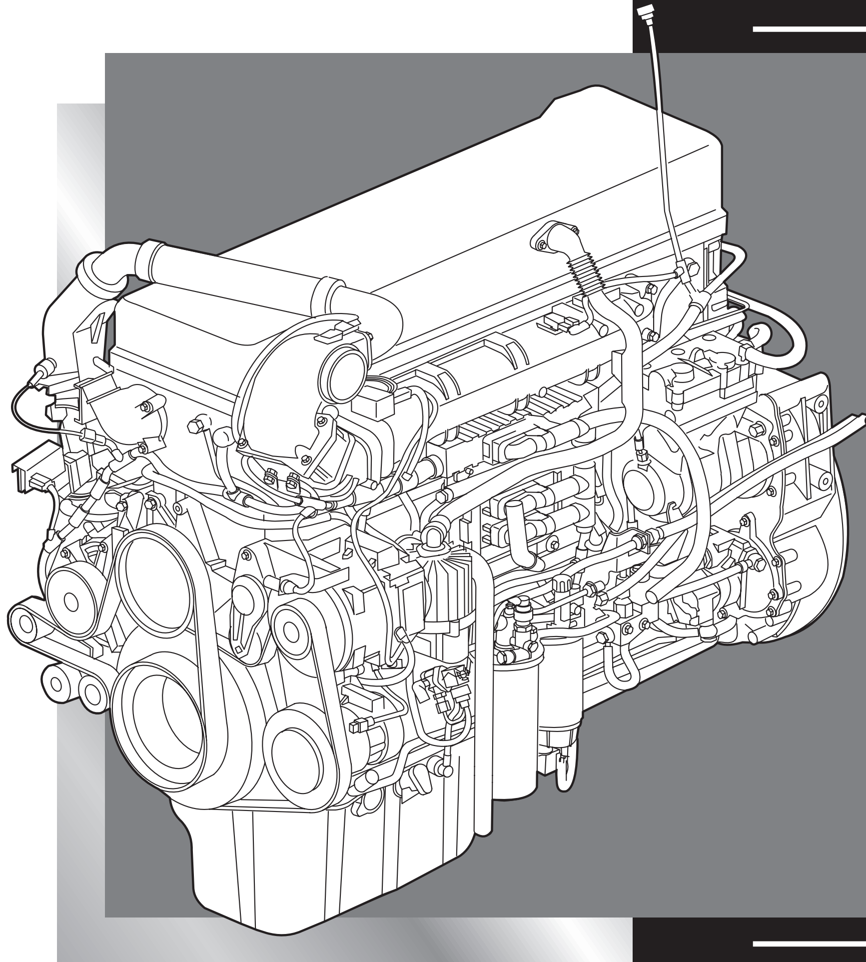


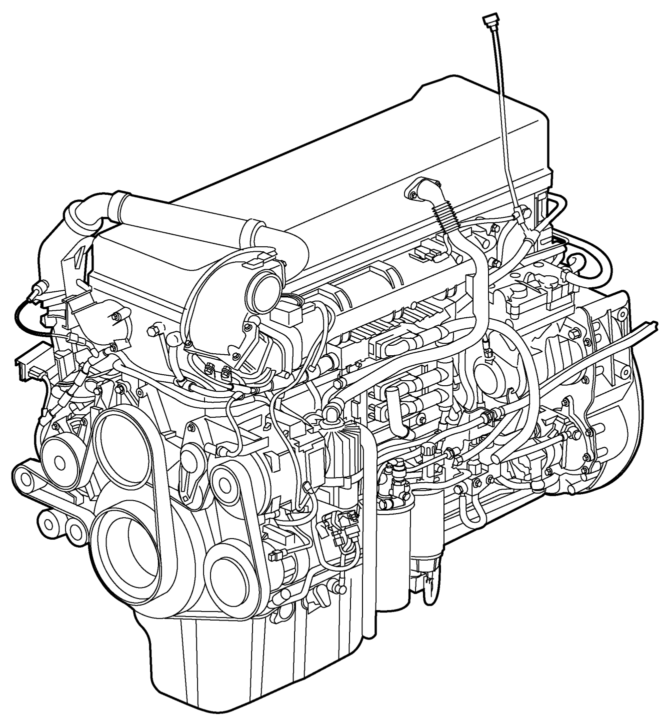
MACK® MP8 DIESEL ENGINE

SERVICE MANUAL

(EURO 4)

JULY 2009
(REVISED)
5-117

MACK® MP8 DIESEL ENGINE SERVICE MANUAL (EURO 4)



JULY 2009
(REVISED — SUPERSEDES ISSUE DATED JANUARY 2009)

ENGINE 5-117

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. Note that illustrations and instructions are based on information that is subject to change as new engine/chassis development continues.

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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.

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!**

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

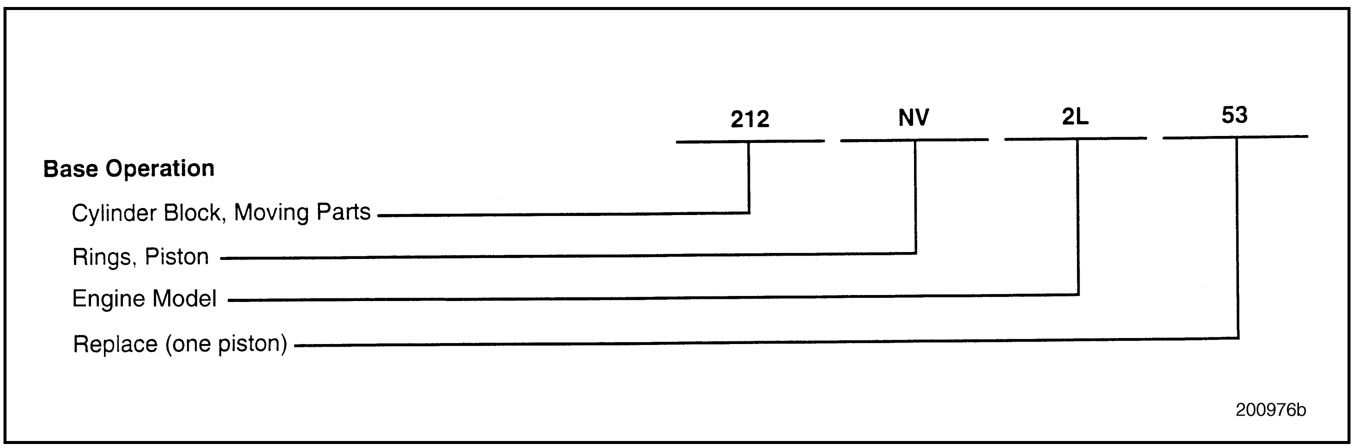
GROUP **6**00 — CAB, TRUCK BODY

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 H2O)	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 H2O)	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 MP8 EURO 4 ENGINE [200 EA]

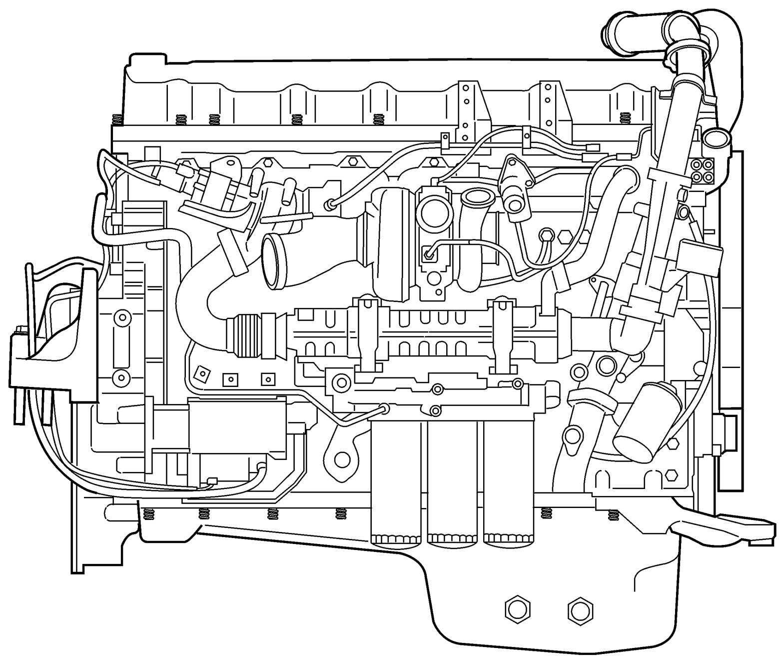


Figure 1 — MACK MP8 Engine — for Conventional Chassis

The MACK MP8 is a 13 liter (800 CID) engine with electronic unit injectors, a cooled Exhaust Gas Recirculation (EGR) system and the Holset Variable Geometry Turbocharger (VGT). The PowerLeash™ engine brake is optional. The engine conforms to Euro 4 emissions requirements.

The MP8 EGR system features reduced restriction plus enhanced efficiency and reliability. Its venturi system is easy to service.

The Holset VGT features fixed vanes with a sliding nozzle ring. The nozzle position is infinitely variable between open and closed. This design reacts quickly to exhaust pressure and controls inlet pressure more precisely. Reliability is enhanced by having fewer moving parts. Its actuator and bearing housing are water cooled and engine oil lubricated for greater durability.

A wide range of the current transmission offerings, including manual, automated manual and automatic, can be teamed with the MP8.

Diagnostic help can be found in the Premium/Volvo Tech Tool. In some markets the diagnostic tool is Premium Tech Tool (PTT) and in other markets the diagnostic tool is Volvo Tech Tool (VTT). Contact your local dealer for Tech Tool availability.

The engine weighs approximately 1200 kg (2646 lb.) dry (with air compressor, without oil, coolant, starter, fan, alternator and clutch). Its design includes a one-piece cylinder head, a single overhead camshaft, three rocker arms per cylinder, unit injectors and no pushrods. PowerLeash™ engine braking, requiring a fourth rocker arm, is optional. Monosteel™ steel pistons are made in one piece.

⚠ DANGER

Do NOT use starting fluid (ether) on engines equipped with an inlet manifold air heater element. An explosion could occur. Failure to heed this danger may result in severe personal injury or death.

Two optional fan drives are available: On/Off and electronically actuated. The electronically actuated viscous fan drive is precisely controlled by the Engine Electronic Control Unit (EECU).

NOTE

The electronically actuated fan drive is not available on vehicles manufactured for Australia.

Timing gears mount on the rear of the MP8 improving the flow of cooling air around the front. Special service instructions apply to the camshaft position sensor. The mounting plate, idler and camshaft gears are marked to facilitate proper installation. The air compressor drive gear meshes with the double idler instead of the auxiliary idler as on the MP7 engine.

Another feature of the MP8 is the rear engine power take-off (REPTO-ready) that is gear driven through the timing gear train. An optional PTO with drive gear, bearing and housing can be added at the factory.

The rocker arm shaft is held in place by camshaft bearing capscrews. There are special instructions for installing the camshaft bearing caps and the rocker arm shaft during service.

A stiffener plate fastens to the bottom of the cylinder block to ensure block strength and rigidity. The engine can be used with axle forward or axle back vehicles by virtue of optional oil pans. The engine fan is mounted high or low depending on vehicle configuration.

The MP8 uses unit injectors. The unit injector incorporates the pump, valve and injector. Its internal solenoids permit fast, precise control of fuel delivery into the cylinder. The unit injectors are encased by the valve cover and not exposed to the heat of exhaust system components.

Replacing injectors requires a specific procedure, and installation requires that the EECU be programmed to recognize replacement injectors. Cleaning injector bores requires a special tool.

An engine compression brake option on the MP8 engine assists deceleration and braking. The operation of the brake differs from earlier engine models. Working in conjunction with the exhaust cycle, the brake requires a camshaft with four cams per cylinder, two rocker arms for the exhaust valves, a bridge over the two exhaust valves, an electronic control valve and a wiring harness that includes the control valve. The exhaust valves are adjusted with shims.

Preventive maintenance is important to get the most from the MACK MP8 engine and to ensure many years of reliable, trouble-free operation. Refer to the current TS943 Maintenance and Lubrication manual for schedules and specifications.

Repair instructions in this manual deal with removal, installation, disassembly, assembly, setup and adjustments of MP8 components.

There are restrictions concerning the reuse of certain fasteners. Refer to current specifications bulletins and the **SPECIFICATIONS** section of this manual for detailed information.

Service Precautions Summary

Following is a summary list of the DO and DON'T issues applying to MP8 engine service.

1. DO NOT machine the cylinder head for clean-up since this will change injector depth, thereby affecting emissions. It will also upset the ability to correctly adjust timing gear backlash.
2. DO NOT grind the injector copper sleeves.
3. Install the crankshaft main bearing caps according to marked assembly number.
4. Connecting rod caps MUST BE mated to their respective connecting rods due to the "fractured manufacturing" process used. Also, the rod caps can be installed only one way because of the difference in spacing between screw holes at each side of the cap.
5. DO NOT use the lifting eye on the flywheel housing when tilting the engine/transmission assembly to an angle greater than 15 degrees.
6. Cylinder head installation requires lowering the head onto the gasket using the alignment screws and washers at the sides of the head and block. The head must be pulled back to the mounting plate using screws inserted through the plate. Pressed bosses in the gasket keep the head from making full contact with the gasket surface and prevent damage to the elastomer sealing rings as the head slides into position.
7. Do NOT use starting fluid (ether) on engines equipped with an inlet manifold air heater element.

⚠ DANGER

The use of starting fluid (ether) on engines equipped with an inlet manifold air heater element is prohibited. An explosion could occur. Failure to heed this danger may result in severe personal injury or death.

8. The MP8 engine uses a number of O-rings for sealing various fluid joints and tubes. It is essential that **new** O-rings of the correct material be used whenever joints are disassembled and reassembled.

NOTES

VISUAL IDENTIFICATION

MP8 EURO 4 ENGINE MODEL IDENTIFICATION

Engine Information Plate

The engine information plate is located on the top of the cylinder head (valve) cover. This plate includes information concerning the following items.

- Engine model and emissions level
- Torque limitation
- SW calibration
- Maximum torque
- Rated power and speed
- Engine displacement
- Low idle speed
- Exhaust brake

In addition to the information plate, there is another label on the cylinder head (valve) cover. This additional label lists the chassis number, engine serial number and respective barcodes.

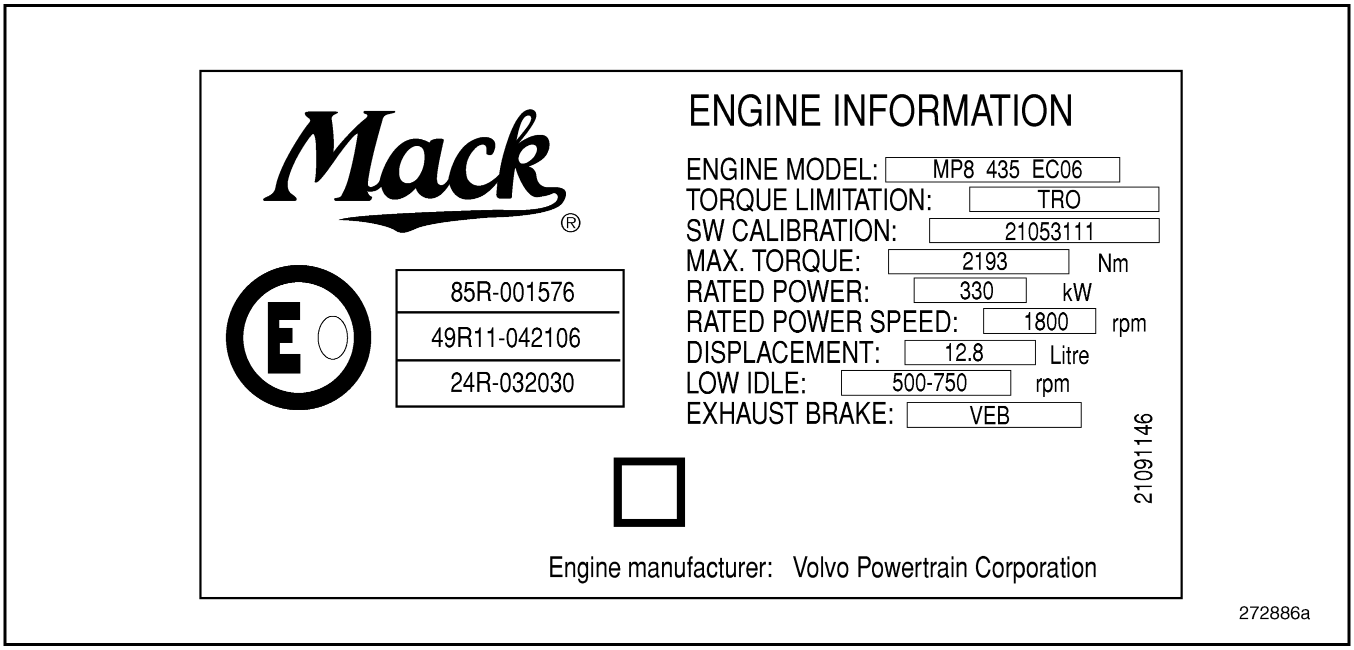


Figure 2 — Engine Information Plate

Engine Serial Number Identification

In addition to the engine information plate on the 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 left side at the front just below the inlet manifold.

DESCRIPTION AND OPERATION

MACK MP8 EURO 4 ENGINE DESIGN FEATURES [200 EA]

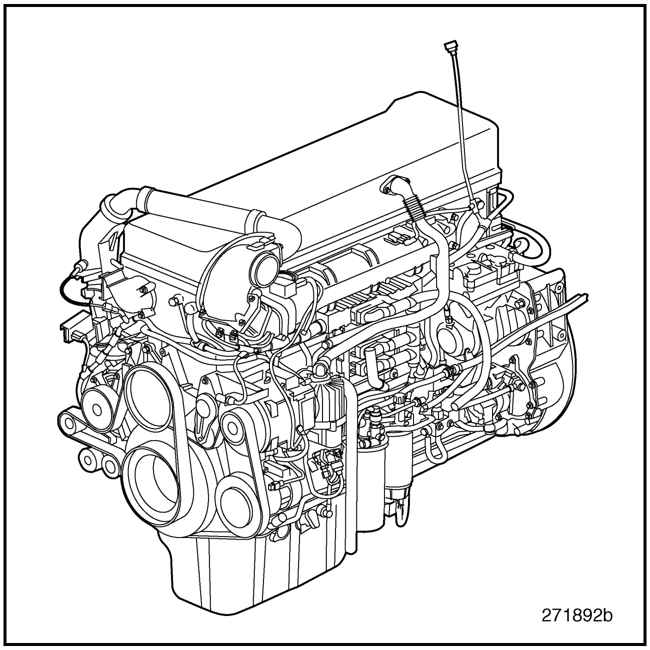


Figure 3 — MACK MP8 Euro 4 Engine — Conventional Chassis

To accommodate the low cab forward design, the EGR system and the inlet manifold are configured differently than for the conventional chassis. The EGR mixer mounts at the front of the inlet manifold on the conventional chassis, but near the rear of the manifold on the low cab forward design.

Engine Components

CYLINDER HEAD

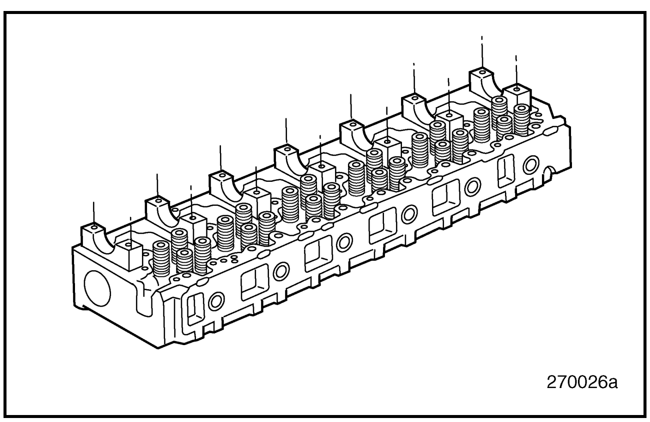


Figure 4 — Cylinder Head with Valves and Camshaft Supports

Main features of the cylinder head are:

- One-piece cast iron
- Integral thermostat housing

Separate chambers for exhaust and inlet at each cylinder make this a “crossflow” design. The fuel channel, drilled from front to rear, connects with grooves machined around each injector opening. A plug at the rear of the cylinder head seals this channel.

CAMSHAFT AND VALVE TRAIN

The engine has an overhead camshaft and rocker arm shaft in support of four valves per cylinder. The camshaft rides on seven journals with a bearing cap and support block (saddle) at each point. The bearing inserts (shells), bearing caps and support blocks are replaceable.

In standard configuration (with VGT exhaust brake only), there are three cams for each cylinder, including inlet, injection and exhaust. There are four cams per cylinder in the optional configuration (VGT exhaust brake plus PowerLeash™) with the addition of a “brake” cam at each cylinder.

The rocker arms are positioned on the shaft (front to back) in the order of inlet, injector, exhaust and brake, if so equipped. Both the inlet and exhaust rocker arms each drive the valve pairs via a pinless yoke (bridge). On engines equipped with PowerLeash™, the “brake” rocker arm works in combination with the exhaust rocker arm to precisely control the opening and closing of the exhaust valves for engine braking.

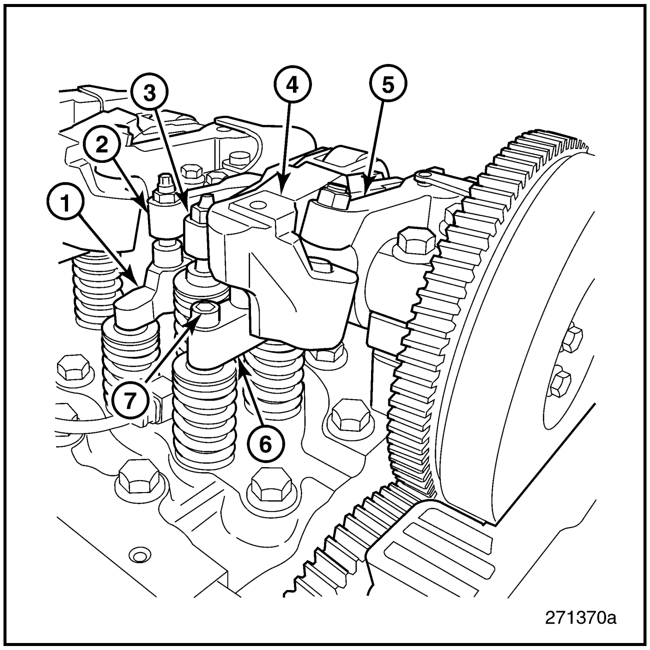


Figure 5 — Valve Train (with PowerLeash™)

1. Inlet Valve Yoke (Bridge) 2. Inlet Valve Rocker Arm 3. Injector Rocker Arm 4. Exhaust Valve Rocker Arm	5. PowerLeash™ Rocker Arm 6. Exhaust Valve Yoke (Bridge) 7. Shim Retaining Screw

Exhaust valve yokes include a shim for adjustment. Replaceable valve guides and seats are made of alloyed cast iron and steel respectively. All valve guides have oil seals. Exhaust valves have double valve springs.

Rollers in the ends of the rocker arms contact the cam shaft. The contacts with the yokes have ball sockets for flexibility.

The camshaft is induction-hardened. Timing marks for valve and injector adjustment are located on the flange forward of the No. 1 camshaft journal. These marks are for adjusting valve clearance. They do not apply to camshaft timing.

Camshaft thrust washers are integral on the No. 7 journal bearing. Smooth rotation is ensured by means of a vibration damper on the camshaft gear. Teeth on the damper interact with the camshaft position sensor for input to the EECU.

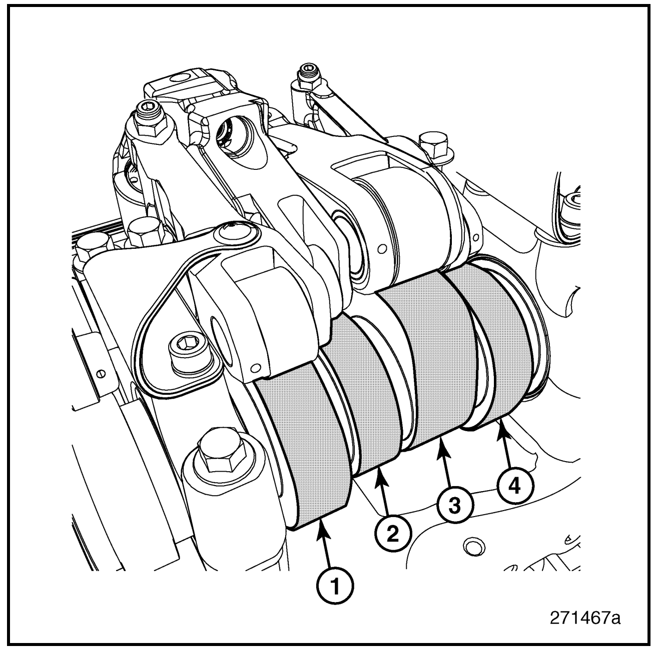


Figure 6 — Camshaft and Rocker Arms (with PowerLeash™)

1. Engine Brake Cam 2. Exhaust Cam	3. Injector Cam 4. Inlet Cam

Timing marks on the camshaft provide for valve and injector adjustment. PowerLeash™ includes its own electronic control governed by driver's choice through a switch near the steering wheel. This control mounts on the cylinder head between the No. 3 and No. 4 cylinder rocker arms. The wiring harness includes additional wire leads for PowerLeash™.

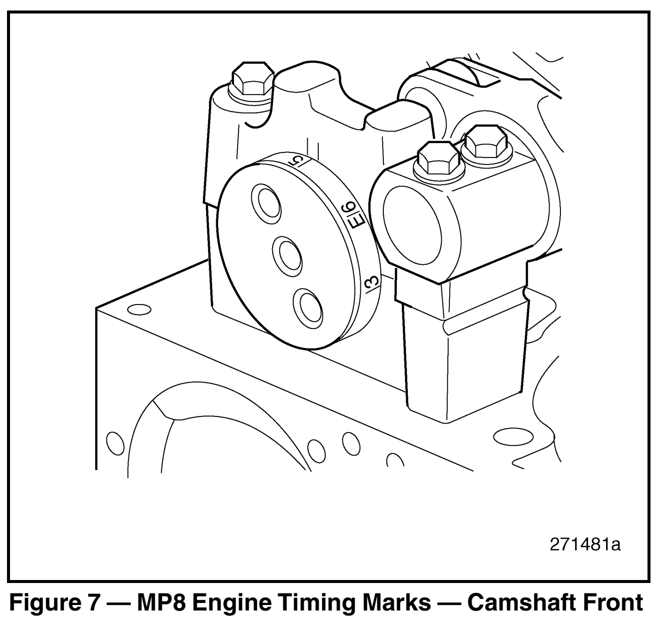


Figure 7 — MP8 Engine Timing Marks — Camshaft Front End

CYLINDER BLOCK

The cylinder block is made of cast iron. For increased cylinder block rigidity and noise and vibration reduction, a steel stiffener plate attaches to the bottom.

The main and piston lubricating channels are drilled longitudinally through the block. These are plugged at the front of the block. The main channel opens into a cast-in channel that supplies oil to the timing gears. The piston cooling channel is covered by the timing gear cover.

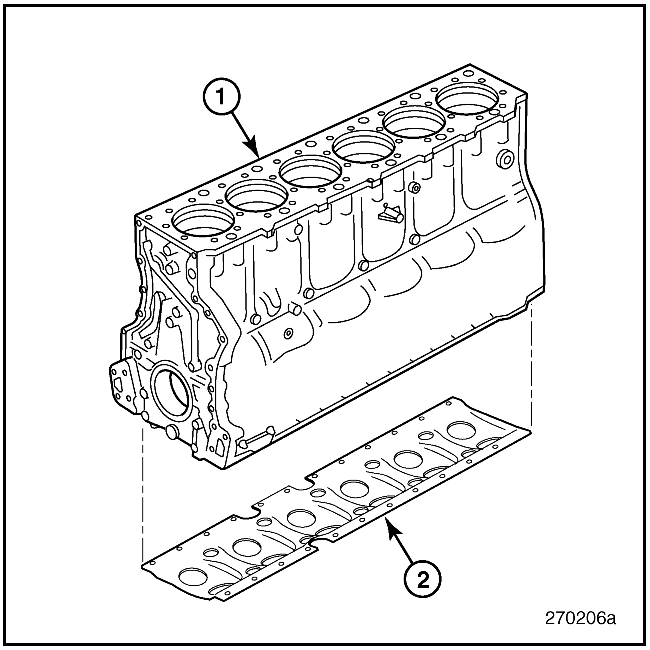


Figure 8 — Cylinder Block and Stiffener Plate

1. Cylinder Block	2. Block Stiffener Plate

Main bearing caps are made of nodular cast iron machined together with the cylinder block. Cast alignment slots in the block and tabs on the caps ensure proper alignment at installation. Each cap is marked with its location beginning with No. 1 at the front. Cap Nos. 4 and 7 are unique and are not numbered.

The block includes cylinder liners that contact the coolant directly (wet liners). The casting shape follows the contours of the cylinders to increase rigidity and reduce noise.

HEAD TO BLOCK ALIGNMENT

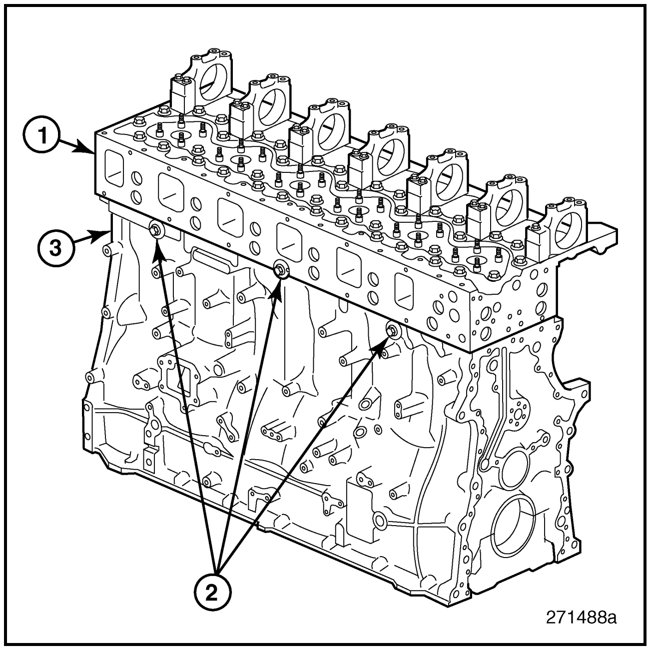


Figure 9 — Head to Block Alignment Screws and Washers

1. Cylinder Head 2. Alignment Screws and Washers	3. Cylinder Block

Three screws and washers installed at the side (two in the block and one in the head) align the head from side to side at assembly. Fore and aft, the head is aligned by contact with the timing gear mounting plate.

CAUTION

The head is aligned with the timing gear plate by screws passed through the plate into the head and tightened securely. It is extremely important to remove these screws before attempting to remove the cylinder head from the block. Failure to heed this caution may result in severe damage to the timing gear plate and other engine components.

CYLINDER HEAD GASKET

The cylinder head gasket is made of one piece of sheet steel with vulcanized elastomer seals on oil and coolant conduits. The design of the engine and head gasket requires a unique procedure for installation of the cylinder head.

The screws and washers at the side guide the head into side-to-side alignment as it is laid on the gasket and block. Screws passed through the timing gear mounting plate into the head pull the head into alignment fore and aft. Small, stamped bosses on the gasket hold the head clear of the seals and allow it to glide accurately into position against the mounting plate during installation. Tightening the head bolts flattens the bosses on the gasket. For this reason, a new head gasket must be installed whenever the head is removed.

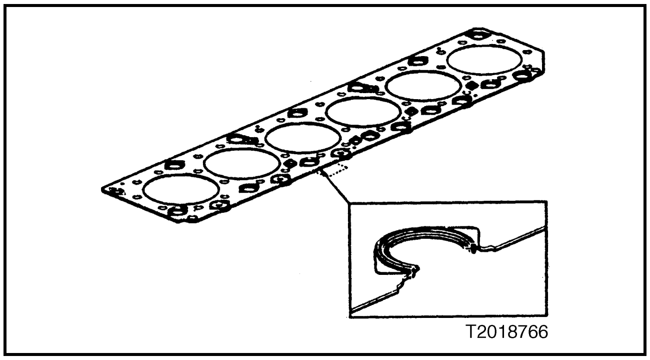


Figure 10 — Cylinder Head Gasket

CYLINDER LINERS

The cylinder block uses replaceable wet cylinder liners. The lower end of each liner is sealed against the block with three elastomer rings. The upper end is sealed with a ring of EPDM elastomer situated directly under the liner collar. This design cools the upper section of the liner better because the area of coolant circulation is larger.

The lower seals are fitted in grooves in the cylinder block. The bottom seal is of a different material and fluorescent violet in color to distinguish it from the intermediate seals.

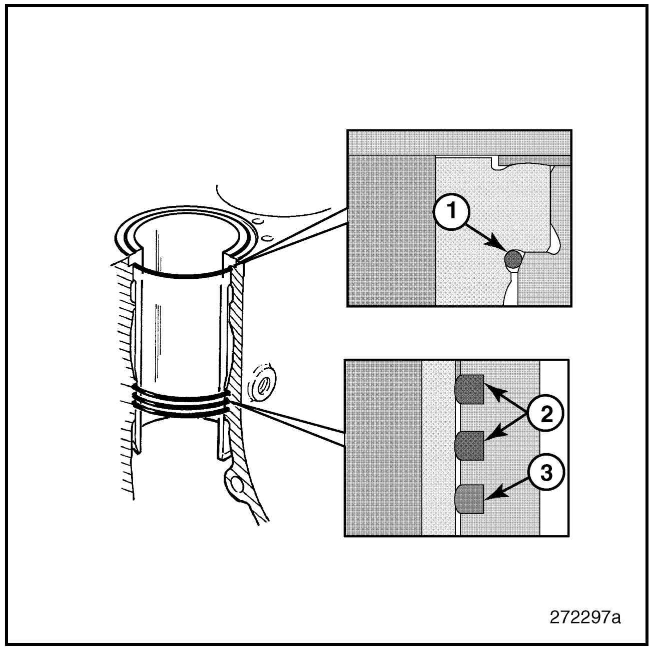


Figure 11 — Cylinder Liner and Seals

1. Upper O-Ring — EPDM (Black) 2. Middle Sealing Rings — EPDM (Black)	3. Lower Sealing Ring — Viton (Purple)

OIL PAN

The oil pan is plastic or steel with a threaded plug for draining. The plastic pan has a groove in the mounting flange which accepts a molded elastomer gasket for a seal. The steel pan is sealed with a gasket on the oil pan flange. Twenty-two spring-loaded screws clamp the pan to the block.

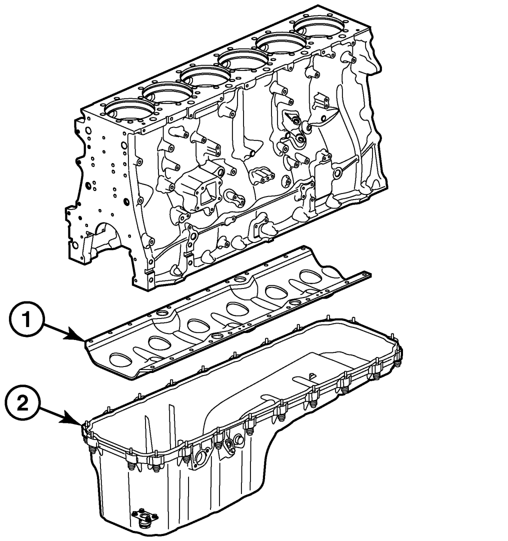


Figure 12 — Oil Pan and Stiffener Plate

1. Block Stiffener Plate	2. Oil Pan with Gasket

The oil pan includes an oil level/temperature sensor with connector. The filler tube and dipstick mounting ports are also components of the oil pan.

NOTE

Oil pans with the sump at the front or at the rear are available to accommodate axle forward or axle back chassis.

CRANKSHAFT

The crankshaft is drop forged steel and induction hardened. It has seven journals with replaceable bearings. Five oversized replacement bearing options are available to accommodate crankshaft regrinding.

The rear main cap (No. 7) includes an attaching point for the lube pump. Thrust washers to control axial movement straddle the central journal (cap No. 4). The remaining caps (Nos. 1–3, 5 and 6) are numbered to facilitate correct assembly.

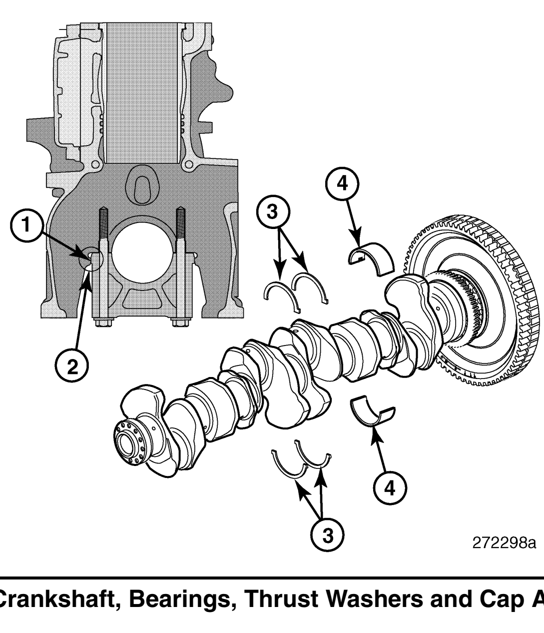


Figure 13 — Crankshaft, Bearings, Thrust Washers and Cap Alignment Tabs

1. Alignment Tab, Block 2. Alignment Tab, Cap	3. Thrust Washers 4. Upper and Lower Bearings

A Teflon® seal bearing directly on the crankshaft flange is used at the front of the crankshaft. The front seal has an outer felt ring which serves as a dust cover. At the rear of the crankshaft is another seal that bears directly on the machined surface of the crankshaft gear. Additionally at the rear, there is a groove in the rear crankshaft flange for an O-ring which forms a seal between the flange and the gear.

NOTE

Whenever the lower main bearing caps are installed in the engine block, pay special attention to ensure the lower main bearing cap is installed in the same location of the engine block as removed. Also, ensure that the aligning mark (boss) on the bearing cap aligns with the mark (boss) on the engine block.

PISTONS AND CONNECTING RODS

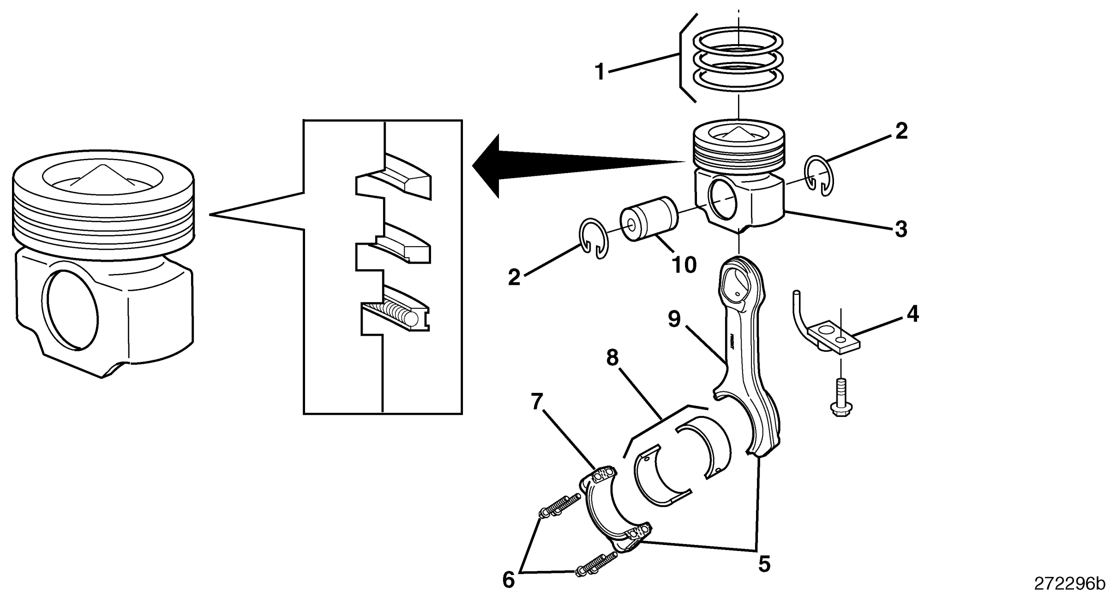


Figure 14 — Piston and Connecting Rod

1. Piston Ring Set	6. Connecting Rod Bolts
2. Wrist Pin Snap Ring	7. Connecting Rod Bearing Cap
3. Piston	8. Upper and Lower Connecting Rod Bearings
4. Piston Cooling Nozzle	9. Connecting Rod
5. Assembly Matching Marks	10. Wrist Pin

Connecting rods are forged steel and are used in combination with one-piece Monosteel™ steel pistons. The bearing caps are attached with four M12 capscrews spaced to prevent misalignment. The rods and caps are made by a “fracture” process that requires a cap be assembled with its original rod. Never attempt to use mismatched rods and caps.

The piston is fitted with three rings. In the top groove is a compression ring with a “keystone” cross section. In the second groove, the compression ring has a rectangular cross section. In the third groove is a spring-loaded oil scraper ring.

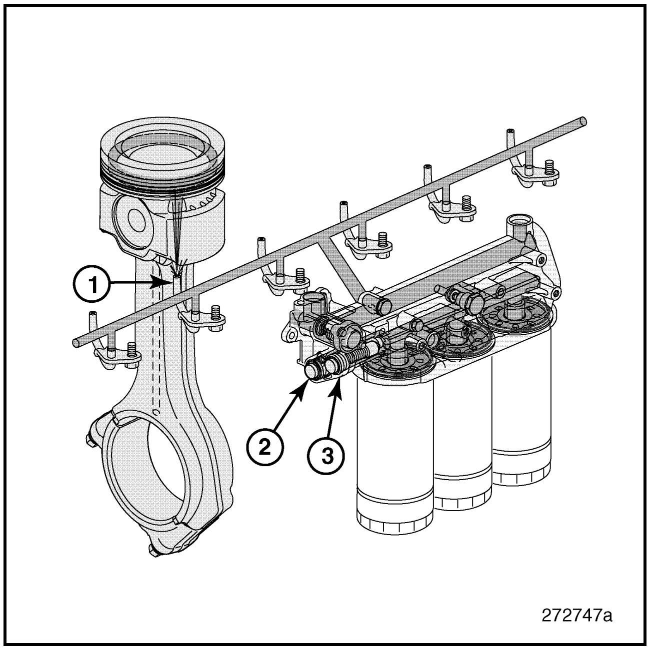


Figure 15 — Piston Cooling

1. Piston Cooling Nozzle 2. Control Valve	3. Opening Valve

Oil flow for the piston cooling system is controlled by two valves. The opening valve supplies oil and the control valve balances the oil flow to the piston cooling channel. The piston cooling nozzle is aligned so that the oil jet hits the underside of the piston crown.

TIMING GEARS

The timing gears are located at the rear of the engine. Backing up the gears is a plate: a 6 mm (1/4 inch) thick steel sheet attached to the cylinder block.

The advantages of this configuration are more precise timing, fewer components and lower noise levels.

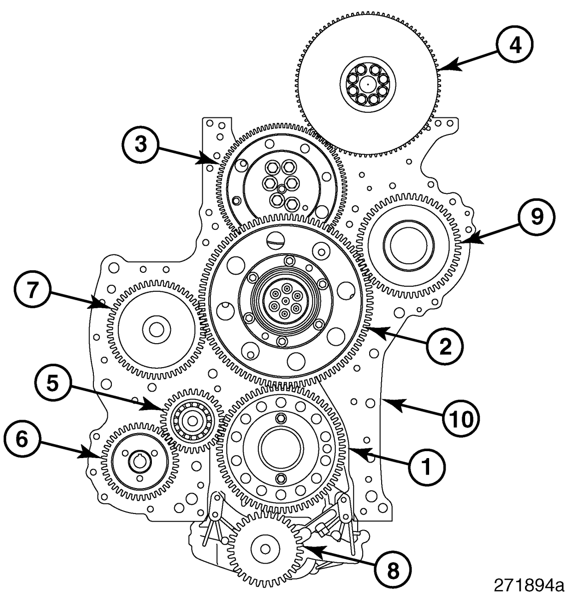


Figure 16 — Timing Gears and Plate

1. Crankshaft Gear 2. Double Idler Gear 3. Adjustable Idler Gear 4. Camshaft Gear and Damper 5. Auxiliary Idler Gear	6. Power Steering/Fuel Pump Gear 7. Air Compressor Gear 8. Oil Pump Gear 9. Power Take-Off Gear (optional) 10. Timing Gear Plate

The power steering/fuel pump gear, the air compressor gear and the PTO gear are not timing gears. The pump and compressor gears fasten to their respective components. The pump gear is driven by the auxiliary idler gear. The compressor gear is driven by the double idler gear.

The double idler drives the adjustable idler and the gear used to drive the power take-off, if so equipped. This is part of the “REPTO-Ready” feature. A PTO unit with drive gear is substituted for a cover on the flywheel housing.

The camshaft gear fastens to the hub on the end of the shaft. A vibration damper also attaches to the hub outboard of the gear. Teeth on the damper actuate the camshaft position sensor. The gear is driven via the adjustable idler.

DRIVE BELTS

This engine can be configured to accommodate either the conventional chassis or the low cab forward (LCF, see note) design. Depending on the vehicle, the fan location may be high or low on the fan bracket.

NOTE

MACK Australian manufacturing covers only conventional chassis models. The low cab forward chassis models (LEU and MRU series) referenced in this section are not manufactured in Australia.

Two poly-V belts drive the front engine accessories. The outer, primary belt (10 or 12 ribs) drives the coolant pump and fan hub from a pulley on the crankshaft flange nested in the vibration damper. The inner, secondary belt (six ribs), driven by the crankshaft vibration damper, drives the alternator and refrigerant compressor.

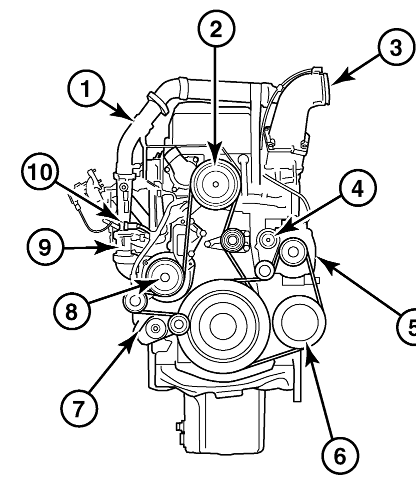


Figure 17 — Primary and Secondary Drive Belts — Conventional Chassis

1. EGR Cooler Outlet Pipe 2. Fan Drive 3. EGR Mixer 4. Belt Tensioner (Alternator/Refrigerant Compressor Belt) 5. Alternator (Pad Mount)	6. Refrigerant Compressor (Pad Mount) 7. Belt Tensioner (Fan Drive/Coolant Pump Belt) 8. Coolant Pump 9. Venturi 10. Differential Pressure Sensors

Each belt uses an automatic tensioner. In the high position, Figure 17, there are two idler pulleys in the primary loop: one between the coolant pump pulley and the tension idler; the other between the crankshaft pulley and the fan hub.

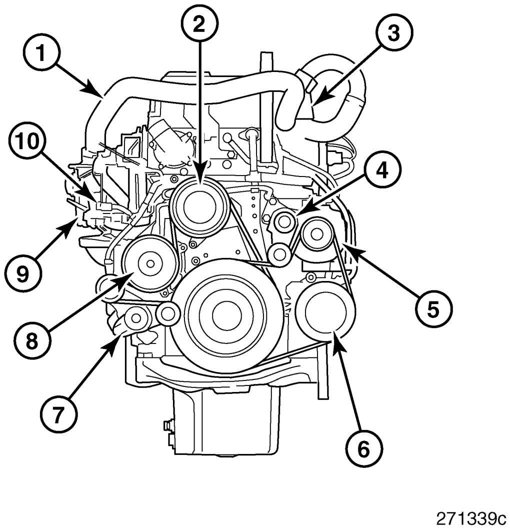


Figure 18 — Primary and Secondary Drive Belts — LCF Chassis (N/A Australia)

1. EGR Cooler Outlet Pipe 2. Fan Drive 3. EGR Mixer 4. Belt Tensioner (Alternator/Refrigerant Compressor Belt) 5. Alternator (Pad Mount)	6. Refrigerant Compressor (Pad Mount) 7. Belt Tensioner (Fan Drive/Coolant Pump Belt) 8. Coolant Pump 9. Venturi 10. Differential Pressure Sensors

In the low position, Figure 18, the idler between the damper and fan pulleys is omitted.

Lubrication System

A gear-type pump at the rear of the engine, driven by the crankshaft gear, draws lubricant from the oil pan and supplies the system. Oil flows from the pump through the distribution housing to the filters, to a gallery at the right side of the engine serving the crankshaft journals, to a gallery at the left side serving piston lubrication and cooling, to the cylinder head and rocker shaft duct (valve rocker and camshaft) and back to the oil pan. The system includes crankcase ventilation.

Two full-flow filters and a by-pass filter maintain clean lubricant. A sensor in the oil pan monitors fluid level. There is an oil cooler immersed in engine coolant inside the cooling duct cover.

OIL PUMP

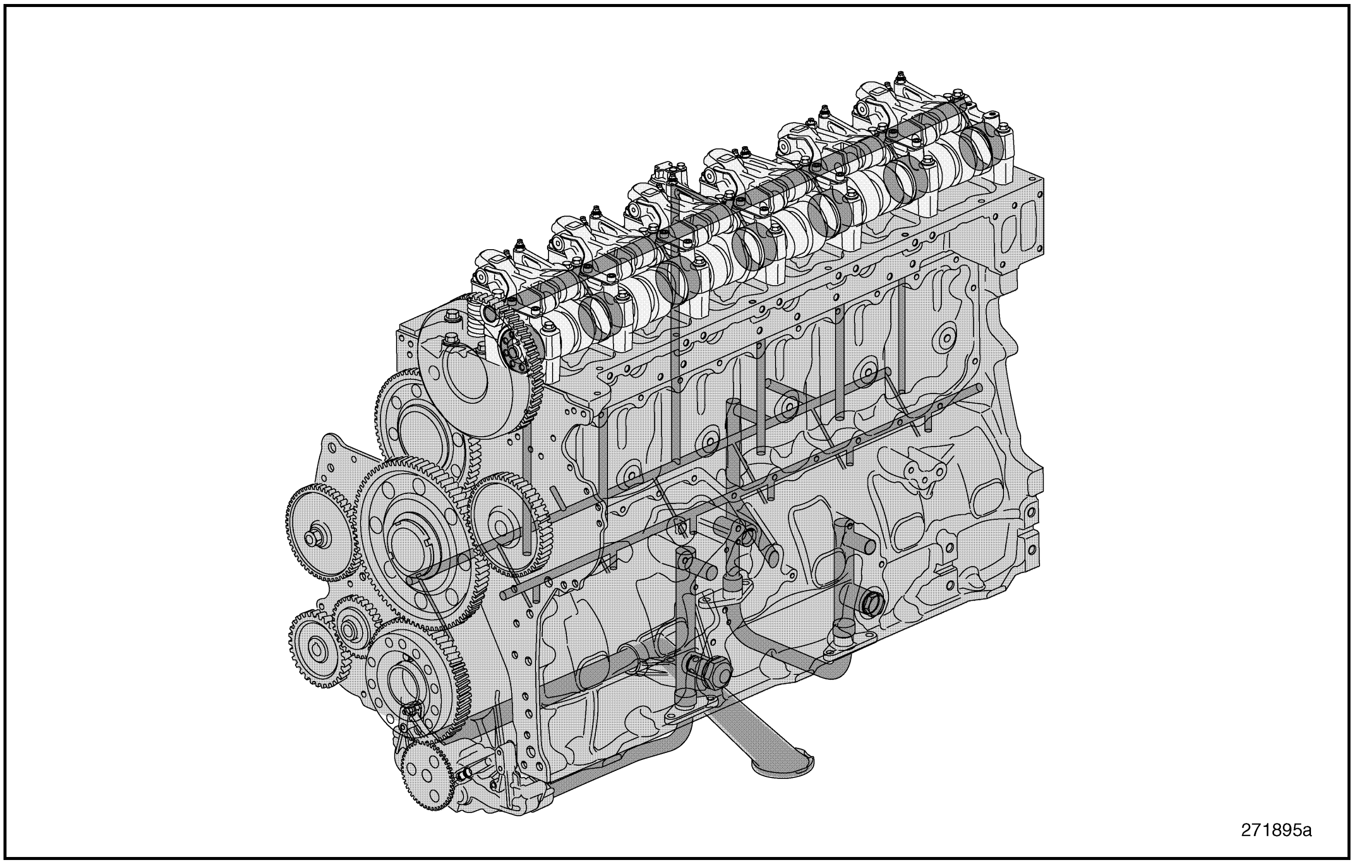


Figure 19 — Lubrication System Diagram

A strainer and pickup tube lead the lubricant into the pump. For the axle forward oil pan, the strainer is mounted on a short tube held in place by a bracket attached to the distribution housing. For the axle back model, a long tube without the bracket is supplied.

OIL FLOW CONTROL AND FILTRATION

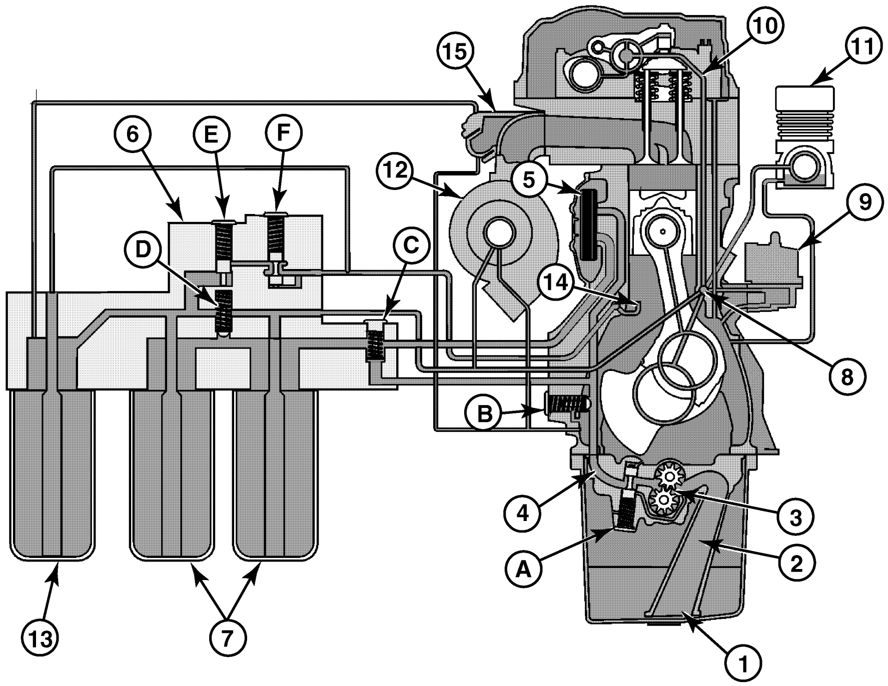


Figure 20 — Lubrication System Flow Diagram

1. Strainer 2. Pickup Tube 3. Oil Pump 4. Pressure Pipe 5. Oil Cooler 6. Filter Housing 7. Full-Flow Filters 8. Main Lubrication Gallery 9. CCV Separator 10. Engine Brake Oil Control Valve 11. Air Compressor	12. Turbocharger 13. By-Pass Filter 14. Piston Cooling Nozzles 15. EGR Valve A. Reducing Valve B. Safety Valve C. Oil Cooler Thermostat Valve D. Overflow Valve, Full-Flow Filter E. Opening Valve, Piston Cooling F. Control Valve, Piston Cooling

There are three filters, one by-pass and two full-flow, attached to a housing mounted at the lower right side of the engine. Oil flow through the filters and the lubrication system is controlled by six valves, including:

- Reducing Valve
- Safety Valve
- Oil Cooler Thermostat Valve
- Overflow Valve, Full-Flow Filter
- Opening Valve, Piston Cooling
- Control Valve, Piston Cooling

The reducing valve maintains constant system oil pressure. The safety valve prevents excessive pressure during periods of high viscosity. The oil cooler thermostat valve prevents oil from entering the cooler until it warms to the set point. The overflow valve allows oil to by-pass the filter if it becomes clogged. The opening valve prevents oil from moving to the piston cooling outlets until the system reaches the set pressure. The control valve regulates the oil flow to the piston cooling channels.

Crankcase Ventilation

Lubricant becomes a mist in many areas of the engine as the result of the motion of the parts (e.g., rocker arms, pistons, crankshaft, camshaft and rocker shaft). The mist rides the drafts of air and other gases that circulate in the open spaces in the engine. To prevent pressure buildup, the open spaces are ducted through a pipe that opens to the atmosphere near the bottom of the engine.

The crankcase ventilation (CCV) system separates the oily mist from the gases by centrifugal force. The oil returns to the oil pan. The remainder escapes to the atmosphere.

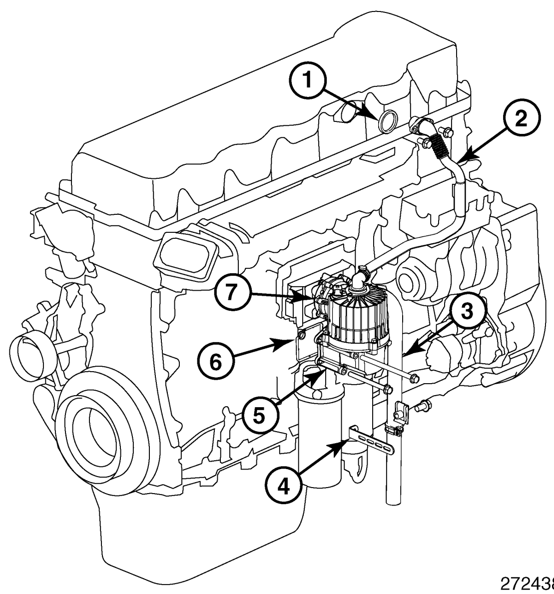


Figure 21 — Crankcase Ventilation System Separator

1. Seal Ring 2. Separator Inlet Hose 3. Separator Vent Tube 4. Vent Tube Bracket	5. Separator Housing 6. Housing Seal 7. Pressure Regulator

A turbine in the CCV separator, driven by a small stream of oil striking its fins, spins at high speed. The mixture of gases and oily mist trapped in the valve cover and the timing gear cover drains onto the top of the center of the turbine and runs down onto several discs rotating with the turbine. Separation occurs as the mixture, flung outward by the turbine, strikes the walls of the CCV. The droplets of mist coalesce into a liquid and drain back into the oil pan along with the oil that drives the turbine. The gases are free to leave via an open port.

The open port connects to a tube leading to the bottom of the engine where road draft draws the gases into the atmosphere.

Fuel System

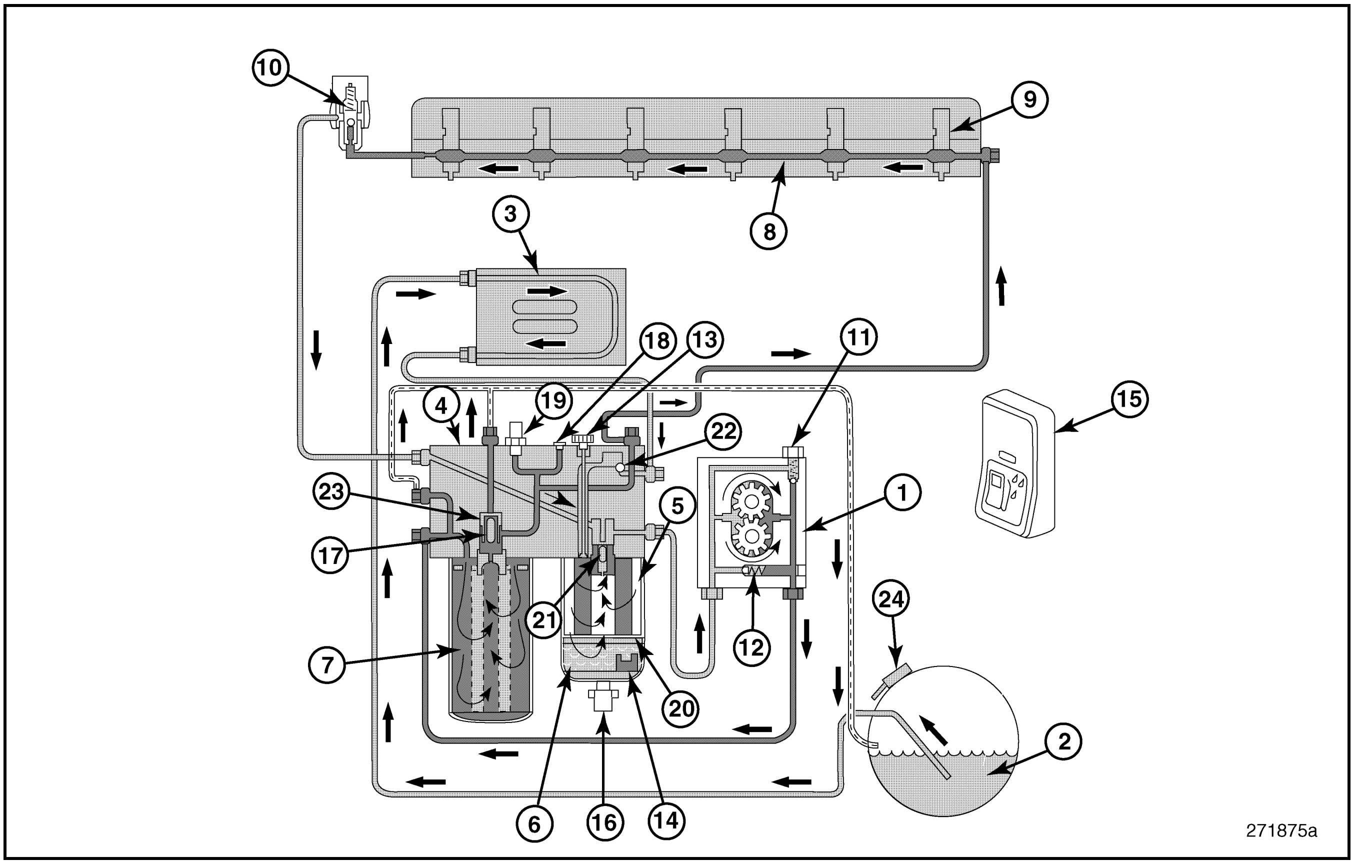


Figure 22 — Fuel System Diagram

1. Fuel Pump 2. Fuel Tank and Inlet Tube 3. EECU Cooler 4. Fuel Filter Housing 5. Fuel Pre-Filter 6. Water Cup 7. Secondary (Main) Filter 8. Fuel Gallery 9. Unit Injector 10. Pressure Regulator Valve 11. Pump Safety Valve (Pressure Regulator) 12. One-Way Valve	13. Hand Pump Handle 14. Water Level Sensor 15. Water Discharge Control Switch (Instrument Panel) (N/A Australia) 16. Electrical Water Drain Valve (non-electric for Australian vehicles) 17. Automatic Air Bleed Valve (closes when filter removed) 18. Service Port (Pressure Gauge) 19. Supply Pressure Sensor 20. Fuel Heater (Optional) 21. Service Shutoff Valve (closes when filter removed) 22. One-Way Valve (Hand Priming) 23. Automatic Air Bleed Valve 24. Fuel Tank Breather

The fuel pump attaches with the power steering pump to the flywheel housing at the rear left side. It turns on the same shaft as the power steering pump. The common drive gear meshes with the auxiliary idler driven by the crankshaft gear. At 600 rpm, the pump delivers a minimum 100 kPa (14.5 psi), and at 1200 rpm, 300 kPa (43.5 psi). At 400–550 kPa (58–80 psi), the gallery regulator valve opens to control fuel gallery pressure.

Fuel is drawn by the suction side of the fuel pump from the fuel tank into the ECU cooling plate and enters the fuel filter housing. Fuel passes by the one-way check valve which prevents the bleeding of fuel back to the fuel tank and into the primary fuel filter. The fuel becomes filtered by passing through the filter media from the outside to the center of the primary fuel filter. The fuel leaves the primary filter and passes by a one-way valve located in the threaded nipple of the primary filter. The fuel flows from the filter housing to the suction side of the fuel pump through an external fuel line. Fuel becomes pressurized after leaving the fuel pump and flows back to the filter housing to enter the secondary filter. The fuel becomes filtered by passing through the filter media from the outside to the center of the secondary filter. The fuel leaves the secondary filter and passes by an automatic air bleed valve which is located in the threaded nipple for the secondary filter. Fuel passes by the fuel pressure sensor and then exits the filter housing to enter the rear of the cylinder head through an external fuel line. After fuel enters the cylinder head, it passes through the fuel gallery of the cylinder head to continuously deliver fuel to all six unit injectors. Fuel leaves the cylinder head after passing by the fuel pressure regulator located at the left front corner of the cylinder head. Fuel is routed back from the cylinder head to the filter housing through an external fuel line to deliver some return fuel back into the suction side which goes to the fuel pump. Any excessive fuel not consumed is bled off through the de-aeration valve and then, directed back to the fuel tank.

FUEL FILTRATION

Primary and secondary filter elements attach to the underside of the fuel filter housing. The housing, located at the front lower left side of the cylinder block, has an integral hand-priming pump for bleeding the system. The 30 micron pre-filter (primary filter) also separates water from the fuel. Water collects in a cup on the bottom of the pre-filter. There is a sensor to keep track of the water and signal the EECU.

NOTE

For vehicles with electrical drain valves, the collected water can be dumped only while the engine is not running, the key is in the ON position and the parking brake is set.

For vehicles manufactured in Australia, only non-electrical drain valves are available.

A one-way check valve located in the filter housing prevents fuel from draining back to the fuel tank when the engine is shut down. Also included in the valve housing is the fuel pressure sensor just above the primary filter.

UNIT INJECTORS

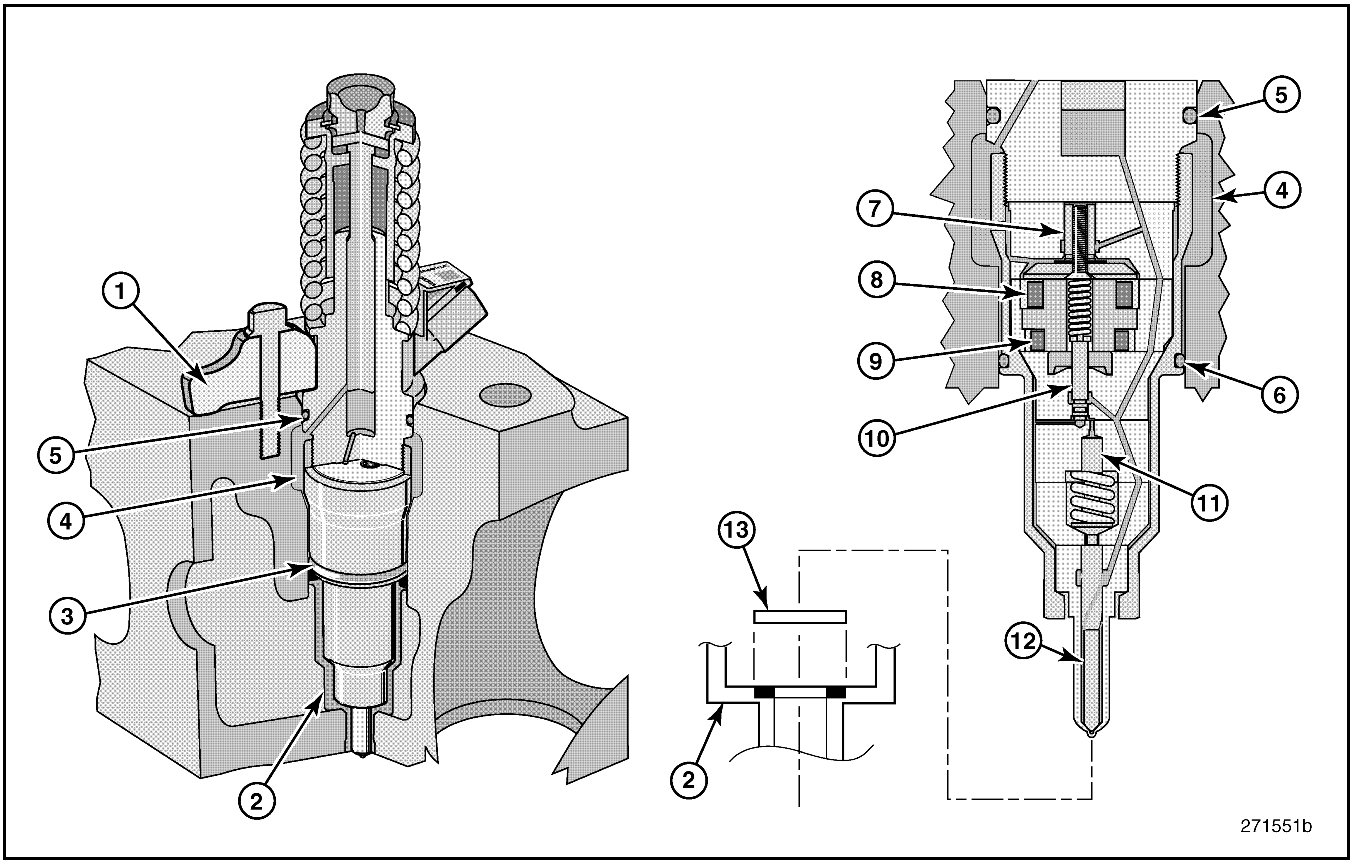


Figure 23 — Unit Injector Diagram

1. Injector Yoke	8. Solenoid Coil
2. Copper Sleeve	9. Solenoid Coil
3. O-Ring	10. Injector Valve
4. Fuel Gallery	11. Injector Piston
5. O-Ring	12. Injector Nozzle
6. O-Ring	13. Washer
7. Pressure Relief Valve	

This engine uses double solenoid unit injectors. Unlike systems that require separate components for delivering, pressurizing and injecting, this unit injector combines these functions. These injectors precisely control the fuel delivery because of the two solenoids. The solenoids, pump and nozzle are in a single body in close proximity to each other.

The injector is set in a pressurized fuel gallery where the fuel temperature is constant. Uniform fuel temperature means uniform quantity in each injection which means uniform power output from each cylinder.

The fuel pump pressurizes the gallery so that fuel rushes into each injector when it opens. Gallery pressure is regulated by a valve that delivers excess fuel back to the tank.

Copper sleeves, acting as coolant jackets, line the bottoms of the injector bores. Engine coolant circulates around these sleeves aiding the process of controlling injection temperature.

There are four phases to the injector cycle of operation. These include:

- Fill phase
- Spill phase
- Injection phase
- Pressure drop phase

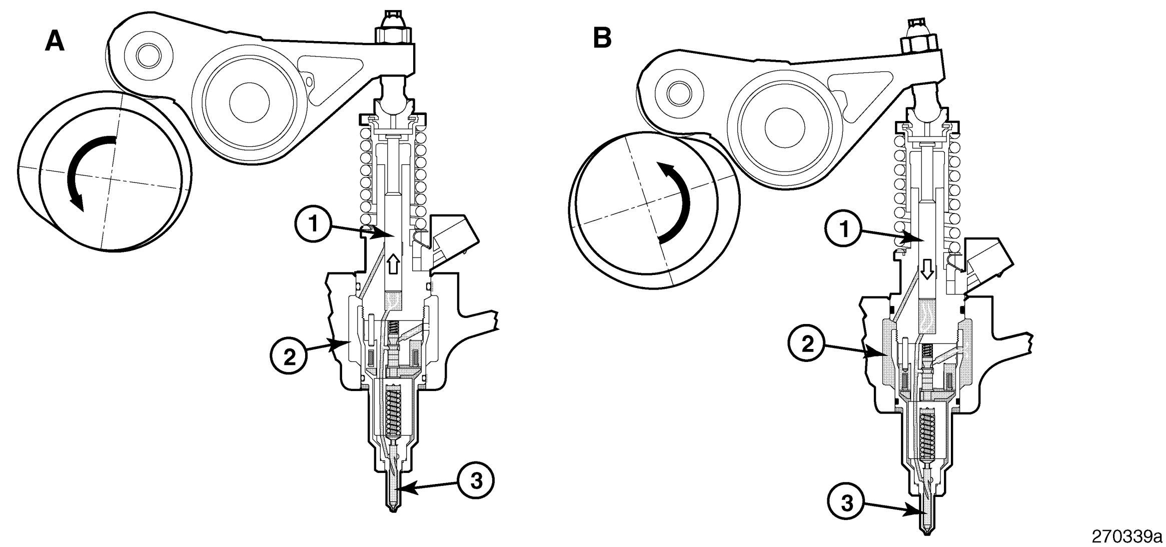


Figure 24 — Unit Injector — Fill and Spill Phases

1. Pump Plunger 2. Fuel Gallery	3. Injector Nozzle

Fill phase (A): During the filling phase, the pump plunger is on its way up, the camshaft lobe is passing its highest point and the rocker arm is on its way toward the camshaft base circle. The fuel valve is open, allowing fuel to flow into the unit injector from the lower fuel gallery. Fuel flows into the cylinder head and the unit injector pump cylinder. Filling continues until the pump plunger reaches its upper position.

Spill phase (B): The spill phase begins when the camshaft lobe forces the rocker arm to push the pump plunger down. The fuel can now flow through the fuel valve, through the holes in the unit injector and out through the fuel gallery. The spill phase continues as long as the fuel valve is open.

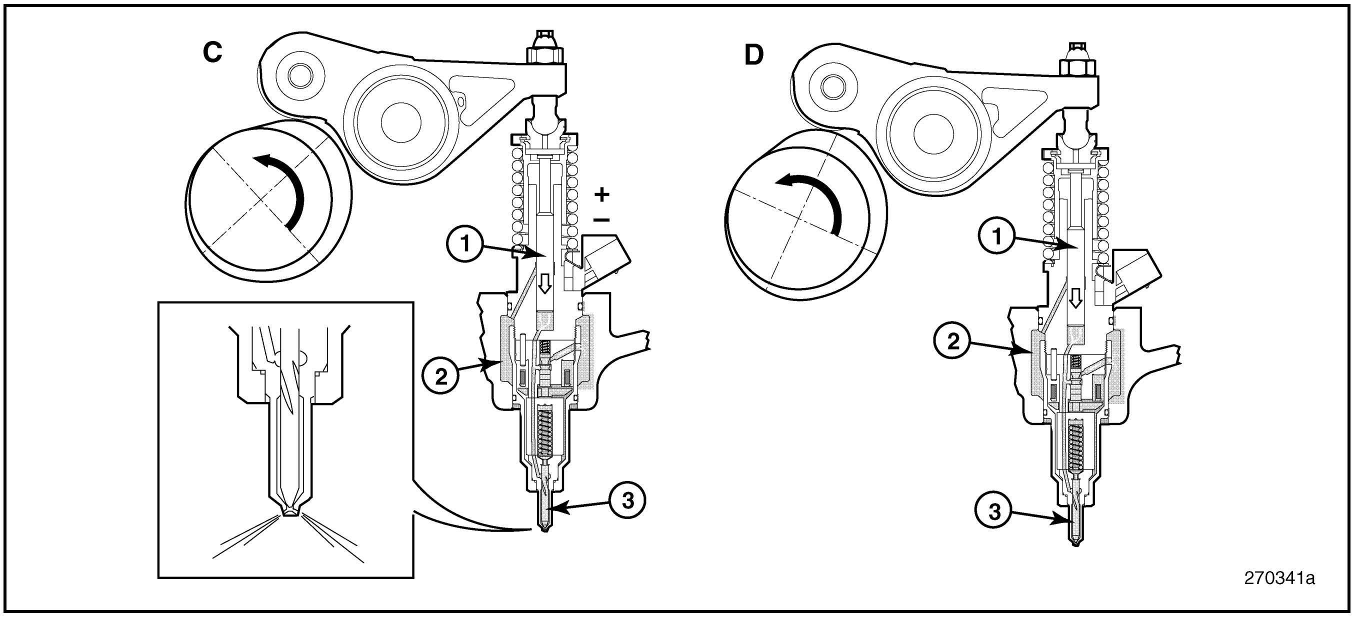


Figure 25 — Unit Injector — Injection and Pressure Drop Phases

1. Pump Plunger 2. Fuel Gallery	3. Injector Nozzle

Injection phase (C): The injection phase begins when the fuel valve closes. The camshaft lobe and rocker arm continue to press down on the pump plunger and injection occurs as the path through the fuel valve closes. The injection phase continues as long as the fuel valve is closed.

Pressure drop phase (D): The injection phase ends when the fuel valve opens and pressure in the unit injector drops below the nozzle opening pressure. The fuel flows through the open fuel valve, through the unit injector holes and out through the fuel gallery. Note that the fuel valve position (closed or open) determines when the injection phase begins and ends. The time during which the fuel valve is closed determines the amount of fuel injected at each pump stroke.

Unit injectors are categorized and coded with regard to tolerances. Whenever a unit injector is replaced, the replacement injector **MUST** be programmed for the cylinder in which it is installed. This is done by programming EECU parameters using the VCADS *pro* or the Premium/Volvo Tech Tool to set *Injector Trim* parameters with the trim codes marked on the injectors.

NOTE

The dimension by which the injector nozzle extends from the head is critical. This means that machining the head in any way that changes this nozzle extension is not permitted.

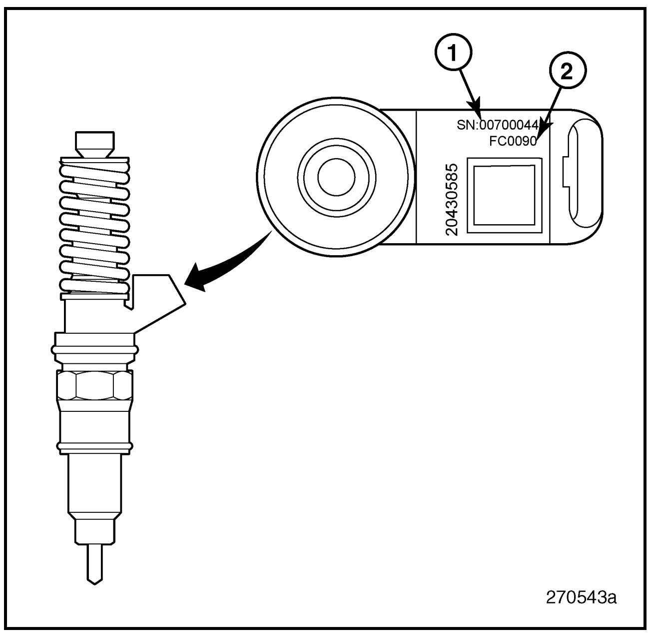


Figure 26 — Injector Coding

1. Serial No.	2. Unit Calibration No.

PowerLeash™ Engine Brake

The engine can be equipped with a PowerLeash™ engine brake system to assist in slowing the vehicle when necessary. The system includes the:

- Wiring harness
- Camshaft
- Oil control valve
- Exhaust rocker arms
- Engine brake rocker arms
- Exhaust valve yokes (bridges)

The exhaust rocker arms contain a pump piston in addition to the power piston and non-return valve. An additional “brake” rocker arm, working in combination with the exhaust rocker arm, drives the pump piston for engine braking.

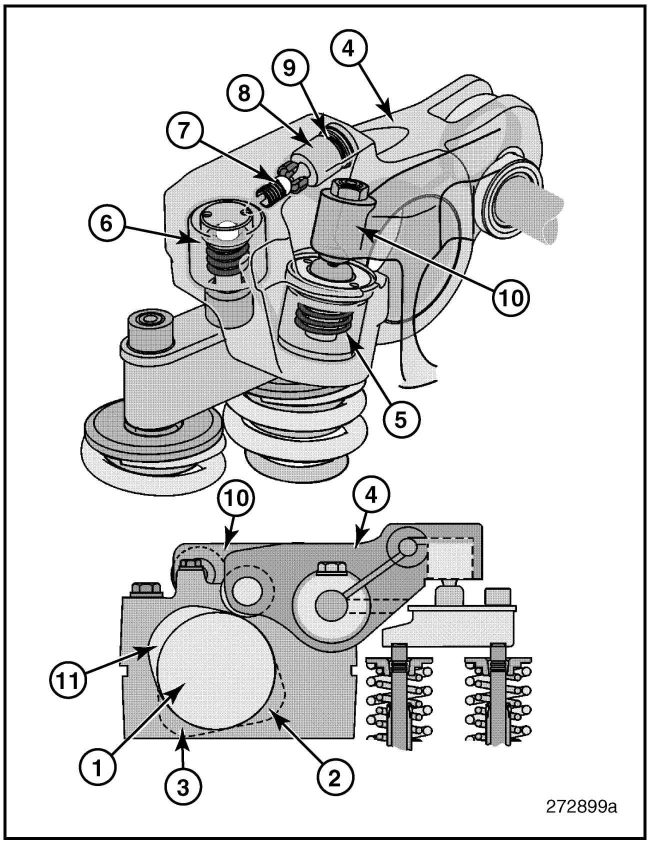


Figure 27 — PowerLeash™ (4-Rocker) Components

1. Camshaft 2. Charging Lobe 3. Decompression Lobe 4. Exhaust Rocker Arm 5. Pump Piston 6. Power Piston	7. Non-Return Valve 8. Piston 9. Spring 10. Brake Rocker Arm 11. Exhaust Lobe

At each cylinder, there is a fourth cam to drive the brake rocker arm. This cam contains the charging and decompression lobes which are timed to open the exhaust valves at the end of the induction stroke and immediately before TDC on the compression stroke when engine braking is activated.

The engine brake rocker arm is equipped with a blade spring. The purpose of the blade spring is to keep the roller in contact with the fourth “brake” cam.

PowerLeash™ operation depends on all of the following conditions which must exist simultaneously.

- Accelerator pedal released
- Engine speed above 1100 rpm
- Clutch pedal released
- Road speed above 5 km/h (3.1 mph)
- ABS inactive
- Transmission in gear
- Oil temperature above 55°C (131°F)
- Charge air pressure below 50 kPa (7.25 psi)

On the cylinder head, the oil control valve connects the oil passages in the head and rocker shaft. The oil pump produces constant pressure at this junction. While the accelerator pedal is depressed, the control valve reduces the oil pressure in the rocker shaft to a minimum 100 kPa (14.5 psi).

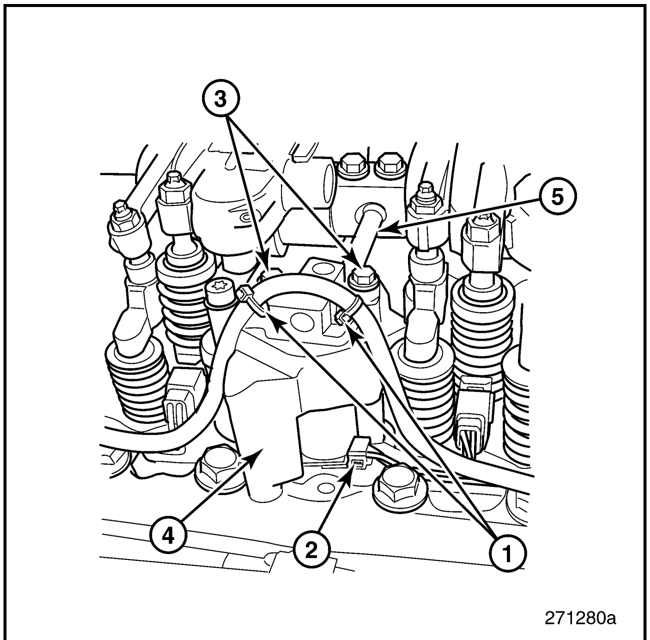


Figure 28 — PowerLeash™ Oil Control Valve — Location

1. Tie Wraps 2. Electrical Connector 3. Attaching Screws	4. Solenoid 5. Tube — Valve to Shaft

When the accelerator pedal is released (and the PowerLeash™ switch is ON), the solenoid opens allowing some oil to escape through a small port. Reduced spring pressure moves the piston, opens the passage to the rocker shaft and increases the oil pressure. The system opens the exhaust valve during induction and again immediately before TDC on the compression stroke.

The engine slows because the extra volume under compression takes more power to compress, and escaping pressure in the combustion stroke reduces the power output. A switch on the instrument panel allows the driver to engage or disengage PowerLeash™.

If the ABS system becomes active, it automatically disables PowerLeash™. If the oil temperature goes below 55°C (131°F), PowerLeash™ cannot be activated. A warning lamp on the instrument panel flashes if the driver attempts to activate it under this condition.

A port located in the front cylinder head near the thermostat allows access to the oil passageway. The plug can be removed and a gauge and hose assembly inserted for use during diagnostic procedures.

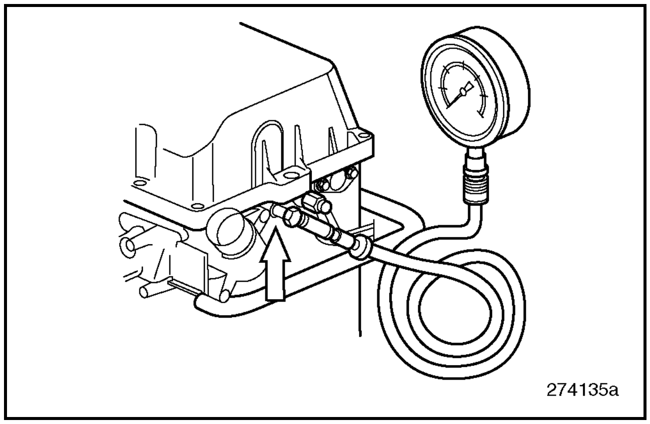


Figure 29 — Cylinder Head Oil Pressure Access Port

System Oil Pressure		
Engine Speed/RPM	**Temperature**	**Pressure**
600	90–110°C (195–230°F)	>250 kPa (>36 psi)
>1100	90–110°C (195–230°F)	300–550 kPa (44–80 psi)
>1100	Cold Engine	650 kPa (95 psi)

Rocker Shaft Engine Brake	Engine Speed/RPM	Oil Pressure
Active	900–2300	220 kPa (32 psi)
Inactive	—	80–120 kPa (12–17 psi)

Exhaust Gas Recirculation System

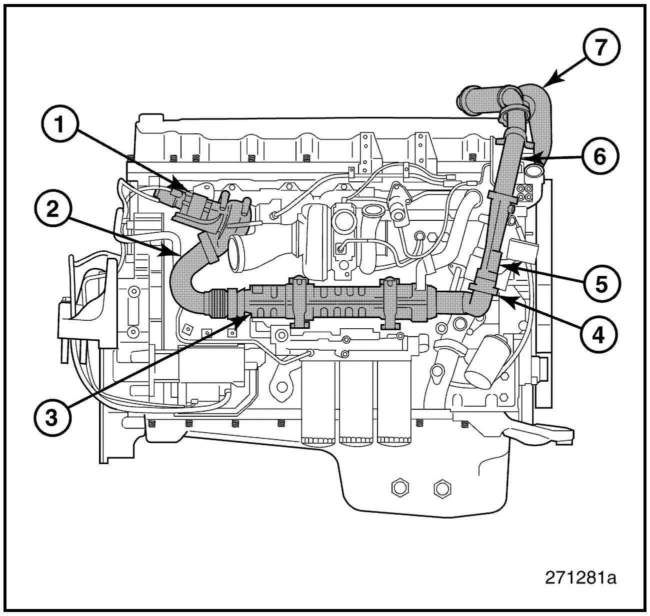


Figure 30 — EGR Components — Conventional Chassis Engine

1. EGR Valve 2. EGR Cooler Inlet Pipe 3. EGR Cooler 4. Venturi	5. Differential Pressure Sensors 6. EGR Cooler Outlet Pipe 7. EGR Mixer

Nitrous oxide (NOx) emission levels increase with combustion temperature. The primary function of the Exhaust Gas Recirculation (EGR) system is to cool exhaust gas and send it back to the combustion chamber to lower the combustion temperature thereby to reduce NOx emissions.

EGR systems are configured differently for the low cab forward (LCF, see note) and conventional chassis engines. The mixer, where the recirculated exhaust joins the inlet air, mounts at the front of the inlet manifold for the conventional chassis, but for the LCF chassis, it is located near the rear of the manifold. This requires differences in the ducting from the EGR cooler to the mixer.

NOTE

MACK Australian manufacturing covers only conventional chassis models. The low cab forward chassis models (LEU and MRU series) referenced in this section are not manufactured in Australia.

EGR VALVE

This engine uses the EGR valve to recirculate exhaust gases. Engine oil operates the EGR valve. The EECU determines the desirable valve opening based on inputs from a number of sensors and commands the EGR valve solenoid to open or close the valve.

Corrosion occurs in the inlet manifold if exhaust gas condenses there. This can produce both internal and external damage. To eliminate corrosion, the EECU compares engine RPM, torque load, ambient temperature, inlet manifold temperature and EGR demand to calculate the dew point in the inlet manifold. It then adjusts the EGR opening to stay above the dew point. Additionally, surfaces within the inlet manifold and the mixing chamber are treated to resist corrosion.

The EGR valve attaches to the rear section of the exhaust manifold for reliable response and turbocharger efficiency. This location also protects the EGR cooler from harmful high pressure exhaust pulses that occur during engine braking.

EGR VALVE FUNCTION

When the EGR valve is open, exhaust gas recirculates into the combustion chamber. The valve is normally closed when engine coolant temperature is below 65°C (149°F) unless the EECU commands the valve open during automatic cooler cleaning mode. When coolant temperature exceeds 65°C (149°F), engine load exceeds 50%, and RPM exceeds 1200, the EECU opens the EGR valve to approximately 90% of its range.

At idle, the EECU monitors exhaust temperature every three minutes. If it exceeds 98°C (208°F), the valve opens to approximately 14% of its range. Otherwise, it remains closed.

EGR COOLER INLET PIPE

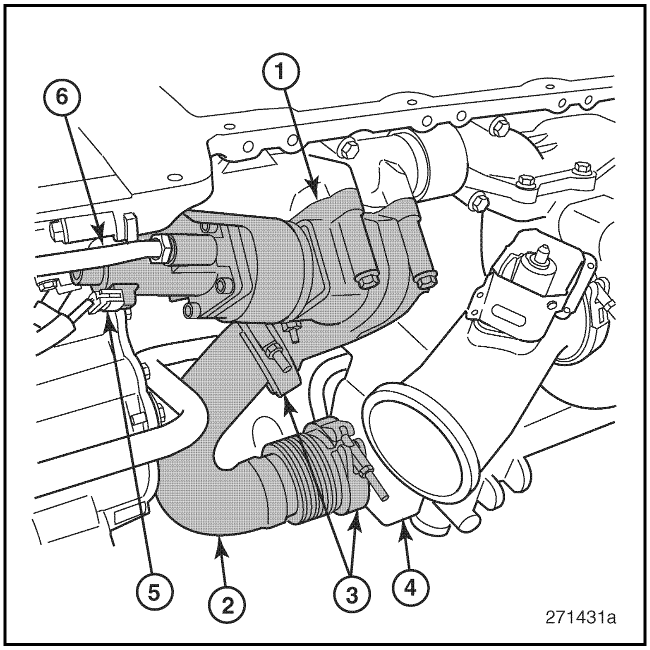


Figure 31 — EGR Valve and Cooler Inlet Pipe

1. EGR Valve	4. EGR Cooler
2. Cooler Inlet Pipe	5. Electrical Connector
3. Clamps	6. Oil Supply Line

The cooler inlet pipe (hot pipe) conducts the exhaust from the EGR valve to the EGR cooler. The cooler lowers the exhaust stream temperature before it reenters the combustion chamber.

EGR COOLER

The EGR valve is connected to the EGR cooler by the cooler inlet pipe (hot pipe). Using engine coolant, the EGR cooler lowers the temperature of the gas coming from the EGR valve. The cooler contains a series of vanes that increase cooling efficiency by swirling the hot gas before it enters the mixer.

EGR VENTURI SYSTEM

On leaving the EGR cooler, the gas flows through a venturi equipped with two pressure sensors. The venturi changes the speed and density of the flow. The sensors report the pressure difference to the EECU.

EGR COOLER OUTLET PIPE

The EGR cooler outlet pipe carries the exhaust gas from the venturi to the mixer. Relatively short, the tube passes over the valve cover, behind and into the mixer at the front end of the inlet manifold on the conventional chassis engine.

Relatively much longer on the LCF (N/A Australia), the tube passes from the venturi around the front of the valve cover and reaches back to the mixer at the rear end of the inlet manifold.

A temperature sensor monitors exhaust temperature sending the data to the EECU. Excessively high temperature, or abnormally high temperature for more than 30 minutes during an hour, causes the EECU to limit engine power to prevent engine damage.

EGR MIXER

The EGR mixer is the meeting point for cooled, recirculating exhaust gas and outside air from the CAC. From here, the combined gases pass into the inlet manifold and on to the combustion chamber.

INLET AIR HEATER

The optional inlet air heater mounts between the mixer and the inlet manifold. It is activated when the operator turns the key to the preheater position and the engine coolant temperature is lower than 10°C (50°F).

Operating time is controlled by the EECU. The operating relay is mounted on the inlet manifold. A lighted icon on the instrument panel signals when the element is **On**.

EGR DIAGNOSTICS

The EECU commands the EGR valve position and monitors electric current consumed by the EGR valve. An abnormally high reading indicates a jammed EGR valve. The EECU verifies that its command was sent and that the valve position reflects the command. If the valve is jammed, or its position doesn't change when commanded, the EECU sets fault codes.

A degraded EGR cooler results in low efficiency. The EECU calculates efficiency by comparing EGR gas temperature with engine coolant and exhaust temperatures. An EGR cooler clogged with soot also causes a fault code to be set.

Air Intake System

On the conventional chassis models, fresh air enters the air filter assembly through intakes and ducts integral to the hood. For the cabover and low cab forward (LCF) chassis models (N/A Australia), fresh air enters the vertical intake stack at the back of the cab. An impregnated paper filter prevents foreign particles from passing through. The assembly design permits the addition of a second filter if needed in extreme environments.

A combination pressure/temperature sensor mounted on the pipe between the filter housing and the turbocharger alerts the driver if the filters need replacement before the scheduled service. The brake system air compressor also draws fresh, clean air from this same pipe.

Variable Geometry Turbocharger (VGT)

The engine is equipped with a variable geometry turbocharger (VGT). The turbine housing has a set of vanes and a sliding nozzle ring that maintains 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.

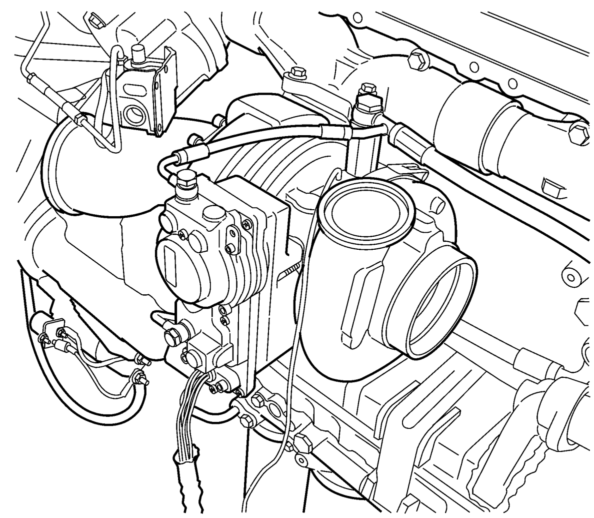


Figure 32 — VGT and Electronic Control

The variable geometry turbocharger is also used as an exhaust brake. The engine control unit (EECU) regulates the turbocharger's sliding nozzle ring and vanes to increase the exhaust back pressure during braking. This causes the engine to drag, producing a braking effect on the vehicle.

Cooling System

The cooling system incorporates a belt-driven coolant pump mounted on the front of the engine on the right. It also uses a piston-type thermostat housed in the front of the cylinder head and a fan with viscous (see note) or air-operated drive mounted above the crankshaft pulley.

NOTE

The electronically actuated viscous fan drive referenced in this section is not available on vehicles manufactured for Australia.

COOLANT PUMP

The back of the coolant (water) pump, with its ducts for distributing coolant, is a separate casting attached to the cylinder block.

The coolant pump contains an impeller, shaft seals, bearing and pulley which attach to the mounting plate. The bearing is a permanently lubricated combination roller and ball bearing. Between the shaft seals and the bearing, there is a ventilated space which leads into a duct behind the pulley. This allows internal leaks to be detected.

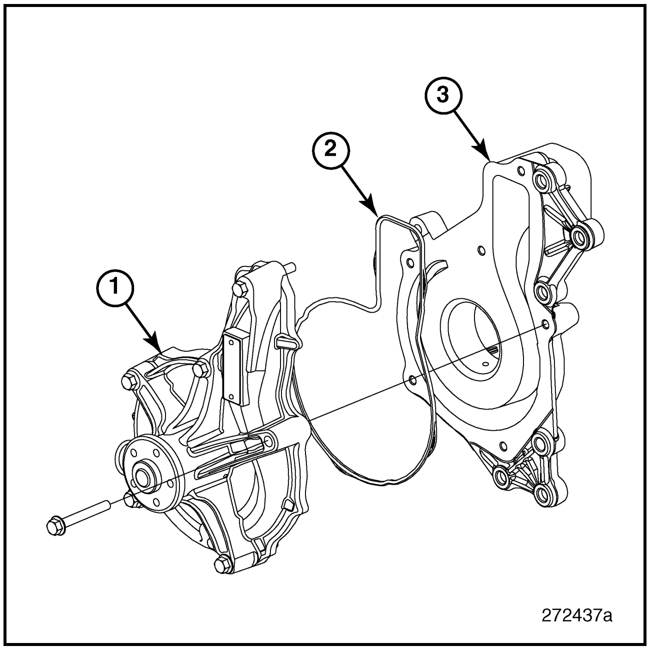


Figure 33 — Coolant (Water) System Components

1. Coolant Pump 2. Coolant Pump Seal	3. Coolant Pump Mounting Plate

THERMOSTAT

This is a piston-type, full-flow thermostat with piston, bulb, seal and housing in a single assembly. Coolant flows continuously, either back to the pump, or to the radiator and back to the pump. It has lower pressure drop compared to other types. The thermostat is mounted in the front of the cylinder head.

ENGINE COOLING FAN

The cooling fan (Figure 34) runs via a viscous (N/A Australia) or air-operated drive through which fan speed is electronically controlled by the EECU. With precise EECU control, fan speed is continuously adjusted in response to several interrelated influences. This makes for efficient cooling with low fuel consumption.

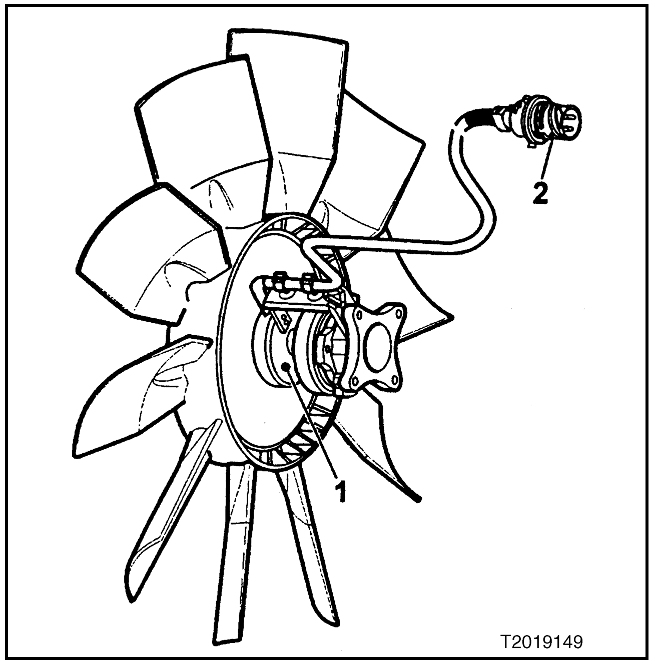


Figure 34 — Electronically Actuated Viscous Fan Drive Assembly (N/A Australia)

1. Solenoid Valve and Speed Sensor	2. Connector (to EECU)

Engine Management System

ENGINE ELECTRONIC CONTROL UNIT (EECU)

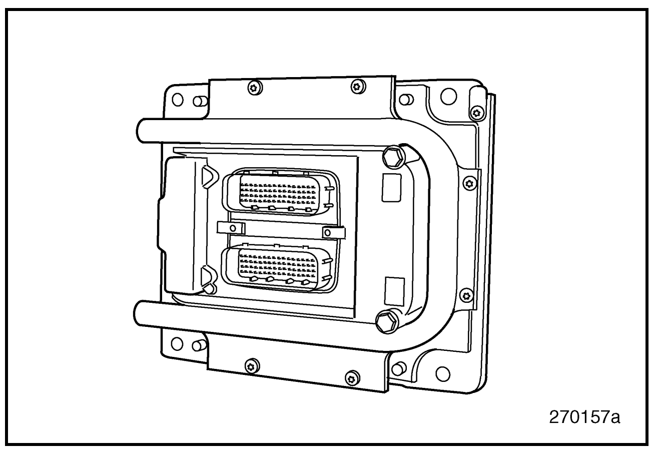


Figure 35 — EECU and Cooler

The engine management system module, also known as the Engine Electronic Control Unit (EECU), is located on the left side of the engine just below the inlet manifold. The EECU is cooled by fuel circulating through a plate attached to the cover of the unit. The fuel comes from the tank on its way to the fuel pump.

Algorithms, called *maps*, are programmed in the EECU so that it can translate sensor data into action. These maps enable the EECU to receive status information from the sensors and send functional data to the actuators so they can simultaneously assume the proper posture for the safest, most efficient operation of the engine in any given instant.

Due to the EECU self-learning capability, it is necessary to reset the learned EECU parameters after servicing some engine-related components. This allows the EECU to learn the new component's behavior. After servicing is complete, perform the “Learned Data Reset” located in the Function Group 1 menu on the PC tool.

SENSORS AND ACTUATORS

Sensors on the engine provide for electronic control. The figures that follow show the locations of the devices on the left and right sides of the engine, respectively.

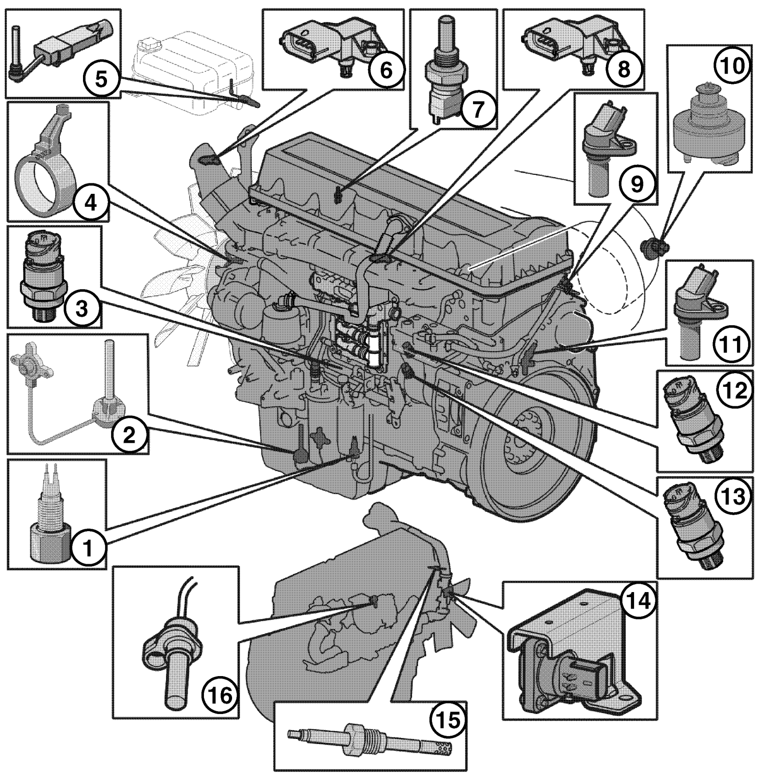


Figure 36 — MP8 Euro 4 Engine Sensors

1. Water Level (in fuel/water separator)	9. Camshaft Position
2. Oil Level/Temperature	10. Inlet Humidity/Temperature
3. Fuel Pressure	11. Engine Position/Speed
4. Fan Speed (in fan hub; N/A Australia)	12. Oil Pressure
5. Coolant Level Sensor (in expansion tank)	13. Crankcase Pressure
6. Charge Air Pressure	14. Differential Pressure (on venturi tube)
7. Coolant Temperature (at front edge of cylinder head)	15. EGR Temperature
8. Charge Air Temperature	16. Turbocharger Speed (on VGT bearing housing)

GLOSSARY OF TERMS

Atmospheric Pressure Sensor

A sensor incorporated into the EECU that detects atmospheric (barometric) pressure and relays this value to the EECU. This pressure is affected by altitude.

Carbon Monoxide (CO)

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

Compressor Discharge Temperature Sensor

Mounted between the turbocharger compressor housing and CAC, detects compressor discharge air temperature and relays this value to the EECU.

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 sent to the inlet manifold for introduction 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).

Electronic Unit Injector (EUI)

Controlled electronically by the EECU, there is one electronic unit injector for each cylinder of an engine. A unit injector incorporates the pump, the injector nozzle and two solenoids in a single body. Actuated by the camshaft via rocker arms with roller followers, electronic unit injectors offer precise fuel metering using a process called “rate shaping.”

Engine Electronic Control Unit (EECU)

A microprocessor-based controller usually mounted on the cylinder block. On the MP8 engine, a cooling plate mounts on the surface of the module. A tube on the plate conducts fuel drawn from the tank on its way to the pump before being pressurized. The fuel acts as the coolant. With the MACK V-MAC® IV system, the EECU controls fuel timing and delivery, exhaust gas recirculation, fan operation, engine protection functions and engine brake operation.

Exhaust Gas Recirculation (EGR)

A system whereby a pre-determined amount of exhaust gas is returned to the combustion chambers. Adding a small percentage of exhaust gas to the fuel/air mixture lowers the combustion temperature reducing the formation of nitrogen oxides (NOx).

Hydrocarbons (HC)

Chemical compounds composed only of carbon and hydrogen. Gasoline, diesel fuel and motor oil are all examples of a very large group of hydrocarbons. The largest source of hydrocarbons is petroleum.

Idler Gear

A gear running between a driving and a driven gear to make the driven gear rotate in the same direction as the driving gear.

Idler Tensioner

A belt tensioning device designed to maintain optimum tension under varying engine speeds and load.

Intake Air Temperature and Humidity Sensor

Mounted in the air intake between the air cleaner and the turbocharger compressor housing, detects outside air temperature and humidity and relays these values to the EECU.

Oxides of Nitrogen (NOx)

High temperatures and pressures of combustion produce oxides of nitrogen (NOx). When combustion temperature exceeds 1372°C (2,500°F), oxygen and nitrogen combine in large quantities to form NOx. By themselves, NOx emissions are no great hazard; however, when mixed with the right amount of HC in the air, NOx will combine in the presence of sunlight to form smog.

Poly-V Belt

A multi-ribbed belt design incorporated into the accessory drive belt and pulley arrangement at the front of the engine.

Pressure Differential Sensors

These are devices designed to read air (gas) pressure at two points in the path of the flow and report the values for use in algorithms in the EECU.

Roller Follower

A type of rocker arm 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 rocker arm design. Roller followers provide the rocker arm lifting action for the electronic unit injector, intake and exhaust valves and exhaust brake.

Variable Geometry Turbocharger (VGT)

The turbocharger turbine housing has moving components to control flow of exhaust gas and build back pressure in the exhaust system for EGR flow. The VGT also performs as an engine brake.

VGT Wheel Speed

A sensor mounted in the turbocharger bearing housing that detects turbine and compressor wheel speed and relays this data to the EECU.

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 IV system, the VECU controls engine speed, cruise control, accessory relay controls, idle shutdown and trip recorder functions.

NOTES

COMPONENT LOCATOR

MP8 EURO 4 ENGINE COMPONENT LOCATION VIEWS [200 EA]

The locations of primary component assemblies of the MP8 engine are identified in the illustrations contained in this section.

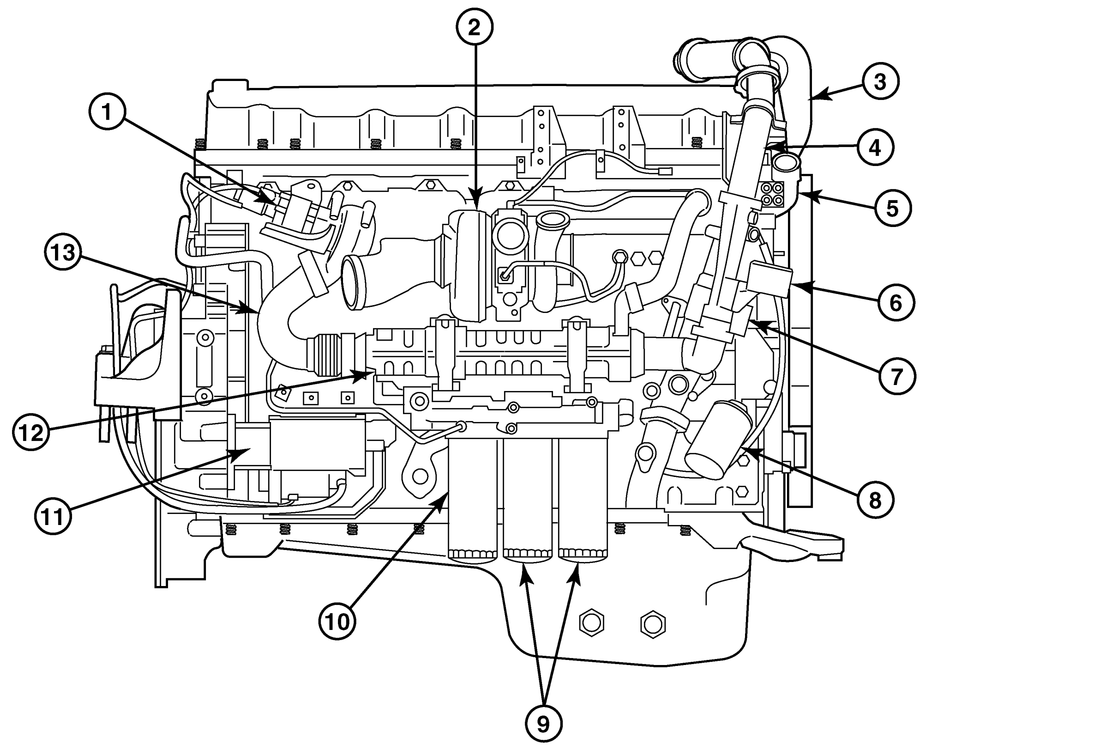


Figure 37 — MACK MP8 Euro 4 Engine, Right-Side View (Front >), Conventional Chassis

1. EGR Valve	8. Coolant Filter (N/A Australia)
2. Variable Geometry Turbocharger	9. Full Flow Oil Filters
3. EGR Mixer	10. Bypass Oil Filter
4. EGR Cooler Outlet Pipe	11. Starter
5. Thermostat	12. EGR Cooler
6. Differential Pressure Sensors	13. EGR Cooler Inlet Pipe
7. Venturi	

NOTE

For Australia, engines are not equipped with the coolant filter shown in Figure 37. VCS coolant is used to protect the cooling system.

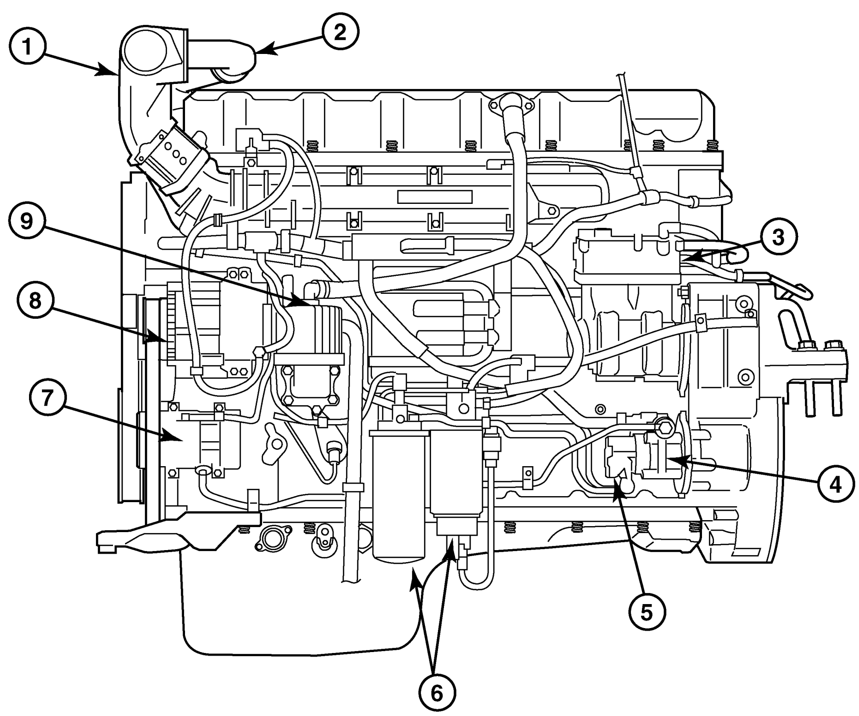


Figure 38 — MACK MP8 Euro 4 Engine, Left-Side View (< Front), Conventional Chassis

1. EGR Mixer 2. EGR Cooler Outlet Pipe 3. Air Compressor 4. Power Steering Pump 5. Low Pressure Fuel Pump	6. Fuel Filters 7. Refrigerant Compressor (Pad Mount) 8. Alternator (Pad Mount) 9. CCV Separator

NOTE

For the conventional chassis, the air inlet is at the front of the inlet manifold which is the configuration shown in Figure 38. For the low cab forward (LCF) and cabover chassis, the air inlet is located near the rear of the manifold.

MACK Australian manufacturing covers only conventional chassis models. The low cab forward chassis models (LEU and MRU series) referenced in this section are not manufactured in Australia.

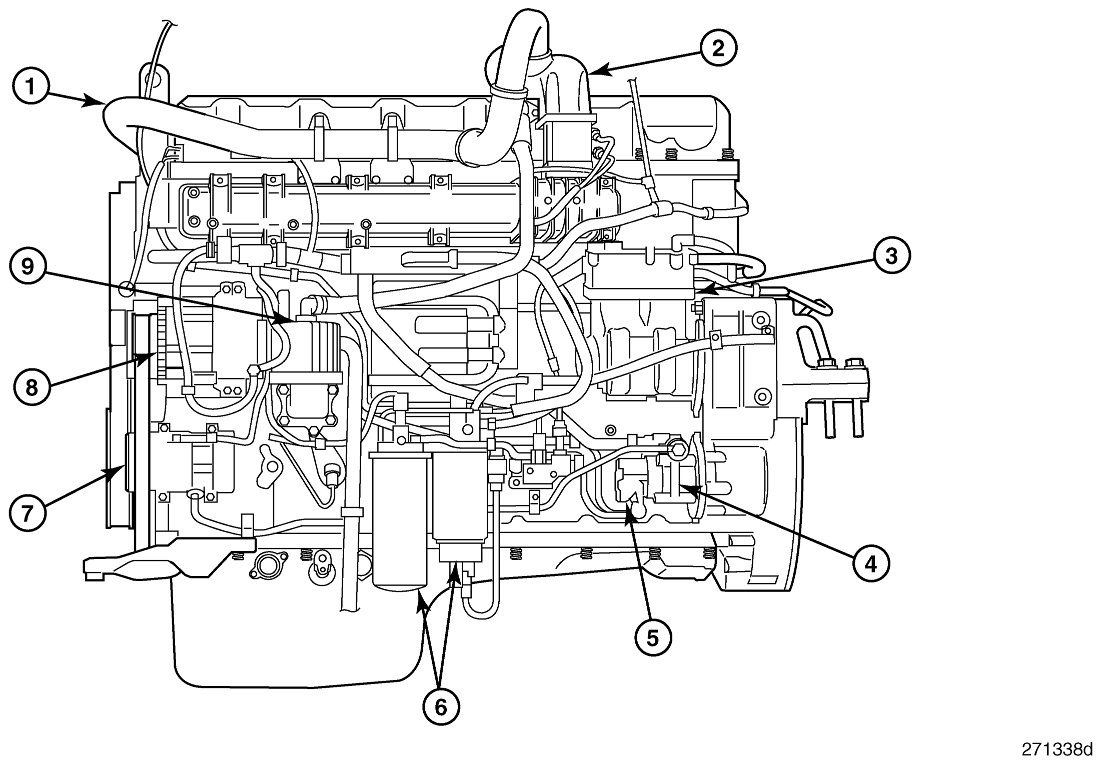


Figure 39 — MACK MP8 Euro 4 Engine, Left-Side View (< Front), LCF Chassis (N/A Australia)

1. EGR Cooler Outlet Pipe 2. EGR Mixer 3. Air Compressor 4. Power Steering Pump 5. Low Pressure Fuel Pump	6. Fuel Filters 7. Refrigerant Compressor (Pad Mount) 8. Alternator (Pad Mount) 9. CCV Separator

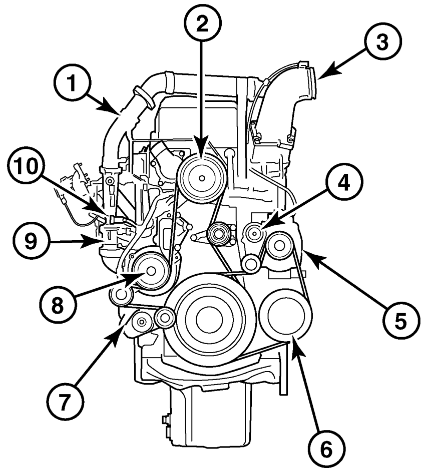


Figure 40 — MACK MP8 Engine, Front View, Conventional Chassis

1. EGR Cooler Outlet Pipe 2. Fan Drive 3. EGR Mixer 4. Belt Tensioner (Alternator/Refrigerant Compressor Belt) 5. Alternator (Pad Mount)	6. Refrigerant Compressor (Pad Mount) 7. Belt Tensioner (Fan Drive/Water Pump Belt) 8. Water Pump 9. Venturi 10. Differential Pressure Sensors

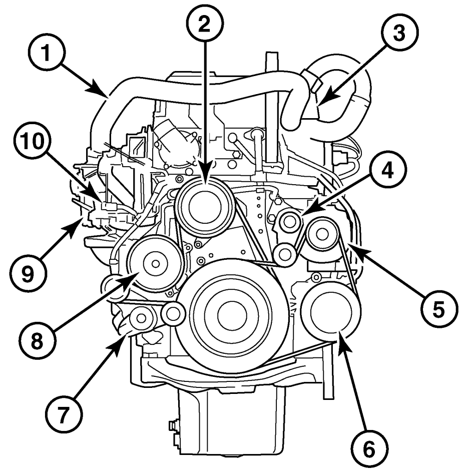


Figure 41 — MACK MP8 Engine, Front View, LCF Chassis (N/A Australia)

1. EGR Cooler Outlet Pipe 2. Fan Drive 3. EGR Mixer 4. Belt Tensioner (Alternator/Refrigerant Compressor Belt) 5. Alternator (Pad Mount)	6. Refrigerant Compressor (Pad Mount) 7. Belt Tensioner (Fan Drive/Water Pump Belt) 8. Water Pump 9. Venturi 10. Differential Pressure Sensors

TROUBLESHOOTING

ENGINE SYMPTOM DIAGNOSIS [200 EA]

The Vehicle Management and Control (V-MAC IV) system monitors engine function and displays a code when a fault is detected. The code can be observed on the instrument panel or through an electronic diagnostic tool. An explanation of the fault codes can be found in VCADS, Guided Diagnostics or the Fault Code Manual, 8-218. Guided Diagnostics also includes symptom-based troubleshooting. To obtain Tech Tool, contact your local MACK dealer.

The Tech Tool provides complete system diagnostics. For more information, see manual 8-371 or the Tech Tool web site. Repair information is available in the respective engine service manuals and from the MACK Electronic Information System (EIS). EIS is easily accessed with Tech Tool.

Troubleshooting Technique

Talk to the vehicle operator. Learn how the engine operated before it failed. Ask about the maintenance schedule and the fuel, coolant and lubricant used. Begin by attempting to determine whether anything has happened recently that could point to the electrical system, but which is not related to the electronic control system.

Depending on the vehicle configuration, a problem may be caused, or influenced, by malfunctions in other vehicle components. Be sure to inspect for unusual conditions among the batteries, tires, axles, trailer, bodybuilder adaptations and other possibilities. Consult specific service information resources according to the conditions observed. Fuel waxing, for example, can cause symptoms easily mistaken for other engine problems.

If possible, recreate the problem in an environment similar to that described by the vehicle operator. Run the engine at the temperature at which the symptom occurred.

Engine problems can be electrical, mechanical or a combination of the two. Electrical and electronic problems will, for the most part, cause fault codes to be set in the V-MAC system.

Before Troubleshooting Begins

Before troubleshooting begins, observe all shop safety procedures.

Noise and Vibration

NORMAL VERSUS ABNORMAL

Noise is the name we give to vibration that irritates us through our ears. *Vibration* can be felt without being heard. Engine operation can cause vibration and noise throughout a vehicle that we regard as “normal.”

Abnormal noises and vibrations suggest that something is not working properly or is not assembled properly. A damaged driveshaft can cause abnormal vibration. A loose fastener allows two surfaces to rub or slap together causing unusual noise in response to the vibration.

Be sure to discuss noise and vibration issues with the driver. It is important to discover under what conditions these occur. Maybe a test drive will be necessary to familiarize yourself with the details of the driver's story. Even so, it will probably be necessary to start the diagnostic process with a guess as to the nature of the difficulty.

The table below affords an opportunity to make note of various influences discovered while investigating the problem and organize thoughts. It is made for you to use as you see fit.

The noise or vibration occurs:	Yes	No	Remarks
When the vehicle is stationary			
At idle			Engine Speed =
When power take-off is engaged			Engine Speed =
Other items of interest			
When the vehicle is in motion			
With a particular superstructure			
At a particular weight			
At a particular speed			
On a particular type of road			
Driving without cruise control			
Driving with cruise control			
Driving using the speed governor			
At full load			
In a particular gear			
When freewheeling (clutch disengaged)			
Vehicle information			
Type of chassis suspension (air?)			
Type of cab suspension (air?)			
Type of driver's seat (make and model)			
Other items of interest			
Notes:			

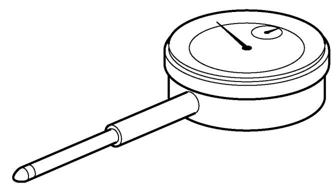
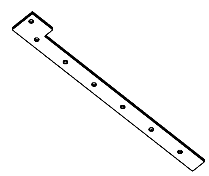
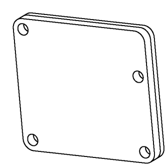
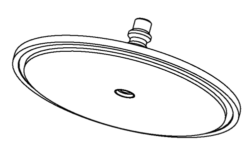
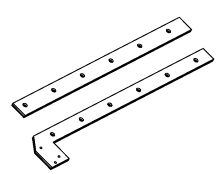
If the solution does not become evident in the course of completing the check list above, use Tech Tool to investigate further.

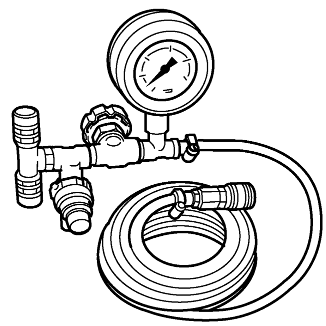
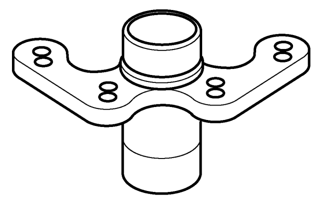
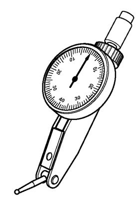
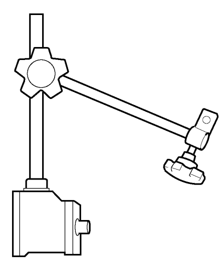
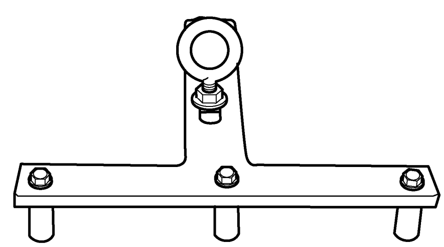
ENGINE CHECKS AND TESTS

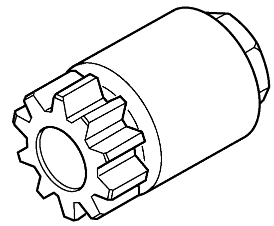
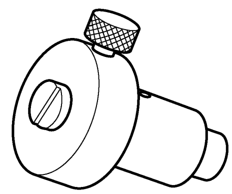
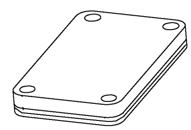
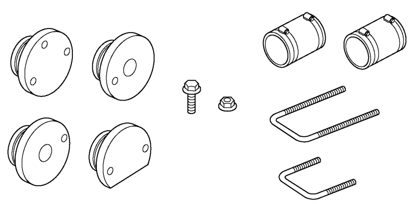
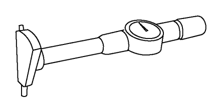
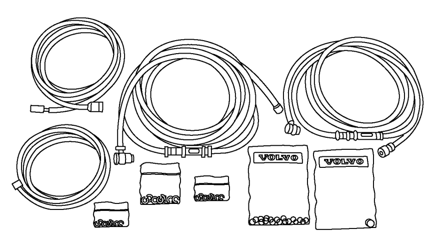
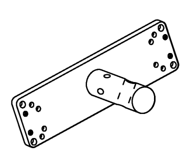
Included in this section are the following engine checks and tests:

- Camshaft Sensor Depth, Check
- Camshaft Timing, Check
- Crankcase Ventilation, Check
- Cylinder Head, Pressure Test
- Cylinder Liner and Piston Wear, Check
- EGR Cooler, Pressure Test
- Engine Compression, Test
- Flywheel Housing Runout, Check
- Oil Cooler, Pressure Test
- Rocker Arm, Check
- Thermostat, Check
- Valve Guide Wear, Check

Special Tools

Tool No.	Description	Image
9989876	Dial Indicator (Available)	 006899a
9990105	Sealing Plate for MP7 Cylinder Head	 274113a
9990106	Sealing Plate for MP7, MP8 and MP10 Cylinder Heads	 274114a
9990107	Connection Disc for MP7, MP8 and MP10 Cylinder Heads	 274115a
9990164	Sealing Plate for MP10 Cylinder Head	 274116a

Tool No.	Description	Image
9996662	Pressure Gauge and Hoses (Available)	 006793a
9996956	Flywheel Turning Tool for MP7 Engine (Essential)	 006795a
9999683	Sweep Dial Indicator (Essential)	 006948a
9999696	Magnetic Stand (Available)	 006900a
85109036	Cylinder Head Lifting Tool (Essential)	 006769a

Tool No.	Description	Image
88800014	Flywheel Turning Tool for MP8 and MP10 Engines (Essential)	 271485a
88800031	Camshaft Sensor Depth Gauge (Available)	 006804a
88800215	Sealing Plate	 007157a
88800216	EGR Cooler Test Kit	 007002c
J 5347-B	Dial Bore Gauge	 000615b
J 42753	Fuel Line Kit	 007158a
J 47364	Cylinder Head Adapter Plate	 007117a

Camshaft Sensor Depth, Check

The signal from the camshaft sensor must exceed 0.5 volt in order to start the engine. If the signal is low, check the depth setting of the sensor following this procedure.

1. Remove the plug from the flywheel housing and install the appropriate flywheel turning tool, 9996956 (MP7) or 88800014 (MP8 and MP10).
2. Check for proper camshaft position sensor clearance using the sensor depth gauge, 88800031, to determine if shims are required for sensor depth.

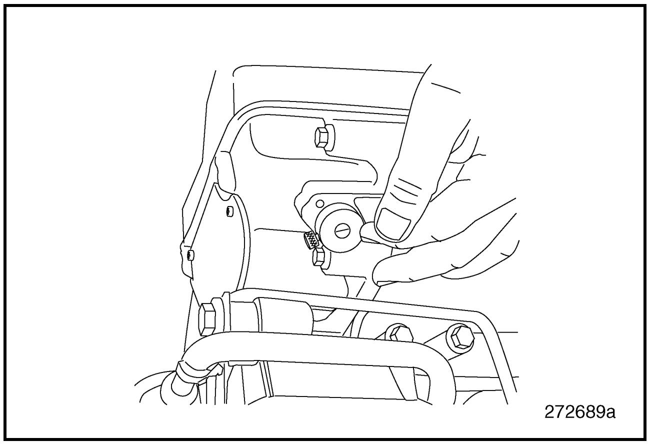


Figure 42 — Using Gauge at Camshaft Sensor Location

   a. Rotate the engine until a tooth of the camshaft toothed wheel is aligned with the sensor bore.

   b. Insert the depth gauge into the sensor bore until the outer part of the gauge is fully seated against the timing gear cover.

   c. Loosen the thumb screw of the gauge and push the inner part of the gauge in until it contacts a tooth of the toothed wheel.

   d. Tighten the thumb screw to secure the inner part of the gauge.

   e. Carefully remove the gauge from the camshaft sensor bore and observe the location of steps between the inner and outer portions of the gauge (Figure 43):

   - Both steps below the surface of the gauge = no shims required.
   - One step below the surface of the gauge = one shim required.
   - Both steps above the surface of the gauge = two shims required.

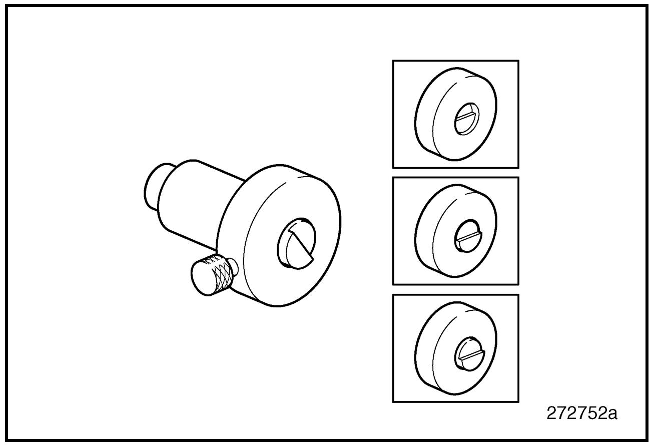


Figure 43 — Depth Gauge

3. Install the camshaft position sensor with the appropriate shim(s) and **new** O-ring. Secure the sensor with a bolt and plug in the harness connector.

Camshaft Timing, Check

1. Remove the cylinder head (valve) cover.
2. Check the camshaft vibration damper for damage to the pulse wheel pins.
3. Check the pulse wheel mounting for secure, square attachment.
4. Turn the engine crankshaft so that the TDC mark on the camshaft corresponds to the marks on the camshaft bearing cap No. 7 (MP7) or camshaft bearing cap No. 1 (MP8 and MP10) and the flywheel TDC mark “0” is opposite the pointer on the flywheel housing.

5. To ensure that the camshaft is correctly installed, complete a valve lift check on the intake valves of cylinder No. 1.
   - Temporarily adjust the No. 1 inlet rocker arm, at the valve yoke, to zero lash.
   - Position a dial indicator at the inlet valve yoke for the No. 1 cylinder.
   - Preload the dial indicator and reset the dial to align with zero.
   - Turn the engine in the normal direction of engine rotation one full rotation to "0" and past to the mark 6 degrees (after TDC) on the flywheel.
   - The dial indicator travel reading should be approximately 1.6 ±0.03 mm (0.06 ±0.01 inch) for MP7 and MP8 or 1.4 ±0.03 mm (0.05 ±0.01 inch) for MP10. This reading indicates a correctly timed camshaft.
   - Readjust the cylinder No. 1 inlet valves and yoke.

NOTE

If the camshaft is one tooth out of time, the dial indicator reading will be approximately 0.762 mm (0.030 inch) out of specification and should experience a fault code for the camshaft sensor.

6. Install the cylinder head (valve) cover.

Crankcase Ventilation, Check

1. Check the inlet pipe to the CCV separator for oil film, oil residue and particles. Remove any accumulated oil and dirt particles from the pipe.

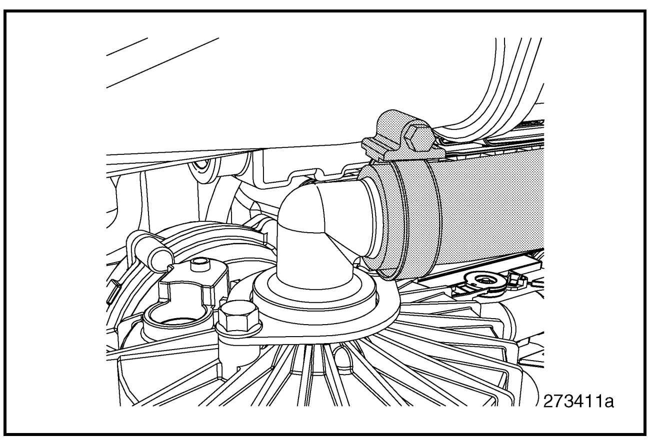


Figure 44 — CCV Inlet Pipe Connection

2. Remove the CCV separator from the engine.
3. With the separator removed, rotate the turbine by hand. It should rotate easily. If it does not rotate easily, replace the separator unit.

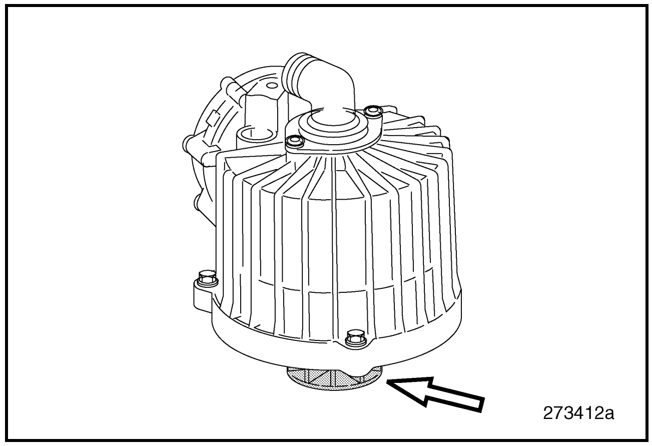


Figure 45 — CCV Separator Turbine Wheel

4. Check the oil nozzle in the CCV base for dirt and any accumulated oily deposits. Clean the nozzle as required. If unable to clean the nozzle sufficiently, replace the complete CCV separator assembly.

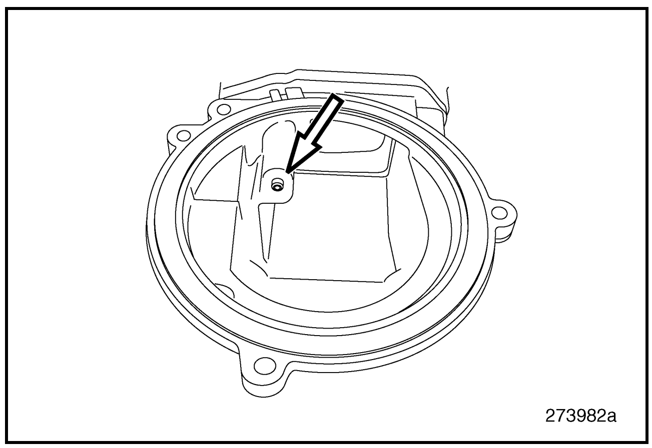


Figure 46 — Oil Nozzle (Separator Base)

NOTE

If the oil nozzle becomes clogged, the oil pressure is reduced and the turbine does not rotate as it should.

Cylinder Head, Pressure Test

(Cylinder Head Removed)

The following procedure applies for MACK MP7, MP8 and MP10 engine cylinder heads. While the procedure is typical, the sealing tools required will be different for each MP engine series.

1. Clean the contact surfaces on the cylinder head. Install the:
   - Sealing plates, 9990105 (MP7), 9809696 and 9998266 (MP8) or 9990164 (MP10), onto the cylinder head coolant ports using cylinder head bolts and M16 nuts
   - Connection disc, 9990107, in position on the thermostat housing bore
   - Plug, M12x1.5, in the temperature sensor hole
   - Sealing plate, 88800215, on the side of the cylinder head

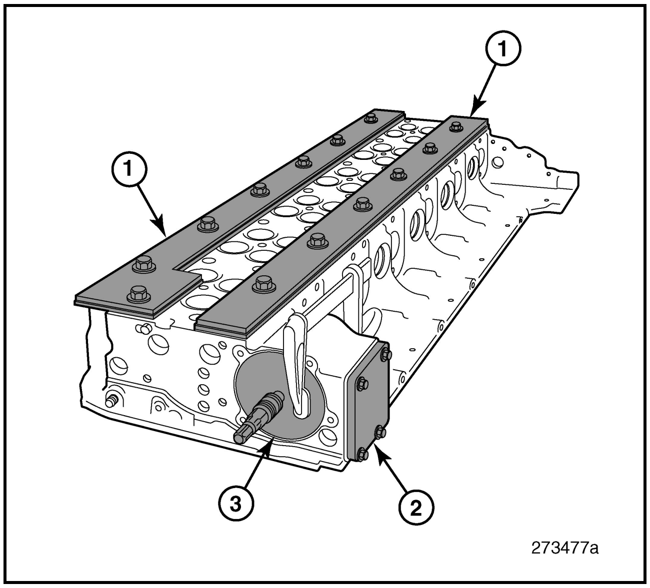


Figure 47 — Sealing Plates Installed (Typical)

1. Sealing Plates (Cooling Ports) 2. Sealing Plate (By-Pass Port)	3. Connection Disc (Thermostat Housing)

2. Connect the pressure gauge, 9996662, to a suitable air supply. Connect the pressure gauge hose to the connection disc on the cylinder head. Adjust the pressure to 100 kPa (14.5 psi) using the control valve. Close the stop valve for two minutes. The pressure should not fall.
3. Lower the pressure in the cylinder head by adjusting the knob on the pressure gauge control valve.

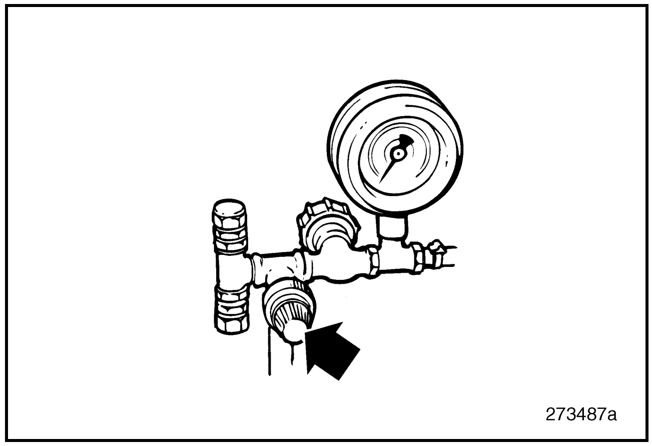


Figure 48 — Pressure Gauge Adjustment Knob

4. Attach the cylinder head lifting tool, 85109036, to the cylinder head.
5. Using a hoist, lower the cylinder head into a container suitable for the pressure test. Fill the container with 70°C (158°F) water.

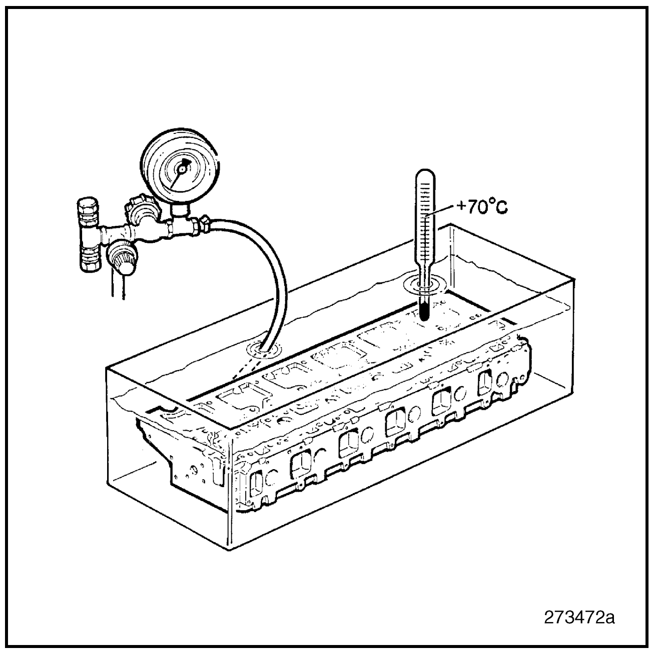


Figure 49 — Testing for Air Leaks

6. With the pressure gauge connected to an air supply and the connection disc on the cylinder head, carefully open the gauge control valve.
7. Set the pressure to 50 kPa (7.25 psi) and hold the pressure for one minute.

8. Raise the pressure to 150 kPa (21.8 psi) and close the stop valve. After two minutes, check for a drop in pressure and for any air bubbles forming around the cylinder head.

NOTE

A drop in pressure and the appearance of air bubbles indicates a leak(s) in the coolant, fuel or oil passages. The source of the leak(s) must be found and the cylinder head repaired or replaced as required.

9. Lower the pressure in the cylinder head by adjusting the knob on the pressure gauge control valve.
10. Using a hoist, remove the cylinder head from the water container.
11. Remove the sealing plates and connection disc from the cylinder head. Using compressed air, blow the water off the cylinder head and out of all threaded holes.

CAUTION

Use care with the fuel passages to make sure that no dirt enters the fuel channels. Dirt can cause the unit injectors to be damaged.

Cylinder Liner and Piston Wear, Check

Thoroughly clean the cylinder liners and pistons before inspecting and measuring. To thoroughly check for cracks, remove the cylinder liner from the cylinder block. Mark the position of the cylinder liner in the cylinder block before removing it so it can be installed in the same position during assembly.

CYLINDER LINER

1. Check the cylinder liner for cracks, paying special attention to the liner flange. The standard dye penetrant or Magnaflux® method can be used for checking.
2. Measure the cylinder liner wear with a cylinder bore gauge. The original bore size of the cylinder liner can be used as a reference measurement.

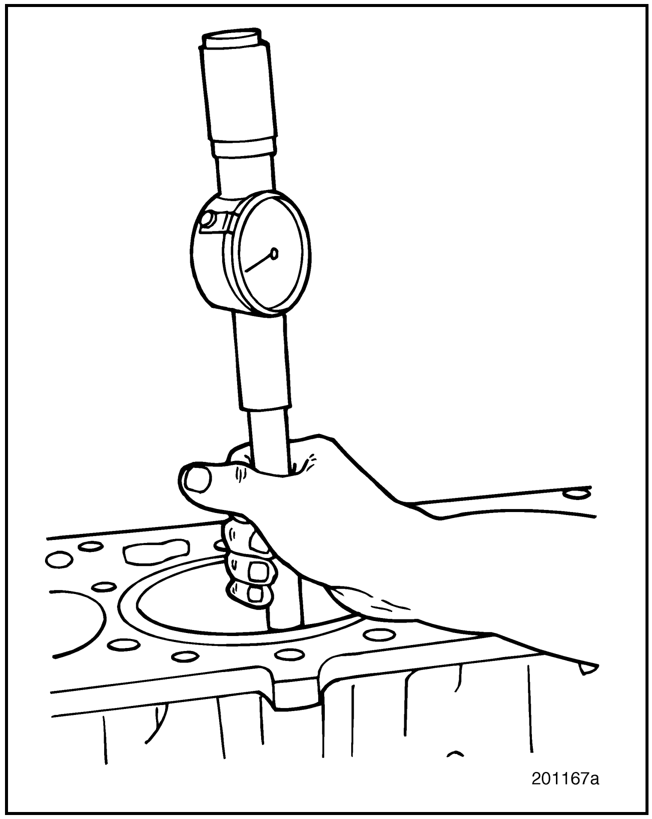


Figure 50 — Measuring Cylinder Liner Wear

3. Measure the cylinder liner at Top Dead Center (TDC), at Bottom Dead Center (BDC) and at a couple of positions in between. At each point, measure in two directions — engine crosswise and engine lengthwise.

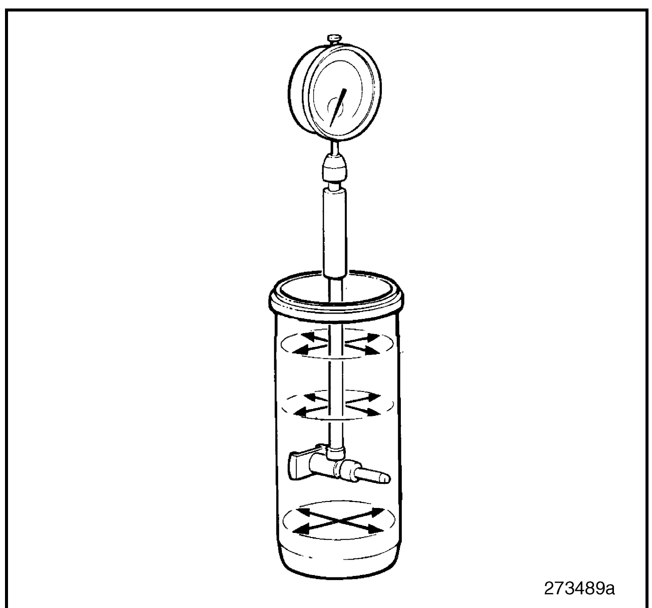


Figure 51 — Measurement Locations

4. If wear is greater than 0.05–0.10 mm (0.002–0.004 inch), use a complete liner kit (cylinder liner, piston, piston rings, piston pin and cylinder liner seals). Also consider engine oil consumption to determine when to replace the cylinder liner.

NOTE

Pistons and cylinder liners are available from stock only as matched pairs and should not be mixed.

PISTON

Inspect the piston ring grooves, lands, skirt and combustion bowl for wear, scuff marks, deep scratches, cracks and blow-by. Pistons are NOT repairable. Discard worn or damaged pistons.

CAUTION

Do not stamp or engrave on the TOP of the piston. Failure to heed this caution may result in severe engine damage.

To ensure that pistons are reinstalled into the same cylinders, the pistons must be tagged with the corresponding cylinder number when removed during disassembly.

EGR Cooler, Pressure Test

(Not Applicable for MP8 Euro 3 Engine)

1. Check inside the gas inlet port. If build-up of soot is seen, perform the EGR cooler cleaning procedure before checking for leaks.
2. Lubricate the O-rings on the coolant inlet and outlet port plugs with a suitable O-ring lubricant. Install the plugs and cap on the EGR cooler. Install the plugs on the EGR cooler coolant inlet and outlet ports. Install the coupler on the plug and connect the gauge to the coupler.

CAUTION

Do NOT over-tighten the fasteners on the plugs and cap.

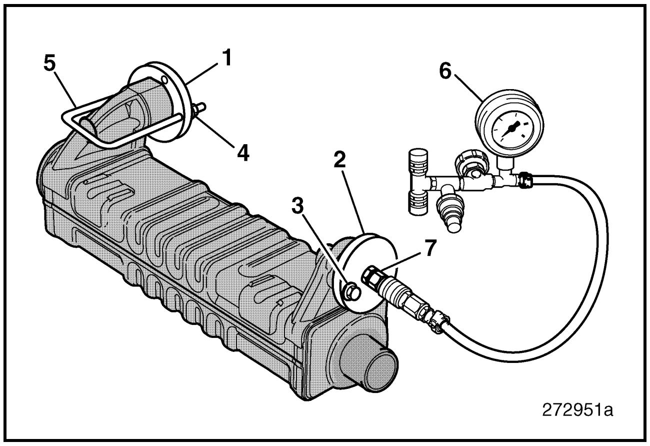


Figure 52 — Installation of Leak Test Kit on Cooler

1. 88800216-1 2. 88800216-2 3. Flange Capscrew 4. Flange Nut	5. U-Bolt 6. 9996662 7. 9998333

3. Fill a container with enough water to cover the EGR cooler.
4. Lower the EGR cooler into the container of water at room temperature (or fill the cooler core with water — see NOTE).

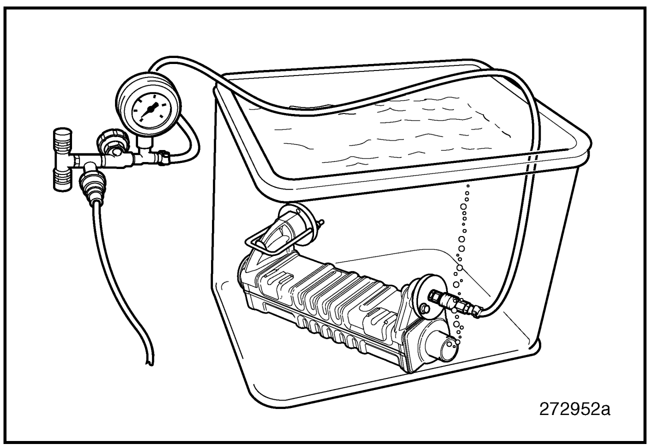


Figure 53 — Conducting Pressure Test

NOTE

If a large enough container cannot be obtained, the EGR cooler can be tested without being immersed in water by using the test plugs included with the kit, 88800216-5, to seal the gas outlet port. The EGR cooler core can then be filled with water and tested by applying air pressure to the coolant outlet port as shown in Figure 54. When using this technique, the cooler must be tested in the upright position.

To ease the installation of the test plug, coat the inside of the hose with a suitable O-ring lubricant.

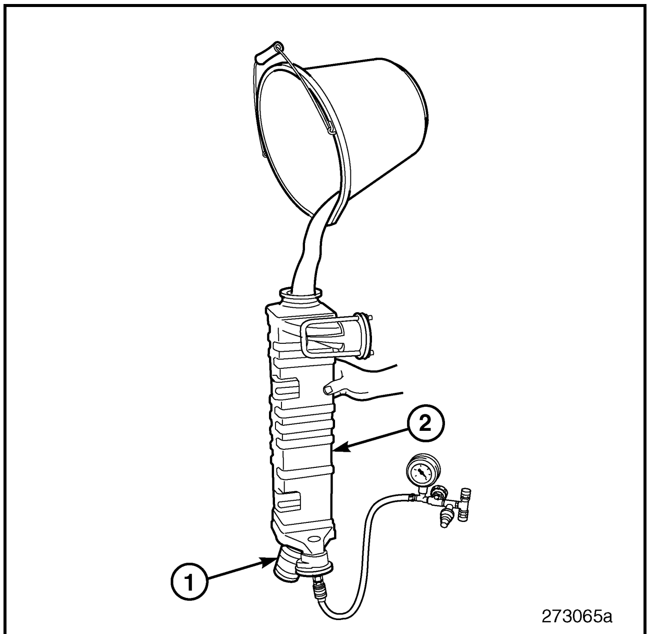


Figure 54 — Test with EGR Gas Outlet Port Plugged

1. Test Plug, 88800216-5	2. EGR Cooler

5. Apply air pressure (240 kPa [35 psi]) to the EGR cooler. Maintain the pressure for 15 minutes. If the EGR cooler is leaking internally, there will be a steady stream of bubbles coming from the gas inlet or outlet openings. If a steady stream of bubbles appears, replace the EGR cooler.

NOTE

If the cooler is being tested without being immersed in water, look inside the gas inlet port. If bubbles are seen, the cooler is leaking internally and must be replaced.

NOTE

A stream of bubbles seen coming from around the plugs in either of the coolant ports indicates that the O-rings may be damaged. If this is the case, remove the plugs, inspect the O-rings and replace as required.

6. Lift the EGR cooler out of the container and remove the pressure testing equipment.
7. Dump the water from inside the EGR cooler and then use compressed air to remove any remaining water from the cooler core and outer cover.

Engine Compression, Test (on Vehicle)

Verify suspected leaks in the cylinder head or block by pressure testing before replacing these. Do not use Magnaflux® inspections alone as replacement criteria.

Before proceeding with the tests, look for coolant stains around the sealing plugs on the cylinder head. Check that the plugs are installed properly and in good condition.

1. Remove the cylinder head (valve) cover.

⚠ CAUTION

On engines fitted with PowerLeash™, secure the pistons in the rocker arms with rubber bands or tie straps so the pistons do not drop out when the rocker assembly is lifted. Pistons and rockers are matched together. Failure to heed this caution may result in severe component damage.

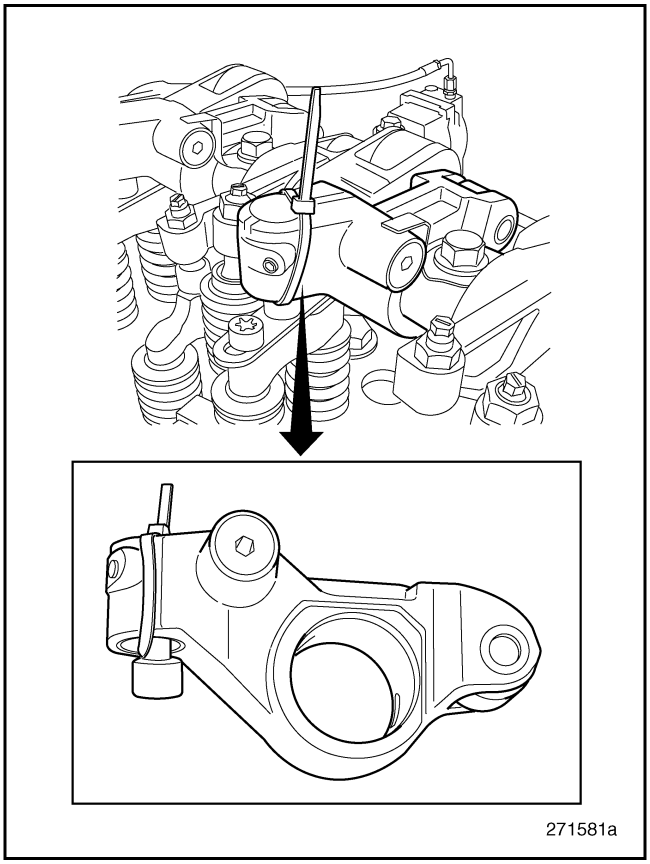


Figure 55 — Tie Strap Holding Engine Brake Piston (MP7 Shown)

2. Remove the PowerLeash™ (engine brake) control valve if so equipped.

⚠ CAUTION

It is very important to loosen the rocker arm shaft assembly uniformly across the complete shaft. Loosening the rocker shaft assembly unevenly can cause damage.

3. Install the appropriate lifting tool, 85109050 (MP7), 85109250 (MP8) or 85109035 (MP10), on the rocker arm assembly. Loosen the rocker arm shaft uniformly across the complete shaft. Remove the rocker arm assembly.
4. Remove the unit injectors and clean the copper sleeves if necessary.
5. Install an adapter, J 47363, in each of the unit injector ports.
6. Refit the rocker arm assembly to the engine.
7. Install the PowerLeash™ control valve and oil tube between the valve and the rocker arm shaft as follows:
   - Lubricate and assemble the seals on each end of the oil tube.
   - Insert the larger end of the oil tube in the rocker shaft.
   - Make sure the oil seal is in place at the bottom of the valve assembly.
   - Position the valve assembly on the mounting plate and insert the free end of the oil tube.
   - Using a torque wrench, tighten the attaching screws according to specification.

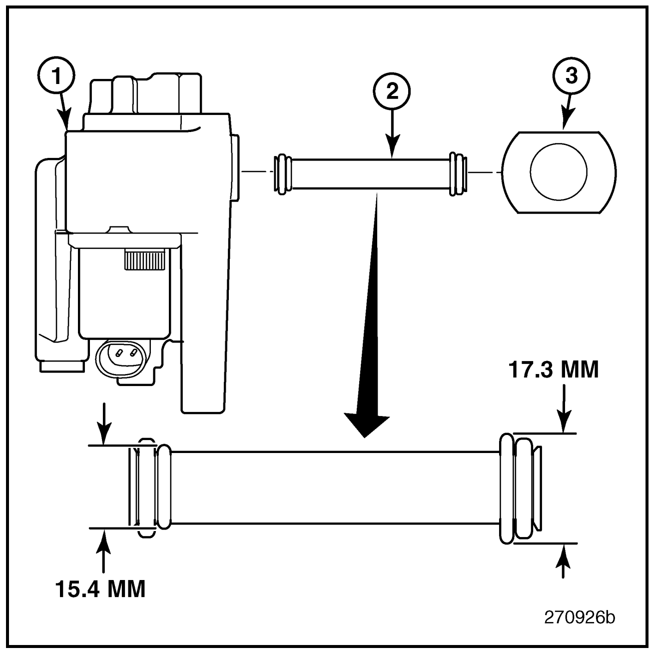


Figure 56 — Engine Brake Control Valve Oil Tube Orientation (MP7 Only)

1. Control Valve 2. Oil Tube	3. Rocker Arm Shaft

8. Connect a remote starter switch to the starter.

⚠ CAUTION

Do not run the starter motor for longer than 15 seconds at a time. Wait 60 seconds before trying again.

9. Connect the compression gauge, J 6692-B, to the adapter on the first cylinder. Crank the engine with the remote starter switch until the needle on the compression gauge stops moving (maximum compression). Record and repeat for all remaining cylinders.
10. Remove the screws for the PowerLeash™ control valve.
11. Remove the control valve and the oil tube between the valve and the rocker arm shaft.
12. Install the lifting tool, 85109050 (MP7), 85109250 (MP8) or 85109035 (MP10), on the rocker arm assembly. Loosen the rocker arm shaft uniformly across the complete shaft. Remove the rocker arm shaft assembly.
13. Remove the J 47363 adapters from all of the cylinders.
14. Install the unit injectors using **new** O-rings and **new** sealing washers.
15. Connect the wiring harness to the unit injectors.
16. Carefully lower the rocker arm shaft assembly onto the head.
17. Remove the lifting tool from the rocker arm shaft.

CAUTION

It is very important to tighten the rocker arm shaft assembly uniformly across the complete shaft. Tightening unevenly can cause damage to the rocker arm shaft assembly.

18. Tighten the rocker arm shaft screws in the sequence specified.
19. Install the PowerLeash™ control valve and oil tube between the valve and the rocker arm shaft making sure the sealing rings are correctly positioned before tightening the screws.

CAUTION

If the oil tube is installed incorrectly with the large end in the control valve and the small end in the rocker arm shaft, oil leaks will occur. This may cause oil starvation in the rocker arms which can result in engine failure.

20. Tighten the control valve screws according to specification and then connect the wiring harness to the valve assembly.
21. Adjust the valve and the unit injector rockers.
22. Install the cylinder head cover.
23. Bleed the fuel system.

Flywheel Housing Runout, Check (Clutch Removed)

CHECKING AXIAL AND RADIAL RUNOUT

1. Clean the flywheel and flywheel housing.
2. Remove the plug from the flywheel housing and install the appropriate flywheel turning tool, 9996956 (MP7) or 88800014 (MP8, MP10).

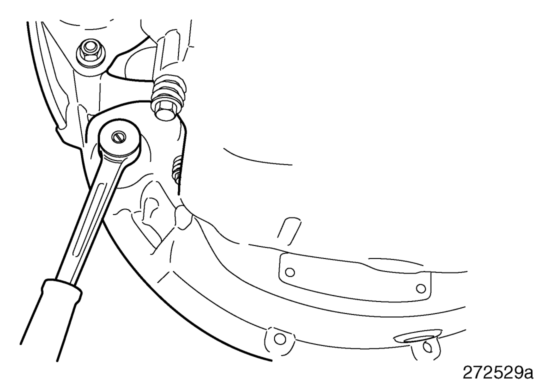


Figure 57 — Turning Flywheel (MP8 Shown, Typical)

3. To check **axial runout**, attach the dial gauge to the flywheel using the magnetic base and position its tip against the outer flange (transmission mounting surface) of the flywheel housing. Set the dial gauge to zero.
4. Rotate the flywheel and note the indicated runout at a minimum of four locations around the outer flange of the housing. Compare the noted runout with the specified axial runout tolerance.

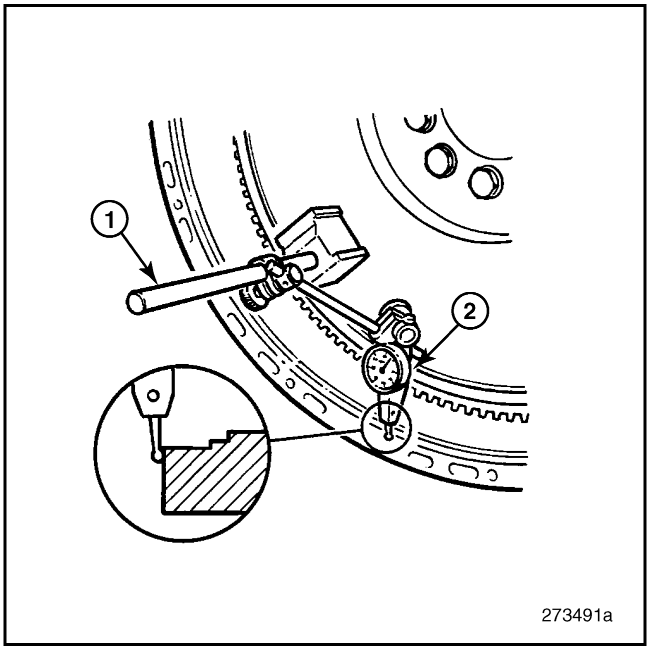


Figure 58 — Checking Axial Runout

1. Magnetic Stand, 9999696	2. Sweep Dial Indicator, 9999683

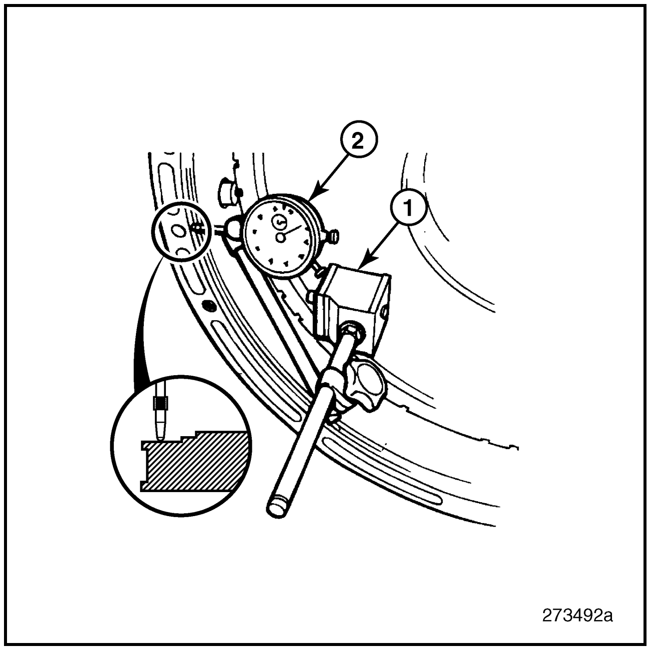


Figure 59 — Checking Radial Runout

1. Dial Gauge, 9989876	2. Magnetic Stand, 9999696

5. To check **radial runout**, position the tip of the dial gauge against the inner flange of the flywheel housing. Rotate the flywheel and note the indicated runout, again at a minimum of four locations around the inner flange of the housing. Compare the noted runout with the specified radial runout tolerance.
6. If the runout values are out of specification, check the mating surface for the flywheel housing against the engine block and the mating surface for the flywheel on the crankshaft. Do this before replacing the flywheel housing.
7. Remove the flywheel turning tool and reinstall the plug in the flywheel housing.

Oil Cooler, Pressure Test

1. Clean the coolant side of the oil cooler with a water-soluble degreasing fluid. Flush the oil side of the cooler with degreasing solvent.
2. Install the clamp tools, 9996845, making sure they are properly seated.

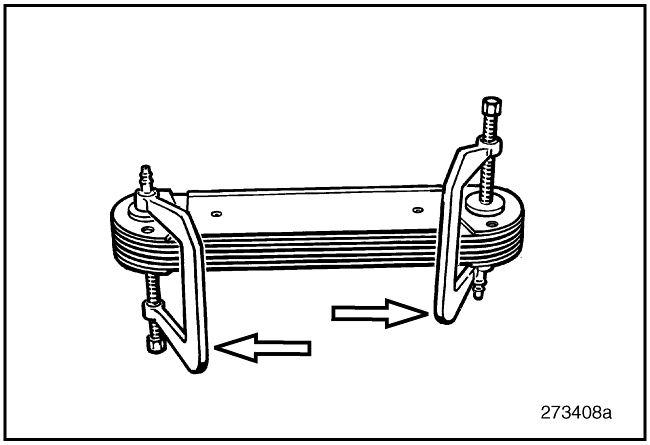


Figure 60 — Clamp Tools, Installed

3. Adjust the pressure gauge reduction valve knob until the pressure gauge needle is at zero.
4. Connect the pressure gauge assembly to the fitting on the clamp. Lower the oil cooler into a bath of water. The water temperature should be at approximately 70°C (160°F).

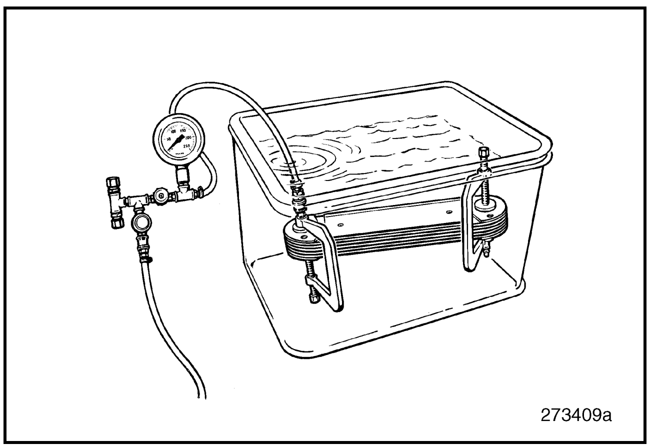


Figure 61 — Testing Oil Cooler

5. Increase the pressure to 250 kPa (35 psi) using the reduction valve knob and check for air bubbles emerging from the oil cooler. The test period should last for at least one minute.

NOTE

Air bubbles emerging from the oil cooler indicate a leak. The oil cooler should be replaced.

Rocker Arm, Check

NOTE

Make sure there is clearance between the rocker arm rollers and the camshaft when performing the following rocker arm bushing and roller bushing checks.

ROCKER ARM BUSHINGS

1. Install the appropriate flywheel turning tool, 9996956 (MP7) or 88800014 (MP8 and MP10), and turn the engine until the camshaft is in a position where the rocker arm roller being checked is on the base circle of the camshaft lobe. Make sure that there is clearance between the roller and camshaft.

NOTE

To check the injector, the rocker arm roller must be on the base circle of the camshaft lobe and the injector adjusting screw backed off (preload must be readjusted).

2. Position the magnetic stand, 9999696, and dial indicator, 9989876, so that the tip of the indicator is on top of the rocker arm above the middle of the rocker arm shaft bushing area.

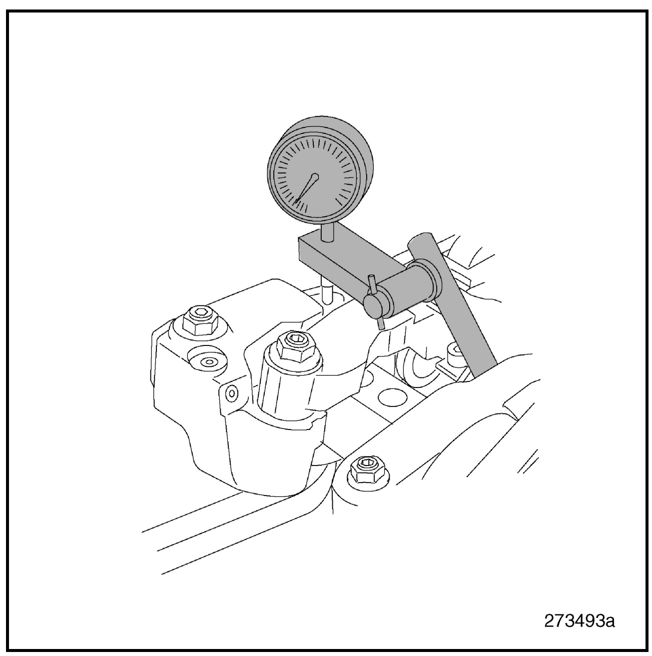


Figure 62 — Dial Indicator Positioning

3. Push down on the rocker arm so that any oil film is forced out of the upper side of the rocker arm shaft.
4. Set the dial indicator to zero.
5. Position a pry bar directly under the rocker arm in the shaft area. Pry the rocker arm up and note the reading on the dial indicator. The maximum clearance allowed between the rocker arm and shaft is 0.1 mm (0.0039 inch). If the clearance is greater, replace the rocker arm and check the shaft for wear.

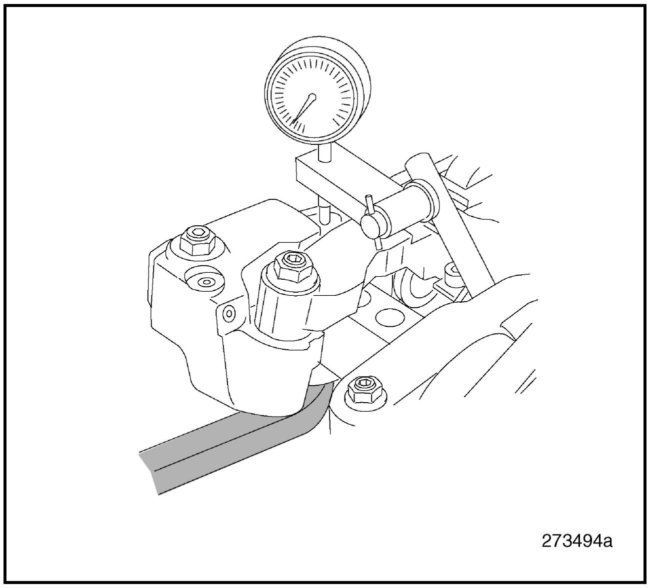


Figure 63 — Prying Rocker Arm Up

6. Repeat the check on all other rocker arm bushings.

ROCKER ARM ROLLER BUSHINGS

1. Using the flywheel turning tool, 9996956 (MP7) or 88800014 (MP8 and MP10), turn the engine until the camshaft is in a position where the rocker arm roller being checked is on the base circle of the camshaft lobe.
2. Make sure there is clearance between the rocker arm roller and the camshaft lobe.

NOTE

To check the injector, the rocker arm roller must be on the base circle of the camshaft lobe and the injector adjusting screw backed off (preload must be readjusted).

3. Rotate the roller a few turns so that the oil film between the roller bushing and shaft is forced out. If the roller jams, is sticky or rough, the rocker arm should be replaced.

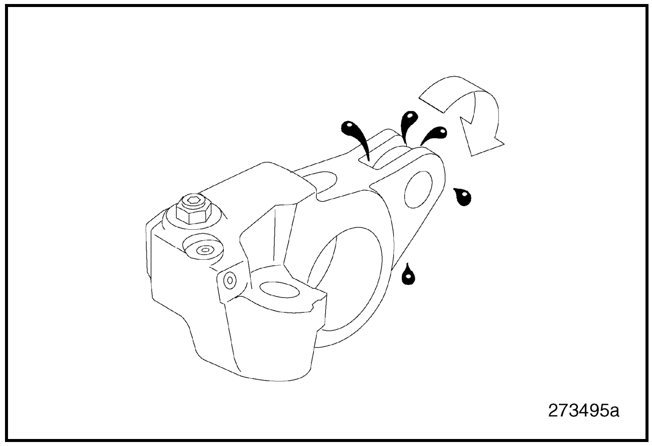


Figure 64 — Forcing Oil from Roller

4. Place the dial indicator, 9989876, into the magnetic stand, 9999696, and position the magnetic stand as level as possible on the rocker arm.

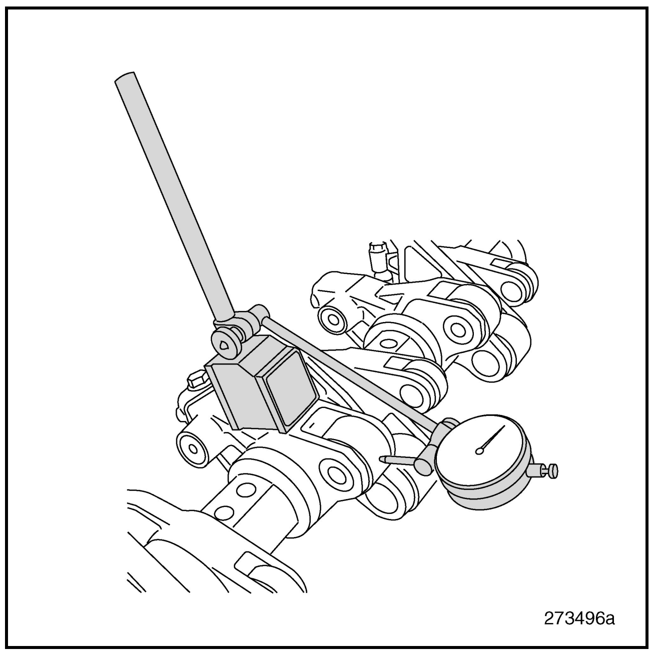


Figure 65 — Dial Indicator Positioning

5. Adjust the tip of the dial indicator so that it is horizontal to the center of the roller. Zero the dial indicator.

NOTE

Check that the tip of the dial indicator is pre-tensioned and can move in both directions.

6. Place a screwdriver between the rocker arm and the roller. Carefully pry the roller out as far as possible and note the value on the dial indicator.

CAUTION

Use care when prying or pressing on the roller to avoid damage to the surface of the roller.

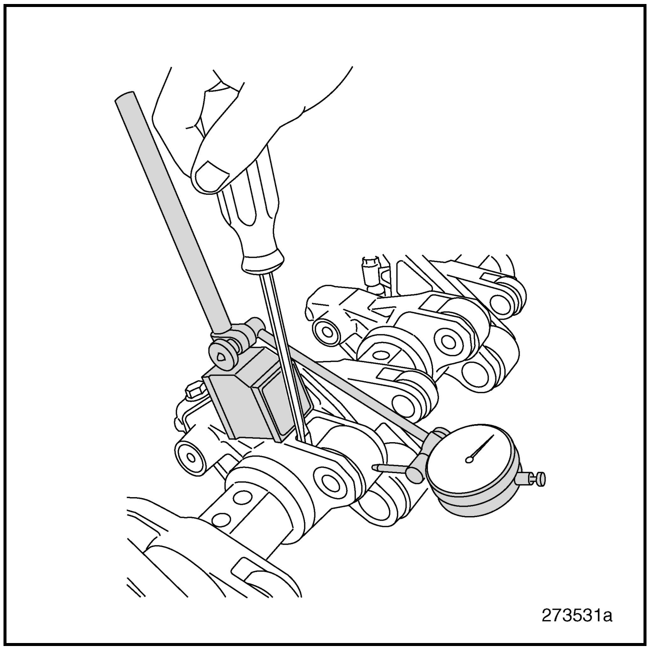


Figure 66 — Prying Roller Out

7. Using a blunt object, press the roller in as far as possible. Note the reading on the dial indicator. The maximum clearance allowed between the roller bushing and shaft is 0.1 mm (0.0039 inch). If the clearance is greater than this, replace the rocker arm.

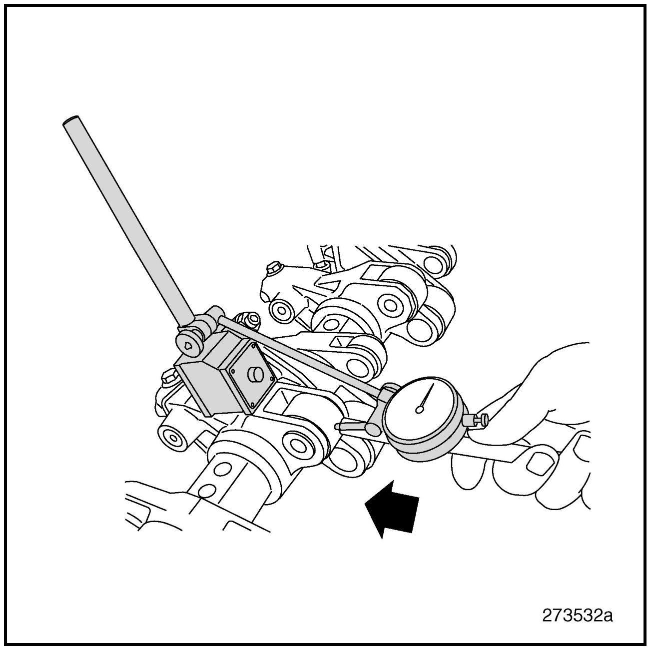


Figure 67 — Pressing Roller In

8. When replacing a rocker arm, lubricate the **new** rocker arm roller bushing with clean engine oil. Use an oil can and insert the nozzle into the oil channel passage. Rotate the roller while lubricating and check that oil comes out on both sides of the roller.

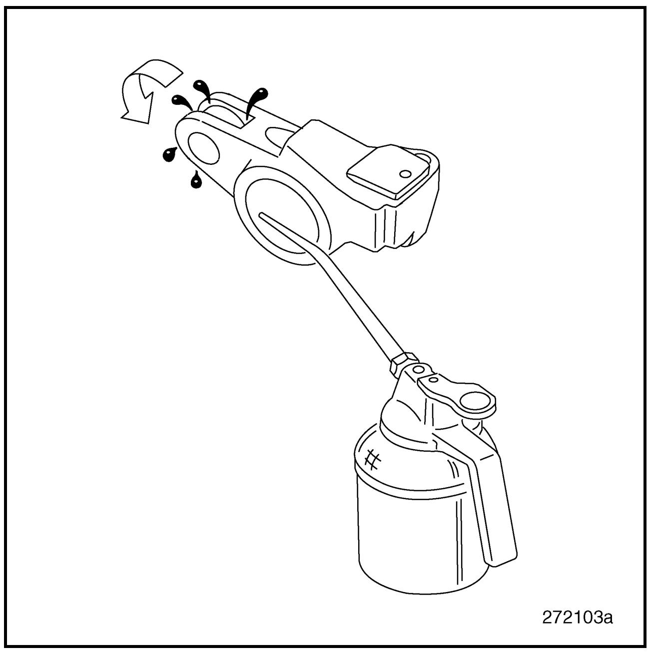


Figure 68 — Lubricating Rocker

9. Repeat the check on all other rocker arm roller bushings as necessary.

Thermostat, Check

With the thermostat removed from the engine, check its operation as follows:

1. Check to be sure that the thermostat closes fully. This can be done by holding it up to the light to verify that there is no visible gap at the opening point. If the thermostat does not close properly, replace it.
2. Add water to a suitable container and warm the water to 75°C (167°F). With the water warmed, immerse the thermostat in the water. Use a piece of wire attached to the thermostat.

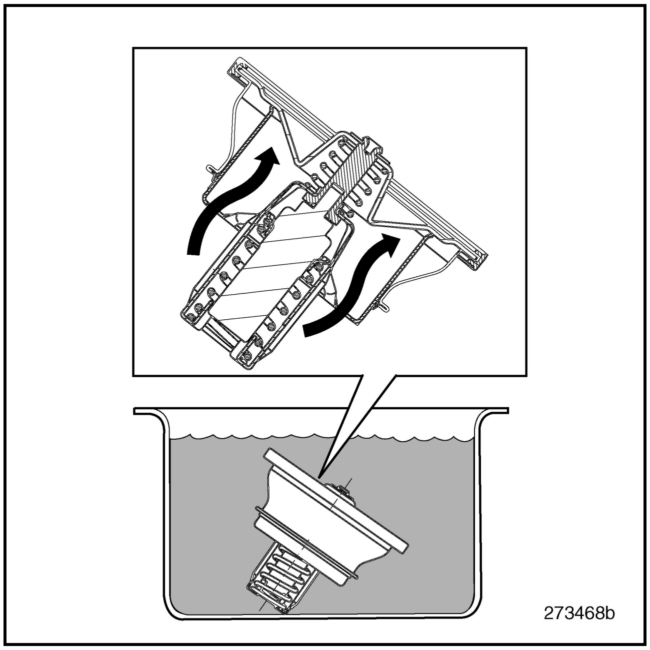


Figure 69 — Thermostat Closed

3. After at least 30 seconds, check that the thermostat is still closed.
4. Now warm the water to 100°C (212°F). After at least 30 seconds at the boiling point, check that the thermostat has opened approximately 16 mm (0.63 inch). If the thermostat has not opened, it must be replaced. A good thermostat starts to close at approximately 92°C (198°F) and is fully closed at approximately 82°C (180°F).

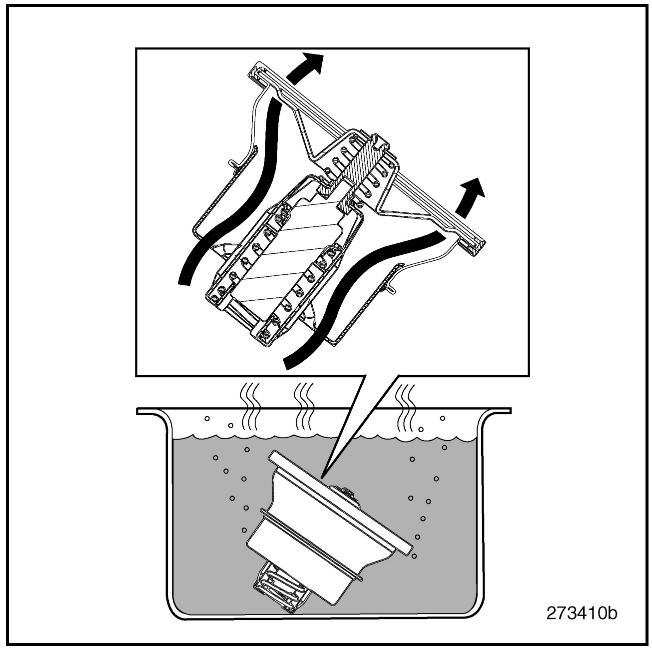


Figure 70 — Thermostat Open

Valve Guide Wear, Check

WEAR CHECK

1. Remove the oil seals from the valve guides.
2. Mount the cylinder head on a suitable engine stand using the cylinder head adapter plate J 47364.
3. Install a **new** valve into the guide so that the end of the valve stem is even with the valve guide edge.
4. Using the dial indicator 9989876 and holder 9999696, place the tip of the dial indicator against the edge of the valve disc. Move the valve back and forth laterally in the direction of the intake/exhaust ports. Note the measured value and compare it with the acceptable wear limit specified for the engine.

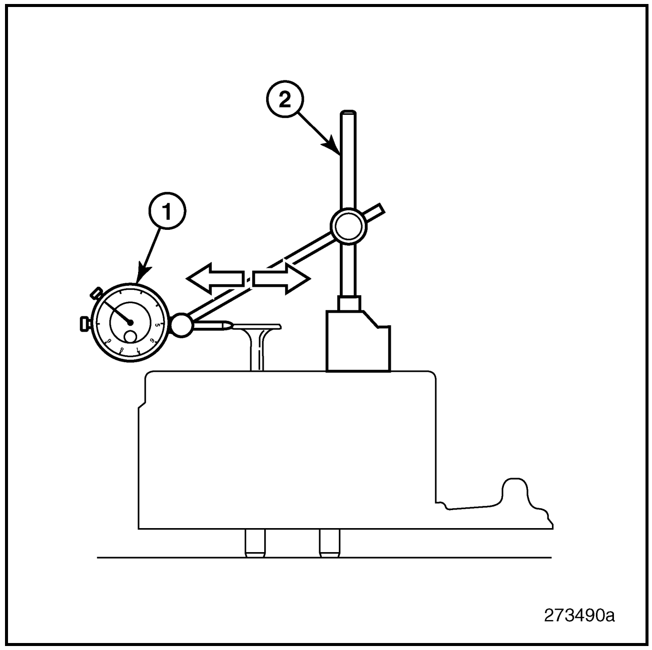


Figure 71 — Measuring Valve Guide Wear

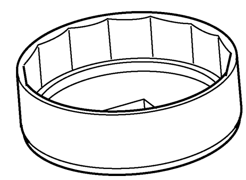
1. Dial Indicator, 9989876	2. Magnetic Stand, 9999696

5. Repeat Step 4 to check all valve guides. Replace the valve guides if the measured values exceed the acceptable wear limit.

MAINTENANCE

LUBRICATION SYSTEM MAINTENANCE

Special Tool

Tool No.	Description	Image
9998487	Oil Filter Wrench (Available)	 006845a

Oil Level Check

When checking oil levels, the vehicle must be parked on level ground. Components must be filled to the correct level. DO NOT OVERFILL.

The best time to check oil level is while the engine is COLD (prior to starting at the beginning of the work day, or after the vehicle has sat approximately 2 hours). At normal operating temperature (engine oil temperature above 80°C [175°F]), oil level can be checked 15 minutes after shut down.

CAUTION

Failure to wait a sufficient amount of time (2 hours if engine oil temperature is below 80°C [175°F]) or 15 minutes if oil temperature is above 80°C [175°F]) will result in an inaccurate dipstick reading.

For accurate oil level readings, the dipstick must be inserted fully into the dipstick tube. The level must be close to the FULL line (at least between the LOW and FULL lines) on the dipstick, but must NOT exceed the FULL line.

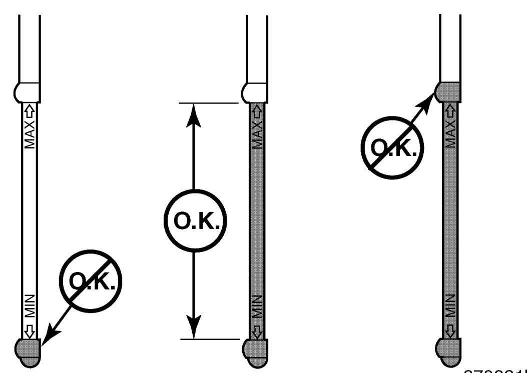


Figure 72 — Oil Level Check

Oil and Filter Change Procedure

[219 EV]

This engine is equipped with improved spin-on type oil filters.

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 filter wrench 9998487 or equivalent, remove the spin-on filters and wipe the filter mounting base clean.
4. Fill each filter with 1.9 liters (2 quarts) of the specified engine oil. DO NOT allow any contaminants to enter the filters while filling.
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.

Crankcase Ventilation System

The crankcase ventilation (CCV) system separator is not repairable. If there is apparently faulty operation, perform these inspections before replacing the separator.

1. Inspect the separator inlet hose and connectors at the valve cover and at the separator. Remove any obstruction, oil film, residue and particles.
2. Inspect the separator outlet hose and connector. Remove any obstruction, oil film, residue and particles.
3. Remove the separator and attempt to turn the turbine manually. If it does not turn easily, replace the separator.
4. If the turbine turns easily, inspect and clean the oil jet nozzle.
5. Reassemble the separator and the hoses.
6. If faulty operation continues, continue fault tracing with Guided Diagnostics.

FUEL FILTER REPLACEMENT

Fuel Filter Change

[231 BA]

FILTER DESCRIPTION

Two filters ensure that clean, waterless fuel reaches the electronic unit injectors. One is a full-flow filter, the other is a water separating pre-filter with a transparent cup to collect and drain the water. A water-in-fuel sensor informs the driver of excessive accumulation in the cup. The water separating pre-filter is in the "suction side" of the fuel circuit. It is a spin-on type with one end of its casing threaded to receive the cup.

The full-flow main filter is on the "pressure side" of the circuit. It is also an easily replaced spin-on filter. The casing completely encloses the filter element. This filter is rated at 3–5 microns.

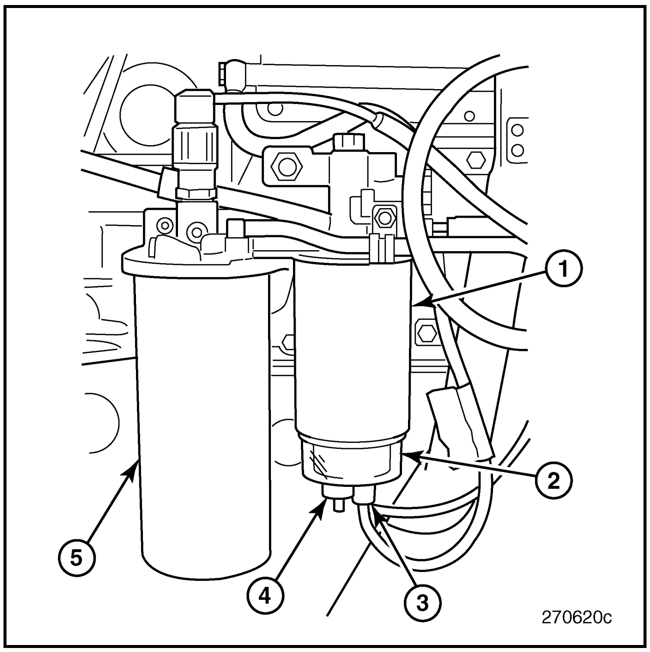


Figure 73 — Fuel Filters

1. Water Separating Pre-Filter 2. Water Separator Bowl 3. Water-in-Fuel Sensor Harness	4. Drain Assembly 5. Full-Flow Main Filter

FUEL FILTER REPLACEMENT

NOTE

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

Be careful to prevent foreign matter of any kind from entering the filters during service.

Install **new** fuel filters dry.

Water Separating Pre-Filter Replacement

To replace the water separating pre-filter:

1. Disconnect the electrical cable.
2. Make sure the filter casing is thoroughly cleaned. If not already done, wash the area around the filter mounting adapter with a suitable solvent and blow dry with compressed air.
3. With a suitable container in place to collect spillage, open the fitting and drain the filter.
4. Unscrew and remove the water cup.
5. Using a filter wrench, remove the filter from the mounting bracket and discard it safely.
6. Apply a thin film of clean engine oil to the sealing gasket of the new filter.
7. Screw the **new** dry filter in place and tighten an additional 3/4 to 1 turn by hand after the gasket contacts the base.

NOTE

After filter installation, operate the hand primer to fill the fuel filters before attempting to start the engine.

8. Screw the water cup into the filter casing.

NOTE

There is a new-style pre-filter with a stepped-down diameter at the bottom of the filter. The earlier-style filter has straight sides with a larger bottom diameter which requires an adapter to attach the fuel/water separator bowl to the filter. When replacing the previous straight-sided filter with the current stepped-down version, the adapter is not used. However, do not discard the adapter as it can be used should inventory of the earlier-style filter still be available.

9. If necessary, replace the full-flow main filter. See the following instructions.
10. Connect the electrical cable.
11. Start the engine and run at idle for five minutes to fill the filter with fuel.
12. Check for leaks.

Full-Flow Main Filter Replacement

To replace the full-flow main filter:

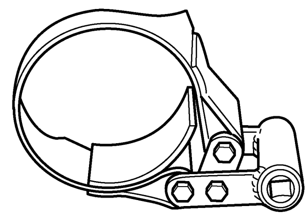
1. Make sure the filter casing is thoroughly cleaned. If not already done, wash the area around the filter mounting adapter with a suitable solvent and blow dry with compressed air.
2. Put a suitable container in place to collect spillage.
3. Using a filter wrench, remove the filter casing from the mounting bracket and discard it.
4. Apply a thin film of clean engine oil to the sealing gasket of the new filter.
5. Screw the **new** dry filter in place and tighten an additional 3/4 to 1 turn by hand after the gasket contacts the base.
6. If necessary, replace the water separating pre-filter. See the preceding instructions.
7. Start the engine and run at idle for five minutes to fill the filter with fuel.
8. Check for leaks.

CAUTION

Severe engine damage may be caused by attempting to prime the fuel system using an auxiliary pump or by applying air pressure in the fuel tank. These techniques may destroy seals that prevent fuel from leaking into the crankcase.

COOLING SYSTEM MAINTENANCE

Special Tool

Tool No.	Description	Image
J 48061	Coolant Filter Wrench (Available)	 006807a

Coolant Drain Outlets

Extra outlets provide convenient drain sites for use during maintenance and other procedures involving coolant.

Coolant Filter

The coolant filter attaches to the back of the coolant pump housing. It resembles a spin-on oil filter. The filter element and casing are replaced as a unit.

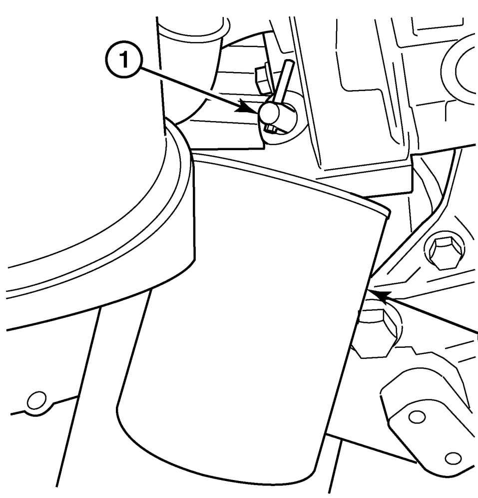


Figure 74 — Coolant Filter

1. Shut-Off Valve	2. Coolant Filter

NOTE

For Australia, engines are not equipped with the coolant filter. VCS coolant is used to protect the cooling system.

REMOVE AND REPLACE

1. Close the shut-off valve on the coolant pump housing.

NOTE

In the closed position, the pin on the shut-off valve should be horizontal.

2. Place a suitable container below the filter to collect spilled coolant.
3. Using filter wrench J 48061 or equivalent, unscrew the filter and discard it safely.
4. Apply a light film of coolant on the face of the **new** filter gasket.
5. Screw the **new** filter on the threaded nipple extending from the mounting flange.
6. Using the filter wrench, tighten the filter one full turn after the gasket contacts the base.
7. Open the shut-off valve on the coolant pump housing.
8. Check for any coolant leaks.

DRIVE BELT REPLACEMENT AND TENSIONING [216 AA]

General Information

The service life of the multi-groove belts is considerably improved over other systems and allows the use of higher horsepower cooling fans. All MP8 engines are equipped with multi-groove belt systems.

MP8 Engine

In the dual multi-groove drive belt arrangement, the fan drive and coolant pump are driven directly from the crankshaft pulley by a 10- or 12-rib multi-groove belt. The alternator and the air conditioning compressor (if equipped) are driven off the crankshaft pulley by a six-rib multi-groove belt (Figure 75). Two automatic tensioners are used, one for the fan drive and one for the accessory drive.

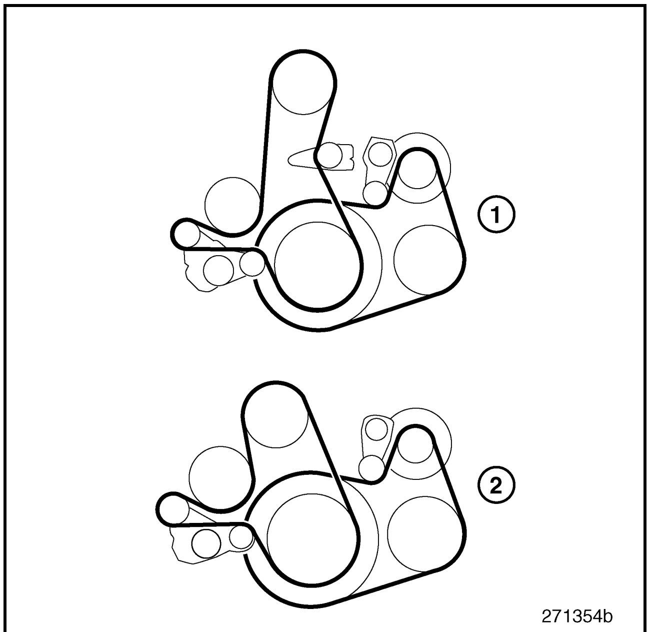


Figure 75 — Belt-Drive Arrangement

1. Conventional	2. LCF (N/A Australia)

The lower tensioner for the fan and coolant pump is mounted on the coolant pump housing. This tensioner applies its load *counterclockwise*. The upper tensioner for the alternator (and refrigerant compressor if so equipped) is mounted on the alternator bracket. The tensioner applies its load in a *counterclockwise* direction.

Automatically Tensioned System

INSTALLATION

Swing the tensioner to the fully sprung position and without force, using belt tensioner tool, J 44392, 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

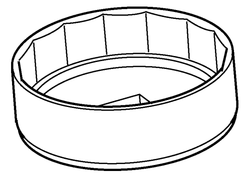
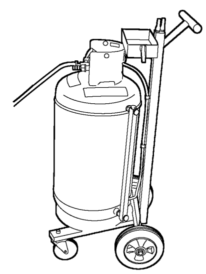
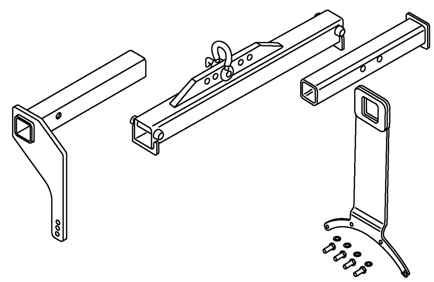
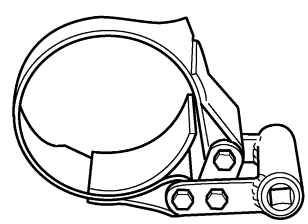
The condition of the belt and tensioner should be checked when performing preventive maintenance inspections. Belt tension levels need not be checked as long as the tensioner is in good condition and there is no evidence of a loose belt.

NOTES

REPAIR INSTRUCTIONS, PART 1

ENGINE REMOVAL

Special Tools

Tool No.	Description	Image
9998487	Oil Filter Wrench (Available)	 006845a
DBT2V700	Coolant Extractor/Injector	 006940a
J 47038-3 J 47038-4 J 47038-6 J 47038-8	Engine Lifting Tool Set	 006927b
J 48061	Coolant Conditioner Filter Wrench (Not required for vehicles manufactured in Australia)	 006807a

General Instructions

NOTE

Before removing the engine, make sure tools and equipment are inspected for safety and available for use.

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.
- Prevent moisture from entering the air intake system. If moisture enters the system, make sure it is removed (dried) before the engine is reinstalled.
- Prevent the steam cleaning nozzle from spraying directly on any electronic components and connections.
- Avoid the use of any caustic or corrosive cleaning detergents.

1. Position the vehicle on a flat, level surface with ample work space around the vehicle.
2. Apply the parking brake and block the wheels to prevent the vehicle from moving. Observe all safety precautions.
3. Disconnect the battery negative (ground) cable.
4. Drain the air tanks.

Removal

1. Remove the hood. On cab over engine models, tilt the cab (N/A Australia).
2. Place suitable containers beneath the engine and drain the oil and coolant. Open the coolant drain valves in the cylinder block, the EGR cooler and the radiator.

NOTE

If available, use the coolant extractor, DBT2V700, to remove coolant from the engine.

3. Using the oil filter wrench, 9998487 or equivalent, remove the oil filters.
4. Using a suitable filter wrench, remove the fuel filters.
5. Using the coolant filter wrench, J 48061 or equivalent, remove the coolant filter.
6. Disconnect the inlet air heater if present.
7. If the vehicle is equipped with air conditioning:
   a. Using A/C refrigerant recovery and recycling equipment, recover the refrigerant.
   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.
8. Disconnect and remove the upper radiator tube from the engine.
9. Disconnect the cab heater and fuel heater coolant return lines from the radiator lower tube (if applicable).
10. Disconnect and remove the lower radiator tube.
11. Remove the charge air cooler inlet tube and hoses.
12. Remove the charge air cooler outlet tube and hoses.
13. Disconnect the radiator fan if electronically controlled.

NOTE

The radiator and charge air cooler assembly is heavy and difficult to handle. Provide a suitable lifting device and a helper to support it safely during removal.

14. Remove the radiator and charge air cooler assembly.

NOTE

The fan assembly is heavy and difficult to handle. Obtain assistance to support it safely during removal.

15. Remove the fan assembly.

NOTE

If equipped with an electronically-controlled viscous fan, store the fan assembly face down (hub flange up) or vertically as shown to prevent fluid leaking from the assembly.

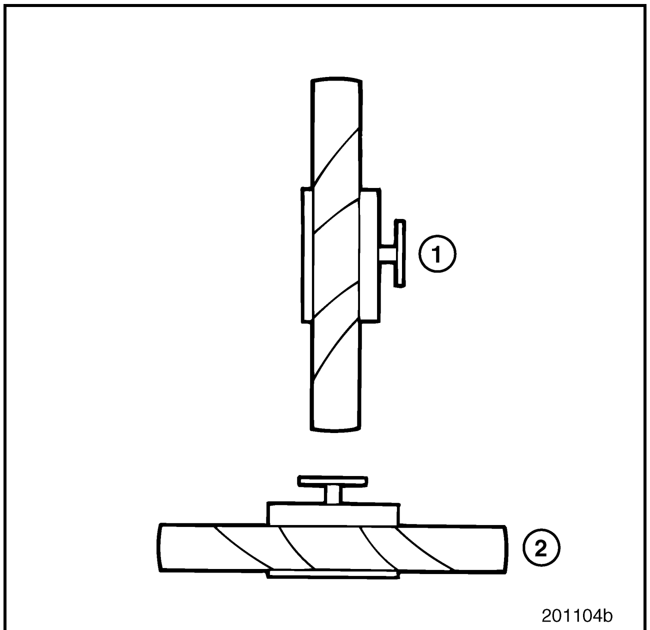


Figure 76 — Viscous Fan Drive Assembly Storage

1. OK to Store with Fan Blade in Vertical Position.	2. OK to Store with Fan Blade in Horizontal Position and Mounting Flange Up. Do Not Store with Mounting Flange Down.

16. If equipped, remove the exhaust bracket from the flywheel housing.

NOTE

Use a container to collect power steering fluid.

17. Remove the power steering hoses.
18. Disconnect the exhaust system from the turbocharger.
19. Disconnect electrical cables or wires connected to the starter.
20. Disconnect or remove all other items attached to the frame or cab that would prevent engine removal, such as:
    a. Clutch linkage
    b. Ground straps
    c. Electrical wiring
    d. Coolant tubing
    e. Air lines
    f. Fuel lines
    g. Hydraulic hoses or tubing
21. Remove the valve cover.

CAUTION

Cover the valve mechanism and gear train with a suitable c\loth or similar covering to prevent dirt and debris from entering the engine.

NOTE

Use a transmission jack to support the transmission when disconnected from the engine.

22. With transmission jack in place, remove the screws attaching the transmission to the engine.
    a. If a manual transmission, make certain the clutch linkage and brackets have been removed.
    b. If an automatic transmission, make certain the torque converter access panel and the torque converter have been removed.

CAUTION

Obtain a helper and use a lifting device, such as engine lifting tool, J 47038, to support the engine safely during removal.

23. Attach the engine lifting tool, J 47038, to the engine. Secure the engine lifting tool to the front of the cylinder head and to the rear at the flywheel housing.

DANGER

Ensure all bolts and pins in the lifting tool are correctly positioned prior to removing the engine from the chassis. Failure to properly install all bolts and pins of the engine lifting tool can result in personal injury or death.

24. Remove the screws that secure the rear engine support brackets to the frame brackets.
25. Remove the bolts that secure the front engine support to the frame crossmember.

CAUTION

While removing the engine, watch for obstructions that may interfere, such as engine and chassis components, brackets, clamps and other parts still attached to the engine. Failure to heed this caution may result in severe damage to the engine and other components.

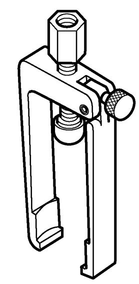
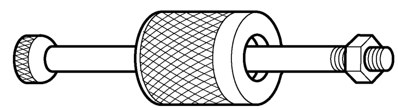
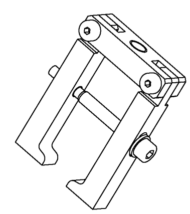
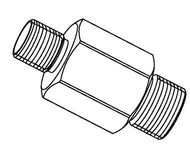
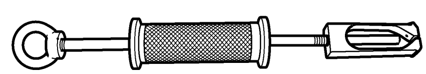
26. Using the lifting device and the aid of the helper, remove the engine from the vehicle.

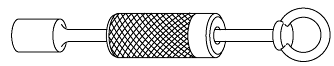
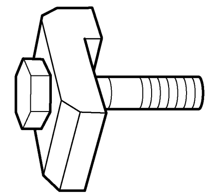
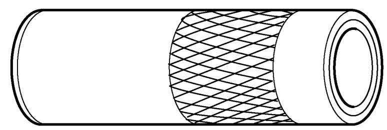
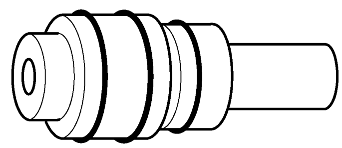
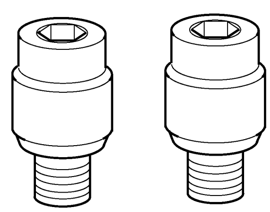
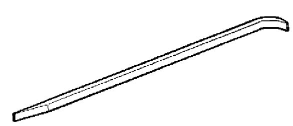
CAUTION

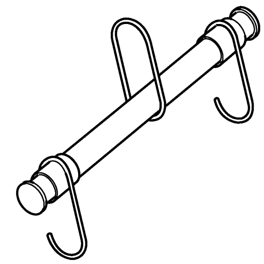
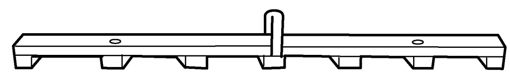
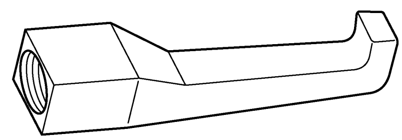
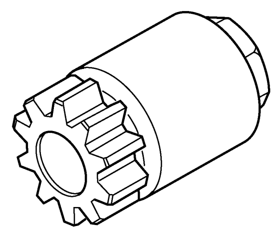
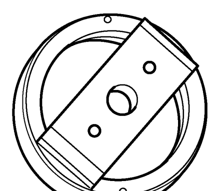
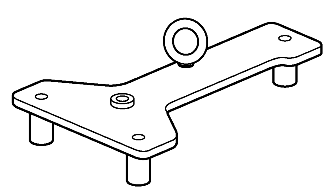
Before attempting to remove the cylinder head from the cylinder block, ensure that the screws holding the head against the timing gear mounting plate have been removed. Failure to heed this caution may result in severe damage to the engine and other components.

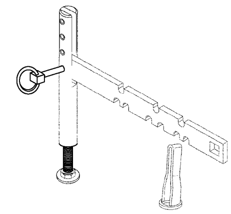
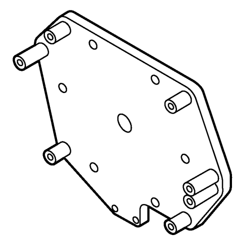
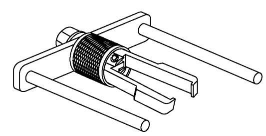
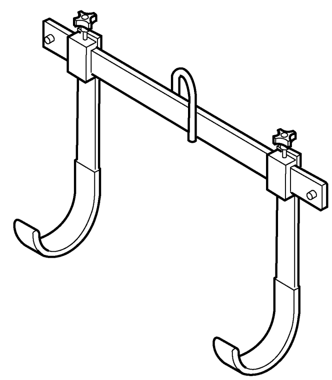
ENGINE DISASSEMBLY
MACK MP8 Euro 4 Engine
[200 EA]

Special Tools

Tool No.	Description	Image
9990006	Two-Jaw Puller for Unit Injector Removal, use with 9990013 (Essential)	 006778a
9990013	Slide Hammer	 006779a
9990114	Main Bearing Cap Puller	 007030a
9990262	Slide Hammer Adapter	 007031a
9991821	Slide Hammer for Pilot Bearing Removal and other various uses (Available)	 006784a

Tool No.	Description	Image
9996400	Slide Hammer	 007032a
9996966	Liner Hold-Down Tools (Essential)	 006796a
9998249	Unit Injector Protection Sleeves (Essential)	 006798a
9998251	Unit Injector Bore Sealing Plug (Essential)	 006800b
9998267	Dowels (Locating Tools for the Timing Gear Mounting Plate)	 006887a
9998511	Lever	 007121a

Tool No.	Description	Image
85109034	Camshaft Lifting Bar (Essential)	 006835a
85109250	Rocker Shaft Assembly Lifting Tool (Essential)	 006770a
85109980	Camshaft Bearing Cap Removal Tool, use with slide hammer, 9990013	 006886a
88800014	Flywheel Turning Tool (Essential)	 271485a
88800021	Front Main Seal Remover/Installer (Essential)	 006774a
88800188	Cylinder Head Lifting Tool (Essential)	 006923a

Tool No.	Description	Image
J 41989-A	Valve Spring Compressor	 007122a
J 48662	Engine Stand Adapter Plate (Available)	 006925a
J 48922	Heavy-Duty Unit Injector Puller	 007000b
J 49002	Crankshaft Lifting Tool (Essential)	 007089a

General Instructions

[210 EN]

This section includes step-by-step procedures for disassembly of the engine. After cleaning components, store them where they will remain clean until needed for reassembly.

The sequence in which components are removed from the engine may vary depending on the type of engine repair stand used. The repair stand identified for this procedure uses a mounting plate attached to the left side of the engine which requires the removal of certain left side components to provide space for attachment of the mounting plate. This must be done prior to mounting the engine on the repair stand.

⚠ WARNING

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

Mounting the Engine on a Repair Stand

[200 EB]

If the engine is to be mounted on a repair stand by means of a mounting plate attached to its left side, the mounting surfaces must be clear of obstruction.

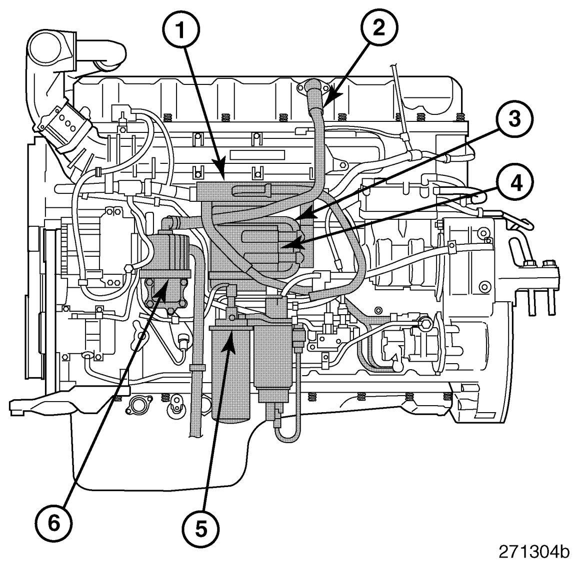


Figure 77 — Components to be Removed Before Mounting on a Repair Stand — Conventional Chassis, Typical

1. Wiring Harness Block 2. CCV Tubing 3. EECU Cooling Plate	4. EECU 5. Fuel Filter Housing Assembly 6. CCV Separator Assembly

In order to attach the mounting plate, J 48662, to the left side of the engine, the following components must also be removed if present.

1. Remove the dipstick and oil fill pipe.
2. Remove the crankcase ventilation (CCV) separator and tubing.
3. Tag the electrical connectors on the left side of the engine to facilitate reconnection upon reassembly.
4. Unlock and remove the harness end connectors attached to the EECU. Remove the screws from the harness retainer clamps. Then, push the connector locks inward and rotate outward to disconnect both wiring harnesses from the EECU.

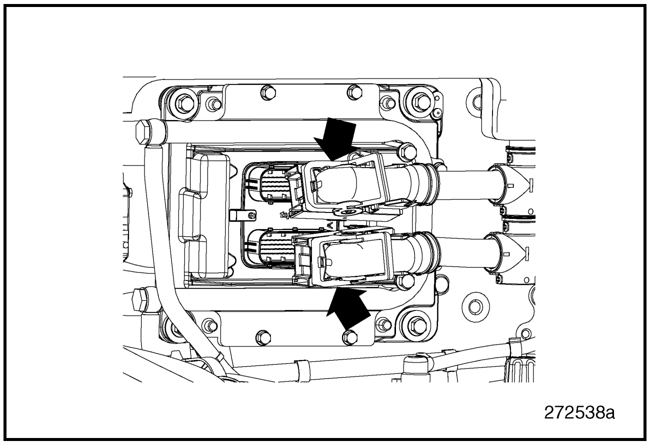


Figure 78 — EECU Harness Connectors

CAUTION

Use care to avoid damaging the terminal pins.

5. Unlock and separate the external wiring harness connectors at the various junctions and sensors.
6. Remove the clamps holding the harness to the cylinder block.
7. Remove the fasteners securing the wiring harness block to the cylinder block. Position the harness block and leads out-of-way.

NOTE

Use suitable rags and containers for collecting fuel and coolant drainage at each of the following steps.

8. Loosen the fuel line banjo fittings. Remove the banjo fittings, clamps and the following fuel lines from the side of the engine.
   - Fuel return line — EECU cooling plate-to-filter valve housing
   - Fuel return line — cylinder head (at front)-to-filter valve housing
   - Fuel supply line — filter valve housing-to-cylinder head (at rear)
   - Fuel supply and return lines — fuel pump-to-filter valve housing
9. Remove the filter housing assembly.
10. Remove the cooling plate and the EECU from the cylinder block.
11. Attach the engine mounting plate, J 48662, to the left side of the engine.
12. Using a suitable hoist and the appropriate lifting device, attach the engine to the repair stand.

EGR Crossover Piping Removal

[214 HN, HP, HR]

1. Loosen and remove the V-clamps at each end of the crossover pipe.

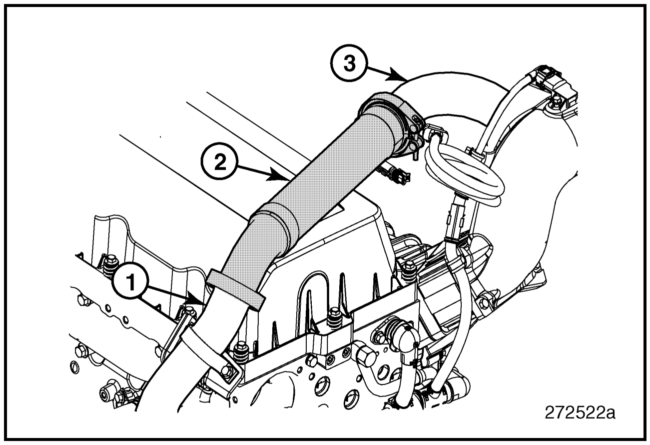


Figure 79 — EGR Crossover Pipe

1. Venturi Outlet Pipe 2. Crossover Pipe	3. Mixer Inlet Pipe (Elbow)

2. Remove the crossover pipe from the engine. Discard the O-ring seals.
3. Remove the fasteners attaching the mixer inlet pipe to the mixer and remove the pipe. Discard the O-ring.

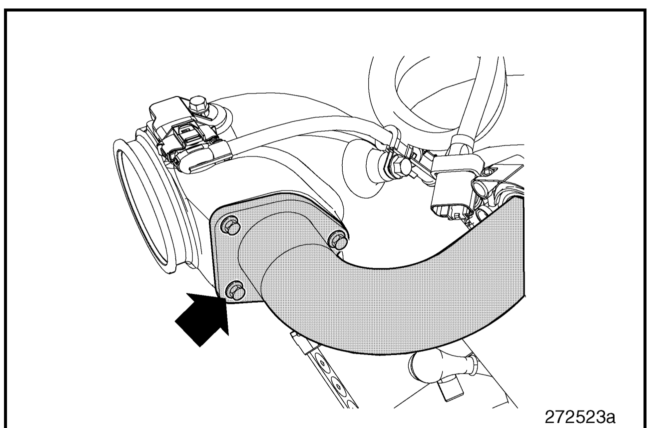


Figure 80 — Mixer Inlet Pipe (Elbow)

4. Disconnect the EGR temperature sensor lead at the wiring harness connector.
5. Loosen the collar nut and remove the EGR temperature sensor from the venturi tube outlet pipe.

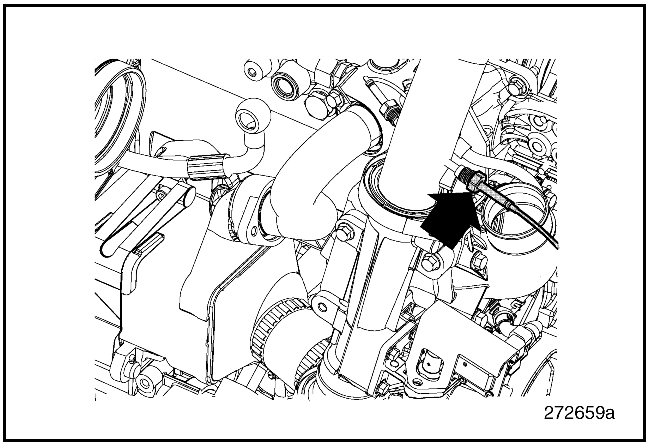


Figure 81 — EGR Temperature Sensor

6. Loosen and remove the V-clamp connecting the outlet pipe at the top end of the venturi tube.
7. Remove the fasteners and retainer strap securing the venturi outlet pipe to the mounting bracket and remove the pipe from the engine.

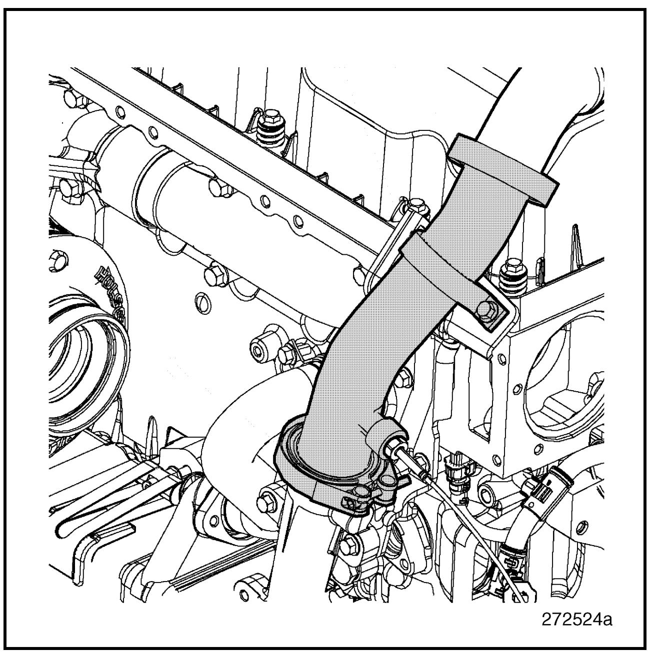


Figure 82 — Venturi Outlet Pipe

EGR Venturi Tube Removal

1. Disconnect the wiring harness at the EGR pressure differential sensor mounted on the venturi tube. Remove the fasteners and remove the sensor from the engine.

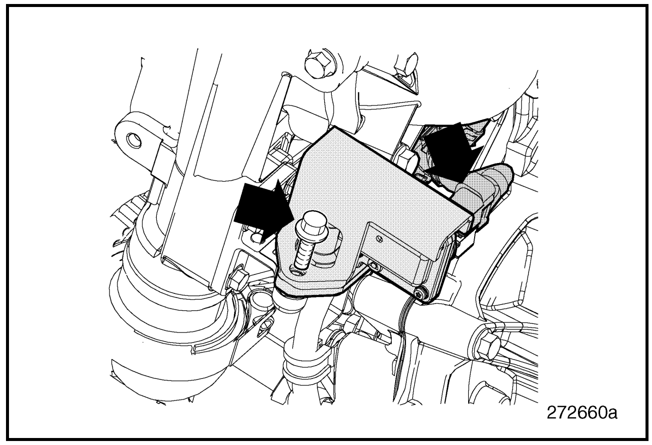


Figure 83 — EGR Pressure Differential Sensor

2. Loosen the clamp on the coupling hose at the venturi tube inlet elbow.

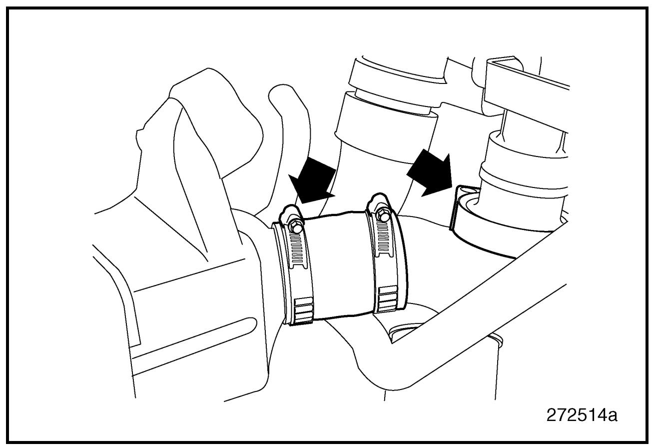


Figure 84 — Venturi Inlet Elbow and Coupling Hose

3. Remove the mounting fasteners and remove the venturi tube assembly (with pressure differential sensor) from the engine.

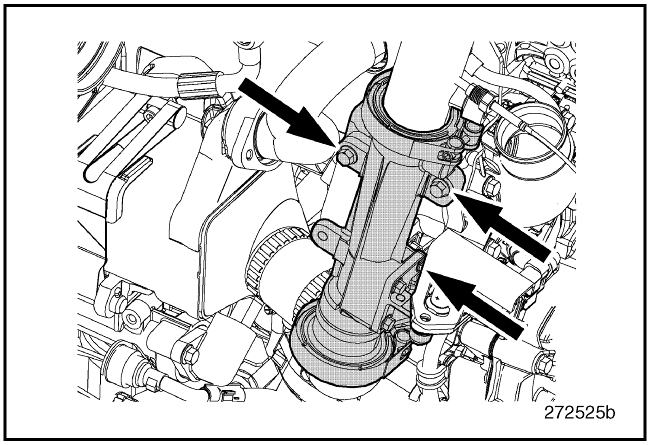


Figure 85 — EGR Venturi Tube

Cylinder Head (Valve) Cover Removal

[211 JB]

1. Remove the fasteners and remove the crankcase ventilation pipe.

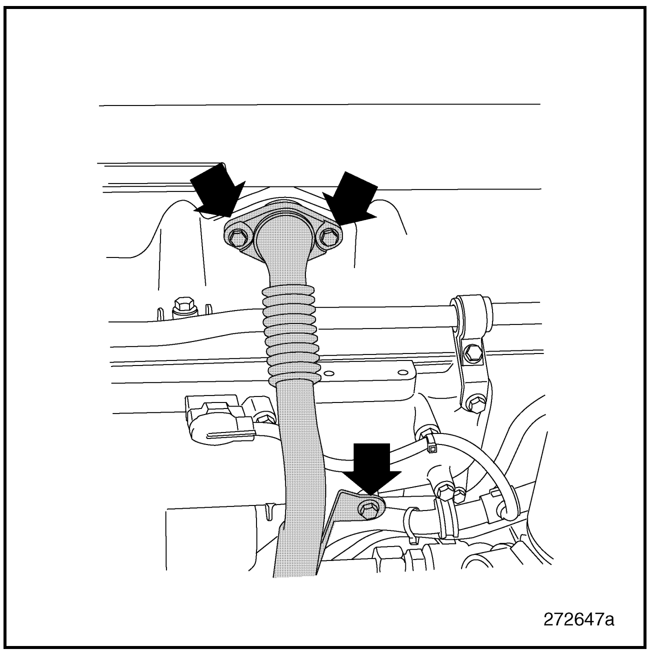


Figure 86 — Crankcase Ventilation Pipe

2. Remove the spring-loaded screws attaching the cylinder head (valve) cover to the cylinder head.

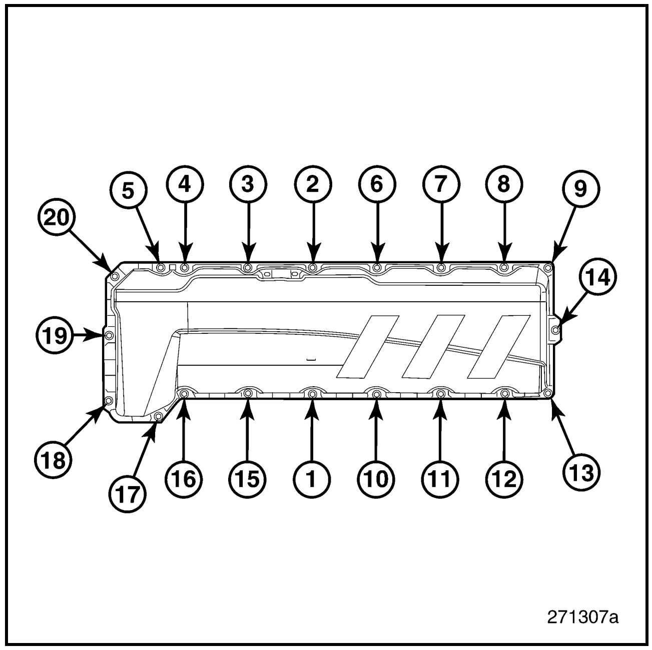


Figure 87 — Cylinder Head Cover

3. Remove the cover from the cylinder head.

Engine Wiring Harness Removal

[723 KA]

1. To facilitate connection at reassembly, tag all harness connectors to the various engine sensors and components prior to disconnecting them. Also, note the routing of the harness and leads for proper installation at reassembly.
2. If not already done, unlock and remove the harness end connectors attached to the EECU.
3. Unlock and separate the connectors at the various sensors, engine components and harness junctions.
4. Remove the clamps holding the harness to the cylinder head and block.
5. At the top of the cylinder head, disconnect the wiring harness at each unit injector.

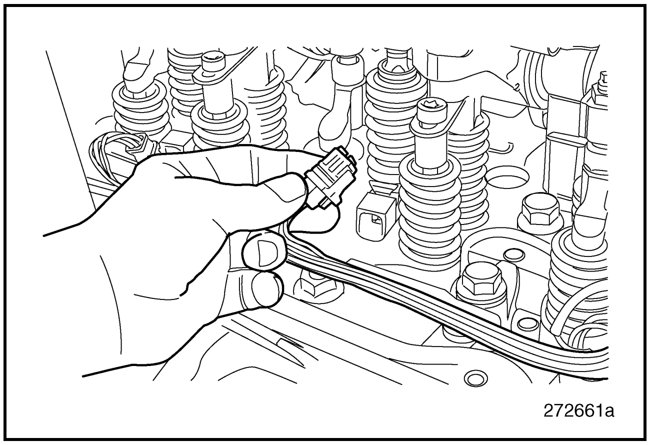


Figure 88 — Disconnecting Harness at Unit Injector

6. If so equipped, disconnect the harness from the engine brake control valve.

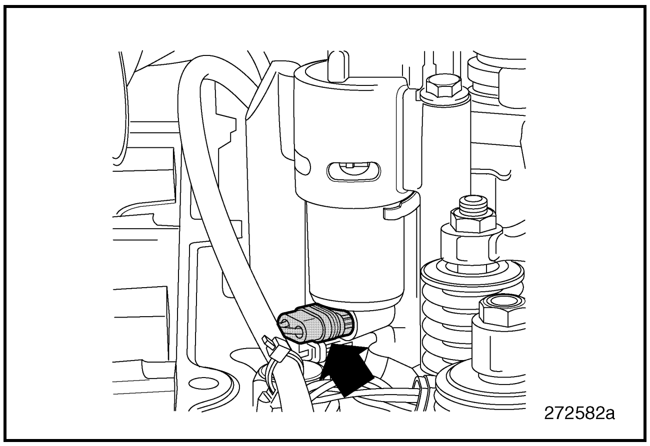


Figure 89 — Engine Brake Control Valve Terminal

7. Cut the cable ties holding the harness to the cylinder head and the engine brake control valve.
8. Carefully pull the harness through the hole at the front of the cylinder head and remove the harness from the engine.

Timing Gear Cover Removal

[211 AA]

1. Disconnect the oil supply line at the EGR valve and at the flywheel housing. Remove the line from the engine.

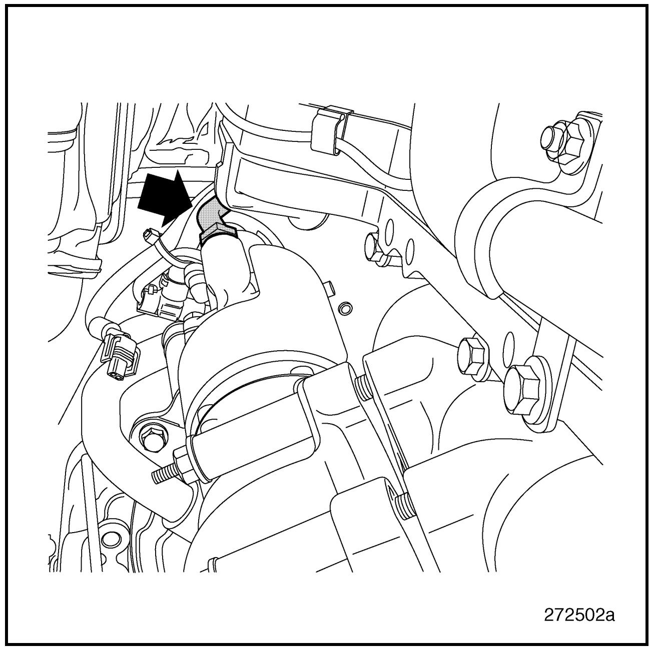


Figure 90 — EGR Valve Oil Supply Line

2. Remove the mounting fastener and remove the camshaft position sensor from the timing gear cover.
3. Remove all straps, P-clamps and other retainers used to restrain harnesses, oil lines and coolant tubes to the rear of the engine. This will allow the support bracket at the rear of the engine to be removed.

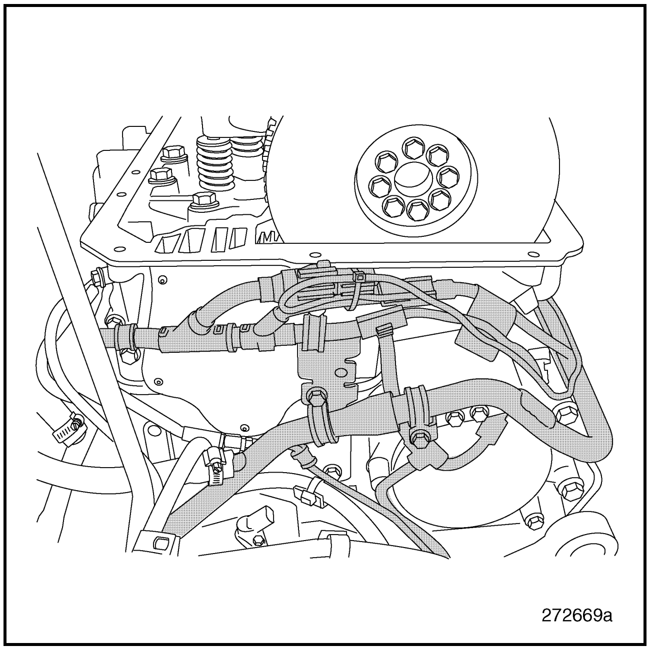


Figure 91 — Harness, Oil and Coolant Lines

4. Remove the support bracket fasteners and remove the rear support bracket.
5. Remove the screws attaching the timing gear cover to the timing gear plate and cylinder head (Figure 92).

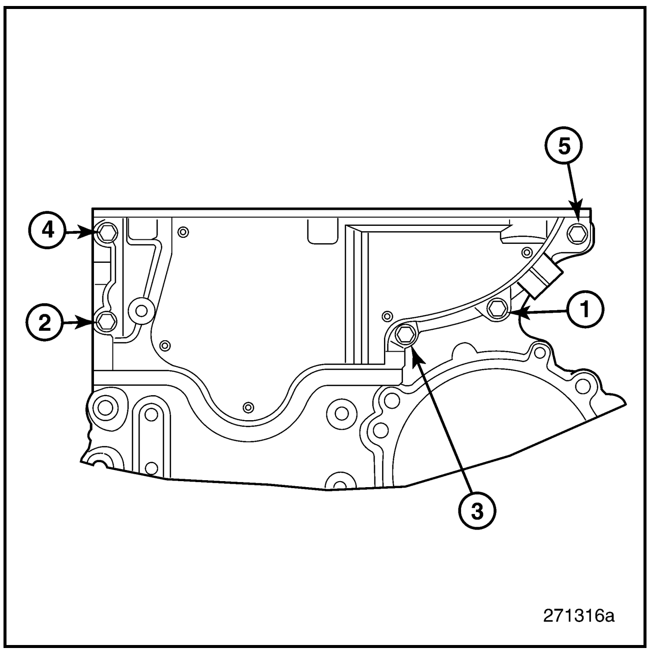


Figure 92 — Timing Gear Cover Fasteners Torque Sequence

6. Remove the cover from the engine.
7. Remove and discard the elastomer seals.

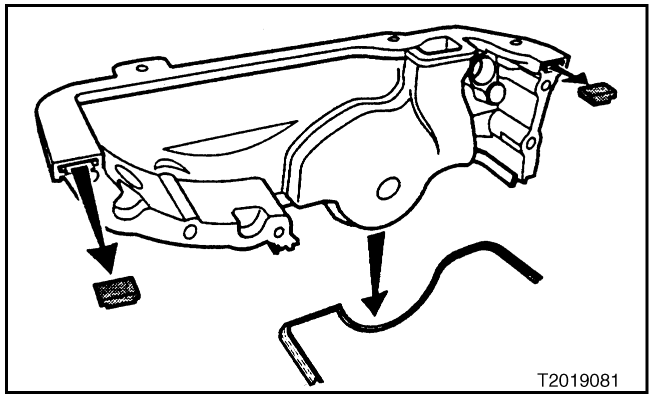


Figure 93 — Timing Gear Cover Seals

Camshaft Gear and Vibration Damper Removal

[213 DE]

NOTE

If the engine is not being completely disassembled for overhaul and only the camshaft is to be removed, crank the engine manually (using the flywheel turning tool, 88800014) so that the camshaft is positioned at top dead center (TDC) by aligning the TDC mark on the camshaft with the timing marks on the No. 1 camshaft bearing cap (Figure 94).

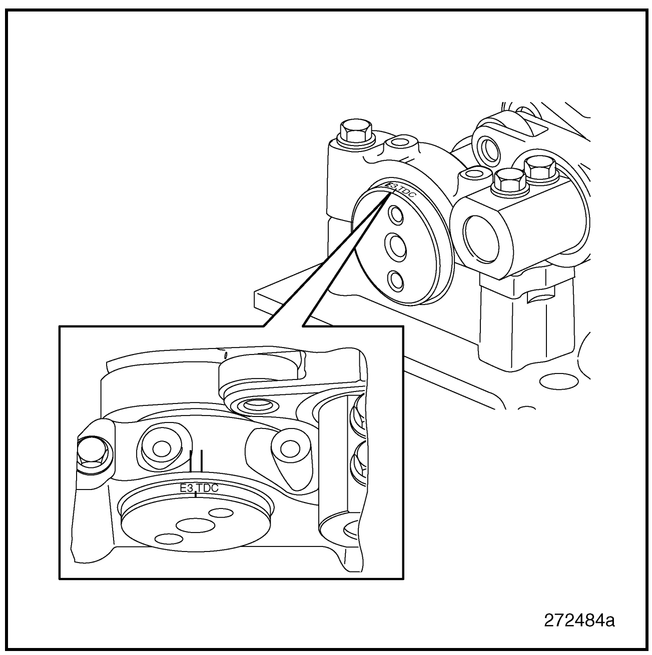


Figure 94 — Camshaft Timing Marks

1. Remove the fasteners securing the vibration damper and camshaft gear to the camshaft.
2. Remove the vibration damper from the camshaft gear.
3. Remove the gear from the camshaft.

Rocker Arm Shaft Removal

[213 LP]

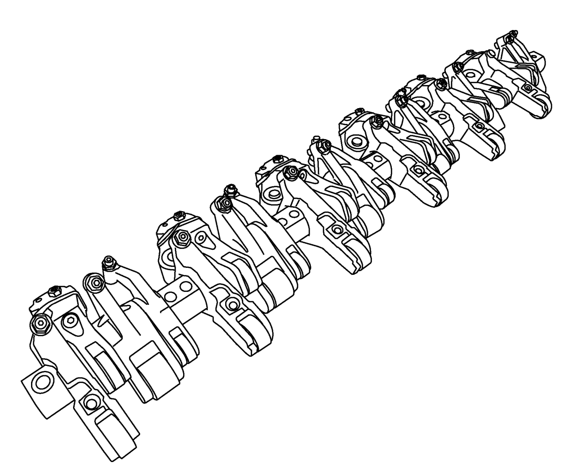


Figure 95 — Rocker Shaft Assembly

⚠ *CAUTION*

On engines fitted with the engine brake, use rubber bands to contain the pistons within the rockers. The match between these pistons and their rockers must be maintained.

If the rocker shaft is to be disassembled, the order of rocker arm assembly must be maintained. Make certain the sets are kept together. Make certain the rocker arms are identified so they can be returned to their original positions on the shaft.

Failure to heed this caution may result in severe engine damage.

1. Remove the engine brake oil control valve (if so equipped) from the engine.

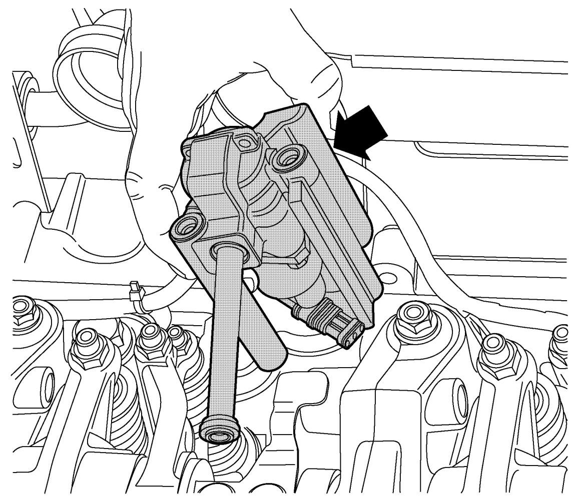


Figure 96 — Removing Engine Brake Oil Control Valve

NOTE

On engines without the engine brake, an oil flow adapter is used in place of the oil control valve. It is mounted in the same location on the cylinder head and provides oil to the rocker shaft.

2. Remove the screws and six engine brake plate springs (if so equipped) attached to the camshaft bearing caps.

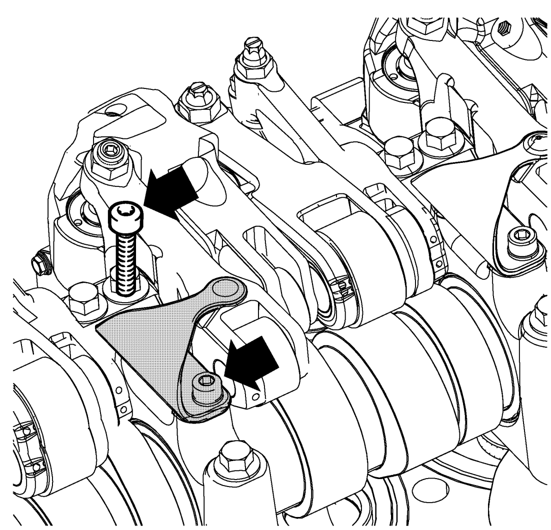


Figure 97 — Engine Brake Plate Spring

3. If equipped with an engine brake, secure the pistons in the exhaust rocker arms using rubber brands (or tie straps) to prevent piston damage.

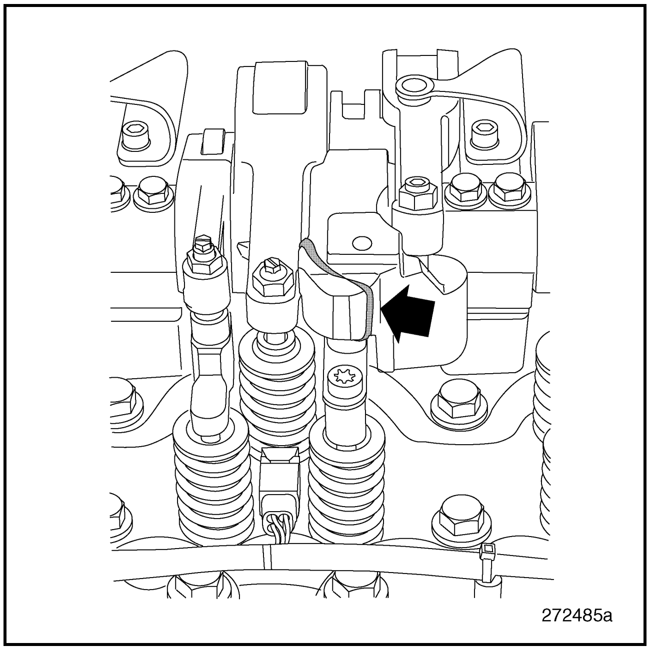


Figure 98 — Securing Pistons in Exhaust Rocker Arms

NOTE

Pistons and rocker arms are matched together and should not be mixed.

4. Beginning at the center camshaft bearing cap, begin loosening the three fasteners at each cap evenly in stages, following the sequence shown in Figure 99 until all fasteners are completely loose. Once loosened, remove the fasteners.

CAUTION

The fasteners must be loosened evenly, in stages and in sequence to prevent bending or damaging the rocker arm shaft.

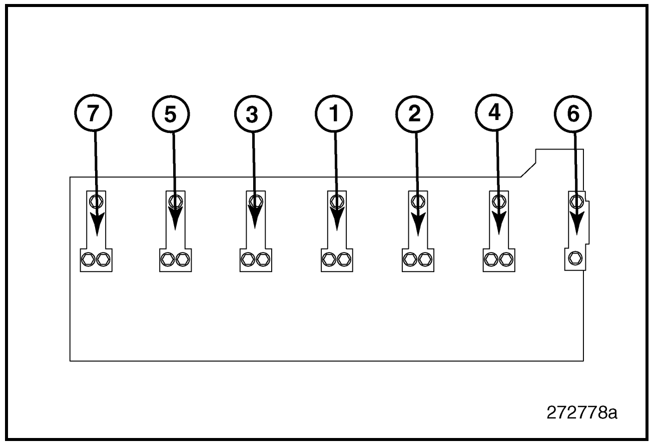


Figure 99 — Rocker Arm Shaft Fastener Loosening Sequence

5. Attach the lifting tool, 85109250, to the rocker arm shaft.
6. With the aid of an assistant, carefully remove the shaft assembly using the lifting tool. Place the shaft assembly in a secure location.

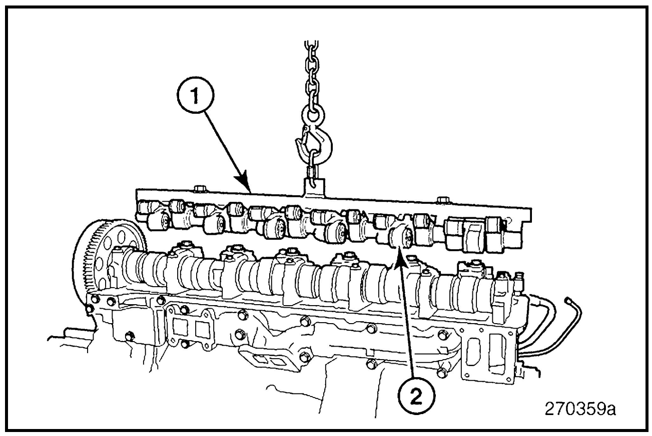


Figure 100 — Lifting Rocker Arm Shaft

1. Lifting Tool, 85109250	2. Rocker Arm Shaft Assembly

Valve Yoke (Bridge) Removal

[213 NV]

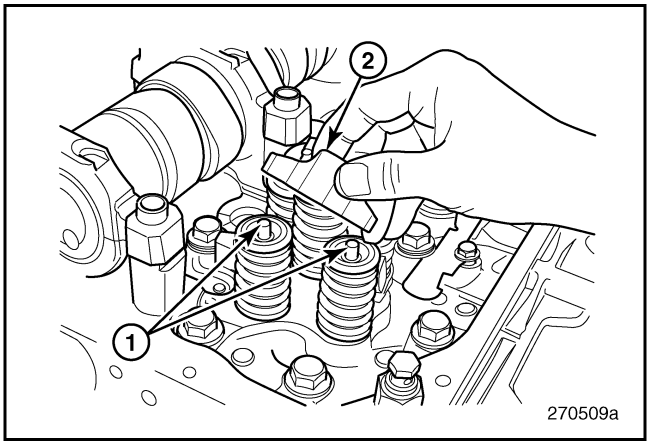


Figure 101 — Removing Valve Yoke (Bridge)

1. Inlet Valve Stems	2. Inlet Valve Yoke

1. Tag the yokes to facilitate reassembly in the locations from which they were removed.
2. Remove the yokes and set them aside.

Camshaft Removal

[213 CH]

PROCEDURE

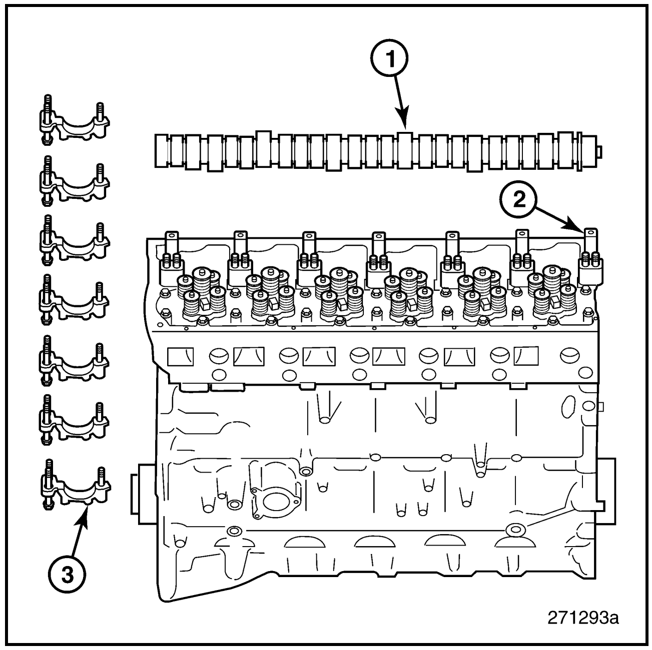


Figure 102 — Camshaft Installation

1. Camshaft 2. Camshaft Lower Bearing Supports (Saddles)	3. Camshaft Upper Bearing Caps

⚠ WARNING

The camshaft is heavy. Do NOT attempt to remove the camshaft without the help of an assistant or the use of a suitable lifting device. Failure to heed this warning may result in personal injury and component damage.

1. Mark the camshaft bearing caps (if not factory marked or identified), so that they can be reinstalled in the original bearing support locations.
2. Remove the remaining fasteners (outboard set) holding the upper bearing caps in place.

3. Use the camshaft bearing cap removal tool, 85109980, in combination with slide hammer, 9990013, to remove the upper bearing caps. The upper bearing caps and lower supports (saddles) must be kept in sets and in their respective locations at reassembly.
4. Attach the lifting bar, 85109034, to the camshaft between the lobes and carefully remove the camshaft from the cylinder head.

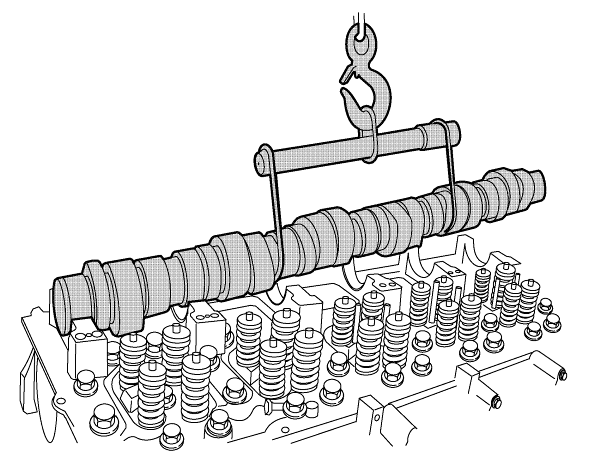


Figure 103 — Removing Camshaft

5. Carefully lift the camshaft and set it aside in a secure location for later inspection.

CAUTION

If the camshaft is not being replaced, stand the camshaft on end and secure it in place for storage. Use care to avoid damage to the guide pin.

6. Remove the bearing inserts (shells) from the camshaft lower bearing supports (saddles) and the upper bearing caps. Inspect the bearing inserts, bearing supports and caps for wear or damage. Replace the parts if excessive wear or damage exists.

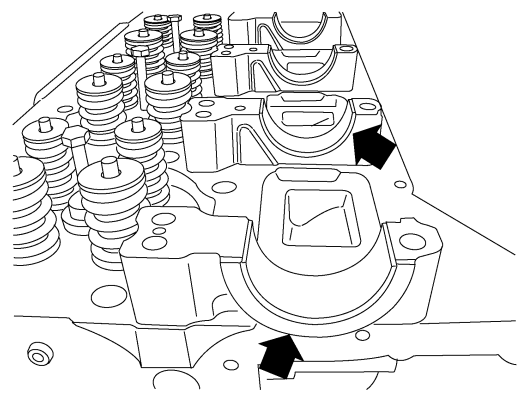


Figure 104 — Lower Bearing Inserts

NOTE

This procedure presumes that the camshaft lower bearing supports (saddles) are in place on the cylinder head, held in position by guide sleeves. If removed, the supports must be marked and returned to their original locations along with the respective bearing caps. If required, remove the bearing supports using a pry bar. Remove the No. 7 rearmost support using a soft-faced mallet by tapping side to side.

Unit Injector Removal

[221 GP]

CAUTION

Do NOT use a steel scraper or a steel wire brush to clean injector tips. Use cleaning kit J 42885 or 9998599.

Failure to heed this caution may result in severe component damage.

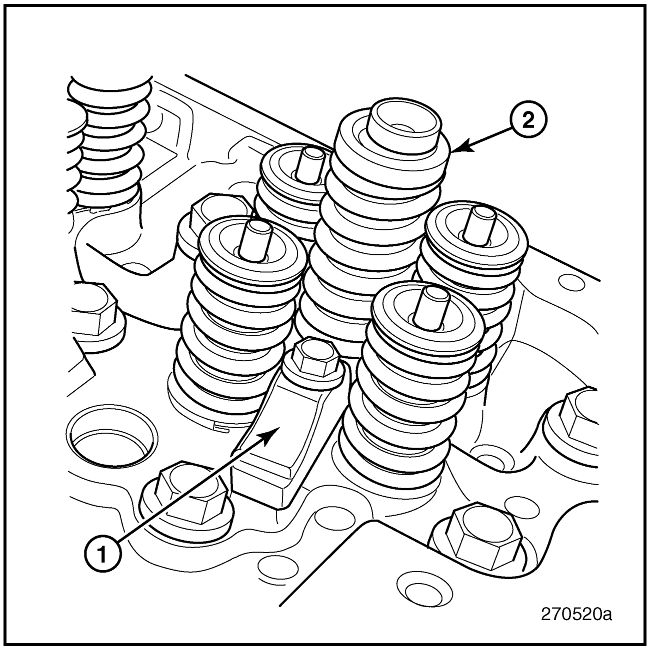


Figure 105 — Unit Injector

1. Injector Hold-Down Yoke and Screw	2. Unit Injector

1. Thoroughly clean around the unit injectors and check to ensure that the engine is completely drained of fuel.
2. Tag the injectors with the cylinder number before their removal from the cylinder head. If new injectors are not being installed, it is essential that the original injectors be reinstalled in the cylinders from which they were removed.
3. Remove the fastener(s) securing the injector hold-down yoke(s).

NOTE

Three different styles of the unit injector hold-down yokes were used in production on MACK MP engines. The first style (1) is 28 mm tall with a pronounced stepped-down area on the end of the yoke that engages the unit injector. The second style (2) is 38 mm tall, and the end of the yoke that engages the unit injector is not stepped-down. The third style (3) is also 38 mm tall, but the end that engages the unit injector is stepped-down to allow the forks of the heavy-duty unit injector puller (tool No. J 48922) to engage the unit injector groove. This allows removal of the unit injector without necessitating the removal of any valve springs.

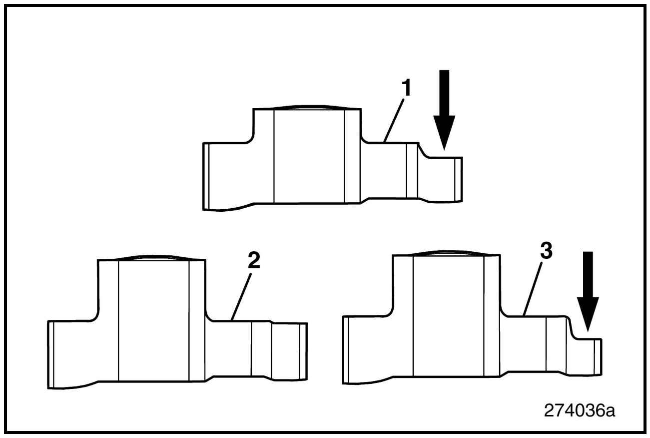


Figure 106 — Unit Injector Hold-Down Yoke Styles

NOTE

When replacing 28 mm height injector yokes with 38 mm height yokes, all six yokes must be changed to the current 38 mm height components. NEVER replace a 38 mm height yoke with a 28 mm height yoke. Once an engine has the new design 38 mm height yoke, either from the OEM or field installation, it must stay with the new design 38 mm high yoke at all cylinder locations.

4. Using the chart below to determine the correct method of unit injector removal based on the status of the injector (immovable [stuck], or removable [not stuck]), remove the unit injector as described in the following steps for the style of hold-down yoke being serviced:

Unit Injector Status	28 mm (Short) Yoke	38 mm (Tall) Yoke	38 mm (Tall) Yoke with Stepped-Down Area
Unit Injector — Immovable (Stuck)	Heavy-Duty Puller J 48922	Heavy-Duty Puller J 48922 **NOTE**: Requires removal of the inlet and exhaust valve springs to allow access for heavy-duty puller.	Heavy-Duty Puller J 48922
Unit Injector — Removable (Not Stuck)	Standard Puller 9990006	Pry Bar 9998511	Standard Puller 9990006

5. **Injector Removal — 28 mm (Short) Yoke**

NOTE

Use care when removing the unit injector because the injector hold-down is not secure and could fall off if not held in place.

a. Initially attempt to remove the unit injector using the standard injector puller (tool No. 9990006).

b. If the unit injector cannot be removed using the standard puller, proceed to using the heavy-duty puller (tool No. J 48922) by positioning the forks of the heavy-duty puller (tool No. J 48922) under the lip on the unit injector. Secure the puller by sliding the lock collar down over the forks. Remove the injector from the cylinder head using hand tools. **The injector must be lifted out along with the hold-down yoke.**

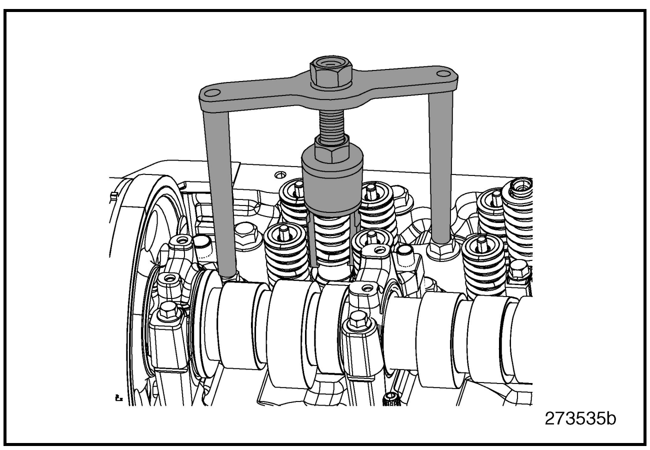


Figure 107 — Removing Injector with the Heavy-Duty Unit Injector Puller (Tool No. J 48922)

CAUTION

If excessive combustion leakage has resulted in the copper sleeve being stuck-fast to the unit injector by carbon, the unit injector must be replaced. The condition is found when the unit injector is removed and the copper sleeve comes out with the injector.

6. **Injector Removal — 38 mm (Tall) Yoke**

NOTE

Use care when removing the unit injector because the injector hold-down is not secure and could fall off if not held in place.

a. Use a pry bar (tool No. 9998511) or equivalent, under the hold-down or injector lip and pry up to remove the injector.

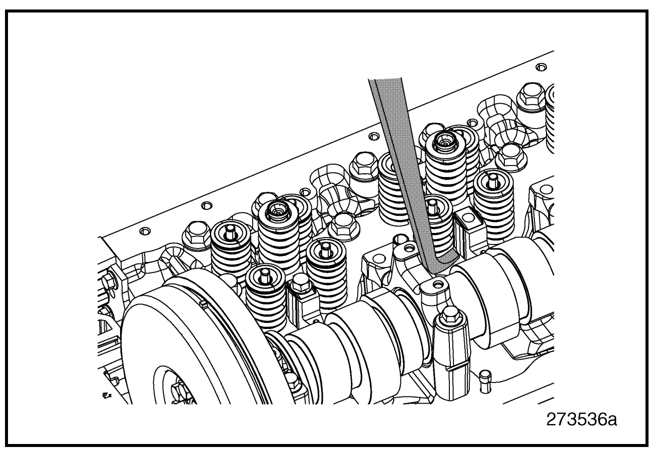


Figure 108 — Removing Injector with a Pry Bar (Tool No. 9998511)

b. If the injector cannot be removed using the pry bar, proceed as follows:

i. Depending on which injector is stuck, remove the unit injector from the companion cylinder (i.e., if the injector in cylinder No. 1 is stuck, remove the injector from cylinder No. 6). Use the appropriate flywheel turning tool to rotate the engine crankshaft to position the camshaft at TDC. Next, rotate the engine from TDC to the appropriate camshaft mark to position the piston at the companion cylinder at TDC. See the following table. Confirm the piston is at the top of the cylinder by inserting a 40 cm (16 inch) piece of straight stiff wire into the injector hole of the companion cylinder.

With Engine Brake

Companion Cylinder	Camshaft Mark
1 and 6	TDC
2 and 5	Between 5E6 and 3E2
3 and 4	Between 3E2 and 6E4

Without Engine Brake

Companion Cylinder	Camshaft Mark
1 and 6	V3TDC
2 and 5	V6
3 and 4	V2

ii. After verifying that the piston in the companion cylinder is at TDC, remove the inlet and exhaust valve springs at the sides of the hold-down yoke on the cylinder where the unit injector is stuck. To do this requires using an alternate valve spring compressor (tool No. J 41989) mounted in the injector hold-down yoke fastener hole of an adjacent cylinder. Compress the valve springs, remove the valve keepers and then slowly release the tool and remove the valve spring.

WARNING

Use protective goggles or injury to the eyes can occur.

NOTE

Cover all passageway holes in the cylinder head and gear train opening with shop towels.

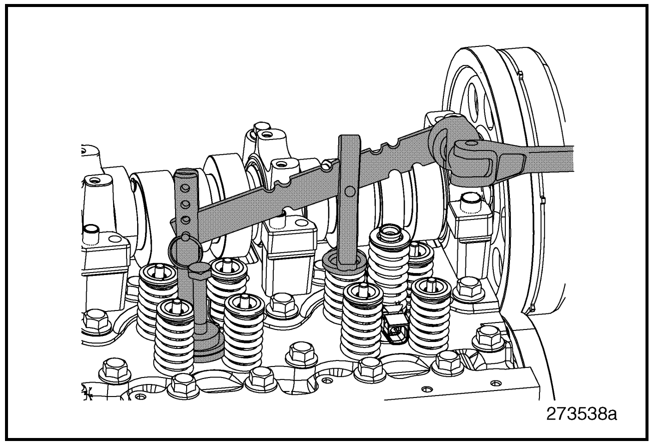


Figure 109 — Removing Valve Springs with Alternate Valve Spring Compressor (Tool No. J 41989)

iii. Position the forks of the heavy-duty puller (tool No. J 48922) under the lip of the unit injector. Secure the puller by sliding the lock collar down over the forks. Remove the injector from the cylinder head using hand tools. **The injector must be lifted out along with the hold-down yoke.**

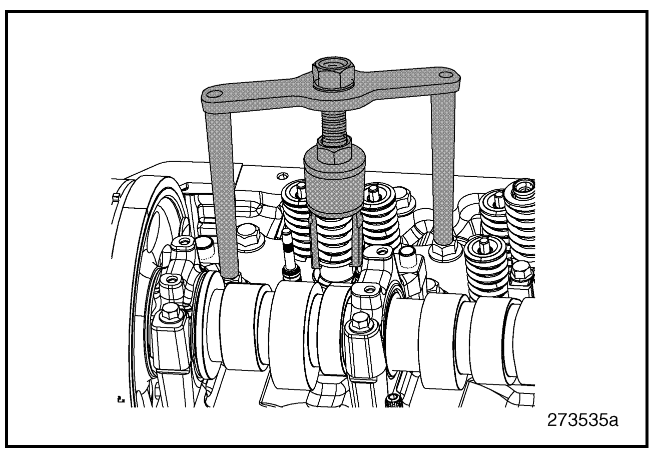


Figure 110 — Removing Injector with J 48922

CAUTION

If excessive combustion leakage has resulted in the copper sleeve being stuck-fast to the unit injector by carbon, the unit injector must be replaced. The condition is found when the unit injector is removed and the copper sleeve comes out with the injector.

iv. Reinstall the valve spring compressor (tool No. J 41989), then position the inlet and exhaust springs over the valves. Compress the springs and install the valve keepers. Tap the valve stem with a soft-faced mallet to make sure the keepers are seated properly. Remove the compressor tool from the cylinder head.

WARNING

Use protective goggles or injury to the eyes can occur.

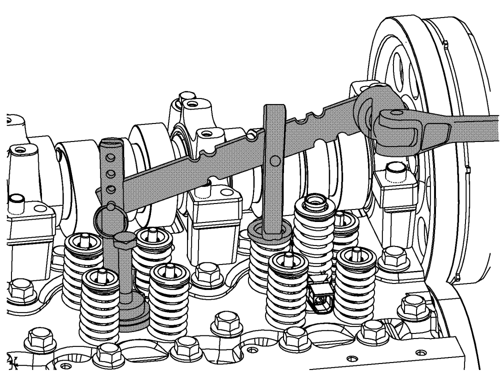


Figure 111 — Installing Valve Springs with Alternate Valve Spring Compressor (Tool No. J 41989)

7. **Injector Removal — 38 mm (Tall) Yoke with Stepped-Down Area**

NOTE

Use care when removing the unit injector because the injector hold-down is not secure and could fall off if not held in place.

a. Initially attempt to remove the unit injector using the standard injector puller (tool No. 9990006).

b. If the unit injector cannot be removed using the standard puller, proceed with using the heavy-duty puller (tool No. J 48922) by positioning the forks of the heavy-duty puller (tool No. J 48922) under the lip of the unit injector, and then secure the puller by sliding the lock collar down over the forks. Remove the injector from the cylinder head using hand tools. **The injector must be lifted out along with the hold-down yoke.**

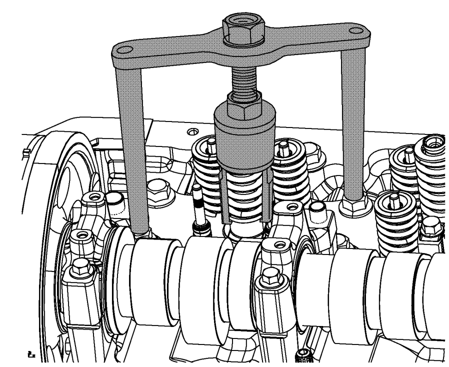


Figure 112 — Removing Injector with Heavy-Duty Puller (Tool No. J 48922)

8. Insert the injector into a protection sleeve, 9998249.

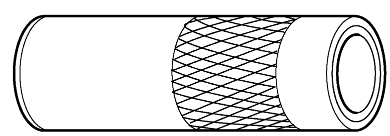


Figure 113 — Injector Protection Sleeve, 9998249

9. Remove and discard all injector nozzle gaskets (flat washers) from injector tips or bottoms of copper sleeves. Also, remove and discard all O-rings and yoke screws. **New** injector nozzle gaskets (flat washers), O-rings and yoke screws are required for installation.

NOTE

- If an injector nozzle gasket (flat washer) had been used for the seal joint between the injector copper sleeve and the injector, discard the used gasket immediately after the injector is removed. A used gasket must not be reused. When the injector is removed, this gasket may come out attached to the injector or it may remain in the bottom of the injector sleeve.
- If the nozzle gasket (flat washer) is attached to the injector, loosen it with gentle prying from a thin flat gasket scrapper blade. If the gasket is in the bottom of the injector sleeve, initially attempt to remove it with a magnet. If this is unsuccessful, use a standard flat blade screwdriver with a long thin shank and narrow width blade to loosen the gasket. Locate the blade in the recess between the outside of the gasket and the injector sleeve. Use the blade to apply force on the outside of the gasket at different locations around the gasket. Continue this until the gasket separates from the sleeve.

10. If the injector is not being installed immediately, install the protective plug into the unit injector bore of the cylinder head to protect it from debris.

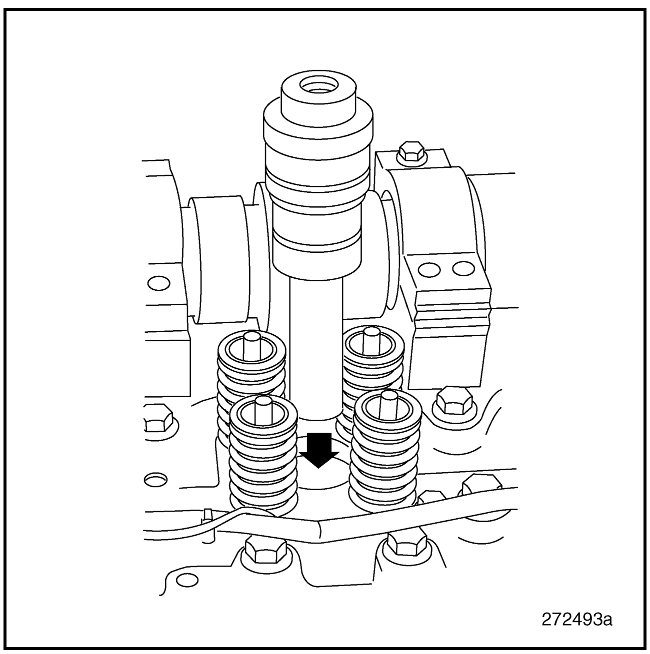


Figure 114 — Installing Injector Bore Protective Plug

11. Repeat the process to remove the remaining unit injectors.

Starter Removal

[272 DH]

The starter is held in place by nuts assembled over studs installed at the front right side of the flywheel housing.

WARNING

The starter is heavy. Do NOT attempt to remove the starter without the help of an assistant or the use of a suitable lifting device. Failure to heed this warning may result in personal injury and component damage.

1. If not already done, disconnect the wiring harness from the starter motor.
2. Loosen the nuts fastening the starter to the flywheel housing.

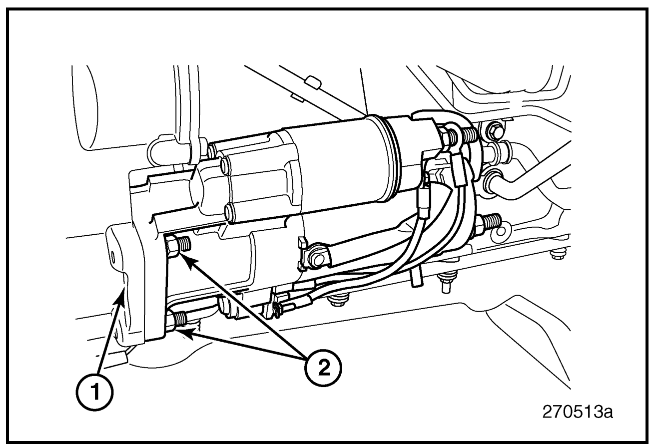


Figure 115 — Starter

1. Flywheel Housing	2. Attaching Nuts

3. With the help of an assistant or a lifting device, remove the starter from the engine.

Turbocharger Removal

[214 SC]

⚠ WARNING

The turbocharger is heavy. Do NOT attempt to remove the turbocharger without the help of an assistant or the use of a suitable lifting device. Failure to heed this warning may result in personal injury and component damage.

⚠ CAUTION

Thorough cleanliness is required. Small particles can cause severe rotor damage and component damage if inducted during high-speed operation. Be sure to plug the inlet and outlet ports while handling the turbocharger. Also, cap the oil line openings to prevent contamination.

1. Install and retain the protective caps over the turbocharger ports to keep debris and dirt out of the turbocharger.
2. Cut the tie straps securing the actuator and turbocharger speed sensor wiring harness leads to the engine. Disconnect and remove the connector ends from the support bracket above the oil filter housing.

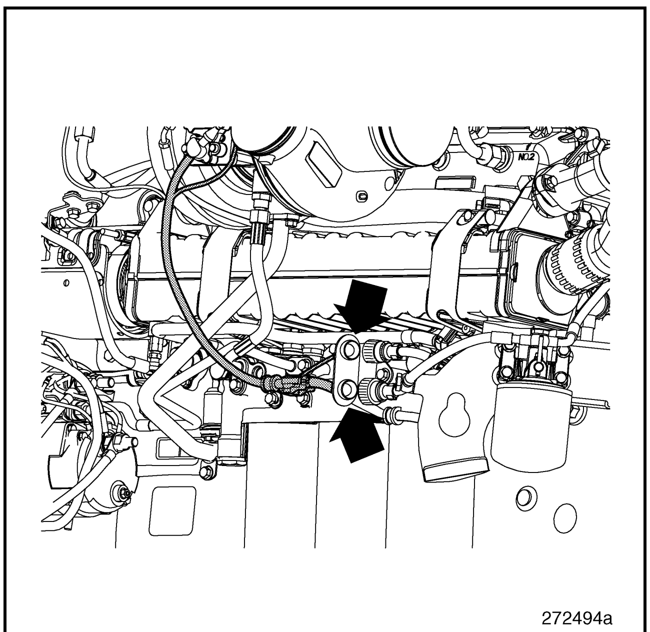


Figure 116 — Sensor Connector Support Bracket

3. Disconnect all coolant supply and return lines from the turbocharger and turbocharger actuator.

NOTE

The bottom line must be removed from the cylinder block.

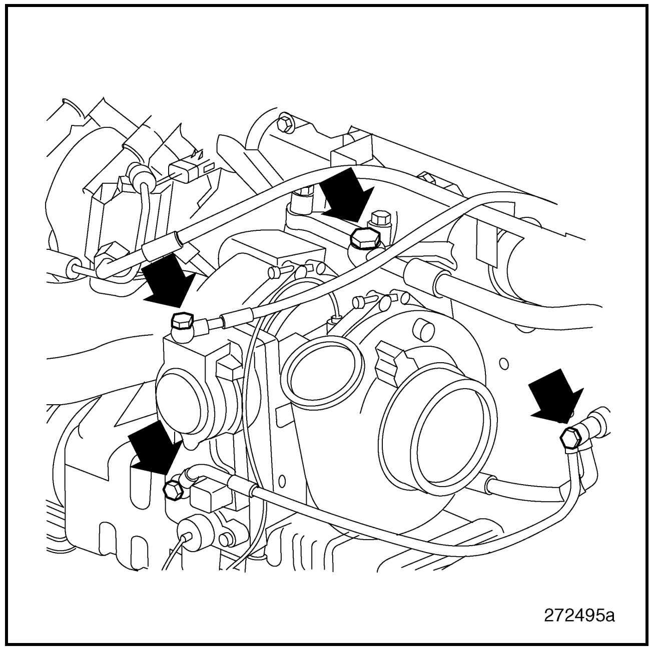


Figure 117 — Coolant Supply and Return Lines

4. Disconnect the oil supply line at the turbocharger.

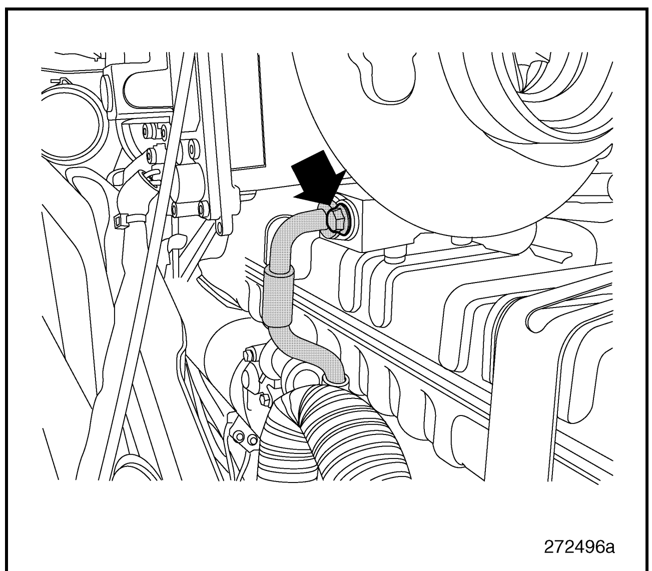


Figure 118 — Turbocharger Oil Supply Line Connection

5. Remove the oil supply line retainer screw at the oil filter housing; remove the line.

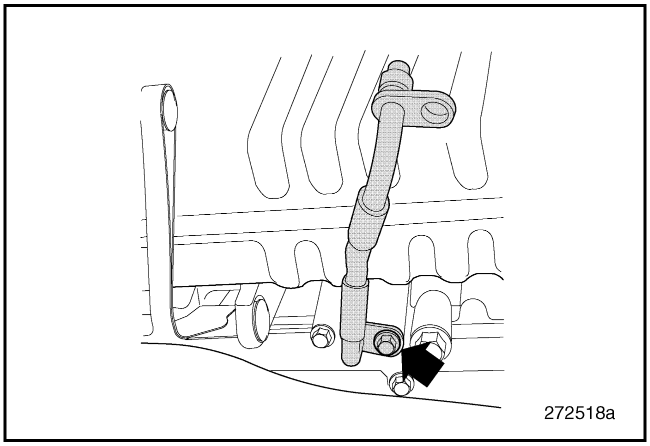


Figure 119 — Oil Supply Line Retainer Screw at Filter Housing

6. While supporting the turbocharger, remove the flange mounting fasteners and spacers.

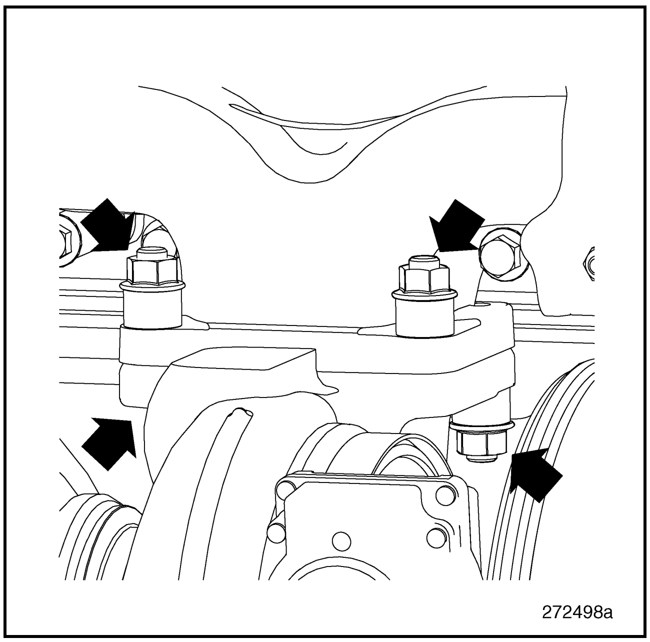


Figure 120 — Turbocharger Mounting Fasteners

7. With the help of an assistant or a lifting device, lower the turbocharger away from the exhaust manifold flange mounting bolts and remove it from the engine. Remove and discard the gasket.

8. Remove the coolant hose and the oil adapter block from the bottom of the turbocharger.

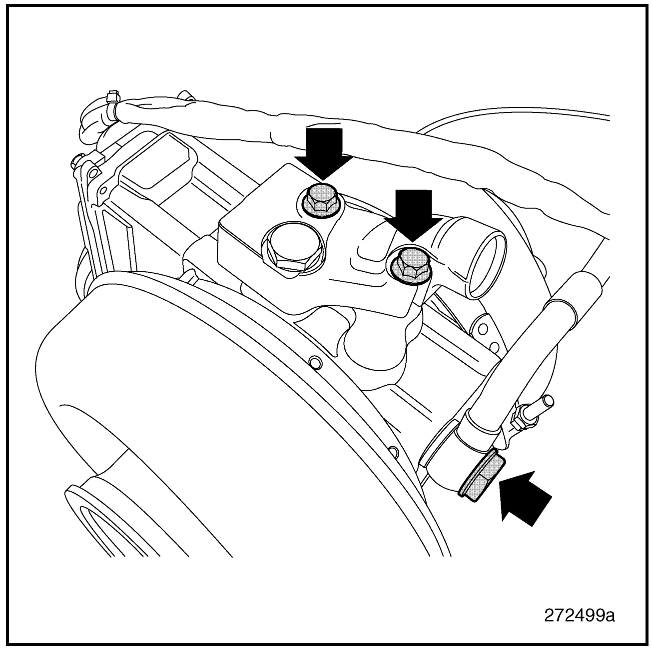


Figure 121 — Adapter Block at Bottom of the Turbocharger

EGR Hot Pipe (Cooler Inlet) Removal

[214 HN, HP, HR]

The hot pipe is the short connector between the EGR valve and the EGR cooler inlet.

CAUTION

Whenever an EGR hot pipe clamp is removed, the retaining nut may gall the threads of the T-bolt. The body of the clamp can be reused and should not be replaced unless it is broken or damaged.

1. Loosen the high temperature V-clamps at the EGR hot pipe by removing the nuts from the T-bolts. Free the clamps from the EGR hot pipe flanges.

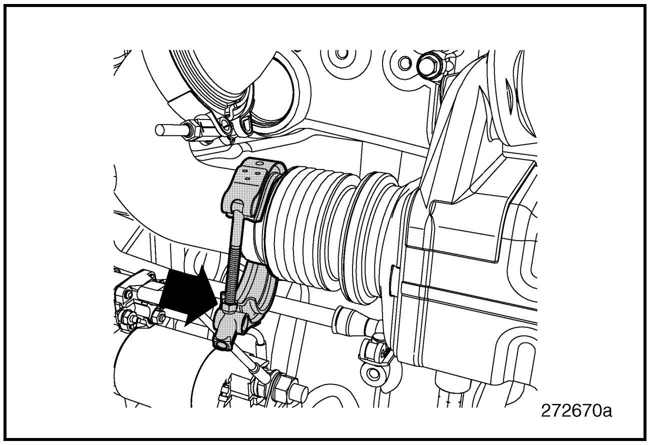


Figure 122 — EGR Hot Pipe Clamps

2. Remove the EGR hot pipe from between the EGR valve and the EGR cooler.

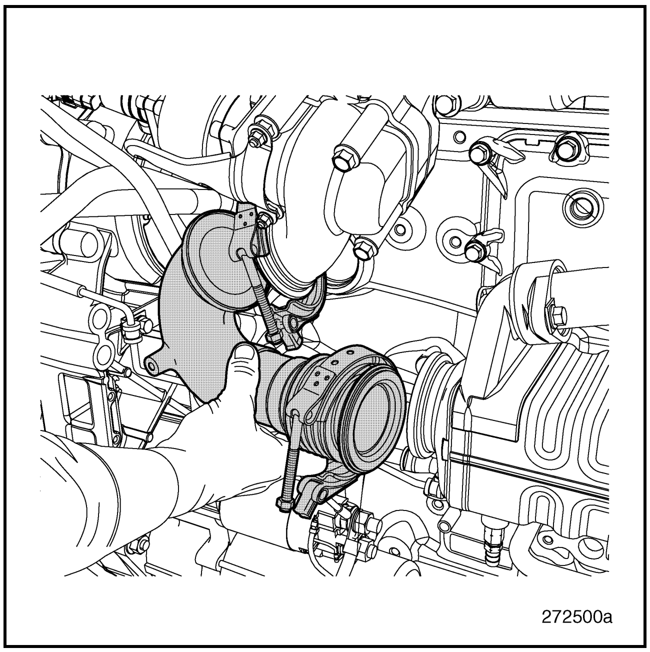


Figure 123 — Removing EGR Hot Pipe

3. Remove and discard the seals at each end of the hot pipe.

EGR Valve Removal

[214 QE]

1. Remove the fasteners securing the EGR valve heat shield and remove the shield.

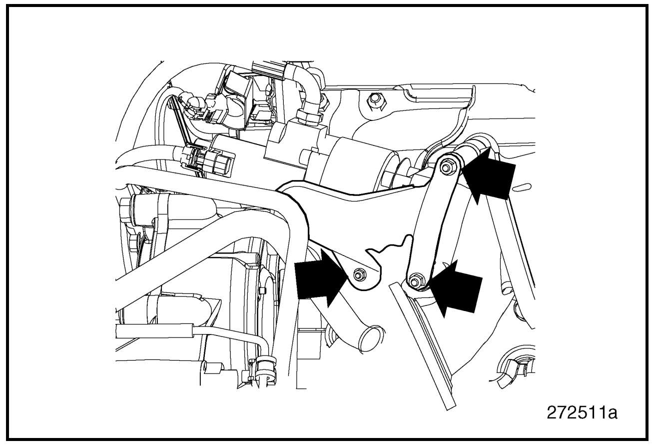


Figure 124 — EGR Valve Heat Shield

2. Loosen the oil return line at the EGR valve.

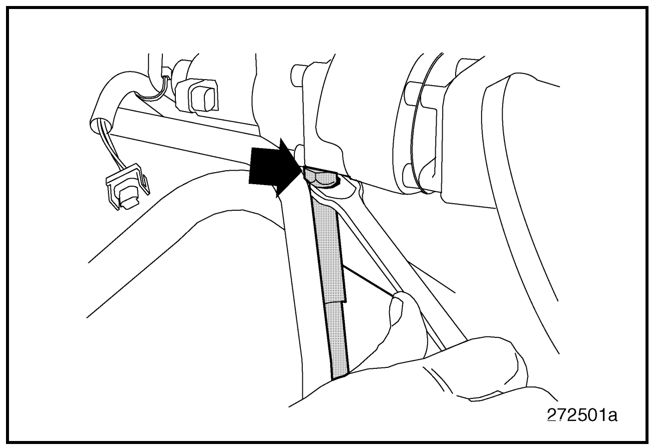


Figure 125 — Removing EGR Valve Oil Return Line

NOTE

It may be necessary to loosen the EGR valve mounting fasteners enough to provide clearance for disconnecting the oil return and supply lines.

3. If not already done, loosen the EGR valve oil supply line.

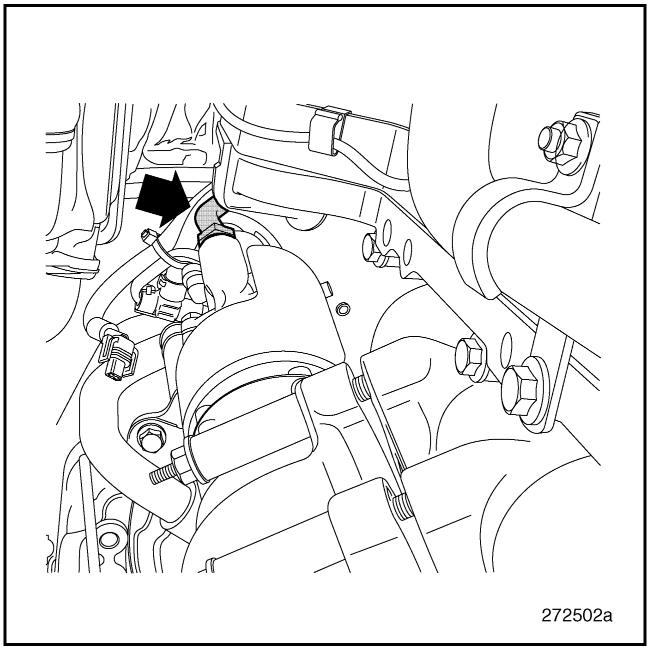


Figure 126 — EGR Valve Oil Supply Line

4. Remove the fasteners and pull the EGR valve away from the exhaust manifold.

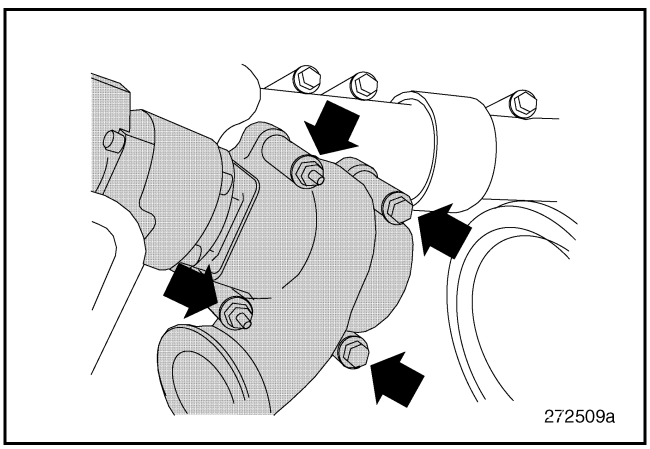


Figure 127 — EGR Valve Removal

5. Remove the oil lines from the EGR valve and remove the valve.

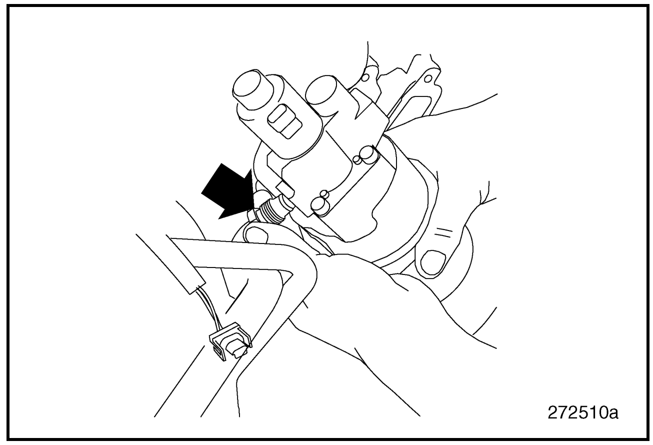


Figure 128 — Removing Oil Lines from Valve

6. Remove and discard the gasket.

EGR Cooler Removal

[214 HM]

1. Remove the retainer screws and clips securing the EGR cooler coolant outlet pipe. Remove the pipe.

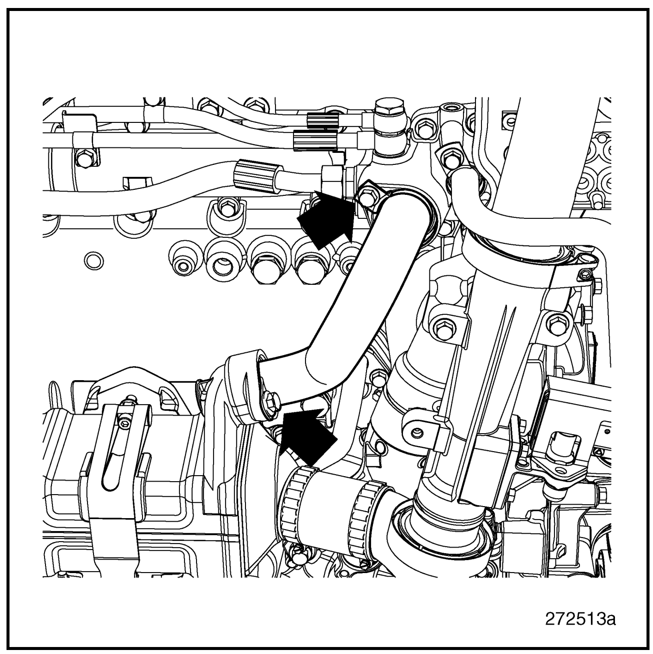


Figure 129 — EGR Cooler Coolant Outlet Pipe

2. If not already done, remove the V-band clamp from the venturi inlet elbow. Loosen the clamp and remove the EGR hose and pipe located between the EGR cooler and the venturi.

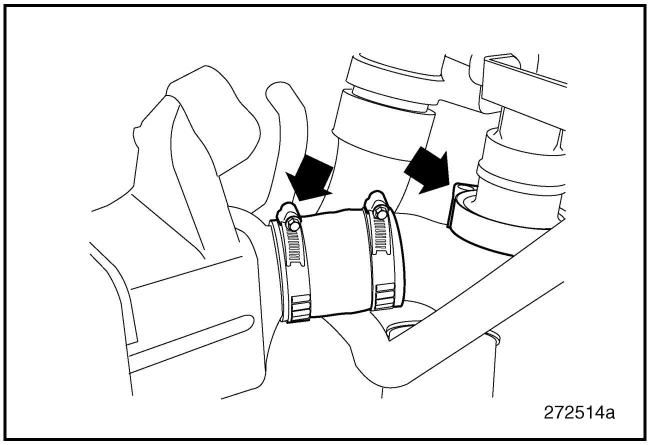


Figure 130 — Venturi Inlet Hose and Elbow

3. Loosen and remove the drain fitting from the EGR cooler. Drain the coolant into a suitable container.

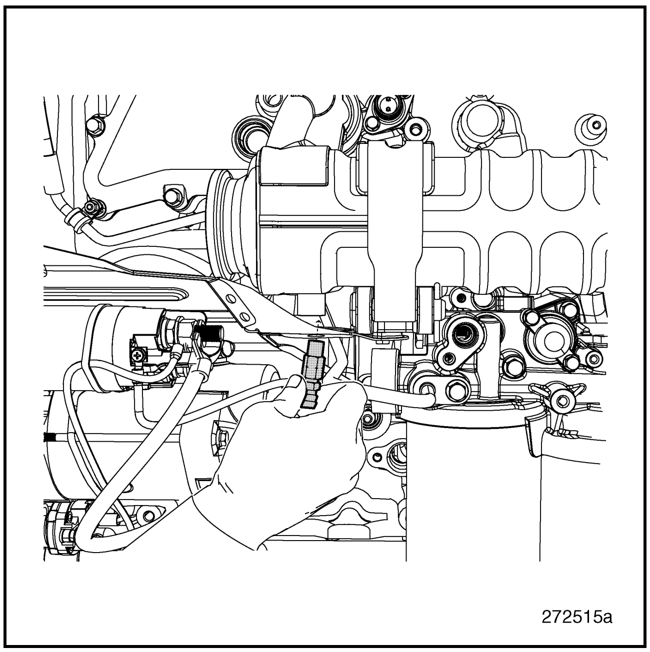


Figure 131 — EGR Cooler Drain Fitting

4. Loosen the jam nuts securing the clamp strap fasteners at the EGR cooler front and rear brackets.

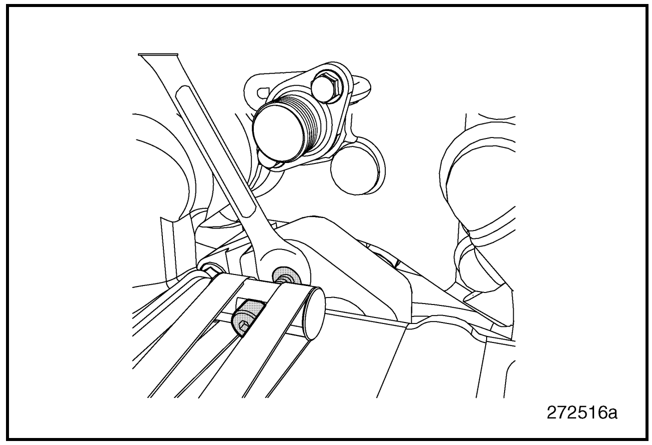


Figure 132 — Loosening Jam Nut

5. Remove the fasteners securing the clamp straps to the EGR mounting brackets. Move the straps out of the way.

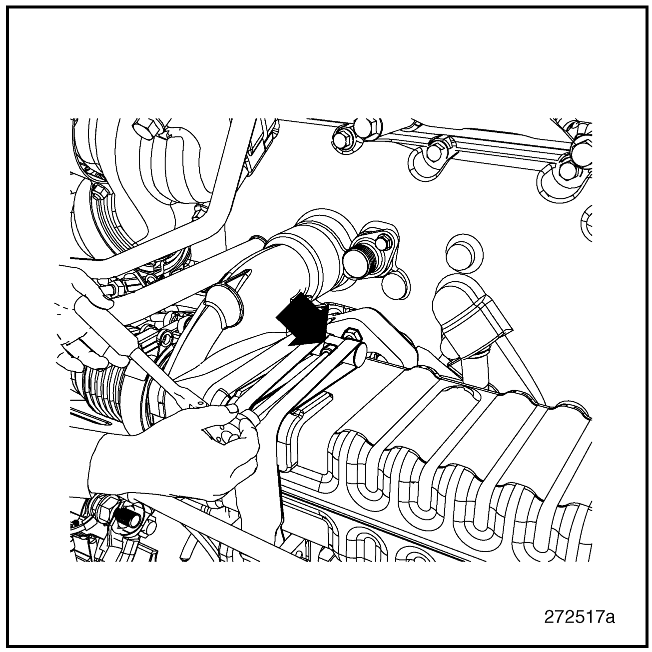


Figure 133 — Removing Clamp Strap Fastener

6. Remove the EGR cooler from the engine.

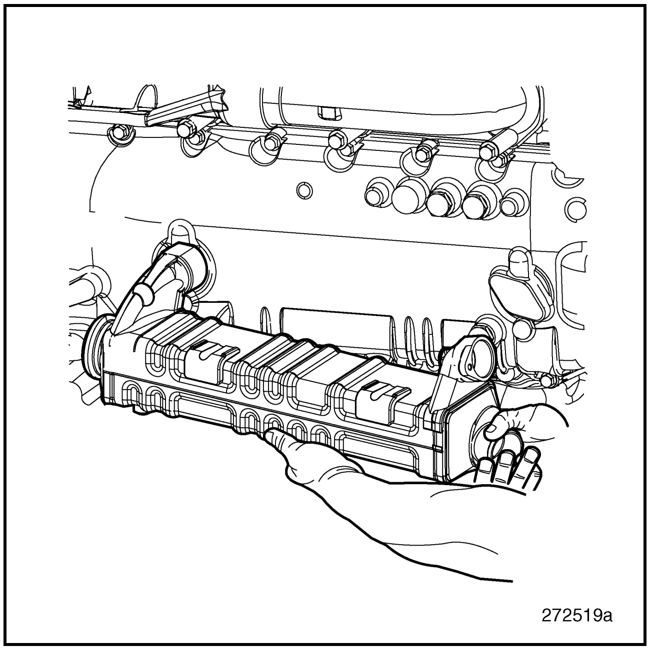


Figure 134 — Removing EGR Cooler

7. Remove the fasteners securing the EGR mounting brackets to the cooling duct cover and cylinder block. Remove the brackets from the engine.

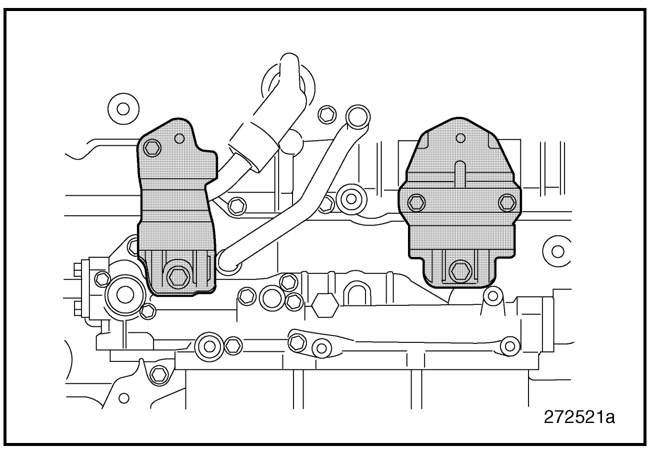


Figure 135 — EGR Cooler Mounting Brackets

Exhaust Manifold Removal

WARNING

The exhaust manifold consists of three castings that are not clamped together. These could separate unexpectedly when the attaching screws are removed from the cylinder head. To prevent personal injury and damage to the parts, take care to control all pieces until they can be separated safely.

1. While supporting the exhaust manifold, remove the attaching screws and spacers.

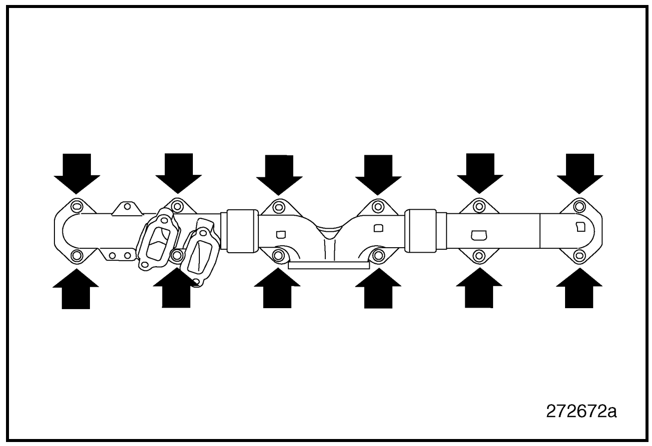


Figure 136 — Exhaust Manifold

2. Set the spacers and screws aside for reassembly.
3. Remove the exhaust manifold from the cylinder head.
4. Remove and discard the exhaust manifold gaskets.
5. Inspect the exhaust manifold. If there are signs of exhaust leakage between the cast segments of the manifold, replace the seals.

Oil Filter Housing Removal

[219 EP]

NOTE

Provide suitable rags and containers for collecting oil drainage at each step.

1. Remove the screws and remove the oil tube from the front of the oil filter housing and the cooling duct cover. Discard the gaskets.

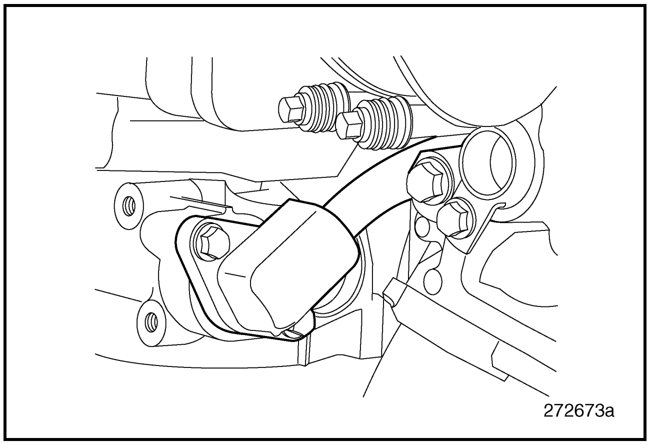


Figure 137 — Oil Tube (at Housing Front)

2. Remove the screws and remove the oil tube between the valve housing at the rear and the duct cover. Discard the gaskets.

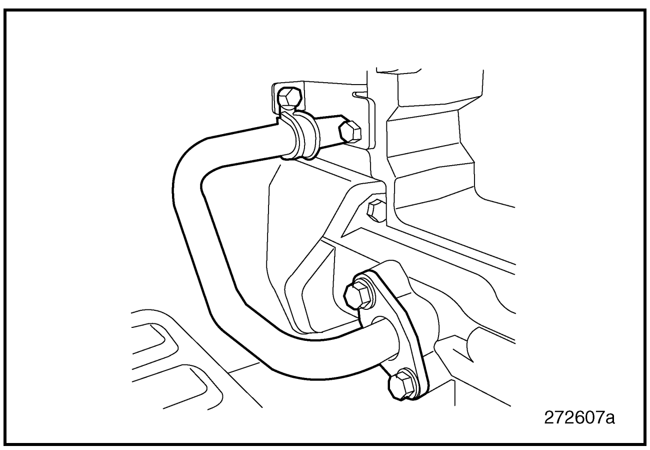


Figure 138 — Oil Tube (at Housing Rear)

3. Remove the fasteners and remove the oil filter valve housing from the cylinder block. Discard the gasket.

Coolant and Pump Inlet Housings Removal

[215 SW]

NOTE

Provide suitable containers to collect coolant that may escape during removal procedures.

1. Remove the fasteners and remove the coolant pipe (bypass) housing from the cylinder head. Discard the flange seal ring.

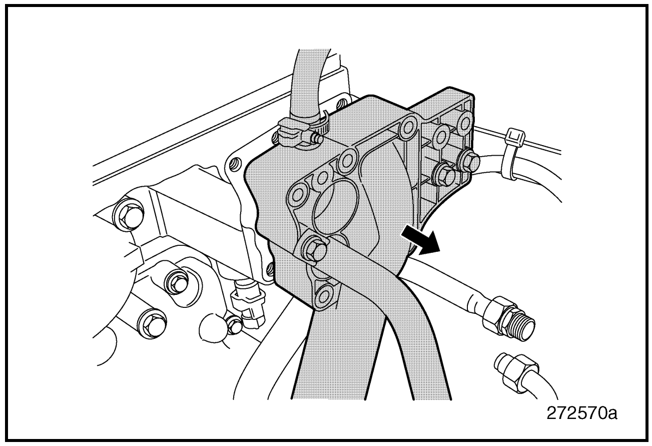


Figure 139 — Upper Coolant Pipe (Bypass) Housing

2. Remove the screws and remove the pump inlet housing at the rear of the coolant pump. Discard the flange seal ring.

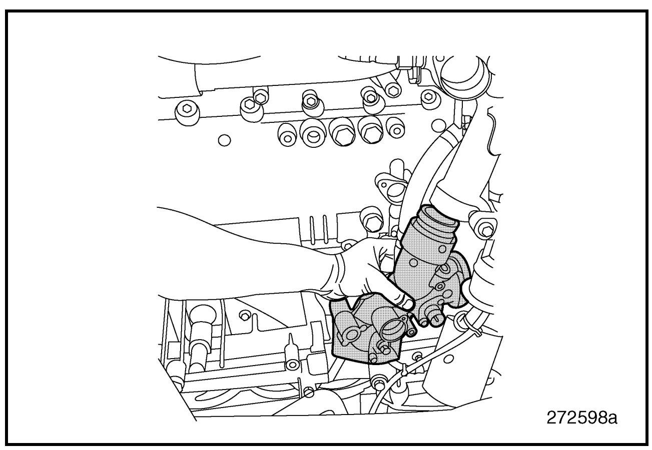


Figure 140 — Removing Pump Inlet Housing

Cooling Duct Cover and Oil Cooler Removal

[215 DW, 219 EP]

To remove the oil cooler, the cooling duct cover must be removed first. The oil cooler is attached to the inside of the cooling duct cover.

COOLING DUCT COVER REMOVAL

1. Remove the cooling duct cover fasteners and remove the duct cover and oil cooler assembly from the cylinder block.

NOTE

Note the location of all fasteners for reassembly; different lengths are used.

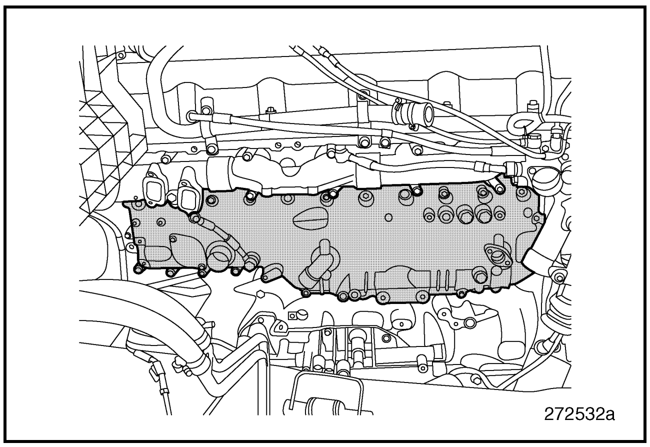


Figure 141 — Cooling Duct Cover

2. Carefully remove the seal from the perimeter groove in the cover. Discard the seal; it cannot be reused.

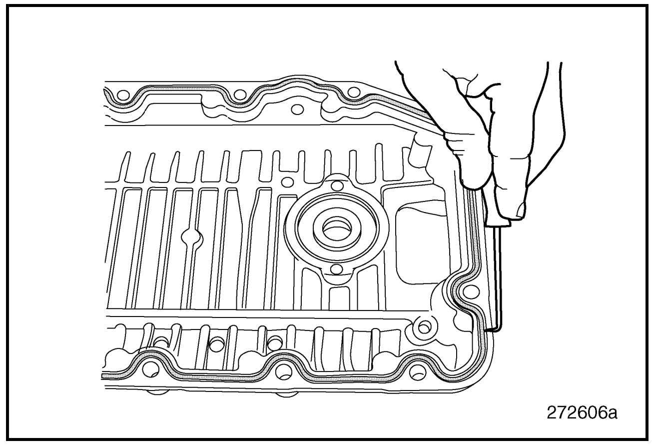


Figure 142 — Removing Duct Cover Seal

3. Remove and discard the cover-to-pump base plate seal.

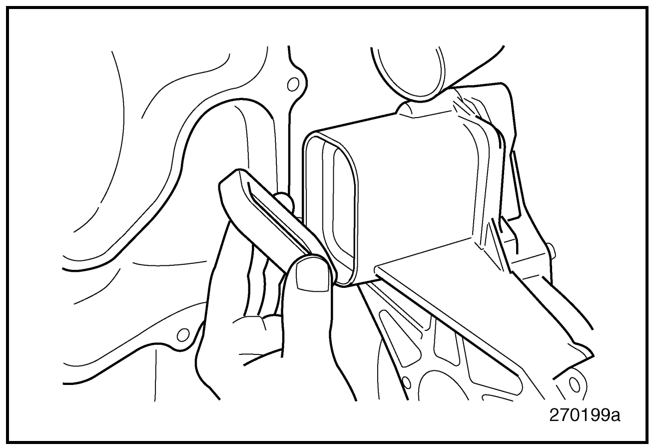


Figure 143 — Cooling Duct Cover-to-Pump Base Plate Seal

OIL COOLER REMOVAL

1. Place the cooling duct cover assembly on a clean work surface. Remove the fasteners and remove the flow plate covering the oil cooler.

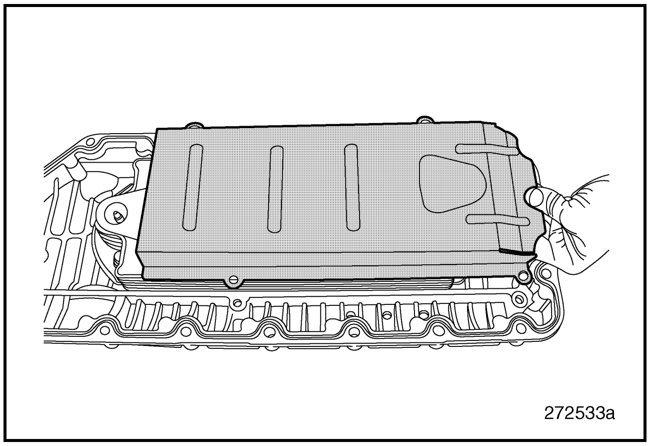


Figure 144 — Removing Flow Plate

2. Remove the oil cooler fasteners and remove the cooler from the cover.

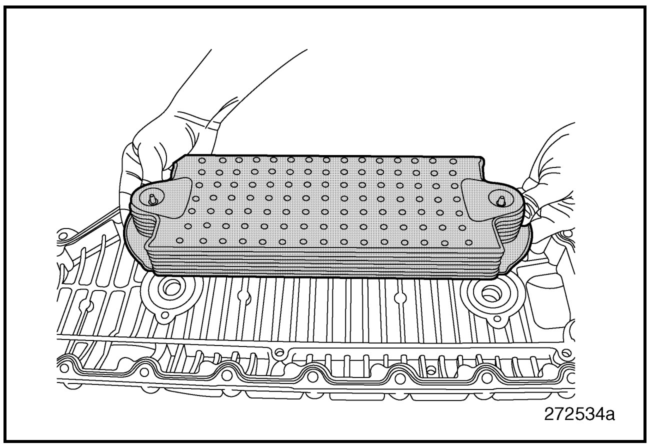


Figure 145 — Removing Oil Cooler

3. Remove the oil cooler sealing O-ring gaskets between the oil cooler and cover. Discard the O-rings.

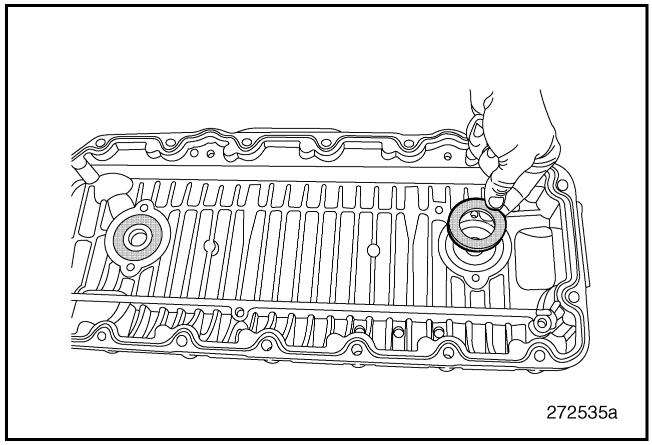


Figure 146 — Removing Cooler O-Rings

Drive Belts and Fan Hub Removal [232 HB]

Remove the drive belts, idlers and hub bracket from the front of the engine as follows:

1. Remove the fasteners and remove the fan drive and coolant pump belt tensioner from the coolant pump housing.
2. Remove the fasteners and remove the accessory drive belt tensioner from the cylinder block.
3. Remove and set aside the drive belts.

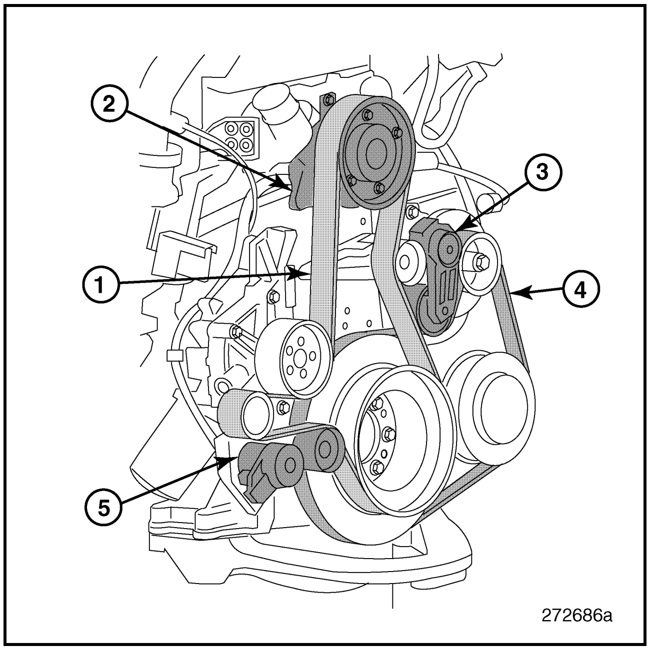


Figure 147 — Fan Hub and Accessory Drive System

1. Fan Drive Belt 2. Fan Hub Bracket 3. Accessory Drive Belt Tensioner	4. Accessory Drive Belt 5. Fan Drive and Coolant Pump Belt Tensioner

4. Remove the fasteners and fan hub bracket assembly.

EGR Mixer Removal

[214 HL]

1. If not already done, remove the fasteners and remove the inlet pipe (elbow) from the EGR mixer.

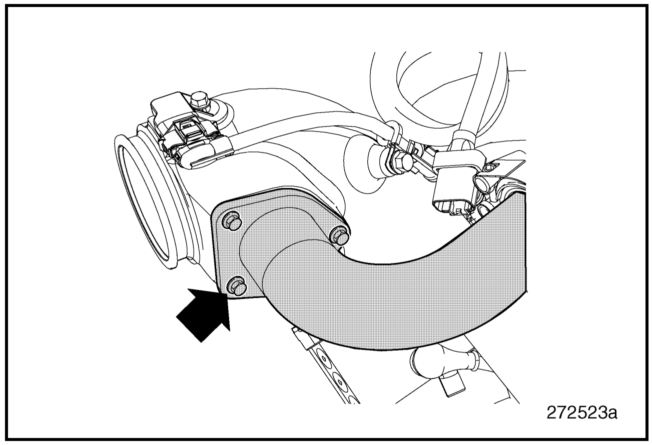


Figure 148 — EGR Mixer Inlet Pipe

2. Remove the fasteners and EGR mixer (including fan ring support bracket) and gasket from the spacer block or inlet air preheater, if so equipped.

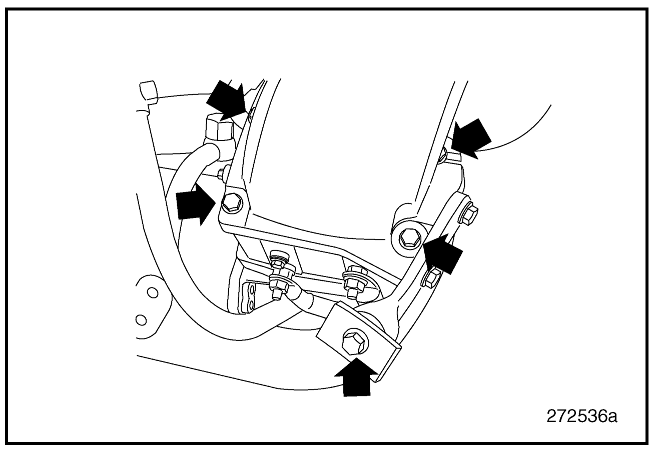


Figure 149 — EGR Mixer Fasteners

3. Remove the spacer block from the inlet air manifold. Or, if so equipped, remove all power and ground cables from the inlet air preheater and remove the preheater from the manifold.

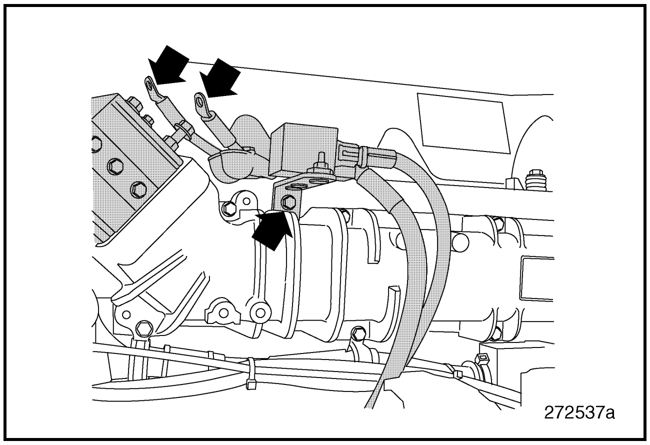


Figure 150 — Preheater Cable Connections

N O T E

Mark the cable locations before removal to ensure correct installation at reassembly.

4. Remove and discard the gasket between the spacer block or preheater base and the inlet manifold.

Crankcase Ventilation (CCV) Separator Removal

1. If not already done, loosen the clamps and disconnect the inlet and outlet hoses at the CCV separator. Remove the retainers and remove the hoses.

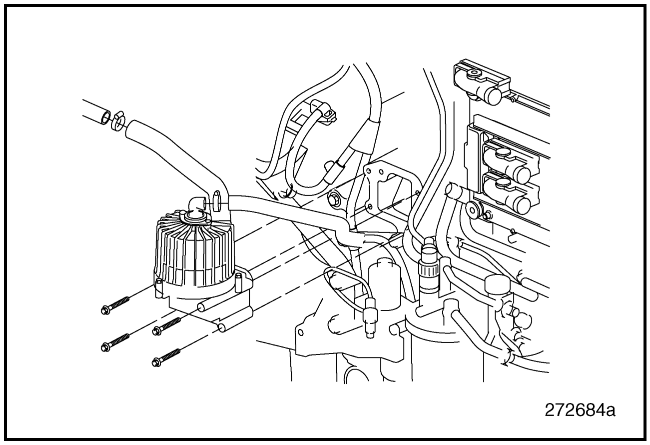


Figure 151 — Crankcase Ventilation Separator

2. Remove the fasteners and remove the separator assembly from the cylinder block.

Fuel Lines and Filter Housing Removal

If not already removed, remove the fuel lines and filter valve housing using the following procedure.

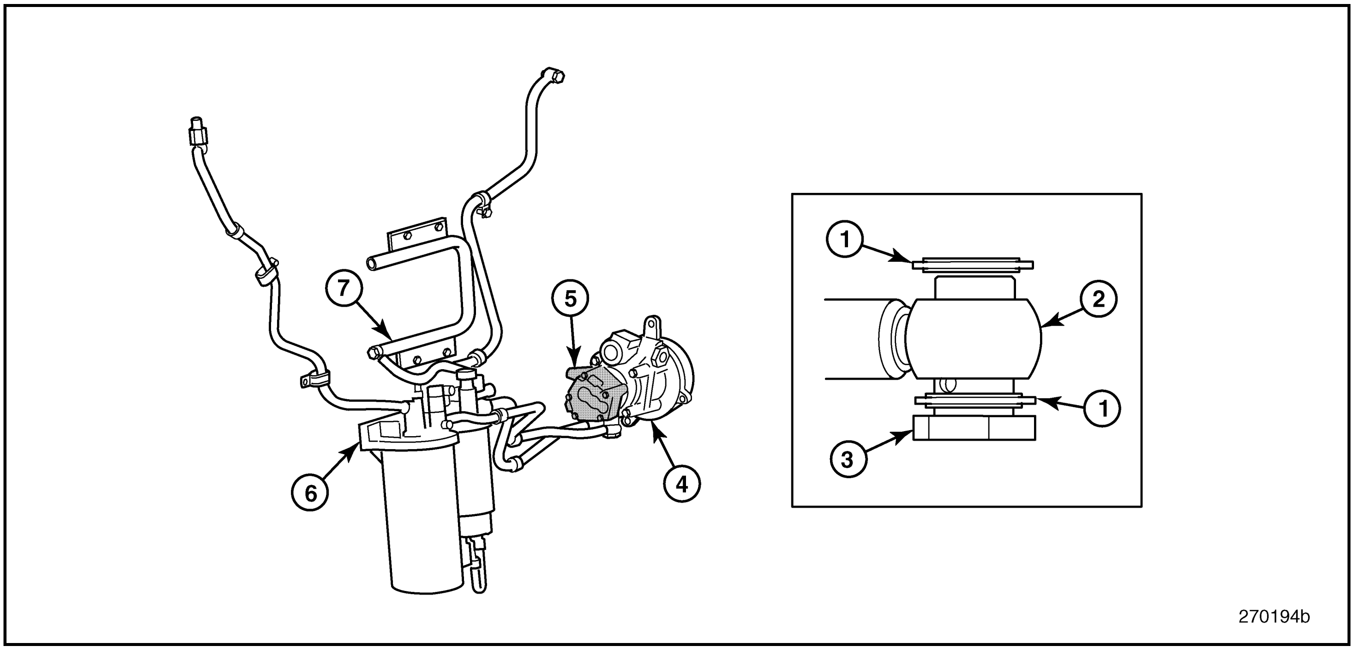


Figure 152 — Fuel Pump, Filter Assembly and Lines

1. Washers 2. Banjo Fitting 3. Banjo Screw 4. Power Steering Pump	5. Fuel Pump 6. Fuel Filter Bracket 7. EECU Cooler

1. Loosen the fuel line banjo fittings. Remove the banjo fittings, clamps and the following fuel lines from the left side of the engine.

NOTE

Be sure to capture the banjo sealing washers and hollow screws while removing them.

- Fuel return line — EECU cooling plate-to-filter housing
- Fuel return line — cylinder head (at front)-to-filter housing
- Fuel supply line — filter housing-to-cylinder head (at rear)
- Fuel supply and return lines — fuel pump-to-filter housing

2. Remove the filter housing.

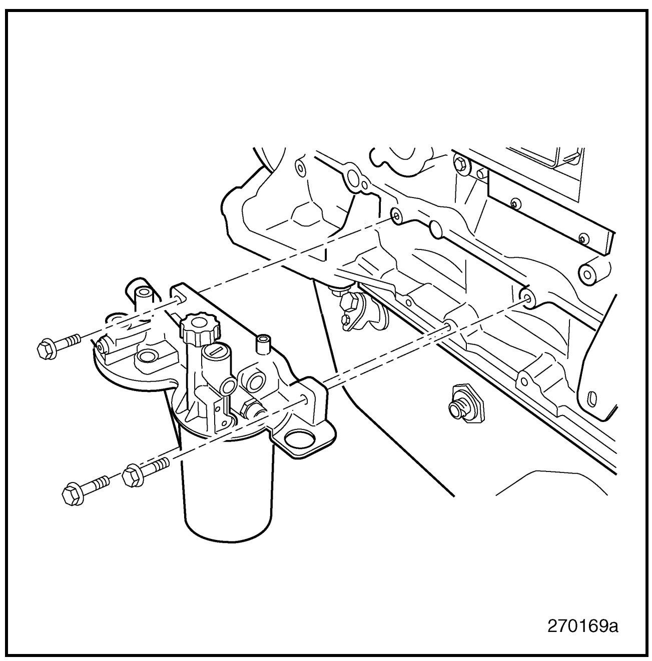


Figure 153 — Fuel Filter Housing

EECU and Cooling Plate Removal

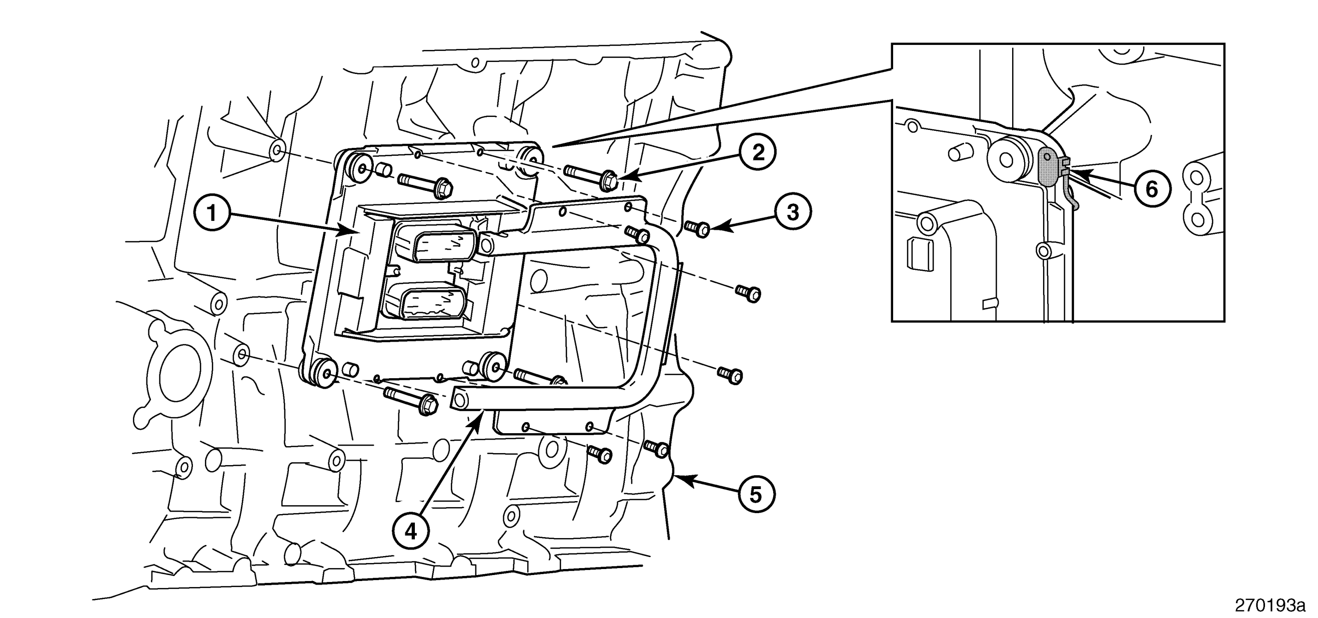


Figure 154 — EECU and Cooling Plate

1. EECU 2. Module Mounting Screws 3. Cooling Plate Mounting Screws	4. Cooling Plate 5. Cylinder Block 6. Ground Strap

If not already done for mounting the engine in the repair stand, or if the engine is not being completely disassembled for overhaul and only the EECU is to be removed, remove the EECU following the procedure below.

1. Unlock and remove the end connectors attached to the EECU. Remove the screws from the harness retainer clamps. Then, push the connector locks inward and rotate outward to disconnect both wiring harnesses from the EECU.

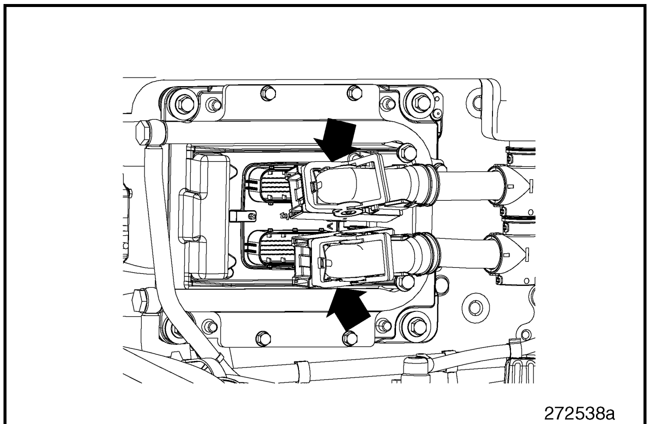


Figure 155 — EECU Harness Connectors

CAUTION

Use care to avoid damaging the terminal pins.

2. Position the harness connectors back out of the way.

NOTE

Provide suitable rags and containers for collecting fuel drainage.

3. Remove the fuel lines from the cooling plate and set aside.

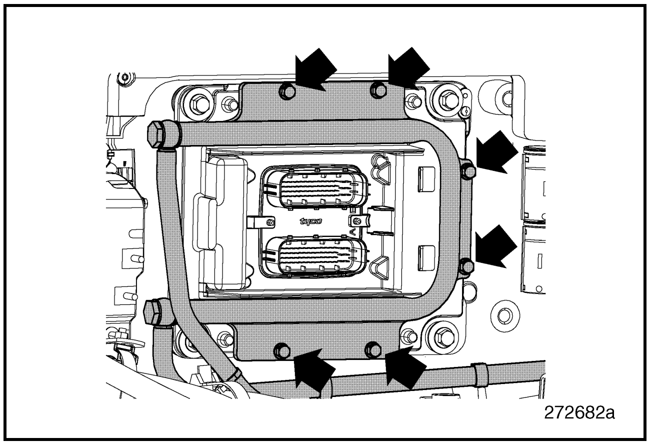


Figure 156 — EECU Mounting Screws

4. Remove the screws and the cooling plate from the EECU.
5. Remove the screws and the EECU from the engine.

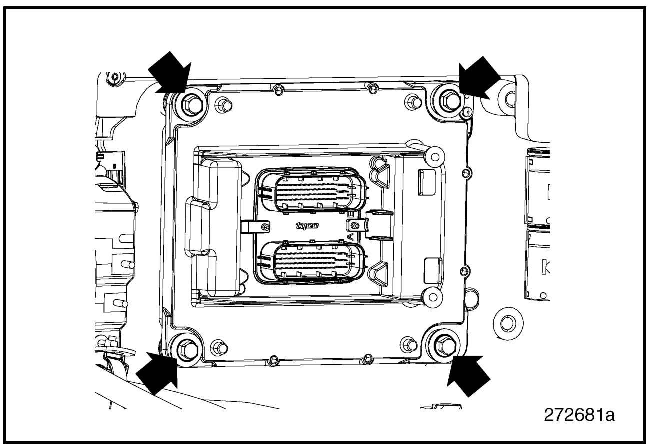


Figure 157 — EECU Mounting Screws

Inlet Manifold Removal

1. Remove the two top intake manifold mounting fasteners and install two alignment pins to support the manifold during removal.
2. Remove the remaining inlet manifold mounting fasteners. Using a plastic mallet, carefully tap the manifold loose and remove it from the cylinder head.

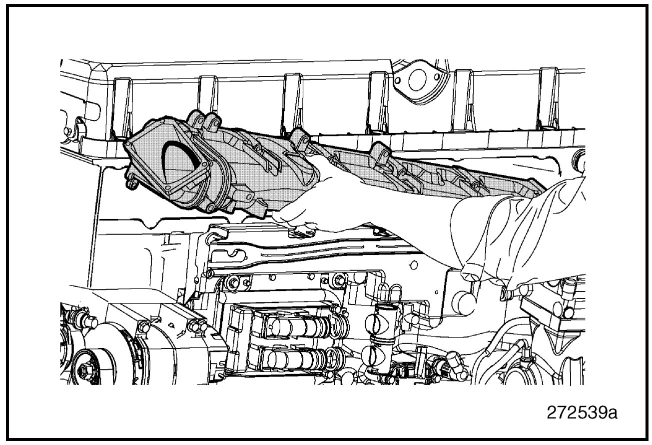


Figure 158 — Removing Inlet Manifold

3. Using a sharp pick, remove the rubber seal (molded gasket) from the groove in the inlet manifold. Discard the manifold seal.

Tandem Pump (Fuel and Power Steering) Removal

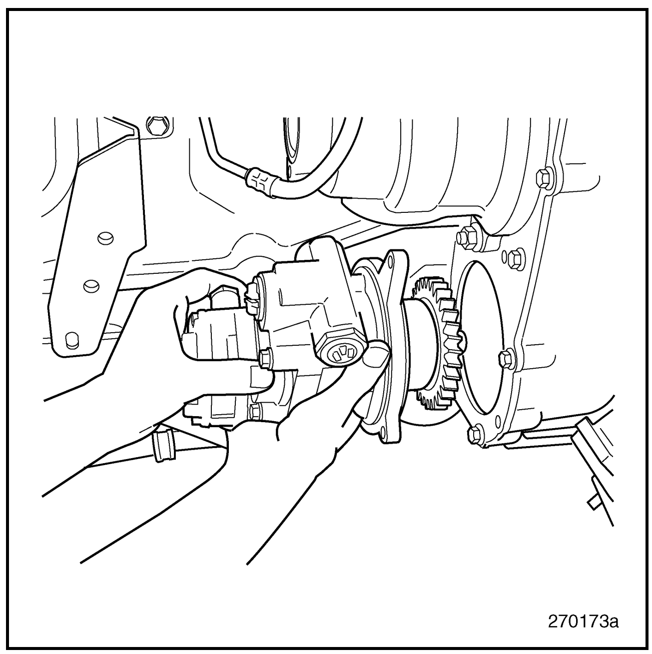


Figure 159 — Removing Tandem Pump

N O T E

Provide suitable rags and containers for collecting oil and fuel drainage at each step.

Be sure to capture the banjo sealing washers and hollow screws while removing them.

1. If not already done, remove the power steering oil supply and return lines from the tandem pump and set aside.
2. Remove the fuel supply and return lines from the fuel pump and set aside.
3. Remove the fasteners securing the pump to the flywheel housing and remove the tandem pump assembly from the engine.

Air Compressor Removal

[261 CK]

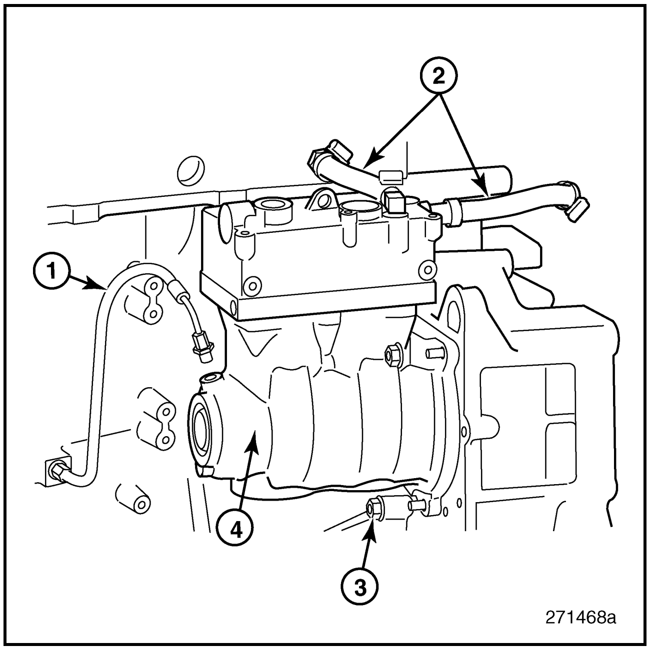


Figure 160 — Air Compressor and Fittings

1. Lubrication Line 2. Coolant Lines	3. Mounting Stud and Nut 4. Air Compressor

1. Disconnect and remove the compressor coolant lines from the engine.
2. Disconnect and remove the compressor oil supply line.
3. While supporting the air compressor, remove the flange nuts securing the compressor to the flywheel housing and remove the compressor from the engine.

Flywheel and Pilot Bearing Removal

TIMING GEAR ALIGNMENT

If the engine is not being completely disassembled for overhaul and only the timing gears are to be removed for replacement, make sure that the camshaft is set at Top Dead Center (TDC) for the No. 1 cylinder, before removing the flywheel. If not, proceed as follows:

1. Using the flywheel turning tool, 88800014, bar the engine over manually so that the camshaft TDC mark is between the two lines on the rear camshaft bearing cap. The flywheel will be at 0° with the camshaft at TDC.

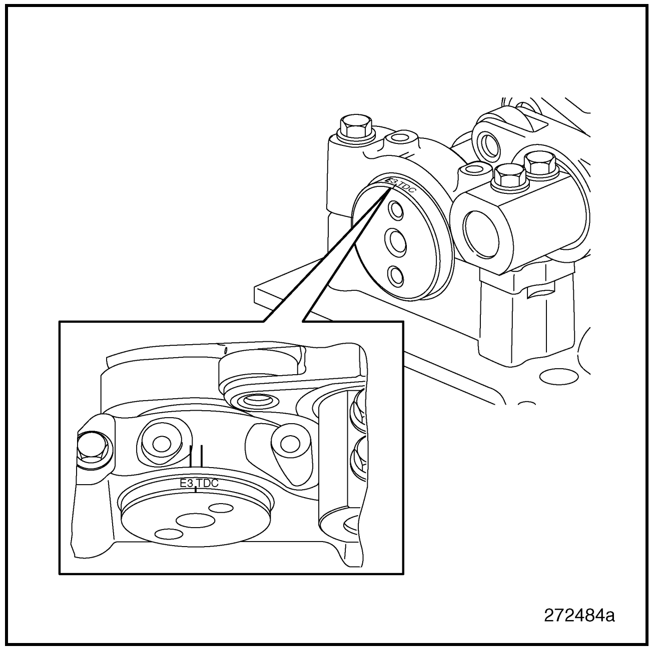


Figure 161 — Camshaft Timing Marks

2. The timing gears can now be removed. Use care to not rotate the gears as they are being removed so that the camshaft and crankshaft remain in the TDC position.

FLYWHEEL REMOVAL PROCEDURE

⚠ WARNING

The flywheel is heavy. Do NOT attempt to remove the flywheel without the help of an assistant or the use of a suitable lifting device. Failure to heed this warning may result in personal injury and component damage.

1. Remove the retainer screw and remove the engine speed sensor from the flywheel housing.

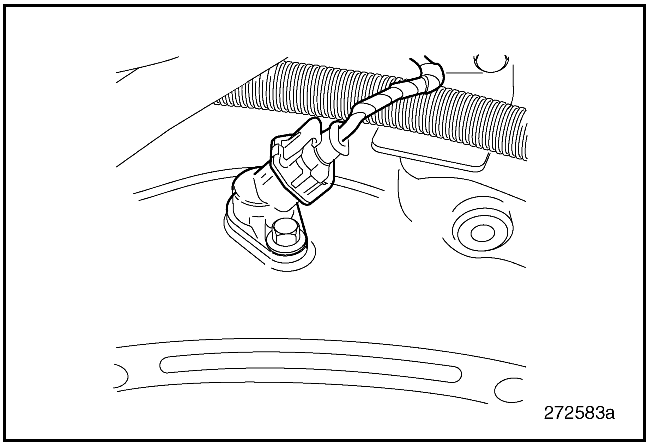


Figure 162 — Engine Speed Sensor

2. If present, remove the transmission pilot bearing using bearing extractor tool, 9991821.

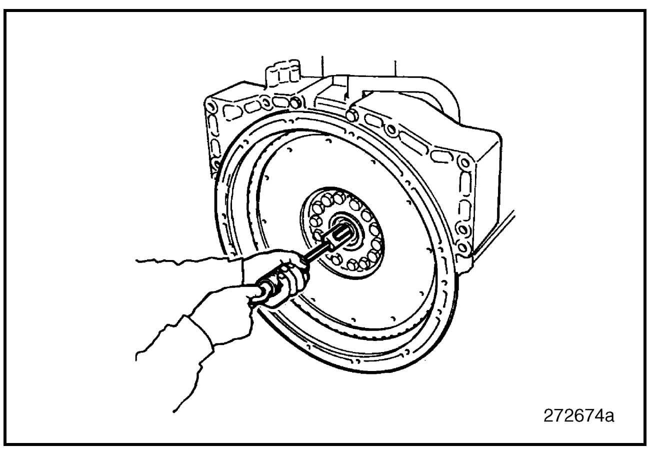


Figure 163 — Removing Pilot Bearing

3. Install two M10 x 100 screws in holes opposite each other at the outer perimeter of the flywheel. These screws will be used as handles to aid removal of the flywheel.

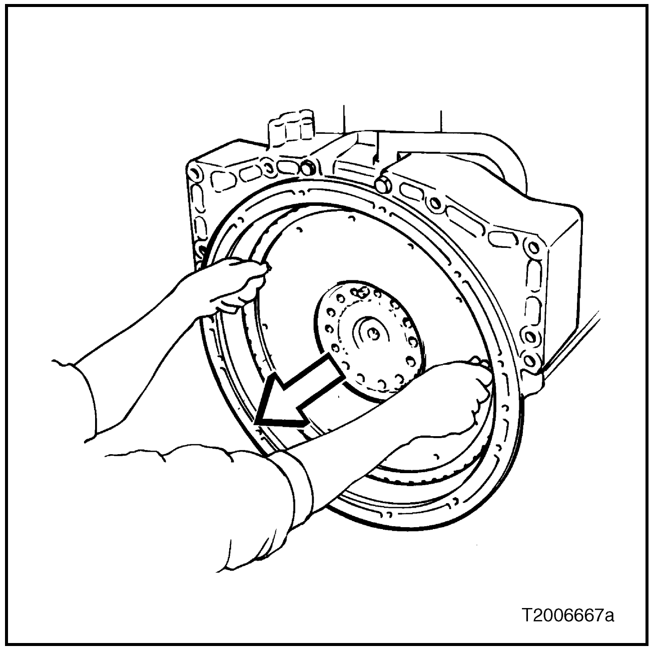


Figure 164 — Removing Flywheel

4. Remove the flywheel mounting fasteners.
5. While supporting the flywheel, carefully tap the flywheel, alternating from side to side, to work it off the aligning dowel pin and remove it from the crankshaft flange.

Power Take-Off (PTO) Assembly Removal

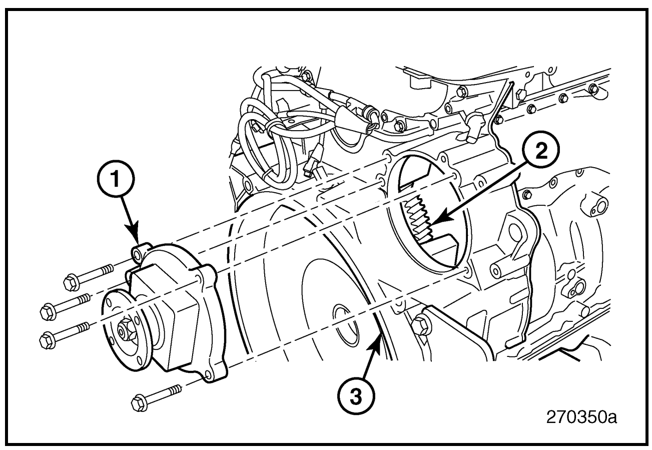


Figure 165 — Power Take-Off Assembly

1. PTO Assembly 2. Intermediate Idler Gearset	3. Flywheel Housing

1. If equipped with the optional PTO assembly, loosen and remove the fasteners securing the assembly to the flywheel housing.
2. Remove the PTO assembly from the flywheel housing and set aside.
3. Remove and discard the PTO housing seal.

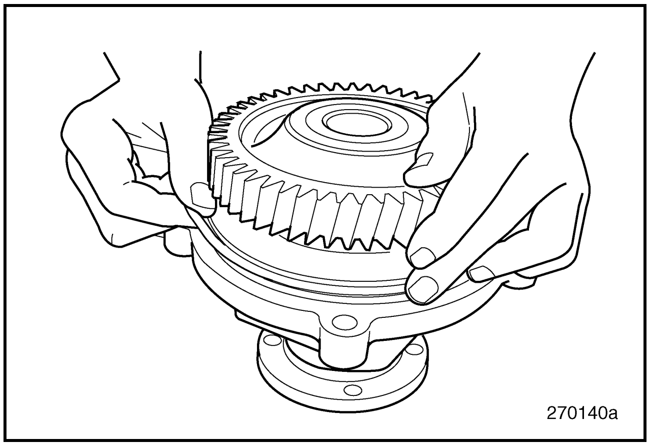


Figure 166 — Removing PTO Housing Seal

Flywheel Housing Removal

1. Remove the flywheel housing fasteners (item 2 in Figure 167) located at the front of the timing gear plate.

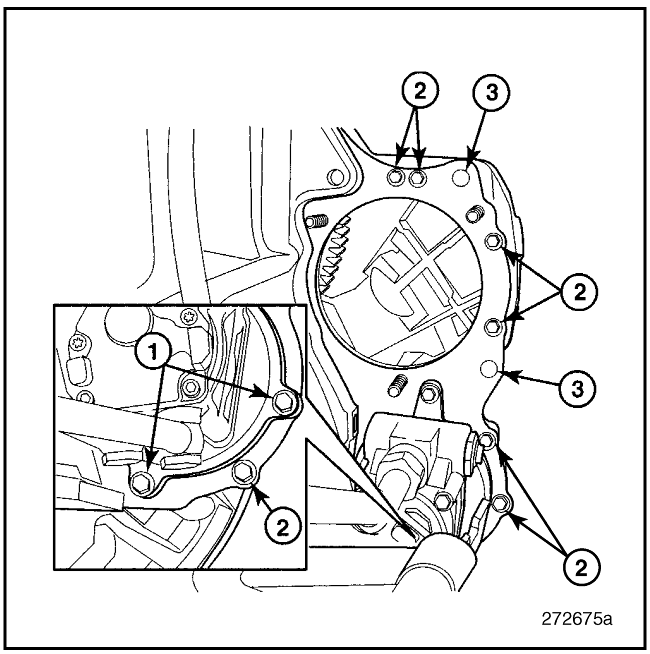


Figure 167 — Timing Gear Plate-to-Flywheel Housing Fasteners

1. Tandem Pump Fasteners 2. Flywheel Housing Fasteners	3. Engine Mounting Bolt Holes

2. Support the flywheel housing and remove the fasteners at the rear of the flywheel housing securing the housing to the cylinder block.

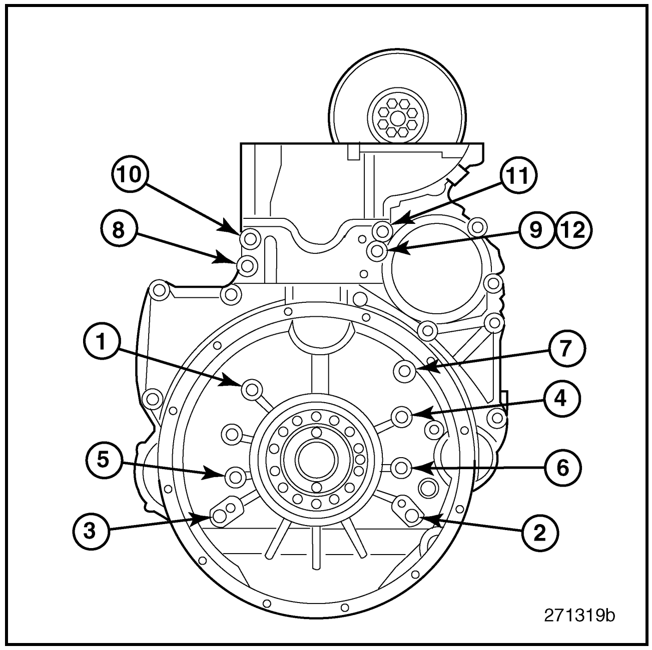


Figure 168 — Flywheel Housing Fasteners (Shown with Torque Sequence)

3. Remove the flywheel housing. It may be necessary to tap lightly on the housing with a soft mallet to separate the housing from the timing gear plate.

Crankshaft Rear Seal Removal

[212 JH]

With the flywheel housing removed, use a drift and hammer to remove the old seal from the crankshaft bore in the housing.

Timing Gear Train Removal

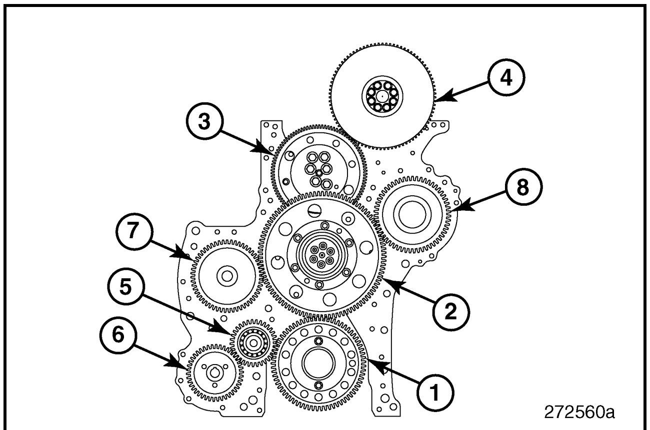


Figure 169 — Timing Gears

1. Crankshaft Gear 2. Intermediate Idler Gearset 3. Adjustable Idler Gear 4. Camshaft Gear	5. Lower Idler Gear 6. Tandem Pump Drive Gear 7. Air Compressor Drive Gear 8. PTO Drive Gear

NOTE

To simplify the reassembly process, avoid rotating the engine or timing gears while performing timing gear removal and reinstallation.

CRANKSHAFT GEAR AND IDLER GEARSET REMOVAL

1. Remove the two Allen-head screws that secure the gear to the crankshaft flange.
2. Using a suitable puller, remove the crankshaft gear.
3. Remove and set aside the lower (auxiliary) idler gear. Remove the seal ring from the bearing journal.
4. Remove the six Allen-head screws (inner circle) securing the intermediate idler gearset hub to the cylinder block and remove the gearset from the engine.

CAUTION

Do NOT disassemble the intermediate idler gearset. The intermediate idler gearset consists of two gears and back-to-back tapered roller bearings set to specified bearing preloads. The assembly is held together by a large spanner nut and six hex-head screws. Loosening and/or removing the fasteners in any way may change the bearing preload settings and result in bearing failure.

ADJUSTABLE IDLER GEAR REMOVAL

To remove the adjustable idler gear from the engine:

1. Remove and discard the six screws securing the adjustable idler gear hub to the cylinder head and engine block.

NOTE

The adjustable idler gear fasteners are one time use only.

2. Remove the adjustable idler gear, hub and thrust washers from the engine.

NOTE

If the engine is not being completely disassembled for overhaul and only the cylinder head is to be removed, it is not necessary to remove the adjustable idler gear. However, the six screws **A** and **B** which secure the timing gear mounting plate to the cylinder head and the four upper screws **C** securing the adjustable idler gear to the cylinder head MUST BE REMOVED (Figure 170). Refer to the “Cylinder Head Removal” procedure which follows later in this section.

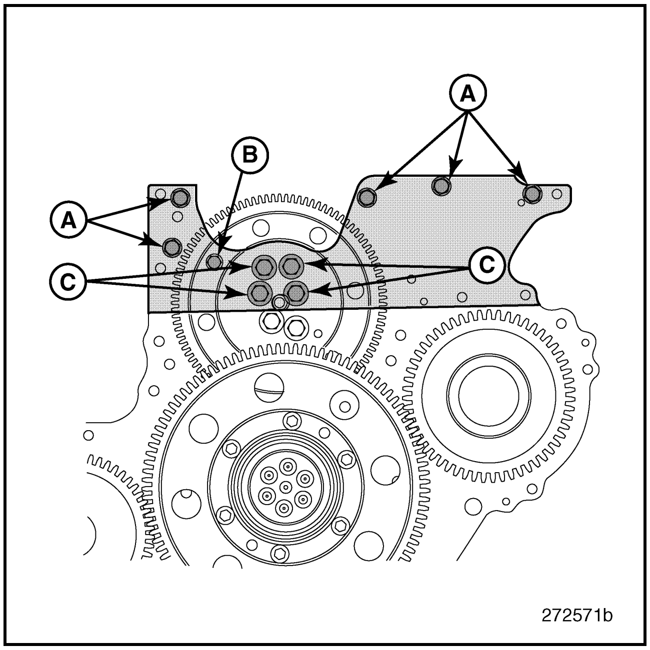


Figure 170 — Cylinder Head-to-Timing Gear Plate Screw Locations

Timing Gear Plate Removal

NOTE

If the engine is not being completely disassembled for overhaul and only the timing gears are being replaced, it is not necessary to remove the gear plate unless it is damaged and requires replacement.

WARNING

The timing gear plate is heavy. Do NOT attempt to remove the plate without the help of an assistant or the use of a suitable lifting device. Failure to heed this warning may result in personal injury and component damage.

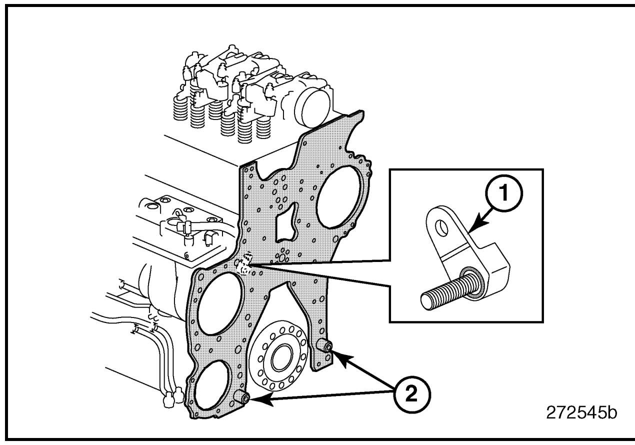


Figure 171 — Timing Gear Plate

1. Air Compressor Mounting Stud	2. Alignment Dowels, 9998267

1. Remove the compressor studs from the timing gear plate. Remove and discard the sealing ring from the studs.
2. Install the alignment dowels, 9998267, and tighten them to specification. This step is necessary to ensure proper alignment of the plate when reassembling the engine.
3. While supporting the plate to prevent it from falling, remove the fasteners.

NOTE

When the timing gear plate is being removed, it must be drawn straight out to avoid moving or damaging the alignment dowels.

4. Remove the plate from the engine.

Alternator and Refrigerant Compressor Removal

[271 CB, 264 DP]

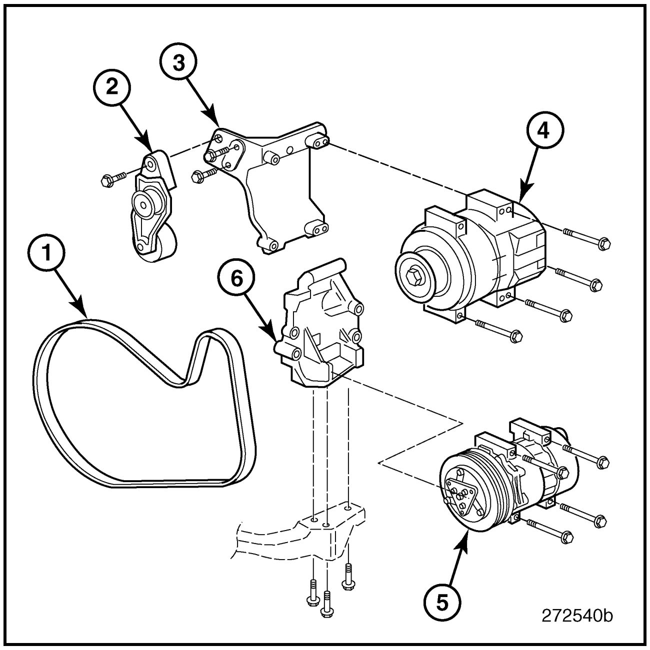


Figure 172 — Alternator and Refrigerant Compressor Mounting

1. Fan Belt 2. Tensioner 3. Alternator Mounting Bracket	4. Alternator 5. Refrigerant Compressor 6. Front Engine Support Mounting Bracket

NOTE

For this procedure, the engine is out-of-chassis, the fan drive and accessory drive belts are removed, the alternator harness wiring is disconnected, and the A/C compressor refrigerant lines are removed.

1. While supporting the alternator, remove the fasteners and remove the alternator from the upper mounting bracket.
2. While supporting the refrigerant compressor, remove the fasteners and remove the compressor from its mounting pads on the front engine support mounting bracket.
3. If necessary, remove the fasteners and remove the belt tensioner from the upper mounting bracket.
4. Remove the fasteners and remove the upper mounting bracket from the cylinder block.

NOTE

It is not necessary to remove the front engine support mounting bracket unless it is damaged and in need of replacement.

Thermostat and Cover Removal

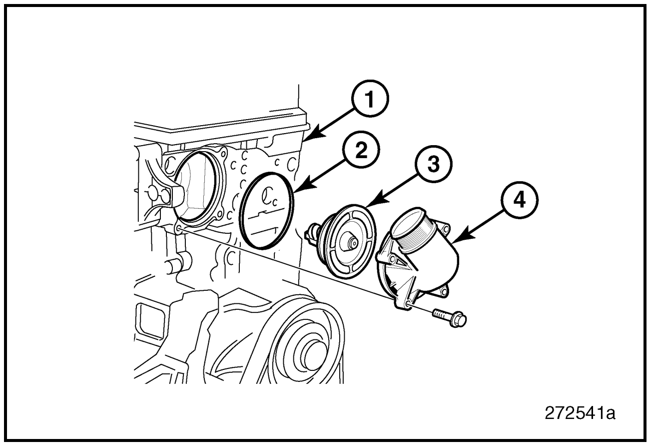


Figure 173 — Thermostat and Cover

1. Cylinder Head 2. Sealing Ring	3. Thermostat 4. Thermostat Cover

1. Remove the fasteners, thermostat cover, thermostat and sealing ring.
2. Carefully clean the thermostat seat and all cylinder head-to-thermostat cover mating surfaces.

Coolant Pump Removal

[215 SW, SG, SR]

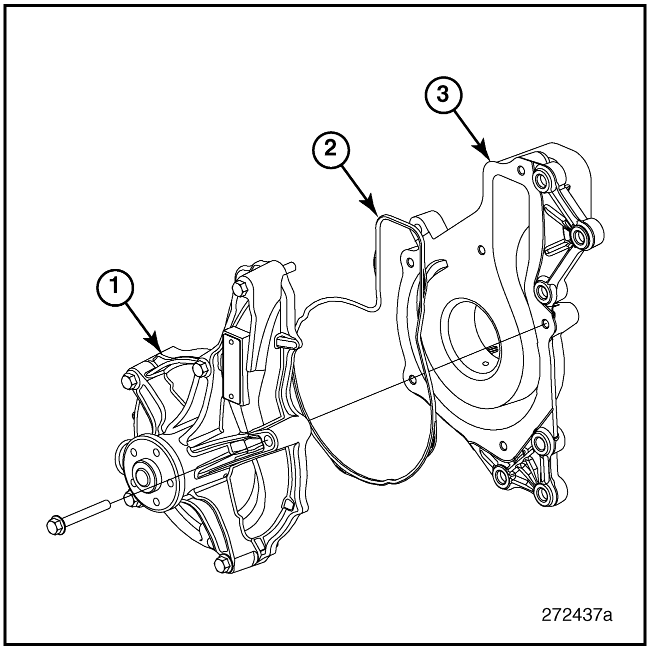


Figure 174 — Coolant Pump

1. Coolant Pump 2. Pump Seal	3. Coolant Pump Mounting Plate

1. Remove the fasteners and remove the belt tensioner and idler bracket from the front of the cylinder block if not already done.
2. Remove the coolant pump fasteners and remove the pump from the mounting plate.
3. Remove and discard the pump seal.
4. Remove the fasteners and the coolant pump mounting plate from the cylinder block.

Cylinder Head Removal

[213 EV]

CAUTION

*If the engine is not being completely disassembled for overhaul and only the cylinder head is to be removed, the six screws **A** and **B** which secure the timing gear plate to the cylinder head and the four upper screws **C** securing the idler gear hub to the cylinder head MUST BE REMOVED (Figure 175). Failure to do so may result in severe damage to the cylinder head and other engine components as the cylinder head is removed. See "REMOVING THE TIMING GEAR PLATE-TO-CYLINDER HEAD SCREWS" on page 122.*

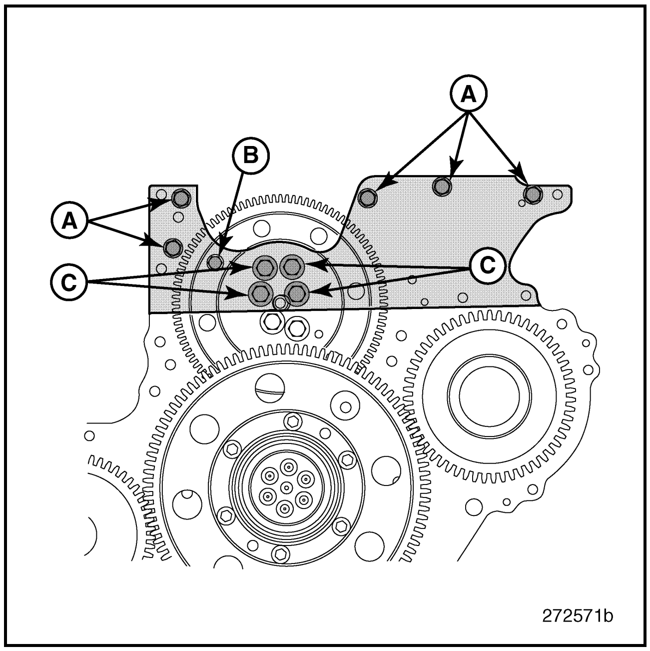


Figure 175 — Cylinder Head-to-Timing Gear Plate Screw Locations

REMOVING THE TIMING GEAR PLATE-TO-CYLINDER HEAD SCREWS

If not already done, remove the 10 screws (**A**, **B** and **C** in Figure 175) securing the cylinder head to the timing gear plate as follows:

1. Remove the five screws through the timing gear plate on either side of the adjustable idler gear.

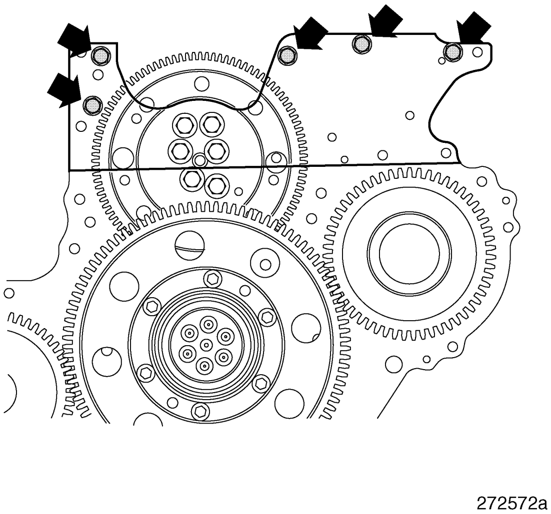


Figure 176 — Head-to-Plate Attaching Screws

2. Bar the engine over to align a hole in the adjustable idler gear with the hidden screw through the plate into the cylinder head. Remove the screw.

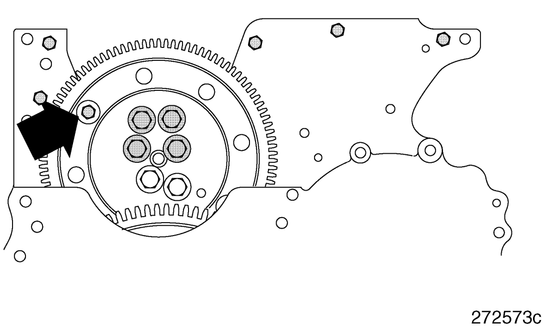


Figure 177 — Hidden Screw (Behind Gear)

3. Remove the four upper screws in the adjustable idler gear hub.

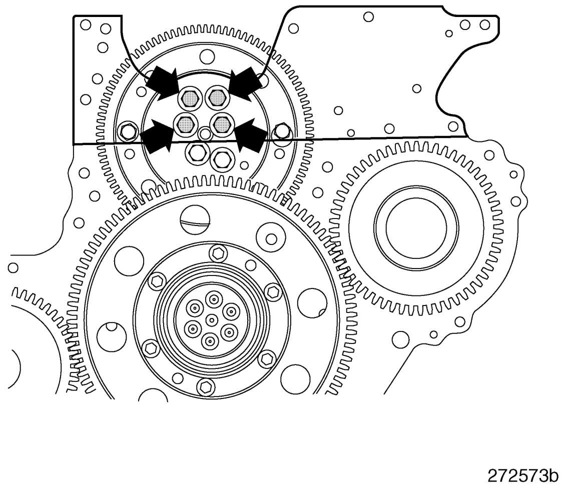


Figure 178 — Upper Four Adjustable Idler Gear Hub Screws

4. Remove any residual engine oil from the "hollows" beneath the camshaft to prevent oil from running into the coolant channels.

REMOVING THE CYLINDER HEAD

With the timing gear mounting plate-to-cylinder head screws removed (**A**, **B** and **C** in Figure 175), proceed as follows to remove the cylinder head.

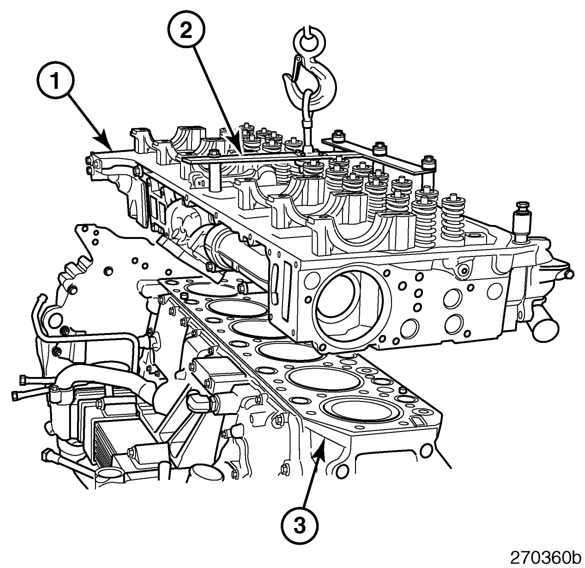


Figure 179 — Cylinder Head Removal

1. Cylinder Head 2. Lifting Tool, 88800188	3. Cylinder Block

1. Remove the cylinder head bolts.
2. Using the cylinder head lifting tool, 88800188, carefully remove and set aside the cylinder head.
3. Remove and discard the cylinder head gasket.
4. Attach cylinder liner hold-down tools, 9996966, to the cylinder block to keep the liners in place temporarily.

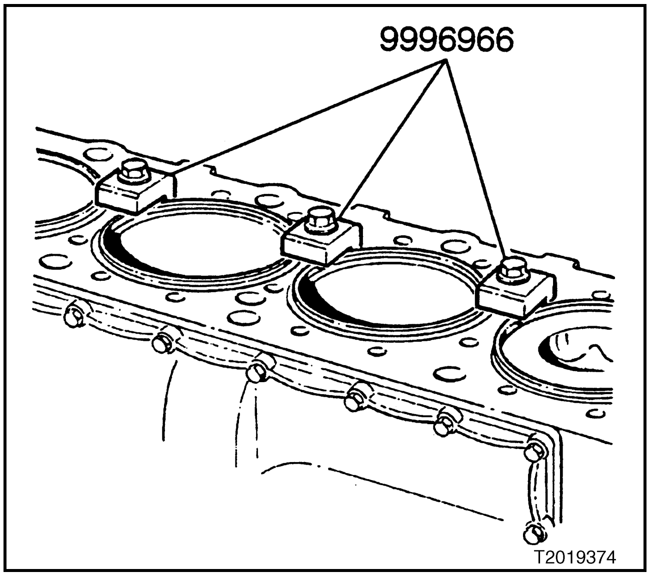


Figure 180 — Cylinder Liner Retainer

Crankshaft Vibration Damper and Fan Pulley Removal

[212 RB, RP]

⚠ CAUTION

When handling a vibration damper, be careful not to damage the housing. Dents in the outer housing may render the damper ineffective, causing an imbalance and vibration in the engine. The vibration damper cannot be repaired.

The fan pulley nests within the damper using the same attaching screws.

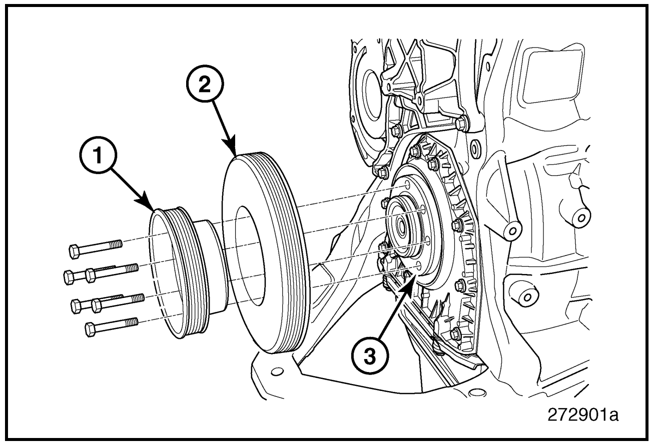


Figure 181 — Vibration Damper and Fan Pulley

1. Pulley, Fan Drive and Coolant Pump	2. Vibration Damper/Pulley 3. Crankshaft Hub

1. If not already done, release the tensioners and remove the drive belts.
2. Remove the front engine power take-off (FEPTO) unit, if so equipped.
3. Remove the fasteners and remove the crankshaft vibration damper and fan pulley.

Crankshaft Front Cover Removal

[211 JB]

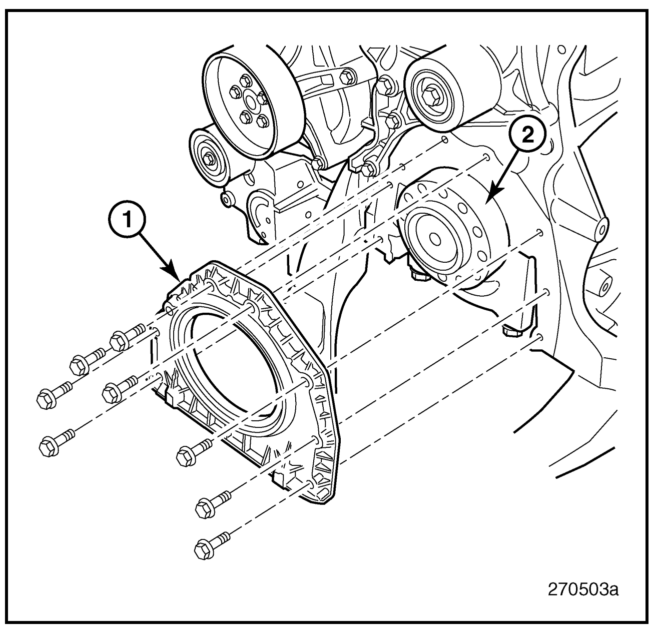


Figure 182 — Crankshaft Front Cover

1. Front Cover	2. Crankshaft Hub

1. While supporting the front cover, remove the eight fasteners attaching the cover to the cylinder block.
2. Remove the crankshaft front cover from the engine by sliding it off the crankshaft flange.

Crankshaft Front Seal Removal

[211 JB]

With the crankshaft front cover removed, use a drift and hammer to remove the old seal from the cover bore.

If the engine is not being completely disassembled for overhaul and only the crankshaft front seal is to be replaced, remove the seal using the following procedure.

1. Drill two 3.5 mm (0.138 inch) holes in the metal rim of the front crankshaft seal using the holes in the rim of the seal remover/installer.

NOTE

Apply grease to the drill bit to collect metal chips when drilling holes in the seal.

2. Using two self-tapping M5 screws of suitable length, attach the front crankshaft seal remover/installer, 88800021, to the seal.
3. Using two M10 screws of suitable length threaded into the tapped holes in the crossmember of the remover/installer, remove the seal and discard it.
4. Clean the seal seating surface in the crankshaft front cover and the sealing surface on the crankshaft hub.

Oil Fill Pipe and Dipstick Retainer Removal

NOTE

Use suitable rags and containers for collecting oil drainage at each step.

1. If not already done, remove and set aside the dipstick.

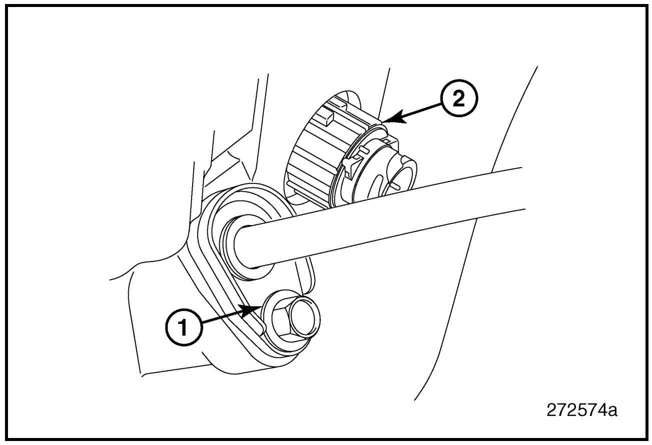


Figure 183 — Oil Dipstick Port

1. Retainer Screw	2. Oil Level Sensor Connector

2. Remove the retainer screw from the dipstick pipe flange and remove the pipe from the engine.
3. Remove the fasteners from the oil fill pipe mounting flange and remove the oil fill pipe.

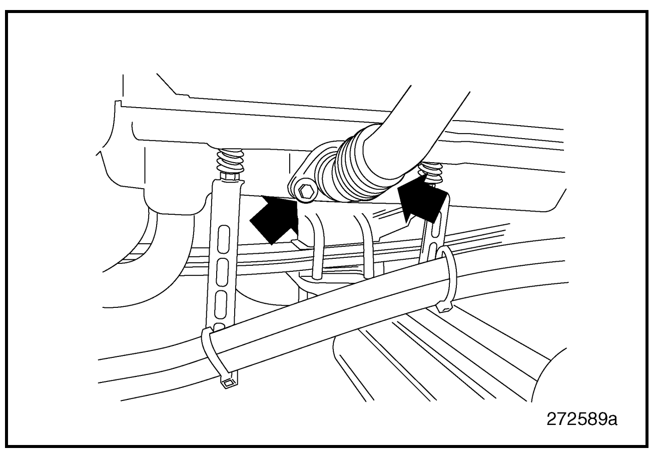


Figure 184 — Oil Fill Pipe Mounting Flange

Oil Pan Removal

[211 NB]

NOTE

If the engine is in the vehicle, use a lifting device to assume the weight of the oil pan during removal.

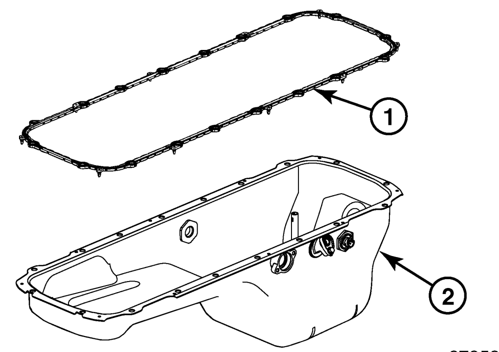


Figure 185 — Oil Pan

1. Elastomer Seal	2. Oil Pan

1. If the vehicle is equipped with an optional transmission oil cooler and not already done, remove the transmission cooler line bracket nuts and separate the brackets from the oil pan fasteners.
2. Remove the screws and springs securing the oil pan to the crankcase.

NOTE

The oil level sensor need not be removed unless it is to be replaced.

3. Remove and set aside the oil pan.
4. Remove and discard any O-rings found on the oil pan screws.
5. Remove the elastomer seal from the oil pan and inspect it. If the seal is damaged, it must be replaced.

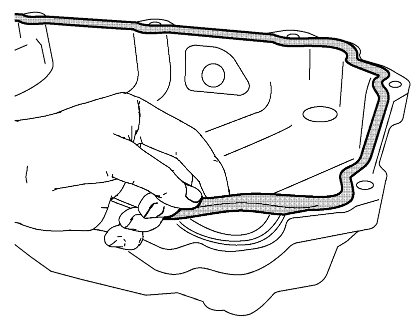


Figure 186 — Removing Oil Pan Gasket

Front Engine Support Removal

[299 GV]

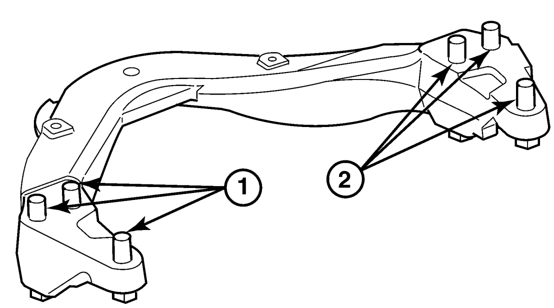


Figure 187 — Front Engine Support

1. Left-Side Attaching Screws	2. Right-Side Attaching Screws

Remove the fasteners at the left and right sides of the engine support and remove the support from the mounting brackets at each side of the cylinder block.

Block Stiffener Plate Removal

The inlet pipe with a front sump oil pan is longer than the one with a rear sump oil pan. Both the shorter and longer pipes attach to a bracket mounted on the stiffener frame and cylinder block.

1. Remove the support retaining fasteners and remove the pump inlet pipe. Remove and discard the seal ring.

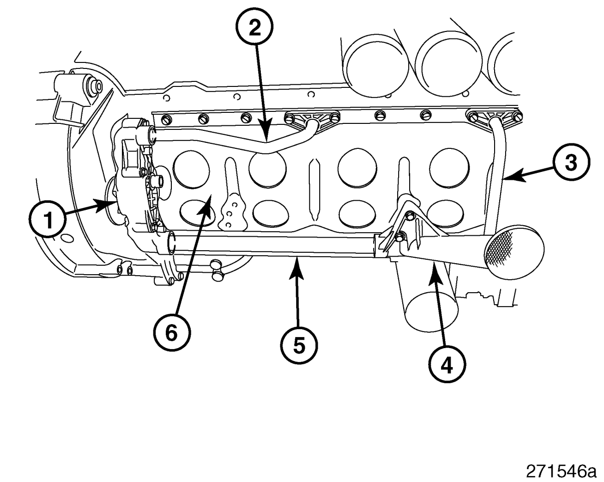


Figure 188 — Inlet, Outlet and Crossover Pipes (Front Sump Shown)

1. Oil Pump	4. Strainer
2. Pump Outlet Pipe	5. Pump Inlet Pipe
3. Crossover Pipe	6. Block Stiffener Plate

2. Remove the fasteners from the pump outlet (pressure side) pipe flange and remove the pipe from the engine. Remove and discard the seal rings.
3. Remove the fasteners from the crossover pipe flange and remove the pipe.
4. Remove the remaining fasteners securing the stiffener plate to the cylinder block.

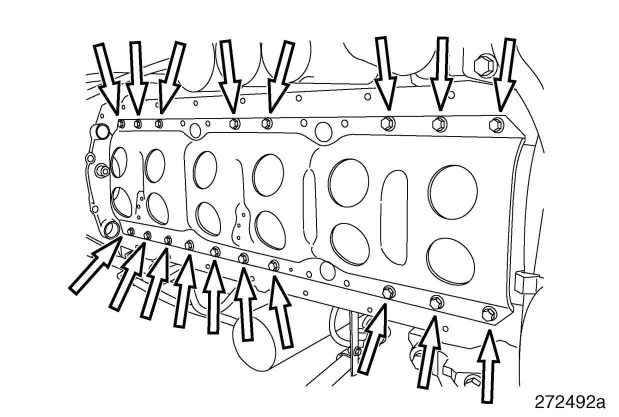


Figure 189 — Block Stiffener Plate

5. With the help of an assistant, remove the block stiffener plate.

Oil Pump Removal

[219 MU, 219 NT]

If the engine is not being completely disassembled for overhaul and only the oil pump is to be replaced, instructions are provided in a separate section entitled “OIL PUMP REPLACEMENT (IN CHASSIS)” for removing and installing the oil pump with the engine in the chassis.

1. If necessary for access to the oil pump mounting fasteners, rotate the crankshaft using flywheel turning tool, 88800014.
2. Remove the fasteners securing the oil pump to the No. 7 main bearing cap.

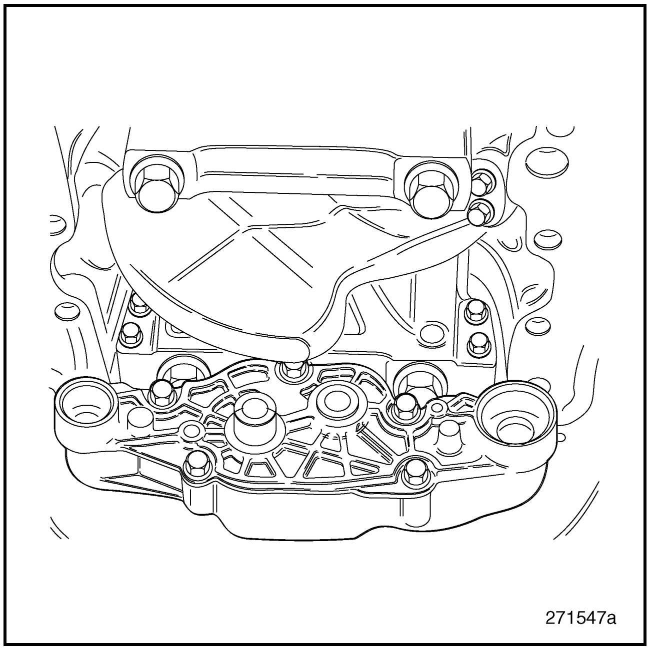


Figure 190 — Oil Pump (Installed on No. 7 Bearing Cap)

3. Carefully remove the oil pump from the bearing cap.

Piston and Connecting Rod Assembly Removal

[212 NP, 212 LP]

1. Rotate the crankshaft so that the connecting rod bearing cap for the desired cylinder is positioned for easy removal of the rod cap bolts.

NOTE

The rod bearing caps can be removed in the companion cylinder sets: Nos. 1 and 6, 2 and 5, and finally 3 and 4.

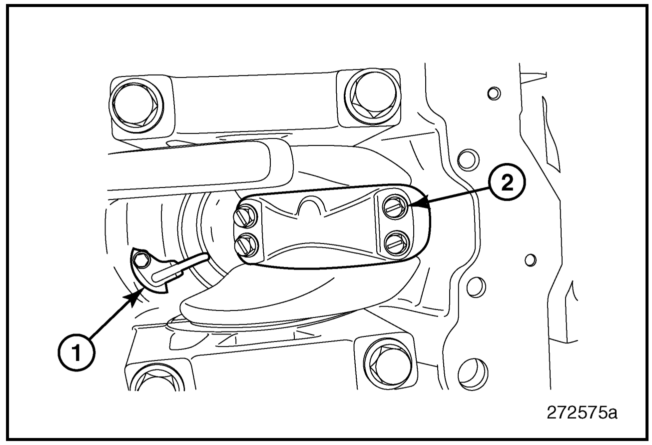


Figure 191 — Connecting Rod Bearing Cap

1. Piston Cooling Nozzle	2. Bearing Cap Bolts

2. Remove the piston cooling nozzle to prevent it from being damaged.
3. Remove the four bolts and remove the bearing cap.
4. Discard the lower bearing insert (shell) in the cap.
5. Using a suitable tool, push up on the bottom of the piston until the rings are free of the cylinder liner. The upper inner surface of the liner may have to be scraped and cleaned if there is excessive carbon build-up to make it easier to remove the piston.

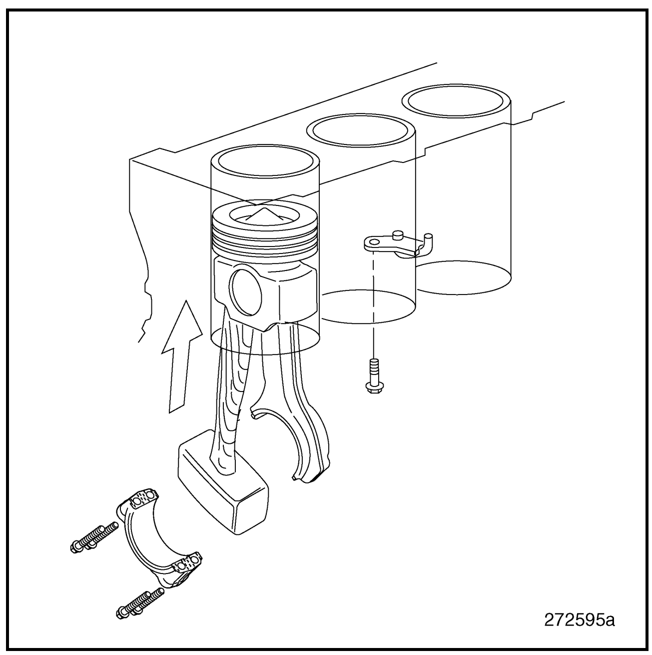


Figure 192 — Piston Removal

CAUTION

Use care to avoid contact between the connecting rod and liner during removal. Contact may cause damage to the liner.

6. From the cylinder deck, pull up to remove the piston and connecting rod from the engine. Mark the piston assembly to show its location in the engine and set it aside for disassembly and inspection (see the CONNECTING ROD AND PISTON BENCH PROCEDURES section).

NOTE

The connecting rod and bearing cap are a matched set. Use care to ensure that the respective bearing caps and rods are kept together.

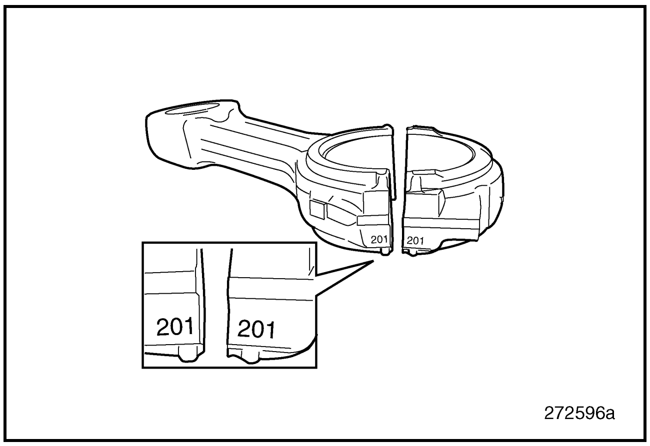


Figure 193 — Connecting Rod-Cap Markings

7. Remove and discard the upper bearing insert in the connecting rod.
8. Repeat steps 1 through 7 to remove the remaining pistons.

Main Bearing Cap Removal

[212 HH]

NOTE

Bearing caps are marked. Be sure to return each bearing cap to its original location at assembly.

1. With the engine inverted (crankcase side up) on the repair stand, loosen and remove the bolts securing the main bearing caps.

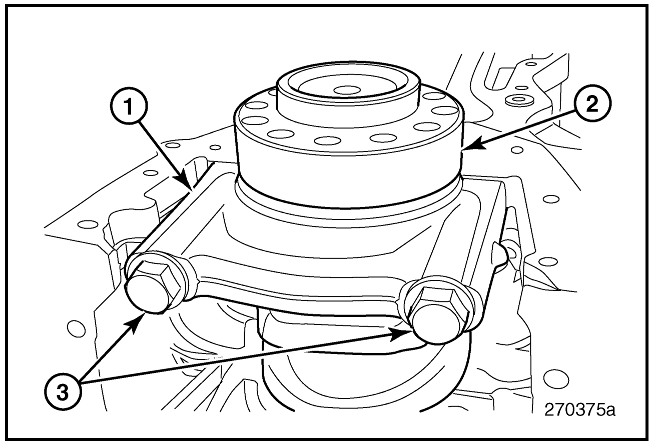


Figure 194 — Crankshaft No. 1 Main Bearing Cap

1. No. 1 Main Bearing Cap 2. Crankshaft Hub	3. Attaching Screws

2. Using puller 9990114, adapter 9990262 and slide hammer 9996400, remove and set aside the bearing caps.

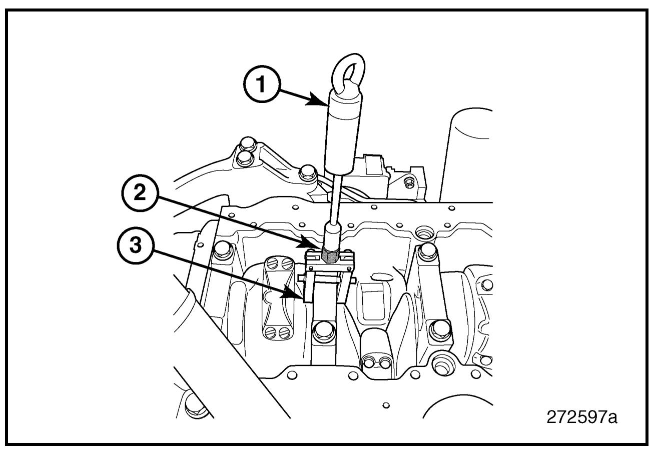


Figure 195 — Removing Main Bearing Caps

1. Tool No. 9996400 2. Tool No. 9990262	3. Tool No. 9990114

3. Remove and make note of the part number on the inserts (shells). Discard the inserts.

NOTE

In addition to the main bearing inserts, the No. 4 crankshaft journal includes four thrust washer inserts, an upper and lower at each side of the crankshaft journal.

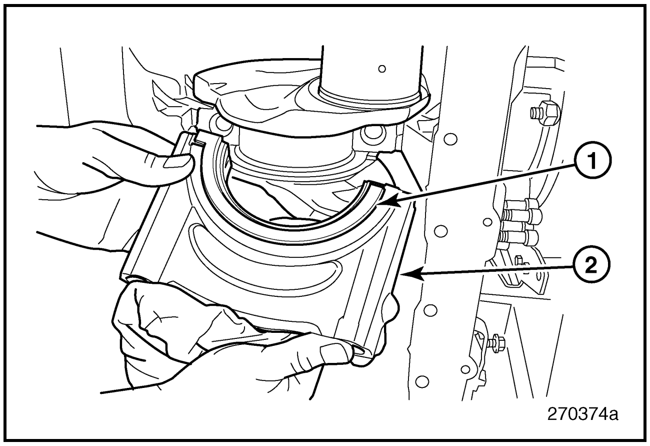


Figure 196 — Crankshaft No. 4 Main Bearing Cap with Thrust Washers

1. Thrust Washer Insert, Lower	2. No. 4 Main Bearing Cap

4. Remove and discard the thrust washer inserts.

Crankshaft Removal

[212 HP]

WARNING

The crankshaft is extremely heavy. Do NOT attempt to remove the crankshaft without the help of an assistant or the use of a suitable lifting device. Failure to heed this warning may result in severe personal injury and component damage.

CAUTION

Exercise extreme care when lifting and moving the crankshaft to avoid striking other objects. No nicks, scratches, burrs or other signs of distress on the journals or fillets are acceptable.

1. With an assistant and using the crankshaft lifting tool, J 49002, lift the crankshaft to remove it from the cylinder block.

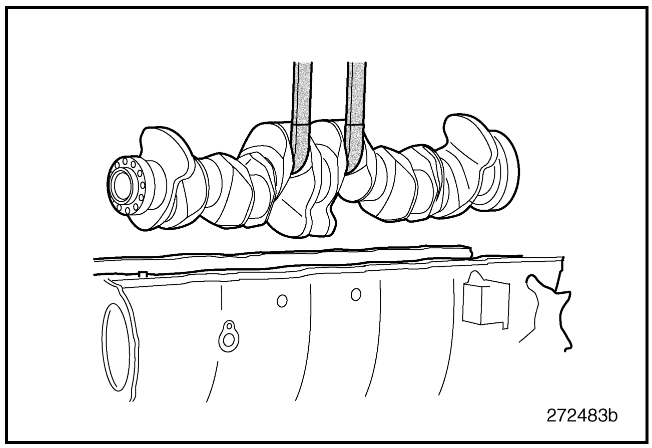


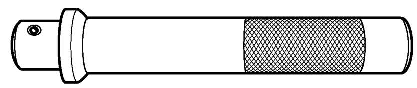
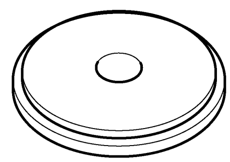
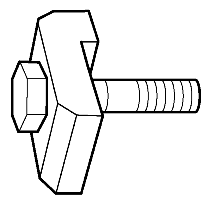
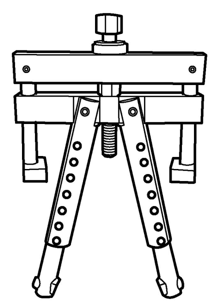
Figure 197 — Removing the Crankshaft

2. Remove and discard the upper main bearing inserts from the cylinder block.

CYLINDER BLOCK RECONDITIONING [211 DB]

Tools and Equipment

SPECIAL TOOLS

Tool No.	Description	Images
9992000	Handle with Various Uses (fits 25 mm/1 inch hole) (Essential)	 006785a
9996599	Liner Installation Plate (Available)	 006792a
9996966	Liner Hold-Down Tool (Essential)	 006796a
PT-6435 or PT-6400-C	Cylinder Liner Puller (Available) **Note:** Alternate tools for liner removal — 9992955, 9996394, 9996395 and 9996645 in combination.	 006808a

Piston Cooling Spray Nozzle Removal

[219 RV]

CAUTION

To avoid damaging the spray nozzles, remove them before removing the liners.

SERVICE HINT

It is best to use a 12 mm, 6-point socket on a 300 mm (12 inch) extension to remove the nozzle retaining capscrews.

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. Repeat steps 1 and 2 to remove the remaining spray nozzles.

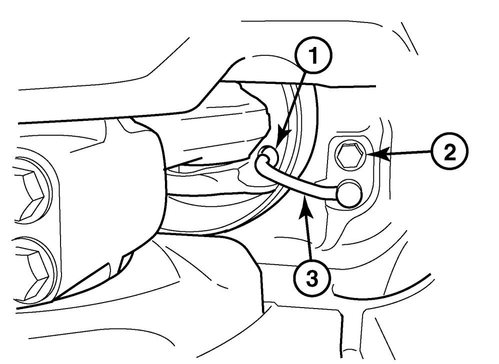


Figure 198 — Spray Nozzle Removal

1. Piston Cooling Duct 2. Attaching Screw	3. Spray Nozzle

Cylinder Liner Removal

[212 NC]

1. Install the cylinder liner puller, tool PT-6435 or equivalent, in position over the cylinder liner to be removed.

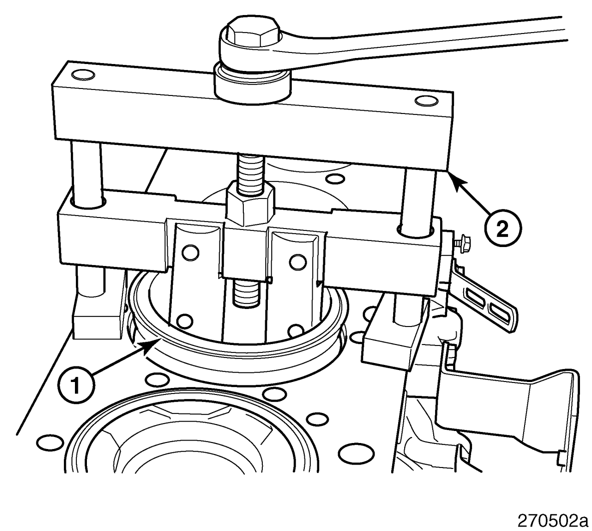


Figure 199 — Cylinder Liner Removal

1. Cylinder Liner	2. Liner Puller Assembly

CAUTION

Be sure the cogs on the puller legs do not extend beyond the outside diameter of the liner. Failure to heed this caution may result in severe component damage.

2. Hooking puller legs on the bottom of the cylinder liner, tighten the center screw on the puller until the liner comes free of the cylinder block bore.
3. Remove the liner and puller assembly from the cylinder block. Then, remove the puller from the liner.
4. Repeat the procedure to remove the remaining cylinder liners.

NOTE

As an alternative, tool Nos. 9992955, 9996394, 9996395 and 9996645 in combination, can be used for cylinder liner removal.

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.

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. Failure to heed this warning may result in severe personal injury.

WARNING

Compressed air used for cleaning can create airborne particles that may enter the eyes or irritate the skin. Pressure must not exceed 207 kPa (30 psi). Eye protection is required. Use only with effective chip guarding and personal protective equipment (goggles/shield, gloves, etc.). Failure to heed this warning may result in severe personal injury.

NOTE

Cleaning the cylinder block is important. While cleaning the cylinder block, carefully inspect the areas around the cup plugs and the coolant duct cover. 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. Parts may be dried with compressed air.

WARNING

Always use caution while cleaning parts with solvents. Failure to heed this warning may result in personal injury.

1. Scrape any remaining gasket material from the cylinder block.
2. Using a wire brush or rotary wheel, remove any rust, corrosion or other debris from the cylinder block.
3. Clean all other cylinder block surfaces with mineral spirits or other suitable solvent.
4. Using due care and caution, clean and dry the cylinder 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 to determine if cracks exist. A cracked cylinder block must be replaced and never reused.

Liner Height Measurement

[212 NC]

To determine liner height above the cylinder block deck, proceed as follows:

1. Insert a replacement liner (**without** sealing rings) into the cylinder block bore. Secure the liner in place, using two hold-down blocks, tool 9996966.
2. Mount the dial indicator, tool 9989876, in the holder, tool 9992479. Place the holder and dial indicator in position across the top of the cylinder liner. Set the tip of the dial indicator against the cylinder block deck and zero the dial indicator gauge.

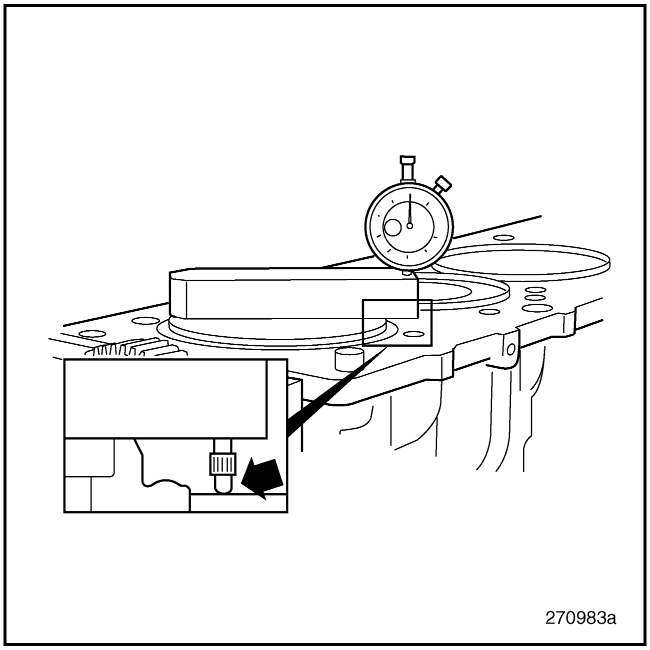


Figure 200 — Zeroing the Dial Indicator to the Block Deck

3. Reset the tip of the dial indicator against the high point on the convex surface of the cylinder liner. Measure and record the height of the liner ledge above the cylinder block deck.

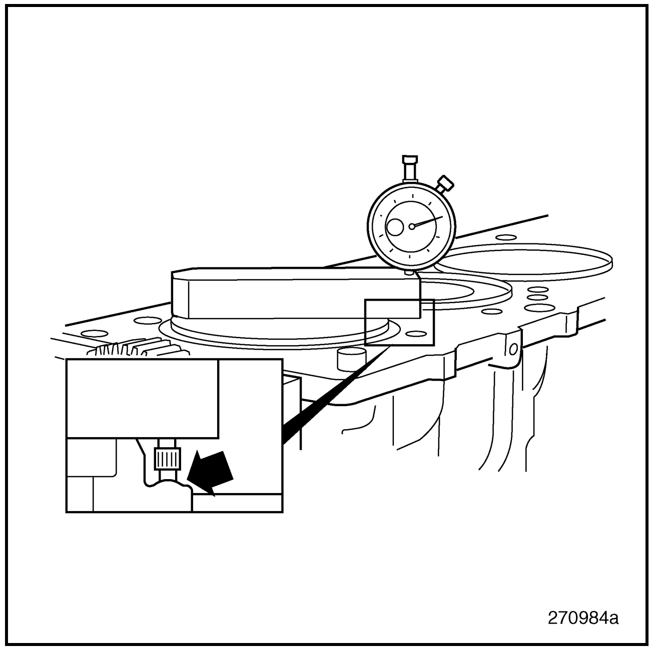


Figure 201 — Measuring the Cylinder Liner Height

4. Measure and record the height of the liner ledge above the cylinder block deck at four points, 90 degrees apart.
5. Calculate an average height, using the **highest** recorded measurement and the measurement taken diagonally across the cylinder bore. Check the calculated height against specifications. Then, calculate the thickness of the shim(s) required, if any. Use the fewest possible number of shims.

6. Using a marking pen, mark the position of the liner in the cylinder bore for final installation. Then, remove the liner and adjustment spacer (if required) from the cylinder block and place on a clean work surface.
7. Repeat the procedure for the remaining cylinders.

Cylinder Liner Installation

[212 NC]

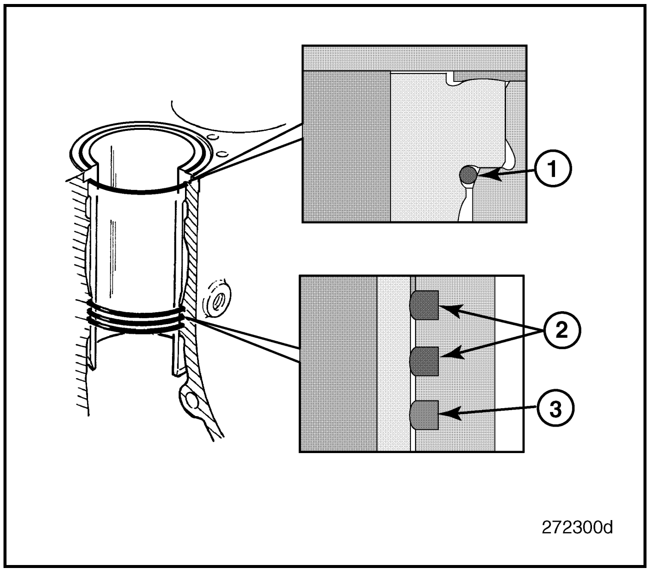


Figure 202 — Seal Ring Installation

1. EPDM (Black) 2. EPDM (Black)	3. Viton (Purple)

1. Apply lubricant (included in liner kit) to **new** seals and install them in the four annular grooves, one under the flange of the cylinder liner and three near the bottom. The purple gasket is installed in the lowest groove.
2. If the cylinder liner is being installed with a spacer (shim), apply a 0.8 mm (0.03 inch) bead of MACK-approved sealant to the counterbore ledge in the cylinder block. Do NOT apply the sealant between the spacer and the cylinder liner flange.

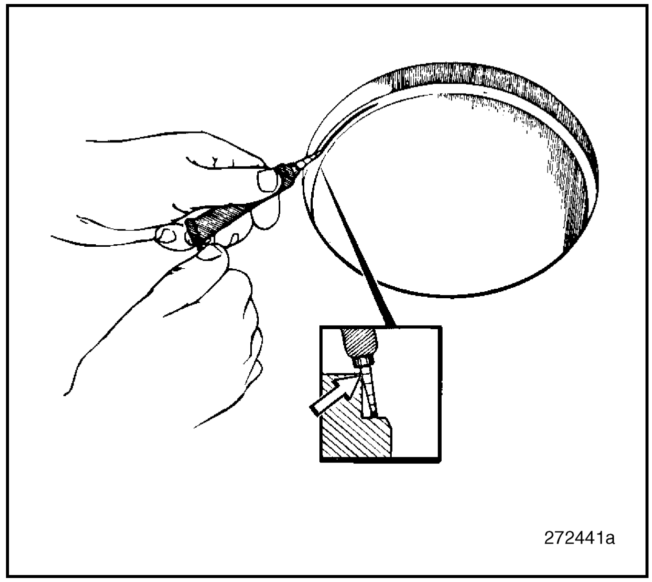


Figure 203 — Applying Sealant to Counterbore

3. Using liner installation plate, 9996599, and handle, 9992000, press the liner (with spacer if appropriate) into the bore until seated.

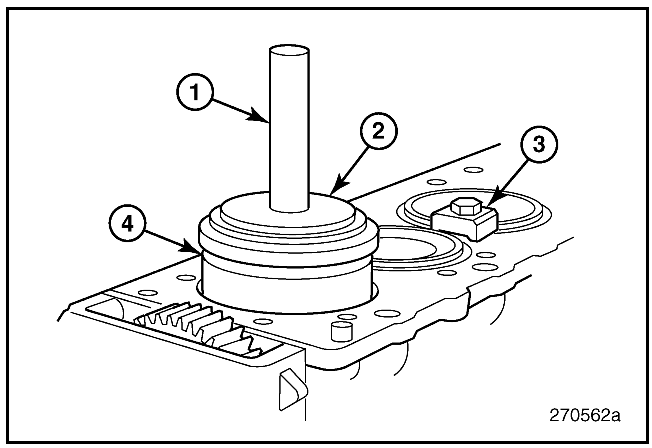


Figure 204 — Cylinder Liner Installation

1. Handle 9992000 2. Liner Installation Plate 9996599	3. Liner Hold-Down Tool 9996966 4. Cylinder Liner

4. Secure the liner in place using two liner hold-down tools, 9996966.

CAUTION

The liners must be installed and secured in place within 20 minutes after application of the sealant to the liners.

FLYWHEEL BENCH PROCEDURES

Flywheel Ring Gear Replacement

[21687-5]

1. Heat the ring gear around the outer edge with a torch.

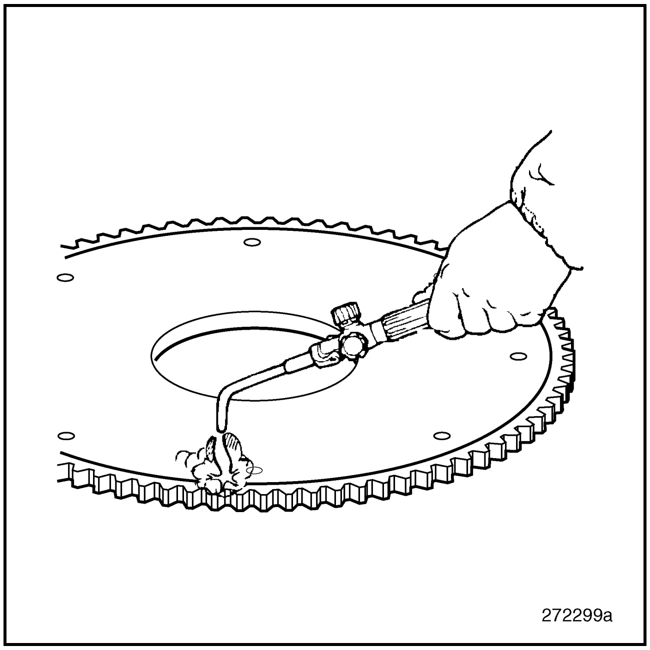


Figure 205 — Ring Gear Removal

2. Use a punch to remove the ring gear from the engine flywheel.
3. Use a steel brush to clean the engine flywheel.

⚠ CAUTION

Use caution not to heat the ring gear excessively or damage will occur to the new ring gear.

4. Heat the new ring gear with a torch or in a furnace to 180–200°C (356–392°F). Heat the gear evenly around the entire surface. A good indication that the correct temperature has been reached is when bright metal turns a bluish color.

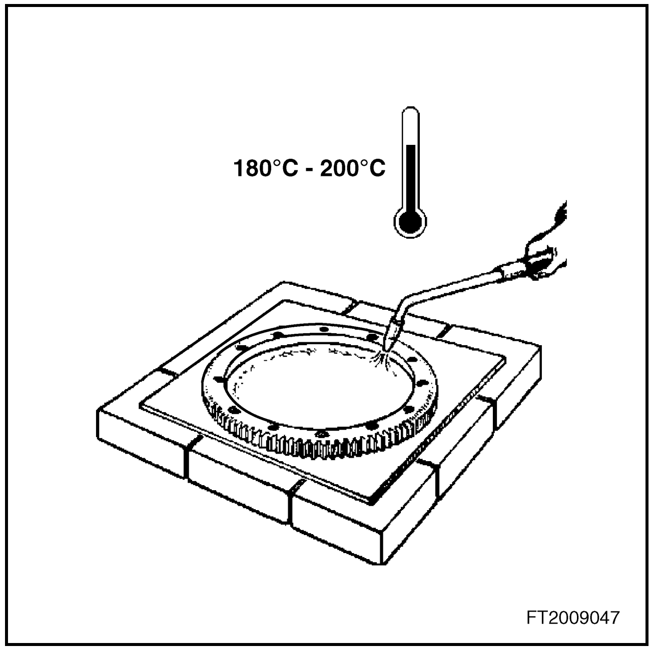


Figure 206 — Ring Gear Heating

5. Install the heated ring gear on the engine flywheel. Let the ring gear air cool naturally.

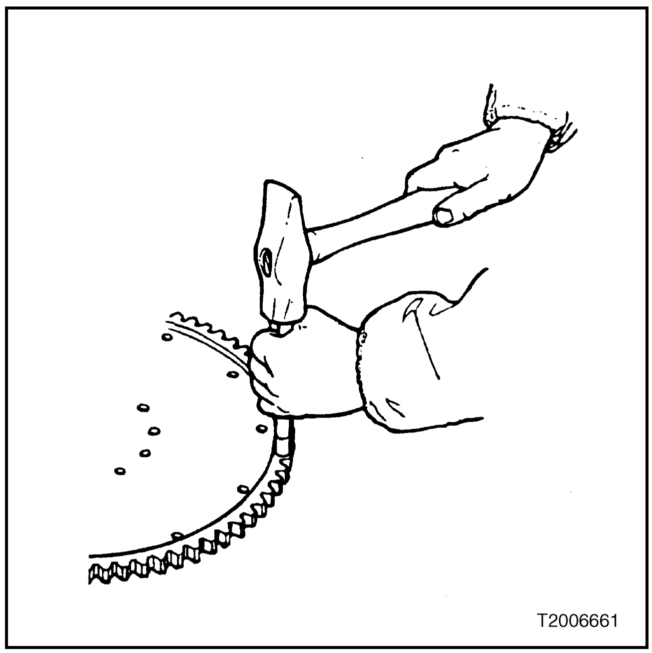


Figure 207 — Ring Gear Installation

CONNECTING ROD AND PISTON BENCH PROCEDURES

Connecting Rod — Piston Disassembly

[212 LP]

New rods for service arrive with caps attached. The cap must be separated by holding the rod in a soft-jawed vise and striking the cap with a rubber-faced hammer. Care must be taken to prevent damage to the rod, cap and bearing surfaces.

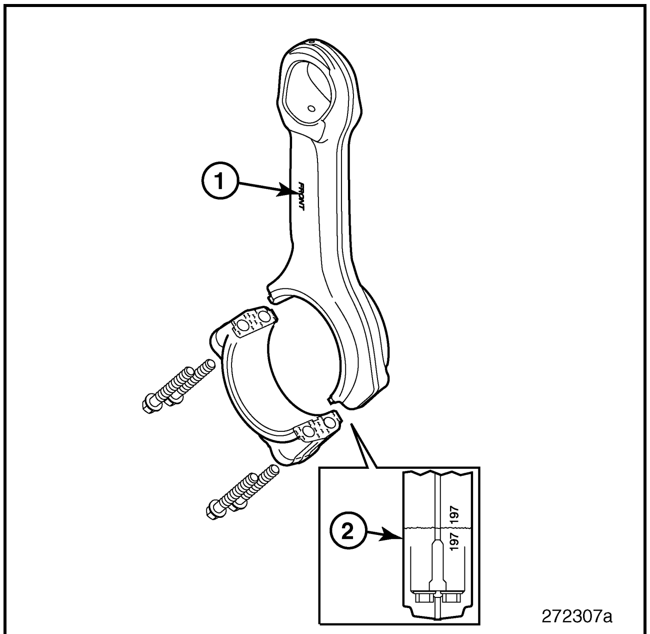


Figure 208 — Connecting Rod

1. The word, **Front**, faces the front of the engine.	2. The numbers must agree and be aligned on the same side.

It is essential that a cap and rod be kept together when removed from the engine and when installed. Each rod and cap is marked with matching numbers to identify them as a set. At assembly, the numbers must appear side by side and the notches must be aligned. Refer to Figure 208. Tag the sets on removal so each set can be returned to the cylinder from which it was removed.

⚠ CAUTION

Do not install a damaged connecting rod assembly. Failure to heed this caution may result in severe component damage.

⚠ CAUTION

*Do **NOT** use a pneumatic impact wrench to tighten connecting rod screws. It will damage the mating surfaces. Failure to heed this caution may result in severe component damage.*

WRIST PIN REMOVAL

1. Using snap ring pliers, remove the snap ring at each end of the wrist pin.
2. Remove the wrist pin from the piston and connecting rod.

INSPECTION

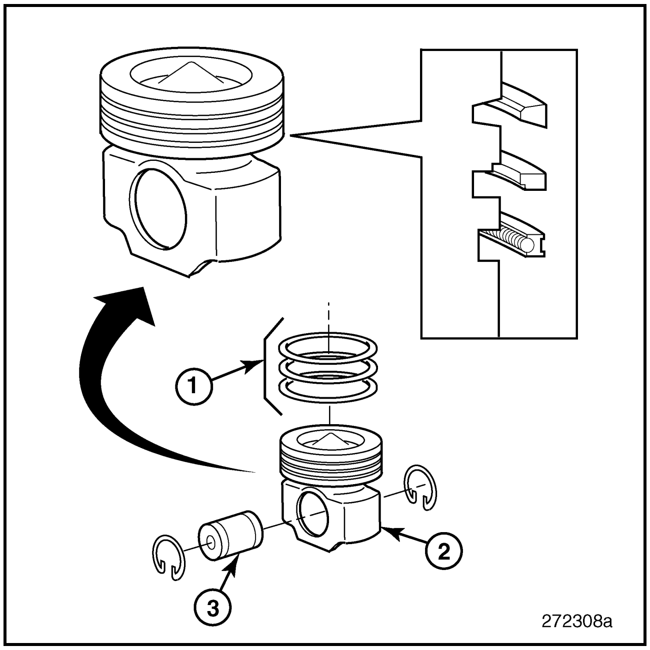


Figure 209 — Piston Assembly — Exploded View

1. Piston Rings 2. Piston	3. Wrist Pin

Inspect each connecting rod and cap for the following conditions. If any fault appears, replace both rod and cap.

1. Inspect the connecting rods for nicks, cracks, signs of overheating and unacceptable bending and twisting.
2. Inspect the bolt holes for elongation and damaged threads.
3. Inspect the mating surfaces between the connecting rod and cap for correct fit.
4. Inspect the bolt holes for elongation or stripped threads.
5. Inspect the wrist pin.
6. Inspect the wrist pin bearing surface in the connecting rod.
7. Inspect the crankshaft journal bearing surfaces of the connecting rod and cap.

SERVICE HINT

If it is determined that any component is in questionable condition, replace it.

CONNECTING ROD ALIGNMENT

Visually inspect the connecting rod for twist and bend. Replace the connecting rod if necessary.

Piston Inspection and Cleaning [212 NP]

DISASSEMBLY

1. Using a suitable piston ring expander, remove the piston rings.
2. Clean the piston ring grooves, combustion bowl area and the snap ring grooves thoroughly.

CAUTION

Remove all carbon. Carbon left in the grooves reduces ring clearance and prevents proper seating.

Be sure that the cleaning solvent is approved for steel and aluminum. Incompatible solvents may damage the pistons.

Failure to heed this caution may result in severe engine damage.

3. Using a brass brush and an approved cleaning solution, clean the pistons.

NOTE

Avoid damaging the pistons while cleaning.

INSPECTION

Inspect the piston ring grooves, lands, skirt and combustion bowl for wear, scuff marks, cracks and blow-by. Pistons are NOT repairable. Discard worn or damaged pistons.

CAUTION

Do not stamp or engrave on the TOP of the piston. Failure to heed this caution may result in severe engine damage.

Piston Ring Inspection and Replacement

[212 NV]

OIL RING GROOVE SIDE CLEARANCE INSPECTION

1. Using a thickness gauge, measure oil ring groove side clearance.

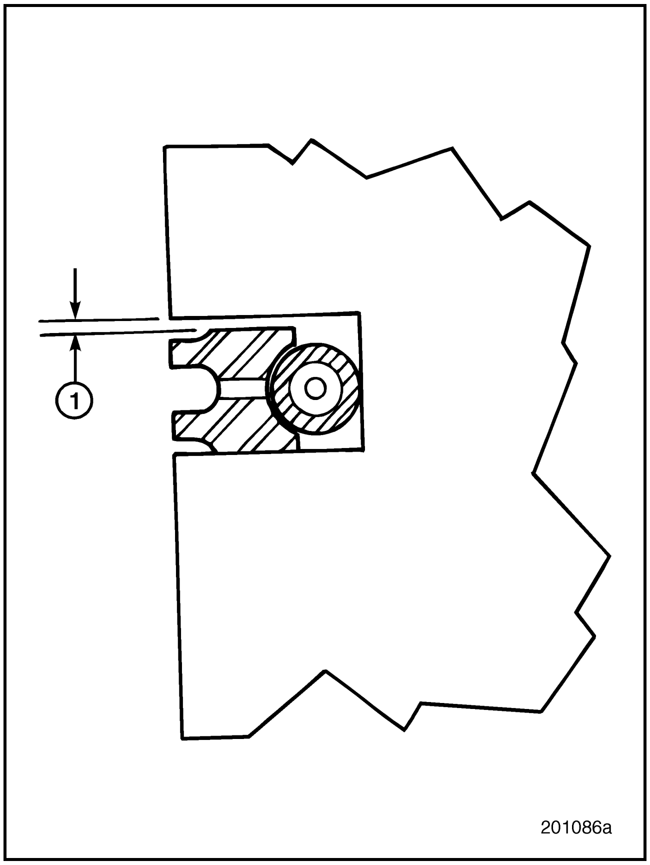


Figure 210 — Side Clearance Measurement

1. Ring Groove Side Clearance

a. Insert a **new** oil control ring in the groove.

b. Insert a thickness gauge between the ring and upper land of the groove.

c. Record the measurement and compare the reading with the information in *Fits and Limits* in the **SPECIFICATIONS** section.

RING END GAP INSPECTION

1. Using an inverted piston, push a piston ring into a cylinder liner making sure it is squarely aligned.
2. Using thickness gauges, measure the gap between the ring ends. Refer to *Fits and Limits* in the **SPECIFICATIONS** section for gap information.
3. Repeat steps 1 and 2 for each ring.

CAUTION

Do not file or grind chrome-plated piston rings. This may cause the chrome to flake resulting in ring failure. Failure to heed this caution may result in severe engine damage.

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.

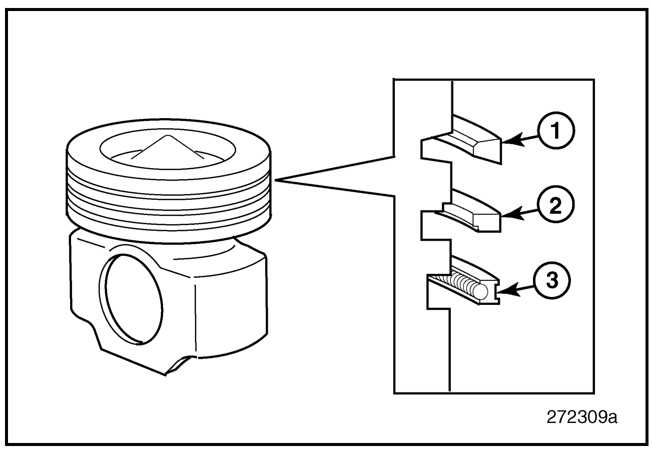


Figure 211 — Piston Rings

1. Upper Compression Ring (Keystone-Shaped)	2. Lower Compression Ring 3. Oil Control Ring

1. To prevent distortion, use the proper size piston ring expander, to insert the rings in the grooves.
2. Stagger the ring gaps so that they are not aligned and none is directly over the wrist-pin bore.

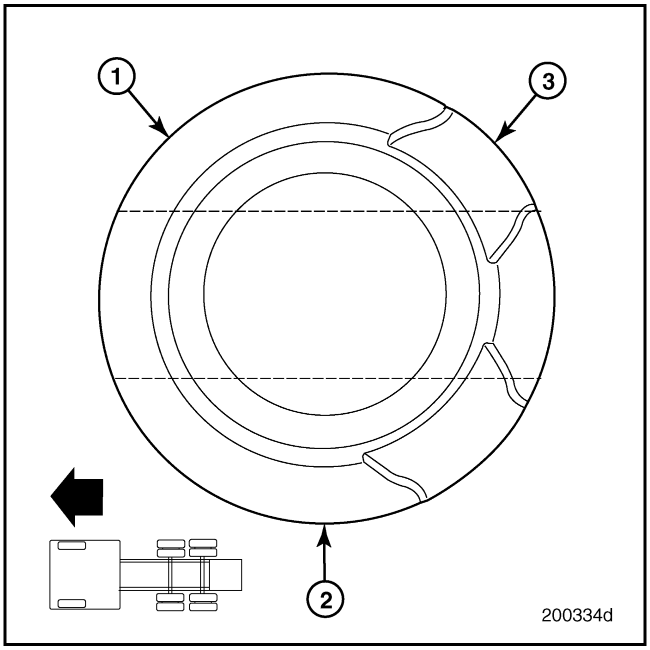


Figure 212 — Ring Gap Locations

Connecting Rod — Piston Assembly

[212 LP & NP]

CAUTION

Be sure that the piston and rod assemblies are clearly marked with their cylinder location. They must be returned to the same cylinder from which they were removed. Failure to heed this caution may result in severe engine damage.

1. Insert a snap ring in one of the wrist pin retaining grooves.
2. Insert the connecting rod in the piston assembly.

NOTE

Align the FRONT mark on the connecting rod with the arrow on the piston. Refer to Figure 208.

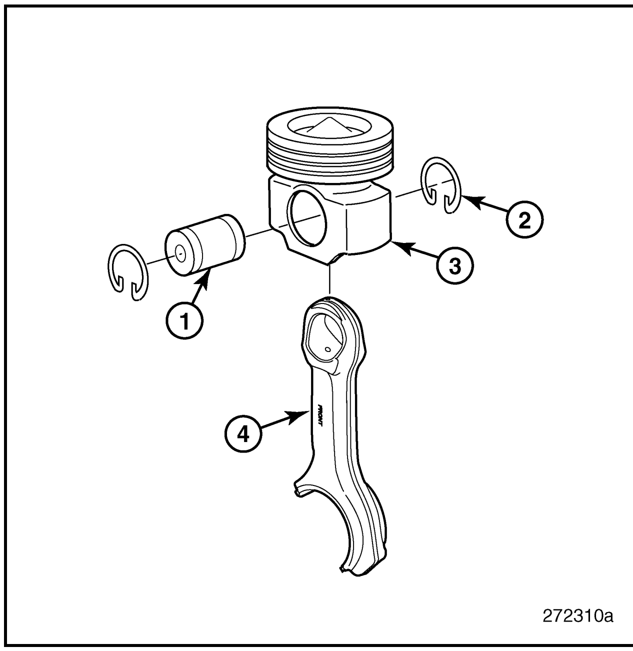


Figure 213 — Connecting Rod Piston Assembly

1. Wrist Pin 2. Snap Ring	3. Piston 4. Connecting Rod

3. Using a generous amount of clean engine oil on the wrist pin and rod bearing, press the wrist pin into the bore.
4. Insert a snap ring in the other wrist pin retaining groove.
5. Set the assembled piston aside in a clean location until it is needed.
6. Repeat steps 1 through 5 for each piston.

CAUTION

Connecting rod capscrews can only be re-used four times. Screw heads must be punched at each overhaul to indicate the number of times used. Failure to heed this caution may result in severe component damage.

A screw with four punch marks (A) must be replaced with a **new** screw.

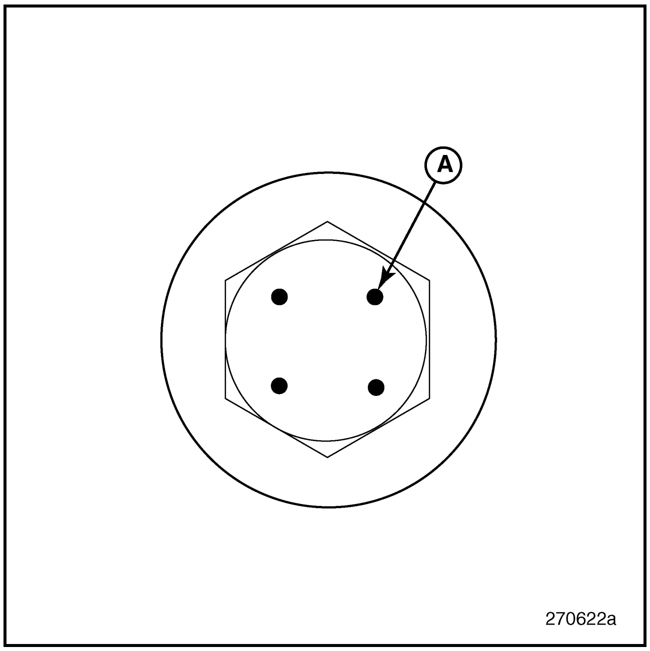


Figure 214 — Connecting Rod Screw with Maximum Punch Marks (Replace)

Used connecting rod screws must be lightly oiled on the threads and under the head. New screws are coated with phosphate and oil and must be assembled dry.

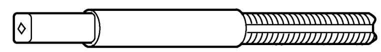
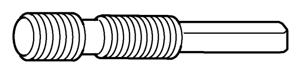
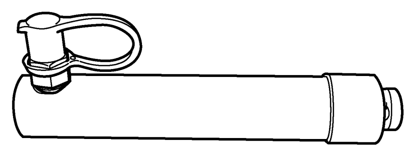
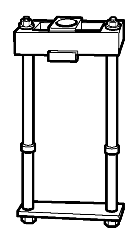
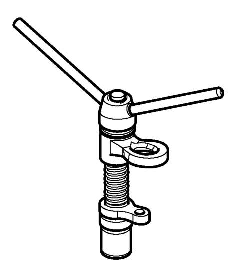
CAUTION

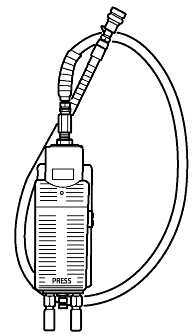
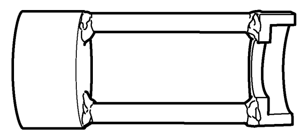
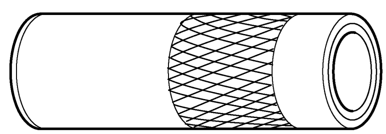
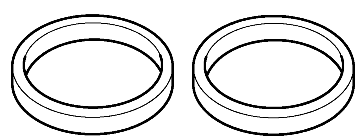
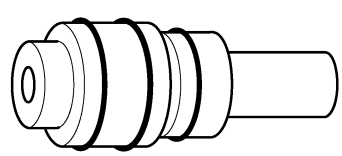
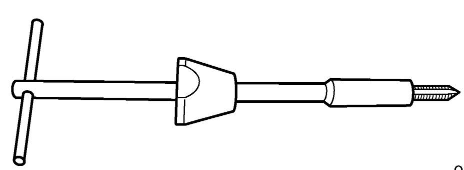
If the capscrews are incorrectly assembled or tightened to an incorrect torque, the assembly must be discarded. Failure to heed this caution may result in severe component damage.

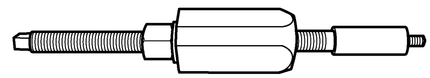
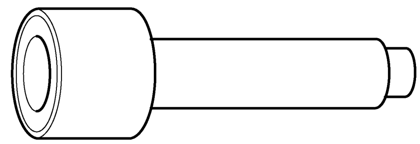
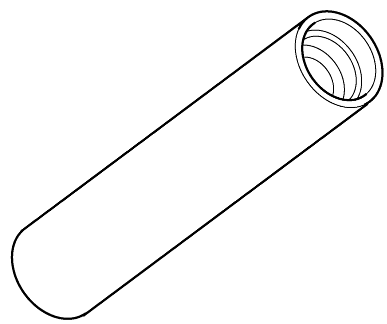
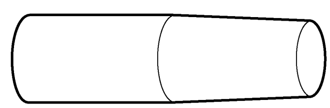
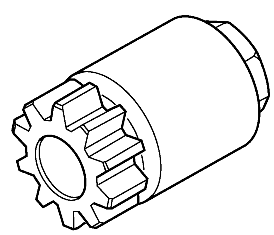
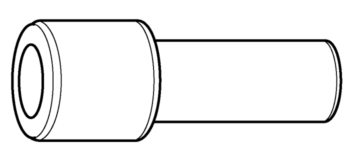
CYLINDER HEAD OVERHAUL [213 EV]

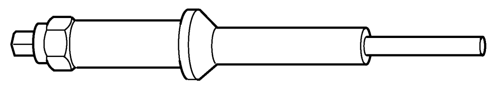
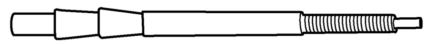
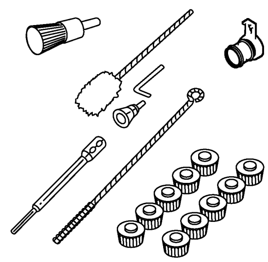
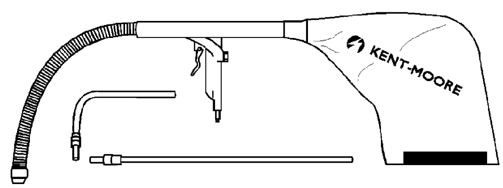
Tools and Equipment

SPECIAL TOOLS

Tool No.	Description	Image
9809667	9 mm Tap, use with 9998252 (Available)	 006840a
9809668	9 mm Bit, use with 9998253 (Available)	 006841a
9809729	Hydraulic Ram (Available)	 006777a
9990176	Tool Press for Valve/Valve Guide Replacement (Available)	 006781a
9990210	Valve Spring Compressor (Essential)	 006782a

Tool No.	Description	Image
9996222	Hydraulic Pump (Available)	 006790a
9998246	Valve Spring Compressor Adapter (Available)	 006797a
9998249	Unit Injector Protection Sleeve (Essential)	 006798a
9998250	Unit Injector Bore Gallery Sealing Rings (Available)	 006799a
9998251	Unit Injector Bore Sealing Plug (Essential)	 006800b
9998252	Unit Injector Sleeve Tap (Essential)	 006801a

Tool No.	Description	Image
9998253	Unit Injector Sleeve Remover (Essential)	 006802a
9998263	Valve Guide Removal Tool (Available)	 006803a
85112460	Valve Stem Seal Installation Tool	 006966a
88800011	Valve Stem Seal Protection Tool	 006773a
88800014	Flywheel Turning Tool (Essential)	 271485a
88800062	Inlet and Exhaust Valve Guide Installation Tool (Available)	 006776a

Tool No.	Description	Image
88800196	Swaging Tool for Installing Unit Injector Copper Sleeve (Essential)	 006805a
88880010	Swaging Bit for Copper Sleeve (Available Separately)	 006842a
J 42885	Unit Injector Bore Cleaning Kit (Essential)	 006926a
PT-2900	Chip Vacuum	 006962a

Inlet and Exhaust Valve Removal

[213 NB]

GENERAL INFORMATION

The MP8 has a single cylinder head, valves in the head and a single overhead camshaft. The single rocker arm shaft rests on the inboard end of seven camshaft bearing caps. The seventh bearing cap also provides a connection for lubricant. The optional engine brake electronic oil control valve connects the oil passages in the head and rocker arm shafts.

A copper sleeve and washer lines the bottom of each injector port. An O-ring seals each sleeve. An opening in the right front corner receives the thermostat. There are three special screws and washers used to align the cylinder head, two in the block and one in the cylinder head. Valve seat counterbores are cut in the block side. Valve guides pressed into place project from the upper side.

A gallery delivers fuel to the injectors and fuel pressure regulator. The inlet manifold attaches to the left (driver's) side of the head; the exhaust manifold to the right side.

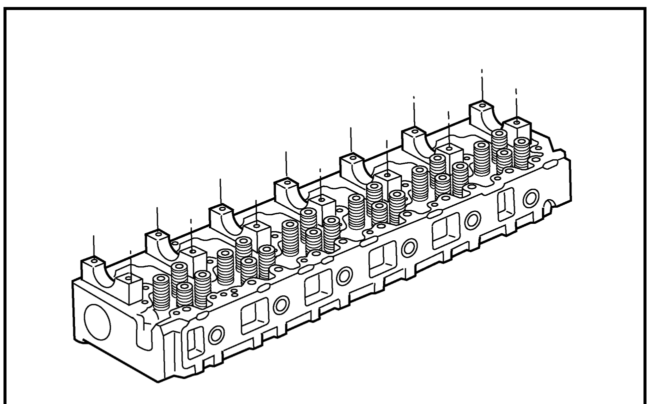


Figure 215 — Cylinder Head

REMOVAL PROCEDURE

1. Using the spring compressor, 9990210, compress a valve spring set to access the keepers.
2. Using a magnet, remove the keepers from the valve stem.
3. Remove the valve spring set.
4. Using a suitable tool, remove the valve stem seals.
5. Remove the valves.

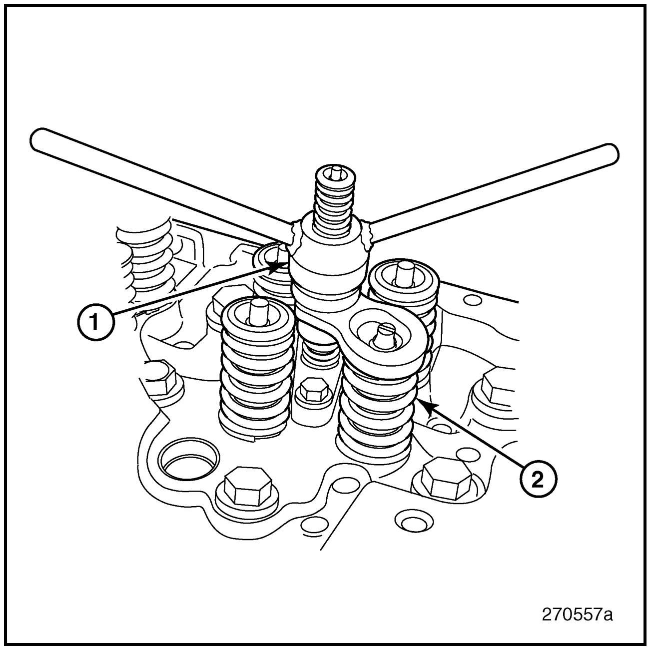


Figure 216 — Valve Spring Keeper Removal

1. Valve Spring Compressor 9990210	2. Valve Spring

Valve Stem Seals

For standardization, the valve guide and seal are used at the inlet locations as well as the exhaust locations.

Cylinder Head Cleaning and Inspection

Cleaning the cylinder head is important. While cleaning the cylinder head, carefully inspect the areas around the expansion plugs and the cooling duct cover. 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

W A R N I N G

Cleaning solvent is flammable and toxic to the eyes, skin and respiratory tract. Skin and eye protection are 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 207 kPa (30 psi). Eye protection is required. Use only with effective chip guarding and personal protective equipment (goggles/shield, gloves, etc.).

Using care and caution at all times:

1. Fill a tank with a suitable solvent.
2. Immerse the parts in the solvent to loosen dirt and debris.
3. Scrape remaining gasket material from the cylinder head.
4. Using a wire brush or rotary wheel, remove rust and other debris from the cylinder head.
5. Rinse the cylinder head making sure that all surfaces are clean and free of debris.
6. Using compressed air, blow dry the cylinder head.

INSPECTION

Check the cylinder head deck surface for warping, pitting and other imperfections.

C A U T I O N

Do NOT machine the cylinder head. This will change the extension of the injector and upset injector timing.

Valve Guide Replacement

[213 EP]

Refer to the “ENGINE MECHANICAL SPECIFICATIONS” section for dimensions applicable to the valve guides.

INSPECTION

N O T E

Worn valve guides may result in poor valve-to-seat contact, valve damage or excessive oil consumption.

1. Inspect the valve guides for wear, damage, cracks and looseness.
2. Using a suitable gauge, measure the inside diameter of each guide.
3. Using a suitable gauge, measure the valve guide extension.

N O T E

When reconditioning the cylinder head, it is recommended that all valve guides be replaced.

VALVE GUIDE REMOVAL

S E R V I C E H I N T

Clean the exhaust valve guide OD (shoulder) before removal. With the guide removed, use a rotary brush to prevent scoring while cleaning the exhaust valve guide bore.

1. Assemble the hydraulic ram, 9809729, press tool, 9990176, pump, 9996222, and valve guide remover, 9998263, on top of the cylinder head.

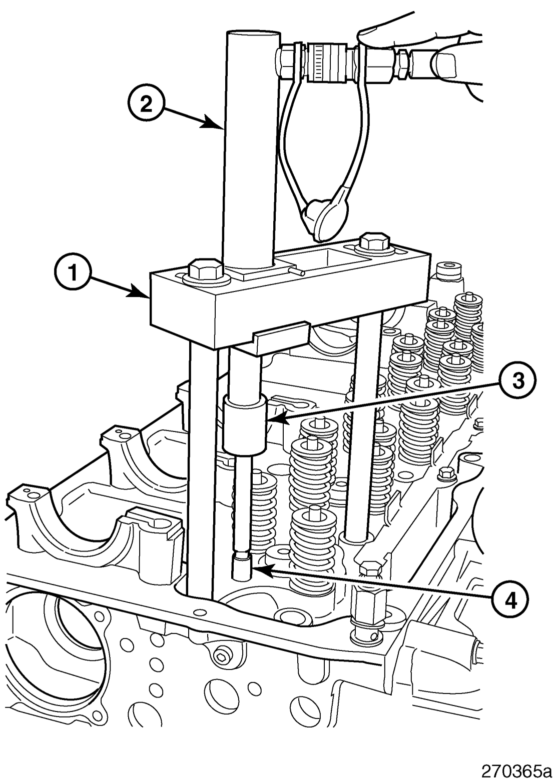


Figure 217 — Valve Guide Removal

1. Press Tool 9990176 2. Hydraulic Ram 9809729	3. Valve Guide Remover 9998263 4. Valve Guide

2. Press out the old valve guides from the top of the cylinder head using the press.
3. Clean all surfaces thoroughly.

VALVE GUIDE INSTALLATION

1. Heat the cylinder head with hot water and at the same time cool valve guide to minus 60–200°C (76–328°F) using dry ice or equivalent. Lubricate cylinder head valve guide bore before installation.
2. Using protective gloves, place a **new** valve guide in position on the cylinder head.
3. Assemble the hydraulic ram, 9809729, press tool, 9990176, pump 99996222, and the appropriate valve guide installer (88800062 for inlet and exhaust) on top of the cylinder head.
4. Oil the outside of the guide before installation.
5. Using the press tool setup, press the valve guide into its bore from the top of the cylinder head.

C A U T I O N

It is essential that the correct valve guide installation tool (88800062 for inlet and exhaust) be used to install the current valve guide. If the incorrect tool is used, the valve guide and seal installed height will be incorrect and may result in premature failure of the components.

6. Thoroughly clean all debris from the valve guides and surrounding area.
7. 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 Spring Inspection

[213 MB]

NOTE

If the inside surface of a spring coil is rough or grooved, it **must** be replaced.

If spring strength is not within specifications, it **must** be replaced.

For indications of grooving or roughness:

1. Inspect the inside surfaces of each spring coil visually.
2. Feel the inside surfaces of each spring coil with a finger.
3. Replace faulty springs with new ones.
4. Using a spring tester as shown in Figure 218, measure the effort required to compress a spring.

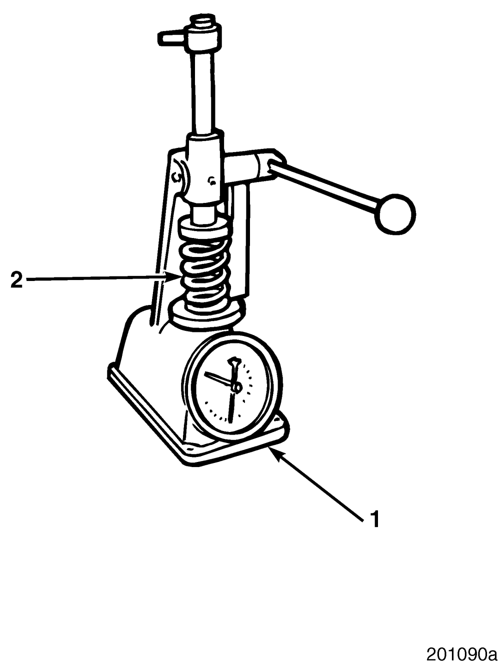


Figure 218 — Checking Valve Spring Pressure

1. Spring Tester	2. Valve Spring

Injector Sleeve Replacement

[213 GB]

CYLINDER HEAD REMOVED

The injector sleeve is swaged in place in its bore.

REMOVAL PROCEDURE

1. Remove the injector or the plug, 9998251, to access the injector sleeve bottom.
2. Remove and discard the sealing washer in the bottom of the copper sleeve.
3. Install two sealing rings to prevent dirt from entering the fuel gallery when the copper sleeve is removed.

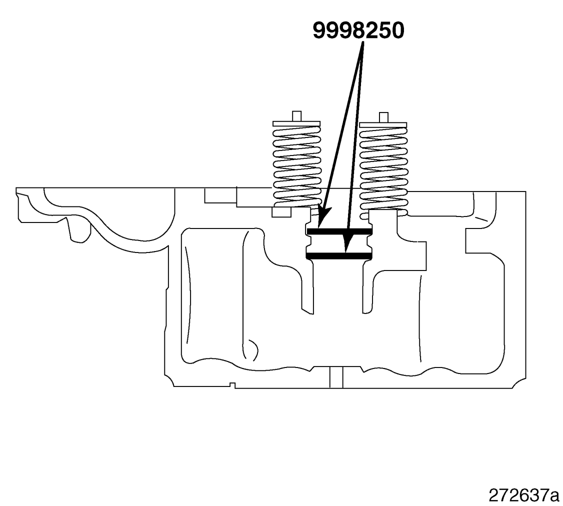


Figure 219 — Fuel Gallery Sealing Rings

NOTE

Two sealing rings are required to cover the fuel gallery.

4. Adjust the 9 mm tap so that it extends a minimum of 25 mm or 1 inch (dimension A) from the end of the tapping tool.

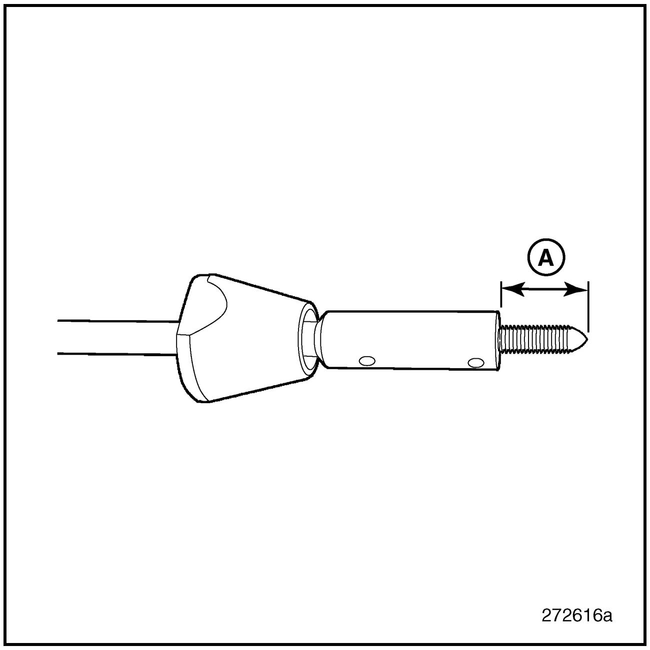


Figure 220 — Copper Sleeve Tapping Tool

NOTE

This ensures that the tip of the copper sleeve is tapped all the way through.

5. Lubricate the tip of the 9 mm tap with grease.
6. Thread the tap in small increments. Remove the tap and wipe off the grease and copper sleeve shavings. Apply fresh grease, reinstall the tapping tool and thread more of the copper sleeve. Continue this process to thread the tap all the way through the copper sleeve until no resistance is felt and the tap turns freely. Tapping in small increments and removing the shavings minimizes the chance of the sleeve turning in the cylinder head. Ensure that the tap is completely through the copper sleeve.

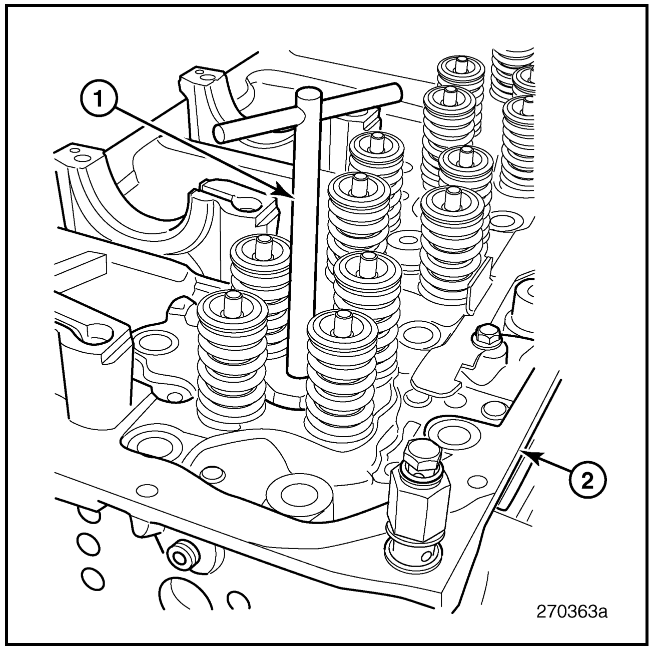


Figure 221 — Tapping Injector Sleeve

1. Tap 9998252	2. Cylinder Head

7. Remove the tap and tapping tool.
8. Using the chip vacuum, remove any remaining shavings from the copper sleeve.
9. Install the extractor bolt into the end of the extractor tool. Adjust the bolt until it extends approximately 22 mm (0.9 inch) beyond the end of the tool (dimension A).

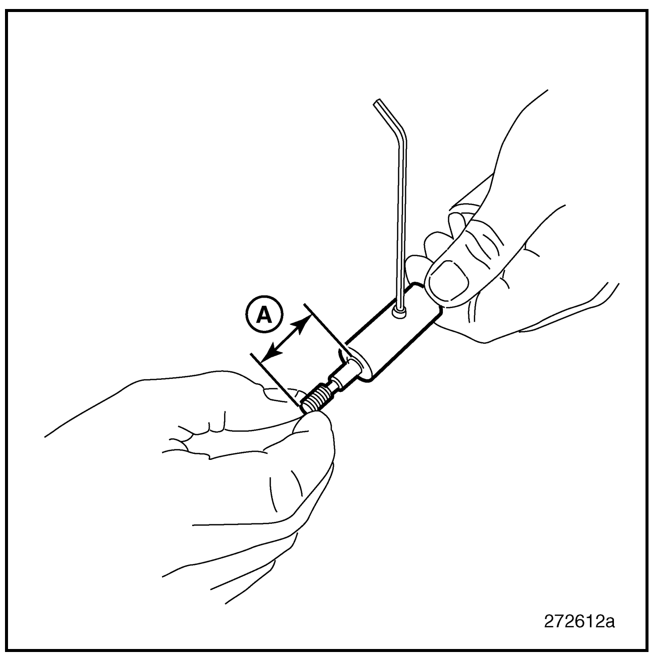


Figure 222 — Adjusting Copper Sleeve Extractor Bolt

10. Tighten the set screw of the extractor tool to secure the bolt. Make sure that the set screw is seated against the flat part of the extractor bolt.
11. Place the extractor tool with the bolt into the injector bore. Make sure the nut on the spindle is backed off so that the threaded end can be completely installed through the copper sleeve tip. Hand tighten until the bolt bottoms out in the sleeve.

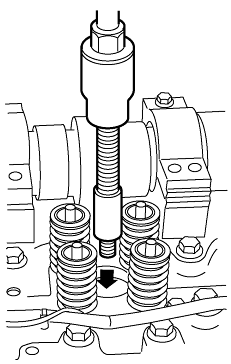


Figure 223 — Extractor Tool Installation

CAUTION

Make sure the extractor bolt is threaded completely into the copper sleeve before attempting to remove it or the tip of the sleeve may break off as it is removed.

12. Screw the injector sleeve removal tool, 9998253, completely into the injector sleeve and then back it out 1/2 turn. Remove the sleeve by turning the nut while holding the threaded shaft of the removal tool.

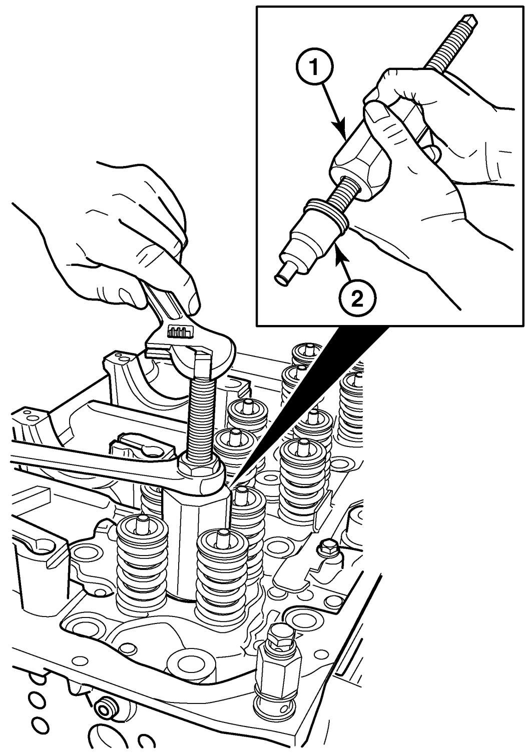


Figure 224 — Removing Injector Sleeve

1. Injector Sleeve Remover 9998253	2. Injector Sleeve

NOTE

When the copper sleeve is removed, make sure that the extractor bolt is extended at least one thread beyond the copper sleeve. If not, make sure that no part of the copper sleeve has broken off.

CAUTION

Do not use air tools to remove copper sleeves, or damage to the injector bore can result.

13. Remove the two sealing rings from the fuel passage. Using the chip vacuum, remove any remaining debris from the injector bore.

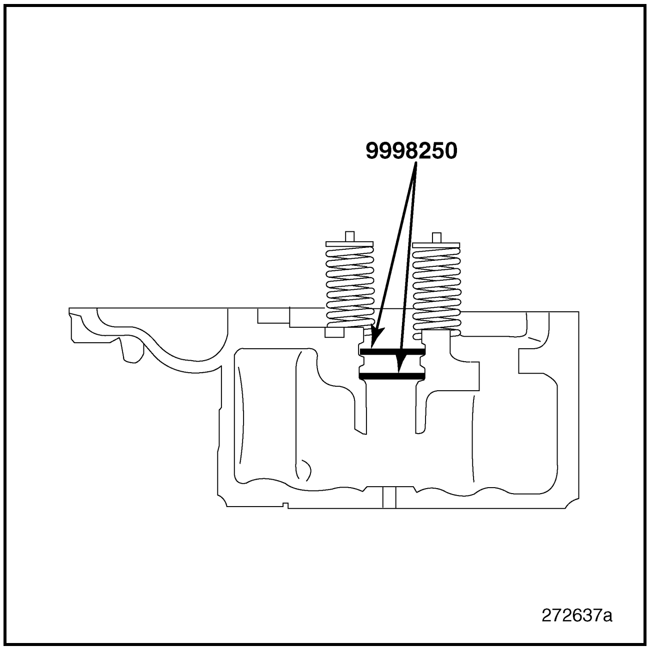


Figure 225 — Fuel Gallery Sealing Rings

14. Install the injector bore sealing tool (J 42885-25) to protect the fuel passage area and prevent debris from entering. Use the unit injector hold down bolt to secure the tool in the cylinder head.
15. Using the injector bore cleaning kit, clean the copper sleeve seat of the cylinder head.

NOTE

The injector bore sealing tool must be used to prevent dirt from entering the fuel passage.

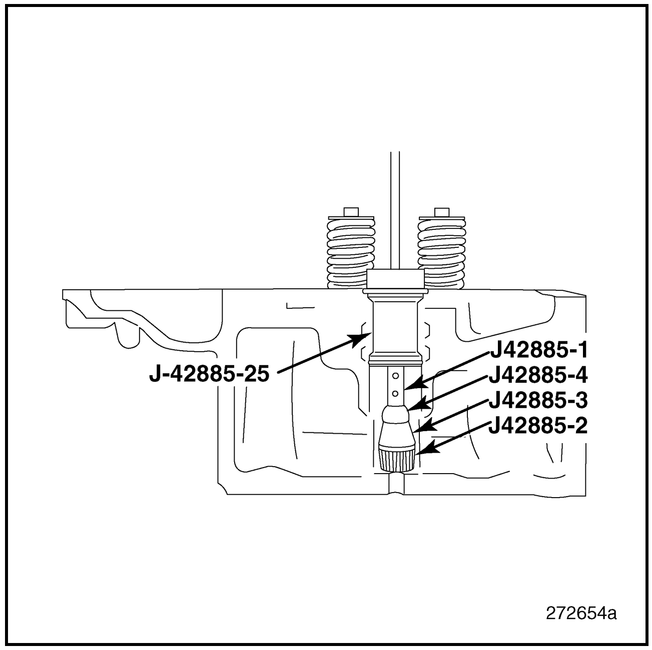


Figure 226 — Cleaning Copper Sleeve Seat

16. Using the brush, clean the cylinder head injector bore walls for the copper sleeve.

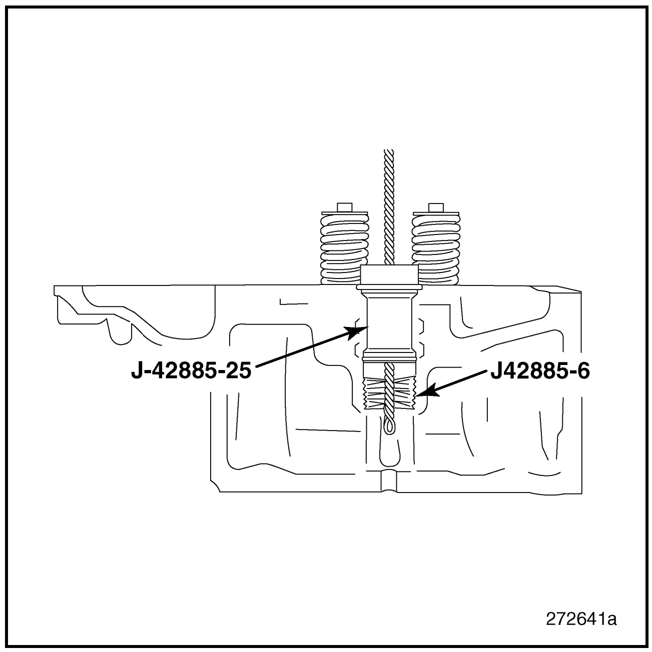


Figure 227 — Cleaning Copper Sleeve Bore Walls

NOTE

The injector bore sealing tool must be used to prevent debris from entering the fuel passage.

17. Using the brush, clean the copper sleeve opening in the cylinder head.

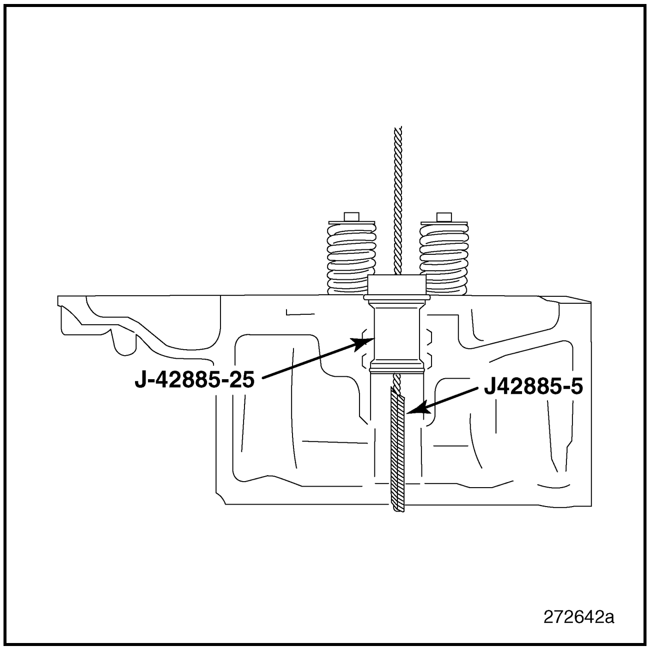


Figure 228 — Cleaning Injector Tip Bore

NOTE

The injector bore sealing tool must be used to prevent debris from entering the fuel passage.

When replacing the copper sleeves, it is important to check that the sleeve bore in the cylinder head is free from any carbon deposits or other residue (i.e., pieces of O-ring, etc.) before installing a new copper sleeve. Reclean if necessary.

18. Using the chip vacuum, remove all debris from the copper sleeve bore.

SERVICE HINT

Do not attempt to blow away debris using compressed air. Doing so can result in eye injury.

19. Remove the injector bore sealing tool from the cylinder head. Using the chip vacuum, remove any remaining debris.

INSTALLATION PROCEDURE

1. Before installing the copper sleeve, inspect it to ensure that it is the correct part. The correct sleeve is identified by two concentric circular grooves machined into the top surface.

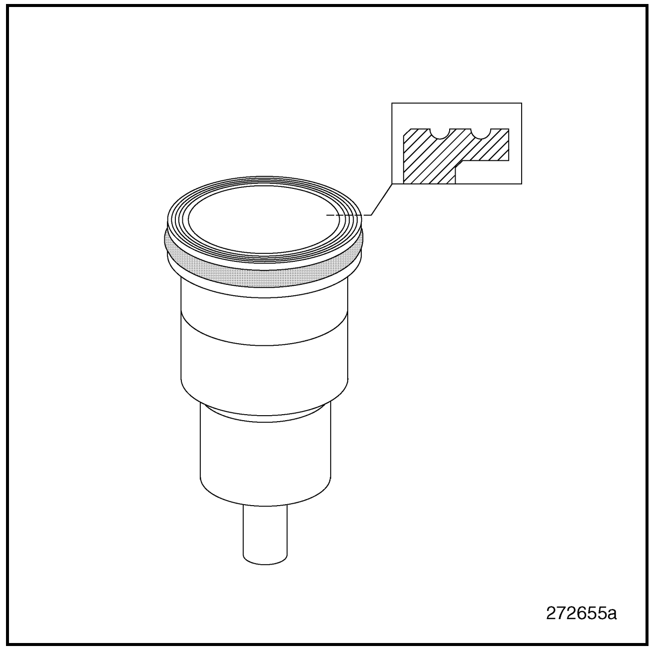


Figure 229 — Copper Sleeve Identification

2. Lubricate a **new** copper sleeve O-ring with coolant. Install the O-ring on the copper sleeve and lubricate again with coolant. Always use a **new** O-ring.
3. Place the **new** copper sleeve on the installation tool.

NOTE

Do not place the injector nozzle gasket (flat washer) in the copper sleeve, as this will damage the swaging bit.

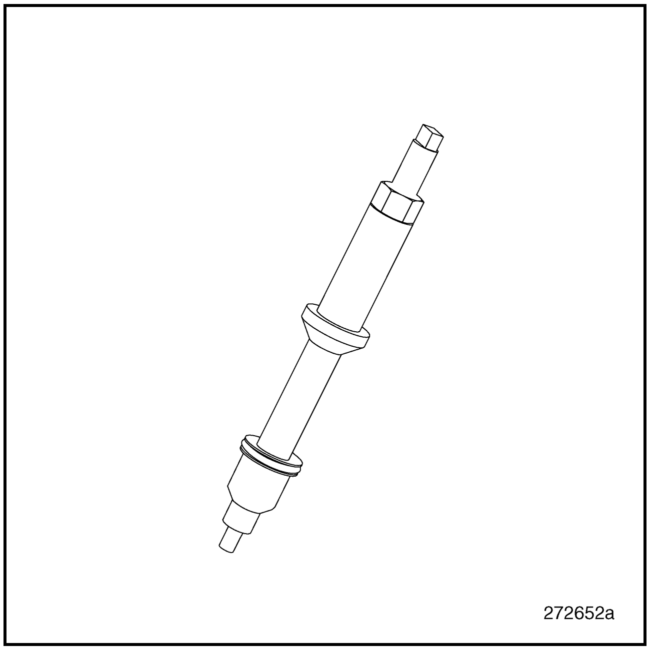


Figure 230 — Installation Tool Identification

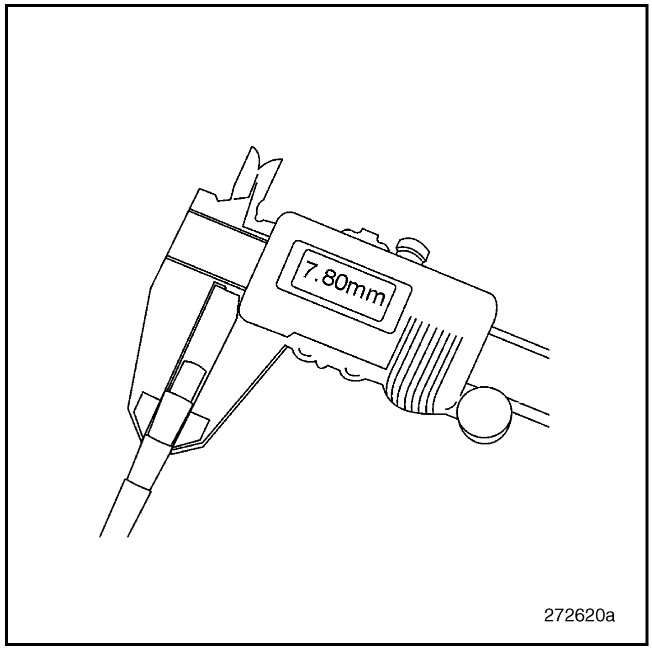


Figure 231 — Swaging Bit Verification

NOTE

Before installing the sleeve on the installation tool, inspect the tool to ensure that it is the correct tool. The correct tool is identified by a bottom surface that is perfectly flat with no machined circular recess. Use of a tool with a machined circular recess on the bottom may result in damage to the copper sleeve.

4. Using calipers, measure the swaging bit to make sure that the proper swaging tool is used. Measurement should read approximately 7.8 mm. Also, verify that the length of the swaging bit is 108 mm.

CAUTION

Failure to use the proper bit can result in the bit breaking off into the cylinder head.

NOTE

Swaging bit can be ordered as a spare part if the bit is worn or broken.

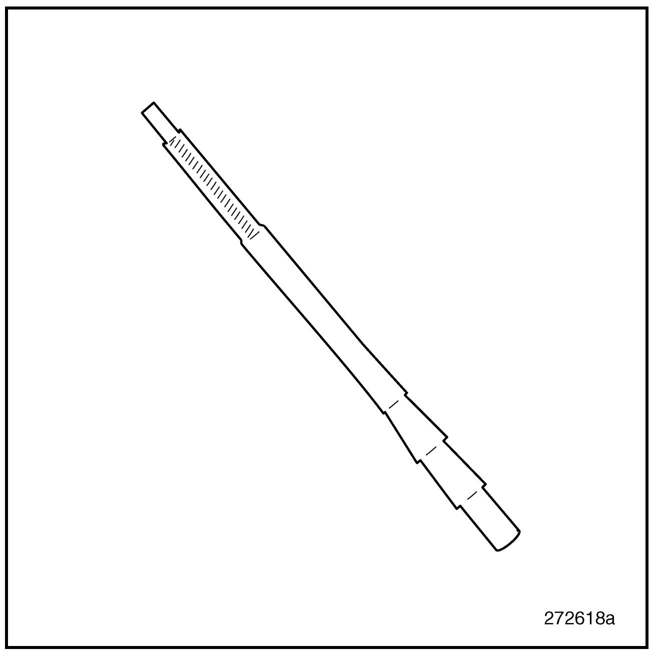


Figure 232 — Swaging Bit

5. Thread the swaging bit completely into the flaring tool until it stops (finger tight).

6. Screw the swaging tip through the copper sleeve and completely into the swaging tool holder, 88800196, until it stops (finger tight). Ensure that the tool is fully seated in the copper sleeve.

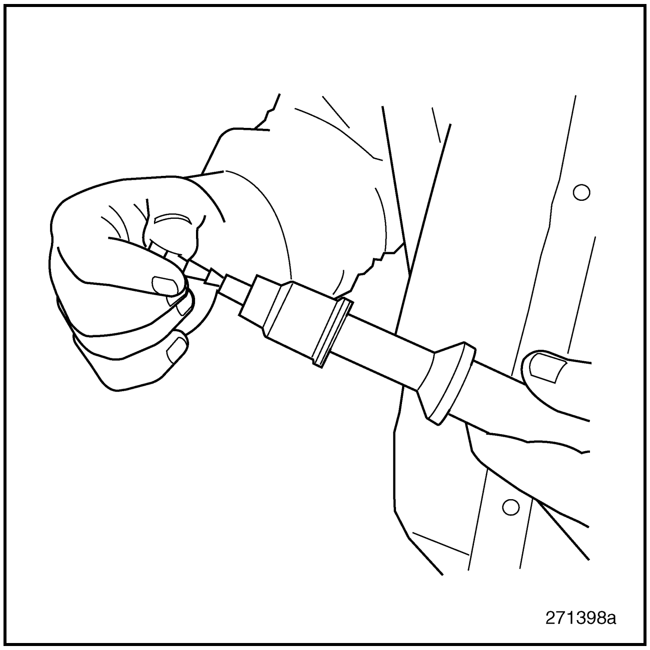


Figure 233 — Swaging Tool

7. Loosen the swaging bit 180 degrees before installing the tool in the cylinder head.

CAUTION

Failure to loosen the swaging bit can result in the bit being twisted or broken.

8. Lubricate the swaging bit and the threads on the tool with oil.
9. Carefully place the sleeve installation tool (with new copper sleeve attached) into the unit injector bore of the cylinder head. Carefully move the copper sleeve downward into the injector bore so that the swaging bit is guided into the injector tip bore in the cylinder head. Push downward on the installation tool using hand force to move the copper sleeve downward until it bottoms out on the injector sleeve seat in the bottom of the injector bore. Use the unit injector hold down and bolt to hold the tool in position. To ensure that the copper sleeve is bottomed in the cylinder head, tighten the unit injector hold down bolt to specification.

NOTE

Remove any oil from the injector hold down bolt holes to avoid hydraulic lock for this step and when the injector is installed.

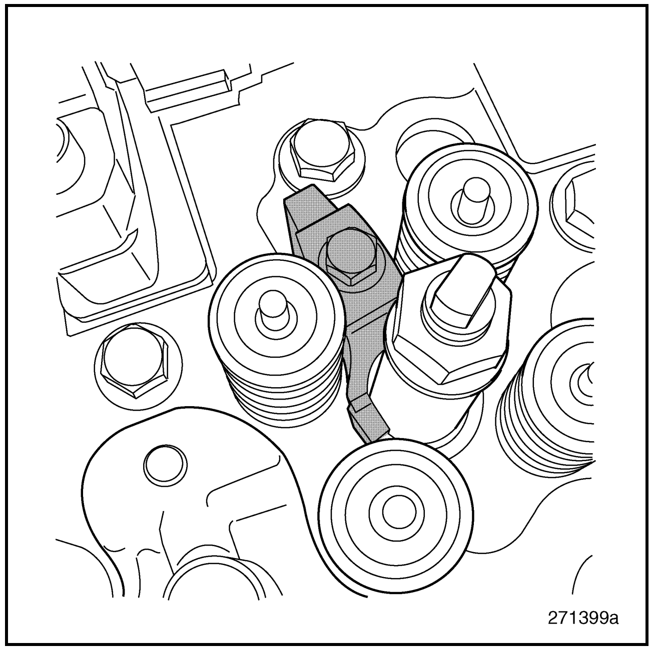


Figure 234 — Injector Yoke and Sleeve Installation Tool

10. Flare the copper sleeve by turning the nut (1) clockwise while holding the spindle until the swaging bit has been pulled completely through the copper sleeve.

CAUTION

Failure to hold the spindle can result in a twisted or broken swaging bit.

NOTE

The swaging tip has three sections of increasing diameter. Resistance increases as the swaging tip advances through the hole. Continue to pull the tip until it is free of the hole.

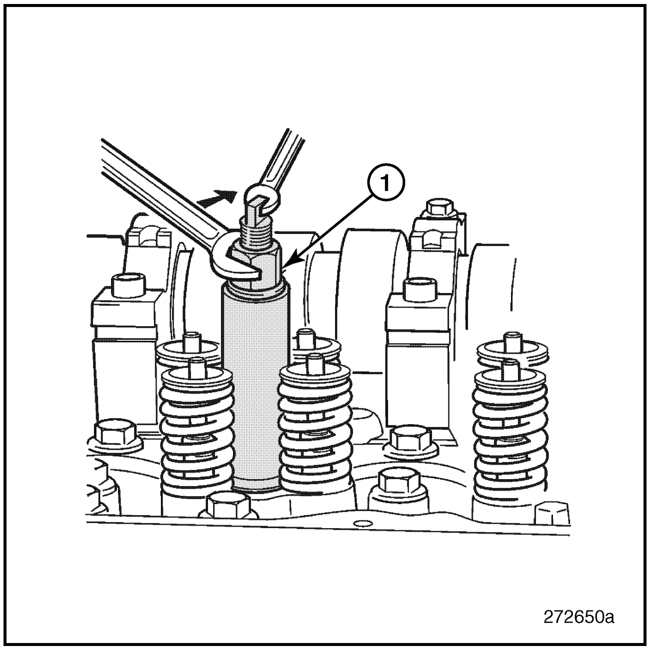


Figure 235 — Flaring Copper Sleeve Using Installation Tool

1. Flaring Tool 88800196

11. Remove the sleeve installation tool from the injector bore.
12. Using brush, J 42885-9, and extension, J 42885-1, ensure that the copper sleeve bore is clean. Insert a **new** washer and the injector or a sealing plug, 9998251.

NOTE

If the injector is not being installed immediately, install the sealing plug into the injector bore to protect it from debris.

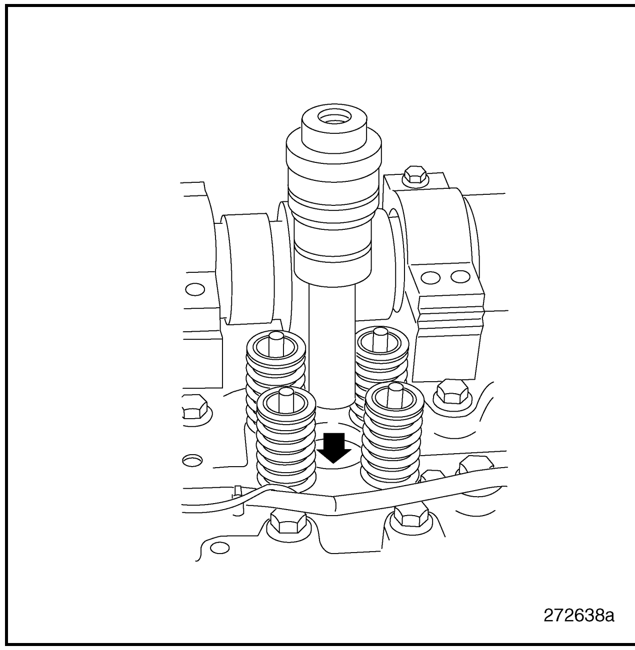


Figure 236 — Unit Injector Bore Sealing Plug

Expansion Plug Replacement [213 FP]

The cylinder head has three expansion plugs of different sizes.

— 29 mm (1-9/64 or 1.142 inch)

— 40 mm (1-37/64 or 1.575 inch)

— 50 mm (1-31/32 or 1.968 inch)

All are installed using the following procedure:

1. Clean the plug bore thoroughly.
2. Apply Loctite® 277 sealer, or equivalent, to the expansion plug and plug bore.
3. Using a socket, extension and a hammer, press the expansion plug into the plug bore.
4. Repeat steps 1–3 for each new plug.

NOTE

The plug should be installed flush to 0.508 mm (0.020 inch) below the surface.

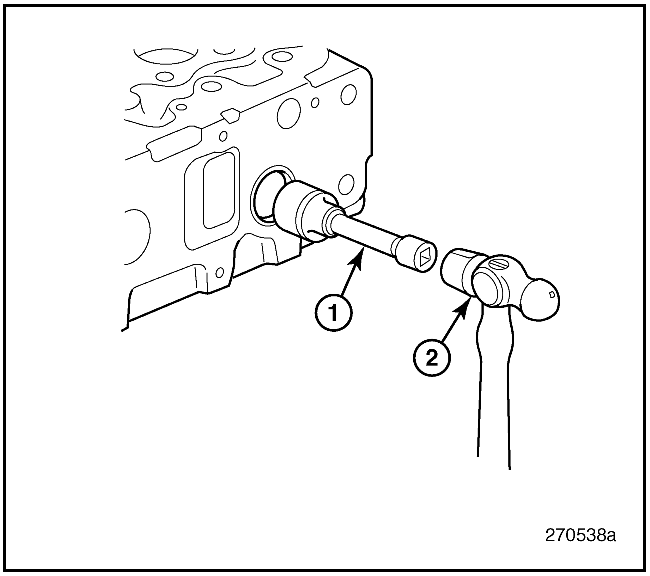


Figure 237 — Expansion Plug Installation

1. Socket and Extension	2. Hammer

Valve Inspection

1. Inspect the valves for cracks, pits and other conditions that may cause improper operation.
2. Inspect the stem ends of the valves for nicks and burrs that may damage the seals at assembly.
3. Measure the valve seat angle.
4. Measure valve stem length and diameter.
5. Discard and replace damaged or worn valves.

Valve Installation

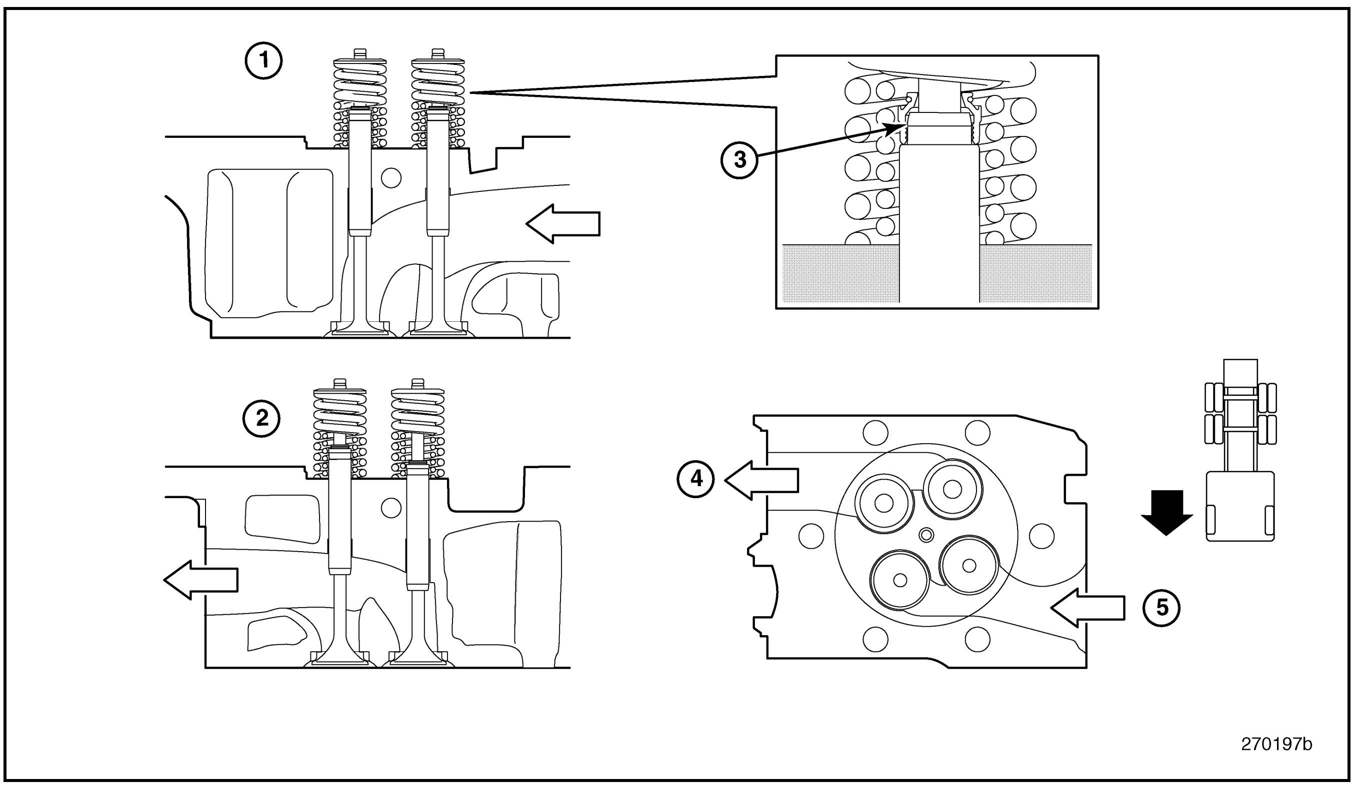


Figure 238 — Valve, Springs and Stem Seals

1. Inlet Valves and Springs 2. Exhaust Valves and Springs 3. Valve Stem Seal	4. Exhaust Port 5. Inlet Port

CAUTION

The inlet and exhaust valve head diameters are different. Take care when installing the valves. Incorrect installation may result in engine failure with extensive damage.

1. Using engine oil, lubricate the valve stems.
2. Slide the stem back and forth in its guide to spread the lubricant.
3. Using the appropriate valve seal installer, 85112460, assemble the seals on the valve guides.
4. Drop a bottom washer, a spring set and a top washer over each stem.
5. Using the spring compressor, 9990210, to compress the springs, assemble the keepers on the stems.

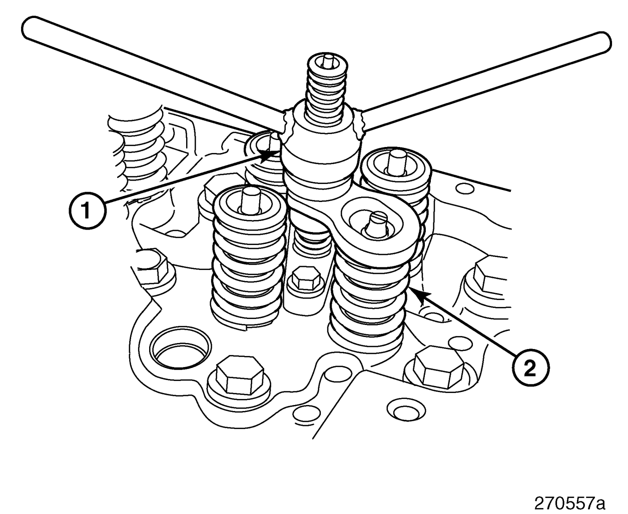


Figure 239 — Valve Spring Keeper Installation

1. Valve Spring Compressor 9990210	2. Valve Spring

ROCKER ARM SHAFT BENCH PROCEDURES [213 LP]

Description

The MP8 rocker arm shaft assembly is held in place by the same screws that hold the inboard ends of the camshaft bearing caps. A specific sequence for tightening these screws is described in the **ENGINE TORQUE SPECIFICATIONS** section.

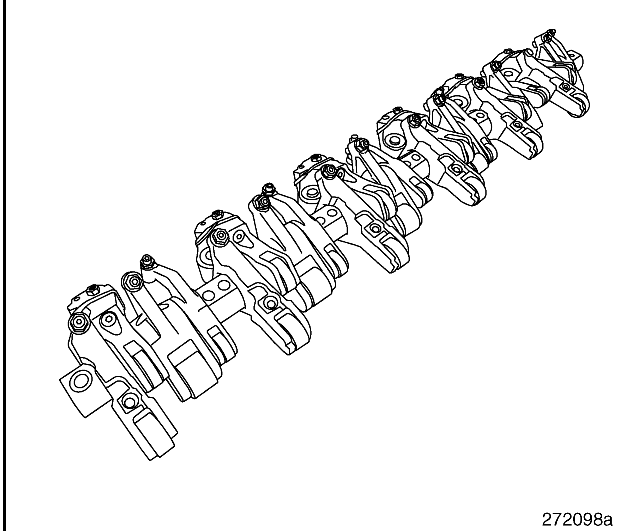


Figure 240 — Rocker Arm Shaft Assembly

Rocker Arm Shaft Disassembly

WITH OR WITHOUT ENGINE BRAKE

Disassemble the shaft and components as follows.

1. Mark the rocker arms and yokes so they can be put back in their original locations.
2. Slide the rocker arms off the shaft.

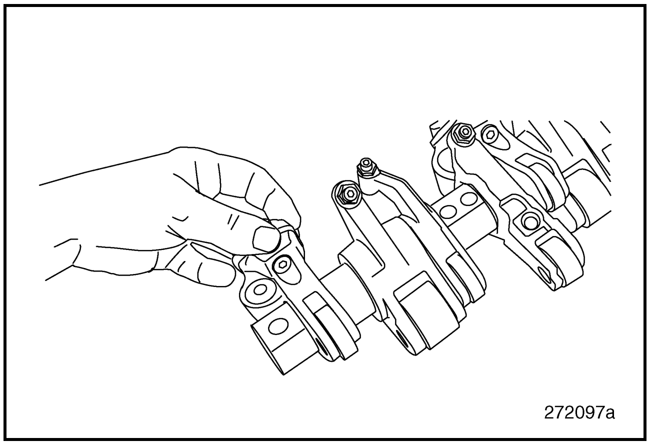


Figure 241 — Rocker Arm Removal

Inspection

ALL COMPONENTS

1. Inspect all components of the rocker arm assembly for damage and excessive wear. If the roller does not move or binds, replace the rocker arm.
2. Check the valve and piston action on the exhaust rocker arms for any signs of binding. Replace as necessary.
3. Inspect the rocker shaft for galling, scoring or excessive wear. Replace as necessary.

Rocker Arm Shaft Assembly

WITH OR WITHOUT ENGINE BRAKE

The assembly procedure for the rocker arm shaft is described below.

1. Arrange the rocker arms in sets according to the markings made at disassembly.
2. Lubricate the rocker shaft, rocker arm bore and oil feed hole in the rocker arm that feeds oil to the roller/axial pin. Turn the rocker roller while injecting clean engine oil to ensure the roller/axial pin is lubricated properly. Then, slide the rocker arm sets onto the shaft according to the markings made at disassembly.

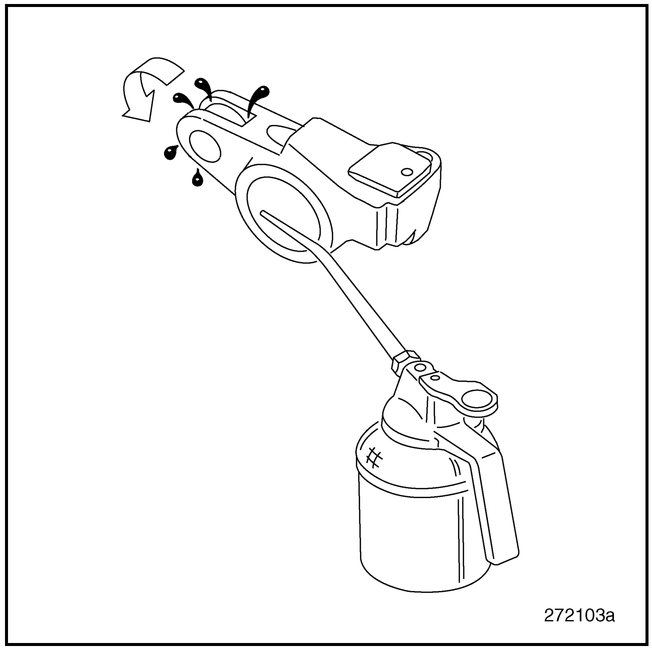


Figure 242 — Rocker Arm Lubrication

CAMSHAFT BENCH PROCEDURES

Camshaft Inspection

[213 CH]

CAMSHAFT GEAR REMOVAL

CAUTION

Handle the camshaft carefully to avoid bending it. Slight but harmful bends can go unnoticed. Failure to heed this caution could result in premature engine failure.

NOTE

The vibration damper and camshaft timing gear are separate components attached to the shaft by the same screws.

The timing gear and vibration damper can be removed while the camshaft remains on the cylinder head.

1. Provide means of controlling the damper and gear when the attaching screws are removed.
2. Remove the attaching screws.
3. Set aside the damper and gear in a safe place.

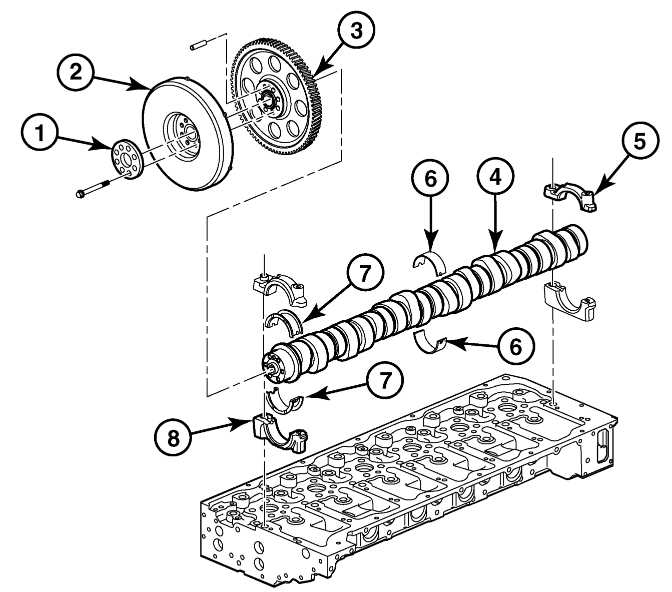


Figure 243 — Camshaft Assembly Components

1. Spacer 2. Vibration Damper 3. Camshaft Gear 4. Camshaft	5. Upper Bearing Cap 6. Bearing Inserts 7. Thrust Bearing Inserts 8. Lower Bearing Cap (Support)

INSPECTION

1. Clean the camshaft thoroughly.

NOTE

If any component displays cracking, pitting, scoring or excessive wear, replace it.

2. Inspect the camshaft, lobes and journals.
3. Inspect the camshaft gear.
4. Inspect the vibration damper.

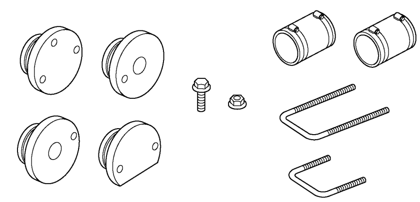
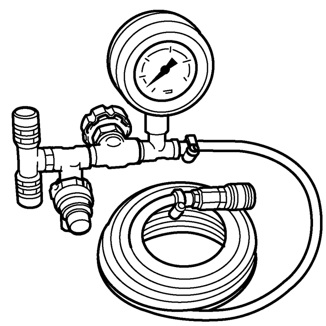
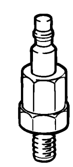
CAMSHAFT GEAR INSTALLATION

The camshaft can be installed on a properly installed cylinder head before attaching the timing gear and vibration damper.

1. Using two or three attaching screws, loosely assemble the damper, gear and shaft.
2. Install the remainder of the screws loosely.
3. Tighten the screws according to the sequence specified in the ENGINE TORQUE SPECIFICATIONS section.

COOLING SYSTEM COMPONENTS BENCH PROCEDURES

Special Tools

Tool No.	Description	Image
88800216	EGR Cooler Leak Test Kit (Essential) **Note:** For the alternate pressure test method, use tools 9988288, 9996662 and 9998143.	 007002c
9996662	Pressure Gauge and Hoses (Available)	 006793a
9998333	Coupler, used with 88800216 (Available)	 273047a

Oil Cooler Reconditioning

[215 DW]

The oil cooler cannot be disassembled. Should it fail, replace it.

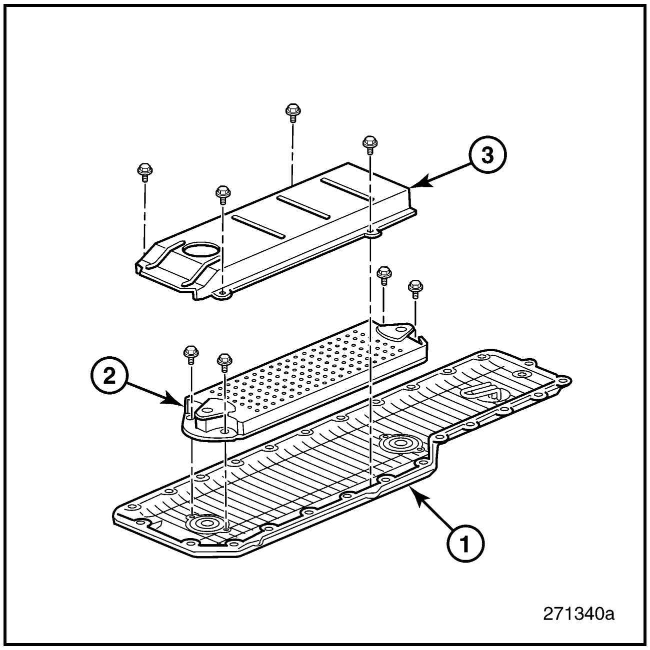


Figure 244 — Oil Cooler Assembly

1. Cooling Duct Cover 2. Oil Cooler	3. Flow Plate

EGR Cooler Cleaning

Prolonged idling and poor fuel quality can cause carbon buildup and blockage in the core and should be avoided.

The EGR cooler cannot be disassembled and reconditioned.

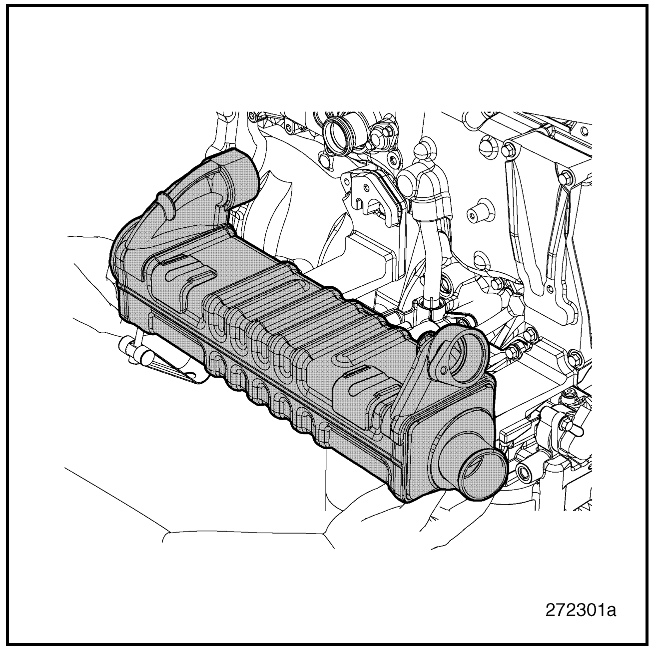


Figure 245 — EGR Cooler Assembly

CLEANING PROCEDURE

Exhaust soot can be cleaned from the EGR cooler using the following procedure.

NOTE

The following procedure covers EGR coolers which have been removed from the engine.

1. Place the cooler in the parts washer and fill it with Dyna 143 cleaning solvent. Let the cooler soak for one hour.

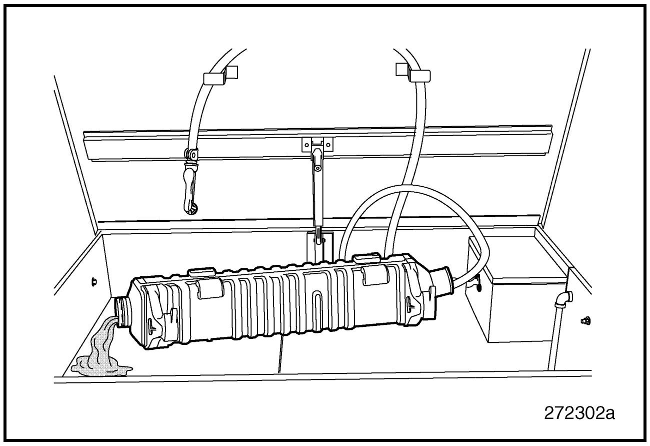


Figure 246 — EGR Cooler in Parts Washer

2. Hang the cooler and steam clean through the inlet end first.

CAUTION

*Do **NOT** let the steam and air nozzles touch the EGR fins during cleaning. Failure to heed this caution may result in severe component damage.*

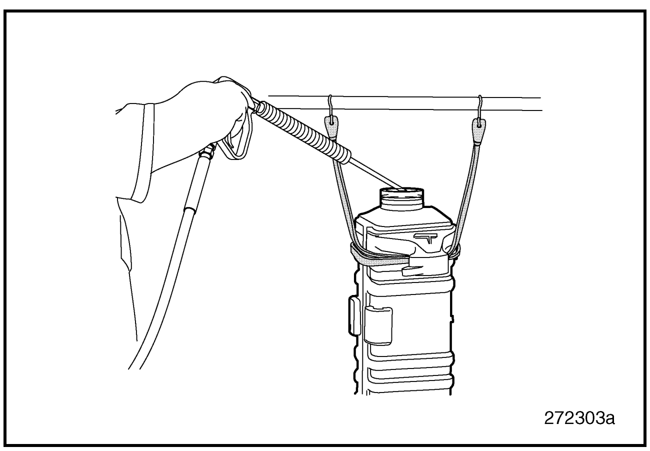


Figure 247 — Steam Cleaning the EGR Cooler

3. Steam and soot should flow out of the lower end of the cooler.

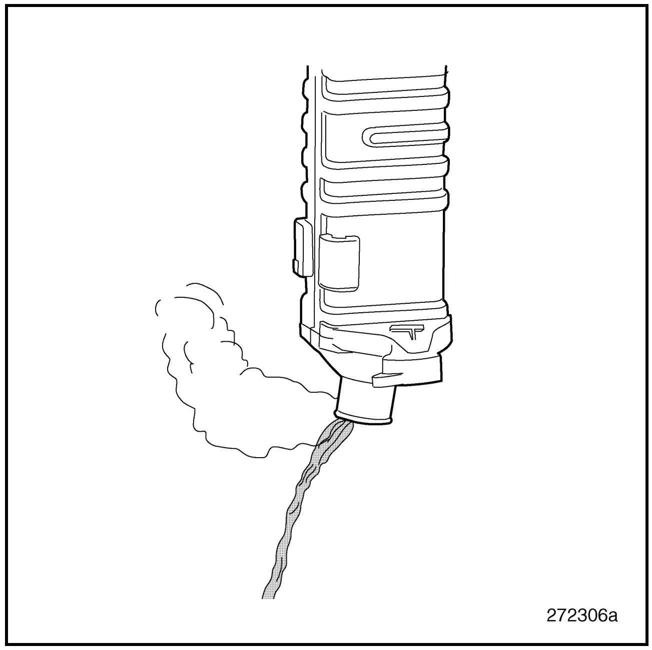


Figure 248 — Draining Soot from the Cooler

4. Turn the cooler end for end and steam clean through the outlet end until clean water flows.

NOTE

Set shop air pressure at 172 kPa (25 psi).

5. While the cooler hangs so that the water flows out, blow clean shop air into the inlet end until the cooler is dry.

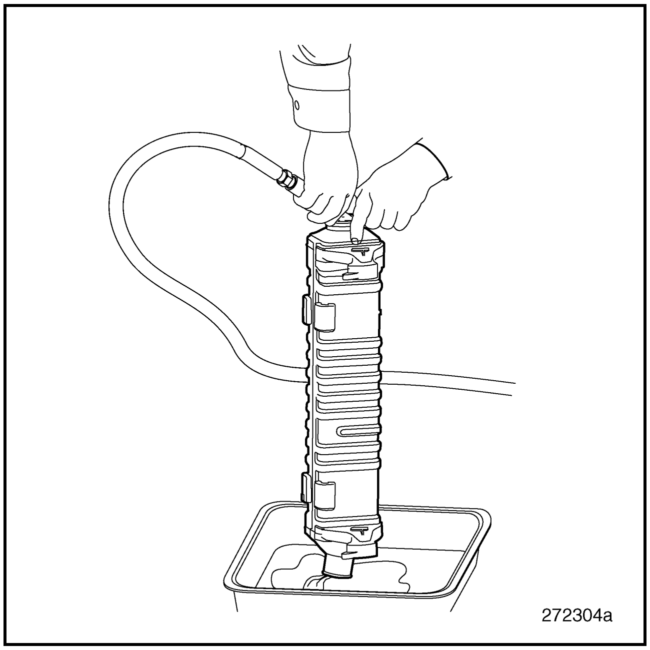


Figure 249 — Blowing Shop Air into EGR Cooler

6. Turn the cooler end for end and, while it hangs so that water flows out, blow clean shop air into the outlet end until the cooler is dry.
7. Visually inspect the exhaust passages. If any soot or carbon remains in the cooler, reclean as needed.
8. When the cooler is dry (clear of water and cleaning solution), assemble it on the engine.

EGR Cooler Pressure Test

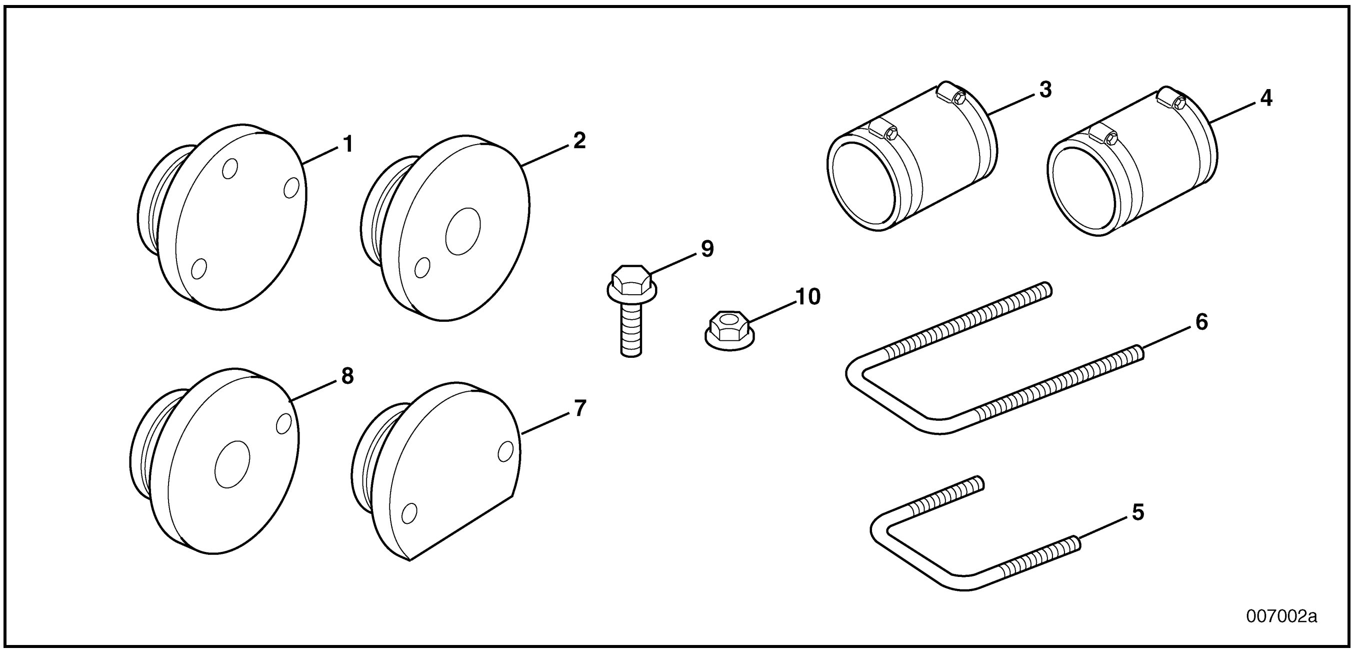


Figure 250 — EGR Cooler Leak Test Kit 88800216

1. 88800216-1 Inlet Plug (MP8 and US07 MP7)	6. 547632 U-Bolt (MP8 and US07 MP7)
2. 88800216-2 Outlet Plug (MP8 and US07 MP7)	7. 88800216-4 Inlet Plug (US04 MP7)
3. 88800216-5 Test Plug (MP8 and US07 MP7)	8. 88800216-3 Outlet Plug (US04 MP7)
4. 88800216-6 Test Plug (US04 MP7)	9. 547638 Flange Capscrew (M8 x 1.25 - 20 mm)
5. 547635 U-Bolt (US04 16L engine, not used on MACK product)	10. 220281 Flange Nut (M8 x 1.25)

1. Check inside the gas inlet port. If build-up of soot is seen, perform the EGR cooler cleaning procedure before checking for leaks.
2. Lubricate the O-rings on the coolant inlet and outlet port plugs with a suitable O-ring lubricant. Install the plugs and cap on the EGR cooler. Install the plugs on the EGR cooler coolant inlet and outlet ports. Install the coupler on the plug and connect the gauge to the coupler.

CAUTION

Do NOT over-tighten the fasteners on the plugs and cap.

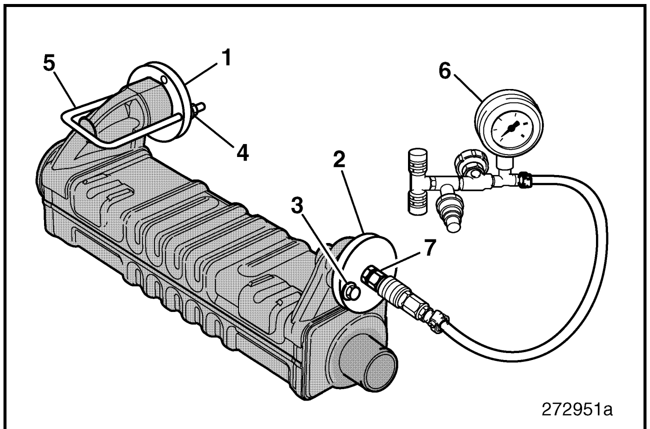


Figure 251 — Installation of Leak Test Kit on Cooler

1. 88800216-1 2. 88800216-2 3. Flange Capscrew 4. Flange Nut	5. U-Bolt 6. 9996662 7. 9998333

3. Fill a container with enough water to cover the EGR cooler.
4. Lower the EGR cooler into the container of water at room temperature (or fill the cooler core with water — see NOTE).

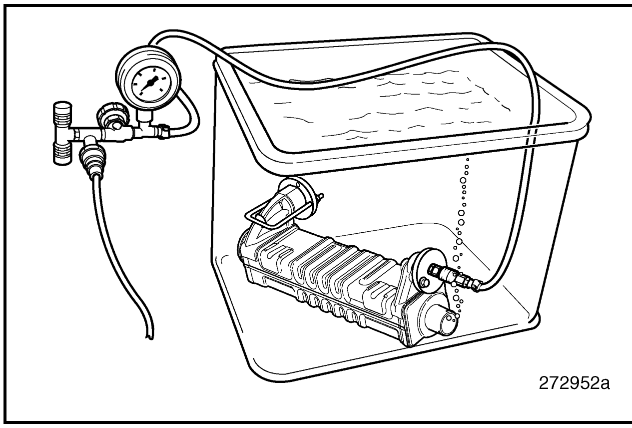


Figure 252 — Conducting Pressure Test

NOTE

If a large enough container cannot be obtained, the EGR cooler can be tested without being immersed in water by using the test plugs included with the kit, 88800216-5, to seal the gas outlet port. The EGR cooler core can then be filled with water and tested by applying air pressure to the coolant outlet port as shown in Figure 253. When using this technique, the cooler must be tested in the upright position.

To ease the installation of the test plug, coat the inside of the hose with a suitable O-ring lubricant.

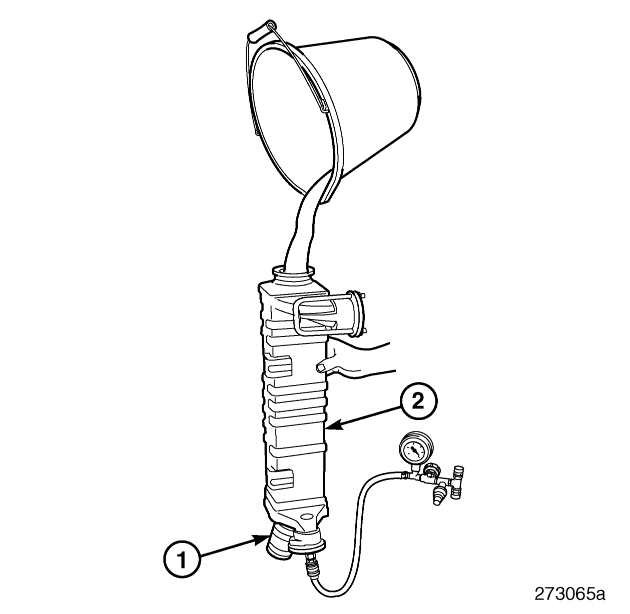


Figure 253 — Test with EGR Gas Outlet Port Plugged

1. Test Plug, 88800216-5	2. EGR Cooler

5. Apply air pressure (240 kPa [35 psi]) to the EGR cooler. Maintain the pressure for 15 minutes. If the EGR cooler is leaking internally, there will be a steady stream of bubbles coming from the gas inlet or outlet openings. If a steady stream of bubbles appears, replace the EGR cooler.

NOTE

If the cooler is being tested without being immersed in water, look inside the gas inlet port. If bubbles are seen, the cooler is leaking internally and must be replaced.

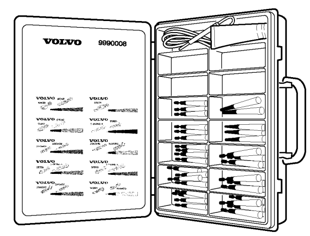
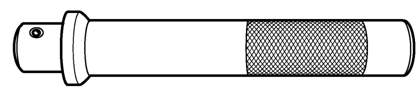
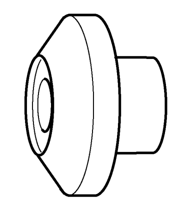
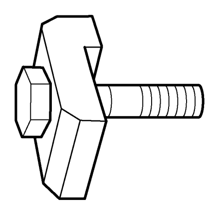
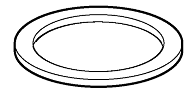
NOTE

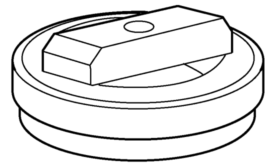
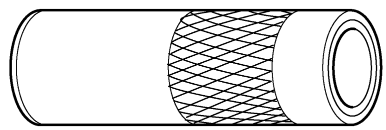
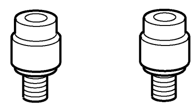
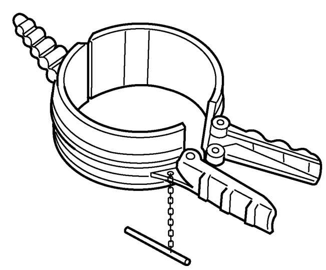
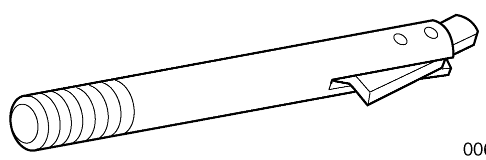
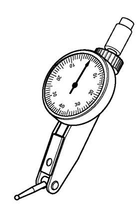
A stream of bubbles seen coming from around the plugs in either of the coolant ports indicates that the O-rings may be damaged. If this is the case, remove the plugs, inspect the O-rings and replace as required.

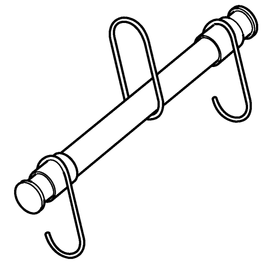
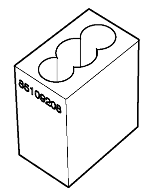
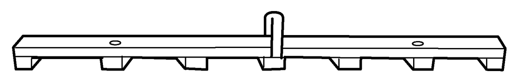
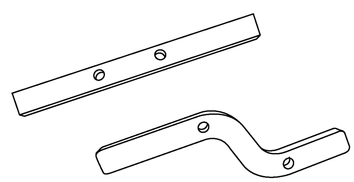
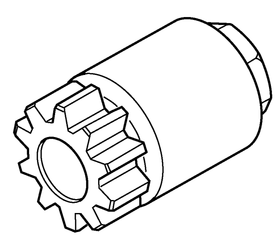
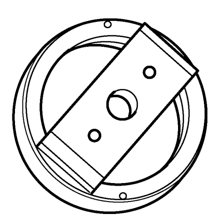
6. Lift the EGR cooler out of the container and remove the pressure testing equipment.
7. Dump the water from inside the EGR cooler and then use compressed air to remove any remaining water from the cooler core and outer cover.

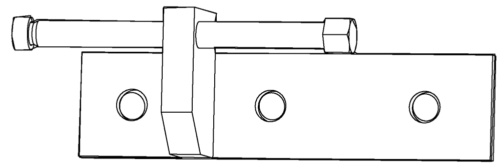
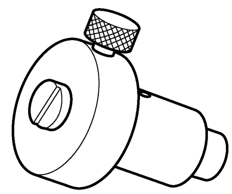
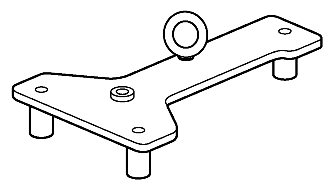
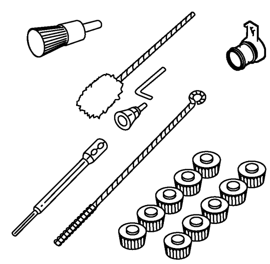
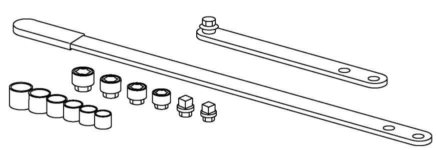
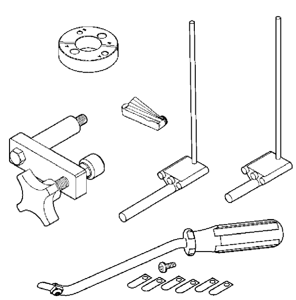
ENGINE REASSEMBLY
MACK MP8 Euro 4 Engine
[200 EA]

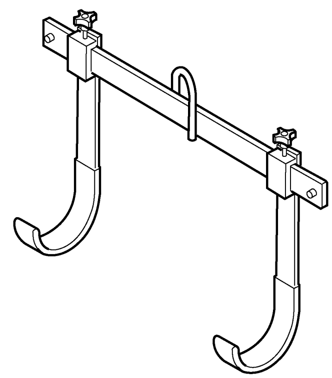
Special Tools

Tool No.	Description	Image
9990008	Set of Test Pins	 006951a
9992000	Handle with various uses (fits 25 mm hole), use with 9990113 (Essential)	 006785a
9992564	Driver for Installation of Pilot Bearing, use with 9991801 (Essential)	 006786a
9998043	Liner Hold-Down Tools (Essential)	 006796a
9998170	Front Cover Spacer Ring (Essential)	 006947a

Tool No.	Description	Image
9998238	Rear Main Seal Remover/Installer for neoprene type seals, use with 9992000 (Essential) **Note:** For Teflon® seal replacement, see“CRANKSHAFT REAR SEAL REPLACEMENT” on page 248.	 006780a
9998249	Unit Injector Protection Sleeves (Essential)	 006798a
9998267	Guide Tool (Essential)	 006952a
9998531	Piston Ring Compressor (Essential)	 006834a
9998649	Stiffening Frame Tool	 006894a
9999683	Sweep Dial Indicator (Essential)	 006948a

Tool No.	Description	Image
85109034	Camshaft Lifting Bar (Essential)	 006835a
85109208	Bearing Cap Press Tool (Essential)	 006949a
85109250	Rocker Shaft Assembly Lifting Tool (Essential)	 006770a
85111422 (A, B)	Upper Rear Cover Alignment Tool (Essential)	 006924a
88800014	Flywheel Turning Tool (Essential)	 271485a
88800021	Front Main Seal Remover/Installer (Essential)	 006774a

Tool No.	Description	Image
88800022	Cooling Duct Cover Installation Tool	 006893a
88800031	Camshaft Sensor Gauge (Essential)	 006804a
88800188	Cylinder Head Lifting Tool (Essential)	 006923a
J 42885	Injection Bore Cleaning Kit (Essential) **Note:** Alternate kit for injector cleaning — 9998599.	 006926a
J 44392	Belt Tensioner Release Tool	 272697a
J 44514-B	Engine Timing Kit (Essential)	 006889a

Tool No.	Description	Image
J 49002	Crankshaft Lifting Tool (Essential)	 007089a

General Instructions

[210 EN]

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. Screw tightening sequences, torque specifications and sealant application patterns for major component parts appear in this section and also in the **ENGINE TORQUE SPECIFICATIONS** section.

W A R N I N G

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

N O T E

- After cleaning the components, 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.
- Do not reuse M8 bolts. Lubricate threads, washers and under screw heads with clean engine oil except as noted.
- Do not lubricate coated bolts.

S E R V I C E H I N T

Room temperature vulcanizing (RTV) sealant cures in 20 minutes of exposure to the atmosphere. If it should cure before assembly of mating components, remove it and apply fresh.

Crankshaft Installation

[212 HP]

W A R N I N G

The crankshaft is heavy. Do NOT attempt to install the crankshaft without the help of an assistant or the use of a suitable lifting device. Failure to heed this warning may result in severe personal injury and component damage.

1. Perform a visual inspection of the crankshaft journals, block and bearing caps for signs of wear and/or damage. Check the back of the bearing for bearing size. Bearings can be stamped as “STD” for standard, or with a number indicating the oversize of the bearing insert (shell).
2. Clean the main bearing seats in the cylinder block and install **new** bearing inserts (shells). Lubricate the bearing insert surfaces with engine oil.

N O T E

The bearing shells should not be lubricated on the outside.

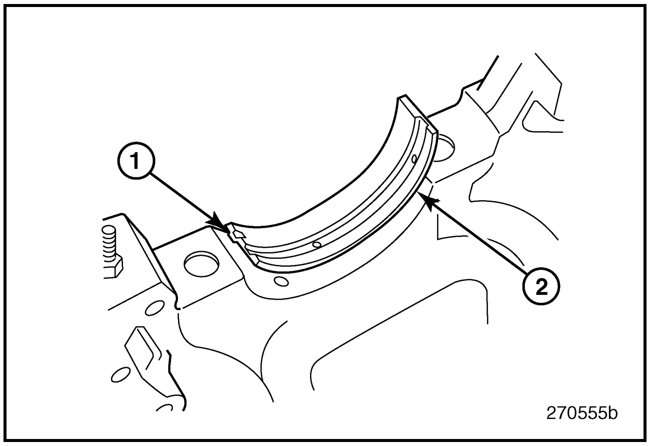


Figure 254 — Main Bearing (Upper)

1. Locating Tab	2. Bearing

3. Using the crankshaft lifting tool, J 49002, carefully position the crankshaft in the cylinder block.

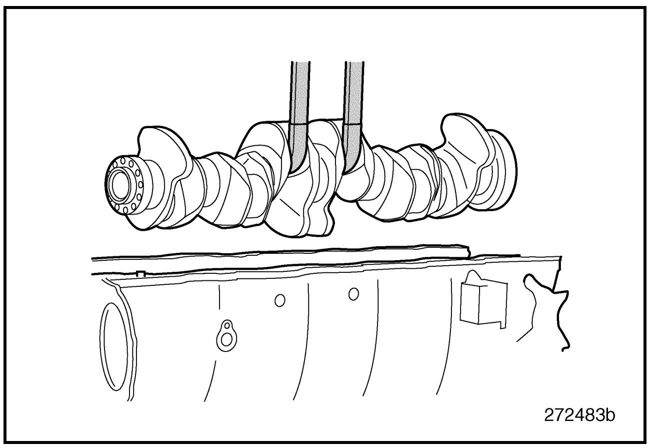


Figure 255 — Crankshaft Installation

Main Bearing Cap Installation

[212 HH]

1. Clean the bore in the bearing cap and back of the lower bearing.
2. Install the bearing in the bearing cap. The bearing must be installed dry.

N O T E

Lubricate the bearing insert surfaces with clean engine oil.

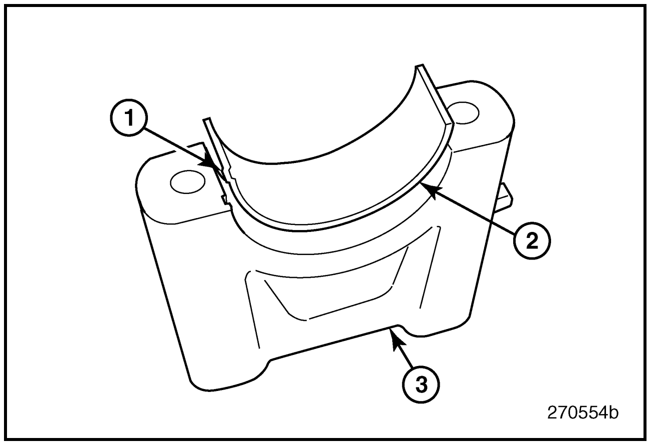


Figure 256 — Main Bearing Cap Installation (Lower)

1. Locating Tab 2. Bearing Insert	3. Bearing Cap

3. Lubricate the threads of the fasteners with clean engine oil and insert in the caps.
4. Position the No. 1 bearing cap over the No. 1 crankshaft journal and start the capscrews in the threaded holes in the cylinder block.

N O T E

Make sure the bearing caps are correctly fitted (see markings on the cap).

5. Using a plastic mallet, tap the bearing cap down until it contacts the machined mounting surface.

6. Tighten the bearing cap screws finger-tight.

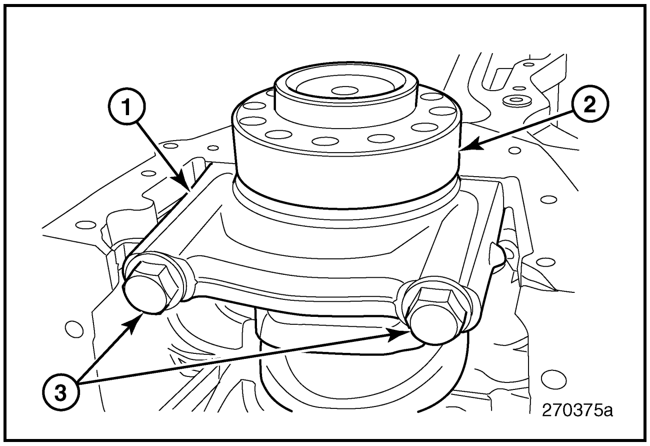


Figure 257 — No. 1 Main Bearing Cap — Assembled

1. No. 1 Main Bearing Cap 2. Crankshaft Hub	3. Cap Attaching Screws

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. Using a torque wrench, tighten the bearing cap screws according to specification.

NOTE

- Thrust washers are steel with a bronze facing. The bronze facing has oil grooves cut into the material.
- Use standard thickness thrust washers initially.

9. Place the upper thrust washer sections in position in the cylinder block at the center bearing location. The steel side of the thrust washer faces the block. The bronze side faces the crankshaft. This applies to both upper and lower thrust washer sections.

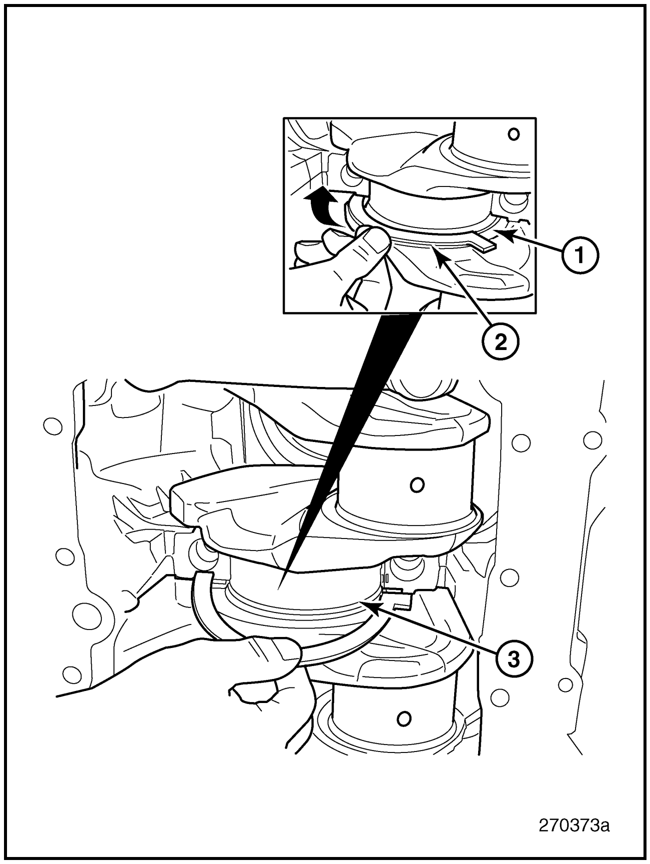


Figure 258 — Crankshaft Thrust Washer Installation

1. Thrust Washer Groove 2. Thrust Washer, Upper Insert	3. No. 4 Crankshaft Journal

10. Position the lower thrust washer sections on the center bearing cap with the bronze side facing the crankshaft and assemble the bearing cap and screws in the cylinder block.

NOTE

Lubricate thrust washer sections with engine oil before installation.

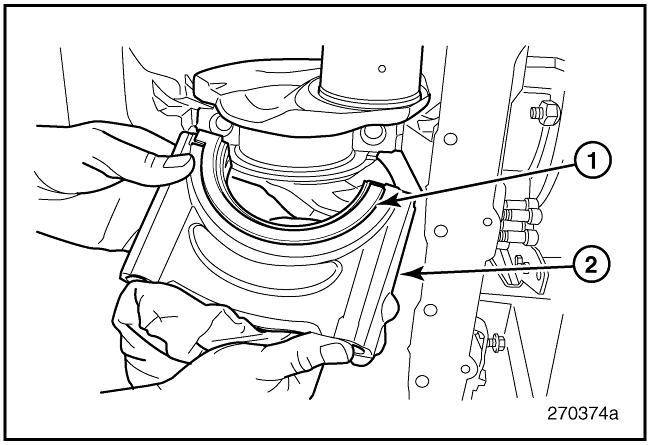


Figure 259 — Main Bearing Cap/Thrust Washer Installation

1. Thrust Washer, Lower Insert	2. No. 4 Main Bearing Cap

11. Using a torque wrench, tighten the bearing cap screws according to specification.
12. Using a suitable pry bar, move the crankshaft toward the front or rear of the engine until it stops.
13. Using a plastic mallet, tap the end of the crankshaft to seat the thrust washers.
14. Using the pry bar, move the crankshaft in the opposite direction.
15. Using a plastic mallet, tap the opposite end of the crankshaft to seat the thrust washers on the other side.

NOTE

Refer to allowable crankshaft end play tolerances under *Fits and Limits* in the **SPECIFICATIONS** section.

16. Using a magnetic base indicator tool with its tip against a crankshaft counterweight, check crankshaft end play as follows.
    a. Set the dial indicator to zero.
    b. Using the pry bar, move the crankshaft endwise and read the indicator.
    c. If end play is out of specification, remove the thrust washers and install washers of suitable thickness to meet specification.

CAUTION

The thickness of the thrust washers in the bearing cap must match the thickness of the thrust washers in the cylinder block. Be sure to put the bronze bearing surface against the crankshaft. Failure to heed this caution may result in severe component damage.

17. Using a torque wrench with the correct thrust washer sections in place, tighten all bearing cap screws according to specification.
18. Recheck the end play to be sure that the thrust washers have been installed correctly and that end play is within specification.
19. Rotate the crankshaft by hand several rotations to verify that the bearings have been properly installed and that the crankshaft turns freely.

Piston and Connecting Rod Assembly Installation

[212 NP, 212 LP]

PISTON AND ROD ASSEMBLY

1. Rotate the crankshaft so that the journals for the No. 1 and No. 6 cylinders are at bottom dead center (BDC).

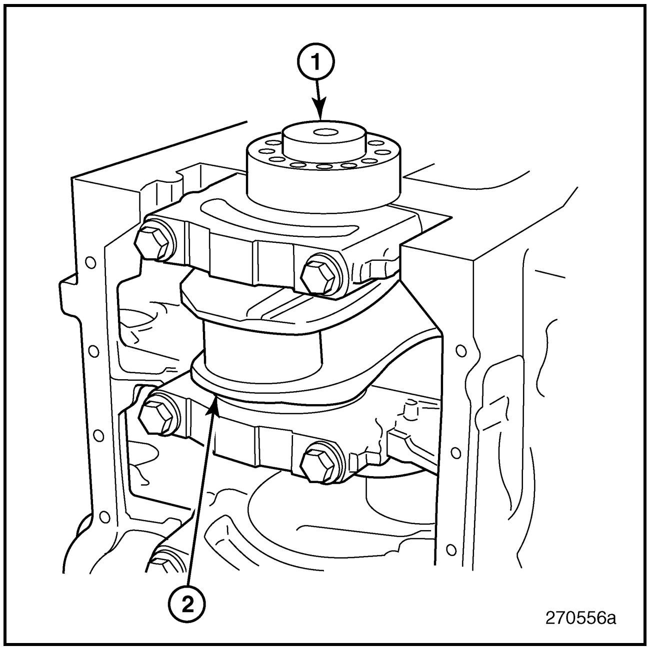


Figure 260 — No. 1 Cylinder (Crankshaft at BDC)

1. Crankshaft	2. No. 1 Journal

2. Apply a light coat of clean engine oil to the piston and rings. Check that the piston ring gaps are equally displaced around the circumference of the piston at a 120-degree relationship to one another.
3. Apply a light coat of clean engine oil to the inside surface of the piston ring compressor tool.
4. Carefully clean the bearing contact on the connecting rods and bearing caps. Also, clean the bearing seats.
5. Position a **new** upper bearing insert into the connecting rod. Align the tab in the bearing with the notch in the rod.

NOTE

The bearing size is found on the back of the bearing shell.

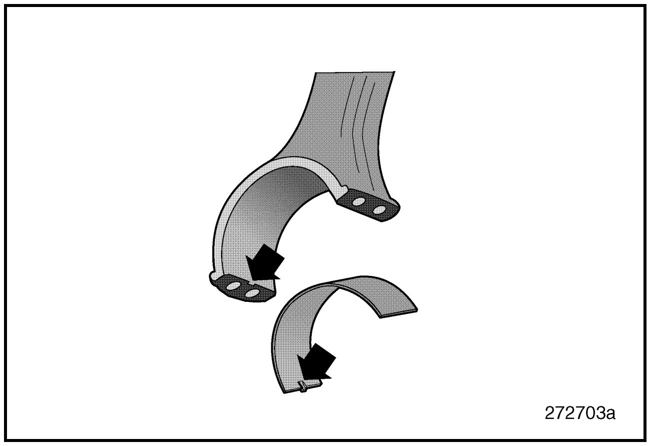


Figure 261 — Connecting Rod Bearing Shell

6. Apply a light coat of clean engine oil to the bearing surface.
7. Apply a light coat of clean engine oil to the inside surface of the cylinder liner.
8. Temporarily remove the press tool, 9996966, when the piston is to be installed. Reinstall the press tools when the piston is in position.

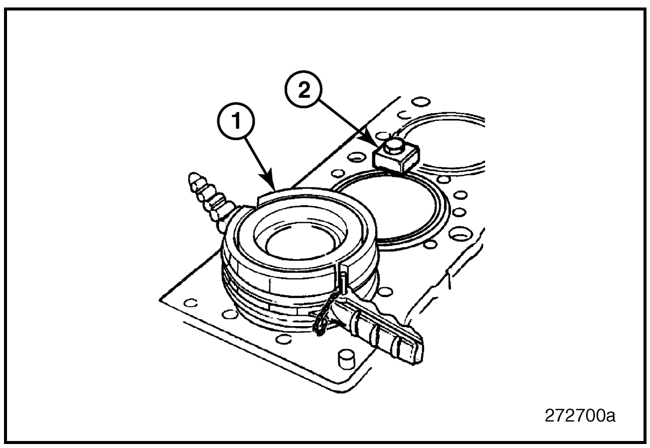


Figure 262 — Piston Installation

1. Piston Ring Compressor, 9998531	2. Press Tool, 9996966

9. Using the ring compressor, slide the piston and rod assembly into the cylinder until the compressor contacts the top of the liner.

⚠ CAUTION

*The arrow on top of the piston and the word **FRONT** on the connecting rod must be facing the front of the engine. This ensures that the notch in the lower rim of the skirt clears the piston cooling nozzle.*

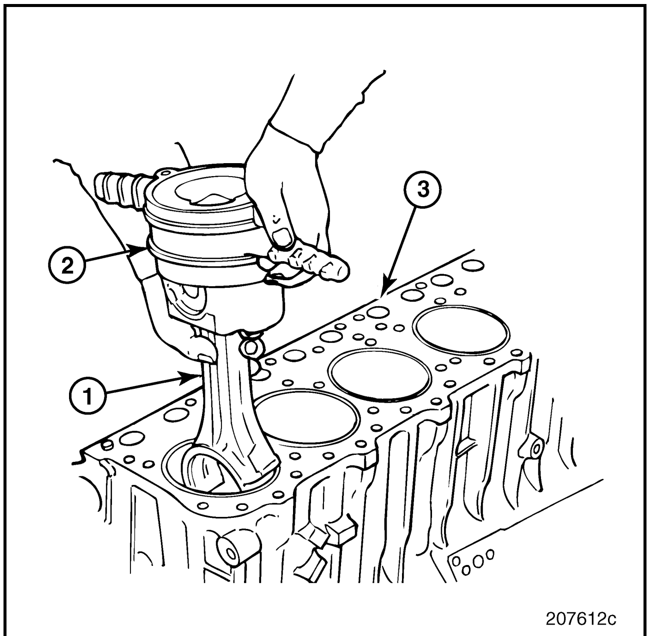


Figure 263 — Piston and Connecting Rod Installation

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 using a hammer handle to push the piston through the tool, apply pressure to the ring compressor tool to maintain contact with the cylinder liner. Continue pushing the piston until the top ring has passed into the cylinder liner.

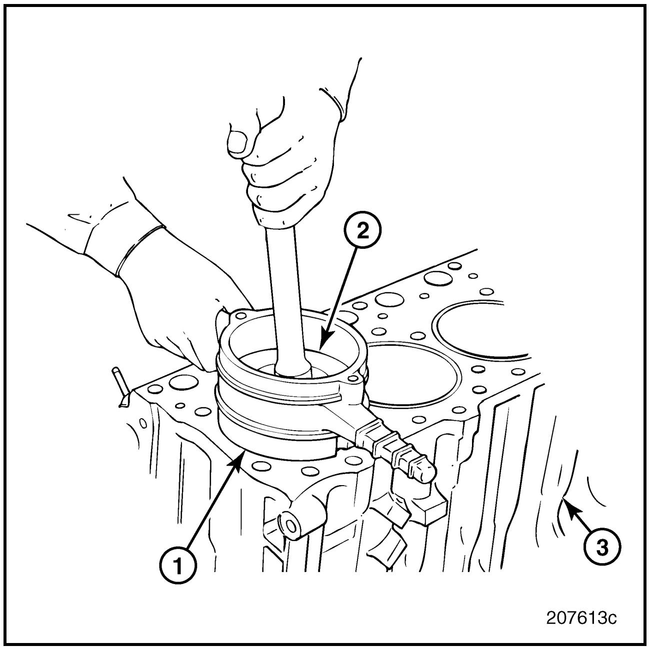


Figure 264 — Pushing Piston into Cylinder Liner

1. Piston Ring Compressor Tool	2. Piston 3. Cylinder Block

⚠ CAUTION

Do not use excessive force on the piston. High resistance indicates an incorrectly aligned ring. Remove the piston assembly, correct the problem, and then reinsert it. Make sure the compressor tool remains in contact with the cylinder liner until the piston clears the tool. Failure to heed this caution may result in severe engine damage.

12. Lubricate the crankshaft bearing inserts and crankshaft journals with engine oil.
13. Ensure that the correct cap is fitted to the correct connecting rod (refer to the marks).

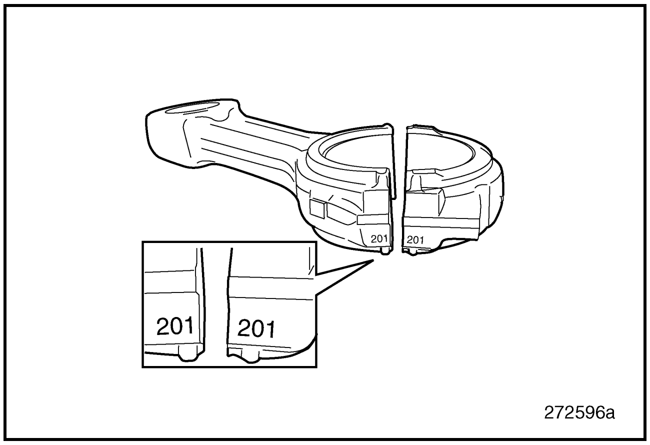


Figure 265 — Connecting Rod Bearing Shell

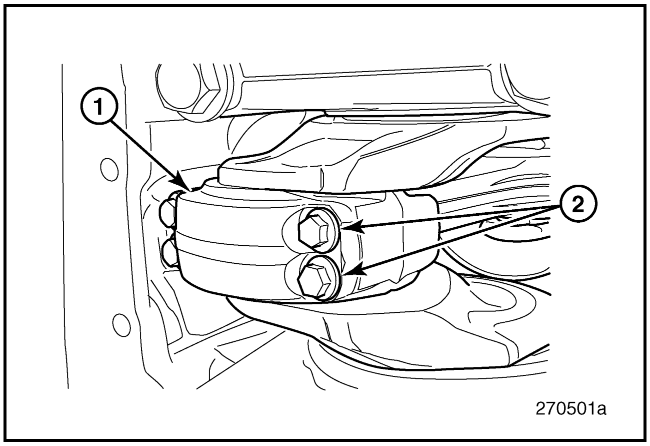


Figure 266 — Connecting Rod Cap Installed

1. Connecting Rod Cap	2. Attaching Screws

14. Repeat the above steps to install the No. 6 piston.
15. 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.
16. 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.
17. Install all piston cooling nozzles using **new** fasteners.

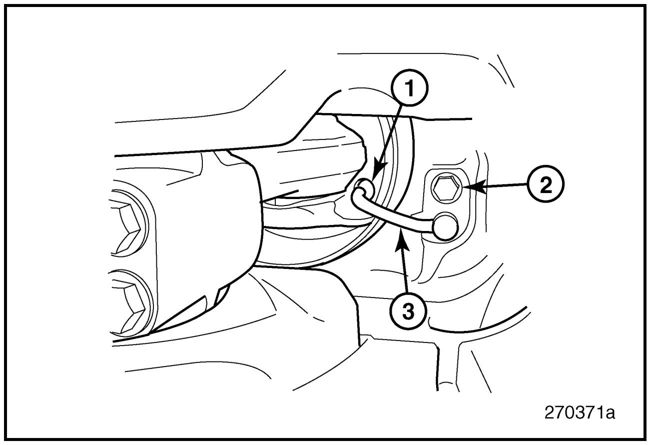


Figure 267 — Piston Cooling Nozzle Installation

1. Piston Duct 2. Attaching Screw	3. Piston Cooling Nozzle

Oil Pump and Block Stiffener Plate Installation

[211 DD]

OIL PUMP

NOTE

Clean the oil pump mounting surface of the rear main bearing cap before installing the **new** oil pump.

1. Position the oil pump to the rear main bearing cap and install the pump attaching screws.

NOTE

The crankshaft may need to be rotated to allow access for the oil pump fasteners.

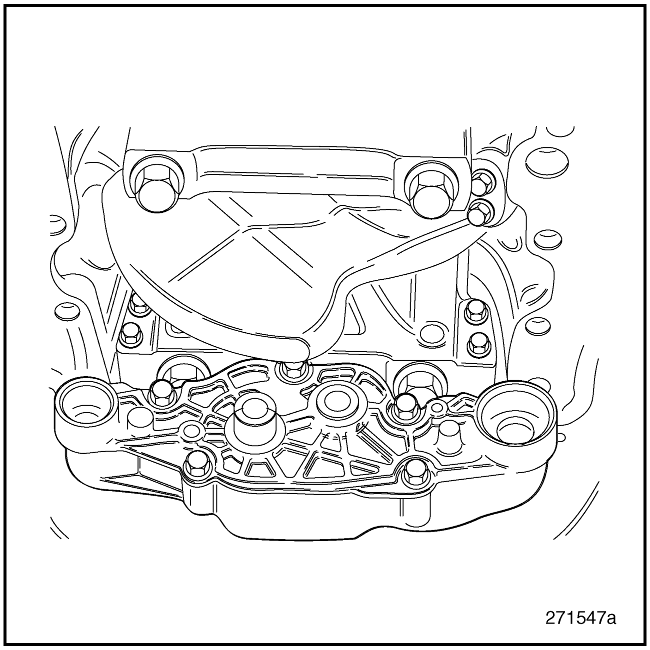


Figure 268 — Oil Pump Fastener Access

2. Tighten the oil pump screws according to specification.

BLOCK STIFFENER PLATE

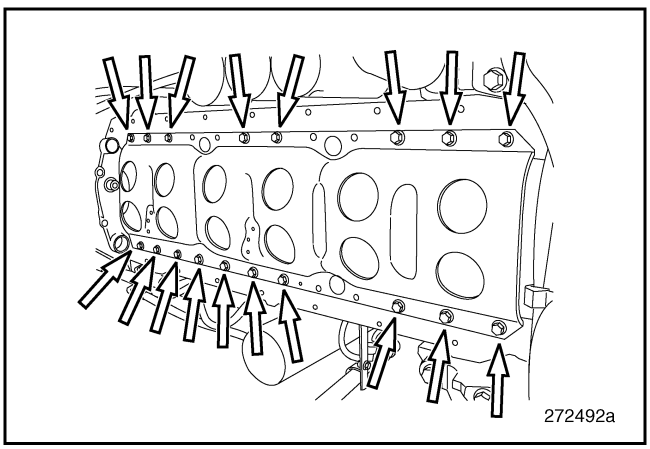


Figure 269 — Block Stiffener Plate

WARNING

The block stiffener plate has sharp edges that can cause injury. To prevent injury, wear protective gloves when handling.

1. Assemble the stiffener plate on the cylinder block with **new** fasteners. Do NOT tighten the fasteners at this time.

NOTE

- The block stiffener plate attaching screws are ONE TIME USE ONLY. New screws must be installed.
- The available tool, 9998649, can be used to hold the stiffener plate in position while the screws are started.

2. Install the oil pressure pipe and the crossover pipe before tightening the stiffening frame.
3. Using a torque wrench, tighten the attaching screws in sequence according to specification.

Oil Pump Pipes and Strainer Installation

[219 MU, 219 NT]

1. Replace the O-rings on the oil pressure pipe, oil suction pipe and oil crossover pipe. Lubricate the O-rings with engine oil before installation.

NOTE

Separate the oil suction pipe from the oil strainer as needed to replace the O-ring. Clean and inspect the oil strainer, suction pipe, crossover pipe and pressure pipe for cracks. Replace if necessary.

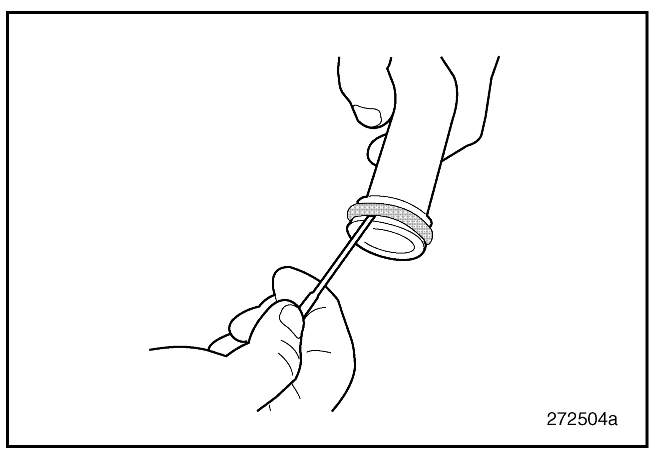


Figure 270 — Oil Pump Pipe O-Ring Replacement

2. Assemble the oil strainer, suction, pressure and crossover pipes into the oil pump as follows:
   - Slide the oil pressure pipe into the oil pump, position the pipe flange to the cylinder block, install the screws and tighten according to specification.
   - Position the oil crossover pipe to the skirts of the cylinder block, install the screws and tighten according to specification.
   - Assemble the oil strainer and oil pickup pipe. Slide the oil pickup pipe into the oil pump, position the oil strainer to the block stiffener plate, install the screws and tighten according to specification.

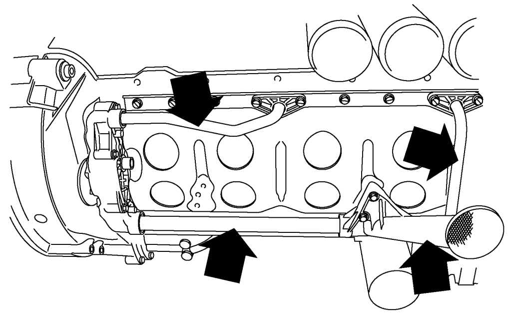


Figure 271 — Oil Pump Pipe Installation

Front Engine Support Installation

[299 GV]

1. If removed, assemble the front engine support mounting bracket to the cylinder block and tighten the screws according to specification.

NOTE

The bracket also serves as the A/C compressor mount.

2. Assemble the front engine support on the cylinder block mounting brackets and install the six screws.
3. Using a torque wrench, tighten all screws in sequence according to specification.

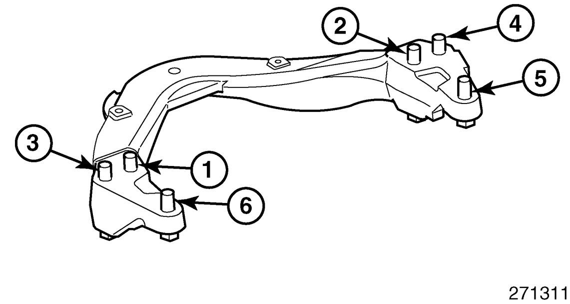


Figure 272 — Front Engine Support

Crankshaft Front Cover and Seal Installation

[211 JB]

1. Place the crankshaft front cover with spacer, 9998170, in the center on a flat surface. Install a **new** crankshaft seal with plastic ring in the crankshaft front cover. The spacer ring prevents the plastic ring from sliding off. Carefully tap the crankshaft seal into the front cover with drift, 88800021, and handle, 9992000, until the crankshaft seal is level with the front cover.

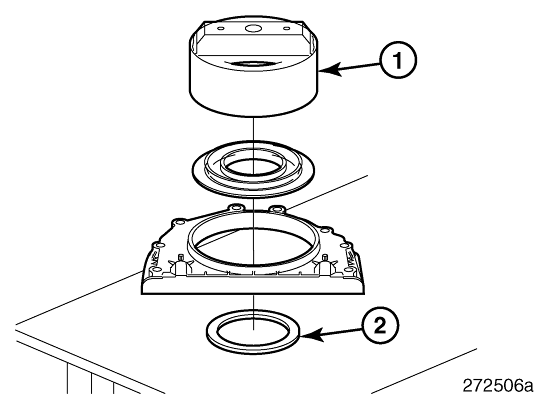


Figure 273 — Crankshaft Front Cover Seal Installation

1. Front Main Seal Remover/installer, 88800021	2. Plastic Spacer, 9998170

2. Apply a 2 mm (5/64 inch) bead of MACK-approved sealant to the rear face of the cover according to the pattern shown.

NOTE

Make sure that the crankshaft front cover and cylinder block flanges are thoroughly cleaned before applying the sealant.

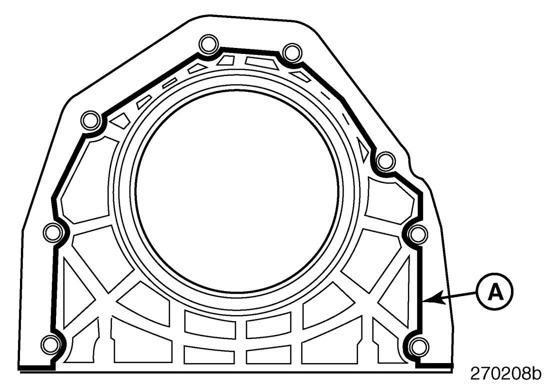


Figure 274 — Sealant Application Pattern — Crankshaft Front Seal Cover to Block

A. Apply sealant here.

3. Within 20 minutes of sealant application, install the front cover to the cylinder block. Center the crankshaft front cover against the crankshaft using the plastic ring.
4. Install the front cover. Note that there are two different types:

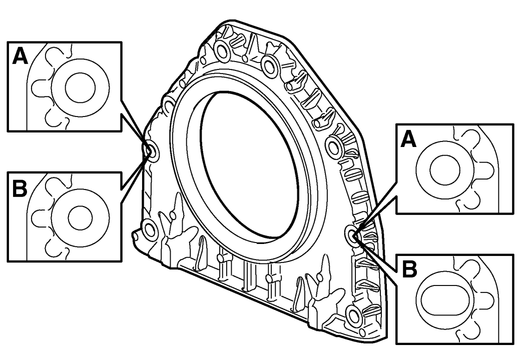


Figure 275 — Crankshaft Front Cover

- **For earlier type (A), the following installation instructions apply:**

  Install the bolts without tightening them. Using a straightedge rule, make sure the cover is flush with the lower edge of the cylinder block.
- **For later type (B), the following installation instructions apply:**

  Install the bolts in both bolt holes that align the cover to the correct position. Tighten by hand so that the cover is fixed. Install the remaining bolts.

NOTE

For the later type cover, the left-hand hole is smaller and the right-hand hole is oval. This change allows the later cover to be correctly aligned.

5. Using a torque wrench, tighten the screws in sequence according to specification.

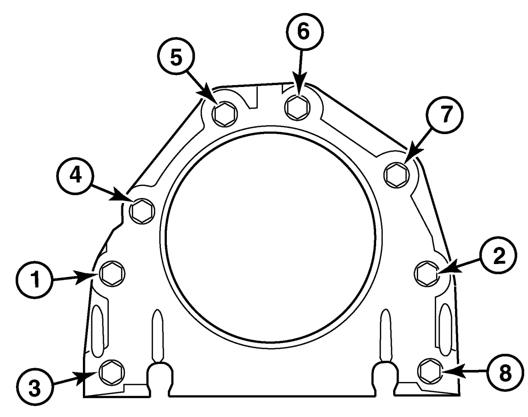


Figure 276 — Front Cover Torque Sequence

6. Remove the plastic ring from the crankshaft hub. Drive in the crankshaft seal with drift, 88800021, and handle, 9992000, until the drift bottoms against the crankshaft.

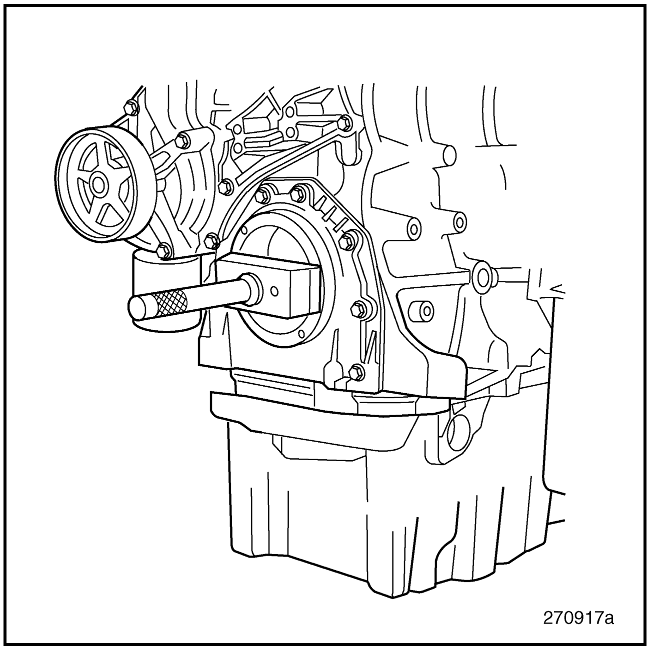


Figure 277 — Crankshaft Front Seal Installation

7. Remove the tool and check the seal to be sure it has been evenly installed.

Timing Gear Plate Installation

[211 AA]

NOTE

Rotate the cylinder block so the rear surface is at the top.

NOTE

If the cylinder head is installed after the timing gear plate is in place, do not apply sealant in the cylinder head area until ready to assemble the head on the cylinder block.

1. Clean the timing gear plate on both sides.
2. Clean the contact surfaces on the cylinder block and cylinder head. Remove sealing compound from the groove on the cylinder block side.
3. Apply a 2 mm (5/64 inch) bead of MACK-approved sealant (A) to the front face of the plate according to the pattern shown.

NOTE

Sealing compound must be applied **outside** the groove in the timing gear plate. This causes the excess compound to be forced down into the groove, which allows for better sealing.

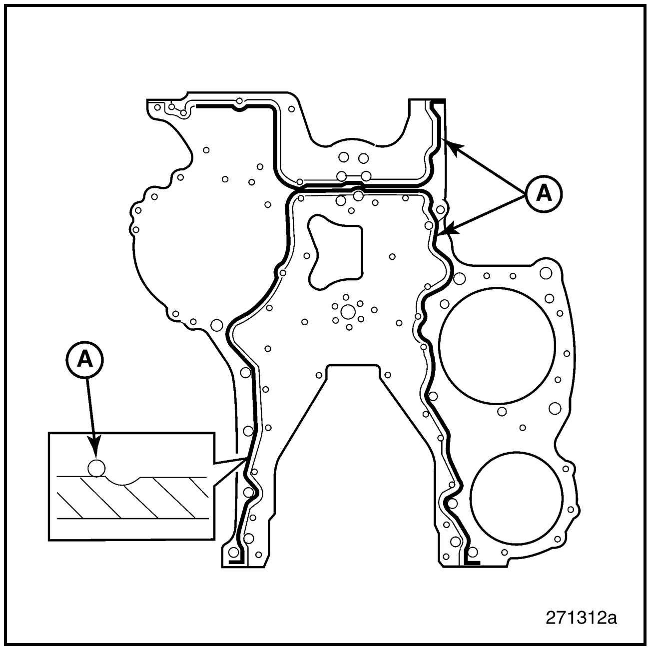


Figure 278 — Sealant Application Patterns — Head and Block to Plate

4. Within 20 minutes of the application of the sealant, assemble the timing gear plate over alignment guides, 9998267, that were installed into the cylinder block at disassembly.

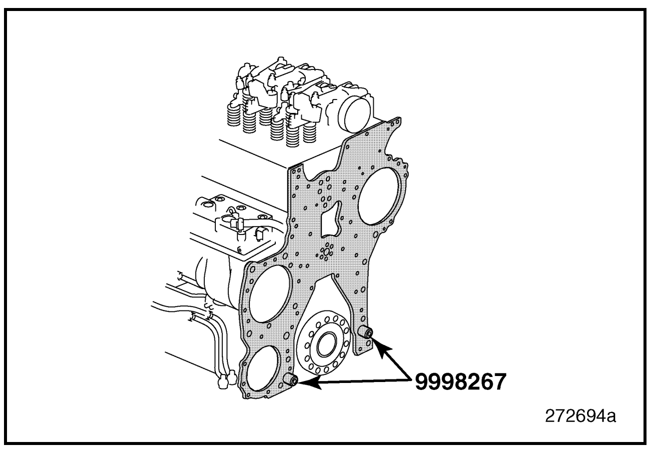


Figure 279 — Gear Plate Installation

5. With timing gear plate in position over the alignment guides, install **new** timing gear plate attaching screws

6. Using a torque wrench, tighten the attaching screws in sequence according to specification.

NOTE

Clean away excessive sealing compound before it dries.

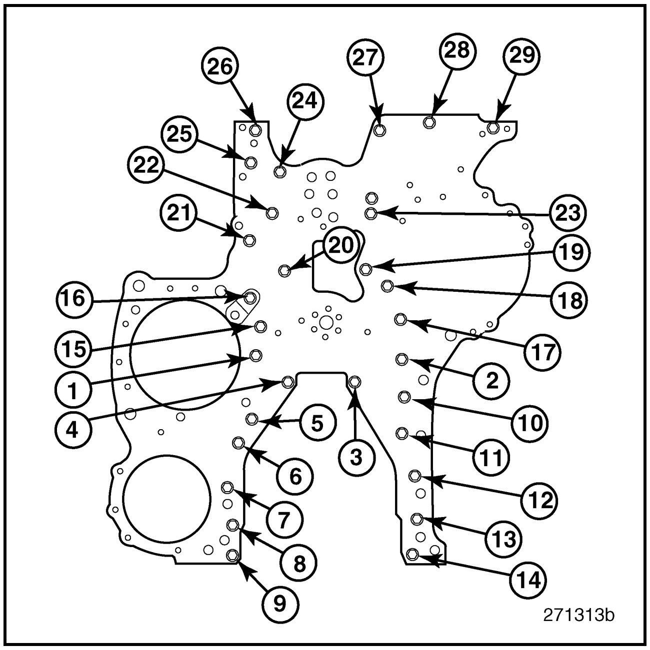


Figure 280 — Timing Gear Plate Tightening Sequence

7. Install the compressor stud with a **new** sealing ring and **new** screw.

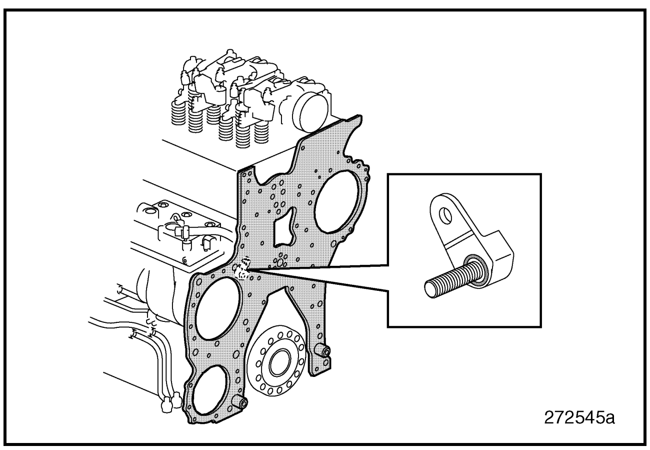


Figure 281 — Compressor Stud

8. Remove the alignment guides from the timing gear plate.

Cylinder Head Installation

[213 EV]

WARNING

The cylinder head is heavy. Do NOT attempt to install the cylinder head without the help of an assistant and the use of a suitable lifting device. Failure to heed this warning may result in severe personal injury and component damage.

NOTE

All MACK head gaskets are precoated and do not require any type of additional sealing compound.

1. If necessary, clean the unit injector copper sleeves with brush J 42885-9 and extension J 42885-1 with J 42885-25 installed to protect the fuel passages. These tools are available in kit J 42885.

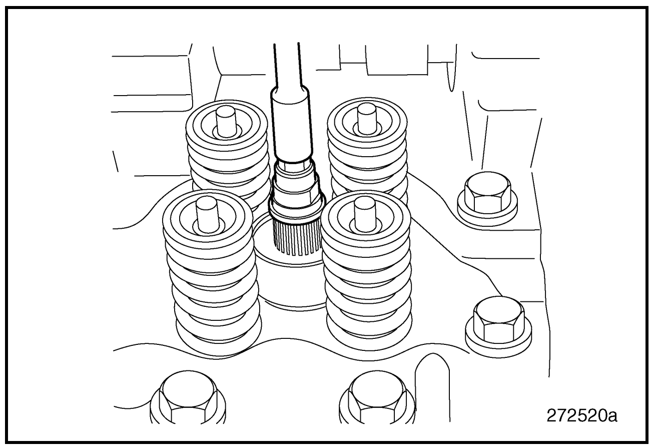


Figure 282 — Injector Copper Sleeve Cleaning

NOTE

With any cleaning of the unit injectors, **under no circumstances** may rotary wire brushes, hand wire brushes or similar tools be used on the injector nozzle. Use of such tools poses a risk that the injector holes could be damaged and blocked, causing power delivery problems. Instead, use a rag soaked in paraffin or equivalent.

2. Install unit injector bore plugs, 9998251.

3. Ensure that the cylinder block and deck are clean and free from any dirt, grease or oil.
4. Carefully clean the cylinder head and install the head lifting tool, 88800188. Check that the guide washers on the cylinder block and cylinder head are clean and free of rust.

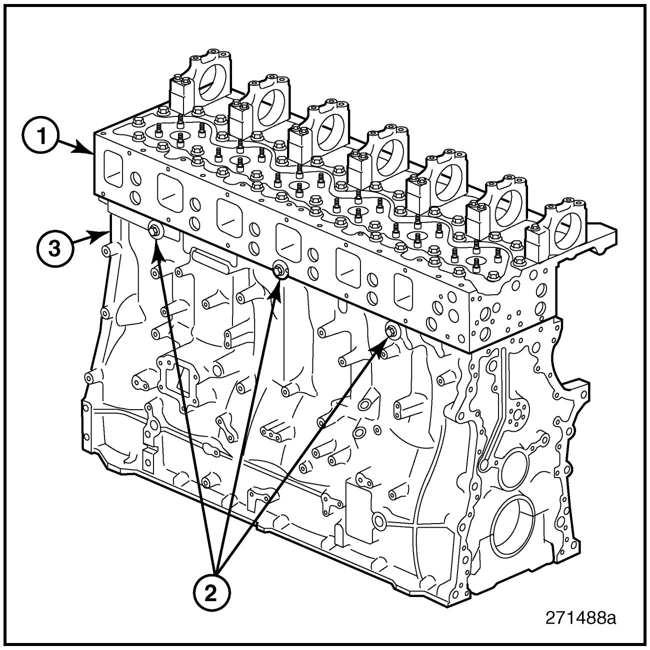


Figure 283 — Guide Washer Locations

1. Cylinder Head 2. Guide Washers	3. Cylinder Block

5. If in place, remove the cylinder liner clamping tools from the cylinder block.

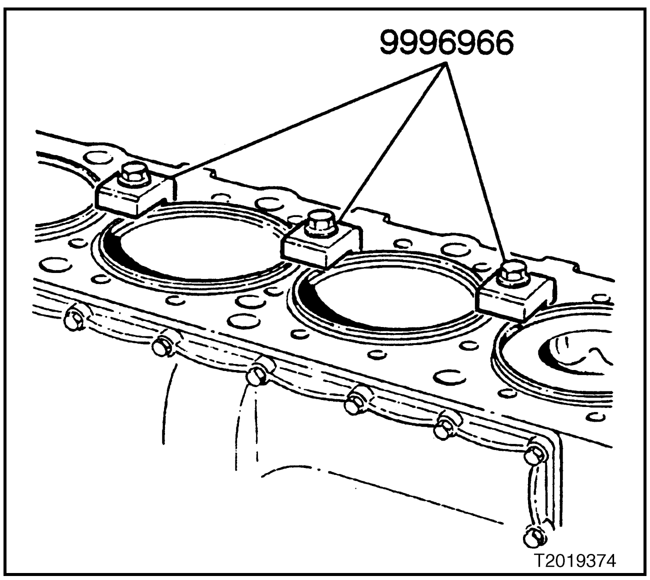


Figure 284 — Cylinder Liner Clamping Tools

6. Apply a 2 mm (5/64 inch) bead of MACK-approved sealant to the surface at the side of the “track” on the timing gear plate (as shown in the illustration).

NOTE

The cylinder head must be installed and tightened within 20 minutes of the sealant being applied.

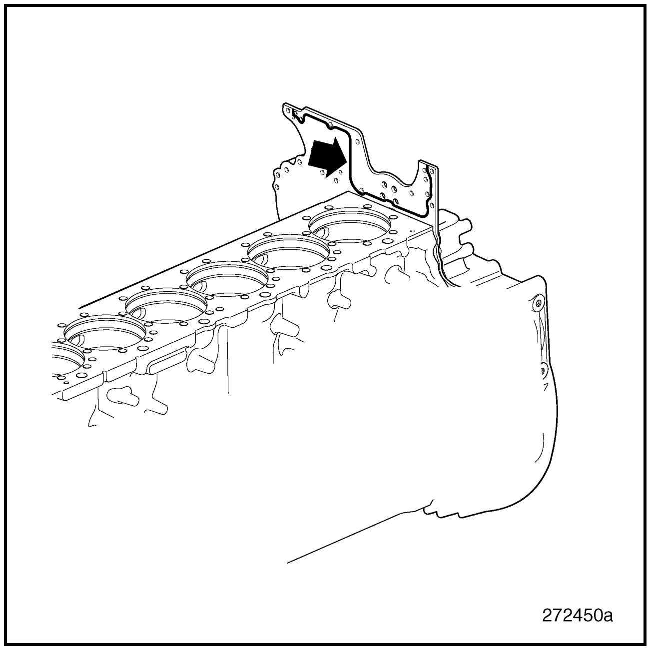


Figure 285 — Sealant Application Pattern — Head to Plate

7. Place a **new** head gasket on the cylinder block deck.

NOTE

- Check that the seals are correctly positioned with their holes all centered.
- There are points embossed in the gasket that will temporarily protect the seals from the head. These will be compressed when the head bolts are tightened.
- The head gasket should be discarded if the head is removed. A **new** gasket should be used when the head is installed.

8. Carefully lower the cylinder head about 9 mm (3/8 inch) forward of the timing gear plate until it makes contact with the cylinder head gasket. Press the cylinder head against the timing gear plate and the guide washers at the left side. (Place two guide washers on the cylinder block and one on the cylinder head for help during installation.)

NOTE

A three-step process is used for installation of the cylinder head.

a. It is first lowered onto the cylinder block deck and gasket, about 9 mm (3/8 inch) forward of the gear plate. As it is lowered, the guide washers ensure proper alignment of the cylinder head with the left side of the cylinder block.

b. Once lowered, plate mounting screws inserted through the adjustable idler gear hub are used to draw the cylinder head rearward against the plate.

c. In the final step, the cylinder head bolts are inserted and tightened to specification.

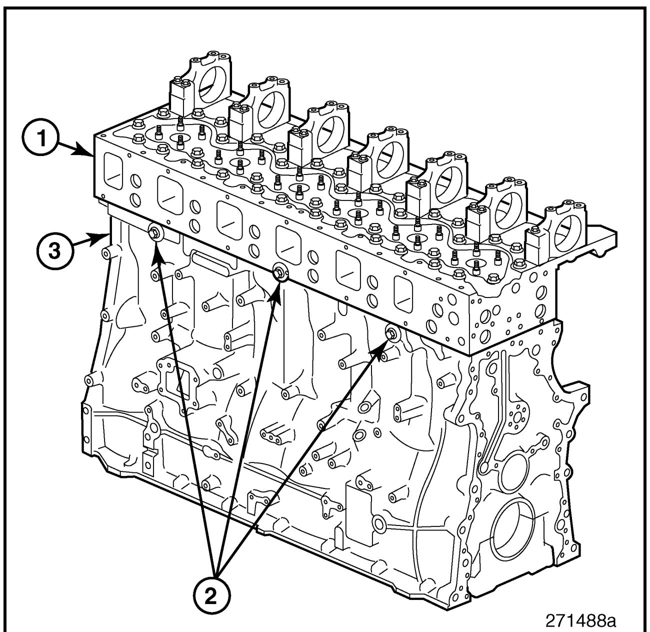


Figure 286 — Guide Washer Locations

1. Cylinder Head	2. Guide Washers 3. Cylinder Block

9. Temporarily install the adjustable idler gear and insert screws through the timing gear plate and the adjustable idler gear hub. Tighten the screws according to specification.

NOTE

If not loosened, there is a risk that the screws will break when the cylinder head screws are tightened.

10. Check the condition of the cylinder head attaching screws and lubricate the underside of the screw heads and threads with clean engine oil.

NOTE

Do NOT oil the threads in the cylinder block.

11. The cylinder head screws must **not** be used more than five times. Mark the cylinder head screws by punching them.
12. Insert four cylinder head screws into the specified locations and tighten the screws according to specification.
13. Remove the cylinder head lifting tool.
14. Tighten all cylinder head screws in sequence according to specification.
15. Install the screws to secure the timing gear plate to the rear of the cylinder head. Tighten the screws according to specification.
16. Ensure that the crankshaft is at the top dead center (TDC) position and assemble the camshaft, camshaft gear and damper according to the instructions under *Timing Gear Train Installation*.

Camshaft Installation

[213 CH]

⚠ WARNING

The camshaft is heavy. Do NOT attempt to install the camshaft without the help of an assistant or the use of a suitable lifting device. Failure to heed this warning may result in severe personal injury and component damage.

1. If removed, install the camshaft bearing saddles to the original positions. Carefully tap the bearing saddles onto the guide pins using a soft-faced hammer until fully seated.
2. Insert the camshaft lower bearings and apply a generous coating of clean engine oil to the camshaft bearings.
3. Make sure there is a bearing insert on each lower bearing saddle. The bearing inserts at the No. 7 camshaft journal have integral thrust washers.

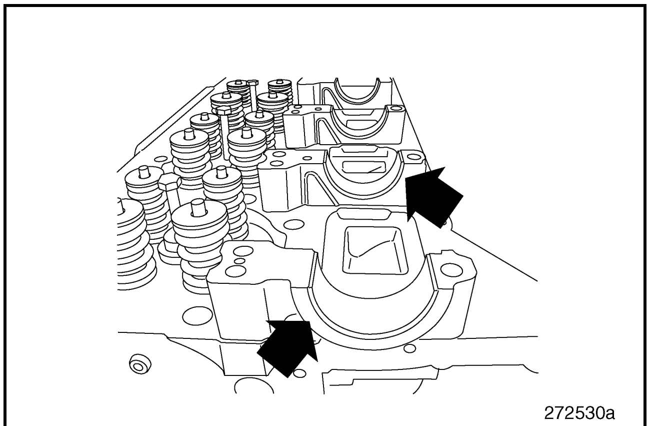


Figure 287 — No. 7 Camshaft Lower Bearing Insert

4. Clean and inspect the camshaft using solvent and compressed air.
5. Lower the camshaft carefully into place on the bearing saddles and remove the lifting tool, 85109034. Rotate the camshaft by hand to ensure the camshaft is not binding on the bearing saddles.

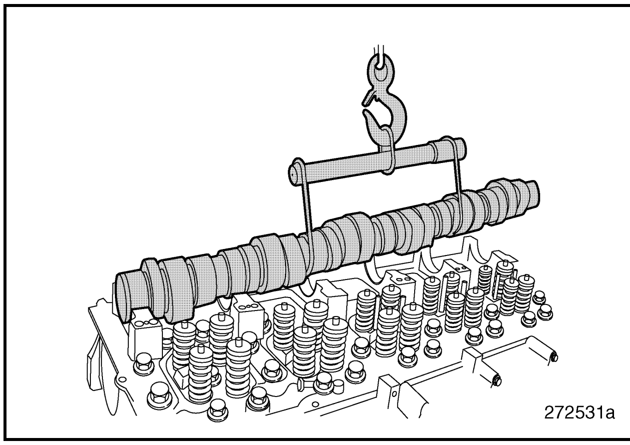


Figure 288 — Camshaft Installation

6. Install the camshaft upper bearing inserts into the camshaft bearing caps, lubricate the bearings and install the bearing caps to the respective bearing saddles. Use a soft-faced mallet to seat the bearing caps over the dowel pins.
7. Insert and hand-tighten the exhaust side bearing cap screws and tighten according to specification. Final tightening to the specified torque value will be done later when the rocker arm shaft is installed.
8. Install the bearing cap press tool (two required) at the number 7 and the number 1 bearing caps as shown in the illustration.

NOTE

The tool is used when adjusting the timing gear backlash when the rocker arm shaft assembly is not installed.

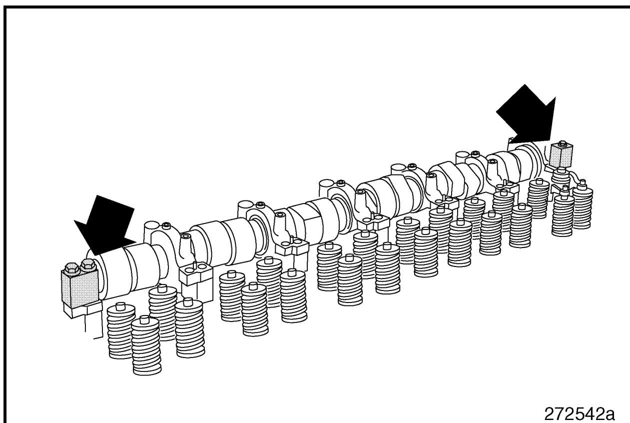


Figure 289 — Bearing Cap Press Tool

Timing Gear Train Installation

NOTE

Apply a light coat of clean engine oil to all parts before assembly.

CAUTION

Do NOT overtighten the mounting flange fasteners when installing any of the gears in the timing gear train. Overtightening the fasteners can cause stripped threads in the cylinder block.

1. Assemble a **new** O-ring on the crankshaft rear hub.
2. Apply a film of oil to the O-ring and assemble the crankshaft gear on the crankshaft hub.

NOTE

Leave two fasteners loose enough to aid in turning the crankshaft with a lever for gear alignment purposes.

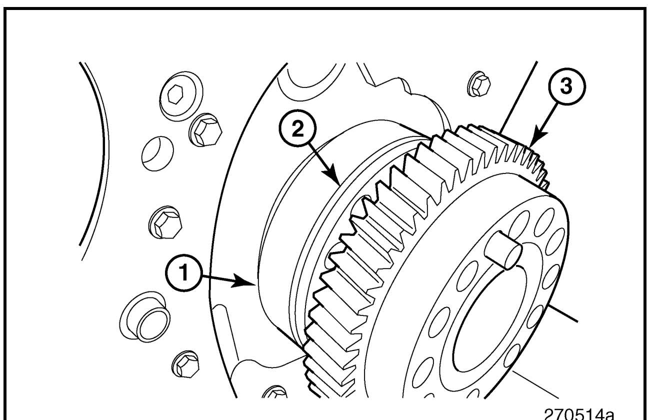


Figure 290 — Crankshaft Gear-to-Hub Assembly

1. Crankshaft Rear Hub 2. O-Ring	3. Crankshaft Gear

3. Assemble the adjustable idler gear (item 3 in Figure 291), hub, bushing, thrust washer and fasteners on the plate. Hand tighten the fasteners.

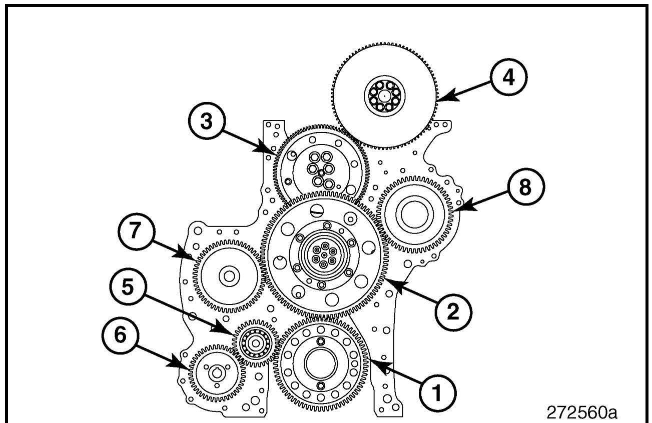


Figure 291 — Adjustable Idler Gear

1. Crankshaft Gear 2. Intermediate Idler Gearset 3. Adjustable Idler Gear 4. Camshaft Gear	5. Lower Idler Gear 6. Tandem Pump Drive Gear 7. Air Compressor Drive Gear 8. PTO Drive Gear

4. Check that the camshaft is positioned at TDC.

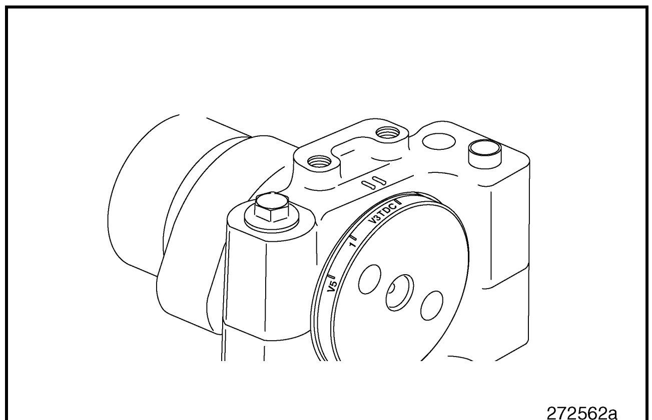


Figure 292 — Camshaft Positioning

5. Align the punch marks on the camshaft gear teeth to straddle the alignment hole in the timing gear plate and install the camshaft gear without the damper as shown in Figure 293. Install the clamp plate tool, J 44514-1A, using **Position B** of the gauge plate tool to secure the camshaft gear to the camshaft and loosely install the two retaining bolts.

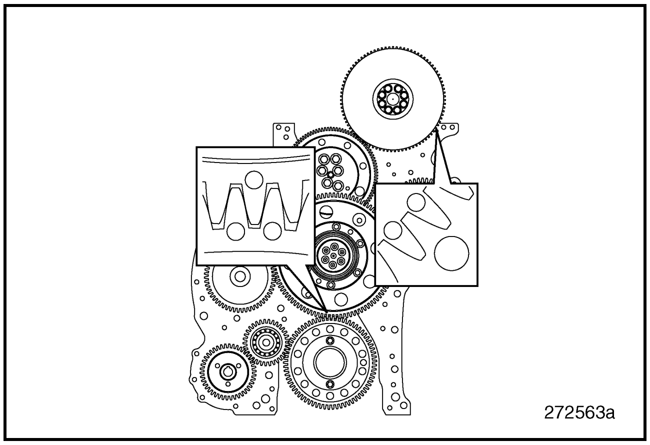


Figure 293 — Camshaft Gear Check

6. Insert the alignment tool J 47450-1 into the hole in the cylinder head to engage the camshaft gear teeth with the rod of the tool in the slot of the clamp tool. It may be necessary to rotate the camshaft until this occurs. With the alignment pin properly positioned in the clamp plate slot, check that the camshaft TDC mark is still positioned between the two timing marks on the bearing cap.

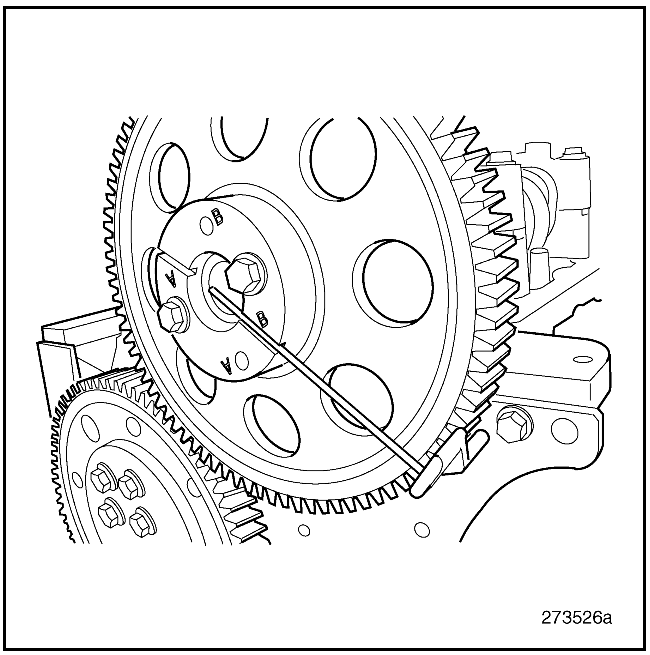


Figure 294 — Camshaft Gear Timing Marks Alignment

7. Remove the alignment pin and clamp plate tool from the camshaft gear and install the vibration damper and clamp plate using **new** bolts. Tighten the bolts according to specification.

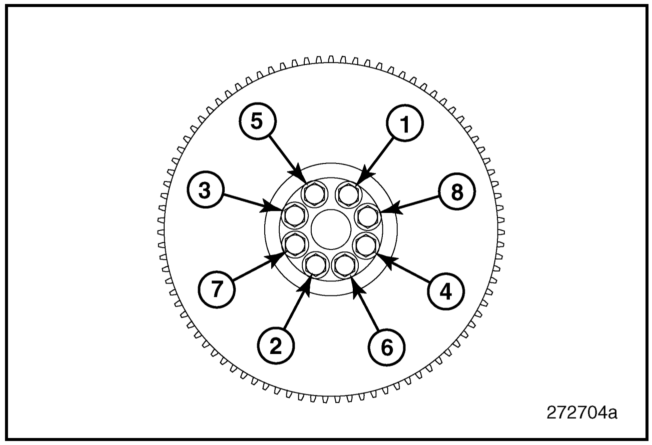


Figure 295 — Camshaft Vibration Damper Tightening Sequence

NOTE

Mark the bolts to aid in tightening the bolts to the degree rotation specification.

8. Insert a 0.1 mm (0.004 inch) thickness gauge. Adjust the idler gear so that there is slight pressure on the thickness gauge. Tighten the bolts by hand only.

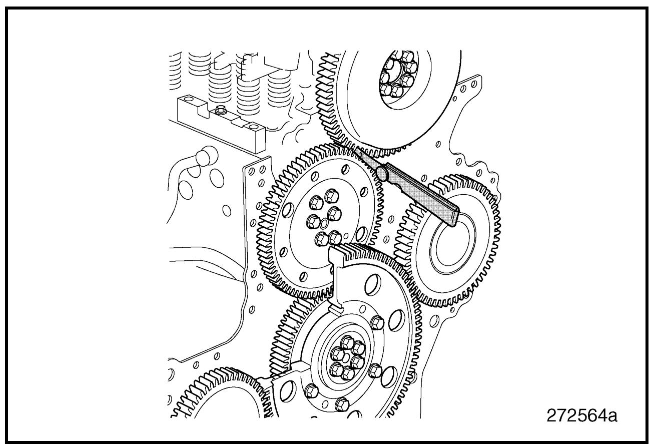


Figure 296 — Camshaft Thickness Gauge Check

9. Remove the thickness gauge.

NOTE

There should be a slight resistance on the thickness gauge when removed.

10. Install the J 44514-5 clamp assembly tool to the timing gear plate. Screw the hold-down against the adjustable idler gear so the adjustable idler gear does not rotate.

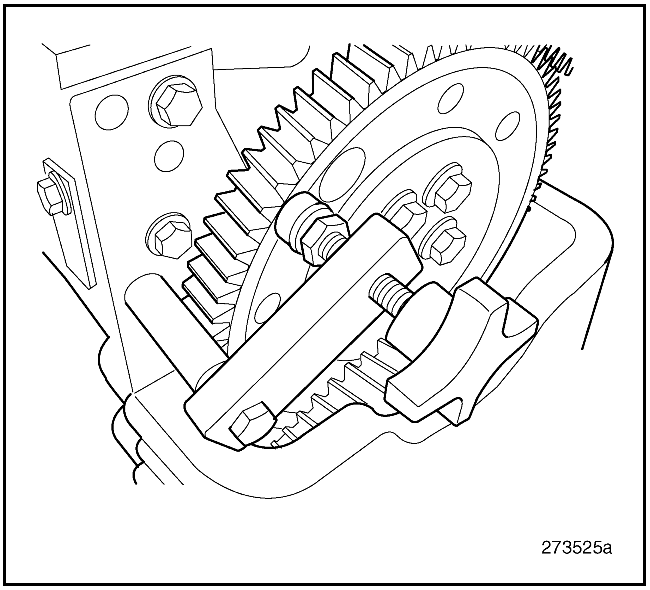


Figure 297 — Clamp Assembly Tool

11. Install the magnetic stand, 9999696, and dial indicator, 9999683, so that the tip of the dial indicator rests on a tooth of the camshaft gear.

    Check the gear backlash by rotating the camshaft gear back and forth slightly to measure the backlash. For backlash specification, refer to the SPECIFICATIONS section.

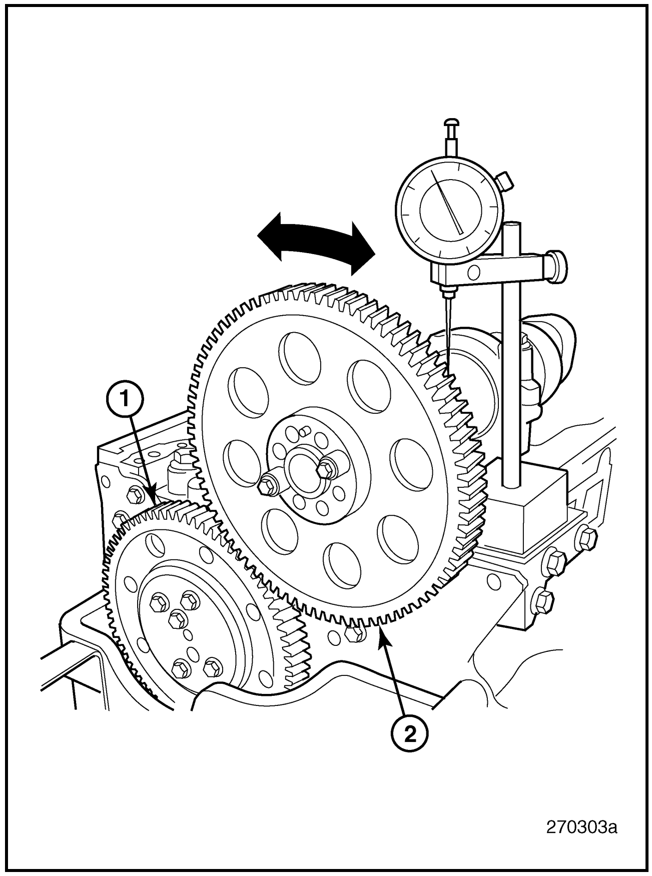


Figure 298 — Camshaft Backlash Check

1. Idler Gear	2. Camshaft Gear

12. If the backlash measurement is out of specification, adjust the gear flank clearance as follows:
    a. Loosen the J 44514-5 clamp assembly tool from the adjustable idler gear hub.
    b. Loosen the adjustable idler gear hub screws slightly. Loosening the hub screws will allow the idler gear to be moved slightly in/out from the camshaft gear.
    c. Insert a 0.1 mm (0.004 inch) thickness gauge on the pressure side of the adjustable idler gear tooth and camshaft gear tooth by using feeler gauge holder J 44935 and J 44514-6 feeler gauge.
    d. While holding the adjustable idler gear in against the thickness gauge and camshaft gear, tighten, but DO NOT torque the adjustable idler gear hub fasteners.
    e. Reinstall and tighten the J 44514-5 clamp assembly tool against the adjustable idler gear.
    f. Remove the feeler gauge from the adjustable idler gear and camshaft gear.
    g. Recheck the backlash. With the specified backlash attained, replace each adjustable idler gear hub screw with **new** and tighten the screws to specification one at a time so the attained backlash is not disturbed.

13. Install the intermediate idler (double idler) gearset (2) to the timing gear plate, using **new** bolts.

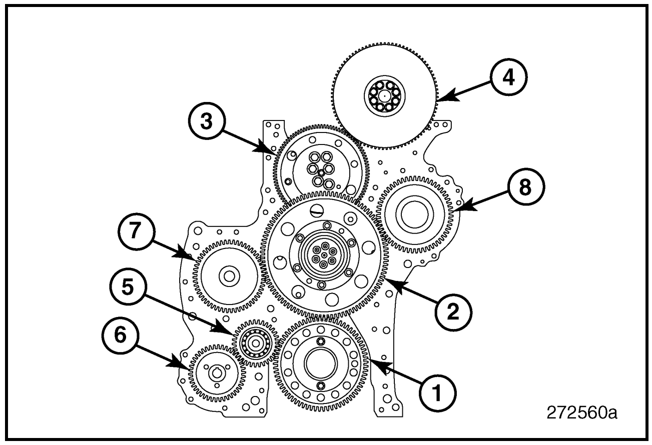


Figure 299 — Intermediate Idler (Double Idler) Gearset

1. Crankshaft Gear 2. Intermediate Idler Gearset 3. Adjustable Idler Gear 4. Camshaft Gear	5. Lower Idler Gear 6. Tandem Pump Drive Gear 7. Air Compressor Drive Gear 8. PTO Drive Gear

14. Check that the idler gear marking aligns with the markings on the crankshaft gear teeth.

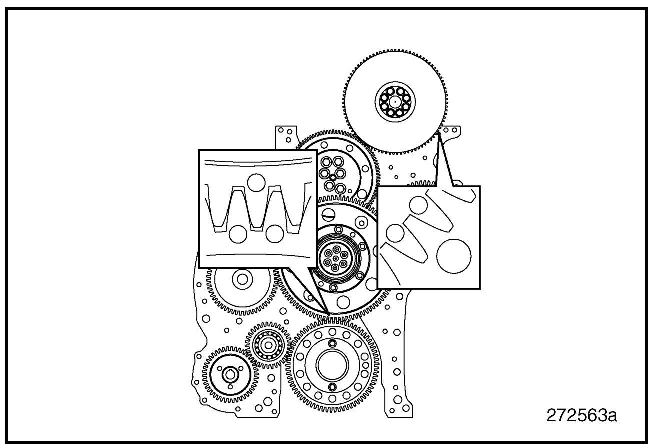


Figure 300 — Camshaft and Double Idler Gear Check

15. Tighten the intermediate gearset (double idler) mounting bolts in sequence according to specification.
16. Install the auxiliary idler gear onto the timing gear plate.
17. Remove the bearing cap press tools.

Unit Injector Installation

[221 GP]

NOTE

If a unit injector is reused, it must be fitted to the bore from which it was removed.

1. If not previously performed, install protective sleeve, J 42885-25, and clean the unit injector copper sleeve with the appropriate brush and extension.

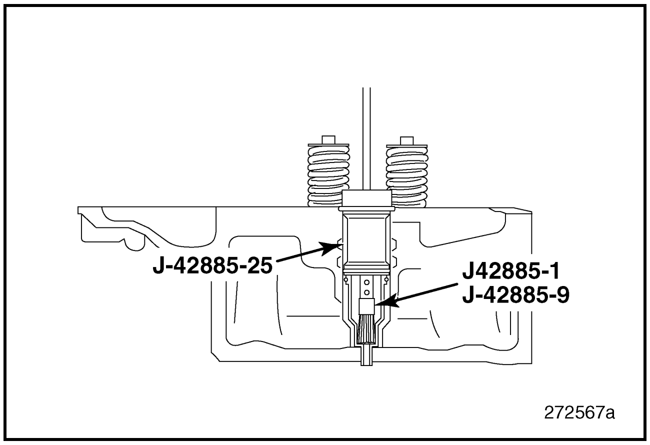


Figure 301 — Unit Injector Copper Sleeve Cleaning

NOTE

After cleaning the copper sleeve, carefully inspect the inside surface of the sleeve, especially the bottom surface where the injector seal is located. Any remaining contamination is unacceptable and must be removed. Also, if there is any indication of a discrepancy that raises concern about suitability of the sleeve for reuse, replace it with a **new** sleeve.

2. Before reusing an injector, cleaning is required to ensure suitability for reuse. Before doing any cleaning, the injector fuel inlet and outlet ports and the electrical connector opening must be covered to prevent contamination from the cleaning process. Also, there must be no lower O-ring installed in the injector. Refer to "UNIT INJECTOR CLEANING" on page 272 for further information.
3. Remove the bore protection sleeve, 9998251.

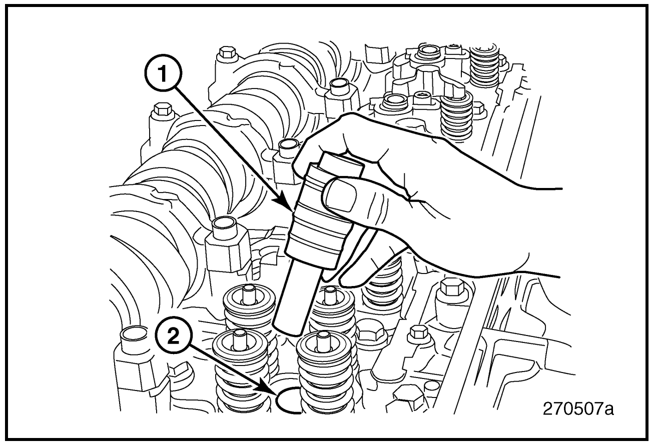


Figure 302 — Unit Injector Bore Protection Sleeve

1. Unit Injector Protection Sleeve, 9998251	2. Unit Injector Bore

4. Install **new** O-rings on the unit injector as follows:
   - Upper ring — large diameter, violet
   - Lower ring — small diameter, violet
5. Lubricate both O-rings and the cylinder head injector bore with clean engine oil.
6. Install a **new** injection nozzle gasket (flat washer) on the injector, using hand force to push it over the tip and down until it is fully seated against the bottom of the injector. DO NOT use grease or any other material to secure the gasket to the injector; the gasket must be installed dry. Three small projections (grippers) on the inside diameter of this gasket retain it to the injector during installation.

NOTE

Some early production MP8 engines used the original design copper sleeves with integral “raised bead” at the bottom of the copper sleeve. This design does NOT use a gasket (flat washer) between the injector tip and the copper sleeve. These original raised-bead design copper sleeves can be identified by a single groove, or no groove at all around the upper circumference.

The current production “flat-bottom” design copper sleeves, which require the gasket (flat washer) at the injector tip, can be identified by two grooves around the upper circumference of the sleeve.

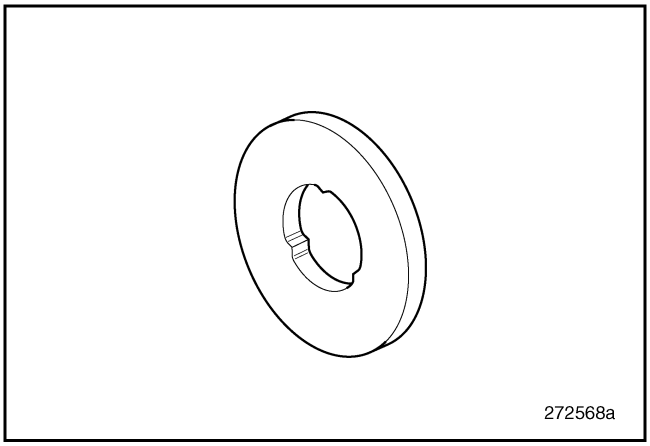


Figure 303 — Injector Nozzle Gasket

NOTE

A revised gasket (flat washer) having a thin black rubber coating for improved sealing was implemented in production beginning mid-August 2008. Service replacement gaskets now have the rubber coating. DO NOT remove the rubber coating.

The gasket (flat washer) is preassembled on new injectors.

7. Slip the injector hold down and a **new** screw of correct length onto the unit injector.

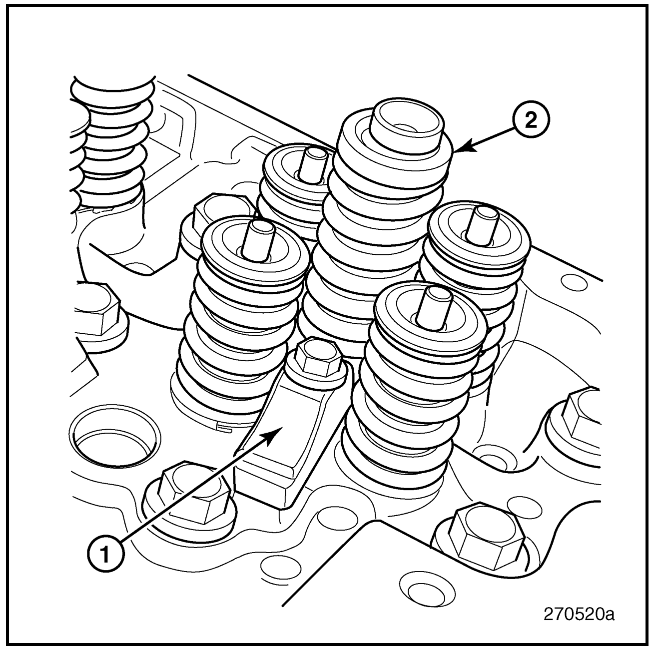


Figure 304 — Unit Injector Retainer

1. Injector Hold-Down Yoke	2. Unit Injector

CAUTION

The engine may be equipped with 28 mm high yokes or 38 mm high injector hold-down yokes. Make sure that the new replacement yoke screws are of the correct length for the injector hold-down yokes being used. Using screws of improper length may result in insufficient thread engagement and damage to the cylinder head threads during tightening.

8. Make sure that the injector is reinstalled to the same cylinder from which it was removed (or injector trim codes will need to be reprogrammed in the EECU).
9. Center the unit injector between the valve springs and then push down on the unit injector using hand pressure to seat the O-rings. Hand tighten the **new** hold-down screw.

NOTE

The injector hold-down screw must be replaced whenever it is removed from the hold-down and cylinder head.

10. Ensure that the injector electrical connector is central between the valve springs with equal space on both sides. If the harness is installed, plug in the injector electrical connector until fully engaged. Push in the connector until you hear a distinct “click”.

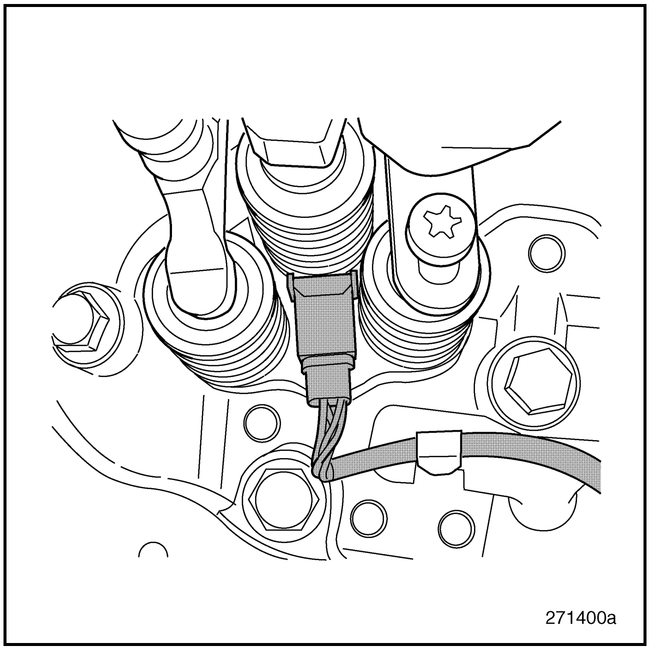


Figure 305 — Electrical Connector for Unit Injector

11. Using a torque wrench, tighten the hold-down screw in stages to specification.
12. When replacing unit injectors, the control unit must be programmed with the new injector's trim codes. The code is printed on top of the unit injector electrical connector. The programming is performed using VCADS/TT and is necessary to ensure that engine timing and emission levels are correct.

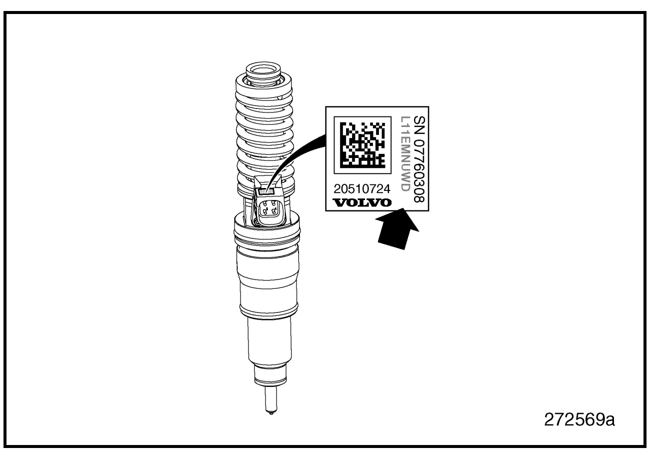


Figure 306 — Injector Trim Codes

N O T E

- Due to the Engine Electronic Control Unit (EECU) self learning capability, it is necessary to reset learned EECU parameters after servicing some engine-related components. This allows the EECU to learn the new component's behavior. After servicing is complete, perform the “Learned Data Reset” located in VCADS/TT.
- If reinstalling an injector into the same location, reprogramming is not required.

13. Repeat the installation steps for the remaining injectors.

Valve Yoke (Bridge) Installation

[213 NV]

N O T E

Used yokes have established wear patterns. Yokes being returned to service must be installed in the same cylinder location from which they were removed.

1. Lubricate the tip of a valve stem with a small drop of clean engine oil.
2. Lubricate the yoke sockets with a small drop of clean engine oil in each one.

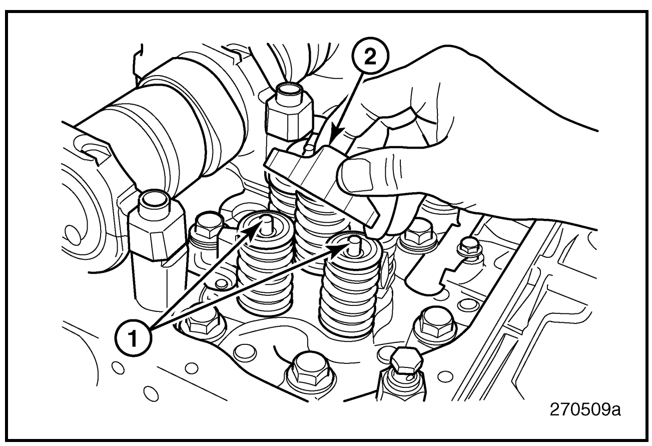


Figure 307 — Installing the Inlet Valve Yoke

1. Valves	2. Valve Yoke

3. Set the yokes on their respective valve stems.

Rocker Arm Shaft and Engine Brake Installation

[213 LP]

1. Oil the valve yokes and the camshaft lobes with engine oil.
2. Using the lifting tool, 85109250, and an assistant, place the shaft with rocker arms in position on the inboard side of the camshaft bearing caps.

NOTE

On engines with an engine brake, the exhaust rocker arm includes an integral valve and piston.

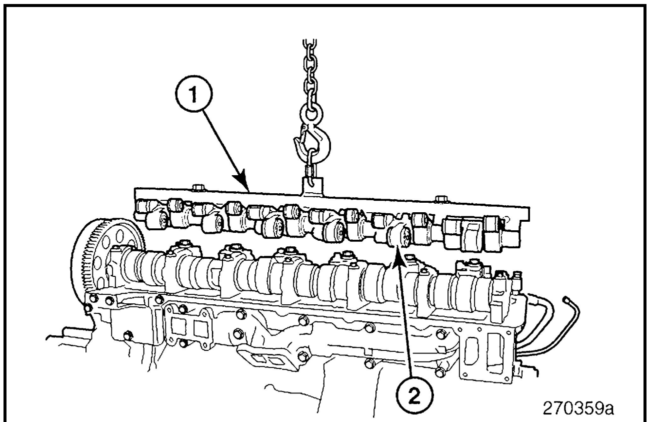


Figure 308 — Rocker Shaft Assembly Installation

1. Lifting Tool, 85109250	2. Rocker Shaft Assembly

3. Remove the lifting tool. Then, install and tighten the rocker arm shaft bolts a little at a time, evenly across the entire shaft so that the shaft does not become distorted, bent or fractured.

NOTE

Make sure that the rocker arm shaft is seated properly in the guide dowels of the camshaft bearing caps. On engines equipped with an engine brake, remove the restraints (rubber bands or tie straps) securing the exhaust rocker arm pistons.

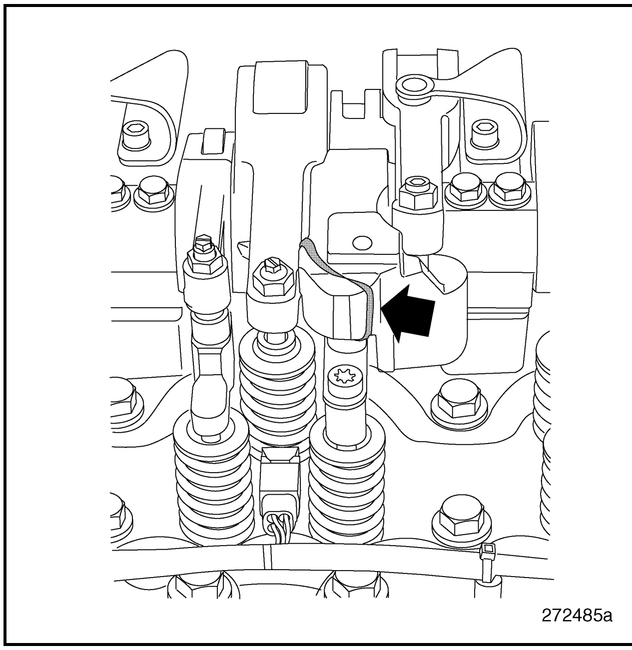


Figure 309 — Engine Brake Restraint

4. Lubricate the rocker arm rollers.
5. Insert the long fasteners (Nos. 8–20 in Figure 310) through the shaft, camshaft bearing caps and into the cylinder head.

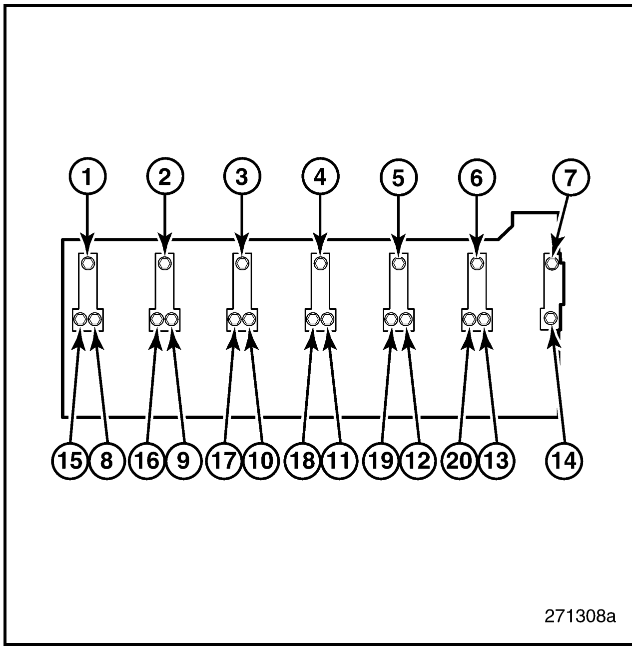


Figure 310 — Rocker Arm Shaft Screw Installation Sequence

6. Insert all remaining bolts into the rocker arm shaft.

7. If the exhaust side bearing cap bolts, 1–7, are not loose, loosen them before proceeding with the next step.
8. Tighten all camshaft bearing cap and rocker arm shaft bolts in sequence according to specification.

NOTE

The bolts have limited reusability and must be marked (A) with a punch each time they are installed in service. Bolts with four punch marks when removed have been tightened five times and must be discarded.

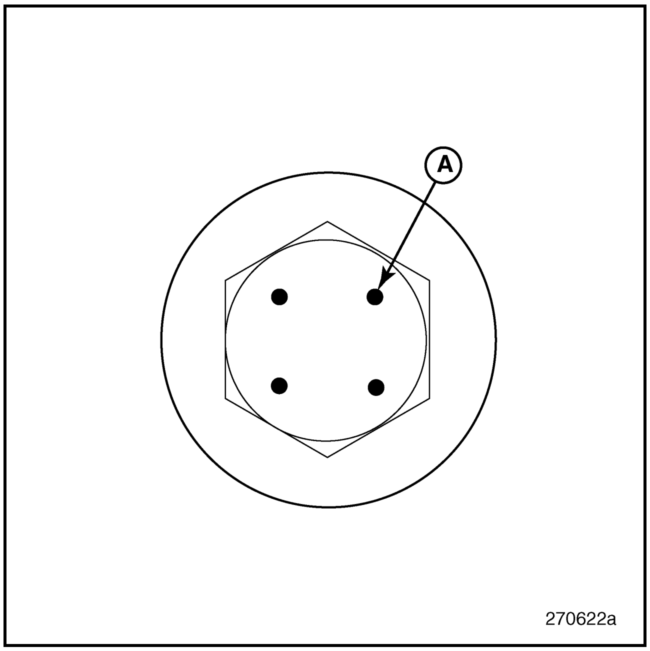


Figure 311 — Usage Marks on Rocker Fasteners

9. Replace the O-ring at the bottom of the engine brake control valve (if equipped with engine brake) or oil flow adapter.

NOTE

On engines without the engine brake, an oil flow adapter is used in place of the oil control valve. It is mounted in the same location on the cylinder head and is installed in the same manner as the engine brake control valve in steps 8 through 13. The adapter provides oil to the rocker shaft.

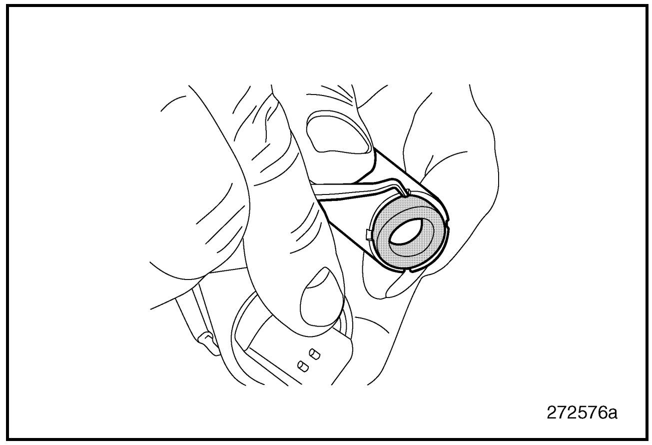


Figure 312 — Engine Brake Control Valve O-Ring

10. Clean the engine brake control valve oil pipe and replace the O-rings. Lubricate the pipe hole in the rocker arm shaft and the O-rings on the pipe.

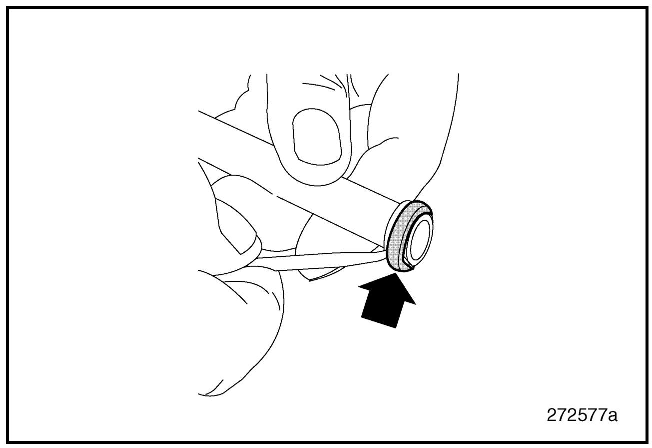


Figure 313 — Control Valve Pipe O-Ring

11. Insert the oil pipe into the oil hole of the engine brake control valve.

NOTE

Make sure that the O-ring is seated fully in the valve.

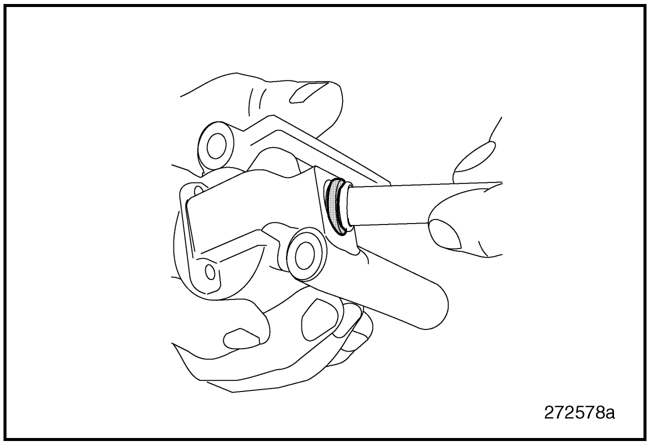


Figure 314 — Engine Brake Control Valve Pipe Installation

12. Position the control valve on the cylinder head.

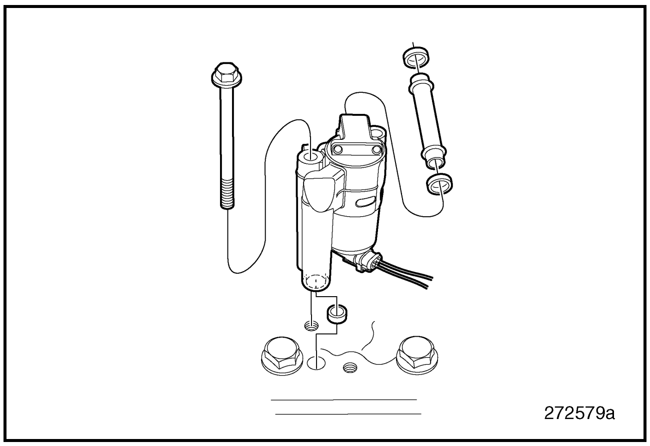


Figure 315 — Control Valve Position

13. Align the engine brake oil pipe and O-ring with the hole in the rocker shaft.

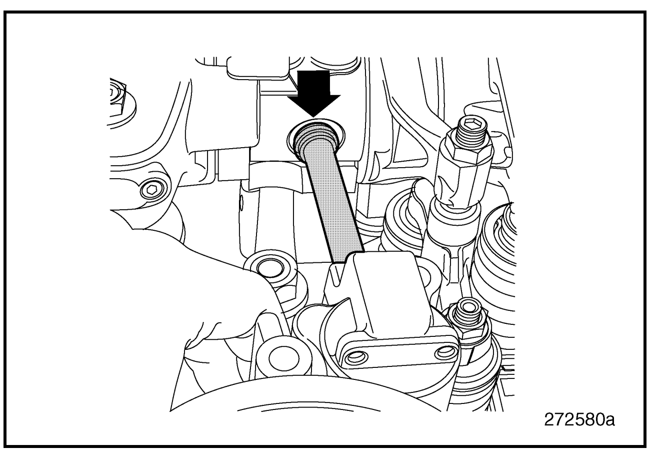


Figure 316 — Engine Brake Control Valve Pipe Installation

NOTE

Make sure the engine brake oil pipe O-ring is fully seated.

14. Install the control valve bolts and tighten to specification.

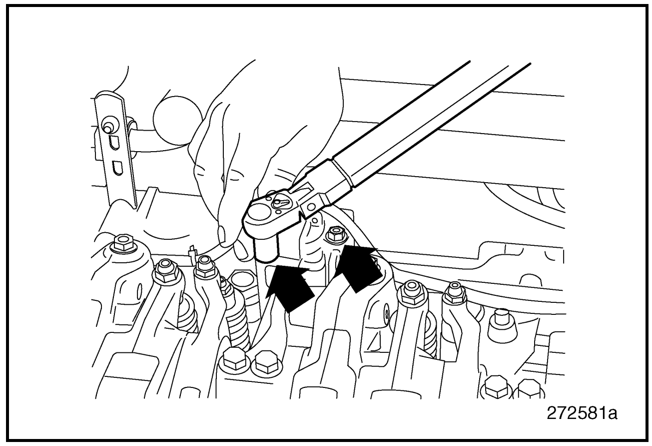


Figure 317 — Engine Brake Control Valve Installation

15. If harness is installed on engine, plug in the control valve harness connector.

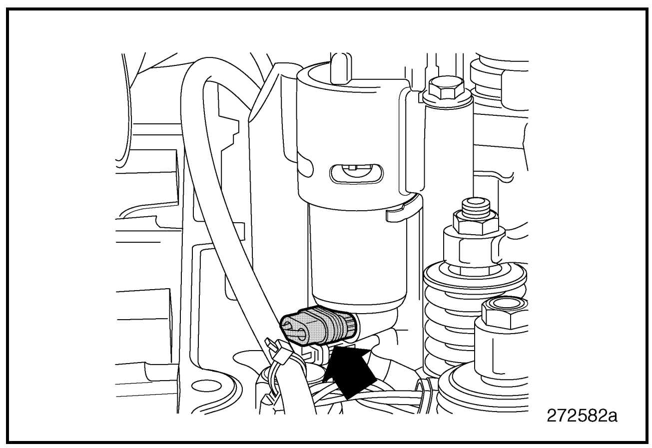


Figure 318 — Engine Brake Control Valve Connector

16. If installed, reposition the fuel injector harness over the control valve and secure with high temperature tie straps, 983472.

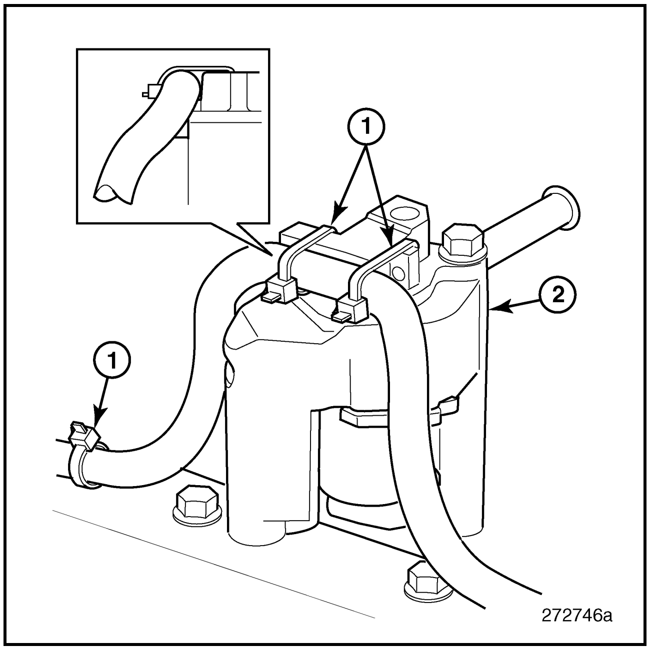


Figure 319 — Harness Routing Over Engine Brake Control Valve

1. Tie Straps	2. Control Valve

Flywheel Housing Installation

[211 HD]

Inspect the flywheel housing machined surfaces, bolt holes and pilot locations for cracks or wear. Replace the housing if cracks are evident.

1. Thoroughly clean the sealing area in the flywheel casing and the sealing surface against the crankshaft.
2. Apply an even 2 mm (5/64 inch) thick bead of MACK-approved sealant to the timing gear plate side of the flywheel housing according to the pattern shown. Sealant must also be applied to the intermediate bearing support in the flywheel housing.

NOTE

The flywheel housing must be installed within 20 minutes of the sealant being applied.

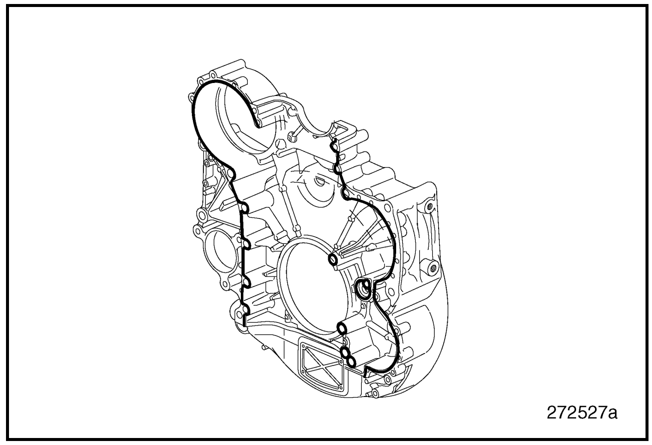


Figure 320 — Flywheel Housing Sealant Application Pattern

NOTE

Be sure to apply beads of sealant around the holes in the bosses as shown in the graphic.

Temporarily install guide pins in the two lower flywheel housing mounting holes in the timing gear plate/cylinder block.

3. Within 20 minutes of the application of the sealant, assemble the flywheel housing over the guide pins.
4. Insert and hand-tighten the attaching bolts. Remove the two guide pins and install the remaining bolts.

NOTE

If the engine was originally built with the longer idler gear bolts, the flywheel housing may need to be updated to block the idler gear bolt hole with a plug and washer from plug kit 21090322. Use the following procedure to thread the hole and install the plug:

a. Using a 3/4-16 UNF x 11.5 tap, thread the hole indicated in Figure 321.
b. Apply thread locking compound (Loctite® 277 or equivalent) to the threads of the plug.
c. Insert the plug with washer and tighten according to specification.

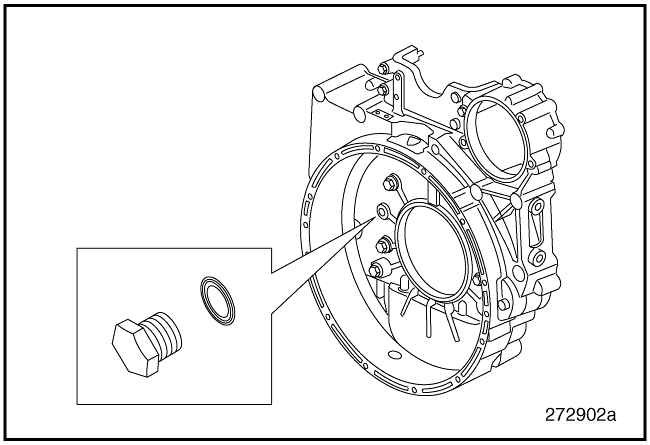


Figure 321 — Flywheel Housing Plug

5. Using a torque wrench, tighten the attaching bolts in sequence according to specification.
6. Remove any excess sealant.
7. Install the timing gear plate to the flywheel housing bolts (item 2 in Figure 322).

NOTE

- Item 1 secures the power steering and fuel pump mounting and is not installed at this time.
- Item 3 secures the rear engine mount to the flywheel housing and will be install upon installation into the chassis.

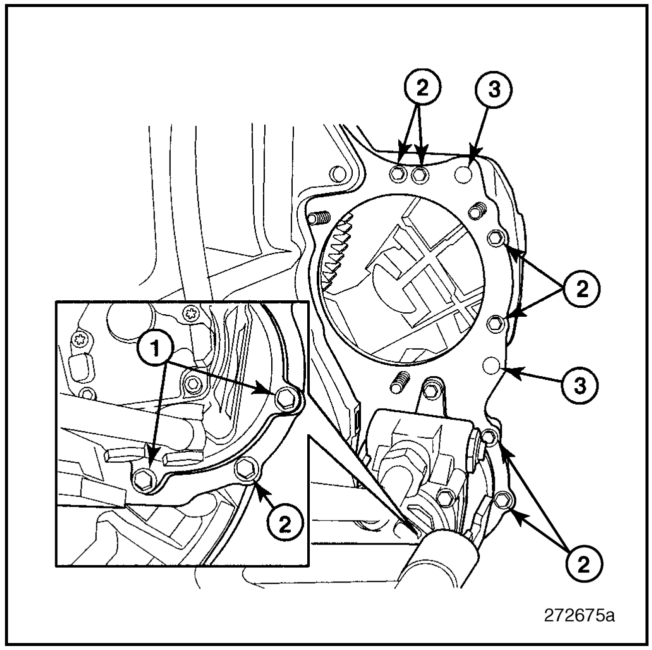


Figure 322 — Timing Gear Plate Attachment

1. Power Steering Attaching Bolts 2. Timing Gear Plate-to-Flywheel Housing Attaching Bolts	3. Rear Engine Mount-to-Flywheel Housing Attaching Bolt and Nut

Crankshaft Rear Seal Installation

[212 JH]

NOTE

For Teflon® type crankshaft rear seal installation procedure using alternate tools, refer to “CRANKSHAFT REAR SEAL REPLACEMENT” on page 248.

1. Thoroughly clean the sealing surfaces of the flywheel housing and the crankshaft gear hub.

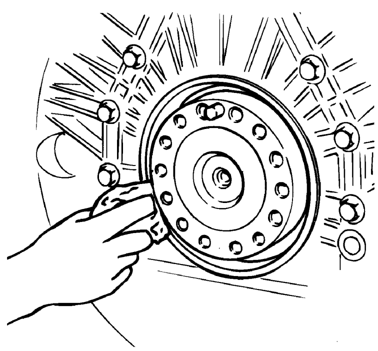


Figure 323 — Cleaning Sealing Surfaces

2. Lubricate the seal lips with clean engine oil.
3. Insert the handle, 9992000, in the remover/installer, 9998238.

⚠ CAUTION

Inspect the remover/installer carefully. Any damage on the tool will destroy the seal.

4. Position the **new** seal on the drift, making sure that the seal is turned in the proper direction. Carefully tap the seal into the flywheel housing using the handle and drift until the drift evenly contacts the crankshaft gear.

NOTE

Position the drift so that it does not interfere with the alignment dowel during installation. The crankshaft rear seal depth is set by the drift tool when fully seated.

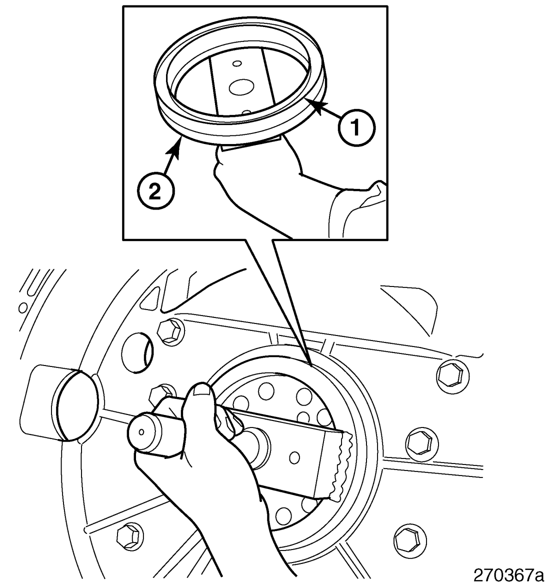


Figure 324 — Crankshaft Rear Seal Installation

1. Rear Main Seal	2. Rear Main Seal Installer, 9998238

5. Remove the tools.
6. Inspect the seal ring for proper seating.

Flywheel and Pilot Bearing Installation

[212 VC]

⚠ 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 fasteners. Refer to the Automatic Transmission Drive Arrangement Assembly Instructions, 5-903, for installation instructions.

1. Clean the surface in the places where the flywheel lies flush against the crankshaft gear hub.

   Clean the flywheel. Check that the grooved surfaces for the flywheel sensor are clean.

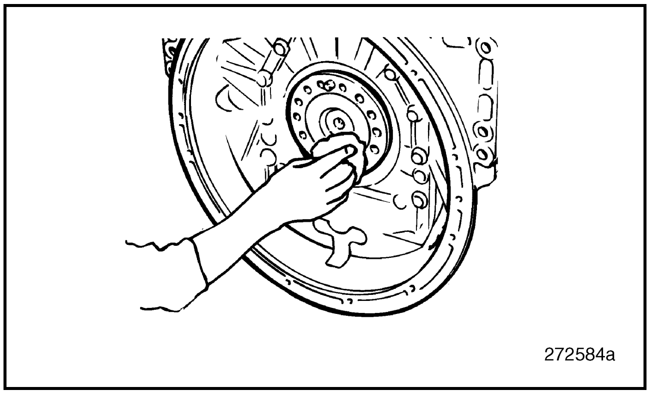


Figure 325 — Cleaning Sealing Surfaces

2. Make sure that the flywheel guide pin is correctly inserted in the crankshaft gear hub. Ensure that there is no damage or leakage at the crankshaft rear seal.
3. Insert two alignment studs in the crankshaft hub to aid in installation.
4. With the aid of the two lifting bolts (M10 x 100), position the flywheel over the dowel pin and alignment studs on the flywheel mounting surface at the rear of the crankshaft.

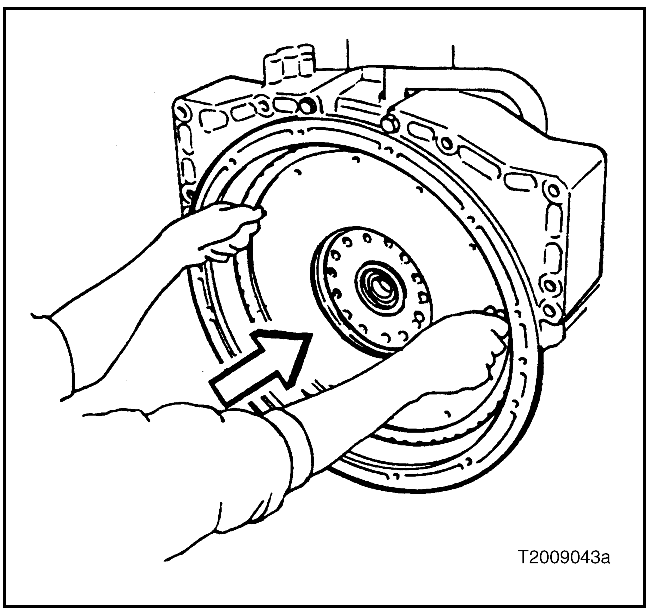


Figure 326 — Flywheel Installation

5. Install the flywheel mounting bolts. Tighten the bolts finger-tight only.
6. Remove the two alignment studs and insert the remaining mounting bolts.
7. Remove the plug from the flywheel housing and install flywheel turning tool, 88800014, and a ratchet handle as a counterhold.

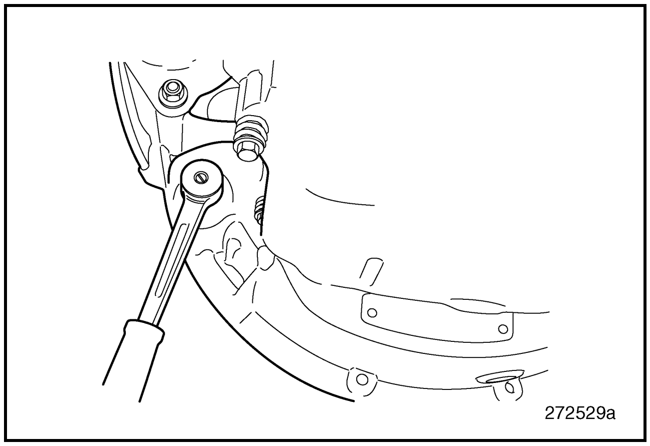


Figure 327 — Flywheel Turning Tool

8. Using a torque wrench, tighten the bolts in sequence according to specification.

CAUTION

Do not tighten adjacent screws sequentially. Doing so can result in uneven flywheel alignment. Failure to heed this caution can result in severe engine damage.

9. Remove the flywheel turning tool. Insert the plug.
10. Using tool assembly, 9991801 and 9992564, install a **new** pilot bearing in the flywheel bore.

NOTE

For this engine, **NO** snap ring is required on the pilot bearing. Do **NOT** substitute pilot bearings that do not bear the correct part number for this application. Failure to heed this caution may result in severe engine damage.

11. Check for proper flywheel-to-position sensor clearance using the sensor depth gauge to determine if shims are required for sensor depth. The flywheel position sensor clearance specification is 0.3–1.0 mm (0.0118–0.0393 in.).
    a. Rotate the engine using the flywheel turning tool until a tooth of the flywheel toothed wheel is aligned with the sensor bore.
    b. Insert the tool into the sensor bore until the outer part of the tool is fully seated against the flywheel housing.
    c. Loosen the thumb screw of the tool and push the inner part of the tool until it contacts a tooth of the toothed wheel.
    d. Tighten the thumb screw to secure the inner part of the tool.
    e. Carefully remove the tool from the flywheel sensor bore and observe the location of the steps between the inner and outer portions of the tool:
        - Both steps below the surface of the tool = no shims required.
        - One step below the surface of the tool = one shim required.
        - Both steps above the surface of the tool = two shims required.

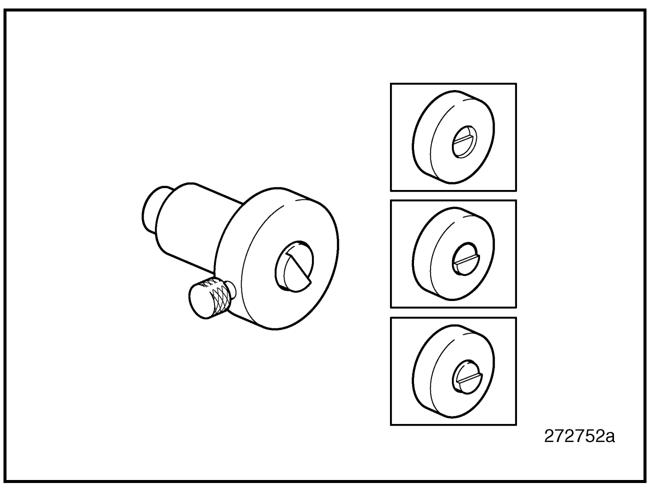


Figure 328 — Depth Sensor Gauge

12. Carefully install the flywheel position sensor with the appropriate shim(s) and **new** O-ring. Secure the sensor with a bolt tightened to specification and plug in the harness connection.

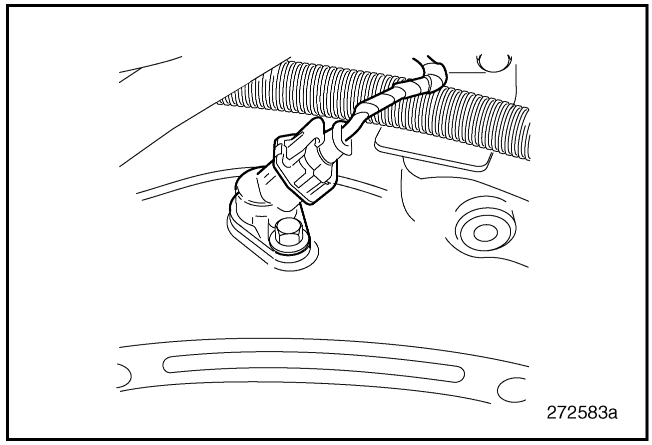


Figure 329 — Flywheel Position Sensor

Oil Pan Installation

[211 NB]

1. Apply a 2 mm (5/64 inch) bead of MACK-approved sealant at the seams between the flywheel housing and the timing gear plate. Also, apply a 2 mm (5/64 inch) bead of sealant at the seams between the timing gear plate and the cylinder block.

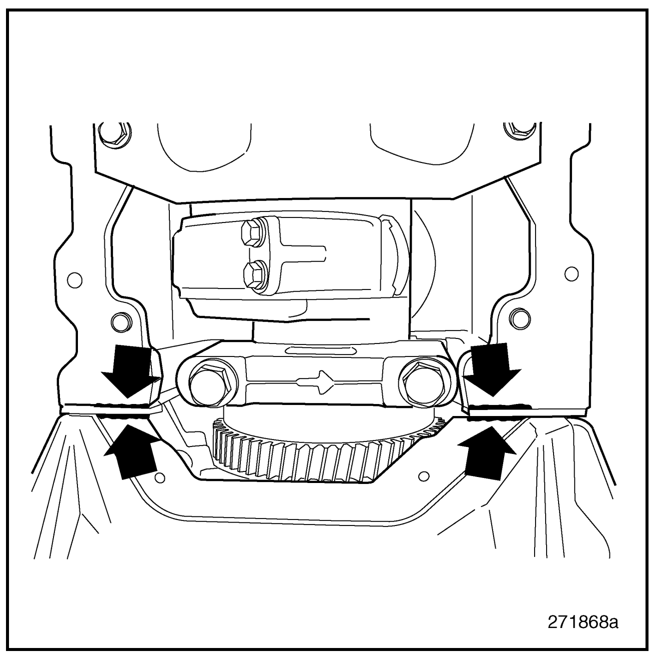


Figure 330 — Sealant Application for Oil Pan — Rear

2. Apply a 2 mm (5/64 inch) bead of MACK-approved sealant to the seam between the front seal cover and the cylinder block.

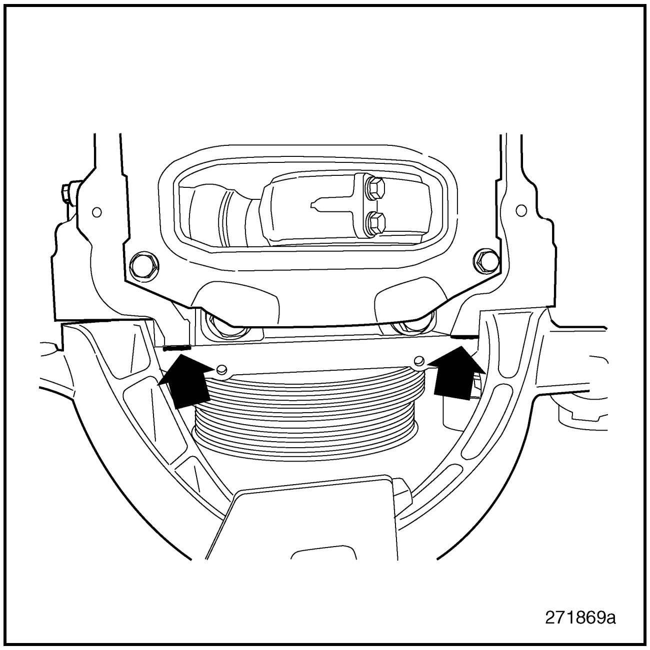


Figure 331 — Sealant Application for Oil Pan — Front

3. For plastic pan applications, install the oil pan seal into the groove of the oil pan. Check that the seal locating tabs are properly aligned and seated in the locating holes on the mounting flange.

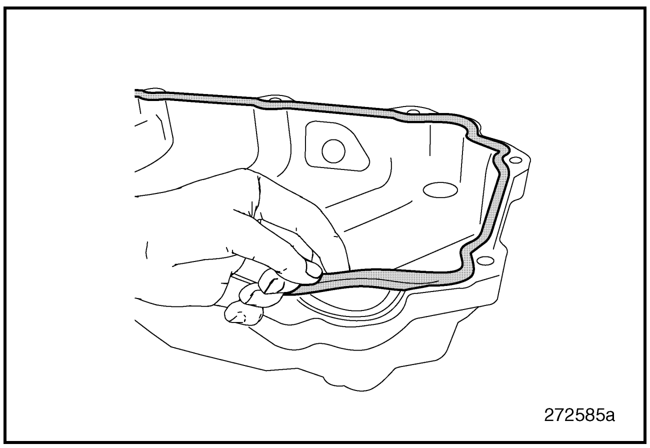


Figure 332 — Plastic Oil Pan

4. For steel pan applications, install the oil pan gasket on the oil pan flange. Check that the gasket locating tabs are properly aligned and inserted in the correct holes on the mounting flange.

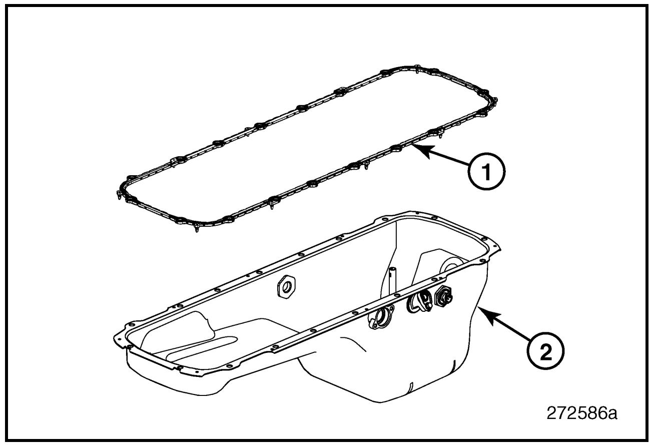


Figure 333 — Steel Oil Pan

1. Gasket	2. Oil Pan

5. With assistance, position the oil pan to the cylinder block and install the bolts marked A and B. Tighten the bolts according to specification.

NOTE

- Use care to prevent damage to the oil pickup.
- The oil pan must be installed within 20 minutes of the sealant being applied.

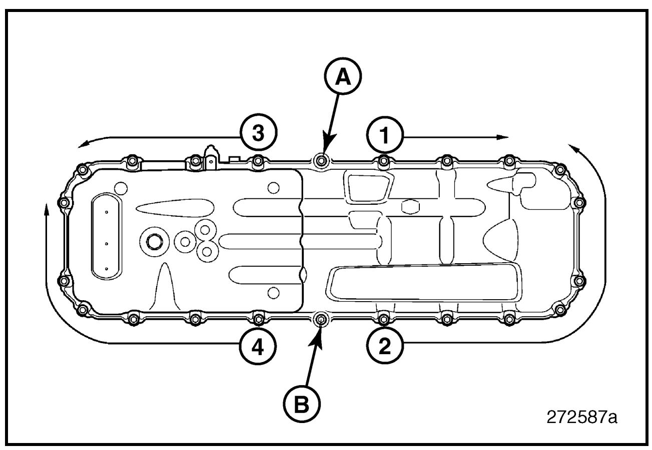


Figure 334 — Oil Pan Installation

6. Tighten the bolts from the middle and outwards in order 1–4 as shown. Tighten the bolts according to specification. Finish by checking the torque for bolts A and B.

NOTE

Install the transmission oil cooler bracket studs in locations marked previously.

7. Install the oil drain plug and tighten according to specification.

CAUTION

Do not use a copper washer with the hex-head oil drain plug. Always use the steel washer with the rubber gasket.

NOTE

Do not use air tools when installing the oil drain plug.

8. Ensure that the 12 locating pins on the seal are properly seated in the locating holes in the mounting flange.

NOTE

Be sure the oil pan seal is properly placed before tightening the fasteners.

9. If harness is installed, reconnect the oil level/temperature sensor connector to the side of the oil pan.

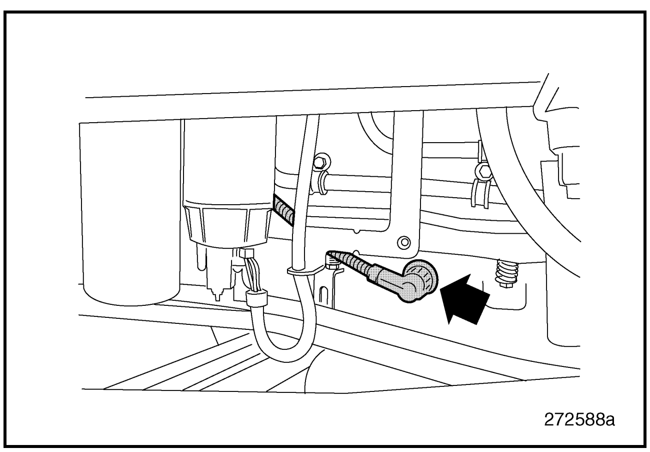


Figure 335 — Oil Level/Temperature Sensor

Oil Filler Pipe and Dipstick Pipe Installation

1. Install a **new** O-ring on the oil fill tube and install the tube to the side of the oil pan. Install the oil fill tube fasteners and tighten to secure.

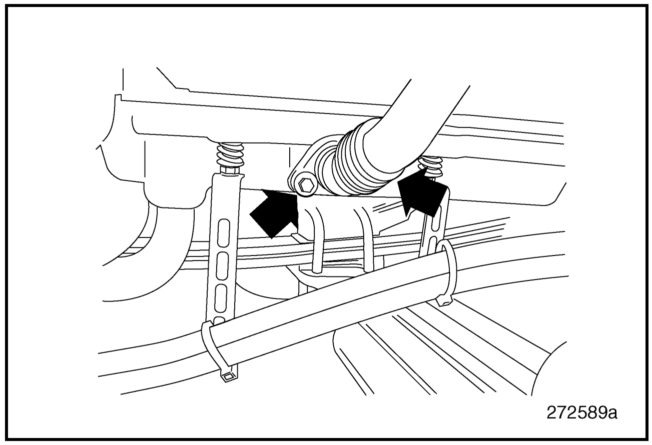


Figure 336 — Oil Fill Tube

2. Install a **new** O-ring on the dipstick tube, then install the tube and secure with the fastener. Install the dipstick.

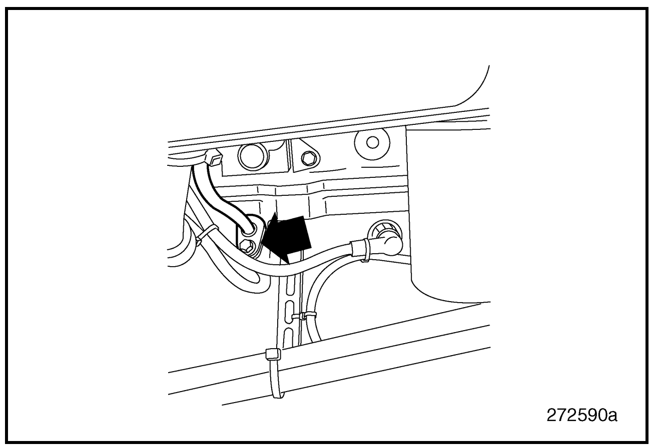


Figure 337 — Oil Dipstick

Power Take-Off Installation

If equipped with a power take-off (PTO), install the assembly using this procedure.

1. Lubricate and assemble a seal in the groove in the PTO assembly housing.

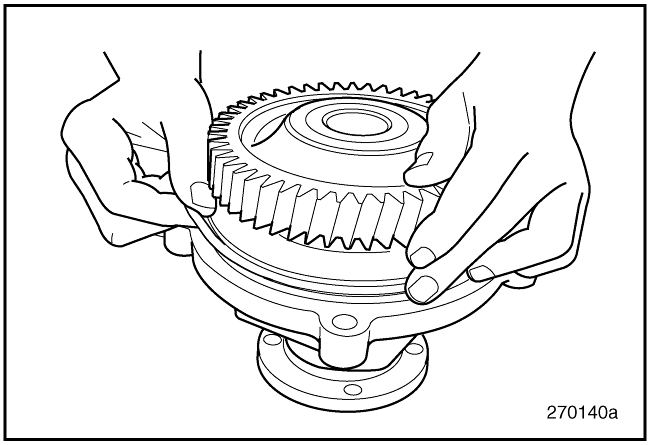


Figure 338 — PTO Housing Seal Installation

2. Assemble the PTO assembly on the flywheel housing.

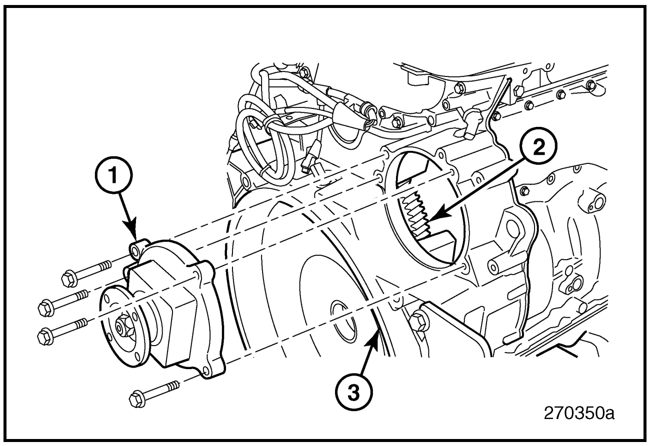


Figure 339 — Power Take-Off Installation

1. PTO Housing 2. Intermediate Idler Gearset	3. Flywheel Housing

3. Using a torque wrench, tighten the fasteners according to specification.

Timing Gear Cover Installation

[211 AA]

1. Apply sealant in the bottom corners where the timing gear plate and the flywheel housing meet. Also apply sealant to the top of the timing gear plate (in the corner) next to the cylinder head.

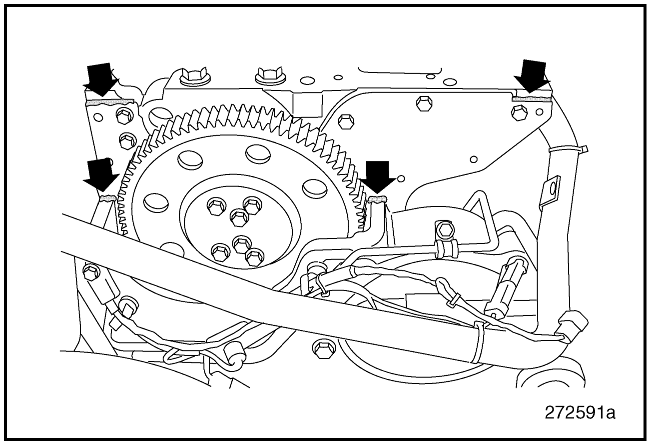


Figure 340 — Sealant Application — Engine

2. Install the timing gear cover seals and gaskets.

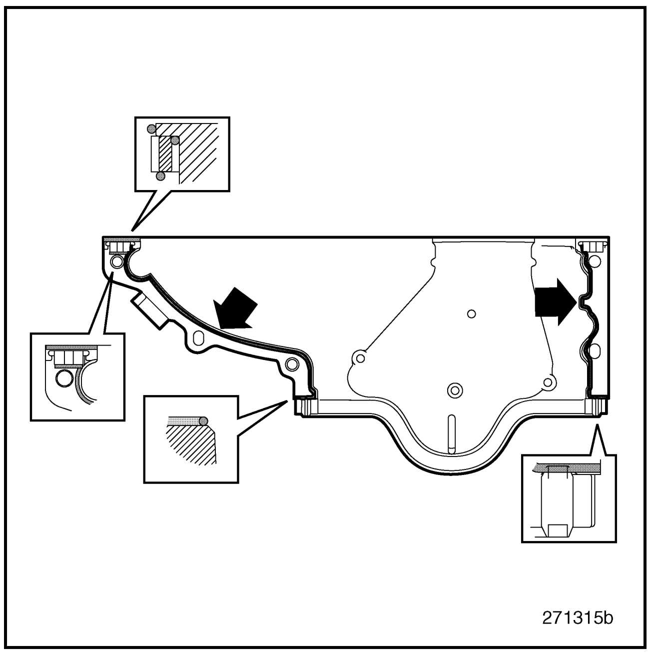


Figure 341 — Timing Gear Cover Seals

3. Apply sealant to the mating surfaces of the timing gear cover.

NOTE

The timing gear cover must be installed within 20 minutes of the sealant being applied.

4. Position the timing gear cover on the flywheel housing at the rear of the cylinder head. Install the fasteners marked 1 and 2.

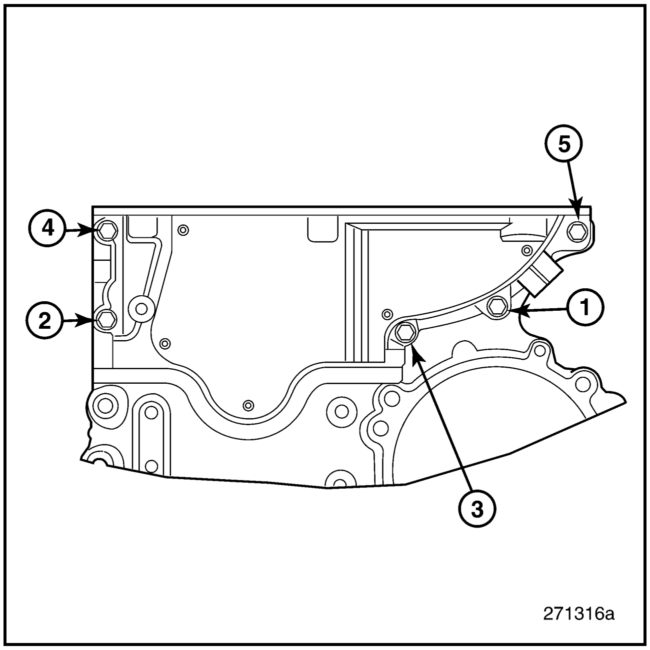


Figure 342 — Timing Gear Cover Installation Sequence

5. Install the timing gear cover alignment tools, 85111422-A and 85111422-B, to the cylinder head and timing gear cover as illustrated. Cover surface must be flush with the seal surface of the cylinder head.

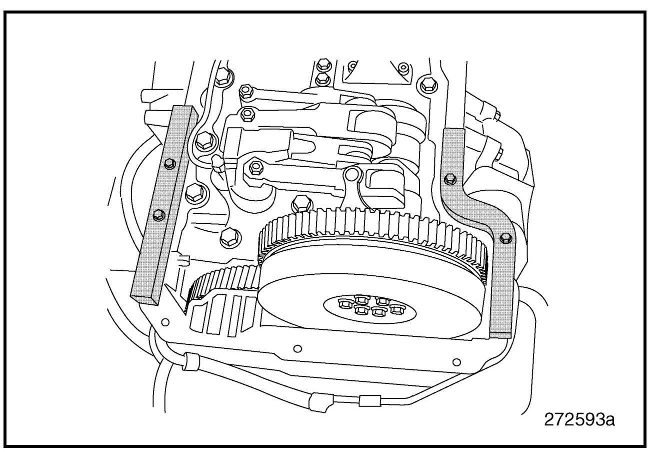


Figure 343 — Timing Gear Cover Alignment Tools

6. Install the remaining fasteners, 3, 4 and 5. Tighten all of the timing gear cover fasteners according to specification.
7. Remove the timing cover clamp tools.
8. Position the rear support bracket onto the rear of the engine and install the support bracket fasteners to secure.
9. Install all tie straps, P-clamps and other retainers used to retain the engine harnesses, oil lines and coolant tubes to the rear of the engine.

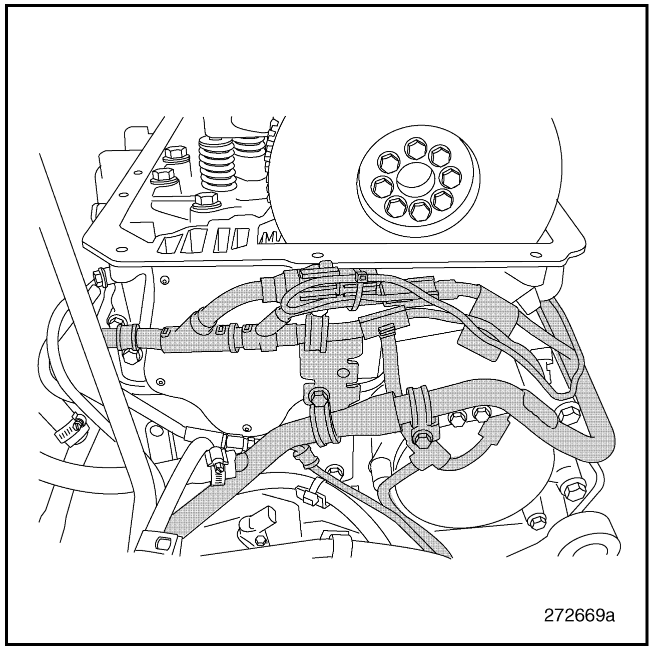


Figure 344 — Rear of Engine

CAMSHAFT SENSOR DEPTH, CHECK

1. Remove the plug from the flywheel housing and install the flywheel turning tool.

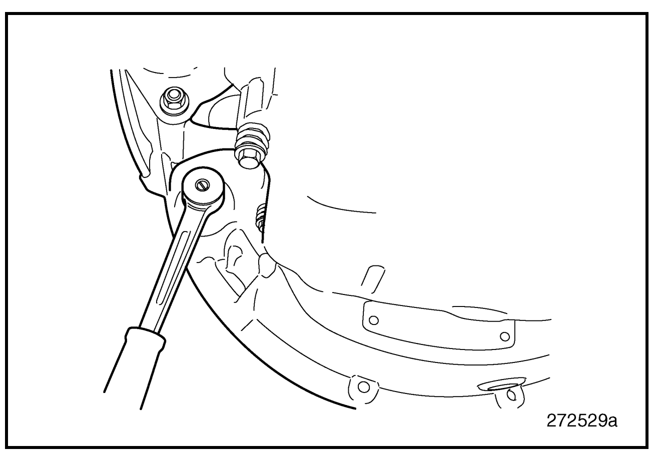


Figure 345 — Flywheel Turning Tool

2. Check for proper camshaft position sensor clearance using the sensor depth gauge, 88800031, to determine if shims are required for sensor depth.

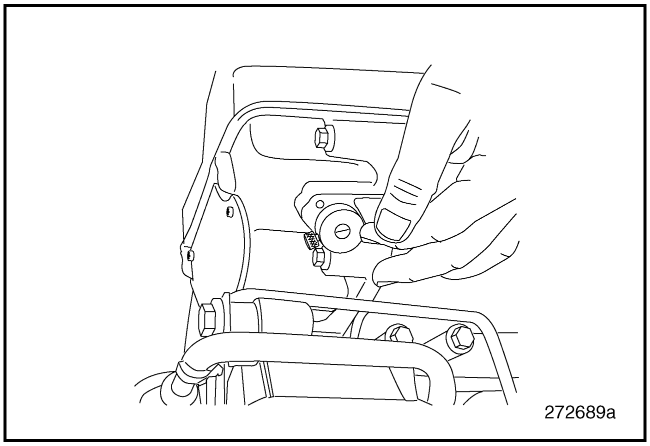


Figure 346 — Camshaft Position Sensor

a. Rotate the engine until a tooth of the camshaft toothed wheel is aligned with the sensor bore.

b. Insert the depth gauge into the sensor bore until the outer part of the gauge is fully seated against the timing gear cover.

c. Loosen the thumb screw of the gauge and push the inner part of the gauge in until it contacts a tooth of the toothed wheel.

d. Tighten the thumb screw to secure the inner part of the gauge.

e. Carefully remove the gauge from the camshaft sensor bore and observe the location of steps between the inner and outer portions of the gauge:

- Both steps below the surface of the gauge = no shims required.
- One step below the surface of the gauge = one shim required.
- Both steps above the surface of the gauge = two shims required.

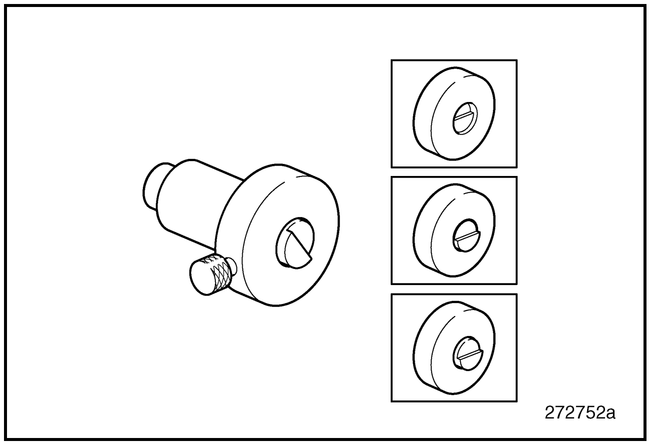


Figure 347 — Depth Sensor Gauge

3. Install the camshaft position sensor with the appropriate shim(s) and **new** O-ring. Secure the sensor with a bolt and plug in the harness connector.

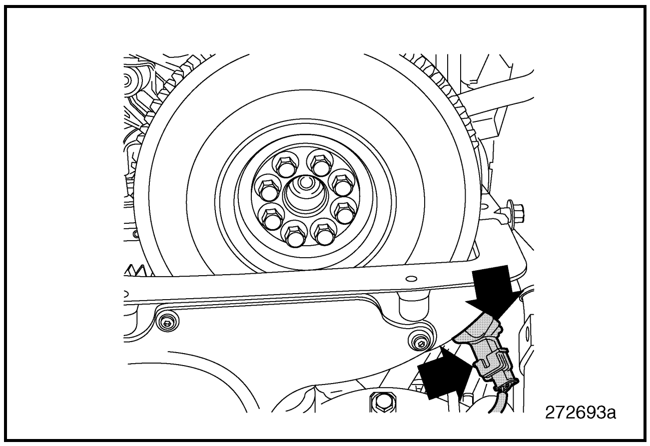


Figure 348 — Camshaft Position Sensor

Coolant Pump Installation

[215 SW, SG, SR]

1. If removed, place the coolant pump housing in position at the front of the cylinder block and install the mounting bolts. Tighten the bolts according to specification.
2. Press a **new** sealing ring into the groove of the coolant pump.

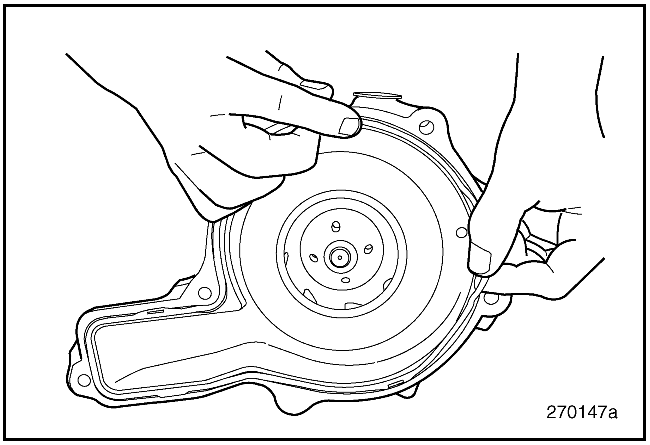


Figure 349 — Inserting Coolant Pump Seal

3. Position the coolant pump on the housing and align the bolt holes.

N O T E

Make sure the sealing ring remains seated in the groove of the coolant pump.

4. Install the coolant pump bolts and tighten according to specification.
5. Position the tensioner pulley on the front of the engine and install the tensioner bolts. Tighten the bolts according to specification.

Thermostat and Cover Installation

[215 NU, NG & LD]

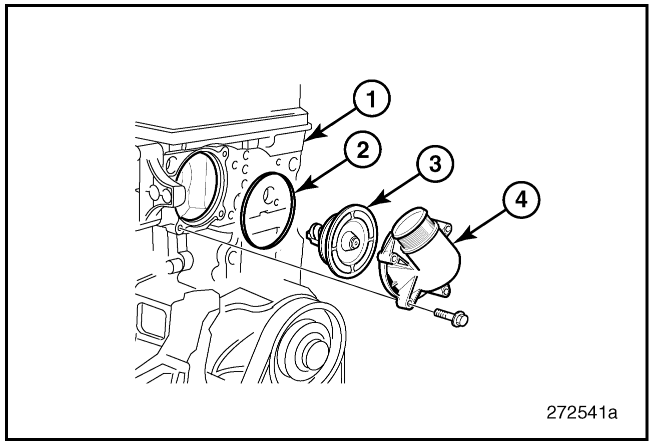


Figure 350 — Thermostat and Cover Installation

1. Cylinder Head 2. Thermostat Seal	3. Thermostat 4. Thermostat Cover

1. Use crocus cloth to remove any surface nicks, burrs, sharp edges and tool marks from the thermostat cover and cylinder head.
2. Lubricate the inner surface of the cover.
3. Install the **new** thermostat.

N O T E

Make sure that the rubber seal remains properly seated.

4. Position the thermostat cover to the cylinder head and install the bolts. Using a torque wrench, tighten the bolts in a cross pattern according to specification.

Coolant Pipe Installation

[215 SW]

UPPER COOLANT PIPE (BYPASS) HOUSING

1. Lubricate and assemble a **new** seal in the upper coolant pipe housing flange.

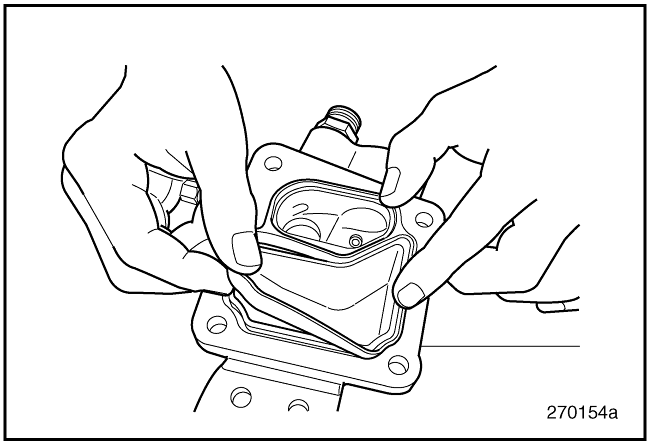


Figure 351 — Seal Installation — Upper Coolant Pipe Housing

2. Assemble the upper coolant pipe housing flange on the head.

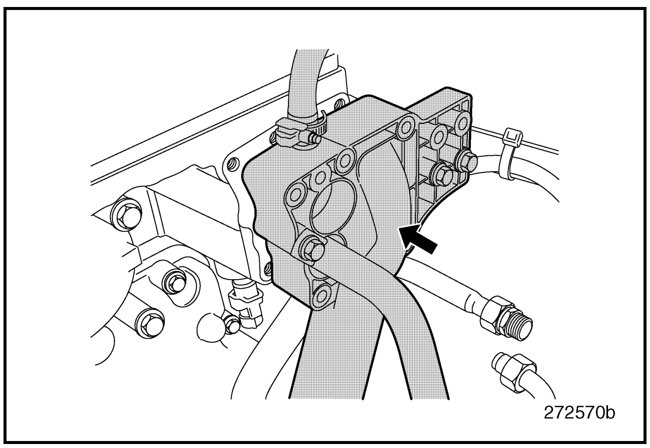


Figure 352 — Upper Coolant Pipe Installation

3. Using a torque wrench, tighten the upper coolant pipe fasteners in sequence according to specification.
4. Assemble the EGR venturi pipe support bracket onto the upper coolant pipe housing.
5. Assemble the fan ring bracket to the upper coolant pipe housing.
6. Using a torque wrench, tighten the fasteners according to specification.

PUMP INLET HOUSING

1. Lubricate and assemble **new** sealing rings on the pump inlet pipe at the joint with the bypass connector.
2. Place the inlet housing in position between the upper coolant pipe and the pump inlet. Replace and lubricate all sealing O-rings.

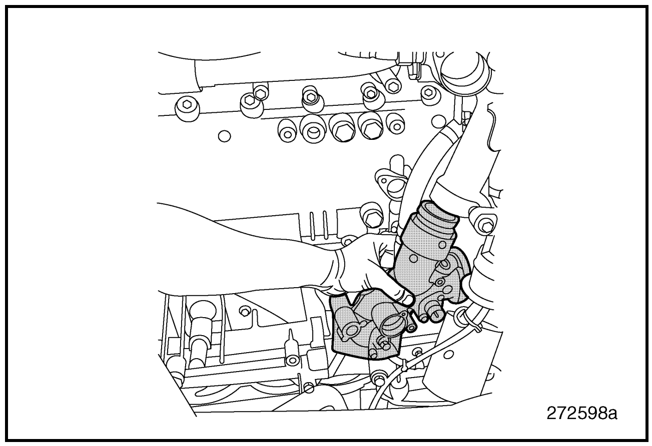


Figure 353 — Installing Pump Inlet Housing

3. Install the fasteners and tighten according to specification.

NOTE

Secure the inlet housing flange to the pump first and then to the cylinder block.

Oil Cooler and Cooling Duct Cover Installation

[215 DW, 219 EP]

The oil cooler must be attached to the cooling duct cover before attaching the cover to the cylinder block.

OIL COOLER INSTALLATION

1. Using a sharp pick, carefully remove the rubber seal (molded gasket) from the groove in the cooling duct cover, if not already done. Clean the cover of any dirt, adhesives and inspect for damage to the sealing surface. Also, inspect the cylinder block and ensure the sealing surface is clean and undamaged.
2. Install a **new** formed gasket in the groove of the cover.

NOTE

Apply a minimal amount of sealant in the seal groove to hold the seal in place during assembly. Install the cover within 20 minutes of applying the sealant.

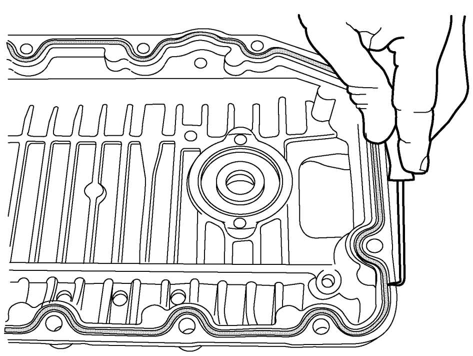


Figure 354 — Oil Cooler Cover Gasket

3. Install **new** oil cooler sealing O-rings between the oil cooler and cover. Install the sealing O-rings into the grooves in the cover.

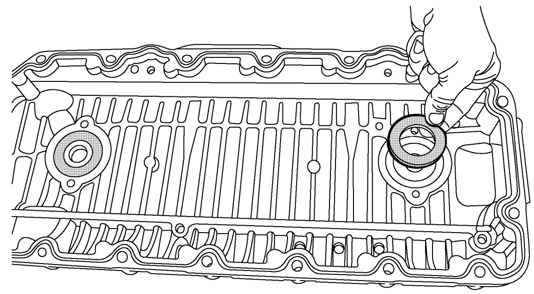


Figure 355 — Installing Cooler Seals

4. Install the oil cooler in the cooling duct cover.

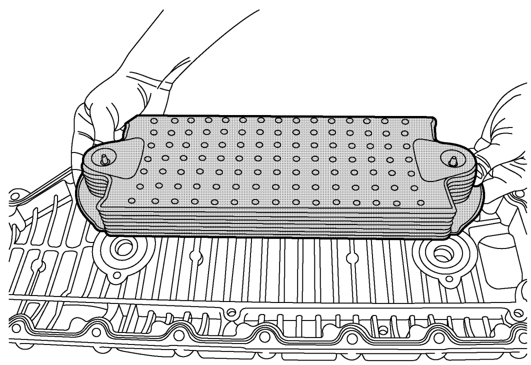


Figure 356 — Installing the Oil Cooler

5. Using a torque wrench, tighten the fasteners in sequence according to specification.
6. Install the oil cooler flow plate over the oil cooler. Tighten the fasteners according to specification.

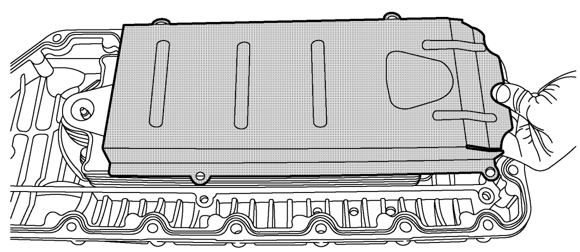


Figure 357 — Oil Cooler Flow Plate

COOLING DUCT COVER INSTALLATION

1. Replace the coolant pump inlet housing formed rubber gasket with a **new** gasket. Lubricate the new gasket before installation.

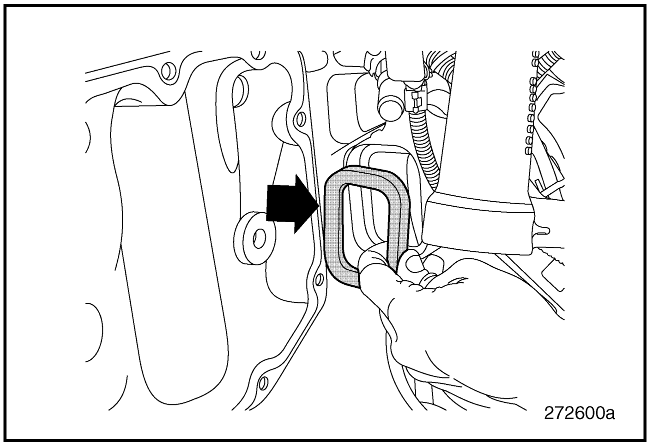


Figure 358 — Coolant Pump Inlet Housing Formed Gasket

2. With assistance, set the cooling duct cover assembly in place. Install the upper left corner fastener.

NOTE

This mounting location is slotted for adjustment.

3. Using the assembly tool, 88800022, push the cover forward to compress the formed rubber gasket at the coolant pump inlet. Install the upper right corner fastener.

NOTE

A small piece of metal stock should be used to keep from deforming the stamped cover that the tool foot is pressing against.

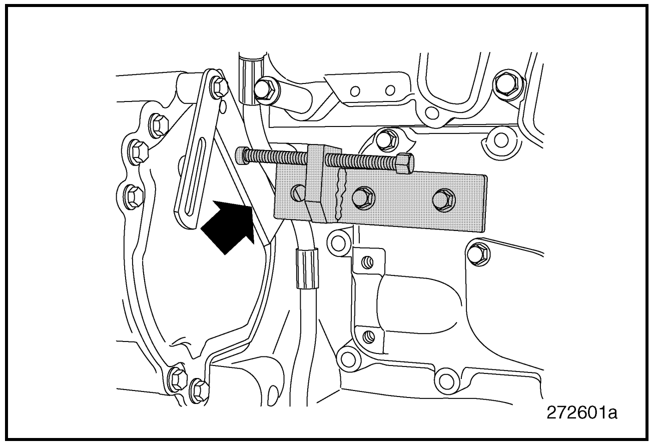


Figure 359 — Cooling Duct Cover Assembly Tool

4. Adjust cover as required to allow upper and lower center fasteners to be installed.

NOTE

The upper center mounting location has a tighter tolerance than other mounting locations.

5. Start all remaining cover fasteners and tighten the fasteners according to specification.

Oil Filter Housing Installation

[219 EP]

1. 1.Install the rear pipe to the oil cooler cover with a **new** gasket. Place the retaining clamps in position on the oil cooler duct cover, install the fasteners and tighten to specification.

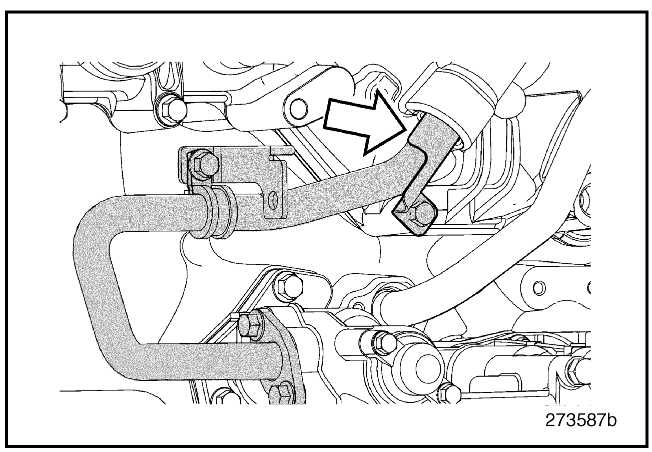


Figure 360 — Rear Pipe to Oil Cooler

2. Install two alignment pins — to hold the gasket in place and to aid in the alignment of the housing.

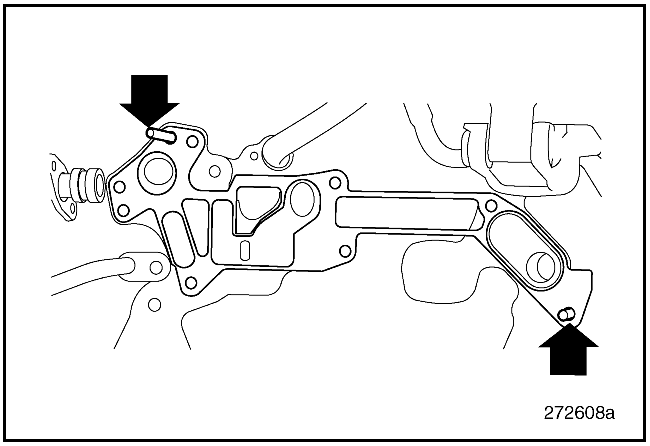


Figure 361 — Alignment Pins and Gaskets

3. Install the gasket to the cylinder block.
4. Install the oil filter housing onto the cylinder block and position the rear pipe. Tighten the fasteners according to specification.
5. Install the fasteners to the rear pipe in the oil filter housing. Tighten the fasteners according to specification.
6. Install the front pipe with **new** seals between the oil filter housing and the cooling duct cover.

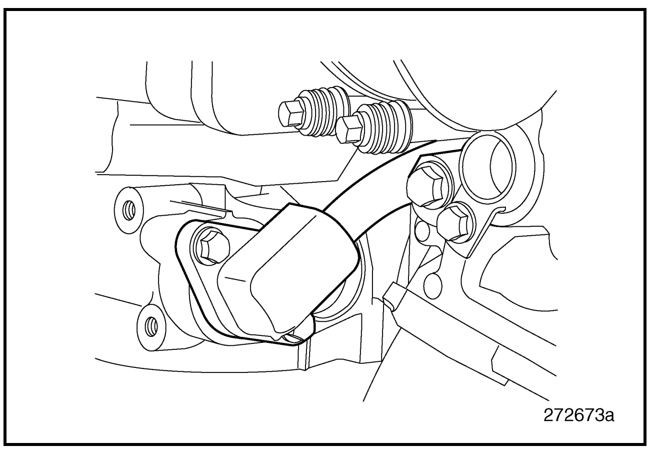


Figure 362 — Front Pipe Installation

7. Install all hard pipes (coolant and oil) to the cooling duct cover. Replace and lubricate all sealing O-rings. Also, replace sealing washers for the banjo fitting on the cooling duct cover. Tighten the banjo fittings according to specification.

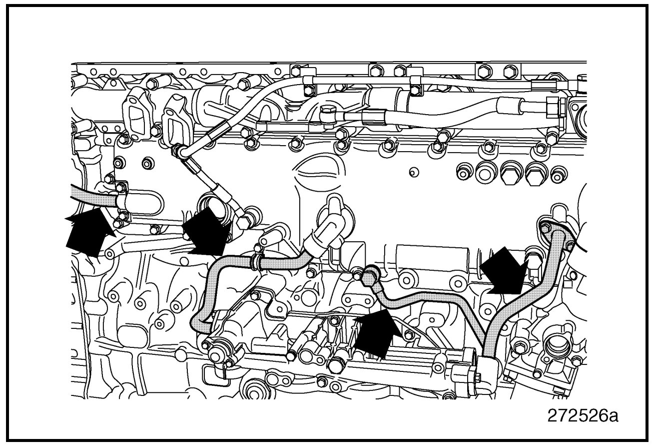


Figure 363 — Oil Cooler Hard Pipes

Exhaust Manifold Installation

[214 EG]

NOTE

The exhaust manifold mounting fasteners can be used five times unless the manifold is being replaced. If the manifold is being replaced, use **new** fasteners.

1. Clean the manifold mounting surface on the cylinder head.
2. Temporarily install an alignment pin at each exhaust manifold flange location on the cylinder head.

NOTE

This is done to hold the manifold while positioning the manifold gaskets for installation of the bolts and spacers.

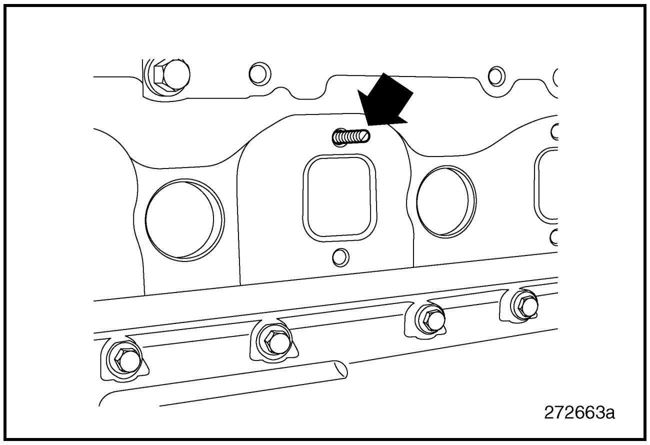


Figure 364 — Alignment Pin Installation

3. Install **new** gaskets onto the alignment pins with the seal side facing the cylinder head.

NOTE

The gaskets are marked "MANIFOLD SIDE" to aid in installation. Make sure to place this side of the gasket toward the exhaust manifold. The graphite fiber side of the gasket faces the cylinder head.

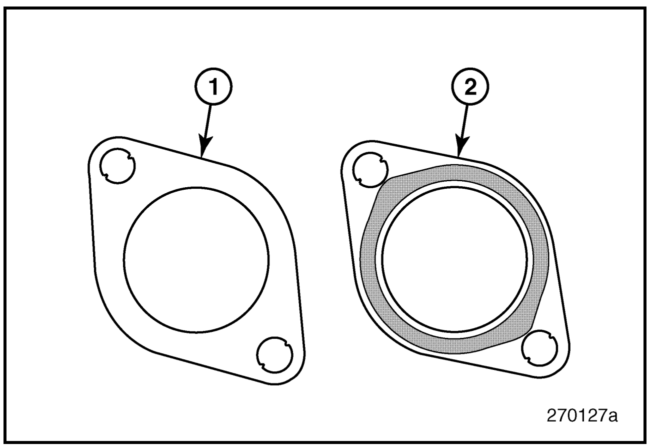


Figure 365 — Manifold Gasket

1. Manifold Side (Metal)	2. Cylinder Head Side (with Seal)

4. Apply anti-seize compound to the threads and under the heads or contact surfaces of all the manifold fasteners.

NOTE

Anti-seize helps prevent fastener oxidation corrosion and reduces friction to help achieve the intended clamp load on the component when tightening the fasteners to specification.

5. Install the exhaust manifold over the alignment pins. Install the fasteners with spacers in the lower holes. Now the upper alignment pins can be removed one at a time and replaced with mounting fasteners and the original spacers.

NOTE

- Make sure the spacers are seated properly in the manifold step bore hole location.
- Exhaust manifold fasteners can be used up to five times.

6. Tighten the fasteners according to specification.
7. Assemble the EGR heat shield on the exhaust manifold studs. Using a torque wrench, tighten the fastener and nuts according to specification.

EGR Valve Installation

[214 QE]

1. Clean any carbon deposits from the sealing surface of the EGR ports of the exhaust manifold.

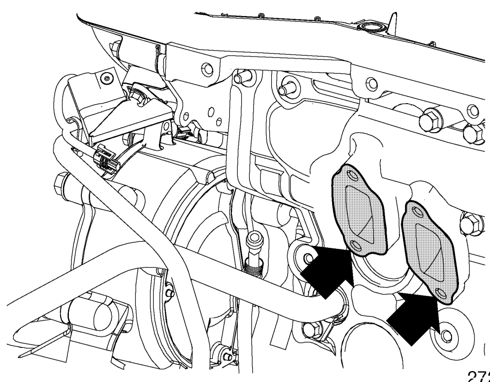


Figure 366 — Cleaning EGR Valve Mounting Surface

2. If the EGR oil lines are equipped with O-rings, replace them with **new** and lubricate.

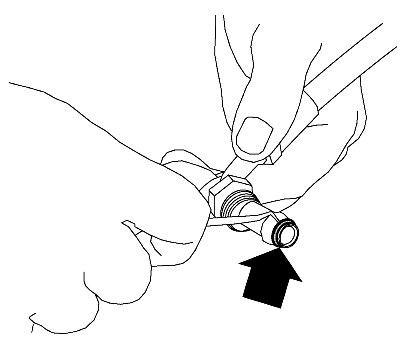


Figure 367 — EGR Valve Oil Line

3. Position the EGR valve near the exhaust manifold EGR ports.

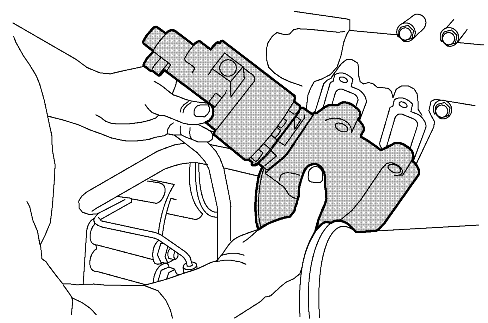


Figure 368 — EGR Valve Installation

4. Install the oil supply and oil return lines to the EGR valve. Finger tighten the fittings.

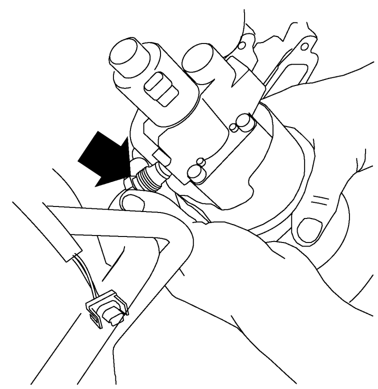


Figure 369 — EGR Valve Oil Line Connections

5. With the EGR valve held near the exhaust manifold ports, slip a **new** metal gasket between the valve and the manifold. Start two **new** bolts at the top of the EGR valve to hold the gasket.

NOTE

Apply anti-seize compound to the threads and under the heads or contact surfaces of the fasteners. Anti-seize helps prevent fastener corrosion and reduces friction to help achieve the intended clamp load on the component when tightening the fasteners to specification.

6. Start the two remaining **new** EGR valve bolts.

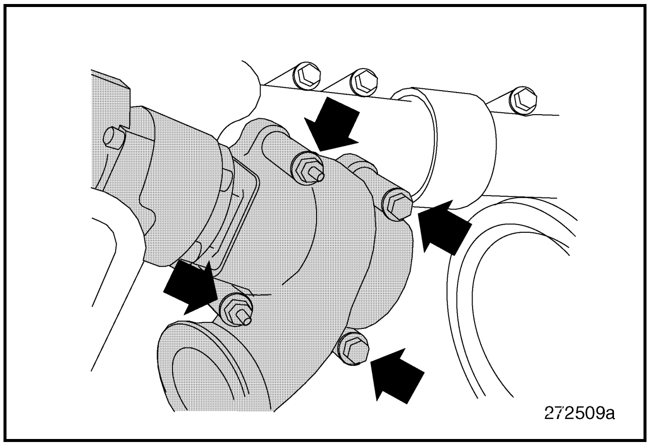


Figure 370 — EGR Valve Attaching Bolts

7. Tighten both oil lines to secure.

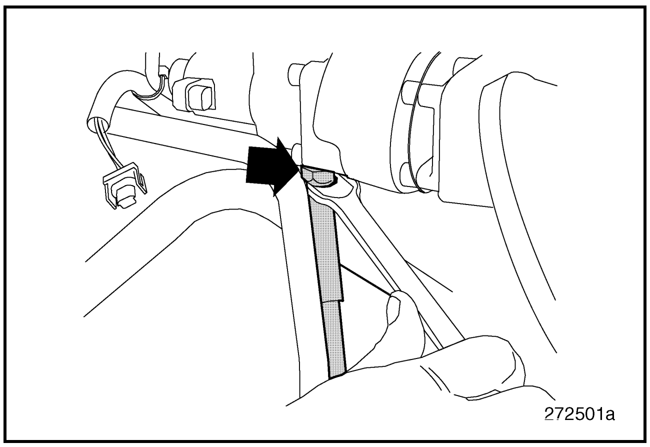


Figure 371 — EGR Valve Oil Line Connections

8. Tighten the EGR valve mounting bolts according to specification.
9. If a harness is installed, connect the wiring harness connector to the EGR valve.

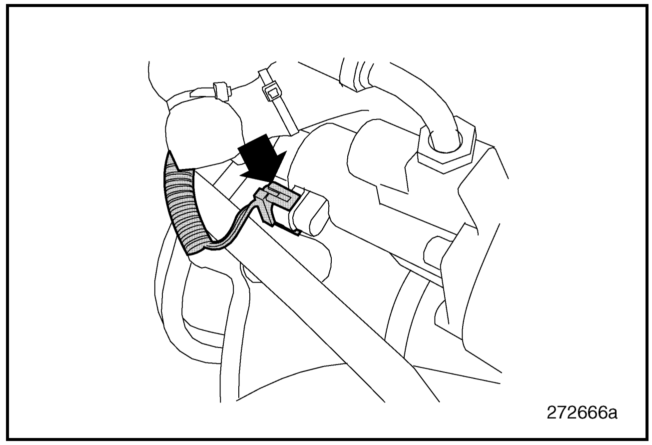


Figure 372 — EGR Valve Electrical Connection

10. Place the EGR heat shield in position over the EGR valve. Install the fasteners to secure the shield to the cylinder block and to the studs on the valve mounting bolt heads. Tighten the fasteners to specification.

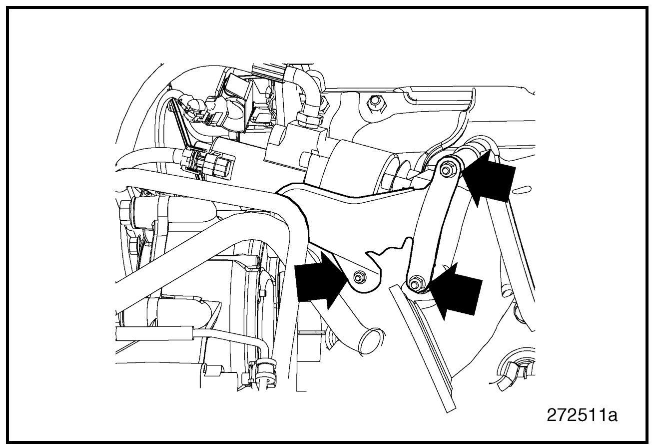


Figure 373 — EGR Valve Heat Shield

EGR Cooler Installation

[214 HM]

1. Install the turbocharger oil return pipe into the cylinder block. Replace with **new** and lubricate all sealing O-rings.

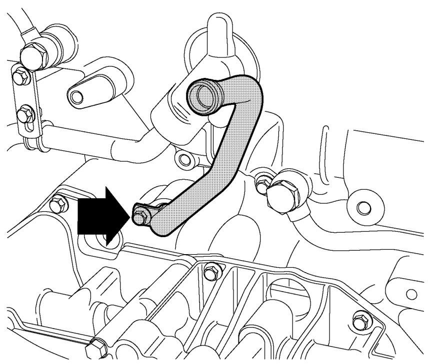


Figure 374 — Turbocharger Oil Return Pipe

2. Install the front and rear EGR cooler brackets in position over the cooling duct cover and cylinder block. Loosely install the mounting bolts. Do not tighten at this time.

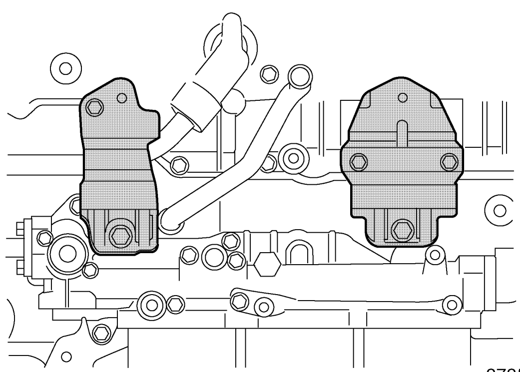


Figure 375 — EGR Cooler Brackets

3. Place a straightedge across the mounting pads of the EGR cooler brackets and clamp the straightedge in place on the pads.

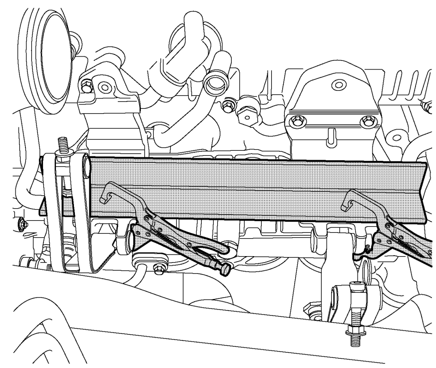


Figure 376 — Straightedge EGR Cooler Brackets

4. Tighten the upper mounting bolts on both brackets to specification. Remove the clamps and alignment straightedge. Now, secure the lower mounting bolts to specification.
5. Replace with **new** and lubricate the O-ring that seals the EGR cooler to the cooling duct cover.
6. Place the EGR cooler in position on the mounting brackets. Align the EGR cooler with the coolant inlet port and engage the cooler.

NOTE

The alignment pin at the bottom of the cooler must fall into the groove on the front bracket.

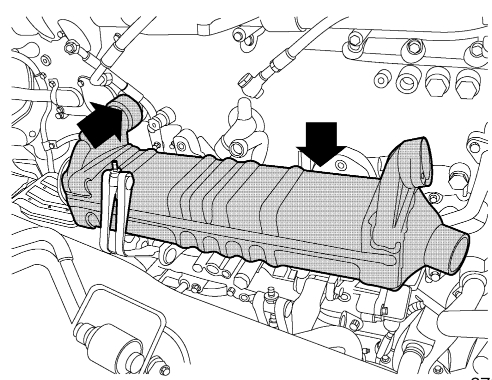


Figure 377 — EGR Cooler Installation

7. Rotate the retaining straps into position and tighten the fasteners on each strap to specification. Tighten the jam nut to secure each fastener.

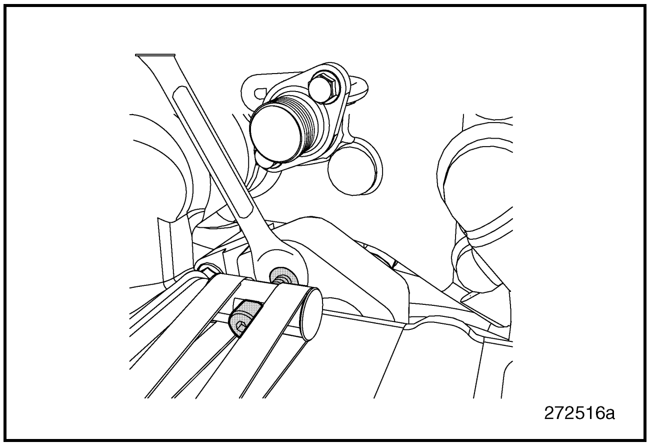


Figure 378 — EGR Cooler Retaining Strap

8. Apply sealant to the threads of the drain valve. Install the drain valve in the cooler and tighten to specification.

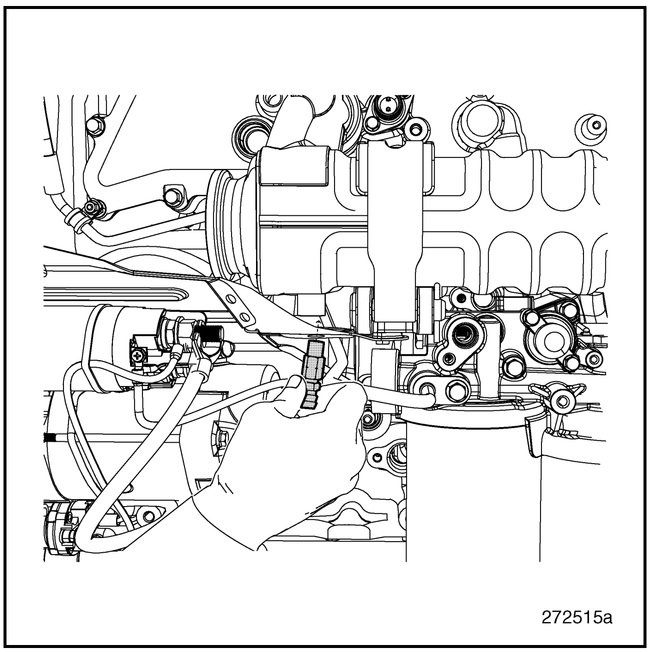


Figure 379 — EGR Cooler Drain Valve

9. Using **new** O-rings, position the EGR cooler coolant return pipe between the engine oil cooler plate and EGR cooler. Next, press the pipe into the oil cooler plate bore first, then into the EGR cooler. Attach pipe clamps and fasteners. Tighten fasteners to specification.

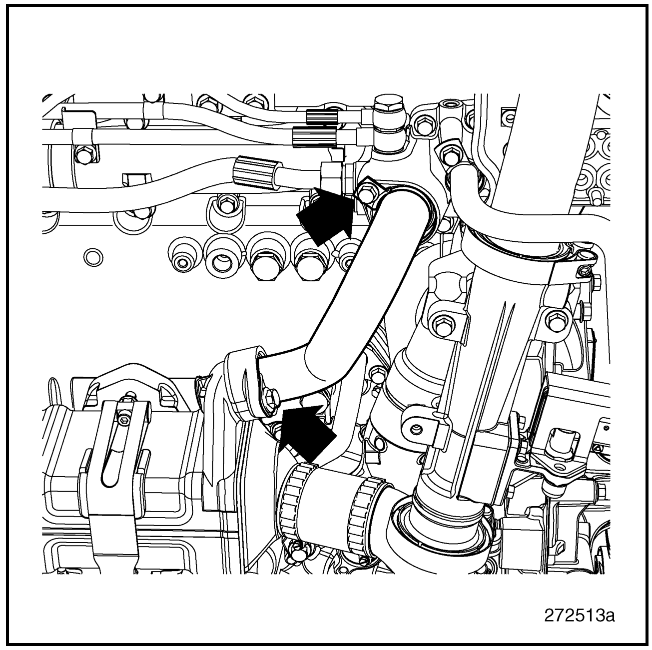


Figure 380 — EGR Cooler Coolant Pipe

EGR Hot Pipe (Cooler Inlet) Installation

[214 HN, HP, HR]

1. Install **new** high-temperature gaskets into the EGR valve end of the hot pipe and the inlet of the EGR cooler. Ensure the gaskets lay flat against the flange surfaces with the bead of the gaskets facing toward the hot pipe.

NOTE

Gaskets are one-time use only. Do not reuse gaskets.

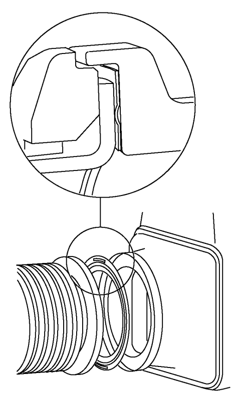


Figure 381 — EGR High-Temperature Gaskets

2. Inspect the V-clamps and T-bolt threads for wear or damage. If they are OK, apply anti-seize compound to the T-bolt threads. Lubricate the V-inserts of the clamps with forminol (or equivalent release and assembly oil) to clamp inner segments.
3. Hook the upper V-clamp over the EGR valve flange. Next, place the remaining V-clamp over the bellows on the hot pipe.

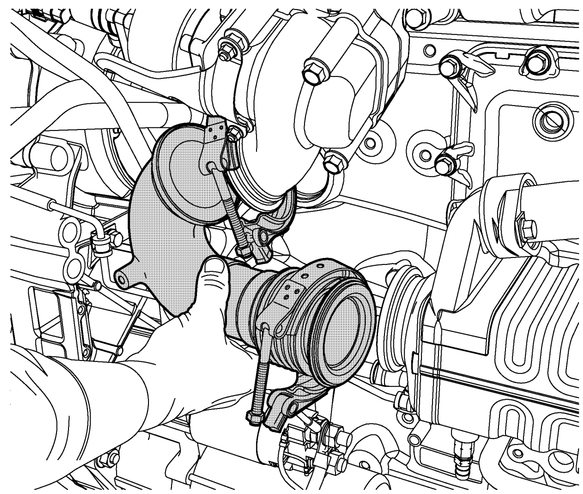


Figure 382 — Installing EGR Hot Pipe

4. Lubricate both the flange on the EGR cooler inlet and the flange on the EGR hot pipe with fresh engine oil. Lubrication aids in proper V-clamp performance.
5. Position the EGR hot pipe between the EGR valve and the EGR cooler. Make sure the flanges engage properly. While holding the hot pipe in position, slide the upper V-clamp over the flange and tighten until snug. Next, slide the lower V-clamp over the flange of the EGR cooler and tighten the clamp until snug.
6. Visually inspect the floating flange through the gap in the V-band clamp to make sure it is properly seated in the EGR cooler flange. The floating flange must be concentric with the EGR cooler flange.

NOTE

If the floating flange is not properly seated in the EGR cooler flange, the gasket will not be compressed and the seal will leak.

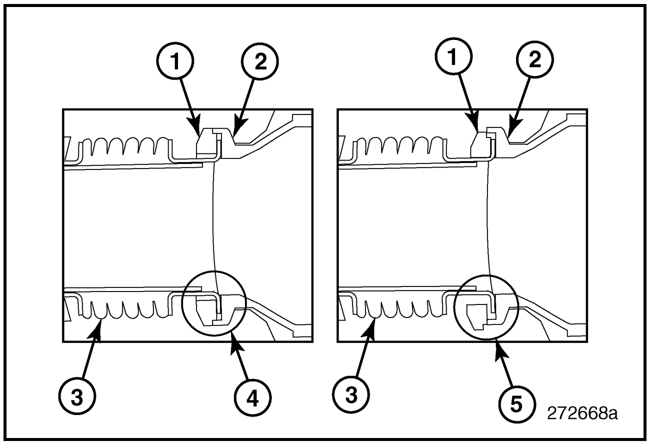


Figure 383 — EGR V-Clamp Floating Flange

1. EGR Pipe Floating Flange 2. EGR Cooler Flange 3. EGR Pipe	4. Flange Assembled Correctly 5. Flange Assembled Incorrectly

7. Position the V-clamps so that the T-bolts clear the heat shield. Tighten the clamps to specification.

N O T E

After reaching the specified torque, inspect the V-clamps to make sure that no portion of the clamp has bottomed out.

Turbocharger Installation

[214 SC]

C A U T I O N

- *Use only **new** and approved gaskets at the various air, oil and exhaust connections to the turbocharger. Avoid the use of sealing or joint compounds at all flanged connections.*
- *Thorough cleanliness is required. Small particles can cause severe rotor damage if inducted during high-speed operation. Be sure to plug the inlet and outlet ports while handling the turbocharger.*
- *After completing engine reassembly, fill the turbocharger oil passage 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 make sure there is no foreign material including burrs and loose lining fragments.
2. Clean the contact surface on the exhaust manifold, oil return/drain back pipe and adapter block.
3. Retain the protective caps over the turbocharger ports to keep debris and dirt out of the turbocharger as engine reassembly progresses.
4. Apply anti-seize compound to the threads and under the heads or contact surfaces of the fasteners. Anti-seize helps prevent fastener oxidation corrosion and reduces friction to help achieve the intended clamp load on the component when tightening the fasteners to specification.
5. Place the spacers and a **new** turbocharger gasket onto the flange rear mounting bolts.

N O T E

- Make sure to use the correct turbocharger gasket designated for the MP8 engine only.
- Orient gasket to allow gasket part number to face toward turbocharger and away from exhaust manifold.

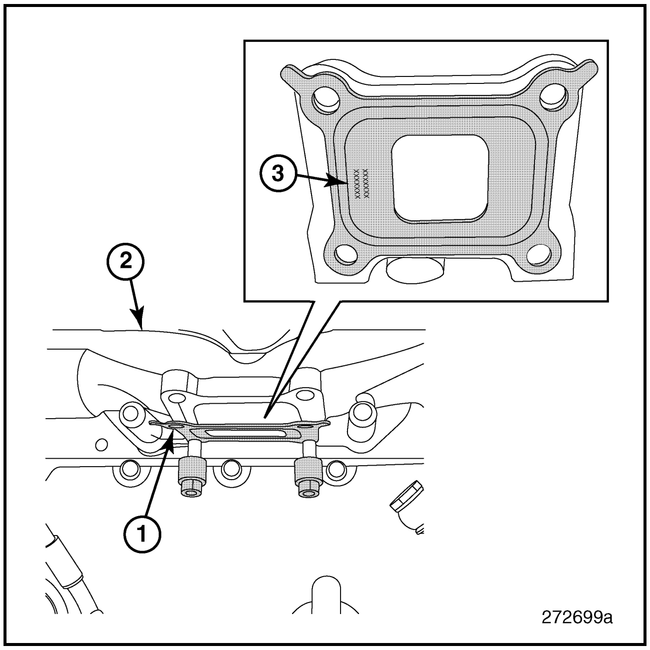


Figure 384 — Turbocharger Gasket Installation

1. Turbocharger Gasket 2. Exhaust Manifold	3. Turbocharger Gasket Part Number Stamping Area

6. Insert the turbocharger oil return line and at the same time, position the turbocharger onto the flange mounting bolts in the exhaust manifold. Turbocharger flange slots slide onto the manifold flange mounting bolts. Install the remaining turbocharger flange mounting bolts and spacers. Tighten the fasteners according to specification in the sequence shown.

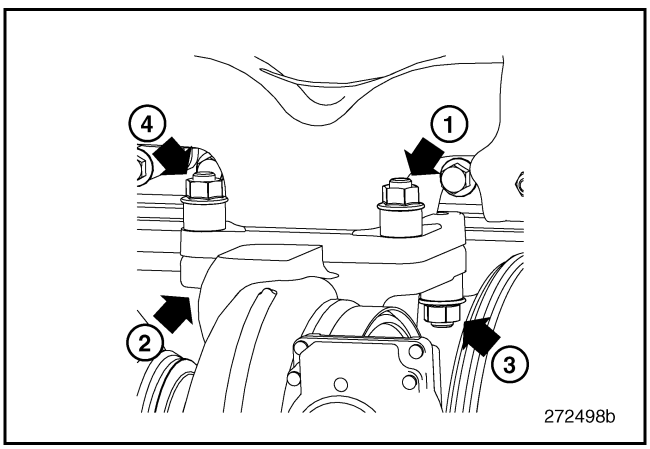


Figure 385 — Turbocharger Fastener Tightening Sequence

7. Replace all sealing washers used on the banjo fittings for the turbocharger and turbocharger actuator.
8. Connect all coolant supply and return lines to the turbocharger and turbocharger actuator.

NOTE

The turbocharger coolant line must be reconnected to the cylinder block.

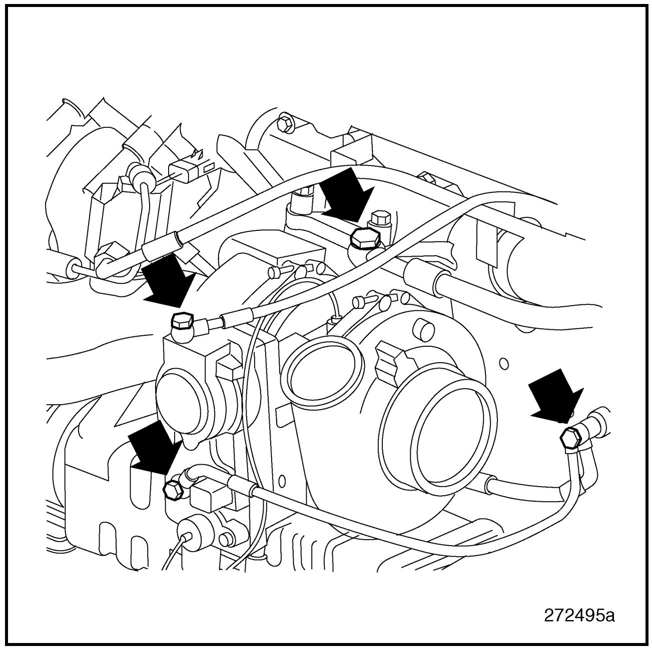


Figure 386 — Turbocharger Coolant Connections

9. Connect the turbocharger oil feed line.

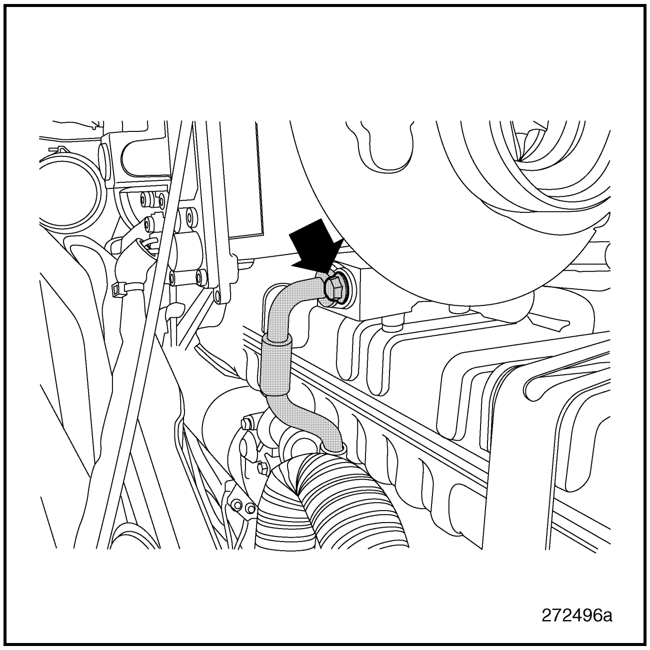


Figure 387 — Turbocharger Oil Feed Connection

10. Connect the turbocharger actuator and turbocharger wheel speed sensor wiring harness. Position the connector with the flat side toward the flat in the bracket. Secure the harness to the oil filter housing using a P-clamp.

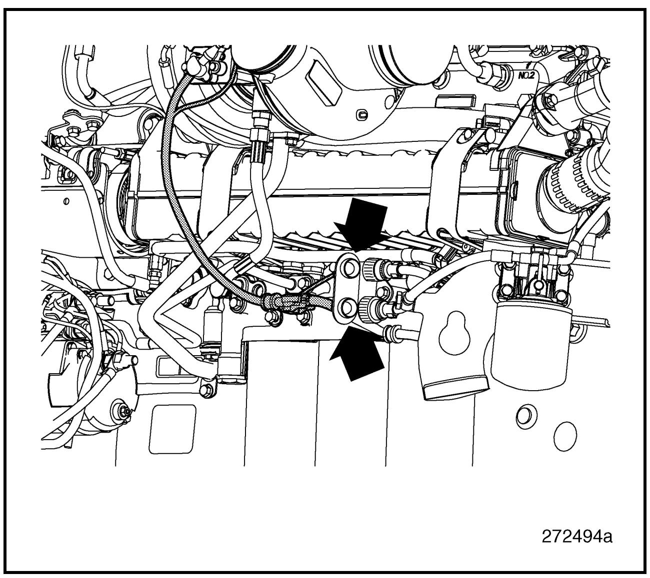


Figure 388 — Turbocharger Actuator and Sensor Connection

11. Using the diagnostic computer, calibrate the variable geometry turbocharger once the engine has been returned to the chassis and started.

Starter Installation

[272 DH]

The starter is held in place by nuts assembled over studs inserted in the block. If a stud is missing, replace it.

1. Using a torque wrench, tighten replacement studs according to specification.
2. Assemble the starter on the studs in the flywheel housing.

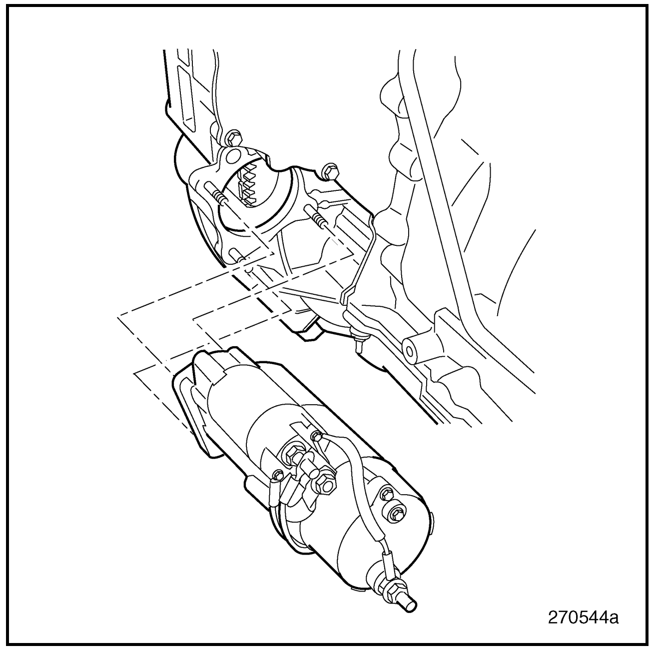


Figure 389 — Starter Installation

3. Using a torque wrench, tighten the nuts according to specification.

Air Compressor Installation

[261 CK]

1. Install a **new** seal in the air compressor housing mounting flange.

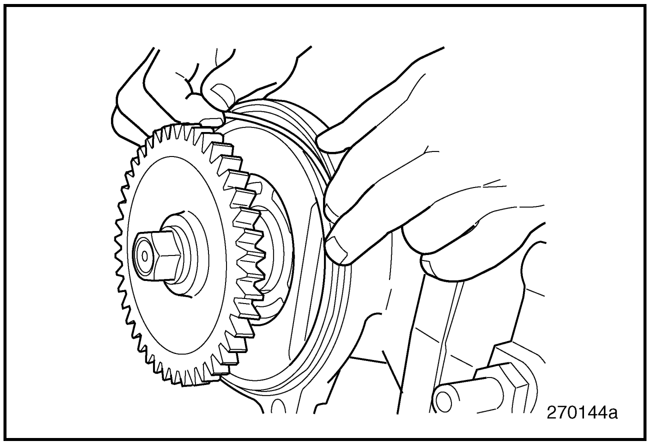


Figure 390 — Installing Air Compressor Mounting Seal

2. Assemble the air compressor on the mounting flange of the timing gear plate.

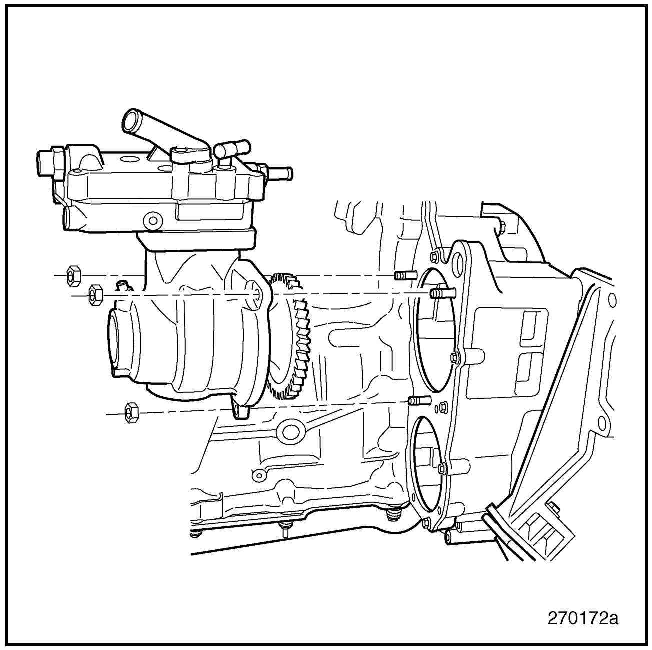


Figure 391 — Air Compressor Installation

3. Using a torque wrench, tighten the attaching nuts in two stages according to specification.

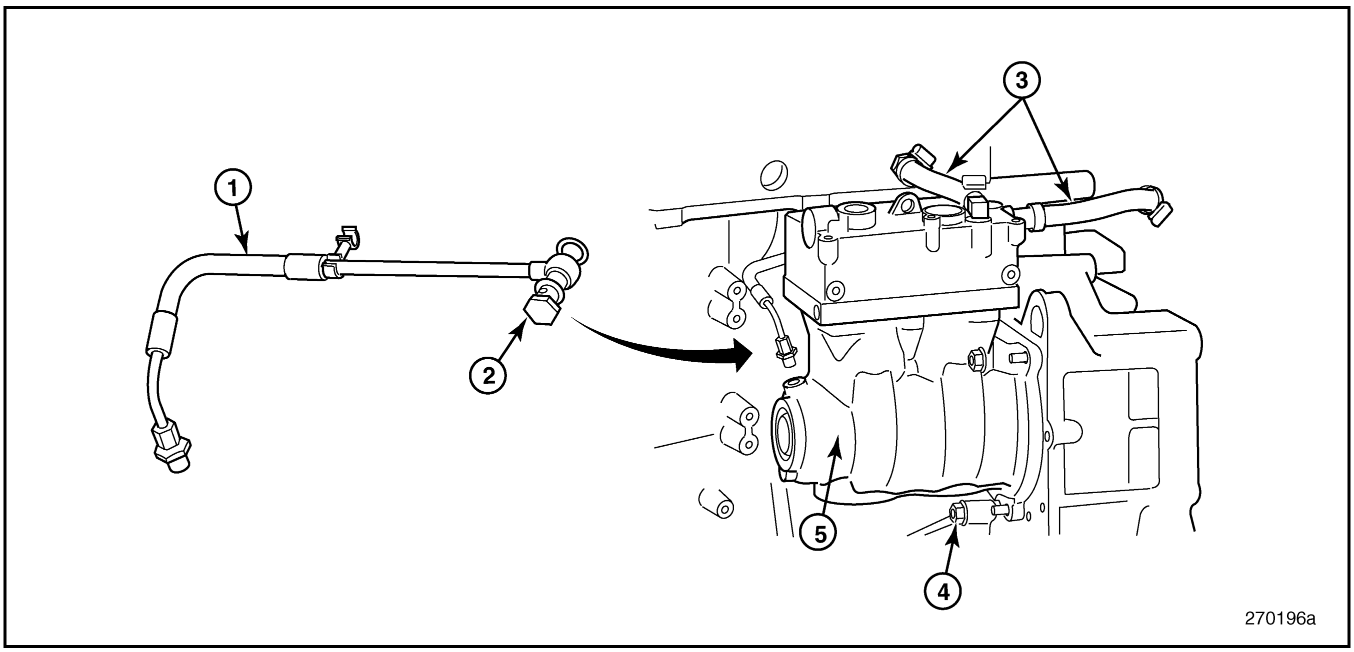


Figure 392 — Air Compressor Coolant and Lubrication Fittings

1. Lubrication Line 2. Banjo Fitting 3. Coolant Lines	4. Attaching Stud and Nut 5. Air Compressor

4. Install the coolant lines to the air compressor.

5. Install the lubrication lines to the air compressor.

Tandem Pump (Fuel and Power Steering) Installation

[231 AA, 262 EB]

1. Install a **new** O-ring in the groove on the tandem pump mounting flange.
2. Assemble the tandem pump on the flywheel housing.

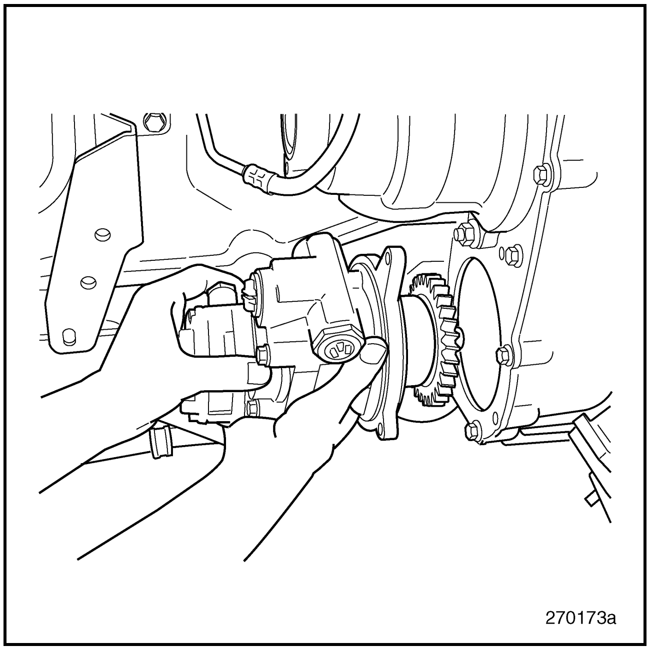


Figure 393 — Tandem Pump (Fuel and Power Steering) Installation

3. Using a torque wrench, tighten the attaching fasteners according to specification.

Inlet Manifold Installation

[214 HD]

1. Using a sharp pick, carefully remove the rubber seal (molded gasket) from the groove in the inlet manifold. Clean the manifold of any dirt, adhesives and inspect for any damage to the sealing surface. Also, inspect the cylinder head and ensure the sealing surface is clean and undamaged.
2. Install a **new** rubber seal (molded gasket) into the groove of the inlet manifold.

NOTE

Apply a minimal amount of MACK-approved sealant in the seal groove to hold the seal in place during assembly. Install the manifold within 20 minutes of applying the sealant.

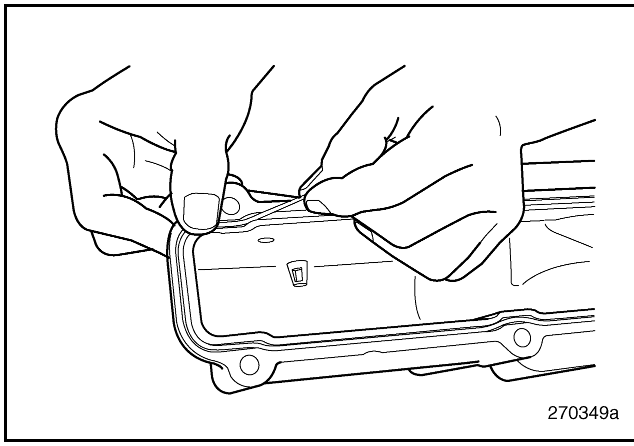


Figure 394 — Installing Inlet Manifold Seal

3. Position the inlet manifold onto the two previously installed alignment pins. Start two **new** mounting bolts with mounting spacers to hold the manifold in place, remove the alignment pins and install the remaining **new** manifold bolts with spacers.

NOTE

Use **new** bolts with mounting spacers when installing the inlet manifold.

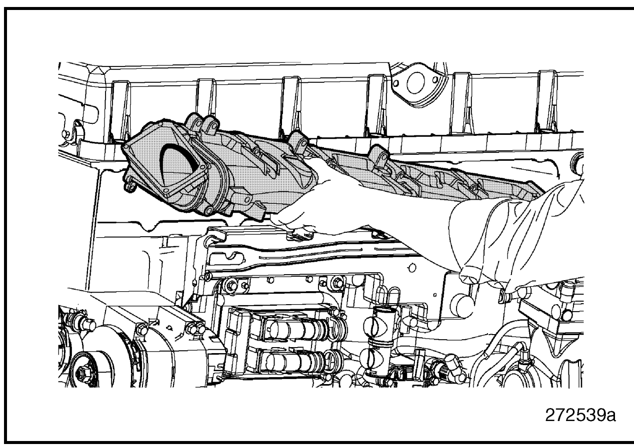


Figure 395 — Inlet Manifold

4. Tighten the inlet manifold bolts in sequence according to specification.

5. Secure the engine harness to the inlet manifold using P-clamps.
6. Install the electrical connector to the charge air temperature sensor located on the top of the inlet manifold and secure the harness with tie straps.

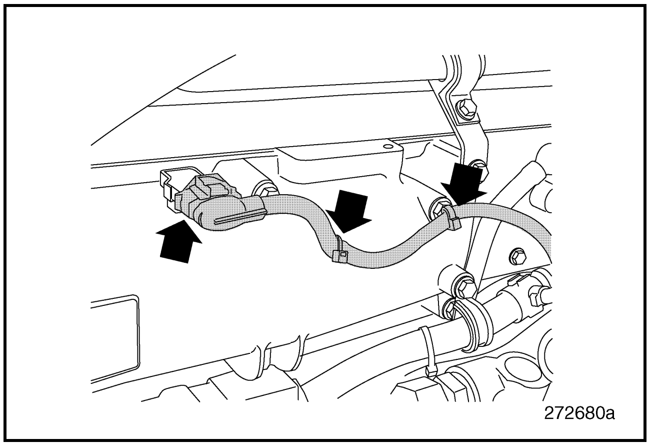


Figure 396 — Charge Air Temperature and Pressure (Boost) Sensor

7. Using a torque wrench, tighten the sensor according to specification.

EGR Mixer Installation

[214 HL]

NOTE

A redesigned single-piece mixer inlet tube (part No. 21153626) was implemented into production in September 2008, replacing the previous style brazed-end tube (part No. 20900934). The revised tube is available through the MACK Parts System and should be used if a replacement part is needed. Refer to SB214058.

1. Clean the forward sealing surface on the inlet manifold, air preheater or spacer, and EGR mixing chamber.
2. Position the EGR mixing chamber and inlet air preheater (if equipped), or spacer block with **new** gaskets onto the inlet manifold. Next, start the bolts to hold the assembly to the inlet manifold.

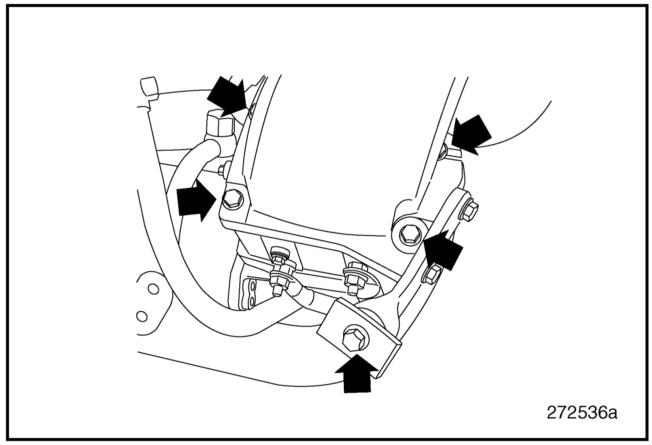


Figure 397 — EGR Mixing Chamber

3. Using a torque wrench, tighten the fasteners in a cross pattern according to specification.
4. Install the fan ring support bracket mounting fastener. Tighten the bolt according to specification.
5. If equipped, position and install the inlet air preheater relay bracket (with relay attached) to the mounting surface on the inlet manifold. Connect and secure the power and ground cables as marked at disassembly.

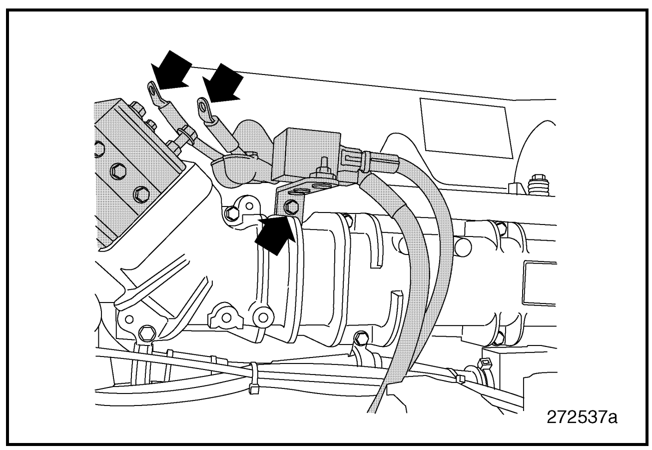


Figure 398 — Inlet Air Preheater Relay

EECU and Cooler Installation

[230 EK]

NOTE

The sequence in which the EGR venturi housing, fuel filter housing, fuel lines and EECU are assembled on the engine depends on the type of engine stand used. For engine stands that use an adapter plate attached to the left side of the engine, these components cannot be installed until after the engine has been removed from the repair stand.

Fuel fresh from the tank serves as coolant for the EECU. The cooler connects into the line carrying the fuel from the tank into the fuel pump.

NOTE

Make sure the cooling plate and EECU mating surfaces are clean.

1. Position the EECU on the cylinder block and install the mounting fasteners.

NOTE

Make sure that rubber isolators are correctly installed and that the ground strap is grounded to the cylinder block.

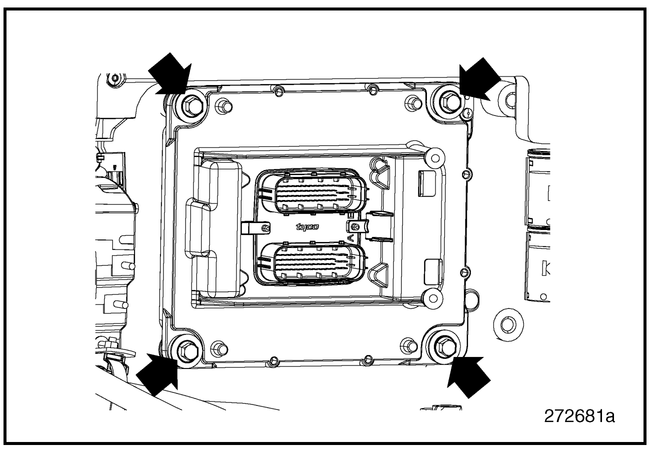


Figure 399 — EECU Installation

2. Using a torque wrench, tighten the fasteners according to specification.
3. Assemble the cooler on the EECU. When positioning the module, make sure that the small ground strap at the upper right of the unit is properly secured and pressed in close.

NOTE

If the EECU is painted in the region contacting the cooler, remove the paint to provide for the most efficient cooling.

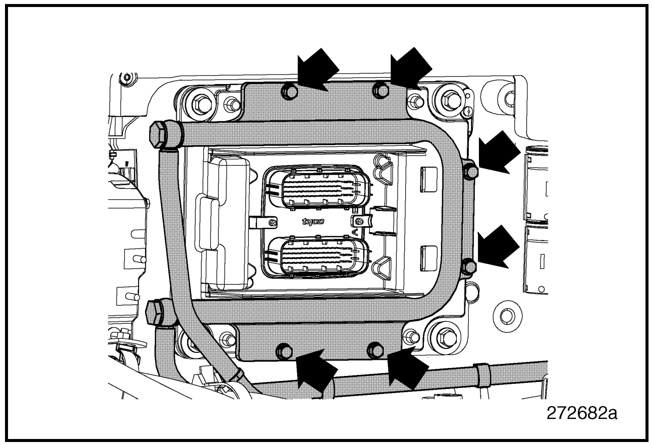


Figure 400 — EECU Cooling Plate

4. Using a torque wrench, tighten the fasteners in sequence according to specification.

Fuel Lines and Filter Housing Installation

NOTE

The sequence in which the EGR venturi housing, fuel filter housing, fuel lines and EECU are assembled on the engine depends on the type of engine stand used. For engine stands that use an adapter plate attached to the left side of the engine, these components cannot be installed until after the engine has been removed from the repair stand.

Figure 401 — Fuel Filter Housing Assembly

1. Assemble the fuel filter housing on the cylinder block.
2. Using a torque wrench, tighten the fasteners according to specification.
3. Attach the fuel line to the side of the cylinder head at the rear and to the fuel filter housing.

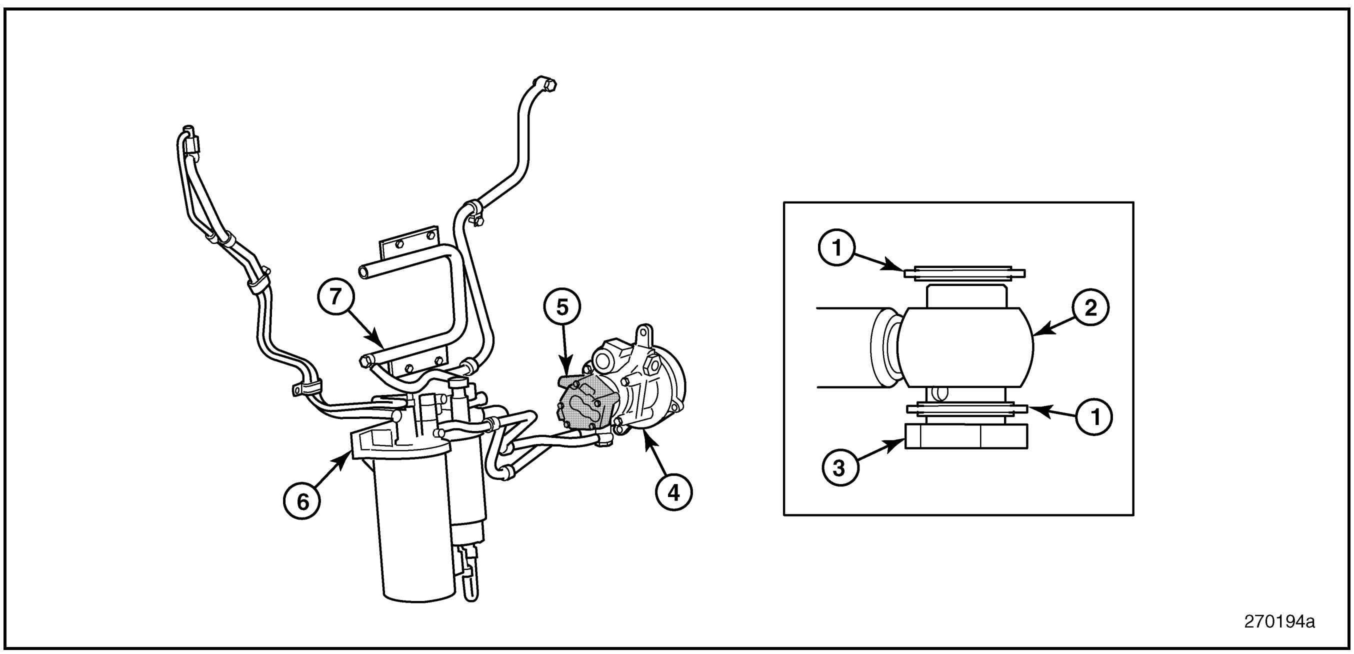


Figure 402 — Fuel Supply Pump, Filter Assembly and Lines

1. Seal Rings	5. Low-Pressure Fuel Supply Pump (Mounted to Power Steering Pump)
2. Banjo Coupling	6. Filter Housing
3. Hollow Screw	7. EECU Cooler
4. Power Steering Pump	

4. Attach the fuel line to the cylinder block with a P-clamp.
5. Install the fuel return line between the cylinder head at the front and the fuel filter housing.
6. Install the fuel line to the cylinder block with P-clamps.
7. Install the fuel return line to the fuel filter housing and to the EECU cooler.
8. Install the fuel supply and fuel return lines to the fuel pump and to the fuel filter housing.
9. Using a torque wrench, tighten the banjo fittings according to specification.

Crankcase Ventilation Separator

1. Clean the crankcase ventilation separator mating surface on the cylinder block. Install a **new** rubber gasket into the separator housing groove.

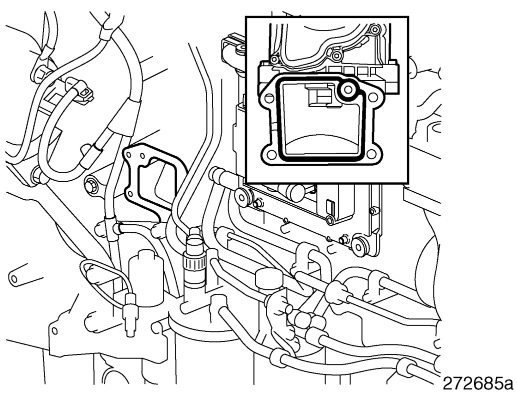


Figure 403 — Separator Mating Surface

2. Assemble the separator on the cylinder block and install the fasteners.

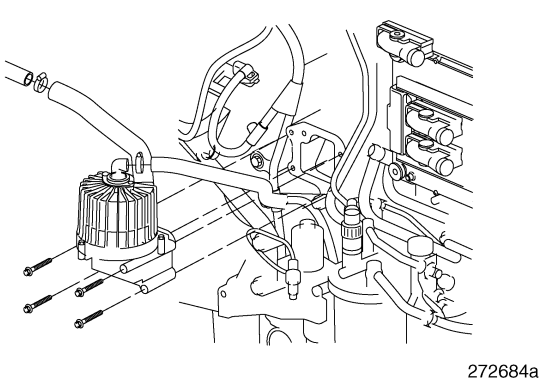


Figure 404 — Separator Installation

3. Using a torque wrench, tighten the fasteners according to specification.
4. Assemble the outlet hose on the separator outlet connector and install the hose clamps.
5. Using a torque wrench, tighten the hose clamp fasteners according to specification.
6. Assemble the inlet hose on the separator inlet. Install the hose clamps.
7. Using a torque wrench, tighten the hose clamp fasteners according to specification.

Crankshaft Vibration Damper and Fan Pulley Installation

[212 RB, 216 1A]

CAUTION

When handling a vibration damper, be careful not to damage the housing. Dents in the outer housing will render the damper ineffective. The vibration damper cannot be repaired. Failure to heed this caution may result in severe engine damage.

Inspect the vibration damper for dents, nicks or fluid leaks in the outer housing. If any of these are evident, the damper must be replaced. Due to the close clearance between the damper housing and the rotor inside, dents or nicks may cause contact between the two components. Fluid loss will deteriorate the dampening effect of the damper.

1. Assemble the crankshaft vibration damper and fan pulley on the crankshaft hub using **new** fasteners.

NOTE

Fasteners are one-time use only. Do **NOT** reuse fasteners.

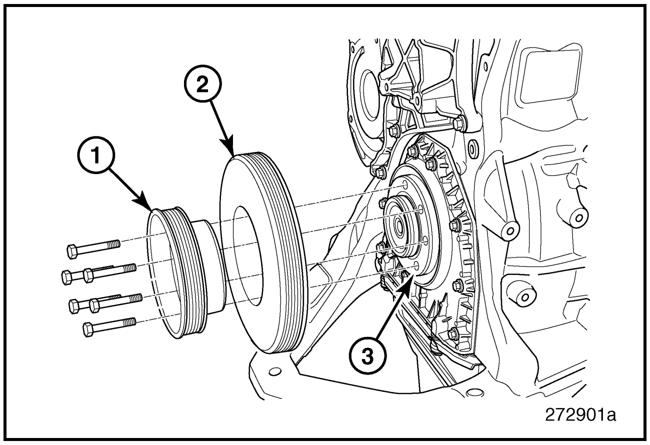


Figure 405 — Fan Drive Pulley and Crankshaft Damper Assembly

1. Fan and Coolant Pump Drive Pulley	2. Vibration Damper 3. Crankshaft Hub

2. Using a torque wrench, tighten the attaching fasteners in sequence in two steps according to specification.
3. Assemble the front engine power take-off (FEPTO) if equipped. Tighten the attaching fasteners in sequence in two steps according to specification.

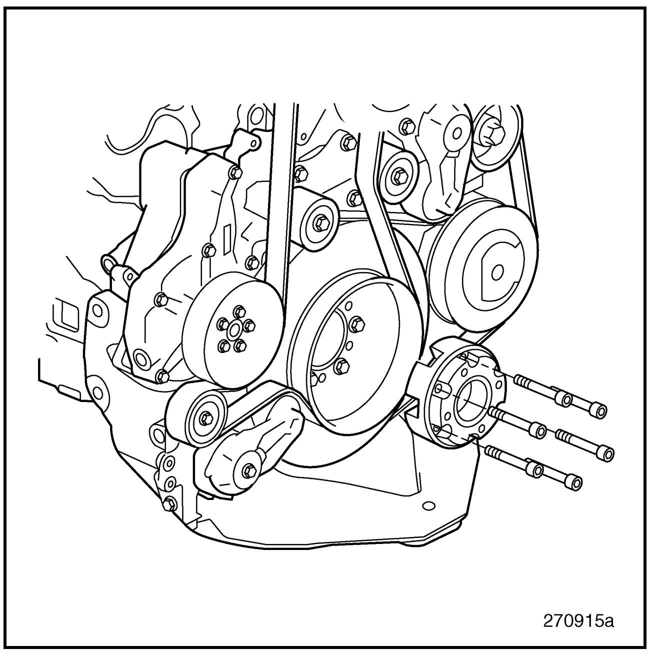


Figure 406 — Front Engine Power Take-Off (FEPTO) Assembly

Alternator and Refrigerant Compressor Installation

[271 CB, 264 DP]

1. Assemble the alternator mounting bracket onto the cylinder block. Tighten the fasteners according to specification.
2. If removed, install the front engine support mounting bracket on the cylinder block. This bracket also provides the mounting points for the refrigerant compressor.
3. Using a torque wrench, tighten the fasteners for the mounting bracket according to specification.
4. If removed, assemble the belt tension idler on the bracket.
5. Using a torque wrench, tighten the fasteners according to specification.
6. Assemble the alternator and refrigerant compressor on their pads.

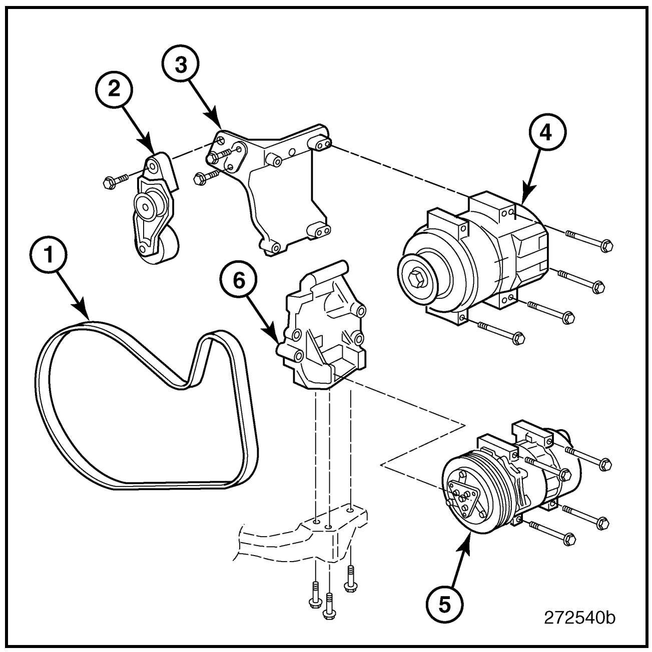


Figure 407 — Alternator and Refrigerant Compressor

1. Drive Belt 2. Belt Tensioner 3. Alternator Mounting Bracket	4. Alternator 5. Refrigerant Compressor 6. Mounting Bracket, Front Engine Support

7. Using a torque wrench, tighten the fasteners according to specification.
8. If a harness is installed, securely connect the electrical wiring as tagged during disassembly.
9. Assemble the belt pulleys on the alternator and compressor hubs, if removed.

Wiring Harness Installation

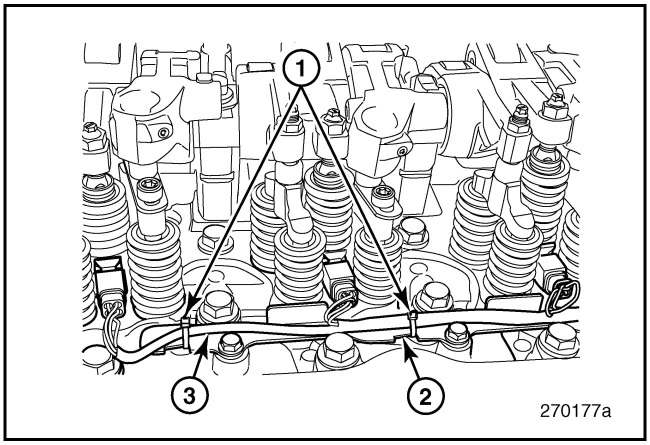


Figure 408 — Internal Wiring Harness

1. Tie Straps 2. Tie Bar Notch	3. Wiring Harness

1. Route and position the harness on the engine as noted during disassembly.
2. Insert the unit injector portion of the harness through the hole in the timing gear cover.
3. Connect the harness to each unit injector.
4. Connect the harness to the engine brake control valve if equipped.
5. Using high-temperature wire ties, 983472, attach the harness to the cylinder head.
6. Carefully route the wiring harness over the engine brake control valve. Secure the harness to the control valve as shown in Figure 409. Make sure that the harness is positioned to the side of the boss at the top of the valve assembly.

CAUTION

Do NOT route the harness over the boss at the top of the engine brake control valve. There is not enough clearance between the valve and the valve cover for the harness when the cover is installed. The harness must be positioned to the side of the boss to avoid damage to the harness.

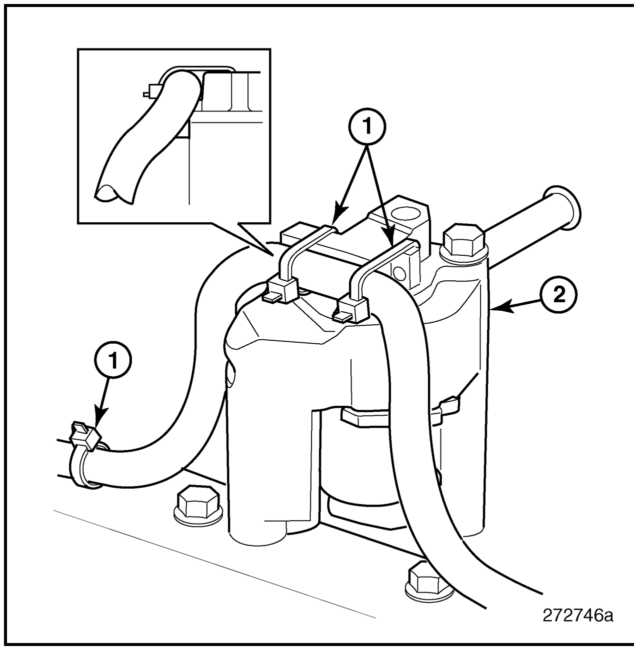


Figure 409 — Harness Routing Over Engine Brake Control Valve

1. Tie Straps	2. Control Valve

The external portion of the wiring harness is encased in accordion tubing. There are several units each of which is fitted with end connectors that permit convenient stringing, joining and attachment to the cylinder block in various locations.

CONNECTING THE EECU

1. Check the tension of the terminal connector pins using the test pins tool kit 9990008.

NOTE

If terminal pins are damaged or corroded, replace as necessary.

2. Carefully engage the upper and lower wiring harness connectors to the EECU. Verify that the connectors are latched and properly locked in position.

CAUTION

Use care to ensure that the EECU terminal pins are straight and undamaged.

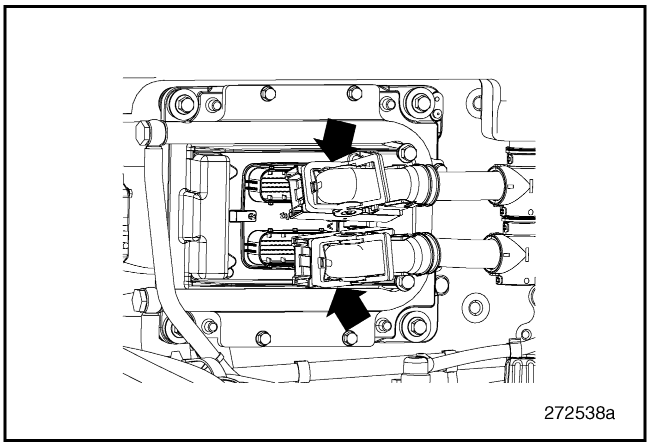


Figure 410 — EECU Harness Connectors

3. Install the bolts to secure the wiring harness clamps to the EECU.

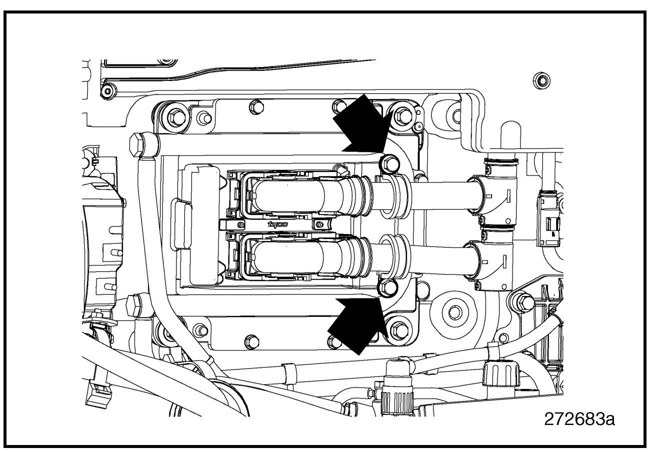


Figure 411 — EECU Harness Clamps

4. Connect the various terminals as tagged at disassembly to all sensors, relays and components such as the starter, alternator and refrigerant compressor among others.
5. Attach the clamps to hold the harness on the cylinder block.

Cylinder Head (Valve) Cover Installation

[211 JB]

1. Clean the gasket sealing surface of the cylinder head. The surfaces should be clear of any dirt or debris and free of any oil.
2. Inspect the gasket for damage. If replacement is necessary, carefully place a **new** gasket into the channel, making sure that it is properly seated and follows the contour of the channel.

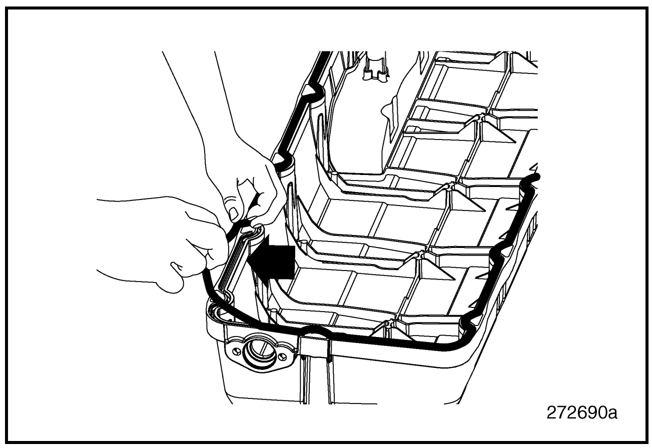


Figure 412 — Cylinder Head Cover Gasket

3. Apply a 2 mm (5/64 inch) bead of MACK-approved sealant to the area where the timing gear cover and the cylinder head meet. This parting line is on both sides of the cylinder head. Carefully position the cylinder head cover on the cylinder head and make sure that the seal remains properly seated.

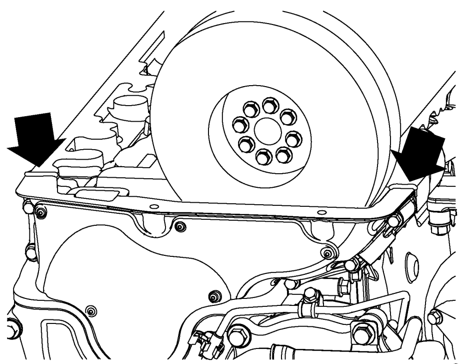


Figure 413 — Sealant Application

4. Install the spring-loaded bolts in the cylinder head cover. Tighten the cylinder head cover bolts in sequence according to specification.

NOTE

- The cylinder head cover must be installed within 20 minutes of the sealant being applied.
- The bolt springs provide even tension on the cylinder head cover gasket.

5. Install the fasteners securing the crankcase ventilation tube and bracket to the cylinder head cover and inlet manifold. Tighten the fasteners according to specification.

NOTE

Inspect the crankcase ventilation tube O-ring and replace if necessary.

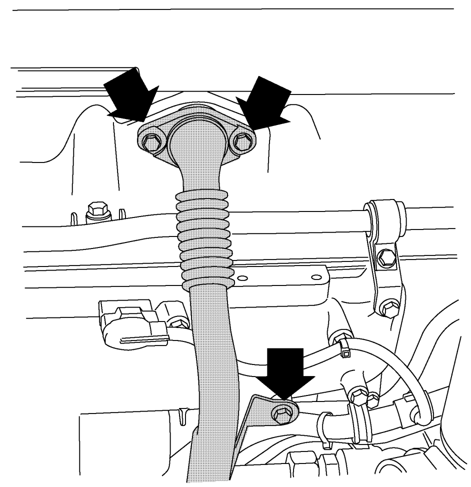


Figure 414 — Crankcase Ventilation Tube

EGR Venturi Tube and Crossover Piping Installation

NOTE

The sequence in which the EGR venturi tube, fuel filter housing, fuel lines and EECU are assembled on the engine depends on the type of engine stand used. For engine stands that use an adapter plate attached to the left side of the engine, these components cannot be installed until after the engine has been removed from the repair stand.

1. Place a **new** O-ring on the venturi tube outlet flange.
2. Place the EGR venturi tube in position on the mounting bracket and install the fasteners. Tighten the tube fasteners according to specification.

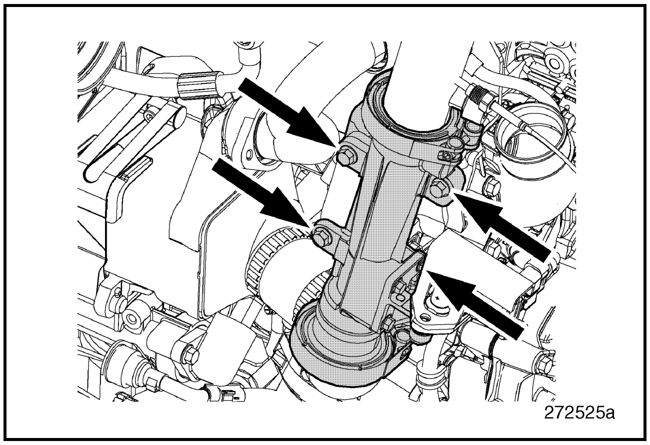


Figure 415 — Venturi Tube

3. Install the retainer strap and fasteners to secure the EGR venturi outlet pipe to the venturi tube mounting bracket.

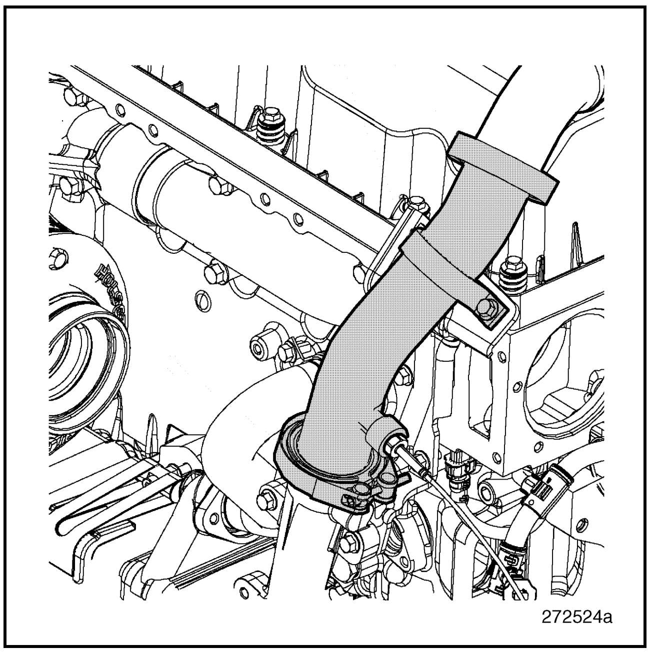


Figure 416 — EGR Venturi Outlet Pipe

4. Install a **new** hose and O-ring on the 90-degree elbow that connects the EGR cooler outlet to the venturi tube.

5. Position the 90-degree elbow with hose to the EGR cooler outlet. Tighten the clamps to secure.

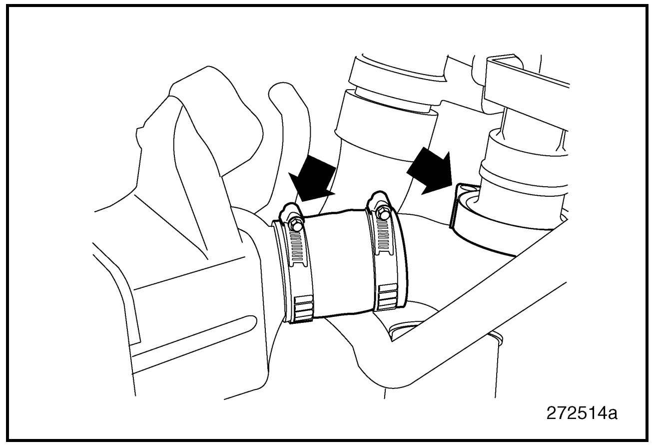


Figure 417 — EGR Cooler Outlet

6. Inspect the venturi tube V-band clamps for wear or damage, and replace as necessary. Position the V-band clamps to the venturi tube inlet and outlet. Lubricate the threads and V-inserts.
7. Tighten the clamps according to specification.

NOTE

Make sure the O-rings remain in place while positioning the pipe.

8. Install a **new** O-ring at the EGR mixer inlet and a **new** O-ring on the crossover pipe clamp flange.

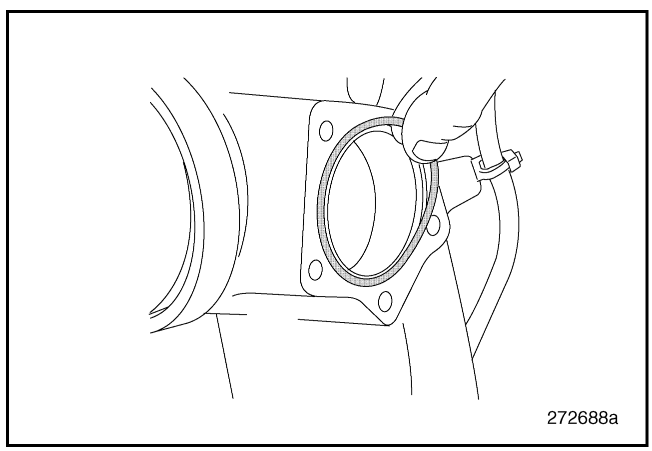


Figure 418 — Mixer Inlet O-Ring

9. Place the EGR inlet pipe in position on the mixer inlet mounting pad and install the mounting fasteners. Tighten the fasteners according to specification.

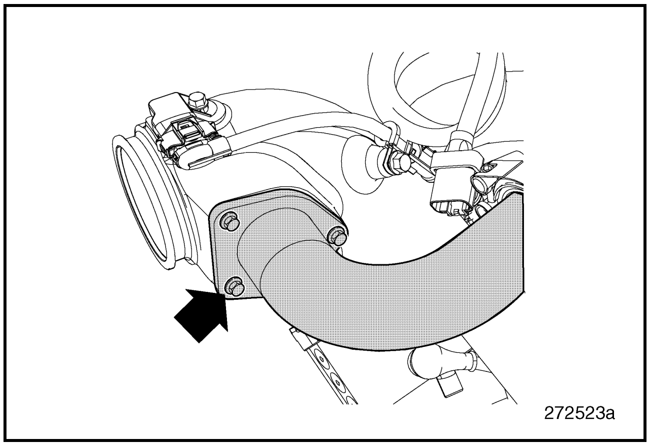


Figure 419 — Mixer Inlet Pipe

10. Inspect the crossover pipe V-band clamps for wear or damage, and replace as necessary. Position the crossover pipe (with **new** O-rings) between the venturi outlet pipe and mixer inlet pipe. Lubricate the threads and V-inserts.

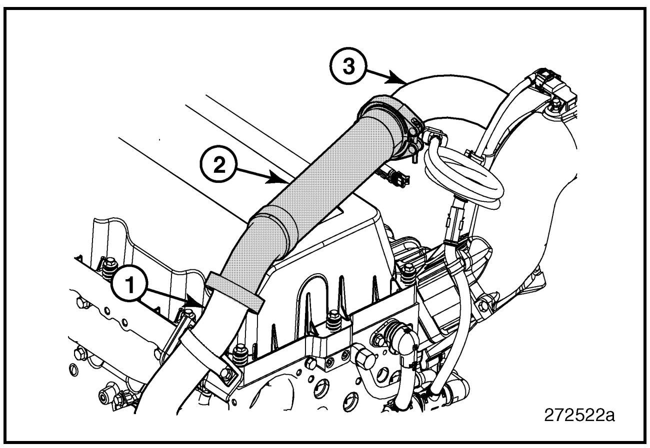


Figure 420 — Crossover Pipe

1. Venturi Outlet Pipe 2. Crossover Pipe	3. Mixer Inlet Pipe

11. Secure the V-band clamp at each end of the crossover pipe and tighten the clamps according to specification.

NOTE

Make sure the O-rings remain in place while positioning the pipe.

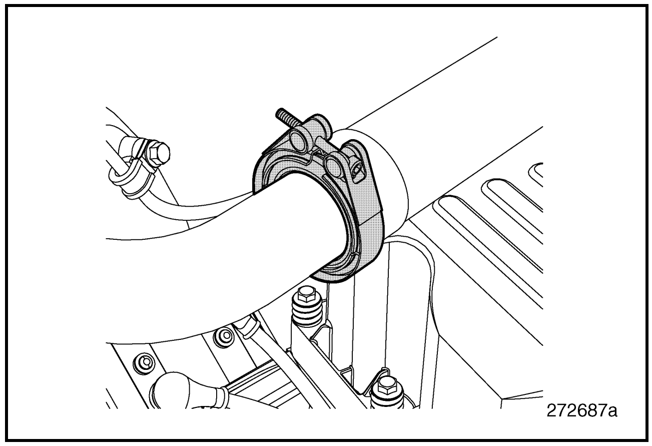


Figure 421 — V-Band Clamp

12. Install **new** seals on the pressure differential sensor mounting flange.
13. Place the pressure differential sensor in position on the venturi tube and install the mounting fasteners.

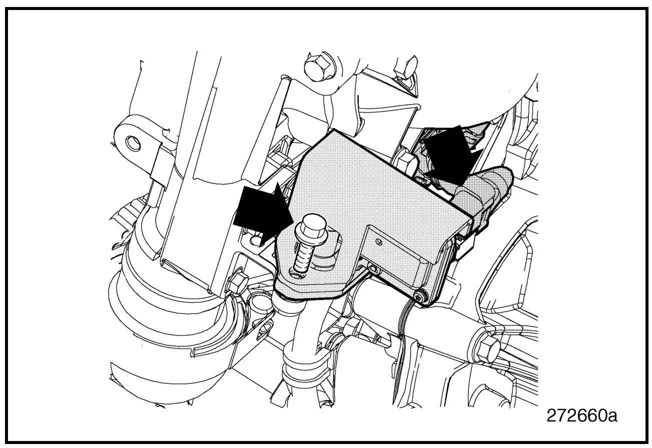


Figure 422 — Pressure Differential Sensor

14. Tighten the mounting fasteners according to specification.
15. Connect the wiring harness lead to the sensor terminal.
16. Install the EGR venturi temperature sensor and tighten according to specifications.

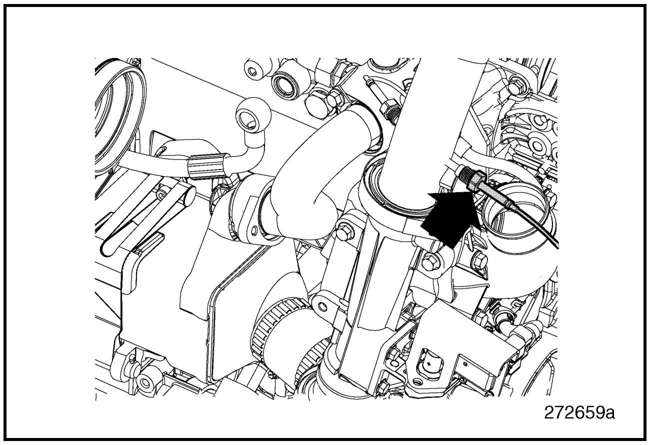


Figure 423 — Temperature Sensor

Fan Hub and Drive Belt Installation

[216 AA]

1. Place the fan hub bracket assembly in position at the front of the cylinder head and block. Install the mounting fasteners and tighten according to specification.

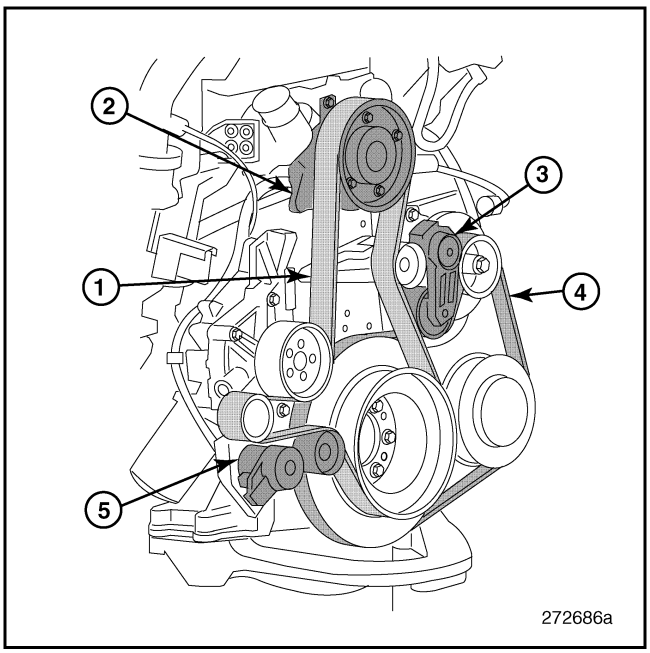


Figure 424 — Fan Hub and Accessory Drive System

1. Fan and Coolant Pump Drive Belt 2. Fan Hub Bracket 3. Accessory Drive Belt Tensioner	4. Accessory Drive Belt 5. Fan and Coolant Pump Drive Belt Tensioner

2. Place the fan and coolant pump drive belt tensioner in position on the coolant pump housing. Install the fasteners and tighten according to specification.
3. If not already done, place the accessory drive belt tensioner in position on the cylinder block. Install the fasteners and tighten according to specification.
4. Check the condition of the drive belts. Check for dry cracks or scuff marks and replace with new belts if any of these conditions are present.
5. Per the accessory routing decal, route the accessory drive and fan and coolant pump drive belts.

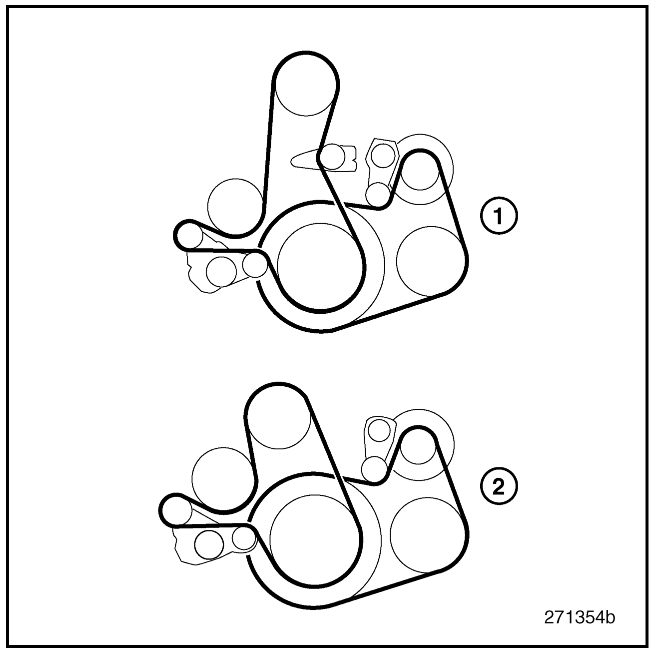


Figure 425 — Drive Belt Arrangement

1. Conventional	2. LCF (N/A Australia)

6. Place a 1/2-inch ratchet or special tool J 44392 in the accessory drive belt tensioner notch. Install the drive belt by prying the tensioner away from the belt to relieve the tension on the adjuster and allow the belt to slip onto the A/C compressor pulley. Release the tension and remove the tool.

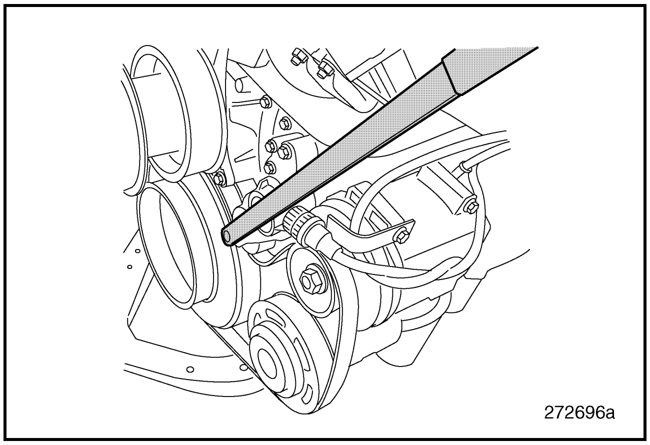


Figure 426 — Accessory Drive Belt Installation

7. Using tool J 44392, pry the belt tensioner away from the fan and coolant pump drive belt and install the belt. Release the tension and remove the tool.

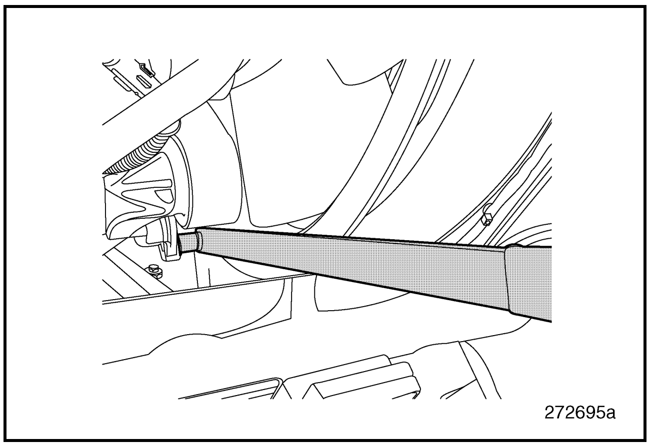


Figure 427 — Fan and Coolant Pump Drive Belt Installation

Removing Engine from Engine Stand

[200 EB]

⚠ DANGER

The engine is very heavy and extreme caution must be exercised while it is being lifted from the stand. Failure to use proper equipment and failure to keep your body clear may result in serious personal injury or death if the engine should fall or suddenly shift out of position.

1. Attach engine lifting tools J 47038-1, J 47038-6 and J 47038-8 as follows:
   a. Slide the center engine lifting bar over the cylinder head cover and install the clevis pin. Connect the center lifting bar clevis to the chain on the hoist.
   b. Place the lifting chain to the engine lift eyes and secure the chain to the bracket.
   c. Slide the rear lifting plate into the center lifting bar and install the pin.
   d. Bolt on the front section of the engine lifting bracket to the cylinder head and install the pin in the bar.
   e. Tighten the lifting bracket fasteners according to specification.

⚠ DANGER

Use only the chains, clevis and lifting plate provided with these special tools. Failure to use the correct special tool components may allow the engine to fall, causing serious personal injury or death.

2. Support the weight of the engine using a mobile floor crane such as OTC 16-1813 or equivalent crane capable of lifting the engine. Position the crane and hook up to the bar as close as possible. Raise the crane slightly to apply tension to the chain.
3. With the lifting device now supporting the engine weight, remove the mounting fasteners from the engine stand.
4. Using the engine hoist, place the engine in a suitable support rack or install the engine in the vehicle (see *Engine Installation* in the **REPAIR INSTRUCTIONS, PART 1** section).

Filters and Miscellaneous Components Installation

[219 EV, 215 LD]

This section covers installation of filters and other components that might get in the way of other assembly operations and to which nothing is assembled.

NOTE

The sequence in which the fuel filter housing, fuel lines and EECU are assembled on the engine depends on the type of engine stand used. For engine stands that use an adapter plate attached to the left side of the engine, these components cannot be installed until after the engine has been removed from the repair stand.

1. If not already done, assemble the following components on the engine using the procedures covered earlier in this section.
   - Engine wiring harness
   - Crankcase ventilation tubing
   - EECU and cooling plate
   - Fuel filter housing and fuel lines
   - Crankcase ventilation separator

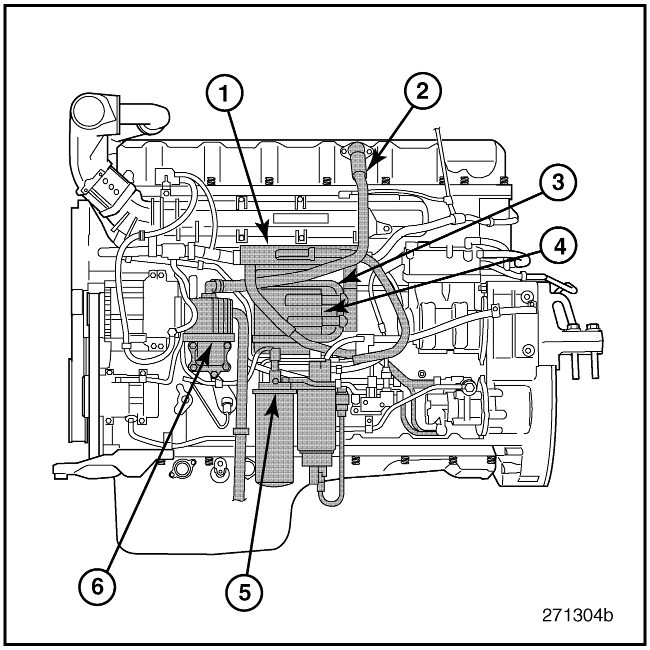


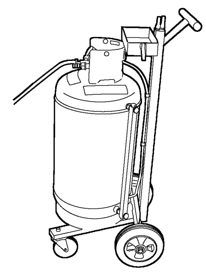
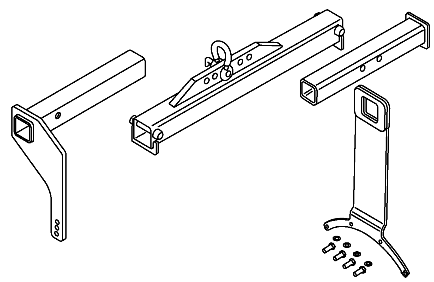
Figure 428 — Components for Installation After Removal from Repair Stand

1. Engine Wiring Harness 2. Crankcase Ventilation Tubing 3. EECU Cooler	4. EECU 5. Fuel Filters 6. Crankcase Ventilation Separator

2. Assemble the full-flow oil filters and tighten to contact plus 3/4 to 1 turn.
3. Assemble the bypass oil filter and tighten to contact plus 3/4 to 1 turn.
4. Assemble the coolant filter and tighten to contact plus 3/4 to 1 turn.

ENGINE INSTALLATION

Special Tools

Tool No.	Description	Image
DBT2V700	Coolant Extractor/Injector	 006940a
J 47038-3 J 47038-4 J 47038-6 J 47038-8	Engine Lifting Tool (Essential)	 006927b

General Instructions

Details of the engine installation procedure vary from one vehicle to another. This section provides general guidelines for installing an MP8 engine into a vehicle.

NOTE

Before installing the engine, make sure tools and equipment are inspected for safety and available for use.

1. Position the vehicle on a flat, level surface with ample work space.
2. Apply the parking brake and block the wheels. Observe all safety precautions.

NOTE

Refer to the **SPECIFICATIONS** section for information about the fasteners mentioned. Some groups of fasteners must be tightened in a specific sequence. Patterns of sequence are also specified in the torque specification section.

Installation

⚠ WARNING

The engine is heavy and difficult to handle. Obtain a helper and use a suitable lifting device to support it safely during installation. Failure to heed this warning may result in severe personal injury.

⚠ CAUTION

While installing the engine, watch for obstructions that may interfere, such as engine and chassis components, brackets, clamps and other parts attached to the frame and cab. Failure to heed this caution may result in severe damage to the engine and other components.

1. Remove the cylinder head cover.
2. Cover the valve mechanism and gear train with a suitable cloth or similar covering to prevent dirt and debris from entering the engine.
3. Attach the engine lifting tool, J 47038, to the engine. Secure the engine lifting tool to the front of the cylinder head and to the rear at the flywheel housing. Adjust the tool to assume the load.

⚠ DANGER

Ensure all bolts and pins are correctly positioned prior to removing the engine from the engine stand. Failure to properly install all bolts and pins of the engine lifting tool can result in personal injury and/or death.

4. Using the engine lifting tool, J 47038, and with the aid of the helper, lift and lower the engine into position.
5. Align the engine with the transmission.
6. Install and, using a torque wrench, tighten the rear engine support attaching screws according to specification.
7. Install and, using a torque wrench, tighten the front engine support attaching screw according to specification.
8. Remove the engine lifting tool from the engine.
9. Apply an even 2 mm (5/64 inch) bead of 342SX33 MACK-approved sealant at the joint lines between the cylinder head and the timing gear cover.

NOTE

Install the cylinder head cover within 20 minutes of applying the sealant.

10. Install the cylinder head cover.
11. Install the transmission and, using a torque wrench, tighten the transmission attaching screws according to specification.
12. Withdraw the transmission jack.
13. As applicable:
    a. If manual transmission, attach the clutch linkage, bracket retaining screws and shift linkage.
    b. If automatic transmission, attach the torque converter access panel and torque converter.
14. Attach the hood rest crossmember if applicable.
15. Connect starter wires and cables.
16. Attach the power steering hoses and reservoir if applicable.
17. Attach the exhaust system brackets.
18. Attach the exhaust system to the turbocharger.
19. Connect the air line to the Discharge Recirculation Valve (DRV).

⚠ WARNING

The radiator and charge air cooler assembly is heavy and difficult to handle. Use a suitable lifting device and a helper to support it safely during installation. Failure to heed this warning may result in severe personal injury.

20. Attach the radiator and charge air cooler assembly.
21. Attach the fan assembly.

NOTE

To allow for chassis articulation in severe service applications, the fan ring rubber seal does not fit flush against the shroud on GU model chassis. A gap of 15–20 mm (0.59–0.79 inch) exists between the front face of the aluminum fan ring to the back face of the fan shroud.

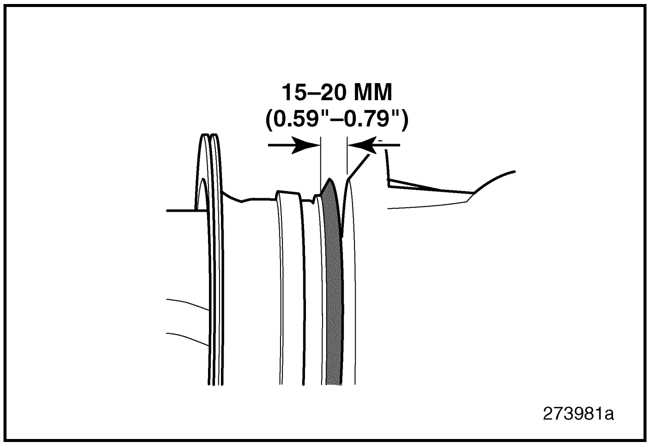


Figure 429 — Fan Ring-to-Shroud Clearance

22. Connect the fan actuator.
23. Connect the engine coolant temperature sensor.
24. Attach the charge air cooler outlet components.
25. Attach the charge air cooler inlet components.
26. Attach the coolant expansion tank.
27. Attach the lower radiator tube.
28. Connect the cab heater and fuel heater coolant return lines to the lower radiator tube.
29. Attach the upper radiator tube.
30. If the vehicle is equipped with air conditioning:
    a. Connect the A/C compressor discharge hose.
    b. Connect the A/C line at the receiver/dryer.
    c. Connect the pressure switch on the receiver/dryer.
    d. Connect the low pressure cutout switch.
    e. Recharge the A/C system with refrigerant using refrigerant recovery and recycling equipment for R134A.
31. Install the inlet air system components including the filter.
32. Connect the inlet air heater if present.
33. Attach the oil and fuel filters and the coolant filter.
34. Close all drains and drain valves.
35. Connect all sensors and actuators.
36. Install the drive belts.
37. Add oil and coolant. If available, use the coolant extractor/injector when adding coolant.
38. Attach the hood, or lower the tilted cab.

REPAIR INSTRUCTIONS, PART 2

IN-CHASSIS PART/COMPONENT PROCEDURES

This section presents standalone replacement operations which can be done in-chassis without a complete engine overhaul. These operations include:

- CAMSHAFT BEARING BRACKETS, REPLACEMENT
- OIL THERMOSTAT AND PRESSURE SAFETY VALVE REPLACEMENT
- CRANKSHAFT FRONT SEAL REPLACEMENT
- CRANKSHAFT REAR SEAL REPLACEMENT
- CRANKCASE VENTILATION (CCV) SEPARATOR REPLACEMENT
- OIL PUMP REPLACEMENT
- INJECTOR COPPER SLEEVE REPLACEMENT
- TURBOCHARGER SMART REMOTE ACTUATOR (SRA) REPLACEMENT
- UNIT INJECTOR CLEANING
- VALVE STEM HEIGHT MEASUREMENT PROCEDURE
- VALVE STEM SEAL REPLACEMENT

Due to the Engine Electronic Control Unit (EECU) self-learning capability, it is necessary to reset learned EECU parameters after servicing some engine-related components. This allows the EECU to learn the new component's behavior. After servicing is complete, perform the “Learned Data Reset” located in VCADS.

CAMSHAFT BEARING BRACKETS, REPLACEMENT (MACK MP8 ENGINE) [213 CJ]

This information covers guidelines when replacing factory or aftermarket camshaft bearing brackets (lower journals) on the MACK MP8 engine.

Preliminary Steps

The following components need to be removed for access to the camshaft bearing brackets:

- Valve Cover
- Compression Brake Solenoid Valve
- Rocker Arm Shaft
- Camshaft Assembly

General Information

Camshaft bearing journals are numbered 1–7, with matching upper and lower halves. Be sure to note and mark the corresponding journal numbers and install them in the correct sequence with matched upper and lower halves.

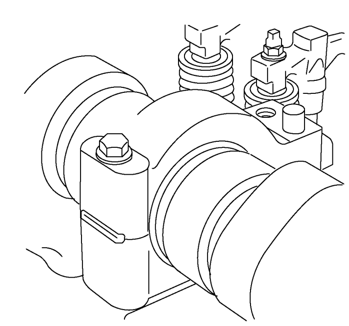


Figure 430 — Camshaft Bearing Bracket Installed

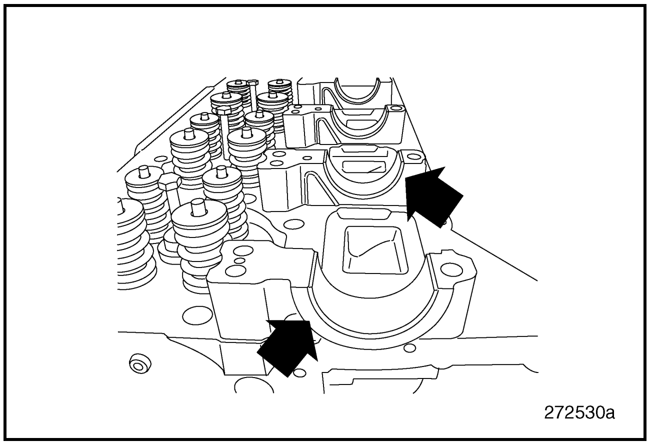


Figure 431 — Camshaft Bearing Bracket Lower Half

WHEN REPLACING FACTORY-INSTALLED JOURNALS

- If a camshaft journal has seized, DO NOT MIX a replacement bearing bracket with the original factory-installed bearing brackets. This is because the original bearing brackets were align-bored when the engine was manufactured. All seven brackets must be replaced.
- When replacing a cylinder head, do not mix new bearing brackets with original bearing brackets from the old cylinder head. Use only new bearing brackets on a new cylinder head.

WHEN REPLACING/INSTALLING AFTERMARKET JOURNALS

- If there are already replacement bearing bracket assemblies on the engine, and one or more assemblies are damaged, all seven assemblies must be replaced. Replacement bracket assemblies can be identified by the oval-shaped alignment pin holes.
- For replacement bracket assemblies used in locations 2 through 6, both alignment pin holes are oval-shaped for side-to-side adjustment. For brackets used in locations 1 and 7, one alignment pin hole is oval-shaped for front-to-rear adjustment; the second pin hole is round with an alignment pin preassembled in it.
- Mark the bearing caps to indicate that aftermarket bearing bracket and cap assemblies have been installed.

Camshaft Inspection

To avoid unnecessary overhauling, conduct a thorough inspection of the camshaft before reinstalling it after replacing the bearing bracket assemblies.

Bracket Replacement Procedure

1. Remove the lower bearing brackets using a pry bar. The rearmost No. 7 bracket can be removed by using a soft-faced mallet and tapping side to side. (The alignment pins should come off the cylinder head with the brackets. If not, remove the pins.)

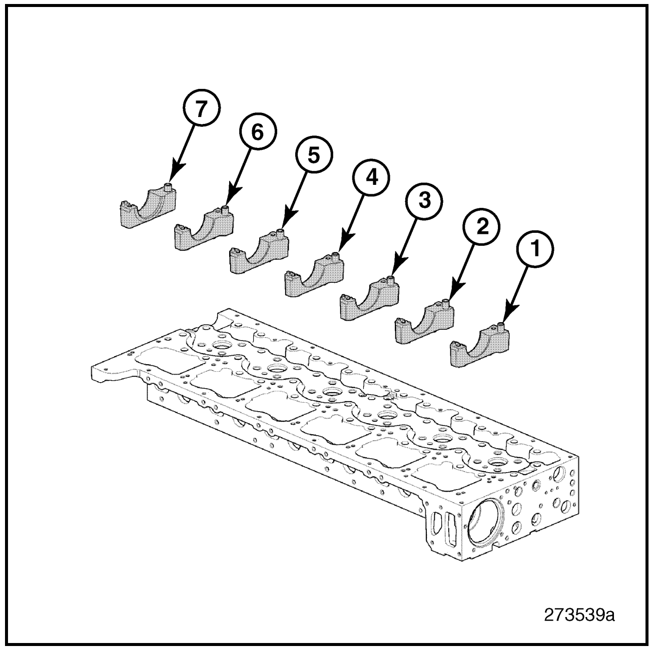


Figure 432 — Camshaft Lower Bearing Brackets

2. Clean the contact surfaces of the cylinder head and the lower bearing brackets.
3. Using a metal stamp or electric etching tool, mark the **new** bearing brackets and caps with the numbers, 1 through 7, indicating the location at which each assembly will be installed.

⚠ CAUTION

Do not use excessive force to punch the bracket assemblies when marking their position on the cylinder head. Damage to components can result.

4. Install 12 **new** locating pins from the parts kit at the cylinder head locations illustrated (Figure 433). Use a plastic mallet so as not to damage the locating pins.

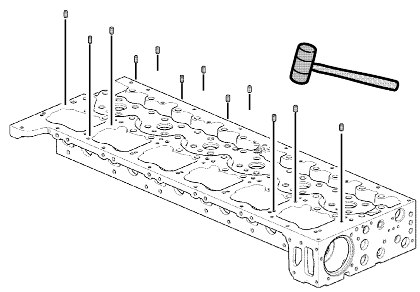


Figure 433 — Locating Pin Installation

5. Install the **new** lower bearing brackets at their respective marked positions on the cylinder head.
6. Check that the bearing brackets can move slightly on the locating pins.
   - Bracket Nos. 1 and 7 should turn slightly forward and back at one side.
   - Bracket Nos. 2 through 6 should move slightly side to side.

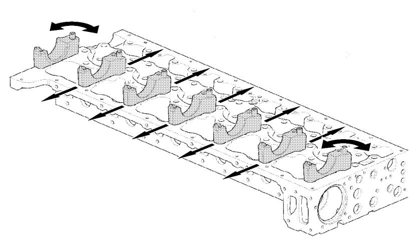


Figure 434 — Bracket Movement on Alignment Pins

Final Steps

Install the following components which were removed for access to the camshaft bearing brackets (see appropriate component for installation procedures):

- Camshaft Assembly
- Rocker Arm Shaft
- Compression Brake Solenoid Valve
- Valve and Unit Injector Adjustment
- Valve Cover Assembly

1. Install all previously removed cables to the ground (negative) battery terminals.
2. Start the engine, check for leaks and proper operation.

OIL THERMOSTAT AND PRESSURE SAFETY VALVE REPLACEMENT

Pressure Safety Valve Removal

Before attempting to remove the oil pressure safety valve, apply the parking brake, shift into neutral and thoroughly clean around the safety valve cover.

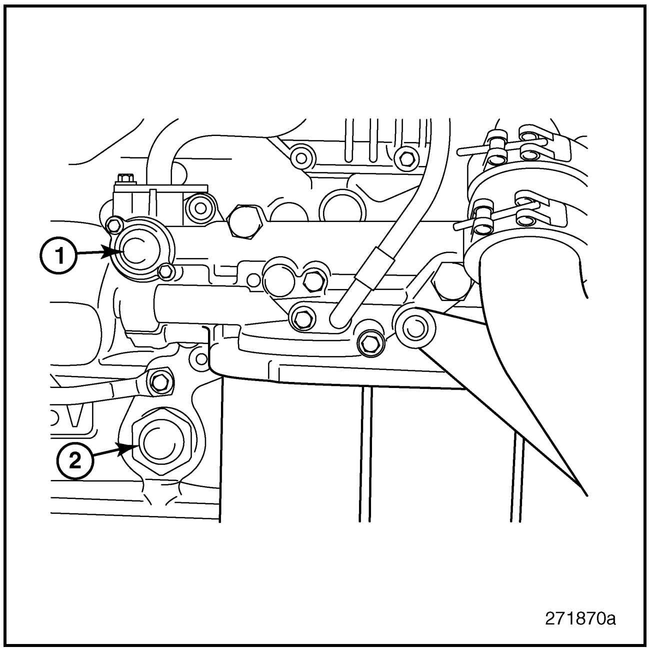


Figure 435 — Oil Valves — Thermostat and Pressure Safety

1. Thermostat Valve	2. Oil Pressure Safety Valve

1. Using the oil valve socket, J 43051, remove the safety valve cover and valve as a unit. Ensure that the seal is also removed with the cover and valve. Dispose of the valve.

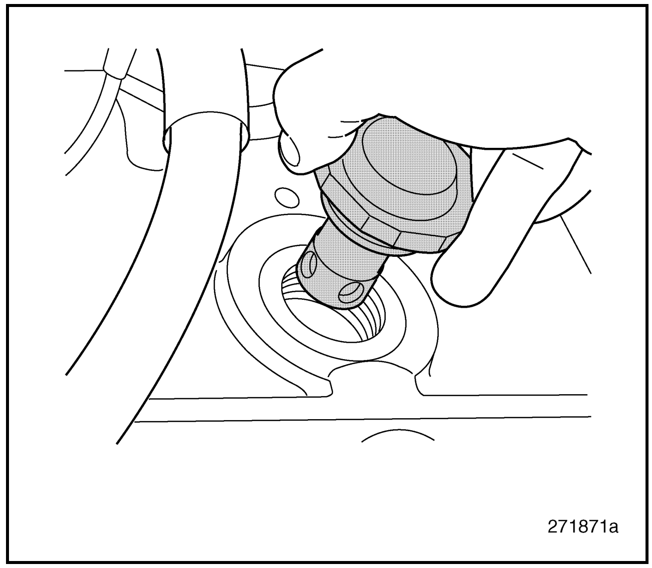


Figure 436 — Oil Pressure Safety Valve and Cover

2. Clean the cover and cylinder block sealing surface.
3. Replace the O-ring on the cover.

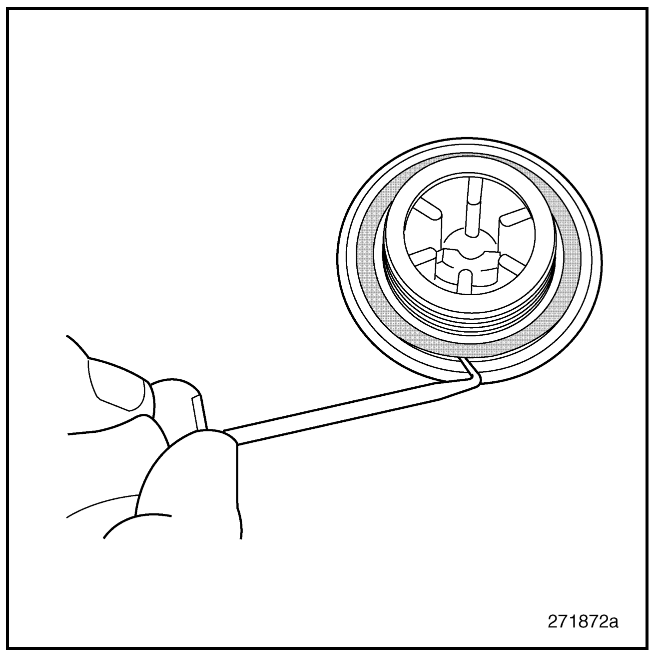


Figure 437 — Removing Safety Valve Cover O-Ring

4. Install a **new** valve in the cover.
5. Install the **new** valve and cover into the cylinder block.
6. Using a torque wrench, tighten the valve according to specification.

Oil Thermostat Valve Replacement

Before attempting to remove the thermostat valve, apply the parking brake, shift into neutral and thoroughly clean around the valve head.

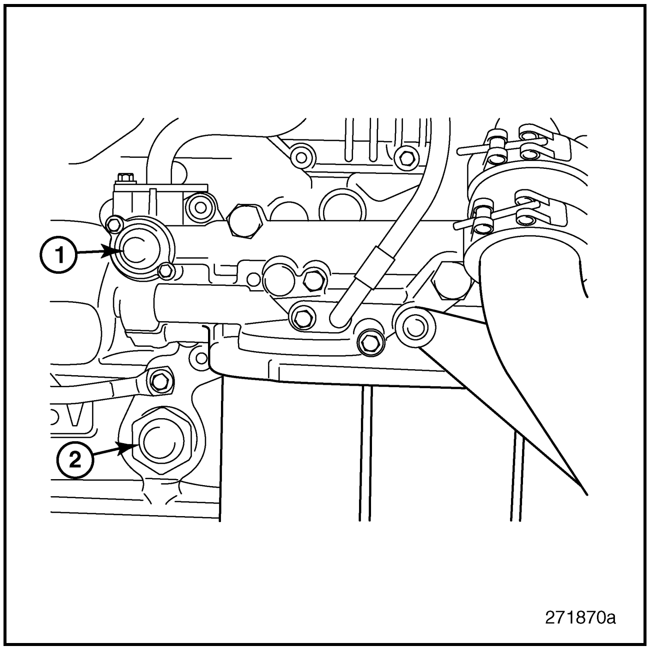


Figure 438 — Oil Valves — Thermostat and Pressure Safety

1. Thermostat Valve	2. Oil Pressure Safety Valve

1. Remove the thermostat valve from the oil filter housing and discard.
2. Replace the O-ring.

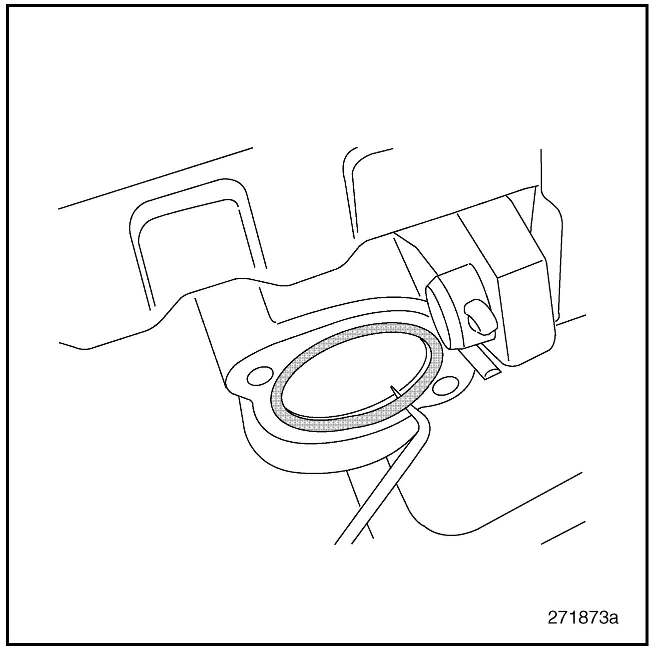
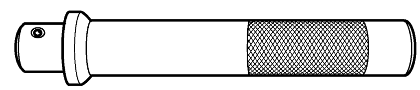
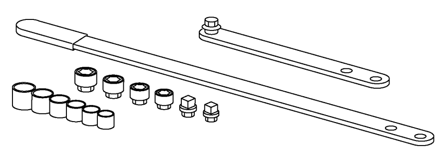
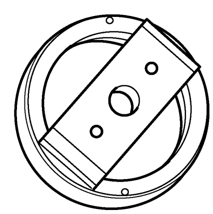


Figure 439 — Thermostat Valve O-Ring

3. Install a **new** thermostat valve with a **new** gasket.
4. Start the engine and check for leaks.

CRANKSHAFT FRONT SEAL REPLACEMENT

Special Tools

Tool No.	Description	Image
9992000	Handle with various uses (fits 25 mm hole) (Essential)	 006785a
J 44392	Drive Belt Tensioner Tool	 272697a
88800021	Front Main Seal Remover/Installer (Essential)	 006774a

Seal Removal

1. Remove the fan blade from the fan clutch hub.
2. Compress the belt tensioner (using J 44392) to release pressure on the fan and coolant pump drive belt and remove the belt.

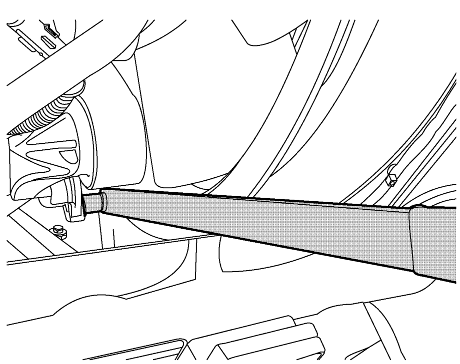


Figure 440 — Drive Belt Tensioner Tool

3. Compress the accessory belt tensioner (using J 44392) and remove the drive belt from the vibration damper pulley, refrigerant compressor pulley and alternator pulley.
4. If equipped, remove the front engine PTO fasteners and PTO.

5. Remove the mounting fasteners that secure the drive belt pulley and vibration damper to the crankshaft hub. Separate the pulley and damper from the hub.

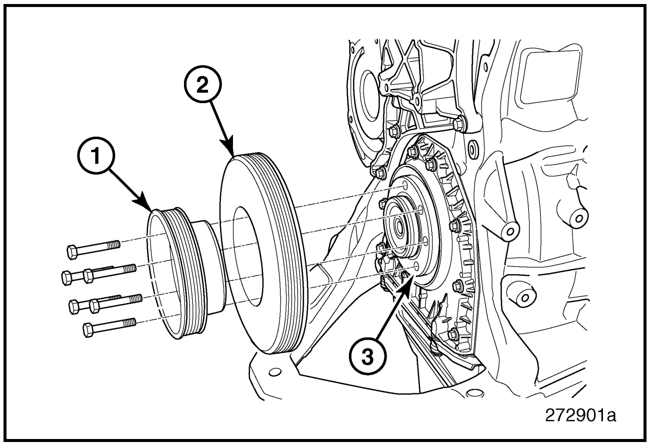


Figure 441 — Vibration Damper and Pulley Removal

1. Fan and Coolant Pump Drive Pulley 2. Vibration Damper	3. Crankshaft Hub

CAUTION

When handling a vibration damper, be careful not to damage the housing. Dents in the outer housing can render the damper ineffective. If damaged, the vibration damper cannot be repaired and must be replaced.

6. Remove the crankshaft seal as follows:
   - A. Drill two 3.5 mm (0.138 inch) holes in the metal rim of the crankshaft front seal. Use the holes in the rim of the front main seal remover/installer (88800021) as a guide.

NOTE

Apply grease on the end of the drill bit to prevent chips from getting into the engine.

   - B. Using two self-tapping M5 screws of suitable length, attach the crankshaft front seal remover/installer to the seal.
   - C. Using two M10 fasteners threaded into the crankshaft front seal remover/installer, remove the crankshaft front seal.

Seal Installation

1. Clean the seal seating surface in the crankshaft front cover and the sealing surface of the crankshaft hub.
2. Assemble the handle (9992000) and front main seal remover/installer (88800021).
3. Place a **new** crankshaft front seal on the crankshaft front seal remover/installer.

NOTE

The crankshaft front seal should be installed dry. No sealant or lubricant is necessary.

4. Position the crankshaft front seal remover/installer and new seal over the crankshaft hub and crankshaft front cover. Carefully drive the seal into the cover until the tool bottoms against the crankshaft hub and front cover.

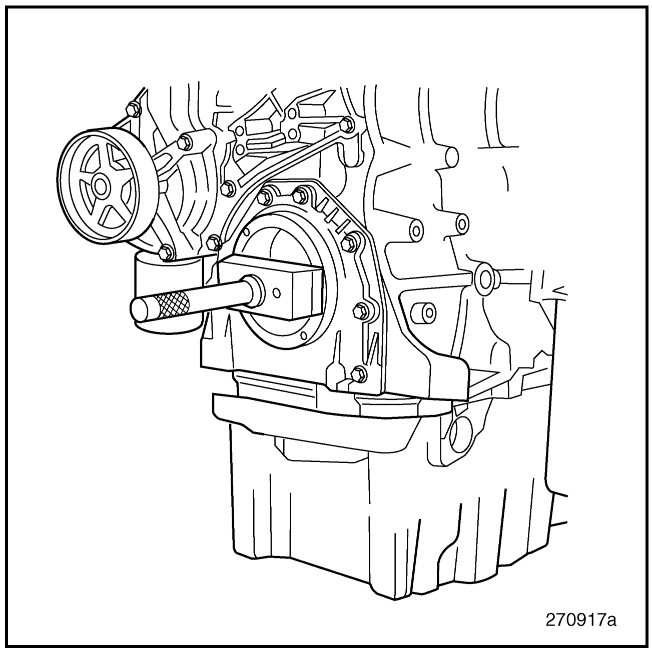


Figure 442 — Seal Installation

5. Remove the tool and inspect the seal to make sure that it is properly installed.

6. Place the vibration damper and fan pulley on the crankshaft hub and align the fastener holes. Install and tighten the mounting fasteners in two steps to specification.

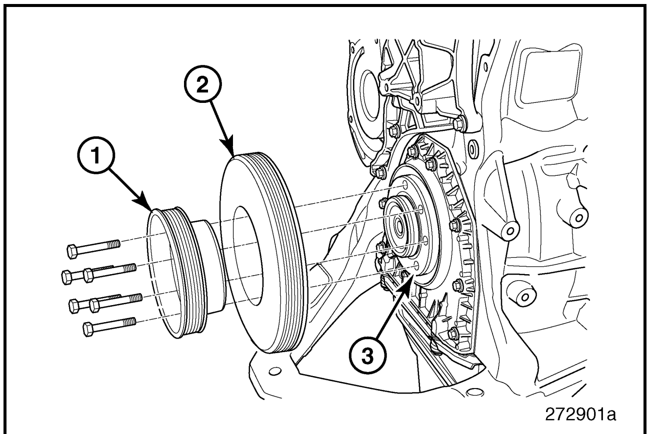


Figure 443 — Vibration Damper and Pulley Installation

1. Fan and Coolant Pump Drive Pulley 2. Vibration Damper	3. Crankshaft Hub

7. If equipped, install the front engine PTO and fasteners. Tighten the mounting fasteners to specification.

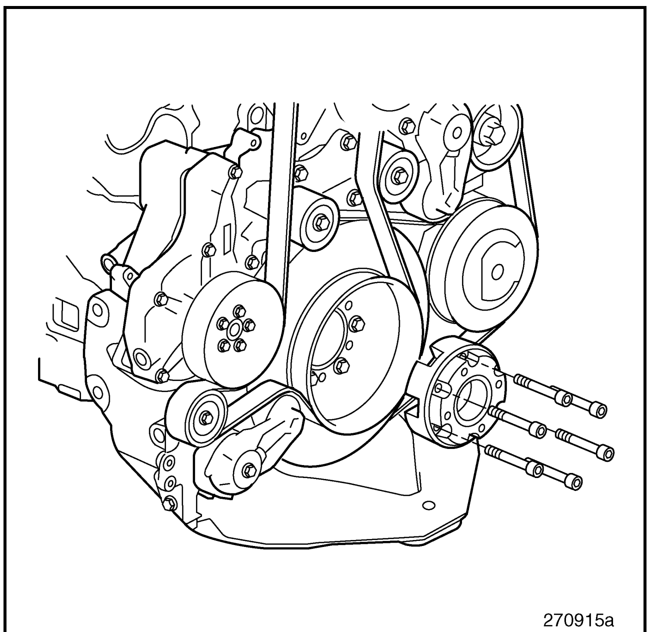


Figure 444 — Front Engine PTO Installation

8. Compress the accessory drive belt tensioner (using J 44392) and install the drive belt over the crankshaft pulley, fan drive pulley and coolant pump pulley.

9. Compress the lower belt tensioner (using J 44392) and install the drive belt over the crankshaft pulley, fan drive pulley and coolant pump pulley.

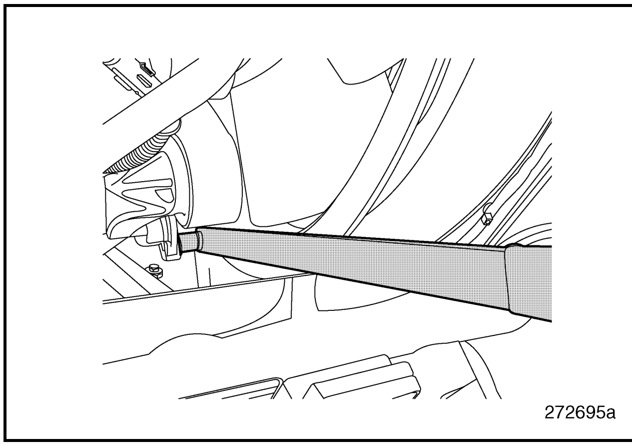
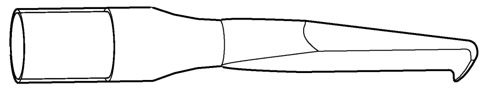
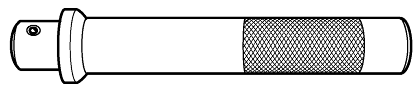
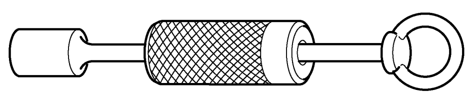
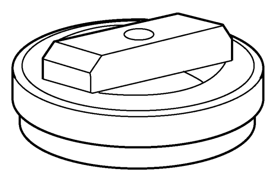


Figure 445 — Drive Belt Tensioner Tool

10. Place the fan blade on the fan clutch hub, install the mounting fasteners and tighten to specification.

CRANKSHAFT REAR SEAL REPLACEMENT

Special Tools

Tool No.	Description	Image
9990192	Crankshaft Seal Puller	 006896a
9992000	Handle with various uses (fits 25 mm hole) (Essential)	 006785a
9996400	Slide Hammer	 006897a
9998238	Rear Main Seal Remover/Installer, for neoprene type seal (Essential) **Note:** For Teflon® seals, use tools 9990166, 9990192 and 9996400.	 006780a

Neoprene Seal Removal

CAUTION

The flywheel is heavy. Do not attempt to remove the flywheel without the help of an assistant or a suitable lifting device. Failure to heed this caution may result in severe personal injury and property damage.

1. Carefully remove the flywheel sensor.
2. Install two M10 screws to use as handles to aid in removal.
3. Remove the flywheel.
4. Using the puller, 9990192, and the slide hammer, 9996400, carefully remove the seal.

Neoprene Seal Installation

1. Clean the flywheel, housing and crankshaft sealing surfaces.
2. Align properly and assemble the new seal on the seal installer, 9998238.

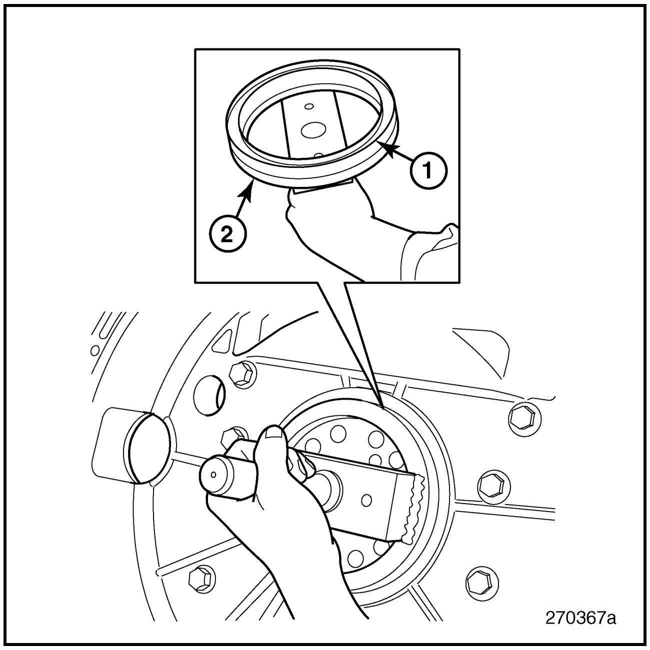


Figure 446 — Seal Installation

1. Rear Main Seal	2. Seal Installer, 9998238

3. Using the handle, 9992000, and the seal installer, carefully tap the seal into the flywheel housing until there is even contact.
4. Using the M10 screws as handles, with the help of an assistant or a lifting device, assemble the flywheel over the dowel and alignment studs on the mounting surface.

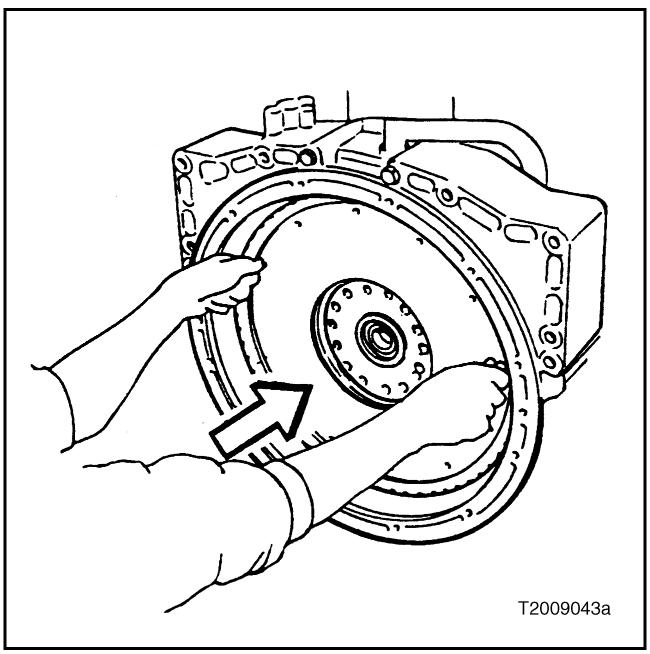


Figure 447 — Flywheel Installation

5. Insert the flywheel mounting screws finger tight. Remove the M10 screws to insert the remaining mounting screws.
6. Using a torque wrench, tighten the mounting screws in sequence according to specification.
7. Carefully install the flywheel sensor and connect it to the harness.

Teflon® Seal Removal

CAUTION

The flywheel is heavy. Do not attempt to remove the flywheel without the help of an assistant or a suitable lifting device. Failure to heed this caution may result in severe personal injury and property damage.

1. Remove the clutch assembly.
2. Carefully remove the flywheel sensor.
3. Install two M10 screws to use as handles to aid in removal.
4. Remove the flywheel.
5. Using the puller, 9990192, and the slide hammer, 9996400, carefully remove the seal. Make sure that the tools are free of burrs and dirt.

NOTE

Take care not to damage the crankshaft or flywheel sealing surfaces. Slant the tools inward to get a good grip on the crankshaft rear seal.

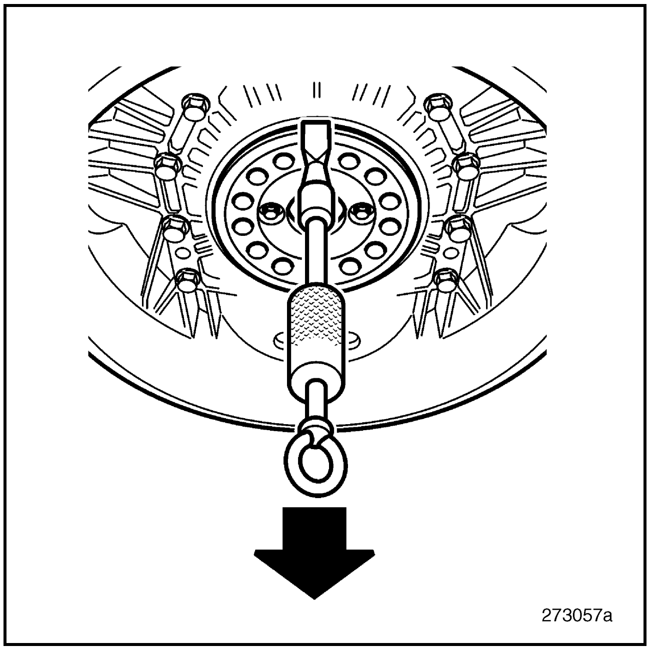


Figure 448 — Removing Crankshaft Rear Seal

6. Tap out the crankshaft rear seal.
7. Thoroughly clean the sealing surfaces of the flywheel, flywheel housing and crankshaft.

Teflon® Seal Installation

1. Install the plate and thrust screw part of tool, 9990166, to the crankshaft. Tighten the assembly screws securely.

NOTE

Make sure that the plate of the tool is positioned properly in the crankshaft internal guide and is flat against the crankshaft before tightening the screws.

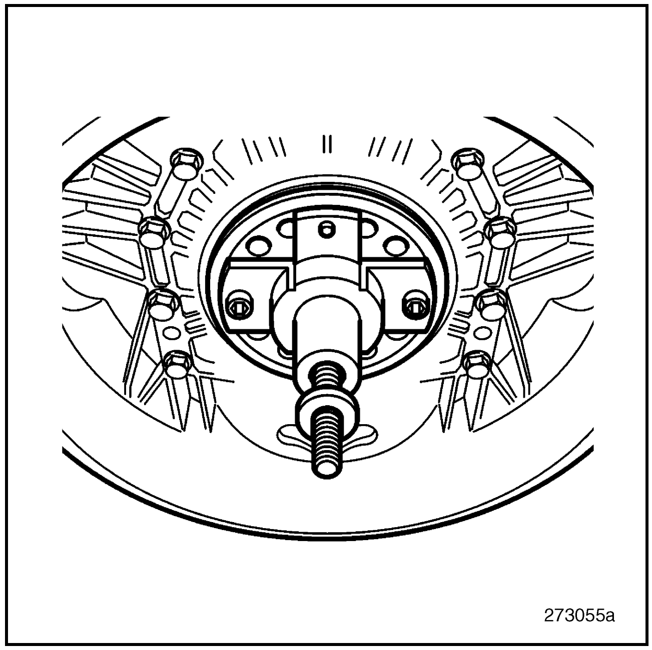


Figure 449 — Install Plate and Thrust Screw Assembly

2. Install the spacer, 88880013, of tool, 9990166, on the thrust screw.

NOTE

The spacer is important because it determines the installation depth of the crankshaft rear seal.

3. The sealing ring is supplied with a plastic installation ring that should be left in place during installation.

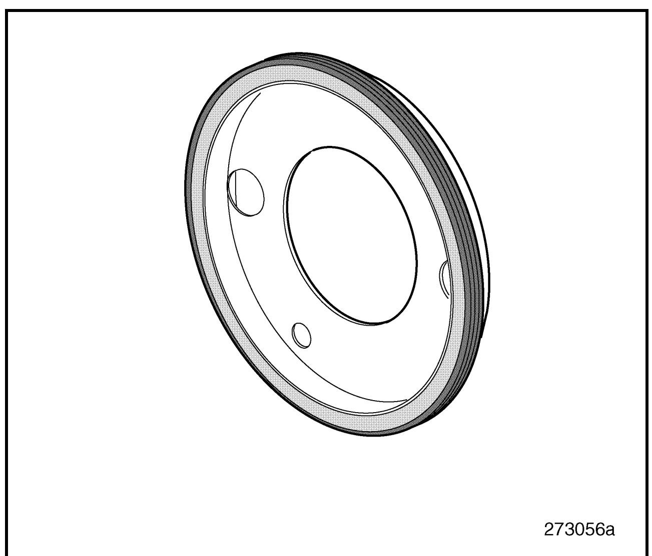


Figure 450 — Crankshaft Rear Seal

4. Install the seal without removing the installation ring over the thrust screw, spacer and plate assembly.

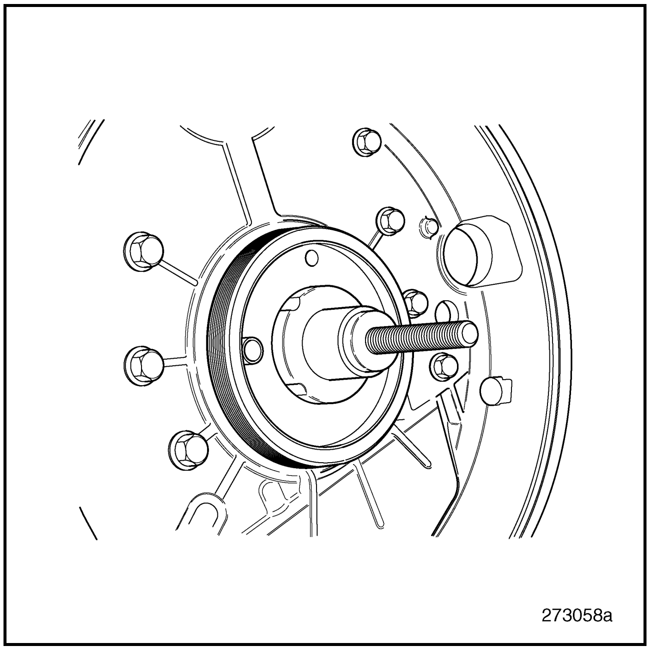


Figure 451 — Crankshaft Rear Seal Positioned on Tool

5. Install the cover and handle over the assembly. Center the cover over the crankshaft rear seal and thread the handle to keep the cover in position.

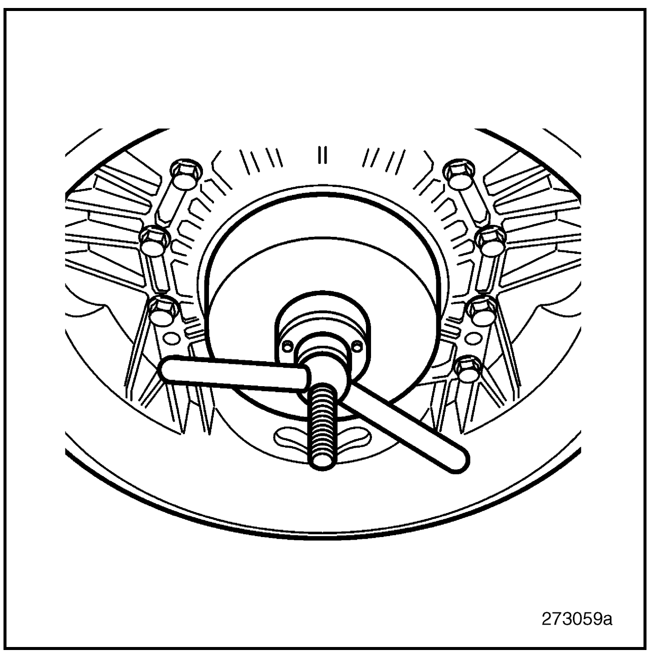


Figure 452 — Cover and Handle Installed

6. Turn the handle to press the crankshaft rear seal over the crankshaft and into the flywheel housing. When the cover bottoms out against the spacer, the rear seal is in proper position.
7. Remove the crankshaft rear seal installation tools.
8. Using the M10 screws as handles, with the help of an assistant or a lifting device, assemble the flywheel over the dowel and alignment studs on the mounting surface.

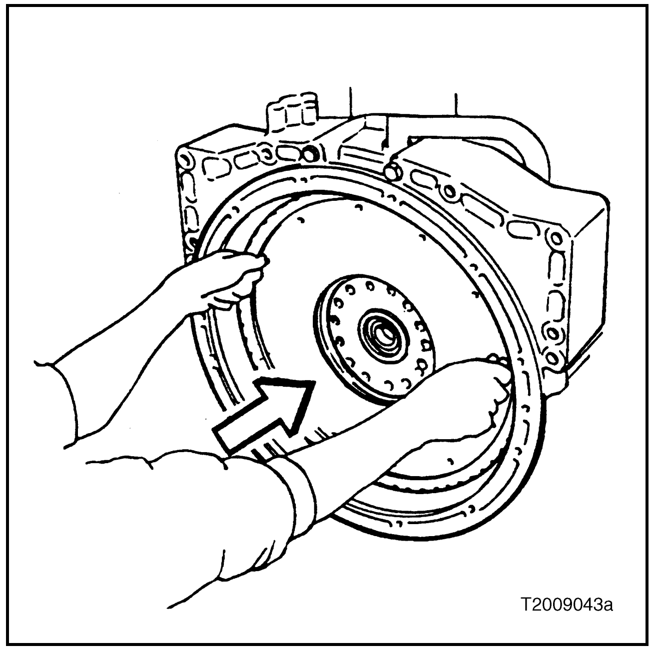


Figure 453 — Flywheel Installation

9. Insert the flywheel mounting screws finger tight. Remove the M10 screws to insert the remaining mounting screws.
10. Using a torque wrench, tighten the mounting screws in sequence according to specification.
11. Carefully install the flywheel sensor and connect it to the harness.

CRANKCASE VENTILATION (CCV) SEPARATOR REPLACEMENT

CCV Separator Removal

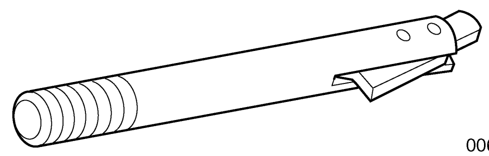
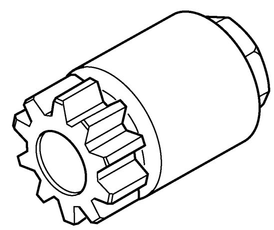
1. Disconnect the batteries, or turn off the main switch.
2. Clean the cylinder block around the CCV separator mounting.
3. Detach the CCV hoses.
4. Remove the CCV separator from the cylinder block.

CCV Separator Installation

1. Clean the mounting surfaces on the cylinder block and the CCV separator.
2. Using a **new** gasket, assemble the CCV separator on the cylinder block.
3. Using a torque wrench, tighten the screws according to specification.
4. Attach the CCV hoses.
5. Turn on the main switch, or reconnect the batteries.
6. Start the engine and check for leaks.

OIL PUMP REPLACEMENT (IN CHASSIS) [219 MU]

Special Tools

Tool No.	Description	Image
9998649	Block Stiffener Plate Assembly Tool	
88800014	Flywheel Turning Tool (Essential)	

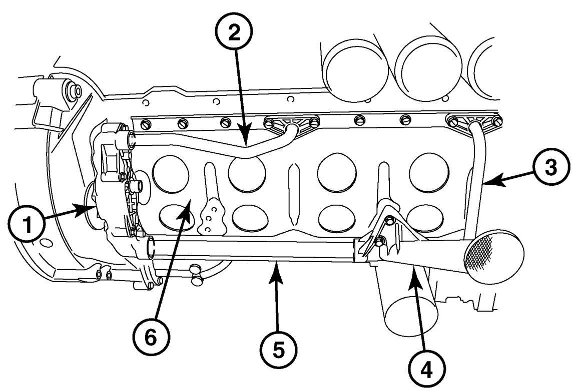


Figure 454 — Oil Pump, Pickup and Distribution System

1. Oil Pump 2. Pump Outlet Pipe 3. Crossover Pipe	4. Strainer 5. Pump Inlet Pipe 6. Block Stiffener Plate

Oil Pump Removal

1. If not already done, remove the oil pan.
2. Remove the pump inlet pipe and strainer.
3. Remove the pump outlet pipe.
4. Remove the crossover pipe.
5. Remove the block stiffener plate.

⚠ CAUTION

Wear gloves when handling the block stiffener plate. It has sharp edges. Failure to heed this caution could result in severe personal injury.

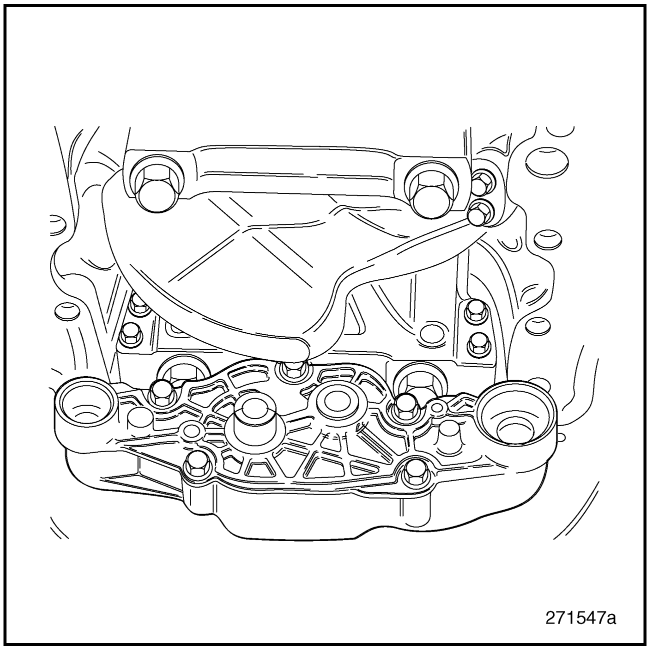


Figure 455 — Oil Pump

6. If necessary, rotate the crankshaft out of the way using flywheel turning tool, 88800014.
7. Remove the oil pump from the bearing cap.

Oil Pump Installation

1. Clean all parts to be reused.
2. Attach the oil pump to the No. 7 main bearing cap.
3. Using a torque wrench, tighten the screws according to specification.

⚠ CAUTION

Make certain that the bearing insert is in good condition and properly installed on the bearing cap. Failure to heed this caution may result in severe component damage.

4. Using **new** screws and assembly tool, 9998649, attach the block stiffener plate to the block. Do NOT torque-tighten the screws at this time.
5. Lubricate and assemble **new** O-rings on the inlet, crossover and outlet pipes.
6. Assemble the crossover and outlet pipes in the pump housing and install the mounting screws to secure the pipe flanges to the stiffener plate and block.
7. Using a torque wrench, tighten the stiffener plate screws (including pipe flange screws) in sequence according to specification.
8. Assemble the inlet pipe and strainer.
9. Assemble the pipe and strainer in the pump housing and on the block.
10. Using a torque wrench, tighten the screws according to specification.
11. Inspect the oil pan seal and replace it if necessary. Lubricate and assemble the seal on the oil pan.

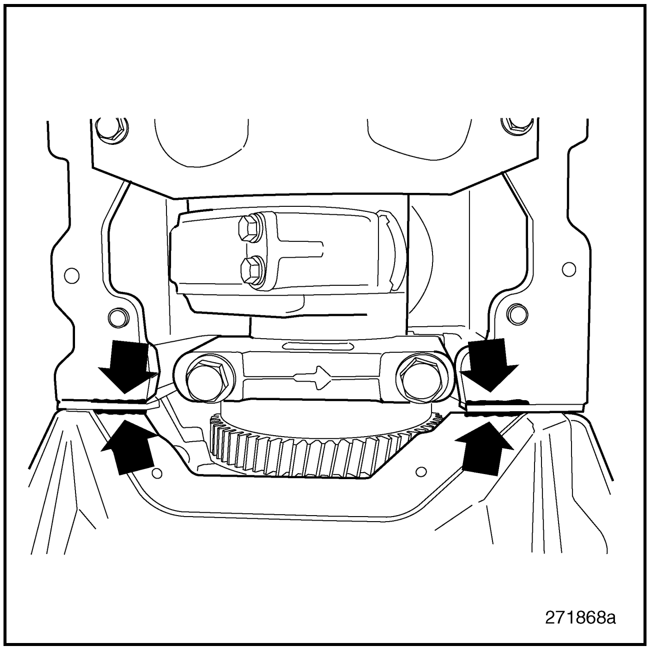


Figure 456 — Sealant Points — Flywheel Housing to Timing Gear Plate and Plate to Block

12. Apply a 2 mm (5/64 inch) bead of 342SX33 MACK-approved sealant to the seams between the flywheel housing and timing gear plate and between the mounting plate and the cylinder block.

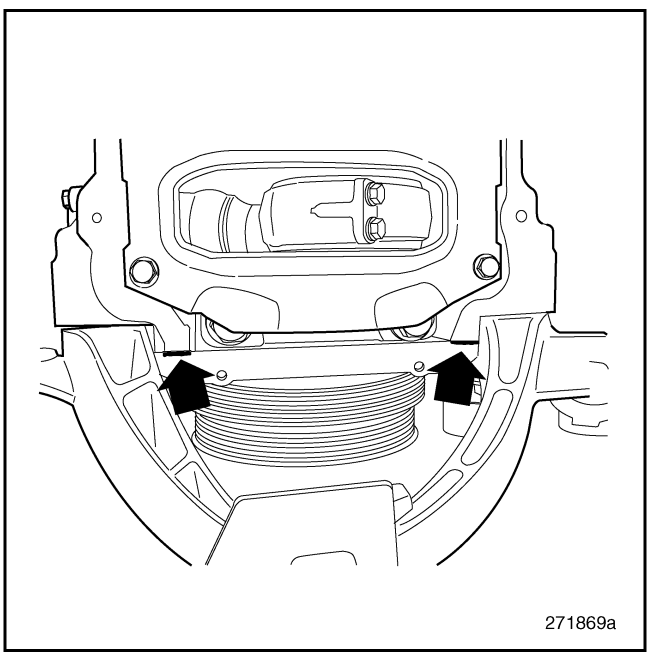


Figure 457 — Sealant Points — Front Seal Cover to Block

13. Apply a 2 mm (5/64 inch) bead of 342SX33 MACK-approved sealant to the seams between the front seal cover and the cylinder block.
14. Attach the oil pan to the cylinder block.
15. Using a torque wrench, tighten the screws in sequence according to specification.

CAUTION

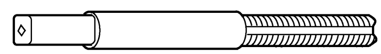
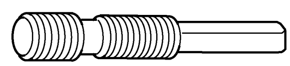
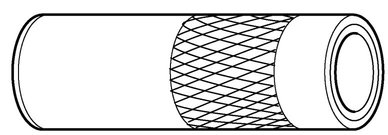
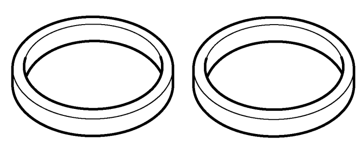
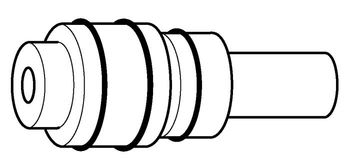
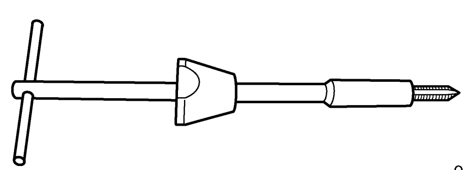
Use a steel washer. Do not use a copper washer. Do not use an impact wrench to install the drain plug. Failure to heed this caution may result in property damage.

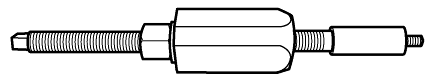
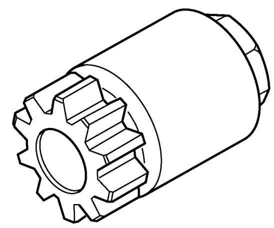
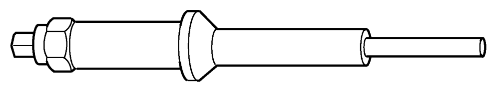
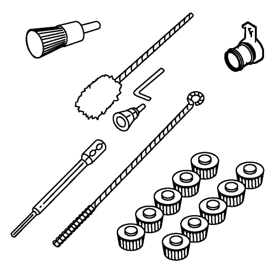
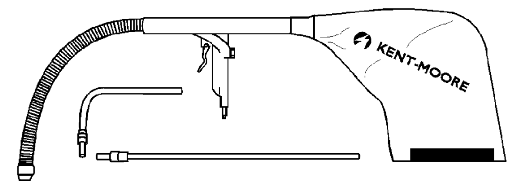
16. Install the drain plug.
17. Check system oil pressure through the pressure sensor port in the oil filter housing.

INJECTOR COPPER SLEEVE REPLACEMENT [213 EV]

Tools and Equipment

SPECIAL TOOLS

Tool No.	Description	Image
9809667	9 mm Tap, use with 9998252 (Available)	 006840a
9809668	9 mm Bit, use with 9998253 (Available)	 006841a
9998249	Unit Injector Protection Sleeve (Essential)	 006798a
9998250	Unit Injector Bore Gallery Sealing Rings (Available)	 006799a
9998251	Unit Injector Bore Sealing Plug (Essential)	 006800b
9998252	Unit Injector Sleeve Tap (Essential)	 006801a

Tool No.	Description	Image
9998253	Unit Injector Sleeve Remover (Essential)	 006802a
88800014	Flywheel Turning Tool (Essential)	 271485a
88800196	Swaging Tool for Installing Unit Injector Copper Sleeve (Essential)	 006805a
88880010	Swaging Bit (Available Separately)	 006842a
J 42885	Unit Injector Bore Cleaning Kit (Essential)	 006926a
PT-2900	Chip Vacuum	 006962a

Preliminary Steps

The following components need to be removed for access to the injector copper sleeves (see ENGINE DISASSEMBLY for procedures):

- Cylinder Head Cover
- Rocker Arm Shaft Assembly
- Unit Injector(s)

Copper Sleeve Removal

1. If the injector sleeve is not being removed immediately, install the protective plug into the unit injector bore of the cylinder head to protect it from debris.

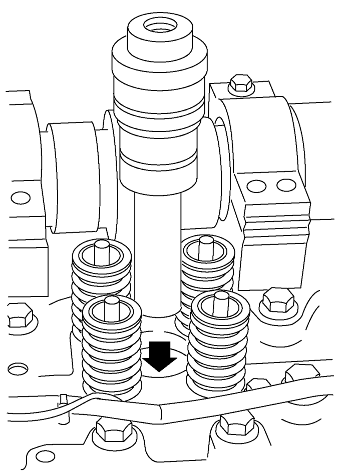


Figure 458 — Unit Injector Bore Protective Plug

2. Install two sealing rings to prevent dirt from entering the fuel gallery when the copper sleeve is removed.

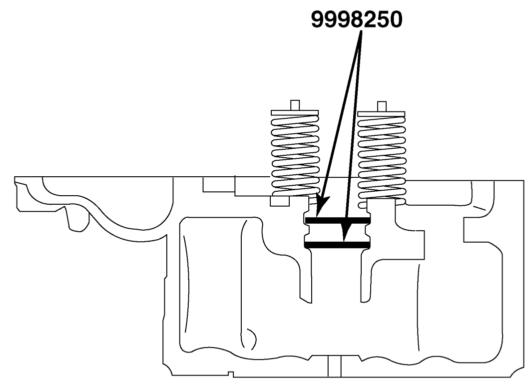


Figure 459 — Fuel Gallery Sealing Rings

NOTE

Two sealing rings are required to cover the fuel gallery.

3. Remove the plug from the lower front side of the flywheel housing and install the flywheel turning tool. Turn the flywheel until the piston is at its lowest position in the cylinder.

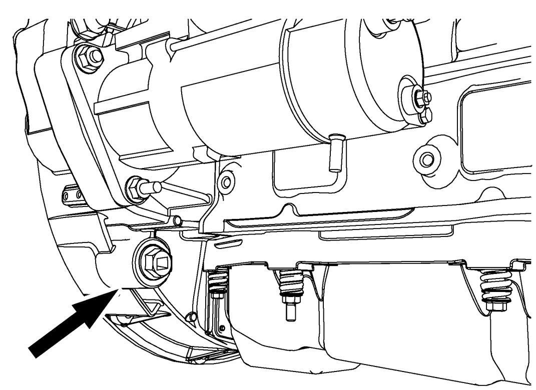


Figure 460 — Flywheel Turning Tool

NOTE

This is to ensure that the copper sleeve tapping tool does not damage the piston due to tool length.

Ensure the turning tool is well greased before attempting to turn the flywheel.

4. Adjust the 9 mm tap so that it extends a minimum of 25 mm or 1 inch (dimension A) from the end of the tapping tool.

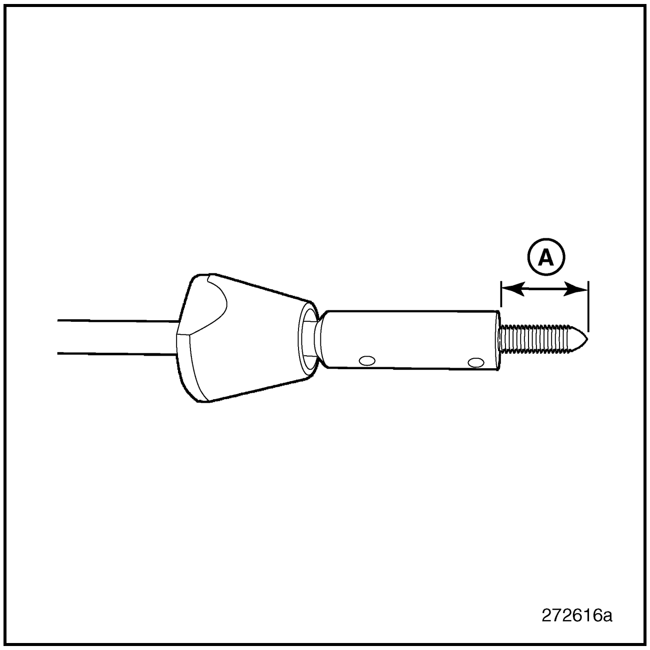


Figure 461 — Copper Sleeve Tapping Tool

NOTE

This ensures that the tip of the copper sleeve is tapped all the way through.

CAUTION

If the copper sleeve is not completely tapped through to the opening of the tip, an end piece of the tip can break off and fall into the cylinder during removal.

5. Lubricate the tip of the 9 mm tap with grease.

NOTE

Applying grease will capture copper cuttings and prevent them from falling down into the cylinder.

6. Thread the tap in small increments. Remove the tap and wipe off the grease and copper sleeve shavings. Apply fresh grease, reinstall the tapping tool and thread more of the copper sleeve. Continue this process to thread the tap all the way through the copper sleeve until no resistance is felt and the tap turns freely. Tapping in small increments and removing the shavings minimizes the chance of shavings falling into the cylinder and the sleeve turning in the cylinder head. Ensure that the tap is completely through the copper sleeve.

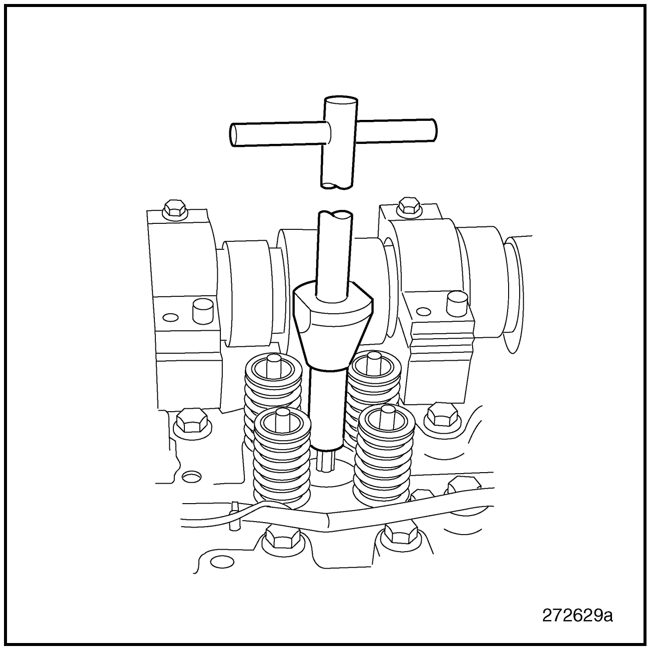


Figure 462 — Tapping Tool Installation

CAUTION

If threads are not cut completely through the tip of the copper sleeve, the tip can break off and fall into the cylinder. This can result in damage to the cylinder, piston, valves or turbocharger.

7. Remove the tap and tapping tool.
8. Using the chip vacuum, remove any remaining shavings from the copper sleeve.

9. Install the extractor bolt into the end of the extractor tool. Adjust the bolt until it extends approximately 22 mm (0.9 inch) beyond the end of the tool (dimension A).

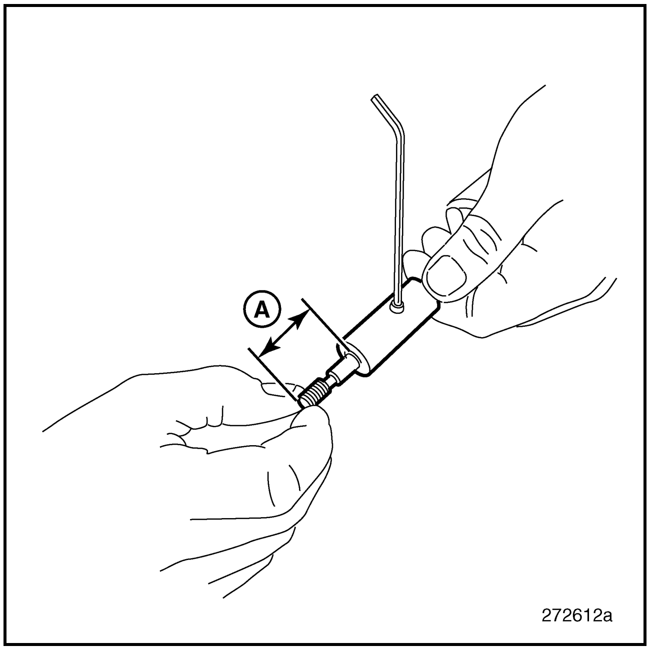


Figure 463 — Adjusting Copper Sleeve Extractor Bolt

10. Tighten the set screw of the extractor tool to secure the bolt. Make sure that the set screw is seated against the flat part of the extractor bolt.
11. Place the extractor tool with the bolt into the injector bore. Make sure the nut on the spindle is backed off so that the threaded end can be completely installed through the copper sleeve tip. Hand tighten until the bolt bottoms out in the sleeve.

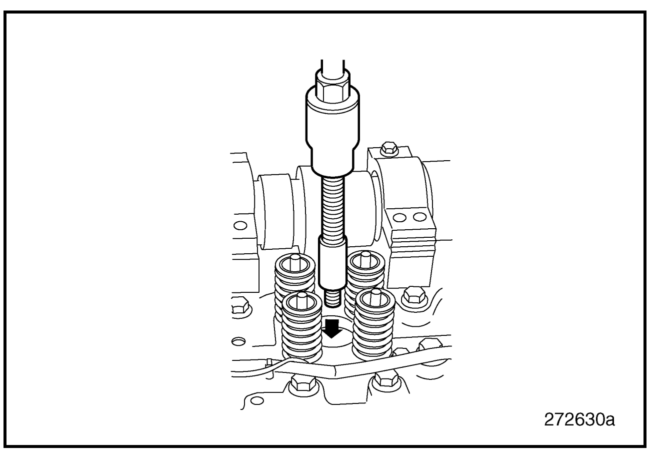


Figure 464 — Extractor Tool Installation

CAUTION

Make sure the extractor bolt is threaded completely into the copper sleeve before attempting to remove it or the tip of the sleeve may break off as it is removed. This broken sleeve tip can seriously damage the piston, valves or turbocharger.

12. While holding the top of the tool stationary, turn the large nut clockwise to extract the copper sleeve.

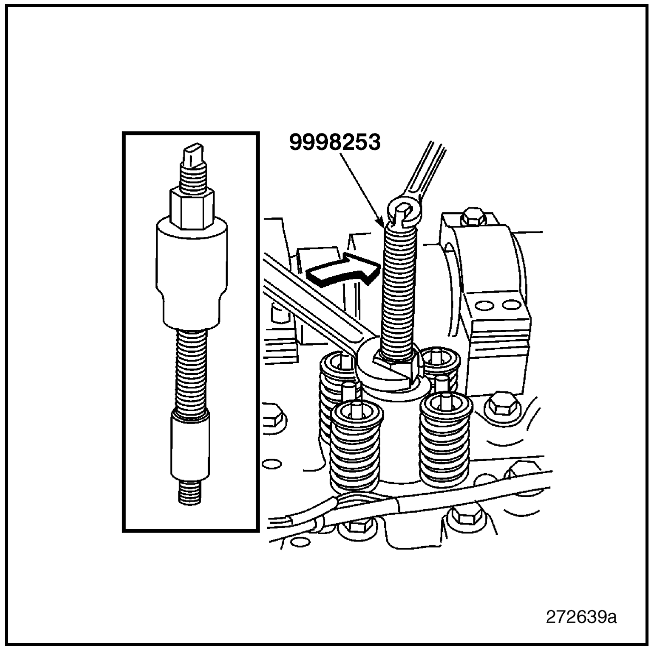


Figure 465 — Copper Sleeve Extraction

NOTE

When the copper sleeve is removed, make sure that the extractor bolt is extended at least one thread beyond the copper sleeve. If not, make sure that no part of the copper sleeve has broken off and fallen into the cylinder.

CAUTION

Do not use air tools to remove copper sleeves, or damage to the injector bore can result.

13. Remove the two sealing rings from the fuel passage. Using the chip vacuum, remove any remaining debris from the injector bore.

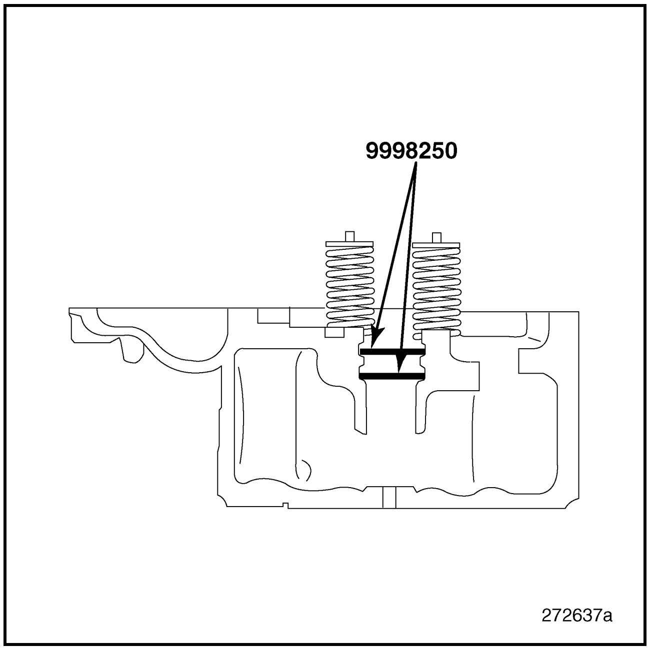


Figure 466 — Fuel Gallery Sealing Rings

14. Install the injector bore sealing tool (J 42885-25) to protect the fuel passage area and prevent debris from entering. Use the unit injector hold down bolt to secure the tool in the cylinder head.
15. Using the injector bore cleaning kit, clean the copper sleeve seat of the cylinder head.

NOTE

The injector bore sealing tool must be used to prevent dirt from entering the fuel passage.

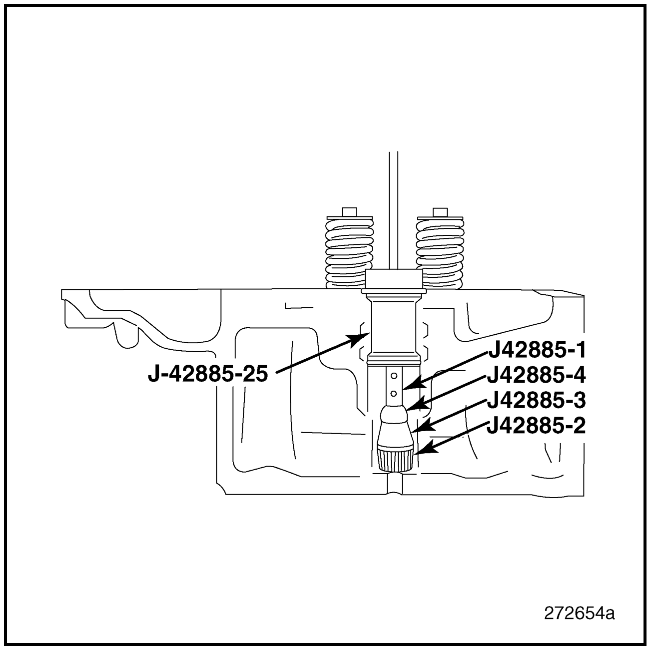


Figure 467 — Cleaning Copper Sleeve Seat

16. Using the brush, clean the cylinder head injector bore walls for the copper sleeve.

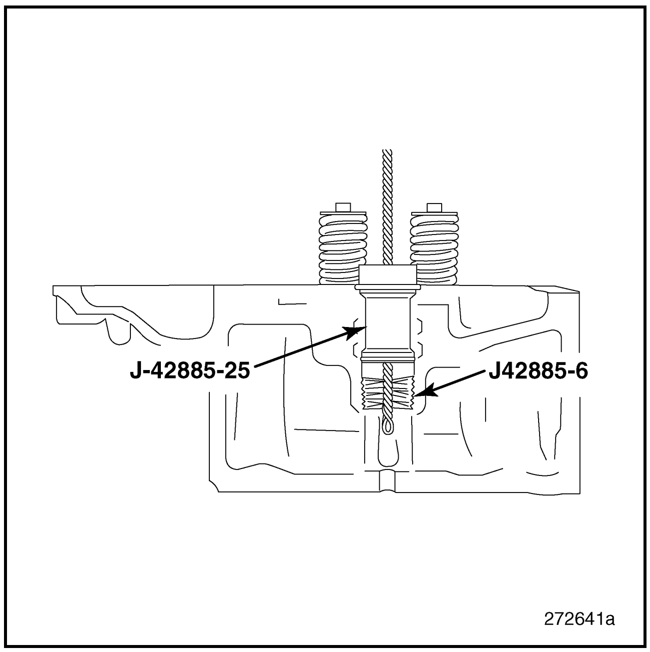


Figure 468 — Cleaning Copper Sleeve Bore Walls

NOTE

The injector bore sealing tool must be used to prevent debris from entering the fuel passage.

17. Using the brush, clean the copper sleeve opening in the cylinder head.

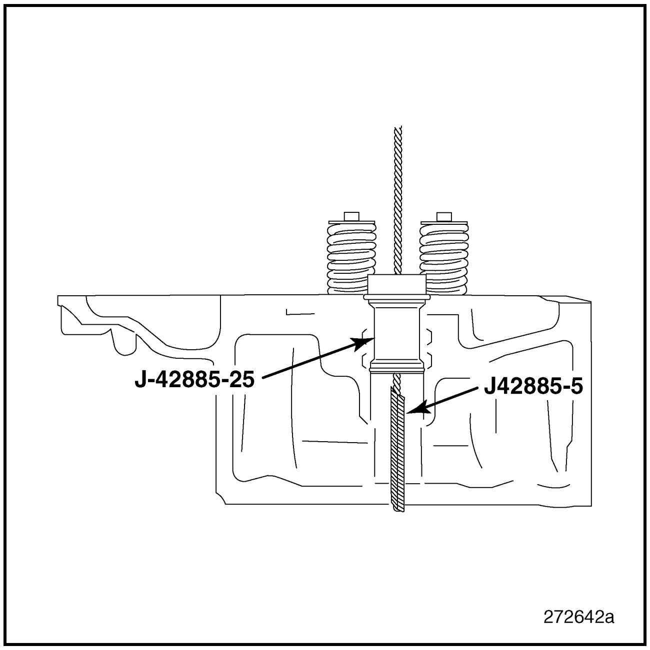


Figure 469 — Cleaning Injector Tip Bore

NOTE

The injector bore sealing tool must be used to prevent debris from entering the fuel passage.

When replacing the copper sleeves, it is important to check that the sleeve bore in the cylinder head is free from any carbon deposits or other residue (i.e., pieces of O-ring, etc.) before installing a new copper sleeve. Reclean if necessary.

18. Using the chip vacuum, remove all debris from the copper sleeve bore.

SERVICE HINT

Do not attempt to blow away debris using compressed air. Doing so can result in eye injury.

19. Remove the injector bore sealing tool from the cylinder head. Using the chip vacuum, remove any remaining debris.

Copper Sleeve Installation

1. Ensure the piston is at the lowest position in the cylinder. If not, use the flywheel turning tool to place the piston at its lowest position.

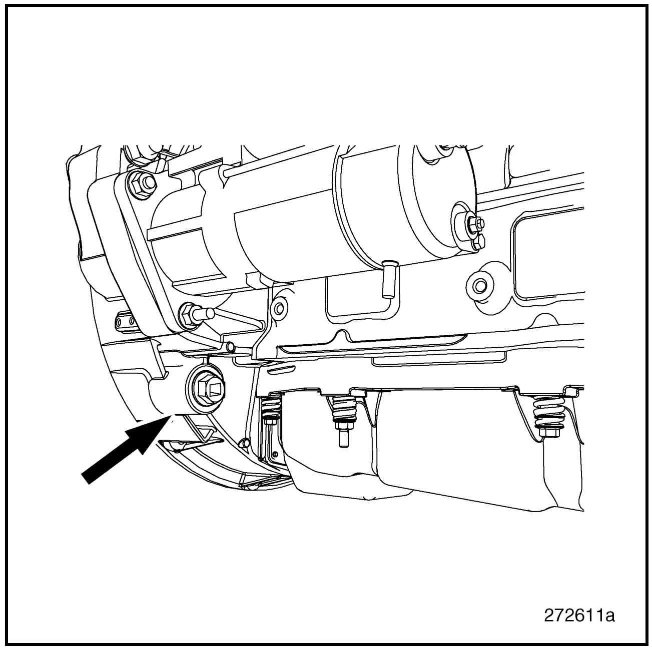


Figure 470 — Flywheel Turning Tool

NOTE

This is to ensure that the copper sleeve installation tool does not damage the piston due to tool length.

2. Before installing the copper sleeve, inspect it to ensure that it is the correct part. The correct sleeve is identified by two concentric circular grooves machined into the top surface.

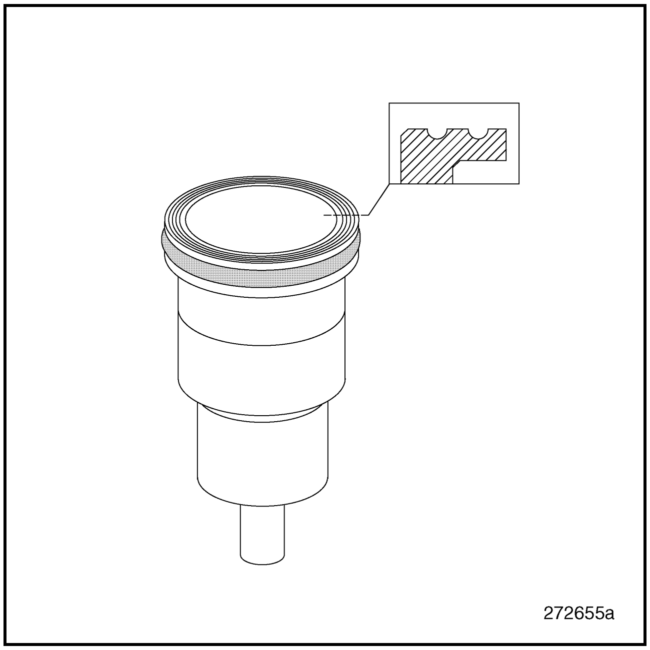


Figure 471 — Copper Sleeve Identification

3. Lubricate a **new** copper sleeve O-ring with coolant. Install the O-ring on the copper sleeve and lubricate again with coolant. Always use a **new** O-ring.
4. Place the **new** copper sleeve on the installation tool.

NOTE

Do not place the injector nozzle gasket (flat washer) in the copper sleeve, as this will damage the swaging bit.

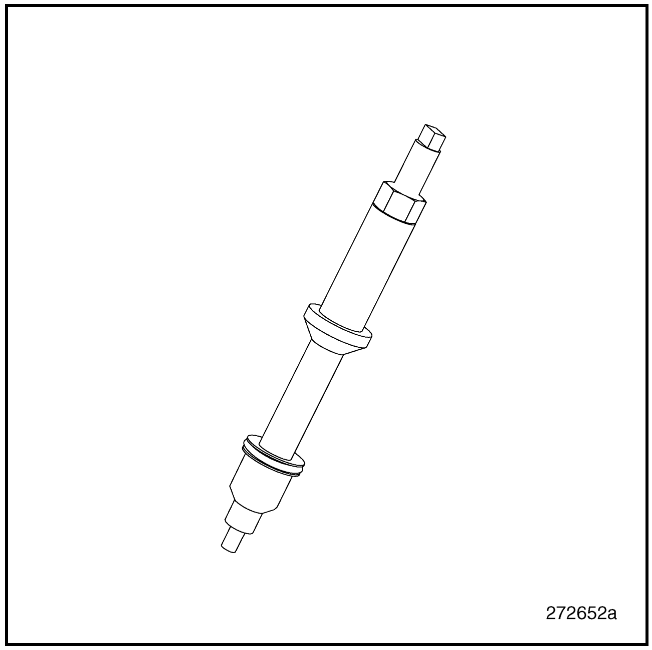


Figure 472 — Installation Tool Identification

NOTE

Before installing the sleeve on the installation tool, inspect the tool to ensure that it is the correct tool. The correct tool is identified by a bottom surface that is perfectly flat with no machined circular recess. Use of a tool with a machined circular recess on the bottom may result in damage to the copper sleeve.

5. Using calipers, measure the swaging bit to make sure that the proper swaging tool is used. Measurement should read approximately 7.8 mm. Also, verify that the length of the swaging bit is 108 mm.

CAUTION

Failure to use the proper bit can result in the bit breaking off into the cylinder head.

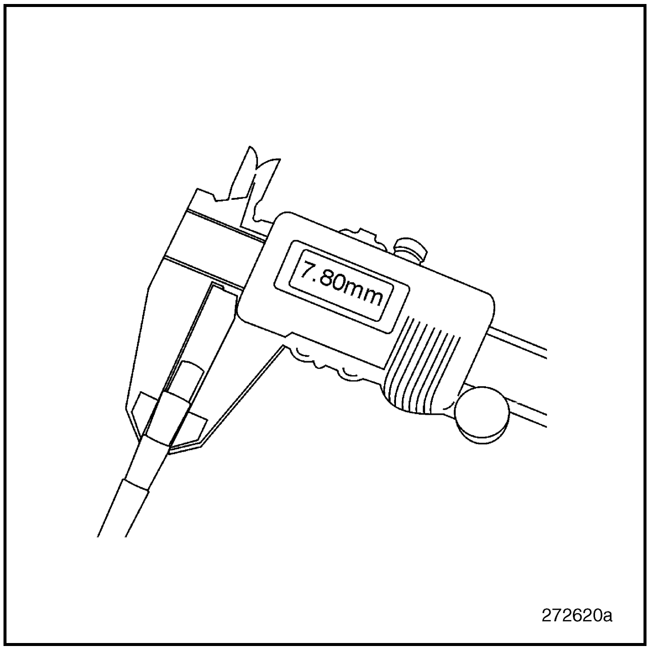


Figure 473 — Swaging Bit Verification

6. Thread the swaging bit completely into the flaring tool until it stops (finger tight).

NOTE

Swaging bit can be ordered as a spare part if the bit is worn or broken.

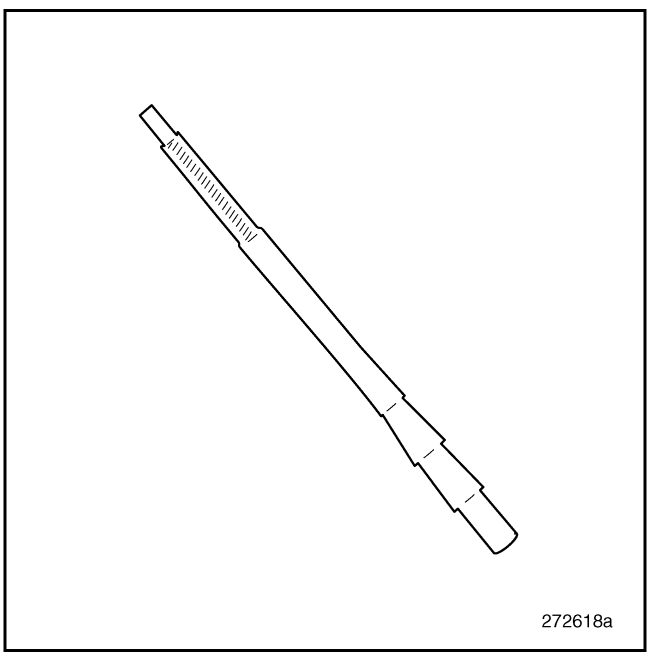


Figure 474 — Swaging Bit

7. Loosen the swaging bit 180 degrees before installing the tool in the cylinder head.

CAUTION

Failure to loosen the swaging bit can result in the bit being twisted or broken.

8. Lubricate the swaging bit and the threads on the tool with oil.
9. Carefully place the sleeve installation tool (with new copper sleeve attached) into the unit injector bore of the cylinder head. Carefully move the copper sleeve downward into the injector bore so that the swaging bit is guided into the injector tip bore in the cylinder head. Push downward on the installation tool using hand force to move the copper sleeve downward until it bottoms out on the injector sleeve seat in the bottom of the injector bore. Use the unit injector hold down and bolt to hold the tool in position. To ensure that the copper sleeve is bottomed in the cylinder head, tighten the unit injector hold down bolt to specification.

NOTE

Remove any oil from the injector hold down bolt holes to avoid hydraulic lock for this step and when the injector is installed.

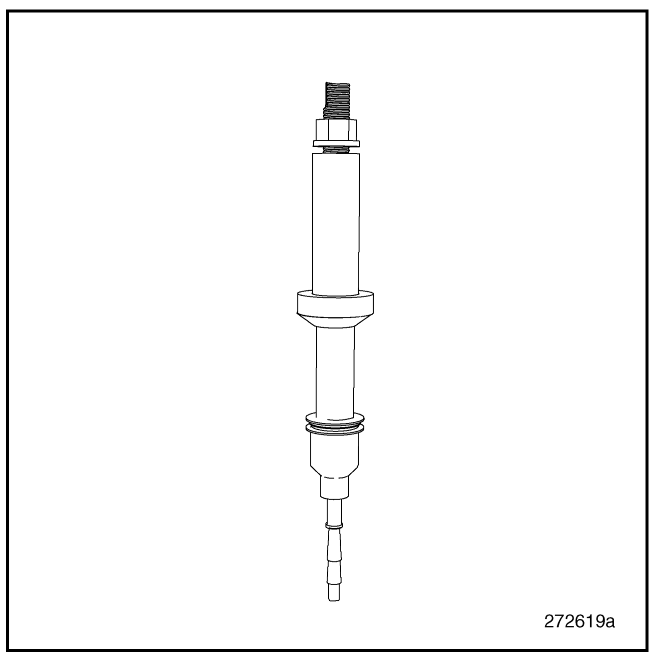


Figure 475 — Copper Sleeve Installation Tool

10. Flare the copper sleeve by turning the nut (1) clockwise while holding the spindle until the swaging bit has been pulled completely through the copper sleeve.

⚠ CAUTION

Failure to hold the spindle can result in a twisted or broken swaging bit.

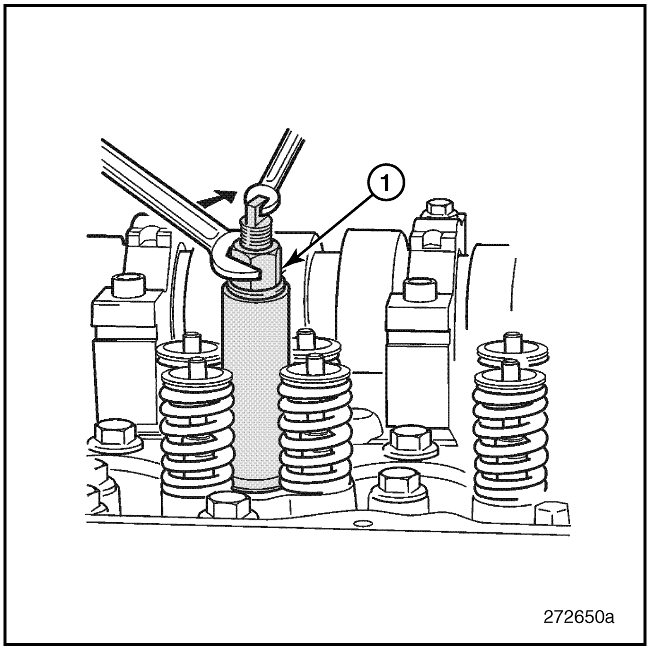


Figure 476 — Flaring Copper Sleeve Using Installation Tool

1. Flaring Tool 88800196

11. Remove the sleeve installation tool from the injector bore.

NOTE

If the injector is not being installed immediately, install the sealing plug into the injector bore to protect it from debris.

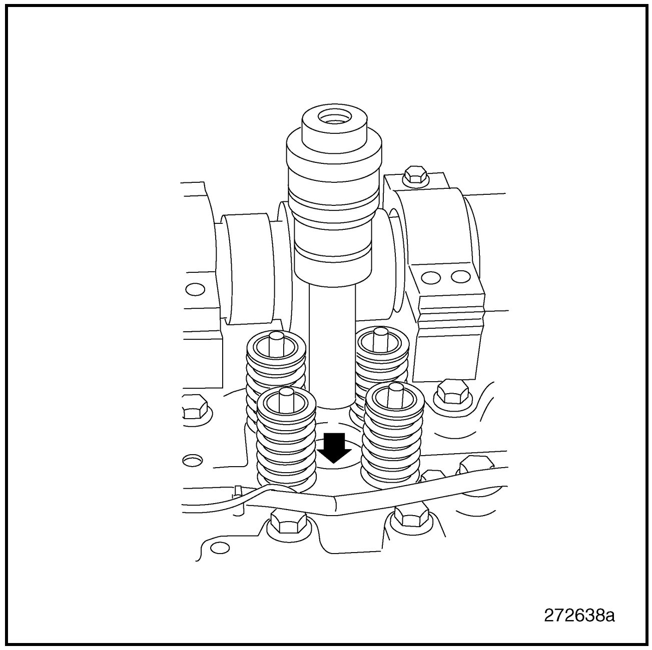


Figure 477 — Unit Injector Bore Sealing Plug

Final Steps

Install the following components on the engine (see ENGINE REASSEMBLY for procedures):

- Unit Injector(s)
- Rocker Arm Shaft Assembly
- Cylinder Head Cover

TURBOCHARGER SMART REMOTE ACTUATOR (SRA) REPLACEMENT [214 SD]

When replacing the Holset VGT Turbocharger as a complete unit, calibration of the Smart Remote Actuator (SRA) is not required. This calibration is completed and stored in the SRA memory at the Holset assembly plant.

Calibration is only necessary if the SRA has been removed from the turbocharger, or when troubleshooting complaints where the turbocharger is the suspected component (low power, regeneration issues, opacity complaints, etc.).

NOTE

The SRA should be removed, and the turbocharger sector gear travel should be checked, prior to performing SRA calibration.

Preliminary Steps

In the event of a suspected problem with the Smart Remote Actuator (SRA), it is essential to diagnose the cause correctly. Diagnostic directions and instructions are in the V-MAC IV Diagnostic Service Manual, 8-213, VCADS *pro* MACK Support Software Guide, 8-364, and the Tech Tool.

Use VCADS *pro* to operate the turbocharger actuator to determine whether the actuator or the complete turbocharger should be replaced. If it is determined that the actuator should be replaced, follow the instructions given here.

NOTE

Refer to manufacturer's service manuals before servicing the turbocharger.

SERVICE HINT

Make certain to record the manufacturer's part number when removing the turbocharger or SRA for use in obtaining the correct replacement parts.

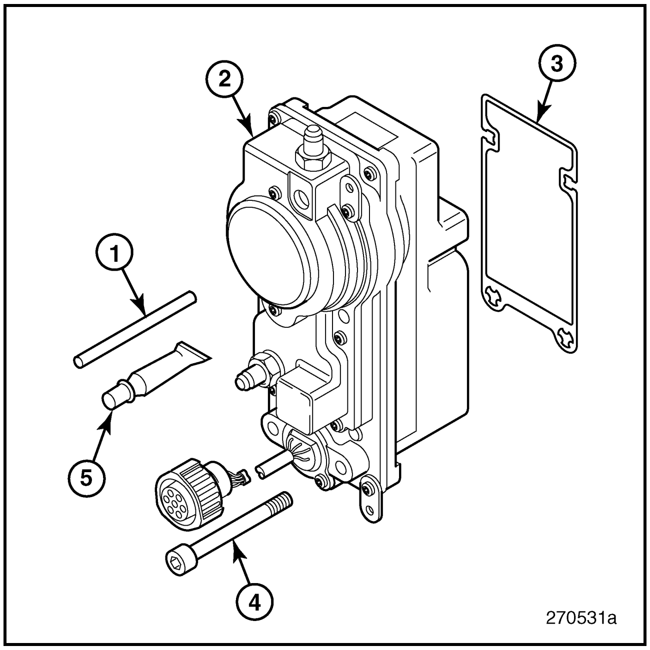


Figure 478 — Turbocharger SRA — Exploded View

1. Alignment Pin, 5 mm (0.197 in.) diameter 2. SRA Housing	3. Gasket 4. Screw (4 required) 5. Grease Applicator Tube

Turbocharger SRA Removal

Provide a suitable clean container and rags for collecting engine coolant while removing the SRA. The fluid may be reusable.

1. Apply the parking brake and place the shift lever in neutral.
2. Disconnect all cables from ground (negative) battery terminals to prevent electrical shock.
3. Using pressure wash equipment, clean the SRA while it is still mounted.

NOTE

Make sure the electrical connections and coolant piping are securely fastened.

WARNING

If the engine has been running recently, the fluids will be hot enough to inflict injury if allowed to contact flesh. Exercise extreme care when opening fluid connections. Failure to heed this warning may result in severe personal injury.

4. Connect the coolant extractor to the drain fitting at the bottom of the radiator and drain the coolant.

NOTE

If the coolant extractor is unavailable, connect the coolant drain hose to the drain fitting and drain the coolant into an appropriate container.

5. Remove ducting and any accessories that will interfere with access to the VGT turbocharger and SRA.
6. Disconnect the SRA assembly electrical connector at the wiring harness. Cut the tie straps as needed.
7. Disconnect the coolant pipes from the SRA.

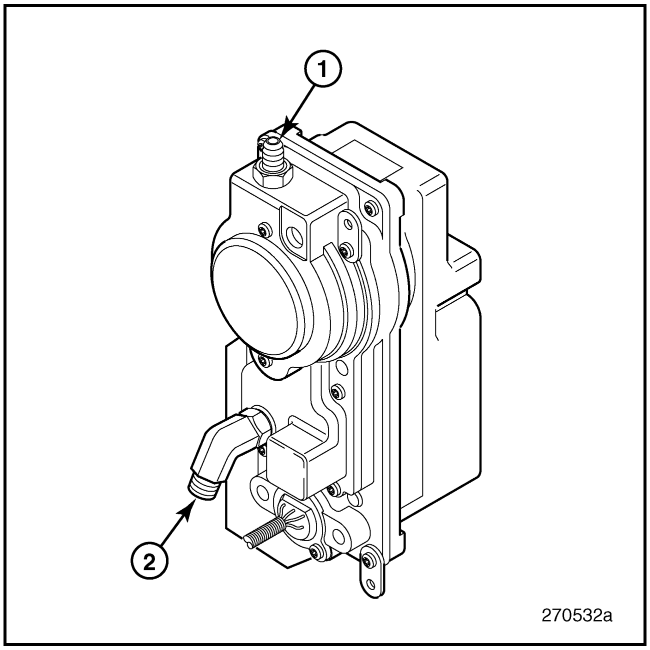


Figure 479 — SRA Coolant Connections

1. Coolant Return Port	2. Coolant Inlet Port

CAUTION

Protect the insides of the SRA housing and the exposed parts from contamination. Failure to heed this caution may result in component malfunction or damage.

8. Remove the SRA from its mounting.
9. Remove and discard the gasket.

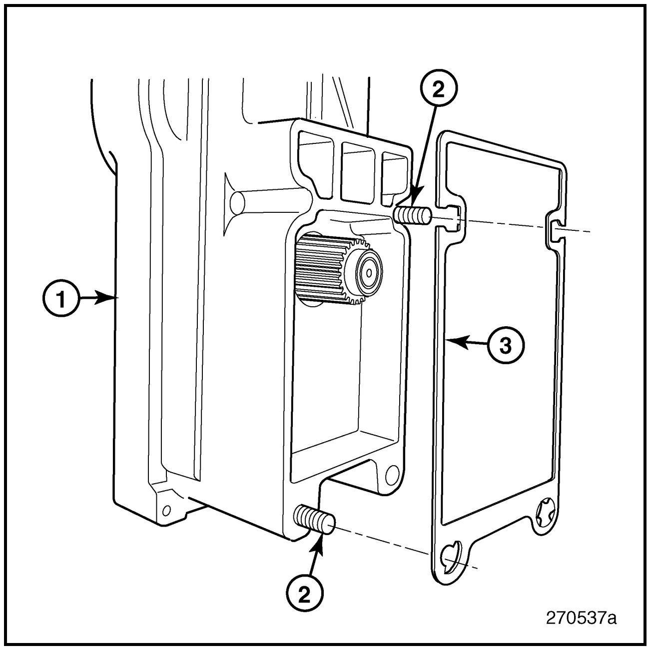


Figure 480 — SRA Mounting Surface

1. SRA Housing 2. Attaching Screws	3. Gasket

10. Clean the actuator drive gear with a lint-free cloth.

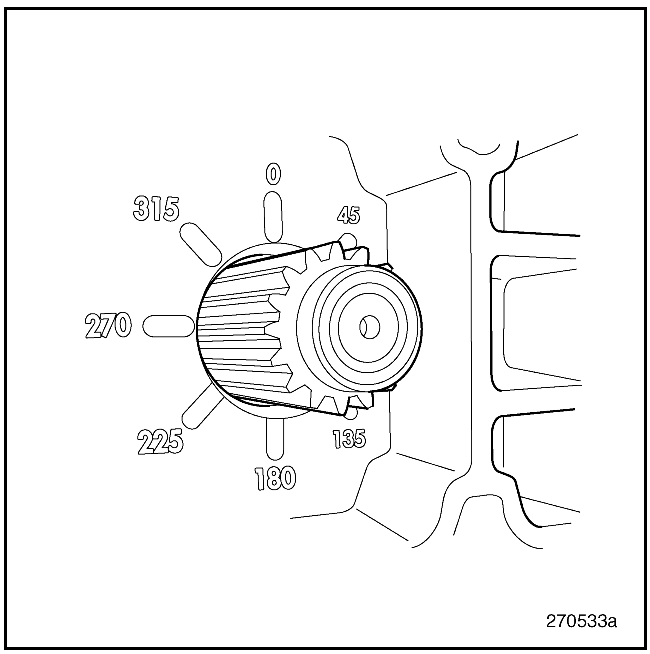


Figure 481 — SRA Drive Gear

11. Inspect the actuator drive gear for wear and damage.
12. Inspect the drive pinion shaft bearings for damage and malfunction.

Turbocharger SRA Inspection and Installation

With the actuator removed, it is possible to check the condition of the variable geometry mechanism by manually moving the sector gear through its full travel, and performing the checks described in the following procedure.

VGT Mechanism Checks

1. Using heavy work gloves, manually rotate the sector gear back and forth (counterclockwise and clockwise). It should be noted that, when the sector gear is at the end of travel (at an end stop), it can require significant force to overcome friction and then start its motion in the opposite direction. This is normal and not cause for concern. By wearing a sturdy work glove, more force can be applied to move the sector gear. Once in motion, the sector gear movement should be smooth without binding or sticking until it reaches its end of travel (end stop).

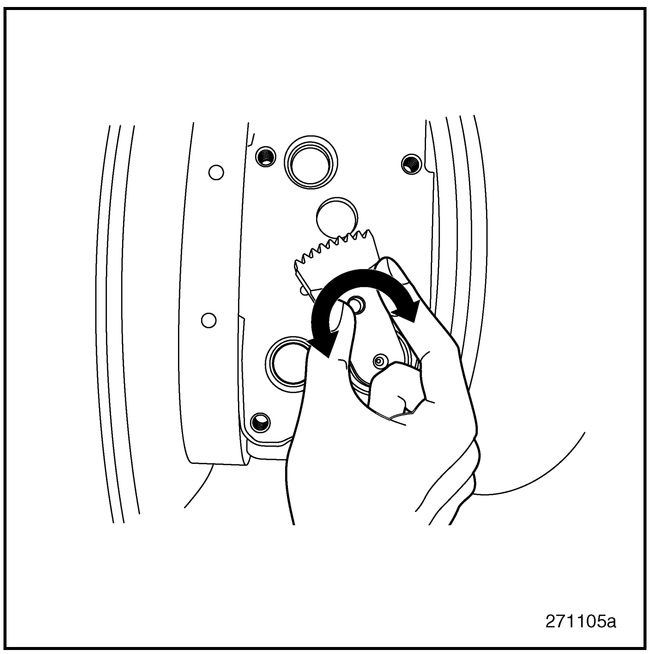


Figure 482 — Rotating the Sector Gear

2. Mount tool 88800265A according to the illustration. Carefully bend the gauge and slide the thin section under the sector gear. If necessary, pull the sector gear out by hand to allow more clearance for the gauge. Verify that the three alignment bosses are fully engaged in the bearing housing.

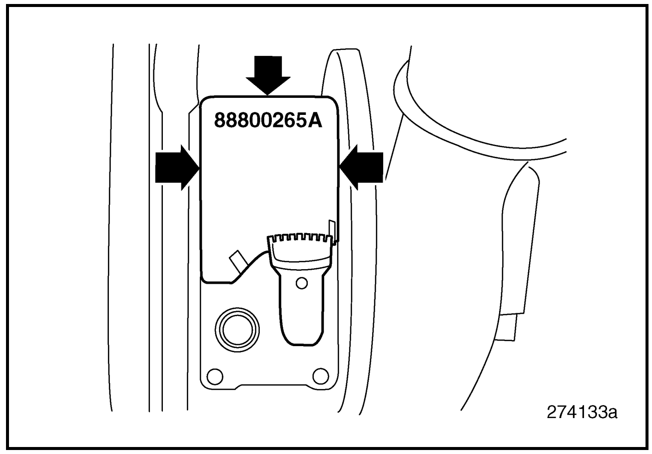


Figure 483 — Sector Gear Alignment Gauge

3. Rotate the sector gear in the counterclockwise direction. The edge of the sector gear must be in the green acceptance zone of the gauge.

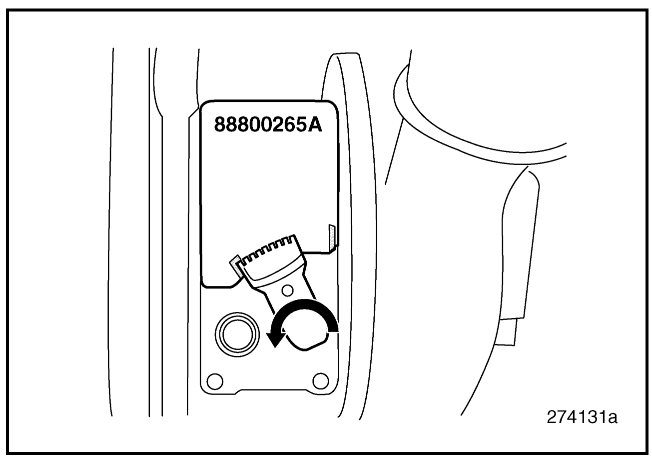


Figure 484 — Gear Rotated Counterclockwise

4. Rotate the sector gear in the clockwise direction. The edge of the sector gear must be in the green acceptance zone of the gauge.

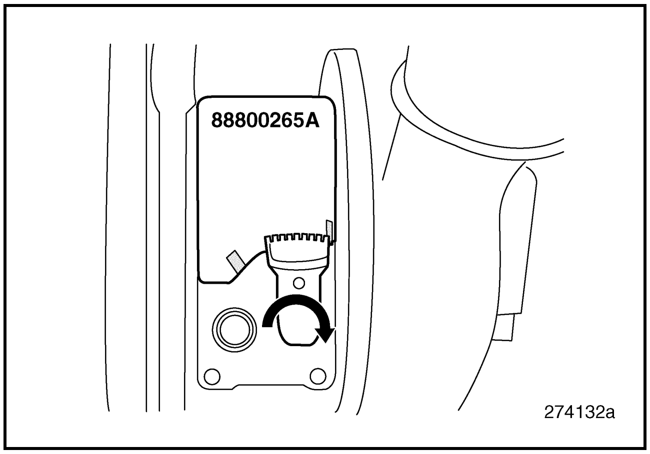


Figure 485 — Gear Rotated Clockwise

NOTE

- If the sector gear does not align with the reference points, or does not rotate properly, the turbocharger must be replaced.
- If the span check is satisfactory, and an actuation problem exists, the actuation problem is likely due to the SRA, and does not require turbocharger replacement. Review the Fault Codes and follow the Actuator Troubleshooting Process in Guided Diagnostics.

5. With the alignment pin installed, apply the recommended grease evenly across all the teeth on the sector gear.

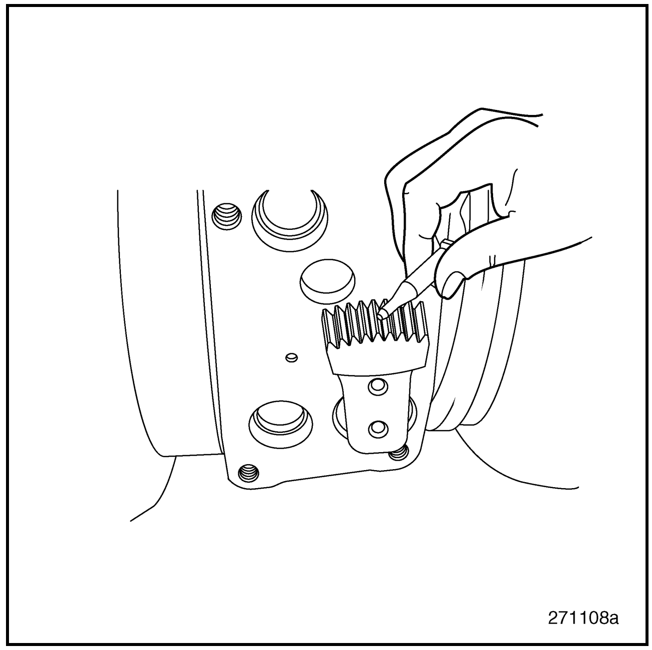


Figure 486 — Lubricating Sector Gear Teeth

6. Carefully remove the alignment pin, taking care not to move the sector gear.

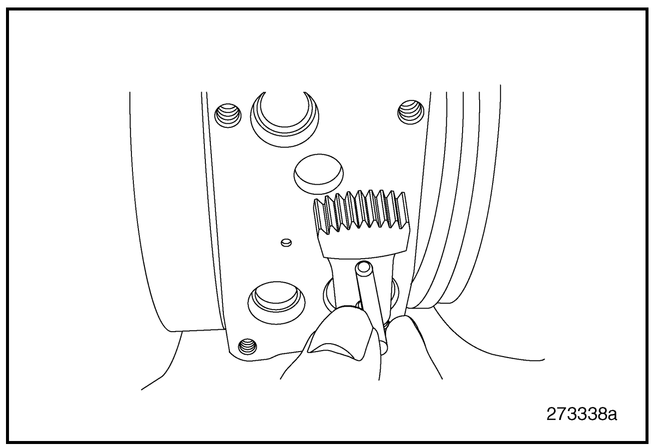


Figure 487 — Removing Alignment Pin

7. Connect the actuator electrical connector to the engine harness connector. Install tie straps as needed to secure the harness.
8. Install all previously removed cables to the ground (negative) battery terminals.
9. Connect the VCADS *pro* PC or the Tech Tool to the vehicle diagnostic connector, and turn the vehicle ignition switch to the ON position.
10. Using VCADS *pro* or Tech Tool, command the actuator to the **Install** position. Turn OFF the ignition when done. The actuator is now ready for installation.

NOTE

Keep hands and obstructions away from the drive gear during installation. The actuator gear must not be moved or the calibration will not be successful.

11. Insert two **new** attaching screws diagonally in the SRA.

NOTE

Use **new** attaching screws and a **new** gasket when assembling the SRA on the turbocharger.

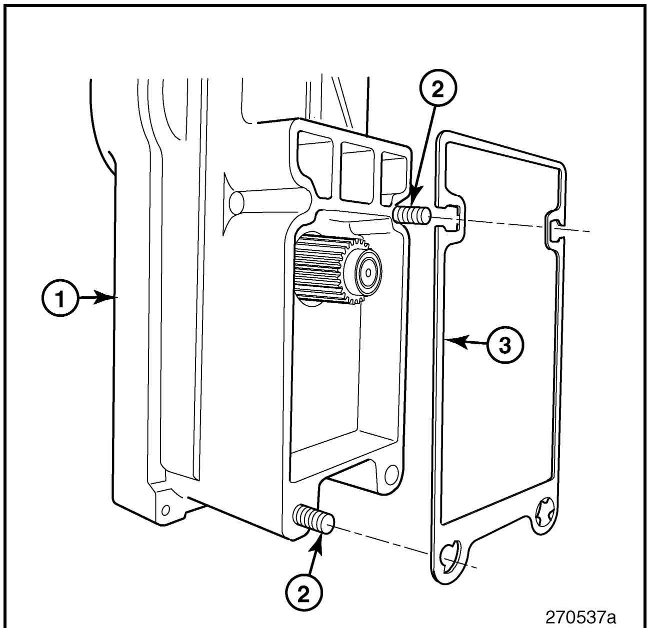


Figure 488 — Attaching SRA to Turbocharger

1. SRA Housing 2. Attaching Screws	3. Gasket

12. Assemble a **new** gasket on the protruding screws at the back of the actuator.
13. Carefully align the actuator with the turbocharger center housing and place the actuator in position on the turbocharger. Hand tighten the two attaching screws.

NOTE

Be careful to preserve the gear tooth alignment and the correct position of the gasket during assembly.

14. Install the remaining two **new** actuator screws.
15. Using a torque wrench, tighten the actuator mounting screws in two steps alternately in a diagonal pattern.

    Step 1: 3 N•m (27 lb-in)

    Step 2: 11 N•m (97 lb-in)
16. Connect the coolant lines to the SRA and using a torque wrench, tighten the coolant line connections to specification.

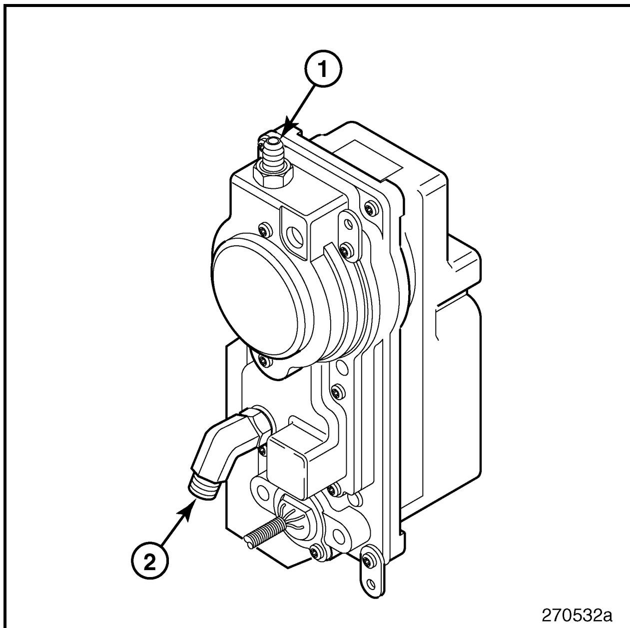


Figure 489 — SRA Coolant Connections

1. Coolant Return Port	2. Coolant Inlet Port

Final Assembly

1. Reinstall all accessory items, ducting, tie straps, etc., that were removed to gain access to the turbocharger and related system components.
2. Using the coolant extractor, fill the system with approved coolant per specification.
3. Using the diagnostic computer, initiate the on-turbocharger calibration command.
4. Start the engine and operate it at low idle for at least three minutes after installing the SRA and before driving the vehicle.

UNIT INJECTOR CLEANING

Preliminary Steps

Remove the following components from the engine (see ENGINE DISASSEMBLY for procedures):

- Cylinder Head Cover
- Rocker Arm Shaft Assembly
- Unit Injectors

Install the sealing plug, 9998251, into the unit injector bore of the cylinder head to prevent dirt and debris from entering the bore.

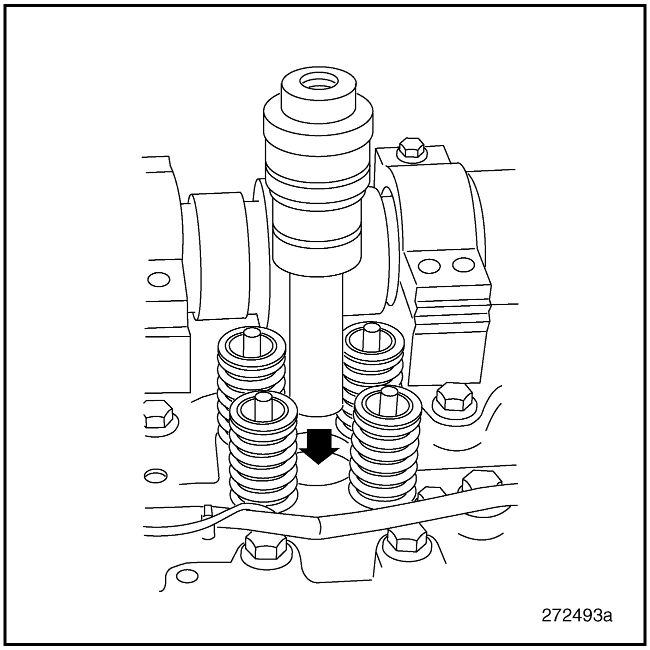


Figure 490 — Installing Injector Bore Sealing Plug, 9998251

Cleaning and Inspection

NOTE

Since the unit injectors operate at very high fuel injection pressures, the nozzle tip spray holes and the immediate area around the spray holes remain clean and free of carbon deposits. This leaves the cap nut seat surface as the only surface which requires a thorough cleaning.

Clean the injector **cap nut surface** as follows:

1. Remove the two O-rings from the injector and discard the O-rings.
2. Cover the O-ring grooves and the complete area between the grooves with tape or equivalent to prevent contaminants from getting into the injector.
3. Cover the opening for the electrical connection.
4. Slide a short section of 6 mm (0.25 inch) ID hose over the injector nozzle tip until it covers approximately half the nozzle tip length. This is necessary to protect the nozzle spray holes from damage when cleaning the cap nut seat surface.

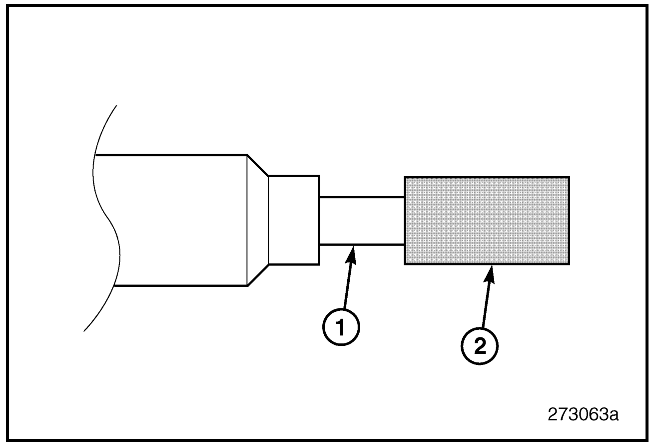


Figure 491 — Injector Nozzle Tip Cover

1. Injector Cap Nut Seat Surface	2. Hose (covering Nozzle Tip)

5. With the unit injector nozzle tip spray holes protected, carefully clean the cap nut seat surface of hard carbon deposits using a wire wheel. Apply only light nominal pressure to hold the wire wheel against the injector surface for short periods of time.

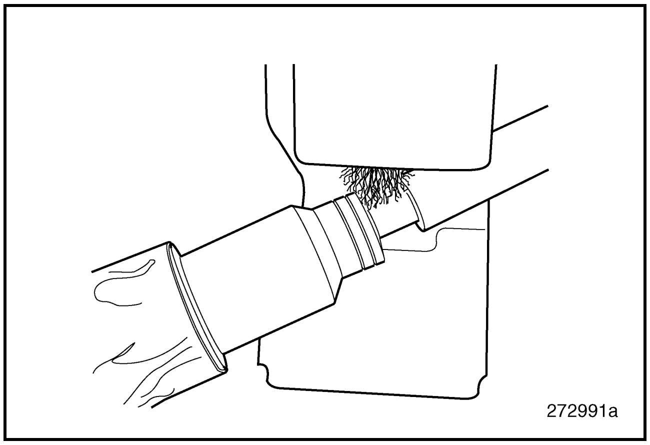


Figure 492 — Cleaning Injector Cap Nut Seat Surface

CAUTION

The carbon will be very hard and difficult to remove. Avoid the tendency to use excessive pressure in holding the wire wheel against the injector cap nut surface. Excessive force can damage the cap nut surface, making the injector unacceptable for reuse.

6. Clean any remaining carbon using hand tools such as a hand scraper or medium grit emery cloth.
7. After cleaning, inspect the injector nozzle cap nut seat surface for pitting or related damage. If there is pitting or other damage, replace the injector.

NOTE

Pitting on surfaces other than the cap nut seat does not affect the function of the unit injector and is acceptable.

8. Install **new** O-rings in the grooves on the injector.
9. Lubricate the injector O-rings with clean engine oil.

Final Steps

Install the following components on the engine (see ENGINE REASSEMBLY for procedures):

- Unit Injectors
- Rocker Arm Shaft Assembly
- Cylinder Head Cover

VALVE STEM HEIGHT MEASUREMENT PROCEDURE [213 FB]

On engines exhibiting poor performance, smoke (at times) and a noticeable engine miss (with the symptoms getting worse as the engine gets hotter), may be an indication of valve seat recession. A decrease in clearance (valve lash) between the valve rocker and valve yoke (bridge) can be measured at the valves to determine if seat recession is occurring. If valve seat recession is suspected, the following procedure can be used to measure valve stem height. To perform this measurement, a valve stem height measurement gauge (tool No. 85112461) and a depth micrometer are required.

NOTE

For detailed information on rocker arm shaft removal and installation procedures, refer to the applicable section of this service manual.

1. Remove components as necessary to gain access to the cylinder head (valve) cover.
2. Remove the cylinder head cover and rocker arm shaft assembly.

CAUTION

On engines equipped with an engine brake, use suitable tie straps or mechanics wire to retain the pistons in the rocker arms. The match between the pistons and rocker arms must be maintained. Failure to secure the engine brake pistons before removing the rocker shaft assembly, allows the pistons to drop from the bore of the rocker arms. If a piston drops out, it might not be noticed, or it may be difficult to push the piston fully back into the bore of the rocker arm. Also, pistons are a match-fit to the rocker arm, and so inadvertent mix-up of components must be avoided. Assembling the rocker arm shaft to the engine, or operating an engine with the engine brake pistons not fully retracted (or missing), results in breakage of valve train components and significant engine damage.

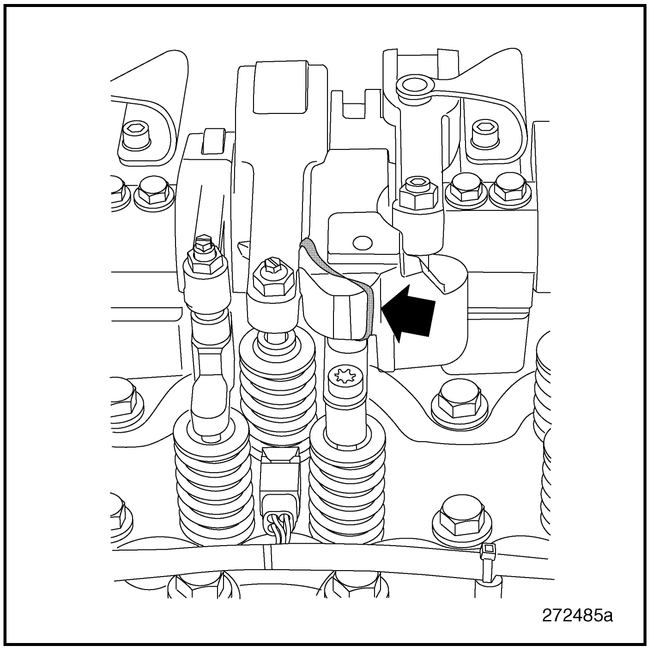


Figure 493 — Engine Brake Piston Retained

3. Remove the valve yokes (bridges).

NOTE

The valve yokes must be installed on the same set of valves that they were removed from. Before removing the valve yokes, mark them to identify their location and orientation. An incorrectly installed valve yoke causes severe engine damage due to a dropped valve. For proper valve yoke removal and installation, refer to the appropriate sections in this service manual.

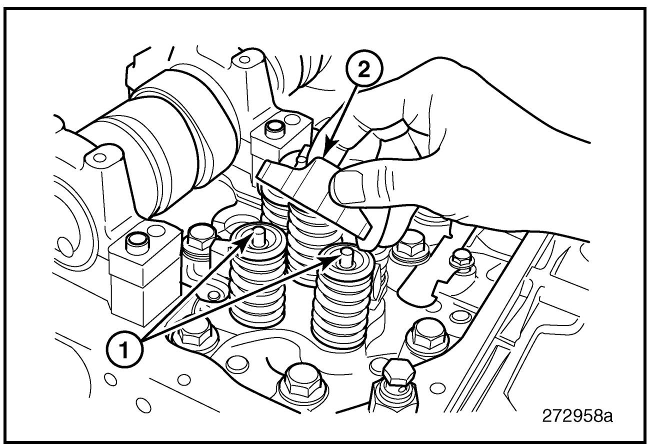


Figure 494 — Removing the Valve Yoke

1. Inlet Valve Stem Tips	2. Inlet Valve Yoke

4. Remove the screws securing the unit injector harness tie bar to the cylinder head. Slide the tie bar outward to provide sufficient clearance for the valve stem height measurement gauge to be installed over the valve springs. Do not disconnect the harness connectors from the unit injectors or cut the tie straps that secure the harness to the tie bar.

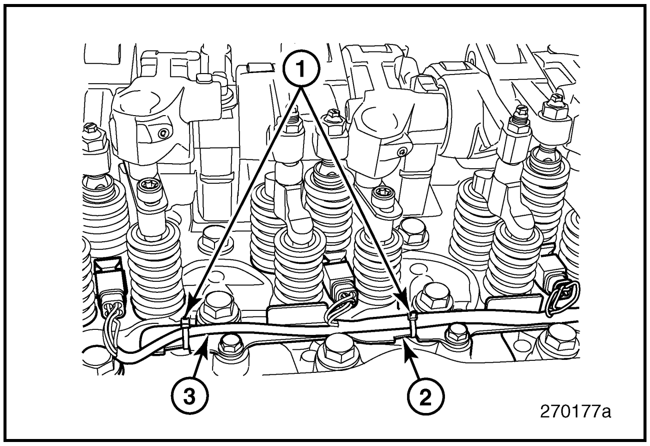


Figure 495 — Move Harness Tie Bar Outward

1. Tie Straps 2. Tie Bar Notch	3. Wiring Harness

5. Set the depth micrometer to 8.10 mm (0.319 inch) to measure stem protrusion.

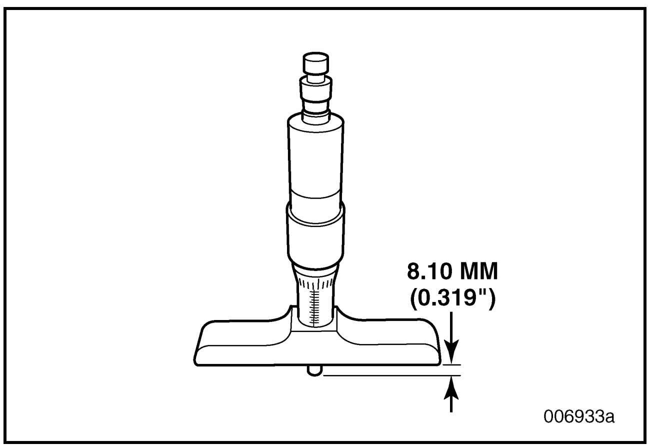


Figure 496 — Set Depth Micrometer

6. Place the valve stem height measurement gauge (tool No. 85112461) over the valve spring of the valve to be measured. Make sure the tool is fully seated on a clean surface.

NOTE

Make sure there are no particles of any kind between the bottom of the valve stem height measurement gauge and the cylinder head surface. Particles between the gauge and the cylinder head surface results in an inaccurate measurement.

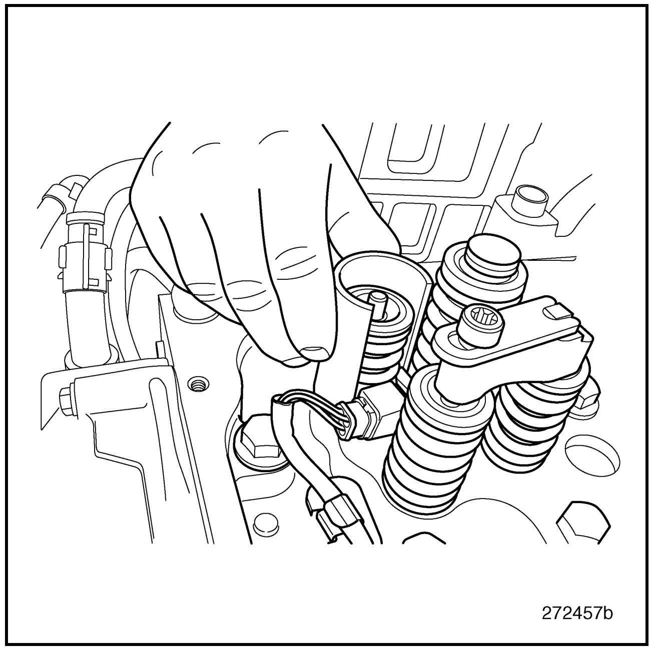


Figure 497 — Place Measurement Gauge over Valve Spring

7. Place the depth micrometer on top of the valve stem height measurement gauge and note if there is clearance between the end of the micrometer spindle and the tip of the valve stem.

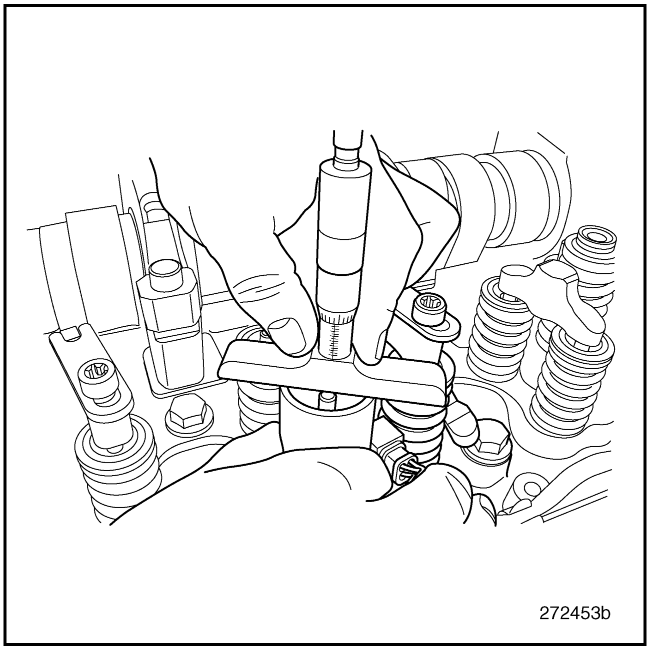


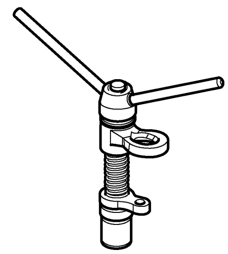
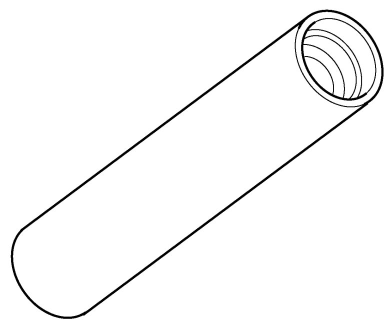
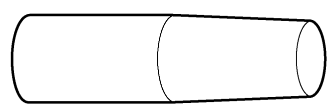
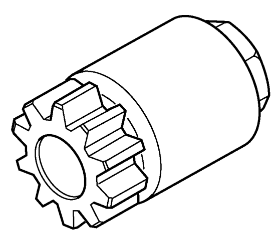
Figure 498 — Measuring Valve Stem Height

- If there is clearance between the tip of the valve stem and the tip of the depth micrometer spindle, valve height is within specification. Measure the next valve stem height using the same method.
- If valve stem height is less than 8.10 mm (0.319 inch), as indicated by the tip of the depth micrometer spindle contacting the tip of the valve stem, the valve seat is recessed. Replacement of the cylinder head is necessary.

8. Position the unit injector harness tie bar to the cylinder head, install the screws and tighten according to specification.
9. Install the valve yokes to their original location.
10. Install the rocker arm shaft assembly and remove the retainers securing the engine brake pistons. Adjust valve lash as necessary.
11. Install the cylinder head cover.
12. Install the components that were removed to gain access to the cylinder head cover.

VALVE STEM SEAL REPLACEMENT [213 MV]

Special Tools

Tool No.	Description	Image
9990210	Valve Spring Compressor (Essential)	 006782a
85112460	Valve Stem Seal Installation Tool	 006966a
88800011	Valve Stem Seal Protection Tool (Essential)	 006773a
88800014	Flywheel Turning Tool (Essential)	 271485a

Preliminary Steps

The following components need to be removed for access to the valve stem seals (see ENGINE DISASSEMBLY for procedures):

- Cylinder Head Cover
- Rocker Arm Shaft Assembly
- Unit Injectors

Seal Removal

NOTE

When replacing the valve stem seals, the pistons must be at TDC when the valves are released so that the valves do not drop into the cylinder.

1. Using the flywheel turning tool, 88800014, rotate the crankshaft so that the pistons are at TDC for the appropriate pair of cylinders where stem seals are being replaced.

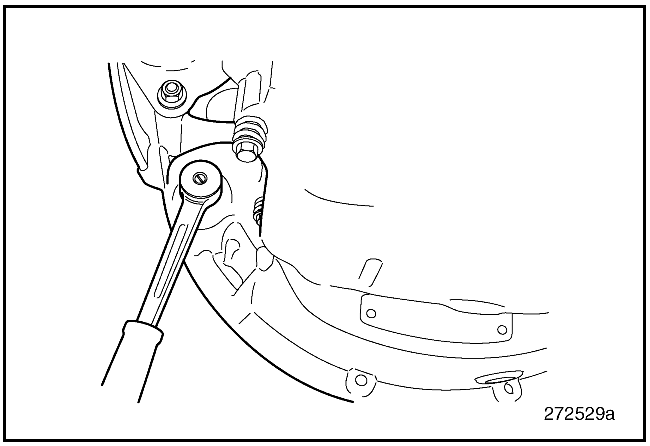


Figure 499 — Rotating Crankshaft

2. Using the valve spring compressor tool, 9990210, press down on the springs (one at a time) and remove the valve retainers and springs for the cylinder.

WARNING

Use protective goggles or eye injury could occur.

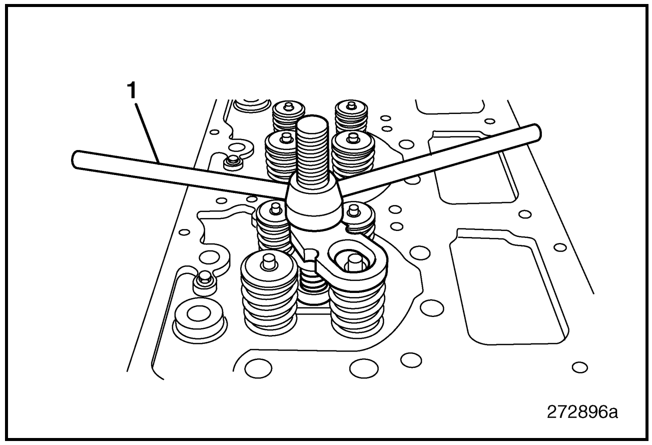


Figure 500 — Compressing Valve Springs

1. Valve Spring Compressor 9990210

3. Remove and discard the valve stem seals.
4. Using a clean cloth, thoroughly clean all engine oil off the valve stem and valve guide.

Seal Installation

1. Apply a thin film of clean engine oil to the outside diameter of the valve seal guide tool and to the sealing lips of the **new** valve stem seal to avoid damage to the seal as it is installed.

NOTE

Do NOT apply oil to the inner surfaces of the seal that contact the valve guide. These surfaces must be dry.

2. Place the seal guide tool, 88800011, in position on the valve stem.
3. Place a **new** valve stem seal in position over the guide tool and onto the valve stem.
4. Using the appropriate end of the seal installation tool, 85112460, seat the valve stem seal on the valve guide by gently tapping the installation tool with a light plastic or rubber mallet. When the seal is fully seated, a normal “spring-back” of the seal will occur, leaving a maximum gap of approximately 0.5 mm (0.02 inch) between the bottom of the seal and the shoulder surface on the valve guide.

CAUTION

Use only gentle taps with the hammer when seating the seal to avoid damage to the seal casing as well as the top rubber portion of the seal.

NOTE

Seal installation tool, 85112460, is designed for use on MP7, MP8 and MP10 engines. Use the appropriate end of the tool for the engine being serviced.

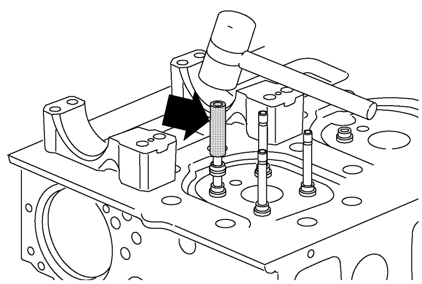


Figure 501 — Seating the Valve Stem Seal

5. Using the valve spring compressor, 9990210, install the valve spring and valve retainers. Carefully tap on the valve stem with a plastic or rubber hammer to ensure that the valve keepers are positioned correctly.

WARNING

Use protective goggles or eye injury could occur.

6. Move the valve spring compressor to the next cylinder of the cylinder pair and repeat the procedure. Rotate the crankshaft so that the pistons are at TDC for the next cylinder pair and repeat the procedure. Continue on and repeat the procedure for the final cylinder pair.

Final Steps

Install the following components which were removed for access to the valve stem seals (see ENGINE REASSEMBLY for procedures):

- Unit Injectors
- Rocker Arm Shaft Assembly
- Cylinder Head Cover

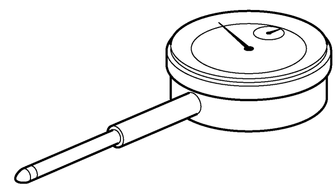
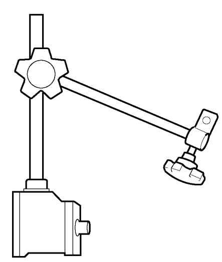
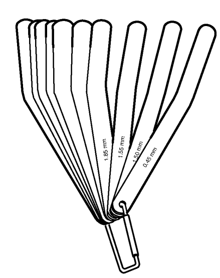
REPAIR INSTRUCTIONS, PART 3

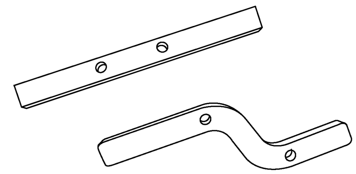
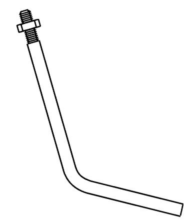
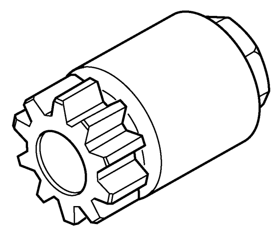
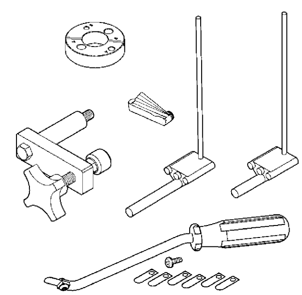
MP8 ENGINE SETUP AND ADJUSTMENT [200 EA]

NOTE

Due to the Engine Electronic Control Unit (EECU) self-learning capability, it is necessary to reset learned EECU parameters after servicing some engine-related components. This allows the EECU to learn the new component's behavior. After servicing is complete, perform the “Learned Data Reset” located in VCADS.

Special Tools

Tool No.	Description	Image
9989876	Dial Indicator (Available)	 006899a
9999696	Magnetic Base (Available)	 006900a
85111377	Feeler Gauge Set	 006844a

Tool No.	Description	Image
85111422 (A, B)	Timing Gear Cover Alignment Tools (Essential)	 006924a
85111493	Angled Extension (Available)	 006898a
88800014	Flywheel Turning Tool (Essential)	 271485a
J 44514-B	Engine Timing Kit (Essential)	 006889a

Valve and Unit Injector Adjustment

[213 NB, 222 KG]

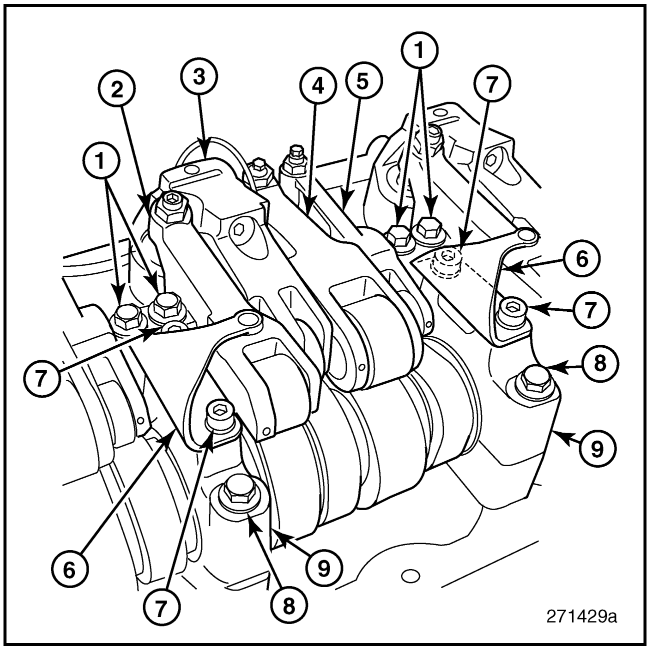


Figure 502 — Exhaust Valve, Injector, Inlet Valve and Exhaust Brake Rocker Arms

1. Rocker Shaft/Bearing Cap Attaching Screws	5. Inlet Valve Rocker Arm
2. Exhaust Brake Rocker Arm	6. Plate Spring
3. Exhaust Valve Rocker Arm	7. Plate Spring Attaching Screws
4. Injector Rocker Arm	8. Bearing Cap Attaching Screws
	9. Camshaft Bearing Cap

GENERAL INFORMATION

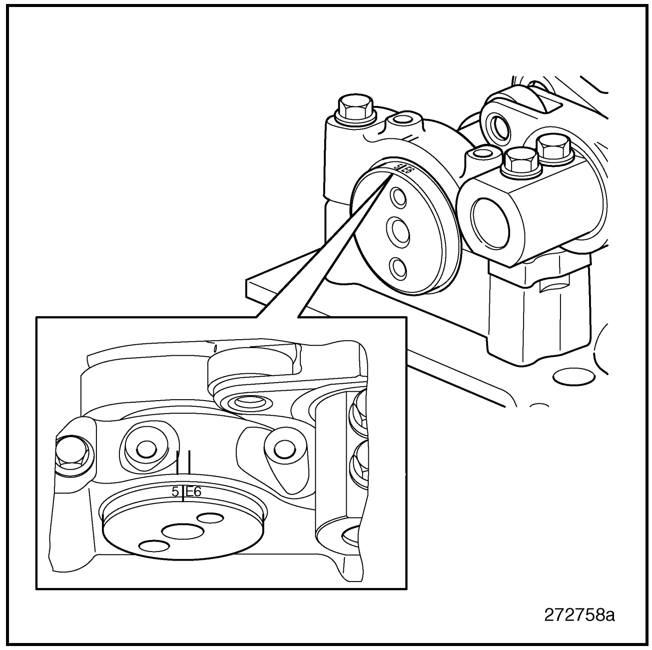


Figure 503 — Camshaft Timing Marks — Front Bearing Cap

Timing marks for basic camshaft timing and adjustment of the valves and unit injectors are located at the front of the camshaft just forward of the No. 1 front bearing journal. Two lines at the top of the front bearing cap mark the alignment point for positioning of the camshaft and making the adjustments.

The top dead center (TDC) mark is used for basic camshaft timing. The TDC mark must be between the two lines on the front camshaft bearing cap when the flywheel is at 0° (top dead center for cylinder No. 1).

The engine must be cold, 60°C (140°F) or less, before making these adjustments.

Camshaft markings for setting of valves and unit injectors:

- **Without PowerLeash™**: Markings 1–6 apply to adjustment of inlet valves, exhaust valves and injectors.
- **With PowerLeash™**: Markings 1–6 apply to adjustment of inlet valves and injectors. Markings E1–E6 apply to adjustment of exhaust valves.

INLET VALVE ADJUSTMENT

WARNING

Apply the parking brake before barring the engine over. Remove the EMS power supply fuse to avoid starting the engine unintentionally. Make sure that the transmission is not in gear.

With the engine cold, 60°C (140°F) or less, check and adjust the valves and injector as required for each cylinder before moving to the next. Follow this sequence of cylinders when adjusting clearances: 5, 3, 6, 2, 4 and 1.

1. Using the flywheel turning tool, 88800014, bar the engine over manually to the appropriate camshaft marking for adjustment of the inlet valves and injector for that cylinder.
2. Using a feeler gauge, check the clearance between the rocker arm adjusting screw and the valve yoke (bridge) of the inlet valves. Refer to Figure 504.

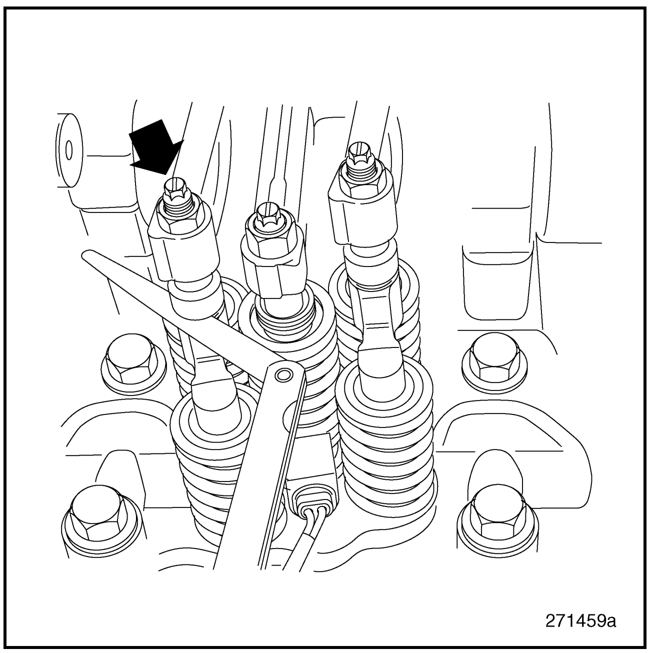


Figure 504 — Checking Inlet Valve Clearance

3. If the clearance is not within specification, loosen the locknut and adjust the clearance as required.
4. Hold the adjusting screw to prevent it from turning and tighten the locknut to specification.
5. Recheck the clearance after tightening the locknut.
6. Mark the respective rocker arm as each adjustment is completed.

UNIT INJECTOR ADJUSTMENT

The unit injector adjustment is done with the engine and camshaft in the same position as for the inlet valve adjustment on each cylinder.

1. Loosen the injector rocker arm adjusting screw jam nut and turn the adjusting screw out (counterclockwise) to relieve the preload.
2. Turn the adjusting screw in (clockwise) until it firmly contacts the injector. Do not compress the spring.
3. Turn the adjusting screw in a further 240° (four flats on the hex head).

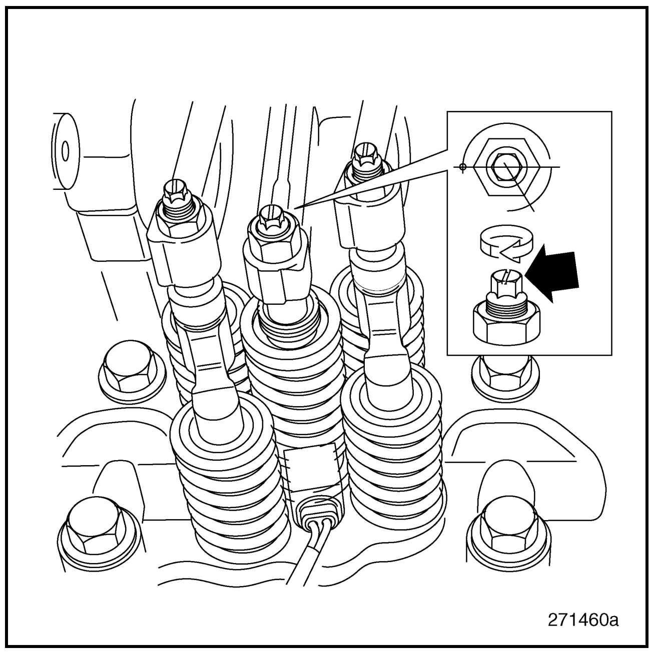


Figure 505 — Adjusting Unit Injector Preload

4. Hold the adjusting screw to prevent it from turning further and, using a torque wrench, tighten the jam nut to specification.
5. Mark the respective rocker arm as each adjustment is completed.

EXHAUST VALVE ADJUSTMENT (WITHOUT POWERLEASH™)

1. At the current camshaft setting used for the inlet valves, adjust the exhaust valves following the same procedure described for adjustment of the inlet valves. However, the valve clearance specification is different.

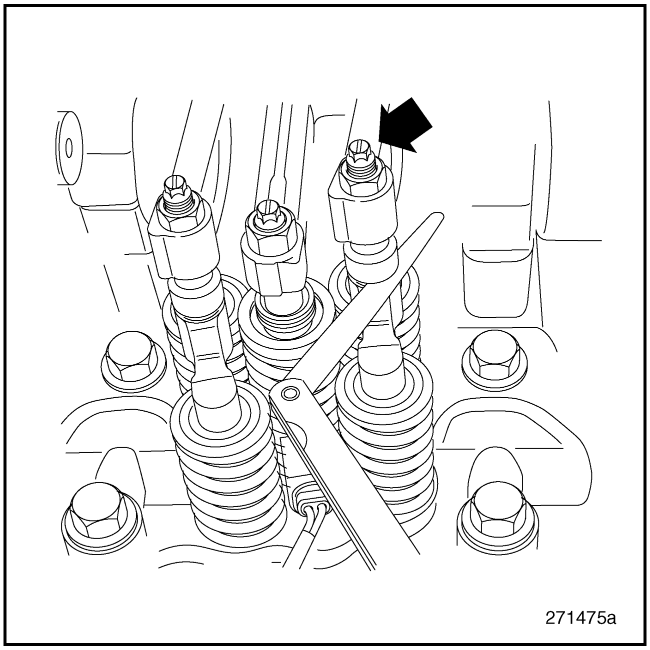


Figure 506 — Checking Exhaust Valve Clearance

2. Mark the rocker arm when adjustment is complete.
3. Using the flywheel turning tool, bar the engine over manually to the appropriate marking for the next cylinder. Adjust the inlet valves, unit injector and exhaust valves at that cylinder.

EXHAUST VALVE ADJUSTMENT (WITH POWERLEASH™)

NOTE

The numbers on the camshaft preceded by an ***E*** are used to adjust the exhaust valves when the engine is equipped with PowerLeash™.

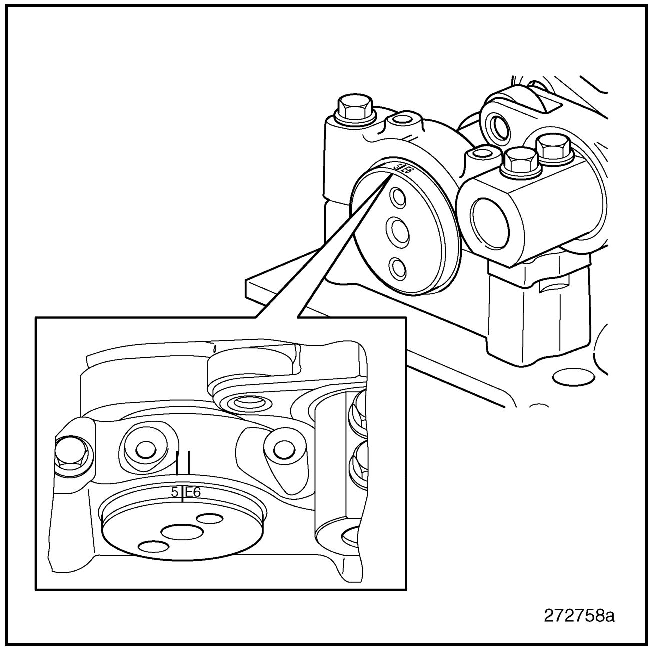


Figure 507 — Camshaft Timing Marks

Engines equipped with the PowerLeash™ engine brake have two rocker arms working in combination to control the exhaust valves. They are the **exhaust rocker arm** and the **brake rocker arm** which are adjusted separately as described in the following procedure.

1. Loosen the screws holding the plate springs to release the spring tension against the engine brake rocker arms.

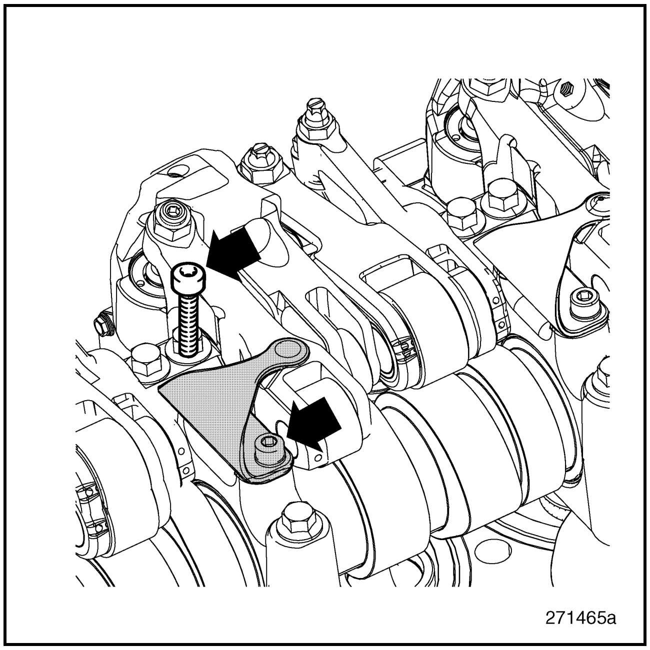


Figure 508 — Plate Spring Attaching Screws

2. Using the flywheel turning tool, 88800014, bar the engine over so that the appropriate ***E*** number marking is between the lines on the front camshaft bearing cap.
3. Measure the clearance between the exhaust rocker arm piston and the shim on top of the valve yoke (bridge) as shown in Figure 509.

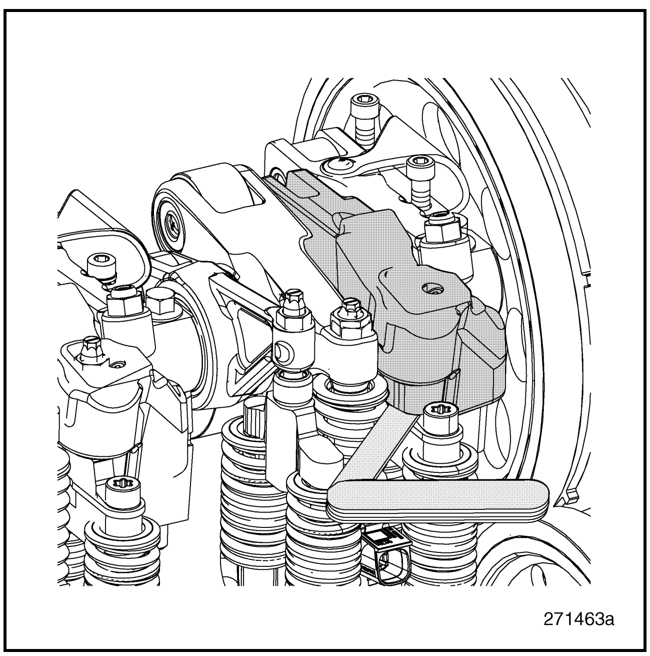


Figure 509 — Measuring Exhaust Valve Clearance

4. If clearance is not within specification, adjust the clearance as follows, using shims (Figure 510) placed on top of the valve yoke (bridge).

Adjusting Exhaust Rocker Arm Clearance

a. Remove the shim retaining screw and remove the shim(s).

b. Determine the thickness of the shim(s) required to provide the specified clearance.

c. Make sure that the valve yoke and shim(s) are clean. Place the shim(s) in position on the valve yoke and install the retaining screw. Tighten the screw to specification.

NOTE

Do NOT use more than two shims. Shims are available in 0.05 mm (0.002 inch) increments with the thickness marked on the surface. If two shims are required to take up the clearance, the shims should be of nearly equal thickness.

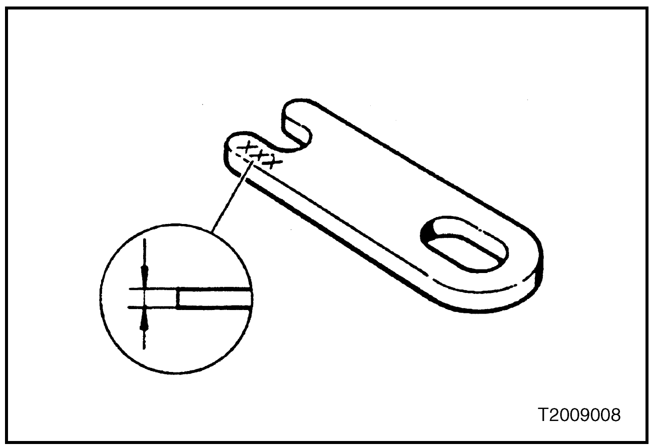


Figure 510 — Engine Compression Brake Adjustment Shim

5. Leave the feeler gauge in place between the exhaust rocker arm piston and the valve yoke shim and adjust the brake rocker arm clearance.

Adjusting Brake Rocker Arm Clearance

a. Loosen the locknut **A** on the brake rocker arm adjusting screw.

b. Using the dial indicator with angled extension and base (9989876, 85111493 and 9999696), place the tip of the dial gauge on the yoke as close as possible to the rocker arm yoke pad. Zero the gauge.

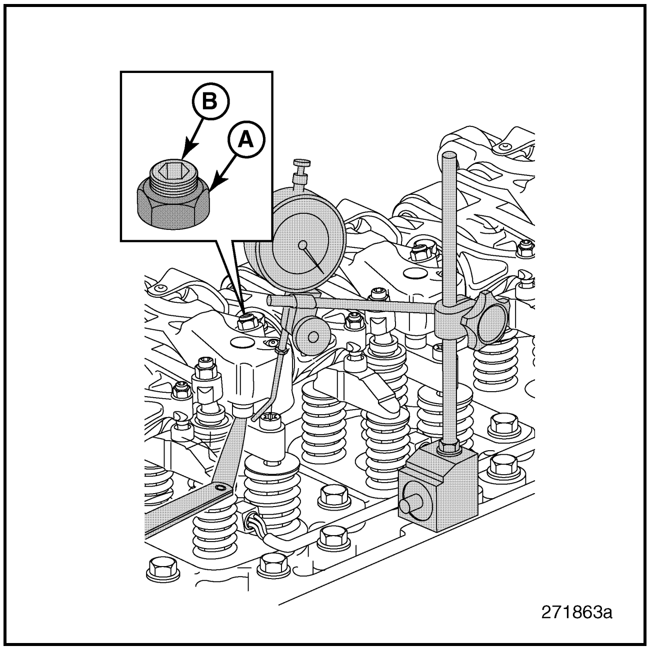


Figure 511 — Brake Rocker Arm Adjustment with Dial Indicator

A. Locknut	B. Adjusting Screw

c. Tighten the rocker arm adjusting screw **B** until the dial shows that the yoke has been pushed downward 0.60 ±0.05 mm (0.024 ±0.002 inch).

d. Loosen the rocker arm adjusting screw two full turns (720°).

e. Hold the adjusting screw to prevent it from turning further and, using a torque wrench, tighten the locknut to specification.

6. Remove the dial indicator and the feeler gauge.
7. Using a 3.6 mm (0.142 inch) feeler gauge, 85111377, check the clearance between the brake rocker arm roller and the cam lobe. If the clearance is incorrect, repeat the brake rocker arm clearance adjustment.

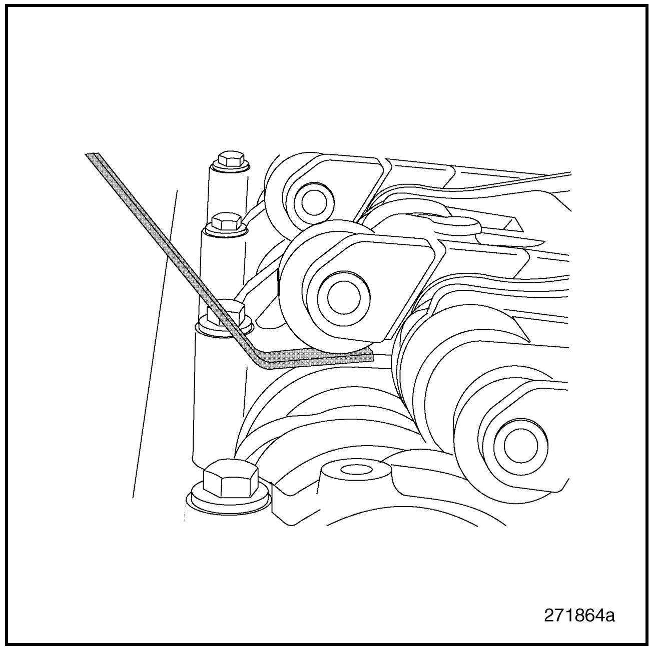


Figure 512 — Checking Brake Rocker Arm Roller to Cam Lobe Clearance

8. Mark the respective rocker arm as each valve adjustment is completed.

CONTINUATION OF ADJUSTMENTS

Continue the procedure by barring the engine to the appropriate timing marks and adjusting the valves and unit injectors at each of the remaining cylinders. Follow the steps described above to adjust the inlet and exhaust valves, and unit injector at each cylinder.

For engines equipped with the PowerLeash™ engine brake, tighten the plate spring attaching screws to specification after the valve and unit injector adjustments have been completed.

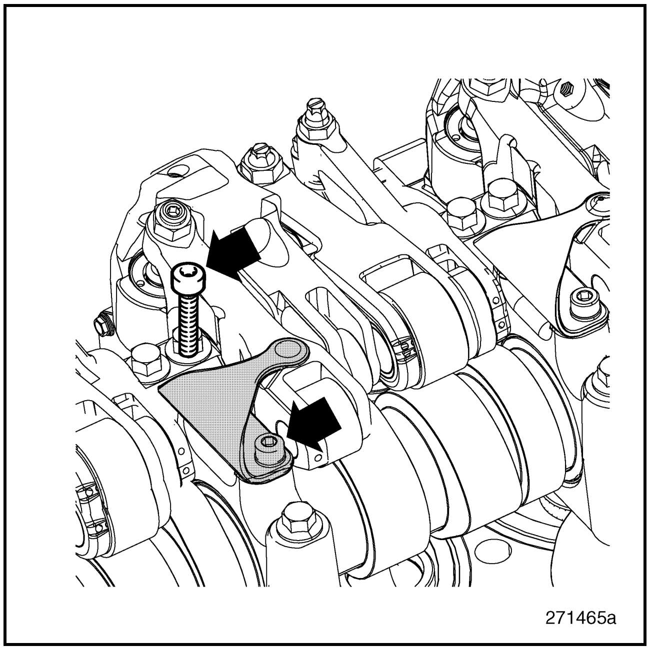


Figure 513 — Plate Spring Attaching Screws

OPERATIONAL CHECK

After the valve and unit injector adjustments have been completed, check engine operation as follows:

1. Using the flywheel turning tool, bar the engine over manually two complete revolutions to ensure that no piston-to-valve contact occurs. If contact does occur, readjust the valves as needed BEFORE starting the engine.
2. Start the engine and bring it up to normal operating temperature.
3. Once normal operating temperature is attained, let the engine idle for an additional five minutes. During this time, the electronic engine management system (EMS) will perform its own cylinder balancing, resulting in smooth engine idling.

NOTE

Do NOT use any form of power consuming equipment, such as PTO or air conditioning, when cylinder balancing is being carried out.

Checking and Adjusting Timing Gear Backlash

(Camshaft Gear to Idler Gear)

WARNING

Apply the parking brake before barring the engine over. Remove the EMS power supply fuse to avoid starting the engine unintentionally. Make sure that the transmission is not in gear.

1. Remove the 16 retaining screws and springs and remove the valve cover from the cylinder head.
2. Disconnect the wiring harness lead at the camshaft sensor connector.
3. Remove the compressor coolant lines.
4. Loosen and remove the capscrews securing the timing gear cover to the cylinder head.
5. Remove the timing gear cover from the engine. Use care when removing the cover to avoid the rubber seals falling into the flywheel housing. Remove the rubber seals from the cover and discard.

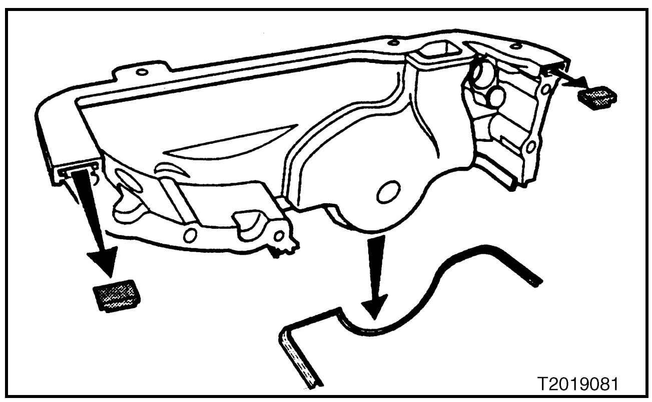


Figure 514 — Timing Gear Cover

6. Using the flywheel turning tool, 88800014, turn the flywheel until the piston in cylinder No. 1 is at top dead center (TDC), zero degree mark on the flywheel aligned with the mark on the flywheel housing. The TDC marking on the camshaft should be aligned with the markings on the No. 1 camshaft bearing cap.

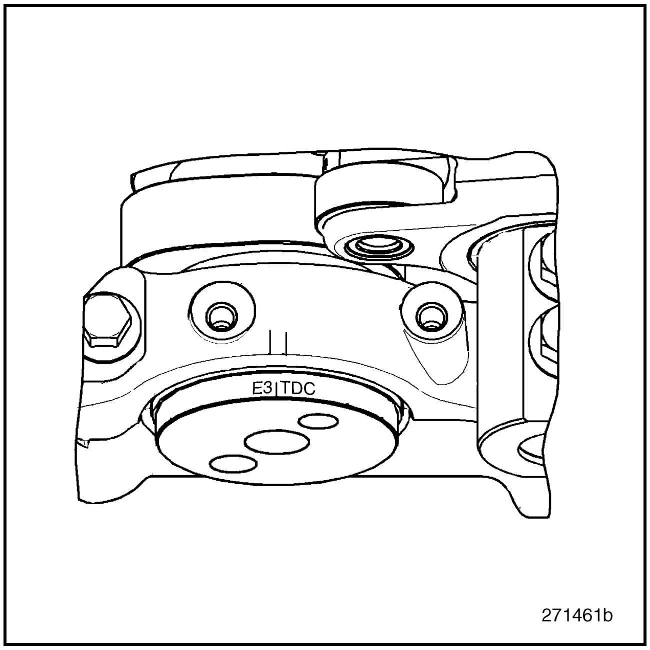


Figure 515 — Camshaft Positioning

7. Loosen and remove the eight screws securing the vibration damper and camshaft gear to the camshaft. Remove the damper from the camshaft, but do NOT remove the camshaft gear.
8. Install the gauge plate tool, J 44514-1A, using **Position B** of the gauge plate tool to secure the camshaft gear to the camshaft and loosely install the two retaining bolts.

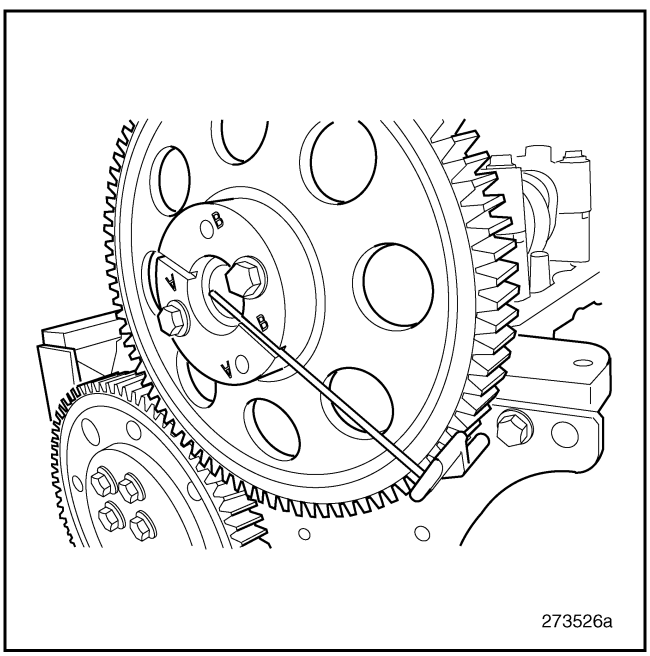


Figure 516 — Camshaft Gear Timing Mark Alignment

9. Insert the camshaft gear alignment tool, J 47450-1, into the hole in the timing gear plate while also engaging into the camshaft gear teeth and place the rod of the tool in the gauge plate slot. It may be necessary to rotate the camshaft slightly until this occurs. With the camshaft gear alignment tool properly positioned in the gauge plate slot, check that the camshaft TDC mark is still positioned between the two timing marks on the No. 1 camshaft bearing cap.
10. Remove the camshaft gear alignment tool, J 47450-1, from the camshaft gear.
11. Insert a 0.1 mm (0.004 inch) thickness gauge on the pressure side of the adjustable idler gear tooth and camshaft gear tooth by using feeler gauge holder J 44935 and J 44514-6 feeler gauge. Tighten the bolts on the adjustable idler gear by hand only.
12. Remove the feeler gauge from the gear teeth.
13. Install the J 44514-5 clamp assembly tool to the timing gear plate. Screw the hold-down against the adjustable idler gear so the adjustable idler gear does not rotate.

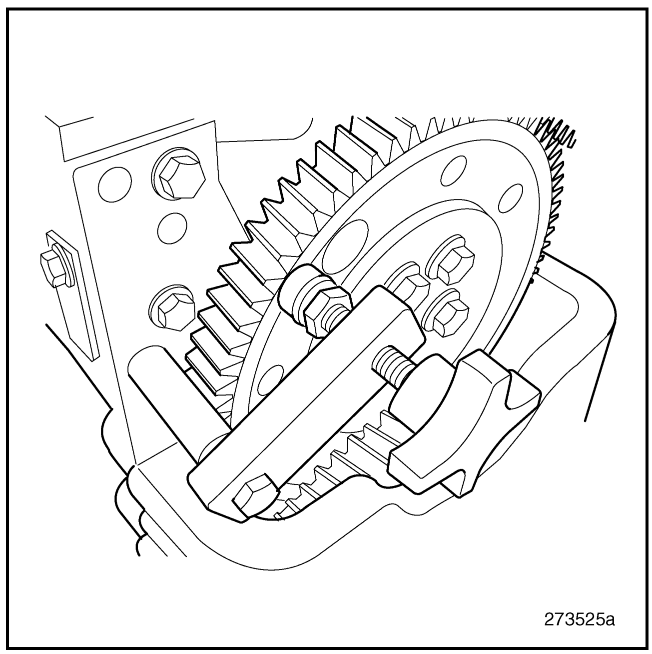


Figure 517 — Clamp Assembly Tool

14. Install the magnetic stand, 9999696, and dial indicator 9999683, so the tip of the dial indicator rests on a tooth of the camshaft gear. Check the gear backlash by rotating the camshaft gear back and forth slightly to measure the backlash. For backlash specification, refer to the SPECIFICATIONS section.

    Check that the camshaft is positioned at TDC by having the TDC marking on the camshaft aligned with the markings on the No. 1 camshaft bearing cap.

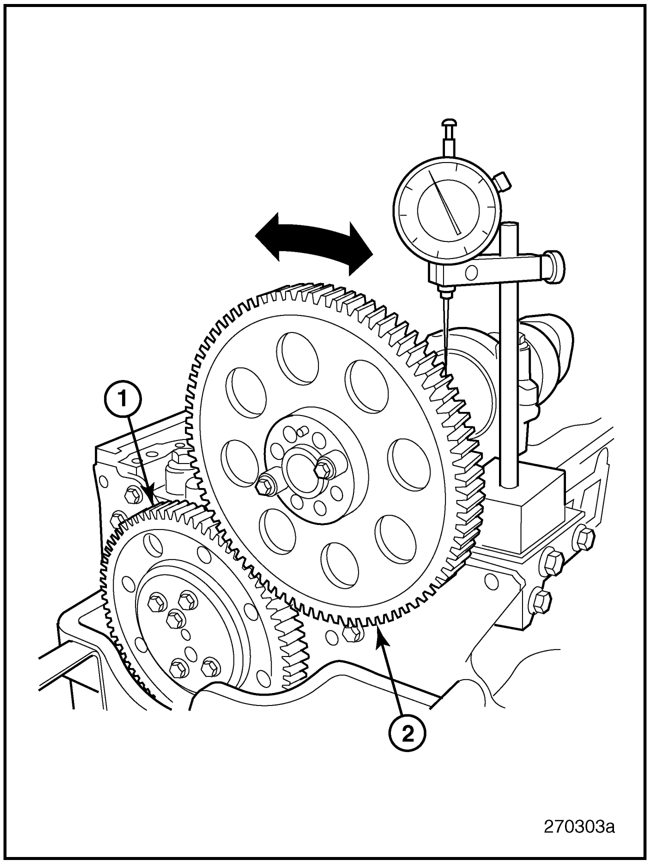


Figure 518 — Camshaft Gear Backlash Measurement

1. Idler Gear	2. Camshaft Gear

15. If the backlash measurement is out of specification, adjust the gear flank clearance as follows:
    a. Loosen the J 44514-5 clamp assembly tool from the adjustable idler gear hub.
    b. Loosen the adjustable idler gear hub screws slightly. Loosening the hub screws will allow the idler gear to be moved slightly in/out from the camshaft gear.
    c. Insert a 0.1 mm (0.004 inch) thickness gauge on the pressure side of the adjustable idler gear tooth and camshaft gear tooth by using feeler gauge holder J 44935 and J 44514-6 feeler gauge.
    d. While holding the adjustable idler gear in against the thickness gauge and camshaft gear, tighten, but do NOT torque, the adjustable idler gear hub fasteners.
    e. Reinstall and tighten the J 44514-5 clamp assembly tool against the adjustable idler gear.
    f. Remove the feeler gauge from the adjustable idler gear and camshaft gear.
    g. Recheck the backlash. With the specified backlash attained, replace each adjustable idler gear hub screw with **new** and tighten the screws to specification one at a time so the attained backlash is not disturbed.

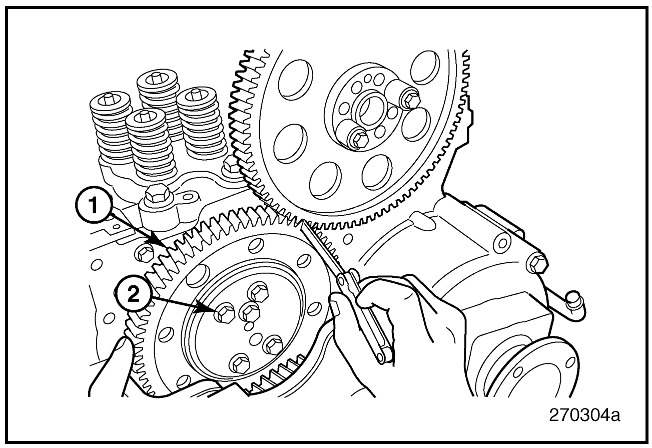


Figure 519 — Idler Gear Flank Clearance Adjustment

1. Idler Gear	2. Hub Screws

16. Remove the J 44514-5 clamp assembly tool from the timing gear plate.
17. Remove the J 44514-1A gauge plate tool and reinstall the vibration damper and clamp plate using **new** fasteners. Torque to specification.

18. Apply a 2 mm (5/64 inch) bead of 342SX33 MACK-approved sealant on the timing gear cover mounting surface and install **new** rubber seals (Figure 520).

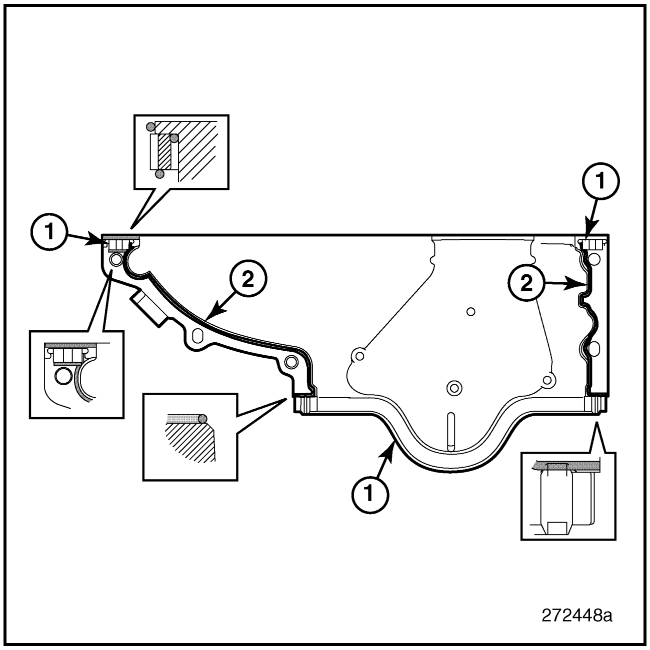


Figure 520 — Timing Cover Seals and Sealant Application

1. Rubber Seals	2. Sealant

19. Place the timing gear cover in position on the engine. Install two capscrews (item 1 in Figure 521) and hand tighten.

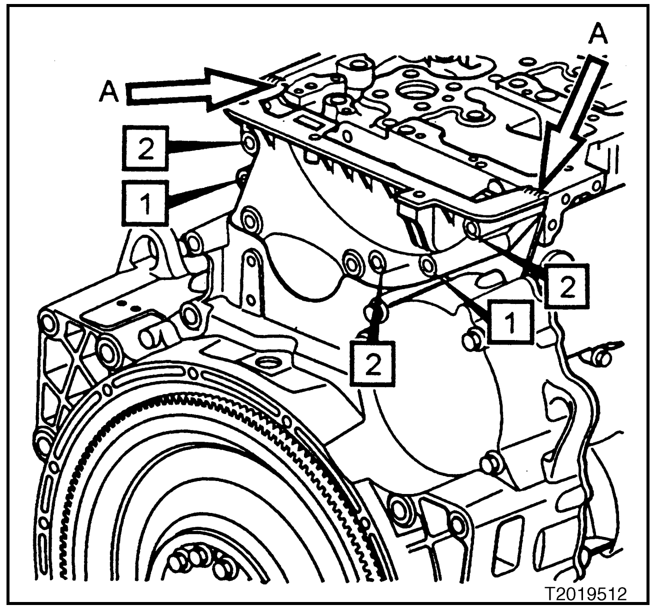


Figure 521 — Timing Gear Cover Installation

20. Using alignment tools, 85111422A and 85111422B, ensure that the upper and lower seals are properly seated and that the upper surface of the cover is flush with the top of the cylinder head (points A in Figure 521).
21. Install the three remaining capscrews (item 2 in Figure 521) and tighten to specification.
22. Reconnect the wiring harness lead at the camshaft sensor connector.
23. Apply an even 2 mm (5/64 inch) bead of 342SX33 MACK-approved sealant at the joint lines (point A) between the cylinder head and the timing cover as Figure 521 indicates.
24. Install the valve cover and the 16 retaining screws and springs. Tighten the screws according to specification.

ENGINE FINAL PREPARATION AND OPERATIONAL CHECK

After Engine Overhaul Procedures

Filter Element Installation

All filters and coolant conditioners must meet MACK specifications.

1. Install a **new** air filter in the air filter housing.
2. Using a torque wrench, tighten the attaching screw to specification.
3. Lubricate the gaskets.
4. Using a filter wrench, tighten the filters to specification.
5. Attach the filters to the valve housing.
6. Using a filter wrench, tighten the filters to specification.

Engine Lubrication System

An 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. Following is the recommended procedure for providing adequate lubrication.

CAUTION

Do not mix brands or types of lubricants. Chemical additives may be incompatible and may contribute to the formation of sludge, acid and hardening.

Failure to heed this caution may result in severe engine damage.

SERVICE HINT

Usually there are various points on the engine where a pressure line may be opened, but if no other is apparent, use the oil pressure sensor port.

PRIMING THE LUBRICATION SYSTEM

1. Fill the engine crankcase with the specified quantity of the specified engine oil.
2. Using a pressure prelubricator filled with the specified oil, prime the engine lubrication system for a minimum of five minutes.
3. Check the crankcase oil level.
4. If necessary, add oil to reach the FULL mark on the dipstick.

NOTE

Do NOT overfill.

Oil Pressure

Engine Speed/RPM	Temperature	Pressure
600	90–110°C (195–230°F)	>250 kPa (36 psi)
>1100	90–110°C (195–230°F)	300–550 kPa (44–80 psi)
>1100	Cold Engine	650 kPa (95 psi)

Rocker Shaft Engine Brake	Engine Speed/RPM	Oil Pressure
Inactive	—	80–120 kPa (12–17 psi)
Active	900–2300	220 kPa (32 psi)

Turbocharger

CAUTION

It is necessary to perform the system 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.

1. Remove and flush the turbocharger oil supply line with a suitable, clean, non-flammable solvent.

SERVICE HINT

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 heed this caution may result in severe component and engine damage.

2. Reinstall the oil supply line.
3. Prime the lubrication system following the procedure described earlier in this section.
4. Following engine overhaul, use the diagnostic computer to calibrate the variable geometry turbocharger.

Cooling System

1. Check the cooling system. Make sure all plugs and coolant drain quick disconnects are installed and are tight.
2. Make sure the thermostat is installed.
3. Install a **new** coolant filter.
4. Fill the system with the recommended coolant.

NOTE

Make sure that all air is purged from the cooling system.

Fuel System

DANGER

Before working on or inspecting a vehicle, set the parking brake, place the transmission in neutral and block the wheels. Failure to heed this warning can result in unexpected vehicle movement and cause severe personal injury or death.

DANGER

To avoid potential fire hazard, do not service any part of the fuel system while smoking or in the presence of flames, sparks or hot surfaces, or when working on an operating engine. Failure to heed this warning can result in fire which can produce severe personal injury or death.

DANGER

Wear adequate protective clothing (face shield, heavy gloves, apron, etc.) when working on a hot engine to guard against burns from direct contact with hot fuel. Failure to heed this warning can result in severe personal injury or death.

WARNING

Do not work near the fan with the engine running. The engine fan can become active at any time without warning. Failure to heed this warning can result in severe personal injury.

WARNING

Before turning the ignition on, make sure no one is near the fan. Failure to heed this warning can result in severe personal injury.

1. Check the fuel system to make sure that all connections are tight.
2. Start the engine and run it at idle for approximately 5 minutes to remove air trapped in the fuel system.

PRIMING THE FUEL SYSTEM

Using the hand priming pump is usually only necessary when the fuel system has air in it, or when replacing filters. If hand priming is needed, use the following procedure.

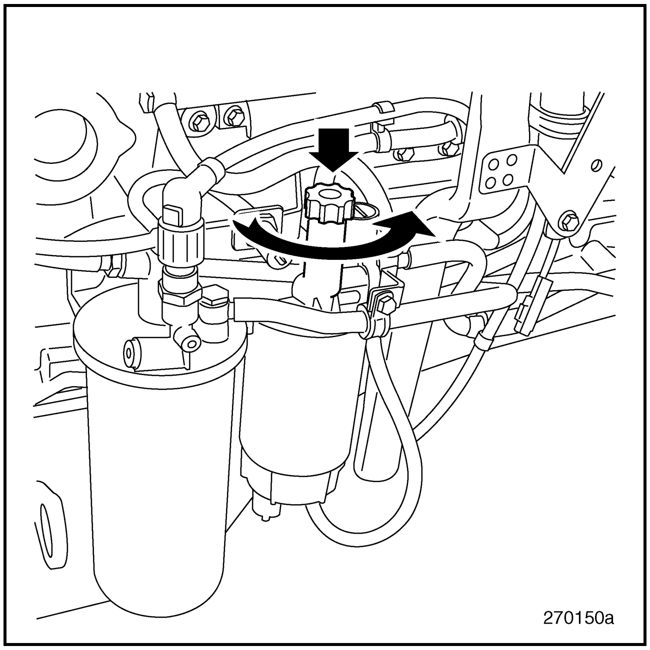


Figure 522 — Unlocking the Hand Primer Pump

1. Unlock the hand primer pump by pushing the handle in and turning it counterclockwise.
2. Pump the hand primer until the force of pumping increases.

NOTE

When the fuel system is completely empty, 200 or more strokes may be needed to prime the system properly.

NOTE

There are NO bleed nipples to be opened in order to prime the fuel system.

3. Lock the pump by pushing the handle into the housing, turning it clockwise and releasing it.
4. Start the engine and run it at an increased idle for approximately 5 minutes to remove air trapped in the fuel system.
5. Check the fuel system to make sure that all connections are tight.

NOTE

If the engine does not start following this procedure, contact your local MACK Truck dealer.

NOTE

Do not crank the engine continuously for more than 30 seconds without allowing the starter to cool for 2 minutes between cranks.

Some starters are equipped with starter protection. If the starter temperature is too high, starter engagement is inhibited to prevent starter damage. Wait until the starter has cooled to crank the engine.

CAUTION

The only acceptable method of priming the fuel system is the hand primer pump. Applying air pressure to the fuel tank or using an auxiliary pump to prime the fuel system is PROHIBITED. These priming techniques may cause fuel to leak past the supply pump seal into the crankcase. Failure to heed this caution may result in severe engine damage.

WARNING

After running for 5 minutes, the engine, all its components and fluids will be hot. Contact with hot components and fluids can cause severe burns. Failure to heed this warning can result in severe personal injury.

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.

NOTE

The following step is important to proper break-in for all new parts at initial startup of the engine.

4. Start the engine and immediately increase the speed to 1200–1600 rpm. During the break-in period, check for leaks and monitor gauges for satisfactory oil pressure, etc.
5. Operate the engine within the 1200–1600 rpm range for 15 minutes.

NOTE

DO NOT allow the engine to drop to idle speed until the 15 minute break-in period at 1200–1600 rpm has been completed.

6. Shut down the engine.
7. Check the fluid levels and fill to capacity before restarting the engine.
8. Refer to *Rebuilt Engine Run-In Procedures* for inspections to be sure of proper engine operation before releasing the vehicle for service.

REBUILT ENGINE RUN-IN PROCEDURES

General

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 liners 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 prepare the engine properly 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 operating procedures.

The operator must be observant throughout the entire run-in procedure in order to detect any problems.

Constantly monitor the instrument display of engine functions and support systems and record all readings.

If the engine develops any of the following abnormal characteristics during run-in, shut it down immediately.

Discover and correct problems 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 116°C (240°F)
- A significant rise in oil temperature that exceeds 116°C (240°F)
- An exhaust temperature that exceeds maximum acceptable limits for the engine involved, as measured by a pyrometer (if applicable)
- Any oil, coolant, fuel or air inlet system leaks

SPECIFICATIONS

MP8 ENGINE MECHANICAL SPECIFICATIONS (MP8 Euro 4 Engine)

Material and Dimensional Data

GENERAL DATA, WEIGHTS AND DIMENSIONS

Item	Specification
Engine Type	In-line, direct injection, diesel
Number of Cylinders	6
Displacement	13 L
Bore and Stroke	131 x 158 mm (5.16 x 6.22 in.)
Compression Ratio	16:1
Emissions Level	Euro 4
Fuel System	Electronic Unit Injector
Valve Actuation	Single Overhead Cam, 4 valves per cylinder
Aspiration	Variable Geometry Turbocharger with sliding nozzle ring
Power Cylinder	Wet sleeve; one-piece steel pistons
Electronic Controls	Electronic Management System (EMS)
Emission Control	Cooled EGR
Peak Power Ratings	265–368 kW (360–500 hp)
Peak Torque Ratings	1800–2400 N•m (1000–1500 lb-ft)
Weight, Dry	1200 kg (2646 lb.)
Firing Order	1–5–3–6–2–4
Length Overall	1366 mm (53.8 in.)
Width Overall	971 mm (38.2 in.)
Height Overall	1170 mm (46.1 in.)

COMPONENT FEATURES AND MATERIALS

Item	Description
Air Compressor	Flange mounted, oil lubricated, water cooled
Camshaft	Induction hardened, gear driven
Connecting Rods	Forged steel, cracked cap design
Coolant Conditioner	Spin-on type, disposable
Coolant Pump	Centrifugal rotor impeller, belt-driven
Crankshaft	Drop forged steel, induction hardened, seven main bearings
Cylinder Block	In-line six cylinder; wet, replaceable cylinder liners; cast iron, machined with bearing caps, stiffener plate added at bottom, timing gear plate added at rear
Cylinder Head	One-piece cast iron alloy; supports overhead camshaft, four valve system, unit injectors; replaceable cast iron valve guides with oil seals; replaceable steel valve seats; copper unit injector sleeves; integral fuel passages; integral thermostat housing

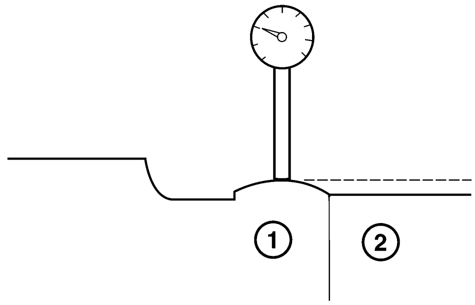
Item	Description
Cylinder Head (Valve) Cover	Plastic, 20 spring tension attaching screws
Cylinder Head — Valve Springs	Double springs on exhaust valves, single on inlet
Cylinder Head — Valve Guides	Cast iron, replaceable; with oil seals
Cylinder Head Gasket	One-piece steel stamping; elastomer seals added; one-time bosses to aid head installation
Cylinder Head Bolts	M16 (38)
Cylinder Liner	Wet; replaceable; with EDPM rubber and Viton seals
Fasteners and Threads	Metric
Flywheel Housing	Die-cast aluminum
Fuel Filters	Two: primary and pre-filter with water separator
Fuel Injection	Individually programmed unit injectors (6): Delphi; EMS module controlled; common fuel gallery in head; constant supply pressure; over-pressure return
Fuel Supply Pump	Gear type pump integral with power steering pump; crankshaft idler gear driven
Lubrication System	Crankshaft gear driven lubrication pump; system integrated within block and head; serves camshaft, rocker arm shaft, pistons, crankshaft, air compressor; three filters, 1 centrifugal and 2 full-flow; lubricant level and temperature sensor in oil pan; distribution housing attaches to bottom of block, holds pump, strainer and pump safety valve
Main Bearing Caps	Nodular iron; machined with block; No. 7 mounts lubrication pump; 1–3, 5 and 6 numbered for consistent reassembly; cast and drilled for consistent reassembly; thrust washers at No. 4 main bearing journal
Manifold — Exhaust	Three-piece, six port
Pistons	Steel; one-piece; 3 ring grooves
Piston Rings — Compression	2: 1 trapezoidal cross section, 1 rectangular cross section
Piston Ring — Oil	1 garter spring type; scraping
Oil Filters	2 full flow; 1 bypass Filter capacity, 2 full flow: • 4.0–4.5 L (4.2–4.8 qts.)
Oil Pan	Plastic or steel; 22 spring-tension screws Sump capacity: • 25 L (26.4 qts.) minimum • 30 L (31.7 qts.) maximum
Thermostat	Piston-type; 82°C (180°F)
Thermostat Housing	Integrated in head
Timing Gear Cover	Die-cast aluminum, elastomer seals
Variable Geometry Turbocharger (VGT)	Holset; exhaust-driven; fixed vanes; sliding ring nozzle; infinitely variable volume; oil- and water-cooled
Valve Rocker Arms	Roller followers
Valve Seat Inserts	Pressed in head, replaceable
Vibration Damper	Internal fluid-filled ring
Coolant Pump	Centrifugal rotor 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	**Metric**	**English**
CAMSHAFT		
Camshaft Journal Diameter	69.97–70.00 mm	2.7547–2.7559 in.
Inlet Valve Lobe Nominal Lift	13.1 mm	0.516 in.
Exhaust Valve Lobe Nominal Lift (with Engine Brake)	12.5 mm	0.492 in.
Cam to Roller Clearance — Exhaust Valve (with Engine Brake)	3.60 mm	0.142 in.
Camshaft End Play	0.24 mm max.	0.0094 in. max.
CONNECTING ROD		
Connecting Rod Journal to Bearing Clearance	0.100 mm max.	0.004 in. max.
Side Clearance	0.35 mm max.	0.014 in. max.
Length between Centers	267.45–267.55 mm	10.5295–10.5334 in.
Twist (within 100 mm [3.937 in.])	0.15 mm max.	0.0059 in. max.
Bend (within 100 mm [3.937 in.])	0.06 mm max.	0.0024 in. max.
CRANKSHAFT		
End Play (lubricated parts)	0.4 mm	0.0157 in.
Crankpin Journal OD (Inspection only: not for machining)	99 mm	3.898 in.
Main Journal OD (Inspection only: not for machining)	107.978–108.000 mm	4.2511–4.2520 in.
Journal Out-of-Round (maximum)	0.006 mm	0.0002 in.
Journal Taper (maximum)	0.02 mm	0.0008 in.
Max. Runout at No. 4 Journal (shaft supported on No. 1 and No. 7)	0.15 mm	0.0059 in.
Main Journal to Bearing Clearance (Lubricated parts)	0.05–0.12 mm max.	0.0019–0.0047 in. max.
CYLINDER BLOCK		
Counterbore Depth	11.0 +0.03/–0.0 mm	0.43 +0.001/–0.0 in.
Deck Flatness	0.06 mm max.	0.002 in.
Main Bearing Bore in Block	113 mm	4.449 in.
Cylinder Sleeve (Flange Thickness)	11.2 +0.0/–0.02 mm	0.44 +0.0/–0.0008 in.
Cylinder Liner Flange Bead to Block Deck (Top of Bead to Block Deck)	0.15–0.20 mm	0.0059–0.0079 in.

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**Metric**	**English**



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1. Cylinder Liner	2. Cylinder Block

CYLINDER HEAD

CAUTION

*Do **NOT** machine the cylinder head. This will change the extension of the injector and upset injector timing as well as the ability to correctly adjust timing gear backlash.*

*Do **NOT** grind copper injector sleeves.*

Component	Metric	English
Overall Height	135 mm	5.315 in.
Valve Guide Height Above Cylinder Head Spring Face — Inlet	24.3–24.7 mm	0.957–0.972 in.
Valve Guide Height Above Cylinder Head Spring Face — Exhaust	24.3–24.7 mm	0.957–0.972 in.
Valve Seat Insert Counterbore Diameter (Inlet)	45 mm	1.771 in.
Valve Seat Insert Counterbore Diameter (Exhaust)	43 mm	1.693 in.
Valve Seat Insert Diameter (Inlet, Press Fit in Head)	45.070–45.086 mm	1.774–1.775 in.
Valve Seat Insert Diameter (Exhaust, Press Fit in Head)	43.070–43.086 mm	1.695–1.696 in.
Valve Seat Height (Inlet)	7.55–7.75 mm	0.2972–0.3051 in.
Valve Seat Height (Exhaust)	7.5–7.7 mm	0.2953–0.3031 in.
Valve Seat Counterbore Depth (Inlet)	11.67–11.93 mm	0.4594–0.4697 in.
Valve Seat Counterbore Depth (Exhaust)	11.07–11.33 mm	0.4358–0.4461 in.
INJECTORS		
Preload (for Rocker arm Adjustment)	240° (4 flats on the hex head)	
PISTON		
Top Extension Above Cylinder Block Deck at TDC	0.15–0.65 mm	0.0059–0.0256 in.
Wrist Pin Diameter	57.994–58.000 mm	2.2834–2.2835 in.
Wrist Pin Bore Diameter	58.076–58.104 mm	2.2865–2.2875 in.

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**Metric**	**English**
PISTON RINGS		
Compression Ring End Gap — Upper	0.40–0.55 mm	0.0157–0.0217 in.
Compression Ring End Gap — Upper: Wear Tolerance	0.9 mm max.	0.0354 in. max.
Compression Ring End Gap — Lower	1.3–1.5 mm	0.0512–0.0591 in.
Compression Ring End Gap — Lower: Wear Tolerance	1.3 mm max.	0.0512 in. max.
Oil Control Ring End Gap	0.30–0.55 mm	0.0118–0.0217 in.
Oil Control Ring End Gap — Wear Tolerance	1.0 mm max.	0.0394 in.
Compression Ring Clearance — Lower Groove	0.09–0.14 mm	0.0035–0.0055 in.
Oil Ring Clearance — Oil Ring Groove	0.05–0.10 mm	0.002–0.0039 in.
OIL PUMP		
Crankshaft Gear to Oil Pump Gear Backlash	0.1–0.4 mm	0.004–0.016 in.
TIMING GEARS		
Adjustable Idler Gear to Camshaft Gear Backlash	0.05–0.17 mm	0.0020–0.0067 in.
TURBOCHARGER		
Shaft End Play	0.15 mm	0.0059 in.
VALVES		
Head Diameter (Inlet Valve)	41.9–42.1 mm	1.650–1.657 in.
Head Diameter (Exhaust Valve)	39.9–40.1 mm	1.571–1.579 in.
Inlet Clearance (cold engine)	0.2 mm	0.008 in.
Exhaust Clearance — without engine brake (cold engine)	0.8 mm	0.031 in.
Exhaust Clearance — with engine brake (cold engine): Valve rocker-to-yoke Brake rocker-to-cam	 1.0 mm 3.6 mm	 0.039 in. 0.142 in.
Valve Face to Cylinder Head Deck (Inlet)	1.0 mm min. 1.7 mm max.	0.039 in. min. 0.067 in. max.
Valve Face to Cylinder Head Deck (Exhaust)	1.35 mm min. 2.1 mm max.	0.053 in. min. 0.083 in. max.
Valve Stem OD (Inlet)	7.960–7.975 mm	0.3134–0.3140 in.
Valve Stem OD (Exhaust)	7.947–7.962 mm	0.3129–0.3135 in.
Note: Replacing valve seats requires replacing valves.		
VALVE SEAT ANGLE		
Inlet Valve Head	24.3–24.7°	
Exhaust Valve Head	39.3–39.7°	
Inlet Valve Seat	24.8–25.2°	
Exhaust Valve Seat	39.8–40.2°	

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**Metric**	**English**
VALVE SPRINGS		
Outer Spring:		
Free Length (approximate)	73.8 mm	2.91 in.
Length under 590 N (133 lb.) load	58.4 mm	2.30 in.
Length under 1150 N (259 lb.) load	45.3 mm	1.78 in.
Length when solid	39.5 mm	1.56 in.
Inner Spring:		
Free Length (approximate)	70.5 mm	2.78 in.
Length under 243 N (55 lb.) load	54.4 mm	2.14 in.
Length under 447 N (100 lb.) load	41.3 mm	1.63 in.
Length when solid	36.5 mm	1.44 in.

Engine Component Torque Specifications (Critical Fasteners)

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, washers, under head of screw and 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.

Fasteners noted by an asterisk (*) require retorque after engine run-in.

FASTENER REUSE

CAUTION

Repeated tightening of fasteners and threaded components reduces their capacity to function adequately. The following table describes the various items and the limits of their reusability. Failure to conform to these limits may result in severe component damage.

Fasteners	Examples	Reusable Limit	Reuse Recommendations
Highly loaded screws (Phosphating plus oil)	Cylinder head Cylinder block Injector yoke Camshaft bearing housing Transmission (except adjustable idler gear) Flywheel	5 times	Apply engine oil on threads and under screw head. Mark bolt head with an indentation. Dry mounting for new screws (delivered with oil pre-applied and anti-rust treatment for spare parts). If a part is replaced, e.g., cylinder head, also replace the screws.
	Connecting rods	5 times	Apply clean engine oil.
	Adjustable idler gear	Do not reuse	
Special screws (specific shape)	Oil pan and valve cover	No limit	No limit if no cracks, corrosion or damage to the flat surfaces.
Flange head screws	EGR valve	Do not reuse	
Flange head screws	Exhaust manifold	5 times	If exhaust manifold is replaced, also replace the screws.
Stainless steel bolts and spacers	Turbocharger	5 times	If turbocharger or the exhaust manifold is replaced, also replace the bolts and spacers and apply anti-seize.
Prevailing torque feature screws (Dri-Loc Plastic or Tuflock)	Piston cooling jets Timing gear plate	Do not reuse	
Standard screws	Property class 8.8 Property class 10.9 Property class 12.9	No limit	No limit if no cracks, corrosion or damage to the flat surfaces.
V-nipples with taper thread	With locking fluid pre-applied	Do not reuse	Before fitting the new nipple, clean the hole with a nipple tap and apply sealant on the nipple thread, or use a new, coated nipple.
Taper plugs or nipples	With sealer fluid pre-applied	Do not reuse	Before fitting the new nipple, clean the hole with a nipple tap and apply sealant on the nipple thread, or use a new, coated nipple.

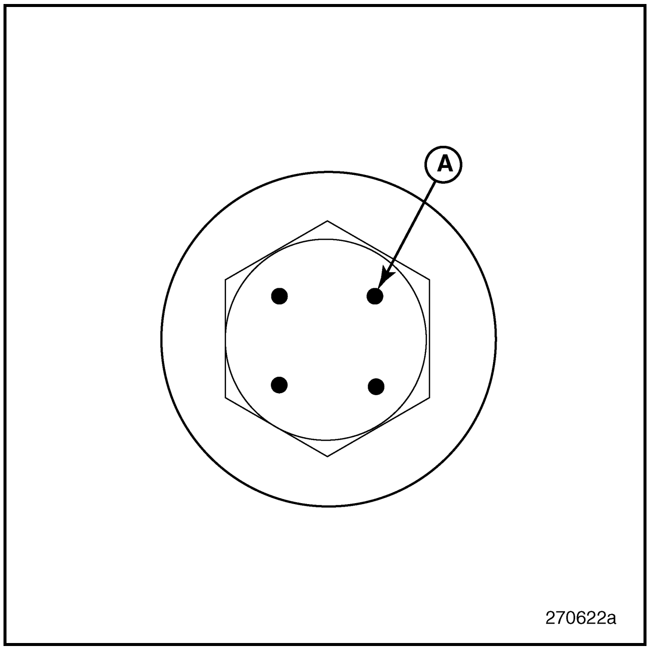


Figure 523 — Usage Marks on Head of Fastener

Bolts and screws that have limited reusability specified in the table above must be marked with a punch **(A)** each time they are installed in service. Bolts and screws with four punch marks when removed have been tightened five times and must be discarded.

CAUTION

Do not reuse timing gear mounting plate bolts.

Do not reuse timing gear mounting bolts.

SENSORS AND WIRING HARNESS

CAUTION

Overtorquing a sensor or sensor mounting screw can result in sensor breakage or thread damage.

Sensors	
Camshaft Position (timing gear cover)	8 ±2 N•m (6 ±1 lb-ft)
Charge Air Pressure (mixing chamber)	10 ±1 N•m (89 ±9 lb-in)
Charge Air Temperature (inlet manifold)	10 ±1 N•m (89 ±9 lb-in)
Coolant Level (surge tank)	Plug-in
Coolant Temperature (front, right side cylinder head)	22 ±3 N•m (16 ±2 lb-ft)
Crankcase Pressure (block, front of air compressor)	25 ±3 N•m (18.5 ±2 lb-ft)
EGR Differential Pressure (EGR venturi)	20 ±3 N•m (15 ±2 lb-ft)
EGR Temperature (EGR venturi)	45 ±4.5 N•m (33 ±3 lb-ft)
Flywheel Position/Speed (top of flywheel housing)	8 ±2 N•m (6 ±1 lb-ft)
Fuel Pressure (fuel filter housing)	25 ±3 N•m (18.5 ±2 lb-ft)
Humidity (fresh air pipe)	27 ±3 N•m (20 ±2 lb-ft)
Oil Level/Temperature (inside sump)	10 ±1 N•m (89 ±9 lb-in)
Oil Pressure (block, front of air compressor)	30 ±5 N•m (22 ±4 lb-ft)
Turbocharger Speed (top middle of turbocharger)	8.5 ±2 N•m (75 ±18 lb-in)
Wiring Harness	
Attaching Screws	24 ±4 N•m (18 ±3 lb-ft)

MP8 ENGINE COMPONENTS — TOP OF ENGINE

Cylinder Head (Valve) Cover

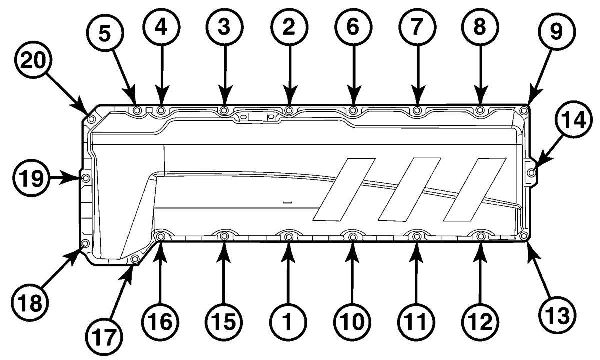


Figure 524 — Cylinder Head Cover Torque Sequence

Install two alignment pins and bushings in the head before assembling the cylinder head cover.	
Tighten screws in the order indicated	24 ±4 N•m (18 ±3 lb-ft)

Camshaft Bearing Caps and Rocker Arm Shaft Assembly

The rocker arm shaft assembly is installed on top of the camshaft bearing caps (inboard side) using the long screws, numbers 8 through 21. The rocker arm shaft and camshaft bearing cap retaining screws are tightened to specification as listed below in the table.

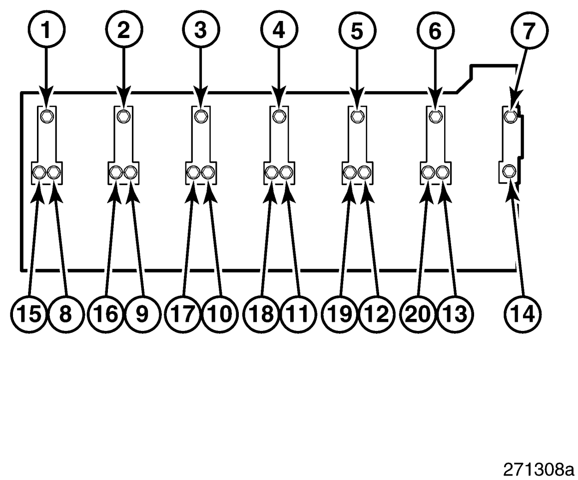


Figure 525 — Camshaft Cap Torque Sequence Screw Numbers

Preliminary steps: • Discard screws with four punch marks when removed and replace with **new** screws. • If not already loose, loosen screws 1–7 before proceeding with the tightening sequence.	
Step 1. Screws 1–7	25 ±3 N•m (18 ±2 lb-ft)
Step 2. Screws 8–14	60 ±5 N•m (44 ±4 lb-ft)
In step 2, tighten the screws progressively beginning with screw No. 11.	
In steps 3–7, tighten the screws progressively from the center to the outer ends.	
Step 3. Screws 1–7, angle tighten	90 ±5°
Step 4. Screws 15–20	25 ±3 N•m (18 ±2 lb-ft)
Step 5. Screws 15–20, angle tighten	120 ±5°
Step 6. Screws 8–13	Loosen completely
Step 7. Screws 8–13	25 ±3 N•m (18 ±2 lb-ft)
Step 8. Screws 8–14, angle tighten	120 ±5°

Cylinder Head

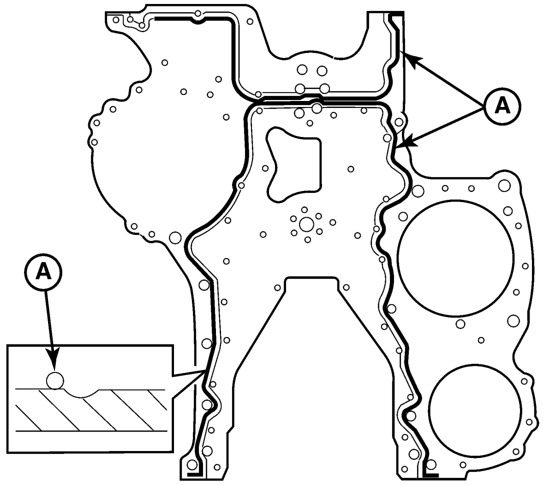


Figure 526 — Sealant Application Pattern — Head to Plate

Remove all old sealant before attempting to apply new sealant. Apply a 2 mm (5/64 inch) bead of 342SX33 MACK-approved sealant to the timing gear plate following the pattern shown. Attach the cylinder head to the timing gear plate within 20 minutes of applying the sealant.

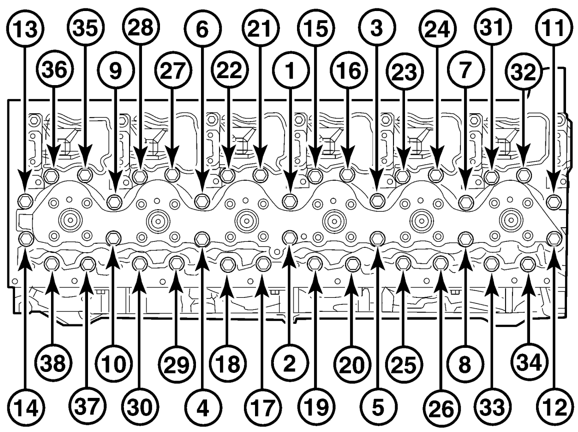


Figure 527 — Torque Sequence Screw Numbers — Head to Block

Discard screws with four marks when removed and substitute new screws. Tighten the screws in the order indicated by the numbers in the graphic.	
Step 1.	100 ±5 N•m (74 ±4 lb-ft)
Step 2. Verify	100 ±5 N•m (74 ±4 lb-ft)
Step 3. Angle tighten	120° ±5°
Step 4. Angle tighten	90° ±5°

Additional Top of Engine Components

Cylinder Head Plugs	
Plug, M10 x 1.00	25 ±3 N•m (18 ±2 lb-ft)
Plug, M10 x 1.00, coated	10 ±2 N•m (7.5 ±1.5 lb-ft)
Plug, M14 x 1.50, coated	30 ±3 N•m (22 ±2 lb-ft)
Plug, M16 x 1.50	50 ±3 N•m (37 ±2 lb-ft)
Cylinder Head Connectors	
Right side, coated	10 N•m (7.5 lb-ft)
Rocker Arm Components	
Locknut, Valve Adjustment (Inlet and Exhaust without Engine Brake)	38 ±4 N•m (28 ±3 lb-ft)
Locknut, Valve Adjustment (Exhaust with Engine Brake)	52 ±4 N•m (38 ±3 lb-ft)
Locknuts, Injector Adjustment	52 ±4 N•m (38 ±3 lb-ft)
Retainer Screw, Shim (Exhaust Yoke)	38 ±4 N•m (28 ±3 lb-ft)
Engine Brake	
Attaching Screws, Solenoid Valve See *Engine Brake Valve* under **Rocker Arm Components**.	24 ±4 N•m (18 ±3 lb-ft)
Engine Brake Plate Spring	25 ±3 N•m (18 ±2 lb-ft)
Injector Retainers	
Step 1.	20 +5/–0 N•m (15 +4/–0 lb-ft)
Step 2. Angle tighten	180° ±5°
Step 3. Loosen the screws until torque is 10–15 N•m (7–11 lb-ft).	
Step 4.	20 +5/–0 N•m (15 +4/–0 lb-ft)
Step 5. Angle tighten	90° ±5°

MP8 ENGINE COMPONENTS — FRONT OF ENGINE

Crankshaft Damper

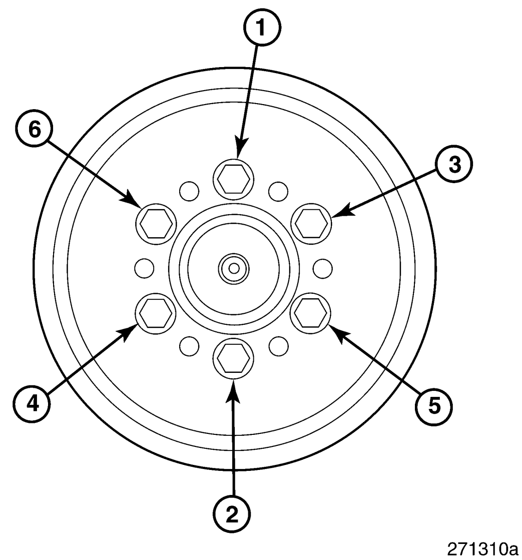


Figure 528 — Torque Sequence Screw Numbers — Damper to Crankshaft

Do **NOT** reuse screws. Use **new** screws in service and tighten in the order indicated.	
Step 1.	35 ±5 N•m (26 ±4 lb-ft)
Step 2.	90 ±10 N•m (66 ±7 lb-ft)

Crankshaft Front Seal Cover

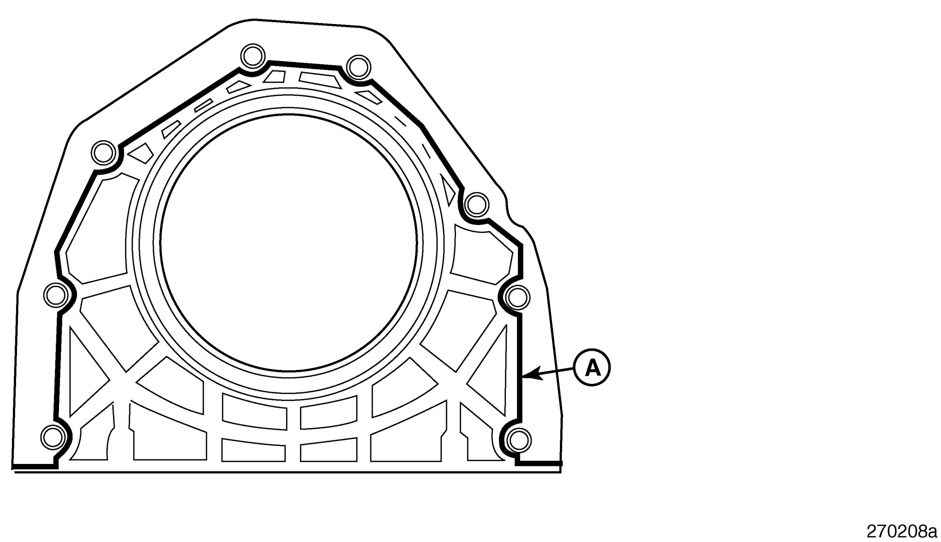


Figure 529 — Sealant Application Pattern — Cover to Block

Remove all old sealant before attempting to apply new sealant. Apply a 2 mm (5/64 inch) bead of 342SX33 MACK-approved sealant to the seal cover following the pattern (A) shown. Attach the front seal cover to the cylinder block within 20 minutes of applying the sealant.

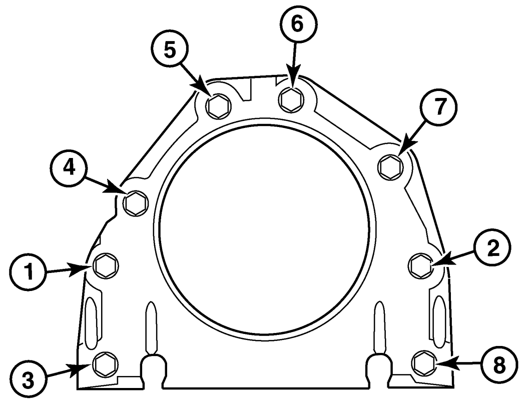


Figure 530 — Torque Sequence Screw Numbers — Cover to Block

Tighten screws in the order indicated according to the following torque specifications.	
Step 1. Secure cover with screws 1 and 2	Hand tighten
Step 2. Screws 1–8	24 ±4 N•m (18 ±3 lb-ft)

Front Engine Support

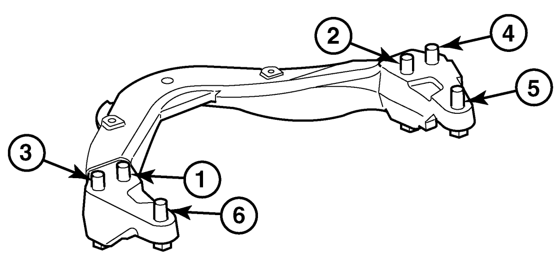


Figure 531 — Torque Sequence Screw Numbers — Support to Brackets

Step 1. Tighten in order: 1, 2, 3, 4, 5 and 6	275 ±45 N•m (203 ±33 lb-ft)
Step 2. Verify in the same order	275 ±45 N•m (203 ±33 lb-ft)

Engine Support Mounting Brackets

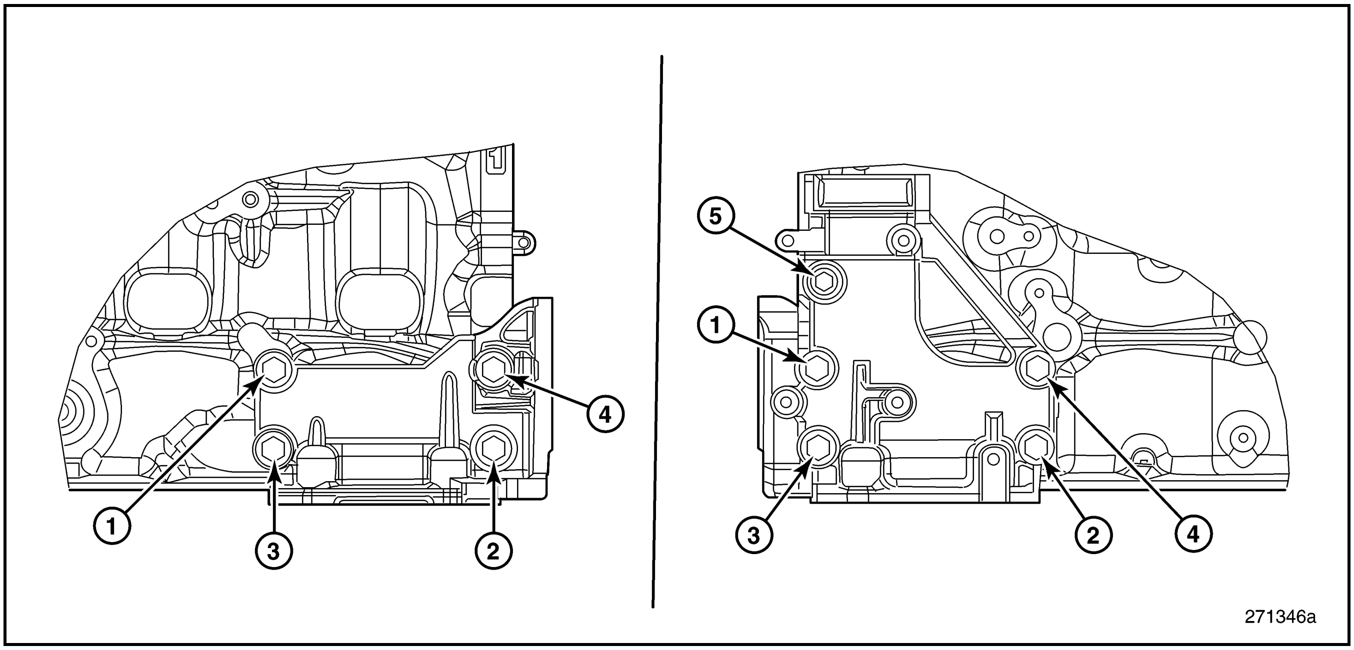


Figure 532 — Engine Support Brackets to Block

Sequence	Torque	Angle Tighten
Step 1. Screw No. 1	80 ±15 N•m (59 ±11 lb-ft)	—
Step 2. Screws No. 2, 3 and 4	105 ±15 N•m (77 ±11 lb-ft)	60 ±5°
Step 3. Screw No. 1	105 ±15 N•m (77 ±11 lb-ft)	60 ±5°
Step 4. Screw No. 5	Standard screw torque	—

Additional Front of Engine Components

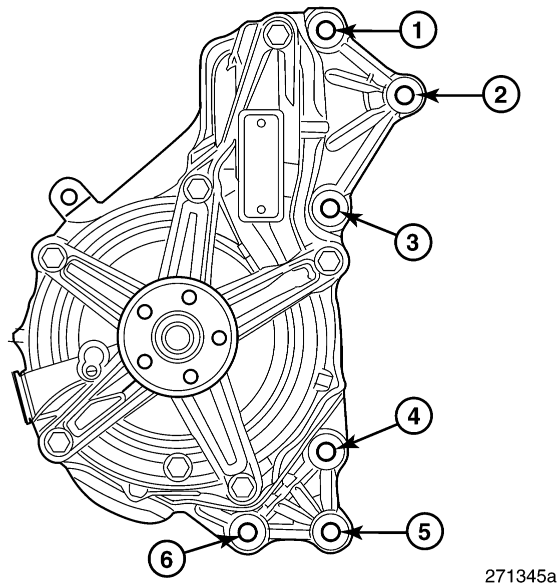


Figure 533 — Coolant Pump

Coolant Pump	
Step 1. Tighten all 6 screws in the following sequence: 2, 5, 6, 4, 3, 1.	48 ±8 N•m (35 ±6 lb-ft)
Step 2. Retighten screws 2 and 5.	48 ±8 N•m (35 ±6 lb-ft)
Fan Drive	
Attaching Nuts, Drive to Hub Mounting Bracket: — For Low-Mounted Fan Position — For High-Mounted Fan Position (with Grade 10.8 studs, 45 mm long and 16 mm nut hex)	 24 ±4 N•m (18 ±3 lb-ft) 70 N•m (52 lb-ft)
Attaching Nuts, Hub Mounting Bracket to Cylinder Head and Block	48 ±8 N•m (35 ±6 lb-ft)

MP8 ENGINE COMPONENTS — REAR OF ENGINE

Timing Gear Plate

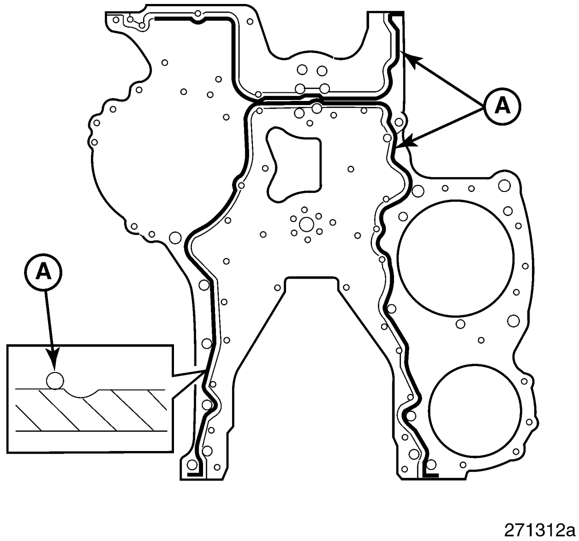


Figure 534 — Sealant Application Patterns — Head and Block to Plate

Remove all old sealant before attempting to apply new sealant.
Apply a 2 mm (5/64 inch) bead of 342SX33 MACK-approved sealant to the timing gear plate next to the groove following the patterns shown.
Attach the timing gear plate to the cylinder head and block within 20 minutes of applying the sealant.

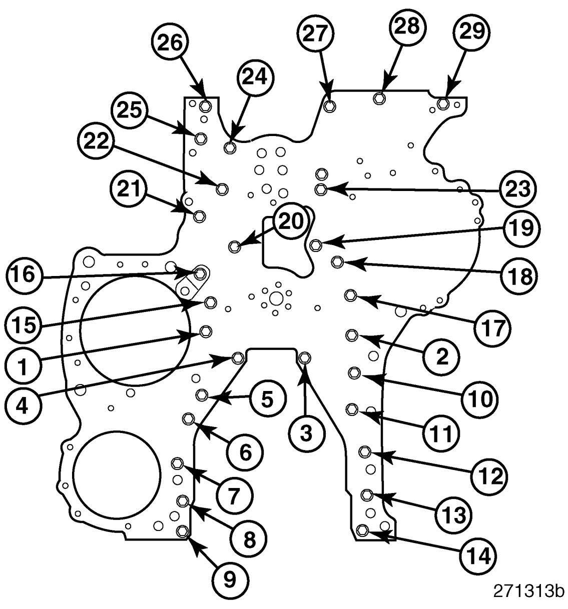


Figure 535 — Torque Sequence Screw Numbers — Plate to Block

Do not reuse mounting plate screws.	
Do NOT apply sealant to new, coated screws.	
Tighten screws in the order indicated.	28 ±4 N•m (21 ±3 lb-ft)

Timing Gears

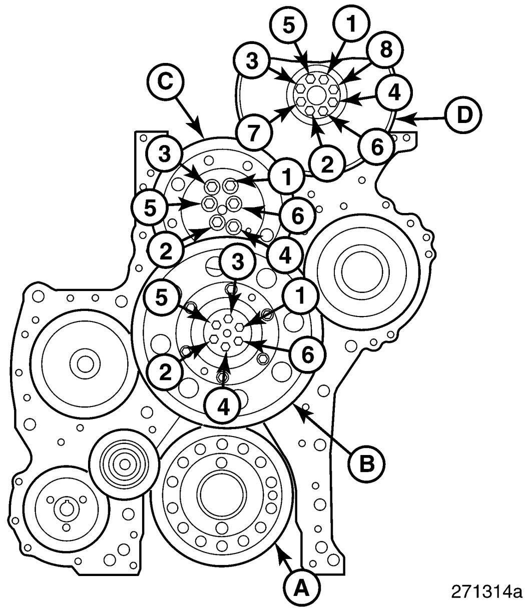


Figure 536 — Torque Sequence Screw Numbers — Gear Mounting

Component	Torque	Plus Angle Tighten
Loosen any screws used to pull the cylinder head into position before beginning this sequence. Tighten screws in the order indicated on each gear.		
(A) Crankshaft Gear (2 screws)	24 ±4 N•m (18 ±3 lb-ft)	
(B) Intermediate Gear Hub (6 screws)	25 ±3 N•m (18 ±2 lb-ft)	110° ±5°
(C) Intermediate Adjustable Gear Hub (5 screws)	35 ±4 N•m (26 ±3 lb-ft)	120° ±5°
(D) Camshaft Gear and Damper (6 screws)	45 ±5 N•m (33 ±4 lb-ft)	90° ±5°

Timing Gear Cover

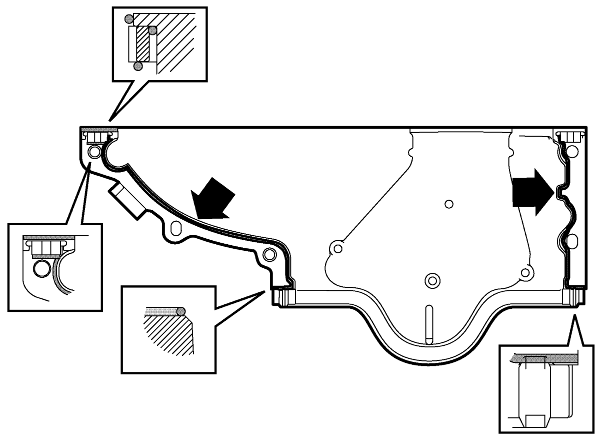


Figure 537 — Sealant Application Pattern — Cover to Plate

Remove all old sealant before attempting to apply new sealant. Apply a 2 mm (5/64 inch) bead of 342SX33 MACK-approved sealant to the timing gear cover following the pattern shown. Attach the timing gear cover to the timing gear plate within 20 minutes of applying the sealant.

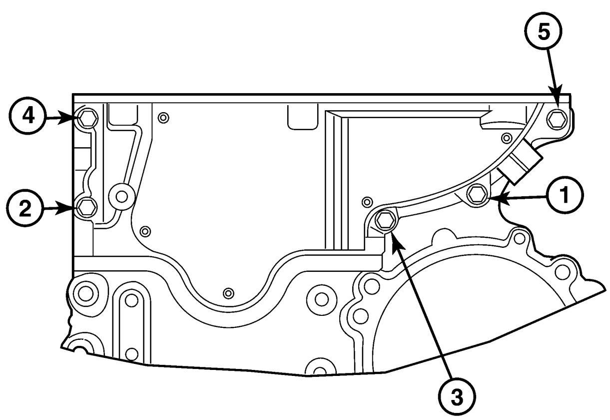


Figure 538 — Torque Sequence Screw Numbers — Cover to Plate

Step 1. Align cover to cylinder head so that sealing surfaces are flush (using alignment tools) and install screws 1 and 2. Hand tighten screws 1 and 2 to hold alignment.	
Step 2. Tighten screws in the order indicated.	24 ±4 N•m (18 ±3 lb-ft)

Flywheel

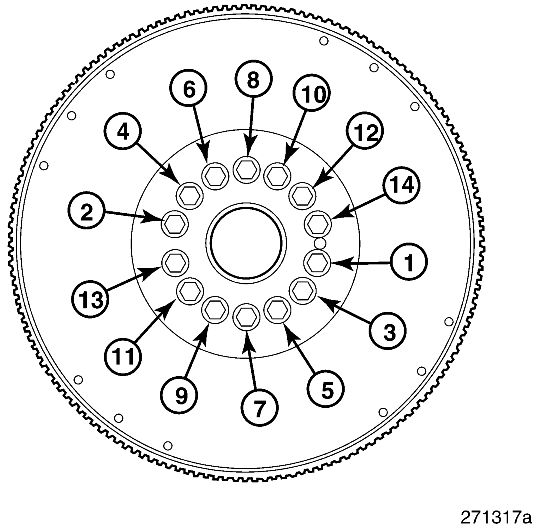


Figure 539 — Torque Sequence Numbers — Flywheel to Crankshaft

Mark the head of each screw after installation. Discard screws with four marks when removed and substitute **new**screws. Lubricate the threads and under the heads of screws to be reused. Do NOT lubricate new screws that are coated.	
Step 1. Tighten screws in the order indicated.	60 ±5 N•m (44 ±4 lb-ft)
Step 2. In the order indicated: angle tighten.	120° ±10°

Flywheel Housing

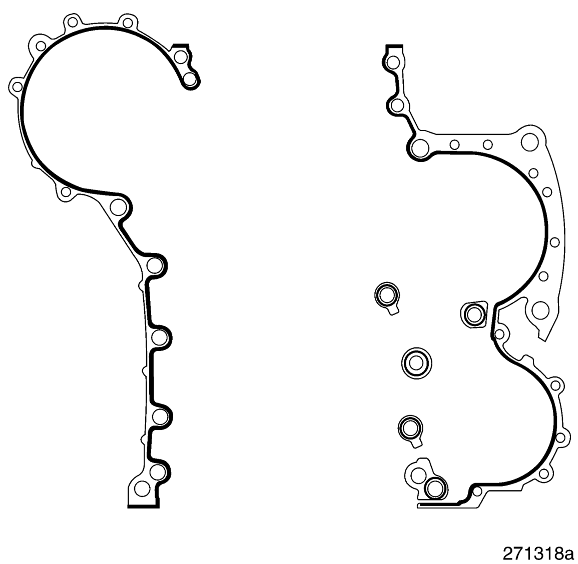


Figure 540 — Sealant Application Pattern — Flywheel Housing to Plate

Remove all old sealant before attempting to apply new sealant. Apply a 2 mm (5/64 inch) bead of 342SX33 MACK-approved sealant to the flywheel housing following the pattern shown. Attach the flywheel housing to the timing gear plate within 20 minutes of applying the sealant.

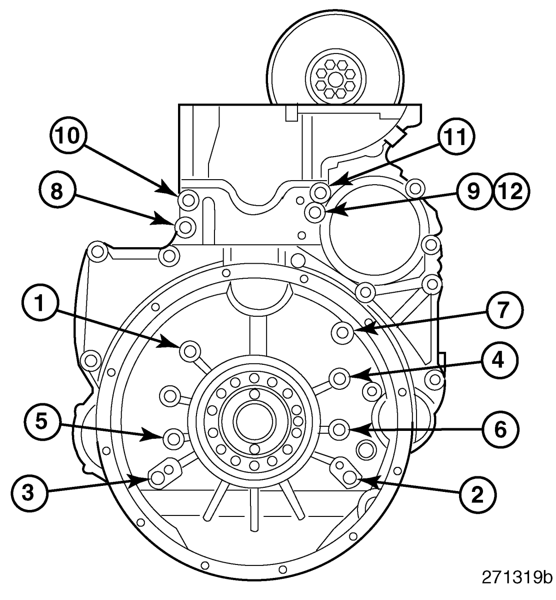


Figure 541 — Torque Sequence — M14 and M10 Screws (Housing to Plate and Block)

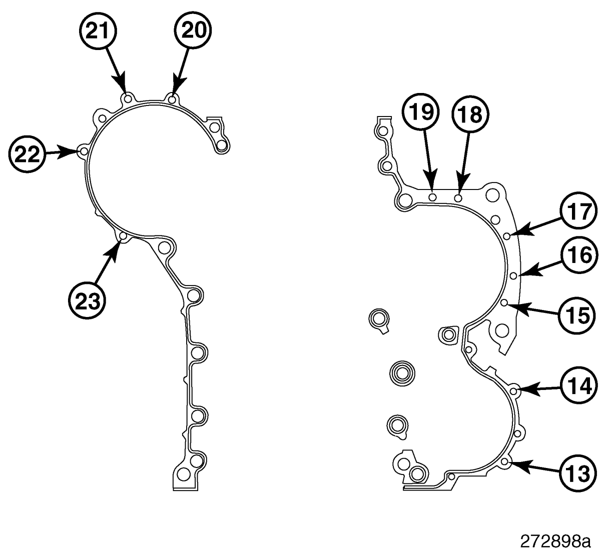


Figure 542 — Torque Sequence — M8 Screws (Plate to Housing)

Tighten the screws in the order indicated according to the following torque values.	
Step 1. M14, M10 and M8 screws	24 ±4 N•m (18 ±3 lb-ft)
Step 2. M14 screws, 1–8	140 ±20 N•m (103 ±15 lb-ft)
Step 3. M10 screws, 9–12	48 ±8 N•m (35 ±6 lb-ft)
Step 4. M8 screws, 13–23 (front of timing gear plate-to-flywheel housing)	24 ±4 N•m (18 ±3 lb-ft)

Additional Rear of Engine Components

Attaching Screws, Rear Engine Support Bracket-to-Flywheel Housing	300 ±45 N•m (221 ±33 lb-ft)

MP8 ENGINE COMPONENTS — BOTTOM OF ENGINE

Oil Pan

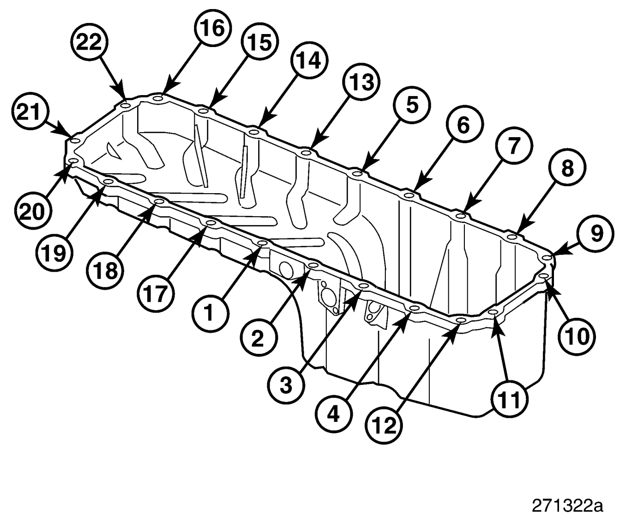


Figure 543 — Torque Sequence Screw Numbers — Oil Pan to Block

Tighten screws in the order indicated	24 ±4 N•m (18 ±3 lb-ft)

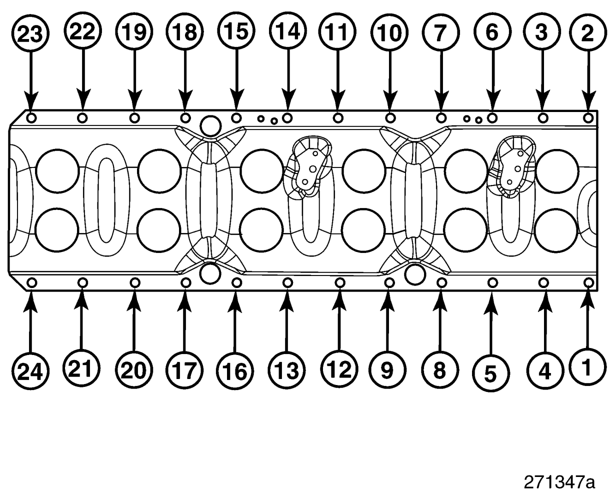


Figure 544 — Torque Sequence — Block Stiffener Plate to Block

Do NOT reuse stiffener plate attaching screws. Always use **new** screws in service. Tighten the screws in the order indicated according to the following torque specifications.	
Step 1. All screws	45 ±5 N•m (33 ±4 lb-ft)
Step 2. Angle tighten	60 ±5°

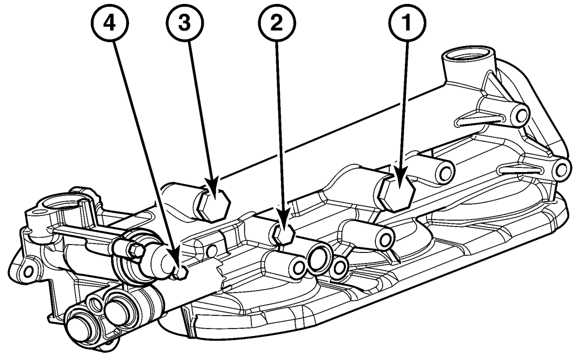


Figure 545 — Oil Filter Housing

Oil Filter Housing Screws	24 ±4 N•m (18 ±3 lb-ft)
Oil Filter	25 +5/–0 N•m (18 +3.5/–0 lb-ft)
1. Plug	55 ±5 N•m (40 ±4 lb-ft)
2. Plug	12 ±2 N•m (9 ±1.5 lb-ft)
3. Plug	55 ±5 N•m (40 ±4 lb-ft)
4. M6 Screws	10 ±2 N•m (7 ±1.5 lb-ft)

Additional Bottom of Engine Components

Crankshaft Bearing Caps	
Discard screws with four marks when removed and substitute new screws.	
Attaching Screws Step 1.	150 ±20 N•m (111 ±15 lb-ft)
Step 2. Angle tighten	120° ±5°
Connecting Rod Bearing Caps	
Discard screws with four marks when removed and substitute new screws. Tighten screws in a cross pattern.	
Attaching Screws Step 1.	20 ±3 N•m (15 ±2 lb-ft)
Step 2.	60 ±3 N•m (44 ±2 lb-ft)
Step 3. Angle tighten	90 ±5°
Oil Pan Drain Plug	60 ±10 N•m (44 ±7 lb-ft)
Oil Pump Attaching Screws	24 ±4 N•m (18 ±3 lb-ft)
Nozzle Attaching Screws, Piston Cooling Do not reuse.	24 ±4 N•m (18 ±3 lb-ft)

MP8 ENGINE COMPONENTS — RIGHT SIDE

EGR System Components

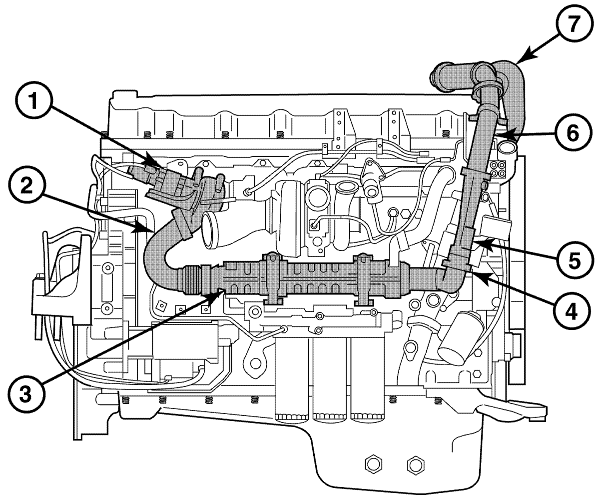


Figure 546 — EGR System Components

1. EGR Valve 2. EGR Hot Pipe 3. EGR Cooler 4. Venturi	5. Differential Pressure Sensor 6. EGR Cooler Outlet Pipe 7. EGR Mixer

Cross Tighten (4) EGR Valve Mounting Screws — Step 1. — Step 2.	 20 ±4 N•m (15 ±3 lb-ft) 61 ±3 N•m (45 ±2 lb-ft)
EGR Cooler Retaining Strap T-bolts and Locknuts	12 ±2 N•m (9 ±1.5 lb-ft)
EGR Hot Pipe (Cooler Inlet) V-band Clamps	20 ±4 N•m (15 ±3 lb-ft)
EGR Cooler Drain Valve Fitting	15 ±3 N•m (11 ±2 lb-ft)
EGR Cooler Drain Valve Closing Torque	3 ±0.5 N•m (27 ±4 **lb-in**)
EGR Venturi Tube Attaching Screws (to Bracket)	24 ±4 N•m (18 ±3 lb-ft)
EGR Cold Pipe V-band Clamps	10 ±2 N•m (7 ±1 lb-ft)
Coupling Hose Clamps	7 ±1 N•m (62 ±9 **lb-in**)

Exhaust Manifold

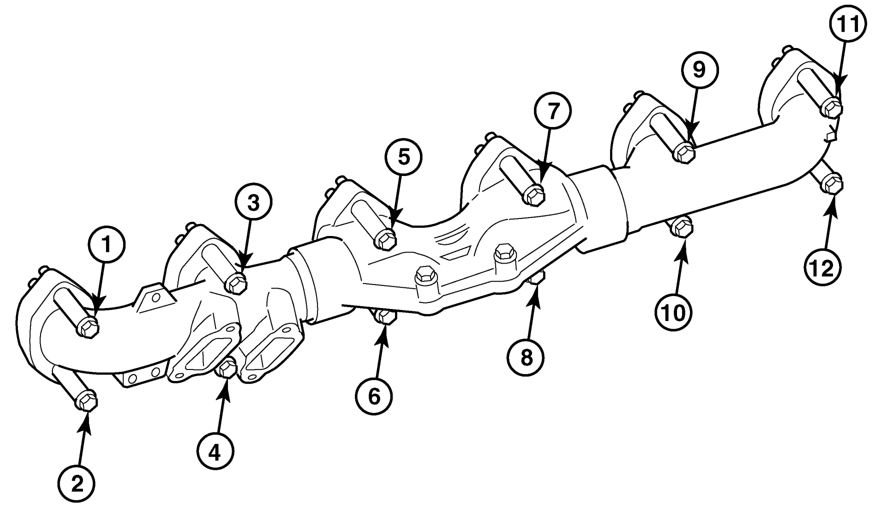


Figure 547 — Torque Sequence Numbers — Manifold to Cylinder Head

Use anti-seize compound on contact surfaces of nuts, bolts and screws when reassembling exhaust system components.	
Step 1. All screws	5 ±1.5 N•m (3.5 ±1 lb-ft)
Step 2. Screws 1, 4, 5, 8, 9 and 12	10 ±1.5 N•m (7.5 ±1 lb-ft)
Step 3. Screws 3, 2, 7, 6, 11, 10, 1, 4, 5, 8, 9 and 12	48 ±8 N•m (35 ±6 lb-ft)

Oil Cooler Cooling Duct Cover

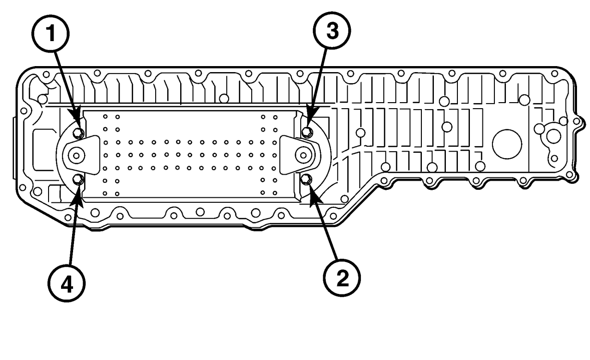


Figure 548 — Oil Cooler to Cooling Duct Cover

Step 1. Screws 1, 2, 3 and 4	5 ±1 N•m (44 ±9 **lb-in**)
Step 2. Screws 1, 2, 3, 4 and 1	27 ±4 N•m (20 ±3 lb-ft)

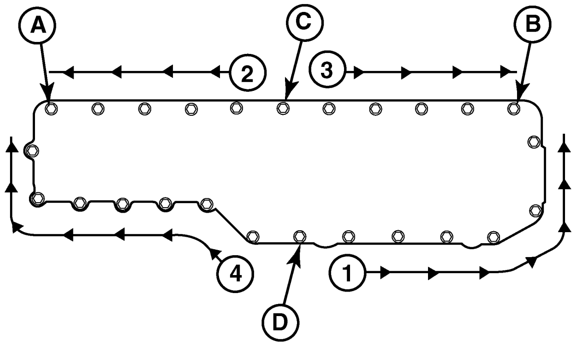


Figure 549 — Torque Sequence Numbers — Cooling Duct Cover to Block

Place the cover in position on the cylinder block and loosely install screw **A**.

Press the cover against the coolant pump housing using the assembly tool 88800022 and loosely install screw **B**.

Check that the duct cover is properly positioned and install the screws following the step sequence listed below.

Step 1. Screws C and D	24 ±4 N•m (18 ±3 lb-ft)
Step 2. Starting at the center and moving outward — all screws in sequence 1, followed by sequences 2 (including A), 3 (including B) and 4.	24 ±4 N•m (18 ±3 lb-ft)
Step 3. Verify screws C and D.	24 ±4 N•m (18 ±3 lb-ft)

EGR Cooler Mounting Brackets

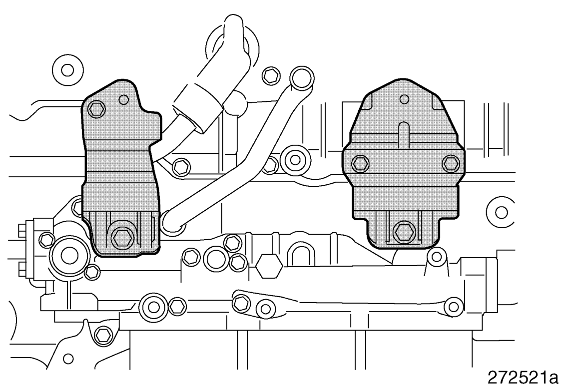


Figure 550 — EGR Cooler Mounting Brackets

Step 1. Upper Screws	24 ±4 N•m (18 ±3 lb-ft)
Step 2. Lower Screws	24 ±4 N•m (18 ±3 lb-ft)

Turbocharger and SRA

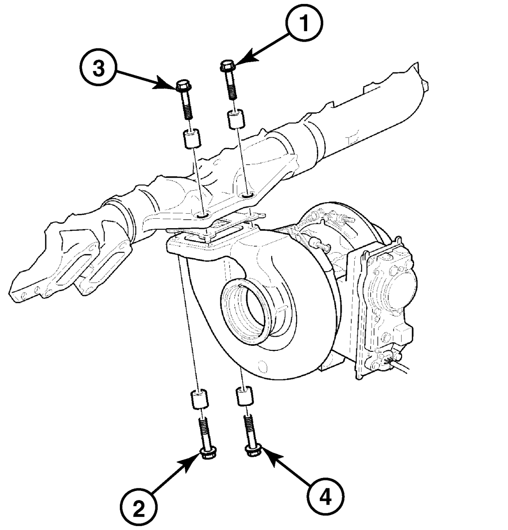


Figure 551 — Torque Sequence — Turbocharger Mounting Fasteners

Fasteners, Turbocharger to Exhaust Manifold (use anti-seize compound at reassembly)	
Step 1.	20 ±4 N•m (15 ±3 lb-ft)
Step 2.	48 ±8 N•m (35 ±6 lb-ft)

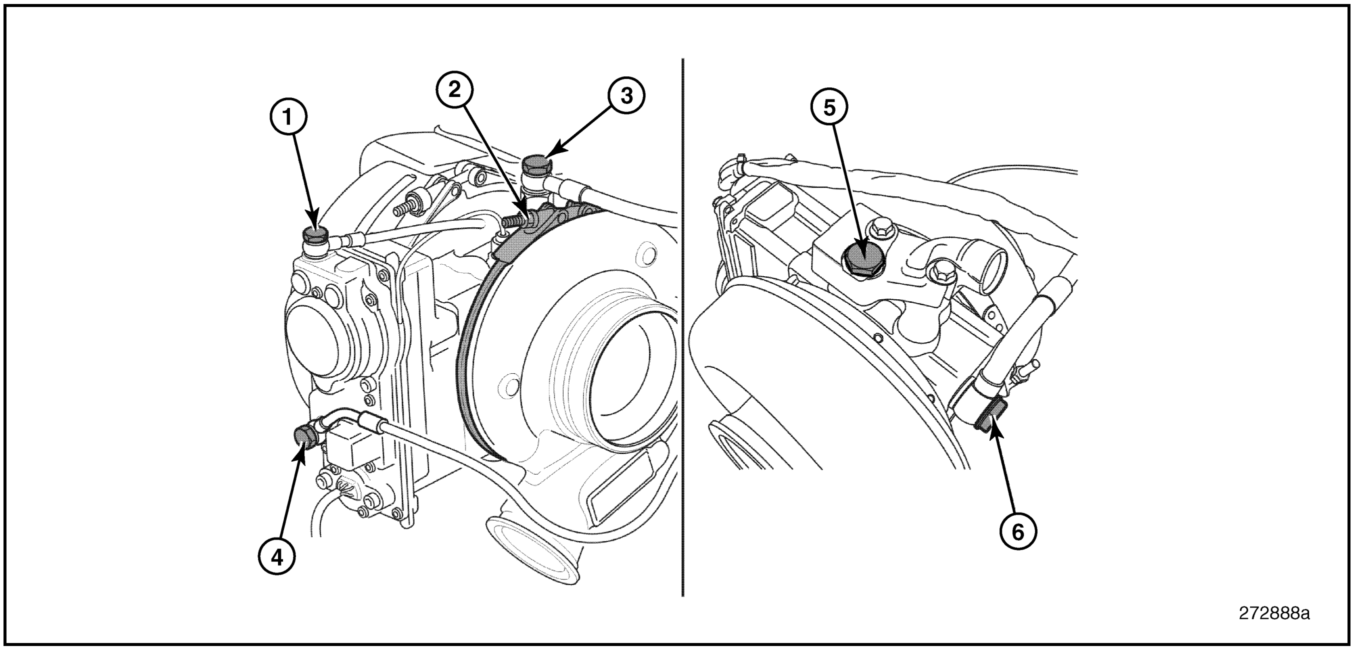


Figure 552 — Turbocharger and SRA Fittings

No. 1	12 ±3 N•m (9 ±2 lb-ft)
No. 2	8.5 ±0.8 N•m (6 ±0.6 lb-ft)
No. 3	48 ±5 N•m (35 ±4 lb-ft)
No. 4	12 ±3 N•m (9 ±2 lb-ft)
No. 5	38 ±6 N•m (28 ±4 lb-ft)
No. 6	48 ±5 N•m (35 ±4 lb-ft)

Oil Pressure Safety Valve

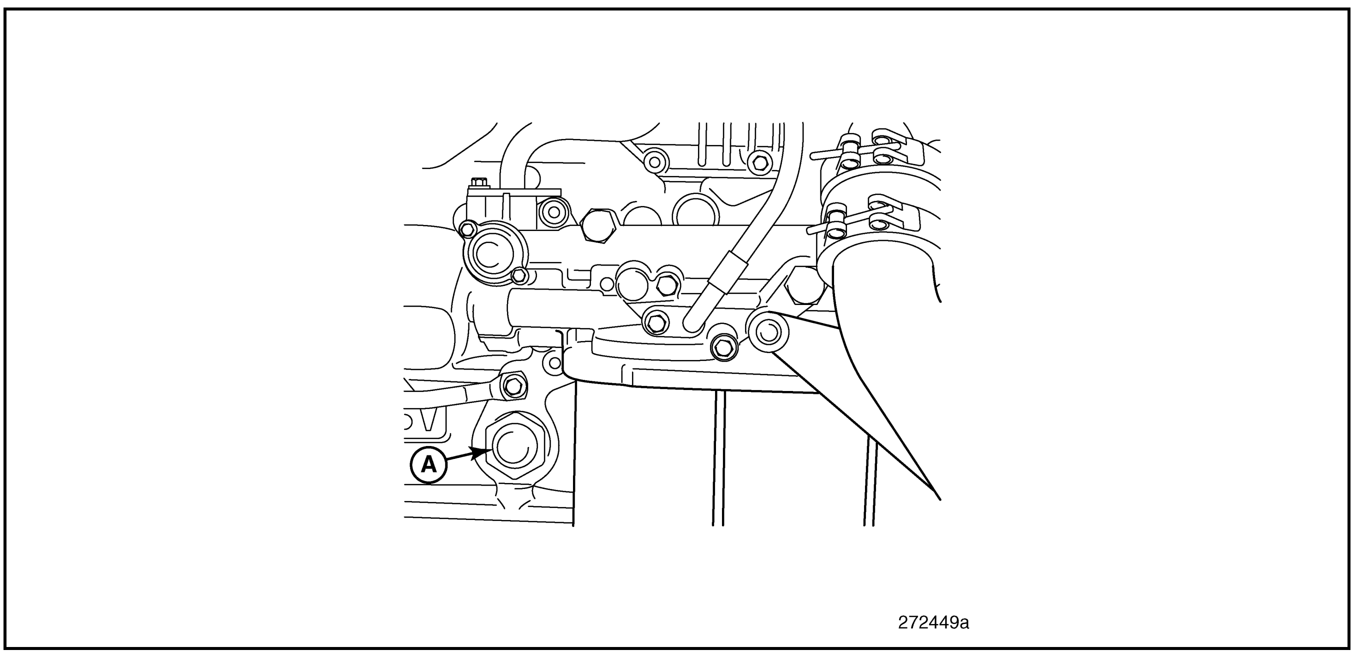


Figure 553 — Oil Pressure Safety Valve

Screws **A**	50 ±5 N•m (37 ±3 lb-ft)

Starter

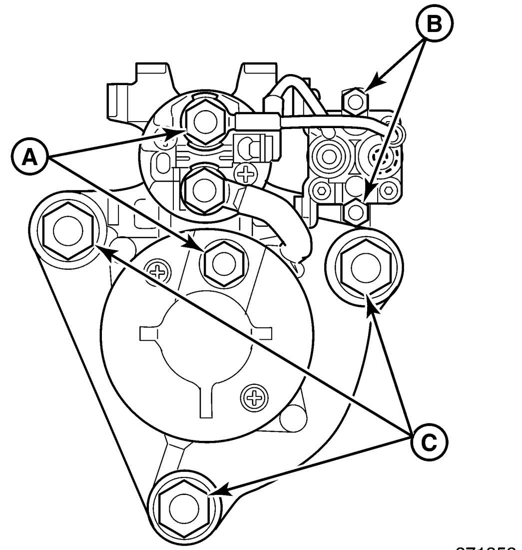


Figure 554 — Starter Attaching Studs

Attaching Studs	24 ±4 N•m (18 ±3 lb-ft)
Screws **A**	18 ±2 N•m (13 ±1.5 lb-ft)
Screws **B**	3 ±0.5 N•m (27 ±4.4 **lb-in**)
Screws **C**	60 ±6 N•m (44 ±4 lb-ft)

Additional Right-Side Engine Components

Oil Filter	
Bracket Attaching Screws	24 ±4 N•m (18 ±3 lb-ft)
Oil Cooler Cooling Duct Cover	
Plug, Oil Cooler Cooling Duct Cover	55 ±8 N•m (40 ±6 lb-ft)
Water Drain Connector	40 ±4 N•m (30 ±3 lb-ft)
Fitting, 90° Elbow	30 ±5 N•m (22 ±4 lb-ft)

MP8 ENGINE COMPONENTS — LEFT SIDE

Inlet Manifold

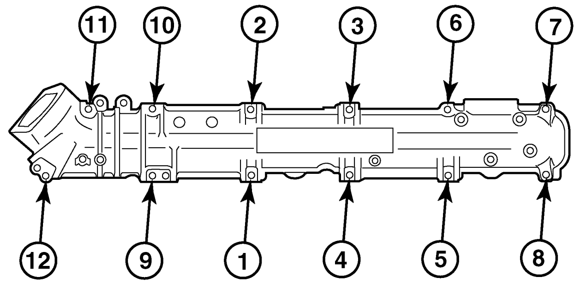


Figure 555 — Torque Sequence — Manifold to Cylinder Head

Tighten screws in the order indicated.	24 ±4 N•m (18 ±3 lb-ft)

EGR Mixer and Inlet Air Heater/Spacer

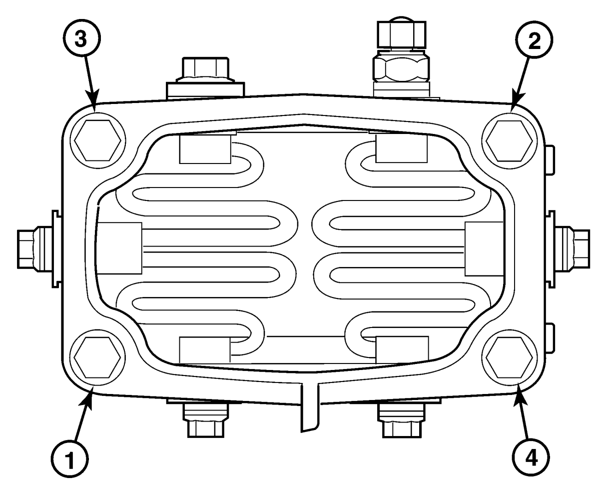


Figure 556 — Torque Sequence — EGR Mixer and Inlet Air Heater/Spacer Mounting

EGR Mixer, Inlet Air Heater/Spacer-to-Inlet Manifold Attaching Screws	Step 1. 10 ±2 N•m (7 ±1.5 lb-ft) Step 2. 24 ±3 N•m (18 ±2 lb-ft)
Inlet Pipe-to-EGR Mixer Attaching Screws	24 ±4 N•m (18 ±3 lb-ft)
V-band Clamp, Crossover-to-Mixer Inlet Pipe	10 ±2 N•m (7 ±1 lb-ft)

Low Pressure Fuel Circuit

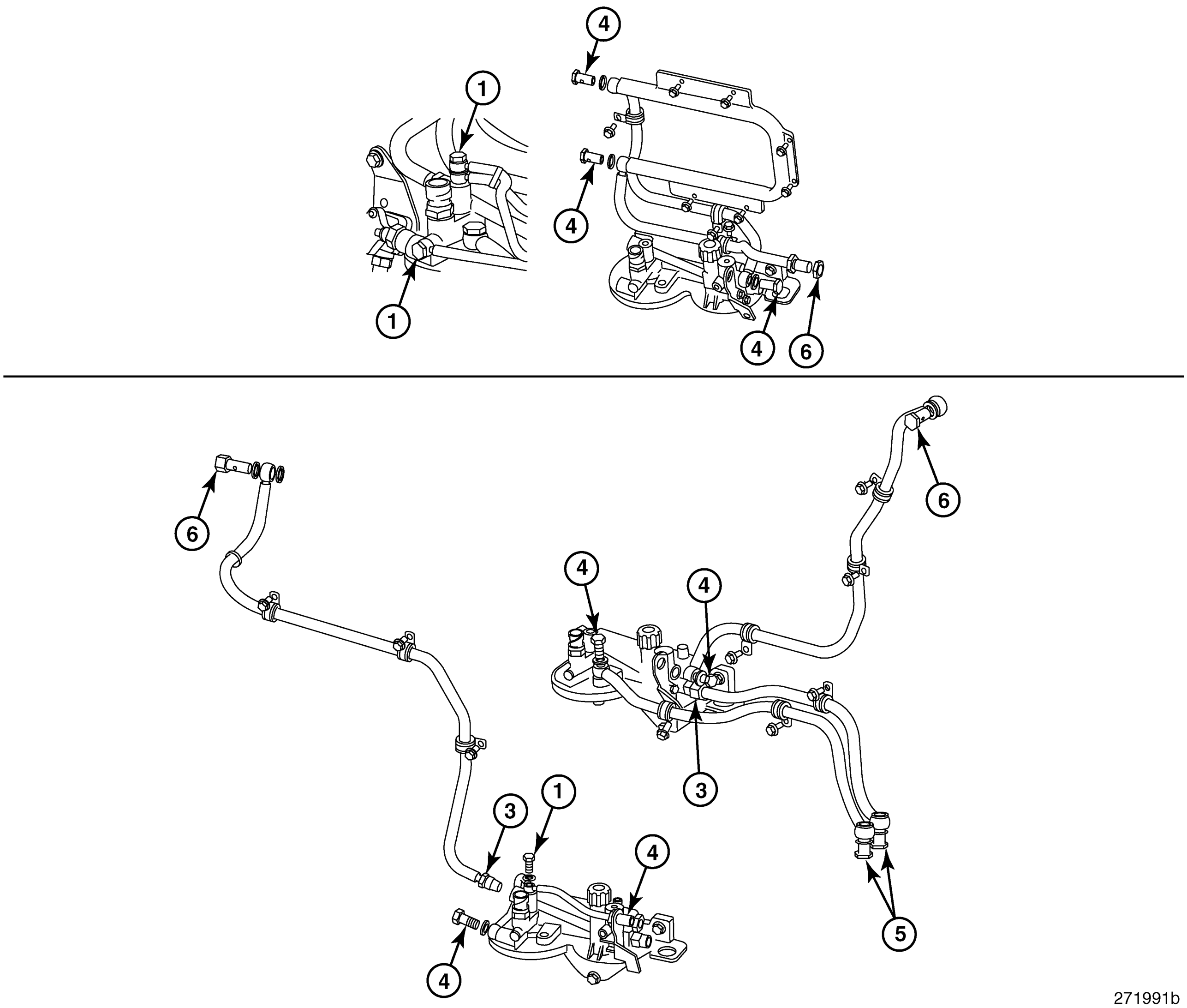


Figure 557 — Screw Number Identification for Torquing — Fuel Circuit

Filter Bracket Attaching Screws, M8 x 1.25	24 ±4 N•m (18 ±3 lb-ft)
No. 1	18 ±3 N•m (13 ±2 lb-ft)
No. 3	30 ±4 N•m (22 ±3 lb-ft)
No. 4	35 ±5 N•m (26 ±4 lb-ft)
No. 5	40 ±5 N•m (29.5 ±4 lb-ft)
No. 6	48 ±5 N•m (35 ±4 lb-ft)

Fuel Filter Housing

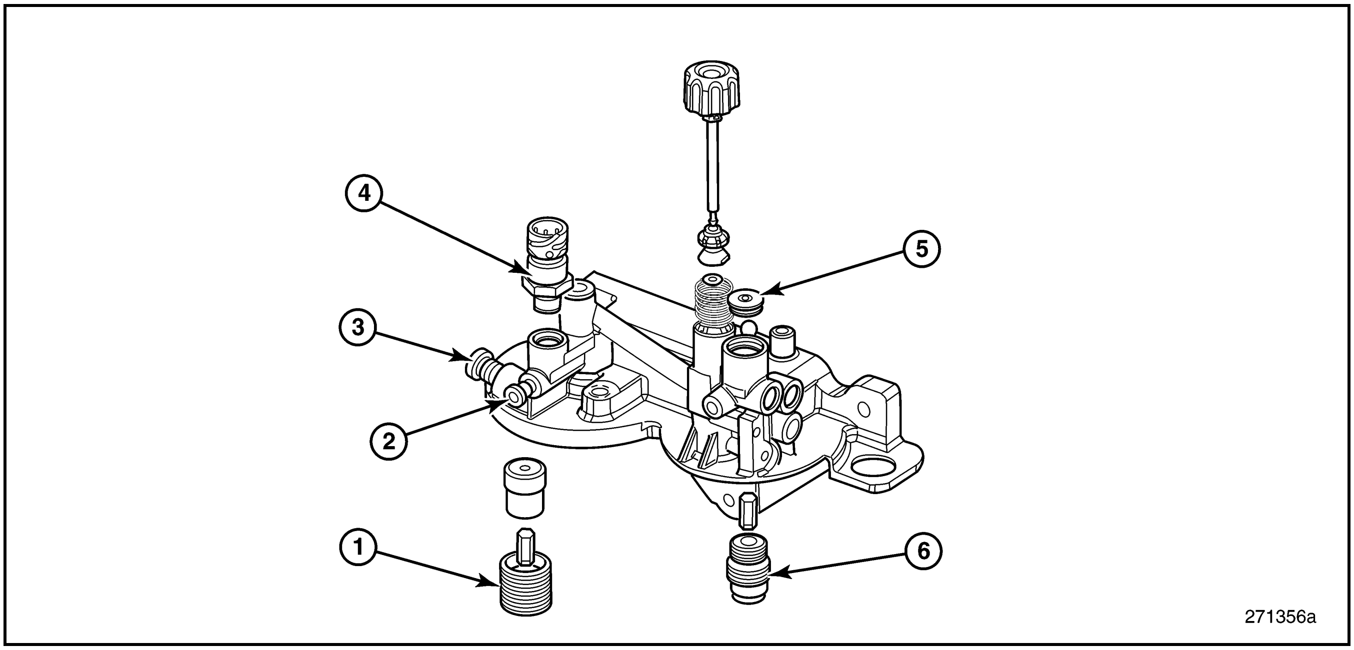


Figure 558 — Fuel Filter Housing — Plugs and Valves

Tighten the plugs and valves according to the following specifications.	
No. 1, 40 ±5 N•m (30 ±4 lb-ft)	No. 4, 30 ±5 N•m (22 ±4 lb-ft)
No. 2, 10 ±1.5 N•m (7 ±1 lb-ft)	No. 5, 2 ±0.5 N•m (18 ±4 lb-in) (Note lb-in)
No. 3, 25 ±1.5 N•m (18 ±1 lb-ft)	No. 6, 40 ±1.5 N•m (30 ±1 lb-ft)

Tandem Pump (Fuel and Power Steering)

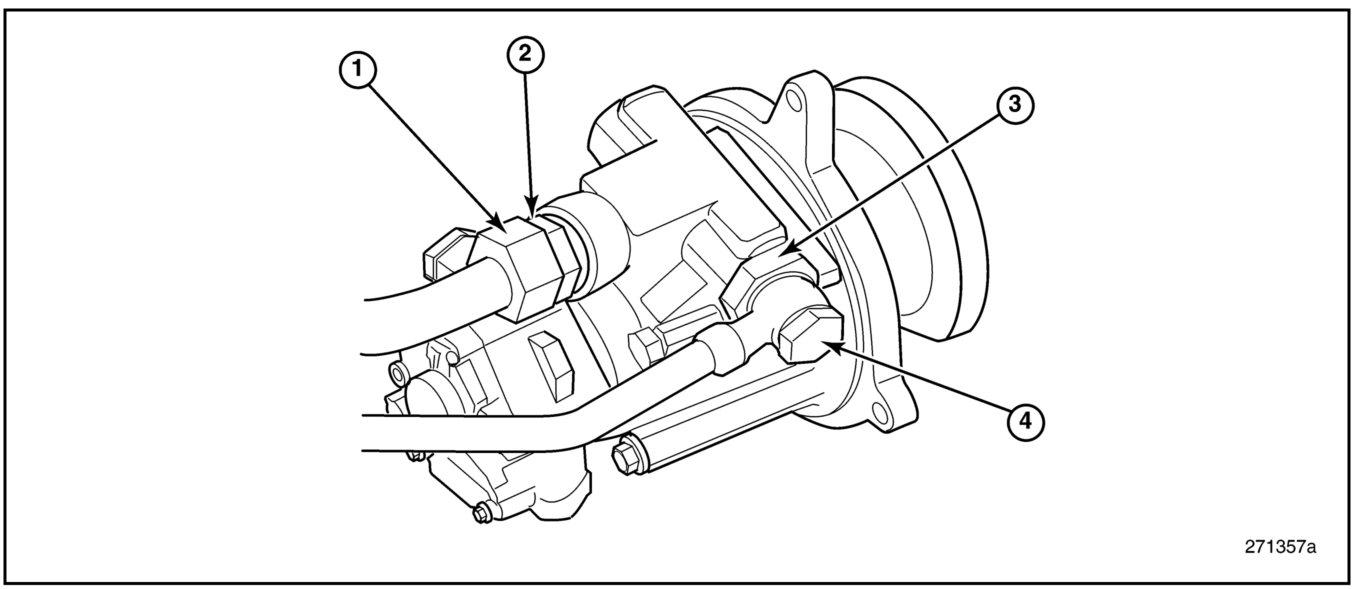


Figure 559 — Power Steering Pump Connectors

Tighten the connectors according to the following specifications.	
No. 1, 80 ±16 N•m (59 ±12 lb-ft)	No. 3, 70 ±10 N•m (52 ±7 lb-ft)
No. 2, 60 ±12 N•m (44 ±9 lb-ft)	No. 4, 37 ±7 N•m (27 ±5 lb-ft)

Additional Left-Side Engine Components

Alternator	
Mounting Bracket Attaching Screws, M10	48 ±8 N•m (35 ±6 lb-ft)
Pad Mount Attaching Screws, M12	85 ±15 N•m (63 ±11 lb-ft)
Attaching Screws, Tension Idler Roller	48 ±8 N•m (35 ±6 lb-ft)
Pulley Nut	101 ±6.5 N•m (75 ±5 lb-ft)
Inlet Manifold	
Plug, Inlet Manifold	20 ±3 N•m (15 ±2 lb-ft)
Air Compressor, Brake System	
Gear Attaching Nut	200 +50/–0 N•m (147 +37/–0 lb-ft)
Compressor Attaching Nuts	85 ±15 N•m (63 ±11 lb-ft)
Grease Connector	25 ±4 N•m (18 ±3 lb-ft)
Attaching Studs	24 ±4 N•m (18 ±3 lb-ft)
Fuel Pump	
Attaching Screws (to Power Steering Pump)	8 +2/–0 N•m (6 +1/–0 lb-ft)
Banjo Bolts	40 ±5 N•m (30 ±4 lb-ft)
Power Steering Pump	
Gear Attaching Nut	100 ±10 N•m (74 ±7 lb-ft)
Attaching Screws	24 ±4 N•m (18 ±3 lb-ft)
Refrigerant Compressor, Air Conditioning	
M8 Attaching Screws	24 ±4 N•m (18 ±3 lb-ft)

Standard Bolt and Nut Torque Values

The torque values in the table below conform to standard STD 5511,15.

	N•m (lb-ft)	
Screw/Bolt (Nut) Metric Size	**Grade 8.8**	**Grade 10.8**
M6 x 1.00	10 ±1.5 (7 ±1)	12 ±2 (9 ±1.5)
M8 x 1.25	24 ±4 (18 ±3)	30 ±5 (22 ±4)
M10 x 1.50	48 ±8 (35 ±6)	60 ±10 (44 ±7)
M12 x 1.75	85 ±15 (63 ±11)	105 ±20 (77 ±15)
M14 x 2.00	140 ±25 (103 ±18)	175 ±30 (129 ±22)
M16 x 2.00	190 ±35 (140 ±26)	275 ±45 (203 ±33)
M18 x 2.50	290 ±45 (214 ±33)	360 ±55 (265 ±40)
M20 x 2.50	430 ±70 (317 ±52)	540 ±90 (398 ±66)
M22 x 2.50	580 ±90 (428 ±66)	730 ±120 (528 ±88)
M24 x 3.00	740 ±120 (546 ±88)	900 ±140 (664 ±103)

ENGINE GASKETS, LUBRICANTS AND SEALANTS

Gasket and Seal Reuse

Some gaskets and seals must be discarded if removed during service. The following table describes the components and their limits.

Components	Examples	Reusable Limit	Reuse Recommendations
Gaskets (steel)	Cylinder head	Do not reuse	Discard the old gasket and substitute new if the head is removed.
Gaskets (hot)	Exhaust manifold Turbocharger EGR system	Do not reuse	Discard old gaskets and substitute new if associated components are removed.
Rubber gaskets (special)	Sealing strip (coolant duct cover, cylinder head cover, oil pan, timing gear cover and inlet manifold)	No limit if no damage and no leaks	Remove old silicone from the T joints. Clean the surfaces. Apply fresh silicone.
Rubber gaskets (standard)	O-rings and sealing rings	Do not reuse	
Bonded seals, steel/rubber gasket	Nipples, hollow screws and oil filter housing	No limit if no damage and no leaks	
Valve seals	Valve stems	No limit if no damage and no leaks	Discard old seals and substitute new if the gasket is removed.
Crankshaft seals		Do not reuse	Discard old seals and substitute new if removed. Do **not** apply oil on the inside or outside diameters of the seal during assembly. **SEALS MUST BE DRY MOUNTED**.
Sealant agent	Sealing between: Timing Gear Plate and Cylinder Block Flywheel Housing and Timing Gear Plate Timing Gear Cover and Gear Plate	Do not reuse	Remove the old sealant. Clean the surfaces. Apply fresh sealant. **Important**: Remove the old silicone from the T joints and apply fresh.

Lubricants and Sealants

Use only the following recommended sealing compounds and lubricants.

NOTE

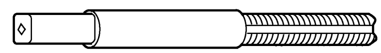
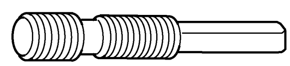
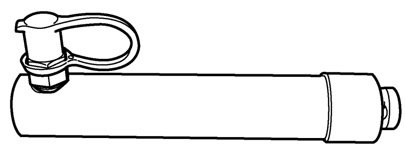
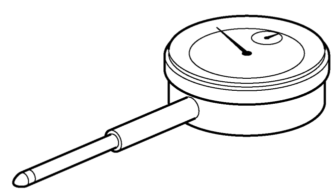
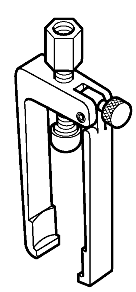
All genuine MACK cylinder head gaskets are precoated and do not require any type of sealing compound. Before installing **new** gaskets, degrease both gasket sealing surfaces to avoid leaks.

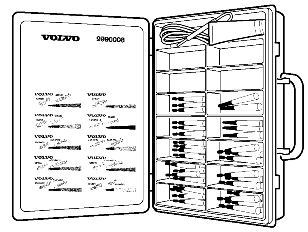
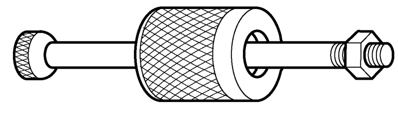
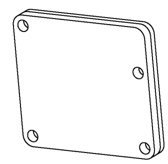
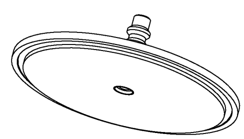
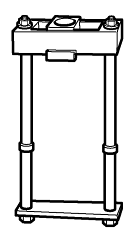
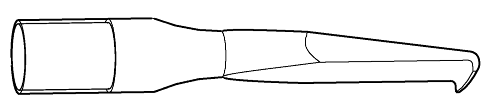
Location	Sealant or Lubricant
Crankshaft front seal cover	Part No. 342SX33 (or Dow Corning® 832)
Cup plugs/threaded plugs	Loctite® 277 or equivalent/Teflon® thread sealer
Cylinder liner seats	Part No. 342SX33 (or Dow Corning® 832)
Engine parts, fasteners (sides and threads), and washers	Clean engine oil
Industrial adhesive	3M Scotch-Grip 4799 Industrial Adhesive
Injector copper sleeve seals	Clean coolant
Oil filter sealing gaskets (full-flow filters)	Clean engine oil
O-rings (fluid systems)	Use the type of fluid that the O-ring contacts in use.
O-ring lubricant (other than above)	243SX56
Sensors with O-ring seals	Assemble dry
Valve stems and guides	SAE 15-40 clean engine oil

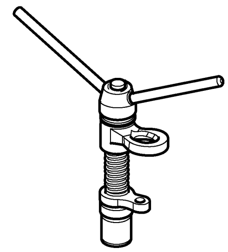
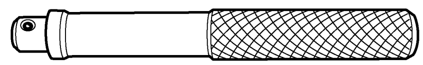
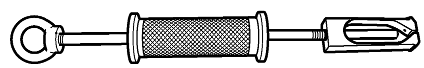
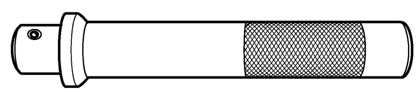
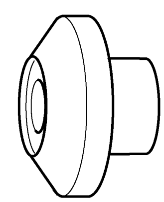
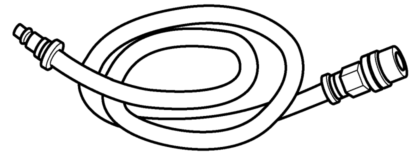
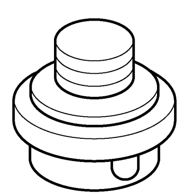
SPECIAL TOOLS & EQUIPMENT

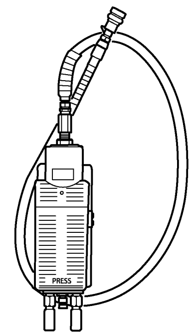
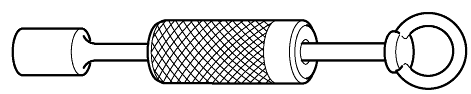
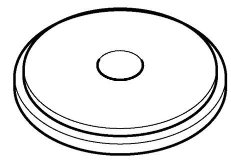
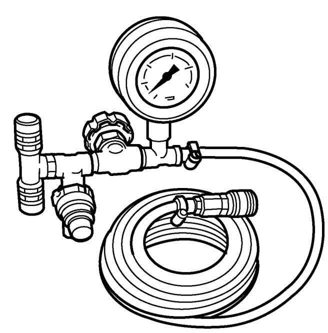
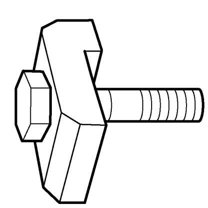
MP8 ENGINE SERVICE TOOLS [200 EA]

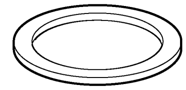
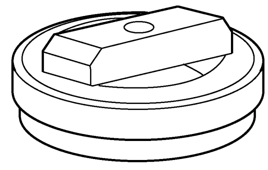
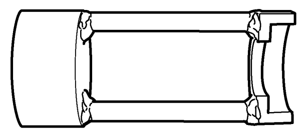
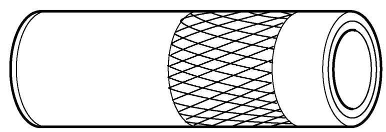
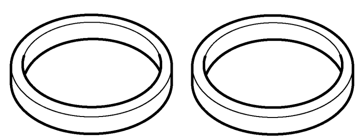
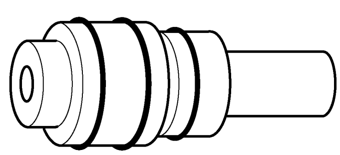
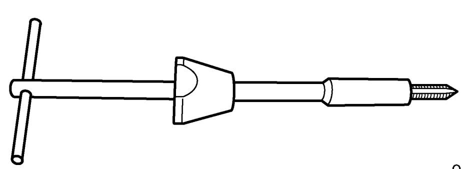
Special Tools for Engine Overhaul

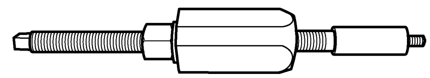
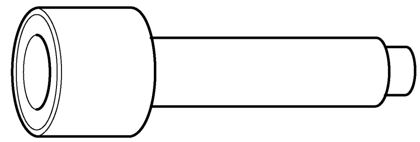
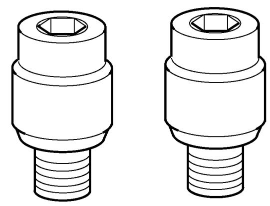
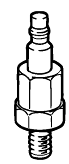
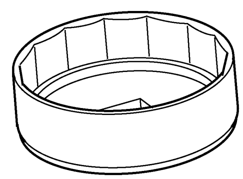
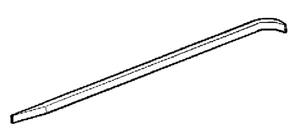
Tool No.	Description	Image
9809667	9 mm Tap, use with 9998252 (Available)	 006840a
9809668	9 mm Bit, use with 9998253 (Available)	 006841a
9809729	Hydraulic Ram (Available)	 006777a
9989876	Dial Indicator (Available)	 006899a
9990006	Two-Jaw Puller for Unit Injector Removal, use with 9990013 (Essential)	 006778a

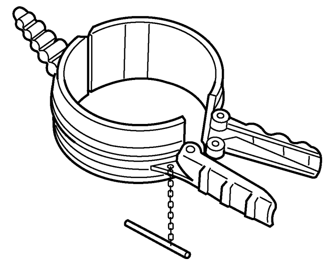
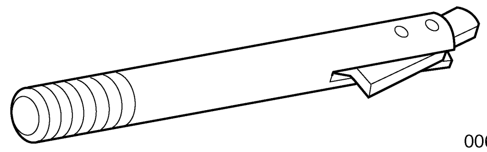
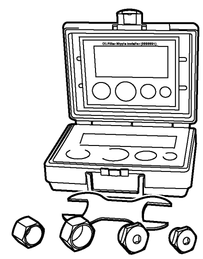
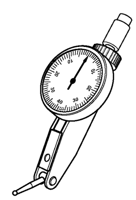
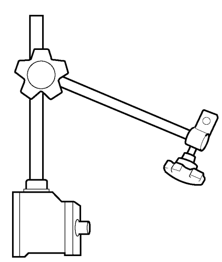
Tool No.	Description	Image
9990008	Set of Test Pins	 006951a
9990013	Slide Hammer	 006779a
9990106	Sealing Plate for MP7, MP8 and MP10 Cylinder Heads	 274114a
9990107	Connection Disc for MP7, MP8 and MP10 Cylinder Heads	 274115a
9990176	Tool Press for Valve/Valve Guide Replacement (Available)	 006781a
9990192	Crankshaft Seal Puller	 006896a

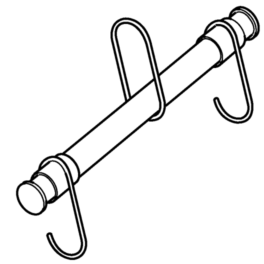
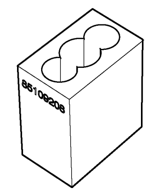
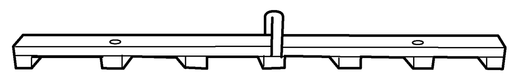
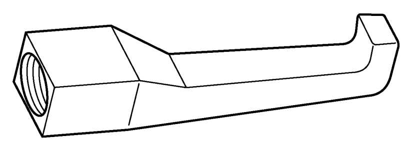
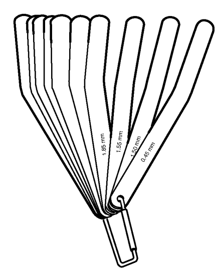
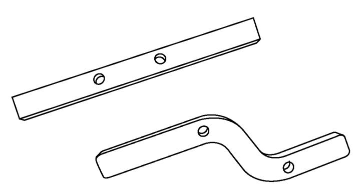
Tool No.	Description	Image
9990210	Valve Spring Compressor (Essential)	 006782a
9991801	Handle with various uses (fits 18 mm hole), use with 9992564 (Essential)	 006783a
9991821	Slide Hammer for Pilot Bearing Removal and other various uses (Available)	 006784a
9992000	Handle with various uses (fits 25 mm hole), use with 9990113 (Essential)	 006785a
9992564	Driver for Installation of Pilot Bearing, use with 9991801 (Essential)	 006786a
9996049	Coolant Drain Hose (Available)	 006788a
9996159	Adapter (Tool Press for Valve/Valve Guide Replacement) (Available)	 006789a

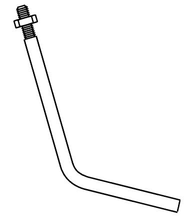
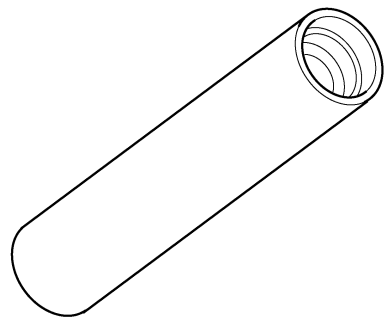
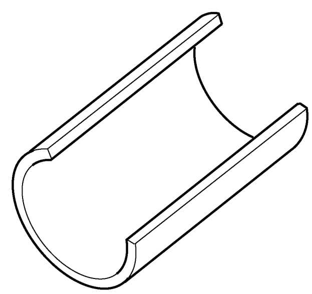
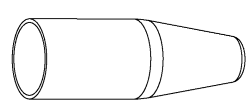
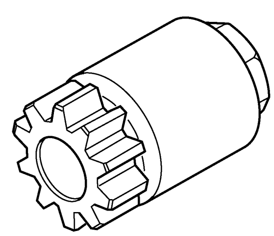
Tool No.	Description	Image
9996222	Hydraulic Pump (Available)	 006790a
9996400	Slide Hammer	 006897a
9996454	Handle for Liner Installation Plate (Available)	 006791a
9996599	Liner Installation Plate (Available)	 006792a
9996662	Pressure Gauge and Hoses (Available)	 006793a
9996966	Liner Hold-Down Tools (Essential)	 006796a

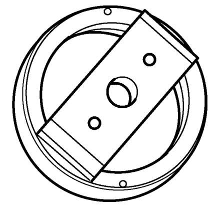
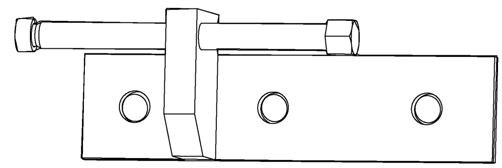
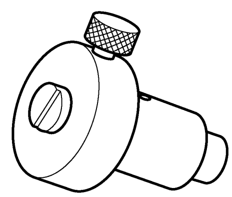
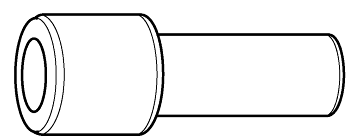
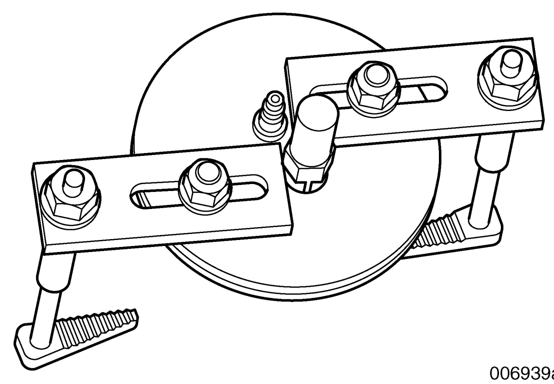
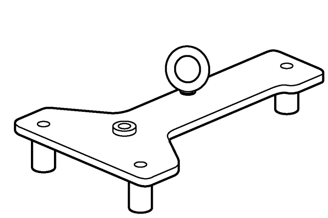
Tool No.	Description	Image
9998170	Seal Spacer (Essential)	 006947a
9998238	Rear Main Seal Remover/Installer for neoprene type seals, use with 9992000 (Essential) **Note:** For Teflon® seals, use tools 9990166, 9990192 and 9996400.	 006780a
9998246	Valve Spring Compressor Adapter (Available)	 006797a
9998249	Unit Injector Protection Sleeve (Essential)	 006798a
9998250	Fuel Gallery Sealing Rings (Available)	 006799a
9998251	Unit Injector Bore Sealing Plug (Essential)	 006800b
9998252	Unit Injector Sleeve Tap (to thread nose of cup) (Essential) This tool comes with both M8 x 1.25 (part No. 9987009) and M9 x 1.25 (part No. 9809667) taps. Use the larger of the two taps, M9 x 1.25 (part No. 9809667), when servicing an MP8 engine.	 006801a

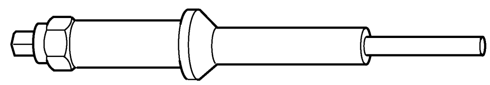
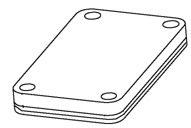
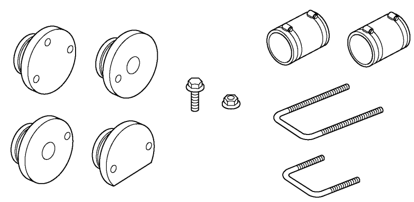
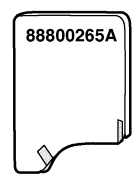
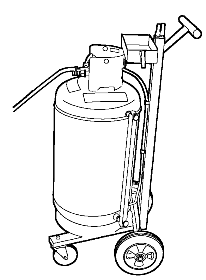
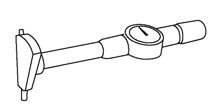
Tool No.	Description	Image
9998253	Unit Injector Sleeve Remover (Essential) This tool comes with both M8 (part No. 9809746) and M9 (part No. 9809668) bits. Use the larger of the two bits, M9 (part No. 9809668), when servicing an MP8 engine.	 006802a
9998263	Valve Guide Removal Tool (Available)	 006803a
9998267	Dowels (Locating Tools for the Timing Gear Plate)	 006887a
9998333	Coupler, for use with EGR Cooler Leak Test Kit 88800216.	 273047a
9998487	Oil Filter Wrench (Available)	 006845a
9998511	Lever	 007121a

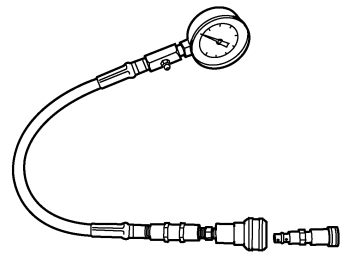
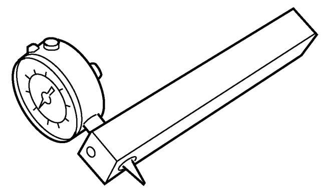
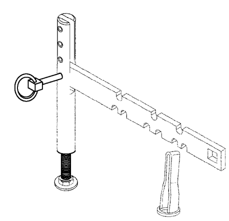
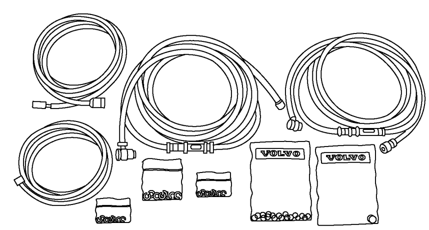
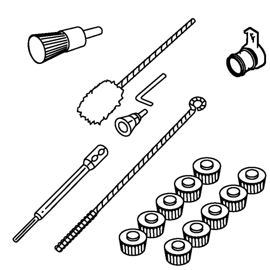
Tool No.	Description	Image
9998531	Piston Ring Compressor (Essential)	 006834a
9998649	Block Stiffener Plate Installation Tool	 006894a
9998691	Oil Filter Nipple (Spud) Installer Kit (Essential)	 007021b
9999683	Sweep Dial Indicator (Essential)	 006948a
9999696	Magnetic Stand (Available)	 006900a

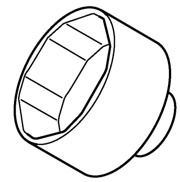
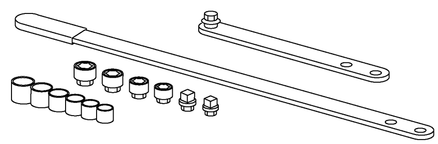
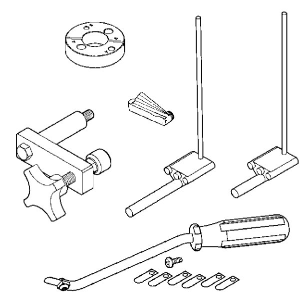
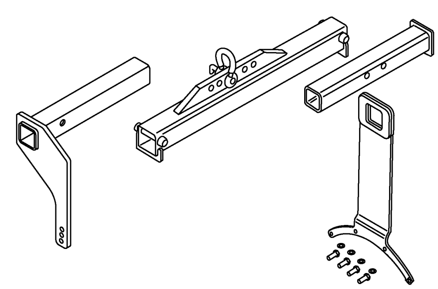
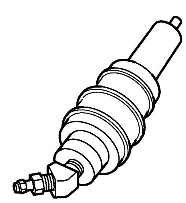
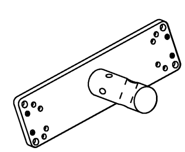
Tool No.	Description	Image
85109034	Camshaft Lifting Bar (Essential) **Note:** Alternate lifting tool — 9998264.	 006835a
85109208	Bearing Cap Press Tool (Essential)	 006949a
85109250	Rocker Shaft Assembly Lifting Tool (Essential) **Note:** Alternate lifting tool — 9990185.	 006770a
85109980	Camshaft Bearing Cap Removal Tool, use with 9990013 (Essential)	 006886a
85111377	Feeler Gauge Set	 006844a
85111422 (A, B)	Timing Gear Cover Alignment Tool (Essential)	 006924a

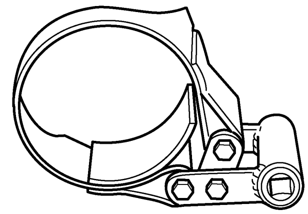
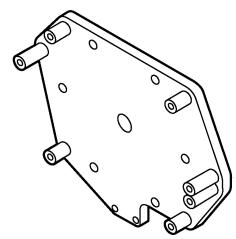
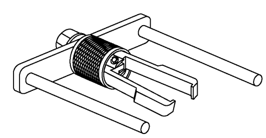
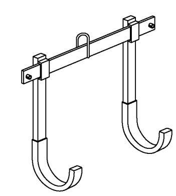
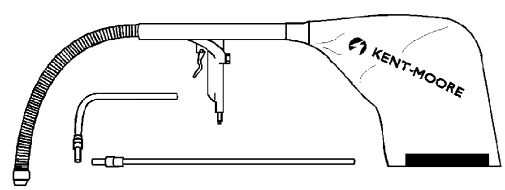
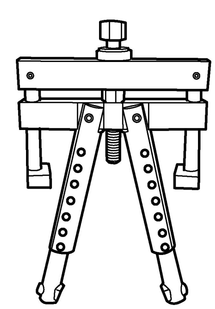
Tool No.	Description	Image
85111493	Angled Extension (Available)	 006898a
85112460	Valve Stem Seal Installation Tool	 006966a
85112461	Valve Stem Height Measurement Gauge (Essential)	 006944a
88800011	Valve Stem Seal Protection Tool (Essential)	 007020a
88800014	Flywheel Turning Tool (Essential)	 271485a

Tool No.	Description	Image
88800021	Front Main Seal Remover/Installer (Essential)	 006774a
88800022	Cooling Duct Cover Installation Tool	 006893a
88800031	Camshaft Sensor Depth Gauge (Available)	 006804a
88800062	Inlet and Exhaust Valve Guide Installation Tool (Available)	 006776a
88800186	Charge Air System Leakage Tester (Essential)	 006939a
88800188	Cylinder Head Lifting Tool (Essential)	 006923a

Tool No.	Description	Image
88800196	Swaging Tool for Installing Unit Injector Copper Sleeve (Essential)	 006805a
88800215	Sealing Plate	 007157a
88800216	EGR Cooler Leak Test Kit (Essential) **Note:** For the alternate pressure test method, use tools 9988288, 9996662 and 9998143.	 007002c
88800265A	VGT Mechanism Gauge (Essential)	 007164a
88880010	Swaging Bit (Available)	 006842a
DBT 2V700 (2815-2V700)	Coolant Extractor/Injector	 006940a
J 5347-B	Dial Bore Gauge	 000615b

Tool No.	Description	Image
J 6692-B	Cylinder Compression Gauge (Available)	 006836a
J 26948	Cylinder Liner Height Measurement Tool (Available)	 006846a
J 41989-A	Valve Spring Compressor	 007122a
J 42752	Fuel Line Kit	 007158a
J 42885	Unit Injector Bore Cleaning Kit (Essential) **Note:** Alternate tool kit for cleaning — 9998599.	 006926a

Tool No.	Description	Image
J 43051	Oil Valve Socket	 006895a
J 44392	Fan Belt Tensioner Tool (Available)	 272697a
J 44514-B	Engine Timing Kit (Essential)	 006889a
J 47038-3 J 47038-4 J 47038-6 J 47038-8	Engine Lifting Tool (Essential)	 006927b
J 47363	Cylinder Compression Gauge Adapter (Essential) **Note:** Alternate tools — 9998248 with 9988539.	 006837a
J 47364	Cylinder Head Adapter Plate	 007117a

Tool No.	Description	Image
J 48061	Coolant Conditioner Filter Wrench (Available)	 006807a
J 48662	Engine Stand Adapter Plate for use with stand J 29109-A (Available) **Note:** Alternate tools — 88800117 with stand 9986485.	 006925a
J 48922	Heavy-Duty Unit Injector Puller	 007000b
J 49002	Crankshaft Lifting Tool (Essential)	 007133a
PT-2900	Chip Vacuum	 006962a
PT-6435 or PT-6400-C	Cylinder Liner Puller (Available) **Note:** Alternate tools for liner removal — 9992955, 9996394, 9996395 and 9996645 in combination.	 006808a

All of the above tools are available through the MACK Parts System with the exception of those beginning with the prefix J or PT-. J and PT- tools are available from Kent-Moore at the following address.

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

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