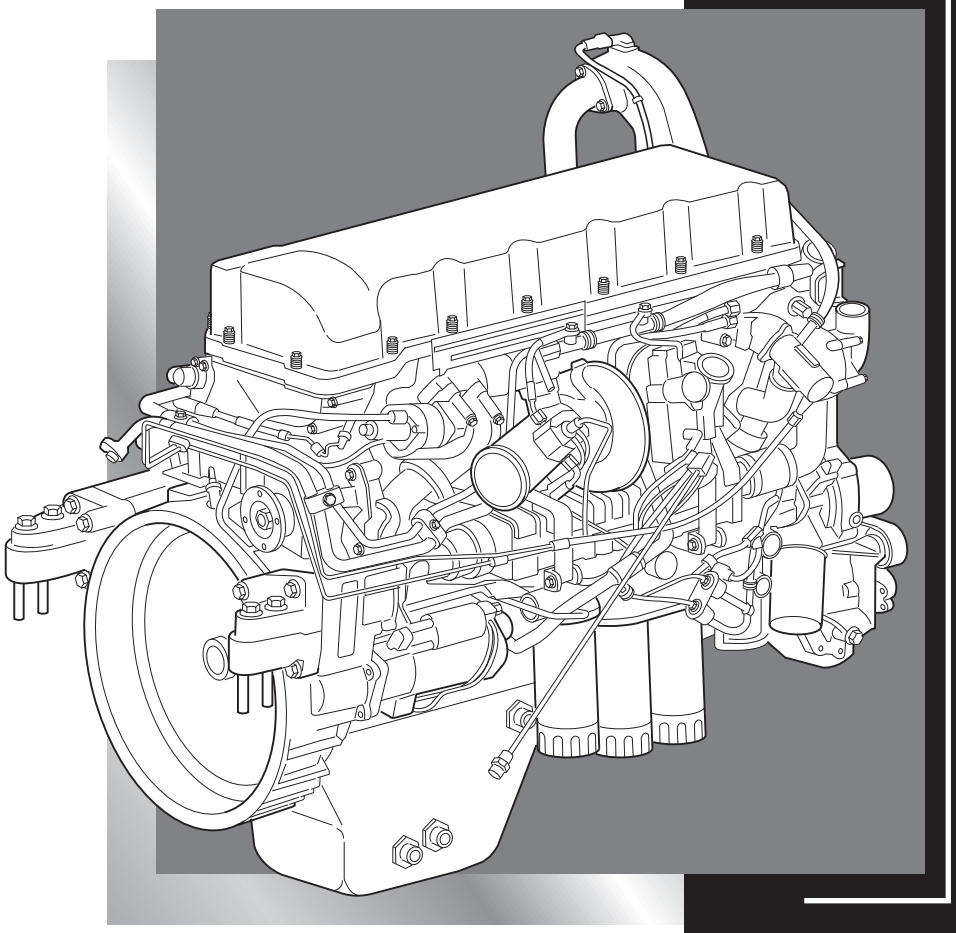

MACK® MP7 DIESEL ENGINE

SERVICE MANUAL
('07 EMISSIONS REGULATIONS)

JULY 2009
(REVISED)
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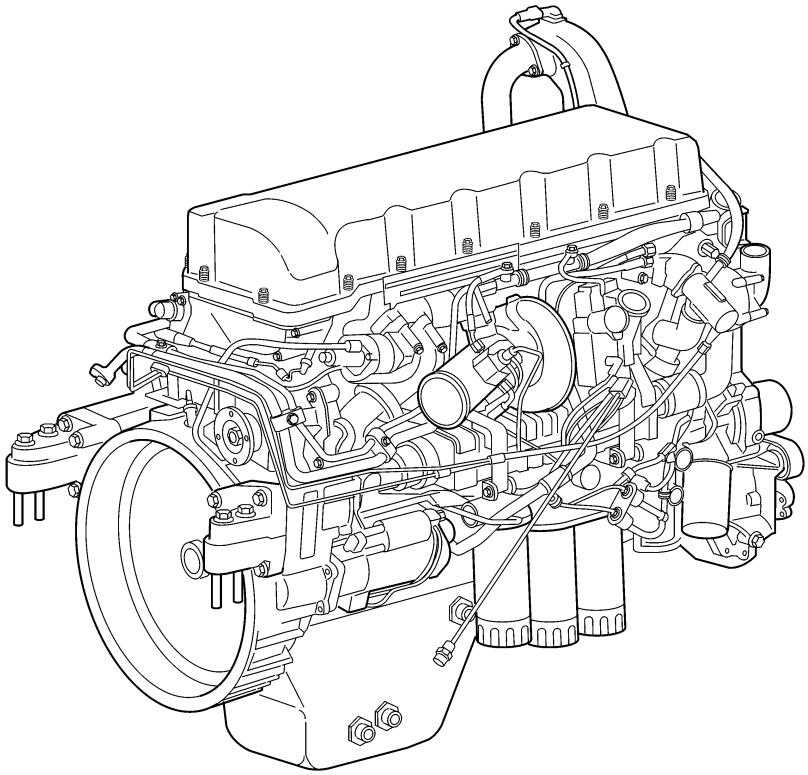
MACK® MP7 DIESEL ENGINE SERVICE MANUAL ('07 EMISSIONS REGULATIONS)



JULY 2009
(REVISED — SUPERSEDES ISSUE DATED JANUARY 2009)

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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:

⚠ DANGER

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.*

⚠ WARNING

***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.**

⚠ CAUTION

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

NOTE

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

SERVICE HINT

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

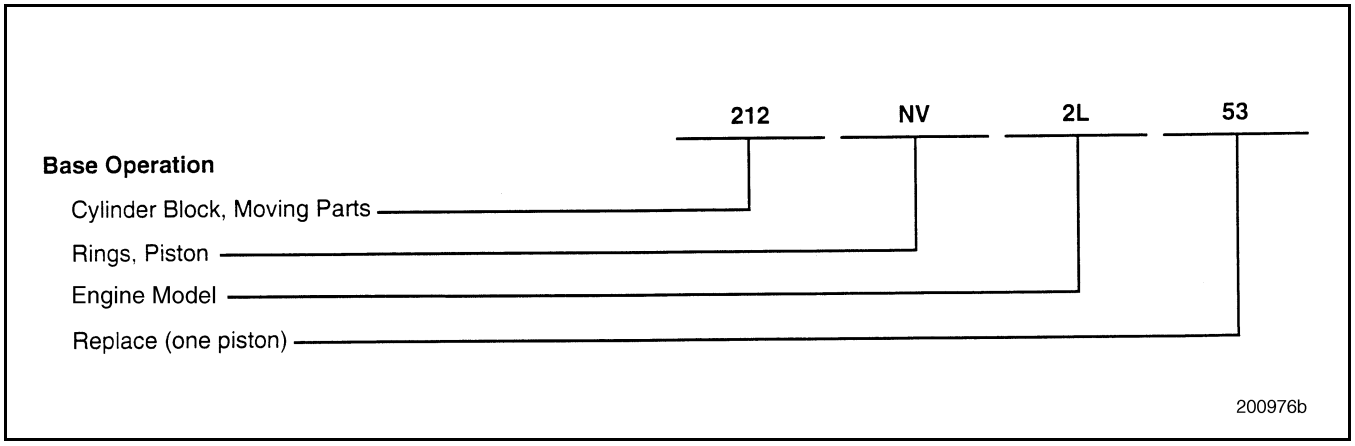
GROUP **6**00 — CAB, TRUCK BODY

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 MP7 ENGINE [200 EA]

The MACK MP7 is a 700 CID (11 liter) engine with unit injectors, a cooled Exhaust Gas Recirculation (EGR) system and the Holset Variable Geometry Turbocharger (VGT). With the addition of a Diesel Particulate Filter (DPF) system and changes in the EGR system, the design now conforms to year 2007 Environmental Protection Agency (EPA) requirements.

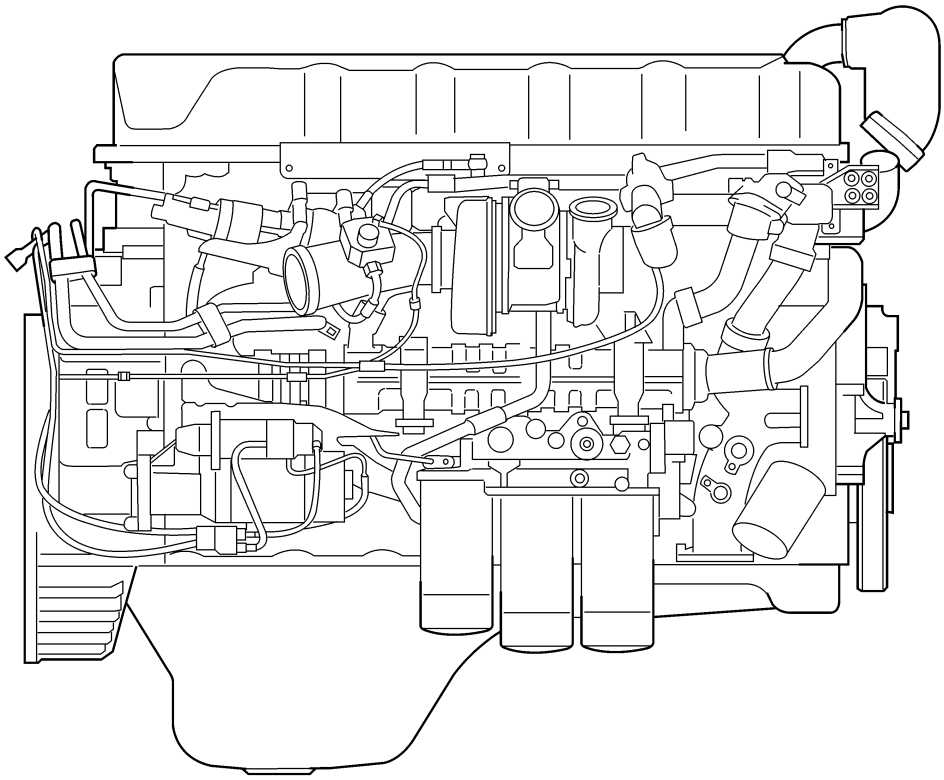


Figure 1 — MP7 Right Side View — Conventional Chassis

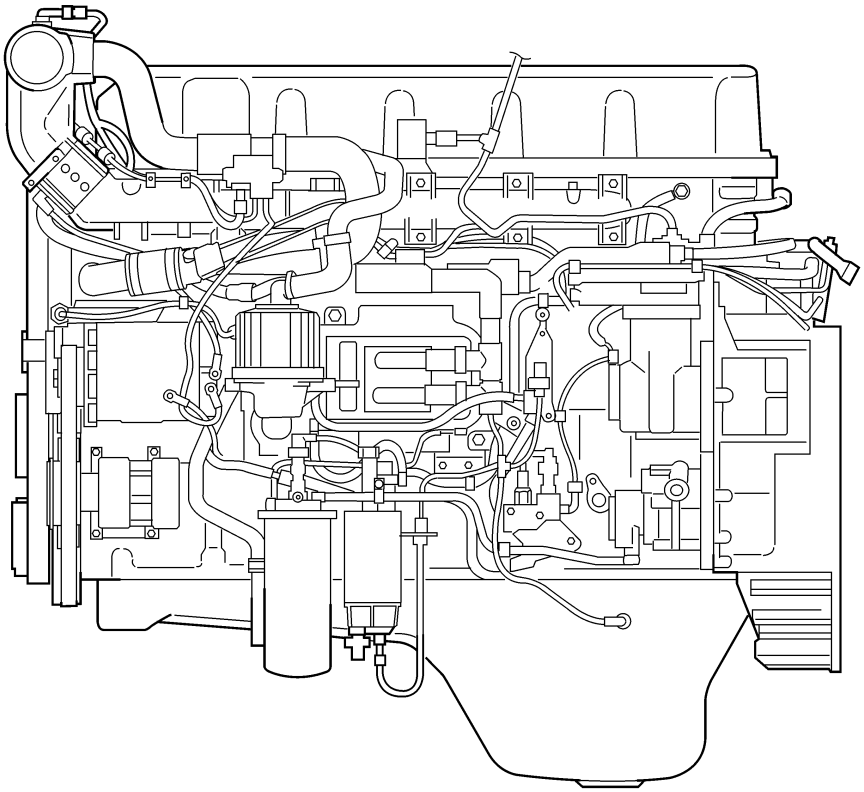


Figure 2 — MP7 Left Side View — Conventional Chassis

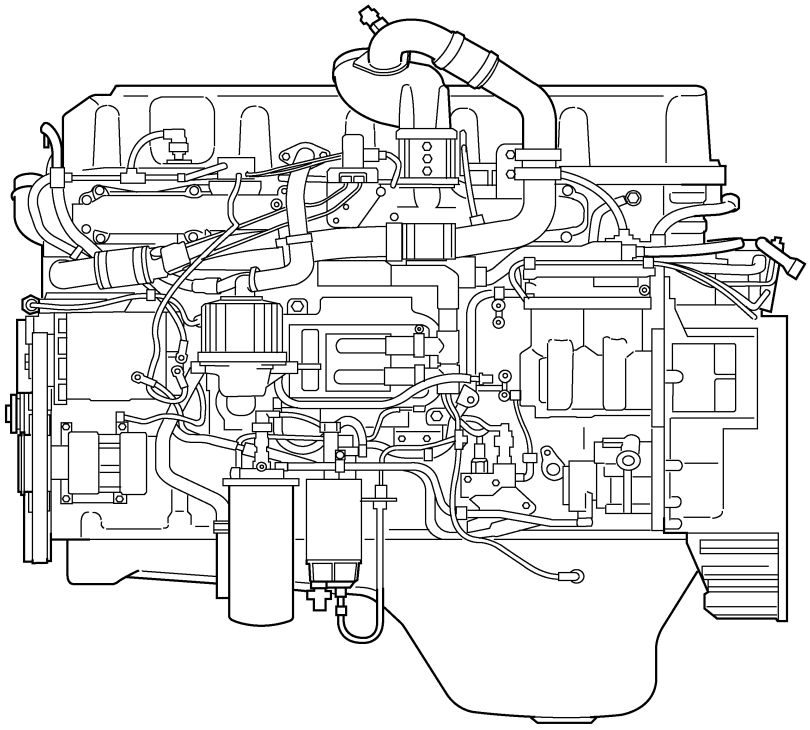


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Figure 3 — MP7 Left Side View — Low Cab Forward (LCF) Chassis

Exhaust Gas Recirculation — 2007

There are two configurations of the new EGR system. For engines installed on conventional chassis, the EGR mixer attaches to the inlet manifold at the top front of the engine. For low cab forward (LCF) chassis, the mixer attaches toward the rear of the inlet manifold. The right side views of the engines are nearly identical. The left side views display the arrangement of components that accommodate the two configurations.

The new MP7 EGR system features a venturi with Delta Pressure sensors. The MASS flow tube has been replaced. The new combination is easy to service.

Variable Geometry Turbocharger

The Holset Variable Geometry Turbocharger (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.

Three Engine Families — Nine Peak Power Options

There are six different power ratings:

- 242 kW (325 hp)
- 257 kW (345 hp)
- 265 kW (355 hp)
- 272 kW (365 hp)
- 295 kW (395 hp)
- 302 kW (405 hp)

Maximum torque ratings fall in the 1700–2115 N•m (1200–1560 lb-ft) range.

The MP7 comes in three families: Econodyne™, MaxiCruise™ and Maxidyne™. Each family has three peak power options. The number after MP7 is the peak power achieved at 1500 rpm. MACK places heavy emphasis on the peak power value. Operators should cruise at approximately 1500 rpm when practical.

Econodyne (Highway Economy)	MaxiCruise (On/Off Road Performance)	Maxidyne (Off Road Performance)
MP7-325E	MP7-345C	MP7-325M
MP7-355E	MP7-365C	MP7-365M
MP7-405E	MP7-395C	MP7-405M

A wide range of the current transmission offerings, especially Allison, can be teamed with the MP7. No new transmissions are required, but the MP7 will readily adapt to the Allison GEN 4 Series transmissions.

Diagnostic help can be found in the Premium Tech Tool (PTT). To obtain PTT, contact your local MACK dealer.

The engine design includes a one-piece cylinder head, a single overhead camshaft, unit injectors and no pushrods. PowerLeash™ engine braking is standard. Monosteel™ steel pistons are made in one piece.

⚠ DANGER

Use of ether or similar types of starting aids in MACK US07 emission compliant engines is strictly prohibited. This applies to engines with or without the electric pre-heater option. An explosion could occur. Failure to heed this danger may result in severe personal injury or death.

There is a cylinder block (coolant) heater in the cooling duct cover. Two optional fan drives are available: On/Off and electronically actuated. The electronically actuated viscous fan drive is precisely controlled by the Engine Management System (EMS) module, commonly referred to as the Engine Electronic Control Unit (EECU).

Timing gears mount on the rear of the MP7 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.

Another feature of the MP7 is the rear engine power take-off (REPTO-ready) that is gear driven through the timing gear train. An optional PTO shaft with drive gear, bearing and housing can be added at the factory. A front engine power take-off is available for simple attachment.

The engine has one-piece forged steel Monosteel™ pistons and wet cylinder liners. Piston rings are coated using a process called Physical Vapor Deposition (PVD) to provide a thin, well adhered material layer for better cylinder cooling and longer ring and liner life.

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. A heater is available to warm the oil before starting the engine.

The MP7 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 under the valve cover and not exposed to the heat of exhaust system components.

Fuel passes through two filters, one of which separates water from the fuel. The primary filter can be mounted on the engine or on the chassis. Fuel pressure in the unit injectors is augmented via the rocker arms with roller followers in constant, direct contact.

Removing injectors for service requires a new technique, and installation requires that the EECU be programmed to recognize replacement injectors. Cleaning injector bores requires a special tool.

The standard MP7 is equipped with an engine compression brake to assist deceleration and vehicle braking. PowerLeash™, the engine compression brake, includes a different 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.

Unique colors and the appearance of the valve cover, filters and logo labels distinguish the MP7 from other engines in the MACK line.

Preventive maintenance is important to get the most from the MACK MP7 engine and to ensure many years of reliable, trouble-free operation.

Repair Instructions sections in this manual deal with removal, installation, disassembly, assembly, setup and adjustments of MP7 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 MP7 engine service:

1. DO NOT machine the cylinder head for clean-up since this will change injector tip protrusion, thereby affecting emissions. It will also upset the ability to correctly adjust timing gear backlash.
2. DO NOT grind the injector copper sleeves.
3. Critical fasteners that can be used four times include main bearing cap bolts, connecting rod bolts, flywheel bolts, turbocharger bolts, injector hold down bolts and camshaft bearing housing bolts.
4. Install the crankshaft main bearing caps according to marked assembly number. Correct alignment is also critical and is aided by the following:
   - Two casting nipples, located in the cylinder block and on the respective bearing cap, eliminate incorrect assembly.
   - Sleeves pressed into the cylinder block guide the bearing caps into position for proper alignment.
5. 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.
6. DO NOT use the lifting eye on the flywheel housing when tilting the engine/transmission assembly to an angle greater than 15 degrees.

7. Cylinder head installation requires lowering the head onto the gasket, then pulling the head horizontally against the timing gear mounting plate using through screws. Pressed bosses in the gasket keep the head from making full contact with the gasket surface and prevent damage to the rubber sealing rings as the head slides into position.
8. DO NOT use ether or similar types of starting aids.

⚠ DANGER

Use of ether or similar types of starting aids in MACK US07 emission compliant engines is strictly prohibited. This applies to engines with or without the electric pre-heater option. An explosion could occur. Failure to heed this danger may result in severe personal injury or death.

9. The MP7 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.
10. Mark the alignment of the sections before disassembling the particulate filters.

VISUAL IDENTIFICATION

MP7 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 in English and French concerning the following items.

- Engine family, model and serial number
- Displacement, horsepower, fuel rate, idle speed and engine brake
- Emissions regulations to which the engine conforms and other pertinent information required by emissions regulations
- Valve lash settings for inlet, exhaust and engine brake
- NOx, NMHC+NOx and particulate matter emissions
- Exhaust emission control systems

A statement concerning the limitation on the fuel to be used in the engine also appears. Code letters under Exhaust Emission Control Systems represent basic engine systems that impact emissions. They are taken from the following list.

- CAC — Charge Air Cooler
- DI — Direct Injection
- DPF — Diesel Particulate Filter
- EC — Engine Control
- EGR — Exhaust Gas Recirculation
- EM — Engine Modification
- TC — Turbocharger

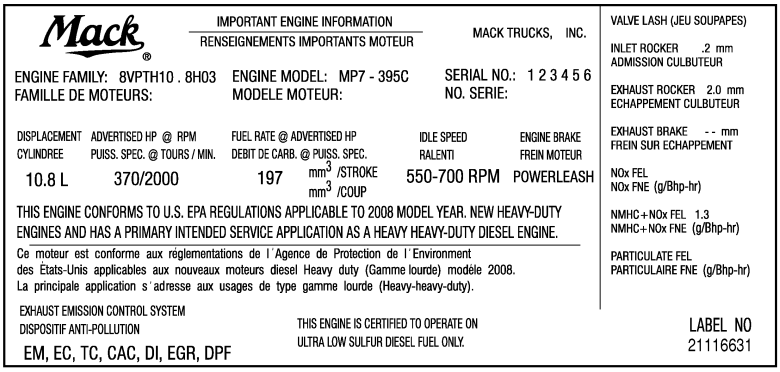


Figure 4 — Engine Information Plate

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 as shown in Figure 5.

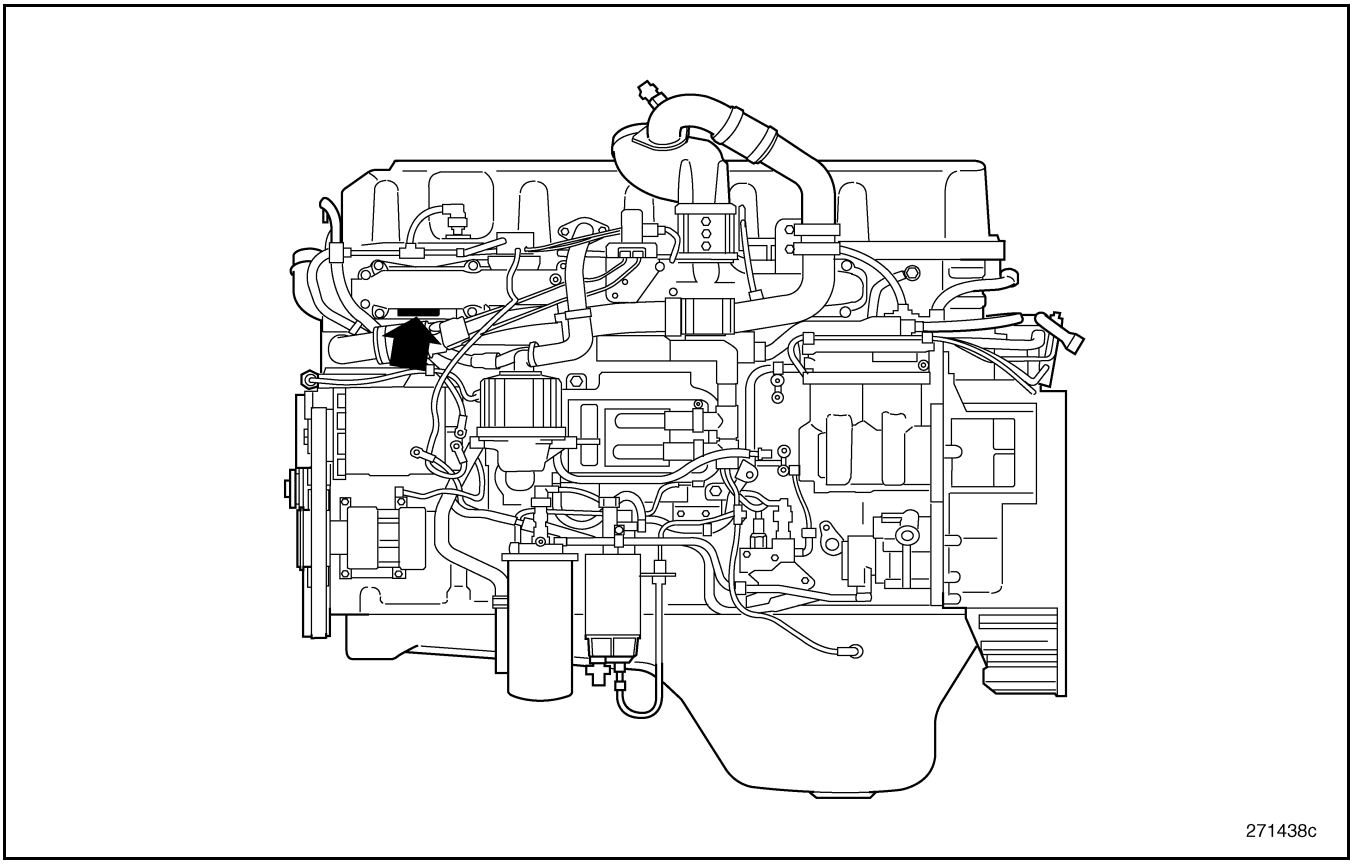


Figure 5 — Engine Serial Number

DESCRIPTION AND OPERATION

MP7 ENGINE DESIGN FEATURES [200 EA]

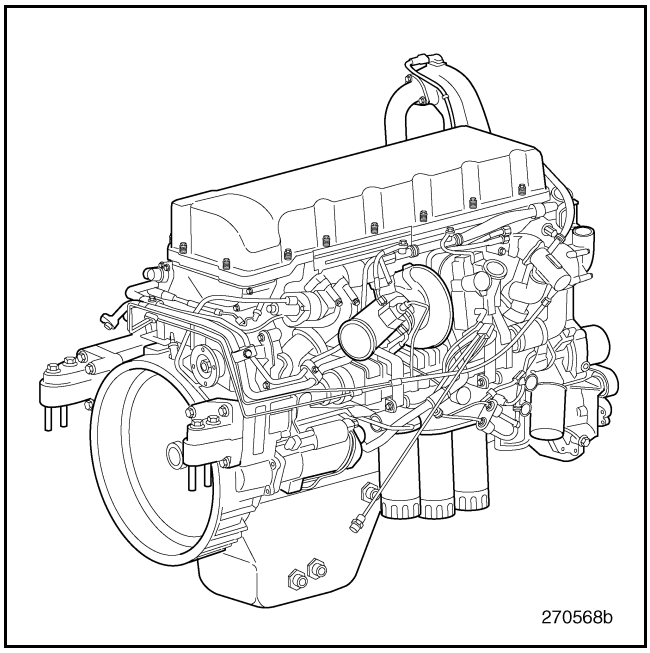


Figure 6 — MP7 Engine — Conventional Chassis — Right Rear Quarter View

Engine Variants

HORSEPOWER AND CLASS

The MP7 engine is an 11-liter engine available with six different peak power ratings.

- 242 kW (325 hp) Econodyne and Maxidyne
- 257 kW (345 hp) MaxiCruise
- 265 kW (355 hp) Econodyne
- 272 kW (365 hp) MaxiCruise and Maxidyne
- 295 kW (395 hp) MaxiCruise
- 302 kW (405 hp) Econodyne and Maxidyne

Peak torque ratings fall within the range of 1627 N•m (1200 lb-ft) to 2115 N•m (1560 lb-ft). Recommended cruising speed for all engines is 1500 rpm where practical. Engine design meets U.S. and California exhaust emissions regulations to be imposed beginning with the year 2007.

Engine Components

CYLINDER HEAD

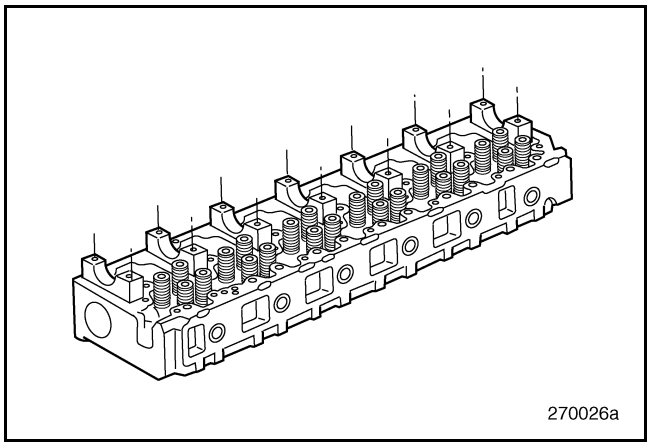


Figure 7 — Cylinder Head with Valves and Camshaft Supports

Main features of the cylinder head are:

- One-piece cast iron
- Integral thermostat housing
- Valves angled 12 degrees from normal (facilitates charge air and exhaust gas flow)
- New aid to installation

CAMSHAFT AND VALVE TRAIN

The engine has an overhead camshaft, rocker arm shaft and four valves per cylinder. Replaceable valve guides and seats are made of alloyed cast iron and steel respectively. All valve guides have oil seals. All of the valves have double valve springs. Each valve rocker arm drives two valves via a pinless yoke. Exhaust valve yokes on PowerLeash™ engines include a shim for adjustment.

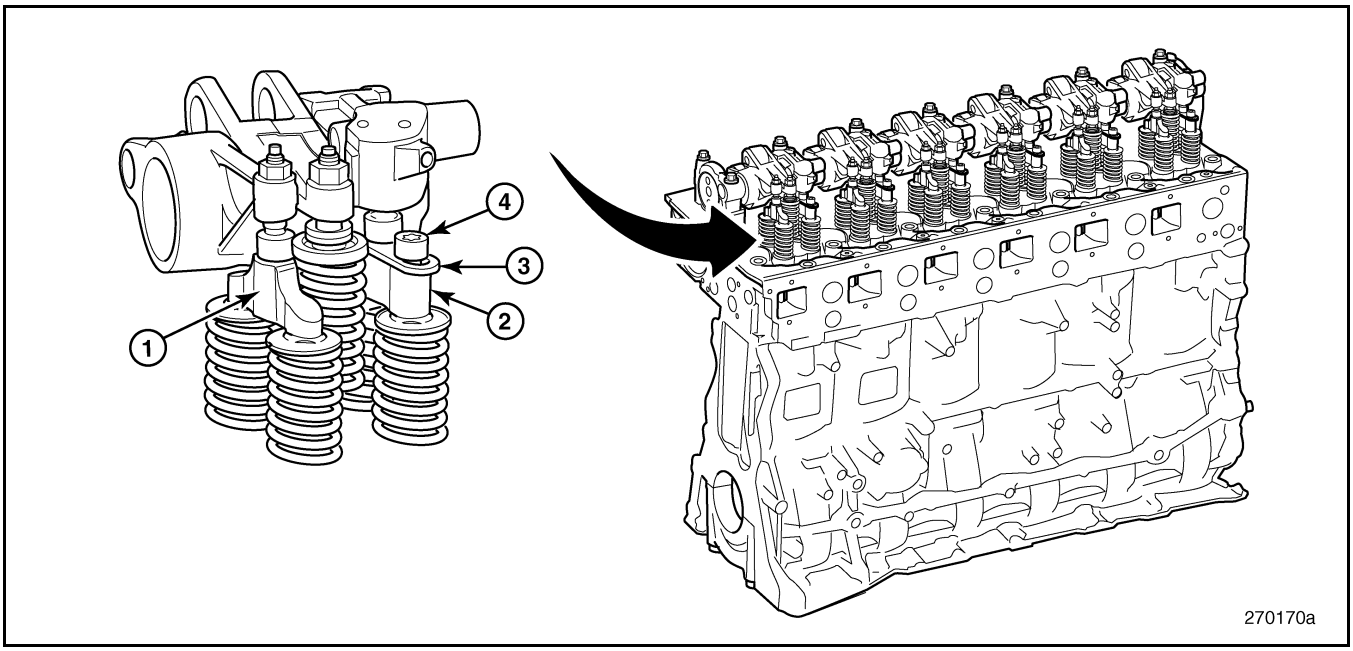


Figure 8 — Valve Train

1. Inlet Valve Yoke	3. Adjustment Shim
2. PowerLeash™ Exhaust Valve Yoke	4. Shim Clamping Screw

The camshaft is induction-hardened and can be ground to accept oversize bearings. Timing marks for valve and injector adjustment are located on the flange forward of the No. 7 camshaft journal.

Camshaft thrust washers are integral on the No. 7 journal bearing.

The PowerLeash™ camshaft differs from the regular by including two additional lobes (charging and decompression) on the exhaust cam. Two sets of timing marks on the PowerLeash™ camshaft provide for valve and injector adjustment. The letter **V** indicates the PowerLeash™ setting points. PowerLeash™ includes its own electronic control valve governed by driver's choice through a switch near the steering wheel. This control valve mounts on the left corner of the cylinder head by the use of two mounting bolts and an oil tube leading from the control valve to the rockershaft. The wiring harness includes additional wire leads for PowerLeash™.

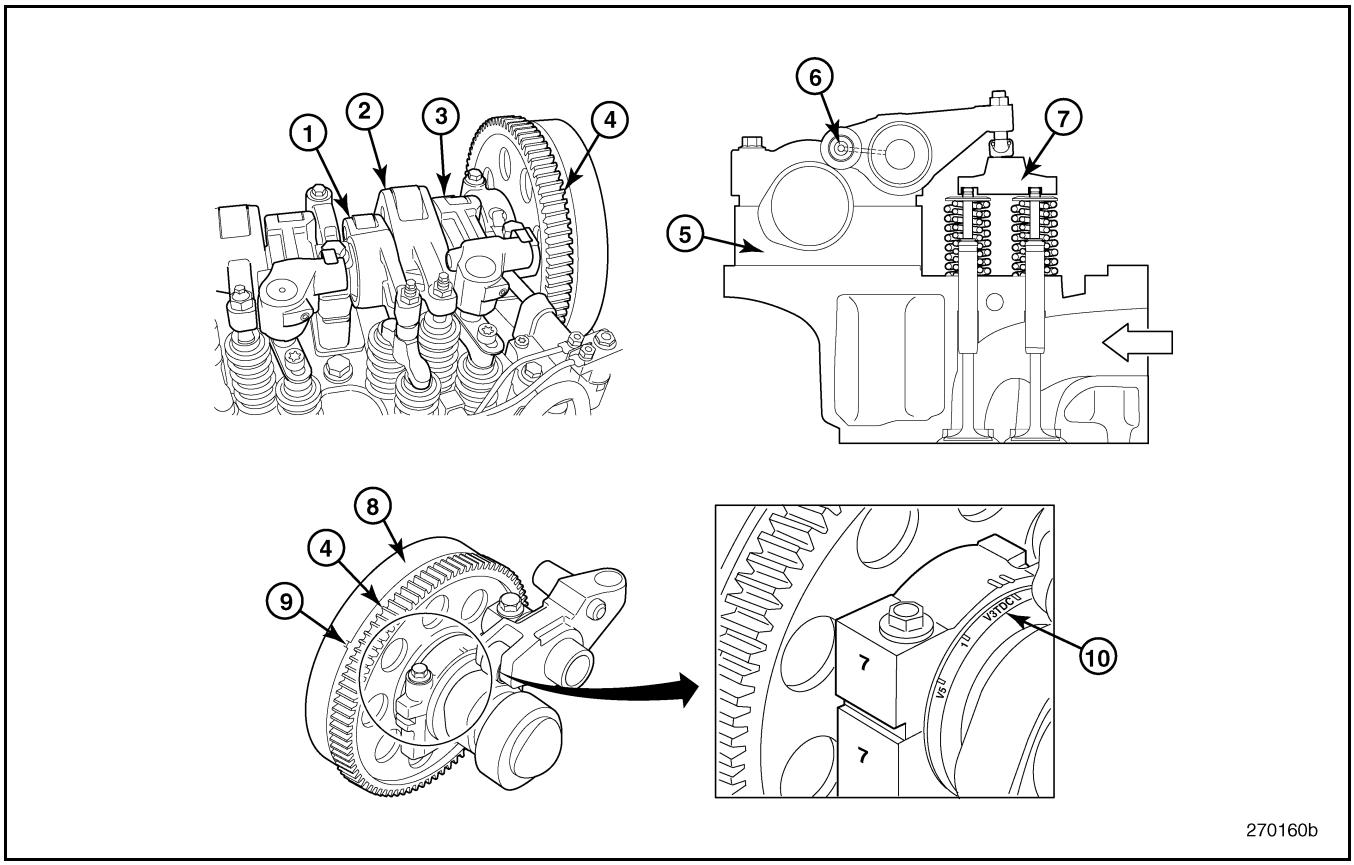


Figure 9 — Valve Timing Marks

1. Inlet Valve Rocker Arm	6. Rocker Arm Roller (Inlet Valves)
2. Injector Rocker Arm	7. Yoke (Inlet Valves)
3. Exhaust Rocker Arm	8. Camshaft Vibration Damper
4. Camshaft Gear	9. Camshaft Position Sensor Tooth
5. Lower Camshaft Bearing Cap	10. PowerLeash™ Timing Marks

CYLINDER BLOCK

The cylinder block is made of nodular cast iron. For increased cylinder block rigidity and noise and vibration reduction, a 5 mm (0.2 inch) thick steel stiffener plate attaches to the bottom.

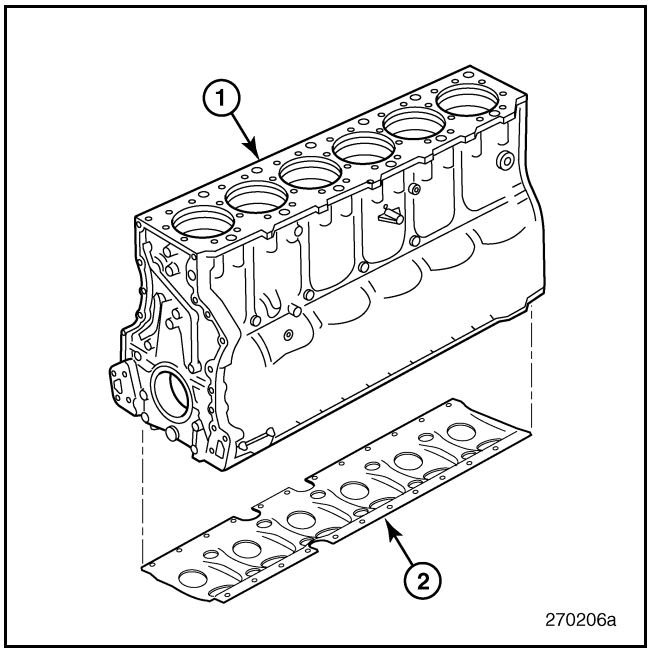


Figure 10 — Cylinder Block and Stiffener Plate

1. Cylinder Block	2. Block Stiffener Plate

Main bearing caps are made of nodular cast iron processed together with the cylinder block. Tapped hole location, cast alignment nipples on the block and caps and sleeves in the tapped holes in the block ensure proper alignment at installation. 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.

GUIDE PINS

In order to facilitate cylinder head installation, there are two guide pins in the cylinder block which match corresponding guide holes in the cylinder head.

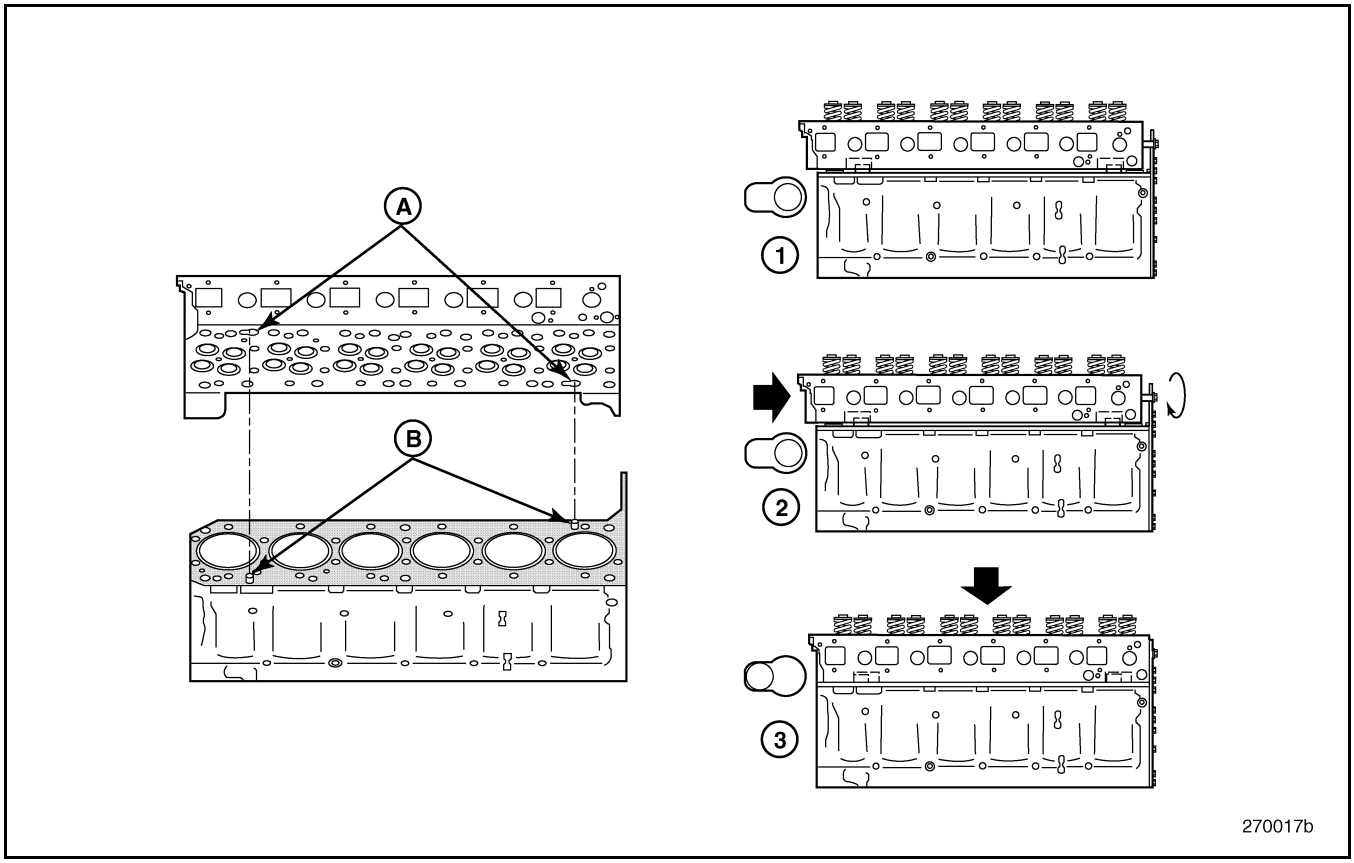


Figure 11 — Cylinder Head Alignment

A. Cylinder Head Locating Holes B. Guide Pins	1. Align Guide Pins and Holes 2. Draw Head to Timing Gear Mounting Plate 3. Fasten Head to Block

The pins allow the cylinder head to be lowered onto the cylinder block a short distance from the timing gear mounting plate. Screws passed through the timing gear mounting plate are tightened to pull the head into alignment with the block. The head gasket has small bosses stamped into its upper surface. These permit the head to slide without damaging the seals. The bosses flatten when the head is fastened to the block.

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.

When the cylinder head rests on the gasket and cylinder block, screws passed through the timing gear mounting plate pull it tight against the plate. 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.

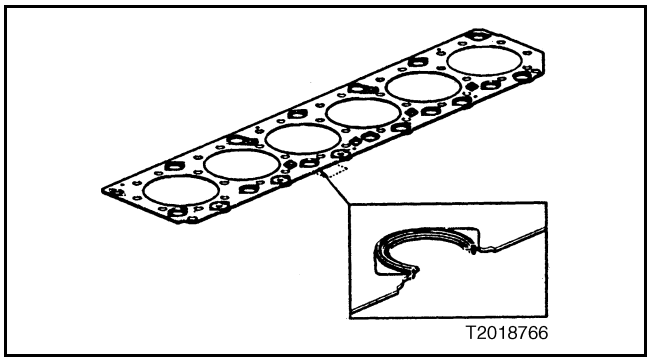


Figure 12 — Cylinder Head Gasket

CYLINDER LINERS

The cylinder block uses replaceable wet cylinder liners. The lower end of each liner is sealed against the cylinder block with two elastomer rings. The upper end is sealed with a ring of EDPM elastomer situated directly under the liner flange. 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 liner. The bottom seal is of a different material and fluorescent violet in color to distinguish it from the intermediate seal.

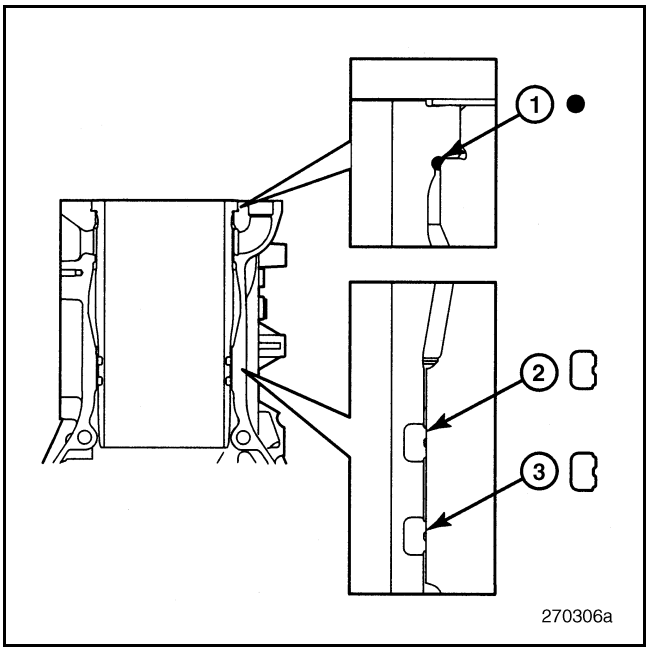


Figure 13 — Cylinder Liner and Seals

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

OIL PAN

The oil pan is steel with a threaded plug for draining. The pan has a groove in the mounting flange which accepts a molded elastomer gasket for a seal. Eighteen spring-loaded screws clamp the pan to the cylinder block.

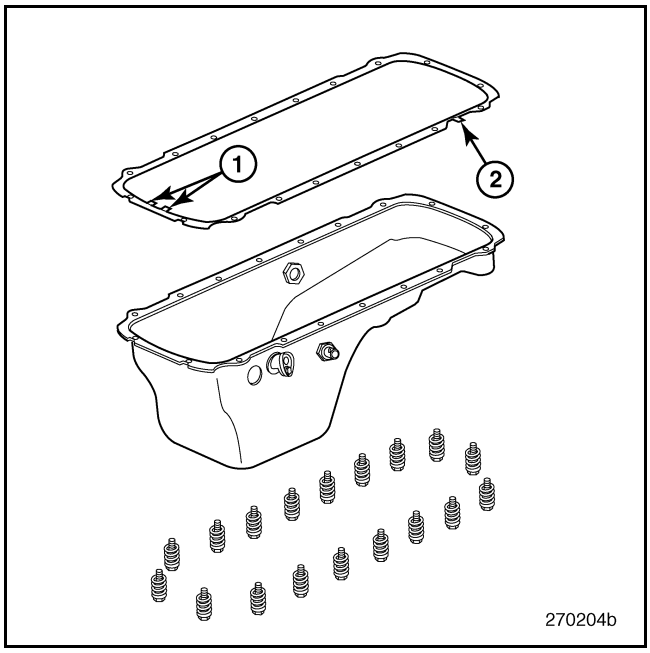


Figure 14 — Oil Pan and Gasket

1. Metal Tabs (Front of Engine)	2. Single Tab (Left Rear of Engine)

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

NOTE

The oil pan can be installed with the sump at the front or at the rear to accommodate chassis model (axle forward vs. axle back).

CRANKSHAFT

The crankshaft is drop forged steel. Bearing surfaces are 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.

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 block as removed and that the alignment boss on the bearing cap aligns with the boss on the engine block.

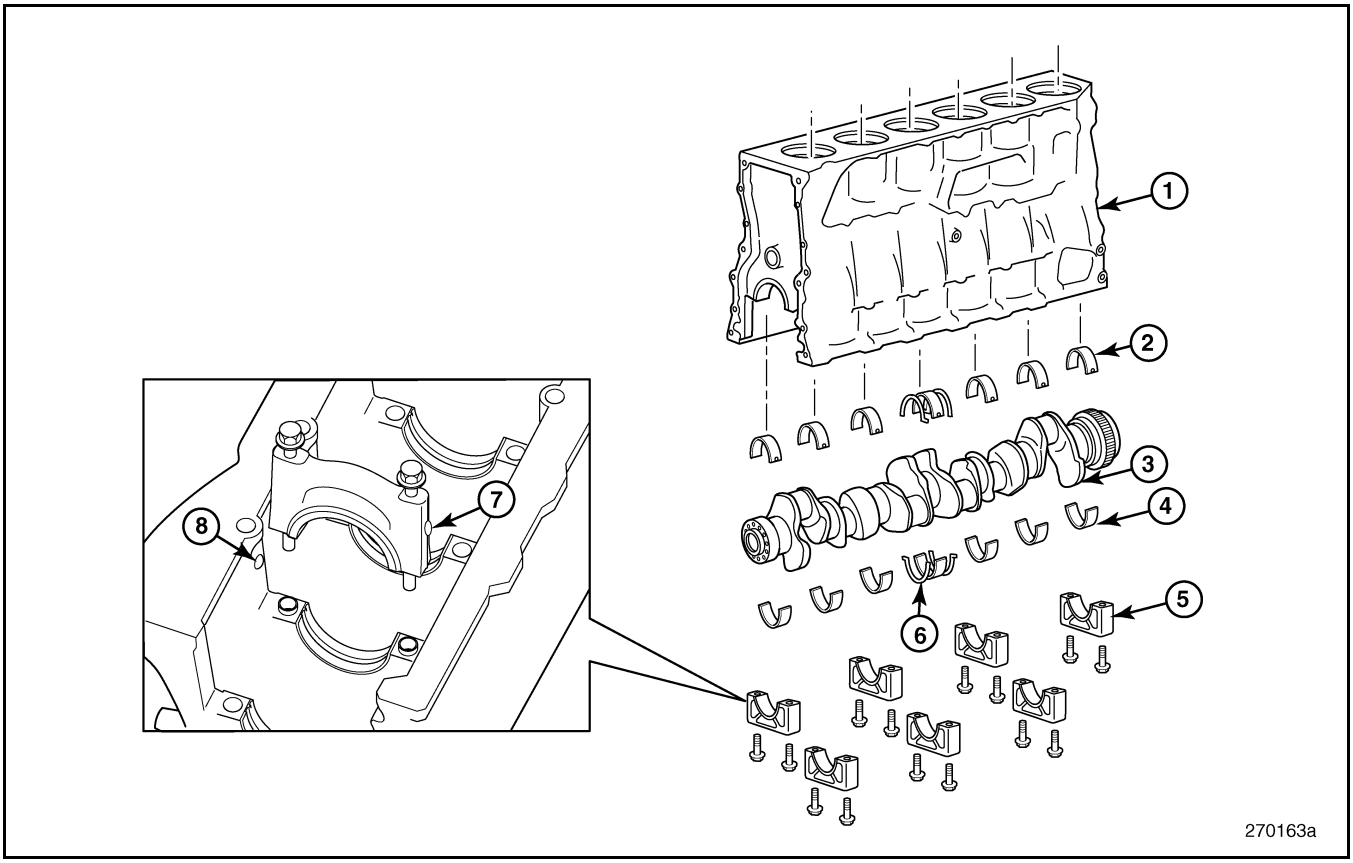


Figure 15 — Crankshaft

1. Cylinder Block	5. Crankshaft Bearing Cap
2. Upper Crankshaft Bearing	6. Lower Crankshaft Thrust Washer
3. Crankshaft	7. Cap Aligning Nipple — on Cap
4. Lower Crankshaft Bearing	8. Cap Aligning Nipple — on Block

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.

PISTONS AND CONNECTING RODS

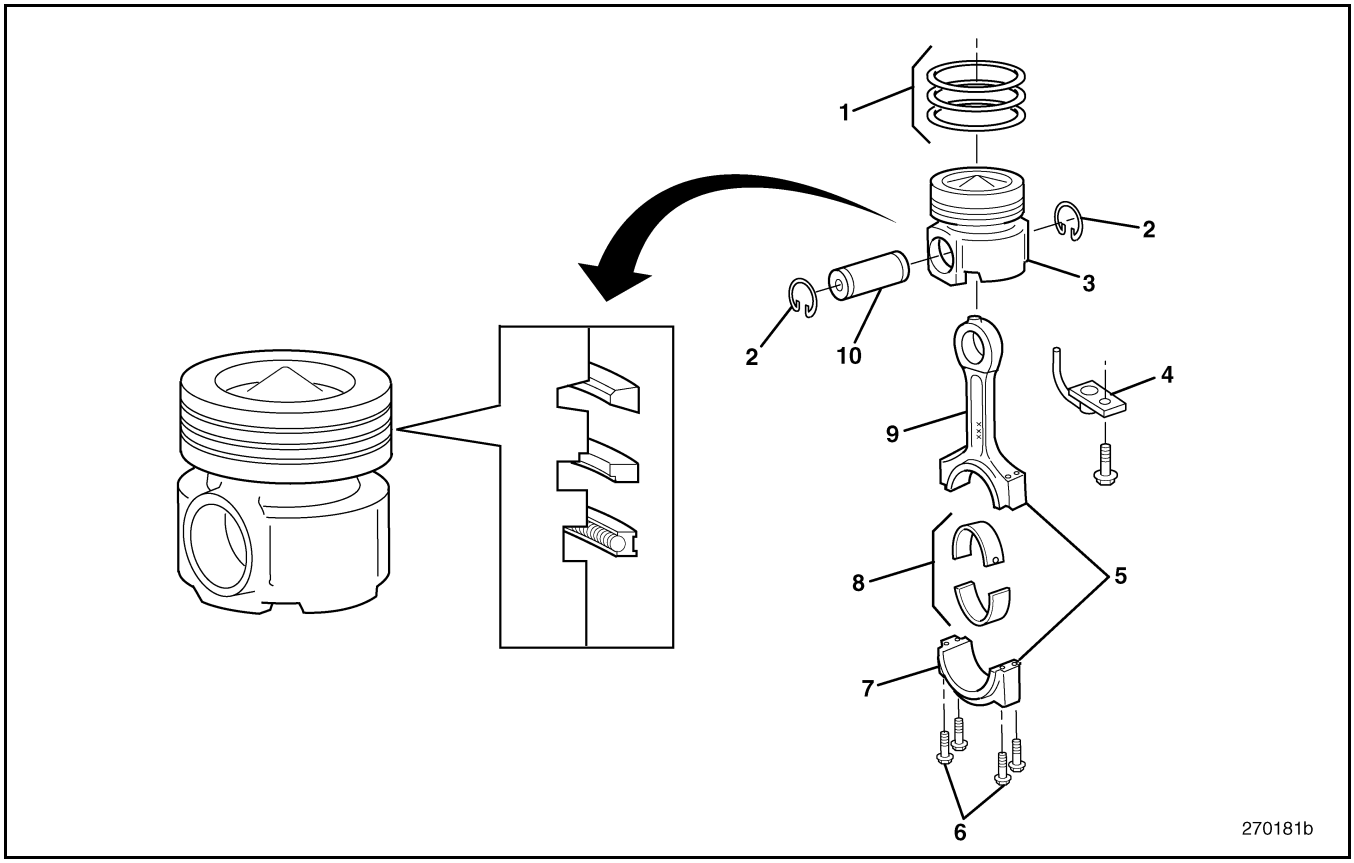


Figure 16 — Piston and Connecting Rod

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 M10 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.

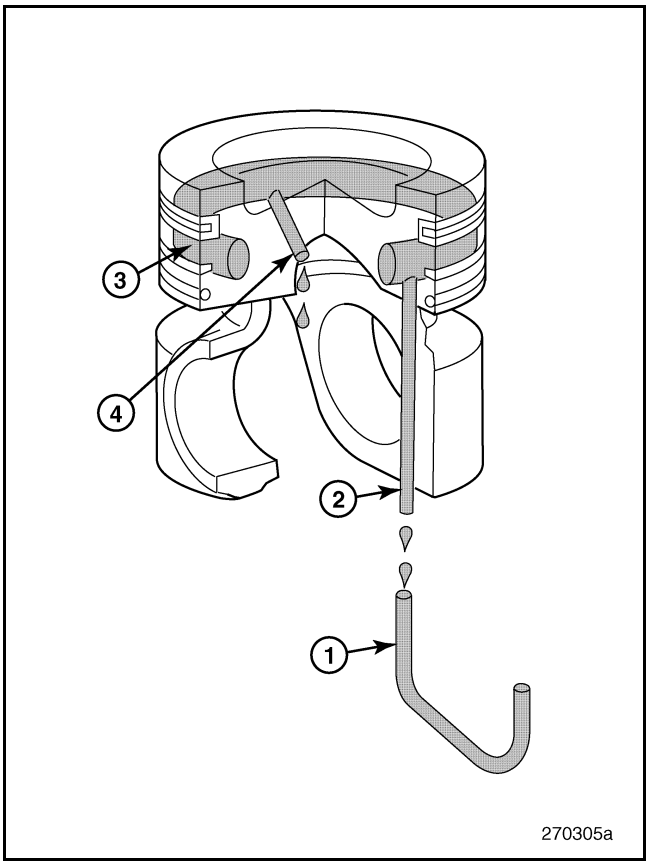


Figure 17 — Piston Cooling

1. Piston Cooling Nozzle	3. Circular Duct
2. Vertical Duct (Oil Inlet)	4. Outlet to Wrist Pin

The pistons are cooled by oil sprayed upward from a nozzle in the cylinder block into a vertical duct in the piston. The oil continues through a circular duct in the piston crown. It flows through the duct to the wrist pin journal where it passes through grooves in the bearing to lubricate the wrist pin.

TIMING GEARS

The timing gears are located at the rear of the engine. All of the gears are helical and nitride hardened. Backing up the gears is a mounting plate: a 6 mm (1/4 inch) thick steel sheet attached to the cylinder block. It is provided with two guide sleeves and a locating pin.

The advantages of this configuration are more precise timing, fewer components and lower noise levels. The two-piece flywheel housing also serves as the timing gear housing.

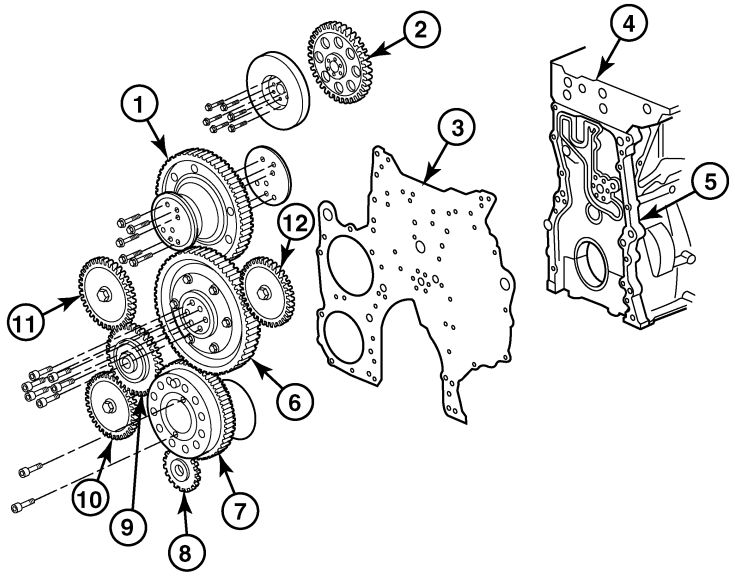


Figure 18 — Timing Gears and Mounting Plate

1. Adjustable Idler Gear	7. Crankshaft Gear
2. Camshaft Gear (with Vibration Damper)	8. Oil Pump Drive Gear
3. Mounting Plate	9. Auxiliary Idler Gear
4. Cylinder Head	10. Fuel and Power Steering Pump Drive Gear
5. Cylinder Block	11. Air Compressor Drive Gear
6. Double Idler Gearset	12. REPTO Drive Gear

The fuel/power steering pump drive gear (10) and the air compressor drive gear (11) are not timing gears. They fasten to their respective components and are driven via the auxiliary idler by the crankshaft 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

Depending on the vehicle, the fan location may be high or low on the fan bracket. Two poly-V belts drive the front engine accessories. The outer, primary belt (10 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.

Each belt uses an automatic tensioner. In the high position, 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. In the low position, the idler between the damper and fan pulleys is omitted.

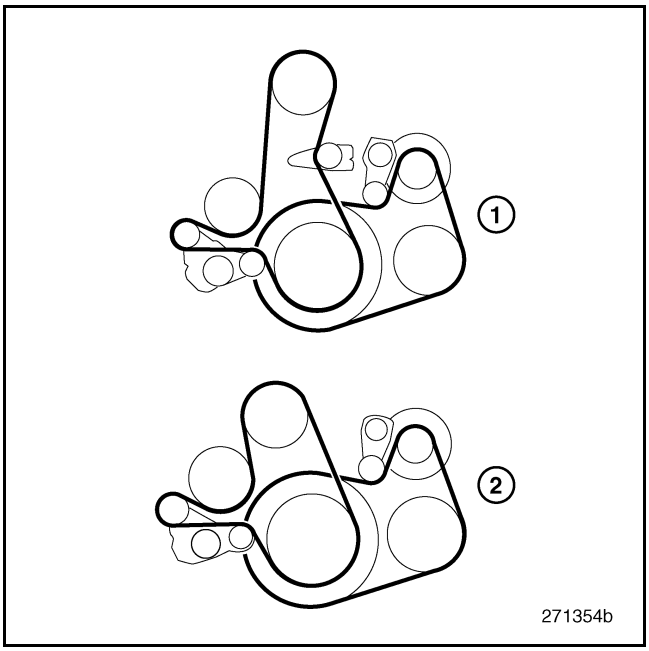


Figure 19 — Primary and Secondary Drive Belts — Conventional and LCF Chassis

1. Conventional Chassis	2. LCF Chassis

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.

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

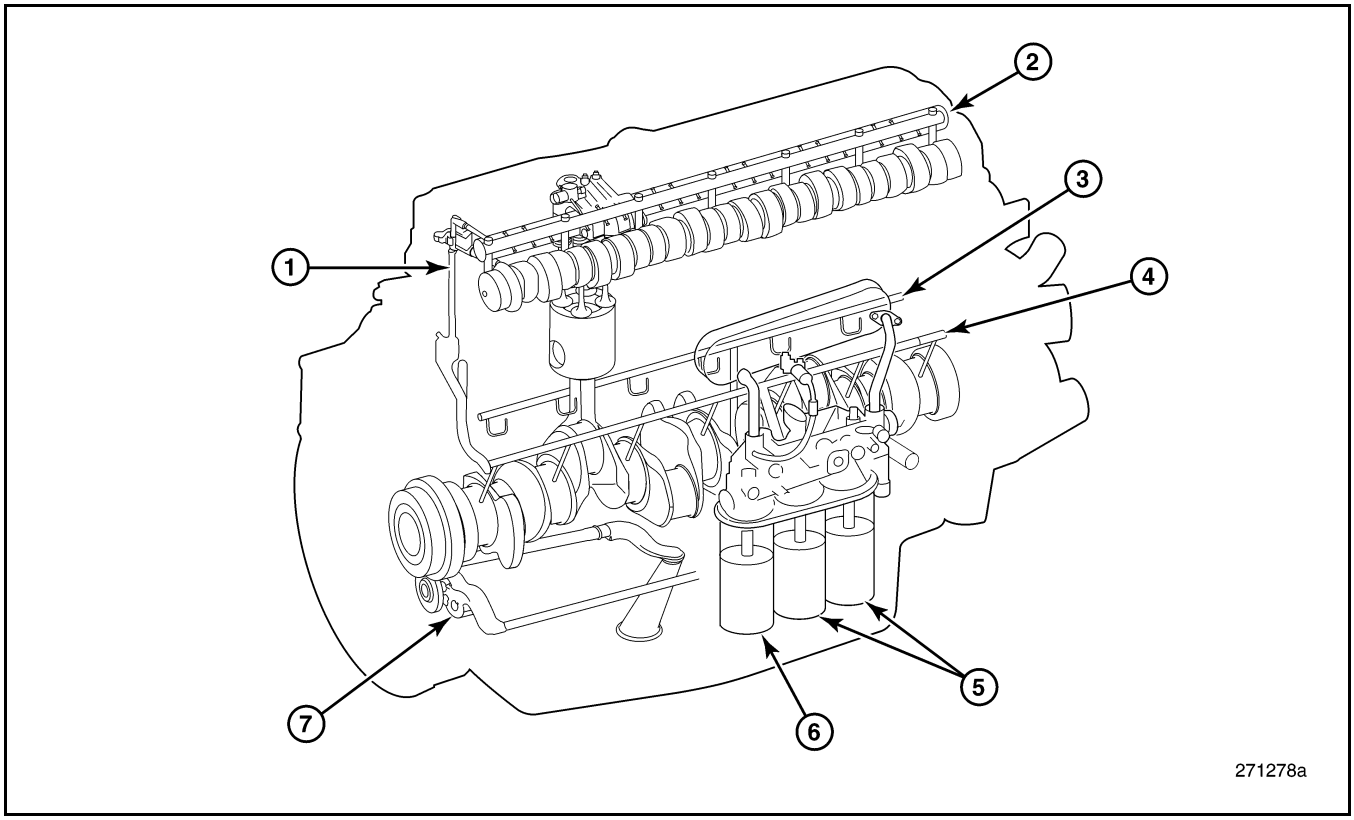


Figure 20 — Oil Pump and Supply Components

1. Oil Passage 2. Rocker Arm Shaft 3. Piston Cooling Passage 4. Crankshaft Passage	5. Full-Flow Filters 6. By-Pass Filter 7. Oil Pump

The oil pump assembly includes an aluminum pump housing and an oil distribution housing. The distribution housing is mounted on the cylinder block at bottom center and contains the system pressure relief valve. A tube connects the pump to the distribution housing. In the distribution housing, flow is divided sending lubricant to the piston cooling circuit and the crankshaft gallery. From the crankshaft gallery, it flows through the rest of the engine circuitry.

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

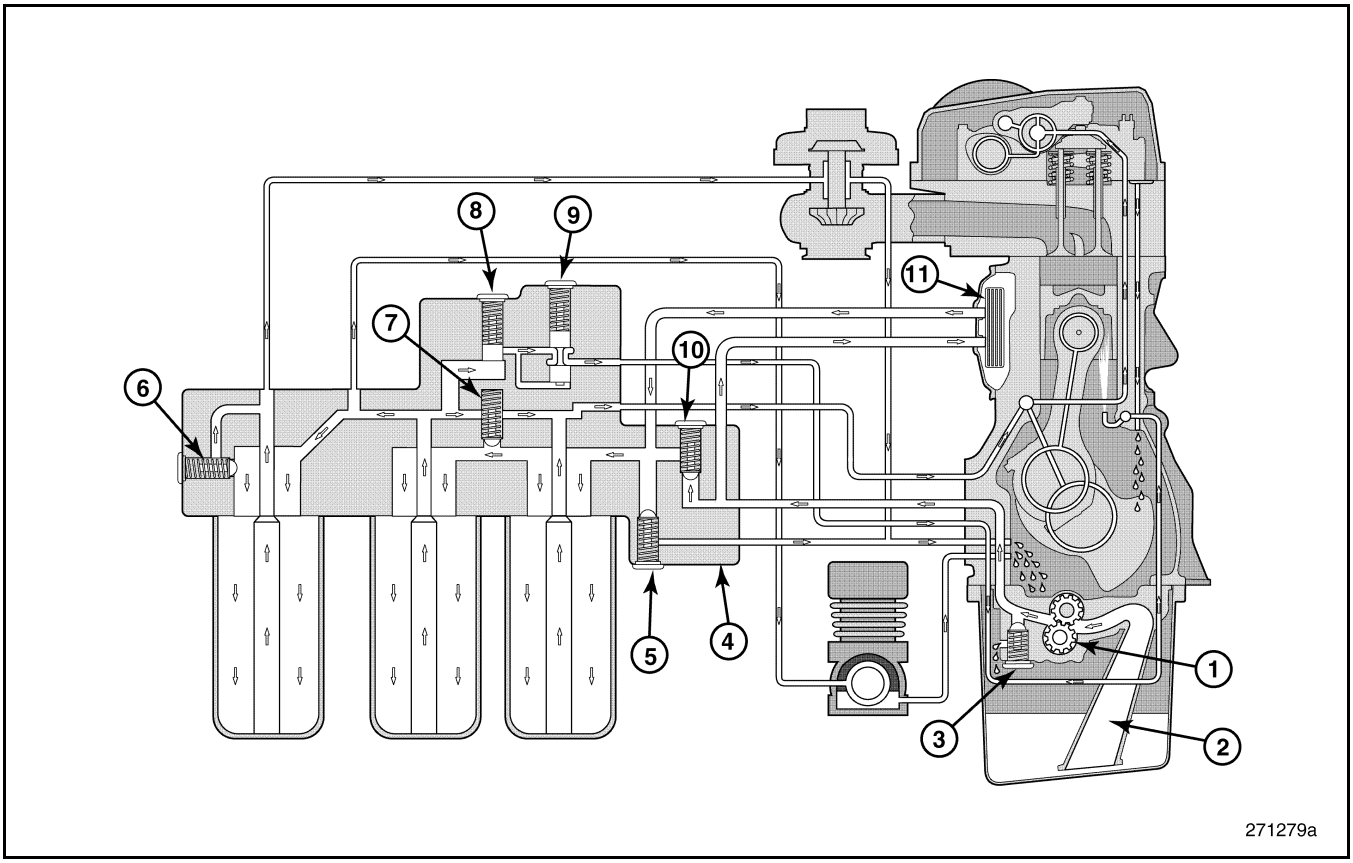


Figure 21 — Lubrication System Flow Diagram

1. Gear Pump 2. Strainer 3. Safety Valve 4. Oil Distributor Housing 5. Reduction Valve 6. By-Pass Filter Overflow Valve	7. Full-Flow Filters Overflow Valve 8. Piston Cooling Opening Valve 9. Piston Cooling Control Valve 10. Oil Cooler By-Pass Valve 11. Oil Cooler

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 seven valves, including:

- Safety Valve
- Reduction Valve
- By-Pass Filter Overflow Valve
- Full-Flow Filters Overflow Valve
- Piston Cooling Opening Valve
- Piston Cooling Control Valve
- Oil Cooler By-Pass Valve

The full-flow filters overflow valve directs oil flow through the by-pass filter when the lubrication system fills to capacity. The safety valve opens to return oil to the oil pan when the oil pressure reaches the set point. The oil cooler by-pass valve prevents oil from circulating into the oil cooler until the oil temperature reaches the set point.

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.

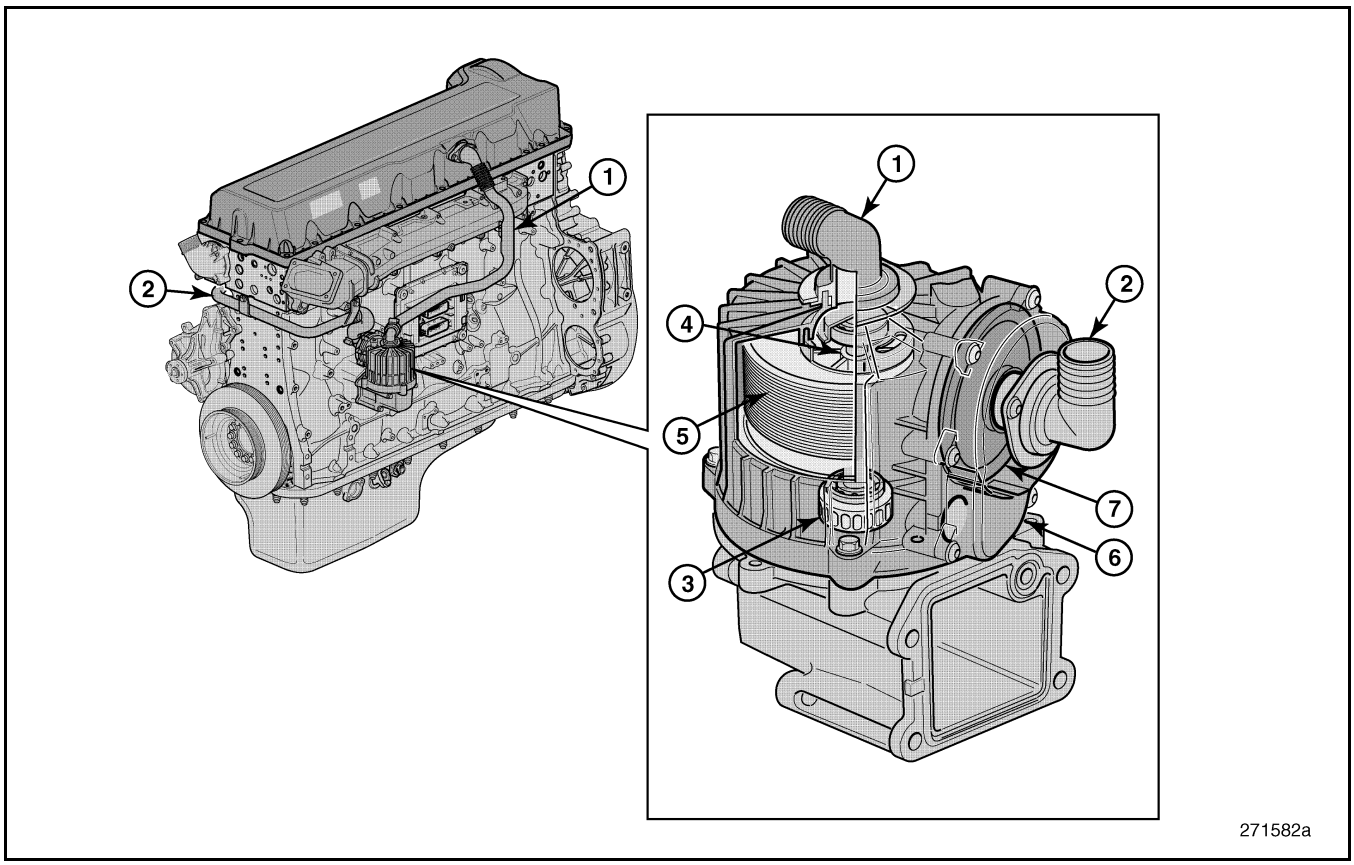


Figure 22 — Crankcase Ventilation System Separator

1. Separator Inlet Hose and Connector 2. Separator Outlet Hose Connector 3. Turbine 4. Drive Shaft	5. Separator Discs 6. Pressure Regulator 7. Pressure Regulator Diaphragm

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. Optionally, the open port may be connected to the turbocharger inlet to close the system. This returns the unburned fuel to the combustion process. In the closed system, a pressure regulator stops the small turbine when the system pressure falls below a safe point.

Fuel System

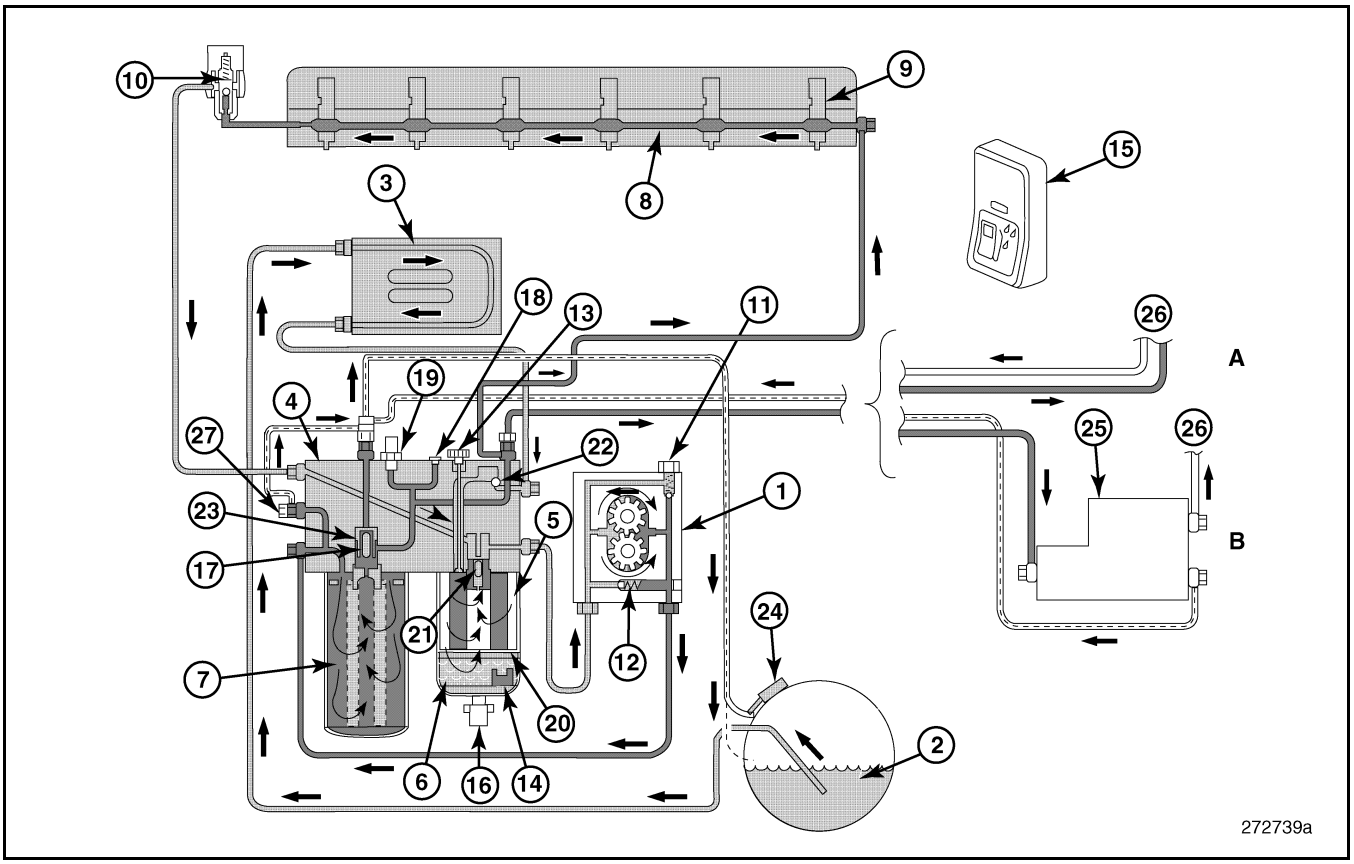


Figure 23 — Fuel System Diagram

1. Fuel Pump 2. Fuel Tank and Inlet Tube 3. EECU Cooler 4. Fuel Filter Housing 5. Fuel Pre-Filter 6. Water Cup 7. Full-Flow (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) 16. Electrical Water Drain Valve 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 25. AFI Shut-Off Valve 26. To Aftertreatment Fuel Injector (AFI) 27. Deaeration Valve
A. With Non-Catalyzed DPF	B. With Catalyzed DPF

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 minimum 100 kPa (14.5 psi); and at 1200 rpm, 300 kPa (43.5 psi). At 400–550 kPa (58–80 psi), the fuel pressure 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 and draining water. The 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

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.

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 fuel filter housing is the fuel pressure sensor just above the secondary filter.

NOTE

Some trucks are built with a remote mounted fuel water separator. In this case, the fuel is drawn through the remote mounted filter before it reaches the ECU cooler plate. On the filter base, the mounting location for the standard primary filter is blocked off with a plate.

UNIT INJECTORS

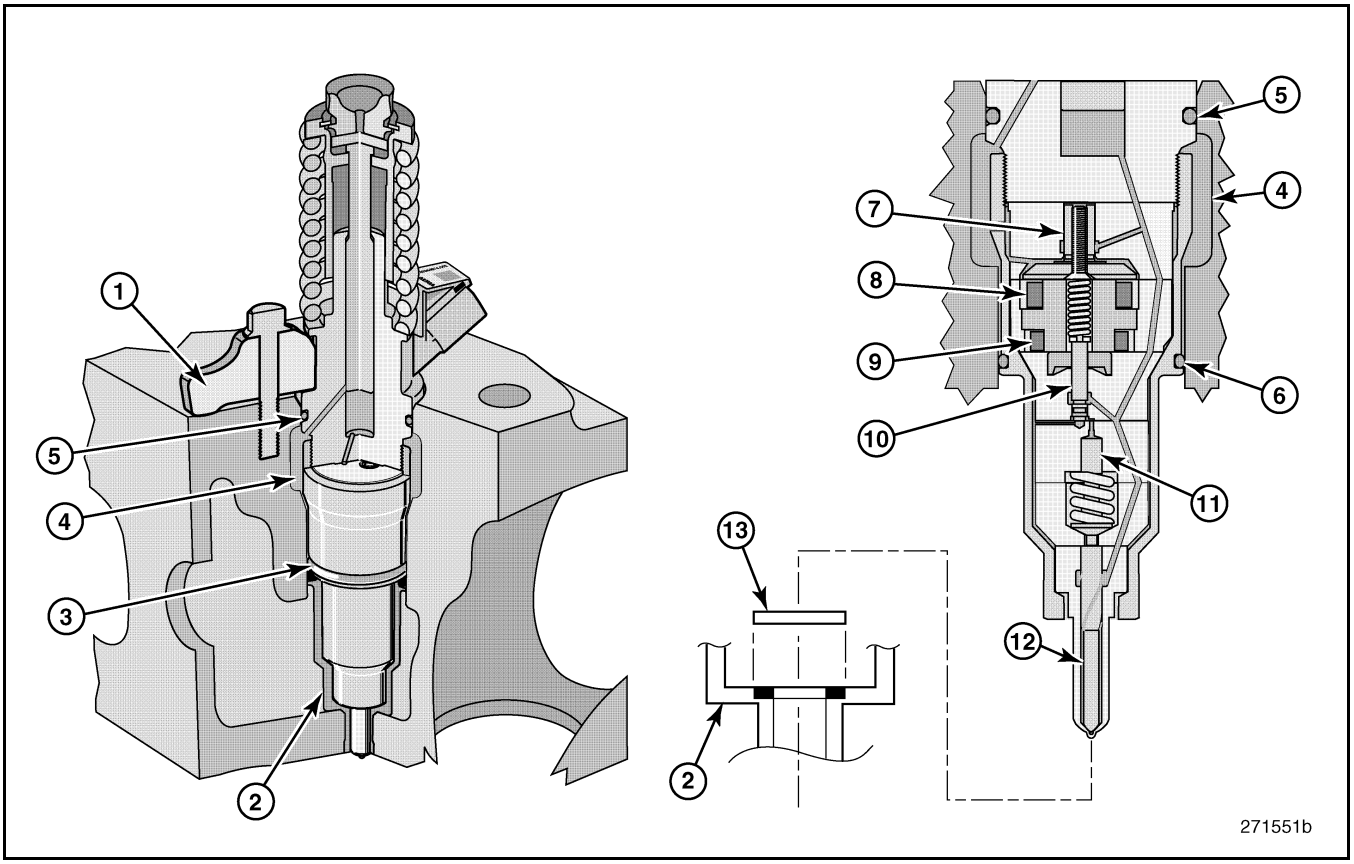


Figure 24 — Unit Injector Diagram

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

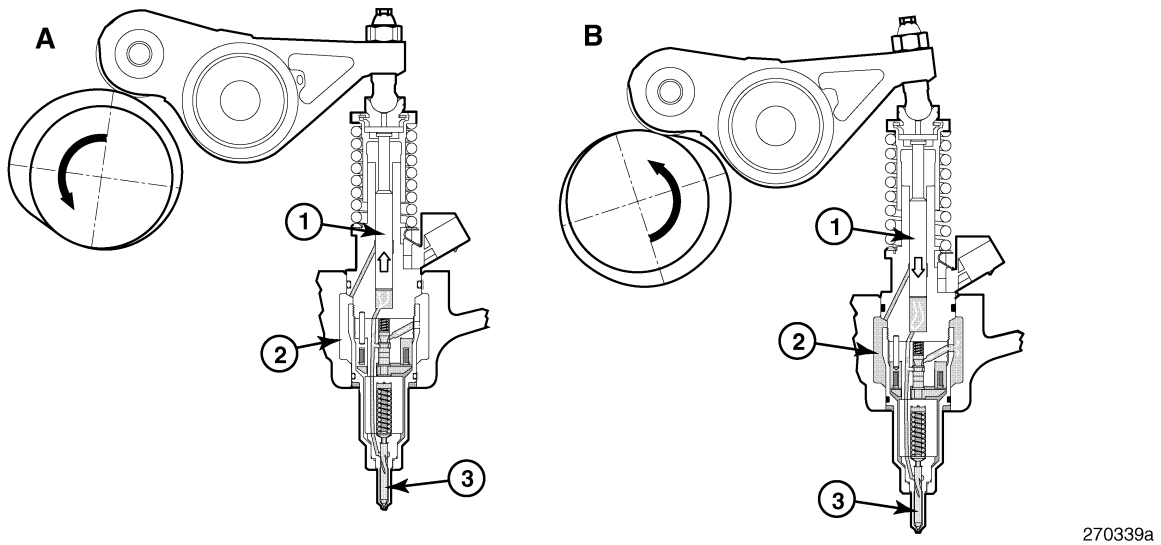


Figure 25 — Unit Injector — Fill and Spill Phases

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.

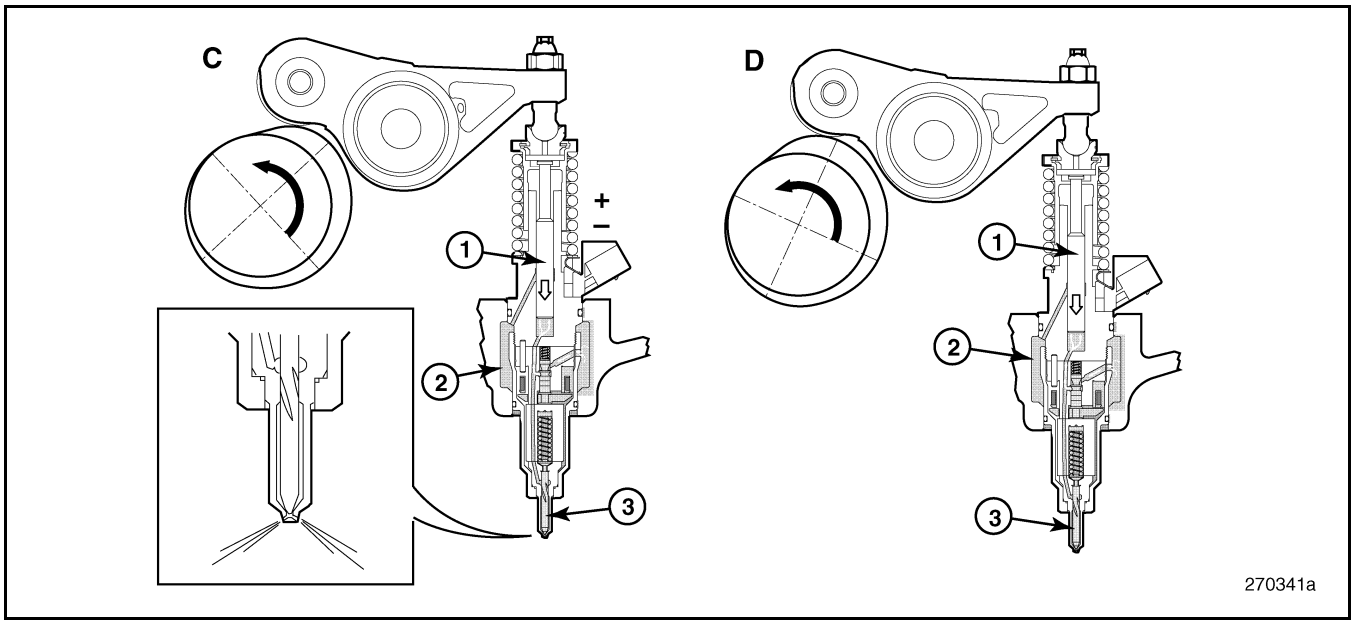


Figure 26 — Unit Injector — Injection and Pressure Drop Phases

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 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.

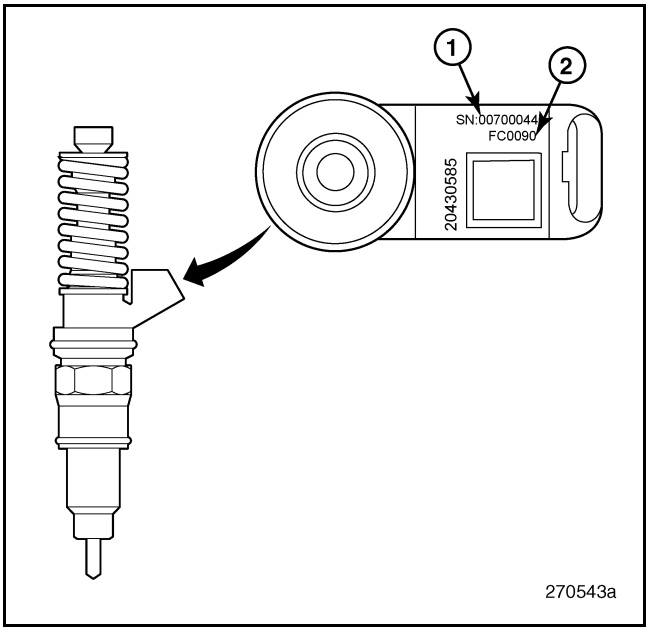


Figure 27 — Injector Coding

1. Serial No.	2. Unit Calibration No.

PowerLeash™ Engine Brake

The engine is equipped with a PowerLeash™ system to assist in slowing the vehicle when necessary. The system includes special:

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

There are two small lobes on the exhaust cams in addition to the regular lobe. Their locations are timed to open the exhaust valves at the end of the induction stroke and immediately before TDC on the compression stroke.

The exhaust rocker arms are sturdier than standard and are equipped with a blade spring which keeps the exhaust rockers in contact with the valve yokes.

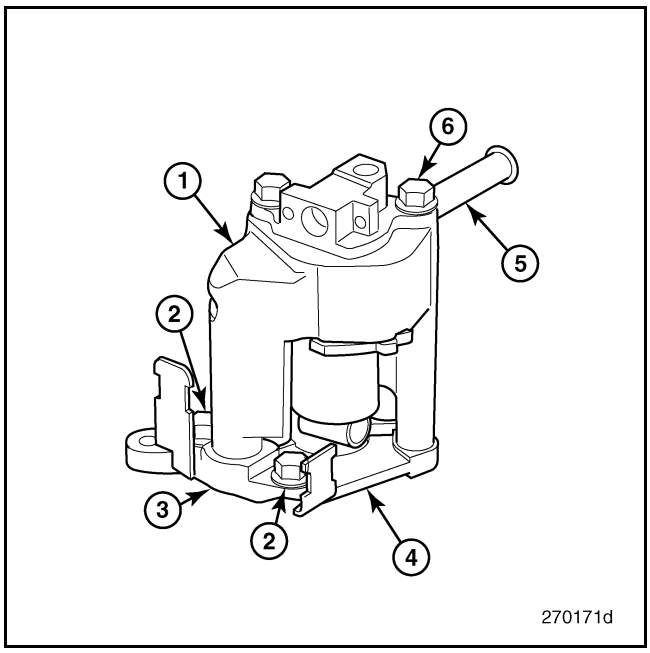


Figure 28 — PowerLeash™ Oil Control Valve

1. Solenoid Control Valve 2. Mounting Plate Attaching Screws 3. Mounting Plate	4. Oil Seal 5. Oil Tube 6. Valve Attaching Screws

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 above 50 kPa (7.25 psi)

On the cylinder head at rear, 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.

A switch on the instrument panel allows the driver to engage or disengage PowerLeash™. 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 resistance 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.

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.

An oil port located in the rear on the right side of the cylinder head and above the EGR valve allows access to the oil passageway. The plug can be removed and a gauge and hose assembly inserted for use during diagnostic procedures.

System Oil Pressure		
RPM	**Temperature**	**Pressure**
600	90–110°C (194–230°F)	>250 kPa (>36 psi)
>1100	90–110°C (194–230°F)	300–550 kPa (44–80 psi)
>1100	Cold Engine	650 kPa (94 psi)

Camshaft Oil Pressure		
Engine Brake	**RPM**	**Pressure**
Active	900–2300	220 kPa (32 psi)
Inactive	—	80–120 kPa (12–17 psi)

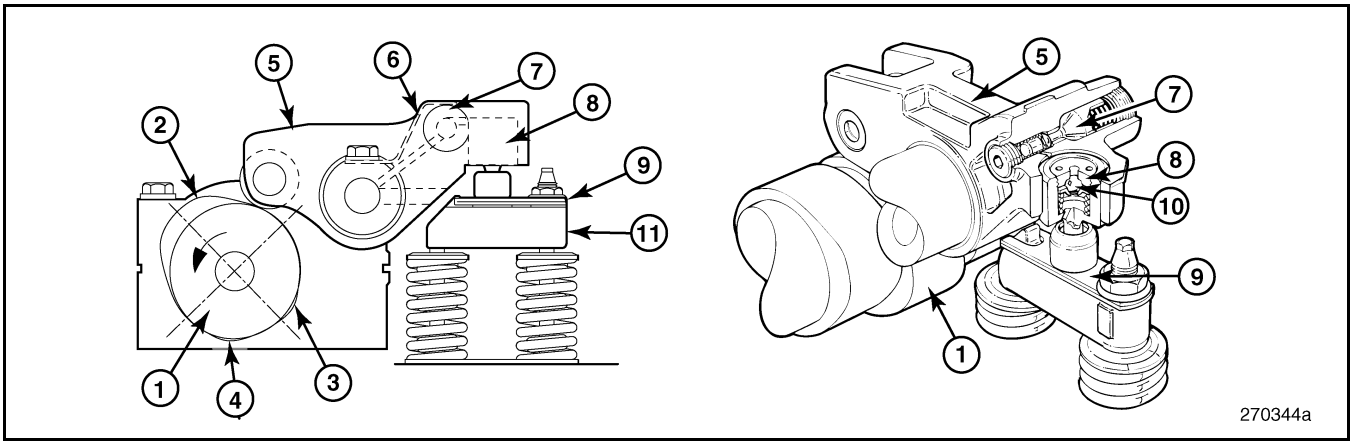


Figure 29 — PowerLeash™ Exhaust Rocker Arm — Components

1. Camshaft 2. Exhaust Cam Profile 3. Charging Cam Profile — Induction Stroke 4. Decompression Cam Profile — Compression Stroke 5. Exhaust Rocker Arm 6. Blade Spring	7. One-Way Valve 8. Plunger 9. Adjustment Shim 10. Pressure Relief Valve 11. Yoke, Exhaust Valve

The rocker arms are sturdier than standard, and they are equipped with blade springs. The rocker arms also contain a one-way valve and a plunger. The one-way valve remains open while the accelerator pedal is depressed. Oil flows either way.

The blade spring maintains positive contact between the plunger and the yoke at all times. On deceleration, pressure (increased by the oil control valve) causes the one-way valve to close raising the pressure on the plunger. The plunger moves to set and maintain zero valve clearance.

Exhaust Gas Recirculation System

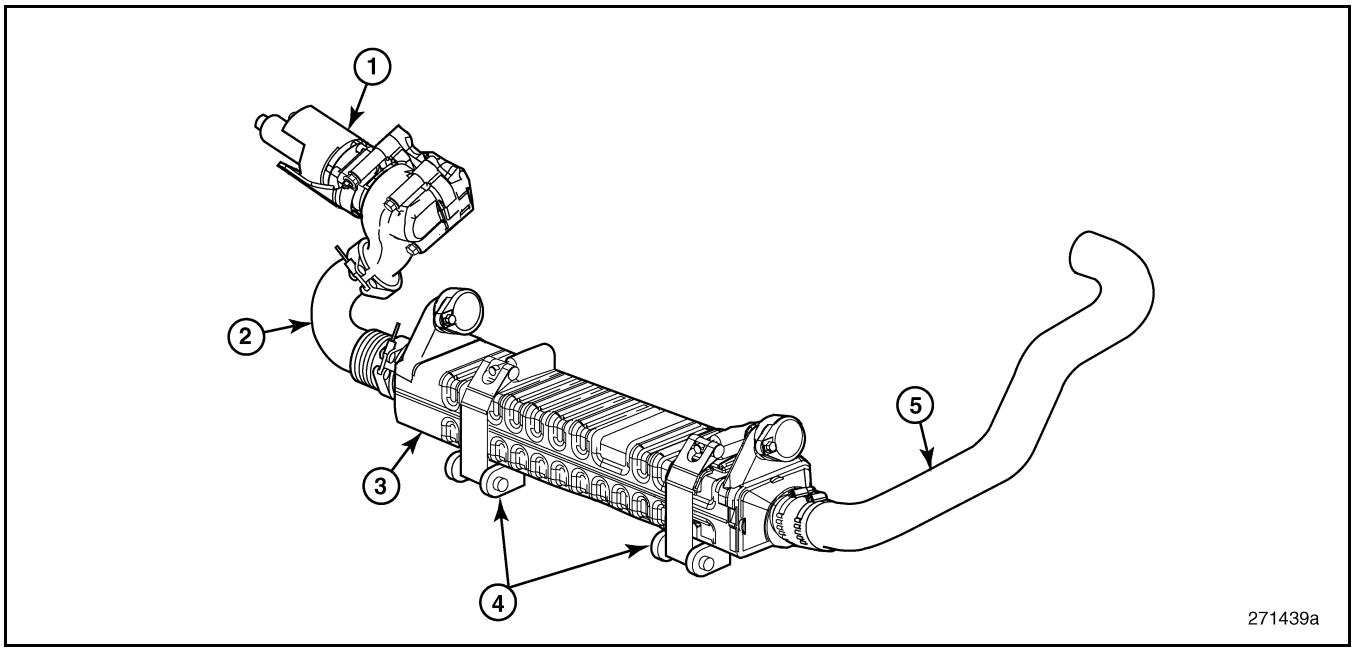


Figure 30 — MP7 EGR System — Right Side

1. EGR Valve 2. EGR Cooler Inlet Pipe 3. EGR Cooler	4. Cooler Mounting Brackets 5. EGR Crossover Pipe

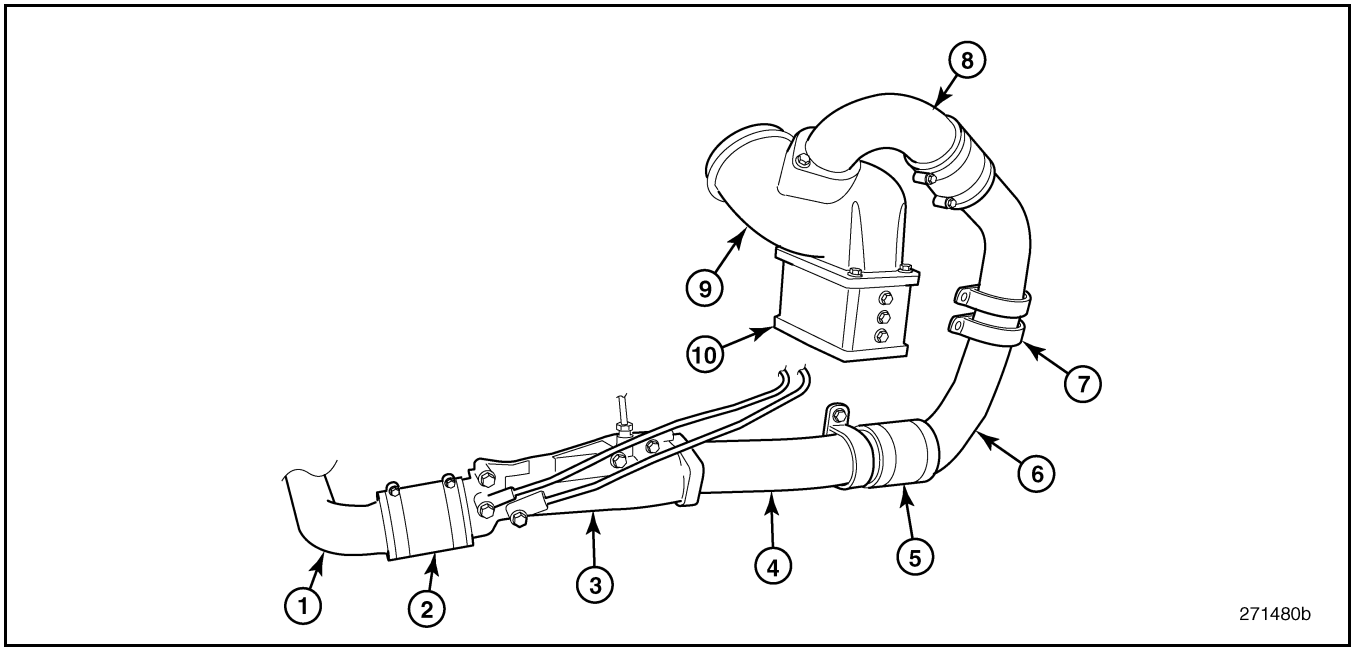


Figure 31 — MP7 EGR System — Left Side — LCF Chassis

1. EGR Crossover Pipe 2. Connecting Hose with Clamps 3. Venturi Housing with Sensors 4. Venturi Outlet Pipe 5. Connecting Hose with Clamps	6. Intermediate Mixer Inlet Pipe 7. Bracket with U-Bolts 8. Mixer Inlet Pipe 9. EGR/Inlet Air Mixer 10. Inlet Air Heater (Optional)

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 reducing NOx.

EGR systems are configured differently for the LCF 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 toward the rear of the manifold. This requires differences in the piping from the EGR cooler to the mixer.

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

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.

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

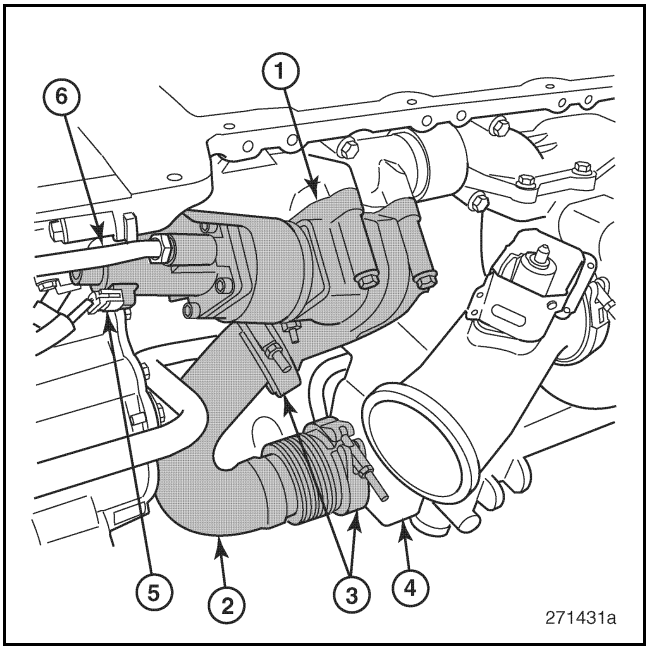


Figure 32 — EGR Valve and Cooler Inlet Pipe

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

The cooler inlet pipe conducts the exhaust from the EGR valve to the EGR cooler where its temperature is reduced prior to being reintroduced into the combustion chamber.

EGR COOLER

Using engine coolant, the EGR cooler lowers the temperature of exhaust 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 EGR mixing chamber with air from the charge air cooler. The swirling action also reduces undesirable solids in the exhaust gas.

EGR CROSSOVER (COOLER OUTLET) PIPE

The EGR crossover pipe carries the exhaust gas from the EGR cooler to the venturi. The tube passes in front of the cylinder block behind the fan mounting bracket. It is connected to the venturi on the left side of the block.

EGR VENTURI SYSTEM

The gas flows through a venturi equipped with two differential pressure sensors. The venturi changes the speed and density of the flow. The sensors report the pressure difference to the EECU.

The venturi system is calibrated as a unit. If replacement is required, the entire assembly along with the sensors must be replaced as a unit.

EGR MIXER

On a conventional chassis, the piping from the venturi returns upward to the EGR mixer at the front of the inlet manifold above the cylinder head (valve) cover.

On an LCF chassis, the piping from the venturi continues rearward to the EGR mixer mounted on top near the rear of the inlet manifold.

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 (OPTIONAL)

The inlet air heater mounts between the mixer and the inlet manifold. The heater maintains a constant temperature of the air inducted into the combustion chamber. Constant air temperature combined with constant fuel temperature maximizes power output and fuel economy and minimizes noxious emissions.

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.

The temperature sensor provides information to the EECU about the temperature of the exhaust gases after the EGR cooler.

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.

Exhaust Aftertreatment System

New, stringent standards for exhaust emission control begin with the 2007 model year. The Exhaust Aftertreatment System (EATS) has been developed to act in combination with Ultra Low Sulfur Diesel (ULSD) fuel and the EGR system to reduce noxious emissions to meet the requirement. This new system treats the exhaust after it leaves the turbocharger on its way to the atmosphere.

EXHAUST GAS RECIRCULATION

Diesel engine combustion does not burn all of the combustible materials injected at each stroke. The mixture of soot and ash and unburned material, if allowed to enter the atmosphere, creates harmful substances. Exhaust Gas Recirculation (EGR) forces a quantity of the exhaust gas back into the combustion chamber. The net result is that a smaller quantity of undesirable (noxious) ingredients reaches the atmosphere.

Reducing the quantity of noxious compounds to an acceptable level beginning in the year 2007 requires altering their chemical composition. Directing the flow of exhaust gas through catalytic and particulate filters makes this happen.

PARTICULATE MATTER

The compounds remaining in the exhaust after passing through the EGR system contain extremely small particles of soot and ash called particulate matter (PM). When these particles contact certain metals under high temperature, they are chemically transformed. The metals that cause this transformation are called catalysts.

CATALYTIC FILTERS

A catalytic filter (converter) is a porous form (like a sponge) that has been coated with a catalytic material. The flow of exhaust gas must pass through the pores on its way to the atmosphere. As a result, a high percentage of the PM is transformed.

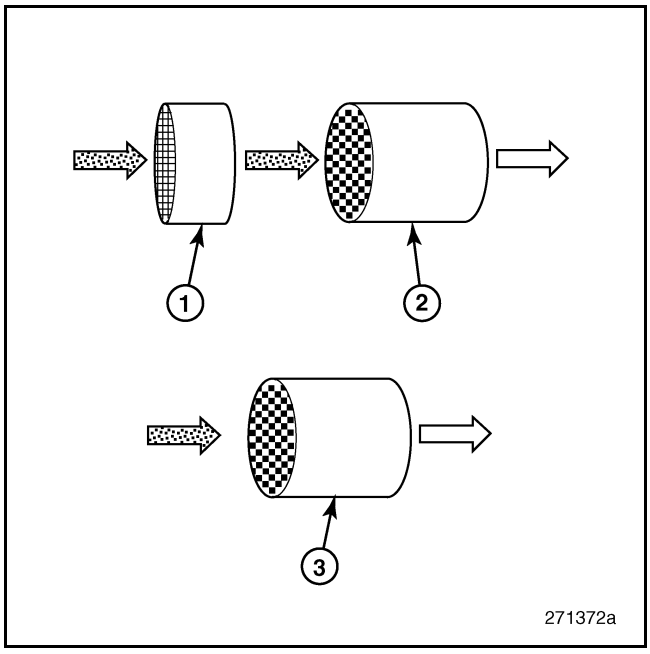


Figure 33 — Diesel Particulate Filter Diagrams

1. Diesel Oxidation Catalyst 2. Catalyzed Diesel Particulate Filter	3. Non-Catalyzed Diesel Particulate Filter

DIESEL OXIDATION CATALYST

A catalytic filter, the diesel oxidation catalyst (DOC) reduces emissions in diesel exhaust by an average of approximately one third over a system without a DOC. Its honeycomb-like structure (called substrate) is coated with an active catalyst. The PM is changed to carbon dioxide and water. The substrate can be made of a wide range of materials. Ceramic (cordierite) and sintered metal are common.

Some PM usually remains unconsumed by the heat and collects on the filter. Eventually, the residue must be removed by other means. Remove the filter and physically remove the remaining material. There is a special machine to do this cleaning.

DIESEL PARTICULATE FILTER

Basically a trap, a diesel particulate filter (DPF) collects the soot and ash to hold until they can be burned off. A catalyzed DPF also transforms unburned fuel, engine lubricant and carbon monoxide into carbon dioxide and water.

Depending on vehicle vocation, the operating temperature of the exhaust may or may not be sufficient to consume the trapped soot and ash. If necessary, a means of elevating the temperature is included in the system.

FILTER REGENERATION

Cleaning a filter so it can continue to function is called “regeneration.” High heat with a catalyst breaks down the chemical properties. Depending on the vehicle usage, the engine will be equipped with a passive or an active regeneration system.

As with any filter, eventually the DOC and the DPF will become clogged. Rising back pressure caused by plugging the exhaust system decreases fuel economy and reduces engine efficiency. It is necessary to clean these filters from time to time.

The filters can be regenerated to continue in use. The high temperature needed to complete the process exists in the exhaust itself. Because some vehicle vocations do not allow the exhaust temperature to rise to, or continue at, adequate levels, a device to control the temperature is included.

PASSIVE REGENERATION

For vehicles that produce and maintain adequate exhaust temperature, the soot and ash are consumed at a rate that prevents clogging the filter prematurely. Setting a DOC ahead of the catalyzed DPF in the exhaust stream reduces the temperature required to regenerate the filters.

However, the process is not complete. Eventually, the filter must be taken out to remove the accumulated residue by other means.

ACTIVE REGENERATION

For vehicles that are unable to develop or sustain adequate temperature, there is more than one system for supplying sufficient heat.

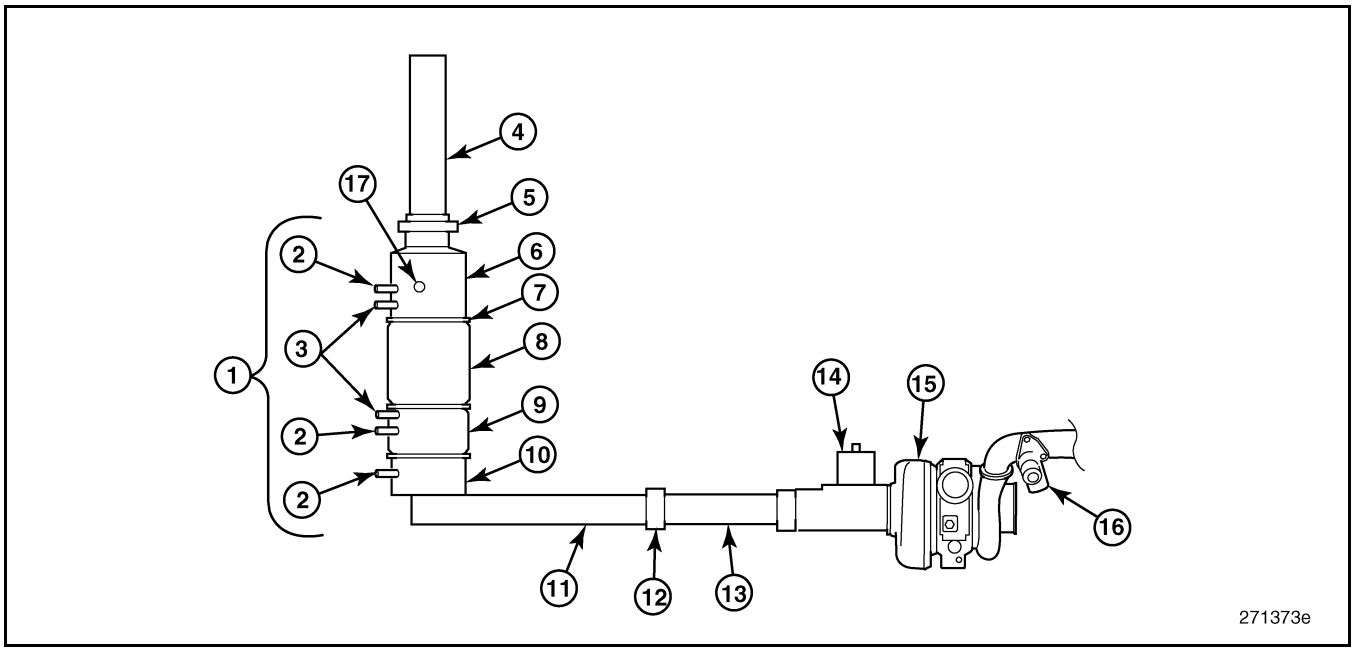


Figure 34 — DPF Catalyzed System Diagram

1. DPF Muffler	10. Inlet Module
2. Temperature Sensors	11. Exhaust Pipe
3. Delta Pressure Differential Sensor	12. Hose Clamp
4. Stack Pipe	13. Flex Pipe
5. Pipe Clamp	14. Aftertreatment Fuel Injector
6. Outlet Module	15. Turbocharger
7. Clamp	16. Discharge Recirculation Valve
8. Filter	17. NOx Sensor
9. Catalyst	

In the catalyzed system (Figure 34), an aftertreatment fuel injector (AFI) adds fuel to the exhaust stream as it leaves the turbocharger. The temperature of the exhaust at this point is hot enough to ignite the fuel which then produces the temperature required to clean the filters. If needed, the discharge recirculation valve (DRV) reroutes some of the turbocharger output back through the turbocharger. This helps to maintain high exhaust temperature. The engine electronic control unit (EECU) controls the cycle based on information from back pressure sensors in the output stream. While the flow rate is correct, the AFI and the DRV are turned off.

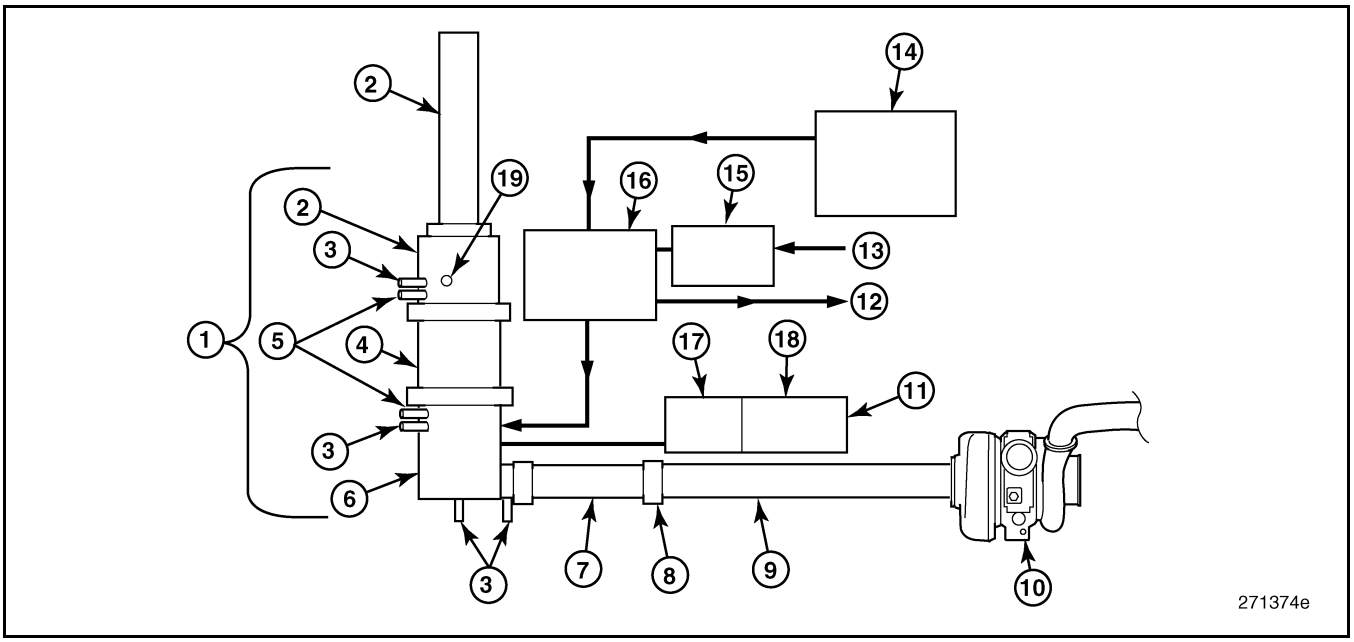


Figure 35 — DPF Non-Catalyzed System Diagram

1. DPF Muffler	11. Inlet Manifold
2. Muffler and Exhaust Stack	12. Fuel Return
3. Temperature Sensors	13. Fuel Supply
4. Diesel Particulate Filter	14. Air Tank
5. Delta Pressure Differential Sensor	15. Fuel Pump
6. Combustion Chamber Assembly	16. Atomization Block
7. Flex Pipe	17. Check Valve
8. Hose Clamp	18. Solenoid Valve
9. Exhaust Pipe	19. NOx Sensor
10. Turbocharger	

In the non-catalyzed system (Figure 35), compressed air and fuel combine with the exhaust gases in an enclosed space. An electrode ignites the mixture. This process also quickly clears the filter. There is a separate controller to manage the combustion cycling based on the back pressure in the output stream.

At these temperatures, the process is rapid (10–12 minutes).

As with passive regeneration, the process is not complete. Remove the filters and physically remove the remaining material using the special machine for cleaning. The filters are reusable.

CONTINUOUS AIR PURGE SYSTEM

The purpose of the Continuous Air Purge System (CAPS) is to purge any residual fuel left in the aftertreatment fuel injector (AFI) to help prevent carbon fouling after regeneration. Any time the engine is running and regeneration is not taking place, air is purged through the AFI. Air for system operation is drawn from the chassis secondary air system.

The CAPS system includes an in-line filter, a chassis-mounted pressure regulator, an in-line check valve and double check valve assembly (CVA) mounted on the AFI. The pressure regulator reduces chassis air pressure to the approximately 32 psi level required for the air purge system operation. The double check valve assembly, which has both air and fuel ports, directs the flow of air and fuel to the AFI while preventing fuel from entering the air system and air from entering the fuel system.

DISCHARGE RECIRCULATION VALVE

The discharge recirculation valve (DRV) redirects some of the turbocharger output back through the turbocharger. This results in elevated exhaust temperature. The EECU uses this feature to maintain adequate exhaust temperature in support of active regeneration in the DPF system.

MANUAL REGENERATION

A procedure called “Manual Regeneration” can be used to regenerate the filters while they remain in the vehicle. The VCADS service tool or the Premium Tech Tool can be used to perform this function.

⚠ WARNING

The exhaust system reaches extremely high temperatures. Ensure that the system components are clear of all combustible materials. Ensure that personnel are aware that the surfaces are extremely hot. Failure to heed this warning may result in severe personal injury and property damage.

ULTRA LOW SULFUR DIESEL FUEL

A catalyst works better the higher the temperature up to about 400°C (750°F). Above this temperature, sulfur can become sulfuric acid. These filtering systems are practical only on vehicles that use ultra low sulfur fuels. It is required that diesel engines operating in conjunction with a DPF system use ultra low sulfur fuel that contains 15 parts per million (ppm), or less, of sulfur.

OPERATIONAL MODES

The exhaust aftertreatment system (EATS) usually operates in one of five modes.

- Normal Mode
- Heat Mode
- Passive Regeneration Mode
- Active Regeneration Mode
- Service Mode

In the Normal Mode, the engine is controlled by its regular calibration. However, the filters can be self-cleaning through passive regeneration. Heat Mode indicates that active regeneration is in process. In Passive Regeneration Mode, the engine creates sufficient exhaust temperature to convert the gases and regenerate (clean) the filters. In Active Regeneration Mode, exhaust temperature is artificially raised for short periods of time to convert the gases and clean the filters. The applicable controller reacts to data from back pressure sensors to start and stop the active regeneration process. A system in Service Mode is being inspected for accumulation of soot and ash in the filters to determine whether they should be manually regenerated or removed for external regeneration.

DPF SYSTEM VEHICLE MOUNTING

The catalyzed DPF system (Figure 36) is either a vertical back-of-cab (VBOC) DPF unit with muffler or a space saver (MACK Cap) DPF unit with muffler for the conventional chassis. The space saver unit attaches to the outside of the right rail under the cab. For the cabover and low cab forward chassis, the non-catalyzed vertical back-of-cab design (Figure 37) in which the combustion chamber is in the structure back-of-cab is used.

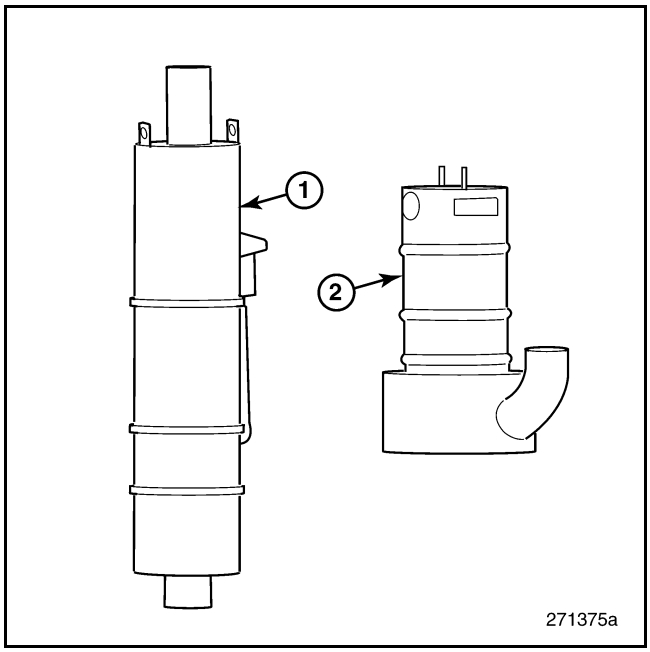


Figure 36 — Catalyzed DPF Units — Vertical Back-of-Cab and Space Saver

1. Vertical Back-of-Cab Unit	2. Space Saver Unit

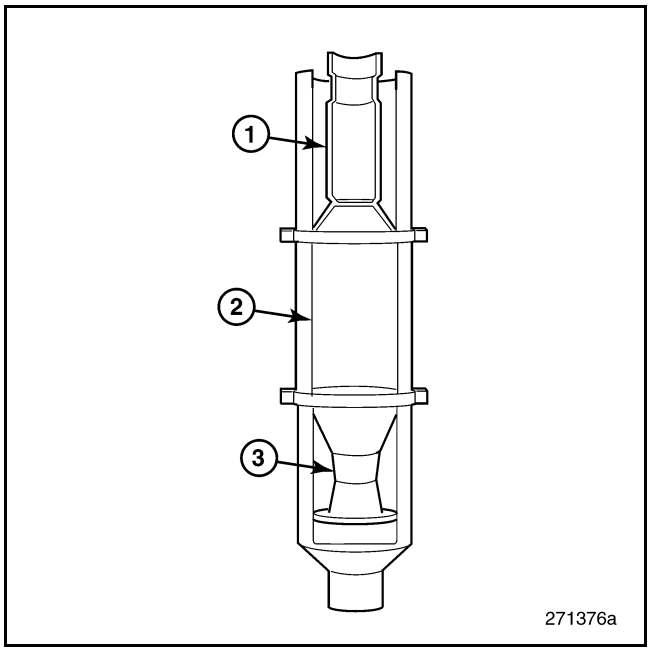


Figure 37 — Non-Catalyzed DPF Unit

1. Muffler 2. Filter	3. Combustion Chamber

Variable Geometry Turbocharger

The engine is equipped with a variable geometry turbocharger. The turbine housing has 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.

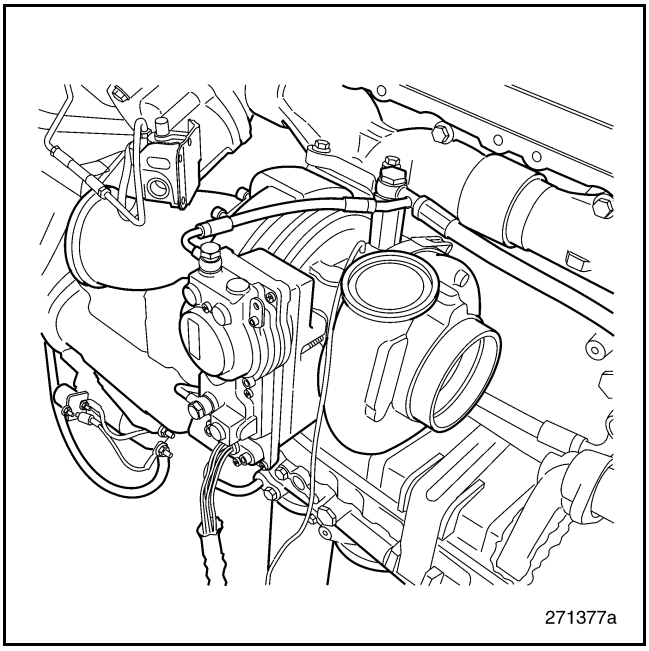


Figure 38 — VGT and Electronic Control

The variable geometry turbocharger (VGT) provides an infinitely variable volume between closed and maximum. The turbocharger maximizes and controls boost pressure over a broad range of engine speeds. Increased exhaust back pressure does not adversely affect turbocharger efficiency. When exhaust manifold pressure, turbine shaft speed and turbo boost are at maximum, the nozzle ring is fully closed. When the nozzle ring is fully open, exhaust manifold pressure, turbine shaft speed and turbo boost are at minimum.

Cooling System

The cooling system incorporates a belt-driven coolant pump integrated into 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 drive mounted above the crankshaft pulley. A coolant filter attached to the pump housing filters impurities from the coolant and can release supplemental coolant additives for system protection.

COOLANT PUMP

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

A housing containing an impeller, shaft seals, bearing and pulley attaches 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 leaks to be detected.

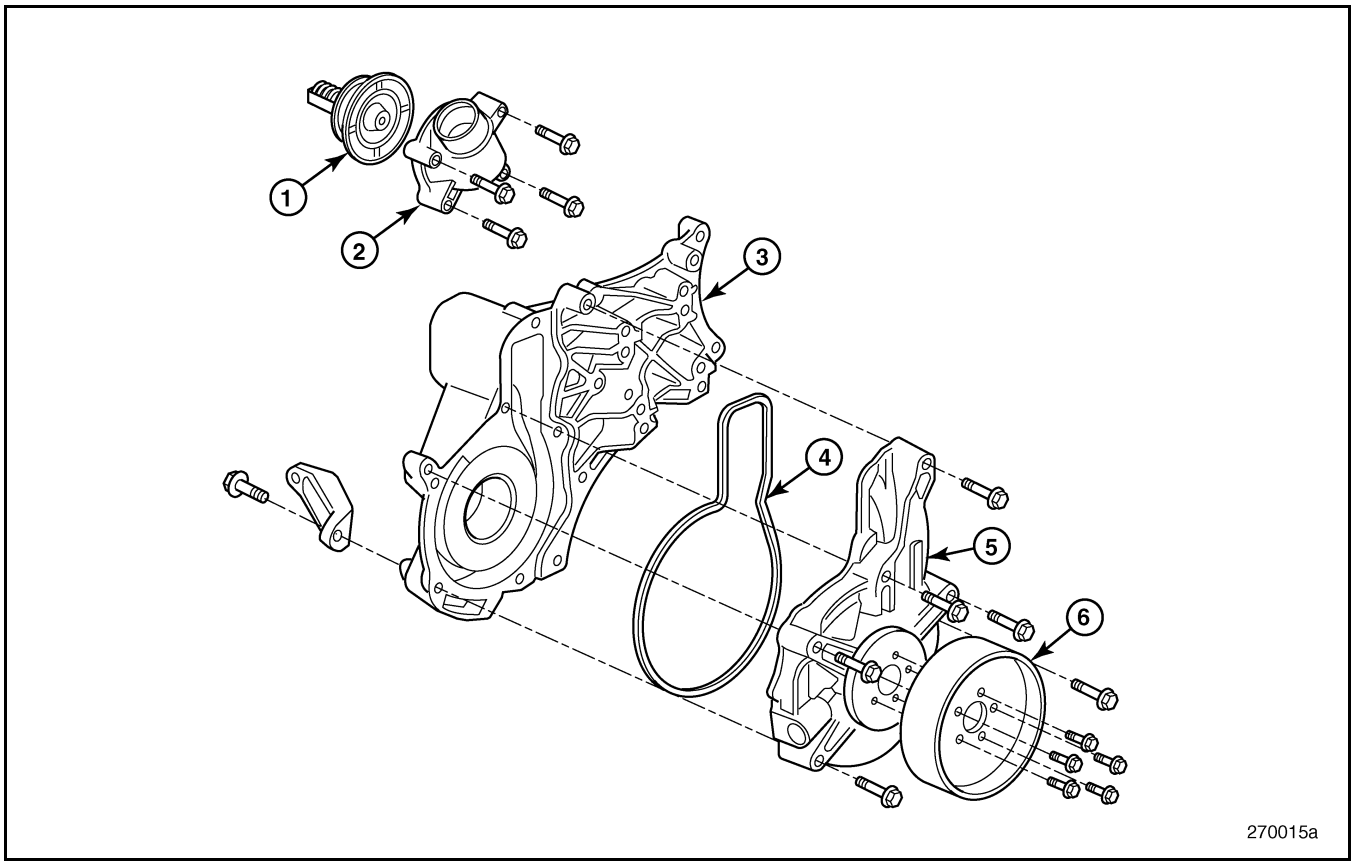


Figure 39 — Coolant (Water) System Components

1. Thermostat 2. Thermostat Housing 3. Coolant Pump Mounting Plate (with Angle Brace)	4. Coolant Pump Seal 5. Coolant Pump Housing 6. Coolant Pump Pulley

THERMOSTAT

This is a piston-type thermostat with piston, bulb, seal and housing in a single assembly. It has lower pressure drop compared to earlier types. The thermostat is mounted on the front of the cylinder head.

ENGINE COOLING FAN

The cooling fan (Figure 40) runs via a viscous drive through which fan speed is electronically controlled by the EECU. In earlier designs, fan speed was controlled by a temperature sensing bi-metal unit. A bi-metal thermostat gauges only the air passing over it. With precise EECU control, fan speed is continuously adjusted in response to several interrelated influences. This makes for efficient cooling with low fuel consumption.

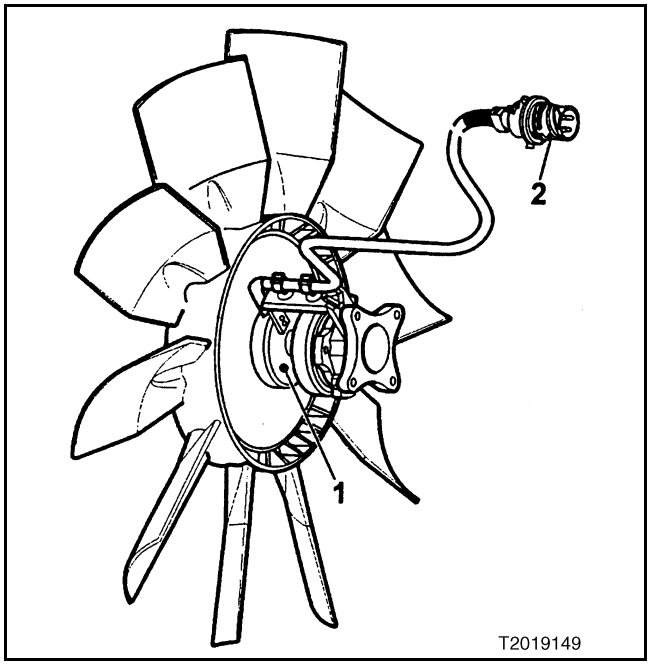


Figure 40 — Engine Cooling Fan

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

Other fan drive options include On/Off Fan Clutches and Electronically Modulated Fan Drives. Refer to Engine Cooling Service Manual, 7-002, for a complete description of all available fan drive systems.

Engine Management System

ENGINE ELECTRONIC CONTROL UNIT (EECU)

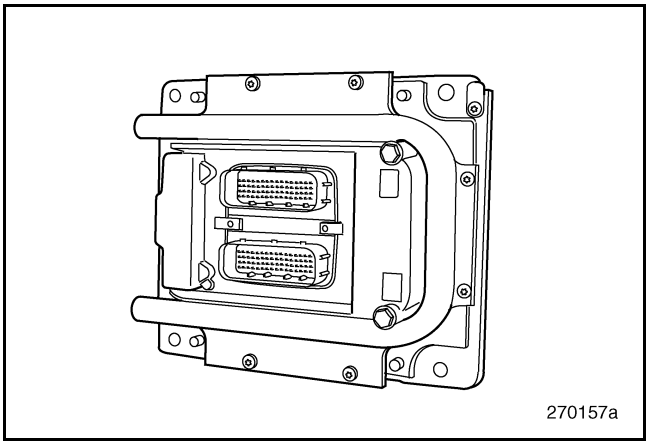


Figure 41 — EECU and Cooler

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 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 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.

SENSORS AND ACTUATORS

There are sensors on the engine providing for electronic control. The following figures show the locations of the devices on the left and right sides of the engine, respectively.

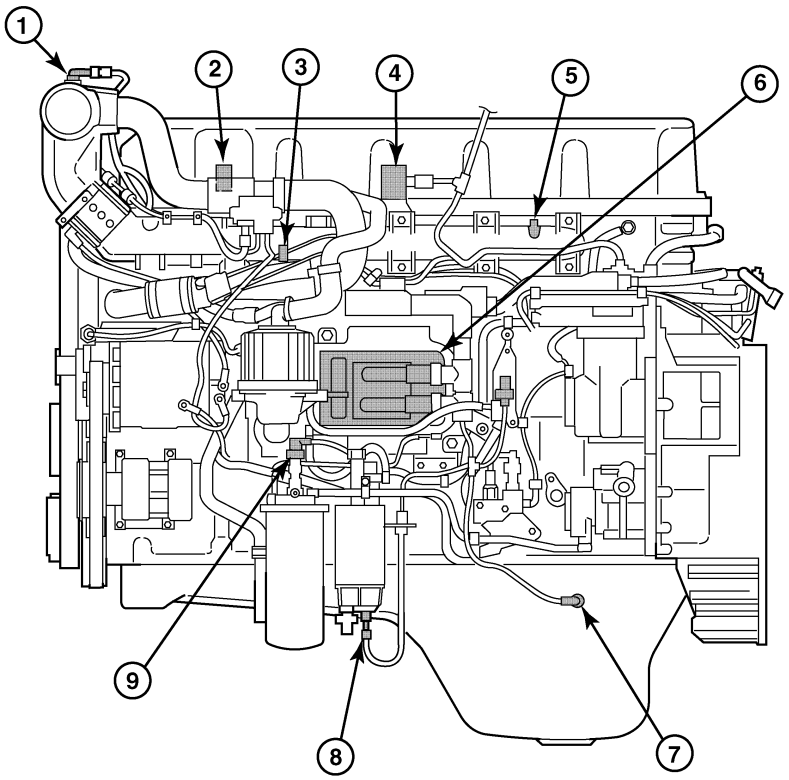


Figure 42 — Engine Sensors, Left Side (< Front)

1. Charge Air Pressure 2. Crankcase Pressure 3. EGR Temperature 4. Differential Pressure 5. Charge Air Temperature	6. Engine Electronic Control Unit (EECU) 7. Oil Level/Temperature 8. Water-in-Fuel 9. Fuel Pressure
NOT SHOWN: Fan Speed (in Fan Hub)	Air Temperature (in Turbocharger Air Inlet Pipe) Filter Indicator (in Air Filter Housing)

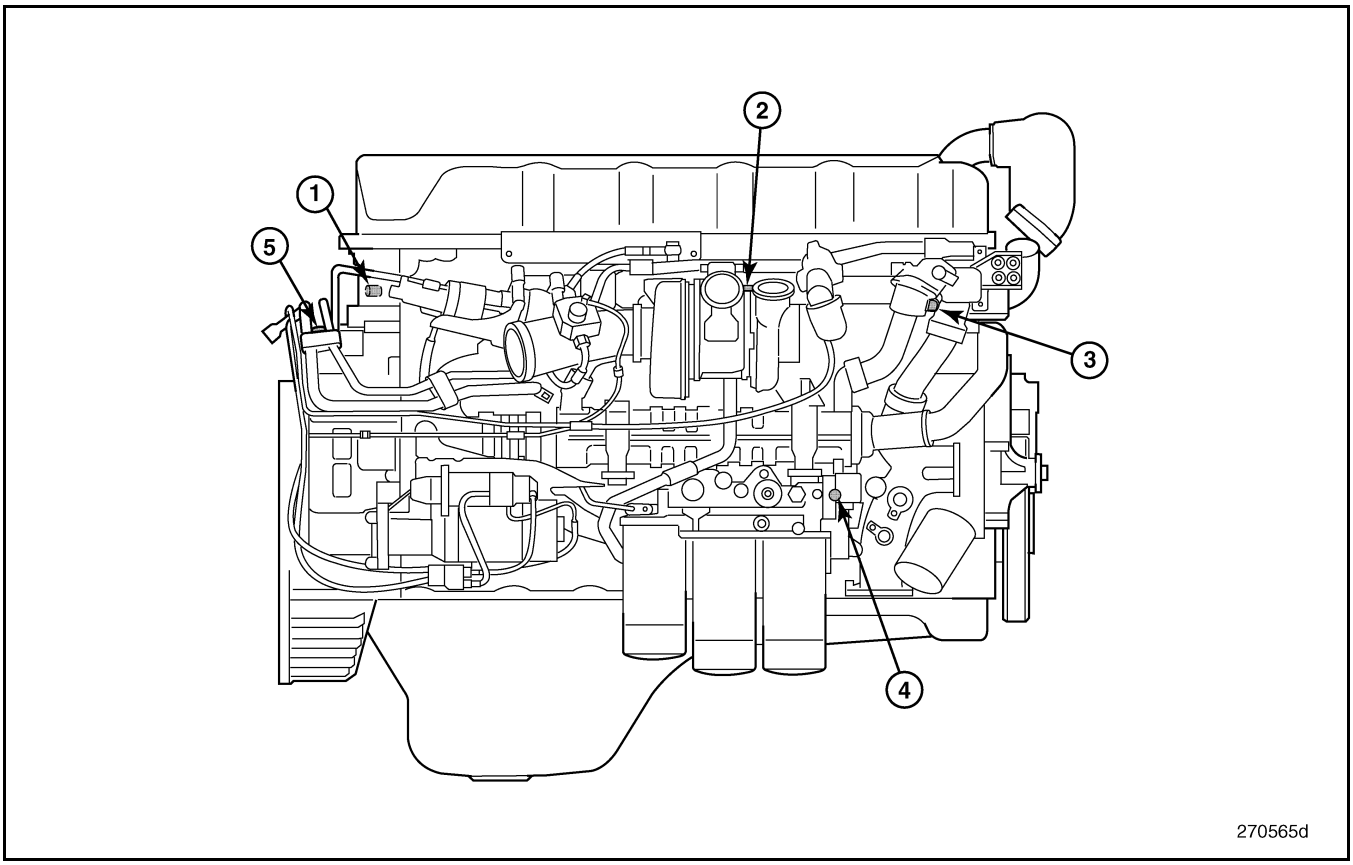


Figure 43 — Engine Sensors, Right Side (Front >)

1. Camshaft Position 2. Turbo Wheel Speed 3. Coolant Temperature	4. Oil Pressure/Temperature 5. Engine (Flywheel) Speed
NOT SHOWN: Coolant Level (in Expansion Tank)	

GLOSSARY OF TERMS

Active Regeneration

Cleaning a diesel particulate filter using an auxiliary heating mechanism to achieve optimum temperature for rapidly inducing chemical changes in the particulate matter trapped in the filter.

Air Pressure Sensor

The air pressure sensor is mounted in the air intake between the CMCAC outlet and the EGR mixer. This sensor monitors CMCAC outlet pressure and relays this value to the EECU module.

Ash

The noncombustible portion of diesel particulate matter. Diesel fuel produces little ash, but crankcase lubricant and fuel-borne catalysts produce considerable ash.

Atmospheric Pressure Sensor

A sensor incorporated into the EECU that detects atmospheric (barometric) pressure. 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.

Catalyst

A substance that promotes or provokes chemical change at a different rate or different temperature than otherwise possible.

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 reintroduction into the combustion chambers. Adding the cooled exhaust gases to the combustible fuel and air mixture lowers the overall combustion temperatures for reduced formation of nitrogen oxides (NOx).

Cordierite

A ceramic material constructed to be used as a substrate in diesel oxidation catalysts. With additional processing, it may also be used as a diesel particulate filter.

Diesel Particulate Matter

The complex mixture of extremely fine particles and liquid droplets that are discharged by an operating diesel engine. The chemical compositions can be broken down to safer substances. The mixture is also called soot and ash.

Differential Pressure 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.

Discharge Recirculation Valve (DRV)

A device used to return some of the turbocharger output air back to the turbocharger to raise the exhaust temperature when needed for active regeneration of the diesel particulate filter.

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 the solenoids in a single body. Actuated by the camshaft via rocker arms with roller followers, electronic unit injectors offer very quick response at very high pressure.

Engine Electronic Control Unit (EECU)

A microprocessor-based controller mounted on the cylinder block. On the MP7 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 Aftertreatment System (EATS)

Equipment installed to remove the maximum amount of noxious emissions from the exhaust gases after they leave the combustion chamber before they reach the atmosphere. This includes exhaust gas recirculation (EGR), the variable geometry turbocharger (VGT), the discharge recirculation valve (DRV), the aftertreatment fuel injector (AFI) and the diesel particulate filter (DPF).

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.

Passive Regeneration

Cleaning a particulate filter by spontaneous burning of soot that collects on it. The exhaust temperature remains continuously high enough to incinerate the soot.

Poly-V Belt

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

Regeneration

Cleaning a diesel particulate filter so as to renew its capacity to function efficiently.

Roller Follower

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

Soot

Carbonaceous particulate matter, black in color, found in diesel exhaust. Soot particles are extremely fine. Captured by the diesel particulate filter, their chemical characteristics are changed by the heat to which they are exposed, turning the soot into ash.

Variable Geometry Turbocharger (VGT)

Turbocharger turbine housing has moving components to control flow of exhaust gas and build back-pressure in the exhaust system for EGR flow. Referred to as Variable Turbine Geometry (VTG) turbocharger on past model engines. The VGT also serves as an exhaust 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 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.

COMPONENT LOCATOR

MP7 ENGINE COMPONENT LOCATION VIEWS [200 EA]

The locations of primary component assemblies of the MP7 engine are identified in the illustrations contained in this section. These views do not include all sensor locations.

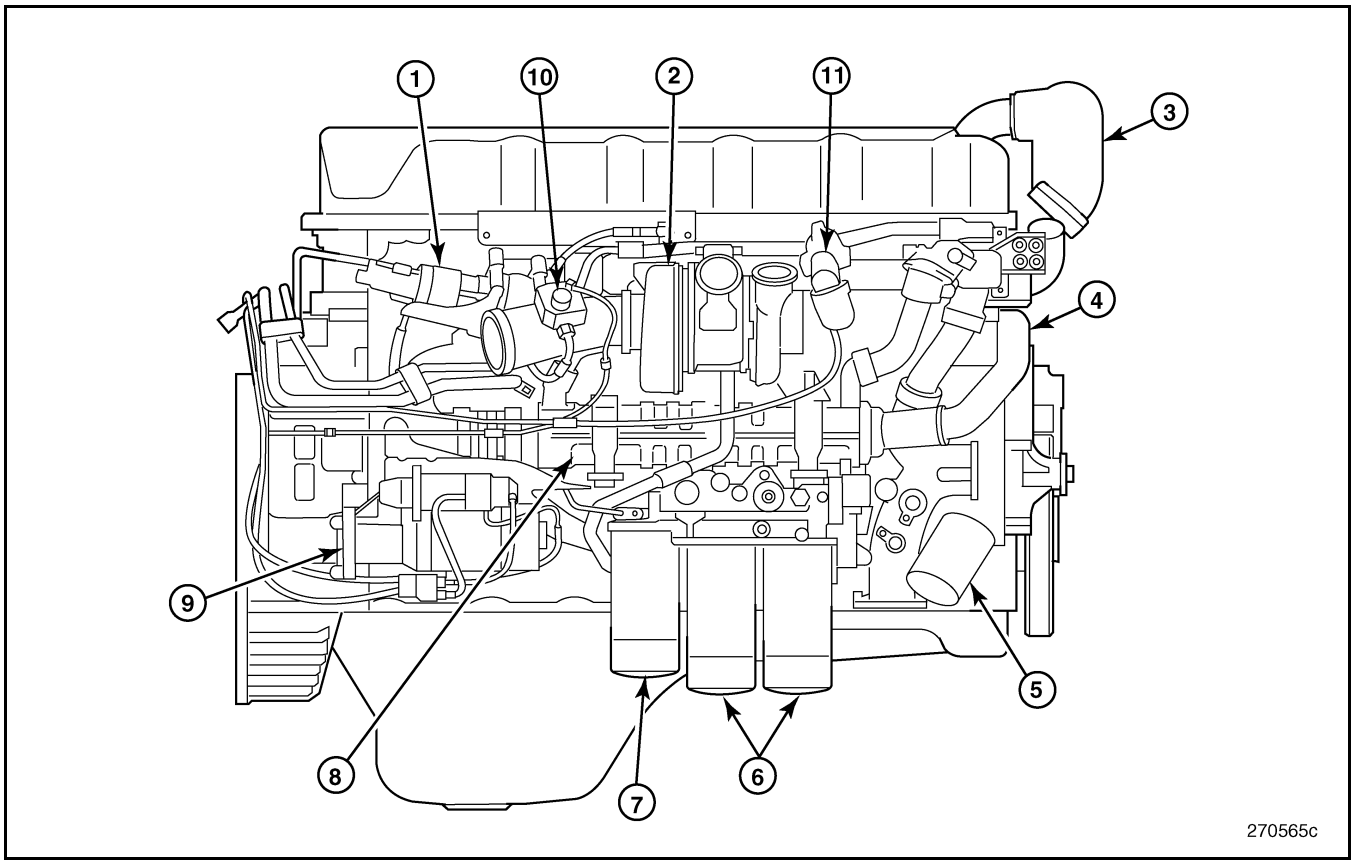


Figure 44 — MACK MP7 Engine, Conventional Chassis — Right Side View

1. EGR Valve 2. VGT 3. EGR Mixer 4. EGR Cold Side Crossover Tube 5. Coolant Conditioner 6. Full-Flow Oil Filters	7. By-Pass Oil Filter 8. EGR Cooler 9. Starter 10. Aftertreatment Hydrocarbon Injector (AHI) 11. Discharge Recirculation Valve (DRV)

The right side views are nearly identical when comparing the low cab forward (LCF) and conventional chassis engine configurations. The major differences are in the length and path of the EGR crossover pipe and the location of the mixer. The mixer appears in the left-side views.

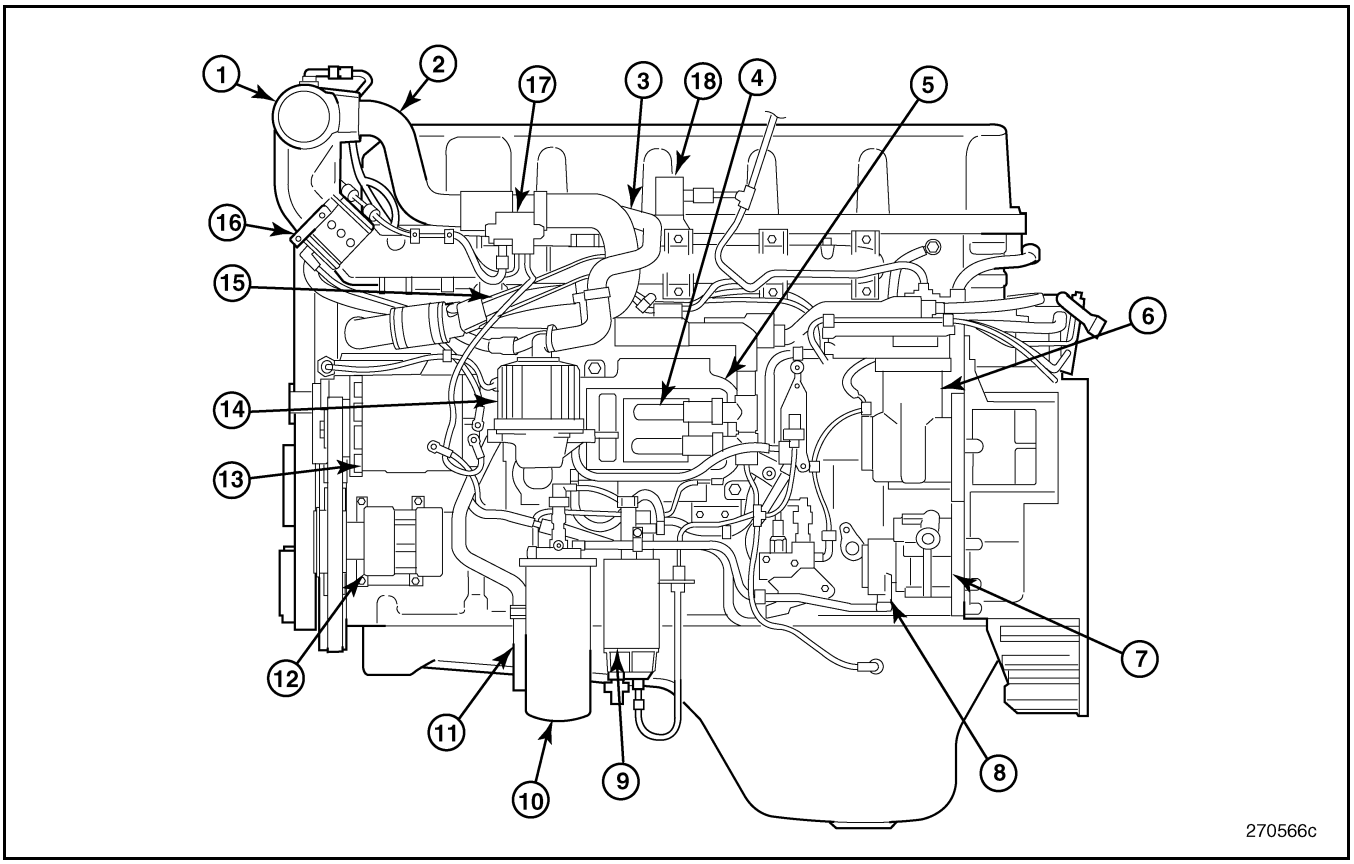


Figure 45 — MACK MP7 Engine, Conventional Chassis — Left Side View

1. EGR Mixer	10. Fuel Filter
2. EGR Mixer Inlet Tube	11. Crankcase Ventilation Tube
3. Crankcase CCV Tube	12. Refrigerant Compressor
4. EMS Module	13. Alternator
5. EMS Module Cooler	14. CCV Separator
6. Air Compressor	15. Venturi
7. Power Steering Pump	16. Inlet Air Heater (Optional)
8. Fuel Pump	17. Inlet Air Heater Relay
9. Fuel/Water Separator	18. Delta P Sensor

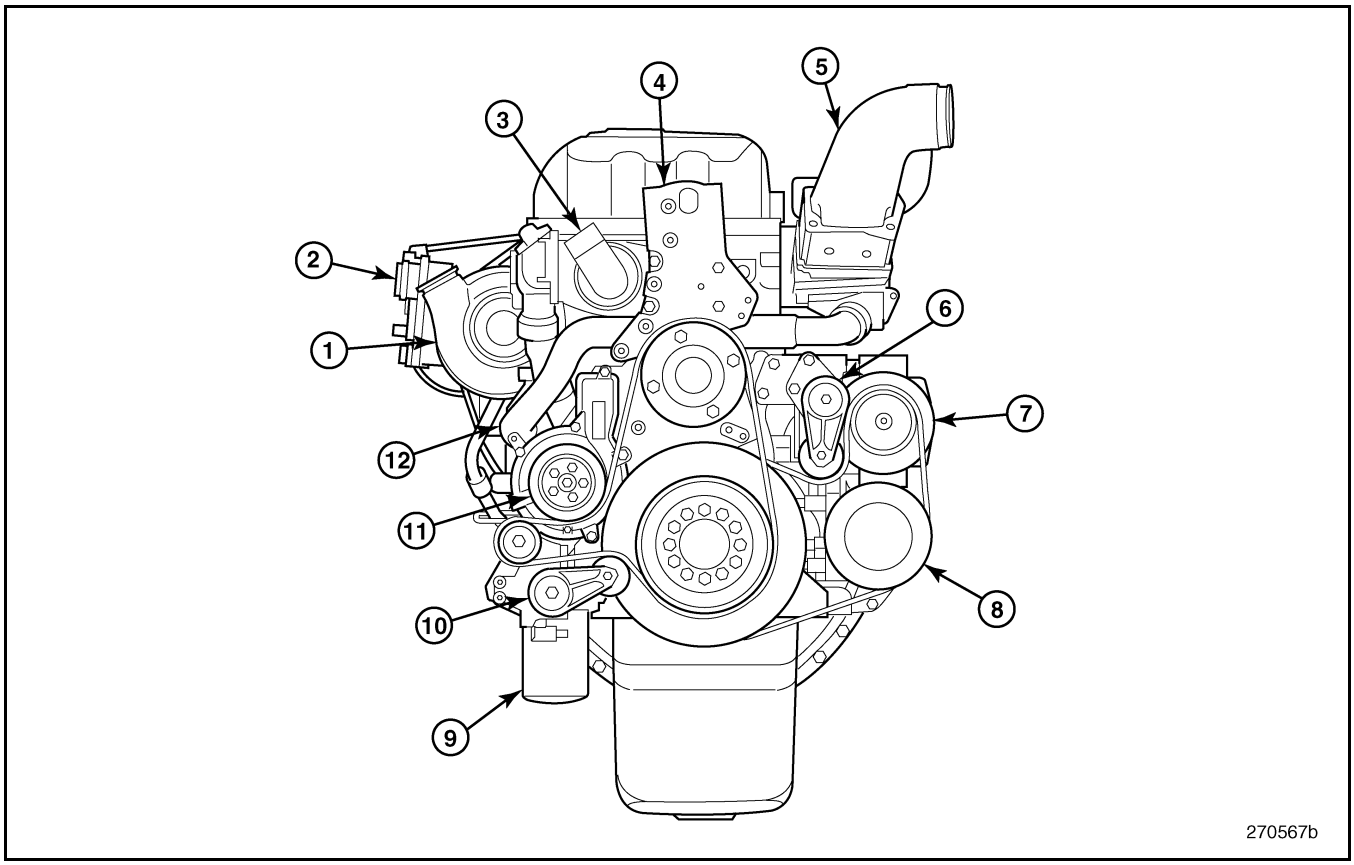


Figure 46 — MACK MP7 Engine, LCF Chassis — Front View

1. VGT	7. Alternator
2. VGT Control	8. Refrigerant Compressor
3. Thermostat	9. Oil Filter
4. Fan Mounting Bracket	10. Belt Tension Idler
5. EGR Mixer	11. Coolant Pump
6. Belt Tension Idler	12. EGR Cold Side Crossover Tube

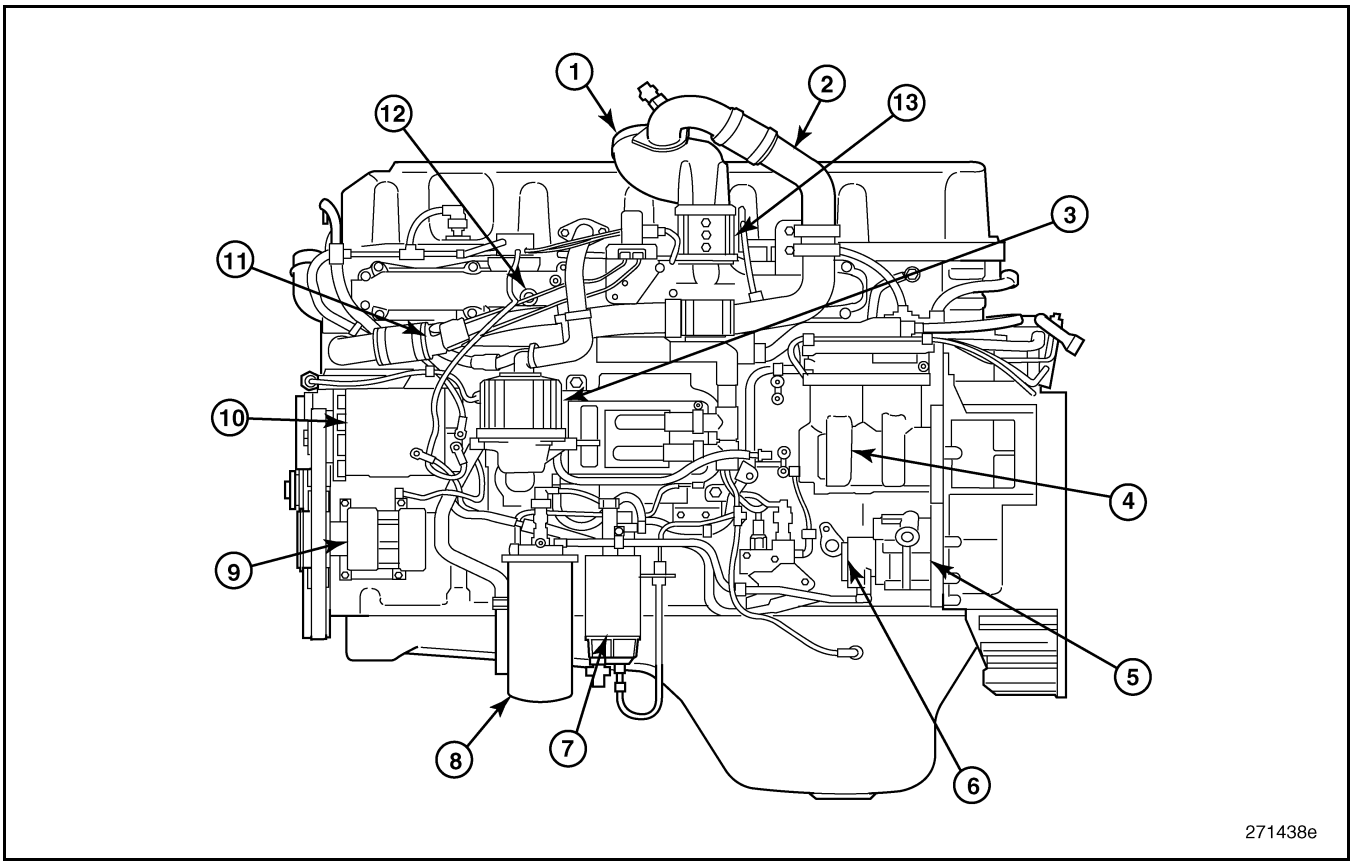


Figure 47 — MACK MP7 Engine, LCF Chassis — Left Side View

1. EGR Mixer 2. EGR Mixer Inlet Tube 3. CCV Separator 4. Air Compressor 5. Power Steering Pump 6. Fuel Pump 7. Fuel/Water Separator	8. Fuel Filter 9. Refrigerant Compressor 10. Alternator 11. Venturi 12. Pressure Differential Sensors 13. Inlet Air Heater (Optional)

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:			

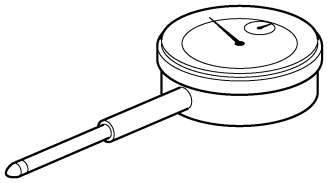
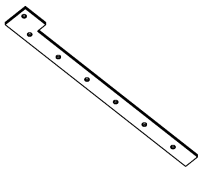
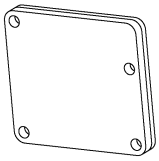
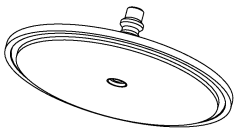
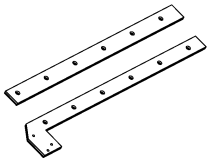
If the solution does not become evident in the course of completing the check list above, use Tech Tool to investigate further.

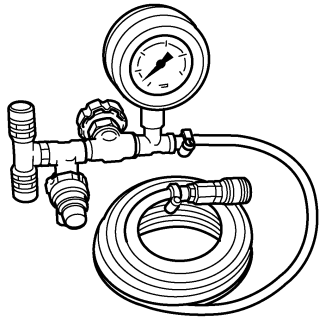
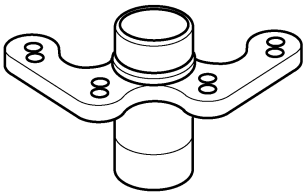
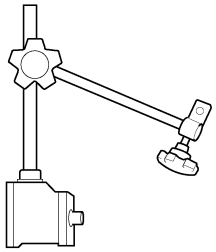
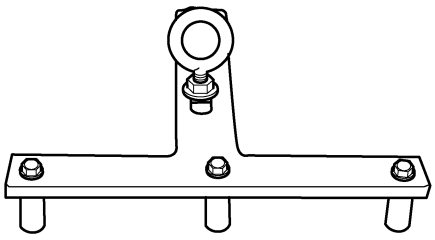
ENGINE CHECKS AND TESTS

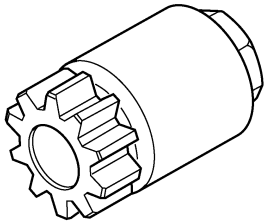
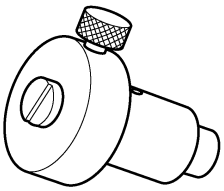
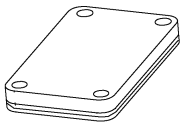
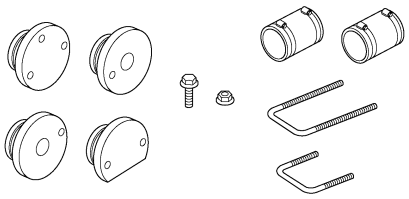
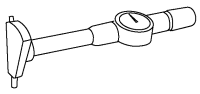
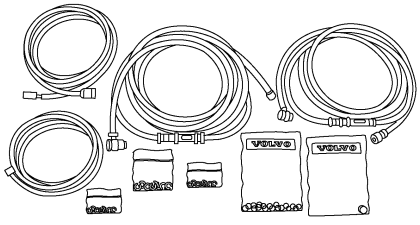
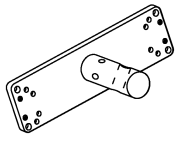
Included in this section are the following engine checks and tests:

- 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.

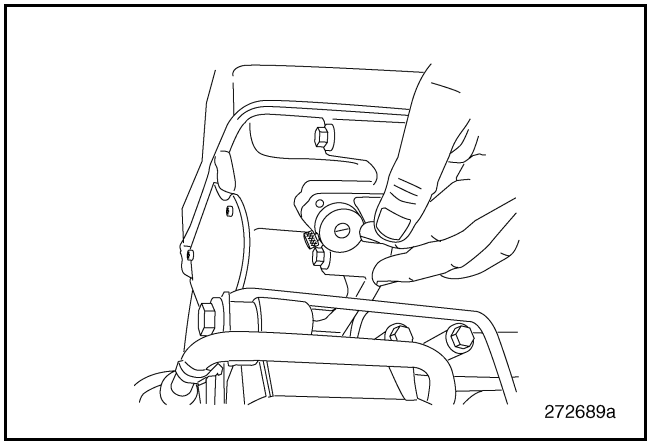


Figure 48 — Using Gauge at Camshaft Sensor Location

   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 49):
      - 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.

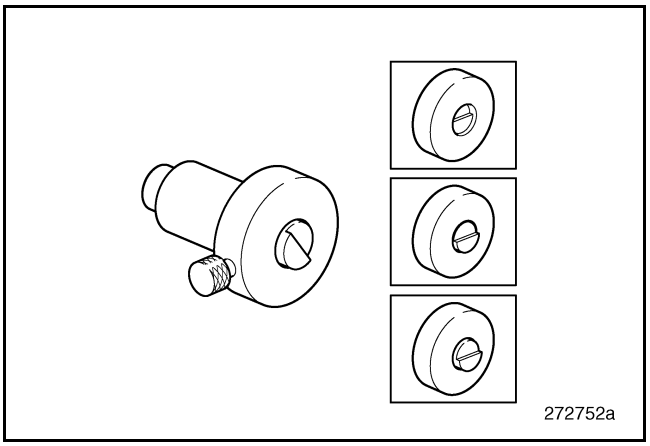


Figure 49 — Depth Gauge

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.

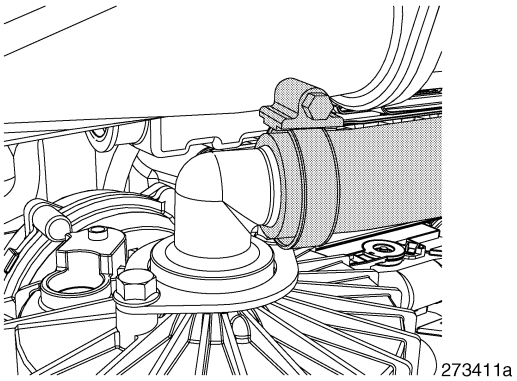


Figure 50 — CCV Inlet Pipe Connection

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.

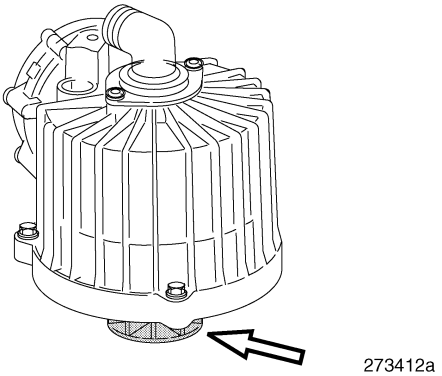


Figure 51 — CCV Separator Turbine Wheel

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.

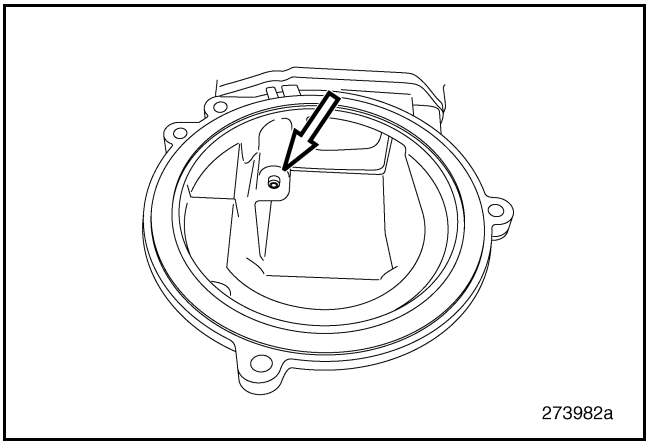


Figure 52 — Oil Nozzle (Separator Base)

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

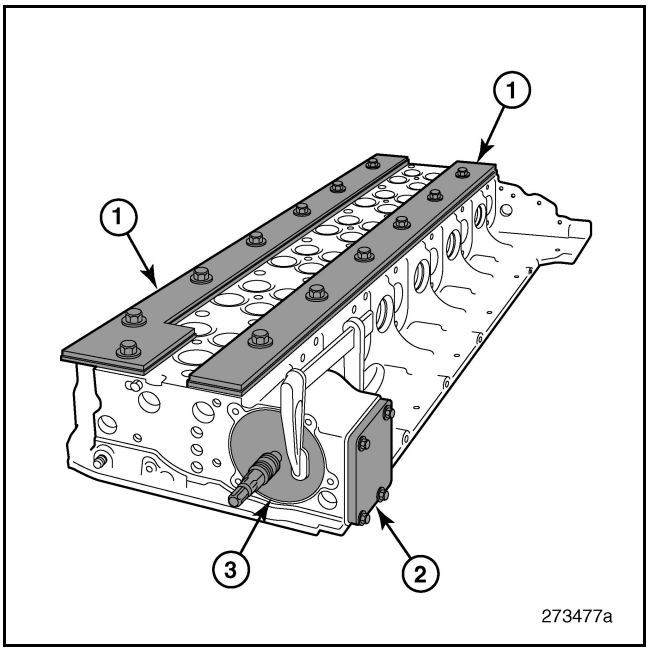


Figure 53 — Sealing Plates Installed (Typical)

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.

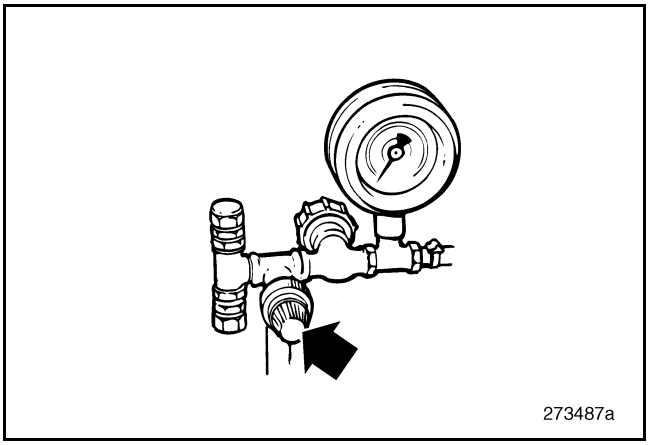


Figure 54 — Pressure Gauge Adjustment Knob

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.

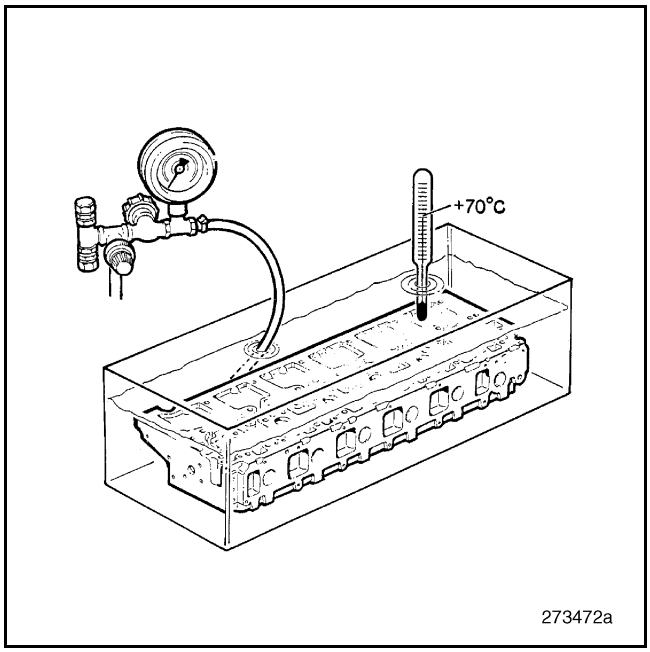


Figure 55 — Testing for Air Leaks

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.

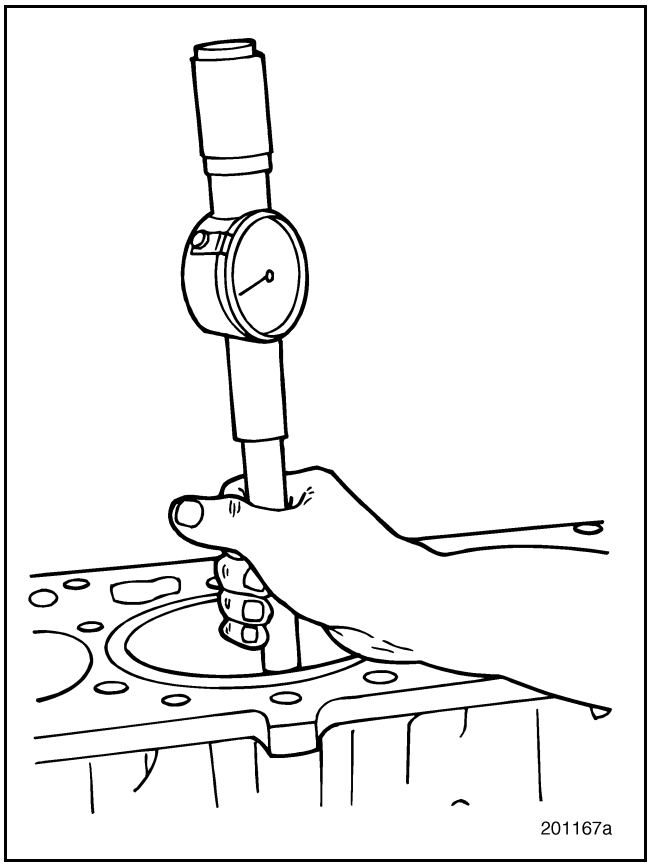


Figure 56 — Measuring Cylinder Liner Wear

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.

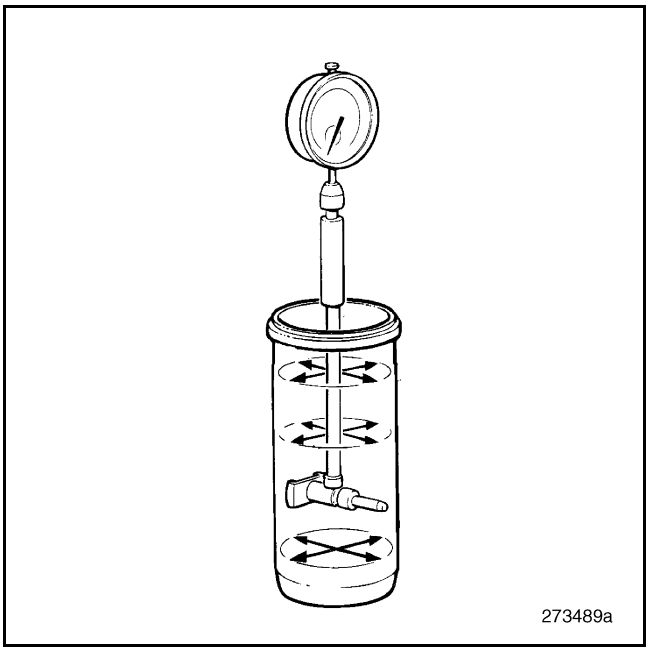


Figure 57 — Measurement Locations

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.

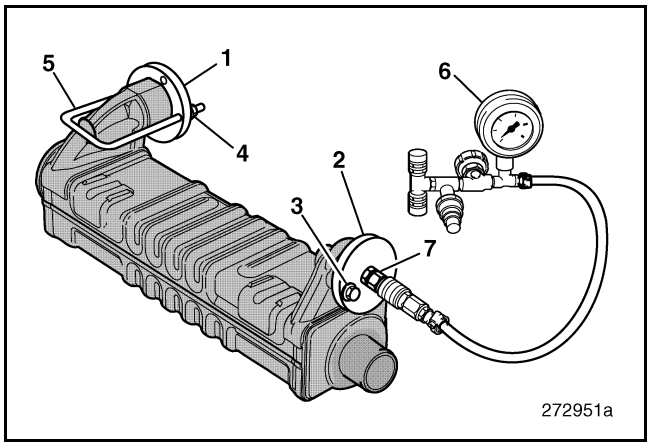


Figure 58 — Installation of Leak Test Kit on Cooler

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).

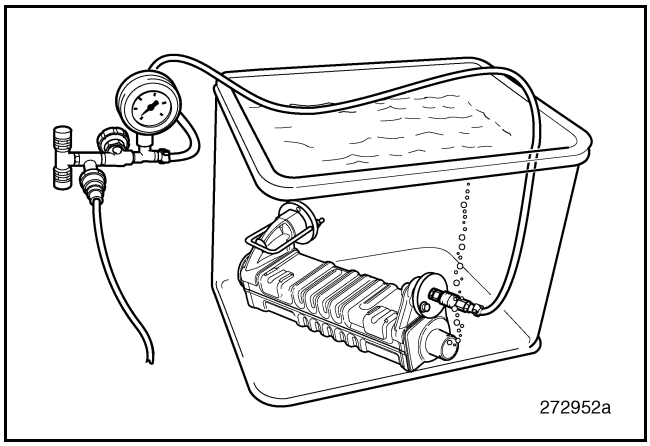


Figure 59 — Conducting Pressure Test

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 60. 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.

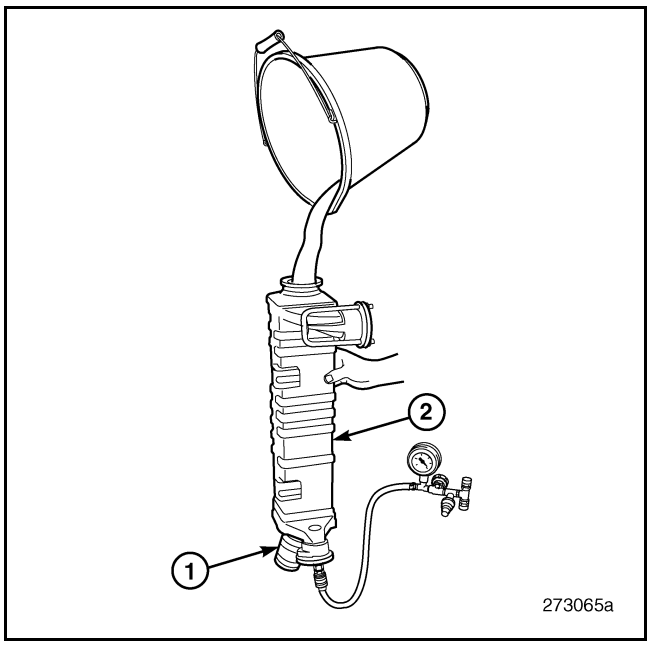


Figure 60 — Test with EGR Gas Outlet Port Plugged

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.

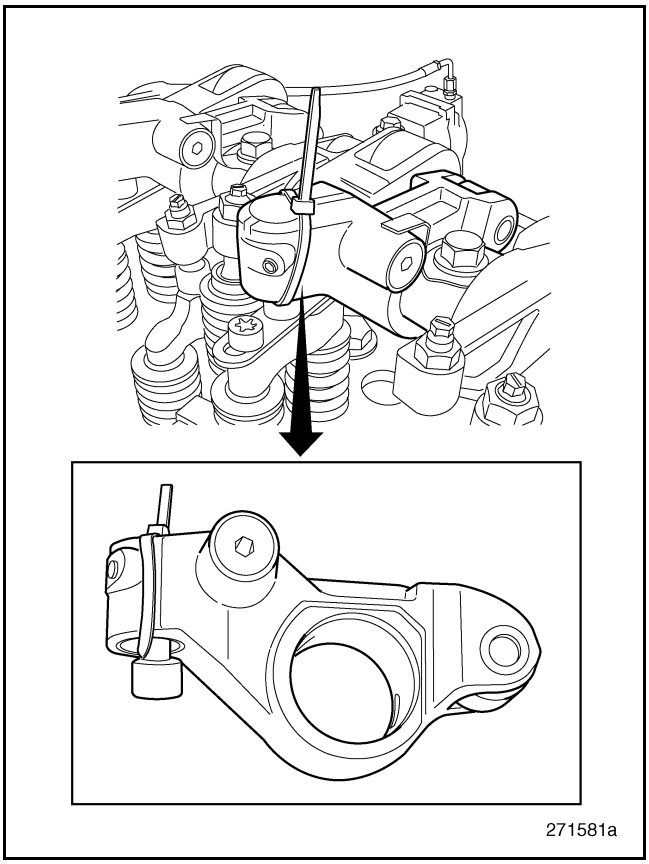


Figure 61 — Tie Strap Holding Engine Brake Piston (MP7 Shown)

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.

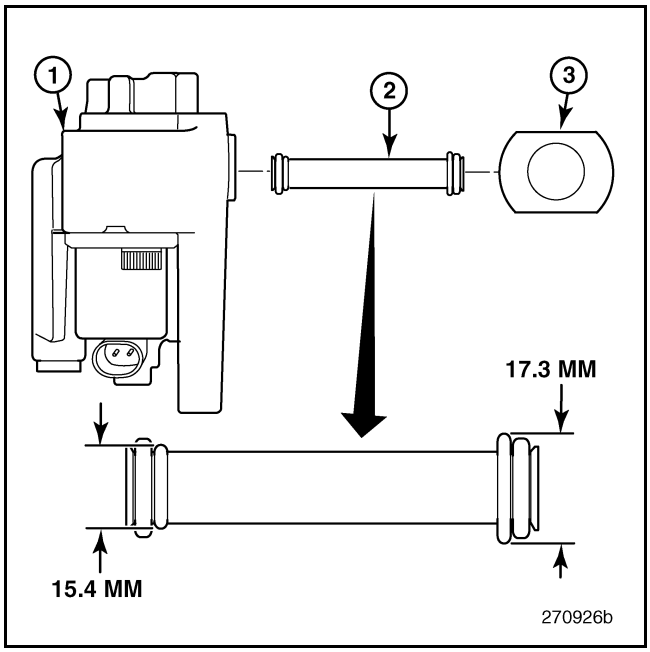


Figure 62 — Engine Brake Control Valve Oil Tube Orientation (MP7 Only)

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).

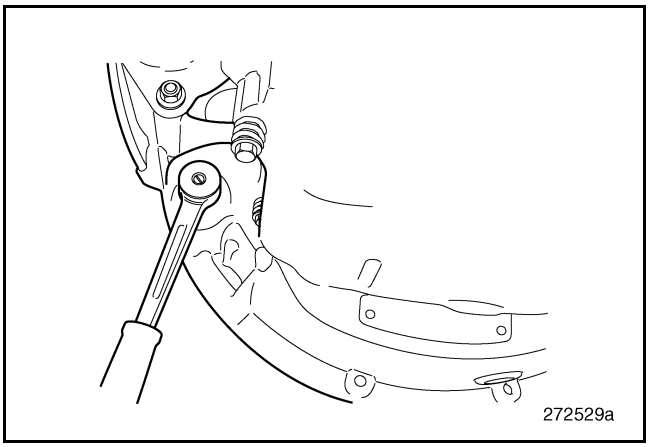


Figure 63 — Turning Flywheel (MP8 Shown, Typical)

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.

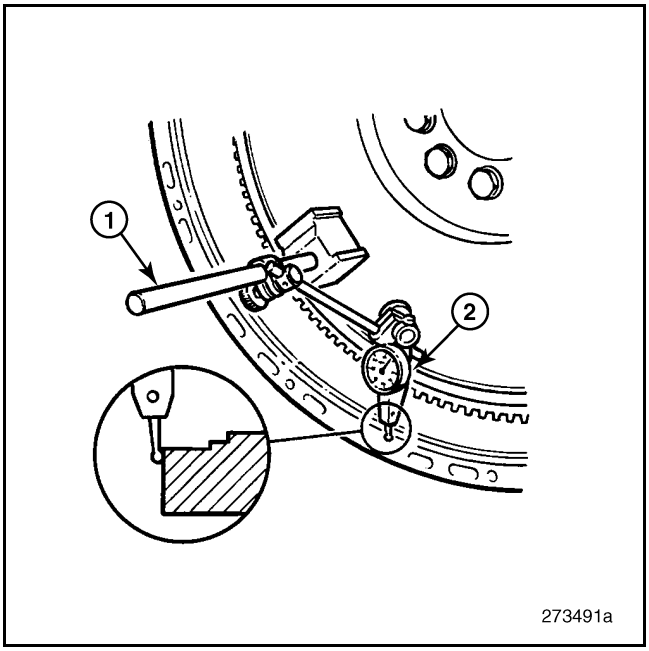


Figure 64 — Checking Axial Runout

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

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.

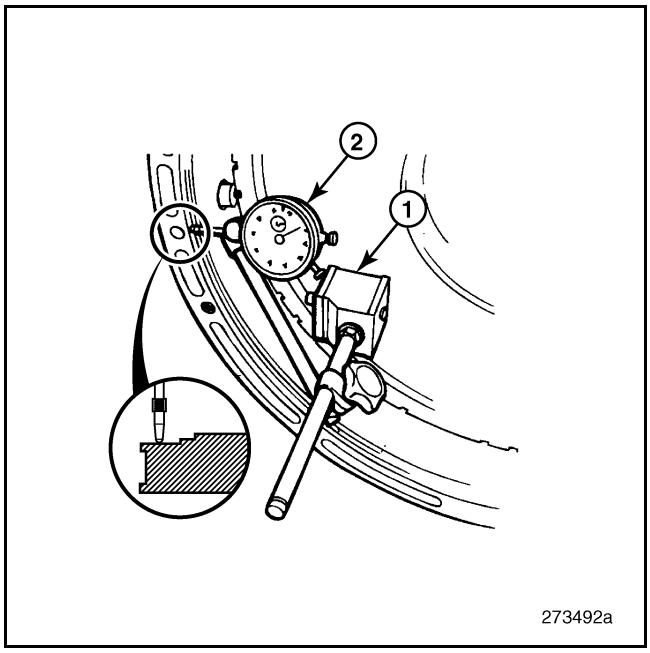


Figure 65 — Checking Radial Runout

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

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.

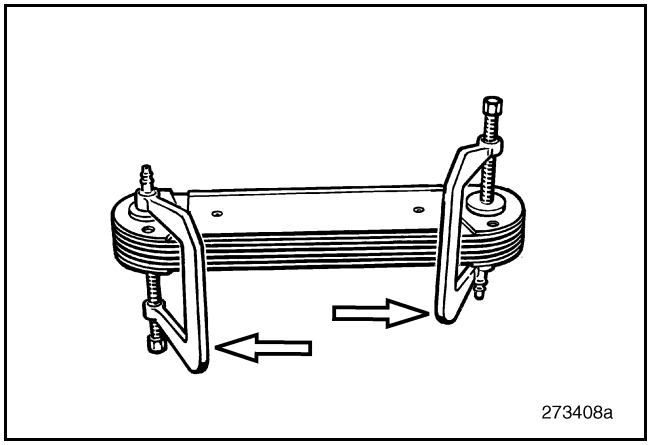


Figure 66 — Clamp Tools, Installed

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).

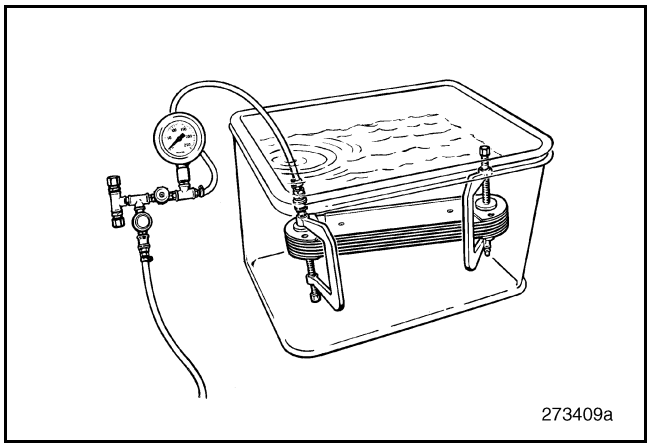


Figure 67 — Testing Oil Cooler

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.

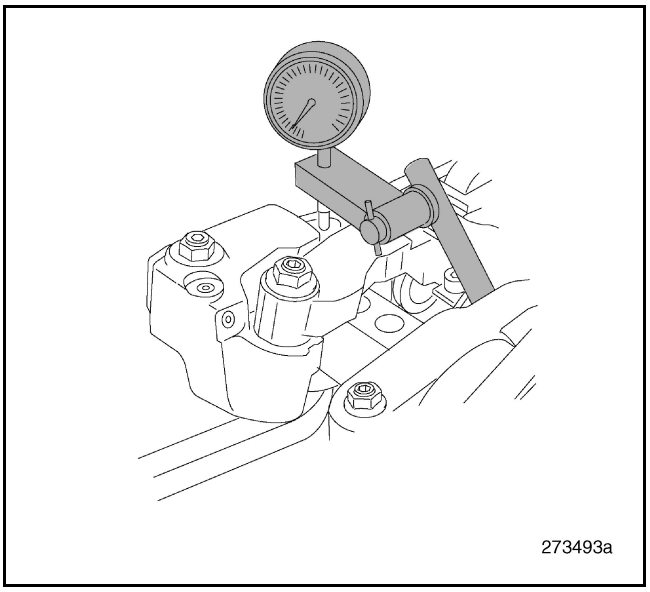


Figure 68 — Dial Indicator Positioning (Typical Rocker Component Shown)

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.

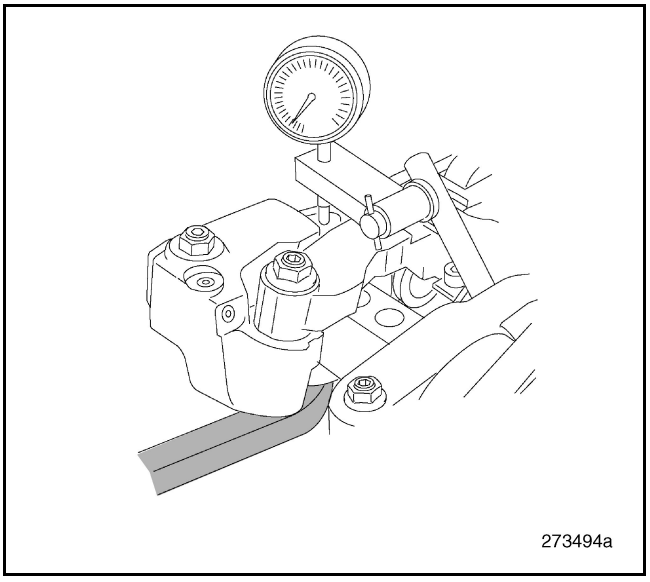


Figure 69 — Prying Rocker Arm Up (Typical Rocker Component Shown)

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.

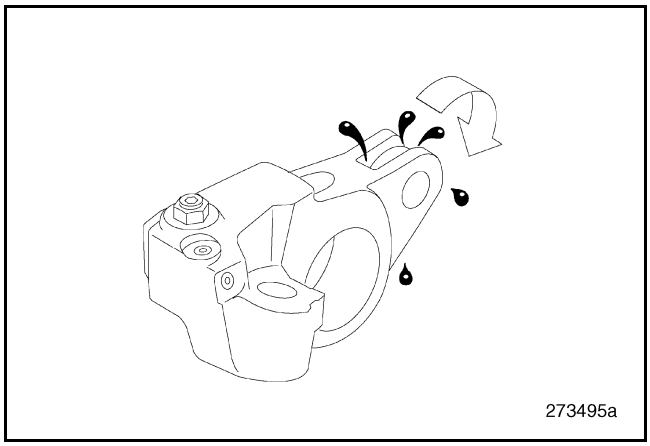


Figure 70 — Forcing Oil from Roller (Typical Rocker Component Shown)

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

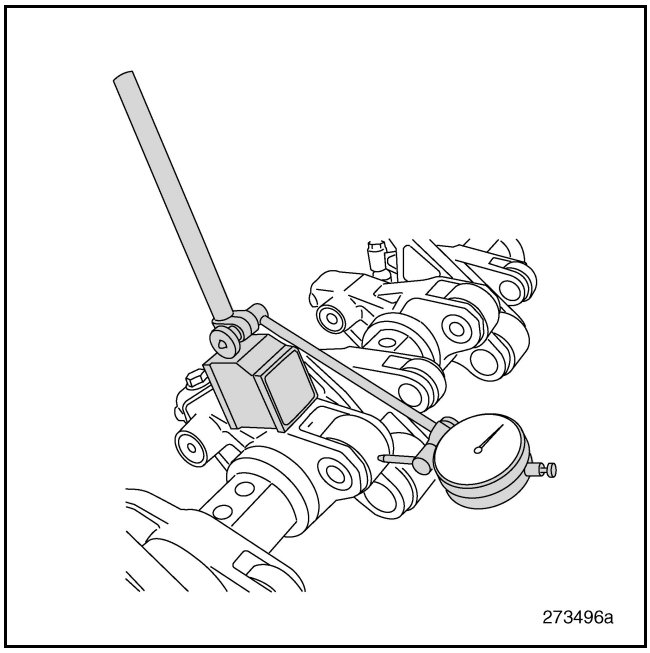


Figure 71 — Dial Indicator Positioning

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.

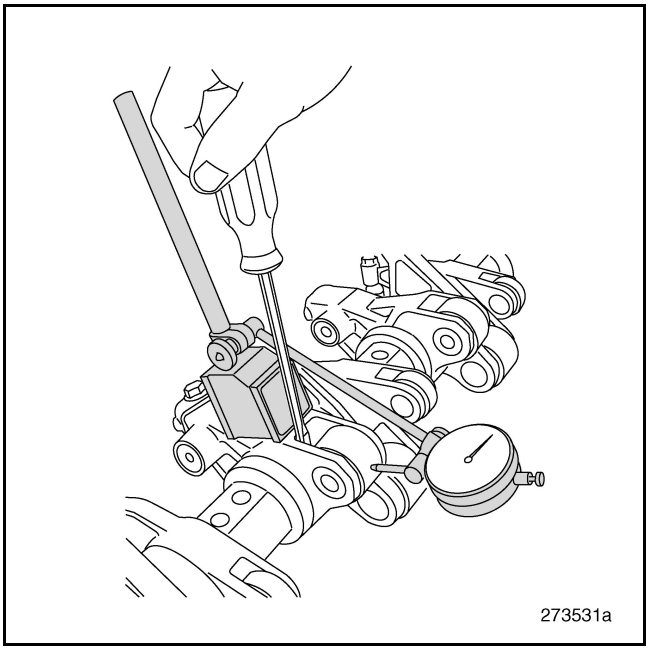


Figure 72 — Prying Roller Out

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.

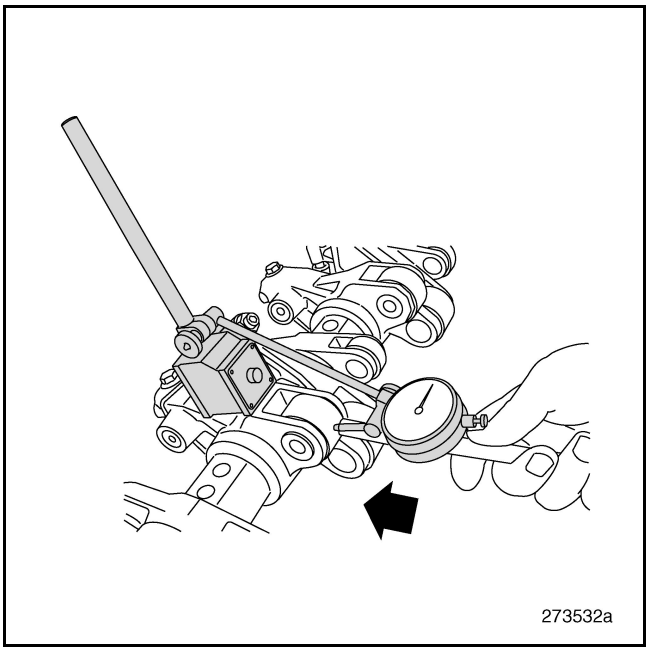


Figure 73 — Pressing Roller In

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.

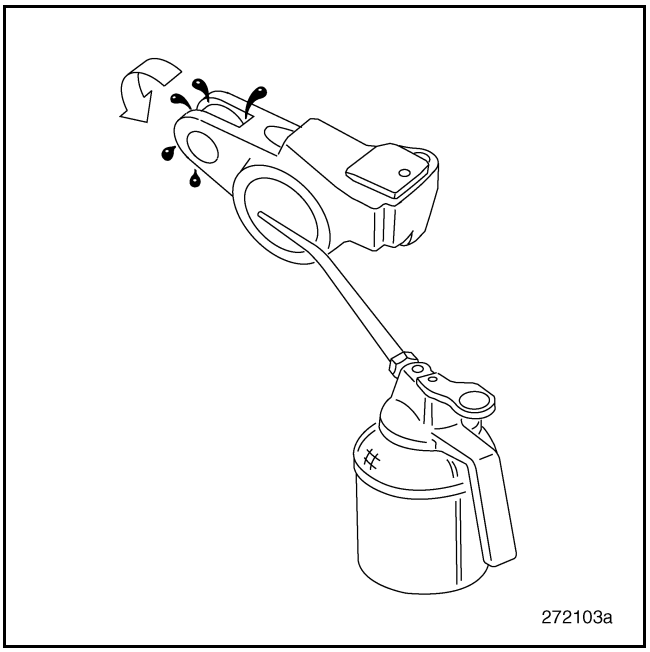


Figure 74 — Lubricating Rocker

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.
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).

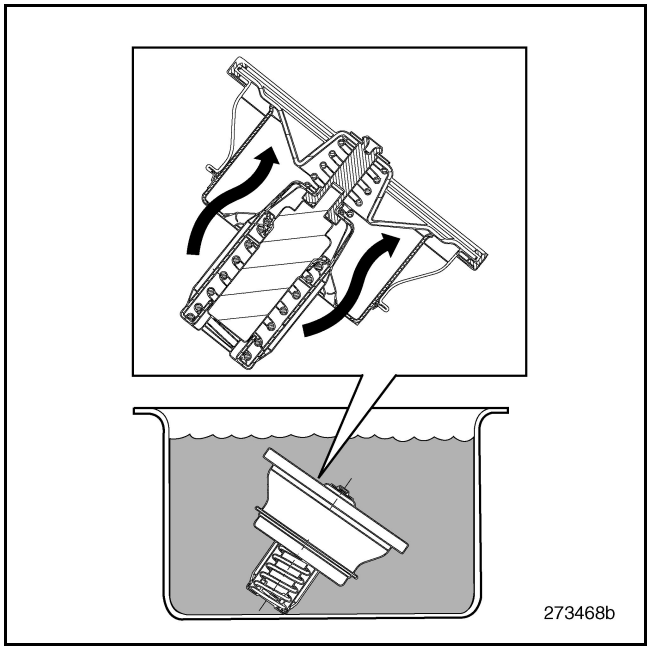


Figure 75 — Thermostat Closed

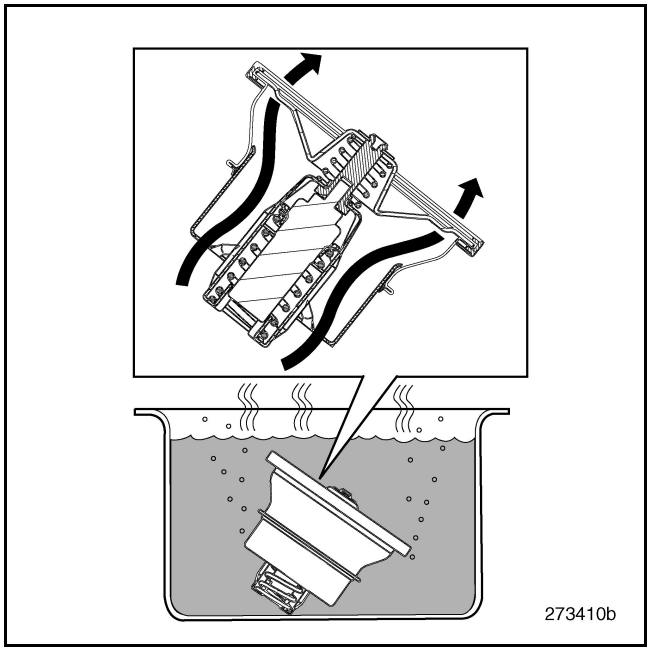


Figure 76 — Thermostat Open

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.

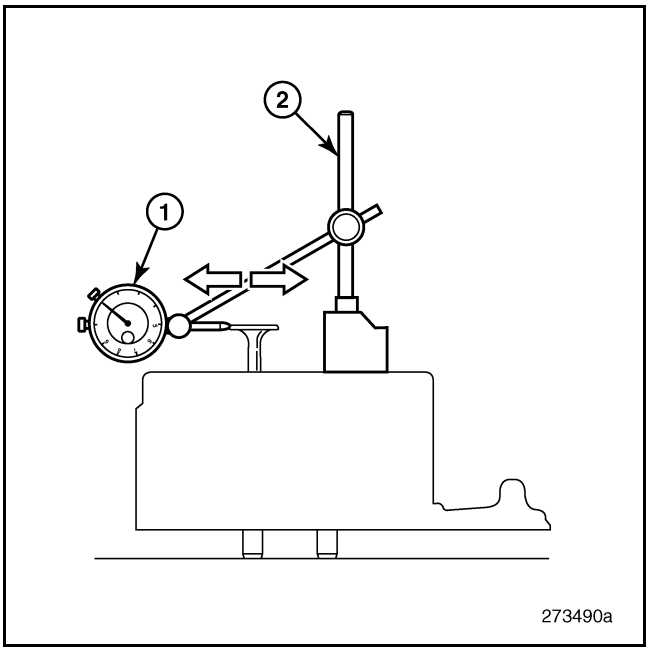


Figure 77 — Measuring Valve Guide Wear

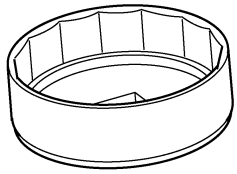
1. Dial Indicator, 9989876	2. Magnetic Stand, 9999696

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.

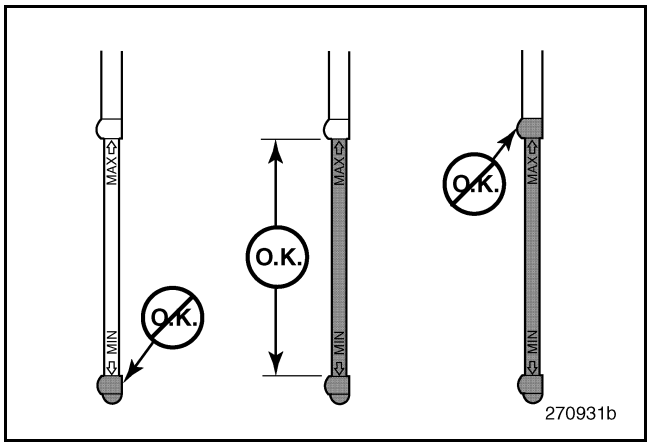


Figure 78 — Oil Level Check

Refer to “ENGINE FINAL PREPARATION AND OPERATIONAL CHECK” on page 294 for oil pressure specifications.

Oil and Filter Change Procedure

[219 EV]

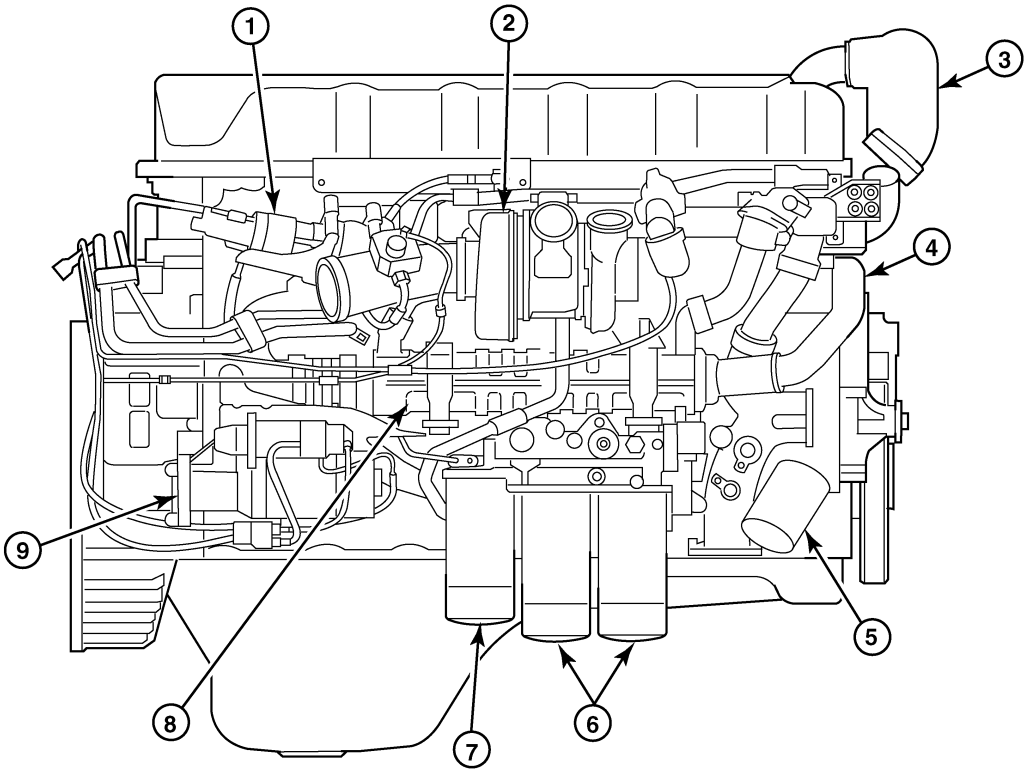


Figure 79 — Oil Filters and Valve Housing

1. EGR Valve 2. VGT 3. EGR Mixer 4. EGR Crossover Pipe 5. Coolant Conditioner	6. Full-Flow Oil Filters 7. By-Pass Oil Filter 8. EGR Cooler 9. Starter

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, remove both 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 may 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 cylinder head 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 the oil jet nozzle. Remove any obstruction and clean the nozzle.
5. Reassemble the separator and the hoses.
6. If faulty operation continues, replace the separator.

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-filter is on the “pressure side” of the fuel 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.

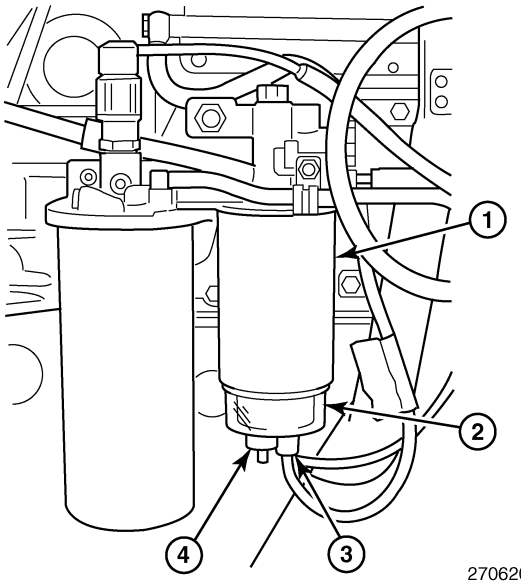


Figure 80 — Fuel Filters

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

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 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 Filter Replacement

To replace the full-flow filter:

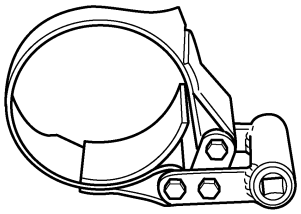
1. Make sure the filter casing is thoroughly cleaned. If not already done, wash the area around the filter mounting adapter with a suitable solvent and blow dry with compressed air.
2. Put a suitable container in place to collect spillage.
3. Using a filter wrench, remove the filter casing from the mounting 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. Use the hand primer on the fuel filter housing to bleed the fuel system.
8. Start the engine and run at idle for five minutes to fill the filter with fuel.
9. 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.

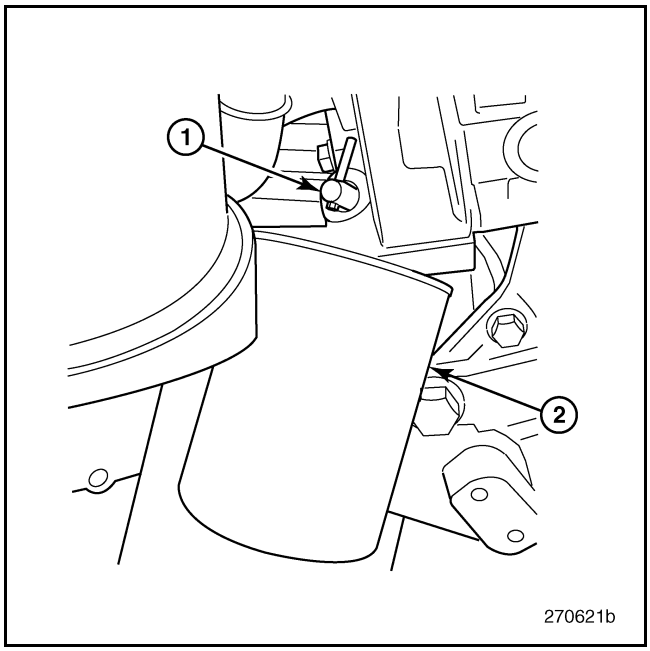


Figure 81 — Coolant Filter

1. Shut-Off Valve	2. Coolant Filter

REMOVE AND REPLACE

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

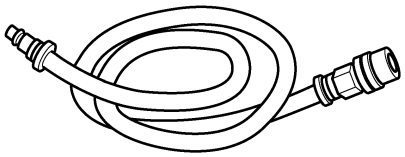
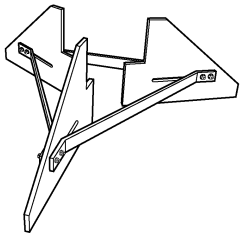
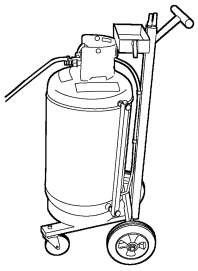
N O T E

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, unscrew the filter and discard it safely.
4. Clean the coolant filter mounting surface.
5. Apply a light film of coolant on the face of a new filter gasket seal.
6. Screw the **new** filter on the threaded nipple extending from the mounting flange.
7. Using the filter wrench, tighten the filter one full turn after the gasket contacts the base.
8. Open the shut-off valve on the coolant pump housing.
9. Check for any coolant leaks.

EXHAUST AFTERTREATMENT SYSTEM MAINTENANCE

Special Tools

Tool No.	Description	Image
9996049	Coolant Drain Hose (Available)	 006788a
85111327	VBOC DPF Support Stand	 006904a
DBT2V700	Coolant Extractor/Injector	 006940a

Diesel Particulate Filter

The diesel particulate filter should be removed from the system and replaced at the recommended service interval. If the filter is not replaced, it will become clogged and increase exhaust back pressure. As back pressure increases, engine power and economy decline as does the ability of the system to remove undesirable emissions.

SPACE SAVER UNIT

⚠ WARNING

The components reach high temperatures during use. Ensure that the unit has cooled to the touch before handling. Failure to heed this warning may result in severe personal injury.

Removal

1. When the fairing (if present), braces and steps have been removed to permit access, remove the lines and sensors connecting the inlet module to the other modules.
2. Disconnect wiring and sensor connectors from the DPF and outlet modules. Cut tie straps securing the lower portion of the DPF harness to the muffler body. Also, remove the pressure differential sensor tube that connects to the outlet module.
3. Using a marker, make alignment marks on each of the module sections, above and below each V-band clamp.

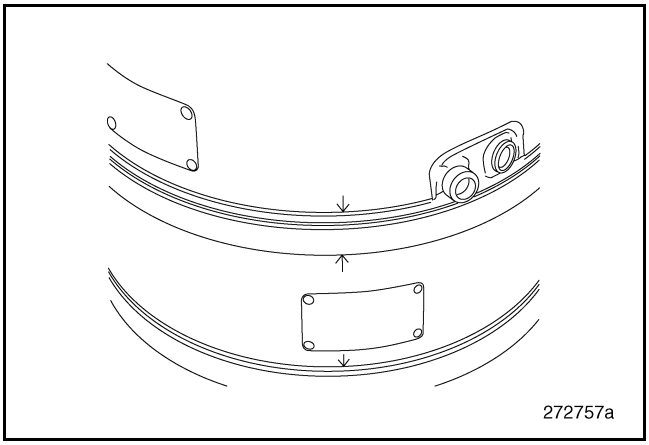


Figure 82 — Marking Module Sections

4. Remove the lower exhaust V-band clamp that connects the DPF outlet module to the exhaust pipe. Also, remove the V-band clamp that connects the catalyst module to the filter module.

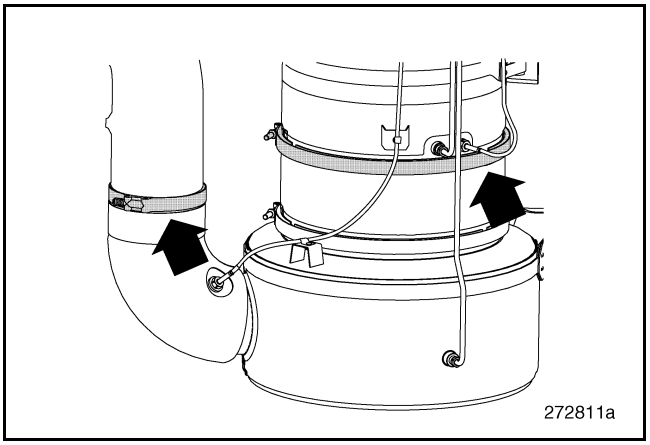


Figure 83 — Separating DPF Module

5. Position a flat surface jack with a very stable support (such as a transmission jack) under the base of the DPF.

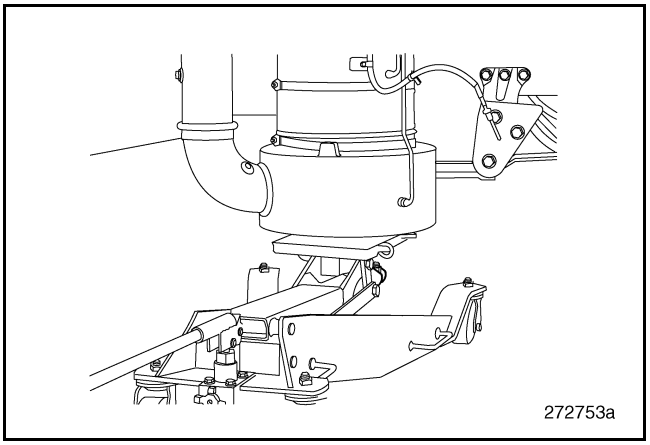


Figure 84 — Positioning Transmission Jack

6. Remove the fasteners that secure the DPF lower supporting bracket to the chassis frame bracket. This releases the weight of the DPF onto the transmission jack.

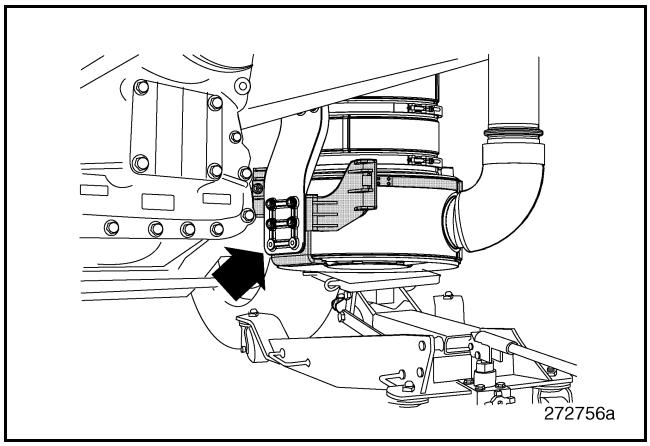


Figure 85 — Removing DPF from Chassis

7. Lower the DPF unit and roll the transmission jack from the right side of the chassis to remove the lower portion of the DPF.
8. Loosen the nut securing the large V-band clamp between the exhaust outlet module and the filter module.
9. Separate the DPF from the outlet module.
10. Remove and discard the gaskets.
11. Inspect and replace the V-band clamps showing galled threads, cracks or heat damage. Clean all exposed gasket surfaces.

Installation

1. Install a **new** gasket between the outlet and DPF modules.
2. Using alignment marks made at disassembly, position the DPF over the outlet module and connect using the V-band clamp tightened to specifications.

NOTE

Make sure the high-temperature gasket remains in place and has not become dislodged.

3. Place a **new** high-temperature gasket on top of the DPF module.
4. Perform the following steps to align and lift the filter and outlet module assembly into position:
   - Align the outlet module flange to the exhaust pipe.
   - Align the locator tab at the filter module with the slot located in the bottom of the catalyst module.
   - Start all fasteners that connect the lower supporting bracket to the chassis frame bracket.
5. Install the V-band clamp that joins the DPF and catalyst modules. Tighten the band clamp fastener to specification.

NOTE

Make sure the high-temperature gasket remains in place and has not become dislodged.

6. Install and tighten the V-band clamp that joins the outlet module to the exhaust pipe.

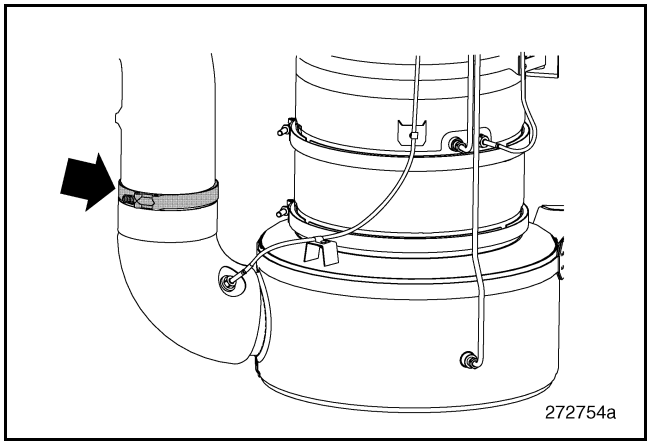


Figure 86 — Exhaust Pipe-to-Outlet Module Connection

7. Secure the DPF bracket to the chassis frame bracket and tighten all fasteners to specification.

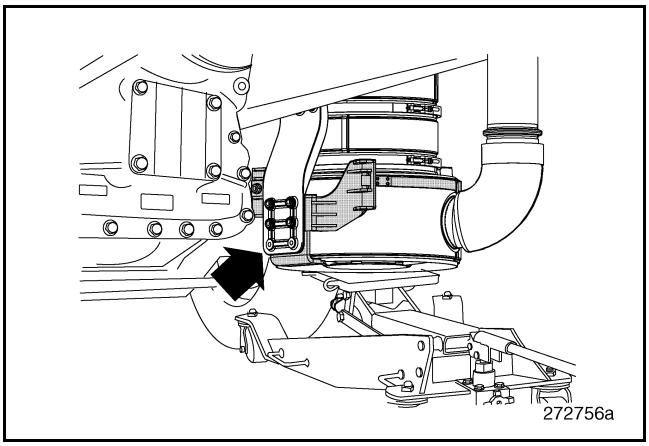


Figure 87 — Supporting DPF with Transmission Jack

8. Remove the transmission jack from under the assembly.
9. Install the pressure differential sensor tube that connects to the outlet module and tighten fitting to specification.

NOTE

A high-temperature anti-seizing compound should always be applied to the threads of the sensors, plugs and fittings in the exhaust system to avoid component seizure or corrosion.

10. Install the lines and sensors connecting the various modules to each other. Refer to torque specifications for the V-band clamp screws, lines and sensors in the SPECIFICATIONS section of this manual.

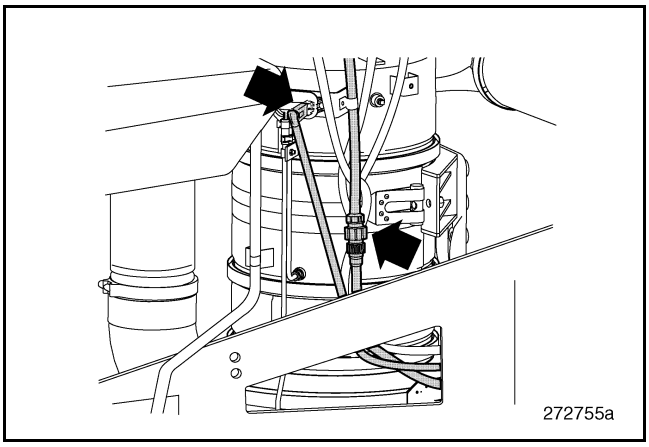


Figure 88 — DPF Connections

11. Install the fairing (if equipped), braces and steps that were removed to permit access.
12. Using Premium Tech Tool (PTT), ensure all soot trigger levels are reset back to zero.

VERTICAL BACK-OF-CAB UNIT

⚠ WARNING

The components reach high temperatures during use. Ensure that the unit has cooled to the touch before handling. Failure to heed this warning may result in severe personal injury.

Removal

1. Remove the heat shield, stack, harness clamps, tie straps and V-band clamp at the exhaust elbow.
2. Disconnect all harness connectors.
3. Using a suitable lifting device, support the assembly. Remove the band clamps and mounting bracket from the stanchion.

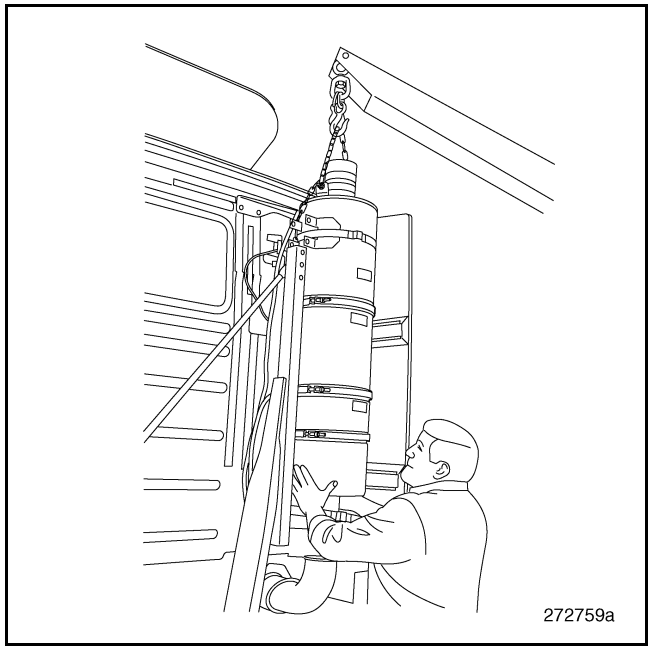


Figure 89 — Supporting DPF Assembly

4. Remove the assembly from the chassis and place it in the VBOC DPF support stand, 85111327, or equivalent.

5. Using a marker, make alignment marks on each of the module sections, above and below each V-band clamp.

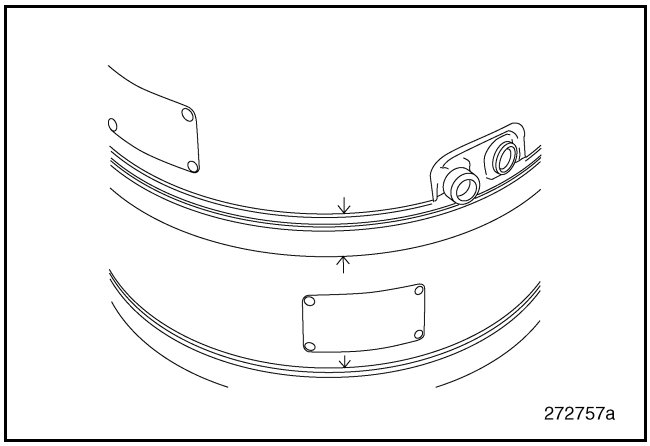


Figure 90 — Marking Module Sections

6. Remove the pressure differential tube from the catalytic filter module.
7. Remove the V-band clamp joining the outlet module to the filter module.
8. With an assistant and a suitable lifting device, remove the outlet module from the DPF filter module.

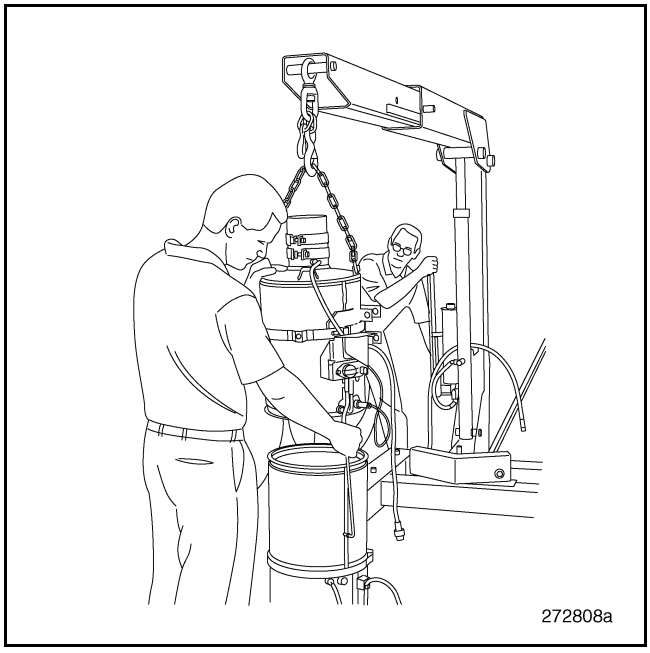


Figure 91 — Removing DPF Outlet Module

9. Remove the V-band clamp joining the DPF filter module to the catalytic filter module.
10. Separate the DPF filter module from the catalytic filter module and discard the gasket.
11. Inspect and replace the V-band clamps showing galled threads, cracks or heat damage. Clean the exposed gasket surfaces.

Installation

1. Install a **new** gasket between the catalytic filter module and the DPF filter module.
2. Align the locator tab located on the bottom of the DPF filter module with the slot located in the top of the catalytic filter module. Install the DPF filter module onto the catalytic filter module and secure the modules together using a V-band clamp tightened to specification.
3. Install a **new** gasket between the outlet module and the DPF filter module.
4. With assistance, use a suitable lifting device to install the outlet module onto the DPF filter module. Ensure that the differential pressure tube does not become damaged during outlet module installation.

N O T E

Make sure the high-temperature gasket remains in place and has not become dislodged.

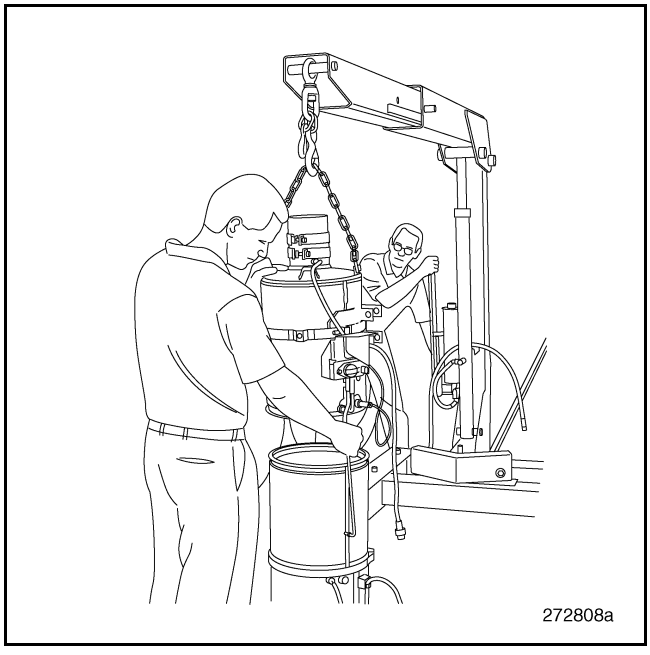


Figure 92 — Installing DPF Outlet Module

5. Install the V-band clamp to secure the outlet module to the DPF filter module and tighten clamp fasteners to specification. All clamps should now be aligned and tightened.
6. Install the pressure differential tube to the port on the catalytic filter module and tighten the fitting securely.

NOTE

A high-temperature anti-seizing compound should always be applied to the threads of the sensors, plugs or fittings in the exhaust system to avoid component seizure or corrosion.

7. Lift the DPF muffler using a suitable lifting device and with assistance, position the muffler next to the frame-mounted stanchion, at the back of the cab.

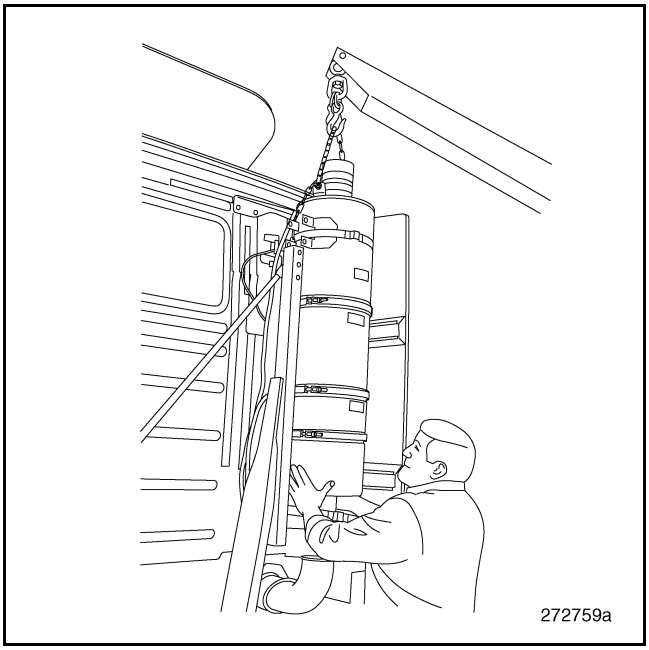


Figure 93 — Supporting DPF Assembly

8. Align the slot in the muffler bottom with the tab on the stanchion.

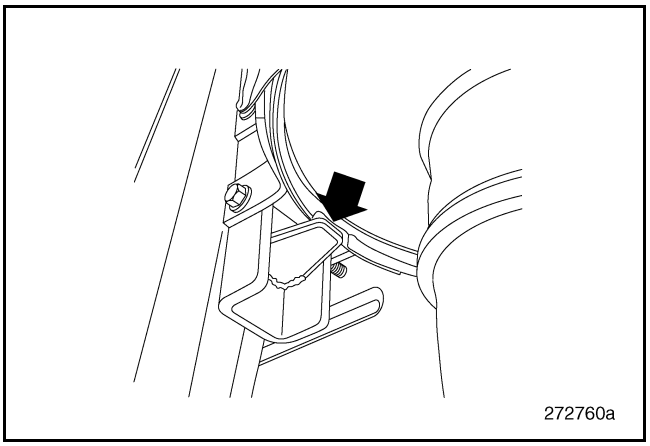


Figure 94 — Align Muffler with Tab

9. Perform the following steps to align the DPF muffler into final position on the muffler stanchion:
   - Align the muffler inlet with the exhaust elbow.
   - Align the muffler upper supporting bracket to the stanchion and install the bolts loose.
   - Loosely install the upper supporting band clamp with attached bracket and install bracket bolts into the stanchion.
   - Loosely install the lower supporting band clamp.
10. With all components aligned, install and secure the lower V-band clamp at the inlet side of the muffler.
11. Install the heat shield onto the DPF muffler.
12. Secure all fasteners and clamps that connect the DPF muffler to the stanchion. Tighten all clamps and muffler fasteners according to specification.
13. Disconnect the lifting device and remove the lifting chain from the muffler.
14. Reconnect the harness connectors for all temperature and pressure differential sensors on the DPF muffler.
15. Locate torque specifications for the V-band clamp screws, lines and sensors in the **SPECIFICATIONS** section of this manual.
16. Using Premium Tech Tool (PTT), ensure all soot trigger levels are reset back to zero.

Aftertreatment Fuel Injector (AFI)

⚠ CAUTION

When replacing the AFI, check the part number of the injector to ensure that an injector with a proper flow rate for the engine is installed. Installing an injector with the incorrect flow rate may cause dangerously high regeneration temperatures and subsequent DPF damage.

REMOVAL

1. Apply the parking brake and place the shift lever in neutral.
2. Disconnect all cables from ground (negative) battery terminals to prevent personal injury from electrical shock.
3. Remove P-clamp screws securing the AFI harness and fuel supply line.
4. Connect the coolant extractor/injector, DBT2V700, to the drain fitting at the bottom of the radiator. Drain the coolant.

NOTE

An alternative method is to use drain hose, 9996049, to drain the engine coolant into a suitable container.

5. Disconnect the aftertreatment fuel injector double check valve assembly (CVA). Collect any residual fuel that might be in the fuel line in a suitable container.

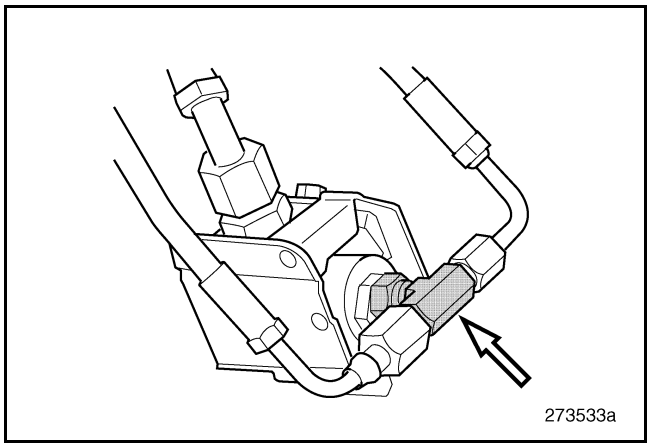


Figure 95 — Disconnecting AFI Check Valve Assembly

6. Disconnect both the inlet and outlet coolant lines from the aftertreatment fuel injector fittings.

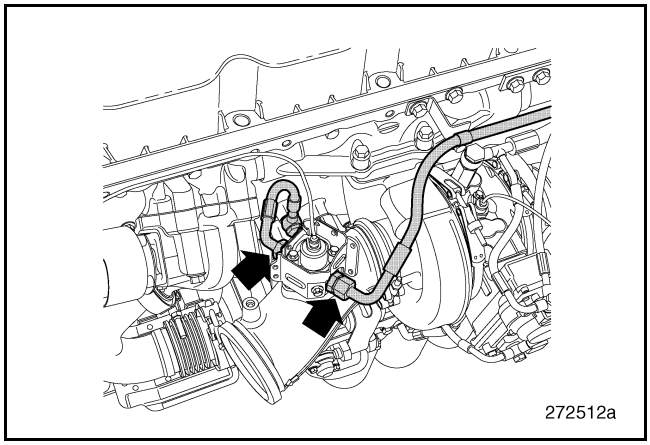


Figure 96 — AFI Coolant Lines

7. Disconnect the aftertreatment fuel injector wiring harness connector. Remove all clips and tie straps to allow the harness to hang free.
8. Remove and discard the aftertreatment fuel injector mounting bolts and spacers, and then remove the injector from the diffuser pipe attached to the turbocharger outlet.

NOTE

Mark the AFI orientation to the diffuser. The higher side of the AFI heat shield faces the turbocharger.

9. Remove and discard the high-temperature gasket and steel plate gasket from the bottom of the injector.

INSTALLATION

1. Install a **new** high-temperature gasket and steel plate gasket onto the bottom of the aftertreatment fuel injector.
2. Apply high-temperature nickel-graphite anti-seize compound to new injector mounting bolt threads and insert the bolts into the spacers. Position the injector onto the diffuser pipe (attached to the turbocharger outlet) and hand start the bolts with spacers.

NOTE

Install the AFI as marked at disassembly, with the higher side of the heat shield toward the turbocharger.

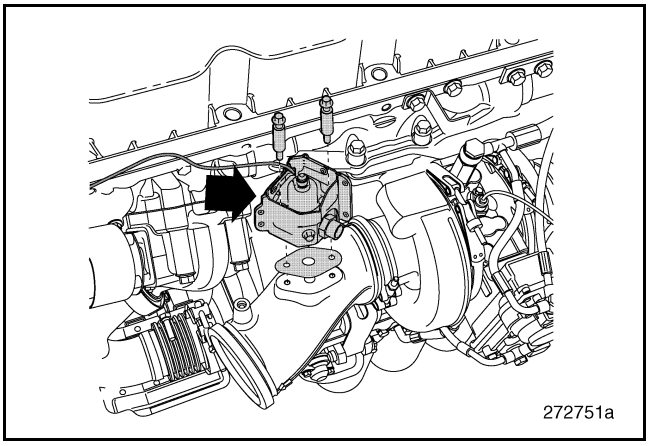


Figure 97 — AFI Installation

3. Secure the injector mounting bolts. Tighten the bolts according to specification.
4. Reconnect the aftertreatment fuel injector wiring harness connector. Secure the injector wiring harness with clips and tie straps.
5. Reconnect the coolant lines to the aftertreatment injector fittings and tighten to specification.

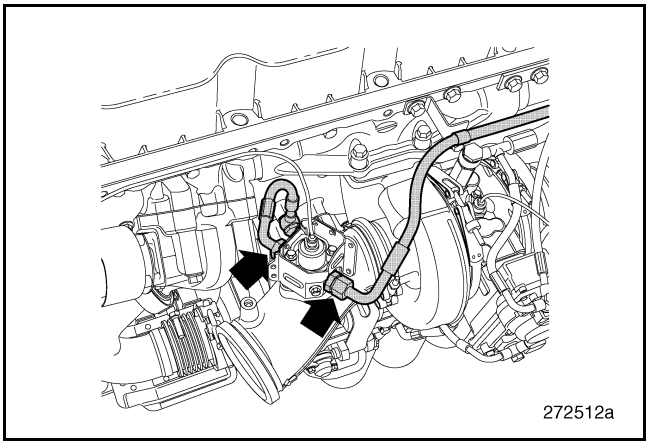


Figure 98 — AFI Coolant Line Connections

6. Connect the aftertreatment fuel injector check valve assembly and tighten to specification.

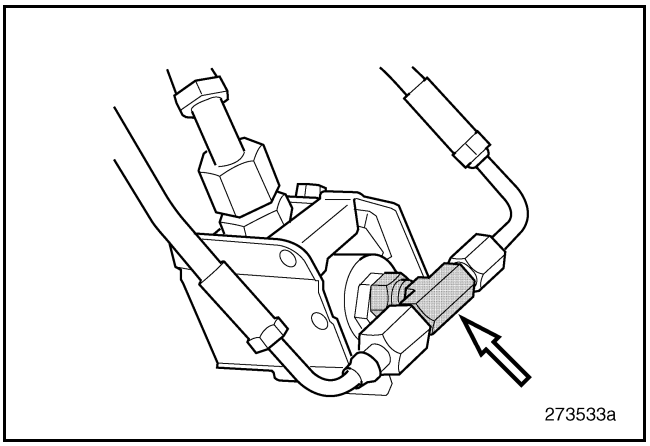


Figure 99 — Connecting AFI Check Valve Assembly

7. Install the P-clamp and screws to secure the AFI harness and fuel supply line to the diffuser.
8. Fill the engine cooling system with the recommended coolant using the coolant extractor.
9. Install all previously removed cables to the ground (negative) battery terminals.
10. Perform Aftertreatment Injector Adaptive Factor Reset using VCADS/Tech Tool.
11. Start the engine, check for leaks and proper operation. After shutdown, replenish fluids as necessary.

CLEANING

1. Apply the parking brake and place the shift lever in neutral.
2. Disconnect all cables from ground (negative) battery terminals to prevent personal injury from electrical shock.
3. Remove P-clamp screws securing the AFI harness and fuel supply line.
4. Disconnect the aftertreatment fuel injector double check valve assembly (CVA). Collect any residual fuel that might be in the fuel line in a suitable container.

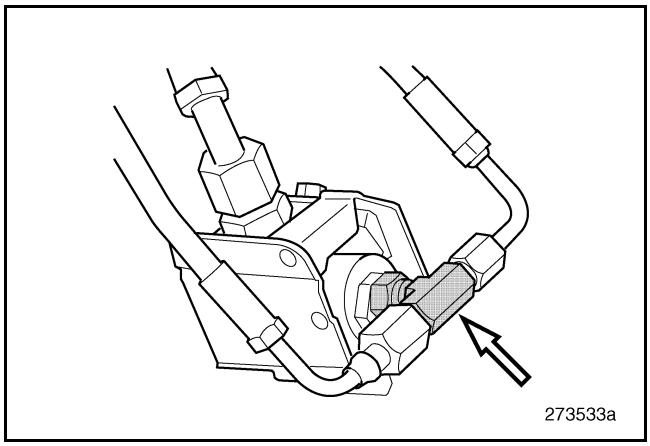


Figure 100 — Disconnecting AFI Check Valve Assembly

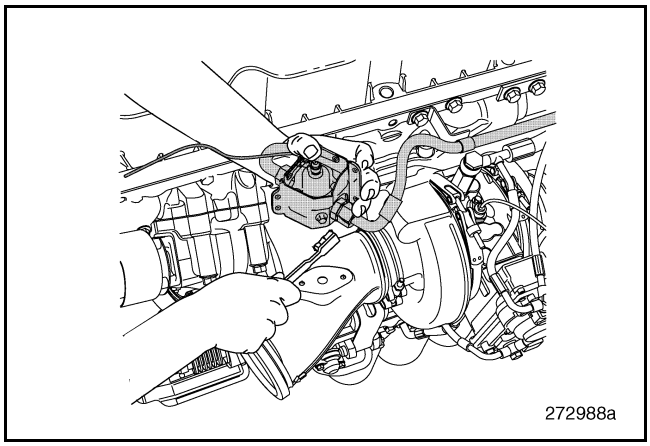


Figure 101 — Removing Carbon Deposits

NOTE

The coolant lines do not have to be disconnected nor coolant drained for AFI cleaning.

5. Remove and discard the aftertreatment fuel injector mounting bolts and spacers, and then remove the injector from the diffuser pipe attached to the turbocharger outlet.
6. Cover the opening in the diffuser pipe to prevent dirt and cleaning fluid from entering the exhaust system.
7. Remove and discard the high-temperature gasket and steel plate gasket from the bottom of the injector.
8. Carefully turn the AFI body and spray the injector tip with carburetor cleaning solution. Brush the injector tip with a stiff bristled nylon toothbrush. Repeat two or three times.

⚠ CAUTION

Do NOT kink the fuel and coolant lines when cleaning the injector. Kinking the lines may result in leakage.

⚠ CAUTION

Only carburetor cleaner should be used for cleaning the injector. Other cleaners, such as brake cleaner products, do not work and may contain chlorine that could damage the catalyst if they enter the exhaust system.

9. Inspect the injector tip to make sure it is thoroughly clean and all soot has been removed. Use a mirror if a clear view of the tip is not possible.

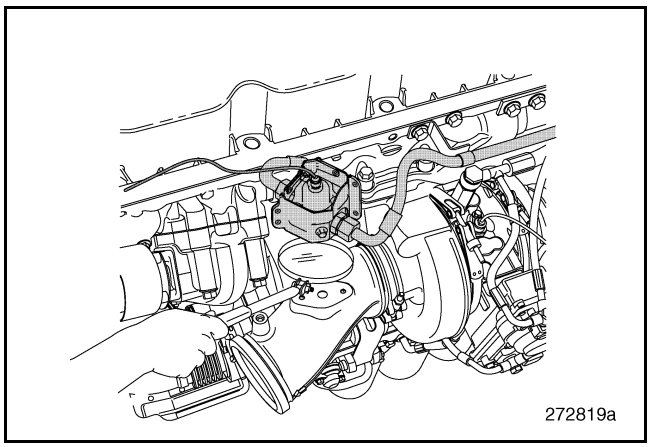


Figure 102 — Inspecting AFI Tip

10. Install a **new** high-temperature gasket and steel plate gasket onto the bottom of the aftertreatment fuel injector.
11. Apply high-temperature nickel-graphite anti-seize compound to the **new** injector mounting bolt threads and insert the bolts into the spacers. Position the injector onto the diffuser pipe (attached to the turbocharger outlet) and hand start the bolts with spacers.
12. Secure the injector mounting bolts. Tighten the bolts according to specification.
13. Connect the aftertreatment fuel injector check valve assembly and tighten to specification.

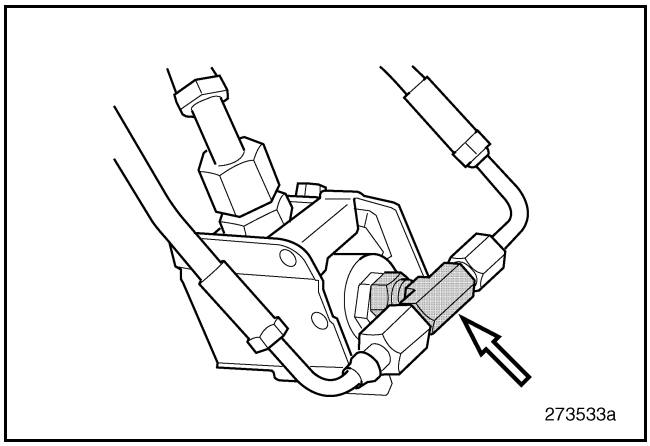


Figure 103 — Connecting AFI Check Valve Assembly

14. Install P-clamp bolts to secure the AFI harness and fuel line.
15. Connect all previously disconnected cables to the ground (negative) battery terminals.
16. Using VCADS/Tech Tool, reset the AFI adaptive factor, clear codes and test the system for proper operation.

DRIVE BELT REPLACEMENT AND TENSIONING [216 AA]

General Information

The service life of the poly-V belts is considerably improved over other systems and allows the use of higher horsepower cooling fans. All MP7 engines are equipped with poly-V belt systems.

MP7 Engine

In the dual poly-V drive belt arrangement, the fan drive and coolant pump are driven directly from the crankshaft pulley by a 10-rib poly-V belt. The alternator and the air conditioning (A/C) refrigerant compressor (if equipped) are driven off the crankshaft pulley by a six-rib poly-V belt (Figure 104). Two automatic tensioners are used, one for the fan drive and coolant pump and one for the accessory drive. An extra idler is provided for the high mount fan drive.

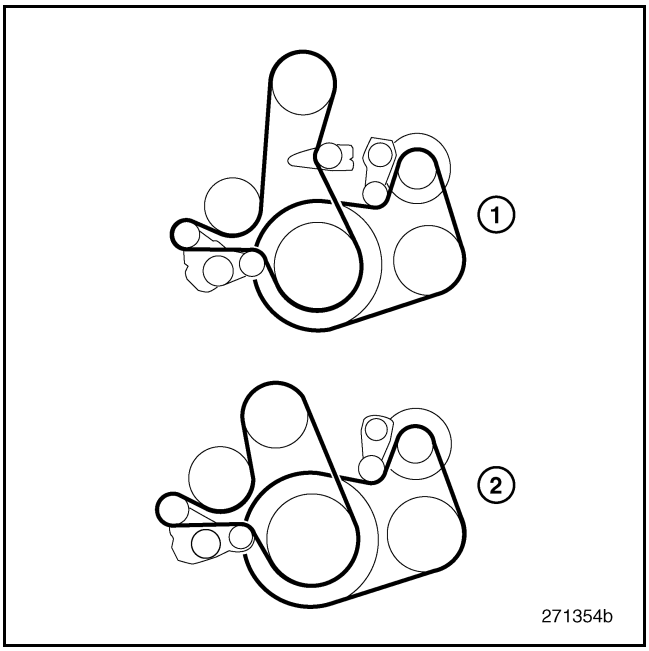


Figure 104 — Drive Belt Arrangement

1. Conventional Chassis	2. LCF Chassis

The tensioner for the crankshaft-to-fan drive hub and coolant pump is mounted to the front engine support. This tensioner spring loads in a *counterclockwise* direction to apply load to the belt. The accessory drive belt tensioner is mounted on the front of the accessory bracket which supports the alternator and A/C refrigerant compressor. This tensioner spring loads in a *counterclockwise* direction to apply load to the belt.

Automatically Tensioned System

INSTALLATION

Swing the tensioner to the fully sprung position and, without force, place the belt over the pulleys. Do not allow the tensioner to snap against its stops. Use belt tensioning tool, J 44392, to install a belt over the pulleys.

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.

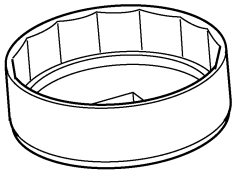
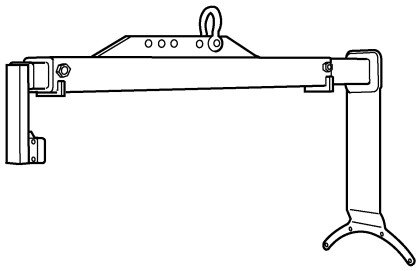
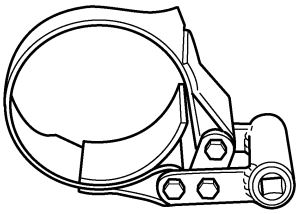
MAINTENANCE

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.

REPAIR INSTRUCTIONS, PART 1

ENGINE REMOVAL

Special Tools

Tool No.	Description	Image
9998487	Oil Filter Wrench (Available)	 006845a
J 47038-3 J 47038-4 J 47038-6 J 47038-7	Engine Lifting Tool (Essential)	 273530a
J 48061	Coolant Filter Wrench (Available)	 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.

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) cables.
4. Drain the air tanks.

Removal

1. Remove the hood. On cab over engine models, tilt the cab.
2. Place suitable containers beneath the engine and drain the oil and coolant. Open the coolant drain valves in the radiator, the cylinder block and the EGR cooler.
3. Using the oil filter wrench, 9998487, remove the oil filters.
4. Using a suitable filter wrench, remove the fuel filters.
5. Using the coolant filter wrench, J 48061, 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

To prevent fluid leaking from the fan assembly, store it horizontally face down (hub flange up) or vertically as shown.

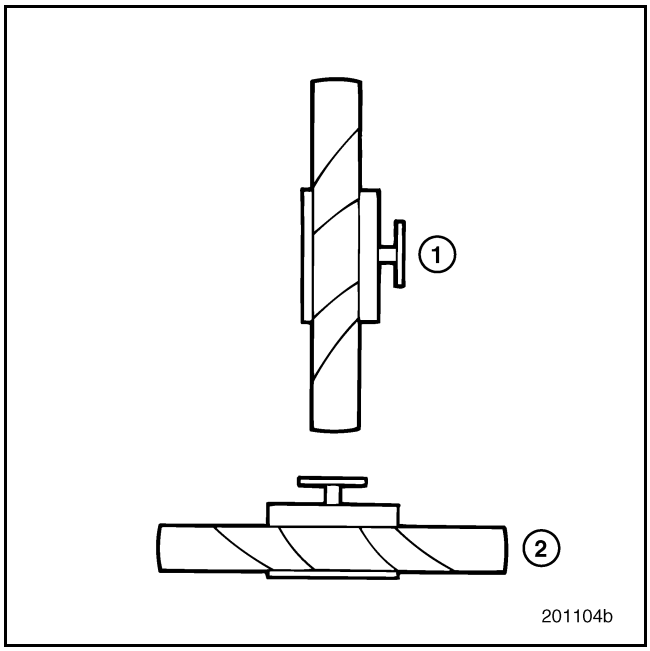


Figure 105 — Viscous Fan Drive Assembly Storage

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. Remove the exhaust bracket from the flywheel housing.

NOTE

Use a container to collect power steering fluid.

17. Remove the power steering hoses.

NOTE

If a fuel line to the DPF system is present, use a container to collect fuel under the connection.

18. If present, disconnect the fuel and electrical lines from the DPF system.

⚠ WARNING

The DPF system is subject to extremely high temperatures and can be very hot at all points. Ensure that the components are cool enough to be handled safely.

19. Disconnect the air line to the discharge recirculation valve (DRV), if so equipped.
20. Disconnect the exhaust system from the turbocharger.
21. Disconnect electrical cables or wires connected to the starter.
22. 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

NOTE

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

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

⚠ CAUTION

With assistance and a suitable lifting device, such as engine lifting tool, J 47038, support the engine safely during removal.

24. Attach the engine lifting tool, J 47038, to the engine. Secure the engine lifting tool to the front of the fan bracket and to the rear at the flywheel housing.

⚠ DANGER

Ensure all bolts and pins 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.

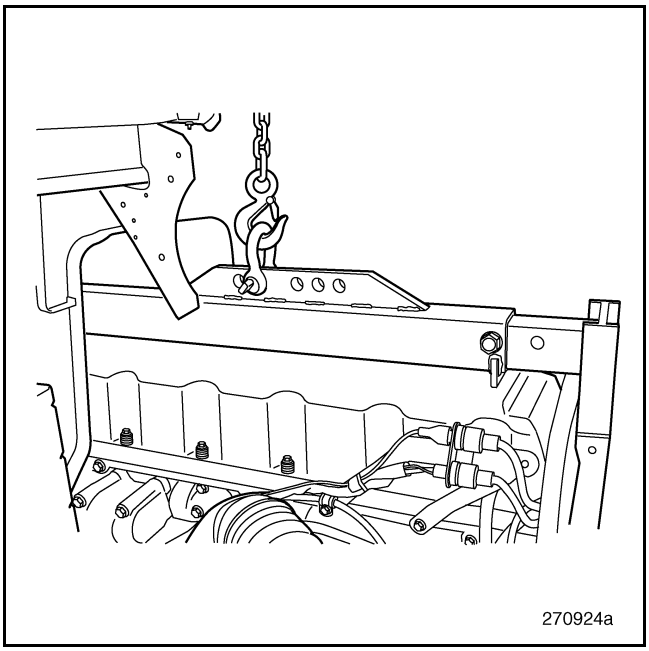


Figure 106 — Attaching the Engine Lifting Tool to the Engine

25. Remove the bolts that secure the front engine support to the frame crossmember.

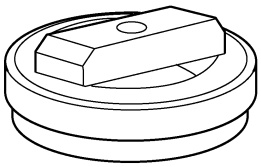
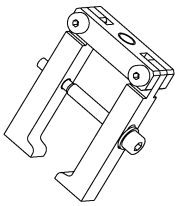
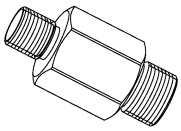
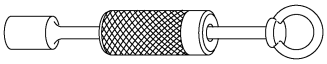
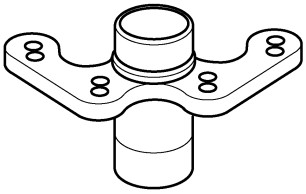
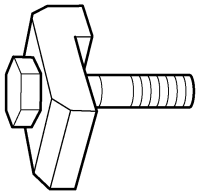
⚠ CAUTION

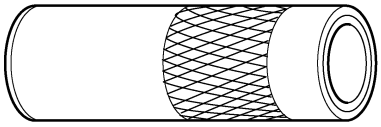
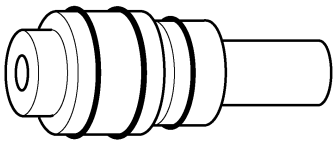
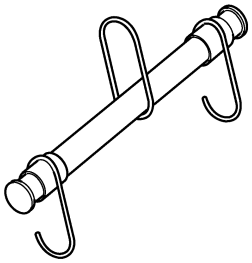
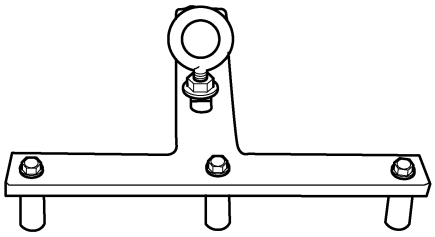
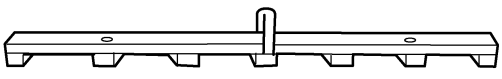
While removing the engine, watch for obstructions that may interfere, such as engine and chassis components, brackets, clamps and other parts still attached to the engine. Failure to heed this caution may result in severe damage to the engine and other components.

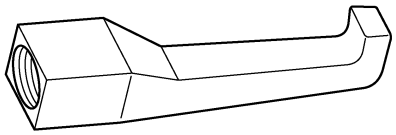
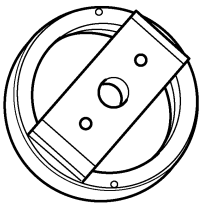
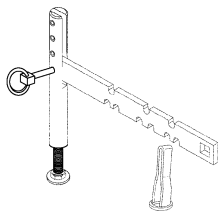
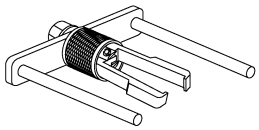
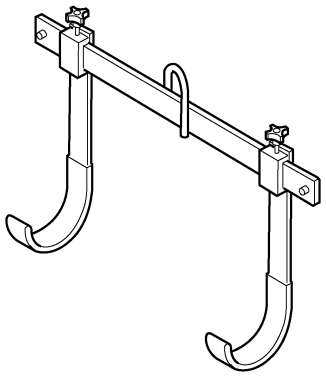
26. Using the lifting device and the aid of a helper, remove the engine from the vehicle.
27. Refer to Engine Disassembly procedures for mounting the engine on an engine stand.

ENGINE DISASSEMBLY
[200 EA]

Special Tools

Tool No.	Description	Image
9990113	Rear Main Seal Remover/Installer, use with 9992000 (Essential)	 006780a
9990114	Main Bearing Cap Puller	 007030a
9990262	Slide Hammer Adapter	 007031a
9996400	Slide Hammer	 007032a
9996956	Flywheel Turning Tool (Essential)	 006795a
9996966	Liner Hold-Down Tool (Essential)	 006796a

Tool No.	Description	Image
9998249	Unit Injector Protection Sleeve (Essential)	 006798a
9998251	Unit Injector Bore Sealing Plug (Essential)	 006800b
9998511	Lever	007121a
85109034	Camshaft Lifting Bar (Essential)	 006835a
85109049	Cylinder Head Lifting Tool (Essential)	 006769a
85109050	Rocker Shaft Assembly Lifting Tool (Essential)	 006770a

Tool No.	Description	Image
85109980	Camshaft Bearing Cap Removal Tool, use with 9990013	 006886a
88800021	Front Main Seal Remover/Installer (Essential)	 006774a
J 41989-A	Valve Spring Compressor	 007122a
J 48922	Heavy-Duty Unit Injector Puller (Essential)	 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.

⚠ CAUTION

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.

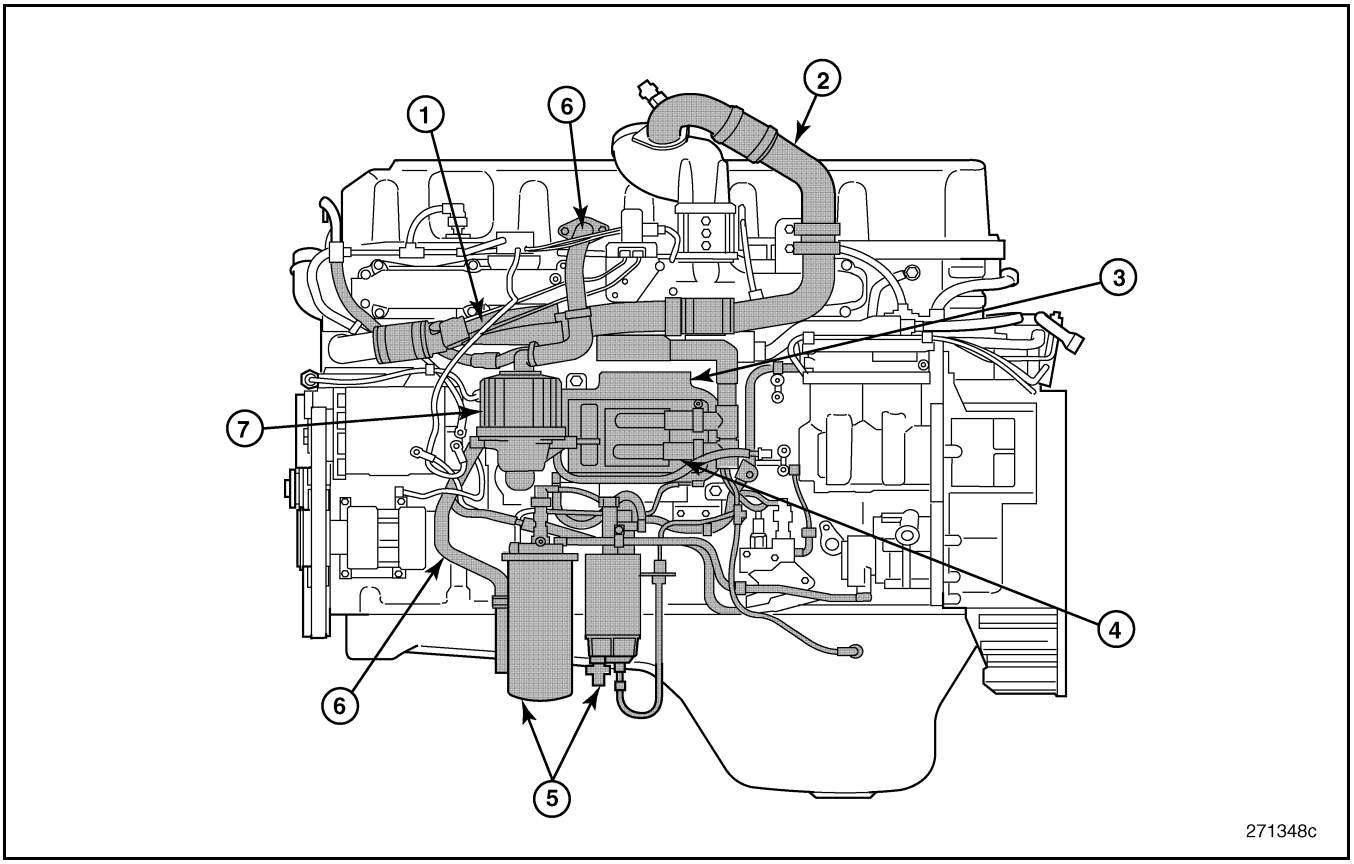


Figure 107 — Components to be Removed Before Mounting on a Repair Stand — LCF Chassis

1. Venturi Housing 2. EGR Mixer Inlet Tubing 3. EECU Cooling Plate 4. EECU	5. Fuel Filters 6. CCV Separator Tubing 7. CCV Separator

If the engine is to be mounted on a repair stand by means of a mounting plate attached to its left side, the following components must also be removed if present.

1. Remove the dipstick pipe.
2. Remove the oil fill pipe.
3. Remove the crankcase ventilation pipe.
4. Tag the electrical connectors to facilitate reconnection in the original configuration.
5. Unlock and remove the end connectors attached to the EECU.
6. Unlock and separate the external connectors at the various junctions, including the differential pressure sensors.
7. Remove the clamps holding the harness to the cylinder block.
8. Set the members of the harness aside in a safe place.

NOTE

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

9. Loosen the fuel line banjo fittings.
10. Remove the fuel line connecting the fuel filter housing to the EECU cooling plate.
11. Remove the strap clamps attaching the double line to the cylinder block.
12. Remove the fuel lines between the top of the cylinder head at the front and the fuel filter housing.
13. Remove the strap clamp from the line to the cylinder block.
14. Remove the fuel line between the side of the cylinder head at the rear and the fuel filter housing.
15. Remove the fuel filter housing.
16. Remove the EECU harness retainers.
17. Remove the harness and set aside.
18. If not already done, remove the fuel lines between the fuel supply pump, fuel filter housing and the EECU cooling plate and set aside.
19. Remove the cooling plate and the EECU from the cylinder block.
20. Separate the cooling plate from the EECU.
21. Attach a suitable lifting device to the lifting points on the engine.
22. Attach an engine hoist to the lifting device.
23. Using the engine hoist, move the engine to a suitable, safe stand.
24. Using an appropriate mounting plate, attach the engine to the stand.

Cylinder Head (Valve) Cover Removal

[211 JB]

1. If not already done, remove the crankcase ventilation pipe.
2. Remove the pressure sensor.
3. Remove the screws attaching the cylinder head (valve) cover to the cylinder head.
4. Remove the cylinder head (valve) cover.

Engine Wiring Harness Removal — External

[723 KA]

The external 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 internal harness in the block in various locations.

1. If not already done, unlock and remove the end connectors attached to the EECU.
2. Tag the connectors to facilitate reconnection.
3. Unlock and separate the external connectors at the various junctions.
4. Remove the clamps holding the harness to the cylinder block.
5. Set the members of the harness aside in a safe place.

Engine Wiring Harness Removal — Internal

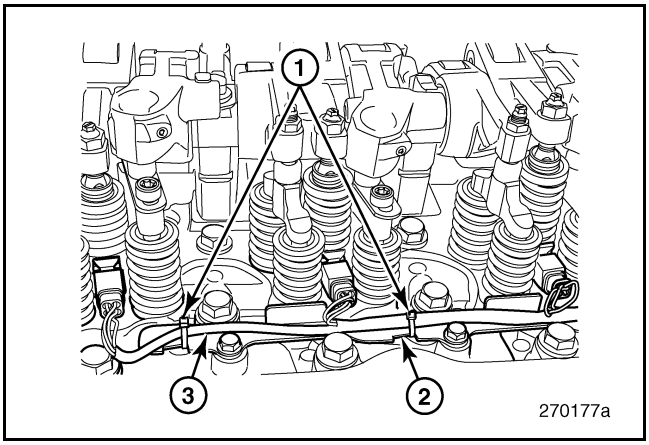


Figure 108 — Internal Wiring Harness

1. Tie Straps 2. Tie Bar Notch	3. Wiring Harness

1. Tag the terminals to facilitate reassembly.

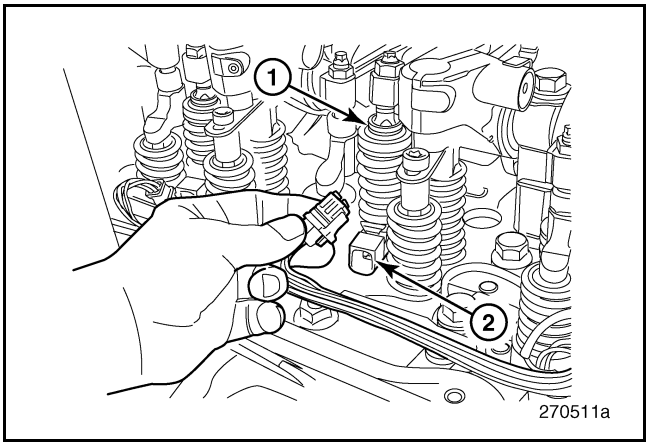


Figure 109 — Unit Injector Terminal

1. Unit Injector	2. Injector Terminal

2. Disconnect the unit injectors.
3. Disconnect the sensors.
4. If so equipped, disconnect the engine brake control valve.
5. Cut the tie straps holding the harness to the tie bar.
6. Remove and set the harness safely aside.

Timing Gear Cover Removal

[211 AA]

1. Remove the screws attaching the timing gear cover to the cylinder head and timing gear plate (Figure 110).

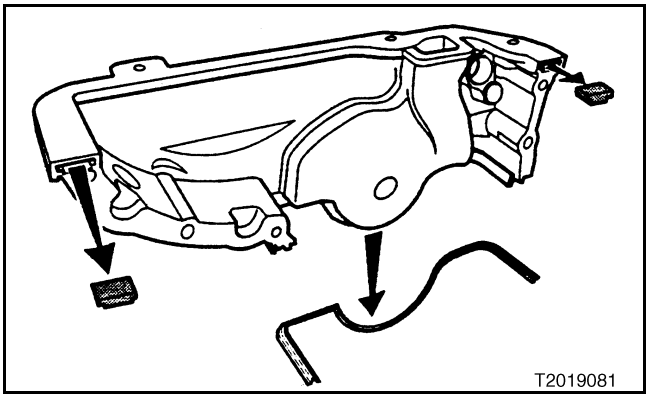


Figure 110 — Timing Gear Cover

2. Remove the cover.
3. Remove and discard the elastomer seals.

Camshaft Gear and Vibration Damper Removal

[213 DE]

1. Remove the attaching screws.
2. Remove the vibration damper from the camshaft gear.
3. Remove the gear from the camshaft.

Rocker Arm Shaft and Engine Brake Removal

[213 LP]

⚠ CAUTION

On engines fitted with the engine brake, use rubber bands or tie straps to contain the pistons within the rockers. The match between these pistons and their rockers must be maintained. The order of rocker arm assembly must be maintained. Make certain the sets of three 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 control valve (if so equipped) from the engine.

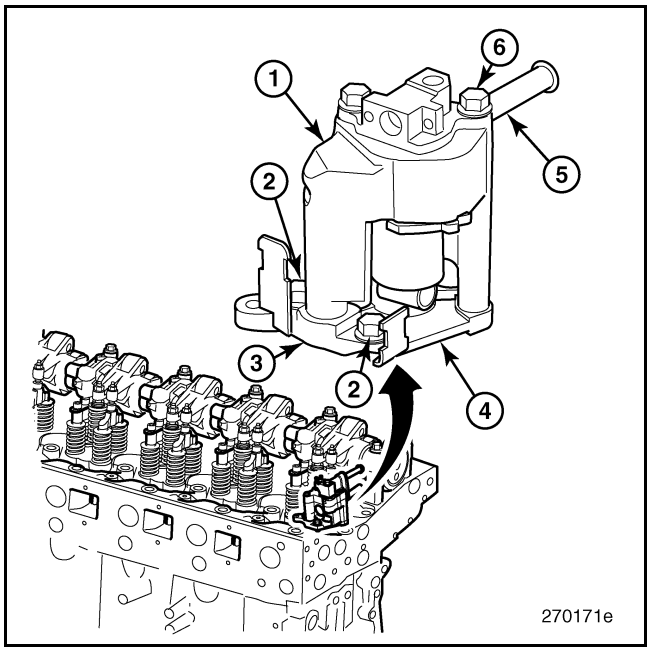


Figure 111 — Engine Brake Control Valve

1. Control Valve Assembly 2. Mounting Plate Attaching Screws 3. Mounting Plate	4. Oil Seal 5. Oil Tube 6. Valve Attaching Screw

NOTE

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

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

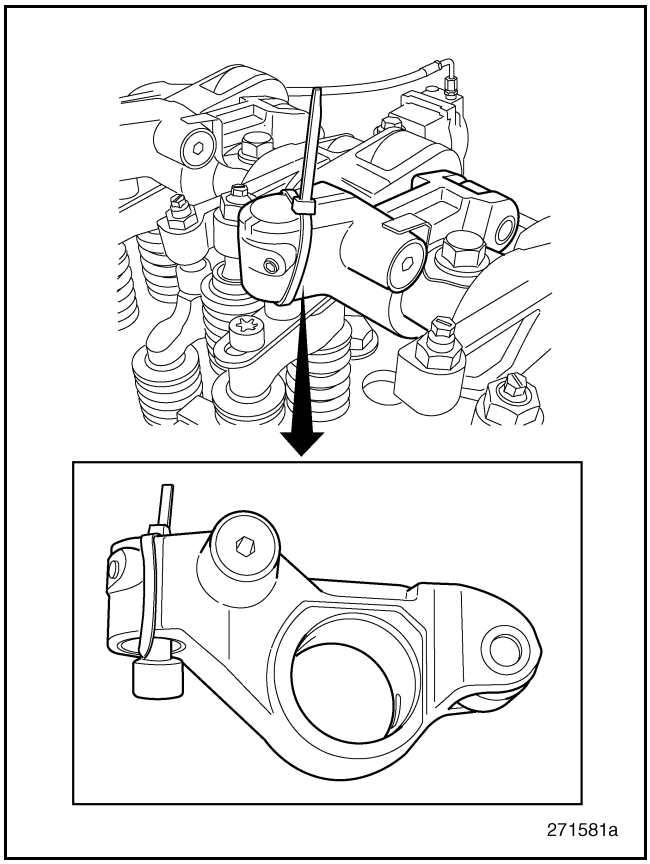


Figure 112 — Tie Strap Holding Engine Brake Piston

NOTE

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

3. Beginning at the center camshaft bearing cap, loosen the fasteners at each bearing cap evenly in stages 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.

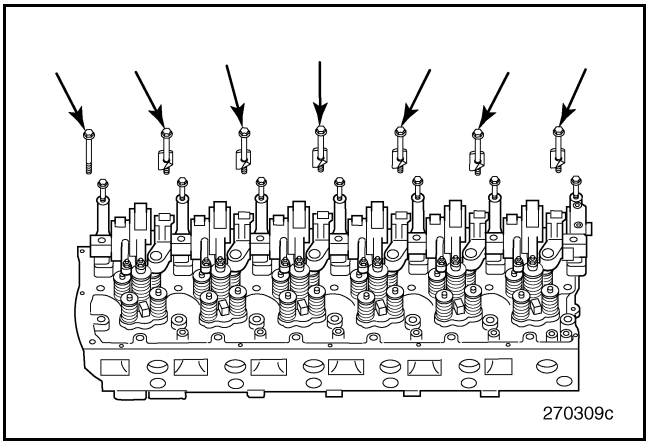


Figure 113 — Rocker Arm Shaft Retaining Screws

4. Attach the lifting tool, 85109050, to the rocker arm shaft.
5. With the aid of an assistant, carefully remove the shaft assembly using the lifting tool. Place the shaft assembly in a secure location.

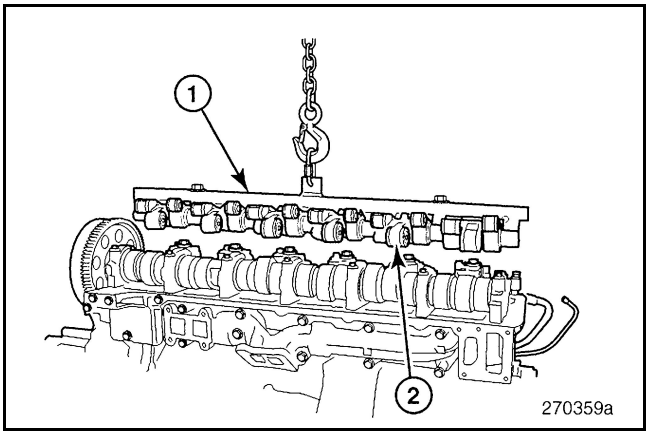


Figure 114 — Removing Rocker Arm Shaft Assembly

1. Lifting Tool 85109050	2. Rocker Arm Shaft Assembly

6. With the rocker arm shaft assembly removed, check to make sure that the alignment sleeves remain in position on each bearing cap.

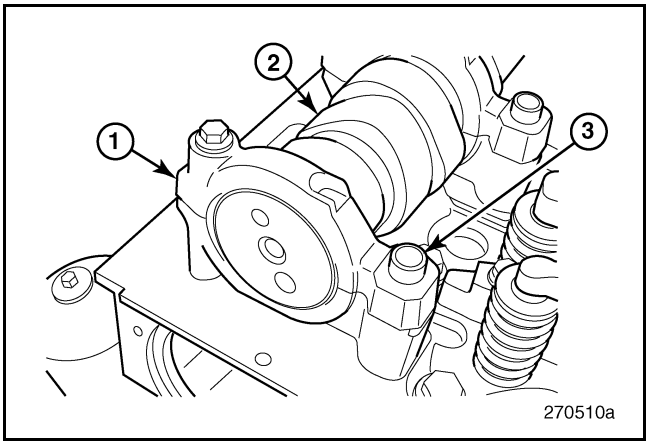


Figure 115 — Rocker Arm Shaft Alignment Sleeve

1. Bearing Cap 2. Camshaft	3. Alignment Sleeve

7. Remove the lifting tool from the rocker arm shaft.

Valve Yoke (Bridge) Removal [213 NV]

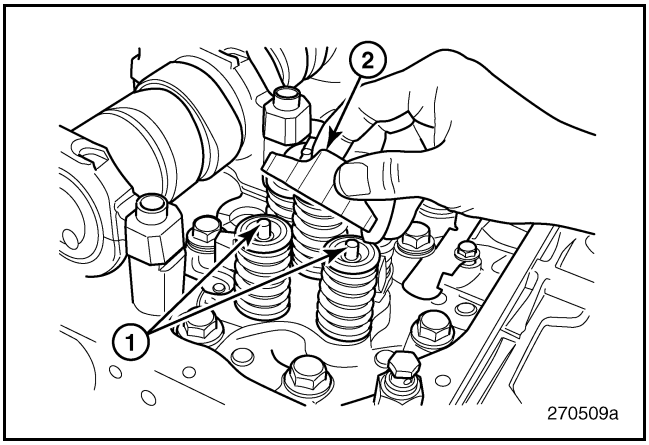


Figure 116 — Valve Yoke (Bridge) Removal

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]

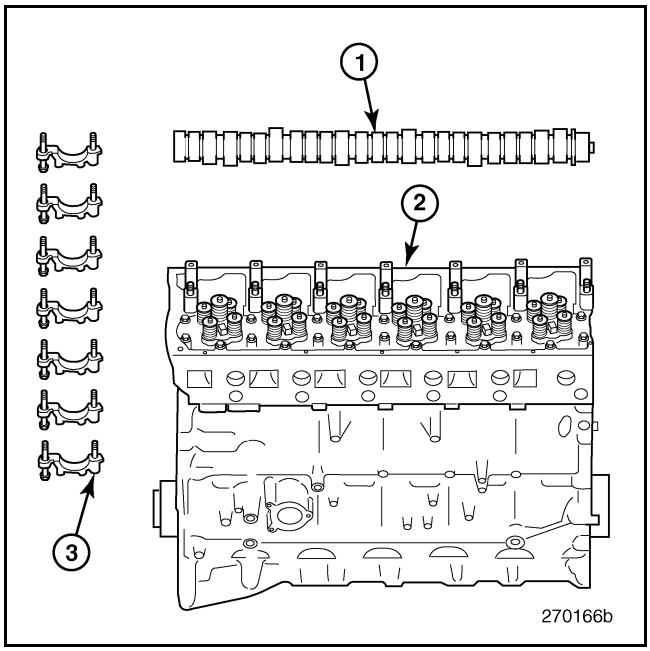


Figure 117 — Camshaft Installation

1. Camshaft 2. Camshaft Lower Bearing Cap	3. Camshaft Upper Bearing Cap

⚠ 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 severe personal injury and component damage.

1. Mark the camshaft bearing caps (if not factory marked or identified), so that they can be installed 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 assembly.
4. Attach the lifting bar, 85109034, to the camshaft between the lobes and carefully remove the camshaft from the cylinder head.

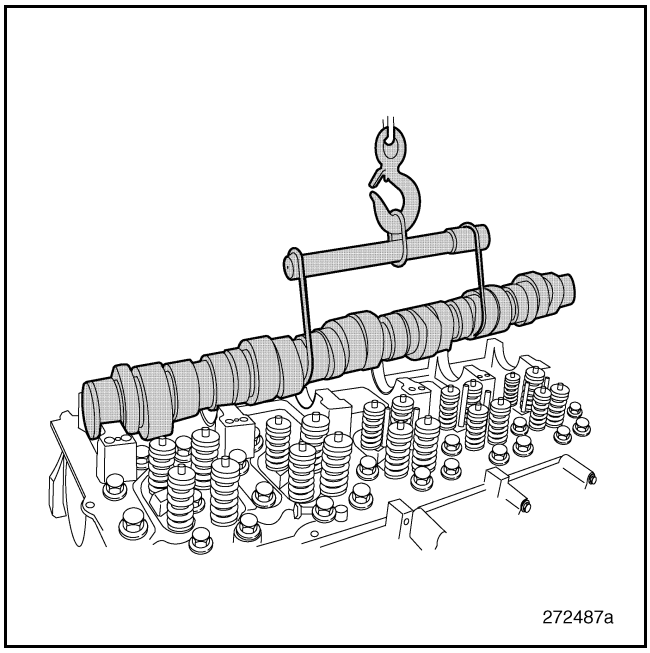


Figure 118 — Removing Camshaft

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 fro storage. Use care to avoid damage to the guide pin.

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

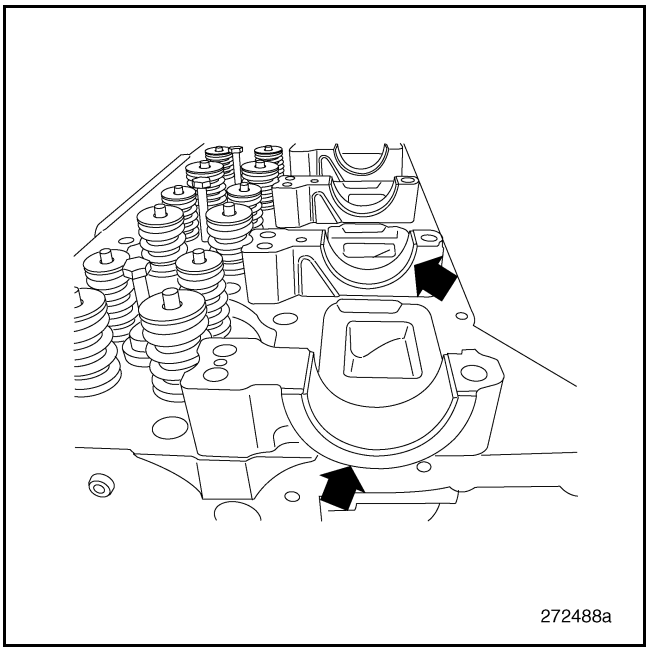


Figure 119 — Lower Bearing Inserts

NOTE

This procedure presumes that the camshaft lower bearing supports (saddles) are in place on the cylinder head and 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. Failure to heed this caution may result in severe component damage.

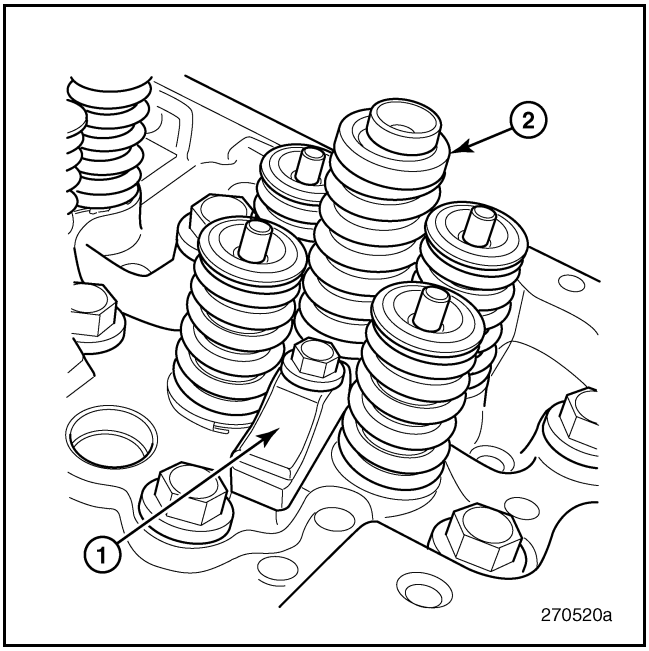


Figure 120 — Unit Injector Installed

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

1. Thoroughly clean around the unit injectors that are to be removed and check to ensure that the engine is completely drained of fuel.
2. Tag the injectors with the cylinder number before removal from the cylinder head. If new injectors are not being installed, it is essential that the original injectors be installed 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.

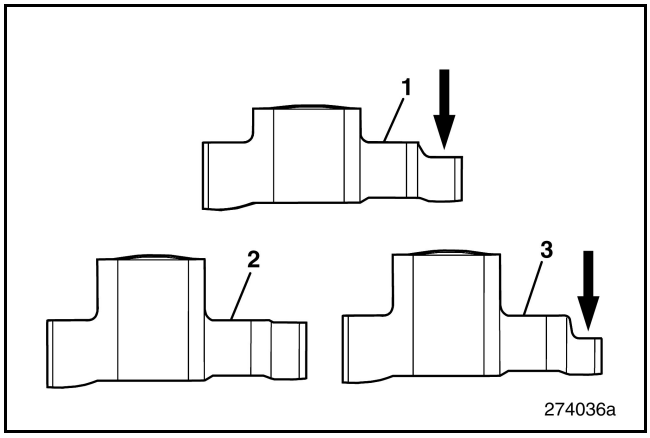


Figure 121 — Unit Injector Hold-Down Yoke Styles

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.**

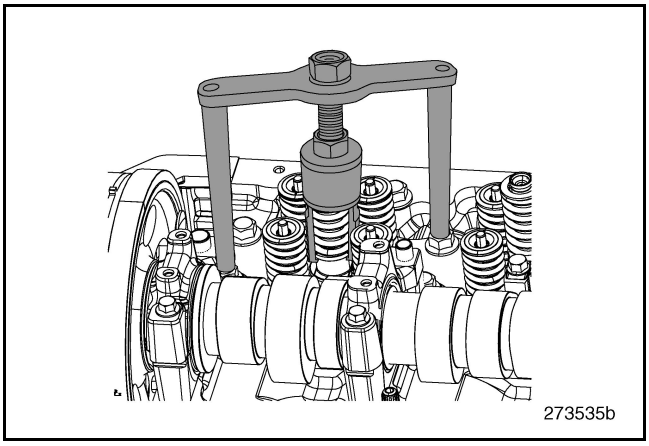


Figure 122 — Removing Injector with the Heavy Duty Unit Injector Puller (Tool No. J 48922)

⚠ 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.

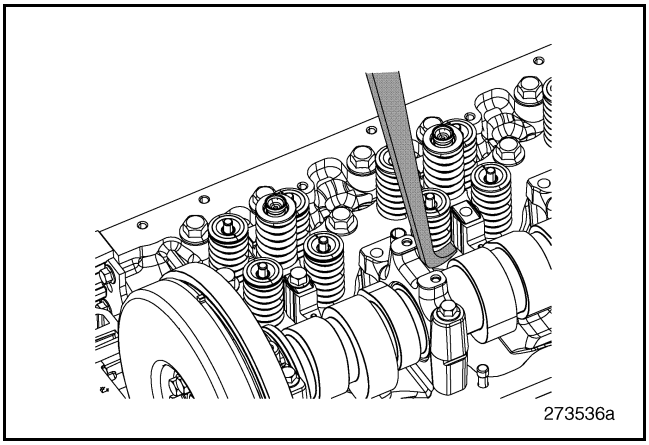


Figure 123 — Removing Injector with a Pry Bar (Tool No. 9998511)

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.

Companion Cylinder	Camshaft Mark
1 and 6	V3 TDC
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.

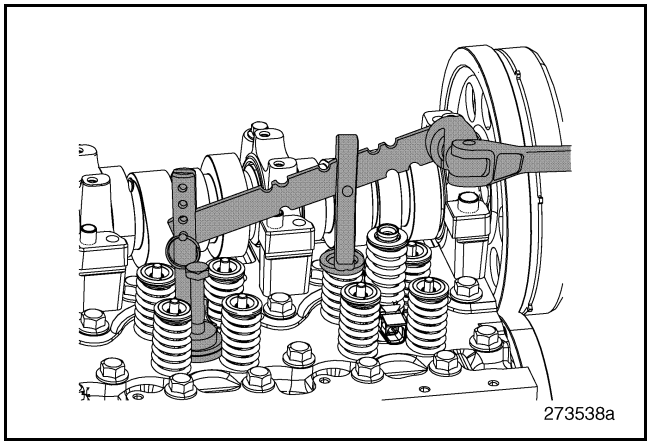


Figure 124 — Removing Valve Springs with Alternate Valve Spring Compressor (Tool No. J 41989)

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.**

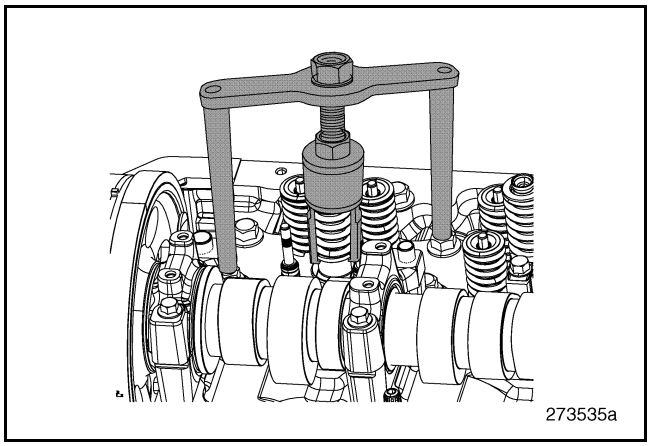


Figure 125 — Removing Injector with J 48922

⚠ 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.

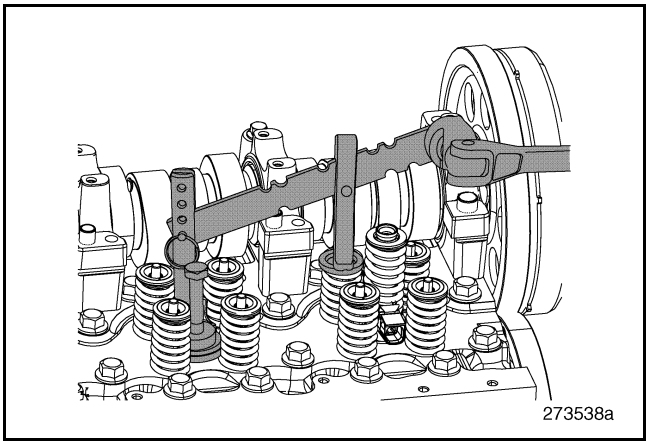


Figure 126 — Installing Valve Springs with Alternate Valve Spring Compressor (Tool No. J 41989)

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.**

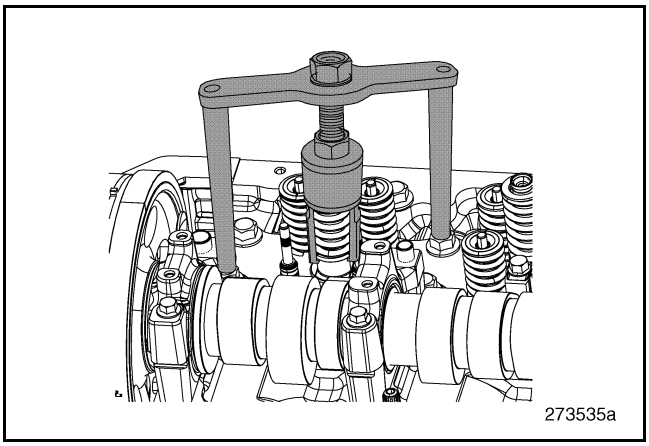


Figure 127 — Removing Injector with Heavy-Duty Puller (Tool No. J 48922)

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

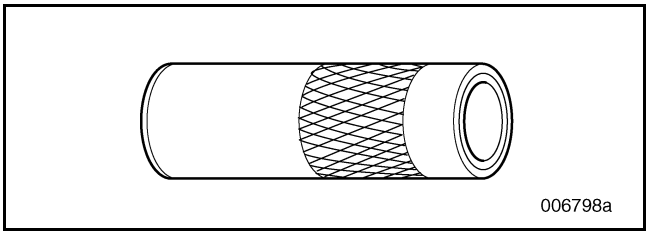


Figure 128 — Injector Protection Sleeve, 9998249

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.

NOTE

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.

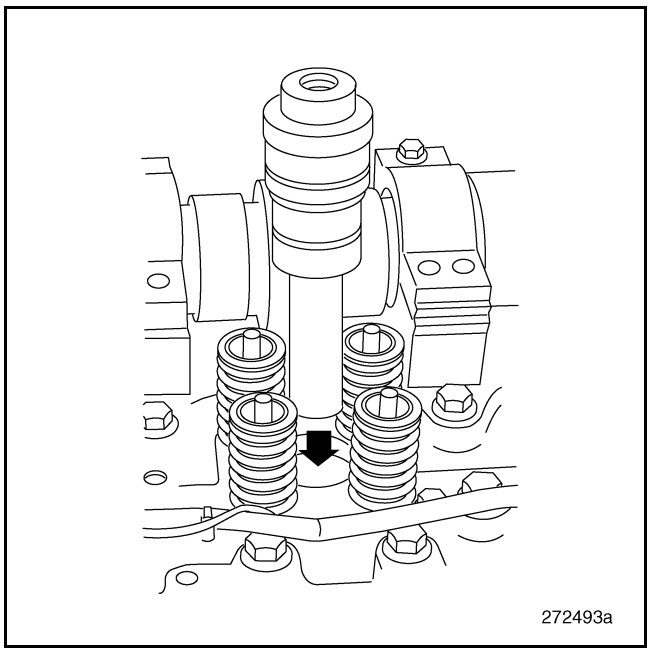


Figure 129 — Installing Injector Bore Protective Plug

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 inserted in the flywheel housing.

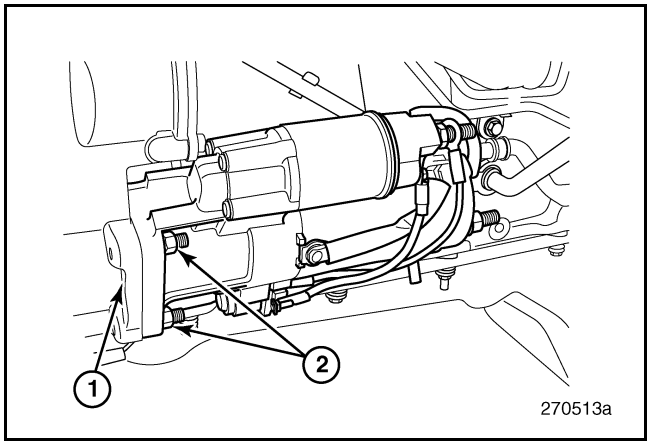


Figure 130 — Starter

1. Flywheel Housing	2. Attaching Nuts

⚠ 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 severe personal injury and component damage.

1. If not already done, disconnect the wiring harness from the starter.
2. Loosen the nuts fastening the starter to the flywheel housing.
3. With the help of an assistant or a lifting device, remove the starter.

Turbocharger Removal

[214 SC]

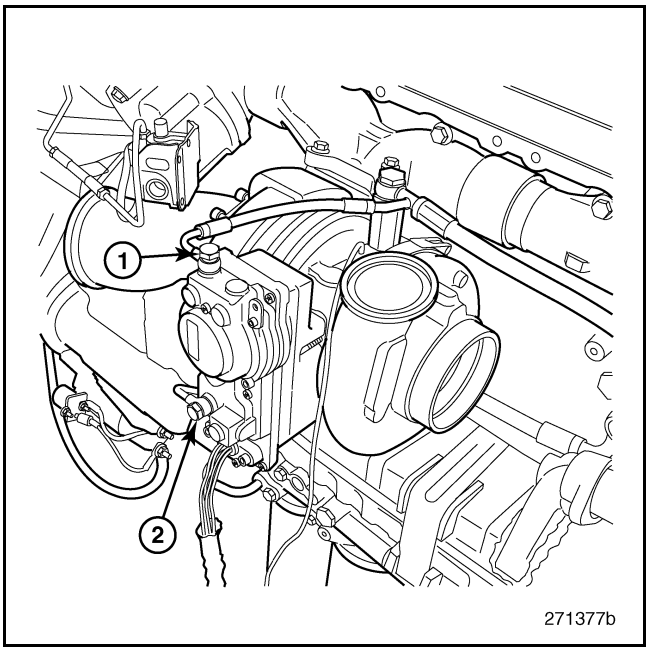


Figure 131 — Turbocharger with Actuator

1. Actuator Coolant Supply Line	2. Actuator Coolant Return Line

⚠ 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 severe personal injury and component damage.

⚠ CAUTION

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

1. Install and retain the protective caps over the turbocharger ports to keep debris and dirt out of the turbocharger.
2. Remove the turbocharger coolant supply line.
3. Remove the turbocharger coolant outlet line.
4. Remove the oil supply line.
5. Remove the oil outlet line.
6. Remove the actuator coolant return line.
7. Remove the actuator coolant supply line.
8. While supporting the turbocharger, remove the flange mounting fasteners and spacers.
9. With the help of an assistant or a lifting device, lower the turbocharger away from the exhaust manifold flange mounting studs and remove it from the engine. Remove and discard the gasket.

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

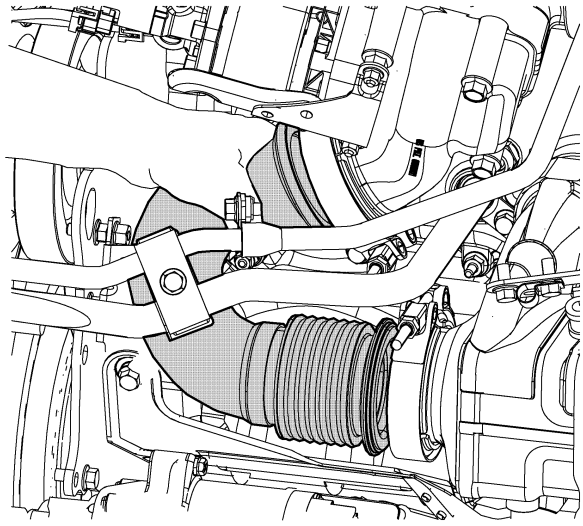


Figure 132 — EGR Hot Pipe Removal

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

EGR Valve Removal

[214 QE]

1. Disconnect the wiring harness lead from the EGR valve, if not already done.
2. Remove the fasteners securing the EGR valve heat shield and remove the shield.

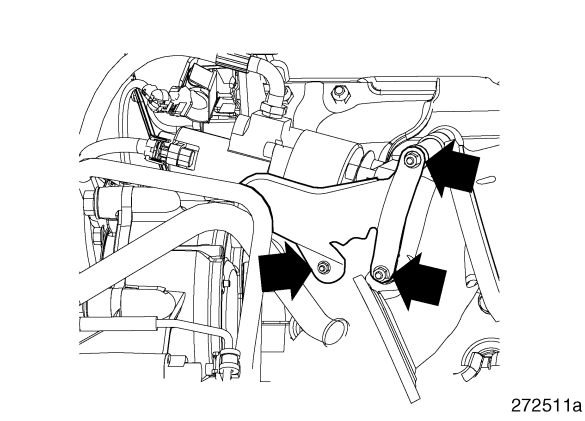


Figure 133 — EGR Valve Heat Shied

3. Loosen the EGR valve oil return line.

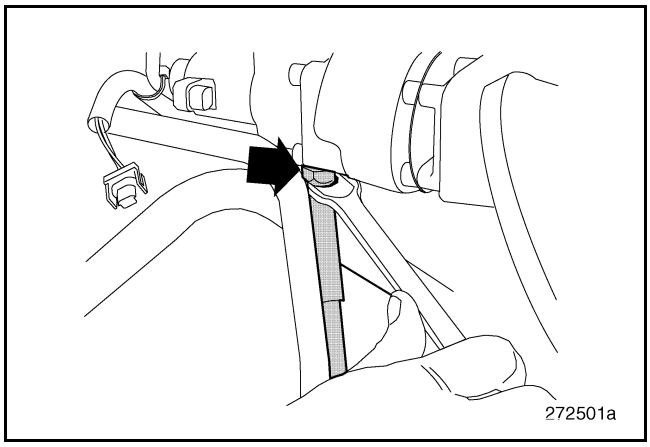


Figure 134 — Loosening EGR Valve Oil Return Line

4. Loosen the EGR valve oil supply line.

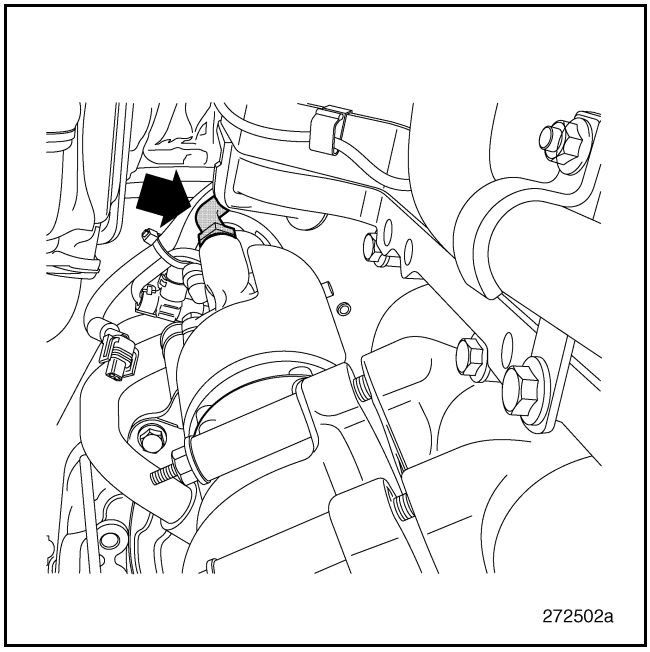


Figure 135 — Loosening EGR Valve Oil Supply Line

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

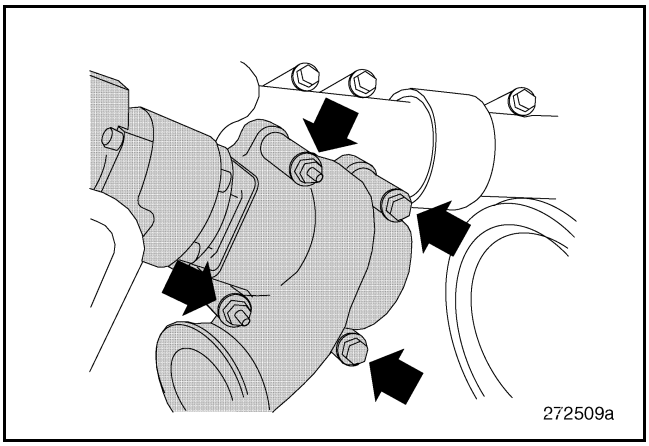


Figure 136 — Removing EGR Valve Fasteners

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

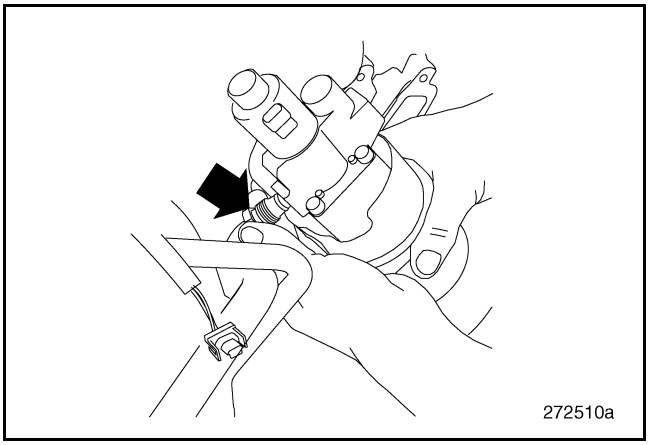


Figure 137 — Removing EGR Valve Oil Lines

7. Remove and discard the EGR valve gasket.

EGR Cooler Removal

[214 HM]

1. Remove the fasteners, the retainer and remove the coolant return line from the EGR cooler.

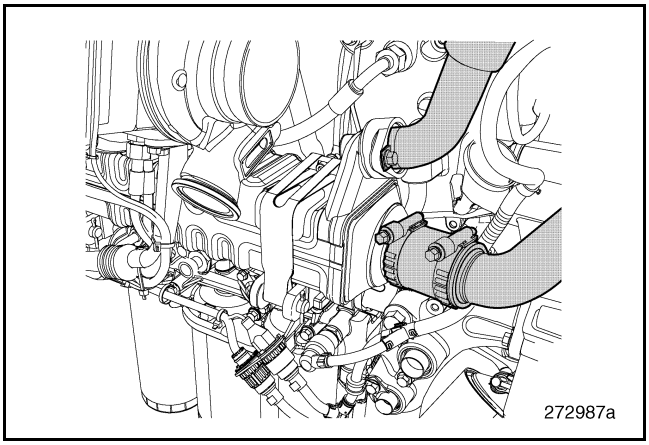


Figure 138 — EGR Cooler Coolant Return Line and Crossover Pipe Coupling Hose

2. Loosen the clamps and slide the coupling hose onto the crossover pipe.
3. Loosen the nut and T-bolt on each EGR cooler clamp strap.

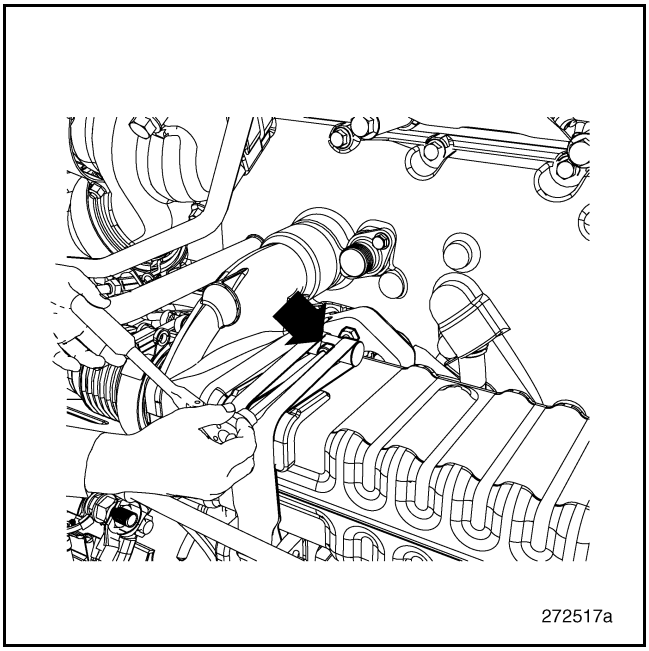


Figure 139 — Loosening EGR Cooler Clamp Strap T-Bolt

4. Rotate the straps out of the way and remove the EGR cooler from the mounting brackets.

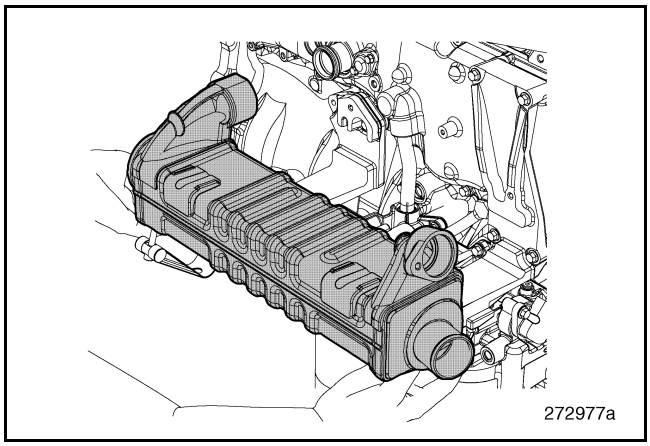


Figure 140 — Removing EGR Cooler

5. Remove the fasteners securing the EGR cooler front and rear mounting brackets to the engine oil cooling duct cover and the cylinder block. Remove the brackets from the engine.

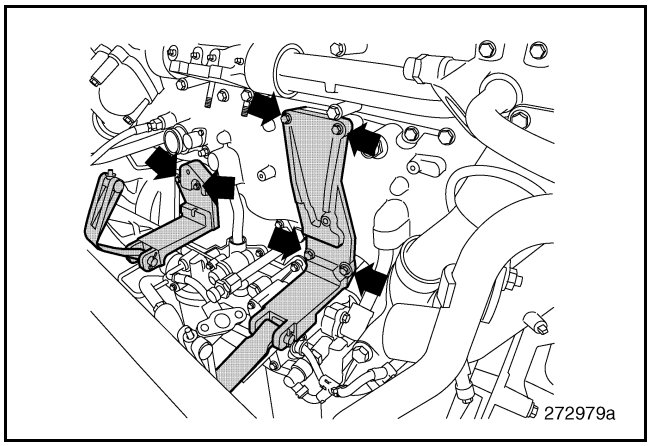


Figure 141 — EGR Cooler Mounting Brackets

6. Remove the coolant inlet coupling tube from the engine oil cooling duct cover. Remove and discard the seal rings.

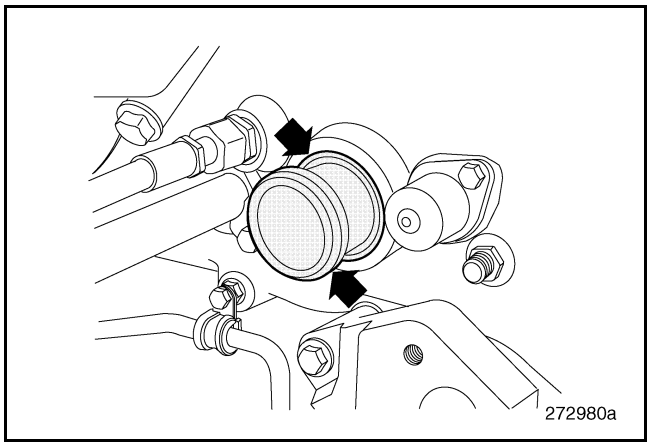


Figure 142 — Coolant Inlet Coupling Tube

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. Remove and discard the exhaust manifold attaching screws.
2. Set aside the spacers.
3. Remove the exhaust manifold from the cylinder head.
4. Remove and discard the exhaust manifold gaskets.

Oil Filter Housing Removal

[219 EP]

N O T E

Use suitable rags and containers for collecting oil drainage.

1. Remove the clamp screw and banjo fitting screw, and remove the oil cooler coolant drain tube.
2. Mark the orientation of the oil filter housing-to-oil cooler inlet and outlet tubes for assembly.

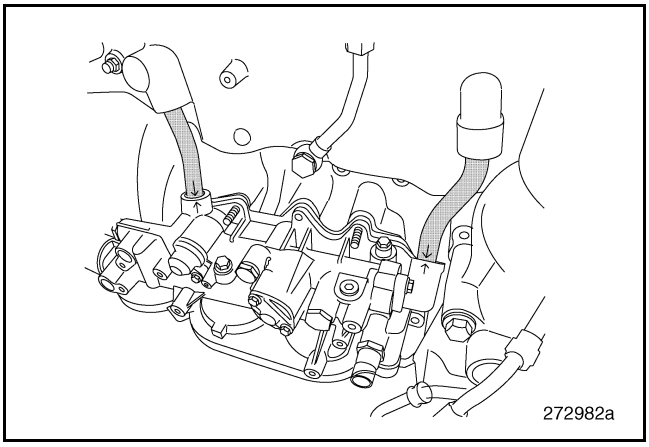


Figure 143 — Oil Filter Housing-to-Oil Cooler Inlet and Outlet Tube Orientation

3. Remove two mounting screws from the oil filter housing and replace them with short alignment pins. Remove the remaining oil filter housing mounting screws.
4. Pull the oil filter housing off the alignment pins and remove from the engine. Remove the filter housing gasket and discard.

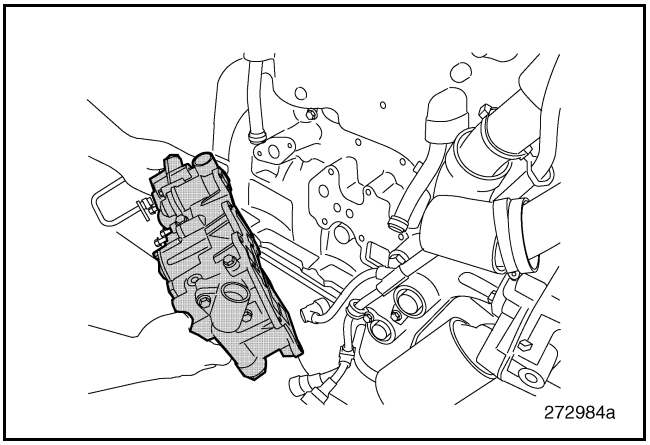


Figure 144 — Removing Oil Filter Housing

5. Remove the inlet and outlet tubes from the oil cooling duct cover. Remove and discard the tube seal rings.

Coolant Pipe Removal

[215 SW]

NOTE

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

1. Remove the screws and remove the upper coolant pipe housing from the cylinder head. Discard the flange seal ring.

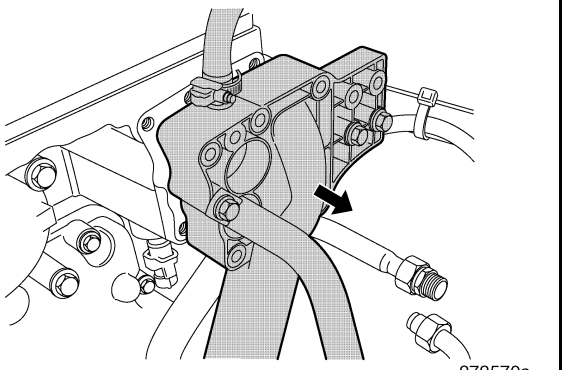


Figure 145 — Upper Coolant Pipe (Bypass) Housing

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

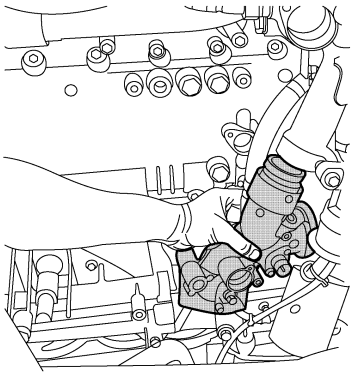


Figure 146 — Removing Pump Inlet Pipe

Cooling Duct Cover and Oil Cooler Removal

[215 DW, 219 EP]

The oil cooler is attached to the inside of the cooling duct cover.

COOLING DUCT COVER REMOVAL

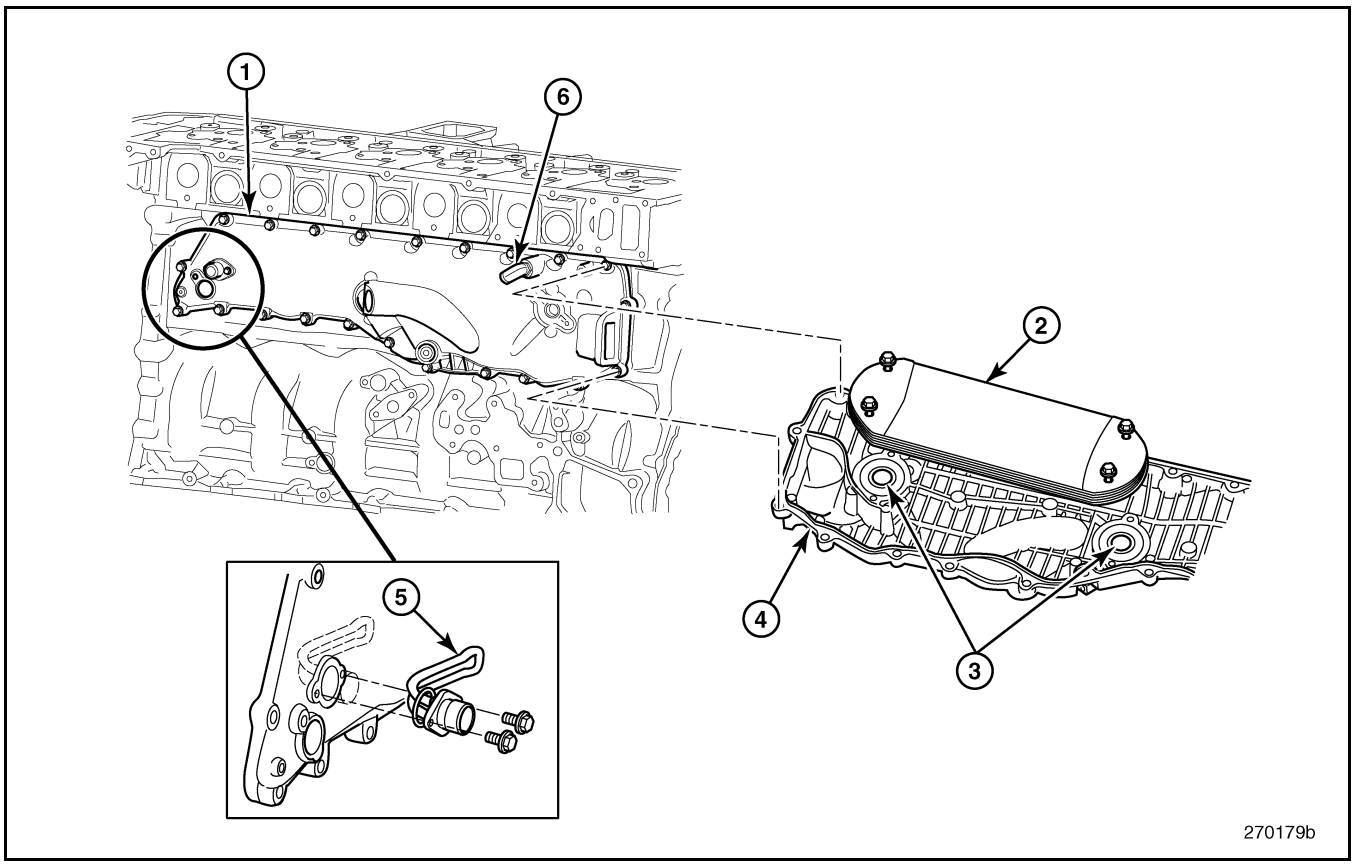


Figure 147 — Cooling Duct Cover, Oil Cooler and Coolant Heater

1. Cooling Duct Cover	4. Cover Seal
2. Oil Cooler	5. Coolant Heater
3. Oil Inlet and Outlet Port Seals	6. Fitting, 90° Elbow

1. Remove the cooling duct cover.
2. Remove the seal from the perimeter groove in the cover. Discard the seal; it should not be reused.

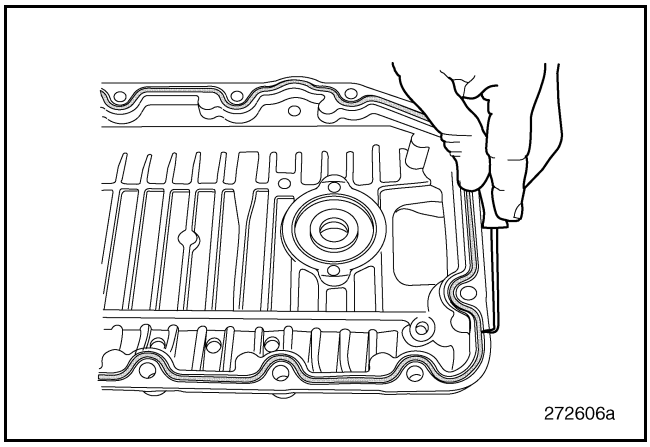


Figure 148 — Removing Duct Cover Seal

3. Remove and discard the port seals.
4. Remove and discard the duct cover-to-coolant pump housing seal.

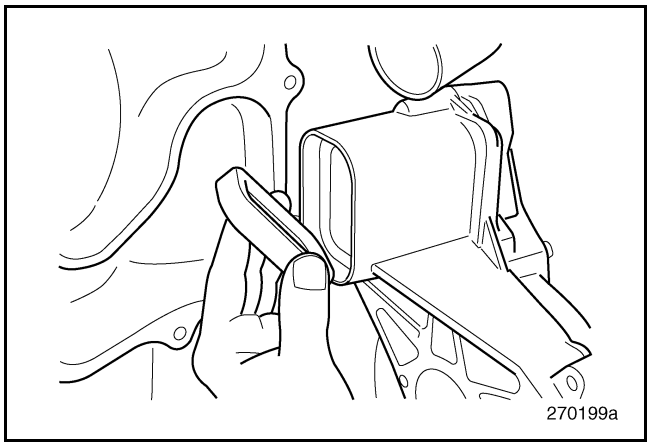


Figure 149 — Cooling Duct Cover-to-Coolant Pump Housing Seal

5. Remove the 90° elbow fitting from the cooling duct cover.
6. Remove the coolant heater from the cooling duct cover.

OIL COOLER REMOVAL

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

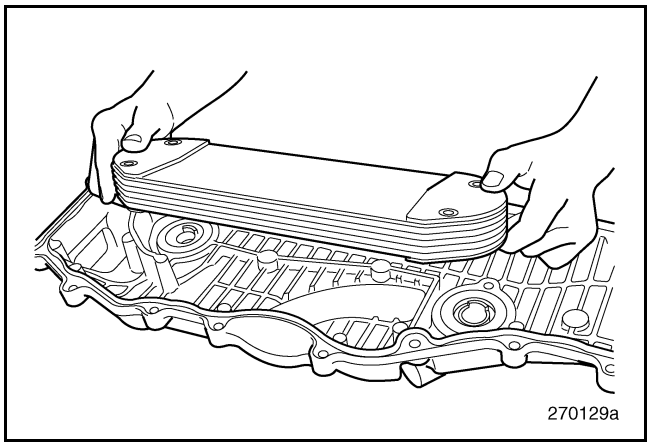


Figure 150 — Removing Oil Cooler

2. Remove the oil cooler sealing rings from the cooling duct cover. Discard the sealing rings.

Fan Drive, Idler and Fan Bracket Removal

[232 HB]

1. If not already done, remove and set aside the drive belts.
2. If not already done, disconnect the fan pigtail from the wiring harness.
3. Remove the fan drive with fan from the fan hub.

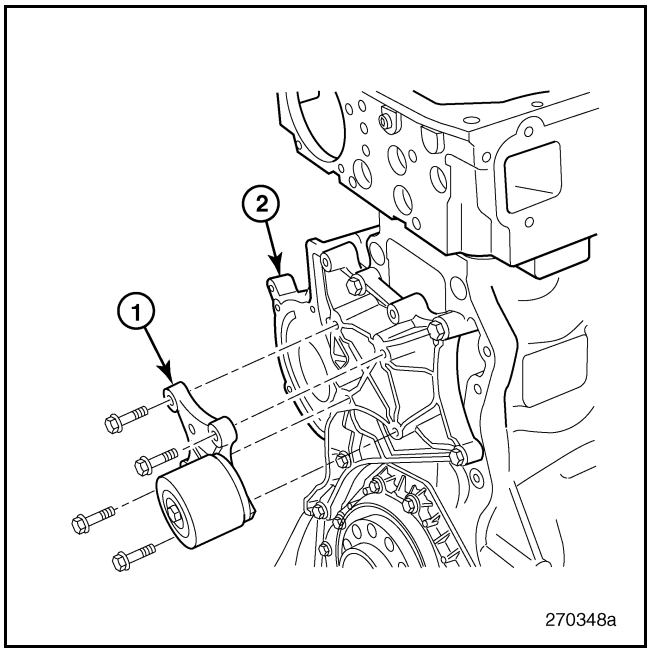


Figure 151 — Idler with Idler Bracket

1. Idler	2. Coolant Pump Base Plate

4. Remove the idler with idler bracket from the coolant pump housing.

NOTE

Fluid will leak from the fan drive if it is placed with the mounting hub down. Ensure that the fan drive is stored as illustrated in the following figure.

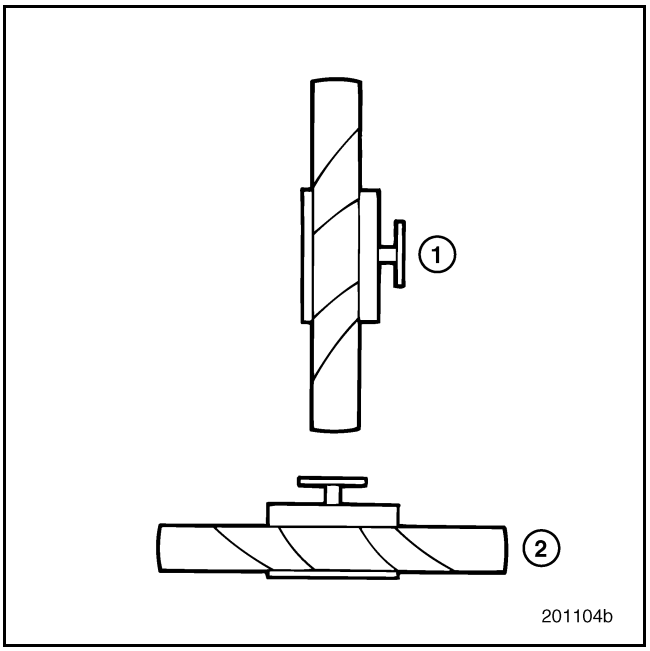


Figure 152 — Viscous Fan Drive Assembly Storage

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.

5. Remove the fan hub from the fan hub bracket.
6. Remove the fan hub bracket from the lifting eye bracket.

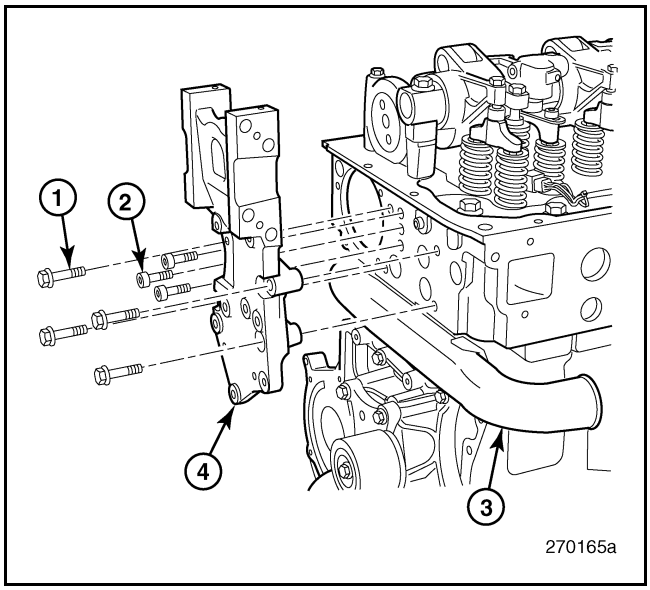


Figure 153 — Lifting Eye Bracket

1. Hex-Head Screws 2. Socket-Head Screws	3. Crossover Pipe 4. Lifting Eye Bracket

7. Remove the lifting eye bracket from the cylinder head and cylinder block.

EGR Crossover (Cooler Outlet) Pipe Removal

[214 HN, HP, HR]

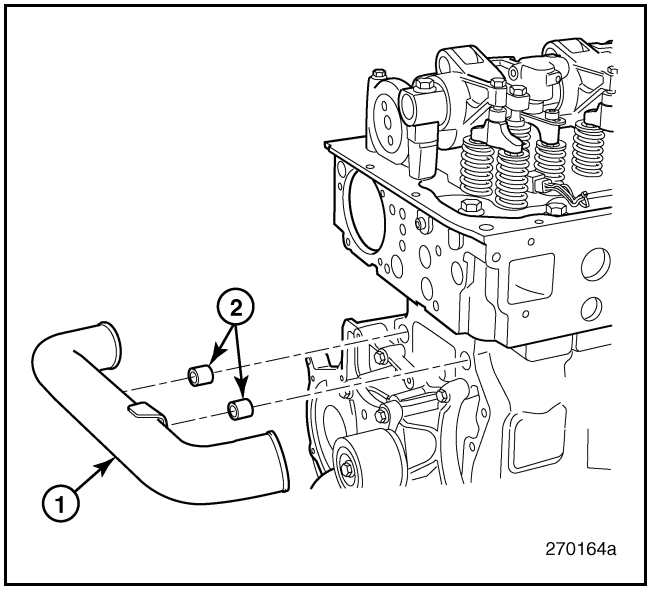


Figure 154 — EGR Crossover Pipe with Elastomer Bushings

1. Crossover Pipe	2. Elastomer Bushings

1. Loosen the clamps on each end of the crossover pipe.
2. Using a pry bar, carefully pull the pipe away from the cylinder block.

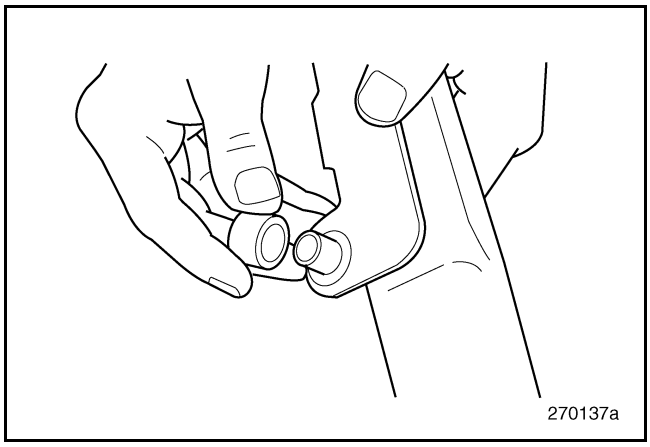


Figure 155 — Elastomer Bushing — Crossover Pipe

3. Remove and set aside the elastomer bushings.

EGR Venturi Housing Removal

If not already removed, follow this procedure.

1. Loosen the connecting sleeve at the EGR crossover pipe.
2. Remove the wiring at the sensor terminals.
3. Loosen the connecting sleeve at the EGR mixer.
4. Detach the strap clamps holding the piping to the cylinder block and brackets.
5. Detach the inlet piping from the venturi housing.
6. Remove the inlet piping, venturi housing and connector sleeves and set aside.

EGR Mixer Removal

[214 HL]

If not already removed, follow this procedure.

1. Remove the EGR mixer, air heater and gasket from the inlet manifold.
2. Discard the gasket.
3. Set the mixer and air heater aside.

Fuel Lines and Fuel Filter Housing Removal

If not already removed, follow this procedure.

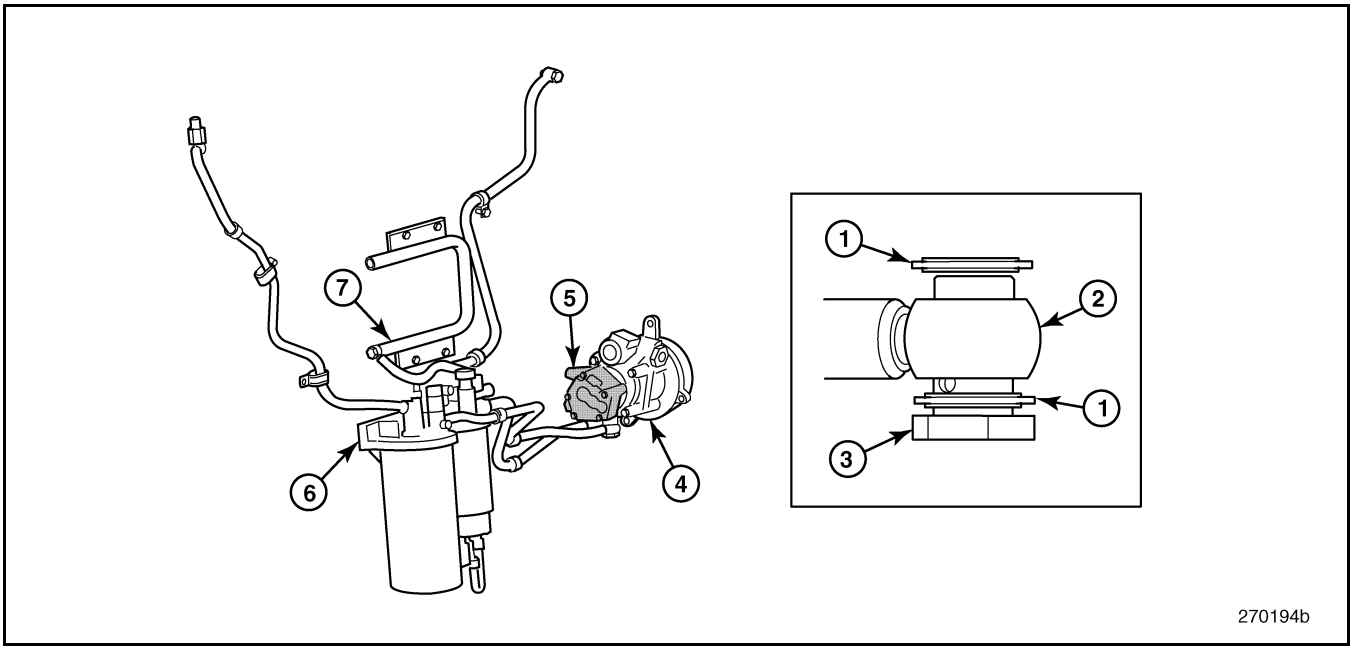


Figure 156 — Fuel Pump, Filter Assembly and Lines

1. Washers 2. Banjo Fitting 3. Banjo Screw 4. Power Steering Pump	5. Fuel Pump 6. Fuel Filter Housing 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 — front of cylinder head-to-filter housing
- Fuel supply line — filter housing-to-cylinder head (at rear left side)
- Fuel supply and return lines — fuel pump-to-filter housing
- Fuel supply line — filter housing-to-AFI shut-off valve
- Fuel supply line — AFI shut-off valve-to-AF injector

2. Remove the screws securing the filter housing to the cylinder block and remove the housing.

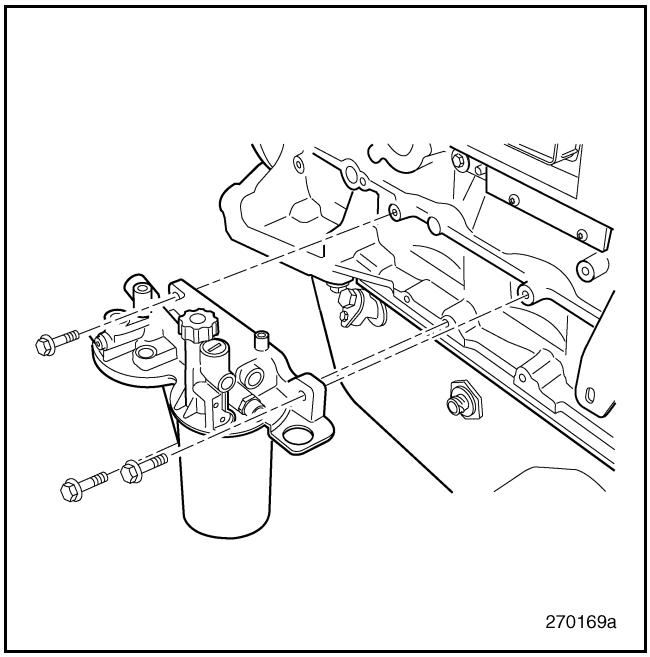


Figure 157 — Fuel Filter Valve Housing

3. Remove the screws securing the AFI shut-off valve to the left side of the cylinder block and remove the valve.

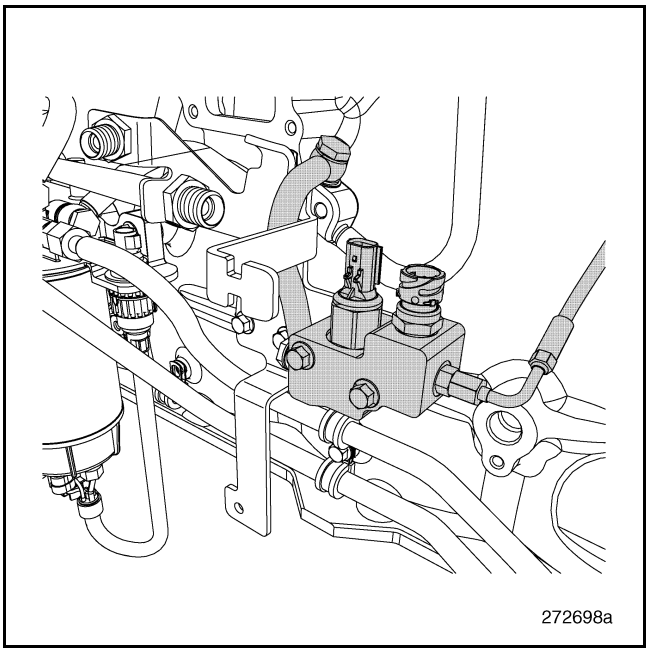


Figure 158 — AFI Shut-Off Valve

EECU and Cooling Plate Removal

If not already removed, follow this procedure.

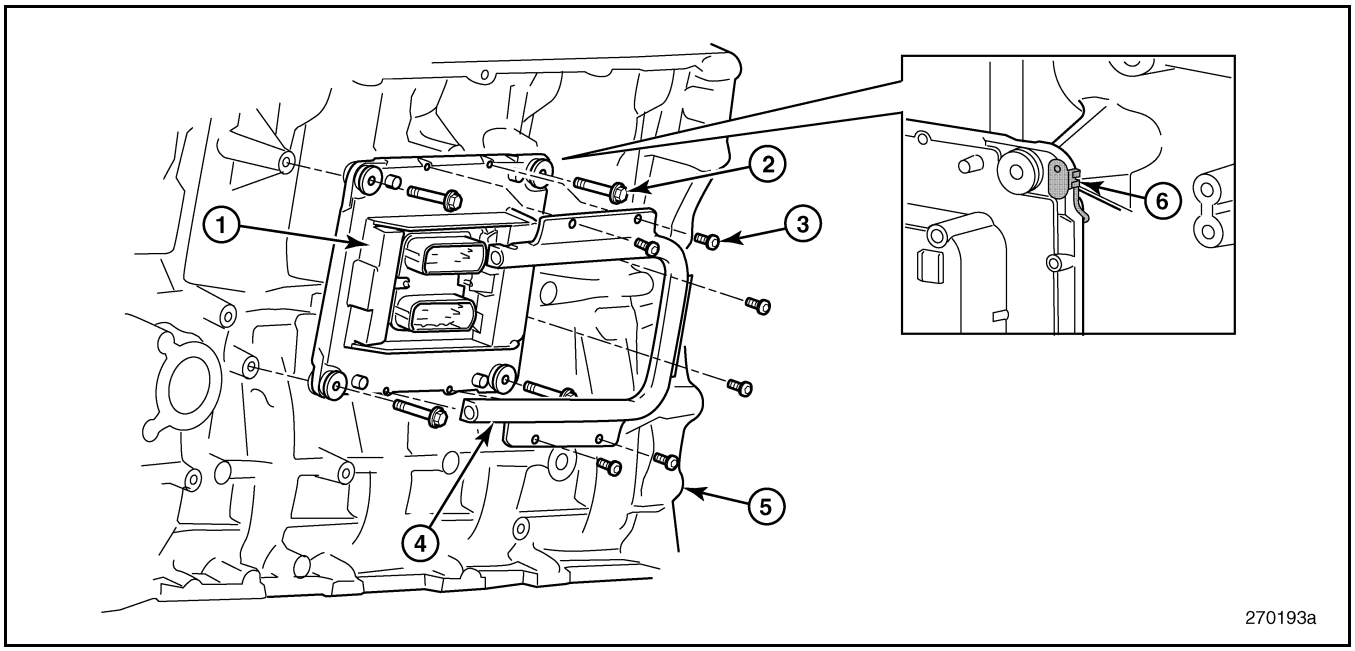


Figure 159 — EECU and Cooling Plate

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

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

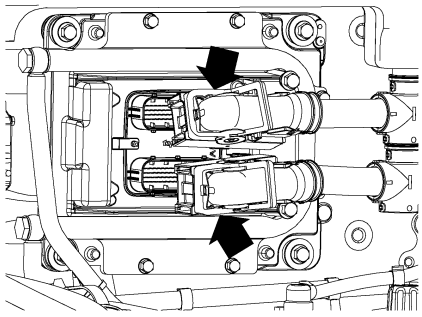


Figure 160 — EECU Harness Connectors

⚠ CAUTION

Use care to avoid damaging the terminal pins.

2. Position the harness connectors out of the way.

NOTE

Use suitable rags and containers for collecting fuel drainage.

3. Remove the fuel lines from the cooling plate.
4. Remove the screws and the cooling plate from the EECU.

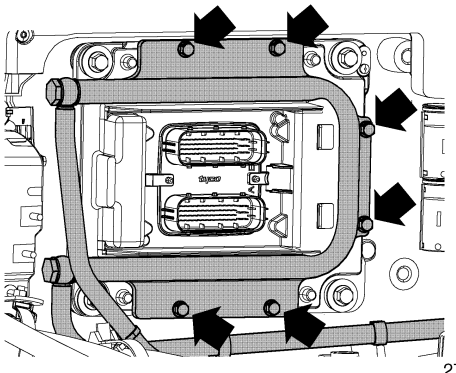


Figure 161 — Cooling Plate Mounting Screws

5. Remove the screws and the EECU from the engine.

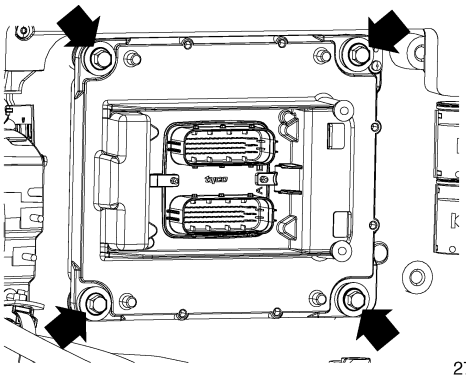


Figure 162 — EECU Mounting Screws

Inlet Manifold Removal

1. Remove two of the top inlet 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.

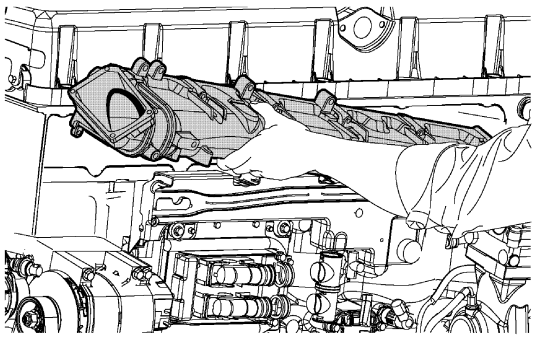


Figure 163 — Removing Inlet Manifold

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

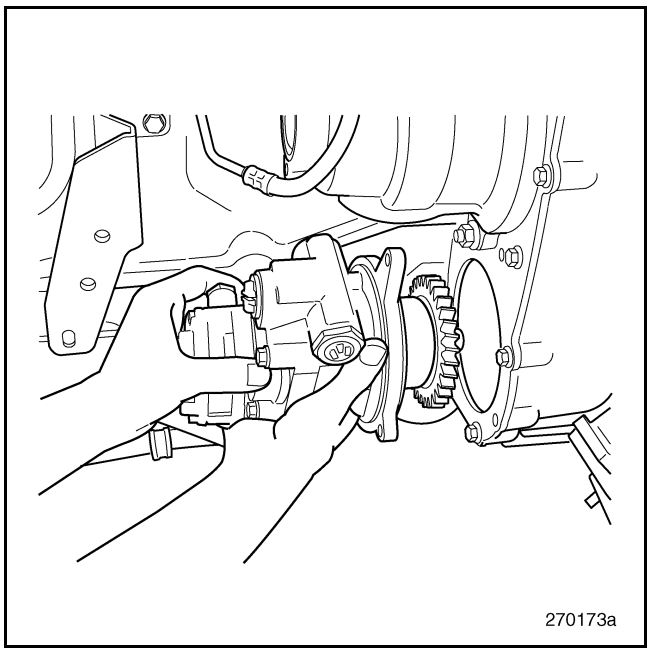


Figure 164 — Tandem Pump (Fuel and Power Steering)

NOTE

Use suitable rags and containers for collecting oil and fuel drainage.

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

Air Compressor Removal

[261 CK]

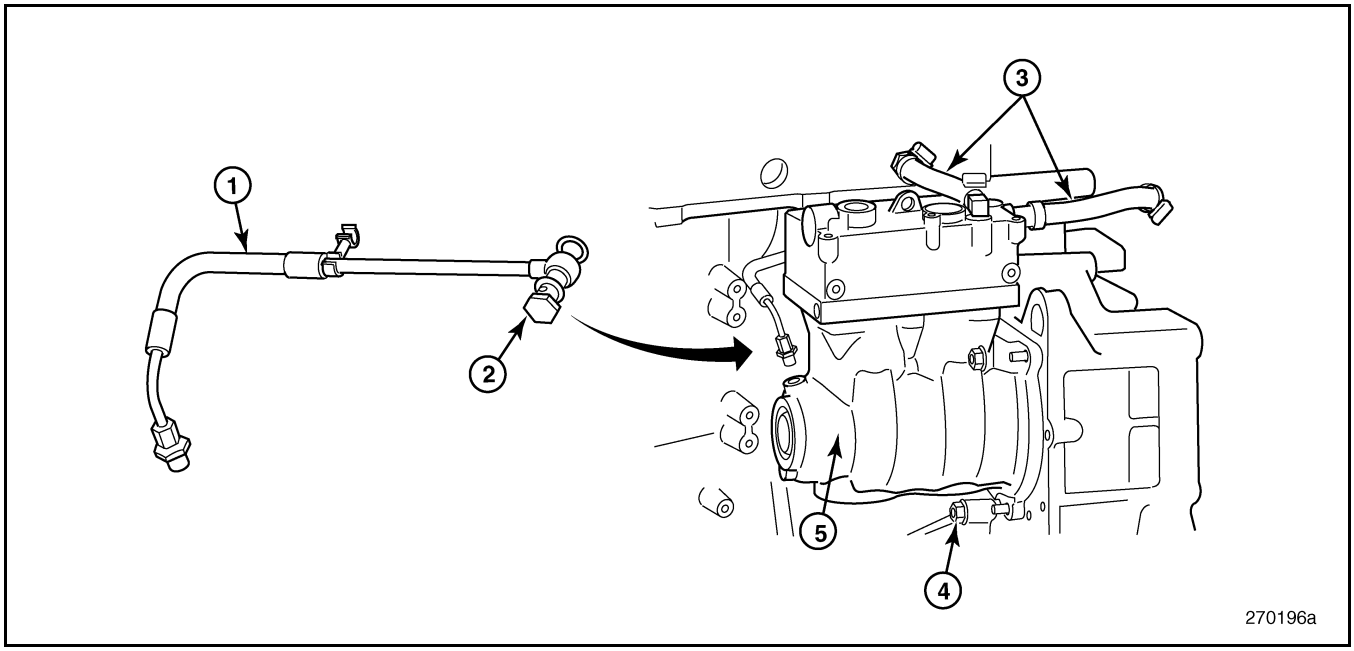


Figure 165 — Air Compressor and Fittings

1. Lubrication Line 2. Banjo Fitting 3. Coolant Lines	4. Attaching Stud and Nut 5. Air Compressor

1. If not already done, remove the compressor coolant lines.
2. If not already done, remove the oil supply and return lines.
3. While supporting the air compressor, remove the flange nuts securing the compressor to the flywheel housing. 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, 9996956, 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.
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 severe personal injury and component damage.

1. Remove the retainer screw and remove the engine speed sensor from the flywheel housing.
2. If present, remove the transmission pilot bearing and set aside.
3. Install two M10x100 screws in holes opposite each other at the outer perimeter of the flywheel. These screws are used as handles to aid removal of the flywheel.

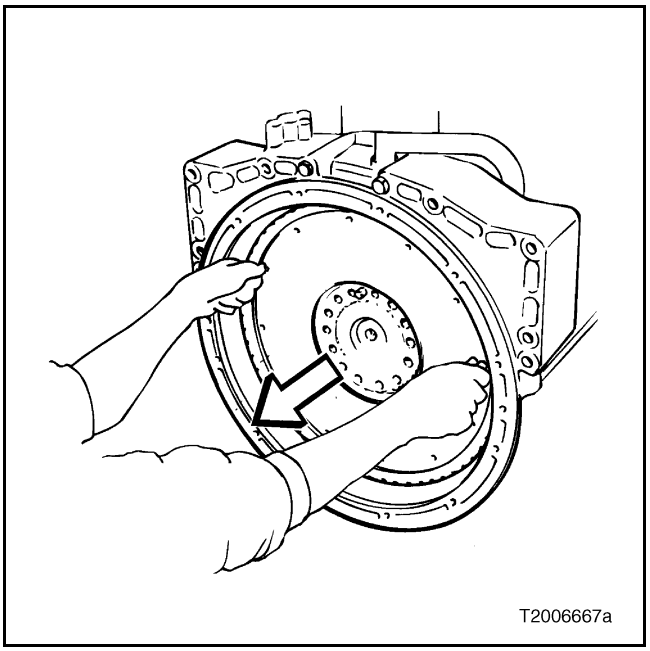


Figure 166 — Flywheel Removal

4. Remove the flywheel mounting screws.
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

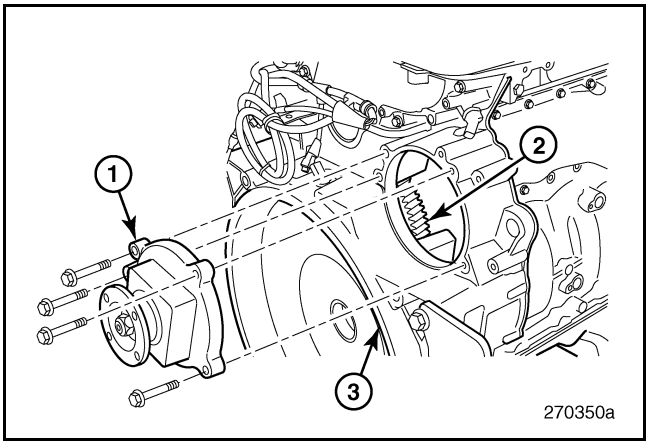


Figure 167 — Power Take-Off Assembly

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

1. If equipped with the optional PTO assembly, loosen and remove the mounting screws securing the assembly to the flywheel housing.
2. Remove the PTO assembly from the flywheel housing and set aside.

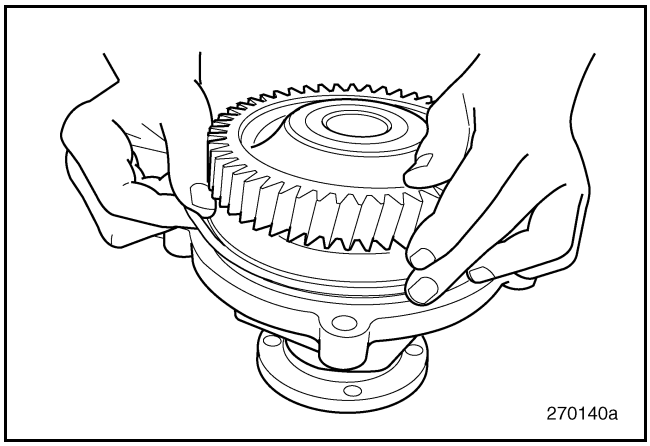


Figure 168 — PTO Housing Seal

3. Remove and discard the PTO housing seal.

Flywheel Housing Removal

1. Remove the flywheel housing fasteners located at the front of the housing at both sides of the engine.

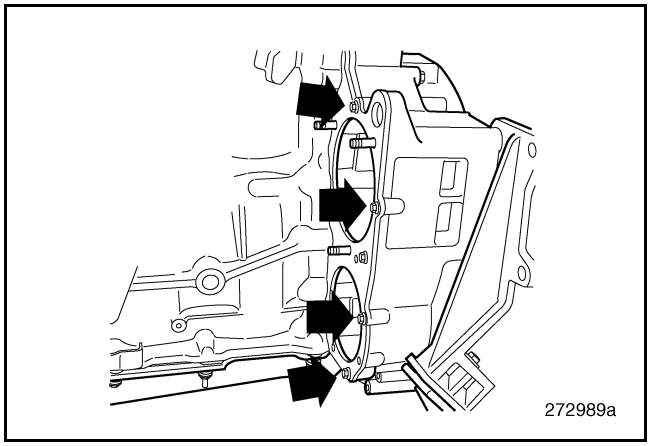


Figure 169 — Timing Gear Plate-to-Flywheel Housing Fasteners (LH Side Shown)

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

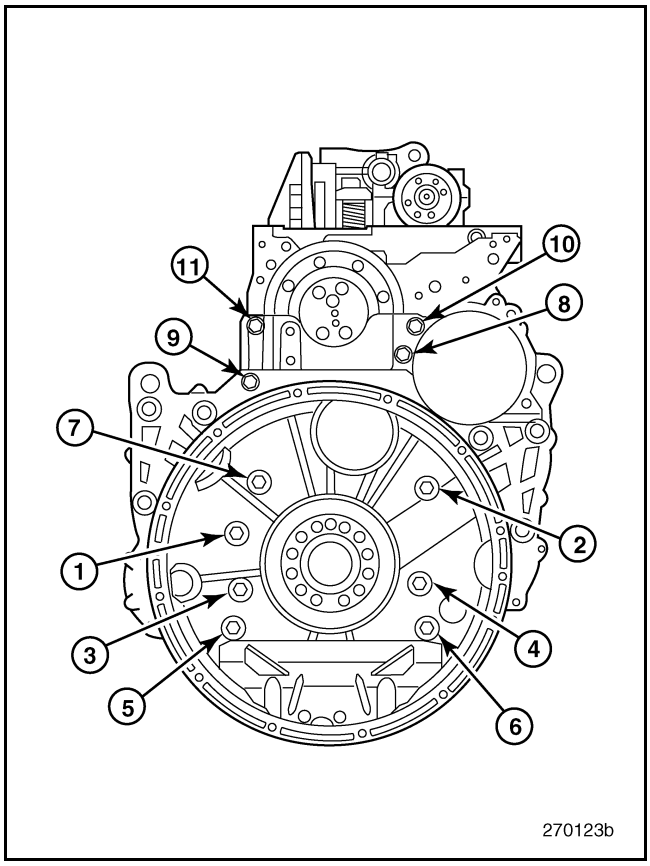


Figure 170 — Flywheel Housing Removal

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 cylinder block.

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

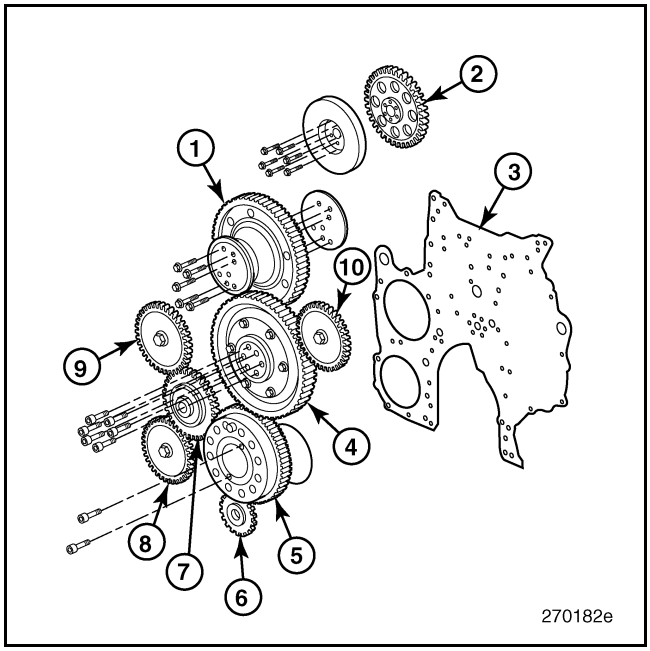


Figure 171 — Timing Gears

1. Adjustable Idler Gear	6. Oil Pump Gear
2. Camshaft Gear and Vibration Damper	7. Auxiliary Idler Gear
3. Timing Gear Plate	8. Tandem Pump Drive Gear
4. Intermediate Idler Gearset	9. Air Compressor Drive Gear
5. Crankshaft Gear	10. PTO Drive Gear

N O T E

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.

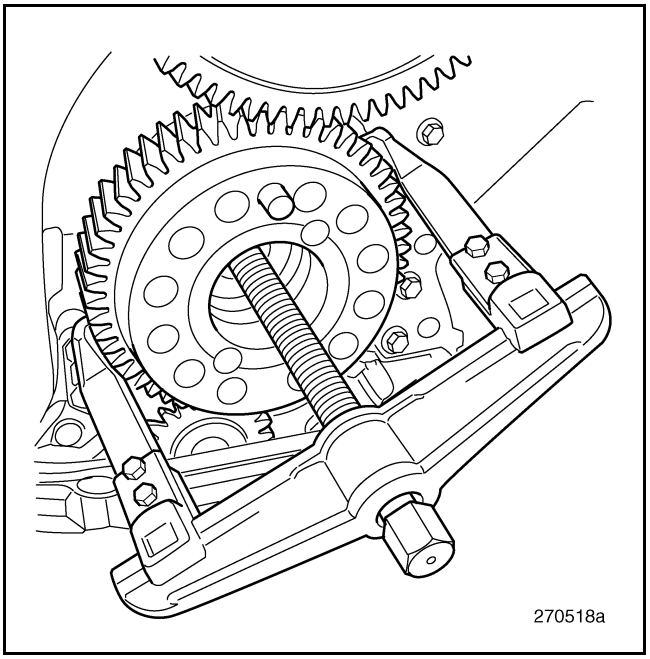


Figure 172 — Crankshaft Gear Puller

3. Remove and set aside the auxiliary idler gear. Remove the O-ring.

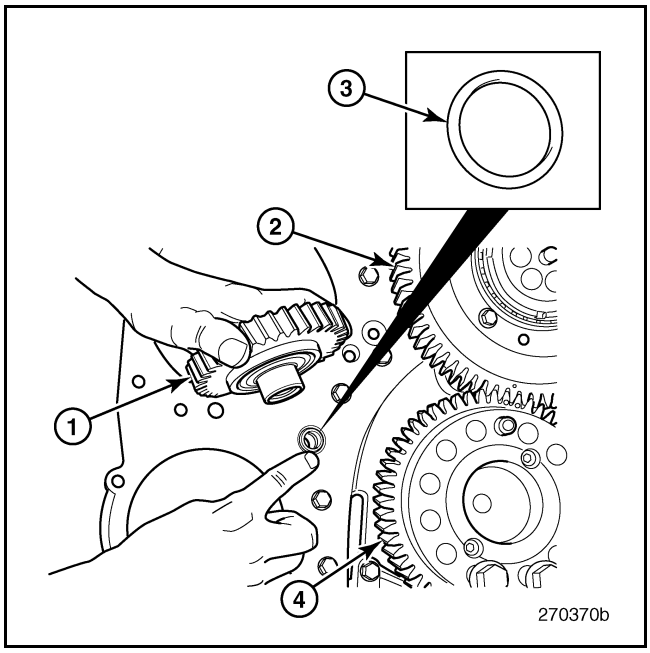


Figure 173 — Auxiliary Idler Placement with O-Ring

1. Auxiliary Idler Gear 2. Intermediate (Double Idler) Gear Set	3. O-Ring 4. Crankshaft Gear

4. Remove the six Allen-head screws 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 five screws securing the adjustable idler gear hub to the cylinder head and cylinder block.

NOTE

The adjustable idler gear fasteners are one time use only.

2. Remove the adjustable idler gear, hub and thrust washer 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 **C** which secure the timing gear plate to the cylinder head and the three upper screws **B** securing the adjustable idler gear to the cylinder head MUST BE REMOVED (Figure 174). Refer to the “Cylinder Head Removal” procedure which follows later in this section.

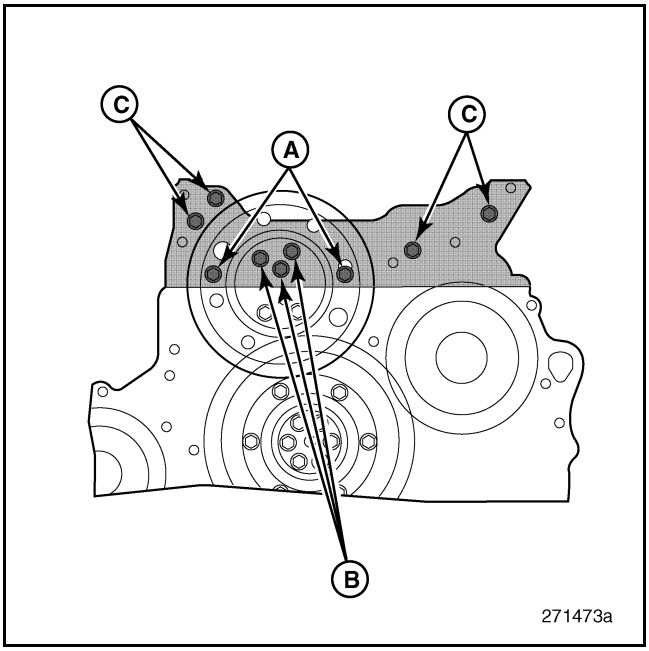


Figure 174 — Cylinder Head-to-Timing Gear Plate Screw Locations

Timing Gear Plate Removal

⚠ WARNING

The timing gear plate is heavy. Do NOT attempt to remove the timing gear plate 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.

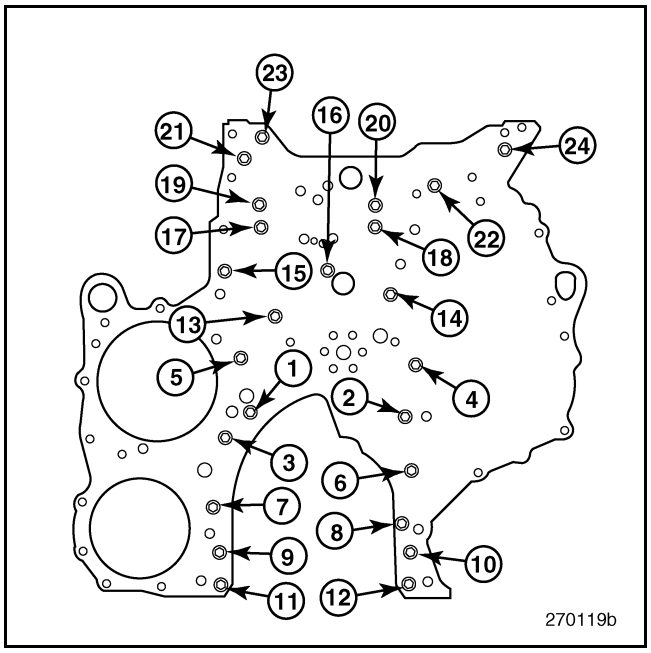


Figure 175 — Timing Gear Plate — Attaching Screw Removal Sequence

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.

1. While supporting the timing gear plate to prevent it from falling, remove the attaching screws.
2. Remove and set aside the plate.

Alternator and Refrigerant Compressor Removal

[271 CB, 264 DP]

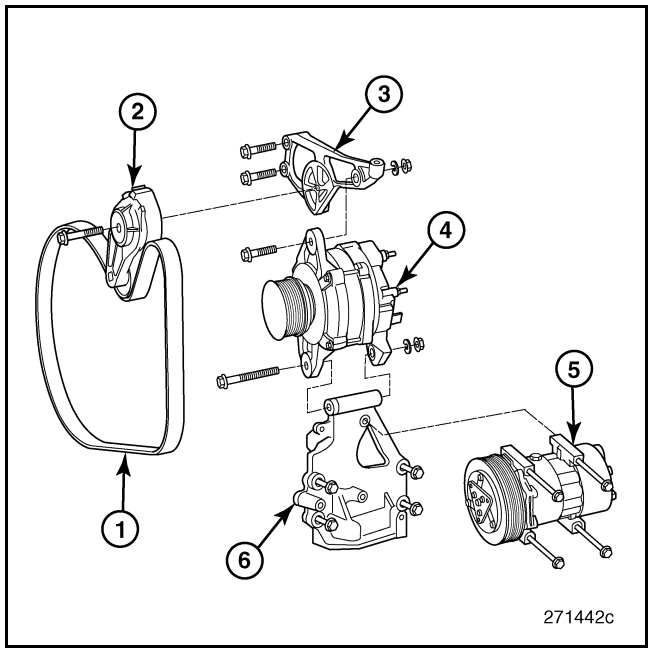


Figure 176 — Alternator and Refrigerant Compressor Mounting

1. Six-Rib Poly-V Belt	4. Alternator
2. Automatic Tensioner	5. Refrigerant Compressor
3. Alternator Support Bracket	6. Compressor and Alternator Support Bracket

NOTE

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

1. Remove the belt pulleys from the hubs of the alternator and the refrigerant compressor.
2. While supporting the alternator, remove the attaching bolts.
3. Remove the alternator.
4. Remove the alternator support bracket.
5. While supporting the refrigerant compressor, remove the attaching screws.
6. Remove the refrigerant compressor.

7. If necessary, remove the belt tension idler bracket.
8. Remove the alternator/compressor mounting bracket.

Thermostat and Cover Removal

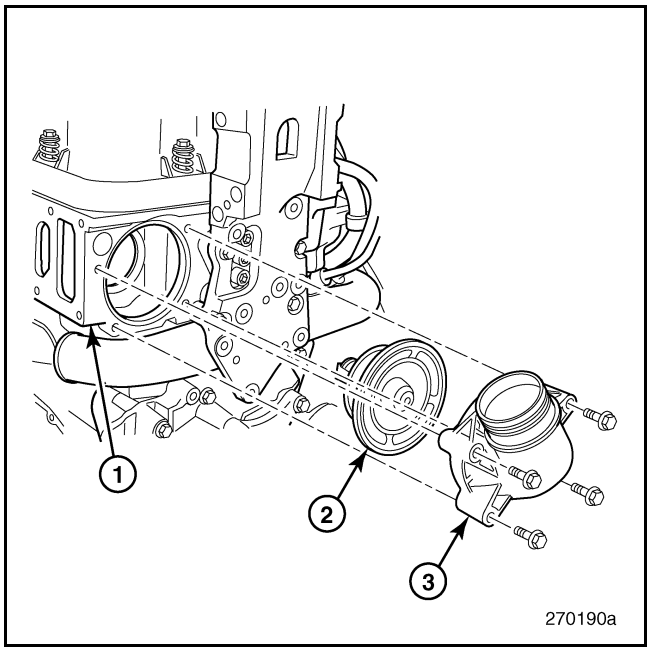


Figure 177 — Thermostat and Cover

1. Cylinder Head 2. Thermostat	3. Thermostat Cover

1. Remove the fasteners and the thermostat cover from the cylinder head.
2. Remove the thermostat from the cylinder head.
3. Carefully clean the thermostat seat and all cylinder head-to-cover mating surfaces.

Coolant Pump Removal

[215 SW, SG, SR]

1. Remove the fasteners, belt tensioner and idler bracket from the front of the cylinder block.
2. Remove the coolant pump fasteners and the coolant pump from the housing.

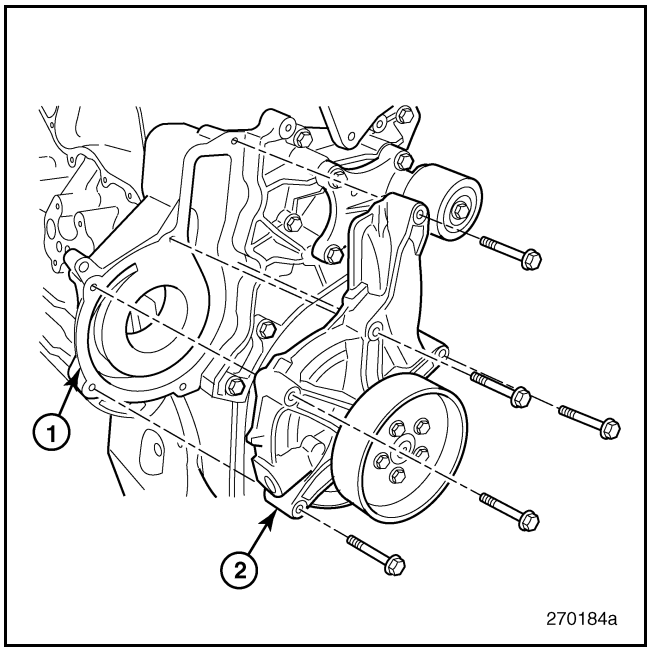


Figure 178 — Coolant Pump and Housing

1. Coolant Pump Housing	2. Coolant Pump

3. Remove and discard the coolant pump seal.

4. Remove the fasteners and the coolant pump housing from the cylinder block.

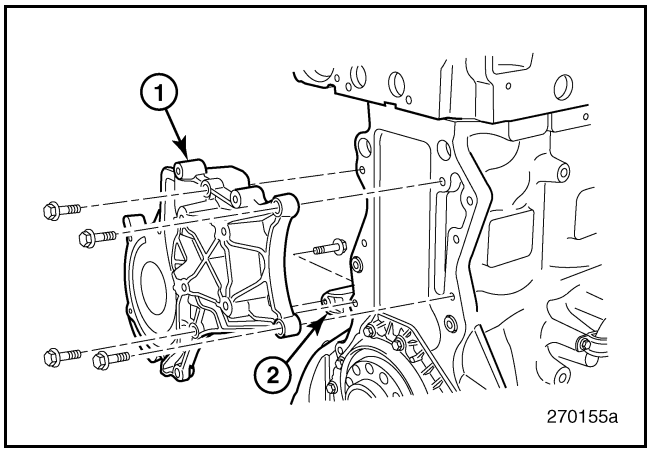


Figure 179 — Coolant Pump Housing and Angle Bracket

1. Coolant Pump Housing	2. Angle Bracket

5. Remove the fastener and the angle bracket from the side of 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 **C** which secure the timing gear plate to the cylinder head and the three upper screws **B** securing the idler gear hub to the cylinder head MUST BE REMOVED (Figure 180). 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 143.*

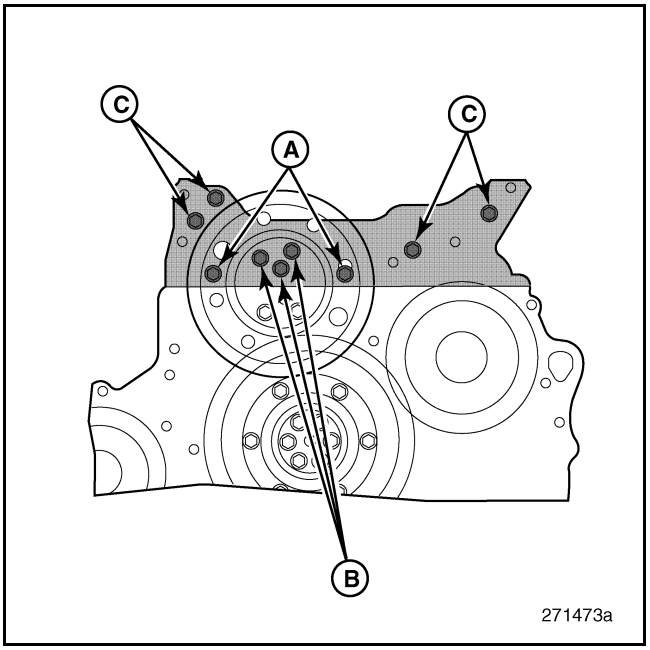


Figure 180 — Cylinder Head-to-Timing Gear Plate Screw Locations

REMOVING THE TIMING GEAR PLATE-TO-CYLINDER HEAD SCREWS

Remove the nine screws (**A**, **B** and **C** in Figure 180) securing the cylinder head to the timing gear plate as follows:

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

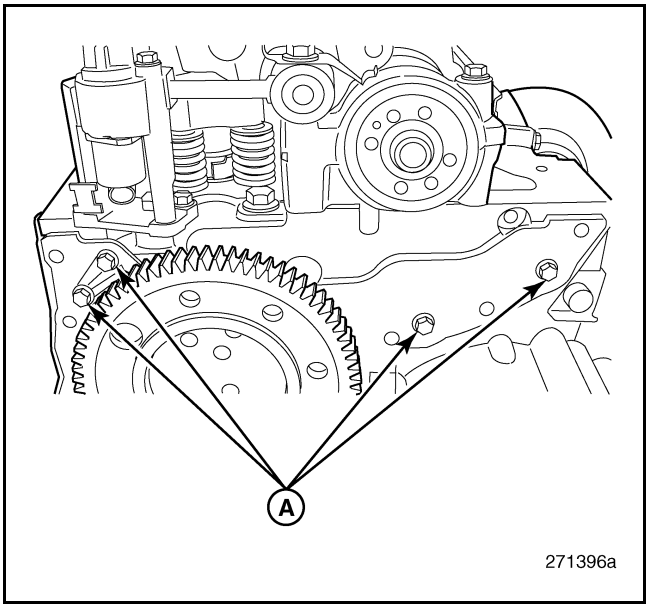


Figure 181 — Head-to-Plate Attaching Screws

A. Remove these screws.

2. Bar the engine over to align a hole in the adjustable idler gear with one of the two hidden screws that are through the plate into the cylinder head. Remove the screw.

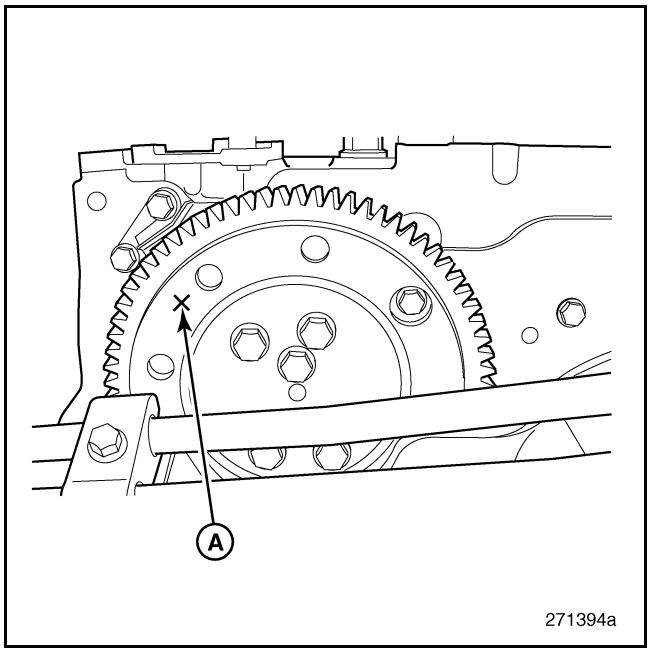


Figure 182 — Hidden Screws

A. Location of Screws Behind Idler Gear

3. Bar the engine over to align a hole with the remaining hidden screw behind the adjustable idler gear. Remove the screw.
4. Remove the three upper screws in the adjustable idler gear hub.

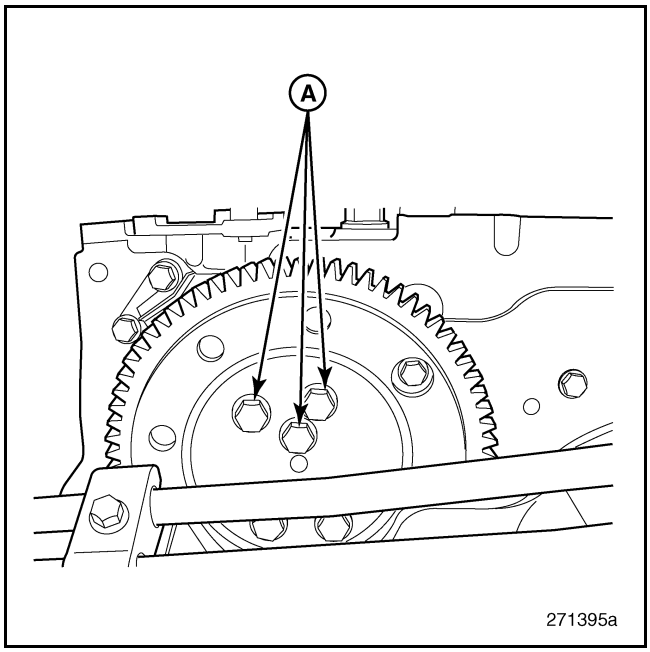


Figure 183 — Upper Three Adjustable Idler Gear Hub Screws

A. Remove these screws.

REMOVING THE CYLINDER HEAD

With the timing gear plate-to-cylinder head screws removed (**A**, **B** and **C** in Figure 180), proceed as follows to remove the cylinder head.

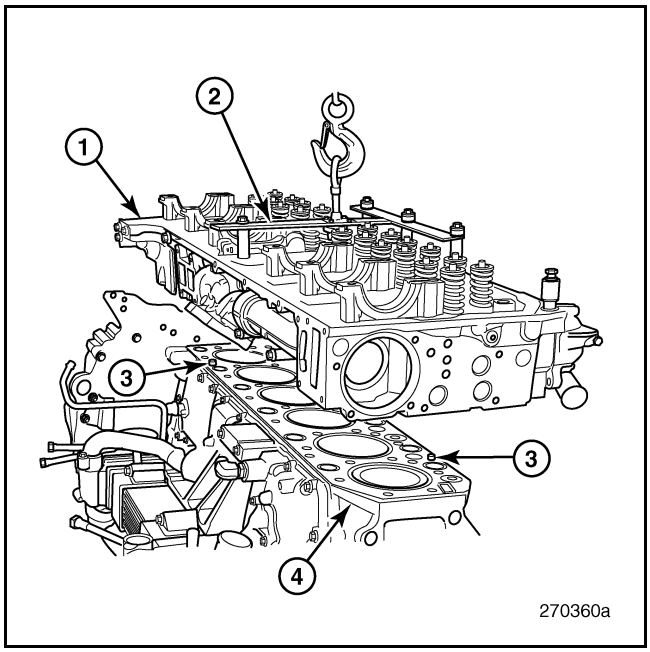


Figure 184 — Cylinder Head Removal

1. Cylinder Head	3. Alignment Pins
2. Lifting Tool, 85109049	4. Cylinder Block

1. Remove the cylinder head screws.
2. Using the cylinder head lifting tool, 85109049, carefully remove and set aside the cylinder head.
3. Remove and discard the cylinder head gasket.

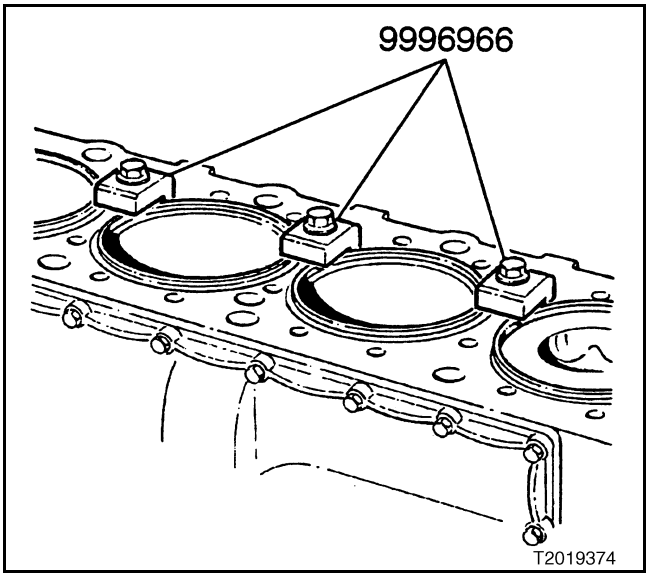


Figure 185 — Cylinder Liner Retainer

4. Attach cylinder liner hold-down tools, 9996966, to the cylinder block to keep the liners in place temporarily.

Crankshaft Vibration Damper and Fan Pulley Removal

[212 RB, 216 1A]

⚠ CAUTION

When handling a vibration damper, be careful not to damage the housing. Dents in the outer housing may render the damper ineffective. The vibration damper cannot be repaired. Failure to heed this caution may result in severe engine damage.

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

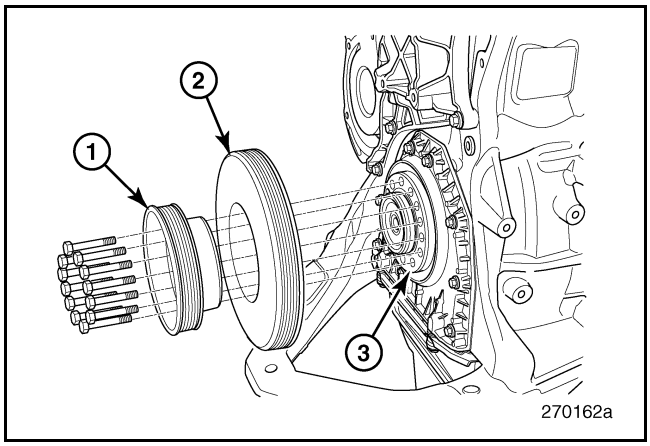


Figure 186 — Vibration Damper and Fan Pulley

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 crankshaft vibration damper and fan pulley.

Crankshaft Front Cover Removal

[211 JB]

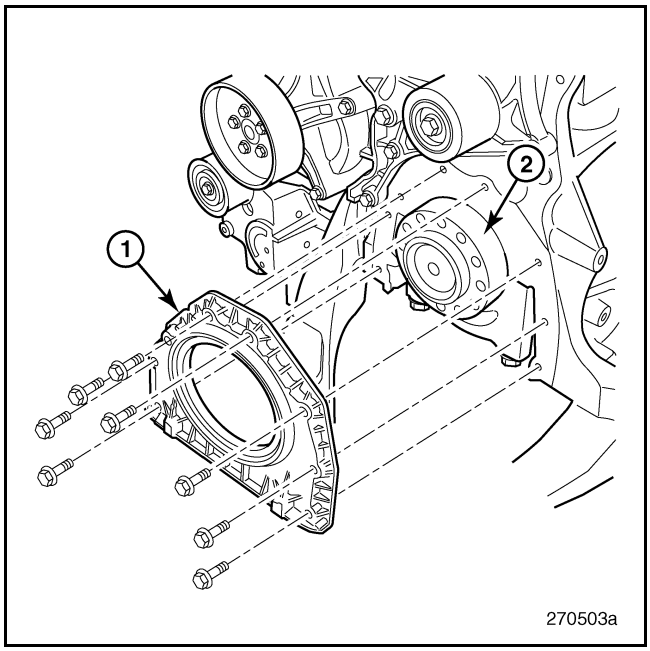


Figure 187 — Crankshaft Front Cover

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 crankshaft front 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 crankshaft front main 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

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

1. Remove and set aside the dipstick.
2. Remove the retainer screw from the pipe flange.
3. Remove and set aside the oil fill pipe.

Oil Pan Removal

[211 NB]

NOTE

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

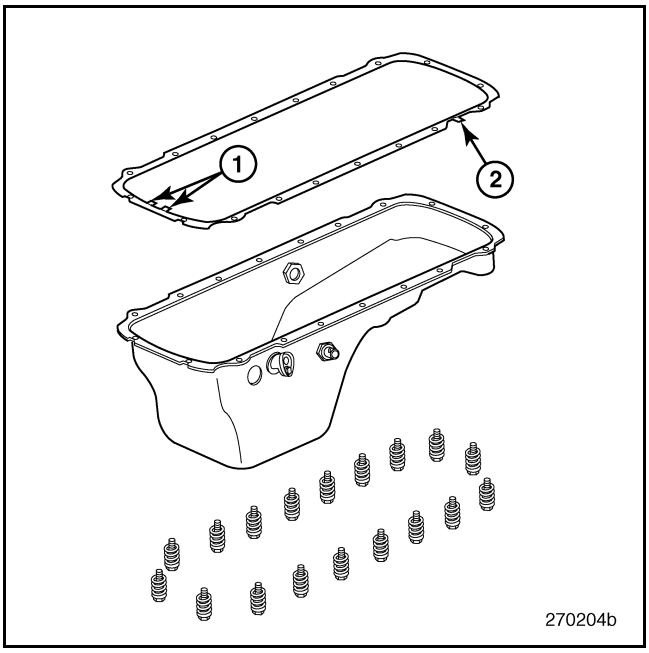


Figure 188 — Oil Pan and Attaching Screws

1. Metal Tabs (Front of Engine)	2. Single Tab (Left Rear of Engine)

1. Support the oil pan and remove the screws, springs and seals securing the oil pan to the crankcase.

NOTE

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

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

Front Engine Support Removal

[299 GV]

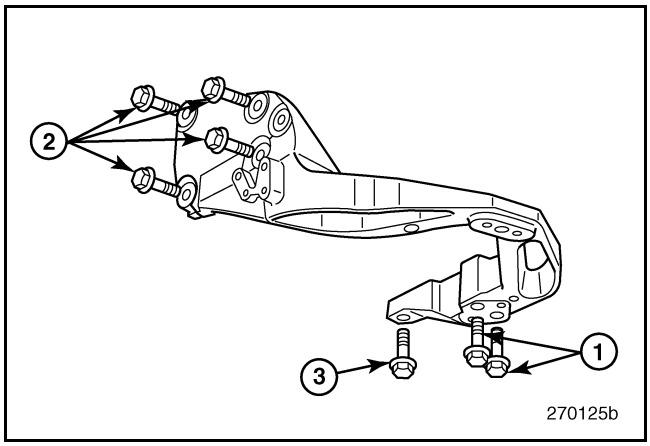


Figure 189 — Front Engine Support

1. Left-Side Attaching Screws 2. Right-Side Attaching Screws	3. Left-Side Attaching Screw

1. Remove the fasteners and the tension idler bracket from the engine support.
2. Remove the fasteners and the oil fill adapter from the oil pan to gain access to screw No. 3.
3. Remove the fasteners and the front engine support from the cylinder block.

Oil Pump and Valve Housing 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.

The inlet pipe with a front sump oil pan is longer than the one with a rear sump oil pan. The shorter pipe attaches to a bracket mounted on the valve housing assembly. A strap clamp holds the longer pipe on the valve assembly.

NOTE

Oil pump screws were installed using Loctite® which increases the effort required to remove them.

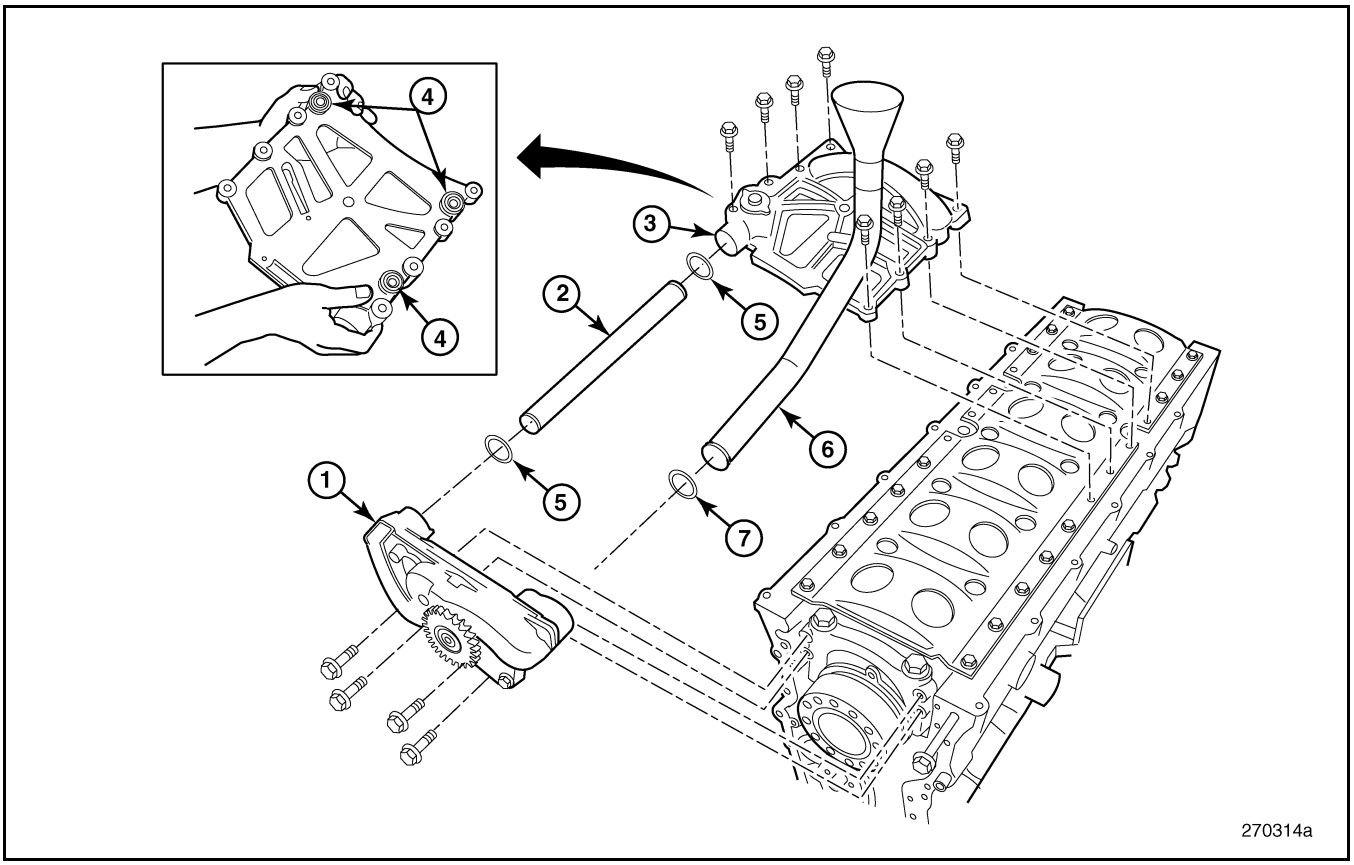


Figure 190 — Oil Pump and Valve Housing Assembly (Front Sump Shown)

1. Oil Pump 2. Pump Outlet Pipe (Pressure Side) 3. Valve Housing 4. Valve Housing Seals (to Block)	5. Small Diameter Seal Rings 6. Pump Inlet Pipe (Suction Side) 7. Large Diameter Seal Rings

NOTE

The inlet and outlet pipe flanges do not have to be removed at this time.

1. Remove the fasteners and the pump inlet pipe.
2. Remove and discard the seal ring.
3. Remove the fasteners and the valve housing.
4. Remove and discard the valve housing seals.
5. Remove the pump outlet (pressure side) pipe.
6. Remove and discard the seal rings.
7. Remove the fasteners and the oil pump and set aside.

Block Stiffener Plate Removal

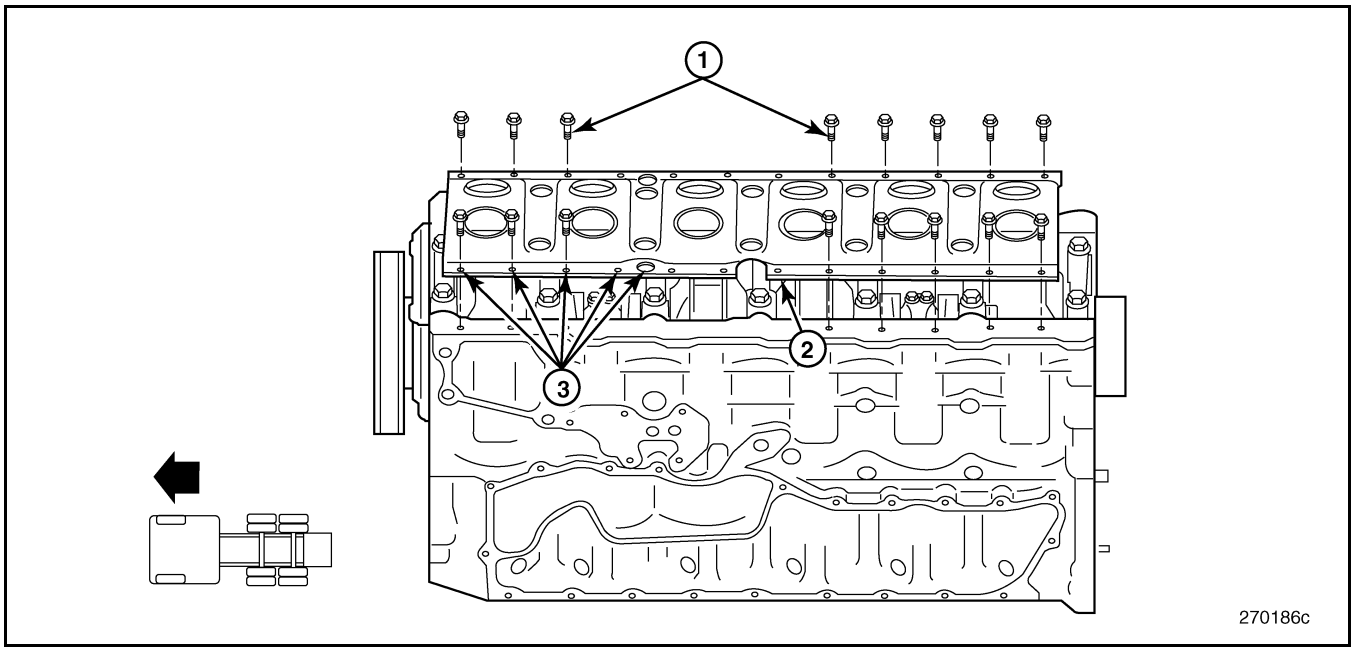


Figure 191 — Block Stiffener Plate

1. Plate Attaching Screws 2. Block Stiffener Plate	3. Plate Orientation Holes

1. Remove the 16 remaining screws securing the stiffener plate to the cylinder block.
2. With the help of an assistant, remove and set aside the block stiffener plate.

Piston and Connecting Rod Assembly Removal

[212 NP, 212 LP]

PISTON AND ROD REMOVAL

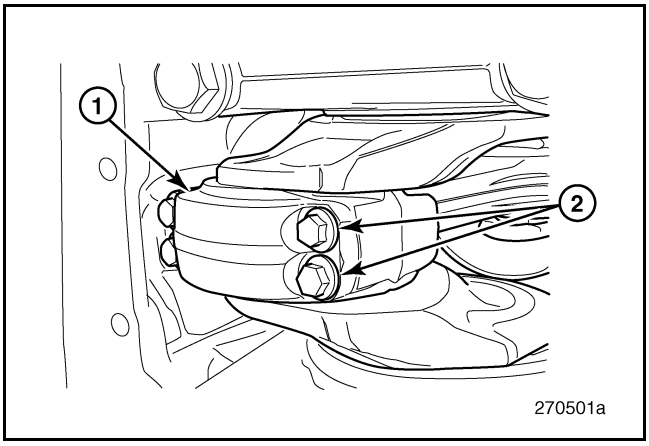


Figure 192 — Connecting Rod Bearing Caps

1. Connecting Rod Bearing Cap	2. Attaching Screws

1. Using flywheel turning tool, 9996956, rotate the crankshaft so that the connecting rod bearing caps for the desired cylinders are positioned for easy removal of the screws.
2. Remove the screws and remove the bearing cap.
3. Remove the bearing from the cap and discard.
4. Using a suitable tool, push up on the bottom of the piston until the rings are free of the cylinder liner. If the cylinder liner is excessively worn, the upper inner surface of the liner may have to be scraped and cleaned to make it easier to remove the piston.

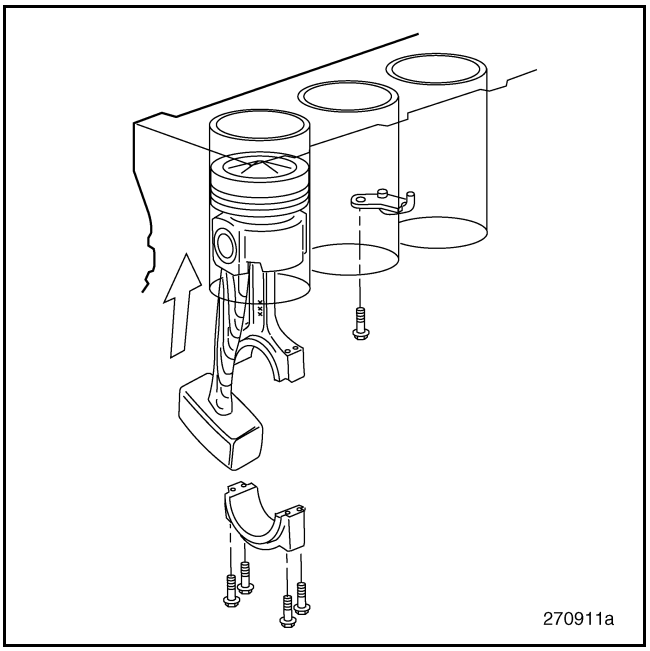


Figure 193 — Piston Removal

⚠ CAUTION

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

5. From the cylinder block deck, pull up to remove the piston and connecting rod from the engine. Mark the piston assembly to show its location in the engine.
6. Remove and discard the bearing in the connecting rod and set the assembly aside for disassembly and inspection (see the “CONNECTING ROD AND PISTON BENCH PROCEDURES” section).
7. Repeat steps 1 through 6 to remove the remaining pistons.

PISTON DISASSEMBLY AND INSPECTION

NOTE

Use care when disassembling, cleaning and inspecting piston and connecting rods. Be sure to identify and mark parts to be reused so they can be installed in the same locations from which they were removed.

1. Using snap ring pliers, remove and set aside the snap rings at each end of the wrist pin bore.

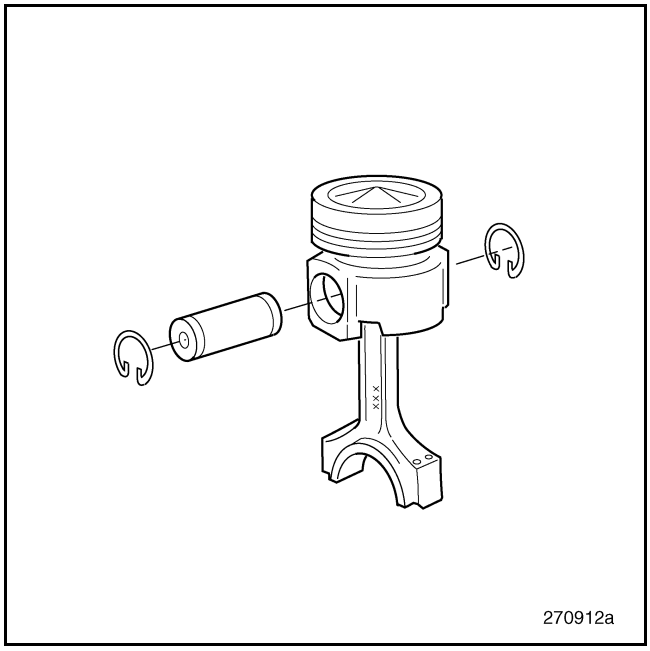


Figure 194 — Wrist Pin Removal

2. Push the wrist pin out of the bore.
3. Remove the connecting rod from the piston.
4. Place the piston on a clean, flat surface. Rest the piston on its crown.
5. Using the piston ring pliers, carefully remove the rings from their grooves.
6. Inspect the piston, pin, connecting rod and bearing for wear and damage. Replace parts as required.
7. Clean the piston and ring lands with a soft brush and appropriate cleaning agents. Do NOT use scrapers or other tools which can damage the sealing surfaces.

Main Bearing Cap Removal [212 HH]

NOTE

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

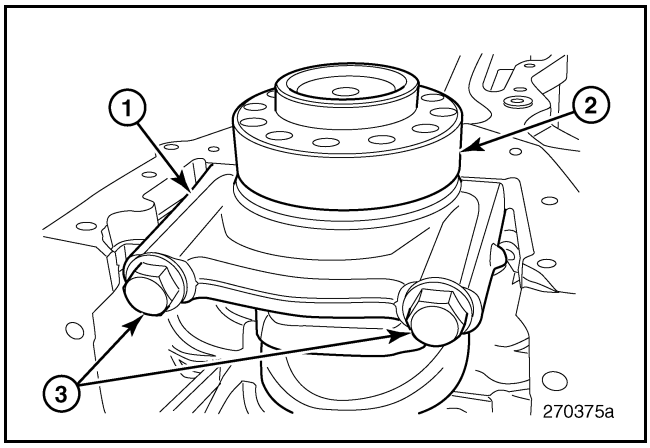


Figure 195 — Crankshaft No. 1 Main Bearing Cap

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

1. Using puller 9990114, adapter 9990262 and slide hammer 9996400, remove the bearing caps.

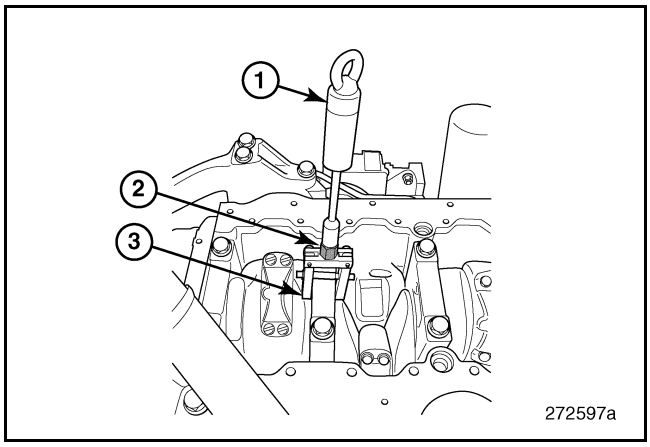


Figure 196 — Removing Main Bearing Cap

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

2. Remove and make note of the part number on the bearing inserts. Discard the bearing inserts.

NOTE

In addition to the main bearing inserts, the No. 4 crankshaft journal includes the thrust washer inserts.

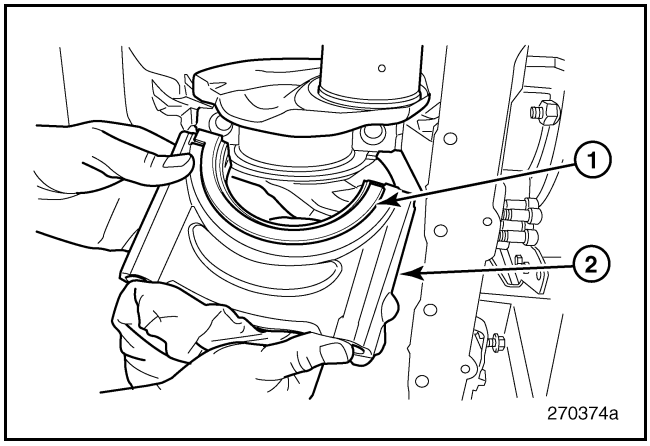


Figure 197 — Crankshaft No. 4 Main Bearing Cap with Lower Thrust Washer

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

3. Remove and discard the thrust washers.

Crankshaft Removal

[212 HP]

⚠ WARNING

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

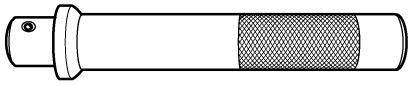
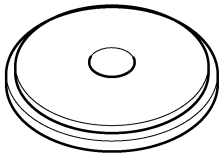
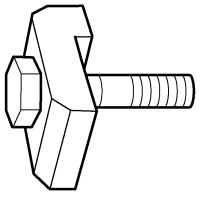
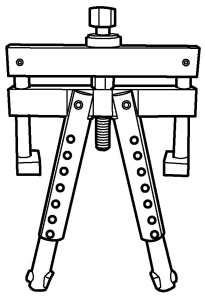
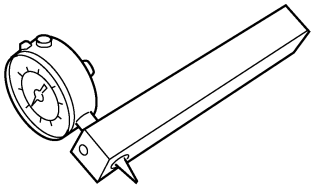
The crankshaft is extremely heavy. Exercise extreme care when lifting and moving the crankshaft to avoid striking other objects. No nicks, scratches, burrs or other signs of distress on the journals or fillets are acceptable.

1. With an assistant and using the crankshaft lifting tool, J 49002, lift the crankshaft from the cylinder block.
2. Remove and discard the crankshaft upper bearing inserts from the cylinder block.
3. Remove the upper thrust washer sections from the No. 4 main bearing location of the cylinder block and discard.

CYLINDER BLOCK RECONDITIONING [211 DB]

Tools and Equipment

SPECIAL TOOLS

Tool No.	Description	Images
9992000	Handle with Various Uses (fits 25 mm 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)	 006808a
J 26948	Cylinder Liner Height Measurement Tool (Available)	 006846a

Piston Cooling Spray Nozzle Removal

[219 RV]

⚠ CAUTION

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

SERVICE HINT

It is best to use a 12 mm, 6-point socket on a 12-inch extension to remove the spray nozzle retaining screws.

1. Remove the piston cooling spray nozzle by removing the retaining screw.
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.

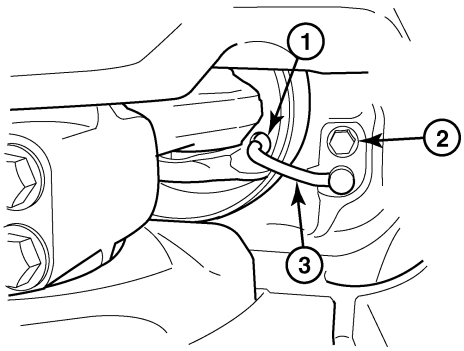


Figure 198 — Spray Nozzle Removal

1. Piston Cooling Duct 2. Retaining 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.

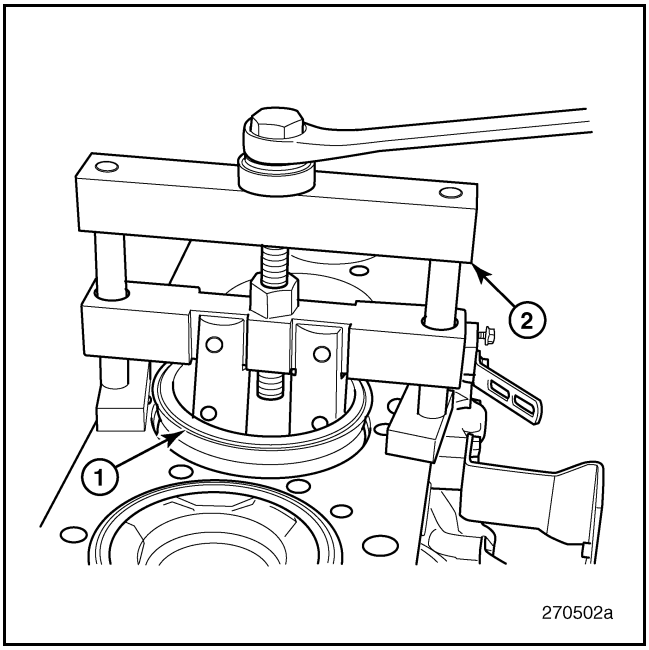


Figure 199 — Cylinder Liner Removal

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

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

Cylinder Block Cleaning and Inspection

The engine should have been thoroughly steam cleaned prior to component removal. If heavy accumulations of dirt and grease are still present, steam clean the cylinder 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 cooling 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 are reason for replacement. 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.

Cylinder 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 tools, 9996966.
2. Place the cylinder liner height measurement tool, J 26948, 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.

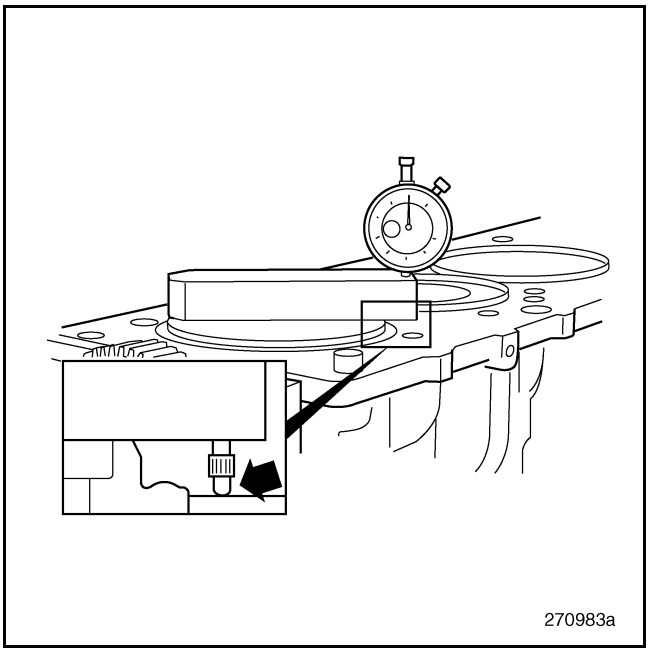


Figure 200 — Zeroing the Dial Indicator to the Block Deck

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.

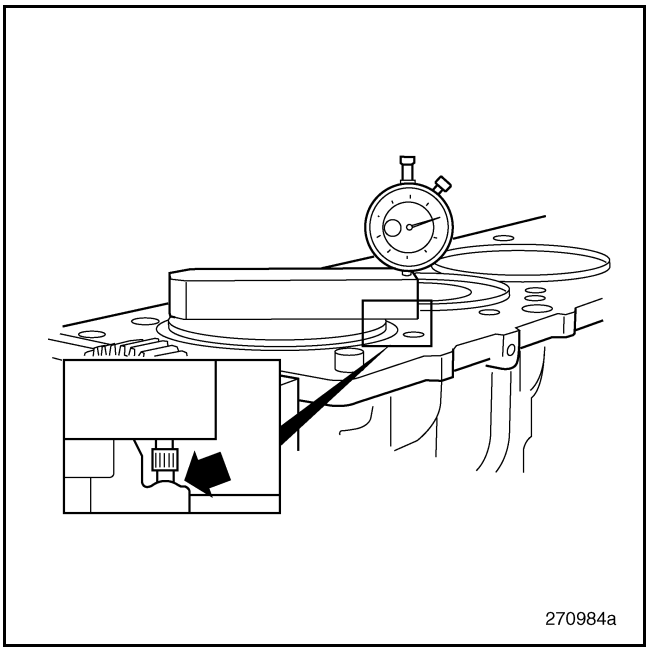


Figure 201 — Measuring the Cylinder Liner Height

4. Measure and record the height of the cylinder 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 cylinder liner in the cylinder bore for final installation. Remove the cylinder 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]

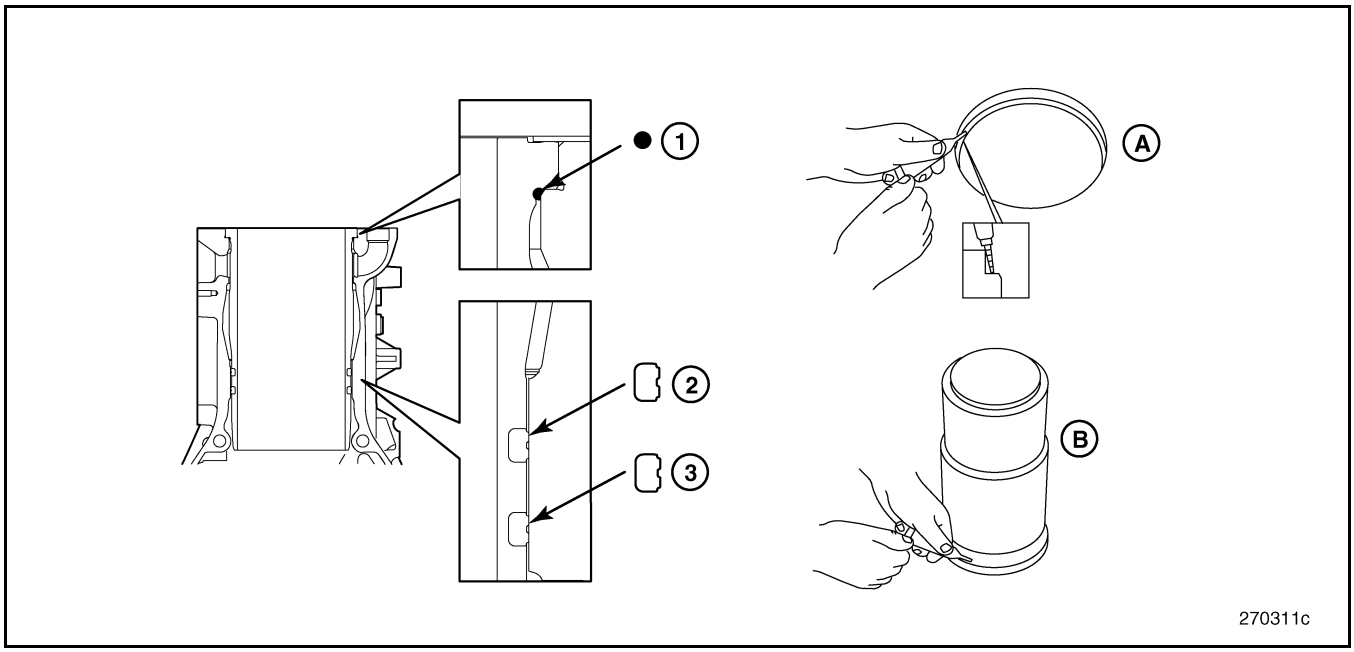


Figure 202 — Seal Ring Installation and Sealant Application

1. EPDM (Black) 2. EPDM (Black) 3. Viton (Purple)	A. With Shims — On Counterbore Ledge B. Without Shims — On Liner Flange

1. Apply lubricant (included in liner kit) to **new** seals and install them in the three annular grooves, one under the flange of the cylinder liner and two near the bottom. The purple gasket is installed in the lowest groove.
2. Apply a bead of MACK approved sealant to the joint between the cylinder liner flange and counterbore ledge. Application of the sealant depends on the use of spacers in attaining the proper cylinder liner height to deck setting:
   - **No spacer required** — Apply a 0.8 mm (0.03-inch) bead of sealant to the underside of the liner flange.
   - **Spacer required** — Apply a 0.8 mm (0.03-inch) bead of sealant to the counterbore ledge in the cylinder block. DO NOT apply sealant between the spacer and the liner flange.

3. Temporarily install a cylinder head screw in a screw hole next to the cylinder.

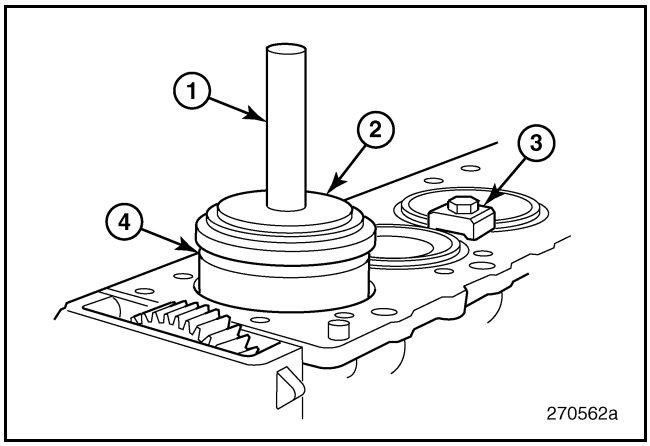


Figure 203 — Cylinder Liner Installation

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

4. Using cylinder liner installation plate, 9996599, and handle, 9992000, press the liner (with spacer if appropriate) into the cylinder bore until seated.
5. Secure the cylinder liner in place using two liner hold-down tools, 9996966.

⚠ CAUTION

The cylinder 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 [212 UB]

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

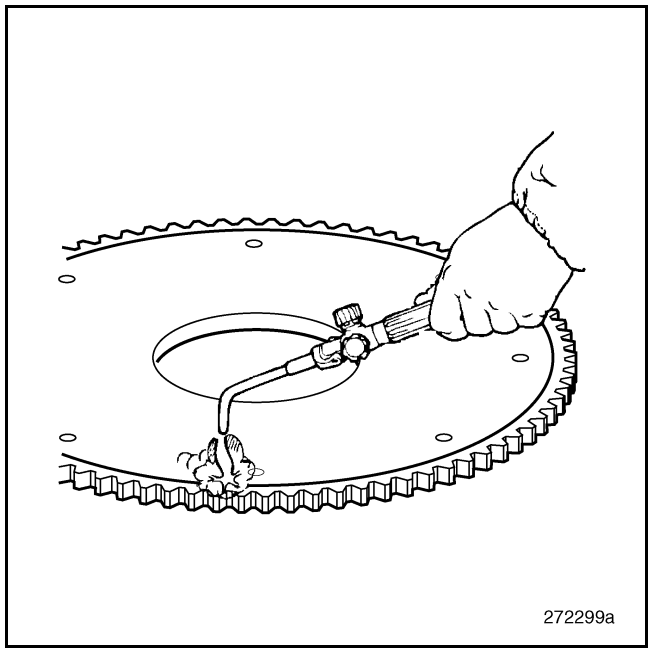


Figure 204 — Ring Gear Removal

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.

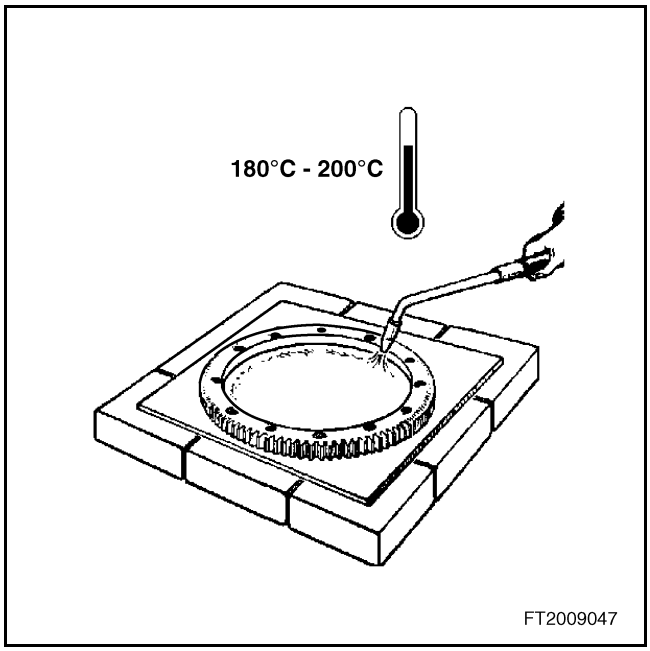


Figure 205 — Ring Gear Heating

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

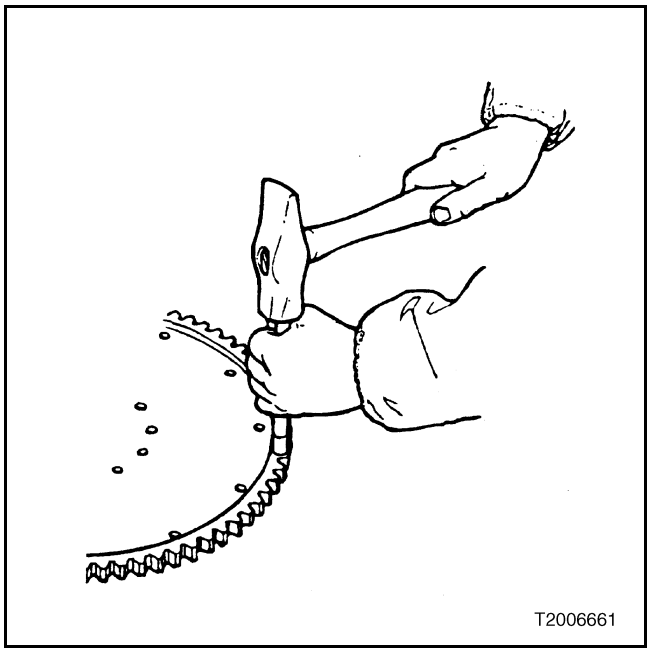


Figure 206 — Ring Gear Installation

CONNECTING ROD AND PISTON BENCH PROCEDURES

Connecting Rod — Piston Disassembly

[212 LP]

Connecting rods are manufactured by a process in which the cap and rod are cast together. 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.

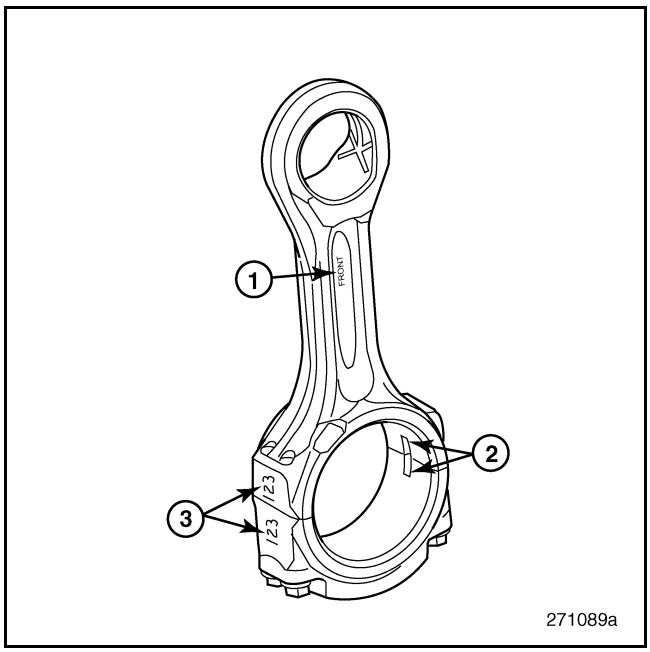


Figure 207 — MP7 Connecting Rod

1. The word, **Front**, faces the front of the engine. 2. The notches must be aligned.	3. The numbers must agree and be aligned on the same side. (The numbers may appear on either side.)

Connecting rod screws on the left side of the engine are 22 mm (0.866 inch) apart. On the right side, they are 21 mm (0.827 inch) apart.

It is essential that the 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 207. 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 retainers at each end of the wrist pin.
2. Remove the wrist pin from the piston and connecting rod.

INSPECTION

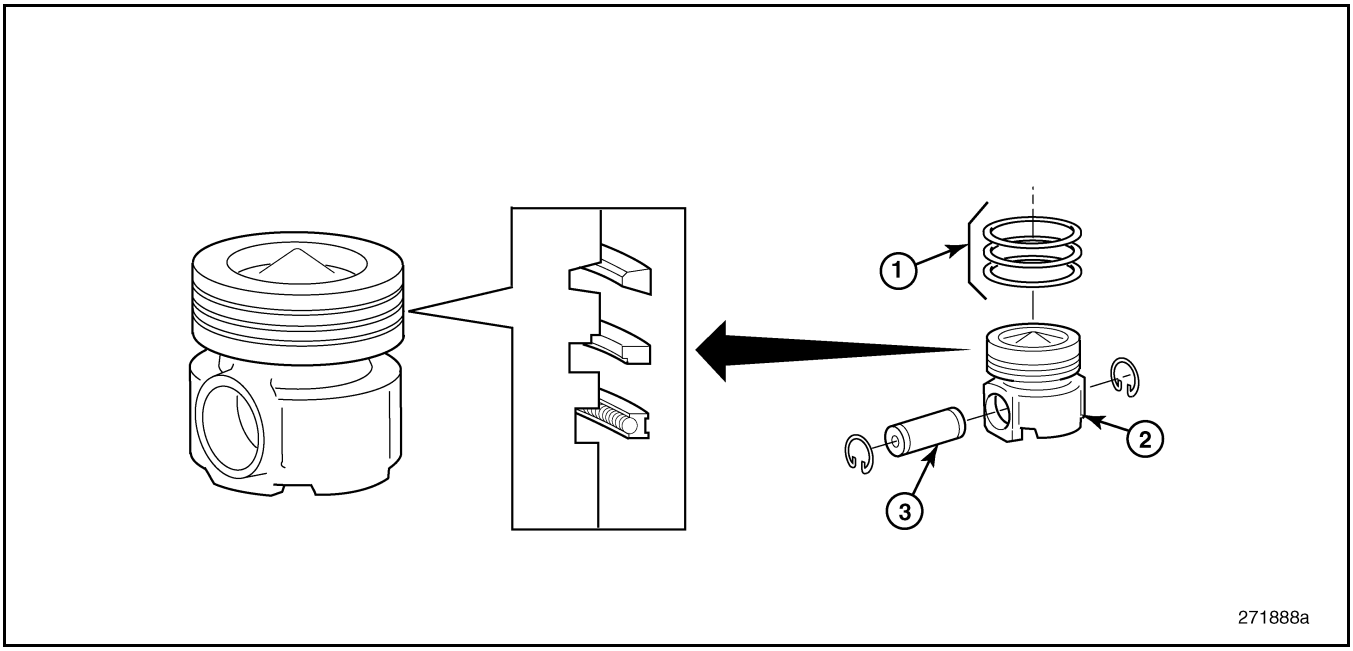


Figure 208 — Piston Assembly — Exploded View

1. Piston Rings 2. Piston	3. Wrist Pin

Connecting rods fall into weight classes. When installing a single rod, or less than a full set, examine the removed rods for a part number. Install parts having the same weight class.

Connecting rods can be weighed to be certain that the proper weight class is used. Rod weights for an engine should not vary by more than 13.04 grams (0.46 ounce) within each weight class.

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 wrist pin.
5. Inspect the wrist pin bearing surface in the connecting rod.
6. Inspect the crankshaft journal bearing surfaces of the rod and cap.

SERVICE HINT

If it is determined that any component is in questionable condition or is at the limit of dimensional tolerance, replace it.

CONNECTING ROD ALIGNMENT

1. Assemble the connecting rod in the connecting rod fixture.

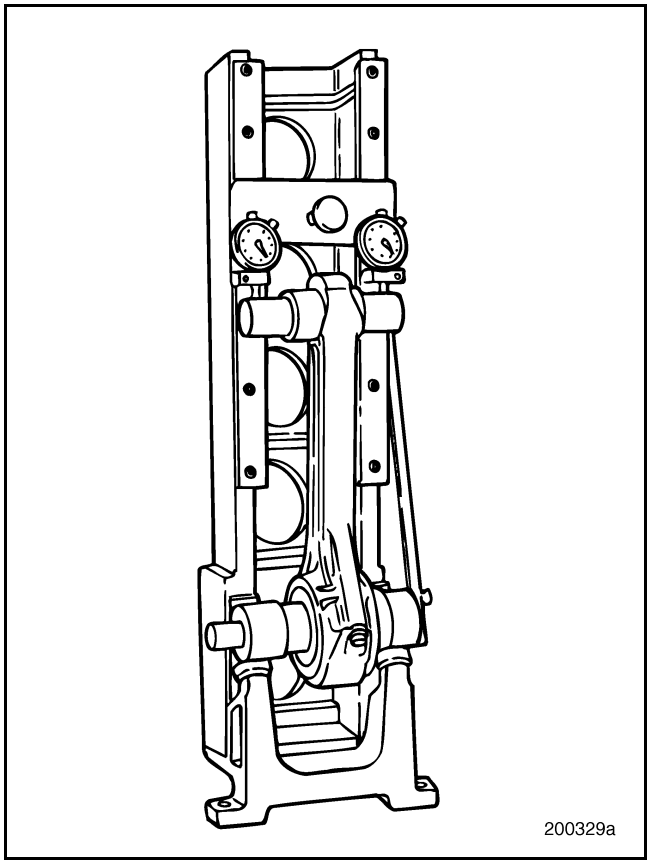


Figure 209 — Connecting Rod Fixture

2. Using the appropriate mandrel and plunger extension, inspect the connecting rod for twist and bend. Replace the connecting rod if twist or bend is beyond the maximum allowable limits.

Piston Inspection and Cleaning [212 NP]

INSPECTION

1. On removal, tag each piston to identify it so that it can be returned to its original cylinder.
2. 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.

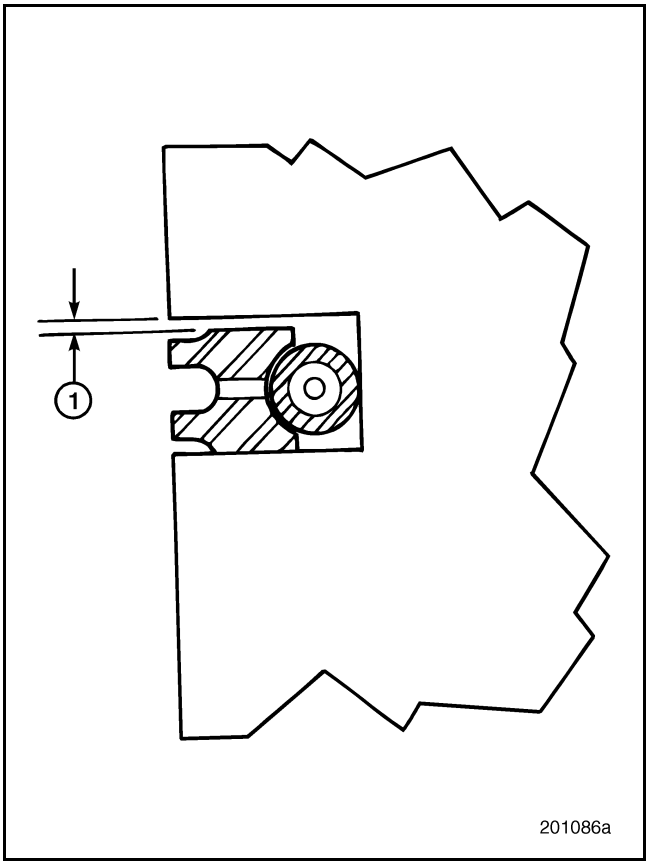


Figure 210 — Side Clearance Measurement

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 sleeve 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.

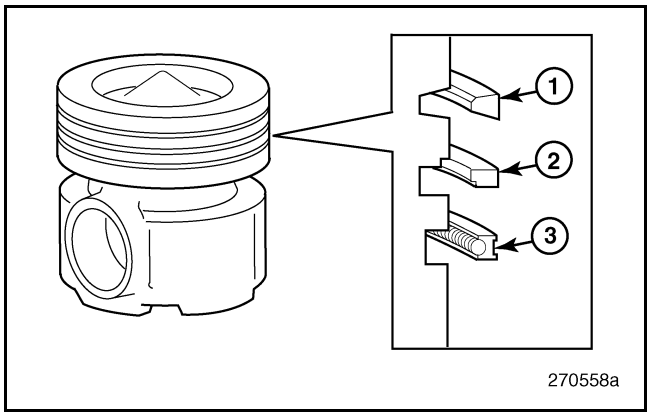


Figure 211 — Piston Rings

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.

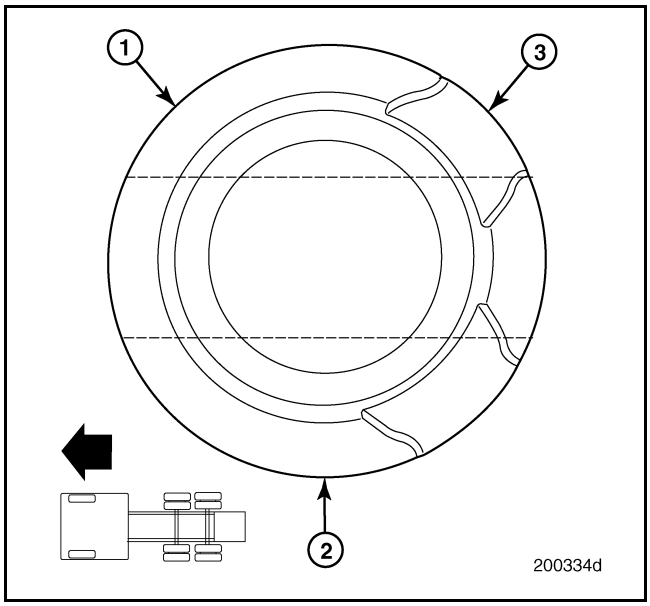


Figure 212 — Ring Gap Locations

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 grooves of the piston.
2. Insert the connecting rod in the piston assembly.

NOTE

Align the FRONT mark on the connecting rod with the FRONT mark on the piston. Refer to Figure 207.

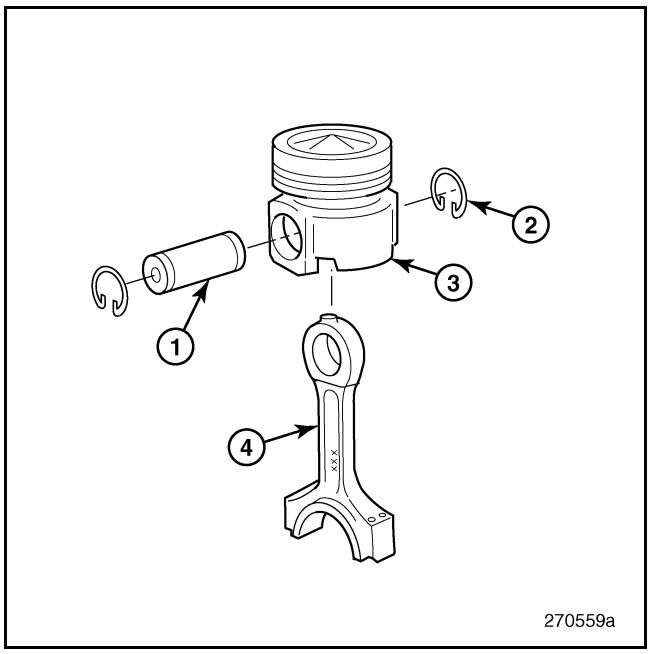


Figure 213 — Connecting Rod Piston Assembly

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

3. Using clean engine oil, press the wrist pin into the bore.
4. Insert a snap ring in the other wrist pin groove of the piston.
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.

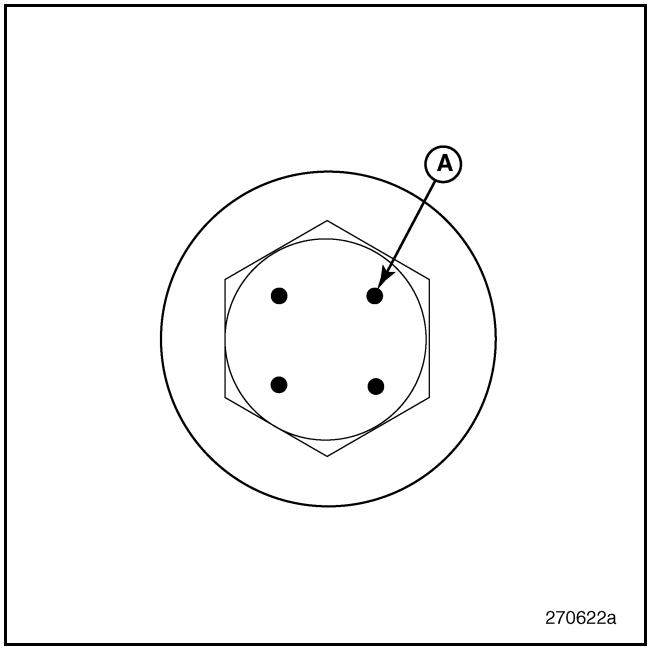


Figure 214 — Connecting Rod Screw with Maximum Punch Marks (Replace)

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.

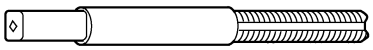
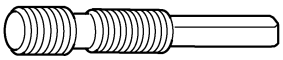
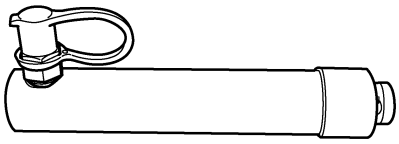
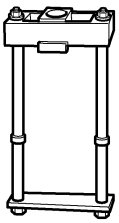
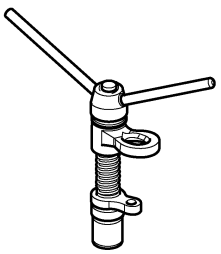
⚠ CAUTION

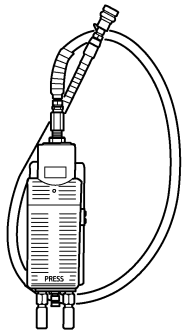
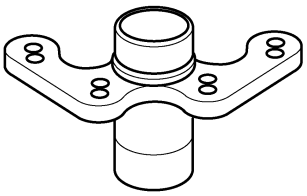
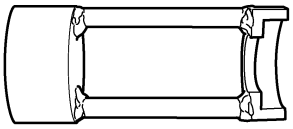
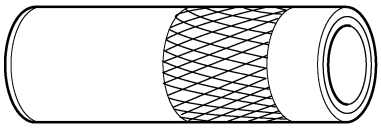
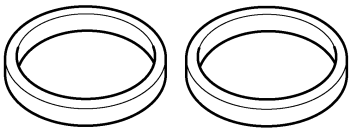
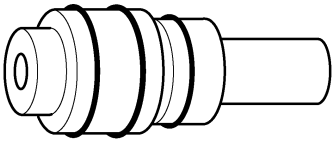
If the screws are incorrectly assembled or tightened to an incorrect torque, the assembly must be discarded. Failure to heed this caution may result in severe component damage.

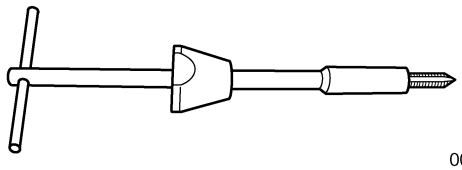
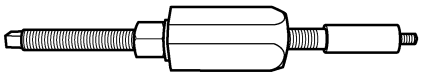
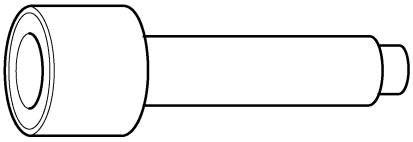
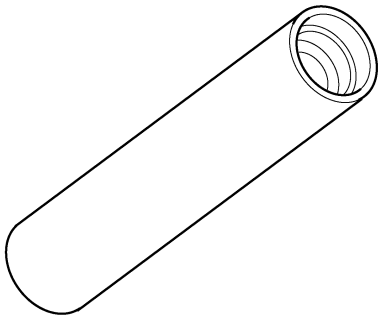
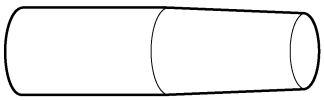
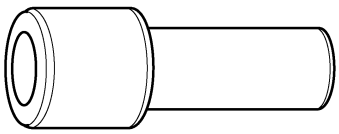
CYLINDER HEAD OVERHAUL [213 EV]

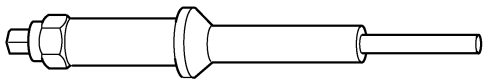
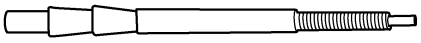
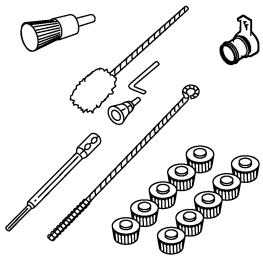
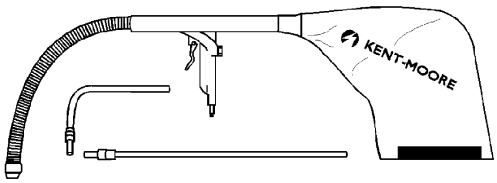
Tools and Equipment

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
9996956	Flywheel Turning Tool (Essential)	 006795a
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

Tool No.	Description	Image
9998252	Unit Injector Sleeve Tap (Essential), use 9809667, M9, for MP7	 006801a
9998253	Unit Injector Sleeve Remover (Essential), use 9809668, M9, for MP7	 006802a
9998263	Valve Guide Removal Tool (Available)	 006803a
85112460	Valve Stem Seal Installation Tool	 006966a
88800011	Valve Stem Seal Protection Tool	 006773a
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 MP7 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 control mounts on this cap and uses the lube connection.

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. Two special holes on the block side aid at assembly. 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.

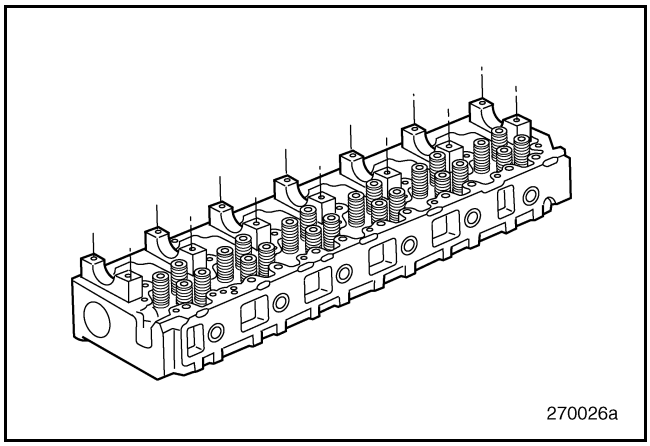


Figure 215 — Cylinder Head

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.

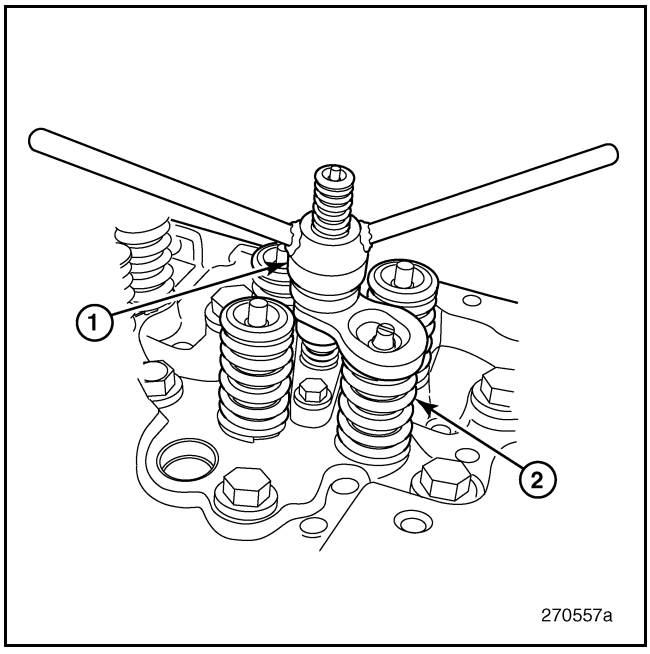


Figure 216 — Valve Spring Keeper Removal

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

⚠ WARNING

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.

⚠ CAUTION

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 “MP7 ENGINE MECHANICAL SPECIFICATIONS” on page 300 for dimensions applicable to the valve guides.

VALVE GUIDE REMOVAL

SERVICE HINT

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.

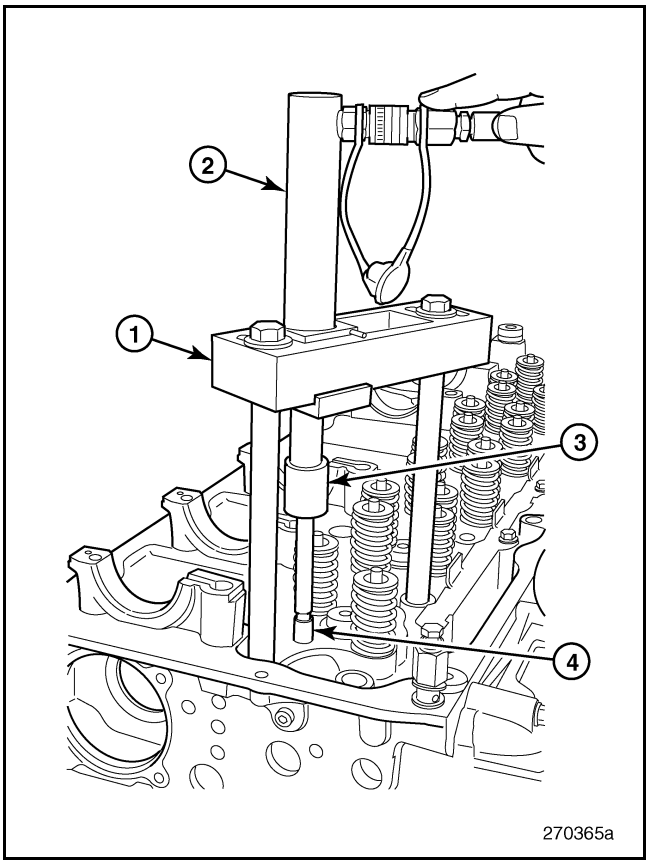


Figure 217 — Valve Guide Removal

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 cylinder head using the press.
3. Clean all surfaces thoroughly.

INSPECTION

NOTE

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.

NOTE

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

VALVE GUIDE INSTALLATION

1. 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.

⚠ CAUTION

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.

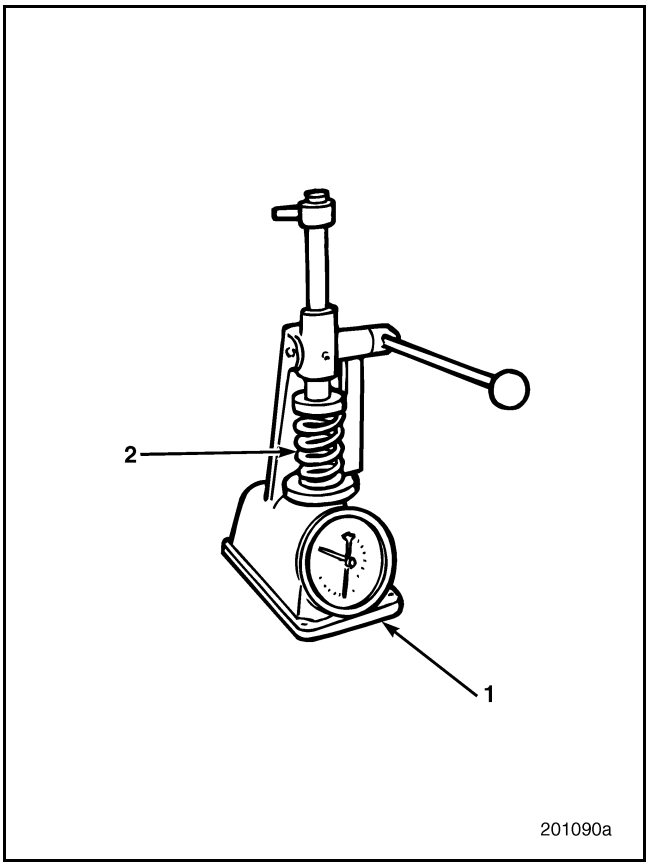


Figure 218 — Checking Valve Spring Pressure

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.

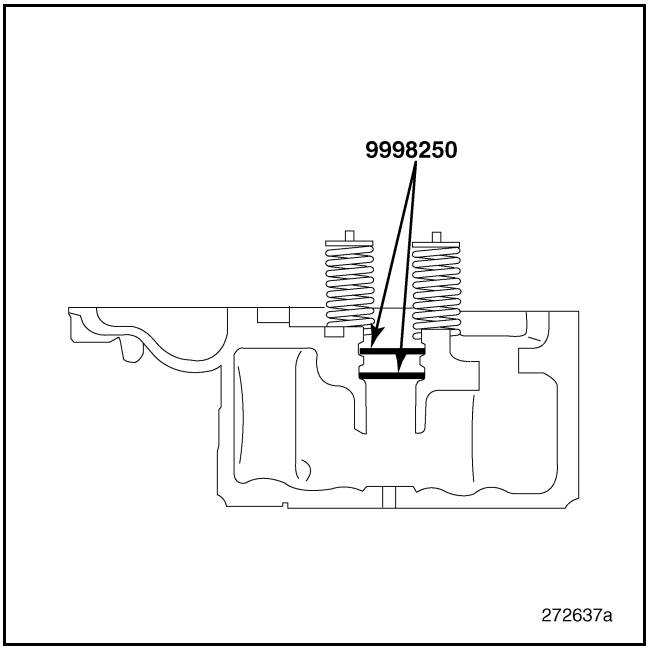


Figure 219 — Fuel Gallery Sealing Rings

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.

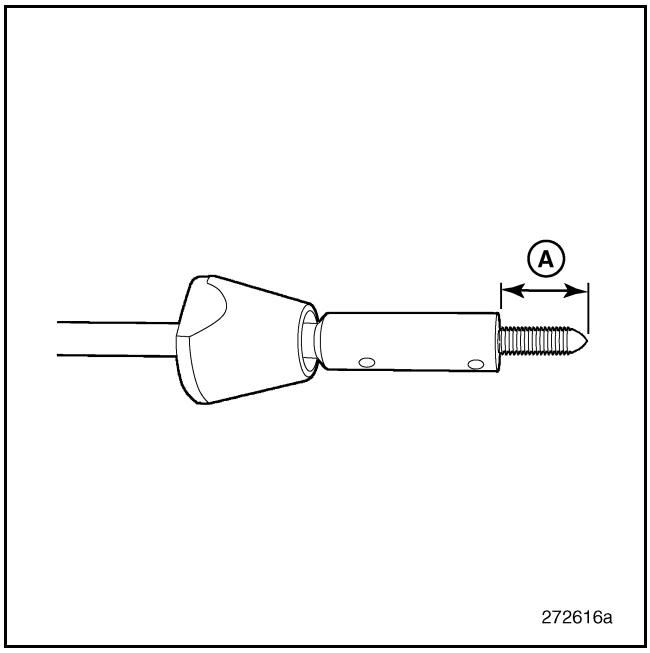


Figure 220 — Copper Sleeve Tapping Tool

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.

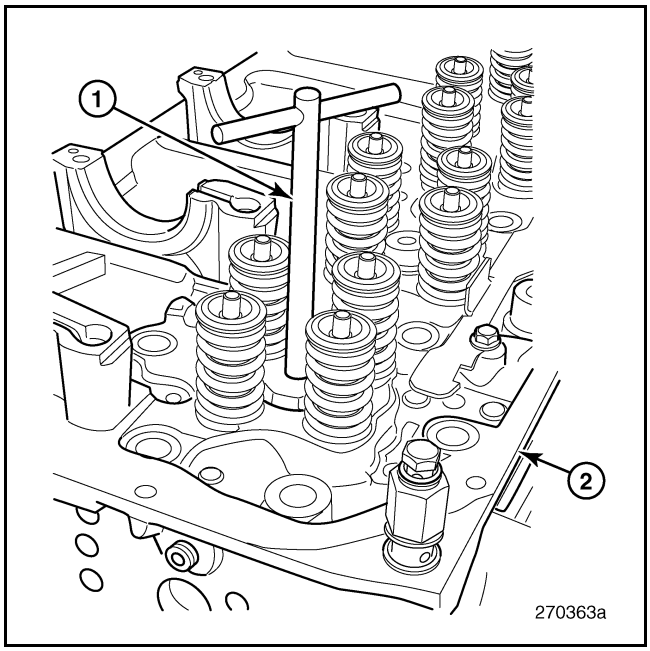


Figure 221 — Tapping Injector Sleeve

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).

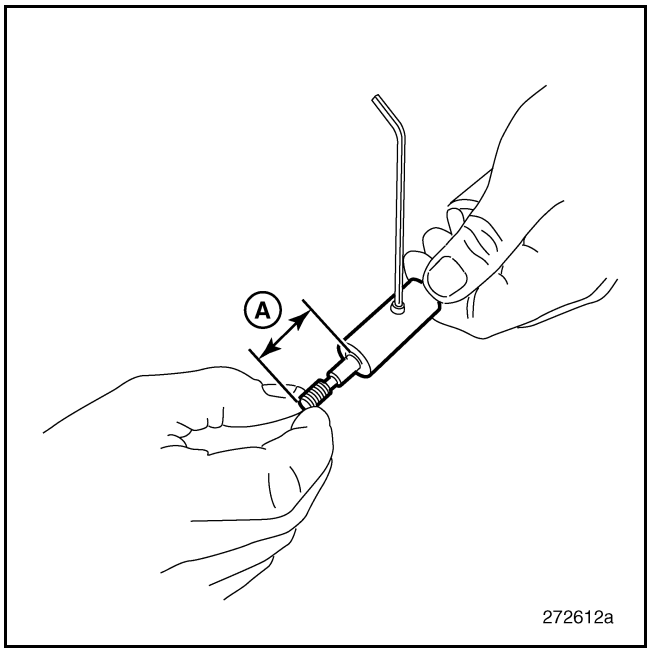


Figure 222 — Adjusting Copper Sleeve Extractor Bolt

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.

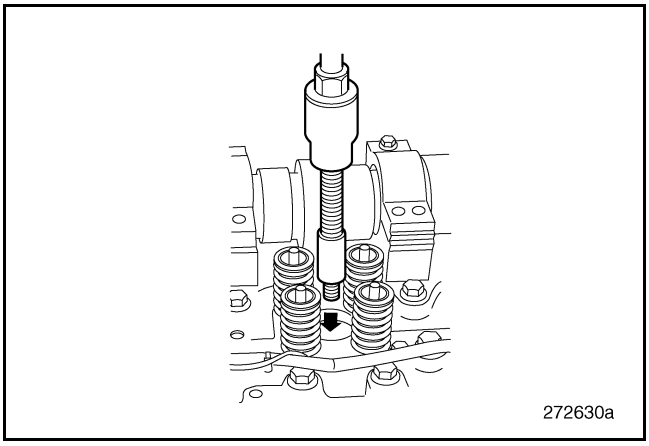


Figure 223 — Extractor Tool Installation

⚠ 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.

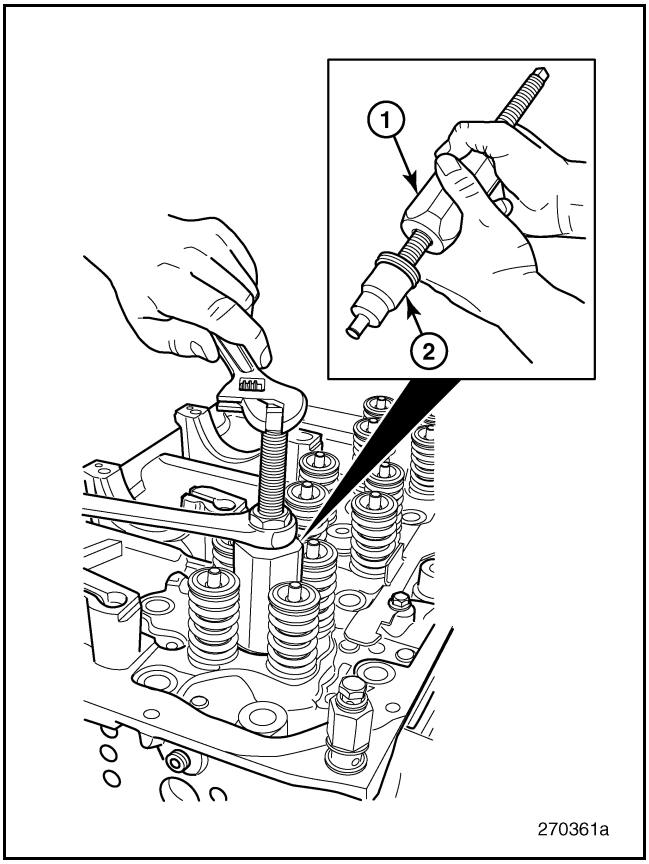


Figure 224 — Removing Injector Sleeve

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.

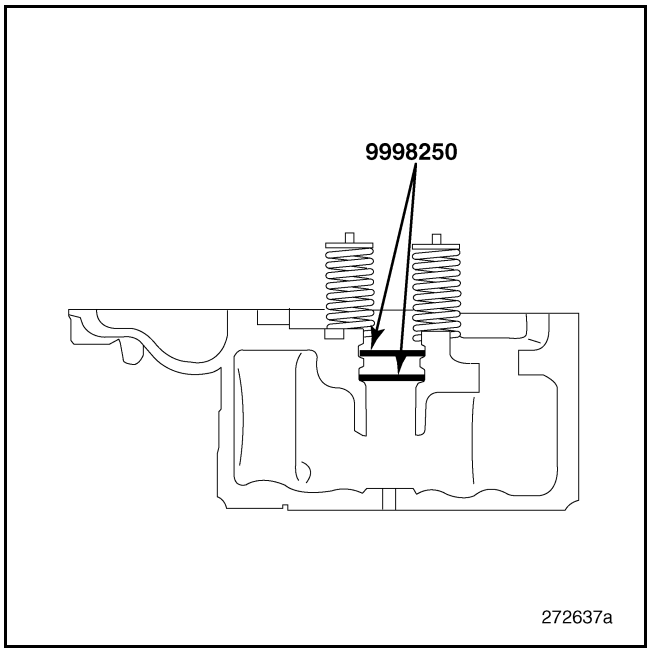


Figure 225 — Fuel Gallery Sealing Rings

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.

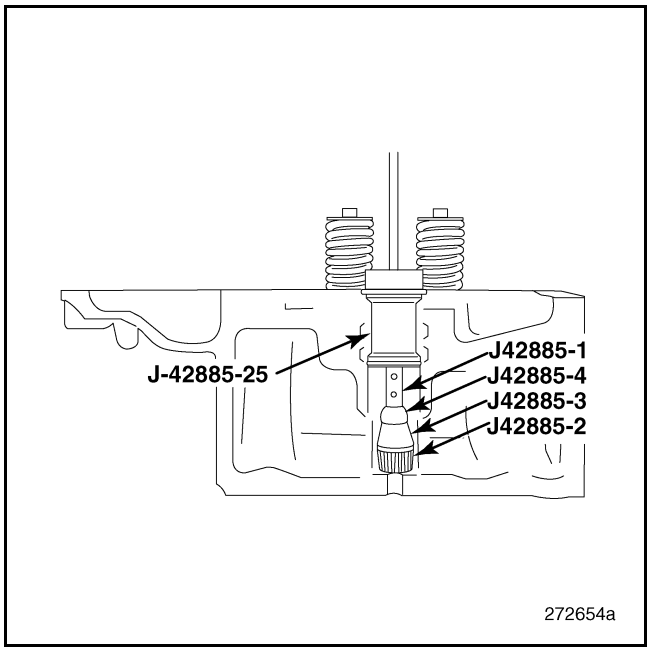


Figure 226 — Cleaning Copper Sleeve Seat

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

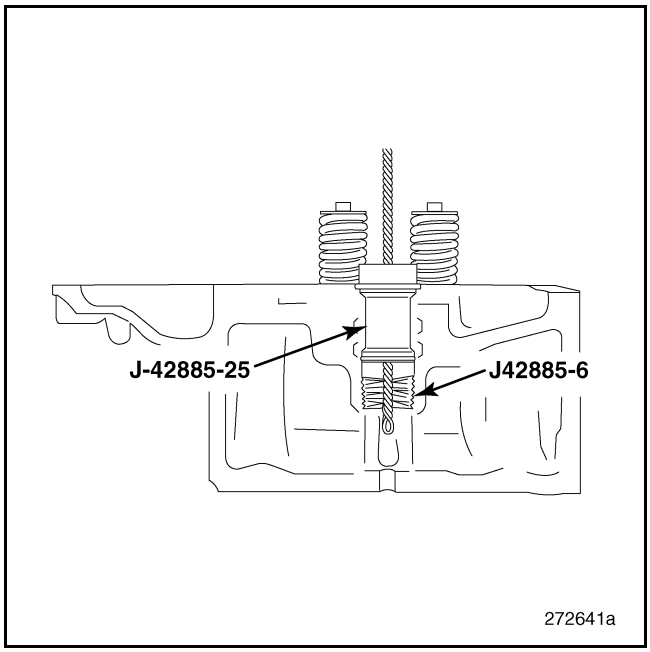


Figure 227 — Cleaning Copper Sleeve Bore Walls

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.

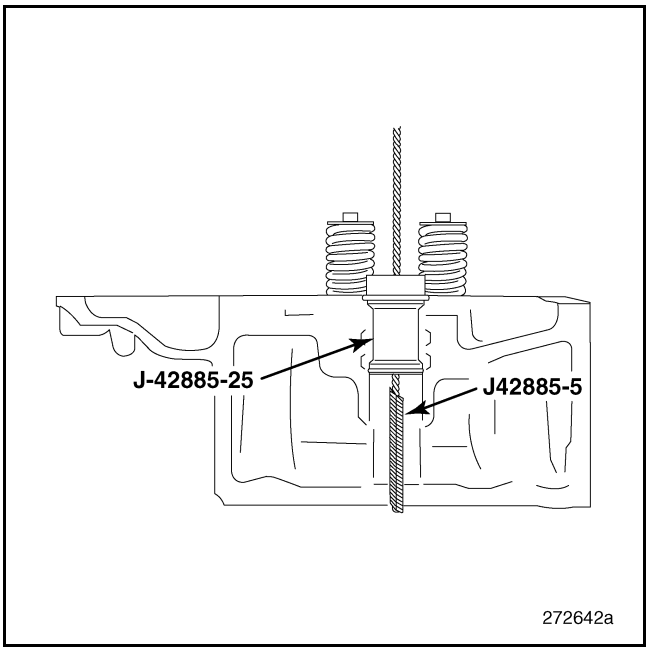


Figure 228 — Cleaning Injector Tip Bore

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.

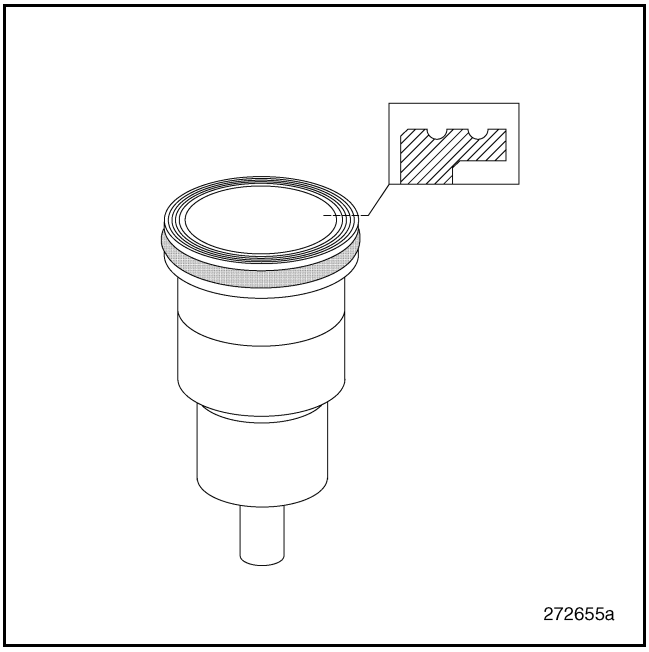


Figure 229 — Copper Sleeve Identification

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.

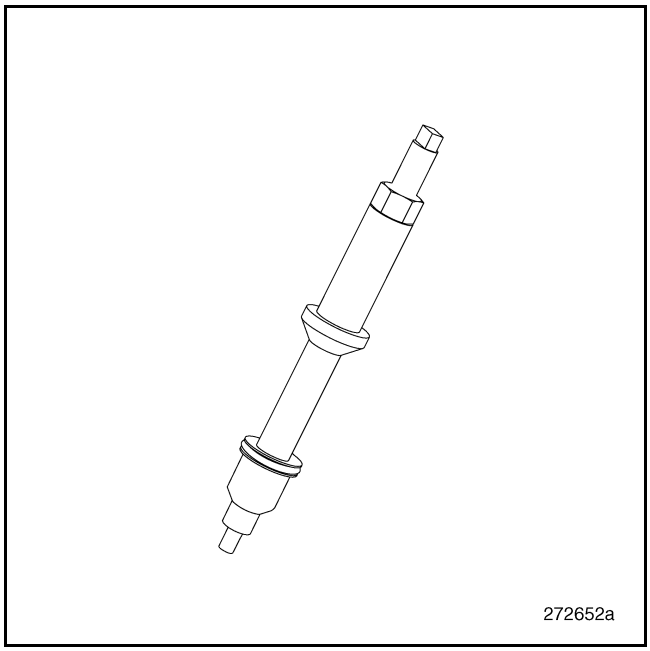


Figure 230 — Installation Tool Identification

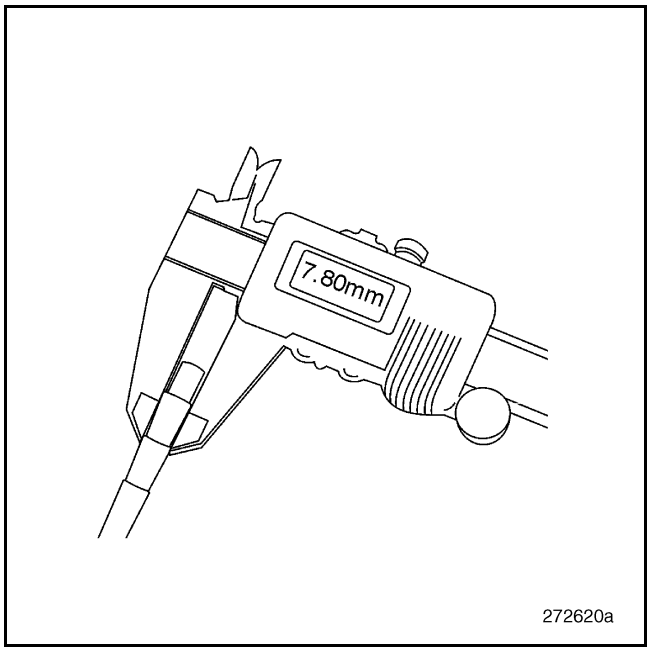


Figure 231 — Swaging Bit Verification

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.

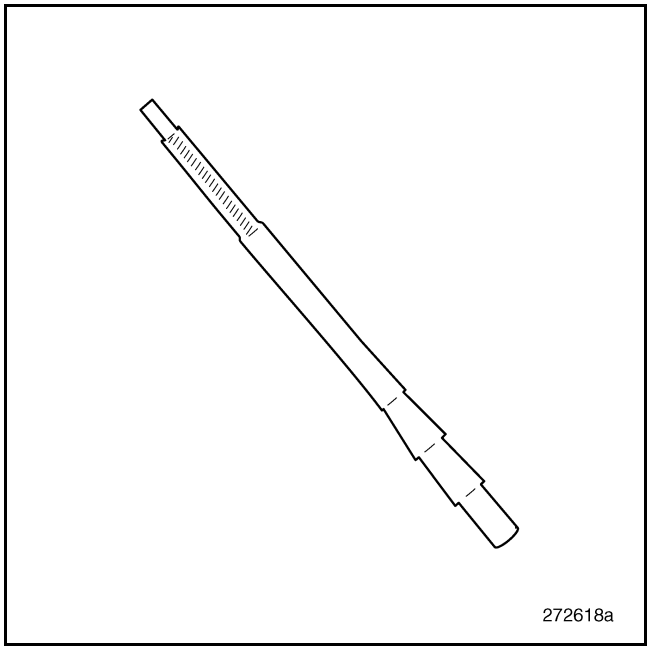


Figure 232 — Swaging Bit

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.

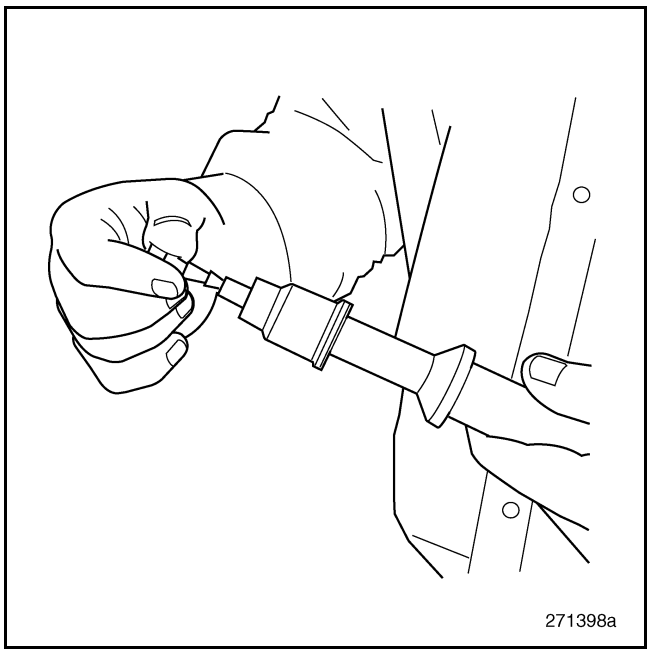


Figure 233 — Swaging Tool

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.

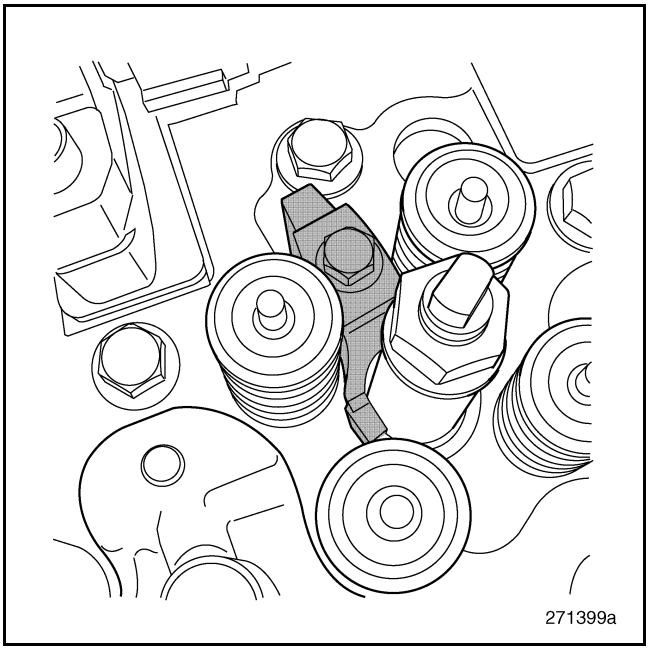


Figure 234 — Injector Yoke and Sleeve Installation Tool

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.

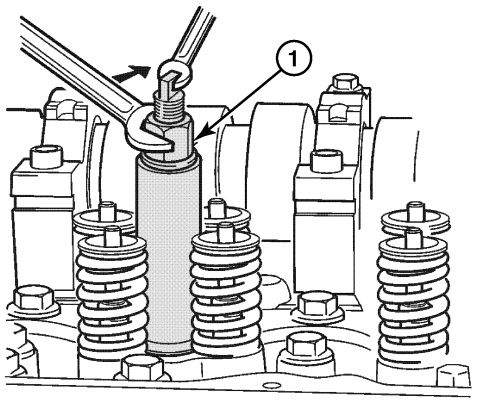


Figure 235 — Flaring Copper Sleeve Using Installation Tool

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.

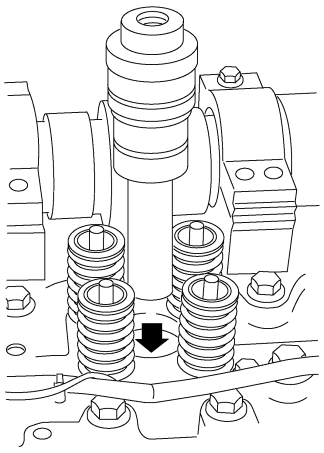


Figure 236 — Unit Injector Bore Sealing Plug

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.

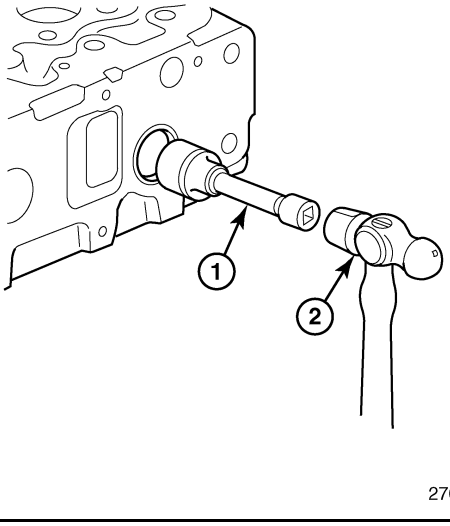


Figure 237 — Expansion Plug Installation

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

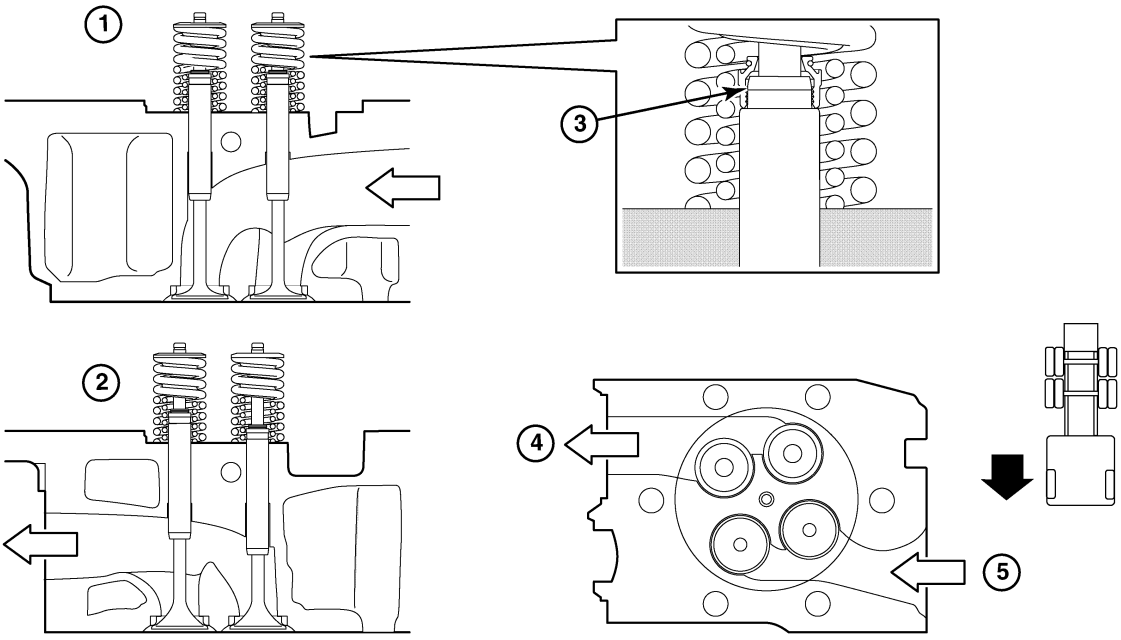


Figure 238 — Valve, Springs and Stem Seals

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.

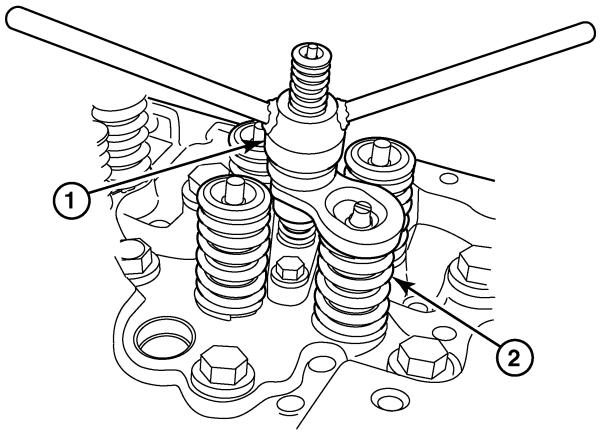


Figure 239 — Valve Spring Keeper Installation

1. Valve Spring Compressor 9990210	2. Valve Spring

ROCKER ARM SHAFT BENCH PROCEDURES [213 LP]

Description

ROCKER ARM SHAFT

The MP7 rocker arm shaft 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 “MP7 ENGINE MECHANICAL SPECIFICATIONS” on page 300.

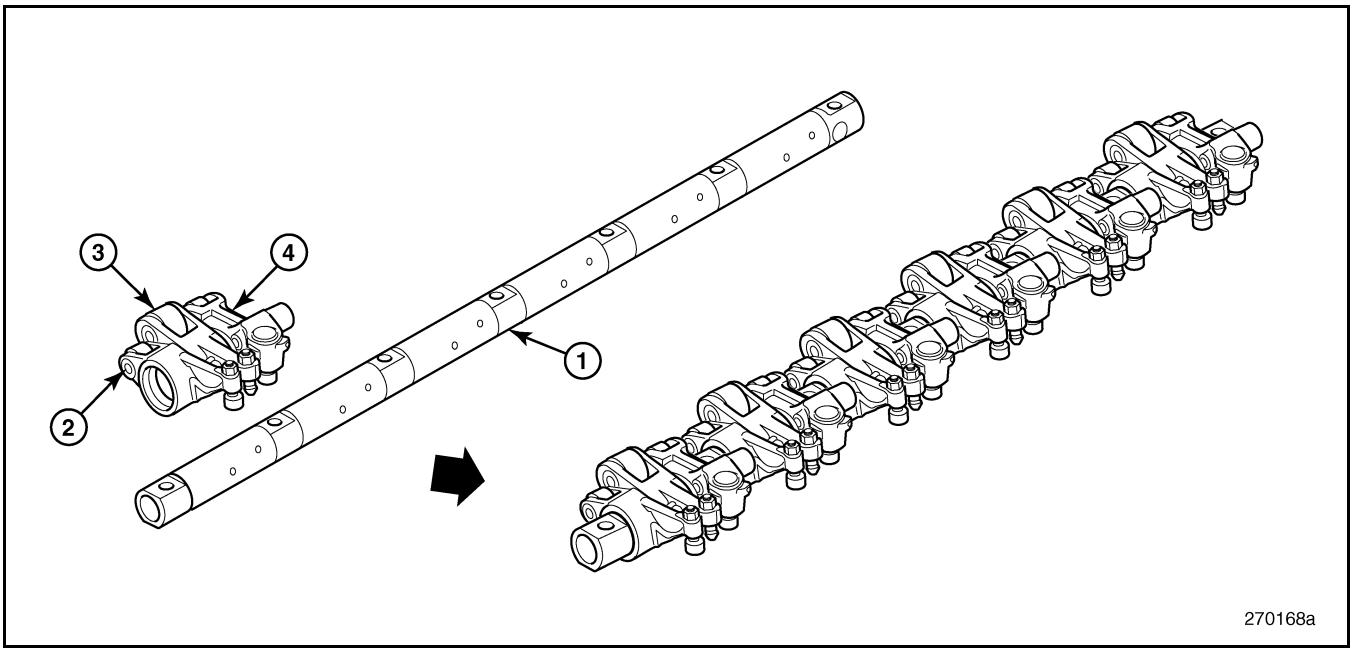


Figure 240 — Rocker Arm Shaft

1. Rocker Shaft 2. Inlet Rocker Arm	3. Unit Injector Rocker Arm 4. Exhaust Rocker Arm

Rocker Arm Shaft Disassembly

Removing the rocker arm shaft from the engine is covered in “Rocker Arm Shaft and Engine Brake Removal” on page 114.

WITH ENGINE BRAKE

⚠ CAUTION

On engines fitted with the engine brake, the exhaust rocker arms contain pistons which must remain with the arms in which they have been operating. Use rubber bands or tie straps to hold the pistons in place during disassembly. Failure to heed this caution may result in severe engine damage.

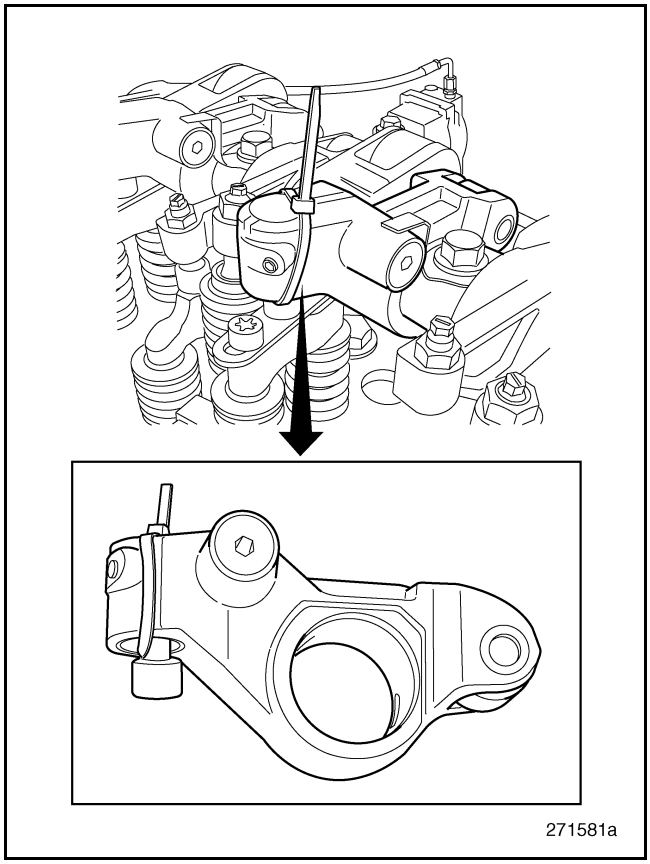


Figure 241 — Tie Strap Holding Engine Brake Piston

WITH OR WITHOUT ENGINE BRAKE

Disassemble the rocker arm 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.
3. Remove and separate the adjusting screws and jam nuts and set them aside.

NOTE

A rocker arm and its yoke must be kept together. They are marked in sets.

Inspection

ALL COMPONENTS

1. Inspect all components of the rocker arm shaft assembly for damage and excessive wear. If a 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 arm shaft for galling, scoring or excessive wear. Replace as necessary.

Rocker Arm Shaft Assembly

WITH OR WITHOUT ENGINE BRAKE

Assemble the rocker arm shaft and components as follows:

1. Lubricate the adjusting screws and jam nuts.
2. Thread the adjusting screws and jam nuts loosely into the rocker arms.
3. Arrange the rocker arms in sets of three according to the markings made at disassembly.
4. Lubricate the rocker arm shaft and the bores of the rocker arms.
5. Slide the rocker arm sets onto the shaft according to the markings made at disassembly.

CAMSHAFT BENCH PROCEDURES

Camshaft Inspection

[213 CH]

There are two configurations of camshafts for the MP7 engine: without engine brake and with engine brake. For the engine brake option, additional lobes are required on the cams that operate the exhaust valves.

CAMSHAFT GEAR REMOVAL

⚠ CAUTION

Handle the camshaft carefully to avoid bending it. Slight but harmful bends can go unnoticed. Failure to heed this caution may 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 is on the cylinder head.

1. Support the vibration damper and camshaft gear while removing the attaching screws.
2. Remove the attaching screws.
3. Separate the vibration damper and gear from the camshaft.

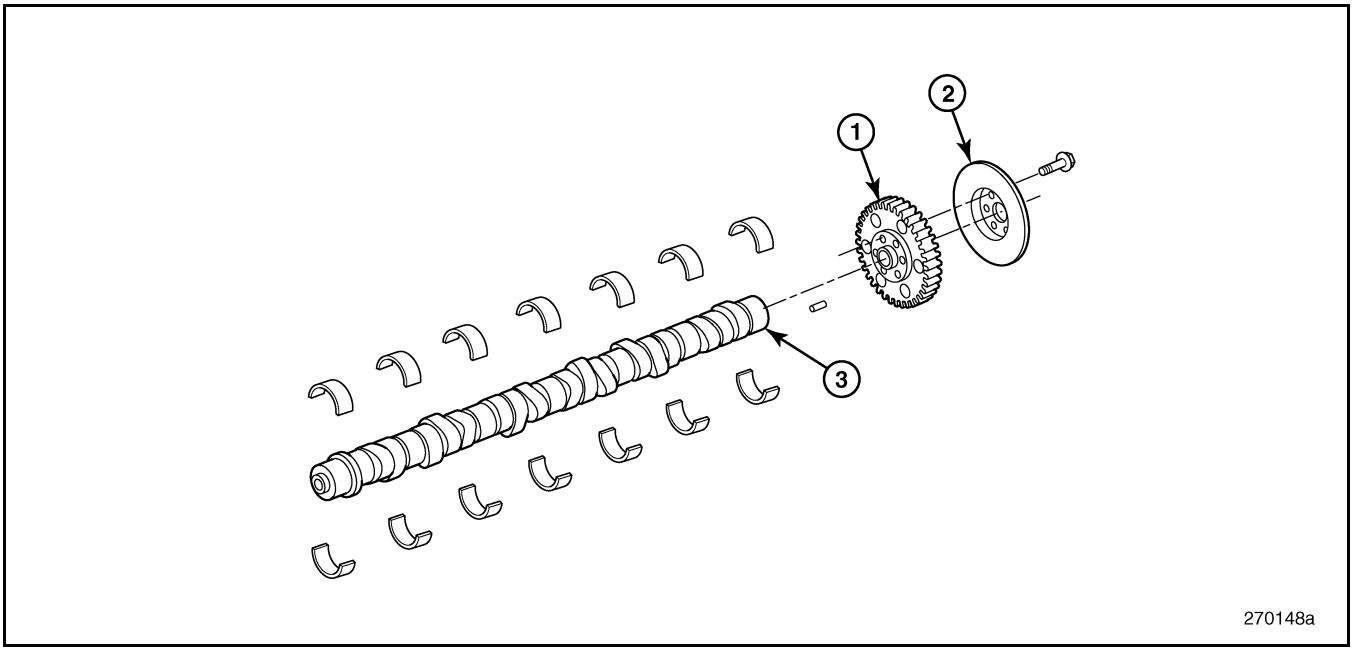


Figure 242 — Camshaft Assembly Components

1. Camshaft Gear 2. Vibration Damper	3. Camshaft

INSPECTION

1. Clean the camshaft thoroughly.

NOTE

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

Follow the Magnaflux® (PT7190) inspection procedure for steps 2 and 3.

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

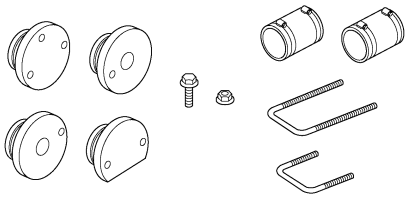
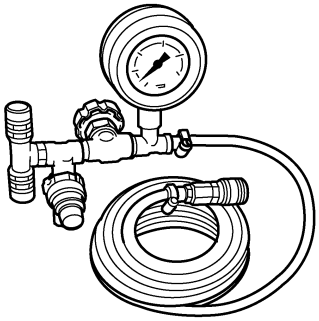
CAMSHAFT GEAR INSTALLATION

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

1. Position the vibration damper and timing gear on the camshaft.
2. Install the retaining screws.
3. Tighten the retaining screws according to the sequence and specification found in “MP7 ENGINE MECHANICAL SPECIFICATIONS” on page 300.

COOLING SYSTEM COMPONENTS BENCH PROCEDURES

Special Tool

Tool No.	Description	Image
88800216	EGR Cooler Leak Test Kit (Essential)	 007002c
9996662	Pressure Gauge and Hoses (Available)	 006793a
9998333	Coupler, used with 88800216 (Available)	273047a

Oil Cooler Reconditioning

[215 DW]

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

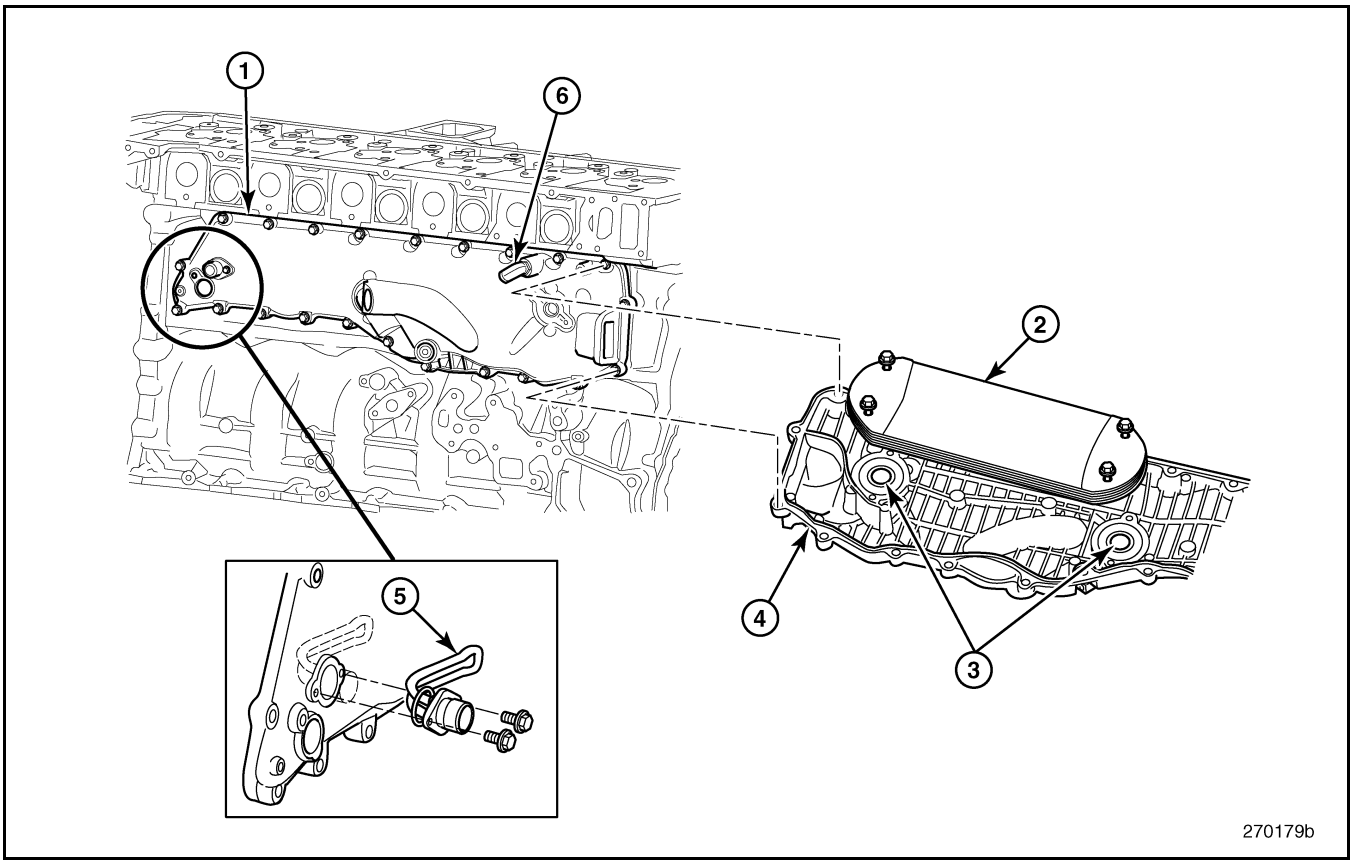


Figure 243 — Oil Cooler Assembly

1. Cooling Duct Cover 2. Oil Cooler 3. Oil Inlet and Outlet Ports	4. Cover Seal 5. Cylinder Block Heater 6. Fitting, 90° Elbow

EGR Cooler Cleaning

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

Although there are no prescribed service intervals for cleaning the EGR cooler, it should be cleaned whenever it becomes restricted.

Driveability concerns and logged faults in the V-MAC IV would be evidence of this type of restriction (e.g., the code appears for EGR High Temperature).

The EGR cooler cannot be disassembled and reconditioned.

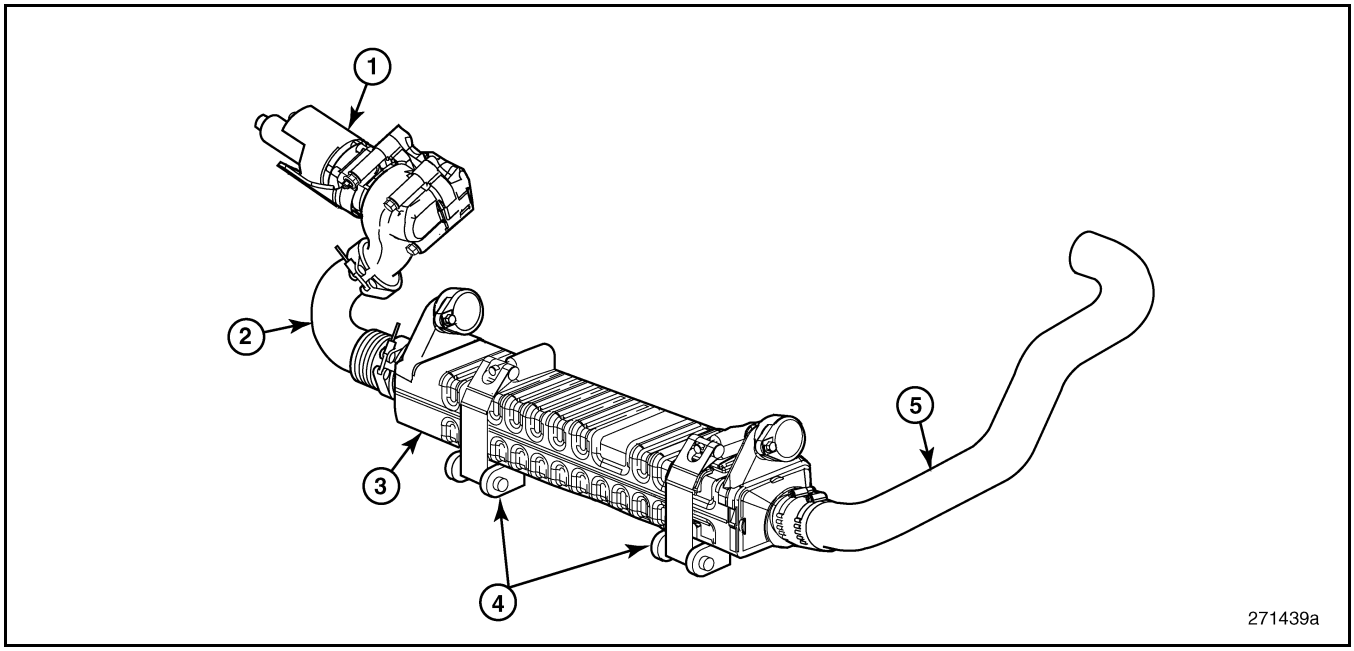


Figure 244 — EGR Cooler Assembly

1. EGR Valve 2. EGR Cooler Inlet Pipe 3. EGR Cooler	4. EGR Cooler Mounting Brackets 5. EGR Cooler Outlet and Crossover Pipe

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.

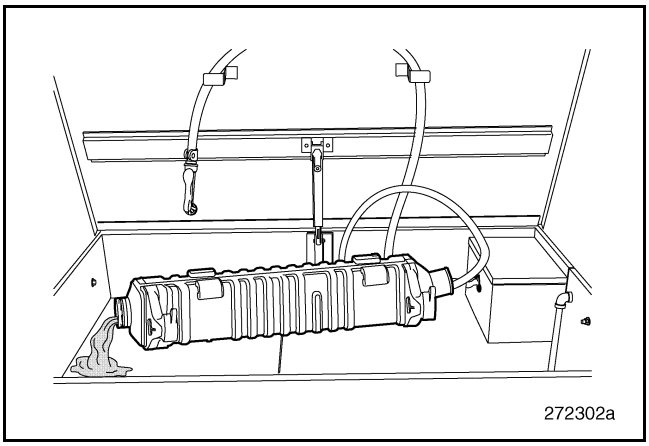


Figure 245 — EGR Cooler in Parts Washer

NOTE

Do not use a solvent solution that has been used for general parts cleaning.

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

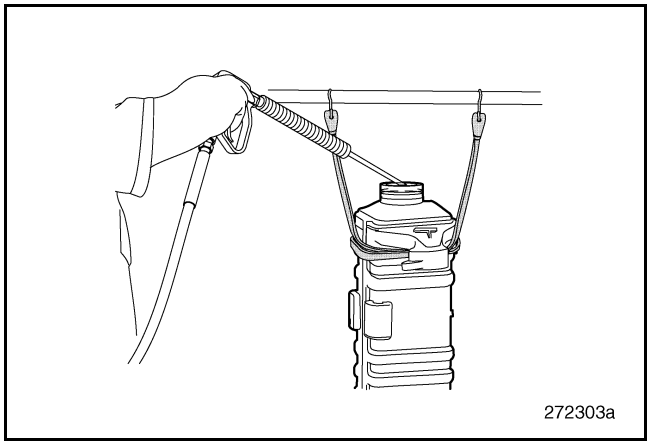


Figure 246 — Steam Cleaning the EGR Cooler

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

⚠ WARNING

Steam is extremely hot. Proceed with caution. Failure to heed this warning may result in severe personal injury.

⚠ 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.*

3. Steam and soot should flow out of the lower end of the cooler.
4. Turn the cooler end for end and steam clean through the outlet end until clear water flows.

NOTE

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

5. While the cooler hangs vertically, blow clean shop air into the inlet end until the cooler is dry.

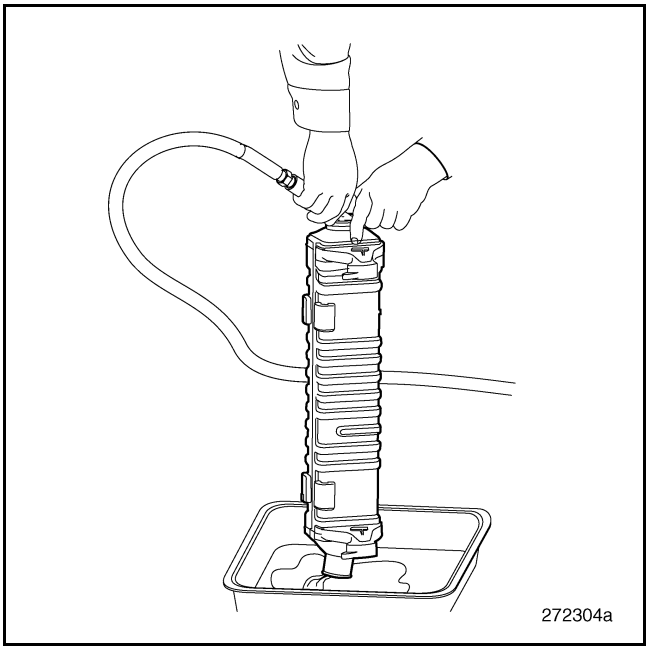


Figure 247 — Blowing Shop Air into EGR Cooler

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

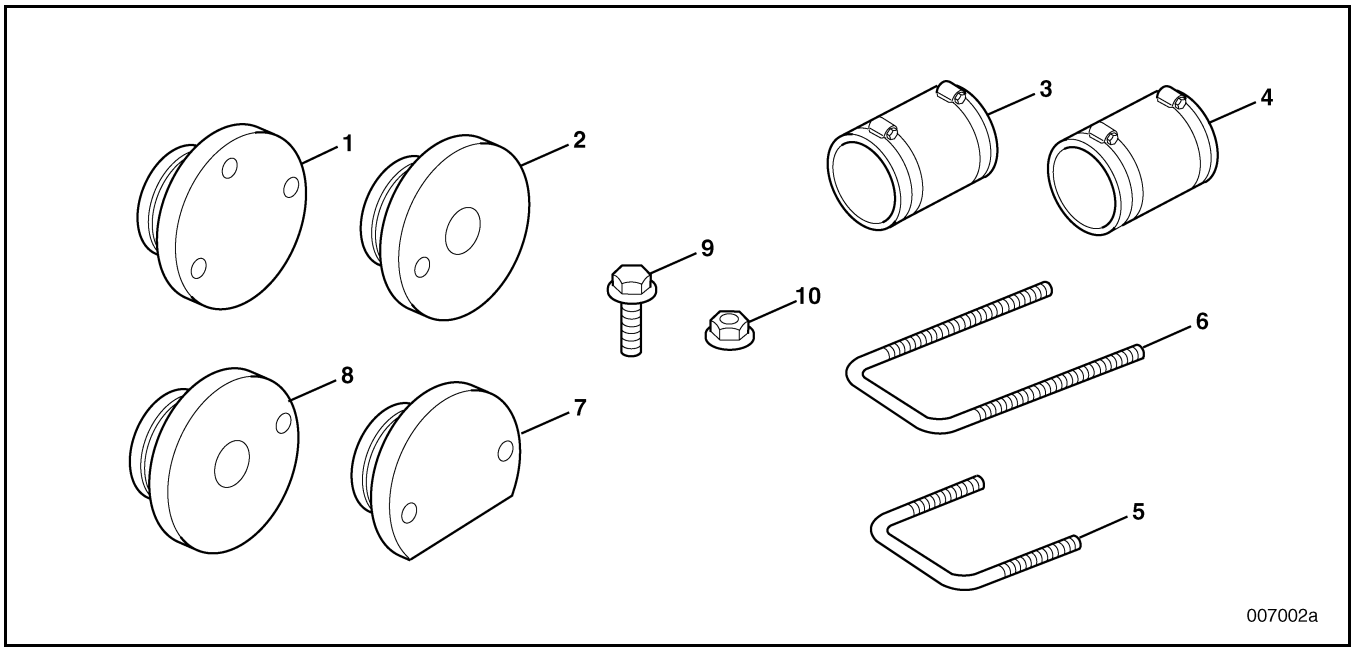


Figure 248 — EGR Cooler Leak Test Kit 88800216

1. 88800216-1 Inlet Plug (MP8 and US07 MP7) 2. 88800216-2 Outlet Plug (MP8 and US07 MP7) 3. 88800216-5 Test Plug (MP8 and US07 MP7) 4. 88800216-6 Test Plug (US04 MP7) 5. 547635 U-Bolt (US04 16L engine, not used on MACK product)	6. 547632 U-Bolt (MP8 and US07 MP7) 7. 88800216-4 Inlet Plug (US04 MP7) 8. 88800216-3 Outlet Plug (US04 MP7) 9. 547638 Flange Capscrew (M8 x 1.25 - 20 mm) 10. 220281 Flange Nut (M8 x 1.25)

1. Perform the EGR cooler cleaning procedure before checking for leaks.
2. Fill a container with enough water to cover the outlet on the EGR cooler.

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 inlet port. The EGR cooler core can then be filled with water and tested by applying air pressure to the coolant inlet port. When testing an MP7 (07 emissions) engine EGR cooler, 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.

3. Lubricate the O-rings on the plugs. Install the plugs and cap on the EGR cooler. 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.

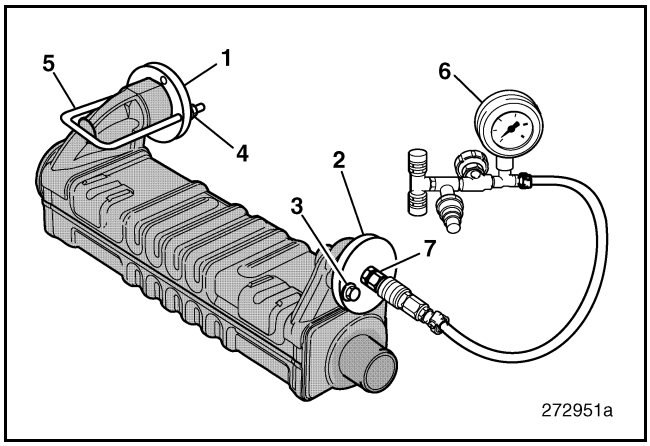


Figure 249 — Installation of Pressure Test Kit on Cooler

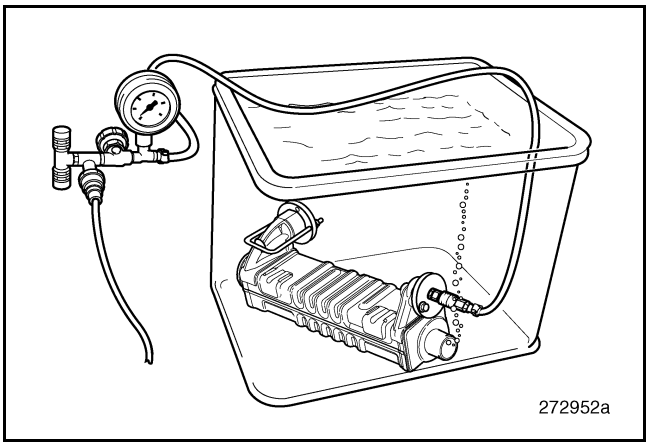


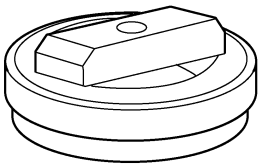
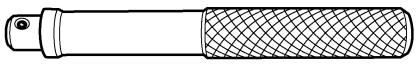
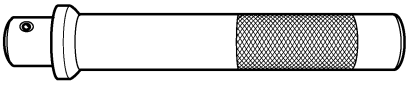
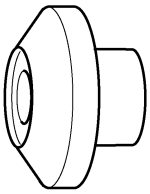
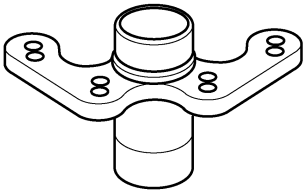
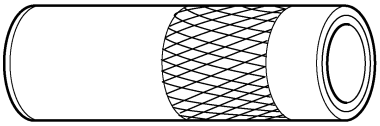
Figure 250 — Conducting Pressure Test

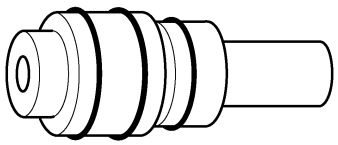
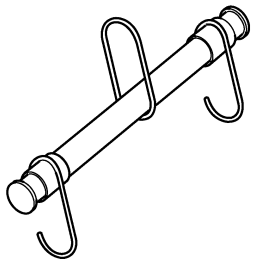
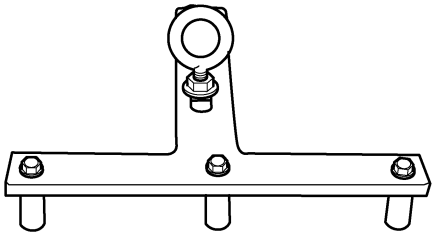
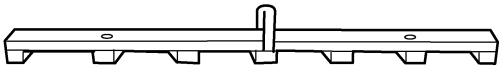
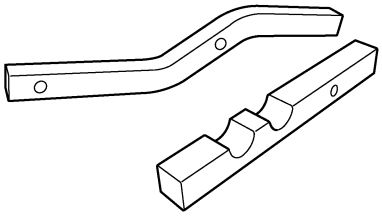
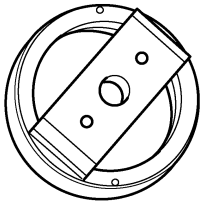
1. 88800216-1 2. 88800216-2 3. Flange Capscrew 4. Flange Nut	5. U-Bolt 6. 9996662 7. 9998333

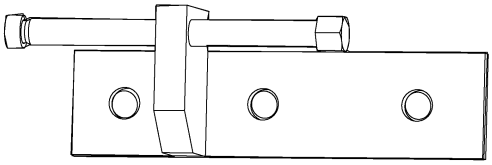
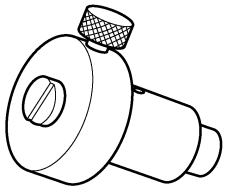
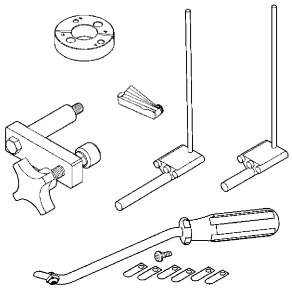
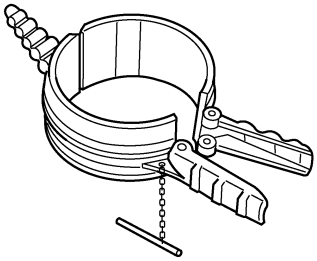
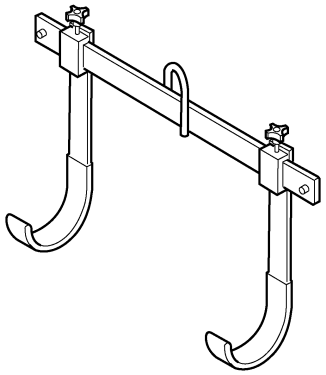
4. Lower the EGR cooler into the container of water at room temperature.
5. Apply air pressure (240 kPa [35 psi]) to the EGR cooler. Maintain the pressure for 15 minutes. If the EGR cooler is leaking, there will be a steady stream of bubbles. If a steady stream of bubbles appears, replace the EGR cooler.
6. Lift the EGR cooler out of the container and remove the pressure testing equipment.
7. Use compressed air to remove water from the EGR cooler and outer cover.

ENGINE REASSEMBLY
[200 EA]

Special Tools

Tool No.	Description	Image
9990113	Rear Main Seal Remover/Installer, use with 9992000 (Essential)	 006780a
9991801	Handle with various uses (fits 18 mm hole), (Essential)	 006783a
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
9996956	Flywheel Turning Tool (Essential)	 006795a
9998249	Unit Injector Protection Sleeve (Essential)	 006798a

Tool No.	Description	Image
9998251	Unit Injector Bore Sealing Plug (Essential)	 006800b
85109034	Camshaft Lifting Bar (Essential)	 006835a
85109049	Cylinder Head Lifting Tool (Essential)	 006769a
85109050	Rocker Shaft Assembly Lifting Tool (Essential)	 006770a
85109051 (A, B)	Timing Gear Cover Alignment Tools (Essential)	 006831a
88800021	Front Main Seal Remover/Installer (Essential)	 006774a

Tool No.	Description	Image
88800022	Cooling Duct Cover Installation Tool	 006893a
88800031	Camshaft Sensor Depth Gauge (Available)	 006804a
J 44514-B	Engine Timing Kit (Essential)	 006889a
J 48205	Piston Ring Compressor (Essential)	 006834a
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 installed 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.

⚠ CAUTION

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

NOTE

After cleaning the components, store them where they will remain clean until needed for assembly.

When required for installing components, be sure to use clean engine oil of the approved type.

NOTE

Do not reuse M8 screws. Lubricate threads, washers and under screw heads with clean engine oil except as noted.

Do not lubricate coated screws.

SERVICE HINT

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.

NOTE

In this manual, it is presumed that attaching screws will be assembled and hand started whenever one component is to be attached to another and screws or bolts are used. It is also presumed that nuts will be started on studs and bolts when it suits the situation. There may be exceptions. These will form part of the procedure as necessary.

For fastener torque and tightening sequence specifications, see the **ENGINE MECHANICAL SPECIFICATIONS** section.

Crankshaft Installation

[212 HP]

⚠ WARNING

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.

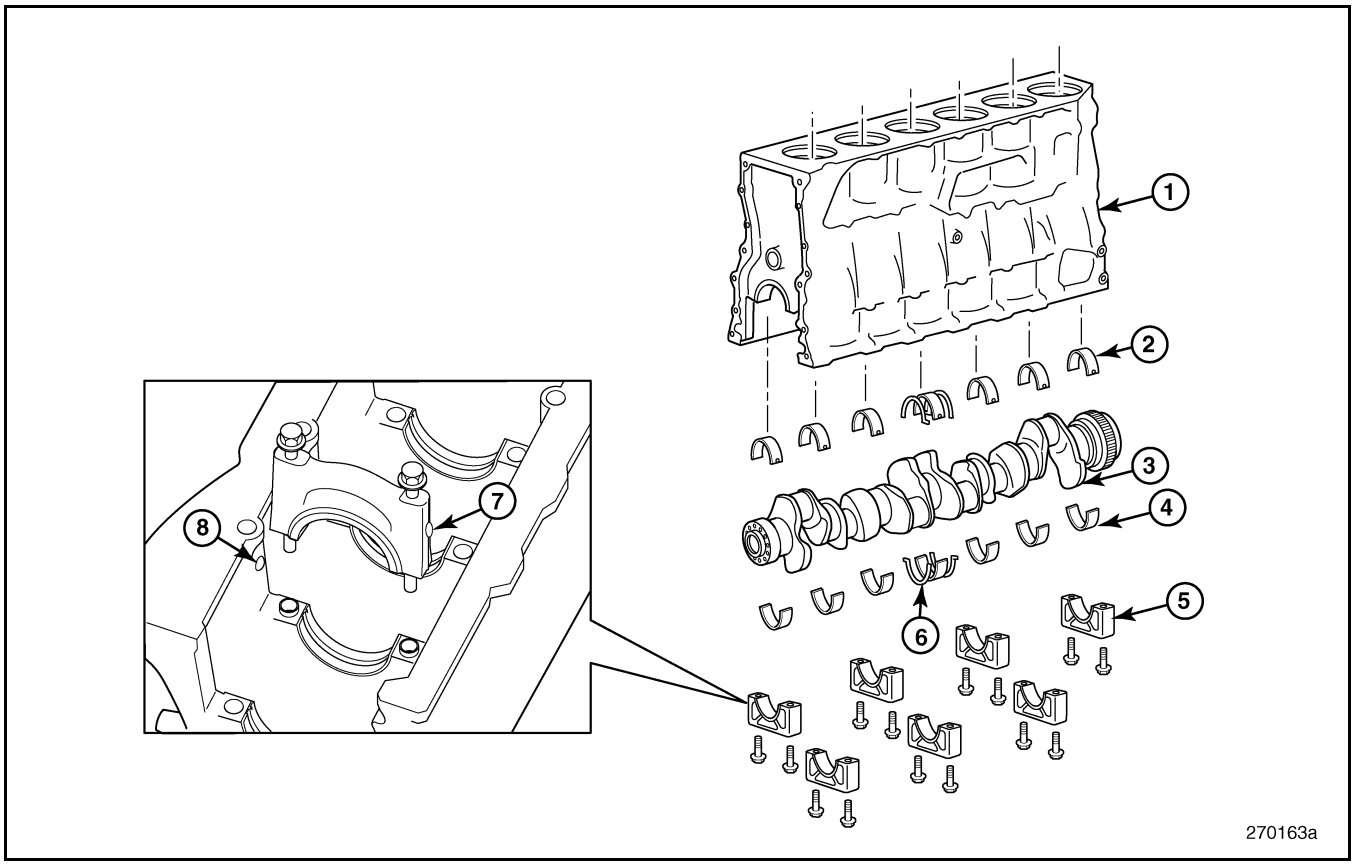


Figure 251 — Crankshaft and Main Bearing Caps

1. Cylinder Block 2. Bearing Inserts, Upper 3. Crankshaft 4. Bearing Inserts, Lower	5. Main Bearing Caps 6. Thrust Washers 7. Bearing Cap Casting Nipple 8. Cylinder Block Casting Nipple

1. Be sure that the crankshaft and the crankcase area of the cylinder block are clean.
2. Thoroughly clean each main journal bore and the back of each bearing before installation. The bearings must be installed dry.

⚠ CAUTION

The hole in the upper bearing insert must line up with the drilled hole in the cylinder block or the bearing will fail due to lack of lubrication. The upper bearing insert is stamped on the back with the word "UPPER." Failure to heed this caution may result in severe component damage.

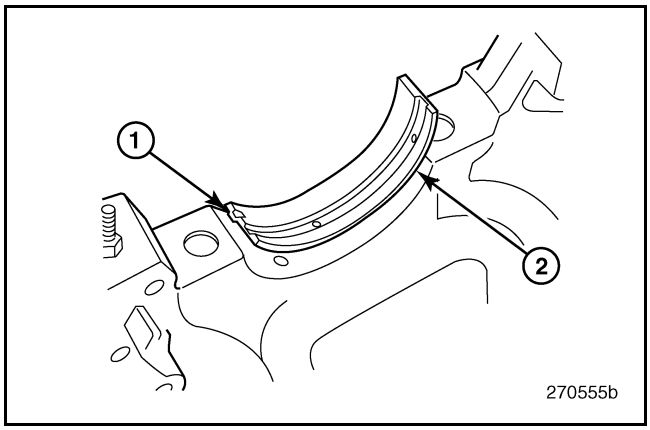


Figure 252 — Main Bearing (Upper)

1. Locating Tab	2. Bearing

3. Place the upper crankshaft main bearing inserts in the cylinder block journals making sure that the locating tabs fit in the notch in the bore.

⚠ CAUTION

Make sure each bearing is installed in its correct location. Failure to heed this caution may result in severe component damage.

4. Apply a light coat of clean engine oil on the bearing surfaces and on the crankshaft main journals.

⚠ CAUTION

Due to the considerable weight of the crankshaft, extreme care must be observed during installation. No nicks, scratches, burrs or other kinds of distress on the bearings, bearing caps, crankshaft journals and fillets are acceptable. Failure to heed this caution may result in severe component damage.

5. Using the crankshaft lifting tool, J 49002, position the crankshaft in the cylinder block.

Main Bearing Cap Installation [212 HH]

PROCEDURE

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.

NOTE

The lower bearings do not have a hole or a groove. They are stamped with the word "LOWER."

⚠ CAUTION

The caps are numbered from 1 through 7, front to rear. Do not mix the caps and bearings. Failure to heed this caution may result in severe component damage.

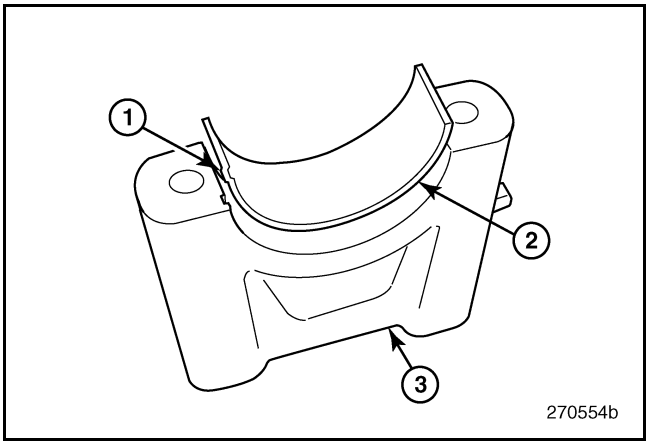


Figure 253 — Main Bearing Cap Installation (Lower)

1. Locating Tab 2. Bearing Insert	3. Bearing Cap

3. Lubricate the threads of the screws 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 screws in the threaded holes in the cylinder block.
5. Using a plastic mallet, tap the bearing cap down until it contacts the machined mounting surface.

6. Tighten the screws finger-tight.

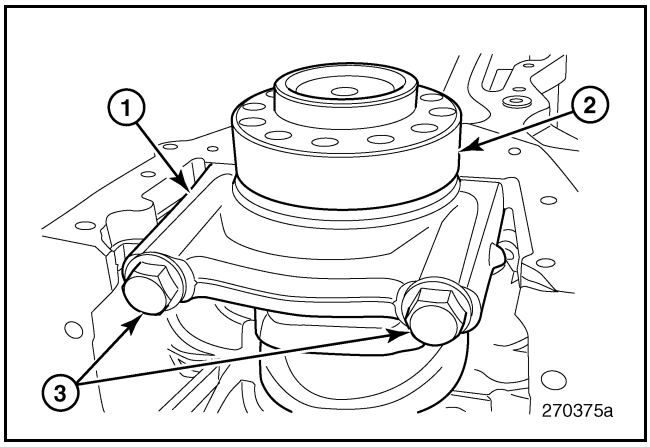


Figure 254 — No. 1 Main Bearing Cap — Assembled

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 an aluminum facing. The aluminum facing has oil reservoir 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 cylinder block. The aluminum side faces the crankshaft. This applies to both upper and lower thrust washer sections.

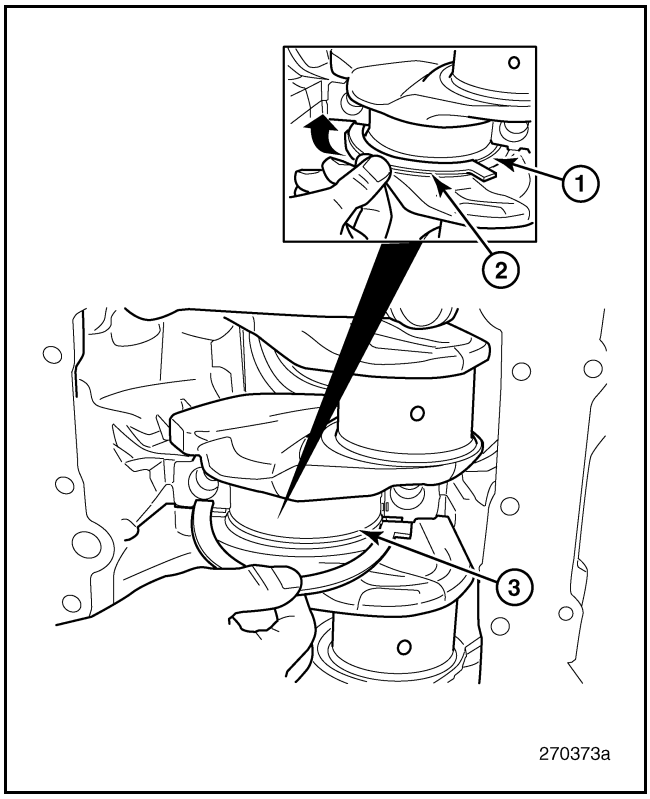


Figure 255 — Crankshaft Thrust Washer Installation

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 aluminum side facing the crankshaft and assemble the cap and screws in the cylinder block.

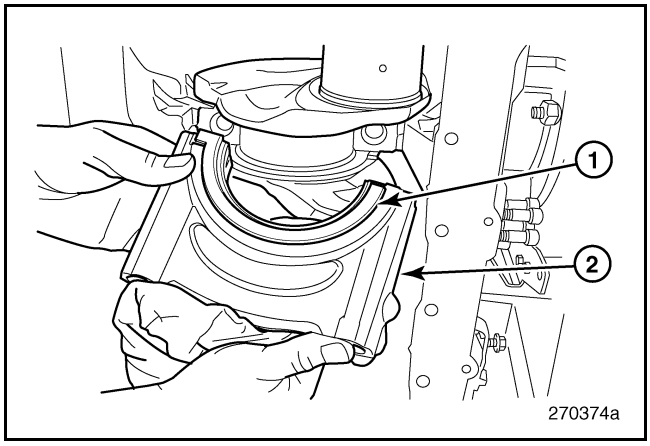


Figure 256 — Main Bearing Cap/Thrust Washer Installation

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

⚠ CAUTION

Make sure that the thrust washers are installed correctly when assembling the engine. Failure to heed this caution may result in severe engine damage.

11. Using a torque wrench, tighten the 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 feeler 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 aluminum 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 to be sure that it 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).

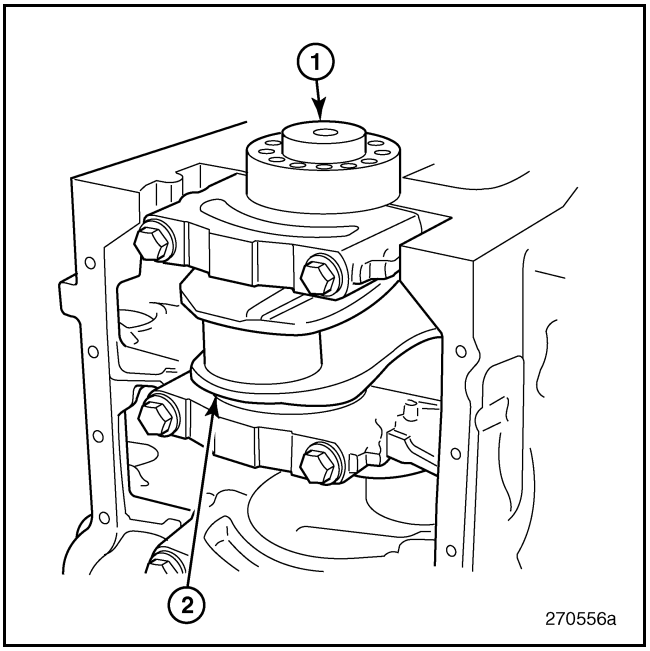


Figure 257 — No. 1 Cylinder (Crankshaft at BDC)

1. Crankshaft	2. No. 1 Journal

2. Place the piston on a clean, flat surface. Rest the piston and rod assembly on the piston crown with the rod upward.
3. Apply a light coat of clean engine oil to the piston and rings.
4. Apply a light coat of clean engine oil to the inside surface of the piston ring compressor tool.

⚠ CAUTION

The hole in the upper connecting rod bearing must be aligned with the oil passage in the connecting rod. Failure to heed this caution may result in severe engine damage.

5. Position the upper bearing insert into the connecting rod. Align the tab in the bearing with the notch in the rod.
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. Using ring compressor, J 48205, 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.

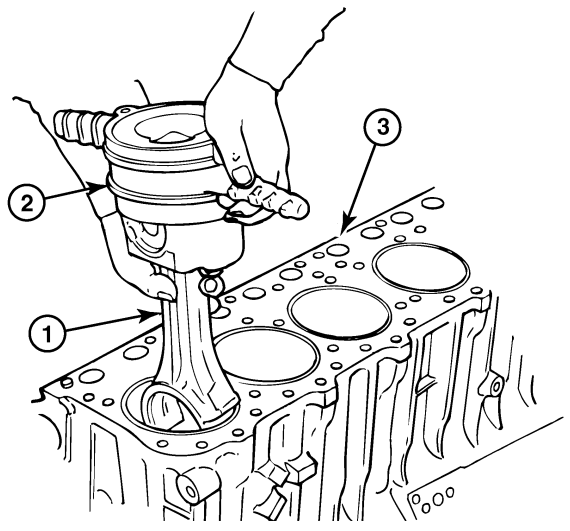


Figure 258 — Piston and Connecting Rod Installation

1. Connecting Rod Assembly	2. Piston Ring Compressor Tool 3. Cylinder Block

9. Make sure the connecting rod is aligned with the crankshaft journal.
10. 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.

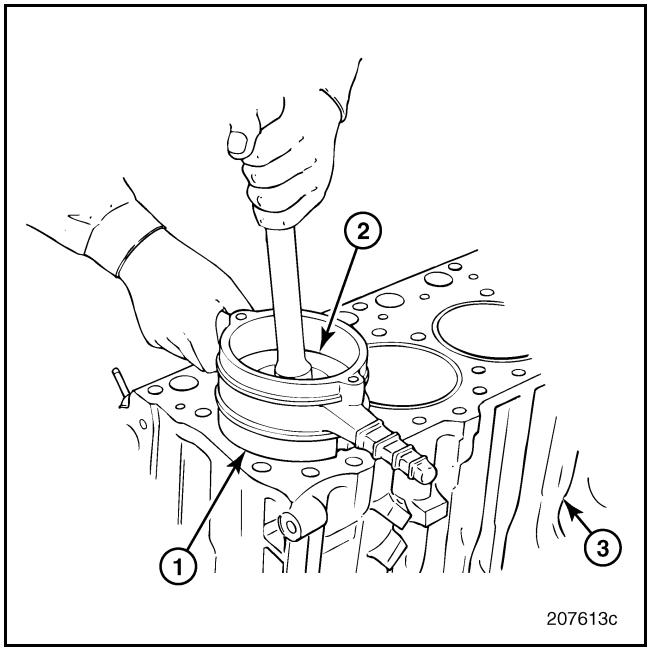


Figure 259 — Pushing Piston into Cylinder Liner

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.

⚠ CAUTION

Be sure that the piston cooling nozzle is aligned with the notch in the lower end of the piston skirt. Failure to heed this caution may result in severe engine damage.

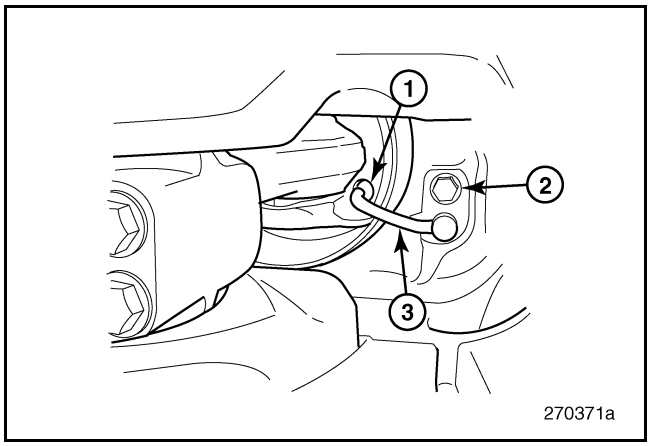


Figure 260 — Piston Skirt/Cooling Nozzle Alignment

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

11. Make sure that the connecting rod lower bearing insert (matched to upper bearing) and the alignment sleeves are positioned in the bearing cap.
12. Begin by installing the bearing cap at the No. 1 connecting rod journal and check **Running Clearance** following the procedure later in this section.

⚠ CAUTION

*Running clearance must be checked after installing **each** piston. Failure to heed this caution may result in severe engine damage.*

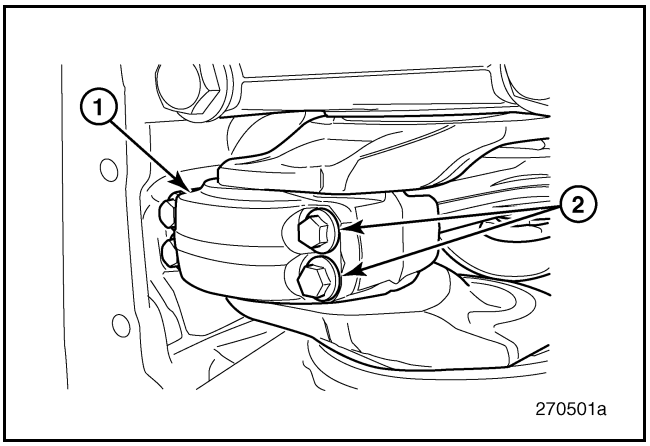


Figure 261 — Connecting Rod Cap Installed

1. Connecting Rod Cap	2. Attaching Screws

13. Repeat the previous steps to install the No. 6 piston.
14. 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 previous steps.
15. 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 following the previous steps.

RUNNING CLEARANCE INSPECTION

1. Place a section of Plastigage® on the connecting rod cap bearing and place the cap and bearing in position on the rod.
2. Apply a light coat of oil on the threads of the rod capscrews and install the screws.
3. Using a torque angle gauge and torque wrench, tighten the screws in a cross pattern according to specification.
4. Remove the screws and cap.
5. Measure the width of the Plastigage® stripe. After determining the clearance, remove the Plastigage®.
6. If the clearance is outside the specification, correct it as required.
   a. If the clearance is less than specified, check behind the bearing for dirt, chips or burrs which would prevent the bearing from seating properly.
   b. If the bearing bores and inserts are clean and undamaged, replace the inserts with inserts sized to provide the specified clearance.
7. Install the connecting rod cap to the journal.

⚠ CAUTION

Make certain that the connecting rod cap and rod are properly aligned to prevent bearing and rod damage. Failure to heed this caution may result in severe engine damage.

8. Lubricate the screws with clean engine oil.
9. Using a torque angle gauge and torque wrench, install and tighten the screws in sequence according to specification.
10. Check the connecting rod side clearance by inserting a thickness gauge between the rod and the side of the journal. Check along the entire parting line area.

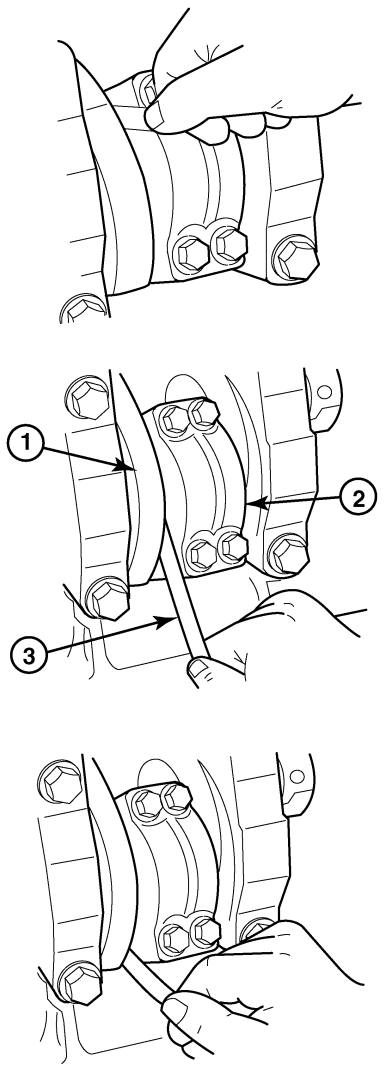


Figure 262 — Connecting Rod Side Clearance Check

1. Crankshaft Journal 2. Connecting Rod Bearing Cap	3. Thickness Gauge

11. The clearance must be within the specification listed under *Fits and Limits* in the **SPECIFICATIONS** section. If not, recheck for proper cap and rod alignment.

Block Stiffener Plate Installation

[211 DD]

N O T E

Align the plate so that the sequence of four mounting holes and one large hole falls at the front of the cylinder block. The arch of the plate provides clearance for the main bearing caps.

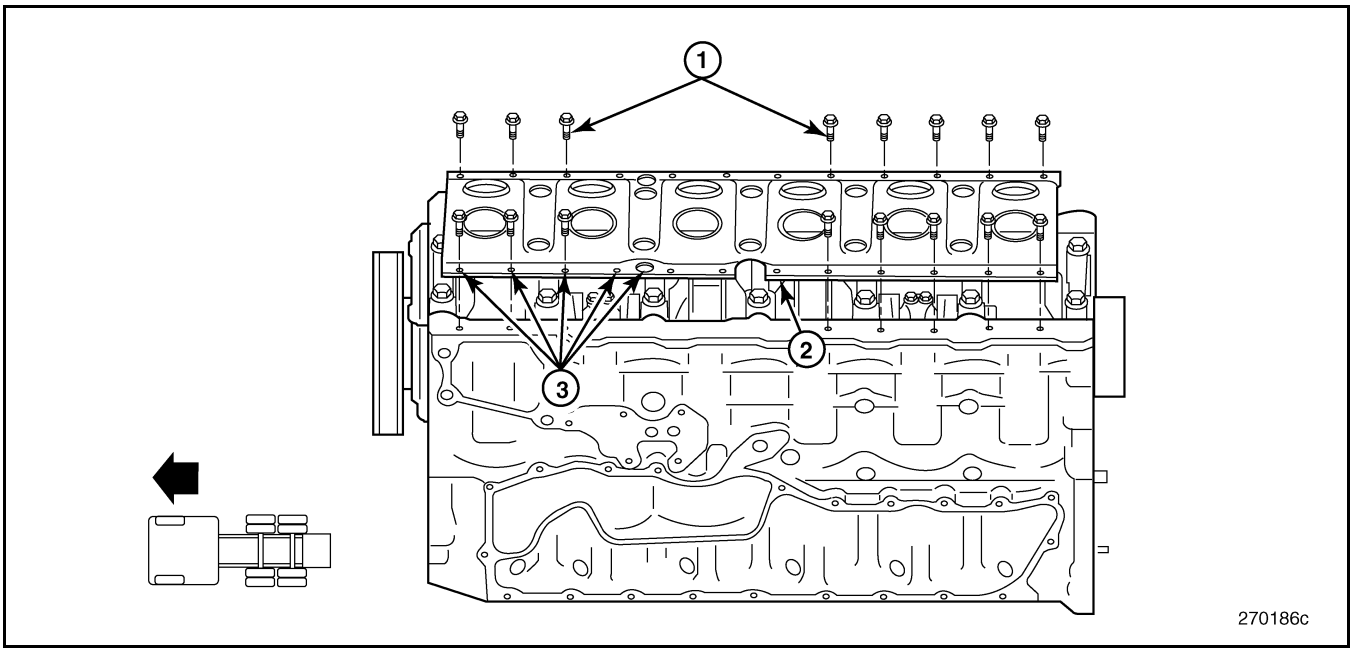


Figure 263 — Block Stiffener Plate

1. Plate Attaching Screws 2. Block Stiffener Plate	3. Plate Orientation Holes

1. Assemble the stiffener plate on the cylinder block.
2. Using a torque wrench, tighten the attaching screws in sequence according to specification.

Oil Pump and Valve Housing Installation

[219 MU, 219 NT]

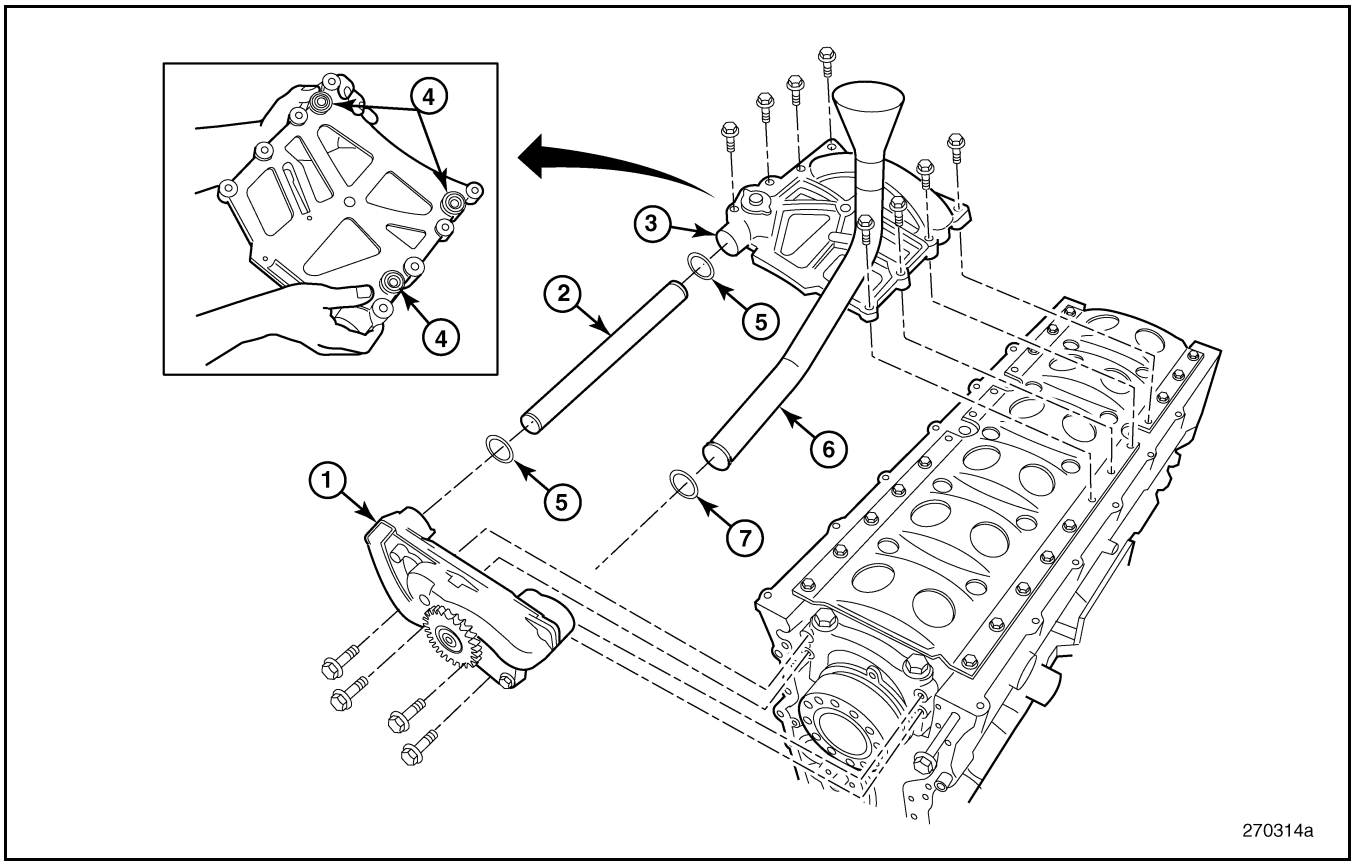


Figure 264 — Oil Pump and Valve Housing Assembly (Axle Back Shown)

1. Oil Pump and Pump Housing 2. Pump Outlet Pipe (Pressure Side) 3. Valve Housing 4. Sealing Rings	5. Small Diameter O-Ring 6. Strainer/Pickup Pipe (Suction Side) 7. Large Diameter O-Ring

OIL PUMP

1. Assemble the pump on the No. 7 main bearing cap.
2. Using a torque wrench, tighten the attaching screws in a cross pattern according to specification.
3. Lubricate and assemble an O-ring on the end of the strainer/pickup pipe (large OD) and insert the pipe in the oil pump housing.
4. Lubricate and assemble an O-ring on each end of the pressure side pipe (small OD) and insert one end in the oil pump housing.
5. Using a torque wrench, tighten the screws according to specification.

OIL PUMP VALVE HOUSING

SERVICE HINT

It may ease assembly if the pressure pipe is started in the valve housing before attempting to seat it.

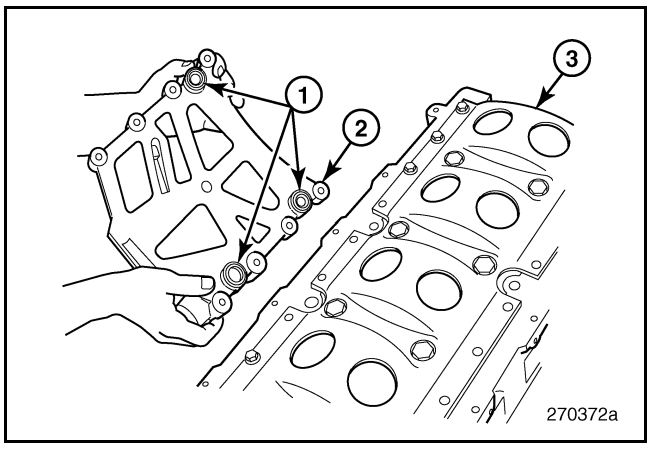


Figure 265 — Oil Pump Valve Housing and Block Stiffener Plate

1. Sealing Rings 2. Valve Housing	3. Stiffener Plate

1. Insert the three lubricated seal rings in the counterbores in the valve housing.
2. Insert the free end of the pressure side pipe with lubricated O-ring in its port in the valve housing until seated.
3. Assemble the valve housing on the cylinder block.
4. Using a torque wrench, tighten the attaching screws in sequence according to specification.
5. Assemble the strainer/pickup pipe on the oil pump.
6. Using a torque wrench, tighten the attaching screws according to specification.

Front Engine Support Installation [299 GV]

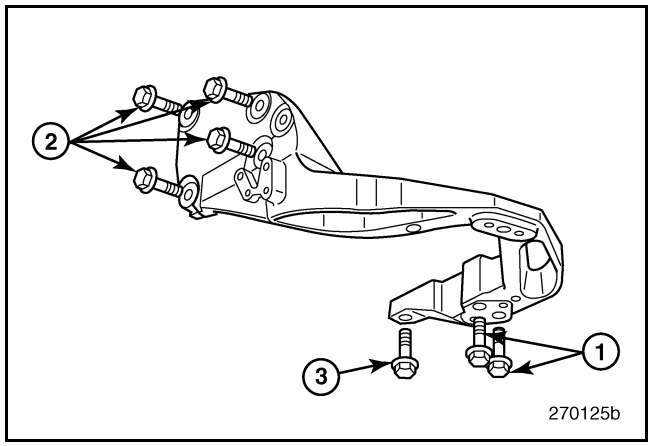


Figure 266 — Front Engine Support

1. Left-Side Attaching Screws 2. Right-Side Attaching Screws	3. Left-Side Attaching Screw

NOTE

The front engine support and belt tension idler bracket must be attached before attempting to assemble the coolant pump assembly.

1. Assemble the front engine support on the cylinder block.
2. Using a torque wrench, tighten the two adjacent M16 screws on the left side according to specification.
3. Using a torque wrench, tighten the three M16 screws (not including the tension idler bracket screw) on the right side according to specification.
4. Using a torque wrench, tighten the three M16 screws on the left side according to specification.
5. Assemble the tension idler bracket on the front engine support.
6. Using a torque wrench, tighten the M16 screw according to specification.
7. Assemble the idler pulley and the tension idler on the bracket.
8. Using a torque wrench, tighten the two M10 screws according to specification.

Crankshaft Front Cover Installation [211 JB]

NOTE

Make sure that the crankshaft front cover and cylinder block flanges are cleaned thoroughly before applying sealant.

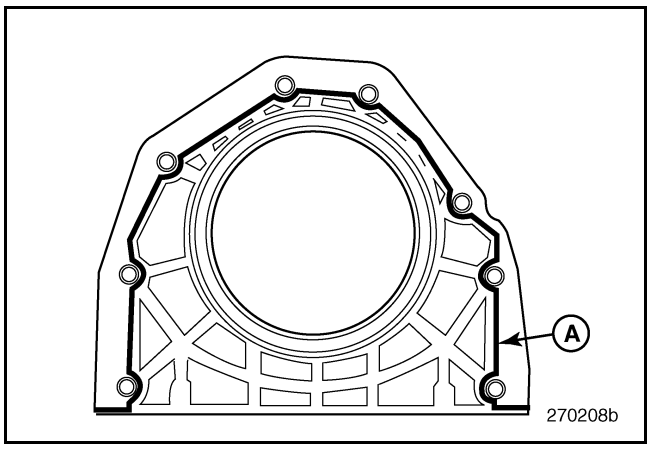


Figure 267 — Sealant Application Pattern — Crankshaft Front Seal Cover to Block

A. Sealant Application Area

1. Apply a 2 mm (5/64-inch) bead of MACK approved sealant to the rear face of the cover following the pattern shown.
2. Within 20 minutes of sealant application, install the front cover to the cylinder block.

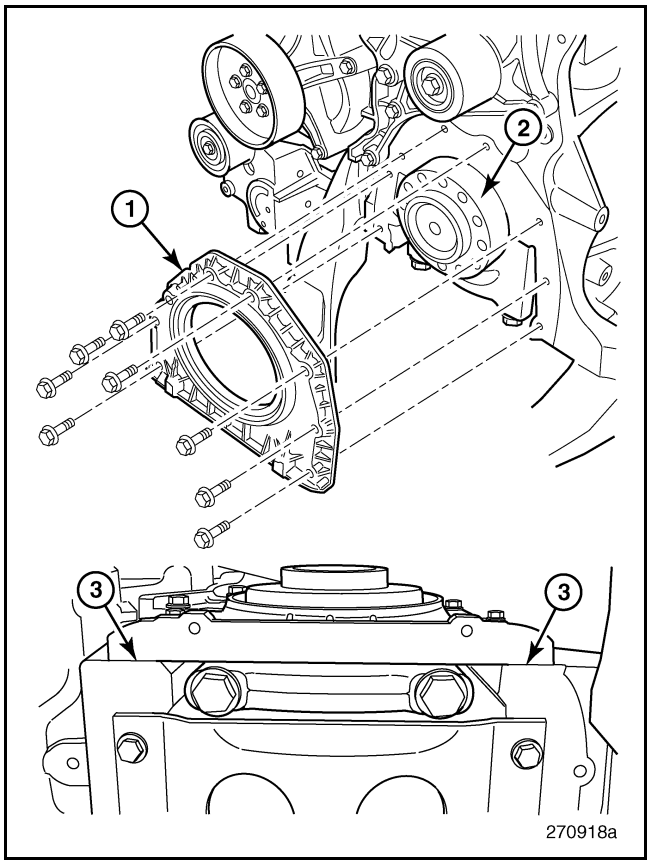


Figure 268 — Crankshaft Hub and Front Cover

1. Front Cover 2. Crankshaft Hub	3. Crankshaft Front Cover and Block Flanges are Flush

NOTE

Make sure that the crankshaft front cover and cylinder block flanges are flush in order to prevent leaking.

3. Using a torque wrench, tighten the screws in sequence according to specification.

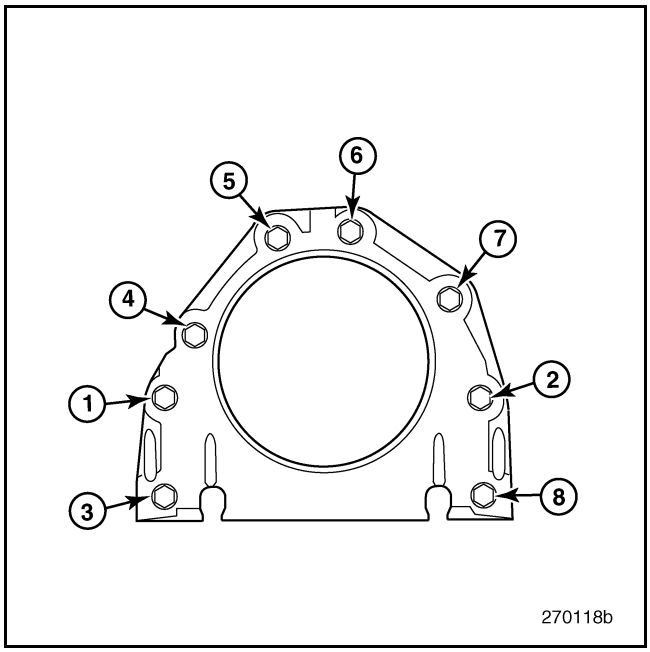


Figure 269 — Front Cover Torque Sequence

Crankshaft Front Seal Installation [211 JB]

PROCEDURE

N O T E

Installation depth of the crankshaft front seal, relative to the crankshaft front stem, is controlled by the installation tool adapter. Be sure to use the correct adapter.

1. Assemble the handle, 9992000, in the front main seal installer tool, 88800021. Remove the protective sleeve from the **new** lip-type seal and place the seal on the installer tool with the flat side of the seal toward the tool.
2. Position the tool over the hub and into the seal opening.
3. Carefully drive the seal into the opening until the tool bottoms.

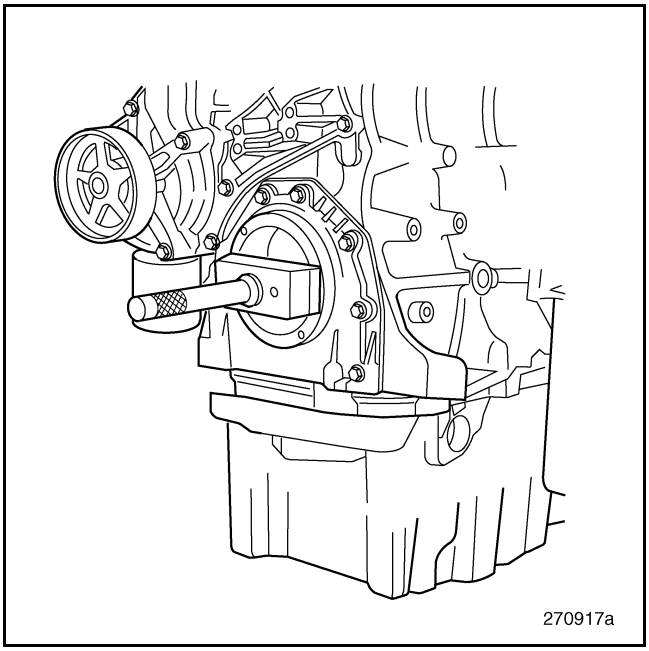


Figure 270 — Crankshaft Front Seal Installation

4. Remove the tool and check the seal to be sure it has been evenly installed.

Timing Gear Mounting Plate Installation

[211 AA]

NOTE

Rotate the cylinder block so the rear surface is at the top.

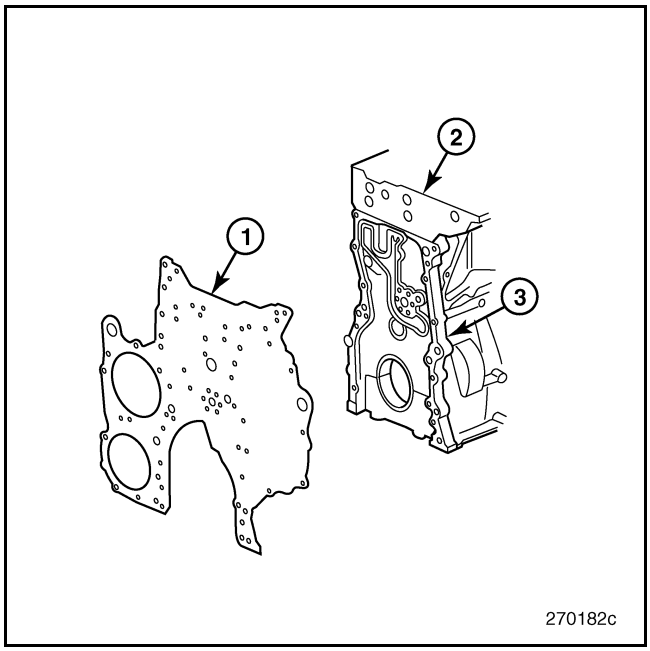


Figure 271 — Timing Gear Mounting Plate and Timing Gears

1. Timing Gear Mounting Plate	2. Cylinder Head 3. Cylinder Block

NOTE

The cylinder head is installed after the timing gear plate is in place. Do not apply sealant to the rear of the cylinder head until ready to assemble the head on the cylinder block.

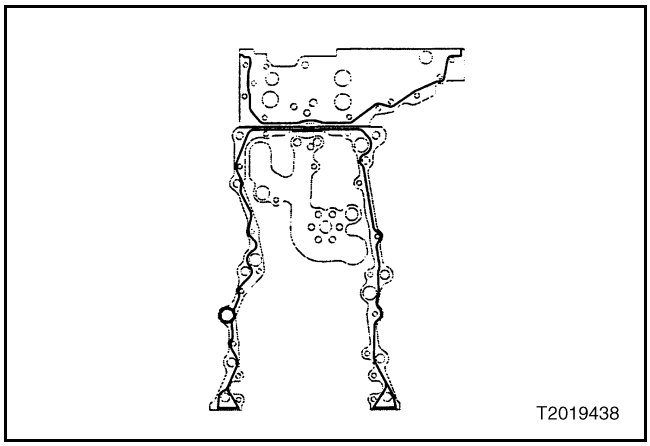


Figure 272 — Sealant Application Patterns — Head and Block to Plate

1. Apply a 2 mm (5/64-inch) bead of MACK approved sealant to the rear face of the cylinder block according to the pattern shown.
2. Within 20 minutes of sealant application, assemble the timing gear mounting plate over the guide pins in the cylinder block.
3. Install **new** timing gear mounting plate attaching screws.
4. Using a torque wrench, tighten the attaching screws in sequence according to specification.

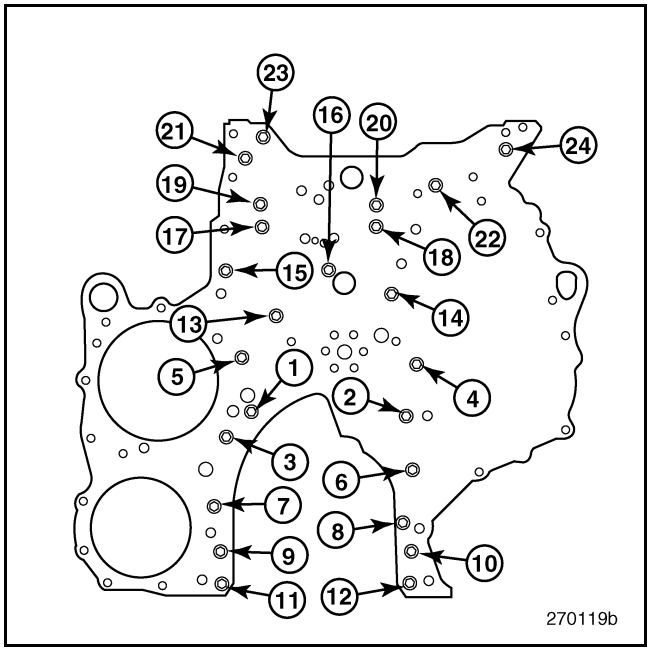


Figure 273 — Timing Gear Plate Torque Sequence

5. Lubricate and assemble an O-ring on the guide pin located between the openings for the air compressor gear and the tandem pump gear.

⚠ CAUTION

Make sure the guide pin O-ring is in place before proceeding. Failure to heed this caution may result in costly repair.

Cylinder Head Installation

[213 EV]

PROCEDURE

⚠ 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.

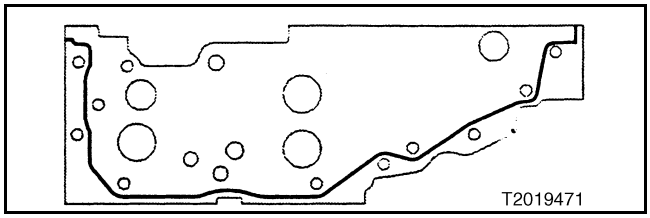


Figure 274 — Sealant Application Pattern — Head to Plate

1. Check the condition of the cylinder head attaching screws and lubricate the screw heads (underside) and threads with clean engine oil.
2. Oil all cylinder head screw bosses.

NOTE

Do NOT oil the threads in the cylinder block.

3. If in place, remove the cylinder liner retainers from the cylinder block.
4. Place a **new** cylinder head gasket on the guide pins in the cylinder block.

NOTE

There are points embossed in the gasket that temporarily protect the seals from the cylinder head. These embossed points are compressed when the cylinder head bolts are tightened.

The cylinder head gasket should be discarded if the head is removed. A **new** gasket should be used when the cylinder head is installed.

5. Apply a 2 mm (5/64-inch) bead of MACK approved sealant to the rear face of the cylinder head according to the pattern shown.

NOTE

Attach the cylinder head to the cylinder block and plate within 20 minutes of sealant application.

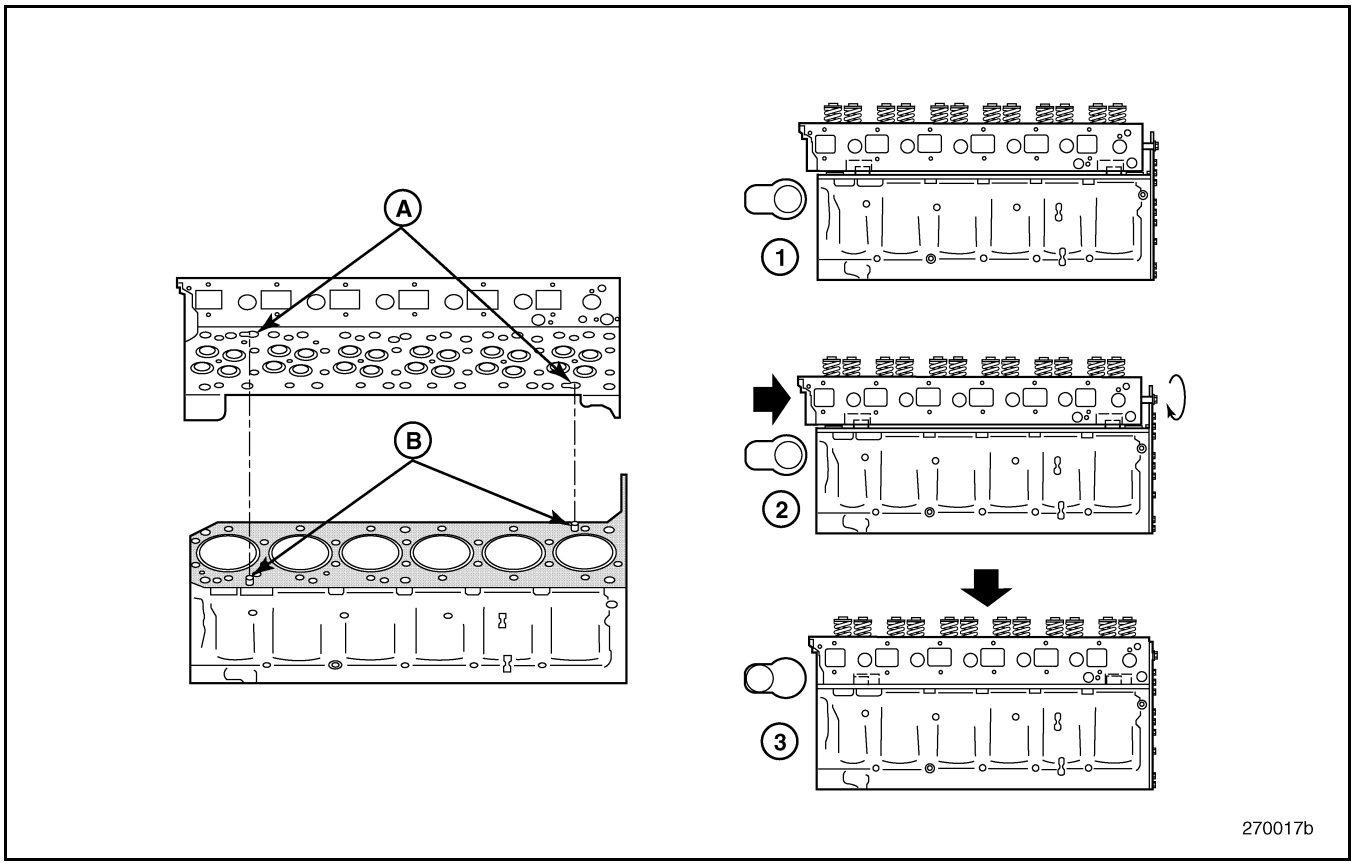


Figure 275 — Cylinder Head Installation

A. Cylinder Head Locating Holes B. Guide Pins	1. Locate gasket and head on block. 2. Draw head against timing plate. 3. Tighten head screws.

6. Using the cylinder head lifting tool, 85109049, lower the cylinder head over the guide pins onto the gasket.

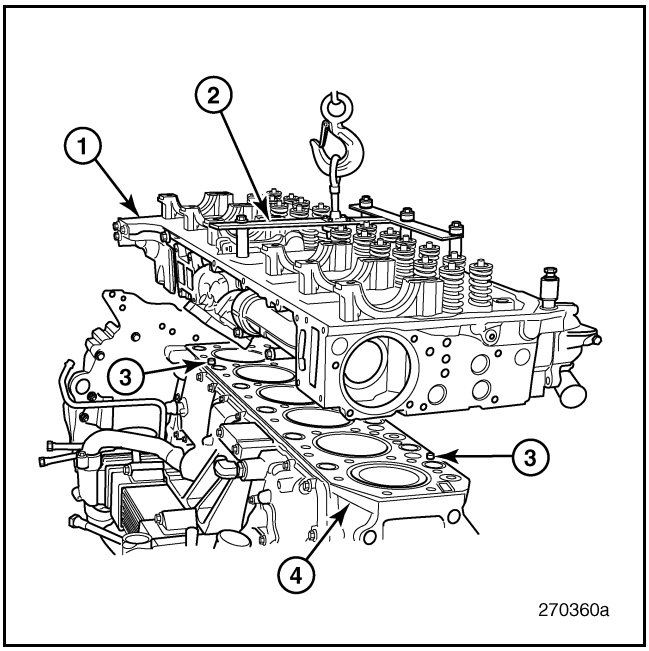


Figure 276 — Cylinder Head Positioning

1. Cylinder Head 2. Lifting Tool, 85109049	3. Alignment Guide Pin 4. Cylinder Block

7. Complete the installation using one of the following methods.

NOTE

The method used depends on whether the engine has been disassembled for overhaul and the adjustable idler gear IS NOT installed, or, only the cylinder head has been removed for service and the adjustable idler gear IS installed.

ADJUSTABLE IDLER GEAR NOT INSTALLED

Use this method when the engine has been disassembled for overhaul and the adjustable timing gear has not been installed.

1. Assemble one of the six M8 x 16 screws through the timing gear mounting plate into the end of the cylinder head.
2. Using a torque wrench, tighten the screw to 10 N•m (7 lb-ft) to pull the cylinder head against the gear mounting plate.
3. Install the cylinder head screws. Using a torque wrench, tighten the screws according to specification.
4. Loosen but do not remove the M8 x 16 screw used to pull the cylinder head to the gear mounting plate.
5. Install the five remaining M8 x 16 screws through the gear mounting plate into the cylinder head.
6. Using a torque wrench, tighten all M8 x 16 screws according to specification.

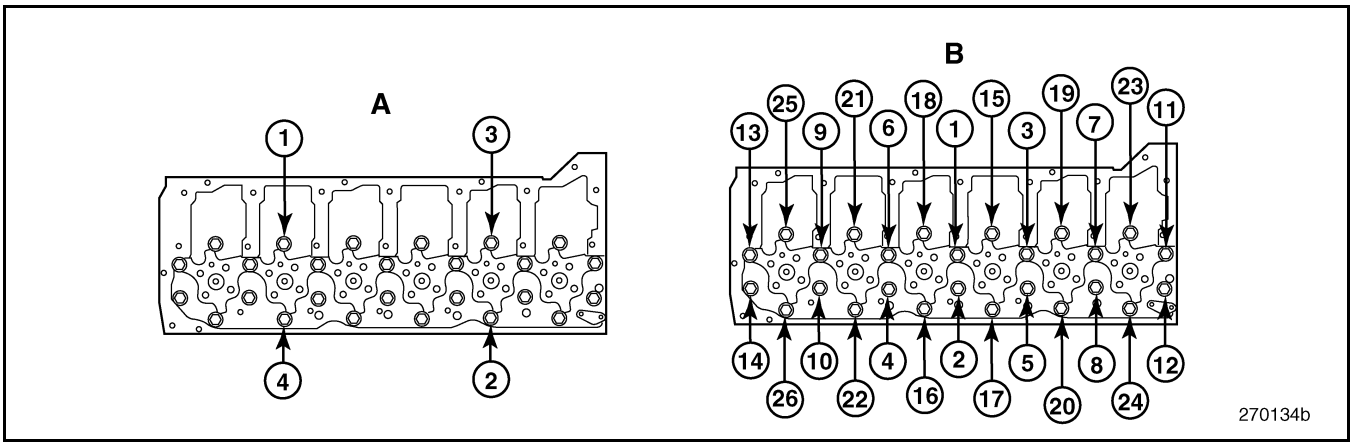


Figure 277 — Torque Sequence — Cylinder Head Screws

ADJUSTABLE IDLER GEAR INSTALLED

Use this method when only the cylinder head has been removed for service and the adjustable idler gear remains installed.

1. Install the three M12 x 48 upper screws through the adjustable timing gear hub and the timing gear mounting plate into the cylinder head.
2. Using a torque wrench, tighten the three screws to approximately 10 N•m (7 lb-ft), to pull the cylinder head against the gear mounting plate.
3. Install the cylinder head screws. Using a torque wrench, tighten the screws according to specification.
4. Loosen the three adjustable idler gear hub screws used to pull the cylinder head to the gear mounting plate, replace the screws and then tighten to specification.
5. Install the two M8 x 16 screws through the holes in the adjustable idler gear and, using a torque wrench, tighten according to specification.
6. Install the four remaining M8 x 16 screws through the gear mounting plate into the cylinder head and, using a torque wrench, tighten according to specification.
7. Make sure that the crankshaft is at the TDC position and assemble the camshaft, camshaft gear and damper according to the instructions under *Timing Gear Train Installation*.

Camshaft Installation

[213 CH]

PROCEDURE

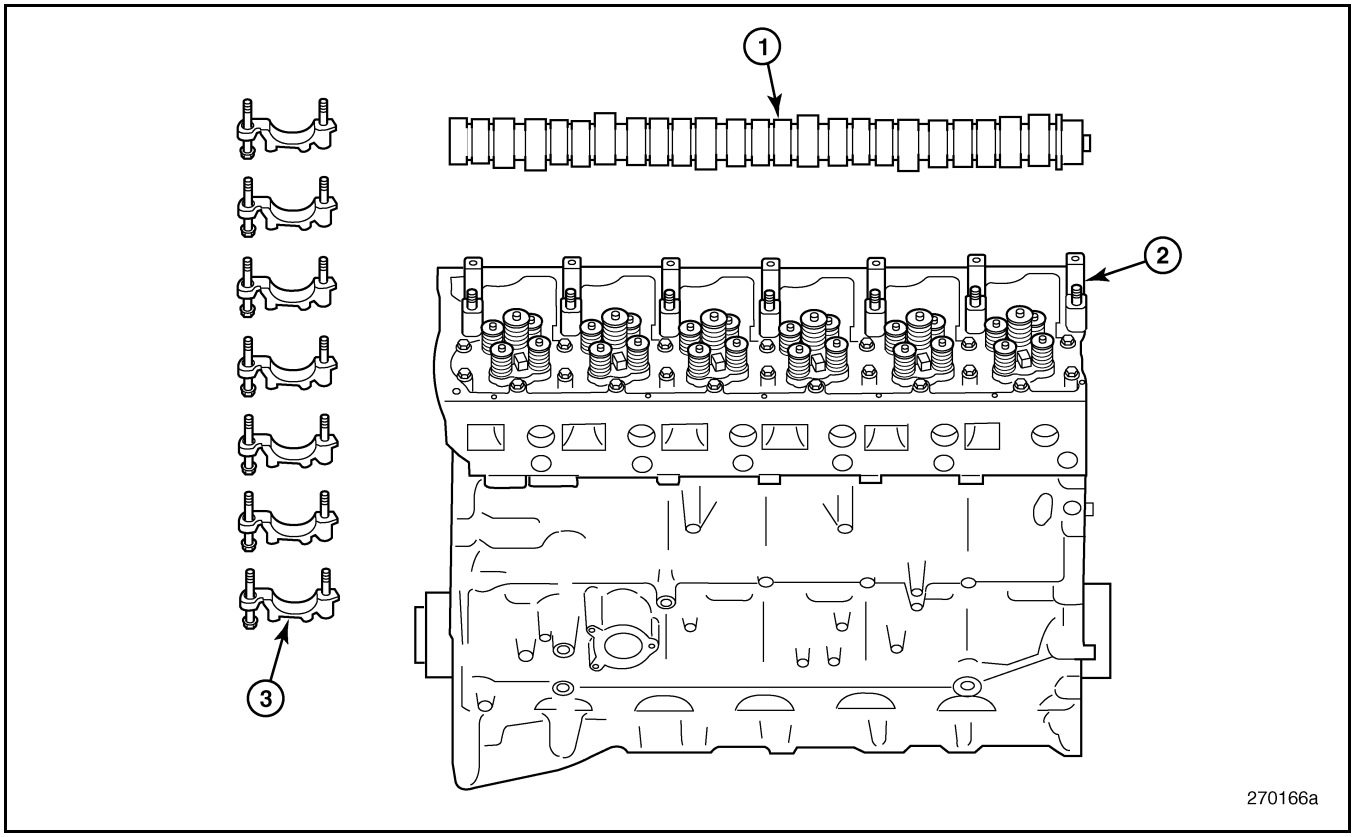


Figure 278 — Camshaft Installation

1. Camshaft 2. Camshaft Lower Bearing Caps	3. Camshaft Upper Bearing Caps

⚠ 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.

Before installing a camshaft, be sure that it is clean, undamaged and well lubricated with clean engine oil. Refer to *Camshaft Bench Procedures* in the **REPAIR INSTRUCTIONS** section.

NOTE

This procedure presumes that the upper camshaft bearing caps are in place on the cylinder head. Keep the bearing caps in sets. Return the upper cap to the lower cap from which it was removed. The lower caps are assembled on guide sleeves in the cylinder head. If the lower caps are removed, they must be returned to their original location.

1. Mark the bearing cap sets and remove the upper bearing caps.
2. Apply a generous coating of clean engine oil to the camshaft bearings.
3. Make sure there is a bearing insert on each lower bearing cap. The bearing inserts at the No. 7 camshaft journal have integral thrust washers.

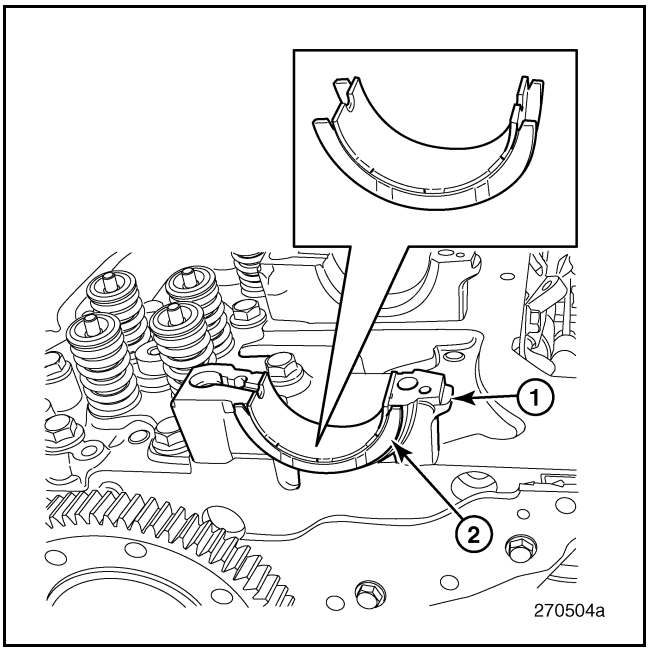


Figure 279 — No. 7 Camshaft Lower Bearing Insert

1. No. 7 Camshaft Lower Bearing Cap	2. Cam Bearing with Integral Thrust Washer

4. Clean the camshaft with a suitable solvent.
5. With an assistant and the camshaft lifting bar, 85109034, position the camshaft on the lower bearing caps and install the upper bearing caps and seven outboard screws.
6. Insert and hand-tighten the outboard screws. Final tightening to the specified torque value will be done later when the rocker arm shaft is installed.

Unit Injector Installation

[221 GP]

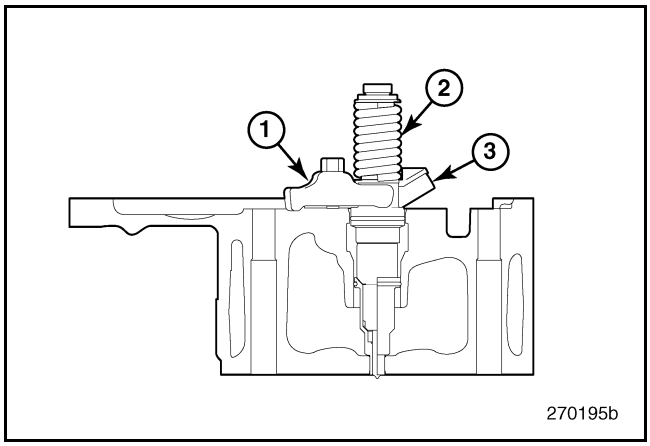


Figure 280 — Unit Injector Installation

1. Injector Hold Down Yoke and Screw	2. Unit Injector 3. Harness Connector

NOTE

Injectors must always be fitted with **new** O-rings, **new** sealing washers and **new** injector yoke screws.

NOTE

If a unit injector is reused, it must be installed into the bore from which it was removed.

1. If new injectors are being installed, unpack them one at a time. Make note of the trim number of each injector and the cylinder number that each injector is being installed.

NOTE

The trim numbers **must** be programmed into the EECU using the VCADS or PTT diagnostic tool.

2. Remove the unit injector bore sealing plug, 9998251.

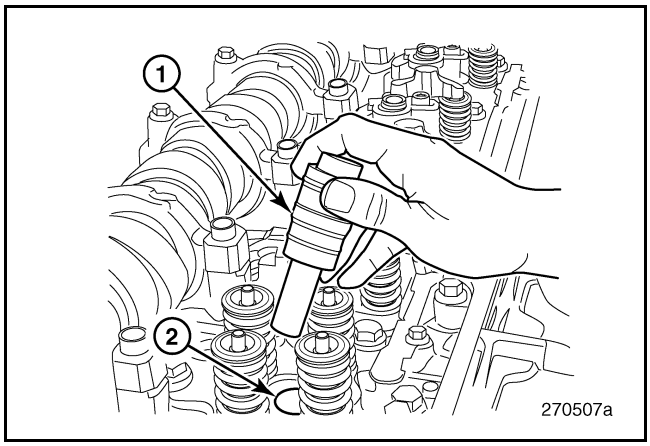


Figure 281 — Unit Injector Bore Sealing Plug

1. Unit Injector Bore Sealing Plug, 9998251	2. Unit Injector Bore

3. If not previously performed, install protective sleeve, J 42885-25, and clean the unit injector copper sleeve with the appropriate brush and extension.

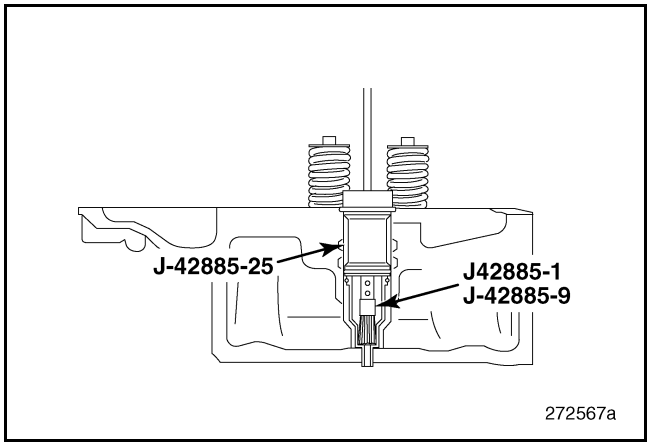


Figure 282 — Unit Injector Copper Sleeve Cleaning

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.

4. 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 268 for further information.
5. Remove the bore sealing plug, 9998251.

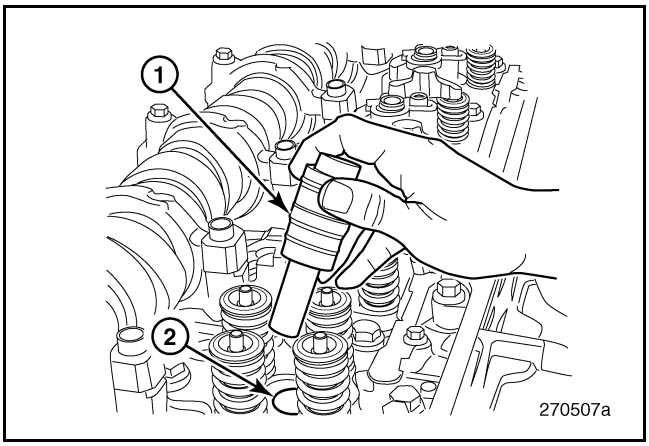


Figure 283 — Unit Injector Bore Sealing Plug

1. Unit Injector Sealing Plug, 9998251	2. Unit Injector Bore

6. Install **new** O-rings on the unit injector as follows:
   - Upper ring — large diameter, violet
   - Lower ring — small diameter, violet
7. Lubricate both O-rings and the cylinder head injector bore with clean engine oil.
8. 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 MP7 US07 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.

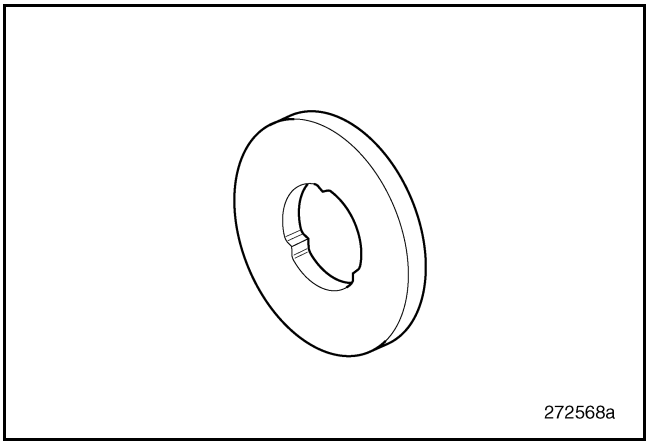


Figure 284 — Injector Nozzle Gasket

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.

9. Slip the injector hold-down yoke and a **new** screw of correct length onto the unit injector.

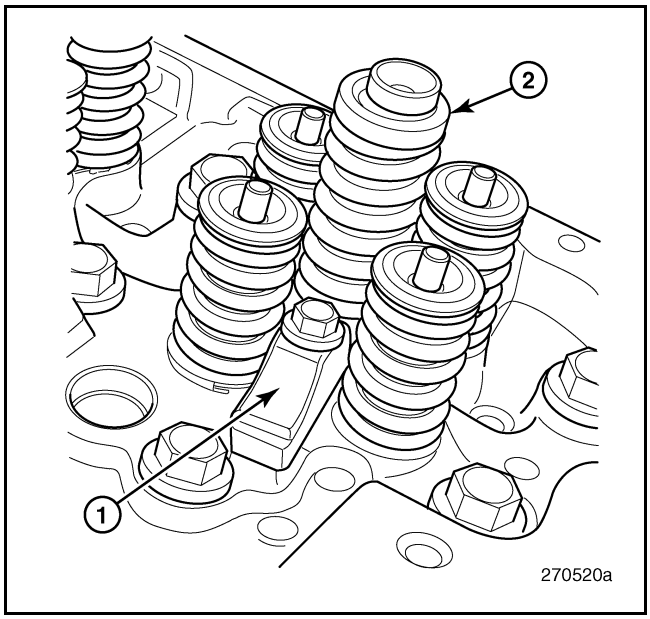


Figure 285 — Unit Injector Retainer

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.

10. 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).
11. 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 unit injector hold-down bolt must be replaced whenever it is removed from the hold-down and cylinder head.
- Before installing, the yoke screw must be cleaned and a light coat of oil applied to the threads and to the underside of the screw head.

12. Plug in the injector electrical connector, making sure it is central between the valve springs with equal space on both sides.

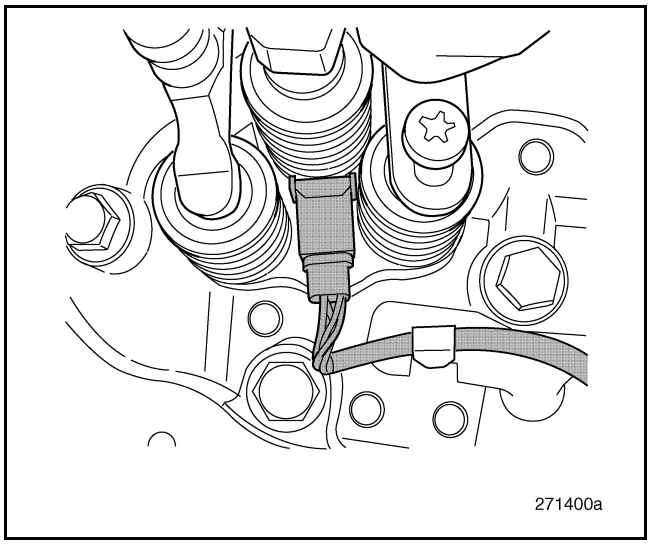


Figure 286 — Electrical Connector for Unit Injector

13. Using a torque wrench, tighten the hold-down screw in stages according to specification.

NOTE

The yoke screw tightening specification varies dependent on if the assembly utilizes an injector sealing gasket/washer or no washer.

14. 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 and is necessary to ensure that engine timing and emission levels are correct.

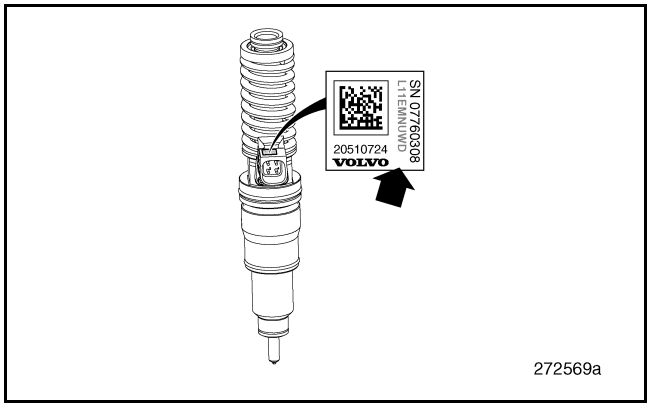


Figure 287 — Injector Trim Codes

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.
- If reinstalling an injector into the same location, reprogramming is not required.

15. Repeat the installation steps for the remaining injectors.
16. Use the hand priming pump to pressurize the fuel delivery system to confirm the correct injector installation before completing assembly.

Valve Yoke (Bridge) Installation

[213 NV]

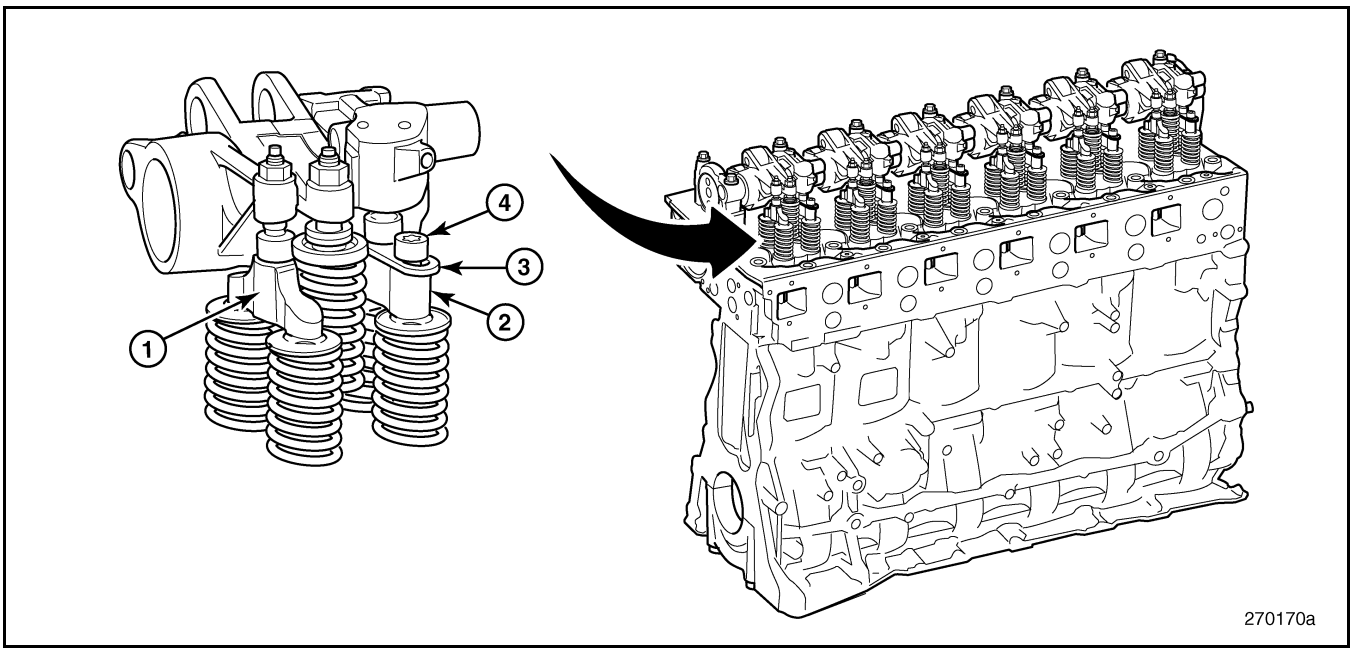


Figure 288 — Inlet and Exhaust Valve Yokes (with Engine Brake)

1. Inlet and Exhaust Valve Yoke without Engine Brake	3. Exhaust Yoke Shim with Engine Brake
2. Exhaust Yoke with Engine Brake	4. Shim Retainer Screw with Engine Brake

NOTE

Used yokes have established wear patterns. Yokes being returned to service must be installed in the same 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.

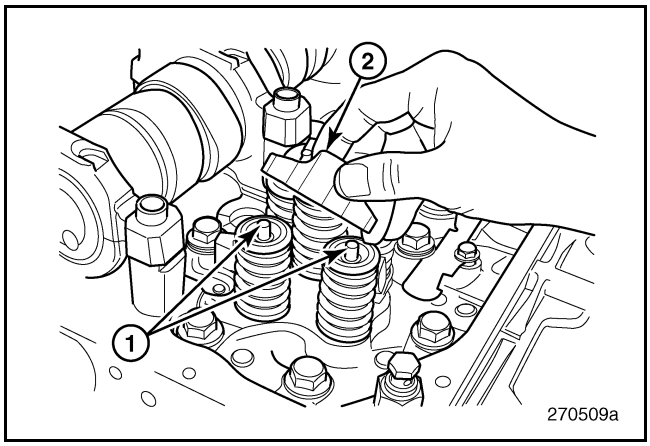


Figure 289 — Installing the Inlet Valve Yoke

1. Inlet Valves	2. Valve Yoke

3. Set the yokes on their respective valve stems.

Rocker Arm Shaft and Engine Brake Installation

[213 LP]

On engines with an engine brake, the exhaust rocker arm includes an integral valve and piston.

⚠ CAUTION

For assemblies with the engine brake, use rubber bands or tie straps to retain the pistons in the exhaust rocker arms during installation. Failure to heed this caution may result in severe engine damage.

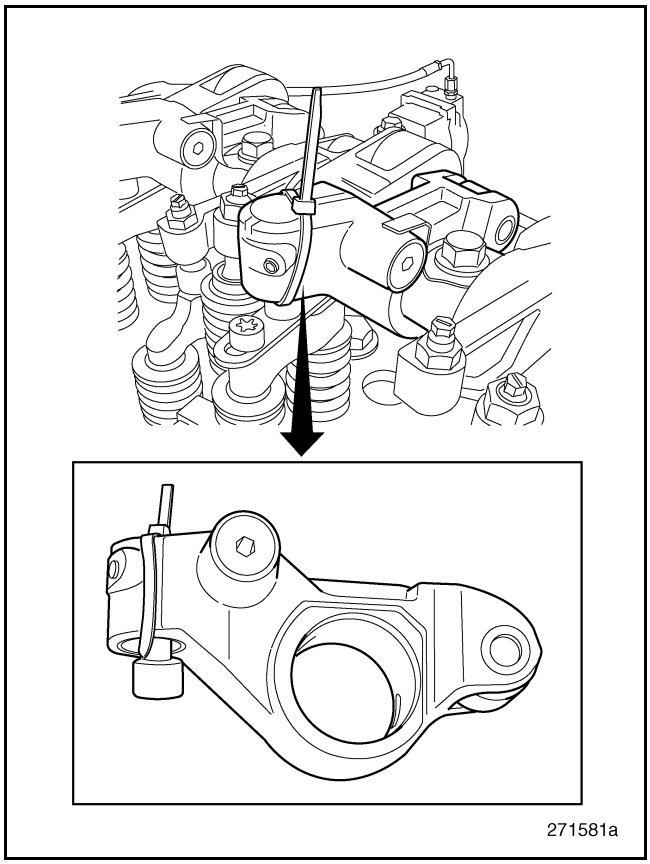


Figure 290 — Tie Strap Holding Engine Brake Piston

Rocker arms for exhaust valves without an engine brake are similar to those for the inlet valve.

NOTE

This procedure presumes that the rocker arms have been correctly assembled on the rocker arm shaft. Make sure the assembly remains in order while lifting.

NOTE

Alignment guide pins extend from the tops of the camshaft upper bearing caps. Make sure these are in place before attaching the rocker shaft.

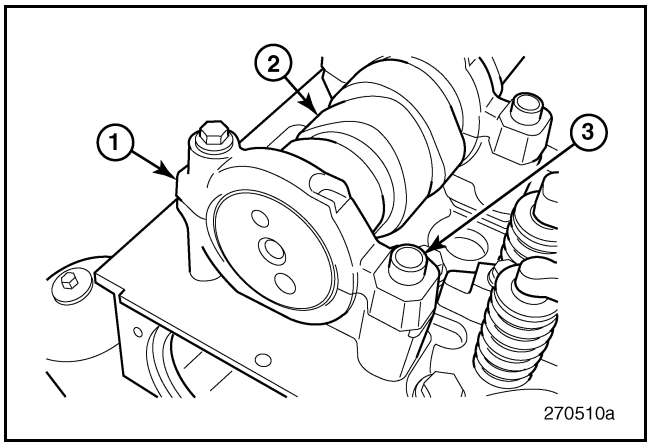


Figure 291 — Rocker Shaft Alignment Guide Pins

1. Camshaft Upper Bearing Cap	2. Camshaft 3. Alignment Guide Pin

WITH ENGINE BRAKE

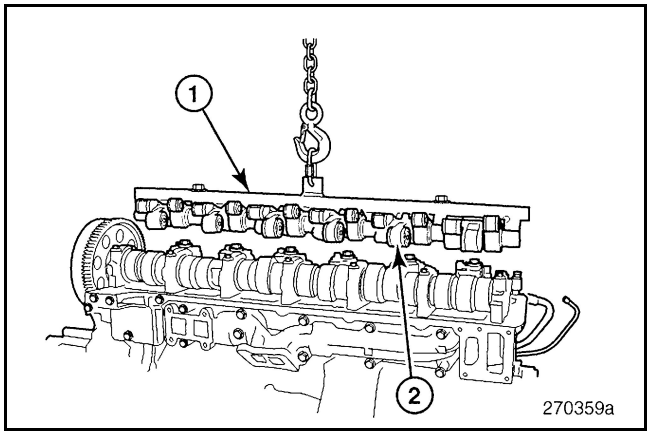


Figure 292 — Rocker Shaft Assembly Installation

1. Lifting Tool 85109050	2. Rocker Shaft Assembly

1. Using the lifting tool, 85109050, and an assistant, place the shaft with rocker arms and springs in position on the inboard side of the camshaft bearing caps.
2. Insert the long screws (Nos. 8–14 in Figure 293) through the shaft, camshaft bearing caps and into the cylinder head.

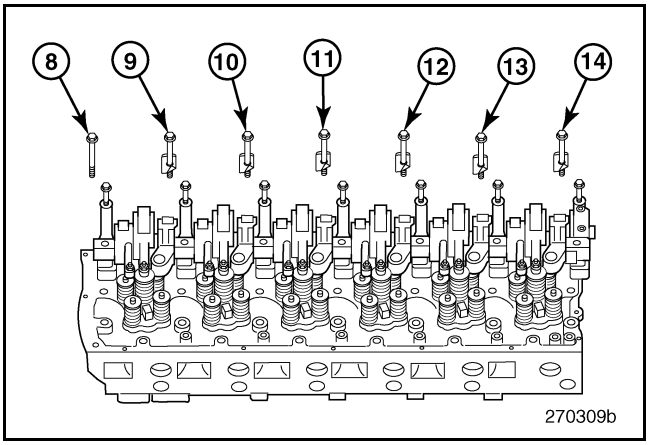


Figure 293 — Rocker Arm Shaft Screw Installation

3. Using a torque wrench, tighten the screws to specification following the seven step process (see Engine Component Torque Specifications [Critical Fasteners]).

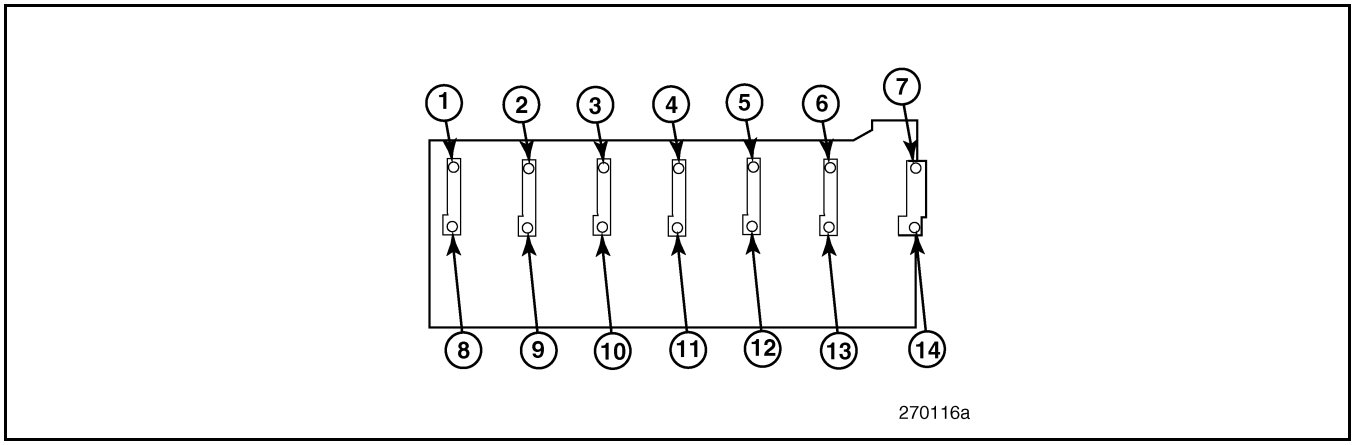


Figure 294 — Camshaft Cap Torque Sequence Screw Numbers

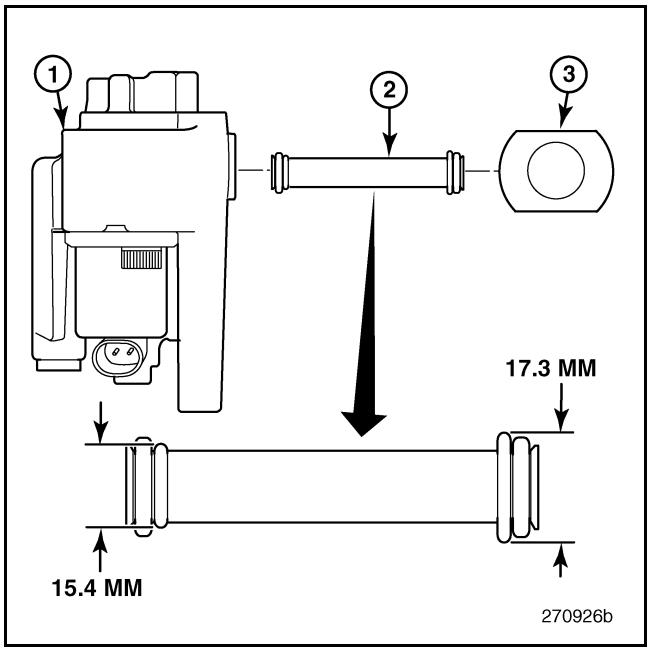


Figure 295 — Engine Brake Oil Control Valve Pipe Installation

1. Engine Brake Control Valve 2. Oil Pipe	3. Rocker Arm Shaft

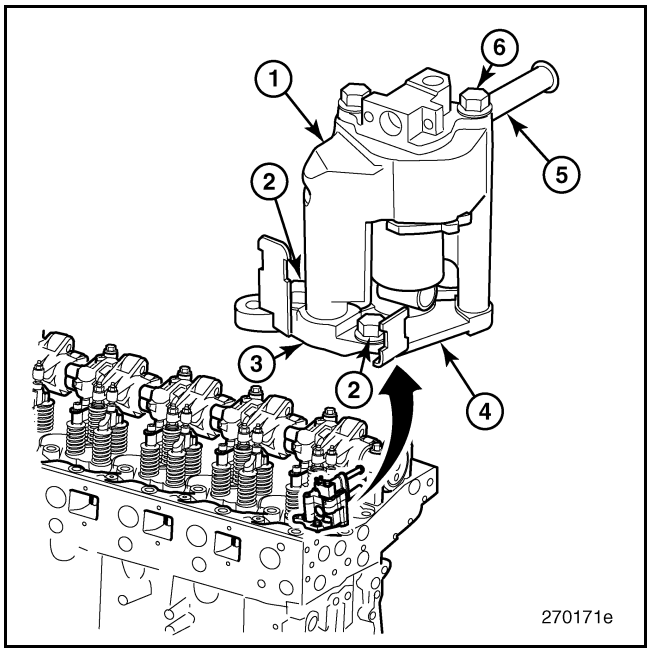


Figure 296 — Engine Brake Oil Control Valve Installation

1. Engine Brake Control Valve 2. Mounting Plate Attaching Screw 3. Oil Seal (between Valve and Mounting Plate)	4. Mounting Plate 5. Oil Pipe 6. Valve Attaching Screw

4. Assemble the valve mounting plate on the cylinder head.
5. Using a torque wrench, tighten the attaching screws according to specification.
6. Lubricate and assemble the seals on each end of the oil pipe.
7. Insert the small end of the oil pipe in the control valve.

NOTE

The oil pipe has a flange and a bead at each end. While the flanges are the same size, the beads differ. One bead is 15.4 mm and the other bead is 17.3 mm. Insert the small diameter (15.4 mm) bead end of the oil pipe into the oil hole of the control valve. Position the large diameter (17.3 mm) bead end of the pipe towards the rocker arm shaft.

⚠ CAUTION

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

8. Ensure the oil seal is in place at the bottom of the valve assembly.
9. Position the valve assembly on the mounting plate and insert the large end of the oil pipe in the rocker arm shaft. Press on the control valve with the heal of your hand to seat the large end of the pipe in the rocker arm shaft.
10. Insert the attaching screws and tighten them according to specification.

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 engine oil to the O-ring and assemble the crankshaft gear on the crankshaft hub. Install two Allen-head bolts through the crankshaft gear and tighten to specification.

NOTE

Leave two fasteners loose enough to aid in turning the crankshaft with a lever for gear alignment purposes.

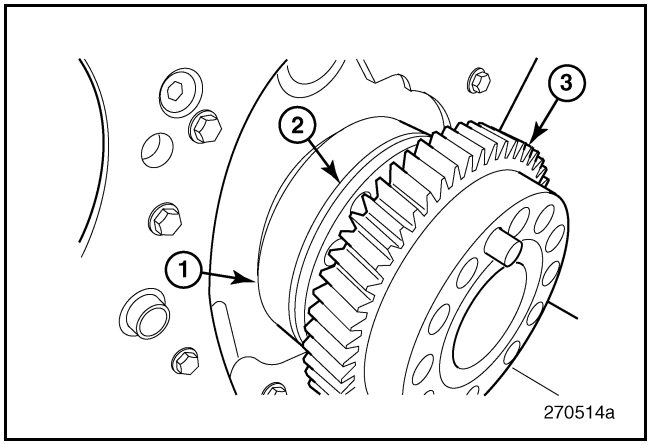


Figure 297 — Crankshaft Gear-to-Hub Assembly

1. Crankshaft Rear Hub 2. O-Ring	3. Crankshaft Gear

3. Assemble the adjustable idler gear (item 3 in Figure 298), hub, bushing, thrust washer and fasteners on the timing gear plate. Hand tighten the fasteners.

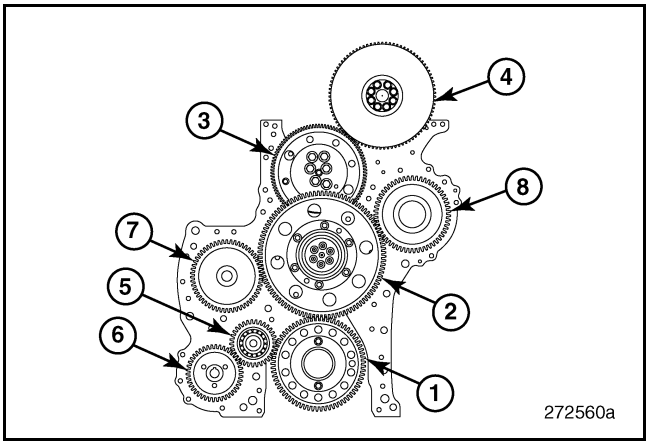


Figure 298 — Adjustable Idler Gear

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 by having the TDC marking on the camshaft aligned with the markings on the No. 7 camshaft bearing cap.

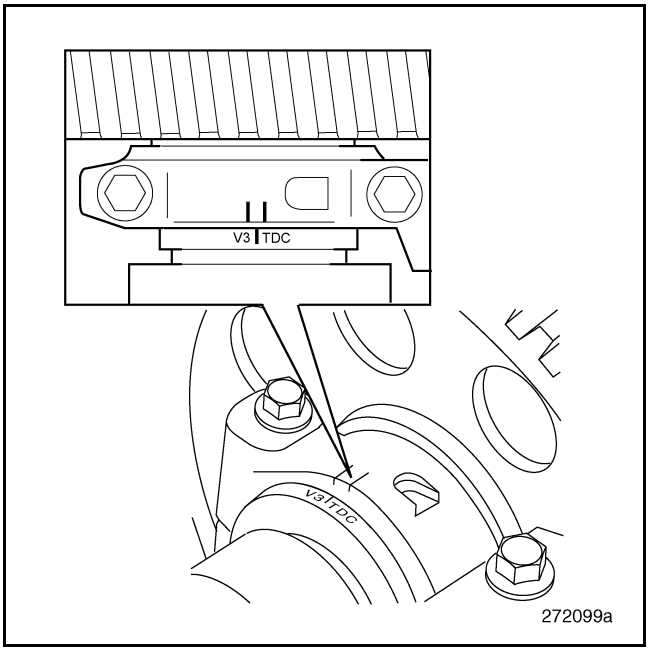


Figure 299 — Camshaft Positioning

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 300. 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.

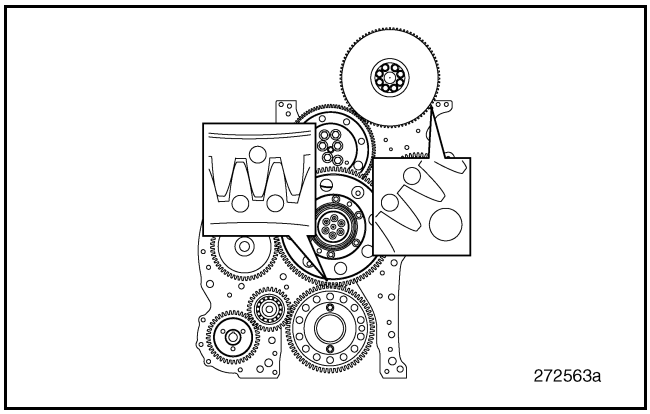


Figure 300 — Camshaft Gear Check

6. 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 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. 7 camshaft bearing cap.

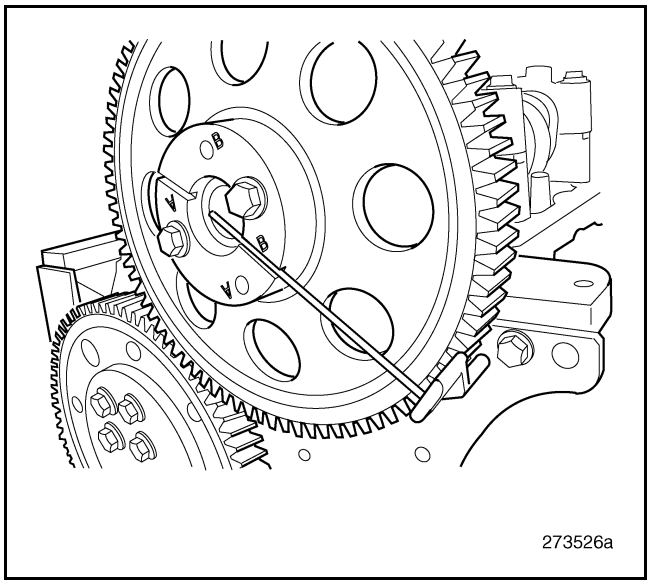


Figure 301 — Camshaft Gear Timing Mark Alignment

7. Remove the camshaft gear alignment tool, J 47450-1, from the camshaft gear.

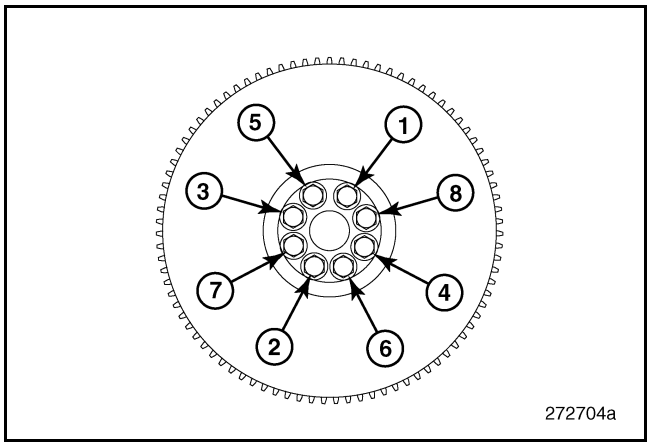


Figure 302 — Camshaft Vibration Damper Tightening Sequence

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 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.

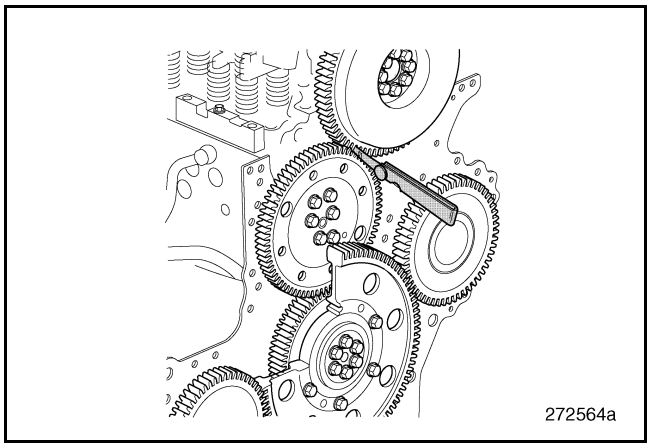


Figure 303 — Camshaft Thickness Gauge Check

9. Remove the feeler gauge from the gear teeth.
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.

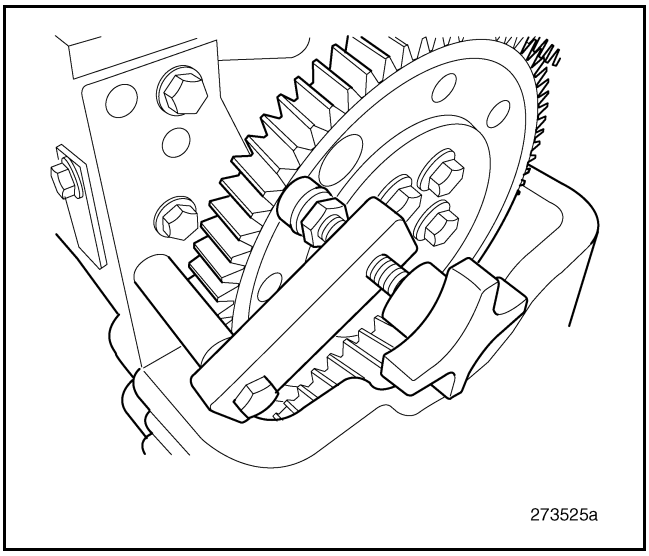


Figure 304 — Clamp Assembly Tool

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.

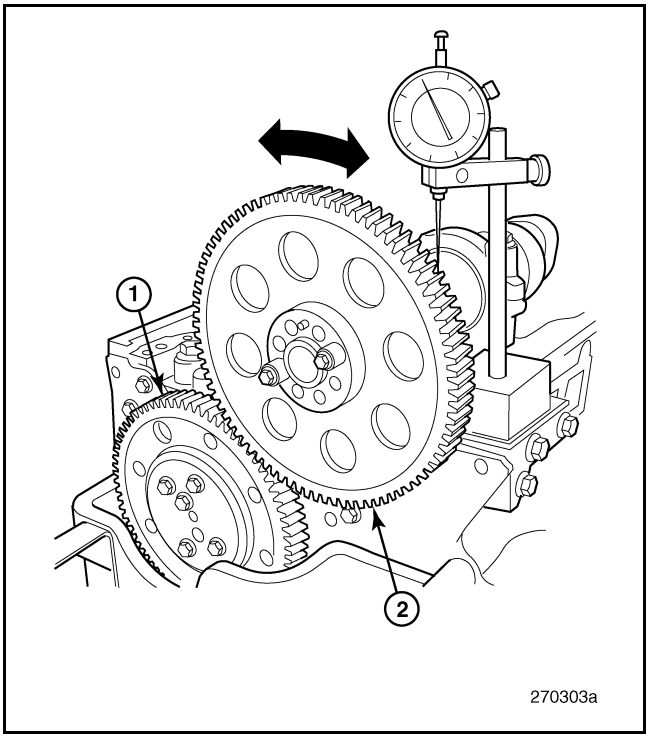


Figure 305 — Camshaft Backlash Check

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 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 idle 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** fasteners.

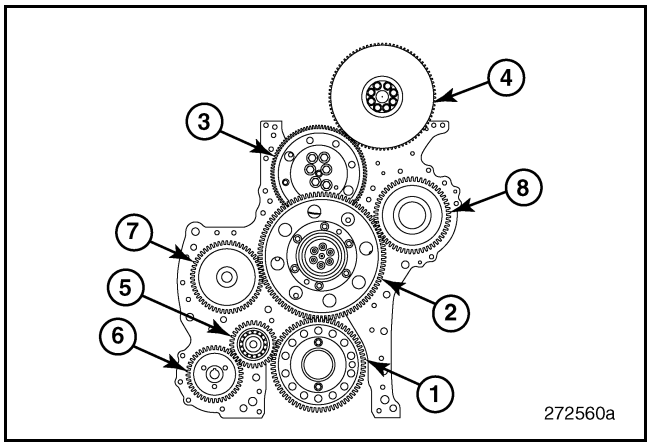


Figure 306 — Intermediate Idler (Double Idler) Gearset

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 intermediate idler gear timing marks align with the timing marks on the crankshaft gear teeth as shown in Figure 307. Check that the camshaft is positioned at TDC by having the TDC marking on the camshaft aligned with the markings on the No. 7 camshaft bearing cap.

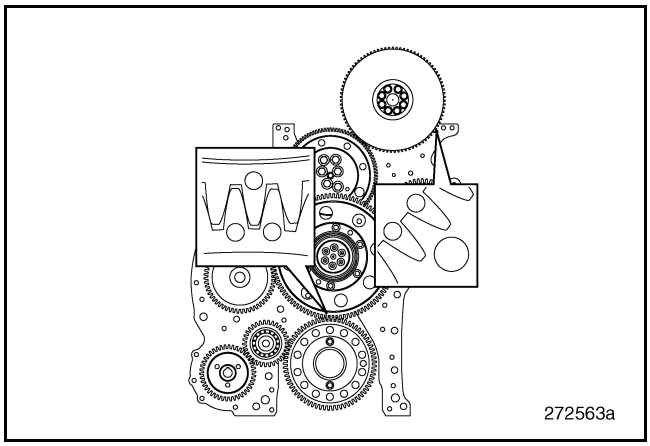


Figure 307 — Camshaft and Double Idler Gear Check

15. Tighten the intermediate gearset (double idler) mounting bolts in sequence to specification.
16. Install the lower idler gear onto the timing gear plate and torque to specification.
17. Remove the J 44514-5 clamp assembly tool from the timing gear plate.
18. Remove the J 44514-1A gauge plate tool and reinstall the vibration damper and clamp plate using **new** fasteners. Torque to specification.

Flywheel Housing Installation [211 HD]

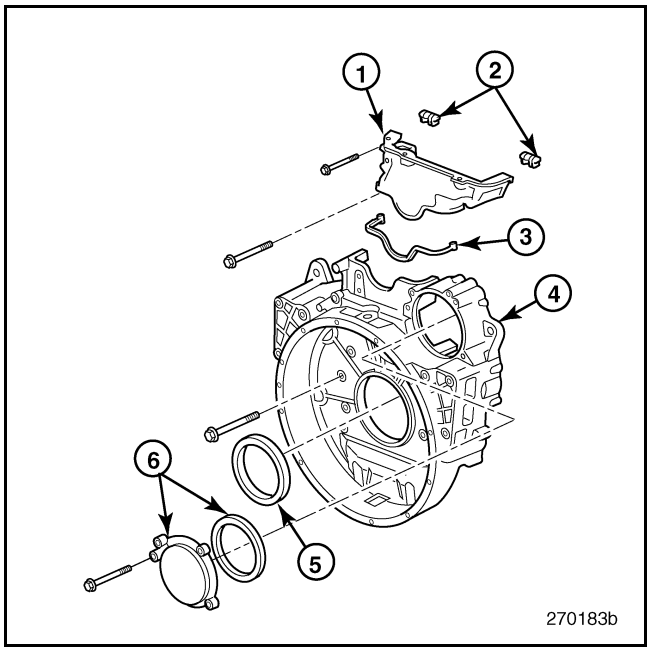


Figure 308 — Flywheel Housing and Timing Gear Cover

1. Timing Gear Cover 2. Cover Seals, Upper 3. Cover Sealing Strip	4. Flywheel Housing 5. Crankshaft Seal 6. REPTO Housing Cover and Seal

NOTE

Rotate the cylinder block so the timing gear mounting plate is at the top.

Inspect the flywheel housing machined surfaces, screw holes and pilot locations for cracks or wear. Replace the housing if cracks are evident.

⚠ CAUTION

Before installing the flywheel housing, examine the crankshaft flange for damage or presence of foreign particles. Failure to heed this caution may result in engine damage.

1. Apply a 2 mm (5/64-inch) bead of MACK approved sealant to the mounting plate side of the flywheel housing according to the pattern shown.

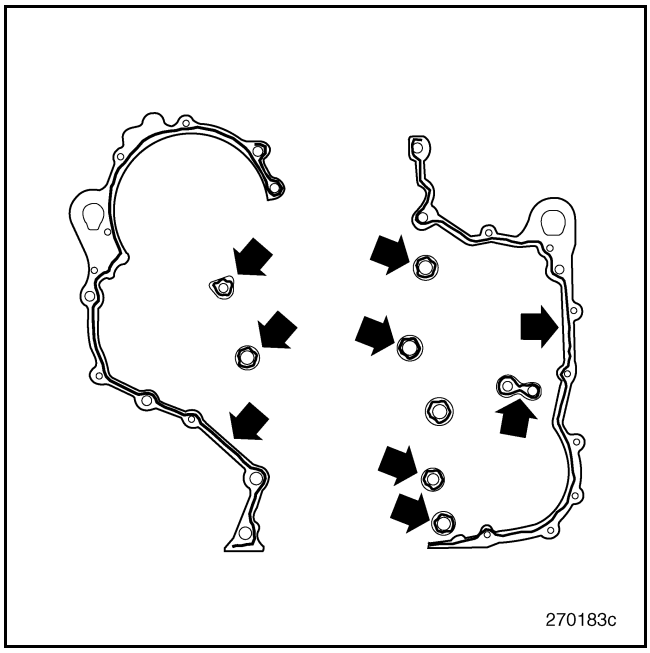


Figure 309 — Flywheel Housing Sealant Application Pattern

N O T E

Be sure to apply beads of sealant around the holes in the bosses as shown.

2. Temporarily install guide pins in the two lower flywheel housing mounting holes in the timing gear mounting plate/cylinder block.
3. Within 20 minutes of the application of the sealant, assemble the flywheel housing over the guide pins in the timing gear mounting plate.
4. Insert and hand-tighten the attaching screws. Remove the two guide pins and install the remaining screws.
5. Using a torque wrench, tighten the attaching screws in sequence in three steps according to specification.

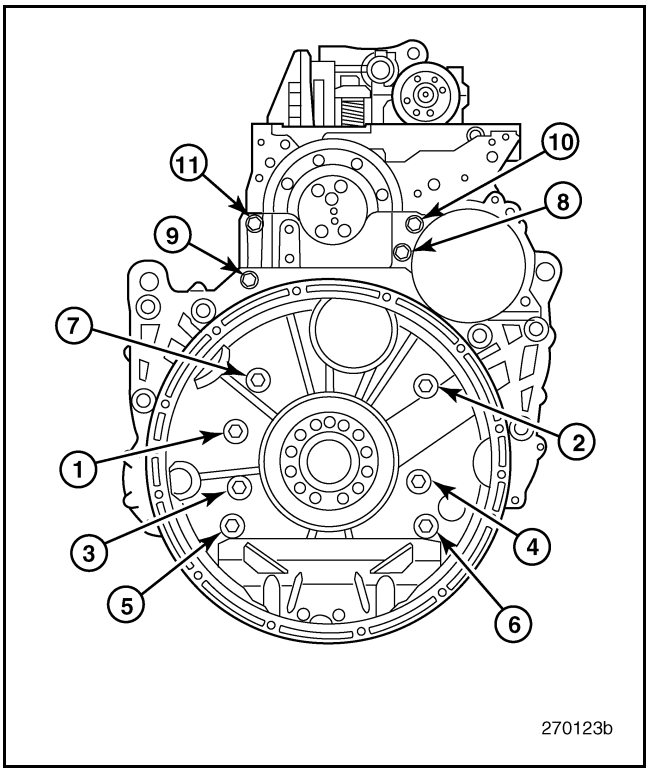


Figure 310 — Torque Sequence, Flywheel Housing Installation

Oil Pan Installation

[211 NB]

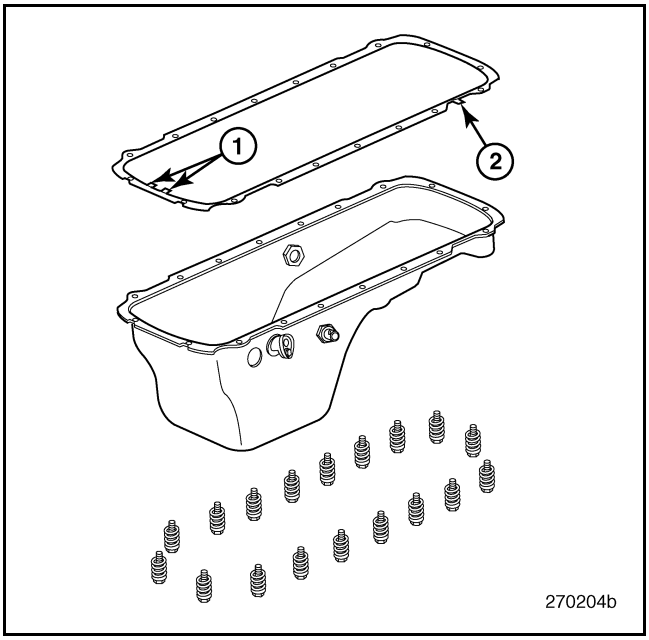


Figure 311 — Oil Pan and Attaching Screws

1. Metal Tabs (Front of Engine)	2. Single Tab (Left Rear of Engine)

NOTE

Make sure that the oil pan flange is flush with the crankshaft front cover and block flanges in order to prevent leaking.

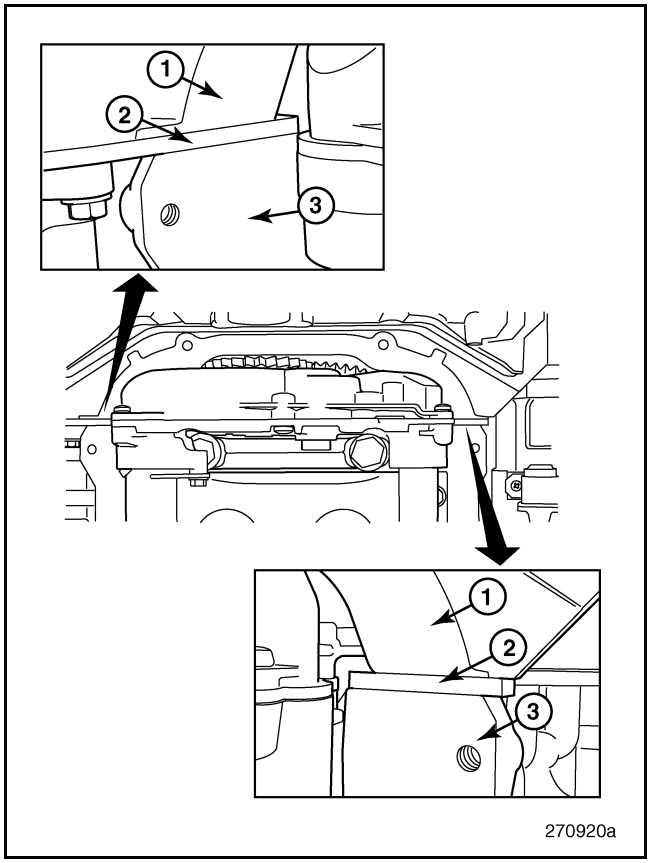


Figure 312 — Flywheel Housing-to-Cylinder Block Mounting Surface

1. Flywheel Housing 2. Timing Gear Mounting Plate	3. Cylinder Block

Eighteen flange head screws with pressed-on springs hold the oil pan to the bottom of the cylinder block. Seventeen have a common hexagonal head with integral washer. One screw, similar to the others, also has a threaded stud on its head. This screw is located third from the rear on the left side of the cylinder block. Tighten the screws in the sequence specified in Figure 313.

1. Install the oil level sensor into the oil pan. Using a torque wrench, tighten the oil level sensor to specification.
2. Install the engine oil fill adapter on the oil fill port fitting of the oil pan and tighten to specification.
3. Place the oil pan seal in position on the oil pan flange. The two metal tabs on the inner edge of the pan seal **must always** be positioned at the front of the engine and the single tab on the outer edge at the left rear for both the front sump and rear sump arrangements.
4. Make sure that the 12 locating pins on the seal are properly seated in the locating holes in the mounting flange.

NOTE

Make sure the oil pan seal is properly placed before tightening the screws.

5. Position the oil pan on the cylinder block.

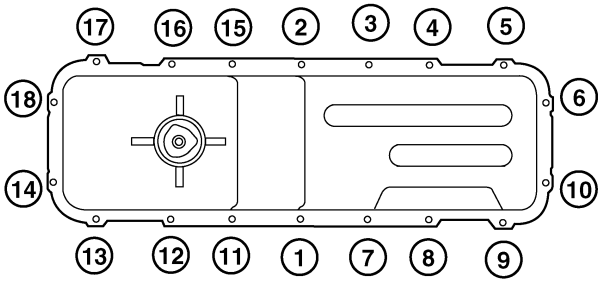


Figure 313 — Torque Sequence for Oil Pan Screws

6. Using a torque wrench, tighten the screws in sequence according to specification.
7. Install the drain plug and tighten to specification using a torque wrench.

Oil Filler Pipe and Dipstick Pipe Installation

1. Assemble the oil filler pipe on the filler retainer on the oil pan.
2. Using a torque wrench, tighten the screws according to specification.
3. Assemble the dipstick pipe on the dipstick retainer on the oil pan.
4. Using a torque wrench, tighten the screw according to specification.

Power Take-Off Installation

If equipped with a power take-off (PTO), install the assembly using this procedure.

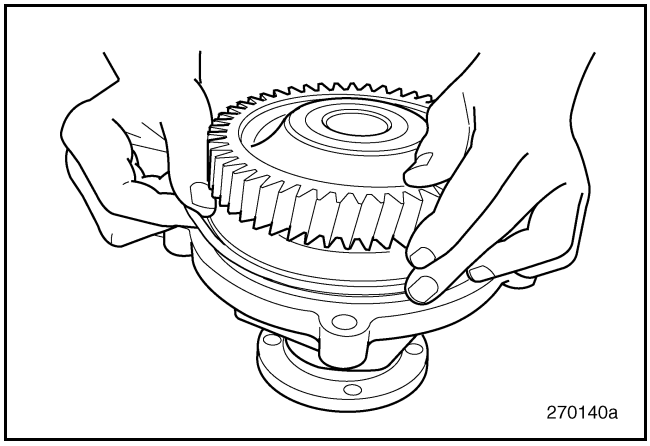


Figure 314 — PTO Housing Seal Installation

1. Lubricate and assemble a seal in the groove in the PTO assembly housing.
2. Assemble the PTO assembly on the flywheel housing.

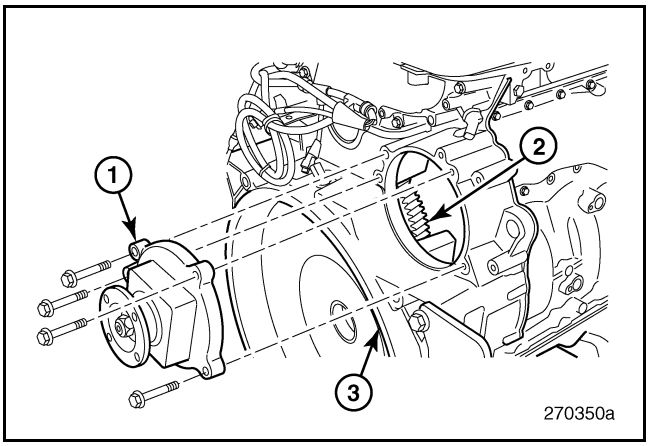


Figure 315 — Power Take-Off Installation

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

3. Using a torque wrench, tighten the screws according to specification.

Timing Gear Cover Installation [211 AA]

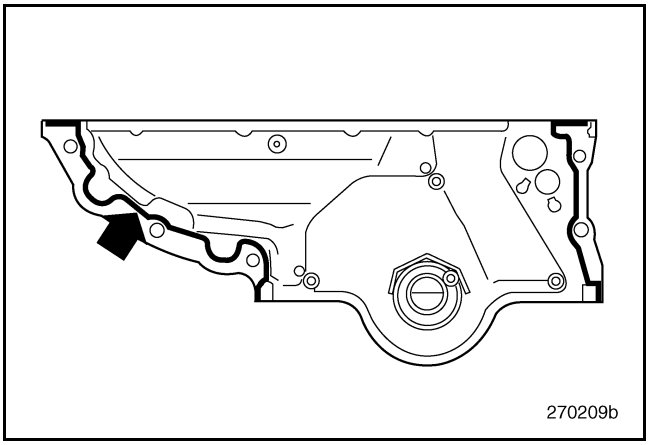


Figure 316 — Sealant Application Pattern on Cover

1. Apply 2 mm (5/64-inch) beads of MACK approved sealant on the mounting plate side of the cover.
2. Install the elastomer seals.
3. Assemble the cover on the flywheel housing and mounting plate.
4. Install the timing gear cover alignment tools, 85109051-A and 85109051-B, to the cylinder head and timing gear cover as illustrated.

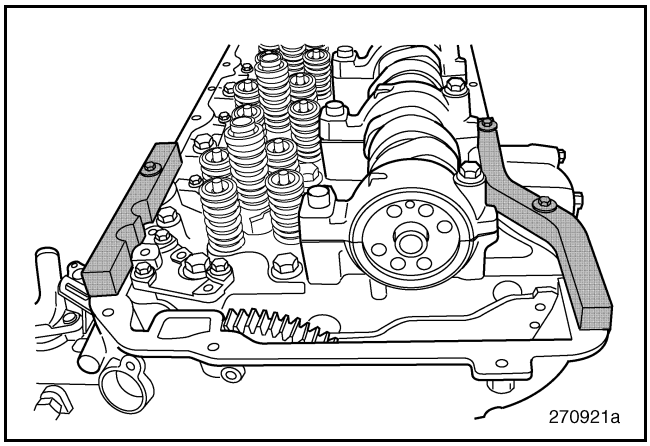


Figure 317 — Timing Gear Cover Alignment Tools

5. Using a torque wrench, tighten the attaching screws in sequence according to specification.

CAMSHAFT SENSOR DEPTH, CHECK

1. If not previously done, remove the fasteners securing the flywheel inspection cover and install the flywheel turning tool, 9996956.
2. Check for proper camshaft position sensor clearance using the sensor depth gauge, 88800031, to determine if shims are required for sensor depth.

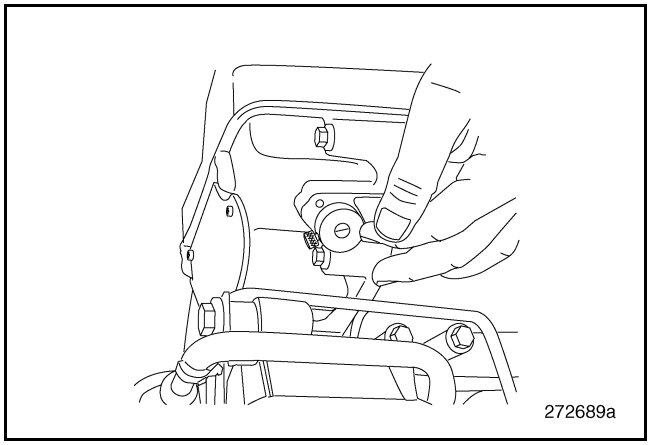


Figure 318 — Camshaft Position Sensor

   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.

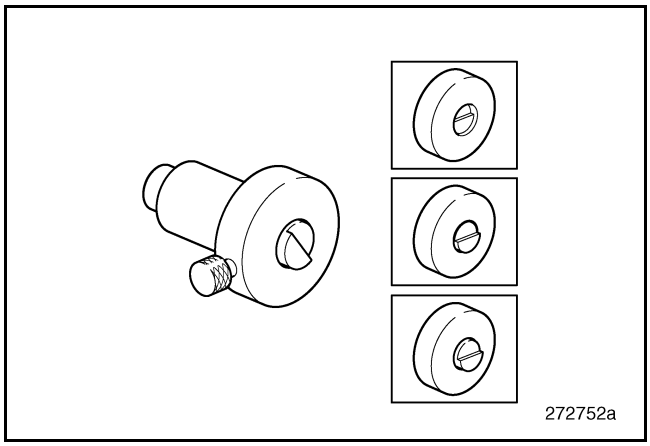


Figure 319 — Sensor Depth Gauge

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.

NOTE

The camshaft position sensor shim part number is 20556179.

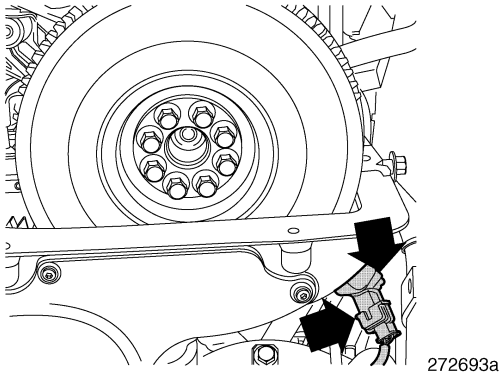


Figure 320 — Camshaft Position Sensor

Crankshaft Rear Seal Installation

[212 JH]

1. Thoroughly clean the surface of the crankshaft flange.

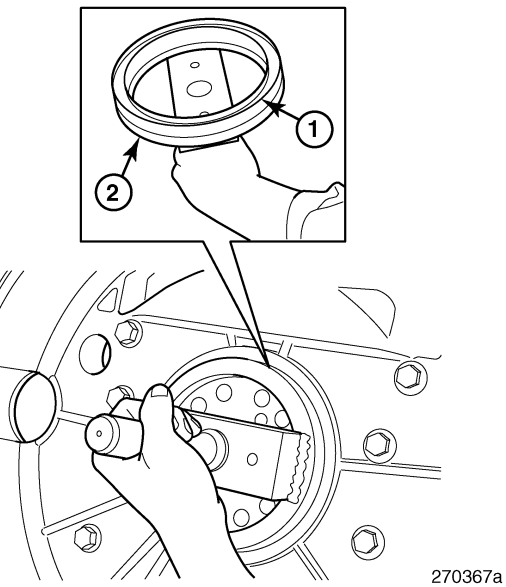


Figure 321 — Crankshaft Rear Seal Installation

1. Rear Main Seal	2. Rear Main Seal Installer, 9990113

2. Apply sealant to the outer rim of the **new** seal.

⚠ CAUTION

Inspect the remover/installer carefully. Any damage on the tool will destroy the seal. Failure to heed this caution may result in severe component damage.

3. Lubricate the seal lips with clean engine oil.
4. Insert the handle, 9992000, in the remover/installer, 9990113.
5. Slide the seal onto the remover/installer, 9990113, flat side toward the tool.
6. Using a hammer, tap the seal into the gear until the remover/installer bottoms.
7. Remove the tools.
8. Inspect the felt 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 screws. Refer to the Automatic Transmission Drive Arrangement Assembly Instructions, 5-903, for installation instructions.

SERVICE HINT

When installing the flywheel, insert two alignment studs in the crankshaft flange to aid in the installation.

1. Position the flywheel over the dowel pin and alignment studs on the crankshaft rear hub.

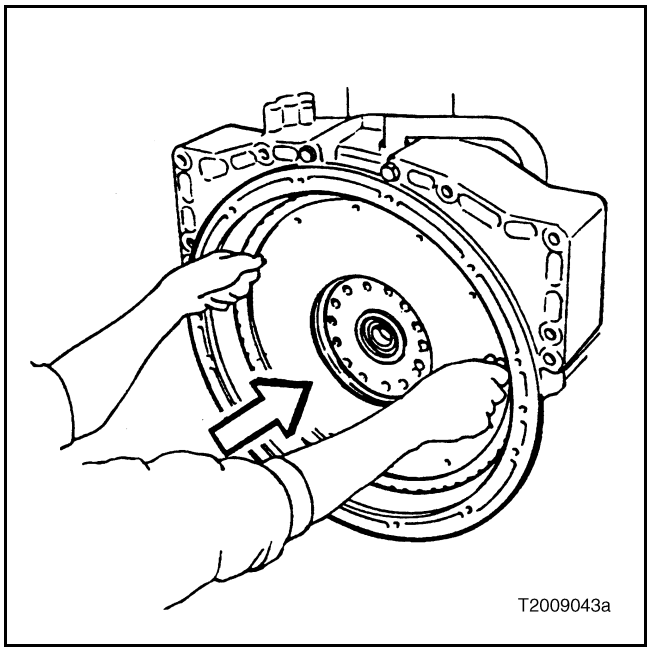


Figure 322 — Flywheel Installation

2. Install the flywheel mounting screws in the exposed mounting holes. At this time, tighten the screws finger-tight only.
3. Remove the two alignment studs and insert the remaining mounting screws.
4. Using a torque wrench, tighten the screws in sequence according to specification.

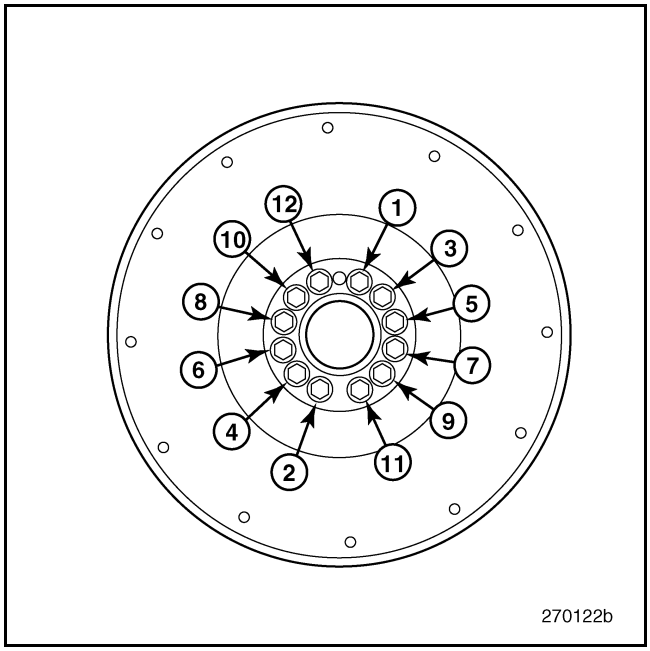


Figure 323 — Flywheel Installation Torque Sequence

⚠ CAUTION

*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.*

5. Using tool assembly, 9991801 and 9992564, install a **new** pilot bearing in the flywheel bore.
6. Carefully install the flywheel position sensor. Install the retaining screw and tighten according to specification.

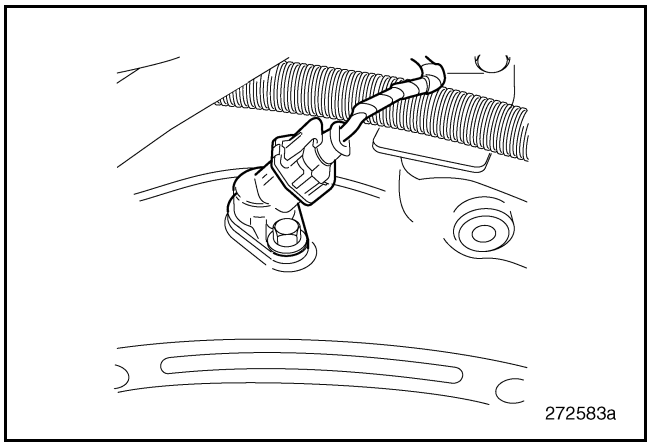


Figure 324 — Flywheel Position Sensor

EGR Crossover (Cooler Outlet) Pipe Installation

[214 HN, HP, HR]

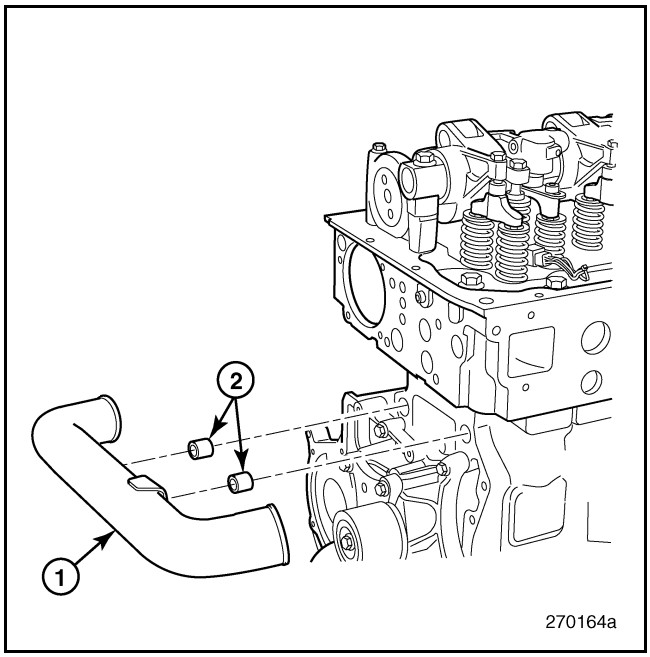


Figure 325 — EGR Crossover Pipe Installation

1. EGR Crossover Pipe	2. Elastomer Bushings

The EGR crossover pipe must be installed before the fan mounting bracket.

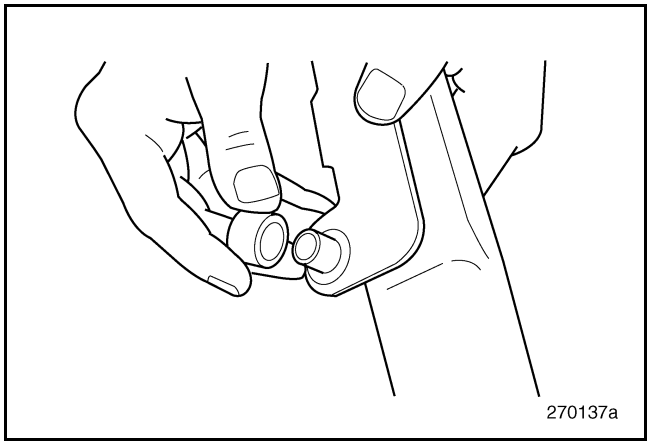


Figure 326 — EGR Crossover Pipe Elastomer Bushing

1. Push the elastomer bushings onto the projections of the crossover pipe.
2. Align the pipe projections with the holes in the cylinder block and push the pipe into place.

Fan Bracket Installation

[215 HA]

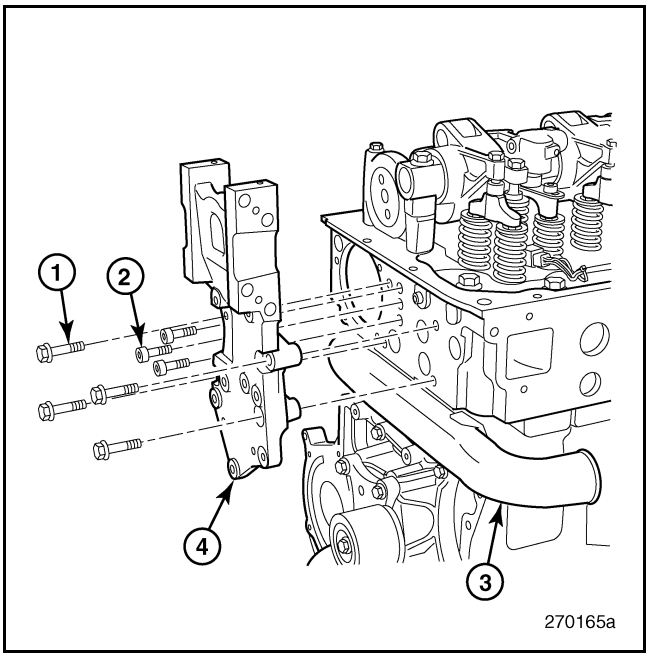


Figure 327 — Fan Bracket Assembly

1. Hex-Head Screws 2. Socket-Head Screws	3. Crossover Pipe 4. Fan Bracket

1. Assemble the fan bracket on the cylinder block.
2. Using a torque wrench, tighten the screws according to specification.

Coolant Pump Installation

[215 SW, SG, SR]

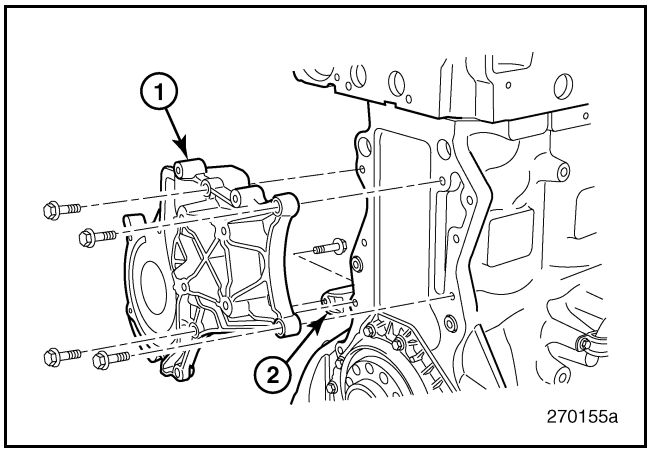


Figure 328 — Coolant Pump Housing

1. Coolant Pump Housing	2. Angle Bracket

1. Assemble the angle bracket on the cylinder block.
2. Install the seal on the back of the coolant pump housing.
3. Install the coolant pump housing on the angle bracket and the cylinder block.
4. Using a torque wrench, tighten the angle bracket screws according to specification.
5. Using a torque wrench, tighten the coolant pump housing screws in a cross pattern according to specification.
6. Install a **new** seal on the back of the coolant pump.

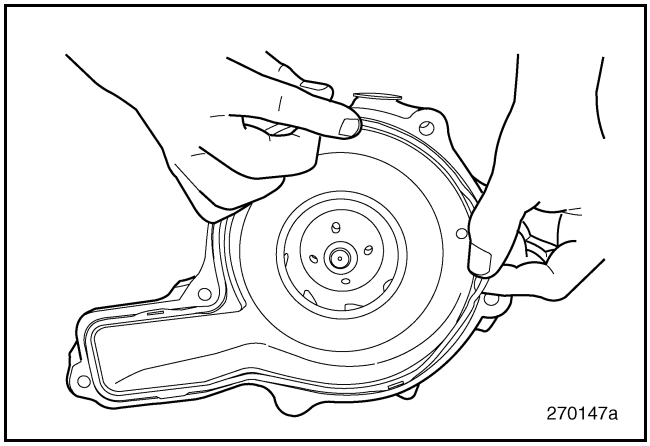


Figure 329 — Installing Coolant Pump Seal

7. Assemble the coolant pump on the coolant pump housing.

NOTE

Be sure the seal is properly assembled before tightening the screws.

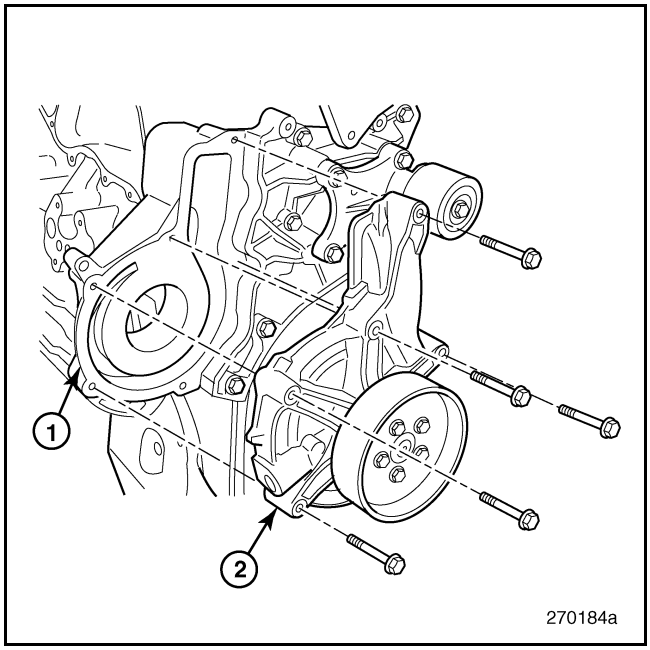


Figure 330 — Coolant Pump and Housing

1. Coolant Pump Housing	2. Coolant Pump

8. Using a torque wrench, tighten the screws according to specification.
9. Install the 10-rib idler bracket on the cylinder block and front engine support.
10. Install the belt tension idler bracket on the cylinder block and front engine support.
11. Assemble the idler bracket on the coolant pump housing.

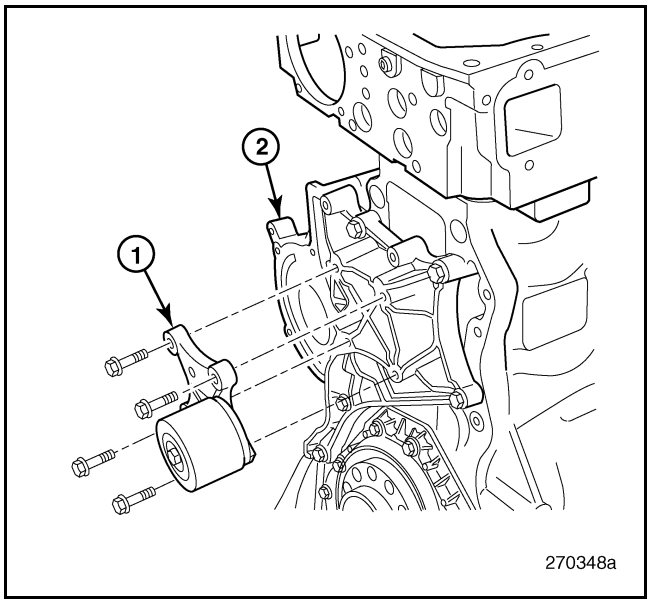


Figure 331 — Idler Bracket Assembly

1. Idler Bracket Assembly	2. Coolant Pump Housing

12. Using a torque wrench, tighten the screws according to specification.

Thermostat and Cover Installation

[215 NU, NG & LD]

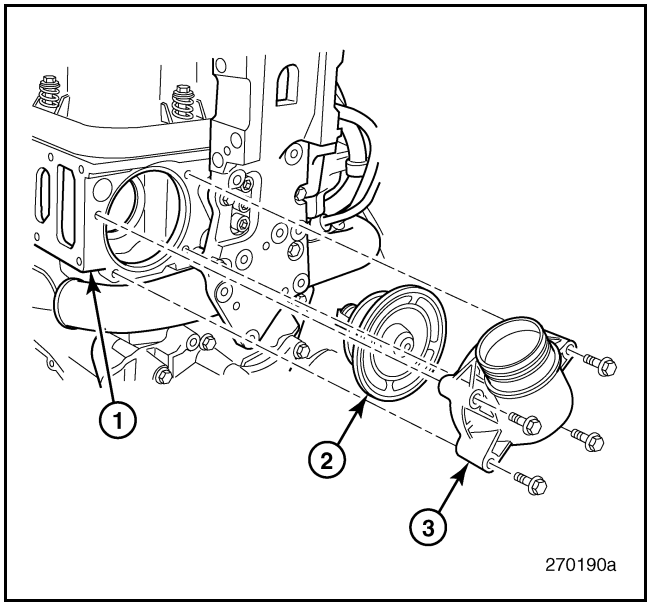


Figure 332 — Thermostat and Cover Installation

1. Cylinder Head 2. Thermostat	3. 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 thermostat cover.
3. Insert the thermostat in the cylinder head.
4. Assemble the cover on the cylinder head.
5. Using a torque wrench, tighten the screws in a cross pattern according to specification.

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. Insert the sealing rings in the ports in the cooling duct cover.

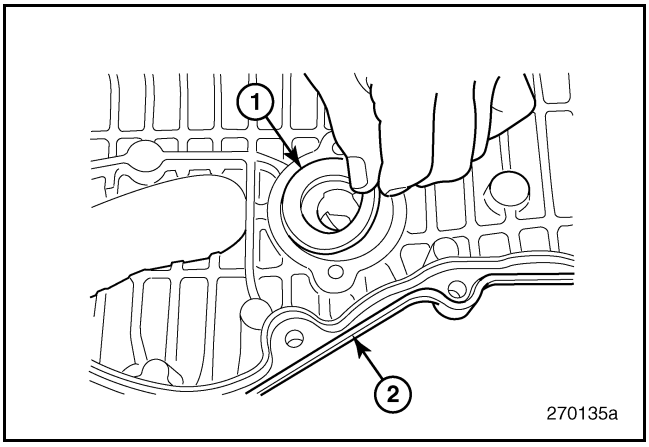


Figure 333 — Installing Cooler Seals

1. Sealing Ring	2. Cooling Duct Cover

2. Assemble the oil cooler on the inside of the cooling duct cover.

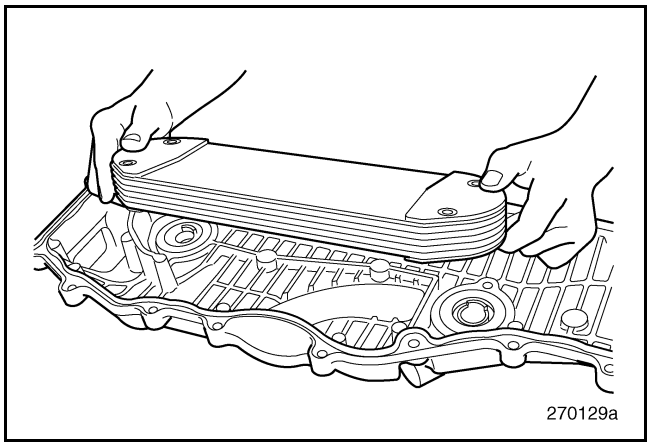


Figure 334 — Installing the Oil Cooler

3. Using a torque wrench, tighten the screws in sequence according to specification.

COOLING DUCT COVER INSTALLATION

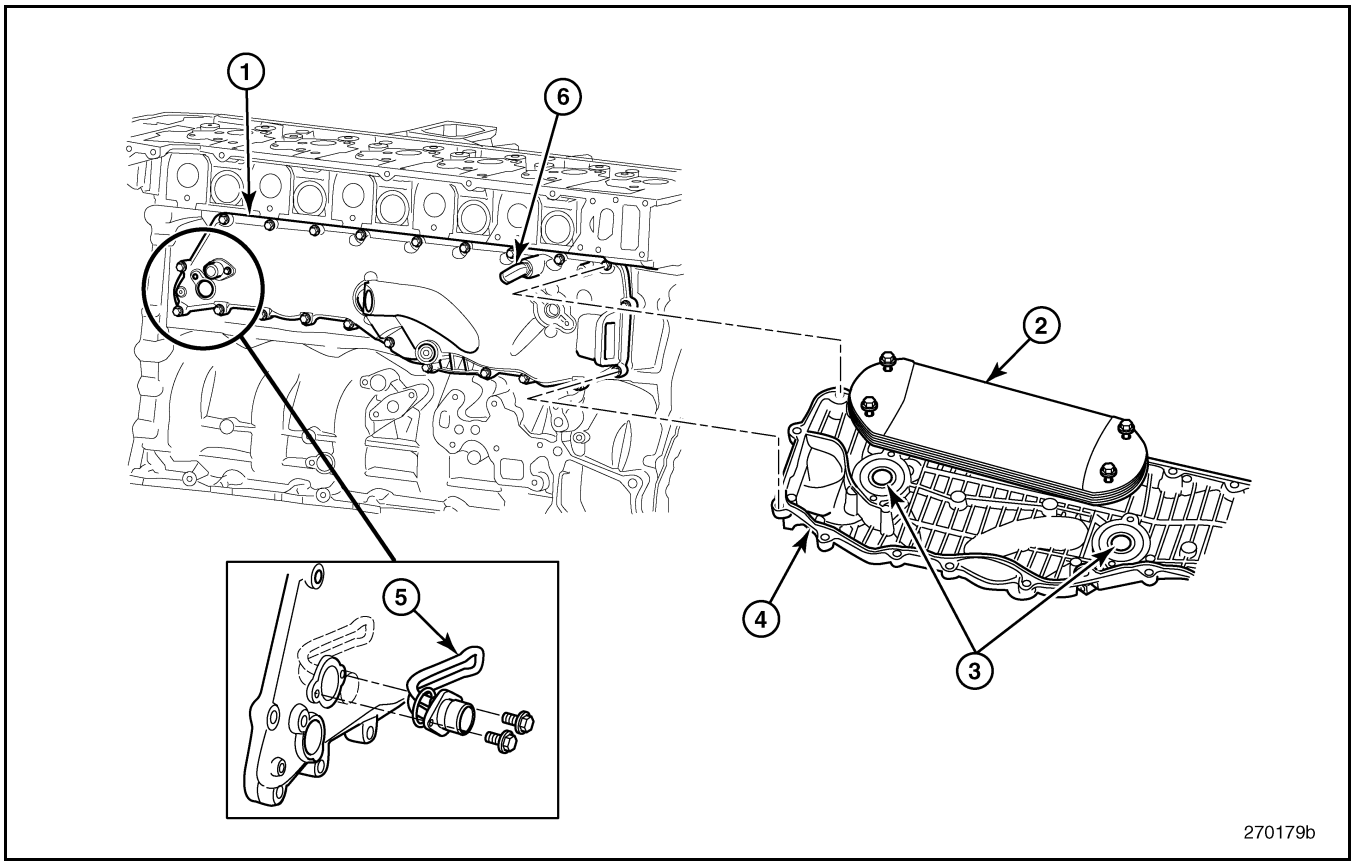


Figure 335 — Oil Cooler and Cooling Duct Cover Installation

1. Cooling Duct Cover 2. Oil Cooler 3. Sealing Rings	4. Cover Seal 5. Cylinder Block Heater 6. Fitting, 90-Degree Elbow

1. Insert the 90-degree elbow fitting in the cooling duct cover oriented toward the rear of the engine as shown.

NOTE

The jam nut must be threaded all the way to the elbow to permit maximum fitting thread engagement.

2. Using a torque wrench, tighten the fitting according to specification.
3. Using a torque wrench, tighten the coolant hose jam nut according to specification.
4. Apply a 2 mm (5/16 inch) bead of 3M Scotch-Grip™ 4799 Industrial Adhesive inside the seal groove near the perimeter of the cooling duct cover.

NOTE

The surface inside the groove must be clean, dry and free of oil, dust and dirt. The adhesive must stay inside the groove. The adhesive cures quickly. After the adhesive is applied, installation of the cover must be completed as quickly as possible.

5. Insert a **new** seal into the groove near the perimeter of the cooling duct cover and press into place.

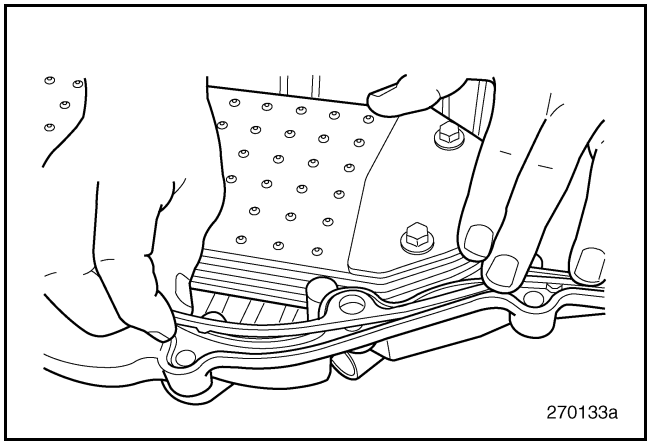


Figure 336 — Installing Cooling Duct Cover Seal

6. Apply a generous coating of Dow Molykote® 55 O-ring lubricant to the cooling duct cover-to-pump outlet seal and then insert the formed rubber seal into the coolant pump base plate outlet.

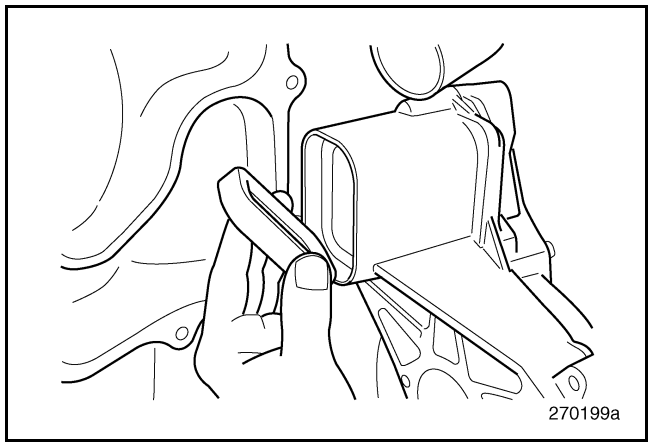


Figure 337 — Installing Cooling Duct Cover-to-Pump Outlet Seal

7. Make sure the cooling duct cover mounting surface on the cylinder block is clean and dry.
8. Apply a generous coating of Dow Molykote® 55 O-ring lubricant to the duct cover seal.

NOTE

The cooling duct cover is installed by positioning the cover against the cylinder block and sliding the cover forward until the cover inlet engages the coolant pump outlet. If the cover seal is not lubricated, the seal can roll out of the duct cover groove as it is being slid forward.

NOTE

The cooling duct cover engages a formed rubber seal in the coolant pump outlet port. Installation of the cooling duct cover without damaging the cover seal or coolant pump outlet seal can be difficult. A tool (88800022) is designed to help install the cover on US07 emission MP7 and MP8 engines and is shipped as an essential tool. For the US04 emission MP7 engine, the tool must have a minor modification so that it can be used to help install the cooling duct cover on this engine. To modify this tool, drill two 9/32 inch diameter holes at the locations shown in the illustration. After the modification, the tool can be secured to the cylinder block heater mounting holes at the rear of the cooling duct cover.

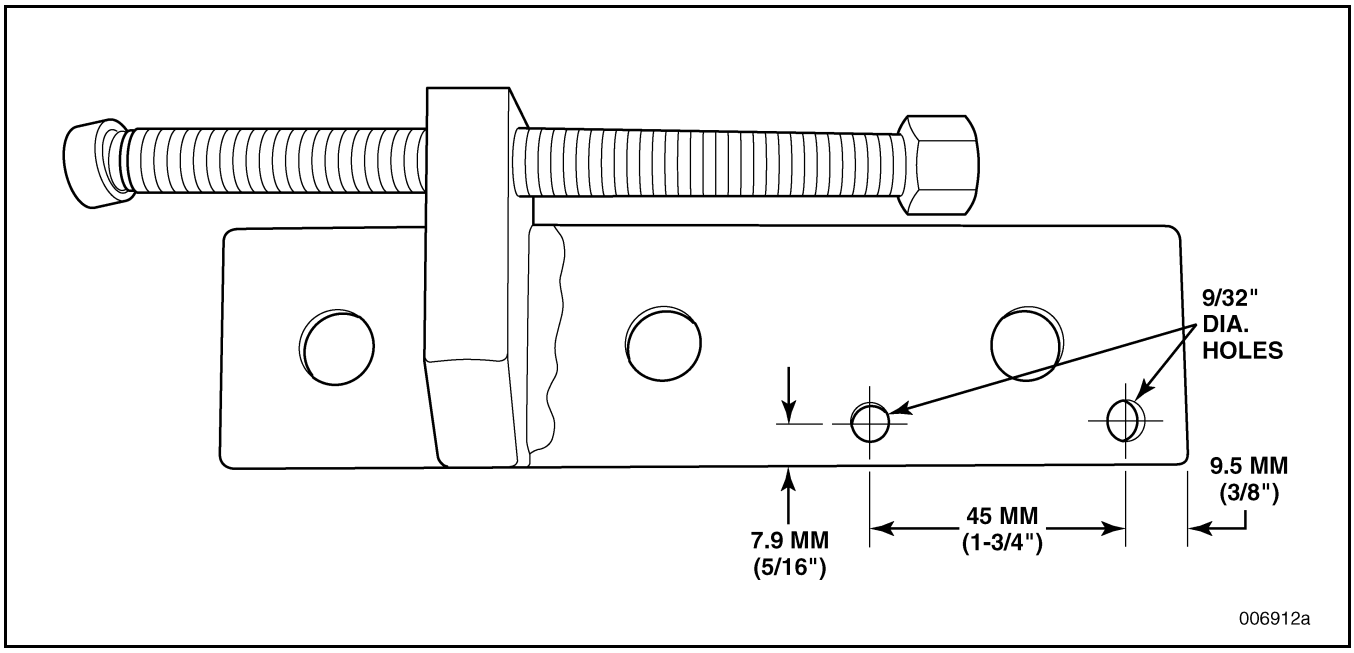


Figure 338 — Cooling Duct Cover Installation Tool Modification

9. Using two cylinder block heater mounting screws, secure the modified installation tool (88800022) to the rear of the cooling duct cover at the cylinder block heater mounting location. Make sure to retract the jackscrew of the tool.

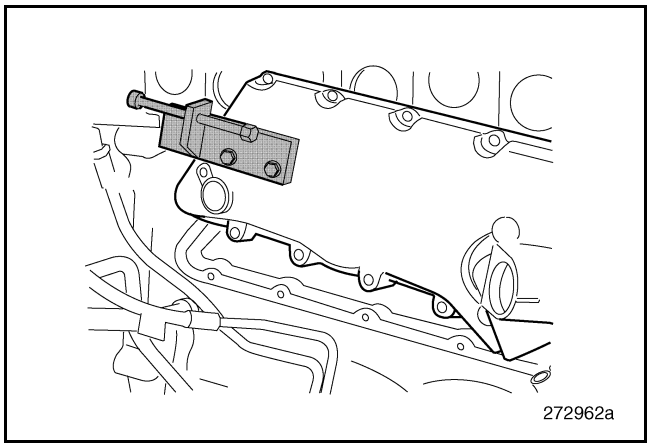


Figure 339 — Installation Tool Placement

10. Position the cooling duct cover against the mounting surface of the cylinder block. Turn the tool jackscrew until it contacts the flywheel housing (timing gear mounting plate). Rotate the jackscrew to push the cooling duct cover forward until the cover inlet fully engages the coolant pump outlet to compress the formed rubber seal. Align the cover mounting holes with the screw holes in the cylinder block.

11. Install 16 of the 22 duct cover mounting screws in the holes not marked **X** as shown in Figure 340.

NOTE

The remaining cover screws are installed later when the EGR cooler mounting bracket is installed.

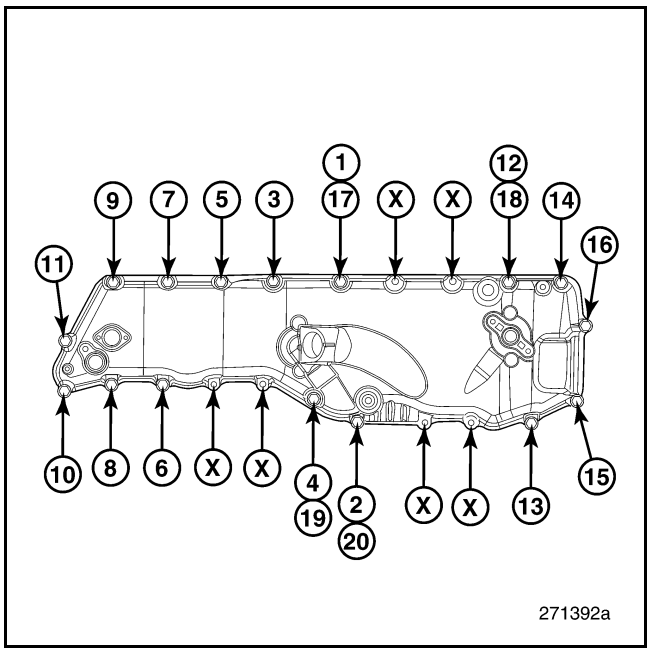


Figure 340 — Torque Sequence for Cooling Duct Cover Screws

12. Using a torque wrench, tighten the cooling duct cover screws in sequence according to specification.
13. Remove the installation tool from the cooling duct cover.
14. Lubricate and assemble a **new** O-ring on the cylinder block heater.
15. Install the cylinder block heater on the cover. Orient the heater coil so that it is horizontal with the ribs inside the cover and facing forward.
16. Using a torque wrench, tighten the cylinder block heater screws according to specification.

Coolant Pipe Installation

[215 SW]

1. Lubricate and assemble a **new** seal ring on the pump inlet pipe at the joint with the bypass connector.
2. Lubricate and assemble a **new** O-ring in the pump inlet pipe flange.

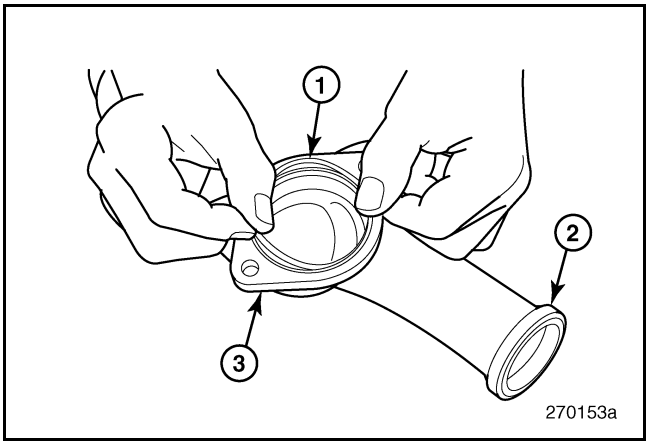


Figure 341 — Seal Ring and O-Ring, Pump Inlet Pipe

1. O-Ring 2. Seal Ring	3. Inlet Pipe Mounting Flange

3. Assemble the bypass connector on the pump inlet pipe.
4. Lubricate and assemble a **new** O-ring on the free end of the bypass connector.
5. Assemble the pump inlet pipe with bypass connector in the upper coolant pipe.

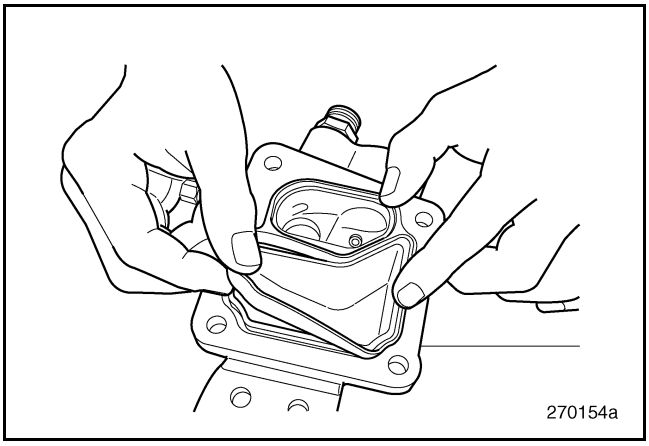


Figure 342 — Seal Installation — Upper Coolant Pipe Housing

6. Lubricate and assemble a **new** seal in the upper coolant pipe housing flange.
7. Assemble the upper coolant pipe housing flange on the head.
8. Assemble the pump inlet pipe flange on the pump.
9. Using a torque wrench, tighten the upper coolant pipe and pump inlet flange screws in sequence according to specification.
10. Assemble the pipe support bracket on the front engine support.
11. Assemble the clamp on the lower coolant pipe support bracket.
12. Using a torque wrench, tighten the screws according to specification.

Oil Filter Housing Installation [219 EP]

SERVICE HINT

It may be helpful to assemble the supply and return pipes in the cooling duct cover before tightening the oil filter housing attaching screws.

1. Assemble the attaching screws in the oil filter housing.
2. Assemble the oil filter housing gasket on the attaching screws.
3. Install the oil filter housing on the cylinder block.
4. Lubricate and assemble O-rings on the ends of the oil cooler-to-housing return pipe.
5. Lubricate and assemble O-rings on the ends of the housing-to-oil cooler supply pipe.

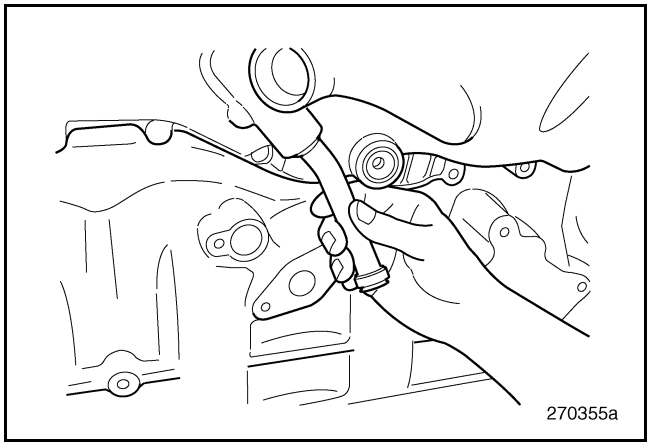


Figure 343 — Oil Return Pipe-to-Cover Installation

6. Assemble the return pipe in the cooling duct cover.
7. Assemble the return and supply pipes between the oil filter housing and cooling duct cover.
8. Using a torque wrench, tighten all screws according to specification.
9. Lubricate and assemble an O-ring on the oil pressure sensor.
10. Using a torque wrench, tighten the sensor according to specification.
11. Lubricate and assemble an elastomer bushing in the port in the cooling duct cover.

Exhaust Manifold Installation [214 EG]

1. Apply anti-seize compound to the exhaust manifold screw threads and also to the underside of the screw heads.
2. Install alignment pins in the upper manifold mounting holes on the cylinder head.

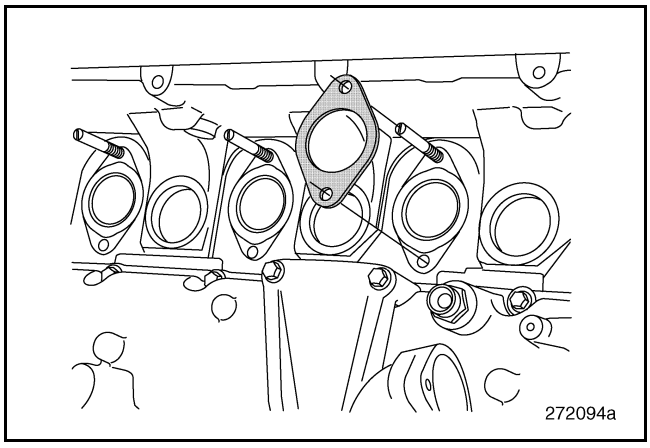


Figure 344 — Alignment Pin Installation

3. Install **new** gaskets onto the alignment pins with the seal side facing the cylinder head.

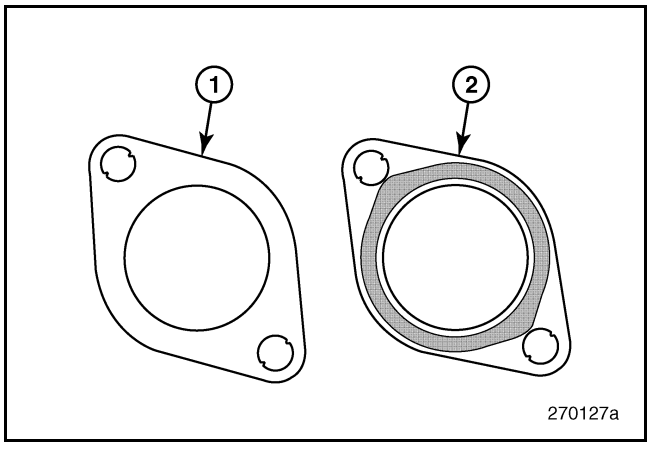


Figure 345 — Exhaust Manifold Gasket

1. Manifold Side (Metal)	2. Cylinder Head Side (with Seal)

4. Install the exhaust manifold over the alignment pins. Install the screws and spacers in the lower holes. Remove the upper alignment pins one at a time and install the screws and spacers.

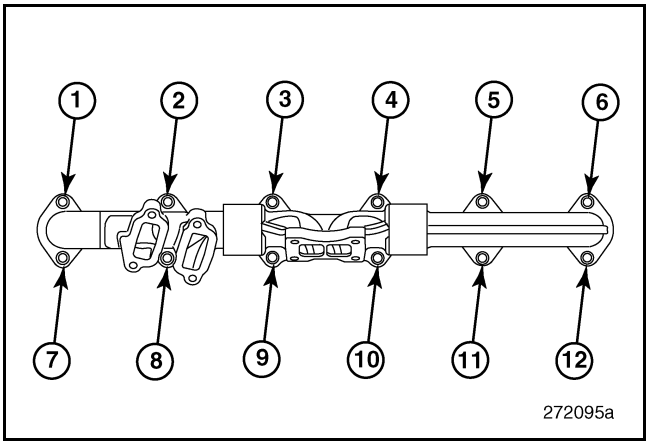


Figure 346 — Exhaust Manifold Installation

5. Using a torque wrench, tighten the screws and stud in two steps according to specification.
6. Assemble the EGR heat shields on the cylinder head and manifold studs.
7. Using a torque wrench, tighten the screws and nut according to specification.

EGR Valve Installation

[214 QE]

⚠ CAUTION

Clean the four threaded holes in the exhaust manifold for the EGR valve mounting bolts. Use care when cleaning components of the EGR system. Dirt and debris could cause blockage within the cooler core or EGR valve. Failure to heed this caution may result in severe engine damage.

1. Assemble the attaching screws in the EGR valve body.

NOTE

Always use **new** screws when installing the EGR valve.

2. Assemble the gasket on the attaching screws.
3. Install the EGR valve on the exhaust manifold.
4. Using a torque wrench, tighten the screws in a crisscross pattern according to specification.
5. Install and tighten the EGR valve oil supply line according to specification.
6. Install and tighten the EGR valve oil return line according to specification.
7. Connect the wiring harness lead to the EGR valve.

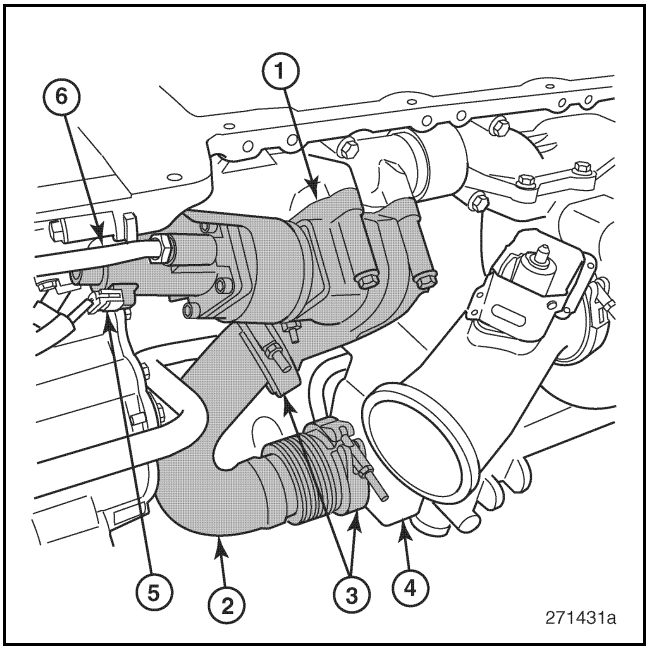


Figure 347 — EGR Valve Installation

1. EGR Valve Assembly 2. EGR Cooler Inlet Pipe 3. EGR Cooler Inlet Pipe Clamps	4. EGR Cooler 5. EGR Solenoid Terminal 6. Oil Inlet Tube

EGR Cooler Installation

[214 HM]

1. Assemble the front and rear EGR cooler mounting brackets on the cooling duct cover. Do not tighten the screws.
2. Clamp a straightedge across the two brackets to align the mounting pads.
3. Using a torque wrench, tighten the mounting bracket screws according to specification.
4. Remove the straightedge and clamps.
5. Assemble the EGR cooler on the mounting bracket pads.
6. Rotate the straps into position and, using a torque wrench, tighten the T-bolts according to specification.
7. Using a torque wrench, tighten the T-bolt locknuts according to specification.
8. Using a torque wrench, tighten the drain valve on the EGR cooler according to specification.
9. Install **new** seals on the engine coolant return pipe and a **new** O-ring on the mounting flange.
10. Install the engine coolant return pipe.
11. Using a torque wrench, tighten the return pipe flange screws according to specification.
12. Slide the coupling hose with clamps over the ends of the cooler outlet port and the crossover pipe.
13. Using a torque wrench, tighten the clamp screws according to specification.

EGR Cooler Inlet Pipe Installation

[214 HN, HP, HR]

1. Assemble **new** gaskets on the EGR cooler inlet pipe and cooler flanges.

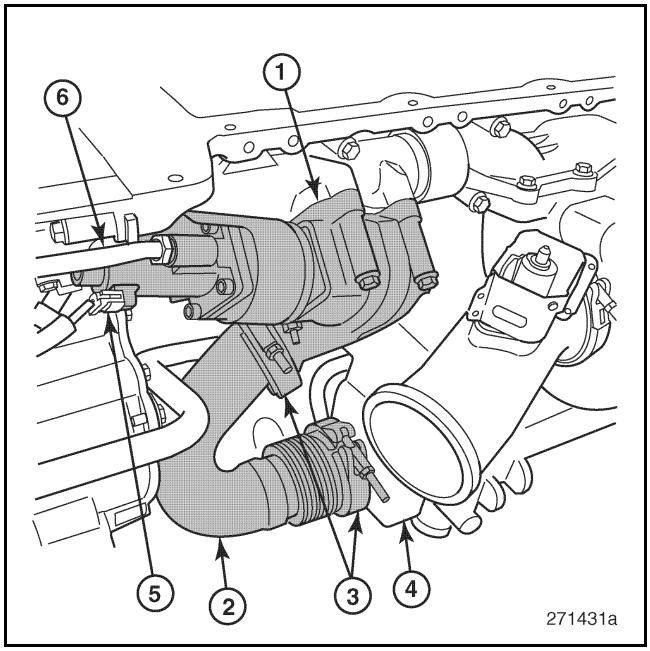


Figure 348 — EGR Cooler Inlet Pipe

1. EGR Valve 2. EGR Cooler Inlet Pipe 3. EGR Cooler Inlet Pipe Clamps	4. EGR Cooler 5. EGR Solenoid Terminal 6. Oil Inlet

2. Position the EGR cooler inlet pipe between the EGR valve and the cooler.
3. Assemble V-band clamps on each end of the cooler inlet pipe. Make sure the floating flanges are correctly aligned.

SERVICE HINT

The clamps can be reused by applying a non-flammable lubricant on the inner side of the clamp.

4. Tighten the clamp screws according to specification.

Turbocharger Installation

[214 SC]

⚠ WARNING

The turbocharger is heavy. Do NOT attempt to install the turbocharger 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.

NOTE

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.

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.

⚠ CAUTION

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 FINAL 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. Retain the protective caps over the turbocharger ports to keep debris and dirt out of the turbocharger as engine reassembly progresses.
3. Apply anti-seize compound to the threads of the turbocharger mounting studs, screws and nuts. Also, apply the compound to the underside of the screw heads and nut flanges.
4. Place a **new** gasket in position and start the nuts and spacers on the studs.

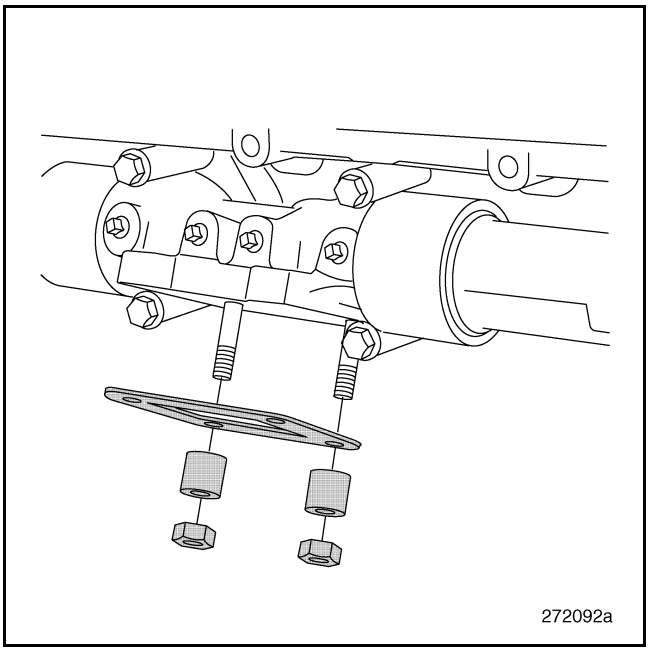


Figure 349 — Turbocharger Gasket Installation

5. Align the slotted holes and support the turbocharger on the lower mounting studs and nuts. Install the upper mounting screws.

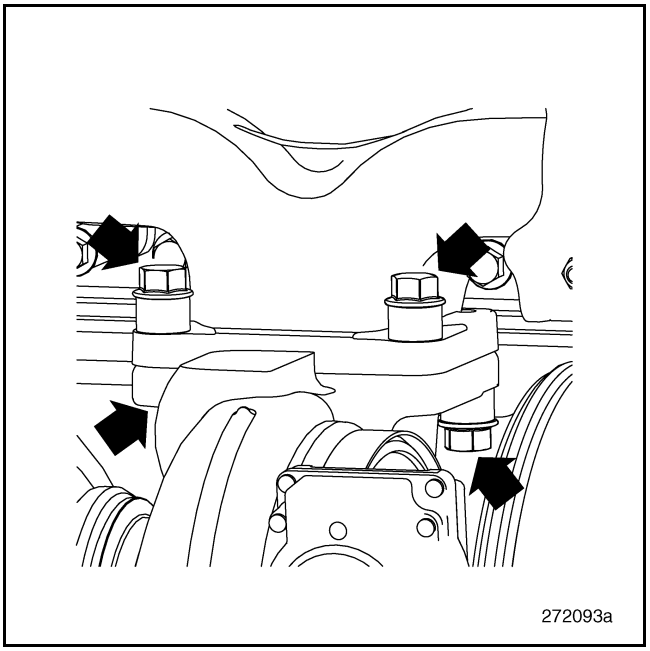


Figure 350 — Turbocharger Mounting Fasteners

6. Using a torque wrench, tighten the screws and nuts in a cross pattern according to specification.

7. Connect the oil supply line to the bottom of the turbocharger. With a **new** gasket, install the turbocharger oil drain pipe, fasteners and retaining clamp.

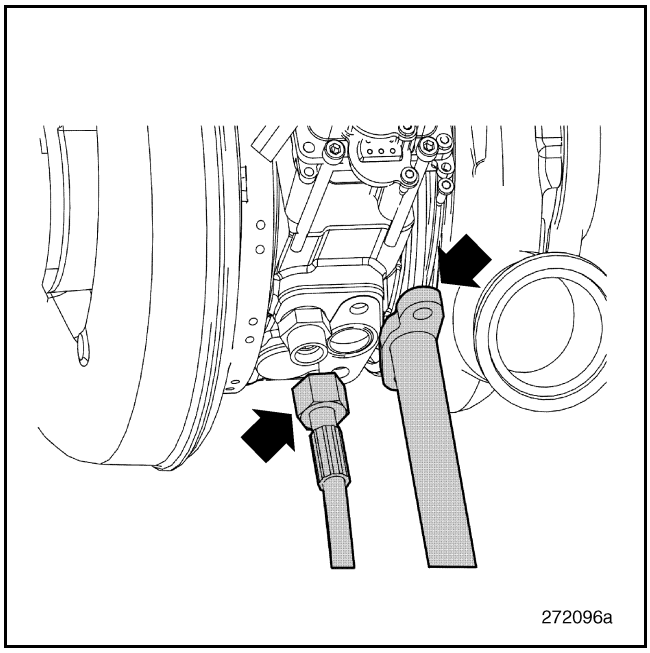


Figure 351 — Turbocharger Oil Supply and Drain Connections

8. Tighten the oil drain pipe clamp screws according to specification.

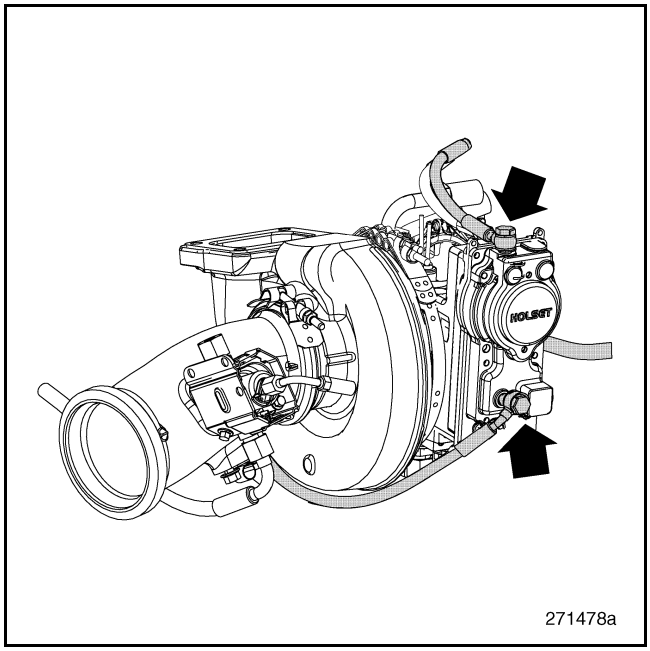


Figure 352 — Smart Remote Actuator (SRA) Coolant Lines

9. Attach the coolant supply line to the SRA.
10. Attach the coolant return line to the SRA.
11. Using a torque wrench, tighten the fittings according to specification.

Starter Installation

[272 DH]

The starter is held in place by nuts assembled over studs inserted in the flywheel housing. If a stud is missing, replace it.

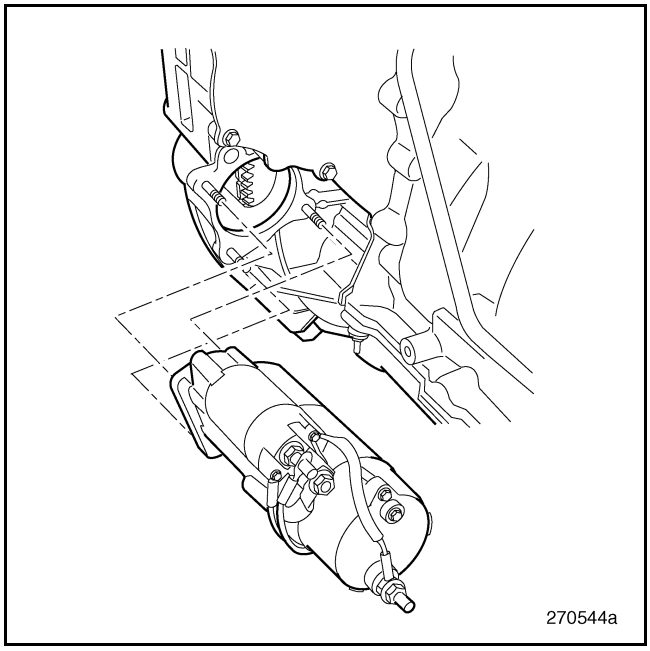


Figure 353 — Starter Installation

1. Using a torque wrench, tighten replacement studs according to specification.
2. Assemble the starter on the studs in the flywheel housing.
3. Using a torque wrench, tighten the nuts according to specification.

Air Compressor Installation

[261 CK]

N O T E

If the timing gears are in place, make sure the gear teeth are properly meshed during assembly of the air compressor.

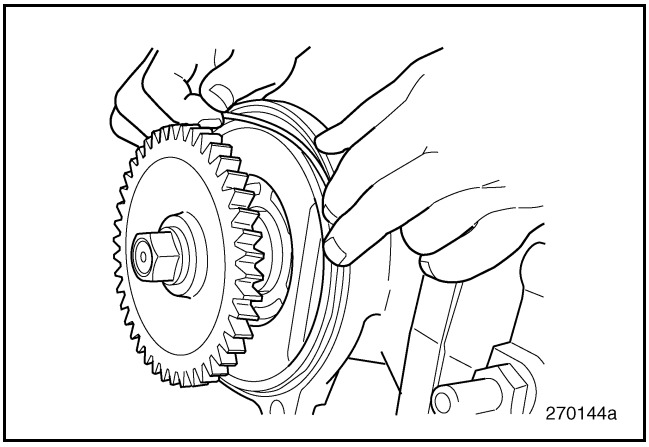


Figure 354 — Installing Air Compressor Mounting Seal

1. Install a **new** seal in the air compressor housing.

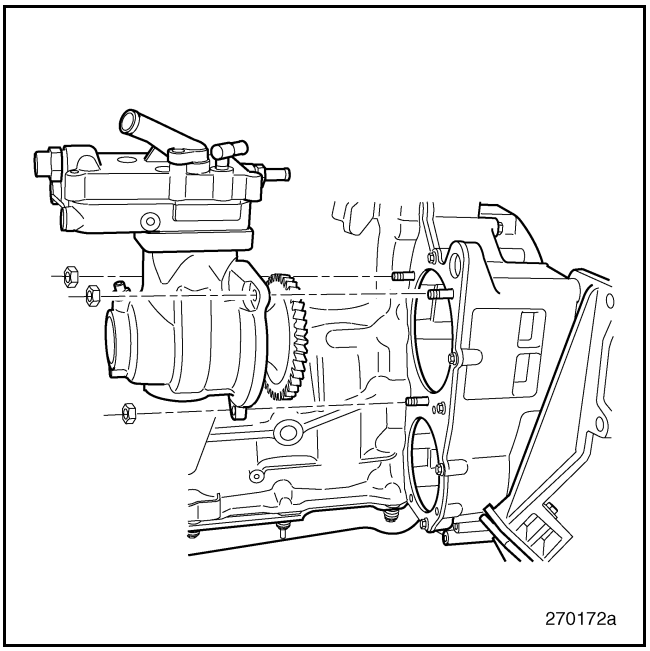


Figure 355 — Air Compressor Installation

2. Install the air compressor mounting flange over the studs in the flywheel housing.
3. Using a torque wrench, tighten the attaching nuts in two stages according to specification.

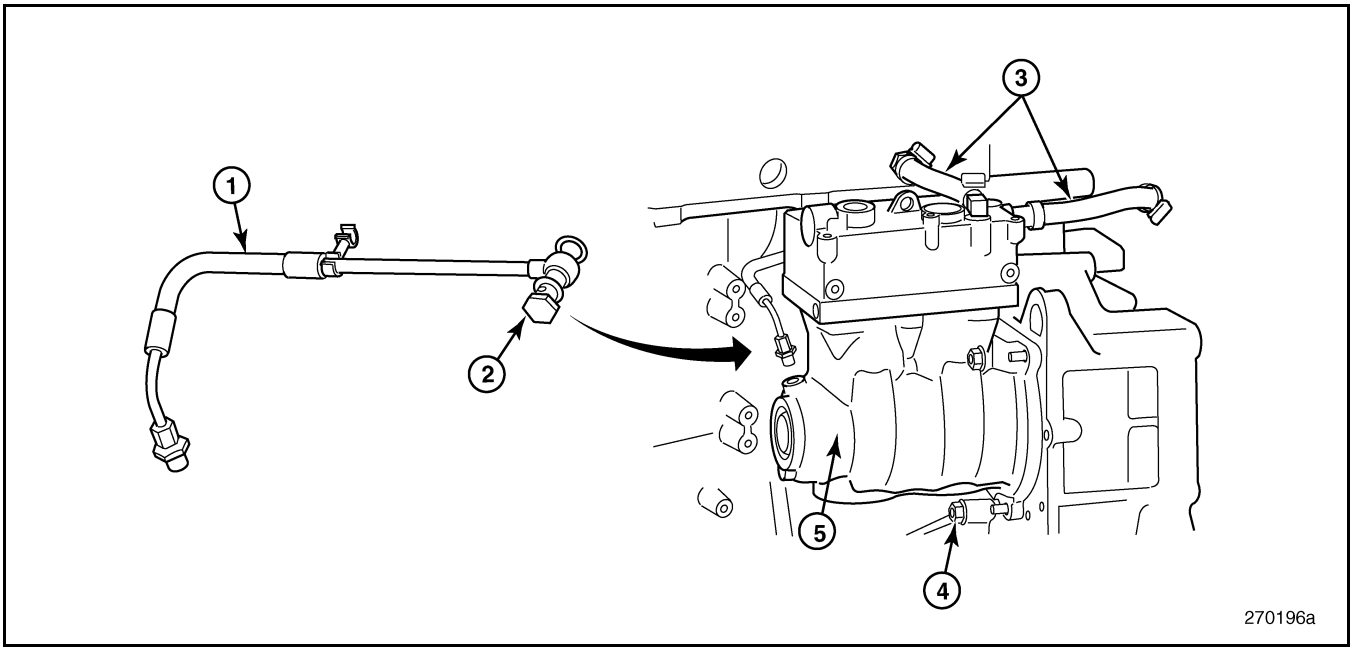


Figure 356 — Air Compressor Coolant and Lubrication Fittings

1. Lubrication Line 2. Banjo Fitting 3. Coolant Lines	4. Attaching Stud and Nut 5. Air Compressor

4. Connect the coolant lines.
5. Connect the lubrication lines.

Tandem Pump (Fuel and Power Steering) Installation

[231 AA, 262 EB]

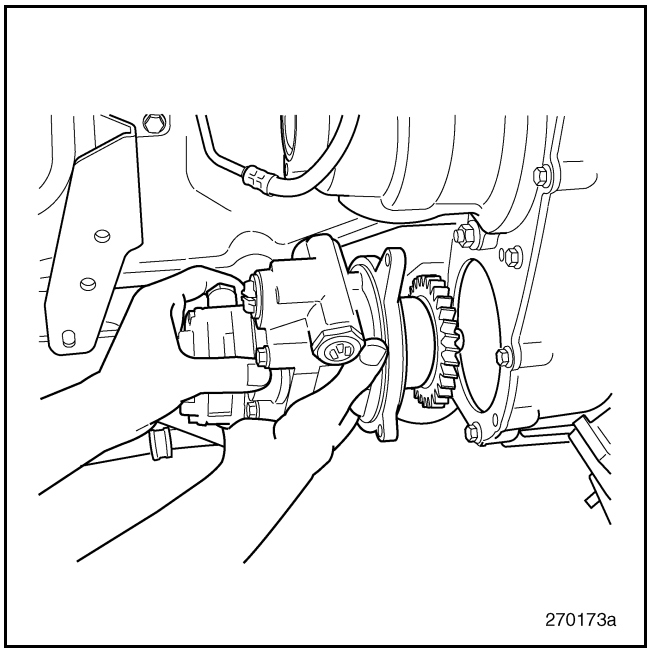


Figure 357 — Tandem Pump (Fuel and Power Steering) Installation

NOTE

If the timing gears are in place, make sure the gear teeth are properly meshed during installation of the tandem pump.

1. Install a **new** O-ring in the groove on the tandem pump mounting flange.
2. Install the tandem pump on the flywheel housing.
3. Using a torque wrench, tighten the attaching screws according to specification.
4. Attach the bypass line to the fuel pump and the filter housing.
5. Attach the low pressure (suction) line to the fuel pump and filter housing.
6. Attach the high pressure line to the fuel pump and filter housing.

NOTE

The power steering lines will be connected to the pump after installation of the engine in the chassis.

7. Install the clamps that hold the lines to the cylinder block.
8. Using a torque wrench, tighten the attaching screws and banjo fittings according to specification.

Inlet Manifold Installation

[214 HD]

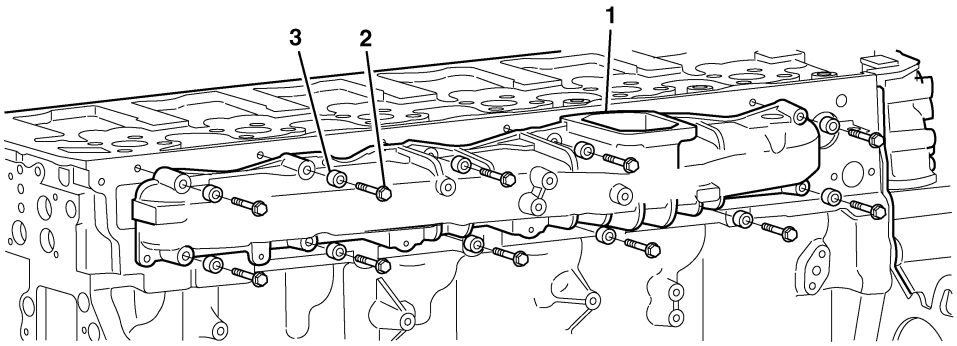


Figure 358 — Inlet Manifold Installation — LCF Chassis

1. Inlet Manifold 2. Inlet Manifold Screw	3. Inlet Manifold Mounting Spacer (Required only with original manifolds)

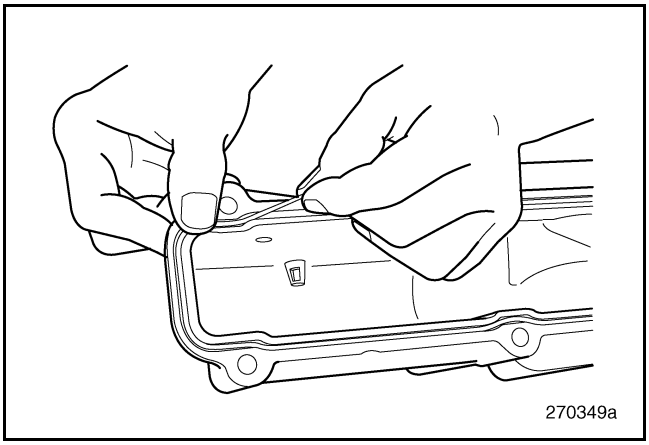


Figure 359 — Installing Inlet Manifold Seal

1. Lubricate and install the inlet manifold seal in the groove in the manifold.

NOTE

Apply a minimal amount of MACK approved silicone sealant in the seal groove to hold the seal in place during assembly. Install the manifold within 20 minutes of applying sealant.

2. Place the manifold in position on the cylinder head and insert the attaching screws with mounting spacers.

NOTE

Replacement inlet manifolds contain longer mounting bosses and require only **new** longer screws to attach them to the cylinder head, no spacers. If the original manifold is to be reused, **new** screws with **mounting spacers** are required.

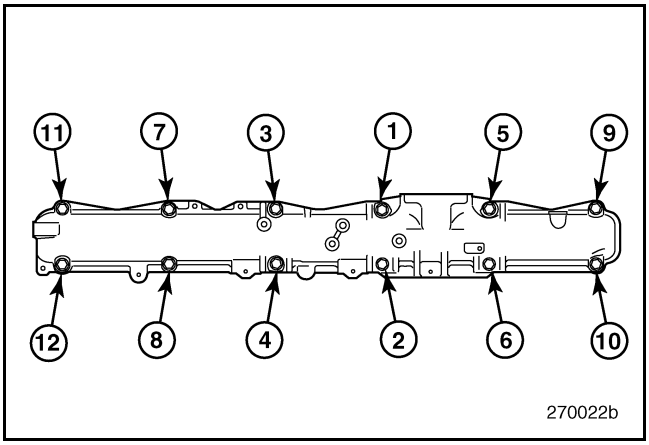


Figure 360 — Torque Sequence for Inlet Manifold Screws

3. Using a torque wrench, tighten the screws in sequence according to specification.
4. Assemble the air pressure/temperature sensor on the manifold at the rear.
5. Using a torque wrench, tighten the sensor according to specification.

EGR Mixer Installation

[214 HL]

1. Inspect and clean the EGR mixer mounting surface on the inlet manifold.
2. Assemble the EGR mixer, air heater and gasket on the inlet manifold.
3. Using a torque wrench, tighten the screws in a cross pattern according to specification.

EGR Venturi Housing Installation

NOTE

The sequence in which the EGR venturi housing, fuel filter valve 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. Assemble the venturi housing and the venturi outlet pipe.
2. Using a torque wrench, tighten the attaching screws according to specification.
3. Assemble the venturi housing and the outlet pipe with a strap clamp on the cylinder block. Do not tighten the screws.
4. Slide the coupling hose with clamps over the ends of the crossover pipe and the venturi housing.
5. Using a torque wrench, tighten the clamp screws according to specification.
6. Using a torque wrench, tighten the venturi housing and outlet pipe attaching screws to specification.
7. Assemble the delta pressure sensors on the housing.
8. Connect the sensors to the wiring harness.

Intermediate and Mixer Inlet Piping Installation

[214 HL]

1. Install the intermediate pipe on its mounting bracket. Do not tighten the clamp screws.
2. Slide the coupling hose with clamps over the ends of the venturi outlet pipe and the intermediate pipe. Do not tighten the clamp screws.
3. Slide the coupling hose with clamps over the ends of the intermediate pipe and the mixer inlet pipe. Do not tighten the clamp screws.
4. Assemble the mixer inlet pipe on the mixer.
5. Using a torque wrench, tighten the mixer inlet attaching screws according to specification.
6. Using a torque wrench, tighten the bracket clamp screws according to specification.
7. Using a torque wrench, tighten all hose clamp screws according to specification.

EECU and Cooler Installation

[230 EK]

NOTE

The sequence in which the EGR venturi housing, fuel filter valve housing, fuel lines and EECU are assembled on the engine depends on the type of the 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 in 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. Assemble the EECU on the cylinder block.

2. Using a torque wrench, tighten the screws 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.
4. Using a torque wrench, tighten the screws in sequence according to specification.
5. Connect the fuel lines to the inlet and outlet ports of the cooling plate.

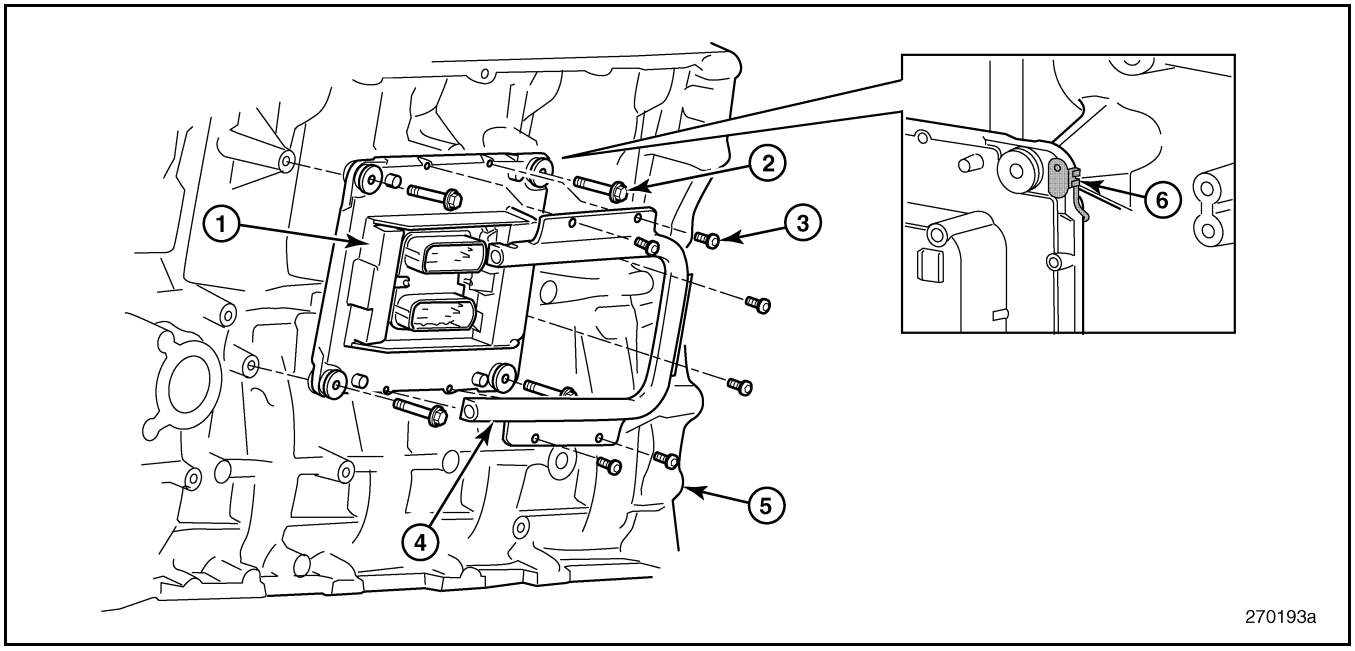


Figure 361 — EECU and Cooling Plate

1. EECU 2. EECU Attaching Screws 3. Cooler Attaching Screws	4. Cooler 5. Cylinder Block 6. Ground Strap

6. Connect the wire harness to the EECU.

⚠ CAUTION

Use care to ensure that the EECU terminal pins are straight and undamaged.

Fuel Lines and Fuel Filter Housing Installation

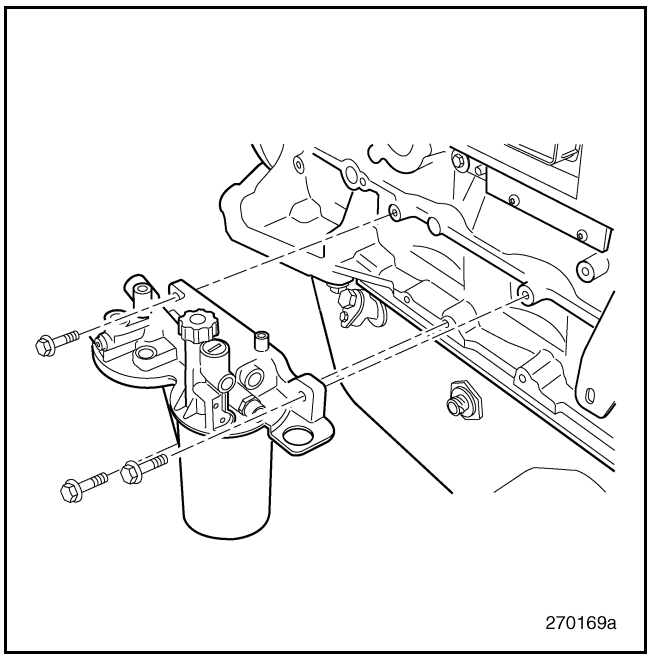


Figure 362 — Fuel Filter and Filter Housing Assembly

1. Make sure that the pipe connected to the fuel filter housing is securely fastened.
2. Assemble the fuel filter housing on the cylinder block.
3. Using a torque wrench, tighten the screws according to specification.
4. Attach the pipe between the side of the cylinder head at the rear and the fuel filter housing.

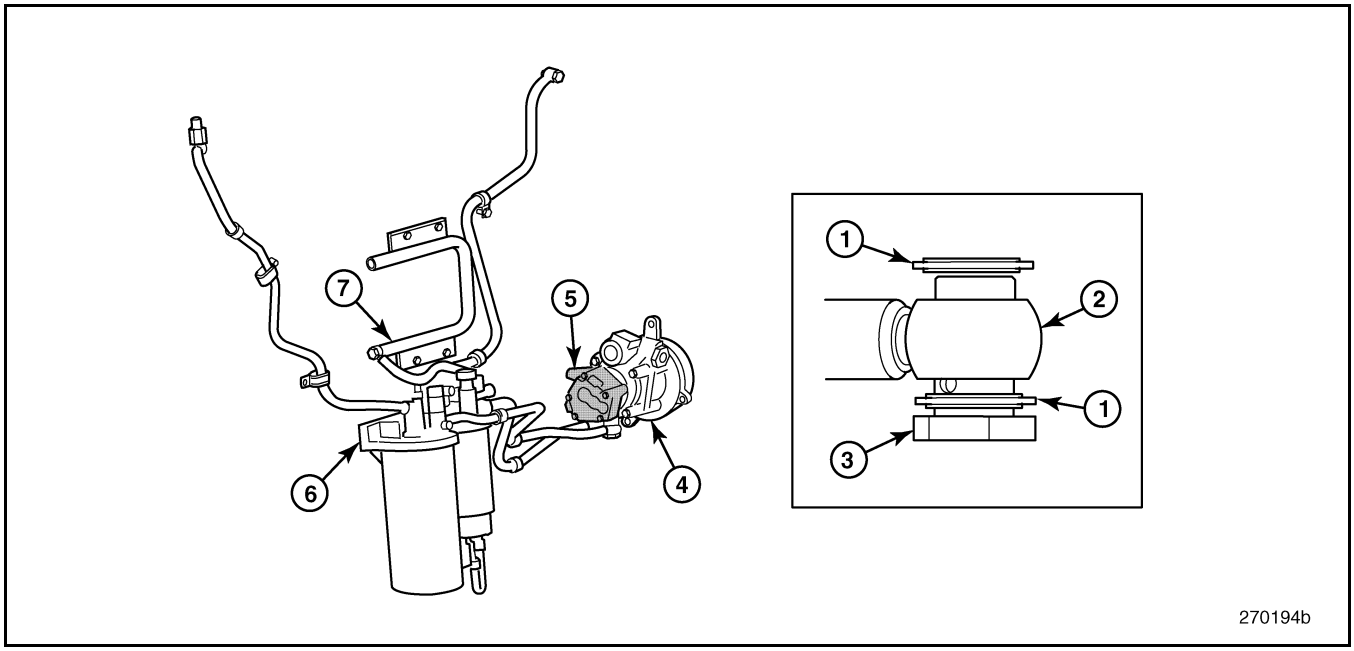


Figure 363 — Fuel Supply Pump, Fuel Filter Housing and Lines

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

5. Attach the line to the cylinder block with a strap clamp.
6. Attach the two pipes between the top of the cylinder head at the front and the fuel filter housing.
7. Attach the two lines to the cylinder block with three strap clamps.
8. Attach the pipe connecting the fuel filter housing to the EECU cooler.
9. Using a torque wrench, tighten the banjo fittings according to specification.

Crankcase Ventilation Separator

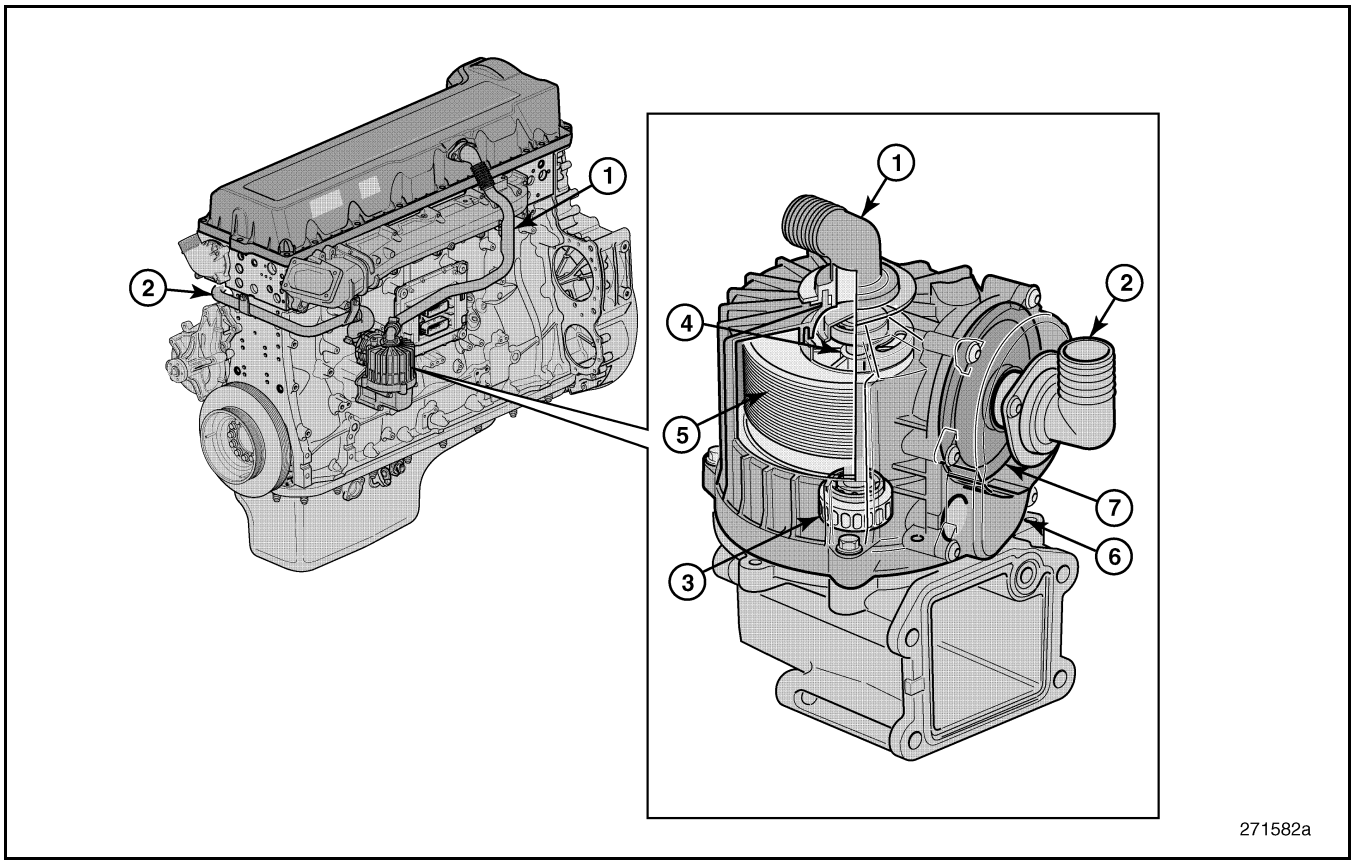


Figure 364 — Crankcase Ventilation System Separator

1. Separator Inlet Hose and Connector 2. Separator Outlet Hose Connector 3. Turbine 4. Drive Shaft	5. Separator Discs 6. Pressure Regulator 7. Pressure Regulator Diaphragm

1. Install the crankcase ventilation separator on the cylinder block.
2. Using a torque wrench, tighten the screws according to specification.
3. Assemble the outlet hose on the ventilation separator outlet connector.
4. Using a torque wrench, tighten the screws according to specification.
5. If turbocharger connection is required, assemble the outlet hose on the turbocharger connector.
6. Using a torque wrench, tighten the screws according to specification.
7. Assemble the inlet hose on the ventilation separator inlet and valve cover outlet connectors.
8. Using a torque wrench, tighten the screws according to specification.

Alternator and Refrigerant Compressor Installation

[271 CB, 264 DP]

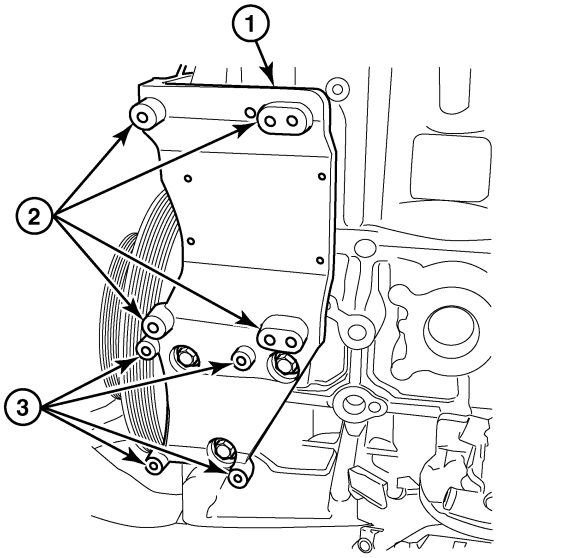


Figure 365 — Alternator and Refrigerant Compressor Mounting

1. Mounting Bracket 2. Alternator Mounting Pads	3. Refrigerant Compressor Mounting Pads

1. Assemble the alternator and refrigerant compressor mounting bracket on the cylinder block.
2. Using a torque wrench, tighten the screws according to specification.
3. If removed, assemble the belt tension idler on the bracket.
4. Using a torque wrench, tighten the screws according to specification.
5. Install the alternator on the mounting pads.
6. Using a torque wrench, tighten the screws according to specification.
7. Install the refrigerant compressor on the mounting pads.
8. Using a torque wrench, tighten the screws according to specification.
9. Securely connect the electrical wiring as tagged during disassembly.
10. Assemble the refrigerant lines on the compressor.
11. Assemble the belt pulleys on the alternator and compressor hubs.

Crankshaft Vibration Damper and Fan Pulley Installation

[212 RB, 216 1A]

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

SERVICE HINT

The spring-loaded idler brackets do not require adjustment.

⚠ 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 deteriorates the dampening effect of the damper.

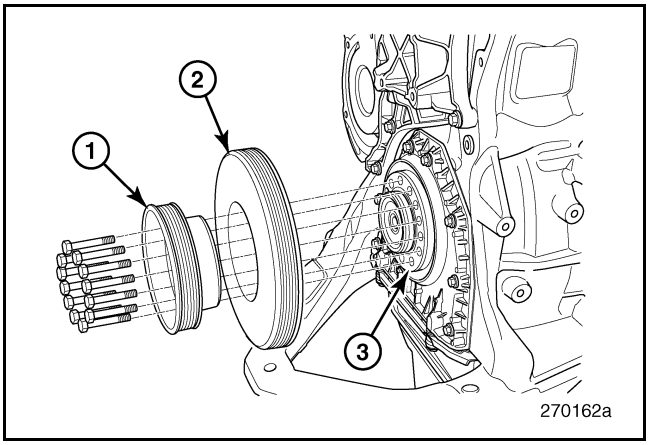


Figure 366 — Fan Drive Pulley and Crankshaft Damper Assembly

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

1. Assemble the crankshaft vibration damper and fan pulley on the crankshaft hub.
2. Using a torque wrench, tighten the attaching screws in sequence in two steps according to specification.
3. Install the Front Engine Power Take-Off (FEPTO) if equipped. Tighten the attaching screws in sequence in two steps according to specification.

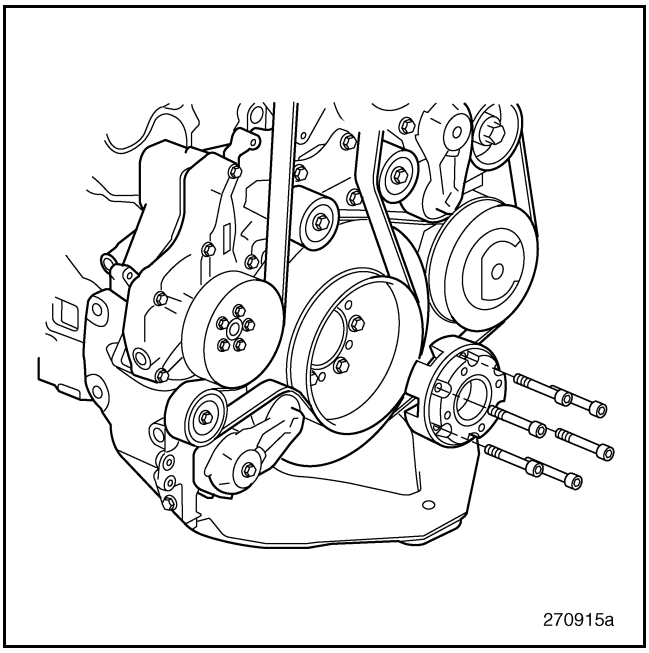


Figure 367 — Front Engine Power Take-Off (FEPTO) Assembly

Wiring Harness Installation

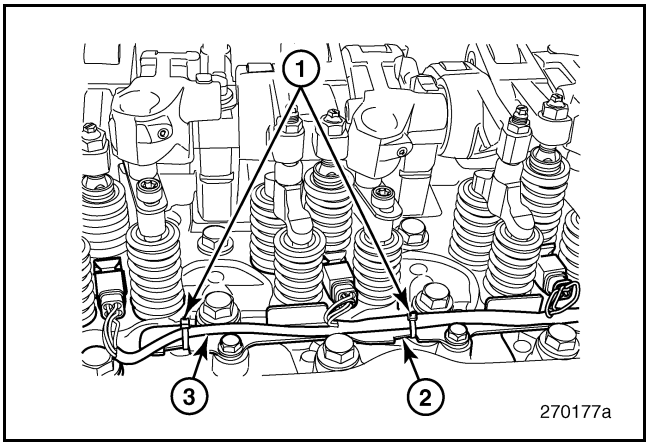


Figure 368 — Internal Wiring Harness

1. Tie Straps 2. Tie Bar Notch	3. Wiring Harness

1. Insert the unit injector portion of the harness through the hole in the timing gear cover.
2. Connect the harness to each unit injector.
3. Connect the harness to the engine brake control valve if installed.
4. Using high temperature wire ties, 983472, attach the harness to the tie bar.
5. Carefully route the wiring harness over the engine brake control valve. Position the harness **to the side of the boss** at the top of the valve assembly. Secure the harness to the control valve and harness bracket in four locations (see Figure 369).

⚠ 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 control valve and the cylinder head 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.

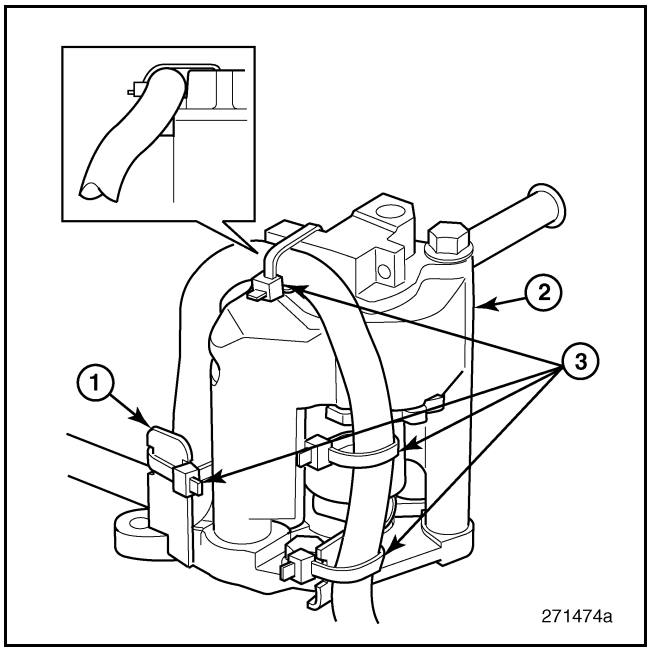


Figure 369 — Harness Routing Over Engine Brake Control Valve

1. Harness Bracket 2. Engine Brake Control Valve	3. Tie Straps

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.

1. Attach and lock the two end connectors to the EECU if installed.
2. Connect the various terminals as tagged at disassembly.
3. Attach the clamps to hold the harness on the cylinder block.

Cylinder Head (Valve) Cover Installation

[211 JB]

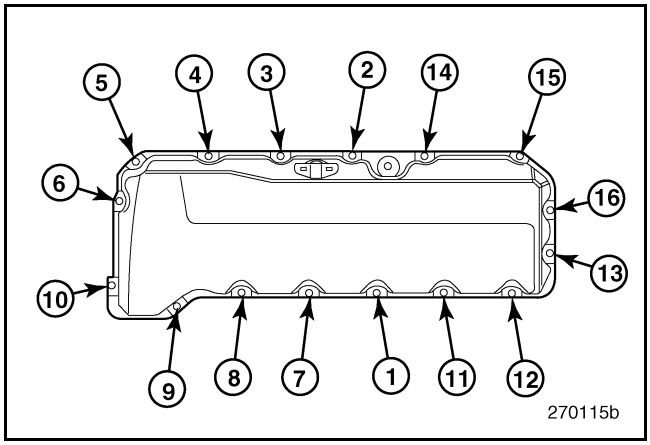


Figure 370 — Engine — Top View

1. Ensure that the cylinder head (valve) cover gasket groove is clean and the gasket is correctly oriented and fully seated in the groove prior to installation of the cover.
2. Install the cover on the cylinder head.
3. Using a torque wrench, tighten the attaching screws in sequence according to specification.
4. Install the pressure sensor on the cylinder head cover.
5. Using a torque wrench, tighten the sensor according to specification.

Removing Engine from Engine Stand

[200 EB]

⚠ CAUTION

The engine is extremely heavy. Make certain the lifting device and hoist are of sufficient capacity to bear the weight. It is necessary to have an assistant help maneuver the engine during removal and installation. Failure to heed this caution may result in serious personal injury and damage to the engine.

1. Attach a suitable lifting device to lifting points on the engine.
2. Position and attach an engine hoist to the lifting device. Operate the hoist to place tension on the lifting device.
3. With the lifting device supporting the engine weight, remove the mounting screws 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.

1. If not already done, assemble the following components on the engine using the procedures covered earlier in this section:
   - Venturi housing and mixer inlet tubing
   - EECU and cooling plate
   - Fuel filter housing and fuel lines
   - Crankcase ventilation tubing
   - Crankcase ventilation separator

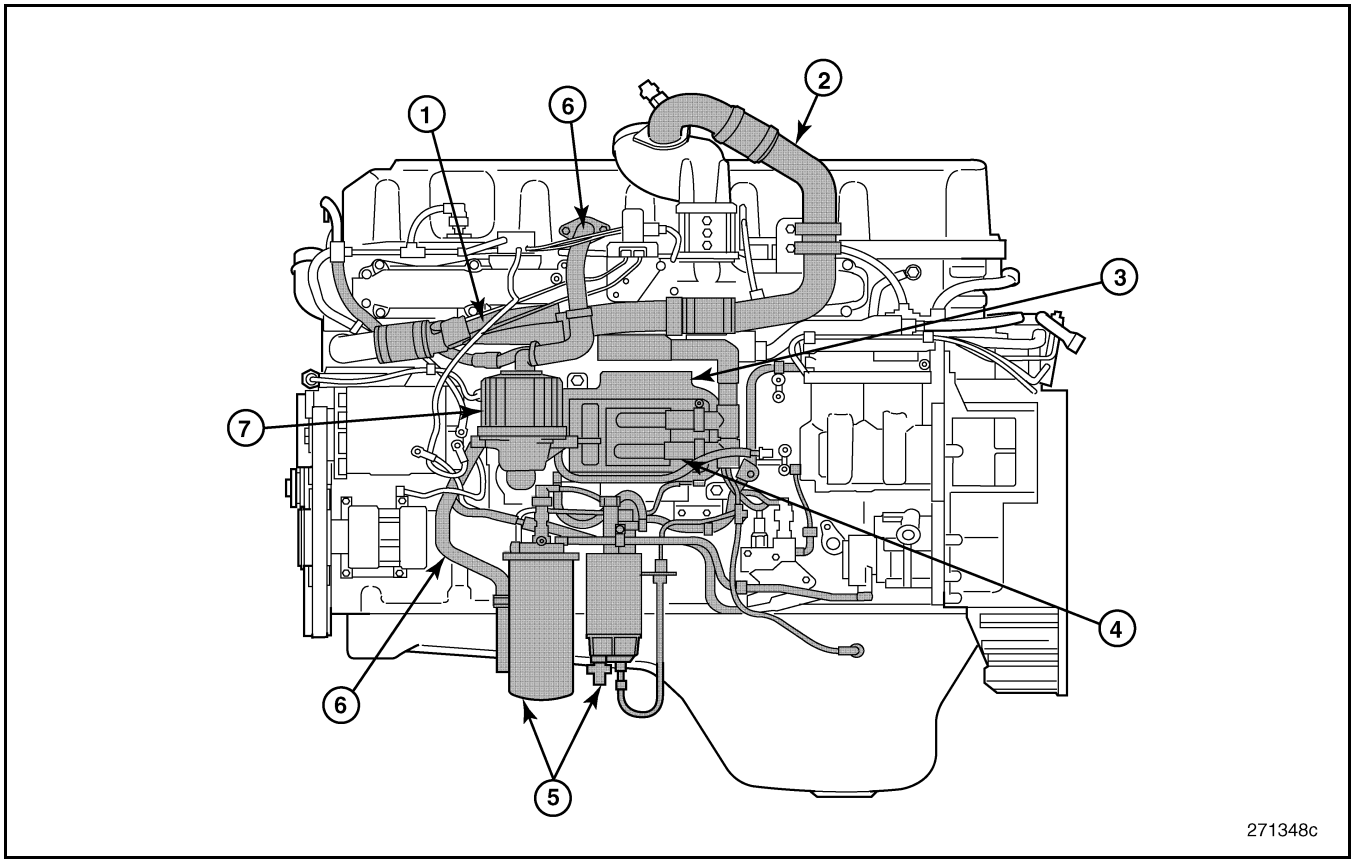


Figure 371 — Components for Installation After Removal from Repair Stand

1. Venturi Housing 2. EGR Mixer Inlet Tubing 3. EECU Cooler 4. EECU	5. Fuel Filters 6. Crankcase Ventilation Tubing 7. Crankcase Ventilation Separator

2. Pre-fill each **new** full-flow oil filter with 1.9L (2 quarts) of the recommended engine oil. Apply a thin film of clean engine oil to the sealing gasket of the new filters. Install the full-flow filters and tighten an additional 3/4 to 1 turn after the gasket contacts the base. DO NOT allow any contaminants to enter the filters while pre-filling.

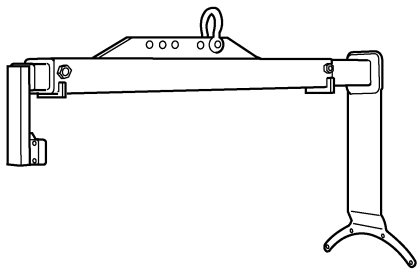
NOTE

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.

3. Pre-fill a **new** bypass oil filter with 1.9L (2 quarts) of the recommended engine oil. Apply a thin film of recommended engine oil to the sealing gasket of the new filters. Install the bypass filter and tighten an additional 3/4 to 1 turn after the gasket contacts the base. DO NOT allow any contaminants to enter the filters while pre-filling.
4. Apply a thin film of clean engine oil or coolant to the sealing gasket of the **new** coolant filter. Install the coolant filter and tighten an additional 3/4 to 1 turn after the gasket contacts the base.

ENGINE INSTALLATION

Special Tools

Tool No.	Description	Image
J 47038-3 J 47038-4 J 47038-6 J 47038-7	Engine Lifting Tool (Essential)	 273530a

General Instructions

Details of the engine installation procedure vary from one vehicle to another. This section provides general guidelines for installing an MP7 engine in 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 during installation. 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 the engine 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. Attach the engine lifting tool, J 47038, to the engine. Secure the engine lifting tool to the front of the fan bracket 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.

2. Using the engine lifting tool, J 47038, and the aid of a helper, lift and lower the engine into position.

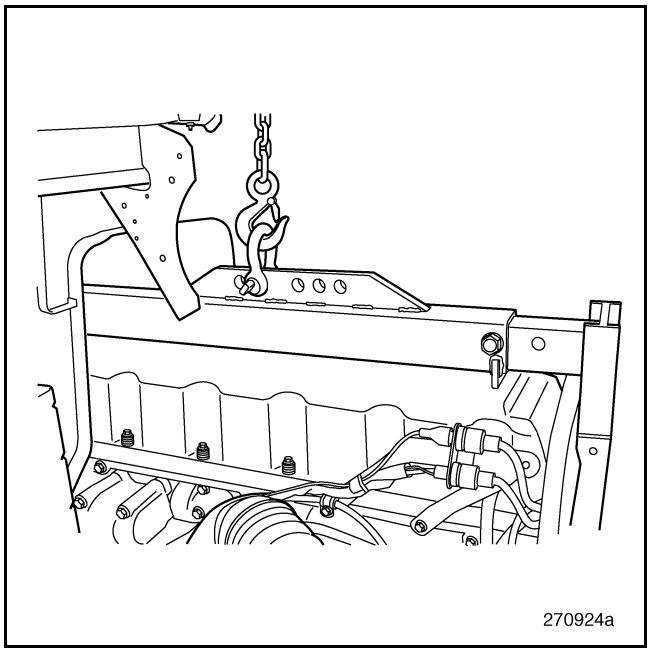


Figure 372 — Engine Installation

3. Align the engine with the transmission.
4. Install and, using a torque wrench, tighten the rear engine support attaching screws according to specification.
5. Install and, using a torque wrench, tighten the front engine support attaching screw according to specification.
6. Remove the engine lifting tool from the engine.
7. Install the transmission and, using a torque wrench, tighten the transmission attaching screws according to specification.
8. Withdraw the transmission jack.
9. As applicable:
   a. If manual transmission, attach the clutch linkage, shift linkage and bracket retaining screws.
   b. If automatic transmission, attach the torque converter access panel and torque converter.
10. Attach the hood rest crossmember if applicable.
11. Connect the starter wires and cables.
12. Attach the power steering hoses and reservoir if applicable.
13. Attach the exhaust system brackets.
14. Attach the exhaust system to the turbocharger.
15. Connect the air line to the discharge recirculation valve (DRV).
16. Connect the coolant lines, fuel line and wiring harness lead to the aftertreatment fuel injector (AFI).

⚠ WARNING

The radiator and charge air cooler assembly is heavy and difficult to handle. Use a suitable lifting device and a helper to support the assembly safely during installation. Failure to heed this warning may result in severe personal injury.

17. Attach the radiator and charge air cooler assembly.
18. 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.

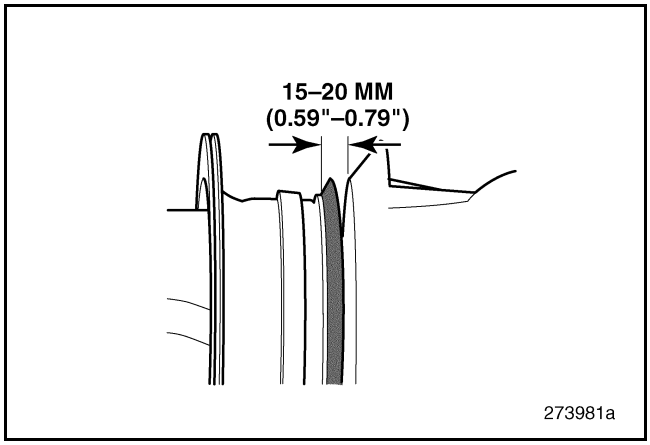


Figure 373 — Fan Ring-to-Shroud Clearance

19. Connect the fan actuator.
20. Connect the engine coolant temperature sensor.
21. Attach the charge air cooler outlet components.
22. Attach the charge air cooler inlet components.
23. Attach the coolant expansion tank.
24. Attach the lower radiator tube.
25. Connect the cab heater and fuel heater coolant return lines to the lower radiator tube.
26. Attach the upper radiator tube.
27. 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.
28. Install the inlet air system components including the filter.
29. Connect the inlet air heater if present.
30. Attach the oil, fuel and coolant filters.
31. Close all drains and drain valves.
32. Connect all sensors and actuators.
33. Install the drive belts.
34. 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:

- OIL PUMP REPLACEMENT (IN CHASSIS)
- CRANKCASE VENTILATION (CCV) SEPARATOR REPLACEMENT
- TURBOCHARGER SMART REMOTE ACTUATOR REPLACEMENT
- UNIT INJECTOR CLEANING
- INJECTOR COPPER SLEEVE REPLACEMENT
- 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.

OIL PUMP REPLACEMENT (IN CHASSIS) [219 MU]

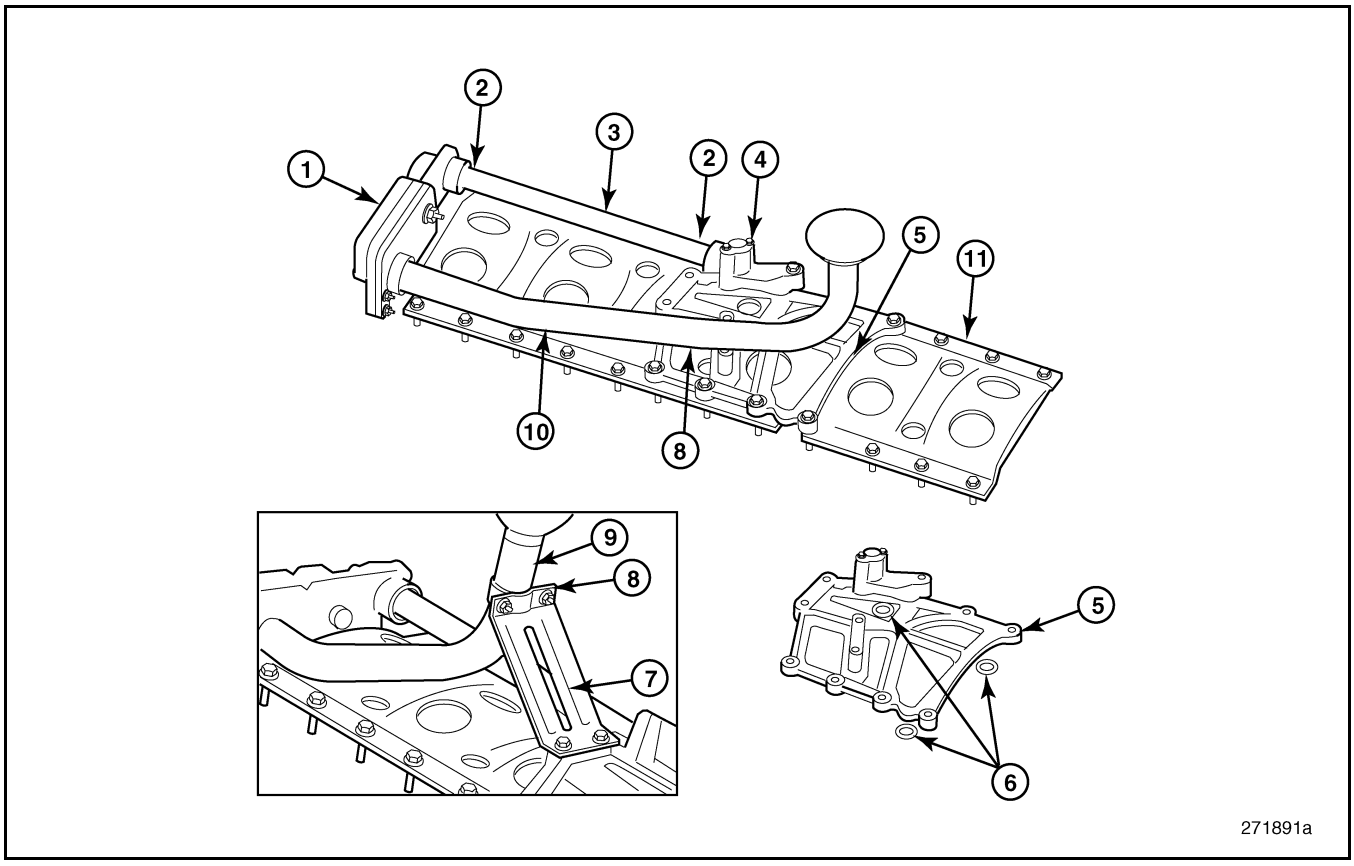


Figure 374 — Oil Pump Pickup and Valve Housing Assembly

1. Oil Pump	7. Bracket
2. Seal Ring	8. Clamp
3. Pressure Side Pipe	9. Strainer and Inlet Pipe — Rear Sump
4. Safety Valve	10. Strainer and Inlet Pipe — Front Sump
5. Valve Housing Assembly	11. Block Stiffener Plate
6. Seal Rings	

Oil Pump Removal

The short oil pump inlet tube included with the rear sump oil pan is clamped by a strap to a bracket that extends from the valve housing assembly. The long tube with the front sump oil pan is clamped to the valve housing assembly by a strap.

1. If not already done, remove the oil pan.
2. Remove the pump inlet pipe and strainer.
3. Remove and discard the seal ring.

NOTE

The pressure side pipe is held in place because it slips into openings in the pump and valve housing.

4. Remove the valve housing.
5. Remove and discard the seal rings.
6. Remove the pressure side pipe.
7. Remove and discard the seal rings.
8. Remove the block stiffener plate.

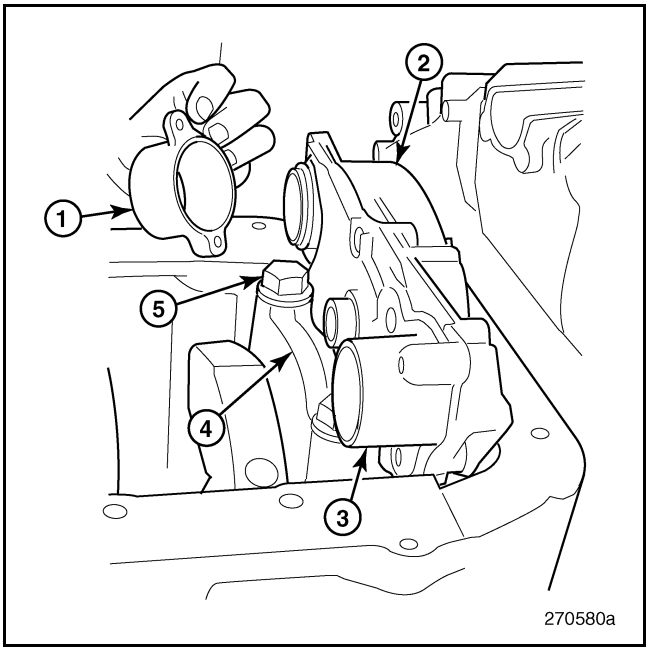


Figure 375 — Oil Pump, Flanges and Main Bearing Cap

1. Inlet Flange 2. Oil Pump Housing 3. Outlet Flange	4. No. 7 Main Bearing Cap 5. Bearing Cap Attaching Screw

SERVICE HINT

Use a very short Torx® bit to access the screws for the flange adapters in order to fit the wrench, bit holder and bit between the flywheel housing and the screws.

9. Remove the inlet flange adapter.
10. Remove the outlet flange adapter.
11. Remove the No. 7 main bearing cap with the oil pump from the cylinder block.
12. Remove the oil pump from the bearing cap.

Oil Pump Installation

1. Attach the oil pump to the No. 7 main bearing cap.

⚠ 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.

2. Using a torque wrench, tighten the screws according to specification.
3. Attach the bearing cap to the cylinder block.
4. Using a torque wrench, tighten the screws according to specification.
5. Attach the outlet flange adapter to the oil pump housing.
6. Attach the inlet flange adapter to the oil pump housing.
7. Using a torque wrench, tighten the screws according to specification.
8. Attach the block stiffener plate to the cylinder block.
9. Using a torque wrench, tighten the screws in sequence according to specification.
10. Lubricate and assemble **new** seal rings on the inlet and pressure side pipes.
11. Assemble the pressure side pipe in the oil pump housing.

NOTE

Ensure that the three valve housing seal rings are properly placed when mounting the housing on the cylinder block.

12. Inserting the pressure side pipe and assemble the valve housing on the cylinder block.
13. Using a torque wrench, tighten the screws in sequence according to specification.
14. Assemble the inlet pipe in the oil pump housing.
15. Depending on usage:
    - Attach the short pipe and strainer to the bracket.
    - Attach the long pipe and strainer to the valve housing assembly.
16. Using a torque wrench, tighten the screws according to specification.
17. Lubricate and assemble a **new** seal on the oil pan.
18. Attach the oil pan to the cylinder block.
19. Using a torque wrench, tighten the screws in sequence according to specification.

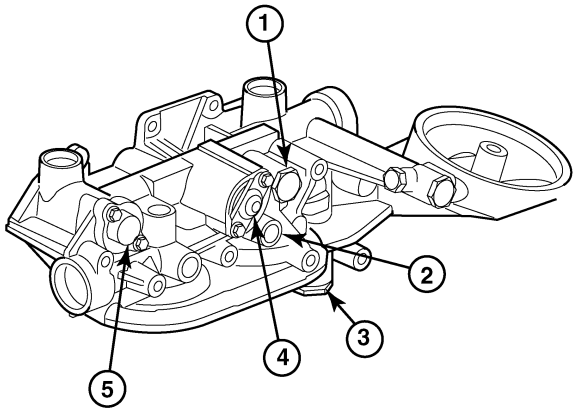


Figure 376 — Oil Filter Housing

1. Full-Flow Filter By-Pass Valve	3. Piston Cooling Valve
2. Oil Pressure Sensor Port (M18 Thread)	4. Main Oil Gallery Regulator Valve
	5. Oil Cooler By-Pass Valve

20. Using a tee fitting with the pressure sensor, check system oil pressure through the pressure sensor port (M18) in the oil filter housing.

NOTE

The engine will shut down if operation is attempted without the pressure sensor.

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.

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.

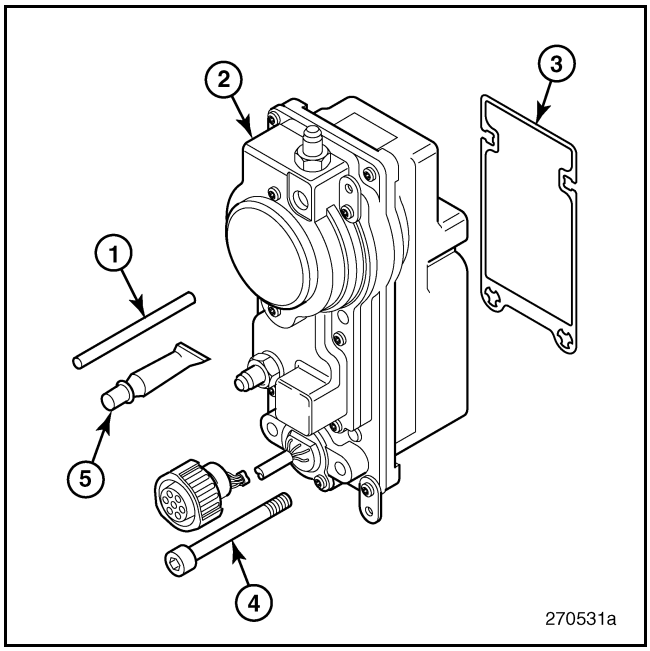


Figure 377 — Turbocharger SRA — Exploded View

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.

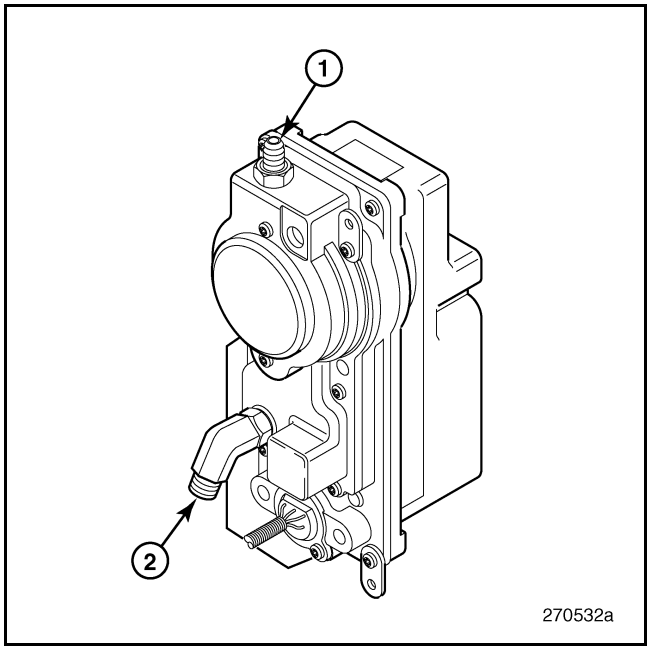


Figure 378 — SRA Coolant Connections

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.

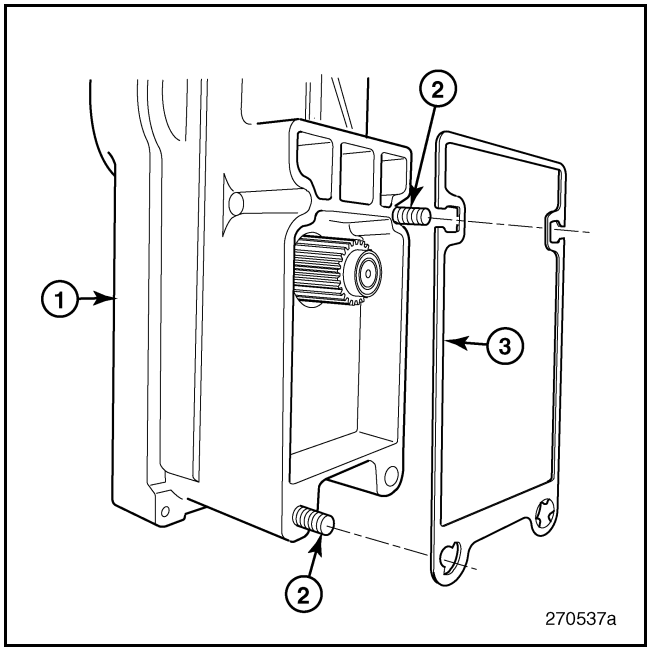


Figure 379 — SRA Mounting Surface

1. SRA Housing 2. Attaching Screws	3. Gasket

10. Clean the actuator drive gear with a lint-free cloth.

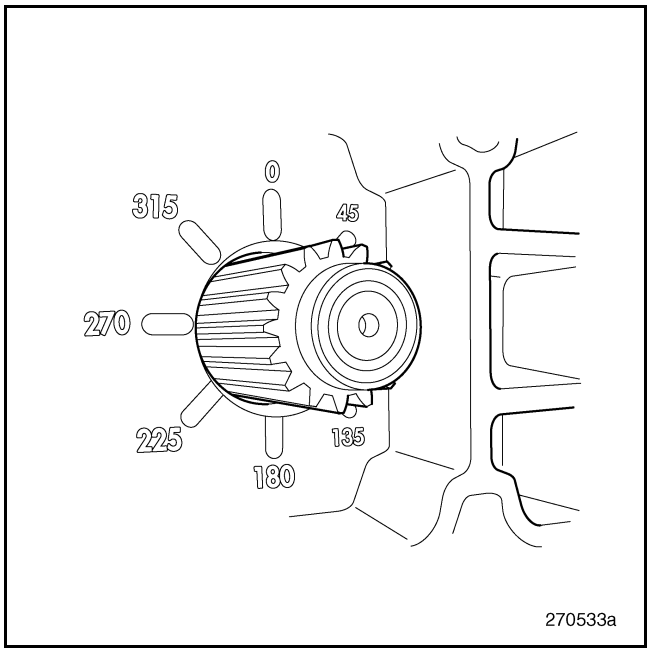


Figure 380 — SRA Drive Gear

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).

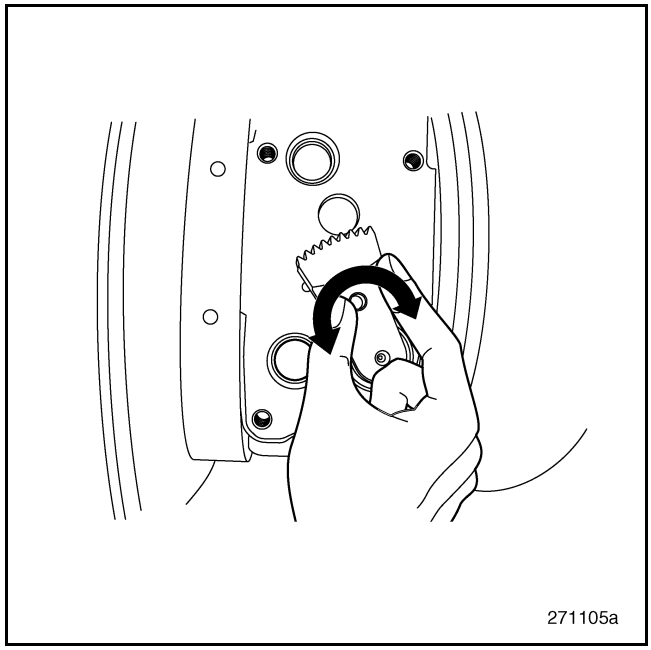


Figure 381 — Rotating the Sector Gear

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.

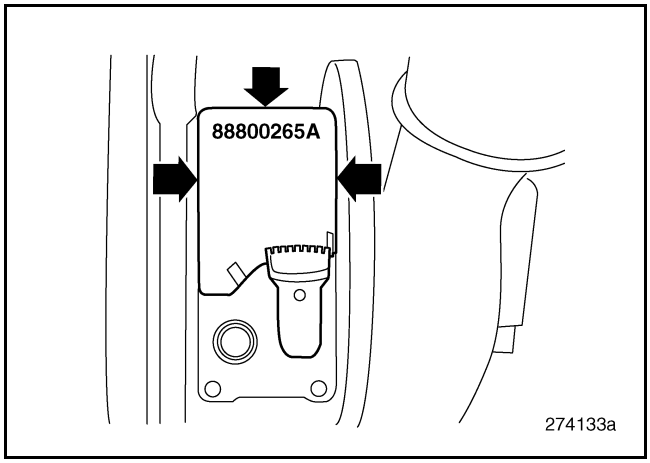


Figure 382 — Sector Gear Alignment Gauge

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.

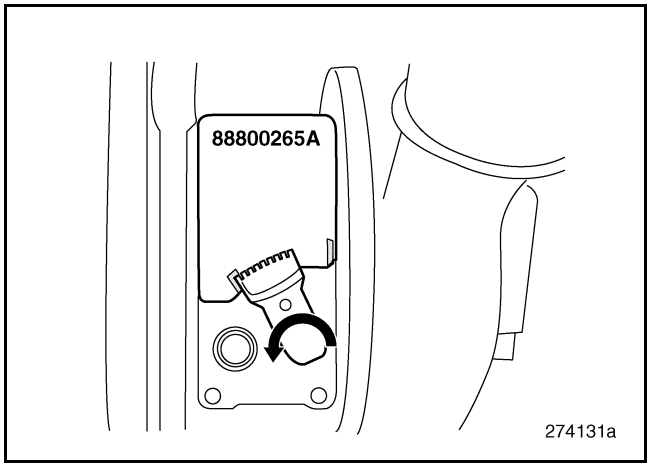


Figure 383 — Gear Rotated Counterclockwise

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.

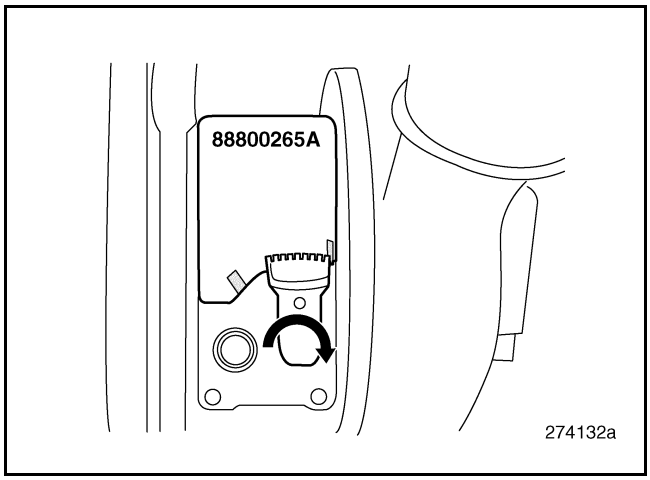


Figure 384 — Gear Rotated Clockwise

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.

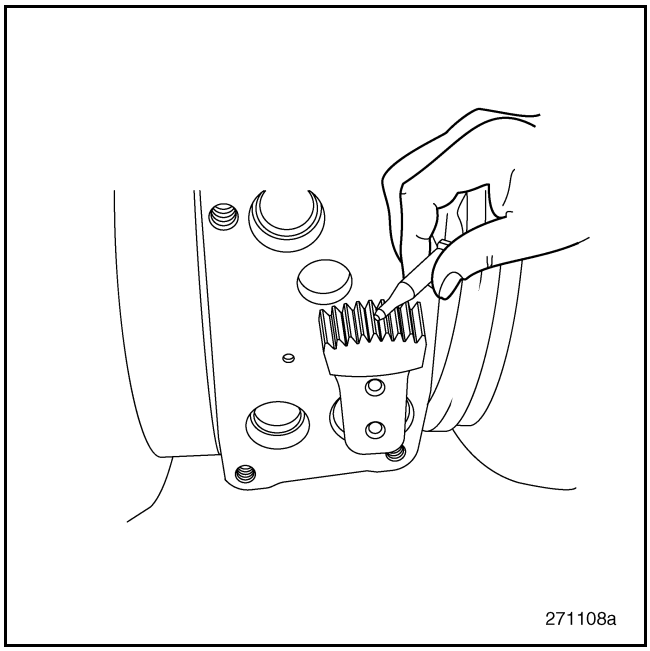


Figure 385 — Lubricating Sector Gear Teeth

6. Carefully remove the alignment pin, taking care not to move the sector gear.

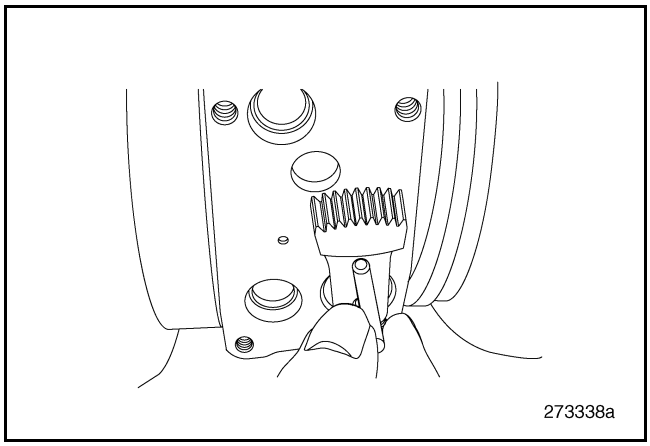


Figure 386 — Removing Alignment Pin

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.

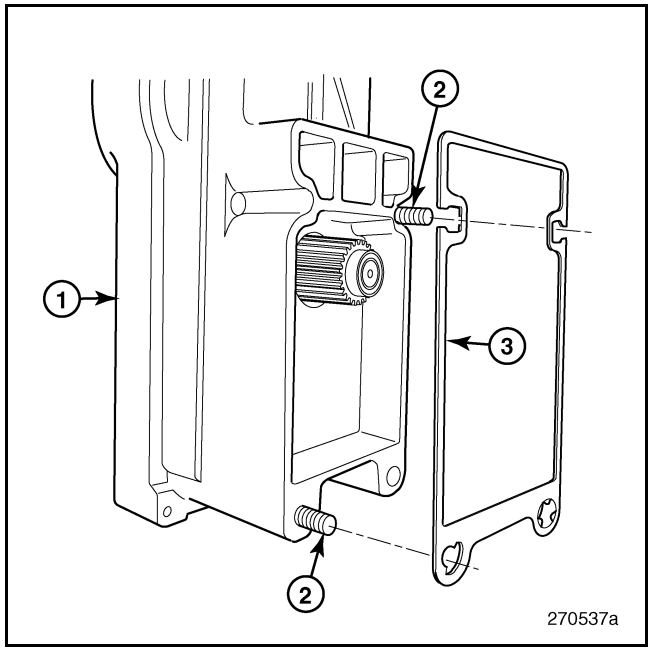


Figure 387 — Attaching SRA to Turbocharger

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.

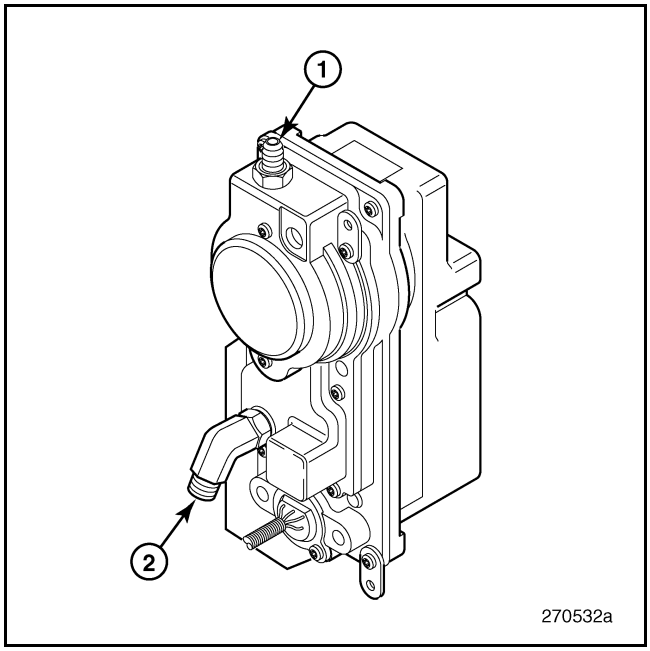


Figure 388 — SRA Coolant Connections

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 a sealing plug, 9998251, into the unit injector bore of the cylinder head to prevent dirt and debris from entering the bore.

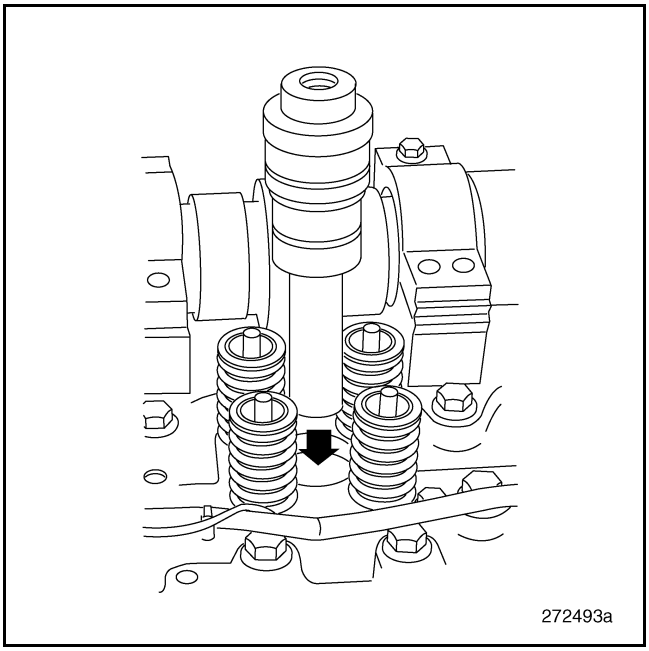


Figure 389 — Installing Injector Bore Sealing Plug, 9998251

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.

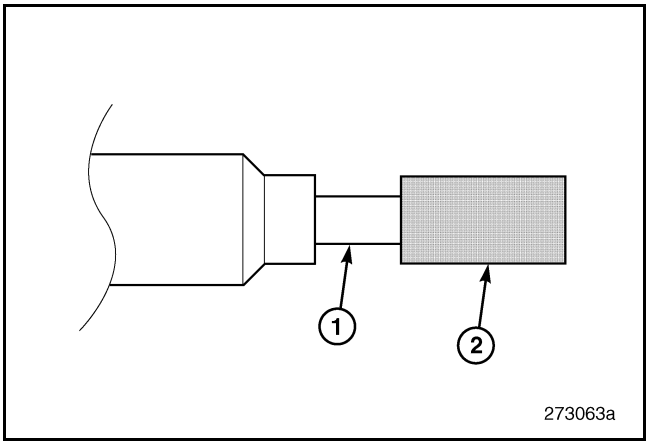


Figure 390 — Injector Nozzle Tip Cover

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.

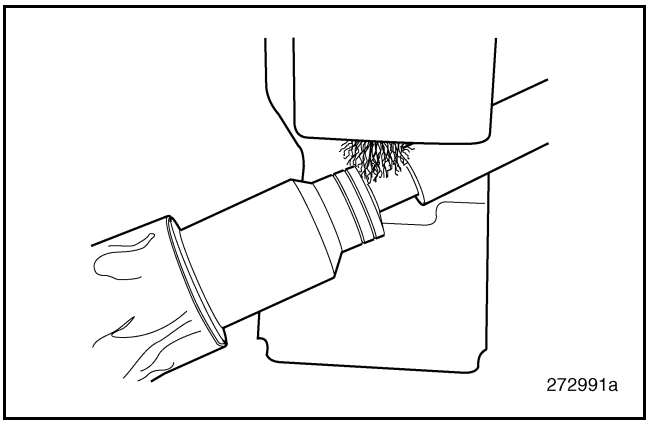


Figure 391 — Cleaning Injector Cap Nut Seat Surface

⚠ 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 along with a **new** sealing washer on the injector.
9. Lubricate the injector O-rings with clean engine oil.

Final Steps

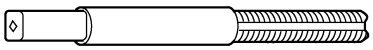
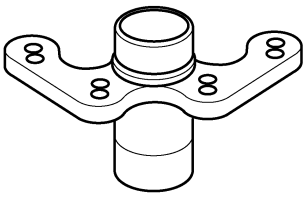
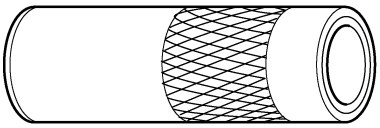
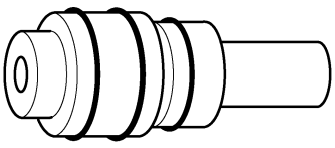
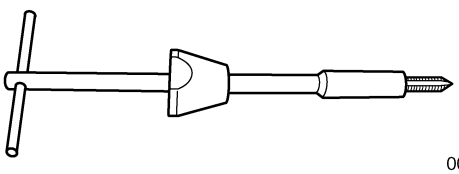
Install the following components on the engine (see ENGINE REASSEMBLY for procedures):

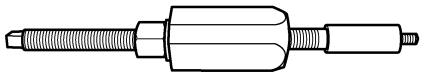
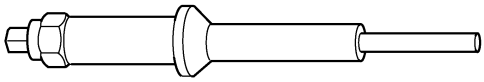
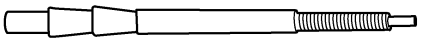
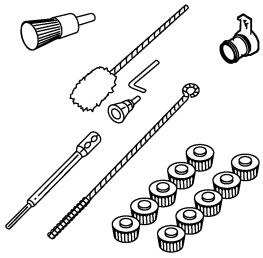
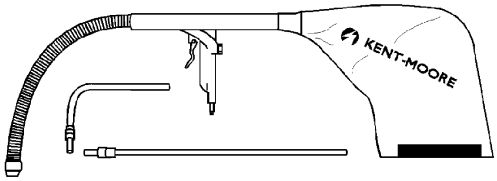
- Unit Injectors
- Rocker Arm Shaft Assembly
- Cylinder Head Cover

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
9996956	Flywheel Turning Tool (Essential)	 006795a
9998249	Unit Injector Protection Sleeve (Essential)	 006798a
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
88800196	Swaging Tool for Installing Unit Injector Copper Sleeve (Essential)	 006805a
88880010	Swaging Tip for Copper Sleeve Swaging Tool (Available Separately)	 006842a
J 42885	Unit Injector Bore Cleaning Kit (Essential)	 006926a
PT2900	Chip Vacuum	 006962a

Preliminary Steps

Remove the following components to gain 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.

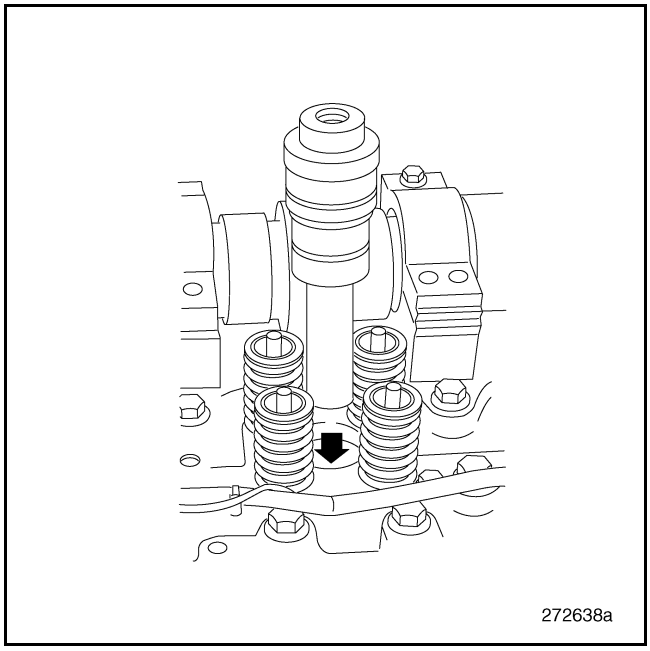


Figure 392 — Unit Injector Bore Protective Plug

2. Install two sealing rings to prevent dirt from entering the fuel gallery when the copper sleeve is removed.

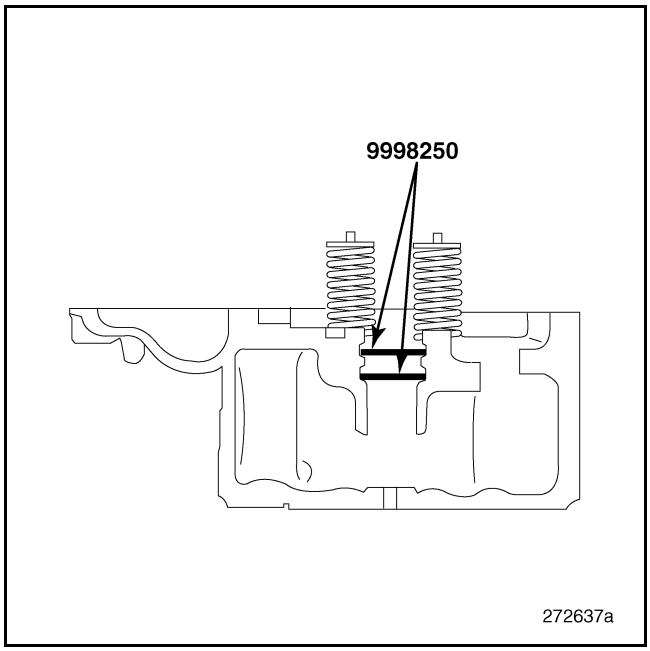


Figure 393 — Fuel Gallery Sealing Rings

NOTE

Two sealing rings are required to cover the fuel gallery.

3. Remove the access cover 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.

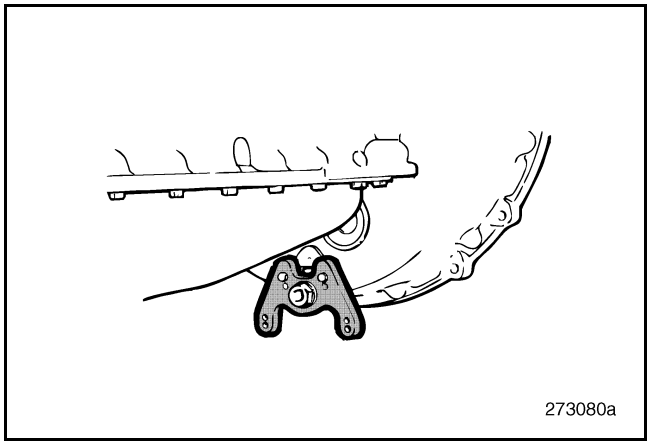


Figure 394 — Flywheel Turning Tool, Installed

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.

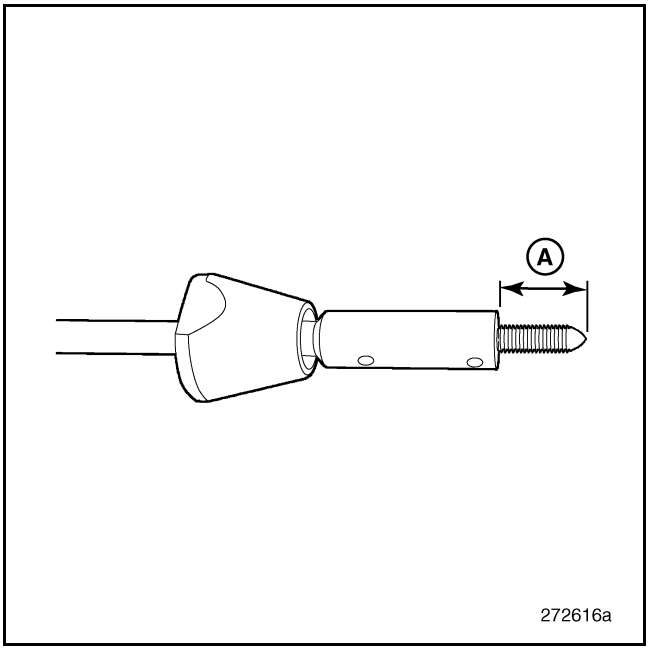


Figure 395 — Copper Sleeve Tapping Tool

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.

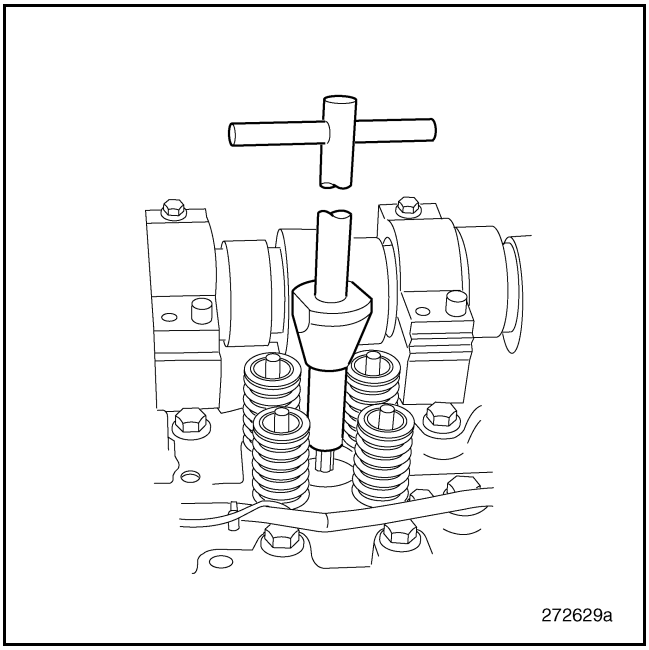


Figure 396 — Tapping Tool Installation

⚠ 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).

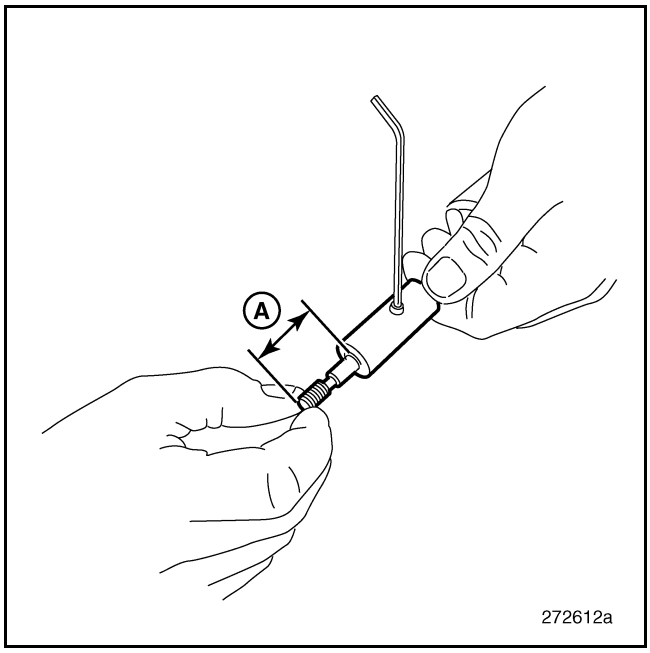


Figure 397 — Adjusting Copper Sleeve Extractor Bolt

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.

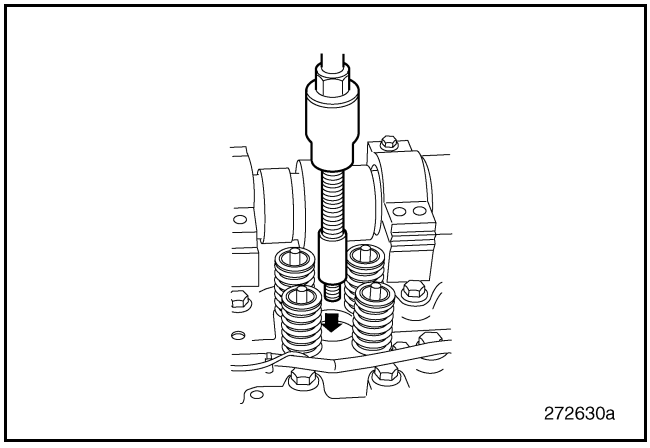


Figure 398 — Extractor Tool Installation

⚠ 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.

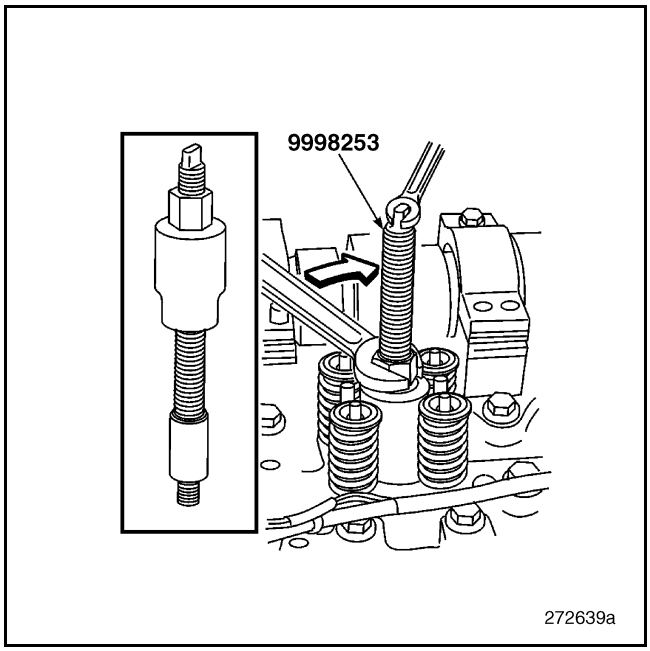


Figure 399 — Copper Sleeve Extraction

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.

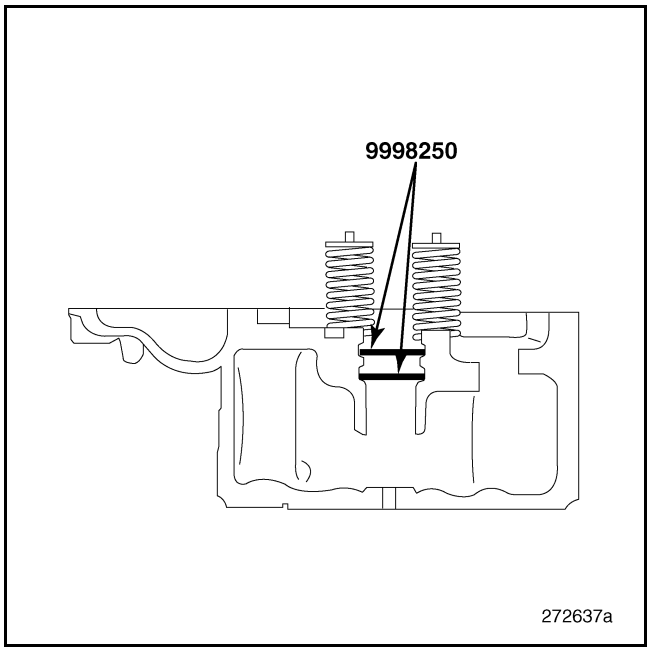


Figure 400 — Fuel Gallery Sealing Rings

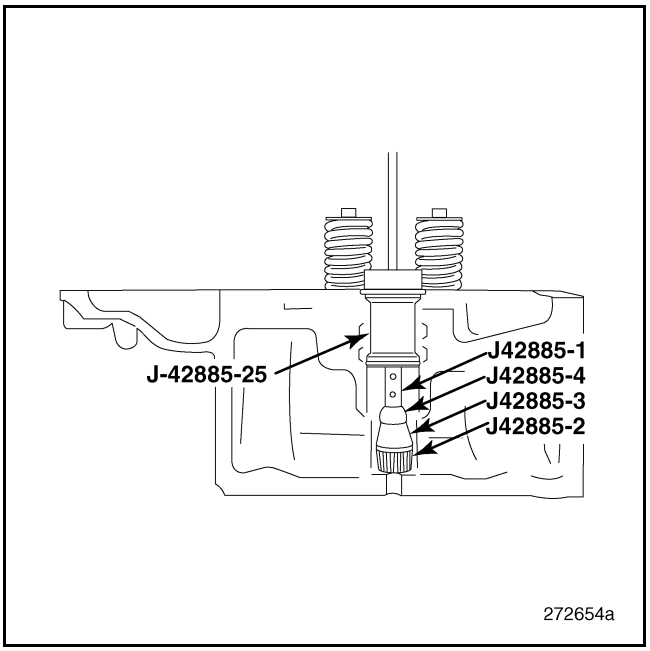


Figure 401 — Cleaning Copper Sleeve Seat

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.

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

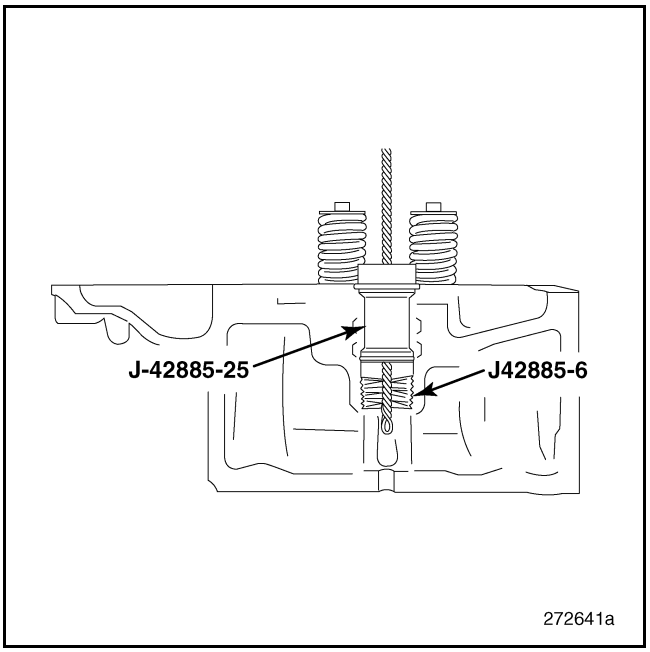


Figure 402 — Cleaning Copper Sleeve Bore Walls

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.

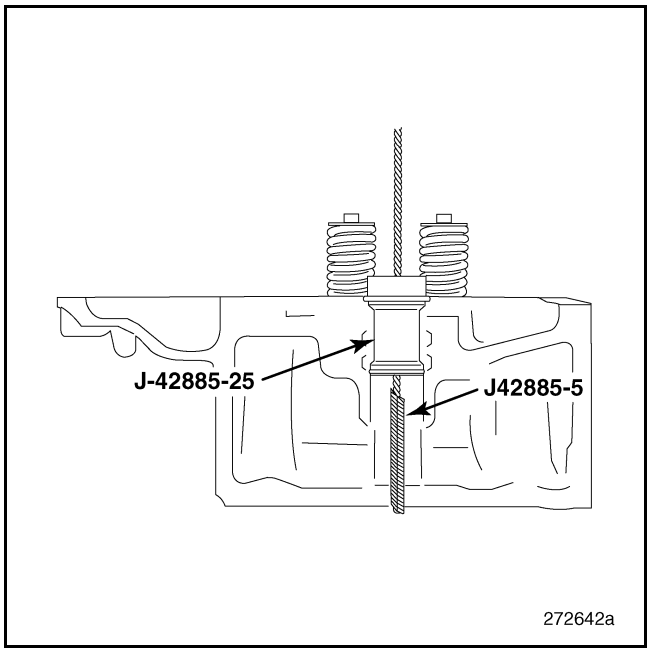


Figure 403 — Cleaning Injector Tip Bore

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.

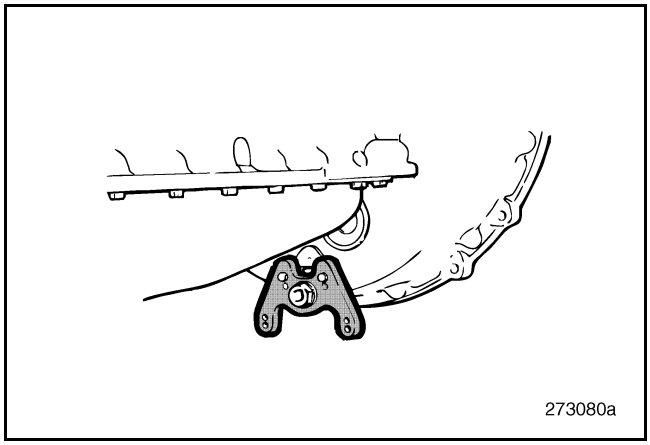


Figure 404 — Flywheel Turning Tool, Installed

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.

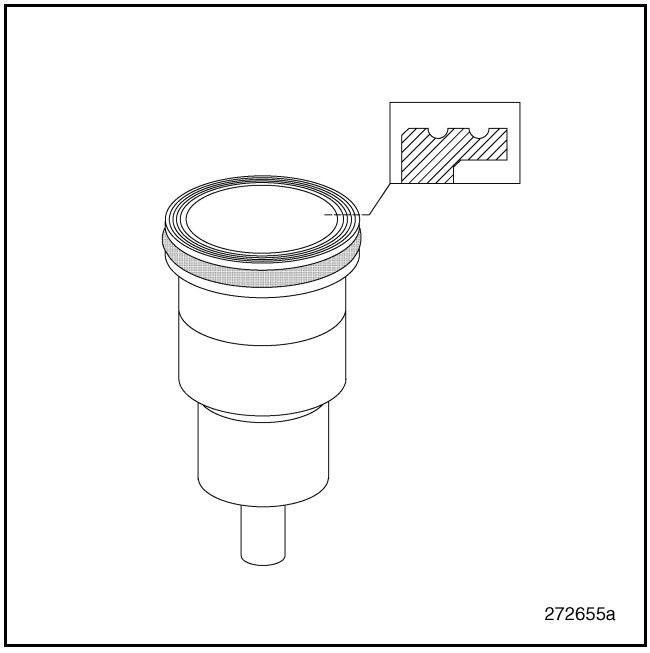


Figure 405 — Copper Sleeve Identification

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.

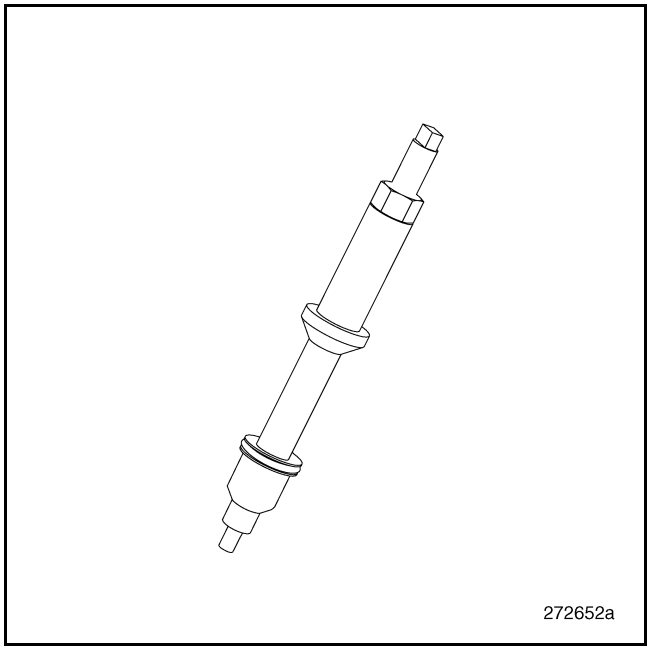


Figure 406 — Installation Tool Identification

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.

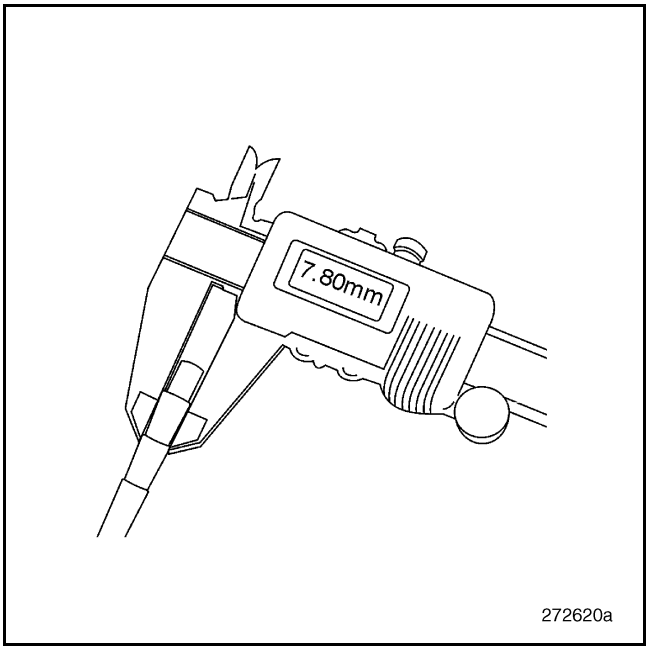


Figure 407 — Swaging Bit Verification

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.

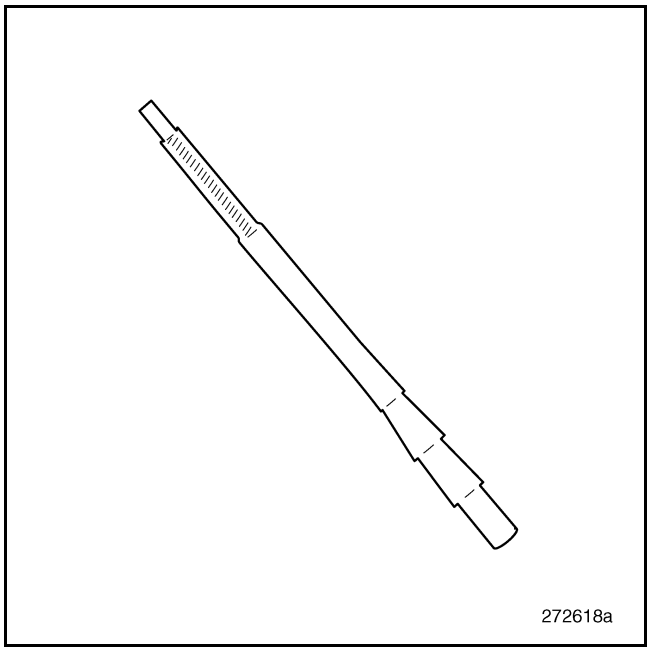


Figure 408 — Swaging Bit

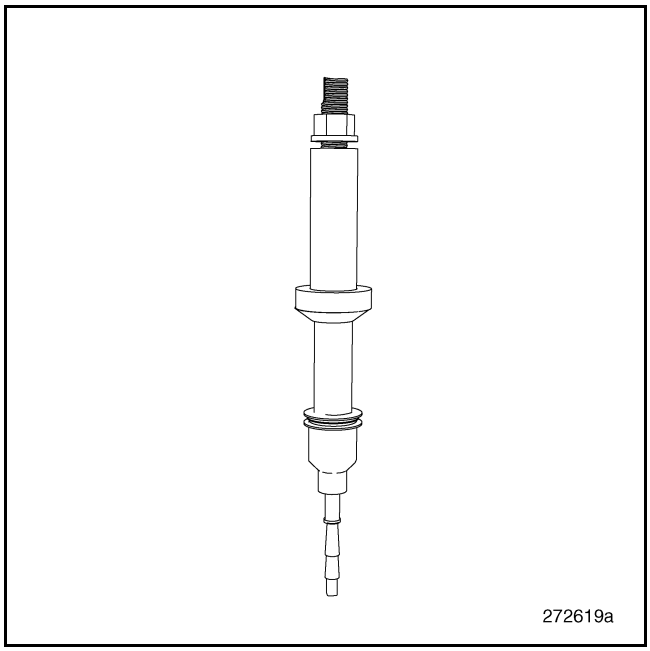


Figure 409 — Copper Sleeve Installation Tool

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.

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.

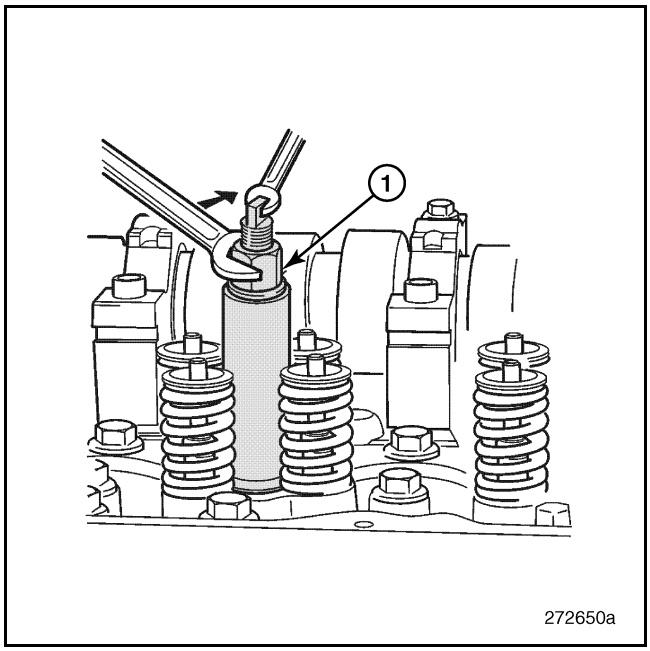


Figure 410 — Flaring Copper Sleeve Using Installation Tool

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.

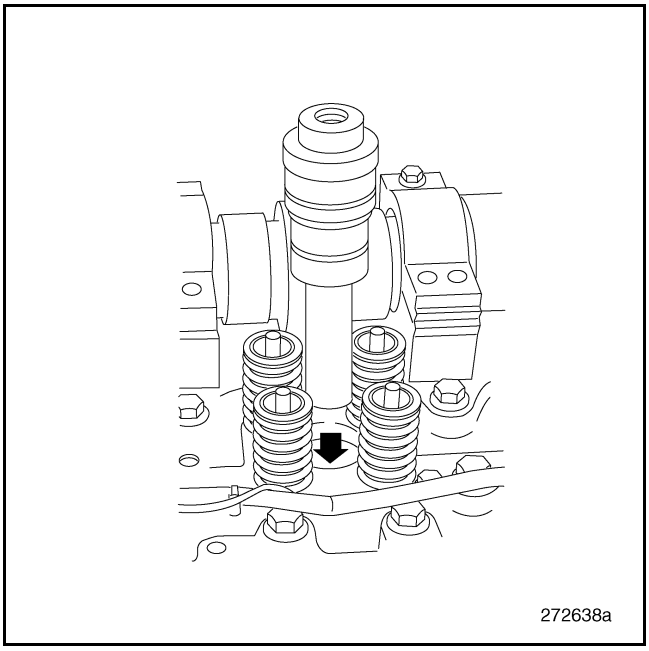


Figure 411 — Unit Injector Bore Sealing Plug

Final Steps

Install the following components after servicing the injector copper sleeves (see ENGINE REASSEMBLY for procedures):

- Unit Injector(s)
- 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.

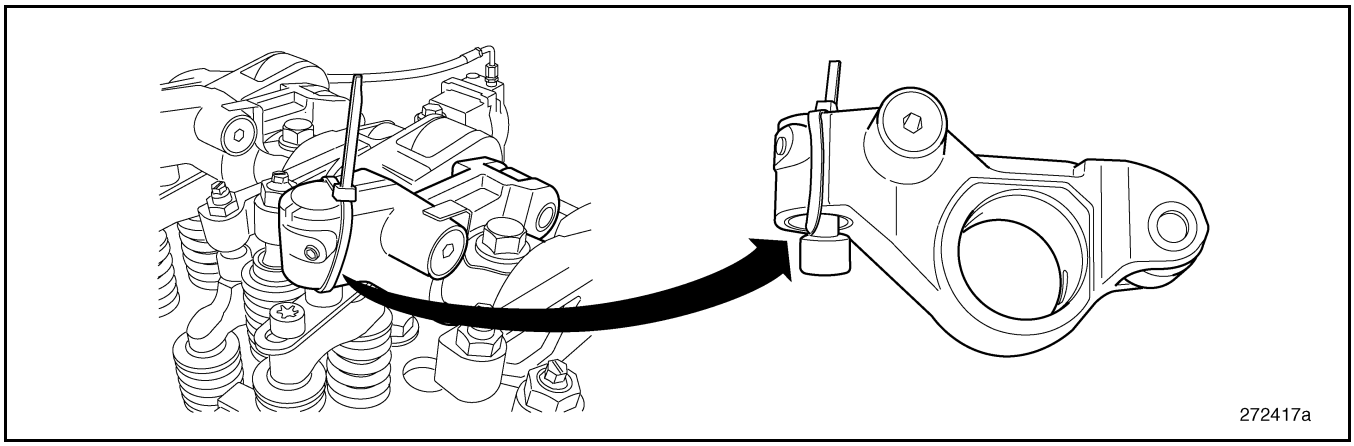


Figure 412 — Engine Brake Piston Retained

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.

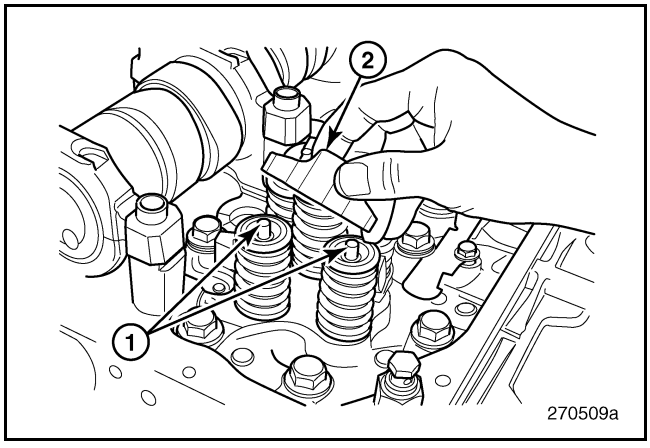


Figure 413 — Removing the Valve Yoke

1. Valve Stem Tips	2. 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.

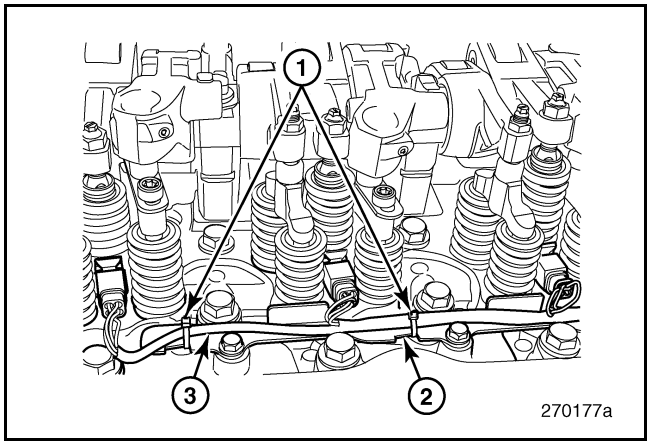


Figure 414 — Move Harness Tie Bar Outward

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.

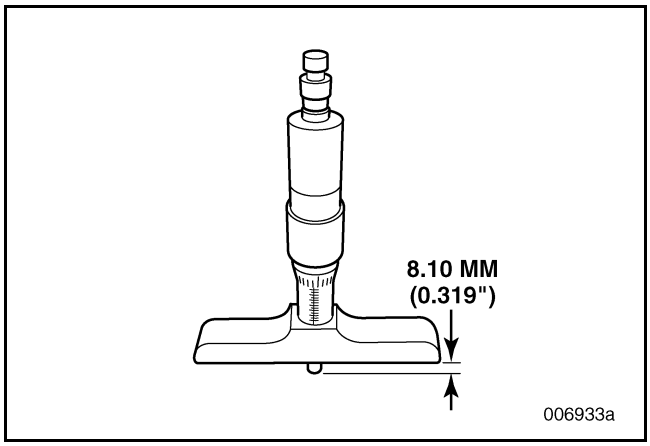


Figure 415 — Set Depth Micrometer

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.

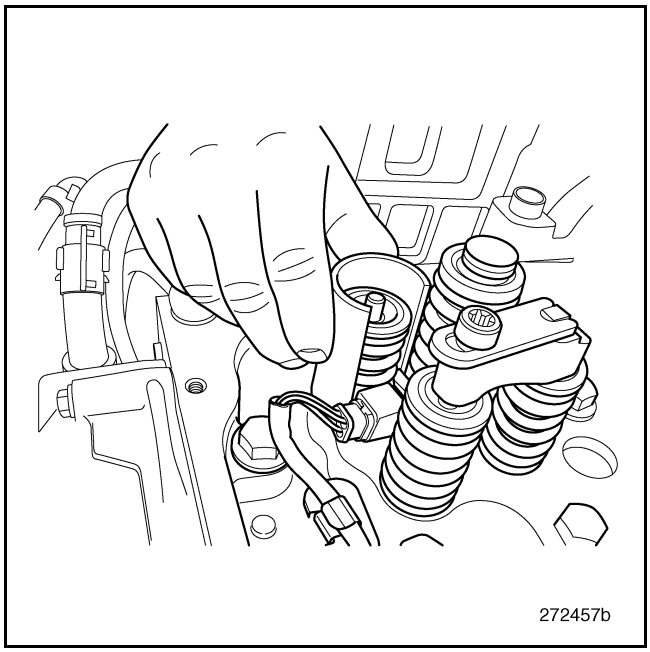


Figure 416 — Place Measurement Gauge over Valve Spring

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.

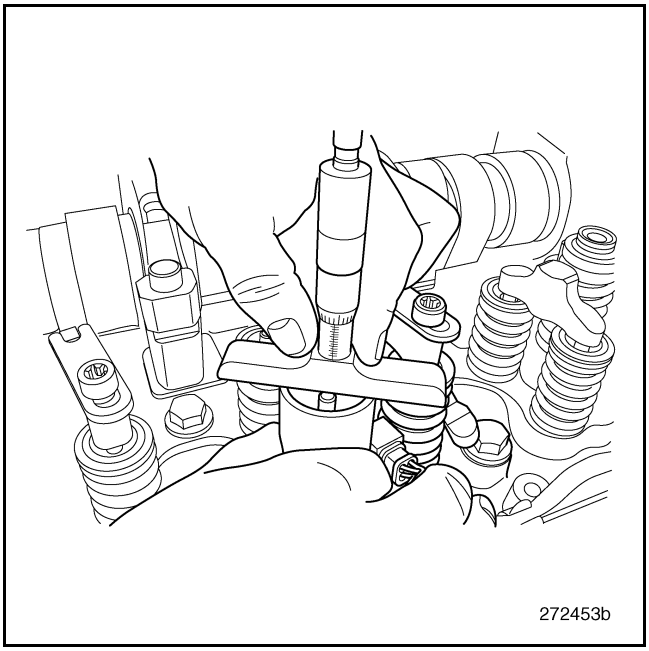


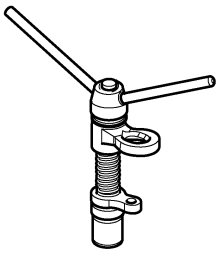
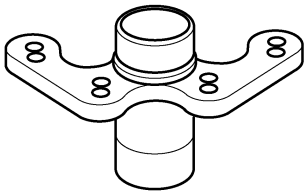
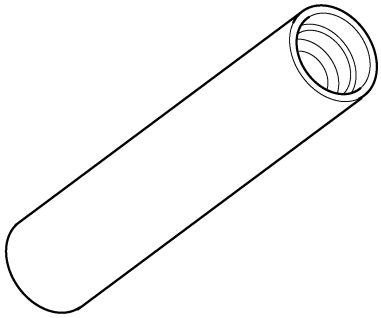
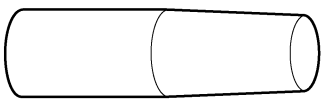
Figure 417 — Measuring Valve Stem Height

- 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 (refer to “Valve and Unit Injector Adjustment” on page 287).
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
9996956	Flywheel Turning Tool (Essential)	 006795a
85112460	Valve Stem Seal Installation Tool	 006966a
88800011	Valve Stem Seal Protection Tool (Essential)	 006773a

Preliminary Steps

Remove the following components to gain 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, 9996956, rotate the crankshaft so that the pistons are at TDC for the appropriate pair of cylinders where stem seals are being replaced.

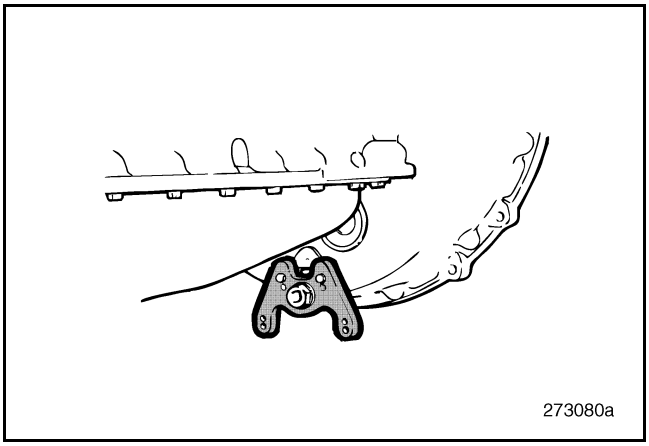


Figure 418 — Flywheel Turning Tool, Installed

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.

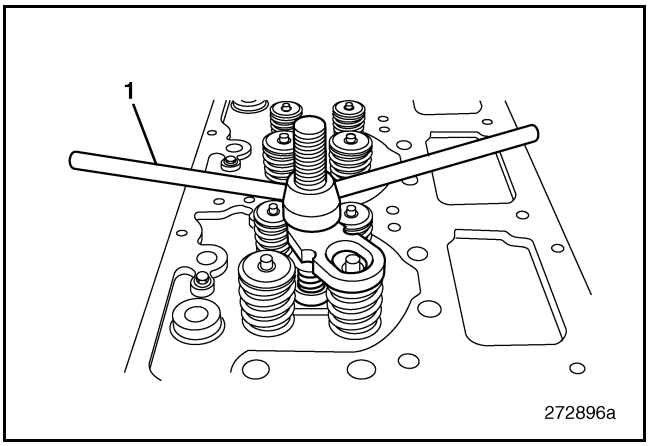


Figure 419 — Compressing Valve Springs

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. Place the seal protection tool, 88800011, in position on the valve stem.
2. Place a **new** valve stem seal in position over the protection tool and onto the valve stem.

NOTE

The valve stem seal must be dry when installed.

3. Using the seal installation tool, 85112460, seat the valve stem seal on the valve guide. Ensure that the seal is pressed all the way down so that the bottom of the seal is in full contact with the valve guide.

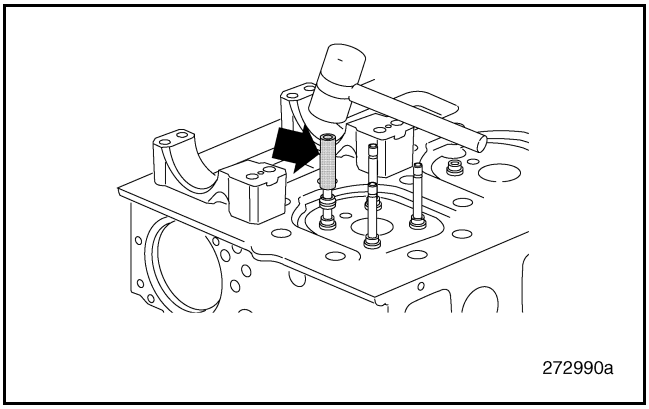


Figure 420 — Seating the Valve Stem Seal

4. 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.

5. 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

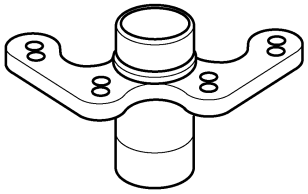
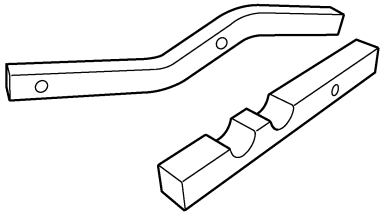
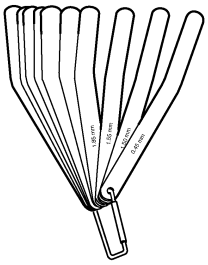
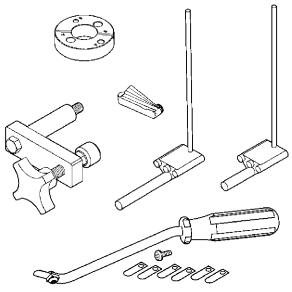
Install the following components that were removed for access to the valve stem seals (see ENGINE REASSEMBLY for procedures):

- Unit Injectors
- Rocker Arm Shaft Assembly
- Cylinder Head Cover

REPAIR INSTRUCTIONS, PART 3

MP7 ENGINE SETUP AND ADJUSTMENT [200 EA]

Special Tools

Tool No.	Description	Image
9996956	Flywheel Turning Tool (Essential)	 006795a
85109051 (A, B)	Timing Gear Cover Alignment Tools	 006831a
85111377	Feeler Gauge Set	 006844a
J 44514-B	Engine Timing Kit (Essential)	 006889a

General Information

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.

Valve and Unit Injector Adjustment

[213 NB, 222 KG]

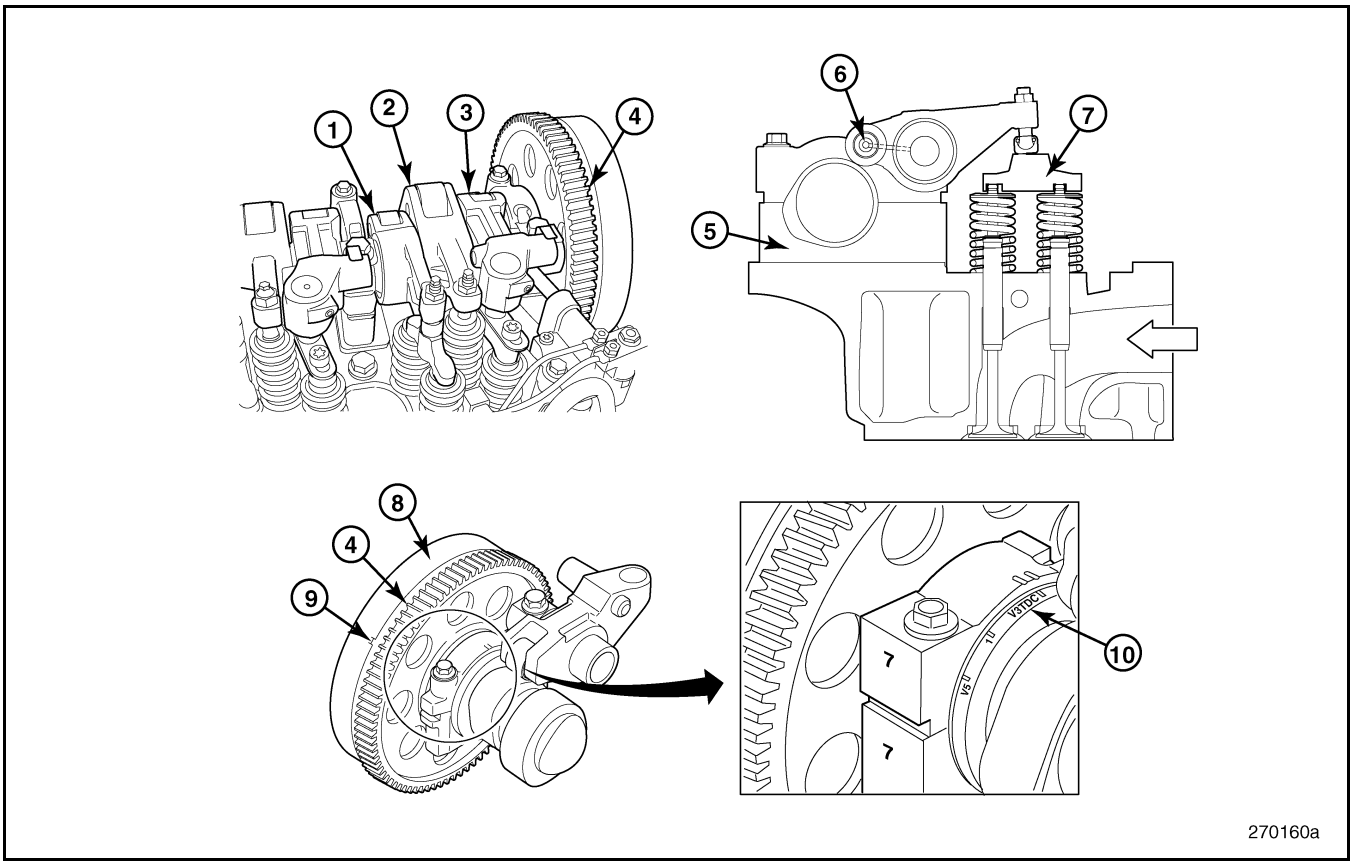


Figure 421 — Inlet/Exhaust Valve and Injector Timing Components

1. Inlet Valve Rocker Arm	6. Rocker Arm Roller
2. Injector Rocker Arm	7. Valve Yoke (Bridge)
3. Exhaust Valve Rocker Arm	8. Camshaft Vibration Damper
4. Camshaft Timing Gear	9. Camshaft Position Sensor Teeth
5. Camshaft Bearing Bracket and Cap	10. Valve Adjustment Reference Marks

GENERAL INFORMATION

Timing marks for basic camshaft timing and adjustment of the valves and unit injectors are located at the rear of the camshaft just forward of the No. 7 rear bearing journal. Two lines at the top of the rear 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 camshaft rear bearing cap when the flywheel is at 0° (top dead center for cylinder No. 1).

Engines without PowerLeash™ — Adjust the inlet valves, exhaust valves and injectors using the timing marks 1–6 on the camshaft.

Engines with PowerLeash™ — Adjust the inlet valves and injectors using the timing marks 1–6 on the camshaft. Adjust the exhaust valves using the timing marks with a **V** in front of the number, V1–V6.

INLET VALVE ADJUSTMENT

⚠ WARNING

Apply the parking brake before turning the engine over. Remove the EECU fuse to avoid starting the engine unintentionally. Make sure that the transmission is not in gear.

1. Using the flywheel turning tool, 9996956, turn the engine over manually to the appropriate camshaft marking for adjustment of the inlet valves and injector of that cylinder.
2. Using a feeler gauge, check the clearance between the rocker arm adjustment screw and the valve yoke (bridge) of the inlet valves (Figure 422). The inlet valve clearance should be 0.2 mm (0.008 inch).
3. If the clearance is not within specification, loosen the locknut and adjust the clearance as required. Hold the adjustment screw to prevent it from turning and tighten the locknut according to specification.

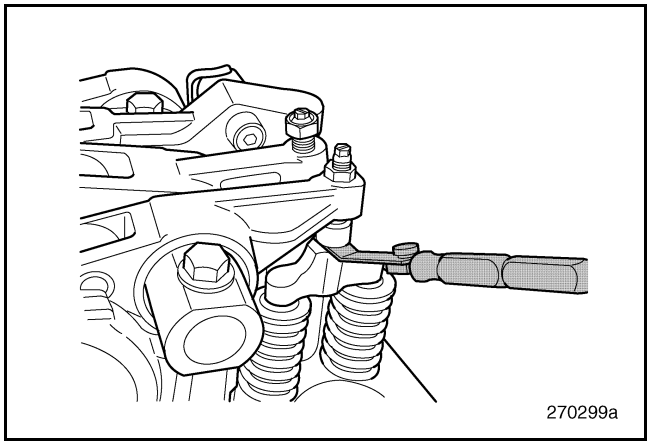


Figure 422 — Checking Inlet Valve Clearance

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 to relieve the preload.
2. Turn the adjusting screw until it firmly contacts the injector. Do not compress the spring.
3. Turn the adjusting screw a further 240 degrees (four flats on the hex head).
4. Using a torque wrench while preventing the adjusting screw from turning further, tighten the jam nut according to specification.

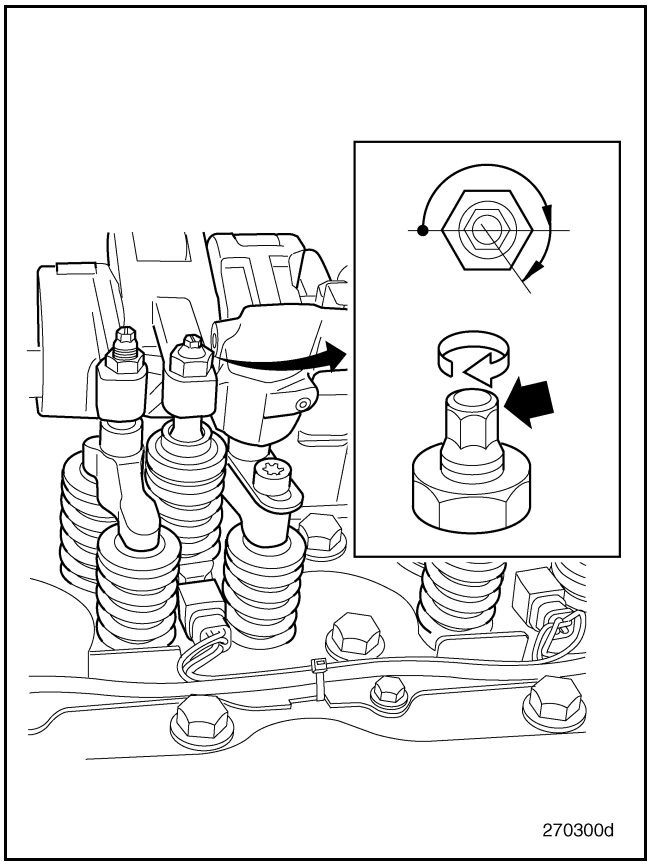


Figure 423 — Adjusting Injectors

EXHAUST VALVE ADJUSTMENT (WITHOUT POWERLEASH™)

1. At the current camshaft setting, adjust the exhaust valves following the same procedure described for adjustment of the inlet valves. However, the valve clearance specification is different, at 0.80 ±0.05 mm (0.031 ±0.002 inch).
2. Using the flywheel turning tool, 9996956, turn 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 used to adjust the exhaust valves are preceded by a **V** in front of the number on the camshaft.

1. Using the flywheel turning tool, 9996956, turn the engine over so that the appropriate V number marking for the respective exhaust valve is between the lines on the camshaft bearing cap.
2. Press down on the rocker arm as shown in Figure 424. If the rocker arm “springs,” the brake piston spring should be pulled outward at the same time as the rocker arm is pressed down to make and ensure contact with the valve stem. Use a strong wire with a hooked end to catch and compress the spring. When the piston spring is loosened from its seat, the residual oil film retaining the spring is punctured, allowing the adjustment setting to be more accurate.

NOTE

When the piston spring is loosened from its seat, the valve allows trapped oil to be released from above the plunger.

⚠ CAUTION

Use care to avoid damaging the sliding surface within the piston and make sure that the wire or other suitable tool used to catch and compress the spring is thoroughly cleaned before use. Any dirt or impurities between the rocker arm piston and rocker arm or other damage can cause piston seizure and malfunctioning engine brake.

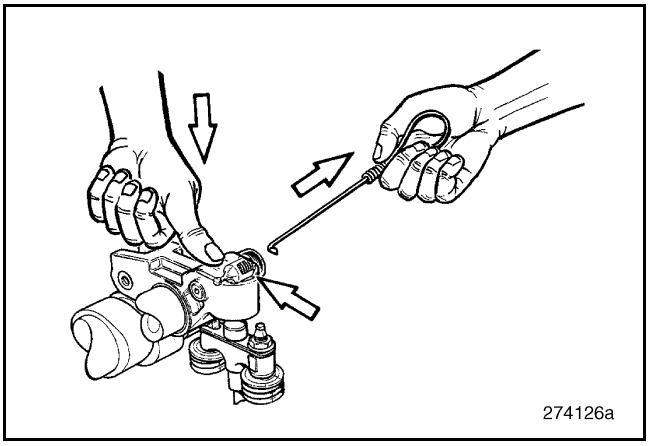


Figure 424 — Releasing Engine Brake Piston Pressure

3. Measure the clearance between the rocker arm piston and the shim on top of the yoke (bridge) as shown in Figure 425. The clearance should be 2.0 ±0.05 mm (0.079 ±0.002 inch).

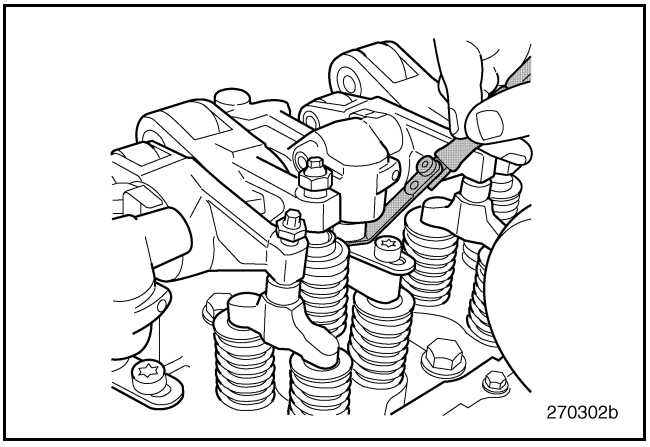


Figure 425 — Measuring Exhaust Valve Clearance

4. If clearance is not within specification, adjust the clearance as required, using shims (Figure 426) placed on top of the valve yoke (bridge).
   a. Remove the shim retaining screw and remove the shim(s).
   b. Determine the thickness of the shim(s) required to match the measured clearance.
   c. Make sure that the valve yoke and shim(s) are clean. Place the shim(s) in position on the valve yoke.

NOTE

Do NOT use more than two shims. Shims are available (shim kit No. 85111158) 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.

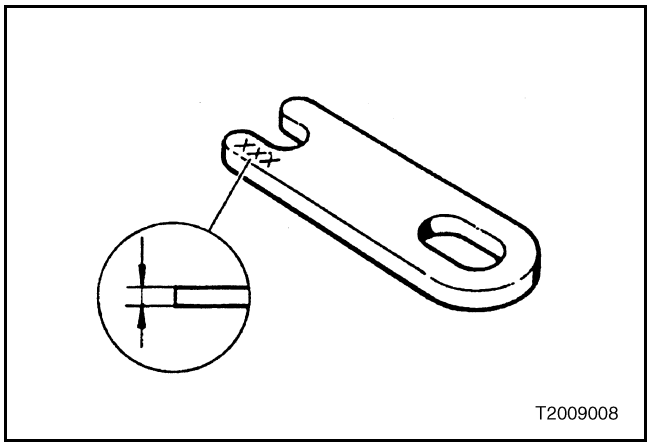


Figure 426 — Engine Compression Brake Adjustment Shim

5. With the required shim(s) in place, install the retainer screw securing the shim(s) to the valve yoke and tighten according to specification. Hold the yoke securely while tightening the retaining screw to avoid bending the valve stems.
6. Recheck the clearance between the exhaust valve rocker arm and the valve yoke.

SERVICE HINT

Mark the respective rocker arm as each valve adjustment is completed.

CONTINUATION OF ADJUSTMENTS

Continue the procedure by turning the engine to the appropriate timing marks and adjusting the valves and unit injectors at each of the remaining cylinders. Follow the steps previously described to adjust the inlet and exhaust valves, and unit injector at each cylinder.

OPERATIONAL CHECK

After the valve and unit injector adjustments have been completed, check engine operation as follows:

1. Using the flywheel turning tool, 9996956, turn 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 EECU 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 turning the engine over. Remove the EECU 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 leads at the unit injectors and camshaft sensor connector. Pull the harness out through the timing gear cover.
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.

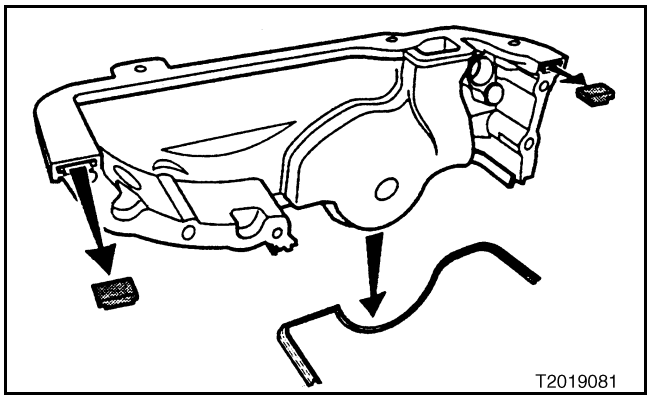


Figure 427 — Timing Gear Cover

6. Using the flywheel turning tool, 9996956, 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. 7 camshaft bearing cap.

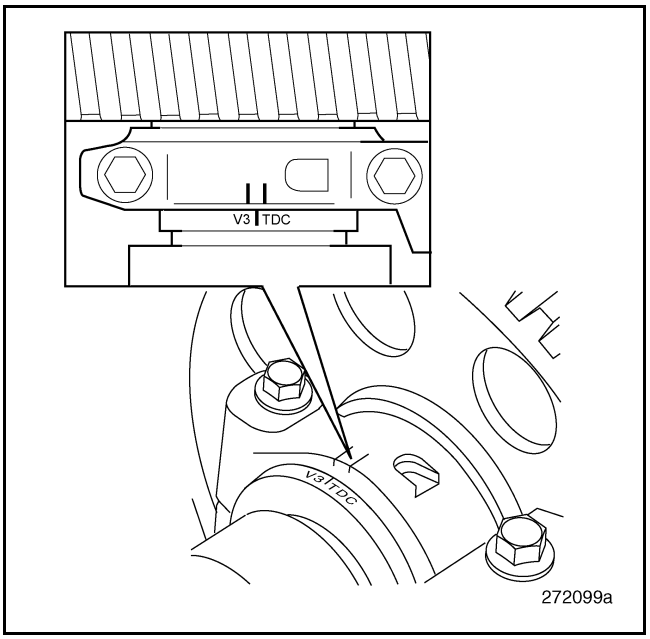


Figure 428 — Camshaft Positioning

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.

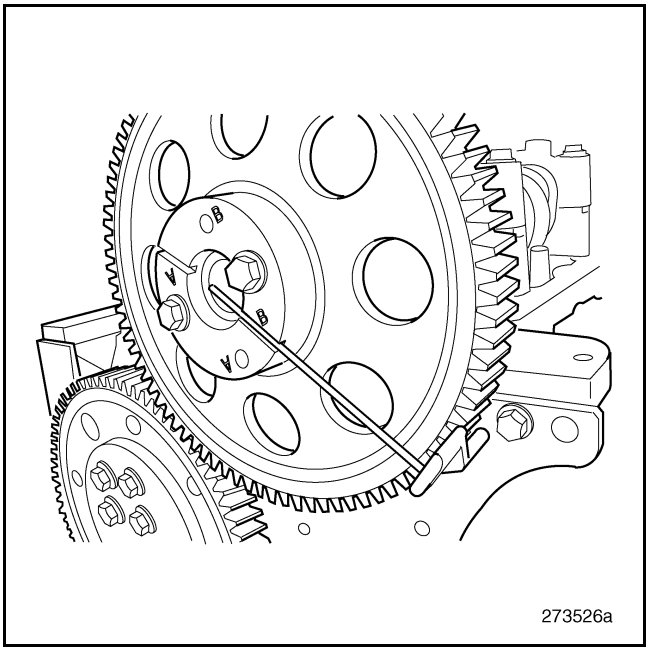


Figure 429 — Camshaft Gear Timing Mark Alignment

9. Insert the camshaft gear alignment tool, J 47450-1, into the hole in the timing gear plate, 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. 7 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 idle 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.

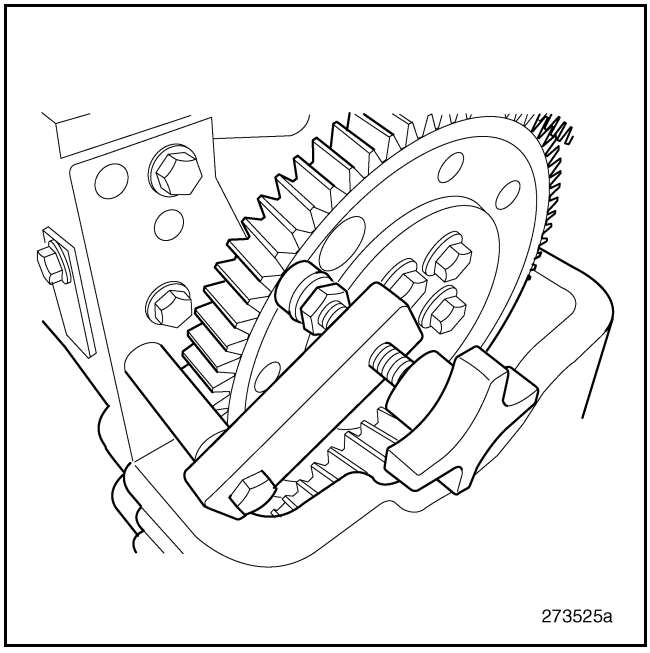


Figure 430 — Clamp Assembly Tool

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. 7 camshaft bearing cap.

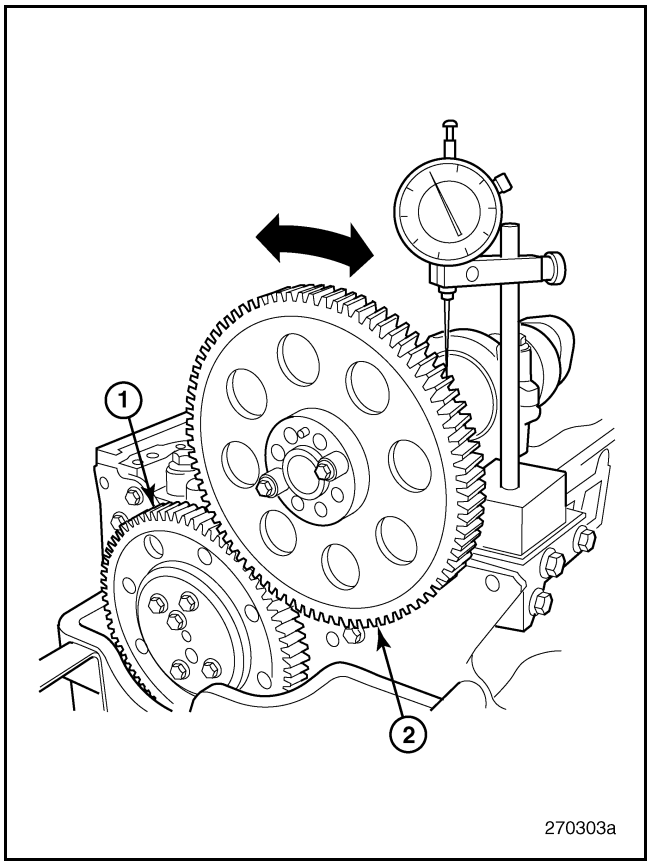


Figure 431 — Camshaft Gear Backlash Measurement

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.

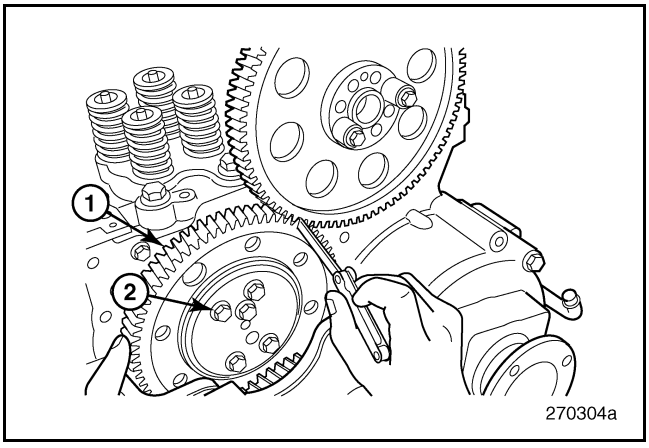


Figure 432 — Idler Gear Flank Clearance Adjustment

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 MACK-approved sealant on the timing gear cover mounting surface and install **new** rubber seals (Figure 433).

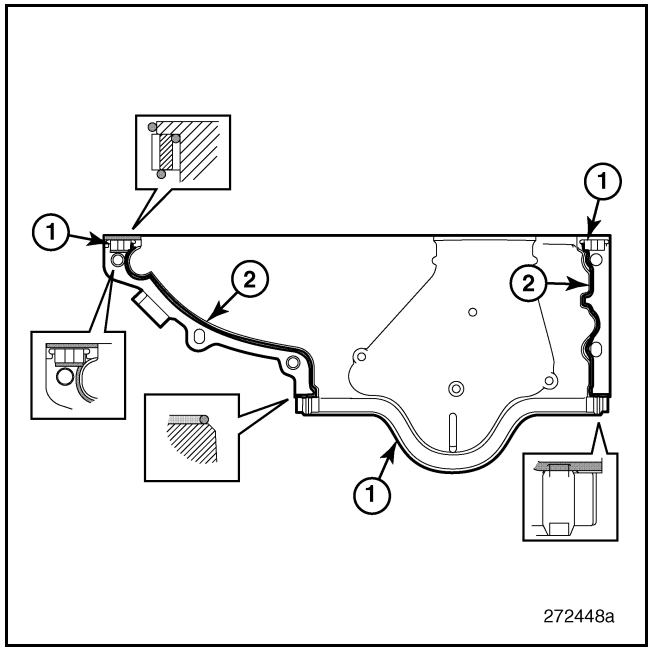


Figure 433 — Timing Cover Seals and Sealant Application

1. Rubber Seals	2. Sealant

19. Place the timing gear cover in position on the engine. Install two capscrews (item 1 in Figure 434) and hand tighten.

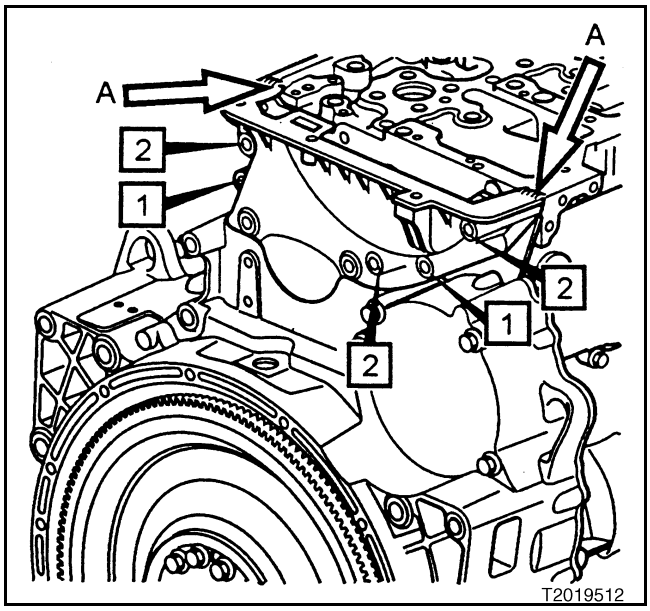


Figure 434 — Timing Gear Cover Installation

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 434).
21. Install the three remaining capscrews (item 2 in Figure 434) and tighten to specification.
22. Install the wiring harness through the timing gear cover.
23. Reconnect the wiring harness leads at the unit injectors and camshaft sensor connector.
24. Apply an even 2 mm (5/64 inch) bead of MACK-approved sealant at the joint lines (point A) between the cylinder head and the timing cover as Figure 434 indicates.
25. Install the valve cover and the 16 retaining screws and springs. Tighten the screws according to specification.

ENGINE FINAL PREPARATION AND OPERATIONAL CHECK

Filter Element Installation

All filters must meet MACK specifications.

NOTE

Do NOT use the center hole to fill the oil and fuel filter elements. Use the holes around the perimeter of the filter housing.

1. Install a **new** air filter in the air filter housing.
2. Using a torque wrench, tighten the attaching screw to specification.
3. Prime the oil filter elements using the specified lubricant.
4. Lubricate the gaskets.
5. Using a filter wrench, tighten the filters to specification.
6. Prime the fuel filter elements using the specified fuel.
7. Attach the fuel filters to the fuel filter housing.
8. 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, the oil gauge line may be disconnected and a pressure tank applied at that point.

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 (94 psi)

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

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 danger 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 danger 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 danger 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 an increased 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 run dry. If hand priming is needed, use the following procedure.

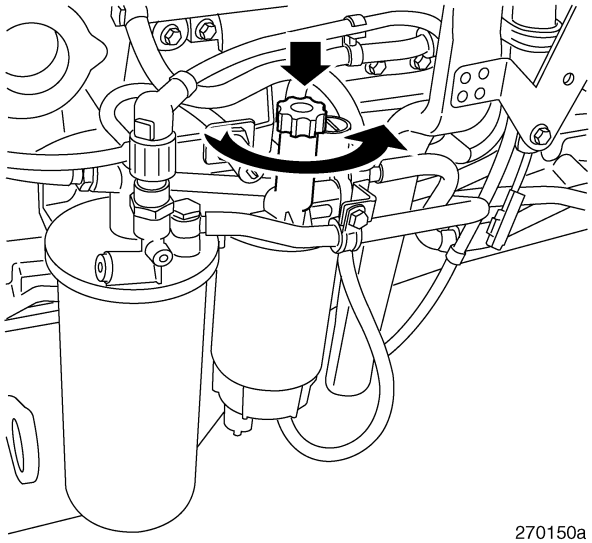


Figure 435 — Unlocking the Hand Primer Pump

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 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

Do not crank the engine continuously for more than 30 seconds without allowing the starter to cool for 2 minutes between cranks.

⚠ CAUTION

The only acceptable method of priming the fuel system is the hand primer pump. 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

MP7 ENGINE MECHANICAL SPECIFICATIONS

Material and Dimensional Data

GENERAL DATA, WEIGHTS AND DIMENSIONS

Item	Specification
Engine Type	In-line, direct injection, diesel
Number of Cylinders	6
Displacement	11 L
Bore and Stroke	123 x 152 mm (4.84 x 5.98 in.)
Compression Ratio	16:1
Emissions Level	EPA 07 (0.20 g NOx, 0.01 g PM, 0.14 g NMHC per bhp/hr using 15 ppm Ultra Low Sulfur Fuel)
Fuel System	Electronic Controlled Unit Injector
Valve Actuation	Single Overhead Cam, 4 valves per cylinder
Aspiration	Variable Geometry Turbocharger with sliding nozzle ring
Power Cylinder	Wet liner; one-piece steel pistons
Electronic Controls	V-MAC IV
Emission Control	Cooled EGR and catalytic Diesel Particulate Filters
Peak Power Ratings	242–302 kW (325–405 hp)
Peak Torque Ratings	1708–2115 N•m (1260–1560 lb-ft)
Engine Families and Operating Ranges	Econodyne 1200–1800 rpm MaxiCruise 1200–1950 rpm Maxidyne 1200–2100 rpm
Weight, Dry	1034 kg (2280 lb.)
Firing Order	1–5–3–6–2–4
Length Overall	1364 mm (53.7 in.)
Width Overall	810 mm (31.9 in.)
Height Overall	1113 mm (43.8 in.)

COMPONENT FEATURES AND MATERIALS

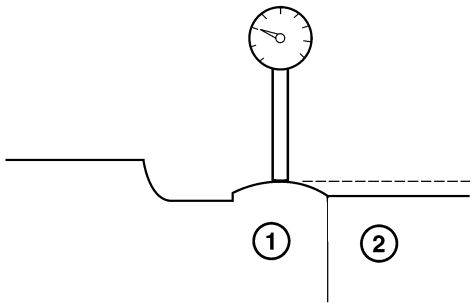
Item	Description
Air Compressor	Flange mounted, oil lubricated, water cooled
Camshaft	Induction hardened, gear driven
Coolant Filter	Spin-on type, disposable
Coolant Pump	Centrifugal rotor impeller, belt-driven
Connecting Rods	Steel forgings (Each bearing cap must be matched to its original rod.)
Crankshaft	Drop forged steel, induction hardened, seven main bearings
Cylinder Block	In-line six cylinder, nodular iron, machined with bearing caps, stiffener plate added at bottom, timing gear train mounting plate added at rear, guide pins for head installation
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; valve alignment 12° from normal; unit injector copper sleeves; integral fuel passages; integral thermostat housing; guide slots for installation on block
Cylinder Head (Valve) Cover	16 attaching screws; mounts crankcase pressure sensor
Cylinder Head — Valve Springs	Double springs on each valve
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 Screws	M16 (26)
Cylinder Liner	Wet; replaceable; with EPDM rubber and Viton seals
Diesel Particulate Filter	Ceramic catalyzed **or** ceramic non-catalyzed depending on chassis model
Flywheel Housing	Die-cast aluminum
Fuel Filters	Two: main and pre-filter
Fuel Injection	Individually programmed unit injectors (6): EECU 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 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; numbered for consistent reassembly; cast and drilled for consistent reassembly; sleeve guides for screws; thrust washers at No. 4 main bearing journal
Manifold — Exhaust	Three-piece, six port
Manifold — Inlet	One-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

Item	Description
Oil Filters	2 full-flow; 1 by-pass Filter capacity, 2 full-flow plus 1 by-pass: • 6 L (6.3 qts.)
Oil Pan	Aluminum; 18 spring-tension screws Sump capacity: • 25 L (26.4 qts.) minimum • 30 L (31.7 qts.) maximum
Thermostat	Piston-type; 82°C (180°F) to 92°C (198°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-lubricated and water-cooled
Valve Lifters	Roller followers
Valve Seat Inserts	Pressed in head, replaceable
Vibration Damper — Camshaft	Fluid filled
Vibration Damper — Crankshaft	Fluid filled

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)	13.1 mm	0.516 in.
Camshaft End Play	0.24 mm max.	0.0094 in. max.
CONNECTING ROD		
Connecting Rod Journal to Bearing Clearance	0.102 mm max.	0.004 in. max.
Side Clearance	0.35 mm max.	0.014 in. max.
Length between Centers	225 mm	8.8583 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)	0.15 mm	0.0059 in.
Crankpin Journal OD (Inspection only: not for machining)	88 mm	3.4646 in.
Main Journal OD (Inspection only: not for machining)	108 mm	4.2520 in.
Journal Out-of-Round (maximum)	0.01 mm	0.0004 in.
Journal Taper (maximum)	0.01 mm	0.0004 in.

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**Metric**	**English**
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)	0.11 mm max.	0.0043 in. max.
CYLINDER BLOCK		
Counterbore Depth	11.0 +0.03/–0.0 mm	0.43 +0.001/–0.0 in.
Main Bearing Bore in Block	113.04 mm	4.45 in.
Cylinder Liner Flange Bead to Block Deck (Top of Bead to Block Deck)	0.14–0.21 mm	0.0055–0.0083 in.
 271110b		
1. Cylinder Liner	2. Cylinder Block	
CYLINDER HEAD		
⚠ CAUTION *Do **NOT** machine the cylinder head. This will change the protrusion of the injector tip and upset injector timing as well as the ability to correctly adjust timing gear backlash.* *Do **NOT** grind copper injector sleeves.*		
Overall Height	135 mm	5.315 in.
Valve Guide Height Above Cylinder Head Spring Face — Inlet	24.5 ±0.5 mm	0.965 ±0.020 in.
Valve Guide Height Above Cylinder Head Spring Face — Exhaust	16.5 ±0.5 mm	0.650 ±0.020 in.
Valve Seat Insert Face Angle (Inlet/Exhaust)	30°	
Valve Seat Insert Counterbore Diameter (Inlet)	42–42.025 mm	1.635–1.6545 in.
Valve Seat Insert Counterbore Diameter (Exhaust)	40–40.025 mm	1.5748–1.5758 in.
Valve Seat Insert Diameter (Inlet, Press Fit in Head)	42.078 ±0.008 mm	1.657 ±0.0003 in.
Valve Seat Insert Diameter (Exhaust, Press Fit in Head)	40.068 ±0.008 mm	1.577 ±0.0003 in.
Valve Seat Height (Inlet)	6.75 ±0.04 mm	0.266 ±0.0016 in.
Valve Seat Height (Exhaust)	6.05 ±0.04 mm	0.238 ±0.0016 in.
Valve Seat Counterbore Depth (Inlet)	11.5 ±0.13 mm	0.453 ±0.005 in.

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**Metric**	**English**
Valve Seat Counterbore Depth (Exhaust)	9.9 ±0.13 mm	0.3898 ±0.005 in.
INJECTORS		
Injector Tip Protrusion	2.9 ±0.1 mm	0.114 ±0.004 in.
Preload (for New Injectors or New Copper Sleeves)	0.85 mm	0.035 in.
PISTON		
Top Extension Above Cylinder Block Deck at TDC	0.15–0.65 mm	0.0059–0.0256 in.
Wrist Pin Diameter	54 mm	2.126 in.
Wrist Pin OD	54 mm	2.125 in.
PISTON RINGS		
Compression Ring End Gap — Upper	0.35–0.55 mm	0.0138–0.0217 in.
Compression Ring End Gap — Upper: Wear Tolerance	0.9 mm max.	0.0354 in. max.
Compression Ring End Gap — Lower	0.8–1.0 mm	0.0315–0.0394 in.
Compression Ring End Gap — Lower: Wear Tolerance	1.3 mm max.	0.0512 in. max.
Oil Control Ring End Gap	0.35–0.75 mm	0.0138–0.0295 in.
Oil Control Ring End Gap — Wear Tolerance	1.0 mm max.	0.0394 in.
Compression Ring Clearance — Lower Groove	0.09–0.13 mm	0.0035–0.0051 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.
Adjustable Idler Gear to Intermediate Idler Gear Backlash		
Intermediate Idler Gear to PTO Gear Backlash		
Intermediate Idler Gear to Crankshaft Gear Backlash		
Lower Idler Gear to Crankshaft Gear Backlash		
Lower Idler Gear to Tandem Pump Gear Backlash		
Intermediate Idler Gear to Air Compressor Gear Backlash		
TURBOCHARGER		
Shaft End Play	0.15 mm	0.0059 in.
VALVES		
Inlet (cold engine) Lash (Clearance)	0.2 ±0.05 mm	0.008 ±0.002 in.
Exhaust (cold engine) Lash (Clearance) — without PowerLeash™	0.80 ±0.05 mm	0.031 ±0.002 in.
Exhaust (cold engine) Lash (Clearance) — with PowerLeash™	2.0 ±0.05 mm	0.079 ±0.002 in.
Valve Face to Deck (Inlet)	1.10 mm min./1.95 mm max.	0.043 in. min./ 0.077 in. max.
Valve Face to Deck (Exhaust)	0.40 mm min./1.25 mm max.	0.016 in. min./0.0492 in. max.
Valve Stem OD (Inlet)	7.961–7.975 mm	0.3134–0.3139 in.
Valve Stem OD (Exhaust)	7.948–7.962 mm	0.3129–0.3135 in.
Note: Replacing valve seats requires replacing valves.		

Tolerances Are Shown Low to High	Standard Size or Fit	
Component	**Metric**	**English**
VALVE SEAT ANGLE		
Inlet/Exhaust: Valves	29.5°	
Inlet/Exhaust: Seats	30°	
VALVE SPRINGS		
Outer Spring:		
Free Length (approximate)	73–74 mm	2.87–2.91 in.
Length under 590 N (133 lb.) load	58 mm	2.28 in.
Length under 1150 N (259 lb.) load	45 mm	1.77 in.
Length when solid	40 mm	1.57 in.
Inner Spring:		
Free Length (approximate)	70–71 mm	2.75–2.80 in.
Length under 243 N (55 lb.) load	54 mm	2.12 in.
Length under 447 N (100 lb.) load	41 mm	1.61 in.
Length when solid	37 mm	1.46 in.

Engine Component Torque Specifications (Standard Fasteners)

N O T E

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 occurs 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.

Standard Bolts, Property Class 8.8

General Tightening Torque	
M6	10 ±1 N•m (7 ±1 lb-ft)
M8	24 ±4 N•m (18 ±3 lb-ft)
M10	48 ±8 N•m (35 ±6 lb-ft)
M12	85 ±15 N•m (63 ±11 lb-ft)
M14	140 ±25 N•m (103 ±18 lb-ft)
M16	190 ±35 N•m (140 ±26 lb-ft)

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 occurs 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 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.
	Injector clamp Adjustable idler gear	Do not reuse	
Highly loaded screws (Phosphating plus oil)	Connecting rods	5 times	Apply clean engine oil.
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	Do not reuse	
Stainless steel/bronze studs and flange locknuts (Spiralock)	Turbocharger	5 times	If turbocharger is replaced, also replace the studs and nuts.
Prevailing torque feature screws (Dri-Loc Plastic or Tuflock)	Piston cooling nozzles Timing gear plate	Do not reuse	
Standard screws	Property class 8.8	No limit	No limit if no cracks, corrosion or damage to the flat surfaces.
Standard screws	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.

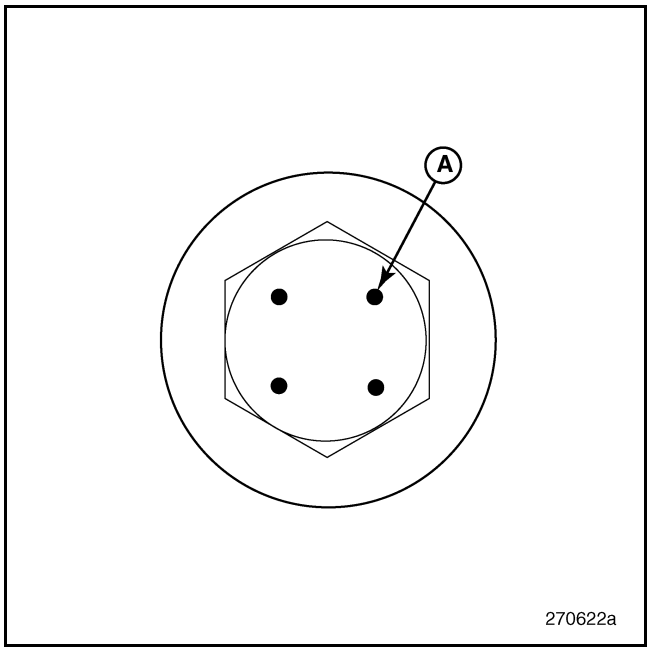


Figure 436 — Usage Marks on Head of Fastener

Bolts and screws that have limited reusability specified in the previous table 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.

SENSORS AND WIRING HARNESS

⚠ CAUTION

Overtorquing a sensor or sensor mounting screw can result in sensor breakage or thread damage.

Sensors	
Air Pressure/Temperature, Inlet Manifold	10 ±1 N•m (7 ±1 lb-ft)
Pressure, Diesel Particulate Filter — Box (**note lb-in**) — Fitting Nuts	 6 ±1 N•m (53 ±9 **lb-in**) 16 ±3 N•m (12 ±2 lb-ft)
Camshaft Position	10 ±1 N•m (7 ±1 lb-ft)
Coolant Level (**note lb-in**)	6 N•m (53 **lb-in**) maximum
Coolant Temperature	22 ±2 N•m (16 ±1 lb-ft)
Crankshaft Position/Engine Speed	10 ±1 N•m (7 ±1 lb-ft)
Crankcase Pressure (on Cylinder Head Cover)	30 ±5 N•m (22 ±4 lb-ft)
Differential Pressure, EGR Venturi	20 ±3 N•m (15 ±2 lb-ft)
Temperature, EGR Venturi	45 ±4 N•m (33 ±3 lb-ft)
Fuel Pressure	30 ±5 N•m (22 ±4 lb-ft)
Oil Level/Temperature, Crankcase (**note lb-in**)	10 ±1 N•m (89 ±9 **lb-in**)
Oil Pressure (on Oil Filter Housing)	30 ±5 N•m (22 ±4 lb-ft)
Temperature, Diesel Particulate Filter	45 ±4 N•m (33 ±3 lb-ft)
Turbocharger Wheel Speed (**note lb-in**)	8 N•m (75 **lb-in**)
Water-in-Fuel (**note lb-in**)	2 ±1 N•m (15 ±5 **lb-in**)
Wiring Harness	
Attaching Screws	24 ±4 N•m (18 ±3 lb-ft)

MP7 ENGINE COMPONENTS — TOP OF ENGINE

Cylinder Head (Valve) Cover

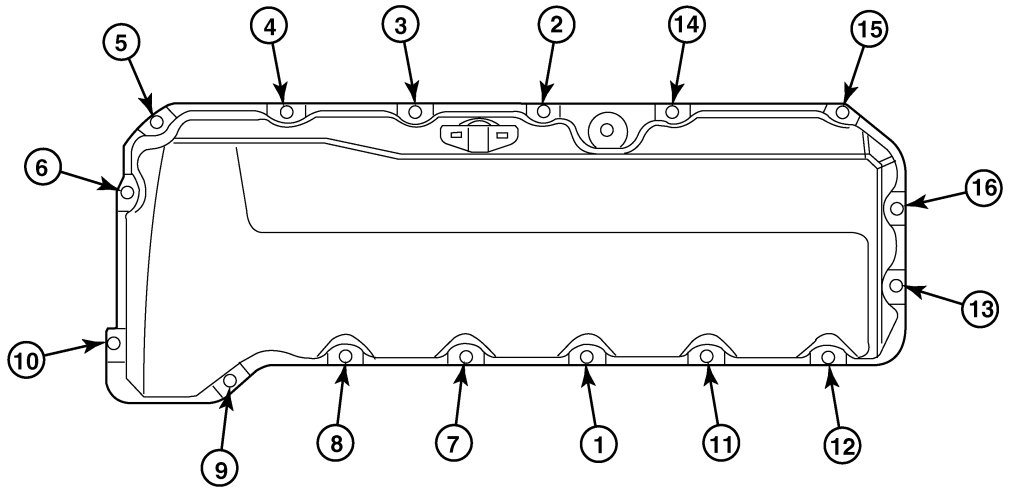


Figure 437 — Cylinder Head Cover Torque Sequence

Tighten screws in the order indicated	24 ±4 N•m (18 ±3 lb-ft)

Camshaft Bearing Caps and Rocker Arm Shaft Assembly

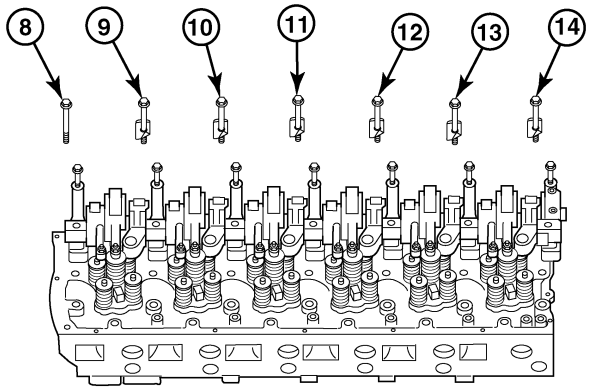


Figure 438 — Rocker Arm Shaft Assembly Installation

The rocker arm shaft assembly is installed on top of the camshaft bearing caps (inboard side) using the long screws, numbers 8 through 14. The rocker arm shaft and camshaft bearing cap retaining screws are tightened to specification in seven steps as listed in the following table.

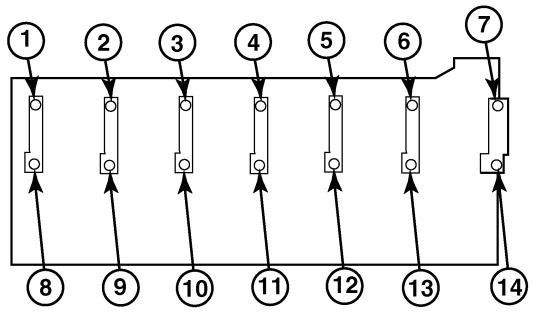


Figure 439 — Camshaft Cap Torque Sequence Screw Numbers

Discard screws with four punch marks when removed and replace with **new** screws.	
Step 1. Screws 1–7	25 ±3 N•m (18 ±2 lb-ft)
Step 2. Screws 11 first, 9 and 13: incrementally	90 ±5 N•m (66 ±4 lb-ft)
Step 3. Screws 8, 10, 12 and 14	60 ±5 N•m (44 ±4 lb-ft)
Step 4. Completely loosen screws 11, 9 and 13.	
Step 5. Screws 11 first, 9 and 13: incrementally	60 ±5 N•m (44 ±4 lb-ft)
Step 6. Screws 1–7, angle tighten	90° ±5°
Step 7. Screws 8–14, angle tighten	100° ±5°

Cylinder Head

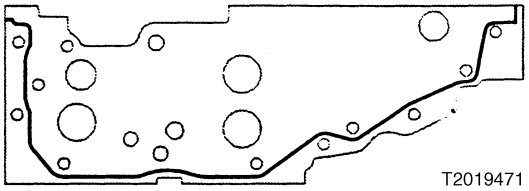


Figure 440 — Sealant Application Pattern — Head to Plate

Remove all old sealant before attempting to apply new sealant.
Apply a 2 mm (5/64 inch) bead of MACK approved sealant to the rear end of the cylinder head following the pattern shown.
Attach the cylinder head to the timing gear mounting plate within 20 minutes of applying the sealant.

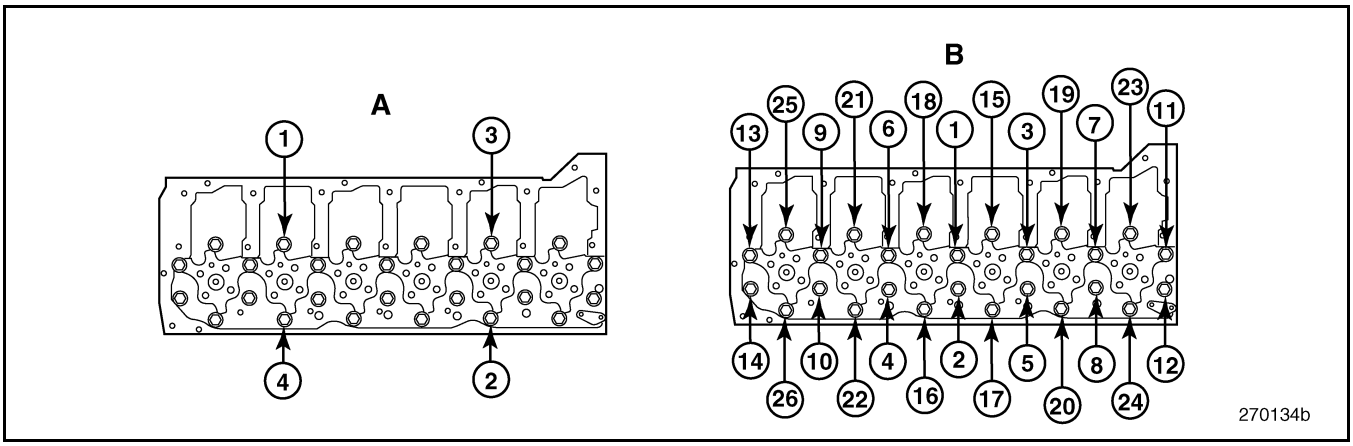


Figure 441 — Torque Sequence Screw Numbers — Head to Block

Cylinder head screws must only be reused four times after initial installation. The number of times a screw has been reused must be identified by a punch mark on the head of the screw. Screws having four punch marks should not be reused and must be replaced with new screws.	
Screws numbered 1, 2, 3 and 4 in the first sequence (A) are numbered 21, 20, 19 and 22 respectively in the second sequence (B).	
Step 1. First sequence (A): screws 1–4	25 N•m (18 lb-ft)
Step 2. Second sequence (B): screws 1–26	65 N•m (48 lb-ft)
Step 3. Repeat second sequence (B): screws 1–26	65 N•m (48 lb-ft)
Step 4. Angle tighten: screws 1–26	120° ±5°
Step 5. Angle tighten: screws 1–26	90° ±5°

Additional Top of Engine Components

Cylinder Head Plugs	
Plug, M10 x 1.00	20 ±4 N•m (15 ±3 lb-ft)
Plug, M10 x 1.00, coated	10 ±2 N•m (7 ±1 lb-ft)
Plug, M14 x 1.50, coated	30 ±3 N•m (22 ±2 lb-ft)
Cylinder Head Connectors	
Right side, coated	10 N•m (7 lb-ft)
Rocker Arm Components	
Locknut, Valve Adjustment (Inlet and Exhaust)	38 ±4 N•m (28 ±3 lb-ft)
Jam Nut, 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, Control Valve	24 ±4 N•m (18 ±3 lb-ft)
Attaching Screws, Control Valve Mounting Plate	24 ±4 N•m (18 ±3 lb-ft)
Attaching Nut, Harness Lead (**note lb-in**)	1.8 ±0.3 N•m (16 ±3 **lb-in**)
Injector Yoke Screws	
Important Note: Do **NOT** apply silicone sealant to new, coated screws. Do **NOT** reuse M8 screws.	
Step 1.	20 +5/–0 N•m (15 +4/–0 lb-ft)
Step 2. Angle tighten	180° ±5°
Step 3. Loosen the screws until the 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°

MP7 ENGINE COMPONENTS — FRONT OF ENGINE

Crankshaft Damper

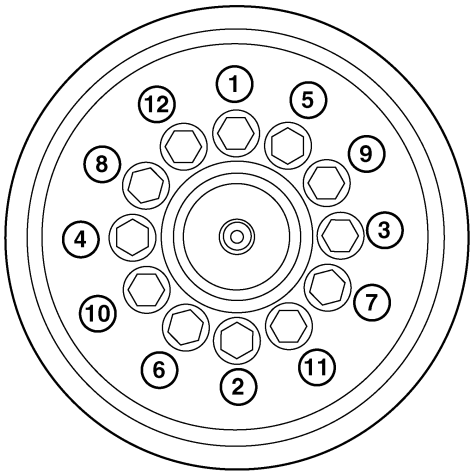


Figure 442 — Torque Sequence Screw Numbers — Damper to Crankshaft

Step 1. In the order indicated	40 ±4 N•m (30 ±3 lb-ft)
Step 2. In the order indicated	90 ±10 N•m (66 ±7 lb-ft)

Crankshaft Front Seal Cover

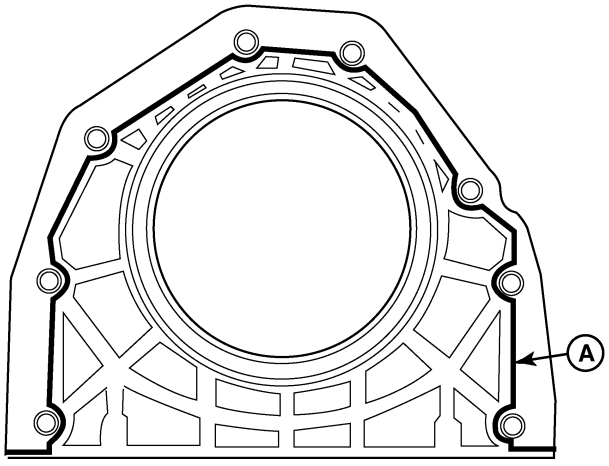


Figure 443 — Sealant Application Pattern — Cover to Block

Remove all old sealant before attempting to apply new sealant.
Apply a 2 mm (5/64 inch) bead of MACK approved sealant to the seal cover following the pattern (A) shown.
Attach the seal cover to the cylinder block within 20 minutes of applying the sealant.

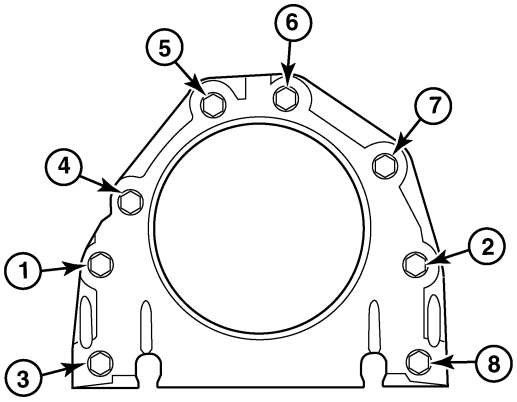


Figure 444 — Torque Sequence Screw Numbers — Cover to Block

Tighten screws in the order indicated	24 ±4 N•m (18 ±3 lb-ft)

Front Engine Support

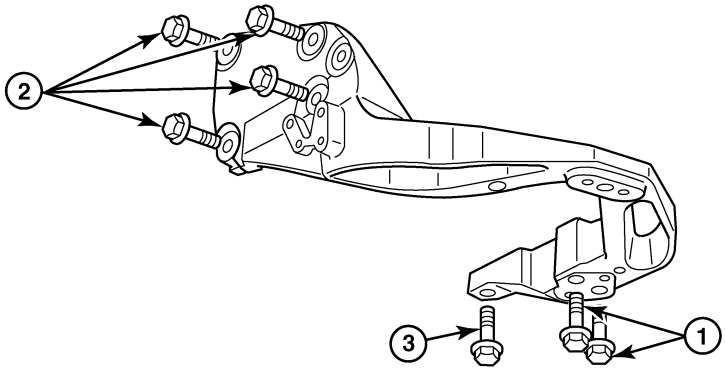


Figure 445 — Torque Sequence Screw Numbers — Support to Block

Step 1. Hand start 7 screws.	
Step 2. Screws No. 1	48 ±8 N•m (35 ±6 lb-ft)
Step 3. Screws No. 2 (Includes tension idler bracket)	275 ±45 N•m (203 ±33 lb-ft)
Step 4. Screws No. 1 and No. 3	275 ±45 N•m (203 ±33 lb-ft)

Front Engine Mounting

Front Engine Mounting, Cushion to Bracket	175 ±13 N•m (130 ±10 lb-ft)
Front Engine Mounting, Cushion to Crossmember	85 ±15 N•m (63 ±11 lb-ft)

Additional Front of Engine Components

Thermostat	
Attaching Screws, Thermostat Cover	24 ±4 N•m (18 ±3 lb-ft)
Coolant Pump	
Attaching Screws, Coolant Pump	24 ±4 N•m (18 ±3 lb-ft)
Attaching Screws, M10, Housing	48 ±8 N•m (35 ±6 lb-ft)
Attaching Screws, Angle Bracket	24 ±4 N•m (18 ±3 lb-ft)
Attaching Screws, Pulley	24 ±4 N•m (18 ±3 lb-ft)
Attaching Screws, M16, Idler Support	275 ±45 N•m (203 ±33 lb-ft)
Attaching Screws, M10, Idler Support Bracket	48 ±8 N•m (35 ±6 lb-ft)
Attaching Screws, M10, Back Side Idler	48 ±8 N•m (35 ±6 lb-ft)
Attaching Screws, M10, Idler Roller	48 ±8 N•m (35 ±6 lb-ft)
Viscous Fan Drive	
Attaching Nuts, Drive to Hub	24 ±4 N•m (18 ±3 lb-ft)
Attaching Nuts, Hub to Coolant Pump Housing	48 ±8 N•m (35 ±6 lb-ft)
Alternator	
Attaching Screws, M10	48 ±8 N•m (35 ±6 lb-ft)
Attaching Screws, M12	85 ±15 N•m (63 ±11 lb-ft)
Attaching Screws, Tension Idler Roller	48 ±8 N•m (35 ±6 lb-ft)
Attaching Screws, Mounting Bracket	48 ±8 N•m (35 ±6 lb-ft)
A/C Refrigerant Compressor	
Attaching Screws, M8	24 ±4 N•m (18 ±3 lb-ft)
Fan Bracket	
Attaching Screws	24 ±4 N•m (18 ±3 lb-ft)

MP7 ENGINE COMPONENTS — REAR OF ENGINE

Timing Gear Mounting Plate

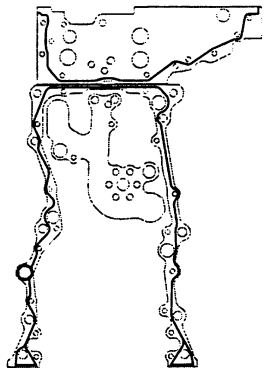


Figure 446 — Sealant Application Patterns — Head and Block to Plate

Remove all old sealant before attempting to apply new sealant.

Apply a 2 mm (5/64 inch) bead of MACK approved sealant to the ends of the cylinder head and cylinder block following the patterns shown.

Attach the timing gear mounting plate to the cylinder head and cylinder block within 20 minutes of applying the sealant.

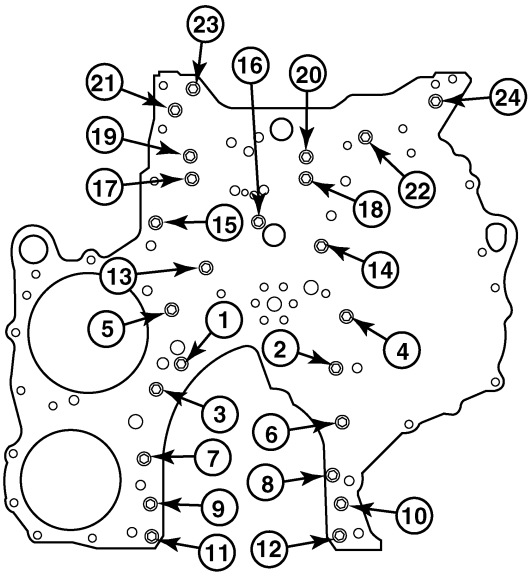


Figure 447 — Torque Sequence Screw Numbers — Plate to Block

Important Note: Do **NOT** apply sealant to new, coated screws.

Do not reuse timing gear plate screws.

Tighten screws in the order indicated	28 ±4 N•m (21 ±3 lb-ft)

Timing Gears

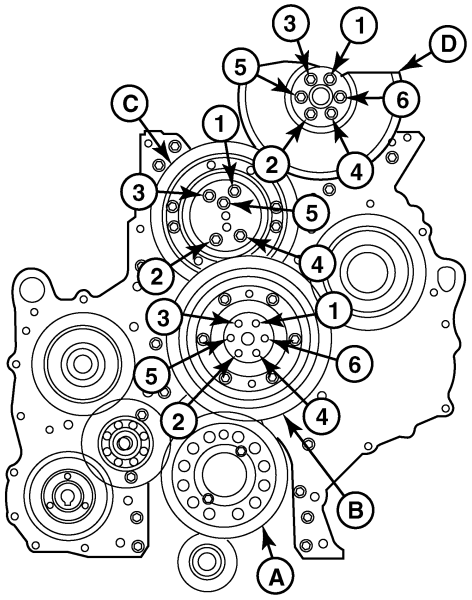


Figure 448 — Torque Sequence Screw Numbers — Gear Mounting

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 Idler Gearset Hub (6 screws)	25 ±3 N•m (18 ±2 lb-ft)	110° ±5°
(C) Adjustable Idler 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

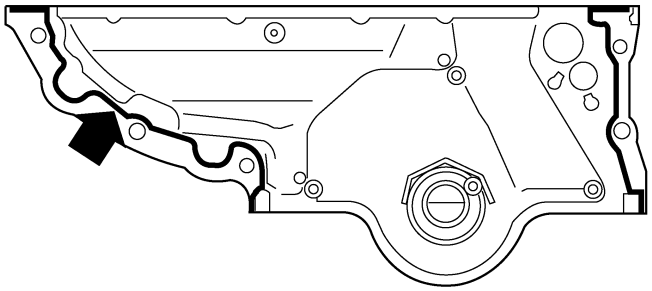


Figure 449 — Sealant Application Pattern — Cover to Mounting Plate

Remove all old sealant before attempting to apply new sealant. Apply a 2 mm (5/64 inch) bead of MACK approved sealant to the timing gear cover following the pattern shown. Attach the cover to the timing gear mounting plate within 20 minutes of applying the sealant.

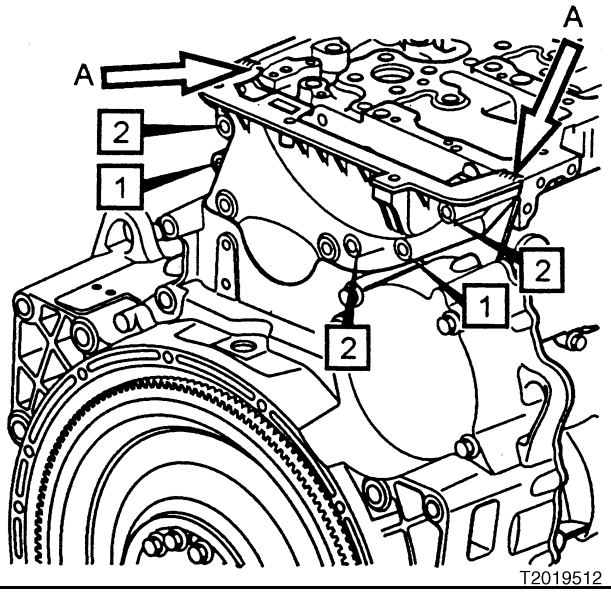


Figure 450 — Torque Sequence Screw Numbers — Cover to Head

Step 1. Screw No. 1	Hand tighten
Step 2. Align cover to cylinder head so that sealing surfaces are flush at points **A**.	
Step 3. Tighten all screws.	24 ±4 N•m (18 ±3 lb-ft)

Flywheel

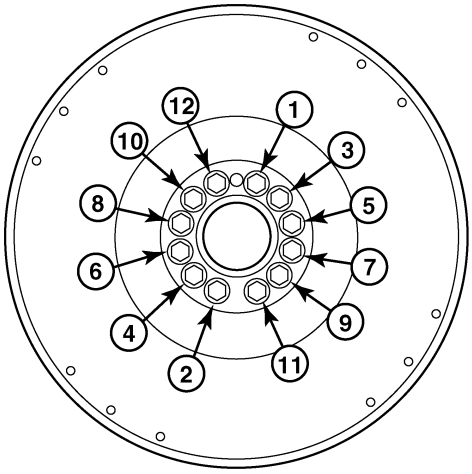


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Figure 451 — Torque Sequence Numbers — Flywheel to Crankshaft

Mark the head of each screw when it is removed. 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.	
Tighten screws in the order indicated	60 ±5 N•m (44 ±4 lb-ft)
In the order indicated: angle tighten	135° ±10°

Flywheel Housing

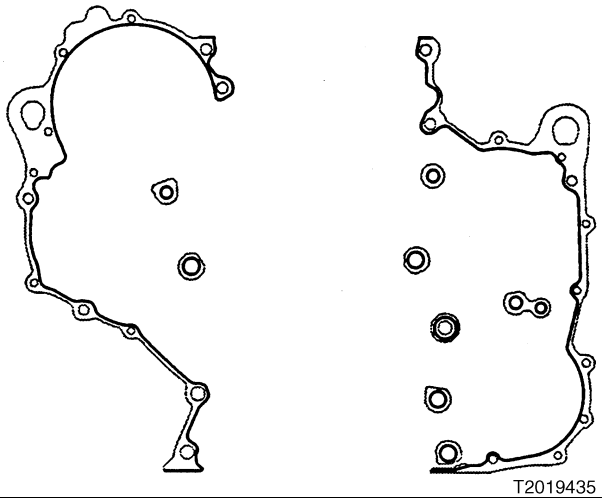

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Figure 452 — Sealant Application Pattern — Flywheel Housing to Plate

Remove all old sealant before attempting to apply new sealant. Apply a 2 mm (5/64 inch) bead of MACK approved sealant to the flywheel housing following the pattern shown. Attach the housing to the timing gear mounting plate within 20 minutes of applying the sealant.

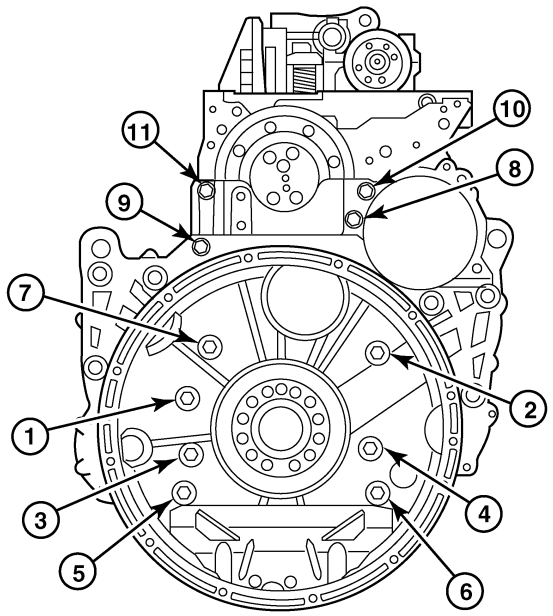

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Figure 453 — Torque Sequence Screw Numbers — Housing to Plate

Hold the engine with the flywheel end uppermost for this procedure. In the order indicated, tighten the screws to the following torque values. **Note:** Screw No. 1 is 120 mm (4.7 inches) long and screw Nos. 2 through 11 are 100 mm (3.9 inches) long. Use care to ensure that the longer screw is installed in the correct position.	
Step 1. Screws 1–11 (M12 and M14)	24 ±4 N•m (18 ±3 lb-ft)
Step 2. Screws 8–11 (M12)	85 ±15 N•m (63 ±11 lb-ft)
Step 3. Screws 1–7 (M14)	140 ±15 N•m (103 ±11 lb-ft)

Additional Rear of Engine Components

Attaching Screws, Rear Engine Support	300 ±30 N•m (221 ±22 lb-ft)
Rear Engine Mounting Pad M20	500–555 N•m (370–410 lb-ft)
Rear Engine PTO	85 ±5 N•m (63 ±11 lb-ft)

MP7 ENGINE COMPONENTS — BOTTOM OF ENGINE

Oil Pan

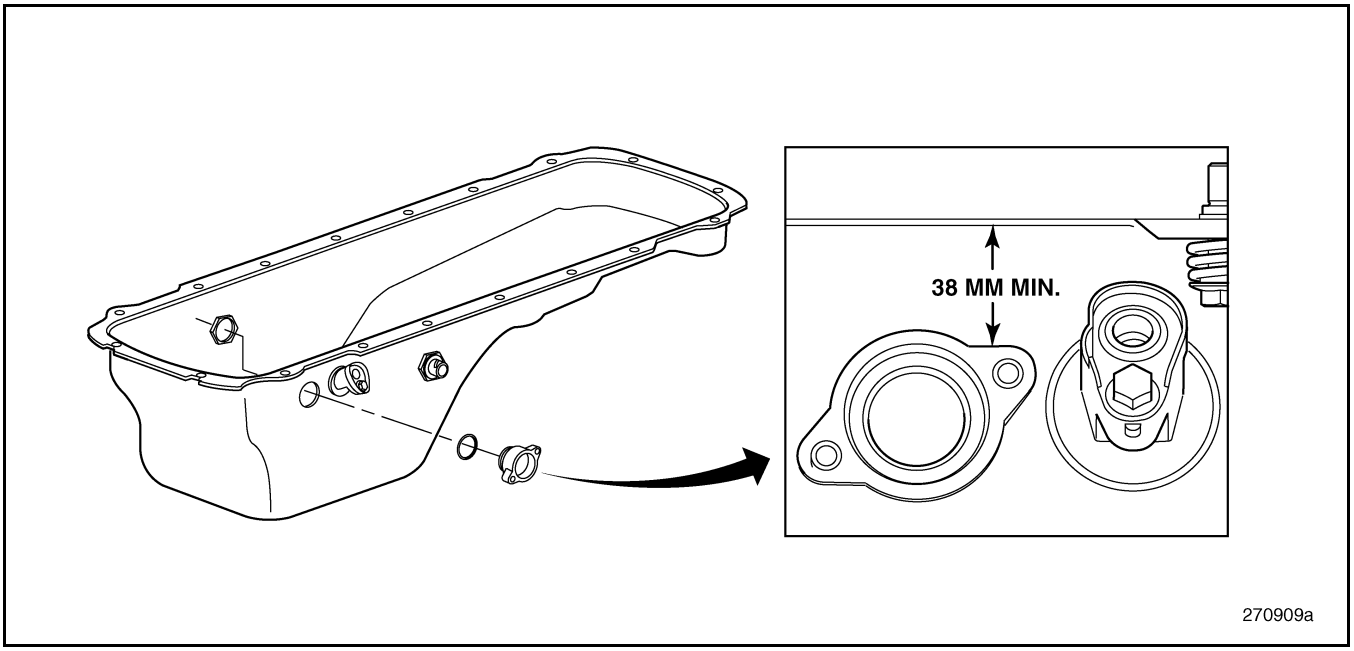


Figure 454 — Oil Pan Fill Pipe Adapter Minimum Clearance Distance

Tighten the Oil Pan Fill Pipe Adapter Nut	80 N•m (60 lb-ft)

Maintain a minimum clearance or 38 mm distance from the oil pan to the oil pan fill pipe adapter. Proper clearance must be maintained in order to provide proper clearance for the front engine mount to the oil fill pipe adapter flange.

NOTE

When the 38 mm minimum clearance is set properly, this provides the clearance of 3 mm (1/8 inch) between the front engine mount bolt and the oil fill pipe adapter flange.

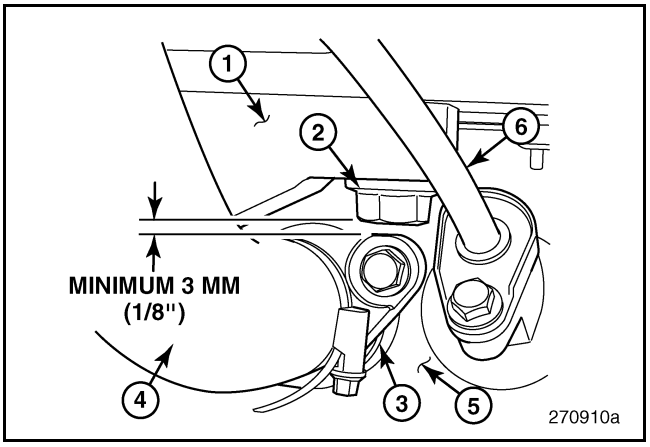


Figure 455 — Engine Oil Fill Pipe Adapter Minimum Clearance Distance

1. Front Engine Support	4. Engine Oil Fill Hose
2. Engine Support Bolt	5. Engine Oil Pan
3. Engine Oil Pan Fill Pipe Adapter	6. Engine Oil Dipstick

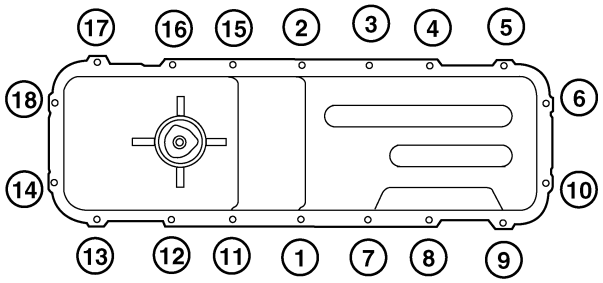


Figure 456 — Torque Sequence Screw Numbers — Oil Pan to Block

Tighten screws in the order indicated	24 ±4 N•m (18 ±3 lb-ft)

Additional Bottom of Engine Components

Block Stiffener Plate	
Attaching Screws, M10 (16)	Hand start all, then tighten to 48 ±8 N•m (35 ±6 lb-ft).
Oil Valve Housing	
Attaching Screws (4)	Hand start all, then tighten to 48 ±8 N•m (35 ±6 lb-ft).
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.	30 ±3 N•m (22 ±2 lb-ft)
Step 2. Angle tighten	180° ±6°
Oil Pan Drain Plug	60 ±5 N•m (44 ±4 lb-ft)
Oil Pan Fill Adapter Screws	24 ±4 N•m (18 ±3 lb-ft)
Dipstick Attaching Screw	10 ±1 N•m (7 ±1 lb-ft)
Oil Pump Attaching Screws	24 ±4 N•m (18 ±3 lb-ft)
Strainer/Pickup Pipe	24 ±4 N•m (18 ±3 lb-ft)
Nozzle Attaching Screws, Piston Cooling Do not reuse.	24 ±3 N•m (18 ±2 lb-ft)

MP7 ENGINE COMPONENTS — RIGHT SIDE

Exhaust Manifold

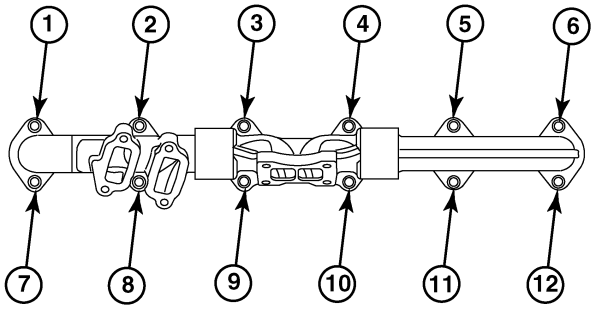


Figure 457 — Torque Sequence Numbers — Manifold to Cylinder Head

Use anti-sieze compound on contact surfaces of nuts, bolts and screws when reassembling exhaust system components.	
Screws 1, 8, 3, 10, 5 and 12	10 ±2 N•m (7 ±1 lb-ft)
Screws 2, 7, 4, 9, 6, 11, 1, 8, 3, 10, 5 and 12	48 ±8 N•m (35 ±6 lb-ft)

Cooling Duct Cover

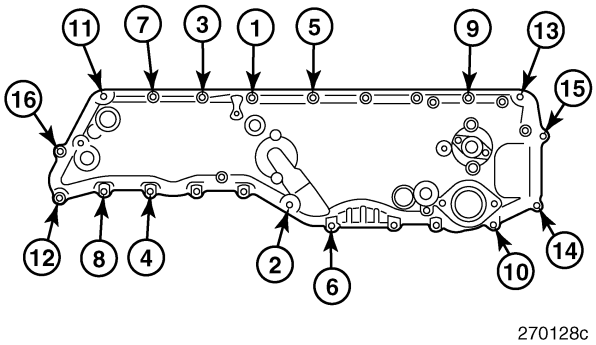


Figure 458 — Torque Sequence Numbers — Cover to Block

Tighten screws in the order indicated	24 ±4 N•m (18 ±3 lb-ft)

EGR Bracket Assembly

Tighten M8 screws (1–6) in the order indicated	24 ±4 N•m (18 ±3 lb-ft)
Tighten M10 screw (7)	48 ±8 N•m (35 ±6 lb-ft)

EGR Cooler Assembly

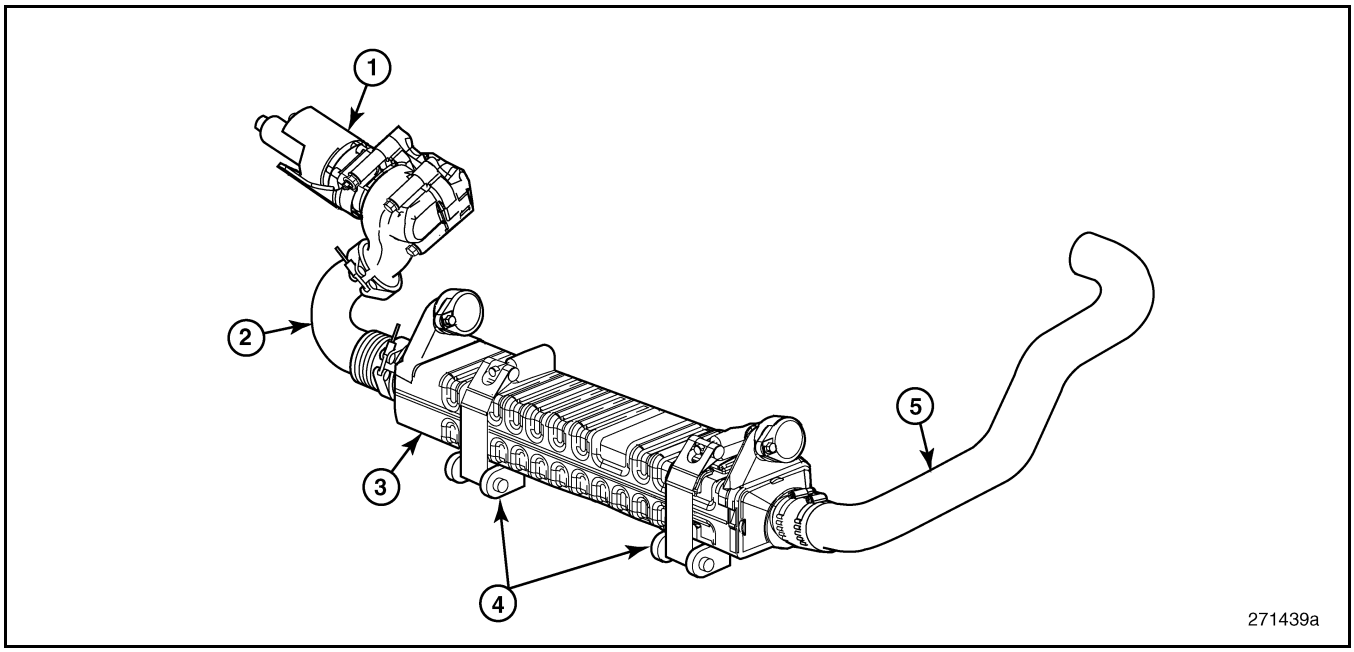


Figure 459 — EGR Cooler Assembly

1. EGR Valve 2. Cooler Inlet (Hot Pipe) 3. EGR Cooler	4. Cooler Mounting Brackets 5. Crossover Pipe

EGR Valve Attaching Screws	Step 1. 20 ±4 N•m (15 ±3 lb-ft) Step 2. 48 ±8 N•m (35 ±6 lb-ft)
EGR Cooler Inlet Pipe (Hot Pipe) V-band Clamps	20 ±4 N•m (15 ±3 lb-ft)
EGR Cooler Attaching T-bolts and Locknuts	12 ±2 N•m (9 ±1 lb-ft)
EGR Cooler Outlet Coupling Hose Clamps (**note lb-in**)	7 ±1 N•m (62 ±9 **lb-in**)
EGR Cooler Drain Valve Fitting	15 ±3 N•m (11 ±2 lb-ft)
EGR Cooler Drain Valve Closing Torque (**note lb-in**)	3 ±1 N•m (27 ±4 **lb-in**)

Additional Right-Side Engine Components

Turbocharger	
Heater, Inlet Air	24 ±4 N•m (18 ±3 lb-ft)
Attaching Nuts, Turbocharger to Exhaust Manifold	48 ±8 N•m (35 ±6 lb-ft)
Oil Supply Line	25 ±5 N•m (18 ±4 lb-ft)
Oil Drain Pipe	24 ±4 N•m (18 ±3 lb-ft)
Turbocharger SRA	
Coolant Return Fitting	18 ±3 N•m (13 ±2 lb-ft)
Elbow (90°) Locking Nut	36 ±6 N•m (27 ±4 lb-ft)
Nut, Fitting (All)	16 ±3 N•m (12 ±2 lb-ft)
Attaching Screws, SRA to Turbocharger Step 1. (**note lb-in**) Step 2. (**note lb-in**)	 3 N•m (26 **lb-in**) 11 N•m (97 **lb-in**)
Starter	
Attaching Nuts	48 ±8 N•m (35 ±6 lb-ft)
Attaching Studs	17 ±2 N•m (13 ±1 lb-ft)
Control Wire Attaching Nut (**note lb-in**)	3 ±1 N•m (24 ±3 **lb-in**)
Power Cable Attaching Nut (M10)	18 ±2 N•m (13 ±1 lb-ft)
Oil Filter	
Filter Housing Attaching Screws	24 ±4 N•m (18 ±3 lb-ft)
Oil Filter	25 ±5 N•m (18 ±4 lb-ft)
M6 Screws	10 ±2 N•m (7 ±1 lb-ft)
Pressure Relief Valve Attaching Screws (**note lb-in**)	10 ±2 N•m (89 ±18 **lb-in**)
Cooling Duct Cover	
Oil Cooler Attaching Screws	27 ±4 N•m (20 ±3 lb-ft)
Plug, Cooling Duct Cover	24 ±4 N•m (18 ±3 lb-ft)
Cylinder Block Heater	10 ±2 N•m (7 ±1 lb-ft)
Water Drain Connector	40 ±4 N•m (30 ±3 lb-ft)
Fitting Jam Nut, 90° V-Nipple Elbow	60 ±6 N•m (44 ±4 lb-ft)
Nut, Coolant Hose	60 ±6 N•m (44 ±4 lb-ft)
Coolant Pipe	
Upper Coolant Pipe Housing	24 ±4 N•m (18 ±3 lb-ft)
Coolant Pump Inlet Flange	24 ±4 N•m (18 ±3 lb-ft)

MP7 ENGINE COMPONENTS — LEFT SIDE

Inlet Manifold

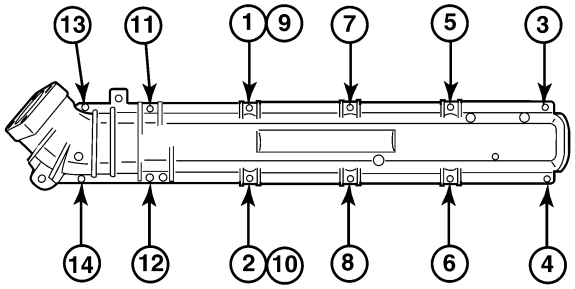


Figure 460 — Torque Sequence Screw Numbers — Manifold to Cylinder Head, Conventional Chassis

Tighten screws in the order indicated	24 ±4 N•m (18 ±3 lb-ft)

Low Pressure Fuel Circuit

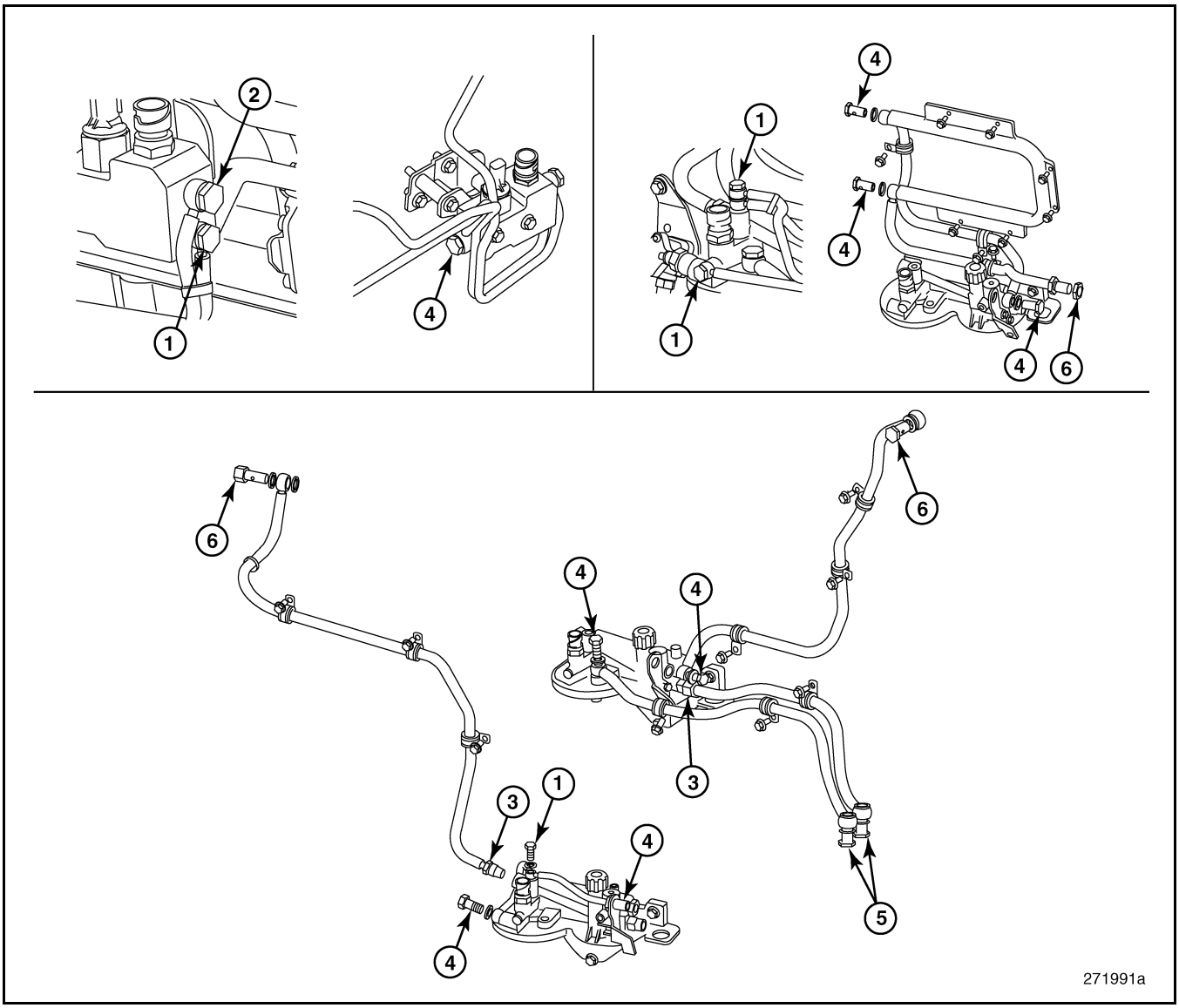


Figure 461 — Screw Number Identification for Torquing — Fuel Circuit

Fuel Filter Housing 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. 2	28 ±4 N•m (21 ±3 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 (30 ±4 lb-ft)
No. 6	48 ±5 N•m (35 ±4 lb-ft)

Additional Left-Side Engine Components

Inlet Manifold	
Plug, Inlet Manifold	20 ±3 N•m (15 ±2 lb-ft)
Inlet Air Heater Attaching Screws	24 ±4 N•m (18 ±3 lb-ft)
EGR Mixer	
Attaching Screws	24 ±4 N•m (18 ±3 lb-ft)
EGR Venturi Housing	
Attaching Screws	24 ±4 N•m (18 ±3 lb-ft)
Coupling Hose Clamps (**note lb-in**)	10 ±1 N•m (90 ±9 **lb-in**)
Outlet Pipe-to-Housing Flange Screws	24 ±4 N•m (18 ±3 lb-ft)
Air Compressor	
Gear Attaching Nut	200 +50 –0 N•m (148 +37 –0 lb-ft)
Compressor Attaching Nuts	85 ±15 N•m (63 ±11 lb-ft)
Fuel Pump	
Attaching Screws	8 ±2 N•m (6 ±1 lb-ft)
Banjo Bolts	40 ±5 N•m (30 ±4 lb-ft)
Power Steering Pump	
Gear Attaching Nut	100 ±10 N•m (74 ±4 lb-ft)
Attaching Screws	24 ±4 N•m (18 ±3 lb-ft)
EECU	
Attaching Screws, EECU	24 ±4 N•m (18 ±3 lb-ft)
Attaching Screws, EECU Cooler	10 ±2 N•m (7 ±1 lb-ft)

Diesel Particulate Filter Assembly

Sensors	
Temperature Sensors	45 ±4 N•m (33 ±3 lb-ft)
Differential Pressure Sensors (**note lb-in**)	6 ±1 N•m (53 ±1 **lb-in**)
Differential Line Connectors (**note lb-in**)	16 ±3 N•m (144 ±24 **lb-in**)
Compact (Right Side Under Cab)	
Lower Mounting Bracket	48 ±8 N•m (35 ±6 lb-ft)
Mounting Strap Fastener	27 ±4 N•m (20 ±3 lb-ft)
Exhaust V-Band Clamp (**note lb-in**)	7 ±2 N•m (62 ±18 **lb-in**)
DPF V-Band Clamp	20 ±3 N•m (15 ±2 lb-ft)
Vertical (Back of Cab)	
Mounting Bracket	85 ±15 N•m (63 ±11 lb-ft)
Mounting Strap Fastener	23 ±1 N•m (17 ±1 lb-ft)
Exhaust V-Band Clamp (**note lb-in**)	7 ±2 N•m (62 ±18 **lb-in**)
DPF V-Band Clamp	20 ±3 N•m (15 ±2 lb-ft)
Aftertreatment Fuel Injector	
Mounting Screws (**note lb-in**)	14 ±1 N•m (125 ±5 **lb-in**)
Fuel Line Fitting (**note lb-in**)	15 ±1 N•m (135 ±5 **lb-in**)
Cooling Lines	48 ±5 N•m (35 ±4 lb-ft)
Shut-Off Valve	
Mounting Screws (**note lb-in**)	14 ±3 N•m (120 ±24 **lb-in**)

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, DPF system	Do not reuse	Discard old gaskets and substitute new if associated components are removed.
Rubber gaskets (special)	Sealing strip (cooling duct cover, cylinder head cover, oil pan and timing gear cover)	No limit if no damage and no leaks	Remove old sealant from the T joints. Clean the surfaces. Apply fresh sealant.
Rubber gaskets (standard)	O-rings and sealing rings	No limit if no damage and no leaks	
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 (MACK-approved sealant)	Sealing between: Timing Gear Plate and Cylinder Block Flywheel Housing and Timing Gear Plate Front Cover and Cylinder Block Timing Gear Cover and Gear Plate	Do not reuse	Remove the old sealant. Clean the surfaces. Apply fresh sealant. **Important**: Remove the old sealant from the T joints and apply fresh.

Lubricants and Sealants

Use only the following recommended sealing compounds and lubricants.

NOTE

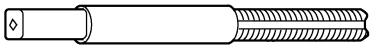
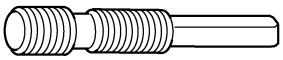
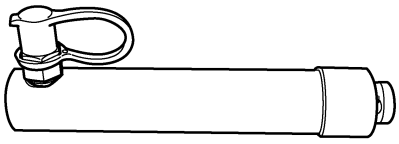
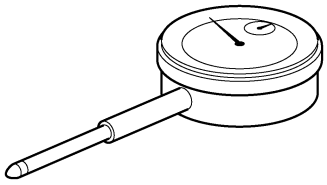
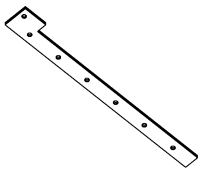
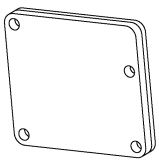
All genuine MACK cylinder head gaskets are precoated and do not require any type of sealing compound. Before installing **new** gaskets, degrease both sealing surfaces to avoid leaks.

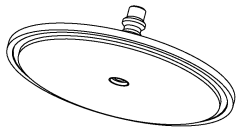
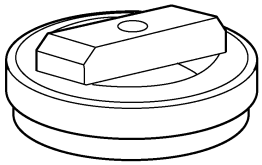
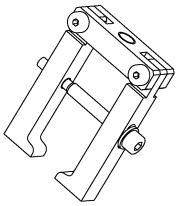
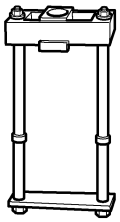
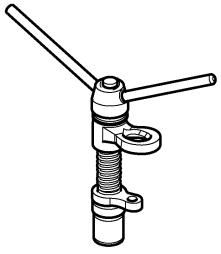
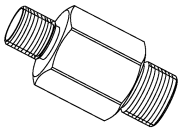
Location	Sealant or Lubricant
Crankshaft front seal cover	Dow Corning® 832
Cup plugs/threaded plugs	Loctite® 277 or equivalent/Teflon® thread sealer
Cylinder liner seats	Dow Corning® 832
Engine parts, fasteners (sides and threads) and washers	Clean engine oil
Industrial adhesive	3M Scotch-Grip 4799 Industrial Adhesive
Injector copper sleeve seals	Clean coolant
Oil filter sealing gaskets (full-flow filters)	Clean engine oil
O-rings	Use the fluid type that the O-ring contacts in use.
Liner seals	Use oil provided with seals
Sensors with O-ring seals	Assemble dry
Valve stems and guides	Clean engine oil

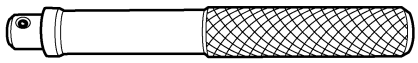
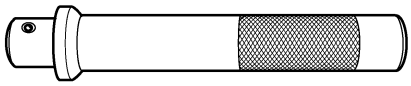
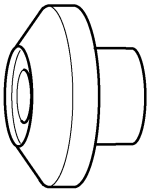
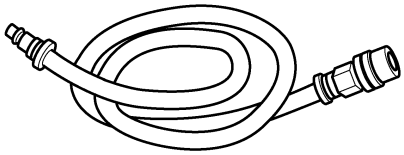
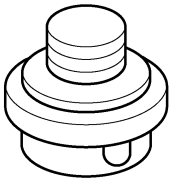
SPECIAL TOOLS & EQUIPMENT

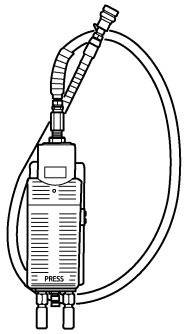
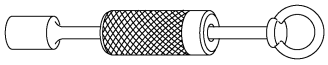
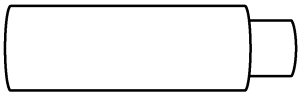
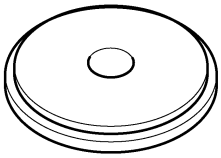
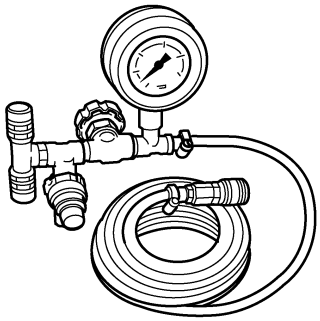
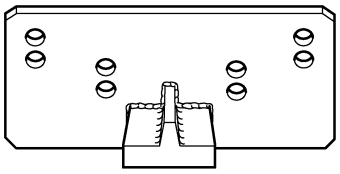
MP7 ENGINE SERVICE TOOLS [200 EA]

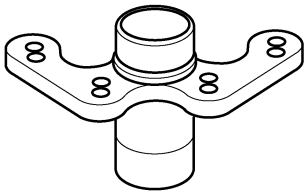
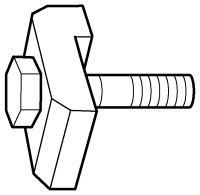
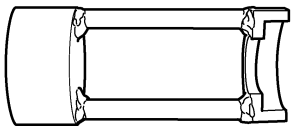
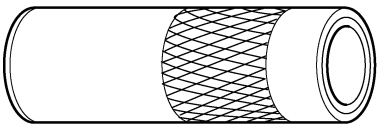
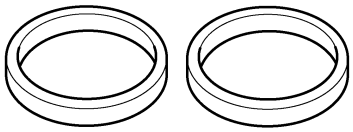
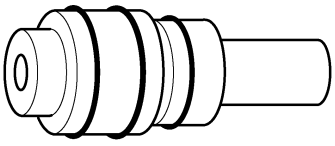
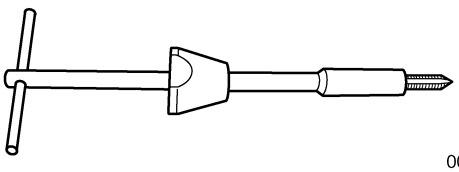
Special Tools for the MP7 Engine

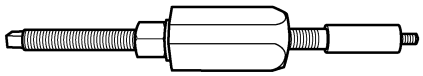
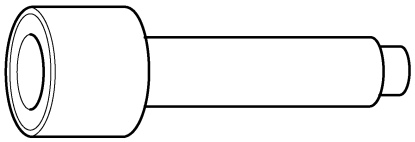
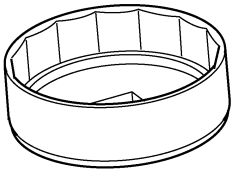
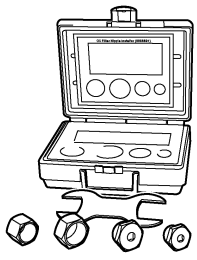
Tool No.	Description	Image
9809667	9 mm Tap, use with 9998252 (Available)	 006840a
9809668	9 mm Bit, use with 9998253 (Available)	 006841a
9809729	Hydraulic Ram (Available)	 006777a
9989876	Dial Indicator (Available)	 006899a
9990105	Sealing Plate for MP7 Cylinder Head	 274113a
9990106	Sealing Plate for MP7 Cylinder Head	 274114a

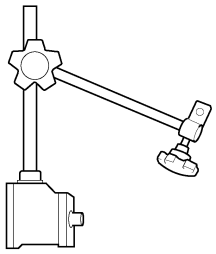
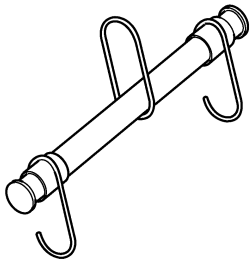
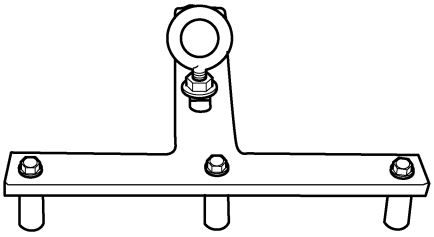
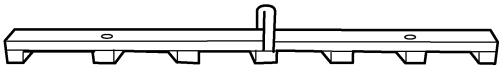
Tool No.	Description	Image
9990107	Connection Disc for MP7 Cylinder Head	 274115a
9990113	Rear Main Seal Remover/Installer, use with 9992000 (Essential)	 006780a
9990114	Main Bearing Cap Puller	 007030a
9990176	Tool Press for Valve/Valve Guide Replacement (Available)	 006781a
9990210	Valve Spring Compressor (Essential)	 006782a
9990262	Slide Hammer Adapter	 007031a

Tool No.	Description	Image
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) (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	 007032a
9996454	Handle for Liner Installation Plate (Available)	 006791a
9996599	Liner Installation Plate (Available)	 006792a
9996662	Pressure Gauge and Hoses (Available)	 006793a
9996950	Center Hold for Flywheel Removal and Installation (Available)	 006794a

Tool No.	Description	Image
9996956	Flywheel Turning Tool (Essential)	 006795a
9996966	Liner Hold-Down Tool (Essential)	 006796a
9998246	Valve Spring Compressor Adapter (Available)	 006797a
9998249	Unit Injector Protection Sleeve (Essential)	 006798a
9998250	Unit Injector Bore Fuel Gallery Sealing Rings (Available)	 006799a
9998251	Unit Injector Bore Sealing Plug (Essential)	 006800b
9998252	Unit Injector Sleeve Tap (to thread nose of sleeve) (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 MP7 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 MP7 engine.	 006802a
9998263	Valve Guide Removal Tool (Available)	 006803a
9998333	Coupler, used with 88800216 (Available)	 273047a
9998487	Oil Filter Wrench (Available)	 006845a
9998511	Lever	 007121a
9998691	Oil Filter Nipple (Spud) Installer Kit (Essential)	 007021b

Tool No.	Description	Image
9999683	Sweep Dial Indicator (Essential)	006948a
9999696	Magnetic Stand (Available)	 006900a
85109034	Camshaft Lifting Bar (Essential)	 006835a
85109049	Cylinder Head Lifting Tool (Essential)	 006769a
85109050	Rocker Shaft Assembly Lifting Tool (Essential)	 006770a

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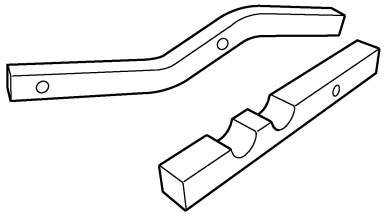
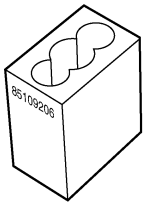
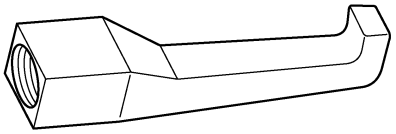
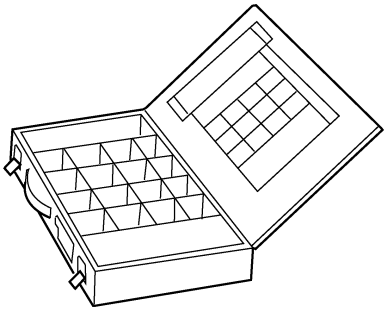
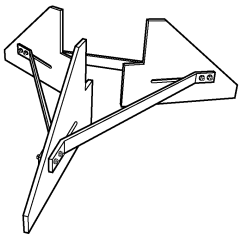
85109051 (A, B)	Timing Gear Cover Alignment Tools (Essential)	 006831a
85109208	Camshaft Bearing Cap Press Tool (Essential)	 006914a
85109980	Camshaft Bearing Cap Removal Tool, use with 9990013	 006886a
85111158	Valve Adjustment Shim Kit (Essential)	 006843a
85111327	VBOC DPF Support Stand	 006904a

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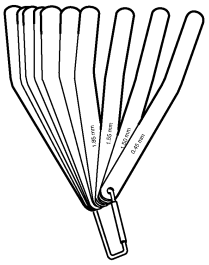
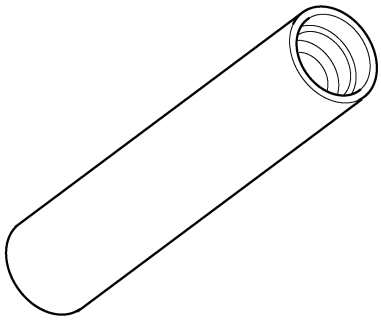
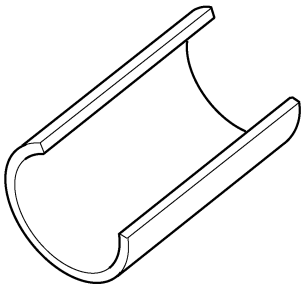
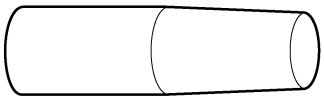
85111377	Feeler Gauge Set	 006844a
85112460	Valve Stem Seal Installation Tool	 006966a
85112461	Valve Stem Height Measurement Gauge	 006944a
88800011	Valve Stem Seal Protection Tool (Essential)	 006773a

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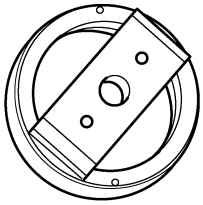
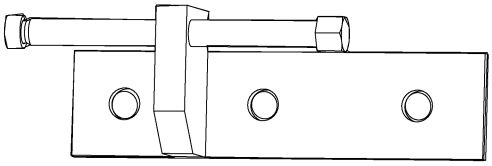
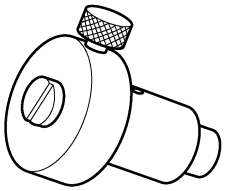
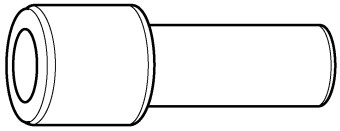
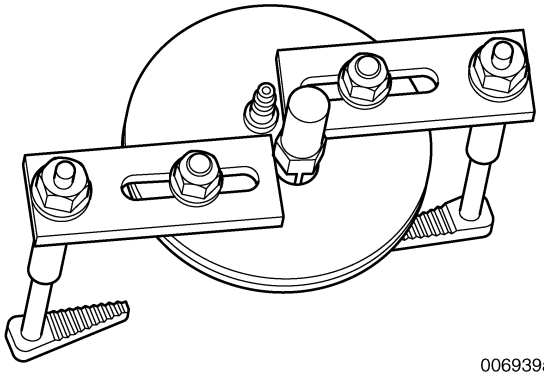
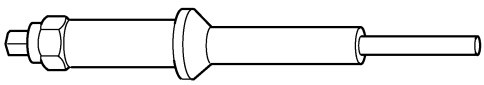
88800021	Front Main Seal Remover/Installer (Essential)	 006774a
88800022	Cooling Duct Cover Installation Tool	 006893a
88800031	Camshaft Sensor Depth Gauge (Available)	 006804a
88800062	Inlet and Exhaust Valve Guide Installation Tool (Available)	 006776a
88800186	Charge Air System Leakage Tester (Essential)	 006939a
88800196	Swaging Tool for Installing Unit Injector Copper Sleeve (Essential)	 006805a

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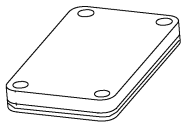
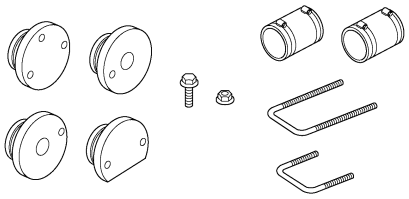
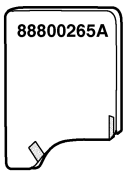
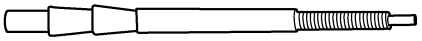
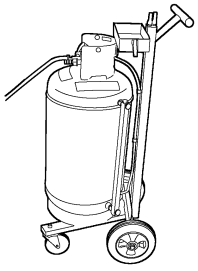
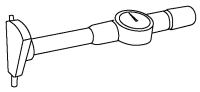
88800215	Sealing Plate	 007157a
88800216	EGR Cooler Leak Test Kit (Essential)	 007002c
88800265A	VGT Mechanism Gauge (Essential)	 007164a
88880010	Swaging Bit (for Copper Sleeve) (Available Separately)	 006842a
DBT2V700 (2815-2V700)	Coolant Extractor/Injector	 006940a
J 5347-B	Dial Bore Gauge	 000615b

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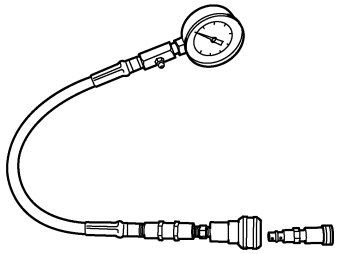
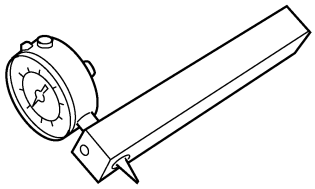
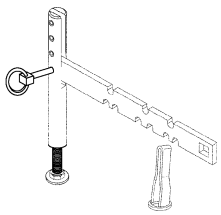
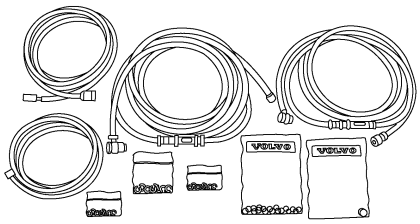
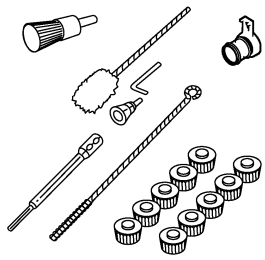
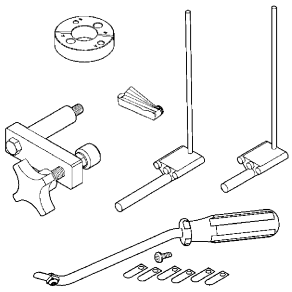
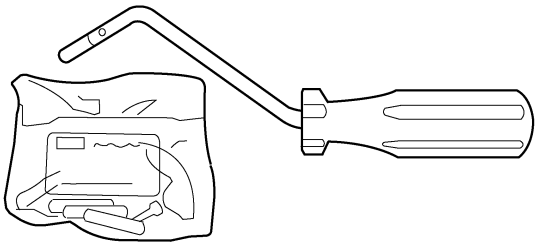
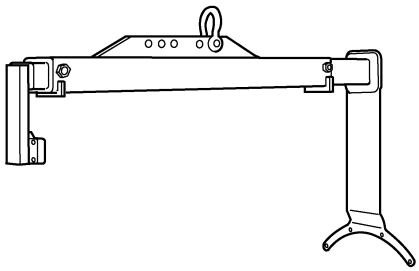
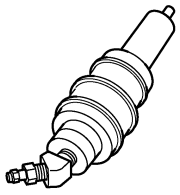
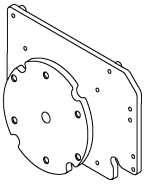
J 6692-B	Cylinder Compression Gauge (Available)	 006836a
J 26948	Cylinder Liner Height Measurement Tool (Available)	 006846a
J 41989-A	Valve Spring Compressor	 007122a
J 42753	Fuel Line Kit	 007158a
J 42885	Unit Injector Bore Cleaning Kit (Essential)	 006926a

Tool No.	Description	Image
J 44514-B	Engine Timing Kit (Essential) Kit includes: • Alignment Pins (two) • Thickness Gauge Set • Gauge Plate • Clamp Assembly	 006889a
J 44935	Gear Lash Setting Tool (Essential) Included in Engine Timing Kit J 44514-B	 271393b
J 47038-3 J 47038-4 J 47038-6 J 47038-7	Engine Lifting Tool (Essential)	 273530a
J 47363	Cylinder Compression Gauge Adapter (Essential)	 006837a
J 47366	Engine Stand Adapter Plate (Available)	 007162a

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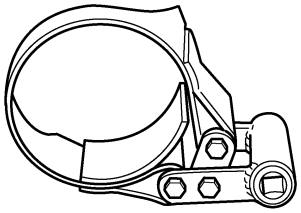
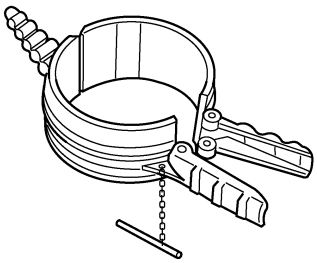
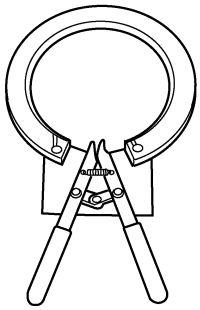
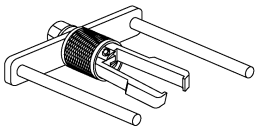
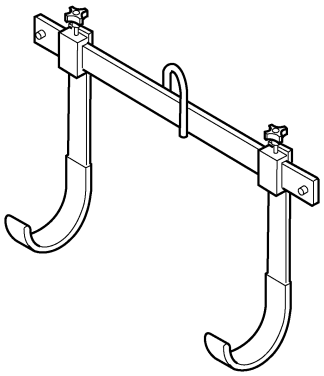
J 48061	Coolant Filter Wrench (Available)	 006807a
J 48205	Piston Ring Compressor (Essential)	 006834a
J 48224	Piston Ring Expander (Essential)	 006847a
J 48922	Heavy-Duty Unit Injector Puller (Essential)	 007000b
J 49002	Crankshaft Lifting Tool (Essential)	 007089a

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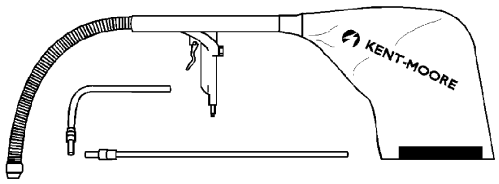
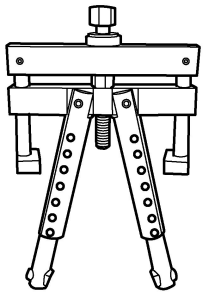
PT-2900	Chip Vacuum	 006962a
PT-6435 or PT-6400-C	Cylinder Liner Puller (Available)	 006808a

All of these 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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