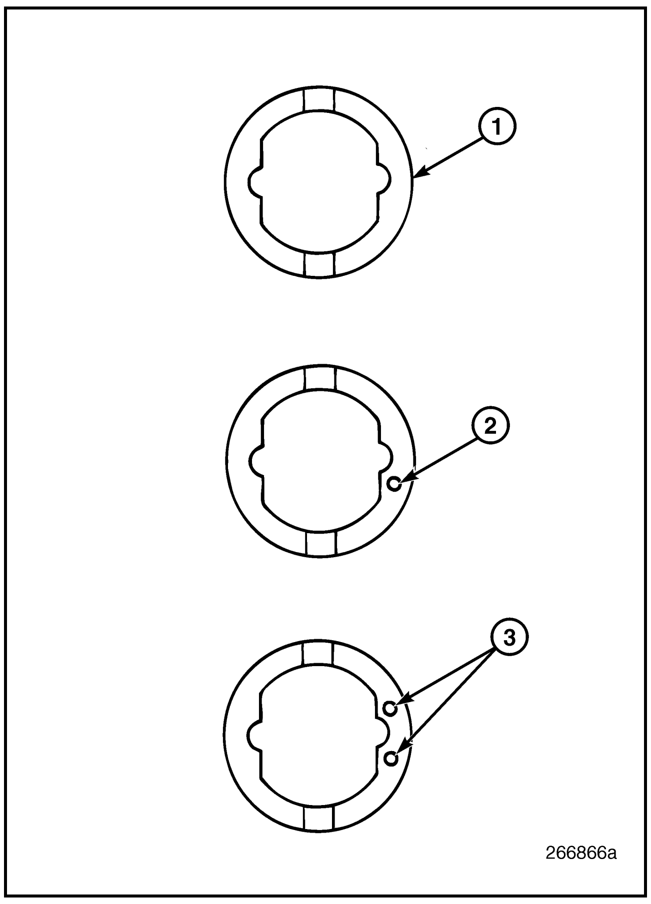

Figure 195 — Available H-RIng Sizes

1. Standard (No Dots) 2. 0.0015-Inch Oversize (1 Dot)	3. 0.0030-Inch Oversize (2 Dots)

3. If the lifter bore appears OK (will support the interference fit of the H-ring), clean the bore and dislodged H-ring (or new H-ring, if required) with Loctite® Primer T. Then apply Loctite® RC/609 to the bore and to the H-ring outside surface.
4. Use service tool J 41683 to install the H-ring. This tool pilots into two lifter bores at the same time to properly align and install the H-ring. If the proper interference fit has been maintained, resistance should be felt as the H-ring is driven into the bore. Refer to Figure 196 and Figure 197.

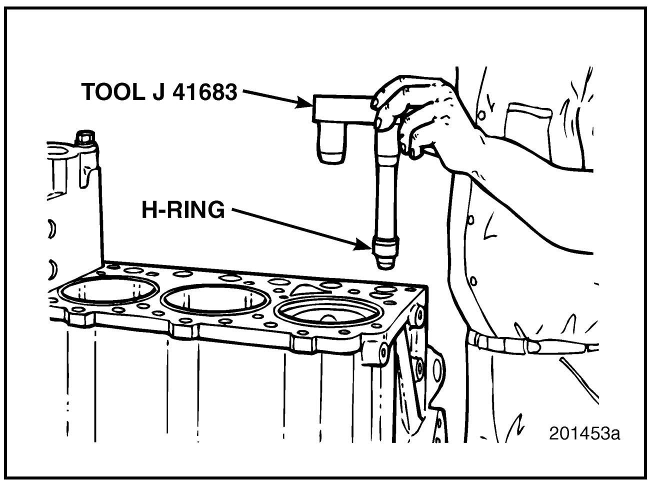

Figure 196 — H-Ring Installation Tool

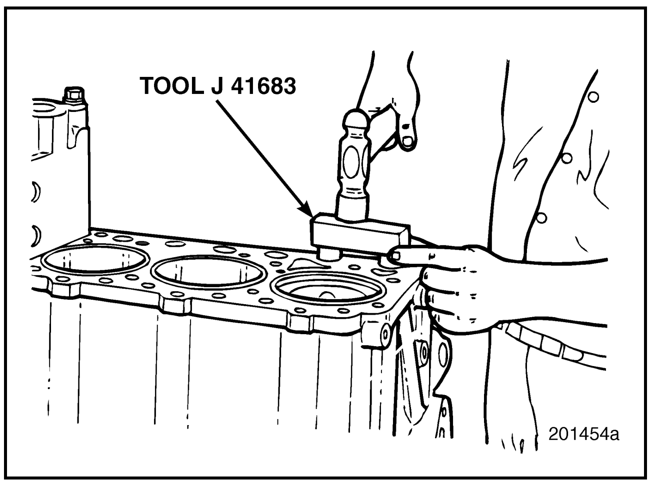

Figure 197 — H-Ring Installation

NOTE

Be sure the H-ring is installed with the grooved side toward the bottom. Refer to Figure 198.

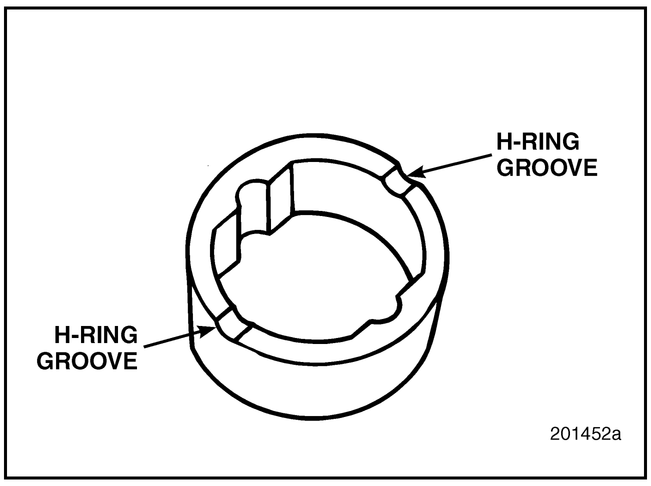

Figure 198 — H-Ring

CAUTION

When installing an H-ring, it is possible for Loctite® to run down the lifter bore. The Loctite® will not cure until the lifter is installed, because the tight clearance between the lifter and the bore produces the environment in which the Loctite® can cure. If a lifter is adhering to the lifter bore because of dried Loctite®, it may "snap" into place when the rocker shaft assembly is installed, or the engine is rotated. The lifter will not have free movement if it is contaminated with dried Loctite®. The result of either of these conditions (snap into place or adhere to the bore), is possible impact damage to the ceramic roller. Use a suitable solvent to clean any excess Loctite® from the lifter bore immediately following H-ring installation.

Camshaft Bushing Replacement

[213 CC]

Typically, camshaft bushings have an extremely long service life and need not be replaced unless they are obviously damaged or worn beyond normal wear limits. However, it is good policy to replace the camshaft bushings when overhauling the engine out of chassis, even if the bushings are within acceptable wear tolerances.

REMOVAL

NOTE

Camshaft bushings are identified in sequence, 1 to 7, starting from the front of the engine.

1. Using camshaft bushing remover/installer J 42377 (with J 21428-01 Cam Bushing Installer Set) and a hammer, remove the No. 1 camshaft bushing from the cylinder block. Refer to Figure 199.

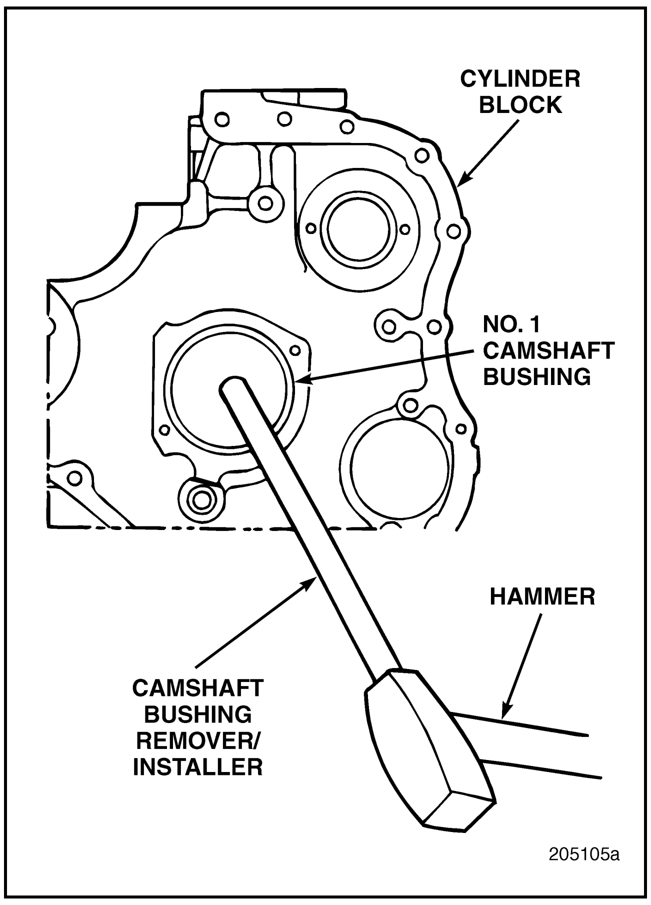

Figure 199 — Camshaft Bushing Removal

2. Remove the remaining six bushings in sequence.

SERVICE HINT

If the camshaft bushings are being replaced in the chassis, a special tool is required to remove the No. 7 camshaft bushing. The tool is included with the J 21428-01 kit. The No. 7 cam bushing removal tool consists of a bushing puller (J 21385-1), a cone (J 21385-4), a threaded mandrel (J 21248-4) and a guide (J 21428-4). These parts are threaded onto the handle (J 21099-9), and a slide hammer is then used to remove the bushing.

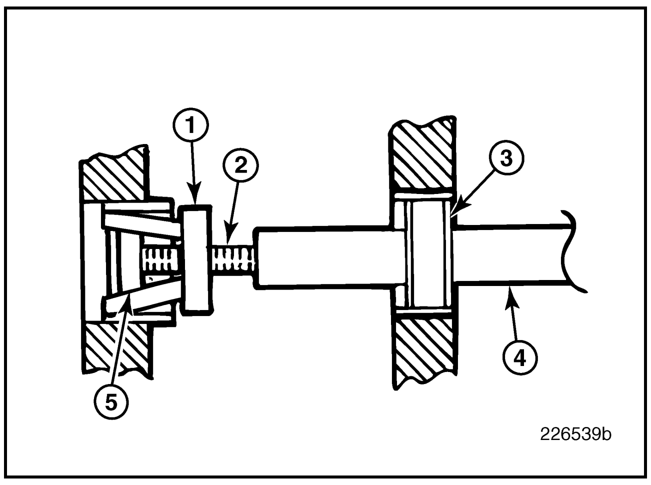

Figure 200 — Rear Cam Bushing Removal Tool

1. Bushing Puller (J 21385-1) 2. Mandrel (J 21248-4)	3. Guide (J 21428-4) 4. Handle (J 21099-9) 5. Cone (J 21385-4)

3. Check the bushing bore diameters and finish in the cylinder block, using a telescoping gauge or inside micrometer.

CAMSHAFT BUSHING ALIGNMENT

Each camshaft bushing is located at set distances from the camshaft thrust washer mounting surface to the forward edge of the bushing. Refer to Figure 201.

When installed to the proper dimensions, the intermediate bushings (locations 2, 3, 5 and 6) are approximately centered in their bores, in the front-to-rear direction. The front, center and rear bushings, however, are not centered. The offsets are described as follows:

- No. 1 bushing — Installed with the front of the bushing flush, to 0.030 inch (0.762 mm) behind the front face of the bore. There is approximately 1/8 inch (3.18 mm) of the bore visible on the rear side of the bushing.
- No. 4 bushing — When installed correctly, there is approximately 0.400 inch (10 mm) of bore visible at the front face of the bushing, and approximately 0.040 inch (1 mm) of bushing protrusion from the rear of the bore.
- No. 7 bushing — When installed correctly, there is an approximate 1/8-inch (3.18 mm) wide section of bore visible at the front face of the bushing.

Installing the cam bushings to the correct dimensions optimizes bushing-to-cylinder block oil hole alignment. Even when installed to the proper dimensions, however, the No. 1 and No. 4 bushings have only approximately 1/2 to 2/3 of the oil hole in alignment with the oil hole in the bore; 100 percent oil hole alignment is not attainable or required.

NOTE

Camshaft bushings (part No. 57GB37) have a groove, 360 degrees around the inside diameter. The grooved bushings can be used with either grooved or non-grooved camshaft journals, and the camshaft with grooved journals can be used with either grooved or non-grooved bushings. Parts can be intermixed in an engine.

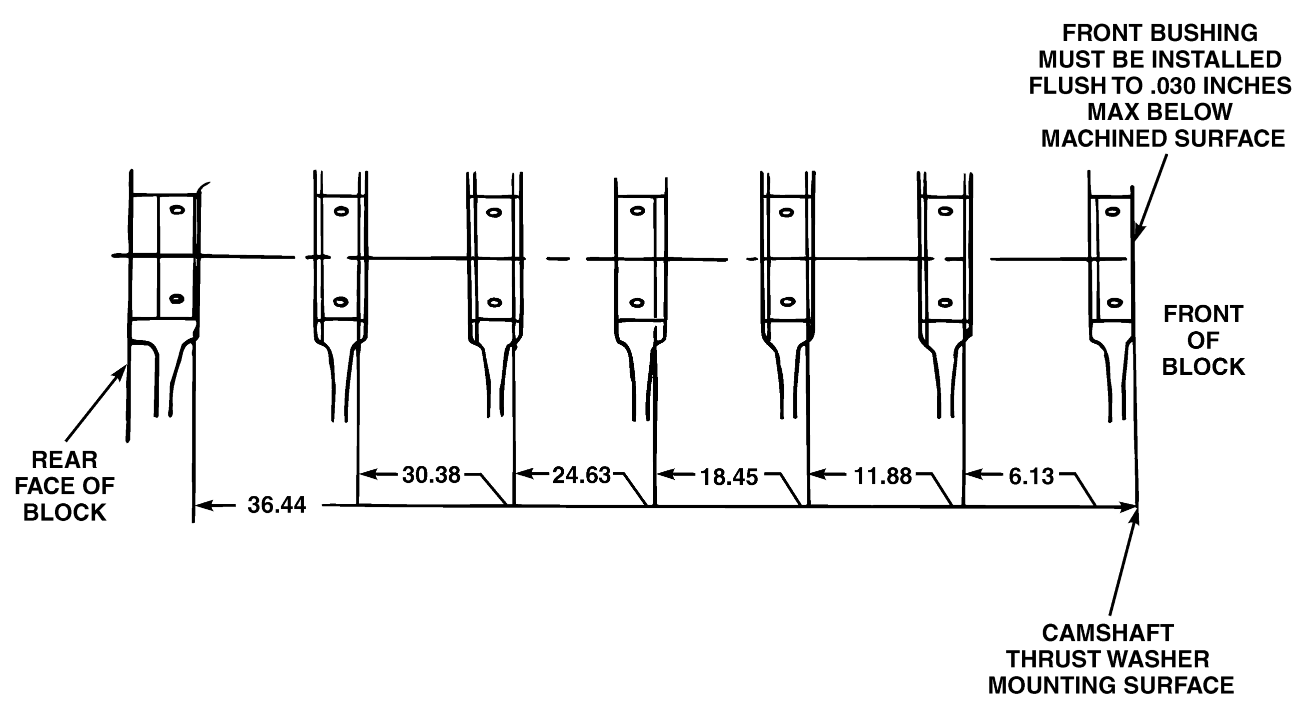

Figure 201 — Camshaft Bushing Locations

BUSHING INSTALLATION

1. Clean the surfaces of the bushing and the bore. Dry both surfaces with compressed air.
2. Using a dark-colored felt-tip marker, mark the cylinder block and bushing with a line to facilitate correct alignment at installation. Refer to Figure 202.

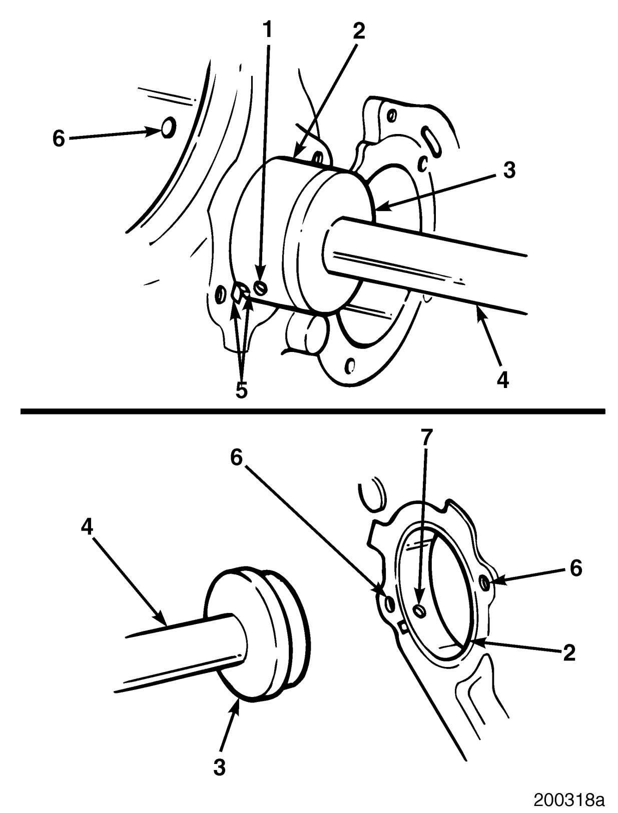

Figure 202 — Camshaft Bushing Installation

1. Bushing Oil Hole 2. Bushing 3. Pilot Adapter (J 42377) 4. Bushing Remover/Installer (J 21428-01 Kit)	5. Alignment Mark 6. Mounting Hole 7. Block Oil Passage

3. Position the replacement bushing against the side of the block at the No. 7 (rear) bushing bore. Align the oil hole in the bushing with the oil passage in the block.
4. Using bushing remover/installer J 42377 (with J 21428-01 Cam Bushing Installer Set), install the bushing.

CAUTION

Correct installation of each camshaft bushing is very important. If a bushing is not properly aligned with both its oil supply and oil feed passages in the cylinder block, either the camshaft bushing will fail or the components lubricated by the bushing feed will fail from inadequate lubrication.

5. Install the camshaft bushings in sequence, starting at the back of the cylinder block with journal No. 7 and finishing with No. 1.
6. After all of the bushings are in place, measure the ID of each to ensure that they are not undersize because of burrs on the OD caused by installation (Figure 203). Refer to the “Fits and Limits” charts in the SPECIFICATIONS section for the correct bushing ID dimensions.

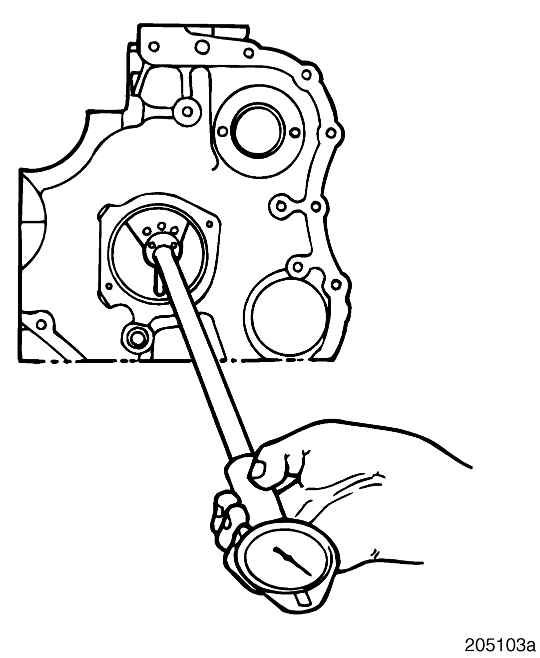

Figure 203 — Camshaft Bushing ID Check

Auxiliary Shaft Bushing Replacement

[212 CB]

The front and rear auxiliary shaft bushings are identical. Procedures for inspection and replacement are as follow:

INSPECTION

1. Using a telescoping gauge or inside micrometer, measure the auxiliary bushing bores. Take two readings, perpendicular to each other, in each bore. Record the readings. Refer to Figure 204.
2. Compare the readings with the tolerances listed under “Fits and Limits” in the SPECIFICATIONS section.

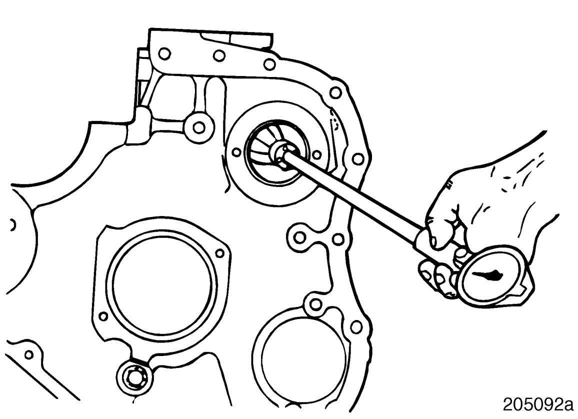

Figure 204 — Auxiliary Shaft Bushing ID Check

BUSHING REMOVAL

Use J 21428-01 to remove the bushings. If there is any indication that a bushing has turned in the block, check the bushing bore diameter with a telescoping gauge or inside micrometer.

BUSHING INSTALLATION

CAUTION

Correct installation of the auxiliary shaft bushings is very important. If the front bushing is misaligned, lubrication oil flow to the front bushing and journal will be blocked. The rear bushing does not have any cylinder block oil passage to align with the holes in the bushing. However, the oil holes in the bushing and the oil groove between those oil holes are in the most desirable location when the bushing is installed with indexing notches at the 5:30 and 10 o’clock positions.

Use care not to lose the short oil feed tube, 1.25 inches (32 mm) in length, which connects the oil feed hole in the rear of the auxiliary shaft to the oil feed hole in the front of the air compressor crankshaft. If it is accidentally lost during air compressor or auxiliary shaft service work and not reinstalled, the compressor will fail from oil starvation. Also, the loss of oil pressure resulting from the missing tube can cause damage and problems in other components and parts.

Oil hole alignment of the front bushing-to-cylinder block oil holes must be checked prior to, and at the completion of, installation. The cylinder block rear bushing bore has no oil holes to align with the bushing oil holes, so simply install the bushings with the indexing notches at the 5:30 and 10 o’clock positions. Refer to Figure 205 and Figure 206.

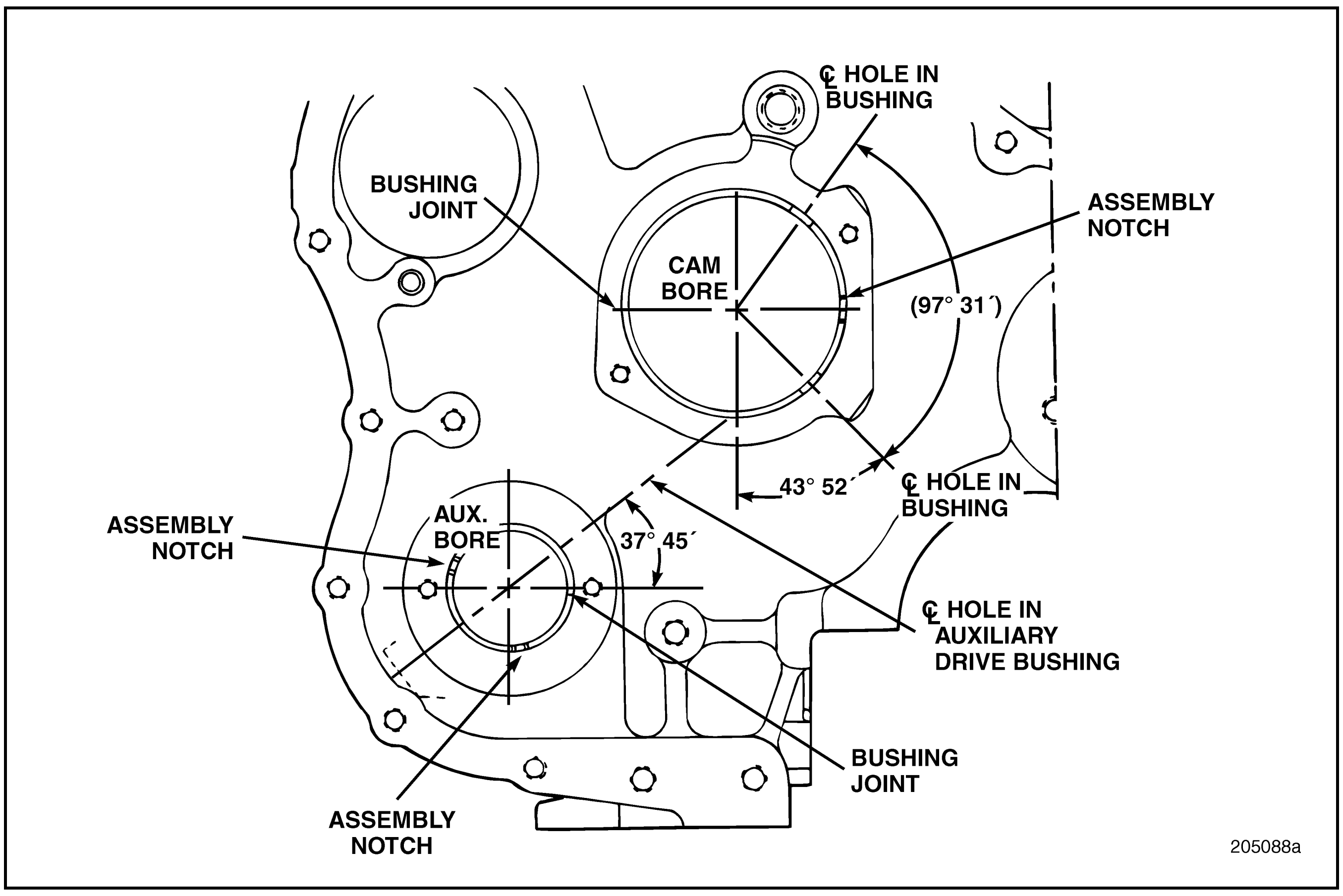

Figure 205 — Front Camshaft and Auxiliary Shaft Assembly Notch Locations

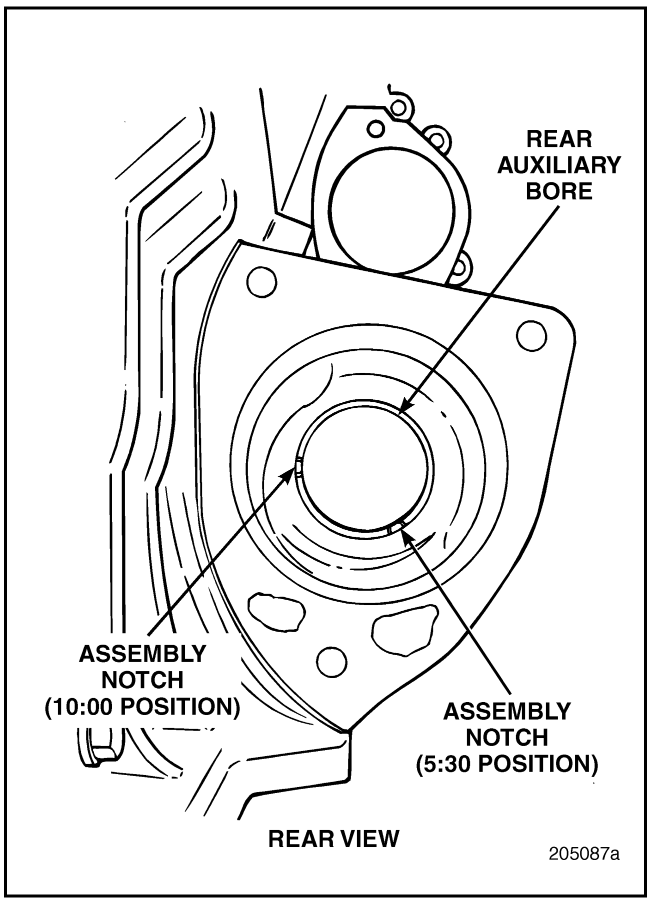

Figure 206 — Rear Auxiliary Bushing Alignment

1. Clean the surfaces of the bushing and the bore. Dry both surfaces with compressed air.
2. Using a dark-colored felt-tip marker, mark the cylinder block and the bushing with a line to facilitate correct alignment during installation. Refer to Figure 207.
3. Position the replacement bushing against the front face of the block at the front bushing bore. Align the oil hole in the bushing with the hole in the block.

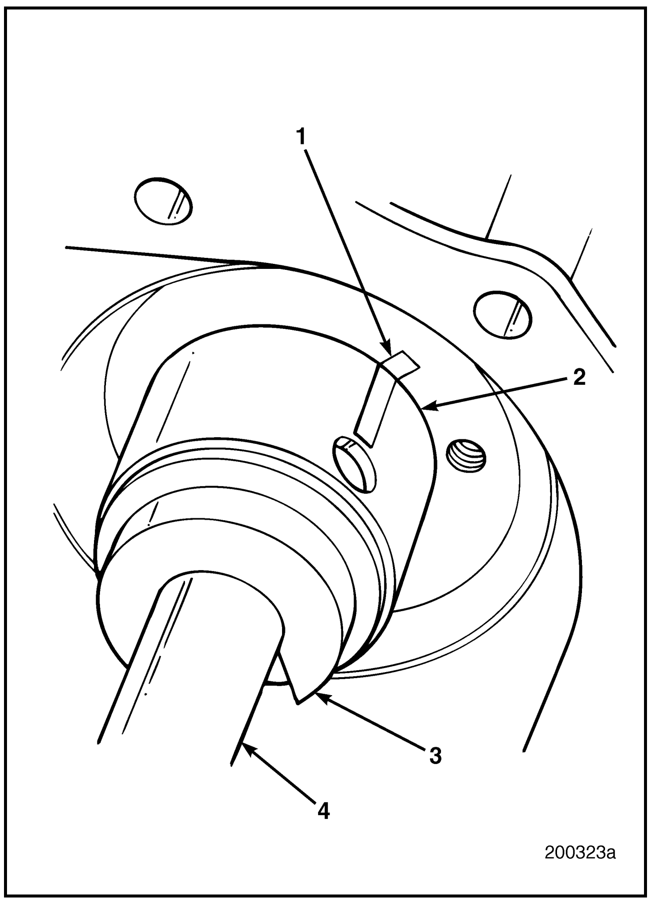

Figure 207 — Auxiliary Shaft Bushing Alignment

1. Alignment Mark 2. Bushing 3. Pilot Adapter J 21428-12	4. Camshaft Bushing Remover/Installer (J 21428-01 Kit)

4. Using camshaft bushing removal/installation tool J 21428-01 and the appropriate pilot adapter J 21428-12, install the bushing.
5. Check the bushing surface for burrs caused by installation.
6. After the bushing is in place, measure the ID to ensure that the bushing is not undersize because of burrs on the OD caused by installation. Refer to the “Fits and Limits” chart in the SPECIFICATIONS section for the bushing ID dimensions.
7. Working from the front of the cylinder block, repeat steps 1 through 6 to install the front bushing.
8. Bushings must be installed to the depths described in Figure 208.

CAUTION

The front auxiliary shaft bushing must be flush or recessed within 0.030 inch (0.763 mm) of the machined front surface of the cylinder block. Incorrect recess will cause misalignment of the oil supply hole, resulting in insufficient lubrication of the journal. Also, any bushing protrusion will allow the thrust washer to seat on the bushing and result in the thrust washer mounting screws coming loose.

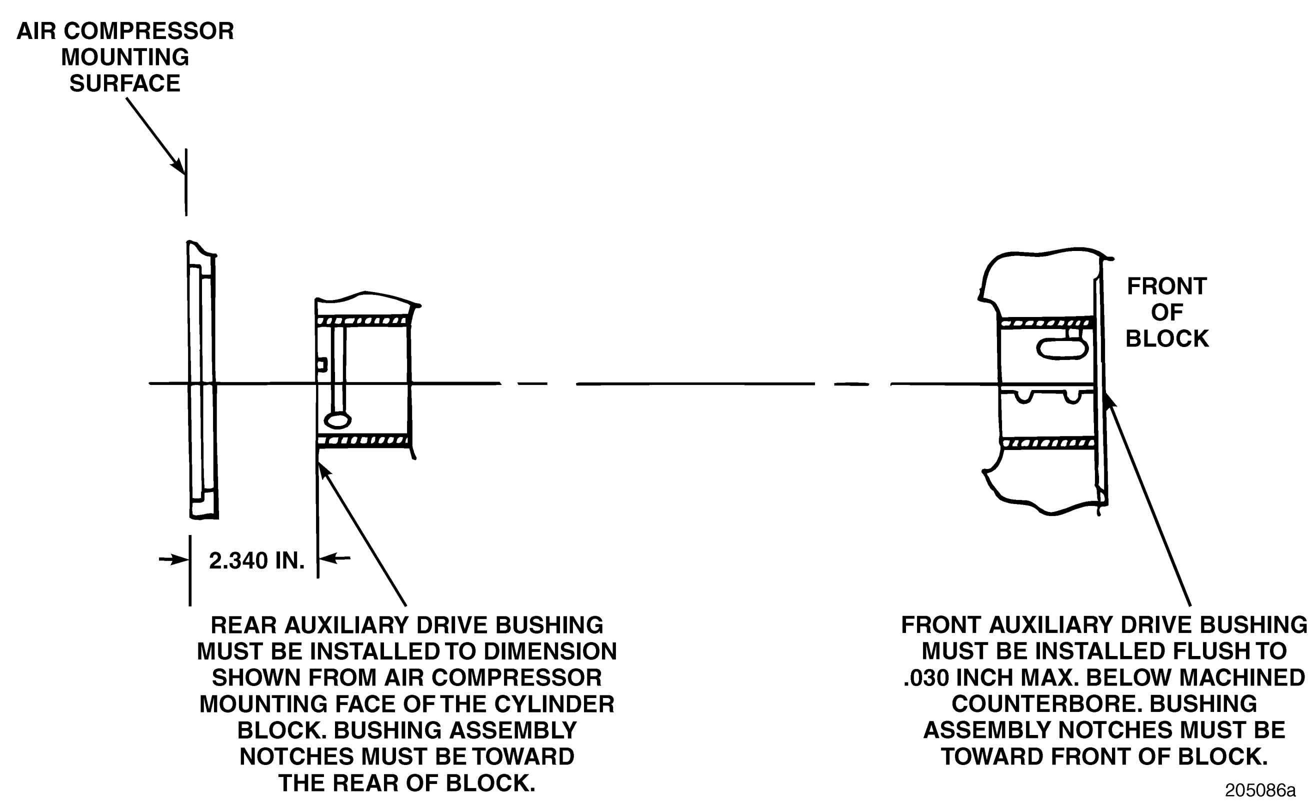

Figure 208 — Auxiliary Bushing Installation Dimensions

9. Install the thrust washer and tighten the retaining screws to the specified torque, 15 lb-ft (20 N•m).

Cylinder Sleeve Installation

[212 NC]

GENERAL INFORMATION

Satisfactory cylinder sleeve service life and good head gasket seal is dependent on uniform cylinder block counterbores and the correct extension of the sleeve flanges above the top deck of the cylinder block.

NOTE

A crevice seal is not used with ASET™ engine cylinder sleeves and should not be used for engine repairs or rebuilds. As such, cylinder sleeve part Nos. 509GC463 and 509GC466 for service use do not have a crevice seal groove.

SPECIAL TOOLS REQUIRED

- Depth Gauge J 26948
- Dial Bore Gauge J 5347-B
- Cylinder Hone and Glaze Breaker J 5902-01

INSTALLATION PROCEDURE

Refer to Figure 209.

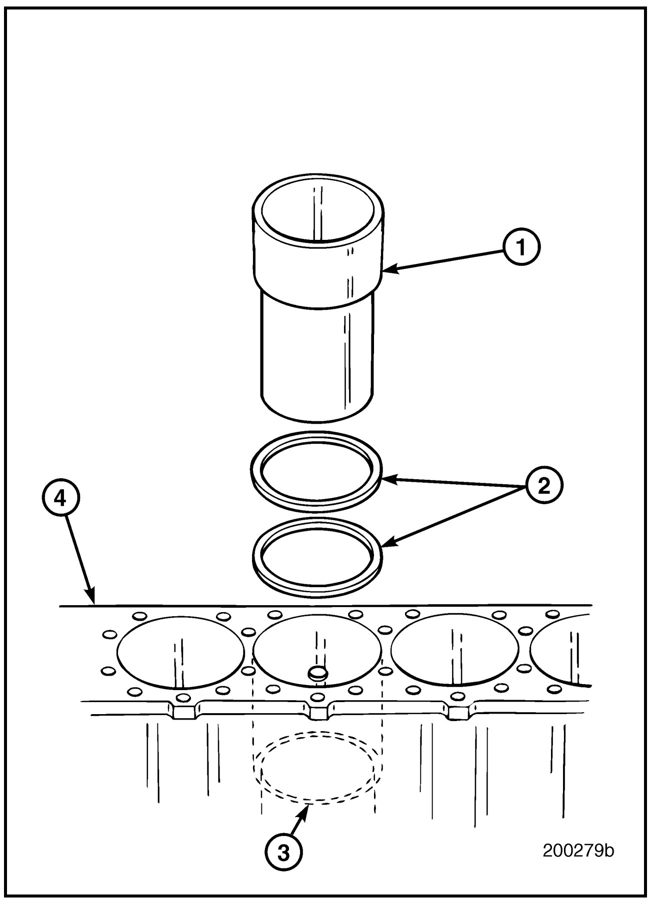

Figure 209 — Sleeve Installation

1. Sleeve 2. Shims (as Required)	3. Counterbore Ledge 4. Cylinder Block

1. Thoroughly clean and dry the prepared cylinder block, counterbore ledge and cylinder sleeves. Refer to the cylinder block cleaning and inspection procedures in this section.
2. If the counterbore ledge has been cut, place the necessary shims on the cylinder block counterbore ledge (sleeve seat). Always try to use a single shim, if possible. If more than one shim is necessary, always use the least number of shims required to achieve the proper cylinder sleeve flange height. Always place the thickest shim on the bottom.

NOTE

If shims are used, they must be placed on a clean, dry cylinder block sleeve seat, with the thickest shim on the bottom. Apply RTV silicone on top of the shims only. If RTV is applied under the shims, the shims may be displaced when the sleeve is installed.

3. Apply approximately a 0.090–0.130-inch (2.286–3.302 mm) bead of RTV silicone (MACK Silastic® 342SX32, Dow Corning Silastic® RTV732, General Electric RTV130 or equivalent) in the corner of the cylinder block sleeve seat and completely around the cylinder wall as shown in Figure 210. Do not use excessive amounts of RTV. Do not apply the bead more than 0.130-inch (3.302 mm) high.

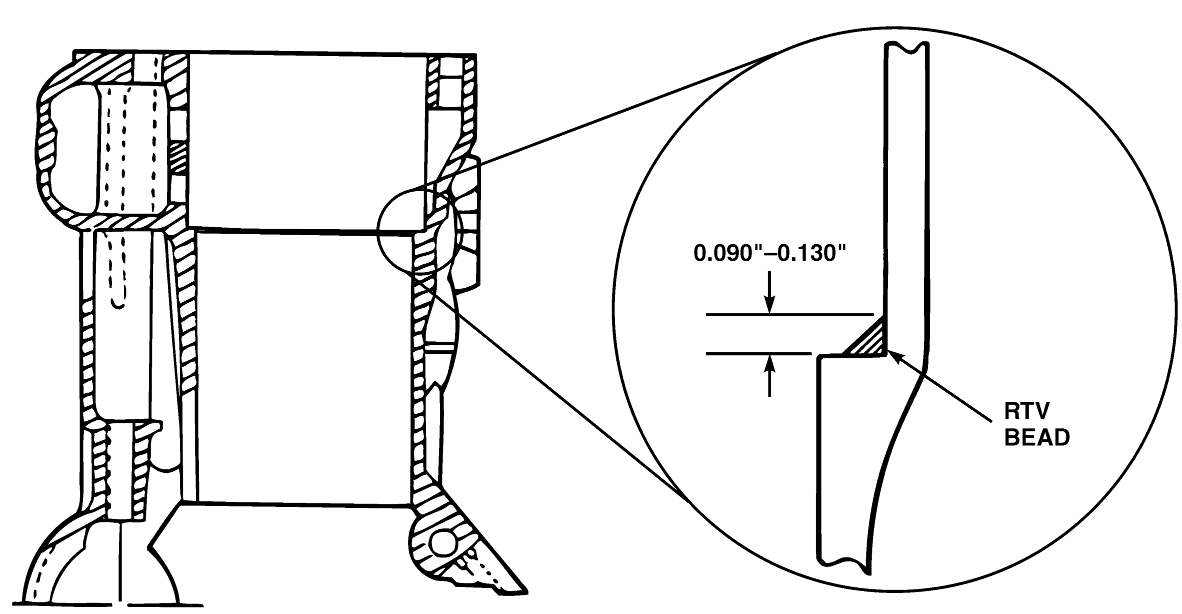

Figure 210 — Cylinder Block Sleeve Seat

NOTE

Applying an RTV silicone bead is mandatory whenever cylinder sleeves are installed.

To prevent partial curing and questionable sealing and bonding, apply RTV silicone just before installing the sleeves.

CAUTION

The cylinder block counterbore ledge and the cylinder sleeve must be kept clean and free of any oil residue to ensure that the RTV silicone bead seals and bonds properly.

4. Position the cylinder sleeve in the cylinder bore of the block.
5. With the palms of the hands placed on the upper end of the cylinder sleeve 180 degrees apart, push downward with quick, even pressure. Then, using a large plastic-faced hammer, tap the sleeve (close to the inside diameter) to fully seat the sleeve. Tap alternately from one side to the other, gradually working around the entire circumference of the sleeve.

NOTE

Clean any RTV from around the bottom of the cylinder sleeve and the block which may have been pressed out from the sealing surfaces of the block and sleeve during installation.

6. After the cylinder sleeve is fully seated, use depth gauge J 26948, or equivalent, to check the flange height-above-deck dimensions. The specified dimension is 0.023–0.029 inch (0.584–0.737 mm). The measurement should be taken in the channel between the sleeve top lip (fire dam) and the coining bead. Refer to Figure 211.

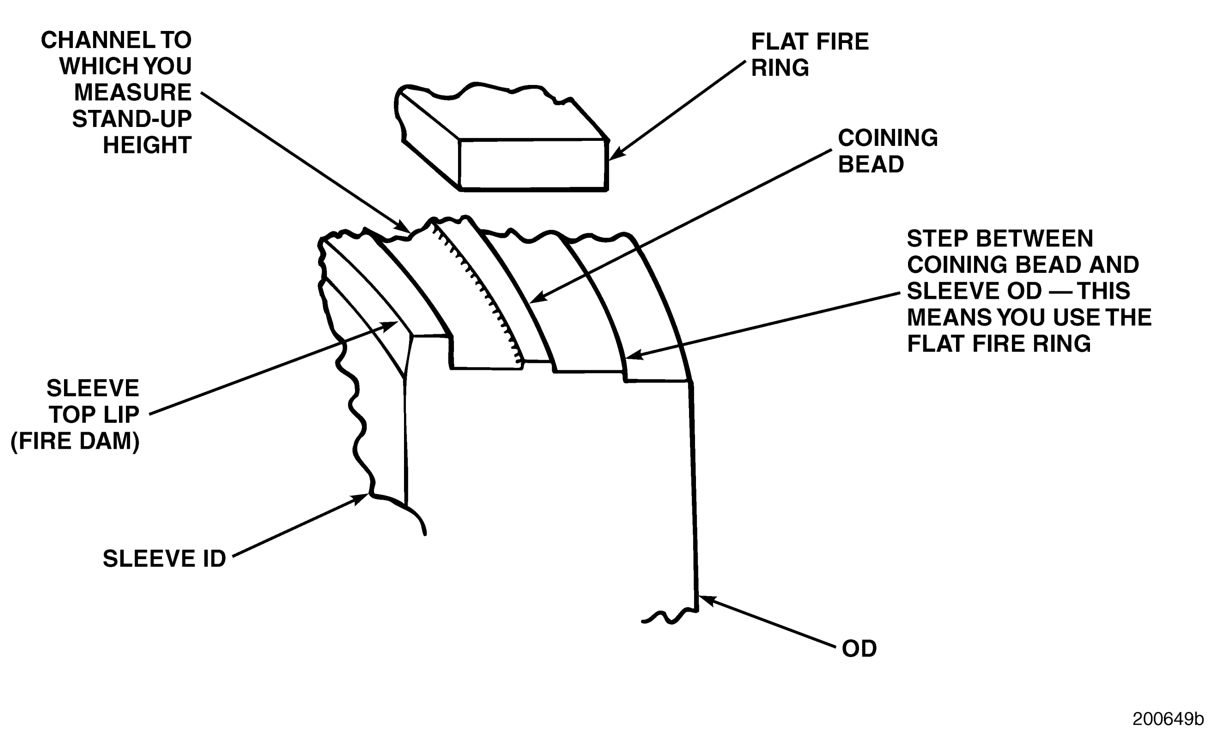

Figure 211 — Cylinder Sleeve/Fire Ring Configuration

NOTE

The height of the cylinder sleeves above the cylinder block deck (under the same cylinder head) can vary as long as all are within specification. Refer to the SPECIFICATIONS section of this manual and ensure the cylinder sleeve height matches the "Cyl. Sleeve Flange Channel-to-Block Deck" extension specification. Cylinder sleeve extension heights above the cylinder block deck are different between the ASET™ AC and AI/AMI engine models.

7. Using dial bore gauge J 5347-B, or equivalent, check the cylinder sleeve for out-of-round and taper limit (Figure 212). Take readings in two directions, 90 degrees apart, at each of three levels.

   Cylinder sleeve ID maximum: 4.877 inches (123.876 mm)

   Cylinder sleeve ID minimum: 4.875 inches (123.825 mm) (The cylinder sleeve ID may be a minimum 4.872 inches [123.749 mm] due to close-in from the press fit.)

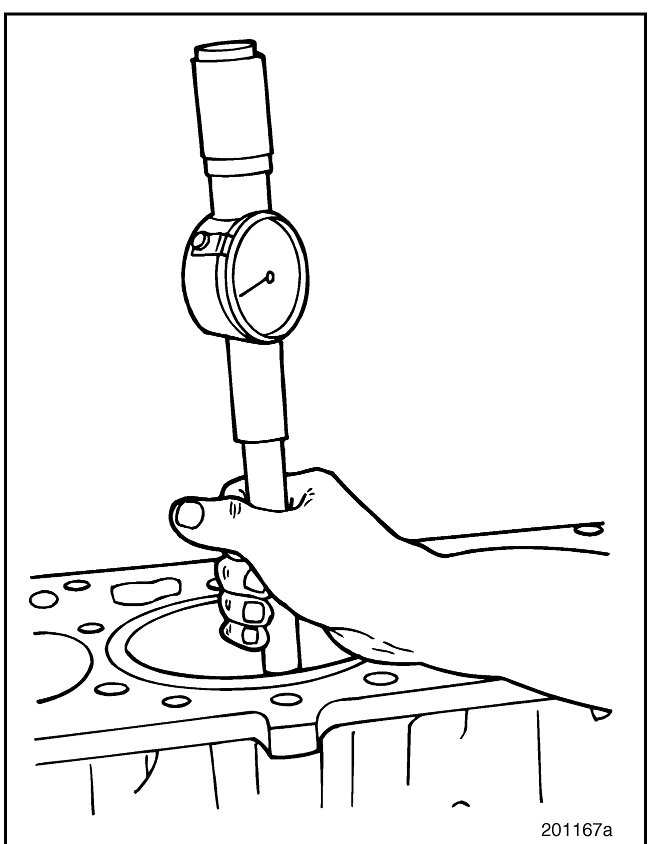

Figure 212 — Checking Cylinder Sleeve for Out-of-Round or Taper

HONING THE CYLINDER SLEEVE BORE

CAUTION

All MACK engines currently produced have fine precision-finished cylinder sleeves. Because of the precision finish, honing is NOT ALLOWED. Particles from the honing process which become wedged in the pattern are impossible to completely remove and can cause further damage.

Piston Cooling Spray Nozzle Installation

[219 RV]

SPECIAL TOOL REQUIRED

- Two-Piece Piston Cooling Nozzle Aimer J 39045

INSTALLATION PROCEDURE

Refer to Figure 213.

1. Using a liberal amount of lubricant, install the elastomer sleeve on the locator tube.
2. Install a retaining screw in the spray nozzle bracket.
3. Position the spray nozzle locator tube in the cylinder block oil passage. Then, using torque wrench J 24406, or equivalent, tighten the retaining screw to the specified torque, 15 lb-ft (20 N•m).

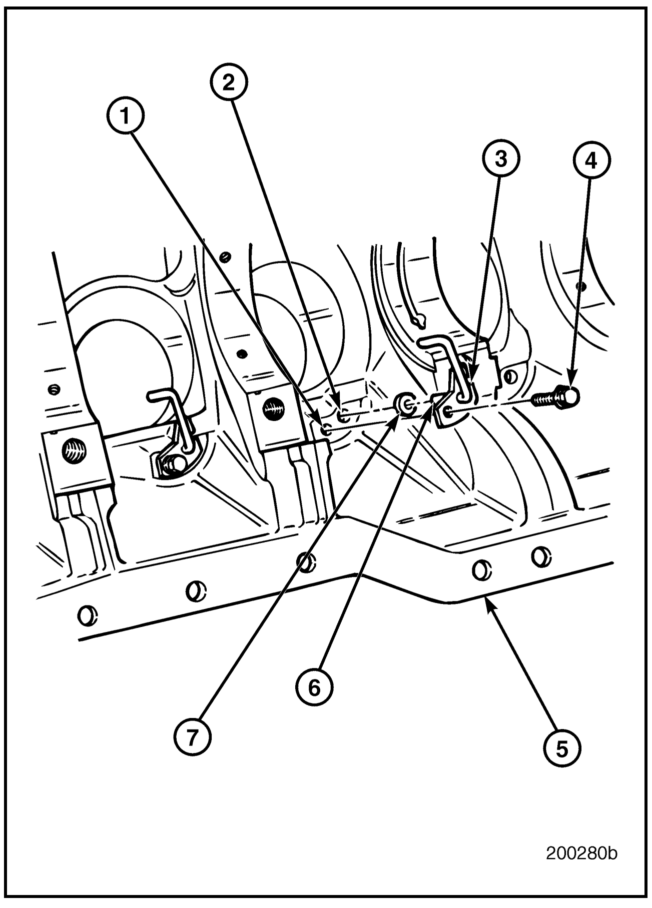

Figure 213 — Spray Nozzle Installation

1. Threaded Hole 2. Oil Passage 3. Spray Nozzle Bracket 4. Retaining Screw	5. Cylinder Block 6. Locator Tube 7. Elastomer Sleeve

PISTON COOLING NOZZLE SPRAY POSITIONING

Refer to Figure 214.

The piston cooling oil spray target location on the underside of the piston is important. It ensures adequate dissipation of heat from the piston. Correct positioning of the nozzles also ensures that the crankshaft counterweights do not strike the nozzles.

SERVICE HINT

For ease of installation and to reduce the amount of crankshaft rotation needed to facilitate access to the spray nozzles, install the spray nozzles in the following set order: cylinders 1 and 6, 5 and 2, 3 and 4.

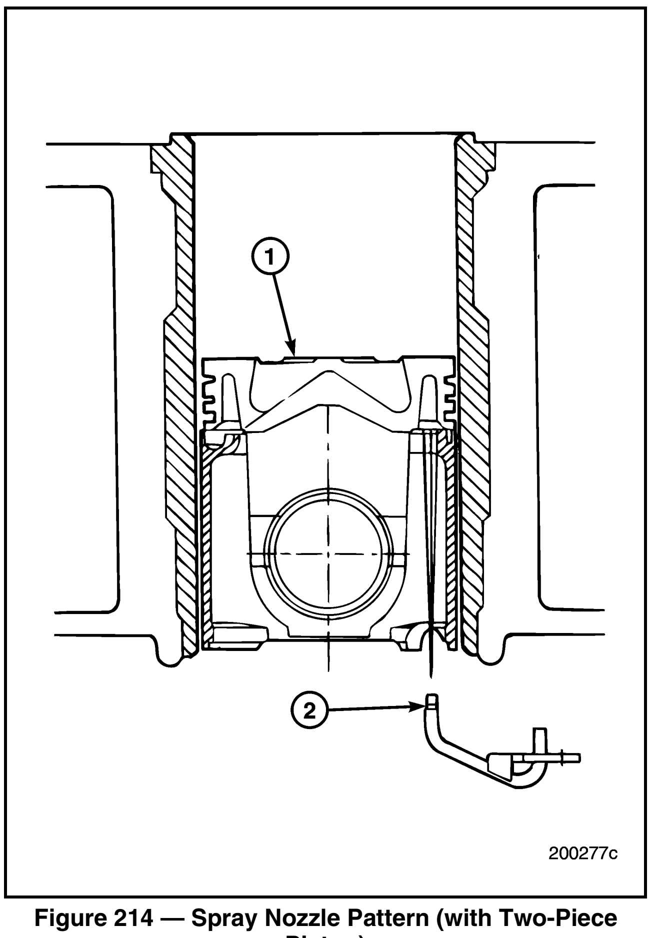

Figure 214 — Spray Nozzle Pattern (with Two-Piece Piston)

1. Piston Crown	2. Nozzle

Using piston cooling nozzle spray position set J 39045, check the direction of the spray from the nozzles. Refer to Figure 215.

1. Position rod in the end of the spray nozzle.
2. Place the applicable plastic target on the cylinder block over the cylinder to be tested.
3. Install a cylinder head bolt through the target alignment hole and into the cylinder block capscrew hole.
4. The rod should now be aligned in the target area. If the rod is at the edge of the target area, center the rod in the target area as follows:
   a. Loosen the nozzle setscrew. A slight adjustment can then be made to center the rod within the target area.
   b. Following adjustment, tighten the setscrew to the specified torque, 15 lb-ft (20 N•m).

CAUTION

Always replace a badly deformed spray nozzle. Do not attempt to realign it. Precise targeting is necessary to adequately cool the piston crown.

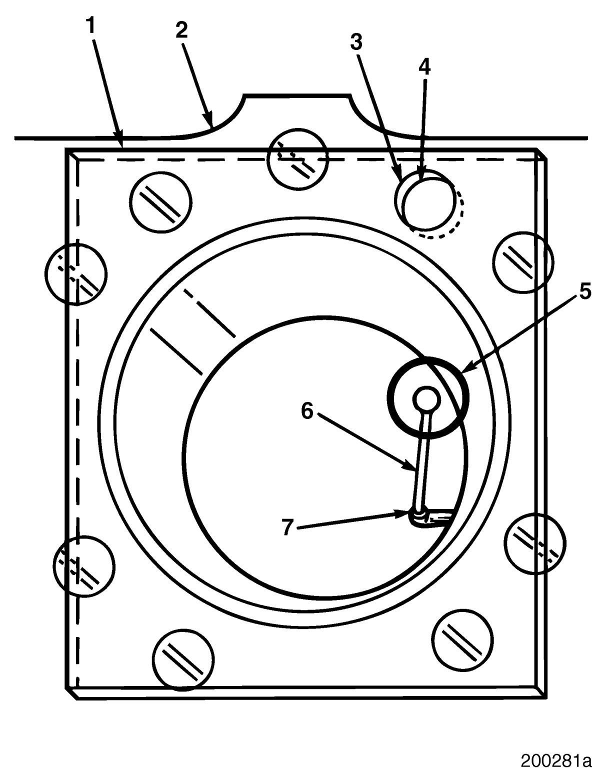

Figure 215 — Spray Nozzle Targeting

1. Plastic Target	5. Target Area
2. Cylinder Block	6. Rod
3. Alignment Hole	7. Spray Nozzle
4. Cylinder Block Hole	

Cylinder Block Dowel Pin Replacement

[211 HA]

GENERAL INFORMATION

Precision-made round-type and blade-type locating dowel pins are used for alignment of the front cover and flywheel housing.

SPECIAL TOOL REQUIRED

- Flywheel Housing/Timing (Front) Cover Locating Pin Driver J 37712

REMOVAL

If it is necessary to remove the front cover or flywheel housing locating dowel pins, do so as follows:

1. Securely clamp the pin with a pair of locking pliers.
2. While exerting an outward force, rotate the pin back and forth until the pin works free from the hole.

INSTALLATION

Two dowel pins are used to locate both the flywheel housing and the front cover to the cylinder block. One dowel is round, the other is a blade type. One end of the blade-type pin is also round and is the end installed in the cylinder block.

NOTE

The dowels used for the front cover installation are similar except for size. The smaller dowels are used for the front cover and the larger dowels for the flywheel housing.

ROUND DOWEL PIN INSTALLATION

1. Insert the round dowel pin into the locating pin driver J 37712. The pin must be positioned in the driver with the tapered end of the dowel facing outward.
2. Position the exposed end of the dowel into the appropriate dowel pin hole in the cylinder block (see Figure 217 or Figure 218 for location).
3. Using a hammer, drive the pin into the block until the driver contacts the cylinder block. When the driver has made contact with the block, the dowel pin will be at the correct dimension above the block surface.

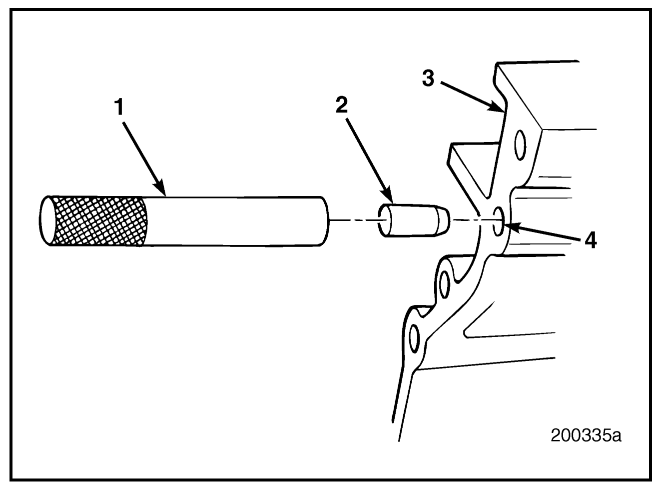

Figure 216 — Round Dowel Pin Installation

1. Locating Pin Driver	3. Cylinder Block
2. Round Dowel Pin	4. Dowel Pin Hole

BLADE-TYPE DOWEL PIN INSTALLATION

Refer to either Figure 217 or Figure 218.

1. Position the round end of the blade-type dowel pin into the dowel pin hole in the cylinder block. The blade end must be aligned vertically (up and down) with the block for the rear position and at approximately a 51-degree angle for the front position.
2. Using a hammer, drive the dowel pin into the block until the shoulder of the pin is flush with the cylinder block surface.
3. Measure the pin protrusion at both the front and the rear blade pin locations. Adjust pin height to match these dimensions, if required.
   - Front location:
     — Blade Pin 0.77 inch (19.56 mm)
   - Rear location:
     — Blade Pin 0.91 inch (23.11 mm)

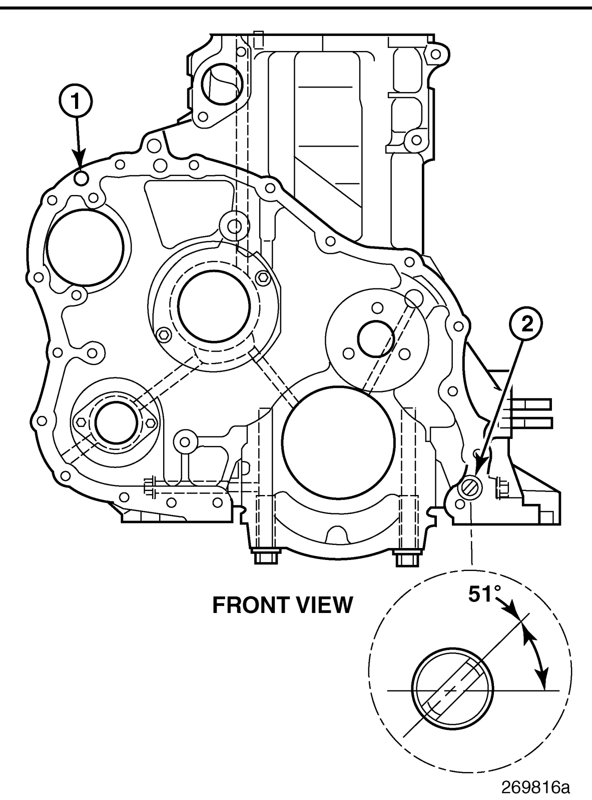

Figure 217 — Pin Angle Alignment (Front)

1. Round Locating Pin	2. Blade Locating Pin (Approximately 51-Degree Angle)

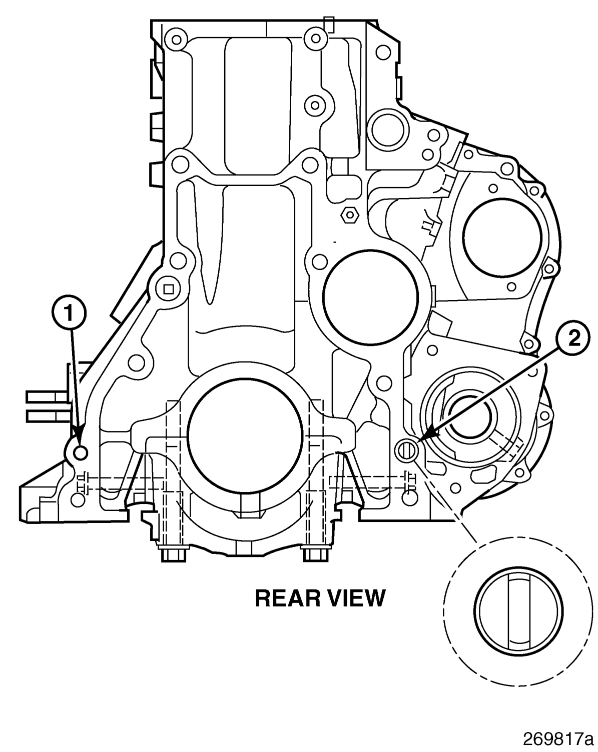

Figure 218 — Pin Angle Alignment (Rear)

1. Round Locating Pin	2. Blade Locating Pin (Vertical)

CRANKSHAFT AND FLYWHEEL BENCH PROCEDURES

General Information

Current-production flywheels no longer have the timing grooves milled into the face surface.

Crankshaft Inspection

[212 HP]

GENERAL INSTRUCTIONS

NOTE

All bearing surfaces must be free of grit and burrs. Small particles of dust and dirt left between the crankshaft and bearings will cause rapid wear and scoring of the crankshaft journal and inserts. Any foreign material left between the crankshaft bearing inserts and caps will cause distortion of the insert and a reduction in operating clearance at that point. The resulting frictional heat at the point of distortion will cause the bearing material to melt away from the steel backing. Such melted material will create further hot spots until complete bearing failure occurs. Anything that interferes with the operating clearance of a bearing and the proper dissipation of heat will affect bearing life. Cleanliness cannot be overstressed.

INSPECTION

1. Inspect the crankshaft journals for out of round, taper and poor surface finish.
2. Visually check the crankshaft for any apparent cracks, worn journals and damage to threads, dowel pin or main drive gear.
3. Magnaflux the crankshaft to check further for cracks. This process requires special equipment and application methods.
4. Using standard machinists' inspection practice, check the crankshaft to ensure that it is straight.
5. Measure the crankshaft journals with a micrometer. Measure each journal in two locations, 90 degrees apart, and record the measurements.
6. Check the measurements against the specifications listed under Fits and Limits in the SPECIFICATIONS section.
7. If the crankshaft journals are worn, out of round, or tapered, replace the crankshaft. New or exchange crankshafts are available from MACK Parts Distribution Centers.

CAUTION

Crankshaft regrinding by anyone other than Mack Trucks, Inc. is NOT recommended due to the tight control required for maintaining geometrical tolerances, and the hardened characteristics of crankshaft journals and journal fillets.

If the crankshaft main journals or connecting rod journals are not a standard size, be sure to use properly sized bearing inserts when reassembling the engine. Bearing insert sizing is identified with a "P" following the part number, and is stamped on the back side of the bearing insert. For example, if a journal is 0.010 inch (0.254 mm) undersize, a 0.010-inch undersize bearing is required and will be stamped "P10."

CAUTION

Some crankshafts may have journals which are 0.002 inch (0.0508 mm) undersize. These crankshafts are marked by a streak of white paint adjacent to the journal. Always check the journals to ensure that the bearing inserts used are of the proper size.

Crankshaft Dowel Pin Replacement

[212 HA]

Current-production crankshafts are equipped with a blade-type flywheel-to-crankshaft dowel pin installed in the rear flange directly opposite the manufacturing locator hole. Hole sizes are as follows:

- Manufacturing locator hole — approximately 1/2 inch (12.7 mm) in diameter and 3/8 inch (9.52 mm) deep; used in the manufacturing process
- Flywheel dowel pin hole — approximately 9/16 inch (14.29 mm) in diameter by 7/8 inch (22.23 mm) deep

All new service replacement crankshafts, short blocks or basic engines will have a dowel pin in the crankshaft rear flange. In nearly all cases, the flywheel will already have a hole in it to accept the dowel pin. If an earlier version flywheel or torque converter drive flange without a dowel pin hole is used for replacement, it must be reworked.

If it is necessary to rework the flywheel or torque converter drive flange, two holes must be added using a 19/32-inch drill bit. One hole is for the dowel pin and another directly opposite the first hole is to maintain balance of the flywheel/torque converter drive flange.

Refer to Figure 219.

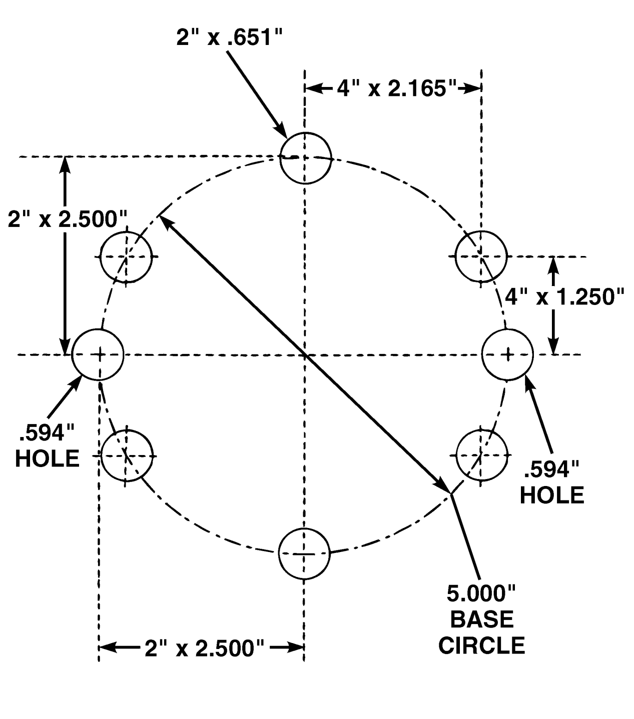

Figure 219 — Dowel Pin Hole Dimensions (Flywheel or Torque Converter Drive Flange)

DOWEL PIN REMOVAL

To remove the crankshaft dowel pin:

1. Securely grip the dowel pin with locking pliers.
2. Rotate the dowel pin back and forth while exerting outward pressure until the pin is removed.

DOWEL PIN INSTALLATION

To install a replacement crankshaft dowel pin:

1. Position the dowel pin in a 0.5562-inch (14.1275 mm) diameter unthreaded hole in the rear flange of the crankshaft. The pin must be installed with the flat surface aligned parallel to the center of the crankshaft as shown in Figure 220.
2. Use a soft metal hammer and punch to drive the pin into the hole. The pin must be firmly seated and protrude 0.77 inch (19.56 mm) from the crankshaft flange surface.

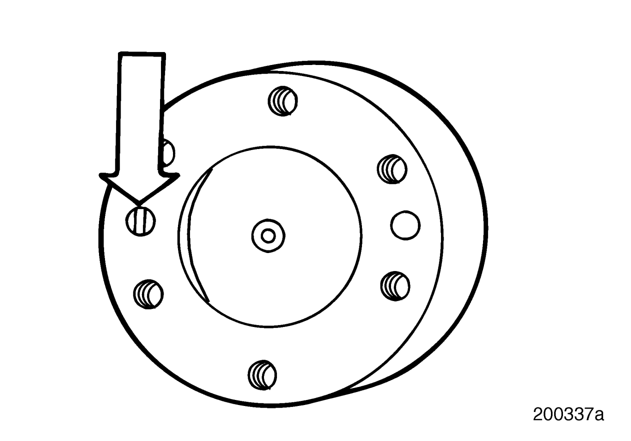

Figure 220 — Dowel Pin Alignment

Crankshaft Gear Replacement

[212 HV]

INSPECTION

After inspecting the crankshaft and determining that it is within specification, inspect the crankshaft gear for cracks and broken, worn or chipped teeth. If the gear is defective, it must be replaced.

REPLACEMENT

Refer to Figure 221.

1. Using a suitable puller, such as J 21834-4A, or equivalent, remove the gear and key.

NOTE

The threads in the end of the crankshaft are M8 x 1.25.

2. Clean the gear mounting surface. It should be free of grooves, scratches and burrs. Use a file, sandpaper or crocus cloth, as required.

CAUTION

Take care not to damage the key slot while installing the key.

3. Insert the key into the key slot. Lightly tap the key with a soft metal hammer to seat it in the slot.
4. Heat the replacement gear to approximately 250°F (121°C) in a temperature-controlled oven or on a hot plate.

CAUTION

Wear protective gloves when handling the heated crankshaft gear to prevent burns or personal injury.

CAUTION

Take care not to damage the gear teeth while seating the gear.

5. Position the gear over the end of the crankshaft with the timing mark facing outward, the chamfer toward the rear of the shaft, and the key slot aligned with the key in the shaft.
6. In one rapid motion, push the heated gear against the crankshaft flange. With the gear properly positioned, immediately and carefully tap the gear to help seat it against the flange.

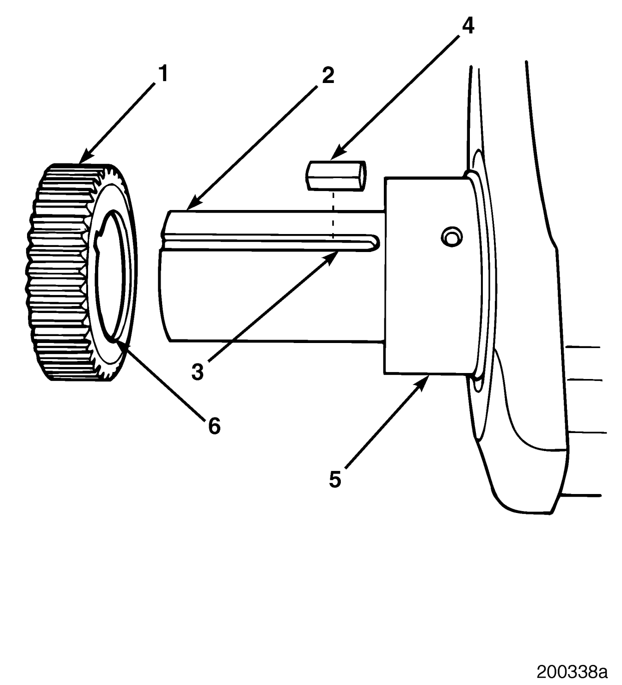

Figure 221 — Drive Gear Installation

1. Gear 2. Shaft 3. Key Slot	4. Key 5. Flange 6. Chamfer

Crankshaft Wear Ring Installation [212 JH]

When the service oil seal is to be replaced and the crankshaft flange is worn, the crankshaft can be salvaged by installing a crankshaft wear ring. An oil seal with a larger inside diameter is used with this wear ring.

SPECIAL TOOLS REQUIRED

- Crankshaft Rear Seal Installer J 37716-A
- Wear Ring Installer J 38880
- Universal Driver Handle J 8092

REMOVAL

CAUTION

A limited number of crankshafts were manufactured with a repair sleeve installed on the flange. The repair sleeve is usually not noticeable and is finish ground to standard flange size. If the repair sleeve is damaged or becomes loose, the crankshaft must be replaced.

Special care must be taken not to damage the crankshaft flange during wear ring removal.

Refer to Figure 222.

1. The wear ring can be removed by carefully applying heat, using a ball-peen hammer to expand the diameter, or by using a chisel to split the wear ring. Use extreme care not to damage the crankshaft flange.

CAUTION

Place the chisel face squarely on the wear ring and carefully strike the chisel with a hammer to cut part-way through the ring. The wear ring will loosen enough to be removed without cutting completely through it. The goal is to carefully remove the wear ring in this manner and not cut, nick or damage the crankshaft flange.

2. Thoroughly clean the flange area of the crankshaft. Check for nicks or scratches and repair any damaged areas with crocus cloth as necessary.

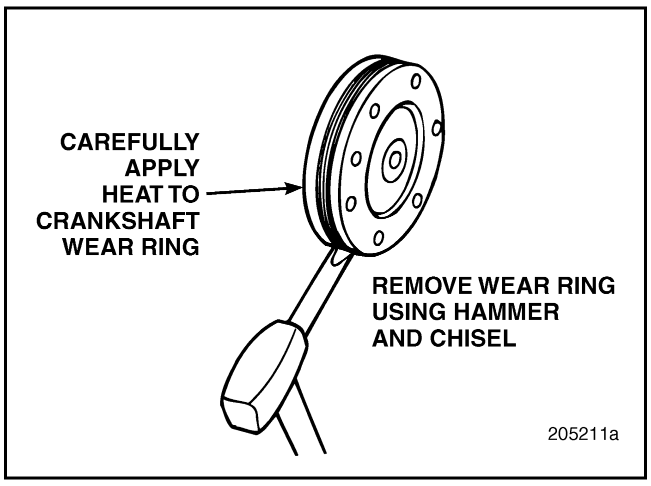

Figure 222 — Crankshaft Wear Ring Removal

INSTALLATION

Refer to Figure 223.

CAUTION

On some wear rings it may be difficult to determine the direction of the arrow on the inside diameter. In this case, ensure proper installation by installing the wear ring with the chamfer on the inside diameter positioned toward the engine. The chamfer on the outside diameter of the wear ring must face away from the engine.

NOTE

The crankshaft wear ring is a shrink fit on the crankshaft flange. Use wear ring installer J 38880 and universal driver handle J 8092 to install the ring to the proper depth.

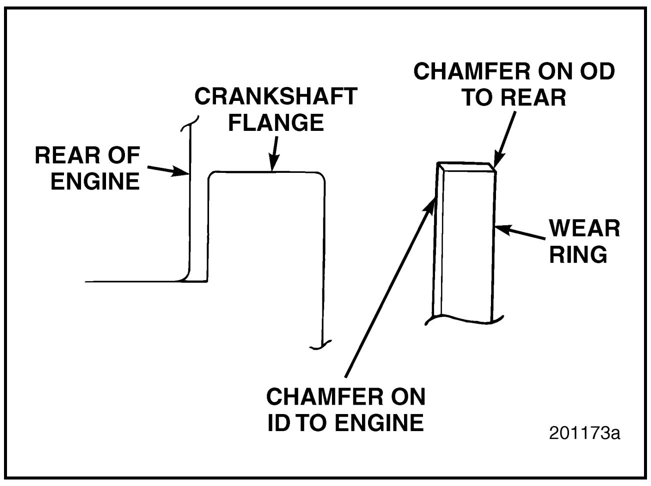

Figure 223 — Proper Crankshaft Wear Ring Installation

1. Position the wear ring in the spring clips of the wear ring installer J 38880 with the arrow pointing away from the installer tool. Refer to Figure 224.

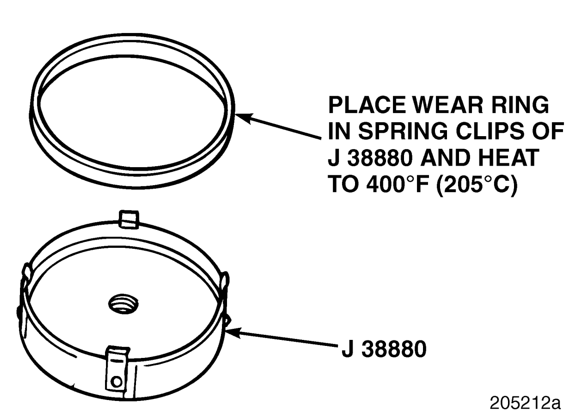

Figure 224 — Crankshaft Wear Ring Installation

2. Heat the wear ring and wear ring installer together in a temperature-controlled oven or on a hot plate, with the wear ring on the bottom and installed in the spring clips of the installer. Work as close as possible to the engine to avoid heat loss after heating the ring. Heat to 400°F (205°C). Do not install the driver handle at this time. This allows the wear ring to maintain sufficient heat until it is fully installed on the flange.

CAUTION

Do not heat the wear ring with a torch. This type of heat source will not heat the ring evenly.

3. Thoroughly clean and dry the crankshaft oil seal mounting flange.
4. After the wear ring is sufficiently heated, use heat-resistant gloves to install the universal driver handle J 8092 into the threaded hole at the center of the installation tool.
5. Remove the wear ring and installation tool from the oven or hot plate and immediately place it in position on the crankshaft flange. Push the wear ring onto the flange until the installation tool is fully seated against the end of the flange. As the wear ring cools, it will shrink-fit onto the crankshaft flange.
6. Allow the wear ring to cool completely. Then remove the installation tool.

WEAR RING WITH DOUBLE-LIP TEFLON® SEAL (AUTOMATIC TRANSMISSION)

The oversize inside diameter lip seal and wear ring are shipped as an assembly with the seal installed on the wear ring. For this combination, the seal and the wear ring are installed as an assembly. Refer to the crankshaft rear oil seal installation procedures under Engine Reassembly in the REPAIR INSTRUCTIONS section.

Flywheel Inspection and Resurfacing

[212 UB]

The flywheel is a design with an integral, non-replaceable ring gear. If the ring gear teeth are in good condition, the flywheel surface should be checked as follows:

1. Inspect the flywheel to determine if it requires resurfacing. The wear areas should be measured using a straightedge across the friction face and a thickness gauge. If the wear measurement is 0.020 inch (0.508 mm) or less, the flywheel does NOT need to be machined when operated against ceramic clutch facings.

2. Resurface the flywheel as required. To ensure satisfactory service life, the maximum amount of material that may be removed from the flywheel surface is 0.070 inch (1.78 mm).

NOTE

When resurfacing a flat-style flywheel, it is very important that the machine shop NOT leave a step on the friction face outer diameter adjacent to the clutch locating pilot. There is an undercut relief in the corner between the friction face and the clutch locating pilot, and resurfacing must go up to this relief. If resurfacing is done to a depth which would eliminate the relief, a new relief must be cut. Refer to Figure 225.

When attempting to resurface as close to the clutch locating pilot as possible, keep in mind that the pilot must not be altered. The pilot controls the location of the clutch. If the locating pilot is altered, an imbalance will result.

Some machine shop operations may not have the tooling and locating equipment necessary for resurfacing a flat-style flywheel.

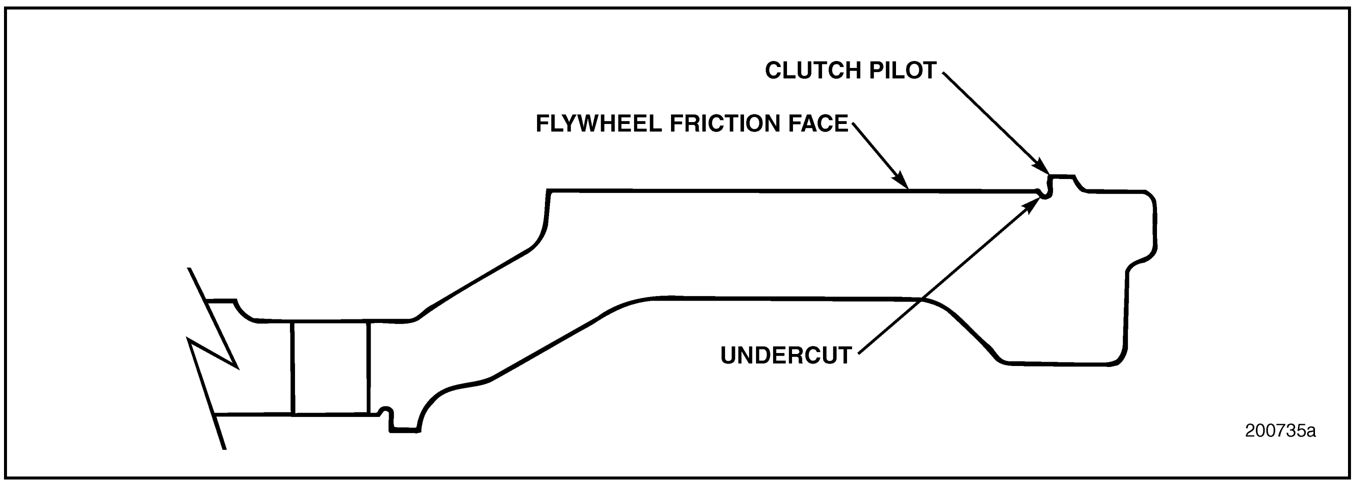

Figure 225 — Flywheel Resurfacing

AUXILIARY SHAFT AND CAMSHAFT BENCH PROCEDURES

Auxiliary Shaft Inspection

[212 CV]

The auxiliary shaft is identified by three machined circumferential cuts in front of the stamped part number.

INSPECTION

Refer to Figure 226.

1. Thoroughly clean the auxiliary shaft.
2. Inspect the shaft journals and splines, and gear teeth and splines for evidence of cracks, pitting, scoring or severe wear. If any of these conditions exist, replace the auxiliary shaft.
3. Make sure the orificed cup plug is in place in the internal passage at the front of the auxiliary shaft.

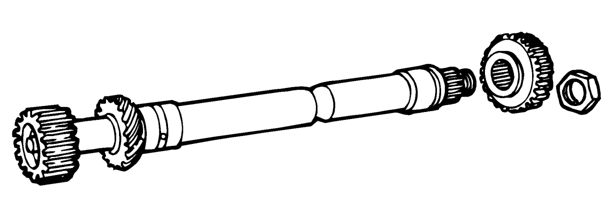

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Figure 226 — Auxiliary Shaft

Camshaft Inspection

[213 CH]

GENERAL INSTRUCTIONS

All ASET™ engine models use a **straight** key, P/N 43AX9, in the camshaft-to-gear keyway. The offset key used in earlier MACK engine models no longer applies.

CAMSHAFT GEAR REMOVAL

An extremely tight interference fit holds the cam gear on the camshaft. Typically, 10 tons of force is required to remove the gear. When cam gear removal or installation is required, use the following procedures.

⚠ DANGER

A considerable amount of force may be necessary to remove damaged or spun gears. DO NOT apply more than 25 tons (22.7 metric tons) of force to gears. Doing so may shatter the gears and result in severe personal injury.

Refer to Figure 227.

1. Position two adequate steel plates on the press to support the camshaft gear. The plates should have a 4-inch (101.6 mm) hole cut out in the center when placed side-by-side, or similar size V-grooves, to allow clearance for the shaft journals while providing optimum support for the gear.
2. Set the camshaft, supported by the gear, into the press.
3. Using a suitable arbor, press the camshaft out of the gear.

⚠ CAUTION

Make sure there is enough clearance between the end of the camshaft and the floor while removing the gear. Do not let the camshaft fall or strike the floor when pressed through the gear. The camshaft can be bent easily, and may go unnoticed. Installing a bent camshaft in the engine could result in cam bushing failure.

4. Remove the thrust washer.

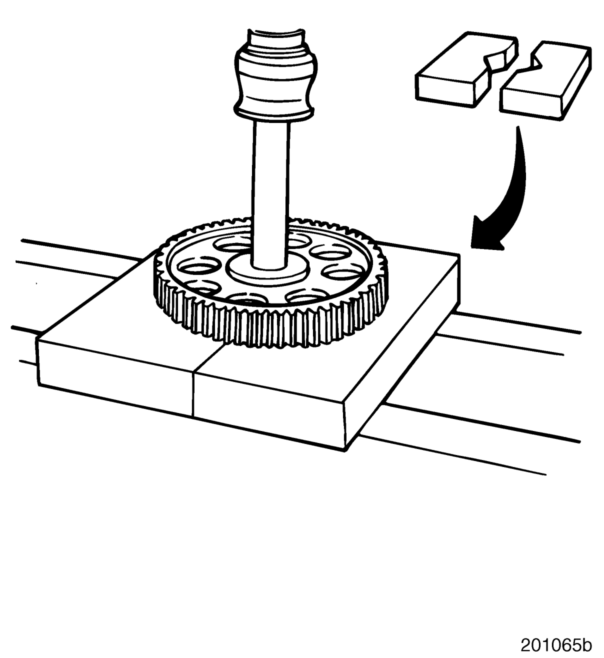


Figure 227 — Camshaft Gear Removal

INSPECTION

Refer to Figure 228.

1. Thoroughly clean the camshaft.

NOTE

Use the magnaflux (PT7190) inspection procedure to detect cracks.

2. Inspect the camshaft lobes and journals for evidence of cracks, pitting, scoring or severe wear. If any of these conditions exist, replace the camshaft.
3. Inspect the camshaft gear and captured thrust washer for cracks, pitting, scoring or adverse wear.
4. Visually inspect the key for signs of distortion or breakage.

CAMSHAFT GEAR INSTALLATION

The camshaft gear is shrink-fitted to the camshaft. To install the gear, it must be heated in an oven to 425°F (204°C). DO NOT attempt to heat the gear with a welding torch as this method will not provide even heating and could cause weakening of the metal.

An oven is the preferred method for heating the camshaft gear. However, an industrial grade hot plate can be used as an alternative to the oven. When using a hot plate, temperature sticks or a thermocouple must be used to determine gear temperature. The hot plate, temperature sticks and thermocouple are available through any industrial supply company.

NOTE

The camshaft gear is a “long-life” part that should be reused providing it is not damaged.

When installing the camshaft gear, use only the heat method procedure below for both new or used parts. DO NOT use a press to install the gear.

HEAT METHOD — CAMSHAFT GEAR INSTALLATION

Refer to Figure 228.

1. Using a suitable contact-type cleaner that dries rapidly and leaves no residue, thoroughly clean the camshaft and the gear.

NOTE

The camshaft and gear must be grease- and oil-free to ensure a good shrink-fit.

2. Install the key into the camshaft keyway. It may be necessary to tap the key with a soft metal hammer to ensure proper seating of the key. The original key should be reused if it not damaged. If the key is slightly loose in the key slot, it may move when the cam gear is being installed. To avoid this use a hammer to make two or three small dings along the top edges of the slot before installing the key. When the key is installed, the dings will help hold the key in place when the gear is being installed.

NOTE

Some non-current MACK engine models had used an offset key which was positioned to the right or left depending on the engine model. This is not an issue with ASET™ engines. All ASET™ engines use a straight key in the camshaft-to-gear keyway.

3. Install a **new** camshaft captured thrust washer on the camshaft.

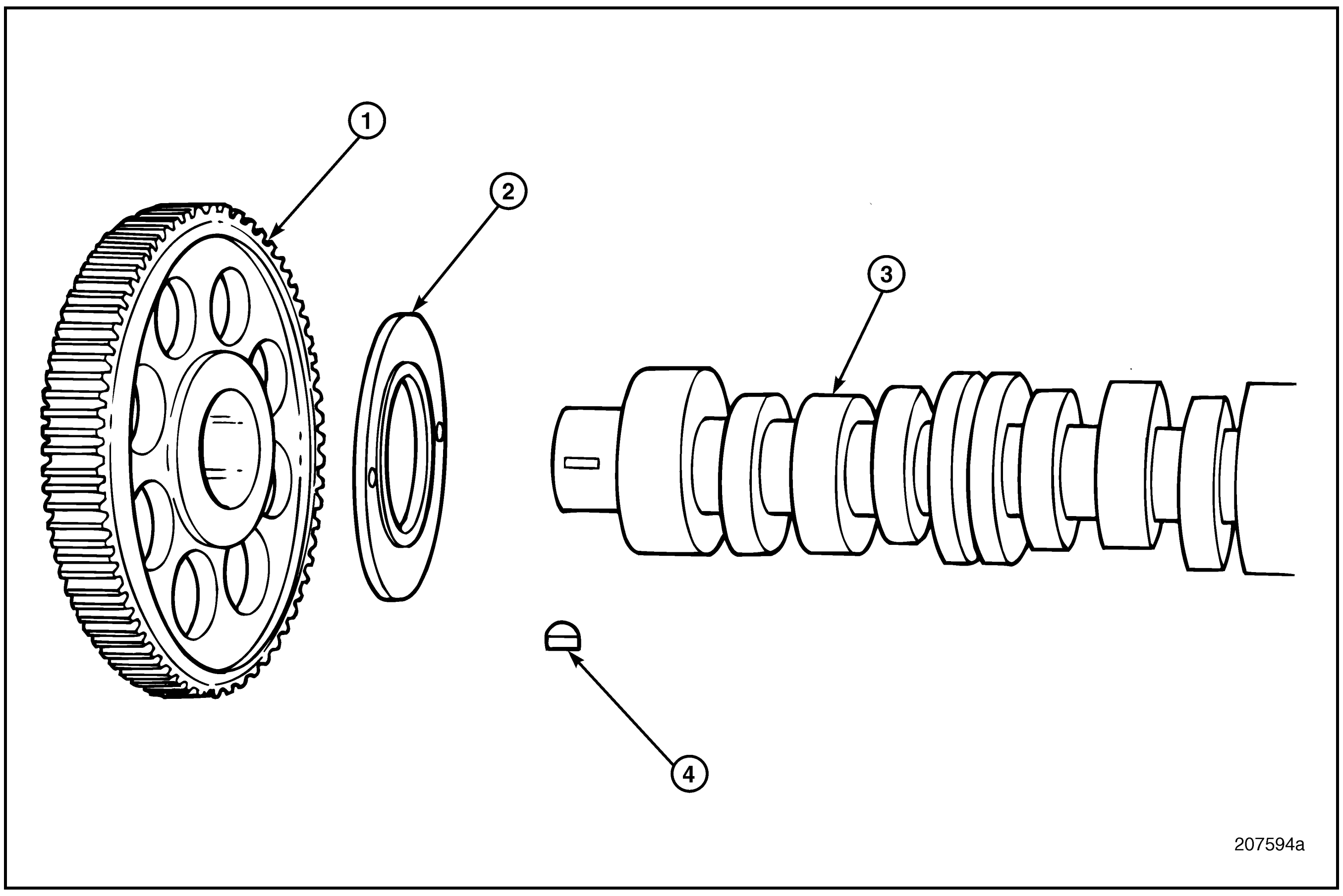


Figure 228 — Camshaft Assembly Components

1. Camshaft Gear 2. Camshaft Captured Thrust Washer	3. Camshaft 4. Key

4. Set the camshaft close to the oven in which the camshaft gear will be heated. It should be set vertically on the floor with the front of the shaft up. Secure the shaft so it cannot wobble or fall over as the gear is being installed.
5. Heat the camshaft gear to 425°F (204°C) in an oven (preferred — an old kitchen oven is sufficient) or on an industrial grade hot plate used in combination with the temperature-sensing equipment described earlier. Adequate heating will require one to two hours. DO NOT heat the gear for more than two hours nor exceed 425°F (204°C) as heat treatment may be affected.

NOTE

DO NOT attempt to heat the gear with a torch. This method will only provide localized heating, will not permit proper expansion and may affect heat treatment of the gear.

6. Remove the gear from the oven and position it on the camshaft with the keyway and key aligned and the timing marks facing up (Figure 229).

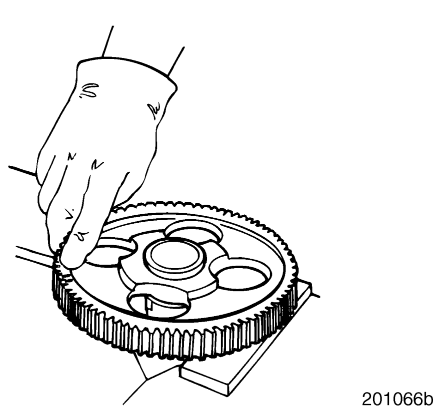


Figure 229 — Camshaft Gear Installation, Heat Method

DANGER

Wear protective gloves when handling the heated gear.

7. Using a quick, steady motion, push downward on the gear until the gear is fully seated against the cam shoulder surface.

CAUTION

The heat-expanded gear bore will begin to transfer heat to the camshaft as soon as contact between the gear and shaft is made. Therefore, it is absolutely necessary that the gear be installed in one rapid motion to the fully seated position.

If the gear is allowed to stop on the camshaft before it is fully seated, it will become immovable. If this occurs, DO NOT press the gear onto the camshaft. Instead, remove the gear with a press and thoroughly inspect the gear bore, camshaft journal and key. If there is no scoring, galling or tearing, repeat the installation procedure using the removed components. If damage is minimal, repair the components and reinstall. If the damage is significant, the components must be replaced.

8. Allow the gear to cool.
9. When the gear is fully seated, there should be 0.003–0.012 inch (0.076–0.31 mm) clearance between the rear face of the gear and the thrust washer. This clearance can be measured with a feeler gauge.

CONNECTING ROD AND PISTON BENCH PROCEDURES

Connecting Rod Inspection and Reconditioning

[212 LP]

GENERAL INSTRUCTIONS

Each connecting rod assembly has two alignment sleeves, one sleeve in each capscrew hole of the rod cap to locate and align the cap and rod thrust faces (Figure 230). These sleeves provide the best alignment when the sleeve gaps are positioned at a location approximately 90 degrees to the tongue or groove. The sleeve gaps MUST NOT be in line with the tongue or groove.

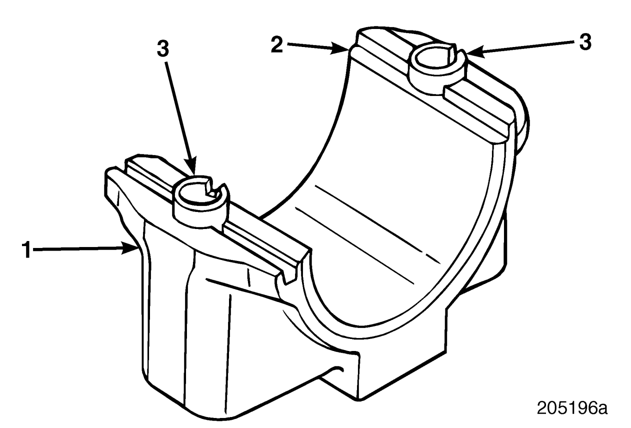


Figure 230 — Connecting Rod with Alignment Sleeves

1. Rod Cap 2. Bearing Insert	3. Alignment Sleeve

It is essential to closely control the weight of reciprocating parts. Connecting rods fall into two weight classes, M1 or M2. Initially, the classes were identified by the respective “M” number (M1 or M2) stamped onto the connecting rod bearing cap. Now, however, only the M1 rod carries the weight class identification stamped on the rod cap. The M2 connecting rod is no longer stamped with the weight class identifier.

When installing a single rod, or less than a full set, examine the removed rod(s) for part number and M number. Installing parts with the same weight class is preferred.

Connecting rods can be weighed to ensure that the proper weight class is used. Connecting rod weights for an engine should not vary by more than 0.46 ounce (13.04 grams) within each weight class.

NOTE

The maximum weight difference between the heaviest possible M2 rod and the lightest possible M1 rod is 0.83 ounce (23.53 grams).

SPECIAL TOOLS REQUIRED

- Piston Pin Bushing Remover/Installer J 37717
- Piston Pin Burnishing Broach J 37718
- Connecting Rod Fixture 945-6041

INSPECTION

Inspect each connecting rod for the following conditions. If any rod(s) is suspected of being faulty, replace it.

- Inspect the rods for nicks, cracks, signs of overheating, bends or twisting that can cause rod failure.
- Inspect the bolt holes for elongation or pulled threads.
- Check the mating surfaces between the rod and cap for correct fit.
- Inspect the crankshaft journal bearing surface of each rod and wrist pin bushing.

SERVICE HINT

If it is determined that the condition of any part or component is questionable or is at the limit of tolerance, replace it. If the questionable part or component is reused, it may fail or become out of tolerance after a short time in operation. It is cost-efficient to replace any questionable items when rebuilding.

Use genuine MACK replacement parts.

WRIST PIN BUSHING REPLACEMENT

If the wrist pin bushing is found to be out of tolerance, it should be replaced.

Refer to Figure 231.

To replace the bushing:

1. Position the rod in a press with the piston pin bushing remover/installer J 37717 inserted into the wrist pin bushing.
2. Press the bushing out of the rod.

⚠ CAUTION

Use care not to twist or bend the connecting rod while pressing the bushing.

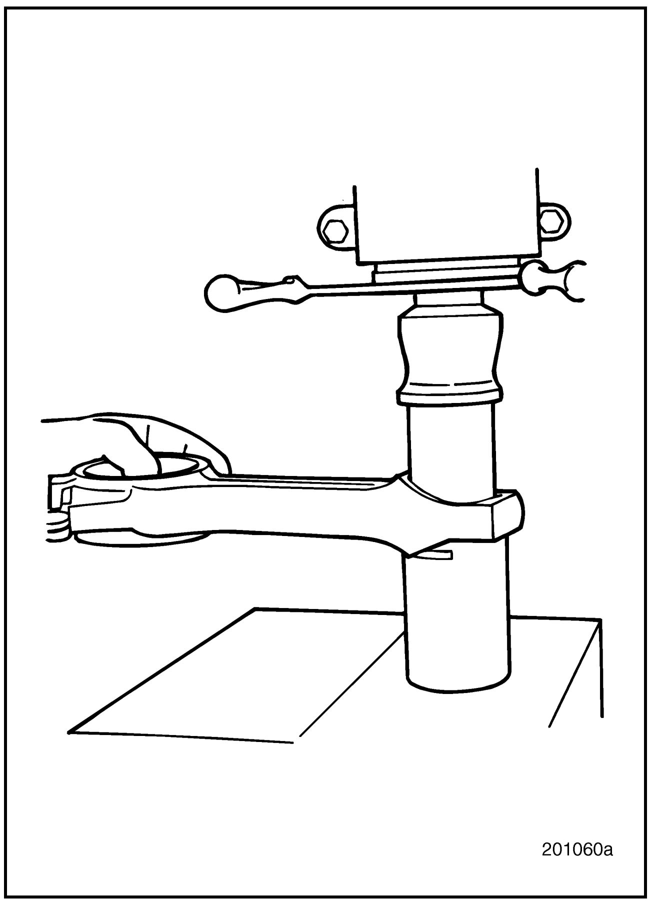


Figure 231 — Wrist Pin Bushing Removal

Wrist Pin Bushing Installation

⚠ CAUTION

The wrist pin bushing has a lubrication hole through it. This hole MUST be aligned with the rifle-drilled hole in the rod to allow oil flow to the wrist pin. If the holes are not aligned, wrist pin, piston, and connecting rod failure will result.

1. Position the connecting rod, a **new** wrist pin bushing and bushing remover/installer J 37717 in a press.
2. Align the hole in the bushing with the rifle-drilled hole in the rod and press the bushing into the rod wrist pin bore.
3. Remove the bushing remover/installer and reposition the rod assembly in the press with the wrist pin bushing burnishing broach J 37718 (Figure 232).

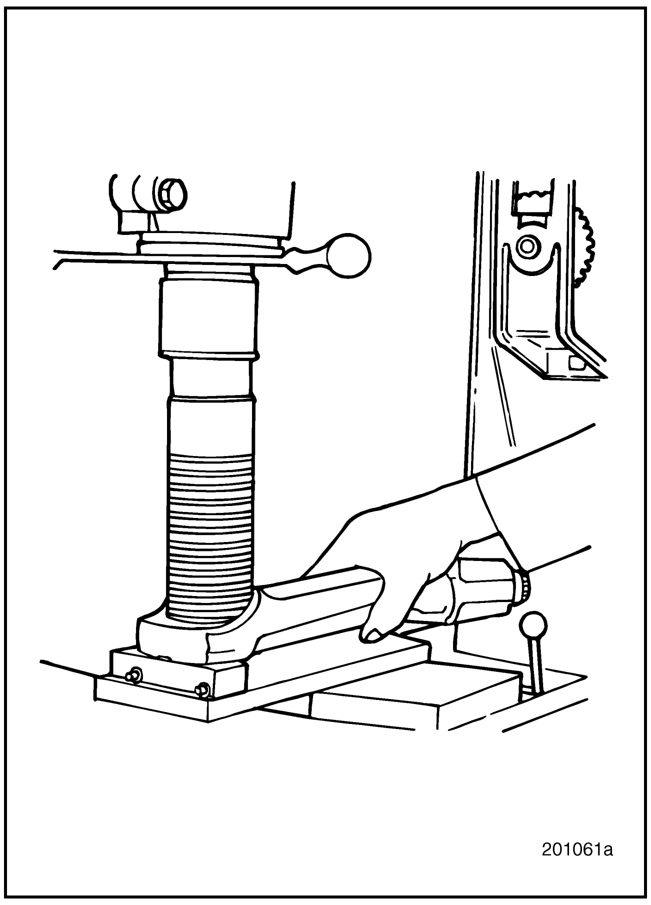


Figure 232 — Burnishing Wrist Pin Bushing

4. Apply a suitable lubricant to the bushing and broach. Then, press the broach through the bushing to expand the bushing for a tight fit in the wrist pin bore.

   Refer to Figure 233.

CAUTION

Make certain that the bushing is fully expanded for a tight fit in the connecting rod bore or it will loosen, rotate and fail.

Use care not to twist or bend the connecting rod while pressing the broach through the bushing.

5. Clean all shavings from the rifle-drilled hole in the rod.
6. Check the alignment of the connecting rod in the following procedure for twist or bend.

CONNECTING ROD ALIGNMENT CHECK

1. Position the connecting rod in a connecting rod fixture, Sweeney 945-6041, or equivalent. Use the appropriate mandrel and plunger extension applicable for the engine.

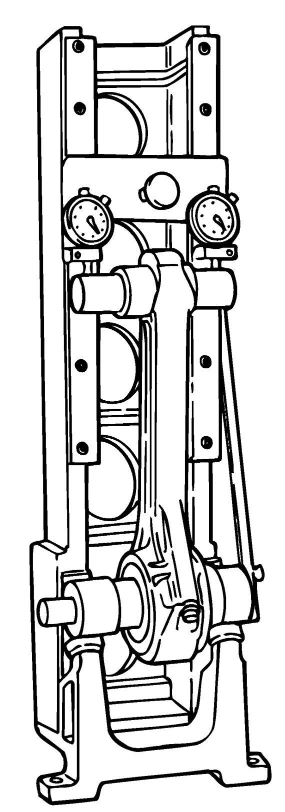


Figure 233 — Connecting Rod Fixture

2. Check the rod for twist or bend exceeding the following specifications. Specified distances are center-to-center.
   - Maximum twist of the connecting rod within 12 inches (30.5 cm) is 0.010 inch (0.254 mm).
   - Maximum bend of the connecting rod within 12 inches (30.5 cm) is 0.004 inch (0.102 mm).

Piston Inspection and Cleaning

[212 NP]

SPECIAL TOOLS REQUIRED

- Piston Ring Expander PT6587
- Keystone Ring Groove Gauge J 29510

DISASSEMBLY

1. Using piston ring expander PT6587, remove the piston rings (Figure 234).

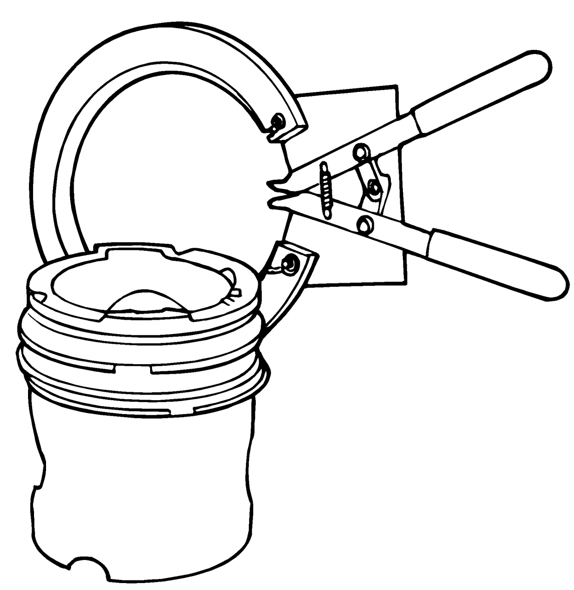


Figure 234 — Piston Ring Removal

2. Thoroughly clean the piston ring grooves, combustion bowl area and the snap ring grooves. All carbon must be removed. Carbon left in the piston ring grooves will reduce ring clearance and prevent the replacement rings from seating properly.

CAUTION

Be sure that the cleaning solvent is approved for steel and aluminum. Incompatible solvents may cause damage to the pistons or skirts.

3. Clean the pistons with the approved solution and a brass brush. Take care to avoid damaging the pistons while cleaning.

INSPECTION

Inspect the piston ring grooves, lands, piston skirt and combustion bowl for wear, scuffing, cracks or blow-by. Pistons are NOT repairable. Discard the piston if it is worn or damaged.

CAUTION

Do not stamp or engrave on the TOP of the piston. Doing so will reduce piston life.

To ensure that pistons are reinstalled in the same cylinders, the pistons must be tagged with the corresponding cylinder number when removed during disassembly.

Piston Ring Replacement

[212 NV]

Before installing the piston rings, check the keystone ring groove wear and ring end gap using the following procedures.

RING END GAP CHECK

1. Place a piston ring in the cylinder sleeve. Push it down into the sleeve with an inverted piston to ensure that it is positioned squarely in the sleeve.
2. Using thickness gauges, check the ring end gap. Refer to Fits and Limits in the SPECIFICATIONS section for end gap tolerance. All rings to be used should be checked in this manner.

CAUTION

Do not file or grind chrome-plated piston rings. This may cause the chrome to flake, resulting in ring failure.

KEYSTONE RING GROOVE CHECK

The keystone piston ring groove gauge J 29510 consists of two 0.120-inch (3.048 mm) diameter pins connected at the ends by two springs (Figure 235).

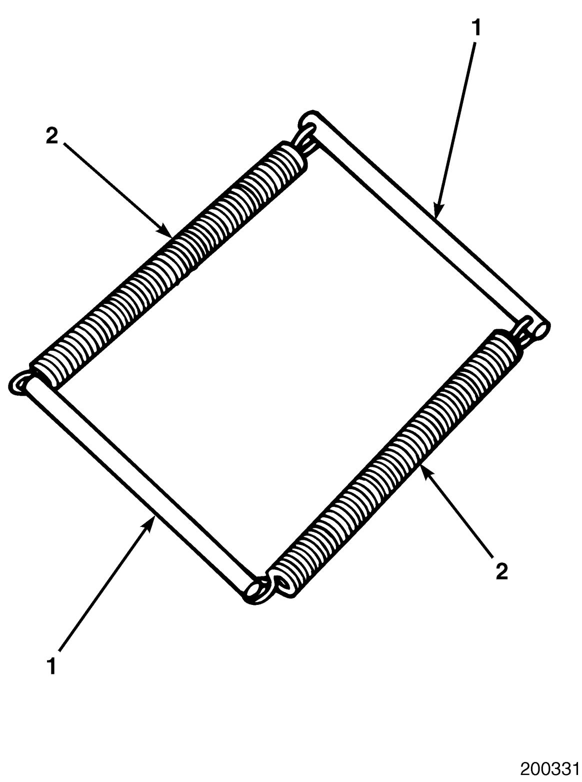


Figure 235 — Ring Groove Gauge

1. Pins	2. Springs

1. Place the pins of the keystone piston ring groove gauge J 29510 opposite each other in the groove to be measured. The pins will be held in position by the springs.
2. Using a four- to five-inch micrometer, measure the distance between the outer edges of the two parallel pins. Check each compression ring groove in two locations: parallel and perpendicular to the wrist pin bore (Figure 236). Record both measurements.
3. Compare the readings with the tolerances listed under Fits and Limits in the SPECIFICATIONS section.

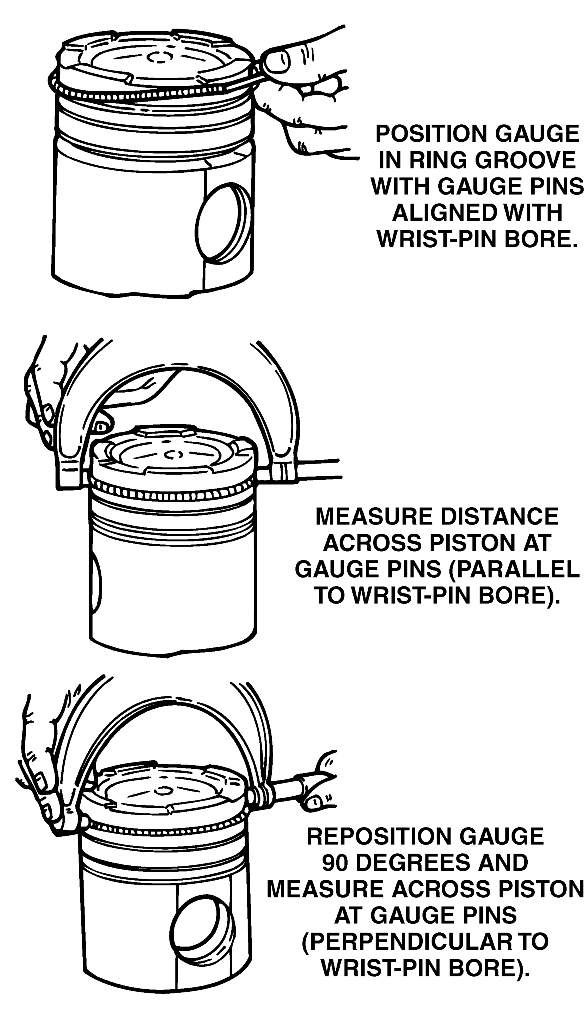


Figure 236 — Ring Groove Wear Measurement

4. Perform steps 1, 2 and 3 on each piston.
5. Check the oil control ring as follows:
   a. Using a thickness gauge, check for excessive wear of the oil control ring groove side clearance (Figure 237). Position a **new** oil control ring in the groove and insert a thickness gauge between the ring and upper land of the groove.
   b. Record the measurement and compare the reading with the tolerance listed under Fits and Limits in the SPECIFICATIONS section.

NOTE

For a new ring and piston, the oil ring side clearance is 0.0016–0.0030 inch (0.0406–0.0762 mm). For an old ring and piston, the clearance should NOT exceed 0.0045 inch (0.1143 mm).

6. Perform step 5 on each piston.

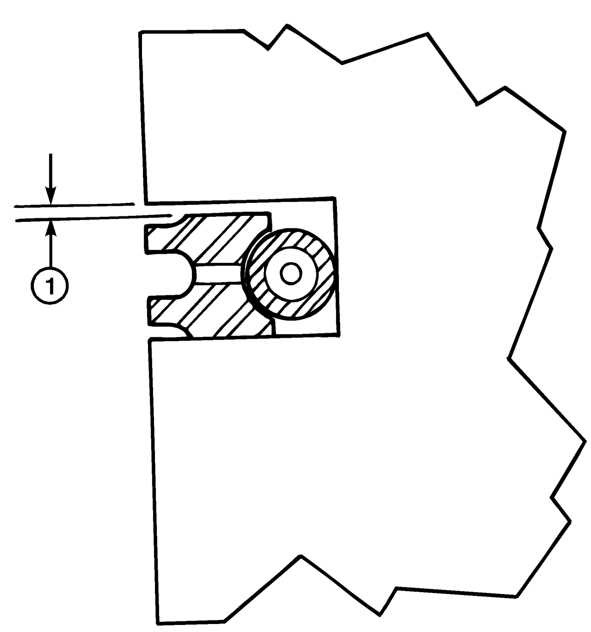


Figure 237 — Side Clearance Measurement

1. Ring Groove Side Clearance

RING INSTALLATION

NOTE

Identification markings on the rings should face the piston top. The keystone ring goes in the top ring groove.

Follow the directions on each piston ring packet.

1. To prevent distortion, use the proper size piston ring expander, PT6587 (Figure 238), to place the rings in the piston grooves.

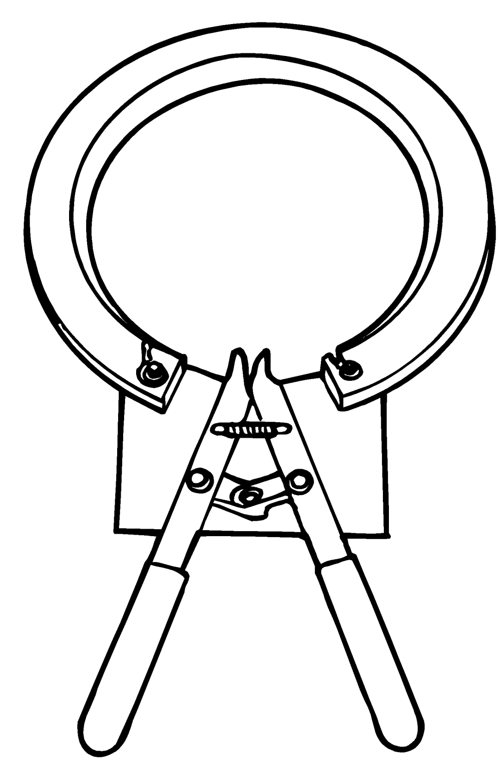


Figure 238 — Piston Ring Expander PT6587

2. Stagger the piston rings so that no ring gap is directly over the wrist pin bore, and no ring end gaps are aligned over each other (Figure 239).

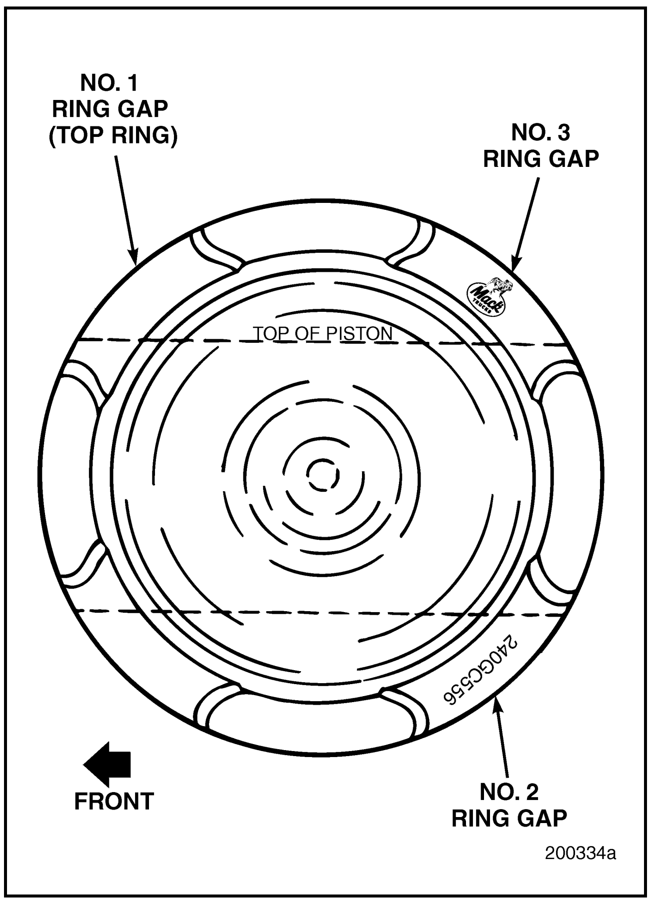


Figure 239 — Ring Gap Locations

Assembling Connecting Rod to Piston

[212 LP & NP]

1. Install a retaining snap ring in one of the wrist pin retaining grooves.
2. Position the connecting rod in the piston assembly. Make sure that the side of the rod marked FRONT is properly aligned with the FRONT markings on the piston crown and skirt (Figure 240).

NOTE

The current piston skirt, part No. 240GC590BM, is symmetrical in design, having piston cooling nozzle clearance cutouts on both the right and left sides. Although the word “FRONT” still appears at the bottom, the symmetrical design allows the skirt to be assembled to the piston crown in either direction.

CAUTION

Be sure that the piston and rod assemblies are clearly marked with the cylinder location. They must be returned to same cylinder from which they were removed.

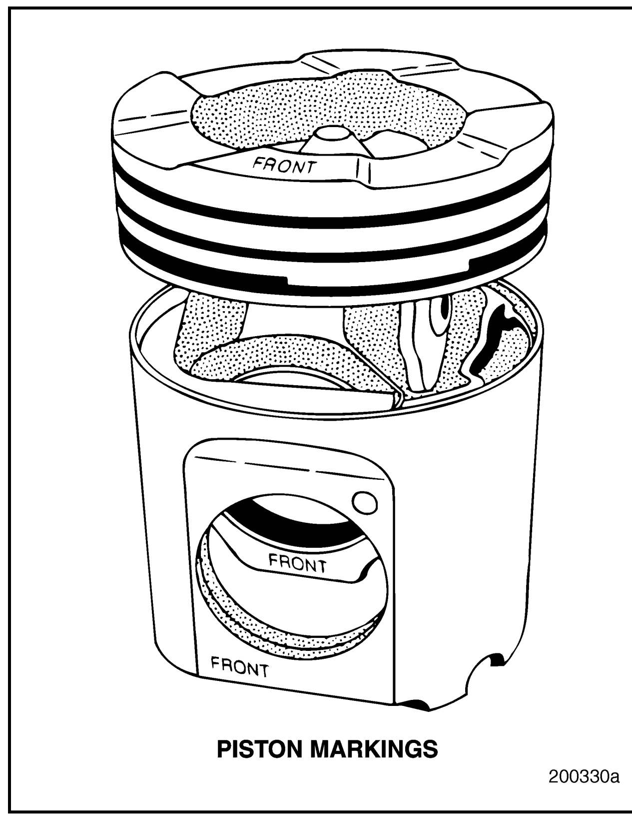


Figure 240 — Piston Markings

3. Using a generous amount of clean engine oil, push the piston wrist pin into the wrist pin bore, aligning the two piston sections and the connecting rod.

NOTE

Current-production piston crowns DO NOT use bushings in the wrist pin bores.

4. Secure the pin in position by inserting a snap ring in the remaining piston snap ring groove.
5. Place the assembled piston in a clean location until it is needed for installation into the engine cylinder sleeve.
6. Perform steps 1 through 5 on the remaining pistons.

CYLINDER HEAD OVERHAUL [213 EV]

Special Tools Required

- Basic Heavy-Duty Dowelout Kit PT6575
- Collet PT6390-4
- Cylinder Head Core Plug Installer (13/16-inch Cup Plugs) J 34684
- Cylinder Head Core Plug Installer (1-1/16-inch Cup Plugs) J 34687
- Depth Gauge J 26948
- Dowelout, Extractor (7/16 inch) PT6570-11
- Driver Handle J 8092
- E7 Cutter Head J 37719
- Fire Ring Groove Cutter J 29600-C
- Injection Nozzle Sleeve Extractor J 29880
- Injection Nozzle Sleeve Installer J 29297
- Model MST 50 Universal Spring Tester J 22738-02
- Prussian Blue
- Slide Hammer J 2619-01
- Torque Wrench J 24407
- Valve Guide Installer J 46549
- Valve Guide Reamer J 37481
- Valve Guide Remover J 37482
- Valve Stem Seal Installer J 45730
- Valve Stem Seal Remover J 38820-1 (Early Seal Design)
- Valve Stem Seal Remover J 45915 (Current Seal Design)
- Valve Seat Extractor Kit PT6391
- Valve Insert Installer Set J 38586
- Valve Seat Insert Counterbore HT77136
- Valve Seat Removal Set J 45796
- Valve Spring Compressor J 43887 (Valves with Tip-End Rotators)
- Valve Spring Compressor J 29294-B (Valves with Bottom Rotators)
- Valve Yoke Guide Pin Installer J 29296

Inlet and Exhaust Valve Removal

[213 NB]

GENERAL INFORMATION

Current-production engines use a bottom valve rotator as shown in Figure 242. The bottom rotator is installed under the valve spring(s), and replaces the tip-end rotator which was used in early-production engines. With the bottom valve rotators, there is a lesser amount of valve key protrusion above the valve spring retainer washer when compared with key protrusion above the rotator on early-production engines. The top of the valve keys are practically flush with the top of the valve retainer washers. The tip-end rotator, however, has an undercut on top, so the top of the key protrudes approximately 3/32-inch as shown in Figure 241.

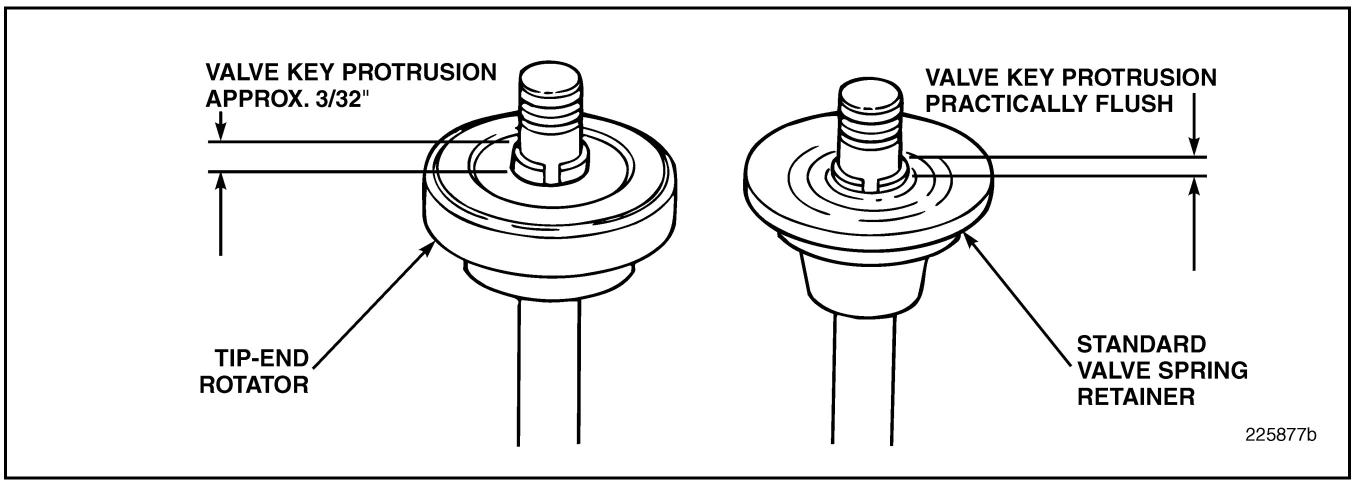


Figure 241 — Valve Key Protrusion

Bottom Rotators

The current configuration of the ASET™ engine uses a bottom valve rotator installed under the valve springs. Removal of the bottom inlet and the exhaust valve rotators requires the use of tool J 29294-B.

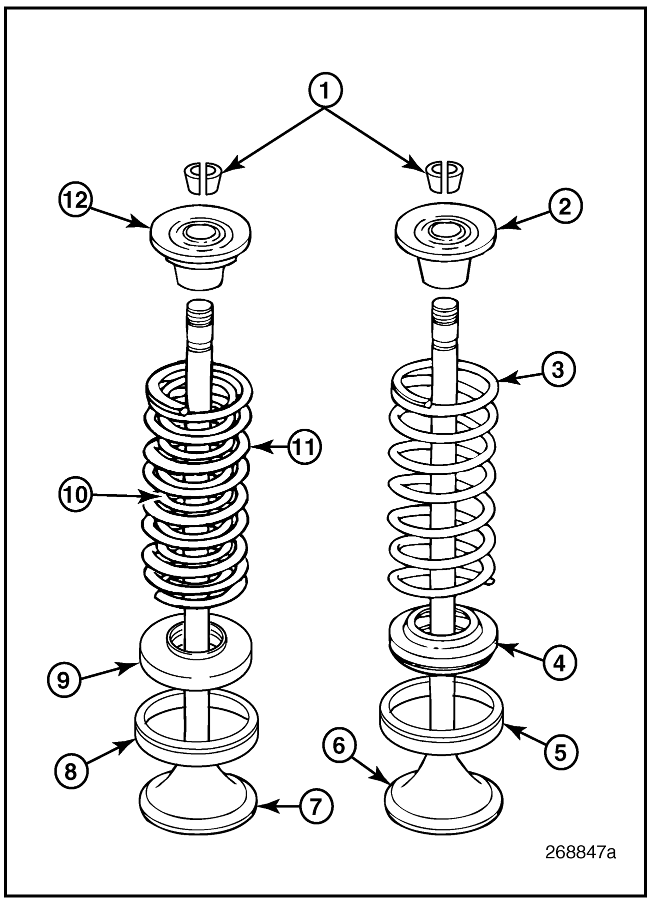


Figure 242 — Valve Spring, Rotator and Valve Seats (Current Design — Mid-2003 and Later)

1. Valve Spring Washer Keys 2. Valve Retaining Washer, Inlet 3. Single Valve Spring 4. Bottom Valve Rotator, Inlet 5. Valve Seat, Inlet 6. Inlet Valve	7. Valve, Exhaust 8. Valve Seat, Exhaust 9. Bottom Valve Rotator, Exhaust 10. Valve Spring, Inner 11. Valve Spring, Outer 12. Valve Retaining Washer, Outer

Tip-End Rotators

ASET™ engines used a tip-end valve rotator installed at the top of the valve springs until approximately mid 2003 (Figure 243). Removal of the “tip-end” inlet and the exhaust valve rotators requires the use of tool J 43887.

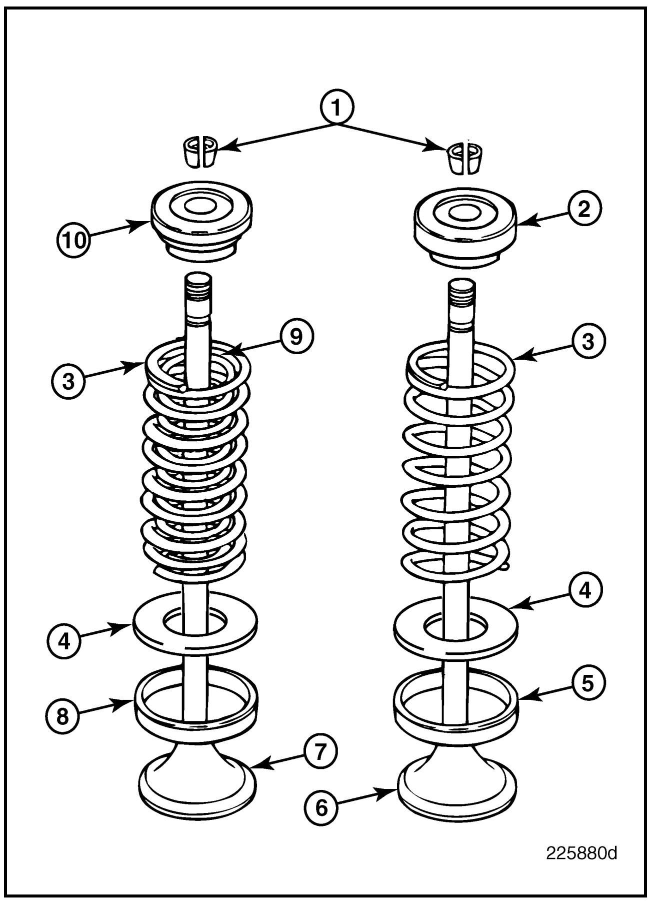


Figure 243 — Valve Spring, Rotator and Valve Seats (Non-Current Design — Prior to Mid-2003)

1. Valve Spring Rotator Keys 2. Tip-End Rotator, Inlet 3. Valve Spring 4. Spring Seat 5. Valve Seat, Inlet	6. Valve, Inlet 7. Valve, Exhaust 8. Valve Seat, Exhaust 9. Valve Spring, Inner 10. Tip-End Rotator, Exhaust

The inlet and exhaust valve rotators are different. The rotators installed on the exhaust valves are stepped to accommodate the dual-spring arrangement used at the exhaust locations. The exhaust rotator contains a second level which supports the inner spring used on exhaust valves; the inlet rotator contains only a single level. This difference is shown in Figure 244.

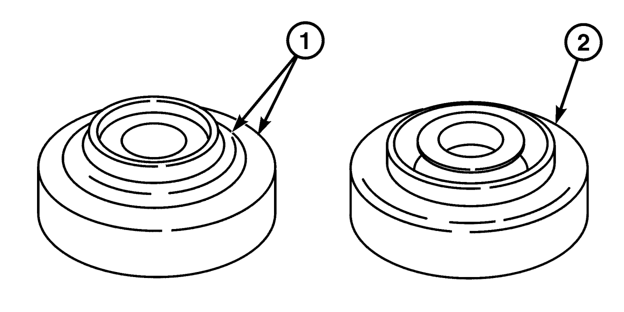


Figure 244 — Valve Rotators

1. Exhaust Rotator Spring Support Area	2. Inlet Rotator Spring Support Area

NOTE

Do not clean the tip-end rotators in a hot tank or use any type of cleaning method which could introduce contaminants to the rotator's internal parts or damage the rotator insert.

REMOVAL PROCEDURE

Refer to Figure 245.

1. Attach the valve spring compressor to the cylinder head. Use compressor J 43887 for valves with tip-end rotators or J 29294-B for valves with bottom rotators.
2. Rest the tool compression forks on top of the tip-end rotator or valve retaining washer and center the forks above the valve.
3. Depress the tool handle until the valve spring is compressed. Remove the valve keys using a magnet.

NOTE

Valve spring compressor J 43887 or J 29294-B must be repositioned for each series of valves (two inlet and two exhaust per cylinder). Drilled and tapped holes are provided for each cylinder.

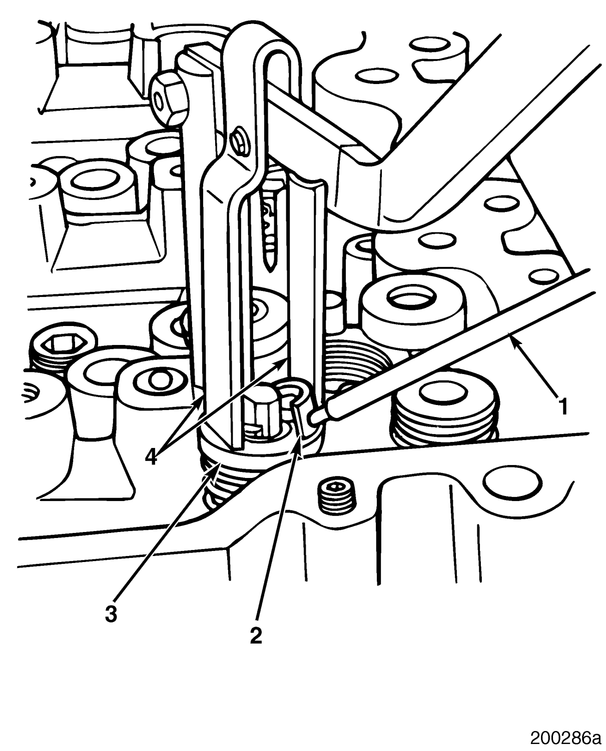


Figure 245 — Valve Spring Keeper Removal

1. Magnet 2. Valve Spring Keys (Keepers)	3. Tip-End Rotator or Valve Retaining Washer 4. Tool Compression Forks

4. For engines built with bottom rotators, following valve spring key (keeper) removal, remove valve retaining washers followed by the single springs on the inlet valves and the inner and outer springs on the exhaust valves. After the springs are removed, remove the bottom rotators and valves.

SERVICE HINT

Current-production exhaust location inner springs are now being painted white. These springs are completely interchangeable with the former bare steel springs. The white paint was added to help verify that the inner spring is present after the cylinder head is built-up.

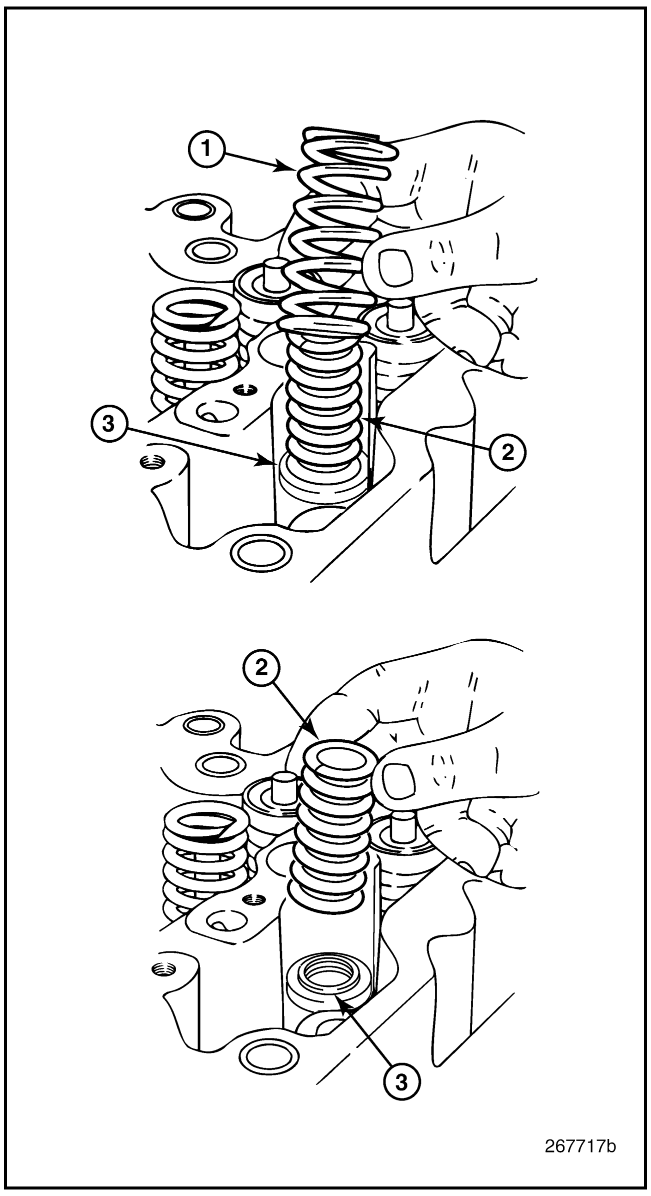


Figure 246 — Rotator and Spring Removal (Current Design)

1. Outer Exhaust Spring 2. Inner Exhaust Spring	3. Spring Rotator (Bottom)

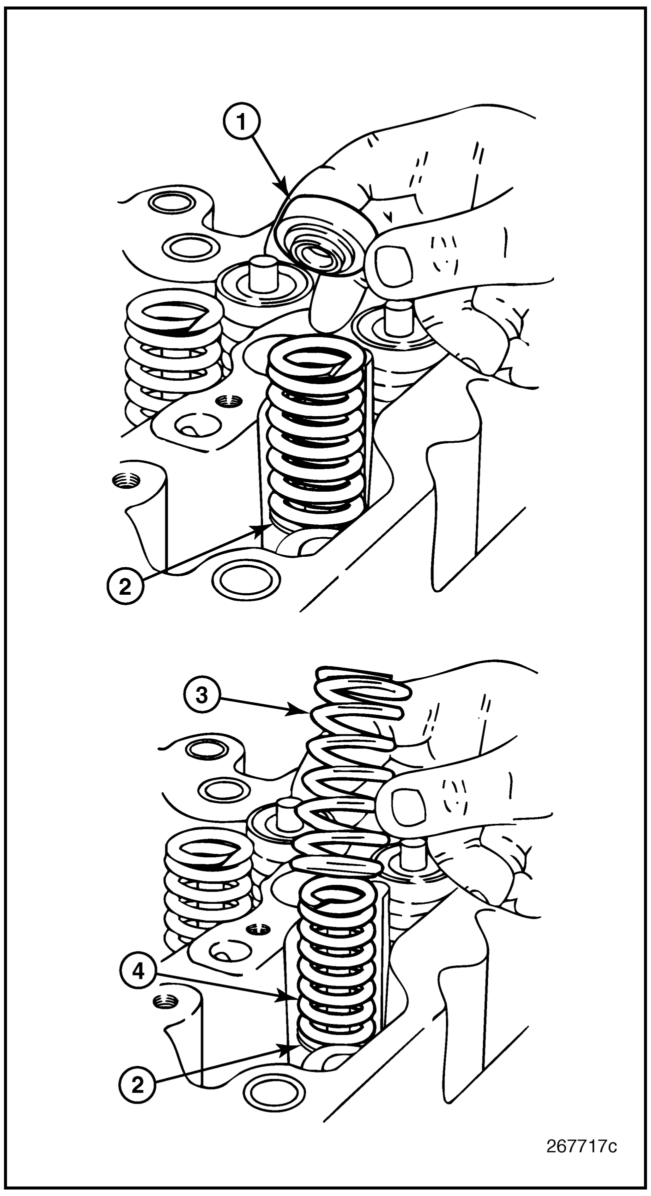


Figure 247 — Tip-End Rotator and Spring Removal (Non-Current Design)

1. Tip-End Rotator 2. Spring Seat	3. Outer Exhaust Spring 4. Inner Exhaust Spring

5. For engines built with tip-end rotators, following valve spring key (keeper) removal, remove the tip-end rotators from the inlet and exhaust valves. Then remove the single springs on the inlet valves and the inner and outer springs on the exhaust valves. After the springs are removed, remove the valves and the hardened spring seat.

6. With the valve springs removed, removal of the valve stem seals can be accomplished easily and quickly using the correct valve stem removal tool for the design of the seal used. Valve stem seal designs can be identified using the following methods.

Valve Stem Seals

The current design valve seal can be identified by the fact that it fits on the top of the valve guide. This seal, and the top of the valve guide are approximately 1/8 inch (6.35 mm) smaller than the previous seal and guide to allow clearance with the inner valve spring at exhaust locations. For standardization, the new valve guide and seal are used at the inlet locations as well as the exhaust locations, with either single springs or dual valve springs.

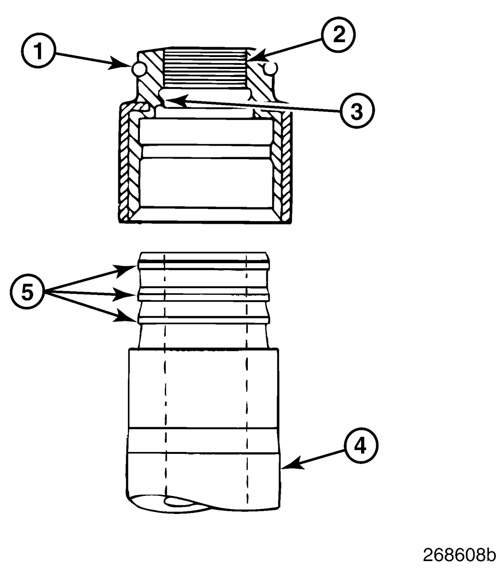


Figure 248 — Valve Stem Seal (Current Design)

1. Steel Retainer Band 2. Multi-Lip Section 3. Primary Lip	4. Valve Guide 5. Three Sharp Edges

NOTE

Approximately the first 200 ASET™ engines used a seal and guide arrangement which if servicing is required, both the guide and the seal must be replaced/updated to the current configuration parts. For detailed instructions, refer to Service Bulletin SB-213-017.

Cylinder Head Cleaning and Inspection

Cleaning the cylinder head is important. While cleaning the cylinder head, carefully inspect the areas around the cup plugs and the coolant jacket. If the cup or pipe plugs show signs of leaking, they should be replaced. The cylinder head should also be inspected for cracks or other possible defects that may be reason for replacement. If damage is not found until after the engine is assembled, the cylinder head must be removed, disassembled and rebuilt again.

SOLVENT TANK CLEANING

WARNING

Cleaning solvent is flammable and toxic to the eyes, skin and respiratory tract. Skin and eye protection is required. Avoid repeated or prolonged contact. Use only in a well-ventilated area.

Compressed air used for cleaning can create airborne particles that may enter the eyes or irritate the skin. Pressure must not exceed 30 psi (207 kPa). Eye protection is required. Use only with effective chip guarding and personal protective equipment (goggles/shield, gloves, etc.).

1. Fill the tank with a suitable solvent and immerse the parts in the solution to loosen any dirt and debris.
2. Scrape any remaining gasket material from the cylinder head.
3. Using a wire brush or rotary wheel, remove any rust, corrosion or other debris from the head.
4. Rinse the cylinder head, making sure that all surfaces are clean and free of debris.
5. Using due care and caution, dry the head with compressed air.

INSPECTION

NOTE

Pressure Test — It is recommended that cylinder heads be pressurized and checked for internal cracks and leaks. Refer to the “Cylinder Head and Cylinder Block Leak Test” procedure in the TROUBLESHOOTING section.

Check the cylinder head deck surface for warping, pitting or other imperfections. Deck surface flatness must not vary more than 0.0015 inch (0.0381 mm) over 18 inches (45.7 cm) of surface area. Resurface or replace as necessary.

When resurfacing, remove a minimum amount of material from the deck to obtain a flat, uniform surface. Standard head height is 6.397–6.391 inches (162.483–162.310 mm). A maximum of 0.010 inch (0.254 mm) of material may be removed, making the minimum height of a resurfaced head 6.381 inches (162.077 mm).

NOTE

When the deck is resurfaced, the fire ring groove and valve seat insert dimensions must be reestablished following the procedure under “Fire Ring Groove Cutting.”

Fire Ring Groove Cutting

GENERAL INFORMATION

Fire ring grooves are located in the machined flat surface (deck) of the cylinder head that mates with the engine block. This design provides a locking groove for the fire ring to seat, as well as a positive-combustion pressure seal.

After resurfacing the cylinder head deck, it is necessary to reestablish the fire ring groove depth using the fire ring groove cutter J 29600-C (Figure 249).

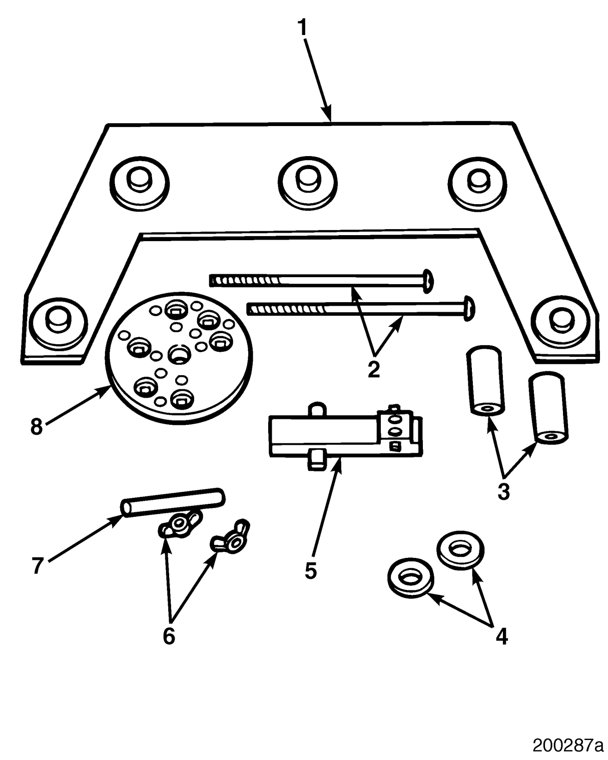


Figure 249 — Fire Ring Groove Cutter J 29600-C

1. Alignment Fixture	5. Cutter Head (J 37719)
2. Hold-Down Capscrews	6. Wing Nuts
3. Spacers	7. Thickness Gauges
4. Washers	8. Cutter Base

GROOVE CUTTING PROCEDURE

1. Place the cutter base on the cylinder head (Figure 250). Insert the hold-down capscrews into the appropriate mounting holes (per application) until the hold-down capscrews bottom out in the mounting holes.

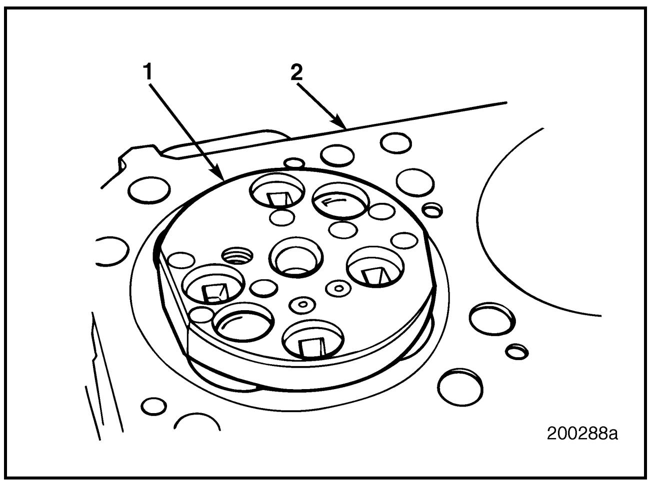


Figure 250 — Cutter Base Alignment

1. Cutter Base	2. Cylinder Head

2. Position the cylinder head so the threaded section of the hold-down capscrews can be reached as shown in Figure 251. Install the spacer, washer and wing nut. Lightly tighten the wing nut.

NOTE

The cutter base must be free to move.

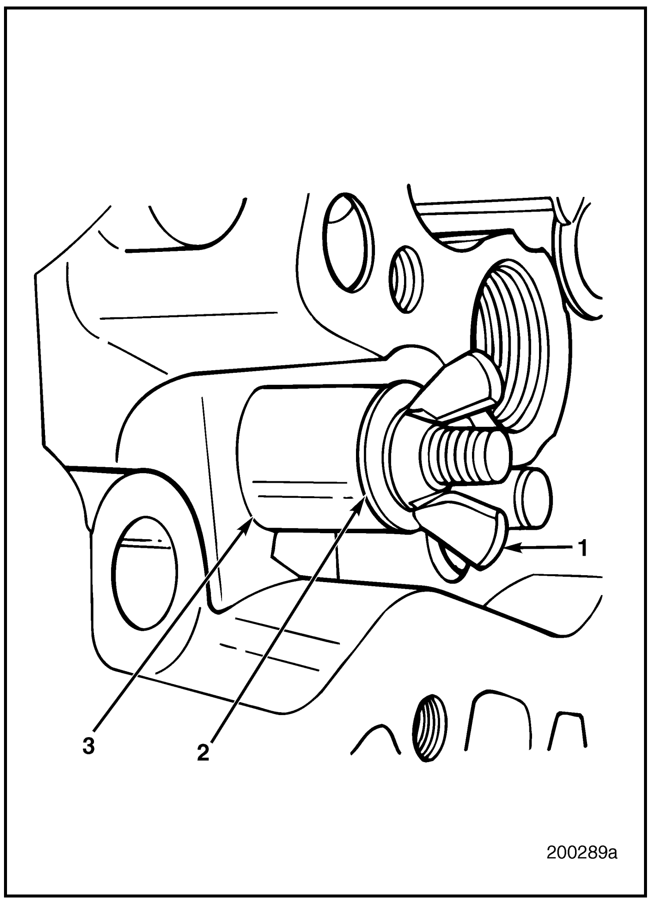


Figure 251 — Cutter Base Attachment

1. Wing Nut 2. Washer	3. Spacer

3. Place the alignment fixture over the cutter base as shown in Figure 252 to ensure proper positioning. With the fixture in place, tighten the wing nuts on the hold-down capscrews. Remove the alignment fixture.

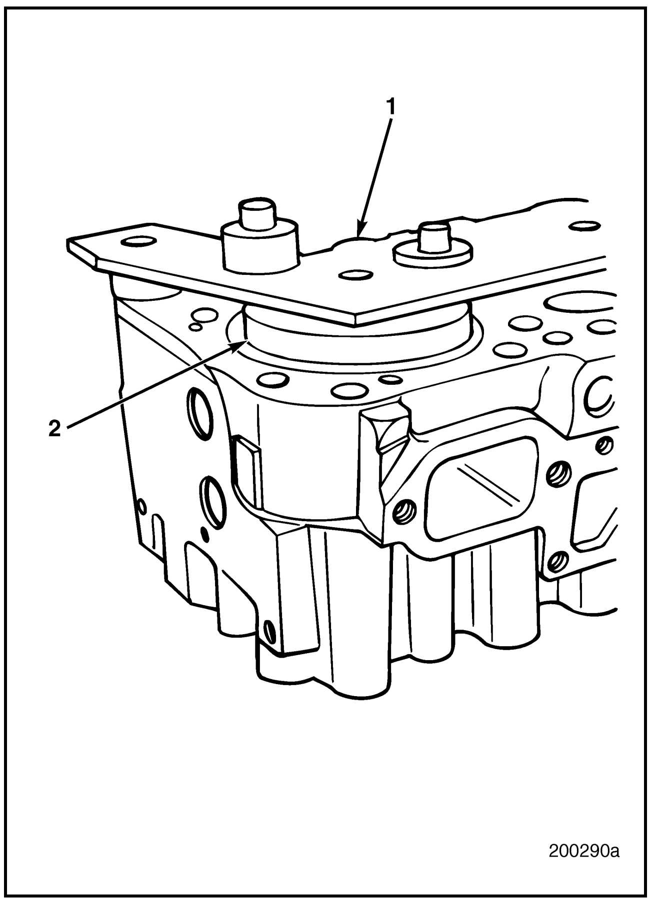


Figure 252 — Alignment Fixture Placement

1. Alignment Fixture	2. Cutter Base

NOTE

The desired finished fire ring groove depth is 0.008 inch (0.203 mm).

4. Install the cutter head J 37719 on the cutter base as shown in Figure 253.
   a. If a fire ring groove is visible, check the existing fire ring groove depth dimension with depth gauge J 26948. The difference between 0.008 inch and the actual remaining depth of the fire ring groove is the amount to cut. Insert two appropriate thickness gauges between the cutter head and base.
   b. If a fire ring groove is not visible, insert two 0.008-inch thickness gauges between the cutter head and base.
5. Adjust the cutter head J 37719 until it bottoms out on the deck surface of the existing fire ring groove. Tighten the cutter head in this position and remove the two thickness gauges.

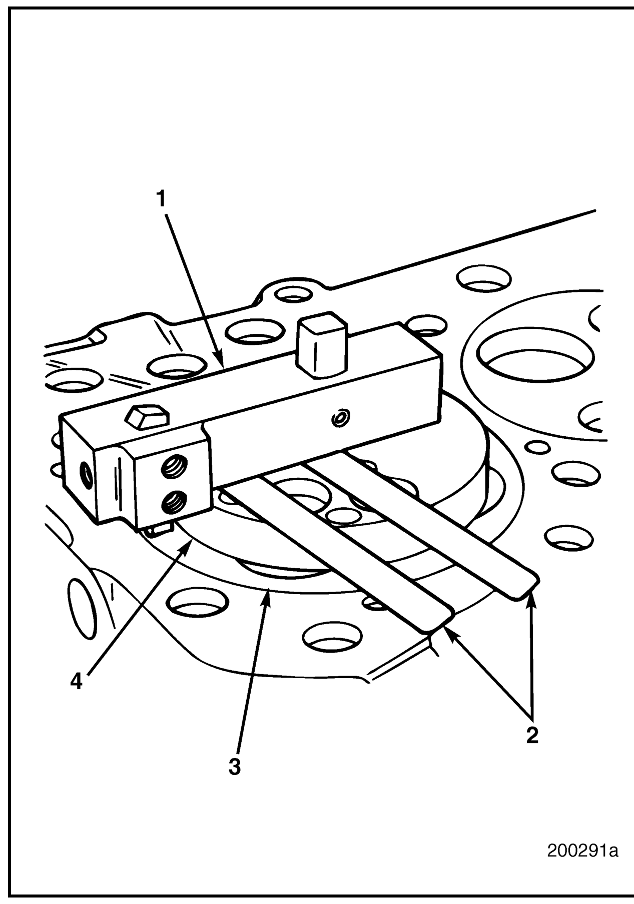


Figure 253 — Cutter Depth Setting

1. Cutter Head (J 37719) 2. Thickness Gauges	3. Fire Ring Groove 4. Cutter Base

6. Install a socket and T-handle on the cutter head as shown in Figure 254. Using the T-handle, rotate the cutter head in a clockwise direction only, applying an even downward pressure to cut the fire ring groove.

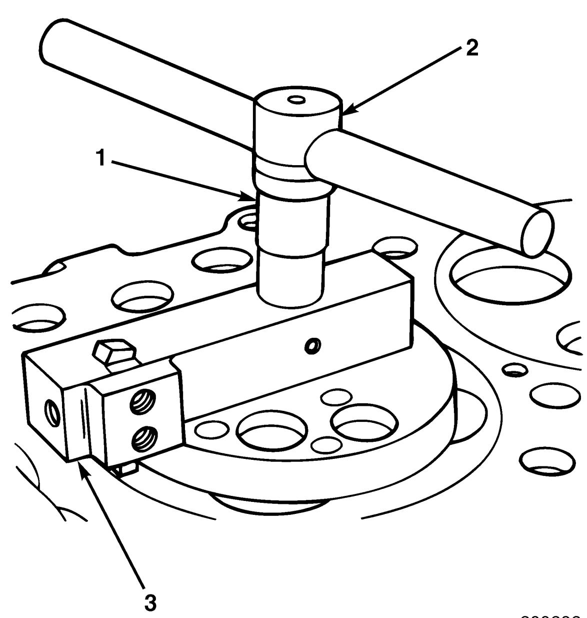


Figure 254 — Ring Groove Cutting

1. Socket 2. T-Handle	3. Cutter Head (J 37719)

7. After the groove is cut, remove the cutter head and base from the cylinder head.
8. Use a honing stone to remove any burrs around the fire ring groove.
9. Check the fire ring groove depth with depth gauge J 26948 to verify that the groove depth meets specification. If the groove depth does not meet specification, recut as necessary.
10. Repeat the above procedure to cut the remaining fire ring grooves.

NOTE

To ensure proper groove depth, always adjust the cutting tool height when cutting the next groove.

Valve Guide Replacement

[213 EP]

INLET AND EXHAUST VALVE GUIDE DIMENSIONS

Refer to Figure 255.

- Valve guide ID (3) — 0.3750 ± 0.0005 inch (9.53 ± 0.012 mm)
- Top end of guide to valve spring seat (4) — 0.857–0.937 inch (21.768–23.710 mm)
- Valve guide extension, fire deck to top of guide (5) — 5.178 ± 0.030 inch (131.52 ± 0.762 mm)
- Valve guide bore in head (6) — 0.687–0.686 inch (17.450–17.424 mm)
- Valve guide OD (7) — 0.6886–0.6881 inch (17.4904–17.4777 mm)

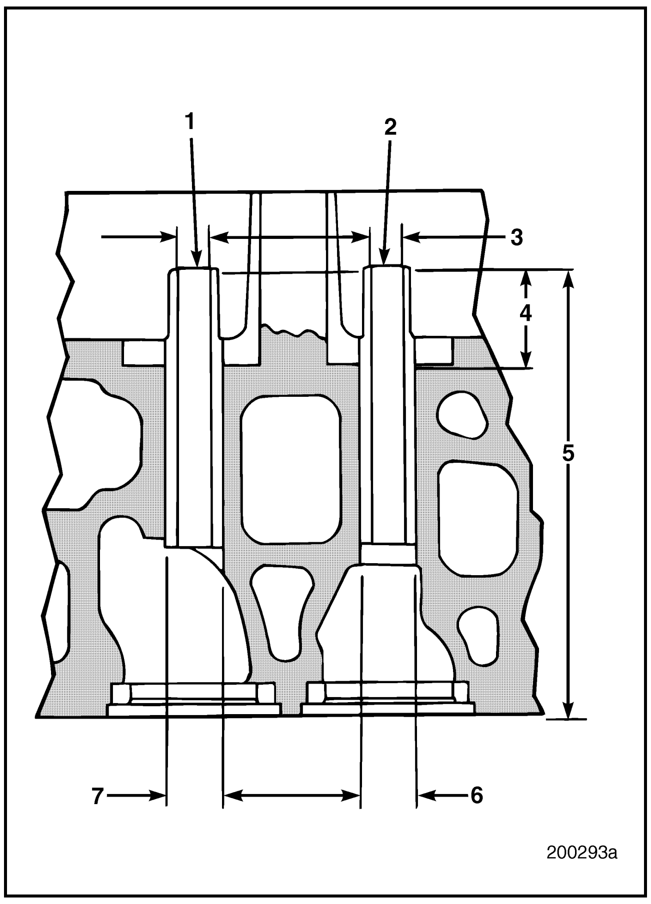


Figure 255 — Valve Guide Dimensions

1. Exhaust Valve Guide 2. Inlet Valve Guide 3. Valve Guide ID 4. Top End of Guide to Valve Spring Seat	5. Valve Guide Extension, Fire Deck to Top of Guide 6. Valve Guide Bore in Head 7. Valve Guide OD

INSPECTION

NOTE

Worn valve guides may result in poor valve-to-seat contact, valve damage or oil consumption.

1. Inspect the valve guides for wear, damage, cracks and looseness. Use a small bore gauge to obtain an accurate valve guide bore measurement (Figure 256).

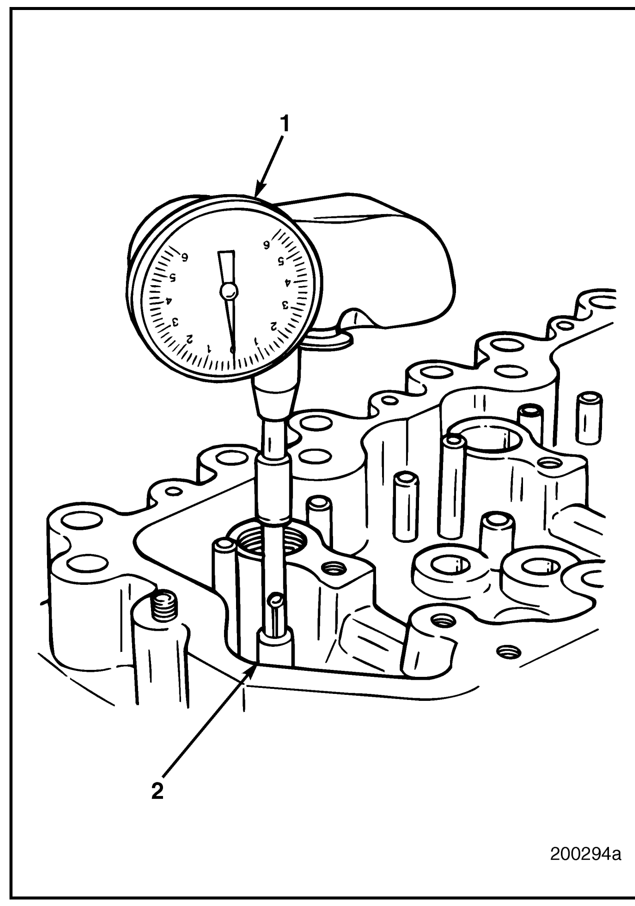


Figure 256 — Measuring Valve Guide Bore

1. Bore Gauge	2. Valve Guide Bore

2. Use a depth gauge to check valve guide extension (Figure 257).

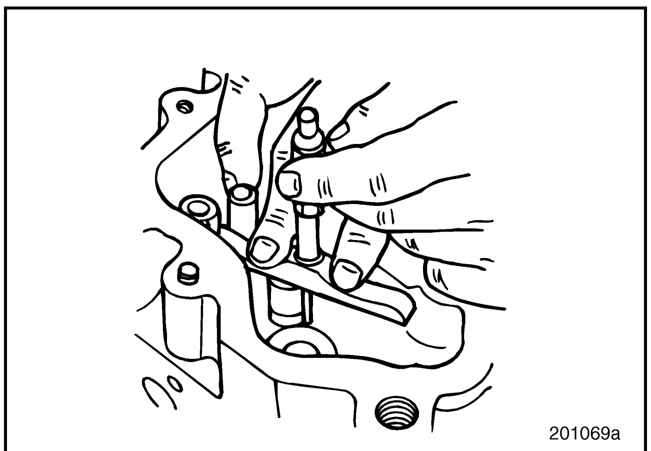


Figure 257 — Checking Valve Guide Extension

NOTE

When reconditioning the cylinder head, it is recommended that all valve guides be replaced.

VALVE GUIDE REMOVAL

SERVICE HINT

Clean the exhaust valve guide OD (shoulder) before removal. With the guide removed, use a rotary brush to clean the exhaust valve guide bore and prevent scoring.

1. Insert valve guide remover J 37482 into the valve guide from the deck side of the cylinder head (Figure 258).

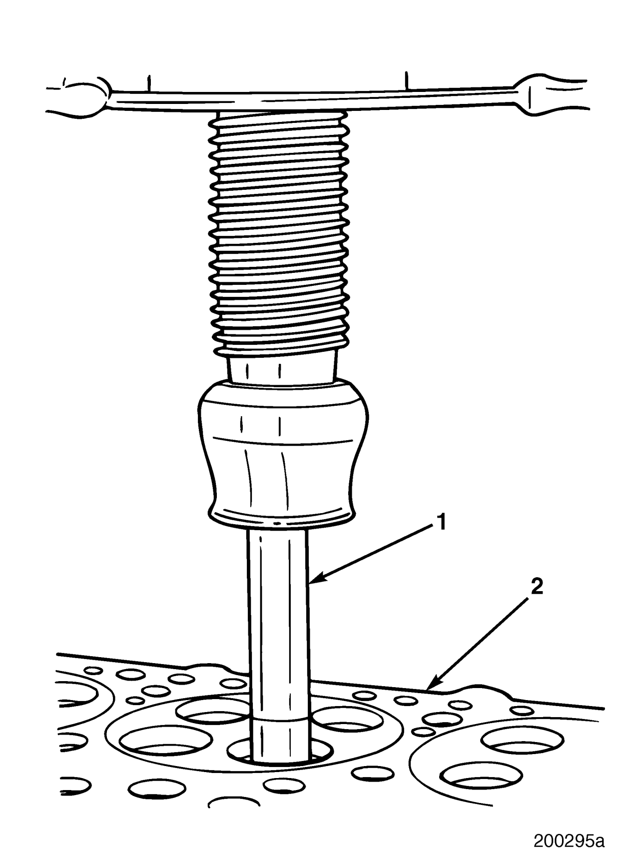


Figure 258 — Valve Guide Remover J 37482

1. Valve Guide Remover J 37482	2. Cylinder Head

2. Press out the old valve guides from the cylinder head.
3. Check the valve guide bores in the cylinder head for wear, cracks or other damage. Clean the surfaces thoroughly and check the ID measurement.

VALVE GUIDE INSTALLATION

1. Insert a **new** valve guide into the valve guide installer J 46549.
2. Oil the OD of the guide before installation.
3. Using tool J 46549, press the guide into its bore from the top of the cylinder head.
4. Using the depth gauge, check the extension of the guide from the valve spring seat to the top end of the guide. Refer back to Figure 257.

CAUTION

The current-production valve guide is 0.042 inch (1.067 mm) shorter that the previously used valve guide. It is essential that the correct valve guide installation tool (J 46549) be used to install the current valve guide. If the incorrect tool is used, the valve guide and seal installed height will be 0.060 inch (1.524 mm) too high, and will result in the seal being contacted by the rotator (if equipped with tip-end rotators), or by the valve spring retaining washer (if equipped with bottom rotators). Contact between the valve seal and rotator/retainer washer will damage the seal.

5. Using valve guide reamer J 37481, ream the valve guide as shown in Figure 259 to the specified dimension.

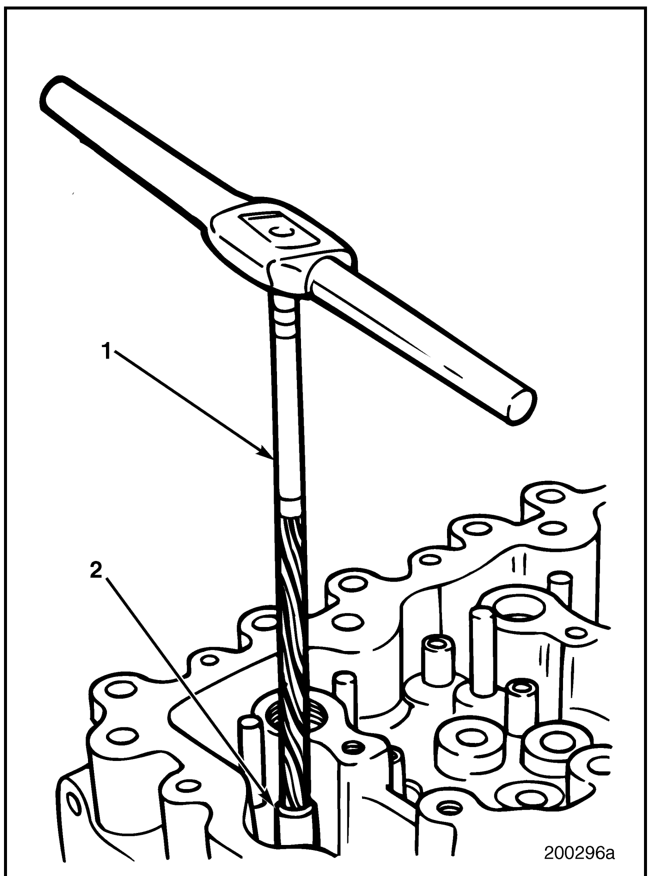


Figure 259 — Reaming Valve Guide

1. Valve Guide Reamer J 37481	2. Valve Guide

6. Repeat steps 1 through 5 to install the remaining valve guides.
7. Thoroughly clean all metal debris from the valve guides and the surrounding area.
8. Install the valves in the cylinder head and check for binding, looseness and other conditions that may result in premature valve or valve guide failure.

Valve Seat Insert Replacement

[213 FB]

INLET AND EXHAUST VALVE SEAT INSERT DIMENSIONS

Refer to Figure 260.

- Valve seat (4) insert face angle (1)
  - Inlet: 20° 30′ ± 15′
  - Exhaust: 30° 15′ ± 15′
- Valve seat insert diameter (2)
  - Inlet Standard Production: 1.832–1.831 inches (46.533–46.507 mm)
  - Inlet Oversize Production (0.005): 1.836–1.837 inches (46.634–46.669 mm)
  - Inlet Oversize Service (0.015): 1.846–1.847 inches (46.888–46.914 mm)
  - Inlet Oversize Service (0.031): 1.862–1.863 inches (47.295–47.320 mm)
  - Inlet Oversize Service (0.047): 1.878–1.879 inches (47.701–47.726 mm)
  - Inlet Oversize Service (0.062): 1.893–1.894 inches (48.082–48.108 mm)
  - Exhaust Standard Production: 1.692–1.693 inches (42.977–43.002 mm)
  - Exhaust Oversize Production (0.005): 1.697–1.698 inches (43.104–43.130 mm)

- — Exhaust Oversize Service (0.015): 1.707–1.708 inches (43.358–43.383 mm)
- — Exhaust Oversize Service (0.031): 1.723–1.724 inches (43.764–43.790 mm)
- — Exhaust Oversize Service (0.047): 1.739–1.740 inches (44.171–44.196 mm)
- — Exhaust Oversize Service (0.062): 1.754–1.755 inches (44.551–44.577 mm)

- Intake valve seat width (3) — 0.060 ± 0.005 inch (1.524 ± 0.127 mm)
- Exhaust valve seat width (3) — 0.069 ± 0.005 inch (1.753 ± 0.127 mm)

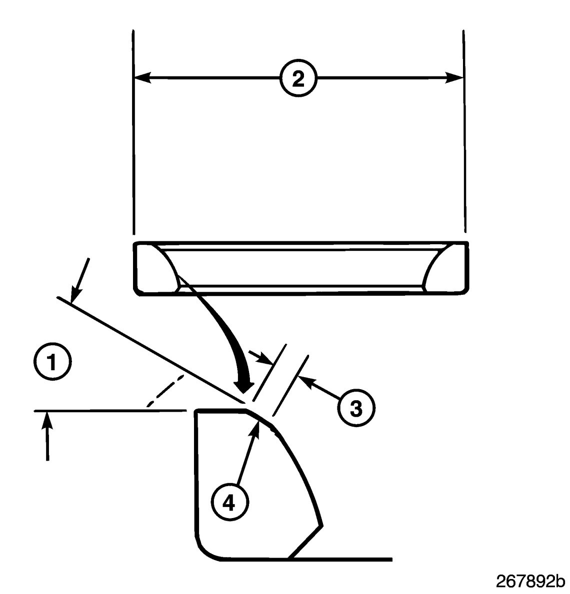


Figure 260 — Valve Seat Insert Dimensions (Exhaust Seat Shown)

1. Valve Seat Insert Face Angle 2. Valve Seat Insert Diameter	3. Valve Seat Width 4. Valve Seat

INSPECTION

Visually inspect the valve seat inserts for looseness, cracks or other conditions that may result in improper operation. Replace seats as necessary.

VALVE SEAT INSERT REMOVAL

Valve seat inserts are designed with a smooth radiused inner surface to achieve an optimum airflow. Because of the radius, cutting a groove on the inner surface for removal of the insert is nearly impossible and no longer recommended. Instead, the inner upper edge of the insert has a chamfer to accept a collet tool. The collet, PT6390-4, is used in combination with the lifting bridge, T-handle and shaft assembly from extractor kit PT6391 (Figure 261), to remove both inlet and exhaust seat inserts.

NOTE

Collet PT6390-4 is not included in the basic kit PT6391.

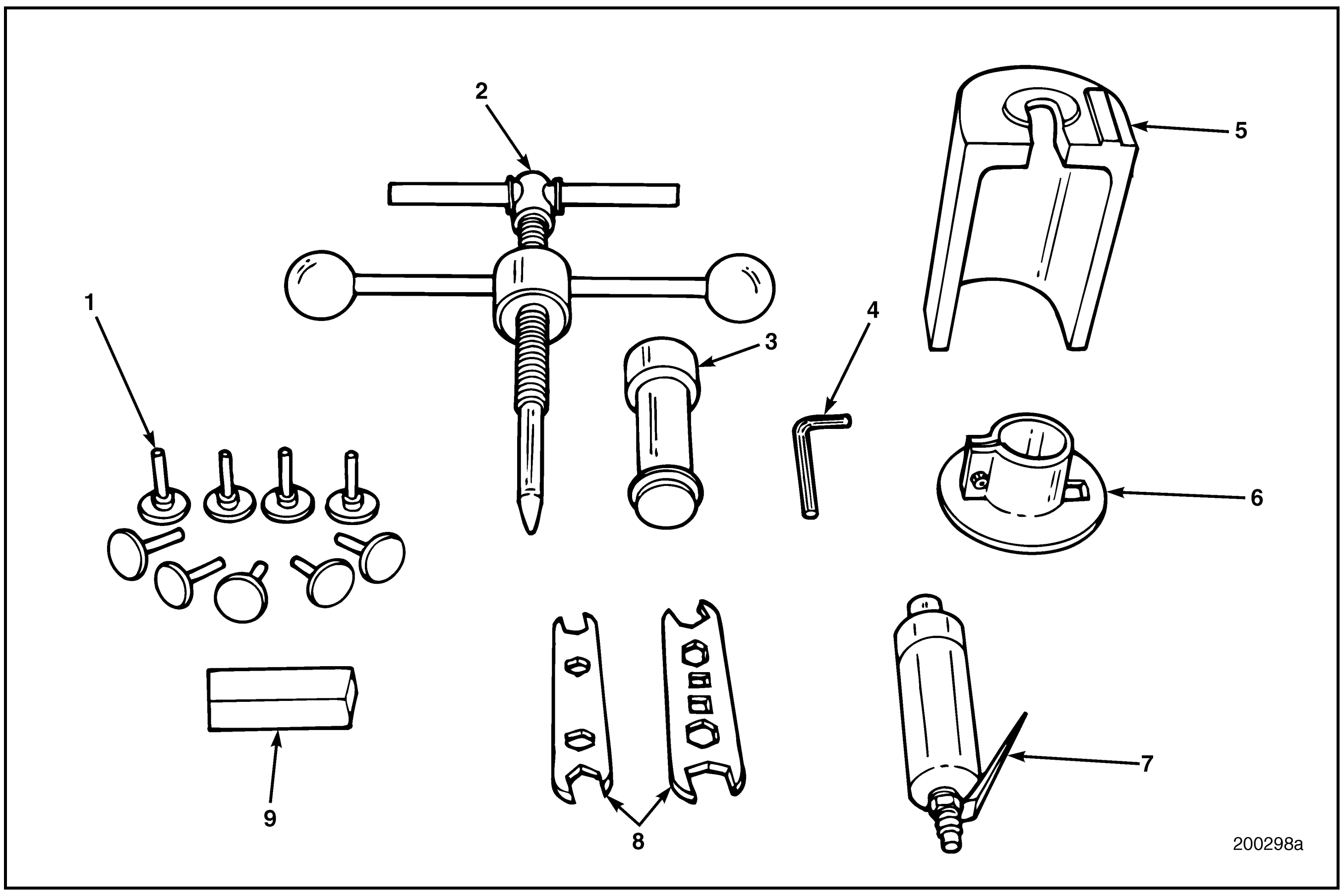


Figure 261 — Valve Seat Extractor Kit PT6391

1. Grinding Wheels 2. T-Handle and Shaft Assembly 3. Collet, PT6390-4 (Not Included in Kit) 4. Allen Wrench 5. Lifting Bridge	6. Grinder Base 7. Grinder 8. Wrenches 9. Dressing Stone

1. Clean any carbon buildup from the removal chamfer in the valve insert.
2. Attach the collet, PT6390-4, to the T-handle and shaft assembly.
3. Position the collet in the valve seat insert so the ridge of the collet will grip the chamfer on the inner upper edge of the insert (Figure 262). Turn the T-handle to fully expand the collet.

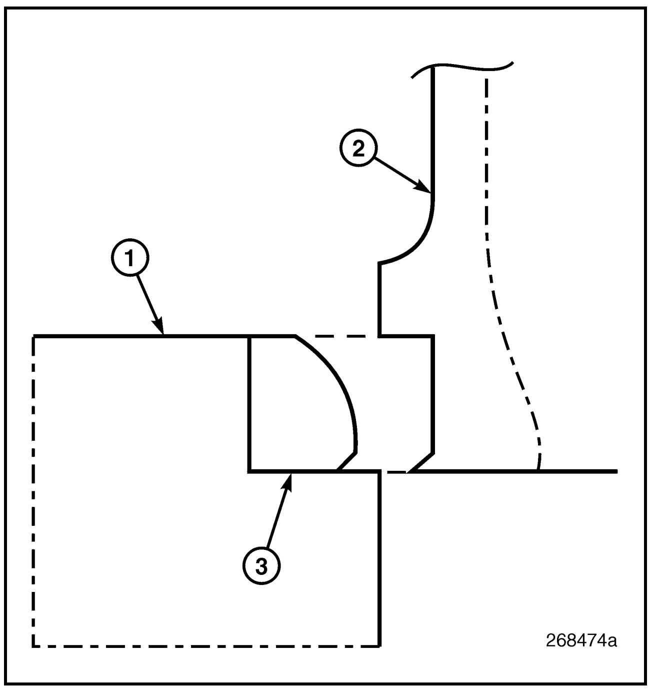


Figure 262 — Collet Positioning

1. Cylinder Head 2. Collet	3. Valve Seat Insert

4. Position the lifting bridge under the crank handle as shown in Figure 263. Turn the crank handle clockwise to remove the insert.
5. Release the insert from the collet by slightly turning the T-handle.

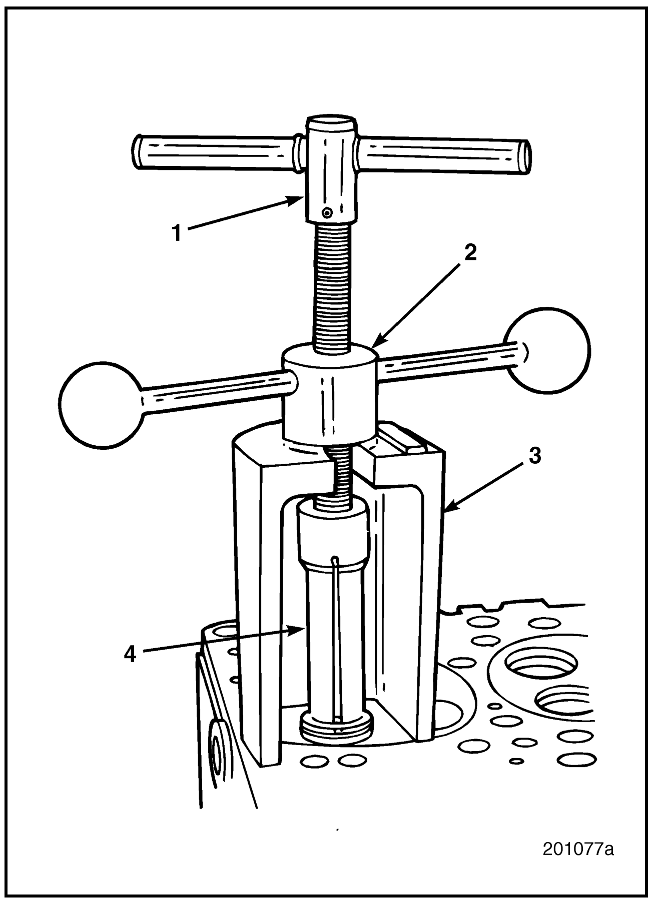


Figure 263 — Removing Valve Insert

1. T-Handle 2. Crank Handle	3. Lifting Bridge 4. Collet

VALVE SEAT INSERT COUNTERBORE

Refer to Figure 264.

- Valve seat counterbore depth (3):
  - Exhaust: 0.376–0.372 inch (9.55–9.449 mm)
  - Inlet: 0.364–0.360 inch (9.246–9.144 mm)
- Inlet valve seat insert counterbore diameter (4): 1.8295–1.8285 inches (46.4693–46.4439 mm)
- Exhaust valve seat counterbore diameter (5): 1.6885–1.6875 inches (42.8879–42.8625 mm)

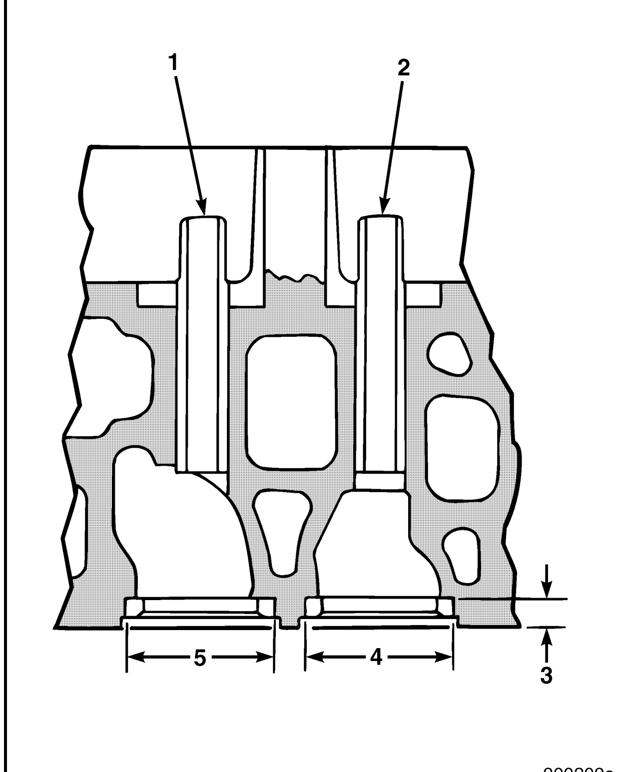


Figure 264 — Valve Seat Insert Counterbore Dimensions

1. Exhaust Valve Guide 2. Inlet Valve Guide 3. Valve Seat Counterbore Depth	4. Inlet Valve Seat Insert Counterbore Diameter 5. Exhaust Valve Seat Counterbore Diameter

INSPECTION

1. With the valve seat insert removed from the cylinder head, clean the surface thoroughly with a wire brush.
2. Check the surface finish for smoothness. Check the counterbore diameter (Figure 265) with an inside diameter micrometer. Compare the measured diameter to specification.

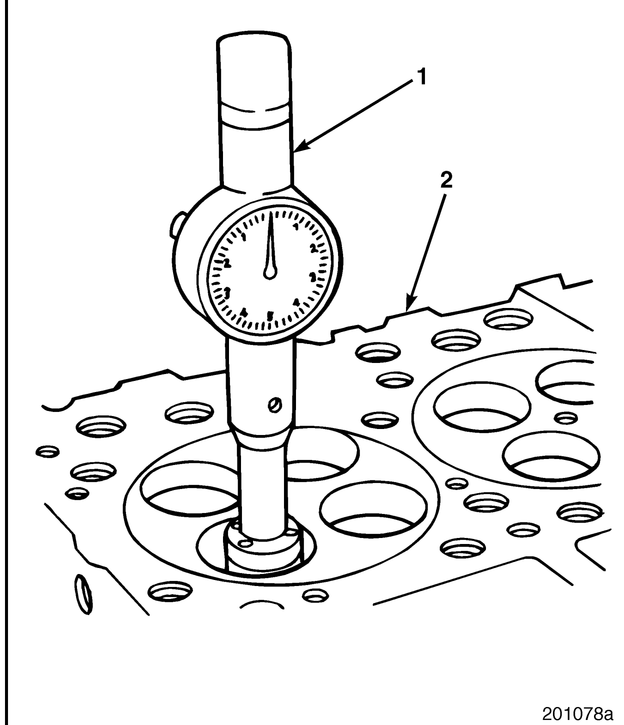


Figure 265 — Checking Counterbore Dimensions

1. Inside Diameter Micrometer	2. Cylinder Head

VALVE SEAT INSERT INSTALLATION

NOTE

Oversize inlet and exhaust valve seat inserts are available in 0.005-, 0.015-, 0.031-, 0.047- and 0.062-inch sizes if the counterbore requires machining.

1. If required, machine the inlet and exhaust valve seat insert counterbores using tool HT77136.
2. Position the valve seat insert over the corresponding counterbore as shown in Figure 266. Install the inserts using valve seat insert installation set J 38586. Use the driver handle J 8092 to drive the valve seat insert into the counterbore.

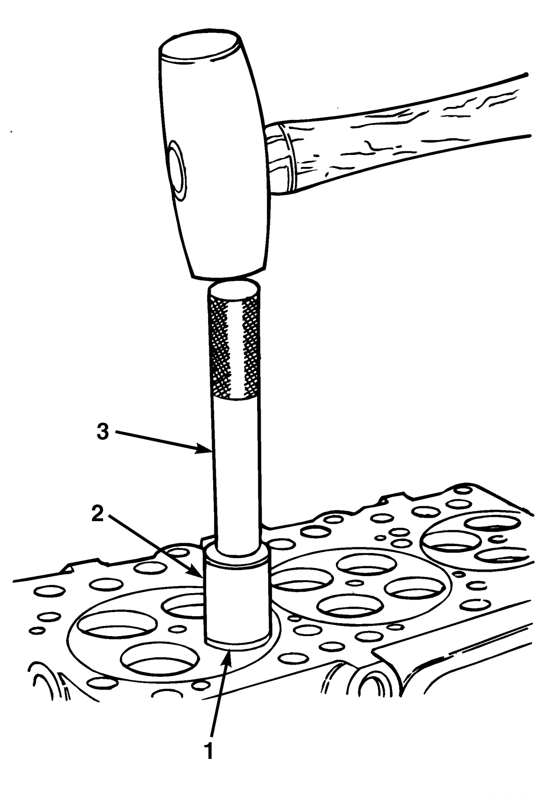


Figure 266 — Valve Seat Insert Installation

1. Valve Seat Insert 2. J 38586	3. J 8092

3. Grind the inlet/exhaust valve seat inserts to specification.
   - Inlet valve inserts: 20° 30′ ± 15′ angle
   - Exhaust valve inserts: 30° 15′ ± 15′

CAUTION

Always use 30-degree valves with 30-degree valve inserts and 20-degree valves with 20-degree valve inserts. Excessive wear and possible failure will result if 30-degree parts are matched with 20-degree parts.

NOTE

If valve seat insert widths exceed specifications when grinding the inserts, use a 15-degree angle grinding stone to obtain the correct width.

4. After grinding, thoroughly clean the valve seat insert.
5. Determine the concentricity of each valve seat insert relative to the valve guide. Valve seat runout is to be held within 0.002 inch (0.051 mm) FIM (Full Indicator Movement). The measurements are to be taken from a snug-fitting arbor through-mounted into finished valve guides as shown in Figure 267.

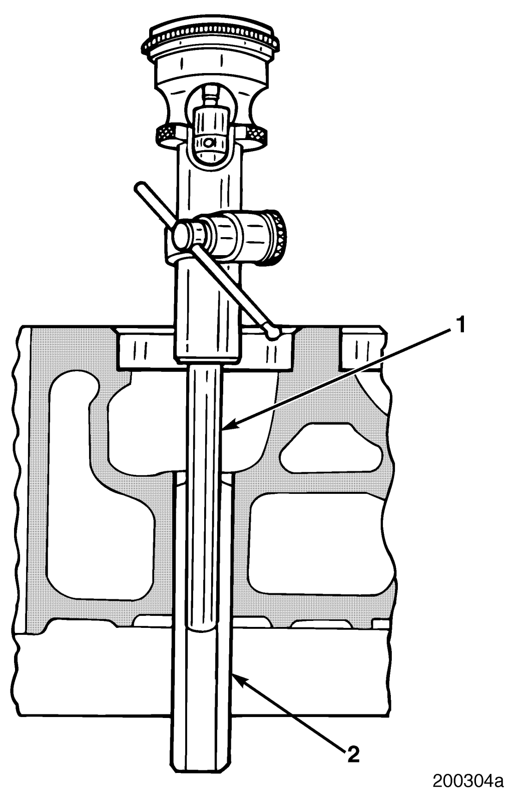


Figure 267 — Checking Valve Seat Runout

1. Arbor	2. Valve Guides

6. After checking runout, determine the position of contact between the valve and valve seat insert. Apply a dab of Prussian Blue to the valve face at four points, 90 degrees apart.
7. Lower the stem of the valve into the valve guide and allow the valve face to rest on the seat insert. Rotate the valve 90 degrees on the insert. Carefully remove the valve without making contact with the valve face. Properly ground inserts should show a full pattern of contact on the insert.

NOTE

Thoroughly clean the cylinder head after checking the valve seat inserts and before installing the valves.

Valve Spring Inspection

[213 MB]

1. Visually inspect the inside surfaces of the spring coils. Also, feel the inside surfaces of each spring for any indication of roughness or grooving. If either of these conditions exists, replace the spring.
2. Check the springs on the universal spring tester J 22738-02 as shown in Figure 268. Measured pressures should be within the allowable limits when springs are compressed to the specified “valve open” and “valve closed” dimensions. **Replace the springs if pressures are not within the specifications listed below:**

— **Outer Spring Specified Pressures**

- At Valve Closed Height: With spring compressed to 1.968 inches (49.987 mm) — 119.5–131.5 lbs (54.204–59.647 kg)
- At Valve Open Height: With spring compressed to 1.468 inches (37.287 mm) — 195–215 lbs (88.450–97.522 kg)

— **Inner Spring Specified Pressures**

- At Valve Closed Height: With spring compressed to 1.868 inches (47.447 mm) — 43.7–47.7 lbs (19.821–21.636 kg)
- At Valve Open Height: With spring compressed to 1.368 inches (34.747 mm) — 66.3–74.3 lbs (30.073–33.701 kg)

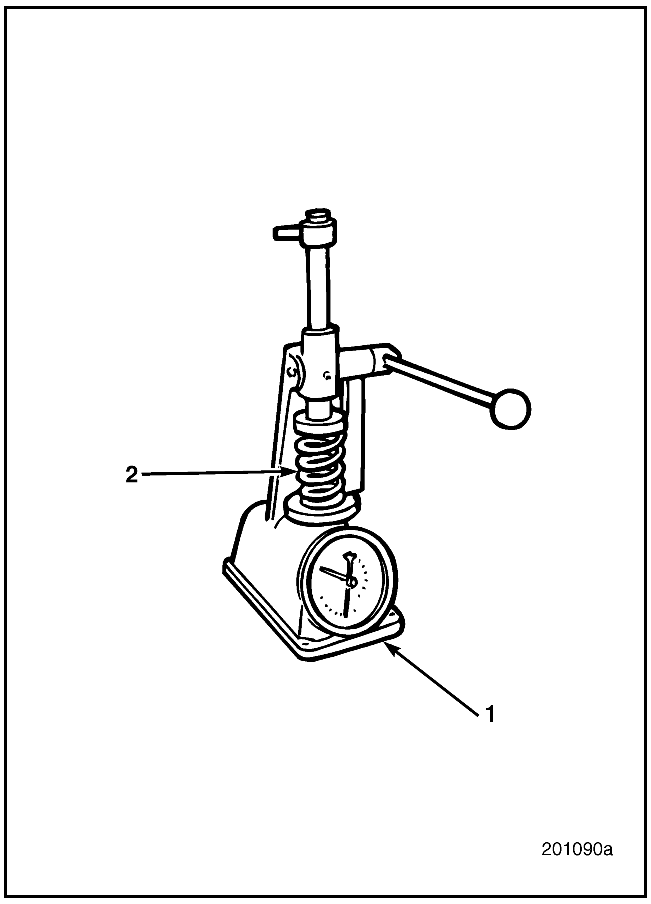


Figure 268 — Checking Valve Spring Pressure

1. Spring Tester J 22738-02	2. Valve Spring

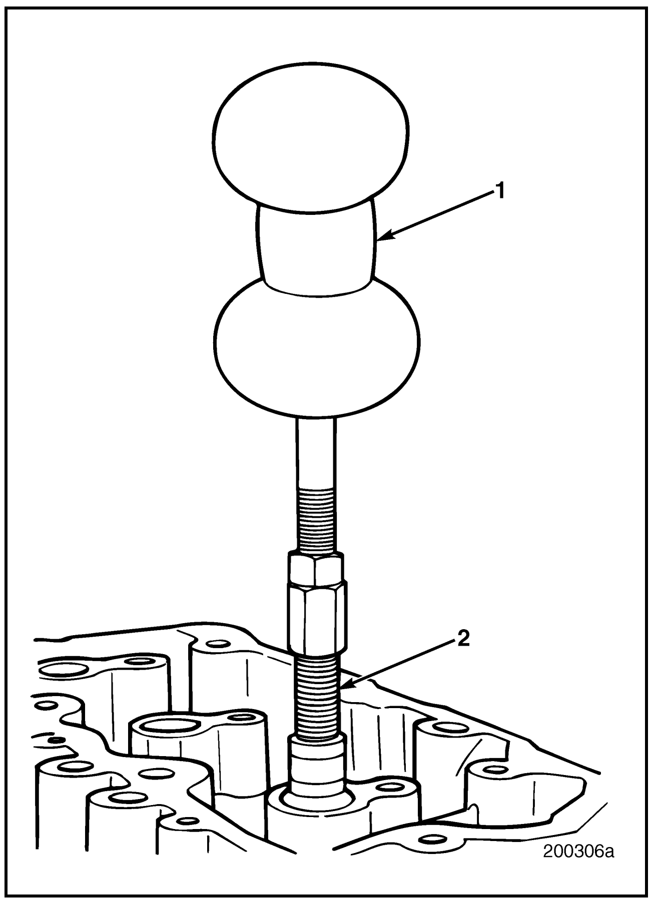


Figure 269 — Removing Injection Nozzle Holder Insert

1. Slide Hammer J 2619-01	2. Sleeve Puller J 42678

Injection Nozzle Holder Insert Replacement

[213 GB]

The injection nozzle holder insert is machined to provide a press-fit in the cylinder head.

REMOVAL PROCEDURE

1. To remove the injection nozzle holder insert, tap the ID with a 24 mm -3 tap to a depth of approximately 1-1/2 inches (38 mm).
2. Install the nozzle sleeve (insert) puller J 42678 to the slide hammer J 2619-01, or equivalent, as shown in Figure 269.
3. Thread the puller into the end of the nozzle holder insert and use the slide hammer to remove the insert.

INSTALLATION PROCEDURE

1. Clean the nozzle insert bore in the cylinder head and the contact surfaces with Loctite® Primer T.
2. Apply Loctite® 620 to the cylinder head and insert surfaces. Refer to Figure 270.

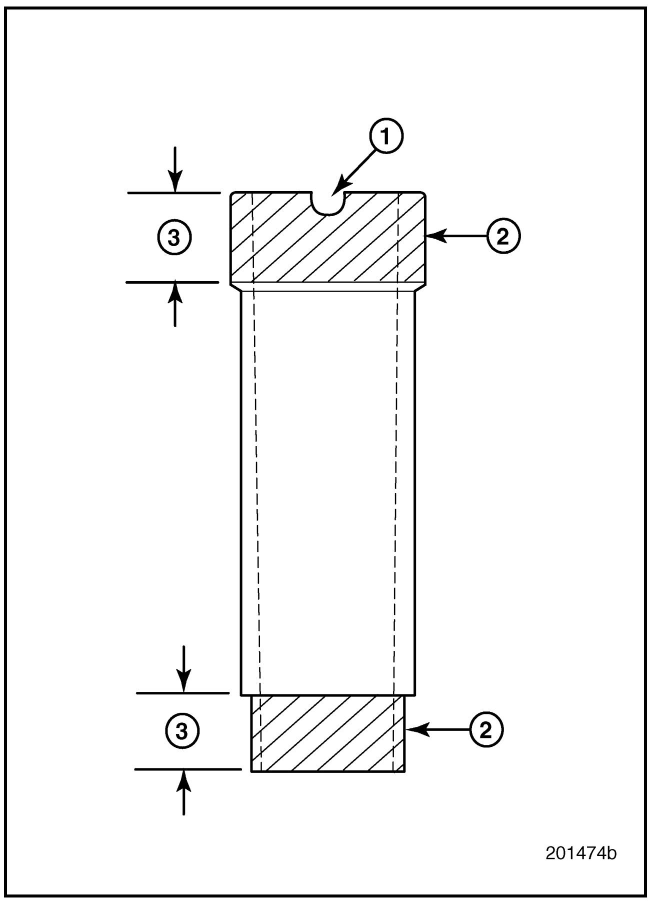


Figure 270 — Fuel-Injection Nozzle Insert

1. Injector Nozzle Locator 2. Apply Loctite to sealing diameter lands.	3. Also apply Loctite to mating bore in the cylinder head.

3. Install the insert in the cylinder head with the locator notch aligned with the high-pressure fuel line hole in the head.
4. Install the alignment pin and using the nozzle insert installer J 42595, drive the insert into the cylinder head until it bottoms on the lower counterbore face. Refer to Figure 271 and Figure 272.

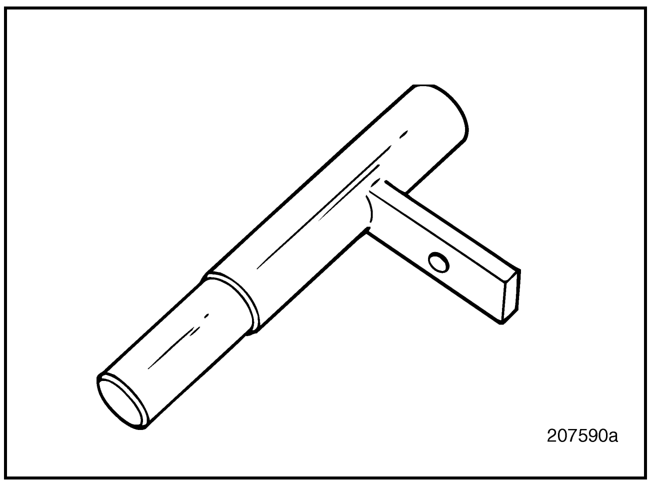


Figure 271 — Nozzle Sleeve (Insert) Installer

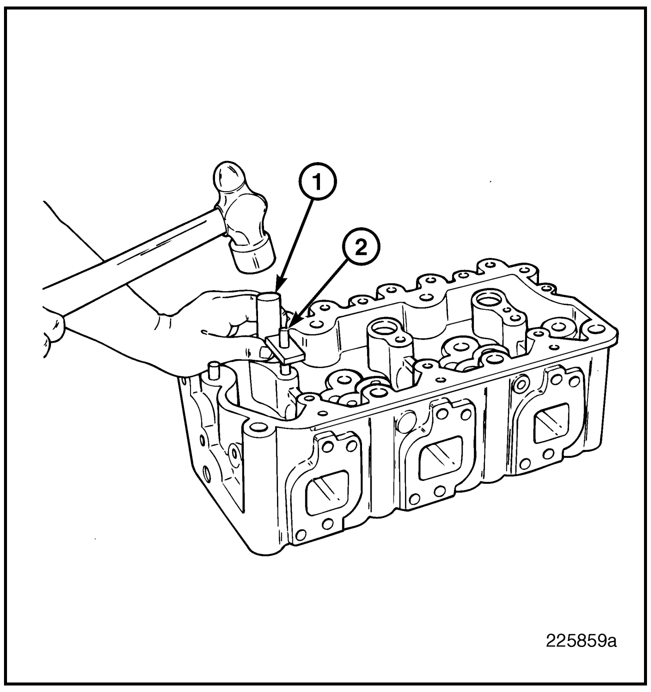


Figure 272 — Injection Nozzle Holder Insert Installation

1. Nozzle Sleeve Installer J 42595	2. Alignment Pin

Valve Yoke Guide Pin Replacement

[213 FH]

Valve yoke guide pins are located only between each set of exhaust valve guides. There are no guide pins for the inlet valves which are actuated by pinless valve yokes.

INSPECTION

Inspect each valve yoke guide pin surface for cracks or other damage. Also check the pin diameter and installed height. If the pin is worn or broken, it can be removed following the applicable procedure below.

REMOVAL PROCEDURE (INTACT PIN)

To remove an unbroken pin, use valve yoke guide pin puller kit PT6575 and the 7/16 inch extractor PT6570-11 as follows:

1. Install the extractor over the guide pin and position the lock on the extractor (Figure 273).
2. Using the slide hammer, firmly tap onto the extractor to lock the puller onto the guide pin.
3. Next, using the slide hammer, remove the worn pin from the cylinder head bore.

REMOVAL PROCEDURE (BROKEN PIN)

Remove a broken pin as follows:

NOTE

Due to the hardness of the valve yoke guide pins, drilling and tapping must be done slowly with sharp tools and with plenty of lubrication.

1. Center punch the broken section of the pin in the cylinder head prior to drilling. The punch mark MUST BE close to the center of the broken pin to control the drilling operation.
2. Using a drill press, drill a 7/64-inch pilot hole completely through the broken section of the yoke pin. A drill press is strongly recommended to keep the drilled hole straight with the yoke pin hole in the cylinder head. Use care when drilling to “feel” when the drill bit passes through the yoke pin and contacts the cylinder head. Stop drilling at that point to avoid drilling through the head and into the water jacket.
3. Drill a 13/64-inch hole completely through the broken section of the yoke pin.
4. Tap all the way through the broken yoke pin, using a 1/4-inch -20 tap and cutting oil. Clean out the cutting chips using compressed air.
5. Using a slide hammer fitted with a 1/4-inch extractor, remove the broken yoke pin from the cylinder head (Figure 273).

NOTE

Thread the slide-hammer extractor as deep as possible into the threaded yoke pin. Failure to install the extractor deep enough will cause the yoke pin to break again.

6. Clean out any remaining chips with compressed air and inspect the yoke pin hole in the cylinder head for drilling or tapping damage.

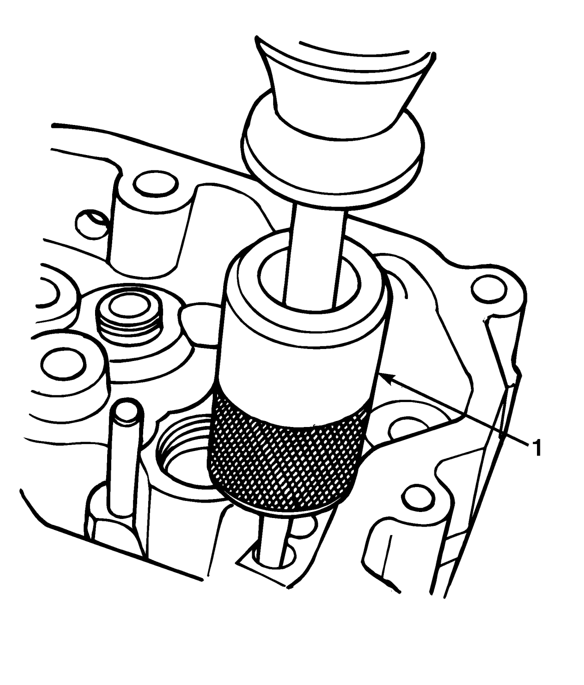


Figure 273 — Valve Yoke Guide Pin Removal

1. Extractor Lock (Part of PT6570-11)

INSTALLATION PROCEDURE

Place the **new** valve yoke guide pin in position and use guide pin installer J 29296 to drive the pin into the cylinder head. The guide pin will be at the correct height when the tool bottoms on the cylinder head. Refer to Figure 274.

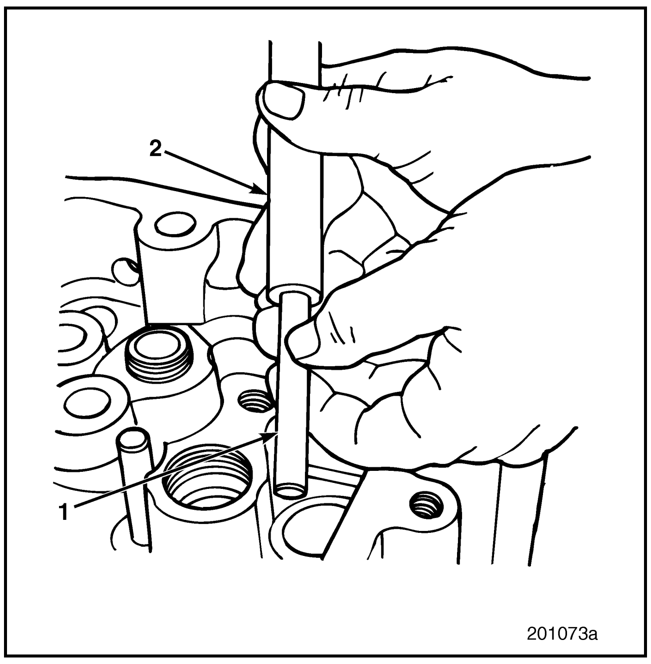


Figure 274 — Valve Yoke Guide Pin Installation

1. Valve Yoke Guide Pin	2. J 29296

Cylinder Head Cup Plug Replacement

[213 FP]

The cylinder head has two different size cup plugs. Both sizes are installed using the following procedure:

1. Clean the cup bore thoroughly.
2. Using Loctite® 277 sealer, or equivalent, apply the sealer to the cup plug and plug bore in the head.
3. Install the cup plugs in the cylinder head, using the appropriate cylinder head core plug installer, J 34684 for 13/16-inch (20.64 mm) cup plugs, and J 34687 for 1-1/16-inch (26.99 mm) cup plugs. Refer to Figure 275.

NOTE

- The cup plug should be driven in until the outer lip of the plug is 0.030 inch (0.762 mm) below the bottom of the lead-in chamfer. An additional driver may be required to achieve this cup plug depth.
- The outer lip of the plug must always locate in the hole and not overlap the lead-in chamfer.

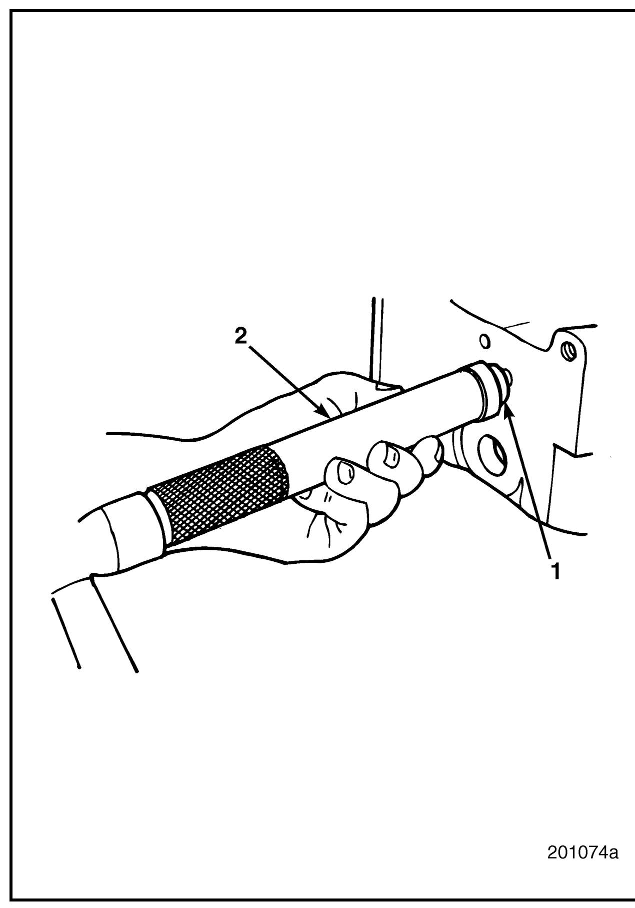


Figure 275 — Cylinder Head Cup Plug Installation

1. Cup Plug	2. Cup Plug Installer

Cylinder Head Pipe Plug Replacement

GENERAL INFORMATION

Current-production 3/4-inch pipe plugs are installed with a preapplied encapsulated epoxy sealant. With the epoxy sealer, the pipe plugs are locked into place, making them immovable when normal loosening/tightening methods are used. Should it become necessary to remove a pipe plug, the following procedure should be used.

NOTE

If a cylinder head has been placed in a hot chemical tank for cleaning and degreasing, the pipe plugs must be checked for looseness. If a plug is found to be loose, the epoxy seal has been broken, making it necessary to remove the plug, clean the plug and cylinder head threads with Loctite® Primer T and reseal the threads with Loctite® 277.

REPLACEMENT (3/4-INCH PLUGS)

Refer to Figure 276.

1. Heat the pipe plug to 400°F (205°C) with a torch.
2. With the pipe plug heated sufficiently, remove the plug from the cylinder head.
3. Remove the epoxy sealant from the threads on both the plug and in the cylinder head.
4. Clean the plug and cylinder head threads with Loctite® Primer T.
5. Apply Loctite® 277 sealant to the plug and cylinder head threads.
6. Install the plugs and tighten to the specified torque, 55 lb-ft (68 N•m).

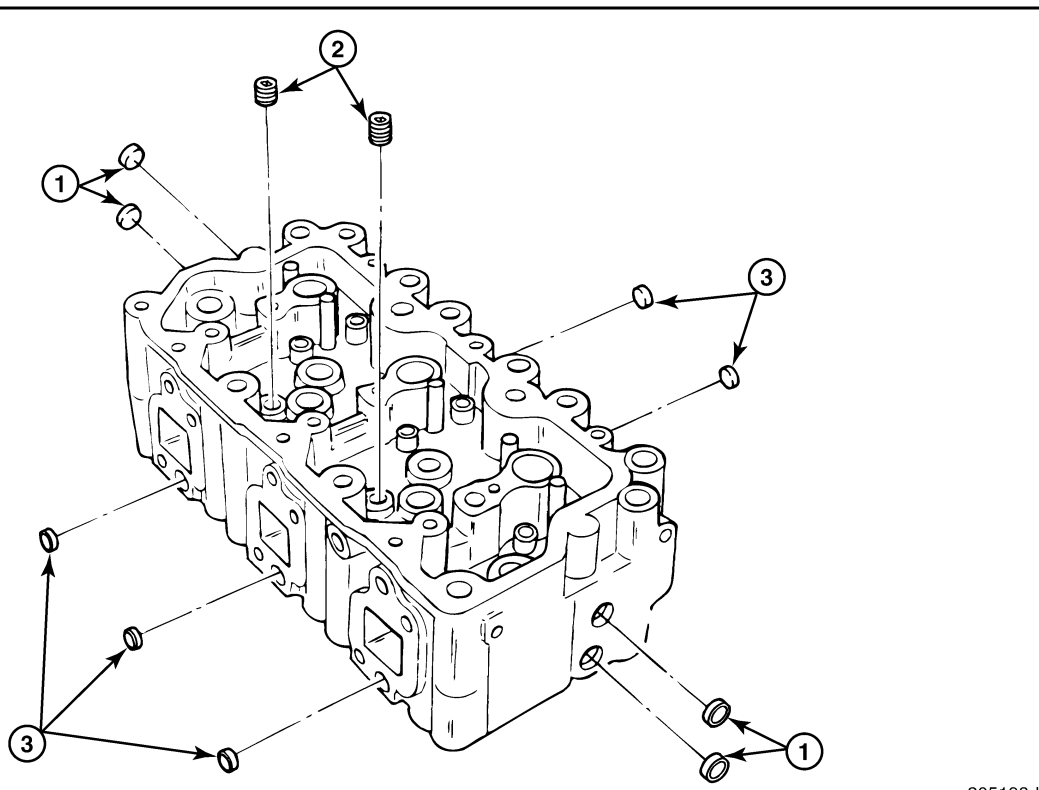


Figure 276 — Cylinder Head Cup and Pipe Plug Locations

1. 1-1/16-inch Cup Plug 2. 3/4-inch NPT Plug	3. 13/16-inch Cup Plug

Inlet and Exhaust Valve Inspection

Visually inspect valves for cracks, pits or other conditions that may cause improper operation. Check valve seat angle. Also check stem length, diameter and condition.

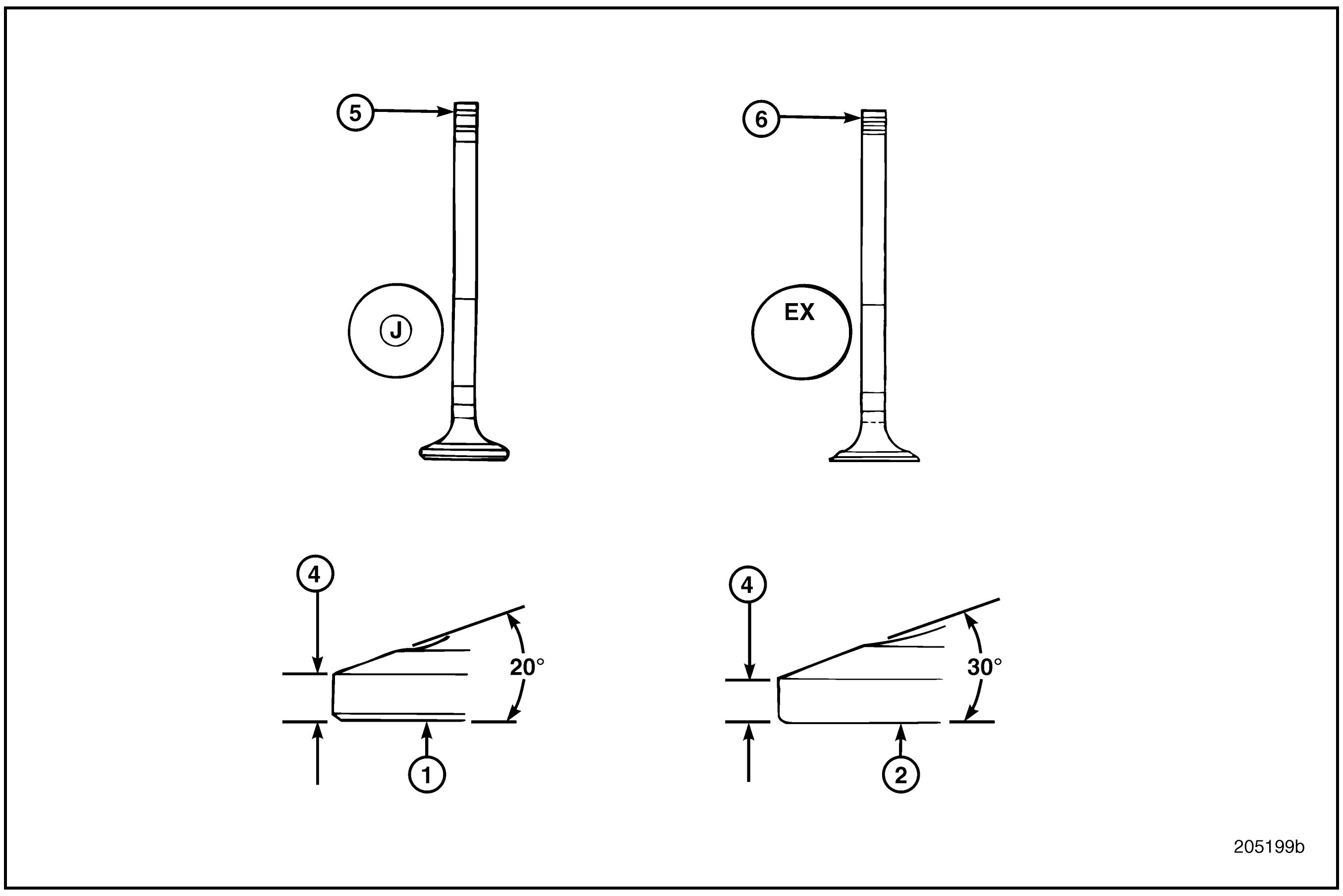


Figure 277 — Valve Dimensions

1. Inlet Valve 2. Pyromet Exhaust Valve 3. Seat Angle: 20° Inlet, 30° Exhaust	4. Minimum After Grinding: 0.130 inch (inlet), 0.0100 inch (Exhaust) 5. One Stem Groove 6. Two Stem Grooves

Inlet and Exhaust Valve Installation

For identification purposes, the exhaust valve has two stem grooves in addition to the valve spring keeper groove; whereas, the inlet valve has one stem groove in addition to the spring keeper groove.

The valves are also identified by the letter “J” (20-degree inlet), and letters “EX” (exhaust), on the bottom face of the valve head. Refer to Figure 278 for an illustration of the inlet valve identification.

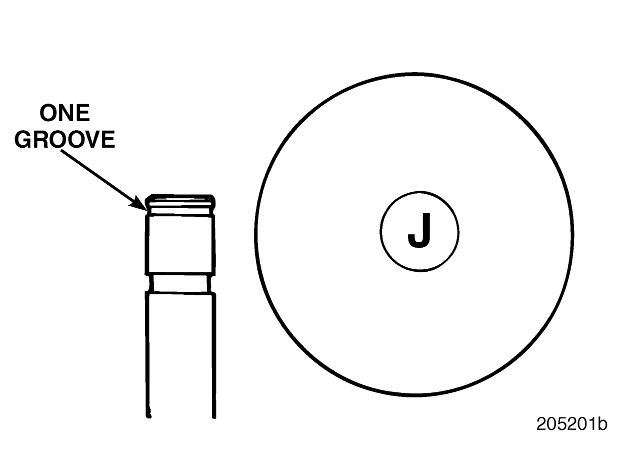


Figure 278 — 20-Degree Intake Valve Identification

CAUTION

The inlet and exhaust valve head diameters are nearly the same size. It is important, therefore, that extra care be taken when installing these valves.

1. Lubricate the inside diameter of the valve guides by using a “bottle brush” coated with Dow Corning® BR2 Plus multipurpose grease. This is particularly important when both the valves and the valve guides are new. (With an on-engine seal replacement, pre-lube the valve stems with clean engine oil while moving the valve up and down, prior to installation of the valve spring.)
2. With these new valve stem seals, pre-lubrication during installation is extremely important. Pre-lubricate the seals as follows:
   - **Valve Stem-to-Guide** — Lubricate the inside diameter of the valve guides by using a “bottle brush” coated with graphite grease. This is particularly important when both the valves and the guides are new. With an on-engine seal replacement, pre-lubricate the valve stems with clean engine oil while moving the valve up and down before installing the valve spring(s).
   - **Valve Stem-to-Seal Lip** — The inside diameter of the seal lip and outside diameter of the valve stem should be well-lubricated with clean engine oil when installing the seal over the valve stem.
3. **Early Design Valve Guide and Stem Seal**
   A combination valve spring seat and integral stem seal was used on the first 200 ASET™ engines. This early design seal is no longer available. Engines built with this seal arrangement will need to be converted to the current configuration multi-lip type seal. This conversion will require the replacement of the valve guides to the current configuration. Refer to “Valve Guide Replacement” earlier in this section.

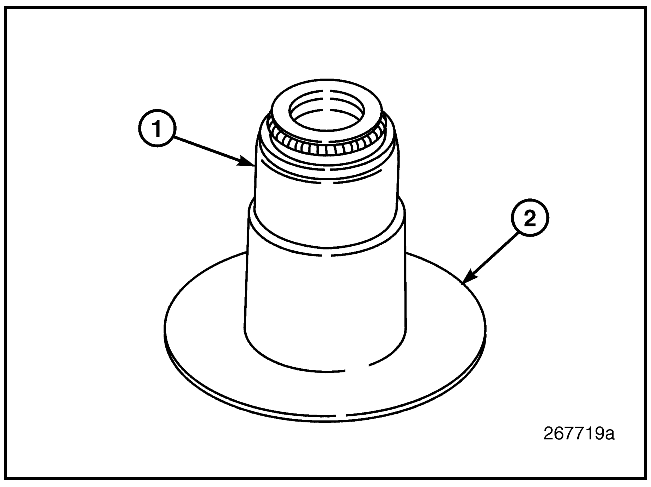


Figure 279 — Valve Stem Seal (Early Design)

1. Valve Stem-to-Seal Lip	2. Valve Stem Seal

4. **Current Design Valve Stem Seal**

   Following valve stem-to-guide and valve stem-to-seal lip lubrication, install the current-production valve stem seals using valve seal installer J 45730.

   It is essential that the valve stem seal installation tool, J 45730, be used to install the seals. This tool ensures that the seal installs over the guide and to the proper depth on the valve guide.

CAUTION

When installing valve seals, it is essential that the proper valve seal installation tool (J 45730) be used. This tool bottoms on the cylinder head rocker arm mounting bracket surface when the seal is installed to the proper depth on the valve guide. Using any non-bottoming type seal driver (such as a socket) may result in distorting the top surface of the seal casing which permanently distorts the seal lip and prevents proper sealing. It can also result in the top rubber portion of the seal being cut off.

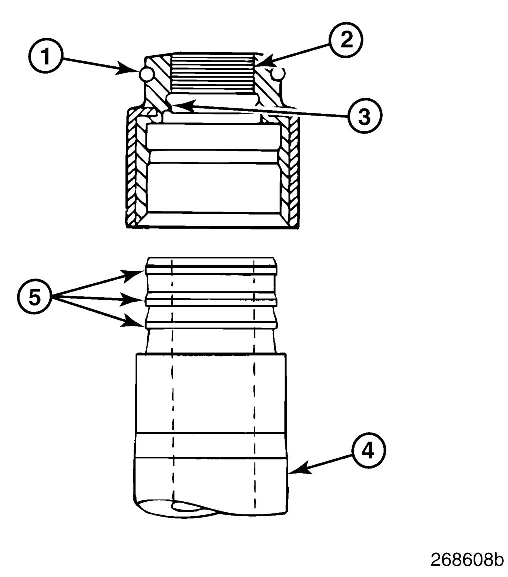


Figure 280 — Valve Stem Seal

1. Steel Retainer Band 2. Multi-Lip Section 3. Primary Lip	4. Valve Guide 5. Three Sharp Edges

5. Check the valve stem tip for nicks or burrs that may damage the valve stem seal upon installation.
6. Install the valve and either install the bottom rotator or the hardened spring washer if tip-end rotators are used. Place the valve springs over the valve stem and onto either valve rotator or hardened spring washers. Intake valves use a single outer spring and the exhaust valves use a combination of inner and outer springs.

SERVICE HINT

Current-production exhaust location inner springs are now being painted white. These springs are completely interchangeable with the former bare steel springs. The white paint was added to help verify that the inner spring is present after the cylinder head is built-up.

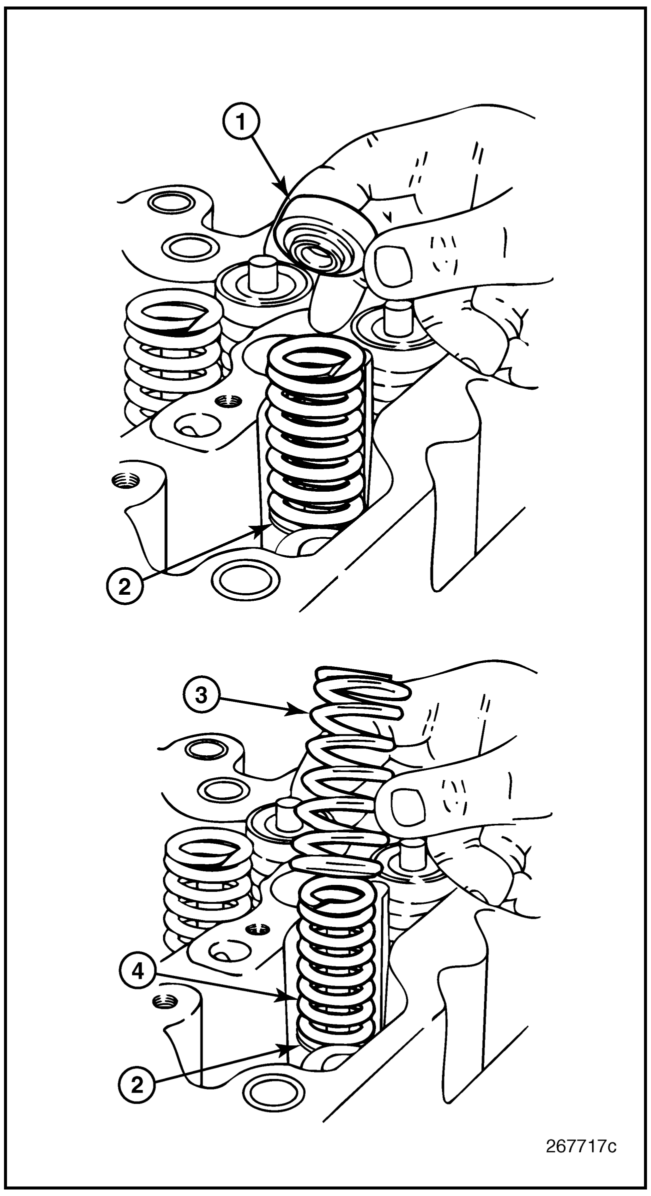


Figure 281 — Spring and Tip-End Rotator Installation (to Mid-Year 2003)

1. Spring Rotator (Tip-End) 2. Spring Seat	3. Outer Exhaust Spring 4. Inner Exhaust Spring

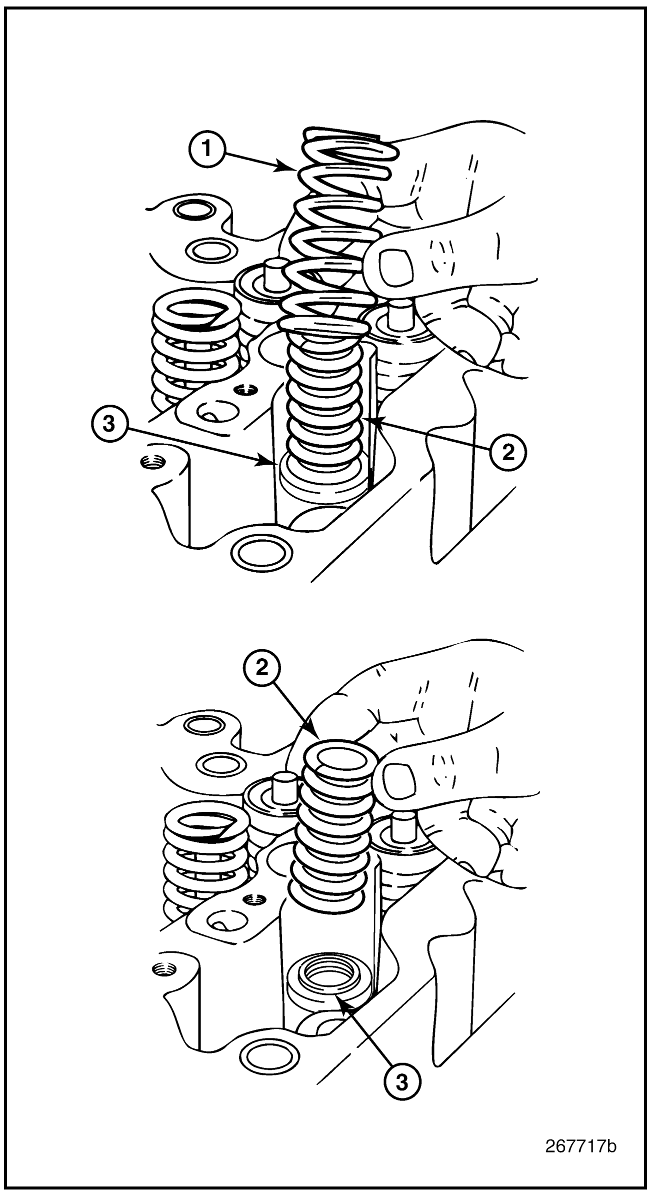


Figure 282 — Spring and Bottom Rotator Installation (Mid-Year 2003 and Later)

1. Outer Exhaust Spring 2. Inner Exhaust Spring	3. Spring Rotator (Bottom)

7. Install the tip-end rotators or valve retaining washers onto the inlet and exhaust valves. Ensure that the correct rotator, inlet or exhaust, is installed at the correct location. Inlet rotators have a flat bottom surface for a single-spring installation while the exhaust rotators have a stepped surface to accommodate inner and outer springs.

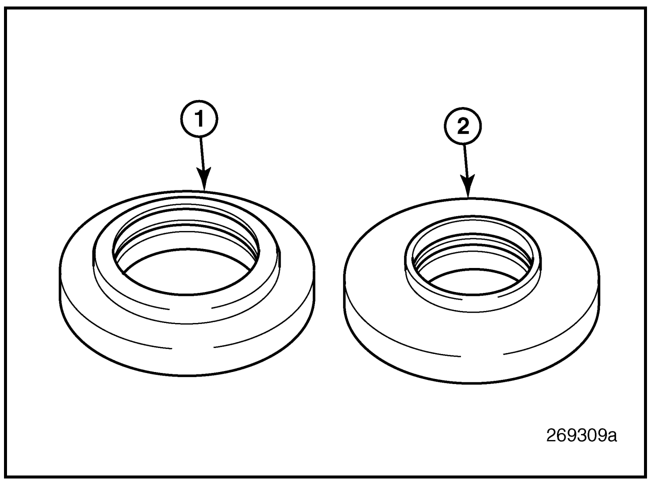


Figure 283 — Exhaust and Inlet Rotators

1. Rotator for Dual Springs (Exhaust Locations)	2. Rotator for Single Valve Spring (Inlet Locations)

8. Reattach the valve spring compressor to the cylinder head. Use spring compressor J 43887 for valves with tip-end rotators or J 29294-B for valves with bottom rotators.
9. Depress the tool handle until the valve spring is compressed. Install the valve keepers into the rotators or valve spring retaining washers using a magnet.

NOTE

Valve spring compressor J 43887 or J 29294-B must be repositioned for each series of valves (two inlet and two exhaust per cylinder). Drilled and tapped holes are provided for each cylinder.

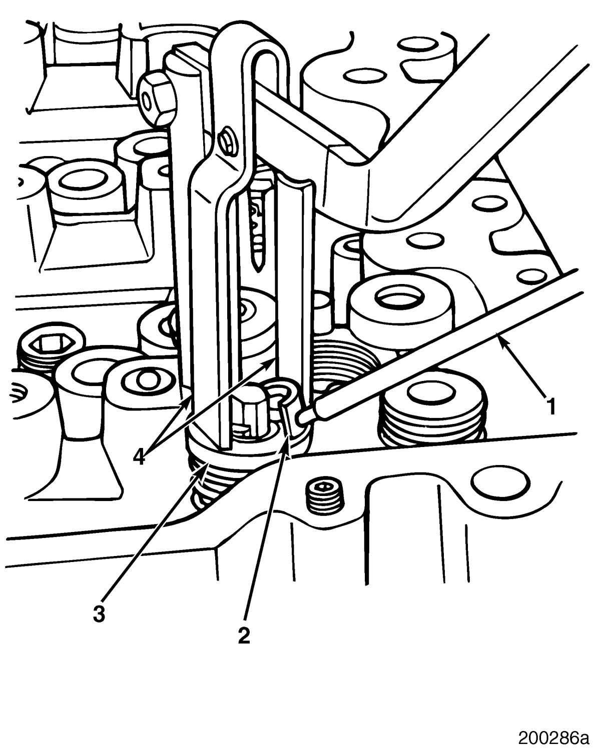


Figure 284 — Valve Spring Keeper Installation

1. Magnet 2. Valve Spring Keys (Keepers)	3. Tip-End Rotator or Valve Retaining Washer 4. Tool Compression Forks

10. After the valves are installed, check each inlet valve for head height above the cylinder deck. The protrusion dimension for inlet valves should be 0.0425 +0.009/–0.007 inch (1.0795 +0.229/–0.178 mm). Refer to Figure 285 and Figure 286.

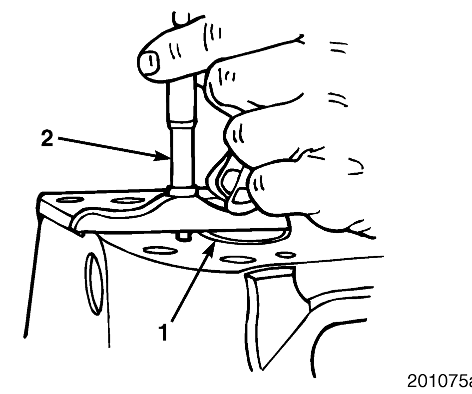


Figure 285 — Checking Valve Assembly Height

1. Inlet Valve	2. Depth/Height Measurement Tool

11. Check each exhaust valve for head depth below the cylinder deck. The depth dimension for the exhaust valve should be 0.021 +0.009/–0.007 inch (0.553 +0.229/–0.178 mm).

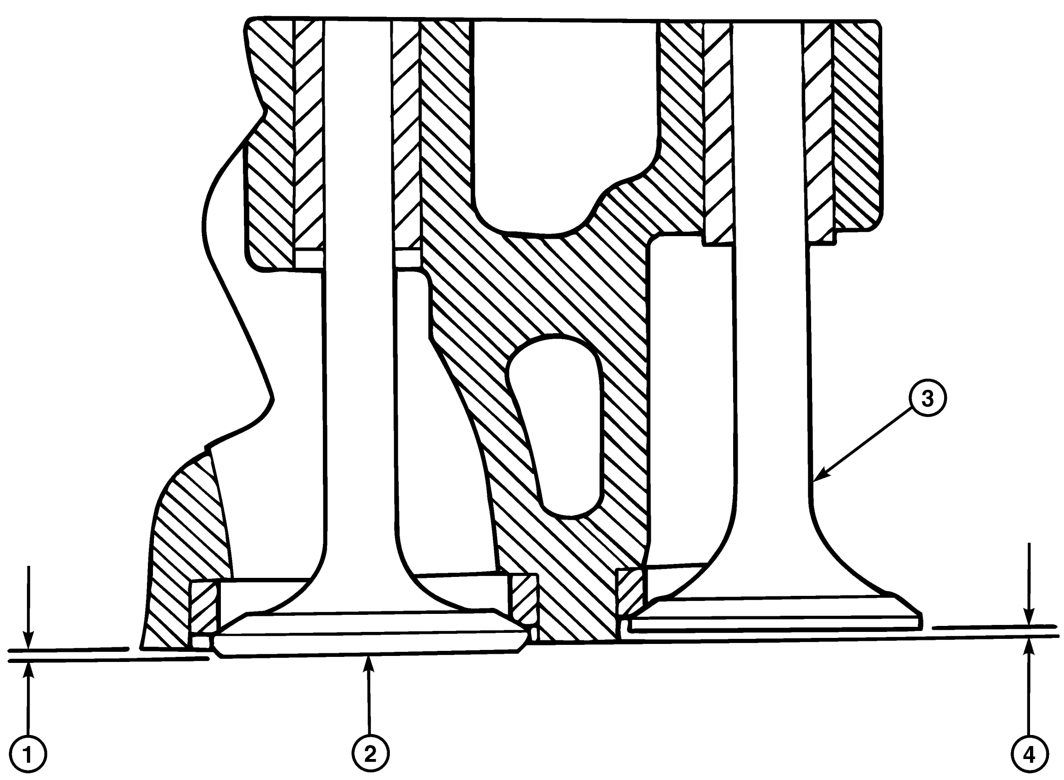


Figure 286 — Inlet/Exhaust Valve Head Height/Depth Measurement

1. Inlet Protrusion Above Deck: 0.047 inch +0.009/–0.007 inch (1.194 +0.229/–0.178 mm) 2. Inlet Valve	3. Exhaust Valve 4. Exhaust Valve Depth Below Deck: 0.021 inch +0.009/–0.007 inch (0.553 +0.229/–0.178 mm)

NOTE

If the dimensions are not within specification, machine the valve seat insert and/or valve face as necessary. Refer back to the “Valve Seat Insert Replacement” procedure in this section.

VALVE ROCKER ARM SHAFT BENCH PROCEDURES [213 LP]

Rocker Arms

Rocker Arm Improvements Effective January 2002

Effective with the January 2002 introduction of the spring-loaded push rods, both inlet and exhaust rocker arms have been revised to provide pressure oil feed to the valve adjusting screws. A vertical groove has been added to the inboard side of the adjusting screw bore, from the top of the bore to the oil supply hole that is just above the bottom of the bore. On the outboard side of the rocker arm adjusting screw boss, a closure plug has been installed into the drilled hole to eliminate the leak path for pressure oil and ensure sufficient oil to the adjusting screw.

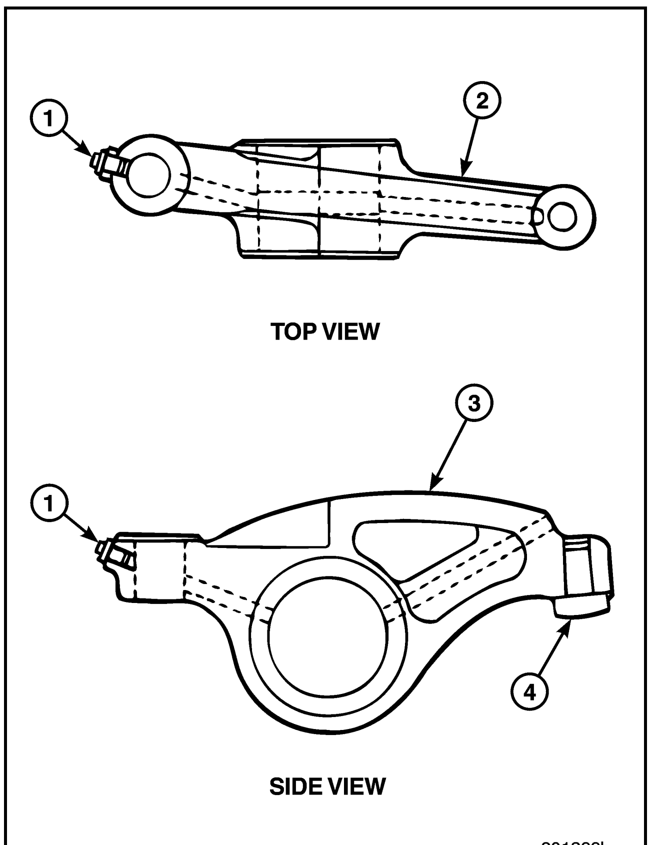


Figure 287 — Rocker Arm (Effective January 2002)

1. Plug 2. Rocker Arm (Top View)	3. Rocker Arm (Side View) 4. Hardened Pin

Further rocker arm improvements include adjusting screws that have a groove around the center of the screw, an oil passage cross-drilled through the shank of the screw and an oil passage drilled along the vertical center line of the screw. These oil passages provide lubrication to the ball end of the adjusting screw and the push rod cup. Additionally, to make it easier to hold the screw during valve adjustment, the new rocker arm adjusting screws have a 5 mm internal hex rather than a screwdriver slot as was used on previous adjusting screws.

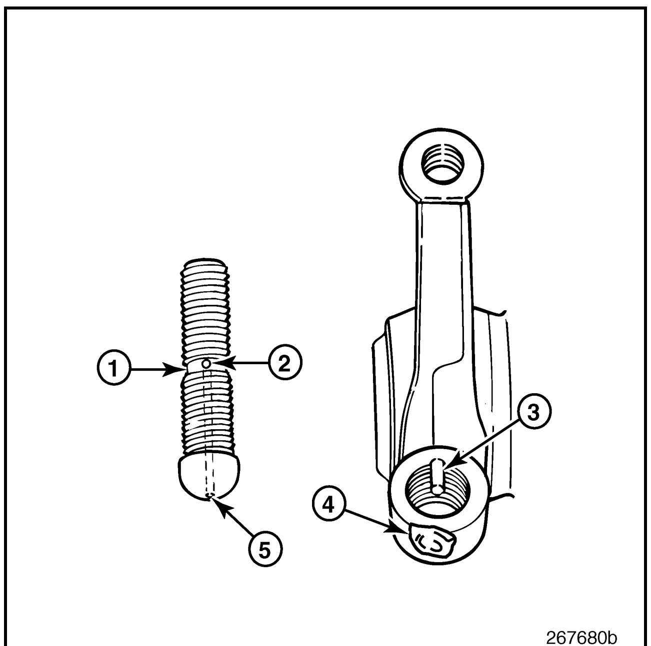


Figure 288 — Rocker Arm and Adjusting Screw with Oil Passages (Introduced January 2002)

1. Oil Supply Groove 2. Drilled Oil Passage 3. Oil Supply Groove	4. Outboard Oil Hole Plugged 5. Drilled Oil Hole Plugged

Rocker Arm Improvements Effective January 2003

Effective January 2003, the following new and improved components were introduced into production.

Rocker Arm Shaft

- Heavier wall thickness for added strength
- Increased radius in all retainer ring grooves, also for strength improvement
- Shaft end closure by pipe plugs, to provide a more secure closure than the previously used cup plugs
- The shaft has two additional oil supply holes to each rocker for directed lubrication to the rocker arm tip-end and adjusting screw

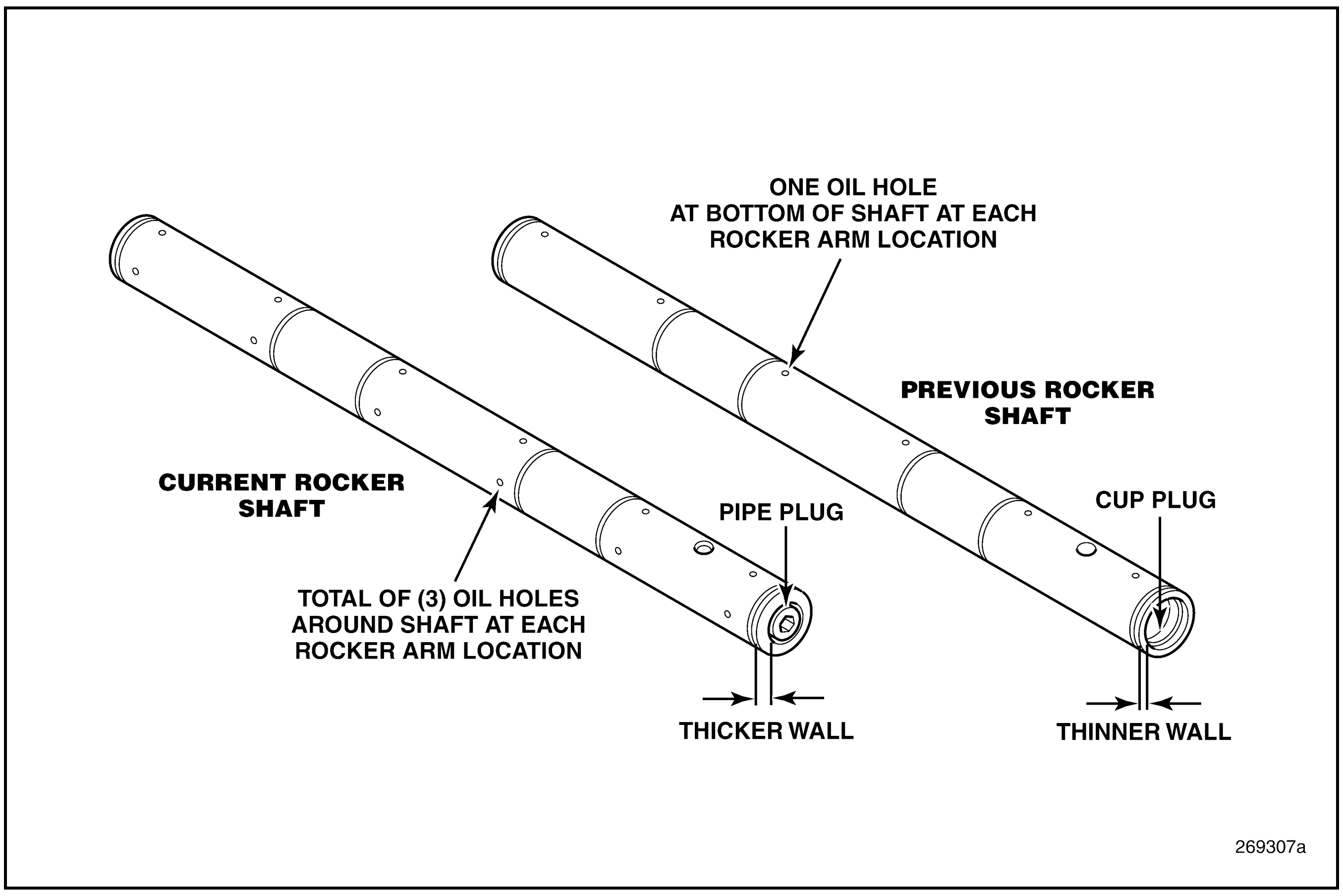


Figure 289 — Rocker Arm Shaft

Rocker Arms

- Increased casting thickness for added strength
- Carbonitrided steel bushing in shaft bore for wear resistance
- Revised oil passage drilling eliminates the adjusting screw bore closure plug

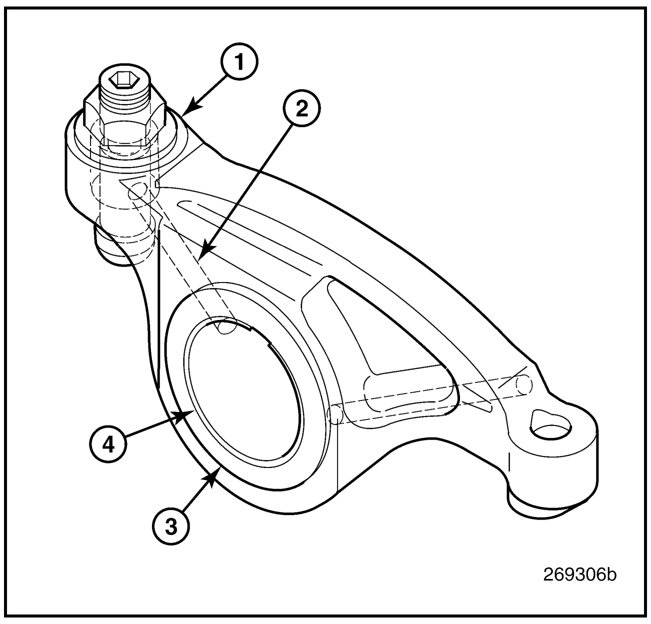


Figure 290 — Rocker Arms

1. Wider Casting at Nut Flange 2. Revised Oil Passage	3. Near-Full Width Casting 4. Steel Bushing

Rocker Arm Adjusting Screws

- The pressure oil fed adjusting screws are Armolloy coated for resistance to galling and wear

Pinless Valve Yoke

- The top inboard corner of yoke has been chamfered at a 45-degree angle, necessary to ensure clearance between yoke tip and the heavier rocker arm casting.

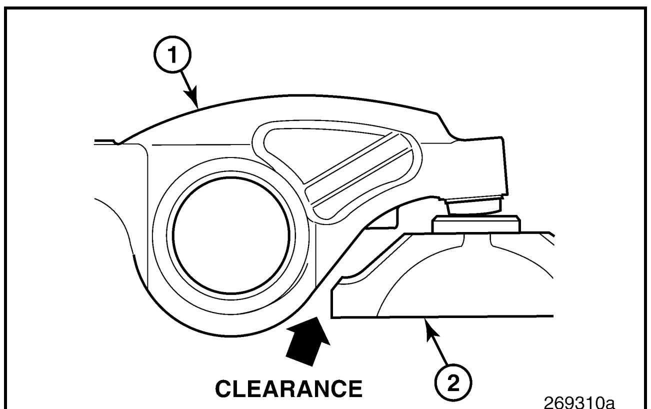


Figure 291 — Pinless Valve Yoke

1. Heavier Rocker Arm Casting	2. Yoke with Chamfered Tip

CAUTION

The revised rocker arm components described above cannot be intermixed with previous version components.

With the heavier rocker arms, it is mandatory to use the pinless valve yoke having the chamfered tip at the top of the inboard end.

Valve Rocker Arm Shaft Disassembly (with/without Engine Brake)

Refer to Figure 295, Figure 296 and Figure 298. The shaft assembly is disassembled as follows:

1. If equipped with MACK PowerLeash™ engine brake, remove the solenoid from the shaft.
2. Remove the C-clip and flat washer from one end of the shaft.
3. Remove the outer rocker arm and spring washer.
4. Press the mounting bracket from the shaft. Use care not to drop the assembly as the bracket is removed.
5. Remove the second spring washer, rocker arm, flat washer and C-clip.
6. Repeat steps 2 through 5 to remove the two remaining rocker arm sets from the shaft.
7. Remove the adjusting screws and jam nuts from the rocker arms.

NOTE

Changes to the rocker arm since January 2003 are significant; therefore, no components from the current rocker arm shafts can be interchanged with the non-current components.

Inspection

A. Perform a general inspection of all components of the rocker arm shaft and bracket assembly for evidence of damage or wear. Replace components as necessary.

B. If loose or broken rocker arm shaft mounting bolts are encountered at disassembly, or if the rocker shaft is bent, contingent damage must be inspected for and repaired as follows:

- Inspect the bottom surfaces of the rocker shaft mounting brackets for signs of fretting damage. Mounting brackets can be reused if only slight signs of fretting and/or polishing are evident, as long as there are no other types of damage which could render the rocker shaft assembly unusable. Replace the mounting brackets if fretting damage is severe enough that a wear step of approximately 0.002" (0.508 mm) is seen. A 0.002" (0.508 mm) wear step can be felt by dragging your fingernail across the step.

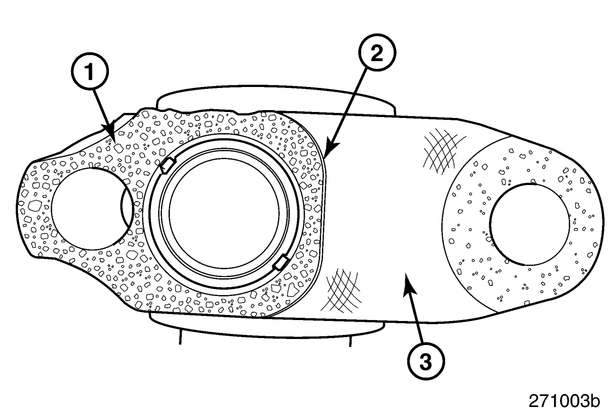


Figure 292 — Rocker Shaft Mounting Bracket Showing Signs of Fretting Damage

1. Severe Fretting 2. Wear Step	3. Machined Surface

NOTE

On engines where the rocker shaft mounting bolts have come loose or have broken on one cylinder head only, the rocker shaft on the other cylinder head must also be removed, and the mounting brackets and the mating surfaces on the cylinder head inspected for fretting damage. Replace the brackets and cylinder head as required.

- Inspect the mating surface on the cylinder head at the locations where fretting damage was found on the corresponding rocker shaft mounting bracket. If fretting damage on the cylinder head is severe (where the machined surface is severely pitted and a step of approximately 0.002" [0.508 mm] is evident), the cylinder head must be replaced.

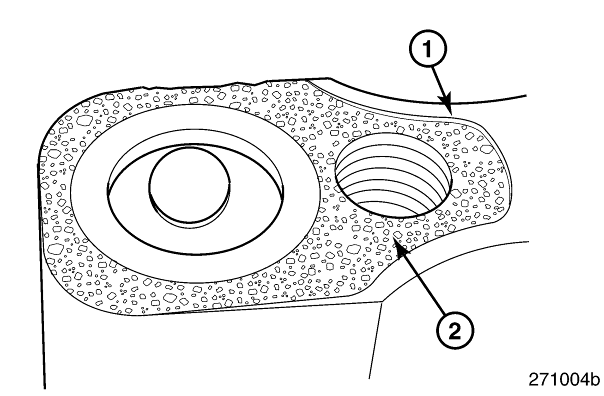


Figure 293 — Severe Fretting Damage on Cylinder Head Rocker Arm Bracket Mounting Surface

1. Wear Step	2. Severe Fretting

A wear step of 0.002" (0.508 mm) on the cylinder head mating surface can be determined by laying a straightedge across the rocker shaft mounting bracket mating surface. If a 0.002" (0.508 mm) thickness gauge can be slid under the straightedge, or if light can be seen under the straightedge in the area of the fretting damage, the damage is severe enough to warrant replacement of the head.

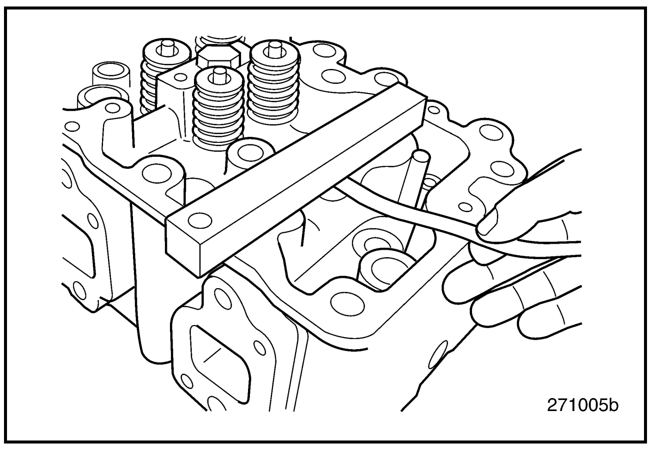


Figure 294 — Checking Cylinder Head for Fretting Damage

- Inspect the push rods, and replace any that are bent or damaged.

Valve Rocker Arm Shaft Reassembly (without Engine Brake)

NOTE

There is a shouldered rocker arm mounting capscrew at one end of each rocker arm assembly to ensure proper alignment.

Refer to Figure 295.

The assembly procedure for the rocker arm shaft is described below. The arrangement includes valve rocker arms (with lash adjusters) and mounting brackets mounted on the shaft. The bracket mounting dimensions are the same for both non-brake and brake assemblies.

1. Lubricate the six adjusting screws and jam nuts, and install one in each of the rocker arms. The adjusting screws are identical for both inlet and exhaust rocker arms.
2. Position the shaft so that the screw locating hole is in line with the bracket locating screw hole. The offset side of the bracket must be positioned toward the right side of the engine.
3. Assemble the bracket on a press table. Press the shaft into the bracket until the oil hole in the shaft is aligned with the hole in the bracket. Install the locating screw and lock washer to secure the bracket on the shaft. Tighten the locating screw to the specified torque.
4. Lubricate the spring washers and install the washers on the shaft, one on each side of the mounting bracket.
5. Lubricate the exhaust rocker arm and install it on the shaft.
6. Install a flat washer and C-clip on the shaft to retain the exhaust rocker arm.
7. Lubricate the inlet rocker arm and install it on the shaft.
8. Install a flat washer and C-clip on the shaft to retain the inlet rocker arm.
9. Install a flat washer and C-clip on the shaft to position and retain the exhaust rocker arm at the center position of the shaft.
10. Lubricate the exhaust rocker arm and install the arm on the shaft.
11. Lubricate a spring washer, install it on the shaft next to the exhaust rocker arm and press the center mounting bracket onto the shaft. This bracket does not have a threaded hole on top or an oil hole at the bottom surface. Align the mounting surface and offset of the bracket with the bracket already installed.
12. Lubricate a spring washer and install it on the shaft next to the center bracket.
13. Lubricate and install the inlet rocker arm on the shaft.
14. Install a flat washer and C-clip on the shaft to retain the center inlet rocker arm.
15. Follow steps 9 through 14 to install the remaining set of rocker arms and mounting bracket.

SERVICE HINT

At this point, a used or scrapped cylinder head can be used as a template for proper bracket alignment and to ensure that the mounting surfaces of each bracket are parallel.

16. Check for proper bracket alignment. Ensure that mounting surfaces of each bracket are parallel.

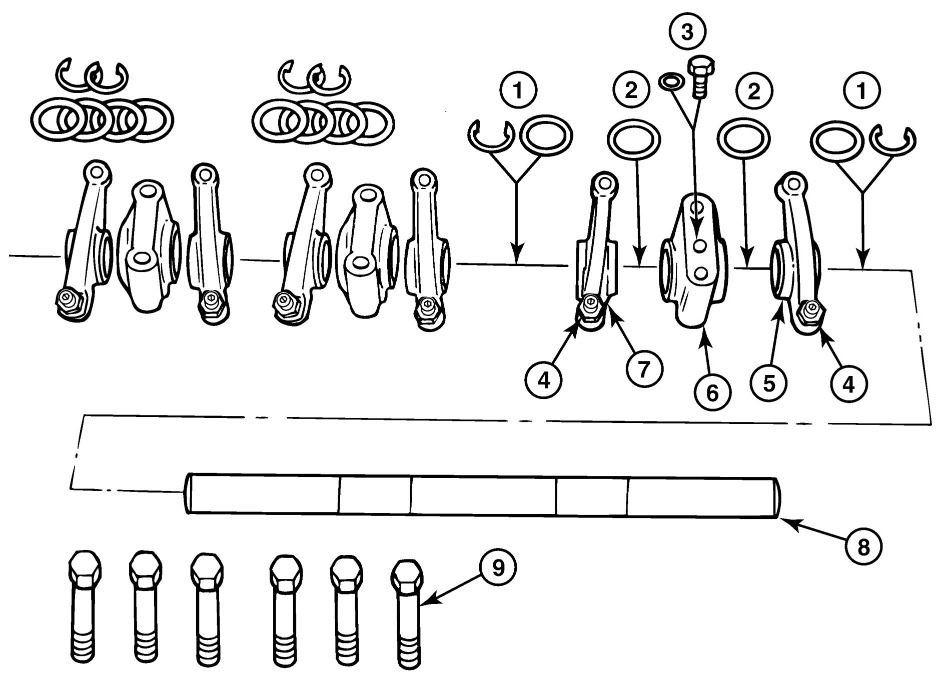


Figure 295 — Valve Rocker Arm Shaft Assembly (without Engine Brake)

1. Flat Washer and C-Clip 2. Spring Washer 3. Locating Screw and Lock Washer 4. Standard Adjusting Screws and Jam Nuts 5. Exhaust Rocker Arm	6. Mounting Bracket 7. Inlet Rocker Arm 8. Shaft 9. Capscrews

Valve Rocker Arm Shaft Reassembly (with J-Tech™ Engine Brake)

NOTE

There is a shouldered rocker arm mounting capscrew at one end of each rocker arm assembly to ensure proper alignment.

Refer to Figure 296.

The assembly procedure for the rocker arm shaft of a J-Tech™ brake-equipped engine is nearly identical to that of the non-brake engine with the following differences:

- An oil supply screw replaces the locating screw and lock washer.
- A spherical jam nut and adjusting screw replace the standard jam nut and adjusting screw on the exhaust rocker arms.

The installation procedure is as follows:

1. Lubricate the three adjusting screws and jam nuts for the **inlet rocker arms**, and install one in each of the arms.
2. Lubricate the three adjusting screws and spherical jam nuts for the **exhaust rocker arms**, and install one in each of the arms.
3. Position the shaft so that the screw locating hole is in line with the bracket locating screw hole. The offset side of the bracket must be positioned toward the right side of the engine.
4. Assemble the bracket on a press table. Press the shaft into the bracket until the oil hole in the shaft is aligned with the hole in the bracket. Install the oil supply screw to secure the bracket on the shaft and tighten the screw to specification, 5 lb-ft (7 N•m).
5. Lubricate the spring washers and install the washers on the shaft, one on each side of the mounting bracket.
6. Lubricate the exhaust rocker arm and install it on the shaft.
7. Install a flat washer and C-clip on the shaft to retain the exhaust rocker arm.
8. Lubricate the inlet rocker arm and install it on the shaft.
9. Install a flat washer and C-clip on the shaft to retain the inlet rocker arm.
10. Install a flat washer and C-clip on the shaft to position and retain the exhaust rocker arm at the center position of the shaft.
11. Lubricate the exhaust rocker arm and install it on the shaft.
12. Lubricate a spring washer, install it on the shaft next to the exhaust rocker arm and press the center mounting bracket onto the shaft. This bracket does not have a threaded hole on top or an oil hole at the bottom surface. Align the mounting surface and offset of the bracket with the bracket already installed.
13. Lubricate a spring washer and install it on the shaft next to the center bracket.
14. Lubricate and install the inlet rocker arm on the shaft.
15. Install a flat washer and C-clip on the shaft to retain the center inlet rocker arm.
16. Follow steps 10 through 15 to install the remaining set of rocker arms and mounting bracket.

SERVICE HINT

At this point, a used or scrapped cylinder head can be used as a template for proper bracket alignment and to ensure mounting surfaces of each bracket are parallel.

17. Check for proper bracket alignment. Ensure that mounting surfaces of each bracket are parallel.

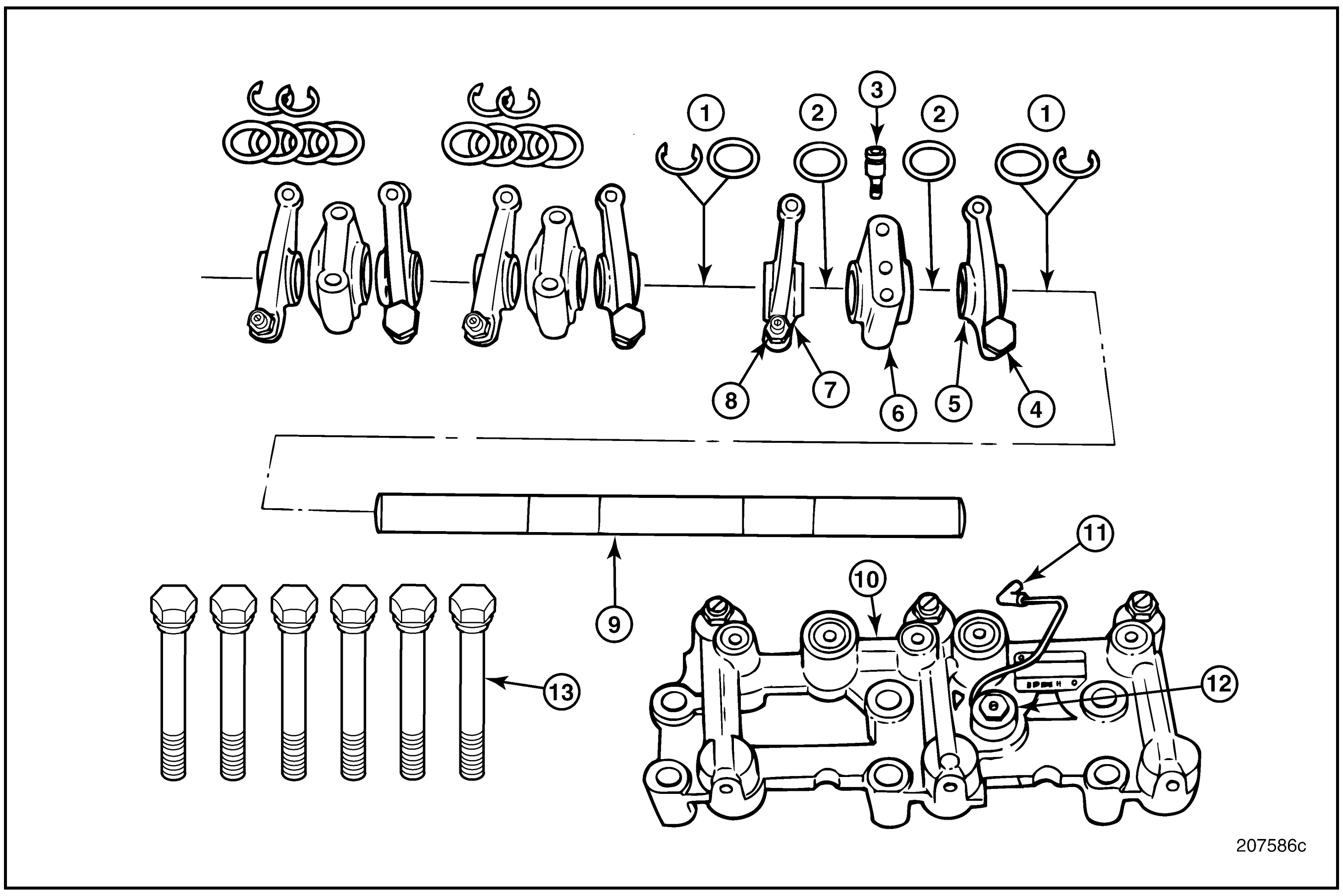


Figure 296 — Valve Rocker Arm Shaft Assembly (with J-Tech™ Engine Brake)

1. Flat Washer and C-Clip	8. Standard Adjusting Screw and Jam Nut
2. Spring Washer	9. Shaft
3. Oil Supply Screw (with Integral Check Valve)*	10. Engine Brake Actuator Assembly
4. Adjusting Screw and Spherical Jam Nut	11. Electrical Connector
5. Exhaust Rocker Arm	12. Solenoid
6. Mounting Bracket	13. Large Hex-Head Capscrews
7. Inlet Rocker Arm	

* This screw incorporates an oil supply check valve, eliminating the need for the oil supply check valve components in the engine brake housing.

Valve Rocker Arm Shaft Reassembly (with MACK PowerLeash™ Engine Brake)

ROCKER SHAFT/FRONT MOUNTING BRACKET ASSEMBLY

The rocker shaft contains oil passages that supply both lubricating oil and control pressure oil to the rocker arms. As with rocker shaft assemblies on non-brake engines, alignment of the oil ports in the front mounting bracket with ports in the rocker shaft is critical. The first rocker shaft mounting bracket is a press-fit onto the shaft, while the center and rear brackets are slip-fit. The rocker shaft and front mounting bracket are an assembly. The rocker shaft assembly consists of the following parts:

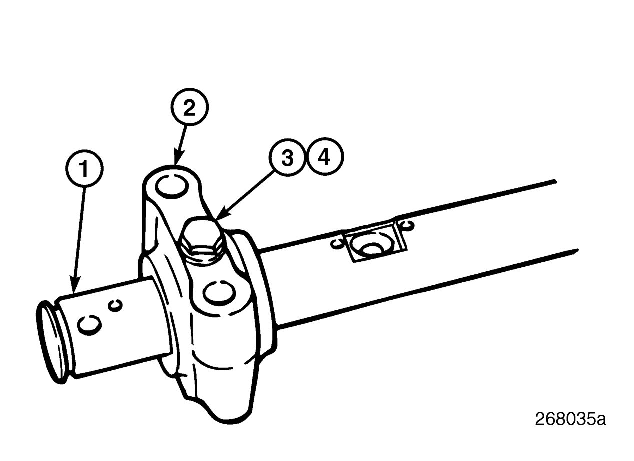


Figure 297 — Rocker Shaft/Front Mounting Bracket Assembly

1. Rocker Shaft 2. Rocker Shaft Mounting Bracket (Press Fit)	3. Mounting Bracket Locating Bolt 4. Lock Washer

NOTE

As mentioned above, the front mounting bracket on MACK PowerLeash™ rocker shafts is a press-fit, and alignment of the oil passage between the bracket and shaft is critical. A pre-assembled rocker shaft/front mounting bracket (part No. 466GC4111M) is available through the MACK Parts System. DO NOT replace the entire rocker arm and shaft assembly.

POWERLEASH™ ROCKER SHAFT ASSEMBLY

Refer to Figure 298.

1. Lubricate a spring washer with clean engine oil, then slide it on the front end of the rocker shaft.
2. Lubricate the bore of the exhaust rocker arm with clean engine oil.
3. Install the exhaust rocker onto the front of the rocker shaft. The push rod end of the rocker faces the large offset end of the rocker shaft mounting bracket.
4. Lubricate a flat washer with clean engine oil, then slide it on the front end of the rocker shaft. Install a retaining ring in the groove at the end of the rocker shaft to secure the rocker arm in place.
5. Lubricate a spring washer with clean engine oil, then slide it onto the opposite end of the rocker shaft and position it against the mounting bracket.

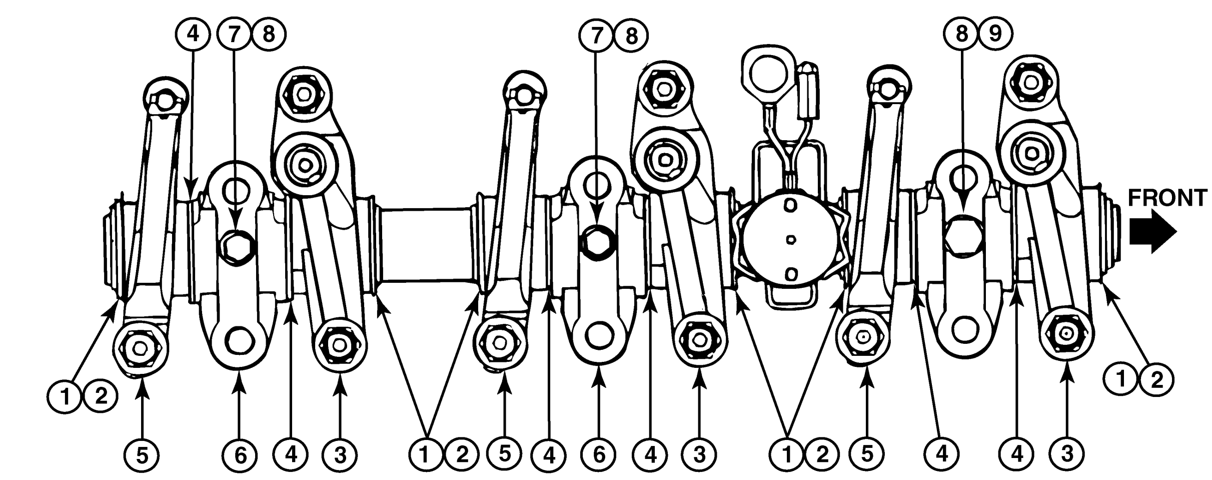


Figure 298 — Mack PowerLeash™ Rocker Shaft Assembly

1. Retaining Ring 2. Flat Washer 3. Exhaust Rocker Arm (with Engine Brake Hydraulic Actuator) 4. Spring Washer	5. Inlet Rocker Arm 6. Rocker Shaft Mounting Bracket (Slip Fit) 7. Mounting Bracket Locating Bolt 8. Lock Washer

6. Lubricate the bore of the inlet rocker arm with clean engine oil, then install the rocker arm on the shaft. The push rod end of the inlet rocker arm faces the long offset side of the rocker shaft mounting bracket.
7. Lubricate a flat washer, then slide it on the rocker shaft. Install a circlip into the groove of the rocker shaft to secure the inlet rocker arm in place.
8. Install a circlip in the groove of the rocker shaft at the location for the second exhaust rocker arm.
9. Lubricate a flat washer with clean engine oil, then slide it onto the rocker shaft, against the circlip.
10. Lubricate the bore of the exhaust rocker arm with clean engine oil, then slide it on the rocker shaft, against the flat washer.

NOTE

When reinstalling PowerLeash™ exhaust rocker arms, always check the engine brake actuator plunger for full travel and freedom of movement by pressing and releasing the plunger. If the plunger binds in the bore or full travel is not achieved, the rocker arm must be replaced.

11. Lubricate a spring washer, then slide it over the end of the rocker shaft, against the second exhaust rocker arm.
12. Lubricate the bore of the rocker shaft mounting bracket, then slide it over the end of the rocker shaft, against the wave washer.
13. Align the locating hole in the mounting bracket with the threaded locating hole in the rocker shaft. Lubricate the threads of the locating bolt. Install the locating bolt and lock washer to the mounting bracket. **Finger-tighten** only at this time.

14. Continue assembly by installing the remaining washers, rocker arms and mounting bracket. Make sure that the mounting bracket-to-rocker shaft bolt is only finger-tight at this time.
15. Complete the assembly by lubricating a spring washer with clean engine oil and sliding it over the end of the rocker shaft against the rear mounting bracket, then lubricating the bore of the third inlet rocker arm with clean engine oil and installing it over the end of the rocker shaft.
16. Lubricate a flat washer, then slide it on the rocker shaft. Install a circlip into the groove at the end of the rocker shaft to secure the assembly.

POWERLEASH™ ENGINE BRAKE SOLENOID INSTALLATION

The PowerLeash™ engine brake solenoid is secured to the rocker shaft with two clip-on type spring retainers. A new solenoid supplied through the MACK Parts System includes the spring retainers and O-ring. The retainers are also available separately through the MACK Parts System. Installation of the solenoid is as follows:

Refer to Figure 299.

1. Place the lower O-ring into position, fully seated in the bottom of the solenoid bore in the rocker shaft.

CAUTION

Do not place the lower O-ring on the solenoid adapter and then install the solenoid assembly to the shaft. Doing so will cut the lower O-ring.

2. Lubricate both of the engine brake solenoid O-rings with clean engine oil.
3. Position the solenoid for installation, with the wire leads on the side of the rocker shaft that faces the valves.

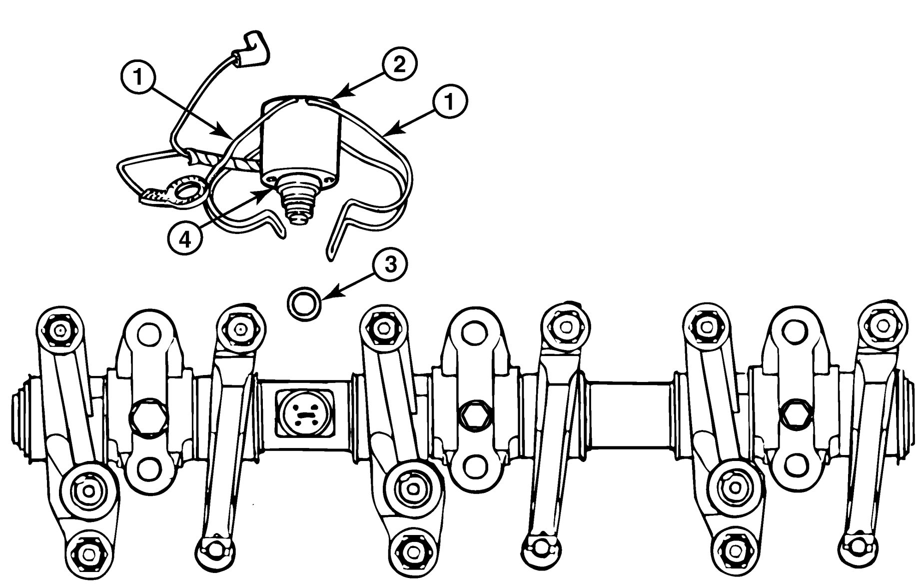


Figure 299 — Engine Brake Solenoid Installation

1. Solenoid Spring Retainer Set 2. Engine Brake Solenoid Assembly	3. Engine Brake Solenoid Lower O-Ring 4. Upper O-Ring Included with Solenoid

4. Insert the solenoid into the rocker shaft port and push downward firmly with the palm of the hand to fully seat the solenoid.

CAUTION

The solenoid must be fully seated by significant hand pressure. The retaining clips will not seat a solenoid that has not already been fully seated.

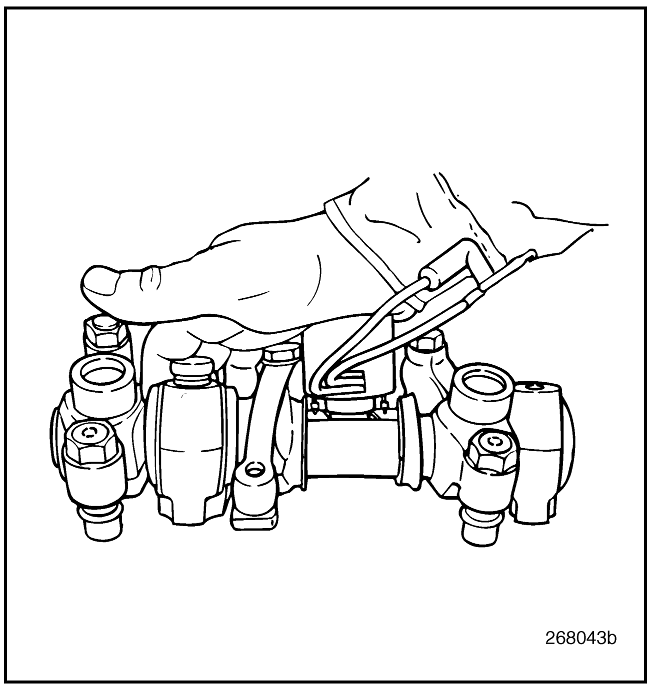


Figure 300 — Installing Engine Brake Solenoid

5. Snap both clips around the bottom of the rocker shaft.

CAUTION

Latching and unlatching the solenoid retaining clips requires a great deal of finger pressure to overcome the large amount of spring tension. Care must be used to avoid pinching the fingers or snapping the latches against the fingers.

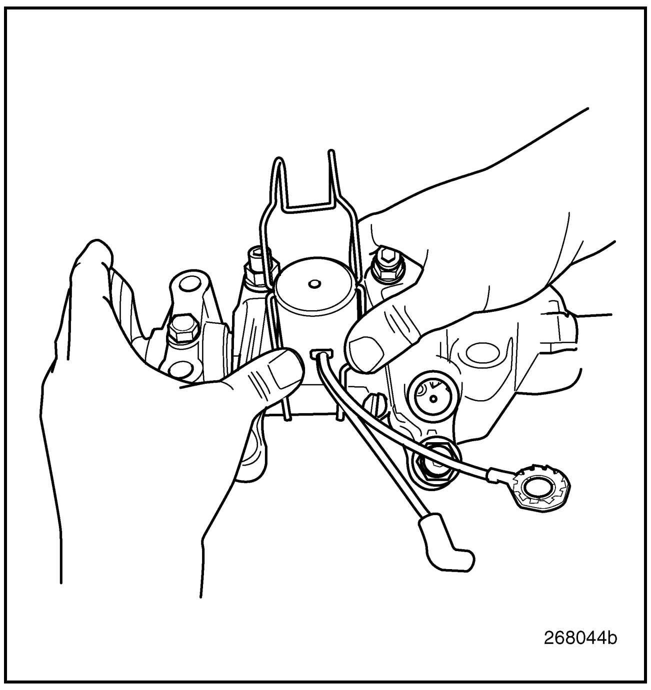


Figure 301 — Force Solenoid Retaining Clips into Position

6. After the retaining clips have been installed, inspect the solenoid-to-rocker shaft mating surfaces. The surfaces of both components must be fully seated against each other.

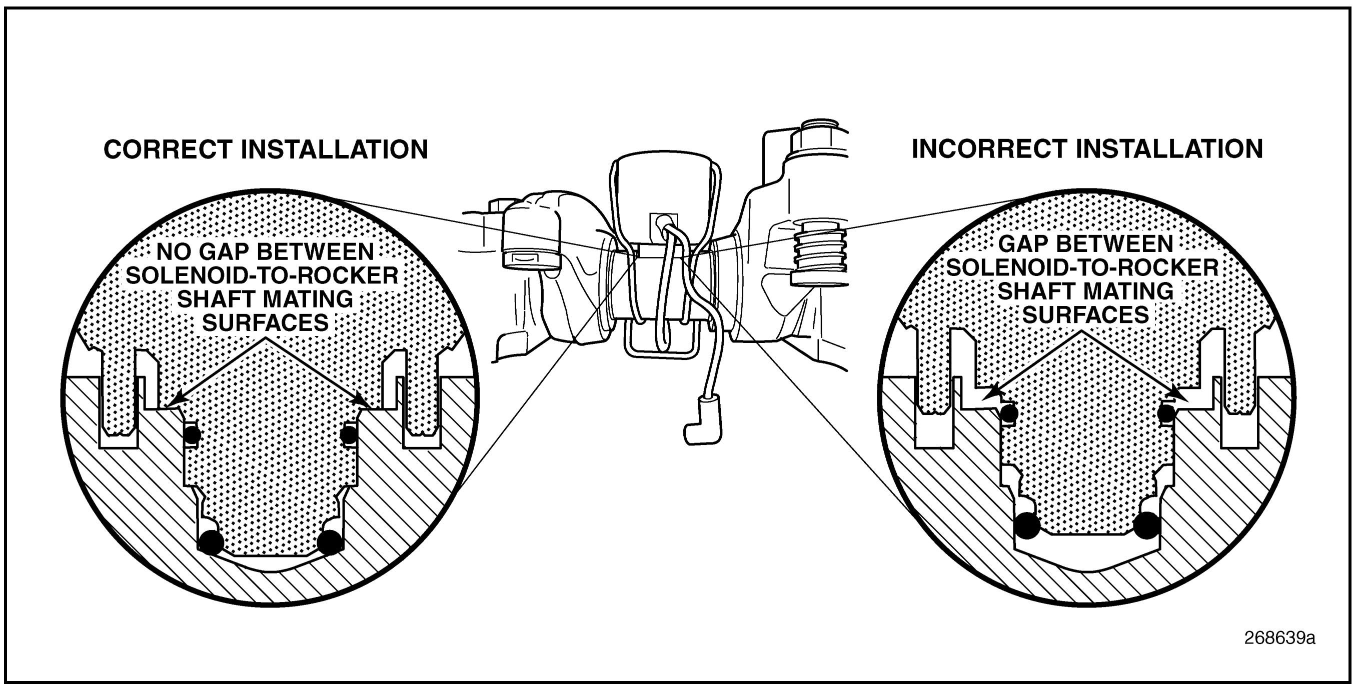


Figure 302 — Inspect Solenoid-to-Rocker Shaft Mounting Surfaces

CAUTION

A solenoid that has not been completely seated on the rocker shaft can partially turn the engine brake ON while the engine is under power, resulting in an engine miss and extremely poor engine performance.

LUBRICATION SYSTEM BENCH PROCEDURES

Oil Cooler Assembly Reconditioning

[215 DW]

See Cooling System Components Bench Procedures in the REPAIR INSTRUCTIONS section.

Oil Pump Reconditioning

[219 MU]

Because of differences in the gear set helixes, it is important that the correct replacement parts are used in making the repair.

- An improper drive gear on the oil pump will prevent oil pump installation, assuming a correct gear is on the auxiliary shaft.
- If an oil pump and an auxiliary shaft assembly were replaced, two improper gears could be installed, and engine failure would result.
- In replacing any of these critical parts, always refer to part number information in the MACK Parts System to ensure the correct component/part is being used.

THREE OIL PUMP CONFIGURATIONS

Three different oil pump versions are possible in an ASET™ engine dependent on date of manufacture or if a remanufactured or new oil pump has been previously installed. The main difference in the three oil pump configurations is in the oil pressure relief valve area. Other areas of the pump, such as the gears and shafts, remain basically the same. The three oil pump configurations are as follows:

- **Standard E-Tech™/ASET™**
  This is the original oil pump configuration from production introduction of E-Tech™/ASET™ through mid-2004. Remanufactured oil pumps will be of this configuration.

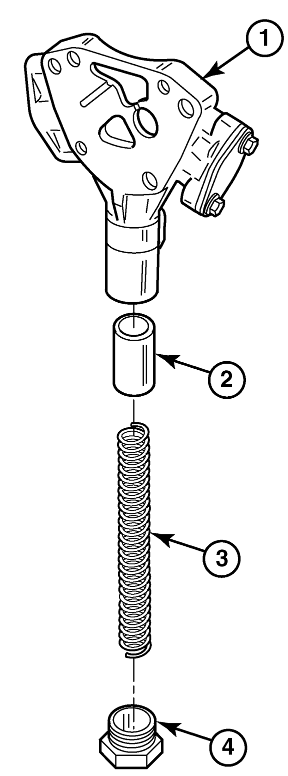


Figure 303 — Oil Pump Pressure Relief Valve

1. Oil Pump Housing Cover	3. Relief Valve Spring
2. Plunger	4. Relief Valve Cap

- **Standard E-Tech™/ASET™ with Oil Pressure Relief Valve Spacers**

  This oil pump configuration is very similar to the original oil pump configuration except that two spacers have been added to the relief valve cap. These spacers are used to provide a 15 psi reduction to cold oil pressure, with no change to hot oil pressure. These spacers were factory installed on MR and LE chassis oil pumps only since January 2003 and have been field installed on many other oil pumps per Service Bulletin SB-219-013 instructions.

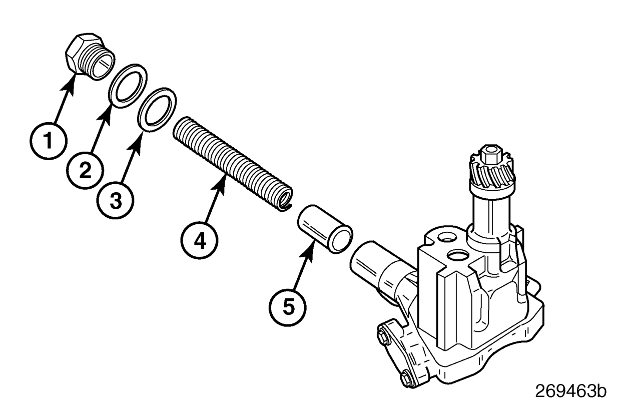


Figure 304 — Oil Pump Pressure Relief Valve Spacers

1. Cap 2. Spacer, 0.093″ Thick 3. Spacer, 0.125″ Thick	4. Spring 5. Plunger

- **ASET™ with Redesigned Oil Pressure Relief Valve Cap**

  New production oil pumps introduced in mid-2004 have a larger relief valve cap in which the spring pocket is counterbored to provide a 15 psi reduction to cold oil pressure. No washers are needed or to be installed on the larger relief valve cap.

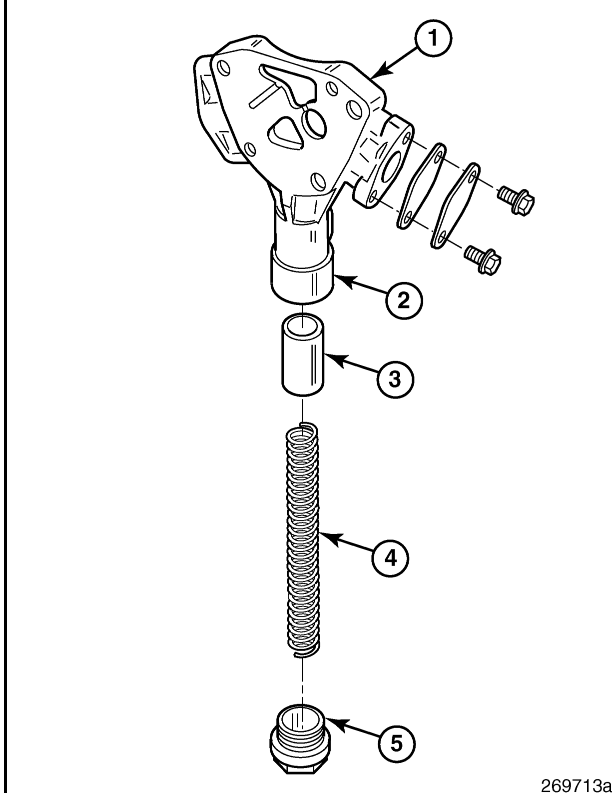


Figure 305 — Oil Pump Pressure Relief Valve

1. Oil Pump Housing Cover 2. Relief Valve Housing (Larger Bore)	3. Plunger 4. Relief Valve Spring 5. Relief Valve Cap (Larger)

DISASSEMBLY

Refer to Figure 306.

1. For ease of disassembly, reinstall the oil pump in the cylinder block or in a suitable holding fixture.
2. Remove the oil inlet (pickup) tube and screen assembly (not shown).

NOTE

Before inlet tube removal, note the orientation of the tube for reassembly purposes. Inlet tubes are positioned differently for front and rear sump applications. Caution must be used to ensure that the correct mounting holes are used for the proper sump application.

3. Remove the oil pressure relief valve cap and collect the pressure relief spacers (if equipped).
4. Remove the oil pressure relief valve spring and plunger.
5. Remove the oil pump housing cover from the oil pump housing.
6. Slide the oil pump idler gear off the shaft.
7. Remove the oil pump from the cylinder block or other suitable holding fixture.
8. Turn the oil pump upside down and remove the oil pump shaft nut and washer.
9. Using a press, remove the driven gear and key from the pump gear and shaft assembly.
10. Remove the pumping gear-shaft assembly and thrust washer from the housing.
11. Remove the oil pump inlet flange plate and gasket from the housing by removing the capscrews.

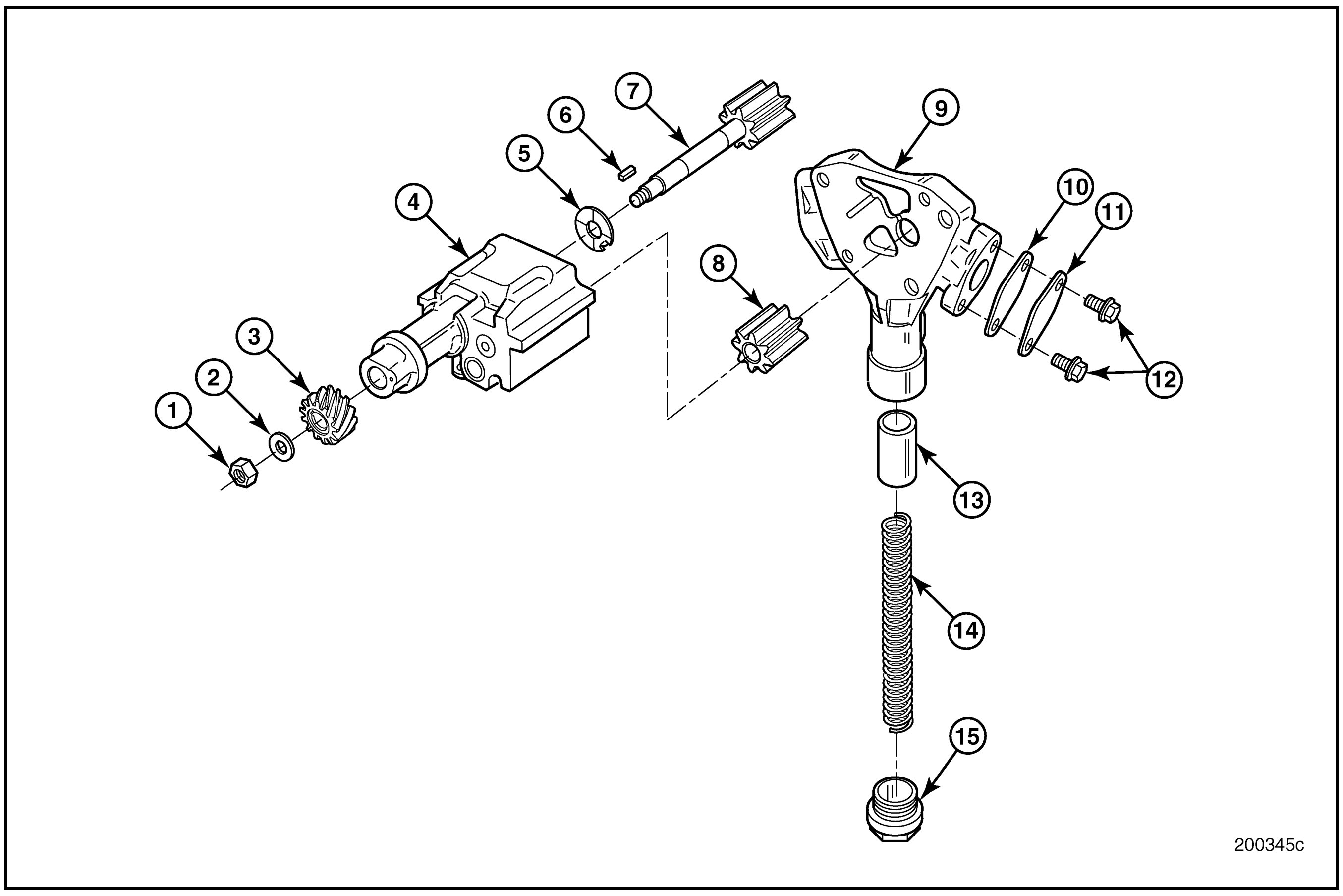


Figure 306 — Lubrication Oil Pump

1. Self-Locking Nut	9. Inlet Flange Plate
2. Washer	10. Capscrews
3. Driven Gear	11. Plunger
4. Housing	12. Relief Valve Spring
5. Key	13. Relief Valve Cap
6. Pump Gear and Shaft	14. Idler Gear
7. Oil Pump Housing Cover	15. Thrust Washer
8. Gasket	

INSPECTION AND CLEARANCE CHECKS

Refer to Figure 306.

1. Clean and inspect the oil pump housing for scoring, cracks or other damage. If any of these conditions exist, replace the oil pump.
2. Check the bushings in the pump housing for burrs, nicks or cracks.

NOTE

The bushings are an integral part of the oil pump housing. If the bushings are damaged, replace the oil pump housing.

3. Clean and inspect the relief valve spring for breaks. Replace as necessary.
4. Clean and inspect the plunger outer diameter for galling and scoring. Light galling or scoring will not affect function of the plunger; if moderate-to-heavy, replace both the plunger and cover.
5. Inspect the plunger seating surface for burrs or nicks. If the seating surface contains burrs or nicks, repair the seat as follows:
   a. Place valve lapping compound on the plunger seat.
   b. Insert the plunger in the relief valve housing and rotate the plunger against the seat to smooth the seat.
   c. Remove the plunger and clean it.
6. Check the pump idler gear for free play by spinning it on its shaft. If any binding occurs, check the housing bore and gear teeth for burrs, nicks or other damage. Replace as necessary.
7. Insert the integral pump gear and shaft, and thrust washer into the housing; check for free play by spinning the gear. If any binding occurs, check the housing and gear teeth for burrs, nicks or other damage. Replace as necessary.

NOTE

Before proceeding with assembly of the pump, insert the integral pump gear and shaft, and idler gear in the housing. Check end clearance, side clearance and backlash of the gears as follows.

End Clearance Check

Refer to Figure 307. With the pump gear and idler gear in place, position a straightedge across the housing and the face of the gears. Check end clearance as follows:

- Low Limit — Run a 0.003-inch (0.076 mm) thickness gauge between the straightedge and the gears. The gauge should move freely without binding. If binding occurs, check the gears for nicks or burrs. Replace as necessary.
- High Limit — Run a 0.007-inch (0.178 mm) thickness gauge between the straightedge and the gears. The gauge should be very tight. If the gauge moves freely, replace the gears.

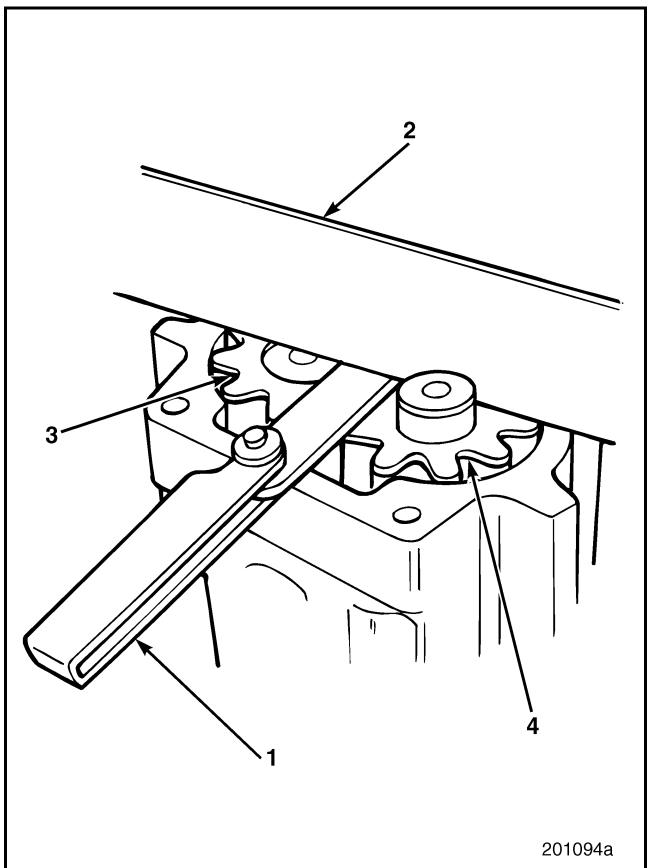


Figure 307 — Oil Pump Gear/Idler Gear Assembly End Clearance Check

1. Thickness Gauge	3. Pump Gear
2. Straightedge	4. Pump Idler Gear

Side Clearance Check

Refer to Figure 308. With the straightedge positioned across the housing and the face of the gears, check side clearance as follows:

- Low Limit — Insert a 0.002-inch (0.051 mm) thickness gauge between side of the gears and the housing. The gauge should pass between the gears and housing without drag. If it drags, check the housing and gears for nicks or burrs. Replace as necessary.
- High Limit — Insert a 0.006-inch (0.152 mm) thickness gauge between the gears and housing. The gauge should not pass through. If the gauge passes through, replace the housing.

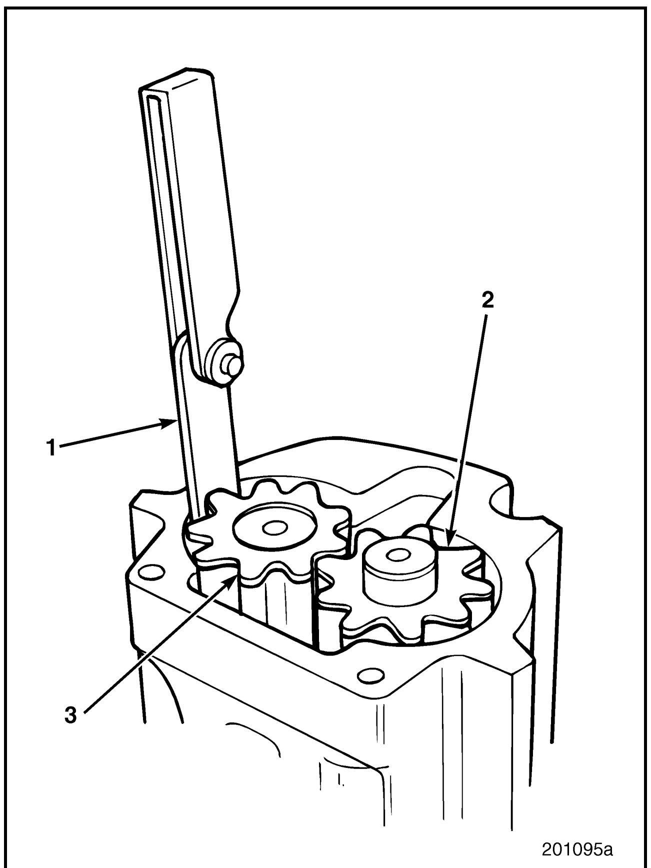


Figure 308 — Oil Pump Gear/Idler Gear Assembly Side Clearance Check

1. Thickness Gauge 2. Pump Idler Gear	3. Pump Gear

Backlash Check

Refer to Figure 309.

Check the backlash between the pump gear and idler gear with a thickness gauge.

- Low Limit — Insert a 0.013-inch (0.33 mm) thickness gauge between the pump idler gear and pump gear. The gauge should pass between the gears without binding. If binding occurs, check for nicks or burrs. Replace as necessary.
- High Limit — Insert a 0.028-inch (0.711 mm) thickness gauge between the pump idler gear and pump gear. The gauge should not pass through. If the gauge passes through, replace the gears.

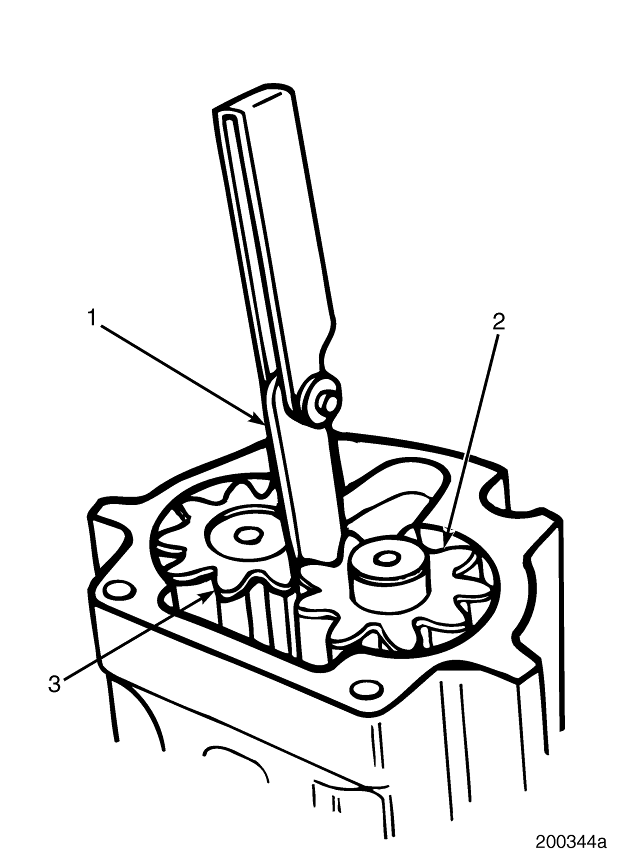


Figure 309 — Checking Oil Pump Gear Backlash

1. Thickness Gauge 2. Pump Idler Gear	3. Pump Gear

REASSEMBLY

Refer back to Figure 306.

1. Install the one-piece pump gear/shaft and thrust washer in the housing and check for free spin.
2. Install the key in the pump gear shaft.
3. Place the driven gear on the shaft, aligning the slot with the shaft key. Then, press the driven gear onto the shaft.
4. Install the washer and self-locking nut on the shaft. Tighten the nut to specification, 60 lb-ft (81 N•m), using torque wrench J 24407, or equivalent.
5. Install the idler gear on the housing shaft.
6. Apply Loctite® 271 to the threads of the cover capscrews and install the cover. Tighten the capscrews to specification, 15 lb-ft (20 N•m).
7. Install the oil pressure relief valve plunger in the relief valve housing.

CAUTION

To maintain correct oil pressure for the various oil system arrangements, the proper oil pressure relief valve spring and cap combination must be used. Using incorrect components may result in either high or low oil pressure, and contribute to premature engine damage.

8. Install the oil pressure relief valve spring in the relief valve housing.
9. Clean the relief valve cap and pressure relief spacers (if equipped with spacers at disassembly). Install the spacers over the cap threads (if required for cold pressure relief) and install the cap in the bore of the oil pump housing cover. Tighten the pressure relief cap to specifications.
10. Apply Loctite® 271 to the threads of the pump inlet flange plate capscrews. Install the flange plate and gasket on the housing and secure the flange plate with the capscrews.
11. Apply Loctite® 271 to the threads of the oil inlet (pickup) tube capscrews. Install the inlet tube and screen assembly. Secure the assembly with the capscrews.

NOTE

Because the inlet tube must be in a vertical position when installed in the engine, the mounting flange bolt pattern is offset to the same degree as the oil pump-to-cylinder block mounting angle. The mounting flange of the inlet tube has four bolt holes marked with an “F” or “R” to distinguish which two holes are used for the front sump, and which two holes are used for rear sump applications. Caution must be used to ensure that the correct mounting holes are used for the proper sump applications.

COOLING SYSTEM COMPONENTS BENCH PROCEDURES

Oil Cooler Reconditioning

[215 DW]

The plate-type oil cooler (Figure 310) on current-production engines cannot be disassembled. Should it fail, it is replaced as an assembly.

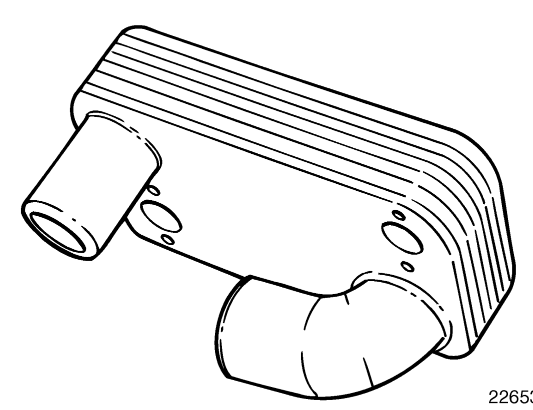


Figure 310 — Plate-Type Oil Cooler Assembly

EGR Cooler Reconditioning

It is essential for coolant quality to be maintained to keep the core from becoming blocked. Also, prolonged idling can cause carbon buildup and blockage with the core and should be avoided.

The EGR cooler cannot be disassembled and reconditioned. However, welding is allowed to repair some damage to the outer shell or bracket so long as it does not involve the side tanks.

CAUTION

If damaged, do not weld repair the support bracket to either side panel or the bottom of the cooler. Do not weld anything to the header panel on the cooler.

EGR COOLER CLEANING

Occasionally an EGR cooler may become plugged with exhaust soot. This is usually caused by idling the engine for prolonged periods of time in cold weather. Should this occur, the EGR cooler can be cleaned using the following procedure.

NOTE

The following procedure covers EGR coolers which have been removed at engine overhaul. However, this procedure could also be used to clean an EGR cooler on the chassis by first removing the piping from the cooler inlet and outlet exhaust ports.

1. Install a vacuum cleaner bag over the outlet port and secure with a suitable size tie wrap or heavy rubber band.
2. Blow compressed shop air (no more than 25 psi) into the cooler inlet port while lightly tapping on the front of the cooler to loosen any lodged soot.

NOTE

Be sure to reduce shop air pressure to 25 psi.

3. When all the soot has been cleaned from the cooler, carefully remove the vacuum cleaner bag from the outlet port.
4. Reinstall the piping if this procedure is performed on the chassis.

Water Pump Reconditioning

[215 SW]

The ASET™ AC engine water pump cartridge is not rebuildable in the field. If a pump failure occurs, exchange it for a new or remanufactured unit available through the MACK Parts System.

FUEL SYSTEM COMPONENT BENCH PROCEDURES

Electronic Unit Pump (EUP) Inspection

[221 GP]

Refer to Figure 311.

Visually inspect each electronic unit pump assembly and O-rings for signs of wear or damage. Replace the O-rings as required. If a pump is damaged or not operating properly, replace the pump; it is not repairable.

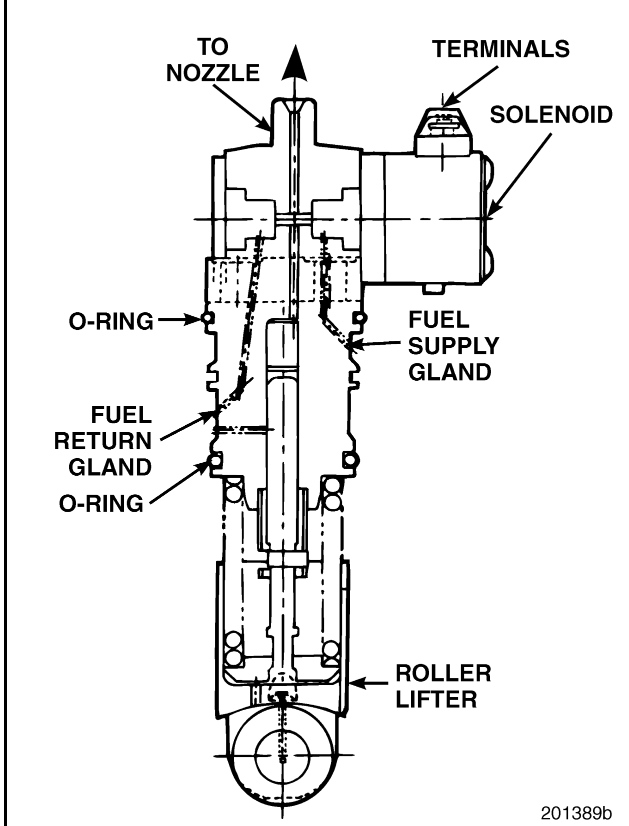


Figure 311 — Electronic Unit Pump Assembly

Installation of Electronic Unit Pump Plunger Spring and Seat

Improper removal of an electronic unit pump (EUP) from an engine, or certain failures such as broken EUP hold-down bolts, will result in a rapid pop-up of the pump from the bore. Should this occur, the unit pump tappet spring seat can dislodge from the plunger foot. The plunger, however, is retained by a retaining clip, so it will remain in place. Should a spring seat dislodge, no damage occurs to any of the parts involved, and the unit pump may be reassembled as described below.

NOTE

When servicing a unit pump, take care not to damage any machined or threaded surfaces. Work should be performed on a clean, non-metallic surface.

1. Remove the plunger retaining clip.

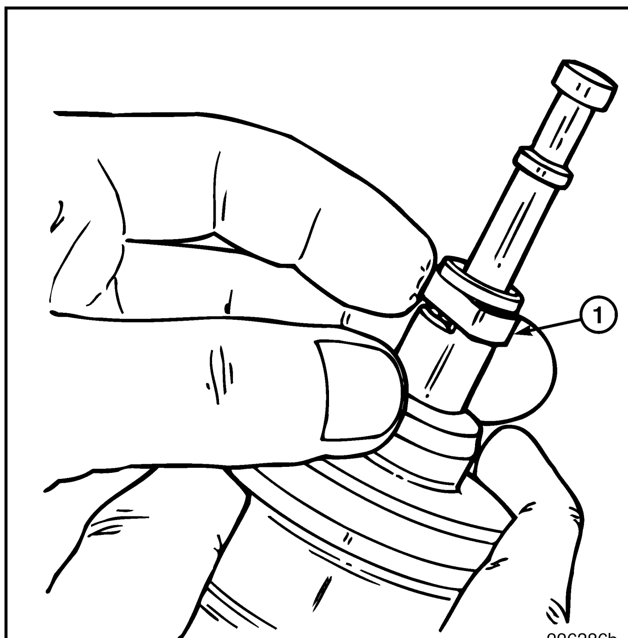


Figure 312 — Plunger Retaining Clip Removal

1. Retaining Clip

2. Pull the plunger out of the unit pump bore until the gold portion of the plunger is visible through the retaining clip slot. The shoulder of the plunger (where the silver-colored and gold-colored areas meet), will just align with the bottom of the unit pump housing.

NOTE

To avoid possible contamination or damage to the plunger, do not remove the plunger completely from the unit pump. If the plunger is inadvertently removed, dip it in clean fuel and carefully reinstall it into the unit pump bore. Then check for smooth, free movement of the plunger in the unit pump bore.

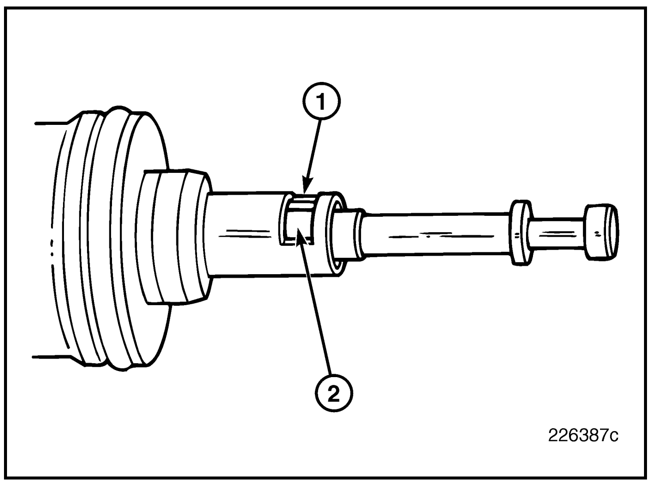


Figure 313 — Gold-Colored Plunger Surface, Behind Retaining Clip Slot

1. Retaining Clip Slot	2. Gold-Colored Surface

3. With the plunger pulled from the unit pump bore as described in step 2, slide the retaining clip into place. The flat side of the clip goes into the retaining clip slot.

NOTE

The plunger must be positioned as described in step 2 when the clip is installed, or reassembling the unit pump spring and spring seat will be difficult, if not impossible.

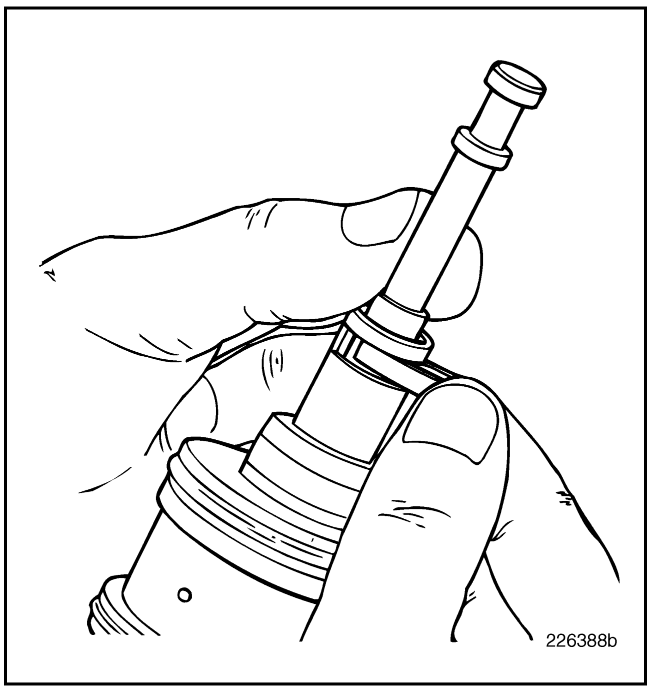


Figure 314 — Plunger Retaining Clip Installation

4. Place the spring onto the unit pump body.

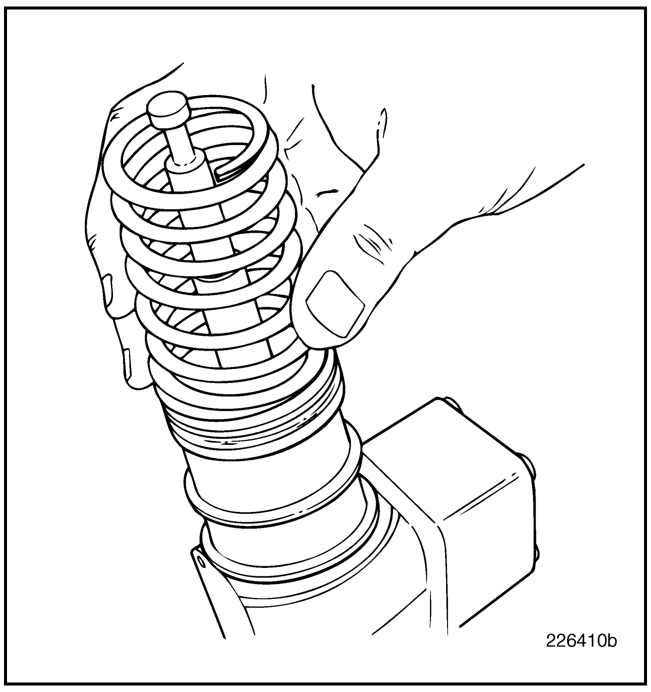


Figure 315 — Plunger Spring Installation

5. Install the spring seat (flat side against the spring) with the larger hole of the spring seat keyhole opening over the plunger foot.
6. Slide the spring seat so that the plunger foot goes into the smaller, center hole of the keyhole slot.

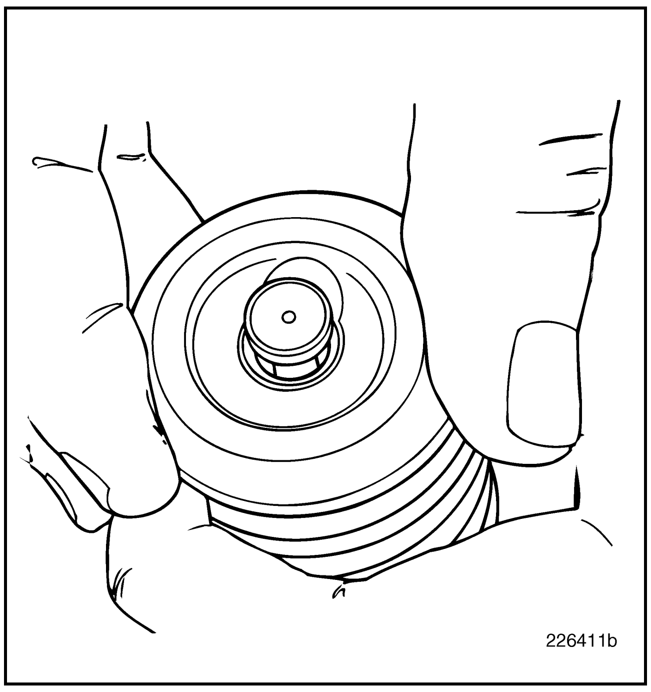


Figure 316 — Spring Seat Installation

7. Using the heel of the hand, press down on the plunger and spring seat until a click is heard. The click indicates that the plunger has been pushed down, and the retaining clip has seated to hold the plunger, spring and spring seat in place.

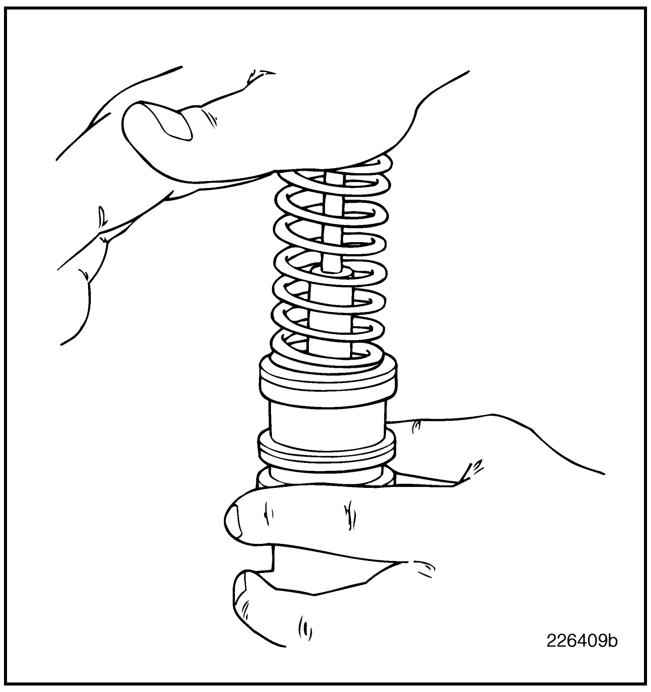


Figure 317 — Plunger and Spring Seat Seating

8. Install **new** O-rings and lubricate with clean engine oil.
9. For engines which have a history of small fuel leakage into the crankcase, a new delta seal (available through the MACK Parts System) should be installed on the lower O-ring position.

CAUTION

Due to the design of the delta seal O-ring, the cam lobe must be positioned with the base circle UP prior to installing each of the EUPs to avoid damaging the delta seals. The engine barring tool (tool No. J 3857-A) must be used to rotate the engine. DO NOT use the starter motor to rotate the engine.

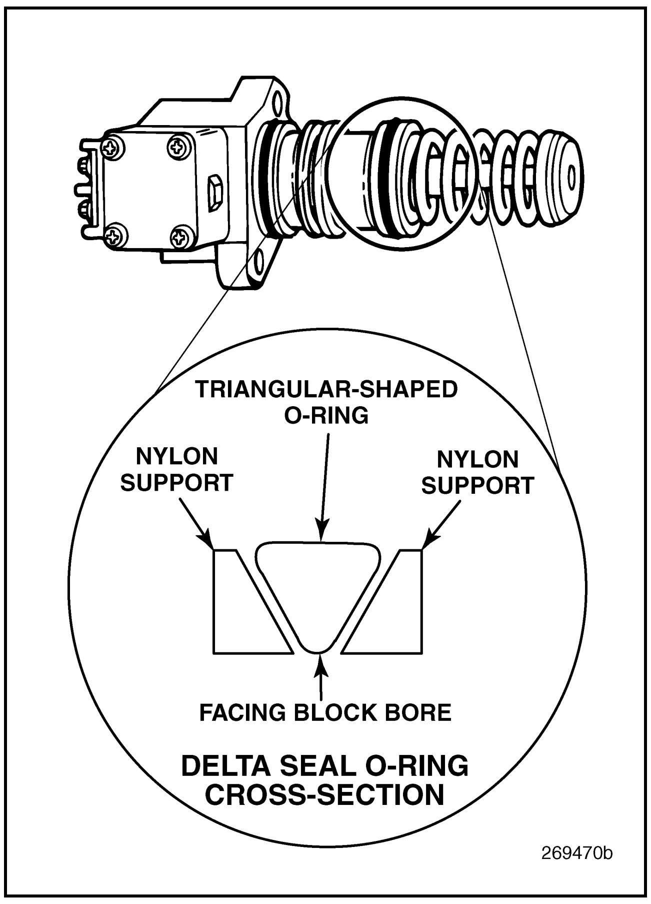


Figure 318 — EUP with Delta O-Ring Seal

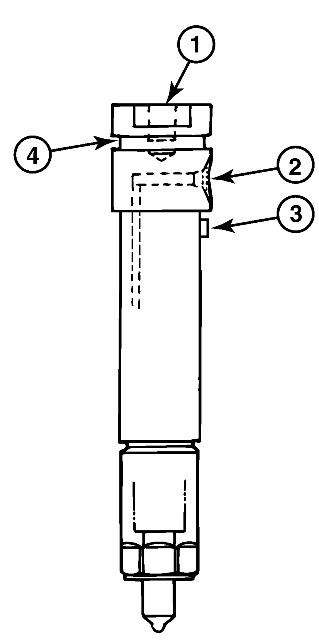
10. Reinstall the unit pump into the engine using the procedures outlined under Engine Reassembly in the REPAIR INSTRUCTIONS section.

Fuel Injector Nozzle Cleaning

[222 KG]

Refer to Figure 319.

When servicing the nozzle holder assemblies, cleaning of the nozzle tips may be necessary. Special care must be taken when cleaning the nozzle tips to avoid damaging the nozzle spray holes.



1. 5/16 INCH-24 THREADS FOR REMOVING NOZZLE FROM CYLINDER HEAD
2. NOZZLE FUEL INLET (HIGH PRESSURE FUEL LINE CONNECTION)
3. NOZZLE-TO-CYLINDER HEAD INDEXING PIN
4. O-RING GROOVE

201402b

Figure 319 — Fuel Injection Nozzle Holder Assembly

ULTRASONIC CLEANING METHOD

Ultrasonic cleaning is the **preferred method** for cleaning the fuel injector nozzles. Ultrasonic cleaning units use sound waves or mechanical vibrations approximately 55,000 cycles per second above human hearing range. The sound waves are generated by the transducer, which changes high-frequency electrical energy into mechanical energy. Ultrasonic cleaning units, such as Branson model 1510-MTH, are available through Process Equipment and Supply (800-539-6336), web address www.ultrasoniccleaners.com, or any equivalent 40 kHz ultrasonic-type cleaner could be used.

BRASS BRUSH/WIRE WHEEL METHOD

Cleaning the fuel injector nozzles with a brass brush or brass wire wheel may be acceptable under some conditions, but it is **not recommended**. The nozzles **will** be damaged if a steel wire wheel is used for cleaning. Damage can also occur if an improper size brass-wire wheel and/or improper speed is used.

VTG SYSTEM BENCH PROCEDURES

VTG Control Valve Solenoid Replacement

[214 QB]

A malfunctioning VTG control valve as indicated by an active 4-5 FMI-7 fault code can sometimes be caused by oil from the vehicle air system entering the valve.

NOTE

Additional troubleshooting information for a 4-5 fault code is outlined in the *V-MAC® III Service Manual*, 8-211.

Oil in the control valve can result in blocked pressure balance ports and a sticking solenoid plunger shaft. If this condition is encountered, replacement of the entire valve is not necessary. A malfunctioning VTG control valve can be repaired by replacing the solenoid with a solenoid replacement kit available through the MACK Parts System.

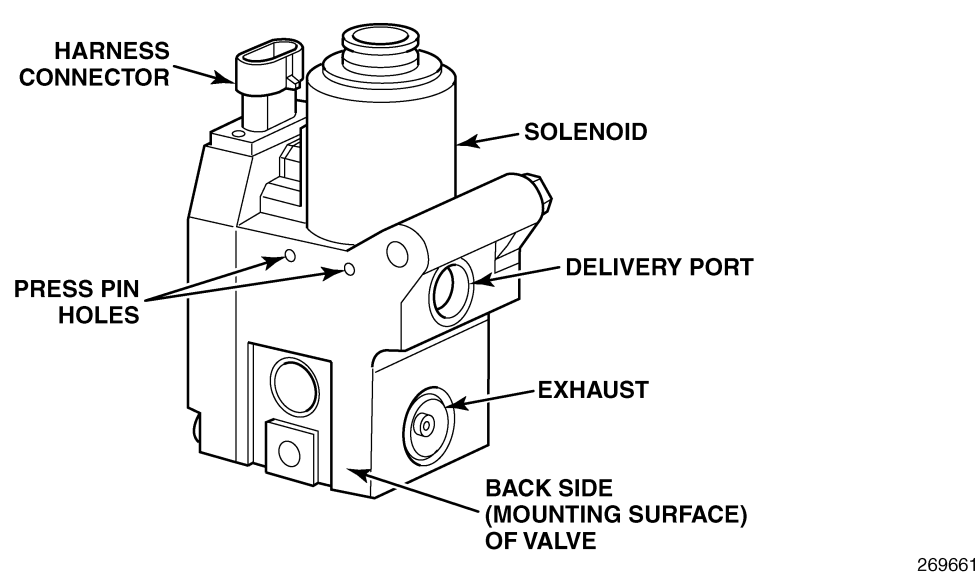


Figure 320 — VTG Control Valve

Using Figure 320 as a reference, replace the solenoid as follows:

1. Remove the VTG control valve from the engine.
2. Cap the air inlet port, outlet port and the electrical connector.
3. Thoroughly clean the control valve external surfaces, paying particular attention to the surfaces around the solenoid-to-valve body mating area where contaminants could enter the valve when the solenoid is removed.
4. Open the jaws of a vise approximately 1-3/4″ (45 mm), and then place the control valve front side down (air inlet port side) on the open jaws so that the two press pin holes clear the jaws.

NOTE

On some of the earlier valves, the press pin holes may be covered by the part number label on the front side of the valve.

NOTE

As an alternative, two bearing press plates could be placed side-by-side on a workbench with a 1-3/4″ (45 mm) space between the two.

5. Using a 1/8″ punch and light-to-medium weight hammer, carefully drive the two press pins from the valve body.

CAUTION

The pin body is approximately 0.155″ (3.937 mm) in diameter, with the ends of the pin tapered to a flat-end diameter of 0.080″ (2.032 mm). The tip of the 1/8″ punch must be in good condition so that it seats squarely against the end of the pin, and care must be used to ensure that the punch tip is kept squarely against the end of the pin as it is being driven from the valve body. If the end of the punch is worn, or if care is not used when driving the pins from the valve, the punch can slip and be driven into the aluminum valve body, thus damaging the valve.

Do not use a punch smaller than 1/8″. Typically, a 1/8″ punch is long enough to drive the pins from the valve body. Small diameter punches are not long enough, and can bend too easily. A 5/32″ punch is too large and will enlarge the holes in the valve body, thus rendering the valve unusable.

As the pins are being driven from the valve, the typical 1/8″ punch will bottom on its tapered shank when the pin protrudes approximately 1/4″ (6.35 mm) from the valve body, and before the pin completely disengages the retaining collar of the solenoid. At that point, remove the punch, then turn the valve over and remove the pins. Some pins may be loose enough to remove with the fingers, while other pins may remain tight, making it necessary to use pliers to grasp and remove the pins.

6. After the pins have been driven from the valve, separate the solenoid from the valve body.
7. Using Permatex® electrical contact cleaner (part No. 5166-24379) or equivalent, clean the interior of the valve body by spraying the cleaner into the solenoid opening and through the inlet and outlet ports.

NOTE

The contact cleaner must be safe for use on plastics (Nylon®) and rubber (Viton®, etc.). Normally, all ozone safe “green” cleaners are acceptable.

8. Clean the solenoid mating surface of the valve body.
9. Lubricate the O-ring on the new solenoid with MACK O-ring lubricant (part No. 243SX41), or equivalent.
10. Insert the solenoid into the valve body, making sure the solenoid is completely seated.

CAUTION

If the solenoid is not seated, the press pins will cock as they are being driven into the valve body. To determine if the solenoid is fully seated, hold the valve up to the light, then look through the pin holes. If the solenoid is fully seated, a clear path will be seen all the way through the holes. If it appears that the solenoid is not fully seated, use a light plastic hammer to gently tap on the top of the solenoid until seated.

11. Place the valve front side up (air inlet port side) on a solid flat surface, then insert the new press pins included with the kit into the holes in the valve body.
12. Using a small hammer and 1/8″ punch, gently tap the pins into the valve body until they are nearly flush with the back surface of the valve.
13. Make a mark on the punch 1/2″ (12.7 mm) from the tip, then tap the pins further until they are 1/2″ (12.7 mm) below the back surface of the valve body as indicated by the mark on the punch.
14. Reinstall the control valve.

ENGINE REASSEMBLY

General Instructions

This section includes step-by-step procedures for complete reassembly of the engine. Major components that were inspected and overhauled or replaced under the respective bench procedure sections of this manual are reinstalled here as assemblies.

CAUTION

Failure to follow the sequence of operations listed may result in damage to components or personal injury.

NOTE

After cleaning the components, properly store them where they will remain clean until needed for reassembly.

When required for installing components, be sure to use clean engine oil of the approved type.

Crankshaft Installation

[212 HP]

1. Be sure that the crankshaft and the crankcase area of the cylinder block are clean.
2. Thoroughly clean each main bearing bore and the back of each bearing insert before installation. The inserts must be installed dry.

CAUTION

The hole in the insert must line up with the drilled hole in the block or the bearing will fail due to lack of lubrication. The upper bearing insert is stamped on the back with the word “UPPER.”

3. Place the upper half of the bearing insert in the cylinder block main bearing bore, making sure that the locating tab fits into the notch in the bore (Figure 321).

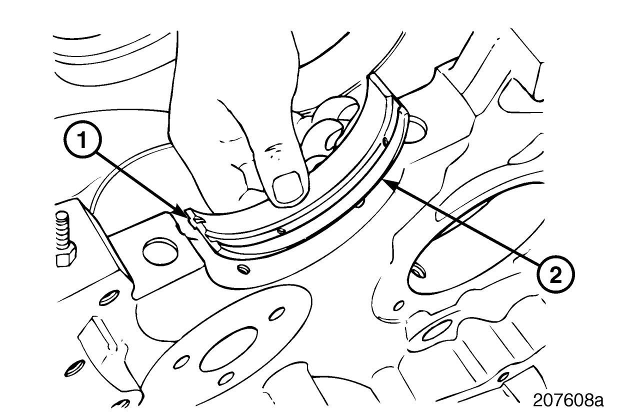


Figure 321 — Main Bearing Insert (Upper)

1. Locating Tab	2. Bearing Insert

4. Repeat the previous step to install the remaining upper inserts. Refer to Figure 322 for the part number and location of each bearing insert.

CAUTION

A bearing insert installed at the wrong location can cause engine failure.

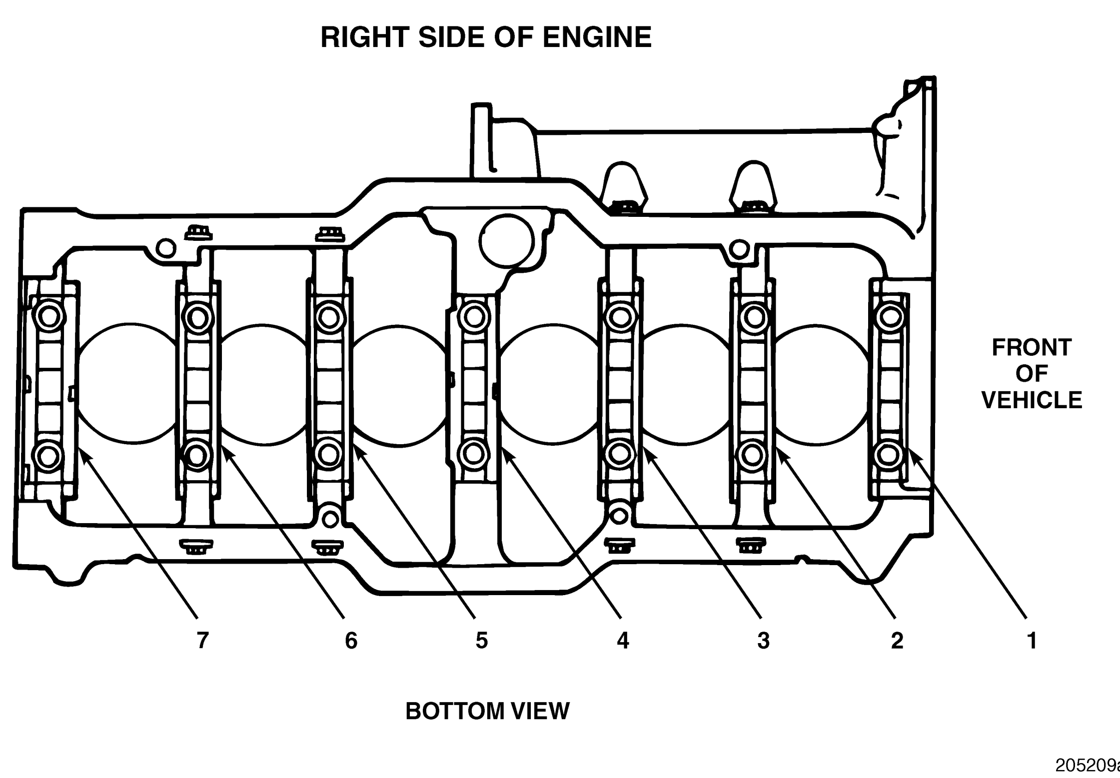


Figure 322 — Main Bearing Insert Part Numbers and Locations

1. Upper Insert — 646B348; Lower Insert — 646B343 2. Upper Insert — 646B345; Lower Insert — 646B343 3. Upper Insert — 646B345; Lower Insert — 646B343 4. Upper Insert — 646B349; Lower Insert — 646B344	5. Upper Insert — 646B345; Lower Insert — 646B343 6. Upper Insert — 646B345; Lower Insert — 646B343 7. Upper Insert — 646B350; Lower Insert — 646B344

5. Apply a light coat of clean engine oil on the insert surfaces and on the crankshaft main bearing journals.

WARNING

Due to the considerable weight of the crankshaft, extreme care must be observed during installation. No nicks, scratches, burrs, or any other kinds of distress are acceptable on the main bearing and/or crankshaft journals and fillets.

6. Using a suitable lifting device, position the crankshaft in the cylinder block.

Main Bearing Cap Installation [212 HH]

NOTE

Unfinished main bearing caps are available for servicing the engines. The bores of these caps are undersize for service rebore:

- Cap, Intermediate and Front Main Bearing (Semi-Finished), No. 223GB2131M
- Cap, Rear and Center Main Bearing (Semi-Finished), No. 223GB2132

SPECIAL TOOL REQUIRED

- Magnetic Base Indicator Tool J 7872

INSTALLATION PROCEDURE

1. Clean the bore in the bearing cap and back of the lower bearing insert.
2. Install the bearing insert in the bearing cap bore (Figure 323). The insert must be installed dry.

NOTE

The lower bearing inserts do not have a hole or a groove. They are stamped with the word "LOWER."

CAUTION

Do not mix the caps or inserts. The caps are numbered from 1 through 7, front to rear.

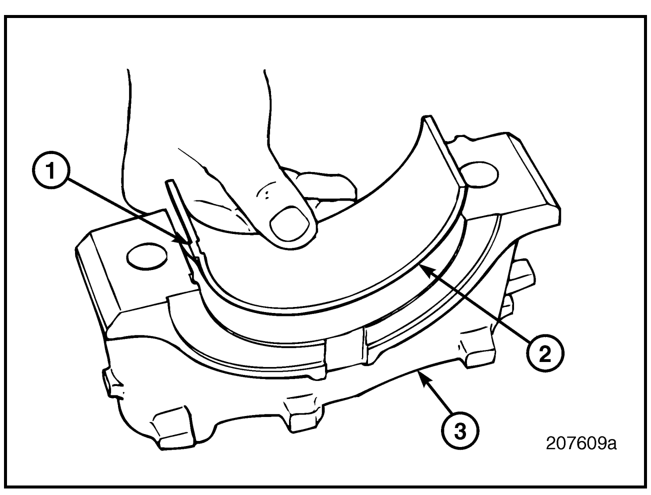


Figure 323 — Main Bearing Installation (Lower)

1. Locating Tab 2. Bearing Insert	3. Bearing Cap

3. Lubricate the threads of the bearing capscrews with clean engine oil and place the capscrews in the cap holes.
4. Position the No. 1 bearing cap over the No. 1 crankshaft journal and start the screws in the threaded holes in the cylinder block.
5. Using a plastic-faced mallet, tap the bearing cap down until it contacts the machined mounting surface.
6. Tighten the screws until they contact the bearing cap. At this time, tighten them only finger-tight.
7. Repeat the above steps for the bearing cap Nos. 2, 3, 5, 6 and 7. The center bearing cap, No. 4, is installed later.
8. Tighten the bearing cap capscrews to specification, 210 lb-ft (285 N•m), using torque wrench J 24407, or equivalent.
9. Place the upper thrust washer sections in position in the cylinder block at the center bearing, No. 4, location as shown in Figure 325. The steel side of the thrust washer goes toward the block, the aluminum-faced or bronze-faced side (side with oil reservoir grooves and tip-face reliefs) goes toward the crankshaft. This applies to both upper and lower thrust washer sections.

NOTE

Use standard thickness thrust washers initially.

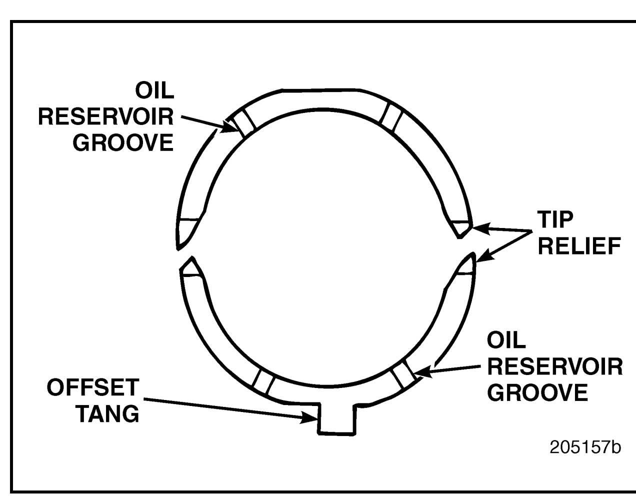


Figure 324 — Thrust Washer Styles

CAUTION

To prevent damage, ensure the thrust washers are installed in the correct position when assembling an engine. Failure to install the thrust washer properly will result in rapid wear of the area where the crankshaft contacts the thrust washer.

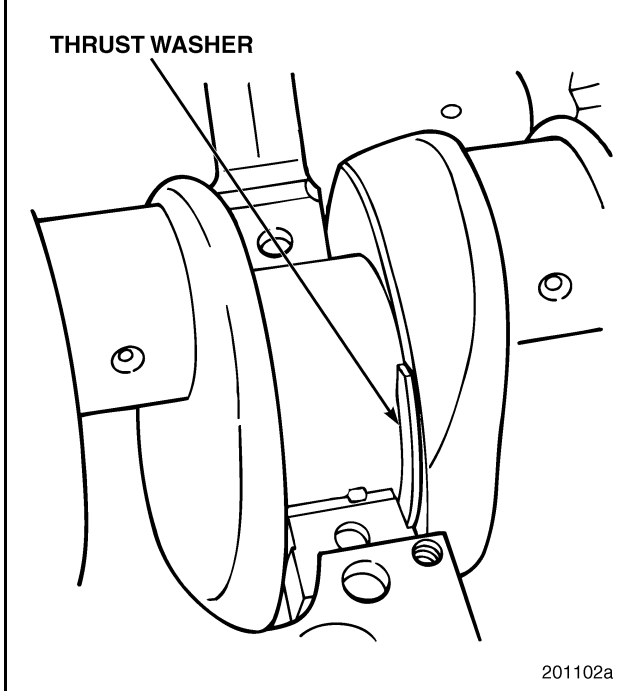


Figure 325 — Crankshaft Thrust Washer Installation

10. Position the lower thrust washer sections on the center bearing cap (aluminum-faced or bronze-faced side with oil reservoir grooves and tip-face reliefs toward crankshaft) and install the cap (Figure 326). Torque the capscrews to specification, 210 lb-ft (285 N•m), using torque wrench J 24407, or equivalent.

NOTE

Thrust washers are steel backed with either an aluminum facing or bronze facing, depending on the date of production. The side with the aluminum- or bronze-facing material has oil reservoir grooves cut into the facing material as well as tip reliefs.

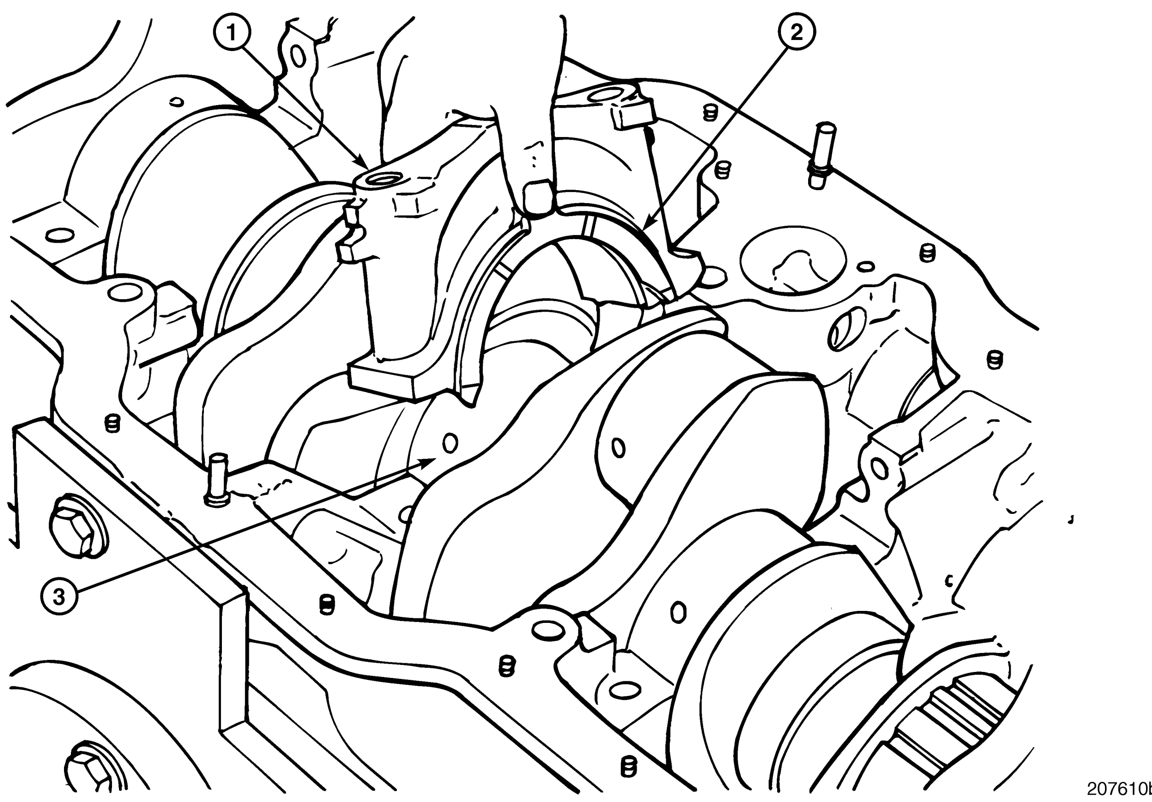


Figure 326 — Main Bearing Cap/Thrust Washer Installation

1. Bearing Cap 2. Thrust Washer	3. No. 4 Journal

11. Install a magnetic base indicator tool, J 7872, or equivalent, on the block and position the plunger against a crankshaft counterweight to check crankshaft end play.
12. Using a suitable pry bar, move the crankshaft either forward or rearward until it stops. Tap the end of the crankshaft with a plastic-faced hammer to seat the thrust washer.
13. Using the pry bar, move the crankshaft in the opposite direction. Tap the end of the crankshaft with a plastic-faced hammer to seat the other thrust washer.
14. Set the dial on the indicator to zero.
15. Using the pry bar, move the crankshaft in the opposite direction and read the dial indicator. Refer to the allowable tolerances under “Fits and Limits” in the SPECIFICATIONS section.
16. If the end play is out of specification, remove the thrust washers and install properly sized thrust washers, as required, to bring the end play into specification.

CAUTION

The thickness of the thrust washers used in the bearing cap must match the thickness of the thrust washers in the block. Be sure to put the aluminum-faced bearing surface (surface with oil reservoir grooves and tip-face reliefs) of the thrust washer against the crankshaft when installing the thrust washers.

17. Install the center main bearing cap, with bearing insert and the correct thrust washer sections in place, and torque the bearing capscrews to specification.

18. Recheck the end play to ensure the thrust washers have been installed correctly and that end play is within specification. Rotate the crankshaft to ensure there is no binding.

CHECKING RUNNING CLEARANCE

CAUTION

When using the Plastigage method of checking running clearance, do not turn the crankshaft. Doing so will destroy the Plastigage.

NOTE

If checking the main bearing clearance with the engine in the upright position (such as in the chassis), the weight of the crankshaft must be removed from the lower half of the bearing being checked. To do this, place cardboard under the crankshaft journal in the main caps adjacent to the journal to be checked and tighten the adjacent caps until the journal to be checked seats against the upper bearing. Do not fully torque screws. Capscrews on the bearing being checked should be torqued to specification after the Plastigage strip has been positioned on the bearing shell and the cap reinstalled. Support the crankshaft at Nos. 1, 4 and 7 main journals, while checking Nos. 2, 3, 5 and 6 bearings. Support the crankshaft at the Nos. 3 and 5 journals, while checking the Nos. 1, 4 and 7 bearings.

Engine Out of Chassis and Inverted

1. Use Plastigage to check the main bearing clearance. Check each bearing, one at a time, by placing a piece of Plastigage on the journal and tightening the cap in place. The bearing clearance is determined by measuring the width of the crushed Plastigage with the supplied gauge.
2. Place a section of Plastigage on the journal to be checked and assemble the main bearing cap to the cylinder block as shown in Figure 327.
3. Apply a light coat of oil on the threads of the bearing cap capscrews and secure the cap.
4. Tighten the capscrews to the specified torque, 210 lb-ft (285 N•m), using torque wrench J 24407, or equivalent. The Plastigage strip will be crushed between the bearing insert and the crankshaft journal.

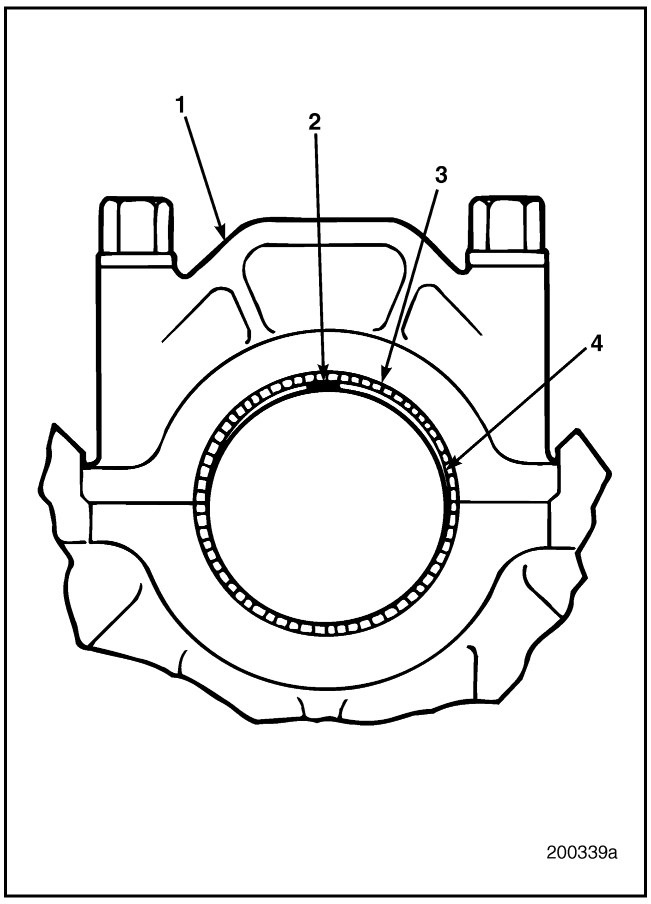


Figure 327 — Checking Running Clearance with Plastigage

1. Main Bearing Cap 2. Plastigage	3. Bearing Insert 4. Crankshaft Journal

5. Remove the capscrews and cap, and check the bearing running clearance.
6. Check the width of the Plastigage using a Plastigage width chart. After measuring the width, remove the Plastigage from the bearing.

7. If the clearance is not within specification, correct the clearance as required. Be sure to use the proper size bearing(s).
   - If the clearance is less than specified, check behind the bearing for dirt, chips or burrs which would prevent the bearing from seating properly.
   - If the bearing bores and inserts are clean and undamaged, replace the inserts with inserts sized to provide the specified clearance.
8. Reposition the cap on the journal. Lubricate the capscrews with clean engine oil of the proper specification. Lubricate and install the bearing cap buttress capscrews as required, finger-tight. Install the bearing cap capscrews and tighten to the specified torque value, 210 lb-ft (285 N•m), using torque wrench J 24407, or equivalent.

   Refer to Figure 328.

NOTE

There are two buttress capscrew dimensions:

- LH side 2, 3, 5, 6 and RH side 5 and 6 (6 total) are 80 mm long (1).
- RH side FRT 2 and 3 (2 total) are 110 mm long (2).

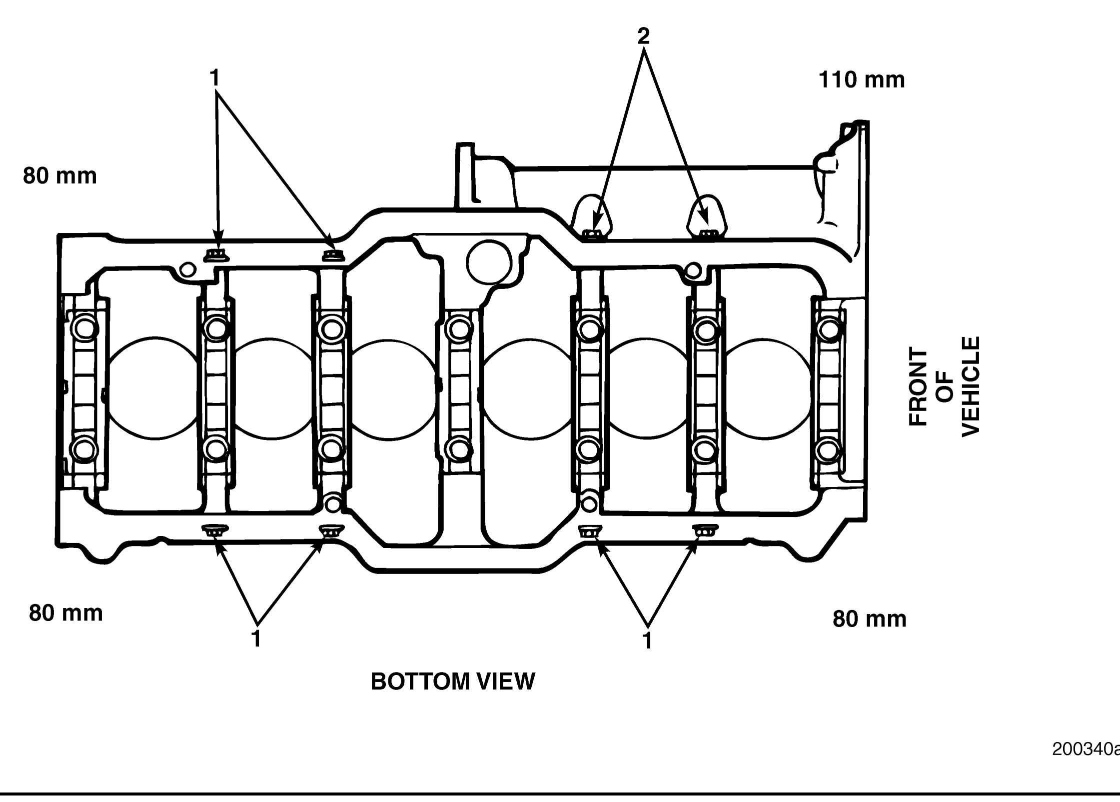


Figure 328 — Buttress Capscrew Locations

1. 80 mm Buttress Capscrews	2. 110 mm Buttress Capscrews

9. After obtaining the proper main bearing clearance at all seven journal locations, check the torque of the main bearing capscrews, 210 lb-ft (285 N•m), using torque wrench J 24407, or equivalent.
10. Tighten the buttress capscrews to the specified torque, 95 lb-ft (128 N•m), using torque wrench J 24407, or equivalent.

Piston and Connecting Rod Installation

[212 NP and 212 LP]

SPECIAL TOOLS REQUIRED

- Piston Ring Compressor J 23442 or Piston Ring Compressor PT7070-A
- BT 91104 — Torque Angle Gauge

INSTALLATION PROCEDURE

1. Rotate the crankshaft so that the journals for the No. 1 and No. 6 cylinders are at bottom dead center (BDC) (Figure 329).

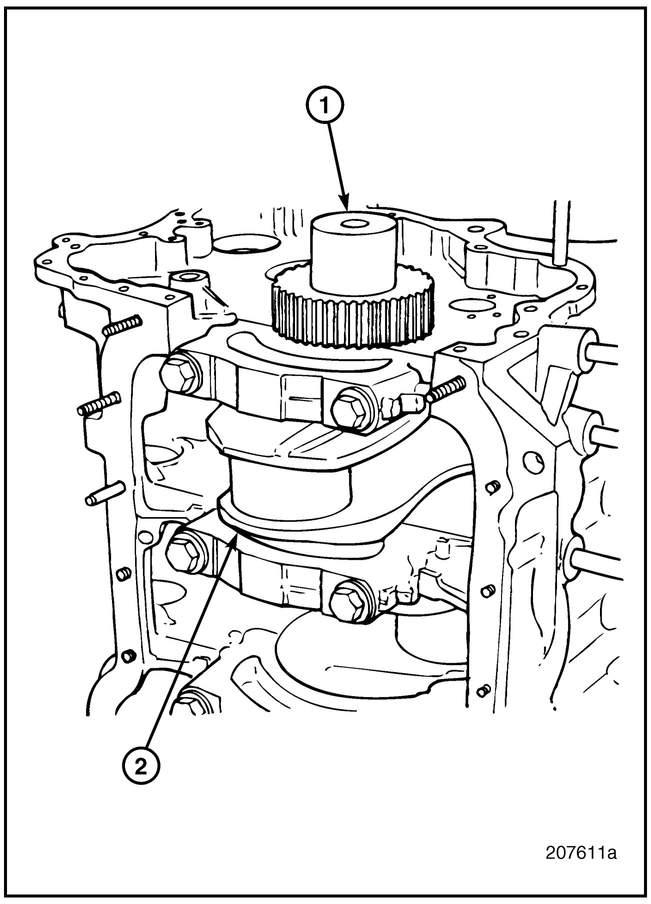


Figure 329 — No. 1 Cylinder (Crankshaft at BDC)

1. Crankshaft	2. No. 1 Journal

CAUTION

The wrist pin bore pedestal of the crown and the piston skirt are stamped FRONT, and must be installed facing the front of engine. This will ensure that the radius cut in the lower edge of the piston skirt is positioned properly to provide clearance for the piston cooling nozzle.

2. Place the piston marked No. 1 on a clean, flat surface. Rest the piston and rod assembly on the piston crown with the rod upward.
3. Apply a light coat of clean engine oil to the piston and rings.
4. Apply a light coat of clean engine oil to the inside surface of the piston ring compressor, J 23442, PT7070-A, or equivalent.
5. Install the ring compressor by slipping it over the rod and down over the piston skirt. Continue to slide the tool downward, carefully guiding the rings into the ring grooves until the tool contacts the surface on which the piston crown is resting.
6. Position the upper bearing insert into the connecting rod. Align the tab in the bearing insert with the notch in the rod. Be sure that the hole in the bearing aligns with the oil passage in the rod.

CAUTION

The hole in the upper connecting rod bearing must be aligned with the oil passage in the connecting rod. Otherwise, damage to the bearing, rod and crankshaft journal will result.

7. Apply a light coat of clean engine oil to the bearing surface.
8. Apply a light coat of clean engine oil to the inside surface of the No. 1 cylinder sleeve.
9. With the ring compressor in place, position the piston and rod assembly into the No. 1 cylinder as shown in Figure 330 until the compressor contacts the top of the sleeve. The arrow and word FRONT on both the piston crown and the connecting rod must be facing the front of the engine.

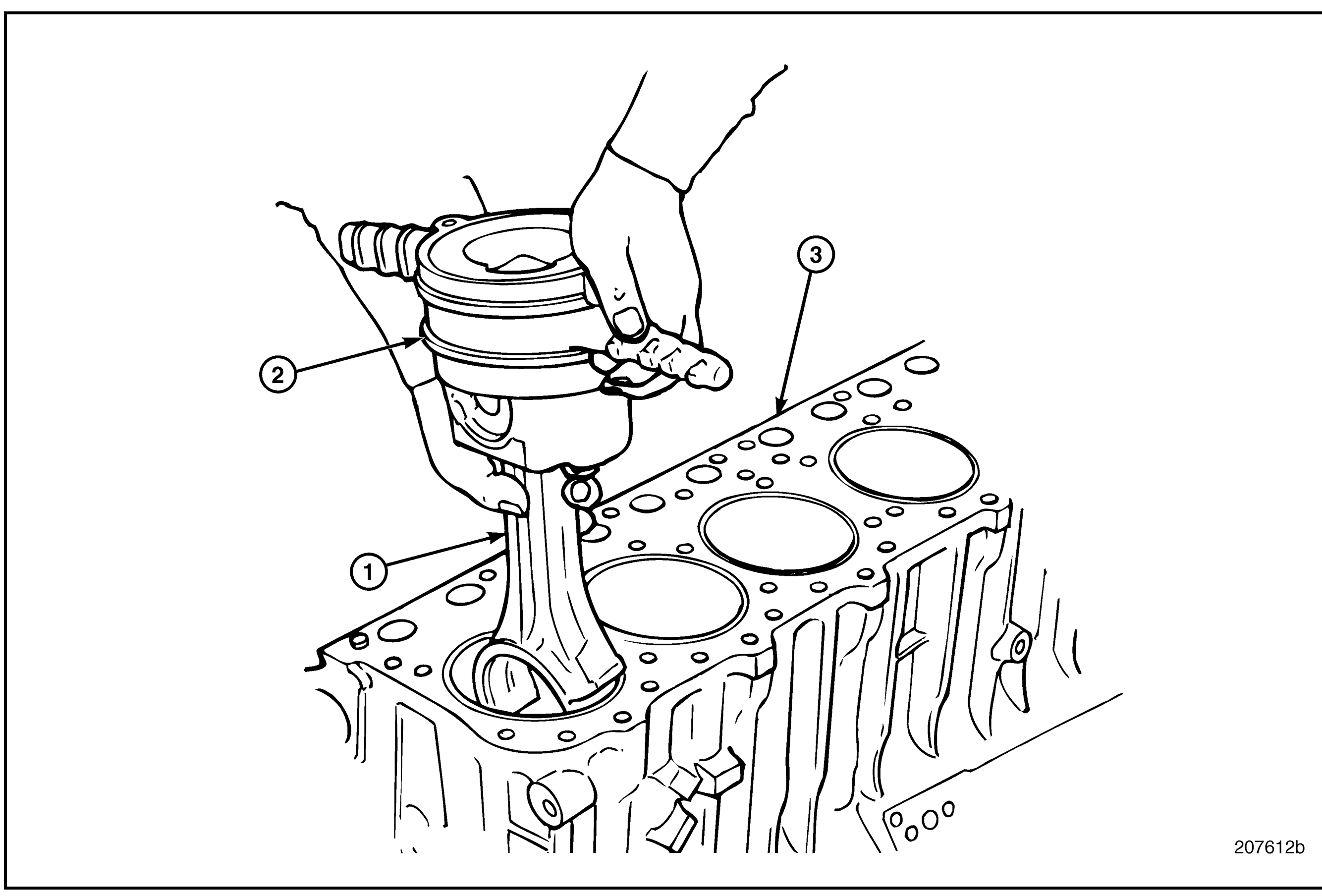


Figure 330 — Piston and Connecting Rod Installation

1. Connecting Rod Assembly 2. Piston Ring Compressor Tool	3. Cylinder Block

10. Make sure the connecting rod is aligned with the crankshaft journal.
11. While applying downward pressure to the ring compressor tool to keep it in contact with the cylinder sleeve, use a hammer handle to push the piston through the tool (Figure 331). Continue pushing on the piston until the top ring has passed into the cylinder sleeve.

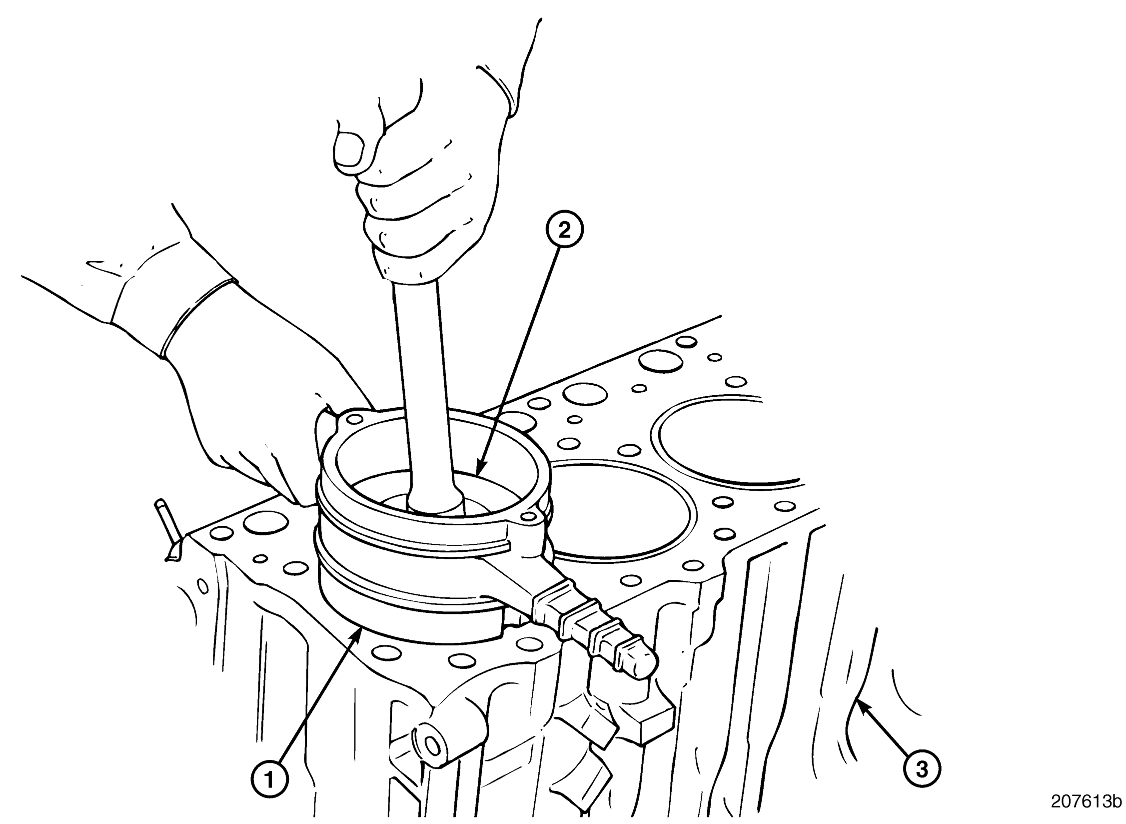


Figure 331 — Pushing Piston into Cylinder Sleeve

1. Piston Ring Compressor Tool 2. Piston	3. Cylinder Block

CAUTION

Do not force the piston. This indicates an incorrectly aligned ring. Remove the piston assembly, correct the problem, and then reinstall it. Make sure the compressor tool remains in contact with the cylinder sleeve until the piston clears the tool. If contact is not maintained, damage to the rings may result.

Before pushing the piston all the way down in the sleeve, check to see that the piston cooling nozzle is aligned with the nozzle clearance notch provided in the lower end of the piston skirt as shown in Figure 332. Damage to piston or spray nozzle may result if it is not aligned.

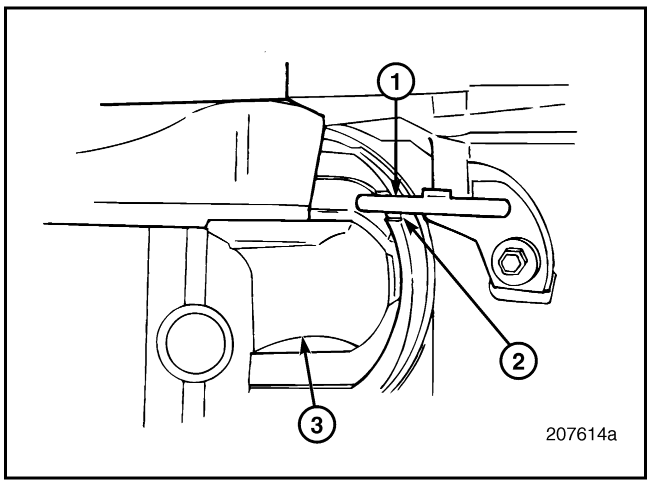


Figure 332 — Piston Skirt/Cooling Nozzle Alignment

1. Cooling Nozzle 2. Clearance Notch	3. Connecting Rod

12. Align the rod with the crankshaft journal and continue pushing the piston into the sleeve while guiding the rod end to clear the piston cooling nozzle and seat properly on the crankshaft journal.
13. Ensure that the correct rod bearing lower insert (matched to upper insert) and the alignment sleeves are positioned in the bearing cap.
14. Begin by installing the bearing cap at the No. 1 connecting rod journal (Figure 333) and check **Running Clearance** following the procedure later in this section. Repeat the running clearance check following the installation of each of the remaining five pistons.

CAUTION

*Running clearance must be checked after installing **each** piston. Damage to the engine may result if clearance is not within specification.*

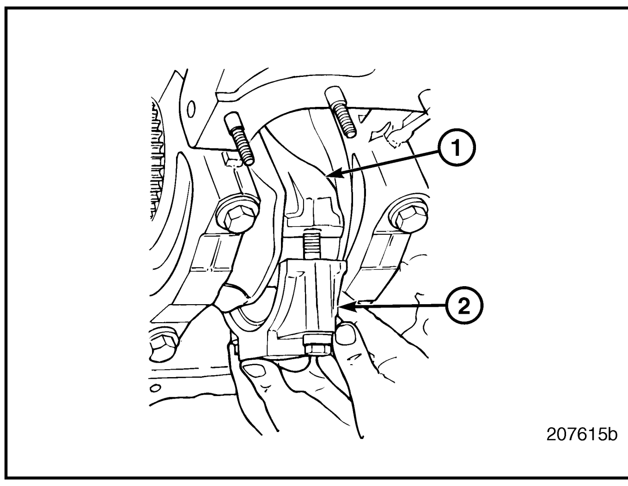


Figure 333 — Connecting Rod Cap Installation

1. Connecting Rod	2. Bearing Cap

15. Repeat the above steps to install the No. 6 piston.
16. Rotate the crankshaft so that the journals for the No. 2 and No. 5 cylinders are at bottom dead center and install the No. 2 and No. 5 pistons following the above steps.
17. Rotate the crankshaft so that the journals for the No. 3 and No. 4 cylinders are at bottom dead center and install the No. 3 and No. 4 pistons, again following the above steps.

RUNNING CLEARANCE CHECK

1. Place a section of Plastigage on the rod cap bearing and place the cap and bearing in position on the rod.
2. Apply a light coat of oil on the threads of the rod cap capscrews and install the screws.
3. Angle torque the capscrews to 30 lb-ft (41 N•m) plus 90 degrees using torque angle gauge set BT 91104, or equivalent.

NOTE

The angle-torque method applies for 14 mm capscrew part Nos. 396GC211M and 396GC212M with partial and full threaded shanks, respectively. Intermixing the partial and full threaded 14 mm capscrews on the same connecting rod is permissible.

4. Remove the capscrews and cap.
5. Check the width of the Plastigage on the removed cap using a Plastigage width chart. After measuring the width, remove the Plastigage from the bearing.
6. If the clearance is not within specification, correct the clearance as required:
   - If the clearance is less than specified, check behind the bearing for dirt, chips or burrs which would prevent the bearing from seating properly.
   - If the bearing bores and inserts are clean and undamaged, replace the inserts with inserts sized to provide the specified clearance.
7. Reposition the cap on the journal. Lubricate the capscrews with clean engine oil, install the capscrews and tighten to the specified torque, 30 lb-ft (41 N•m) plus 90 degrees using torque angle gauge set BT 91104, or equivalent.

CAUTION

If the cap and rod are not properly aligned, bearing and rod damage may result.

8. Check the rod side clearance (Figure 334) by installing a thickness gauge between the rod and the side of the journal. Check along the entire parting line area.

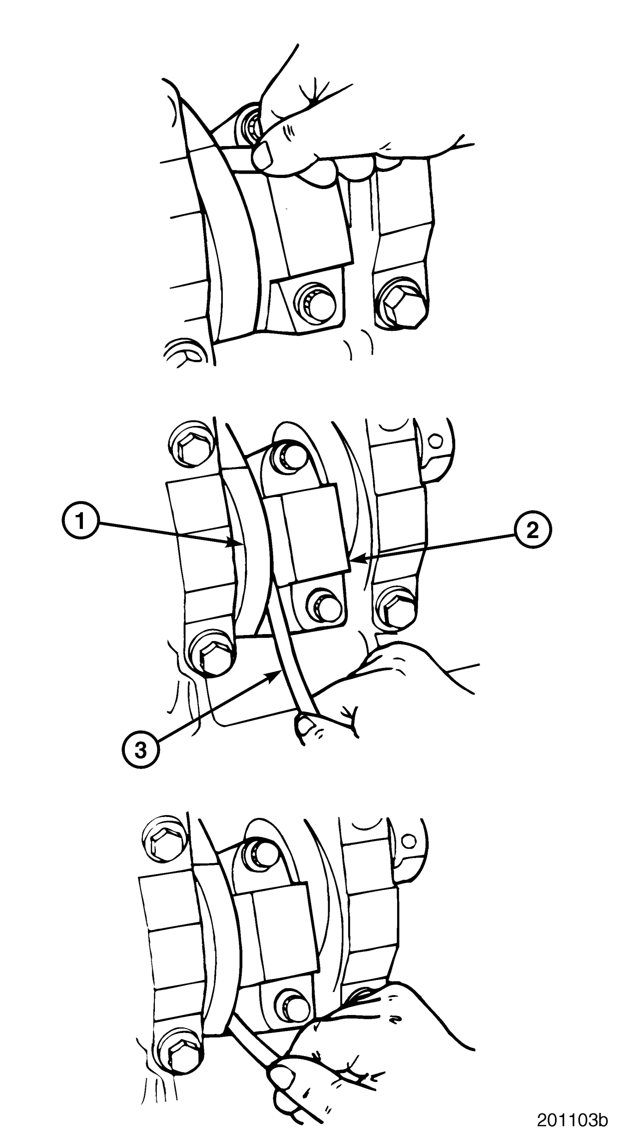


Figure 334 — Connecting Rod Side Clearance Check

1. Crankshaft Journal 2. Rod Bearing Cap	3. Thickness Gauge

9. The clearance must be within the specification listed under “Fits and Limits” in the SPECIFICATIONS section. If not, recheck for proper cap and rod alignment.

Flywheel Housing Installation

[211 HD]

GENERAL INFORMATION

The current die-cast aluminum and ductile iron flywheel housings for standard and automatic transmissions can be identified by the two side pads which contain six M16 x 2 holes and larger diameter transmission mounting screw holes (7/16 inch versus 10 mm). Flywheel housings having the above changes replaced all previous ASET™ flywheel housings (aluminum, ductile iron, standard and automatic transmissions). These current housings (Figure 336) are manufactured to use standardized housing mounting hardware as follows:

- Two upper external mounting location capscrews — M3 (3 inches long)
- Six internal mounting location capscrews — M (2 inches long)
- Eight washers used with aluminum or current ductile iron housing — part No. 35AX1489
- Eight washers used with non-current ductile iron housing — part No. 271AM5008

SERVICE HINT

Old can be serviced with new; however, new cannot be serviced with old.

CAUTION

Service replacement flywheel housings are the standardized flywheel housing. The appropriate mounting hardware comes with the new-style flywheel housing supplied by the Mack Trucks Parts System.

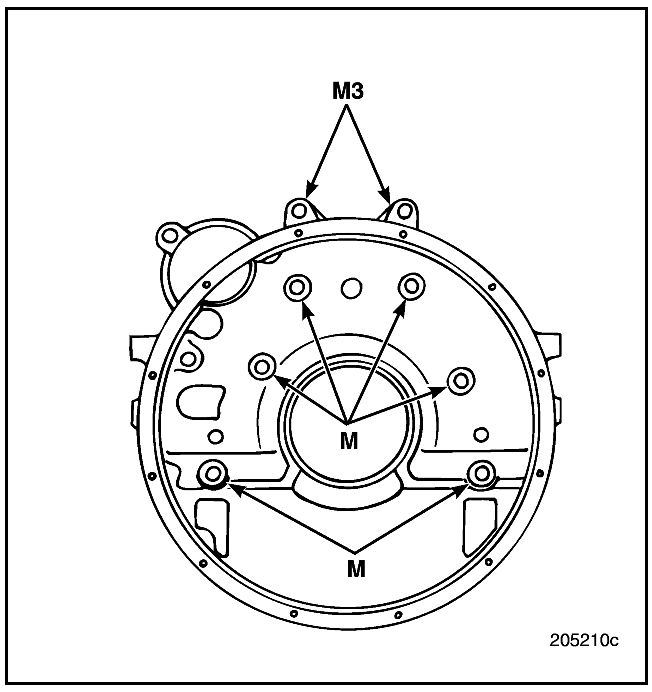


Figure 335 — Aluminum Flywheel Housing with Four-Hole Side Pads (Non-Current Housing)

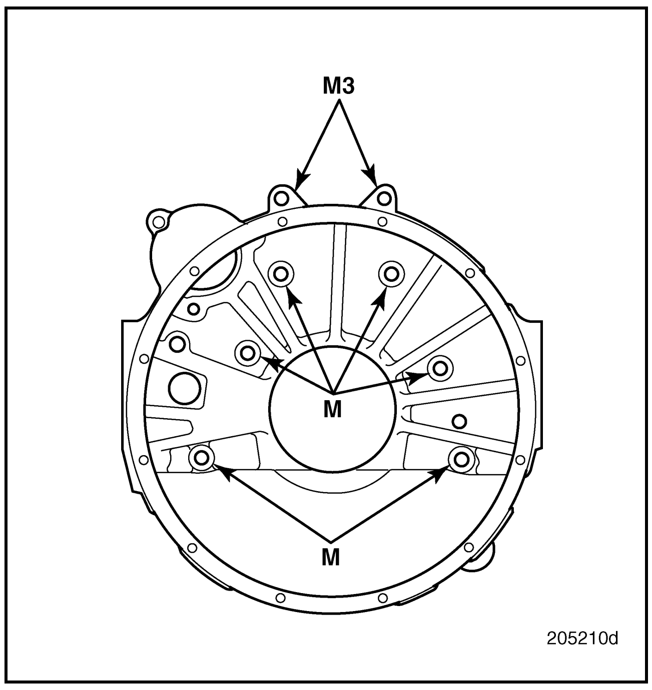


Figure 336 — Ductile Iron Flywheel Housing with Internal Structure Ribs (Current Production)

NOTE

Not Shown — Aluminum flywheel housing (current production) has external structural ribs.

Dowel Pins — A combination of round- and blade-style locating dowel pins are used to install the front cover and flywheel housing. A blade-style pin is used for the flywheel. When installing the blade-style pins, make sure the blade is properly positioned:

- Vertically (pointing up and down) — for the flywheel housing
- Parallel to crankshaft center line — for the flywheel
- Angled (perpendicular to the pin hole centerline of the dowel pin holes) — for the front cover

INSPECTION

Inspect the flywheel housing machined surfaces, capscrews, holes and dowel locations for cracks or wear. Replace the housing if cracks are evident.

CAUTION

Before installing the flywheel housing, examine the crankshaft flange for any cracks, surface damage or presence of foreign particles. This type of damage could ruin the sealing capabilities of the new seal and lead to oil leakage.

INSTALLATION

1. Remove the rear crankshaft oil seal from the flywheel housing by drilling two 3 mm holes, 180 degrees apart, into the outer edge of the seal. Remove the seal with a slide hammer fitted with a No. 10 sheet metal screw. Thread it into each of the holes alternately and work the seal free.
2. Using standard shop cleaning procedures for aluminum, clean the seal mounting surface.
3. Insert the two dowel pins in the cylinder block if they were removed. Refer to Figure 337.

NOTE

The flywheel housing dowels maintain the alignment of the flywheel housing on the engine. This is necessary to center the transmission with respect to the engine flywheel and crankshaft.

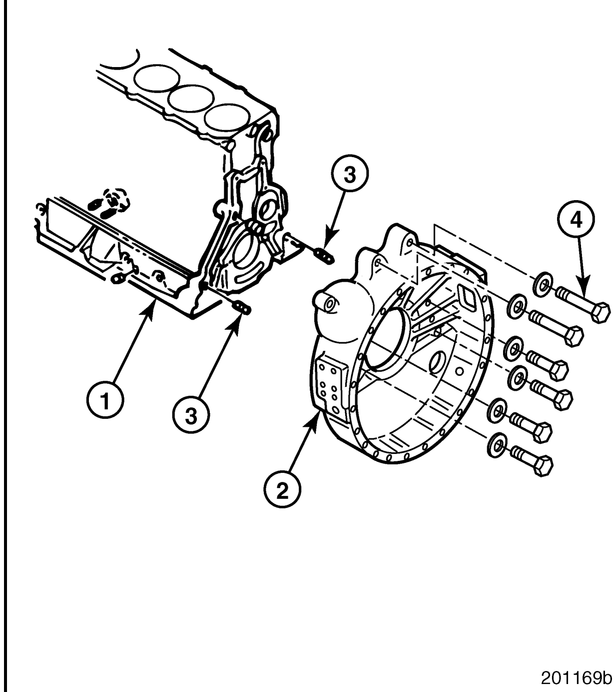


Figure 337 — Flywheel Housing Installation

1. Cylinder Block	3. Dowel Pin
2. Flywheel Housing	4. Capscrews

4. Apply an even coat of RTV silicone (approximately a 1/16-inch [2 mm] bead) to the flywheel housing mounting surface of the cylinder block. Refer to Figure 338.

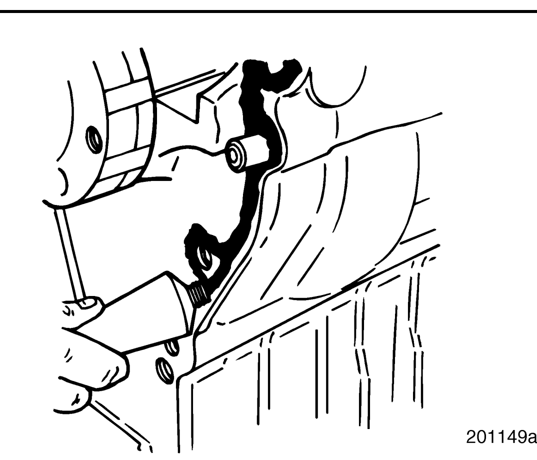


Figure 338 — Applying Sealant

5. Align the flywheel housing on the dowels and position it flush against the cylinder block surface. Refer to Figure 339.

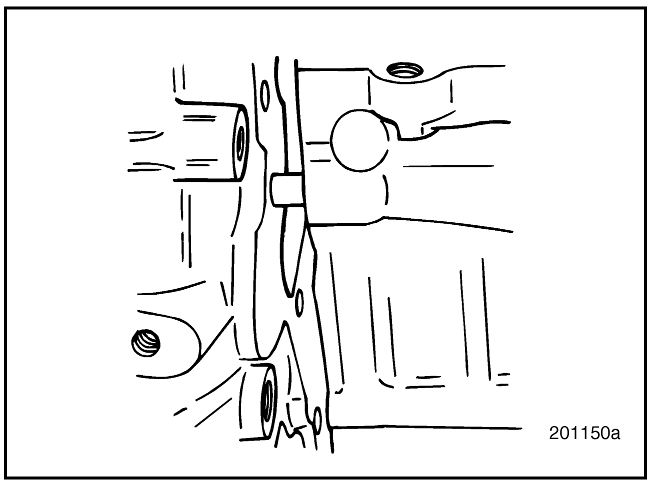


Figure 339 — Positioning Flywheel Housing

6. Install the flywheel housing mounting capscrews and tighten them finger-tight.
7. Tighten all flywheel housing capscrews to the specified torque, 170 lb-ft (230 N•m), using torque wrench J 24407, or equivalent.

RUNOUT

With the machined dowel method of installation, flywheel housing runout is well within the old service specification of 0.010 inch (0.254 mm) Total Indicated Runout (TIR), when checked with an alignment bar through the cylinder block main bearing bores. However, when checking flywheel runout using a dial indicator on the crankshaft rear flange or the flywheel, results may exceed 0.010 inch (0.254 mm) due to factors such as crankshaft movement within the bearing clearances and other variables.

NOTE

The dial indicator is the only method which can be used at this stage of assembly (with crankshaft in place). The machined dowel method requires that crankshaft and piston assemblies be removed.

Flywheel housing runout specifications are as follows:

- Runout checked with an alignment bar installed through the cylinder block main bearing bores: 0.010 inch (0.254 mm) TIR maximum. Refer to Figure 340.
- Runout checked with a dial indicator (PT5035 with Z adapter PT5035-1) mounted on the crankshaft rear flange or flywheel as shown in Figure 341 is 0.020 inch (0.508 mm) TIR maximum. Using this method, the runout specification is higher due to crankshaft movement within bearings and other variables.

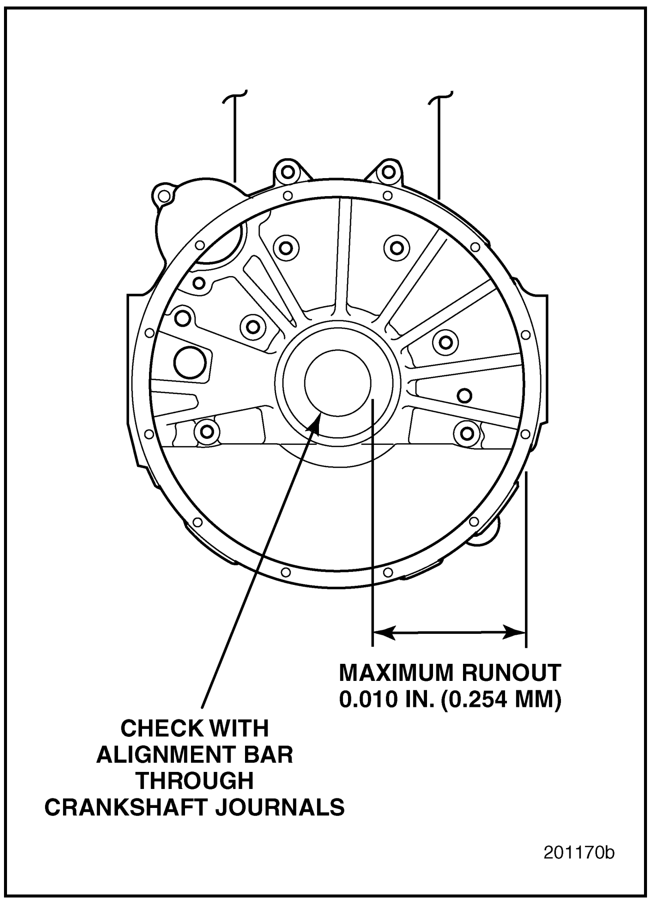


Figure 340 — Flywheel Housing Runout Check with Alignment Bar

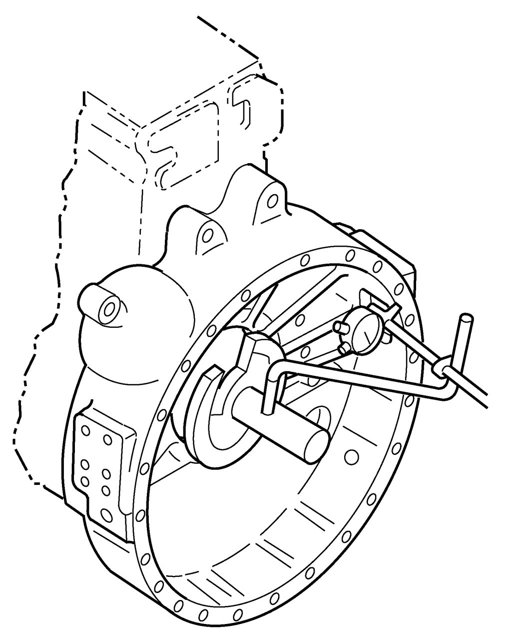


Figure 341 — Flywheel Housing Runout Check with Dial Indicator

Crankshaft Rear Oil Seal Installation

[212 JH]

MACK engines with dry flywheel housings (standard transmission) use single-lip seals, while those with wet flywheel housings (automatic transmission) use double-lip seals. The single-lip replacement seals are available in either Viton or Teflon® while the double-lip replacement seals are available in Teflon® only. The single-lip Viton seals have an oversized inside diameter and are supplied with a corresponding wear ring.

INSTALLATION — SINGLE-LIP SEAL

Crankshaft design allows the single-lip seal to be installed at the production depth of 0.344 inch ± 0.005 inch (8.74 mm ± 0.127 mm), or a service depth of 0.250 inch ± 0.005 inch (6.35 mm ± 0.127 mm) from the rear outer edge of the crankshaft flange.

NOTE

Special handling precautions must be taken while installing Teflon® seals. Do not lubricate the lips of a Teflon seal before installation. Teflon® seals function most effectively when installed dry.

Standard-size Teflon® seals are shipped on a plastic installation sleeve. Do not remove the seal from the sleeve before installation. The installation sleeve provides a smooth surface for the seal as it moves from the tool to the crankshaft flange.

1. Thoroughly clean the surface of the crankshaft flange.
2. Position the oil seal and installation sleeve onto the recessed side of the J 37716-B oil seal installation tool adapter plate as shown in Figure 342. The single-lip seal must be installed with the lip toward the engine.

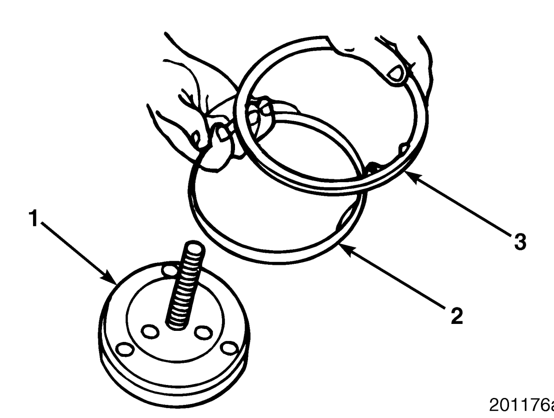


Figure 342 — Crankshaft Rear Oil Seal Installation

1. J 37716-B 2. Oil Seal	3. Installation Sleeve

3. Using the three guide pins, attach the adapter plate to the crankshaft flange. Refer to Figure 343.

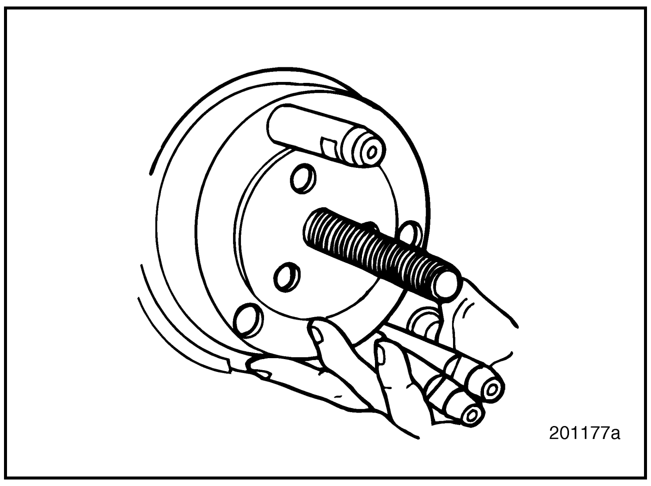


Figure 343 — Adapter Plate J 37716-B Installation

4. Determine the seal and wear ring installation depth:

   Refer to Figure 344.

   - **New** seal on a **new** crankshaft or service crankshaft with a **new** wear ring — Install to the initial production depth of 0.339–0.349 inch (8.611–8.865 mm).
   - **New** seal on a service crankshaft with/without a used wear ring — Install to the service depth of 0.245–0.255 inch (6.223–6.477 mm).
   - Wear ring installation depth — 0.15–0.220 inch (5.461–5.588 mm)

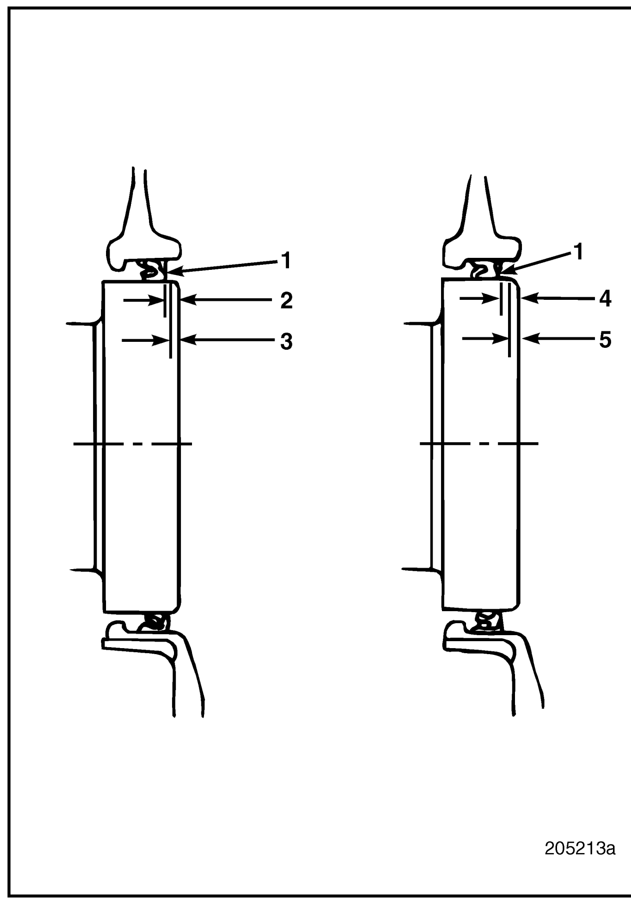


Figure 344 — Crankshaft Rear Oil Seal

1. Crankshaft Rear Oil Seal 2. Production Seal Installation Depth 3. Service Seal Installation Depth	4. Service Seal Installation Depth with Wear Ring 5. Wear Ring Installation Depth

5. The two installation depths are stamped above two of the guide pin bores on the installation tool press plate. To install the seal to the desired depth, position the press plate so that the guide pins go through the bore stamped with the desired depth.
6. Install the press plate driver hex nut and continue tightening until a positive stop is felt. At this point, the seal is installed to the proper depth.
7. Remove the installation tool.

INSTALLATION — WEAR RING WITH DOUBLE-LIP TEFLON® SEAL

(WET-TYPE FLYWHEEL HOUSING)

The oversize inside diameter lip seal and wear ring are shipped as an assembly, with the seal installed on the wear ring. Do not remove the seal from the wear ring prior to installation. The wear ring and seal installer J 35529 is required for installation. This tool presses both the wear ring and the oil seal onto the crankshaft flange.

SPECIAL TOOL REQUIRED

- Wear Ring and Seal Installer J 35529

Refer to Figure 345.

1. Remove the existing wear ring from the crankshaft before installing the **new** wear ring.
2. Thoroughly clean and dry the crankshaft flange.
3. Apply a thin, even layer of Loctite® 609 to the circumference of the crankshaft flange.

NOTE

Do not lubricate the lips of a Teflon® seal before installation. Teflon® seals function most effectively when installed dry.

4. The lip of one side of the oil seal is yellow. Install the seal with the yellow lip toward the transmission. Position the oil seal and wear ring assembly onto the recessed side of the installation tool adapter plate with the yellow lip facing away from the direction of installation (toward the transmission).
5. Using the three guide pins, attach the oil seal installation tool adapter plate to the crankshaft flange.
6. Install the press cup over the guide pins. Then install the press cup driver hex nut.
7. Tighten the hex nut until a positive stop is felt. At that point, the oil seal and wear ring are properly installed on the crankshaft flange. The double-lip seal is properly installed to a depth of 0.250 inch ± 0.005 inch (6.35 mm ± 0.127 mm).
8. Remove the installation tool.

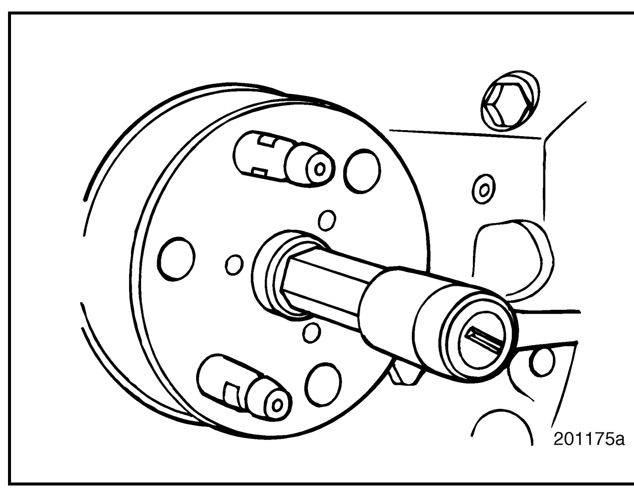


Figure 345 — Crankshaft Wear Ring (with Double-Lip Teflon® Seal) Installation

Flywheel Installation

[212 VC]

TIMING SCALE

The flywheel has a stamped timing scale of top center (TC) to 45 degrees of engine travel (engine timing) and three stamped locations, 120 degrees apart, for valve settings as shown in Figure 346. The flywheel still has pump timing marks for application to both current and older engines; the marks are not needed for current engines.

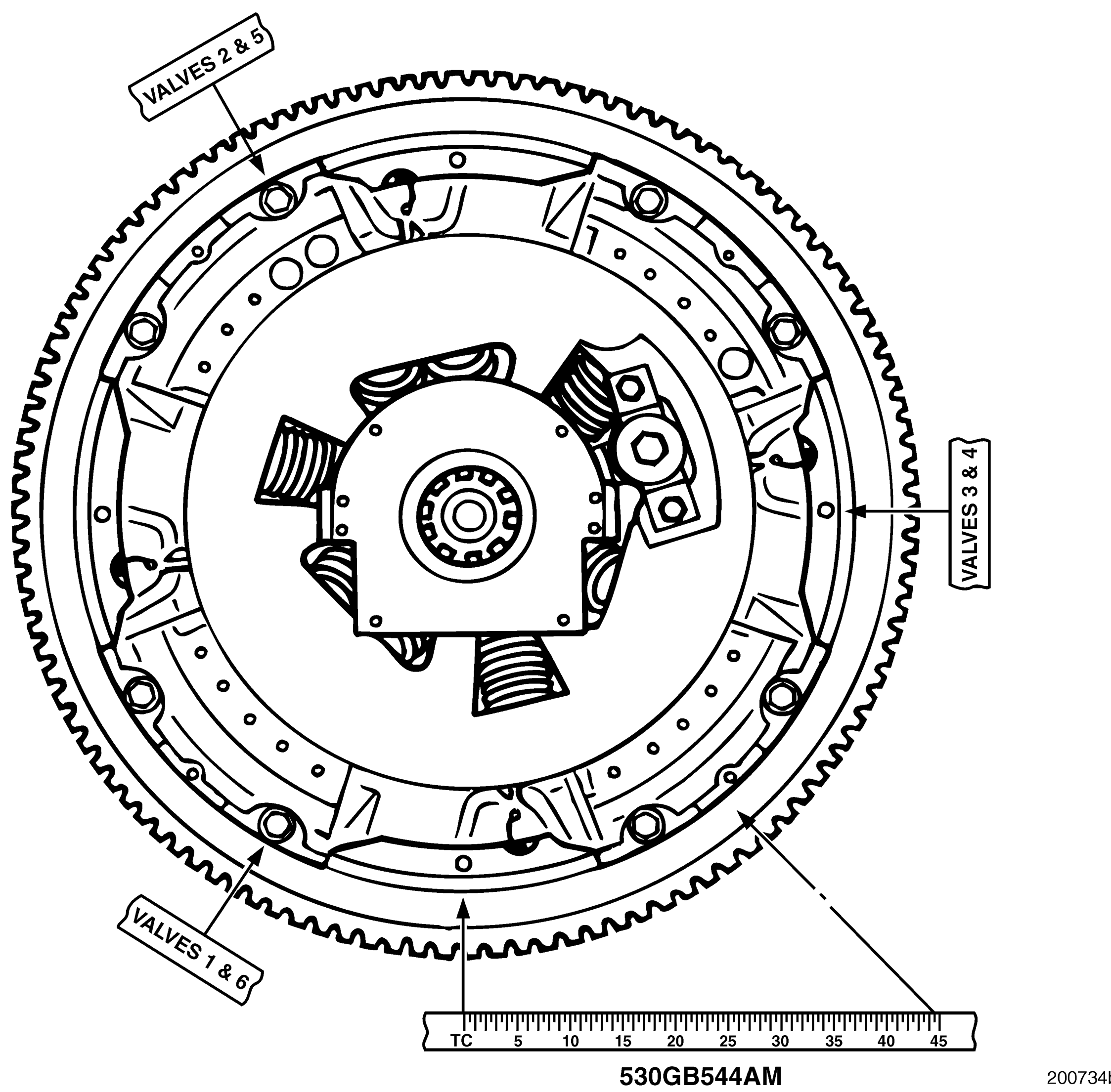


Figure 346 — Flywheel Markings

INSTALLATION PROCEDURE

CAUTION

After resurfacing, any flywheel with drilled balance holes on the clutch side requires rebalancing by a machine shop.

NOTE

On vehicles equipped with an automatic transmission, it may be necessary to install different components to the flywheel retaining capscrews. Refer to the Automatic Transmission Drive Arrangement Assembly Instructions, 5-902, for installation instructions regarding these arrangements.

SERVICE HINT

When installing the flywheel, insert two alignment studs in the crankshaft flange to aid in the installation.

Refer to Figure 347.

1. Position the flywheel over the dowel pin and alignment studs on the flywheel mounting surface at the rear of the crankshaft.
2. Install the flywheel mounting capscrews in the exposed mounting holes. At this time, tighten the capscrews finger-tight only.
3. Remove the two alignment studs and insert the remaining mounting capscrews.

CAUTION

Do not torque capscrews adjacent to each other in sequence. Doing so may result in uneven flywheel alignment. Capscrews on opposite sides of the flywheel should be alternately tightened to the specified torque.

4. Tighten the capscrews to the specified torque, 185 lb-ft (250 N•m), alternating from opposite sides to apply even pressure to the flywheel (use torque wrench J 24407, or equivalent).

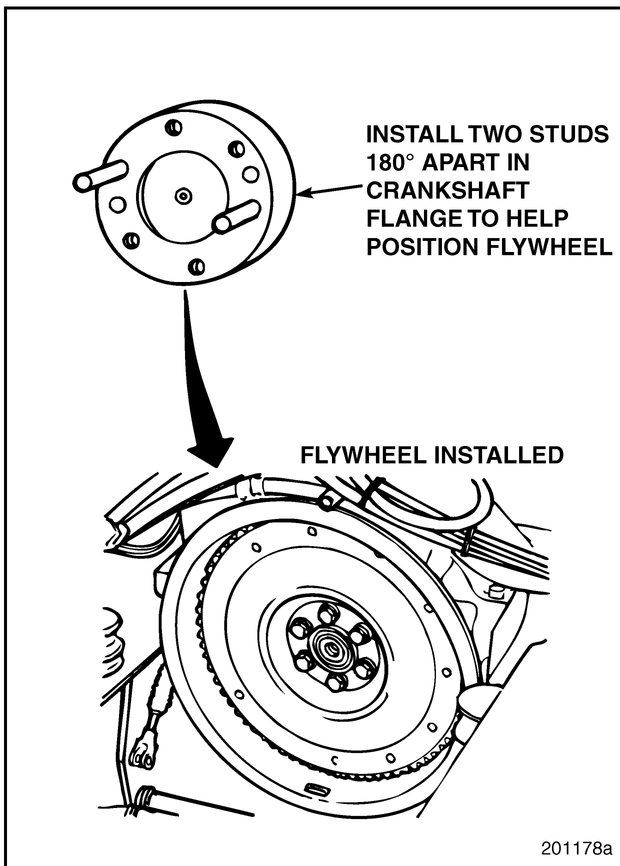


Figure 347 — Flywheel Installation

Valve Lifter Installation

[213 LB]

Check the condition of the valve lifters before installing them. Replace any lifters that are broken, damaged or show signs of excessive wear.

CAUTION

Ceramic lifter rollers will not tolerate high impact loads. Such loads can crack the ceramic, resulting in breakage or spalling of the ceramic roller. Use care when handling the lifters. DO NOT use a lifter that has been dropped or subjected to any type of engine failure which would have subjected the ceramic roller to high impact loads.

1. Rotate the engine 180 degrees, so that the bottom of the engine is facing up.

2. Submerge the valve lifters into a container of clean engine oil to allow oil to fill the passages to the roller axles. Remove each lifter and while holding it vertically, spin the roller to make sure the oil flows to the surfaces between the axle and roller. This step is important to provide adequate break-in to the axle and roller at initial start-up of the engine.
3. Install the lifters into the cylinder block lifter bores as shown in Figure 348.

NOTE

Used valve lifters have established wear patterns. Valve lifters being returned to service should be installed in the same location from which they were removed.

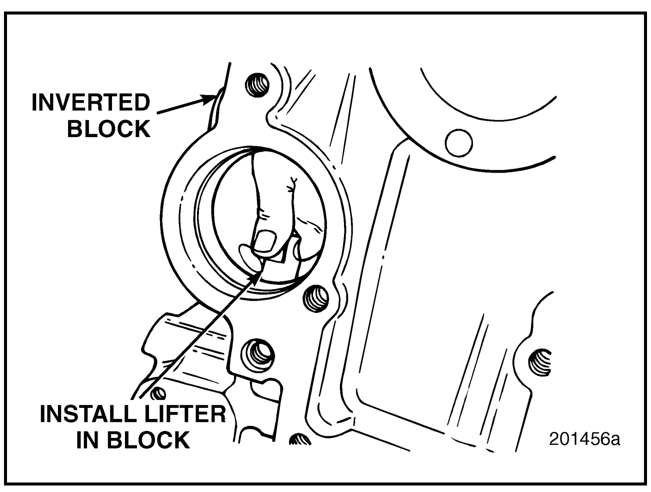


Figure 348 — Valve Lifter Installation

4. Install a lifter in the lifter bore by aligning the lifter flats with the H-ring flats (Figure 349). Use only light finger pressure when installing the lifters. Verify that the lifter has complete freedom of movement in the bore and H-ring in both the upward and downward directions. When the lifter is seated, it should be possible to rotate it slightly from left to right. If the lifter is sticky or tight, or if additional force is required to install the lifter, proceed as follows:
   a. If new lifters are being installed and the fit is tight, try the lifter in another lifter bore. A stack-up of component tolerances can result in a lifter being free in another bore. This is acceptable.
   b. If the original lifters are being reused and the fit is tight, trial fit a **new** lifter(s) in the bore. If the tightness persists, the problem may be in the lifter bore or H-ring. (Because of established wear patterns, it is not recommended to install a used lifter in any bore other than the bore from which it was removed.)
   c. If the problem is confined to a particular bore, determine if the lifter tightness is due to the lifter bore or the H-ring by trial fitting another lifter. To correct the problem condition, refer to the procedure under "Salvaging a Valve Lifter Bore" or "H-Ring Replacement" in the CYLINDER BLOCK RECONDITIONING section.

CAUTION

A lifter that does not move freely in the lifter bore can be impacted by the cam lobe during engine operation. This will result in damage or breakage of the ceramic roller.

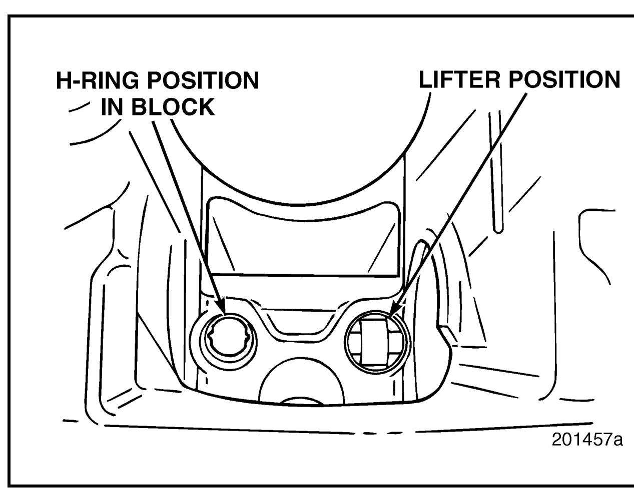


Figure 349 — Installed Valve Lifter

Camshaft Installation

[213 CH]

Before installing a camshaft in any engine, ensure that cam is clean, undamaged and well-lubricated with clean engine oil. Refer to “Auxiliary Shaft and Camshaft Bench Procedures” in the REPAIR INSTRUCTIONS section.

SERVICE HINT

When installing the camshaft, it is easier to remove the camshaft guide from the camshaft (after installation) when the idler gear is removed and alignment of the timing marks is not being attempted at the same time. The final step in the process is to reinstall the idler gear.

NOTE

Use camshaft guide tool J 41682 to ease installation of the camshaft and avoid damage to the camshaft bushings.

Install the camshaft as follows:

1. Apply a generous coating of clean engine oil to the camshaft bushings.
2. Clean the camshaft with a suitable solvent.
3. Install the camshaft installation guide over the large flat of the injector lobe, between the last two cam journals (journals at the back of shaft). Refer to Figure 350.

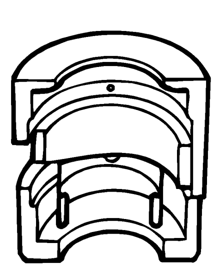


Figure 350 — Camshaft Installation Guide

4. Apply clean engine oil to the installation guide.

NOTE

The camshaft is heavy, weighing approximately 90 pounds with the gear. The installation guide allows the camshaft to slide from one cam bushing to the next without allowing the cam to drop when one journal clears the bushing bore.

5. With the engine still rotated 180 degrees (crankcase facing up, head deck facing down), position the camshaft in the block with the cam installation guide facing down toward the floor as shown in Figure 351.
6. Slide the cam all the way into the block.

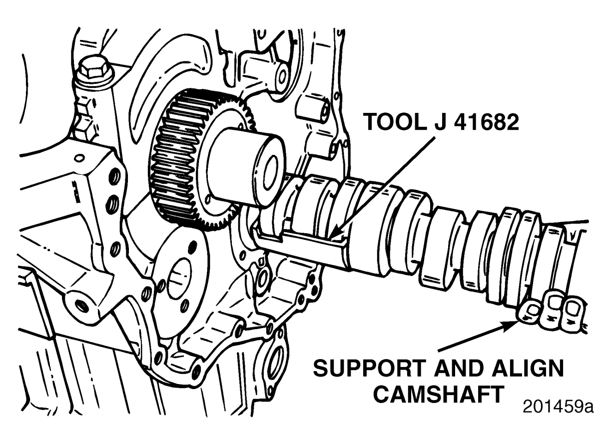


Figure 351 — Camshaft Installation

7. After the camshaft is fully installed, install the thrust washer screws and tighten to specification, 15 lb-ft (20 N•m).
8. Rotate the crankshaft and camshaft to facilitate removal of the installation guide. The camshaft must be rotated so that the installation guide faces up toward the cylinder block pan rail. The crankshaft must be rotated so the No. 6 connecting rod journal faces down toward the cylinder block top deck (piston at TDC).
9. Remove the installation guide tool J 41682.

Camshaft Core Plug Installation

[213]

After the camshaft is installed, install the core plug.

1. Position the core plug onto the core plug installation tool J 42490 (used with J 8092 driver handle). Refer to Figure 352.

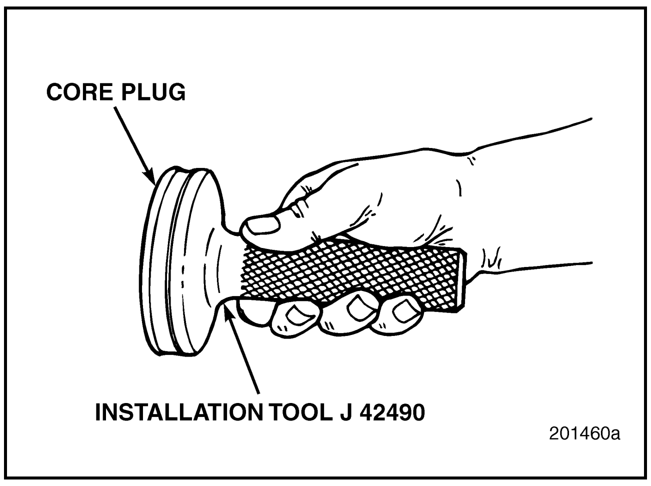


Figure 352 — Camshaft Core Plug Installation Tool

2. Position the core plug in the cylinder block.
3. Drive the core plug into place by striking the installation tool with a hammer (Figure 353) until the core plug is seated. The core plug is fully seated when the step in the installation tool bottoms against the block.

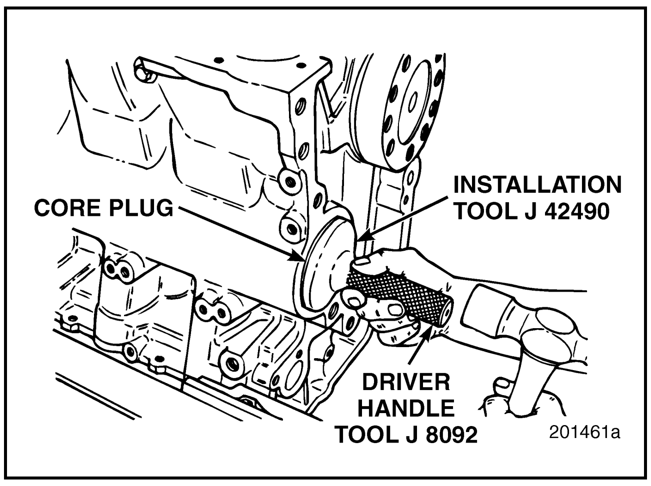


Figure 353 — Camshaft Core Plug Installation

Camshaft Idler Gear Installation

[213 DE]

Before installing the idler gear/hub assembly, determine which is the top mounting hole on the hub.

The idler gear is held in place with a flanged hub mounted to the cylinder block by three bolts. Although the bolt-mounting pattern may *appear* symmetrical, it is not. The non-symmetrical mounting pattern ensures that oil feed passages in the hub will be properly aligned with the oil feed passage in the cylinder block, which lubricates the idler gear hub bushing.

To aid in aligning the hub to the mounting holes in the cylinder block, at the 12-o'clock position (engine upright), the hub mounting bolt hole is identified by the word "UP" steel-stamped just below the mounting hole.

1. With the engine in an upright position, place the idler hub in position against the engine block and verify good alignment with the mounting bolt holes in the block (Figure 354).

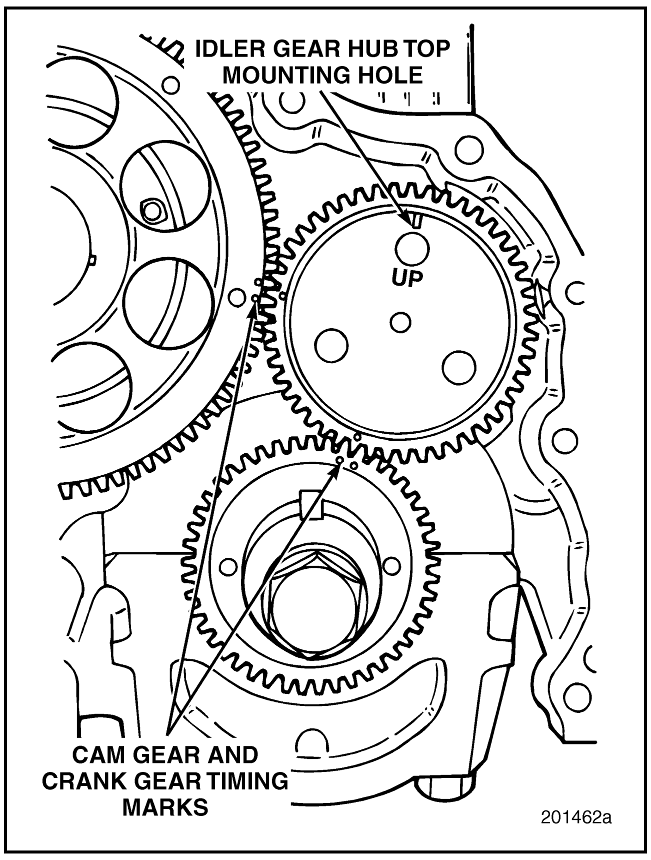


Figure 354 — Hub Correctly Positioned on Block

2. Align the timing marks. First look at the timing marks on both the camshaft and crankshaft gears. Note that two teeth are marked (side-by-side) on each gear. These double timing marks must align with the single timing marks on the idler gear. When properly installed, the two single timing marks on the idler gear will fall between the double timing marks on the camshaft and crankshaft gears. To attain correct alignment, rotate the crankshaft and camshaft gears until the camshaft timing marks are in approximately the 3:30 position, and the crankshaft gear timing marks are in approximately the 1 o'clock position (with engine in the upright position and viewed from the front).

NOTE

There are 45 gear teeth on the crankshaft gear, 90 teeth on the camshaft gear and 48 on the idler gear. Because the idler gear has 3 more teeth than the crankshaft gear, the timing marks align only once every 16 revolutions of the crankshaft. This is called a "hunting tooth" system.

3. Slide the idler gear onto the hub assembly with timing marks facing out.
4. Position the idler gear timing marks so they align (Figure 355) with the crankshaft and camshaft gear timing marks. Then, slide the idler gear/hub assembly into position on the cylinder block.

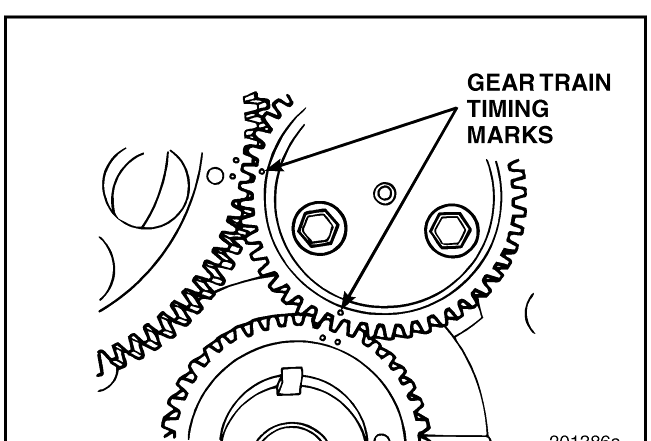


Figure 355 — Timing Marks Properly Aligned

5. Coat the hub bolts with clean engine oil and thread the bolts a few turns into the respective bolt holes at the front of the engine block.
6. Tap the hub portion of the assembly with a brass hammer to seat the components.
7. Tighten the bolts evenly to specification, 70 lb-ft (95 N•m). Do not use an impact wrench or other air tool to tighten bolts.

Auxiliary Shaft Installation

[212 CV]

Before installing the auxiliary shaft in the engine, ensure that the shaft is clean, undamaged and well-lubricated with clean engine oil. Refer to "Auxiliary Shaft and Camshaft Bench Procedures" in the REPAIR INSTRUCTIONS section.

Refer to Figure 356.

⚠ CAUTION

Replace the auxiliary shaft as an assembly only. Do not try to dismantle or rework the shaft since doing so may result in damage to the engine.

1. Lubricate the front auxiliary shaft journal, rear auxiliary shaft journal and shaft bearings (in cylinder block) with clean engine oil.

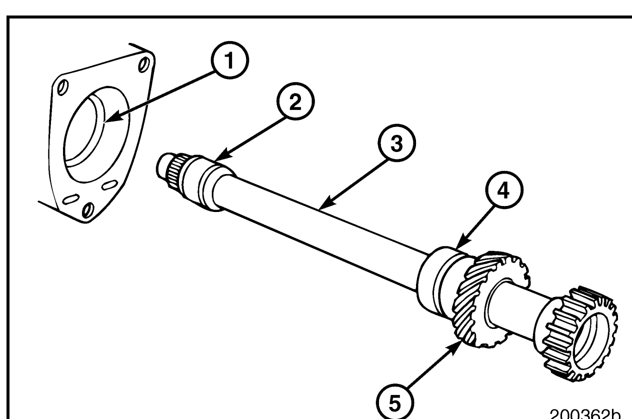


Figure 356 — Auxiliary Shaft Installation

1. Rear Bearing 2. Auxiliary Shaft Front Journal 3. Shaft	4. Auxiliary Shaft Rear Journal 5. Oil Pump Drive Gear

2. Install the shaft through the rear of the auxiliary shaft housing. Use care when aligning the shaft to avoid damage to the rear bearing.

   Refer to Figure 357.

3. Install the thrust washer and secure it in position with the patch-lock capscrews and hardened washers.
4. Tighten the thrust washer retaining patch-lock capscrews to the specified torque, 15 lb-ft (20 N•m), using torque wrench J 24406, or equivalent.
5. Install the auxiliary shaft gear on the shaft splines.

NOTE

The auxiliary shaft and nut threads must be clean and dry before assembly. Clean the threads thoroughly with Brakleen® or electrical contact cleaner. If reusing the old nut, apply Loctite® 271 or 277 to the threads and install the nut. If using a new nut from the MACK Parts System, it is not necessary to apply Loctite® as the nut threads are coated with a pre-applied thread locker.

6. Install the auxiliary shaft nut and tighten to the specified torque, 300 lb-ft (405 N•m), using torque wrench J 23775-01, or equivalent.

NOTE

Whether using a new or revised nut, it is critical that the ground face of the nut (if applicable) be installed toward the gear. Any identifications on the nut face must be installed away from the gear.

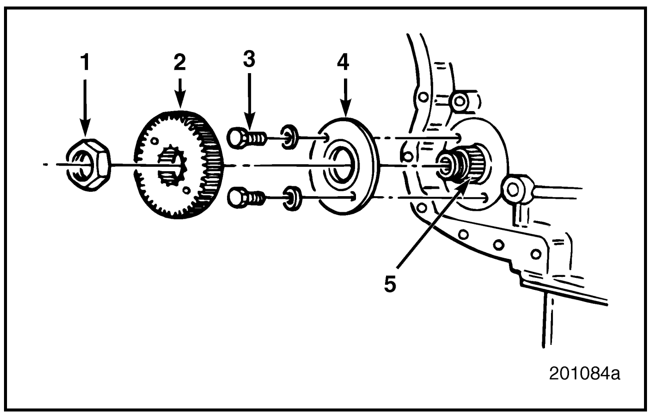


Figure 357 — Auxiliary Shaft Gear Installation

1. Nut 2. Auxiliary Shaft Gear 3. Capscrew	4. Thrust Washer 5. Shaft Splines

Oil Pump Installation

[219 MU]

Make sure that the oil pump is in satisfactory condition as covered under “Lubrication System Components Bench Procedures” in the REPAIR INSTRUCTIONS section.

NOTE

Because of differences in the gear set helixes of current and earlier design engines, it is important that the correct component/parts are installed.

- An improper drive gear on the oil pump will prevent oil pump installation, assuming a correct gear is on the auxiliary shaft.
- If an oil pump and an auxiliary shaft assembly were replaced, two improper gears could be installed, and engine failure would result.
- In replacing any of these critical parts, always refer to part number information in the MACK Parts System to ensure the correct component/part is being used.

1. Place the oil pump in position on the cylinder block. Refer to Figure 358.
2. Apply Loctite® 271 to the threads of the pump mounting capscrews and install them. Tighten the mounting capscrews to the specified torque, 40 lb-ft (55 N•m), using torque wrench J 24407, or equivalent.

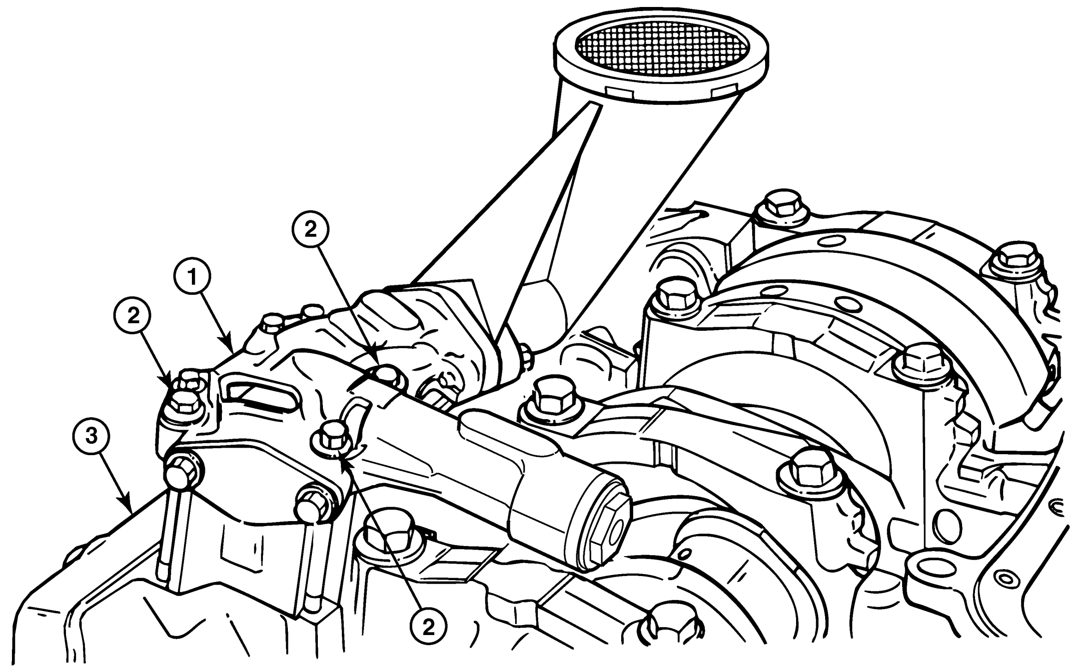


Figure 358 — Oil Pump Installation

1. Lubrication Oil Pump 2. Mounting Capscrews	3. Cylinder Block

CAUTION

After the oil pump has been installed, check the backlash between the auxiliary shaft gear and the oil pump driven gear.

3. Check the auxiliary shaft gear-to-oil pump driven gear backlash, using a thickness gauge inserted between the auxiliary shaft gear and the oil pump driven gear. The backlash should be within specification, 0.0072–0.0138 inch (0.1829–0.3505 mm)

Front Cover Installation

[211 RP]

With the crankshaft, camshaft and auxiliary shaft in place, install the front cover.

1. Apply a light coat of RTV silicone to the timing cover mounting surface.
2. Position the timing cover on the cylinder block mounting surface.
3. Install the mounting capscrews in the timing cover and tighten the capscrews to specification, 40 lb-ft (55 N•m), using torque wrench J 24407, or equivalent.
4. Position the front pedestal mount on the timing cover and install the mounting capscrews. Tighten the pedestal mounting capscrews to 70 lb-ft (95 N•m), using torque wrench J 24407, or equivalent.

Crankshaft Front Seal Installation [211 JB]

SPECIAL TOOLS REQUIRED

- Crankshaft Front Seal Installer J 37715-A
- Crankshaft Front Seal Adapter J 37715-2

INSTALLATION PROCEDURE

NOTE

Installation depth of the front crankshaft seal, relative to the front crankshaft stem, is controlled by the installation tool adapter. Ensure that the correct adapter, J 37715-2, is used.

Refer to Figure 359.

1. Position the lip-type seal on the seal installer (J 37715-2 adapter in combination with J 37715-A), with the solid portion of the seal outward (toward the tool).
2. Position the tool over the hub and into the seal opening.
3. Insert the hub capscrew into the hole in the seal installation tool and draw the seal in until the tool bottoms out on the face of the crankshaft.

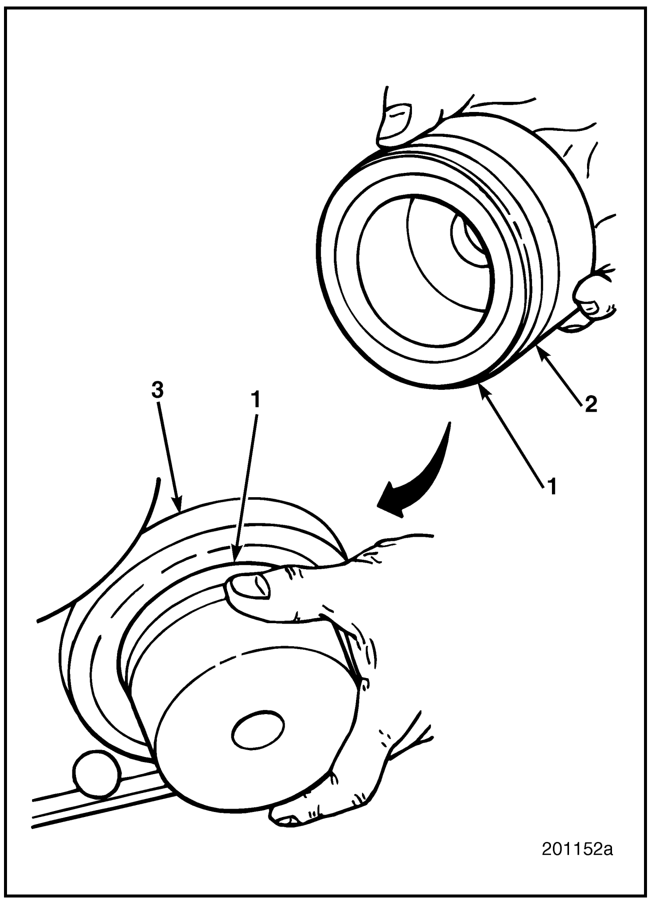


Figure 359 — Crankshaft Front Seal Installation

1. Front Cover Seal 2. Seal Installer J 37715-A	3. Front Cover

4. Remove the tool and check the seal to ensure it has been evenly installed.

Crankshaft Hub Installation

[212 RH]

INSPECTION

Inspect the bore of the crankshaft hub for scoring. Also, check the condition of the hub flange and the threaded holes.

CAUTION

Replace the hub if the crankshaft seal lip has made a significant wear groove on the outer diameter of the hub. Mack Trucks, Inc. DOES NOT recommend the use of a service sleeve to repair this type of hub damage. Also, if there is any galling, scoring or fretting on the inner diameter, replace the hub.

INSTALLATION PROCEDURE

Refer to Figure 360.

1. Using a suitable grease-type lubricant, coat the working surface of the seal in preparation for installation of the crankshaft hub.

NOTE

Teflon®-type seals do not require greasing the working surface of the seal.

2. Heat the hub to approximately 250°F (121°C) prior to installation.
3. Using heat-resistant gloves, position the hub on the crankshaft.

NOTE

While the crankshaft has a keyway slot, the crankshaft hub does not. Timing is set in relation to the flywheel position and not the crankshaft hub, eliminating the need for a hub key and precise alignment.

4. In a quick, even motion, push the hub onto the crankshaft.
5. Install the hub washer and capscrew. Tighten the capscrew to the specified torque, 360 lb-ft (490 N•m), using torque wrench J 23775-01, or equivalent.

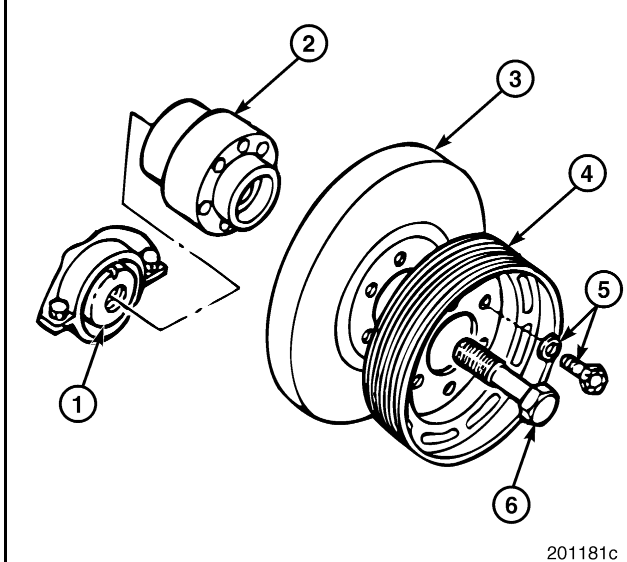


Figure 360 — Crankshaft Hub/Vibration Damper

1. Crankshaft 2. Crankshaft Hub 3. Vibration Damper 4. Pulley	5. Damper/Puller Capscrews and Washers 6. Hub Capscrew

Vibration Damper Installation

[212 RB]

INSPECTION

CAUTION

When removing or handling the vibration damper, be careful not to damage the housing. Any dents in the outer housing may render the damper ineffective and result in cracks in the crankshaft. The vibration damper cannot be repaired.

Inspect the vibration damper for dents, nicks or fluid leaks in the outer housing. If any of the above are evident, the vibration damper must be replaced. Due to the close clearances between the damper housing and its internal flywheel, dents or nicks may cause contact between the two components. Fluid loss will deteriorate the dampening effect of the damper.

INSTALLATION PROCEDURE

1. Place the vibration damper and drive pulley in position on the crankshaft hub.
2. Install the mounting capscrews and tighten the capscrews to the specified torque, 45 lb-ft (61 N•m).

NOTE

Vibration dampers are attached to the crankshaft hub with six or 12 mounting bolts, depending on date of production.

Oil Pan Installation

[211 NB]

GENERAL INFORMATION

With the isolating oil pan gasket arrangement, 8 mm mounting holes are tapped into the cylinder block, front cover and flywheel housing. Figure 361 shows the production arrangement. The oil pan is secured with shouldered bolts at the timing cover and flywheel housing and a combination of shouldered bolts and integral hex-head shoulder studs (one piece) along the pan rails.

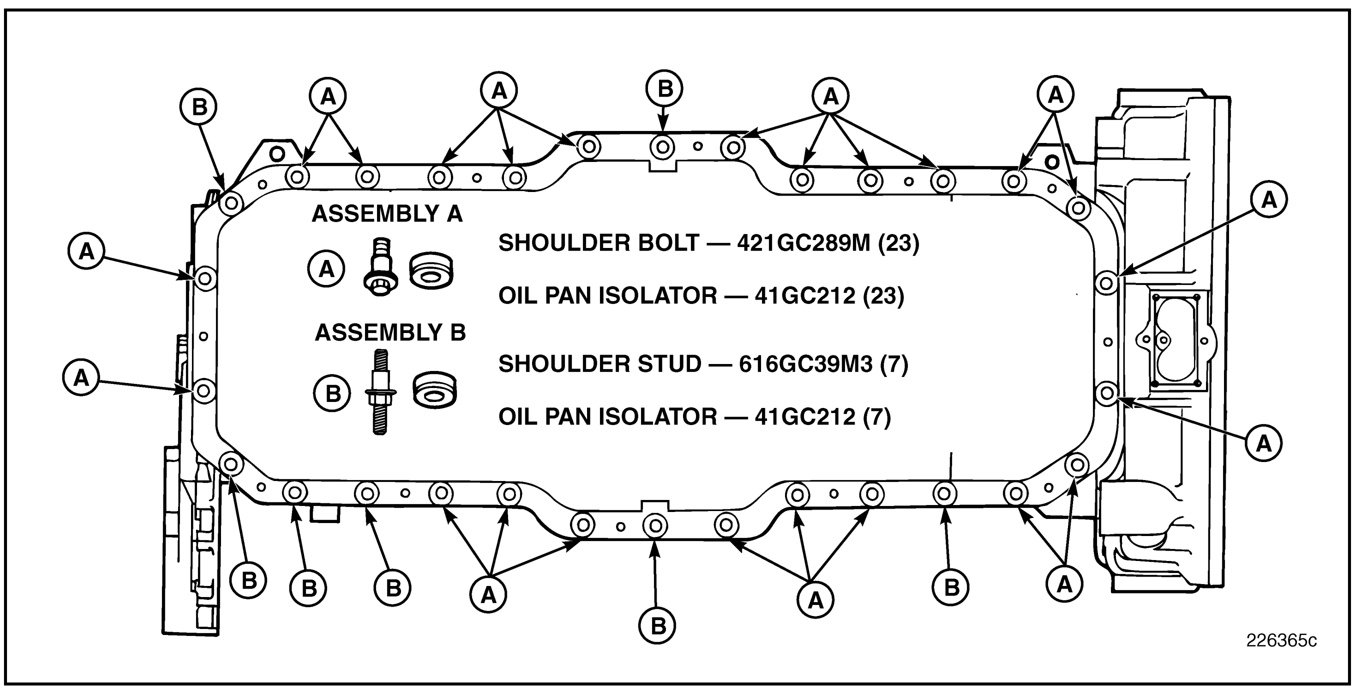


Figure 361 — Oil Pan Stud Identification

The isolating oil pan gasket contains 12 integral locating/retaining cones which lock into holes drilled through the oil pan rails, and two large rectangular tabs located directly across from each other on the inner perimeter of the gasket. The cones keep the gasket properly located during oil pan installation, and the rectangular tabs serve as a starting point for locating the gasket at the mid-points of the oil pan rail.

INSTALLATION PROCEDURE

1. Clean any oil from the cylinder block mounting surface and the oil pan rail. The oil pan must be installed dry.

CAUTION

Oil on the surface of the gasket or the rails of the cylinder block and oil pan during the oil pan installation can cause the gasket to bulge out between any two bolts, particularly those at the mid-section corners. This condition may not occur immediately, but can do so at any time after installation. To avoid this occurrence, wipe any oil from the inner walls of the cylinder block crankcase. Then, clean the rails of the cylinder block and oil pan with a suitable non-flammable solvent. Dry the cleaned surfaces completely.

2. Before installing the oil pan gasket, apply a bead (approximately 1/8–1/4 inch [0.014–0.028 mm] wide) of RTV silicone sealant (MACK Silastic® 342SX32, Dow Corning Silastic® RTV732 or General Electric RTV130) along the joint between the flywheel housing and the cylinder block (refer to the following illustration).

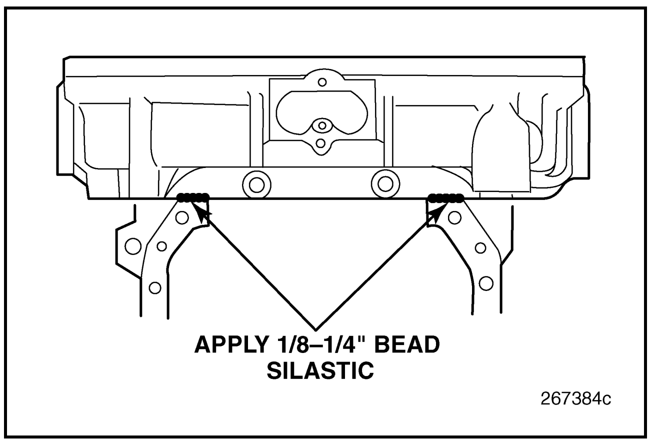


Figure 362 — Apply RTV Sealant to Joint Between Flywheel Housing and Cylinder Block

NOTE

The RTV sealant should not be allowed to “skin over” before the oil pan gasket is installed.

3. Position the isolating oil pan gasket on the oil pan rails with the ribbed side facing up.
4. Beginning at the center of the pan at one of the rectangular tabs, align the rubber locating cones with the corresponding holes in the pan rails (Figure 363).

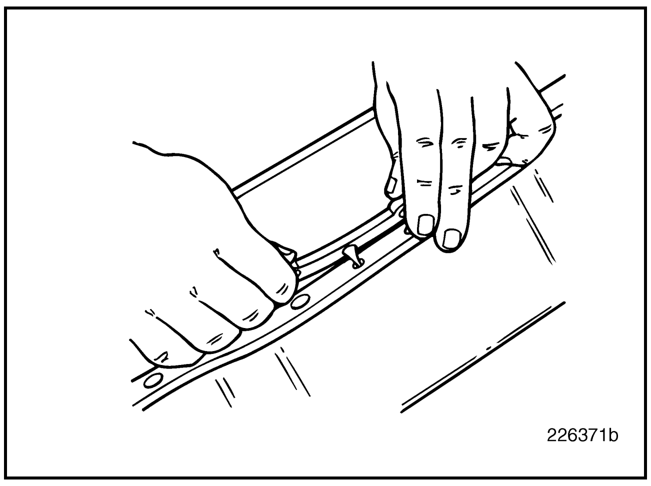


Figure 363 — Locating Cone Alignment

5. In one motion, firmly press down on the gasket with one hand while carefully pulling the rubber cone through the hole with the other hand until seated (Figure 364). Continue this procedure for the remaining locating cones.

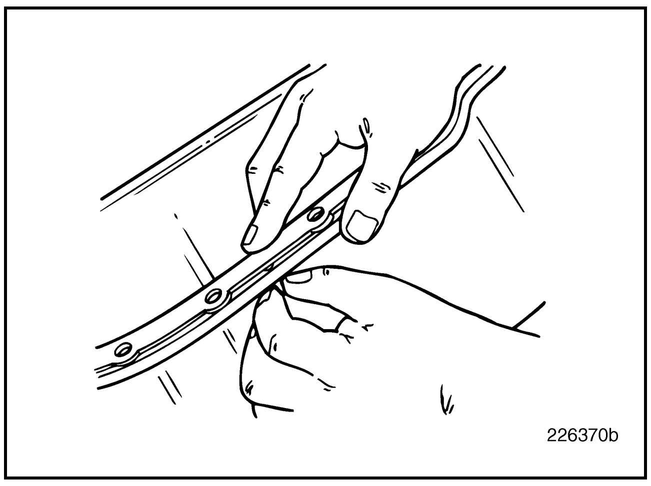


Figure 364 — Locating Cone Installation

6. Visually check the underside of the pan rail to ensure that all locating cones are properly seated.

NOTE

During removal of the isolating oil pan from the engine, the studs may have backed out while loosening the stud nuts. Be sure they are fully seated prior to installing the oil pan.

7. When installing the oil pan on the engine, center the pan before tightening the fasteners so that the edges of the metal isolator washers do not touch the pan. Refer to Figure 365.

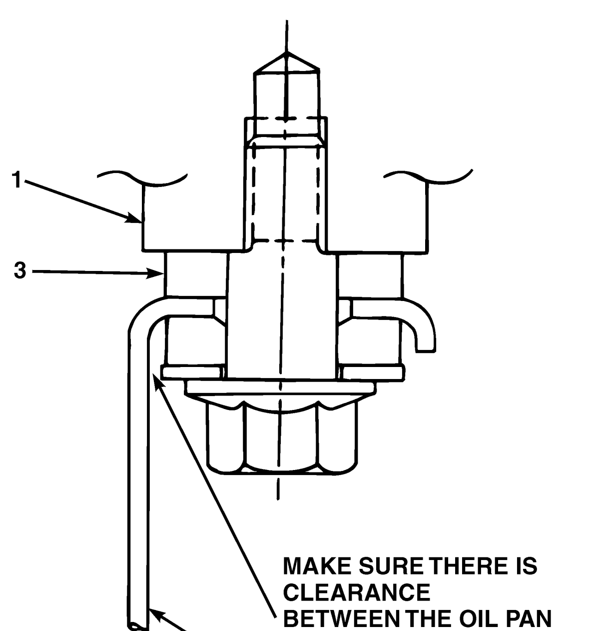


Figure 365 — Checking Clearance

1. Cylinder Block 2. Oil Pan	3. Rubber Gasket

Cylinder Head Installation

[213 EV]

Ensure that the cylinder heads are in acceptable condition. Refer to the cylinder head inspection procedures under "Cylinder Head Reconditioning" in the REPAIR INSTRUCTIONS section.

NOTE

All MACK head gaskets are precoated and do not require any type of additional sealing compound.

Refer to Figure 366.

1. Place the head gaskets in position on the locating pins in the cylinder block deck.
2. Place a fire ring carefully in position on top of each cylinder sleeve.

CAUTION

Check that the design of the fire rings used is the correct match for the cylinder sleeves installed.

3. Place the partially assembled cylinder heads (valves, nozzle holder sleeves, core/pipe plugs installed) in position over the guide pins on the cylinder block.

NOTE

Two of the head mounting capscrews have threaded holes drilled in the heads for bracket-mounting purposes. The drilled capscrews must be located in the correct positions for proper bracket installation.

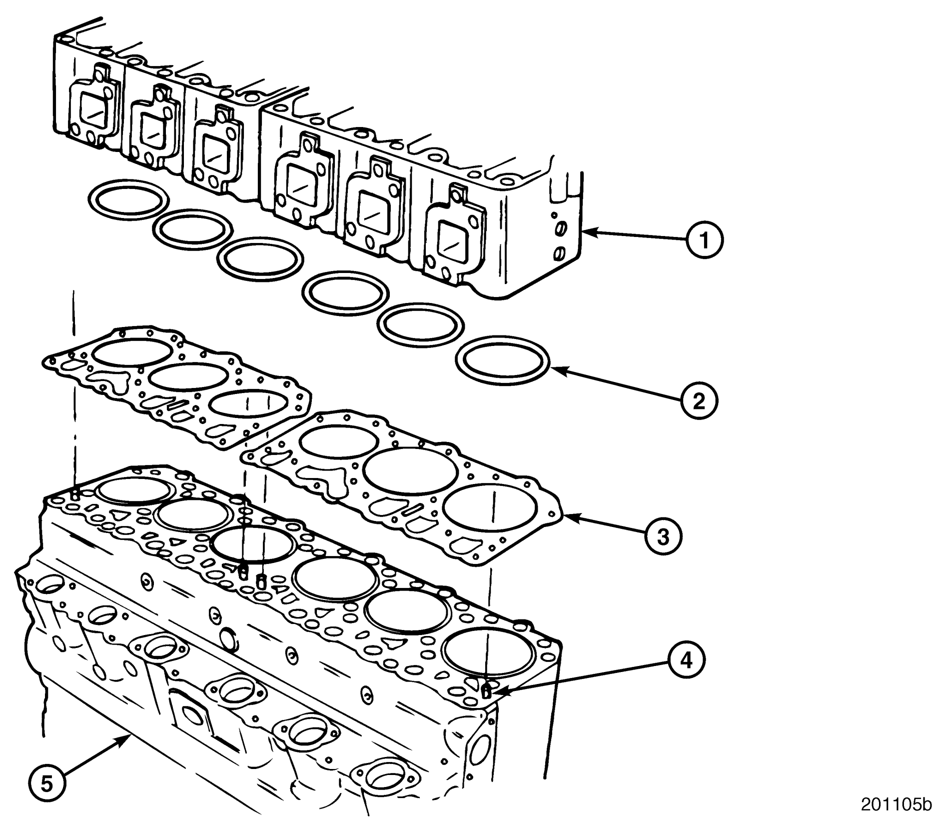


Figure 366 — Cylinder Head Gasket and Fire Ring Positioning

1. Cylinder Head 2. Fire Rings 3. Gasket	4. Guide Pins 5. Cylinder Block

4. Check the condition of the capscrews and lubricate the capscrew heads (underside), threads and washers with clean engine oil. Oil all cylinder head capscrew bosses, but DO NOT oil threads in the cylinder block.

CAUTION

Do not install painted capscrews at locations that are under the cylinder head cover.

5. Insert the short and long capscrews, 7-51/64 inches and 8-55/64 inches (198.0 mm and 225.0 mm), in the respective mounting holes. Tighten all cylinder head capscrews finger-tight.
6. Check the alignment of the cylinder heads by placing a straightedge against the exhaust manifold mounting surfaces (Figure 367). Using a feeler gauge, measure any gaps between the straightedge and manifold mounting surfaces. The heads should be in alignment within 0.005 inch (0.127 mm). If not, reposition the heads to achieve the specified alignment.

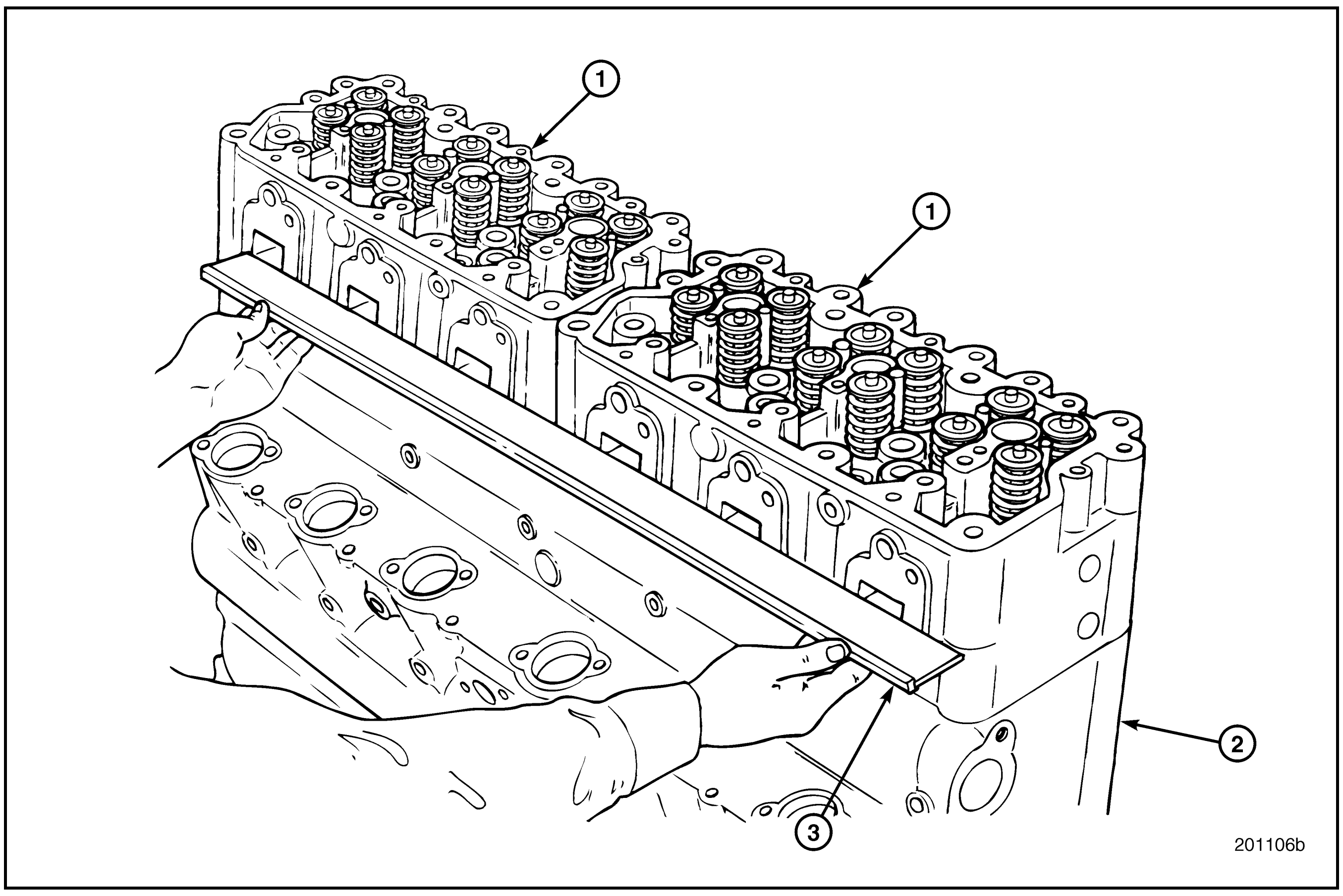


Figure 367 — Cylinder Head Alignment

1. Cylinder Heads 2. Cylinder Block	3. Straightedge

7. Using torque wrench J 24407, or equivalent, tighten all cylinder head mounting capscrews to specification in three steps as listed below. Refer to Figure 368 for the tightening sequence.
   a. Tighten all capscrews in sequence to 50 lb-ft (68 N•m).
   b. Tighten all capscrews in sequence to 125 lb-ft (170 N•m).
   c. Tighten all capscrews in sequence to the final specified torque value of 205 lb-ft (278 N•m).

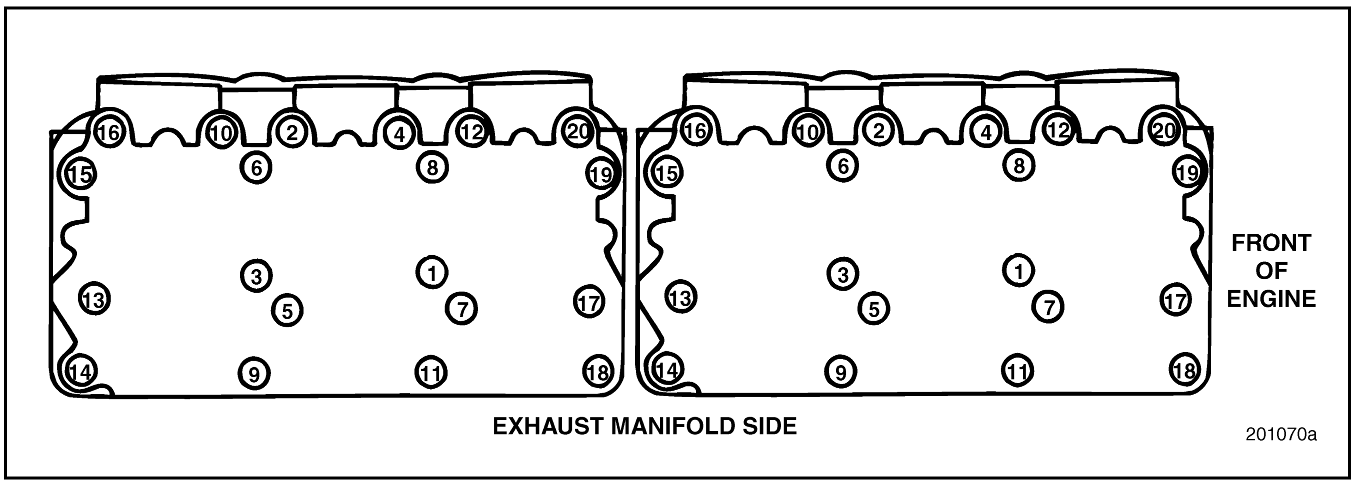


Figure 368 — Head Bolt Torque Sequence Chart

Exhaust Manifold Installation

[214 EG]

MANIFOLD STUD INSTALLATION

It is recommended that all 12 manifold mounting studs be replaced any time the exhaust manifold has been removed.

⚠ CAUTION

Lower exhaust stud holes intersect with the push rod holes; upper exhaust holes may intersect as well. This requires that all exhaust studs be sealed at installation to prevent oil leakage. Replacement studs from the MACK Parts System come with thread sealer pre-applied.

On some engines, the lower or upper exhaust manifold-to-cylinder head stud hole may be drilled deep enough to allow the stud to enter the push rod bore. In these instances, the 20 lb-ft (27 N•m) of torque may not be reached until the stud contacts the push rod. In all cases, a stud protrusion of 1.75 inches (44.45 mm) must be maintained, even if the full torque of 20 lb-ft (27 N•m) is never reached. Refer to Figure 369.

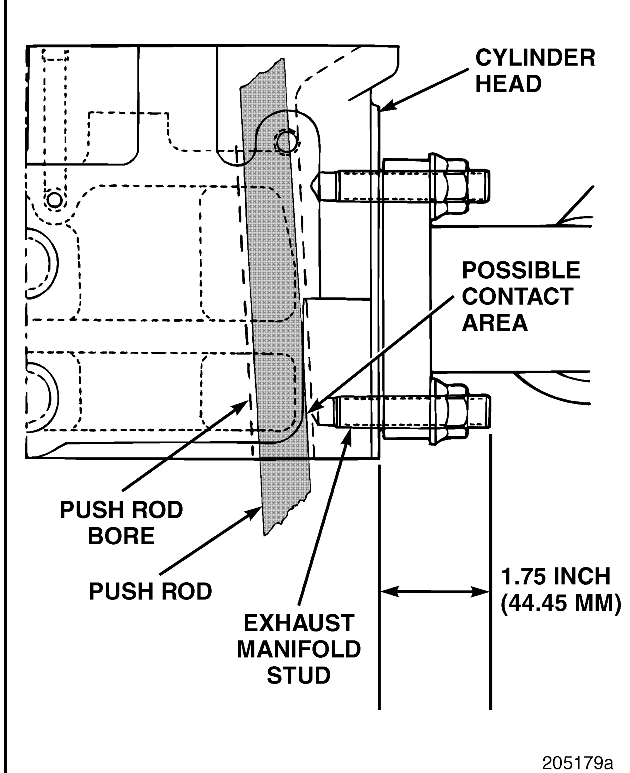


Figure 369 — Exhaust Stud Protrusion

MANIFOLD INSTALLATION

1. Install the 12 **new** studs from the MACK Parts System in position on the cylinder head. Studs must be installed dry (no lubrication). Tighten the studs to the specified torque while maintaining mandatory stud protrusion of 1.75 inches (44.45 mm).
2. Place six **new** manifold gaskets in position on the studs.
3. Place the exhaust manifold in position on the mounting studs. Oil the nut threads and flanges with clean engine oil and install the 12 retaining nuts.
4. Tighten the nuts in two stages following the sequence shown in Figure 370:
   - First stage — 50 lb-ft (68 N•m)
   - Second stage — 100 lb-ft (136 N•m)

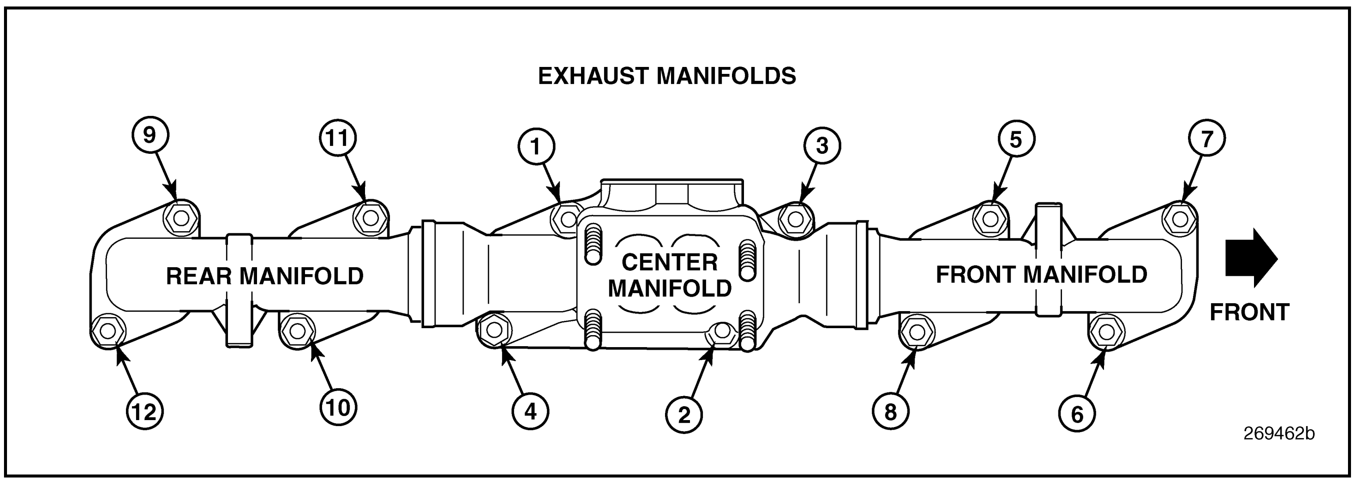


Figure 370 — Exhaust Manifold Tightening Sequence

Nozzle Holder Assembly Installation [222 KG]

GENERAL INFORMATION

The nozzle holder is positioned vertically in the cylinder head and centered in the cylinder between the four valves. The nozzle fuel inlet tube is inserted through the side of the cylinder head with the tapered end of the inlet tube sealing the area between the tube and the nozzle holder. The tube is secured in position with a sleeve nut.

SPECIAL TOOL REQUIRED

- Injection Nozzle Puller J 37093

INSTALLATION PROCEDURE

1. Install the washer-type gasket in place on the bottom of the nozzle, using a small dab of grease to hold it in place (recommended method).

NOTE

An alternate method is to drop the washer-type gasket into the nozzle holder sleeve bore as shown in Figure 371. Make sure that the gasket is centered and lying flat in the bottom of the bore.

CAUTION

Care must be taken with either method of installation to NOT misposition the gasket. If mispositioned, the washer may be damaged and result in severe combustion leakage.

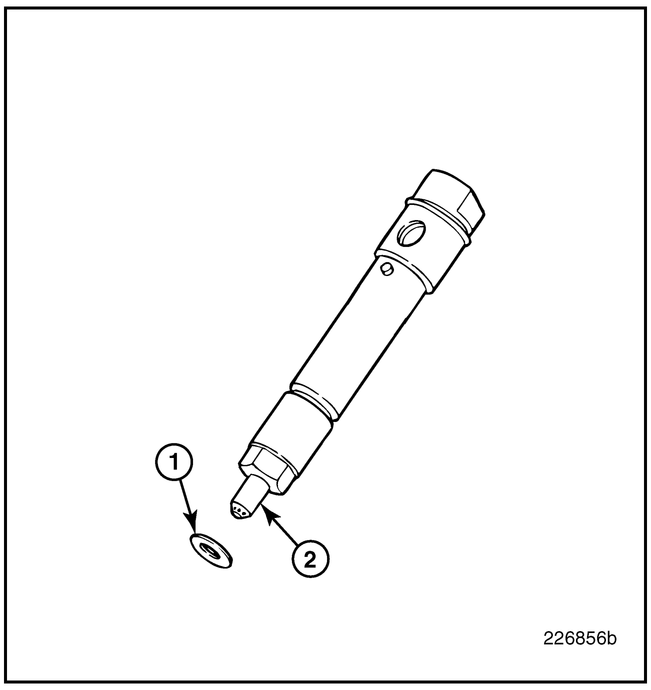


Figure 371 — Nozzle Holder Gasket Installation

1. Washer	2. Nozzle

2. Lubricate the surface of the nozzle holder with clean engine oil and install the top O-ring on the holder.
3. Thread injection nozzle puller J 37093 into the top of nozzle holder as shown in Figure 372.

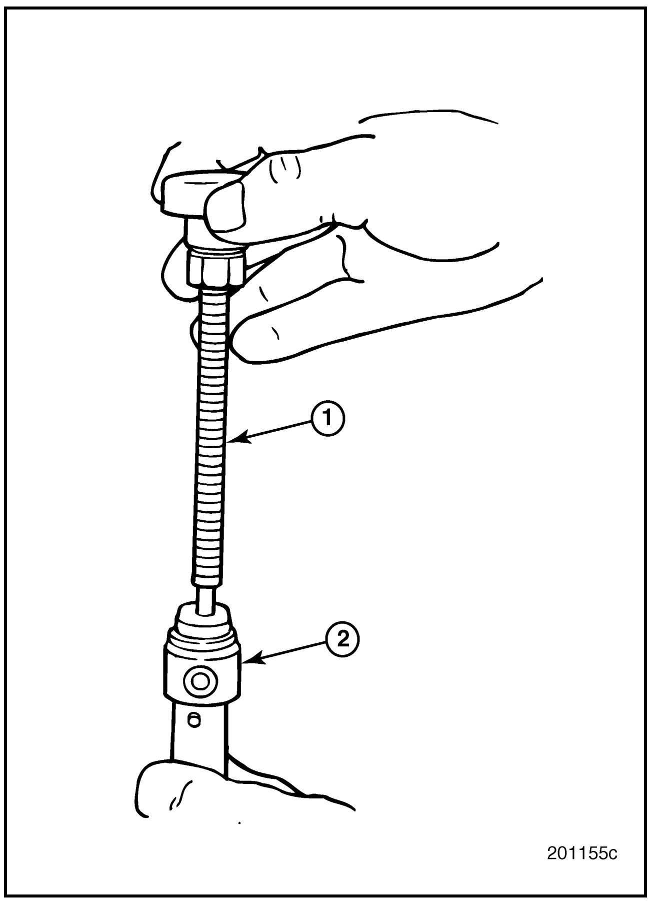


Figure 372 — Puller Application

1. Nozzle Holder Puller J 37093	2. Nozzle Holder

4. Insert the nozzle holder in the nozzle holder sleeve. Be sure to align the locator pin in the nozzle holder with the notch in the holder sleeve to ensure inlet tube alignment. Refer to Figure 373.

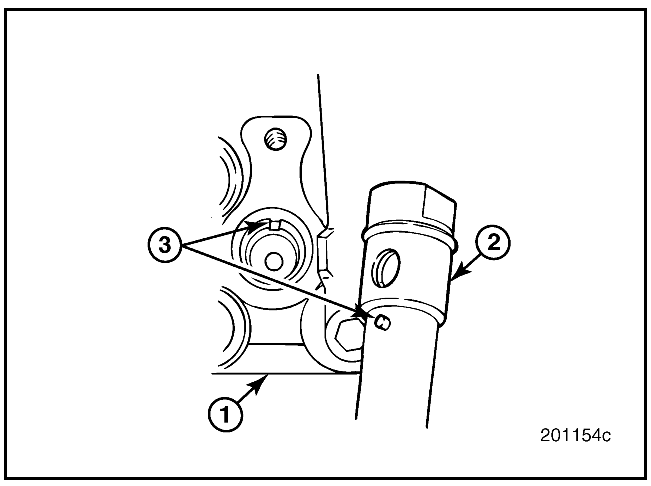


Figure 373 — Nozzle Holder Alignment

1. Cylinder Head 2. Nozzle Holder	3. Locator Pin and Sleeve Notch Must Align.

5. After ensuring that the nozzle holder locator pin is properly aligned with the alignment notch in the nozzle holder sleeve, push downward on the handle of the installation tool driving the nozzle holder into position. Refer to Figure 374.

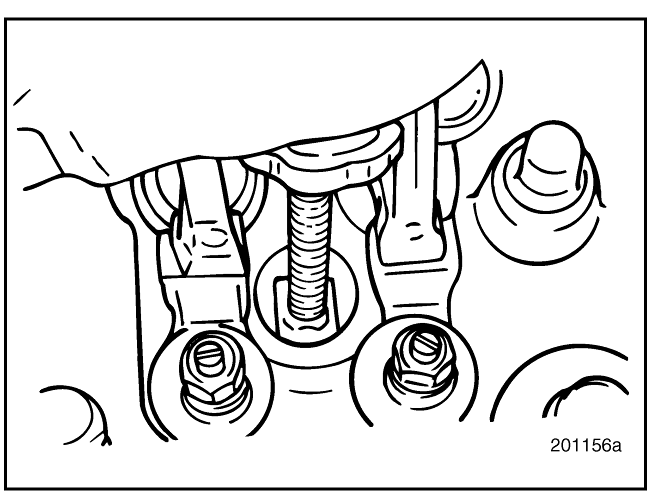


Figure 374 — Nozzle Holder Installation

6. Remove the tool from the nozzle holder and insert the gauge block on the end of the tool handle.

7. Insert the gauge block into the nozzle holder sleeve bore. The gauge block should be flush with the top surface of the cylinder head nozzle sleeve bore. Refer to Figure 375.
   - If the gauge block is below the surface, it may indicate that the gasket was omitted.
   - If the gauge block is too high, it may indicate that there are two gaskets installed under the nozzle holder, or the nozzle holder has not been fully seated in the sleeve.
   - If a gauge block is not available, measure the distance from the top surface of the cylinder head sleeve bore to the top of the nozzle holder. The nominal measurement should be 0.564 inch (14.326 mm).

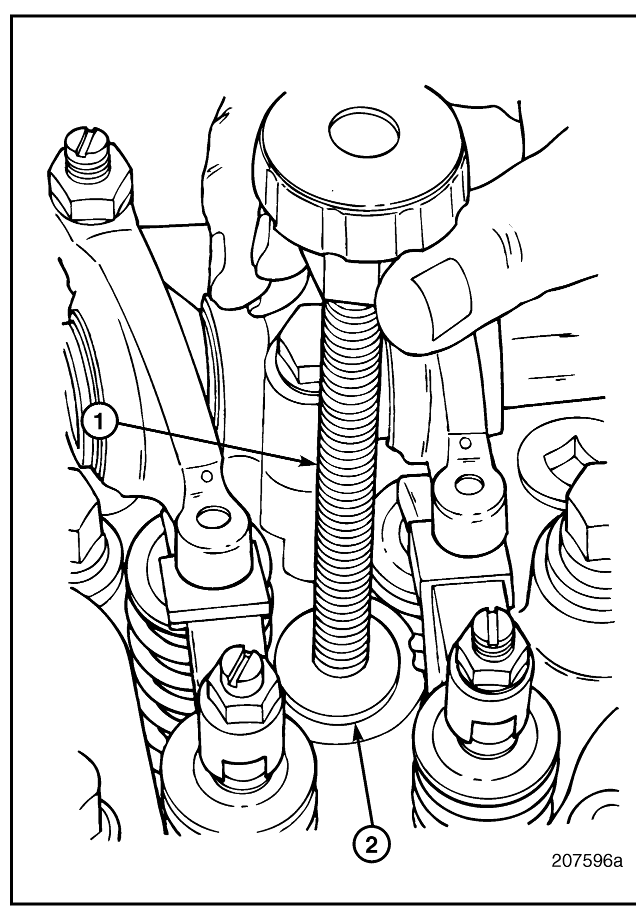


Figure 375 — Nozzle Holder Installation Check

1. Nozzle Holder Puller J 37093	2. Gauge Block

8. Lubricate the threads of the retaining plug and install it as shown in Figure 376. Tighten the plug to the specified torque, 45 lb-ft (61 N•m), using torque wrench J 24407, or equivalent.

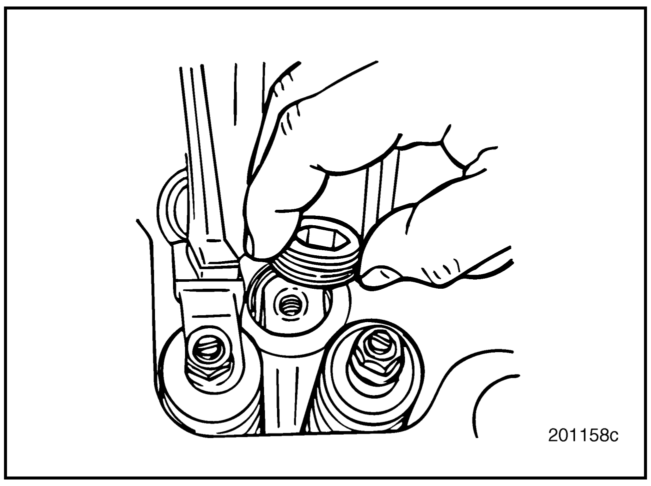


Figure 376 — Retaining Plug Installation

Push Rod Installation

[213 LH]

Check the condition of the push rods before installing them. Replace any rods that have loose ends, are bent, or show signs of excessive wear.

NOTE

Used push rods have established wear patterns. Push rods being returned to service should be installed in the same position from which they were removed.

When installing **new push rods**, make sure that the correct replacement rods are used. There are differences in the rods used for engines with or without an engine brake.

1. Apply lubricating oil to the spherical end of each push rod.
2. Insert the standard fixed-length push rods into the lifter openings at the six inlet valve locations. Use care to gently lower them into position in the lifter cups. DO NOT drop the push rods onto the lifters. Ensure that each rod has engaged the respective lifter by lifting it slightly. If the lifter has been properly contacted, some resistance will be felt in the rod as the lifter is raised.

CAUTION

If a push rod is not properly inserted in the lifter cup and the rocker shaft has been installed, the push rod will "snap" into the cup when the engine crankshaft is rotated for the first time. This impact will break or damage the ceramic roller of the lifter which will require replacement.

3. Insert the standard spring-loaded push rods into the lifter openings at the six exhaust valve locations. Again, ensure that each rod has engaged the lifter by lifting it slightly.

NOTE

Spring-loaded push rods must be pre-lubed by submerging the spring end of the push rod in clean engine oil prior to installation.

Valve Yoke Installation

[213 NV]

GENERAL INFORMATION

There are two exhaust valves and two inlet valves for each cylinder. Each rocker arm, in conjunction with the valve yoke, operates both valves together as a set (exhaust or inlet). It is important that the correct yokes are used. There are two ways of identifying the current and non-current yokes by shape. The current yoke has the nose end of the slipper pad area ground flat as shown in Figure 377.

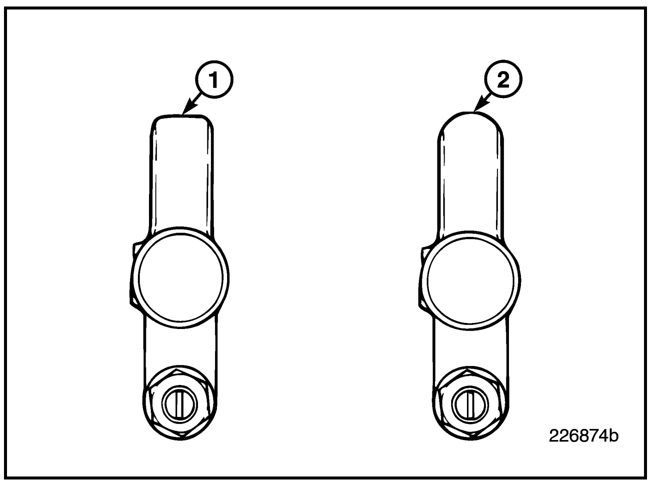


Figure 377 — Valve Yoke Comparison (Top View)

1. Flat Ground Nose (Current)	2. Rounded Nose (Non-Current)

The second method of identifying the valve yoke is by viewing the yoke from the side. The top surface of the adjusting screw end will appear on the same plane as the bottom surface of the "button-head." On earlier engine models, the top surface of the adjusting screw area is 0.145 inch below the bottom surface of the "button-head." Refer to Figure 378 for an illustration of these differences.

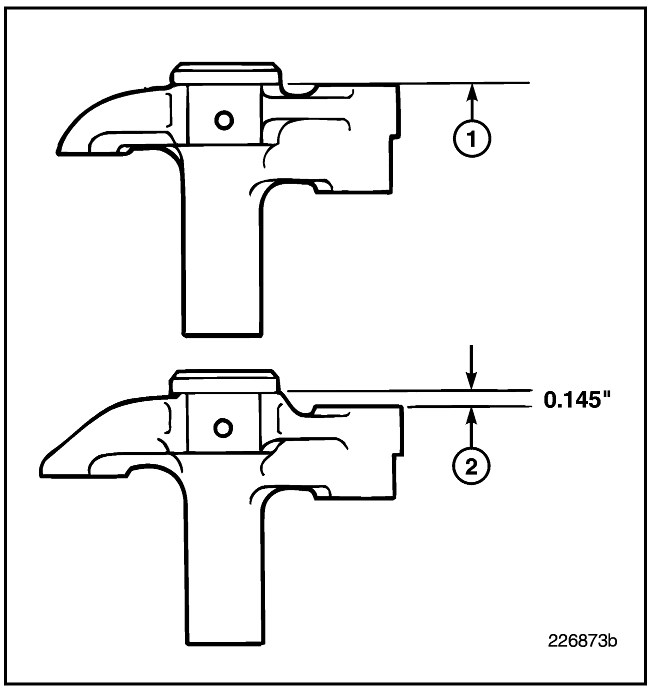


Figure 378 — Valve Yoke Side View

1. Same Plane (Current)	2. Below (Non-Current)

MACK PowerLeash™ Exhaust Valve Yoke

The PowerLeash™ exhaust yokes are different from either the J-Tech™ and the non-brake yokes in that they contain a hole for the exhaust valve actuating pin. The actuating pin rests on a cap that is installed over the tip of the valve stem on the inboard exhaust valve.

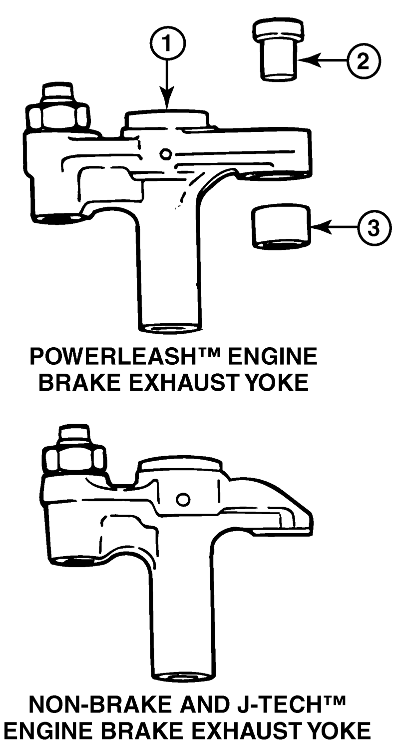


Figure 379 — Valve Yoke Side View

1. Yoke, Exhaust Valve 2. Actuating Pin	3. Cap, Inboard Exhaust Valve Stem Tip

INSTALLATION PROCEDURE

CAUTION

Make sure the correct yokes are used. If an incorrect valve yoke from an earlier engine model is used, the valve keepers will dislodge and cause a dropped valve, resulting in severe engine damage. If an incorrect valve yoke is used on a J-Tech™ brake-equipped engine, the yoke will disengage from the valve stem tip during engine brake operation.

NOTE

Used yokes have established wear patterns. Yokes being returned to service should be installed in the same position from which they were removed.

Refer to Figure 381 for non-brake installations. Although the valve yoke configuration is different, the following installation procedure applies for both non-brake and brake-equipped engines.

1. Lubricate the tips of the exhaust valve stems with a small drop of clean engine oil.
2. For MACK PowerLeash™ engine brake-equipped engines, install the valve stem cap on the tip of the inboard exhaust valve stem.

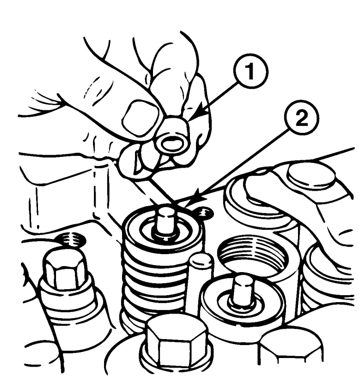


Figure 380 — Installing Valve Stem Cap

1. Cap	2. Inboard Exhaust Valve

3. Lubricate the yoke guide pins (if equipped) with clean engine oil.

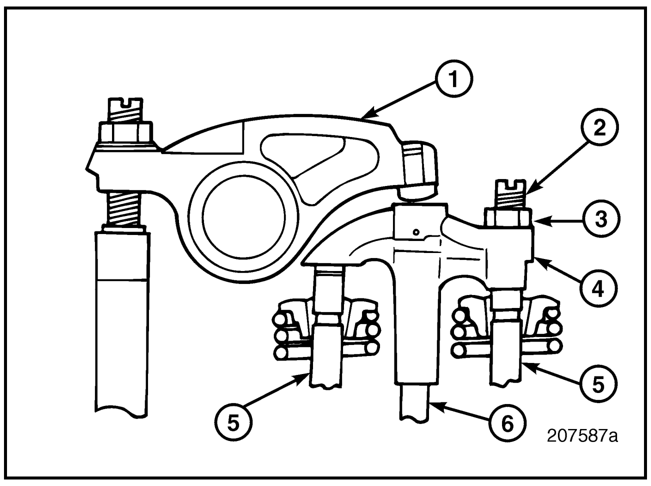


Figure 381 — Pin-Type Valve Yoke (Non-Brake Shown)

1. Rocker Arm	4. Valve Yoke
2. Yoke Adjusting Screw	5. Valve Stem
3. Jam Nut	6. Yoke Guide Pin

4. For non-brake and J-Tech™-equipped engines, place the six exhaust valve yokes on the yoke guide pins from which they were removed.

CAUTION

The exhaust valve yokes on engines equipped with the J-Tech™ engine brake use an actuating pin adjusting screw assembly, part Nos. 421GC41M, 421GC41AM, 421GC41BM or 421GC41CM, in place of the standard yoke adjusting screw at the exhaust valve locations. Make sure that the yokes with the actuator pin assemblies are in position over the exhaust valves.

If the actuating pin adjusting screw assemblies, part Nos. 421GC41M or 421GC41AM, are worn, or there are broken valve yoke guide pins or broken rotator springs, the possibility exists that the engine brake slave piston springs are also broken. The slave piston springs should be removed and inspected as outlined in service bulletin SB-213-027, and replaced as required.

A parts kit, part No. 215SB321, that contains new design reset screws, slave piston springs and actuating pin adjusting screws (part No. 421GC41CM) is available through the MACK Parts System to update the engine brake units. However, always verify that the engine is not already equipped with these new components.

5. For the PowerLeash™ exhaust brake, place the exhaust yoke over the guide pin. The adjusting screw end of the yoke goes over the outboard exhaust valve.

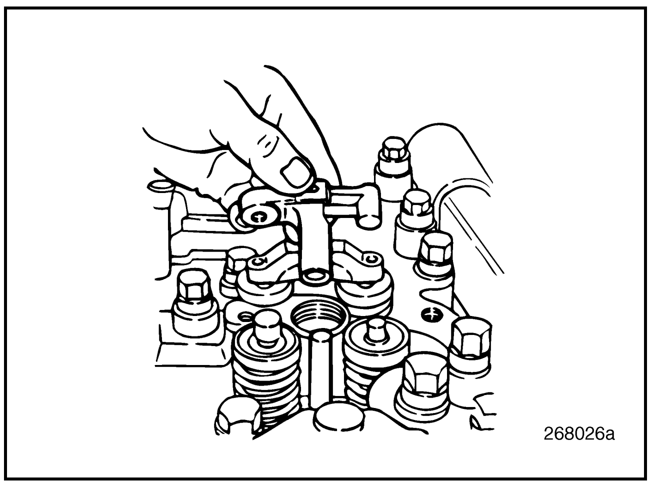


Figure 382 — Installing Exhaust Yoke

6. After the PowerLeash™ exhaust brake valve yokes have been installed, yoke balance can be adjusted. Refer to “Valve Yoke, Valve Lash and Slave Piston Adjustments” in the ENGINE SETUP AND ADJUSTMENTS section.

SERVICE HINT

When assembling the cylinder heads, it is easier to adjust the exhaust valve yoke balance on all the yokes before the rocker shaft assembly is installed.

7. On the PowerLeash™ exhaust brake valve yokes, after adjusting the exhaust yoke lash, lubricate the brake actuating pins with clean engine oil and install.

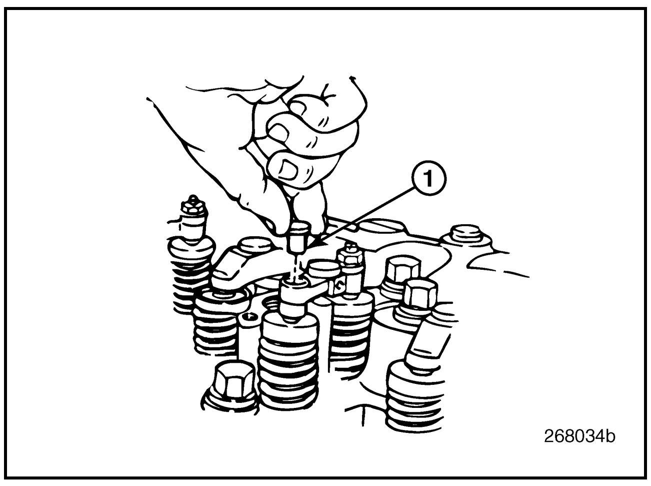


Figure 383 — Installing Brake Actuating Pin in Exhaust Yoke

1. Actuating Pin

8. Place the six pinless-type yokes in position over the inlet valve pairs at each cylinder. The notch and the elongated hole in the valve yoke must be facing away from the rocker arm as shown in Figure 384.

CAUTION

When installing pinless yokes, the end of the yoke with the two notches must face away from the valve rocker shaft. If the yoke is installed incorrectly, it will contact the rocker arm. See Figure 384.

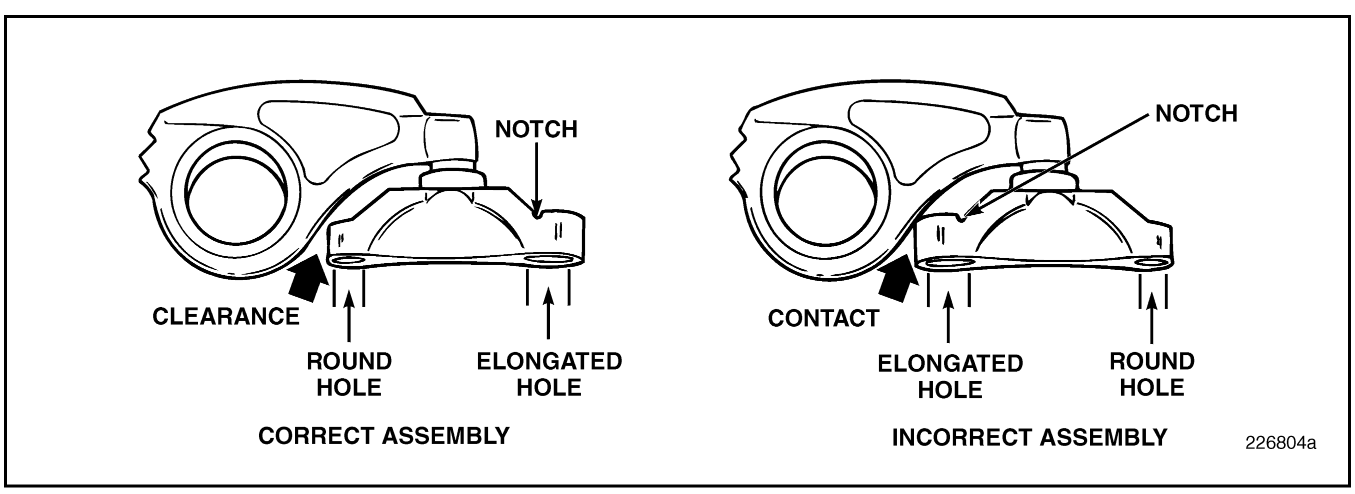


Figure 384 — Proper Assembly of the Pinless Valve Yoke

9. Rock the yokes slightly from side-to-side to be sure they are seated on the valve stems.

CAUTION

The exhaust valve yokes on engines equipped with an engine brake (J-Tech™ or MACK) use an actuator pin assembly in place of the standard yoke adjusting screw. Ensure that the yokes with actuator pin assemblies are in position over the exhaust valves.

Rocker Arm and Engine Brake Installation

[213 LP]

GENERAL INFORMATION

The rocker arms at the inlet valve locations are identical for both non-brake and brake-equipped engines. However, there are three exhaust rocker arm designs used. The MACK PowerLeash™ engine brake uses a completely different exhaust rocker arm design, while the non-brake and J-Tech™-equipped engines use the same design, but with different adjusting screw arrangements:

- **Non-brake engines** use the internal hex adjusting screw with jam nut.
- **J-Tech™-equipped engines** use adjusting screws with spherical jam nuts at the exhaust rocker arms.

In addition, J-Tech™-equipped engines use an oil supply screw in place of the locating screw and lock washer on the rocker arm mounting bracket. This screw provides a passage for supplying oil to the brake housing mounted on top of the rocker arm. The screw also has an integral check valve, eliminating the need for check valve components in the engine brake housing.

The MACK PowerLeash™ engine brake uses a completely different exhaust rocker arm design with an integral brake piston. This design incorporates a hydraulic actuator which hydraulically locks to contact the inboard exhaust valve.

INSTALLATION (NON-BRAKE EQUIPPED ENGINES)

1. Make sure the locating screw and lock washer are in position on the rocker arm mounting bracket for each cylinder head.
2. Make sure that all 12 push rods are properly seated in the respective lifter sockets with standard push rods at the inlet valve locations and spring-loaded at the exhaust valve locations. Use care when checking the push rod seating. DO NOT drop the push rods onto the lifters.

CAUTION

Make sure the rocker adjusting screws are turned completely upward into the rocker arms before installing the rocker shaft or engine brake units on the engine. If this is not done, tightening the mounting bolts for the rocker shafts or engine brake units, or rotating the engine to adjust the valves, can bend the push rods or subject the ceramic rollers to excessive loads which can damage or break the rollers.

3. Place the rocker shaft assemblies in position on the cylinder heads, making sure that the mounting screw holes are properly aligned. Depress the adjusting screw end of each rocker arm so that the adjusting screw ball end is down and in full contact with the push rod cup. With the rocker arm depressed in this fashion, rotate each push rod to be sure it is properly seated in the lifter cup and at the rocker arm adjusting screw.

CAUTION

If the rocker shaft assembly is lifted off the cylinder head anytime during the installation procedure, either partially or completely, steps 2 and 3 above must be repeated. Not having the rockers properly positioned as described in step 3, is the usual cause of a push rod being dislodged from the lifter cup. If this should occur and not be corrected, the ceramic roller will break when the engine is rotated.

4. Lubricate the threads and undersides of the heads of the rocker arm capscrews with clean engine oil. Place the capscrews in the mounting brackets and tighten **by hand** as much as possible.

NOTE

Effective 4th quarter 2005, a revised rocker arm shaft mounting bolt (part No. 416GC23M) was implemented into production. These bolts are available through the MACK Parts System, and should be used as the replacement bolt anytime the rocker arm shaft bolts are removed.

NOTE

If any rocker arm shaft mounting bolts were found to be broken at disassembly, all 12 mounting bolts MUST be replaced.

5. Again, depress each rocker arm adjusting screw so that the ball end is down and in full contact with the push rod cup. As each rocker arm is depressed, rotate the push rod to ensure proper installation.
6. Beginning at the center mounting bracket with capscrew No. 1, tighten the capscrews in the sequence shown in Figure 385. Tighten the capscrews to the specified torque, 45 lb-ft (61 N•m), using an accurately calibrated torque wrench J 24407, or equivalent.

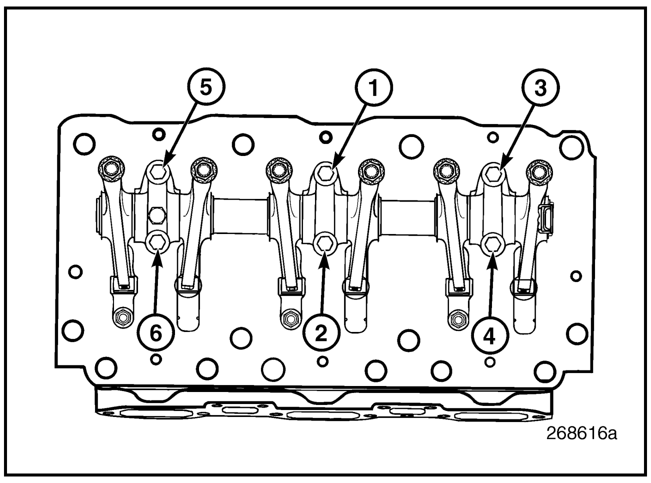


Figure 385 — Rocker Shaft Assembly Capscrew Tightening Sequence

7. Adjust the valve lash to the specified settings. Refer to “Valve Yoke and Valve Lash Adjustments” in the ENGINE SETUP AND ADJUSTMENTS section.

INSTALLATION (J-TECH™ BRAKE-EQUIPPED ENGINES)

Refer to Figure 387.

1. Make sure the oil supply screw is in position on the rocker arm mounting bracket for each cylinder head and tightened to specification, 5 lb-ft (6.8 N•m).
2. Make sure that all 12 push rods are properly seated in the respective lifter sockets with standard push rods at the inlet valve locations and spring-loaded at the exhaust valve locations. Use care when checking the push rod seating. DO NOT drop the push rods onto the lifters.

CAUTION

Make sure the rocker adjusting screws are turned completely upward into the rocker arms before installing the rocker shaft or engine brake units on the engine. If this is not done, tightening the mounting bolts for the rocker shafts or engine brake units, or rotating the engine to adjust the valves, can bend the push rods or subject the ceramic rollers to excessive loads which can damage or break the rollers.

3. Place the rocker shaft assemblies in position on the cylinder heads, making sure that the mounting screw holes are properly aligned. Depress the adjusting screw end of each rocker arm so that the adjusting screw ball end is down and in full contact with the push rod cup. With the rocker arm depressed in this fashion, rotate each push rod to be sure it is properly seated in the lifter cup and at the rocker arm adjusting screw.

CAUTION

If the rocker shaft assembly is lifted off the cylinder head anytime during the installation procedure, either partially or completely, steps 2 and 3 above must be repeated. Not having the rockers properly positioned as described in step 3 is the usual cause of a push rod being dislodged from the lifter cup. If this should occur and not be corrected, the ceramic roller will break when the engine is rotated.

4. Loosen the three slave piston adjusting screw jam nuts on each brake assembly and back out the adjusting screws so that the slave pistons are fully retracted into the housings.
5. Carefully place each housing on the appropriate rocker arm shaft assembly so the oil supply screw engages the locating hole in the brake housing.
6. Lubricate the threads of the brake housing mounting bolts with clean engine oil and install the bolts in the housing mounting bolt holes. Ensure that the correct mounting bolts are used:

   Bolt P/N 416GC22M — use with housing P/N 757GB58.

   Bolt P/N 421GC314M — use with housing P/Ns 757GB58A and 757GB58B.
7. Starting with the center pair of mounting bolts, tighten all six bolts on each housing just enough to seat the housing on the rocker shaft brackets. Make sure the brake housings come down level to avoid possible damage to the rocker shaft brackets.
8. Again, depress each rocker arm adjusting screw so that the ball end is down and in full contact with the push rod cup. As each rocker arm is depressed, rotate the push rod to ensure proper installation.
9. After each brake housing is seated on the cylinder head, tighten the mounting bolts to specification, 45 lb-ft (61 N•m), in the sequence shown (Figure 386).

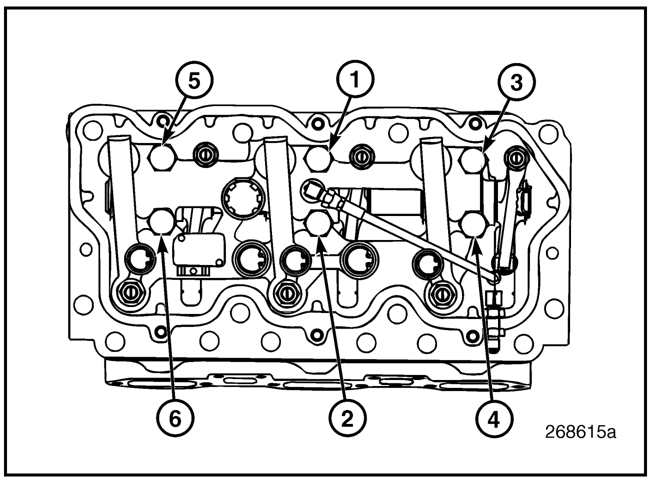


Figure 386 — Engine Brake Assembly Mounting Bolt Tightening Sequence

10. Adjust the valve lash to the specified settings. Refer to “Valve Yoke, Valve Lash and Slave Piston Adjustments” in the ENGINE SETUP AND ADJUSTMENTS section.

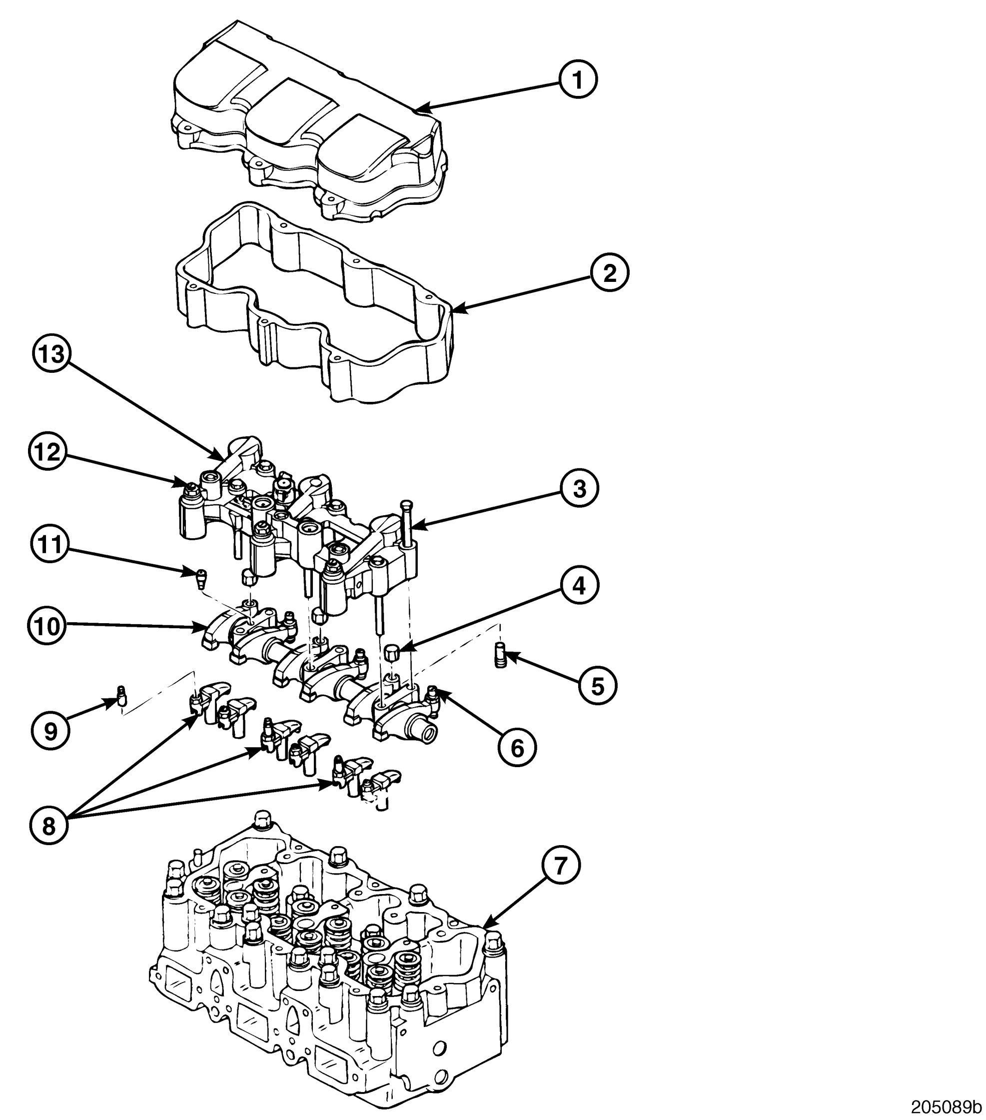
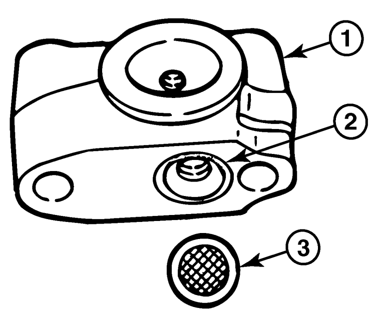


Figure 387 — Rocker Arm Shaft and J-Tech™ Engine Brake Components

1. Cylinder Head Cover	8. Exhaust Valve Yokes
2. Spacer	9. Actuator Pin Assembly
3. Long Capscrew	10. Rocker Arm Shaft Assembly
4. Spherical Jam Nut	11. Oil Supply Screw (New Style Design with Integral Check Valve)
5. Exhaust Adjusting Screw	12. Slave Piston Adjusting Screw
6. Standard Adjusting Screw and Jam Nut (Inlet Valves)	13. Engine Brake Assembly
7. Cylinder Head	

INSTALLATION (MACK POWERLEASH™ BRAKE-EQUIPPED ENGINES)

Before installing the PowerLeash™ rocker shaft, verify that the oil supply screen is positioned in the counterbore at the bottom of the front rocker shaft mounting bracket. If the screen fits loosely in the bore, use some grease to hold the screen in place while the rocker shaft assembly is being installed on the engine.



268028b

Figure 388 — Oil Supply Screen in Front Mounting Bracket

1. Front Mounting Bracket 2. Oil Supply Port	3. Oil Supply Screen

CAUTION

If the screen should slip out of place during installation of the rocker shaft assembly to the engine, the screen edge may become pinched between the rocker shaft mounting bracket and the surface of the cylinder head. If this occurs, broken hold-down bolts, a broken rocker shaft or both can result with the possibility of major engine damage.

1. Make sure all 12 push rods are properly seated in the respective lifter sockets. When installing push rods, use care to gently lower them into position on the lifter cups. DO NOT drop the push rods onto the lifters.

CAUTION

Make sure that all adjusting screws and brake lash adjusting screws are screwed completely upward into the rocker arms before installing the rocker shaft on the engine. If this is not done, tightening the mounting bolts for the rocker shafts or rotating the engine to adjust the valves, can bend the push rods.

2. Place the rocker shaft assemblies on the cylinder heads and align the rocker bracket mounting holes with the holes in the cylinder head. Depress the adjusting screw end of each rocker arm so that the adjusting screw ball end is fully down into each push rod cup. With the rocker arm depressed, rotate each push rod to be sure it is fully seated in the lifter cup and at the rocker arm adjusting screw.

CAUTION

If the rocker shaft assembly is lifted off, or partially lifted off the cylinder head at anytime during the installation procedures, steps 1 and 2 above must be repeated. Not having the rockers positioned as described in step 2 above, or lifting the rockers are the usual causes of dislodging a push rod from the lifter cup.

3. Lubricate the threads of the rocker shaft mounting bracket bolts and the undersides of the bolt heads with clean engine oil. Place the bolts into the mounting brackets, then start each bolt by hand and tighten **by hand** as much as possible.

NOTE

Effective 4th quarter 2005, a revised rocker arm shaft mounting bolt (part No. 416GC23M) was implemented into production. These bolts are available through the MACK Parts System, and should be used as the replacement bolt anytime the rocker arm shaft bolts are removed.

NOTE

If any rocker arm shaft mounting bolts were found to be broken at disassembly, all 12 mounting bolts MUST be replaced.

4. Again, depress the rocker arm screw end of each rocker arm into each push rod and rotate each push rod to ensure proper installation.
5. Beginning at the center mounting bracket with bolt No. 1 (as shown in Figure 389), tighten each rocker shaft mounting bracket bolt evenly (in the sequence shown in Figure 389), keeping the rocker shaft assembly level until the brackets are against the cylinder head. When the brackets have contacted the cylinder head, tighten the mounting bracket bolts in the sequence shown, using a two-step process; first tighten the mounting bolts to 25 lb-ft (34 N•m), then, using the same sequence, tighten the mounting bolts to 45 lb-ft (61 N•m).

CAUTION

The mounting bracket-to-rocker shaft bolts at the center and rear mounting brackets must be FINGER-TIGHT ONLY when the rocker shaft assembly is being installed on the engine. This allows the slip-fit mounting brackets to align and properly seat firmly on the cylinder head surface. After the rocker shaft mounting bolts have been tightened to the proper specifications, the mounting bracket-to-shaft bolts must then be tightened to proper specifications. This ensures that there is no possibility of any relative motion between the mounting bracket and the rocker shaft. Failure to follow this assembly procedure can result in broken hold-down bolts, broken shaft or both, with the possibility of major engine damage.

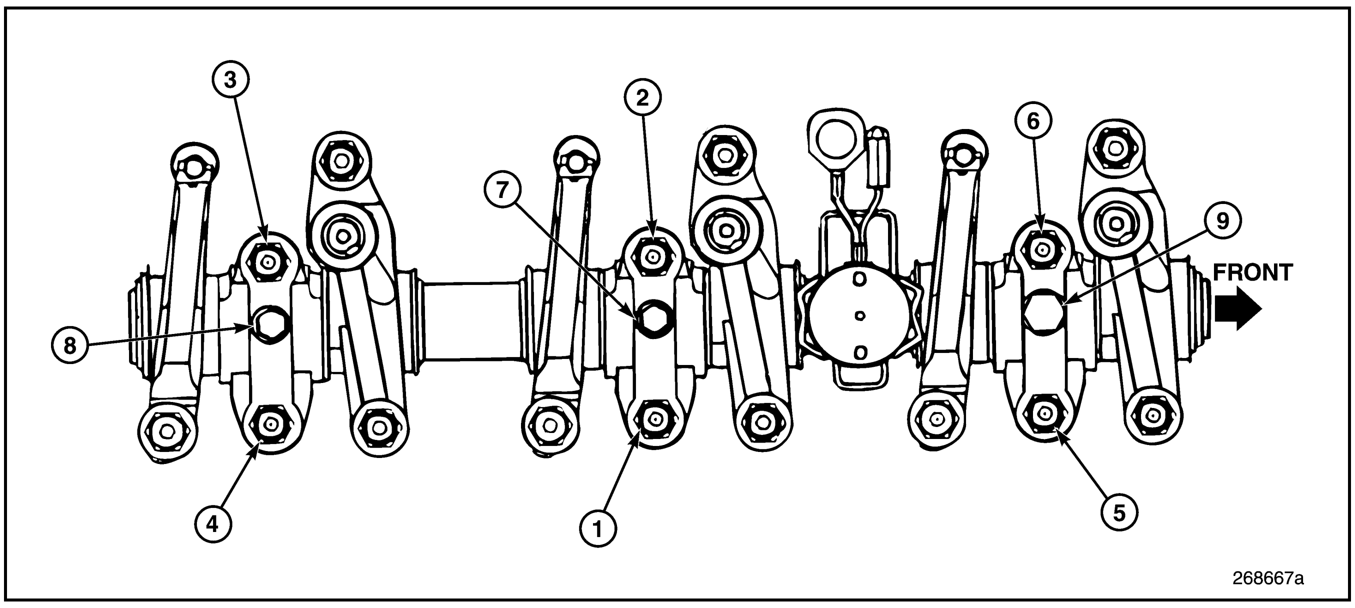


Figure 389 — Tightening Sequence — Rocker Shaft Mounting Bracket and Locating Bolts

6. After the rocker shaft mounting bracket bolts have been properly tightened (bolt Nos. 1 through 6 in Figure 389), tighten the center and rear mounting bracket-to-rocker shaft locating bolts (bolt Nos. 7 and 8 in Figure 389) to 18 lb-ft (24 N•m). The front mounting bracket-to-rocker shaft bolt (bolt No. 9 in Figure 389) can be tightened to 23 lb-ft (31 N•m) anytime during the process.

CAUTION

Whenever the rocker shaft assembly is removed for any type of service procedure, the mounting bracket-to-rocker shaft locating bolts must be loosened. Upon reassembly, the rocker shaft mounting bracket bolts must be tightened as outlined in the procedures above, or serious engine damage may result.

7. After the rocker shaft assembly has been installed, route the solenoid ground wire under the rocker shaft and up through the end of the solenoid retainer clip. Secure the ground wire terminal to the cylinder head mounting bolt located directly to the right of the solenoid. This mounting bolt has a threaded hole in the center of the bolt head. Use a bolt and flat washer to secure the ground wire.

NOTE

While tightening the ground wire terminal retaining bolt, do not allow the terminal to rotate and twist the wire. Use of the flat washer will prevent this from occurring.

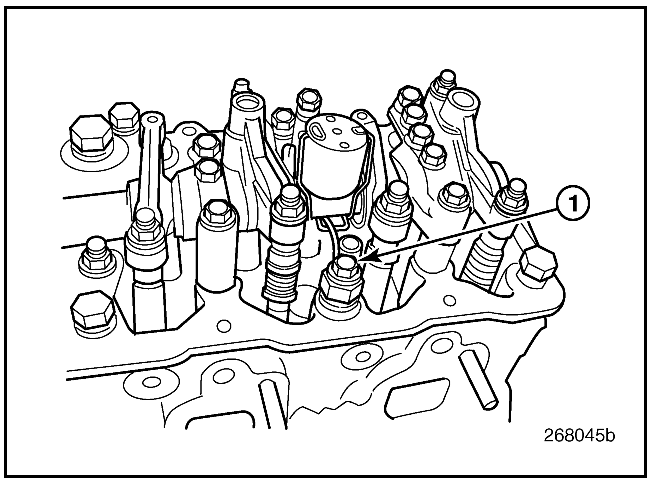


Figure 390 — Engine Brake Solenoid Ground Wire

1. Ground Wire Location

Cylinder Head Cover and Spacer Installation

[213 JB]

GENERAL INFORMATION

A one-piece gasket is used as a seal for the cylinder head cover (and spacer, if equipped with a J-Tech™ engine brake). Sealing compounds are NOT required for this type of gasket. To reduce noise, isolating-type mounting hardware is used to secure the cover to the cylinder head.

To prevent heat-related damage which can occur to the cylinder head cover/J-Tech™ engine brake spacer gaskets, particularly in the area of the turbocharger, a new gasket is now available for all ASET™ engines. The new gasket, which is made from Vamac® G, a material more resistant to hot oil, was phased into production late-December 2002, beginning with serial No. 2Y0622.

In addition to the cylinder head cover gasket, new isolators were implemented into production along with the new gaskets. These isolators are manufactured of a harder material to provide the adequate "crush" necessary for the new gasket material.

NOTE

- When replacing a previous style gasket with the new-style gasket, the existing isolators must also be replaced with the new-style isolators.
- The new cylinder head cover/J-Tech™ spacer gaskets and isolators are easily identifiable by their color. The new gasket and isolators are black in color, whereas the previous parts were gray.

INSTALLATION PROCEDURE

Refer to Figure 391.

NOTE

Installation procedures for the spacer and the cylinder head cover seal are identical.

1. Install a seal in the seal groove of each spacer (if so equipped) and cylinder head cover groove.
   a. Thoroughly clean the seal contact surface on the cylinder head and seal contact surface on the spacer (if so equipped).
   b. Install the offset joined section of the seal in the widened section of the seal groove in the cylinder head cover or spacer.
   c. Guide the seal into the groove around the circumference of the cylinder head cover or spacer.

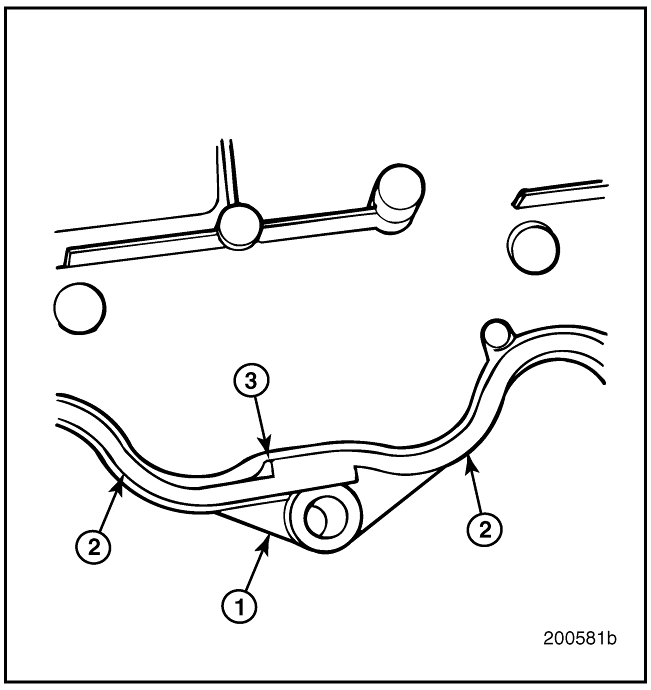


Figure 391 — Gasket Installation (Offset Joined Section Shown)

1. Cylinder Head Cover 2. Seal Strip	3. Seal Groove

2. Place the spacers (if equipped) in position on the cylinder heads.
3. For the engines equipped with J-Tech™ engine brake, connect the electrical lead between the spacer and the actuator on the brake housing.
4. On the MACK PowerLeash™ engine brake, connect the electrical lead from the rocker arm solenoid to the cylinder head cover electrical pass-through connector, inside the cover.

NOTE

At installation of the cylinder head covers, do not place any pull-stress on the solenoid wire. Overstressing the wire could result in engine brake malfunction.

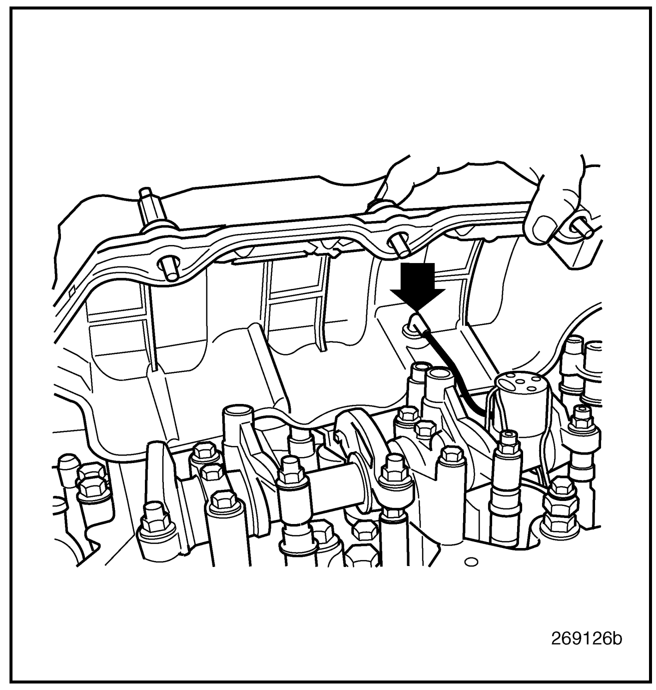


Figure 392 — Cylinder Head Cover Inner Connection

5. For the PowerLeash™, connect the electrical lead from the engine harness to the electrical pass-through connector on the outside of the cylinder head cover.

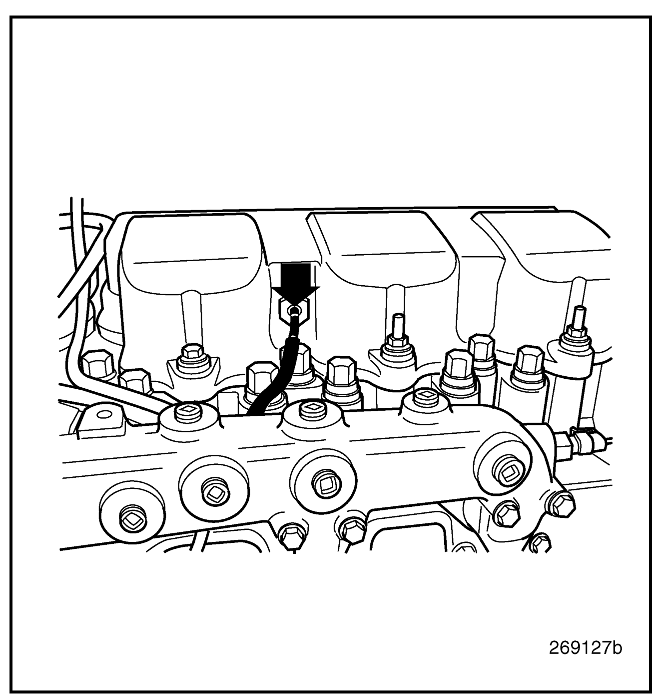


Figure 393 — Cylinder Head Cover Electrical Connection

6. Place the cylinder head covers in position on the cylinder heads or on the J-Tech™ spacers (if so equipped) as shown in Figure 394.

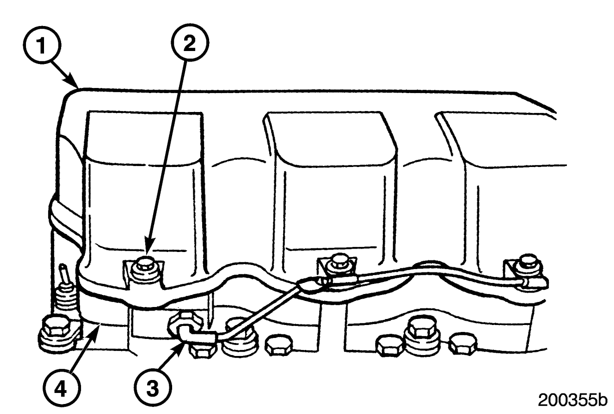


Figure 394 — Cylinder Head Cover Installation

1. Cylinder Head Cover	3. Actuator
2. Capscrew	4. Spacer

7. Place the isolators in position on top of the cylinder head cover's bolt holes.
8. Lubricate the threads of the capscrews and install the capscrews in the cylinder head covers. Tighten the capscrews to the specified torque, 16 lb-ft (22 N•m).

Oil Fill Tube/Dipstick Installation

ASET™ AC ENGINE

The oil fill and dipstick tubes are located on the left side of the engine. As such, it cannot be reinstalled until the engine has been removed from the engine stand.

Air Compressor Installation

[261 CK]

Refer to Figure 395.

NOTE

If the compressor drive coupling has been removed or a replacement compressor is being installed, air compressor coupling holder tool J 41071 will be required to hold the compressor shaft while the coupling nut is being torqued. Torque the coupling nut to 60 lb-ft (81 N•m). Do not use air impact wrench (air gun), use an accurately calibrated torque wrench such as J 24406, or equivalent.

1. Install a **new** gasket on the air compressor mounting flange.
2. Check to ensure that the lubrication oil supply tube is in place and position the air compressor on the mounting flange.

CAUTION

If the oil supply tube is lost, the air compressor will fail from lack of oil.

3. Install the three mounting capscrews and tighten to the specified torque, 80 lb-ft (108 N•m), using torque wrench J 24407, or equivalent.
4. Reconnect the coolant lines to the air compressor cylinder head.

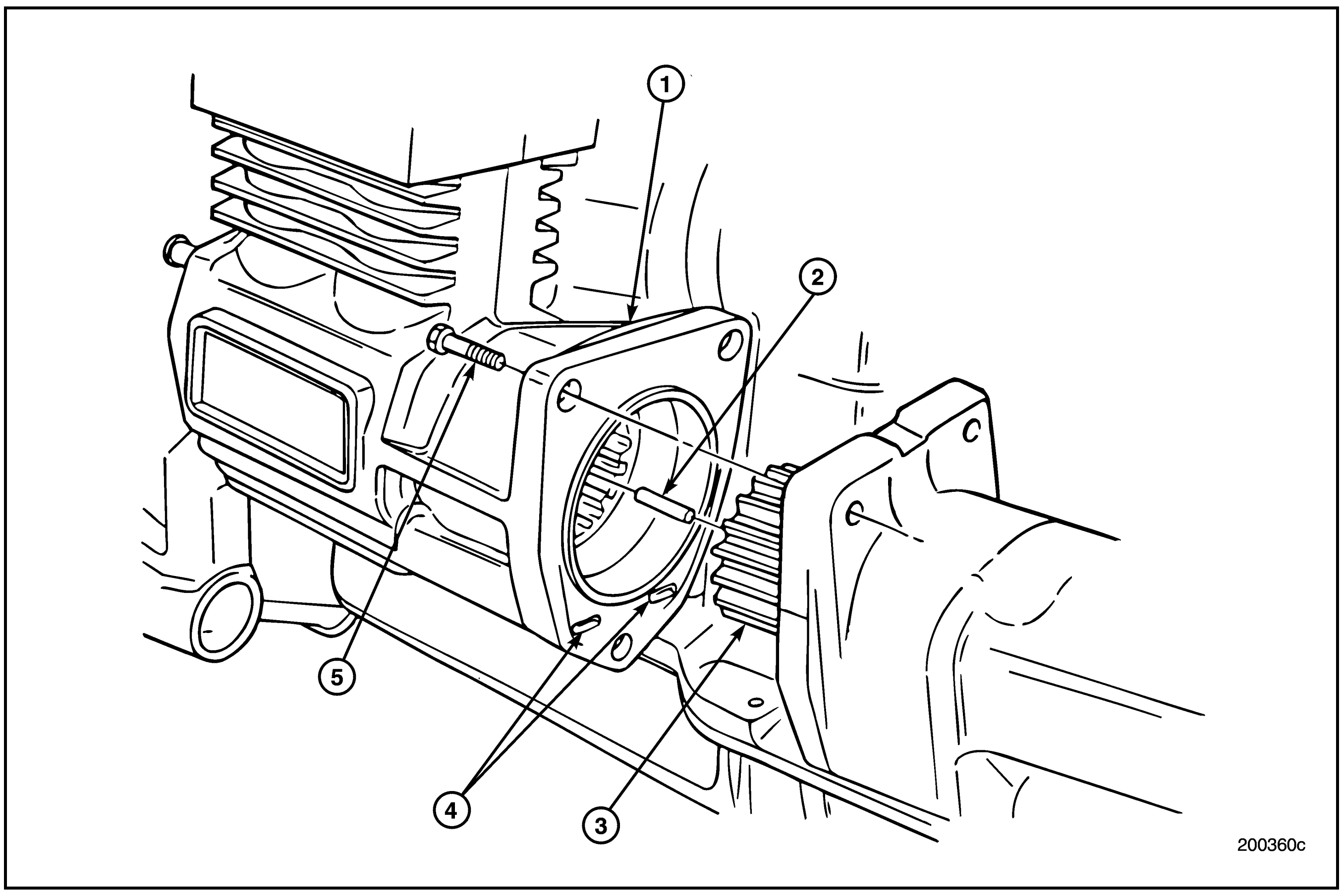


Figure 395 — Air Compressor Installation

1. Air Compressor 2. Oil Supply Tube 3. Auxiliary Shaft	4. Oil Drain Openings 5. Capscrew

Electronic Unit Pump (EUP) Installation

[221 GP]

TAPPET INSTALLATION

1. If not previously done, inspect each EUP mounting screw hole in the engine block for rusty or damaged threads. Clean or tap the block screw holes to remove any rust or dirt as required. Use an M10 x 1.5 bottom tap.
2. Clean the cylinder block at the pump mounting surface and bores, if required.

NOTE

Use only a soft rag and solvent to clean the cylinder block. Minor fretting at the EUP mounting surface is acceptable.

3. Submerge the roller tappets into a container of clean engine oil to allow oil to fill the passages to the roller axles. Remove each tappet and while holding it vertically, spin the roller to make sure the oil flows to the surfaces between the axle and roller. This step is important to provide adequate break-in of the axle and roller at initial start-up of the engine.
4. Carefully install each roller tappet into the bore, pushing it down until it contacts the camshaft lobe. The slot in the roller tappet MUST be oriented outward to align with the pin in the bore. Once installed, the roller tappet should slide freely in the bore.

NOTE

The tappet guide pins in the EUP bores are factory-installed in all cylinder blocks and should not be removed unless damaged.

PUMP INSTALLATION

1. Install **new** O-rings on each of the EUP assemblies.

NOTE

For engines with a history of fuel leakage into the crankcase, a new delta seal O-ring (Figure 396) is available through the MACK Parts System. This seal should be used in the lower O-ring position when necessary to correct leakage.

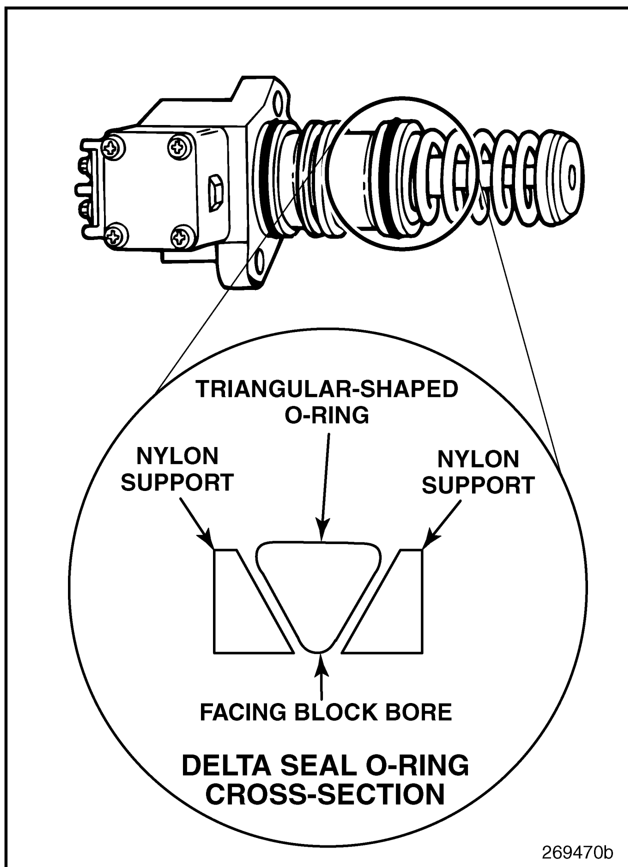


Figure 396 — EUP with Delta Seal O-Ring

2. Generously lubricate the EUP O-rings with clean engine oil and install the No. 1 EUP into the cylinder block (Figure 397).

SERVICE HINT

Oil above the top O-ring should be kept to a minimum to avoid weepage of excess oil (trapped above the top O-ring) onto the cylinder block.

CAUTION

To avoid O-ring damage, the cam lobe must be positioned with the base circle up prior to installation of each EUP. Engine barring tool (tool No. J 3857-A) MUST be used to rotate the engine. DO NOT use the starter to rotate the engine.

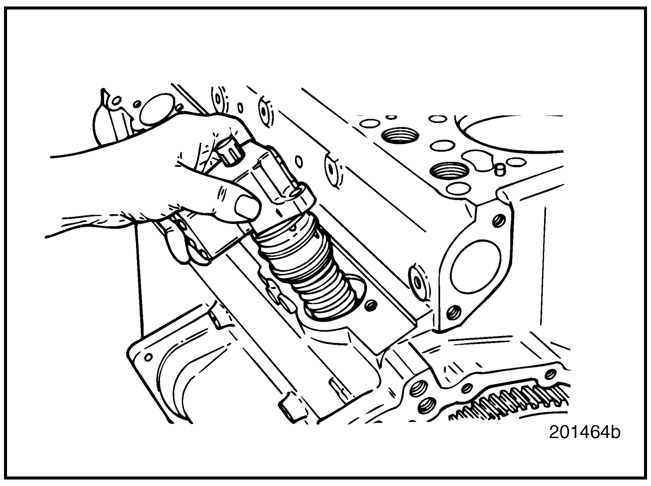


Figure 397 — Unit Pump Installation

3. Install **new** mounting screws. Lubricate the threads and underside of each screw with clean engine oil prior to installation. Tighten the screws evenly to draw the EUP into the cylinder block (Figure 398). Final tighten the screws to the specified torque, 60 lb-ft (81 N•m).

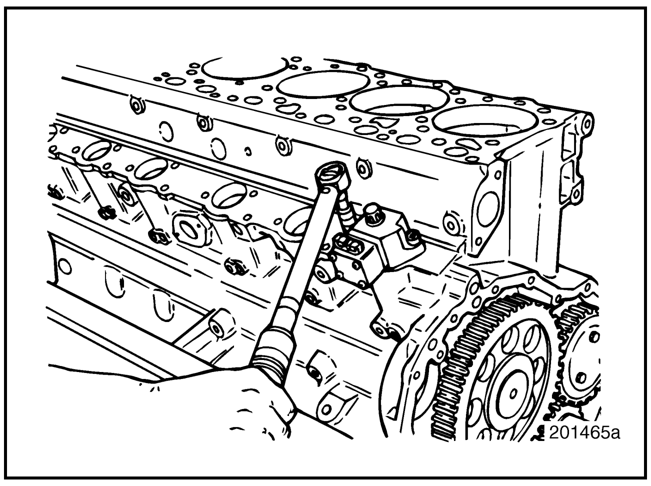


Figure 398 — Tightening Unit Pump Fasteners

4. Repeat steps 2 and 3 to install the five remaining EUP assemblies.

NOTE

If an EUP has been replaced with a new unit, the new unit must be calibrated as described under “Engine Setup and Adjustments” in the REPAIR INSTRUCTIONS section. Calibration of the unit pumps ensures optimum engine performance.

Engine Wiring Harness Installation

1. Place the wiring harness in position on the engine and secure it with the attaching hardware.
2. Connect the harness at each of the EUP terminals.
3. Connect the harness at the EECU. Make sure the locking tabs are in place.
4. Connect the harness to any sensors or other components now installed or as reassembly progresses.

Fuel Nozzle Inlet Tube Assembly Installation

[222 KD]

The fuel nozzle inlet tube assemblies are identical for all six cylinders and are installed in the same way. Refer to Figure 400.

1. Place the EGR heat shield in position over the front section of the exhaust manifold (Figure 401). Install the top capscrew attaching the shield to the cylinder block and tighten it to specification. DO NOT install the bottom capscrews at this time.
2. Inspect the high-pressure fuel lines before installation. If the collars of any of the high-pressure lines are “mushroomed” or exhibit other types of damage, replace with a **new** fuel line. An example of a mushroomed collar is shown in Figure 399.

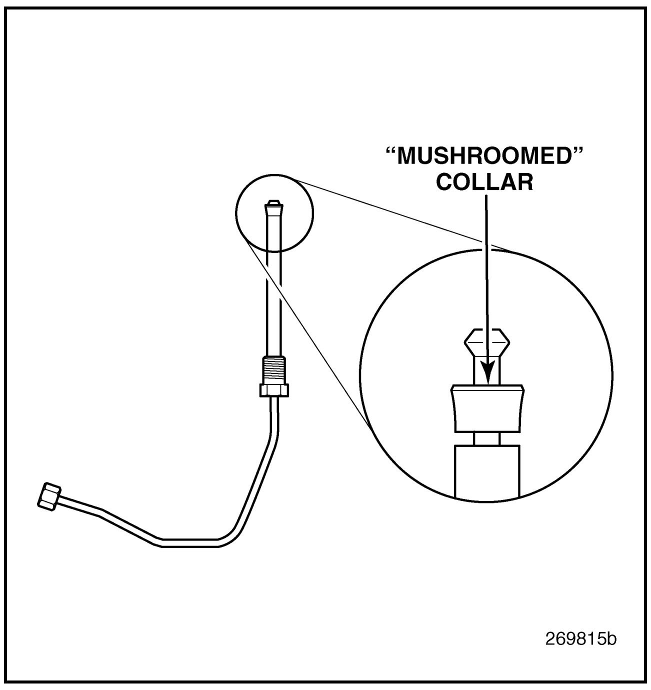


Figure 399 — "Mushroomed" Collar

3. Lubricate the nozzle inlet tube line nut threads on each assembly before installation.

NOTE

Fuel lines should not be bent at any time during the installation process. If lines are bent, damage to the fuel line may result. Even bending the line slightly and then bending it back to its original shape can damage the line.

4. Install the No. 1 cylinder fuel nozzle inlet tube assembly into the cylinder head until light contact is made with the nozzle holder. Lightly tighten the fuel inlet tube line nut clamping screw.

NOTE

The fuel inlet tube assemblies are identical for all six cylinders.

5. Connect the line at the No. 1 unit pump. Tighten the line nut to the specified torque, using torque wrench J 24407, or equivalent.
   - Line nut at cylinder head: 35 lb-ft (47 N•m)
   - Line nut at EUP: 25 lb-ft (34 N•m)

NOTE

An open-ended "crow's foot" adapter is required with the torque wrench for installing the nozzle fuel inlet tube assemblies. Avoid twisting the lines when tightening the line nuts.

6. Repeat steps 1 through 3 for the five remaining fuel nozzle inlet tube assemblies.

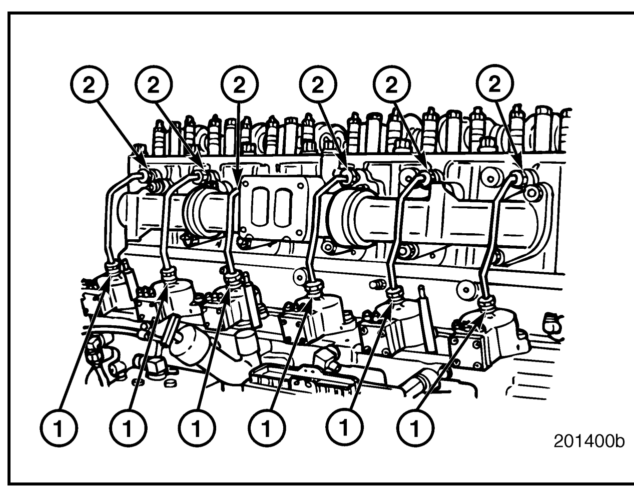


Figure 400 — Fuel Nozzle Inlet Tube Assembly Installation

1. EUP Line Nut	2. Fuel Inlet Tube Line Nut

7. Place the inner EUP heat shield in position against the cylinder block. The bottom flange of the lower EGR heat shield fits between the EUP heat shield and the block.
8. Install the four capscrews to secure the inner EUP heat shield and EGR heat shield. Tighten the capscrews to specification, 15 lb-ft (20 N•m).
9. Install the outer EUP heat shields and retaining nuts. Tighten the nuts to specification, 15 lb-ft (20•m).

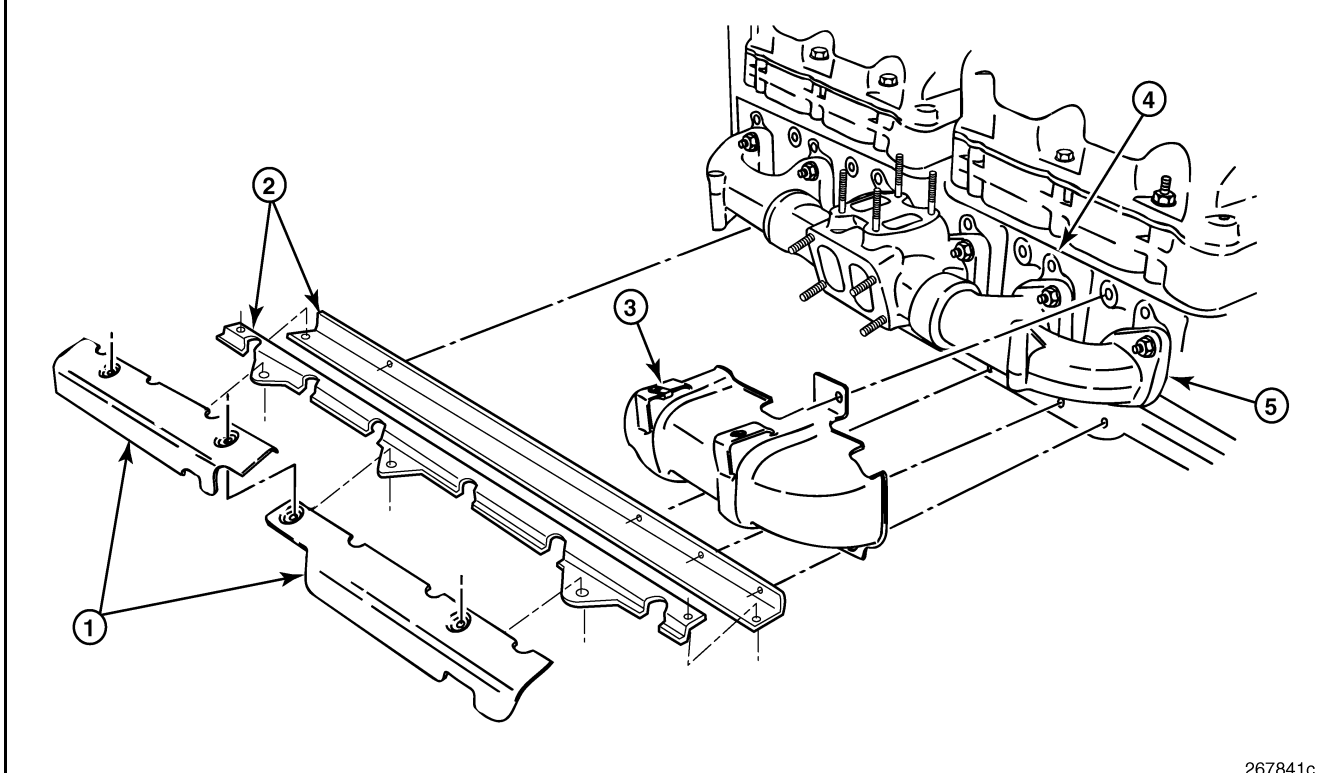


Figure 401 — EGR and EUP Heat Shield Installation

1. Outer EUP Heat Shields 2. Inner EUP Heat Shield (Two Piece) 3. EGR Valve Heat Shield	4. Cylinder Heads 5. Exhaust Manifold

Turbocharger Installation

[214 SC]

Refer to Figure 403.

NOTE

A thorough inspection is required as even small particles can cause severe rotor damage if inducted during high-speed operation.

Use only **new** and approved gaskets at the various air, oil and exhaust connections to the turbocharger. Avoid the use of sealing or jointing compounds at all flanged connections.

CAUTION

After completing the reassembly of the engine, the turbocharger must be prelubricated with clean engine oil before starting the engine. Refer to the procedure under "Turbocharger" in the ENGINE PREPARATION AND OPERATIONAL CHECK section.

1. Inspect the intake and exhaust systems leading to and from the turbocharger to ensure absence of foreign material, including burrs and loose lining fragments. Place protective caps over the compressor and turbine outlets to keep debris and dirt out of the turbocharger as engine reassembly progresses.
2. Install a **new** turbocharger gasket over the four mounting studs.

CAUTION

The turbocharger is heavy, weighing approximately 76 lbs. DO NOT attempt to remove or install the turbocharger without the help of an assistant or the use of a suitable lifting device.

3. Place the turbocharger in position over the mounting studs on the exhaust manifold.
4. Apply a coating of clean engine oil to the flanges and threads of the four nuts. Install the nuts and using torque wrench J 24406, or equivalent, tighten the nuts in a cross-pattern sequence (Figure 402) in two stages:
   - First stage — 50 lb-ft (68 N•m)
   - Second stage — 100 lb-ft (136 N•m)

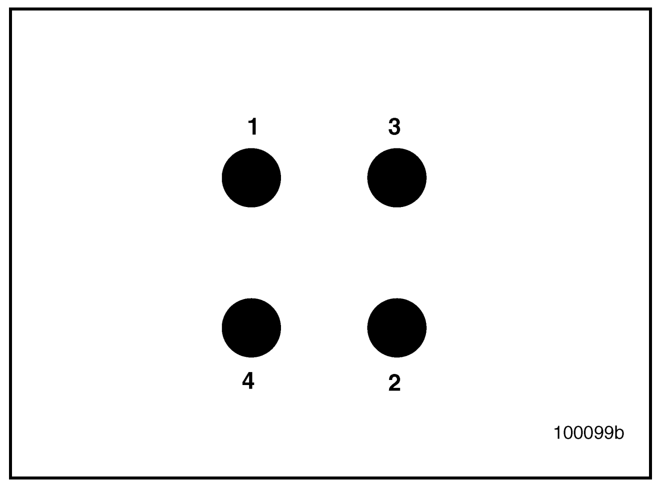


Figure 402 — Turbocharger Tightening Sequence

5. Inspect the turbocharger oil supply line to make sure it is flushed clean and free of all debris. Then, install the supply line.
6. Place the oil drain tube in position between the port on the engine block and the turbocharger. Apply anti-seize compound to the threads of the capscrews and install the capscrews. Tighten the capscrews to the specified torque, 15 lb-ft (20 N•m), using torque wrench J 24406, or equivalent.

NOTE

If the VTG actuator has been removed, refer to "VTG TURBOCHARGER SERVICE PROCEDURES (ASET™ AC ENGINE)" for installation and adjustment procedures.

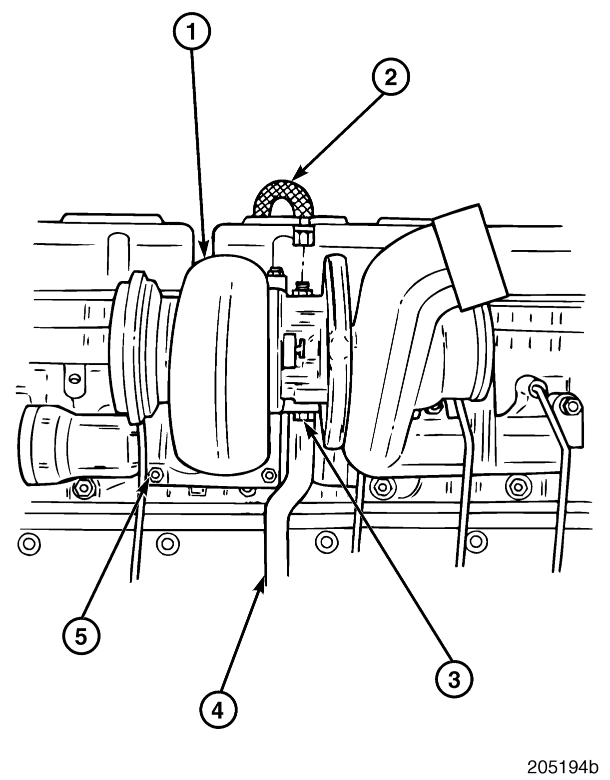


Figure 403 — Turbocharger Installation

1. Turbocharger 2. Lubrication Supply Hose 3. Capscrew	4. Lubrication Drain Tube 5. Mounting Nut

Coolant Manifold Installation

[215 NK]

INSPECTION

Check the coolant manifold for restrictions, cracks and flange wear. The manifold cannot be repaired. Replace if any signs of damage are present.

INSTALLATION PROCEDURE

Refer to Figure 404

1. Ensure that the manifold is clean. Place a **new** coolant/air inlet manifold gasket in position on the mounting surface of each cylinder head.
2. Lubricate the threads of the coolant manifold flangehead capscrews with clean engine oil.
3. Place the manifold in position on the cylinder heads and insert the capscrews. Tighten the capscrews to the specified torque, 40 lb-ft (55 N•m), using torque wrench J 24406, or equivalent.

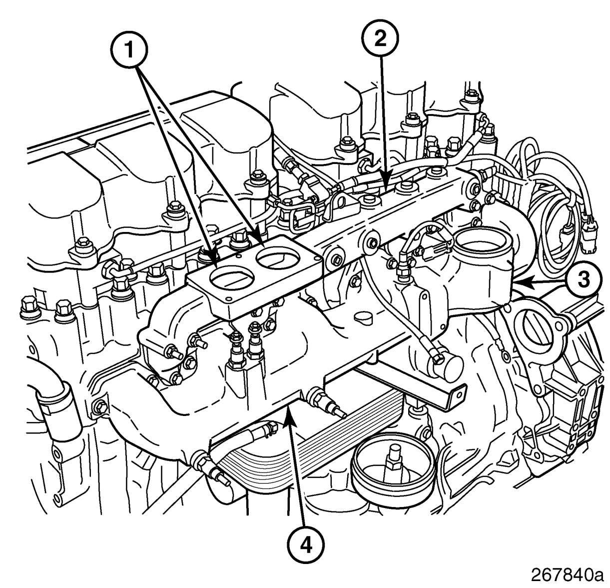


Figure 404 — Coolant and Air Inlet Manifolds

1. Thermostat Ports 2. Coolant Manifold	3. Mixer Tube Mounting 4. Inlet Manifold

Air Inlet Manifold Installation

[214 HD]

Refer to Figure 404.

1. Lubricate the threads of the air inlet manifold capscrews.
2. Place the inlet manifold in position on the cylinder head and install the capscrews.
3. Torque the capscrews to 40 lb-ft (54 N•m), using torque wrench J 24407, or equivalent.

VTG Position Control Valve Installation

[214 QB]

Refer to Figure 405 as reference for installing the VTG position control valve.

1. Place the control valve assembly in position on the inlet manifold and install the two mounting capscrews. Tighten the capscrews to specification.
2. Connect the actuator air line to the fitting at the side of the valve.
3. Connect the harness electrical lead to the terminal at the top of the valve.

NOTE

If the engine is equipped with a coalescing air filter, the air line between the VTG position control valve and the filter IS NOT installed until after the engine is removed from the engine stand.

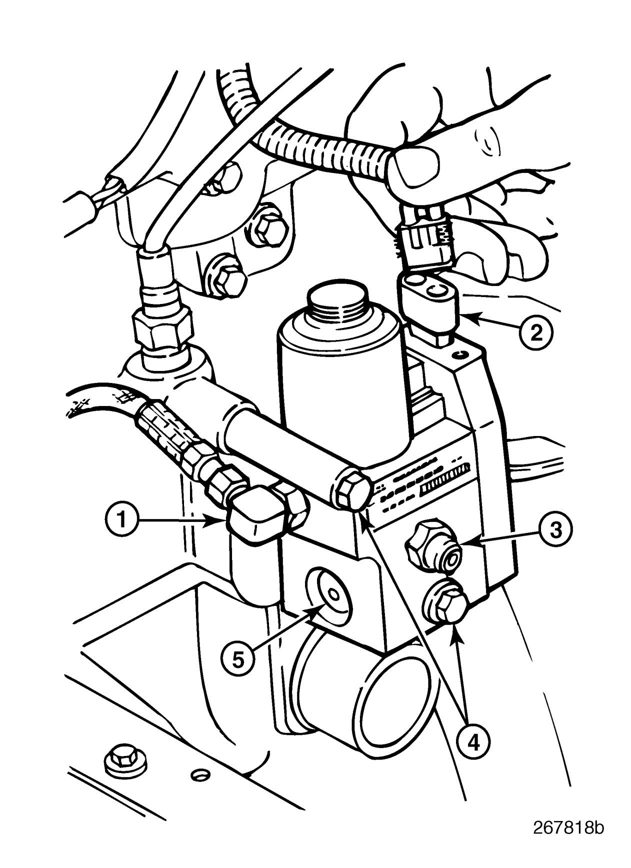


Figure 405 — VTG Position Control Valve

1. Air Line to VTG Actuator 2. Electrical Connector 3. Air Supply Port	4. Mounting Capscrews 5. Air Bleed Port

Water Pump Housing Installation

[215 SD]

The ASET™ AC water pump assembly is completely redesigned with very different and essential steps required for proper installation. Refer to Figure 406 as you work through the procedure.

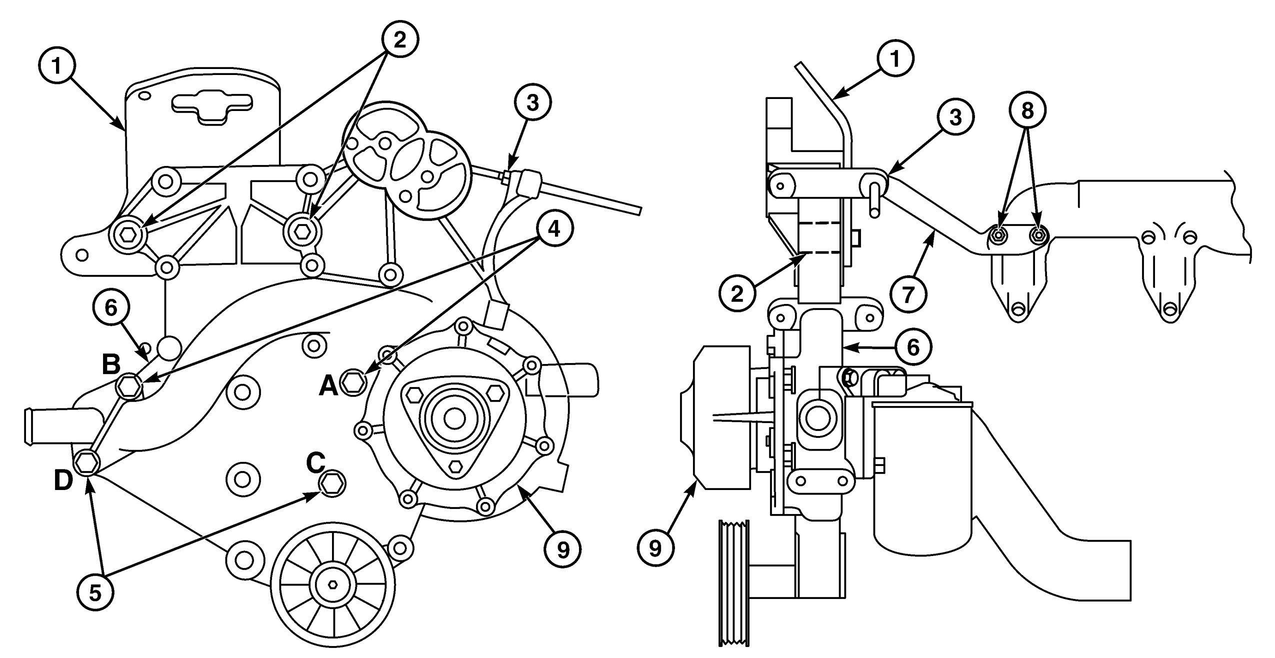


Figure 406 — Water Pump Installation

1. Engine Lifting Bracket 2. Threaded Inserts and Upper Mounting Capscrews 3. Stiffening Bracket Forward Mount 4. Mid-Position Mounting Capscrews 5. Low-Position Mounting Capscrews	6. Water Pump Assembly (Housing and Cartridge) 7. Water Pump Stiffening Bracket 8. Stiffening Bracket Rear Mount 9. Water Pump Cartridge

1. With the water pump housing positioned on a bench with the cylinder block/head mounting surface facing up, place a **new** O-ring in the groove at the coolant inlet flange. Use MACK Code 442 grease or any quality O-ring grease to hold the O-rings in place for assembly.
2. Stand the housing on edge and from the front, start the threaded inserts into the mounting bores at the top of the housing (Figure 407). Turn them in until the collar of each protrudes from the back side and the shoulder is 0.020-inch (0.5 mm) under to flush with the back side.

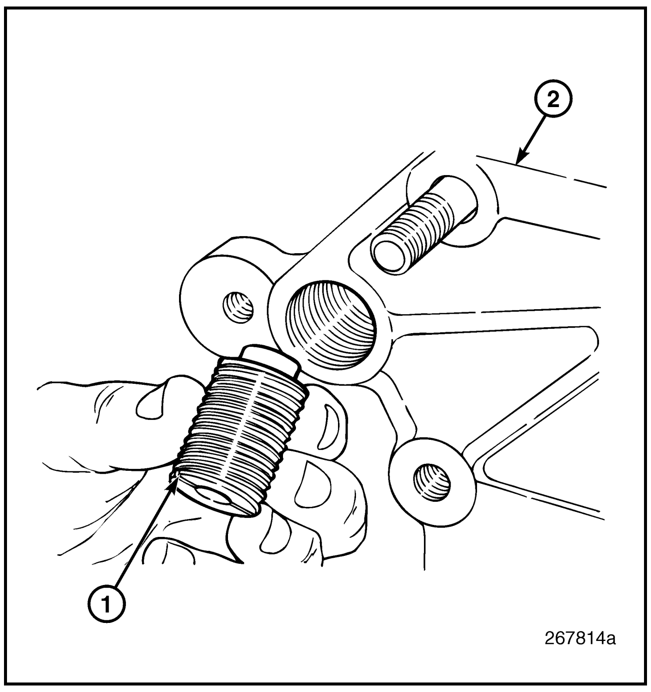


Figure 407 — Threaded Insert Installation

1. Threaded Insert	2. Pump Housing

3. Again, with the housing standing on edge and from the front, insert two mounting capscrews and washers into the mid-position bolt holes. The two mid-position holes are slightly smaller to serve as pilot holes for installation.

CAUTION

The water pump cartridge assembly and water pump housing mounting bolts should not be lubricated before installation. Instead, apply thread sealing compound to all cartridge assembly and housing capscrews.

4. Place the housing in position at the front of the cylinder block and start the mid-position capscrews into the block, far enough to secure the housing from falling. The housing should be free to move slightly back for installation of the engine lifting bracket in the following steps.
5. Place the engine lifting bracket in position (bend angle facing forward) between the housing and cylinder head (Figure 406). Make sure the bracket mounting holes clear and slip into position on the insert collars.
6. Push the housing against the block and hand-tighten the mid-position mounting capscrews.
7. Install the two mounting capscrews and washers in the low-position mounting holes, hand-tight.
8. Make sure the lifting bracket mounting holes are properly positioned on the insert collars and then tighten the mid-position and low-position capscrews to specification, 69 lb-ft (94 N•m), in sequence A, B, C, D shown in Figure 406.
9. Using a suitable slotted socket, tighten the two threaded inserts to specification, 50 lb-in (5.6 N•m).

CAUTION

*Insert is to be tightened to **51 lb-in (5.6 N•m)**. Use care not to overtighten the threaded inserts. Doing so could place undue stress on the housing, causing it to bow and eventually break.*

10. Install the remaining two mounting capscrews (no washers) through the threaded inserts and tighten to specification, 40 lb-ft (55 N•m).

11. Position the water pump stiffening bracket over the two studs at the forward position of the coolant manifold. At the same time, position the forward section of the stiffening bracket over the backside of the A/C compressor upper rear mounting stud. Install the three M8 flanged nuts on the stiffening bracket and tighten to 20 lb-ft (27 N•m). Refer to Figure 408.

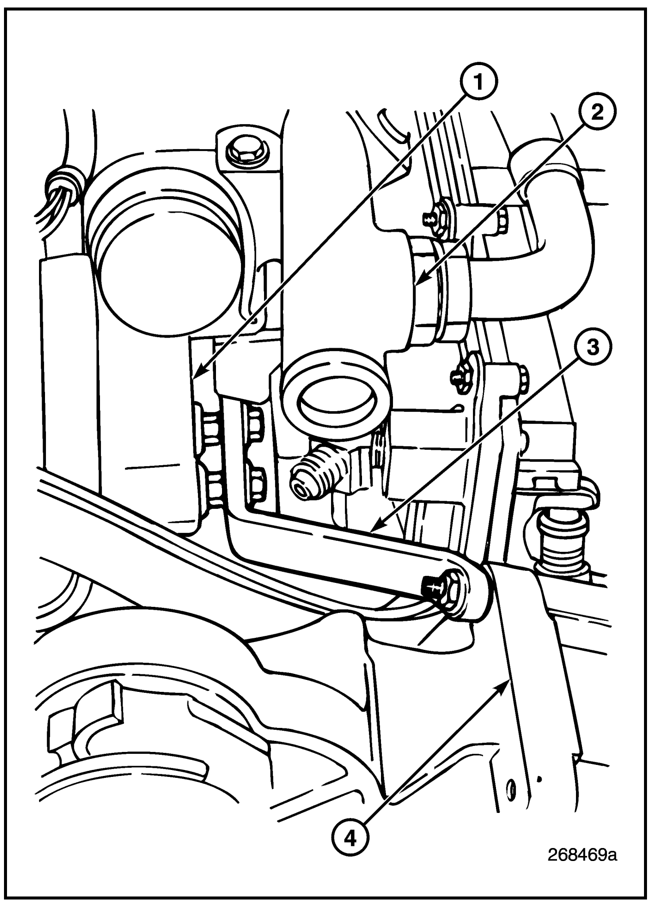


Figure 408 — Stiffening Bracket

1. Coolant Manifold	3. Stiffening Bracket
2. Thermostat Housing	4. Water Pump Housing

NOTE

It is important not to install the stiffening bracket before the water pump housing fasteners have been torqued in place. Installing the bracket before the housing capscrews have been tightened may put undue stress on the top of the housing and cause damage to the housing.

12. Install the coolant inlet tube (from the oil cooler) on the inlet port at the back of the water pump on the left side of the engine (Figure 409). Tighten the capscrews to 40 lb-ft (55 N•m).

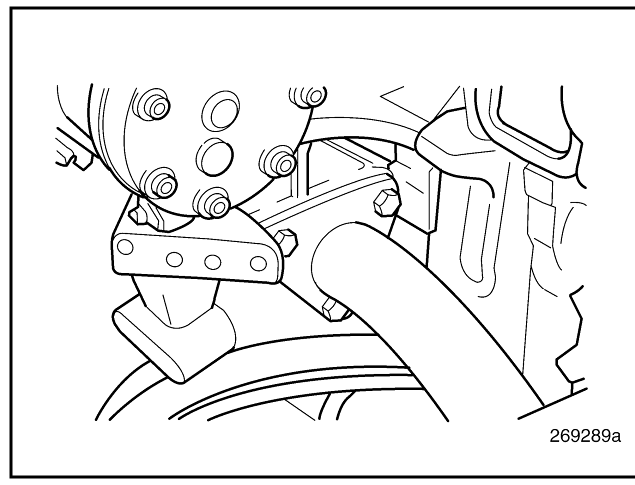


Figure 409 — Coolant Inlet Tube Mounting (Back of Front-Redesign Water Pump)

13. Connect the EGR cooler coolant supply hose to the water pump on the right side of the engine.
14. If the pump cartridge assembly has been removed, install a **new** O-ring on the water pump cartridge assembly mounting flange (Figure 410).

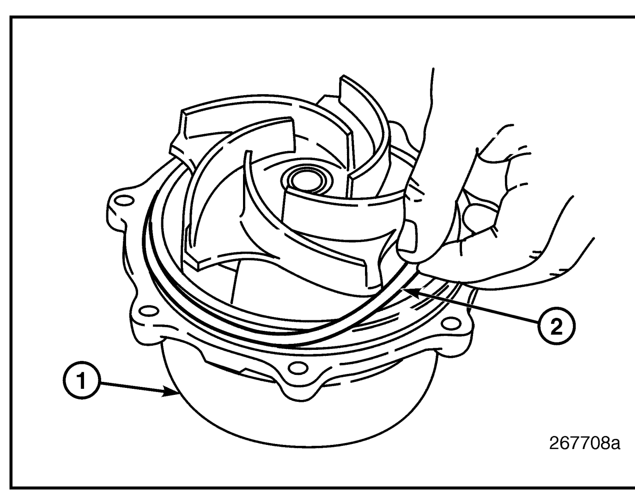


Figure 410 — O-Ring Installation

1. Water Pump Cartridge Assembly	2. O-Ring

15. Place the pump cartridge assembly in position on the pump housing (pump only fits one way due to the spacing of the seven holes) and install the seven mounting capscrews (Figure 411). Tighten the capscrews to 17 lb-ft (23 N•m).

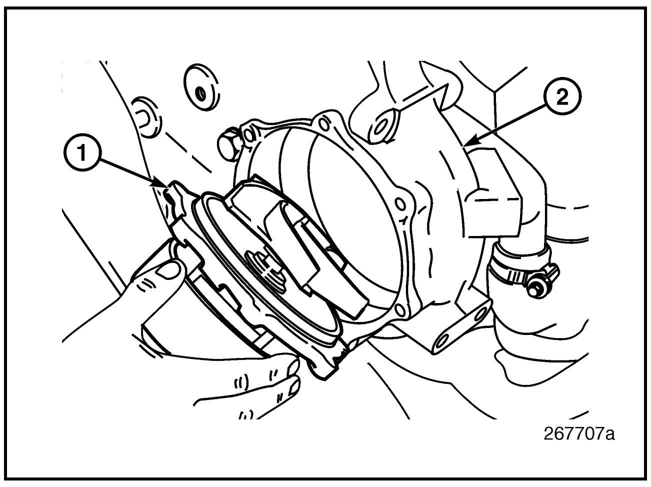


Figure 411 — Water Pump Cartridge Assembly Installation

1. Water Pump Cartridge Assembly	2. Pump Housing

16. Install the fan drive assembly, drive belts and connect the fan-speed sensor lead.

EGR Valve Installation

[214 QE]

CAUTION

Use care when cleaning component parts of the EGR system. Dirt and debris entering the system could cause blockage within the cooler core or EGR valve.

1. Clean and inspect the valve mounting surface of the exhaust manifold and the tube flange and mounting base of the valve assembly. Again, use care to avoid getting dirt and debris in the system.

NOTE

A metal gasket, shown in Figure 412, is used between the mounting base of the EGR valve assembly and the exhaust manifold.

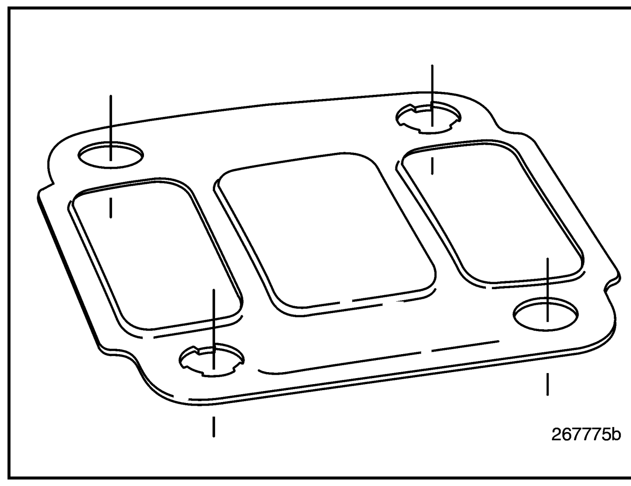


Figure 412 — EGR Valve Gasket

2. Install a **new** gasket on the EGR valve assembly mounting surface of the exhaust manifold (Figure 413).

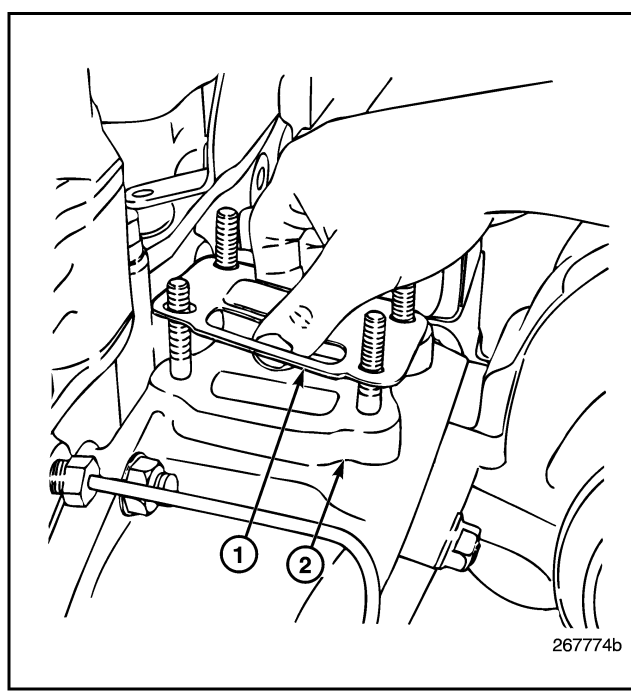


Figure 413 — Gasket Installation

1. EGR Valve Gasket	2. Exhaust Manifold

3. Place the valve assembly in position on the exhaust manifold studs (Figure 414). Loosely install the retaining nuts. DO NOT tighten them at this time.

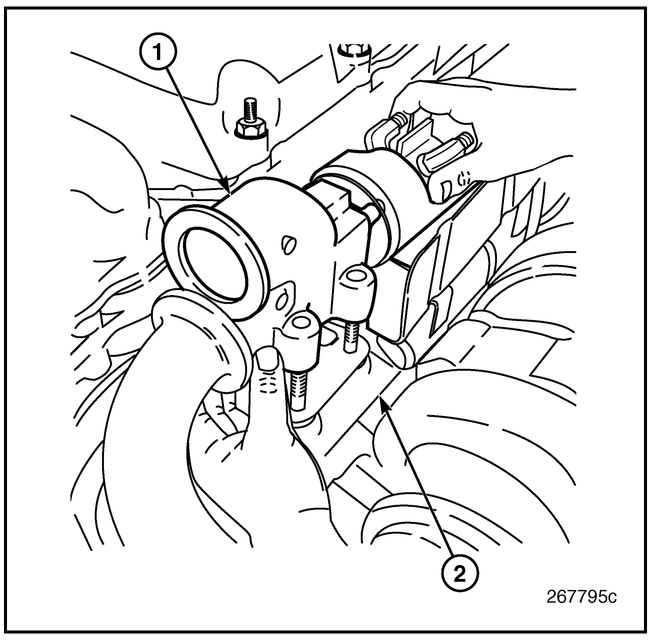


Figure 414 — EGR Valve Installation

1. EGR Valve Assembly	2. Exhaust Manifold

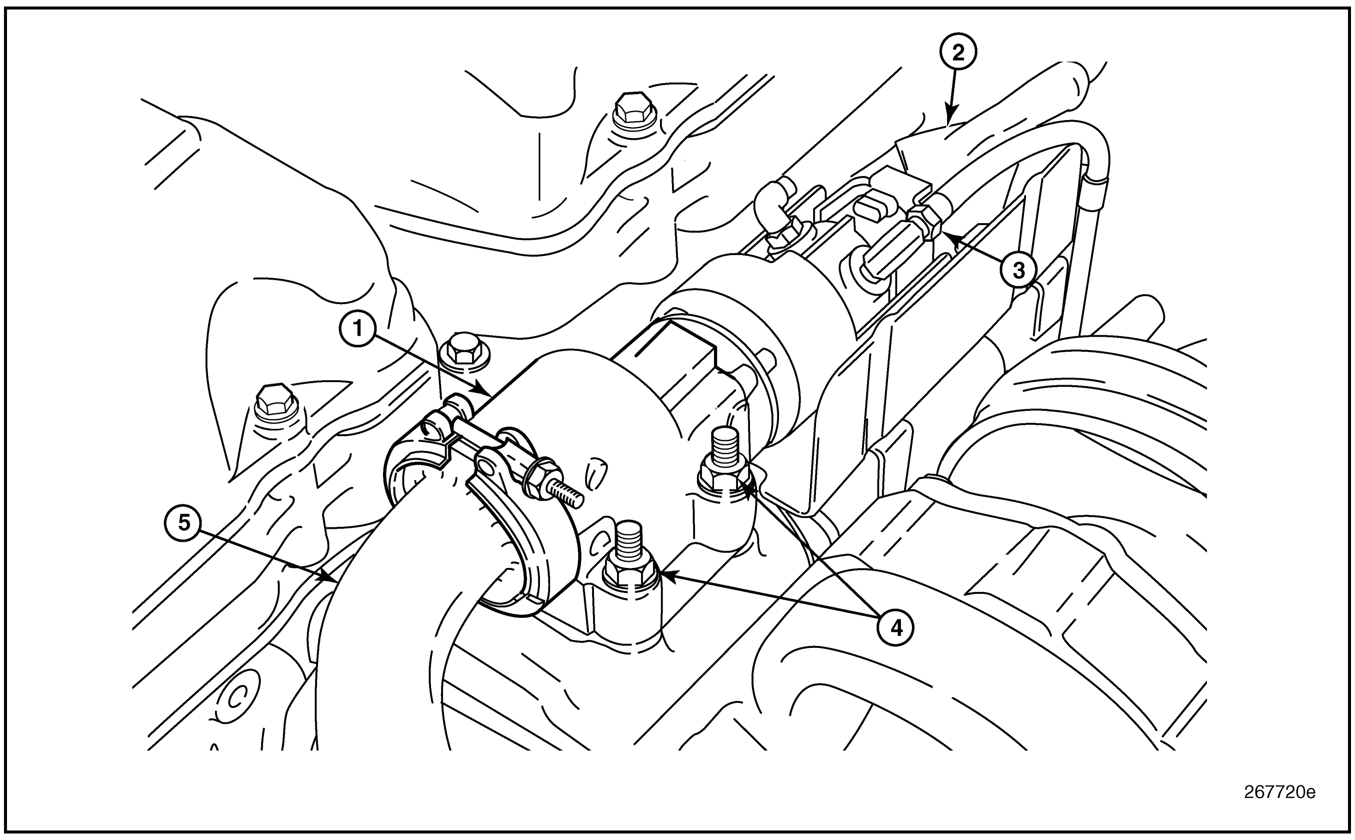


Figure 415 — EGR Valve, Installed

1. EGR Valve 2. Electrical Connection 3. Oil Return Line	4. Mounting Studs/Nuts 5. EGR Hot Tube

Oil Supply Lines Installation

[214 HS, HT & RN]

EXTERNAL OIL SUPPLY ARRANGEMENT ASET™ AC ENGINES BUILT DECEMBER 2003 AND PRIOR

NOTE

This procedure covers external oil supply arrangements for AC engines built December 2003 and prior. For engines built after December 2003, refer to the procedure which follows this procedure.

For all ASET™ AC engines produced before December 2003, the oil supply source for the EGR valve, J-Tech™ engine brake assemblies and VTG turbocharger is from the supply port on top of the oil filter mounting bracket as illustrated in Figure 416. A No. 10 size line for J-Tech™ or No. 8 size line for non-J-Tech™ is connected between this port and the junction block at the left side of the cylinder heads. Oil is supplied to the J-Tech™ engine brake assemblies (if equipped) from this block. A No. 8 size line passes between the cylinder heads to a second junction block on the right side of the cylinder head near the EGR valve. Smaller No. 6 size lines are used to supply oil to the EGR valve and the turbocharger.

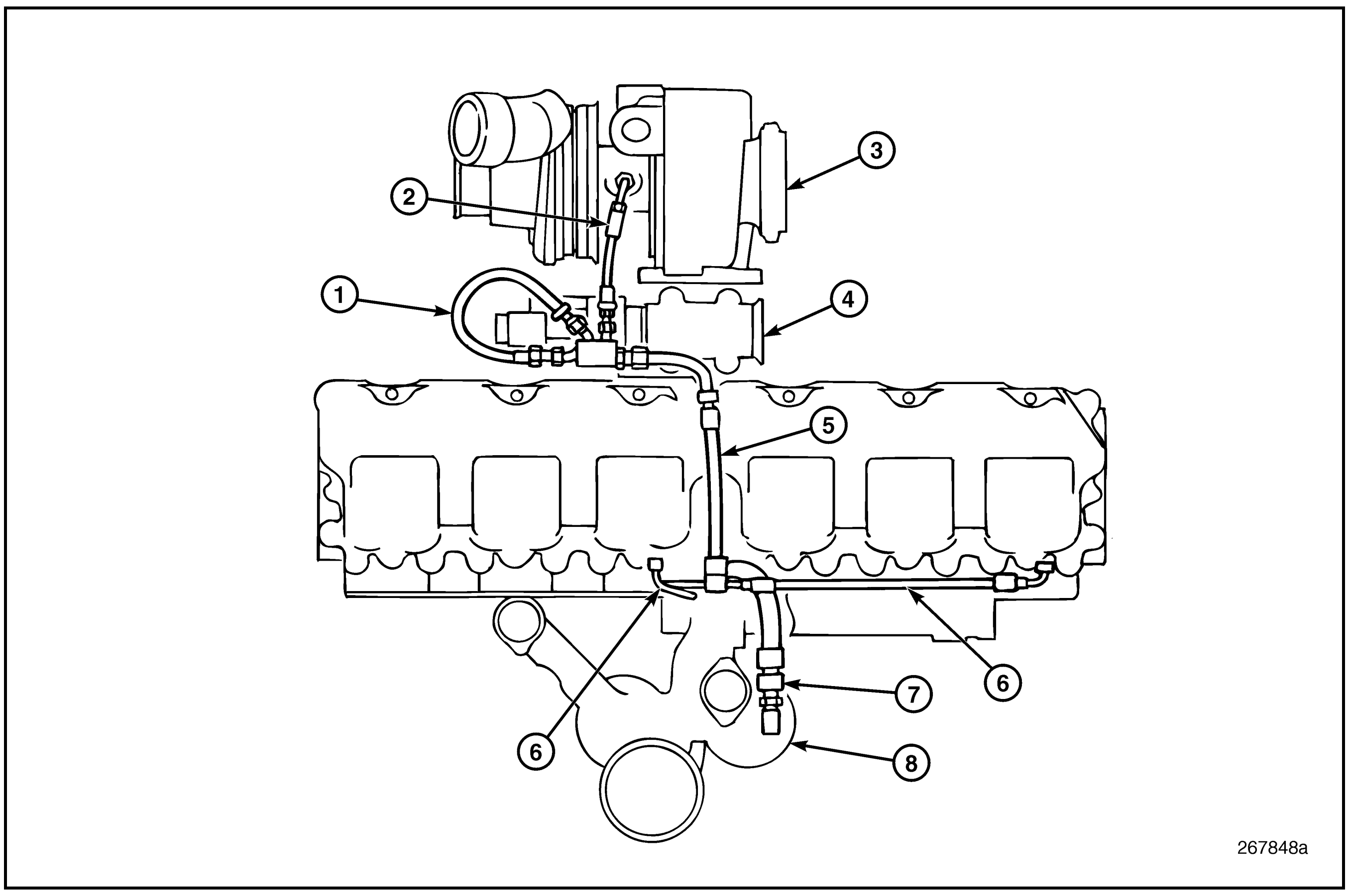


Figure 416 — EGR and VTG Oil Supply Lines (AC Engines Built December 2003 and Prior)

1. EGR Valve Supply Line, No. 6 Size 2. Turbocharger Supply Line, No. 6 Size 3. Turbocharger (VTG) 4. EGR Valve	5. Supply Line, No. 8 Size (LH Junction-to-RH Junction) 6. J-Tech™ Engine Brake Supply Lines 7. Oil Supply Line, No. 10 Size J-Tech™ or No. 8 Non-J-Tech™ (Filter Bracket Oil Port-to-LH Junction) 8. Filter Mounting Bracket

1. If the engine is equipped with a J-Tech™ engine brake, install the respective junction blocks (with brackets) at the left and right sides of the engine. Only a right-side junction block is used on non-brake-equipped engines.
2. Install the No. 10 size line between the fittings at the oil filter mounting bracket and the junction block at the left side of the engine. Install the No. 8 size supply line from the left to the right junction block.
3. Install a No. 6 size supply line between the right junction block and the EGR valve and another between the right junction block and the turbocharger.
4. Install the external J-Tech™ oil supply lines to the ports at the left junction block. Cap the open end of each line until ready for connection when the cylinder head cover spacer is installed. This will keep dirt and any other contaminants from entering the system.

Because the line routings are close to the EGR gas tubes, exhaust manifold and turbocharger, all lines are steel braided and heat resistant. To tie these lines together, special Panduit® stainless steel straps are required. These straps are fitted with a slip collar at one end and are installed in a similar manner as the typical nylon tie (Figure 417).

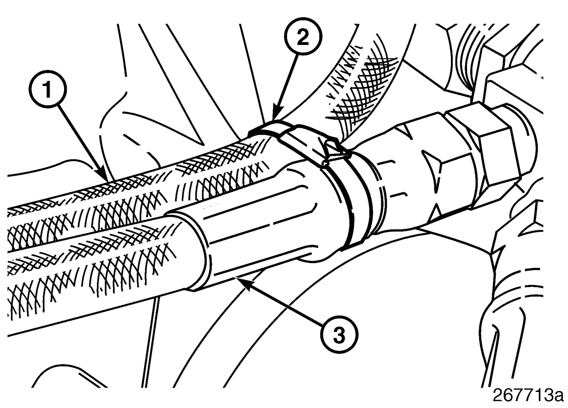


Figure 417 — Stainless Steel Strap, Installed

1. VTG Actuator Air Line 2. Stainless Steel Strap	3. Turbocharger Oil Supply Line

To install a stainless steel strap:

1. Bend the strap around the lines to be tied together and slide the open end into the collar at the opposite end.
2. Pull the strap through the collar to cinch the connection. Using pliers, crimp the collar to secure the strap and cut off the excess.

SERVICE HINT

While pliers work for making this connection, Panduit has a special tool designed specifically for installing the straps.

NOTE

These stainless steel straps were eliminated in April 2003 with the introduction of the new EGR valve-mounted bracket and clamp arrangement.

EXTERNAL OIL SUPPLY ARRANGEMENT ASET™ AC ENGINES BUILT AFTER DECEMBER 2003

For all ASET™ AC engines produced after December 2003, the oil supply source for the VTG turbocharger is from the supply port on top of the oil filter mounting bracket. The oil supply for the EGR valve is now a separate oil supply line from a cylinder block oil supply port as illustrated in Figure 418. These are both direct oil lines without the use of any junction blocks or F-fittings. For J-Tech™-equipped engines, a No. 10 size line is connected between the oil filter mounting bracket and a junction block at the left side of the cylinder heads. Oil is supplied to the J-Tech™ engine brake assemblies (if equipped) from this block. A No. 6 size line passes between the cylinder heads directly to the turbocharger.

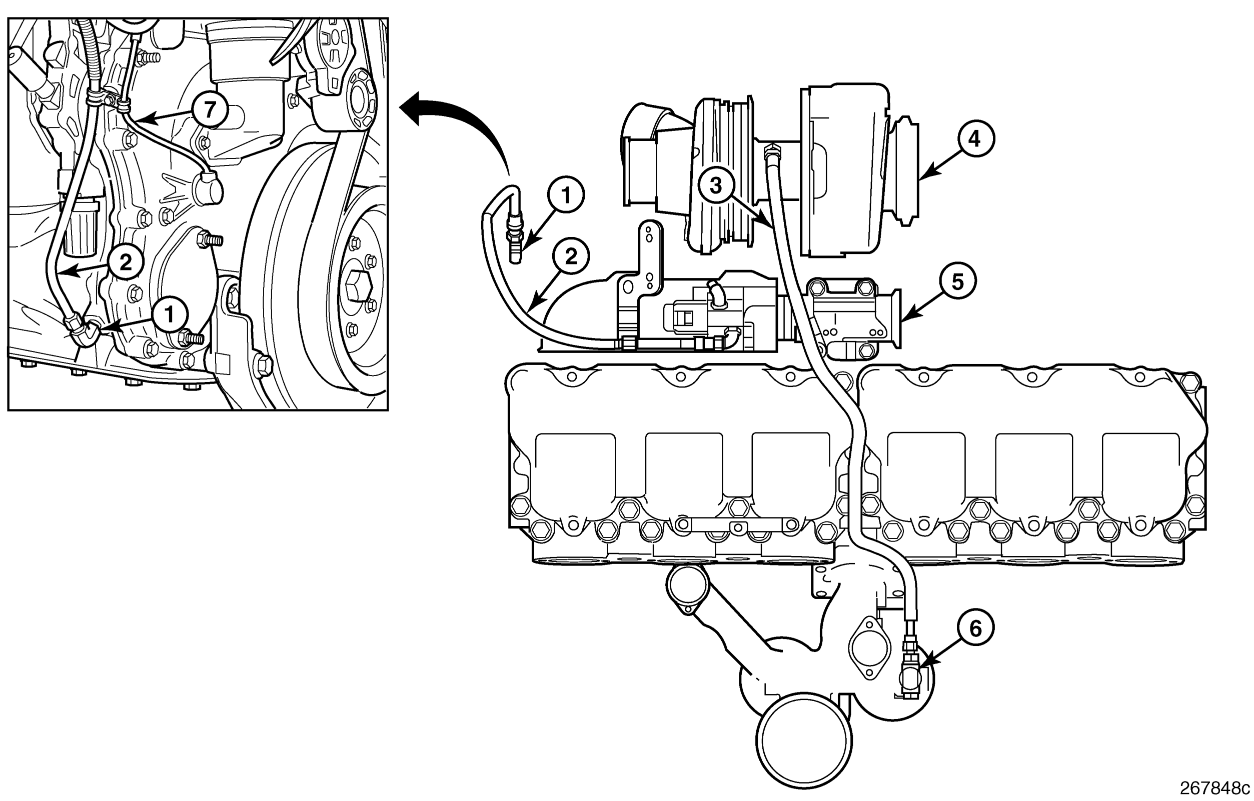


Figure 418 — EGR and VTG Oil Supply Lines (AC Engines Built After December 2003)

1. EGR Valve Oil Supply Line Fitting at Cylinder Block	5. EGR Valve
2. EGR Valve Oil Supply Line, No. 6 Size	6. Oil Supply Fitting at Filter Bracket
3. Turbocharger Supply Line, No. 6 Size	7. Harness (Ref.)
4. Turbocharger (VTG)	

1. Ensure that the convoluted tubing is in place over the EGR valve oil supply line.
2. Reconnect the EGR oil line to the fitting on the cylinder block oil supply port (item No. 1, Figure 418).
3. Reconnect the other end of the EGR oil supply line to the EGR valve fitting and tighten to specification.

NOTE

Beginning with March 2004 production, a filter screen has been added to the oil inlet port on the EGR valve. It is retained in place by a wave washer and inlet hose fitting (Figure 419). Valves fitted with the filter screen are identified by a green dot (interim identification) on the valve body or by the new part number, 691GC514C, on the sheet metal cover. When connecting the oil line to the EGR valve, make sure that the screen and wave washer are in place and secured by the hose fitting.

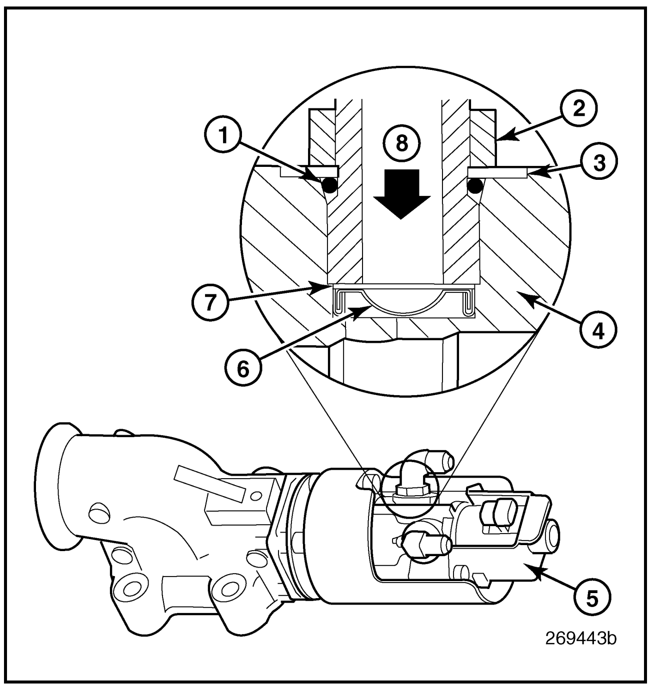


Figure 419 — EGR Valve Oil Inlet Filter Screen

1. O-Ring	5. Part Number Location
2. Fitting Jam Nut	6. Filter Screen
3. Integral Washer	7. Wave Washer
4. Valve Body	8. Oil Flow Direction

4. Position the turbocharger oil supply line over the top of the engine and in between the cylinder heads.
5. Reconnect the oil supply line from the oil filter adapter to the turbocharger oil supply by routing the oil supply line between the cylinder heads and reconnect the line to the turbocharger oil inlet fitting and tighten to specifications.

Thermostat Housing Installation

[215 NU, NG & LD]

1. Check to see that the stainless steel wear rings/shields are properly installed in the thermostat housing (Figure 420).

NOTE

If the wear rings/shields are not in place, the thermostats can wear into the aluminum casting of the thermostat housing. If the wear rings/shields become dislodged or out of position, they can be replaced, or if necessary, crimped to attain a tight fit, and then reinstalled. The shields have a very slight press-fit to the bore. An installation tool is not used. Use finger pressure to push each shield to full seating.

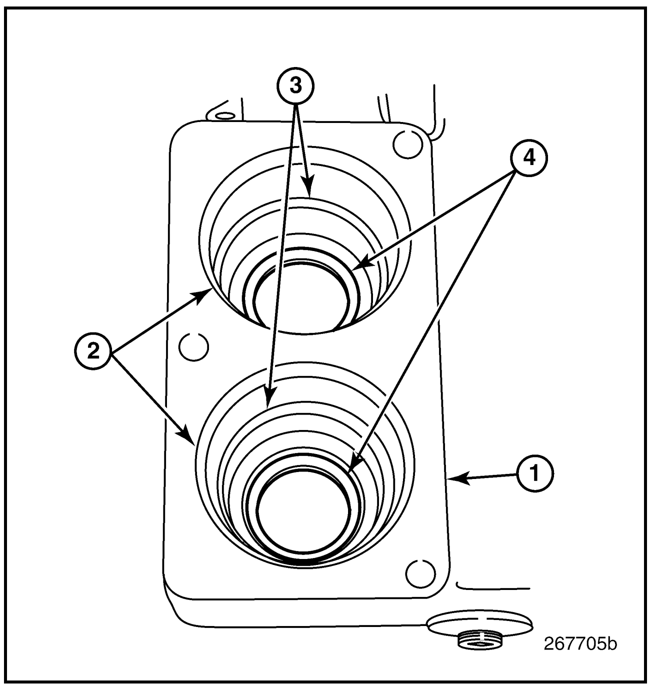


Figure 420 — Wear Rings Installed

1. Thermostat Housing	3. Thermostat Barrel Seal Bore
2. Thermostat Rubber Seal Bore	4. Wear Rings/Shields (Pressed In)

NOTE

When replacement is required, always replace thermostats in pairs. Always install a **new** seal in each housing bore and place the thermostats in position in the housing bores with the valve spring up. Check to see that the bores are free from any contaminants such as chips, grit, dust or any other debris that would damage the barrel seals or prevent the thermostat from seating properly when it is fully closed.

2. If required, install a **new** thermostat barrel seal in each of the thermostat chambers using the following procedure:
   a. Use crocus cloth to remove any surface nicks, burrs, sharp edges and tool marks from the thermostat sleeve and housing bore area.

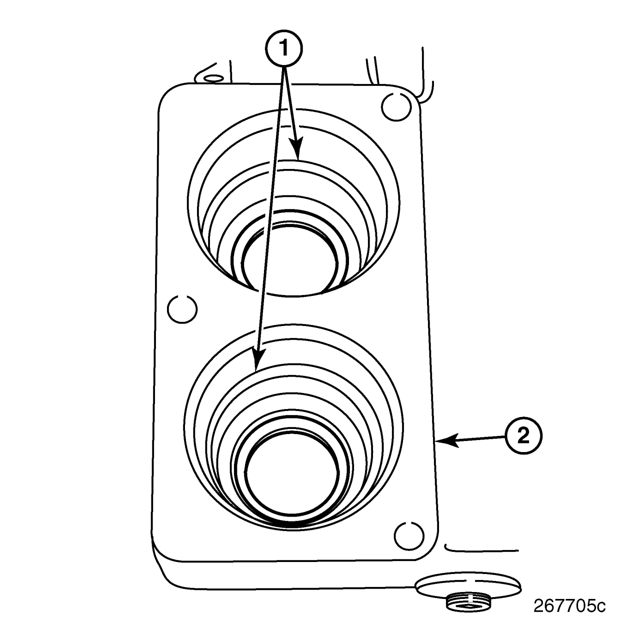


Figure 421 — Thermostat Housing

1. Barrel Seal Bore	2. Thermostat Housing

   b. Check to see that replacement barrel seals are free from any contaminants such as chips, grit, dust or any other debris that would prevent the seal from properly seating in the thermostat housing bore.
   c. Press the barrel seal into the housing bore by applying smooth, uniform pressure with a press fitting tool. Press fitting tools are available through the Kent-Moore tool company.
   d. A complete set of installation tools includes thermostat seal installers (J 26637-A) and (J 26638-B) and a driver handle (J 8092). Use Kent-Moore tools, or equivalent, for this procedure.

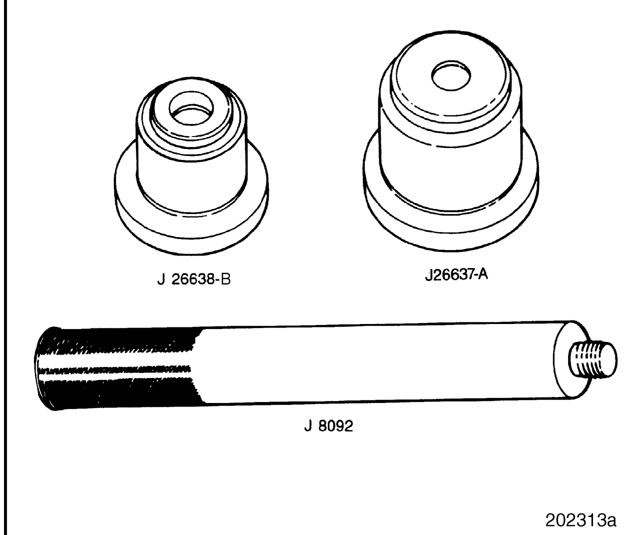


Figure 422 — Thermostat Barrel Seal Installation Tool

   e. Always use the proper seal installer. Do not use a hammer or apply uneven pressure directly to seal surfaces. Precautions should be taken against cocking of the seal throughout the installation operation. Make sure that when the seal is in the final position, it is not cocked.

3. Ensure the thermostat flange seal is in proper position on each thermostat (seal is an integral part of the thermostat) and place the thermostats in position in the housing bores with the valve spring up (Figure 423). Make sure that the thermostat flange seals are properly seated in the thermostat housing bore.

NOTE

The seals attached to the thermostats provide total sealing for the housing-to-coolant manifold joint. No other sealant is required.

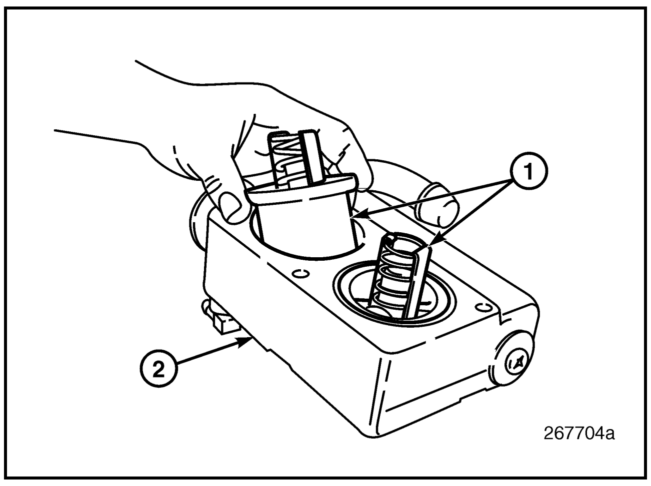


Figure 423 — Thermostat Positioning

1. Thermostats	2. Thermostat Housing

4. Position the thermostats with the ball check valves facing toward the front of the assembled engine.

CAUTION

Make sure the ball check valves on the thermostats are facing forward. Proper positioning of the ball check valve is critical for proper de-aeration of the cooling system and proper and complete coolant fill.

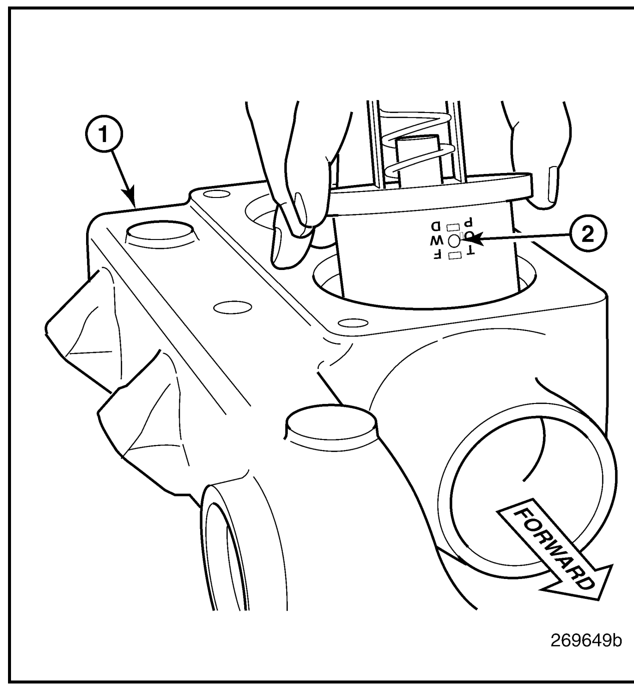


Figure 424 — Thermostat Positioning on Dual Thermostat Housing

1. Thermostat Housing	2. Vent Port/Ball Check Valve Faces Front

5. Position the housing assembly on the coolant manifold mounting surface and install the three mounting capscrews. Tighten the capscrews to specification.

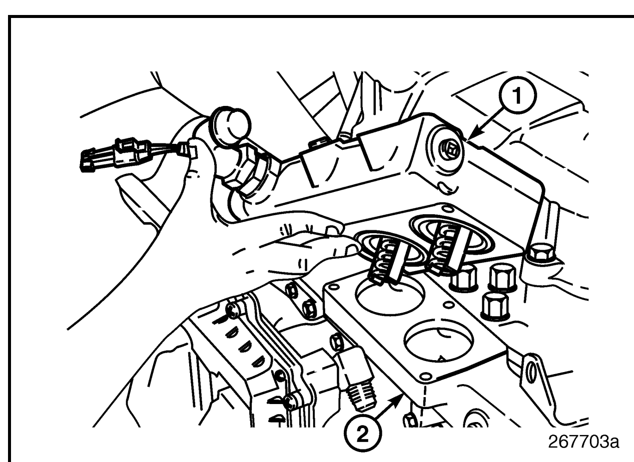


Figure 425 — Thermostat Housing Installation

1. Thermostat Housing	2. Coolant Manifold

6. Install the cab heater coolant return hose and valve into the thermostat housing (if applicable). Also install the optional fuel heater coolant return hose into the thermostat housing (if equipped). The cab heater and optional fuel heater coolant return hoses were relocated from the thermostat housing to the radiator lower tube in mid-2004.
7. Reconnect the bypass and radiator hoses at the front of the thermostat housing (Figure 426) and reconnect the surge tank hose. Tighten all hose clamps to specifications.

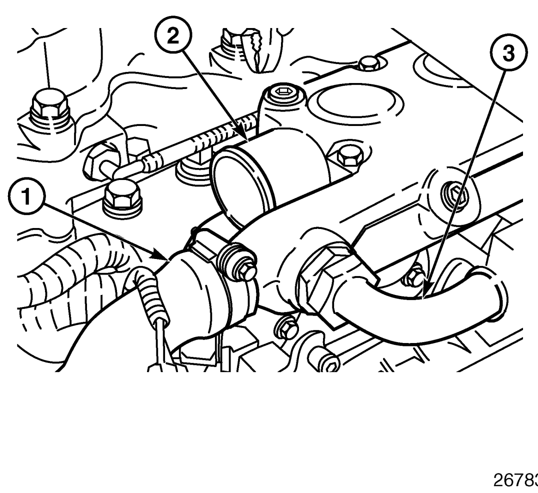


Figure 426 — Thermostat Housing Hose Connections

1. Bypass Hose 2. Radiator Hose Port	3. Surge Tank Port

8. Refill the surge tank with the coolant removed at disassembly.

EGR Mixer Tube Installation

[214 HL]

1. Clean and inspect the mating flange for the EGR cool tube. Install a **new** graphite wire-mesh seal in the flange.
2. Clean and inspect the mounting collar on the inlet manifold. Then, install a **new** O-ring on the collar (Figure 427).

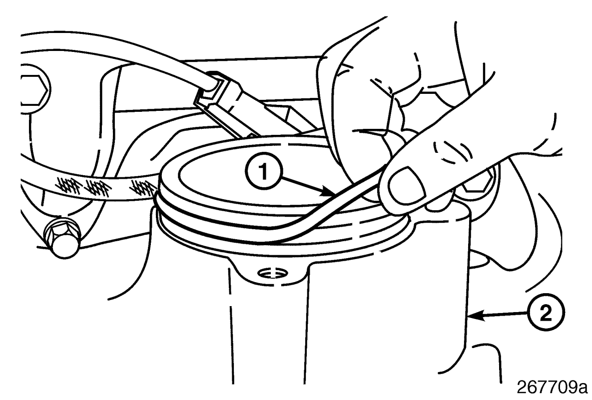


Figure 427 — O-Ring Installation

1. O-Ring	2. Inlet Manifold

3. Place the mixer tube in position on the inlet manifold (Figure 428) and install the two mounting capscrews. Tighten the capscrews to specification, 40 lb-ft (55 N•m).

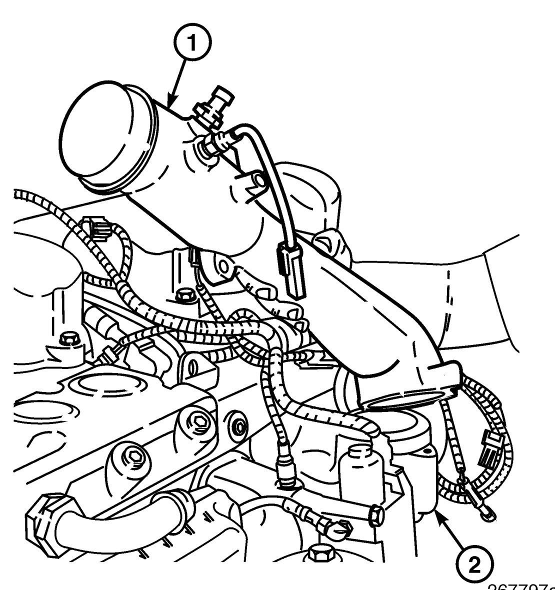


Figure 428 — EGR Mixer Tube Installation

1. EGR Mixer Tube	2. Inlet Manifold

4. Install the capscrew attaching the support bracket to the side of the mixer tube. Tighten the capscrew to specification, 40 lb-ft (55 N•m).

EGR Cooler Installation

[214 HM]

1. Place the EGR cooler assembly in position at the right side of the cylinder block (Figure 429). Install the four retaining nuts and tighten to specification.

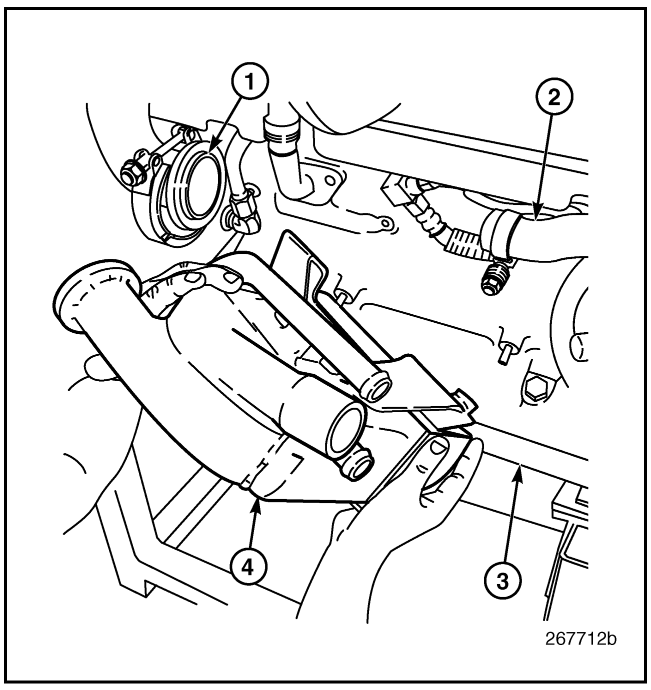


Figure 429 — EGR Cooler Installation

1. EGR Hot Tube 2. Coolant Return Hose	3. Cylinder Block 4. EGR Cooler

2. Install the coolant supply and return hoses at the cooler inlet and outlet tubes. Install the clamps and tighten to specification (Figure 430).

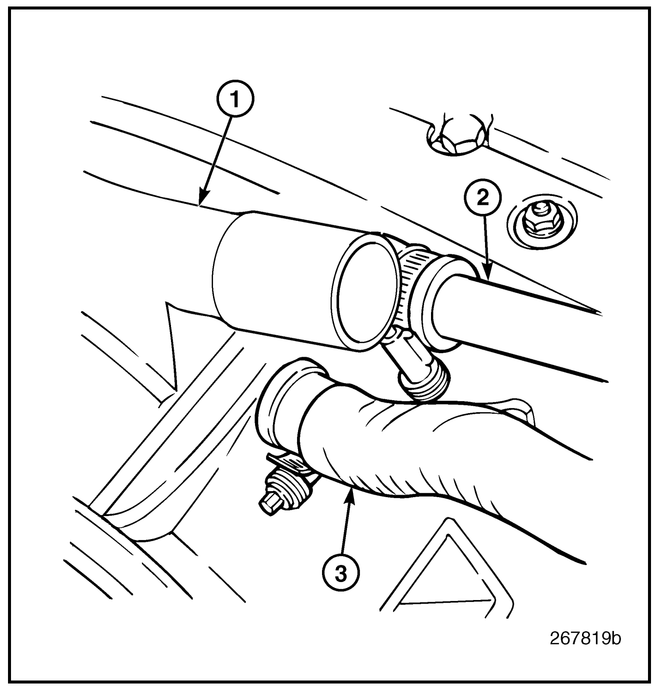


Figure 430 — Coolant Connections

1. EGR Cooler 2. Coolant Supply Pipe	3. Coolant Return Hose

EGR Gas Tube Installation

[214 HN, HP, HR]

The following procedure covers the installation of the EGR gas tubes in order of:

- Hot tube
- Cool tube, one-piece assembly

HOT TUBE INSTALLATION

N O T E

Whenever an EGR hot tube clamp has been in service and is removed, the retaining nut may gall the threads of the T-bolt. Always install a **new** T-bolt and nut in the clamp body whenever a clamp has been removed. However, the body of the clamp can be reused and should not be replaced unless it is broken or damaged.

1. Install **new** seals in the flanges at each end of the EGR hot tube. Place the hot tube in position between the EGR valve and cooler (Figure 431). Install **new** T-bolts and nuts in the clamps and tighten to specification, 110 lb-in (12.4 N•m).

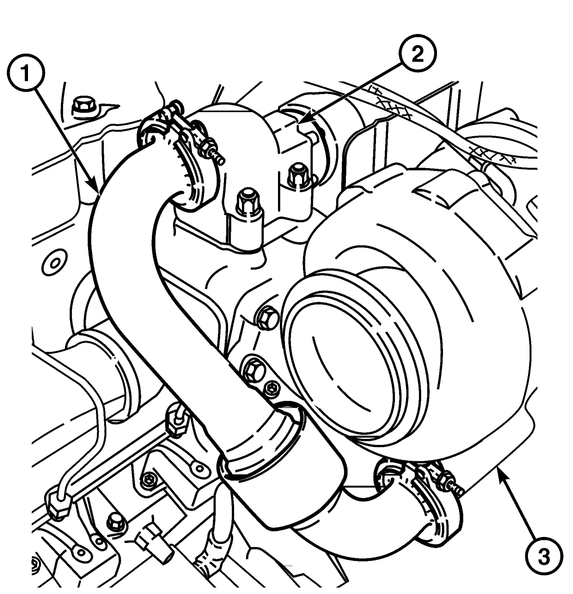


Figure 431 — EGR Gas Hot Tube, Installed

1. EGR Gas Hot Tube 2. EGR Valve	3. EGR Cooler

2. Lightly tap the clamps with a hammer and retighten them to specification.
3. Tighten the EGR valve retaining nuts to specification, 40 lb-ft (55 N•m).
4. Install the three spacer studs on the longer EGR valve mounting studs. Tighten the spacer studs to 40 lb-ft (54 N•m).
5. Install a flat washer on top of each spacer stud and then install the clamp bracket and three bracket retaining nuts. Tighten the nuts to 40 lb-ft (54 N•m).

COOL TUBE INSTALLATION (ONE-PIECE ASSEMBLY)

Early-production engines use flange-style coupling adapters at both the EGR cooler and mixer tube port connections in combination with the one-piece cool tube. For current-production engines, the coupling adapter is used only at the EGR mixer tube port and not at the cooler port. As production continues in the future, the need for coupling adapters will be eliminated altogether as the mixer tube cool-tube port design is changed to accept a hose connection.

On vehicles so equipped, install the coupling adapter(s) as follows before installing the cool tube:

- Install a **new** wire-mesh gasket on the EGR cool tube coupling adapter(s).
- Install the coupling adapter(s) to the EGR cooler flange and/or the EGR mixer tube flange using a band clamp. Tighten the band clamp nut to 110 lb-in (12.4 N•m).

N O T E

On systems equipped with flange-style coupling adapters on the EGR cool tube side of the system, the flange clamps can be reused if there is no damage and the threads are not corroded. However, with damaged or corroded threads, the flange clamps cannot be tightened to the proper torque specification for a gas-tight seal. Replace the T-bolt and nut or complete clamp assembly if corrosion or damage is present.

Install the one-piece cool tube assembly as instructed below:

1. Slide a hose clamp onto the EGR mixer tube and the EGR cooler cool-tube ports (or coupling adapters, if so equipped).
2. Slide a hose clamp and the appropriate coupling hose over each end of the EGR cool tube assembly. The stepped-design hose is used at the cooler connection.
3. Place the cool tube assembly in position on the engine between the EGR mixer tube and cooler ports (or coupling adapters). Slide the coupling hoses onto the ports/adapters and secure with the hose clamps (Figure 432).

NOTE

Place the cool tube in position under the turbocharger oil supply and VTG actuator air lines if the lines are already installed.

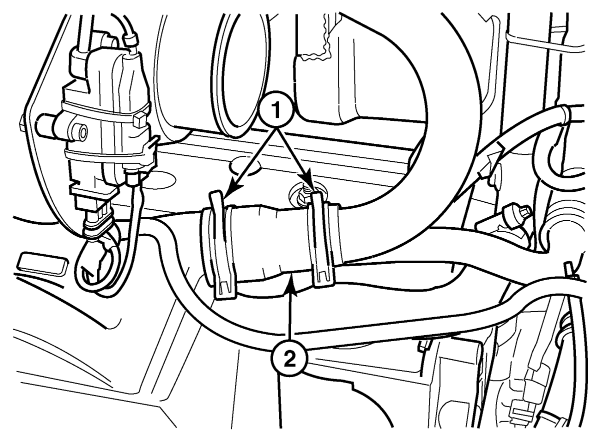


Figure 432 — Cool Tube Hose Connection (Cooler Connection Shown)

1. Hose Clamps	2. Coupling Hose

4. Install the clamps and mounting bolts to secure the cool tube to the mounting brackets at the EGR valve and the front exhaust manifold (Figure 433). Tighten the bolts to 96 lb-in (11 N•m).

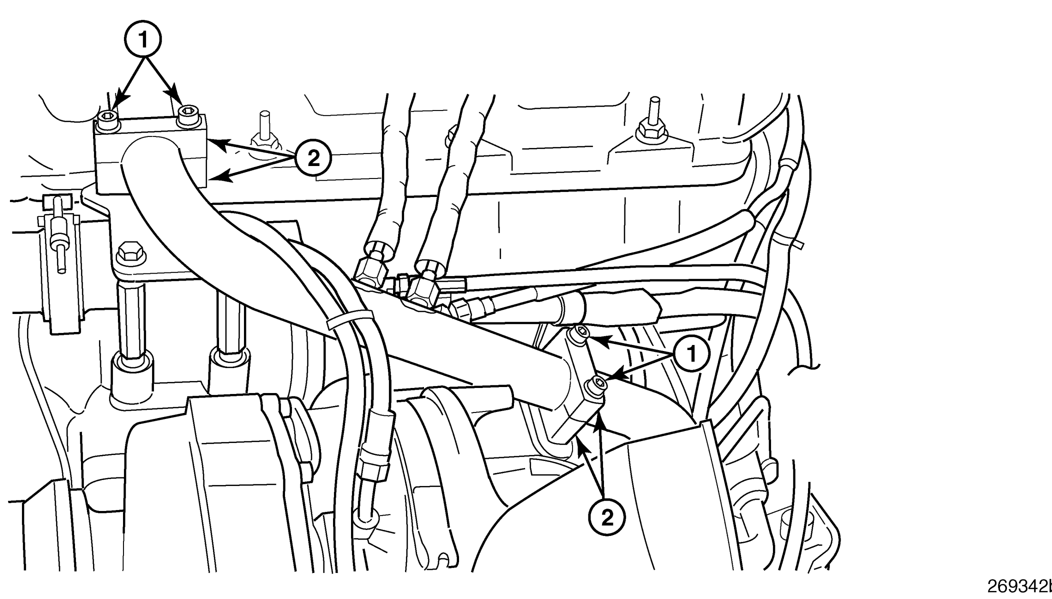


Figure 433 — Cool Tube Clamp Installation

1. Mounting Bolts	2. Clamps, Upper and Lower Halves

EECU and Cooling Plate Installation

[230 EA]

The EECU cooling plate mounting arrangement was changed in mid-May 2003 to eliminate a tolerance stack-up condition that may leave each isolator loose even though the nut securing them is torqued properly. To correct this condition reinstall the cooling plate using the following procedure:

Non-Current Cooling Plate Design

The EECU cooling plate used on ASET™ AC engines from the beginning of production through mid-May 2003 has two 0.580-inch (14.7 mm) diameter mounting holes at the lower corners of the plate. The lower mounting isolators are installed through these holes, and each isolator is then secured with two 0.188-inch thick washers and one nut.

Due to tolerance stack-up between the thickness of the cooling plate and the dimensions of the isolators, some isolators may not clamp onto the cooling plate when the nut is tightened. When this occurs, tightening the nut further will cause the washers to rotate, which places force on the rubber portion of the isolator, resulting in tearing or breaking of the rubber. To prevent this from occurring, it is recommended that another washer (part No. 35A1446X) be added between the two 0.188-inch washers. This should be done whenever the EECU or cooling plate is removed for any reason, or if torn or broken mounting isolators are encountered.

1. For the non-current cooling plate design, upper isolators are secured with flanged nuts only; washers are not used. The upper mounting nuts must be tightened to 108 lb-in (12 N•m).
2. Non-current lower mounting nuts must be tightened to 180 lb-in (20 N•m).

   Current Cooling Plate Design

   Beginning 5/15/03, the EECU cooling plate arrangement used on the ASET™ AC engines was changed to include integral bushings at the two lower mounting bolt holes. The lower mounting isolators are installed through these bushings and secured by one 0.065-inch thick washer and one nut.
3. For the current cooling plate design, upper isolators are secured with flanged nuts only; washers are not used. The upper mounting nuts must be tightened to 108 lb-in (12 N•m).
4. Current design lower mounting nuts must be tightened to 180 lb-in (20 N•m).
5. Connect the fuel lines to the inlet and outlet ports of the cooling plate (Figure 434).

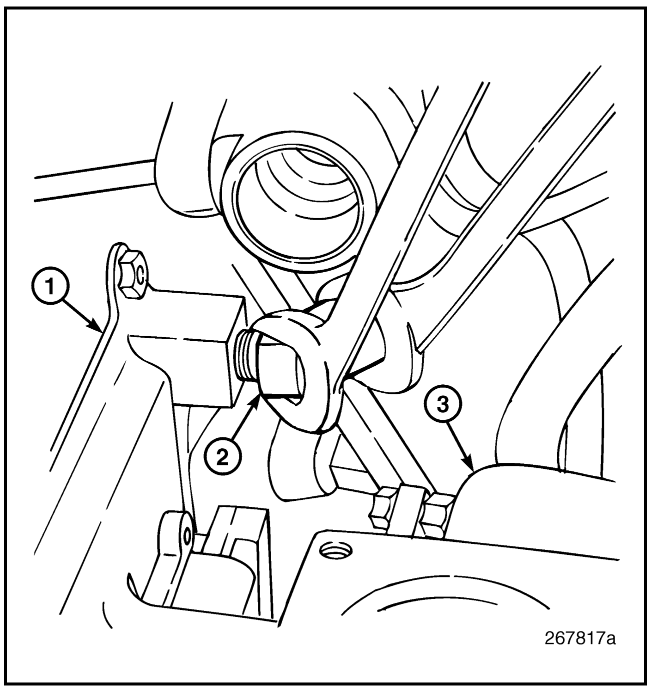


Figure 434 — Cooling Plate Fuel Lines

1. Cooling Plate 2. Fuel Line	3. Thermostat Housing

6. Connect the wiring harness leads to the EGR MASS Flow module (Figure 435).

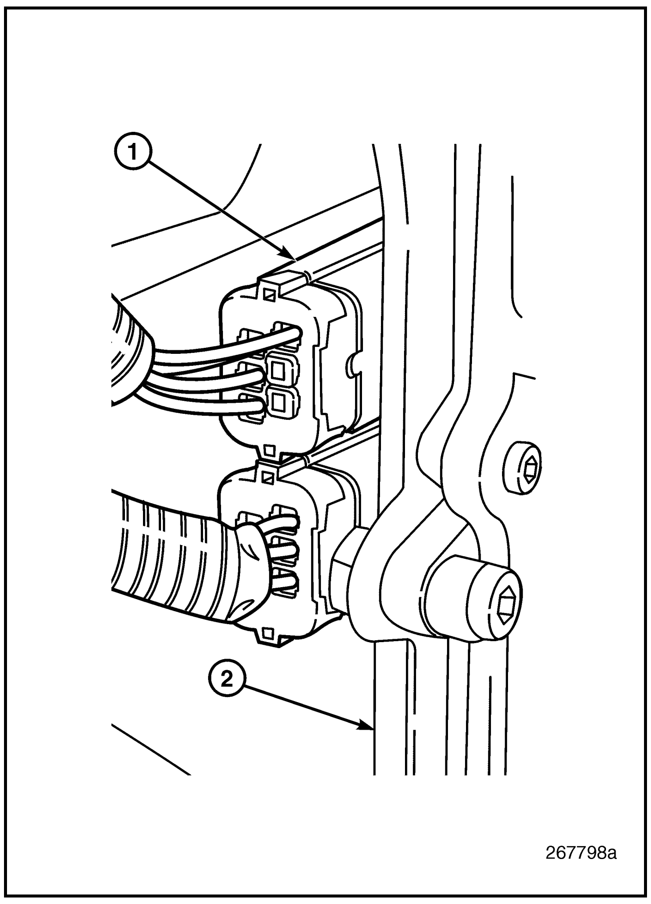


Figure 435 — MASS Flow Module Connections

1. Module Connections	2. Cooling Plate

7. Make sure the cooling plate and EECU mating surfaces are clean. Place the EECU in position on the cooling plate and install the eight retaining bolts. Tighten the bolts to specification (Figure 436).

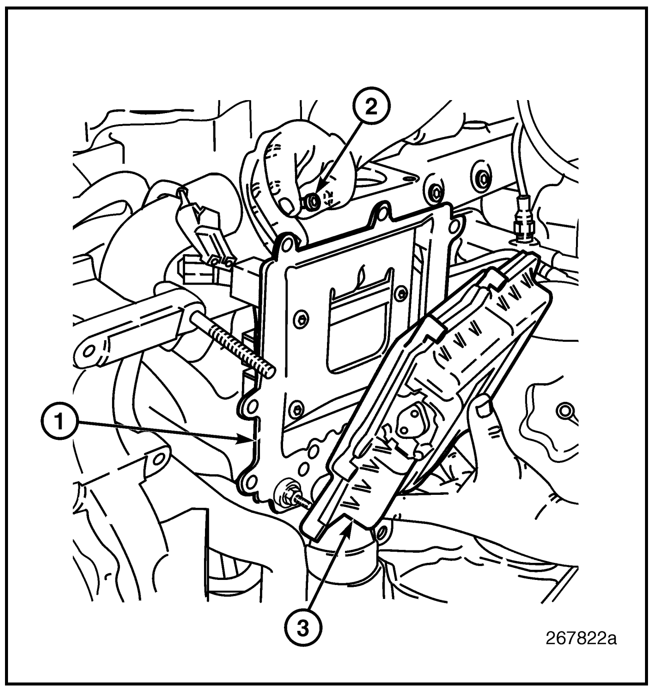


Figure 436 — EECU Installation

1. Cooling Plate 2. Retaining Bolt	3. EECU

8. Connect the wiring harness to the EECU (Figure 437).

CAUTION

Make sure that the seals are firmly seated on the connectors and that the EECU terminal pins are straight and not damaged.

- *EJ2 (89-pin connector) — Lift the locking lever to the full-open position and place the connector in position squarely over the module terminals. Push the connector into the module until firmly seated. Then, close the locking lever to secure the connection. DO NOT use the locking lever to seat the connector.*
- *EJ1 (36-pin connector) and EJ3 (16-pin connector) — Lift the metal locking lever to the full-open position and place the connector in position squarely over the module terminals. Push the connector into the module until firmly seated. And last, push down on the center crosspiece of the lever to close and secure the connection. DO NOT apply pressure to the outer edges of the locking lever which then can be bent and fail to secure the connection.*

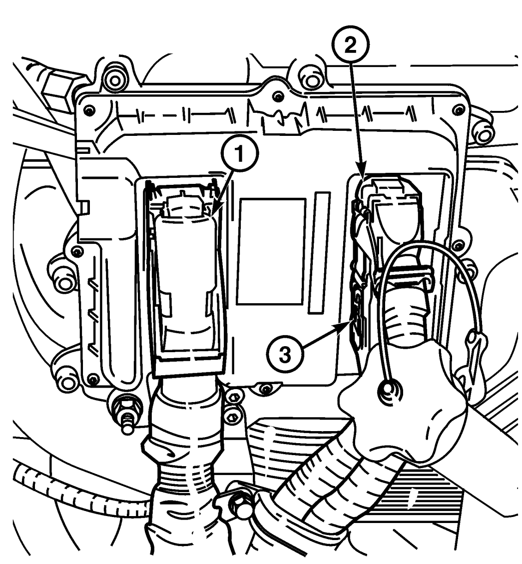


Figure 437 — EECU Connectors

1. Connector EJ2 (89 Pin) 2. Connector EJ1 (36 Pin)	3. Connector EJ3 (16 Pin)

Place the harness retainer in position on the support bracket and install the retaining screw.

Coolant Conditioner Installation [215 LD]

The coolant conditioner adapter (if equipped) is located at the left rear side of the water pump housing. The adapter has both inlet and outlet ports in the water pump mounting flange (Figure 438).

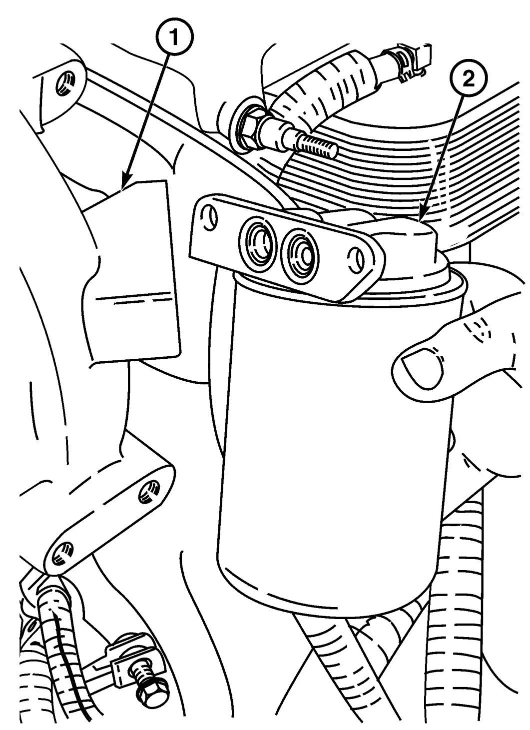


Figure 438 — Conditioner Adapter Installation

1. Pump Housing	2. Adapter

1. Check to ensure that the check valves have been properly installed.

NOTE

Inlet and outlet check valves must be installed with the direction arrows on the barrels of the check valves matching the arrows on the filter casing. If not indexed correctly, the coolant will not flow through the coolant conditioner.

2. Install **new** O-rings in the grooves at the inlet and outlet ports.
3. Place the adapter assembly in position on the water pump mounting flange and install the two mounting capscrews. Tighten the capscrews to 15 lb-ft (20 N•m).
4. Apply a light film of engine coolant on the face of the coolant conditioner filter gasket seal.
5. Install the coolant conditioner filter element on the adapter. Tighten the filter element one full turn after the gasket contacts the base.

Alternator Installation

[271 CB]

Refer to Figure 439.

1. Install the alternator plate and mounting hardware.
2. Place the alternator in position on the plate and install the capscrews, washers and mounting nuts.
3. Connect the electrical wires as tagged during disassembly.
4. Install the poly-V drive belt.
5. Adjust the drive belt tension to specification as described under Drive Belt Replacement and Tensioning procedures in the MAINTENANCE section.

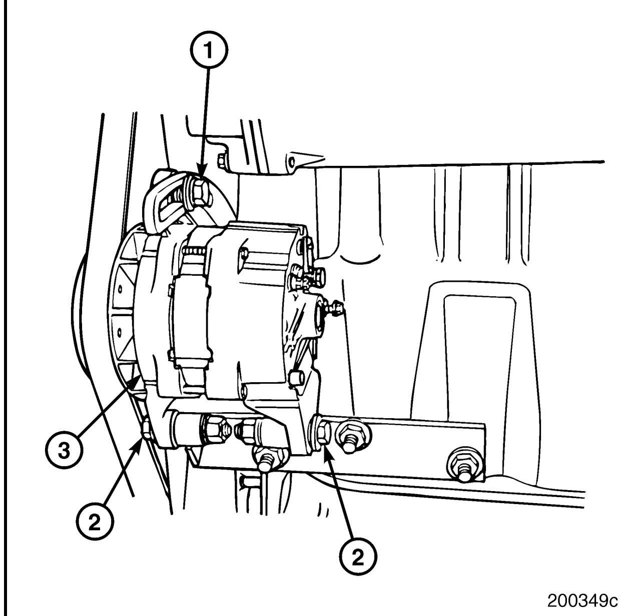


Figure 439 — Alternator Installation

1. Adjusting Capscrew 2. Mounting Capscrews	3. Alternator

Removing Engine from Engine Stand

[200 EA]

1. Attach a suitable lifting device to lifting points on the engine.
2. Position and attach an engine hoist to the lifting device; operate the hoist to place tension on the lifting device.
3. With the lifting device now supporting the engine weight, remove the mounting capscrews from the engine stand.
4. Using the lifting device, place the engine in a suitable support rack or install the engine in the vehicle (see Engine Installation in the REPAIR INSTRUCTIONS section).

Oil Coalescing Air Filter Installation

If so equipped, install the oil coalescing air filter as follows:

1. Make sure the surface around the block port area is clean and then apply RTV silicone sealant to the machined mating surface around the circumference of the port.
2. Place the filter mounting bracket in position on the studs and install the retaining nuts. Tighten the nuts to 40 lb-ft (54 N•m).
3. Install the engine wiring harness clamps and bolts on the mounting bracket. Tighten the clamp bolts to 25 lb-ft (34 N•m).
4. Place the filter adapter in position on the mounting bracket (if removed from the bracket during disassembly) and install the two mounting screws. Tighten the screws to 40 lb-ft (54 N•m).
5. Install the air line between the filter outlet port and the VTG position control valve. Secure the air line to the engine wiring harness with tie straps. Cap the inlet port to keep dirt and debris out until after the engine is installed in the chassis and the chassis air supply line is connected.

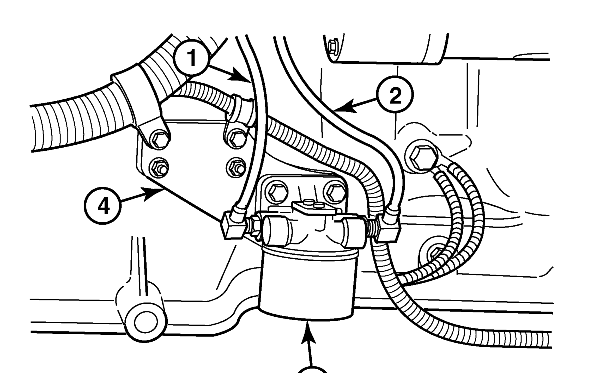


Figure 440 — Oil Coalescing Air Filter Installation

1. Outlet Air Line 2. Inlet Air Line	3. Oil Coalescing Air Filter 4. Mounting Bracket

Oil Cooler and Oil Filter Mounting Bracket Assembly Installation

[215 DW, 219 EP]

The plate-type oil cooler and oil filter mounting bracket cannot be installed until the engine is removed from the repair stand.

Refer to Figure 442 and install the assembly as follows:

1. Install an alternator mounting stud (part No. 107AM5009) or stud of the same thread into the upper right-hand corner of the oil filter pedestal mounting pad. Only one stud can be installed due to the close proximity of the oil cooler to the inlet manifold.
2. Apply a small amount of grease to the back of the oil filter mounting bracket pedestal gasket around the area of the mounting hole on the left-hand side of the gasket as shown in Figure 441. This will hold the gasket in place as the oil cooler and filter assembly is installed.

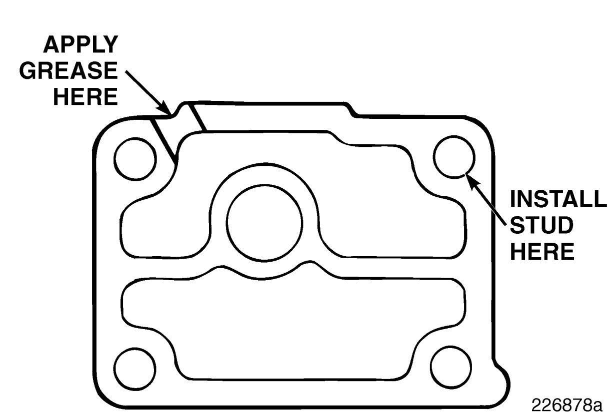


Figure 441 — Gasket Grease Application

3. Install the gasket on the engine block over the previously installed alternator stud.
4. If not previously done, install the cooler-to-water pipe hose onto the water pump inlet pipe and slide completely onto the pipe to allow installation of the oil cooler. Also loosely install both hose clamps.

5. Install the filter assembly pedestal onto the stud with the forward end of the assembly tilted downward approximately 1 inch (to allow clearance with the inlet manifold). Once the assembly is mounted on the stud, pivot the assembly clockwise to align the remaining three mounting holes of the pedestal, making sure the gasket remains in the proper position.
6. With the mounting holes of the pedestal aligned, install the bolt in the upper front mounting hole position. Then, install the remaining two bolts in the lower mounting holes.
7. Remove the stud from the upper right mounting hole, then install the mounting bolt.
8. Snug all bolts in a criss-cross pattern, then tighten to 40 lb-ft (55 N•m).
9. Slide the cooler-to-water pipe hose from its previously positioned location on the pipe to be centered between the cooler and the water pipe.
10. Properly position the two hose clamps and tighten in position.
11. Install the Y-hose and clamps at the bottom of the by-pass tube and the oil cooler inlet. Tighten the clamps to specification.
12. Install the turbocharger lubrication supply line.
13. Connect the harness to the oil pressure and oil temperature sensors on the filter mounting bracket.

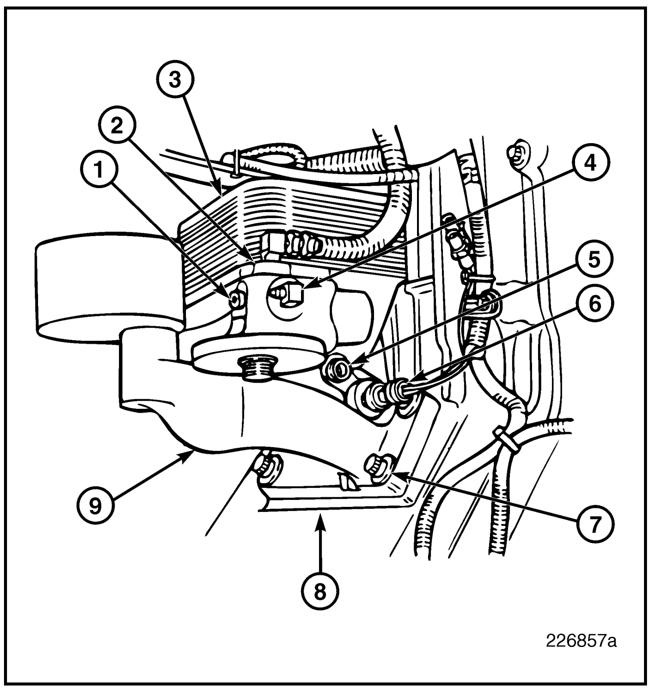


Figure 442 — Plate-Type Oil Cooler and Oil Filter Mounting Bracket Installation

1. Oil Supply Port for Mechanical Oil Pressure Dashboard Gauge 2. Turbocharger Lubrication Supply Port 3. Oil Cooler 4. Oil Supply Port for REPTO, Turbo Unloader and Remote-Mounted Oil Filter	5. Oil Temperature Sensor Port 6. Oil Pressure Sensor 7. Mounting Capscrews 8. Cylinder Block 9. Oil Filter Mounting Bracket

Dipstick Tube Installation

All AC engines have the dipstick tube installed in the oil pan on the left side of the engine. Installation instructions are as follows:

1. Install the tube guide into the side of the oil pan and tighten the guide nut to specifications.
2. Apply Loctite® 242 (blue) to the threads of the dipstick tube attaching capscrew.
3. Insert the dipstick tube into the guide tube and attach the tube to the oil filter pedestal bracket with the capscrew. Locate the isolator between the tube bracket and oil filter pedestal, as shown in Figure 443.

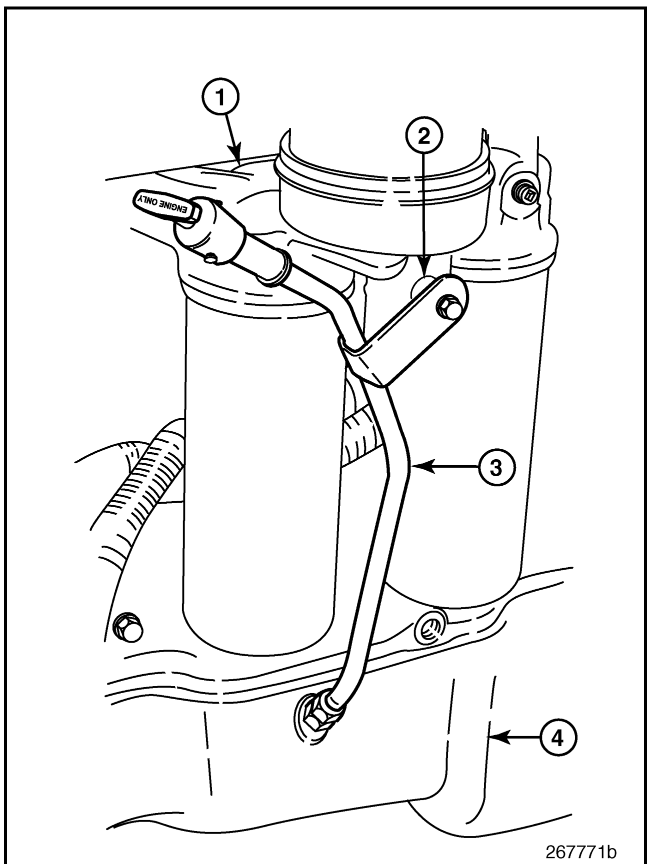


Figure 443 — Dipstick, Left-Side Installation

1. Filter Mounting Bracket 2. Isolator	3. Dipstick Tube 4. Oil Pan

4. Tighten the dipstick tube attaching capscrew to the specified torque of 24 lb-in (3 N•m).
5. Install the dipstick guide tube compression nut and tighten to specifications.

ENGINE INSTALLATION

General Instructions

Engine installation details vary from vehicle to vehicle. The following procedure provides general installation guidelines for MACK engines.

Before beginning, make sure all equipment has been inspected for safety and is available for use. Place the vehicle on a flat, level surface. Make sure the area has ample work space.

Engine Installation into Vehicle

NOTE

Obtain assistance when installing the engine. Be sure to watch for obstructions, such as engine or chassis components, brackets, clamps or other components, that may interfere with installation of the engine.

1. Using a suitable lifting device, lower the engine into position on the chassis.
2. Align the engine with the torque converter or clutch (as applicable) and install the transmission bell housing-to-flywheel housing capscrews. Tighten the capscrews to specification which is dependent on size of fastener.

NOTE

A new-style flywheel housing initiated into production in mid-2004, introduced a larger transmission-to-flywheel housing connection bolt. The bolt size increases from 10 mm to 7/16-inch. This bolt size change will need to be considered if the flywheel housing was replaced during overhaul.

CAUTION

If the flywheel housing was replaced with the new-style which uses a 7/16-inch transmission-to-flywheel housing bolt, it is very important to also use the correct hardened washer with this bolt.

3. Install the engine mount capscrews to secure the engine to the engine mounts. Tighten the capscrews to specification.
4. Remove the transmission jack from under the transmission.
5. Install the clutch linkage and bracket-retaining capscrews.
6. Install the power steering hoses and reservoir, if applicable.
7. Install the hood rest crossmember(s), if applicable.
8. Support the exhaust pipe to prevent it from dropping onto the EGR hot tube bellows. Then, install the exhaust bracket to the flywheel housing and install the exhaust clamp at the turbocharger.

CAUTION

DO NOT let the exhaust pipe drop onto the bellows of the EGR hot tube as the exhaust pipe clamp is being installed at the turbocharger. The bellows could be damaged requiring replacement of the hot tube.

NOTE

If the V-band is loosened for angular orientation of the compressor cover, ensure that the mating flanges are tightly seated and that the V-band is snug but will still allow cover orientation.

Complete the orientation of the cover and housing before making any rigid connections to the compressor inlet. Tighten the V-band retaining nut to 105 lb-in (12 N•m), using torque wrench J 5853-C, or equivalent. Then make certain that all ducting aligns closely with the turbocharger. This minimizes external stresses acting on the unit.

9. Reinstall the boost pressure relief valve tube. Reconnect the boost pressure relief outlet tube at the exhaust pipe connection.

CAUTION

Use care when installing the boost pressure relief valve tube. The tube can be damaged if bent excessively at the bellows.

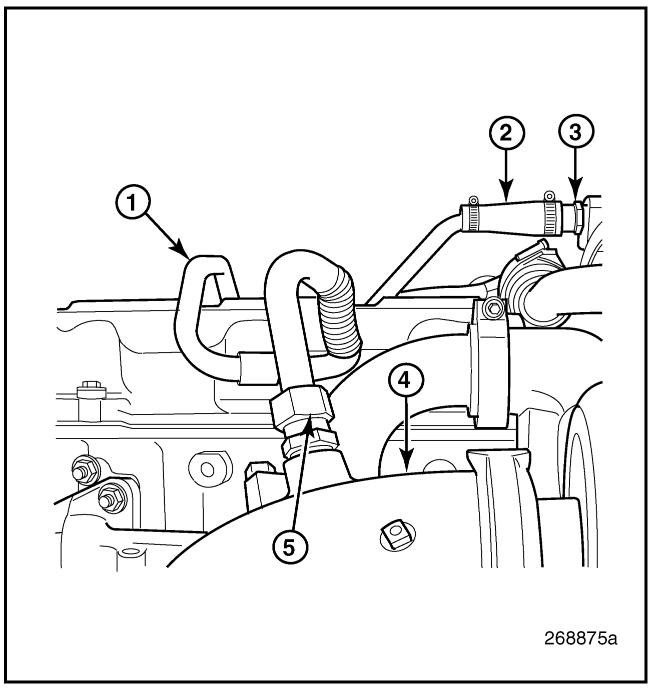


Figure 444 — Boost Pressure Relief Tube

1. Outlet Tube-to-Exhaust 2. Valve-to-Outlet Tube Coupling 3. Boost Pressure Relief Valve (Turbo By-Pass)	4. Exhaust Pipe 5. Outlet Tube-to-Exhaust Pipe Connection

10. Install the starter. Then, connect the wiring and cables.
11. Install the air cleaner housing, if required.
12. Install all coolant tubes, ground straps, air lines, fuel lines, hydraulic hoses or tubes, throttle linkage and electrical wiring harnesses that were removed from the engine during removal.
13. Connect the air inlet tube between the turbocharger and the air cleaner assembly.
14. Connect the heater hoses and A/C refrigerant lines, if applicable, where attached at the lower dash panel behind the engine.
15. Install the fan, fan clutch assembly and bracket on the water pump housing. There are three sets of screw holes in the housing for mounting the fan clutch assembly bracket (Figure 445). The hole set used is dependent on the chassis application.

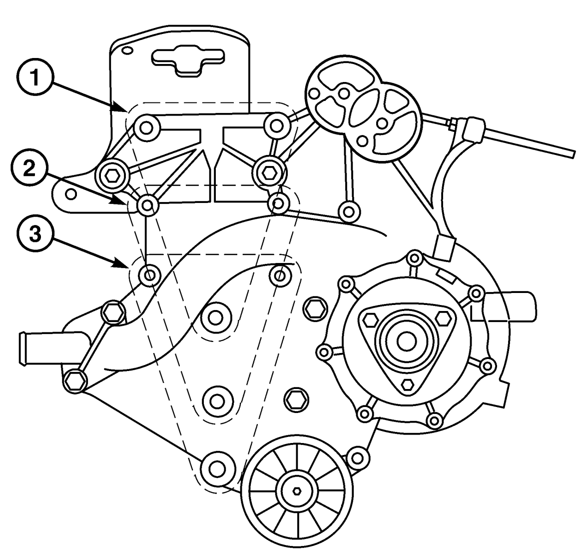


Figure 445 — Fan Clutch Assembly Bracket Mounting Locations

1. Bracket Upper Mounting Location 2. Bracket Middle Mounting Location	3. Bracket Lower Mounting Location

16. Install the accessory drive belts and adjust the belts to specification.
17. Using a lifting device, place the radiator in position at the front of the engine.
18. Install the retaining capscrews to the lower radiator support mounts.
19. Install the retaining capscrews to the radiator support rods.
20. Position the fan clutch air solenoid valve, if so equipped, on the radiator support and install the retaining fastener.
21. Locate the engine coolant temperature sensor, if applicable, and connect it to the wiring harness. Fasten the sensor harness to the radiator support.
22. Install the chassis-mounted charge air cooler (CMCAC) outlet tube and hoses between the cooler and EGR mixer tube.

CAUTION

Be sure to position the CMCAC hose clamps with the bolts on the underside of the hose connection at the EGR mixer tube. If the clamp bolts are installed at the top position, the bolts could rub against the air cleaner duct causing damage to the duct.

23. Install the CMCAC inlet tube and hoses between the turbocharger and the cooler.
24. Place the coolant overflow tank in position and install the retaining clamps.
25. Install the lower radiator hose and tube. Connect the tube to the Y-hose at the coolant inlet of the oil cooler assembly.
26. Reconnect the cab heater and fuel heater coolant return lines to the radiator lower tube (if applicable). The cab heater and optional fuel heater coolant return hoses were relocated from the thermostat housing to the radiator lower tube during mid-2004.

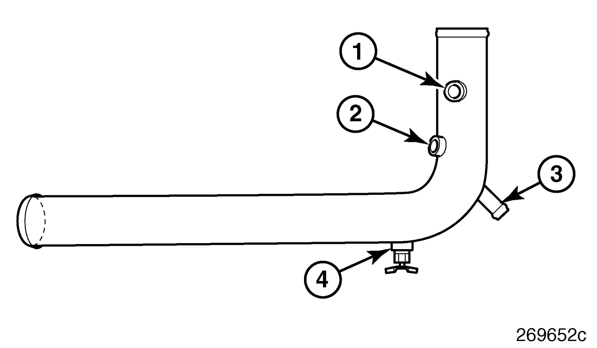


Figure 446 — Radiator Lower Tube with Welded Bosses (Spuds) for Heater Hose Connections (CH Lower Tube Shown)

1. Fuel Heater Coolant Return 2. Cab/Sleeper Heater Coolant Return	3. Transmission Oil Cooler (If Equipped) 4. Draincock

27. Install upper radiator tube and hoses. The connection is made at the coolant outlet fitting on the thermostat housing.
28. If the vehicle is equipped with air conditioning:
    a. Connect the A/C refrigerant low-pressure cutout switch to the wiring harness connector.
    b. Connect the binary (cycling clutch) pressure switch on the receiver/dryer to the wiring harness connector.
    c. Connect the A/C line at the receiver/dryer.
    d. Connect the A/C compressor discharge hose to the system at the connection point near the radiator support.
    e. Recharge the A/C system with refrigerant using the refrigerant recovery and recycling equipment, J 39500-B, or equivalent for R134A.
29. Place the air intake tube in position and tighten the clamps securing the intake tube to the turbocharger and air filter.
30. Install the hood, if applicable. Refer to the Hood Installation procedures in the appropriate vehicle manual.

NOTES

REPAIR INSTRUCTIONS, PART 2

IN-CHASSIS PART/COMPONENT PROCEDURES

This section presents standalone replacement operations which can be done in-chassis and not involve a full engine overhaul. These operations include Electronic Unit Pump Replacement, Camshaft Replacement and Valve Lifter H-Ring Installation Check. In addition, in-chassis service procedures are included for the EECU and MASS Flow System, the cooling system, EGR system and VTG turbocharger.

ELECTRONIC UNIT PUMP REPLACEMENT (IN-CHASSIS) [221 GP]

To properly service the electronic unit pumps (EUPs), it is essential to understand unit pump removal, pin and tappet installation, and unit pump installation. Each of these procedures is covered individually.

Unit Pump Removal

NOTE

When it is necessary to remove more than one EUP, the removed EUPs must be paint-marked with the cylinder number, and reinstalled at their original locations. This will eliminate any need to reprogram the EUP information. If a new or remanufactured EUP is installed, reprogramming must be performed as described at the conclusion of the EUP installation section.

1. Remove both the EGR hot and cool tubes from the right side of the engine (AC engine only).
2. Remove the heat shields.
3. Clean the EUP and cylinder block around the EUP to ensure that no debris enters the engine during EUP removal.

CAUTION

To avoid engine damage due to debris entering EUP bores of the cylinder block, step 2 MUST be followed.

4. On chassis with inlet manifold-mounted fuel filters, remove both the inlet and outlet fuel hoses from the secondary fuel filter. This allows additional fuel to drain from the hose, through the cylinder block, and out of the internal passages.

   On chassis with remote-mounted fuel filters, remove the fuel hose from the cylinder block fuel-inlet fitting, which is behind the EECU at the top. This allows additional fuel to drain through the cylinder block and out of the internal passages.
5. Place a drain pan beneath the right side of the engine. Remove the fuel-outlet fitting from the cylinder block fuel return gallery above the air compressor. This allows fuel to drain from the internal passages.

CAUTION

To ensure that minimal fuel enters the crankcase oil during EUP removal, steps 3 and 4 MUST be followed. To avoid fuel spillage, do not crank the engine with the starter at any time during EUP removal or replacement.

6. Remove the injection tube.
7. Remove the harness wire connections at the EUP terminals.
8. Remove the inboard EUP mounting screw completely.
9. Loosen the outboard EUP mounting screw and back it out 1/2 inch (12 mm).
10. Insert screwdrivers under the bolt bosses (front and rear) and pry until the EUP comes out against the screw head. (The EUP may spring out against the screw head.)

WARNING

The EUP spring may be preloaded with significant spring tension, depending upon cam lobe position. To avoid injury from the EUP springing outward, steps 7–9 must be followed.

11. Remove the outboard EUP screw completely and remove the EUP from the cylinder block. Place the EUP in a clean area and cover it to prevent entry of dirt and other contaminants.

12. Remove the roller tappet from the EUP bore by hand. Do not use a tool as it could damage the bore. Place the roller tappet in a clean area and cover it to prevent the entry of dirt and other contaminants.

Tappet Guide Pin and Tappet Bore Inspection

1. Visually inspect the EUP bore in the cylinder block for protrusion of the guide pin into the bore. If the pin protrudes approximately 0.080 inch (2 mm) into the bore and is not damaged, it is OK and no further action is required.
2. If the guide pin end is damaged or does not protrude approximately 0.080 inch (2 mm) into the bore, replace it as follows:
   a. Using a 1/4-inch diameter punch from outside of the cylinder block, drive the guide pin from its bore.
   b. Clean the pin bore in the block and a **new** pin, part No. 183GC252, with Loctite® primer "T." Then, coat the bore and pin with Loctite® 609, or equivalent.
   c. Drive the pin into the bore until it is flush with the cylinder block outer surface as shown in Figure 447.

NOTE

Occasionally, a failure will result in severe wear and breakage of the roller and roller axle, causing these parts to separate from the lifter body. Subsequently, the lifter legs (which had retained the axle in the lifter body) are bent outward and driven up into the lifter bore by the cam lobe. This action damages the bottom 1/4 to 3/8 inch (6.4–9.5 mm) of the bore, preventing installation of a new lifter.

The damaged bore area must be cleaned up with a file, stone or emery paper before the new lifter can be installed. Use care when removing raised metal so not to enlarge the bore diameter. Any remaining nicks or scores will not inhibit proper function of the parts and cause no problem.

NOTE

A small amount of scuffing or foreign particle scoring in a lifter bore can inhibit static-free movement of a lifter. While this will not cause a lifter to hang-up during engine operation, it is sometimes noticed during lifter removal or installation. If this condition is encountered, use a brake hone to lightly finish the bottom area of the lifter bore. Trial-fit the lifter until the high spots have been removed and free-movement is re-established.

NOTE

If the EUP tappet bore is damaged due to a tappet and tappet guide pin failure, the damaged bore is usable as long as a new tappet cannot be "rocked" from side-to-side in the bore.

If a new guide pin does not have the proper interference fit in the guide bore, meaning the pin fit in the bore is a slip-fit (pin and bore diameter is the same) to 0.001inch (0.025 mm) loose, then the pin will need to be retained with Loctite®.

If a new EUP tappet does not move freely in the bore, clean the bore as described below.

Salvaging a Damaged EUP Tappet Bore

Occasionally, severe failure of an EUP tappet roller and axle will result in parts of the tappet being driven up against the bottom of the tappet bore, causing damage to the bottom of the bore. This damage must be repaired. Depending upon the extent of the damage, it may be necessary to begin with a small die grinder to remove the displaced material, removing only the high spots to bring them down to the remaining bore surface, then finishing with a fine file, stone or emery paper. The bore and adjacent areas must be thoroughly cleaned to remove all metal particles and abrasive material. Perform a trial-fit of the EUP tappet and check for freedom of movement in the bore.

NOTE

Whenever a lifter bore is reworked or honed, be sure that all metal and honing debris is cleaned from all affected areas by flushing with a fresh supply of suitable brake/parts cleaner.

Tappet Installation

1. Clean the cylinder block at the mounting surface and bore, if required.

NOTE

Use only a soft rag and solvent to clean the cylinder block. Minor fretting at the EUP mounting surface is acceptable.

2. Submerge the roller tappet into a container of clean engine oil to allow oil to fill the passage to the roller axle. Remove the roller tappet and while holding it vertically, spin the roller to make sure that oil flows to the surfaces between the axle and roller. This step is important to provide adequate break-in to the axle and roller at initial start-up of new components. Then, carefully install the tappet into the bore using a finger. Refer to Figure 447.

NOTE

Pre-lubrication of the tappets is critical to provide adequate break-in for new axle and roller parts at initial engine start-up.

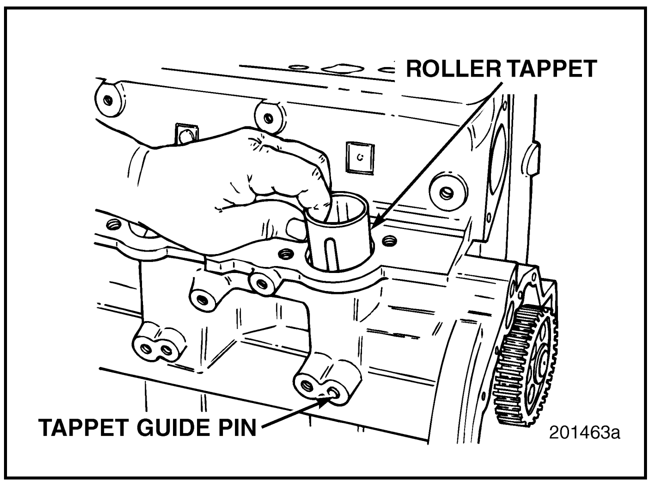


Figure 447 — Positioning Tappet

NOTE

- The slot in the roller tappet MUST be oriented outward to align with the pin in the bore. The roller tappet should slide freely in the bore.
- The tappet guide pins in the EUP bores are factory-installed in all cylinder blocks and should not be removed unless damaged.

Unit Pump Installation

1. Install two **new** O-rings on the replacement EUP in the upper and lower O-ring grooves.

NOTE

For engines with a history of fuel leakage into the crankcase, a new delta seal O-ring (Figure 448) is available through the MACK Parts System. This seal should be used in the lower O-ring position when necessary to correct leakage.

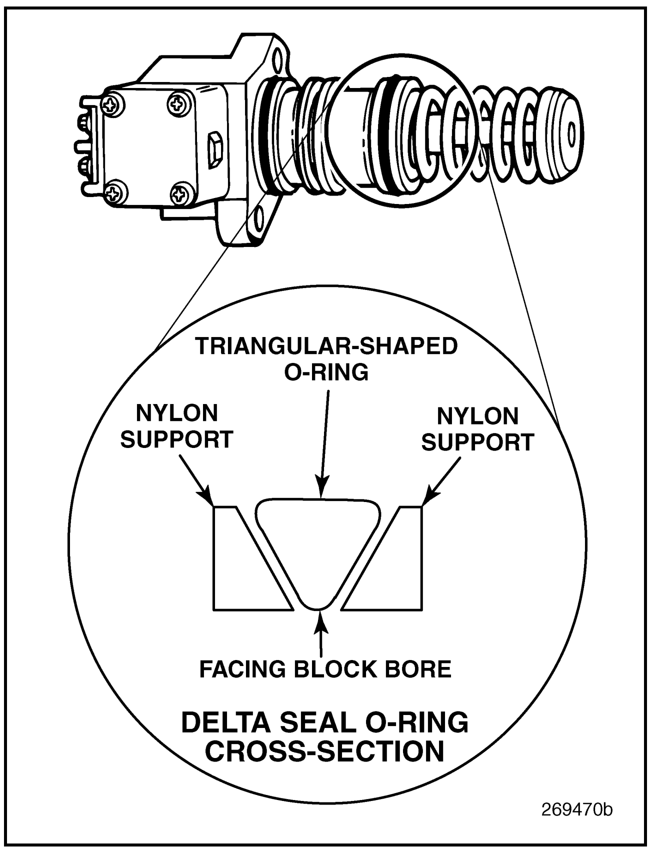


Figure 448 — Delta Seal O-Ring

2. Generously lubricate EUP O-rings with clean engine oil and install the EUP into the cylinder block (Figure 449).

SERVICE HINT

Minimize oil above the top O-ring to avoid weepage of excess oil (trapped above the top O-ring) onto the cylinder block.

CAUTION

To avoid O-ring damage, the cam lobe must be positioned with the base circle UP prior to installation of each EUP. Engine barring tool (tool No. J 3857-A) MUST be used to rotate the engine. DO NOT use the starter to rotate the engine.

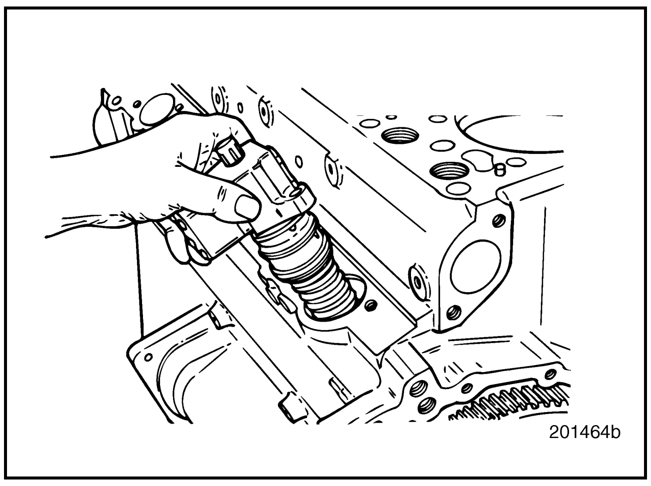


Figure 449 — Unit Pump Installation

3. If not previously done, inspect each EUP hold-down bolt hole in the engine block for rusty or damaged threads. Clean or tap block bolt holes to remove rust or dirt as required. Use an M10 x 1.5 bottom tap.
4. Install **new** EUP hold-down bolts and lightly lubricate the threads and underside of the bolt head with clean engine oil prior to installation. Tighten bolts evenly to draw the EUP into the cylinder block. Tighten the screws to 60 lb-ft (81 N•m).
5. Reinstall the injection line and torque to specification as follows:
   - Line nut at cylinder head: 35 lb-ft (47 N•m)
   - Line nut at EUP: 25 lb-ft (34 N•m)
6. Reinstall the harness wire connections at the EUP terminals and tighten to specification, 13 lb-in ± 2 lb-in (1.5 ± 0.2 N•m). Do not bend the wire terminals down after installation.

NOTE

If an EUP has been replaced with a new or remanufactured unit, the replacement unit must be calibrated as described under “Electronic Pump Calibration” in the ENGINE SETUP AND ADJUSTMENTS section. This will ensure optimum engine performance.

7. Reinstall both the EGR hot and cool tubes (AC engine only).
8. Reinstall the heat shields.

CAMSHAFT REPLACEMENT (IN-CHASSIS) [213 CH]

Preliminary Steps

NOTE

It is a good practice to steam clean the engine to remove road grime, grease and oil before starting work. Steam cleaning the engine allows more detailed inspection and improved workmanship.

Care must be used to keep moisture from entering the air intake system. If moisture does enter the system, make sure it is removed (dried out) immediately, to prevent damage to the engine components.

The preliminary steps for replacing the camshaft will vary depending on the chassis configuration and engine model. As such, these steps are general in nature. Begin the operation by disconnecting the battery and draining all fluids from the engine. Then, remove the hood and fender assembly, radiator, engine accessories/drives, ducts, EGR components (AC engine only), electronic unit pump assemblies and roller tappets, valve covers, engine brake assemblies (if equipped), rocker shaft assemblies, push rods, water pump/housing, oil pan and front cover, etc. Refer to the appropriate sections in this manual for replacement procedures for the various engine components.

The cylinder heads will remain installed. Removal of the cylinder heads will only be necessary if it is determined that the H-ring(s) must be replaced.

Camshaft/Lifter Removal

SERVICE HINT

- When removing or installing the camshaft, first remove the idler gear and hub. It is easier to remove the camshaft guide from the camshaft (after installation) when the idler gear has been removed and alignment of the timing marks is not being attempted at the same time. The final step in the process is to reinstall the idler gear.
- When preparing to install the camshaft removal/installation tool (tool No. J 41682), the engine should be rotated so that the cam timing marks are approximately at the 1–2 o'clock position when viewed from the front. With the engine in this position, adequate clearance will be provided to install the tool.

CAUTION

With the engine in the chassis, the valve lifters must be held in the UP position, using tappet holder J 37720-C in combination with J 42425.

1. Insert the tappet holder in the lifter bore so that the magnetic head of the tool holds the lifter in position. Check to see if the tool has captured the valve lifter by drawing upward on the tool. A resistance will be felt that cannot be felt if the magnet has contacted something other than a valve lifter.
2. Secure the lifter in the UP position with grommets provided with the tappet holders. The holding tool shafts of two adjacent valve lifters can be prevented from dropping by wrapping a rubber band around the two shafts. This draws the shafts together and holds them in position. Refer to Figure 450.

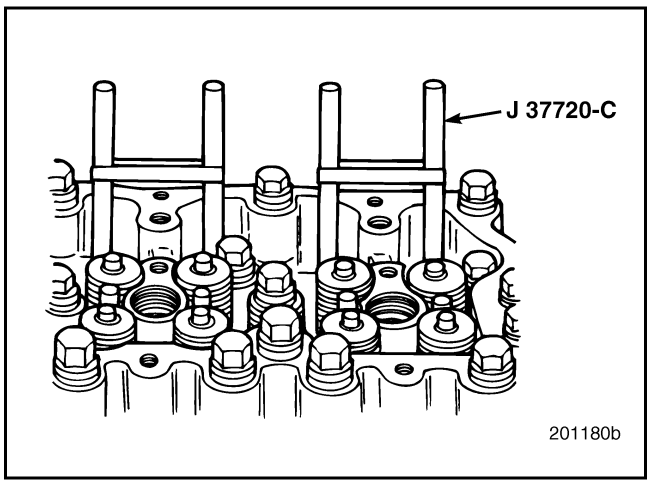


Figure 450 — Valve Lifter (Tappet) Holder Tool J 37720-C

3. If not previously done, rotate the engine in direction of normal rotation so that the cam timing marks are positioned at approximately the 1–2 o'clock position.
4. Remove the two 12-point capscrews that retain the camshaft thrust washer. The camshaft may have to be rotated slightly to make the capscrews accessible through the openings in the camshaft drive gear. Refer to Figure 451.

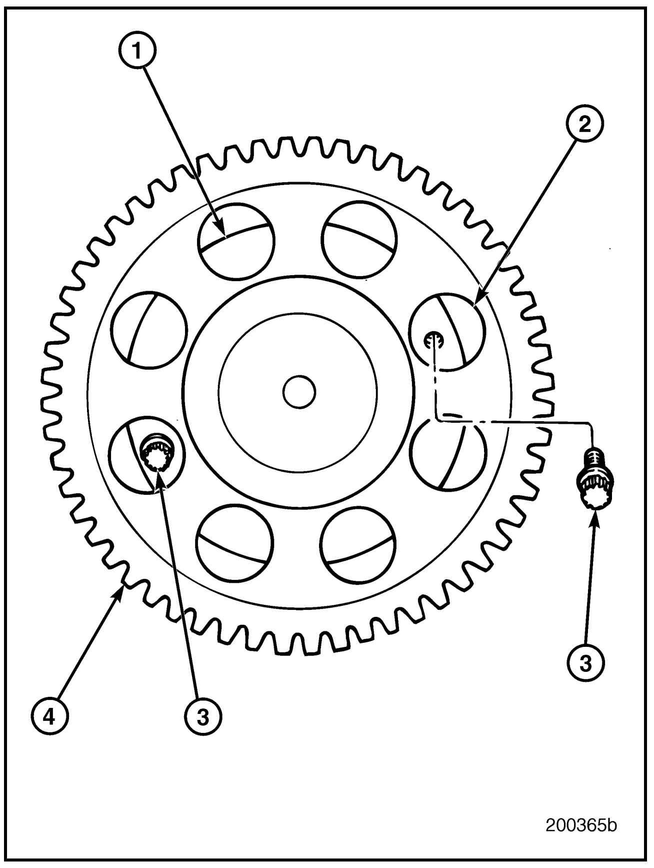


Figure 451 — Camshaft Thrust Washer Capscrews

1. Thrust Washer 2. Openings (8, Current-Production)	3. Capscrew, 12-Point 4. Camshaft Drive Gear

5. Install the camshaft removal/installation tool J 41682 (Figure 452) in position on the rear segment of the camshaft, securing it with the clip to the shaft.

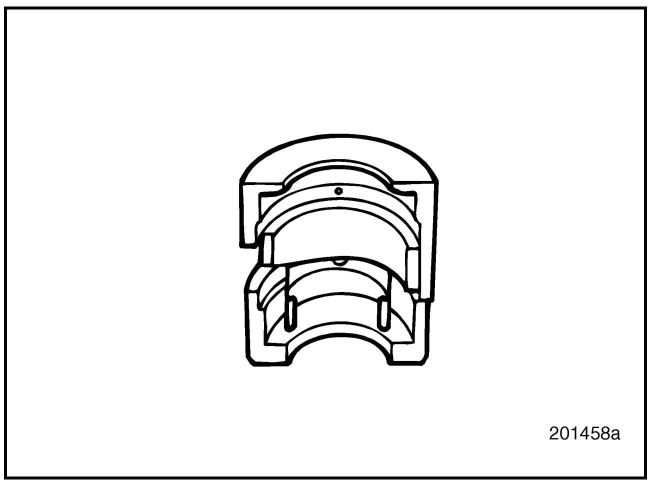


Figure 452 — Camshaft Removal/Installation Tool

6. After installing the removal/installation tool J 41682, remove the idler gear and hub.

SERVICE HINT

Following camshaft installation, it is easier to remove the camshaft removal/installation tool J 41682 if the idler gear and hub have been removed first. For this reason, the idler gear and hub should be removed at this time.

7. Taking care not to damage the camshaft or bushings, pull the camshaft out from the front of the engine. Carefully guide the rear of the shaft through the journals. If the shaft does not come out freely, ensure that all valve lifters are clear of the camshaft lobes and journals.
8. Remove and inspect the valve lifters.

SERVICE HINT

Valve lifters have established wear patterns and should be reinstalled in the same locations. Label each valve lifter upon removal and place it on a clean work surface.

Cleaning and Inspection of Cylinder Block

Salvaging a Damaged Valve Lifter Bore

Refer to “SALVAGING A DAMAGED VALVE LIFTER BORE” on page 189 for complete valve lifter bore repair criteria.

Salvaging a Damaged EUP Tappet Bore

Refer to “SALVAGING A DAMAGED EUP TAPPET BORE” on page 188 for complete EUP tappet bore repair criteria.

Cylinder Block Cleaning and Lifter Checks

While the camshaft is removed and lifter bores are relatively accessible, it is a good practice to clean all the lifter bores and then trial-fit all the lifters into their respective bores and H-rings. Clean and trial-fit lifters as follows:

1. Clean all lifter bores with a fresh supply of suitable brake/parts cleaner. Ensure all Loctite® residue and dried contamination has been removed.
2. Trial-fit a lifter back into its original lifter bore by aligning the lifter flats with the H-ring flats as shown in Figure 453. Use only light finger pressure when installing the lifters. Verify that the lifter has complete freedom of movement in the bore and H-ring in both the upward and downward directions. When the lifter is seated, it should be possible to rotate it slightly from left to right. If the lifter is sticky or tight, or if additional force was required to install the lifter, proceed as follows:

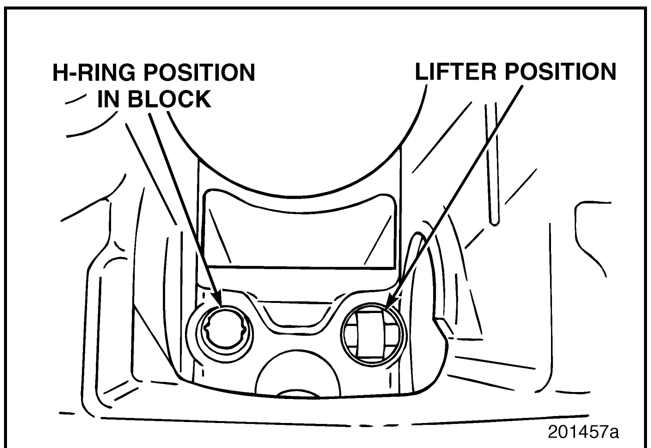


Figure 453 — Installed Valve Lifter

a. If **new** lifters are being installed and the fit is tight, try the lifter in another lifter bore. A stack-up of component tolerances can result in a lifter being free in another bore. This is acceptable.
b. If the original lifters are being reused and the fit is tight, trial-fit a new lifter(s) in the bore. If the tightness persists, the problem may be in the lifter bore or H-ring. (Because of established wear patterns, it is not recommended to install a used lifter in any bore other than the bore from which it was removed.)
c. If the problem is confined to a particular bore, determine if the lifter tightness is due to the lifter bore or the H-ring by trial-fitting another lifter. To correct the problem condition, refer to the procedure under “Salvaging a Valve Lifter Bore” or “H-Ring Replacement” in the CYLINDER BLOCK RECONDITIONING section.

CAUTION

A lifter that does not move freely in the lifter bore can be impacted by the cam lobe during engine operation. This will result in damage or breakage of the ceramic roller.

3. Once all lifters have been trial-fit to their respective bores and H-rings, label each valve lifter and place on a clean work surface until reassembly.

Camshaft Installation

General Instructions

Before installing a camshaft in any engine, ensure that it is clean. Parts that are free of dirt/contamination and are well-lubricated with clean engine oil are essential for initial start-up and run-in. If necessary, wash and brush the camshaft in solvent and blow-dry with compressed air. Also, check the camshaft for possible handling burrs on the edges of journals and lobes. Any minor burrs can be removed with a fine stone.

NOTE

Use camshaft guide tool J 41682 to ease installation of the camshaft and avoid damage to the camshaft bushings.

Procedure

Install the camshaft as follows:

NOTE

In order to use the valve lifter tool to hold the valve lifters in position, the cylinder heads must be installed on the engine.

Check the condition of the valve lifters before installing them. Replace any lifters that are broken, damaged or show signs of excessive wear. Arrange the valve lifters in the order identified so that they can be reinstalled back into the original location from which they were removed.

CAUTION

Ceramic lifter rollers will not tolerate high impact loads. Such loads can crack the ceramic, resulting in breakage or spalling of the ceramic roller. If damaged, cracks too small to detect may be present and result in failure of the ceramic roller. It is extremely important that a ceramic roller lifter that has been subjected to high impact or dropped not be used.

NOTE

Pre-lubrication of the lifters is critical to provide adequate break-in for new roller and roller axle parts at initial engine start-up.

1. Submerge the valve lifters into a container of clean engine oil to allow oil to fill the passages to the roller axles. Remove each lifter and while holding it vertically, spin the roller to make sure the oil flows to the surfaces between the axle and roller. This step is important to provide adequate break-in of the axle and roller at initial start-up of new components.
2. Install a lifter into the lifter bore by aligning the lifter flats with the H-ring flats. As the lifter is seated, it should be possible to rotate it slightly from left to right. Verify that all lifters have complete freedom of movement in the bore and H-rings in both the upward and downward direction. Any sticky or tight lifter conditions can be resolved by referring to "LIFTER BORE CLEANING AND LIFTER CHECKS" on page 189.

CAUTION

With the engine in the chassis, the valve lifters must be held in the UP position, using tappet holder J 37720-C in combination with J 42425.

3. As the lifter is installed, it must be held in position by inserting a tappet holder into the opening through the top of the cylinder head and block. The tappet holder must be positioned so that the magnetic head of the tool holds the lifter in position. Check to see if the tool has captured the valve lifter by drawing upward on the tool. A resistance will be felt that cannot be felt if the magnet has contacted something other than a valve lifter.

4. Secure the lifter in the UP position with grommets provided with the tappet holders. The holding tool shafts of two adjacent valve lifters can be prevented from dropping by wrapping a rubber band around the two shafts. This draws the shafts together and holds them in position. Refer to Figure 450.
5. Repeat steps 2 through 4 to install each of the remaining valve lifters.
6. Apply a generous coating of clean engine oil to the camshaft bushings.
7. Clean the camshaft with a suitable solvent.
8. Apply clean engine oil completely around the running surfaces of the camshaft lobes and bearing journals. Lubriplate-type grease may be substituted for engine oil.

CAUTION

Make sure the captured thrust washer and camshaft gear are properly installed on the camshaft.

9. Install the camshaft installation guide tool over the large flat of the injector lobe, between the last two cam journals (journals at back of shaft).
10. Apply clean engine oil to the installation guide.

NOTE

The camshaft is heavy, approximately 90 pounds with the gear. The installation guide allows the camshaft to slide from one cam bushing to the next without allowing the cam to drop when one journal clears the bushing bore.

11. Slide the camshaft into the block with the cam installation guide facing down toward the floor. Refer to Figure 454.
12. Slide the cam all the way into the block.

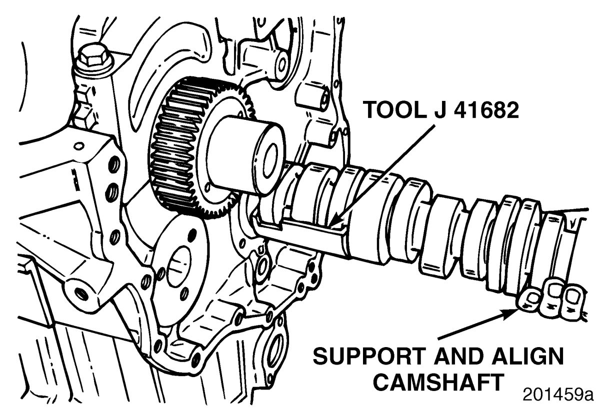


Figure 454 — Camshaft Installation

13. After the camshaft is fully installed, install the thrust washer screws and tighten to specification.
14. Rotate the crankshaft and camshaft to facilitate installation guide removal. The camshaft must be rotated so that the installation guide faces the cylinder block pan rail. The crankshaft must be rotated so the No. 6 connecting rod journal faces the cylinder block top deck (piston at TDC).
15. Remove the installation guide tool J 41682.

Camshaft Idler Gear Installation [213]

Before installing the idler gear/hub assembly, determine which is the top mounting hole on the hub.

The idler gear is held in place by a flanged hub mounted to the cylinder block by three bolts. Although the bolt-mounting pattern may *appear* symmetrical, it is not. The non-symmetrical mounting pattern ensures that the oil feed passages in the hub will be properly aligned with the oil feed passage in the cylinder block, which lubricates the idler gear hub bushing.

To aid in aligning the hub to the mounting holes in the cylinder block, the hub mounting-bolt hole at the 12 o'clock position (engine upright) is identified by the word "UP" steel-stamped just below the mounting hole. Refer to Figure 455.

1. With the engine in an upright position and the hub correctly aligned with the mounting bolt holes, place the idler hub against the block and verify proper alignment of the mounting holes.

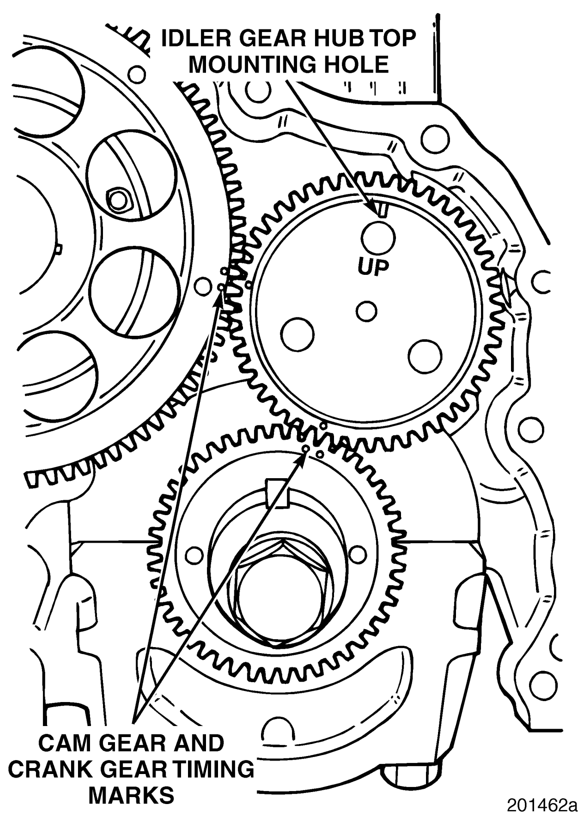


Figure 455 — Hub Correctly Positioned on Block

2. Align the timing marks. First look at the timing marks on both the camshaft and crankshaft gears. Note that two teeth are marked (side-by-side) on each gear. These double timing marks must align with the single timing marks on the idler gear. When properly installed, the two single timing marks on the idler gear will fall between the double timing marks on the camshaft and crankshaft gears. To attain correct alignment, rotate the crankshaft and camshaft gears until the camshaft timing marks are in approximately the 3:30 position, and the crankshaft gear timing marks are in approximately the 1 o'clock position (with engine in upright position and viewed from the front).

NOTE

There are 45 gear teeth on the crankshaft gear, 90 teeth on the camshaft gear and 48 on the idler gear. Because the idler gear has three more teeth than the crankshaft gear, the timing marks align only once every 16 revolutions of the crankshaft. This is called a "hunting tooth" system.

3. Slide the idler gear onto the hub assembly with the timing marks facing out.
4. Position the idler gear timing marks so they align with the crankshaft and camshaft gear timing marks. Then slide the idler gear/hub assembly into position on the engine block.
5. Coat the hub bolts with clean engine oil and thread the bolts a few turns into the respective bolt holes at the front of the engine block.
6. Tap the hub portion of the assembly with a brass hammer to seat the components.
7. Tighten the bolts evenly to specification, 70 lb-ft (95 N•m). Do not use an impact wrench or other air tool to tighten the bolts.

Final Assembly

Complete the reassembly of the engine by installing the front cover, water pump/housing, seals, oil pan, push rods, rocker shaft assemblies, engine brake assemblies (if equipped), valve covers, electronic unit pumps and roller tappets, EGR components (AC engine only), other engine accessories/drives, radiator, hood and fender assembly, etc.

Once the engine reassembly has been accomplished, follow the procedures under "Engine Setup and Adjustments," and "Final Preparation and Operational Check" in the REPAIR INSTRUCTIONS section to complete the camshaft replacement.

EXHAUST VALVE YOKE PIN AND VALVE ROTATOR INSPECTION AND REPLACEMENT CRITERIA (IN-CHASSIS)

On engines that have experienced a camshaft failure, it is likely that excessive valve lash exists at the locations where the cam lobe/lifter roller is severely damaged or worn. Excessive valve lash can cause damage to the exhaust valve yoke guide pins and the valve rotators. To prevent a repeat engine failure, integrity of the guide pins and valve rotators must be determined, and damaged rotators replaced. Procedures for determining valve rotator integrity are as follows:

1. Inspect the oil pan magnetic drain plug for very small pieces of broken-up coil springs. These small pieces of spring coils are approximately 0.0150″ in diameter, and are what remains of a rotator internal spring that has broken apart.
2. Remove the rocker shafts and use a magnet to search all accessible top surfaces of the cylinder head for pieces of rotator springs.

CAUTION

Do not wash the top surfaces of the head. If any pieces of rotator spring are washed down the push rod hole, cam/lifter failure will result.

NOTE

When the rotator internal spring breaks apart, it will break into small pieces of coil. These small pieces will remain inside the rotator for a period of time, but will eventually migrate out of the rotator. The greatest concentration of these small spring coil pieces will be found in the valve spring seat counterbore areas of the cylinder head. To find these small pieces, it will be necessary to remove the rotator and valve spring to check the spring seat counterbore area.

3. Perform the following inspections to determine the likely locations for damaged valve rotators:
   a. Inspect and record the locations where the cam lobes (both inlet and exhaust) and the lifter rollers exhibit moderate-to-severe wear/damage. Rotate the engine to bring the piston to top-dead-center at that location, then remove the valve keys and carefully remove the rotator and valve spring. Use a magnet to search for and remove pieces of the rotator spring coil.
   b. If the engine is equipped with a J-Tech™ engine brake, measure the exhaust yoke actuating pin adjusting screw assemblies and record the locations where any screw has an overall height dimension of 0.945″ (24.00 mm) or less.
   c. If the actuating pin adjusting screw assemblies measure 0.945″ (24.00 mm) or less, the valve yoke guide pin at the location of this extreme wear must be replace. Use dowel extrator (tool No. PT 6575) to remove the guide pins.

REPAIR INSTRUCTIONS, PART 2

NOTE

- On engines equipped with a J-Tech™ engine brake, new actuating pin adjusting screw assemblies were implemented into production. These new assemblies feature a XADC-ARMOLOY® coating on the bottom pin seat area of the screw body and on the entire surface of the floating pin. This coating provides a more durable seat area for the actuating pin. This coating gives a the pin seat area and the bottom side of the first thread a dull aluminum color. If the existing actuating pin adjusting screw assemblies are not the XADC-ARMOLOY® coated type, replace with **new** screw assemblies.
- On J-Tech™ equipped engines that exhibit worn actuating pin adjusting screws, broken exhaust valve yoke guide pins and broken rotator springs, the possibility exists that the engine brake slave pistons may also be broken. The slave piston springs should be removed and inspected as outlined in service bulletin SB-213-027, and replaced as required. A parts kit (part No. 215SB321) that contains new design reset screws, slave piston springs and the actuating pin adjusting screws with the XADC-ARMOLOY® coating is available through the MACK Parts System to update the engine brake units with new and improved component. Always verify that the engine is not already equipped with these new components.

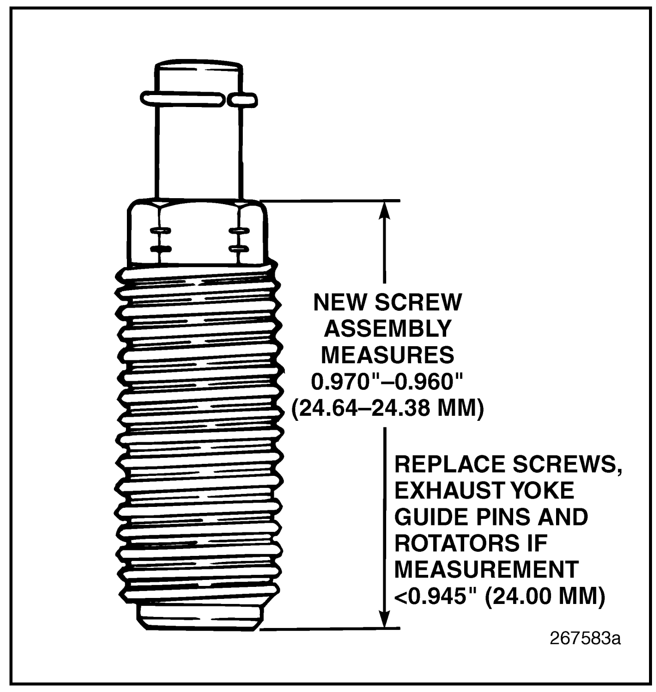


Figure 456 — J-Tech™ Exhaust Valve Adjusting Screw Dimensions

4. At the locations recorded in steps “a” and “b” above, the rotators must be replaced. Be sure to use a magnet to clean all the pieces of broken rotator springs from the valve spring seat counterbores before the valve springs and rotators are reinstalled.

NOTE

If the above inspections, plus any obviously failed rotators, determine that replacement of 12 valve rotators is necessary, then all 24 rotators should be replaced.

NOTE

If a significant amount of coil spring pieces are found on the magnetic drain plug and cylinder head top surface, but the inspections performed in steps “a” and “b” indicate that less than 12 rotators must be replaced, all rotators should be removed and the valve spring seat counterbores checked for pieces of coil spring. Any location where pieces of coil spring are found require that the rotators be replaced.

CAUTION

Failure to replace a rotator that has a broken spring will result in complete failure of the rotator, and will eventually lead to major engine damage.

VALVE LIFTER H-RING DISLODGEMENT AND ALIGNMENT INSPECTIONS (IN-CHASSIS)
[213 CH]

After the camshaft has been removed, the valve lifter H-rings must be inspected for dislodgement and alignment. H-ring dislodgement is checked by using a piece of welding rod as described in the following procedure; whereas, H-ring alignment checked with special tool No. J 46083 is described in the procedure outlined under “Alignment Inspection.”

NOTE

The H-ring alignment checking tool cannot be used to determine if an H-ring has been dislodged and pushed up into the lifter bore. H-ring height must be checked using the following “Dislodgement Inspection” procedure.

CAUTION

Any valve train failure that results in excessive valve lash or subjects the lifter body to rotational force can result in the H-ring being dislodged, or rotated out of proper alignment. This can be caused by a cam/lifter failure or by breakage of a rocker arm, rocker arm shaft or mounting bolts. When any such failure has occurred, inspection of the lifters and H-rings must be conducted to ensure that the H-rings are properly aligned. An existing out-of-alignment condition that is not corrected will result in subsequent cam/lifter failure.

H-Ring Dislodgement Inspection

Dislodging of the H-ring from its bore results from valve lifter inertia forcing the H-ring upward. When the H-ring at a failure cylinder is higher than that of an adjacent cylinder, the appropriate action must be taken depending upon how much the H-ring has been pushed upward. Measure the installation depth of the H-ring as follows:

1. If not previously done, remove the push rod and look down the push rod hole, observing the top of the lifter and the top of the H-ring.
2. Place a length of welding rod (approximately 15 inches long) on top of the H-ring, at the outboard side. Refer to Figure 457.

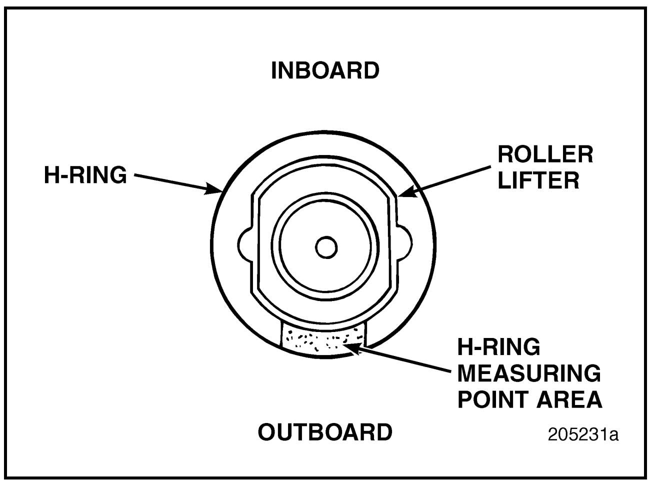


Figure 457 — H-Ring Measuring Point

3. Place a straightedge on the cylinder head top rail surface, in contact with the welding rod.
4. Mark the welding rod at the point where it contacts the straightedge.
5. Perform the same check at an adjacent cylinder and mark its point of contact on the welding rod. Compare the measurement taken at the adjacent cylinder with the measurement taken at the suspect failure cylinder.
   - If the H-ring at the failure cylinder is the same height-to-1/16 inch (0–1.587 mm) higher as compared to that of an adjacent OK cylinder, it is concluded that no partial dislodging of the H-ring has occurred. No further action is required.
   - If the H-ring at the failure cylinder is 1/16–1/8 inch (1.587–3.175 mm) higher than that of an adjacent OK cylinder, the H-ring position is OK.
   - If the H-ring is more than 1/8 inch (3.175 mm) higher than that of an adjacent OK cylinder, the H-ring has become dislodged and must be replaced.

H-Ring Alignment Inspection

H-ring alignment is checked with H-ring alignment checking tool No. J 46083 as follows:

1. With the camshaft and lifters removed, insert the alignment checking tool J 46083 into the mating pair of lifter bores from the crankcase side.

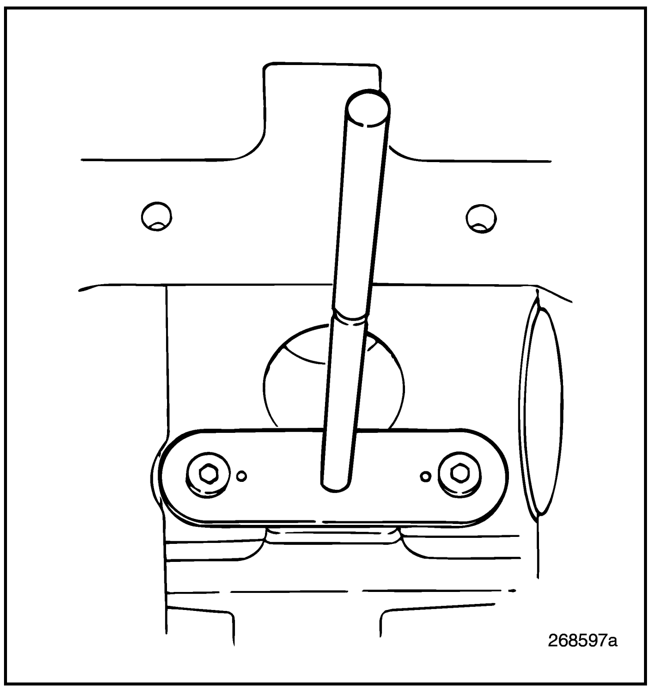


Figure 458 — Alignment Tool Inserted into Lifter Bore

2. Check to see if the depth groove on the tool handle aligns with the oil pan mounting surface of the cylinder block. If both H-rings are in alignment, the tool will be inserted all the way into the lifter bores, and the depth groove on the handle will align with the oil pan mounting surface. If either of the H-rings is not in alignment, the tool will not fully insert into the lifter bores and the insertion depth groove on the tool handle will not align with the oil pan mounting surface.

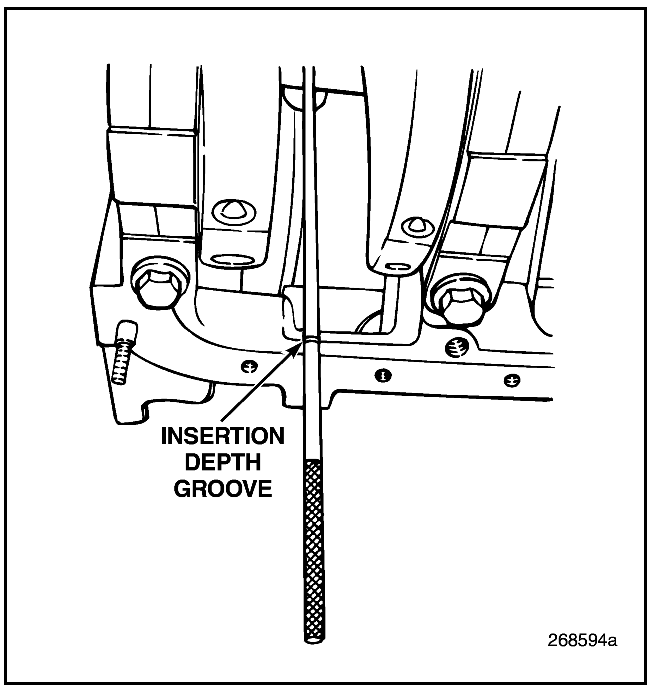


Figure 459 — Checking Insertion Depth Groove

If it has been determined that an H-ring is not in alignment, the cylinder head must be removed and the pair of H-rings must be checked with the H-ring installation tool (tool No. J 41683-A) to determine which H-ring is misaligned.

CAUTION

It is mandatory that the H-ring alignment checking tool be used to check H-ring alignment whenever the camshaft is removed.

If it has been determined that an H-ring is not properly aligned, the cylinder head(s) must be removed and the H-ring installation tool (tool No. J 41683-A) must be used to properly install the ***new*** *H-rings. Under no circumstances should the H-ring alignment checking tool, or any other method of installation, be used to install the H-rings from the bottom of the engines.*

H-Ring Dislodgement Check and Alignment Verification

Requires Removal of Cylinder Head(s)

NOTE

If the H-ring dislodgement or alignment checks performed previously reveal that an H-ring is dislodged or out of alignment, the cylinder head(s) must be removed, and the position of the H-ring verified with the H-ring installation tool (tool No. J 41683-A).

With the cylinder heads removed, insert the H-ring installation leg of tool J 41683-A into the push rod bore with the suspected dislodged H-ring and the shorter alignment leg into an adjacent push rod hole.

- If the tool seats on the cylinder block top deck, the H-ring is properly aligned and not dislodged upward.
- If the tool does not seat on the cylinder block top deck, then the H-ring is dislodged upward and/or is rotated out of alignment. If this occurs, remove and replace the H-ring as described in "H-Ring Replacement" on page 195.

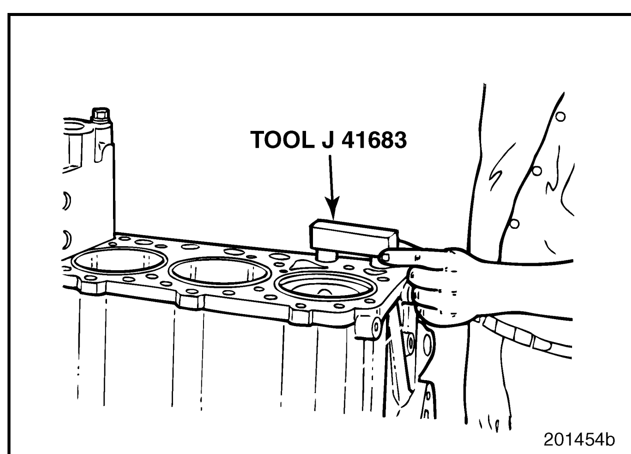


Figure 460 — Checking H-Ring Installation

EECU AND SENSOR SERVICE PROCEDURES (IN-CHASSIS)

Engine Electronic Control Unit (EECU) and Cooling Plate Removal

[230 EA]

NOTE

The following procedure applies for an EECU mounted to the cooling plate at the front left side of the engine.

1. Thoroughly clean and dry the area around the EECU harness connector to make sure the terminals remain clean and dry for reassembly.
2. Remove the bolt securing the EECU wiring harness clamps to the EECU cooling plate bracket.
3. Disconnect the wiring harness connectors from the EECU (Figure 461).

CAUTION

Use care when removing the harness connectors from the module. Be sure to lift the locking lever to the full-open position before pulling a connector from the module to avoid damage to the lever.

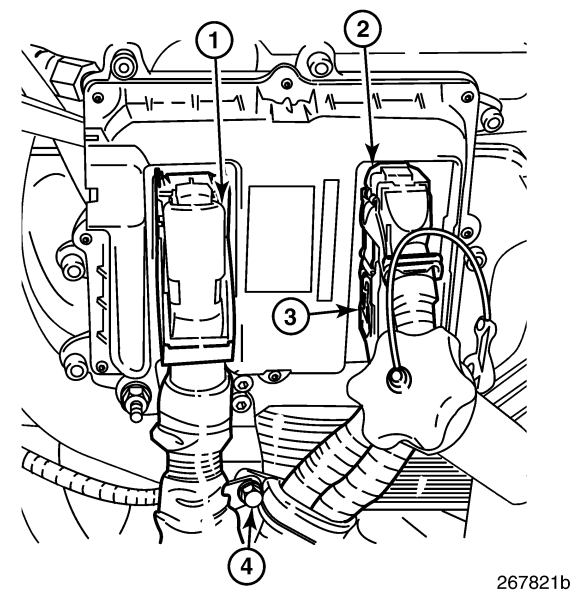


Figure 461 — EECU Connectors

1. Connector EJ2 (89 Pin) 2. Connector EJ1 (36 Pin) 3. Connector EJ3 (16 Pin)	4. EECU Harness Clamp Bolt

4. Remove the eight bolts, two each at the top, bottom and sides, that secure the EECU to the cooling plate.
5. Carefully remove the EECU from the cooling plate (Figure 462). The cooling plate can remain attached to the inlet and coolant manifolds providing the plate is not being replaced. If the plated is to be replaced, continue on with the next step.

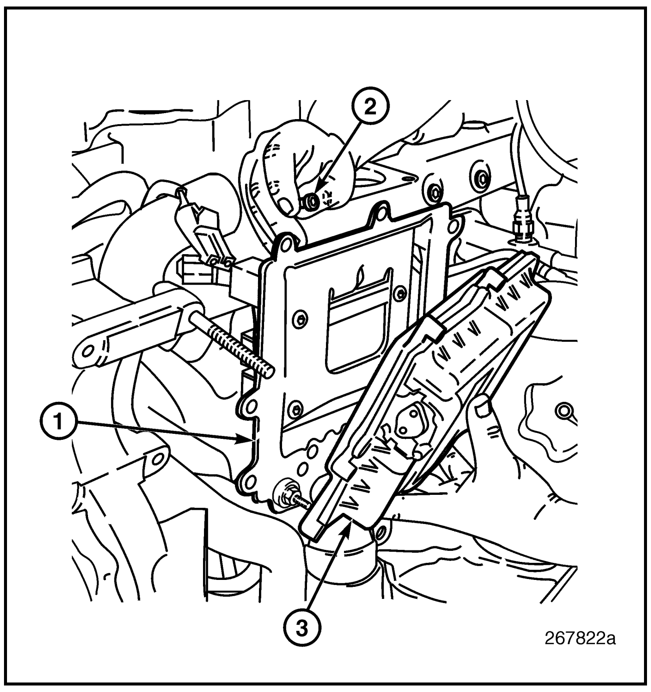


Figure 462 — EECU Removal/Installation

1. Cooling Plate 2. Retaining Bolt	3. EECU

6. Disconnect the two harness leads from the EGR MASS Flow module mounted to the back side of the cooling plate (Figure 463).

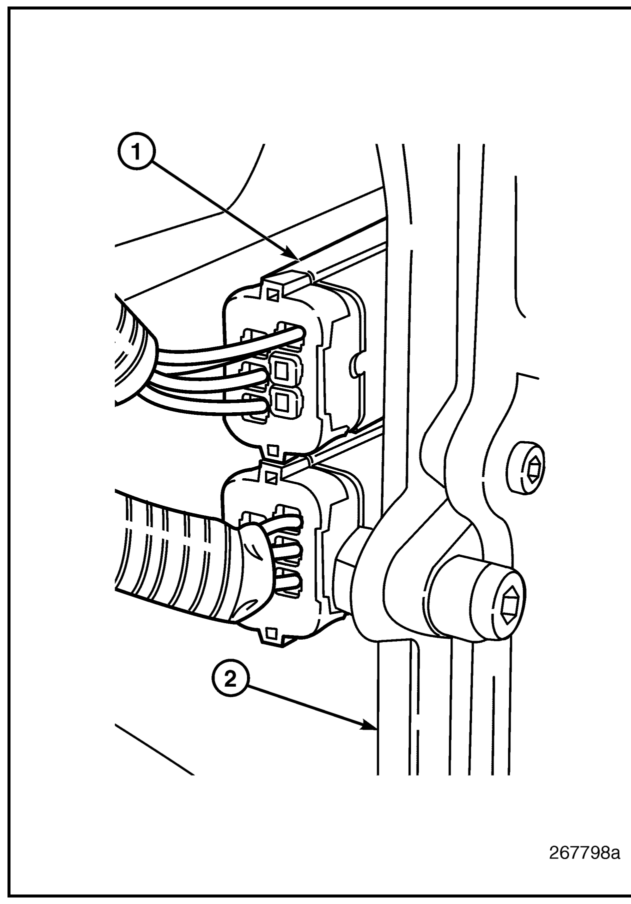


Figure 463 — EGR MASS Flow Module Connections

1. Module Connections	2. Cooling Plate

7. Disconnect the fuel lines at the inlet and outlet ports at the top of the cooling plate (Figure 464) and position the lines out-of-way.

CAUTION

Use care when disconnecting the fuel lines to avoid putting stress on the plate fittings and damaging the plate. Use two wrenches, one to support the plate fitting and the second to disconnect the line.

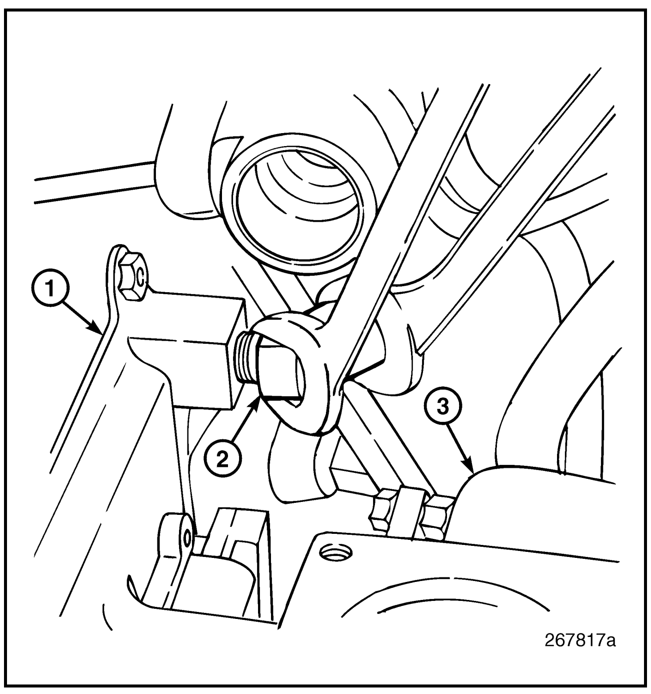


Figure 464 — Cooling Plate Fuel Lines

1. Cooling Plate 2. Fuel Line	3. Thermostat Housing

8. Loosen the two retaining nuts securing the plate support bracket to the mounting studs on top of the coolant manifold. The bracket has slotted attachment points so the retaining nuts need only to be loosened and not removed.
9. Remove the two retaining nuts from the mounting studs at the bottom of the cooling plate and remove cooling plate assembly.

NOTE

The EGR MASS Flow module is attached at the back side of the cooling plate with mounting screws.

EECU and Cooling Plate Installation [230 EA]

1. Check to make sure that the rubber insulators are in position on the mounting studs at the inlet and coolant manifold positions.
2. Place the cooling plate in position over the mounting studs and install the retaining nuts. Tighten the nuts to specification.
3. Connect the fuel lines to the inlet and outlet ports of the cooling plate (Figure 464).
4. Connect the wiring harness leads to the EGR MASS Flow module (Figure 463).
5. Make sure the cooling plate and EECU mating surfaces are clean. Place the EECU in position on the cooling plate and install the eight retaining bolts. Tighten the bolts to specification (Figure 462).
6. Reinstall the bolt securing the EECU wiring harness clamps to the EECU cooling plate bracket (Figure 461).
7. Connect the wiring harness to the EECU (Figure 461).

CAUTION

Make sure that the seals are firmly seated on the connectors and that the EECU terminal pins are straight and not damaged.

- *EJ2 (89-pin connector) — Lift the locking lever to the full-open position and place the connector in position squarely over the module terminals. Push the connector into the module until firmly seated. Then, close the locking lever to secure the connection. DO NOT use the locking lever to seat the connector.*
- *EJ1 (36-pin connector) and EJ3 (16-pin connector) — Lift the metal locking lever to the full-open position and place the connector in position squarely over the module terminals. Push the connector into the module until firmly seated. And last, push down on the center crosspiece of the lever to close and secure the connection. DO NOT apply pressure to the outer edges of the locking lever which then can be bent and fail to secure the connection.*

Sensors Installation and Adjustment

ASET™ AC ENGINE SENSORS

The engine speed and engine position sensors are adjustable following the procedures covered in the ENGINE SETUP AND ADJUSTMENTS section. The remaining engine-mounted sensors are thread-mounted and are not adjustable. Refer to “Torque Specifications” for engine-mounted sensors in the SPECIFICATIONS section for thread sizes and torque specifications. The following is a list of the thread-mounted sensors:

- Oil pressure sensors
- Oil temperature
- Coolant temperature
- Boost pressure
- Boost air temperature
- Fuel temperature
- Air Temperature/Humidity Sensor
- Compressor Discharge Temperature Sensor
- CMCAC Outlet Temperature Sensor
- Inlet Manifold Temperature Sensor
- VTG Position Sensor
- VTG Wheel-Speed Sensor

The **EGR Temperature and EGR MASS Flow sensors**, however, are an integral part of the upper EGR gas tube and are not serviceable as separate items. If replacement is required, the upper EGR gas tube must be replaced along with the EGR MASS Flow module to maintain proper system calibration.

COOLING SYSTEM SERVICE PROCEDURES (IN-CHASSIS)

Thermostat Replacement

[215 NU, NG & LD]

The EGR mixer tube must be removed to gain access to the thermostat housing for replacement of the thermostats. Once the mixer tube is removed, proceed as follows:

WARNING

Allow the cooling system to cool completely before attempting to remove the thermostat or thermostat housing. To avoid injury when removing the pressure cap from the surge tank, turn the cap counterclockwise to the first stop, but do not depress. Allow pressure to dissipate completely, and then press on the cap downward and continue turning to remove.

THERMOSTAT HOUSING REMOVAL

[215 NG & NU]

1. Loosen the hose clamp for the surge tank port at the side of the thermostat housing. Allow the surge tank to drain into an approved container and save the coolant for reuse.
2. Loosen the hose clamps and disconnect the bypass and radiator hoses at the front of the thermostat housing (Figure 465).

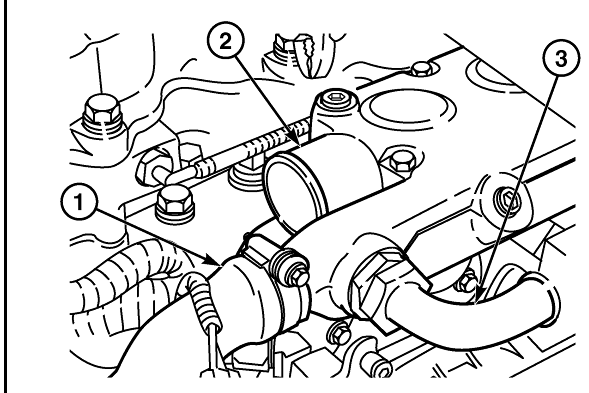


Figure 465 — Thermostat Housing Hose Connections

1. Bypass Hose 2. Radiator Hose Port	3. Surge Tank Port

3. Remove the cab heater and optional fuel heater coolant return hoses from the thermostat housing (if applicable). The cab heater and optional fuel heater coolant return hoses were relocated from the thermostat housing to the radiator lower tube in mid-2004.
4. Loosen and remove the three mounting capscrews from the thermostat housing.

5. Remove the thermostat housing assembly (Figure 466).

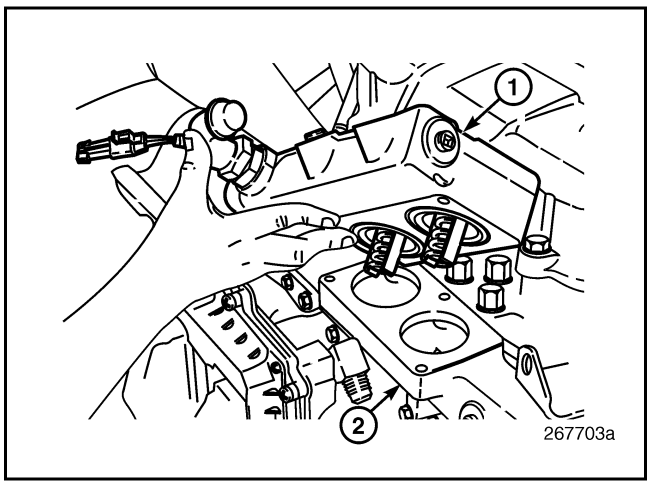


Figure 466 — Thermostat Housing

1. Thermostat Housing	2. Coolant Manifold

6. Remove the thermostats from the housing.
7. Examine the surface of the thermostat sleeves and the housing bore area. Using crocus cloth, remove any surface nicks, burrs, sharp edges and tool marks from the sleeves and bore area to prevent premature failure of the seals.

COOLANT BYPASS TUBE AND Y-HOSE

With the EECU, cooling plate and thermostat housing removed, the bypass tube and Y-hose can be removed from the oil cooler if required.

1. Loosen the clamp and remove the tube from the Y-hose.
2. Carefully remove the tube through the tight spacing between the water pump housing and the inlet manifold (Figure 467).

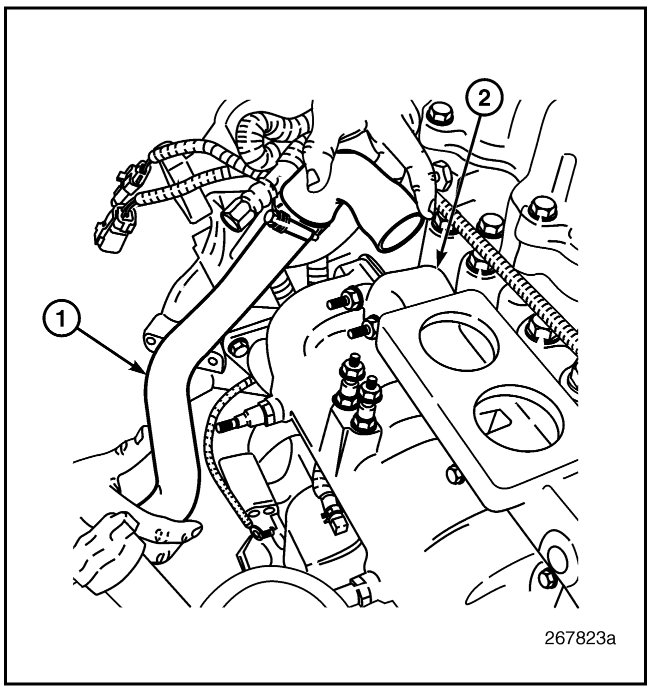


Figure 467 — Coolant Bypass Tube

1. Bypass Tube	2. Thermostat Housing

3. Loosen the clamp securing the Y-hose to the oil cooler inlet port and remove the hose and filter screen (Figure 468).

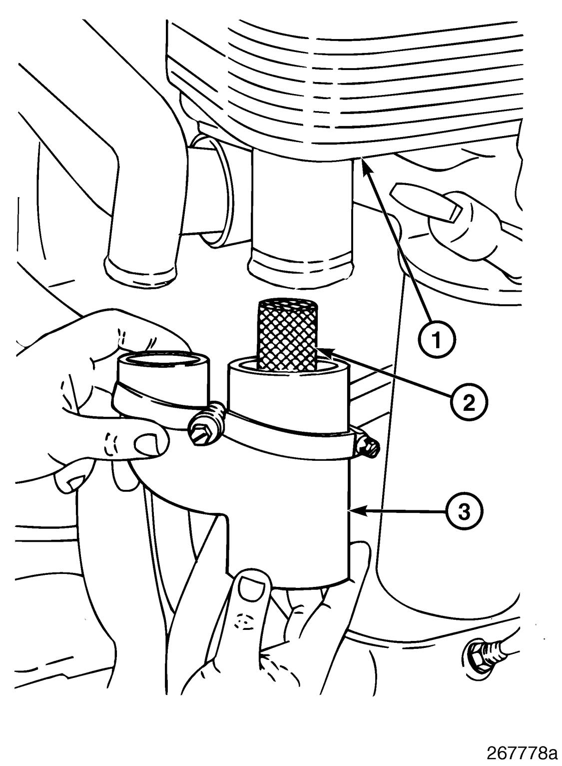


Figure 468 — Y-Hose, Coolant Screen and Oil Cooler Inlet

1. Oil Cooler 2. Coolant Screen	3. Y-Hose

4. Remove the screen from the hose. Clean the screen and inspect for tears or other damage. Replace the screen if required.
5. Place the screen in position in the Y-hose.
6. With the clamps positioned on the Y-hose, install the hose on the oil cooler inlet port. Tighten the clamp to specification.

CAUTION

Use care not to slide the Y-hose so far onto the oil cooler inlet port that it blocks the bypass coolant flow circuit. If the bypass circuit is blocked, coolant can be forced out of the expansion tank.

7. Slide the bypass tube into position between the water pump housing and the inlet manifold.
8. Connect the tube to the Y-hose and secure with the clamp tightened to specification.

THERMOSTAT HOUSING INSTALLATION

1. Check to see that the stainless steel wear rings/shields are properly installed in the thermostat housing (Figure 469).

NOTE

If the wear rings/shields are not in place, the thermostats can wear into the aluminum casting of the thermostat housing. If the wear rings/shields become dislodged or out of position, they can be replaced, or if necessary, crimped to attain a tight fit, and then reinstalled. The shields have a very slight press-fit to the bore. An installation tool is not used. Use finger pressure to push each shield to full seating.

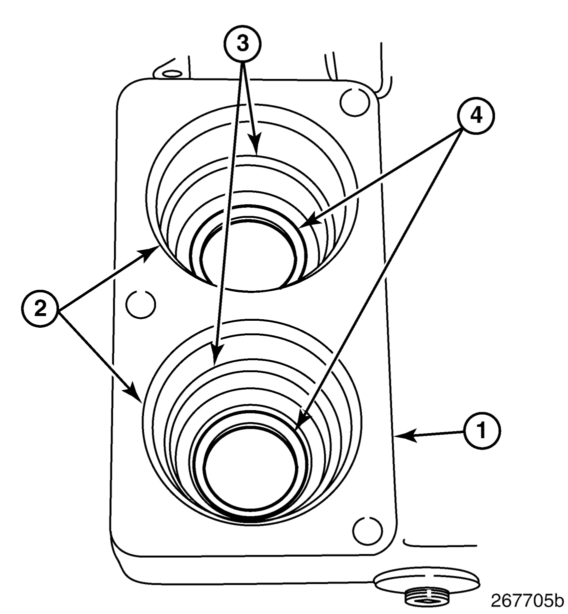


Figure 469 — Wear Rings Installed

1. Thermostat Housing 2. Thermostat Rubber Seal Bore	3. Thermostat Barrel Seal Bore 4. Wear Rings/Shields (Pressed In)

NOTE

When replacement is required, always replace thermostats in pairs. Always install a **new** seal in each housing bore and place the thermostats in position in the housing bores with the valve spring up. Check to see that the bores are free from any contaminants such as chips, grit, dust or any other debris that would damage the barrel seals or prevent the thermostat from seating properly when it is fully closed.

2. If required, install a **new** thermostat barrel seal in each of the thermostat chambers using the following procedure:

   a. Use crocus cloth to remove any surface nicks, burrs, sharp edges and tool marks from the thermostat sleeve and housing bore area.

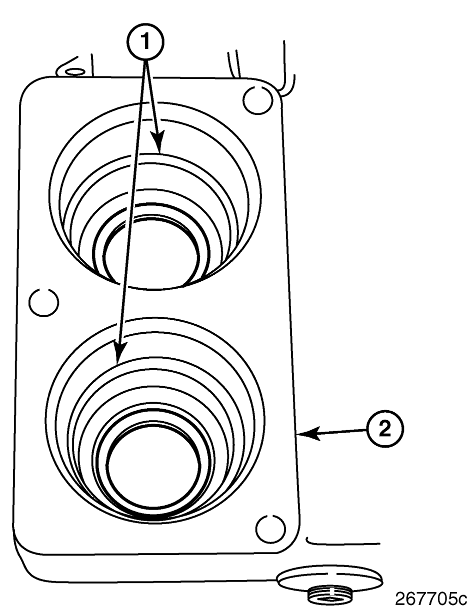


Figure 470 — Thermostat Housing

1. Barrel Seal Bore	2. Thermostat Housing

   b. Check to see that replacement barrel seals are free from any contaminants such as chips, grit, dust or any other debris that would prevent the seal from properly seating in the thermostat housing bore.

   c. Press the barrel seal into the housing bore by applying smooth, uniform pressure with a press fitting tool. Press fitting tools are available through the Kent-Moore tool company.

   d. A complete set of installation tools includes thermostat seal installers (J 26637-A and J 26638-B) and a driver handle (J 8092). Use Kent-Moore tools, or equivalent, for this procedure.

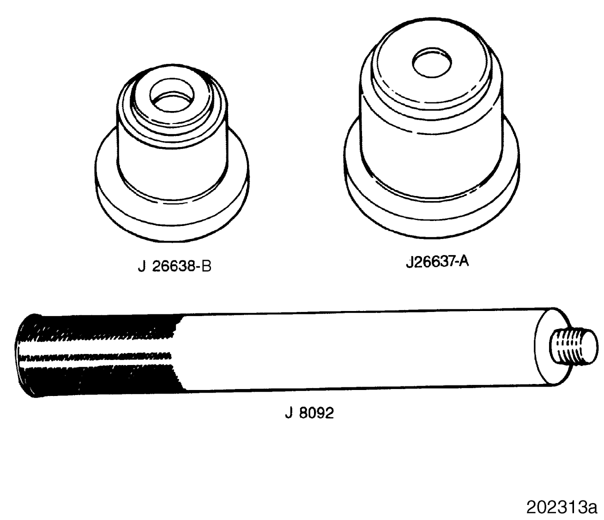


Figure 471 — Thermostat Barrel Seal Installation Tool

   e. Always use the proper seal installer. Do not use a hammer or apply uneven pressure directly to seal surfaces. Precautions should be taken against cocking of the seal throughout the installation operation. Make sure that when the seal is in the final position, it is not cocked.

3. Ensure the thermostat flange seal is in proper position on each thermostat (seal is an integral part of the thermostat) and place the thermostats in position in the housing bores with the valve spring up (Figure 472). Make sure that the thermostat flange seals are properly seated in the thermostat housing bore.

NOTE

The seals attached to the thermostats provide total sealing for the housing-to-coolant manifold joint. No other sealant is required.

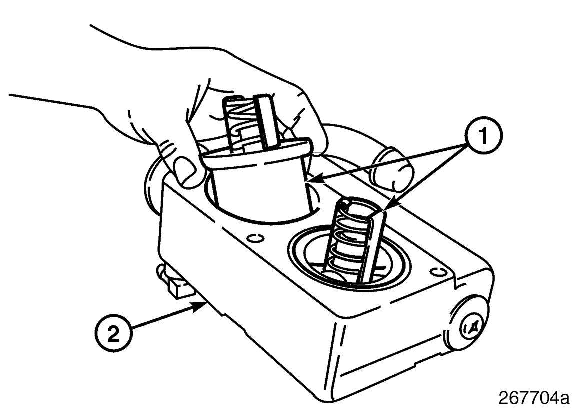


Figure 472 — Thermostat Positioning

1. Thermostats	2. Thermostat Housing

4. Position the thermostats with the ball check valves facing toward the front of the assembled engine.

CAUTION

Make sure the ball check valves on the thermostats are facing forward. Proper positioning of the ball check valve is critical for proper de-aeration of the cooling system and proper and complete coolant fill.

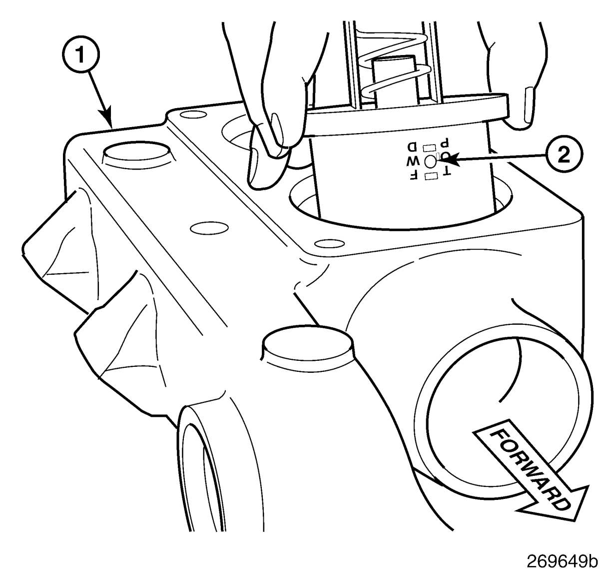


Figure 473 — Thermostat Positioning on Dual Thermostat Housing

1. Thermostat Housing	2. Vent Port/Ball Check Valve Faces Front

5. Position the housing assembly on the coolant manifold mounting surface and install the three mounting capscrews (Figure 466). Tighten the capscrews to specification.
6. Install the cab heater and optional fuel heater coolant return hoses into the thermostat housing (if applicable). The cab heater and optional fuel heater coolant return hoses were relocated from the thermostat housing to the radiator lower tube in mid-2004.
7. Reconnect the bypass and radiator hoses at the front of the thermostat housing (Figure 474) and reconnect the surge tank hose. Tighten all hose clamps to specifications.

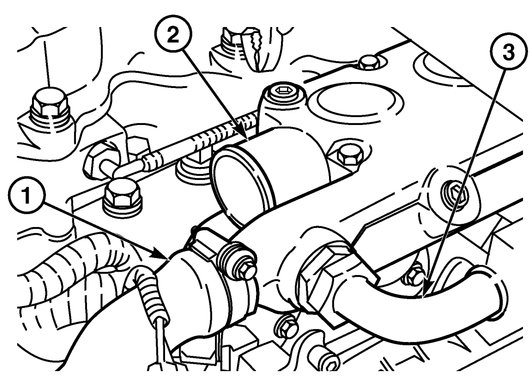


Figure 474 — Thermostat Housing Hose Connections

1. Bypass Hose 2. Radiator Hose Port	3. Surge Tank Port

8. Reinstall the EGR mixer tube.
9. Refill the surge tank with the coolant removed at disassembly.

Water Pump Housing Assembly Removal and Installation

[215 SW]

The preliminary steps for replacing the water pump housing will vary depending on the chassis configuration. As such, these steps are general in nature. Begin the operation by disconnecting the battery and draining coolant from the engine. Then, remove the hood and fender assembly, charge air cooler and radiator.

NOTE

For problems with the water pump, DO NOT replace the entire water pump and housing assembly. Replace only the water pump cartridge if the problem is in the impeller unit.

PUMP REMOVAL

Refer to Figure 477 as required to identify parts referenced in the steps below.

1. Remove the drive belts, fan-speed sensor lead and fan drive assembly from the water pump housing.
2. Remove the seven mounting capscrews and remove the pump impeller assembly from the water pump housing (Figure 475). Discard the O-ring.

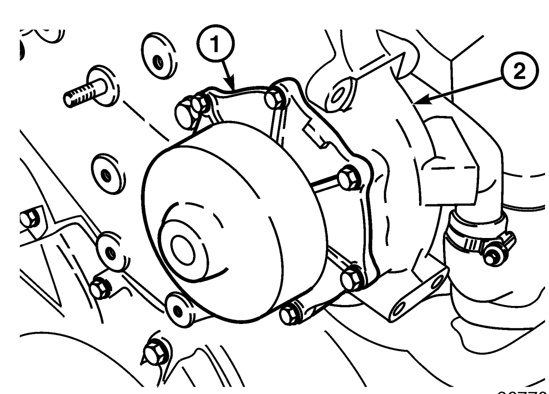


Figure 475 — Water Pump Cartridge

1. Water Pump Cartridge	2. Water Pump Housing

3. Disconnect the coolant supply hose to EGR cooler from the fitting on the water pump.
4. Disconnect the coolant inlet tube from the inlet port at the back of the water pump on the left side of the engine. If required, disconnect the tube from the oil cooler and remove the tube.
5. Remove the two mounting bolts from the threaded inserts at the top of the pump housing.
6. Using a suitable slotted-socket tool, remove the two inserts from the housing (Figure 479) and remove the engine lifting bracket from between the housing and the cylinder head.
7. Remove the two bottom mounting and two mid-position mounting bolts from the pump housing.
8. Remove the water pump stiffening bracket by first removing the two M8 flanged nuts from the studs at the forward position of the water manifold. Then remove the M8 flanged nut from the backside of the A/C compressor upper mounting stud to release the water pump stiffening bracket. Refer to Figure 477.
9. Remove the housing from the cylinder block (Figure 476).

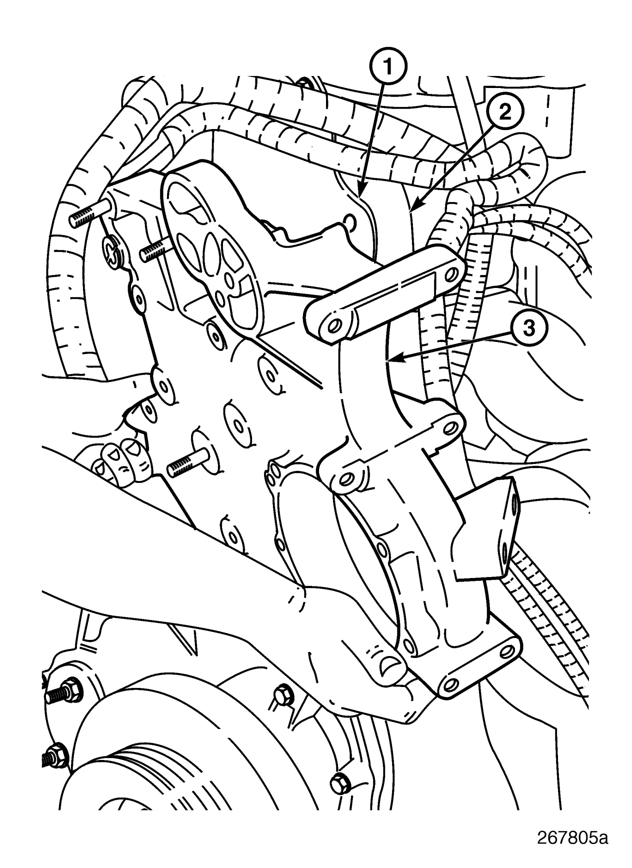


Figure 476 — Water Pump Housing

1. Lifting Bracket 2. Cylinder Head	3. Water Pump Housing

PUMP INSTALLATION

The ASET™ AC water pump assembly is quite different in design with some essential steps required for proper installation. Refer to Figure 477 as you work through the procedure.

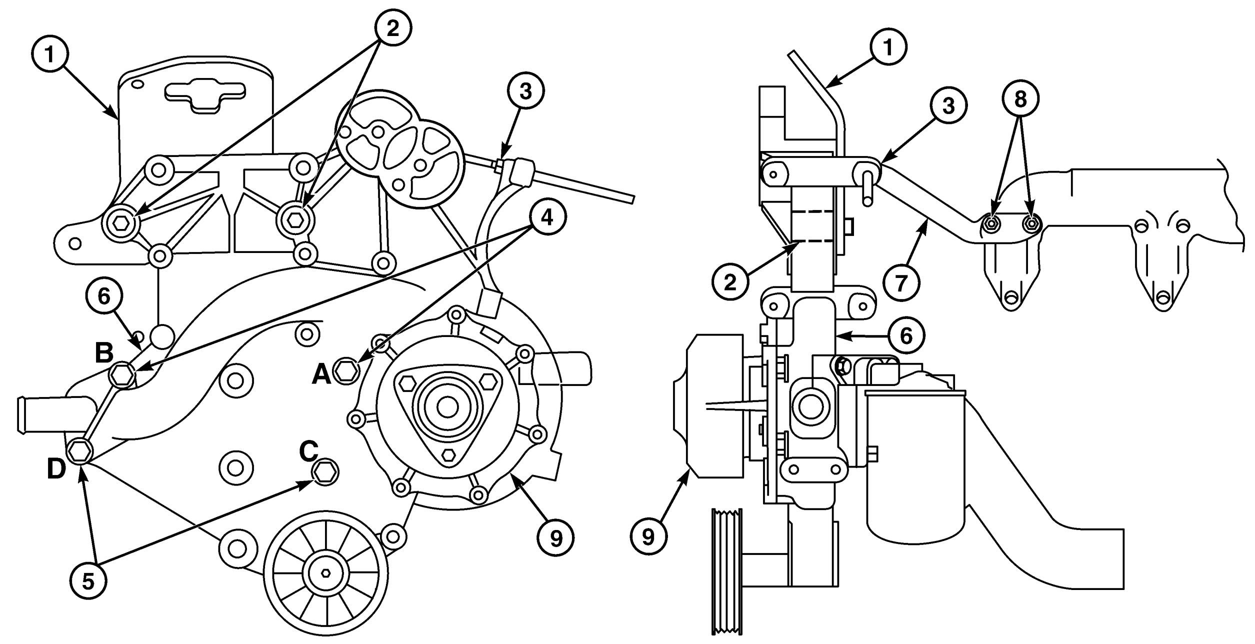


Figure 477 — Water Pump Installation

1. Engine Lifting Bracket 2. Threaded Inserts and Upper Mounting Bolts 3. Stiffening Bracket Forward Mount 4. Mid-Position Mounting Bolts 5. Low-Position Mounting Bolts	6. Water Pump Assembly (Housing and Cartridge) 7. Water Pump Stiffening Bracket 8. Stiffening Bracket Rear Mount 9. Water Pump Cartridge

1. Install the water pump coolant inlet tube from the oil cooler if removed (Figure 478).

Figure 478 — Coolant Inlet Tube Removal

1. Pump Inlet Tube	2. Oil Cooler

2. With the water pump housing positioned on a bench with the cylinder block/head mounting surface facing up, position two **new** O-rings in the grooves at the coolant inlet and outlet flanges, respectively. Use MACK Code 442 grease or any quality O-ring grease to hold the O-rings in place for assembly.
3. Stand the housing on edge and from the front, start the threaded inserts into the mounting bores at the top of the housing (Figure 479). Turn them in until the collar of each protrudes from the back side and the shoulder is flush with the back side to 0.020-inch (0.5 mm) below flush.

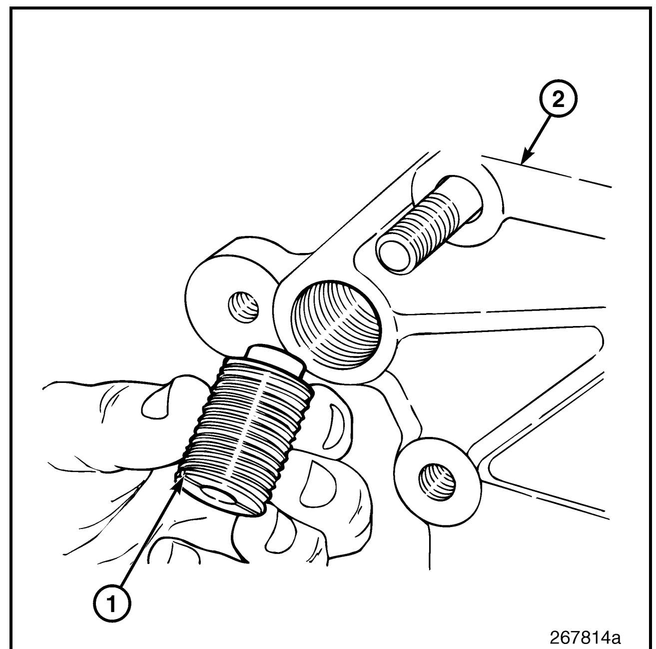


Figure 479 — Threaded Insert Installation

1. Threaded Insert	2. Pump Housing

4. Again, with the housing standing on edge and from the front, insert two mounting bolts and washers into the mid-position bolt holes. The two mid-position holes are slightly smaller to serve as pilot holes for installation.

CAUTION

The water pump cartridge assembly and water pump housing mounting bolts should not be lubricated before installation. Instead, apply thread sealing compound to all cartridge assembly and housing bolts.

5. Place the housing in position at the front of the cylinder block (Figure 476) and start the mid-position bolts into the block, far enough to secure the housing from falling. The housing should be free to move slightly back for installation of the engine lifting bracket in the following steps.
6. Place the engine lifting bracket in position (bend angle facing forward) between the housing and cylinder head (Figure 477). Make sure the bracket mounting holes clear and slip into position on the insert collars.

7. Push the housing against the block and hand-tighten the mid-position mounting bolts (item 4 in Figure 477).
8. Install the two mounting bolts and washers in the low-position mounting holes (item 5), hand-tight.
9. Make sure the lifting bracket mounting holes are properly positioned on the insert collars and then tighten the mid-position and low-position bolts to specification, 69 lb-ft (94 N•m), in sequence A, B, C, D shown in Figure 477.
10. Using a suitable slotted socket, tighten the two threaded inserts to specification, 50 **lb-in** (5.6 N•m).

CAUTION

*Use care not to overtighten the threaded inserts. Doing so could place undue stress on the housing, causing it to bow and eventually break. Tighten the insert only to 50 **pound-inches**.*

11. Install the remaining two mounting bolts (no washers) through the threaded inserts and tighten to specification, 40 lb-ft (55 N•m).
12. Position the water pump stiffening bracket (item 1 in Figure 477) over the two studs at the forward position of the water manifold. At the same time, position the forward section of the stiffening bracket over the backside of the A/C compressor upper rear mounting stud. Install the three M8 flanged nuts on the stiffening bracket and tighten to 20 lb-ft (27 N•m). Refer to Figure 477.

NOTE

It is important not to install the stiffening bracket before the water pump housing fasteners have been torqued in place. Installing the bracket before the housing bolts have been tightened may put undue stress on the top of the housing and cause damage to the housing.

13. Connect the coolant inlet tube from the oil cooler to the inlet port at the back of the water pump on the left side of the engine.
14. Connect the EGR cooler coolant supply hose to the water pump on the right side of the engine.
15. Install a **new** O-ring on the pump cartridge housing mounting flange (Figure 480).

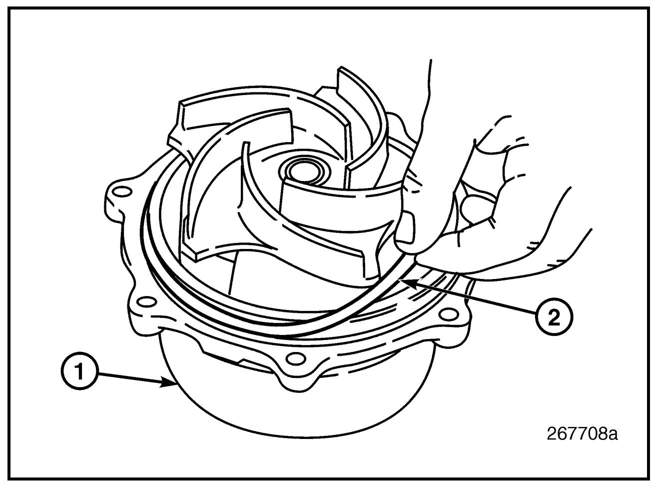


Figure 480 — O-Ring Installation

1. Water Pump Cartridge	2. O-Ring

16. Place the pump cartridge assembly in position on the pump housing (pump only fits one way due to the spacing of the seven holes) and install the seven mounting capscrews (Figure 481). Tighten the capscrews to 17 lb-ft (23 N•m).

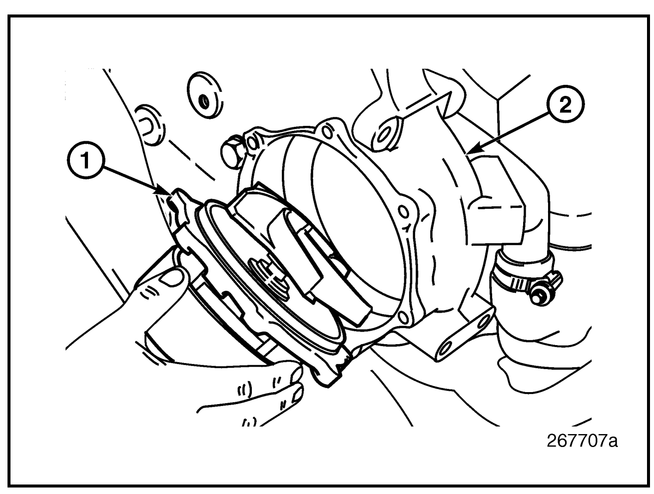


Figure 481 — Water Pump Cartridge

1. Water Pump Cartridge	2. Water Pump Housing

17. Install the fan drive assembly, drive belts and connect the fan-speed sensor lead.

FINAL ASSEMBLY

Complete the procedure by installing the radiator, charge air cooler and hood and fender assembly, etc. Fill the cooling system and reconnect the batteries.

Coolant Conditioner Adapter Removal and Installation

[215 LD]

The coolant conditioner adapter (if so equipped) is located at the left rear side of the water pump housing. An external conditioner inlet (supply) tube port is not used. The unit has both inlet and outlet ports in the water pump mounting flange (Figure 482).

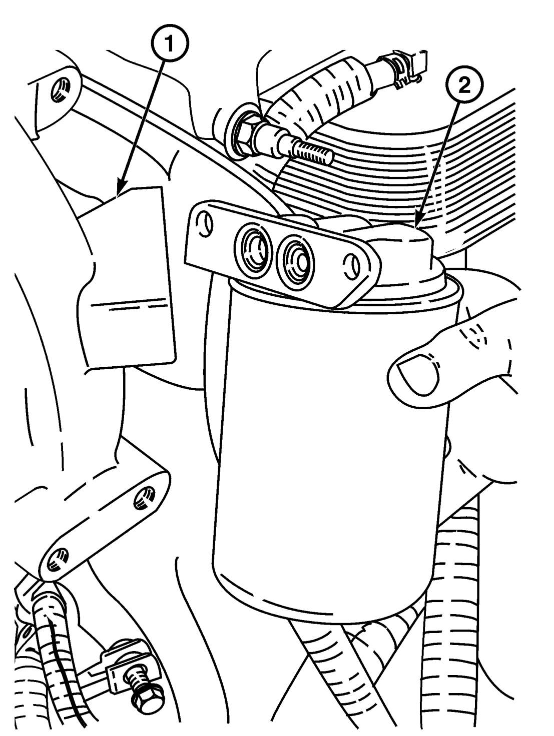


Figure 482 — Conditioner Adapter Installation

1. Pump Housing	2. Adapter

1. Place a suitable container below the coolant filter area to catch any spilled coolant.
2. Using a suitable filter wrench, J 29927 or equivalent, remove the coolant conditioner filter element. Discard the element.
3. Remove the adapter assembly from the water pump housing by removing the two mounting capscrews.
4. Remove and discard the O-rings at the inlet and outlet ports.
5. Carefully remove and examine the check valve assemblies in the inlet and outlet ports. Check each assembly by depressing the check ball. If it resists movement and does not return to its seat freely, the check valve assembly must be replaced.

NOTE

Inlet and outlet check valves must be reinstalled with the direction arrows on the barrels of the check valves matching the arrows on the filter casing. If not indexed correctly, the coolant will not flow through the coolant conditioner.

6. Install **new** O-rings in the grooves at the inlet and outlet ports.
7. Place the adapter assembly in position on the water pump mounting flange and install the two mounting capscrews. Tighten the capscrews to 15 lb-ft (20 N•m).
8. Apply a light film of engine coolant on the face of the coolant conditioner filter gasket seal.
9. Install the coolant conditioner filter element on the adapter. Turn the filter element one full turn after the gasket contacts the base.

EGR SYSTEM SERVICE PROCEDURES (IN-CHASSIS) FOR ASET™ AC ENGINE

Preliminary Steps

The preliminary steps for replacing the EGR system components will vary depending on the chassis configuration. As such, the steps in the procedures that follow are general in nature. Begin the operations by disconnecting the battery and draining fluids from the engine as required (draining fluids is only required to remove the EGR cooler assembly). Then, remove ducting and any accessory items, etc., that may interfere with access to the EGR components.

EGR Gas Tube(s) Removal and Installation

NOTE

Early-production engines are equipped with a two-piece cool tube assembly. The two-piece cool tube, however, has been replaced with a one-piece assembly effective with December 2003 production. The one-piece assembly uses coupling hoses for the connections at the mixer tube and EGR cooler. If the mixer tube and EGR cooler have flange-style port connections, coupling adapters are used in combination with the coupling hoses.

COOL TUBE REMOVAL (ONE-PIECE ASSEMBLY)

1. Disconnect the turbocharger oil supply line and the air line to the VTG actuator at the turbocharger (Figure 483). Plug the fittings to keep dirt and debris out.

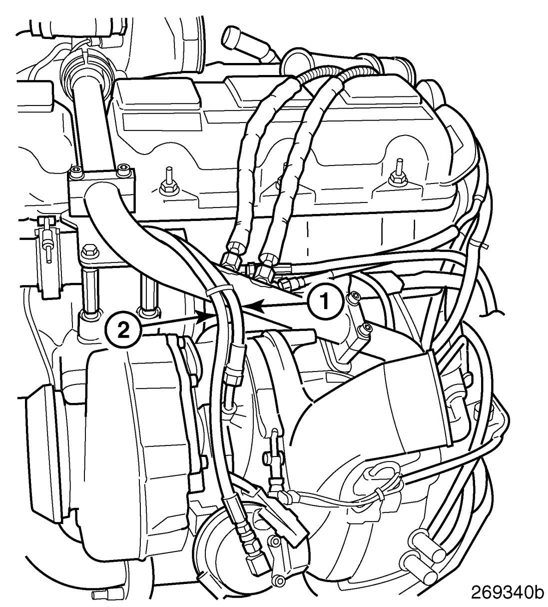


Figure 483 — Oil Supply and Air Lines

1. Turbocharger Oil Supply Line	2. VTG Actuator Air Line

2. Loosen and remove the clamps securing the cool tube to the brackets at the EGR valve and the front section of the exhaust manifold (Figure 484).

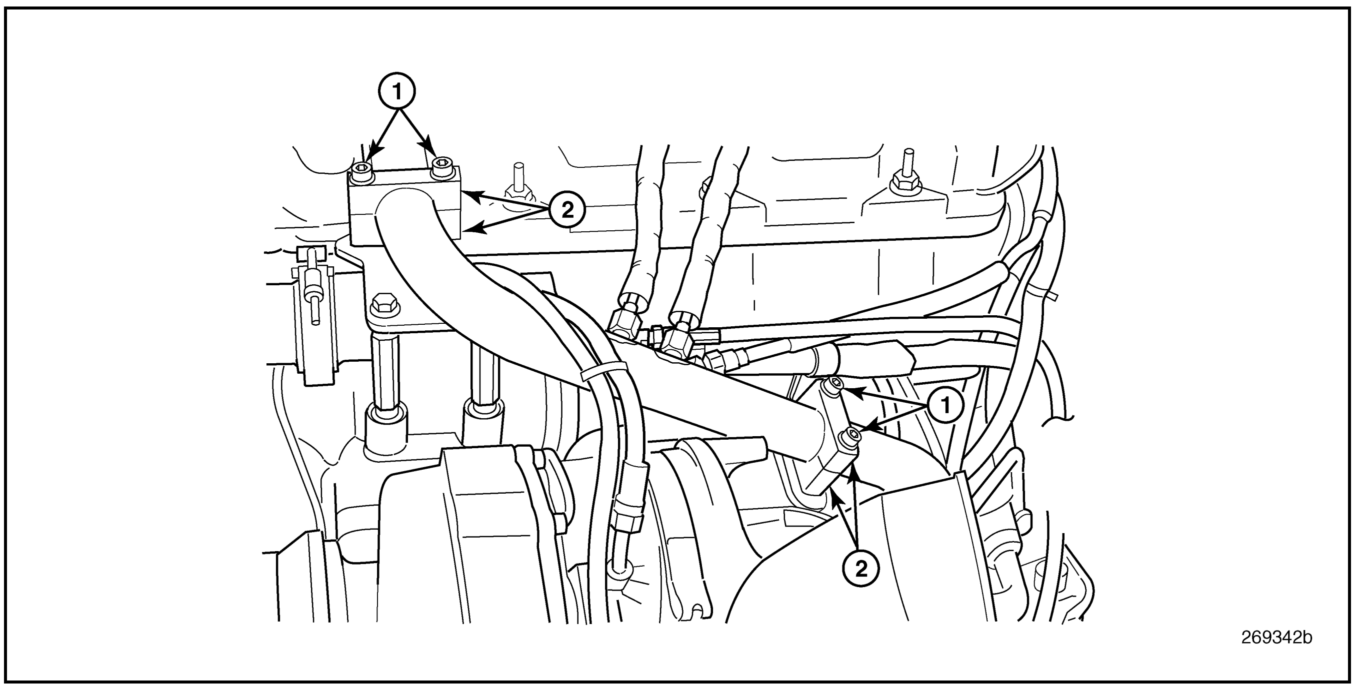


Figure 484 — Cool Tube Clamps

1. Clamp Bolts	2. Clamp, Upper and Lower Sections

3. Loosen and remove the clamps from the coupling hose at each end of the cool tube (Figure 485).

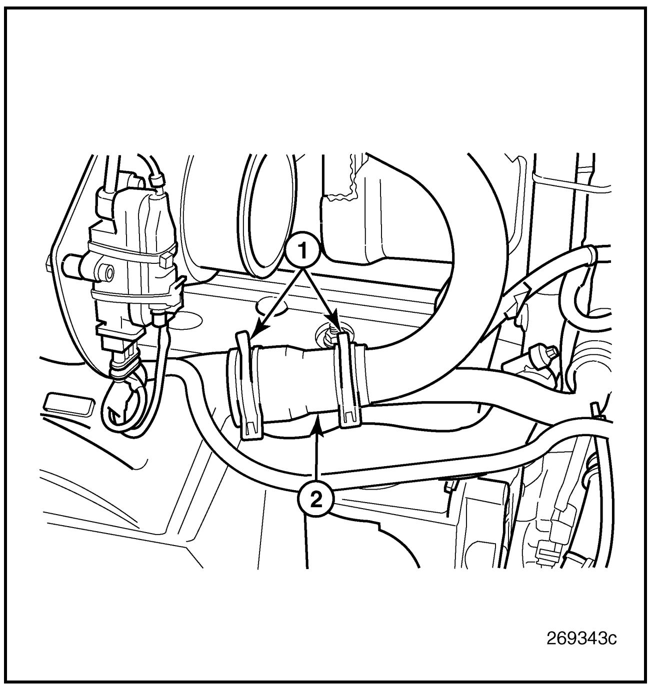


Figure 485 — Coupling Hose Clamps

1. Hose Clamps	2. Coupling Hose

4. Remove the cool tube and coupling hoses from the engine (Figure 486). Inspect the tube for corrosion or damage and the hoses for deterioration. Replace as required.

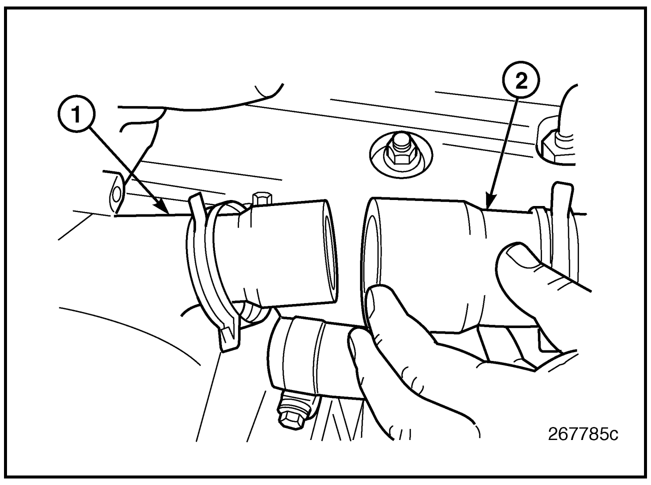


Figure 486 — Cool Tube Coupling Hose Removal

1. EGR Cooler	2. Coupling Hose

NOTE

Early-production engines will use coupling adapters in combination with the one-piece cool tube assembly. On vehicles so equipped:

- Loosen and remove the clamp from the cool tube coupling hose adapter at the EGR cooler tube mounting flange. Remove and discard the wire-mesh seal. Inspect the adapter for corrosion or damage and replace as required.
- Loosen and remove the clamp from the cool tube coupling hose adapter at the EGR mixer tube. Remove and discard the wire-mesh seal. Inspect the adapter and replace as required.

CAUTION

Do not attempt to remove the EGR MASS Flow sensors from the tube. The sensors are an integral part of the tube and must be replaced as an assembly.

HOT TUBE REMOVAL

NOTE

If the hot tube is to be removed, the cool tube clamp bracket and spacer studs must also be removed from the top of the EGR valve. This is necessary to loosen the EGR valve on its mounting for reinstallation of the hot tube.

1. With the cool tube removed, loosen and remove the three retaining nuts securing the clamp bracket to the top of the EGR valve (Figure 487). Remove the bracket and washers from the spacer studs.

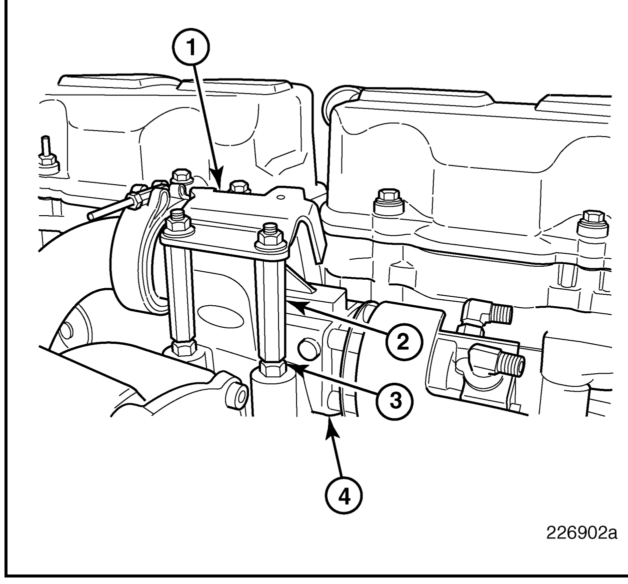


Figure 487 — Clamp Bracket Removal

1. Clamp Bracket 2. Spacer Studs	3. EGR Valve Retaining Nuts 4. EGR Valve

2. Loosen and remove the spacer studs from the EGR valve mounting studs. DO NOT loosen the valve retaining nuts at this time.
3. Loosen and remove the clamp connecting the hot tube-to-EGR cooler inlet flange (Figure 488).

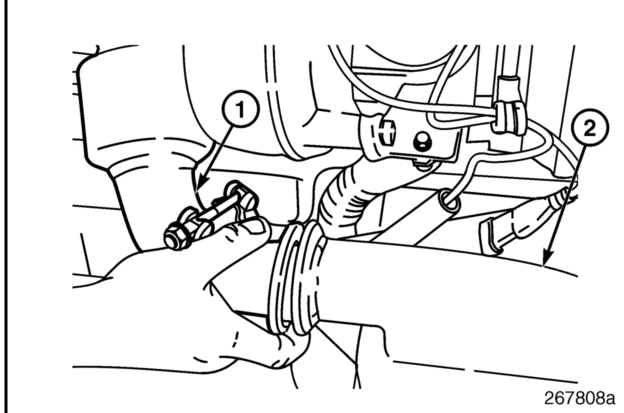


Figure 488 — Hot Tube-to-Cooler Connection

1. EGR Gas Hot Tube	2. EGR Cooler

4. Loosen and remove the clamp connecting the hot tube-to-EGR valve outlet flange. The hot tube also is fitted with wire-mesh seals in the flanges at both ends. Remove and discard the seals. Inspect the tube for corrosion or damage and replace as required.

HOT TUBE INSTALLATION

CAUTION

*Whenever an EGR hot tube clamp has been in service and is removed, the retaining nut may gall the threads of the T-bolt. Always install a **new** T-bolt and nut in the clamp body whenever a clamp has been removed. However, the body of the clamp can be reused and should not be replaced unless it is broken or damaged.*

1. Loosen the four mounting nuts securing the EGR valve to the exhaust manifold. DO NOT remove the valve.

NOTE

If reusing the EGR hot tube, make sure that there is flex in the tube to ensure good alignment with the mating flanges of the EGR valve and cooler.

2. Install **new** seals in the flanges at each end of the EGR hot tube. Place the hot tube in position between the EGR valve and cooler (Figure 489). Make sure that the gap between each set of flanges is uniform all around. Install **new** T-bolts and nuts in the clamps and tighten to specification, 110 lb-in (12.4 N•m).

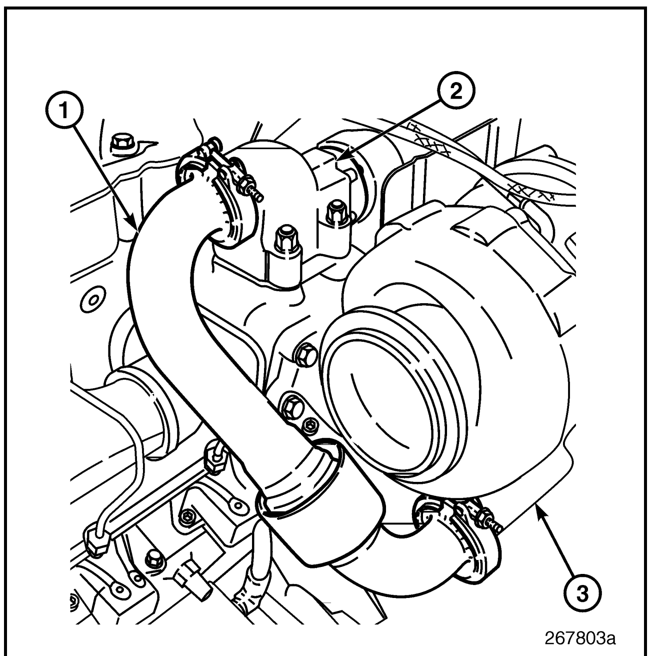


Figure 489 — EGR Gas Hot Tube, Installed

1. EGR Gas Hot Tube 2. EGR Valve	3. EGR Cooler

3. Tighten the EGR valve mounting nuts to specification, 40 lb-ft (54 N•m).
4. Install the three spacer studs on the longer EGR valve mounting studs. Tighten the spacer studs to 40 lb-ft (54 N•m).
5. Install a flat washer on top of each spacer stud and then install the clamp bracket and three bracket retaining nuts. Tighten the nuts to 40 lb-ft (54 N•m).
6. With the installation complete, tap each new clamp several times with a light rubber mallet and then retorque the clamps.

COOL TUBE INSTALLATION (ONE-PIECE ASSEMBLY)

Early-production engines use flange-style coupling adapters at both the EGR cooler and mixer tube port connections in combination with the one-piece cool tube. For current-production engines, the coupling adapter is used only at the EGR mixer tube port and not at the cooler port. As production continues in the future, the need for coupling adapters will be eliminated altogether as the mixer tube cool-tube port design is changed to accept a hose connection.

On vehicles so equipped, install the coupling adapter(s) as follows before installing the cool tube:

- Install a **new** wire-mesh gasket on the EGR cool tube coupling adapter(s).
- Install the coupling adapter(s) to the EGR cooler flange and/or the EGR mixer tube flange using a band clamp. Tighten the band clamp nut to 110 lb-in (12.4 N•m).

NOTE

On systems equipped with flange-style coupling adapters on the EGR cool tube side of the system, the flange clamps can be reused if there is no damage and the threads are not corroded. However, with damaged or corroded threads, the clamps cannot be tightened to the proper torque specification for a gas-tight seal. Replace the T-bolt and nut or complete clamp assembly, if corrosion or damage is present.

Install the one-piece cool tube assembly as instructed below:

1. Slide a hose clamp onto the EGR mixer tube and the EGR cooler cool-tube ports (or coupling adapters, if so equipped).
2. Slide a hose clamp and the appropriate coupling hose over each end of the EGR cool tube assembly. The stepped-design hose is used at the cooler connection.
3. Place the cool tube assembly in position on the engine between the EGR mixer tube and cooler ports (or coupling adapters). Slide the coupling hoses onto the ports/adapters and secure with the hose clamps (Figure 490).

NOTE

Place the cool tube in position under the turbocharger oil supply and VTG actuator air lines if the lines are already installed.

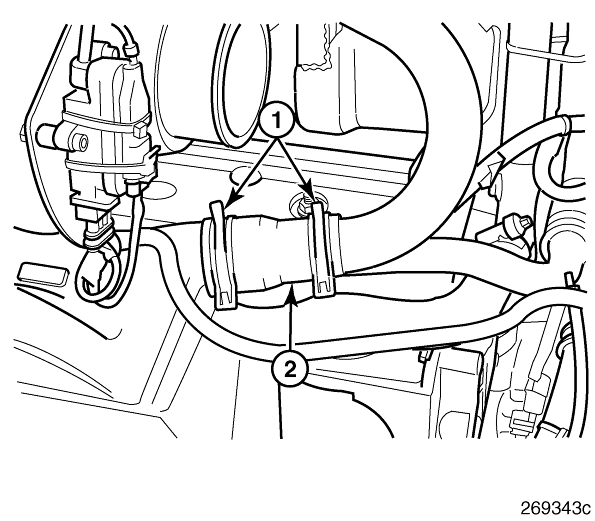


Figure 490 — Cool Tube Hose Connection (Cooler Connection Shown)

1. Hose Clamps	2. Coupling Hose

4. Install the clamps and mounting bolts to secure the cool tube to the mounting brackets at the EGR valve and the front exhaust manifold (Figure 491). Tighten the bolts to 96 lb-in (11 N•m).

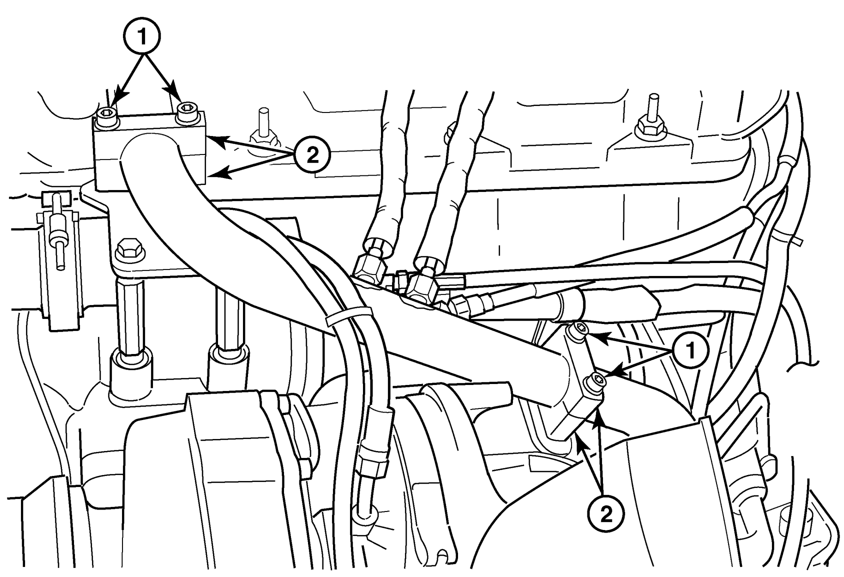


Figure 491 — Cool Tube Clamp Installation

1. Mounting Bolts	2. Clamps, Upper and Lower Halves

5. Start the engine and allow it to warm up. Check for leaks in the EGR system.
6. Stop the engine. Allow it to cool down and then retorque the clamps.

EGR Cooler Removal and Installation

REMOVAL PROCEDURE

1. Drain the cooling system in preparation for removal of the EGR cooler. A petcock is located at the lower rear corner of the cooler to drain coolant retained in the cooler (Figure 492).

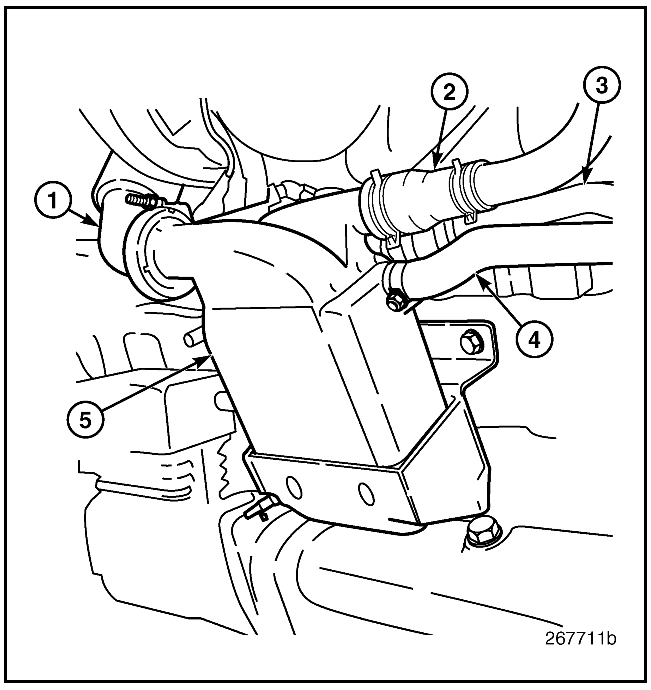


Figure 492 — EGR Cooler, Installed

1. EGR Gas Hot Tube 2. EGR Gas Cool Tube Coupling Hose 3. Coolant Supply Pipe 4. Coolant Return Hose	5. EGR Cooler (Note that the petcock for the coolant drain is at the lower left corner of the cooler.)

2. Loosen and remove the hot tube clamp at the EGR cooler gas inlet port (Figure 493).

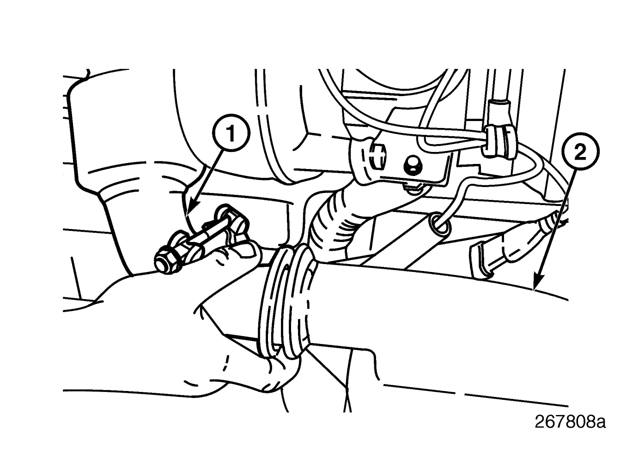


Figure 493 — Hot Tube-to-Cooler Connection

1. EGR Gas Hot Tube	2. EGR Cooler

3. Loosen and remove the cool tube coupling hose clamp at the EGR cooler gas outlet port (Figure 494).

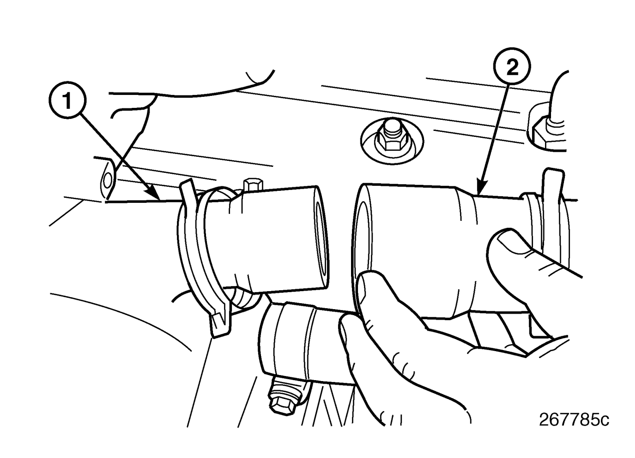


Figure 494 — Cool Tube-to-Cooler Connection

1. EGR Cooler	2. EGR Gas Cool Tube Coupling Hose

NOTE

Early-production engines have a flange-style outlet port which requires a coupling adapter in combination with the one-piece cool tube. If so equipped, the coupling adapter can be removed as an assembly with the cooler.

4. Loosen the clamps and disconnect the coolant inlet and outlet hose connections at the front side of the EGR cooler (Figure 495).

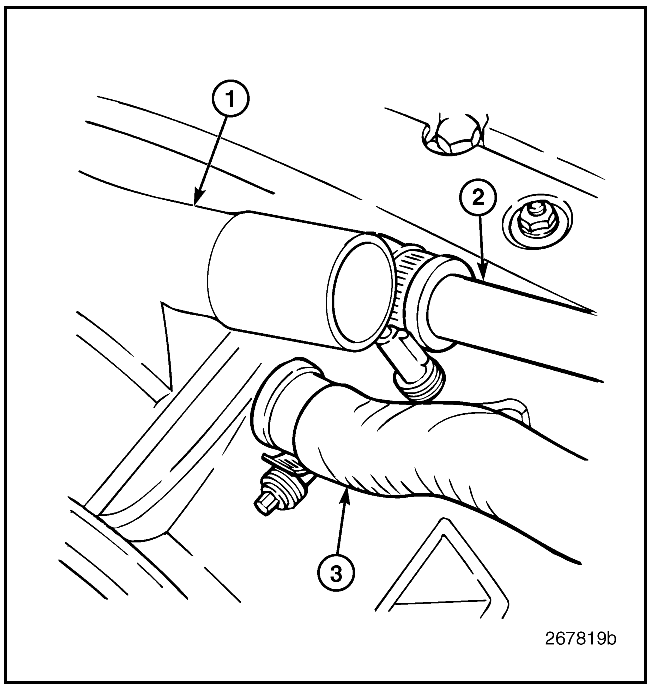


Figure 495 — Coolant Connections

1. EGR Cooler 2. Coolant Supply Pipe	3. Coolant Return Hose

5. Remove the four retaining nuts, two at each side, attaching the cooler assembly to the cylinder block and remove the assembly (Figure 496). Inspect the cooler assembly for damage and test for leaks as required.

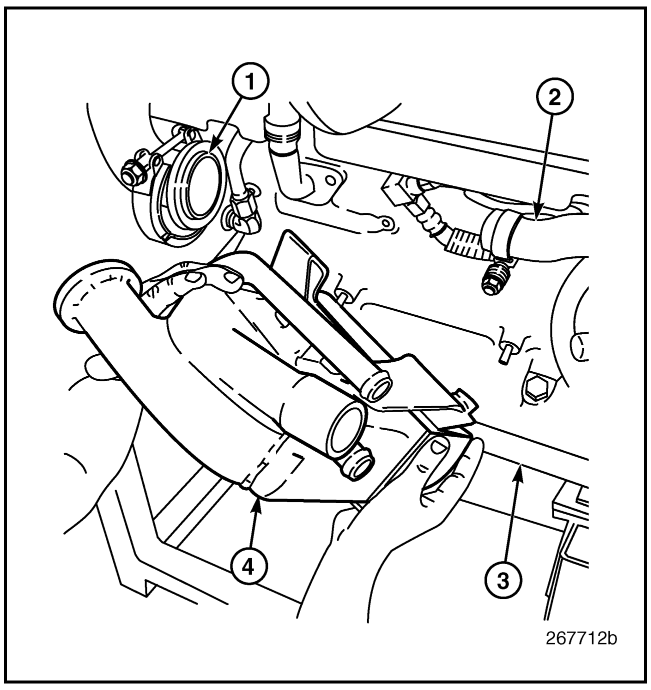


Figure 496 — EGR Cooler Removal

1. EGR Hot Tube 2. Coolant Return Hose	3. Cylinder Block 4. EGR Cooler

6. Remove and discard the seal in the lower flange of the hot tube. If so equipped, also remove the coupling adapter from the cool-tube port and remove and discard the seal in the flange of the adapter.

INSTALLATION PROCEDURE

NOTE

Clamps used on the hot-side tube are prone to corrosion and damage and should be replaced. If the engine is equipped with coupling adapters for connection of the one-piece cool tube and coupling hoses, the gas tube clamps can be reused if there is no damage and the threads are not corroded. However, with damaged or corroded threads, the clamps cannot be tightened to the proper torque specification for a gas-tight seal.

1. Place the EGR cooler assembly in position at the right side of the cylinder block (Figure 496). Install the four retaining nuts and tighten to specification.
2. Connect the coolant supply and return hoses at the cooler inlet and outlet tubes. Install the clamps and tighten to specification (Figure 495).
3. Slide a hose clamp onto the EGR cooler cool-tube port (or coupling adapter, if so equipped).

NOTE

Early-production engines will have flange-style coupling adapters in combination with the one-piece cool tube assembly. On vehicles so equipped, install the coupling adapter on the cooler before connecting the cool tube.

- Install a **new** wire-mesh seal in the flange of the coupling adapter.
- Place the coupling adapter flange in position against the cool-tube port flange. Make sure the gap between the flanges is uniform, and install the band clamp. Tighten the clamp to 110 lb-in (12.4 N•m).

4. Slide the coupling hose onto the cooler port/adapter and secure with the hose clamp (Figure 497).

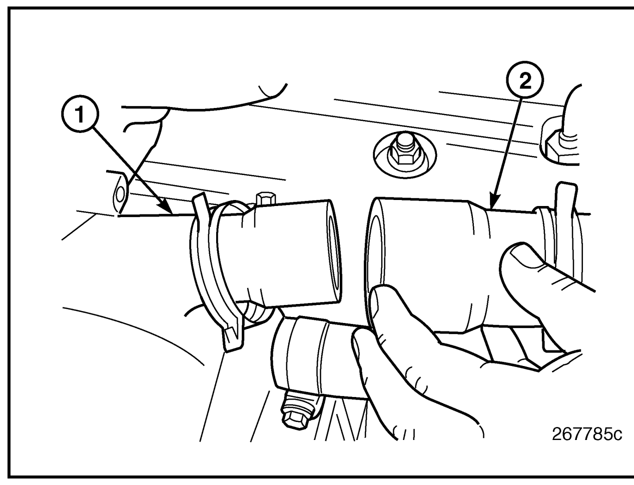


Figure 497 — Cool Tube-to-Cooler Installation

1. EGR Cooler	2. EGR Gas Cool Tube Coupling Hose

5. Install a **new** wire-mesh seal in the lower flange of the hot tube and position the flange against the cooler gas inlet flange (Figure 498). Make sure the gap between the flanges is uniform. Install the clamp and tighten to specification, 110 lb-in (12.4 N•m).

NOTE

If alignment of the EGR hot tube is difficult, complete the following:

a. Remove the clamps from the EGR hot tube and remove the tube.

b. Remove the mounting nuts and remove the EGR valve and gasket from the exhaust manifold. Discard the gasket.

c. Install a **new** gasket and reinstall the EGR valve. DO NOT tighten the mounting nuts at this time. While the nuts can be snug, the valve should be allowed to shift within the limits of the bolt holes.

d. Install **new** upper and lower gaskets and clamps and reinstall the EGR hot tube. Tighten the clamps to specification, 110 lb-in (12.4 N•m). The EGR valve will “float” into the best alignment position.

e. Tighten the EGR valve mounting nuts to specification, 40 lb-ft (55 N•m).

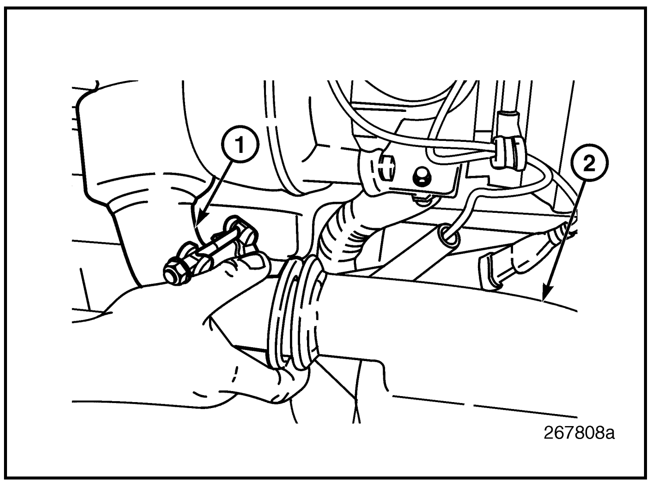


Figure 498 — Hot Tube-to-Cooler Connection

1. EGR Gas Hot Tube	2. EGR Cooler

6. Lightly tap the tube clamps at each side of the cooler with a light rubber mallet and then retighten them to specification.
7. Fill the cooling system.
8. With the installation complete, tap each new clamp several times with a light rubber mallet and then retorque the clamps.
9. Start the engine and allow it to warm up. Check for leaks in the EGR system.
10. Stop the engine. Allow it to cool down and then retorque the clamps.

EGR Valve Removal and Installation

REMOVAL PROCEDURE

NOTE

Soot coating of the EGR valve heat shield surfaces in the vicinity of the valve shaft is to be expected. The sealing method used is similar to a piston ring, and therefore, a small amount of soot leakage will always be present.

1. Remove the one-piece EGR gas cool tube following the instructions covered earlier in this section.
2. Disconnect the oil supply and oil return lines at the EGR valve (Figure 499).
3. Disconnect the electrical lead from the terminal on the valve.

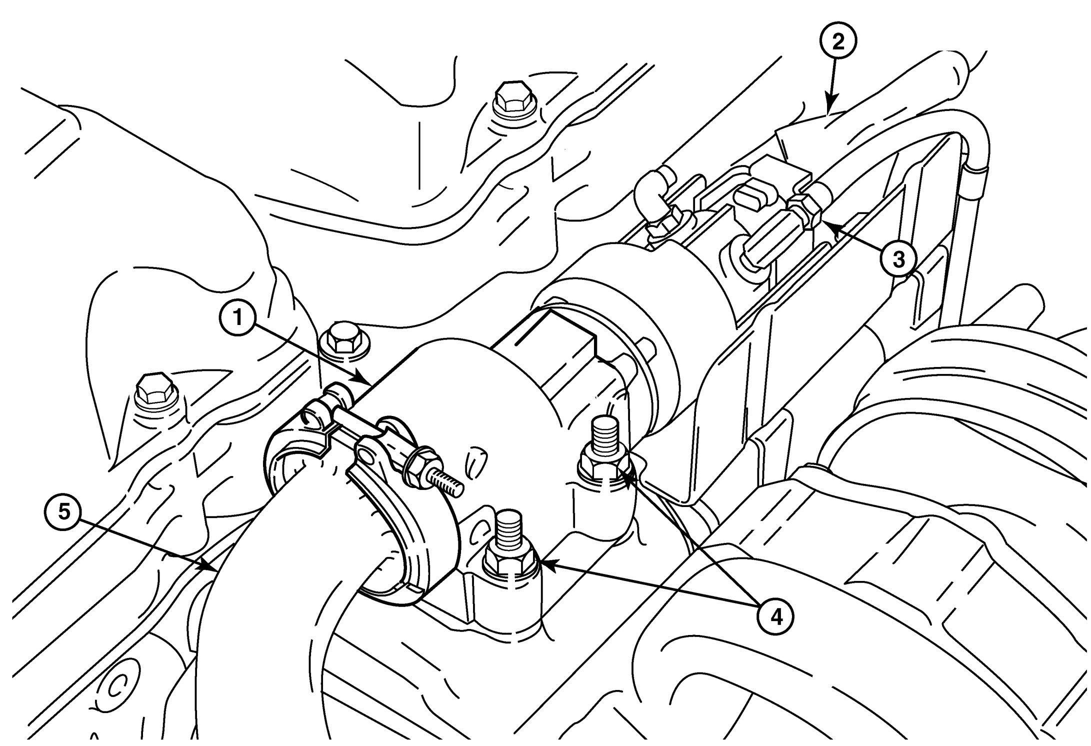


Figure 499 — EGR Valve, Installed

1. EGR Valve 2. Electrical Connection 3. Oil Return Line	4. Mounting Studs/Nuts 5. EGR Hot Tube

4. Loosen and remove the clamp from the gas hot tube at the EGR valve. Remove and discard the seal in the tube flange.
5. Remove the four nuts retaining the EGR valve assembly to the exhaust manifold and remove the valve assembly (Figure 500). Remove and discard the metal gasket from the manifold.

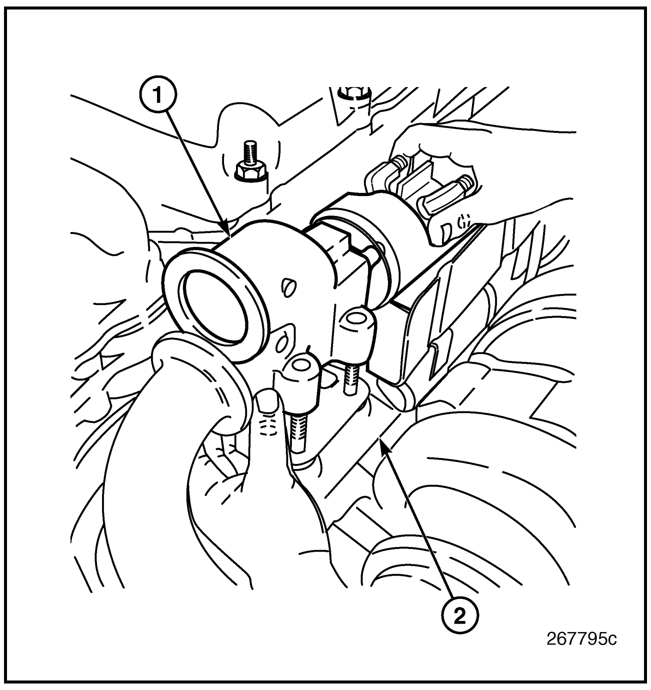


Figure 500 — EGR Valve Removal

1. EGR Valve Assembly	2. Exhaust Manifold

6. Inspect the valve assembly for damage and test as required. Replace the assembly if necessary.

INSTALLATION PROCEDURE

1. Carefully clean and inspect the mounting flange of the EGR gas hot tube.

CAUTION

Use care when cleaning component parts of the EGR system. Dirt and debris entering the system could cause blockage within the cooler core or EGR valve.

2. Clean and inspect the valve mounting surface of the exhaust manifold and the tube flange and mounting base of the valve assembly. Again, use care to avoid getting dirt and debris in the system.

NOTE

A metal gasket, shown in Figure 501, is used between the mounting base of the EGR valve assembly and the exhaust manifold. Make sure that it is installed.

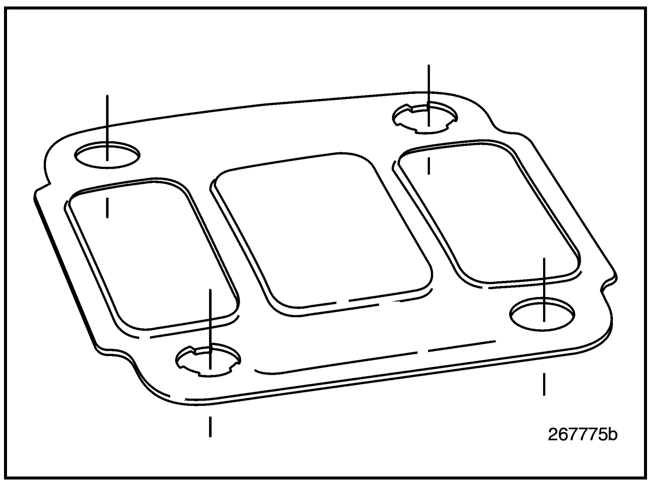


Figure 501 — EGR Valve Gaskets

3. Install a **new** gasket on the EGR valve assembly mounting surface of the exhaust manifold (Figure 502).

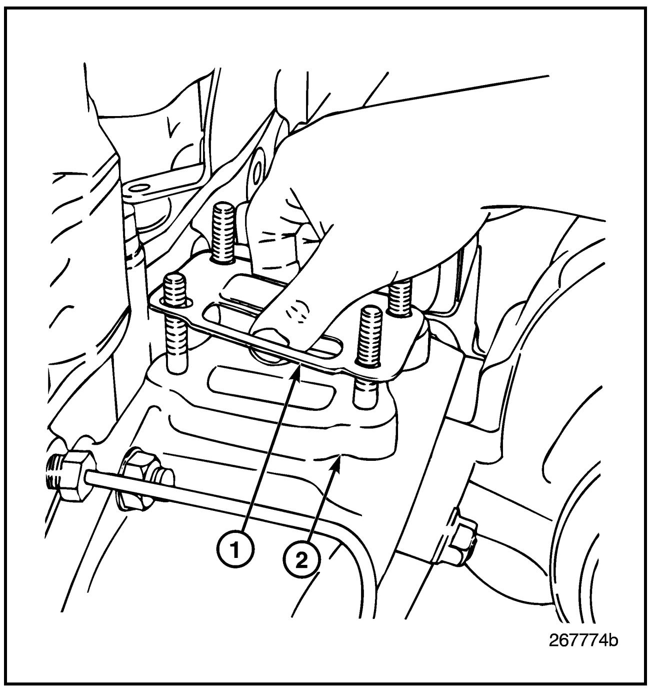


Figure 502 — Gasket Installation

1. EGR Valve Gasket	2. Exhaust Manifold

4. Place the valve assembly in position on the exhaust manifold studs (Figure 503). Loosely install the retaining nuts. DO NOT tighten them at this time. This allows the EGR valve to "float" into the best alignment position.

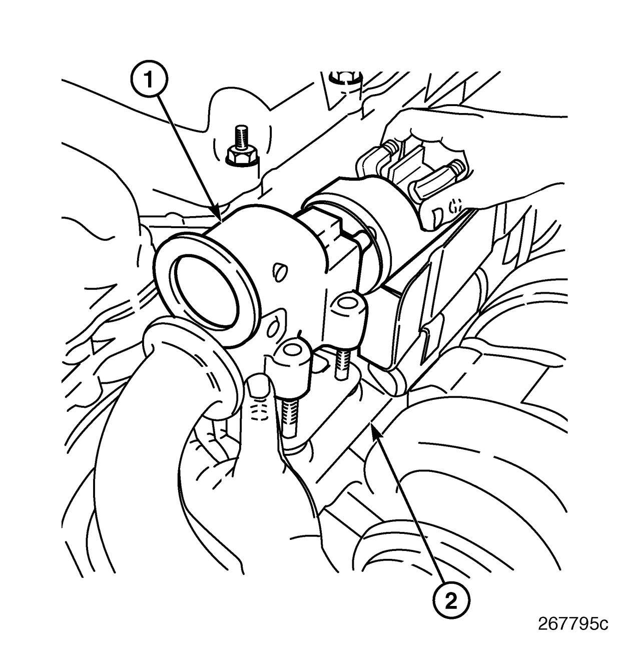


Figure 503 — EGR Valve Installation

1. EGR Valve Assembly	2. Exhaust Manifold

5. Install a **new** wire-mesh seal in the flange of the gas hot tube. Place the tube in position on the valve gas outlet flange, install a **new** clamp and tighten to specification, 110 lb-in (12.4 N•m).

NOTE

EGR gas tube clamps can be reused if there is no damage and the threads are not corroded. However, with damaged or corroded threads, the clamps cannot be tightened to the proper torque specification for a gas-tight seal. Clamps used on the hot-side tube are prone to corrosion and damage and should be replaced.

6. Lightly tap the clamp with a light rubber mallet and then retighten it to specification.
7. Tighten the EGR valve retaining nuts to specification, 40 lb-ft (55 N•m).
8. Reconnect the oil supply line to the external oil manifold and tighten to specification.
9. Connect the oil supply and oil return lines to the valve assembly (Figure 505).

NOTE

Beginning with March 2004 production, a filter screen has been added to the oil inlet port on the EGR valve. It is retained in place by a wave washer and inlet hose fitting (Figure 504). Valves fitted with the filter screen are identified by a green dot (interim identification) on the valve body or by the new part number, 691GC514C, on the sheet metal cover. When connecting the oil line to the EGR valve, make sure that the screen and wave washer are in place and secured by the hose fitting.

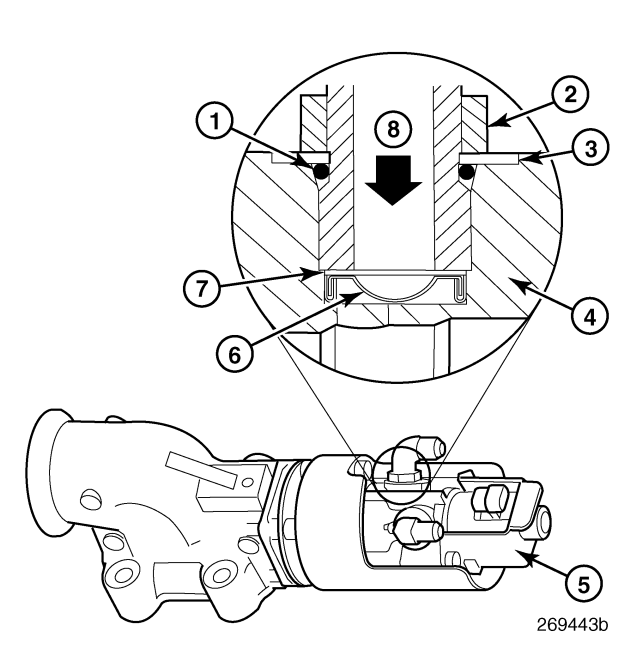


Figure 504 — EGR Valve Oil Inlet Filter Screen

1. O-Ring 2. Fitting Jam Nut 3. Integral Washer 4. Valve Body	5. Part Number Location 6. Filter Screen 7. Wave Washer 8. Oil Flow Direction

10. Connect the electrical lead to the terminal on the valve assembly.

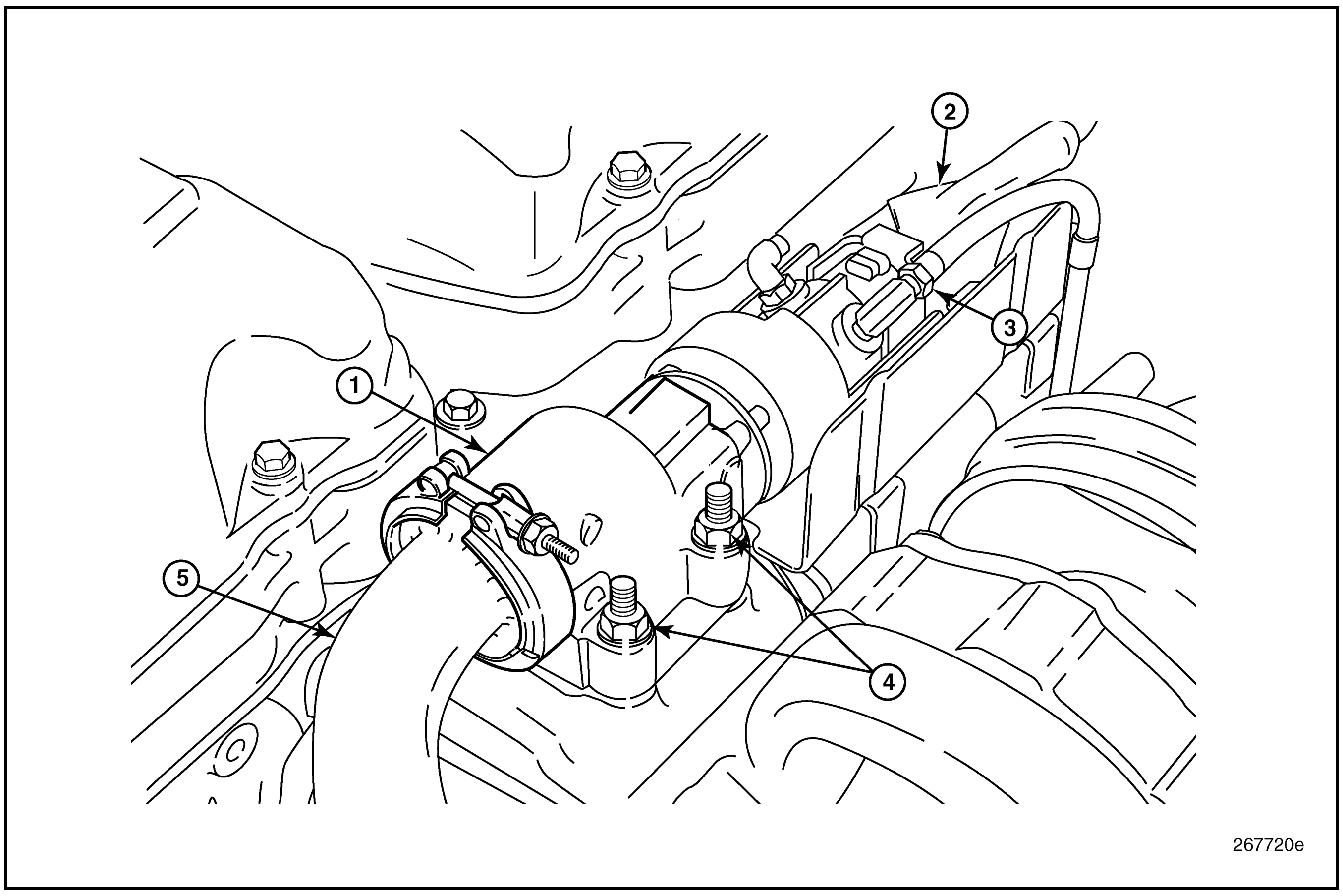


Figure 505 — EGR Valve, Installed

1. EGR Valve 2. Electrical Connection 3. Oil Return Line	4. Mounting Studs/Nuts 5. EGR Hot Tube

EGR Valve Heat Shields Removal and Installation

All ASET™ engines are equipped with EUP shields carried over from the current E-Tech™ engine. However, an additional shield is installed on the AC engine to protect the EGR valve, harness connections and oil lines. The EGR valve heat shield protects the valve from heat radiating off the turbocharger and exhaust manifold.

Procedures for removing and installing the EGR heat shield with the EGR valve assembly removed are described in the following section:

REMOVAL PROCEDURE

NOTE

Soot coating of the EGR valve heat shield surfaces in the vicinity of the valve shaft is to be expected. The sealing method used is similar to a piston ring, and therefore, a small amount of soot leakage will always be present.

1. Remove the three retaining nuts and remove the two outer EUP heat shields.
2. Remove the four capscrews retaining the inner EUP heat shield and tilt the shield up to gain access to the EUPs. Secure the inner shield in this position, out-of-the-way.

NOTE

The later design inner heat shield is a two-piece unit.

3. Remove the fuel nozzle inlet tube assemblies for the Nos. 1 and 2 cylinders as follows:
   - Loosen the tube sleeve nut at the electronic unit pump (EUP). Be careful to avoid twisting the line while loosening the nut.
   - Loosen the tube clamping screw at the cylinder head and remove the tube assembly. Cap the line and fittings to prevent contaminants from entering the system.
4. Remove the EGR valve heat shield.

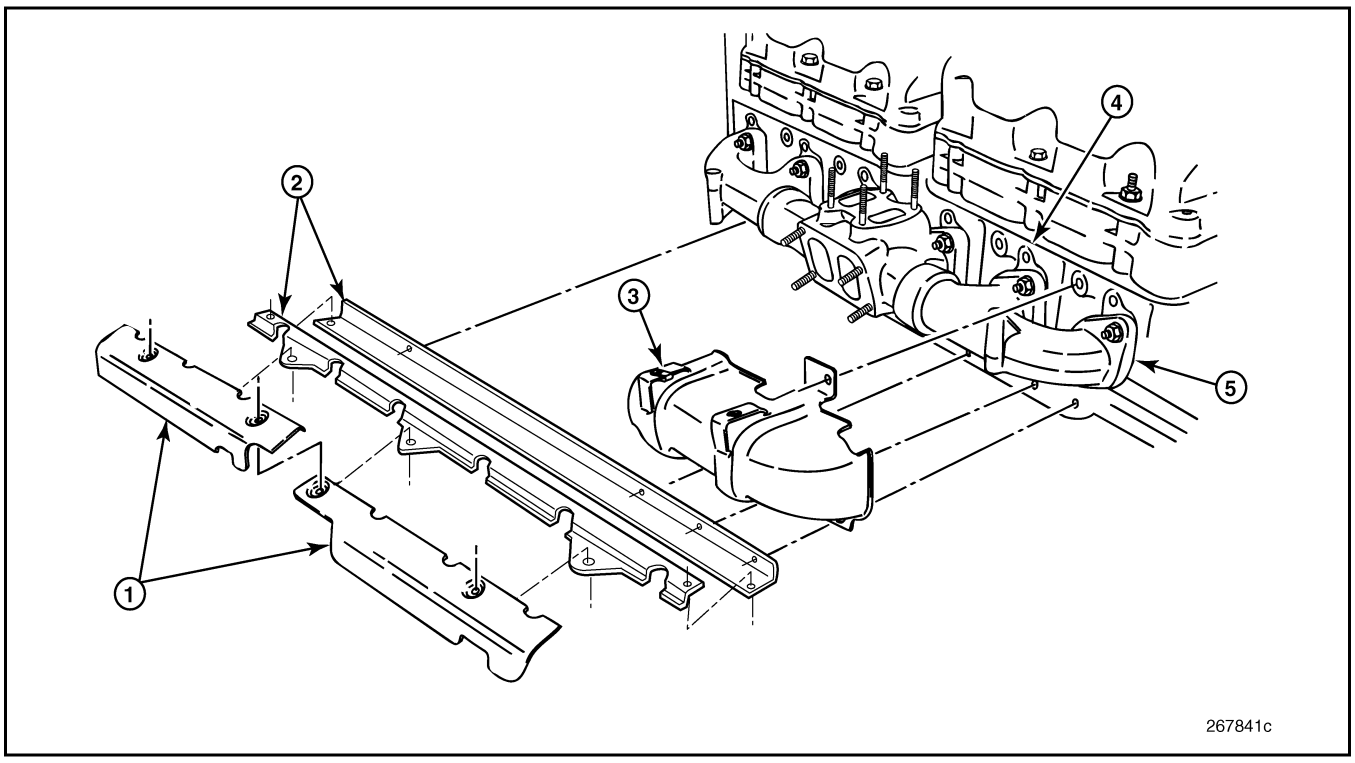


Figure 506 — EGR and EUP Heat Shields

1. Outer EUP Heat Shields 2. Inner EUP Heat Shield (Two Piece) 3. EGR Valve Heat Shield	4. Cylinder Heads 5. Exhaust Manifold

INSTALLATION PROCEDURE

Refer to Figure 506.

1. Place the EGR valve heat shield in position over the front section of the exhaust manifold.
2. Lubricate the fuel nozzle inlet tube clamping screw threads for each assembly before installing.
3. Install the No. 1 fuel nozzle inlet tube assembly into the cylinder head until light contact is made with the nozzle holder. Lightly tighten the clamping screw.
4. Connect the line at the No. 1 unit pump. Tighten the clamping screw to the specified torque using torque wrench J 24407, or equivalent.
   - Line clamping screw at cylinder head: 35 lb-ft (47 N•m)
   - Line nut at EUP: 25 lb-ft (34 N•m)
5. Repeat steps 3 and 4 to install the fuel nozzle inlet tube assembly at the No. 2 cylinder.
6. Place the inner EUP heat shield in position against the cylinder block. The bottom flange of the lower EGR heat shield fits between the EUP heat shield and the block.
7. Install the four capscrews to secure the inner EUP heat shield. Tighten the capscrews to specification, 15 lb-ft (20 N•m).
8. Install the outer EUP heat shields and retaining nuts. Tighten the nuts to specification, 15 lb-ft (20 N•m).

EGR Gas Mixer Tube Removal and Installation

REMOVAL PROCEDURE

1. Disconnect the electrical leads to the CMCAC outlet pressure and temperature sensors.

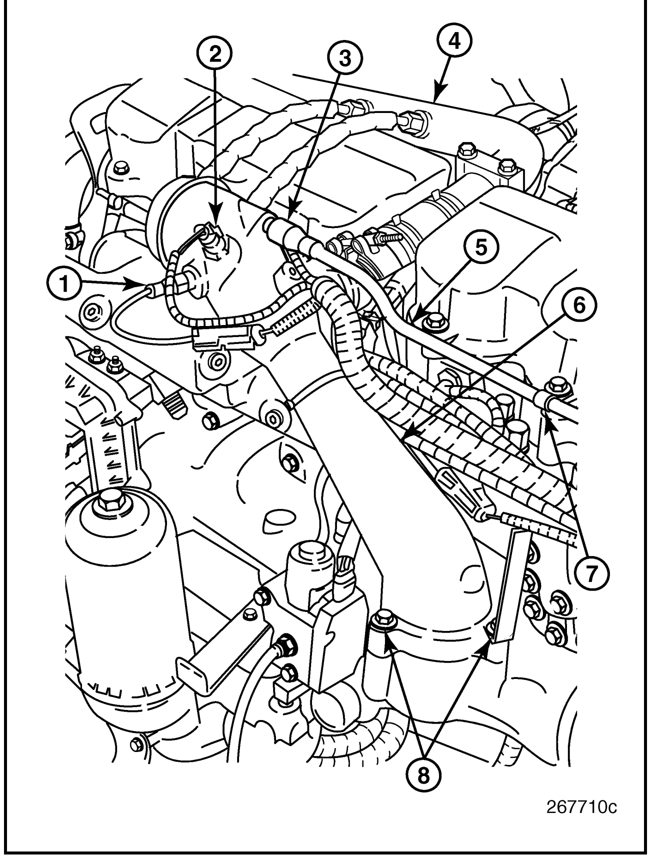


Figure 507 — EGR Gas Mixer Tube

1. CMCAC Pressure Sensor	5. Boost Pressure Relief Outlet Tube
2. CMCAC Temperature Sensor	6. Mixer Tube
3. Boost Pressure Relief Valve (Turbo By-Pass)	7. Boost Pressure Relief Outlet Tube Clamp
4. EGR Cool Tube	8. Capscrews

2. Loosen the two band clamps securing the flexible tapered boost pressure relief valve (turbo by-pass) coupling hose. Remove the two clamps and coupling hose.

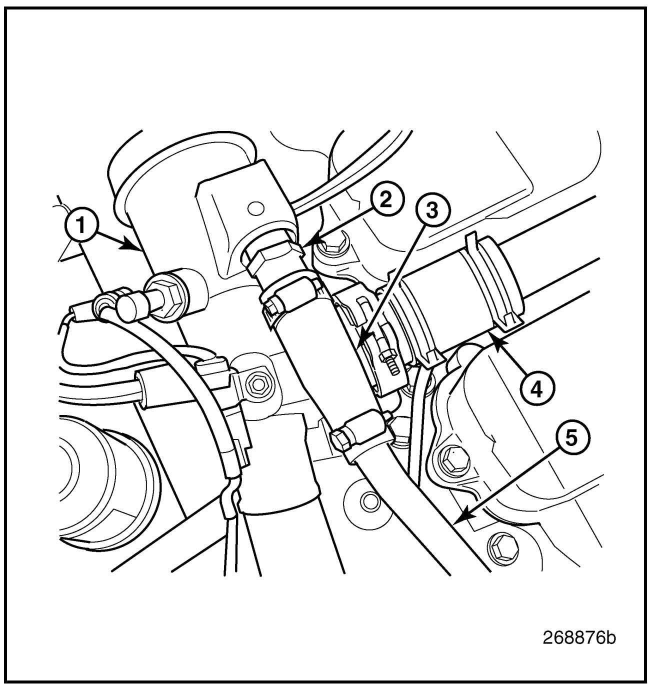


Figure 508 — Boost Pressure Relief Valve (Turbo By-Pass)

1. EGR Gas Mixer Tube 2. Boost Pressure Relief Valve (Turbo By-Pass) 3. Valve-to-Outlet Tube Coupling	4. EGR Gas Tube (Reference) 5. Outlet Tube-to-Exhaust

3. Loosen and remove the clamp attaching the upper EGR gas tube to the EGR gas mixer tube (Figure 509). Remove and discard the seal in the gas-tube flange.

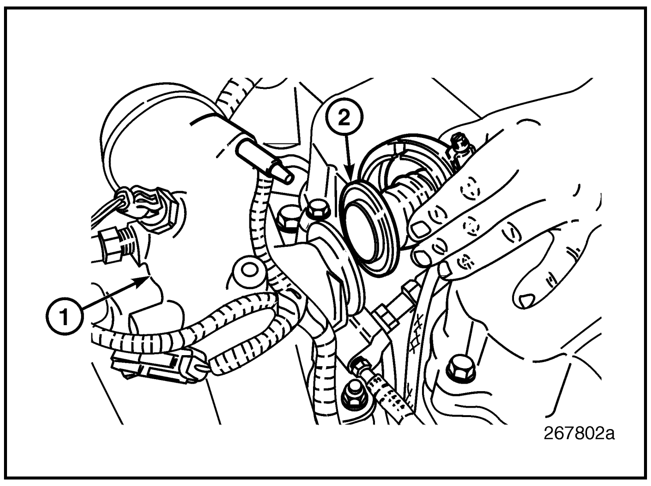


Figure 509 — EGR Tube-to-Mixer Connection

1. EGR Gas Mixer	2. Upper EGR Gas Tube

4. Remove the capscrew from the support bracket at the side of the EGR gas mixer tube. The bracket is attached between the mixer tube and the coolant manifold.
5. Remove the capscrews attaching the mixer tube to the inlet manifold (Figure 507) and remove the tube.

INSTALLATION PROCEDURE

NOTE

EGR gas tube clamps can be reused if there is no damage and the threads are not corroded. However, with damaged or corroded threads, the clamps cannot be tightened to the proper torque specification for a gas-tight seal. Clamps used on the hot-side tube are prone to corrosion and damage and should be replaced.

1. Clean and inspect the mating flange of the upper EGR gas tube. Install a **new** graphite wire-mesh seal in the flange.
2. Clean and inspect the mounting collar on the inlet manifold. Then, install a **new** O-ring on the collar (Figure 510).

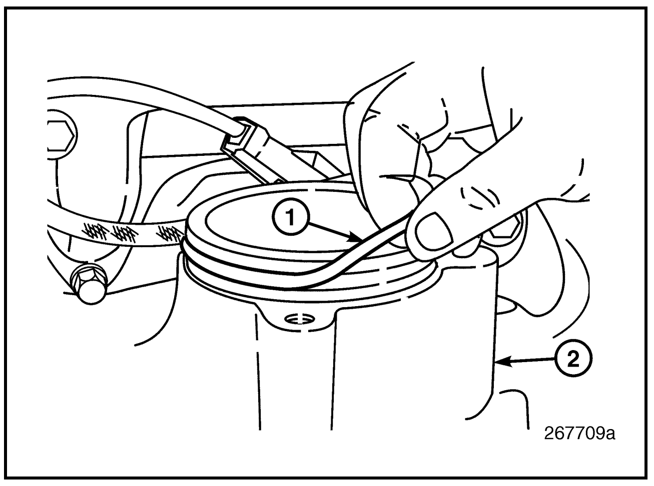


Figure 510 — O-Ring Installation

1. O-Ring	2. Inlet Manifold

3. Place the mixer tube in position on the inlet manifold (Figure 511) and install the two mounting capscrews. Tighten the capscrews to specification, 40 lb-ft (55 N•m).

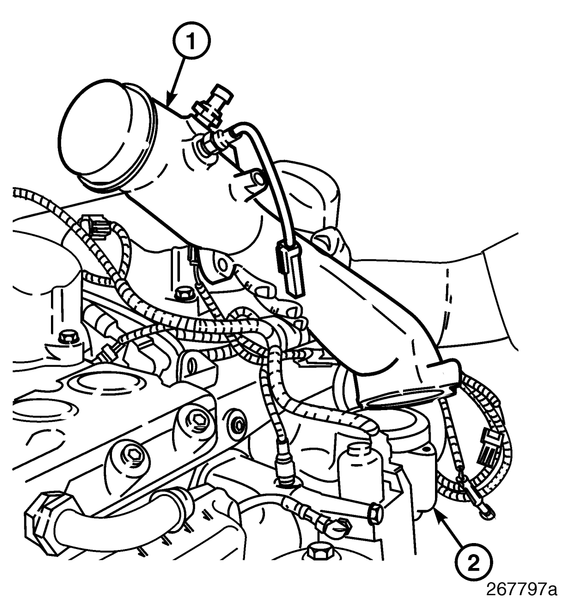


Figure 511 — EGR Gas Mixer

1. EGR Gas Mixer	2. Inlet Manifold

4. Install the capscrew attaching the support bracket to the side of the mixer tube. Tighten the capscrew to specification, 40 lb-ft (55 N•m).
5. With the **new** seal in place, position the upper EGR gas tube on the mixer tube flange and install the clamp (Figure 509).
6. Lightly tap the clamps with a light rubber mallet and then retighten them to specification.
7. Reposition the boost pressure relief valve outlet tubing to reconnect with the boost pressure relief valve. Connect the outlet tube to the valve using the flexible coupling hose. Secure the coupling hose using two hose clamps.

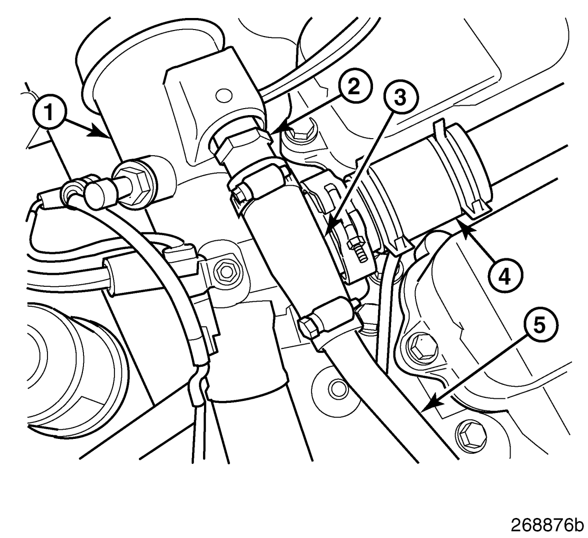


Figure 512 — Boost Pressure Relief Valve (Turbo By-Pass)

1. EGR Gas Mixer Tube 2. Boost Pressure Relief Valve (Turbo By-Pass) 3. Valve-to-Outlet Tube Coupling	4. EGR Gas Tube (Reference) 5. Outlet Tube-to-Exhaust

8. Connect the electrical leads to the CMCAC outlet pressure and temperature sensors (Figure 507).

MASS Flow System Replacement Instructions

NOTE

The EGR MASS Flow sensors are an integral part of the upper EGR gas tube and cannot be removed. The sensors are calibrated specifically to the upper EGR tube and the EGR MASS Flow System module. If replacement is required, the entire tube assembly with its integral sensors must be replaced along with the MASS Flow System module attached to the back of the EECU cooling plate.

Effective with engine production beginning 5/15/03, changes were made to the MASS Flow System (MFS) and the Engine Electronic Control Unit (EECU) cooling plate on which the MFS electronic module is mounted. These MFS changes caused the sensor wire harness to be shortened from 39 inches (99.06 cm) to 30 inches (76.2 cm). The module cooling plate was also revised to mount the MASS flow module toward the rear of the cooling plate with the harness connector also facing the rear. Depending upon the availability of parts through the MACK Parts System, it is acceptable to use either wire length MASS flow system in place of the other. MASS flow system parts for non-brake and brake-equipped engines, however, are not interchangeable.

The following description covers the differences between the MASS flow system used on engines manufactured prior to 5/15/03 and the system after this date:

- For engines manufactured prior to 5/15/03, the EGR tube and sensor assemblies contain harness wires that are approximately 39 inches (99.06 cm) long. These wire harnesses route from the sensors, around the front of the engine to the MFS electronic module which is mounted on the EECU cooling plate. With this longer harness, the MFS module harness connectors will face the front of the engine.
- For engines manufactured after 5/15/03, the EGR tube and sensor assemblies contain harness wires that are approximately 30 inches (76.2 cm) long. These wire harnesses are routed over the top of the front cylinder head cover to the MASS flow system electronic module. For this configuration, the module is mounted on the EECU cooling plate with the harness facing the rear of the chassis.

MASS FLOW SYSTEM INSTALLATION

EGR Tube Installation Instructions

To properly install the EGR tube assembly, the clamps must be fully seated by tapping each clamp with a rubber mallet and torquing three times as described in “EGR Gas Tube(s) Removal and Installation” on page 402.

MASS Flow System Module Installation Instructions

The MASS flow system module is mounted on the back of the engine electronic control unit (EECU) cooling plate. To replace the module, it is necessary to disconnect the EECU and mass flow system module connectors, then to remove the EECU, cooling plate and MASS flow system module as an assembly. Once the cooling plate is removed, the four screws retaining the module to the plate can be accessed and removed.

Installation of the MFS module can either be facing toward the front or the rear of the chassis depending on configuration of the cooling plate.

1. Reinstall the four module retaining screws and torque to specifications.
2. Route the sensor wire harness either over top of the front valve cover or around the front of the engine depending on harness length and configuration.
3. Clamp and tie the harnesses as necessary to prevent the harness from rubbing against any engine components.

4. Reinstall the non-current design EECU cooling plate as follows:

   Non-Current Cooling Plate Design

   The EECU cooling plate used on ASET™ AC engines from the beginning of production through mid-May 2003 has two 0.580-inch (14.7 mm) diameter mounting holes at the lower corners of the plate. The lower mounting isolators are installed through these holes, and each isolator is then secured with two 0.188-inch thick washers and one nut.

   Due to tolerance stack-up between the thickness of the cooling plate and the dimensions of the isolators, some isolators may not clamp onto the cooling plate when the nut is tightened. When this occurs, tightening the nut further will cause the washers to rotate, which places force on the rubber portion of the isolator, resulting in tearing or breaking of the rubber. To prevent this from occurring, it is recommended that another washer (part No. 35A1446X) be added between the two 0.188-inch washers. This should be done whenever the EECU or cooling plate is removed for any reason, or if torn or broken mounting isolators are encountered.

   a. For the non-current cooling plate design, upper isolators are secured with flanged nuts only; washers are not used. The upper mounting nuts must be tightened to 108 lb-in (12 N•m).
   b. Non-current lower mounting nuts must be tightened to 180 lb-in (20 N•m).

5. Reinstall the current design EECU cooling plate as follows:

   Current Cooling Plate Design

   Beginning 5/15/03, the EECU cooling plate arrangement used on the ASET™ AC engines was changed to include integral bushings at the two lower mounting bolt holes. The lower mounting isolators are installed through these bushings and secured by one 0.065-inch thick washer and one nut.

   a. For the current cooling plate design, upper isolators are secured with flanged nuts only; washers are not used. The upper mounting nuts must be tightened to 108 lb-in (12 N•m).
   b. Current design lower mounting nuts must be tightened to 180 lb-in (20 N•m).

Final Assembly

Reinstall all accessory items, ducting, etc., that were removed to gain access to the EGR components. Replace all fluids drained from the engine and reconnect the batteries.

VTG TURBOCHARGER SERVICE PROCEDURES ASET™ AC (CEGR) ENGINE [214 SD]

Preliminary Steps

The preliminary steps for replacing the VTG turbocharger components will vary depending on the chassis configuration. As such, the steps in the procedures that follow are general in nature. Begin the operations by disconnecting the batteries and draining fluids from the engine as required. Then, remove ducting and any accessory items, etc., that may interfere with access to the VTG turbocharger and related components.

VTG Position Control Valve Removal and Installation

GENERAL INFORMATION

The electronically controlled VTG Position Control Valve incorporates a bleed port that exhausts air continually when the key is in the "on" position and the engine is running. There is no air flowing from the bleed port when the engine is not running except under the following conditions:

- When calibrating the VTG actuating system, the control valve is operational and will bleed air. This is normal.
- Statically, the VTG vanes should be fully open. If there is a problem which has resulted in the vanes not being fully open, the VTG control valve may be operating and trying to open the vanes. Under this condition, the valve may bleed air. If this occurs, the source of the problem must be found and corrected.

On early-production engines (prior to May 4, 2004), supply air enters the control valve directly from the chassis air system. As a result, small amounts of oil mist in the chassis air system can condense inside the valve. It is a normal condition to notice some oil seepage from the bleed port.

NOTE

If the amount of oil is deemed excessive, the root cause must be corrected. The VTG control valve IS NOT the cause and should not be replaced because of an excessive oil leak at the valve port. The valve should only be replaced when it is not functioning properly as identified by a fault code and verified by troubleshooting procedures.

Engines produced after May 4, 2004 have an oil coalescing air filter incorporated into the air line supplying the control valve to prevent oil condensation and possible "coking" inside the VTG position control valve. The filter is mounted on a bracket at the lower side of the cylinder block, to the rear of the oil filters. A service parts kit is available to retrofit early-production engines if conditions warrant it.

REMOVAL AND INSTALLATION PROCEDURE

Refer to Figure 513 for reference in removing and installing the VTG position control valve.

1. Disconnect the harness electrical lead from the terminal on the control valve assembly.
2. Disconnect the VTG position actuator air supply line from the valve.
3. Disconnect the air line from the air supply port on the valve.
4. Loosen and remove the two capscrews attaching the valve to the inlet manifold.
5. Check the valve for proper operation. Replace as required.

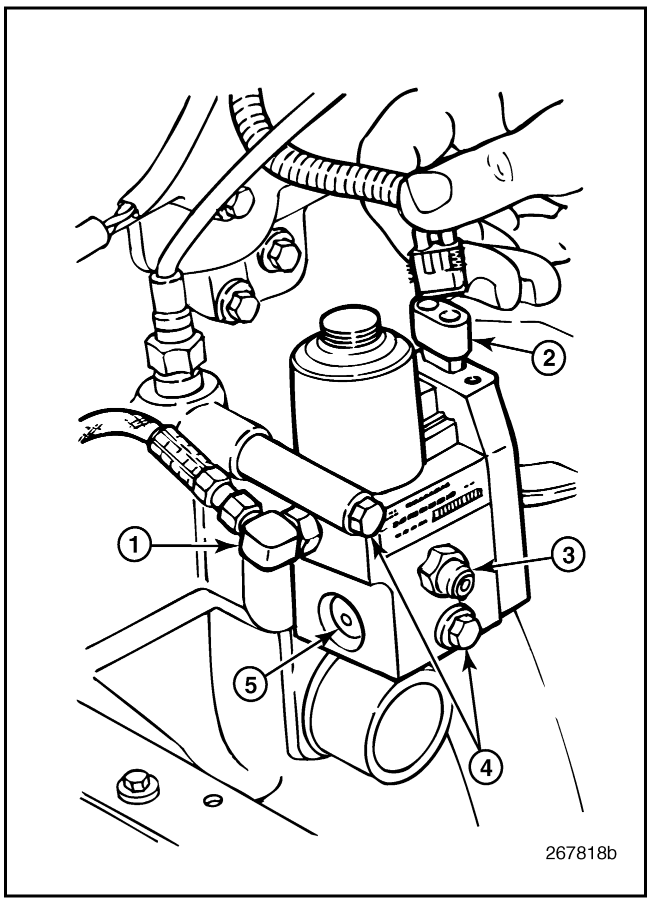


Figure 513 — VTG Position Control Valve

1. Air Line to Turbocharger 2. Electrical Connector 3. Air Supply Port	4. Mounting Capscrews 5. Air Bleed Port

6. Place the control valve assembly in position on the inlet manifold and install the two mounting capscrews. Tighten the capscrews to specification.
7. Connect the air supply line to the air supply port on the valve.
8. Connect the actuator air line to the fitting at the side of the valve.
9. Connect the harness electrical lead to the terminal at the top of the valve.

Turbocharger Removal

1. Disconnect the air inlet and outlet ducting from the turbocharger compressor housing.
2. Support the exhaust pipe so that it does not drop onto the EGR hot tube bellows and remove the exhaust clamp at the turbocharger.

CAUTION

DO NOT let the exhaust pipe drop onto the bellows of the EGR hot tube as the exhaust pipe clamp is being removed at the turbocharger. The bellows could be damaged requiring replacement of the hot tube.

3. Disconnect the air line and the sensor electrical lead at the VTG actuator assembly (Figure 514) and the line at the turbocharger wheel-speed sensor.

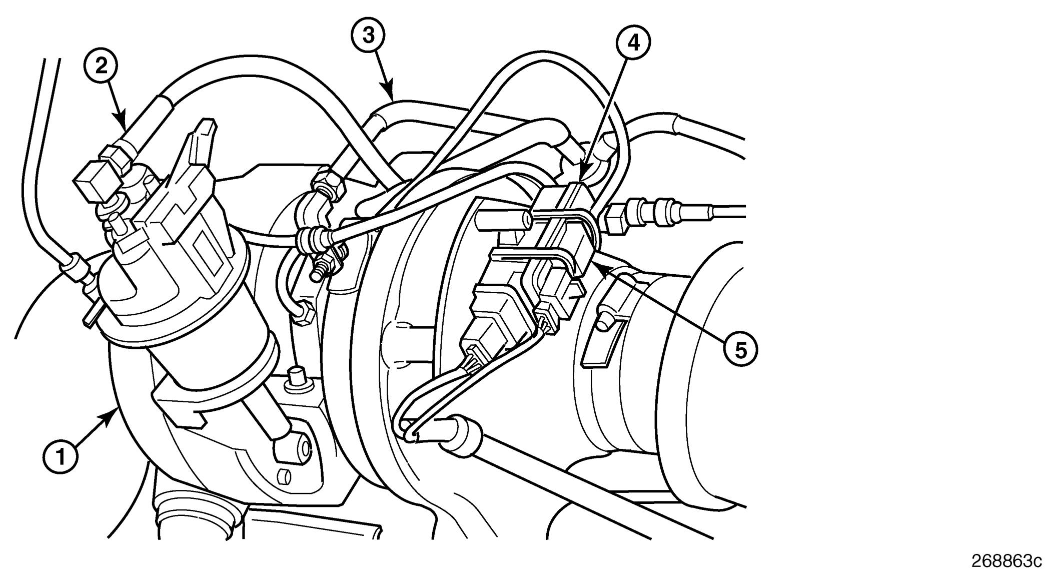


Figure 514 — Line Connections

1. Turbocharger Assembly 2. Actuator Air Line 3. Turbocharger Oil Supply Line	4. VTG Position Sensor Module 5. Wheel-Speed Sensor Connector

4. Disconnect the oil supply line from the fitting in the turbocharger center housing.
5. Remove the two capscrews securing the oil drain tube at the bottom of the turbocharger center housing (Figure 515).
6. If the oil drain tube is to be removed, disconnect the EGR oil return line from the drain tube and remove the two capscrews from the drain tube flange at the cylinder block. Remove the drain tube.

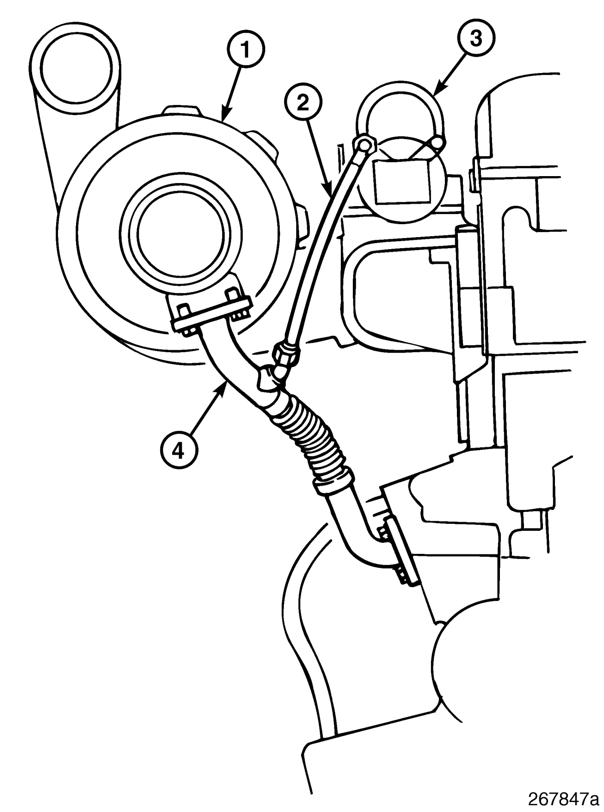


Figure 515 — Turbocharger Oil Drain

1. Turbocharger 2. EGR Valve Oil Return Line	3. EGR Valve 4. Turbocharger Oil Drain Tube

CAUTION

The turbocharger is heavy, weighing approximately 76 lbs. DO NOT attempt to remove or install the turbocharger without the help of an assistant or the use of a suitable lifting device.

7. Loosen and remove the four turbocharger mounting nuts and remove the turbocharger from the engine.

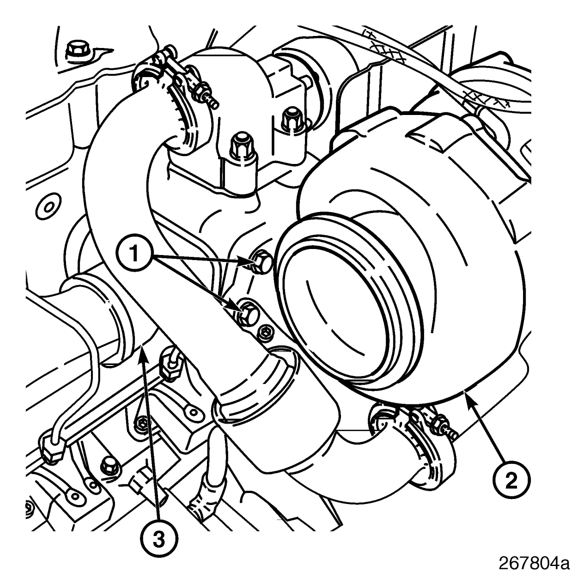


Figure 516 — Turbocharger Mounting

1. Retaining Nuts (4) 2. Turbocharger Assembly	3. Exhaust Manifold (Center Section)

Turbocharger Installation (Includes Pre-Lubing Procedures)

1. Inspect the intake and exhaust systems leading to and from the turbocharger to ensure absence of foreign material, including burrs and loose lining fragments.

NOTE

A thorough inspection is required as even small particles can cause severe rotor damage if inducted during high-speed operation.

2. Use **new** and approved gaskets at the various air, oil and exhaust connections to the turbocharger. Avoid the use of sealing or jointing compounds at all flanged connections.

NOTE

The turbocharger-to-manifold gasket is unique for the VTG turbocharger. When installing the turbocharger, be sure to use the correct gasket; the gasket used with a standard turbocharger will not work for this application.

CAUTION

The turbocharger is heavy, weighing approximately 76 lbs. DO NOT attempt to remove or install the turbocharger without the help of an assistant or the use of a suitable lifting device.

3. Place the turbocharger in position over the mounting studs on the exhaust manifold (Figure 516).
4. Apply a coating of clean engine oil to the flanges and threads of the four nuts. Install the nuts and using torque wrench J 24406, or equivalent, tighten the nuts in a cross-pattern sequence (Figure 517) in two stages:
   - First stage — 50 lb-ft (68 N•m)
   - Second stage — 100 lb-ft (136 N•m)

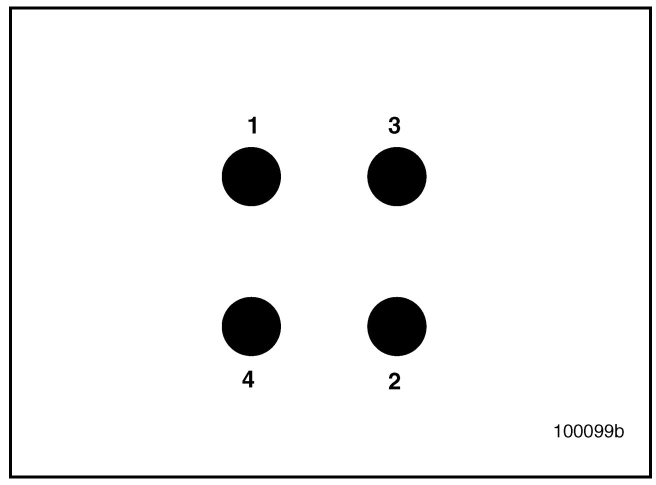


Figure 517 — Turbocharger Tightening Sequence

NOTE

The mounting nut at the upper front location is difficult to access and will require the use of an offset wrench or crow's foot to tighten.

5. Support the exhaust pipe to prevent it from dropping onto the EGR hot tube bellows. Then, install the exhaust bracket to the flywheel housing and install the exhaust clamp at the turbocharger.

CAUTION

DO NOT let the exhaust pipe drop onto the bellows of the EGR hot tube as the exhaust pipe clamp is being installed at the turbocharger. The bellows could be damaged requiring replacement of the hot tube.

6. Fill the oil inlet port to overflowing with clean engine oil. Next, using your fingers at the compressor wheel, carefully spin and wiggle the turbocharger shaft to distribute the oil over all bearing surfaces. Then, again fill the oil inlet port to overflowing.

7. If the V-band is loosened for angular orientation of the compressor housing, ensure that the mating flanges are tightly seated and that the V-band is snug but will still allow cover orientation.

   Complete the orientation of the cover and housing before making any rigid connections to the compressor inlet. Tighten the V-band retaining nut to 105 lb-in (12 N•m), using torque wrench J 5853-C, or equivalent. Make certain that all ducting aligns closely with the turbocharger. This minimizes external stresses acting on the unit. Then, taking care to not pinch the wires in the wire routing clamp, tighten the clamp retaining nut on the V-band bolt to 48 lb-in (5 N•m). Make sure the wire clamp remains vertical when tightening the nut, to keep the wires away from the hot surfaces of the compressor cover, bearing and turbine housings.

NOTE

Replacement VTG turbochargers have not been given the final orientation of the housings and the fasteners that allow orientation are not tightened to specification. When installing a replacement turbocharger, orient the housings and tighten the fasteners as follows:

- Tighten the compressor housing clamp band retaining nut and wire routing clamp nut as described in the above step.
- Tighten the six screws that secure the three clamp plates and bearing housing to the turbine housing. Tighten the screws to 30 lb-ft (41 N•m).

8. Install the oil drain tube (Figure 515) and tighten the capscrews to the specification, 15 lb-ft (20 N•m), using torque wrench J 24406, or equivalent.
9. Connect the EGR valve oil return line to the oil drain tube.
10. Remove and flush the turbocharger oil supply line to make sure it is clean and free of debris. Then, reinstall the supply line.
11. Install and adjust the VTG actuator (if removed) using the procedure under “VTG Removal and Installation” included in this section.
12. Route and tie the VTG air line to the oil lines supplying the EGR valve and the turbocharger. Use stainless steel tie straps to secure the lines together.

CAUTION

Proper routing will hold the air line in a position maximizing its distance away from and avoiding contact with the EGR valve casting and the upper EGR cool tube bellows. If this is not done, heat from the EGR valve can damage the Teflon® core of the line causing an air leak. In addition, the outer braid of the air line can chafe the cool tube bellows and cause an exhaust leak.

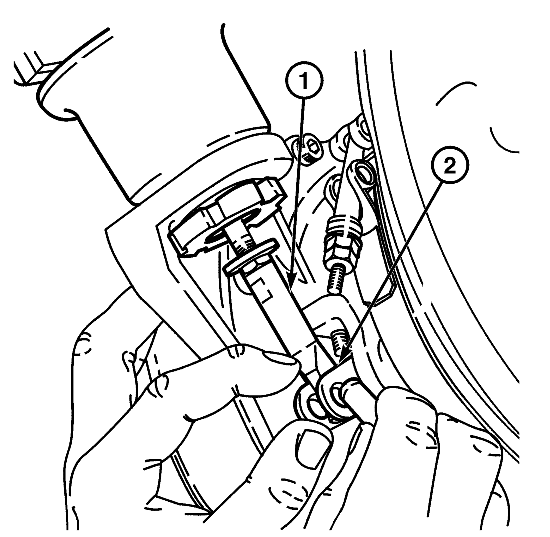


Figure 518 — Vane Operating Lever Connection

1. Actuator Rod	2. Vane Operating Lever

13. Connect the actuator air line and the VTG position sensor electrical lead to complete the procedure.

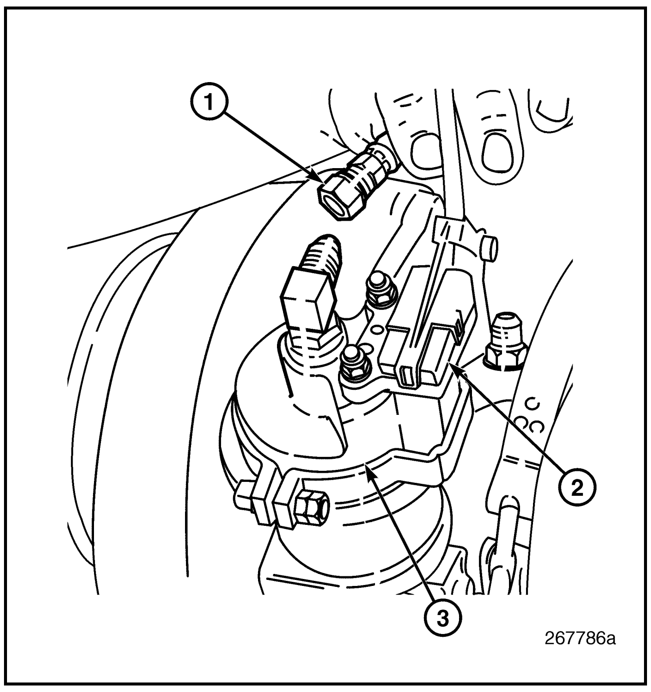


Figure 519 — Actuator Line Connections

1. Actuator Air Line 2. VTG Position Sensor	3. VTG Actuator Assembly

NOTE

The VTG system must be re-calibrated for proper open and closed vane-position voltages after installation and adjustment of the VTG actuator.

14. Reinstall all accessory items, ducting, etc., that were removed to gain access to the VTG turbocharger and related system components. Replace all fluids drained from the engine and reconnect the batteries.
15. Operate the engine at low idle for at least three minutes after completing the installation of the turbocharger and before driving the vehicle.

VTG Actuator Removal and Installation

A damaged and/or malfunctioning VTG actuator can be serviced as a separate unit without replacing the complete turbocharger assembly. A replacement VTG actuator kit is available through the MACK Parts System. Use the following procedure to reinstall the original actuator or to install a new unit.

VTG ACTUATOR REMOVAL

1. Disconnect the air line from the VTG actuator.
2. Connect a shop air pressure line to the air fitting at the top of the actuator assembly (Figure 520) and apply 40–60 psi air pressure to extend the actuator rod downward.

CAUTION

Use care in applying air pressure to the actuator assembly. DO NOT apply pressure greater than 100 psi to the actuator at any time, as damage to the actuator diaphragm may result.

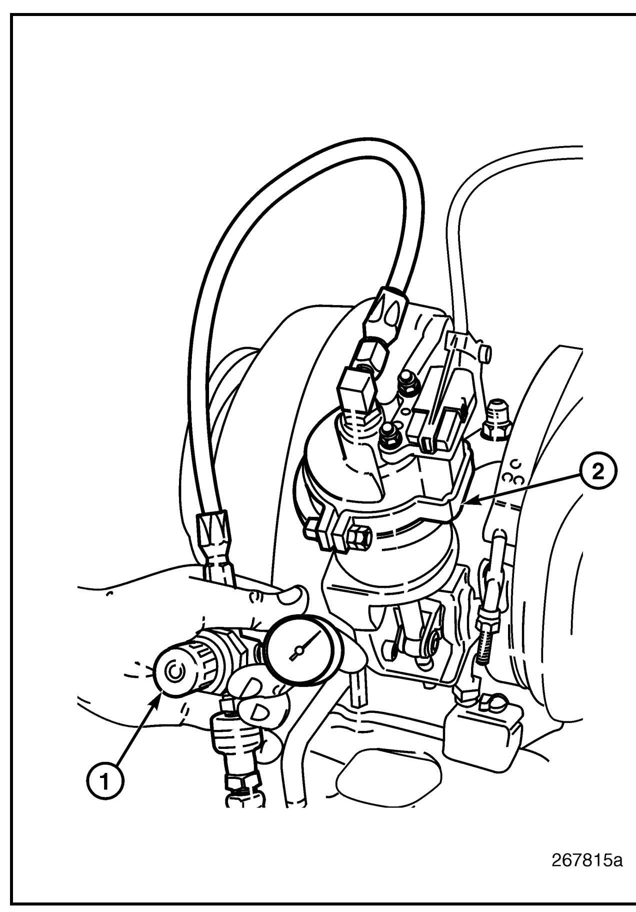


Figure 520 — Air Pressure Application

1. Shop Air Supply Line	2. VTG Actuator Assembly

3. Remove the C-clip and remove the pin connecting the actuator rod to the vane operating lever clevis (Figure 521).

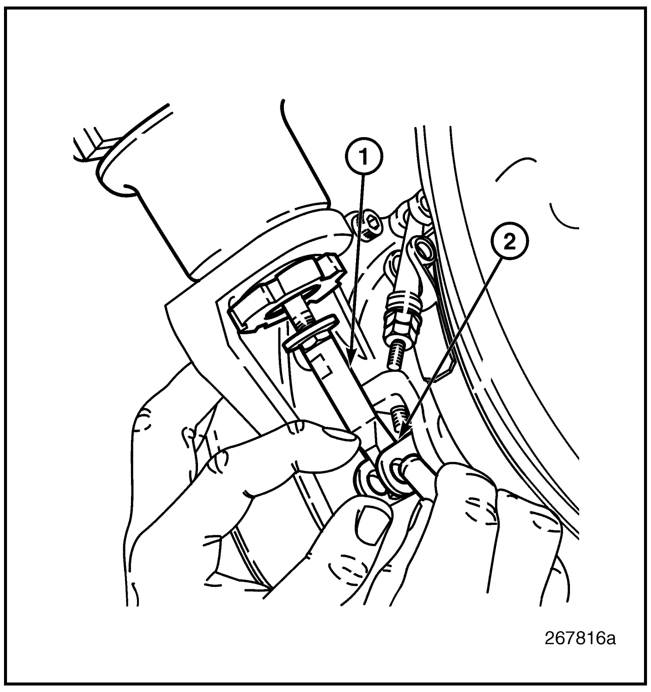


Figure 521 — Vane Operating Lever Connection

1. Actuator Rod	2. Vane Operating Lever

4. Release the air pressure and disconnect the shop air line.
5. Cut the two tie straps that attach the turbocharger wheel speed sensor harness connector to the top of the vane position sensor module at the front of the turbocharger compressor housing (refer to Figure 522). Note the way the position sensor and wheel speed sensor wires are routed, and also note the orientation of the harness clamp.
6. Loosen and remove the nut and washer that secures the wire harness clamp to the turbocharger compressor housing V-band clamp, then remove the clamp.
7. Remove the three 6 mm Allen-head bolts and washers that secure the position sensor connector and thermal isolation plate assembly to the compressor housing.

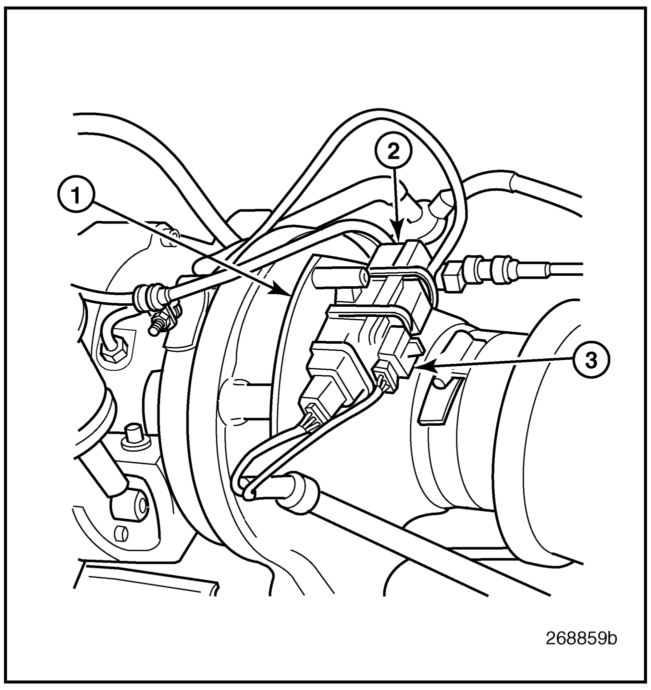


Figure 522 — Position Sensor Module and Thermal Isolation Plate Assembly

1. Thermal Isolation Plate 2. Vane Position Sensor Module	3. Wheel Speed Sensor Harness Connector

8. Using spanner wrench J 47019, remove the spanner nut (Figure 523) that retains the actuator to the actuator mounting flange, then remove the actuator/position sensor/isolation plate assembly from the mounting flange.

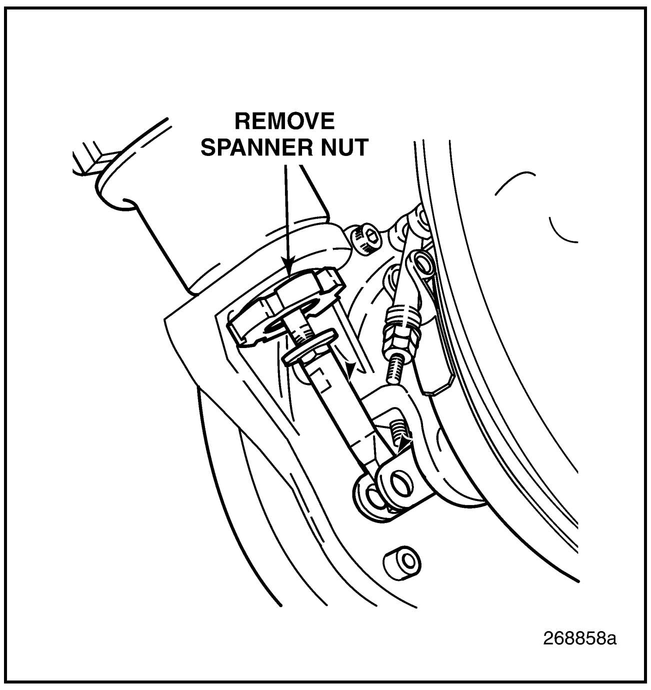


Figure 523 — Actuator Assembly Removal

VTG ACTUATOR INSTALLATION

1. Place the VTG actuator assembly in position on the mounting flange at the center of the turbocharger. Make sure the alignment pin is positioned in the hole on the flange (Figure 524).

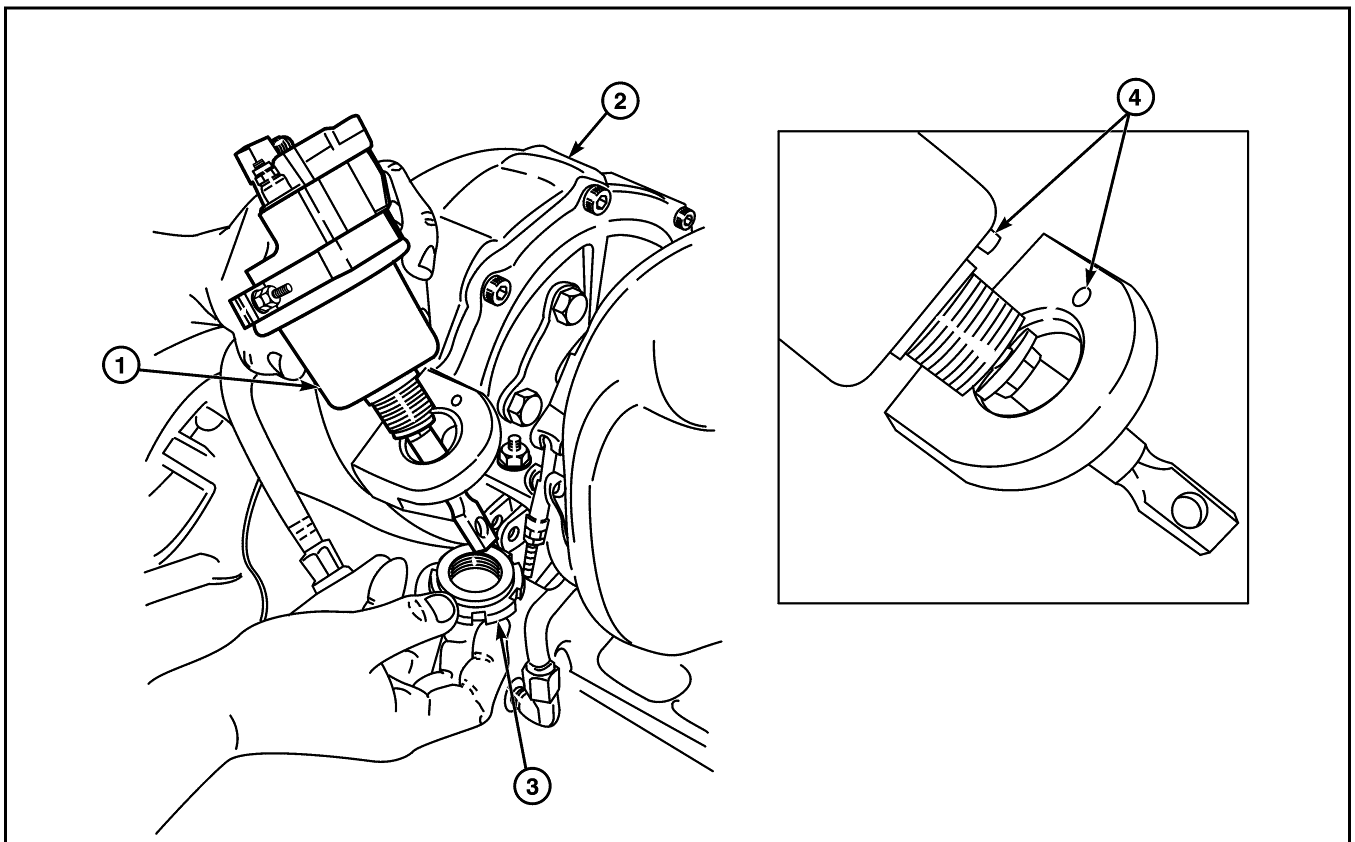


Figure 524 — VTG Actuator Installation

1. VTG Actuator Assembly 2. Turbocharger Assembly	3. Actuator Spanner Nut 4. Alignment Pin/Hole

2. Using spanner wrench J 47019, install the spanner nut securing the actuator assembly to the mounting flange. Tighten the nut to specification, 92 lb-ft (125 N•m).

NOTE

To ensure that the spanner nut is tightened to the proper torque value, spanner wrench J 47019 (Figure 525) is required.

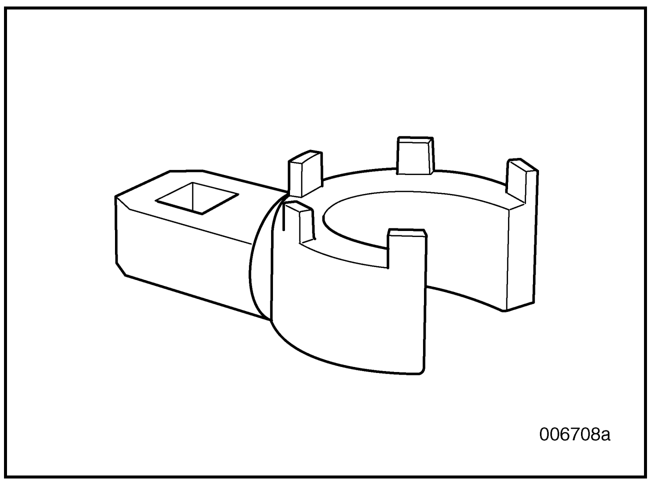


Figure 525 — Spanner Wrench (J 47019)

3. When tightening the spanner nut, make sure that the spanner wrench fully engages the nut as shown in the Figure 526. If not properly engaged, the wrench tangs can be damaged if the wrench slips out of engagement when torque is applied.

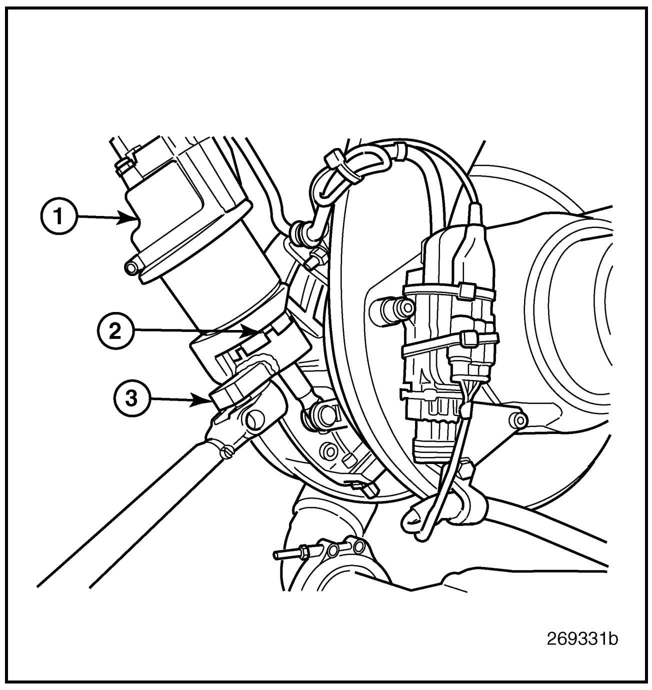


Figure 526 — Using Spanner Wrench to Tighten Spanner Nut

1. VTG Actuator Assembly 2. Spanner Nut	3. Spanner Wrench (J 47019)

4. Adjust and verify actuator rod length as follows:
   a. Manually move the VTG lever arm clevis against the upper stop (vanes fully opened).
   b. With the actuator rod fully retracted and the lever arm clevis against the upper stop, note the alignment of the hole in the lever arm clevis with the hole in the actuator rod end. If not in alignment, release the lever arm clevis and allow it to rest on the lower stop, then loosen the actuator rod end jam nut and adjust the rod end until the holes are in alignment (when the lever arm clevis is against the upper stop). The adjusted actuator rod length can be verified by inserting the rod end pin and making sure the clevis remains against the upper stop.

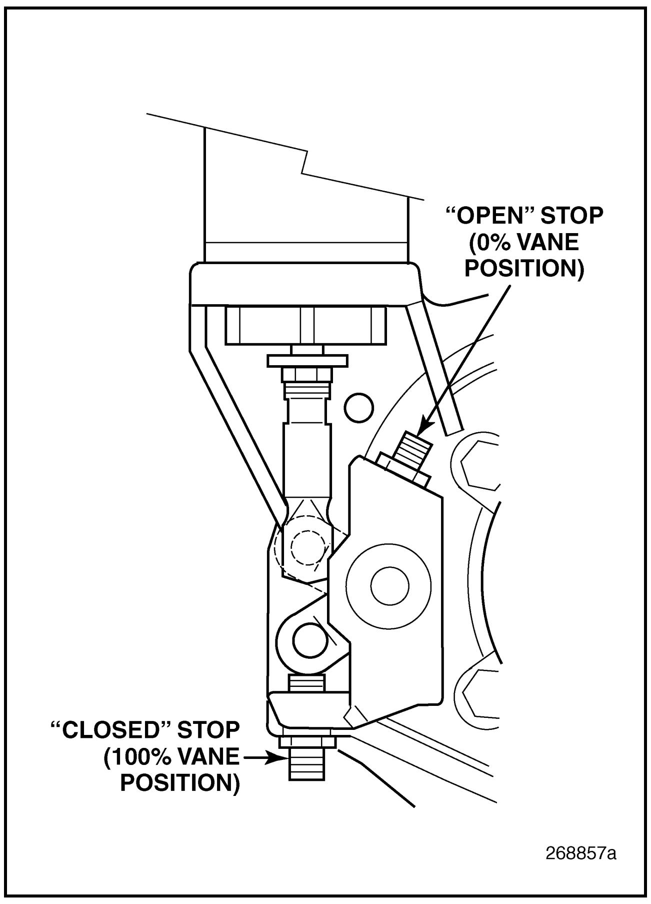


Figure 527 — Rod End-to-Lever Arm Clevis Alignment

c. Once the adjusted actuator rod length has been obtained, release the lever arm clevis and allow it to rest against the lower stop. Turn the rod end two complete turns clockwise (when viewed from the rod end side of the actuator assembly) to shorten the actuator rod length.

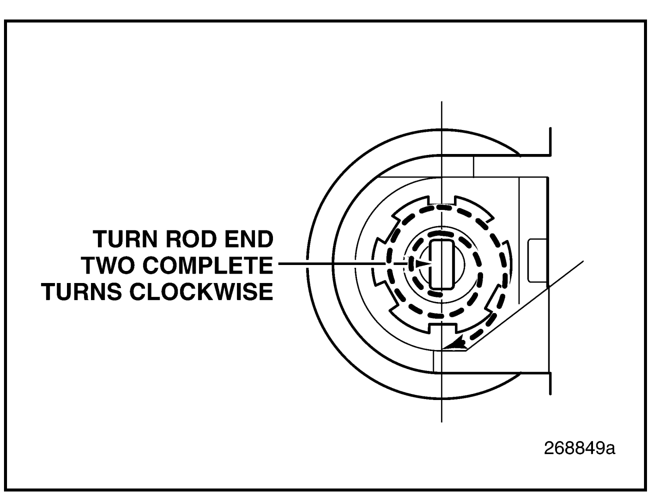


Figure 528 — Completing Rod End Adjustment

NOTE

Step c must be completed or the actuator will be out of range and cause a fault to be logged in the V-MAC® system.

d. Using an open-end wrench on the two flats on the rod end, tighten the jam nut.

NOTE

The actuator rod end must be held with an open-end wrench to avoid torsional damage to the actuator diaphragm.

5. Connect a regulated shop air supply (with a pressure gauge) to the air fitting at the top of the actuator assembly (Figure 529) and apply 40–60 psi of air pressure to extend the actuator rod downward.

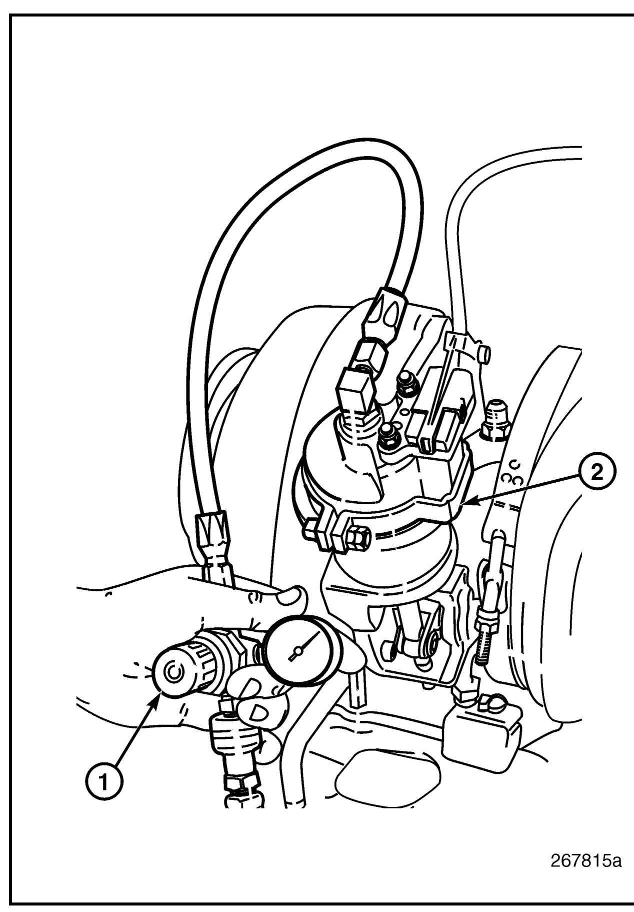


Figure 529 — Air Pressure Application

1. Shop Air Supply Line	2. VTG Actuator Assembly

6. With air pressure applied and the actuator rod extended, move the lever arm clevis to align the hole in the clevis with the hole in the rod end and insert the clevis pin (Figure 530).

SERVICE HINT

Because of preload, it is easier to install the pin through the vane lever arm clevis and actuator rod hole when the rod is in an extended position and not retracted into the housing.

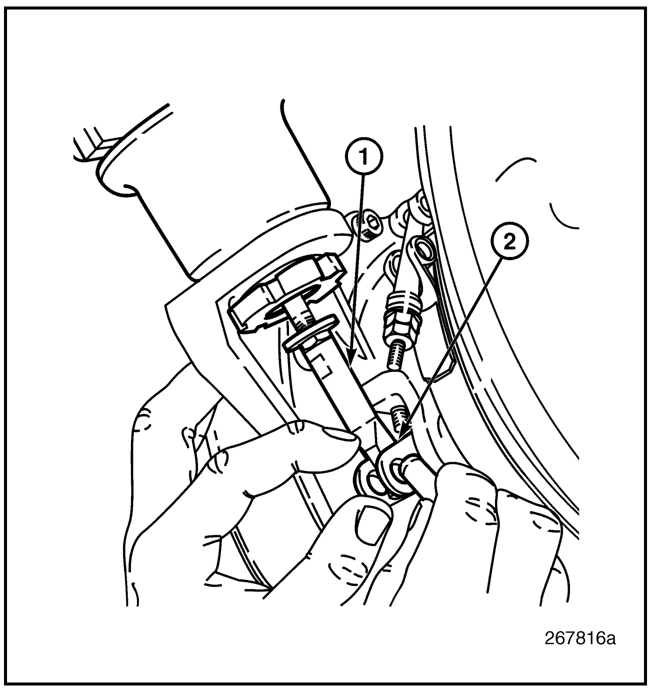


Figure 530 — Vane Operating Lever Connection

1. Actuator Rod	2. Lever Arm Clevis

7. Set the pressure regulator to 0 psi. The actuator rod should retract and pull the vane operating lever against the upper stop (vanes open).
8. Adjust the regulator to apply 95–100 psi of shop air pressure to the actuator. The actuator rod should extend, pushing the vane operating lever down against the lower stop (vanes fully closed).

CAUTION

Use care in applying air pressure to the actuator assembly. DO NOT apply more than 100 psi. Pressures greater than 100 psi will result in damage to the actuator.

9. Verify that the lever arm clevis moves fully from stop-to-stop. Then, carefully tighten the actuator rod end jam nut to 106 lb-in (12 N•m) while using an open-end wrench on the flats of the rod end to hold the end in place.

CAUTION

Damage to the actuator diaphragm will occur if the actuator rod is allowed to twist while tightening the jam nut.

10. Install the C-clip to secure the secure the pin in the lever arm clevis.
11. Disconnect the regulated shop air line from the actuator and reconnect the air line from the VTG position control valve to the actuator. Tighten the fitting to 140 lb-in (16 N•m).
12. Re-calibrate the VTG actuating system for proper open and closed vane-position voltages using the procedure that follows in this section.
13. After the VTG vane position calibration has been successful, complete the installation procedures by routing the vane position sensor and turbocharger wheel speed sensor wire harnesses as shown in Figure 531.

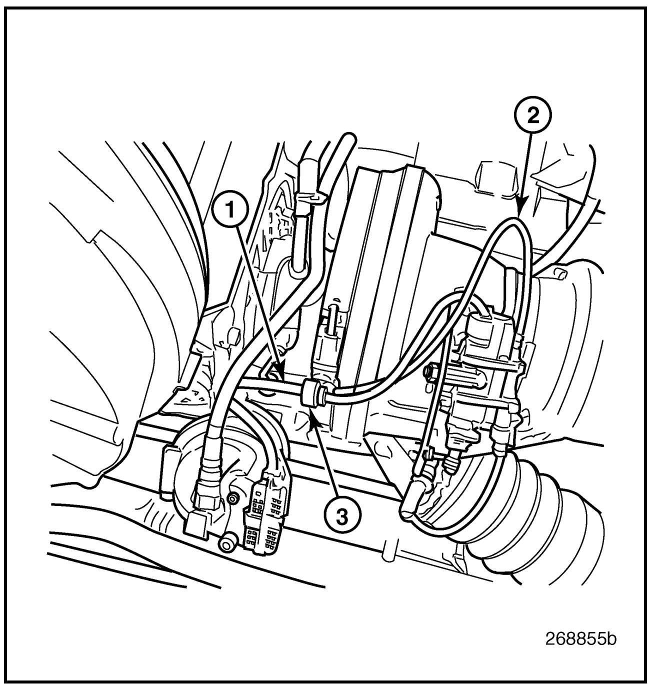


Figure 531 — Vane Position and Wheel Speed Sensor Harness Routing

1. Vane Position Sensor Harness 2. Harness Clamp	2. Wheel Speed Sensor Harness

14. Insert the harnesses into the harness clamp, then assemble the clamp on the turbocharger compressor V-band clamp stud. Secure with the existing flat washer and nut, and tighten the nut to 48 lb-in (5 N•m). When tightening the harness clamp nut, take care not to pinch the wires in the clamp, and make sure the harness clamp remains in the vertical position. Having the clamp oriented vertically ensures proper clearance between the harnesses and the turbocharger compressor housing, bearing housing and turbine housing.

CAUTION

Proper routing is essential to avoid heat damage to the wires and premature failure of the VTG components.

15. Connect the vane position sensor harness connector to the engine harness connector, then secure the connector to the isolation plate mounted on the turbocharger compressor housing. Use the existing washers, spacers and bolts previously removed.
16. Connect the turbocharger wheel speed sensor connector to the engine harness connector, then secure the connector on top of the vane position sensor with two tie straps as shown in Figure 532.

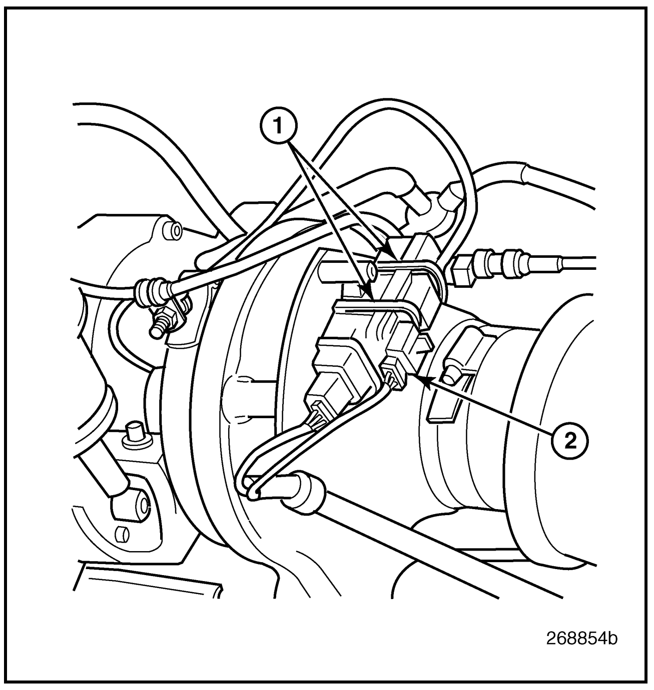


Figure 532 — Turbocharger Wheel Speed Sensor Connector Mounting

1. Tie Straps	2. Wheel Speed Sensor Harness Connector

VTG Actuating System Calibration

The VTG actuating system must be recalibrated for proper open and closed vane position voltages and full stop-to-stop travel whenever parts are replaced, or when diagnosing certain conditions (such as an active 4-5 fault code). Recalibrate the VTG actuating system during any of the following circumstances:

- Turbocharger replacement
- VTG actuator replacement
- Actuator control valve replacement
- Active code 4-5, MID 128, PID269, FMI7 (Refer to the V-MAC® III Service Manual, 8-311.)
- Complaints of low power or low boost pressure

VTG CALIBRATION TEST

To perform the VTG calibration test, use **V-MAC® III Support Software,** *Service Diagnostics.* The VTG calibration test is located within *Special Diagnostic Modes, VTG Vane Position Calibration*.

When performing the VTG Vane Position Calibration test, engine coolant temperature must be above 140°F (60°C), engine not running, and the key switch in the ON position. Air system pressure (both primary and secondary) must be at least 110 psi. Air system pressure at 110 psi is mandatory to ensure that at all times during the calibration procedures, the vane actuator receives a minimum of 95 psi. This pressure is required for the vanes to reach full travel.

CAUTION

If the turbocharger is too hot to touch, the engine should be run at an idle, then allowed to cool before the calibration procedure is performed.

During the calibration test, the actuator rod must be observed to ensure that full rod travel takes place, and that the vane operating lever reaches both the upper and lower stops. If the actuator does not visibly reach the full stop positions, the test results have failed, even if the diagnostic tool reports a successful test. If the actuator did not reach the full stop positions, either air system pressure was too low, or there was a mechanical problem with the vane operating lever, actuator, control valve, etc., that must be resolved. Verify that air system pressure is at least 110 psi (95 psi delivered to the actuator), and check the actuator and vanes for proper function as outlined under the heading "Checking Actuator and Vane Function."

CALIBRATING ACTUATOR ROD TRAVEL

If the calibration test results indicated that adjustment of actuator rod travel is necessary, adjust the rod as follows:

1. Loosen the actuator rod end jam nut while holding the rod end with an open-end wrench to prevent the actuator rod from twisting.
2. Disconnect the air line from the 90-degree fitting at the top of the actuator.
3. Connect a regulated shop air supply (with a pressure gauge) to the actuator, and apply 40–60 psi. Be careful not to apply pressure greater than 100 psi, as damage to the actuator will result.

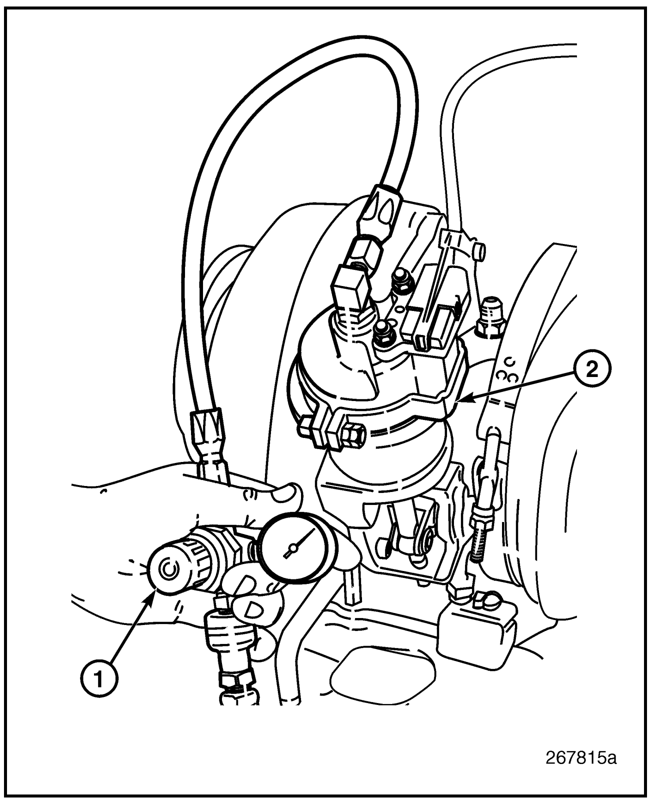


Figure 533 — Regulated Shop Air Connected to Actuator

1. Regulated Shop Air Supply Line	2. Vane Actuator

4. With the actuator rod extended, remove the C-clip from the clevis pin, then remove the pin from the clevis.
5. Set the pressure regulator to 0 psi.
6. With the lever arm clevis resting against the lower stop, turn the rod end 180 degrees as follows:
   - If voltage readings obtained from the calibration test are high (greater than 4500 mV at 0 percent vane position), rotate the rod end 180 degrees clockwise (when viewed from the rod end of the actuator) to shorten rod length.
   - If voltage readings obtained from the calibration test are low (less than 650 mV at 100 percent vane position), rotate the rod end 180 degrees counterclockwise (when viewed from the rod end of the actuator) to lengthen rod length.

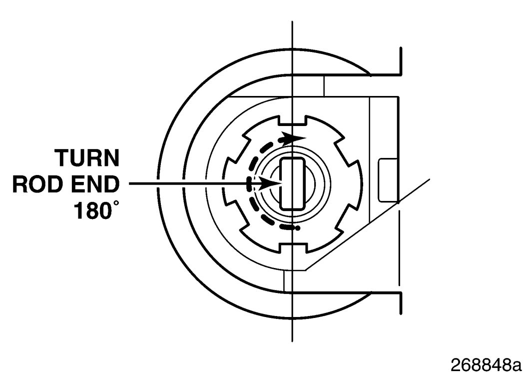


Figure 534 — Rotate Actuator Rod End 180 Degrees

NOTE

Rotating the rod end 180 degrees will change voltage approximately 0.025 volt.

CAUTION

At no time and under no circumstances should the lever stop screws ever be adjusted in an attempt to adjust actuator rod travel. These stop screws are factory-adjusted, and changing the adjustment will result in "over-travel" and possible jamming of the vanes in one position.

7. Set the pressure regulator to apply 40–60 psi to extend the actuator rod, then align the hole in the actuator rod end with the hole in the clevis and install the clevis pin and C-clip.
8. Adjust the pressure regulator to 0 psi and ensure that the lever arm moves fully to the upper stop (vanes fully opened).
9. Adjust the regulator to apply 100 psi and ensure that the lever arm clevis moves fully to the lower stop (vanes fully closed).
10. Adjust the regulator to 0 psi, then remove the regulated air supply from the actuator.
11. While using an open-end wrench on the flats of the rod end to hold the actuator rod in place, tighten the rod jam nut to 106 lb-in (12 N•m).
12. Reconnect the air line running from the VTG position control valve to the actuator assembly. Tighten the line fitting to 140 lb-in (16 N•m).
13. Recheck the adjustment by performing the VTG Vane Position Calibration procedures.

CHECKING ACTUATOR AND VANE FUNCTION

Actuator and vane function is checked as follows:

1. Verify that air system pressure is at a minimum of 110 psi and engine coolant temperature is above 140°F (60°C). If not, start the engine and run the engine until coolant temperature is above 140°F (60°C) and air system pressure builds to the governor cut-out.
2. With the ignition key switch turned OFF, connect an air pressure gauge in the air line between the solenoid control valve and the vane actuator.

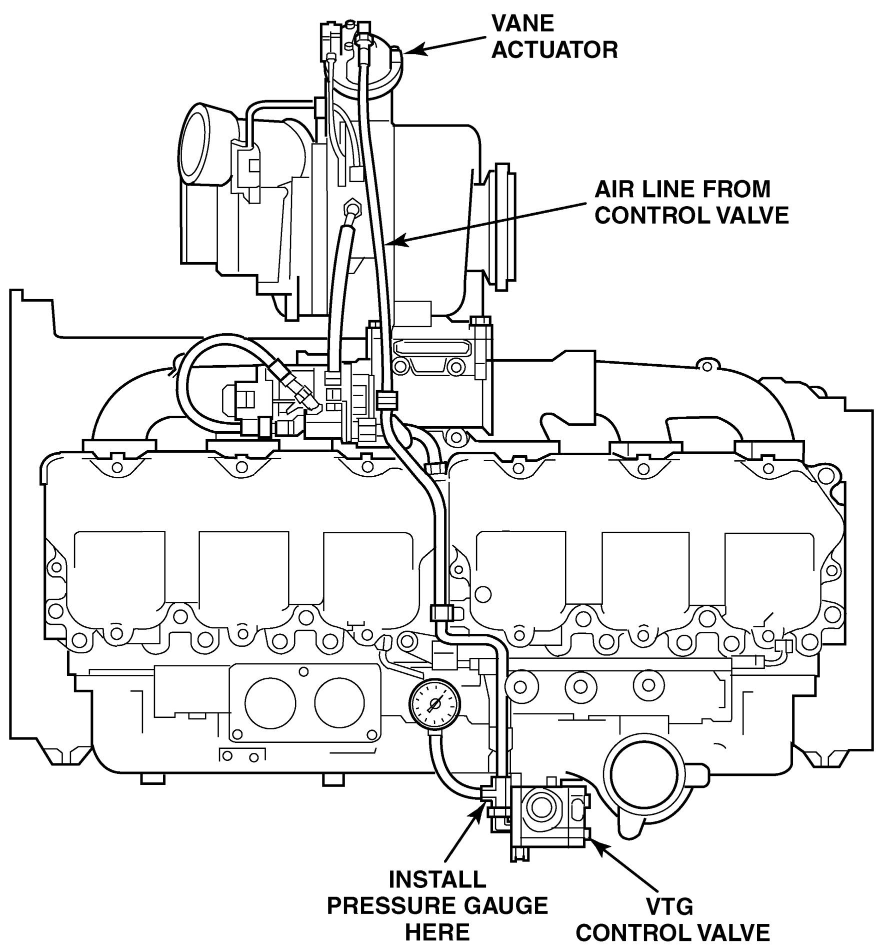


Figure 535 — Install Air Pressure Gauge in Air Line

3. Turn the ignition key switch ON, then note the reading indicated on the pressure gauge. If a reading of 95 psi is not obtained with system pressure at 110 psi, apply clean, dry, regulated shop air to the actuator as follows:
   a. Disconnect the air line at the 90-degree fitting located at the top of the actuator.
   b. Connect a regulated shop air supply and pressure gauge to the 90-degree fitting.
   c. Apply 100 psi pressure to the actuator and observe the actuator rod travel.
4. If full stop-to-stop rod travel occurs with 100 psi shop air applied to the actuator, verify that coolant temperature was at 140°F (60°C) and air system pressure was at 110 psi when the first test was performed. Also, check the harness connectors to ensure good connections. If no faults are found, replace the VTG control valve with a known good valve and rerun the VTG calibration.

NOTE

If a VTG control valve is installed for troubleshooting purposes and the problem is not resolved, the original control valve is to be reinstalled.

If no travel, or less than full travel was observed when 100 psi shop air was applied to the actuator, remove the C-clip and pin that connect the actuator rod to the clevis on the vane operating lever. Manually move the operating lever through its entire range of travel in both directions. If the lever moves smoothly with little resistance through the entire range of travel, the vane assembly is mechanically OK.

CAUTION

If free movement of the vane operating lever is not achieved, DO NOT pry or hammer on the lever. Doing so will damage the lever, vanes or both.

VTG ACTUATOR CLEVIS PIN SEIZURE

The VTG actuator rod is connected to the lever arm clevis by a clevis pin, and the pin is secured in place by a C-clip.

NOTE

Vane position is monitored by V-MAC®. If vane positioning cannot be changed by the VTG actuator, a cut-back in engine power will result, and a 4-5 fault code will be logged. Possible causes of a 4-5 fault code are a seized actuator rod clevis pin, or an attempt was made to readjust the VTG actuator lever stop screws.

CAUTION

Under no circumstances should the actuator lever stops ever be adjusted. These stop screws are adjusted to provide proper travel of the vanes when the turbocharger is assembled, and attempting to readjust the screws will cause vane damage or seizure. If readjusted stop screws are the cause of vane sticking or seizure, the only corrective action is replacement of the turbocharger, resulting in a denied warranty claim.

If a seized actuator rod clevis pin is encountered, spray/soak the pin with penetrating oil, then operate the VTG actuator by alternately applying and removing 100 psi to the actuator air fitting.

DO NOT attempt to rotate the pin. The head of the pin has a flat which will not allow the pin to be rotated.

CAUTION

DO NOT exceed 100 psi, or damage to the actuator may result.

Replacing a Clevis Pin

A clevis pin can be replaced if it is worn, seized, damaged or lost. If replacement of the clevis pin is required, a pin and clip kit (part No. 7536-174126) is available through the MACK Parts System. When removing the existing pin and installing a new pin:

1. Disconnect the air line from the actuator and apply 40–60 psi of clean dry shop air to extend the actuator rod slightly. This must be done to remove the pre-load on the actuator rod.
2. After removing the existing pin, align the hole in the actuator rod end with the hole in the clevis, then install the new pin. Ensure that the flat on the top of the pin is aligned with the straight edge of the lever arm clevis and that the pin is completely seated.
3. Secure the pin in place with the C-clip, making sure the clip is fully seated in the groove.

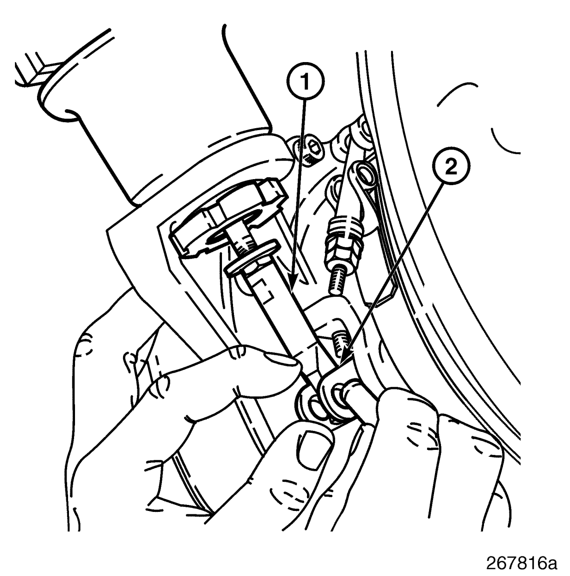


Figure 536 — Actuator Rod Clevis Pin Installation

1. Actuator Rod	2. Vane Operating Lever

Turbocharger Wheel Speed Sensor Replacement

The turbocharger wheel speed sensor is located near the top of the VTG turbocharger bearing housing, between the oil inlet port and the VTG vane actuator. This sensor provides turbine wheel speed input to the EECU. The sensor assembly consists of the sensor and a short length of wire with a connector.

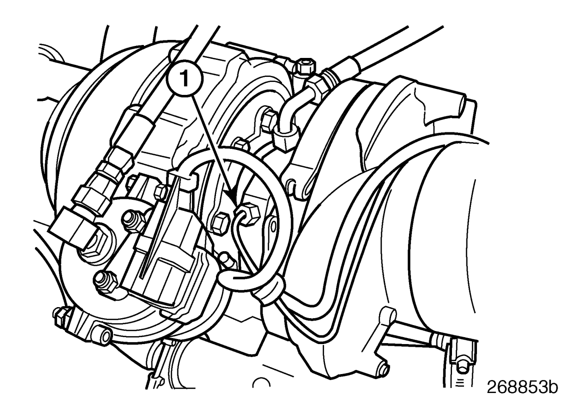


Figure 537 — Turbocharger Wheel Speed Sensor

1. Wheel Speed Sensor

Complete diagnostic procedures for wheel speed sensor faults are outlined in the *V-MAC® III Service Manual,* 8-311. When diagnostic procedures indicate that the turbocharger wheel speed sensor must be replaced, replacement procedures are as follows:

1. Cut the two tie straps that attach the turbocharger wheel speed sensor harness connector to the front of the vane position sensor module at the front of the turbocharger compressor housing (Figure 538). Note the way the position sensor and wheel speed sensor wires are routed, and also note the orientation of the harness clamp.

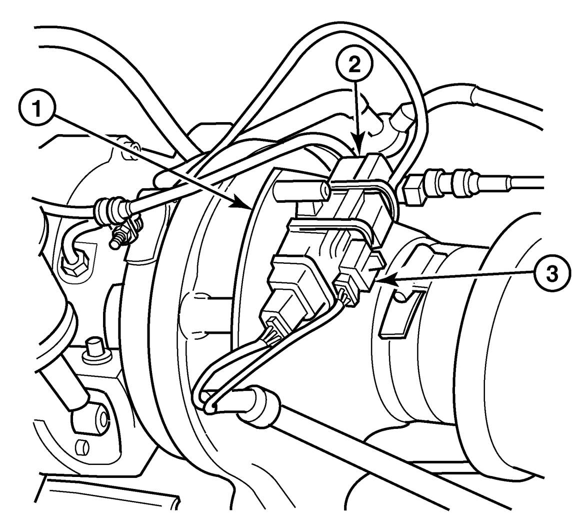


Figure 538 — Wheel Speed Sensor Connector

1. Thermal Isolation Plate 2. Vane Position Sensor Module	3. Wheel Speed Sensor Harness Connector

2. Disconnect the sensor harness connector. The connector is located at the front of the actuator position sensor that is mounted on the front of the turbocharger compressor housing.
3. Loosen and remove the nut and washer that secures the wire harness clamp to the turbocharger compressor housing V-band clamp, then remove the clamp.
4. Using a 13 mm wrench, remove the sensor from the turbocharger bearing housing.

Installation of the replacement sensor is the reverse of removal. Tighten the sensor to 106 lb-in (12 N•m). Route the wire harness in such a way so as to prevent contact with any hot surfaces of the turbocharger. Tighten the clamp retaining nut to 48 lb-in (5.4 N•m), and use two tie straps to attach the wire harness connectors to the front of the vane position sensor module.

CAUTION

Incorrect position sensor and wheel speed sensor wire harness routing can result in damage to the harnesses.

REPAIR INSTRUCTIONS, PART 3

ENGINE SETUP AND ADJUSTMENTS

Fuel Injection Timing

There is no need to set injection pump-to-engine timing. Unit pump-to-engine timing is programmed into and controlled by the EECU. However, the flywheel still has pump timing marks to accommodate application to non-current engines.

Valve Adjustment

[213 NB]

NOTE

Do not remove the EGR MASS Flow sensors from the cool tube to allow access to the cylinder head covers (if so equipped). Remove the EGR cool tube as an assembly to access the cylinder head covers and upper valve train components.

LOCATING AND MARKING FLYWHEEL VALVE ADJUSTMENT MARKINGS

NOTE

Some engines may be equipped with flywheels that have missing or illegible valve adjustment markings. If this problem is encountered, a typical flywheel can be marked while the engine is in the chassis.

TYPICAL FLYWHEELS

On a typical flywheel, the top center (TC) markings, and the valve adjustment markings, are directly in line with the clutch mounting bolt/bolt holes. To determine if the engine is equipped with a typical flywheel, view the flywheel through the timing access hole in the flywheel housing. Align the TC markings with the timing pointer. If the flywheel is typical, there should be a clutch mounting bolt/bolt hole directly in line with the TC marking. In this case, the valve adjustment markings should be in line with a clutch mounting bolt at three locations. Refer to Figure 539.

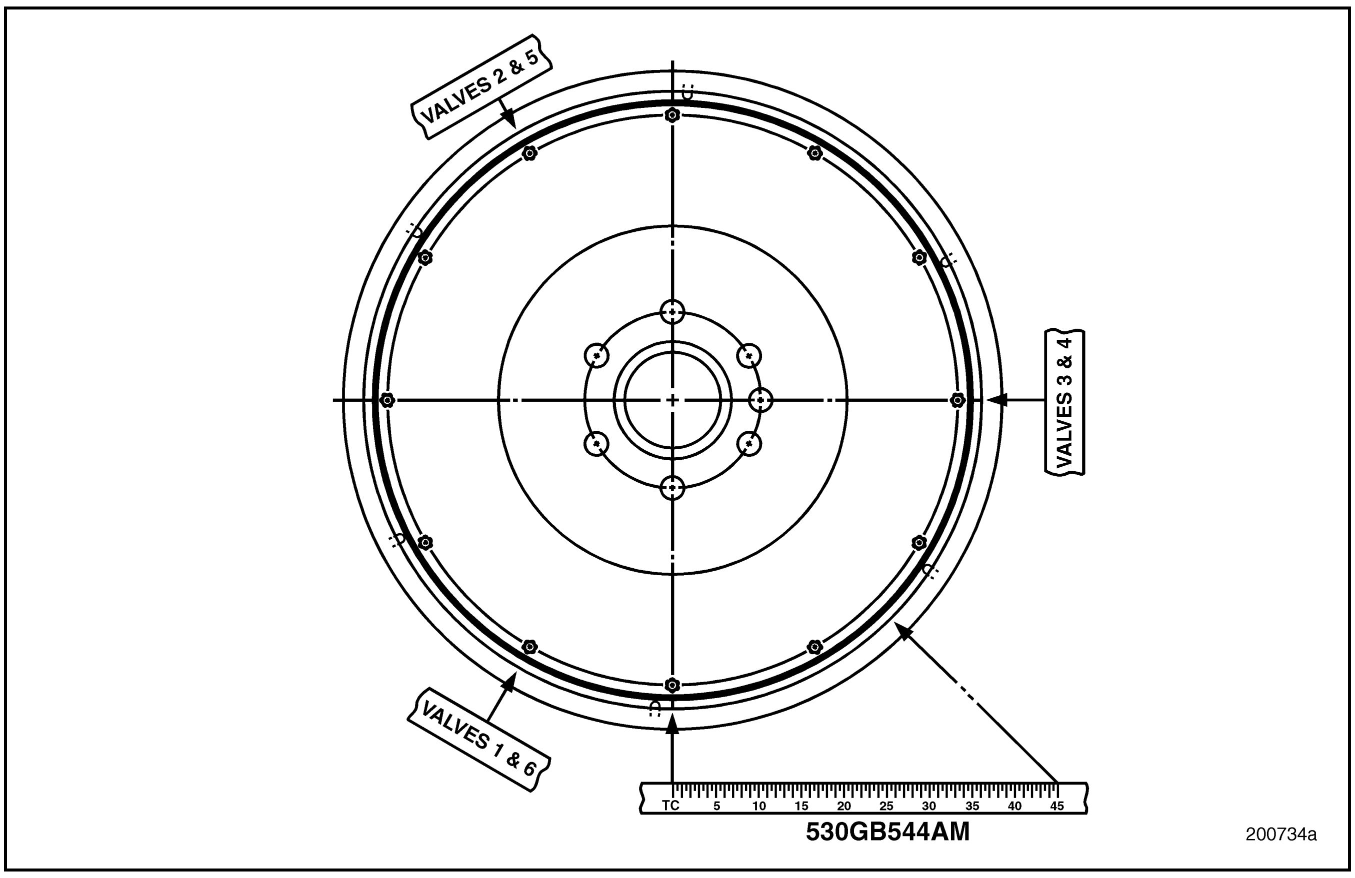


Figure 539 — Flywheel Marks

There are 12 clutch mounting bolt holes in the flywheel, but only 8 of these holes are used to mount the clutch. Every third bolt hole, for a total of four, is not used. These holes are in an open area between the clutch mounting flanges. The unused holes are easy to see through the timing access hole in the flywheel housing. The bolt holes where there are clutch mounting bolts are more difficult to see because the clutch mounting bolt head is somewhat rearward of the timing access opening. To aid in counting the clutch mounting bolt/bolt holes, keep in mind that there is slightly over four inches between one bolt hole and the next. Locating the clutch mounting bolts may be made easier by removing the bell housing inspection cover and viewing or feeling for the bolts through the access hole.

After verifying that there is a clutch mounting bolt/bolt hole in line with the TC mark, the next step is to find the three locations where the valve adjustment marks should be. Put a temporary mark (chalk, grease pencil, paint, etc.) at each of the three locations. Proceed as follows:

1. Beginning with the TC mark aligned with the timing pointer, rotate the engine in the direction of normal rotation (counterclockwise, viewed from rear) to the next clutch mounting bolt/bolt hole. Temporarily mark this location for cylinders 1 and 6.
2. Continue rotating the engine in the normal direction and count the clutch mounting bolt/bolt holes as they pass the timing access opening. At the fourth mounting bolt/bolt hole, make a temporary mark on the flywheel for cylinders 2 and 5.
3. Rotate the engine another four mounting bolt/bolt holes and make a temporary mark on the flywheel for cylinders 3 and 4.
4. Rotate the engine another three clutch mounting bolt/bolt holes and verify that the flywheel is at the TC mark. Then, rotate the engine one more bolt/bolt hole and verify that the flywheel is at the temporary mark made for cylinders 1 and 6.
5. Permanently mark the flywheel at this location for cylinders 1 and 6. To gain access, rotate the engine slightly so that the area to be marked is either to the right or left side of the timing pointer. Place a chisel mark directly in line with the clutch mounting bolt/bolt hole. Then, stamp or electric-etch the cylinder numbers on either side of the chisel mark.
6. Rotate the engine to the remaining locations and make sure to count the clutch mounting bolt/bolt holes to verify the locations of the temporary markings. Once verified, permanently mark each location as described.

NON-TYPICAL FLYWHEELS

If the engine is equipped with a non-typical flywheel, the TC markings will be halfway between two clutch mounting bolts. If this type of flywheel has no valve adjustment markings, it should be replaced.

Valve Adjustment Procedure [213 NB]

GENERAL INSTRUCTIONS

Due to the push rod spring load, valve lash adjustment procedures for engines equipped with spring-loaded push rods are different than the procedures used on engines equipped with solid push rods. Whenever spring-loaded push rods are used, the valve lash must be set with the push rods fully compressed. Valve lash clearances, however, remain the same at 0.016 inch (0.406 mm) for the inlet valves and 0.024 inch (0.610 mm) for exhaust valves.

CAUTION

The following procedures explain how to adjust valves on engines equipped with spring-loaded push rods. These procedures involve using a torque screwdriver to turn the adjusting screw. When the preset torque value of the screwdriver is reached, the push rod is compressed far enough that the spring stops are in contact with each other, thus ensuring a proper valve lash setting.

Valve adjustments must be made in firing order sequence (1-5-3-6-2-4) with the engine cold (coolant temperature below 100°F [38°C]), and not running. The flywheel should be rotated in its normal direction of rotation to bring cylinder No. 1 up on the compression stroke and TDC (inlet and exhaust valves closed). Continue to turn the engine another 30 degrees to the mark on the flywheel “Valves 1 & 6”. Adjust the valve yokes and valves of the number one cylinder at this position. Thereafter, continue to turn the engine through its firing order sequence, adjusting the valves at each “Valve” mark. The flywheel is marked at 120-degree increments to indicate the engine position at which the valves must be adjusted. It is necessary to turn the engine through two complete revolutions in order to adjust the valves completely on an engine. Access to the valve adjustment markings on the flywheel is achieved by removing the cover from the bottom of the flywheel housing. Tool No. J 38587, which engages the flywheel through an access hole in the flywheel housing, is recommended to rotate the engine.

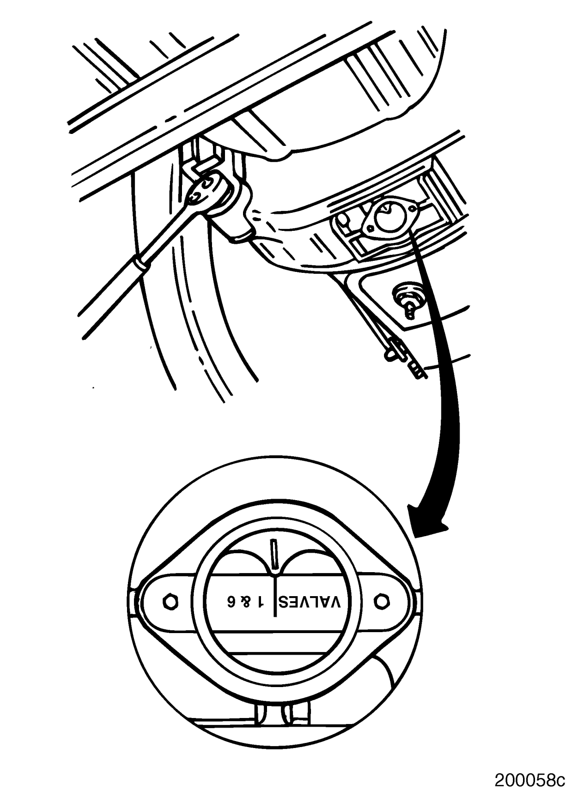


Figure 540 — Flywheel Valve Adjustment Markings

Valve adjustments are made in two stages. The exhaust valve yoke is adjusted first, and then the valve lash. Rotate the engine in the direction of normal rotation until the valve adjustment marking is aligned in the center of the access window.

SPECIAL TOOLS REQUIRED

- Engine Barring Socket J 38587-A
- Torque Wrench J 24407
- T-Handle Torque Screwdriver J 29919 (Torque value preset to 6 lb-in)
- Hex Internal Bit, 5 mm
- Crow’s Foot Wrench, 8 mm 3/8-Inch Drive
- Crow’s Foot Wrench, 13 mm 3/8-Inch Drive
- Crow’s Foot Wrench, 14 mm 3/8-Inch Drive
- Adapter, 3/8-Inch to 1/4-Inch
- Drive Extension, 1/4-Inch

VALVE YOKE AND VALVE LASH ADJUSTMENT FOR NON-BRAKE ENGINES

Valve Yoke Adjustment Procedure (Non-Brake Engines)

Adjust the valve yokes at the exhaust valve positions using the following procedure. As these engines are equipped with the self-leveling pinless valve yokes at the inlet positions, only the exhaust valve yokes need to be adjusted.

CAUTION

Make sure that adjusting screws are retracted upward in the rocker arms. If the adjusting screws are not retracted and extend too far below the rocker arm, the push rods can be bent and valve lifter rollers damaged or broken when tightening the rocker arm assembly brackets.

1. Using engine barring socket J 38587-A, or equivalent, manually rotate engine in normal rotation direction until pointer in flywheel housing aligns with the valves 1 and 6 marks on the flywheel and the No. 1 piston is at top dead center on the compression stroke.

NOTE

Valve lash must be set using the valve adjustment marks on the engine flywheel, which are at 30 degrees ATC. This ensures that the lifter is on the camshaft base circle and not on the brake ramp portion of the lobe.

2. Loosen the rocker arm adjusting screw jam nuts and back out the adjusting screws several turns. ASET™ engine rocker arm adjusting screws have a 5 mm internal hex at the screw head.

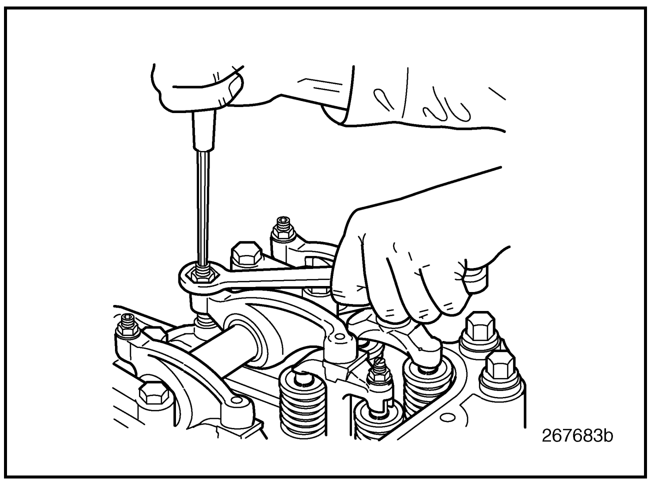


Figure 541 — Loosening Exhaust Rocker Arm Locknut and Backing Out Adjusting Screw

3. Loosen the No. 1 cylinder yoke adjusting screw jam nuts for the exhaust valves. Yoke adjusting screws for non-brake engines have a screwdriver slot at the top.

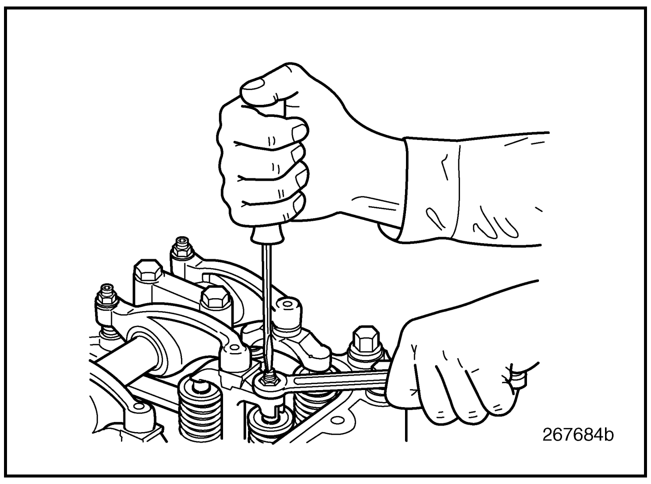


Figure 542 — Loosening Exhaust Valve Yoke Adjusting Screw Locknut

4. Exert moderate force on the valve yoke by pressing on the rocker arm slipper end. Turn the yoke adjusting screw clockwise until it makes solid contact with the outboard valve stem tip (a light drag should be felt on the adjusting screw).

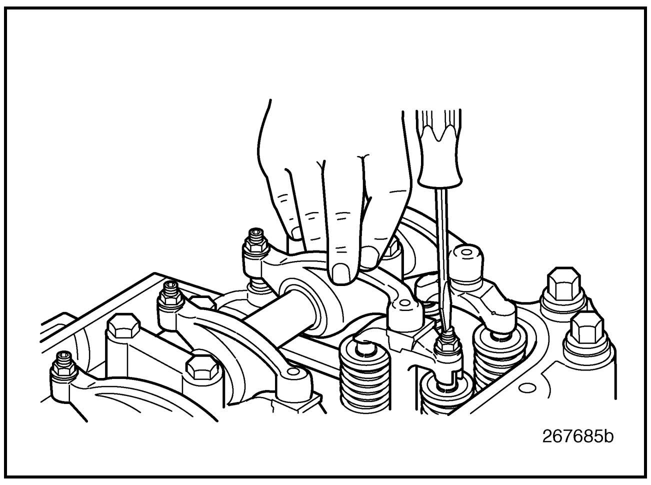


Figure 543 — Turning Yoke Adjusting Screw Until It Contacts Valve Stem

5. After the adjusting screw makes solid contact with the valve stem, turn the screw clockwise an additional 30 degrees.

SERVICE HINT

A 30-degree turn is equal to 1/2 of a flat on the adjusting screw jam nut.

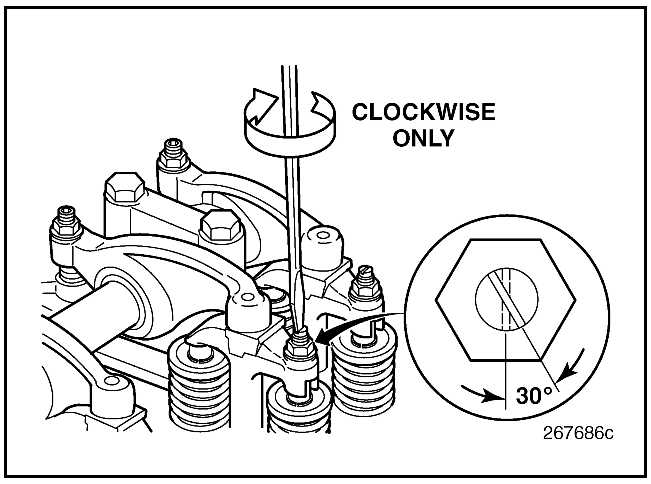


Figure 544 — Turning Adjusting Screw an Additional 30 Degrees

6. Hold the valve yoke adjusting screw in this position and tighten the adjusting screw jam nut to the specified torque, 33 lb-ft (45 N•m), using torque wrench J 24407, or equivalent.

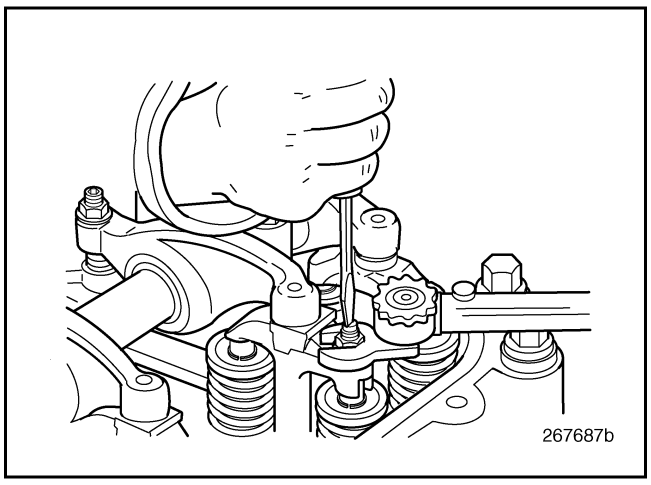


Figure 545 — Yoke Adjusting Screw and Jam Nut (Slotted Screw Shown)

7. Check the valve yoke adjustment as follows:
   a. Insert 0.010-inch (0.25 mm) thickness gauges between the inboard and outboard valve stem tips and the valve yoke.
   b. Exert moderate force on the yoke by pressing on the rocker arm slipper end. An equal “drag” should be felt on both thickness gauges. If drag is not equal, readjust the valve yoke.

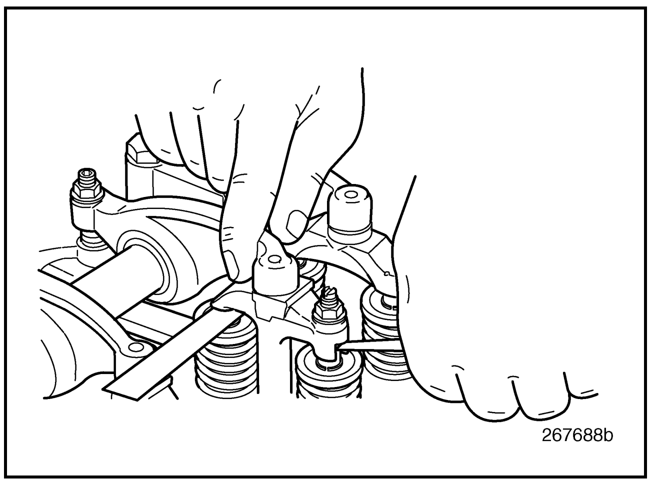


Figure 546 — Checking Yoke Adjustment

Inlet and Exhaust Valve Lash Adjustment (Non-Brake Engines)

NOTE

The following procedure was developed for adjusting exhaust valve lash on engines equipped with spring-loaded push rods. This same procedure, however, can be used for adjusting inlet valve lash, even though the inlet valves use standard push rods. If the torque screwdriver is not available, an alternate procedure that does not require the torque screwdriver is outlined in the “Inlet and Exhaust Valve Lash Adjustment for Non-Brake Engines (Alternate Procedure)” section that follows.

1. Loosen the rocker arm nut and back out the adjusting screws at the No. 1 cylinder a couple of turns and thread the new flange-head jam nuts on the adjusting screws, leaving them loose so that adjustments can be made.
2. Push down on the adjusting screw side of the rocker arm and insert the appropriate thickness gauge (inlet — 0.016-inch [0.406 mm], exhaust — 0.024-inch [0.610 mm]) between the slipper face of the rocker arm and the top of the valve yoke. **Leave the thickness gauge in place.**

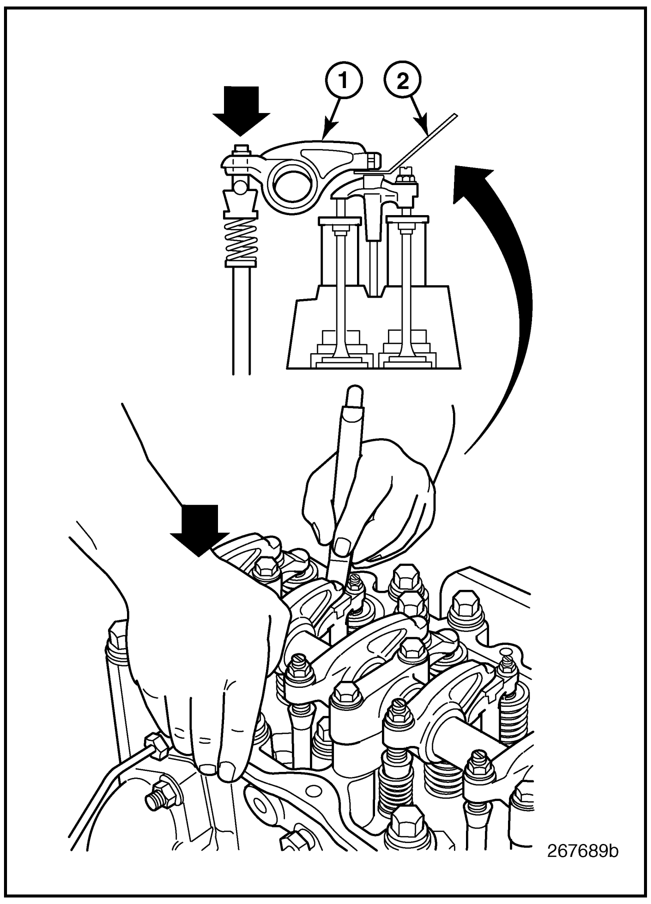


Figure 547 — Inserting Thickness Gauge

1. Rocker Arm	2. Feeler Gauge

3. Using the torque screwdriver, J 29919 or equivalent, slowly turn the rocker arm adjusting screw clockwise. At the exhaust locations, the push rod spring will compress as the adjusting screw is being tightened. At the inlet locations, the extra clearance will be “taken-up” as the adjusting screw is being tightened.

4. Continue tightening the adjusting screw until the torque screwdriver clicks. At the exhaust locations, the push rod spring seats are now in contact and the push rod is solid and the valve lash is now properly set. Do not tighten the adjusting screw any further. At the inlet locations, when the torque screwdriver clicks, all excessive lash has been “taken-up” and inlet lash is now set to the thickness of the feeler gauge.

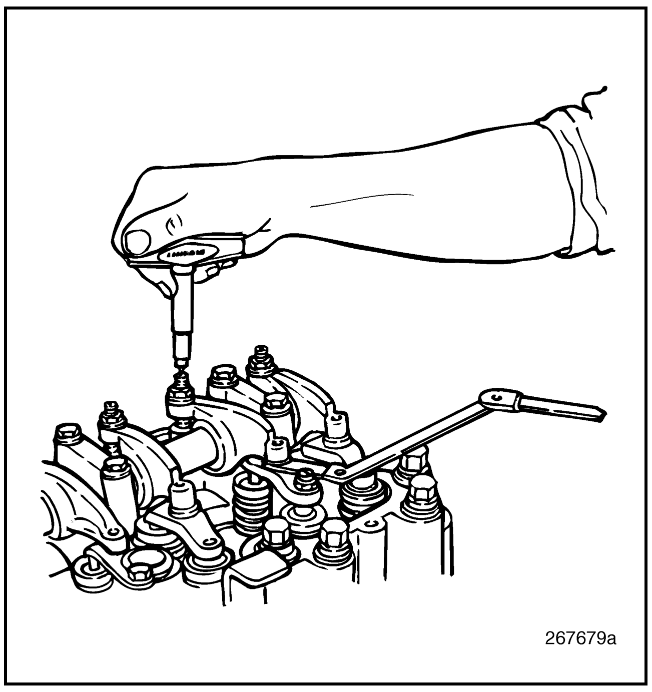


Figure 548 — Adjusting Exhaust Valve Lash

NOTE

The torque screwdriver may allow the valve adjusting screw to loosen slightly when it clicks at the pre-set torque. Always recheck valve lash adjustment as described in step 7.

5. Remove the torque screwdriver and hold the adjusting screw in position with a standard 5 mm Allen wrench to keep it from turning. Tighten the flange-head jam nut to specification, 45 lb-ft (61 N•m).

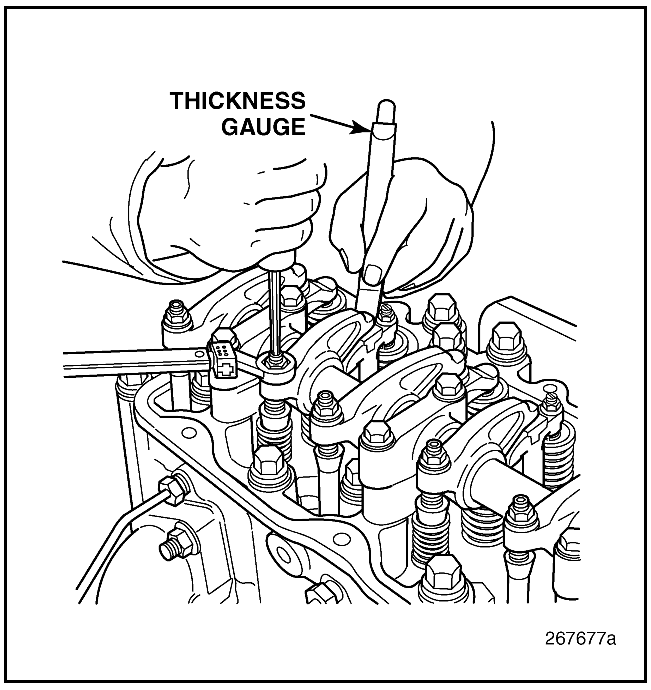


Figure 549 — Tightening Adjusting Screw Jam Nut

6. Remove the thickness gauge.
7. Check the exhaust valve lash adjustments by pushing down on the adjusting screw end of the rocker arm to compress the push rod spring and inserting the appropriate thickness gauge (inlet — 0.016 inch [0.406 mm]; exhaust — 0.024 inch [0.610 mm]) between the rocker arm slipper face and the valve yoke. Continue exerting downward pressure on the rocker arm to keep the push rod spring compressed while checking the adjustment. The thickness gauge should be snug between the slipper face and valve yoke. If not, repeat the adjustment procedure. Inlet valve lash adjustment may be checked in the same manner, except there is no push rod spring to compress.

NOTE

When exerting pressure on the rocker arm to keep the push rod spring compressed, drag on the thickness gauge should feel normal, as when performing an adjustment on an engine that is not equipped with spring-loaded push rods. When hand-pressure is released, a significant increase in drag on the thickness gauge will be felt due to the force of the push rod spring.

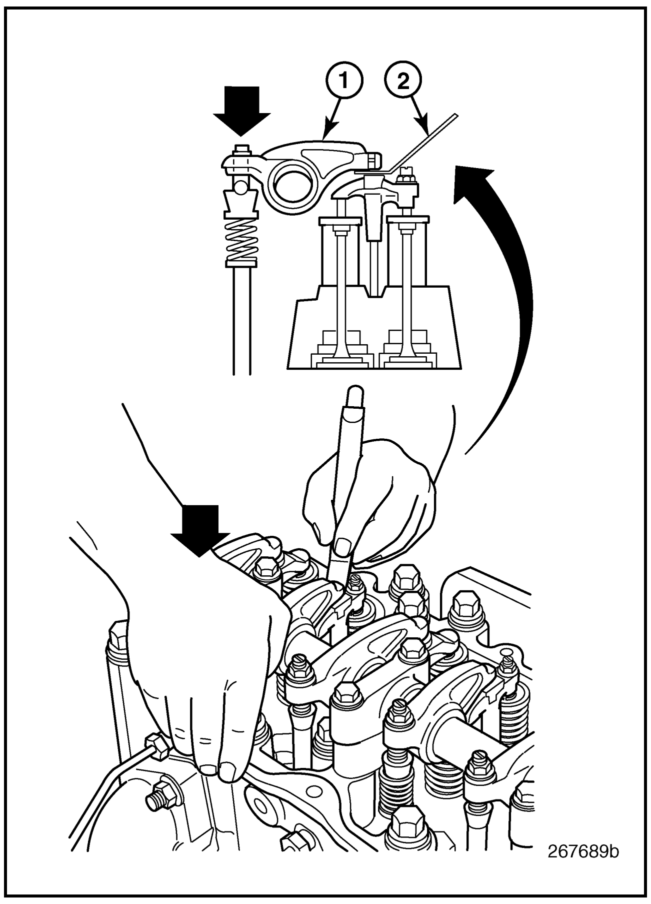


Figure 550 — Checking Valve Lash Adjustment

1. Rocker Arm	2. Feeler Gauge

Inlet and Exhaust Valve Lash Adjustment for Non-Brake Engines (Alternate Procedure)

If an oz-in or lb-in torque screwdriver or torque wrench is not available, valve lash can be adjusted (for both brake and non-brake engines) in the same manner as described above (by installing the appropriate thickness gauge and tightening the adjusting screw), but using careful hand-pressure to compress the push rod spring instead of the 6 lb-in torque screwdriver.

Use a 5 mm internal hex wrench in place of the torque screwdriver to turn the adjusting screw. Turn the screw clockwise until a large increase in resistance is felt, indicating that the push rod is fully compressed and the internal stops of the push rod upper and lower spring seats are bottom against each other. No further tightening force is to be applied to the adjusting screw, or an inaccurate valve adjustment may result. At that point, valve lash should be properly set and the adjusting screw jam nut can be tightened to 45 lb-ft (61 N•m).

Always recheck the adjustment by exerting downward pressure by hand on the adjusting screw and on the rocker arm to fully compress the push rod while rechecking with the thickness gauge. When holding the push rod compressed for the lash overcheck, normal thickness gauge drag will result. However, after the valve lash is set, and downward pressure on the rocker arm is released, the push rod spring pressure will put increased drag on the thickness gauge.

Continuation of Adjustments for Remaining Cylinders

1. Using a barring socket, manually rotate the engine crankshaft (Figure 551) in normal rotation direction 120 degrees until the center of the timing pointer hole in the flywheel housing aligns with the “2 and 5” mark on the flywheel and the No. 5 piston is on the compression stroke.

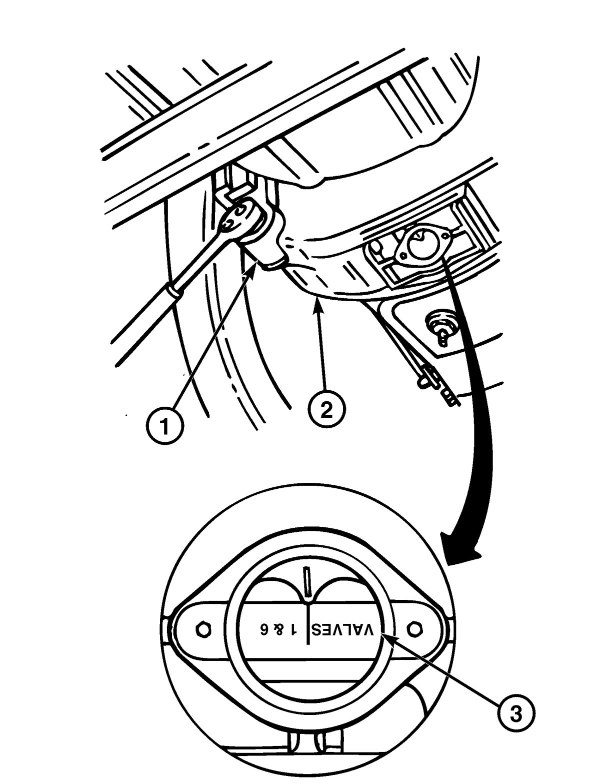


Figure 551 — Valve Adjustment Markings on Flywheel

1. Barring Socket J 38587-A 2. Flywheel Housing	3. Flywheel

2. Adjust the final intake and exhaust valve lash for cylinder No. 5 as described for cylinder No. 1. Continue this procedure for each of the remaining cylinders, following the engine firing order sequence, 1-5-3-6-2-4.

VALVE YOKE, VALVE LASH AND BRAKE LASH ADJUSTMENT FOR J-TECH™ BRAKE-EQUIPPED ENGINES

Valve Yoke Adjustment Procedure (J-Tech™ Brake Engines)

Adjust the valve yokes at the exhaust valve positions using the following procedure. As these engines are equipped with the self-leveling pinless valve yokes at the inlet positions, only the exhaust valve yokes need to be adjusted.

CAUTION

Make sure that adjusting screws are retracted upward in the rocker arms. If the adjusting screws are not retracted and extend too far below the rocker arm, the push rods can be bent and valve lifter rollers damaged or broken when tightening the rocker arm assembly brackets.

Verify that the slave piston adjusting screws are fully retracted and that all the spherical jam nuts are turned down snug against the rocker arms before rotating the engine crankshaft for valve lash adjustment. Rotating the engine crankshaft with the spherical jam nuts loose, or the slave piston adjusting screws not fully retracted, could damage the brake master pistons or damage or break the ceramic lifters.

1. Using engine barring socket J 38587-A, or equivalent, manually rotate engine in normal rotation direction until pointer in flywheel housing aligns with the valves 1 and 6 marks on the flywheel and the No. 1 piston is at top dead center on the compression stroke.

NOTE

Valve lash must be set using the valve adjustment marks on the engine flywheel, which are at 30 degrees ATC. This ensures that the lifter is on the camshaft base circle and not on the brake ramp portion of the lobe.

2. Loosen the rocker arm adjusting screw jam nuts and back out the adjusting screws several turns. ASET™ engine rocker arm adjusting screws have a 5 mm internal hex at the screw head.

NOTE

For clarity, most of the illustrations in this section show adjustments being performed without the Jake brake units being installed. However, the Jake units must be installed to correctly adjust the inlet and exhaust valve lash.

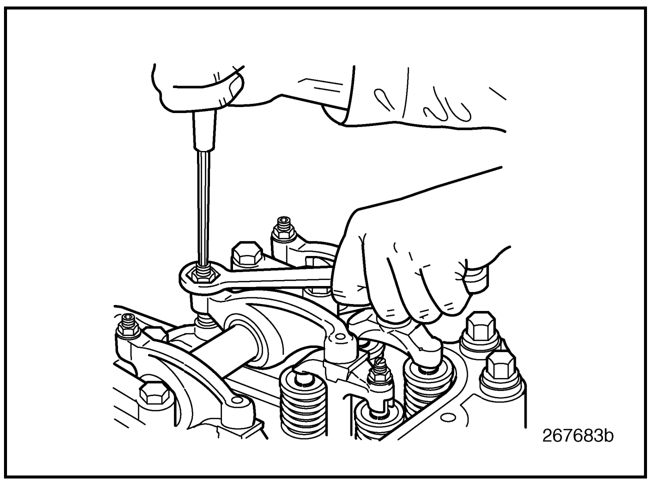


Figure 552 — Loosening Exhaust Rocker Arm Locknut and Backing Out Adjusting Screw

3. Loosen the No. 1 cylinder yoke adjusting screw jam nuts for the exhaust valves. Yoke adjusting screws used with the J-Tech™ brake have a 8 mm hex at the top of the screw body.

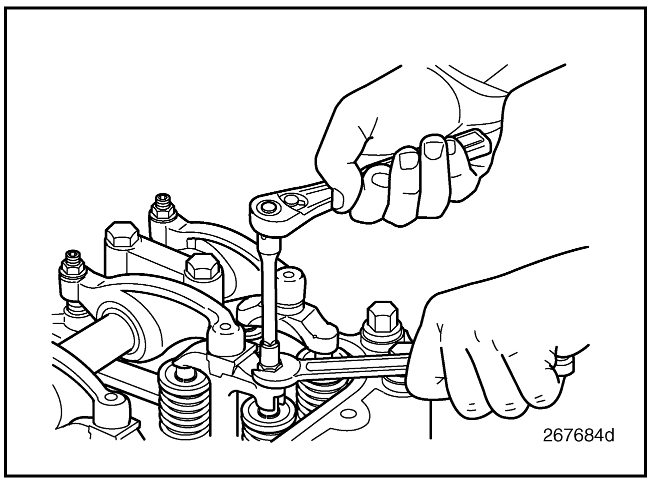


Figure 553 — Loosening Valve Yoke Adjusting Screw Locknut

4. Exert moderate force on the valve yoke by pressing on the rocker arm slipper end. Turn the yoke adjusting screw clockwise until it makes solid contact with the outboard valve stem tip (a light drag should be felt on the adjusting screw).

CAUTION

Engines equipped with a J-Tech™ engine brake will have an actuator pin adjusting screw in the exhaust yoke.

Do not allow anything to press down on the actuating pin during adjustment. The pin must be fully extended, approximately 1/4 inch (6.350 mm) above the top of the hollow adjusting screw. If the pin is held down and not fully extended, an improper adjustment and engine failure will result.

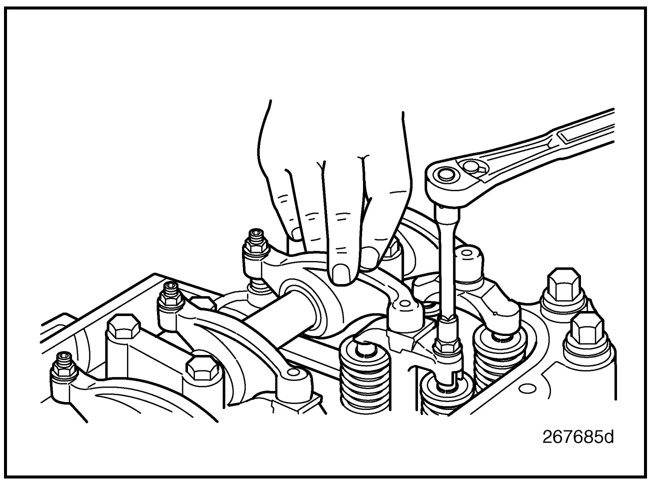


Figure 554 — Turning Yoke Adjusting Screw Until It Contacts Valve Stem

5. After the adjusting screw makes solid contact with the valve stem, turn the screw clockwise an additional 30 degrees.

SERVICE HINT

A 30-degree turn is equal to 1/2 of a flat on the adjusting screw jam nut.

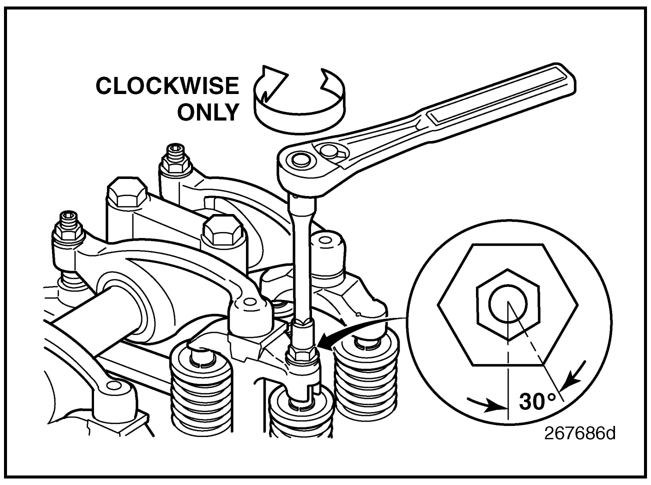


Figure 555 — Turning Adjusting Screw an Additional 30-Degree Turn

6. Hold the valve yoke adjusting screw in this position and tighten the adjusting screw jam nut to the specified torque, 33 lb-ft (45 N•m), using torque wrench J 24407, or equivalent.

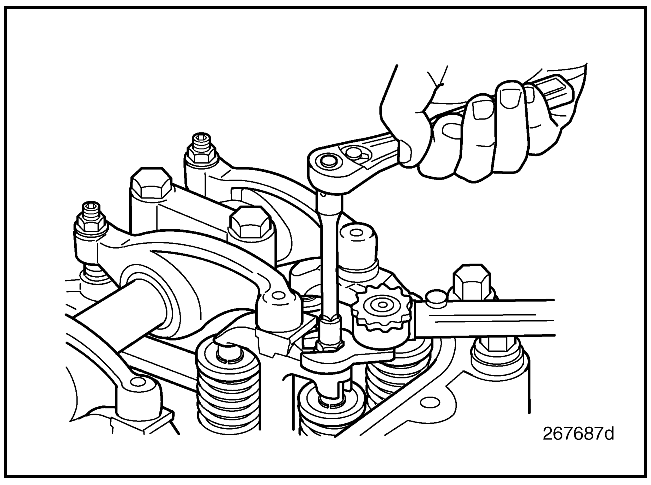


Figure 556 — Yoke Adjusting Screw and Jam Nut

7. Check the valve yoke adjustment as follows:
   a. Insert 0.010-inch (0.25 mm) thickness gauges between the inboard and outboard valve stem tips and the valve yoke.
   b. Exert moderate force on the yoke by pressing on the rocker arm slipper end. An equal “drag” should be felt on both thickness gauges. If drag is not equal, readjust the valve yoke.

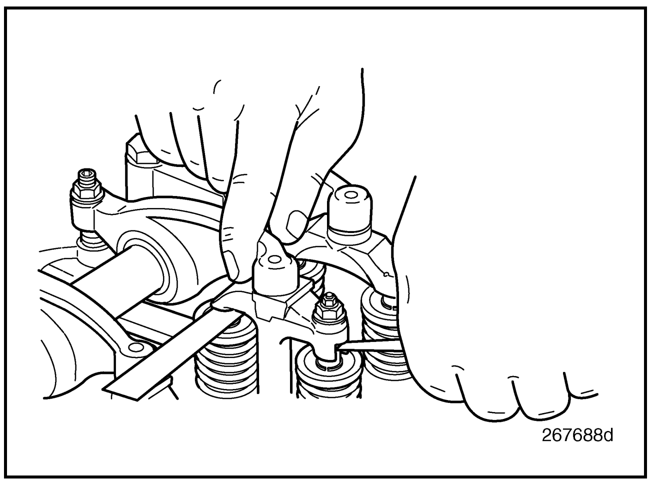


Figure 557 — Checking Yoke Adjustment

Exhaust Valve Lash Adjustment (J-Tech™-Equipped Engines)

When adjusting exhaust valve lash on an engine equipped with a J-Tech™ engine brake, the same procedure is used as on a non-brake-equipped engine except that the 14 mm crow's foot wrench, adapter and long extension are required in place of the screwdriver. These tools are required because the spherical nut covers the top of the adjusting screw, so the 14 mm hex at the bottom side of the adjusting screw must be used.

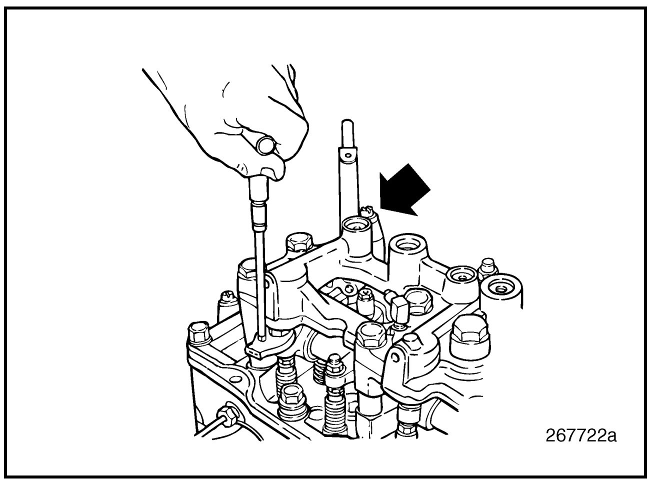


Figure 558 — Adjusting Valve Lash on Engines Equipped with a J-Tech™ Engine Brake

CAUTION

The J-Tech™ exhaust rocker arm adjusting screw spherical jam nut is a through-hardened nut. When tightening these nuts, be aware of the following:

- *Always use the proper 20 mm size wrench to tighten the spherical jam nut. Tighten the nut to 45 lb-ft (61 N•m). Using an improper size wrench will lead to jam nut breakage.*
- *Overtightening the spherical jam nut when adjusting the valves may result in jam nut breakage. If there is too much or too little drag on the thickness gauge, loosen the jam nut and readjust valve lash. Do not overtighten the spherical nut in an attempt to obtain correct valve lash.*

Alternate Valve Lash Adjustment Procedure (J-Tech™ Brake Engines)

If an oz-in or lb-in torque screwdriver or torque wrench is not available, valve lash can be adjusted (for both brake and non-brake engines) in the same manner as described above (by installing the appropriate thickness gauge and tightening the adjusting screw). Use a 5 mm internal hex wrench in place of the torque screwdriver to turn the adjusting screw. Turn the screw clockwise until a large increase is felt, indicating that the push rod is fully compressed and the spring has hit the stop. At this point, valve lash should be properly set and the adjusting screw jam nut can be tightened to 45 lb-ft (61 N•m). Always recheck the adjustment by exerting downward pressure by hand on the adjusting screw end of the rocker arm to fully compress the push rod while rechecking with the thickness gauge.

Brake Lash Adjustment (J-Tech™ Brake Engines)

The engine brake lash specification is based on the reset screw part number. All ASET™ engines utilize reset screw part No. 032053A, which requires a 0.021-inch (0.533 mm) lash specification. Adjust the engine brake using the following procedure:

1. If not previously done, use a 3/4-inch wrench to loosen the slave piston adjusting screw (reset screw) jam nut. Back-off the adjusting screw until the slave piston seats at the top of its bore.
2. Place the appropriate 0.021-inch (0.533 mm) thickness gauge between the slave piston stem and the top of the actuator pin in the yoke adjusting screw.
3. Turn the slave piston adjusting screw to set the brake lash.
4. Tighten the jam nut to specification, 25 lb-ft (34 N•m).

CAUTION

DO NOT overtighten the slave piston adjusting screw jam nut. To do so will cause malfunction of this screw in performing the brake reset function and possibly result in reset screw breakage.

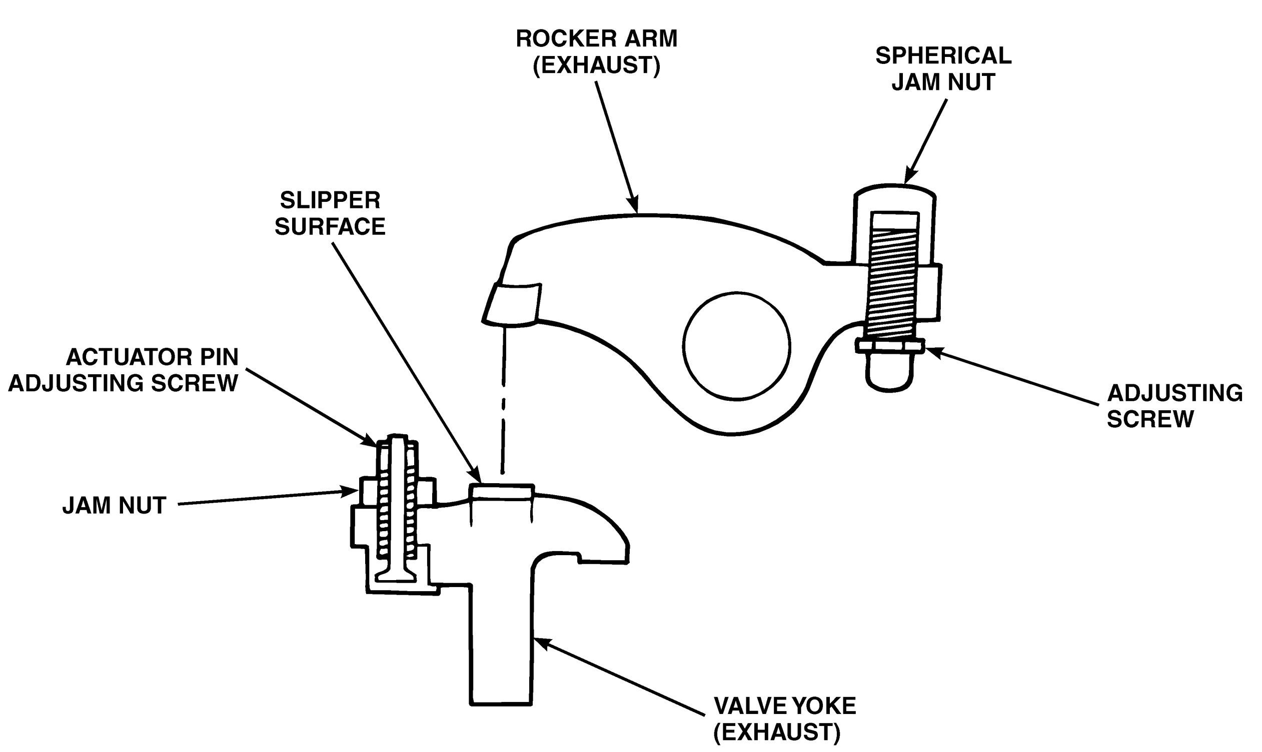


Figure 559 — J-Tech™ Exhaust Valve Rocker Arm and Yoke

Continuation of Adjustments for Remaining Cylinders

1. Using a barring socket, manually rotate the engine crankshaft (Figure 560) in normal rotation direction 120 degrees until the center of the timing pointer hole in the flywheel housing aligns with the "2 and 5" mark on the flywheel and the No. 5 piston is on the compression stroke.

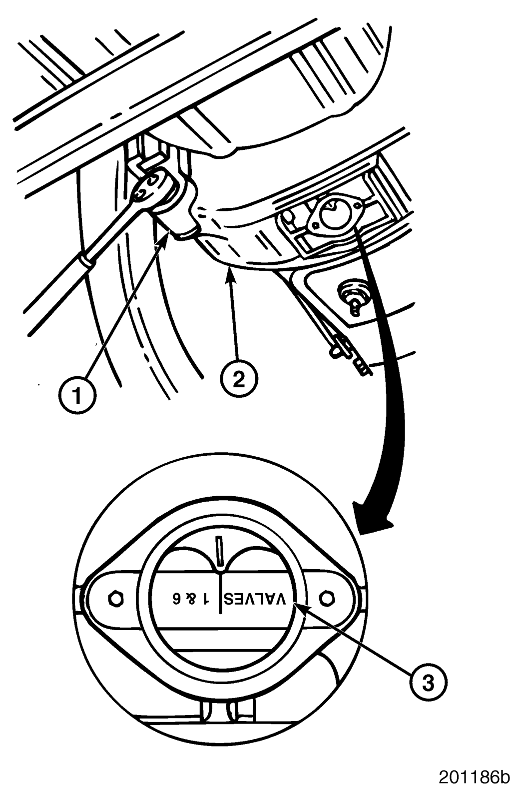


Figure 560 — Valve Adjustment Markings on Flywheel

1. Barring Socket J 38587-A 2. Flywheel Housing	3. Flywheel

2. Adjust the final intake and exhaust valve lash, and engine brake slave piston lash for cylinder No. 5 as described for cylinder No. 1. Continue this procedure for each of the remaining cylinders, following the engine firing order sequence, 1-5-3-6-2-4.

VALVE YOKE, BRAKE LASH AND VALVE LASH ADJUSTMENT FOR ENGINES EQUIPPED WITH MACK POWERLEASH™ ENGINE BRAKE

Valve adjustments are made in firing order sequence (1-5-3-6-2-4) with the engine cold (coolant temperature below 100°F [38°C]), not running and with the piston at 30 degrees after top dead center on the compression stroke (inlet valve closed). The flywheel is marked in 120-degree increments to indicate markings on the flywheel by removing the cover from the bottom of the flywheel housing. Tool J 38587-A, which engages the flywheel through the access hole in the flywheel housing, is recommended to rotate the engine.

NOTE

Engines equipped with PowerLeash™ brake have TWO ADJUSTING SCREWS located on each exhaust rocker arm and a different procedure. The rocker arm adjusting screw at the push rod was traditionally used for adjusting valve lash. With PowerLeash™, this adjusting screw is used for BRAKE LASH ADJUSTMENT. A second adjusting screw, located at the other end of the rocker arm just above the valve yoke is used for VALVE LASH ADJUSTMENT. The push rod must be fully compressed and the brake lash adjustment set first, and then with the push rod remaining fully compressed and the brake lash feeler gauge remaining in-place, the exhaust valve lash adjustment is performed.

Adjust the valve yokes at the exhaust valve positions using the following procedure. As these engines are equipped with the self-leveling pinless valve yokes at the inlet positions, only the exhaust valve yokes need to be adjusted. Valve yoke balance, engine brake lash and valve lash must be adjusted in the following order:

a. Valve yoke balance is adjusted first.

b. Engine brake actuator lash is adjusted second, using the adjusting screw on the push rod side of the rocker arm.

c. Valve lash is adjusted last, using the adjusting screw located over the valve yoke.

Valve Yoke Adjustment Procedure (PowerLeash™ Brake Engines)

N O T E

Yoke adjusting screws used with the PowerLeash™ brake have a screwdriver slot at the top.

1. Loosen the engine brake hydraulic actuator adjusting screw locknut (located on the push rod end of the exhaust rocker arm) and back the adjusting screw out several turns.

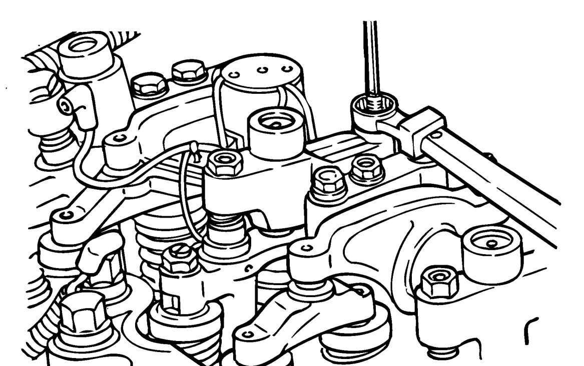


Figure 561 — Loosening Hydraulic Actuator Locknut and Backing Out Adjusting Screw

2. Loosen the exhaust valve yoke screw locknut.

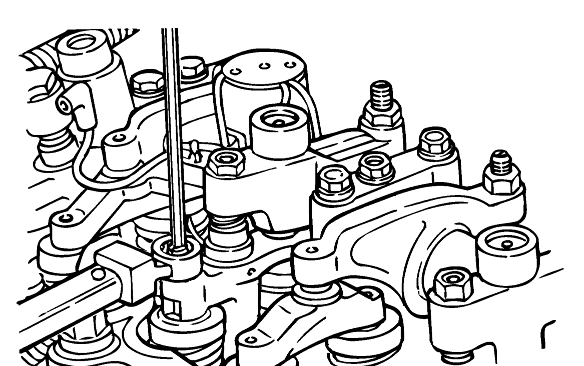


Figure 562 — Loosening Exhaust Valve Yoke Adjusting Screw Locknut

3. Exert moderate force on the exhaust valve yoke by pressing on the end of the exhaust rocker arm above the yoke. Turn the yoke adjusting screw clockwise until it solidly contacts the outboard valve stem tip (a light drag should be felt on the adjusting screw).

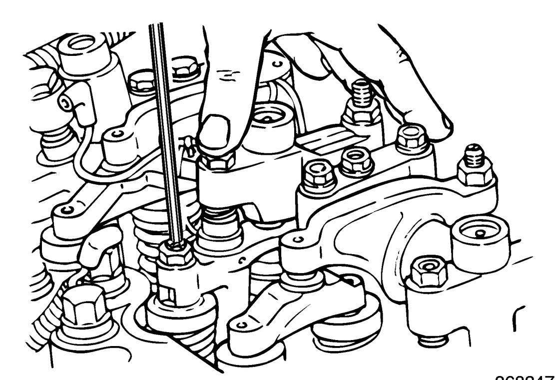


Figure 563 — Turning the Exhaust Valve Yoke Adjusting Screw Until it Contacts Valve Stem

4. After the adjusting screw solidly contacts the valve stem tip, turn the screw clockwise an additional 30 degrees.

S E R V I C E   H I N T

A 30-degree turn is equal to 1/2 of a flat on the adjusting screw jam nut.

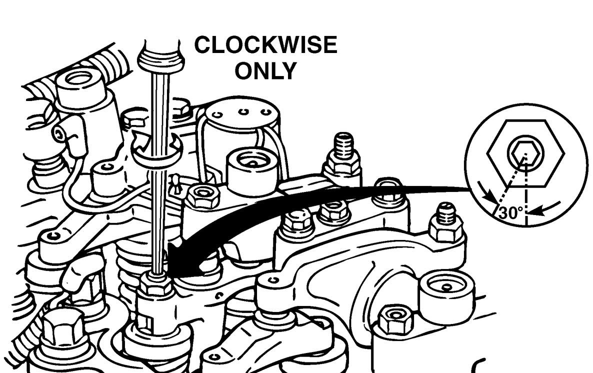


Figure 564 — Turning Adjusting Screw an Additional 30-Degree Turn

5. While holding the valve yoke adjusting screw in this position, tighten the adjusting screw locknut to 33 lb-ft (44 N•m).

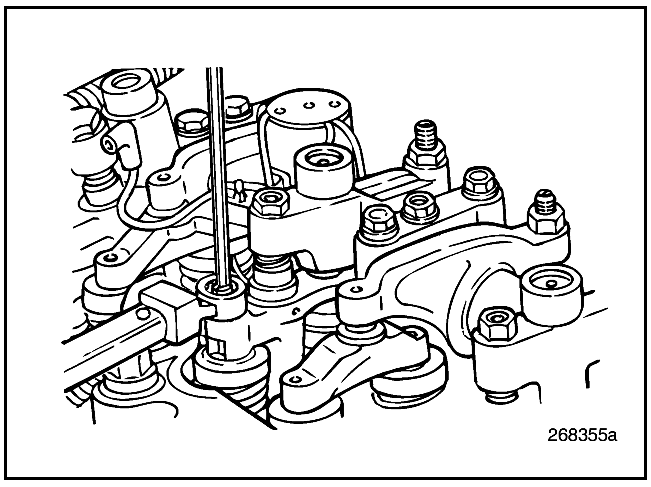


Figure 565 — Tightening Valve Yoke Locknut

6. Check the valve yoke adjustment by inserting 0.010-inch (0.25 mm) thickness gauges between the inboard and outboard valve stem tips and the valve yoke. It will be necessary to pull the valve yoke up to insert the thickness gauge between the valve stem tip and the yoke.

NOTE

Inserting the thickness gauges may be made easier if the gauge is inserted under the inboard portion of the valve yoke first, then under the outboard portion.

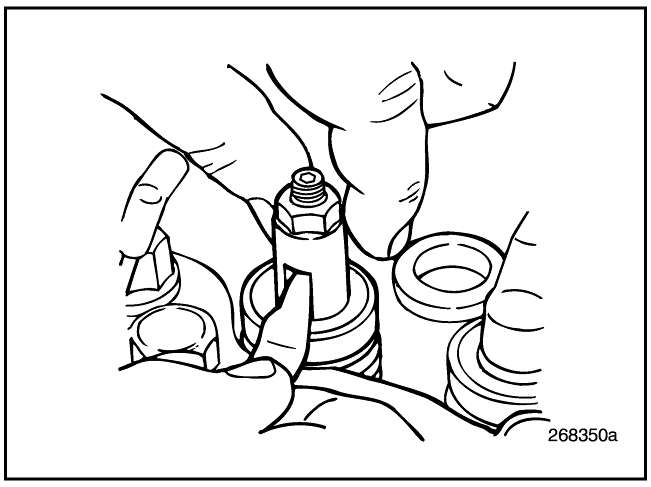


Figure 566 — Inserting Thickness Gauge

7. While exerting a moderate force on the rocker arm end above the yoke, check that an equal “drag” is felt on both thickness gauges. If drag is not equal, readjust the valve yoke.

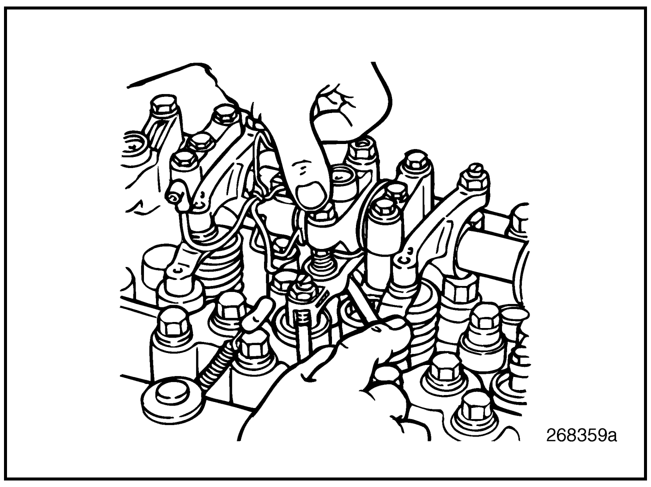


Figure 567 — Checking Valve Yoke Adjustment

Brake Actuator Lash Adjustment (PowerLeash™ Brake Engines)

Spring-loaded push rods are used at the exhaust valve locations. In order to properly adjust the engine brake hydraulic actuator lash, the push rod springs must be compressed. In addition to the hand tools normally used to adjust valves, a T-handle torque screwdriver (tool No. J 29919) with a 5 mm internal hex bit is required. This torque screwdriver is preset to 6 lb-in.

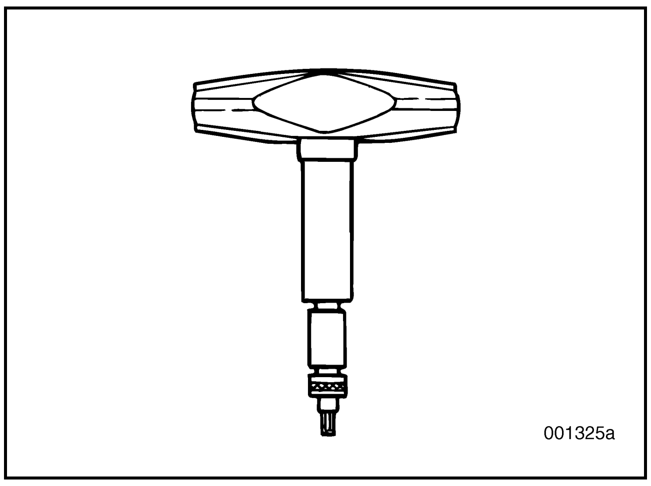


Figure 568 — T-Handle Torque Screwdriver, J 29919

NOTE

It is mandatory that the T-handle torque screwdriver (tool No. J 29919) be used to adjust the MACK PowerLeash™ engine brake hydraulic actuator.

The engine brake hydraulic actuator must be adjusted prior to adjusting the exhaust valve lash.

1. Loosen the engine brake adjusting screw (located above the push rod) locknut and back the adjusting screw out several turns.
2. Loosen the swivel-head adjusting screw locknut (located on the valve actuating side of the exhaust rocker arm) and back the adjusting screw out a couple of turns.

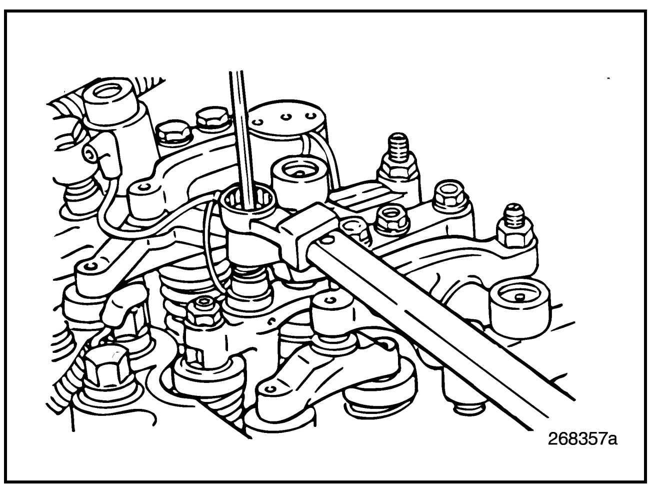


Figure 569 — Loosening Swivel-Head Adjusting Screw

3. Push down on the push rod end of the exhaust rocker arm to fully depress the push rod spring, then insert a 0.045-inch (1.14 mm) thickness gauge between the hydraulic actuator plunger and the actuator pin located above the inboard exhaust valve.

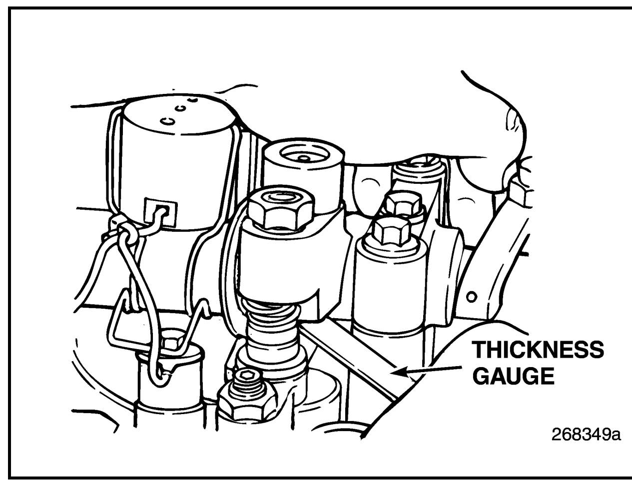


Figure 570 — Inserting Thickness Gauge Between Brake Plunger and Actuator Pin

NOTE

It is recommended that a dull knife-edge be ground onto the leading edge of the 0.045-inch (1.14 mm) thickness gauge to facilitate inserting it between the brake plunger and the actuator pin. Doing this will eliminate the need for backing off the adjusting screw to insert the thickness gauge. A relief is cut in the lower surface of the rocker arm to provide clearance for inserting the thickness gauge. The thickness gauge must be installed from the side of the rocker arm that faces the rear of the engine, and at the angle shown in the previous illustration.

4. Using the T-handle torque screwdriver (tool No. J 29919), slowly turn the actuator adjusting screw clockwise. As the screwdriver is being turned, the push rod spring will be compressed. Continue tightening the adjusting screw until the screwdriver clicks. At the point that the screwdriver clicks, the push rod spring seats are in contact and the push rod is solid. At that point, hydraulic actuator lash is properly set. Do not tighten the screwdriver any further.

NOTE

- The torque screwdriver may allow the adjusting screw to loosen slightly when it "clicks" at the pre-set torque. It is important to develop a "feel" for when the screwdriver click occurs and feel for the actual setting of the lash. To develop a feel for when the screwdriver will click, slowly turn the screwdriver through the function once or twice, and for the third time, bring the screwdriver just to the point before it clicks. Also, at no time should the screwdriver be turned clockwise after the click has occurred. Always recheck the adjustment.
- When tightening the adjusting screw, it is important to make sure that the adjusting screw jam nut is NOT bottomed against the rocker arm, and that the swivel-head adjusting screw at the nose end of the rocker arm is NOT in contact with the valve yoke.
- If either the push rod spring or the brake actuator plunger are not compressed, brake lash is not set correctly and the adjustment procedure must be repeated.

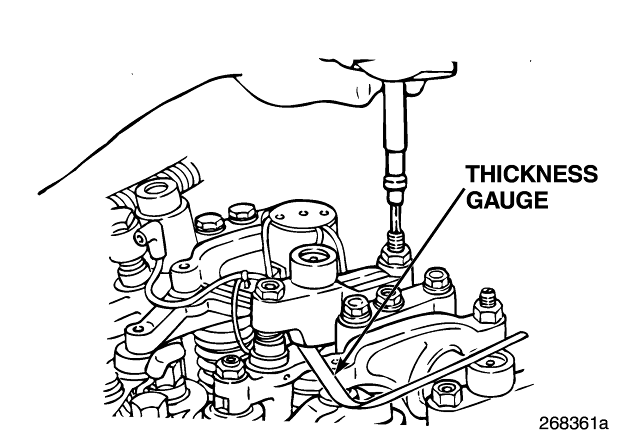


Figure 571 — Adjusting Engine Brake Hydraulic Actuator Lash

5. Remove the T-handle torque screwdriver, then use a hex-bit screwdriver to hold the adjusting screw in position. Use an accurately calibrated torque wrench to tighten the jam nut to 45 lb-ft (61 N•m).

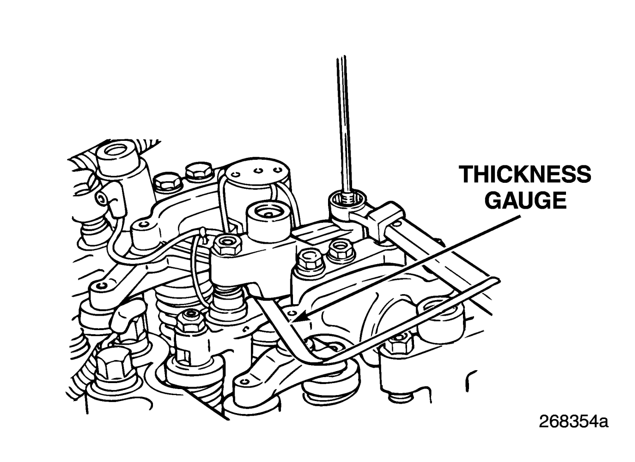


Figure 572 — Tightening Adjusting Screw Jam Nut

NOTE

After completing the brake plunger lash adjustment, leave the 0.045-inch (1.14 mm) thickness gauge in place. This keeps the plunger and push rod spring compressed so that the exhaust valve lash can be adjusted.

Exhaust Valve Lash Adjustment (PowerLeash™ Brake Engine)

1. With the 0.045-inch (1.14 mm) thickness gauge in place between the valve yoke and the hydraulic actuator plunger, insert a 0.024-inch (0.610 mm) thickness gauge between the adjusting screw "foot" and the valve yoke. Using a 5 mm Allen wrench, turn the adjusting screw until a light "drag" is felt on the thickness gauge.

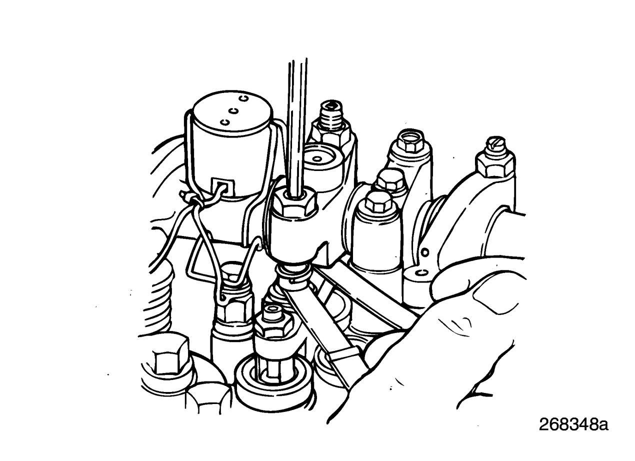


Figure 573 — Adjusting Exhaust Valve Lash

2. Holding the adjusting screw in position, use an accurately calibrated torque wrench to tighten the jam nut to 45 lb-ft (61 N•m).

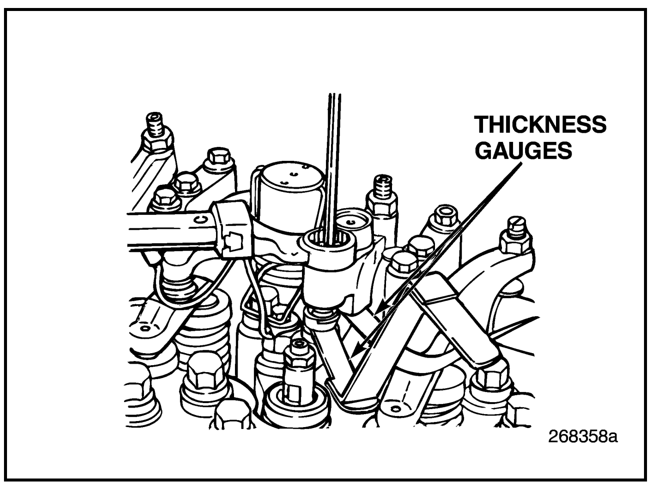


Figure 574 — Tightening Swivel-Head Adjusting Screw Jam Nut

3. Remove the thickness gauges from between the swivel-head adjusting screw and valve yoke, and from between the brake lash adjuster plunger and the actuating pin.
4. Recheck the exhaust valve lash adjustment by pressing down on the push rod end of the rocker arm and inserting the 0.024-inch (0.610 mm) thickness gauge between the swivel-head adjusting screw and the valve yoke. If the adjustment is not correct, **both** engine brake and exhaust valve lash must be re-checked and readjusted as required.

Inlet Valve Adjustment (PowerLeash™ Brake Engines)

Inlet valve lash is adjusted in the same manner as non-brake engines.

Continuation of Adjustments for Remaining Cylinders

1. Using a barring socket, manually rotate the engine crankshaft (Figure 575) in normal rotation direction 120 degrees until the center of the timing pointer hole in the flywheel housing aligns with the “2 and 5” mark on the flywheel and the No. 5 piston is on the compression stroke.

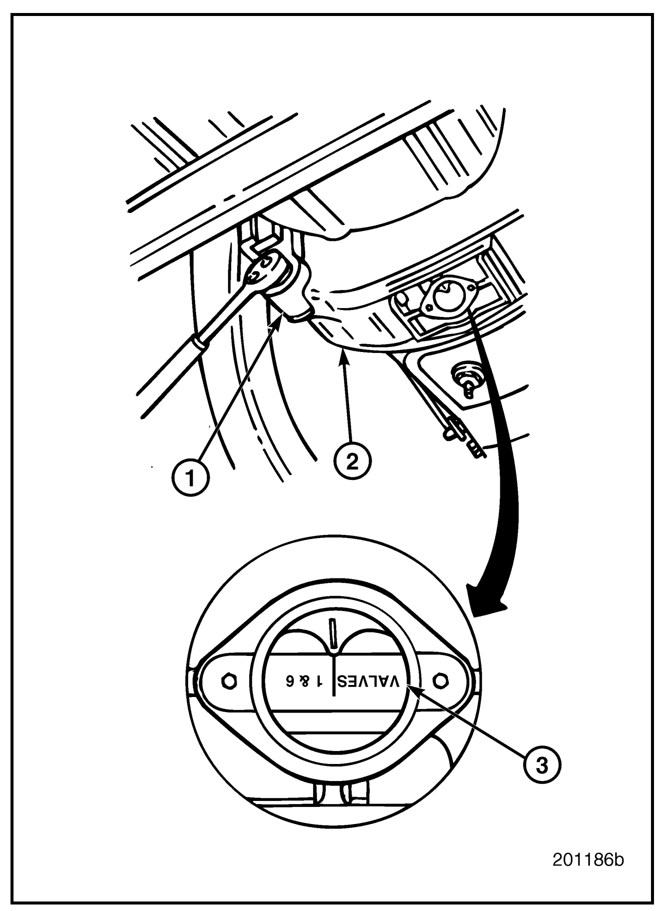


Figure 575 — Valve Adjustment Markings on Flywheel

1. Barring Socket J 38587-A 2. Flywheel Housing	3. Flywheel

2. Adjust the final intake valve lash, engine brake piston lash, and exhaust valve lash for cylinder No. 5 as described for cylinder No. 1. Continue this procedure for each of the remaining cylinders, following the engine firing order sequence, 1-5-3-6-2-4.

Electronic Unit Pump (EUP) Calibration

[221 GP]

Whenever an electronic unit pump(s) is replaced in an engine, it is necessary to recalibrate the pump(s) by entering the calibration code into the engine electronic control unit (EECU). The calibration code is a four-digit number that can be found on the data plate of each individual unit pump. This calibration code is then entered by using a personal computer that is running the V-MAC® Service Support Software.

The four-digit calibration code can be found on the EUP data plate, shown after the letters “CAL” for early production EUPs. For later-production EUPs, the calibration code is still found in the same location on the data plate (next to the word MACK), only the identification letters “CAL” have been eliminated to provide room for larger bar codes.

ENGINE SPEED AND POSITION SENSORS INSTALLATION AND ADJUSTMENT

Engine Speed Sensor

Because the engine speed sensor (Figure 576) is controlled by the measurement and selection of proper mounting shims, the installation procedure is as follows:

1. Using a depth micrometer or vernier caliper, measure from the sensor mounting surface on the flywheel housing to the outside diameter (OD) of a flywheel ring tooth.

NOTE

Measurement must be made to the tooth OD or an inaccurate measurement will result.

2. Select and install a shim on the sensor mounting flange. Refer to following chart for shim selection.

SHIM SELECTION CHART FOR ENGINE SPEED AND ENGINE POSITION SENSORS

Depth as Measured	Use the Following P/N 505GC28 Shims
Less than/equal to 1.328	(2) P30
1.329 through 1.343	(1) P45
1.344 through 1.358	(1) P30
1.359 through 1.373	(1) P15
Equal to/greater than 1.374	None

3. Install the sensor with the appropriate shim. Tighten the sensor retaining capscrew to the proper specification.

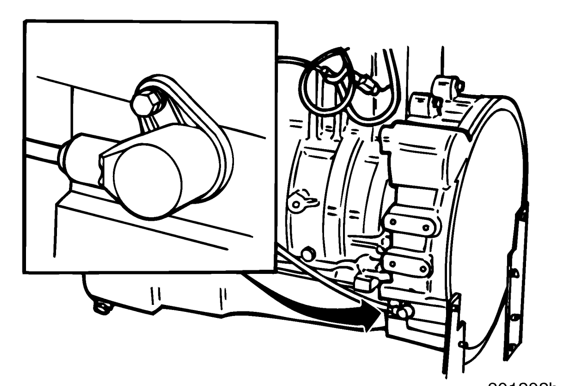


Figure 576 — Engine Speed Sensor

Engine Position Sensor

Installation of the engine position sensor (Figure 577) is the same as the engine speed sensor except for the first step. When installing the engine position sensor, make the shim calculation measurement from the sensor mounting surface on the front timing gear cover to the face of the camshaft gear.

NOTE

Do not measure into one of the sensing holes in the gear face or an inaccurate measurement will result.

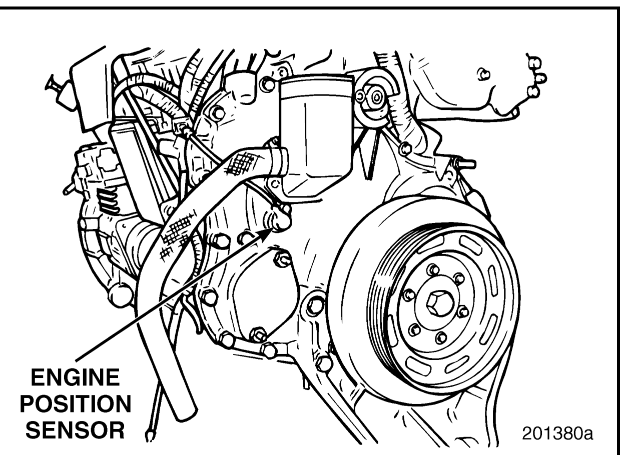


Figure 577 — Engine Position Sensor

Other Engine-Mounted Sensors

The remaining engine-mounted sensors are thread-mounted and are not adjustable. Mounting torque values for these sensors are listed under "Torque Specifications for Engine-Mounted Sensors" in the SPECIFICATIONS section.

- Fuel Temperature
- Boost Air Temperature
- Boost Air Pressure
- Coolant Temperature
- Oil Temperature
- Oil Pressure
- Air Temperature/Humidity
- CMCAC Outlet Temperature/Pressure
- VTG Position
- VTG Wheel-Speed
- EGR Temperature
- EGR MASS Flow

The **EGR Temperature and MASS Flow sensors**, however, are an integral part of the upper EGR gas tube and are not serviceable as separate items. If replacement is required, the upper EGR gas tube must be replaced along with the MASS Flow module to maintain proper system calibration.

CAUTION

Do not use a non-current E7 English pipe-thread sensor in place of a metric straight-thread sensor (or vice versa). Doing so will result in thread damage to both the sensor and the tapped hole into which the sensor is installed.

ENGINE FINAL PREPARATION AND OPERATIONAL CHECK

Filter Element Installation

CAUTION

All filters and coolant conditioners must meet MACK specifications. Prime oil filters before installation using the correct specification engine oil.

1. Install a **new** air filter in the air filter housing.
2. Install the Centri-Max® ULTRA or ULTRA PLUS (internally drained and vented) filter assembly. Be sure to use a **new** rotor element and O-ring.

CAUTION

There are different rotor assemblies for the standard Centri-Max®, Centri-Max® PLUS and Centri-Max® ULTRA or ULTRA PLUS filter assemblies. All ASET™ engines are equipped with the ULTRA or ULTRA PLUS filter assemblies. Be sure to use the correct rotor for the ULTRA or ULTRA PLUS applications; the unit will not function if an incorrect rotor is used.

3. Using an appropriate filter wrench such as J 29927, install the two full-flow oil filter elements and the coolant conditioner element.

NOTE

Prime the fuel filter element(s) before installation. Use only clean, MACK-specified, Grade 2D diesel fuel.

4. Prime the fuel filter element(s) as follows:

   ASET™ Engines with Combination Primary/Secondary and Pre-Pump Filters — Fill the pre-pump filter housing with clean No. 2 fuel oil and insert the screen cartridge (spring end up) into the housing. With the seal in place, install the housing to the pump base and tighten securely. Fill the COMBINATION spin-on fuel filter element with clean No. 2 fuel oil through the small holes at the perimeter of the element. Do not fill the filter element through the center hole. Lubricate the gasket with oil and install the filter on the pressure side of the pump.

   ASET™ Engines with Manifold-Mounted Primary and Secondary Filters — Fill the PRIMARY (red) and SECONDARY (green) fuel filter elements with clean No. 2 fuel oil. Do not fill the filter elements through the center hole; each must be filled using the outer holes. Lubricate the gaskets with oil and install the filters.

   ASET™ Engines with Chassis-Mounted Primary and Supply Pump-Mounted Secondary Filters — Fill the PRIMARY (red) and SUPPLY PUMP fuel filter elements with clean No. 2 fuel oil. Do not fill the filter elements through the center hole; each must be filled using the outer holes. Lubricate the gaskets with oil and install the filters.

Engine Lubrication System

GENERAL INSTRUCTIONS

A lubricating oil film coats rotating parts and bearings of an overhauled engine, but this may not provide sufficient lubrication when the engine is started for the first time. The following briefly describes the recommended procedure for ensuring proper lubrication.

CAUTION

Do not mix brands or types of lubricants. Chemical additives may be incompatible and may contribute to the formation of sludge, acid or hardening.

SERVICE HINT

Usually there are various points on the engine where a pressure line may be tapped into, but if no other is apparent, the oil gauge line may be disconnected and a pressure tank applied at that point.

PRIMING THE LUBRICATION SYSTEM

1. Fill the engine crankcase to the specified capacity with the recommended MACK-specified EO-N PREMIUM PLUS ’03 engine oil.
2. Fill a pressure prelubricator (J 39258-A) with the recommended oil and connect the pressure prelubricator to the main oil gallery. Prime the engine lubrication system for a minimum of five minutes to ensure a sufficient supply of oil to all respective parts and components.
3. Remove the oil level dipstick and check the crankcase level. Add sufficient oil, if necessary, to bring it to the FULL mark on the dipstick. Do not overfill.

Turbocharger

1. Remove and flush the turbocharger oil supply line with a suitable, clean, non-flammable solvent, Allow solvent to run through the line to flush any debris, then blow the line dry with clean compressed air.

CAUTION

A turbocharger failure can result in debris contaminating the turbocharger oil supply line. It is EXTREMELY IMPORTANT to remove, flush and thoroughly clean the line prior to starting the engine. Failure to do so can result in debris from the oil line entering the turbocharger, causing damage to the bearings and eventual failure of the turbocharger.

Refer to “TURBOCHARGER FAILURE AND ACTIONS REQUIRED TO AVOID REPEAT FAILURE” to acquire more information regarding the procedures required to avoid a repeat turbocharger failure. The text of these procedures is included in the APPENDIX section.

2. Reconnect the oil supply line to the external junction block, but allow the oil supply line to the turbocharger to remain disconnected.
3. Remove the turbocharger air inlet duct.
4. Fill the oil inlet port to overflowing with clean engine oil. Next, using your fingers at the compressor wheel, carefully spin and wiggle the turbocharger shaft to distribute the oil over all bearing surfaces. Then, again fill the oil inlet port to overflowing.
5. Install the turbocharger air inlet duct and reconnect the oil supply line at the turbocharger.

CAUTION

It is also necessary to perform the above turbocharger pre-lubrication procedure anytime the vehicle has not been operated for a period exceeding 30 days to avoid damage to the turbocharger. During this extended period, all oil will have drained away from the bearing and shaft surfaces.

Cooling System

1. Check the cooling system. Make sure all plugs are installed and tight. Make sure the thermostat(s) is installed.
2. Install a **new** coolant conditioner if so equipped.
3. Fill the system with the recommended coolant.

NOTE

To ensure that all air is purged from the cooling system, remove a plug from the top (or end) of the coolant manifold during filling. This will eliminate any air that is trapped as a result of rapid filling.

Fuel System

GENERAL INSTRUCTIONS

1. Check the fuel system to ensure that all connections are tight.
2. Remove any trapped air by operating the manual priming pump located on the side of the fuel supply pump, using the following procedure.

NOTE

Prime the fuel system with clean, Grade 2D diesel fuel (DF-A).

PRIMING THE FUEL SYSTEM

Using a hand-priming pump is usually only necessary when the fuel system has run dry. If the hand-priming pump is needed, use the following procedure for priming a dry fuel system.

1. Install a hand-priming pump at the fuel tank.
2. Fill the pre-pump and primary filters (if equipped) or the primary and secondary fuel filters (if equipped) if not already done.
3. Disconnect the applicable fuel line for the engine configuration:
   - **ASET™ Engine with Combination Primary/Secondary and Pre-Pump Filters** — outlet hose from the fitting at the top of the supply pump
   - **ASET™ Engine with Chassis-Mounted Primary and Supply Pump-Mounted Secondary Filters** — outlet hose from the fitting at the top of the supply pump
   - **ASET™ Engine with Manifold-Mounted Primary and Secondary Filters** — inlet hose from the fitting at the secondary fuel filter
4. Hand-prime the system until fuel is seen at the disconnected hose fitting for the applicable engine. This should take approximately 50 hand pumps.

SERVICE HINT

Excessive hand-priming after fuel is seen at the fitting may make the engine difficult to start.

5. Reconnect the fuel hose at the supply pump outlet fitting (if equipped) or at the secondary fuel filter inlet fitting (if equipped).
6. Remove the hand-priming pump from the fuel tank and perform the “Engine Operational Check” that follows in this section.

SERVICE HINT

If the engine does not start, refill both filters and repeat the priming procedure outlined in steps 3, 4 and 5.

NOTE

Do not crank the engine continuously for more than 30 seconds without allowing the starter to cool for 2 minutes between cranks.

CAUTION

The only acceptable method of priming the fuel system is the hand primer pump. The application of air pressure to the fuel tank or the use of an auxiliary pump to prime the fuel system is PROHIBITED. These priming techniques may result in severe engine damage caused by leakage of fuel past the supply pump seal and into the crankcase.

Engine Operational Check

1. Remove all tools from the engine compartment.
2. Connect the battery cables (negative cable last).
3. Clear the work area of debris and personnel.

CAUTION

The following step is important to ensure adequate break-in for all new parts — camshaft, lifters, crankshaft, bearings, etc. — at initial startup of the engine.

4. Start the engine and immediately increase the speed to 1200 rpm. Operate the engine in the range of 1200–1600 rpm for 15 minutes. DO NOT allow the engine to drop to idle speed until the 15 minute break-in period at 1200–1600 rpm has been completed. During the break-in period, check for leaks and monitor gauges for satisfactory oil pressure, etc.
5. After the break-in is complete, shut down the engine. Check the fluid levels and fill to capacity before restarting the engine.
6. Refer to the "Rebuilt Engine Run-In Procedures" for checks to ensure proper engine operation before releasing the vehicle for service.

REBUILT ENGINE RUN-IN PROCEDURES

General Instructions

The durability and service life of a rebuilt engine is directly related to its initial run-in following overhaul. After a complete overhaul or any major repair job involving installation of piston rings, pistons, cylinder sleeves or bearings, the engine must be run-in prior to release for service.

Run-in procedures vary depending on method used (i.e., engine dynamometer, chassis dynamometer or highway run-in). Regardless of method, however, always properly prepare the engine before starting it for the first time.

Run-In Check

NOTE

Install any additional instrumentation needed for the run-in method selected.

The operator should be familiar with the correct, established procedure for checking chassis power *before* using the chassis dynamometer method for run-in (refer to applicable chassis dynamometer operation procedures).

The operator must be observant throughout the entire run-in procedure, in order to detect any problems that develop. Constantly monitor the instrumentation displaying functions of the engine and support systems, and record all readings.

If, during run-in, the engine develops any of the following abnormal running characteristics, shut it down immediately. Investigate and correct the problem before continuing the run-in procedure.

Always investigate the following conditions:

- Unusual noises such as knocking, scraping, etc.
- A significant drop in engine oil pressure
- A significant rise in coolant temperature, exceeding 240°F (116°C)
- A significant rise in oil temperature that exceeds 240°F (116°C)
- An exhaust temperature that exceeds maximum acceptable limits for the specific engine involved, as measured by a pyrometer (if vehicle is equipped with a pyrometer)
- Any oil, coolant or air inlet system leaks

CYLINDER HEAD RETORQUING

After completing the run-in procedure, in sequence, back off each cylinder head capscrew individually until free. Then retorque the same capscrew to 205 lb-ft (278 N•m).

NOTES

SPECIFICATIONS

ASET™ AC ENGINE MECHANICAL SPECIFICATIONS

Performance Specifications

ASET™ AC-310/330 (CEGR) MAXICRUISE®

— ***Speed Range*** — 1100–1800 rpm

— ***Power at Governed Speed*** — 310 hp (231 kW) at 1800 rpm

— ***Peak Power*** — 330 hp (246 kW) at 1400–1500 rpm

— ***Maximum Torque*** — 1,360 lb-ft (1 844 N•m) at 1100 rpm

— ***Torque Rise*** — 50 percent

ASET™ AC-330/350 (CEGR) MAXICRUISE

— ***Speed Range*** — 1100–1800 rpm

— ***Power at Governed Speed —*** 330 hp (246 kW) at 1800 rpm

— ***Peak Power*** — 350 hp (261 kW) at 1400–1500 rpm

— ***Maximum Torque*** — 1,460 lb-ft (1 980 N•m) at 1100 rpm

— ***Torque Rise*** — 52 percent

ASET™ AC-355/380 (CEGR) MAXICRUISE

— ***Speed Range*** — 1100–1800 rpm

— ***Power at Governed Speed*** — 355 hp (265 kW) at 1800 rpm

— ***Peak Power*** — 380 hp (283 kW) at 1400–1500 rpm

— ***Maximum Torque*** — 1,560 lb-ft (2 115 N•m) at 1100 rpm

— ***Torque Rise*** — 51 percent

ASET™ AC-380/410 (CEGR) MAXICRUISE

— ***Speed Range*** — 1100–1800 rpm

— ***Power at Governed Speed*** — 380 hp (283 kW) at 1800 rpm

— ***Peak Power*** — 410 hp (306 kW) at 1400–1500 rpm

— ***Maximum Torque*** — 1,660 lb-ft (2 250 N•m) at 1100 rpm

— ***Torque Rise*** — 50 percent

ASET™ AC-350 (CEGR) ECONODYNE®

— ***Speed Range*** — 1200–1800 rpm

— ***Power at Governed Speed*** — 350 hp (261 kW) at 1800 rpm

— ***Peak Power*** — 350 hp (261 kW) at 1500–1800 rpm

— ***Maximum Torque*** — 1,360 lb-ft (1 844 N•m) at 1200 rpm

— ***Torque Rise*** — 33 percent

ASET™ AC-400 (CEGR) ECONODYNE

— ***Speed Range*** — 1200–1800 rpm

— ***Power at Governed Speed*** — 400 hp (298 kW) at 1800 rpm

— ***Peak Power*** — 400 hp (298 kW) at 1500–1800 rpm

— ***Maximum Torque*** — 1,460 lb-ft (1 980 N•m) at 1200 rpm

— ***Torque Rise*** — 25 percent

ASET™ AC-427 (CEGR) ECONODYNE

— ***Speed Range*** — 1200–1800 rpm

— ***Power at Governed Speed*** — 427 hp (318 kW) at 1800 rpm

— ***Peak Power*** — 429 hp (320 kW) at 1700 rpm

— ***Maximum Torque*** — 1,560 lb-ft (2 115 N•m) at 1200 rpm

— ***Torque Rise*** — 25 percent

ASET™ AC-460(E) (CEGR) ECONODYNE

- — ***Speed Range*** — 1200–1800 rpm
- — ***Power at Governed Speed*** — 460 hp (343 kW) at 1800 rpm
- — ***Peak Power*** — 460 hp (343 kW) at 1600–1800 rpm
- — ***Maximum Torque*** — 1,660 lb-ft (2 251 N•m) at 1200 rpm
- — ***Torque Rise*** — 24 percent

ASET™ AC-460(P) (CEGR) ECONODYNE

- — ***Speed Range*** — 1200–1800 rpm
- — ***Power at Governed Speed*** — 480 hp (359 kW) at 1800 rpm
- — ***Peak Power*** — 487 hp (363 kW) at 1600 rpm
- — ***Maximum Torque*** — 1,660 lb-ft (2 251 N•m) at 1200 rpm
- — ***Torque Rise*** — 19 percent

Material and Dimensional Data

WEIGHTS AND DIMENSIONS

Item	Specification
Weight (wet) — includes oil and coolant	2340 lbs. (1062 kg)
Weight (dry)	2290 lbs. (1039 kg)
Displacement	728 cu. in. (12 L)
Bore and stroke	4-7/8 in. x 6-1/2 in. (124 mm x 165 mm)
Coolant capacity	13 qts. (12.3 L)
Sleeve design	Wet/dry
Compression ratio	16:1
Fasteners and threads	Metric
Flywheel housing — standard	Aluminum
Flywheel housing — optional (required for certain engine and transmission combinations)	Ductile iron

COMPONENT FEATURES AND MATERIALS

Item	Description
Air compressor	Flange-mounted, drive coupling, oil-lubricated and water-cooled from engine; Bendix or Meritor WABCO
Bearings — connecting rod	Steel back, cast copper-lead intermediate layer, lead-tin overlay, deltawall
Bearings — main	Steel back, cast copper-lead intermediate layer, lead-tin overlay
Camshaft	Carbon steel with induction-hardened journals and lobes, gear driven
Coolant conditioner	Spin-on type, disposable, head assembly attaches to front cover
Connecting rods	Forged steel, I-beam type with tapered pin end, 35-degree cap angle, 10.4 inches (264 mm) center-to-center length
Crankshaft	Drop-forged, medium carbon steel, elotherm-hardened journals and fillets, eight integral counterweights, 3.25-inch (83 mm) pin journal diameter, 4.5-inch (114 mm) main journal diameter
Cylinder block	Alloyed gray cast iron

Item	Description
Cylinder head cover	Casting is changed to allow space between the front and rear cover assemblies, to accommodate the upper EGR gas tube
Cylinder sleeve	Wet/dry, replaceable, centrifugally cast, alloyed cast iron
Cylinder heads	Alloyed gray cast iron, two per engine, four valves per cylinder. Intake port design changed to achieve optimum air flow and desired swirl characteristics
Cylinder head — valve springs	Progressive rate design capable of working under higher engine speeds. Exhaust valves have additional inner springs
Cylinder head — valve guides	Machined to a smaller diameter to accommodate the new design valve stem seal. Smaller diameter also required to provide sufficient room for the inner valve spring
Cylinder head gaskets — body	Nonasbestos material with steel core, two per engine
Cylinder head gaskets — fire ring	Steel, keyed, six per engine
EGR cooler	Stainless steel construction with lower petcock for draining
EGR gas tubing	All tubes and clamps are made of stainless steel
EGR valve	Poppet-type valve with two sealing surfaces on a common shaft
Engine front cover (timing gear cover)	Die-cast aluminum, precision-doweled
Flywheel housing	Die-cast aluminum or ductile iron, standard SAE No. 1, precision-doweled
Fuel filters	Spin-on disposal type with metric mounting threads
Fuel injection nozzles	8-hole, 140-degree spray angle, Bosch
Fuel injection pumps	Electronic unit pumps, Bosch
Fuel supply pump	Gear type, Bosch
Lubrication system	Full pressure, wet sump Oil capacities — • Total system capacity (dry, after engine overhaul) — 41.5 qts. (39.3 L) • Oil change capacity without filter replacement — 36 qts. (34 L) • Oil change capacity with filter replacement — 40 qts. (38.9 L)
Main bearing caps	Ductile iron, intermediates supported with buttress screws
Manifold — air inlet	One-piece aluminum alloy, six port
Manifold — EGR gas mixer	One-piece aluminum alloy
Manifold — exhaust	Three-piece, six port includes EGR valve mounting and inlet chamber
Manifold — water	All new one-piece aluminum with three-bolt pattern at each point the manifold contacts the head
Pistons	Two-piece articulated, steel crown with three rings, aluminum alloy skirt, pin bushingless. The crown of piston contains the swirl/combustion chamber incorporated into its design
Piston rings — compression	Keystone, plasma-faced top ring. Rectangular, chrome, tapered-face second ring

Item	Description
Piston ring — oil	Dual chrome-faced rails, conformable with coil spring expander
Piston pin	Full-floating, 2.25-inch (57 mm) diameter, full-pressure lubrication through rifle-drilled holes in connecting rod
Oil filters	Two spin-on disposable, one Centri-Max®
Oil pan	Sump capacity, 36 qts. (34 L)
Thermostat	180°F (82°C) opening with rubber-seated flange seal
Thermostat housing	A two thermostat housing is provided to allow the additional coolant flow needed by the emission-controlled engines
Variable Turbine Geometry (VTG) Turbocharger	Radial-flow type, exhaust gas driven, oil-lubricated variable position vanes. Manifold middle section is of high sil-moly composition to withstand increased temperatures and load
Valves — inlet	Poppet type with positive rotators, 20-degree seat, two per cylinder
Valves — exhaust	Poppet type with positive rotators, 30-degree seat, two per cylinder
Valve lifters	Roller follower type
Valve seat inserts	Pressed-in head, replaceable
Vibration damper	Constructed with internal metal inertia ring, viscous fluid filled
Water pump	Centrifugal-rotor type impeller, belt driven

FITS AND LIMITS

The specifications as listed are for new parts, and therefore, maximum wear must be established by good judgment, experience and sound shop practice.

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**English**	**Metric**
AUXILIARY SHAFT		
Shaft End Play	0.003–0.012 in.	0.076–0.305 mm
Shaft Journal Clearance	0.0020–0.0072 in.	0.051–0.183 mm
Shaft Bushing, Presized ID (front and rear)	2.064–2.068 in.	52.426–52.527 mm
Shaft Bushing, Presized OD (front and rear)	2.3140–2.3155 in.	58.7756–58.8137 mm
Shaft Bushing, Bore in Block (front and rear)	2.311–2.312 in.	58.699–58.725 mm
Shaft Bushing, Press-Fit in Bore (front and rear)	0.002–0.0045 in.	0.0518–0.1143 mm
Shaft Journal-to-Bushing (front and rear)	0.0020–0.0072 in.	0.0508–0.1829 mm
Shaft Journal Diameter OD (front and rear)	2.061–2.062 in.	52.349–52.375 mm
Oil Pump Driving Gear ID (press-fit)	1.6255–1.6250 in.	41.2877–41.2750 mm
Auxiliary Shaft Oil Pump Drive Journal	1.6278–1.6272 in.	41.3461–41.3309 mm
Air Compressor Drive Sprocket (press-fit)	1.1250–1.242 in.	28.575–31.547 mm
Auxiliary Shaft Air Compressor Sprocket Journal	1.1272–1.1268 in.	28.6309–28.6207 mm
CAMSHAFT		
Bushing Free OD	4.0045–4.0065 in.	101.714–101.765 mm
Bushing Bore in Cylinder Block	3.9995–4.0005 in.	101.587–101.613 mm

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**English**	**Metric**
Bushing Press-Fit in Bore	0.004–0.007 in.	0.102–0.178 mm
Bushing ID (installed)	3.8188–3.8213 in.	96.998–97.061 mm
Cam Journal Diameter	3.8150–3.8160 in.	96.901–96.926 mm
Journal-to-Bushing Clearance	0.003–0.006 in.	0.076–0.152 mm
Cam Gear Journal OD on Camshaft	2.50205–2.50255 in.	63.552–63.565 mm
Cam Gear Bore ID	2.4983–2.4993 in.	63.457–63.482 mm
Cam Gear-to-Journal Press-Fit	0.00275–0.00425 in.	0.070–0.108 mm
Inlet Valve Lobe Nominal Lift	0.320 in.	8.128 mm
Exhaust Valve Lobe Nominal Lift	0.334 in.	8.484 mm
EUP Lobe Nominal Lift	0.704 in.	17.882 mm
Camshaft End Play	0.003–0.012 in.	0.076–0.305 mm
CONNECTING ROD		
Connecting Rod Journal-to-Bearing Clearance	0.0012–0.0054 in.	0.030–0.137 mm
Side Clearance	0.007–0.014 in.	0.178–0.355 mm
Length between Centers	10.4375 in.	26.5113 cm
Cap Angle	35 degrees	
Bore for Bushing	2.4355–2.4345 in.	61.8617–61.8363 mm
Burnish Bushing to:	2.2305–2.2275 in.	56.6547–56.5785 mm
Finish Bore to:	2.2504–2.2500 in.	57.1602–57.1500 mm
Crankpin Bore Diameter (as bored)	3.4305–3.4297 in.	87.1347–87.1144 mm
Crankpin Bore Diameter (reassembled)	3.4309–3.4294 in.	87.1449–87.1068 mm
Bearing ID (in place)	2.9993–3.0013 in.	76.1822–76.2330 mm
Twist (within 12 in./30.48 cm)	0.010 in.	0.254 mm
Bend (within 12 in./30.48 cm)	0.004 in.	0.1016 mm
CRANKSHAFT		
End Play	0.004–0.014 in.	0.102–0.356 mm
Crankpin Journal OD	3.248–3.247 in.	82.4992–82.4738 mm
Main Journal OD	4.4974–4.4964 in.	114.2340–114.2086 mm
Journal Out-of-Round or Taper (maximum diameter)	0.00035 in.	0.00889 mm
Max. Runout at No. 4 journal (shaft supported on No. 1 and No. 7)	0.007 in.	0.178 mm
Front Oil Seal Installation Depth:		
Production	0.125 in.	3.175 mm
Service Replacement	0.219 in.	5.563 mm
Main Journal-to-Bearing Clearance	0.0021–0.0054 in.	0.053–0.137 mm
Front Oil Seal Square-to-Crankshaft (must be held relative to hub)	0.010 in.	0.254 mm
Rear Oil Seal Square-to-Crankshaft (must be held relative to main bearing bores)	0.016 in.	0.406 mm
Rear Oil Seal Installation Depth:		
Production	0.344 in.	8.738 mm
Service Replacement	0.250 in.	6.350 mm

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**English**	**Metric**
CYLINDER BLOCK		
Deck Flatness (across one cylinder head)	0.002 in.	0.0508 mm
Deck Flatness (across both cylinder heads)	0.004 in.	0.1016 mm
Dowel Pin Holes (flywheel housing-to-block mounting, left side)	0.6237–0.6247 in.	15.8420–15.8674 mm
Dowel Pin Holes (flywheel housing-to-block mounting, right side)	0.6807–0.6817 in.	17.2898–17.3152 mm
Dowel Pin Holes (front cover-to-block mounting, left side)	0.5557–0.5567 in.	14.1148–14.1402 mm
Dowel Pin Holes (front cover-to-block mounting, right side)	0.4987–0.4997 in.	12.6670–12.6924 mm
Cylinder Bore in Block (upper)	5.501–5.500 in.	139.725–139.970 mm
Cylinder Bore in Block (lower)	5.1266–5.1250 in.	130.2156–130.1750 mm
Cylinder Bore Out-of-Round or Taper (on diameter) (During manufacturing, the cylinder bores are honed with a torque-plate [simulated cylinder head] installed.)	0.004 in. max., without torque plate installed	0.1016 mm
Sleeve OD (at upper pilot diameter)	5.5040–5.5030 in.	139.8016–139.7762 mm
Sleeve Bead for Fire Ring (protrusion above sleeve channel)	0.0067–0.010 in.	0.1702–0.2540 mm
Sleeve in Bore (upper press-fit)	0.004–0.002 in.	0.1016–0.0508 mm
Sleeve in Bore (lower loose fit)	0.0029–0.0003 in.	0.0737–0.0076 mm
Main Bearing Bore in Block	4.818–4.817 in.	122.3772–122.3518 mm
Main Bearing ID (in place)	4.502–4.4996 in.	104.3508–114.2898 mm
Note: Extension of the cylinder sleeve above the cylinder block deck can vary under the same head, as long as all are within the 0.024–0.029 inch (0.610–0.737 mm) specification for ASET™ AC engines.		
Cyl. Sleeve Flange Channel-to-Block Deck (DO NOT measure from top of bead.)	0.024–0.029 in.	0.610–0.737 mm
Cyl. Sleeve ID (installed, See "NOTE 8 — CYLINDER SLEEVE ID" on page 489.)	4.876–4.877 in.	123.850–123.876 mm
EUP Tappet Bore	1.7334 + 0.0012/–0.0004 in.	44.028 + 0.0305/–0.0102 mm
EUP Tappet OD	1.7299–1.7307 in.	43.939–43.960 mm
EUP Tappet-to-Bore Clearance	0.0023–0.0047 in.	0.058–0.119 mm
Valve Roller Follower Bore	1.1245–1.1255 in.	28.562–28.588 mm
Valve Roller Follower OD	1.122–1.123 in.	28.499–28.524 mm
Valve Roller Follower-to-Bore Clearance	0.0015–0.0035 in.	0.038–0.089 mm
Valve Roller Follower H-Ring Bore	1.1245–1.1255 in.	28.562–28.588 mm
Valve Roller Follower H-Ring OD	1.1261–1.1265 in.	28.603–28.613 mm
Valve Roller Follower H-Ring-to-Bore Press Fit	0.0006–0.0020 in.	0.015–0.051 mm
CYLINDER HEAD		
Alignment Across Exhaust Ports	0.005 in.	0.127 mm
Deck Flatness (over 18 in./45.72 cm)	0.0015 in.	0.0381 mm
Overall Height	6.391–6.397 in.	162.331–162.484 mm
Fire Ring Groove (width)	0.030–0.036 in.	0.762–0.914 mm
Fire Ring Groove (depth)	0.005–0.013 in.	0.127–0.330 mm
Fire Ring Groove ID	5.137–5.139 in.	130.479–130.531 mm
Valve Guide OD	0.6886–0.6881 in.	17.4904–17.4777 mm

SPECIFICATIONS

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**English**	**Metric**
Valve Guide Ream ID (after installation, inlet and exhaust, used with 3/8 valve stem)	0.3745–0.3755 in.	9.5123–9.5377 mm
Top End of Valve Guide-to-Valve Spring Seat	0.857–0.937 in.	21.768–23.710 mm
Valve Guide Bore in Head	0.686–0.687 in.	17.424–17.450 mm
Valve Guide-to-Bore (press-fit)	0.0011–0.0026 in.	0.0279–0.0660 mm
Valve Guide Extension (fire deck to top of guide)	5.178 ± 0.030 in.	131.521 ± 0.762 mm
Yoke Guide Pin OD	0.4389–0.4392 in.	11.1481–11.1557 mm
Yoke Guide Pin Installed Height (above top surface of guide pin bore to top of pin)	1.848–1.918 in.	46.939–48.717 mm
Valve Seat Width (Inlet) (Exhaust)	0.060 ± 0.005 in. 0.069 ± 0.005 in.	1.524 ± 0.127 mm 1.753 ± 0.127 mm
Valve Seat Insert Face Angle (inlet)	20° 30′ ± 15′	
Valve Seat Insert Face Angle (exhaust)	30° 15′ ± 15′	
Valve Seat-to-Guide Runout	0.002 in. F.I.M.	0.0508 mm
Valve Seat Insert Counterbore Diameter (inlet)	1.8285–1.8295 in.	46.4439–46.4693 mm
Valve Seat Insert Counterbore Diameter (exhaust)	1.6875–1.6885 in.	42.8625–42.8879 mm
Valve Seat OD (inlet)	1.831–1.832 in.	46.507–46.533 mm
Valve Seat OD (exhaust)	1.692–1.693 in.	42.977–43.002 mm
Valve Seat Insert (inlet, press-fit in head)	0.0015–0.0035 in.	0.0381–0.0889 mm
Valve Seat Insert (exhaust, press-fit in head)	0.0035–0.0055 in.	0.0889–0.1397 mm
Valve Seat Counterbore Depth (inlet)	0.360–0.364 in.	9.144–9.246 mm
Valve Seat Counterbore Depth (exhaust)	0.372–0.376 in.	9.449–9.550 mm
Injection Nozzle Holder Insert Bore:		
Upper Bore	1.07395–1.07545 in.	27.2784–27.3165 mm
Lower Bore	1.058–1.060 in.	26.873–26.924 mm
Lobing (Max. per 30-degree segment)	0.0004 in.	0.010 mm
Injection Nozzle Holder Insert OD:		
Upper Sealing Diameter	1.0773–1.0781 in.	27.363–27.384 mm
Lower Sealing Diameter	1.06145–1.06225 in.	26.961–26.981 mm
FLYWHEEL HOUSING		
Dowel Pin Hole, Flywheel Housing (round pin, LH)	0.6259–0.6263 in.	15.8979–15.9080 mm
Dowel Pin Hole, Flywheel Housing (blade pin, RH)	0.6831–0.6835 in.	17.3507–17.3609 mm
Dowel Pin Diameter (round pin, LH)	0.6251–0.6255 in.	15.8775–15.8877 mm
Dowel Pin Diameter (blade pin, RH)	0.6821–0.6825 in.	17.3254–17.3355 mm
Crankshaft Seal Mounting Bore	6.748–6.752 in.	171.3992–171.5008 mm
Starter Motor Mounting Bore	3.625–3.629 in.	92.075–92.117 mm
Transmission Mounting Face Axial Runout	0.008 in. TIR (Max)*	0.203 mm TIR (Max)*
Transmission Pilot Bore Radial Runout	0.010 in. TIR (Max)*	0.254 mm TIR (Max)*
Rear Seal Bore Radial Runout (See "NOTE 9 — REAR SEAL BORE RADIAL RUNOUT" on page 489.)	0.009 in. TIR (Max)*	0.2329 mm TIR (Max)*
* **Note:** Must be held relative to main bearing bores. Check runout with an alignment bar installed through the cylinder block main bearing bores.		

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**English**	**Metric**
FUEL SUPPLY PUMP		
Pump Gear End Play (steel gear)	0.008 in. (Max)	0.203 mm (Max)
Pump Gear End Play (plastic gear)	0.019 in. (Max)	0.483 mm (Max)
IDLER GEAR		
Gear Journal Clearance	0.0027–0.0062 in.	0.069–0.158 mm
Gear End Play	0.003–0.009 in.	0.076–0.228 mm
JACOBS ENGINE BRAKE		
Slave Piston Lash Adjustment	0.021 in.	0.381 mm
POWERLEASH™ ENGINE BRAKE		
Hydraulic Actuator Lash Adjustment	0.045 in.	1.14 mm
OIL PUMP		
Gear-to-Cover End Clearance	0.0035–0.0060 in.	0.089–0.152 mm
Oil Pump OD-to-Cavity Clearance	0.003–0.0045 in.	0.076–0.114 mm
Oil Pump Gear Backlash (inside pump)	0.008–0.022 in.	0.203–0.559 mm
Oil Pump Drive Gear-to-Driven Gear Backlash	0.006–0.016 in.	0.152–0.406 mm
Relief Valve Spring (free length)	6.4 in.	162.6 mm
Relief Valve Spring Pressure (compressed to 5.56 in./14.12 cm)	63 lbs.	28.6 kg
Relief Valve Opening Pressure	90–115 psi	621–793 kPa
PISTON		
Top Extension Above/Below Cyl. Block Deck at TDC	+0.020 to –0.002 in.	+0.508 to –0.051 mm
Wrist Pin Bore	2.2501–2.2509 in.	57.153–57.173 mm
Wrist Pin Length	3.820–3.825 in.	97.028–97.155 mm
Wrist Pin-to-Piston/Bore Clearance	0.0012–0.0021 in.	0.0297–0.0547 mm
Wrist Pin OD	2.24875–2.24895 in.	57.11825–57.12333 mm
Piston-to-Liner Clearance (Two-piece piston, 90 degrees from pin axis)	0.0030–0.0050 in.	0.0762–0.1270 mm
Ring Groove Service Limit, Top (over 0.120 in./3.048 mm pins)	4.912 in.	124.765 mm
PISTON RINGS		
Compression Ring End Gap (No. 349GC3113)	0.016–0.028 in.	0.406–0.711 mm
Compression Ring End Gap (No. 349GC3102)	0.013–0.025 in.	0.330–0.635 mm
Oil Control Ring End Gap (No. 350GC340)	0.013–0.028 in.	0.330–0.711 mm
Piston Ring Side Clearance (new)	0.0016–0.0030 in.	0.0406–0.0762 mm
Piston Ring Side Clearance (used)	Maximum 0.0045 in.	Maximum 0.1143 mm
Note: End gap checked in 4.875 gauge diameter. For every 0.001-inch (0.0254 mm) increase in gauge diameter, ring gap will increase by 0.003 inch (0.076 mm). Refer to a MACK branch or dealer for specifications for piston ring part numbers not listed above.		
ROCKER ARM		
Rocker Arm Ratio	1.5:1	
Rocker Arm Hole ID	1.1306–1.1326 in.	28.7172–28.7680 mm
Rocker Arm Hole-to-Shaft Clearance	0.004–0.0015 in.	0.1016–0.0381 mm
Rocker Arm Shaft OD	1.1286–1.1291 in.	28.6664–28.6791 mm

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**English**	**Metric**
Push Rod Overall Length (intake) (from ball end, 0.560 in./14.224 mm ball placed in cup)	14.108–14.170 in.	358.343–359.918 mm
Push Rod Overall Length (spring-loaded exhaust [compressed]) (from ball end, 0.0560 in./14.224 mm ball placed in cup)	14.086–14.148 in.	357.784–359.359 mm
TIMING GEAR AND FRONT COVER		
Idler Gear-to-Camshaft Gear Backlash	0.001–0.008 in.	0.025–0.203 mm
Camshaft Gear-to-Auxiliary Shaft Gear Backlash	0.001–0.009 in.	0.025–0.229 mm
Camshaft Gear-to-Fuel Supply Pump Gear Backlash	0.001–0.019 in.	0.025–0.483 mm
Crankshaft Gear-to-Idler Gear Backlash	0.001–0.008 in.	0.025–0.203 mm
Dowel Pin Hole (round pin, in front cover, RH)	0.5005–0.5012 in.	12.7127–12.7305 mm
Dowel Pin Hole (blade pin, in front cover, LH)	0.5577–0.5584 in.	14.1656–14.1834 mm
Dowel Pin OD (round pin, RH)	0.5000–0.5004 in.	12.7000–12.7102 mm
Dowel Pin OD (blade pin, LH)	0.5571–0.5575 in.	14.1504–14.1605 mm
Crankshaft Seal Mounting Bore	3.9995–4.0025 in.	101.5873–101.6635 mm
Timing Gear Cover Seal Mounting Bore-to-Crankshaft Runout	0.015 in. TIR (Max)	0.381 mm TIR (Max)
Timing Gear Cover Seal Square-to-Crankshaft	0.010 in. (Max)	0.254 mm (Max)
Hydraulic Steering Pump Mounting Bore	3.2525–3.2545 in.	82.6135–82.6643 mm
Note: Must be held relative to main bearing bores. Check runout with an alignment bar installed through the cylinder block main bearing bores.		
TURBOCHARGER		
Shaft End Play (models S300, S400, S410)	0.002–0.005 in.	0.051–0.127 mm
Radial Tilt (measured at shaft ends)	0.046 in. (MAX)	1.168 mm (MAX)
Bearing Radial Check (measured at compressor wheel nut)	0.018–0.029 in.	0.4572–0.7366 mm
VALVES		
Lash Setting, Rocker Arm-to-Valve Guide Yoke Clearance (cold*):		
Inlet (adjustment at scheduled intervals)	0.016 in.	0.406 mm
Inlet (acceptable range for interim checks)	0.012–0.020 in.	0.305–0.508 mm
Exhaust (adjustment at scheduled intervals)	0.024 in.	0.601 mm
Exhaust (acceptable range for interim checks)	0.020–0.028 in.	0.508–0.711 mm
* **Note:** Valve Yoke Setting must be completed at each location with the respective piston at TDC firing position prior to setting the (cold static) rocker arm lash. (See procedure for engines with J-Tech™ or MACK PowerLeash™ engine brakes.)		
Valve Face-to-Deck (inlet)	0.047 + 0.009/–0.007 in.	1.194 + 0.229/0.178 mm
Valve Face-to-Deck (exhaust)	–0.021 + 0.009/–0.007 in.	–1.5334 + 0.229/0.178 mm
Valve Stem-to-Guide (inlet)	0.0015–0.0035 in.	0.0381–0.0889 mm
Valve Stem-to-Guide (exhaust)	0.0025–0.0045 in.	0.0635–0.1143 mm
Valve Stem OD (inlet, 3/8 in.)	0.373–0.372 in.	9.474–9.449 mm
Valve Stem OD (exhaust, 3/8 in.)	0.3720–0.3710 in.	9.4488–9.4234 mm

SPECIFICATIONS

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**English**	**Metric**
VALVE SEAT ANGLE		
Exhaust	30° 15′ ±15′	
Inlet	20° 30′ ± 15′	
VALVE SPRINGS		
Outer Spring:		
Free length (approximate)	2.89 in.	73.4 mm
Spring pressure — when compressed to 1.5 in. (38 mm)	195–215 lbs.	88–98 kg
Inner Spring:		
Free length (approximate)	2.76 in.	70.1 mm
Spring pressure — when compressed to 1.4 in. (35 mm)	65–74 lbs.	29–34 kg

Engine Component Torque Specifications

NOTE

All components are to be clean and free from foreign material or corrosion. Assemblies are to be made using suitable tools and procedures so that no permanent damage will occur as a result of the assembly.

Threads, washer and underhead of screw or washer face of nuts should be lubricated with clean engine oil, unless otherwise specified.

The following listed fasteners require the use of a calibrated manual torque wrench. If an ADAPTER IS REQUIRED in combination with a torque wrench, a correction factor **must be** applied to the torque wrench readings in order to obtain accurate fastener torque values. Refer to the procedures under TORQUE WRENCH USE in the APPENDIX section for instructions in determining the factor.

Fasteners noted by an asterisk (*) require retorque after engine run-in.

TORQUE SPECIFICATIONS FOR CRITICAL FASTENERS

CRITICAL FASTENERS

Fastener Name	Torque	
	Lb-Ft	N•m
AIR COMPRESSOR		
Air Compressor Coupling-to-Air Compressor Retaining Nut	60	81
Air Compressor-to-Cylinder Block Mounting Screw	80 (Dry)	108 (Dry)
AUXILIARY DRIVE		
Auxiliary Shaft Gear Retaining Nut (See “NOTE 1 — AUXILIARY SHAFT GEAR RETAINING NUT INSTALLATION” on page 488.)	300 (Dry)	405 (Dry)
Auxiliary Shaft Thrust Washer-to-Block Screw	15	20
Auxiliary Shaft Hole Cover Stud Nut	40	55
BRAKE COMPONENTS — JACOBS		
Oil Supply Screw	4–6	5–8
Jake Brake Housing Hold-Down Screw	45	61
Rocker Arm Adjusting Screw Jam Nut	45	61
Slave Piston Adjusting Screw Jam Nut	25	34
Yoke Adjusting Screw Nut (locknut on actuator pin screw)	33	44

SPECIFICATIONS

Fastener Name	Torque	
	Lb-Ft	N•m
BRAKE COMPONENTS — MACK POWERLEASH™		
Engine Brake Hydraulic Actuator Jam Nut	45	61
Rocker Arm Adjusting Screw Nut	45	61
Rocker Arm Shaft Locating Screw (1 Per Shaft Assembly)	23	31
Rocker Arm Bracket-to-Rocker Arm Shaft Screw (2 Per Shaft Assembly)	18	24
Rocker Arm Bracket-to-Cylinder Head Screw	45	61
CAMSHAFT		
Camshaft Thrust Washer-to-Cylinder Block Screw	15	20
CONNECTING ROD		
Connecting Rod Screw Angle Torque	30 + 90°	41 + 90°
CRANKSHAFT		
Vibration Damper Hub-to-Crank Screw	360	490
Vibration Damper-to-Hub Screw	45	61
CYLINDER BLOCK		
Main Bearing Capscrew (See “NOTE 2 — MAIN BEARING CAP INSTALLATION” on page 488.)	210	285
Cylinder Block Main Bearing Cap Buttress Screw (See “NOTE 2 — MAIN BEARING CAP INSTALLATION” on page 488.)	95	128
CYLINDER HEAD		
Cylinder Head Capscrew* (See “NOTE 3 — CYLINDER HEAD TORQUING” on page 488.)	205	278
Cylinder Head Cover Screw	16	22
Inlet Manifold-to-Cylinder Head Screw	40	55
ELECTRONIC UNITS		
EECU Cooler Plate-to-Isolator Nut	108 lb-in	12
EECU Isolator-to-Inlet Manifold	16	22
EECU Harness Clamp	11	15
EECU Cooler Plate Swivel Fittings	20	27
EECU-to-Cooler Plate Screw	96 lb-in	11
Electronic Unit Pump Terminal Screw	13 lb-in ± 2 lb-in	1.5 ± 0.2
Electronic Unit Pump-to-Cylinder Block Screw	60	81
EGR COMPONENTS		
EGR Mixer-to-Manifold Screw	40	55
EGR Mixer Support Bracket Screw	40	55
EGR Mass Flow System (MFS) Module Screw	48 lb-in	5.5
EGR Valve Mounting Nuts	40	55
EGR Valve and Manifold Heat Shield Screws:		
M10	20	27
M8	8	11
EGR Cooler Inlet Piping (hot side) Clamps	110 lb-in	12.4
EGR Cooler Outlet Piping (cold side) Clamps	110 lb-in	12.4

SPECIFICATIONS

Fastener Name	Torque	
	Lb-Ft	N•m
FAN DRIVE		
Fan Drive Pulley-to-Hub Screw	25	34
Poly-V Belt Tensioner Mounting Screw	40	55
FLYWHEEL, FLYWHEEL HOUSING AND CLUTCH		
Flywheel Housing-to-Cylinder Block Screw	170	230
Flywheel-to-Crankshaft Screw	185	250
Clutch-to-Flywheel Mounting Screw	40	55
Transmission-to-Flywheel Housing Screw:		
10 mm	40	55
7/16-inch	56	76
FUEL SYSTEM		
Fuel Supply Gallery Fitting Locknut	35	47
Fuel Return Gallery Fitting (check valve) Locknut	35	47
Fuel Supply Pre-Pump Filter Housing-to-Base	6–7	8–10
Fuel Supply Pump-to-Cylinder Block Screw	40	55
HEAT SHIELDS		
Heat Shield-to-Cylinder Block Mounting Screws	15	20
Heat Shield Mounting Nuts	15	20
Heat Shield Standoff Studs	18	24
INLET MANIFOLD		
Inlet Manifold-to-Cylinder Head	40	55
INJECTOR NOZZLE AND NOZZLE FUEL INLET TUBE		
Injection Nozzle Holder Hold-Down Screw	45	61
Nozzle Fuel Inlet Tube Line Nut at Cylinder Head	35	47
Nozzle Fuel Inlet Tube Line Nut at EUP	25	34
OIL COOLER — Plate-Type		
Oil Cooler Tube-to-Water Pump (MR model stud)	20	27
Oil Cooler Tube-to-Water Pump	40	55
Oil Cooler-to-Bracket	20	27
Oil Cooler/Oil Filter Bracket Fittings 1/4 NPT (turbo, REPTO)	12	16
Oil Cooler/Oil Filter Bracket-to-Cylinder Block	40	55
OIL FILTER		
Centrifugal Oil Filter Drain Fitting Stud Nut	40	55
Centri-Max® ULTRA or ULTRA PLUS Spud/Spindle	26	35
Centri-Max® ULTRA or ULTRA PLUS Cover	19	26
Oil Filter Adapter-to-Oil Cooler Bracket Screw	40	55
OIL PAN		
Oil Pan Drain Plug	55	75
Oil Pan-to-Cylinder Block Shoulder Bolt/Stud	20	27

Fastener Name	Torque	
	Lb-Ft	N•m
OIL PUMP		
Oil Pump Cover-to-Housing Screw	15	20
Oil Pump-to-Cylinder Block Mounting Screw	40	55
Oil Pump Shaft Driven Gear Retaining Nut	60	81
Oil Pump Inlet Fitting-to-Oil Pump Housing Screw	35	47
Oil Pump Pressure Relief Valve Cap	80	108
PISTON COOLING		
Piston Cooling Nozzle-to-Cylinder Block Screw	15	20
SENSORS (FOR DASH GAUGES)		
Coolant Temp. (1/2 NPT, side mount on water manifold)	23	31
Oil Temp. (1/4 NPT, mount on oil filter pedestal)	18	24
Oil Temperature (1/2 NPT, side mount on oil pan)	23	31
SENSORS (V-MAC III)		
Air Temperature (3/8 NPT)	18	24
Ambient Air Temperature (1/2 NPT)	23	31
Boost Air Temperature (M16 x 2)	28	38
Coolant Temperature (3/8 NPT, rear mount on water manifold)	23	31
Fuel Temperature (3/8 NPT)	23	31
Oil Pressure (1/8 NPT)	13.5	18
Oil Temperature (3/8 NPT) Optional	23	31
Engine Speed and Position (flywheel housing and engine front cover)	7	10
Turbocharger Wheel-Speed Sensor	9	12
TIMING GEAR COVER (ENGINE FRONT COVER)		
Breather Mounting Screws	15	20
Front Engine Mounting Bracket-to-Crossmember	180	245
Timing Cover and Front Support Bracket-to-Cylinder Block Screw	70	95
Timing Cover-to-Cylinder Block Screw	40	55
TURBO AND EXHAUST MANIFOLD		
Turbo-to-Exhaust Manifold Stud Nut	100	136
Turbo Oil Inlet Tube-to-Turbo Screw	15	20
Turbo Oil Drain Tube-to-Turbo Screw	15	20
Exhaust Manifold-to-Cylinder Head Stud (Install with Loctite® 272. See “NOTE 4 — EXHAUST MANIFOLD TORQUING” on page 488.)	20 (Dry)	27 (Dry)
Exhaust Manifold-to-Cylinder Head Stud Nut (12 mm full threaded stud, See “NOTE 4 — EXHAUST MANIFOLD TORQUING” on page 488.)	100	136
Turbo Drain-to-Cylinder Block Screw	40	55
Turbo Center Bearing-to-Turbo Housing	30	41
Turbo Compressor Housing Clamp Band Retaining Nut	105 lb-in	11.9

SPECIFICATIONS

Fastener Name	Torque	
	Lb-Ft	N•m
VALVE ROCKER ARM		
Valve Rocker Arm Bracket-to-Cylinder Head Screw	40	55
Valve Rocker Arm Adjusting Screw Jam Nut	45	61
Valve Yoke Adjusting Screw Jam Nut (See “NOTE 5 — VALVE YOKE SETTING” on page 489.)	33	45
Valve Rocker Arm Shaft Locating Screw:		
Non-Brake/J-Tech™	23	31
PowerLeash™	23	31
VTG CONTROL VALVE		
VTG Control Valve Mounting Screw	15	20
VTG Control Valve Air Fitting Jam Nut	19	25.8
WATER MANIFOLD AND WATER PUMP		
Water Manifold-to-Cylinder Head Screw	40	55
Water Pump Inlet Tube Screw	40	55
Water Pump Housing-to-Cylinder Block Screw:		
M12	69	94
M10	40	55
Water Pump Slotted Insert (M27)	50 in-lb	5.6
Water Pump Stiffening Bracket (8M Flanged Nut)	20	27
Water Pump Cartridge to Water Pump Housing Screw	17	23
MISCELLANEOUS		
Air Conditioner Compressor Mounting Bracket-to-Engine Block	69	94
Air Conditioner Compressor Mounting Bracket-to-Timing Cover	48	68
Air Conditioner Compressor-to-Radiator Support	17	23
Alternator Mounting Stud Nut	70	95
Battery Cable (stud type)	10–15	14–20
Coolant Conditioner Adapter Mounting Screw	15	20
Hydraulic Steering Pump-to-Engine Front Cover Stud Nut	40	55
Idler Gear Hub-to-Cylinder Block Screw	70	95
Oil Dipstick Hole Plug (M20 tapered thread)	20	27
Oil Dipstick Hole Plug (M16 x 1.5)	20	27
Oil Dipstick Guide Tube Compression Nut (at oil pan)	20	27
Oil Dipstick Guide Tube Screw (at Filter Bracket)	24 lb-in	3
Radiator Mount-to-Front Crossmember	85	115
Radiator Tie Bar-to-Radiator Side Bracket	30	41
Starter Motor Wiring Harness:		
1/2 x 13	22.5	30.5
#10–32	23 lb-in	2.6

TORQUE SPECIFICATIONS FOR HOSE CLAMPS

HOSE CLAMPS (SEE “NOTE 6 — HOSE CLAMP INSTALLATION POSITIONING INFORMATION” ON PAGE 489.)

	Torque	
Fastener Name	**Lb-In**	**N•m**
For Standard SAE J536 Type F Hose Clamps:		
Air Inlet Systems	38	4
Oil Drain Systems	28	3
Water or Coolant Systems	28	3
Hi-Torque Heavy-Duty Worm Clamp	80	9
T-Bolt Type Hose Clamp	50	6
Constant Torque (Bellville Spring) Clamp	55	6.2
Dual Bead Clamps	38	4.3

TORQUE SPECIFICATIONS FOR PIPE PLUGS

PIPE PLUGS (SEE “NOTE 7 — PIPE PLUG SEALING” ON PAGE 489.)

	Torque	
Pipe Plug Size	**Lb-Ft**	**N•m**
1/8 NPT	6	8
1/4 NPT	18	24
3/8 NPT	23	31
1/2 NPT	23	31
3/4 NPT — Cylinder Head 3/4 NPT — Other	55 35–65	68 48–88
1 NPT	43	58
1-1/4 NPT	75	101

TORQUE SPECIFICATIONS FOR ENGINE-MOUNTED SENSORS

ASET™ AC ENGINE-MOUNTED SENSORS

Description	Sensor and Sensor Mounting Hardware	Sensor Threads	Mounting Torque
Air Temperature Sensor (wide range and fast response)	64MT450 sensor only; sensor is used in three locations: • Compressor discharge temperature • CMCAC outlet temperature • Inlet manifold temperature **NOTE** Reinstallation of this sensor requires application of stainless steel pipe thread sealing tape. This tape is identified as Mill-Ross type TF5-28, catalog number 70981-st, size 1/2" x 260".		23 lb-ft (31 N•m)
Ambient Air Temperature Sensor (mounted at front of chassis)	64MT2118M	Press Fit (Snap In)	N/A
Boost Air Temperature Sensor	64MT445 sensor only (no washer required)	1/2-inch NPT English pipe threads	23 lb-ft (31 N•m)
Boost Pressure Sensor	46MT446	1/4-inch NPT	18 lb-ft (24 N•m)
Coolant Temperature Sensor (dash gauge)	64MT2112M sensor only	1/2-inch NPT English pipe threads	23 lb-ft (31 N•m)
Coolant Temperature Sensor (V-MAC III)	64MT2103 sensor only	3/8-inch NPT English pipe threads	23 lb-ft (31 N•m)
Engine Position Sensor	64MT348M sensor and 505GC28 P15 and P30 shims, as required. Sensor is retained by one 66AM3 capscrew with M6 x 1.0 metric threads.	None	7 lb-ft (10 N•m)
Engine Speed Sensor	64MT348M sensor and 505GC28 P15 and P30 shims, as required. Sensor is retained by one 66AM3 capscrew with M6 x 1.0 metric threads.	None	7 lb-ft (10 N•m)
Fuel Temperature Sensor	64MT2103 sensor only	3/8-inch NPT English pipe threads	23 lb-ft (31 N•m)
Oil Pressure Sensor	64MT2114 sensor only	1/8-inch NPT English pipe threads	13.5 lb-ft (18 N•m)
Oil Temperature Sensor (electronic dash gauge)	64MT2103 (Sensor mounts in oil filter pedestal.)	3/8-inch NPT English pipe threads	23 lb-ft (31 N•m)
Oil Temperature Sensor (standard dash gauge)	64T2116 (Sensor mounts in oil filter pedestal.)	3/8-inch NPT English pipe threads	23 lb-ft (31 N•m)
VTG Turbocharger Position Sensor	Not serviced separately; replaced as part of actuator assembly.	—	—
VTG Turbocharger Wheel-Speed Sensor	64MT457	M10 x 1	9 lb-ft (12 N•m)

⚠ CAUTION

Overtorquing a sensor or sensor mounting screw can result in sensor breakage or thread damage.

TORQUE SPECIFICATIONS FOR NON-CRITICAL FASTENERS

PROPERTY CLASS 8.8

Size (mm)	Pitch	Tightening Torques	
		Lb-Ft	N•m
6	0.75	6	8
6	1.00	6	8
8	1.00	15	20
8	1.25	14	19
10	1.25	30	41
10	1.50	28	38
12	1.25	55	75
12	1.75	50	68
14	1.50	86	117
14	2.00	80	109
16	1.50	133	180
16	2.00	124	168
18	1.50	193	262
18	2.50	172	233
20	1.50	270	366
20	2.50	244	331
22	1.50	365	495
22	2.50	332	450
24	2.00	459	622
24	3.00	421	571
27	2.00	666	903
27	3.00	618	838
30	2.00	928	1258
30	3.50	838	1136
33	2.00	1250	1695
33	3.50	1140	1546
36	3.00	1551	2103
36	4.00	1465	1986

PROPERTY CLASS 9.8

Size (mm)	Pitch	Tightening Torques	
		Lb-Ft	N•m
6	0.75	7	10
6	1.00	6	8
8	1.00	16	22
8	1.25	15	20
10	1.25	33	45
10	1.50	31	42
12	1.25	59	80
12	1.75	54	73
14	1.50	94	127
14	2.00	87	118
16	1.50	144	195
16	2.00	135	183
18	1.50	210	285
18	2.50	187	254
20	1.50	293	397
20	2.50	264	358
22	1.50	395	536
22	2.50	360	488
24	2.00	498	675
24	3.00	456	618
27	2.00	722	979
27	3.00	669	907
30	2.00	1005	1363
30	3.50	908	1231
33	2.00	1355	1837
33	3.50	1235	1674
36	3.00	1681	2279
36	4.00	1587	2152

PROPERTY CLASS 10.9

		Tightening Torques	
Size (mm)	Pitch	Lb-Ft	N•m
6	0.75	9	12
6	1.00	8	11
8	1.00	21	29
8	1.25	20	27
10	1.25	42	57
10	1.50	40	54
12	1.25	76	103
12	1.75	69	94
14	1.50	120	163
14	2.00	111	151
16	1.50	184	250
16	2.00	172	233
18	1.50	268	363
18	2.50	239	324
20	1.50	374	507
20	2.50	337	457
22	1.50	505	685
22	2.50	460	624
24	2.00	636	862
24	3.00	583	790
27	2.00	922	1250
27	3.00	855	1159
30	2.00	1284	1741
30	3.50	1159	1571
33	2.00	1730	2346
33	3.50	1578	2140
36	3.00	2146	2910
36	4.00	2027	2748

SPECIFICATION FOOTNOTES

NOTE 1 — AUXILIARY SHAFT GEAR RETAINING NUT INSTALLATION

- A new nut has pre-applied thread locker. No degreasing of a new nut is recommended. However, degrease the shaft threads thoroughly with Loctite® Primer-T, or equivalent, prior to nut installation.
- It is acceptable to reuse an auxiliary drive gear retaining nut. If reusing a nut, the nut threads, as well as the shaft threads, must also be thoroughly cleaned with Loctite® Primer-T, or equivalent. Then, apply Loctite® 271 or 277 on the nut and shaft threads.
- Whether using a new or revised nut, it is critical that the ground face of the nut (if applicable) be installed toward the gear. Any identifications on the nut face must be installed away from the gear.

NOTE 2 — MAIN BEARING CAP INSTALLATION

Main bearing cap assembly shall be performed in the following steps:

1. Buttress screws installed finger-tight in order to align the hole in the block and the hole in the main bearing cap.
2. Main bearing capscrews torqued.
3. Buttress screws torqued.

NOTE 3 — CYLINDER HEAD TORQUING

Cylinder head assembly and torquing is to be performed as follows:

1. Oil all cylinder head capscrew bosses, capscrew threads and washers with clean engine oil prior to assembly. Do not oil threads in the cylinder block. Using torque wrench J 24407, or equivalent, tighten the capscrews to specification in three stages on any one head in the proper sequence, as shown in the “Engine Reassembly” procedures section.
   a. Initially, torque all capscrews in sequence to 50 lb-ft (68 N•m).
   b. Tighten all capscrews in sequence to 125 lb-ft (170 N•m).
   c. Tighten all capscrews in sequence to the final torque value of 205 lb-ft (278 N•m).
2. After completing the run-in procedure, in sequence, back off each capscrew individually until free. Then, retorque the same capscrew to 205 lb-ft (278 N•m).

NOTE 4 — EXHAUST MANIFOLD TORQUING

NOTE

On some engines, the exhaust manifold-to-cylinder head stud hole may be drilled deep enough to allow the stud to enter the push rod bore. In these instances, the 20 lb-ft (27 N•m) torque may not be reached until the stud contacts the push rod. In all cases, a stud protrusion of 1.75 inches (44.45 mm) must be maintained.

1. Oil the nut threads and flanges with clean engine oil and install the 12 retaining nuts.
2. Tighten the nuts in two stages per the following sequence:
   - First stage — 50 lb-ft (68 N•m)
   - Second stage — 100 lb-ft (136 N•m)

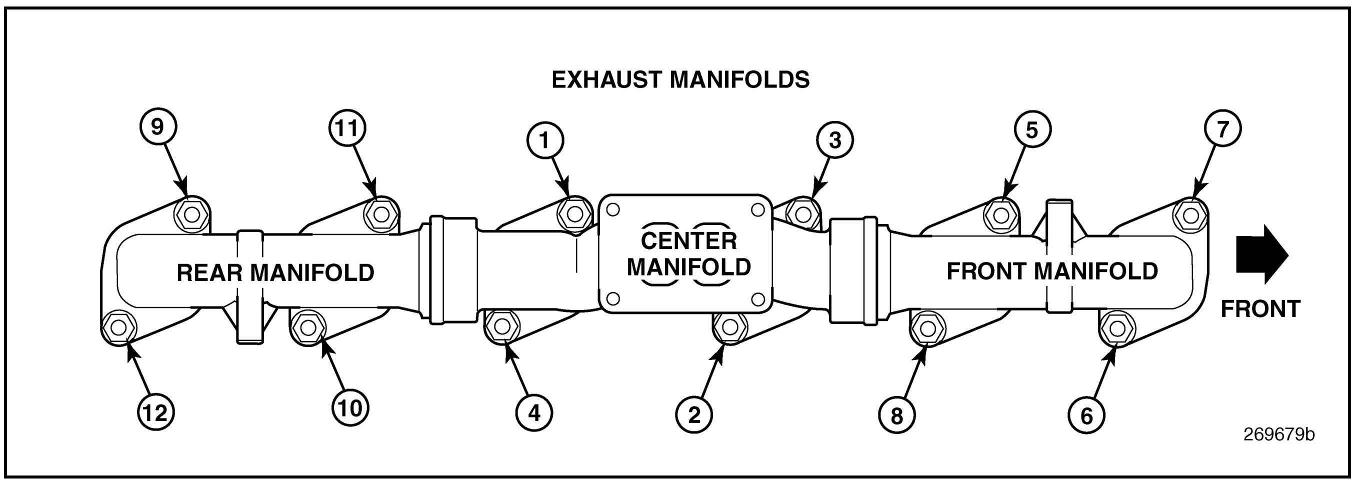


Figure 578 — Exhaust Manifold Tightening Sequence

NOTE 5 — VALVE YOKE SETTING

1. Push down on the slipper face of the yoke. Turn down the yoke adjusting screw until it contacts the outboard valve stem tip, as sensed by a light drag on the adjusting screw.
2. Turn the adjusting screw an additional 60 degrees (1/6 turn) clockwise.
3. Holding the yoke adjusting screw in this position, lock the jam nut.

NOTE 6 — HOSE CLAMP INSTALLATION POSITIONING INFORMATION

The band of any hose clamp in all installations should be a minimum of 0.090 inch (2.3 mm) from the end of the hose and must be clear of the tube bead.

NOTE 7 — PIPE PLUG SEALING

All pipe plugs must be sealed using Loctite® PST pipe thread sealant with Teflon®, or equivalent.

NOTE 8 — CYLINDER SLEEVE ID

Cylinder sleeve ID may be 4.872 inches (123.749 mm) minimum at the top of the sleeve due to close-in from the press fit.

NOTE 9 — REAR SEAL BORE RADIAL RUNOUT

Runout is to be checked with an alignment bar installed through the cylinder block main bearing bores.

ASET™ ENGINE ASSEMBLY LUBRICANTS AND SEALANTS

Use only the following recommended sealing compounds and lubricants.

NOTE

All genuine MACK cylinder head gaskets are precoated and do not require any type of sealing compound. Before installing **new** gaskets, degrease both gasket sealing surfaces to avoid leaks.

Location	Sealant or Lubricant
Camshaft gear assembly	Loctite® 609
Cup plugs/threaded plugs	Loctite® 277 or equivalent/Teflon® thread sealer
Injection nozzle holder inserts (upper and lower end)	Loctite® 620
Chassis-mounted charge air cooling system (core sealing)	Dow Corning® No. 1200 primer, Dow Corning® RTV 734 adhesive (clear), and naphtha solvent or equivalent
Cylinder sleeve seat	MACK Silastic (RTV silicone adhesive sealant) part No. 342SX32
Oil filter sealing gasket	Clean engine oil
Holding metal parts in place	MACK MG-C grease or petroleum jelly (Vaseline®)
Valve stems and guides	Dow Corning® BR2 Plus Multi-Purpose Grease
Engine front cover (timing gear cover)	MACK Silastic (RTV silicone adhesive sealant) part No. 342SX32
Engine parts, fasteners (sides and threads), and washers	Clean engine oil
Exhaust manifold studs	Loctite® 272 high temperature thread sealer
Oil cooler assembly	Permatex® gasket sealer
Oil cooler assembly O-ring	Drydene® No. 4000
O-rings (except as noted)	MACK O-ring lubricant, part No. 243SX41
Sensor, air temperature wide range and fast response (compressor discharge temperature)	Mill-Rose type TF5-28, catalog No. 70981-ST, size 1/2″ x 260″ stainless steel pipe thread sealing tape
Sensor, engine oil pressure and temperature	Sealing compound on threads
Sensor, inlet manifold air temperature	
Sensor, coolant temperature	
Sensor, coolant level	
Sensor, air humidity	
Sensor, CMCAC outlet temperature and pressure	
Crankshaft flange and wear ring	Loctite® 609
Turbocharger mounting nuts	Clean engine oil
Centri-Max® ULTRA or ULTRA PLUS spindle threads	Loctite® 271

ASET™ AC ENGINE DRIVE BELT SPECIFICATIONS

Fan Drive		A/C	Belts		Tensioner Part No.
Mounting	**Ratio**		**Length**	**Part No. (HL No.)**	
10-Rib Poly-V Belt (Main Drive)					
High	1.68:1	—	67.8 in. (172.2 cm)	88GB449P678 (HL62-87)	87GB41
Low	1.68:1	—	55.5 in. (141.0 cm)	88GB449P555 (HL62-84)	87GB45
6-Rib Poly-V Belt (Accessory Drive)					
High	1.68:1	Yes	84.75 in. (215.3 cm)	88GB450P847	87GB46
High	1.68:1	No	67.0 in. (170.2 cm)	88GB450P670	87GB44
Low	1.68:1	Yes	73.5 in. (186.7 cm)	88GB450P735	87GB46
Low	1.68:1	No	58.5 in. (148.6 cm)	88GB450P585	87GB44

SCHEMATIC & ROUTING DIAGRAMS

ASET™ AC ENGINE SYSTEMS SCHEMATICS

Cooling System Flow Diagrams

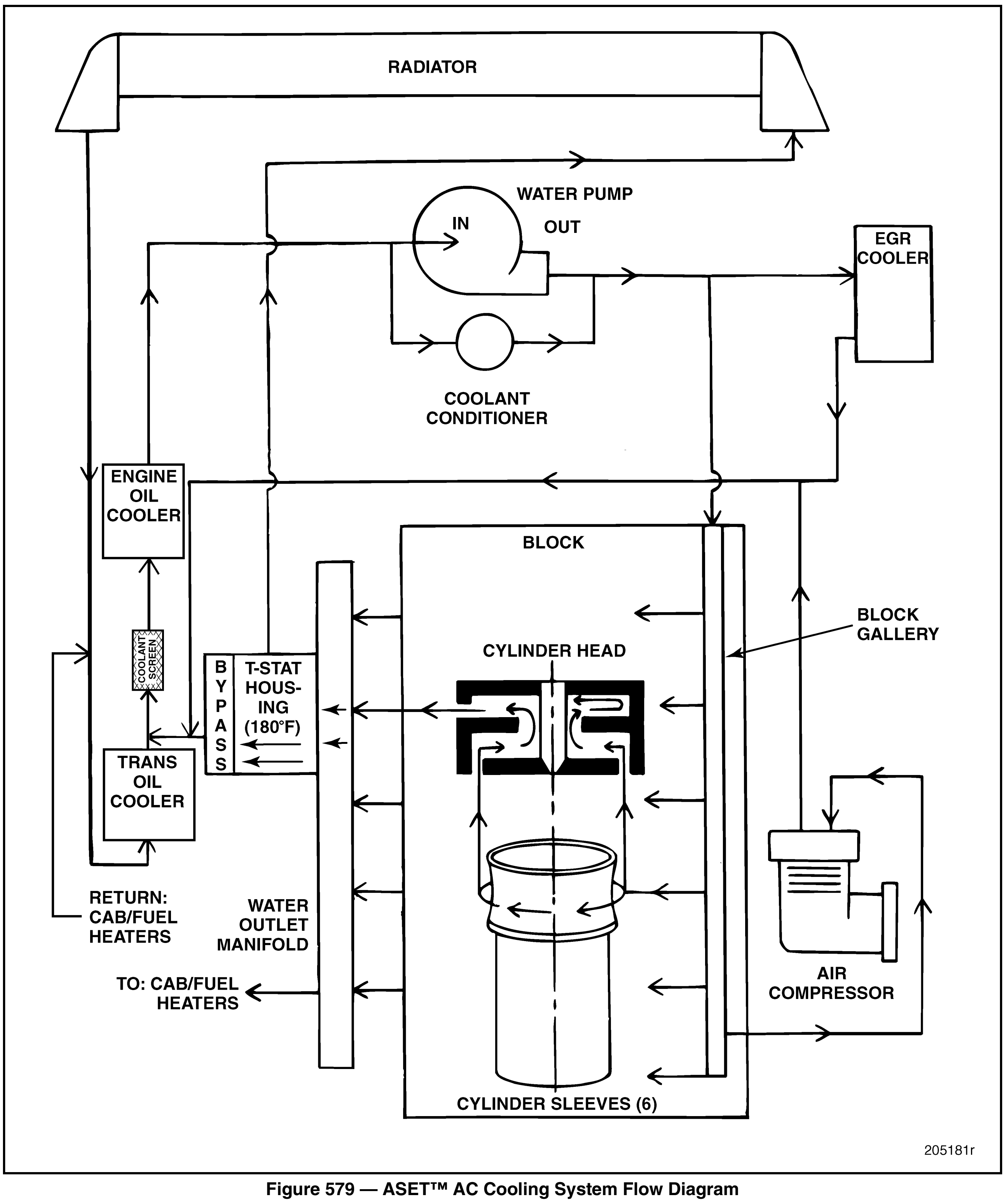


Figure 579 — ASET™ AC Cooling System Flow Diagram

Lubrication System Flow Diagrams

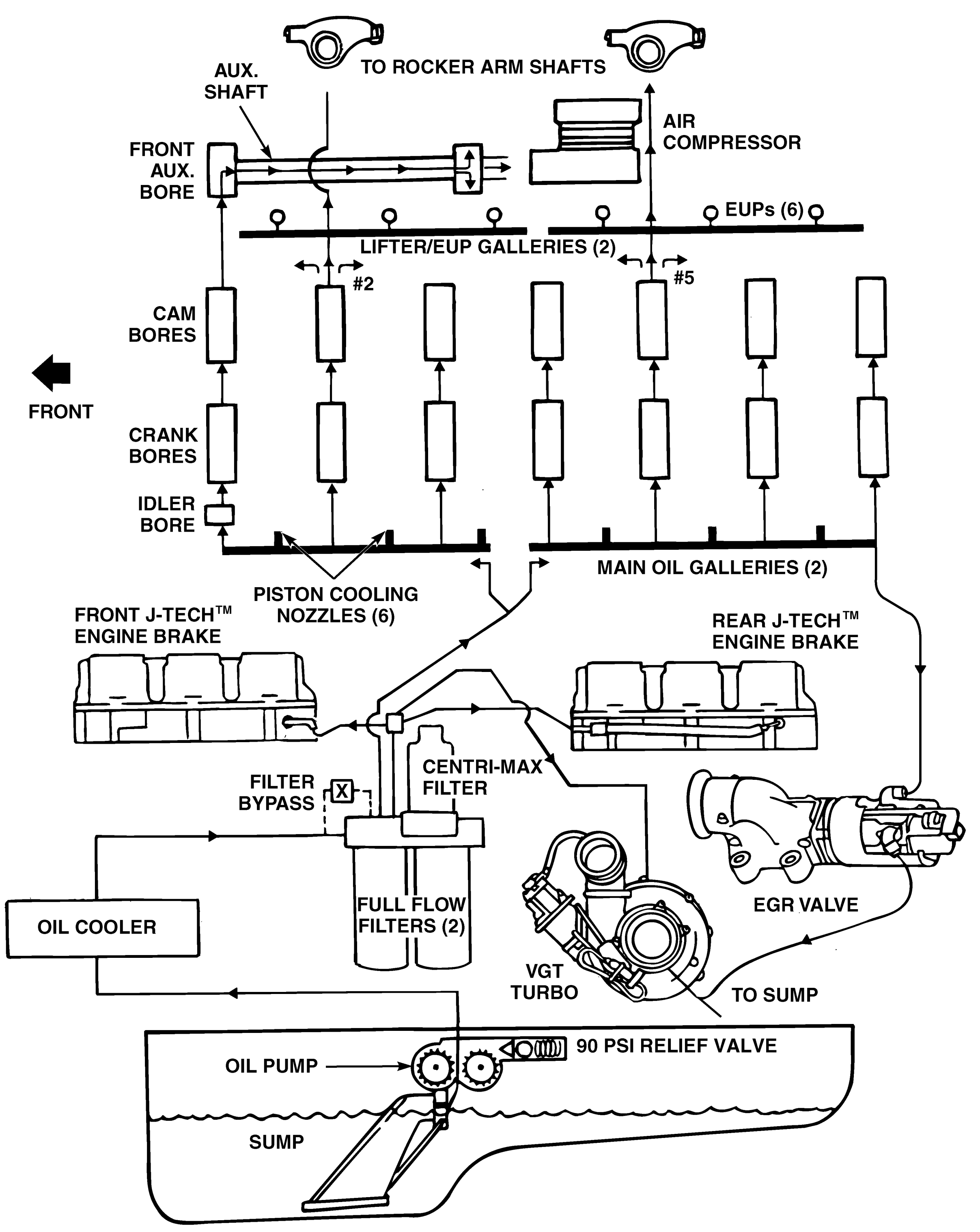


Figure 580 — ASET™ AC Lubrication System Flow Diagram

Fuel System Flow Diagrams

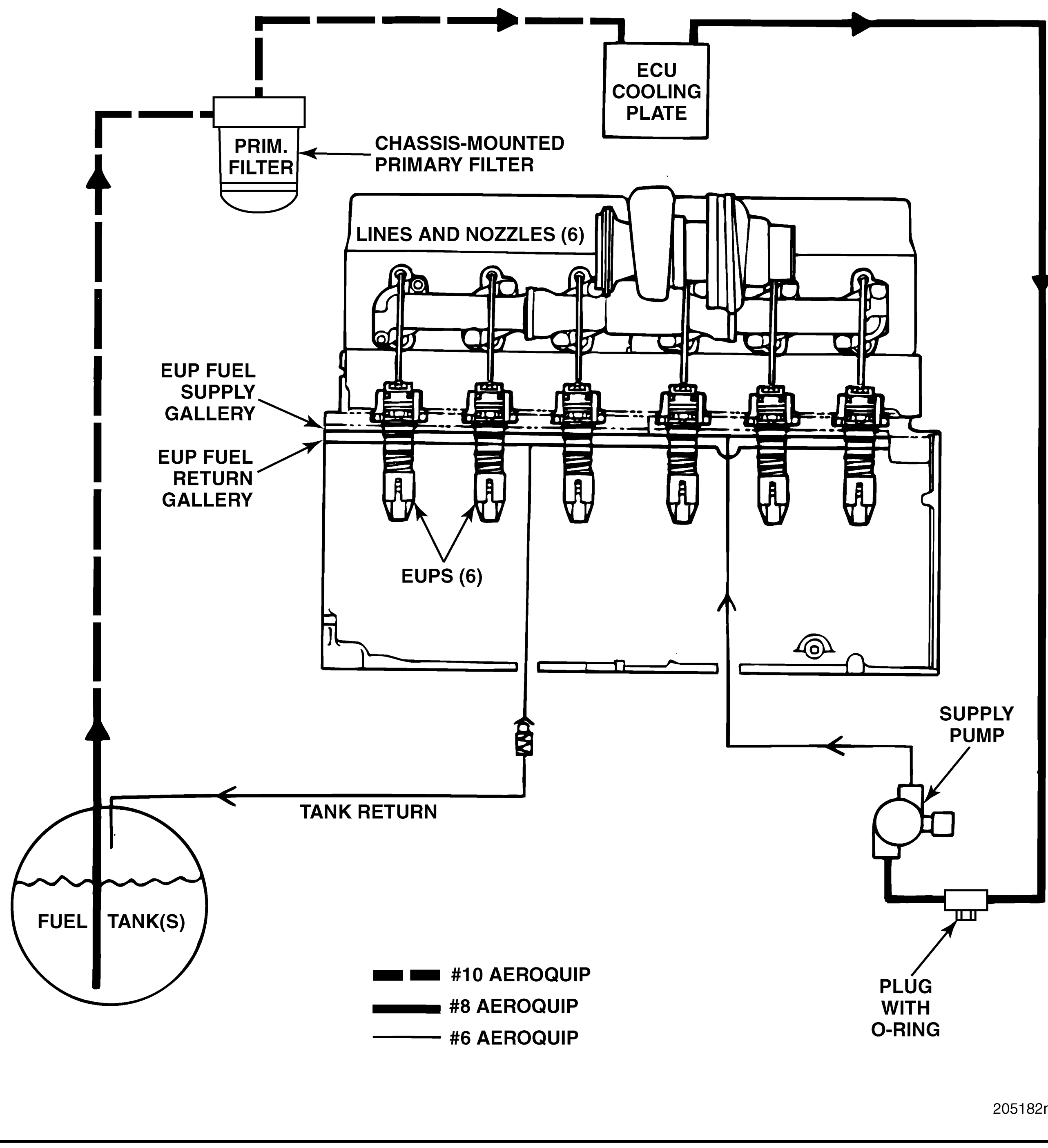


Figure 581 — Fuel System Flow Diagram, ASET™ AC Engine Standard Fuel Filter Arrangement with Chassis-Mounted Primary Filter (December 22, 2003 and Later Production)

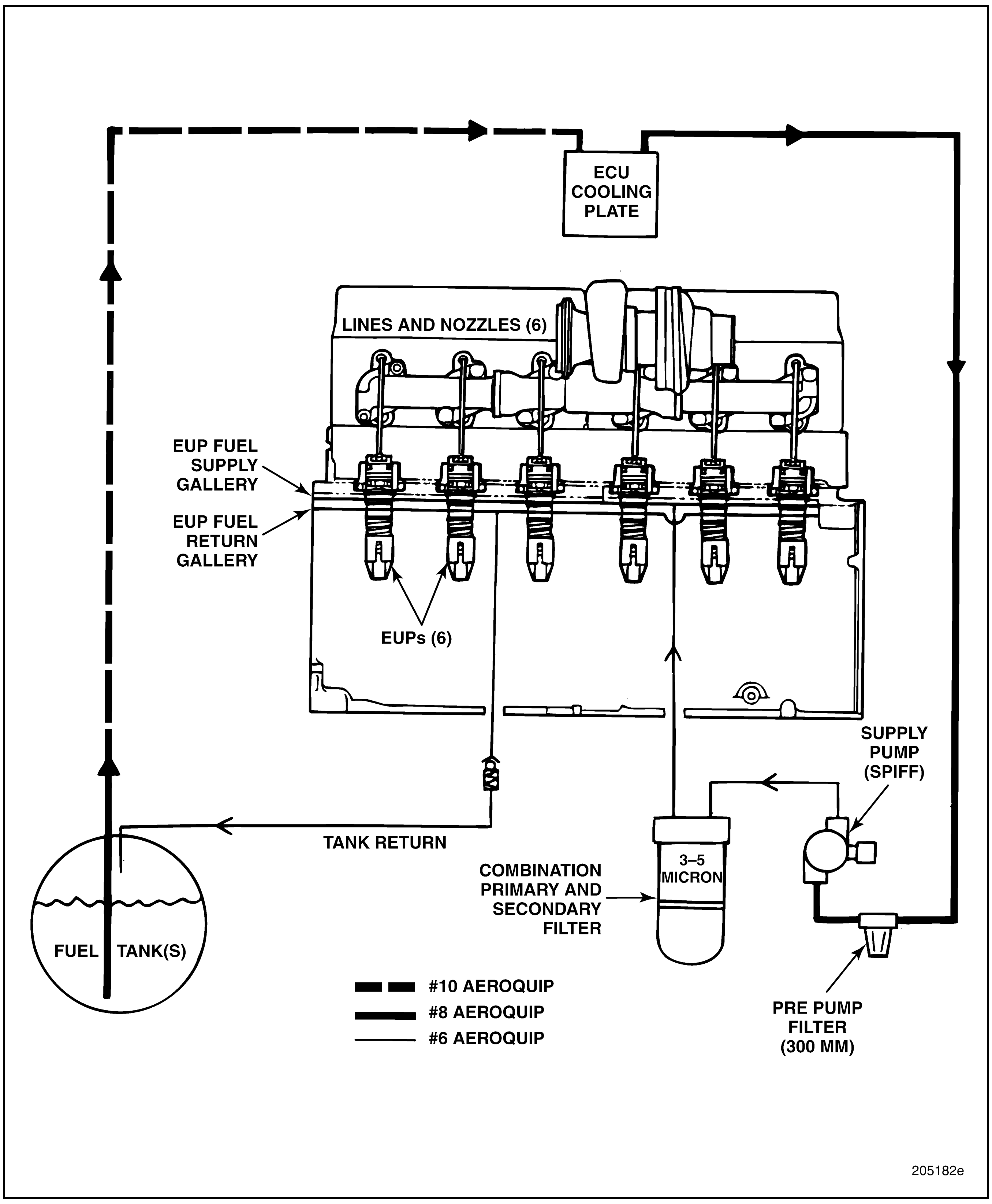


Figure 582 — Fuel System Flow Diagram, ASET™ AC Engine Standard Fuel Filter Arrangement with Pre-Pump Filter (Production Prior to December 22, 2003)

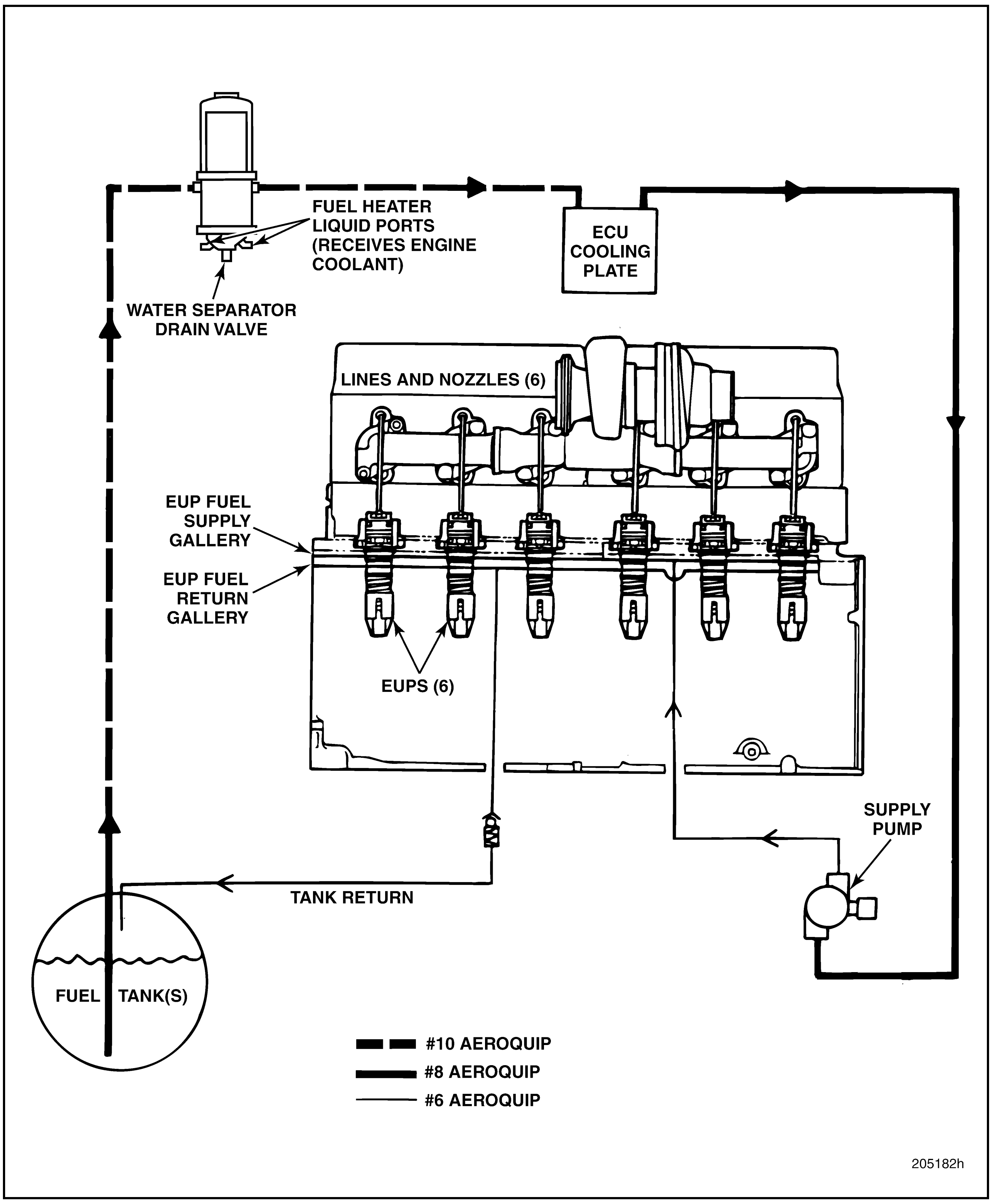


Figure 583 — Fuel System Flow Diagram, ASET™ AC Engine with Optional Fuel Filter Arrangement

Accessory Drive Belt Routings

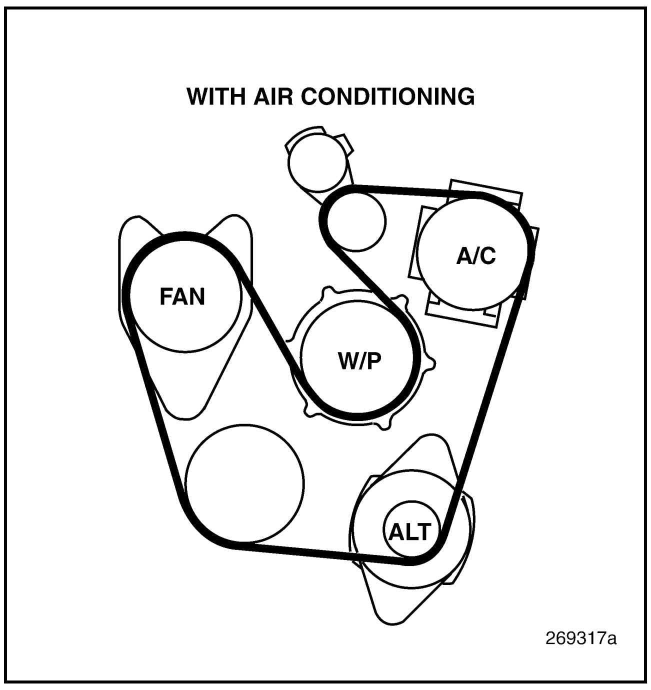


Figure 584 — Accessory Drive Belt Routing with AC

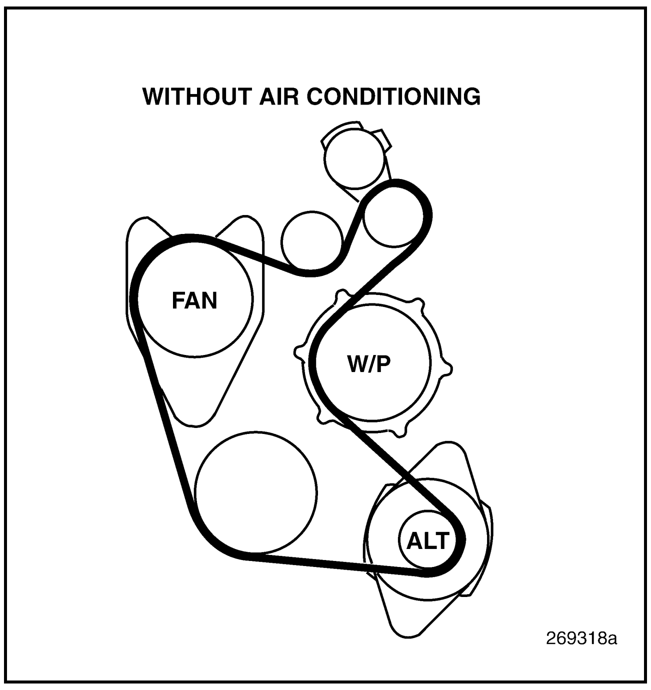


Figure 585 — Accessory Drive Belt Routing without AC

NOTES

SPECIAL TOOLS & EQUIPMENT

ASET™ ENGINE SPECIAL TOOLS

Special Tools for Engine Overhaul

Tool No.	Description
814	Midget Seal Tool
HT77136	Valve Seat Insert Counterbore
J 2619-01	Slide Hammer
J 5347-B	Dial Bore Gauge
J 5853-C	Torque Wrench (3/8 DR, 0–600 lb-in)
J 5902-01	Cylinder Hone and Glaze Breaker
J 6125-1B	Slide Hammer (5/16-18 thread with 3/8-16 adapter)
J 6692-B	Cylinder Compression Gauge
J 7872	Magnetic Base Indicator Tool
J 8092	Universal Driver Handle (threaded 3/4-10)
J 21428-01	Camshaft Bushing Remover and Installer Set
J 21588	Injector Gasket Retriever
J 21834-4A	Two Jaw Adjustable Puller
J 22738-02	Universal Spring Tester, Model MST 50
J 23442	Piston Ring Compressor
J 23775-01	Torque Wrench (100–600 lb-ft)
J 24406	Torque Wrench (15–100 lb-ft)
J 24407	Torque Wrench (30–250 lb-ft)
J 24783	Fuel/Oil Filter Wrench (spin-on)
J 25026-A	Flywheel Lifting Sling
J 26589	Nozzle Insert Carbon Reamer
J 26637-A	Thermostat Seal Installer
J 26948	Depth Gauge
J 29075-B	Fuel Injection Nozzle Tester (use with J 42639 Adapter Set)
J 29109	Engine Stand
J 29294-B	Valve Spring Compressor (for valves with bottom rotators)
J 29296	Valve Yoke Guide Pin Installer
J 29297	Nozzle Sleeve Installer
J 29510	Keystone Piston Ring Groove Gauge
J 29539-15	Top Dead Center Indicator Metric Adapter
J 29539-A	Top Dead Center (TDC) Indicator
J 29600-C	Fire Ring Groove Cutter
J 29880	Nozzle Sleeve Extractor
J 29919	T-Handle Torque Screwdriver
J 34046-A	Compression Gauge Adapter Set
J 34046-5	Compression Tester Metric Adapter (used with J 34046-A)
J 34684	Cylinder Head Core Plug Installer (13/16 inch)
J 34687	Cylinder Head Core Plug Installer (1-1/16 inch)

Tool No.	Description
J 35529	Wear Ring and Seal Installer
J 37077	Position Sensor
J 37093	Injection Nozzle Puller
J 37481	Valve Guide Reamer (3/8-inch diameter)
J 37482	Valve Guide Remover (3/8 inch)
J 37712	Flywheel Housing/Timing Cover Locating Pin Driver
J 37713	Camshaft Bushing Installation Removal Kit (use with J 21428-01 Kit)
J 37715-A	Crankshaft Front Seal Installer
J 37715-2	Crankshaft Front Seal Installation Spacer (use with J 37715-A Front Seal Installer)
J 37716-A	Rear Seal Installer
J 37716-B	Crankshaft Rear Seal Installer
J 37717	Connecting Rod Bushing Remover/Installer
J 37718	Piston Pin Burnishing Broach
J 37719	Fire Ring Groove Cutter
J 37720-C	Tappet Holders
J 37809	Valve Guide Installer (3/8 inch, non-current)
J 38048	Engine Stand Adapter Plate
J 38586	Valve Seat Installation Set
J 38587-A	Engine Barring Socket
J 38820-1	Valve Stem Seal Removal (non-current)
J 38880	Wear Ring Installer
J 39045	Two-Piece Piston Cooling Nozzle Aimer
J 39258-A	Engine Pre-Luber
J 39460	Valve Stem Seal Remover (non-current)
J 39500-B	A/C Recovery and Recycling Unit (R-134a)
J 41071	Air Compressor Coupling Holding Wrench
J 41251-B	Belt Tension Gauge
J 41461	Camshaft Removal/Installation Tool
J 41473	Charge Air Cooler Tester
J 41682	Camshaft Removal/Installation Guide
J 41683	Valve Roller Follower H-Ring Installer
J 42185	Belt Tension Gauge
J 42377	Camshaft Bushing Remover/Installer (use with J 21428-01 Cam Bushing Remover/Installer Set)
J 42425	Valve Lifter/Roller Follower Magnetic Retainers (use with top rods from J 37720-B Tappet Holder Kit)
J 42426	Valve Roller Follower H-Ring Remover (use with J 6125-1B Slide Hammer)
J 42453	Valve Seal Installer
J 42490	Camshaft Cup Plug Installer (use with J 8092 Driver Handle)
J 42595	Fuel Injection Nozzle Sleeve Installer

Tool No.	Description
J 42639	Fuel Injection Nozzle Tester Adapter Set (use with J 29075-B Nozzle Tester)
J 42678	Fuel Injection Nozzle Sleeve Puller (use with J 2619-01 Slide Hammer)
J 42680	Fuel Injection Nozzle Combustion Gasket Seat Carbon Reamer
J 43887	Valve Spring Compressor (for valves with tip-end rotators)
J 45730	Valve Stem Seal Installer
J 45796	Valve Seat Removal Set
J 45915	Valve Stem Seal Remover (current production)
J 46549	Valve Guide Installer (current production)
J 47019	Turbo Actuator Spanner Wrench (AC engine only)
PT2210	Counterbore Tool
PT2210-14	Hex Key Wrench
PT2210-3A	Counterbore Cutter Plate
PT5025	Universal Dial Depth Gauge
PT5025-11	3-inch Stylus Extension
PT 5027	Cylinder Head/Block Straightedge (36 in.)
PT5035	Flywheel Housing Dial Indicator Set
PT5035-1	Flywheel Housing Indicator Extension
PT6390	Valve Seat Extractor Kit (complete with collets)
PT6390-4	Collet
PT6391	Valve Seat Extractor Kit (basic)
PT6435	Cylinder Liner/Sleeve Puller (lubricate with extreme pressure lubricant J 23444-A)
PT6570-11	Dowelout, Extractor (7/16 inch)
PT6575	Basic Heavy-Duty Dowelout Kit
PT6587	Piston Ring Expander
PT7070-A	Piston Ring Compressor
00-18238	Jacobs Slave Piston Tool
014177	Jacobs Thickness Gauge, 0.085 inch (2.16 mm)
018781	Jacobs Thickness Gauge, 0.080 inch (2.03 mm)
021327	Jacobs Thickness Gauge, 0.100 inch (2.54 mm)
022001	Jacobs Thickness Gauge, 0.060 inch (1.52 mm)
945-6041	Connecting Rod Fixture (Sweeney)
Model 1510-MTH	Ultrasonic Nozzle Cleaner (Process Equipment & Supply [800-539-6336])

Above tools are available from Kent-Moore (except as noted):

KENT-MOORE
O.E. TOOL AND EQUIPMENT GROUP
SPX CORPORATION
28635 MOUND ROAD
WARREN, MICHIGAN 48092-3499
TEL: 1-800-328-6657
FAX: 1-800-578-7375

V-MAC III Special Tools

Tool No.	Description
J 37490	Diesel Electronic Connector Replacement Kit
J 38351-B	Serial Link Adapter Assembly
J 38480	Portable Printer (use with J 38500-1)
J 38500-1	Pro-Link Diagnostic Scan Tool
J 38500-60A	Pro-Link Cable (to vehicle), 6-Pin Deutsch
J 38500-61	PC Interface Cable
J 38500-63	Serial Link Jumper (Deutsch-to-Deutsch)
J 38500-630A	Pro-Link V-MAC III Diagnostic Cartridge
J 38500-1500C	Pro-Link Multi-Protocol Cartridge
J 38581	Connector, Test Adapter Kit
J 38582	Terminal Crimping and Removal Tool Kit
J 38675B	Pro-Link® 9000 Analyzer with V-MAC III Diagnostic Cartridge
J 38740	V-MAC Hub Barring Tool
J 38748	V-MAC Test Lead, 7-Pin Connector
J 39200	Fluke Model 87 Digital Multi-Meter
J 47021	Terminal Probe for Size 16 and 20 Terminal Sockets

APPENDIX

FASTENER IDENTIFICATION

Fastener Selection and Installation

Selection and correct installation of threaded fasteners are essential parts of any assembly or rebuild procedure. Fasteners hold much of a vehicle together. If a fastener fails to do its job properly, it can cause a minor problem such as a loose mirror, or a large problem, such as loss of steering control.

Because there are so many styles of fasteners, in various sizes and quality grades, a mechanic must have a working familiarity with the fasteners commonly used in vehicles. Only in this way can the correct selection and installation of the proper fastener be ensured. Each fastener is intended to do a particular job, and is selected by the vehicle manufacturer for its suitability for that job.

Equally important as the selection of the correct fastener is its proper installation. Improperly installing a correct fastener is just as bad as using an incorrect one. Undertightening and overtightening both result in an improperly installed fastener. When threaded fasteners are tightened, a slight stretching of the fastener occurs, and it is this elongation that binds the assembly together. If too little tightening occurs, the slight stretching does not happen, and the joint is not clamped securely. If too much tightening occurs, the fastener will be stretched too much, causing narrowing of the fastener and possible breaking. Correct and consistent use of a torque wrench will ensure that the fasteners are properly tightened, and therefore are clamping the pieces of the assembly together properly.

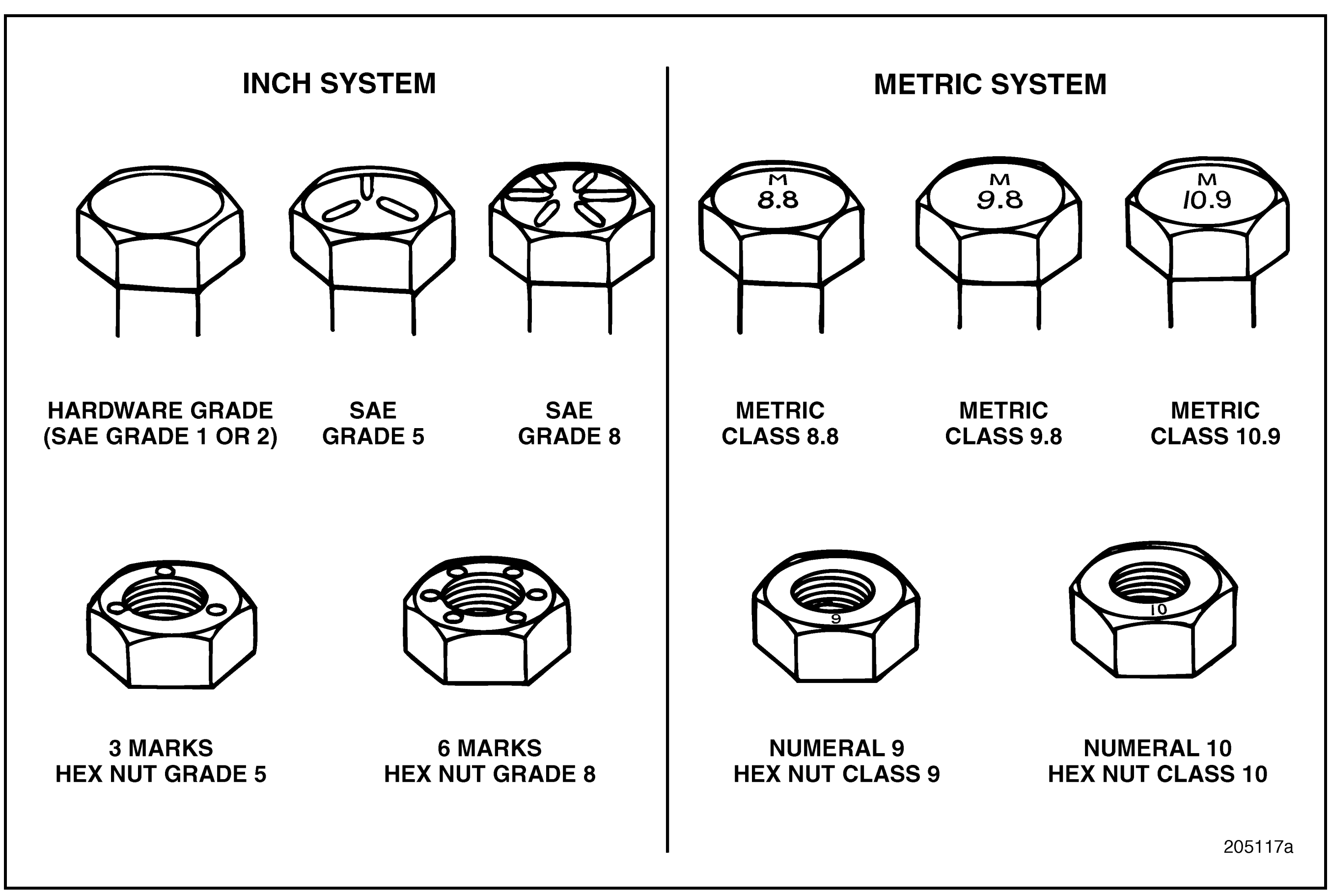


Figure 586 — Fastener Grading System

Fastener Sizes and Types

The first and most important fact that the mechanic must know about a fastener is whether it is a U.S. (Inch System) or a metric thread. Next, the size of the fastener, which is usually determined by the diameter of the shank, the length of the fastener, which is usually measured from the bottom of the head to the end of the thread, and the pitch of the threads.

The pitch of U.S. (Inch System) fasteners is measured by determining the number of threads per inch. The two pitches commonly used in vehicles are coarse thread, officially called Unified National Coarse (UNC), and fine thread, officially called Unified National Fine (UNF).

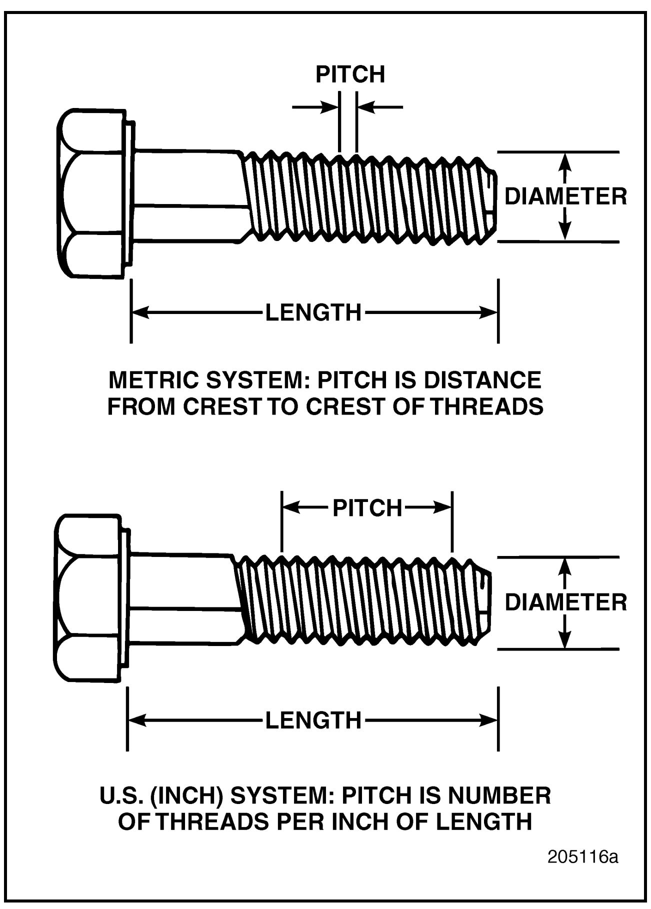


Figure 587 — Fastener Dimension

The pitch of metric fasteners is measured by determining the millimeters per thread. For example, a bolt with 0.8 pitch would have 125 complete threads in a 100 millimeter section (100 mm divided by 125 threads equals 0.8), and a bolt with 1.0 pitch would have 100 threads in a 100 millimeter section. Pitch may be measured directly, using a ruler and counting the threads. Also, thread pitch gauges are available for both U.S. and metric threads, which make it easy to check the pitch of a fastener.

In the U.S. system, a typical designation would be 7/16-20x1. This describes a bolt that is 7/16 inch in diameter, has 20 threads per inch, and is one inch long. The metric system is similar. A typical metric designation would be 10 x 0.8 x 25 mm. This describes a bolt that is 10 mm in diameter, has a thread pitch of 0.8 (0.8 mm per thread) and is 25 mm long.

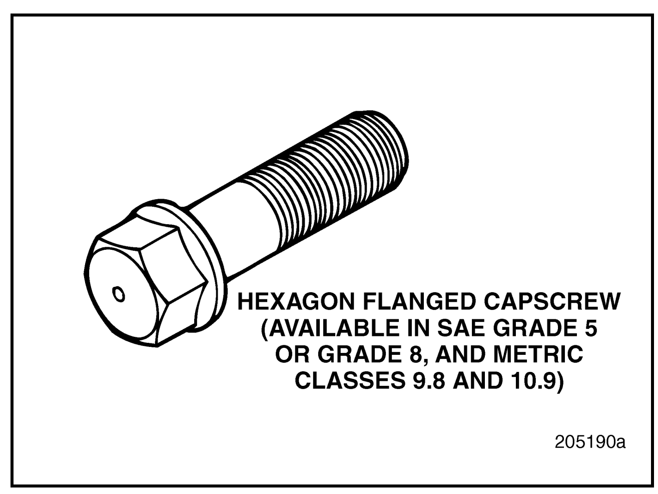


Figure 588 — Flanged Capscrew

TORQUE WRENCH USE

When tightening a fastener, it is important to use a steady pull on the torque wrench. Only in this way can accurate torque values be achieved. If the torque value required cannot be obtained with the existing torque wrench, a longer wrench should be used. Dial indicator-type torque wrenches can be used accurately when an extension is added to the handle to gain more leverage. With most click-type torque wrenches, however, accuracy can be obtained only if the point of pull remains at the center of the hand grip area. Therefore, no handle extension can be used with most click-type torque wrenches, unless the tool is designed and calibrated for this purpose.

Using an Adapter in Combination with a Torque Wrench

It is sometimes necessary to use an adapter at the drive end of a torque wrench. When an adapter is attached to the square drive end of a dial indicator-type torque wrench, the dial reading (compared to the actual torque applied) will be affected if the leverage length of the torque wrench is increased. A correction factor is then needed to achieve an accurate dial reading.

In the example that follows, a torque wrench with a working length of 20 inches and an adapter with a working length of 2 inches are used in combination. The correction factor is obtained as follows:

1. Divide total length “A” by torque wrench length “B”.

   Example:

   — Total Length A = 20 in.

   — Torque Wrench Length B = 18 in.

   — A ÷ B = 20 in. ÷ 18 in. = 1.1 (Quotient)

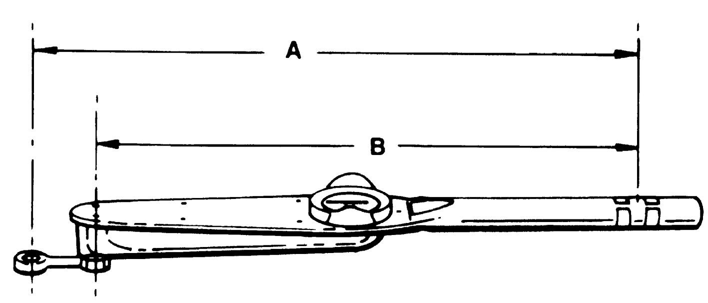


Figure 589 — Torque Wrench with Adapter

A. Total Length (Torque Wrench Plus Adapter)	B. Torque Wrench Length

2. Multiply the dial reading times the Quotient found above to determine the torque at the end of the adapter.

   Example:

   — Dial Reading = 50 lb-ft

   — Quotient = 1.1

   — Torque at End of Adapter = 50 lb-ft x 1.1 = 55 lb-ft

3. If the required torque is known, divide by the Quotient to determine what the torque reading should be.

   Example:

   — Required Torque = 55 lb-ft

   — Quotient = 1.1

   — Desired Torque Reading = 55 lb-ft ÷ 1.1 = 50 lb-ft

NOTE

It is recommended that torque wrenches be checked on a regular basis for correct calibration.

TURBOCHARGER FAILURE AND ACTIONS REQUIRED TO AVOID REPEAT FAILURE

A turbocharger failure can introduce a volume of oil and other debris into the charge air cooler and other components of the inlet air system. Additionally, engine oil can also become contaminated with soot and other debris due to a turbocharger failure. To avoid a repeat failure, the following procedures should be followed whenever a failed turbocharger is replaced.

NOTE

Early E-Tech™ engines utilized a two-piece inlet manifold, whereas later E-Tech™ and all ASET™ engines utilize a one-piece manifold. With the two-piece manifold, the bottom of the manifold is approximately the same level as the port floor of the cylinder head. Therefore, any oil which may be introduced into the inlet air system due to a turbocharger failure will accumulate in the charge air cooler, but very little oil can accumulate in the inlet manifold.

On engines having the one-piece manifold, the bottom of the manifold is more than 2″ lower than the port floor of the cylinder head. In the event of a turbocharger failure, this area of the inlet manifold can become a reservoir for oil. If accumulated oil is not removed from the inlet manifold, the engine may experience “diesel engine run-away” when the engine is first started after the replacement turbocharger has been installed.

Whenever a turbocharger failure has introduced a volume of oil into the charge air cooler, the cooler must be thoroughly cleaned or replaced before the engine is started. Additionally, on engines having the one-piece inlet manifold, the manifold must be checked for the presence of oil and cleaned as necessary. The manifold can be checked without removing it from the engine by removing the inlet hose from the manifold and using a flashlight to look inside.

NOTE

On ASET™ AC engines, it will be necessary to remove the mixer tube to view the inside of the manifold.

If it is not possible to see inside the manifold, a piece of wire or similar object could be inserted into the manifold and used to check if oil is present. Accumulated oil can be removed with a suction pump by removing the air compressor boost pressure supply line and fitting located at the rear of the manifold, then inserting a suction pump hose into the opened port. Make sure the hose extends all the way to the bottom of the manifold. Using this method ensures that oil accumulated at the rear of the manifold will be removed.

CAUTION

In most instances, the engine is mounted in the chassis tilted toward the rear. Because of this, oil will collect at the back of the inlet manifold making it possible for some oil to enter cylinder No. 6. If enough oil enters the cylinder, hydraulic lock could occur and result in severe damage when attempting to start the engine. To avoid such damage, use the barring tool to rotate the engine several revolutions before starting. Resistance felt as the engine is rotated (as cylinder No. 6 approaches TDC of the compression stroke), indicates that oil may be present in the combustion chamber. To remove this oil, remove the injection nozzle from cylinder No. 6 and rotate the engine several more revolutions to push the oil from the cylinder. Before reinstalling the nozzle, clean the oil from the nozzle hole in the cylinder head.

Cleaning Oil from the Charge Air Cooler

Oil can be removed from the charge air cooler as follows:

1. Remove the charge air cooler and flush the inside with a safety solvent to remove oil and other debris.
2. Shake the cooler from side-to-side to remove large pieces.
3. Wash the cooler with hot, soapy water (use liquid gel automatic dishwasher detergent to minimize foaming). Rinse with clean water and blow dry with compressed air in the reverse direction of flow.
4. Carefully inspect the cooler to ensure cleanliness.

CAUTION

Do not use caustic cleaners when flushing the cooler. Be extremely careful when handling the cooler so as not to damage the core.

NOTE

When flushing the charge air cooler, it is recommended that the cooler be turned upside down and a reverse flow be used to flush the inside.

NOTE

If oil and debris are still evident inside the charge air cooler after it has been thoroughly cleaned, contact the Mack Trucks, Inc. Warranty Department to authorize replacement.

Cleaning the Intake Air System

When a turbocharger fails, debris from the compressor wheel and surrounding area has very high inertia and can travel throughout the intake air piping and into the air cleaner. Additionally, small metal pieces resulting from the failure are extremely hot and will melt into and stick to the insides of the plastic hoses and tubing. All these pieces must be removed from the intake air system. Because the turbocharger wheels spin at such high speeds, even a small piece of debris can throw the wheels out of balance, resulting in eventual failure of the replacement turbocharger.

The intake air ducts should be disassembled and the insides of the ducts, elbows, hoses, etc., carefully checked for debris and cleaned as necessary. The air filter element should also be removed, inspected (be sure to check the inside of the filter) and replaced as necessary. Thoroughly clean the inside of the air cleaner canister of any debris.

CAUTION

To check the intake air ducts and air cleaner canister, carefully wipe the inside surfaces with a rag held by gloved hand. The rag will snag on pieces that may be imbedded in the inner surfaces of the ducts and canister. The glove and rag will protect the hand from being scratched or cut on any imbedded objects.

Cleaning the Turbocharger Oil Supply Line, Changing the Engine Oil and Pre-Lubricating the Turbocharger Following a Failure

CAUTION

A turbocharger failure can result in debris contaminating the turbocharger oil supply line. It is EXTREMELY IMPORTANT to remove, flush and thoroughly clean the line prior to installing the replacement turbocharger. Failure to do so can result in debris from the oil line entering the replacement turbocharger, causing damage to the bearings and eventual failure of the replacement turbocharger.

1. Drain the engine oil.
2. Remove the turbocharger oil supply line and inspect for kinks or other types of damage. Replace the line as required. If the oil line is undamaged, it can be reused.

CAUTION

Stainless steel braided lines can be crimped shut if not handled or installed correctly. If the steel braid has been kinked, it pinches the inner tube, and even if the steel braid is straightened, the inner tube will remain pinched. Caution must be used not to bend or twist the steel braided line to the point where it becomes kinked. If the line has been kinked, it must be replaced to eliminate turbocharger damage resulting from restricted oil flow.

If the oil line is being reused, it must be flushed with a clean, suitable, non-flammable solvent. Allow solvent to run through the line to flush any debris from the inside, and then blow the line dry with clean shop air.

3. Mount the turbocharger on the exhaust manifold, install the oil drain tube and connect the exhaust pipe. Do not connect the oil supply line or the inlet air duct to the turbocharger.
4. Pour clean engine oil into the oil inlet port at the top of the turbocharger until overflowing.

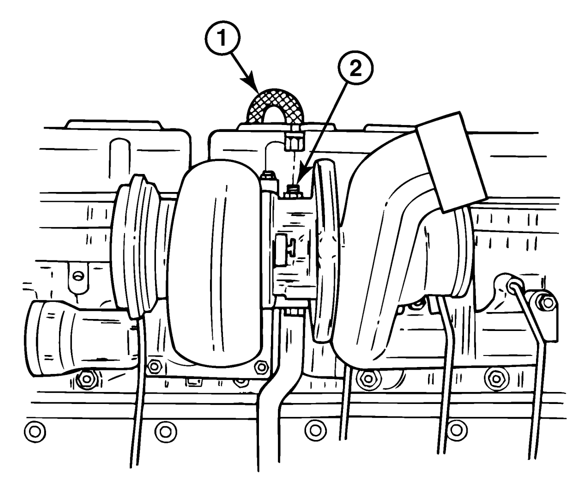


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Figure 590 — Turbocharger Oil Inlet Port

1. Oil Inlet Line	2. Oil Inlet Port

5. Spin the compressor wheel by hand several revolutions and wiggle the shaft back and forth. This will ensure that oil is distributed over all bearing surfaces.
6. Install the inlet air duct to the turbocharger, but do not connect the oil supply line at this time.
7. Change the spin-on oil filters and the centrifugal oil filter as outlined in the *Maintenance and Lubrication Manual,* TS494. Be sure to prefill each new spin-on filter with 2 quarts of new engine oil.
8. Fill the engine crankcase with the proper specification and grade of engine oil (refer to the *Maintenance and Lubrication Manual,* TS494, for current engine oil specifications).

9. Again, pour clean engine oil into the turbocharger oil inlet port until overflowing, and then install the oil supply line.
10. Start the engine and let it run at an idle. Typically, it should take approximately eight seconds or less for sufficient oil pressure to build. Allow the engine to idle for approximately five minutes before increasing engine speed or driving the vehicle.

CAUTION

For ASET™ AC engines, disconnect the connector from the VTG control valve prior to starting the engine. This will prevent the turbocharger from reaching excessive speeds when the engine is first started. Run the engine for five minutes, and then shut the engine off. Reconnect the VTG control valve connector and use the V-MAC® service tool to clear the fault code.

Pre-Lubricating a Turbocharger After Sitting Idle for an Extended Period of Time

Turbochargers operate at very high speeds, temperatures and pressures, making lubrication of the turbocharger bearings extremely important, particularly for a turbocharger that has just been installed, and also for a turbocharger that has not been operated for a period of time.

When the engine is first started after a new turbocharger has been installed, or after the engine has been sitting without being started for a period of time (approximately 30 days or more), the bearings are basically dry, and damage to the bearings due to lack of lubrication can occur during the first couple minutes of operation. Except in extreme cases, the turbocharger can continue to operate for several thousand miles, but will eventually fail due to the damage caused at the initial start-up.

Before starting the engine on a vehicle that has been sitting for an extended period of time (approximately 30 days), pre-lubricate the turbocharger as follows:

1. Disconnect the oil supply line and the inlet air duct from the turbocharger.
2. Pour clean engine oil into the oil inlet port located at the top of the turbocharger until overflowing.
3. Spin the compressor wheel by hand several revolutions and wiggle the shaft back and forth. This will ensure that oil is distributed over all bearing surfaces.
4. Reconnect the air inlet duct to the turbocharger.
5. Again, pour clean engine oil into the turbocharger oil inlet port until overflowing.
6. Reconnect the oil supply line and start the engine. Allow the engine to idle approximately five minutes before increasing engine speed or driving the vehicle.

CAUTION

For ASET™ AC engines, disconnect the connector from the VTG control valve prior to starting the engine. This will prevent the turbocharger from reaching excessive speeds when the engine is first started. Run the engine for five minutes, and then shut the engine off. Reconnect the VTG control valve connector and use the V-MAC® service tool to clear the fault code.

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ENGINE 5-111

ASET™ AC DIESEL ENGINE

SERVICE MANUAL

for Engines with Exhaust Gas Recirculation (EGR)