

EPA07 MBE 4000 Workshop Manual



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ABSTRACT

This manual provides instruction for servicing the MBE 4000 Diesel Engine. Specifically, a basic overview of each major component and the system, along with the recommendations for removal, cleaning, inspection, criteria for replacement, repair, installation, and mechanical troubleshooting are contained in this manual.

TRADEMARK INFORMATION

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ENGINE EXHAUST

Consider the following before servicing engines:

 WARNING: PERSONAL INJURY
Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm. ☐ Always start and operate an engine in a well ventilated area. ☐ If operating an engine in an enclosed area, vent the exhaust to the outside. ☐ Do not modify or tamper with the exhaust system or emission control system.

REVISION NOTIFICATION

Modifications to this manual are announced in the form of Service Information Bulletins. The bulletins are posted on the World Wide Web (www.detroitdiesel.com/public/sibs/sibnav.asp).

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SCOPE AND USE OF THIS MANUAL

This manual contains complete instructions on operation, adjustment (tune-up), preventive maintenance, and repair (including complete overhaul) for the MBE 4000 engine. This manual was written primarily for persons servicing and overhauling the engine. In addition, this manual contains all of the instructions essential to the operators and users. Basic maintenance and overhaul procedures are common to all MBE 4000 engines, and apply to all engine models.

This manual is divided into numbered sections. Section one covers the engine (less major assemblies). The remaining sections cover a complete system such as the fuel system, lubrication system, or air system. Each section is divided into subsections which contain complete maintenance and operating instructions for a specific engine subassembly. Each section begins with a table of contents. Pages and illustrations are numbered consecutively within each section.

Information can be located by using the table of contents at the front of the manual or the table of contents at the beginning of each section. Information on specific subassemblies or accessories within the major section is listed immediately following the section title.

GENERAL DESCRIPTION

The MBE 4000 Engine described in this manual is a water-cooled, four-stroke, direct injection diesel engine. The cylinders are arranged in line. Each cylinder has a separate fuel injection pump (unit pump) with a short injection line to the injection nozzle, which is located in the center of the combustion chamber. The unit pumps are attached to the crankcase and are driven from the camshaft. Each cylinder has two intake valves and two exhaust valves.

Charge-air cooling and an exhaust gas turbocharger are standard equipment on all MBE 4000 engines.

The engine is equipped with a fully electronic control system. Besides the engine and its related sensors, this system is composed of the Motor Control Module (MCM), and the Common Powertrain Controller (CPC). The two units are connected by a proprietary datalink through which all necessary data and information can be exchanged.

Engine braking is controlled by a pneumatically-operated exhaust brake and by a hydraulically operated constant throttle system. For greater braking power, an optional engine brake is available.

The cylinder block has integrated oil and water channels. The six individual cylinder heads are made of cast iron. The cylinder head gasket is an adjustment-free seal with elastomer sealing elements.

The pistons are made of aluminum alloy with ring carriers and a shallow combustion chamber recess. The pistons are cooled by oil spray nozzles.

The crankshaft is precision-forged with seven main bearings and eight custom-forged counter weights, and a vibration damper at the front end.

The camshaft is made of induction-hardened steel and has seven main bearings. Each cylinder has cams for intake and exhaust valves and a unit pump.

The valves are controlled by mushroom tappets, pushrods, and rocker arms. The intake and exhaust valves are opened and closed by a valve-guided bridge.

There is a force-feed lubricating oil circuit supplied by a gear-type oil pump. This pump is positioned at the rear of the oil pan and driven by gears from the crankshaft. The oil heat exchanger is located near the front of the crankcase on the right-hand side near the turbocharger.

The gear-type fuel pump is located near the front of the crankcase on the left hand side. The pump is driven from the forward end of the camshaft.

The air compressor, with a power-steering pump attached, is driven by a gear on the camshaft.

The engine is cooled by a closed system using recirculated coolant; temperature is regulated automatically by a thermostat.

There are two drive belts, each with its own automatic belt tensioner. The fan is driven by one belt. The alternator, coolant pump (and any other accessories) are driven by a main drive belt.

AFTERTREATMENT SYSTEM

In order to meet current emissions regulations, the traditional muffler has been replaced by a new aftertreatment device. This device consists of a diesel oxidation catalyst and a diesel particulate filter and together these two components burn off collected particulate matter in a process called "Regeneration." The key to successful regeneration is high exhaust temperature for an extended period of time. Without adequate temperatures for regeneration, the filter will continue to trap particulates and eventually plug. In order to avoid plugging, Detroit Diesel has designed an actively regenerated aftertreatment system. For additional information refer to the *Aftertreatment System Technician's Guide* 7SE63.

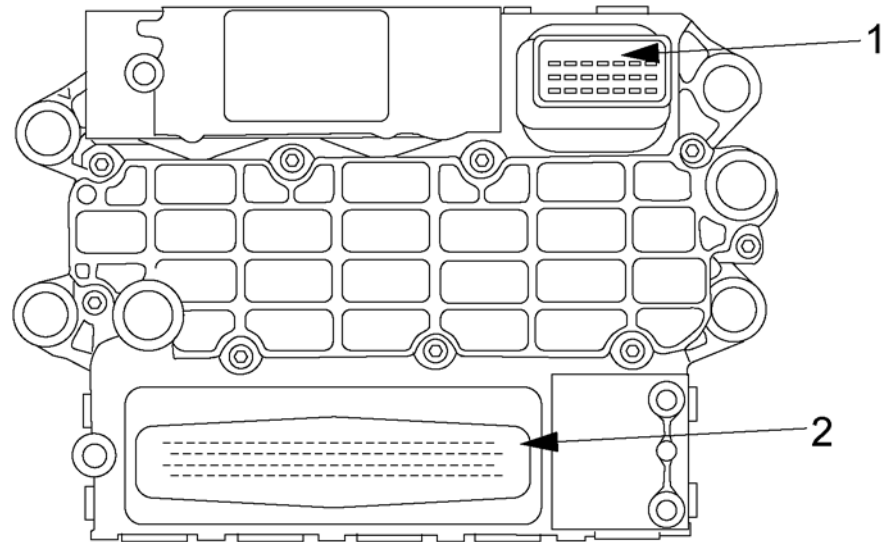
ELECTRONIC ENGINE CONTROL SYSTEM

The engine is equipped with a fully electronic control system, Detroit Diesel Electronic Controls (DDEC®) VI. Besides the engine and its related sensors, this system is composed of the Motor Control Module (MCM), and the Common Powertrain Controller (CPC). The two units are connected by a proprietary datalink through which all necessary data and information can be exchanged.

The MCM monitors both the engine and the datalink. When a malfunction or other problem is detected, the system selects an appropriate response; for example, the emergency running mode may be activated.

Motor Control Module

The engine mounted MCM includes control logic to provide overall engine management. See Figure 1. The MCM processes the data received from the CPC, for example the position of the accelerator pedal, engine brake, etc. These data are evaluated together with the data from the sensors on the engine, such as, charge and oil pressure and coolant and fuel temperature. The data is then compared to the characteristic maps or lines stored in the MCM. From these data, quantity and timing of injection are calculated and the unit pumps are actuated accordingly through the solenoid valves.



45802

1. 21-Pin Connector

2. 120-Pin Connector

Figure 1 Motor Control Module

NOTE:

Do NOT ground the MCM. This can result in false codes being logged.

Engine Harness

The MCM has a 120-pin connector Engine Harness which is factory installed. It also has a 21-pin connector and 31-pin connector which are the responsibility of the OEM.

Common Powertrain Controller

The CPC has three 18-pin connectors and one 21-pin connector. The following sections contain the connector pin-outs for truck, vocational, transit bus, fire truck, and crane applications.

The CPC is the interface between the MCM and the vehicle/equipment for engine control and manages other vehicle/equipment functions. See Figure 2.

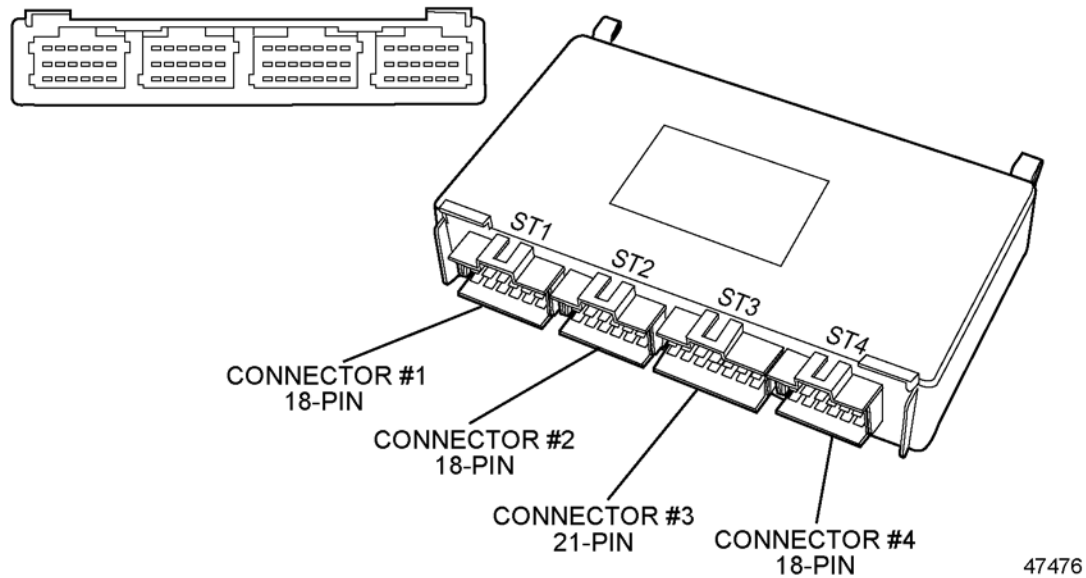
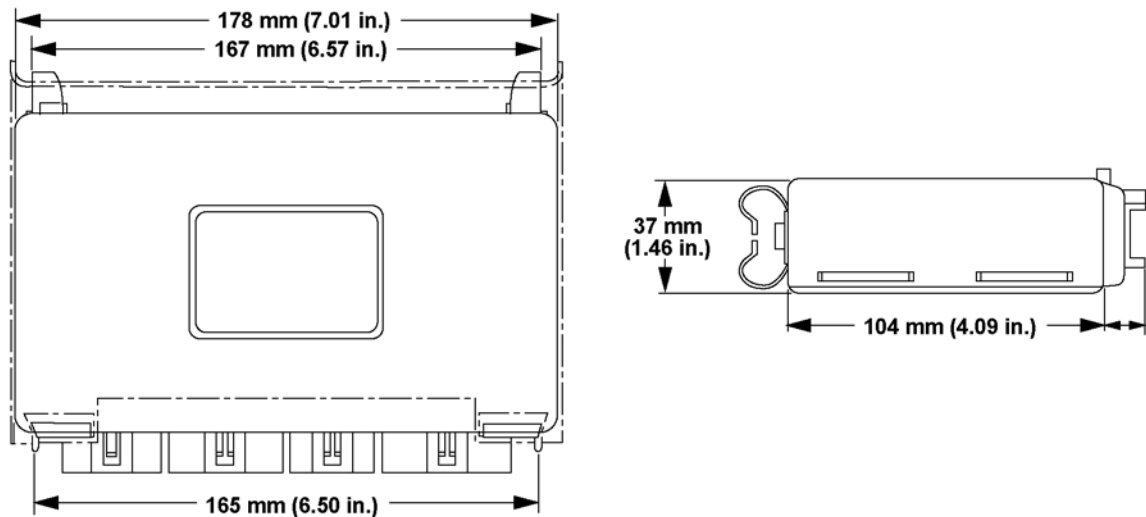


Figure 2 Common Powertrain Controller

The OEM is responsible for mounting this part in an enclosed, protected environment. The mounting bracket is the responsibility of the OEM. There must be maximum physical separation of the Vehicle Interface Harness (VIH) from other vehicle/equipment electrical systems. Other electrical system wires should ideally be at least three feet away from the VIH and should not be parallel to the VIH. This will eliminate coupling electromagnetic energy from other systems into the VIH. See Figure 3.



45407

Figure 3 CPC Dimensions

The CPC receives data from the operator (accelerator pedal position, switches, various sensors) and other electronic control units (for example, synchronization controllers for more than one genset, air compressor controls).

NOTE:

The CPC should be mounted with the connectors pointing down.

ENVIRONMENTAL CONDITIONS

Temperature, vibration, and water intrusion must be considered.

Temperature

The ambient operating temperature range is -40°F to 185°F (-40°C to 85°C).

Water Intrusion

The CPC is not water tight and cannot be subject to water spray. It must be mounted in an enclosed, protected environment.

SAFETY INSTRUCTIONS AND PRECAUTIONS

The following safety measures are essential when working on the MBE 4000 engine.

To reduce the chance of personal injury and/or property damage, the following instructions must be carefully observed:

- Proper service and repair are important to the service technician and the safe, reliable operation of the engine. If part replacement is necessary, the part must be replaced with one of the same part number or with an equivalent part number. Do not use a replacement part of lesser quality.
- The service procedures recommended and described in this manual are effective methods of performing repair. Some of these procedures require the use of specially designed tools.

Accordingly, anyone who intends to use a replacement part, procedure or tool that is not recommended, must first determine that neither personal safety nor the safe operation of the engine will be jeopardized by the replacement part, procedure or tool selected.

- It is important to note that this manual contains various “Cautions” and “Notices” that must be carefully observed in order to reduce the risk of personal injury during repair or the possibility that improper repair may damage the engine or render it unsafe. It is also important to understand that these “Cautions” and “Notices” are not exhaustive, because it is impossible to warn personnel of the possible hazardous consequences that might result from failure to follow these instructions.

Exhaust (Start/Run Engine)

Before starting and running an engine, adhere to the following safety precautions:



WARNING:

PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.



WARNING:

PERSONAL INJURY

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

Stands

Safety stands are required in conjunction with hydraulic jacks or hoists. Do not rely on either the jack or the hoist to carry the load. When lifting an engine, ensure the lifting device is fastened securely. Ensure the item to be lifted does not exceed the capacity of the lifting device.



WARNING:

PERSONAL INJURY

To avoid injury when removing or installing a heavy engine component, ensure the component is properly supported and securely attached to an adequate lifting device to prevent the component from falling.

Glasses

Select appropriate safety glasses for the job. It is especially important to wear safety glasses when using tools such as hammers, chisels, pullers or punches.



WARNING:
PERSONAL INJURY

To avoid injury when working on or near an operating engine, wear protective clothing, eye protection, and hearing protection.

Work Place

Organize your work area and keep it clean. A fall could result in a serious injury. Eliminate the possibility of a fall by:

- ☐ Wiping up oil spills
- ☐ Keeping tools and parts off the floor

After servicing or adjusting the engine:

- ☐ Reinstall all safety devices, guards or shields
- ☐ Ensure that all tools and servicing equipment are removed from the engine

Welding

Wear welding goggles and gloves when welding or using an acetylene torch.



WARNING:

PERSONAL INJURY

To avoid injury from arc welding, gas welding, or cutting, wear required safety equipment such as an arc welder's face plate or gas welder's goggles, welding gloves, protective apron, long sleeve shirt, head protection, and safety shoes. Always perform welding or cutting operations in a well ventilated area. The gas in oxygen/acetylene cylinders used in gas welding and cutting is under high pressure. If a cylinder should fall due to careless handling, the gage end could strike an obstruction and fracture, resulting in a gas leak leading to fire or an explosion. If a cylinder should fall resulting in the gage end breaking off, the sudden release of cylinder pressure will turn the cylinder into a dangerous projectile. Observe the following precautions when using oxygen/acetylene gas cylinders:

- ☐ Always wear required safety shoes.
- ☐ Do not handle tanks in a careless manner or with greasy gloves or slippery hands.
- ☐ Use a chain, bracket, or other restraining device at all times to prevent gas cylinders from falling.
- ☐ Do not place gas cylinders on their sides, but stand them upright when in use.
- ☐ Do not drop, drag, roll, or strike a cylinder forcefully.
- ☐ Always close valves completely when finished welding or cutting.



WARNING:

FIRE

To avoid injury from fire, check for fuel or oil leaks before welding or carrying an open flame near the engine.

NOTICE:

Use proper shielding around hydraulic lines when welding to prevent hydraulic line damage.

Ensure that a metal shield separates the acetylene and oxygen that must be chained to a cart.

Clothing

Safe work clothing fits and is in good repair. Work shoes are sturdy and rough-soled. Bare feet, sandals or sneakers are not acceptable foot wear when adjusting and/or servicing an engine. Do not wear the following when working on an engine:

 WARNING: PERSONAL INJURY
To avoid injury when working near or on an operating engine, remove loose items of clothing and jewelry. Tie back or contain long hair that could be caught in any moving part causing injury.

 WARNING: PERSONAL INJURY
To avoid injury when working on or near an operating engine, wear protective clothing, eye protection, and hearing protection.

- ☐ Rings
- ☐ Wrist watches
- ☐ Loose fitting clothing

Any of these items could catch on moving parts causing serious injury.

Power Tools

Do not use defective portable power tools.

 WARNING: ELECTRICAL SHOCK
To avoid injury from electrical shock, follow OEM furnished operating instructions prior to usage.

Check for frayed cords prior to using the tool. Be sure all electric tools are grounded. Defective electrical equipment can cause severe injury. Improper use of electrical equipment can cause severe injury.

Air

Recommendations regarding the use of compressed air are indicated throughout the manual.



WARNING:

EYE INJURY

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 276 kPa (40 psi) air pressure.

Fuel Lines

Remove fuel lines as an assembly. Do not remove fuel lines individually. Avoid getting fuel injection lines mixed up.

Fluids and Pressure

Be extremely careful when dealing with fluids under pressure.



WARNING:

PERSONAL INJURY

To avoid injury from penetrating fluids, do not put your hands in front of fluid under pressure. Fluids under pressure can penetrate skin and clothing.

Fluids under pressure can have enough force to penetrate the skin. These fluids can infect a minor cut or opening in the skin. If injured by escaping fluid, see a doctor at once. Serious infection or reaction can result without immediate medical treatment.

Fuel

Keep the hose and nozzle or the funnel and container in contact with the metal of the fuel tank when refueling to avoid the possibility of an electric spark igniting the fuel.



WARNING:

FIRE

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not smoke or allow open flames when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**



WARNING:

GASOLINE VAPOR IGNITION

To avoid injury from possible gasoline vapor ignition when refueling, keep the hose, nozzle, funnel, or container in contact with the metal opening of the fuel tank. This will reduce the likelihood of a dangerous spark.

The following cautions should be followed when filling a fuel tank:

 CAUTION:
PERSONAL INJURY
To avoid injury from fuel spills, do not overfill the fuel tank.

 WARNING:
FIRE
To avoid injury from fire, keep all potential ignition sources away from diesel fuel, including open flames, sparks, and electrical resistance heating elements. Do not smoke when refueling.

Batteries

Electrical storage batteries emit highly flammable hydrogen gas when charging and continue to do so for some time after receiving a steady charge.

 WARNING:
Battery Explosion and Acid Burn
To avoid injury from battery explosion or contact with battery acid, work in a well ventilated area, wear protective clothing, and avoid sparks or flames near the battery. If you come in contact with battery acid: ☐ Flush your skin with water. ☐ Apply baking soda or lime to help neutralize the acid. ☐ Flush your eyes with water. ☐ Get medical attention immediately.

Always disconnect the battery cable before working on the electrical system.

 WARNING:
PERSONAL INJURY
To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

Disconnect the batteries or disable an air starter when working on the engine to prevent accidental starting.

Fire

Keep a charged fire extinguisher within reach. Be sure you have the correct type of extinguisher for the situation.

Cleaning Agent

Avoid the use of carbon tetrachloride as a cleaning agent because of the harmful vapors that it releases. Ensure the work area is adequately ventilated. Use protective gloves, goggles or face shield, and apron.

 WARNING: PERSONAL INJURY
To avoid injury from harmful vapors or skin contact, do not use carbon tetrachloride as a cleaning agent.

Exercise caution against burns when using oxalic acid to clean the cooling passages of the engine.

Working on a Running Engine

When working on an engine that is running, accidental contact with the hot exhaust manifold can cause severe burns.

 CAUTION: PERSONAL INJURY
To avoid injury from unguarded rotating and moving engine components, check that all protective devices have been reinstalled after working on the engine.

 WARNING: PERSONAL INJURY
To avoid injury, use care when working around moving belts and rotating parts on the engine.

Start Attempts

Avoid excessive injection of ether into the engine during start attempts.

NOTICE:
Avoid excessive injection of ether into the engine during start attempts. Injection of excessive ether may result in an uncontrolled internal engine explosion that could cause engine damage. Follow the manufacturer's instructions on proper product use.

Follow the instructions on the container or by the manufacturer of the starting aid.

Fluoroelastomer (Viton) Use

Under normal design conditions, fluoroelastomer (VITON) parts, such as O-rings and seals, are perfectly safe to handle.



WARNING:
CHEMICAL BURNS
To avoid injury from chemical burns, wear a face shield and neoprene or PVC gloves when handling fluoroelastomer O-rings or seals that have been degraded by excessive heat. Discard gloves after handling degraded fluoroelastomer parts.

However, a potential hazard may occur if these components are raised to a temperature above 316°C (600°F), such as during a cylinder failure or engine fire. At temperatures above 316°C (600°F) fluoroelastomer will decompose (indicated by charring or the appearance of a black, sticky mass) and produce hydrofluoric acid. This is extremely corrosive and, if touched by bare skin, may cause severe burns, sometimes with symptoms delayed for several hours.

CPC VEHICLE INTERFACE HARNESS

The OEM supplied Vehicle Interface Harness (VIH) connects the CPC to the MCM and other vehicle systems. See Figure 4.

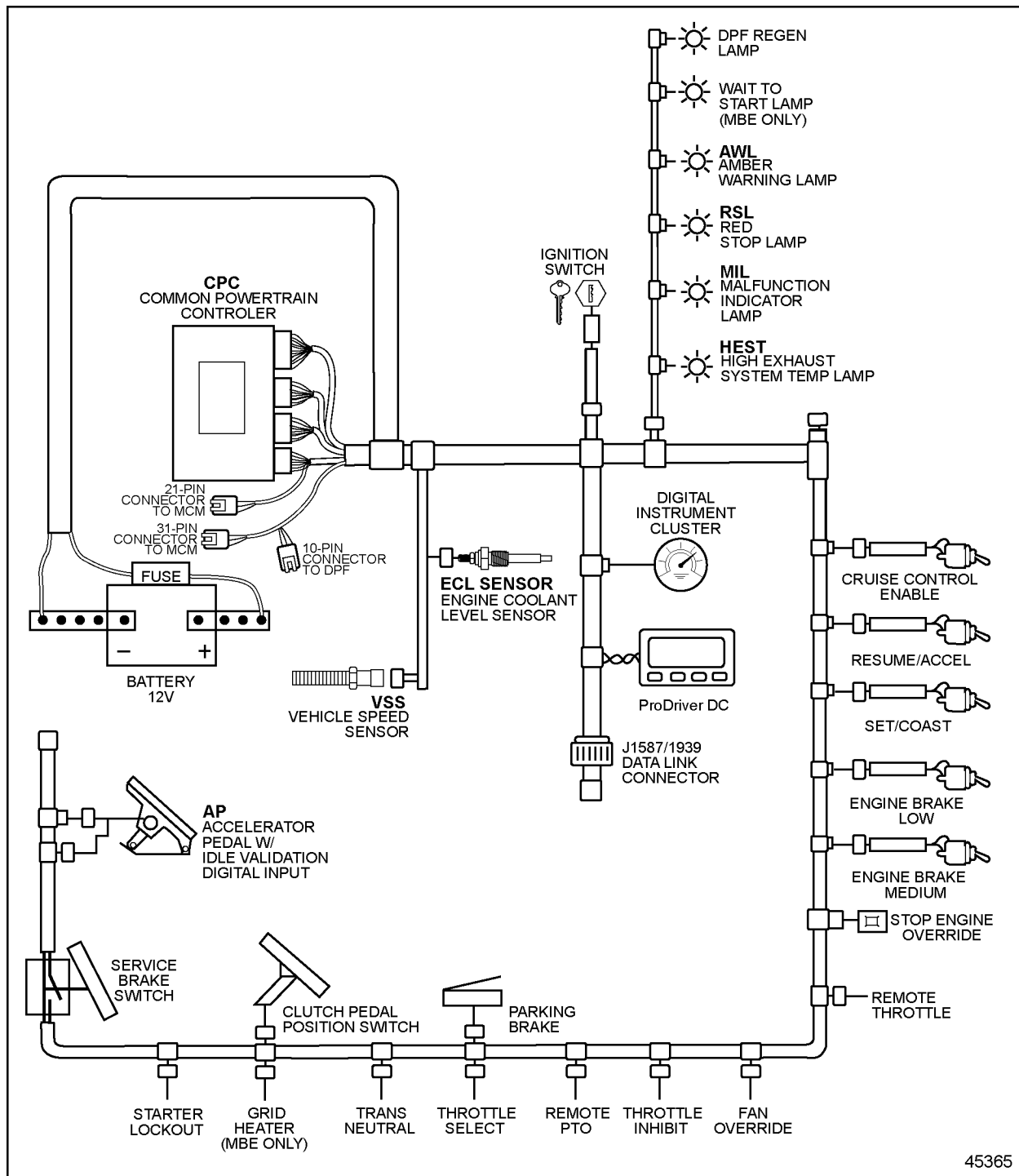


Figure 4 Vehicle Interface Harness

ENGINE BRAKING POWER

To supplement vehicle braking, the MBE 4000 engine can be equipped with an engine brake.

Exhaust Brake/Constant Throttle Valves

To increase braking performance, the engine is equipped with an exhaust brake on the turbocharger in conjunction with constant throttle valves on the cylinder head.

NOTE:

The constant throttle valves are activated by engine oil pressure.

The exhaust back-pressure is used by the exhaust brake to increase braking performance.

Optional Engine Brake

For high braking output, the MBE 4000 engine can be equipped with an optional engine brake. The engine brake increases the air mass flow through the engine to provide up to 600 brake horsepower. The engine brake can be operated either manually, in different stages, or automatically, through the cruise control function.

Because the charge air pressure is maintained at a high level during braking, full throttle response is available immediately, if the operator desires it, without any turbo lag.

1 ENGINE

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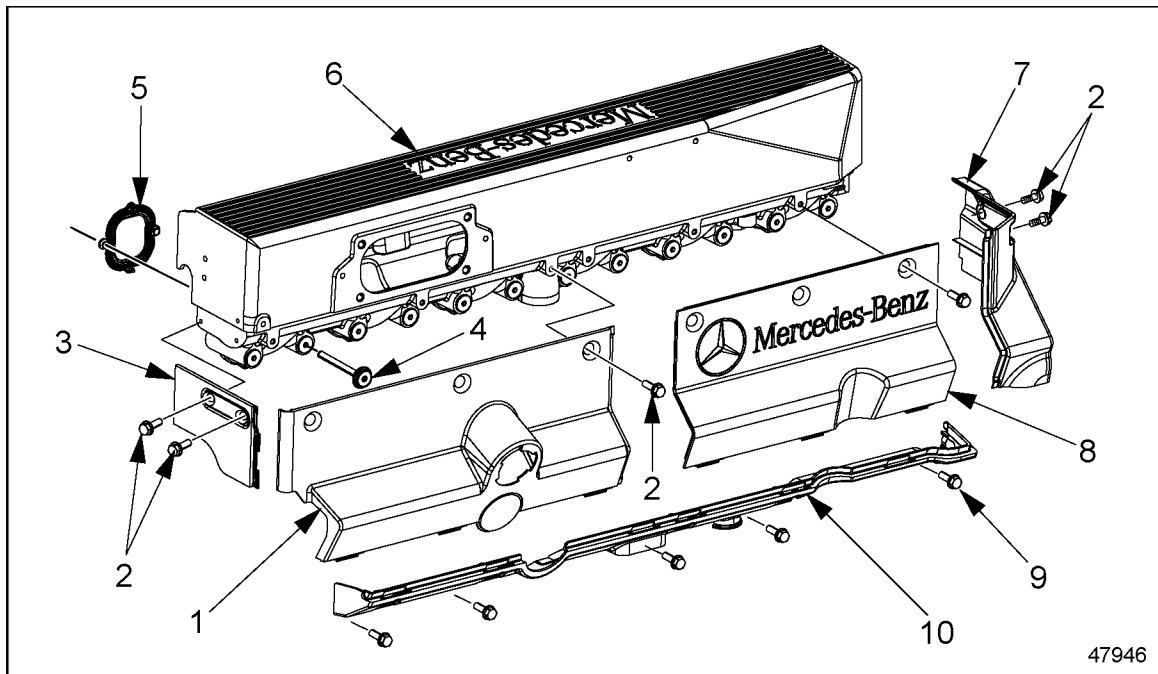
1.1 ENGINE TRIM COVERS AND FRAMES

The engine trim covers enclose the unit pumps and high pressure fuel lines on the left side of the engine.

1.1.1 Removal of Engine Trim Covers

removal steps are as follows:

1. Loosen the hose clamp at the air inlet hose at the air compressor and move hose out of the way.
2. Disconnect the 31-pin vehicle harness connector at the front trim cover by pushing on tab of 31-pin connector and rotating the connector counterclockwise.
3. Remove the two engine side trim covers by removing six bolts securing the cover to the air intake manifold. See Figure 1-1.



- | | |
|---------------------------------------|-------------------------|
| 1. Front Side Trim Cover | 6. Air Intake Manifold |
| 2. Bolts | 7. Rear Trim Cover |
| 3. Front Trim Cover | 8. Rear Side Trim Cover |
| 4. Air Intake Manifold Bolts (qty 12) | 9. Bolts (qty 5) |
| 5. Gaskets (qty 6) | 10. Trim Cover Frame |

Figure 1-1 Engine Trim Covers and Frame

4. Remove the rear engine trim cover by removing the two bolts securing it to the rear of the air intake manifold. See Figure 1-1.

- Remove the two bolts from the front trim cover and remove cover. See Figure 1-1.

1.1.2 Installation of Engine Trim Covers

Installation steps are as follows:

- Insert the front trim cover into the frame and secure to the front of the air intake manifold with two bolts. Torque the bolts to 12 N·m (9 lb·ft). See Figure 1-2.

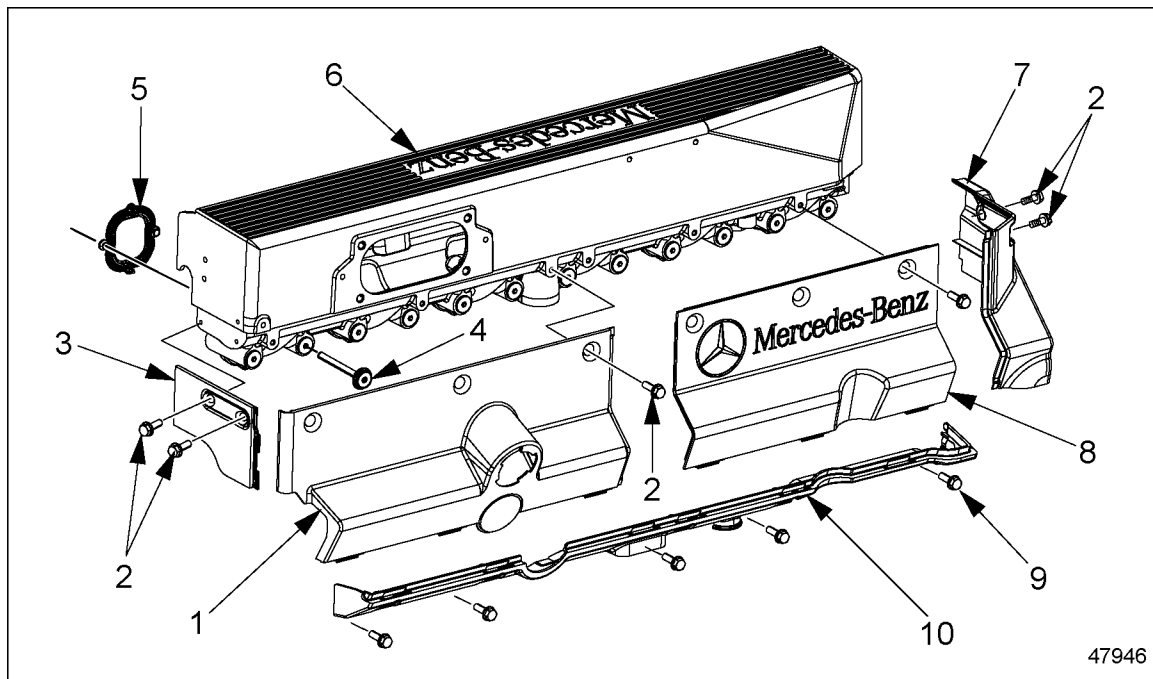


Figure 1-2 Engine Trim Covers and Frame

- Insert the rear trim cover into the frame and secure to rear of air intake manifold with two bolts. Torque the bolts to 12 N·m (9 lb·ft). See Figure 1-2.
- Insert two side trim cover into the trim frame and secure cover with six bolts. Torque bolts to 12 N·m (9 lb·ft). See Figure 1-2.
- Connect the 31-pin vehicle harness connector at the front trim cover.

1.1.3 Removal of Engine Trim Covers Frame

Removal steps are as follows:

- Remove the engine trim covers. Refer to section 1.1.1.
- Remove the trim cover frame from the cylinder block by removing five bolts. See Figure 1-2.

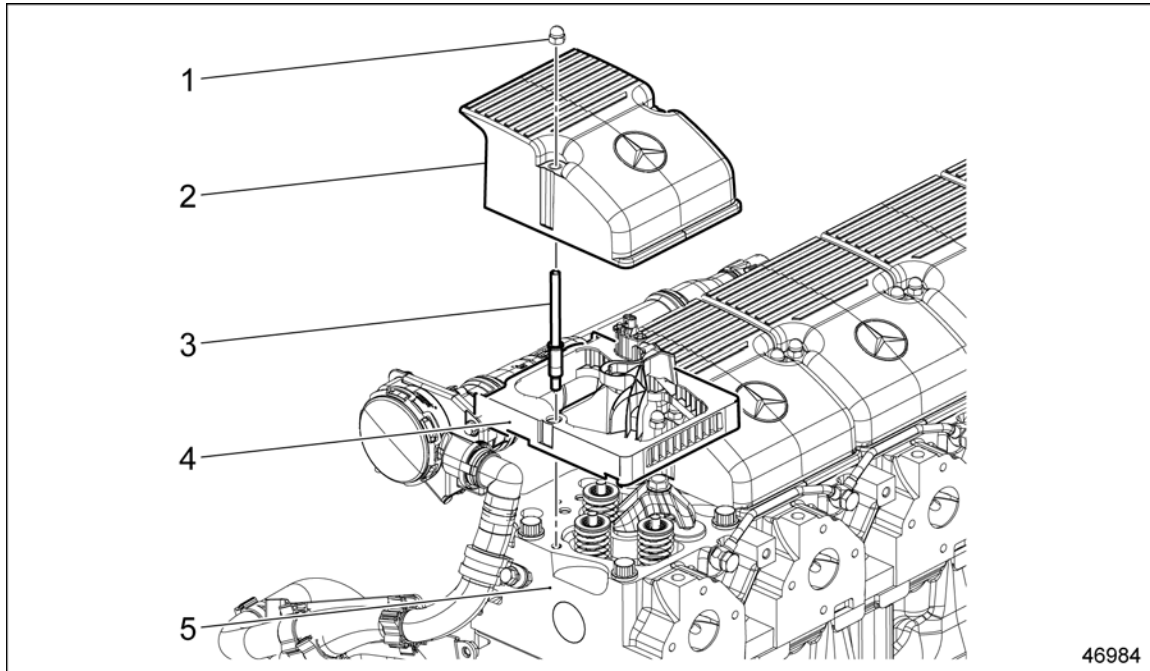
1.1.4 Installation of Engine Trim Covers Frame

Installation steps are as follows:

1. Secure the trim cover frame to the cylinder block with five bolts. Torque the bolts to 25 N·m (18 lb·ft). See Figure 1-1.
2. Install the engine trim covers. Refer to section 1.1.2.

1.2 CYLINDER HEAD COVER

The cylinder head cover completely encloses the valve mechanism on top of the cylinder head. See Figure 1-3 for a general view of the cylinder head cover.



- | | |
|------------------------|-----------------------------------|
| 1. Cap Nuts | 4. Injector Harness Adaptor Frame |
| 2. Cylinder Head Cover | 5. Cylinder Head |
| 3. Studs (qty 2) | |

Figure 1-3 Cylinder Head Cover

1.2.1 Removal of Cylinder Head Cover

Removal steps are as follows:

1. Remove the cylinder head cover cap nuts. See Figure 1-3.
2. Remove the cylinder head cover and gasket. Inspect the gasket, if damaged replace. See Figure 1-3.
3. If necessary, remove the cylinder head cover studs.
4. Clean the sealing surfaces of the cylinder head cover and the cylinder head.

1.2.2 Installation of Cylinder Head Cover

Installation steps are as follows:

1. If removed, install the two cylinder head cover studs. Torque the studs to 20–25 N·m (15–18 lb·ft).

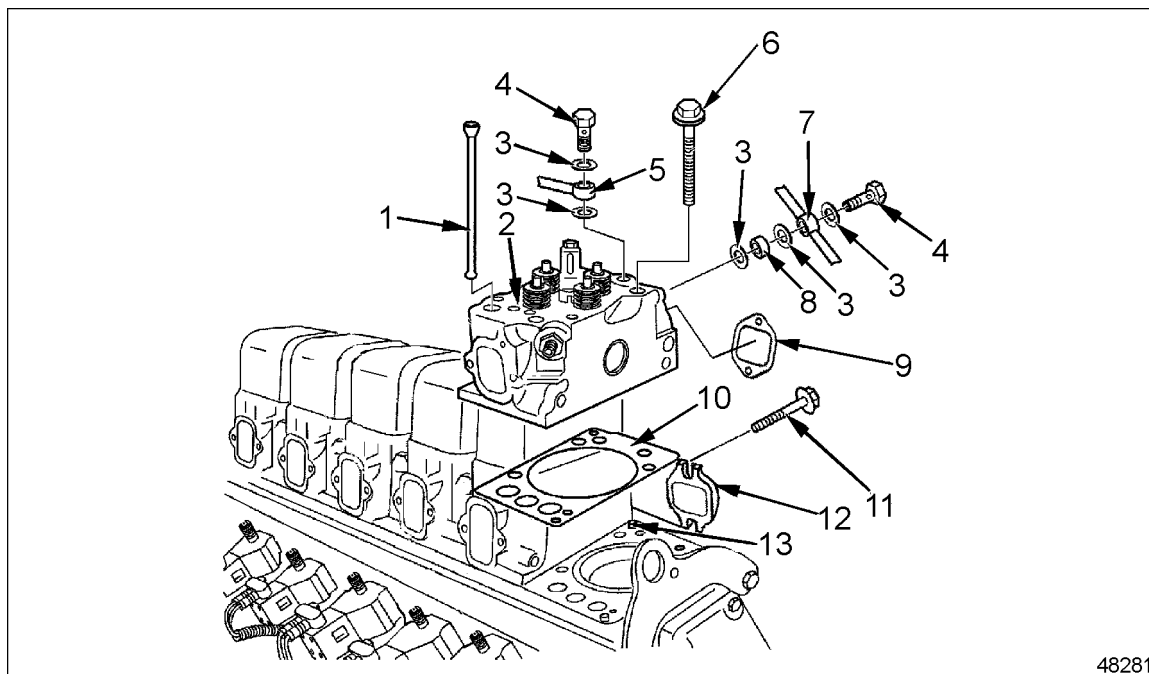
2. Install the gasket and the cylinder head cover on the cylinder head. See Figure 1-3.
3. Secure the cylinder head cover with two cap nuts. Torque the nuts 18–20 N·m (13–15 lb·ft).

1.3 CYLINDER HEAD

The MBE 4000 engine has individual heads for each cylinder. To remove one head, follow these instructions, step by step. To remove all the heads, repeat each step in these instructions, as applicable, for all six cylinders.

1.3.1 Removal of Cylinder Head

See Figure 1-4 for an exploded view of a cylinder head.



- | | |
|-----------------------------|------------------------------------|
| 1. Pushrod | 8. Spacer |
| 2. Cylinder Head | 9. Exhaust Port Gasket |
| 3. Seal Ring | 10. Cylinder Head Gasket |
| 4. Hollow Core (Banjo) Bolt | 11. Exhaust Manifold |
| 5. Coolant Line | 12. Exhaust Manifold Mounting Bolt |
| 6. Cylinder Head Bolt | 13. Guide Pin |
| 7. Constant-Throttle Line | |

Figure 1-4 **Exploded View of Cylinder Head**

Removal steps are as follows:

**WARNING:****HOT COOLANT**

To avoid scalding from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Wear adequate protective clothing (face shield, rubber gloves, apron, and boots). Remove the cap slowly to relieve pressure.

1. Drain the coolant from the radiator. Refer to section 4.1.1.

NOTE:

Clean the cylinder head cover before removing it.

2. Remove the trim cover frame. Refer to section 1.1.3.
3. Remove the rocker arm assembly. Mark the valve bridges and pushrods in order of removal. Refer to section 1.21.1.
4. Remove the EGR cooler support bracket. Refer to section 8.3.3.
5. Remove the air intake manifold. Refer to section 6.4.1.

NOTICE:

Do not move the thrust bolt, because there is danger of causing a change in the position of the transfer-tube. If the position of the transfer-tube is changed, engine damage could result.

6. Remove the high-pressure fuel line and transfer tube. Refer to section 2.4.1.
7. To prevent any dirt from entering, cover the openings in the unit.
8. Remove the turbocharger from the exhaust manifold. Refer to section 6.7.2.

NOTE:

If removing one or two cylinder heads, loosen the bolts on the rest of the exhaust manifold.

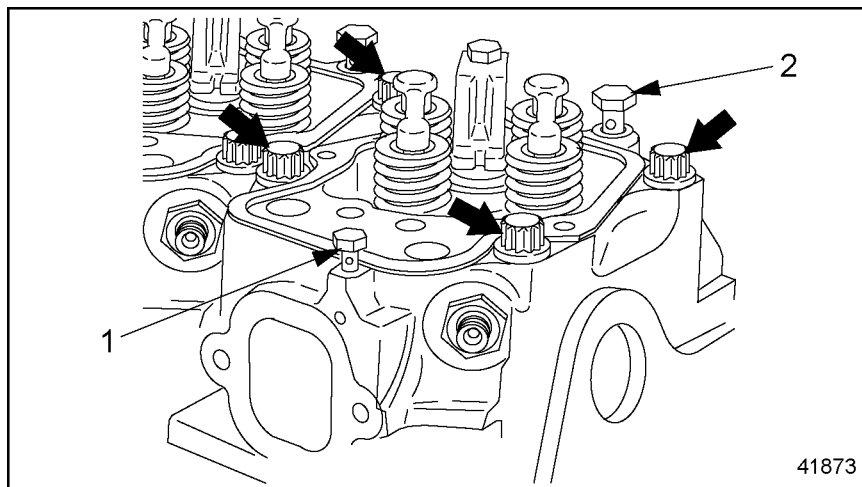
9. Remove the fuel return line from the cylinder head. Discard the seal rings. See Figure 1-5.

NOTE:

If removing all cylinder heads, remove the exhaust manifold from the engine.

10. Disconnect the constant throttle line from the cylinder head. Discard the seal rings.
11. Disconnect the coolant line from the cylinder head. See Figure 1-5.

12. Using the head bolt impact socket (J-45389), loosen the cylinder head bolts. When all the bolts are loose, remove the bolts from the cylinder head. See Figure 1-5.



1. Fuel Return Line Connection

2. Coolant Line Connection

Figure 1-5 Cylinder Head Bolts

NOTICE:

Do not place the head mating surface down on a flat surface. This would damage the fuel injector nozzles, which protrude slightly.

13. Remove the cylinder head and set it on wooden blocks or on its side.
14. Remove the head gasket from the block and discard gasket.
15. Thoroughly clean the cylinder head, both contact surfaces (head and block), and surfaces inside the cylinder of excess oil, grime, and paint chips.
16. With a straightedge, check the cylinder head surface for warpage. Refer to section 1.3.1.1. Listed in Table 1-1 are warpage limits.

Description	Limit mm (in.)
Over a length of 150 mm (6 in.)	0.15 (0.006)

Table 1-1 Head Warpage Limits

17. Check the cylinder liner protrusion from the cylinder block. Listed in Table 1-2 are the specifications. Refer to section 1.4.1.3.

Description	Specifications: mm (in.)
Cylinder Liner Protrusion from block	0.230-0.330 (0.0090-0.0130)
Difference between the four measuring points	Max.: 0.02 (0.0008)

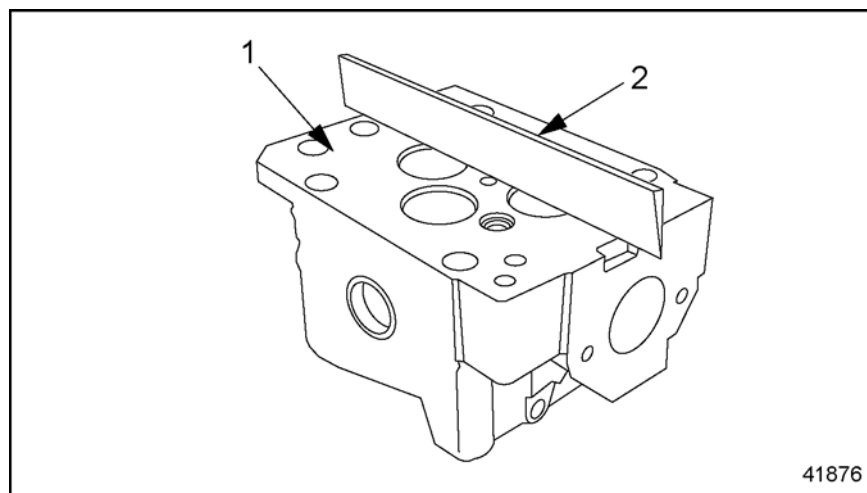
Table 1-2 Specifications for Measuring Cylinder Liner Protrusion

18. Inspect the cylinder head for cracks or signs of damage. Replace if necessary.

1.3.1.1 Inspection of Cylinder Head

Inspection steps are as follows:

1. Remove the cylinder head. Refer to section 1.3.1.
2. Remove the fuel injector. Refer to section 2.6.1.
3. Remove the intake and exhaust valves. Refer to section 1.20.3.
4. Remove the constant throttle valve. Refer to section 1.6.1.
5. Inspect the contact surface (bottom face) of the cylinder head for warpage, both lengthwise and diagonally. See Figure 1-6. If the gap is larger than 0.15 mm (0.006 in.), machine the cylinder head.



1. Contact Surface

2. Straightedge

Figure 1-6 Measuring Cylinder Head Warpage

- [a] Place a straightedge lengthwise across the cylinder head contact surface (bottom face).

- [b] If there is a gap between the lower edge of the straightedge and the contact surface of the cylinder head that is large enough to let light through, insert a feeler gauge into the gap.
- [c] Measure the amount of warpage with the feeler gauge and compare it to the value listed in Table 1-3. If the gap is larger than 0.15 mm (0.006 in.), machine the cylinder head.

What To Measure	How To Measure	Specifications mm (in.)
Maximum Permissible Warpage of Head Mating Surface	Lengthwise and Diagonally	0.015 (0.006)
Maximum Permissible Parallelism Deviation of Head Mating Surface	At Each of the Four Corners	0.1 (0.004)
Overall Height of Cylinder Head	When New	113.85-114.15 (4.482-4.494)
	After Machining (Minimum Height)	113.5 (4.47)

Table 1-3 Cylinder Head Specifications

- [d] Place the straightedge diagonally across the cylinder head. Repeat the procedure above.
6. Check the cylinder head contact surface for parallelism, at each corner. See Figure 1-7. If the four measurements deviate by more than 0.1 mm (0.004 inch), machine the cylinder head.

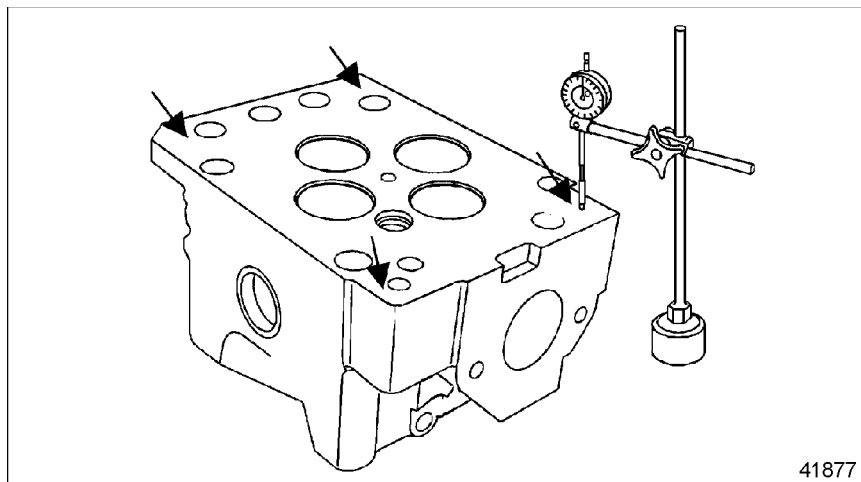


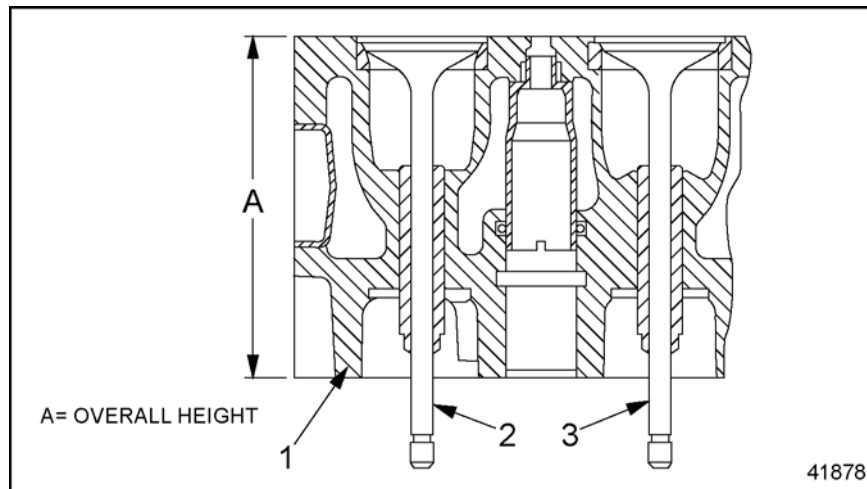
Figure 1-7 Measuring Cylinder Head Parallelism

- [a] Rest the cylinder head on a flat surface, with the contact surface exposed (bottom face up).

NOTE:

Make sure the head is level before going on with this check.

- [b] Install a dial gauge so that the feeler touches the contact surface with some preload.
 - [c] Fasten the dial gauge and adjust the scale to "0" (zero).
 - [d] Check the reading on the dial gauge. If the reading is larger than 0.1 mm (0.004 in.), machine the cylinder head.
 - [e] Repeat this procedure at each spot marked by an arrow (each corner of the cylinder head).
7. Measure the overall height of the cylinder head. See Figure 1-8. Replace the head if below the minimum height. If above the maximum height, machine the head down to the maximum height listed in Table 1-3.



1. Cylinder Head

2. Exhaust Valve

3. Intake Valve

Figure 1-8 Measuring Cylinder Head Height

1.3.1.2 Machining of Cylinder Head

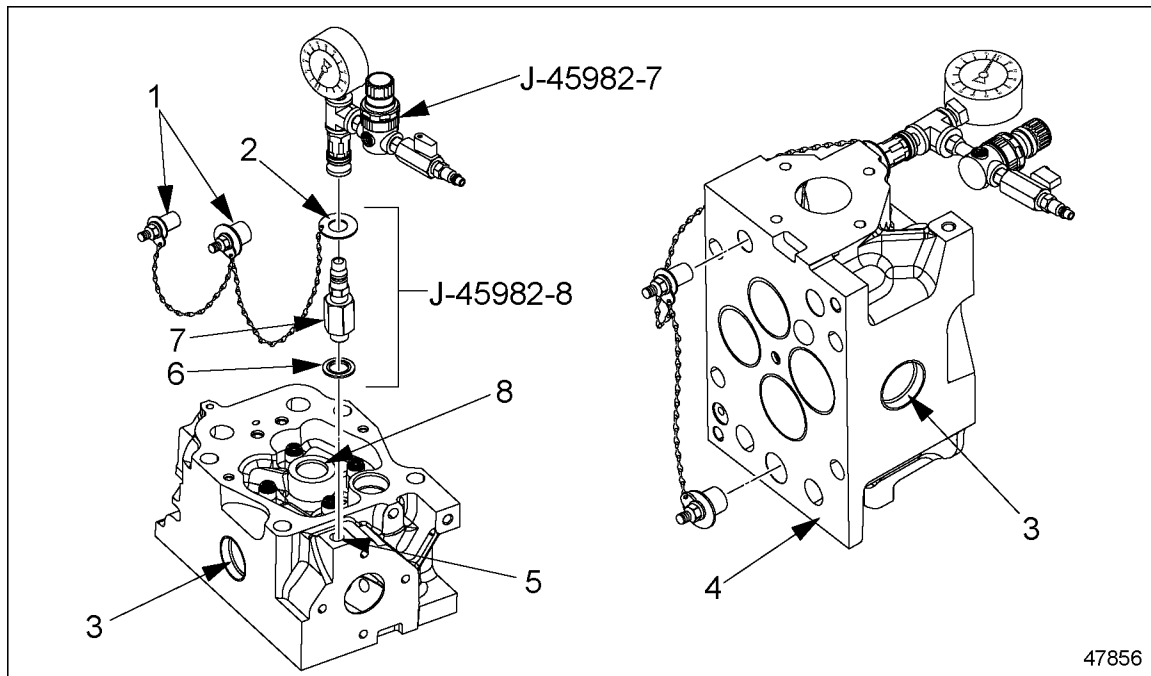
Machining steps are as follows:

1. Machine the contact surface of the cylinder head, to correct any problems found during inspection.
 - [a] If rejected for warpage, check warpage again until it is within specifications.
 - [b] If rejected for lack of parallelism, check parallelism again until it is within specifications.
2. After machining, check again the overall height of the cylinder head.
3. Install the constant throttle valve. Refer to section 1.6.2.
4. Install the intake and exhaust valves. Refer to section 1.20.4.
5. Install the fuel injector. Refer to section 2.6.2.
6. Install the cylinder head. Refer to section 1.3.2.

1.3.1.3 Testing of Cylinder Head

Testing steps are as follows:

1. Remove the exhaust brake compressed-air line from the exhaust brake cylinder.
2. Remove the v-band clamp connecting the exhaust pipe to the brake valve housing.
3. Remove the turbocharger. Refer to section 6.7.2.
4. Remove the exhaust manifold. Refer to section 7.1.1.
5. Remove the cylinder head. Refer to section 1.3.1.



- | | |
|----------------------------|--------------------------|
| 1. Test Plugs | 5. Coolant line Hole |
| 2. Safety Retaining Washer | 6. Sealing Washer |
| 3. Cast Iron Plugs | 7. Air Test Plug Adaptor |
| 4. Firedeck | 8. Protective Sleeve |

Figure 1-9 Cylinder Head Leak Test Kit J-45982-8

6. Remove the fuel injector nozzle from the cylinder head. Refer to section 2.6.1.
7. Using the Cylinder Head Leak Test Kit (J-45982-8 part of Head and Block Leak Test Kit J-45982), install two plugs into the appropriate holes on firedeck of cylinder head. Tighten the nuts to expand the plugs. See Figure 1-9.
8. Install the air test plug adaptor into the coolant line hole on the top of the cylinder head. See Figure 1-9.
9. Place the safety retaining washer over the test plug adaptor. See Figure 1-9.

10. With the shutoff valve on the regulator in the off position, set the regulator to zero pressure by pulling up on the adjusting knob and turning counter-clockwise.

**WARNING:****EYE INJURY**

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 276 kPa (40 psi) air pressure.

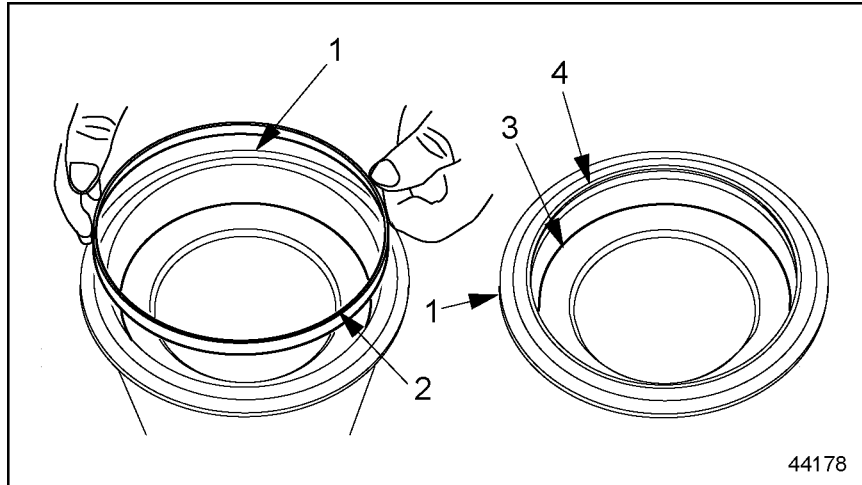
11. Connect a shop air supply to the pressure regulator (J-45982-7 part of kit J-45982) then turn the shutoff valve to the ON position.
12. Adjust the system pressure by pulling up on the adjusting knob and turn clockwise until a pressure of reading on the gauge is 200 kPa (29 psi).
13. Connect the Regulator and Gage (J-45982-7 part of kit J-45982) to the air test plug on the cylinder head. See Figure 1-9.
14. Check for leaks around the test plugs and fittings with a soapy water solution. Repair any leaks found.
15. With a soapy water solution check the cup plugs on the sides of the cylinder head and the injector nozzle protective sleeve area.
 - [a] If the cup plug(s) are leaking, replace the plug(s).
 - [b] If the injector protective sleeve is leaking, replace the protective sleeve O-ring. Refer to section 2.7.1.
16. Close the air supply and watch the pressure gauge for 30 seconds. If the air pressure drops during this time the cylinder head has leakage from the cooling passages and is not suitable for reuse.
17. Remove the test equipment from the cylinder head and repeat leak test for any additional cylinder heads.
18. Install the fuel injector nozzle in the cylinder head. Refer to section 2.6.2.
19. Install the cylinder head. Refer to section 1.3.2.
20. Install the exhaust manifold. Refer to section 7.1.2.
21. Install the turbocharger. Refer to section 6.7.3.
22. Install the air line on the exhaust brake cylinder.
23. Clean the sealing surfaces on the exhaust pipe and brake valve housing.
24. Slide the exhaust pipe and clamp over the end of the housing. Tighten the clamp.

1.3.2 Installation of Cylinder Head

Installation steps are as follows:

NOTICE:

Be sure the carbon scraper ring is seated in the groove on the top part of the cylinder liner before installing a new cylinder head gasket and the cylinder head, component damage will result.



1. Cylinder Liner
2. Carbon Scraper Ring

3. Installed Piston
4. Carbon Scraper Ring located in groove in cylinder liner

Figure 1-10 Carbon Scraper Ring

NOTICE:

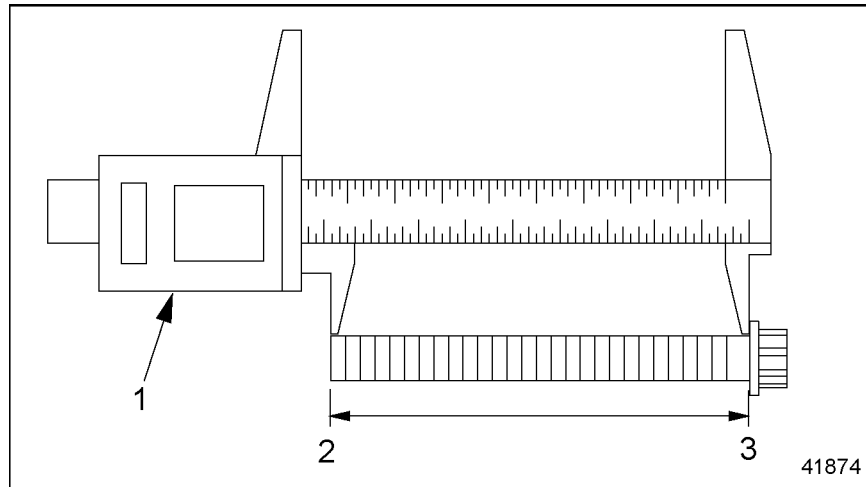
The cylinder head gasket on the engine has a thick rubber seal at the coolant inlet and outlet ports. The cylinder head has a machined 1.3 mm recess at the mating surface. Correct gasket with head configuration must be used. Failure to use the correct gasket could result in engine failure.

1. Install a new head gasket. Match up the holes in gasket with those in the cylinder block and place the head gasket over the guide pins in the block.
2. Position the cylinder head on the head gasket. Make sure the head is seated onto the guide pins.

NOTICE:

Head and gasket must be seated properly, or engine damage could result.

3. Using a dial caliper, measure the length of the cylinder head bolts from the end of the bolt to the bottom of the flange. See Figure 1-11. Listed in Table 1-4 are the acceptable lengths. Replace any bolts which do not meet these specifications.



1. Dial Caliper

3. Bottom of Flange

2. End of Cylinder Head Bolt

Figure 1-11 Measuring Head Bolts

Description	Length mm (in.)
Shaft length when new	210.0 (8.27)
Maximum shaft length	212.0 (8.35)

Table 1-4 Cylinder Head Bolt Lengths

4. Lubricate the cylinder head bolts with engine oil.

5. Using the head bolt socket (J-45389), install the cylinder head bolts.

NOTE:

For the correct tightening sequence, see Figure 1-12. Listed in Table 1-5 are the specific stages in the tightening sequence.

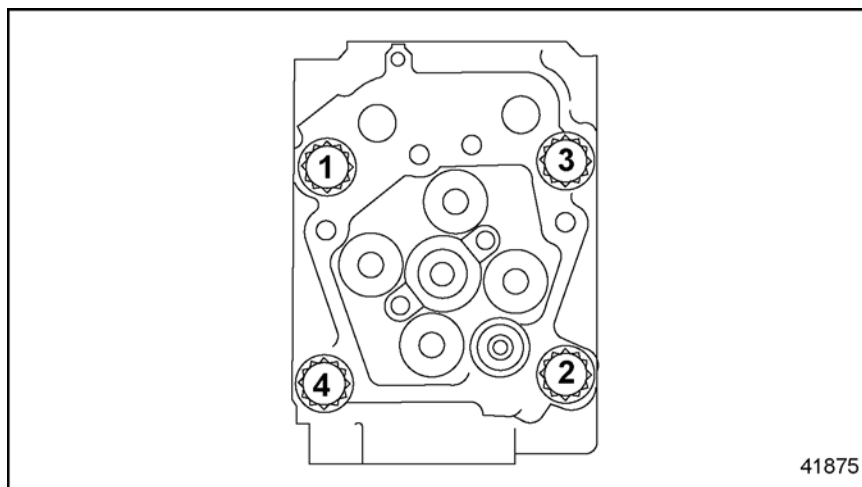


Figure 1-12 Tightening Sequence, Cylinder Head Bolts

Size	Max. Shaft Length mm (in.)	Tightening Stage	Torque N·m (lb·ft) (Repair work in the field)
M15 x 2	212.0 (8.35)	Stage 1	10 (7)
		Stage 2	50 (37)
		Stage 3	100 (74)
		Stage 4	200 (148)
		Stage 5	additional 90°
		Stage 6	additional 90°

Table 1-5 Cylinder Head Bolts Tightening Stages

NOTE:

If the stretch bolt tightening torque is exceeded, remove it, check its maximum permissible shaft length (replace if necessary), and tighten it from Stage 1. Unconditionally replace all bolts whose shaft length exceeds the maximum permissible value.

6. Replace the seal rings and connect the fuel injector spill line to the cylinder head. Torque banjo bolt to 15 N·m (11 lb·ft).
7. Replace the seal rings and install the constant throttle line on the cylinder head. Torque banjo bolt to 35 N·m (26 lb·ft).
8. Connect the coolant line to the cylinder head. Torque banjo bolt to 35 N·m (26 lb·ft).

NOTICE:

Correct torque on the high-pressure fuel lines are critical. Incorrect torques could result in leaks or lack of power due to restricted fuel flow.

9. Install the high-pressure fuel line and transfer tube. Refer to section 2.4.2.
10. Install exhaust manifold. Refer to section 7.1.2.
11. Install the EGR cooler support bracket. Refer to section 8.3.4.
12. Install the EGR cooler. Refer to section 8.3.2
13. Install the air intake manifold. Refer to section 6.4.2.
14. Install the injector harness(s). Refer to section 2.5.2.
15. Lubricate the pushrods with a light coating of engine oil and install the pushrods, in order, as removed.

NOTE:

Make sure the pushrods are correctly seated in the valve tappets.

16. Install the valve bridges, in order, as removed.
17. Install the rocker arm assembly, in order, as removed. Tighten each rocker arm mounting bolt first to 60 N·m (44 lb·ft); then an additional 90°. Refer to section 1.21.4.
18. Install the engine barring tool (J-46392) and adjust the valves. For valve lash adjustment procedures, refer to section 13.1.
19. Remove the engine barring tool. (J-46392) Refer to section 1.17.1.
20. Install the inspection hole end cover on the flywheel housing and secure with two bolts. Torque the bolts to 25 N·m (18 lb·ft).
21. Check that the coolant drain plug is tight and not leaking.
22. Fill the radiator with coolant. Refer to section 4.1.1.
23. Install the cylinder head cover. Refer to section 1.2.2.
24. Install the engine trim covers. Refer to section 1.1.2.

NOTE:

Prime the fuel system. Refer to section 12.1.5.

**WARNING:**
ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

25. Start the engine. Observe the oil pressure gauge to verify the correct oil pressure. The maximum oil pressure readings at idle speed are listed in Table 1-6. Pay attention to the coolant temperature gauge, warning lights, fluid leaks, and any other signs of a problem.

Description	Minimum Oil Pressure Reading kPa (psi)
Engine at Idle Speed	50 (7)
Engine at Max. rpm	250 (36)

Table 1-6 Oil Pressure Readings

26. Stop the engine, check the coolant level, and top off if necessary.

1.4 CYLINDER BLOCK

The cylinder block has integrated oil and water channels. The upper section of the cylinder bore is induction-hardened. The cylinder block has additional ribs for strength and an improved casting design in the area of the high pressure unit pumps. A flange was added to the left side of the cylinder block for the pre-separator crankcase breather. The purpose of the cylinder liner with an additional sealing ring is to prevent high mileage coolant leakage due to wear in the balcony area of the cylinder block. The ring will keep the coolant away from the balcony area. This service procedure applies to all models of the MBE 4000 engine.

This procedure describes the steps needed to service the engine with the installation of the new design liner with the D-ring seal.

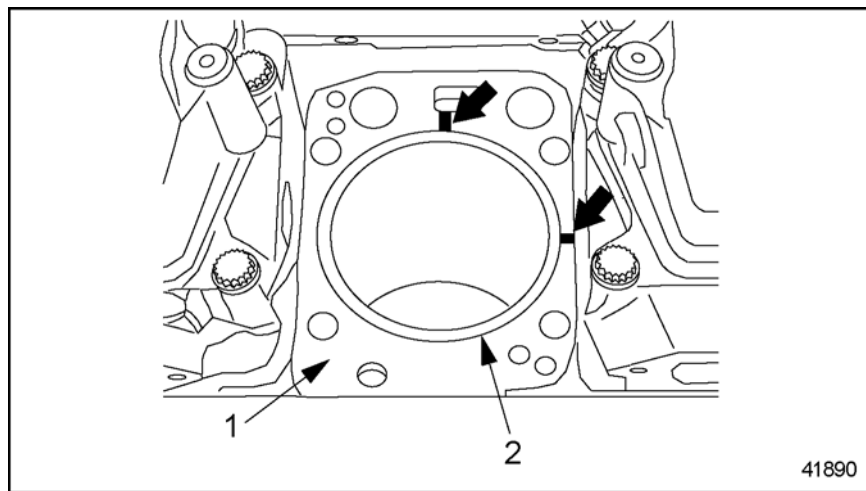
1.4.1 Removal of Cylinder Liner

Removal steps are as follows:

1. Remove the piston. Refer to section 1.19.1.
2. Using a paint pen, mark the position of the cylinder liner in the cylinder block. Mark both the cylinder liner and the block. Then make another set of marks 90 degrees from the first set, in a clockwise direction. See Figure 1-13.

NOTE:

If the same cylinder liner is used again, it must be installed at an offset of 90 degrees from its last position. This reference will not be needed if the cylinder liner is being replaced.



1. Cylinder Block

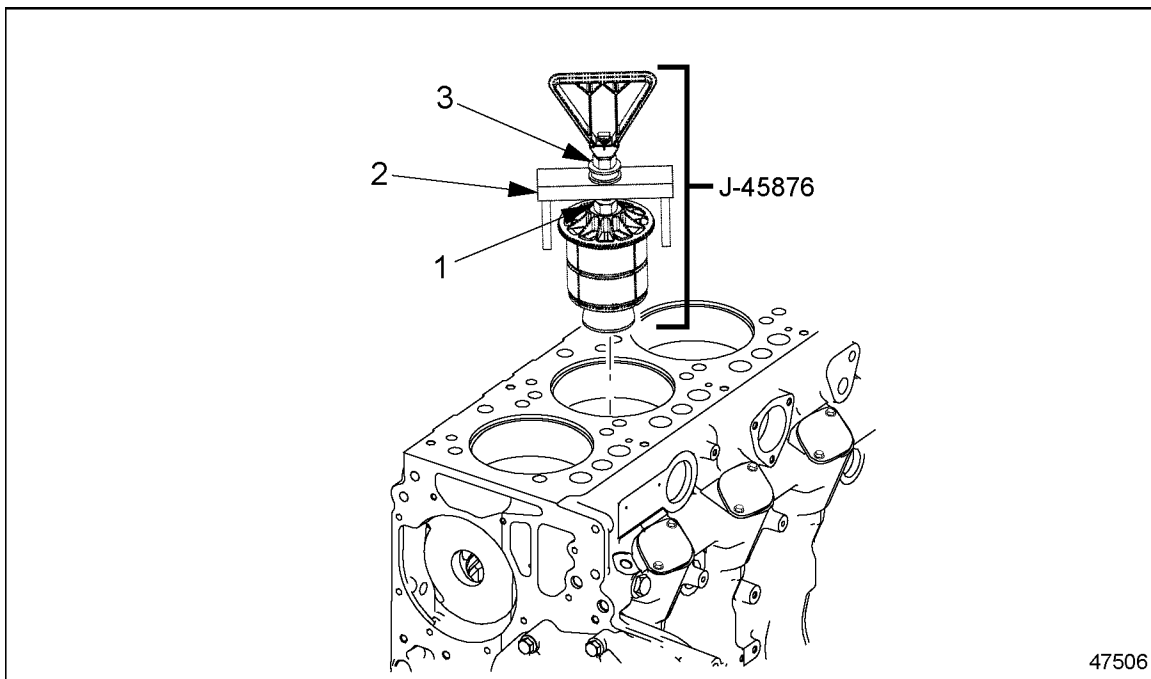
2. Cylinder Liner

Figure 1-13 Mark the Cylinder Liner

NOTICE:

To prevent cylinder liner damage, never use a hammer or other unsuitable device to remove the cylinder liner.

3. Remove the cylinder liner, using the cylinder liner removal tool, (J-45876). See Figure 1-14.
 - [a] Clean and wipe out the inside of the cylinder liner of any oil or coolant.
 - [b] Install the cylinder liner removal tool in the cylinder liner to be removed with bridge resting on deck of cylinder block and lip of tool resting on the top of the cylinder liner. See Figure 1-14.
 - [c] Tighten the lower nut to expand the tool in the cylinder liner. See Figure 1-14.
 - [d] Tighten the upper nut on the tool until the cylinder liner is pulled from the cylinder block. Remove the cylinder liner and tool. See Figure 1-14.
 - [e] Remove the tool from the cylinder liner.

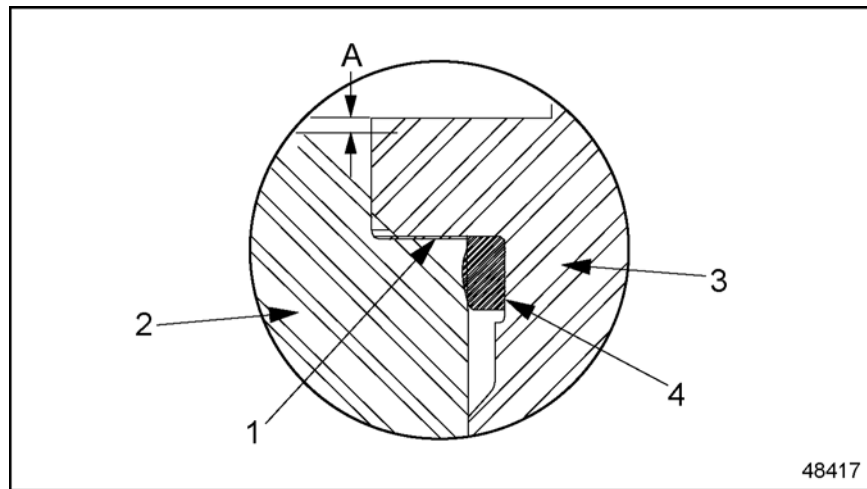


1. Lower Nut
2. Resting Bridge

3. Upper Nut

Figure 1-14 **Cylinder Liner Removal Tool J-45876**

4. Remove the shim from the block counterbore. See Figure 1-15.



1. Collar Seat Insert (shim)

2. Cylinder Block

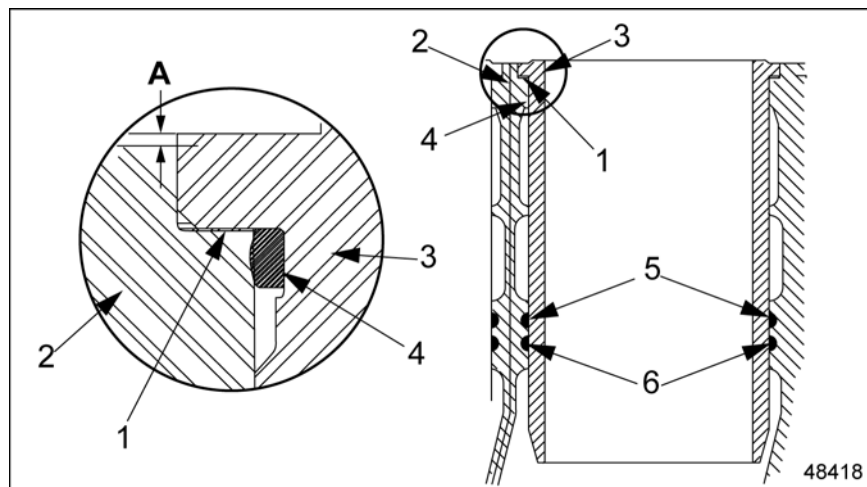
3. Cylinder Liner

4. Liner Seat D-Ring

A. Specified in Measuring Cylinder Liner Protrusion Table

Figure 1-15 Cylinder Liner Seat

5. Remove and discard the two O-rings from the block. See Figure 1-16.



1. Collar Seat Insert (shim)

2. Block

3. Cylinder Liner

4. Liner D-Ring

5. Upper O-ring

6. Lower O-ring

A. Specified in Measuring Cylinder Liner Protrusion Table

Figure 1-16 Cylinder Liner O-rings

6. Clean the cylinder block sealing areas and inspect for corrosion.
7. Check the condition of the cylinder liner collar seat. Ensure that the depth of the collar seat is within the specifications listed in Table 1-7.

Description	Dimensions: mm (in.)
Cylinder Liner Protrusion, From Block, see Figure 1-15, Ref. A.	0.230–0.330 (0.0090–0.0130)
Height of the Cylinder Liner Collar, see Figure 1-15	10.10–10.12 (0.3976–0.3984)
Depth of the Collar Seat, see Figure 1-15	9.950–10.010 (0.3917–0.3941)
Thickness of the Seat Insert	0.14–0.16 (0.0055–0.0063)

Table 1-7 Cylinder Liner Installation Tolerances

8. Looking for rust or corrosion, check the condition of the cylinder liner collar seat, listed in Table 1-8.

Description	Dimensions: mm (in.)
Admissible Out-of-Round of the Cylinder Liner, where it contacts the O-rings	Max.: 0.02 (0.0008)
Admissible Deformation of the Cylinder Liner Collar, at the Contact Surface with the Seat Insert	Max.: 0.02 (0.0008)
Admissible Deformation of the Cylinder Liner Collar Seat, at the Contact Surface with the Seat Insert	Max.: 0.03 (0.0012)

Table 1-8 Cylinder Liner Inspection Tolerances

1.4.1.1 Inspection of Cylinder Liner Bore

Inspection steps are as follows:

1. Check the wall of the cylinder liner for signs of excessive wear or deformation.
2. Check the honing pattern on the cylinder liner for damage caused by penetration of dirt into the cylinder. If the honing pattern is faded or no longer visible, discard the cylinder liner. See Figure 1-17 for an intact honing pattern and see Figure 1-18 for a faded honing pattern.

NOTE:

Minor fading of the honing pattern at the top ring inversion area is not sufficient cause to reject the cylinder liner.

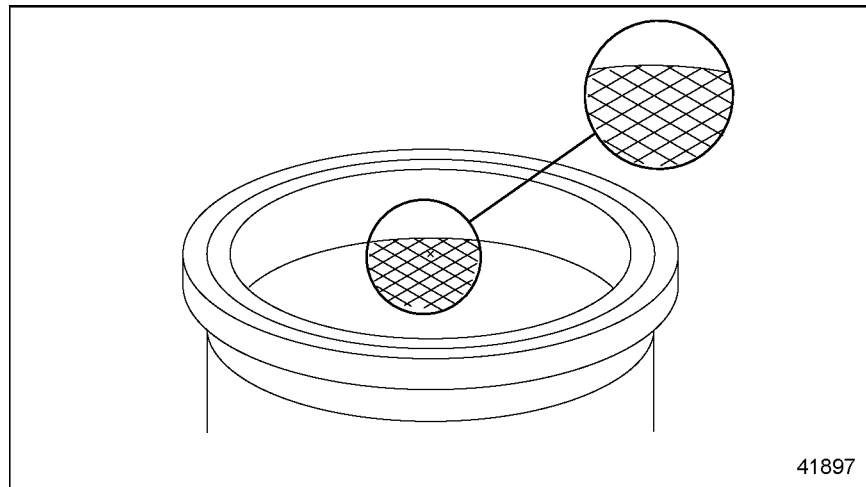


Figure 1-17 Intact Honing Pattern

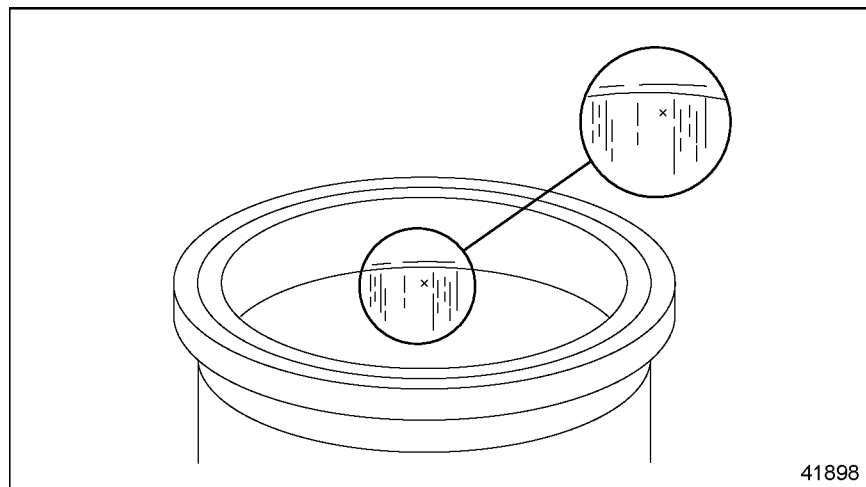


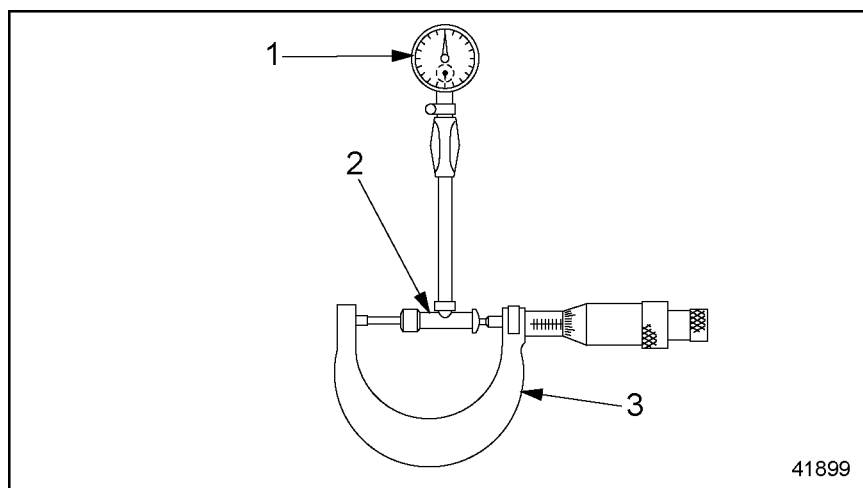
Figure 1-18 Faded Honing Pattern

3. Do an external visual check of the cylinder liner for signs of cavitation and corrosion. Discard the cylinder liner if any damage is noted.

1.4.1.2 Measurement of Cylinder Liner Bore

Measurement steps are as follows:

1. Set the dial gauge and quick calipers with a dial caliper to the inside diameter of the cylinder liner. Preload the dial gauge to 5 mm (0.20 in.). See Figure 1-19 for set-up and listed in Table 1-9 are specifications.



1. Dial Gauge

3. Dial Caliper

2. Quick Calipers (for internal measurements)

Figure 1-19 Setting the Dial Gauge

Where To Measure	What To Measure	Dimensions: mm (in.)
Measuring Point 1: At the area of the O-rings	Inside Diameter of the Cylinder Liner, A Class	127.990–127.995 (5.0390–5.0392)
Measuring Point 1: At the area of the O-rings	Inside Diameter of the Cylinder Liner, B Class	127.995–128.005 (5.0392–5.0396)
Measuring Point 1: At the area of the O-rings	Inside Diameter of the Cylinder Liner, C Class	128.005–128.010 (5.0396–5.0398)
Measuring Point 2: Upper Reversal Point of the First Piston Ring	Max. Wear to Cylinder Liner, Measured Along Axis A and Axis B	0.08 (0.003)
At Measuring Point 2, Compare Axis A to Axis B	Admissible Wear Out	Max.: 0.08 (0.003)

Table 1-9 Cylinder Liner Measurements

NOTE:

This measurement serves as a baseline against which to measure the actual wear.

2. Measure the inside diameter of the cylinder liner at measuring point 1: near the O-ring area. See Figure 1-20.

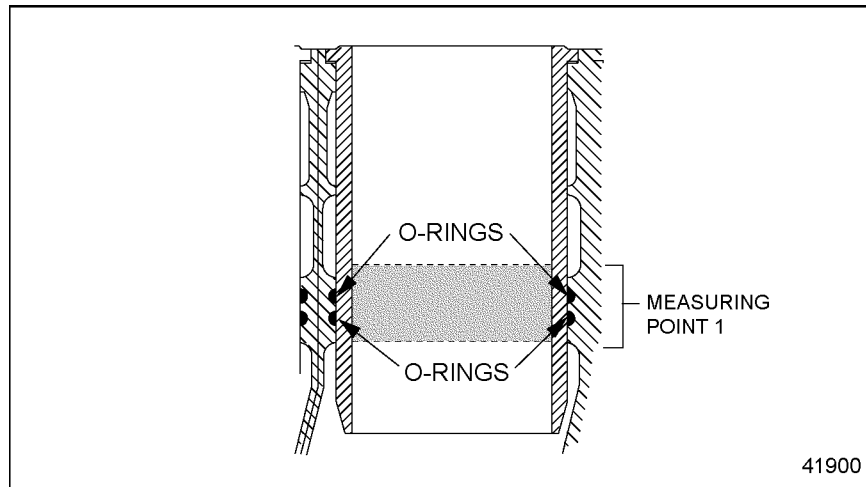
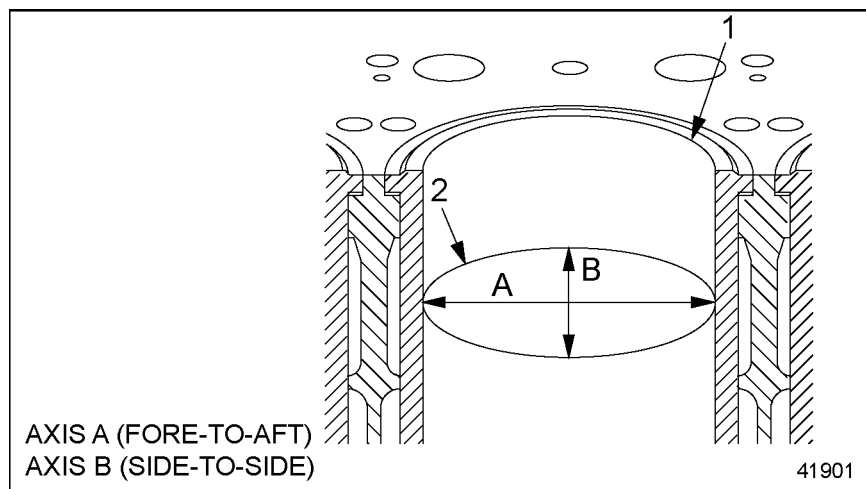


Figure 1-20 Measuring the Inside Diameter

- [a] Make the first measurement along the fore-to-aft axis.
 - [b] Make the second measurement 90 degrees away, along the side-to-side axis.
 - [c] When finished, set the dial gauge to zero.
3. Measure the wear on the inside diameter of the cylinder liner at measuring point 2: the upper reversal point of the first piston ring. Measure the cylinder liner in both directions: fore-to-aft and side-to-side. See Figure 1-21. The specifications are listed in Table 1-9.



1. Cylinder Liner

2. Measuring Point 2 (upper reversal point of the first piston ring)

Figure 1-21 Measuring Points

- [a] Make the first measurement along the fore-to-aft axis (axis A).
 - [b] Make the second measurement 90 degrees away, along the side-to-side axis (axis B).
 - [c] If there is more than 0.08 mm (0.003 inch) of wear, replace the cylinder liner.
4. Check the cylinder liner for out-of-round. If the two measurements vary by more than 0.010 mm (0.0004 in.), replace the cylinder liner.
 5. Replace the cylinder liner, if required. Refer to section 1.4.1.

1.4.1.3 Measurement of Cylinder Liner Protrusion

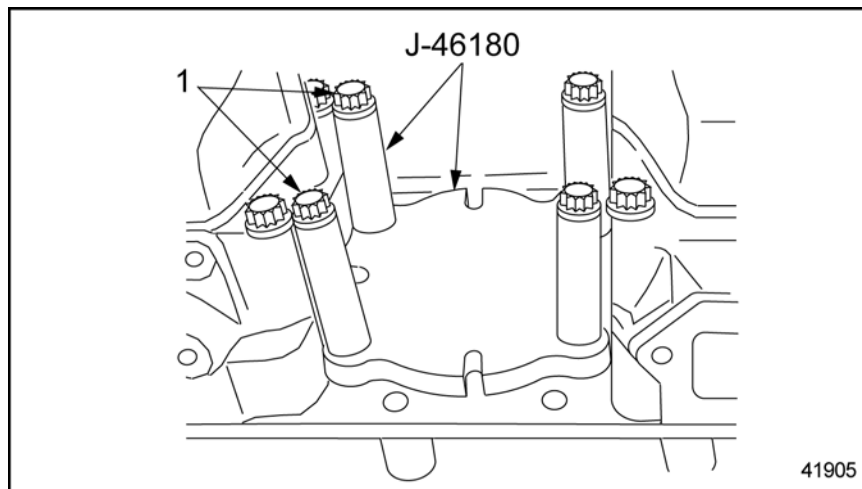
Measurement steps are as follows:

1. Clean the contact surfaces of the cylinder block, the cylinder liner, and the measuring plate.

NOTE:

Correct cylinder liner protrusion is necessary to obtain a perfect seal when the head gasket is compressed by the cylinder head.

2. Install the liner and shim into the block without the seals.
3. Install the measuring plate (J-46180) on the cylinder block and cylinder liner. Fasten the measuring plate to the block by inserting the cylinder head bolts into the spacers and then threading them into the holes in the cylinder block. See Figure 1-22.

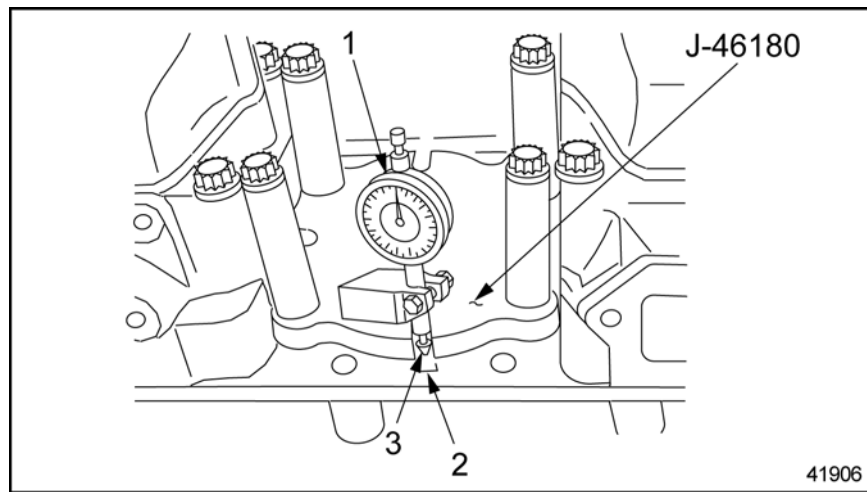


1. Cylinder Head Bolts

Figure 1-22 Measuring Plate

4. Tighten the cylinder head bolts to 50 N·m (37 lb·ft).

5. Install the dial gauge so that the feeler on the dial gauge extends into the slot in the measuring plate. The feeler must touch the contact surface of the cylinder block with some preload. Support the dial gauge. See Figure 1-23.

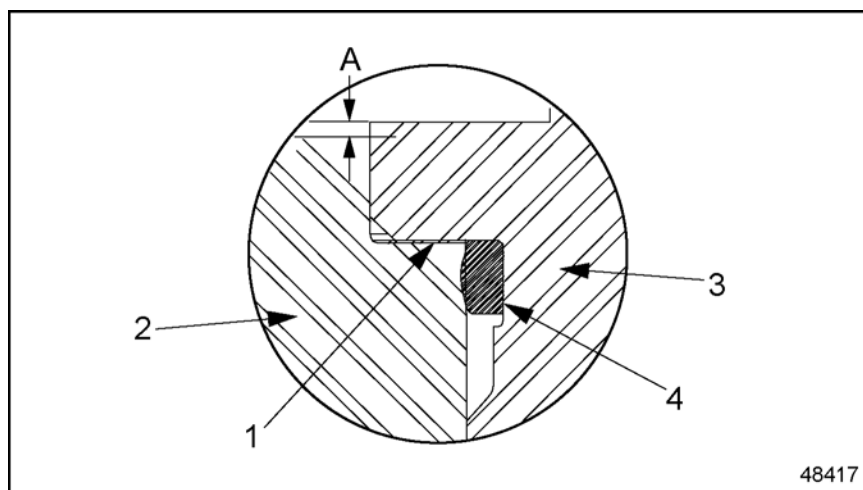


1. Dial Gauge
2. Slot (4 qty.)

3. Feeler

Figure 1-23 **Dial Gauge**

6. Measure the cylinder liner protrusion from the block in four places, once at each slot in the measuring plate. See Figure 1-24. The acceptance/rejection criteria is listed in Table 1-10.



1. Collar Seat Insert (shim)

2. Cylinder Block

3. Cylinder Liner

4. Liner Seat D-Ring

A. Specified in Measuring Cylinder Liner Protrusion Table

Figure 1-24 Measuring Protrusion

Description	Dimensions: mm (in.)
Cylinder Liner Protrusion From Block	0.230–0.330 (0.0090–0.0130)
Difference Between the Four Measuring Points	Max.: 0.02 (0.0007)

Table 1-10 Specifications for Measuring Cylinder Liner Protrusion

- [a] Set the scale on the dial gauge to zero.
- [b] Move the dial gauge until the feeler touches the cylinder liner collar. Record the reading on the dial gauge.
- [c] Move the dial gauge and support to the next slot, and repeat the measurement process, until four measurements have been made, one at each slot. Record each measurement.
- [d] Check each measurement. If any one measurement records protrusion of less than 0.230 mm (0.0090 in.), or more than 0.330 mm (0.0130 in.), remove the cylinder liner and check it according to the procedures that refer to section 1.4.1.

NOTE:

There are three different cylinder liner shim thicknesses that are available, 0.15mm, 0.30mm and 0.50mm.

- [e] Compare the four measurements. If any measurement differs from any one of the others by more than 0.02 mm (0.0008 in.), replace the cylinder liner and repeat

steps “a” through “e”. If the cylinder liner measurements are within specification continue to step 7.

7. Remove the bolts, spacers and measuring plate, as installed.

1.4.1.4 Testing of Fuel System

Fuel system leak testing steps are as follows:

NOTE:

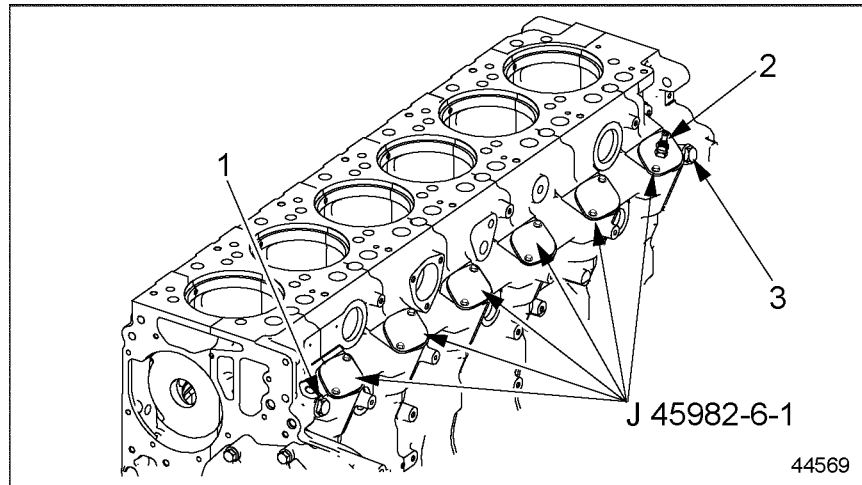
This procedure can be performed with the engine installed or removed from the vehicle.

! WARNING:

FIRE

To avoid injury from fire, keep all potential ignition sources away from diesel fuel, including open flames, sparks, and electrical resistance heating elements. Do not smoke when refueling.

1. Drain all fuel from engine.
2. Remove all six injector unit pumps from the engine block. Refer to section 2.1.1.
3. Install all six dummy unit pumps (J-45982-6-1), from the Head and Block Leak Tester Tool Kit (J-45982). See Figure 1-25.

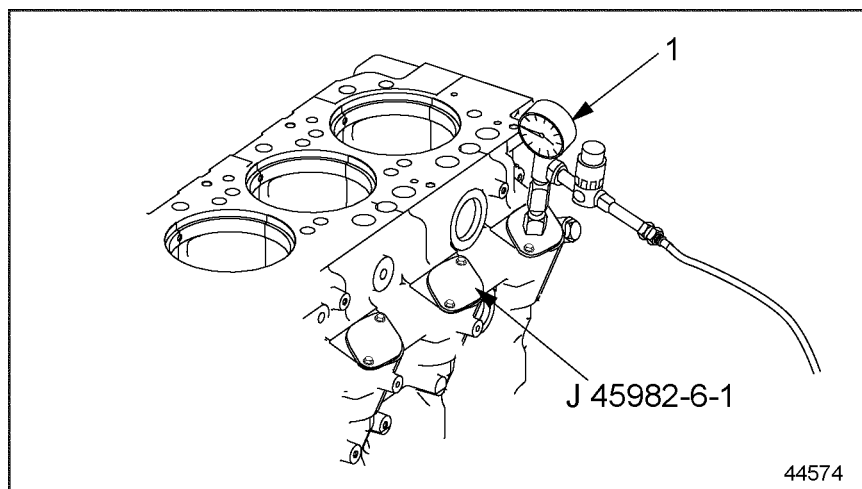


1. Fuel Gallery Inlet
2. Pressure Gauge Fitting
3. Fuel Gallery Outlet

Figure 1-25 Dummy Injector Unit Pumps**NOTE:**

One of the dummy unit pumps has a fitting for pressure gauge installation and it must be installed at the easiest position for gauge installation.

4. Block the fuel gallery inlet and outlet with special plugs from kit (J-45982). See Figure 1-25.
5. Install the pressure gauge assembly (pressure gauge, pressure regulator, and shut off valve) from kit (J-45982) . See Figure 1-26.
6. Connect a compressed air supply to the pressure gauge assembly.



1. Pressure Gauge on Dummy Unit Pump

Figure 1-26 Pressure Gauge Assembly to Dummy Unit Pump

! WARNING:

EYE INJURY

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 276 kPa (40 psi) air pressure.

7. Pressurize the system with 2 bar (29 psi). Use the pressure regulator to set the pressure.
8. Check for leaks around the dummy unit pumps and inlet/outlet plugs using a soap solution. Eliminate leaks.
9. Close the shut off valve.

10. Watch the pressure for 30 seconds. If the pressure holds at 2 bar (29 psi), the fuel gallery is properly sealing. In case of a pressure drop, the engine block should not be reused.

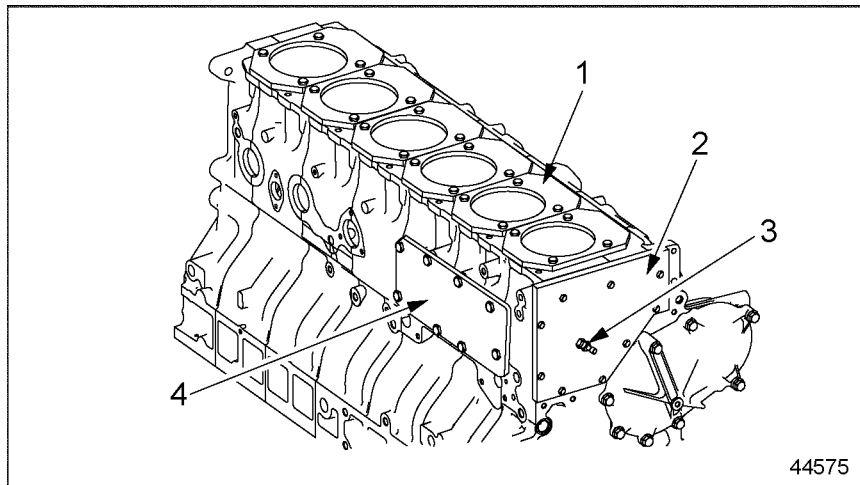
1.4.1.5 Testing of Cylinder Block

Cylinder block leak testing steps are as follows:

NOTE:

This procedure can only be performed with the engine removed from the vehicle and using only the engine block with the cylinder liners installed.

1. Place the engine block with installed cylinder liners on the engine stand. Install the engine on an engine stand. Use OTC engine stand 1750A or equivalent and engine stand adaptor plate J-41576.
2. Install all six top block cover plates(J-45982-1) from the Head and Block Leak Test kit (J-45982) using the special bolts supplied. See Figure 1-27.



- | | |
|---|---|
| 1. Block Cover Plates (6) - part of kit J-45982 | 3. Pressure Gauge Fitting |
| 2. Water Pump Cover Plate - part of kit J-45982 | 4. Oil Cooler Cover Plate - part of kit J-45982 |

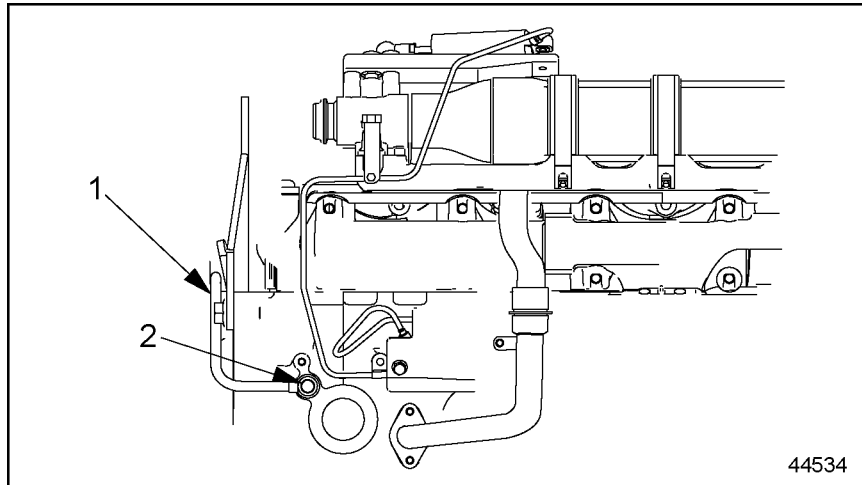
Figure 1-27 Block Cover Plates

3. Install the oil cooler/filter housing cover plate, from the kit, on the right hand side of the engine block using supplied hardware. See Figure 1-27.
4. Install the water pump cover plate, from the kit, on the front of the engine using supplied hardware. See Figure 1-27.

NOTE:

The water pump cover plate has a fitting for installing the supplied pressure gauge.

5. Block the air compressor coolant inlet and outlet from the engine block with the special plugs and copper washers as supplied in the leak test kit (J-45982). See Figure 1-28.

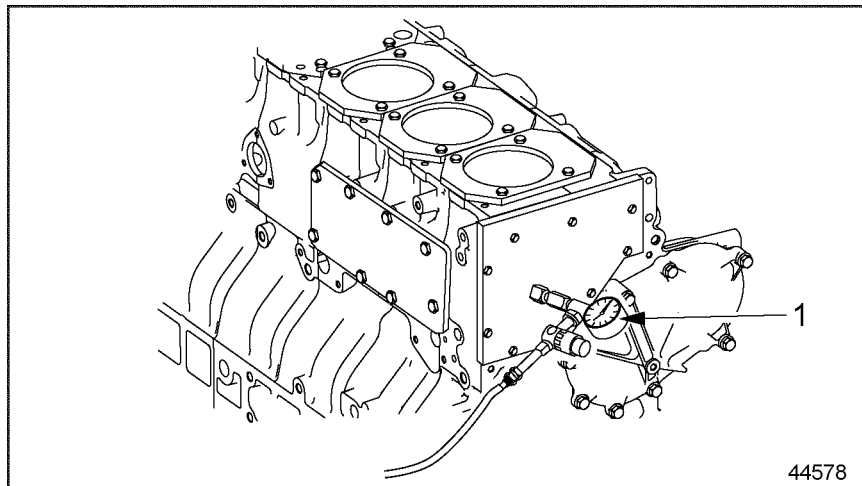


1. Coolant Line to Air Compressor

2. Air Compressor Outlet location from Engine Block

Figure 1-28 Blocking Air Compressor Inlet / Outlet from Engine Block

6. Install the pressure gauge assembly (pressure gauge, pressure regulator, and shut off valve) from kit (J-45982). See Figure 1-29.



1. Pressure Gauge Assembly

Figure 1-29 Pressure Gauge Assembly

7. Connect a compressed air supply to the pressure gauge assembly. See Figure 1-29.

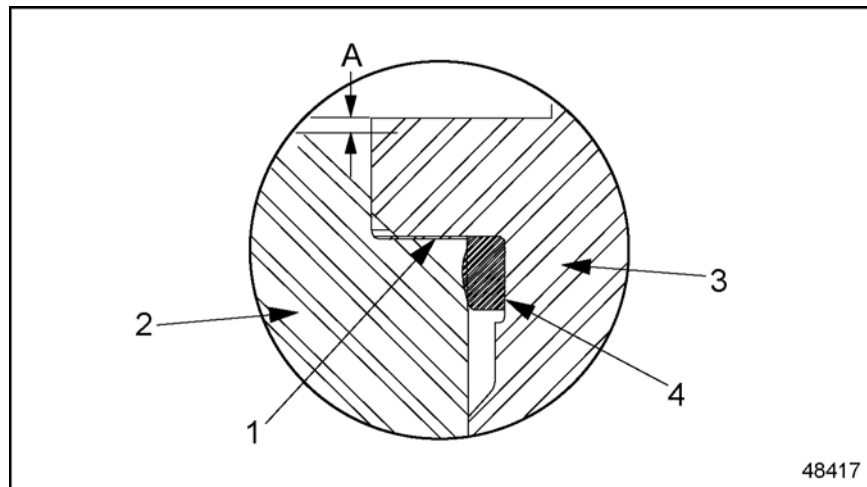
**WARNING:****EYE INJURY**

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 276 kPa (40 psi) air pressure.

8. Pressurize the system with 2 bar (29 psi). Use the pressure regulator to set the pressure.
9. Check for leaks around the all cover plates and plugs using a soap solution. Eliminate leaks.
10. Close the shut off valve.
11. Watch the pressure for 30 seconds. If the pressure holds at the 2 bar (29 psi), the cylinder block coolant system is properly sealed. In case of a pressure drop, the engine block should not be reused.

1.4.2 Cylinder Block Preparation

This procedure is used with the PT-2250-B counterbore tool and J-41065.



1. Collar Seat Insert (shim)

2. Cylinder Block

3. Cylinder Liner

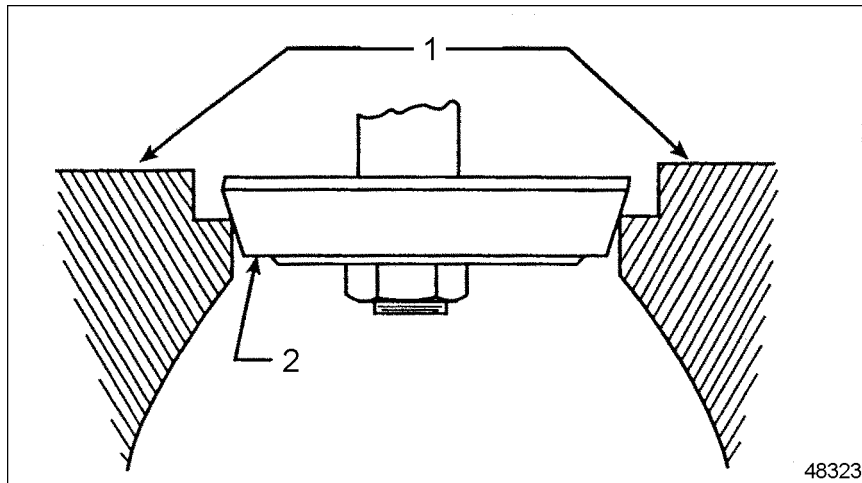
4. Liner Seat D-Ring

A. Specified in Measuring Cylinder Liner Protrusion Table

Figure 1-30 Cylinder Liner Collar Seat

1. Remove the cylinder heads, pistons, liners, and other hardware.

2. Protect the crankshaft, oil, and coolant passages from machining debris by covering with a shop towel or a suitable clean cover. Clean the top surface of the block to remove any debris from the machining area.
3. Remove the cylinder block dowel pins using (Snap-On CG503 or equivalent).
4. Remove the coolant pump refer to section 4.2.1 and the rear lifting bracket. narf
5. Protect internal engine parts from cutting debris using an oiled sponge filler in the cylinder block.
6. The cutting edge of the cutting bit should be retracted to protect the cutting tool. Cap screws of the cutter should be loose at this time.



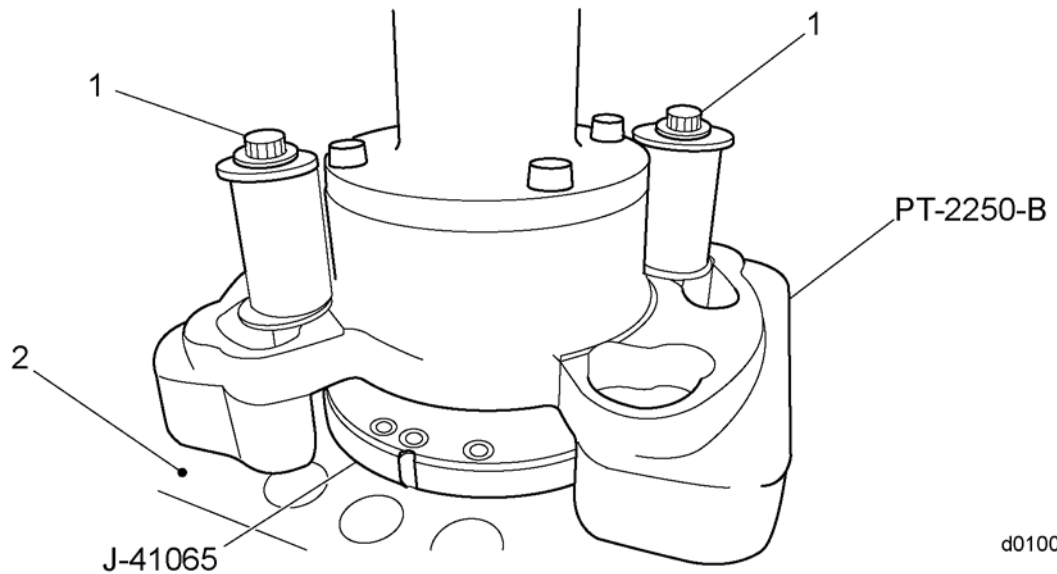
1. Cylinder Block

2. Cutter Plate

Figure 1-31 Cross Section

7. Center the tool on the top of the block using the Counter Bore Cutter tool(J-41065).
8. Raise the depth stop adjustment collars and lower the tapered cutter plate into the bore. Rotate the tool and allow it to center itself in the bore. See Figure 1-31.

9. Install two opposing cylinder head bolts, with the washers and spacers through the base plate of the tool. See Figure 1-32. Tighten securely to 41 N·m (30 lbs. ft.).



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- | | |
|-----------------------------|---------------------------|
| 1. Cylinder Head Bolt | 3. Special Tool (J-41065) |
| 2. Special Tool (PT-2250-B) | 4. Cylinder Block |

Figure 1-32 Cutting Tool

NOTICE:

After machining the cylinder block, inspect for the presence of a chamfer on the edge of the balcony. Use a hand stone to break the sharp edge if needed.

10. Raise the tapered cutter head from the block and install the depth set spacer provided. While there is no load, extend the cutting tool outward (using a clockwise rotation of the cutting screw) until it just touches a 0.15mm feeler gauge or shim placed next to the vertical wall of the counterbore. Tighten the Allen head hold-down screws. See Figure 1-32.

NOTICE:

Do not turn past this position or the cutter plate will fit and prevent an accurate reading.

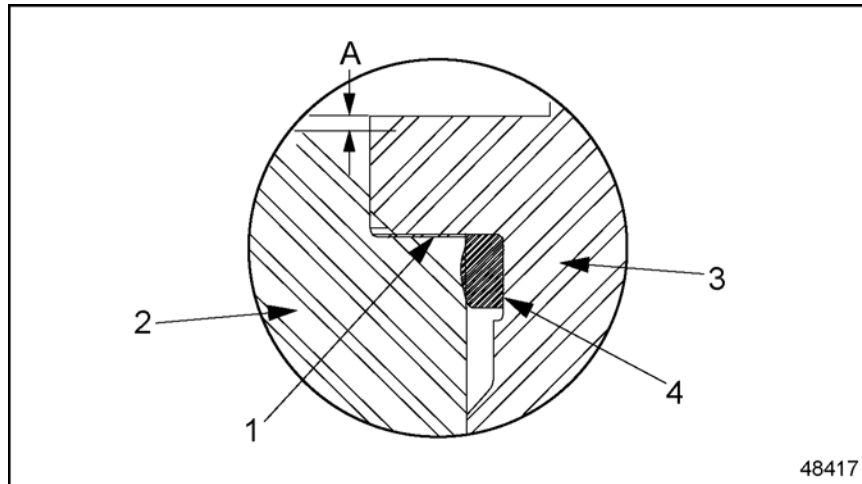
11. Lower the cutting plate and cutter tool into the counterbore until it just touches the lower surface of the counterbore. Rotate the lock collars downward until they touch the bronze bushing of the tool.

12. Set the depth of cut by adjusting the top collar upwards to allow the liner shim to be inserted between the two collars. Tighten the thumb screw of the top collar. Remove the shim.
13. Lubricate the tool bushing. Back off the lower collar by two graduations 0.0254 mm (0.001 in. each). Rotate the T-handle clockwise with a moderate, constant pressure. Stop at random positions to prevent creating a ridge in the counterbore. Continue backing off the adjustment in 0.0508 mm (0.002 in.) increments for the balance of the cutting operation until the collars come together.
14. Raise the handle and insert the spacer block under the lower collar. Remove the hold-down bolts and spacers to remove the tool from the block.
15. Retract the cutter bit into the cutter plate to protect during storage.

1.4.3 Installation of Cylinder Liner

Installation steps are as follows:

1. Perform the Measurement of Cylinder Liner Protrusion procedure. refer to section 1.4.1.3
2. Install new O-rings, clean and dry, in the cylinder block.
3. Install Liner Seat D-Ring to Cylinder Liner. Be sure the D-ring is installed with the flat surface of the of the ring against the liner. Be careful not to over-stretch the ring as it is installed over the liner flange. See Figure 1-33.



1. Collar Seat Insert (shim)

2. Cylinder Block

3. Cylinder Liner

4. Liner Seat D-Ring

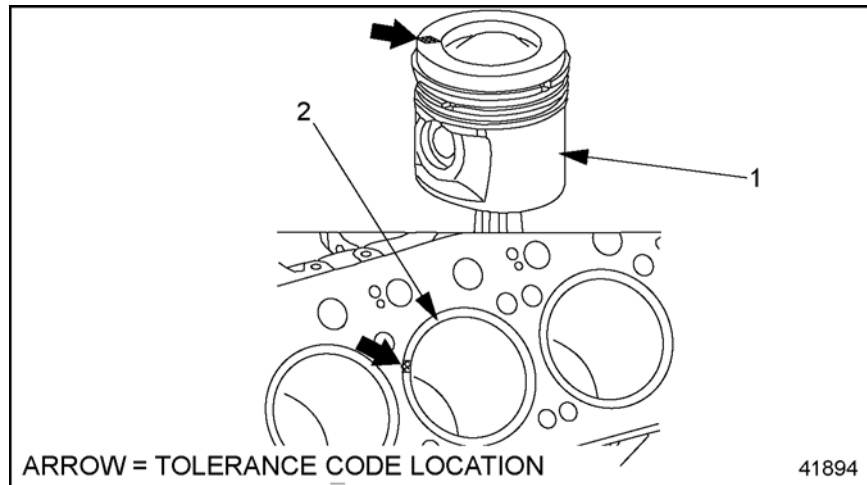
A. Specified in Measuring Cylinder Liner Protrusion Table

Figure 1-33 **Cylinder Liner Seat**

NOTE:

The cylinder liner collar and collar seat must remain completely free of oil.

4. Install a new seat insert, clean and dry, into the block counterbore. See Figure 1-33.
5. Apply a light coating of engine oil to the lower part of the cylinder liner, from where it contacts the O-rings up to the bevelled area.
6. When installing a new cylinder liner, make sure that the diameter tolerance code corresponds to the one marked on the piston. See Figure 1-34 for the location of tolerance codes.



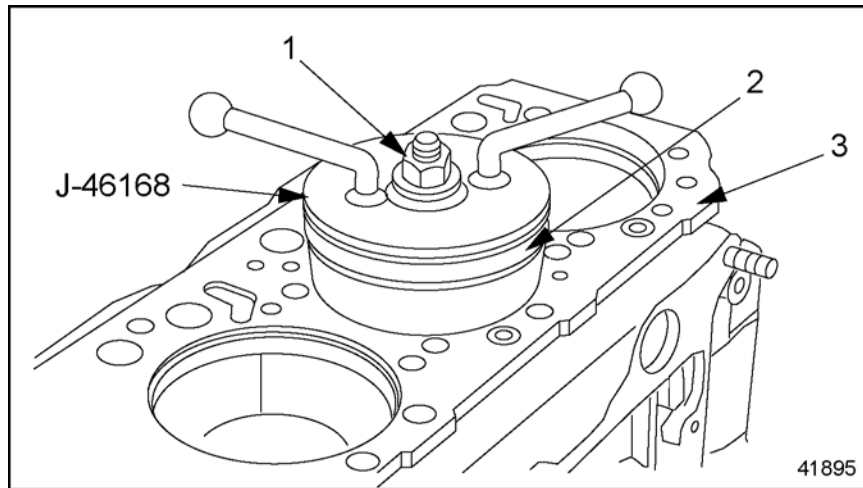
1. Piston

2. Cylinder Liner

Figure 1-34 Tolerance Codes

- [a] Cylinder liners with tolerance code A require a piston of code BA.
- [b] Cylinder liners with tolerance code B require a piston of either code BA or BC.
- [c] Cylinder liners with tolerance code C require a piston of code BC.

7. Install the cylinder liner, using the cylinder liner installation tool (J-46168). See Figure 1-35.



1. Installation Nut

3. Cylinder Block

2. Cylinder Liner

Figure 1-35 **Cylinder Liner**

NOTICE:

Do not overtighten the installation tool. This may deform the cylinder liner and make the installation tool more difficult to remove.

- [a] Tighten the installation tool just enough to hold the installation tool inside the cylinder liner without turning.

NOTICE:

To prevent damage to the O-rings, the cylinder liner must be rotated during installation.

NOTE:

If installing the old cylinder liner, offset the reference marks 90 degrees from the previous ones.

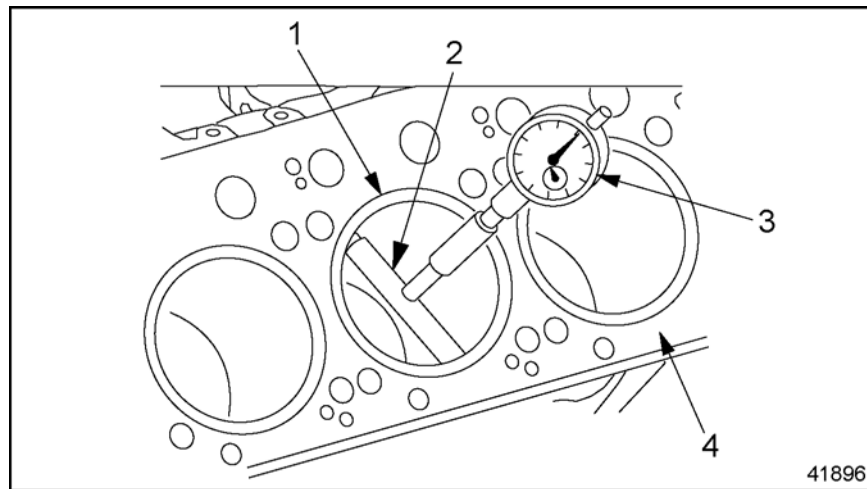
- [b] Insert the cylinder liner into the cylinder block until it contacts the O-rings. Continue to insert the cylinder liner past the O-rings, being careful to keep turning the installation tool until the cylinder liner is properly seated.
- [c] Remove the installation tool from the cylinder liner.

8. Measure the cylinder liner protrusion from the block. See Figure 1-15. The specifications are listed in Table 1-11.

Description	Dimensions: mm (in.)
Cylinder Liner Protrusion, From Block, see Figure 1-15, Ref. A.	0.230–0.330 (0.0090–0.0130)
Height of the Cylinder Liner Collar, see Figure 1-15	10.10–10.12 (0.3976–0.3984)
Depth of the Collar Seat, see Figure 1-15	9.950–10.010 (0.3917–0.3941)
Thickness of the Seat Insert	0.14–0.16 (0.0055–0.0063)

Table 1-11 Cylinder Liner Installation Tolerances

9. Measure the inside diameter of the cylinder liner and check for out-of-round. See Figure 1-36.



- | | |
|-------------------|-------------------|
| 1. Cylinder Liner | 3. Dial Gauge |
| 2. Quick Calipers | 4. Cylinder Block |

Figure 1-36 Measuring the Cylinder Liner Inside Diameter

- [a] Measure at three different locations 60 degrees apart in the area of the two O-rings.
 - [b] Compare the three measurements. If they differ by more than the maximum admissible out-of-round listed in Table 1-8, remove the cylinder liner and inspect the two O-rings and their seating area in the cylinder block.
 - [c] If the O-rings are damaged, replace them.
 - [d] Check the out-of-round again until it meets specifications.
10. Install the piston. Refer to section 1.19.2.

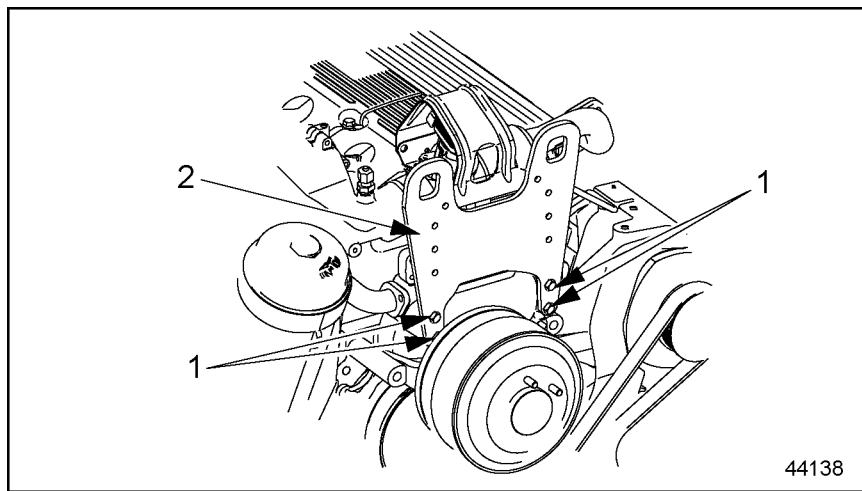
1.5 FRONT AND REAR ENGINE LIFTING BRACKETS

The engine has separate front and rear engine lifting brackets.

1.5.1 Removal of Front and Rear Lifting Brackets

Removal steps are as follows:

1. Remove the four M10 x 25 mm mounting bolts from the front engine lifting bracket and remove the bracket. See Figure 1-37.



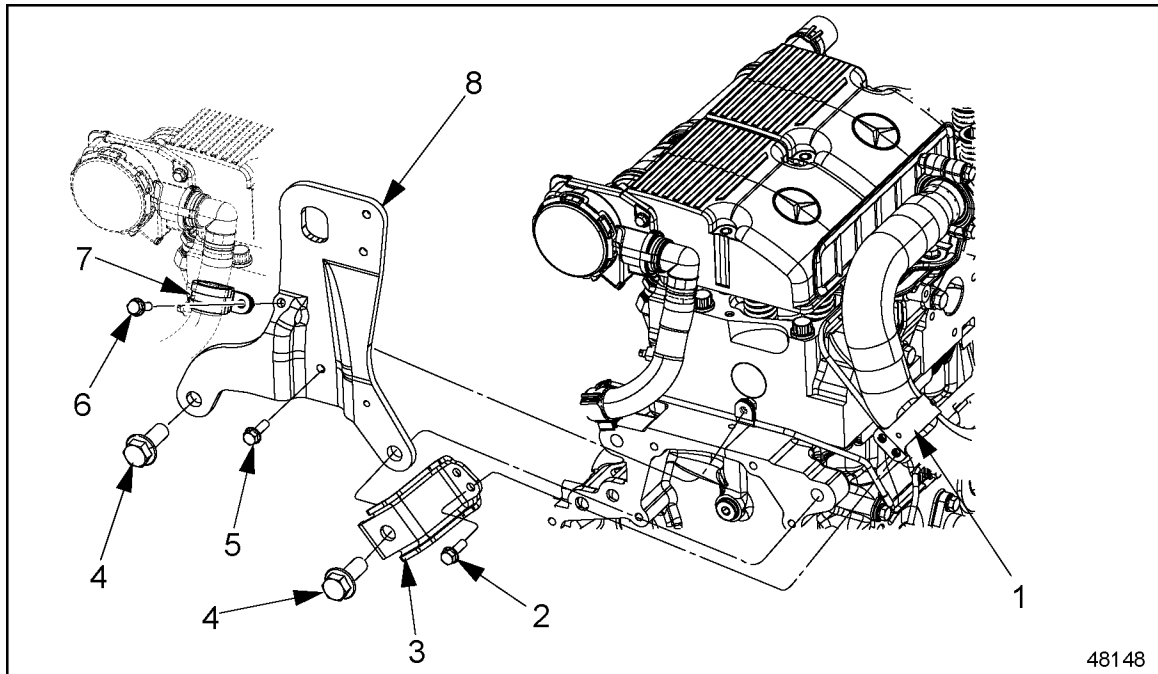
1. Front Engine Lifting Bracket Mounting Bolts

2. Front Engine Lifting Bracket

Figure 1-37 Front Engine Lifting Bracket

2. Remove the bolt from the air compressor coolant line bracket on the rear lifting bracket. See Figure 1-38.
3. Remove the bolt securing the crankcase vent pipe bracket to the rear lifting bracket.

4. Remove the two bolts from the rear engine lifting bracket and remove the bracket. See Figure 1-38.



- | | |
|---|---|
| 1. Clamp (EGR Cooler Gas Inlet Pipe) | 5. Bolt and Nut (Air Compressor Coolant Line) |
| 2. Bolts (Gas Inlet Pipe Mounting Bracket) | 6. Bolt |
| 3. Mounting Bracket (EGR Cooler Gas Inlet Pipe) | 7. Clamp (Crankcase Breather Tube) |
| 4. Rear Engine Lifting Bracket Mounting Bolts | 8. Rear Engine Lifting Bracket |

Figure 1-38 Rear Engine Lifting Bracket

1.5.2 Installation of Front and Rear Engine Lifting Brackets

Installation steps are as follows:

1. Install the front engine lifting bracket using the four mounting bolts. See Figure 1-37.
2. Torque the four bolts to 60 N·m (44 lb·ft).
3. Install the rear engine lifting bracket using two mounting bolts. Torque the two bolts to 200 N·m (148 lb·ft). See Figure 1-38.
4. Install the bolt securing the air compressor coolant line bracket to the rear lifting bracket. Torque the bolt to 30 N·m (22 lb·ft). See Figure 1-38.
5. Install the bolt securing the crankcase vent pipe bracket to the rear lifting bracket. Torque the bolt to 50 N·m (37 lb·ft).

1.6 ENGINE BRAKE

Engine braking is controlled by a pneumatically-operated exhaust brake in the center exhaust housing in conjunction with constant throttle valves on the cylinder heads. The exhaust back-pressure is used by the exhaust brake to increase braking performance. The constant throttle valves use the air that escapes through them on the compression stroke to provide braking force.

The constant throttles are hydraulically-operated single piston valves which are built into the cylinder heads and positioned opposite the exhaust valves. When open, a link is created between the combustion chamber and the exhaust port. When the engine brake is switched on, the constant throttle valves are opened by hydraulic pressure.

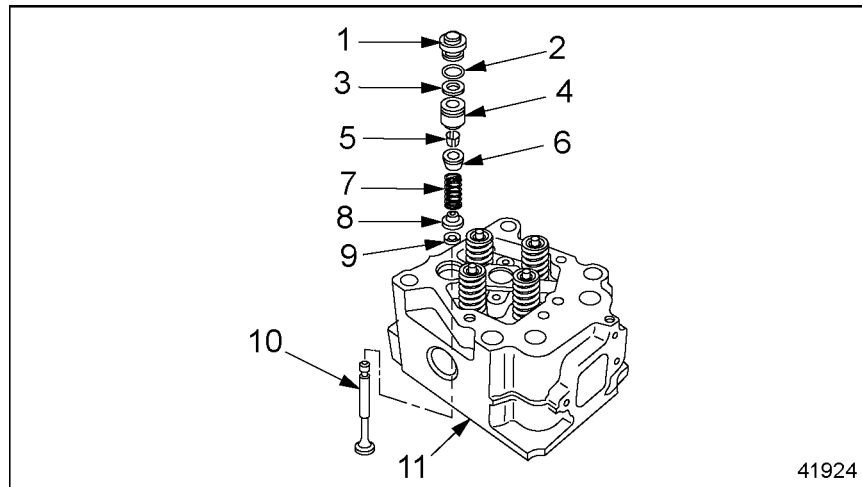
NOTE:

When in emergency running mode (constant rpm), the engine brake can be activated only when the engine is in overrun. When constant rpm has been attained, the engine brake is automatically turned off.

1.6.1 Removal of Constant Throttle Valve

Removal steps are as follows:

1. Remove the cylinder head. Refer to section 1.3.1.
2. Remove the fuel injector nozzle. Refer to section 2.6.1.
3. From the top of the cylinder head, remove the end cover on the constant-throttle valve. See Figure 1-39.



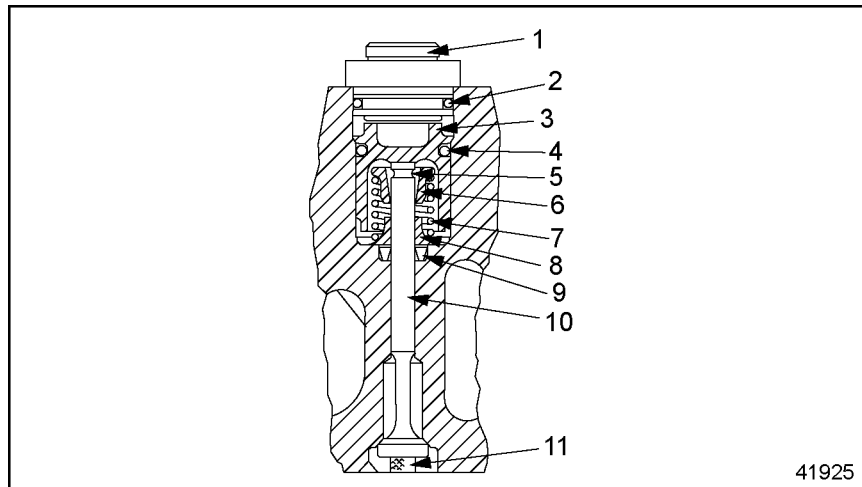
- | | |
|--------------------|--------------------|
| 1. End Cover | 7. Spring |
| 2. O-ring | 8. Spring Guide |
| 3. Piston Seal | 9. Valve Stem Seal |
| 4. Piston | 10. Valve |
| 5. Valve Keepers | 11. Cylinder Head |
| 6. Spring Retainer | |

Figure 1-39 Constant-Throttle Valve

NOTE:

Insert a spacer beneath the valve head to prevent the valve from opening while doing the rest of the removal procedures. See Figure 1-40.

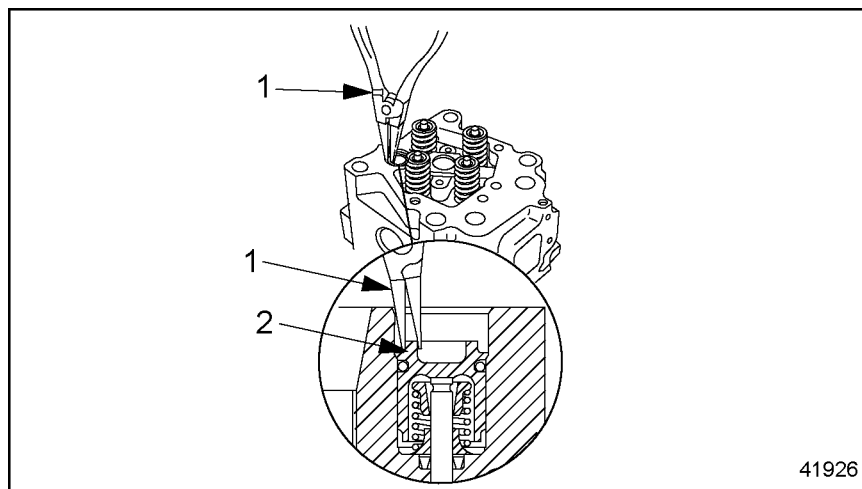
4. From the bottom of the cylinder head, insert a suitable spacer about 6.0 mm (1/4 in.) in height. See Figure 1-40.



- | | |
|--------------------|--------------------|
| 1. End Cover | 7. Spring |
| 2. O-ring | 8. Spring Guide |
| 3. Piston | 9. Valve Stem Seal |
| 4. Piston Seal | 10. Valve |
| 5. Valve Keepers | 11. Spacer |
| 6. Spring Retainer | |

Figure 1-40 **Cutaway View of Constant Throttle Valve**

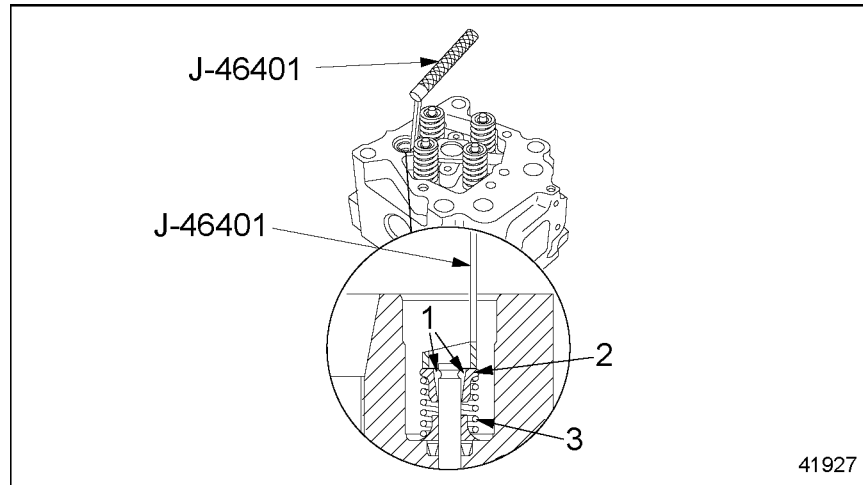
5. Using needle-nose pliers, remove the piston. Pull the piston and piston seal out of the valve bore. See Figure 1-41.



- | | |
|-----------------------|-----------|
| 1. Needle-Nose Pliers | 2. Piston |
|-----------------------|-----------|

Figure 1-41 **Piston**

6. Inspect the piston for damage and signs of wear. Remove the seal ring from the piston and discard. If necessary, replace the piston.
7. Insert the constant throttle valve (CTV) spring remover (J-46401) down onto the spring retainer. Remove the valve keepers with a magnet. See Figure 1-42.



- | | |
|--------------------|-----------|
| 1. Valve Keepers | 3. Spring |
| 2. Spring Retainer | |

Figure 1-42 Compressing the Spring

8. Relieve the pressure on the spring. Remove the spring retainer, spring and spring guide. For ease of installation, mark the spring retainer and spring guide with a paint pen.
9. Turn over the cylinder head. From the bottom of the cylinder head, draw out the valve and spacer. For ease of installation, mark the valve with a paint pen.
10. Using a small hook, remove and discard the valve stem seal.

NOTE:

Always replace the valve stem seal whenever the constant-throttle valve is removed.

11. Repeat this procedure for each constant-throttle valve.

1.6.2 Installation of Constant Throttle Valve

Installation steps are as follows:

1. Lubricate the valve stem with a light coating of clean engine oil. From the bottom of the cylinder head, push the valve, as marked on removal, into the valve bore.

NOTE:

Insert a spacer beneath the valve head to prevent the valve from opening while installing the valve spring and piston.

2. Insert a suitable spacer about 6.0 mm (1/4 in.) in height. See Figure 1-40.
3. Install a new seal on the valve stem.
 - [a] With the fingers, press the seal onto the valve stem past the indentation that houses the valve keepers when the valve is installed.
 - [b] Insert the spring guide over the end of the valve stem and push down until the spring guide bottoms out.
4. From the top of the cylinder head, fit the spring and spring retainer, as marked on removal, onto the valve stem.
5. Push the spring down with the CTV spring remover and insert the valve keepers into the spring retainer. Push until they lock into place.
6. Install the piston and new seal, as removed. Be careful not to damage the seal on installation. See Figure 1-41.
7. From the bottom of the cylinder head, remove the spacer.
8. From the top of the cylinder head, install a new O-ring on the end cover.
9. Install the end cover.
10. Install the fuel injector nozzle. Refer to section 2.6.2.
11. Install the cylinder head. Refer to section 1.3.1.
12. Repeat this procedure for each constant-throttle valve.

1.6.3 Removal of Constant Throttle Valve Solenoid

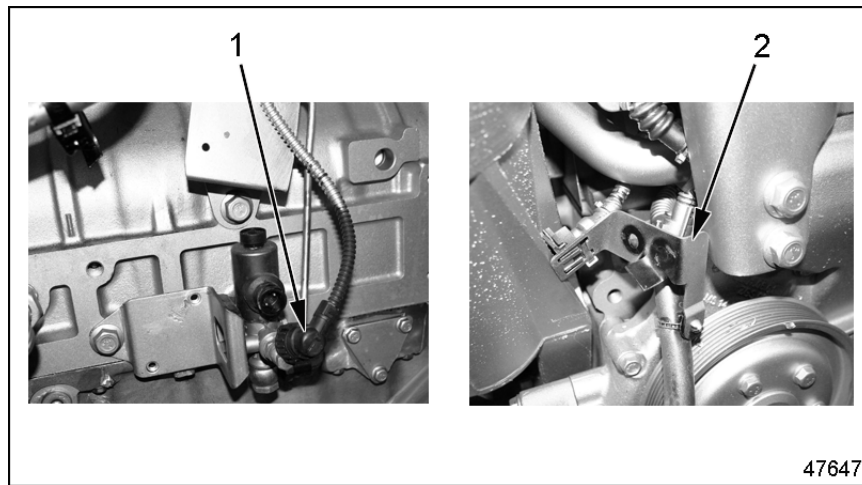
Removal steps are as follows:

NOTE:

A Kent-Moore tool, CTV solenoid socket (J-47398) is required for this procedure.

1. Remove the lower exhaust manifold heat shield.

2. Disconnect the harness connector at the CTV solenoid.

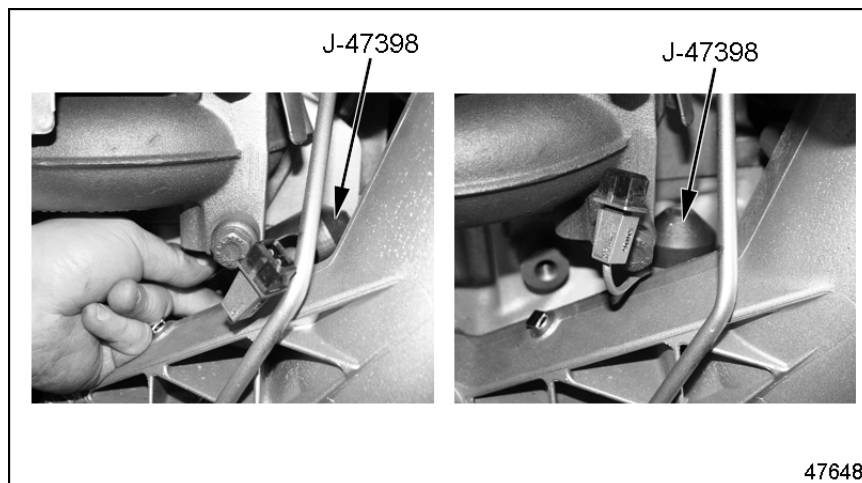


1. EPV Harness Connector

2. Wiring Harness Bracket

Figure 1-43 Harness Bracket

3. Remove the bolt securing the wiring harness bracket and remove the bracket. See Figure 1-43.
4. Disconnect the harness connector from the EPV solenoid. See Figure 1-43.
5. Disconnect the harness connector from the and Oil Pressure/Temperature sensor oil filter.
6. Remove the plastic ties securing the harness to the brackets.
7. Pull the harness to the front of the engine through the opening between the oil filter housing and engine.

**Figure 1-44 CTV Solenoid**

8. Position CTV solenoid socket (J-47398) under the exhaust manifold and between the engine and oil cooler.
9. Slide the socket from rear to front until it is positioned over the solenoid.

NOTICE:

Ensure that the CTV solenoid harness does not get pinched . Damage to the harness could cause engine braking problems.

10. Using a 3/8 in. drive extension and a universal swivel remove the CTV solenoid.
11. Remove the O-ring from the solenoid and discard.

1.6.4 Installation of Constant Throttle Valve Solenoid

Installation steps are as follows:

1. Install a new O-ring on the CTV solenoid and lubricate with clean engine oil.
2. Position the CTV solenoid into the oil cooler housing and start threads by hand.

NOTICE:

Ensure that the CTV solenoid harness does not get pinched . Damage to the harness could cause engine braking problems.

3. Using a 3/8 in. drive extension and a universal swivel torque, the CTV solenoid to 35 N·m (26 lb·ft).
4. Connect the harness connectors to the CTV solenoid, Oil Pressure/Temperature Sensor, and EPV solenoid. Secure harness with nylon tie straps.
5. Installed the removed lower exhaust manifold heat shield. Torque the bolts to 25 N·m (18 lb·ft).

1.7 FRONT RADIAL SEAL

The following sections support the repair of the front radial seal.

1.7.1 Removal of Front Radial Seal

Removal steps are as follows:

Two special tools are required for this procedure:

- ☐ Front Seal Puller (J-47272)
- ☐ Front Seal Installer (J-45391)



WARNING:

PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Park the vehicle on a level spot, set the parking brakes, and chock the tires.
2. Tilt the hood.
3. From underneath the front of the engine, remove the bumper beam. Push the support angle bracket fairing down to create an opening in the bumper.
4. Remove the vibration damper and pulley from the engine through the opening in the bumper. Refer to section 1.13.1.
5. Check the seal for leaks at the places where it contacts the crankshaft.

NOTICE:

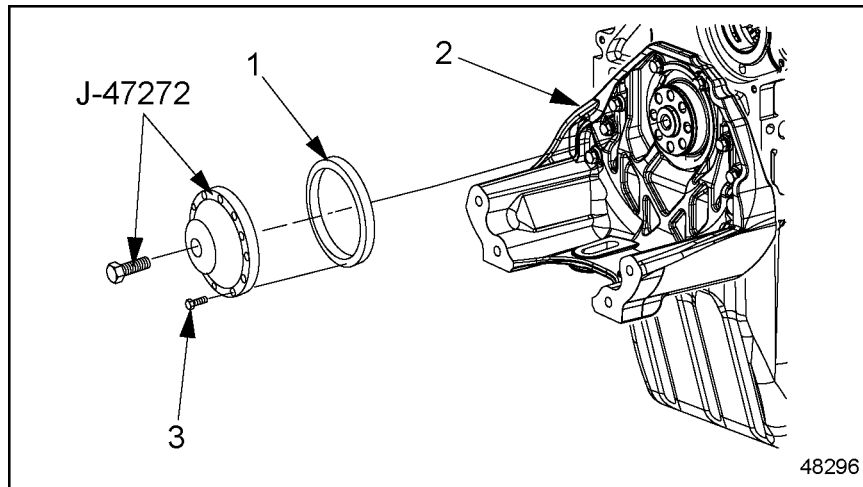
When drilling pilot holes for the removal of the seal ensure that the drill is straight and perpendicular to the seal. Failure to drill

NOTICE:

the hole straight could result in damage to the seal bore, resulting in the replacement of the front cover housing.

NOTE:

When drilling holes for screws, make sure to coat the drill bit with grease to catch the shavings.



1. Front Radial Seal

2. Front Cover Housing

3. Screws

Figure 1-45 Front Radial Seal

6. Drill 3.174 mm (0.125 in.) pilot holes and use the sheet metal screws and the front seal puller (J-47272, part of toolset J-47273), remove the front radial seal from the front cover housing. Discard the seal.
7. If installed, check wear sleeve for nicks, scratches or grooves. If necessary, replace wear sleeve. Refer to section 1.9.1.

1.7.2 Installation of Front Radial Seal

Installation steps are as follows:

NOTE:

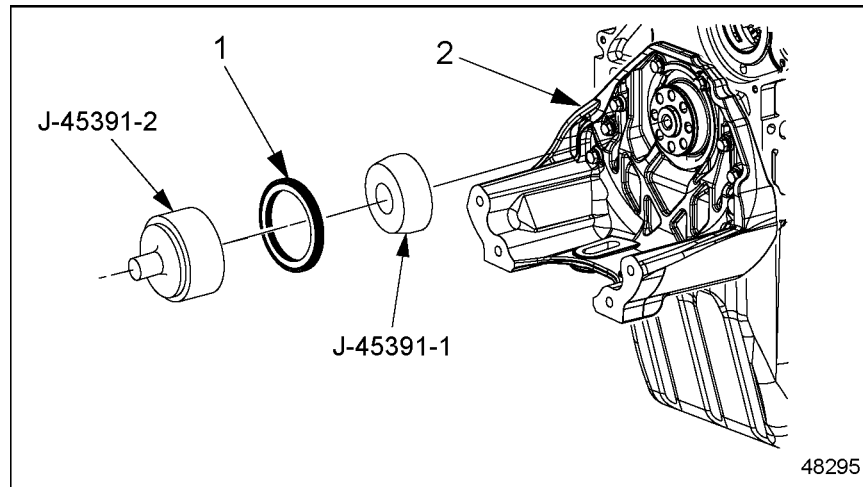
The radial seal does not need to be lubricated.

1. Clean the sealing surfaces on the cover and the cylinder block.

NOTE:

The seal installation is the same for a standard size and oversize front radial seal. The front standard size radial seal has an inside diameter of 100.0 mm (3.94 in.). The oversize radial seal has an inside diameter of 105.0 mm (4.13 in.).

2. Slide the seal over the center guide (J-45391-2, part of toolset J-45391 and service kit J-47273). Place the guide on the front of the crankshaft. Fit the front seal installer (J-45391-1, part of toolset J-45391 and service kit J-47273) over the guide and tap it into the front cover housing until it bottoms. Visually check the seal and sealing lip for correct installation.



1. Front Radial Seal

2. Front Cover Housing

Figure 1-46 Front Radial Seal

3. Install the oil deflector on the front cover housing. See Figure 1-46.
4. Install the vibration damper and pulley on the crankshaft. Tighten the vibration damper mounting bolts to 200 N·m (148 lb·ft). See Figure 1-46.
5. Install the main drive belt. Refer to section 9.1.2.
6. Install the fan drive belt. Refer to section 9.1.4.
7. Install the support angle bracket fairing. Install the bumper beam.

! WARNING:

ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

8. Start the engine and check the engine oil pressure at idle. Engine oil pressure at idle should be at least 50 kPa (7 psi). Look for any oil leaks, repair as necessary.
9. Close the hood, and remove the chocks from the tires.

1.8 REAR RADIAL SEAL

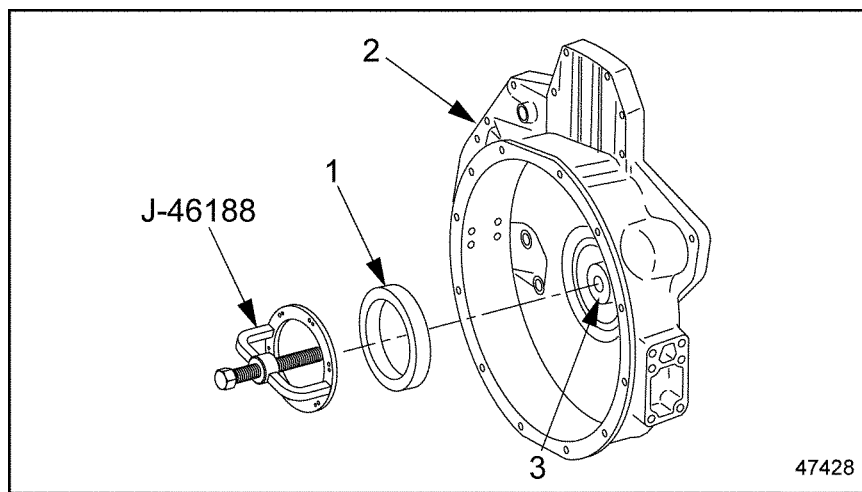
The below listed special tools are required for this procedure.

- Rear Seal Puller, J-46188 (part of service kit J-47273)
- Rear Seal Puller (std seal), J-45393-A (part of service kit J-47273)
- Front/Rear Oversize Seal Installer Kit, J-47067 (part of service kit J-47273)
- Seal and Wear Sleeve Service Kit, J-47273

1.8.1 Removal of Rear Radial Seal

Removal steps are as follows:

1. Remove the flywheel.



1. Rear Radial Seal
2. Flywheel Housing

3. End of Crankshaft

Figure 1-47 Rear Radial Seal

NOTICE:

When drilling pilot holes for the removal of seal ensure that the drill is straight and perpendicular to the seal. Failure drill the hole straight could result in damage to the seal bore, resulting in the replacement of the flywheel housing.

NOTE:

When drilling holes for screws, make sure to coat the drill bit with grease to catch the shavings.

2. Drill 3.174 mm (0.125 in.) pilot holes and use the sheet metal screws and the rear seal puller J-46188 (part of service kit J-47273) , remove the rear radial seal from the flywheel housing. Discard the seal. See Figure 1-47.

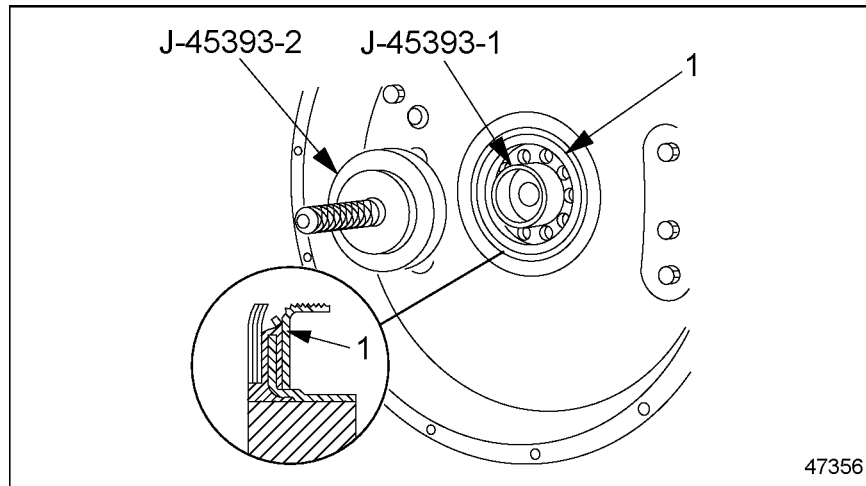
1.8.2 Installation of Rear Radial Seal

Installation steps are as follows:

NOTE:

The radial seal does not need to be lubricated.

1. Inspect the contact surface of the flywheel for damage and wear. If it is scored or worn, replace it.



1. Rear Radial Seal

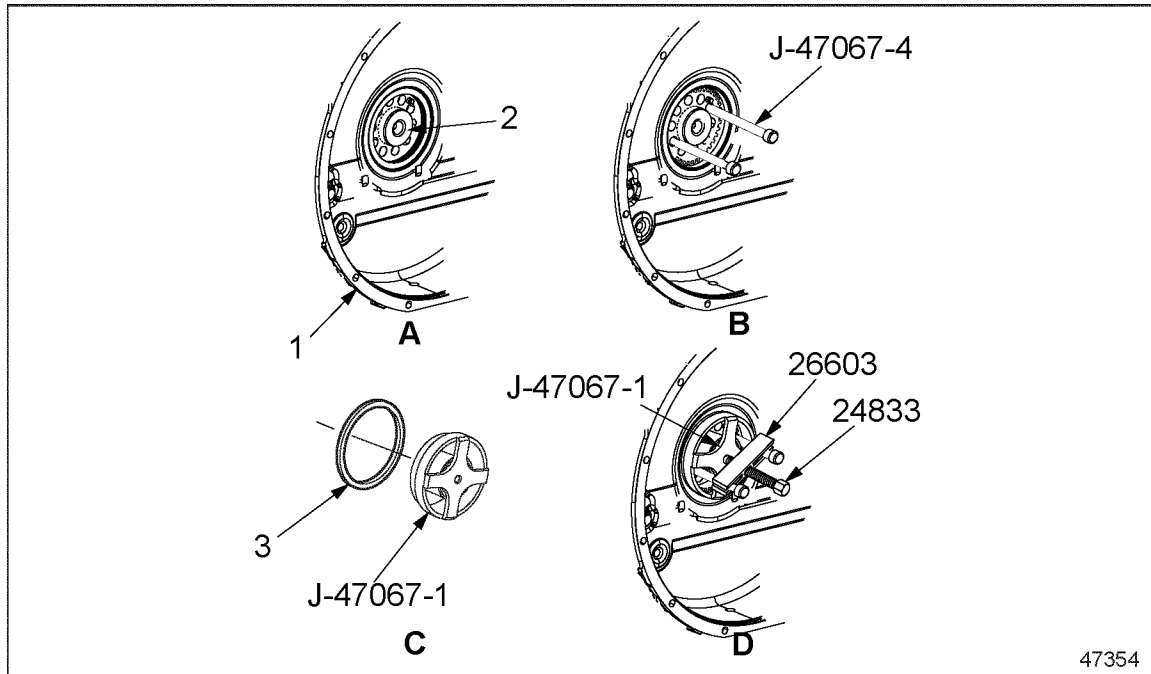
Figure 1-48 Rear Radial Seal

NOTE:

The standard size rear radial seal has an inside diameter of 115.0 mm (4.53 in.).

2. To replace a standard rear crankshaft seal do the following:
 - [a] Place the seal installer guide, (J-45393-1, part of toolset J-45393-A and service kit J-47273), on the end of the crankshaft. See Figure 1-48.
 - [b] Put the new radial seal in place on the rear seal installer, (J-45393-2, part of toolset J-45393-A and service kit J-47273). See Figure 1-48.
 - [c] Position the rear seal installer on the receptacle, and drive the seal in until it bottoms out.
3. To replace an oversize rear crankshaft seal do the following:
 - [a] Install the crankshaft rear wear sleeve. Refer to section 1.9.4.

- [b] Install two seal guide pins (J-47067-4, part of toolset J-47067 and service kit J-47273). See detail “B” in Figure 1-49.



1. Flywheel Housing

2. Crankshaft

3. Seal

Figure 1-49 Rear Oversize Crankshaft Seal

NOTE:

The oversize rear radial seal has an inside diameter of 120.0 mm (4.72 in.).

- [c] Put the new radial seal in place on the rear seal installer, (J-47067-1, part of toolset J-47067 and service kit J-47273). See detail “C” in Figure 1-49.
- [d] Slide the seal installer (J-47067-1, part of toolset J-47067 and service kit J-47273), over the guide pins (J-47067-4) part of toolset J-47067 and service kit J-47273) and position the seal into the flywheel housing. See detail “D” in Figure 1-49.
- [e] Install the forcing screw (24833, part of toolset J-47067 and service kit J-47273) and crossbar (26603, part of toolset J-47067 and service kit J-47273) onto the guide pins. See detail “D” in Figure 1-49.
- [f] Install the seal by turning the forcing screw until the tool bottoms on the butt of the crankshaft.
- [g] Remove the tool and visually check the seal and sealing lip for correct installation.
- [h] Install the flywheel. Refer to section 1.14.2.

1.9 CRANKSHAFT WEAR SLEEVE

The crankshaft wear sleeve is used on the front or rear of the crankshaft in conjunction with an oversize seal.

These special tools are required for this procedure:

- Seal and Wear Sleeve Service Kit, J-47273
 - Universal Driver Handle, (J-8092, part of toolset J-47273)
 - Front/Rear Wear Sleeve Installer, (J-45989, part of service kit J-47273)
 - Front/Rear Wear Sleeve Installer, (J-47271, part of service kit J-47273)

1.9.1 Removal of Front Crankshaft Wear Sleeve

Removal steps are as follows:

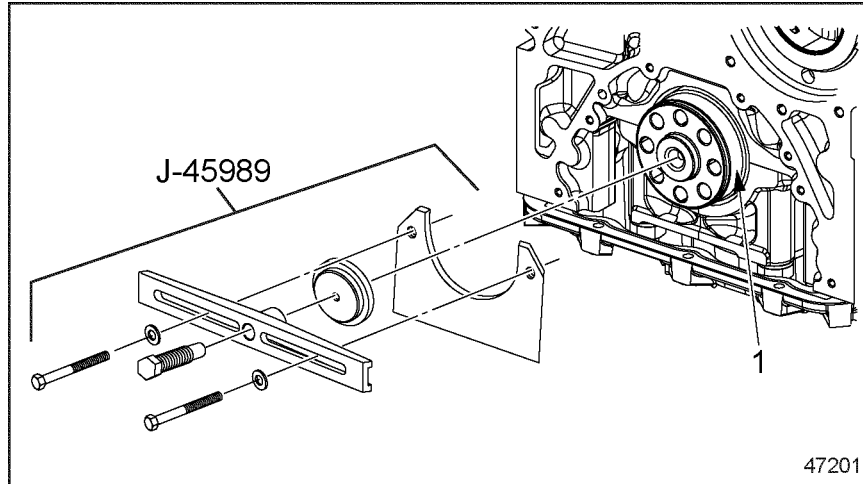
 WARNING:
PERSONAL INJURY
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Park the vehicle on a level spot, set the parking brakes, and chock the tires.
2. Tilt the hood.
3. From underneath the front of the engine, remove the bumper beam. Push the support angle bracket fairing down to create an opening in the bumper.
4. Remove the vibration damper and pulley from the engine through the opening in the bumper. Refer to section 1.13.1.
5. Remove the front radial seal. Refer to section 1.7.1.
6. Clean the wear sleeve seat area on the crankshaft.

WARNING:**BURNS**

To avoid injury from burning, use lifting tools and heat-resistant gloves when handling heated components.

7. Assemble the front wear sleeve removal tool (J-45989, part of service kit J-47273). See Figure 1-50.



1. Crankshaft Wear Sleeve

Figure 1-50 Front Seal Wear Sleeve Removal Tool J-45989

NOTE:

Ensure that the forcing screw is coated with the supplied high-pressure grease.

8. Install the assembled tool J-45989 into place by sliding from the bottom up along the rear of the wear sleeve. See Figure 1-51.

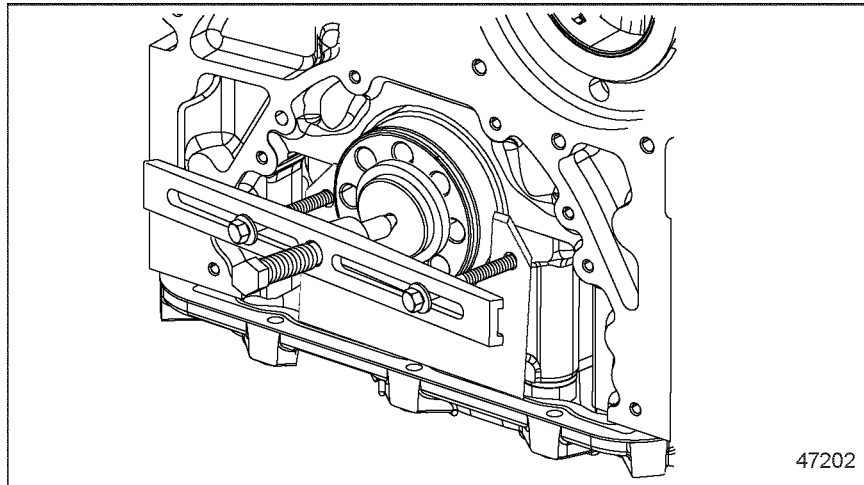


Figure 1-51 Front Seal Wear Sleeve

9. Turn the forcing screw in a slow and continuous motion until the wear sleeve is removed.

NOTE:

Once the wear sleeve is fully removed the tool will drop. Use care to support the tool during the removal procedure.

1.9.2 Installation of Front Crankshaft Wear Sleeve

Installation steps are as follows:

1. Clean the wear sleeve seat area on the crankshaft.



WARNING:

BURNS

To avoid injury from burning, use lifting tools and heat-resistant gloves when handling heated components.

NOTICE:

Be sure to heat the new wear sleeve as evenly as possible. If available, an oven should be used. Uneven heating of the wear sleeve can weaken the material and reduce the service life.

2. Install the wear sleeve with the rounded edge toward the inside of the wear sleeve installer tool (J-47271, part of toolset J-47273). Heat the tool and sleeve together in an oven to a maximum of 150° C (302°F).

3. Remove the tool and sleeve from the oven and thread driver handle (J-8092, part of toolset J-47273) into the wear sleeve installer tool (J-47271, part of toolset J-47273).

NOTICE:

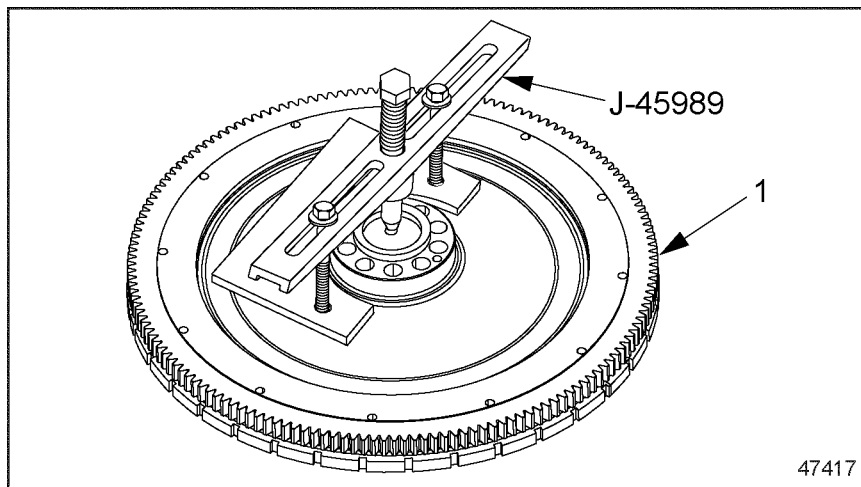
Ensure that the rounded edge of the wear sleeve faces out and is flush with the crankshaft. The installer tool guarantees the wear sleeve position onto the crankshaft. Failing to use the correct tool may affect the service life of the seal.

4. Drive the wear sleeve onto the front of the crankshaft.
5. Wait until the wear sleeve cools to room temperature before installing the oversize radial seal. Refer to section 1.7.2 to install the front oversize radial seal.

1.9.3 Removal of Rear Crankshaft Wear Sleeve

Removal steps are as follows:

1. Remove the flywheel. Refer to section 1.14.1.



1. Flywheel

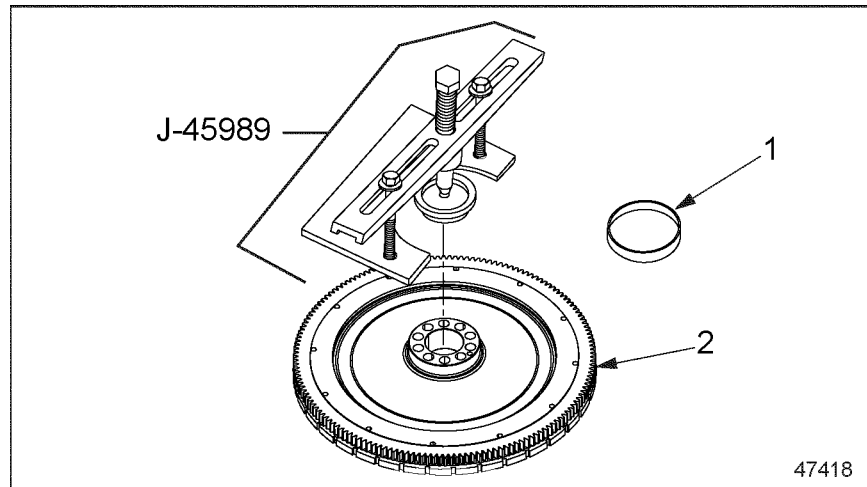
Figure 1-52 Rear Wear Sleeve Tool J-45989

2. Position the assembled wear sleeve removal to (J-47271, part of toolset J-47273) ensuring that the plate is positioned behind the lip of the wear sleeve. See Figure 1-52.

NOTE:

Lubricate the forcing screw with the supplied high-pressure lubricant.

3. Turn the forcing screw until the wear sleeve has been removed from the flywheel. Discard the wear sleeve. See Figure 1-53.



1. Wear Sleeve

2. Flywheel

Figure 1-53 Wear Sleeve

1.9.4 Installation of Rear Crankshaft Wear Sleeve

Installation steps are as follows:

1. Remove the flywheel. Refer to section 1.14.1.
2. Install the wear sleeve with the rounded edge toward the inside of the wear sleeve installer tool (J-47271, part of toolset J-47273). Heat the tool and sleeve together in an oven to a maximum of 150° C (302°F).

! WARNING:

BURNS

To avoid injury from burning, use lifting tools and heat-resistant gloves when handling heated components.

NOTICE:

Be sure to heat the new wear sleeve as evenly as possible. If available, an oven should be used. Uneven heating of the wear sleeve can weaken the material and reduce the service life.

3. Remove the tool and sleeve from the oven and thread driver handle (J-8092, part of toolset J-47273) into the wear sleeve installer tool (J-47271, part of toolset J-47273).

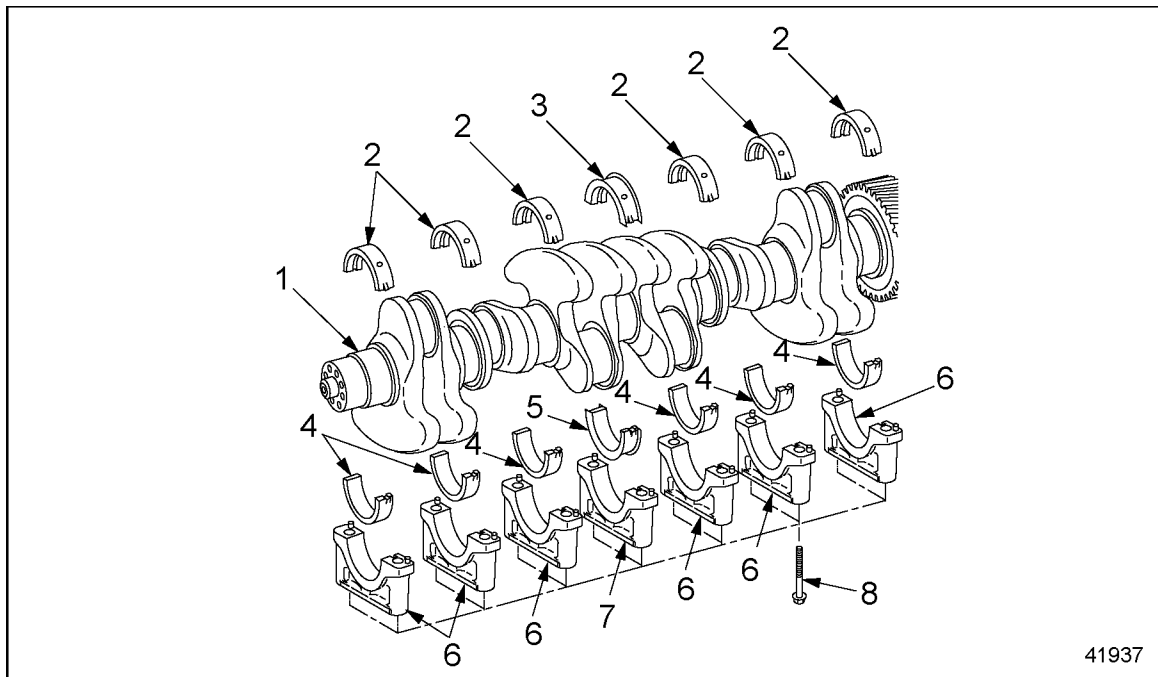
NOTICE:

Ensure that the rounded edge of the wear sleeve faces out and is flush with the crankshaft. The installer tool guarantees the wear sleeve position onto the crankshaft. Failing to use the correct tool may affect the service life of the seal.
--

4. Drive the wear sleeve onto the flywheel hub area.
5. Wait until the wear sleeve cools to room temperature before installing the oversize radial seal. Refer to section 1.7.2 to install the front oversize radial seal.

1.10 CRANKSHAFT ASSEMBLY

The crankshaft is precision-forged with seven main bearings and eight custom-forged counter weights, and a vibration damper at the front end. For an exploded view of the crankshaft, main bearings, and main bearing caps, see Figure 1-54.



- | | |
|---------------------------------|---------------------------------|
| 1. Crankshaft | 5. Lower Bearing Shell (center) |
| 2. Upper Bearing Shell(s) | 6. Main Bearing Cap(s) |
| 3. Upper Bearing Shell (center) | 7. Main Bearing Cap (center) |
| 4. Lower Bearing Shell(s) | 8. Main Bearing Cap Bolt |

Figure 1-54 Crankshaft, Main Bearings, and Main Bearing Caps

1.10.1 Removal of Crankshaft

Removal steps are as follows:

 DANGER: FALLING ENGINE
To avoid injury from a falling engine, an adequate lifting device with a spreader bar and sling should be used to lift the engine. The sling and spreader bar should be adjusted so the lifting hooks are vertical to prevent bending the lifter brackets. To ensure proper weight distribution, all provided lifter brackets must be used.

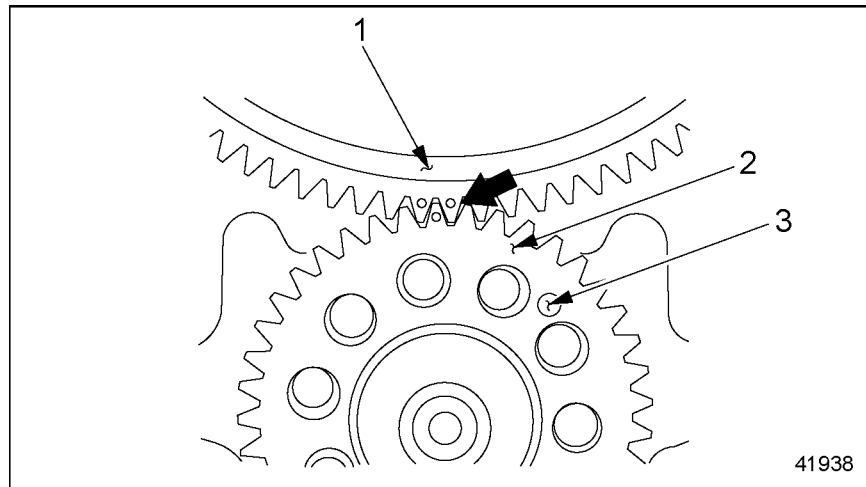
NOTICE:
A spreader bar <i>must</i> be used at all times in conjunction with the front and rear lifter brackets to lift the EGR engine to ensure that no engine damage will result. The brackets are designed to lift vertically.

1. Remove the engine from the vehicle.

 WARNING: FALLING ENGINE
To avoid injury from a falling engine, ensure the engine is securely attached to the engine overhaul stand before releasing the lifting sling.

2. Mount the engine on an engine stand. Install the engine on an engine stand. Use OTC engine stand 1750A or equivalent and engine stand adaptor plate J-41576.
3. Remove the cylinder heads. Refer to section 1.3.1.
4. Remove the oil pan. Refer to section 3.2.1.
5. Remove oil pump. Refer to section 3.5.1.
6. Remove the flywheel. Refer to section 1.14.1.
7. Remove the flywheel housing. Refer to section 1.18.1.
8. Remove the front cover housing. Refer to section 1.11.1.
9. Remove the pistons. Refer to section 1.19.1.

10. Turn the crankshaft until the marked gear teeth on the camshaft gear line up with the marked tooth on the crankshaft gear. See Figure 1-55.



1. Camshaft Gear

2. Crankshaft Gear

3. Dowel Pin Location

Figure 1-55 **Aligning the Marked Gear Teeth**

11. Remove the crankshaft gear from the crankshaft. Refer to section 1.10.3.
12. Mark the order of the main bearing caps, then remove the main bearing-cap bolts. See Figure 1-56.

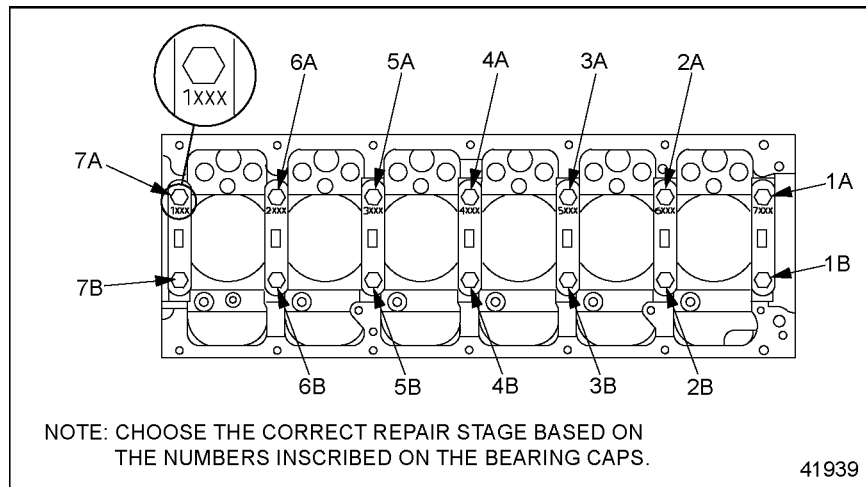


Figure 1-56 **Removal Order, Main Bearing Cap Bolts**

13. Loosen the main bearing caps with a plastic hammer, if necessary. Remove the main bearing caps.

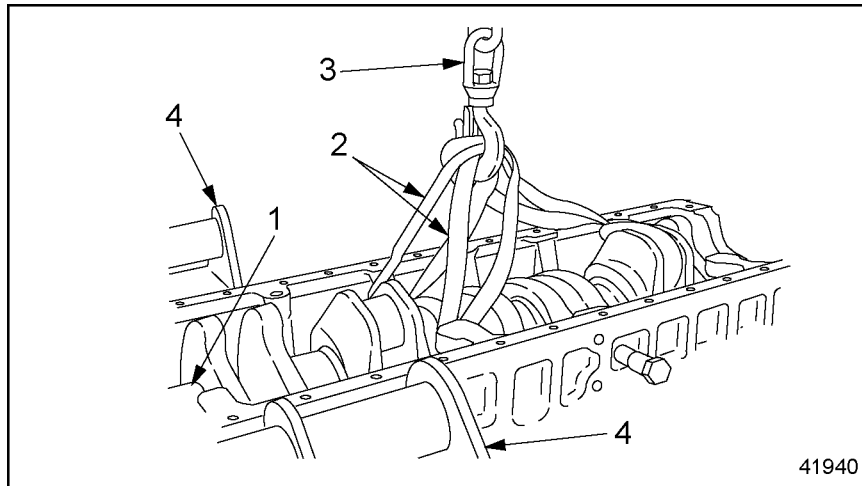


DANGER:

FALLING COMPONENT

To avoid injury from a falling component, ensure a proper lifting device is used.

14. Attach a suitable hoist to the crankshaft, using flexible straps to hold the crankshaft without bending or scratching it. Then lift the crankshaft out of the block. See Figure 1-57.

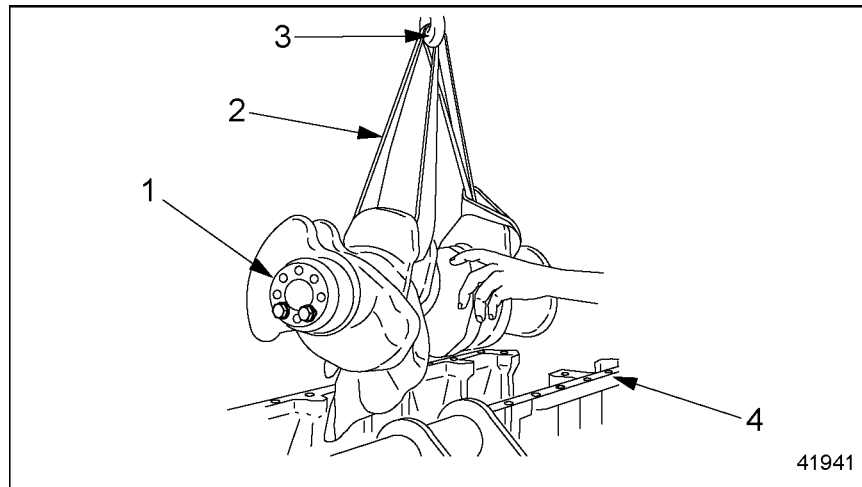


1. Crankshaft
2. Flexible Straps

3. Hoisting Chain
4. Engine Stand

Figure 1-57 Attaching the Hoist

15. Lift the crankshaft out of the cylinder block. Make sure the crankshaft doesn't twist from side to side. See Figure 1-58.



- | | |
|--------------------|---------------------------|
| 1. Crankshaft | 3. Hook of Hoisting Chain |
| 2. Flexible Straps | 4. Cylinder Block |

Figure 1-58 Lifting the Crankshaft

- [a] Lower the crankshaft gently onto a flat surface covered with clean cardboard.
- [b] Remove the hoist.
16. Mark each upper bearing shell and its corresponding race before removing the bearing shells from the crankcase.
17. Check all parts for wear or damage. Measure the various crankshaft specifications. Refer to section 1.10.2.3.

1.10.2 Installation of Crankshaft

Install the crankshaft as follows:

1. Clean the crankshaft oil passages with a wire brush and blow compressed air through the passages. Clean the crankshaft, bearings, and bearing seats with a chamois.
2. Lubricate the bearing surfaces with a light coating of clean engine oil.
3. Install the upper bearing shells into the block, in the same order as they were removed. Make sure the locking lugs of the bearing shells fit into the slots of the block bores. Refer to section 1.10.2.2.

NOTE:

The center bearing shell halves must be mounted in the center crankcase race and bearing cap (fourth from either end).

4. Install the lower bearing shells into the main bearing caps, in the same order as they were removed. Make sure the locking lugs are fully seated in the grooves of the bearing caps. Refer to section 1.10.2.2.
5. Screw a crankshaft and flywheel guide pin into each end of the crankshaft.

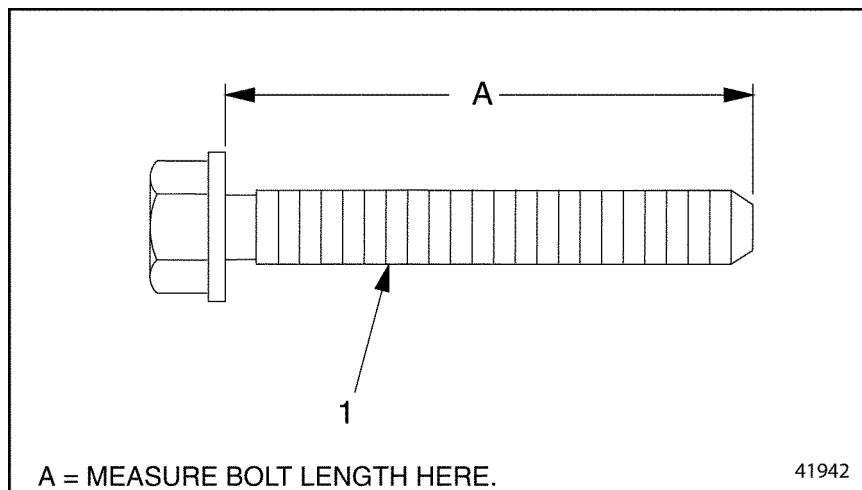
 DANGER: FALLING COMPONENT
To avoid injury from a falling component, ensure a proper lifting device is used.

6. Using a suitable hoist, lower the crankshaft into the block.
7. As you set the crankshaft into the block, use the guide pins to maneuver the crankshaft into position to align the crankshaft gear with the camshaft gear. Fit the marked gear tooth on the crankshaft gear between the two marked teeth on the camshaft gear. See Figure 1-55.
8. Install all the main bearing caps (including the center bearing cap), with their bearing shells, on the crankcase journals, as removed. See Figure 1-56.

NOTE:

Make sure the numbers on the bearing caps are in ascending order, starting from the front of the engine.

9. Measure the shaft length of the main bearing-cap bolts. Replace any bolts that exceed the maximum shaft length of 156.0 mm (6.14 in.). See Figure 1-59.



1. Main Bearing-Cap Bolt

Figure 1-59 Measuring a Main Bearing-Cap Bolt

10. Lubricate the main bearing-cap bolts with a light coating of clean engine oil. Install all the M18 x 2 main bearing-cap bolts, in the correct order, as removed. Tighten each one in four stages, listed in Table 1-12, stage by stage.

Max. Shaft Length: mm (in.)	Tightening Stage	Torque: N·m (lb·ft)
156.0 (6.14)	Stage 1	100 (74)
156.0 (6.14)	Stage 2	200 (148)
156.0 (6.14)	Stage 3	300-330 (221-243)
156.0 (6.14)	Stage 4	90 degrees

Table 1-12 Tightening Stages, Main Bearing-Cap Bolts

11. Measure the crankshaft end play (fore-to-aft motion) at the center bearing journal. Refer to section 1.10.2.1.
12. Install the pistons. Refer to section 1.19.2.
13. Install the oil pump. Refer to section 3.5.3.
14. Install the oil pan. Refer to section 3.2.2.
15. Install the flywheel housing. Refer to section 1.18.2.
16. Install the flywheel. Refer to section 1.14.2.
17. Install the front cover housing. Refer to section 1.11.2.
18. Install the cylinder heads. Refer to section 1.3.2.



DANGER:

FALLING ENGINE

To avoid injury from a falling engine, an adequate lifting device with a spreader bar and sling should be used to lift the engine. The sling and spreader bar should be adjusted so the lifting hooks are vertical to prevent bending the lifter brackets. To ensure proper weight distribution, all provided lifter brackets must be used.

NOTICE:

A spreader bar *must* be used at all times in conjunction with the front and rear lifter brackets to lift the EGR engine to ensure that no engine damage will result. The brackets are designed to lift vertically.

19. Remove the engine from the stand.
20. Install the engine in the vehicle.

1.10.2.1 Measurement and Inspection of Crankshaft

Inspection steps are as follows:

1. Remove the crankshaft. Refer to section 1.10.1.
2. Clean the crankshaft with a chamois.
3. Check the crankshaft for condition. If cracks or fissures are found, replace the crankshaft.
4. Test the hardness of the journals. Each journal must pass the hardness test at two thirds of its circumference. If it doesn't, either replace the crankshaft, or have it re-hardened. See Table 1-13 for hardness specifications
 - [a] Place a hard base underneath the bearing journal to be tested.
 - [b] Test hardness all the way around the journal circumference. Hardness must be 53 to 59 HRC as listed in Table 1-13.

Description	Specification in mm (in.)*
Main Bearing and Connecting Rod Journal Hardness (Rockwell hardness)	53 to 59 HRC
Permissible Deviation From True of Crankshaft†	0.09 (0.004)
Permissible Out-Of-Round for Main and Connecting-Rod Bearing Journals - When New reground	0.01 (0.0004)
Permissible Out-Of-Round for Main and Connecting-Rod Bearing Journals - Wear Limit	0.02 (0.0008)
Fillet Radii of Main Bearing Journals	4.2-4.5 (0.165-0.177)
Fillet Radii of Connecting Rod Bearing Journals	3.7-4.0 (0.146 - 0.157)
Crown of Main Bearing Journals and Connecting-Rod Journals	0.000-0.004 (0.0000-0.0002)
Main Bearing Outside Diameter (diameter of bearing shell housing)	111.000-111.022 (4.3701-4.3709)
Permissible Imbalance of Crankshaft‡ -at 400 rpm	0.6 N·cm (0.05 lb·in)

* Except as otherwise noted.

†Measure with the crankshaft mounted on the outer main bearing journals.

‡With the pin for the flywheel installed, but without the flywheel, and with the crankshaft mounted on the outer bearings.

Table 1-13 Crankshaft Specifications

5. Measure the deviation from true of the crankshaft. If the deviation from true is greater than 0.09 mm (0.004 inch), regrind the crankshaft.
 - [a] Support the crankshaft on a stand, held by the two external journals.
 - [b] Set up a dial gauge and holder on the center journal, with some preload on the gauge.
 - [c] Set the dial gauge to "0" (zero).
 - [d] Turn the crankshaft through one full revolution, and check the dial gauge. If the dial gauge deviates by more than 0.09 mm (0.004 in.), regrind the crankshaft.

6. Check the crankshaft for dynamic balance. Permissible imbalance is listed in Table 1-13.
7. Using a micrometer, measure the diameters of the main journals and the connecting-rod journals. Measure in both the vertical and horizontal directions on each journal. Refer to section 1.10.2.2 for detailed procedures.
8. Comparing the two measurements taken above, check each crankshaft main and connecting-rod journal for out-of-round.

If, for any one journal, the two measurements differ by more than 0.01 mm (0.0004 in.), regrind the crankshaft.

If, for any one journal, the two measurements differ by more than 0.02 mm (0.0008 in.), replace the crankshaft. Refer to section 1.10.1.

Listed in Table 1-14 are the permissible ranges at the various repair stages.

Size: mm (in.)	Main Bearing Journal Diameter: mm (in.)	Connecting-Rod Bearing Journal Diameter: mm (in.)
Standard	103.980-104.000 (4.0937-4.0945)	93.980-94.000 (3.7000-3.7007)
Undersize - 0.10 (0.004)	103.880-103.900 (4.0898-4.0905)	93.880-93.900 (3.6960-3.6968)
Undersize - 0.25 (0.010)	103.730-103.750 (4.0839-4.0846)	93.730-93.750 (3.6901-3.6909)
Undersize - 0.50 (0.020)	103.480-103.500 (4.0740-4.0748)	93.480-93.500 (3.6803-3.6811)
Undersize - 0.75 (0.030)	103.230-103.250 (4.0642-4.0650)	93.230-93.250 (3.6705-3.6712)
Undersize - 1.00 (0.040)	102.980-103.000 (4.0543-4.0551)	92.980-93.000 (3.6606-3.6614)

Table 1-14 Crankshaft Journal Diameters

9. Measure the width of all the main and connecting-rod journals. See Figure 1-60. Listed in Table 1-15 are the permissible ranges.

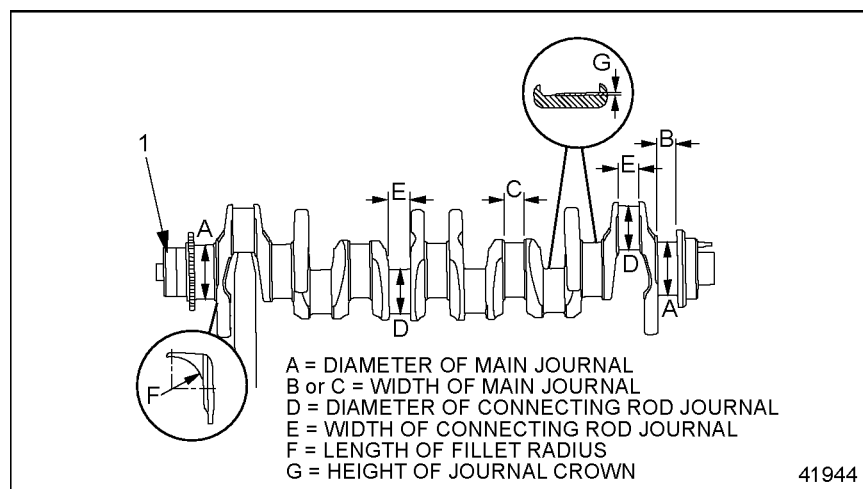


Figure 1-60 Journal Measurements

Type of Journal: mm (in.)	Width mm (in.)
Main Journal	46.000-46.250 (1.8110-1.8209)
Connecting-Rod Journal	44.5-44.6 (1.752-1.756)

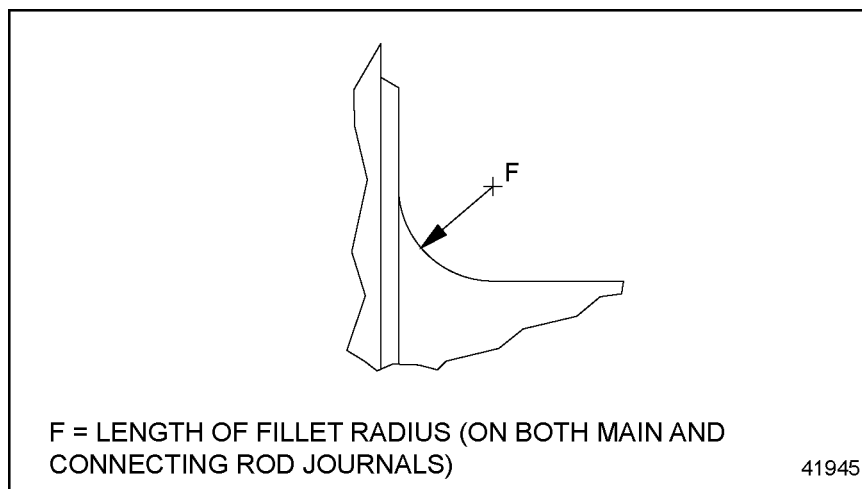
Table 1-15 Bearing Journal Width

10. Check the width of the center bearing shell and journal. See Figure 1-60. Listed in Table 1-16 are the permissible ranges at the various repair stages.

Size: mm (in.)	Thrust Bearing Shell Width mm (in.)	Thrust Bearing Journal Width mm (in.)
Standard	45.74-45.81 (1.801-1.804)	46.000-46.062 (1.8110-1.8135)
Undersize - 0.50 (0.020)	46.24-46.31 (1.820-1.823)	46.500-46.562 (1.8307-1.8331)
Undersize - 1.00 (0.040)	46.74-46.81 (1.840-1.843)	47.000-47.062 (1.8504-1.8528)

Table 1-16 Bearing Shell and Bearing Journal Width

11. Measure the fillet radius of the main journals and the connecting-rod journals as listed in Table 1-13. See Figure 1-61.

**Figure 1-61 Measuring the Fillet Radius**

12. Measure the crown of the main journals and the connecting-rod journals as listed in Table 1-13. See Figure 1-62.

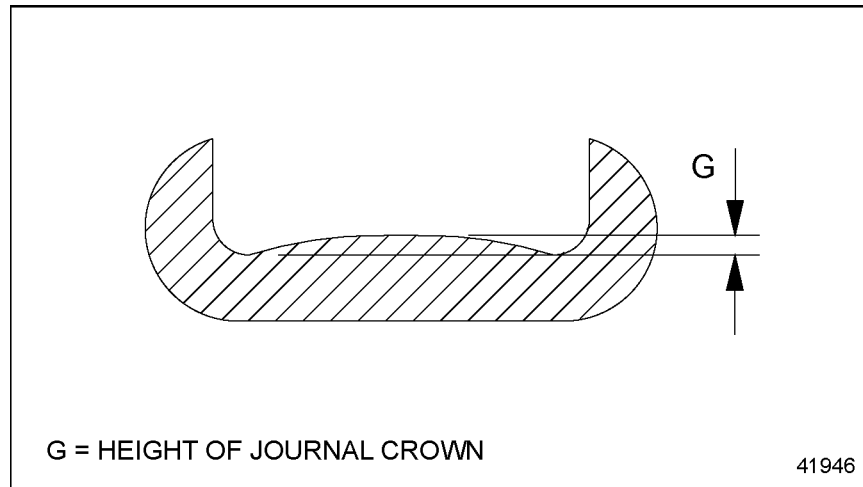


Figure 1-62 Measuring the Crown of the Journal

13. Regrind the main journals. After grinding, see Figure 1-60 for dimensions.
- [a] Check the outside diameter of each main journal.
 - [b] Check the width of the center main journal.
 - [c] Check the width of the remaining main journals.
 - [d] Check the fillet radius of each main journal.
 - [e] Check the crown of each main journal.
 - [f] Check each main journal for out-of-round.
14. Regrind the connecting-rod journals. After grinding, check the following dimensions.
- [a] Check the outside diameter of each connecting-rod journal.
 - [b] Check the width of the each connecting-rod journal.
 - [c] Check the fillet radius of each connecting-rod journal.
 - [d] Check the crown of each connecting-rod journal.
 - [e] Check each connecting-rod journal for out-of-round.
15. Install the crankshaft. Refer to section 1.10.2.
- [a] When the main bearing caps have been installed, measure the radial play (radial runout) of the crankshaft. Refer to section 1.10.2.2.
 - [b] With the crankshaft fully installed, measure the end play (lateral runout) of the crankshaft. Refer to section 1.10.2.3.

1.10.2.2 Checking of Crankshaft Radial Play

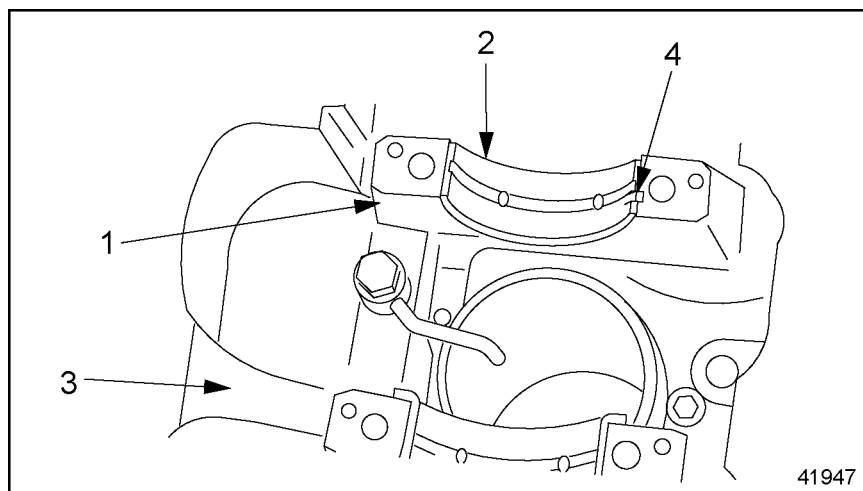
Checking steps are as follows:

1. Clean the bearing races in the crankcase (cylinder block) and the bearing seats in the bearing caps with a chamois.

NOTE:

The center bearing shell halves must be mounted in the center crankcase race and bearing cap (fourth from either end).

2. Install the upper bearing shell on the bearing race in the crankcase. The locking lugs of the bearing shells must fit into the slots in the crankcase races. See Figure 1-63.



1. Crankcase Race

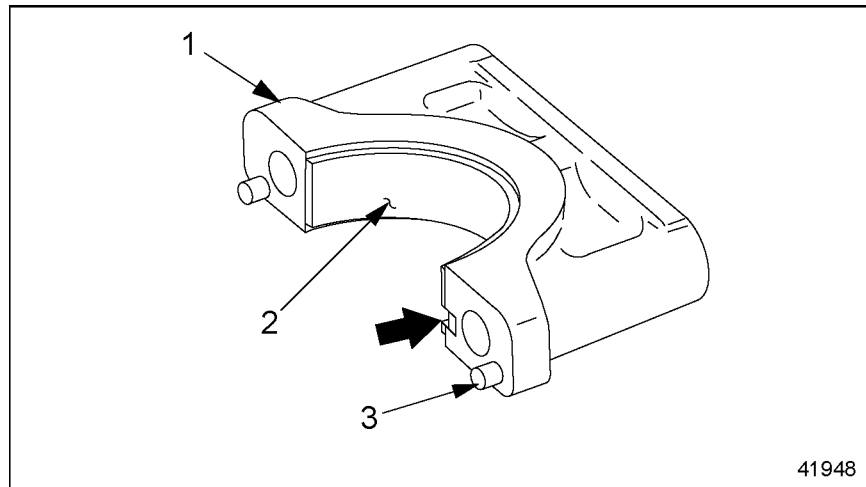
2. Upper Bearing Shell

3. Cylinder Block

4. Bearing Shells Locking Lug

Figure 1-63 Upper Bearing Shell

3. Install the lower bearing shell on the bearing seat in the bearing cap. The locking lugs in the bearing shells must fit into the grooves in the bearing cap. See Figure 1-64.



1. Main Bearing Cap

3. Guide Pin

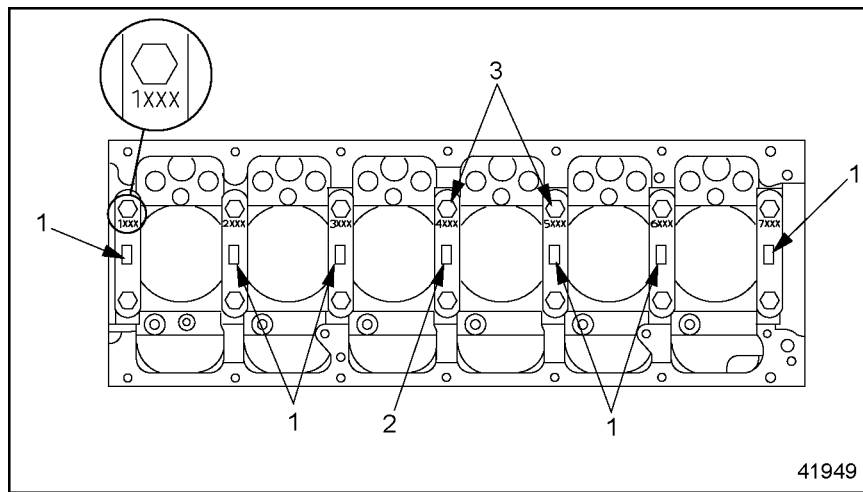
2. Lower Bearing Shell

Figure 1-64 Lower Bearing Shell

NOTE:

The guide pins on the bearing cap ensure correct seating of the cap on the crankcase race.

4. Install all the main bearing caps (including the center bearing cap) with their bearing shells, on the crankcase journals, pressing them in with the fingers and making sure the guide pins are correctly aligned. See Figure 1-65.



1. Main Bearing Cap(s)

3. Bearing Cap Bolts (14 qty.)

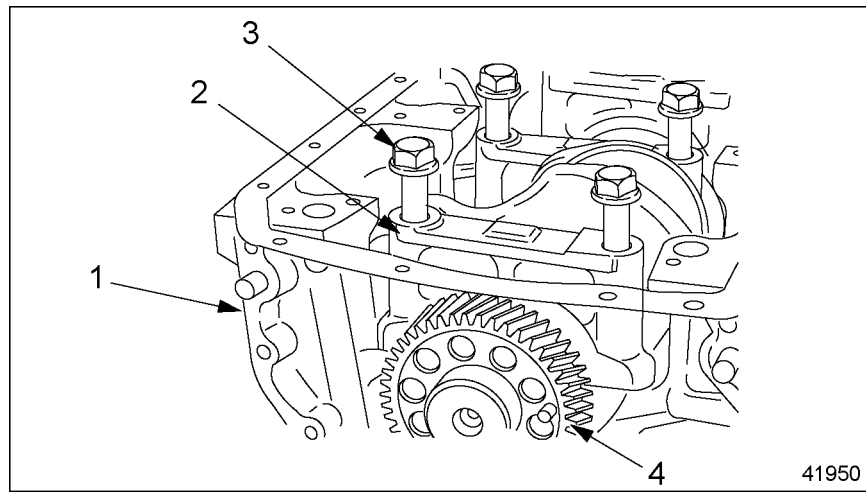
2. Main Bearing Cap (center)

Figure 1-65 **Bearing Caps**

NOTE:

Make sure the numbers on the bearing caps are in ascending order, starting from the front of the engine.

5. Lubricate the main bearing cap bolts with a light coating of clean engine oil. Install them on the main bearing caps. See Figure 1-66. Refer to section 1.10.2 for instructions and tightening torques.

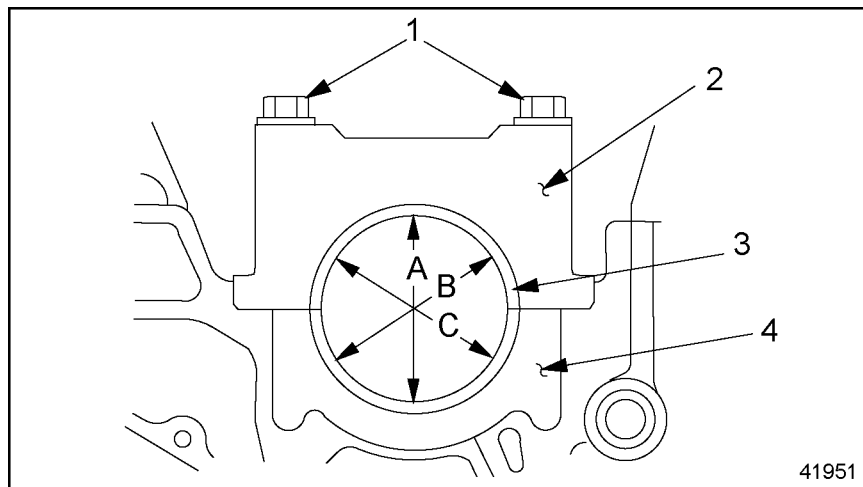


- | | |
|---------------------|---------------------|
| 1. Cylinder Block | 3. Bearing-Cap Bolt |
| 2. Main Bearing Cap | 4. Crankshaft Gear |

Figure 1-66 Main Bearing Caps

6. Using a dial gauge and quick-release calipers, measure the inside diameter of each of the main bearings. See Figure 1-67.
 - [a] Measure vertically from the top to the bottom of the bore. (see Figure 1-67, A.)
 - [b] Measure 30 degrees counterclockwise from the separation point of the bearing shells. (see Figure 1-67, B.)

- [c] Measure 30 degrees clockwise from the separation point of the bearing shells.
(see Figure 1-67, C.)



- | | |
|----------------------|-----------------------|
| 1. Bearing Cap Bolts | 3. Main Bearing Shell |
| 2. Main Bearing Cap | 4. Crankcase Race |

Figure 1-67 Inside Diameter of the Main Bearing Shells

7. If any one of the readings is not within tolerances listed in Table 1-17, then replace the main bearing shells as applicable.

Size: mm (in.)	Main Bearing Inside Diameter mm (in.)	Main Journal Outside Diameter mm (in.)
Standard	104.060-104.106 (4.0968-4.0987)	103.980-104.000 (4.0937-4.0945)
Undersize - 0.10 (0.004)	103.960-104.006 (4.0929-4.0947)	103.880-103.900 (4.0898-4.0905)
Undersize - 0.25 (0.010)	103.810-103.856 (4.0870-4.0888)	103.730-103.750 (4.0839-4.0846)
Undersize - 0.50 (0.020)	103.560-103.606 (4.0772-4.0790)	103.480-103.500 (4.0740-4.0748)
Undersize - 0.75 (0.030)	103.310-103.356 (4.0673-4.0691)	103.230-103.250 (4.0642-4.0650)
Undersize - 1.00 (0.040)	103.060-103.106 (4.0575-4.0593)	102.980-103.000 (4.0543-4.0551)

Table 1-17 Bearing Shell and Bearing Journal Diameter

NOTE:

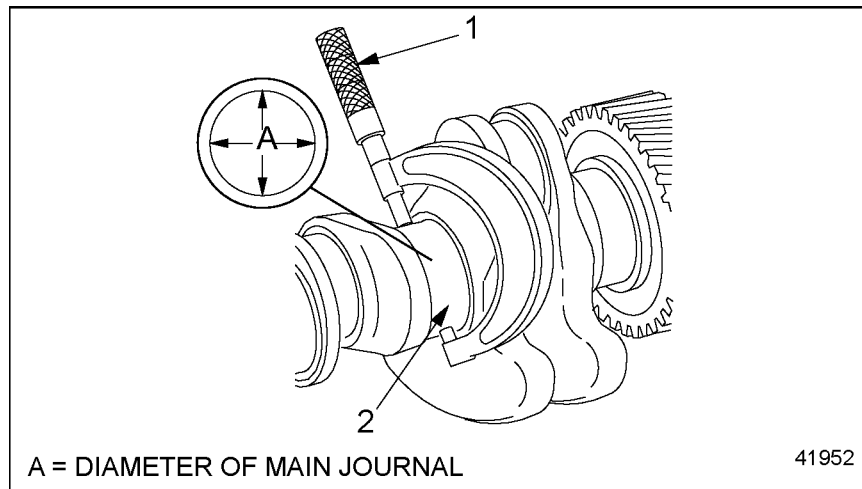
New bearing shells are supplied ready for installation. Do not machine them or remove any material from them. Refer to section 1.10.2.

8. Remove the bearing caps.

NOTE:

If the bolts are going to be used again, check their length.

9. Using a micrometer, measure the outside diameter of the main journals. See Figure 1-68.



1. Micrometer

2. Main Journal

Figure 1-68 Outside Diameter of the Main Journals

NOTE:

To obtain a correct value for crankshaft radial play, the diameters of each bearing bore and its corresponding journal must belong to the same repair stage (both must be "Standard," "Undersize - 0.004 in.," etc.).

10. Calculate the radial play (up-and-down movement) of the main bearings on the crankshaft journals. If the radial play is less than 0.060 mm (0.0024 in.), or more than 0.126 mm (0.0050 in.) as listed in Table 1-18, then replace the crankshaft.

Description	Dimensions mm (in.)
Main Journal Radial Play	0.060-0.126 (0.0024-0.0050)

Table 1-18 Crankshaft Radial Play

- [a] For the main bearing shell, note the inside diameter of the bearing shell. *Example:* $D_s = 4.0875$ in.
- [b] For the main bearing journal, note the outside diameter of the journal. *Example:* $D_j = 4.0850$ in.
- [c] From the value for the bearing shell diameter, subtract the value for the journal diameter. This result is the radial play. *Example:* $D_s - D_j = 0.0025$ in.

NOTE:

In the above example, both measurements belonged to repair stage "Undersize - 0.010 in." Listed in Table 1-17 is the correct repair stage for each measurement.

11. Install the crankshaft into the crankcase. Refer to section 1.10.2.

⚠ DANGER:

FALLING ENGINE

To avoid injury from a falling engine, an adequate lifting device with a spreader bar and sling should be used to lift the engine. The sling and spreader bar should be adjusted so the lifting hooks are vertical to prevent bending the lifter brackets. To ensure proper weight distribution, all provided lifter brackets must be used.

NOTICE:

A spreader bar *must* be used at all times in conjunction with the front and rear lifter brackets to lift the EGR engine to ensure that no engine damage will result. The brackets are designed to lift vertically.

12. Install the engine in the vehicle.

1.10.2.3 Checking of Crankshaft End Play

Checking steps are as follows:

1. Remove the crankshaft. Refer to section 1.10.1.
2. Check the width of the center main bearing journal. If damage or cracks are present, replace the crankshaft. See Figure 1-69.

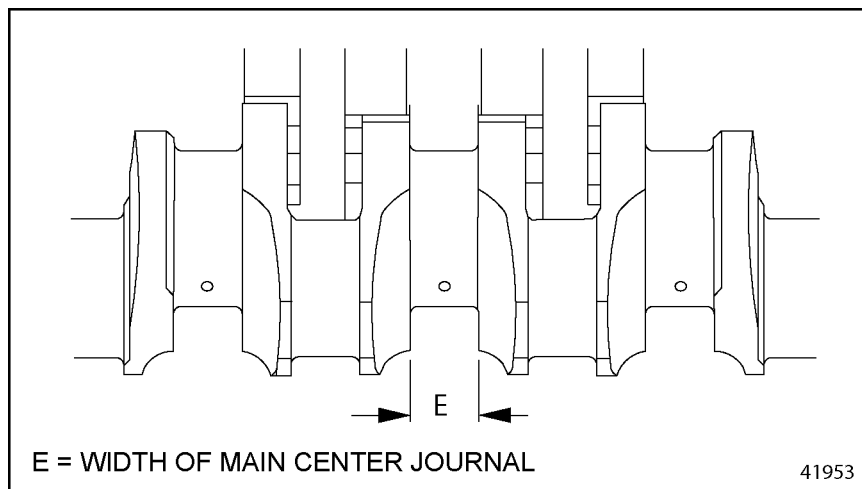


Figure 1-69 Measuring the Width of the Center Journal

3. Check the width of the center main bearing shell. If damage or cracks are present, replace the crankshaft. See Figure 1-70.

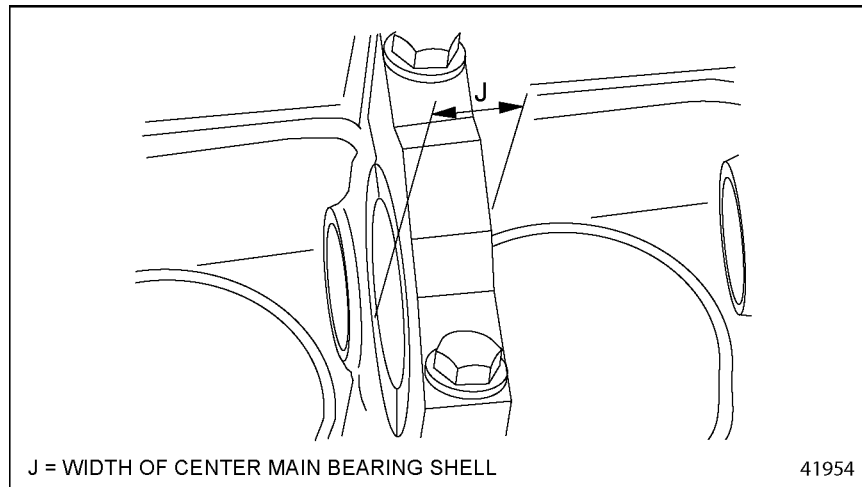


Figure 1-70 Measuring the Width of the Center Main Bearing Shell

NOTE:

To obtain a correct value for crankshaft end play, the width of each bearing shell and its corresponding journal must belong to the same repair stage (both must be "Standard," "Undersize - 0.020 in.," etc.).

4. Calculate the end play, or axial play, (fore-to-aft movement) of the crankshaft. If the end play is less than 0.190 mm (0.0075 in.), or more than 0.322 mm (0.0127 in.) as listed in Table 1-19, then replace the crankshaft.

Description	Dimensions mm (in.)
End Play (Axial Play) Measured at Center Bearing Journal	0.190-0.322 (0.0075-0.0127)

Table 1-19 Crankshaft End Play

- [a] For the center main bearing journal, note the width (thickness) of the bearing journal.
Example: $W_m = 1.8120$ in.
- [b] For the center main bearing shell, note the width (thickness) of the bearing shell.
Example: $W_s = 1.8030$ in.

- [c] From the value for the journal width, subtract the value for the bearing shell width. This result is the end play. *Example:* $W_m - W_s = 0.0090$ inch.

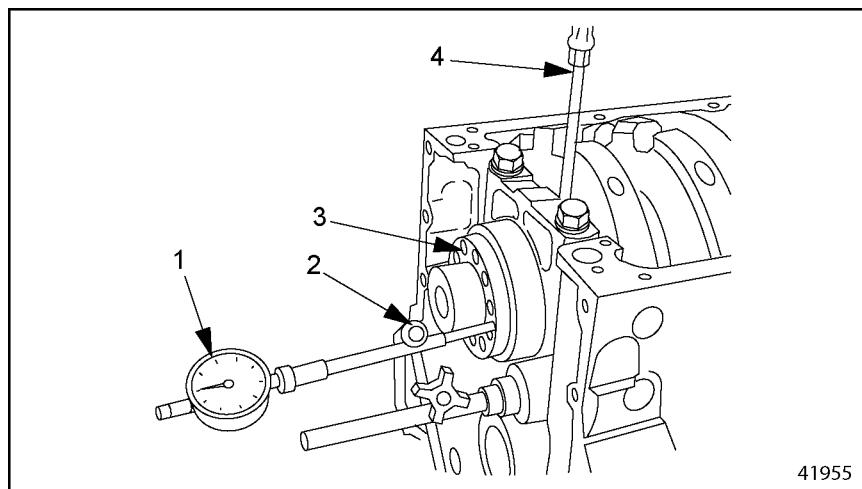
NOTE:

In the above example, both measurements belonged to repair stage "Standard." If necessary, listed in Table 1-20 are the correct repair stages for each measurement.

Size: mm (in.)	Center Bearing Shell Width mm (in.)	Center Bearing Journal Width mm (in.)
Standard	45.74-45.81 (1.801-1.804)	46.000-46.062 (1.8110-1.8135)
Undersize - 0.020 (0.50)	46.24-46.31 (1.820-1.823)	46.500-46.562 (1.8307-1.8331)
Undersize - 1.00 (0.040)	46.74-46.81 (1.840-1.843)	47.000-47.062 (1.8504-1.8528)

Table 1-20 Bearing Shell and Bearing Journal Width

5. Install the crankshaft. Refer to section 1.10.2.
6. Using a dial gauge and holder, measure the end play of the crankshaft. Measure at the front end of the crankshaft, with the crankshaft fully installed and all the bearing caps tightened to the correct torque. See Figure 1-71.



- | | |
|----------------------|----------------|
| 1. Dial Gauge | 3. Crankshaft |
| 2. Dial Gauge Holder | 4. Screwdriver |

Figure 1-71 Measuring the End Play of the Crankshaft

- [a] Set up a dial gauge and a dial gauge holder on the front end of the crankshaft. Set the dial gauge to 5 mm (0.2 in.) preload.
- [b] Move the crankshaft all the way forward by prying on one of the bearing caps, then reset the dial gauge to "0" (zero).
- [c] Move the crankshaft all the way aft. Note the end play on the dial gauge.

- [d] If the end play does not correspond to the calculated amount (in the example above: 0.0090 inch), replace the crankshaft.

**DANGER:****FALLING ENGINE**

To avoid injury from a falling engine, an adequate lifting device with a spreader bar and sling should be used to lift the engine. The sling and spreader bar should be adjusted so the lifting hooks are vertical to prevent bending the lifter brackets. To ensure proper weight distribution, all provided lifter brackets must be used.

NOTICE:

A spreader bar *must* be used at all times in conjunction with the front and rear lifter brackets to lift the EGR engine to ensure that no engine damage will result. The brackets are designed to lift vertically.

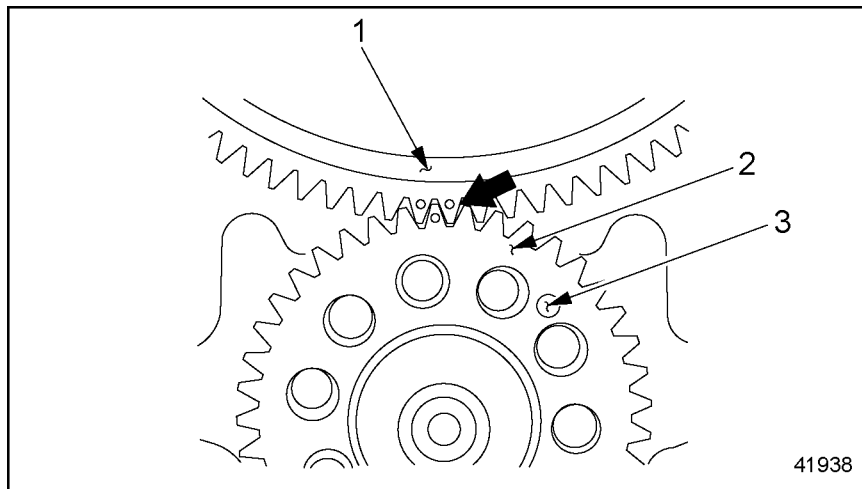
7. Install the engine in the vehicle.

1.10.3 Replacement of Crankshaft Gear

Replacement steps are as follows:

1. Remove the transmission and clutch. Refer to the appropriate vehicle service manual.
2. Remove the oil pan and gasket. Refer to section 3.2.1.
3. Support the engine by placing suitable jack stands under the cylinder block pan rails. Make sure not to damage the sealing surfaces of the pan rails.
4. Remove the rear engine mounts from the flywheel housing. Refer to the applicable vehicle service manual.

5. Remove the flywheel housing. Refer to section 1.18.1.

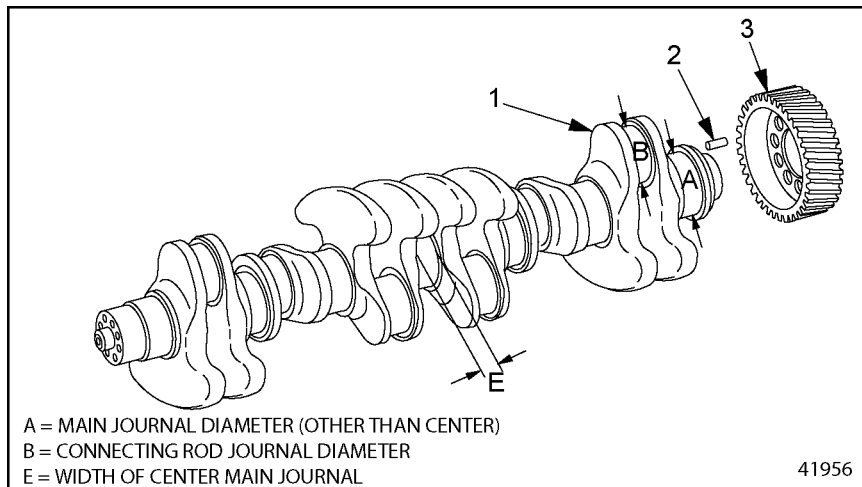


1. Camshaft Gear
2. Crankshaft Gear

3. Dowel Pin

Figure 1-72 **Aligning the Marked Gear Teeth**

6. Rotate the crankshaft until the marked gear tooth on the crankshaft gear is aligned between the two similarly marked teeth on the camshaft gear. See Figure 1-72.
7. Remove the crankshaft gear from the end of the crankshaft. If necessary, use a plastic hammer to loosen the gear. See Figure 1-73.



1. Crankshaft
2. Guide Pin

3. Crankshaft Gear

Figure 1-73 **Crankshaft Gear**

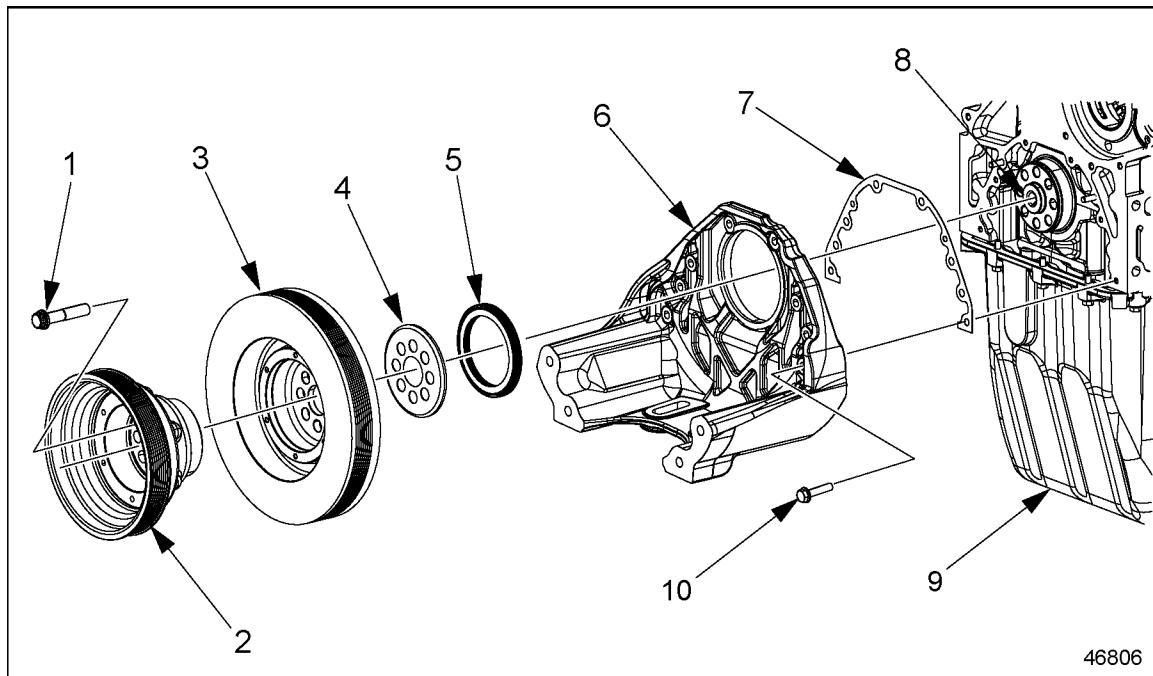
NOTICE:

Ensure that the mark on the crankshaft gear is aligned between the two marks on the camshaft gear and the dowel pin in the crankshaft gear is aligned with the dowel hole in the crankshaft. Failure to properly align the timing marks and dowel pin will cause improper operation of the engine and component damage.

8. Align the dowel pin in the crankshaft gear with the dowel pin hole in the crankshaft while aligning the timing marks on the camshaft gear and crankshaft gear and install gear. If necessary rotate the camshaft slightly until the two marked gear teeth on the camshaft gear are aligned with the marked tooth on the crankshaft gear. See Figure 1-73.
9. Install the flywheel housing. Refer to section 1.18.2.
10. Attach the rear engine mounts to the flywheel housing. Refer to the applicable vehicle service manual.
11. Remove the jack stands supporting the engine.
12. Install the oil pan. Refer to section 3.2.2.

1.11 FRONT COVER HOUSING

For an exploded view of the front cover housing, see Figure 1-74.



- | | |
|----------------------|---------------------------|
| 1. Bolt | 6. Front Cover Housing |
| 2. Pulley | 7. Cover Housing Gasket |
| 3. Vibration Damper | 8. Crankshaft |
| 4. Oil Deflector | 9. Oil Pan |
| 5. Front Radial Seal | 10. Housing Mounting Bolt |

Figure 1-74 Front Cover Housing

1.11.1 Removal of Front Cover Housing

Removal steps are as follows:



WARNING: **PERSONAL INJURY**

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Park the vehicle on a level spot, set the parking brakes, and chock the tires.
2. Tilt the hood.

3. Remove the front engine mounting bolts attaching the front cover housing to the front crossmember.

NOTICE:

To prevent damage to the oil pan, protect the pan by placing a board on the jack lifting surface.

4. Using a floor jack, lift up the oil pan.
5. Remove the vibration damper and pulley from the engine through the opening in the bumper. Refer to section 1.13.1.
6. Remove the mounting bolts attaching the front cover housing to the block. Remove the front cover housing from the cylinder block. Remove and discard the cover housing gasket. See Figure 1-74.
7. Remove the front radial seal from the front cover housing.

1.11.2 Installation of Front Cover Housing

Installation steps are as follows:

1. Install a new gasket on the cylinder block. See Figure 1-74.
2. Lubricate the seal race on the crankshaft with a light coating of engine oil.
3. Install the front cover on the cylinder block. Tighten the front cover mounting bolts 60 N·m (44 lb·ft).
4. Install the front radial seal. Refer to section 1.7.2.
5. Install the oil deflector on the front of the crankshaft.
6. Install the vibration damper and pulley on the crankshaft. Torque the vibration damper mounting bolts 200 N·m (148 lb·ft). Refer to section 1.13.2.
7. Lower the oil pan and remove the floor jack.
8. Install the front engine mounting bolts attaching the front cover housing to the front crossmember. Torque the front engine mounting bolts 325 N·m (240 lb·ft).
9. Close the hood, and remove the chocks from the tires.

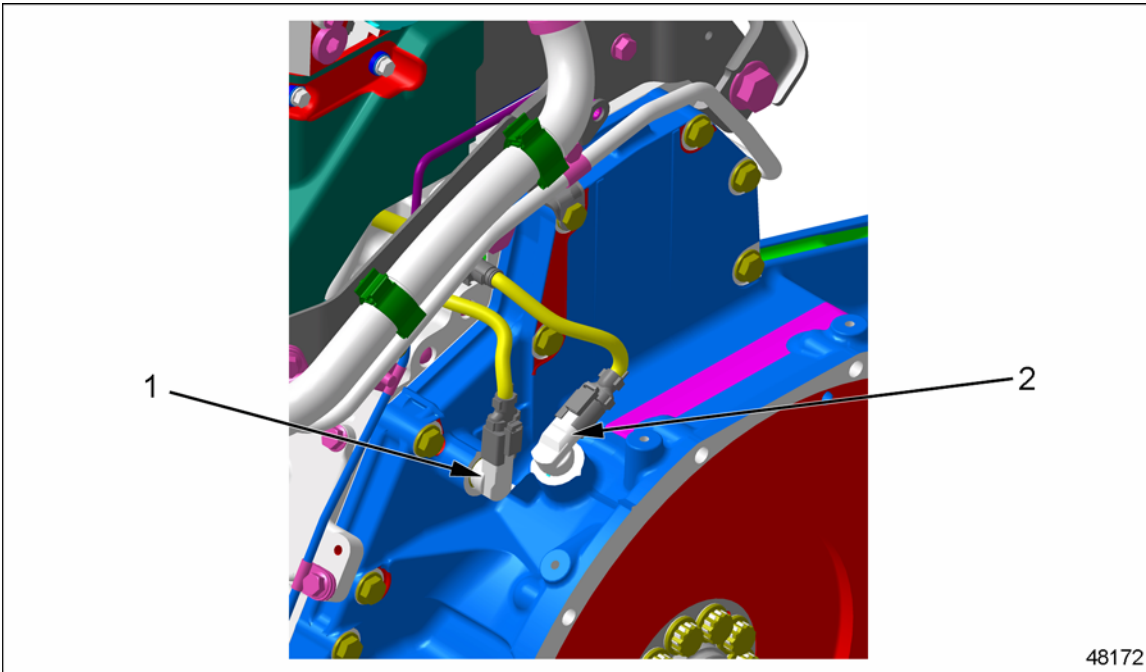
1.12 CRANKSHAFT POSITION SENSOR

The Crankshaft Position (CKP) sensor is located on the rear of the flywheel housing and is used to indicate specific cylinder positions and engine speed.

1.12.1 Replacement of Crankshaft Position Sensor

Replacement steps are as follows:

1. Disconnect the electrical connector. See Figure 1-75.



1. Camshaft Position Sensor

2. Crankshaft Position Sensor

Figure 1-75 Crankshaft Position Sensor

2. Pull outward to remove the sensor from the access hole in the flywheel housing.
3. Install a new sensor in the flywheel housing. Push the sensor in until it is fully seated.
4. Connect the electrical connector to the CKP sensor.

NOTE:

Be sure that the correct electrical connector is connected to the CKP sensor.

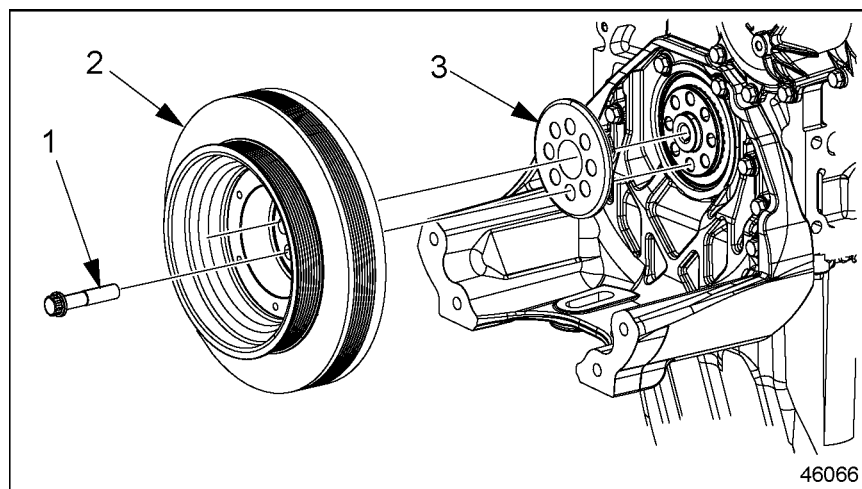
1.13 CRANKSHAFT VIBRATION DAMPER AND PULLEY

The following sections support the crankshaft vibration damper and pulley.

1.13.1 Removal of Crankshaft Vibration Damper and Pulley

Removal steps are as follows:

1. Remove the fan belt from the vibration damper. Refer to section 9.1.3.
2. Remove the main drive belt from the alternator, coolant-pump, idler, and air-conditioner compressor pulleys. Refer to section 9.1.1.
3. Remove the inspection cover from the flywheel housing and install the engine barring tool (J-46392), with the locking pin in place. Refer to section 1.17.2.
4. To gain access to the vibration damper, remove the lower mounting bolts from the bottom of the front fairing/bumper.
5. Remove the mounting bolts from the vibration damper and pulley. Drop the vibration damper and pulley down below the radiator and remove it from the engine. See Figure 1-76.



1. Mounting Bolts
2. Vibration Damper and Pulley
3. Oil Deflector

Figure 1-76 **Vibration Damper and Pulley**

6. Remove the oil deflector from the crankshaft.
7. Inspect the vibration damper and pulley for signs of wear, dents, deformation, or other signs of damage. Replace the damper and/or pulley if damaged.

1.13.2 Installation of Crankshaft Vibration Damper and Pulley

Installation steps are as follows:

NOTE:

Check the crankshaft front seal for oil leaks. If leakage is found, replace the front seal. Refer to section 1.7.

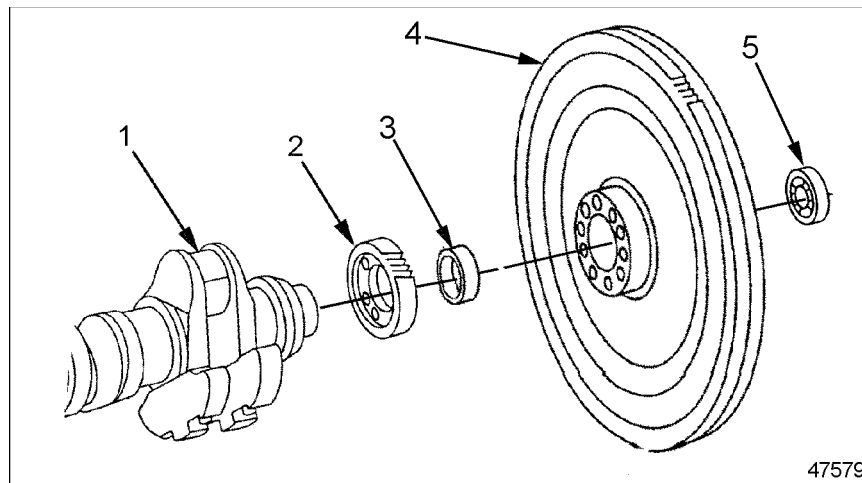
1. Install the oil deflector. Ensure the rim is facing the engine.
2. Install the vibration damper and pulley on the crankshaft. Torque the bolts to 200 N·m (148 lb·ft). See Figure 1-76.
3. Install the main drive belt on the alternator, coolant-pump, idler, and air-conditioner compressor pulleys. Refer to section 9.1.2.
4. Install the fan belt on the vibration damper. Refer to section 9.1.4.
5. Remove the engine barring tool (J-46392). Refer to section 1.17.2.
6. Install the lower mounting bolts on the bottom of the front fairing/bumper, as removed.

1.14 FLYWHEEL

The below listed special tools are required for this procedure:

- Engine Barring Tool (J-46392)
- 19-mm Flywheel and Main Pulley Socket (J-45390)
- Flywheel Guide Pins (set of 2) (J-46172)

The flywheel has a pilot bearing and spacer pressed into the flywheel hub bore.



- 1. Crankshaft
- 2. Crankshaft Gear
- 3. Spacer

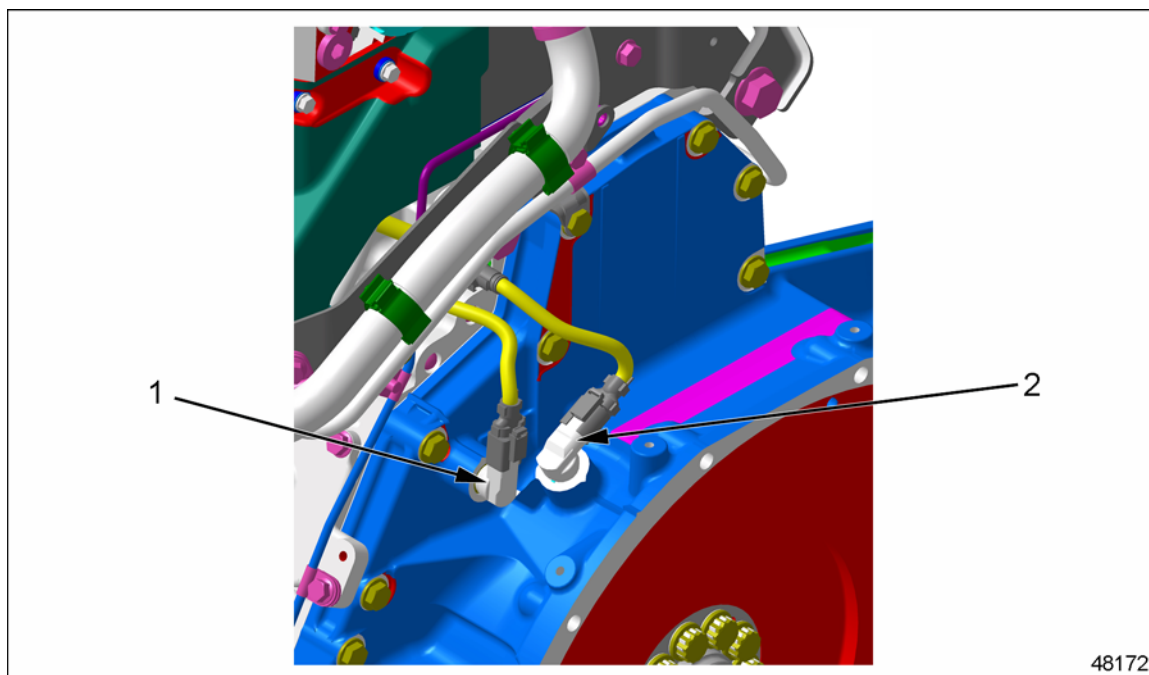
- 4. Flywheel
- 5. Pilot Bearing

Figure 1-77 Flywheel and Components

1.14.1 Flywheel Removal

Removal steps are as follows:

1. Remove the transmission.
2. Remove the clutch from the flywheel.
3. Disconnect the electrical connector from the crankshaft position sensor and remove the sensor from the flywheel housing. See Figure 1-78.



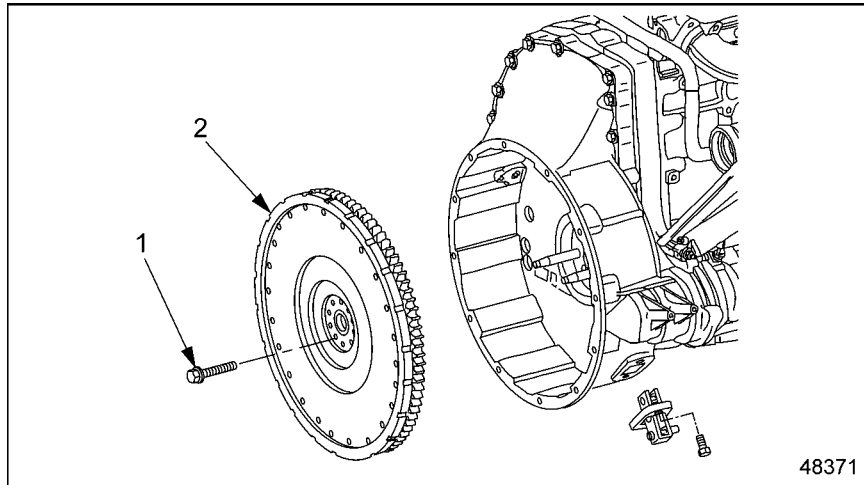
1. Camshaft Position (CMP) Sensor

2. Crankshaft Position (CKP) Sensor

Figure 1-78 Crankshaft Position Sensor

4. Remove the inspection cover from the flywheel housing and install the engine barring tool (J-46392). Insert the pin and make sure the tool is locked. Refer to section 1.17.2.

5. Using the 19-mm socket (J-45390), remove two flywheel socket-head bolts from the flywheel, one from each side of the bolt circle. See Figure 1-79.

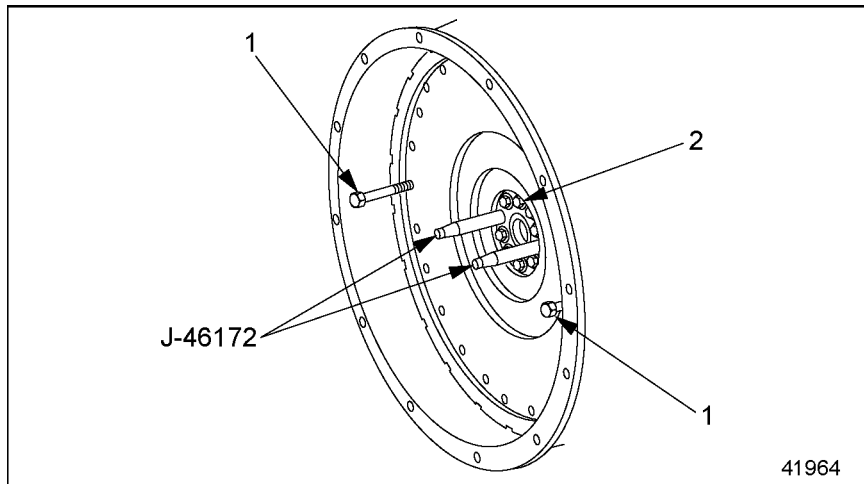


1. Flywheel Mounting Bolt (10 qty.)

2. Flywheel

Figure 1-79 Flywheel and Related Components

6. Screw the two flywheel guide pins (J-46172) into the empty bolt holes in the center of the flywheel. See Figure 1-80.



1. Bolt used as a handle

2. Flywheel Mounting Bolt

Figure 1-80 Flywheel

⚠ CAUTION:

FALLING FLYWHEEL

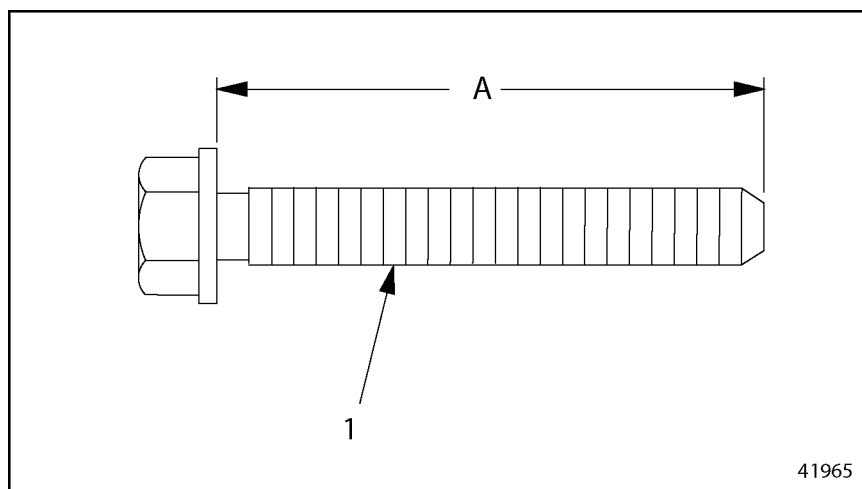
To avoid injury from a falling flywheel when removing the last bolt, hold the flywheel against the crankshaft by hand to prevent it from slipping off the crankshaft. The flywheel is not doweled to the crankshaft.

⚠ DANGER:

FALLING COMPONENT

To avoid injury from a falling component, ensure a proper lifting device is used.

7. Remove the remaining eight flywheel bolts.
8. Remove the engine barring tool (J-46392). Refer to section 1.17.2.
9. Remove the flywheel, leaving the guide pins (J-46172) in place. See Figure 1-80.
 - [a] On opposite sides of the bolt circle, screw a bolt into each of two threaded clutch bolt holes.
 - [b] Using the two bolts as handles, dislodge the flywheel from the crankshaft flange and remove it from the flywheel housing.
 - [c] After removing the flywheel, remove the bolts from the clutch bolt holes.
10. Inspect the flywheel bolts. Replace the bolts if any of the shanks are stretched beyond the maximum length of 77.0 mm (3.03 in.). See Figure 1-81.



1. Shank

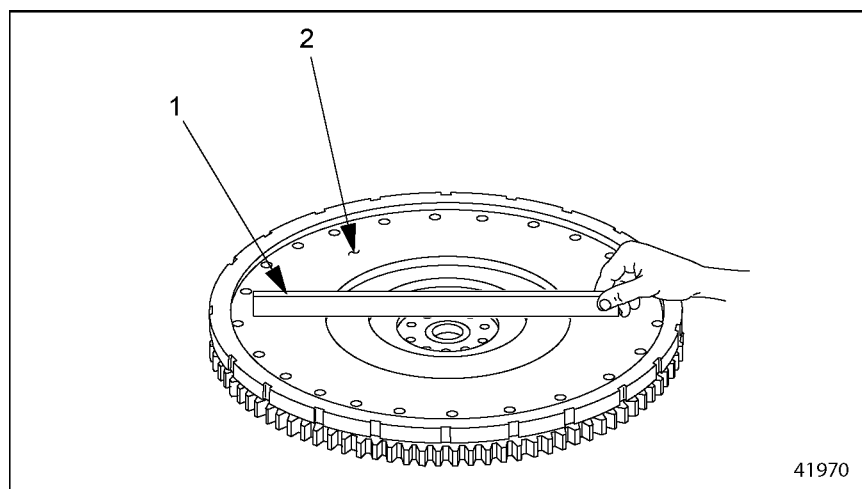
Figure 1-81 Measuring the Flywheel Bolts

11. Thoroughly clean the flywheel and check the clutch surface for cracks, burned spots, or scoring. If the damage exceeds the maximum depth of stock, replace the flywheel. Refer to section 1.14.1.2.
12. Inspect the flywheel flange for signs of wear or traces of hollowing caused by the radial seal.
13. Inspect the flywheel ring gear for damaged teeth or signs of wear. Replace the ring gear if necessary. Refer to section 1.15.1.

1.14.1.1 Inspection of Flywheel

Inspection steps are as follows:

1. Remove the flywheel. Refer to section 1.14.1.
2. Thoroughly clean the flywheel and check it for cracks, scoring, burned areas, or rough spots.
3. Using an accurate straightedge and a feeler gauge, check the friction (clutch) surface for evenness. See Figure 1-82. If the surface has areas that are too high or too low, replace the flywheel.



1. Straightedge

2. Friction Surface

Figure 1-82 Checking the Friction Surface for Evenness

4. Check the bearing surface and the threaded holes for wear and damage.

1.14.1.2 Machining of Flywheel

Machining steps are as follows:

NOTE:

Before beginning any machining work on the flywheel, check it to see if machining is possible. If the scores or cracks are deeper than 1 mm (0.04 in.), replace the flywheel. If the width of the flywheel between the friction surface and the mounting flange is less than 60 mm (2.4 in.), replace the flywheel.

 WARNING:
PERSONAL INJURY
To avoid injury while performing the test or procedure, wear adequate eye, face protection, and heat-resistant gloves.

1. Machine the flywheel friction surface, if required, to the specifications listed in Table 1-21. See Figure 1-83. The surface finish (peak-to-valley height) after machining should be 0.016 mm (0.006 in.). A rougher surface finish will cause rapid clutch lining wear, while a smoother finish could cause difficulties in clutch disengagement. See Figure 1-84 for the locations on the flywheel to coordinate with the specifications in the table.

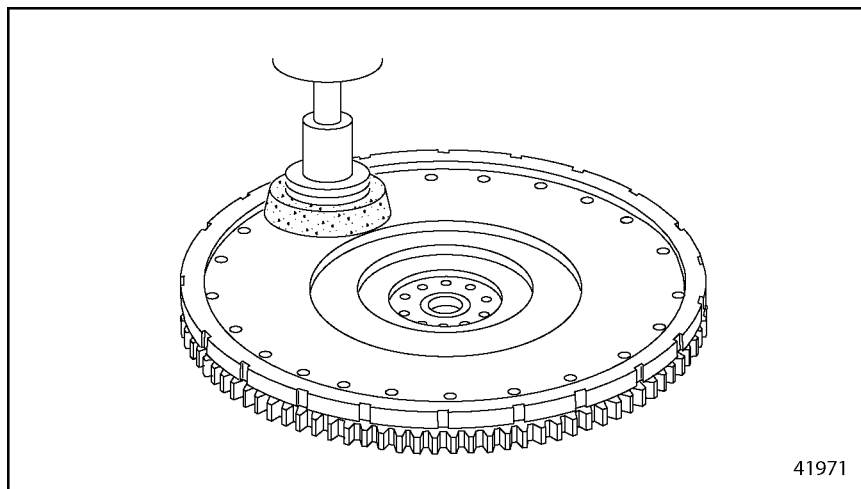
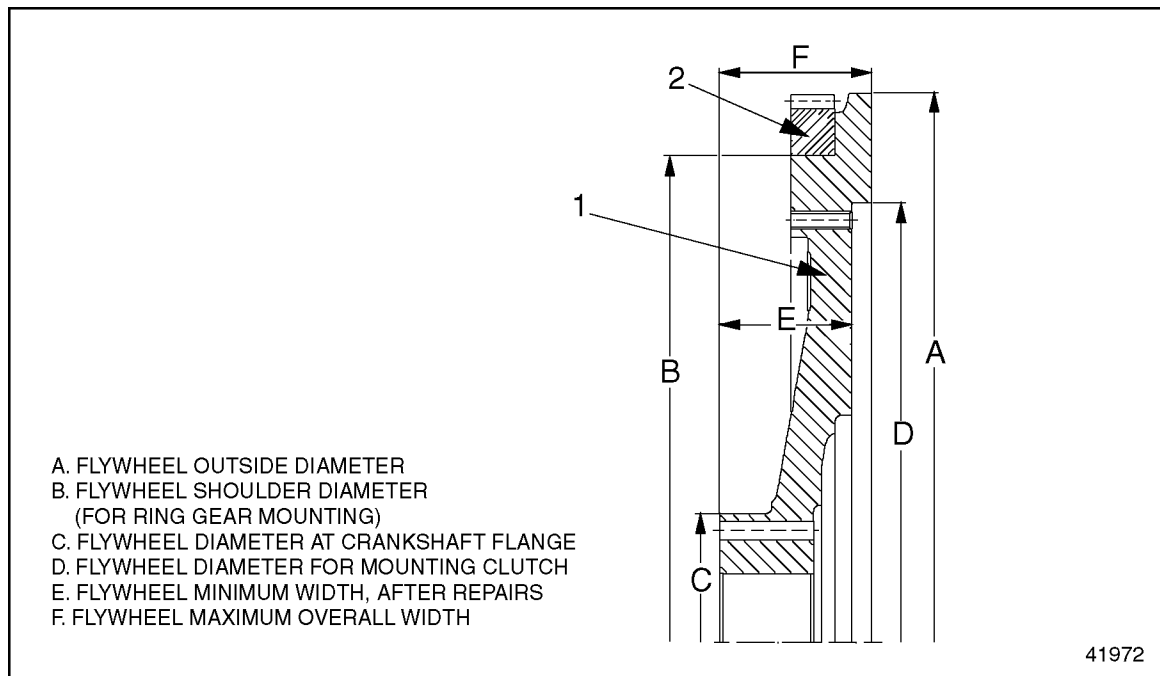


Figure 1-83 Machining the Flywheel Friction Surface

Description	Specification in mm (inches)
A - Flywheel Outside Diameter	486.60-487.40 (19.157-19.189)
B - Flywheel Shoulder Diameter (for ring gear mounting)	432.450-432.645 (17.0256-17.0333)
C - Flywheel Diameter at Crankshaft Flange	114.980-115.015 (4.5268-4.5281)
D - Flywheel Diameter for Mounting Clutch	475.000-475.063 (18.7008-18.7033)
E - Flywheel Minimum Width Between Friction Surface and Mounting Flange After Machining	60 (2.4)
F - Flywheel Maximum Overall Width	70 (2.8)
Peak-to-Valley Height (R_z) of Clutch Friction Surface	0.016 (0.0006)
Flywheel Permissible Deviation From True (radial and lateral)	0.2 (0.008)

Table 1-21 Flywheel Specifications

1. Flywheel

2. Ring Gear

Figure 1-84 Flywheel Cross Section

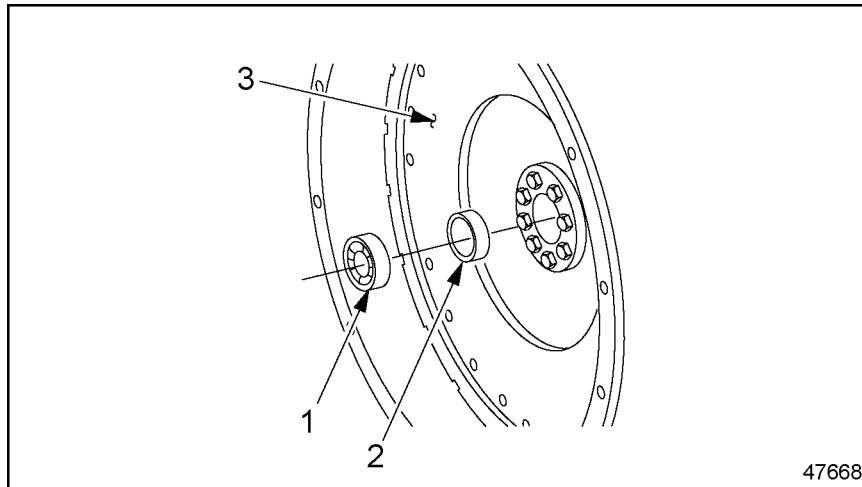
After machining, the friction surface must not have any cavities or chatter marks.

2. Check the radial and lateral deviation from true of the flywheel. The deviation from true must not exceed 0.2 mm (0.008 in.).
3. Install the flywheel. Refer to section 1.14.2.

1.14.2 Installation of Flywheel

Installation steps are as follows:

1. Grease the ring gear with a suitable heavy-duty grease.



1. Pilot Bearing

3. Flywheel

2. Spacer Ring

Figure 1-85 Pilot Bearing and Spacer Ring

 DANGER:
FALLING COMPONENT
To avoid injury from a falling component, ensure a proper lifting device is used.

NOTICE:
Ensure that the spacer ring is installed in the flywheel to prior to installing the flywheel on the crankshaft. Failure to install the spacer ring will result in improper operation of the transmission.

2. Ensure that the spacer ring is installed in the flywheel to prior to installing the flywheel on the crankshaft. See Figure 1-85.
3. Install guide pins (J-46172) then install the flywheel over the guide pins. Align the dowel on the crankshaft with the guide hole in the flywheel (arrow). See Figure 1-86.

4. Install the engine barring tool (J-46392) in the flywheel housing and secure with two bolts. Insert the pin and make sure the tool is blocked. Refer to section 1.17.2.

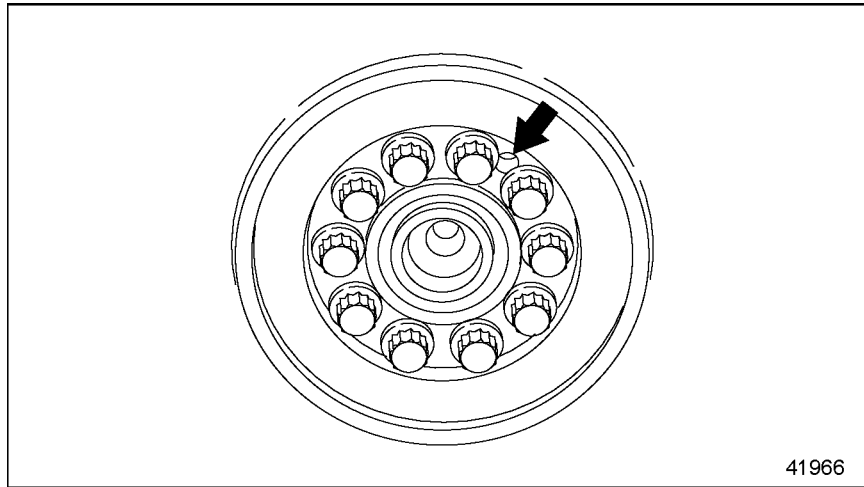


Figure 1-86 Flywheel Alignment Mark

NOTE:

Verify the alignment of the crankshaft dowel with the guide hole in the flywheel.

5. With a light coating of engine oil, lubricate the threads of the ten multipoint socket-head flywheel bolts.
6. Using the 19-mm socket (J-45390), tighten the eight bolts in two stages. In each stage, use an alternate sequence to tighten the bolts, as listed in Table 1-22.

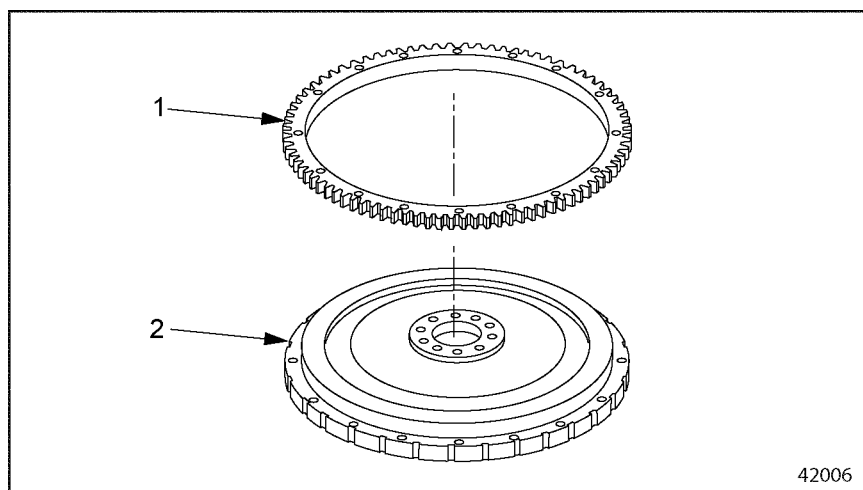
Max. Shaft Length, mm (in.)	Tightening Stage	Torque N·m (lb·ft)
77.0 (3.03)	Stage 1	200 (147.5)
77.0 (3.03)	Stage 2	90 degrees

Table 1-22 Tightening Stages, Flywheel Mounting Bolts

- [a] Install eight bolts to hold the flywheel in position.
- [b] Remove the two guide pins (J-46172) and install the two remaining bolts in their place.
- [c] Tighten the bolts, in an alternate tightening sequence, 200 N·m (147.5 lb·ft).
- [d] Using the same tightening sequence, turn the flywheel bolts 90 degrees.
7. Remove the engine barring tool (J-46392). Install the inspection cover on the flywheel housing with two bolts. Tighten the bolts 25 N·m (18 lb·ft).
8. Install the Crankshaft Position (CKP) sensor into the flywheel housing. Refer to section 1.12.1.
9. Install the clutch on the flywheel. Install the transmission.

1.15 RING GEAR

See Figure 1-87 for an exploded view of the flywheel ring gear.



1. Ring Gear

2. Flywheel

Figure 1-87 Flywheel Ring Gear

1.15.1 Replacement of Ring Gear

Replacement steps are as follows:

1. Remove the flywheel from the crankshaft flange. Refer to section 1.14.1.

WARNING:
BURNS

To avoid injury from burning, use lifting tools and heat-resistant gloves when handling heated components.

2. Heat the ring gear on the flywheel with a torch and press the gear off. See Figure 1-88.

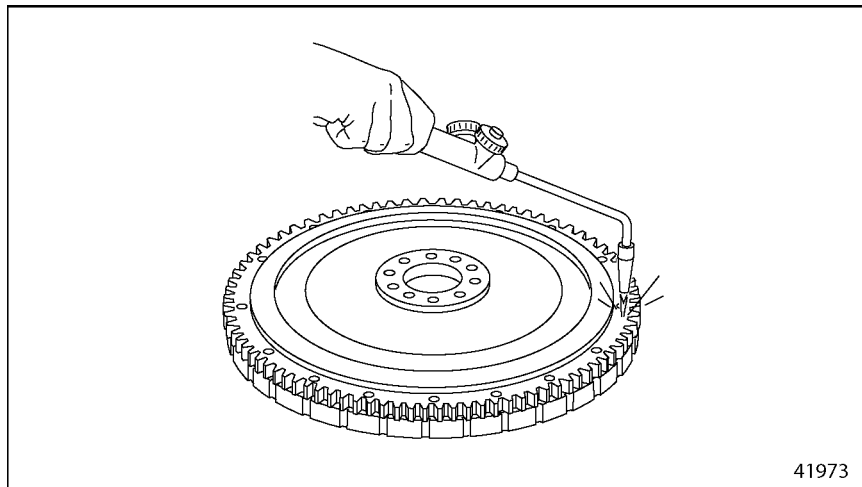
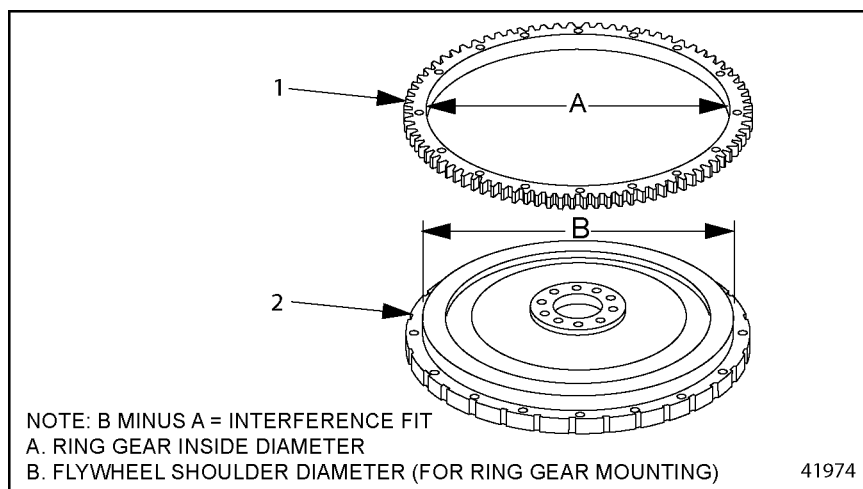


Figure 1-88 Ring Gear

3. Check the amount of interference fit between the flywheel mounting shoulder and the ring gear. See Figure 1-89. The interference fit must be within the permissible values listed in Table 1-23.



1. Ring Gear

2. Flywheel

Figure 1-89 Flywheel Ring Gear Interference Fit

Description	Specification, mm (in.)
Flywheel Shoulder Diameter (for ring gear mounting)	432.450-432.645 (17.0256-17.0333)
Hole for Mounting Clutch Pressure Plate	M10 x 1.5
Ring Gear Inside Diameter	432.000-432.155 (17.0079-17.0140)
Ring Gear/Flywheel Interference Fit	0.295-0.645 (0.0116-0.0254)
Ring Gear/Flywheel Permissible Radial Runout	0.5 (0.02)
Ring Gear Width	18.4-18.6 (0.72-0.73)
Ring Gear Fitting Temperature	200-230°C (392-446°F)

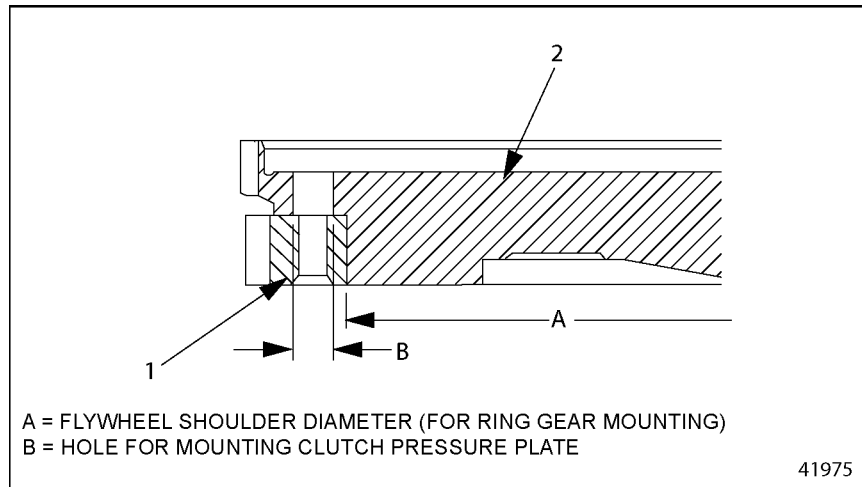
Table 1-23 Flywheel Ring Gear Specifications

- [a] Measure the flywheel shoulder diameter (B).
- [b] Measure the inside diameter of the new ring gear (A).
- [c] Determine the amount of interference fit by subtracting the ring gear inside diameter (A) from the flywheel shoulder diameter (B).
- [d] Make sure that the amount of interference fit lies between 0.295 and 0.645 mm (0.0116 and 0.0254 in.).

NOTICE:

Be careful to heat the new ring gear as evenly as possible. If available, an oven can be used. Uneven heating of the ring gear can weaken the ring gear and reduce service life.

4. Heat the new ring gear to 200-230°C (392-446°F).
5. Press the heated ring gear completely onto the mounting shoulder of the flywheel.
6. Bore and tap the holes for the clutch mounting bolts. See Figure 1-90. The specifications are listed in Table 1-23.



1. Ring Gear

2. Flywheel

Figure 1-90 Flywheel Ring Gear Cross Section

- [a] With the flywheel friction surface facing up (ring gear down), bore holes for the clutch mounting bolts.
- [b] Tap the bore holes with M10 x 1.5 metric threads.
7. Check the ring gear/flywheel radial runout.

NOTE:

With the ring gear pressed onto the flywheel, make sure the radial run-out of the ring gear does not exceed 0.5 mm (0.02 in.).

8. Install the flywheel on the crankshaft flange. Refer to section 1.14.2.

1.16 PILOT BEARING

The special tools listed below are required for this procedure:

- Engine Barring Tool (J-46392)
- 19mm Flywheel and Main Pulley Socket (J-45390)
- Flywheel Pilot Bearing Remover J-46170
- Flywheel Pilot Bearing Installer J-46169
- Slide Hammer J-6471-02
- Driver Handle J-8092

Perform the following procedures for removal and installation of the pilot bearing.

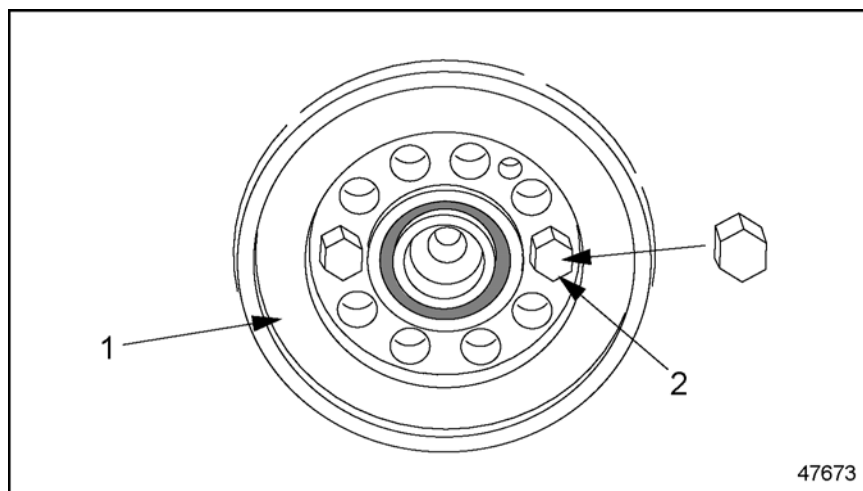
1.16.1 Removal of Pilot Bearing

Removal steps are as follows:

1. Remove the transmission. Refer to the appropriate vehicle service manual.
2. Remove the clutch from the flywheel. Refer to the appropriate vehicle service manual.
3. Install the engine barring tool (J-46392). Refer to section 1.17.1.
4. Using the 19mm socket (J-45390), remove eight flywheel socket-head bolts from the flywheel leaving one bolt across from each other on the bolt circle.
5. Install and finger tighten two M16 x 1.5 x 70 mm hex-head bolts (locally procured) across from each other in the flywheel. Position the two bolts with the flats of the bolt head parallel to the pilot bearing bore. See Figure 1-91.

NOTE:

The flats on the hex-head bolts must be parallel to the pilot bearing bore in order to have sufficient clearance to remove the pilot bearing.

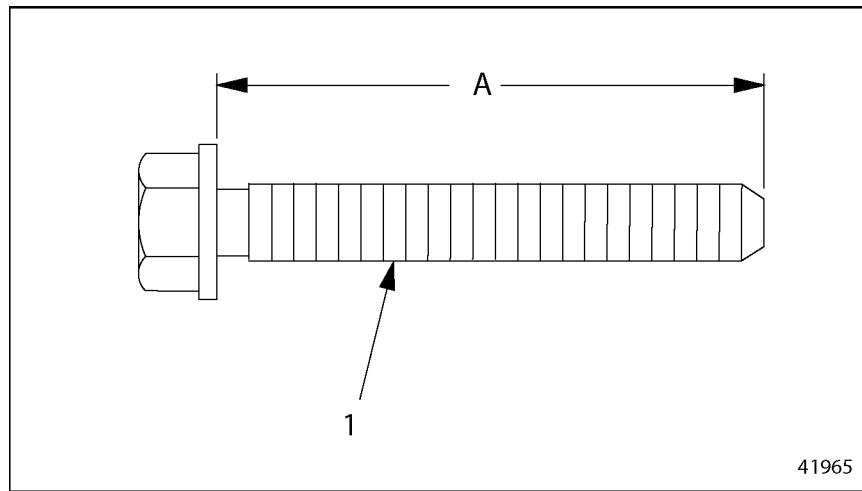


1. Flywheel

2. M16 x 1.5 x 70mm Hex-Head Bolt

Figure 1-91 Flywheel Bolt Positioning

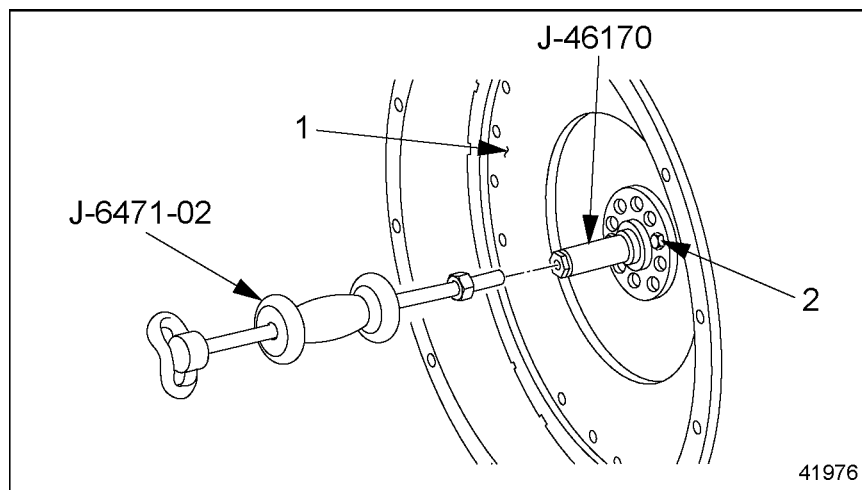
6. Remove the remaining two flywheel bolts.
7. Inspect the flywheel bolts. Replace the bolts if any of the shanks are stretched beyond the maximum length of 77.0 mm (3.03 in.). See Figure 1-92.



1. Shank

Figure 1-92 Measuring the Flywheel Bolts

8. Install pilot bearing remover tool (J-46170) into the bearing and expand the tool to fit snug in the bearing inside diameter..
9. Attach a suitable slide hammer (J-6471-02), with 5/8-18 male threads, on the extractor and remove the bearing. See Figure 1-93.



1. Flywheel

2. Crankshaft

Figure 1-93 Pilot Bearing

10. Clean the pilot bearing bore in the flywheel and inspect for damage or spun bearing, replace flywheel if damage is found.

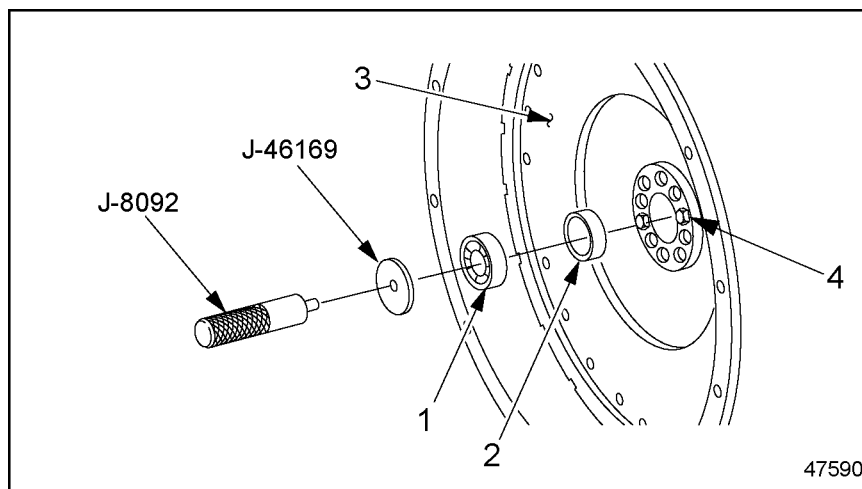
1.16.2 Installation of Pilot Bearing

Installation steps are as follows:

NOTICE:

Ensure that the spacer ring is installed prior to installing the pilot bearing in the flywheel. Failure to install the spacer ring will result in improper operation of the transmission.

1. Ensure that the spacer ring is installed in the flywheel prior to installing the pilot bearing. See Figure 1-94.
2. Using the flywheel pilot bearing installer (J-46169) and driver handle (J-8092), position the bearing on the flywheel and drive it into the flywheel until seated. See Figure 1-94.



- | | |
|------------------|-----------------------------------|
| 1. Pilot Bearing | 3. Flywheel |
| 2. Spacer Ring | 4. M16 x 1.5 x 70mm Hex-Head Bolt |

Figure 1-94 Pilot Bearing

3. Lubricate the flywheel bolts with a light coat of engine oil.
4. Install two standard flywheel bolts, finger tight, perpendicular to the M16 x 1.5 x 70mm bolts. Remove the special bolts.
5. Install the remaining eight flywheel bolts.

6. Tighten the flywheel bolts in two stages. In each stage, use an alternate sequence to tighten the bolts, as listed in Table 1-24.

Max. Shaft Length, mm (in.)	Tightening Stage	Torque Value, N·m (lb·ft)
77.0 (3.03)	Stage 1	200 (147.5)
77.0 (3.03)	Stage 2	90 degrees

Table 1-24 Flywheel Mounting Bolts Tightening Stages

7. Remove the engine barring tool (J-46392). Refer to section 1.17.2.
8. Install the clutch on the flywheel. Refer to the appropriate vehicle service manual.
9. Install the transmission. Refer to the appropriate vehicle service manual.

1.17 ENGINE BARRING TOOL

A special tool is required for this procedure: Engine Barring Tool (J-46392) which is used for two separate functions, locking and barring..

- With the pin inserted, the tool blocks the flywheel ring gear to prevent rotation during removal and installation of the flywheel.
- Without the pin, the tool can be used with a wrench to turn the flywheel and crankshaft manually.

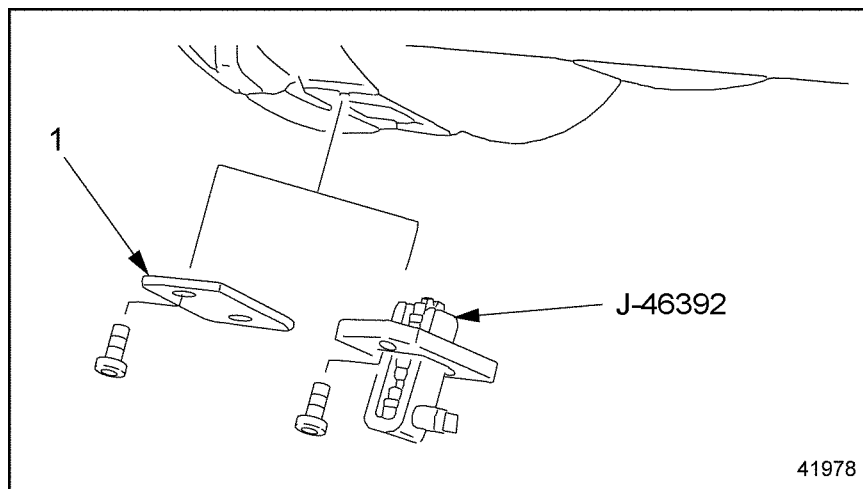
NOTE:

The first time an engine barring tool is installed on the engine to turn the flywheel, the teeth on the rotating gear may rub on the flywheel housing. This does not cause a problem and should not occur the next time the tool is used.

1.17.1 Installation of Engine Barring Tool

Installation steps are as follows:

1. Remove the two bolts holding the inspection cover to the flywheel housing. See Figure 1-95.



1. Inspection Cover

Figure 1-95 Engine Barring Tool

2. Remove the pin from the engine barring tool (J-46392).
3. Install the tool in the flywheel housing and secure with two bolts of sufficient length.

NOTE:

The inspection cover bolts are not long enough to install the engine barring tool. Longer ones will be needed.

4. As needed, insert the pin to lock the tool and block movement of the flywheel ring gear.

1.17.2 Removal of Engine Barring Tool

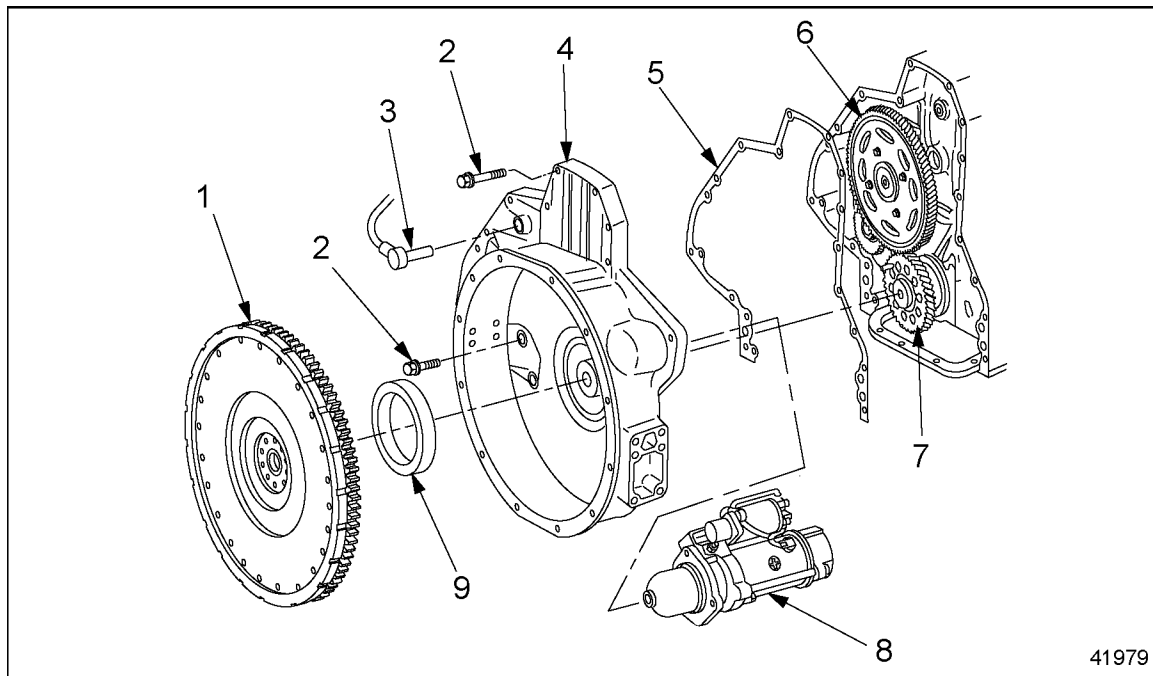
Removal steps are as follows:

1. Remove the two bolts and the engine barring tool from the flywheel housing. It is not necessary to remove the pin.
2. Install the inspection cover on the flywheel housing with the two bolts. Tighten the bolts 25 N·m (18 lb·ft).

NOTICE:
The engine barring tool must be removed from the timing case before starting the engine. Failure to do so could damage the flywheel ring gear.

1.18 FLYWHEEL HOUSING

See Figure 1-96 for an exploded view of the flywheel housing assembly.



- | | |
|-----------------------------------|---------------------|
| 1. Flywheel | 6. Camshaft Gear |
| 2. Flywheel Housing Mounting Bolt | 7. Crankshaft Gear |
| 3. Camshaft Position Sensor | 8. Starter |
| 4. Flywheel Housing | 9. Rear Radial Seal |
| 5. Gasket | |

Figure 1-96 Flywheel Housing and Related Components

1.18.1 Removal of Flywheel Housing

Removal steps are as follows:

1. Remove the Crankshaft Position (CKP) sensor. Refer to section 1.12.1.
2. Remove the Camshaft Position (CMP) sensor. Refer to section 1.22.3.
3. Remove the flywheel. Refer to section 1.14.1.
4. Remove the starter from the flywheel housing.
5. Remove the crankcase breather from the flywheel housing.
6. Remove the oil pan and gasket. Refer to section 3.2.1.
7. Support the engine by placing suitable jack stands under the cylinder block pan rails. Make sure not to damage the sealing surfaces of the oil pan rails.
8. Remove the rear engine mounts from the flywheel housing. Refer to the applicable vehicle service manual.
9. Remove the flywheel housing mounting bolts. Then remove the flywheel housing from the cylinder block. See Figure 1-96.
10. Remove and discard the flywheel housing gasket.
11. Remove the rear radial seal from the housing and discard seal.

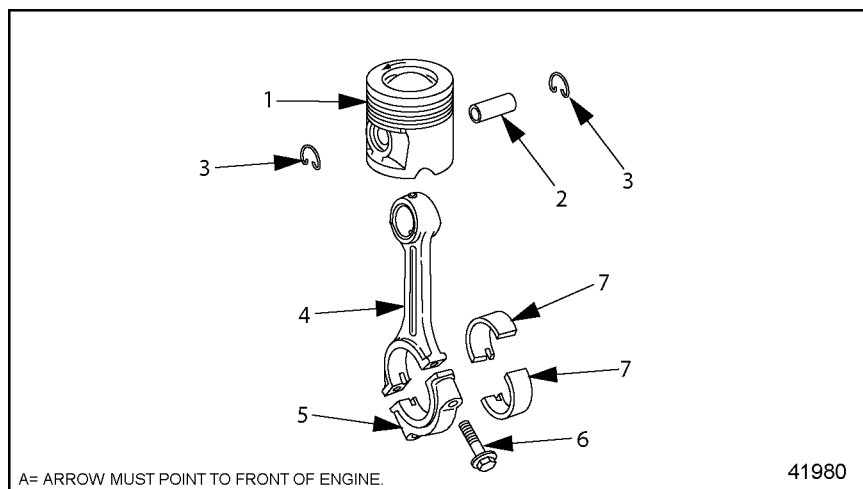
1.18.2 Installation of Flywheel Housing

Installation steps are as follows:

1. Check the flywheel housing for damage.
2. Install a new rear radial seal. Refer to section 1.8.2.
3. Using a suitable scraper, such as a putty knife, clean the mating surfaces of the cylinder block and the flywheel housing. Remove any dirt or grease, and any traces of gasket material.
4. Install a new flywheel housing gasket.
5. Install the flywheel housing mounting bolts and torque to 70 N·m (52 lb·ft).
6. Attach the rear engine mounts to the flywheel housing. Refer to the applicable vehicle service manual.
7. Install the oil pan and new gasket. Refer to section 3.2.2.
8. Install the starter. Torque bolts to 80 N·m (59 lb·ft)
9. Install the flywheel. Refer to section 1.14.2.
10. Install the Camshaft Position (CMP) sensor. Refer to section 1.22.3.
11. Install the Crankshaft Position (CKP) sensor. Refer to section 1.12.1.

1.19 PISTON, PISTON RING, AND CONNECTING ROD

The pistons are made of aluminum alloy with ring carriers and a shallow combustion chamber recess. The pistons are cooled by oil spray nozzles. See Figure 1-99. See Figure 1-97 for an exploded view of the piston and connecting rod assembly.



1. Piston and Rings

2. Wrist Pin

3. Snap Ring

4. Connecting Rod

5. Bearing Cap

6. Connecting Rod Stretch Bolt

7. Bearing Shell

Figure 1-97 **Piston and Related Components**

1.19.1 Removal of Piston

Removal steps are as follows:

1. Remove the oil pan. Refer to section 3.2.1.

NOTE:

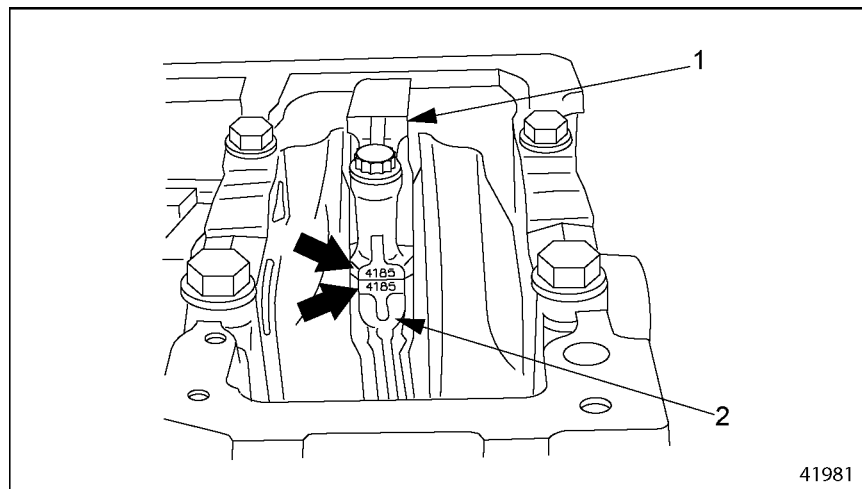
The MBE 4000 engine has individual heads for each cylinder. To remove one piston, do these procedures step by step. To remove all the pistons, repeat each step in these instructions, as applicable, for all six pistons.

2. Remove each cylinder head, as required. Refer to section 1.3.1.

NOTICE:

Do not damage the piston travel surface of the cylinder.

3. Using a plastic scraping tool, carefully scrape off any combustion residues from the combustion area in the cylinder in order to avoid damage to the piston rings when the piston is removed.
4. Install the engine barring tool (J-46392). Refer to section 1.17.1.
5. Be sure the connecting rods and the bearing caps are marked so that they can be matched for installation. See Figure 1-98.

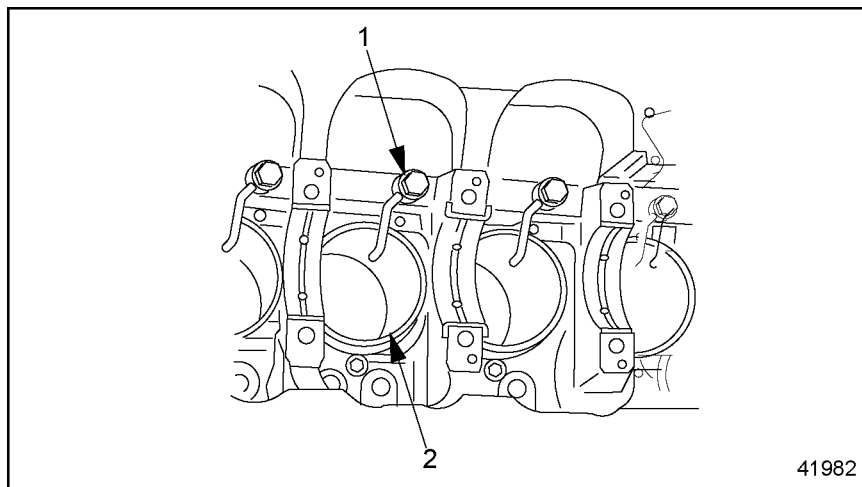


1. Bearing Cap

2. Connecting Rod

Figure 1-98 Checking Rod and Bearing Cap Markings

6. Remove and inspect the oil spray nozzles. See Figure 1-99. Refer to section 3.3.1. Replace them if damaged.



1. Oil Spray Nozzle

2. Cylinder Liner

Figure 1-99 Location of Oil Spray Nozzle

7. Remove the connecting rod stretch bolts and bearing cap. See Figure 1-100.

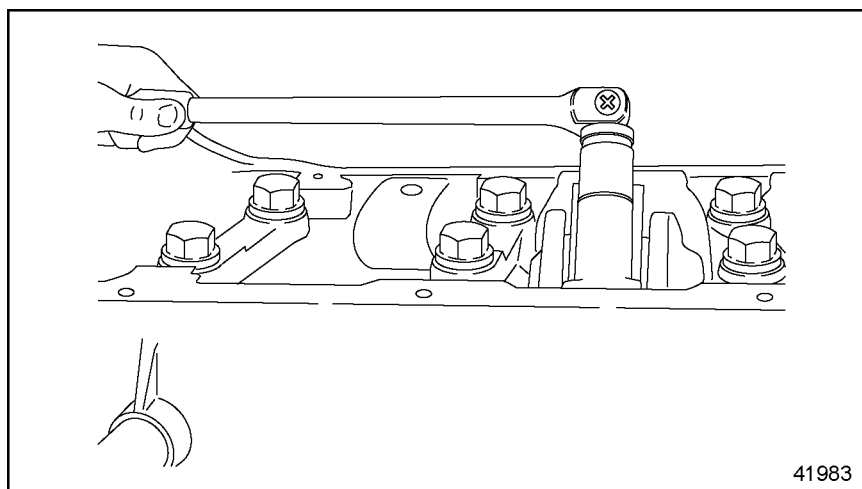


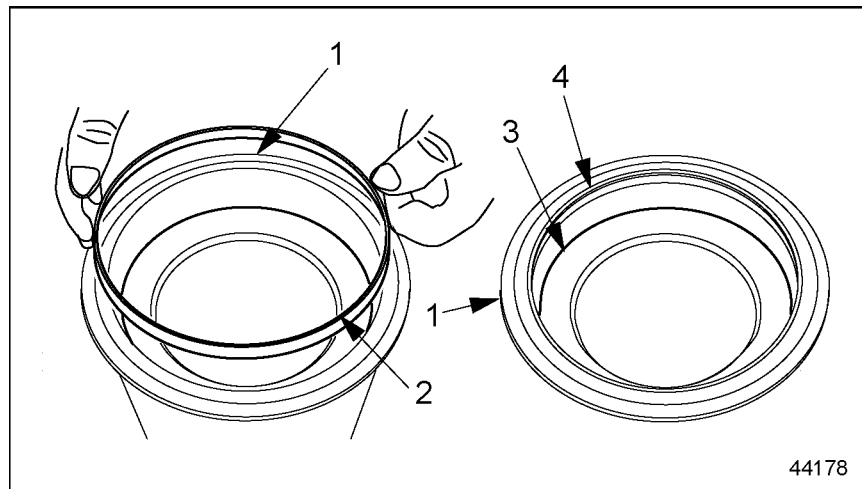
Figure 1-100 Bearing Caps

NOTE:

If the bearing shell halves are removed from the rods and caps, be sure to mark them so they can be matched for installation.

8. Remove the bearing shell halves from the bearing cap and connecting rod.

9. Remove the carbon scraper ring from the cylinder liner groove.



1. Cylinder Liner

2. Carbon Scraper Ring

3. Installed Piston

4. Installed Carbon Scraper Ring

Figure 1-101 Carbon Scraper Ring

10. Push the piston and connecting rod out of the cylinder, and remove them both from the cylinder block.
11. Secure the connecting rod in a vise with protective jaws.

NOTICE:

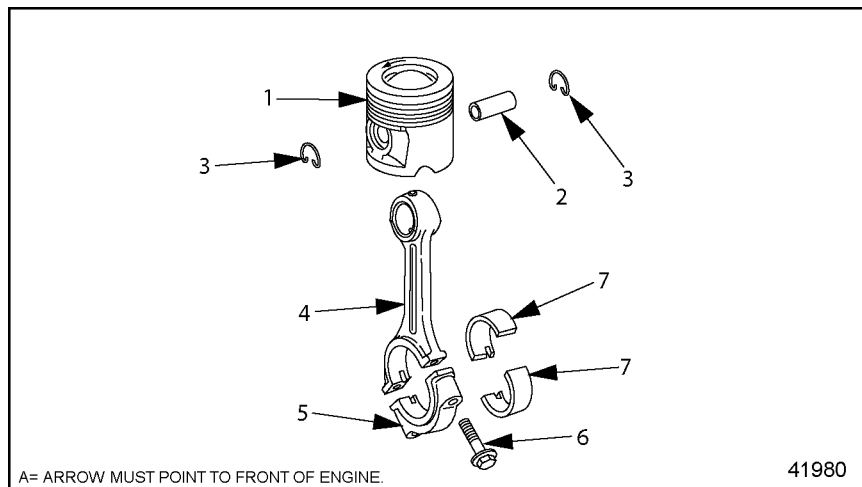
Be sure the vise jaws are adequately lined to prevent the rod surface from being nicked or marred in any way. Such surface damage could lead to later rod cracking or breaking.

12. Remove the piston rings from the piston. Refer to section 1.19.3.
13. Remove the wrist-pin snap rings. Push the wrist pin out and remove the piston from the connecting rod.

1.19.1.1 Inspection of Piston

Inspection steps are as follows:

1. Remove the piston. Refer to section 1.19.1.
2. Check the diameter of the wrist pin and the wrist pin bore. See Figure 1-102. Specifications are listed in Table 1-25.



- | | |
|---------------------|--------------------------------|
| 1. Piston and Rings | 5. Bearing Cap |
| 2. Wrist Pin | 6. Connecting Rod Stretch Bolt |
| 3. Snap Ring | 7. Bearing Shell |
| 4. Connecting Rod | |

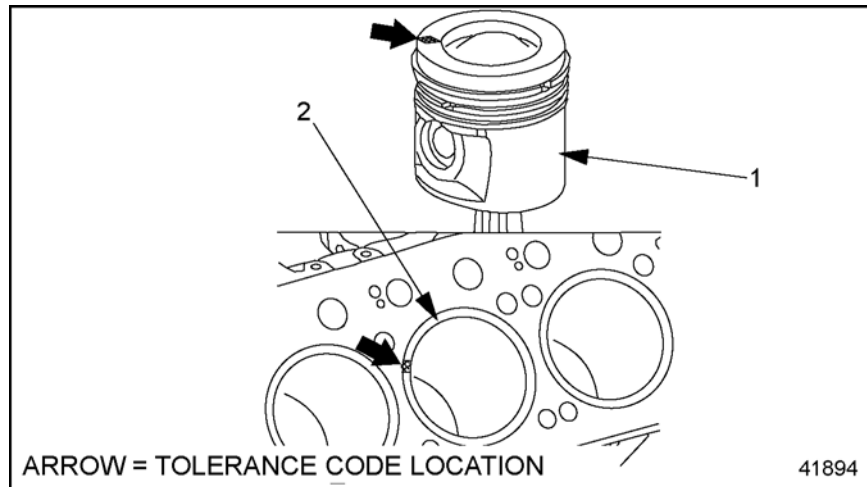
Figure 1-102 Piston and Related Components

Description	Dimensions: mm (in.)
Piston Compression Height	79.50-79.55 (3.130-3.132)
Wrist Pin Bore Diameter	52.03-52.04 (2.0484-2.0488)
Wrist Pin Diameter	51.992-51.998 (2.0469-2.0472)

Table 1-25 Piston Inspection Specifications

3. Inspect the cylinder liner and piston for damage and signs of wear. Replace any piston with damage to the snap ring grooves, cracks in the piston wall, or signs of seizing and/or erosion.

4. Check the tolerance code on the piston and compare it to the tolerance code on the cylinder liner. See Figure 1-103. for location of tolerance codes.



1. Piston

2. Cylinder Liner

Figure 1-103 Tolerance Codes

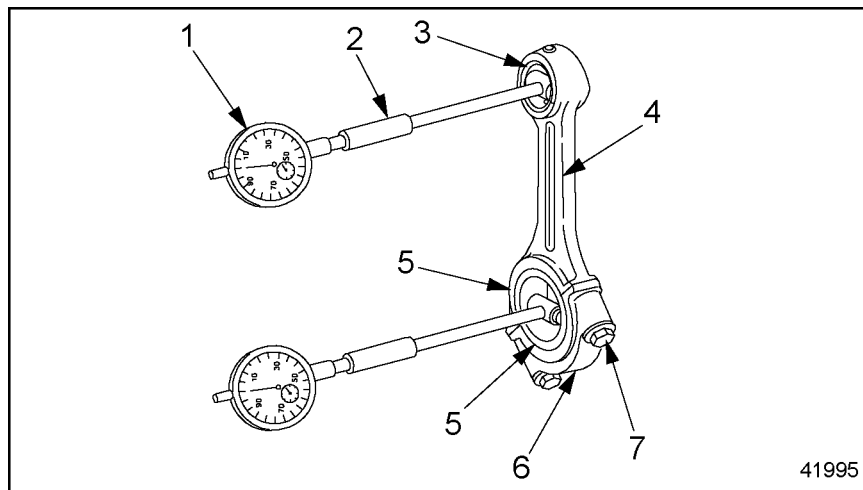
- [a] Cylinder liners with tolerance code A require a piston of code BA.
 - [b] Cylinder liners with tolerance code B require a piston of either code BA or BC.
 - [c] Cylinder liners with tolerance code C require a piston of code BC.
5. Check the condition of the piston rings. Replace any worn, damaged, or chipped rings. Refer to section 1.19.3.
 6. Check the connecting rod for any unusual condition. Refer to section 1.19.1.2.
 7. Measure the diameters of the bearing shell bore and crankshaft journals. Refer to section 1.19.1.3 for instructions.
 8. Check the length of the connecting rod stretch bolts. Replace any bolts that exceed the maximum length of 68.5 mm (2.70 in.).

1.19.1.2 Measurement of Connecting Rod End Play

Measurement steps are as follows:

1. Remove the piston. Refer to section 1.19.1.
2. Inspect the connecting rod for blue discoloration (indicates bearing damage), scoring, notches, and cracks. If any of these conditions are found, replace the connecting rod.

3. Measure the inside diameter of the bushing in the small bore of the connecting rod. Use a quick-release caliper (internal measurement, 40-60 mm) [1.57-2.36 in.], with a dial gauge and holder. If the value exceeds 52.07 mm (2.050 in.), replace the connecting rod.



- | | |
|----------------------|-----------------------------|
| 1. Dial Gauge | 5. Bearing Shell (2 halves) |
| 2. Dial Gauge Holder | 6. Bearing Cap |
| 3. Bushing | 7. Stretch Bolt (2 qty.) |
| 4. Connecting Rod | |

Figure 1-104 **Connecting Rod Inside Diameters**

NOTE:

Checking the connecting rod for a twisted or bent condition in the next step requires machine shop equipment such as a caliper gauge with a round scale.

NOTICE:

Do not attempt to straighten the connecting rod. This could result in severe engine damage.

4. Inspect the connecting rod for twisting and dimensional tolerance, see Figure 1-105. If any value exceeds those listed in Table 1-26, replace the connecting rod.

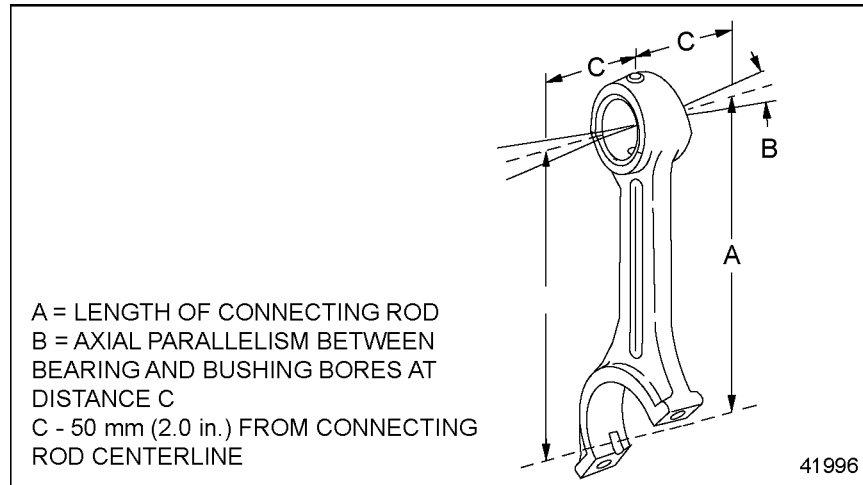


Figure 1-105 Connecting Rod Measurements

Description	Dimensions: mm (in.)
Length of Connecting Rod	255.970-256.030 (10.0776-10.0799)
Basic Bore Diameter for Connecting Rod Bearings	99.000-99.022 (3.8976-3.8985)
Maximum Permissible Out-of-Round in Bearing Bore	0.01 (0.0004)
Maximum Permissible Out-of-Round in Bushing Bore	0.01 (0.0004)
Maximum Difference in Axial Parallelism Between Bearing Bore and Bushing Inner Surface	0.030 (0.0012)
Width of Connecting Rod (at big end)	44.308-44.370 (1.7444-1.7468)
Width of Connecting Rod Journal	44.5-44.6 (1.75-1.76)
Distance from Connecting Rod Center Line for Measuring Parallelism	50 (2)

Table 1-26 Connecting Rod Dimensional Tolerances

- [a] On each side of the connecting rod, measure the length of the connecting rod (Dimension A in see Figure 1-105) : the distance from the center bearing bore (big-end bore) to the center of the bushing (small-end bore). The measurement must be within 255.970-256.030 mm (10.0776-10.0799 in.).
- [b] Measure the difference in axial parallelism (Dimension B in see Figure 1-105) between the bearing bore and the inner surface of the bushing, at 50 mm (2 in.) from

the connecting-rod centerline (Dimension C in see Figure 1-105). The maximum allowed difference is 0.030 mm (0.0012 in.).

- [c] Measure the diameter of the connecting rod basic bore, with the bearing shells removed. The diameter of the basic bore must be between 99.000-99.022 mm (3.8976-3.8985 in.).
 - [d] Measure the maximum permissible out-of-round in the bearing bore, with the bearing shells removed. The maximum permissible is 0.01 mm (0.0004 in.).
5. Calculate the connecting rod end play (fore-to-aft movement) on the crankshaft. If the end play is less than 0.130 mm (0.0051 in.), or more than 0.292 mm (0.0115 in.), replace the connecting rod. Listed in Table 1-27

Description	Dimensions: mm (in.)
Radial Play	0.054 - 0.116 (0.0021 - 0.0046)
End Play (axial play)	0.130 - 0.292 (0.0051 - 0.0115)

Table 1-27 Connecting Rod Bearing Play Specifications

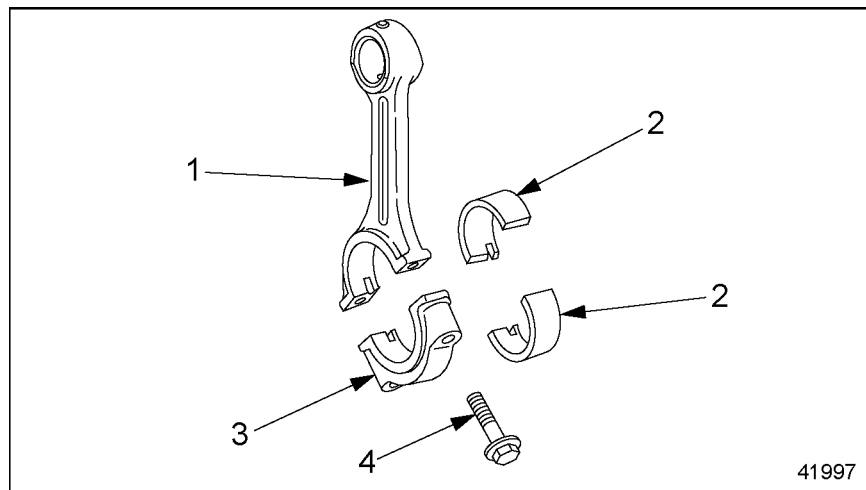
- [a] For each bearing journal, note the width (thickness) of the bearing journal. Example: $W_j = 1.8120$ in.
 - [b] For each connecting rod, note the width (thickness) of the rod. Example: $W_r = 1.8050$ in.
 - [c] From the value for the journal width, subtract the value for the connecting rod width. This result is the end play. Example: W_j minus $W_r = 0.0070$ in.
6. Remove the bolts and bearing cap when ready to install the piston.
 7. Install the piston. Refer to section 1.19.2.

1.19.1.3 Measurement of Connecting Rod Radial Play

Measurement steps are as follows:

1. Remove the piston. Refer to section 1.19.1.
2. Using a chamois cloth, clean the bearing bores in both the connecting rod and the bearing cap.

3. Install the two matched halves of the bearing shell, as marked on removal, into the connecting rod and into the bearing cap. Be sure the locking lugs on the bearing shells fit into the grooves in the rod and cap. See Figure 1-106.



1. Connecting Rod

2. Bearing Shell (2 halves)

3. Bearing Cap

4. Connecting Rod Bolt

Figure 1-106 Bearing Shell Replacement

4. Install the bearing cap on the connecting rod, pressing it on by hand. Be sure that the marks on the cap and rod match.
5. Lubricate the threads and the contact surface of the head of each stretch bolt with a light coating of engine oil.
6. Install the stretch bolts in the connecting rod, and tighten them alternately. Tighten each one in turn to the first stage and then go on to the next stage, listed in Table 1-28.

Max. Shaft Length mm (in.)	Tightening Stage	Torque Value N·m (lb·ft)
68.5 (2.70)	Stage 1	108 (80)
68.5 (2.70)	Stage 2	additional 90 degrees

Table 1-28 Connecting Rod Stretch Bolts Tightening Stages

7. Using a micrometer, measure the bearing journal on the crankshaft in both the vertical and horizontal plane and note the measurements. See Figure 1-107 to locate the measuring points and listed in Table 1-29 are the current repair stage specifications.

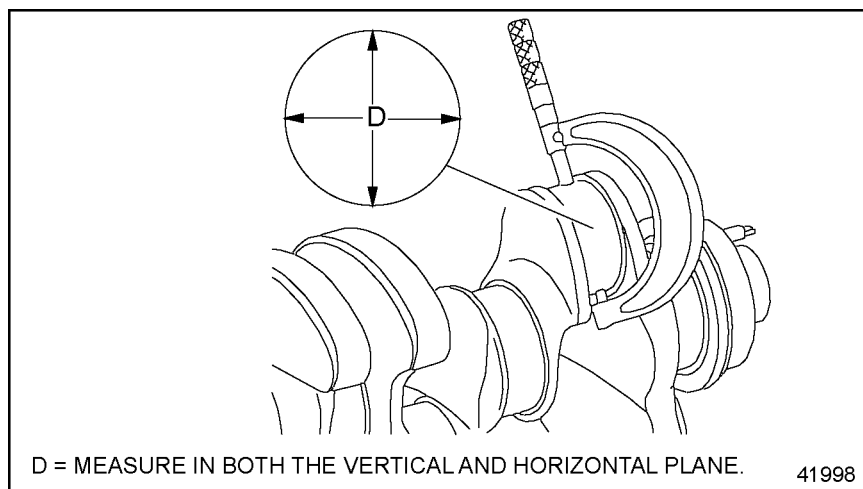


Figure 1-107 Bearing Journal

Repair Stage: mm (in.)	Diameter: mm (in.)
Standard	93.980-94.000 (3.7000-3.7007)
Undersize - 0.1 (0.004)	93.880-93.900 (3.6960-3.6968)
Undersize - 0.25 (0.010)	93.730-93.750 (3.6901-3.6909)
Undersize - 0.50 (0.020)	93.480-93.500 (3.6803-3.6811)
Undersize - 0.75 (0.030)	93.230-93.250 (3.6705-3.6712)
Undersize - 1.00 (0.040)	92.980-93.000 (3.6606-3.6614)

Table 1-29 Bearing Journal Specifications

- [a] Measure the bearing journal in the vertical plane and note the reading.
- [b] Measure the bearing journal in the horizontal plane and note the reading.

- [c] Calculate the average (nominal) bearing-journal diameter from these two measurements, and determine the current repair stage listed in Table 1-30.

Repair Stage: mm (in.)	Diameter: mm (in.)
Standard	94.054-94.096 (3.7029-3.7046)
Undersize - 0.10 (0.004)	93.954-93.996 (3.6990-3.7006)
Undersize - 0.25 (0.010)	93.804-93.846 (3.6931-3.6947)
Undersize - 0.50 (0.020)	93.554-93.596 (3.6832-3.6848)
Undersize - 0.75 (0.030)	93.304-93.346 (3.6734-3.6750)
Undersize - 1.00 (0.040)	93.054-93.096 (3.6635-3.6652)

Table 1-30 Bearing Bore Inside Diameter with Bearing Shells Installed

NOTICE:
Be sure the vise jaws in the next step are adequately lined to prevent the connecting rod surface from being nicked or marred in any way. Such surface damage could lead to later cracking or breaking of the rod.

8. Place the connecting rod in a vise with protective jaws. To prevent the rod from twisting excessively, position the rod in the vise as close as possible to the big-end bore.
9. Set the caliper internal measurement 80-100 mm (3.15-3.94 in.) to the nominal bearing-journal diameter calculated above. Use a 75-100 mm micrometer (2.95-3.94 in.) for the setting. Preload the setting 5 mm (0.2 in.). See Figure 1-108.

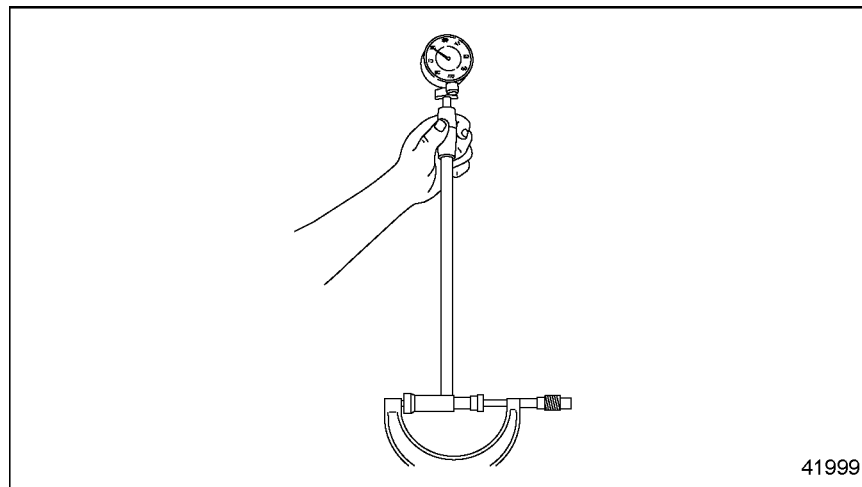
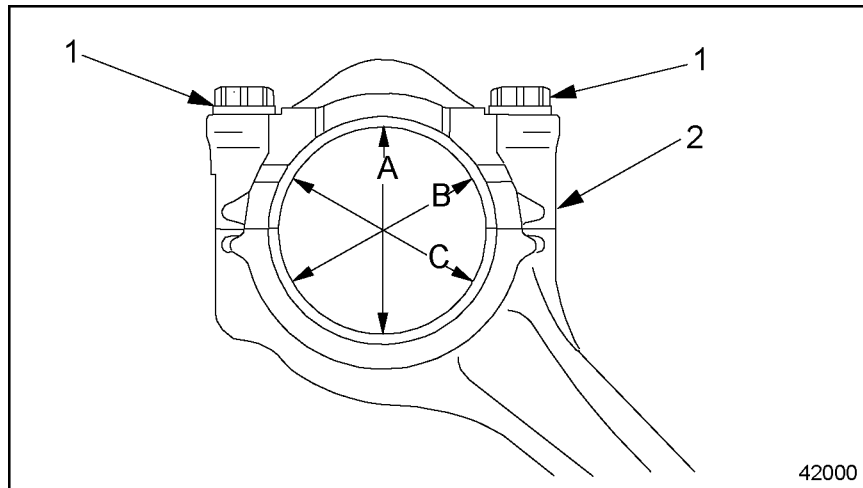


Figure 1-108 Setting the Caliper

10. Using a quick-release caliper (internal measurement 80-120 mm [3.15-4.72 in.]), dial gauge, and holder, measure the inside diameter of the bearing bore (with the shells installed) at three points. Measure vertically and about 60 degrees each side of vertical.

See Figure 1-109 to locate the measuring points, and find the current specifications listed in Table 1-30.



1. Bolt

2. Bearing Cap

Figure 1-109 Measuring the Inside Diameter of the Bearing Shell

- [a] Measure the bearing bore in the vertical dimension and note the reading.
- [b] Mark off a point 60 degrees counterclockwise from vertical. Measure the bearing bore in this dimension and note the reading.
- [c] Mark off a point 60 degrees clockwise from vertical. Measure the bearing bore in this dimension and note the reading.
- [d] Calculate the average (nominal) bearing-journal diameter from these three measurements, and determine the current repair stage listed in Table 1-30. If any of the measurements are out of tolerance, replace the bearing shells.

NOTE:

Connecting-rod bearings for all repair stages are delivered from the factory ready to install. Do not refinish them in any way.

NOTE:

To obtain a correct value for connecting-rod radial play, the diameters of each bearing bore and its corresponding journal must belong to the same repair stage (both must be "standard," "undersize 0.1 mm," etc.).

11. Calculate the connecting rod radial play (up-and-down movement) at the bearing journal. If the radial play is less than 0.054 mm (0.0021 in.), or more than 0.116 mm (0.0046 in.), replace the connecting rod. Listed in Table 1-31 is the radial play.

Description	Dimensions: mm (in.)
Radial Play	0.054 - 0.116 (0.0021 - 0.0046)

Table 1-31 Connecting Rod Radial Play

- [a] For each connecting rod, note the average value for the bearing bore diameter, as calculated. Example: $D_s = 3.5421$ in.
- [b] For each bearing journal, note the average value for the bearing journal diameter, as calculated. Example: $D_j = 3.5391$ in.
- [c] From the value for the bearing bore diameter, subtract the value for the bearing journal diameter. This result is the radial play. Example: D_s minus $D_j = 0.0030$ inch.

NOTE:

In the above example, both measurements belonged to repair stage "undersize 0.1 mm."

- 12. Remove the bearing cap from the connecting rod.
- 13. Install the piston. Refer to section 1.19.2.

1.19.2 Installation of Piston

Installation steps are as follows:

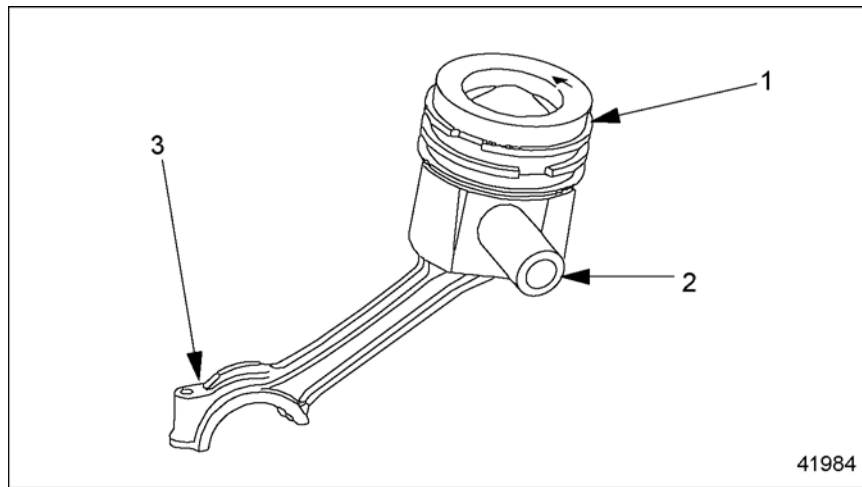
NOTICE:
The carbon scraper ring has a smaller internal diameter than the piston skirt diameter; therefore, the piston installation and removal must be carried out with the carbon scraper ring <i>uninstalled or removed</i> .

NOTE:

Piston installation in the EGR engine is performed with the engine facing upright – not turned on its side.

- 1. Position the connecting rod in the piston so that the longer end side is on the unit pump side (left side), and arrow on piston, if present, points toward the front of the engine.

2. Install the wrist pin in the piston. See Figure 1-110.



1. Piston

2. Wrist Pin

3. Connecting Rod

Figure 1-110 Wrist Pin

- [a] Lubricate the wrist pin with a light coating of clean engine oil.
 - [b] Insert the wrist pin into the wrist pin bore.
 - [c] Secure the wrist pin with the two snap rings. Orient the rings at a 12 o'clock and 6 o'clock position.
3. Install the piston rings on the piston (1). See Figure 1-111. Refer to section 1.19.3.

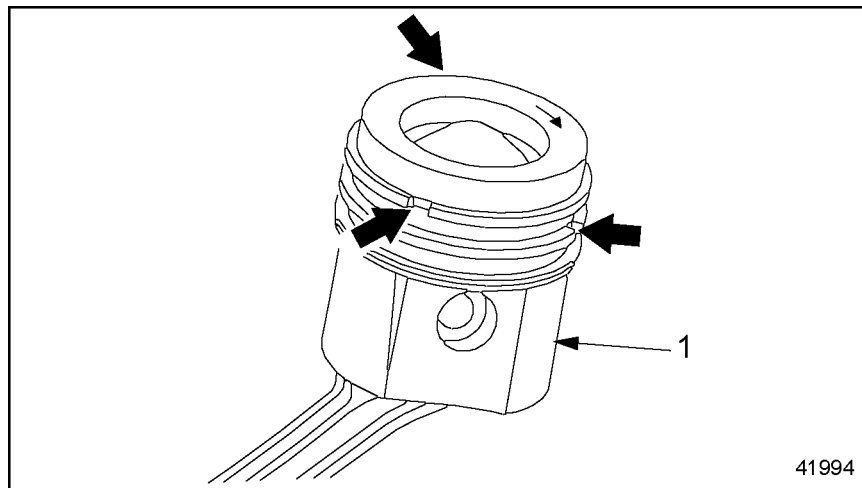


Figure 1-111 Ring Gaps Offset 120 Degrees

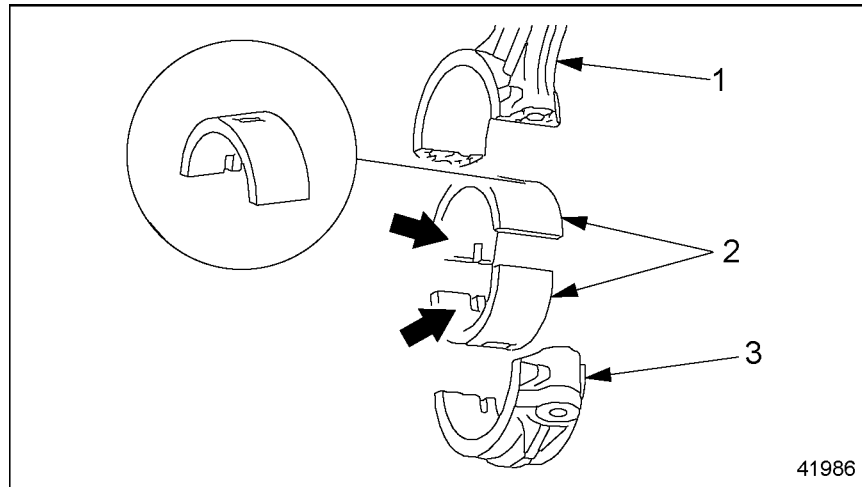
- [a] Lubricate the piston with a light coating of clean engine oil.
- [b] Install each piston ring in the appropriate groove on the piston.

4. Offset the ring gaps alternately by 120 degrees.

NOTICE:

The half of the bearing shell installed in the connecting rod (rod half) has a specially-treated friction surface that allows it to bear higher loads. It *cannot* be interchanged (swapped) with the other half of the bearing shell installed in the bearing cap (cap half).

5. Install the rod half of the bearing shell in the connecting rod, as marked on removal. See Figure 1-112.



1. Connecting Rod
2. Bearing Shells

3. Bearing Cap

Figure 1-112 Bearing Shells

- [a] Be sure that the locking lug in the bearing shell is fully seated in the groove of the rod.
- [b] Lubricate the bearing surface with a light coating of clean engine oil.
6. Lubricate the cylinder liners with a light coating of clean engine oil.

NOTICE:

Be careful not to scratch the crankshaft journals with the connecting rod. This can lead to premature wear of the crankshaft.

7. Clamp ring compressor (J-45983) to compress the piston rings.
8. If reusing a cylinder liner, thoroughly clean the carbon scraper ring seat.

9. Install sleeve(J-47710) to the cylinder block. See Figure 1-113.

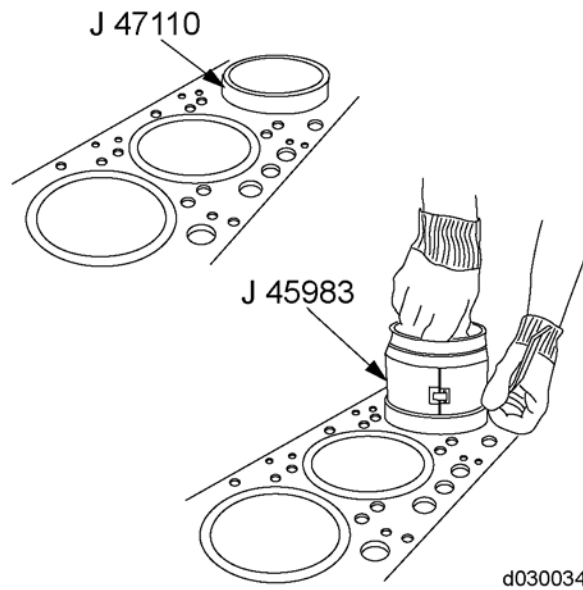
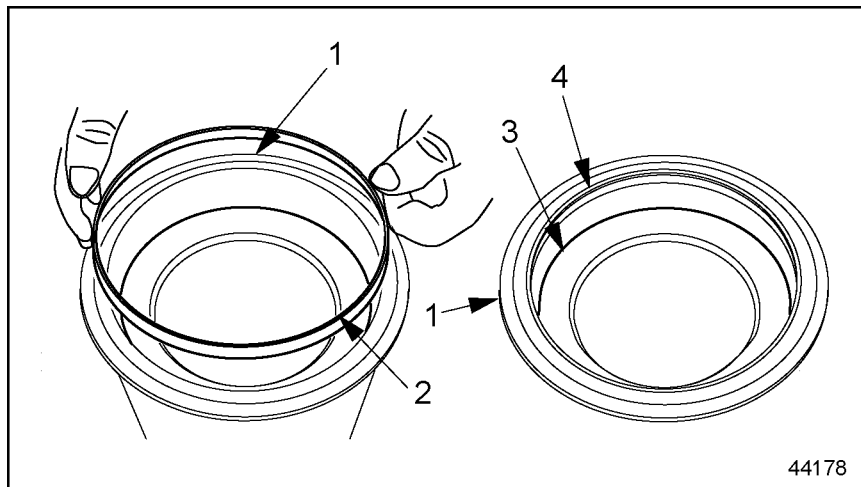


Figure 1-113 **Piston**

NOTE:

If the replacement piston has a locating arrow, it must point toward the front of the engine.

10. Push the piston and connecting rod into cylinder liner.
11. Remove sleeve (J-47710) and wipe the carbon scraper ring seat clean. See Figure 1-114.



- | | |
|------------------------|----------------------------------|
| 1. Cylinder Liner | 3. Installed Piston |
| 2. Carbon Scraper Ring | 4. Installed Carbon Scraper Ring |

Figure 1-114 **Carbon Scraper Ring**

12. Install carbon scraper ring in the cylinder liner groove. See Figure 1-114.
13. Check carbon scraper ring for correct fit after installation.
14. Install the cap half of the bearing shell in the bearing cap, as marked on removal. See Figure 1-112.
 - [a] Be sure that the locking lug in the bearing shell is fully seated in the groove of the cap.
 - [b] Lubricate the bearing surface with a light coating of clean engine oil.
15. Measure the connecting rod bolts stretched length. Replace any bolts that exceed the maximum length of 68.5 mm (2.70 in.). Lubricate the stretch bolt threads with a light coating of engine oil.
16. Install the bearing cap on the connecting rod and hand-tighten the stretch bolts. Be sure that the marks on the cap and the rod match.
17. Tighten the M16 x 1.5 connecting rod stretch bolts alternately. Tighten each one in turn to the first stage and then go on to the next stage. Listed in Table .

Max. Shaft Length mm (in.)	Tightening Stage	Torque N·m (lb·ft)
68.5 (2.70)	Stage 1	108 (80)
	Stage 2	Additional 90 degree rotation

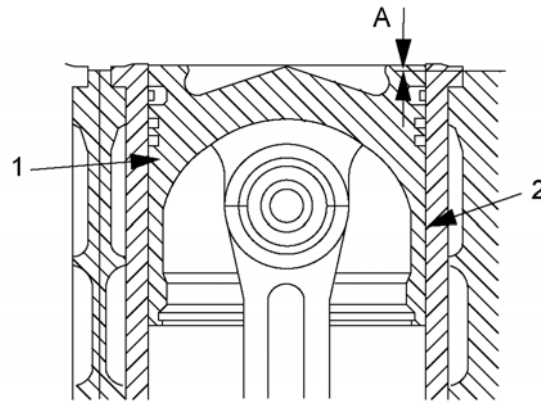
Table 1-32 Connecting Rod Stretch Bolts Tightening Stages

18. Check the connecting rod end play (axial play). Refer to section 1.19.1.2.
19. Rotate the crankshaft to make sure it turns freely.

NOTE:

If it is necessary to turn the crankshaft and the flywheel has been removed, install the flywheel guide pins in the crankshaft gear.

20. Using a dial gauge and holder, measure the piston protrusion relative to crankcase top dead center at all the pistons. See Figure 1-115.



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1. Piston

2. Cylinder Liner

A. Protrusion = 0.244 to 0.715 mm
(0.0096 to 0.0281 in.)

Figure 1-115 Piston Protrusion at Top Dead Center

21. If piston protrusion is between 0.244 mm (0.0096 in.) minimum and 0.715 mm (0.0281 in.) maximum then continue to next step. If not within specification, check piston, piston pin, piston pin bushings, connecting rod and crankshaft. Refer to piston protrusion specifications, listed in Table 1-33.

- [a] Inspect piston, piston pin bushings and piston pin for wear or damage. If damaged, repair as necessary.
- [b] Inspect connecting rod for bent rod, pin bushing wear or damage. If damaged, repair as necessary.
- [c] Inspect rod bearings for wear or damage. If damaged, repair as necessary.
- [d] Inspect crankshaft for damage to rod journal or for evidence of spun bearing. If damaged, repair as necessary.

Description	Specification: mm (in.)
Piston Protrusion (at TDC)	0.244 – 0.715 (0.0096 – 0.0281)

Table 1-33 Piston Protrusion Specifications

22. Remove the engine barring tool (J-46392). Refer to section “Engine Barring Tool Removal.”

NOTICE:

Be careful not to damage the oil spray nozzles. Damaged oil spray nozzles could result in a loss of oil pressure and cause engine damage.

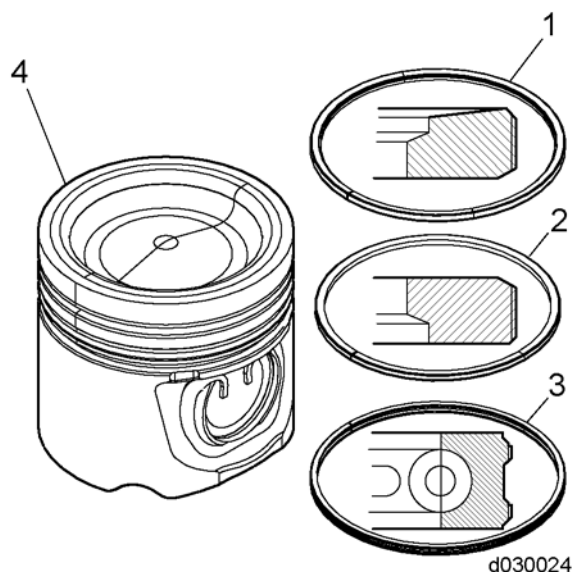
23. Install the oil spray nozzles. Be sure they are seated and aligned correctly. Refer to section 3.3.2 .
24. Install the oil pan. Refer to section 3.2.2 .
25. Install each cylinder head. Refer to section 1.3.2 .

1.19.3 Replacement of Piston Ring

Replacement steps are as follows:

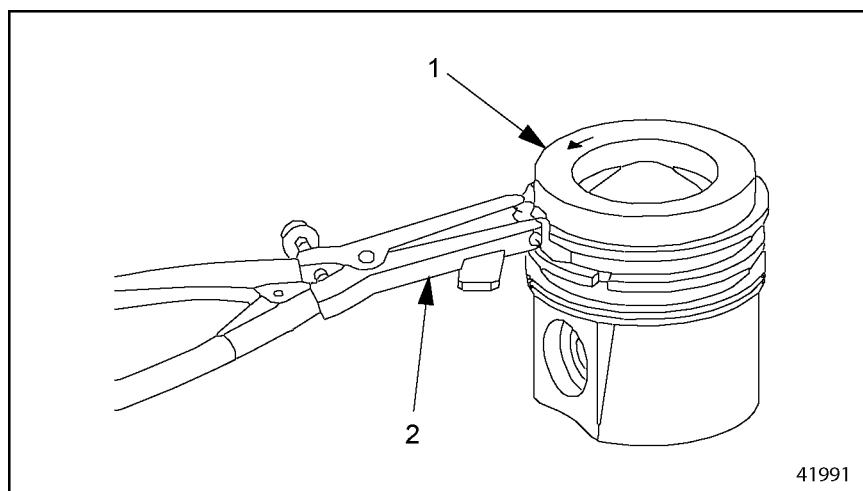
1. Remove the piston. Refer to section 1.19.1.

2. Remove the piston rings using ring pliers (J-46072). Remove the rings in order, starting from the top of the piston down. See Figure 1-116. See Figure 1-117.



- | | |
|--|--|
| 1. Keystone Piston Ring (Groove I) | 3. Double Chamfered Oil Control Ring with Garter Spring (Groove III) |
| 2. Taper Face Ring with Internal Angle (Groove II) | 4. Piston |

Figure 1-116 Piston Rings



- | | |
|-----------|--------------------------|
| 1. Piston | 2. Ring Pliers (J-46072) |
|-----------|--------------------------|

Figure 1-117 Piston Rings

3. Clean all the carbon from the ring grooves. Be sure the grooves are not damaged, and that there are no burrs or combustion residue in the grooves.

4. Before installing the new rings, check the end gap. The correct end-gap measurements are listed in Table 1-34.

Ring Designation	Groove	Gap When New, mm (in.)	Maximum End Gap, mm (in.)
Keystone	I	0.45 to 0.60 (0.018 to 0.024)	1.0 (.039)
Taper-Faced with Internal Angle	II	0.40 to 0.55 (0.016 to 0.022)	1.0 (.039)
Double-Chamfered Oil Control with Garter Spring	III	0.40 to 0.55 (0.016 to 0.022)	1.0 (.039)

Table 1-34 Piston Ring End-Gap Dimensions

NOTE:

Check the end gap of the upper two piston rings first. The garter spring must be removed from the third (lowest) piston ring before you can measure its end gap.

- [a] Place each ring squarely into the combustion area of a cylinder liner or cylinder. Measure the end gap using a feeler gauge. See Figure 1-118.

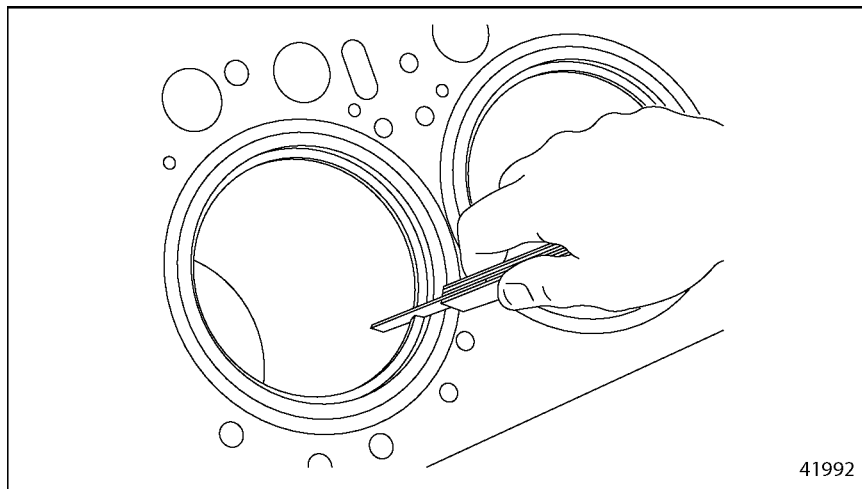
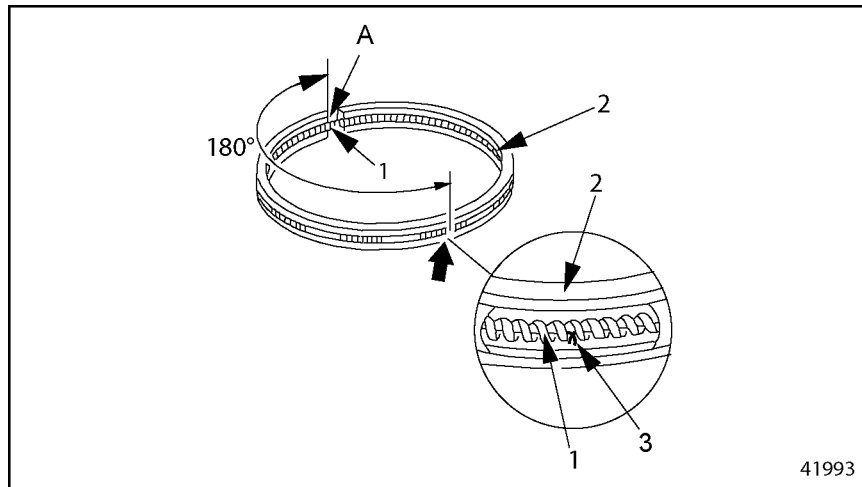


Figure 1-118 Ring End Gap

- [b] Remove the spring garter from the third (lowest) ring. Measure its gap in the same way as the other two rings.

- [c] Install the garter spring into the ring. The garter spring joint should be positioned 180 degrees from the gap (A) in the piston ring. See Figure 1-119.

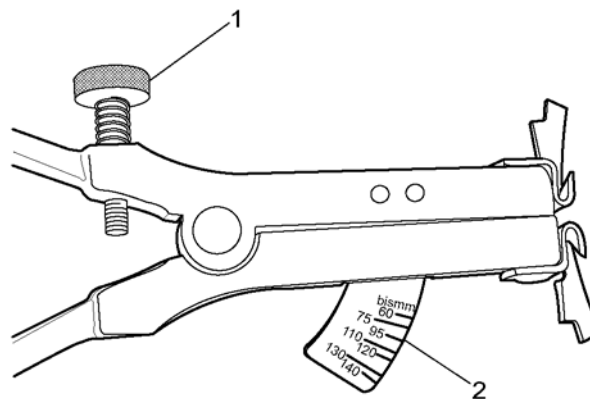


1. Garter Spring
2. Piston Ring

3. Garter Spring Joint

Figure 1-119 Garter Spring

5. Using the knob, set the maximum ring expansion stop on the piston ring pliers (J-46072) or equivalent to the corresponding piston diameter. Be careful not to over-expand the rings during installation. See Figure 1-120.



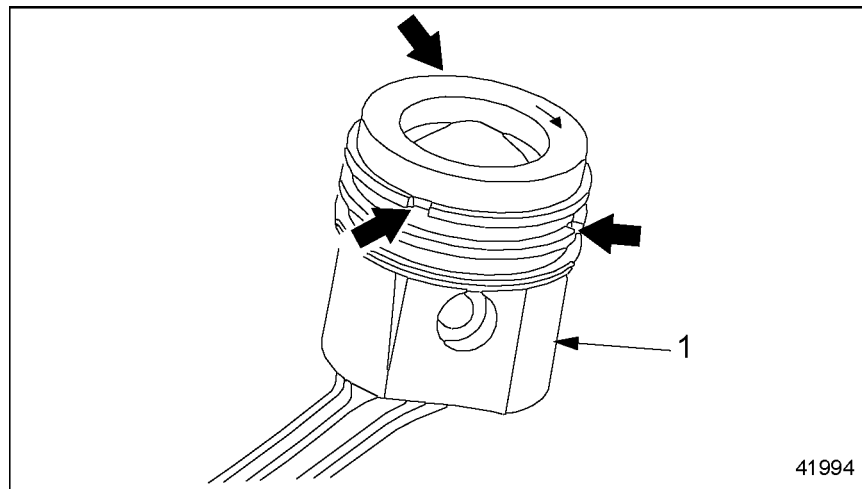
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1. Ring Expansion Stop Knob

2. Piston Diameter (mm)

Figure 1-120 Piston Ring Pliers (J-46072)

6. Make sure the word "TOP" on each ring is facing toward the crown of the piston. Install the rings in the reverse order of their removal; from the bottom to the top of the piston.
7. Offset the ring gaps alternately by 120 degrees. See Figure 1-121.



Piston

Figure 1-121 Piston Rings Offset 120 Degrees

8. Install the piston. Refer to section 1.19.2.

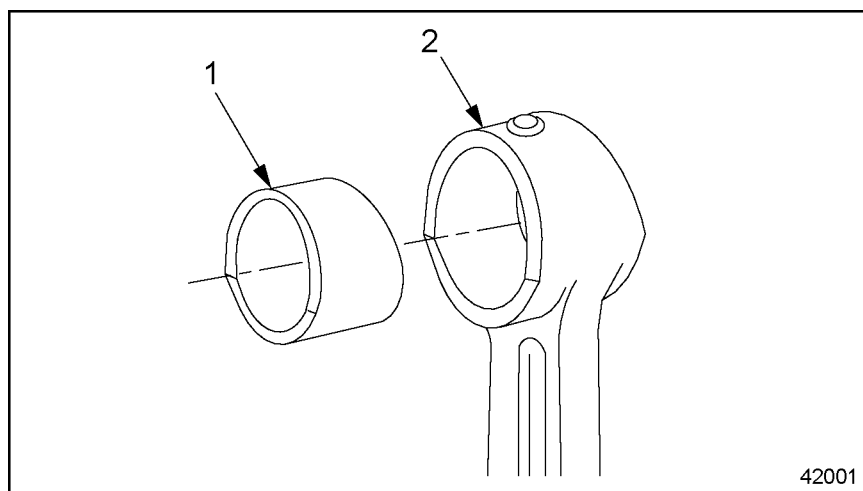
1.19.4 Replacement of Connecting Rod Bushing

Replacement steps are as follows:

NOTICE:

Be careful to avoid damaging the bushing bore when removing the bushing. A damaged connecting rod can seize up suddenly, causing major engine repairs.

1. Rest the connecting rod on a flat surface. Using an appropriate drift, press the bushing out of the connecting rod. See Figure 1-122.



1. Bushing

2. Connecting Rod

Figure 1-122 Connecting Rod Bushing

2. Check the bushing bore in the connecting rod. If surface material is missing from the bushing bore, replace the connecting rod.
3. Measure the inside diameter of the bushing bore in the small bore of the connecting rod. If the measurement exceeds 57.019 mm (2.2448 in.), replace the connecting rod. Refer to section 1.19.1.2.

NOTE:

The inside diameter of the bushing bore and the outside diameter of the bushing must conform to the specifications listed in Table 1-35. This is necessary to obtain the required interference fit.

Description	Dimensions: mm (in.)
Inside Diameter of Bushing	52.05-52.07 (2.049-2.050)
Outside Diameter of Bushing	57.080-57.100 (2.2472-2.2480)
Inside Diameter of Bushing Bore	57.000-57.019 (2.2441-2.2448)
Bushing Interference Fit	0.061-0.100 (0.0024-0.0039)
Maximum Permissible Out-of-Round in Bushing Bore	0.01 (0.0004)

Table 1-35 Bushing Specifications

4. Measure the outside diameter of the bushing. If the measurement exceeds 57.100 mm (2.2480 in.), replace the bushing.
5. Measure the bushing bore in the connecting rod for deformation. If the bushing bore is out-of-round by more than 0.01 mm (0.0004 in.), replace the connecting rod.
6. Rest the connecting rod on a flat surface. Using an appropriate drift, press the bushing into the connecting rod.
7. Measure the inside diameter of the bushing. If the measurement is shorter than 52.05 mm (2.049 in.), machine the inside contact surface of the bushing until the measurement is correct.

1.20 VALVES

The valves are controlled by mushroom tappets, pushrods, and rocker arms. The intake and exhaust valves are opened and closed by a valve-guided bridge.

1.20.1 Checking of Valve Lift

Checking steps are as follows:

NOTE:

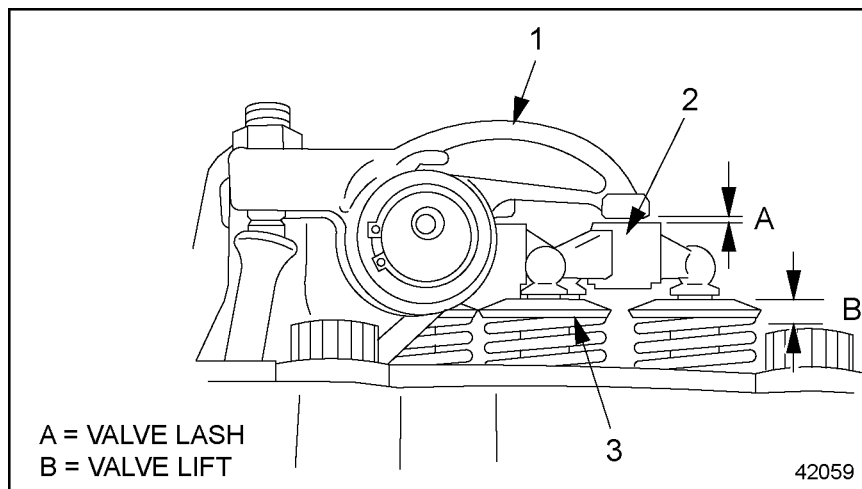
Do this procedure to determine, without removing the camshaft, if the camshaft, or parts of the valve train, have suffered excessive wear. If the camshaft itself is suspect, check the lift on every valve.

1. Remove the cylinder head cover(s). Refer to section 1.2.1.
2. Remove the inspection cover on the flywheel housing and install the engine barring tool (J-46392), Refer to section 1.17.1.

NOTE:

Check cylinders one at a time.

3. Select the first cylinder. Using the engine barring tool (J-46392), rotate the flywheel until the piston in that cylinder is at ignition TDC.
4. Adjust the valve lash. See Figure 1-123. Refer to section 13.1.

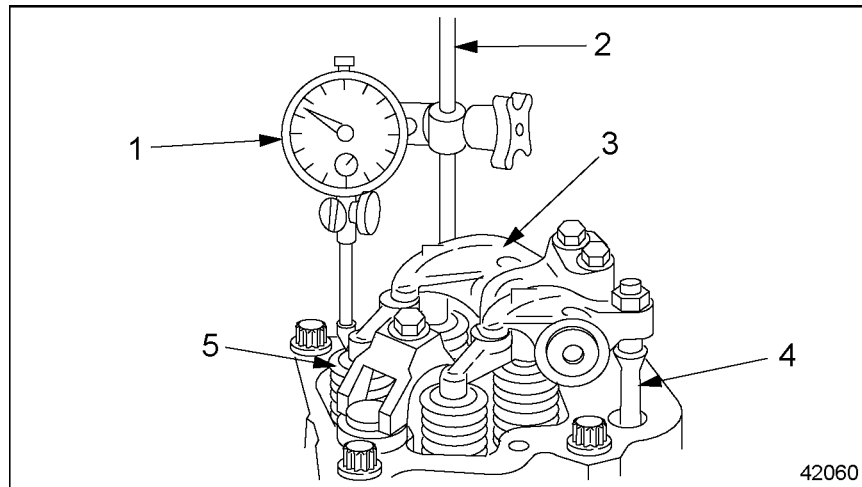


1. Rocker Arm
2. Valve Bridge

3. Valve Spring Retainer

Figure 1-123 Valve Lash and Valve Lift

5. Check the valve lift on the intake valves. See Figure 1-124. Listed in Table 1-36 are the specifications.



- | | |
|----------------------|-----------------|
| 1. Dial Gauge | 4. Pushrod |
| 2. Gauge Holder | 5. Intake Valve |
| 3. Intake Rocker Arm | |

Figure 1-124 Checking Valve Lift, Intake Valves

Description	Specification mm (in.)
Specified Dial Gauge Preload for Checking Valve Lift	15 (0.60)
Valve Lift with Intake Valves Completely Open	11.546 (at least 0.4546)
Valve Lift with Exhaust Valves Completely Open	11.963 (at least 0.4710)

Table 1-36 Valve Lift Specifications

- [a] Mount a dial gauge and a gauge holder on the valve bridge. Mount the dial gauge with a preload of approximately 15 mm (0.60 in.) to provide adequate travel for checking the intake valve lift.
- [b] Set the scale on the dial gauge to "0" (zero).
- [c] Using the engine barring tool (J-46392), rotate the flywheel in a counterclockwise direction (as viewed from the flywheel end).

NOTE:

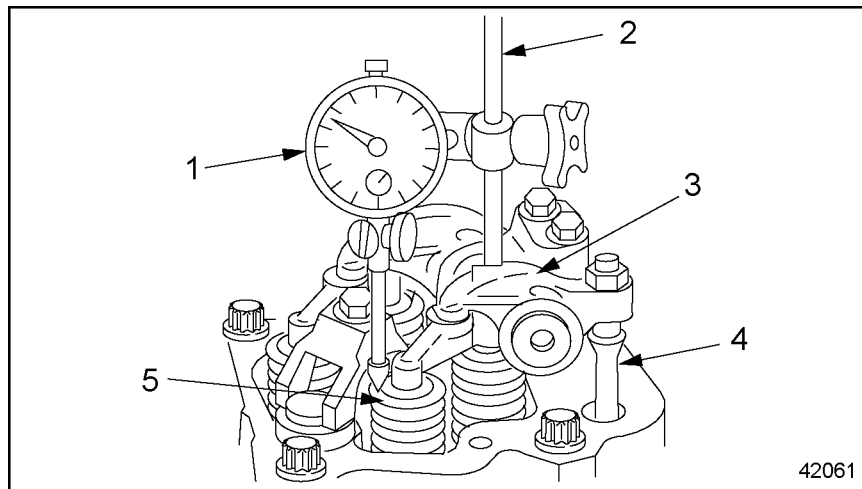
The dial gauge will show the highest reading when the valve is completely open.

- [d] When the intake valves are completely open, read off the value on the dial gauge. If the intake valve lift reaches at least 11.546 mm (0.4546 in.) at its highest point, the intake valves are lifting correctly. If the intake valve lift fails to reach 11.546 mm (0.4546 in.) at its highest point, remove the camshaft and inspect the cams for wear. Refer to section 1.22.1.

NOTE:

If the gauge reading fails to reach 11.546 mm (0.4546 inch), be sure the valves were completely open. The dial gauge will show the highest reading when the valve is completely open.

6. Check the lift on the exhaust valves. See Figure 1-125.



- | | |
|-----------------------|------------------|
| 1. Dial Gauge | 4. Pushrod |
| 2. Gauge Holder | 5. Exhaust Valve |
| 3. Exhaust Rocker Arm | |

Figure 1-125 Checking Exhaust Valve Lift

- [a] Turn the flywheel in a counterclockwise direction until both exhaust valves are closed.
- [b] Move the dial gauge and gauge holder to the spring retainer on the exhaust valve. Make sure the dial gauge still has a preload of approximately 15 mm (0.60 in.) to provide adequate travel for checking the exhaust valve lift.
- [c] Set the scale on the dial gauge to "0" (zero).
- [d] Using the engine barring tool, (J-46392) turn the flywheel in a counterclockwise direction (as viewed from the flywheel end).

NOTE:

The dial gauge will show the highest reading when the valve is completely open.

- [e] When the exhaust valve is completely open, read off the value on the dial gauge. If the exhaust valve lift reaches at least 11.963 mm (0.4710 in.) at its highest point, the exhaust valve is lifting correctly. If the exhaust valve lift fails to reach 11.963 mm (0.4710 in.) at its highest point, remove the camshaft and inspect the cams for wear. Refer to section 1.22.1.

NOTE:

If the gauge reading fails to reach 11.963 mm (0.4710 in.), be sure the valves were completely open. The dial gauge will show the highest reading when the valve is completely open.

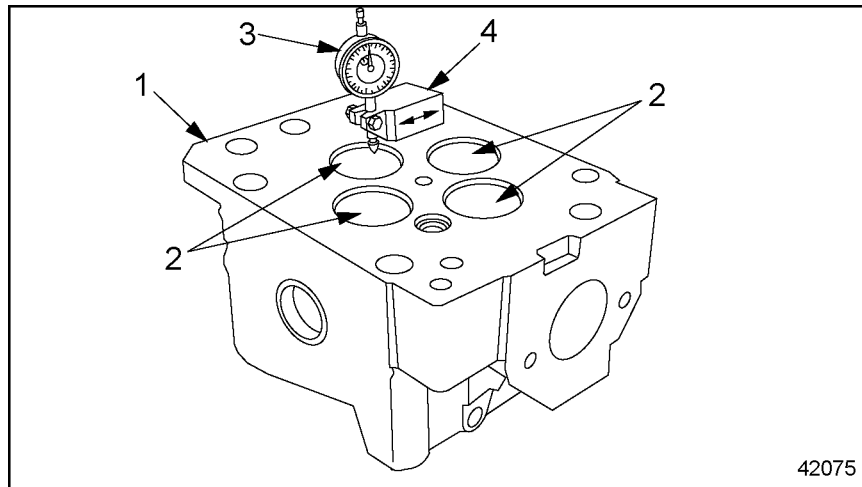
7. Check the valve lift, both intake and exhaust, on the remaining cylinders, one at a time, until all have been checked.
8. Remove the dial gauge and holder from the cylinder head.
9. Check and adjust the valves. Refer to section 13.1.
10. Remove the engine barring tool (J-46392) from the flywheel housing and install the inspection cover. Tighten the inspection cover bolts 25 N·m (18 lb·ft).
11. Install the cylinder head cover(s). Refer to section 1.2.2.

1.20.2 Measurement of Valve Head Recess Depth

Measurement steps are as follows:

1. Remove the cylinder head from the engine. Refer to section 1.3.1.

2. Set up a dial gauge and dial gauge holder with a preload on the lower contact surface of the cylinder head. See Figure 1-126.



- | | |
|---|----------------------|
| 1. Lower Contact Surface of Cylinder Head | 3. Dial Gauge |
| 2. Valve Head | 4. Dial Gauge Holder |

Figure 1-126 **Setting the Dial Gauge Preload**

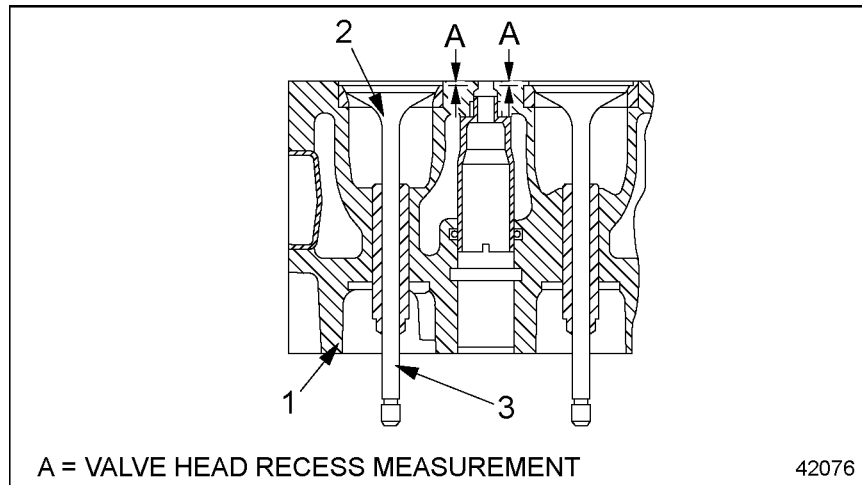
NOTE:

Before doing this procedure, make sure the valve head is making contact with the valve seat.

3. Measure the valve head recess depth listed in Table 1-37, from the cylinder head.
See Figure 1-127.

NOTE:

The valve head recess depth is the difference in height between the lower contact surface of the cylinder head and the valve head, when it is touching the valve seat.



1. Cylinder Head

3. Valve Stem

2. Valve Head

Figure 1-127 Measuring Valve Head Recess Depth

Valve Type	Description	Recess Depth mm (in.)
Intake	Normal	0.7-1.1 (0.03-0.04)
Intake	Wear Limit	1.6 (0.06)
Exhaust	Normal	0.7-1.1 (0.03-0.04)
Exhaust	Wear Limit	1.6 (0.06)

Table 1-37 Valve Head Recess Depth

- [a] Set the scale of the dial gauge to "0" (zero).
 - [b] Move the dial gauge enough so that its probe is touching the valve head.
 - [c] If the gauge reads between 0.7 and 1.1 mm (0.03 and 0.04 inch), the valve head recess depth is within specifications for new cylinder heads.
 - [d] If the gauge reads less than 0.7 mm (0.03 inch), or more than 1.1 mm (0.04 inch), the valve head recess depth is not within specifications, Refer to section 1.20.3.
 - [e] For used heads, if the gauge reads more than 1.6 mm (0.06 in.), inspect valves and valve seats. Listed in Table 1-40 are the specifications.
4. Install the cylinder head. Refer to section 1.3.2.

1.20.3 Removal of Valve

Removal steps are as follows:

NOTE:

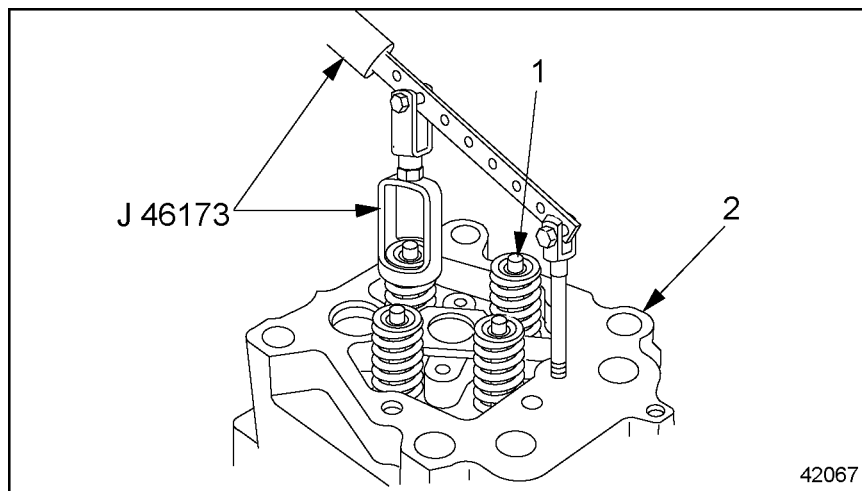
The MBE 4000 engine has individual heads for each cylinder. To replace the valves on one head, follow these instructions, step by step. To replace all the valves, repeat these instructions for all six cylinder heads.

1. Remove the cylinder head from the engine. Refer to section 1.3.1.
2. Using a dial gauge and holder, measure the valve head recess depth from the cylinder head. Refer to section 1.20.2. Listed in Table 1-38 are the normal tolerances and wear limits.

Valve Type	Description	Recess Depth mm (in.)
Intake	Normal	0.7-1.1 (0.03-0.04)
Intake	Wear Limit	1.6 (0.06)
Exhaust	Normal	0.7-1.1 (0.03-0.04)
Exhaust	Wear Limit	1.6 (0.06)

Table 1-38 Valve Head Recess Depth

3. Place the cylinder head on cylinder head fixture,(J-46175).
4. Attach the valve spring remover tool, (J-46173), to the cylinder head. See Figure1-128.

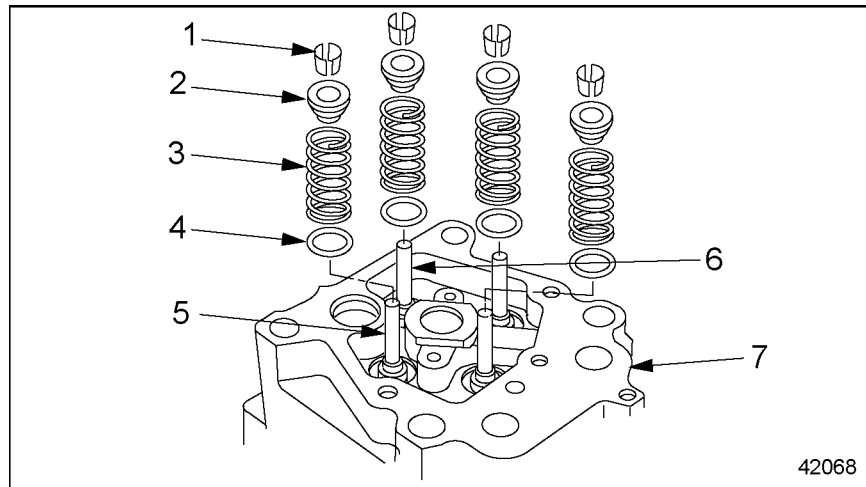


1. Valve

2. Cylinder Head

Figure 1-128 Valve

5. Using the valve spring remover tool (J-46173), press down on the valve spring retainer. Remove the valve keepers with a magnet. See Figure 1-129.



- | | |
|--------------------|------------------|
| 1. Valve Keepers | 5. Exhaust Valve |
| 2. Spring Retainer | 6. Intake Valve |
| 3. Valve Spring | 7. Cylinder Head |
| 4. Spring Base | |

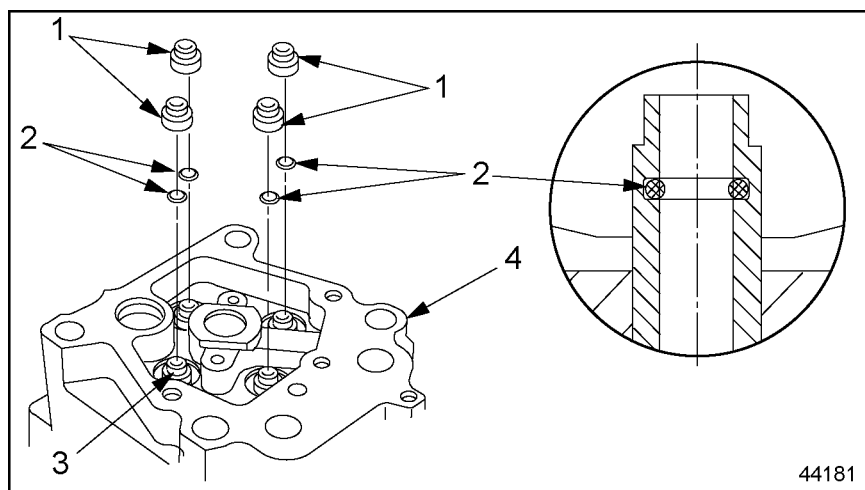
Figure 1-129 Valves and Related Components

6. Relieve the pressure on the valve spring remover. Remove the valve spring retainers, valve springs, and spring base.
7. Turn over the cylinder head and remove the valves.

NOTE:

Mark the valves in order for ease of installation.

8. With the cylinder head again in the upright position, remove and discard the valve stem seal and sealing ring. See Figure 1-130.



1. Valve Stem Seal

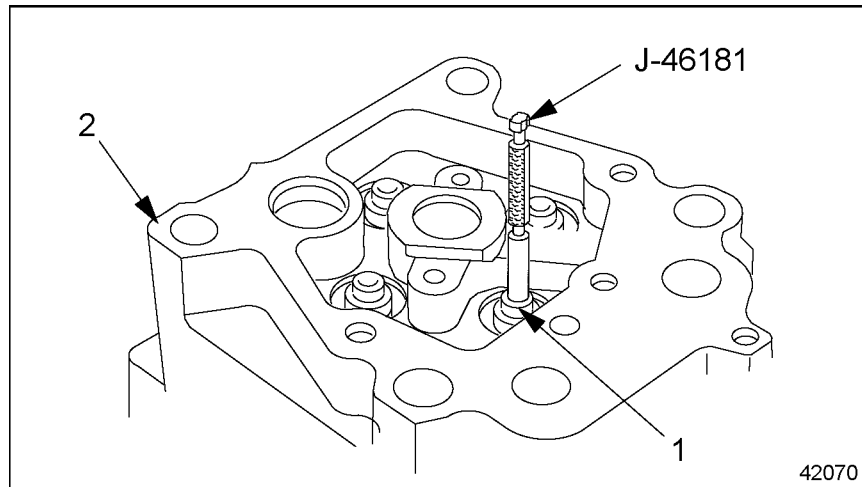
2. Valve Stem Sealing Ring

3. Valve Guide

4. Cylinder Head

Figure 1-130 **Valve Stem Seals**

9. Inspect the valve guides for wear. See Figure 1-131. Listed in Table 1-39 are the specifications.



1. Valve Guide

2. Cylinder Head

Figure 1-131 Measuring the Inside Diameter of the Valve Guide

Description	Value: mm (in.)
Normal	9.000-9.022 (0.3543-0.3552)
Wear Limit	9.050 (0.3563)

Table 1-39 Inside Diameter of Valve Guide

- [a] Measure the inside diameter of the valve guide by inserting the go/no go gauge (J-46181) into the valve guide.
 - [b] Replace the valve guide if the larger diameter end of the go/no go gauge tool (J-46181) fits into either end of the guide.
10. Clean the valves thoroughly. Remove any traces of combustion residue.
11. Check the valves to see if they can be re-used. Replace the valves if the stem ends are damaged or bent, if the valve grooves are deformed, if the seat is burned, or if the chrome surface of the shaft is not entirely intact.

12. Check the following critical valve dimensions, and repair as necessary. See Figure 1-132 to determine the dimensions given in the table. Listed in Table 1-40 are the dimensions.

- Valve stem diameter (A)
- Valve seat diameter at the contact surface of the cylinder head (B)
- Valve head diameter (C)
- Valve seat height (D)
- Valve seat width at the valve head (E)
- Valve seat angle (F)
- Valve length (G)

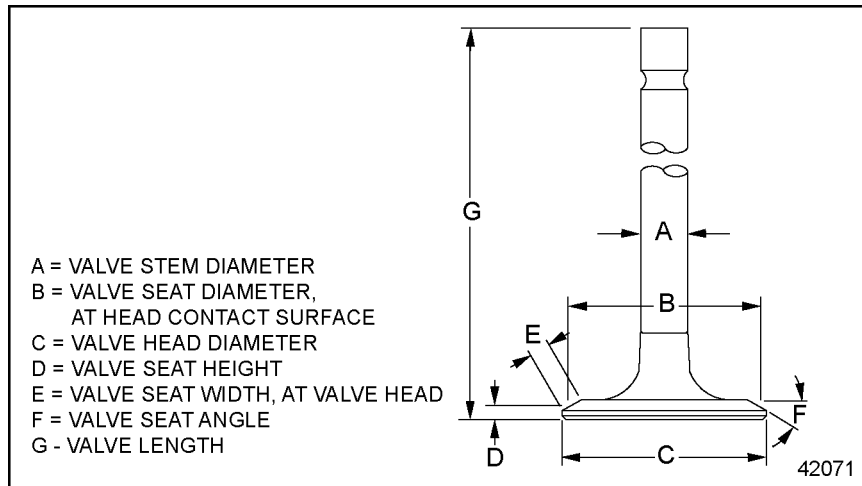


Figure 1-132 Critical Dimensions, Valve Stem and Head

Description	Intake mm (in.)	Exhaust mm (in.)
Valve Stem Diameter (A)	8.935-8.950 (0.3518-0.3524)	8.925-8.940 (0.3514-0.3520)
Valve Seat Diameter, at Head Contact Surface (B)	42.0 (1.65)	39.0 (1.54)
Valve Head Diameter (C)	45.4-45.6 (1.79-1.80)	41.9-42.3 (1.65-1.67)
Valve Seat Height-New (D)	3.1-3.3 (0.12-0.13)	3.0-3.3 (0.12-0.13)
Minimum Valve Seat Height-After Grinding (D)	2.9 (0.11)	2.9 (0.11)
Valve Seat Width, at Valve Head (E)	3.5-4.5 (0.14-0.18)	min. 3.5 (0.14)
Valve Seat Angle (F)	30 degrees	36 degrees
Valve Length (G)	145.0 (5.71)	145.0 (5.71)

Table 1-40 Valve Specifications

13. Check the condition of the valve seat insert. Repair the insert if necessary. Refer to section 1.20.6.

14. Inspect the valve springs. Check the springs for correct pressure, using the values listed in Table 1-41. If damaged, replace the springs.

Description	mm (in.)
Length, Without Load	69.7 (2.74)
Length, Under Load of 382-418 N (86-94 lbf)	49 (1.9)
Length, Under Load of 644-706 N (145-159 lbf)	37 (1.5)
Diameter of Spring Wire	4.2 (0.17)
Outside Diameter of Spring Coil	28.9 (1.14)
Inside Diameter of Spring Coil	24.5-24.9 (0.96-0.98)

Table 1-41 Spring Specifications, Intake and Exhaust Valves

1.20.4 Installation of Valve

Installation steps are as follows:

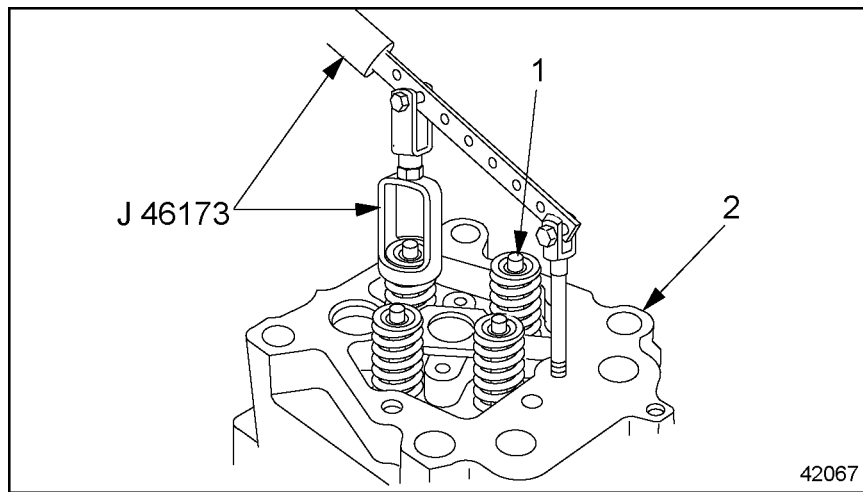
1. Install the valve stem sealing ring in the valve guide in the cylinder head.
2. Lubricate each valve with a light coating of engine oil.
3. Install the valves in order, as marked on removal.

NOTE:

Always replace the valve stem seal and valve stem sealing ring if the valve has been removed. Check the valve stem seal to make sure it is correctly seated on the valve guide.

4. Using valve stem seal protector (J-46174), install new valve stem seals and seat the valve stem seal with installer tool, (J-46184). Refer to section 1.20.5.

5. Using the valve spring compressor (J-46173), install the spring seats, springs, spring retainers, and valve keepers. Check the valve keepers to ensure they are locked in place. See Figure 1-133.



1. Valve

2. Cylinder Head

Figure 1-133 Valve

6. Remove the valve spring compressor (J-46173) from the cylinder head.
7. Install the cylinder head. Refer to section 1.3.2.

1.20.5 Replacement of Valve Stem Seal and Valve Stem Sealing Ring

Replacement steps are as follows:

NOTE:

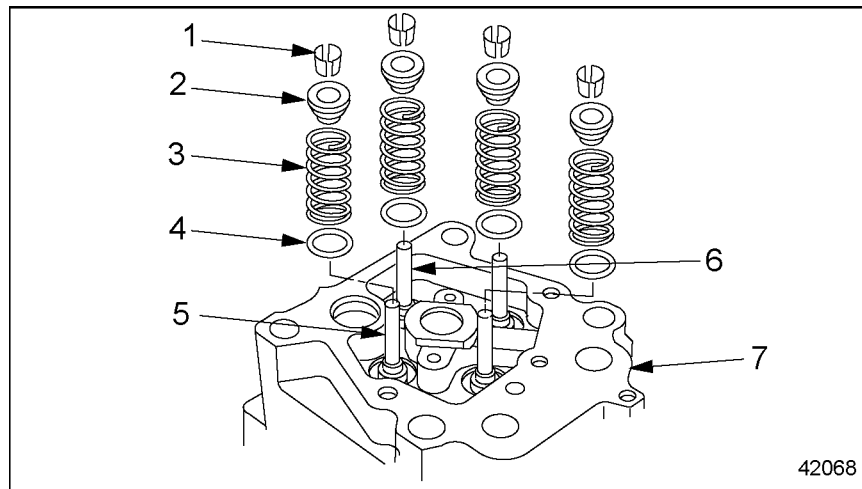
Always replace the valve stem seal and valve stem sealing ring if the exhaust valve has been removed.

1. Remove the cylinder head from the engine. Refer to section 1.3.1.

NOTE:

Use care during removal to not damage the valve guides and valve stems.

2. Remove the valve keepers, spring retainer, valve spring, and spring base.

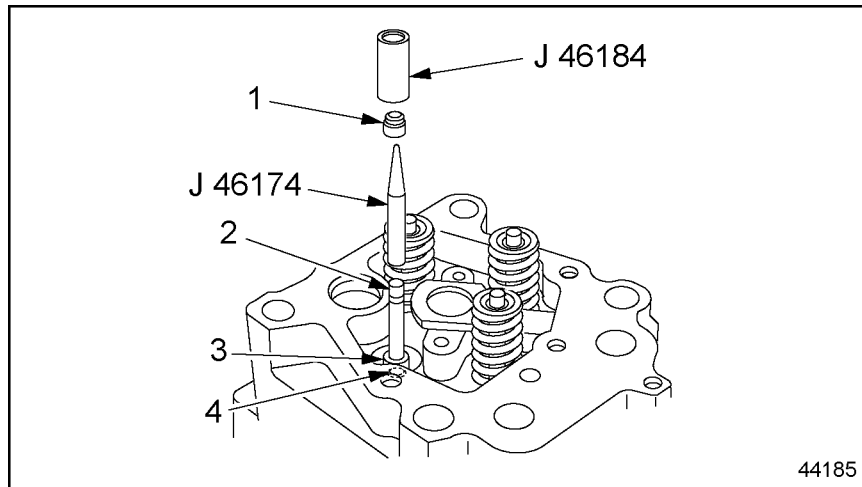


- | | |
|--------------------|------------------|
| 1. Valve Keepers | 5. Exhaust Valve |
| 2. Spring Retainer | 6. Intake Valve |
| 3. Valve Spring | 7. Cylinder Head |
| 4. Spring Base | |

Figure 1-134 Valves and Related Components

3. Remove the valve keepers, spring retainer, valve spring, and spring base. See Figure 1-134.
4. Remove the valve stem seal and discard.
5. Remove the valve.
6. Remove the valve stem sealing ring from inside of valve guide and discard. Repeat procedure for all remaining valves.
7. Clean all parts before reinstalling components.
8. Install the valve stem sealing ring in the valve guide and then install the valve in the head. Repeat procedure for all remaining valves.

9. Lubricate the valve stem and valve stem seal protector (J-46174) with a light coating of clean engine oil.



1. Valve Stem Seal

2. Valve Stem

3. Valve Guide

4. Valve Stem Sealing Ring (installed)

Figure 1-135 Valve Stem Seal and Sealing Ring

NOTE:

The installer prevents the groove on the valve stem from damaging the valve stem seal.

10. Push the valve stem seal protector, (J-46174) over the valve stem until it makes contact with the valve.
11. Slide the valve stem seal over the valve stem seal protector, (J-46174) and onto the valve stem. Using fingers, press valve stem seal into place until the seal seats on the valve guide.
12. Remove the valve stem seal protector, (J-46174).
13. Using valve stem seal installer, (J-46184) and the appropriate hammer, drive the valve stem seal onto the guide.

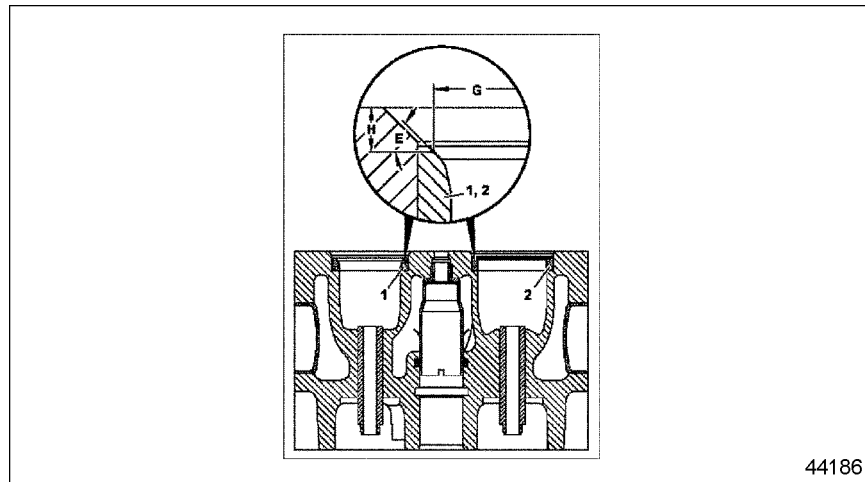
NOTE:

Check the seal to make sure it is correctly seated on the valve guide.

14. Remove the installer (J-46184) from the valve stem seal and the valve.
15. Install the valve keepers, spring retainer, valve spring and spring base, as removed.
16. Repeat the procedure for the other valves.
17. Install the cylinder head on the engine. Refer to section 1.3.2.

1.20.6 Valve Seat Specifications

See Figure 1-136 and listed in Table 1-42 are the specifications for valve seats.



1. Exhaust Valve Seat

2. Intake Valve Seat

Figure 1-136 Valve Seats EGR Engines

Description	Intake Valve, mm (in.)	Exhaust Valve-EGR, mm (in.)
Valve seat angle (E)	30 Degree	36 Degree
Valve seat surface diameter (G)	41.99-42.01(1.65-1.654)	38.99-39.01(1.535-1.536)
Relative position (H) to diameter G	4.00-4.15 (0.157-0.163)	4.00-4.15 (0.157-0.163)

Table 1-42 Valve Seat Specifications EGR Engines

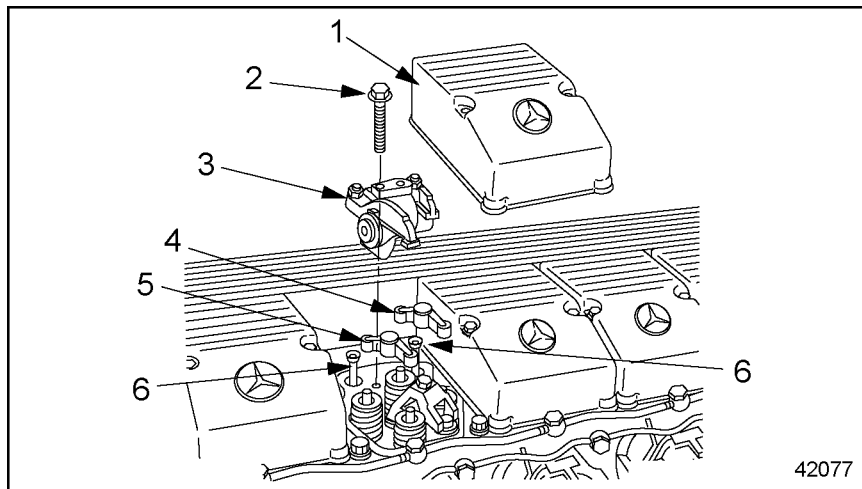
1.21 ROCKER ARM

Perform the following procedures for removal and installation of the rocker arm:

1.21.1 Removal of Rocker Arm Assembly

Removal steps are as follows:

1. Remove the injector harness adaptor frame. Refer to section 2.5.1.
2. Remove the rocker arm assembly. See Figure 1-137.



- | | |
|-----------------------------|-------------------------|
| 1. Cylinder Head Cover | 4. Intake Valve Bridge |
| 2. Rocker Arm Mounting Bolt | 5. Exhaust Valve Bridge |
| 3. Rocker Arm Assembly | 6. Pushrods |

Figure 1-137 Rocker Arm Assembly

- [a] Loosen the each valve lash adjusting screw.
 - [b] Remove each rocker arm mounting bolt.
 - [c] If removing more than one rocker arm assembly, mark the assembly with a paint pen to identify it on installation.
 - [d] Remove the rocker arm assembly from the cylinder head.
3. Inspect the rocker arm assembly for wear. If necessary, disassemble the rocker arm assembly and replace any worn parts. Refer to section 1.21.2.

4. Measure each rocker arm mounting bolt. Replace each bolt longer than 91 mm (3.6 inches), as listed in Table 1-43.

Size	Max. Shaft Length mm (in.)	Torque Nm (lb ft)
M10	91 (3.6)	60 (44)
M10	91 (3.6)	additional 90°

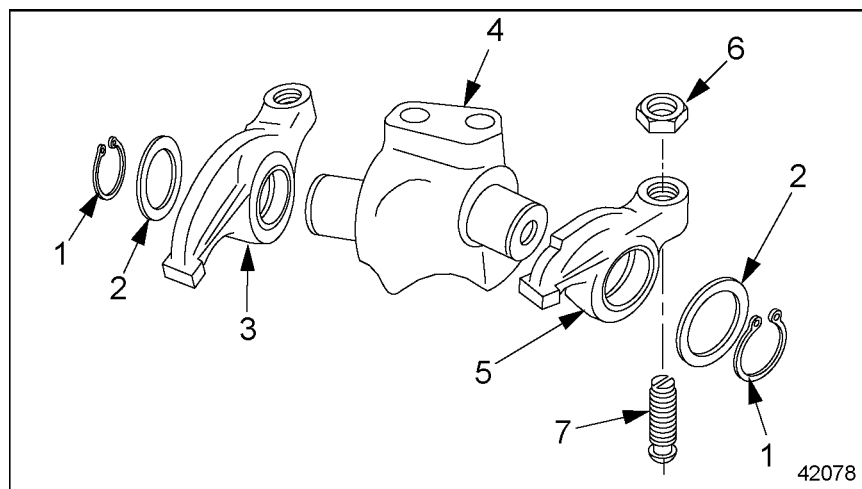
Table 1-43 Rocker Arm Mounting Bolts Specifications

5. Remove the valve bridge from each set of valves, intake and exhaust.
6. Inspect the valve bridges for wear. If necessary, replace any worn valve bridge(s).

1.21.2 Disassembly of Rocker Arm

Disassembly steps are as follows:

1. Remove the rocker arm assembly from the cylinder head. Refer to section 1.21.1.
2. Remove the snap rings from each end of the rocker arm shaft. See Figure 1-138.



- | | |
|-----------------------|----------------------|
| 1. Snap Ring | 5. Intake Rocker Arm |
| 2. Washer | 6. Locknut |
| 3. Exhaust Rocker Arm | 7. Adjusting Screw |
| 4. Rocker Support | |

Figure 1-138 Rocker Arm Components

3. Remove the rocker arms and washers from the shafts on each end of the rocker arm support. Keep all parts in order, as removed, for ease of assembly.
 - [a] Remove the intake rocker arm and washer.
 - [b] Remove the exhaust rocker arm and washer.

- [c] Remove the adjusting screw and locknut from both intake and exhaust rocker arms.
 - [d] Mark each rocker arm and shaft with paint pens, for ease of installation.
4. Inspect the parts of the rocker arm assembly for wear, and replace if necessary.

1.21.3 Assembly of Rocker Arm

Assembly steps are as follows:

1. Install the adjusting screw and locknut on both intake and exhaust rocker arms. Tighten the locknut 50 N·m (37 lb·ft).
2. Inspect the inside diameter of the rocker arm bushing. Replace the rocker arm bushing if the inside diameter is smaller than 25.005 mm (0.9844 in.) or larger than 25.021 mm (0.9851 in.) as listed in Table 1-44.

Description	Specification, mm (in.)
Bushing Inside Diameter (when installed)	25.005-25.021 (0.9844-0.9851)
Shaft Diameter	24.967-24.980 (0.9830-0.9835)

Table 1-44 Rocker Arm Bushing Specifications

3. Inspect the diameter of the rocker arm shaft. Replace the rocker arm shaft if the diameter is smaller than 24.967 mm (0.9830 in.) or larger than 24.980 mm (0.9835 in.).
4. Lubricate the washers, rocker arm bushings, and the shafts of the support with a light coating of engine oil.
5. Install the rocker arms and washers on the correct rocker arm shaft, as marked on removal. Make sure both intake and exhaust rocker arms are installed correctly.
6. When the assembly is complete, secure the assembly by installing a snap ring on the end of each rocker arm shaft.

1.21.4 Installation of Rocker Arm

Installation steps are as follows:

1. Install a valve bridge on each set of valves, both intake and exhaust.
2. Lubricate each pushrod with a light coating of engine oil.

3. Inspect each pushrod to be sure it is correctly seated in its tappet. Replace any pushrods that are warped, are not correctly seated, or are not the correct length as listed in Table 1-45.

Description	Specification mm (in.)
Total Length of Pushrods	345.0-346.5 (13.58-13.64)
Maximum Pushrod Warp	0.5 (0.02)
Maximum Length of Rocker Arm Mounting Bolts	91 (3.6)

Table 1-45 Rocker Arm Specifications

4. Install the rocker arm assembly.
 - [a] Position the rocker arm assembly on the cylinder head, as removed.
 - [b] Install the mounting bolts in the holes in the cylinder head.
 - [c] Tighten each mounting bolt 60 N·m (44 lb·ft). Final angular tightening: 90 degrees.
5. Adjust the valve lash. Refer to section 13.1.
6. Install the injector harness adaptor frame. Refer to section 2.5.2.

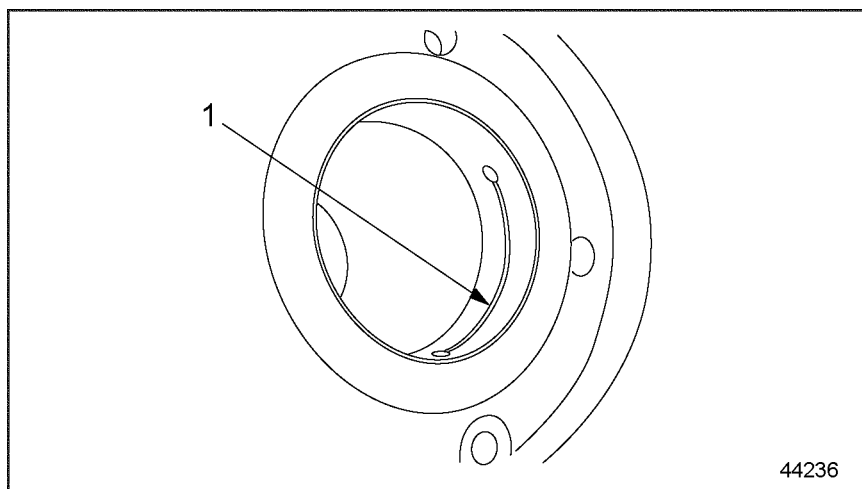
1.22 CAMSHAFT AND GEAR ASSEMBLY

The camshaft is made of induction-hardened steel and has seven main bearings. Each cylinder has lobes for intake and exhaust valves and a unit pump. The camshaft and gear is serviced as an assembly.

In the engine, there is a possibility of installing the camshaft bushings in an inverted (wrong) position.

NOTICE:

If the camshaft bushings are installed in an inverted (wrong) channel position, there is potential for engine damage due to lack of lubrication. The holes in the camshaft journal *must* be lined up with the holes in the camshaft bushing.



44236

1. Bushing Groove

Figure 1-139 **Camshaft Bushing**

1.22.1 Removal of Camshaft and Gear Assembly

Removal steps are as follows:

NOTE:

Before removing the camshaft and gear assembly, clean the engine to prevent road dirt, grease, or other foreign matter from contaminating the exposed gears and other engine parts.

1. Drain the coolant from the engine. Refer to section 4.1.1.
2. Drain the engine oil.



DANGER:

FALLING ENGINE

To avoid injury from a falling engine, an adequate lifting device with a spreader bar and sling should be used to lift the engine. The sling and spreader bar should be adjusted so the lifting hooks are vertical to prevent bending the lifter brackets. To ensure proper weight distribution, all provided lifter brackets must be used.

NOTICE:

A spreader bar *must* be used at all times in conjunction with the front and rear lifter brackets to lift the EGR engine to ensure that no engine damage will result. The brackets are designed to lift vertically.

3. Remove the engine from the vehicle.



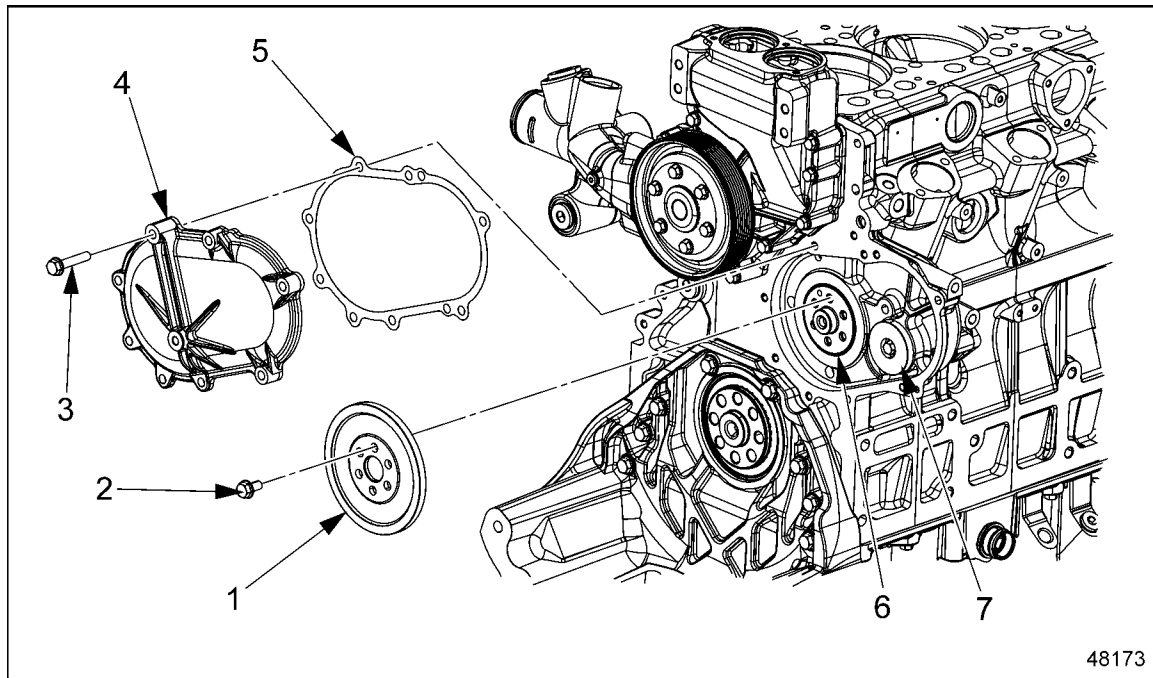
WARNING:

FALLING ENGINE

To avoid injury from a falling engine, ensure the engine is securely attached to the engine overhaul stand before releasing the lifting sling.

4. Install the engine on an engine stand. Use OTC engine stand 1750A or equivalent and engine stand adaptor plate J-41576.
5. Remove the unit pumps. Refer to section 2.1.1.
6. Remove the vibration damper. Refer to section 1.13.1.
7. Remove the fan support. Refer to section 4.3.1.

8. Remove the air conditioning compressor, alternator, and mounting bracket. Refer to section 9.2.1.
9. Remove the mounting bolts attaching the camshaft front cover to the cylinder block. See Figure 1-140.
10. Remove the bolts securing the fuel pump drive gear to the front of the camshaft. Discard the bolts. See Figure 1-140.



- | | |
|-----------------------------|--------------------------|
| 1. Fuel Pump Drive Gear | 5. Camshaft Cover Gasket |
| 2. Drive Gear Mounting Bolt | 6. Front of Camshaft |
| 3. Cover Mounting Bolt | 7. Fuel Pump Driven Gear |
| 4. Front Camshaft Cover | |

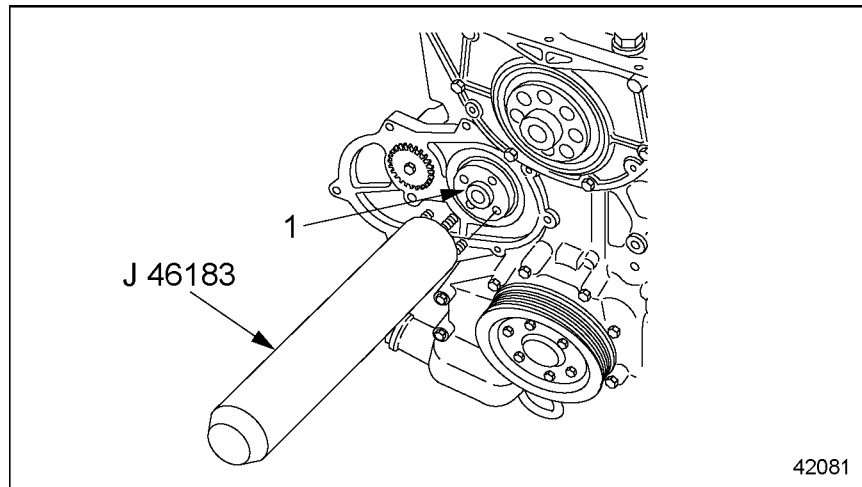
Figure 1-140 Camshaft Assembly

11. Remove all rocker arm assemblies and pushrods. Refer to section 1.21.1.
12. Turn the engine on the stand until it is upside down.
13. Remove the oil pan. Refer to section 3.2.1.
14. Remove the flywheel housing. Refer to section 1.18.1.

15. Attach the camshaft pilot disc (J-46183-1, part of toolset J-46183) finger tight to the front of the camshaft. See Figure 1-141.

NOTE:

Leave pilot disc attaching bolts finger tight in order to adjust guide sleeve during removal procedure.



1. Front of Camshaft

Figure 1-141 Camshaft Guide Tool

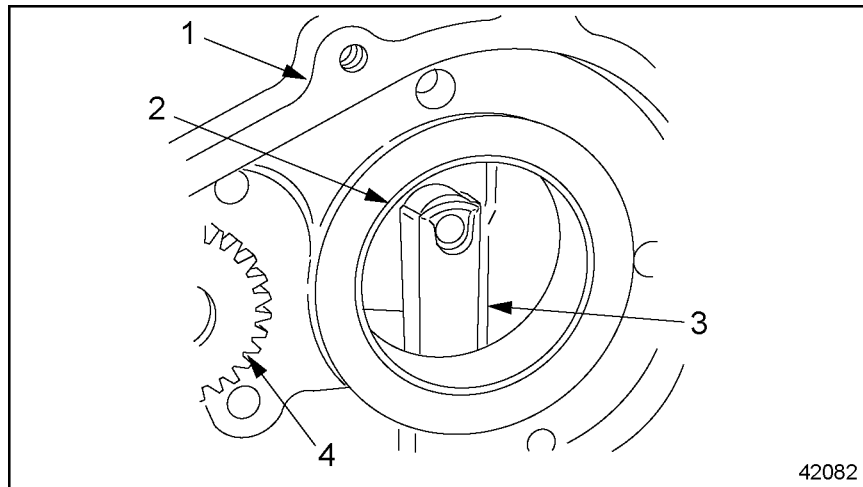
16. Thread the guide sleeve (J-41580-1, part of toolset J-46183) onto the pilot disc.
17. Lubricate the guide sleeve with a light coat of clean engine oil.

NOTICE:

Do not damage the camshaft bearings in the crankcase. If the camshaft bearings are damaged, the bearings will have to be replaced.

18. Using clean shop towels or gloves and from the gear end (rear of the engine), carefully remove the camshaft and gear assembly from the block. See Figure 1-141.

19. Remove the tappets (valve lifters) from the block. Mark the tappets, in order, as removed. See Figure 1-142.



- | | |
|------------------------|--------------------------|
| 1. Cylinder Block | 3. Tappet (valve lifter) |
| 2. Camshaft Entry Hole | 4. Fuel Pump Driven Gear |

Figure 1-142 Tappets

20. Clean and inspect the tappets. Replace the tappets if there are signs of damage or wear, or if any of the measurements do not meet the specifications listed in Table 1-46.

Description	Repair Stage	Specifications, mm (in.)
Tappet Outside Diameter	Standard	29.931-29.952 (1.1784-1.1792)
Tappet Outside Diameter	Repair Stage I	30.444-30.465 (1.1986-1.1994)
Tappet Bore Diameter (in cylinder block)	Standard	30.000-30.021 (1.1811-1.1819)
Tappet Bore Diameter (in cylinder block)	Repair Stage I	30.500-30.525 (1.2008-1.2018)

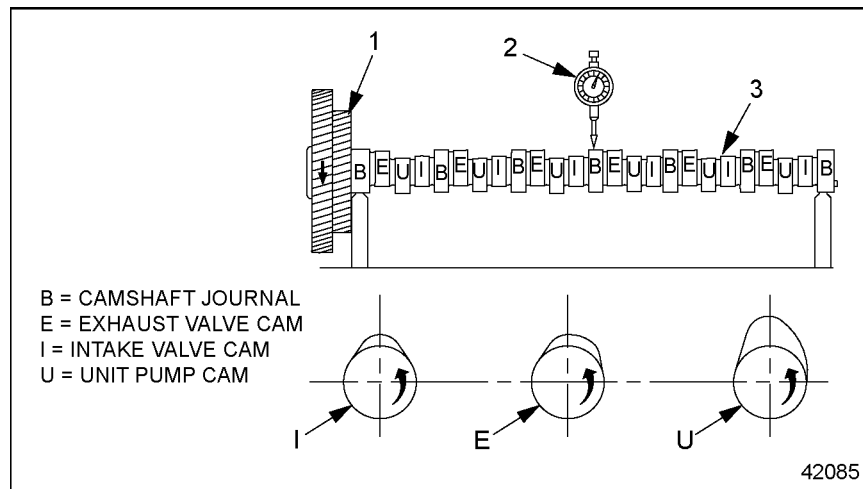
Table 1-46 Valve Tappet Specifications

- [a] Measure the outside diameter of each tappet.
- [b] Measure the diameter of the tappet bore in the cylinder block.
21. Inspect the camshaft and gear assembly. Refer to section 1.22.1.1.

1.22.1.1 Inspection of Camshaft and Gear Assembly

Inspection steps are as follows:

1. Inspect the camshaft gear teeth for evidence of scoring, pitting, overheating or wear. Replace the camshaft and gear assembly if any of these conditions are found. Refer to section 1.22.1.
2. Check the hardness of the cam lobes and bearing journals on the camshaft. Listed in Table 1-47 is the permissible range for camshaft hardness.
3. Measure the diameter of each bearing journal. Measure the diameter of the bushing at each journal. See Figure 1-143. The camshaft measurement specifications are listed in Table 1-47.



1. Camshaft Gear

3. Camshaft

2. Dial Gauge

Figure 1-143 Measuring the Cam Rise

4. Mount the camshaft at the outer journals.

NOTE:

For all of the following steps, use a dial gauge.

5. Measure the radial runout of the cam basic circle.
6. Measure the cam rise of the intake valve cams. See Figure 1-143, Ref. I.
7. Measure the cam rise of the exhaust valve cams. See Figure 1-143, Ref. E.
8. Measure the cam rise of the unit pump valve cams. See Figure 1-143, Ref. U.

9. Replace the camshaft if any of the measurements do not meet the specifications listed in Table 1-47.

What To Measure	Where To Measure	Value: mm (in.) Unless otherwise noted
Hardness of Surface	At Cams and Journals	57–63 HRC
Camshaft Radial Runout When Mounted on Outer Bearing Journals	At Gear Seat	0.020 (0.0008)
Camshaft Radial Runout When Mounted on Outer Bearing Journals	At Cam Circle	0.025 (0.0010)
Camshaft Radial Runout When Mounted on Outer Bearing Journals	At Camshaft Journals	0.030 (0.0012)
Minimum Valve Cam Rise—Above Basic Circle	Intake Valve	7.3 (0.29)
Minimum Valve Cam Rise—Above Basic Circle	Exhaust Valve	8.2 (0.32)
Camshaft Journal Diameter	For New Camshaft	81.893–81.928 (3.2241–3.2255)
Bushing Diameter	At Camshaft Journals in Cylinder Block	82.000–82.035 (3.2283–3.2297)
Gear Back Lash	Cam Gear to Crank Gear	0.074–0.176 (0.0029–0.0069)
Gear Back Lash	Cam Gear to Air Compressor Gear	0.082–0.168 (0.0032–0.0066)

Table 1-47 Camshaft Specifications

1.22.2 Installation of Camshaft and Gear Assembly

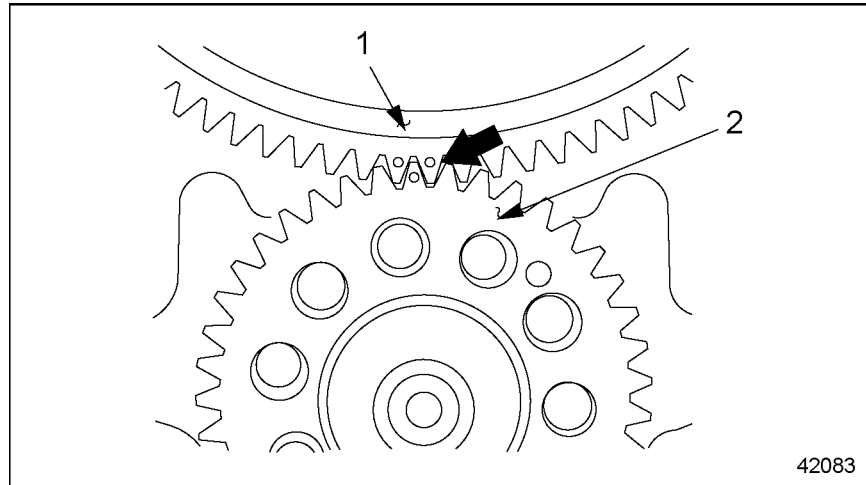
Installation steps are as follows:

1. Lubricate the tappets with a light coating of clean engine oil.
2. Install the tappets in the block, in order, as removed.
3. Install the camshaft and gear assembly.
 - [a] Attach the camshaft pilot disc (J-46183-1, part of toolset J-46183) bolts finger tight to the front of the camshaft.
 - [b] Thread the guide sleeve (J-41580-1, part of toolset J-46183) onto the pilot disc.

NOTE:

Leave pilot disc attaching bolts finger tight in order to adjust guide sleeve during installation procedure.

- [c] Rotate the camshaft and gear assembly until the marked gear teeth on the camshaft gear are aligned with the marked tooth on the crankshaft gear. See Figure 1-144.



1. Camshaft Gear

2. Crankshaft Gear

Figure 1-144 Aligning the Marked Gear Teeth

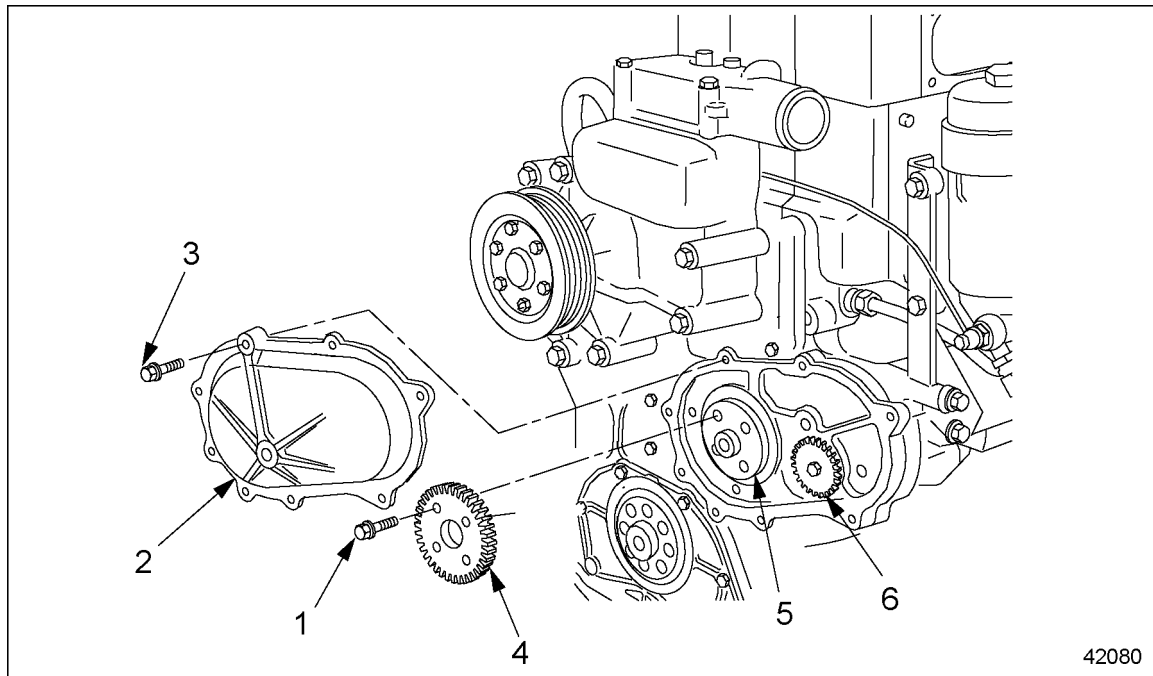
- [d] Lubricate the cam lobes, camshaft journals and guide sleeve with a light coating of clean engine oil.

NOTICE:

Do not damage the camshaft bearings in the crankcase. If the camshaft bearings are damaged, the crankcase will have to be replaced.

- [e] Using clean shop towels or gloves and from the gear end (rear of the engine), carefully insert the sleeve and guide the camshaft and gear assembly into the block.

[f] Remove the guide sleeve and pilot disc from the camshaft.



- | | |
|-----------------------------|--------------------------|
| 1. Drive Gear Mounting Bolt | 4. Fuel Pump Drive Gear |
| 2. Front Camshaft Cover | 5. Front of Camshaft |
| 3. Cover Mounting Bolt | 6. Fuel Pump Driven Gear |

Figure 1-145 Camshaft Assembly

4. Secure the fuel pump drive gear to the front of the camshaft with four new bolts. Torque the bolts to 60 N·m (44 lb·ft.). See Figure 1-145.
5. Check the backlash between the camshaft gear and the crankshaft gear, see specification listed in Table 1-47.
6. Install the flywheel housing. Refer to section 1.18.2.
7. Install the oil pan. Refer to section 3.2.2
8. Turn the engine on the stand until it is top side up.
9. Install the unit pumps. Refer to section 2.1.3.
10. Install the camshaft front cover on the cylinder block, as removed. Torque the mounting bolts to 50 N·m (37 lb·ft.). See Figure 1-140.
11. Install the air conditioning compressor, alternator, and mounting bracket. Refer to section 9.2.2.
12. Install the fan support. Refer to section 4.3.2.
13. Install the vibration damper. Refer to section 1.13.2.

14. Lubricate the pushrods with a light coating of clean engine oil. Install the pushrods and the rocker arm assemblies. Refer to section 1.21.4.

**DANGER:****FALLING ENGINE**

To avoid injury from a falling engine, an adequate lifting device with a spreader bar and sling should be used to lift the engine. The sling and spreader bar should be adjusted so the lifting hooks are vertical to prevent bending the lifter brackets. To ensure proper weight distribution, all provided lifter brackets must be used.

NOTICE:

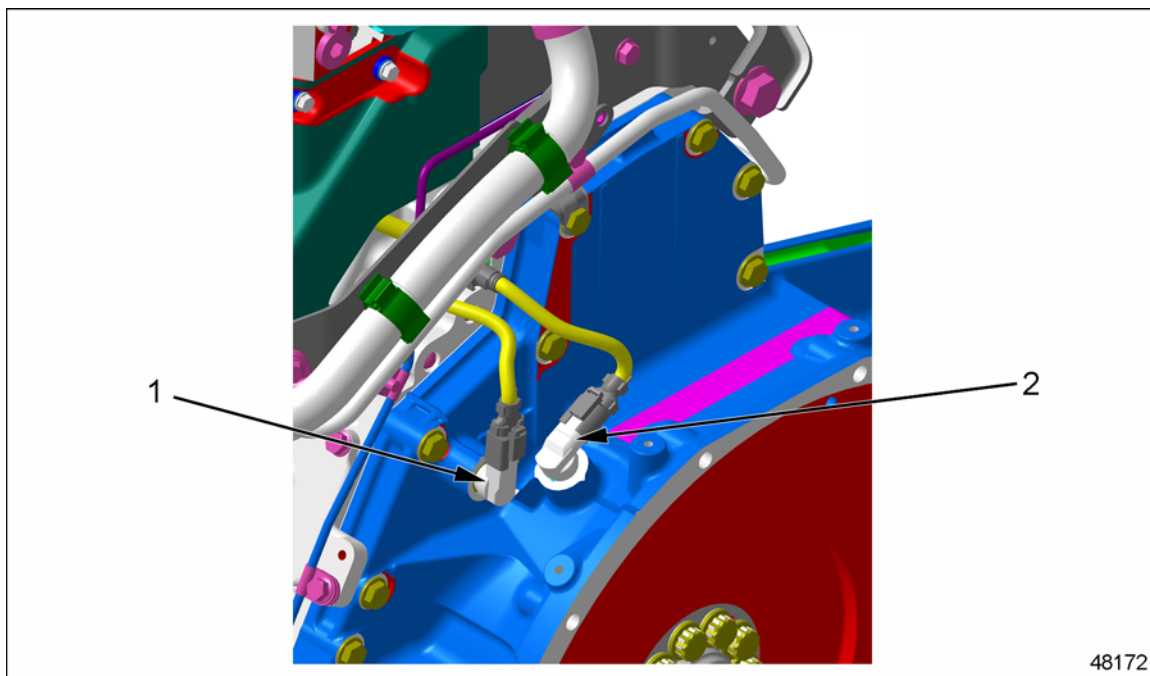
A spreader bar *must* be used at all times in conjunction with the front and rear lifter brackets to lift the EGR engine to ensure that no engine damage will result. The brackets are designed to lift vertically.

15. Remove the engine from the stand and install it in the vehicle.
16. Fill the engine with oil.
17. Fill the engine with coolant. Refer to section 4.1.1.

1.22.3 Replacement of Camshaft Position Sensor

Replacement steps are as follows:

1. Disconnect the electrical connector. See Figure 1-146.



1. Camshaft Position Sensor

2. Crankshaft Position Sensor

Figure 1-146 Camshaft Position Sensor

2. Remove the CMP sensor from the access hole in the flywheel housing.
3. Install a new CMP sensor in the flywheel housing. Push sensor downward until it contacts the flywheel housing.
4. Connect the electrical connector to the CMP.

NOTE:

Be sure that the correct electrical connector is connected to the sensor.

1.A ADDITIONAL INFORMATION

Description	Page
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SPECIFICATIONS

This section contains the specifications for servicing the engine.

Cylinder Head Cover

The torque specifications for the cylinder head cover are listed in Table 1-48.

Description	Torque N·m (lb·ft)
Cylinder Head Cover Studs	20–25 (15–18)
Cylinder Head Cover Cap Nuts	18–20 (13–15)

Table 1-48 Cylinder Head Cover Torque Values

Cylinder Head

The cylinder head warpage limits are listed in Table 1-49. The specifications for measuring cylinder liner protrusion are listed in Table 1-50. Cylinder head bolt length is listed in Table 1-51. The tightening stages for cylinder head bolts are listed in Table 1-52. Oil pressure readings are listed in Table 1-53. Cylinder head torque values are listed in Table 1-54. Cylinder head specifications are listed in Table 1-55. The specifications for compression testing are listed in Table 1-56 and listed in Table 1-57.

Description mm (in.)	Limit mm (in.)
Over a length of 150 (6)	0.15 (0.006)

Table 1-49 Head Warpage Limits

Description	Value: mm (in.)
Cylinder Liner Protrusion from block	0.2305-0.330 (0.0090-0.0130)
Difference between the four measuring points	Max.: 0.02 (0.0008)

Table 1-50 Specifications for Measuring Cylinder Liner Protrusion

Description	Length mm (in.)
Shaft length when new	210.0 (8.27)
Maximum shaft length	212.0 (8.35)

Table 1-51 Cylinder Head Bolt Lengths

Size	Max. Shaft Length mm (in.)	Tightening Stage	Torque Nm (lb ft) (Repair work in the field)
M15 x 2	212.0 (8.35)	Stage 1	10 (7)
		Stage 2	50 (37)
		Stage 3	100 (74)
		Stage 4	200 (148)
		Stage 5	90° more
		Stage 6	90° more

Table 1-52 Tightening Stages, Cylinder Head Bolts

Description	Minimum Oil Pressure Reading kPa (psi)
Engine at Idle Speed	50 (7)
Engine at Max. rpm	250 (36)

Table 1-53 Oil Pressure Readings

Description	Torque N·m (lb·ft)
Exhaust Manifold Bolts	50 (37); then another 90°
Inspection Cover on Flywheel Housing	25 (18)
Rocker Arm Mounting Bolts	60 (44); then another 90°

Table 1-54 Cylinder Head Torque Values

What To Measure	How To Measure	mm (in.)
Maximum Permissible Warpage of Head Mating Surface	Lengthwise and Diagonally	0.015 (0.006)
Maximum Permissible Parallelism Deviation of Head Mating Surface	At Each of the Four Corners	0.1 (0.004)
Overall Height of Cylinder Head	When New	113.85-114.15 (4.482-4.494)
	After Machining	113.5 (4.47)

Table 1-55 Cylinder Head Specifications

Description	Pressure kPa (psi)
Minimum Compression Pressure Valve	2800 (406)
Permissible Difference Between Individual Cylinders	400 (58)

Table 1-56 Compression Pressure Test Data

Description	N·m (lb·ft)
Tensioning Arm Bolts	50 (37)

Table 1-57 Tensioning Arm Bolt Torque Values

Cylinder Block

The cylinder liner installation tolerances are listed in Table 1-58. The cylinder liner inspection tolerances are listed in Table 1-59. Cylinder Liner measurements are listed in Table 1-60. The specifications for measuring cylinder liner protrusion are listed in Table 1-61.

Description	Value: mm (in.)
Cylinder Liner Protrusion, From Block, Fig. 1-15, Ref. A.	0.230–0.330 (0.0090–0.0130)
Height of the Cylinder Liner Collar, Fig. 1-15, Ref. B.	10.10–10.12 (0.3976–0.3984)
Depth of the Collar Seat, Fig. 1-15, Ref. C.	9.950–10.010 (0.3917–0.3941)
Thickness of the Seat Insert	0.14–0.16 (0.0055–0.0063)

Table 1-58 Cylinder Liner Installation Tolerances

Description	Value: mm (in.)
Admissible Out-of-Round of the Cylinder Liner, where it contacts the O-rings	Max.: 0.02 (0.0007)
Admissible Deformation of the Cylinder Liner Collar, at the Contact Surface with the Seat Insert	Max.: 0.02 (0.0007)
Admissible Deformation of the Liner Collar Seat, at the Contact Surface with the Seat Insert	Max.: 0.03 (0.0012)

Table 1-59 Cylinder Liner Inspection Tolerances

Where To Measure	What To Measure	Value: mm (in.)
Measuring Point 1: at the O-ring area	Inside Diameter of the Cylinder Liner, A class	127.990–127.995 (5.0390–5.0392)
Measuring Point 1: at the O-ring area	Inside Diameter of the Cylinder Liner, B class	127.995–128.005 (5.0392–5.0396)
Measuring Point 1: at the O-ring area	Inside Diameter of the Cylinder Liner, C class	128.005–128.010 (5.0396–5.0398)
Measuring Point 2: Upper Reversal Point of the First Piston Ring	Max. Wear to Cylinder Liner, Measured Along Axis A and Axis B	0.08 (0.003)
At Measuring Point 2, Compare Axis A to Axis B	Admissible Wear-Out	Max.: 0.08 (0.003)

Table 1-60 Cylinder Liner Measurements

Description	Value: mm (in.)
Cylinder Liner Protrusion From Block	0.245–0.315 (0.0096–0.0124)
Difference Between the Four Measuring Points	Max.: 0.02 (0.0008)

Table 1-61 Specifications for Measuring Cylinder Liner Protrusion

Crankshaft Assembly

The specifications for the torque of the main bearing-cap bolts is listed in Table 1-62. Crankshaft specifications are listed in Table 1-63. The dimensions for the center bearing shell and bearing journal are listed in Table 1-64. The crankshaft bearing journal dimensions are listed in Table 1-65. The main and connecting-rod bearing as well as the main bearing shell dimensions are listed in Table 1-66 and listed in Table 1-67. The torque values for the crankshaft counterweight bolts are listed in Table 1-68.

Max. Shaft Length: mm (in.)	Tightening Stage	Torque N·m (lb·ft)
156.0 (6.14)	Stage 1	100 (74)
156.0 (6.14)	Stage 2	200 (148)
156.0 (6.14)	Stage 3	300-330 (221-243)
156.0 (6.14)	Stage 4	additional 90-100 degrees

Table 1-62 Tightening Stages, Main Bearing-Cap Bolts

Description	Specification mm (in.)*
Main Bearing and Connecting Rod Journal Hardness (Rockwell hardness)	53 to 59 HRC
Permissible Deviation From True of Crankshaft†	0.09 (0.004)
Permissible Out-Of-Round for Main and Connecting-Rod Bearing Journals - When New or Reground	0.01 (0.0004)
Permissible Out-Of-Round for Main and Connecting-Rod Bearing Journals - Wear Limit	0.02 (0.0008)
Fillet Radii of Main Bearing and Connecting-Rod Bearing Journals	4.2-4.5 (0.165-0.177)
Crown of Main Bearing Journals and Connecting-Rod Journals	0.000-0.004 (0.0000-0.0002)
Main Bearing Outside Diameter (diameter of bearing shell housing)	111.000-111.022 (4.3701-4.3709)
Permissible Imbalance of Crankshaft‡ -at 400 rpm	0.6 N·cm (0.05 lb·in)

* Except as otherwise noted.

†Measure with the crankshaft mounted on the outer main bearing journals.

‡With the pin for the flywheel installed, but without the flywheel, and with the crankshaft mounted on the outer bearings.

Table 1-63 Crankshaft Specifications

Size: mm (in.)	Center Bearing Shell Width mm (in)	Center Bearing Journal Width mm (in.)
Standard	45.74-45.81 (1.801-1.804)	46.000-46.062 (1.8110-1.8135)
Undersize - 0.50 (0.020)	46.24-46.31 (1.820-1.823)	46.500-46.562 (1.8307-1.8331)
Undersize - 1.00 (0.040)	46.74-46.81 (1.840-1.843)	47.000-47.062 (1.8504-1.8528)

Table 1-64 Bearing Shell and Bearing Journal Width

Size: mm (in.)	Main Bearing Journal Diameter: mm (in.)	Connecting-Rod Bearing Journal Diameter: mm (in.)
Standard	103.980-104.000 (4.0937-4.0945)	93.980-94.000 (3.7000-3.7007)
Undersize - 0.10 (0.004)	103.880-103.900 (4.0898-4.0905)	93.880-93.900 (3.6960-3.6968)
Undersize - 0.25 (0.010)	103.730-103.750 (4.0839-4.0846)	93.730-93.750 (3.6901-3.6909)
Undersize - 0.50 (0.020)	103.480-103.500 (4.0740-4.0748)	93.480-93.500 (3.6803-3.6811)
Undersize - 0.75 (0.030)	103.230-103.250 (4.0642-4.0650)	93.230-93.250 (3.6705-3.6712)
Undersize - 1.00 (0.040)	102.980-103.000 (4.0543-4.0551)	92.980-93.000 (3.6606-3.6614)

Table 1-65 Crankshaft Journal Diameters

Type of Journal:	Width mm (in.)
Main Journal	46.000-46.250 (1.8110-1.8209)
Connecting-Rod Journal	46.0-46.1 (1.811-1.815)

Table 1-66 Bearing Journal Width

Size: mm (in.)	Main Bearing Inside Diameter mm (in.)	Main Journal Outside Diameter mm (in.)
Standard	104.060-104.106 (4.0969-4.0987)	103.980-104.000 (4.0937-4.0945)
Undersize - 0.10 (0.004)	103.960-104.006 (4.0929-4.0947)	103.880-103.900 (4.0898-4.0905)
Undersize - 0.25 (0.010)	103.810-103.856 (4.0870-4.0888)	103.730-103.750 (4.0839-4.0846)
Undersize - 0.50 (0.020)	103.560-103.606 (4.0772-4.0790)	103.480-103.500 (4.0740-4.0748)
Undersize - 0.75 (0.030)	103.310-103.356 (4.0673-4.0691)	103.230-103.250 (4.0642-4.0650)
Undersize - 1.00 (0.040)	103.060-103.106 (4.0575-4.0593)	102.980-103.000 (4.0543-4.0551)

Table 1-67 Bearing Shell and Bearing Journal Diameter

Size	Shaft Length when New mm (in.)	Max. Bolt Length mm (in.)	Tightening Stage	Torque N·m (lb·ft)
-	69.95 - 70.00 (2.754 - 2.756)	71.20 (2.803)	Stage 1	150 (111)
			Stage 2	Additional 90°

Table 1-68 Torque Values for Crankshaft Counterweight Bolts

Flywheel and Flywheel Housing

The flywheel specifications are listed in Table 1-69. The ring gear specifications are listed in Table 1-70. Listed in Table 1-71 are the torque values for the flywheel and the flywheel housing. The tightening stages for the flywheel mounting bolts are listed in Table 1-72.

Description	Specification mm (in.)
Flywheel Outside Diameter	486.60-487.40 (19.157-19.189)
Flywheel Shoulder Diameter (for ring gear mounting)	432.450-432.645 (17.0256-17.0333)
Flywheel Diameter at Crankshaft Flange	114.980-115.015 (4.5268-4.5282)
Flywheel Diameter for Mounting Clutch	475.000-475.063 (18.7008-18.7033)
Flywheel Minimum Width Between Friction Surface and Mounting Flange After Machining	60 (2.4)
Flywheel Maximum Overall Width	70 (2.8)
Peak-to-Valley Height (R_z) of Clutch Friction Surface	0.016 (0.006)
Flywheel Permissible Deviation From True (radial and lateral)	0.2 (0.008)

Table 1-69 Flywheel Specifications

Description	Specification, mm (in.)
Flywheel Shoulder Diameter (for ring gear mounting)	432.450-432.645 (17.0256-17.0333)
Hole for Mounting Clutch Pressure Plate	M10 x 1.5
Ring Gear Inside Diameter	432.000-432.155 (17.0078-17.0140)
Ring Gear/Flywheel Interference Fit	0.295-0.645 (0.0116-0.0254)
Ring Gear/Flywheel Permissible Radial Runout	0.5 (0.02)
Ring Gear Width	18.4-18.6 (0.72-0.73)
Ring Gear Fitting Temperature	200-230°C (390-450°F)

Table 1-70 Flywheel Ring Gear Specifications

Item	Torque, N·m (lb·ft)
Inspection Cover on Flywheel Housing	25 (18)
Flywheel Housing Mounting Bolts (to cylinder block)	70 (52)
Vibration Damper Mounting Bolts (to crankshaft)	200 (148)

Table 1-71 Torque Values for Flywheel and Flywheel Housing

Max. Shaft Length, mm (in.)	Tightening Stage	Torque N·m (lb·ft)
77.0 (3.03)	Stage 1	200 (148)
77.0 (3.03)	Stage 2	90 degrees

Table 1-72 Tightening Stages, Flywheel Mounting Bolts

Piston, Piston Ring and Connecting Rod

The piston projection specifications are listed in Table 1-73. The piston ring end-gap dimensions are listed in Table 1-74. Listed in Table 1-75 are the pistons inspection specifications. The tightening stages for the connecting rod stretch bolts are listed in Table 1-76. The connecting rod dimensional tolerances are listed in Table 1-77. Listed in Table 1-78 are the connecting rod bearing play specifications. The specifications for the diameter of the bearing bore are listed in Table 1-79. Listed in Table 1-80 are the bearing journal specifications. The connecting rod bushing specifications are listed in Table 1-81.

Description	mm (in.)
Piston Projection (from TDC)	0.244 to 0.715 (0.0096 to 0.0282)

Table 1-73 Piston Projection Specifications

Ring Designation	Groove	Gap When New, mm (in.)	Maximum End Gap, mm (in.)
Keystone	I	0.45 to 0.60 (0.018 to 0.024)	1.0 (.039)
Taper-Faced with Internal Angle	II	0.40 to 0.55 (0.016 to 0.022)	1.0 (.039)
Double-Chamfered Oil Control with Garter Spring	III	0.40 to 0.55 (0.016 to 0.022)	1.0 (.039)

Table 1-74 Piston Ring End-Gap Dimensions

Description	Dimensions: mm (in.)
Piston Compression Height	79.50-79.55 (3.130-3.132)
Wrist Pin Bore Diameter	52.03-52.04 (2.0484-2.0488)
Wrist Pin Diameter	51.992-51.998 (2.0469-2.0472)

Table 1-75 Piston Inspection Specifications

Max. Shaft Length mm (in.)	Tightening Stage	Torque Value N·m (lb·ft)
68.5 (2.70)	Stage 1	108 (80)
	Stage 2	Additional 90 degree rotation

Table 1-76 Tightening Stages, Connecting Rod Stretch Bolts

Description	Dimensions: mm (in.)
Length of Connecting Rod	255.970-256.030 (10.0776-10.0799)
Basic Bore Diameter for Connecting Rod Bearings	99.000-99.022 (3.8976-3.8985)
Maximum Permissible Out-of-Round in Bearing Bore	0.01 (0.0004)
Maximum Permissible Out-of-Round in Bushing Bore	0.01 (0.0004)
Maximum Difference in Axial Parallelism Between Bearing Bore and Bushing Inner Surface	0.030 (0.0012)
Width of Connecting Rod (at big end)	44.308-44.370 (1.7444-1.7469)
Width of Connecting Rod Journal	44.5-44.6 (1.75-1.76)
Distance from Connecting Rod Center Line for Measuring Parallelism	50 (2)

Table 1-77 Connecting Rod Dimensional Tolerances

Description	Dimensions: mm (in.)
Radial Play	0.054 - 0.116 (0.0021 - 0.0046)
End Play (axial play)	0.130 - 0.292 (0.0051 - 0.0115)

Table 1-78 Connecting Rod Bearing Play Specifications

Repair Stage: mm (in.)	Diameter: mm (in.)
Standard	94.054-94.096 (3.7029-3.7046)
Undersize - 0.1 (0.004)	93.954-93.996 (3.6990-3.7006)
Undersize - 0.25 (0.010)	93.804-93.846 (3.6931-3.6947)
Undersize - 0.50 (0.020)	93.554-93.596 (3.6832-3.6849)
Undersize - 0.75 (0.030)	93.304-93.346 (3.6734-3.6750)
Undersize - 1.00 (0.040)	93.054-93.096 (3.6635-3.6652)

Table 1-79 Bearing Bore Inside Diameter with Bearing Shells Installed

Repair Stage: mm (in.)	Diameter: mm (in.)
Standard	93.980-94.000 (3.7000-3.7008)
Undersize - 0.10 (0.004)	93.880-93.900 (3.6961-3.6969)
Undersize 0.25 (0.010)	93.730-93.750 (3.6902-3.6909)
Undersize 0.50 (0.020)	93.480-93.500 (3.6803-3.6811)
Undersize 0.75 (0.030)	93.230-93.250 (3.6705-3.6713)
Undersize 1.00 (0.040)	92.980-93.000 (3.6606-3.6614)

Table 1-80 Bearing Journal Specifications

Description	Dimensions: mm (in.)
Inside Diameter of Bushing	52.05-52.07 (2.049-2.050)
Outside Diameter of Bushing	57.080-57.100 (2.2472-2.2480)
Inside Diameter of Bushing Bore	57.000-57.019 (2.2441-2.2448)
Bushing Interference Fit	0.061-0.100 (0.0024-0.0039)
Maximum Permissible Out-of-Round in Bushing Bore	0.01 (0.0004)

Table 1-81 Bushing Specifications

Valves

The valve removal/installation specifications are listed in Table 1-82. The valve head recess depth specifications are listed in Table 1-83. The valve guide inside diameter measurements are listed in Table 1-84. The spring specifications for the intake and exhaust valves are listed in Table 1-85. The valve lift specifications are listed in Table 1-86. The measurements for valve lash checking are listed in Table 1-87. The measurements for valve seat specifications for an EGR engine are listed in Table 1-88.

Description	Intake, mm (in.)	Exhaust, mm (in.)
Valve stem diameter (A)	8.935-8.950 (0.3518-0.3524)	8.925-8.940 (0.3514-0.3520)
Valve seat diameter at head contact surface (B)	42.0 (1.65)	39.0 (1.54)
Valve head diameter (C)	45.4-45.6 (1.79-1.80)	41.9-42.3 (1.65-1.67)
Valve seat height-new (D)	3.1-3.3 (0.12-0.13)	3.0-3.3 (0.12-0.13)
Minimum valve seat height-after grinding (D)	2.9 (0.11)	2.9 (0.11)
Valve seat width at valve head (E)	3.5-4.5 (0.14-0.18)	min. 3.5 (0.14)
Valve seat angle (F)	30 degrees	36 degrees
Valve length (G)	145.0 (5.71)	145.0 (5.71)

Table 1-82 Valve Removal/Installation Specifications

Valve Type	Description	mm (in.)
Intake	Normal	0.7-1.1 (0.03-0.04)
Intake	Wear Limit	1.6 (0.06)
Exhaust	Normal	0.7-1.1 (0.03-0.04)
Exhaust	Wear Limit	1.6 (0.06)

Table 1-83 Valve Head Recess Depth

Description	mm (in.)
Normal	9.000-9.022 (0.3543-0.3552)
Wear Limit	9.050 (0.3563)

Table 1-84 Inside Diameter of Valve Guide

Description	mm (in.)
Length, Without Load	69.7 (2.74)
Length, Under Load of 382-418 N·m (86-94 lb-ft)	49 (1.9)
Length, Under Load of 644-706 N·m (145-159 lb-ft)	37 (1.5)
Diameter of Spring Wire	4.2 (0.17)
Outside Diameter of Spring Coil	28.9 (1.14)
Inside Diameter of Spring Coil	24.5-24.9 (0.96-0.98)

Table 1-85 Spring Specifications, Intake and Exhaust Valves

Description	Specification mm (in.)
Specified Dial Gauge Preload for Checking Valve Lift	15 (0.60)
Valve Lift with Intake Valves Completely Open	11.546 (at least 0.4546)
Valve Lift with Exhaust Valves Completely Open	11.963 (at least 0.4710)

Table 1-86 Valve Lift Specifications

Valve Type	Adjust to: mm (in.)
Intake	0.40 (0.016)
Exhaust	0.60 (0.024)

Table 1-87 Valve Lash Adjustment

Description	Intake Valve, mm (in.)	Exhaust Valve-EGR, mm (in.)
Valve seat angle (E)	30 Degree	36 Degree
Valve seat surface diameter (G)	41.99-42.01(1.65-1.654)	38.99-39.01(1.535-1.536)
Relative position (H) to diameter G	4.00-4.15 (0.157-0.163)	4.00-4.15 (0.157-0.163)

Table 1-88 Valve Seat Specifications

Rocker Arm

The rocker arm mounting bolt specifications are listed in Table 1-89. Listed in Table 1-90 are the rocker arm specifications. Listed in Table 1-91 are the rocker arm bushing specifications.

Size	Max. Shaft Length mm (in.)	Torque N·m (b·ft)
M12	91 (3.6)	60 (44)
		additional 90°

Table 1-89 Specifications, Rocker Arm Mounting Bolts

Description	Stage	Specification mm (in.)
Outside Diameter of Valve Tappets	Normal	29.931-29.952 (1.1784-1.1792)
Outside Diameter of Valve Tappets	Repair Stage I	30.444-30.465 (1.1986-1.1994)
Diameter of Tappet Seats (in cylinder block)	Normal	30.000-30.021 (1.1811-1.1819)
Diameter of Tappet Seats (in cylinder block)	Repair Stage I	30.500-30.525 (1.2008-1.2018)
Total Length of Pushrods		345.0-346.5 (13.58-13.64)
Maximum Pushrod Warp		0.5 (0.02)
Maximum Length of Rocker Arm Mounting Bolts		91 (3.6)

Table 1-90 Rocker Arm Specifications

Description	Specification, mm (in.)
Bushing Inside Diameter (when installed)	25.005-25.021 (0.9844-0.9851)
Shaft Diameter	24.967-24.980 (0.9830-0.9835)

Table 1-91 Rocker Arm Bushing Specifications

Camshaft and Camshaft Sensor

The camshaft specifications are listed in Table 1-92. The valve tappet specifications are listed in Table 1-93. Listed in Table 1-94 are the torque values for the camshaft.

What To Measure	Where To Measure	Value: mm (in.) Unless otherwise noted
Hardness of Surface	At Cams and Journals	57–63 HRC
Camshaft Radial Runout When Mounted on Outer Bearing Journals	At Gear Seat	0.020 (0.0008)
Camshaft Radial Runout When Mounted on Outer Bearing Journals	At Cam Circle	0.025 (0.0010)
Camshaft Radial Runout When Mounted on Outer Bearing Journals	At Camshaft Journals	0.030 (0.0012)
Minimum Valve Cam Rise—Above Basic Circle	Intake Valve	7.3 (0.29)
Minimum Valve Cam Rise—Above Basic Circle	Exhaust Valve	8.2 (0.32)
Camshaft Journal Diameter	For New Camshaft	81.893–81.928 (3.2241–3.2255)
Bushing Diameter	At Camshaft Journals	82.000–82.035 (3.2283–3.2297)
Gear Back Lash	Cam Gear to Crank Gear	0.074–0.176 (0.0029–0.0069)
Gear Back Lash	Cam Gear to Air Compressor Gear	0.082–0.168 (0.0032–0.0066)

Table 1-92 Camshaft Specifications

Description	Repair Stage	Specifications, mm (in.)
Tappet Outside Diameter	Standard	29.931–29.952 (1.1784–1.1792)
Tappet Outside Diameter	Repair Stage I	30.444–30.465 (1.1986–1.1994)
Tappet Housing Diameter (in cylinder block)	Standard	30.000–30.021 (1.1811–1.1819)
Tappet Housing Diameter (in cylinder block)	Repair Stage I	30.500–30.525 (1.2008–1.2018)

Table 1-93 Valve Tappet Specifications

Fastener Type	N·m (lb·ft)
Camshaft Front Cover	50 (37)
Fuel Pump Drive Gear	60 (44)

Table 1-94 Camshaft Torque Values

Sensor and Fittings

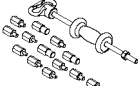
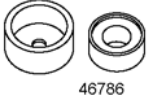
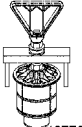
The torque specifications for the fuel and coolant temperature sensors as well as some fittings are listed in Table 1-95.

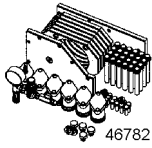
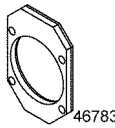
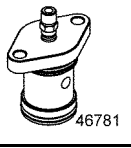
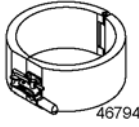
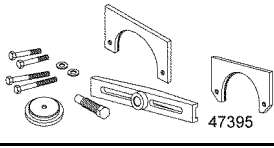
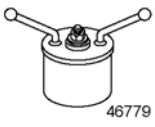
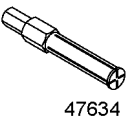
Description	Torque N·m (lb·ft)
Deaeration Line Banjo Bolt	35 (26)
Constant Throttle Valve (CTV) Air Supply Line Banjo Bolt	45 (33)
Fuel Temperature Sensor to Engine Block	30 (22)
Coolant Temperature Sensor to the Engine Block	30 (22)
Trim Cover Bolts	12 (9)

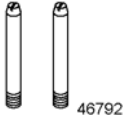
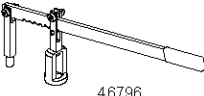
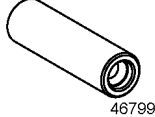
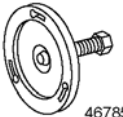
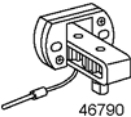
Table 1-95 Sensor and Fittings Torque Values

Special Tools

The special tools used within this chapter are listed in Table 1-96.

Tool	Description	Usage	Part Number
 47635	Slide Hammer	Used to remove the flywheel pilot bearing.	J-6471-02
 46775	Impact Socket	Use to remove and install the cylinder head bolts.	J-45389
 46791	19-mm Flywheel and Main Pulley Socket	Use to remove and install the flywheel and main front pulley.	J-45390
 46786	Front Seal Installer	Used to install the front crankshaft radial seal.	J-45391 (part of kit J-47273)
 46789	Rear Crankshaft Seal Installer	Used to install the rear crankshaft radial seal.	J-45393-A (part of kit J-47273)
 46778	Cylinder Liner Removal Tool	Used when removing the cylinder liner.	J-45876

Tool	Description	Usage	Part Number
 46782	Head and Block Leak Tester Tool Kit	Used to pressure check the cylinder block.	J-45982
 46783	Top Block Cover Plate	Used to pressure check the cylinder block.	J-45982-1 (part of kit J-45982)
 46781	Dummy Unit Pump	Used to pressure check the cylinder block.	J-45982-6-1
 47938	Cylinder Head Leak Test Kit	Used to pressure test the cylinder head.	J-45982-8
 46794	Ring Compressor	Used to compress the piston rings when installing the piston in the cylinder block.	J-45983
 47395	Front/Rear Wear Sleeve Remover (Crankshaft)	Used to remove the front or rear crankshaft seal wear sleeve.	J-45989 (part of kit J-47273)
 46780	Measuring Plate	Used to measure cylinder liner protrusion.	J-46071
 46779	Cylinder Liner Installation Tool	Used when installing the cylinder liner.	J-46168
 47632	Flywheel Pilot Bearing Installer	Used to install the flywheel pilot bearing.	J-46169
 47634	Flywheel Pilot Bearing Remover	Used to remove the flywheel pilot bearing.	J-46170

Tool	Description	Usage	Part Number
 46792	Flywheel Guide Pins (set of 2)	Used to guide the flywheel during removal and installation.	J-46172
 46796	Valve Spring Remover Tool	Used to remove the valve springs from the cylinder head.	J-46173
 46798	Valve Stem Seal Protector	Used to protect the valve stem seals during installation.	J-46174
 46795	Cylinder Head Fixture	Used when removing the valves from the cylinder head.	J-46175
 46797	Go/no Go Gauge	Used to measure the inside diameter of the valve guide.	J-46181
 46800	Camshaft Remover/Installer	Used to remove and install the camshaft in the engine.	J-46183
 46799	Valve Stem Seal Installer	Used to install the valve stem seal.	J-46184
 46788	Rear Seal Puller	Used to remove the rear crankshaft radial seal.	J-46188 (part of kit J-47273)
 46785	Front Seal Puller	Used to remove the front crankshaft radial seal.	J-46383
 46790	Engine Barring Tool	Used to lock or rotate the engine flywheel.	J-46392

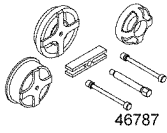
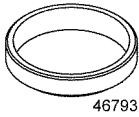
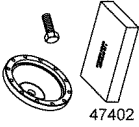
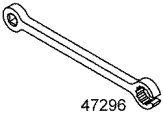
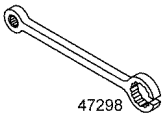
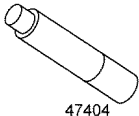
Tool	Description	Usage	Part Number
	Constant-Throttle Valve (CTV) Spring Remover	Used to remove constant throttle valve spring.	J-46401
	Front/Rear Oversize Seal Installer	Used to remove and install the oversize front and rear crankshaft radial seal.	J-47067 (part of kit J-47273)
	Sleeve	Used when installing the piston in the cylinder block.	J-47110
	Front/Rear Wear Sleeve Installer (Crankshaft)	Used to install the front or rear crankshaft seal wear sleeve.	J-47271 (part of kit J-47273)
	Front Crankshaft Seal Puller	Used to remove the front crankshaft seal.	J-47272 (part of kit J-47273)
	17MM Fuel Line Wrench	Used to remove the high pressure fuel lines	J-47483
	24MM Fuel Line Wrench	Used to remove or hold thrust bolt at the high pressure fuel lines	J-47484
	Universal Driver Handle	Used with various tools as a driver.	J-8092 (part of kit J-47273)

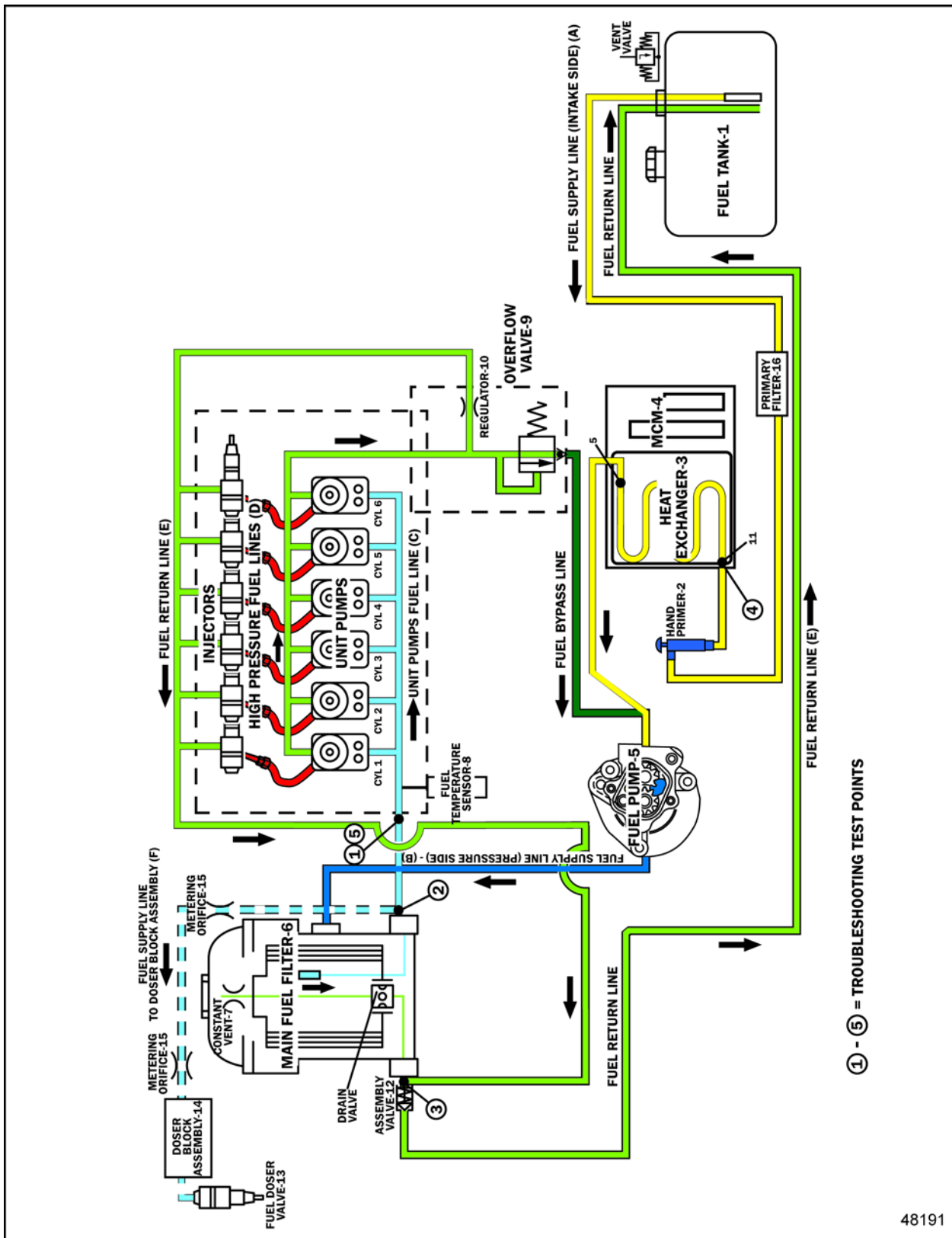
Table 1-96 Special Tools

2 FUEL SYSTEM

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2.1 ELECTRONIC UNIT PUMP

The electronic unit pump is controlled by the Motor Control Module (MCM). The electronic unit pump produces the fuel pressure required for injection and delivers the fuel under pressure to the respective fuel injection. See Figure 2-1 for an overview of the fuel system.



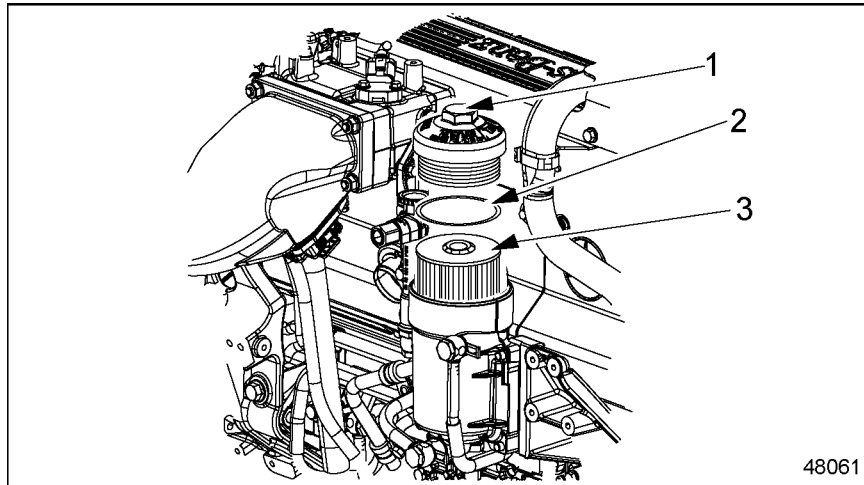
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Figure 2-1 Fuel System Schematic

2.1.1 Removal of electronic unit pump

Removal steps are as follows:

1. Remove the engine trim cover.
2. Unscrew the fuel filter cap to allow fuel to drain back to tank. See Figure 2-2.



1. Fuel Filter Cap

3. Filter Element

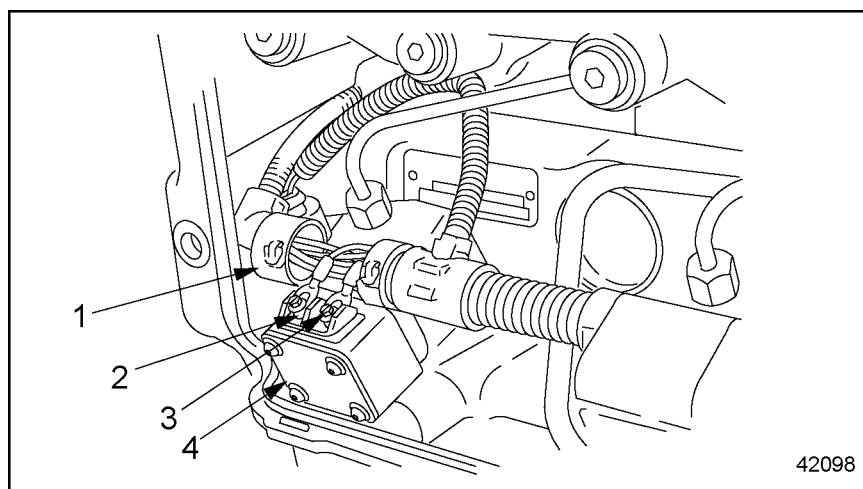
2. O-ring

Figure 2-2 Main Fuel Filter

NOTE:

Unscrewing the fuel filter cap releases pressure in the fuel system, causing fuel to flow through the return lines and back into the tank.

3. Disconnect the engine wiring harness from the electronic unit pump. See Figure 2-3.



1. Engine Wiring Harness

2. Terminal

3. Terminal Screw

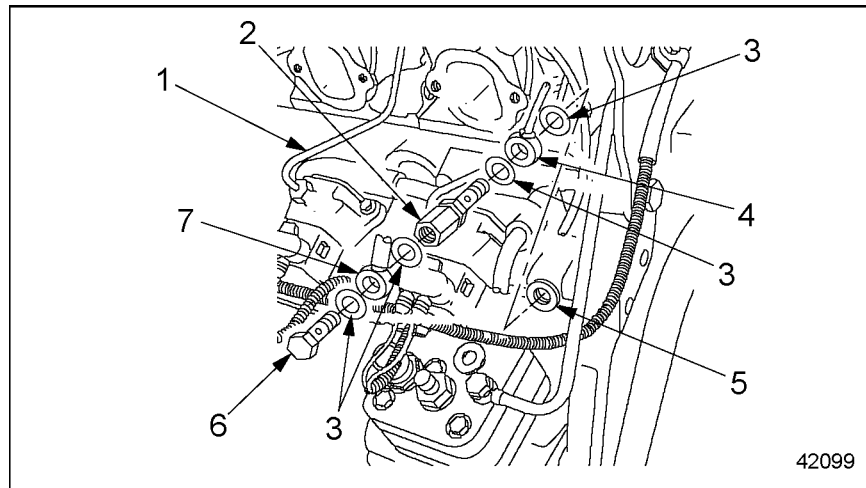
4. Electronic unit pump

Figure 2-3 electronic unit pump Electrical Wires

 WARNING: PERSONAL INJURY
To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles.

4. Remove the high-pressure fuel line and transfer tube. Refer to section 2.4.1.
5. Disconnect the fuel line at the fuel gallery inlet. Have a suitable container ready to catch any fuel that comes out of the cylinder block or fuel line.

6. Drain fuel from the engine through the fuel gallery outlet on the return lines. See Figure 2-4.



- | | |
|------------------------------|-----------------------------------|
| 1. High-Pressure Fuel Line | 5. Fuel Gallery Outlet |
| 2. Overflow Valve | 6. Hollow-Core Banjo Bolt |
| 3. Washers | 7. Fuel Return Line Banjo Fitting |
| 4. Nozzle Line Banjo Fitting | |

Figure 2-4 Fuel Return Lines

- [a] Remove the fuel return line banjo bolt and fitting from the overflow valve. Discard the seal rings.
- [b] Have a suitable container ready to catch any fuel that runs out of the cylinder block or return lines.
- [c] Unscrew the threaded end of the overflow valve from the fuel gallery outlet.
- [d] Remove the nozzle line banjo fitting from the overflow valve. Discard the seal rings.
- [e] Mark the fasteners with a paint pen for ease of installation.
- [f] Clean out the fuel gallery outlet with compressed air.

NOTE:

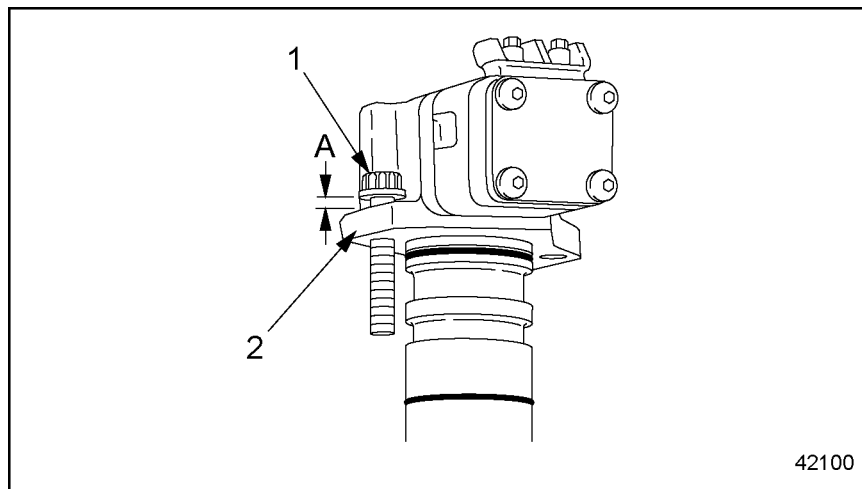
This step is necessary to prevent fuel from contaminating the engine oil in the block.

- 7. Remove the end cover from the lower right side of the flywheel housing, then attach the engine barring tool (J-46392).

! WARNING:**EYE INJURY**

To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).

8. Carefully loosen the EUP mounting bolts about 6 mm (1/4 inch), but do not remove them yet. See Figure 2-5.



1. Mounting Bolt

2. Head of electronic unit pump

Figure 2-5 Mounting Bolts

9. Using the engine barring tool (J-46392), rotate the crankshaft until the cam pushes the electronic unit pump upwards.

NOTICE:

If the electronic unit pump doesn't come out easily, do not try to pry up on the body of the pump. This will damage it.

10. If the electronic unit pump is locked up, or frozen, in its seat, release it using the blade of a small screwdriver under the flange where the mounting bolt attaches. See arrow in Figure 2-6.

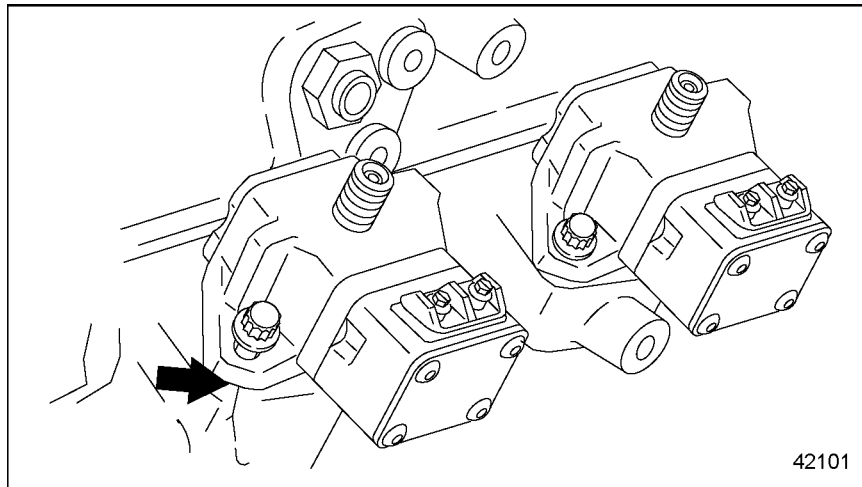
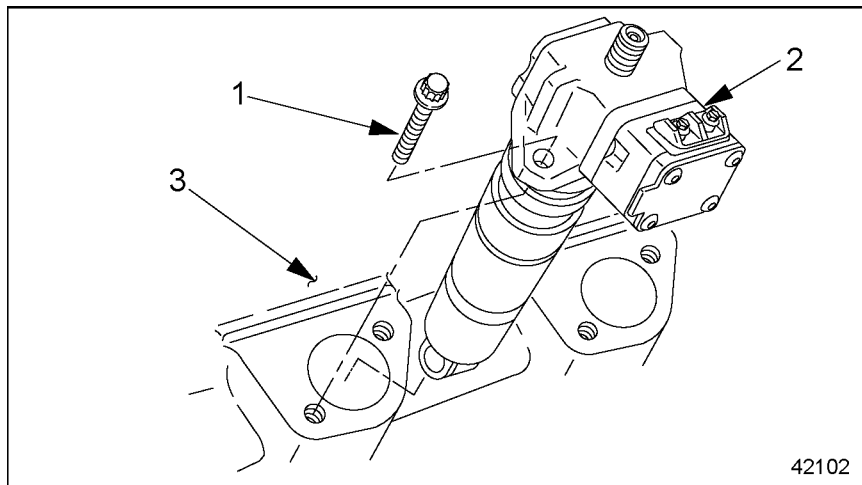


Figure 2-6 **Locked-up electronic unit pump**

11. Remove both mounting bolts completely. Carefully pull the electronic unit pump out of the cylinder block. See Figure 2-7.



1. Mounting Bolt

3. Cylinder Block

2. electronic unit pump

Figure 2-7 **electronic unit pump**

12. Check the EUP for fuel leakage at the solenoid. If leakage is found, refer to section 2.1.2.
13. Check the EUP for wear or damage. If any is found, refer to section 2.1.3.
14. Remove and discard the two O-rings on the electronic unit pump shaft.

2.1.2 Repair of electronic unit pump Solenoid

Repair steps are as follows:

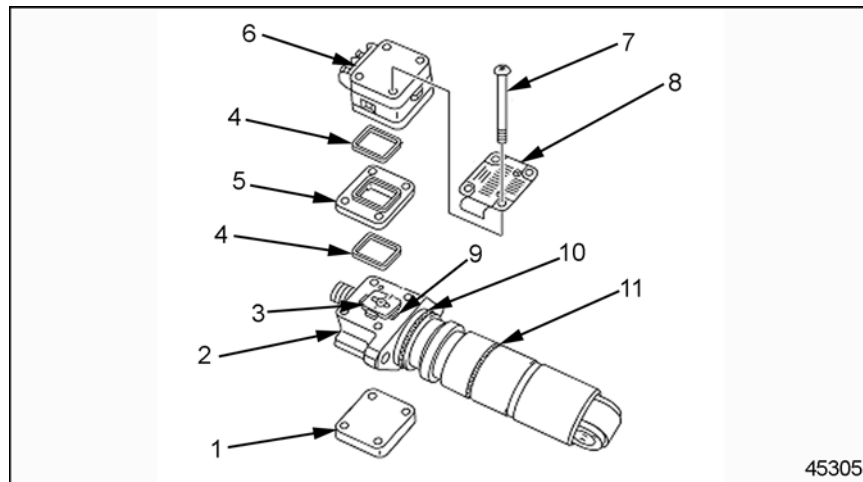
**WARNING:****PERSONAL INJURY**

To avoid injury from penetrating fluids, do not put your hands in front of fluid under pressure. Fluids under pressure can penetrate skin and clothing.

**WARNING:****FIRE**

To avoid injury from fire, keep all potential ignition sources away from diesel fuel, including open flames, sparks, and electrical resistance heating elements. Do not smoke when refueling.

1. Identify the failed electronic unit pump and failure mode (fuel leak at the solenoid). Remove the failed electronic unit pump. Refer to section 2.1.1 for electronic unit pump removal procedure. See Figure 2-8.

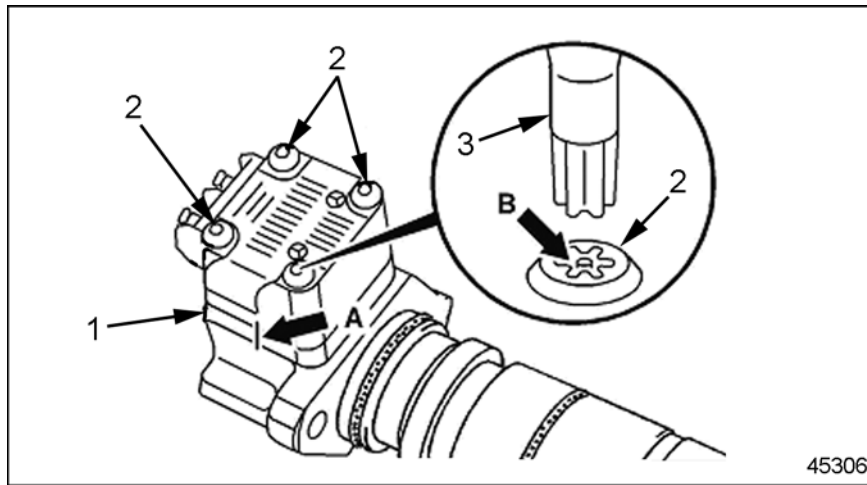


- | | | |
|-------------------------|-----------------------|----------------|
| 1. Stop Plate | 5. Intermediate Plate | 9. Cross Piece |
| 2. electronic unit pump | 6. Magnet | 10. O-ring |
| 3. Anchor Plate | 7. Screw | 11. O-ring |
| 4. Seal | 8. Model Plate | |

Figure 2-8 electronic unit pump Components

2. Wipe the pump clean, removing excess fuel.
3. Remove the O-rings from the electronic unit pump. Push the electronic unit pump O-ring installer (J-45373) onto the electronic unit pump. This will prevent dirt from entering the electronic unit pump holes.

4. Mark the position of the intermediate plate in relation to the electronic unit pump body (See arrow A of Figure 2-9) and rest the electronic unit pump on the stop plate. Use a pencil or scribe for marking. Do not use any stamping tools.



1. Intermediate Plate

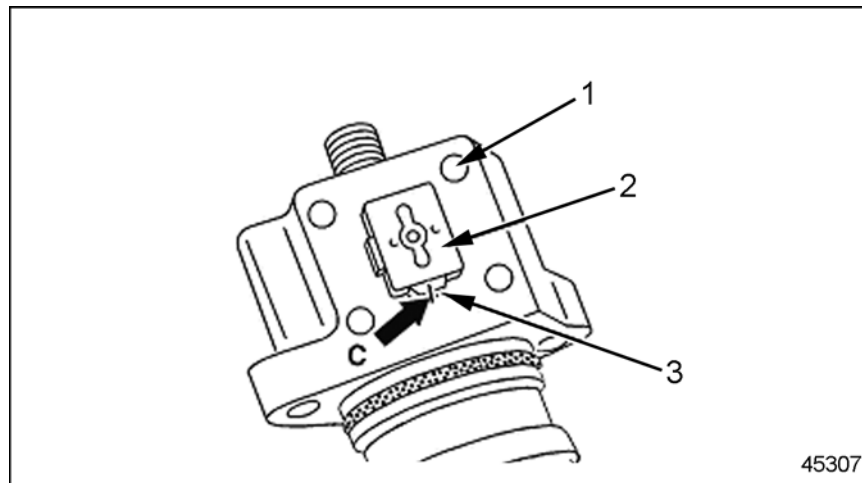
3. Torx Bit

2. Screw

Figure 2-9 Magnet and Intermediate Plate

5. Remove all traces of paint from screw heads. Remove screws using the torx bit (P/N: 9045890210/00) and lift off the magnet together with the intermediate plate and model plate. (See arrow B of Figure 2-9).
6. Remove the intermediate plate and the model plate from the magnet. Wipe clean the sealing surface on the magnet, removing any excess fuel. Clean the model plate and remove paint from the screw heads contact area.
7. Remove the two spacer seals and clean the intermediate plate. Do not damage sealing surfaces.

8. Mark the cross piece and anchor plate in relation to the electronic unit pump. (See arrow C of Figure 2-10). Use a marker; do not use a scribe or stamping tool. The cross piece should not be moved or twisted.



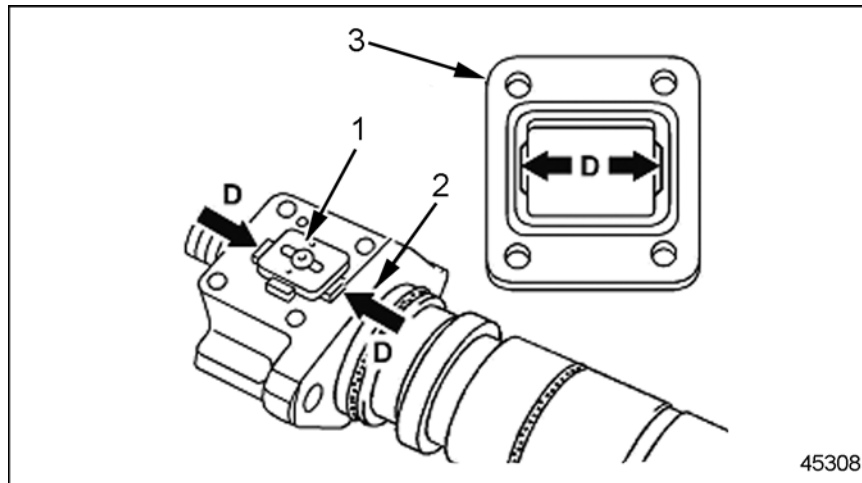
1. electronic unit pump
2. Anchor Plate

3. Cross Piece

Figure 2-10 Cross Piece and Anchor Plate

9. Wipe clean the sealing surfaces on the electronic unit pump, cross piece, and anchor plate, removing any excess fuel. Clean the parts thoroughly. Do not remove the paint on the electronic unit pump; it is used as a reference point for the intermediate plate assembly.
10. Remove the stop plate.
11. Place a new stop plate under the electronic unit pump body.
12. Install the new seals in the intermediate plate. Protect the seals with a thin layer of high-temperature grease.
13. Place the intermediate plate on the electronic unit pump body. Observe the identification mark on the cross piece and anchor plate for the electronic unit pump body. The cutouts (see arrows D of Figure 2-11) at the opening in the intermediate plate must face towards

the cross piece. The painted surface is a reference mark to the intermediate plate assembly on the electronic unit pump.



- 1. Anchor Plate
- 2. Cross Piece

- 3. Intermediate Plate

Figure 2-11 Intermediate Plate

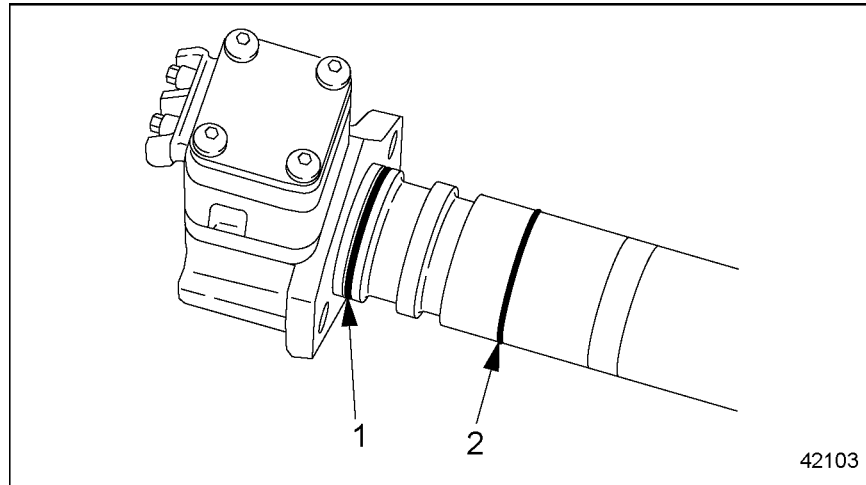
14. Place the magnet on the intermediate plate and place the model plate on the magnet.
15. Secure the model plate, magnet, intermediate plate, electronic unit pump and stop plate together using new screws. Hand tighten.
16. Tighten the screws in a crosswise pattern to 5 N·m (4 lb·ft), using torx bit (P/N: 9045890210/00).
17. Push the electronic unit pump O-ring installer (J-45373) onto the electronic unit pump.
18. Install new O-rings on the electronic unit pump and install the electronic unit pump in the engine. Refer to section 2.1.3 for installation procedures.

2.1.3 Installation of electronic unit pump

Installation steps are as follows:

1. Lubricate two new O-rings with a light coating of engine oil.

2. Install the two new O-rings on the electronic unit pump shaft using the electronic unit pump O-ring installer (J-45373). See Figure 2-12.



1. Inner (larger) O-ring

2. Outer (smaller) O-ring

Figure 2-12 O-ring

3. Install the EUP into the cylinder block.
 - [a] Insert the EUP into the mounting hole in the cylinder block.
 - [b] Use light hand pressure to push in the electronic unit pump until it seats, about 4 mm (0.16 inch). If it won't seat easily, rotate the crankshaft until the electronic unit pump seats.

NOTE:

Use the bolt mounting holes on the engine as a guide for positioning the injector pump.

4. Install the mounting bolts, and tighten to 65 N·m (48 lb·ft).
5. Connect the engine wiring harness to the EUP.
6. Remove the engine barring tool (J-46392) and replace the inspection cover on the flywheel housing. Tighten the inspection cover mounting bolts to 25 N·m (18 lb·ft).



WARNING:

PERSONAL INJURY

To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles.

7. Connect the fuel line at the fuel gallery inlet. Tighten the fitting to 50 N·m (37 lb·ft).
8. Install the fuel lines and overflow valve on the fuel gallery outlet. Tighten all fasteners to 50 N·m (37 lb·ft).

- [a] Install the inner banjo fitting, and two new seal rings, on the overflow valve, as marked on removal.
 - [b] Install the threaded end of the overflow valve in the fuel gallery outlet. When the valve is firmly seated, tighten to 50 N·m (37 lb·ft).
 - [c] Install the outer banjo fitting, again with two new seal rings, on the banjo bolt, as marked on removal.
 - [d] Install the banjo bolt on the overflow valve and tighten to 50 N·m (37 lb·ft).
9. Install the fuel filter cap. Inspect the O-ring in the fuel filter and replace it if worn. Tighten the cap nut to 25 N·m (18 lb·ft).
10. Install the high-pressure fuel line and transfer tube. Refer to section 2.4.2.

**WARNING:****ENGINE EXHAUST**

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

11. Start the engine and check for leaks. Tighten connections as needed.
12. Install the engine trim cover.

2.2 FUEL RETURN AND NOZZLE SPILL LINE

The following sections support the repair of the fuel spill line.

2.2.1 Removal of Fuel Return and Nozzle Line

Removal steps are as follows:

 WARNING: FIRE
To avoid injury from fire, keep all potential ignition sources away from diesel fuel, including open flames, sparks, and electrical resistance heating elements. Do not smoke when refueling.
 WARNING: FIRE
To avoid injury from fire caused by heated diesel-fuel vapors: ☐ Keep those people who are not directly involved in servicing away from the engine. ☐ Stop the engine immediately if a fuel leak is detected. ☐ Do not smoke or allow open flames when working on an operating engine. ☐ Wear adequate protective clothing (face shield, insulated gloves and apron, etc.). ☐ To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.

1. Remove two side and one rear engine trim cover.
2. Remove bolt (M6 x 20 mm) from rear trim cover bracket at air intake manifold and side bracket.
3. Remove air intake manifold.
4. Disconnect electrical connector at the electrostatic oil separator.
5. Remove the cylinder head covers.
6. Remove the fuel spill banjo bolt (M16) and washers at overflow valve on left side rear of the cylinder block.
7. Remove banjo bolt and washers (M8) from rear of fuel filter. Discard washers.
8. Remove three bolts (M8 x 35) on clamps securing the return line on the left side of the cylinder block.

9. Remove six banjo bolts and washers (M8) securing the nozzle spill line at each cylinder head and remove line. Discard the washers.

2.2.2 Installation of Fuel Return and Nozzle Line

Installation steps are as follows:

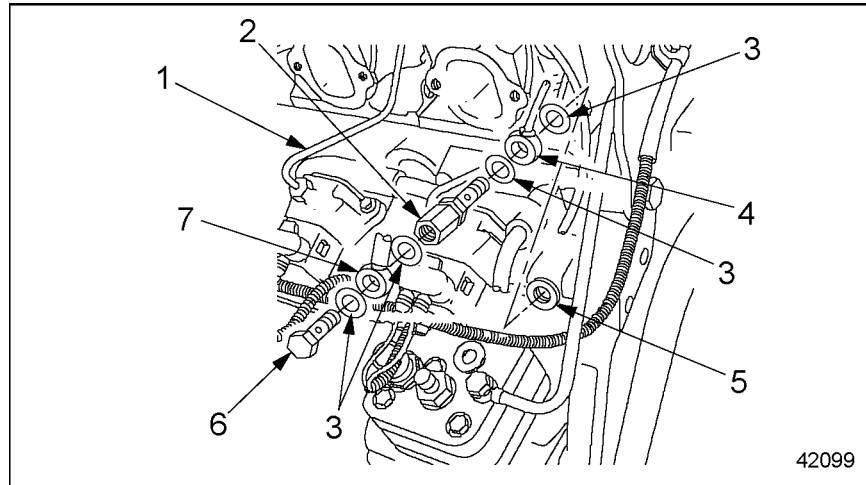
1. Install six banjo bolts and new washers and secure the spill line at each cylinder head. Torque the banjo bolts to 15 N·m (11 lb·ft).
2. Install three bolts in clamps securing the fuel return line on the left side of the cylinder block. Torque the bolts to 25 N·m (18 lb·ft).
3. Secure the small nozzle spill line from the cylinder heads to the cylinder block with overflow valve and new washers. Torque the overflow valve to 50 N·m (37 lb·ft).
4. Connect the large fuel return line to the overflow valve with the banjo bolt and new washers. Hold the overflow valve with a wrench and torque the banjo bolt (M16) to 50 N·m (37 lb·ft).
5. Install the banjo bolt and new washers in the large and small fuel spill line to the fuel pump. Torque the banjo bolt to 40-50 N·m (30-37 lb·ft).
6. Install the cylinder head covers.
7. Connect the electrical connector at the electrostatic oil separator.
8. Install the air intake manifold.
9. Install the two side and one rear engine trim cover.

2.3 FUEL OVERFLOW VALVE

The following sections support the repair of the fuel overflow valve.

2.3.1 Removal of Fuel Overflow Valve

Removal steps are as follows:



- | | |
|------------------------------|-----------------------------------|
| 1. High-Pressure Fuel Line | 5. Fuel Gallery Outlet |
| 2. Overflow Valve | 6. Hollow-Core Banjo Bolt |
| 3. Washers | 7. Fuel Return Line Banjo Fitting |
| 4. Nozzle Line Banjo Fitting | |

Figure 2-13 Overflow Valve

1. Remove the banjo bolt and washers securing the fuel return line to the overflow valve. Discard the washers.
2. Remove the overflow valve and washers from the fuel spill banjo fitting. Discard the washers.

2.3.2 Installation of Fuel Overflow Valve

Installation steps are as follows:

1. Install new washers between the fuel spill banjo fitting and install the fuel overflow valve. Torque the overflow valve to 50 N·m (37 (lb·ft)).
2. Secure the fuel return line to the overflow valve with banjo bolt and new washers. Torque the banjo bolt to 50 N·m (37 (lb·ft)).

2.4 HIGH PRESSURE FUEL LINE AND TRANSFER TUBE

The following sections support the repair of the high pressure fuel line and transfer tubes.

NOTICE:

When replacing high pressure fuel line(s), always replace the associated transfer tube. High pressure fuel lines and transfer tubes are one-time use components. Always discard the old high pressure fuel line and transfer tube.
--

NOTICE:

Any repair to the fuel system requires the fuel tank cap to be removed, to release any trapped air pressure in the fuel tank.

2.4.1 Removal of High Pressure Fuel Line and Transfer Tube

Remove as follows:

**WARNING:****PERSONAL INJURY**

To prevent the escape of high pressure fuel that can penetrate skin, ensure the engine has been shut down for a minimum of 10 minutes before servicing any component within the high pressure circuit. Residual high fuel pressure may be present within the circuit.

**WARNING:****FIRE**

To avoid injury from fire, keep all potential ignition sources away from diesel fuel, including open flames, sparks, and electrical resistance heating elements. Do not smoke when refueling.

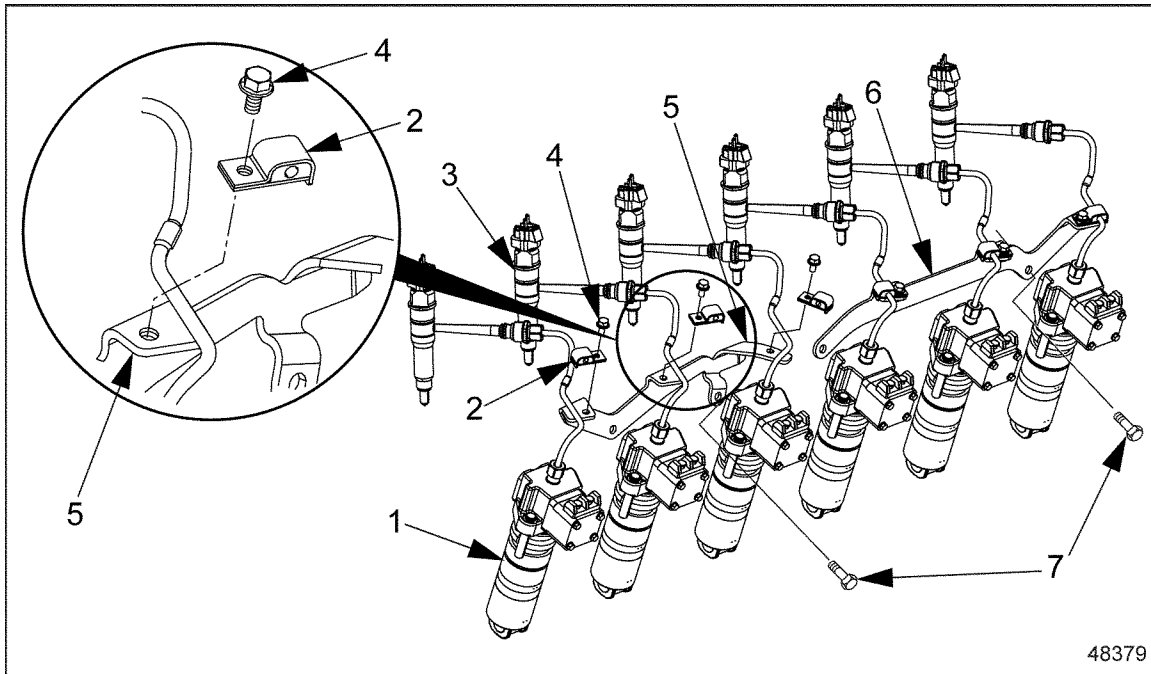
**WARNING:****FIRE**

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ Keep those people who are not directly involved in servicing away from the engine.
- ☐ Stop the engine immediately if a fuel leak is detected.
- ☐ Do not smoke or allow open flames when working on an operating engine.
- ☐ Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).
- ☐ To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.

1. Remove both engine trim covers.
2. Remove the cylinder head cover for each cylinder head.
3. Remove the intake manifold.
4. To prevent the transfer tube from rotating during the high pressure fuel line disassembly, secure the transfer tube thrust nut using a 24 mm fuel line wrench (J-47484 or J-45063)

and loosen the high pressure fuel line nut at the transfer tube using a 17 mm fuel line wrench (J-47483) or a 17 mm open end wrench. See Figure 2-14.



- | | |
|------------------|---------------------|
| 1. Unit Pumps | 5. Mounting Bracket |
| 2. Damper Clamps | 6. Mounting Bracket |
| 3. Fuel Injector | 7. Bracket Bolts |
| 4. Bolts | |

Figure 2-14 High Pressure Fuel Line

! WARNING:

PERSONAL INJURY

To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles.

NOTICE:

The high pressure fuel line and transfer tube are one-time use items. Failure to install a new high pressure fuel line and transfer tube will cause fuel leaks and high pressure fuel line failures.

5. Using a 17 mm fuel line wrench (J-47483) or a 17 mm open end wrench, loosen the high pressure fuel injector line nut at the injector unit pump. Discard the high pressure fuel injector line. See Figure 2-14.
6. Using 24 mm fuel line wrench (J-45063 or J-47484), loosen the thrust nut on the transfer tube. Remove and discard the transfer tube and the O-ring. See Figure 2-14.

2.4.2 Installation of High Pressure Fuel Line and Transfer Tube

Installation steps are as follows:

NOTICE:

New high pressure fuel injector lines are supplied ready for installation. Never use pliers or sharp-edged tools to bend injector lines. Doing so could damage them. High pressure fuel injector lines should fit without tension over the transfer tube and unit pump fittings.
--

NOTICE:

Discard the old high pressure fuel line and transfer tube. Do not re-use them!
--

1. Apply a light coat of clean engine oil to the transfer tube O-ring and install the transfer tube into the cylinder head.
2. Using a 24 mm socket, torque the thrust nut to 45 N·m (33 lb·ft).
3. Align the new high pressure fuel injector line fittings to the transfer tube and unit pump. Ensure the fuel line is not installed backwards, and that the end of the high pressure fuel line is properly seated in the transfer tube and unit pump fitting.
4. Hand tighten the high pressure fuel injector line nut first at the unit pump, and then at the transfer tube. While hand tightening the nuts, gently move the high pressure fuel line back and forth to ensure the end of the line is properly seated in the transfer tube and unit pump fitting. See Figure 2-15 for the proper orientation of the fuel line. If the high pressure fuel injector line has been installed incorrectly and torqued, remove the high pressure fuel

injector line and transfer tube and replace with new parts. Ensure that the damper is not touching any other fuel lines or other engine or vehicle components.

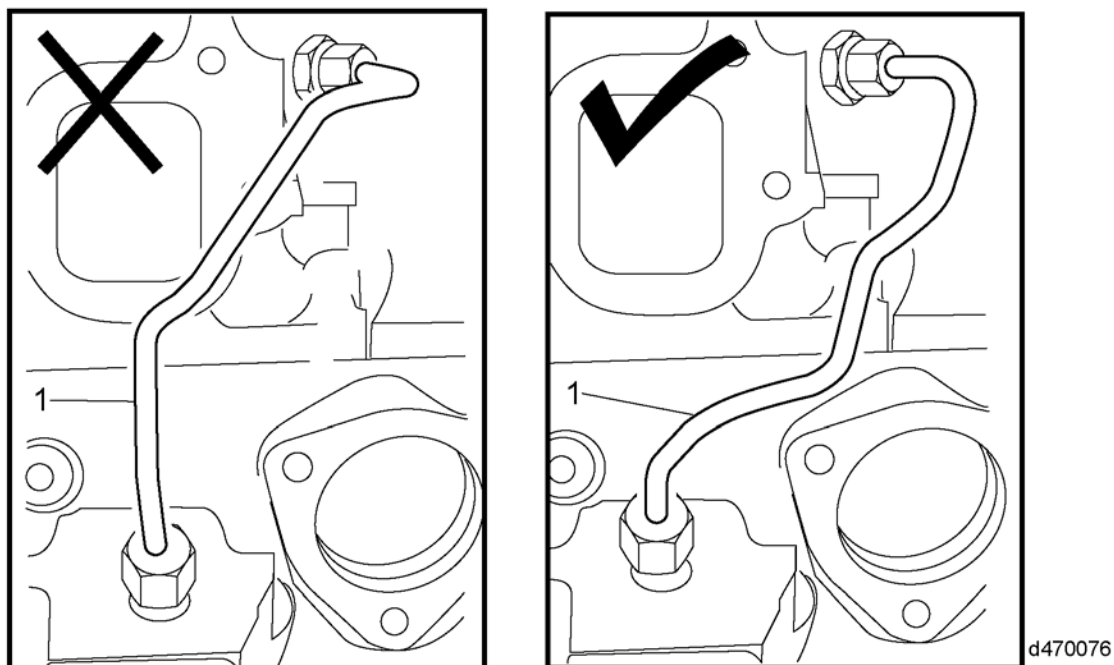
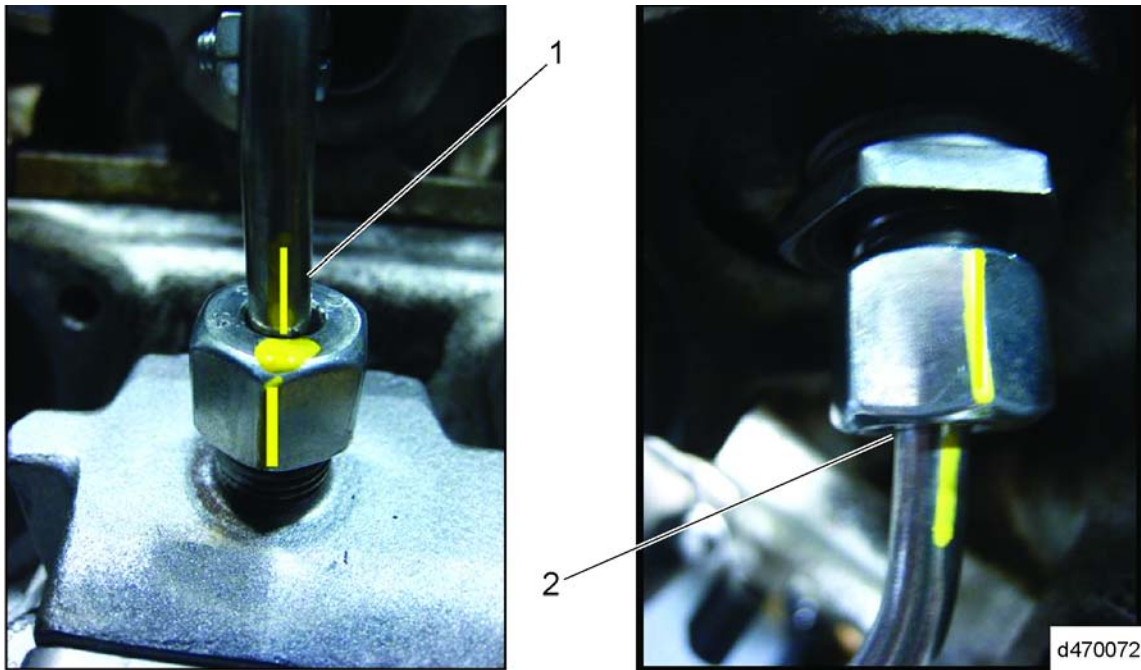


Figure 2-15 **Orientation of Fuel Line**

5. Once the high pressure fuel injector line nuts are hand tight, draw a vertical line with a highly visible marker along the front edge of both of the nuts and up the fuel line. The line drawn along the edge of the nuts and the fuel line should be aligned.



1. Electronic Unit Pump End

2. Transfer Tube End

Figure 2-16 Marking Of High Pressure Fuel Injector Line And Nuts

6. Using a 17 mm fuel line wrench (J-47483) or a 17 mm open end wrench, tighten the high pressure fuel line nut at the unit pump end by turning the nut through 120 degrees. 120 degrees can be measured by turning the nut so that the nut edge which had been marked has been turned through 1/3 of a full turn, or through two nut flats. Lack of space in some

engine configurations may mean that the 120 degree turn will have to be completed in two turns of 60 degrees, or one nut flat each.

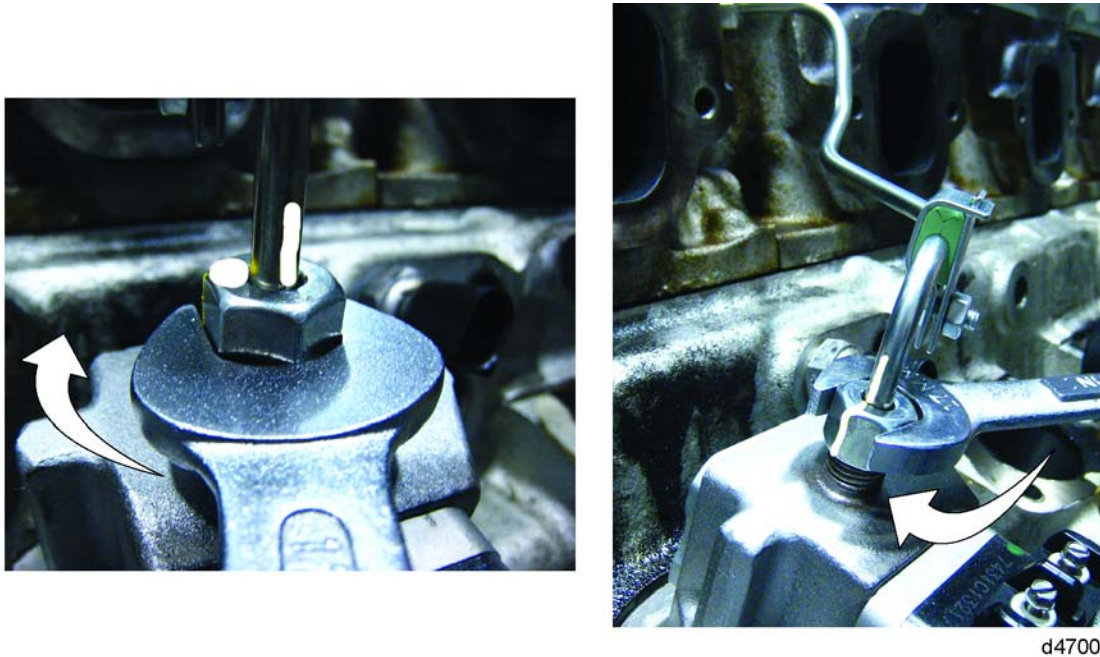
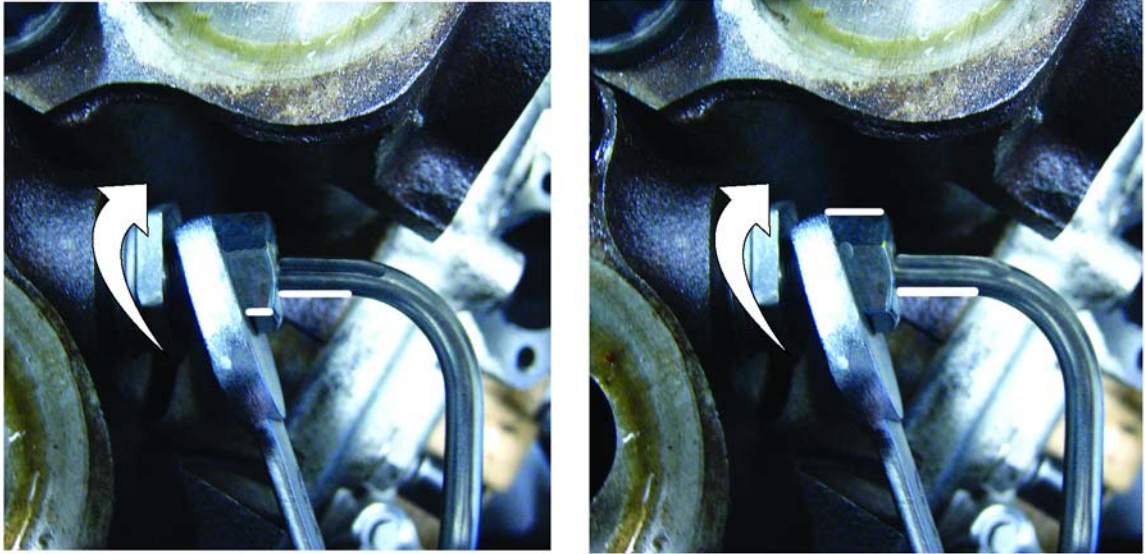


Figure 2-17 Turning Fuel Line Nut 120 Degrees at Unit Pump End

7. Use a 24 mm fuel line wrench (J-45063 or J-47484), hold the transfer tube thrust nut. Using a 17 mm fuel line wrench (J-47483) or a 17 mm open end wrench, tighten the high pressure fuel injector line nut at the transfer tube end by turning the nut through 120 degrees. 120 degrees can be measured by turning the nut so that the nut edge which had been marked has been turned through 1/3 of a full turn, or through two nut flats. Lack of

space in some engine configurations may mean that the 120 degree turn will have to be completed in two turns of 60 degrees, or one nut flat each.



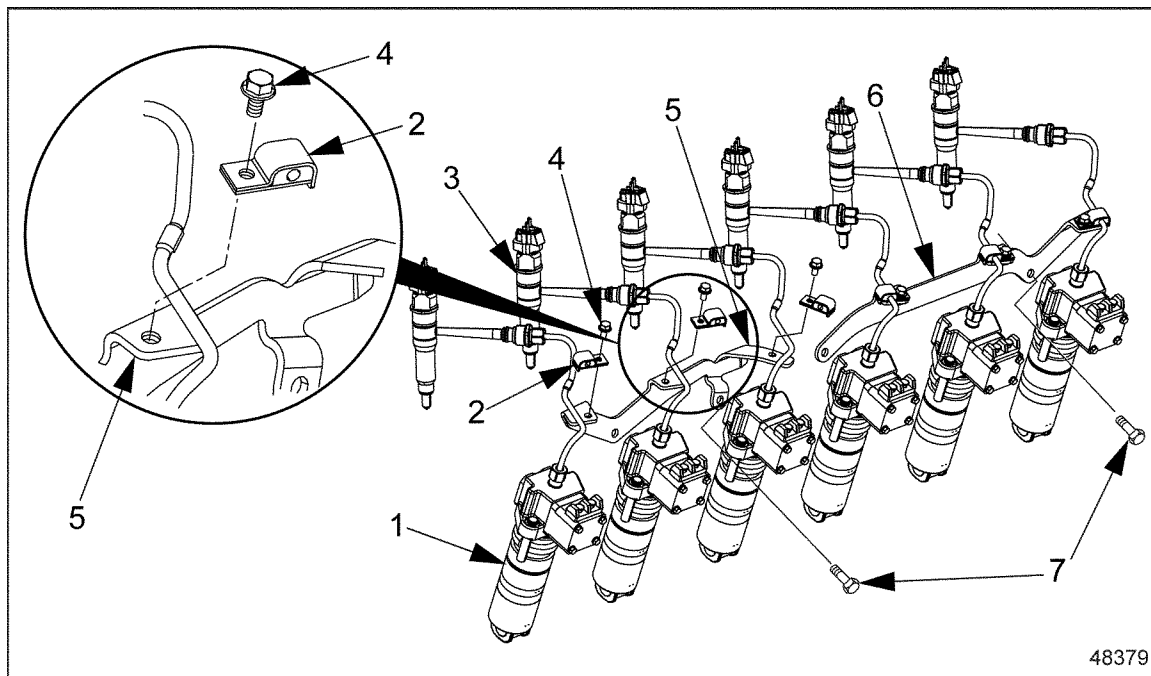
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Figure 2-18 Turning Fuel Line Nut 120 Degrees At Transfer Tube End

NOTICE:
To avoid damage to the high pressure fuel injector lines when applying torque, ensure that the transfer tube thrust nut is held in place with a 24 mm wrench such as (J-45063 or J-47484).

- Loosely install the damper clamp onto the high-pressure fuel line and attach it to the mounting bracket. See Figure 2-19.

9. Torque the high pressure fuel line mounting bracket bolts to 25 N·m (18 lb·ft.). Torque the damper clamp bolt and nut to 12 N·m (9 lb·ft.).



- | | |
|------------------|---------------------|
| 1. Unit Pumps | 5. Mounting Bracket |
| 2. Damper Clamps | 6. Mounting Bracket |
| 3. Fuel Injector | 7. Bracket Bolts |
| 4. Bolts | |

Figure 2-19 Mounting Bracket

10. Install the air intake manifold.
11. Install the cylinder head cover.



WARNING:

ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

NOTICE:

Do NOT loosen any high pressure fuel injector line nuts or other fuel line connections for priming purposes. Use the priming port on the fuel filter housing for engine S/N 0460810824 (EGR) or S/N 0460805219 (non-EGR) and higher. Engines built prior to the change points will have the priming port installed through

NOTICE:

Campaigns 06C-2 (EGR) and 06C-1 (non-EGR). Never loosen fuel line connections to bleed air from the fuel system.

12. Prime the fuel system. Refer to section "Priming the Fuel System".
13. Run the engine and check for leaks.

NOTICE:

Do NOT re-torque high pressure fuel injector line nuts. If leaks are detected after installation, remove the necessary high pressure fuel injector line and transfer tube, discard them, and install new parts.

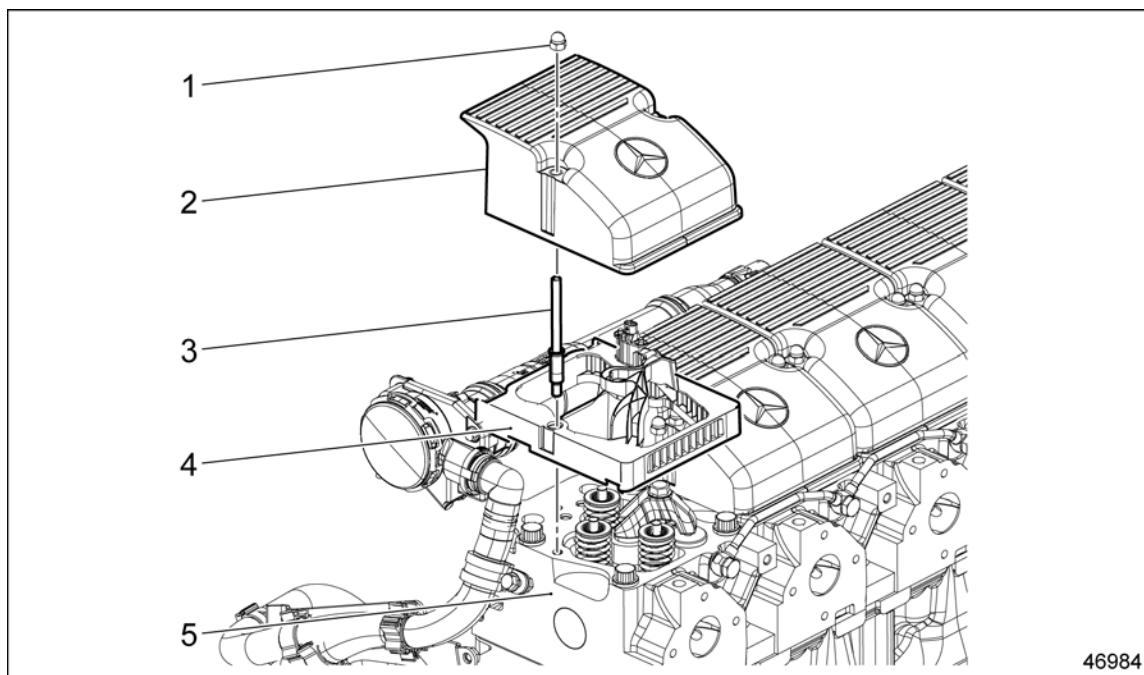
14. Shut down the engine and install the engine trim covers.

2.5 FUEL INJECTOR HARNESS ADAPTOR FRAME

The following sections support the fuel injector harness adaptor frame.

2.5.1 Removal of Fuel Injector Harness Adaptor Frame

Removal steps are as follows:



- | | |
|------------------------|-----------------------------------|
| 1. Caps Nuts | 4. Injector Harness Adaptor Frame |
| 2. Cylinder Head Cover | 5. Cylinder Head |
| 3. Studs (qty 2) | |

Figure 2-20 **Injector Harness Adaptor Frame**

1. Remove the cylinder head cover(s).
2. Disconnect the electrical harness connector from the harness adaptor frame.
3. Disconnect the fuel injector electrical connector harness nuts from the fuel injector.
4. Using a stud removing tool, carefully remove the two cylinder head cover studs from the cylinder head.
5. Remove the injector harness adaptor frame and adapter frame gasket from the cylinder head. Inspect the gasket, if damaged replace. See Figure 2-20.

2.5.2 Installation of Fuel Injector Harness Adaptor Frame

Installation steps are as follows:

1. Install the gasket and adaptor frame on the cylinder head. See Figure 2-20.
2. Install the two cylinder head cover studs in the cylinder head. Torque the studs to 25 N·m (18 lb·ft). See Figure 2-20.
3. Connect the electrical harness connector nuts to the fuel injector. Torque the nuts to 2 N·m (1.5 lb·ft.).
4. Connect the electrical harness connector to the harness adaptor frame.
5. Install the gasket and the cylinder head cover(s).

2.6 FUEL INJECTOR

The following sections support the repair of the fuel injector.

2.6.1 Removal of Fuel Injector

Removal steps are as follows:

1. Remove the injector harness adaptor frame from the required cylinder head.
Refer to section 2.5.2.

NOTE:

The MBE 4000 engine has individual heads for each cylinder. To remove the injector for one cylinder, do these procedures step by step. To remove all the fuel injectors, repeat each step in these instructions, as applicable, for all six cylinders.

2. Remove the air intake manifold.



WARNING:

FIRE

To avoid injury from fire, keep all potential ignition sources away from diesel fuel, including open flames, sparks, and electrical resistance heating elements. Do not smoke when refueling.



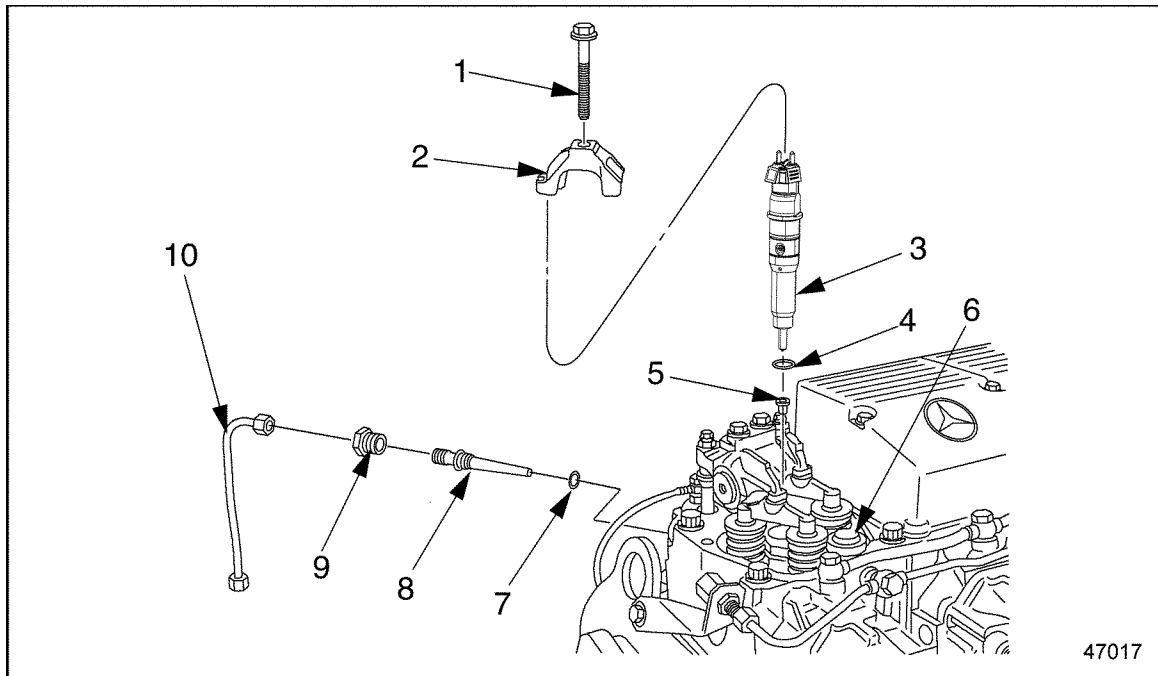
WARNING:

FIRE

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ Keep those people who are not directly involved in servicing away from the engine.
- ☐ Stop the engine immediately if a fuel leak is detected.
- ☐ Do not smoke or allow open flames when working on an operating engine.
- ☐ Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).
- ☐ To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.

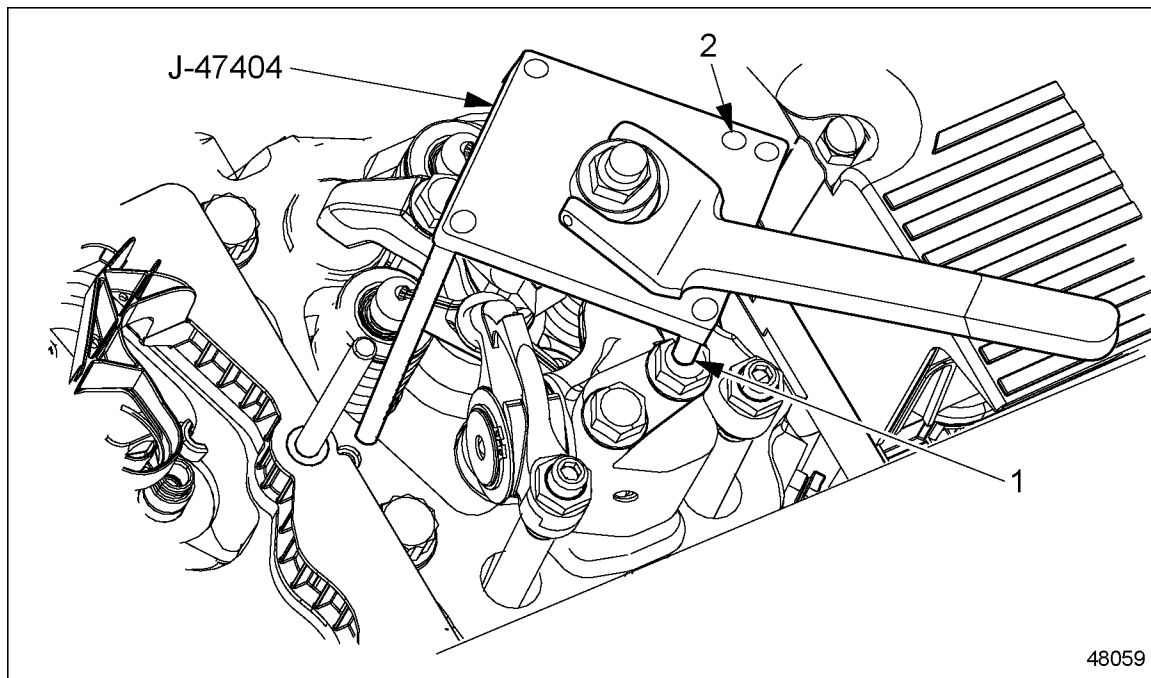
3. Remove the high pressure fuel line and transfer tube. Refer to section 2.4.1.



- | | |
|---------------------------|--------------------------------|
| 1. Tensioning Arm Bolt | 6. Constant-Throttle End Cover |
| 2. Tensioning Arm | 7. O-ring (transfer-tube) |
| 3. Smart Injector | 8. Transfer-Tube |
| 4. O-ring | 9. Thrust Bolt |
| 5. Injector Heat Isolator | 10. High Pressure Fuel Line |

Figure 2-21 Fuel Injection System

4. Remove the tensioning arm bolt. See Figure 2-21.



1. Short Leg

2. Long Leg

Figure 2-22 **Injector Removal Tool**

5. Using the injector removal tool (J-47404) to remove the fuel injector from the cylinder head as follows:
 - [a] Spread the jaws on the adaptor and position the adapter over the injector and secure in place with the sleeve ring. See Figure 2-23.
 - [b] Install the base of the injector removal tool (J-47404) over the tool adapter. The long legs of the J-47404 should rest on the cylinder head, the short leg should rest on the rocker arm pedestal bolt. See Figure 2-22.
 - [c] Install the prying handle and nut on the tool adapter, then push down on the handle and remove the injector. If there is insufficient clearance to use the prying handle, use a wrench on the nut to remove the injector.

NOTE:

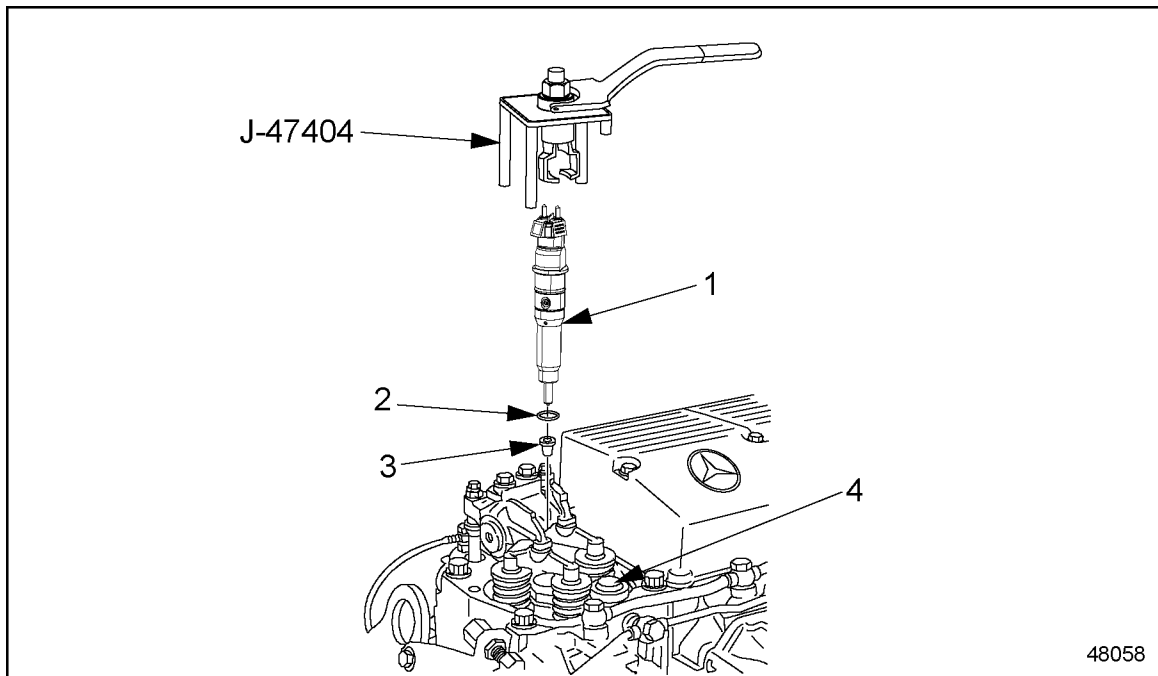
In cases where the injector removal tool (J-47404), with prying handle, cannot be used due to clearance, use a wrench on the nut to remove the injector.

- [d] Remove the tool from the injector.

NOTE:

Do not attempt to take apart the fuel injector. If there is a problem, replace the fuel injector.

- [e] Clean and remove any debris found in the protective sleeve. If the sleeve cannot be cleaned remove the protective sleeve refer to section 2.7.1, and replace the sleeve refer to section 2.7.2.



1. Fuel Injector

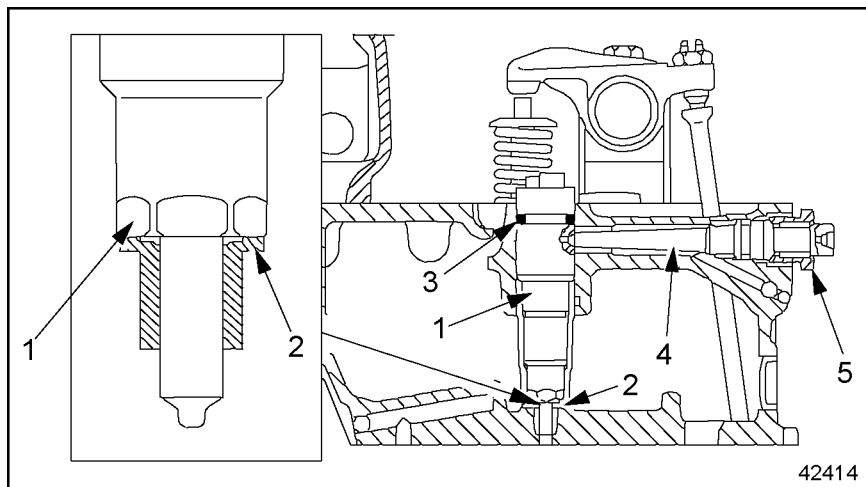
2. O-ring

3. Injector Heat Isolator

4. Constant-Throttle End Cover

Figure 2-23 Fuel Injector

6. Remove the heat isolator from the end of the fuel injector. Remove and discard the O-ring from the injector. See Figure 2-24.



1. Fuel Injector
2. Heat Isolator
3. O-ring

4. Transfer-Tube
5. Thrust Bolt

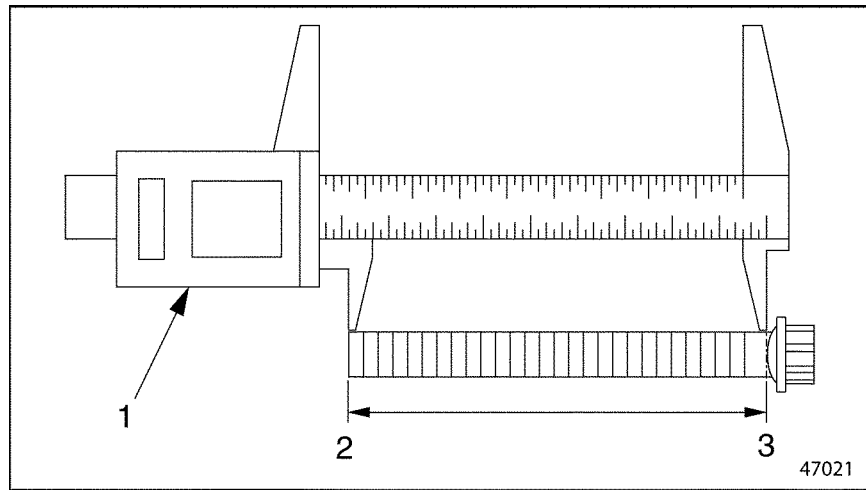
Figure 2-24 Heat Isolator

7. If the injector heat isolator remains in the cylinder head during the removal of the fuel injector it can be removed by using the injector tip copper puller (J-46933).
 - [a] Install the end of the puller (J-46933) into the tip in the cylinder head. Turn the shaft of the tool to expand into the tip.
 - [b] Use the slide hammer on the puller tool and remove and discard the heat isolator.
 - [c] Remove the heat isolator from the tool.
 - [d] Clean and remove any debris found in the protective sleeve. If the sleeve cannot be cleaned remove the protective sleeve

2.6.2 Installation of Fuel Injector

Installation steps are as follows:

- Using a dial caliper, measure the length of the M10 tensioning arm bolt from the end of the bolt to the bottom of the flange. See Figure 2-25. The acceptable lengths are listed in Table 2-1. Replace any bolt which does not meet these specifications.



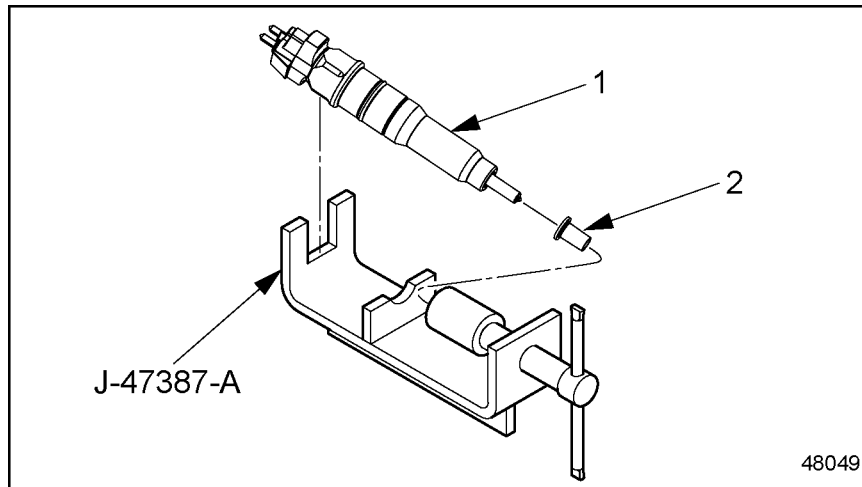
- Dial Caliper
- End of Tensioning Arm Bolt
- Bottom of Flange

Figure 2-25 Tensioning Arm Bolt

Description	Length, mm (in.)
Shaft length when new	90.0 (3.54)
Maximum shaft length	91.0 (3.58)

Table 2-1 Specifications for M10 Tensioning Arm Bolt

2. Lubricate a new fuel injector O-ring with a light coating of engine oil and install it on the fuel injector.



1. Fuel Injector

2. Heat Isolator

Figure 2-26 Fuel Injector Heat Isolator

3. Using the injector heat isolator installer (J-47387-A), press the new heat isolator onto the fuel injector as follows:
 - [a] Place the heat isolator installation tool (J-47387-A) in a vise.
 - [b] Position the new heat isolator over the tip of the fuel injector.

NOTICE:

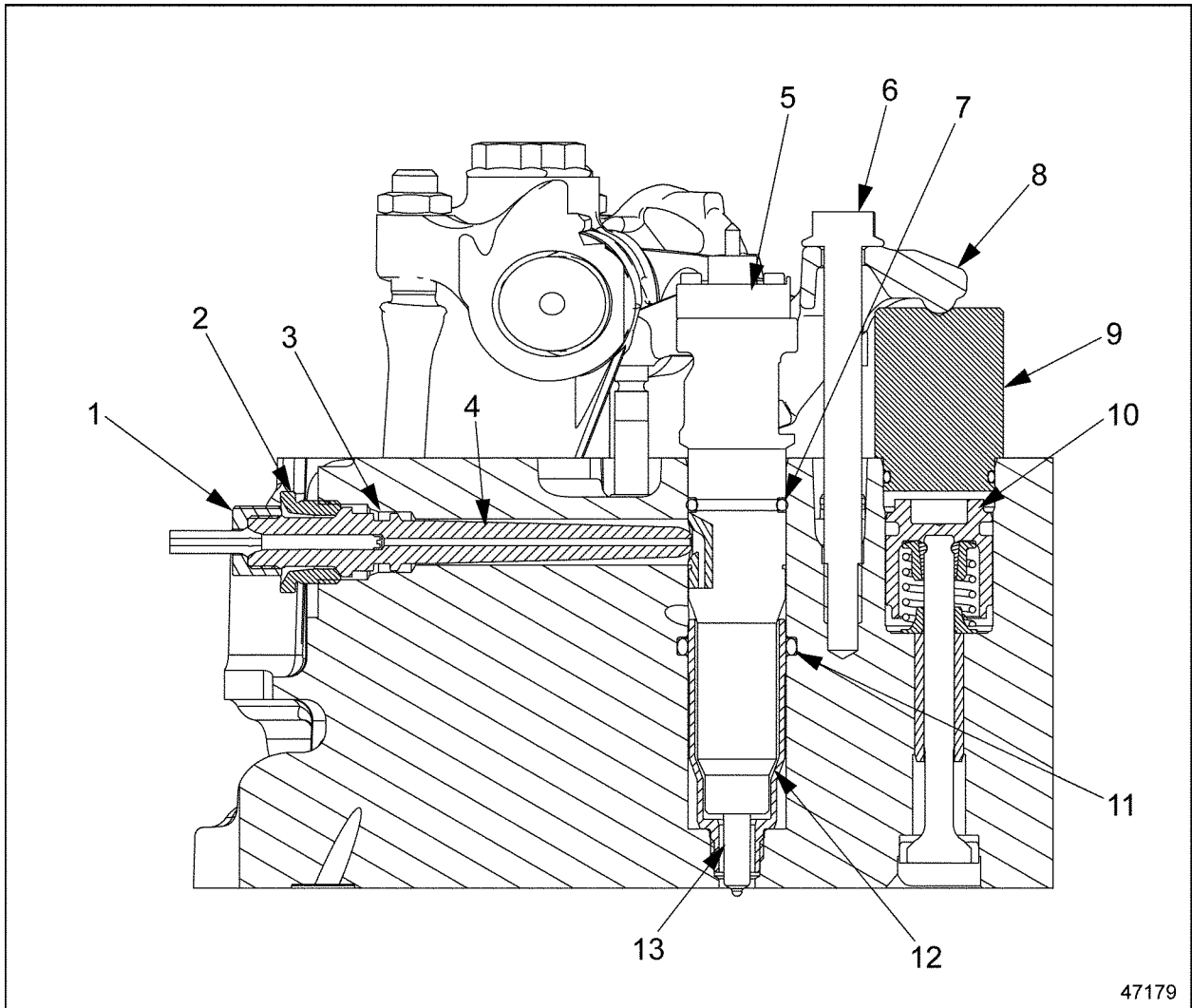
Ensure that the injector is properly seated in the installation tool or damage to the injector will result. Do not apply excessive pressure to the injector or pound the heat isolator onto the injector, damage to the injector will result.

- [c] Install the tip of the injector into the installation tool and align the flats near the top of the injector with the slots in the installation tool. See Figure 2-26.
- [d] Turn the handle on the installation tool and press the heat isolator onto the injector tip.
- [e] Remove the injector from the installation tool and inspect the heat isolator for proper fit.

NOTE:

Take care that the fuel injector is installed correctly and is aligned properly with respect to the transfer-tube.

4. Install the fuel injector in the cylinder head and align the hole in the side of the fuel injector to face the transfer-tube. See Figure 2-27.



- | | |
|------------------------------------|-----------------------------------|
| 1. High Pressure Fuel Line Fitting | 8. Tensioning Arm |
| 2. Thrust Bolt | 9. CTV Spacer |
| 3. O-ring (transfer-tube) | 10. Constant Throttle Valve (CTV) |
| 4. Transfer-Tube | 11. O-ring (protective sleeve) |
| 5. Fuel Injector | 12. Protective Sleeve |
| 6. Tensioning Arm Bolt | 13. Injector Heat Isolator |
| 7. O-ring (fuel injector) | |

Figure 2-27 Fuel Injector

5. Install the tensioning arm bolt in the tensioning arm. Torque the bolt to 50 N·m (37 lb·ft).

6. Lubricate a new transfer-tube O-ring with a light coating of engine oil and install it on the transfer-tube.

NOTE:

Do not tighten the thrust bolt until after the tensioning arm has been fully tightened to the correct torque value.

7. Install the transfer-tube in the cylinder head and secure with thrust bolt. Torque the thrust bolt 45 N·m (33 lb·ft).
8. Install the high pressure fuel line and transfer tube. Refer to section 2.4.2.
9. Install the air intake manifold.
10. Install the injector harness adaptor frame and new gasket and connect harness the electrical connector.
11. Install the cylinder head cover(s), as removed.

2.7 PROTECTIVE SLEEVE

The following sections support the repair of the protective sleeve.

2.7.1 Removal of Protective Sleeve

Removal steps are as follows:

! WARNING:
HOT COOLANT

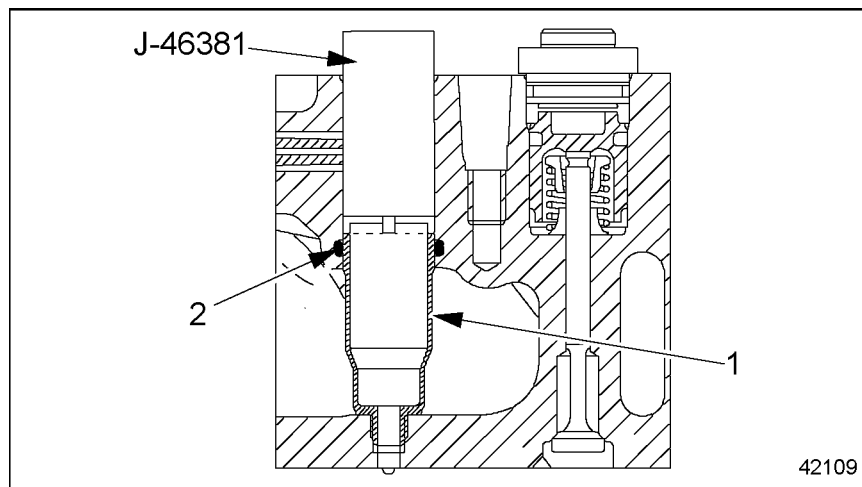
To avoid scalding from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Wear adequate protective clothing (face shield, rubber gloves, apron, and boots). Remove the cap slowly to relieve pressure.

1. Drain the engine coolant into a clean container. If the coolant is clean, save it for later use.
2. Remove the fuel injector. Refer to section 2.6.1.

NOTE:

The injector sleeve puller kit (J-46381) comes with two sockets; a 4-toothed and a rubber-ended socket.

3. Using the injector sleeve puller (J-46381), remove the protective sleeve from the cylinder head. See Figure 2-28.

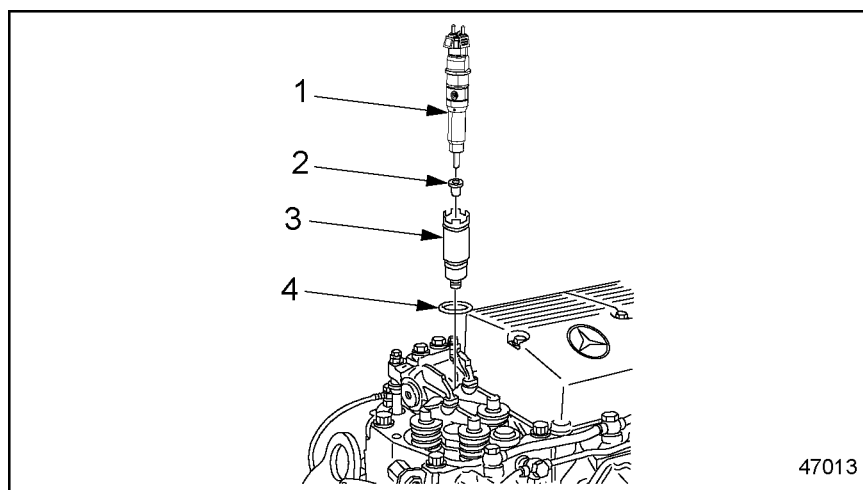


1. Protective Sleeve

2. O-ring

Figure 2-28 Protective Sleeve

- [a] Insert the 4-toothed socket (J-46186) into the protective sleeve. Make sure the teeth of the socket engage the four openings on the protective sleeve. See Figure 2-28.
 - [b] Loosen the protective sleeve with a ratchet by turning counterclockwise until the threads of the sleeve are disengaged from the cylinder head.
 - [c] Attach the rubber-ended socket to the puller from injector sleeve puller (J-46381).
 - [d] Insert the rubber-ended socket into the protective sleeve. Expand the rubber-ended socket by turning the handle on the tool counterclockwise.
 - [e] Pull while rotating the protective sleeve counterclockwise to remove it from the cylinder head.
4. Remove the O-ring from the cylinder head. See Figure 2-29.



1. Fuel Injector
2. Injector Heat Isolator

3. Protective Sleeve
4. O-ring

Figure 2-29 Protective Sleeve O-ring

NOTE:

Replace the O-ring whenever the protective sleeve is removed.

2.7.2 Installation of Protective Sleeve

Installation steps are as follows:

1. Clean the sealing surfaces of the protective sleeve and the cylinder head.
2. Lubricate the new O-ring with a light coating of engine oil. Install the O-ring in the cylinder head.
3. Install the protective sleeve into the cylinder head. Using the 4-toothed socket (J-46186) and turning in a clockwise direction torque the protective sleeve to 45 N·m (33 lb·ft).
4. Install the fuel injector. Refer to section 2.6.2.

5. Fill the cooling system with clean coolant. For types of coolant, refer to the “Coolant Selections Guide” 7SE298.

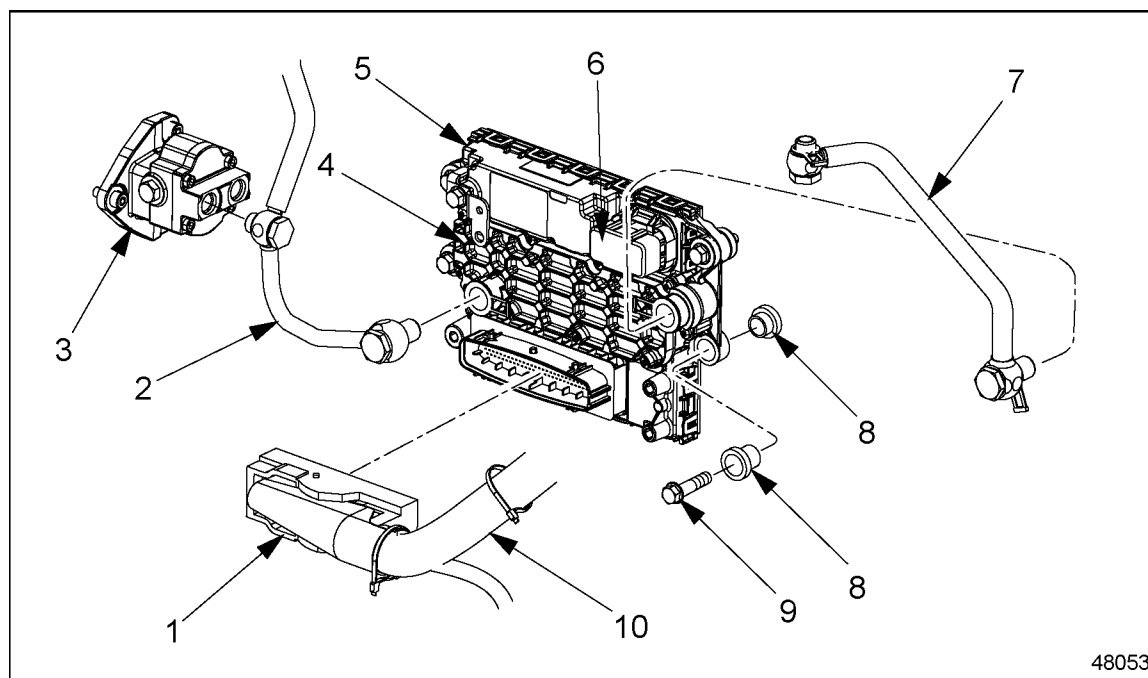
2.8 MOTOR CONTROL MODULE

The following sections support the repair of the motor control module.

2.8.1 Removal of Motor Control Module

Removal steps are as follows:

1. Disconnect the batteries.
2. Open the hood.



- | | |
|--|--|
| 1. Engine Harness Electrical Connector (120-pin) | 6. Vehicle Harness Electrical Connector (21-pin) |
| 2. MCM Fuel Outlet Line to Fuel Pump | 7. Hand Pump Fuel Line |
| 3. Fuel Pump | 8. Isolators |
| 4. Fuel Heat Exchanger | 9. MCM Mounting Bolts |
| 5. Motor Control Module | 10. Engine Harness |

Figure 2-30 Motor Control Module

3. Remove the banjo bolts and washers from fuel in and outlet lines on the fuel cooler of the MCM. Discard the washers.
4. Lift up the slide on the locking unit to release the 21-pin vehicle wiring harness connector and disconnect it from the MCM. See Figure 2-30.
5. Rotate the safety latch to release the 120-pin engine harness connector and disconnect it from the MCM.

6. Remove the mounting bolts and isolators securing the MCM to the engine. Then remove the unit. See Figure 2-30.

NOTE:

Do not disassemble the MCM. It cannot be serviced.

2.8.1.1 Inspection of Motor Control Module

Inspection steps are as follows:

1. Inspect the MCM for damage and replace if necessary.
2. Inspect the isolator for damage and replace if necessary.

2.8.2 Installation of Motor Control Module

Installation steps are as follows:

NOTE:

If installing a new MCM after installation, program to proper settings for that engine serial number (ESN) using the programming station.

1. Position the bolts and isolators in MCM.
2. Install the MCM on the cylinder block. Tighten the mounting bolts to 15 N·m (11 lb·ft).
3. Install the banjo bolts and new washers and secure the fuel in and outlet lines to the fuel cooler on the MCM.
4. Connect the vehicle wiring harness (21-pin) connector to the MCM. Pull sideways on the locking unit to lock it in place.
5. Connect the engine wiring harness (120-pin) connector to the MCM. Rotate the safety latch sideways to lock it in place.
6. Connect the batteries.
7. If a new MCM was installed it must be program to proper settings for the engine serial number using the programing station.

8. Close the hood. Start and run the engine, check for normal operation.

NOTICE:
Whenever the MCM is replaced or the EEPROM values are lost, the air mass flow of the engine must be re-calibrated to ensure proper engine EGR and smoke control operation.

9. Connect DDDL® 7.0 and turn the ignition to the "ON" position,. code SPN 132 FMI 13 (Air Mass Adaptation Required) will appear. To clear the code run the Air Mass Adaptation service routine. If any other codes appear, refer to the MBE 4000 DDEC VI Troubleshooting Guide, 6SE568.

2.9 FUEL FILTER

The following sections support the fuel filter.

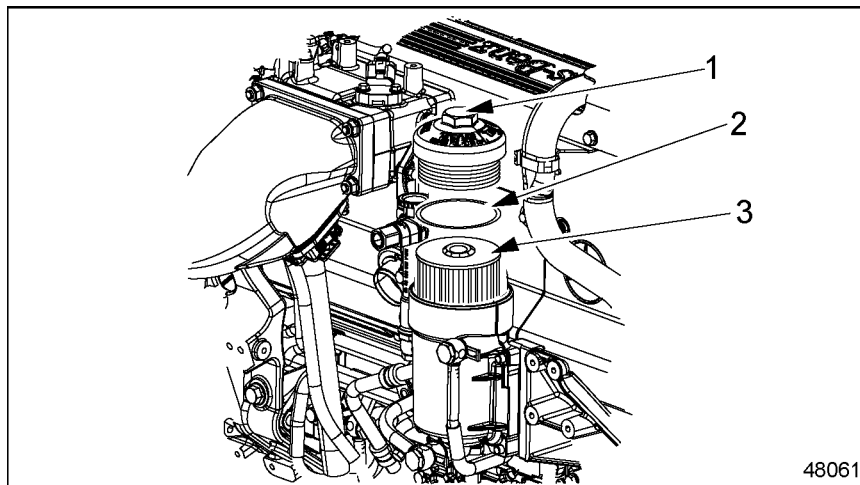
2.9.1 Removal of Fuel Filter

Removal steps are as follows:

! WARNING:
FIRE

To avoid injury from fire, keep all potential ignition sources away from diesel fuel, including open flames, sparks, and electrical resistance heating elements. Do not smoke when refueling.

1. Disconnect the batteries.
2. Open the fuel tank fill cap to release pressure in the fuel system. Replace and tighten the cap.
3. Clean the outside of the fuel filter housing.
4. Using a 36-mm socket, unscrew the cap on the main fuel filter housing. Remove the cap and lift the filter element a short distance within the filter housing allowing the fuel to drain off the filter. Allow the fuel to drain off the filter into the housing. See Figure 2-31.



1. Filter Housing Cap
2. O-ring

3. Fuel Filter Element

Figure 2-31 Fuel Filter Element



WARNING:
PERSONAL INJURY

To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles.

5. Remove the filter element from the cap and clean the fuel filter cap. Discard the filter element and the O-ring from the cap

NOTE:

Catch any fuel that runs out of the filter housing or fuel return line.

2.9.2 Installation of Fuel Filter

Installation steps are as follows:

1. Lubricate the filter element rubber seal with a light coating of fuel oil and insert it into the filter housing. Push down and rotate the filter element while installing to ensure it is seated properly at the base of the housing.
2. Fill fuel filter housing with clean fuel oil.

NOTE:

Note: A properly seated filter element will hold the fuel in the filter housing and prevent it from draining back to the tank. If the fuel does not stay in the housing the element is not seated properly, repeat steps 1 and 2.

3. Install a new O-ring on the filter cap and screw the cap onto the filter housing. Tighten the cap to 25 N·m (18 lb·ft). See Figure 2-31.
4. Work the fuel pump until resistance is felt.

NOTE:

There should be a strong resistance in the hand pump, caused by the pressure build-up within the fuel system.

5. Connect the batteries.
6. Crank the engine for 30 seconds at a time, but no longer. Before cranking the engine again, wait at least two minutes. The engine should start within four 30-second attempts.

**WARNING:****ENGINE EXHAUST**

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

7. Once the engine starts allow it to idle for at least one minute or until idle is smooth before applying the throttle. Check the fuel filter housing for leaks.

NOTICE:

To avoid engine damage, never open the high pressure fuel lines to bleed off tramped air.

8. If the engine will not start and run smoothly, prime the fuel system.

2.10 FUEL FILTER HOUSING

The following sections support the fuel filter housing.

2.10.1 Removal of Fuel Filter Housing

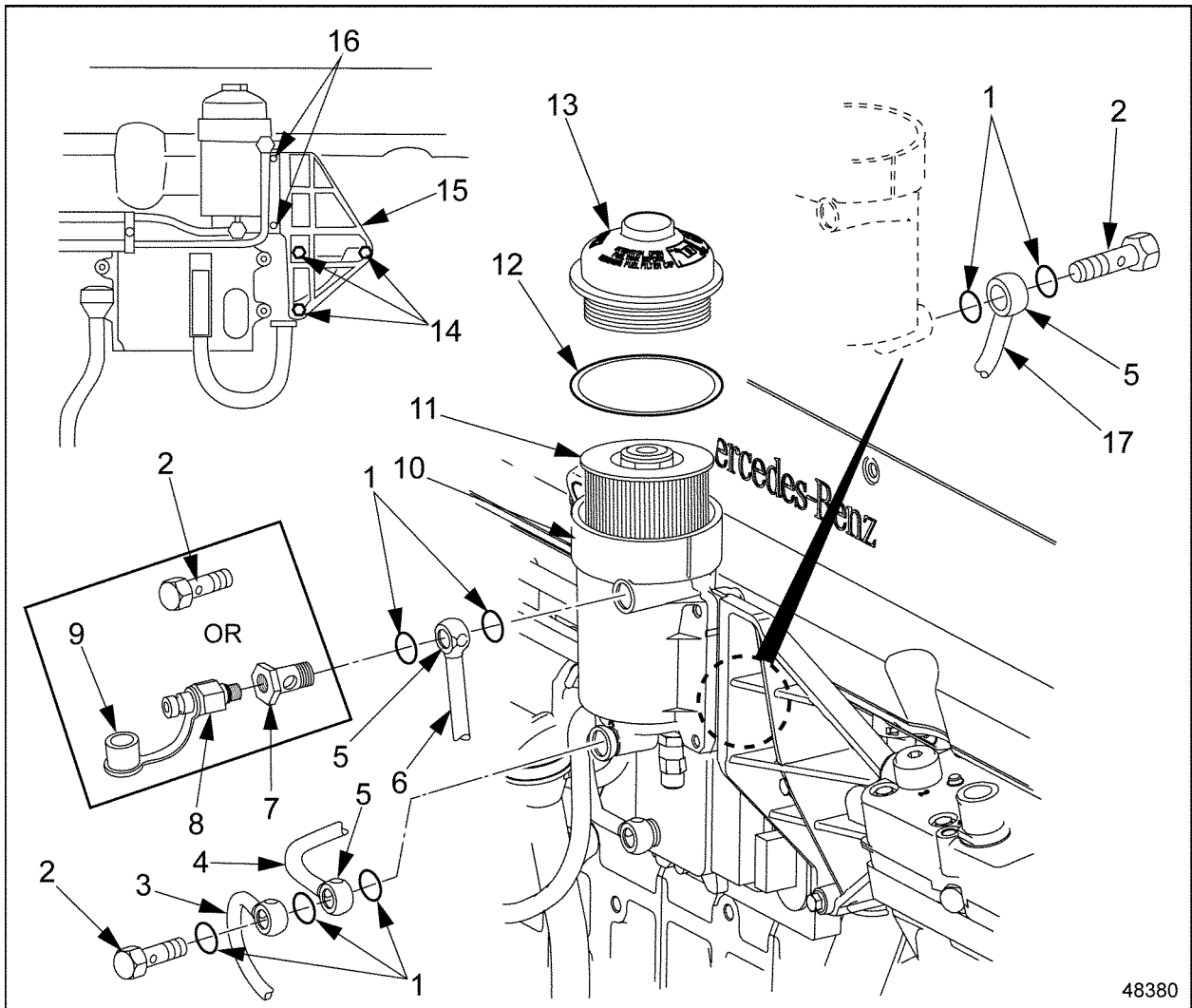
Removal steps are as follows:

**FIRE**

To avoid injury from fire, keep all potential ignition sources away from diesel fuel, including open flames, sparks, and electrical resistance heating elements. Do not smoke when refueling.

1. Disconnect the batteries.
2. Open the fuel tank fill cap to release pressure in the fuel system. Replace and tighten the cap.

3. Using a 36-mm socket, unscrew the cap on the fuel filter. Lift both the cap and the filter element a short distance above the filter housing. Allow the fuel to drain off the filter into the housing. See Figure 2-32.



- | | |
|---------------------------------------|---|
| 1. Washers | 9. Fuel Filter Housing |
| 2. Banjo Bolt | 10. Filter Element |
| 3. Fuel Supply Line to HC Doser | 11. O-ring |
| 4. Fuel Delivery Line to Main Gallery | 12. Fuel Filter Cap |
| 5. Banjo Fitting | 13. Bracket Mounting Bolts |
| 6. Fuel from Pump to Filter | 14. Fuel Filter Housing Mounting Bracket |
| 7. Priming Nipple Valve | 15. Fuel Filter Housing-to-Bracket Mounting Bolts |
| 8. Dust Cover | 16. Fuel Drain Line (return to tank) |

Figure 2-32 Engine Fuel Filter Housing

4. Remove the priming valve assembly or banjo bolt and washers from the delivery line on the filter housing. Mark both sides of the connection with a paint pen. Discard the washers. See Figure 2-32.
5. Disconnect the fuel return line from the filter housing. Mark both sides of the connection with a paint pen. Discard the washers.

NOTE:

In a suitable container, catch any fuel that runs out of the filter housing or fuel return line.

6. Remove the drain line from the filter housing. Mark both sides of each connection with a paint pen. Discard the washers.
7. Remove the two bolts attaching the filter housing to the mounting bracket.
8. Remove the filter housing from the engine.
9. Clean the fuel filter cap. Discard the filter element.

2.10.2 Installation of Fuel Filter Housing

Installation steps are as follows:

1. Install the fuel filter housing on the mounting bracket and secure with two M10 x 40 mm bolts. Tighten the mounting bolts to 60 N·m (44 lb·ft). See Figure 2-32.
2. Install the drain line as removed. Install new washers on the M8 banjo bolt. Tighten the banjo bolt to 40–50 N·m (30–37 lb·ft).
3. Install the fuel delivery line, as removed. Install a new washers on the priming valve or M16 banjo bolt. Tighten the banjo bolt to 50 N·m (37 lb·ft). If removed, install priming nipple valve and torque to 15 N·m (11 lb·ft).
4. Install the fuel return line, as removed. Install new washers on the M16 banjo bolt. Tighten the banjo bolt to 40–50 N·m (30–37 lb·ft).
5. Install a new filter element. Refer to section 2.9.2.

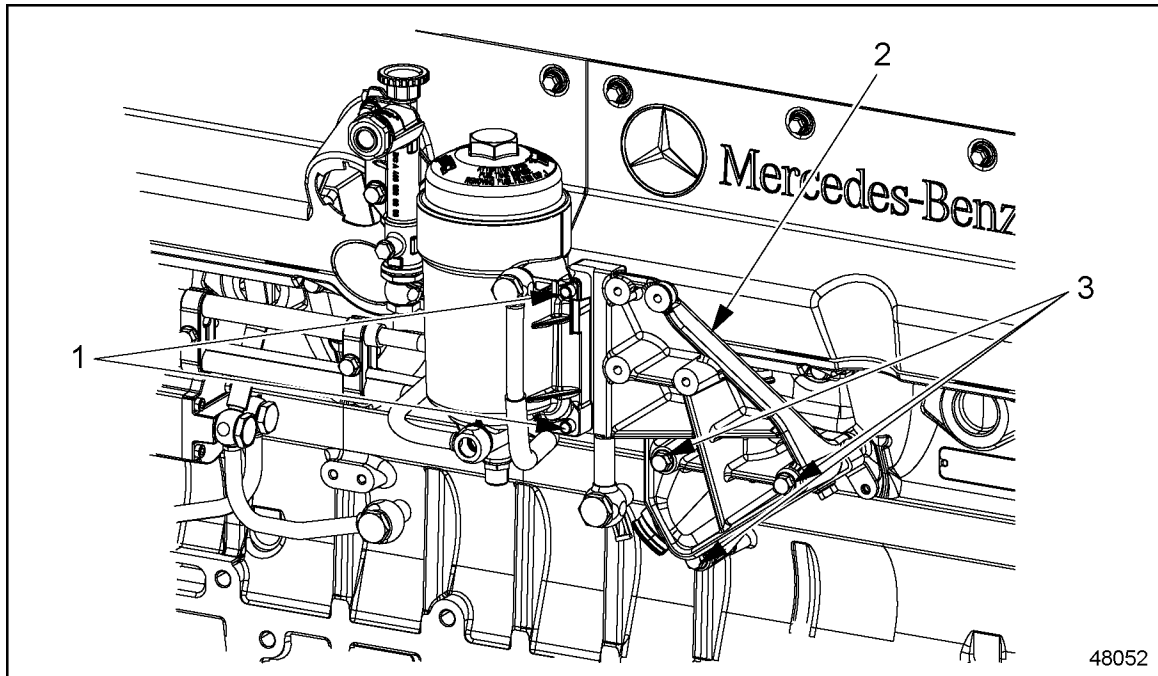
2.11 FUEL FILTER BRACKET

Perform the following procedures for removal and installation of the fuel filter bracket.

2.11.1 Removal of Fuel Filter Bracket

Removal steps are as follows:

1. Remove the two filter-to-bracket mounting bolts and support the filter assembly. See Figure 2-33.



1. Fuel Filter-to-Bracket Mounting Bolts

3. Bracket Mounting Bolts

2. Fuel Filter Mounting Bracket

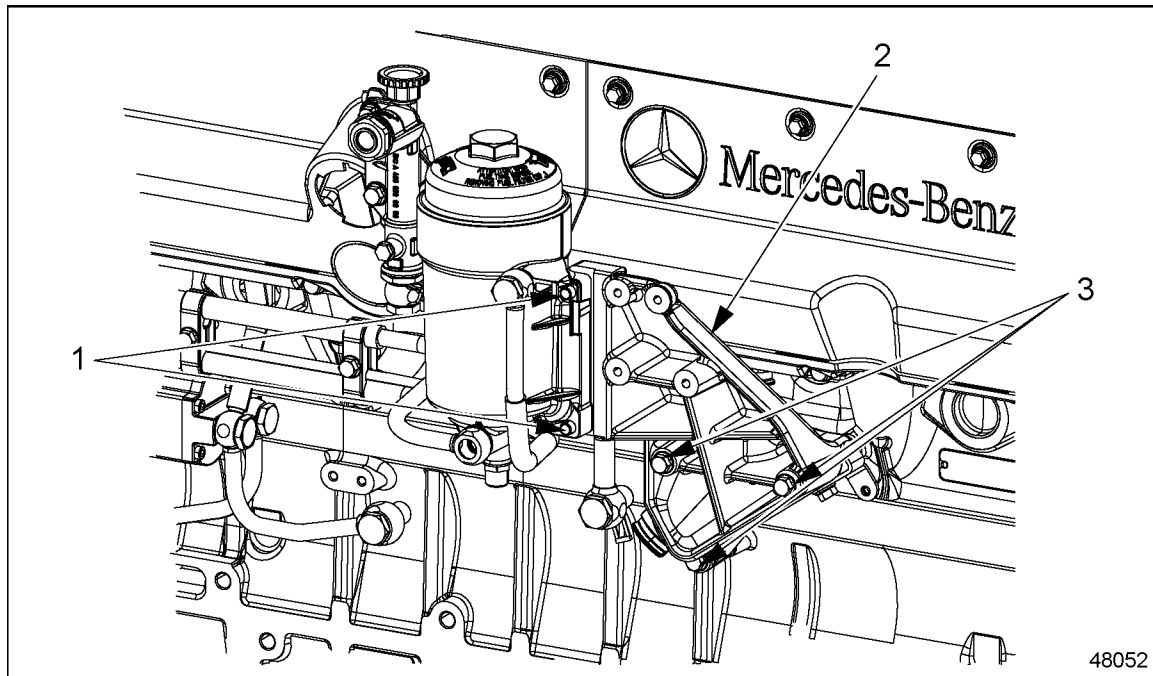
Figure 2-33 Fuel Filter Bracket

2. Remove the three filter bracket mounting bolts from bracket and block.
3. Remove the filter bracket.

2.11.2 Installation of Fuel Filter Bracket

Installation steps are as follows:

1. Install the fuel filter bracket to the block using the two M8 x 105 mm fuel filter bracket mounting bolts and one M8 x 55 mm mounting bolt. Torque bolts to 25 N·m (18 lb·ft). See Figure 2-34.



1. Fuel Filter-to-Bracket Mounting Bolts

3. Bracket Mounting Bolts

2. Fuel Filter Mounting Bracket

Figure 2-34 Fuel Filter Bracket

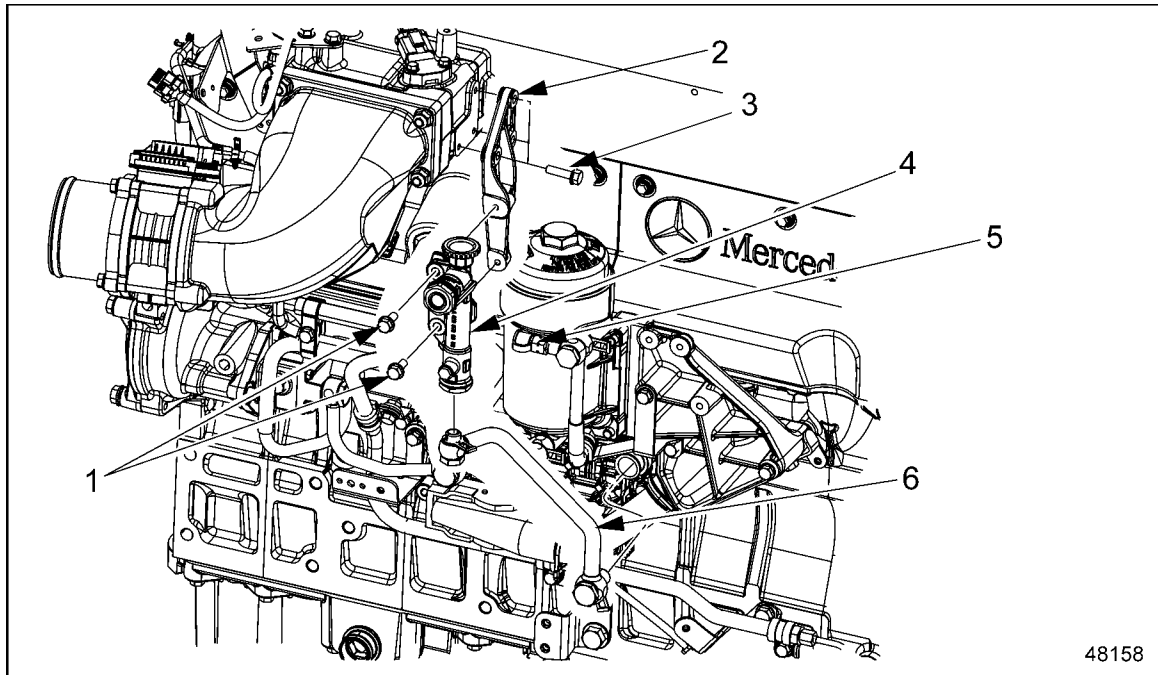
2. Secure the fuel filter assembly to the mounting bracket using the two M10 x 40 mm bolts. Torque bolts to 60 N·m (44 lb·ft).
3. Prime the fuel system.

2.12 FUEL HAND PRIMER PUMP

The following sections support the fuel primer.

2.12.1 Removal of Fuel Hand Primer Pump

Removal steps are as follows:



- | | |
|-----------------------------|----------------------------|
| 1. Bolts (Primer Mounting) | 4. Fuel Hand Primer Pump |
| 2. Mounting Bracket | 5. Additional Priming Port |
| 3. Bolts (Bracket Mounting) | 6. Fuel Outlet Line |

Figure 2-35 Fuel Hand Primer Pump

1. Remove the banjo bolt and washers attaching fuel outlet line to bottom of fuel primer. Discard the washers. See Figure 2-35.
2. Remove the fuel inlet connection to the fuel primer.
3. Remove two bolts securing the fuel primer to the mounting bracket and remove the primer. See Figure 2-35.
4. If necessary, remove the fuel primer mounting bracket by removing three bolts securing the primer to the air mixer housing. See Figure 2-35.

2.12.2 Installation of Fuel Hand Primer Pump

Installation steps are as follows:

1. If removed, attach the fuel primer mounting bracket to the air mixer housing and secure with three bolts. Torque the bolts to 25 N·m (18 lb·ft).
2. Secure the fuel primer to the mounting bracket with two bolts. Torque the bolts to 25 N·m (18 lb·ft).
3. Install the fuel inlet line to the fuel primer.
4. Attaching the fuel outlet line to bottom of fuel primer and secure with banjo bolt. Torque the banjo bolt to 50 N·m (37 lb·ft).

2.13 FUEL PUMP

The following sections support the fuel pump.

2.13.1 Removal of Fuel Pump

Removal steps are as follows:

! WARNING:
FIRE

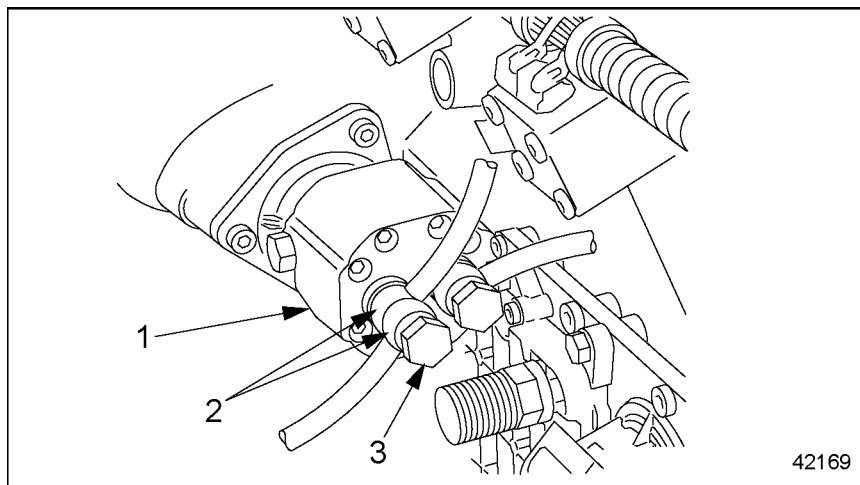
To avoid injury from fire, keep all potential ignition sources away from diesel fuel, including open flames, sparks, and electrical resistance heating elements. Do not smoke when refueling.

1. Disconnect the batteries.

! WARNING:
PERSONAL INJURY

To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles.

2. Remove the fuel lines from the fuel pump by removing the banjo bolts and washers. Discard the seal rings on the banjo fitting. See Figure 2-36.



1. Fuel Pump

2. Banjo Fittings

3. Banjo (Hollow-Core) Bolt

Figure 2-36 Fuel Lines at the Fuel Pump

NOTE:

Catch any fuel that runs out of the fuel pump or the fuel lines.

3. Remove the socket-head bolts attaching the fuel pump to the cylinder block. Discard the gasket.
4. Slowly remove the fuel pump from the engine, taking care not to damage the splined shaft on the fuel pump.
5. Discharge the fuel pump gasket.

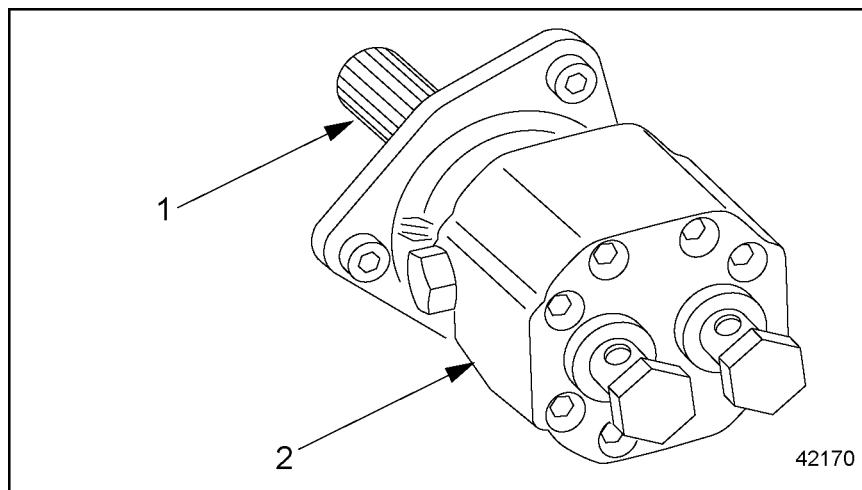
2.13.2 Installation of Fuel Pump

Installation steps are as follows:

NOTICE:

When inserting the fuel pump into the opening in the cylinder block directly behind the front camshaft cover, be careful not to damage the splined shaft of the pump.

1. Install the fuel pump on the cylinder block. See Figure 2-37.



1. Splined Shaft

2. Fuel Pump

Figure 2-37 Fuel Pump Shaft

- [a] Install a new gasket on the connection to the cylinder block.
- [b] Work the splined shaft slowly and carefully into the opening in the cylinder block until it meshes with the camshaft drive gear.
- [c] Install and tighten the three socket-head bolts that attach the fuel pump to the cylinder block. Tighten the socket-head bolts to 25 N·m (18 lb·ft).

**WARNING:****PERSONAL INJURY**

To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles.

2. Install the fuel lines, as removed. Install new seal rings on the banjo fittings. Tighten the banjo bolts to 40-50 N·m (30-37 lb·ft).
3. Connect the batteries.

**WARNING:****ENGINE EXHAUST**

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

4. Prime the fuel system.
5. With the engine running, check the fuel pump and the rest of the fuel system for leaks. Shut down the engine.

2.14 FUEL PUMP DRIVE

The following sections support the fuel pump drive.

2.14.1 Removal of Fuel Pump Drive

Removal steps are as follows:

1. Remove the fan from the water pump pulley by removing six bolts.
2. Remove the crankshaft vibration damper from the engine through the opening in the bumper.
3. Remove the fuel pump. Refer to section 2.13.1.
4. Remove the alternator/air conditioning bracket.
5. Remove the bolts securing the camshaft cover to the cylinder block and remove the cover.
6. Remove the fuel pump driven gear bolt while holding the fuel pump drive splines with locking tool (J-46187). See Figure 2-38.

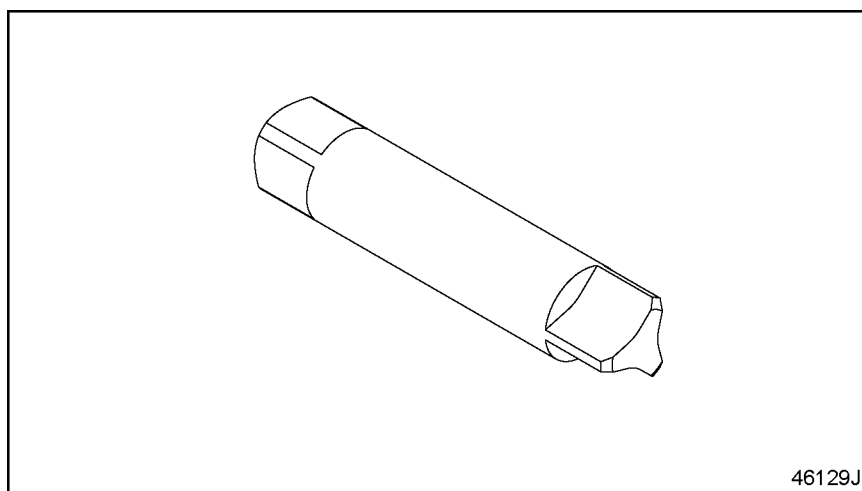
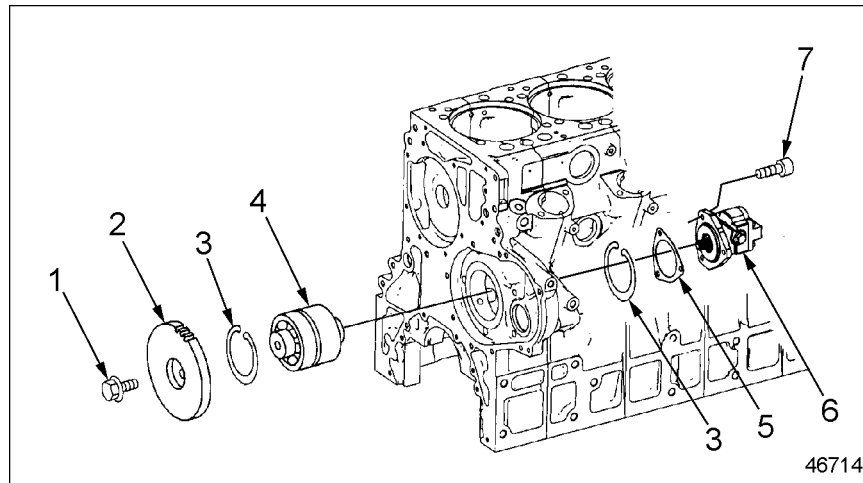


Figure 2-38 Fuel Pump Gear Locking Device J-46187

7. Remove the bolt from the fuel pump driven gear and use a puller to remove the gear. See Figure 2-39.



- | | |
|------------------------------|-----------------------------|
| 1. Driven Gear Mounting Bolt | 5. Fuel Pump Gasket |
| 2. Fuel Pump Driven Gear | 6. Fuel Pump Assembly |
| 3. Retaining Ring (2) | 7. Fuel Pump Mounting Bolts |
| 4. Fuel Pump Drive Assembly | |

Figure 2-39 Fuel Pump Drive Assembly

8. Remove the snap ring from the front of the cylinder block and inside the drive assembly bore.
9. Using fuel pump bearing driver (J-47073), drive the bearing out from the front of engine. If bearing is bad replace the bearing, refer to section 2.14.2 and see Figure 2-40.

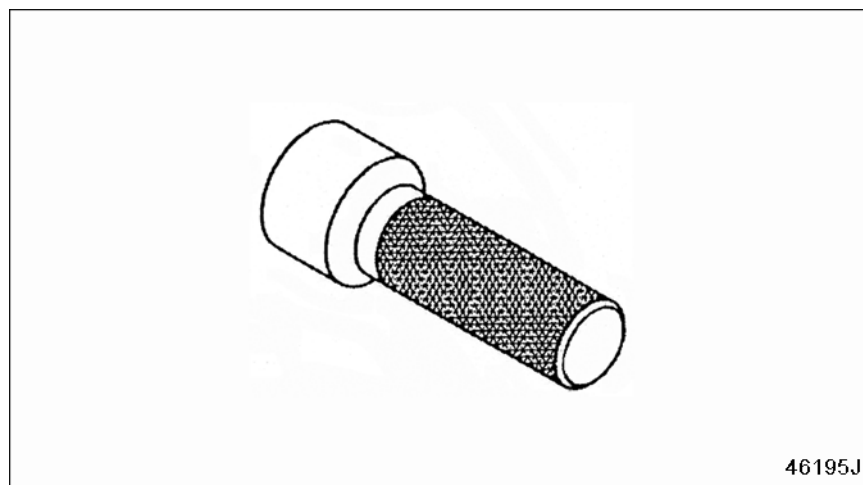
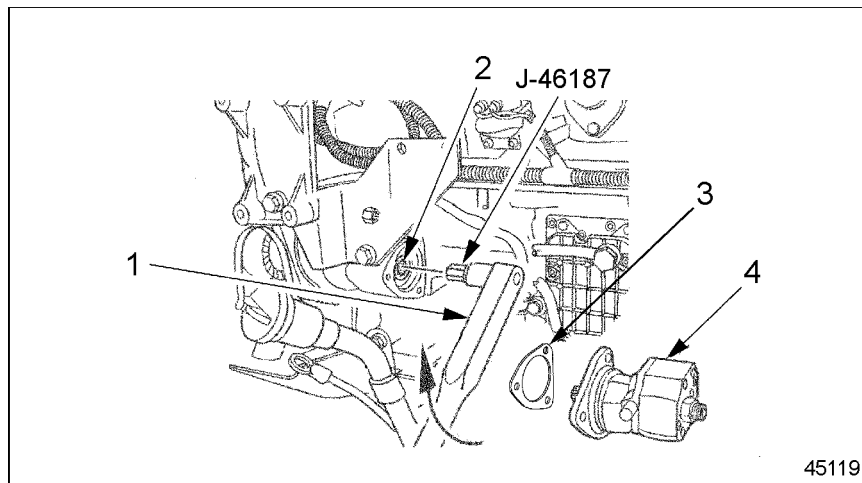


Figure 2-40 Fuel Pump Bearing Driver J-47073

2.14.2 Installation of Fuel Pump Drive

Installation steps are as follows:

1. Install the snap ring in the backside of the cylinder block fuel pump drive bore. See Figure 2-39.
2. From the front of the engine and using fuel pump bearing driver (J-47073) drive the fuel pump drive assembly into the housing until it contacts the snap ring. See Figure 2-40.



- | | |
|---------------------------------|---------------------|
| 1. Torque Wrench | 3. Fuel Pump |
| 2. Fuel Pump Drive Gear Splines | 4. Fuel Pump Gasket |

Figure 2-41 Fuel Pump Drive Gear

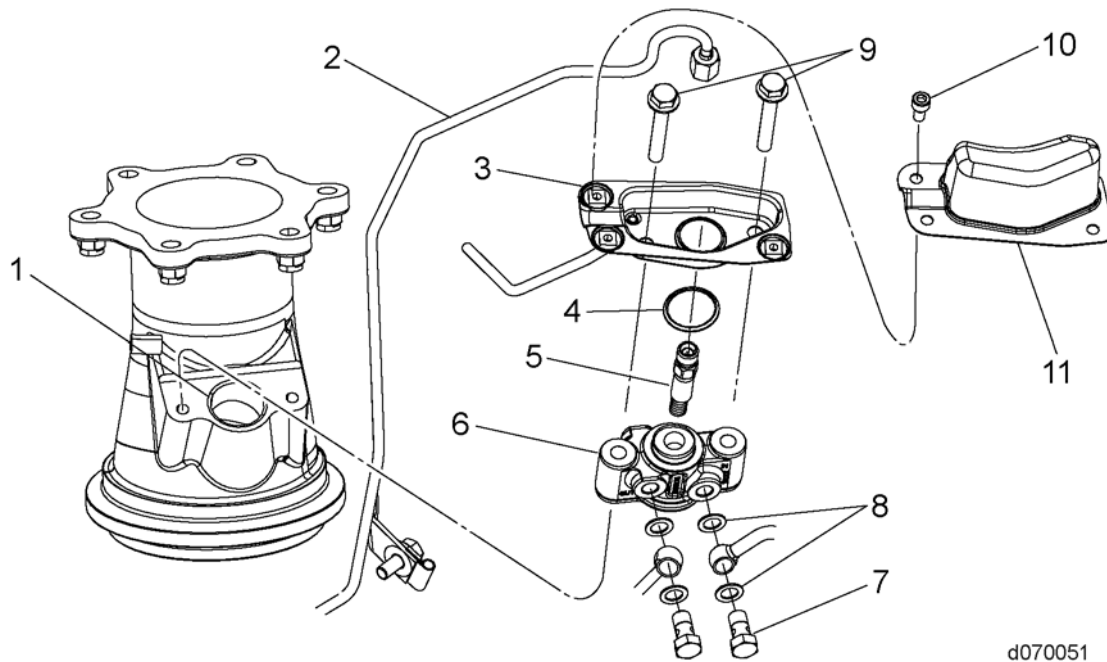
3. Install the snap ring in the front side of the cylinder block fuel pump drive bore to secure the fuel pump drive. See Figure 2-39.
4. Install fuel pump driven gear and bolt. Apply Loctite® 271 sealant to the bolt threads and install gear and bolt. Install the fuel pump gear locking device (J-46187) to the fuel pump drive splines and secure the shaft from turning while torquing bolt. See Figure 2-41 and Figure 2-38.
5. Torque the driven gear bolt to 35 N·m (26 lb·ft).
6. Install the camshaft cover. Torque the bolts to 50 N·m (37 lb·ft).
7. Install the fuel pump and a new fuel pump gasket. Refer to section 2.13.2.
8. Install the alternator/air conditioning bracket.
9. Install the crankshaft vibration damper on the crankshaft.
10. Install the fan on the water pump pulley and secure with six bolts (M8 x 12mm). Torque the bolts to 25 N·m (18 lb·ft).

2.15 FUEL DOSER VALVE (FDV)

The following sections support the fuel doser valve.

2.15.1 Removal of Fuel Doser Injector Valve

The Fuel Doser Injector Valve is mounted in the exhaust pipe that is mounted to the turbocharger. Fuel injected from the valve will atomize with the exhaust gas and combust across the Diesel Oxidation Catalyst (DOC) to create the heat required to regenerate the Diesel Particulate Filter (DPF).



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- | | |
|--|---|
| 1. Exhaust Pipe | 7. Banjo Bolts |
| 2. Fuel Doser Supply Line | 8. Washers |
| 3. Lower Fuel Doser Valve Spray Shield and Drain | 9. Bolts |
| 4. Seal | 10. Torx Head Screws (qty 3) |
| 5. Fuel Doser Injector Valve | 11. Upper Fuel Doser Valve Spray Shield |
| 6. Fuel Doser Housing | |

Figure 2-42 Fuel Doser Valve and Related Components

Removal steps are as follows:

1. Remove the protection cover for the fuel doser injector valve, if equipped.
2. Remove the bracket securing the fuel doser supply line to the block.

3. Disconnect the fuel doser supply line from the fuel doser injector valve. Hold the fuel doser injector valve with a wrench when loosening the fuel doser supply line fitting.

NOTE:

Use care not to bend the fuel line during injection valve removal.

4. Remove the fuel doser injector valve from the housing.

2.15.2 Installation of Fuel Doser Injector Valve

Installation steps are as follows:

1. Clean the doser housing injector valve seat with a suitable brush, taking care not to damage the seat.

NOTE:

Do not use a hard bristle brush as it could damage the seat.

2. Install the fuel doser injector valve into the fuel doser housing and torque to 20 N·m (14 lb·ft).
3. Connect the fuel doser supply line to the fuel doser injector valve. Hold the fuel doser injector valve with a wrench while torquing. Torque to 18 N·m (13 lb·ft).
4. Install the protective cover (if equipped).



WARNING:
ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

5. Start the engine.

NOTE:

It may take more than one purge attempt to completely purge all of the air from the fuel line.

6. Using DDDL 7.X, command the Purge function.
7. Check for exhaust leaks.
8. Shut off the engine.

2.15.3 Removal of the Fuel Doser Housing

Remove as follows:

1. Drain the cooling system.

2. Disconnect the fuel doser supply line from the fuel doser injector valve. Hold the injector valve with a wrench when loosening the line fitting.
3. Disconnect the lines for coolant in and coolant out from the doser housing.
4. Loosen two bolts and remove the fuel doser housing from the exhaust pipe.

2.15.4 Installation of the Fuel Doser Housing

Install as follows:

1. Install the fuel doser housing to the exhaust pipe with two bolts. Torque the bolts to 34 N·m (25 lb·ft).
2. Connect the coolant feed and return lines using new seal rings. Torque the banjo bolts to 15 N·m (11 lb·ft).
3. Connect the fuel doser supply line to the fuel doser injector valve. Hold the fuel doser injector valve with a wrench while torquing. Torque to 16-20 N·m (12-14 lb·ft).
4. Install the protective cover (if equipped).



WARNING:
ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

5. Fill the cooling system.
6. Start the engine.

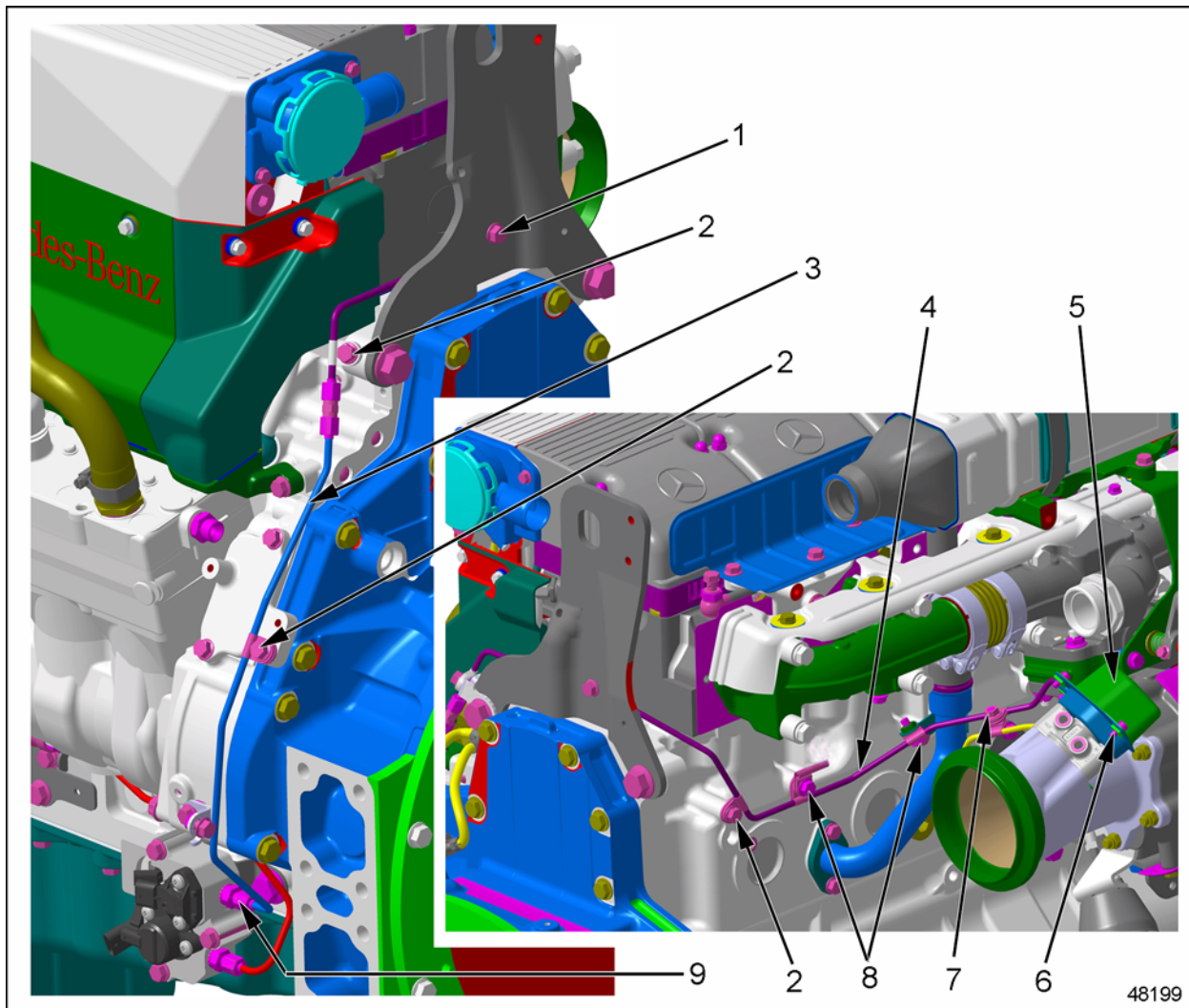
NOTE:

It may take more than one purge attempt to completely purge all of the air from the fuel line.

7. Using DDDL 7.X, command the Purge function.
8. Check for exhaust leaks.
9. Shut off the engine.

2.15.5 Removal of Dosing Fuel Line

Removal steps are as follows:



- | | |
|---|-----------------------|
| 1. Bolt and Nut | 6. Bolts (qty 3) |
| 2. Bolts | 7. Bolt |
| 3. Lower Dosing Fuel Line to Doser Block Assembly | 8. Bolts |
| 4. Upper Dosing Fuel Line to FDV | 9. Fitting Connection |
| 5. Upper Cover | |

Figure 2-43 Dosing Fuel Line

1. Remove the three bolts securing the upper cover on the Fuel Dosing Valve (FDV) and remove the cover. See Figure 2-43.

2. Disconnect the upper dosing fuel line from the FDV.
3. Remove the two bolts at clamps securing the upper dosing fuel line to brackets. See Figure 2-43.
4. Remove the two bolts at clamps securing the upper dosing fuel line to the right side rear of the cylinder block. See Figure 2-43.
5. Remove the bolt and nut at the clamp securing the upper dosing fuel line to the rear engine lifting bracket. See Figure 2-43.
6. Disconnect fitting at the connector union and remove the upper dosing fuel line.
7. Remove the two bolts at the clamps securing the lower dosing fuel line to the rear left side of the flywheel housing. See Figure 2-43.
8. Disconnect the fitting connection at the doser block assembly, located on the left side rear of the engine, and remove the lower fuel dosing line. See Figure 2-43.

2.15.6 Installation of Dosing Fuel Line

Installation steps are as follows:

1. Connect and hand-tighten the dosing fuel line fitting connection to the doser block assembly.
2. Connect and hand-tighten the upper dosing fuel line to the connector union fitting which is installed on the fuel line going to the doser block assembly.
3. Connect and hand-tighten the upper fuel dosing line to the Fuel Dosing Valve (FDV).
4. Install and hand-tighten all securing clamps to the engine block and the flywheel housing.
5. Move the dosing fuel line assembly forward and backward to ensure it is tension-free.
6. Torque the nut connections at the doser block assembly to 15 N·m (11 lb·ft).
7. Torque the FDV connector union fitting to 15 N·m (11 lb·ft).
8. Torque all clamps to 25 N·m (18 lb·ft).
9. Secure the upper cover of the FDV with three bolts. Torque the bolts to 10 N·m (7 lb·ft).

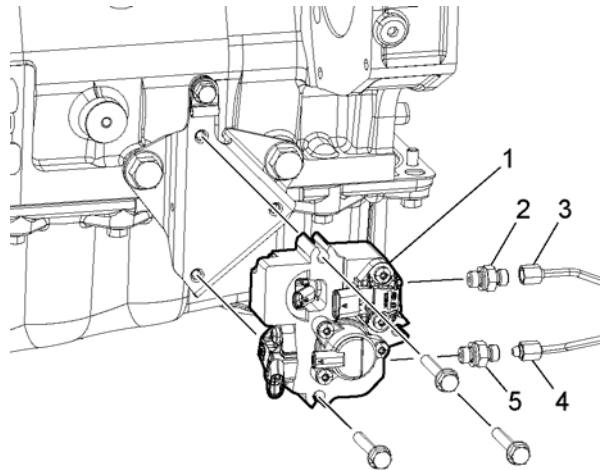
2.16 DOSER BLOCK ASSEMBLY

The Doser Block Assembly is part of the Aftertreatment System (ATS) and is used to control the fuel being injected into the exhaust for the cleaning of the Diesel Particulate Filter (DPF).

2.16.1 Removal of Doser Block Assembly

Removal steps as are follows:

1. Disconnect the electrical harness connectors to the fuel cutoff valve, fuel compensation pressure sensor, electronic dosing valve and fuel line pressure sensor, on the doser block assembly (1).



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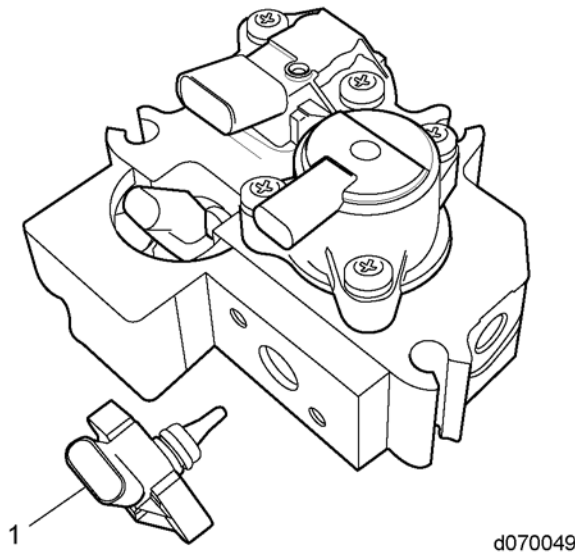
2. Disconnect the fitting (2) to the dosing fuel line (3) on the doser block assembly (1).
3. Remove the banjo bolt, fitting and washers (5) connecting the fuel supply line (4) to doser block assembly (1). Discard the washers.
4. Remove the three bolts securing the doser block assembly to the mounting bracket and remove the assembly.

2.16.2 Removal and Cleaning of the Fuel Compensation Pressure Sensor

Remove the Fuel Compensation Pressure sensor as follows:

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.
2. Clean all dirt and debris from the surrounding area of the Fuel Compensation Pressure sensor prior to removal.
3. Remove the Fuel Compensation Pressure sensor electrical connector.

4. Remove the two torx bolts from the sensor housing.
5. Remove the Fuel Compensation Pressure sensor (1) from the Doser block assembly.



6. Clean the Doser block where the Fuel Compensation Pressure sensor attaches.

2.16.3 Installation of the Fuel Compensation Pressure Sensor

Install the new sensor as follows:

1. Lubricate the new O-ring with clean diesel fuel and install it on the fuel compensation sensor.
2. Install the Fuel Compensation Pressure sensor using two bolts; torque the bolts to 11 N·m (8 lb·ft).
3. Start the engine and check for diesel fuel leaks.
4. Perform a Fuel Doser Purge Service Routine using the DDDL 7.X.

NOTE:

Perform the Fuel Doser Purge Service Routine only once.

- [a] Using DDDL 7.X, initiate a parked regeneration.
- [b] Verify that a parked regeneration has completed.
- [c] Verify repair.

2.16.4 Installation of Doser Block Assembly

Installation steps are as follows:

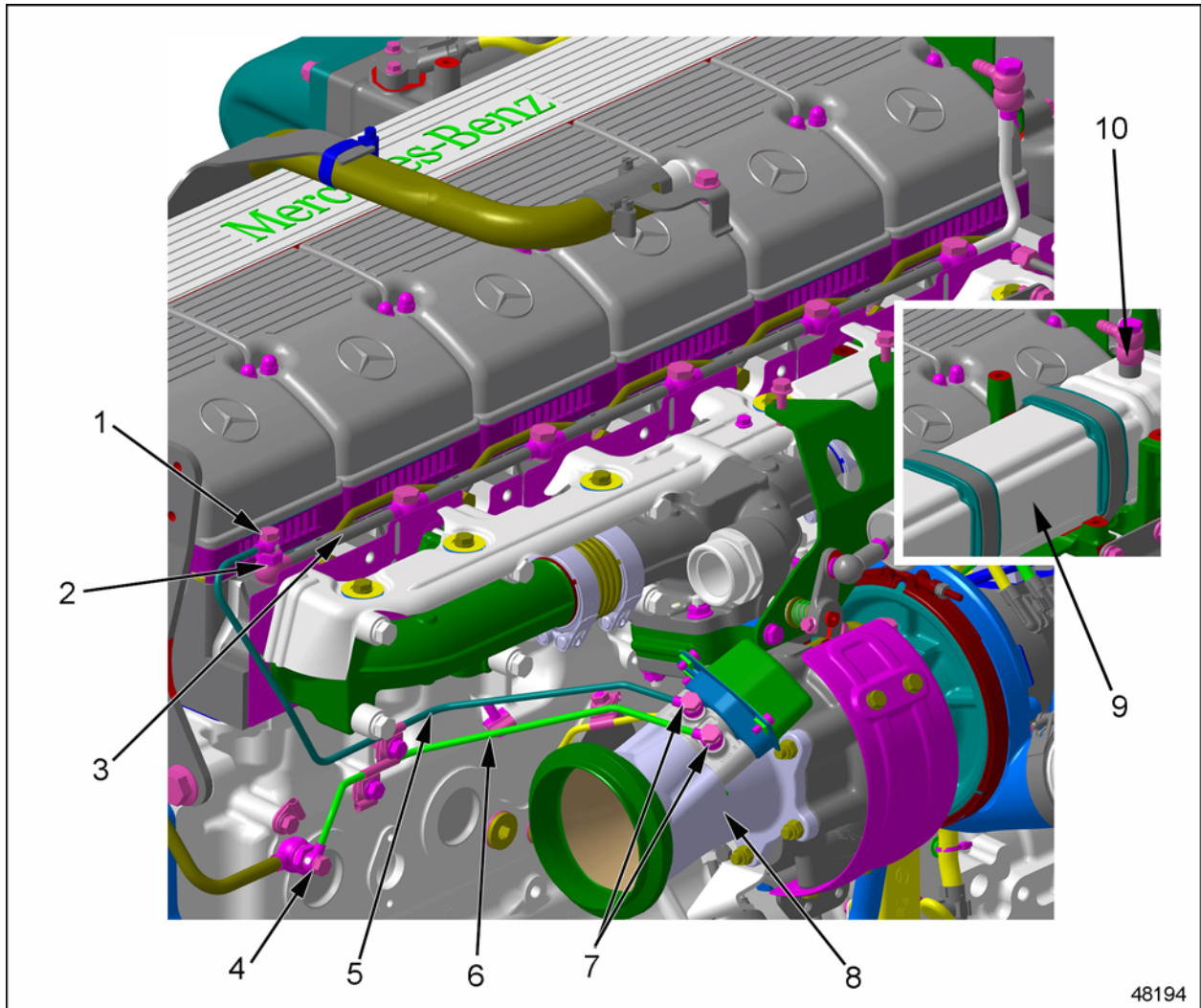
1. Secure the doser block assembly to the mounting bracket with three bolts. Torque the bolts to 25 N·m (18 lb·ft).
2. Torque the fuel doser valve connector union fitting to 15 N·m (11 lb·ft).
3. Torque the fuel supply line connector fitting to 15 N·m (11 lb·ft).
4. Connect the electrical harness connectors to the fuel cutoff valve, fuel compensation pressure sensor, electronic dosing valve and fuel line pressure sensor, on the doser block assembly.

2.17 FUEL DOSER VALVE COOLANT LINES

The following sections support the fuel doser valve coolant lines.

2.17.1 Fuel Doser Valve Coolant Lines Removal

Perform the following for the removal of the fuel doser valve coolant lines:



- | | |
|----------------------------|---------------------------|
| 1. Banjo Bolt | 6. FDV Coolant Inlet Line |
| 2. Banjo Adaptor Fitting | 7. Banjo Bolts |
| 3. Coolant Return Line | 8. FDV Housing |
| 4. Banjo Bolt | 9. EGR Cooler |
| 5. FDV Coolant Return Line | 10. Banjo Fitting |

Figure 2-44 FDV Coolant Lines

1. Drain the coolant from the engine and save for reuse.
2. Remove the bolt securing the clamp on the FDV coolant inlet line to the cylinder block.
3. Remove the banjo bolts and washers for the FDV coolant inlet from the cylinder block and FDV and remove the line. Discard the washers. See Figure 2-44.
4. Remove the bolt securing the clamp on the FDV coolant outlet line to the cylinder block.
5. Remove the banjo bolts and washers for the FDV coolant outlet line from the cylinder head and FDV and remove the line. Discard the washers. See Figure 2-44.

2.17.2 Installation of Fuel Doser Valve Coolant Lines

Installation steps are as follows:

1. Install the banjo bolts and new washers and secure the FDV coolant outlet line to the cylinder head and FDV. Torque the banjo bolts to 16-20 N·m (12-15 lb·ft). See Figure 2-44.
2. Secure the FDV coolant inlet line with clamp and bolt to the cylinder block. Torque the bolt to 25-30 N·m (18-22 lb·ft).
3. Install the banjo bolts and new washers and secure the FDV coolant inlet line to the cylinder block and FDV. Torque the banjo bolts to 16-20 N·m (12-15 lb·ft). See Figure 2-44.
4. Secure the FDV coolant outlet line with clamp and bolt to the cylinder block. Torque the bolt to 25-30 N·m (18-22 lb·ft).

2.A ADDITIONAL INFORMATION

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SPECIFICATIONS

This section contains the specifications for servicing the engine.

Fuel Injectors

The fuel system torque values are listed in Table 2-2. The torque values for the fuel lines are listed in Table 2-3.

Fastener Type	N·m (lb·ft)
Protective Sleeve	45 (33)
Cylinder Head Tensioning Arm Bolt	50 (37)
Electronic unit pump Mounting Bolts	65 (48)
Fuel Pump Mounting Bolts	25 (18)
Fuel Pump Driven Gear Bolt Checking Torque	30 (22)
Fuel Temperature Sensor to Engine Block	30 (22)
Fuel/Water Separator Mounting Nuts	50 (37)
Fuel Pump Mounting Bolts	25 (18)
Fuel Pump Driven Gear Bolt Checking Torque	30 (22)
Fuel/Water Separator Mounting Nuts	50 (37)
Fuel Injector Harness Nuts	2 (1.5)
Dosing Fuel Line Nut at the FDV Connector	15 (11)
Dosing Fuel Line Nut at the Doser Block Assembly Connection	15 (11)
Dosing Fuel Line Nut at the Fitting Connector	15 (11)
FDV Lower Cover Bolts	25 (18)
FDVUpper Cover Bolts	10 (7)

Table 2-2 Fuel System Torque Values

Required Torque on Fastener	N·m (lb·ft)
High Pressure Fuel Line Nuts	35 (26)
Transfer-Tube Thrust Bolt	45 (33)
High Pressure Fuel Line Dampers	6 (4)
High Pressure Fuel Line damper Mounting Bracket Bolts	25 (18)
Fuel Return Line Banjo Bolts (at fuel gallery inlet)	50 (37)
Fuel Spill Line Banjo Bolts	20 (11)
Fuel Spill Line Clamp Bolts	20 (14)
Fuel Overflow Valve (at fuel gallery outlet)	50 (37)
Banjo Bolt at Fuel Overflow Valve	50 (37)
Fuel Line Banjo Bolts at Fuel Pump	50 (37)
Fuel Filter Cap	25 (18)
Fuel Delivery Line Banjo Bolt	50 (37)
Fuel Drain Line Banjo Bolt	50 (37)
Fuel Filter Housing to Mounting Bracket Bolts	60 (44)
Fuel Delivery Line Banjo Bolt on Fuel Filter	50 (37)
Fuel Return Line Banjo Bolt on Fuel Filter	50 (37)
Fuel Priming Nipple Valve on Fuel Filter	15 (11)
Fuel Filter Mounting Bracket to Cylinder Block Bolts	25 (18)
Fuel Priming Pump to Bracket Bolts	25 (18)
Fuel Priming Pump Bracket to Mixer Housing Bolts	25 (18)
Banjo Bolt on Bottom of Fuel Priming Pump	50 (37)

Table 2-3 Fuel Line Torque Values

Fuel and Fuel Control

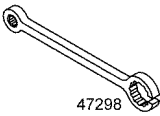
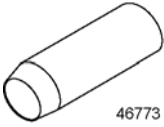
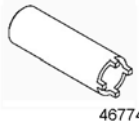
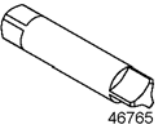
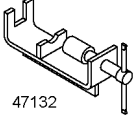
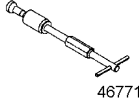
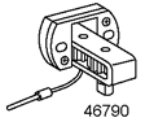
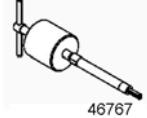
The fuel control torque values are listed in Table 2-4.

Fastener Type	N·m (lb·ft)
Fuel Heat Exchanger Fuel Line Banjo Bolts	50 (37)
MCM Mounting Bolts	15 (11)

Table 2-4 Fuel Control Torque Values

Special Tools

The special tools used in this chapter are listed in Table 2-5.

Tool	Tool Name	Usage	Part Number
 47298	Thrust Bolt Torque Wrench Adaptor 24 mm	Used to hold or torque the thrust bolt.	J-47484
 46773	electronic unit pump O-ring Installer	Used to remove and install O-rings on electronic unit pump.	J-45373
 46774	4-Toothed Socket	Used to remove the injector protective sleeve from the cylinder head.	J-46186
 46765	Fuel Pump Gear Locking Tool	Used to lock the fuel pump drive when installing driven gear.	J-46187
 46769	High Pressure Line Torque Wrench Adaptor 24 mm	Used to remove, install and torque the injector high pressure fuel lines.	J-46371
 47132	Injector Heat Isolator Installer	Used to install the heat isolator on the fuel injector.	J-47387-A
 46771	Injector Sleeve Puller	Used to remove the injector protective sleeve from the cylinder head.	J-46381
 46790	Engine Barring Tool	Used to lock or rotate the engine flywheel.	J-46392
 46767	Injector Heat Isolator Remover	Used to remove a stuck injector heat isolator from the cylinder head.	J-46933

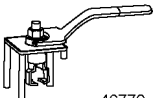
Tool	Tool Name	Usage	Part Number
 46764	Fuel Pump Bearing Driver	Used to remove and install the fuel pump drive bearing.	J-47073
 46770	Injector Removal Tool	Used to remove the injector from the cylinder head.	J-47404

Table 2-5 Special Tools

3 LUBRICATION SYSTEM

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3.1 LUBRICATION SYSTEM DESCRIPTION	3-3
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3.1 LUBRICATION SYSTEM DESCRIPTION

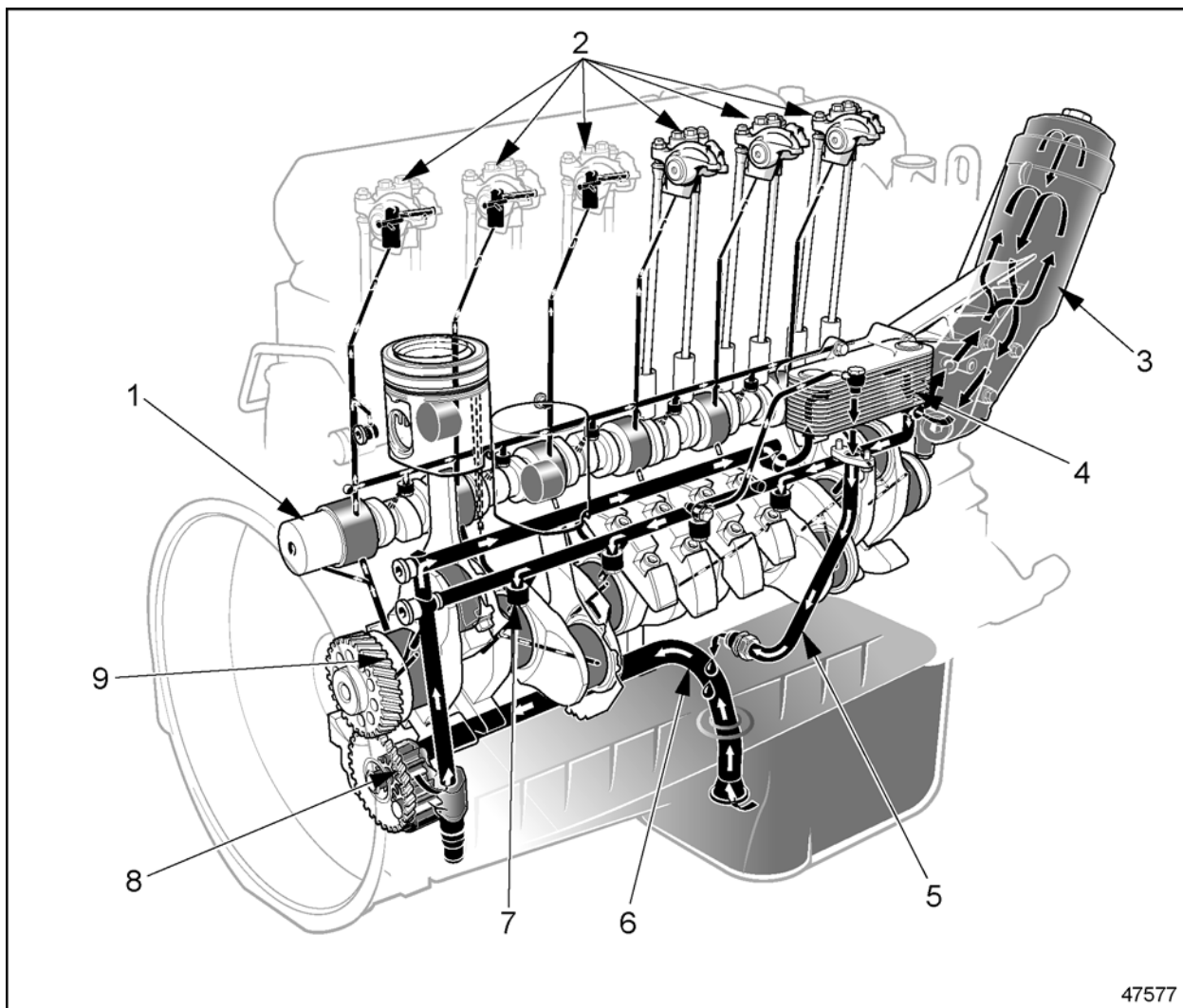
The MBE 4000 engine features a full-flow filtered, pressurized lubricating oil system. The system incorporates various valves and restricted orifices to optimize the oil flow. External piping and plumbing is kept to a minimum to avoid oil leakage.

The lubricating system consists of the following components:

- ☐ Oil pump
- ☐ Pressure regulator valve
- ☐ Pressure relief valve
- ☐ Oil filters and adaptor
- ☐ Oil cooler
- ☐ Oil level dipstick
- ☐ Oil pan
- ☐ Ventilation System

An internal tooth gear pump is mounted to the bottom rear of the engine block and direct driven by the crankshaft at 1.06 times engine speed. The location of the oil sump pick-up tube varies with oil pan choice.

Oil leaving the pump is routed through the oil cooler, then to the oil filter and bypass valve. The oil is then routed into the main oil gallery in the cylinder block. From there, the oil is distributed to the crankshaft, rods, pistons and then to the camshaft bearings. Oil spray nozzles are installed in the block, which provide a continuous spray of oil to the underside of the pistons. From the cam bearings, oil is routed to oil passages in the cylinder head, which deliver oil to the valve train components and rocker arm pedestals. A camshaft bearing galley supplies oil for spray nozzles, cam lobes, valve tappets, and the unit pumps. Drains from the head return oil to the pan. Oil for gear train components at the front of the engine is fed through drilled holes out of the main gallery. The turbochargers oil supply is taken from the oil galley circuit. Oil from the turbocharger returns to the crankcase via an external tube. An Electrostatic Oil Separator (EOS) pulls any oil droplets out of the crankcase vapor and returns the oil back into the oil pan. The clean air is then returned to the atmosphere. see Figure 3-1.



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- | | |
|---------------------------------|-------------------------------|
| 1. Camshaft | 6. Oil Pick-up Tube |
| 2. Rocker Arms and Shafts | 7. Piston Oil Spray Nozzle(s) |
| 3. Oil Filter | 8. Oil Pump |
| 4. Oil Cooler Element | 9. Crankshaft |
| 5. Turbocharger Oil Return Line | |

Figure 3-1 Engine Oil Flow Diagram

3.2 OIL PAN

Perform the following procedures for removal and installation of the oil pan.

3.2.1 Removal of Oil Pan

Removal steps are as follows:

1. Drain the engine oil. See Figure 3-2 for location of the drain plug. Discard the drain plug seal.

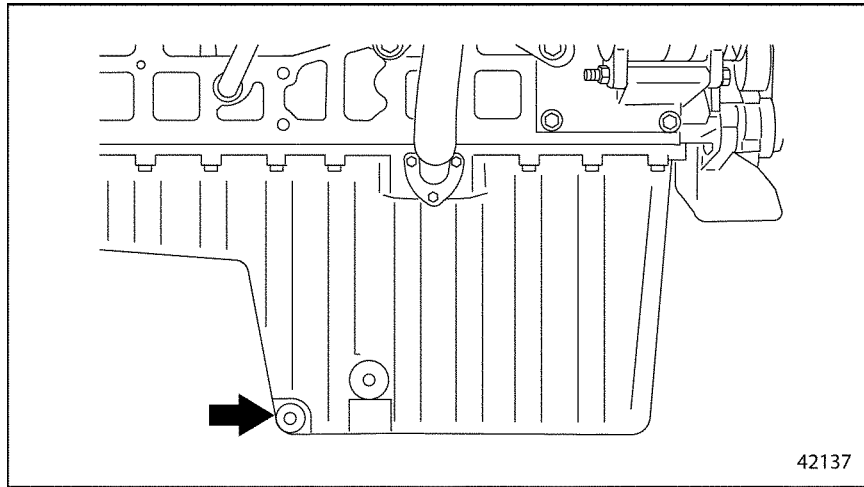


Figure 3-2 Engine Oil Drain Plug



WARNING:

PERSONAL INJURY

To avoid injury when removing or installing a heavy engine component, ensure the component is properly supported and securely attached to an adequate lifting device to prevent the component from falling.

2. Using a floor jack, raise up the vehicle and place it on stands located behind the front suspension.
3. Loosen all front suspension shackle bolts.
4. Remove the front spring bolts and shock absorber bolts. Using the floor jack, lower the axle to the ground.
5. Remove the oil fill-tube and oil dipstick. Refer to section 3.9.1.
6. Remove the oil pan from the cylinder block.
7. Remove and discard the oil pan gasket. Save the bolts.

8. Thoroughly clean the pan. Remove all traces of gasket material from the pan and from the block.

3.2.2 Installation of Oil Pan

Installation steps are as follows:

1. Position a new gasket on the oil pan.
2. Install the pan on the block and tighten each oil pan bolts to 35 N·m (26 lb·ft). See Figure 3-3 for the tightening pattern. When all the bolts have been tightened, go back and re-tighten the four corner bolts (positions #1 through #4).

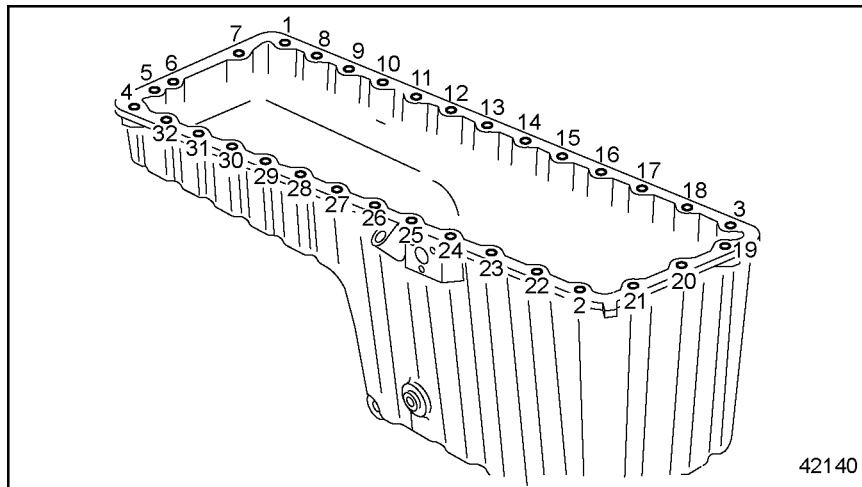


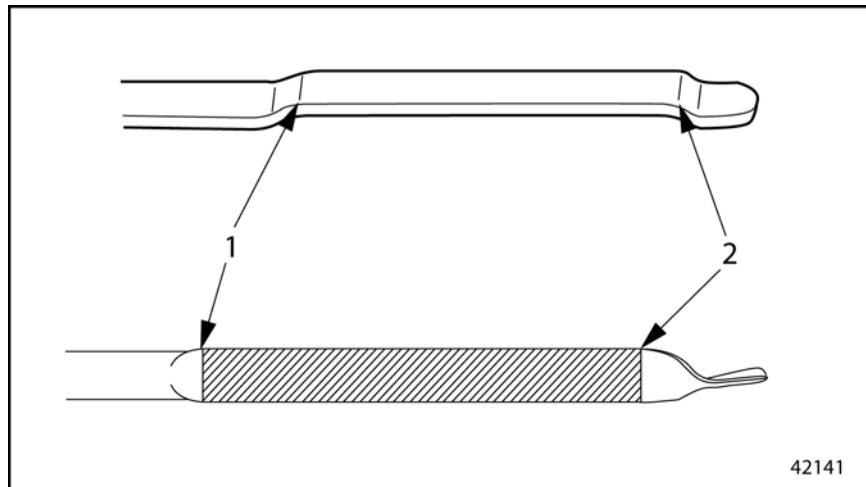
Figure 3-3 Oil Pan Bolt Tightening Pattern

3. Install the oil fill-tube and oil dipstick. Refer to section 3.9.2.
4. Fill the engine oil circuit. The correct oil fill capacity is listed in table. See Table 3-4 in the Additional Information section.
5. Using the floor jack, raise the axle until it is in position to install the spring bolts and shock absorber bolts. Install the front suspension.
6. Tighten the shackle bolts and adjust the suspension. Refer to the appropriate vehicle service manual.
7. Remove the stands and lower the vehicle to the ground.

**WARNING:****ENGINE EXHAUST**

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

8. Start the engine and check for leaks.
9. Shut down the engine. Check the oil level with the oil dipstick and add oil if necessary. See Figure 3-4.



1. Maximum Fill Level

2. Minimum Fill Level

Figure 3-4 Oil Dipstick

NOTE:

Do not fill beyond the maximum fill level on the dipstick, since overfilling may result in high oil consumption.

3.3 PISTON OIL SPRAY NOZZLE

The six piston oil spray nozzles are internally located in the cylinder block. The nozzles provide additional lubrication and cooling to the piston and rings.

Perform the following procedures for the removal and installation of the piston oil spray nozzle(s).

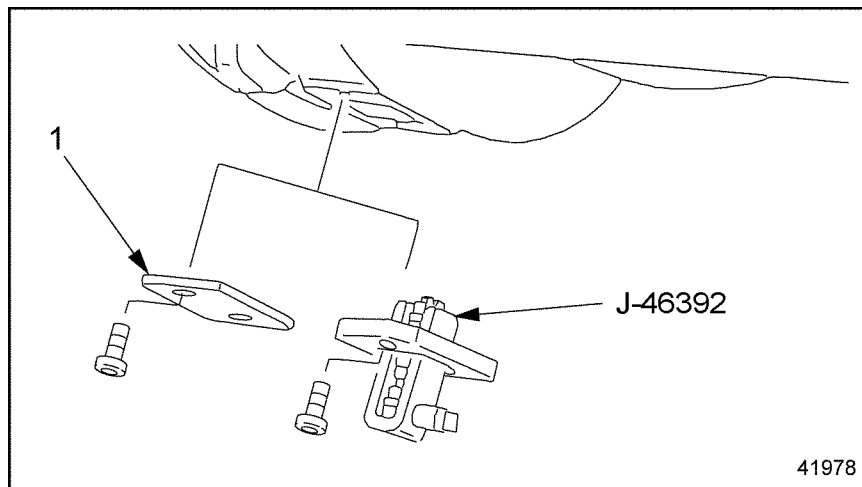
3.3.1 Removal of Piston Oil Spray Nozzle(s)

Removal steps are as follows:

NOTE:

These procedures refer to bolt-on piston oil spray nozzles only.

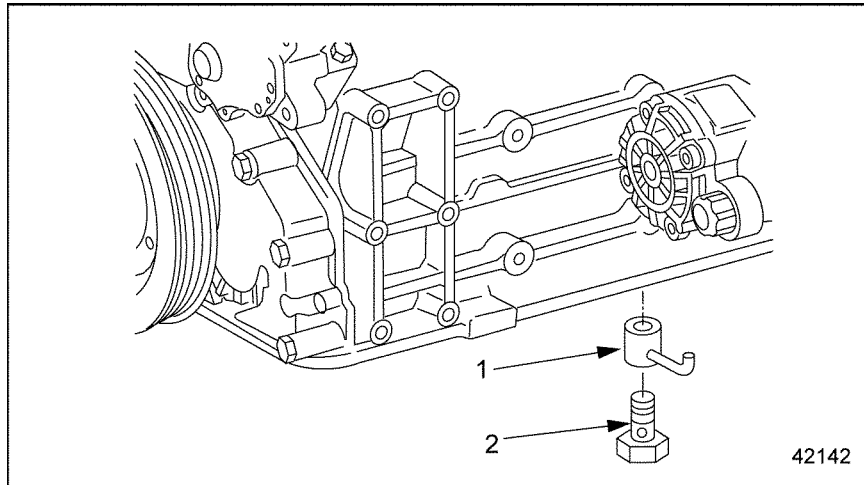
1. Remove the oil pan. Refer to section 3.2.1.
2. Remove the inspection cover on the flywheel housing and install the engine barring tool (J-46392). See figure 3-5. Rotate the crankshaft to gain access to the nozzles.



1. Flywheel Housing Inspection Cover

Figure 3-5 Engine Barring Tool

3. Remove the hollow-core bolt that attaches each piston oil spray nozzle to the underside of the cylinder block. Remove the piston oil spray nozzle from the engine. See Figure 3-6.



1. Piston Oil Spray Nozzle

2. Hollow-Core Bolt

Figure 3-6 Piston Oil Spray Nozzle(s)

4. Check the piston oil spray nozzle(s) for damage or contact by the piston.. Replace any nozzle that has been damaged.

3.3.2 Installation of Piston Oil Spray Nozzle(s)

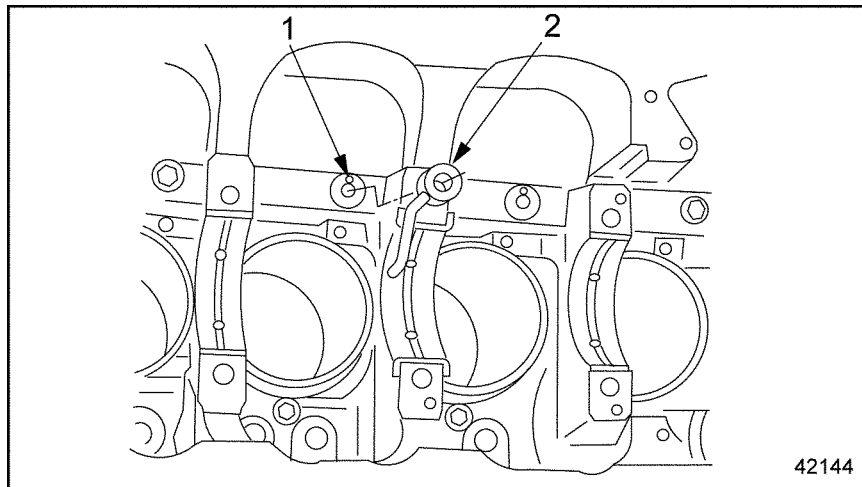
Installation steps are as follows:

NOTICE:

Ensure that the oil spray nozzle is properly aligned in the center of the lubrication hole in the bottom of the piston. Incorrect alignment will result in inadequate lubrication and cooling of the piston and piston failure.
--

1. Install each piston oil spray nozzle in the block with the locator pin correctly installed. Tighten the hollow core bolt finger tight to ensure proper alignment with the lubrication

hole in the bottom of the piston. See Figure 3-7. Torque the hollow-core bolt to 40 N·m (30 lb·ft).



1. Pin Seat

2. Locator Pin

Figure 3-7 **Piston Oil Spray Nozzle(s)**

NOTE:

The locator pin on the base of the piston oil spray nozzle must be inserted into the pin seat in the cylinder block until it engages.

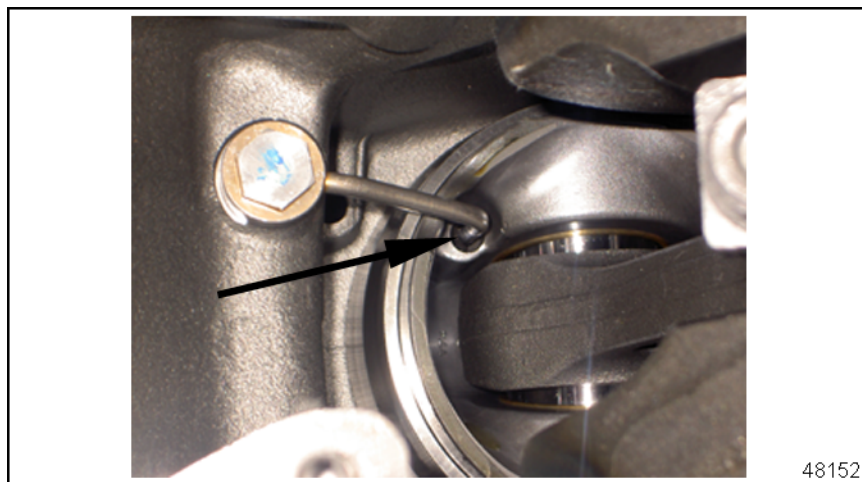


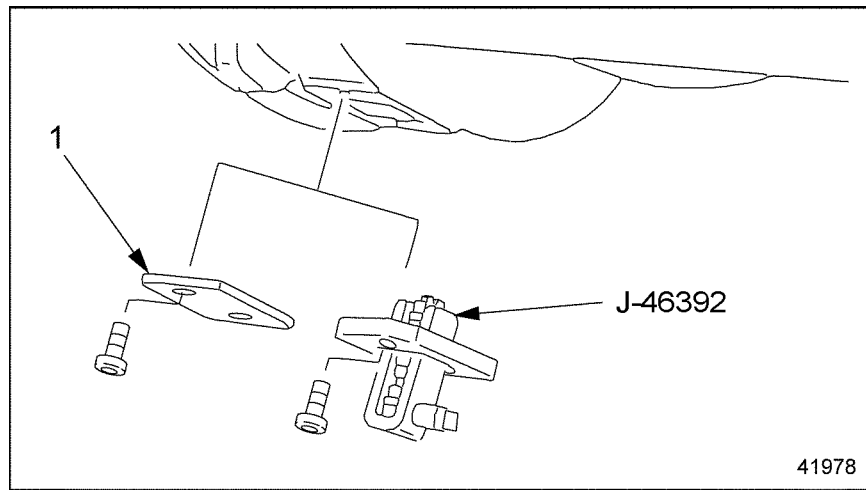
Figure 3-8 **Spray Nozzle Alignment with Piston Oil Hole**

NOTICE:

It is critical that the oil spray nozzle(s) are aligned and in center of the oil hole in the bottom of the piston. Improper alignment of nozzle and piston oil hole will result in engine failure.

2. Check to ensure that the piston oil spray nozzle(s) are aligned with the center of the oil hole in the base of the piston as follows:

- [a] Slowly bar the engine while observing the hole in the bottom of the piston and the alignment with the oil spray nozzle. Check that the alignment of the oil spray nozzle tip is in the center of the piston oil lubricating hole. The tip of the nozzle should be inside the piston oil hole and centered. Repeat the check for the remaining nozzles. See Figure 3-8.
 - [b] If the oil spray nozzle does not align in the center of the piston oil lubricating hole or is not inside the oil hole in the piston, replace the nozzle. Do not bend the nozzles to align.
3. Remove the engine barring tool (J-46392) and install the inspection cover. Torque bolts on cover to 25 N·m (18 lb ft). See figure3-9.



1. Flywheel Housing Inspection Cover

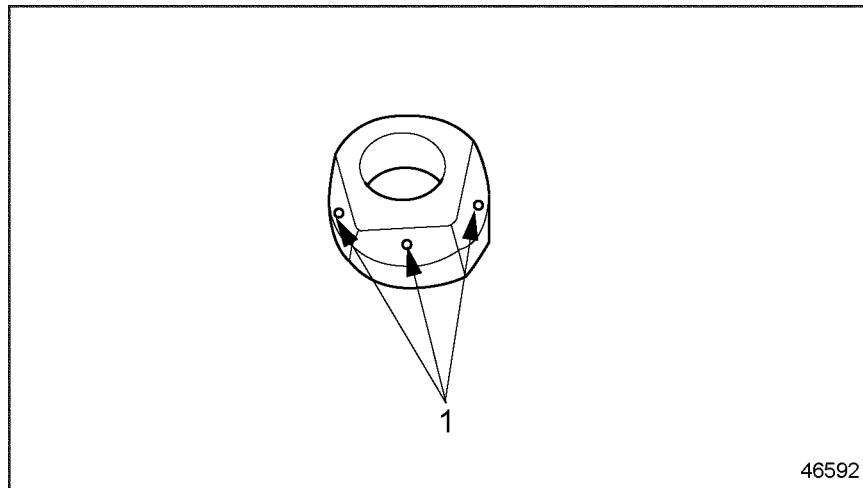
Figure 3-9 Engine Barring Tool

4. Install the oil pan. Refer to section 3.2.2.
5. Fill the crankcase to the specified oil capacity listed in Table 3-4. Do not overfill the crankcase.

3.4 CAMSHAFT LUBRICATION NOZZLE

The six camshaft lubrication nozzles are located internally in the upper portion of the cylinder block near the camshaft and have a guide pin for proper location during installation.

The camshaft lubrication nozzle has three drilled oil passage holes – they spray oil onto the camshaft lobes for the injector pump, intake cam followers and exhaust cam followers. See Figure 3-10.

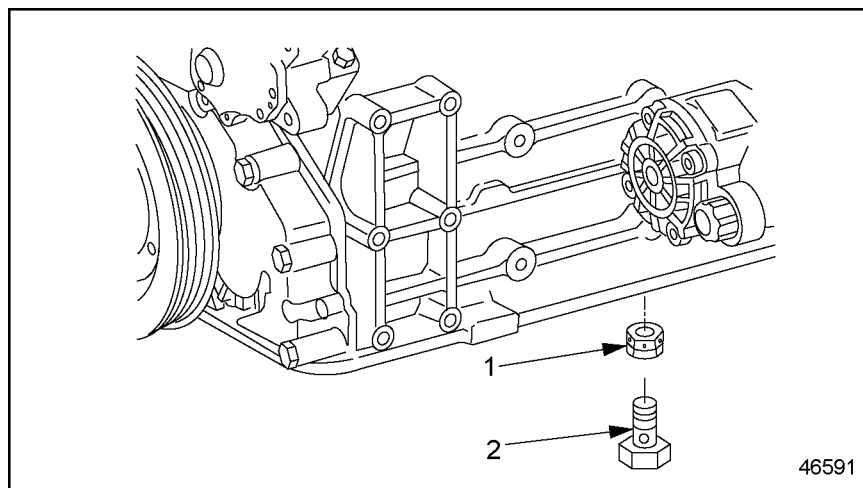


1. Oil Passages

Figure 3-10 Camshaft Lubrication Nozzle

3.4.1 Removal of Camshaft Lubrication Nozzle

Removal steps are as follows:

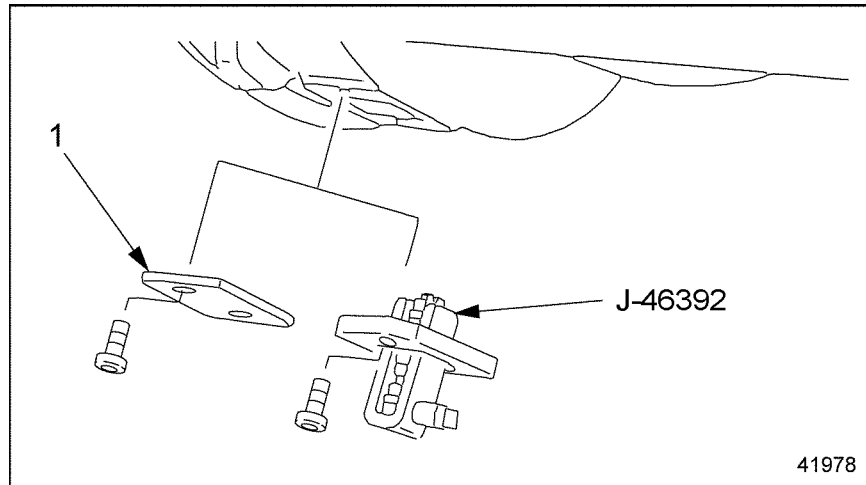


1. Camshaft Lubrication Nozzle

2. Hollow-Core Bolt

Figure 3-11 Camshaft Lubrication Nozzle

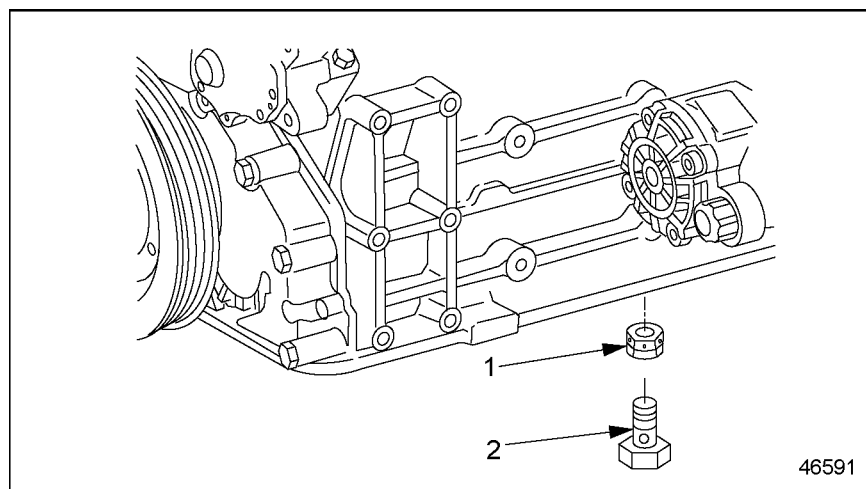
1. Remove the oil pan. Refer to section 3.2.1.
2. Remove the inspection cover on the flywheel housing and install the engine barring tool (J-46392). See Figure 3-12. Rotate the crankshaft to gain access to the lubrication sprayer(s).



1. Flywheel Housing Inspection Cover

Figure 3-12 Engine Barring Tool

3. Remove the hollow-core bolt holding the lubrication nozzle in place. See Figure 3-13.



1. Camshaft Lubrication Nozzle

2. Hollow-Core Bolt

Figure 3-13 Hollow-Core Camshaft Lubrication Nozzle

4. Remove the lubrication nozzle.
5. Clean any clogged holes with solvent.

3.4.2 Installation of Camshaft Lubrication Nozzle

Installation steps are as follows:

1. Align the guide pin on the lubrication nozzle with the hole in the block and secure with the hollow-core bolt. See Figure 3-11.
2. Torque the hollow-core bolt to 20 N·m (15 lb·ft).
3. Remove the engine barring tool (J-46392) and install the inspection cover. Torque bolts on the cover to 25 N·m (18 lb·ft) See figure3-9.
4. Install the oil pan. Refer to section 3.2.2.
5. Fill the crankcase to the specified oil capacity listed in Table 3-4. Do not overfill the crankcase.

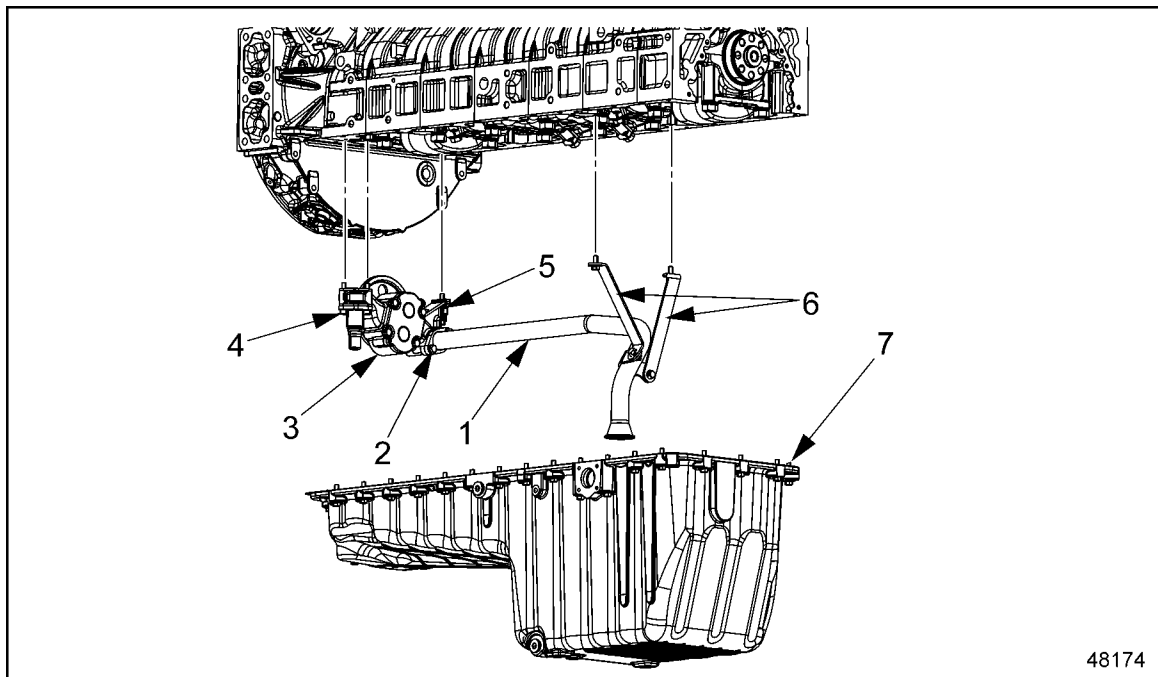
3.5 OIL PUMP AND SUCTION PIPE

The follow sections support the repair of the oil pump and suction pump.

3.5.1 Removal of Oil Pump and Suction Pipe

Removal steps are as follows:

1. Remove the oil pan from the cylinder block. Refer to section 3.2.1.
2. Remove the suction pipe and gasket from the oil pump, see Figure 3-14. Discard the gasket.
 - [a] Remove the bolts attaching the suction pipe brackets to the cylinder block and to the suction pipe.
 - [b] Remove the two bolts attaching the suction pipe to the oil pump. Discard the gasket.
 - [c] Remove the suction pipe and bracket from the oil pump.
3. Remove the bolts attaching the pressure relief valve to the oil pump and lower edge of the cylinder block. Remove the pressure relief valve from the oil pump. See Figure 3-14.



- | | |
|---------------------------------|-----------------------------|
| 1. Suction Pipe | 5. Bolts (Relief Valve) |
| 2. Bolt (Suction Pipe Mounting) | 6. Bracket and Suction Pipe |
| 3. Oil Pump | 7. Oil Pan |
| 4. Oil Pressure Relief Valve | |

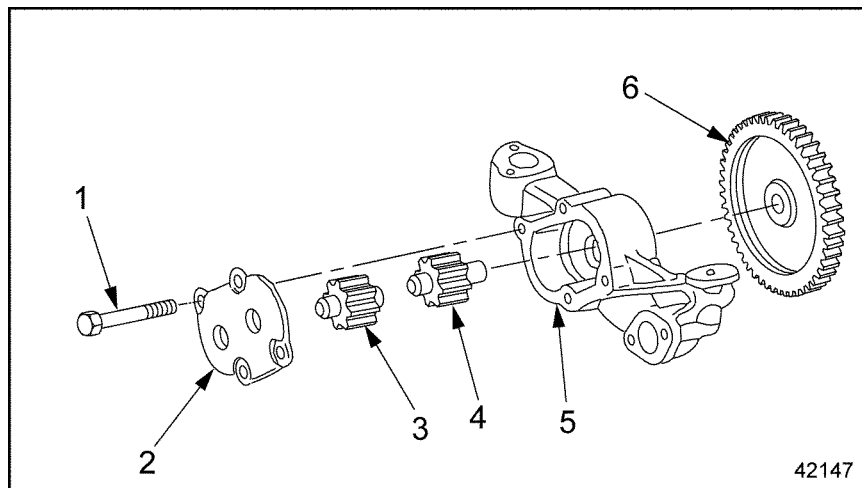
Figure 3-14 Oil Pump and Suction Pipe

4. Remove the bolt attaching the oil pump to the cylinder block. Remove the oil pump from the cylinder block. See Figure 3-14.
5. Thoroughly clean the contact surfaces of the oil pump and cylinder block.

3.5.2 Disassembly of Oil Pump

Disassembly steps are as follows:

1. Remove the oil pump from the cylinder block. Refer to section 3.5.1.
2. Remove the face plate mounting bolts and remove the face plate from the oil pump housing. See Figure 3-15.



- | | |
|-----------------------------|--------------------|
| 1. Face Plate Mounting Bolt | 4. Pump Drive Gear |
| 2. Face Plate | 5. Pump Housing |
| 3. Idler Gear | 6. Drive Wheel |

Figure 3-15 Oil Pump and Related Components

3. Remove the idler gear from the pump housing.
4. Using an appropriate drift, press the drive wheel off the pump drive gear.
5. Remove the pump drive gear from the pump housing.
6. Inspect the idler gear, pump drive gear, face plate, and pump housing for damage and excessive wear. Replace any worn or damaged parts.

NOTE:

If either the idler gear or pump drive gear needs replacing, replace both gears as a set.

7. Check the idler and pump drive gears. Check their seats in the pump housing and face plate. Listed in Table 3-1 are the acceptable limits.

Description	Limits mm (in.)
Diameter of Shaft Bore (in pump housing and face plate)	22.000-22.021 (0.8661-0.8670)
Diameter of Idler Gear and Pump Drive Gear Shaft	21.93-21.94 (0.8634-0.8638)
Clearance of Pump/Idler Gear to Walls of Pump Housing	0.030-0.122 (0.0012-0.0048)
Gear Backlash (clearance between gear cogs)	0.312-0.476 (0.0123-0.0187)

Table 3-1 Oil Pump Inspection Limits

- [a] In the pump housing, measure the diameter of both gear shaft bores, the idler gear seat and the pump drive gear seat. If the measurements are not within acceptable limits, replace the pump housing.
- [b] Measure the diameter of both shaft bores in the face plate. If the measurements are not within acceptable limits, replace the face plate.
- [c] Measure the diameter of the pump drive gear shaft and the idler gear shaft. If the measurements are not within acceptable limits, replace both gears as a set.
- [d] Using a feeler gauge, measure the clearance between the gears and the pump housing wall. If the measurements are not within acceptable limits, replace both gears as a set.
- [e] Using a feeler gauge, measure gear backlash (the clearance between two adjacent cogs on different gears). If the measurements are not within acceptable limits, replace both gears as a set.

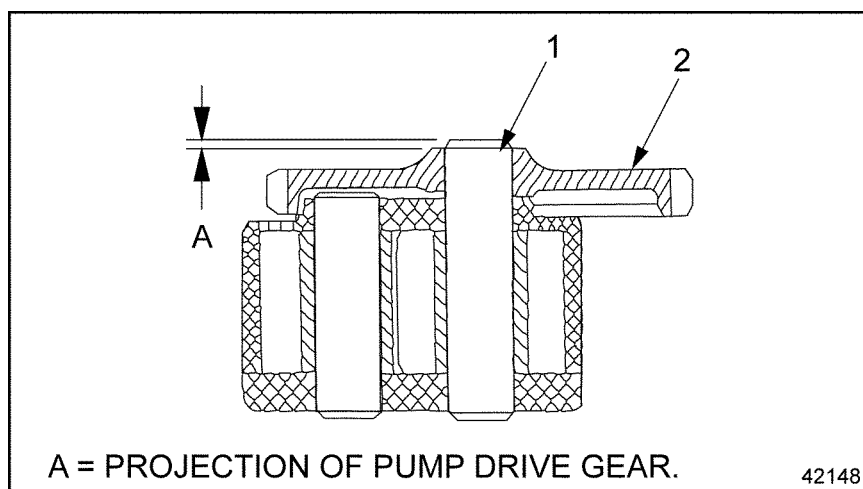
3.5.3 Assembly of Oil Pump

Assembly steps are as follows:

 WARNING: BURNS
To avoid injury from burning, use lifting tools and heat-resistant gloves when handling heated components.

1. Heat the drive wheel to approximately 80°C (176°F) in a hot water tank.

2. Seat the pump drive gear in the pump housing. Using an appropriate drift, press in the heated drive wheel until the pump drive gear projects slightly past the top of the drive wheel. See Figure 3-16.



1. Pump Drive Gear

2. Drive Wheel

Figure 3-16 Positioning the Drive Wheel on the Pump Drive Gear

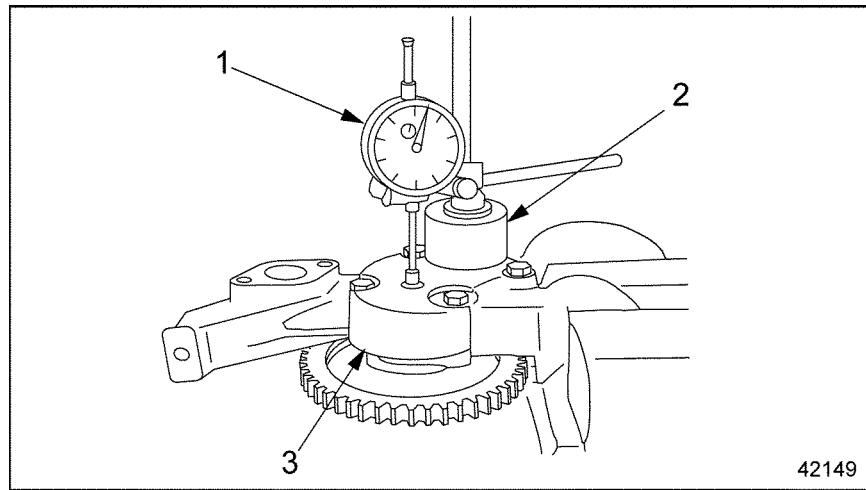
3. Using a feeler gauge, measure the projection of the pump drive gear. Adjust the position of the pump drive gear until the projection equals 0.5 mm (0.02 in.), as listed in Table 3-2.

Description	mm (in.)
Projection of Pump Drive Gear	0.5 (0.02)
Pump/Idler Gear End Play	0.050-0.128 (0.0020-0.0050)
Backlash of Oil Pump Drive Gear and Crankshaft Gear	0.077-0.333 (0.0030-0.1311)

Table 3-2 Oil Pump Installation Specifications

4. Seat the idler gear in the pump housing.
5. Install the face plate on the pump housing. Tighten the mounting bolts 25 N·m (18 lb·ft).

6. Using a dial gauge, measure the end play of the pump drive gear and idler gear against the walls of the pump housing. See Figure 3-17 for set-up and listed in Table 3-2 are the specifications.



1. Dial Gauge

3. Oil Pump

2. Support

Figure 3-17 Measuring the Clearance of the Pump Drive Gears

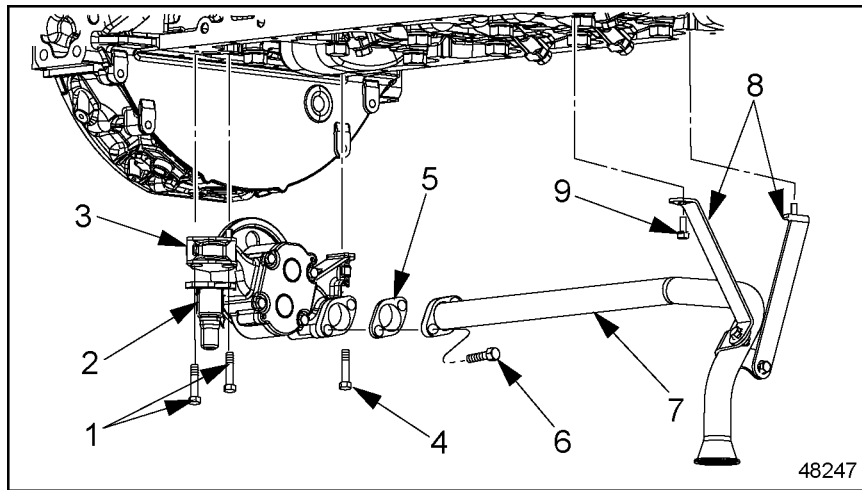
- [a] Secure the assembled oil pump in a vise, with the face plate pointing up.
 - [b] Rest the dial gauge support on the face plate.
 - [c] Set up the dial gauge so that the feeler on the end of the gauge touches the exposed end of the pump drive gear with some preload.
 - [d] Force the pump drive gear downward as far as it will go.
 - [e] At this position, adjust the scale of the dial gauge to "0" (zero).
 - [f] Now force the pump drive gear upward as far as it will go. Read the measurement on the dial gauge and make sure it conforms to the range listed in Table 3-2. Replace the pump, if necessary.
 - [g] Repeat this procedure for the idler gear.
7. Install the oil pump in the cylinder block. Refer to section 3.5.4.

3.5.4 Installation of Oil Pump and Sump Pipe

Installation steps are as follows:

1. Coat the contact surface between the block and the oil pump with Loctite® 574.

2. Position the oil pump on the cylinder block. Make sure the teeth on the drive wheel of the oil pump mesh with the teeth of the crankshaft drive gear. Tighten the oil pump mounting bolt to 35 N·m (26 lb·ft). See Figure 3-14.



- | | |
|---------------------------|----------------------------|
| 1. Valve Mounting Bolts | 6. Sump Pipe Mounting Bolt |
| 2. Pressure Relief Valve | 7. Sump Pipe |
| 3. Oil Pump | 8. Bracket |
| 4. Oil Pump Mounting Bolt | 9. Bracket Mounting Bolt |
| 5. Gasket | |

Figure 3-18 Oil Pump and Sump Pipe

NOTE:

It may be necessary to rock the pump counterclockwise so the teeth of the drive wheel can properly align with the crankshaft drive gear.

3. Check the backlash between the oil pump drive and the crankshaft gear. The specification is 0.077-0.333 mm (0.003-0.131 in.)
4. Install the pressure relief valve on the oil pump. Tighten the valve mounting bolt 35 N·m (26 lb·ft).
5. Install the sump pipe to the oil pump. Tighten all mounting bolts to 25 N·m (18 lb·ft).
 - [a] Install the sump pipe bracket on the cylinder block.
 - [b] Install the sump pipe, with a new gasket, on the oil pump.
6. Install the oil pan with a new gasket. Refer to section 3.2.2.
7. Fill the engine oil circuit. The correct oil fill capacity is listed in Table 3-4. Do not overfill the crankcase.

**WARNING:****ENGINE EXHAUST**

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

8. Start the engine and check for leaks.
9. Stop engine and wait 10 minutes and check the engine oil level and add oil if necessary.

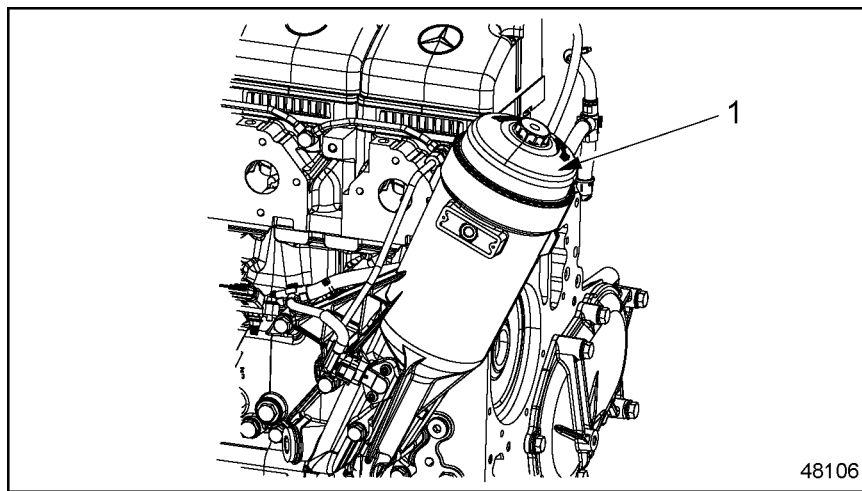
3.6 OIL FILTER

Perform the following procedures for removal and installation of the oil filter.

3.6.1 Replacement of Oil Filter Element

Replacement steps are as follows:

1. Clean the outside of the oil filter housing, then unscrew the oil filter cap from the housing. See Figure 3-19.



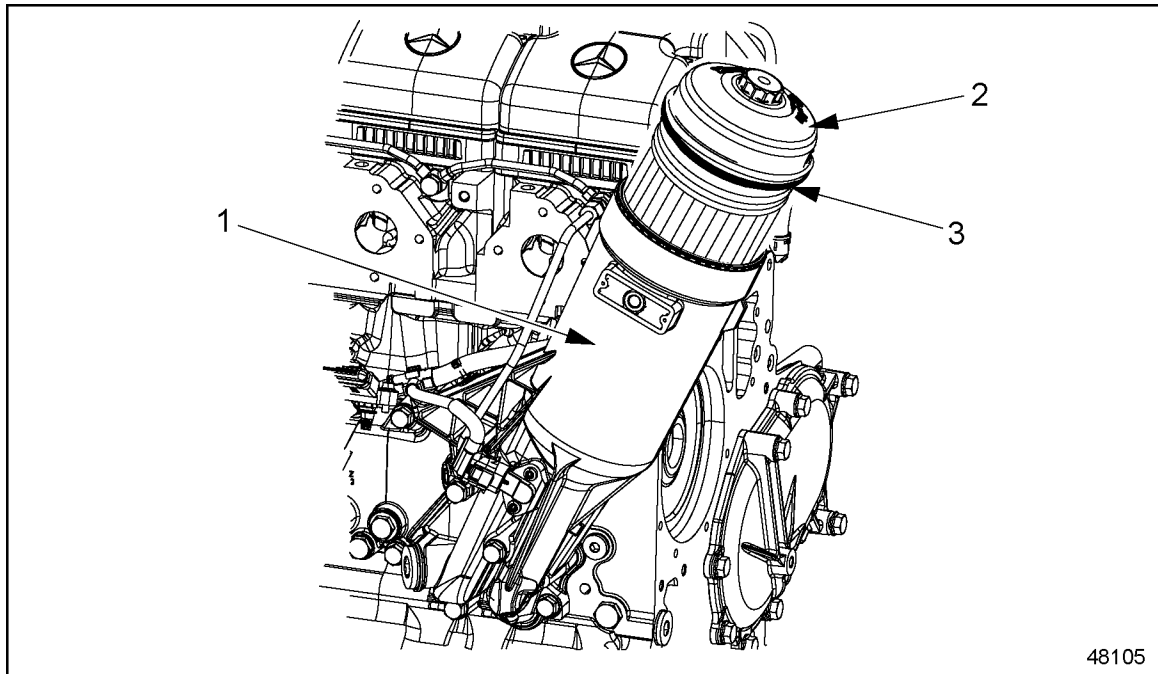
1. Oil Filter Cap

Figure 3-19 Oil Filter Cap

NOTE:

Use care to prevent foreign objects from entering the filter housing.

2. Using a 36-mm socket, unscrew the cap and filter and allow the oil to drain into the housing. After draining, remove the assembly from the housing. See Figure 3-20.



1. Oil Filter Housing

3. O-ring

2. Oil Filter Cap

Figure 3-20 Oil Filter Element

3. Remove the element by pressing and twisting the side and detaching it from the cap.
4. Remove the oil filter O-ring and discard it. Lightly lubricate a new O-ring with engine oil and install it on the filter cap.
5. Check the filter housing for any debris.
6. Insert a new filter element into the cap.
7. Insert the element and cap assembly into the housing. Torque the cap to 25 N·m (18 lb·ft).



WARNING:

ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

8. Start the engine and check for leaks.
9. Stop engine and wait 10 minutes and check the engine oil level and add oil if necessary.

3.7 OIL COOLER/FILTER HOUSING

Perform the following procedures for removal and installation of the oil cooler/filter housing.

3.7.1 Removal of Oil Cooler/Filter Housing

Removal steps are as follows:



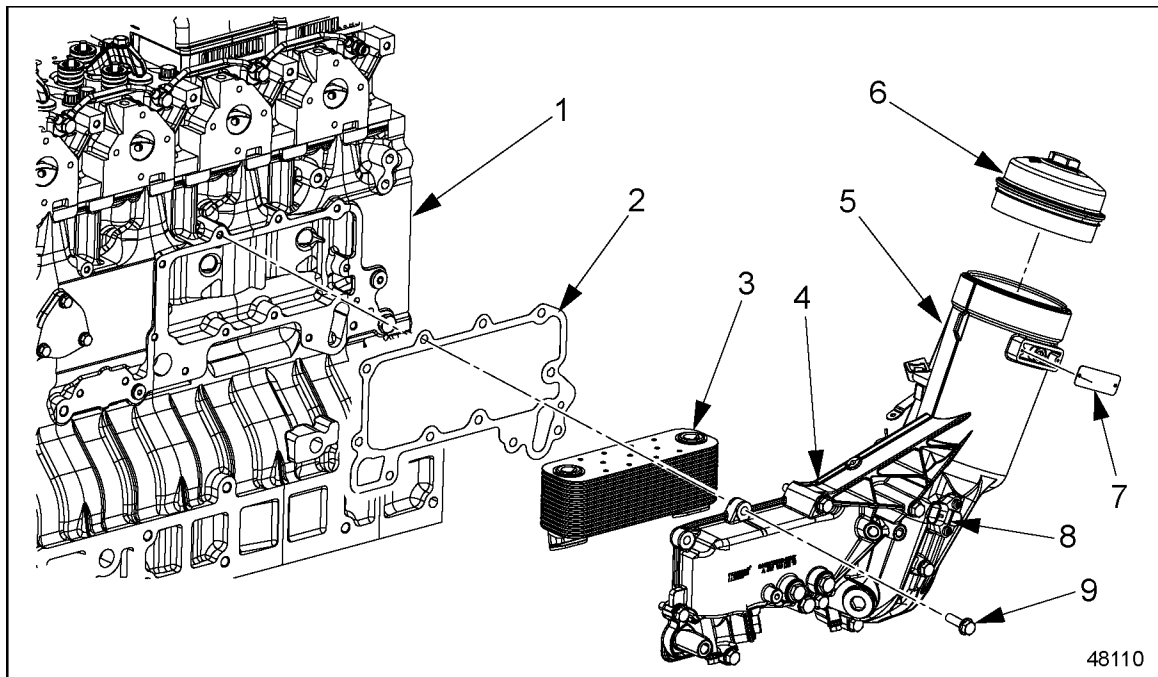
WARNING:

HOT COOLANT

To avoid scalding from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Wear adequate protective clothing (face shield, rubber gloves, apron, and boots). Remove the cap slowly to relieve pressure.

1. When the engine is cool, drain the coolant from the radiator.
2. Remove the turbocharger from the engine.
3. Disconnect the coolant pump shunt line from the coolant pump inlet pipe and move it out of the way.
4. Remove the oil filter cap. Inspect the O-ring and filter for damage and replace them if necessary. Drain the oil remaining in the filter into a clean container.
5. Disconnect the wiring harness from the oil pressure/temperature sensor.
6. Remove the banjo bolt and washers securing the oil lines to the oil cooler/filter housing. Discard washers.

7. Remove the oil cooler/filter housing from the cylinder block. See Figure 3-21. Catch any oil that drains out in a clean container. Discard the gasket and set aside the housing. Mark the bolts with a paint marker for location and later installation.



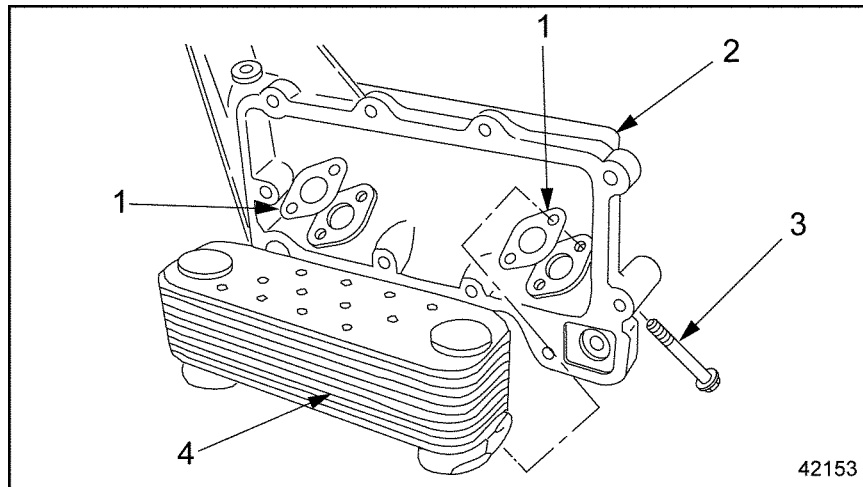
- | | |
|------------------------------|------------------------------------|
| 1. Cylinder Block | 6. Oil Filter Cap |
| 2. Gasket | 7. Engine Identification Plate |
| 3. Oil Filter Element | 8. Oil Pressure/Temperature Sensor |
| 4. Oil Cooler/Filter Housing | 9. Oil Cooler Bolts |
| 5. Oil Filter Housing | |

Figure 3-21 Oil Cooler/Filter Housing

NOTE:

The oil filter housing and the oil cooler housing are part of the same casting.

8. Remove the oil cooler element from the oil cooler/filter housing. Discard the gaskets and save the cooler bolts for later installation. See Figure 3-22.



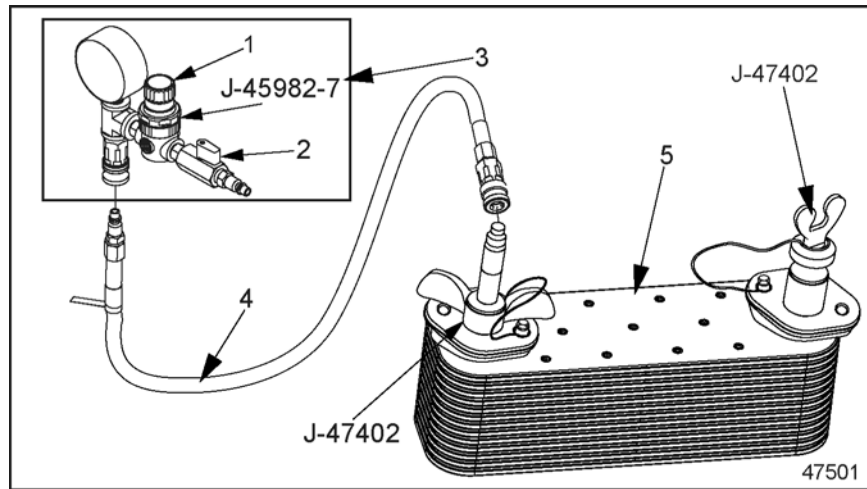
- | | |
|------------------------------|-----------------------|
| 1. Gasket | 3. Oil Cooler Bolt |
| 2. Oil Cooler/Filter Housing | 4. Oil Cooler Element |

Figure 3-22 Oil Heat Exchanger Assembly

9. Remove the oil pressure/temperature sensor from the oil cooler/filter housing. Refer to Section 3.8.1.

3.7.1.1 Testing of Oil Cooler Element Pressure

Testing steps are as follows:



- | | |
|------------------------|-----------------------|
| 1. Regulator Valve | 4. Pressure Hose |
| 2. Shutoff Valve | 5. Oil Cooler Element |
| 3. Regulator and Gauge | |

Figure 3-23 Pressure Checking the Oil Cooler Element

1. Install the air supply test adapter to one of the oil passages on the oil cooler element. See Figure 3-23.
2. Install test adapter plug to the opposite oil passage. See Figure 3-23.
3. Using the existing bolts from the oil cooler cover attach the safety straps. See Figure 3-23.
4. Connect pressure hose to the pressure regulator (J-45982-7). See Figure 3-23.
5. Check and ensure that the shutoff valve is in the OFF position and connect shop air to the pressure regulator.
6. Set the regulator pressure to zero by pulling up on the adjusting knob and turning counterclockwise until it stops.
7. Turn shutoff valve to the ON position.
8. Adjust system pressure by pulling up on the adjusting knob and turn clockwise until pressure reading on gauge is 344 kPa (50 psi).

NOTE:

DO NOT connect pressure hose (J-47313-2) to air supply fitting on the oil cooler until the pressure regulator has been adjusted to 344 kPa (50 psi).

**CAUTION:****EYE INJURY**

To avoid injury from flying debris, wear a face shield or goggles.

9. Once the pressure regulator has been adjusted, connect the pressure hose to air supply fitting on the oil cooler element.

**WARNING:****BURNS**

To avoid injury from burning, use lifting tools and heat-resistant gloves when handling heated components.

10. Submerge the oil cooler element completely in a hot water tank. Leave the element submerged for five minutes.
11. In the event of failed oil cooler element, a steady stream of air bubbles will come out of the oil cooler. Replace the element.

NOTE:

Some leakage may occur from the J-47402 fittings. Do not mistake this for a leaking oil cooler element.

12. If the oil cooler element shows no signs of leakage, inspect the sealing surfaces and conditions of each gasket.
13. Remove the oil cooler test kit components from the oil cooler element.

3.7.2 Installation of Oil Cooler/Filter Housing

Install the oil cooler/filter housing as follows:

1. Check the oil cooler element and the inside of the cooler housing for corrosion, contamination by metal particles, or abrasive material, such as sand.
 - [a] If corrosion is found, clean or replace the oil cooler, as necessary.
 - [b] Clean the mating surfaces of the oil cooler element and cooler housing. Remove any bits of adhering gasket material.
2. Install the oil cooler element and new gaskets on the heat cooler/filter housing. Tighten the element bolts to 25 N·m (18 lb·ft).

3. Install the oil cooler/filter housing on the cylinder block. Install the housing bolts and tighten them in the order shown in see Figure 3-24. Tighten each bolt to 60 N·m (44 lb·ft).

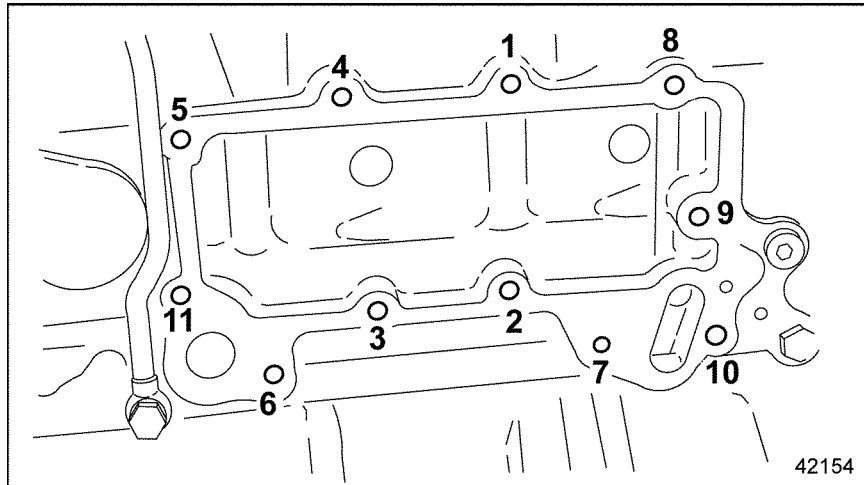
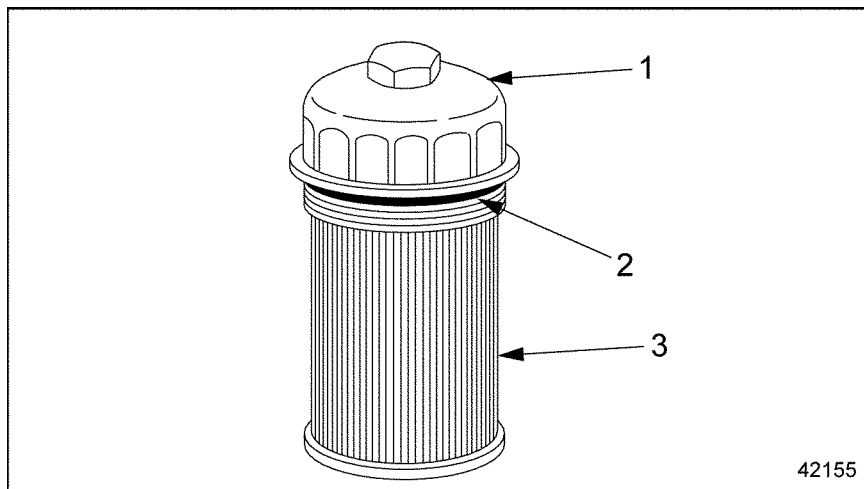


Figure 3-24 Oil Cooler Housing Bolts

- [a] Clean the mating surfaces of the oil cooler/filter housing and the cylinder block. Remove any bits of adhering gasket material.
 - [b] Replace the oil cooler/filter housing gasket.
4. Install a new filter element and O-ring in the oil filter housing. See Figure 3-25.



1. Oil Filter Cap

3. Oil Filter Element

2. O-ring

Figure 3-25 Oil Filter Element

5. Install the oil filter cap. Tighten the cap nut to 25 N·m (18 lb·ft).

6. Secure the oil lines to the oil cooler/filter housing with a banjo bolt and new washers. Tighten the banjo bolt to xx N·m (xx lb·ft).
7. Install the oil pressure/temperature sensor on the oil cooler/filter housing. Refer to Section 3.8.2.
8. Connect the wiring harness to the oil pressure/temperature sensor.
9. Install the turbocharger on the engine. Refer to section 6.7.3.
10. Connect the coolant pump shunt line to the coolant pump inlet pipe.
11. Fill the cooling system. Refer to section 4.1.1.



WARNING:
ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

12. Start the engine. Check the gauge for the correct oil pressure; check the oil lubrication system and the coolant pump inlet pipe for leaks. The correct oil pressures are listed in Table 3-3.

Engine Speed	Minimum Pressure kPa (psi)
At idling rpm	50 (7)
At maximum rpm	250 (36)

Table 3-3 Engine Oil Pressures

3.8 ENGINE OIL PRESSURE/TEMPERATURE SENSOR

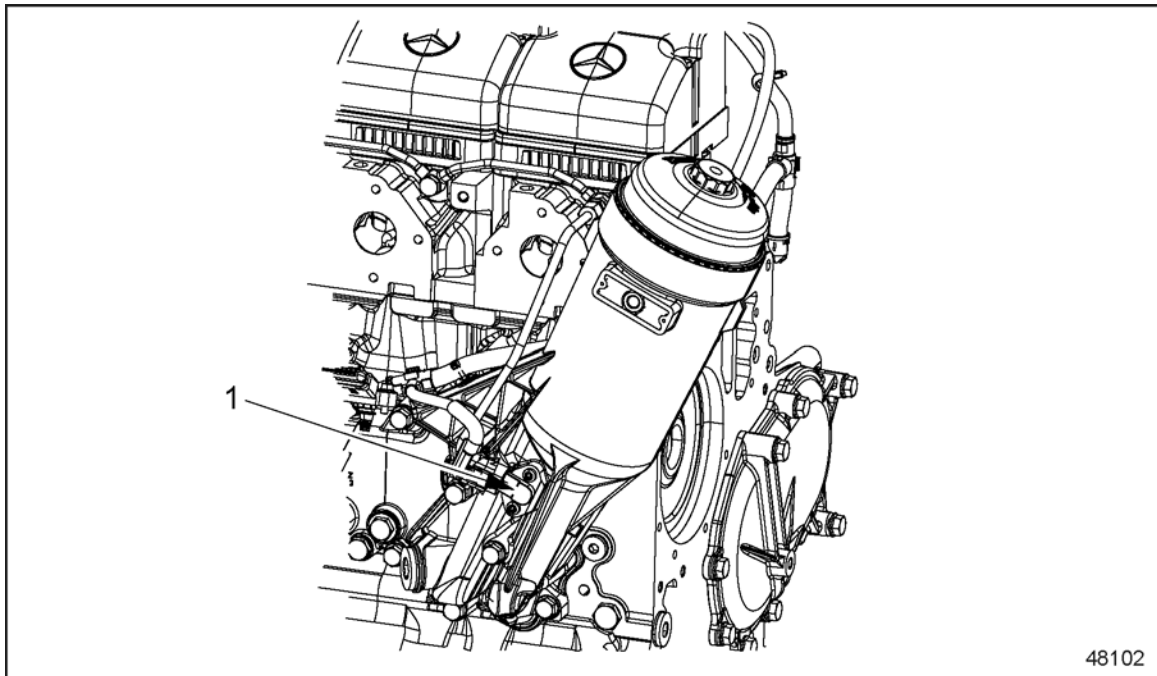
The Engine Oil Pressure/Temperature Sensor is located on the oil cooler/filter housing.

Perform the following procedures for removal and installation of the oil pressure/temperature sensor.

3.8.1 Removal of Engine Oil Pressure/Temperature Sensor

Removal steps are as follows:

1. Loosen the oil filter cap. Lift up the cap and filter to allow the oil to drain. Inspect the O-ring for damage and replace if necessary.
2. Disconnect the wiring connector from the oil pressure/temperature sensor. See Figure 3-26.



1. Oil Filter

2. Engine Oil Pressure/Temperature Sensor

Figure 3-26 Engine Oil Pressure/Temperature Sensor Location

3. Remove the two bolts securing the Engine Oil Pressure/Temperature Sensor to the oil filter housing.

3.8.2 Installation of Engine Oil Pressure/Temperature Sensor

Install the Engine Oil Pressure/Temperature Sensor as follows:

1. Install the Engine Oil Pressure/Temperature Sensor in the oil filter housing and secure with two screws. Torque the screws to 8 N·m (6 lb·ft).

2. Connect the wiring harness at the Engine Oil Pressure/Temperature Sensor.
3. Using a new O-ring (if necessary), install the oil filter cap. Tighten the nut to 25 N·m (18 lb·ft).



WARNING:
ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

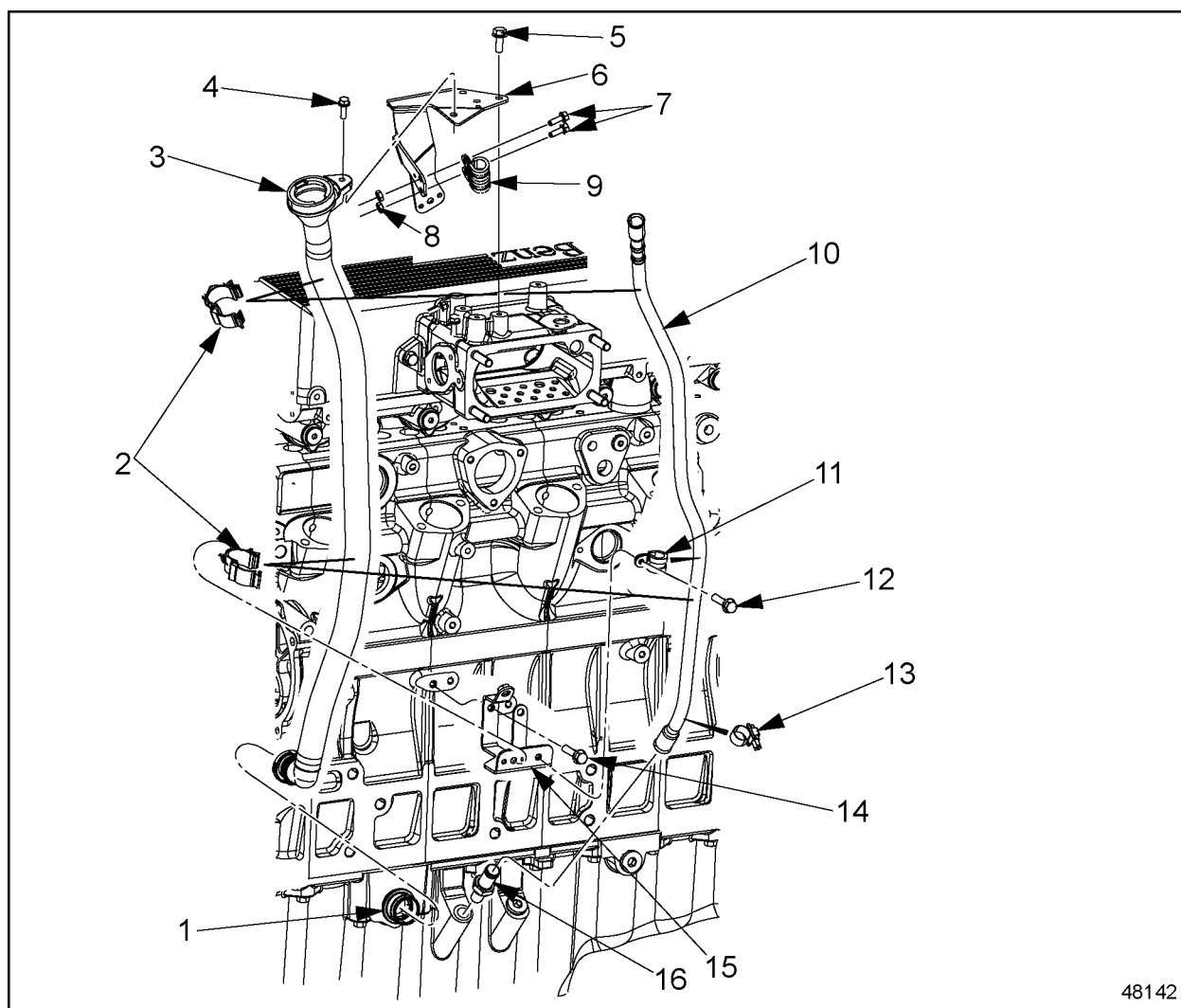
4. Start the engine. Check the gauge for the correct oil pressure as listed in Table 3-3.
5. Check and add engine oil as needed.

3.9 OIL FILL-TUBE AND OIL DIPSTICK

Perform the following procedures for removal and installation of the oil fill-tube and oil dipstick.

3.9.1 Removal of Oil Fill-Tube and Oil Dipstick

Removal steps are as follows:



- | | |
|---------------------------------------|--------------------------------------|
| 1. Fill-Tube Adaptor | 9. Clamp (Oil Dipstick Mounting) |
| 2. Snap Clamps | 10. Oil Dipstick Tube |
| 3. Oil Fill-Tube | 11. Clamp (Oil Dipstick Mounting) |
| 4. Bolt (Fill-Tube Mounting) | 12. Bolt |
| 5. Bolts (Fill-Tube Mounting Bracket) | 13. Hose Clamp |
| 6. Fill-Tube Mounting Bracket | 14. Bolts |
| 7. Bolts | 15. Mounting Bracket (Dipstick Tube) |
| 8. Nuts | 16. Dipstick Tube Adaptor |

Figure 3-27 Oil Fill-Tube and Oil Dipstick

1. Remove the oil fill-tube as follows:
 - [a] Remove the bolt securing oil fill-tube to the mounting bracket. See Figure 3-27.
 - [b] Unsnap the clamps securing the oil fill-tube to the cylinder block. See Figure 3-27.
 - [c] Squeeze the clamp at the bottom of the oil fill-tube and pull from adaptor to remove the tube.
 - [d] If necessary, remove the adaptor from the cylinder block. See Figure 3-27.
 - [e] If necessary, remove the oil fill-tube mounting bracket by removing three bolts securing the bracket to the top of the EGR gas mixer housing. See Figure 3-27.
2. Remove the oil dipstick as follows:
 - [a] Remove the dipstick from the dipstick tube.
 - [b] Remove two bolts and nuts securing two clamps on the oil dipstick to the mounting bracket. Remove the clamps from the oil dipstick. See Figure 3-27.
 - [c] Remove bolt from the clamp securing the oil dipstick to the side of the cylinder block. Remove the clamp from the dipstick. See Figure 3-27.
 - [d] Remove hose clamp at the bottom of the dipstick tube and pull tube from adaptor. See Figure 3-27.
 - [e] If necessary, remove the oil dipstick adaptor from the oil pan.

3.9.2 Installation of Oil Fill-Tube and Oil Dipstick

Installation steps are as follows:

1. Install the oil fill-tube as follows:
 - [a] If removed, install oil fill-tube adaptor in the oil pan. Torque the adaptor to 35 N·m (26 lb·ft). See Figure 3-27.
 - [b] If removed, attach the oil fill-tube mounting bracket to the top of the EGR gas mixer housing and secure with three bolts. Torque the bolts to 30 N·m (22 lb·ft). See Figure 3-27.
 - [c] Install the bottom of the oil fill-tube on the adaptor at the oil pan and snap in place. See Figure 3-27.
 - [d] Install the oil fill-tube in the snap clamps and lock the clamps. See Figure 3-27.
 - [e] Secure the oil fill-tube to the top of the mounting bracket with a bolt. Torque the bolts to 15 N·m (11 lb·ft). See Figure 3-27.
2. Install the oil dipstick as follows:
 - [a] If removed install the oil dipstick adaptor in the oil pan. Torque the adaptor to 50 N·m (37 lb·ft). See Figure 3-27.
 - [b] Install the dipstick tube over the adaptor in the oil pan and secure with hose clamp. Tighten the clamp securely. See Figure 3-27.

- [c] Install the clamp over the dipstick tube and secure to the cylinder block with a bolt. Torque the bolt to 15 N·m (11 lb·ft). See Figure 3-27.
- [d] Install two clamps over the dipstick tube near the top and secure to the mounting bracket with two bolts and nuts. Torque the bolts and nuts to 15 N·m (11 lb·ft). See Figure 3-27.
- [e] Install the dipstick into the dipstick tube.

3.A ADDITIONAL INFORMATION

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Lubrication System	3-37
Oil Pump	3-39
Oil Cooler	3-39

SPECIFICATIONS

This section contains the specifications for servicing the engine.

Lubrication System

Listed in Table 3-4 is the lubricating oil capacity for the engine. The lubrication system torque values are listed in Table 3-5. and listed in Table 3-6 are the cylinder block oil gallery plug torque values.

Description *	Value: L (qts)
Oil Pan Capacity	36.0 (38.0)
Engine Oil Fill Capacity (Includes Oil Filter)	39.5 (41.7)

* In standard oil pan

Table 3-4 Lubricating Oil Capacity

Description	Torque N·m (lb·ft)
Oil Heat Exchanger Housing Bolts (to block)	60 (44)
Oil Heat Exchanger Element Bolts (to cooler housing)	25 (18)
Oil Filter Cap	25 (18)
Oil Pan Drain Plug	80 (59)
Oil Pan Bolts (to block)	35 (26)
Oil Pressure/Temperature Sensor Mounting Screws	10 (7)
Oil Pump Face Plate Mounting Bolts (to oil pump housing)	25 (18)
Oil Pump Mounting Bolt (to block)	35 (26)
Piston Oil Spray Nozzle Hollow-Core Bolt	40 (30)
Pressure Relief Valve Bolts (to block)	35 (26)
Suction Pipe Bracket to Crankcase Bolt	25 (18)
Suction Pipe Mounting Bolt (to oil pump)	25 (18)
Camshaft Lubrication Nozzle Hollow Core Bolt	20 (15)
Oil Line Banjo Bolt (to filter housing)	35 (26)
Oil Fill-tube Adaptor to Oil Pan	35 (26)
Oil Fill-tube Mounting Bracket Bolt	15 (11)
Oil Fill-tube to Mounting Bracket to Mixer Housing Bolts	30 (22)
Bolts and Nuts to Two Clamps Oil Dipstick Tube to Mounting Bracket	15 (11)
Oil Dipstick Adaptor in the Oil Pan)	50 (37)
Bolt to Clamp on Dipstick Tube to Cylinder Block	15 (11)

Table 3-5 Torque Values

Description	Torque, N·m (lb·ft)
Main Oil Gallery - Engine Block Rear bottom plug - M26 x 1.5	150 (110)
Main Oil Gallery - Inner Plug - M22 x 1.5	50 (37)
Main Oil Gallery - Engine Block Rear Top Plug - M24 x 1.5	120 (89)
Main Oil Gallery - Engine Block Front Plug - M22 X 1.5	100 (74)
Main Oil Gallery - Engine Right Hand Side Top Plug before the Oil Filter Housing - M18 x 1.5	60 (44)
Main Oil Gallery - Engine Right Hand Side Bottom Plug before the Oil Filter Housing - M16 x 1.5	60 (44)
Main Oil Gallery - Engine Right Hand Side Bottom Plug after the Oil Filter Housing - M16 x 1.5	60 (44)

Table 3-6 Cylinder Block Oil Gallery Plug Torque Values

Oil Pump

The oil pump inspection limits are listed in Table 3-7. Listed in Table 3-8 are the oil pump installation specifications.

Description	Limits mm (in.)
Diameter of Shaft Bore (in pump housing and face plate)	22.000-22.021 (0.8661-0.8670)
Diameter of Idler Gear and Pump Drive Gear Shaft	21.93-21.94 (0.8634-0.8638)
Clearance of Pump/Idler Gear to Walls of Pump Housing	0.030-0.122 (0.0012-0.0048)
Oil Pump Gear Backlash (clearance between gear teeth)	0.312-0.476 (0.0123-0.0187)

Table 3-7 Oil Pump Inspection Limits

Description	Specifications mm (in.)
Projection of Pump Drive Gear	0.5 (0.02)
Pump/Idler Gear End Play	0.050-0.128 (0.0020-0.005)
Backlash of Oil Pump Drive Gear and Crankshaft Gear	0.077-0.333 (0.0030-0.1311)

Table 3-8 Oil Pump Installation Specifications

Oil Cooler

The minimum engine oil pressure is listed in Table 3-9.

Engine Speed	Minimum Pressure kPa (psi)
At idling rpm	50 (7)
At maximum rpm	250 (36)

Table 3-9 Engine Oil Pressures

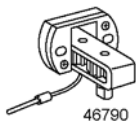
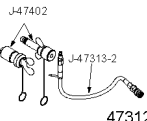
Tool	Description	Usage	Part Number
	Engine Barring Tool	Used to lock or rotate the flywheel.	J-46392
	Oil Cooler Leak Test Kit	Used to pressure test the oil cooler element.	J-47402

Table 3-10 Special Tools

4 COOLING SYSTEM

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4.2 COOLANT PUMP	4-8
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4.1 COOLING SYSTEM

See Figure 4-1 for cooling system schematic.

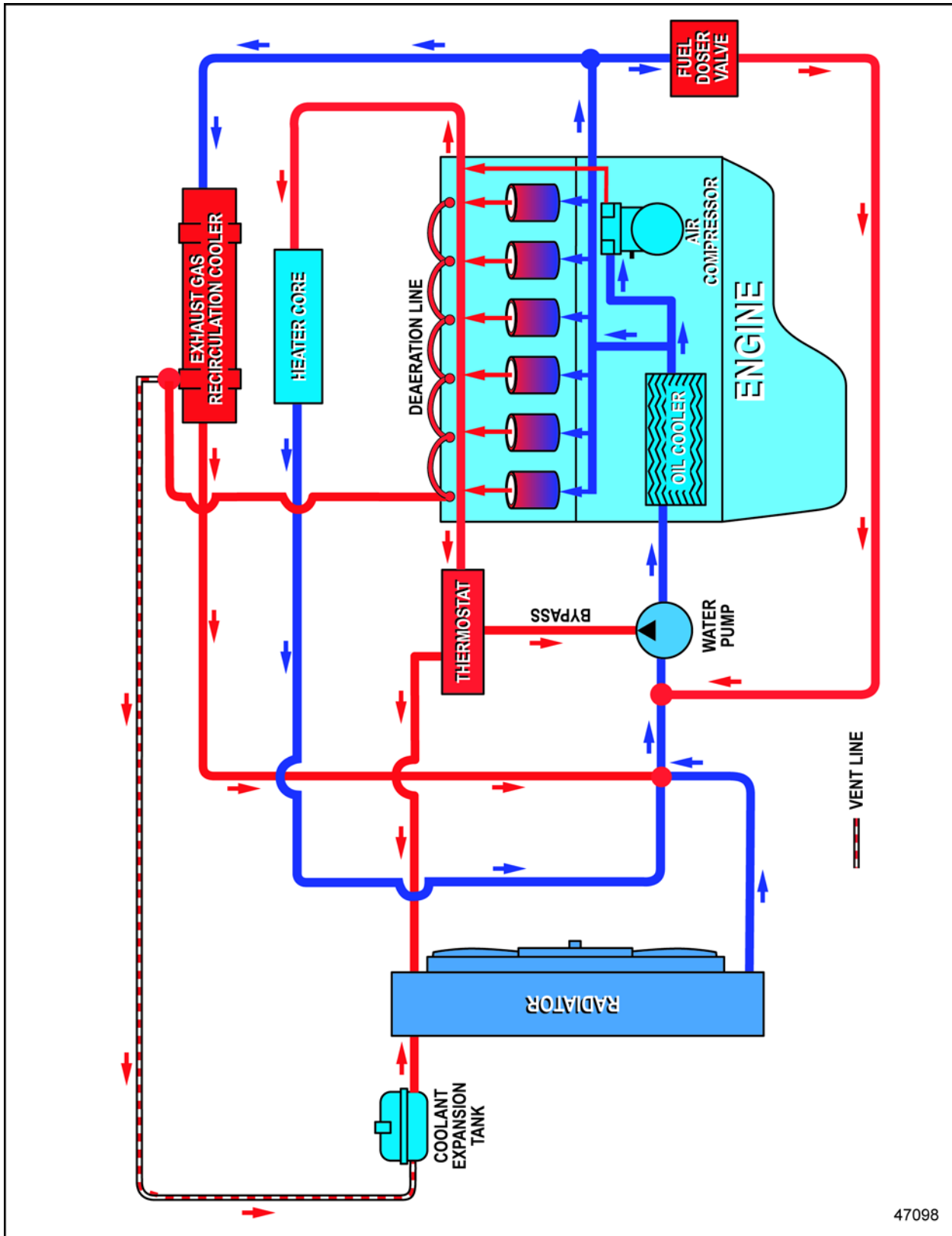


Figure 4-1 MBE 4000 Cooling System Schematic

4.1.1 Draining and Flushing the Cooling System

Drain and flush the cooling system as follows:

 WARNING: HOT COOLANT
To avoid scalding from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Wear adequate protective clothing (face shield, rubber gloves, apron, and boots). Remove the cap slowly to relieve pressure.

1. Open the cap on the surge tank slowly, to allow excess pressure to escape. Set the cap aside.
2. Open the water regulating valve for the heating system.
3. Drain the coolant from the radiator. The cooling system capacity is listed in Table 4-1.

Description	Capacity L (qts)
Engine Coolant Capacity (all vehicles)	
Engine capacity*	30.0 (31.7)
Century Class and Columbia Cooling System Capacity	
Total capacity†	57.4 (60.7)
Antifreeze quantity at 50 percent	28.7 (30.3)
Antifreeze quantity at 55 percent	31.6 (33.4)
Sterling A-Line and L-Line Cooling System Capacity	
Total capacity	53.8 (56.8)
Antifreeze quantity at 50 percent	26.9 (28.4)
Antifreeze quantity at 55 percent	29.6 (31.3)
FL112 Cooling System Capacity	
Total capacity	42.0 (44.4)
Antifreeze quantity at 50 percent	21.0 (22.2)
Antifreeze quantity at 55 percent	23.1 (24.4)

* Does not include capacity of cooling system.

†With 1200 sq. in. radiator.

Table 4-1 Cooling System Capacity

- [a] Place a receptacle underneath the coolant drain plug. Choose one that is large enough to hold the expected quantity of coolant.

NOTE:

Make sure the coolant can flow unobstructed into the receptacle.

- [b] Open the coolant drain plug located on the bottom of the radiator.

 WARNING: EYE INJURY
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 276 kPa (40 psi) air pressure.

4. Flush the radiator.

- [a] Attach a flushing gun nozzle to the radiator outlet.
- [b] Run water in until the radiator is full.
- [c] Apply no more than 140 kPa (20 psi) air pressure intermittently to help dislodge sediment buildup in the core.

NOTICE:
When flushing the radiator, do not apply more than 140 kPa (20 psi) air pressure. Excessive pressure can damage the radiator or heater core.

5. Drain the radiator, and flush the radiator until clean water flows from the radiator. Remove the flushing gun.
6. When the coolant has drained, install the coolant drain plug on the bottom of the radiator.
7. Add coolant in the specified concentration. Listed in Table 4-1 is the cooling system capacity. Listed in Table 4-2 is the coolant mixing ratio. For types of coolant, refer to the “Coolant Selections Guide” 7SE298.

Antifreeze Protection Down to °C(°F)	Water Percentage by Volume	Corrosion-Inhibiting Antifreeze Percentage by Volume
-37 (-34)	50	50
-45 (-49)	40	Maximum 60

Table 4-2 Coolant Mixing Ratio

- [a] Tighten the coolant drain plug to 30 N·m (22 ft·lb).
- [b] Add coolant up to the maximum fill level on the surge tank.

8. Check the coolant level and check the cooling system for leaks.

**WARNING:****ENGINE EXHAUST**

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

- [a] Start the engine and run it for about one minute at varying speeds to release air pockets in the cooling system.
 - [b] Check all hoses at the radiator, coolant pump, and surge tank for leaks.
 - [c] Check the coolant level and add more coolant if necessary.
9. Shut down the engine.
10. Close and tighten the cap on the surge tank.

4.2 COOLANT PUMP

Perform the following procedures for removal and installation of the coolant pump.

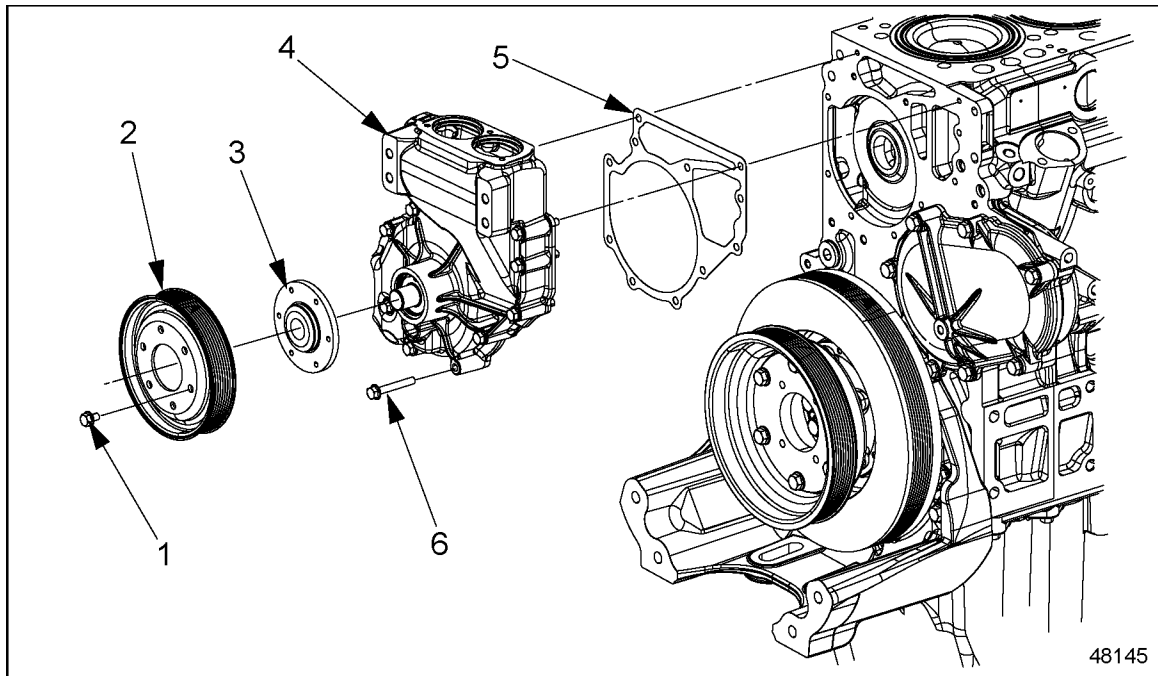
4.2.1 Removal of Coolant Pump

Removal steps are as follows:

 WARNING: HOT COOLANT
To avoid scalding from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Wear adequate protective clothing (face shield, rubber gloves, apron, and boots). Remove the cap slowly to relieve pressure.

1. Drain the coolant from the engine. Refer to section 4.1.1.
2. For engines equipped with the Extreme Cold Climate (EC2) package, remove the coolant return line from the air intake manifold to the coolant pump.
3. Remove the fan from the coolant pump.
4. Release the tension on the main drive belt and the fan belt and remove the belts.
5. Remove the plate covering the EGR valve.
6. Remove the two bolts securing the EGR valve to the thermostat housing.
7. Remove the front lifting bracket.
8. Remove the banjo fitting and washers securing the Fuel Doser Valve (FDV) coolant return line for the coolant pump. Discard the washers.
9. Remove the thermostats. Refer to section 4.4.1.

10. Remove the coolant pump pulley from the coolant pump housing. See Figure 4-2.



- | | |
|--------------------------------------|-------------------------------|
| 1. Coolant Pump Pulley Mounting Bolt | 4. Coolant Pump Housing |
| 2. Coolant Pump Pulley | 5. Gasket |
| 3. Hub | 6. Coolant Pump Mounting Bolt |

Figure 4-2 Coolant Pump

11. Remove the coolant pump from the cylinder block. Discard the gasket. See Figure 4-2.

NOTE:

Catch any coolant that runs out of the inlet pipe or coolant pump in a suitable container.

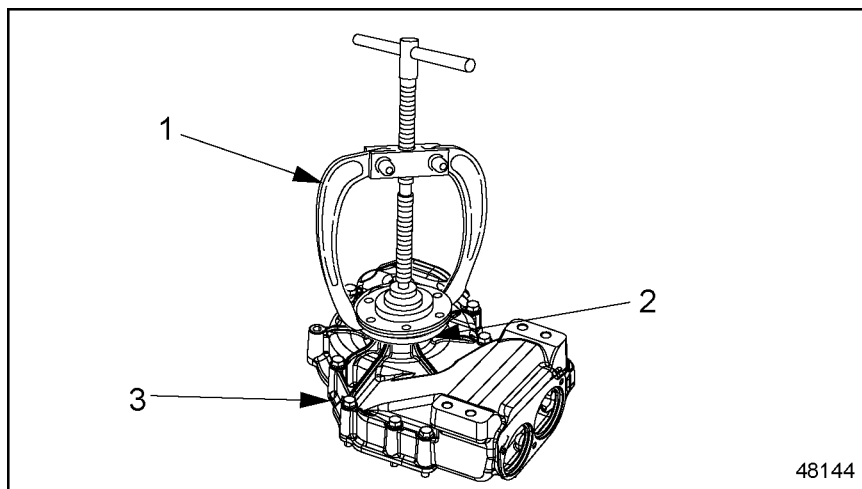
12. On both the coolant pump and the cylinder block, clean the sealing surfaces (where the gasket was attached) of any adhering bits of gasket material.
13. Remove the thermostat housing, thermostats and seal rings from the coolant pump housing. Refer to section 4.4.1.
14. Remove any other hose or fitting connections.

4.2.2 Disassembly of Coolant Pump

Disassembly steps are as follows:

1. Remove the coolant pump from the engine. Refer to section 4.2.1.

2. Using a puller, pull the coolant pump hub away from the bearing. See Figure 4-3.



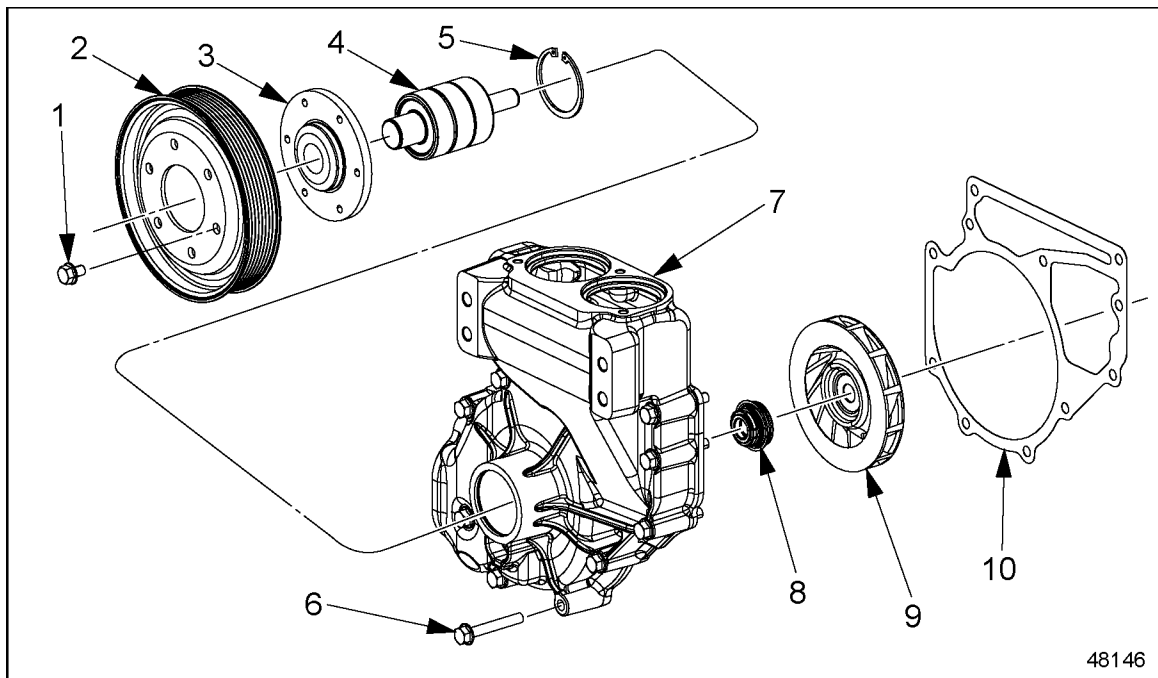
1. Puller

2. Hub

3. Coolant Pump Housing

Figure 4-3 **Pulling the Hub**

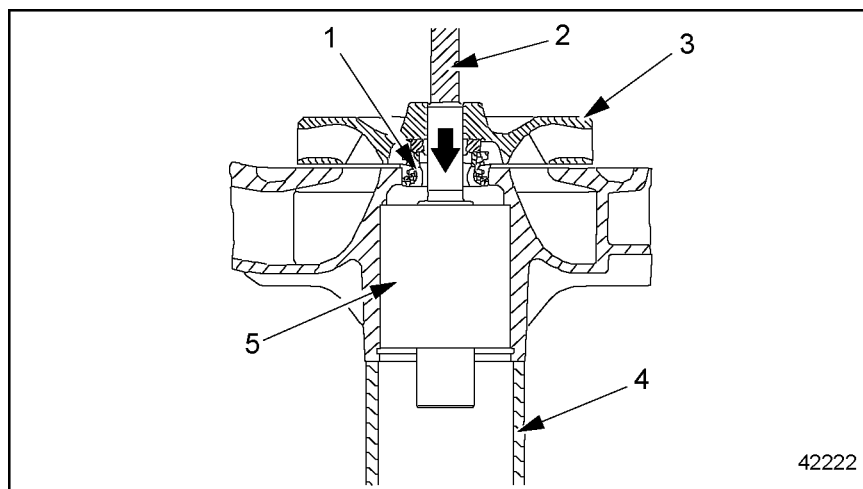
3. Remove the snap ring from the coolant pump housing. See Figure 4-4.



- | | | |
|-------------------------------------|-------------------------------|-------------|
| 1. Pulley Bolts | 5. Retaining Ring | 9. Impeller |
| 2. Pulley | 6. Coolant Pump Housing Bolts | 10. Gasket |
| 3. Hub | 7. Coolant Pump Housing | |
| 4. Drive Shaft and Bearing Assembly | 8. Seal | |

Figure 4-4 Coolant Pump Assembly

4. Using an appropriate drift, press the drive shaft and bearing assembly out of the impeller and through the coolant pump housing. This frees the impeller from the housing. See Figure 4-5.



- | | |
|----------------|-------------------------------------|
| 1. Sleeve Seal | 4. Receptacle |
| 2. Drift | 5. Drive Shaft and Bearing Assembly |
| 3. Impeller | |

Figure 4-5 Drive Shaft

5. Remove the sleeve seal from the coolant pump housing.

4.2.2.1 Inspection of Coolant Pump

Inspection steps are as follows:

1. Check all coolant pump components for signs of damage. Replace any damaged components.

2. Measure the following wear dimensions. Replace any component that is not within tolerance as listed in Table 4-3.

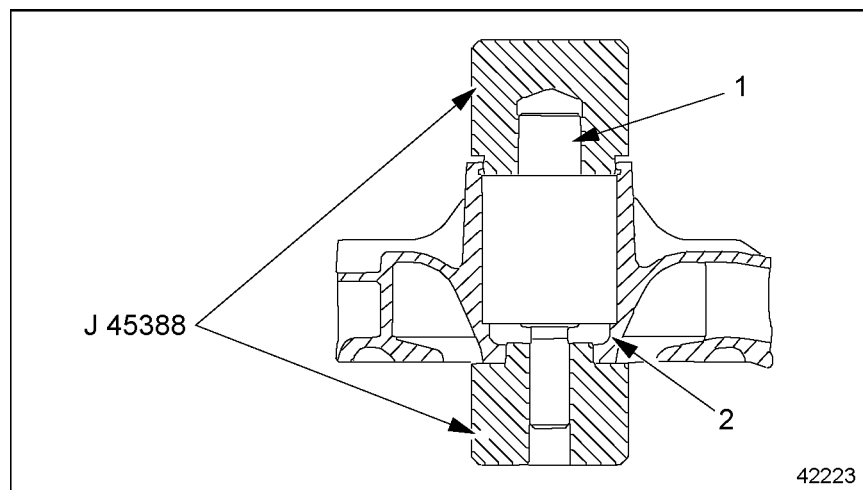
Description	Wear Dimensions, mm (in.)
Drive Shaft Diameter (at the hub)	25.048-25.061 (0.9861-0.9867)
Hub Inside Diameter	24.995-25.008 (0.9841-0.9846)
Bearing Outside Diameter	54.981-54.994 (2.1646-2.1651)
Bearing Housing Diameter	54.930-54.960 (2.1626-2.1638)
Drive Shaft Diameter (at the impeller)	15.045-15.056 (0.5923-0.5928)
Impeller Inside Diameter	15.000-15.018 (0.5906-0.5913)
Impeller Outside Diameter	124-125 (4.88-4.92)
Impeller - Maximum Out-Of-Round	0.15 (0.0059)

Table 4-3 Coolant Pump Assembly Wear Dimensions

4.2.3 Assembly of Coolant Pump

Assembly steps are as follows:

1. Press the drive shaft and bearing assembly into the coolant pump housing. See Figure 4-6.



1. Impeller Shaft and Bearing Assembly

2. Coolant Pump Housing

Figure 4-6 Impeller Shaft

- [a] Place the coolant pump housing in a press.
- [b] Place the coolant pump pressure piece (Part of Toolset J-45388) over the outer bearing race.
- [c] Place the receptacle (Part of Toolset J-45388) under the coolant pump housing.

NOTICE:

To prevent damage to the drive shaft and bearing assembly, press only on the outer bearing race.

- [d] Press the outer race of the bearing into the coolant pump housing.
2. Secure the bearing in place with the snap ring.

**WARNING:****PERSONAL INJURY**

To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

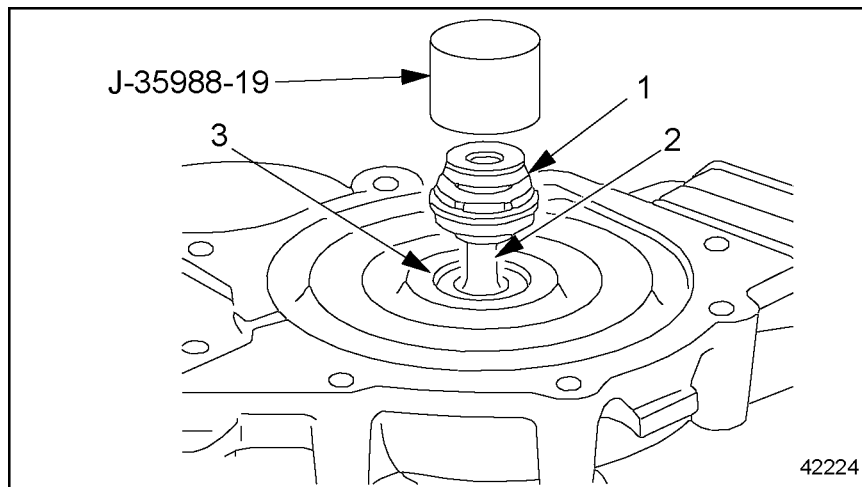
3. Press the hub onto the impeller shaft and bearing assembly.

[a] Heat the hub to 80°C (175°F).

NOTICE:

To prevent damage to the bearing, make sure the drive shaft is supported evenly before pressing on the hub.

- [b] Press the hub onto the impeller shaft, while holding the bearing and shaft assembly to prevent it from turning. Make sure the hub is flush with the end of the drive shaft.
4. Using the coolant pump bearing drift (J-35988-19), press the sleeve seal into the coolant pump housing. See Figure 4-7.



1. Impeller
2. Drive Shaft

3. Sleeve Seal

Figure 4-7 Sleeve Seal

5. Press the impeller onto the shaft and bearing assembly. See Figure 4-8.

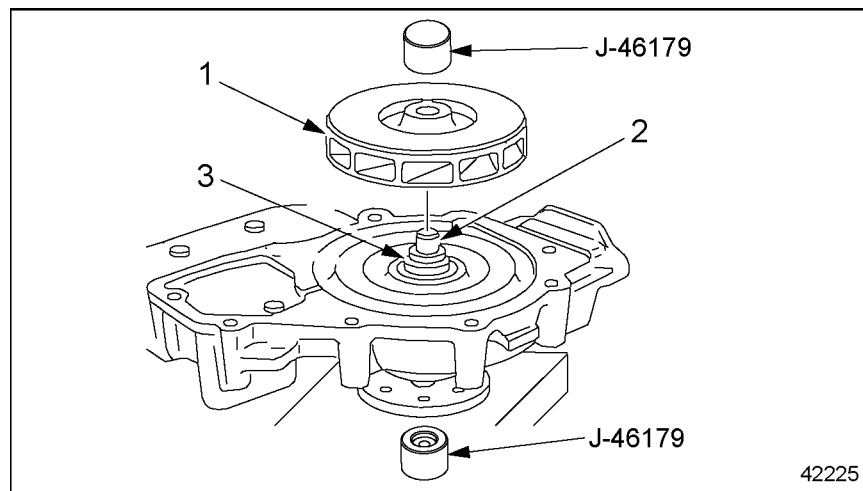


Figure 4-8 **Impeller**

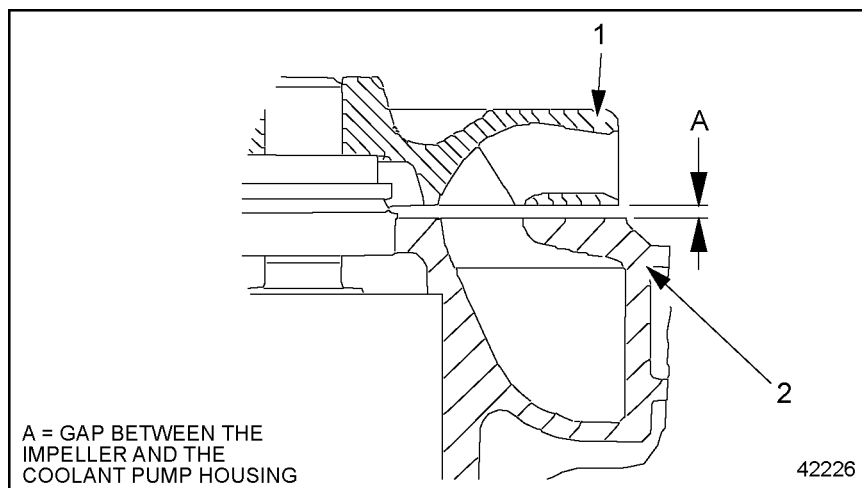
NOTE:

Secure both the drive shaft and hub to prevent them from turning while the impeller is being installed.

6. Measure the gap between the impeller and the coolant pump housing. This gap, listed in Table 4-4, must be more than 0.6 mm (0.024 in.) and less than 1.0 mm (0.039 in.). See Figure 4-9.

Description	mm (in.)
Gap Between the Impeller and the Coolant Pump Housing	0.6-1.0 (0.024-0.039)

Table 4-4 Critical Dimension for Coolant Pump



1. Impeller

2. Coolant Pump Housing

Figure 4-9 Gap Between the Impeller and the Housing

7. Rotate the coolant pump drive shaft to make sure it moves easily and freely.
8. Install the coolant pump on the engine.

4.2.4 Installation of Coolant Pump

Installation steps are as follows:

1. Install the thermostats. Refer to section 4.4.2.
2. Install the coolant pump and new gasket on the cylinder block. Tighten the mounting bolts to 30 N·m (22 lb·ft).
3. Install EGR cooler coolant return tube. Refer to section 8.6.2.
4. For engines equipped with the Extreme Cold Climate (EC2) Package, install the coolant return line from the air intake manifold to the coolant pump. Torque to 50 N·m (37 lb·ft).
5. Connect the inlet pipe to the coolant pump housing, as removed. Install a new gasket on the mating surface between the inlet pipe and the coolant pump housing. Tighten the inlet pipe mounting bolts to 50 N·m (37 lb·ft).

6. Install the upper coolant tube onto the thermostat housing.
7. Secure the coolant pump pulley to the coolant pump. Torque the bolts to 25 N·m (18 lb·ft).
8. Move the front idler and tensioner support back into place on the cylinder block. Tighten the mounting bolts to 60 N·m (44 lb·ft).
9. Release the belt tensioners for the main drive and fan belts. Route the two belts around their pulleys and restore the belt tension.
10. Install the fan on the coolant pump pulley. Torque the bolts to 25 N·m (18 lb·ft).
11. Secure the front engine lifting bracket to the coolant pump and EGR valve. Torque the bolts to 50 N·m (37 lb·ft).
12. Secure the EGR valve cover plate to the EGR valve and the front lifting bracket. Torque the bolts to 25 N·m (18 lb·ft).
13. Fill the engine with coolant, as removed, and check for leaks. The cooling system capacity is listed in Table 4-1.

4.3 FRONT IDLER AND TENSIONER SUPPORT

Perform the following procedures for removal and installation of the front idler and tensioner support.

4.3.1 Removal of Front Idler and Tensioner Support

Removal steps are as follows:

1. Disconnect the batteries.
2. Release the tension on the main drive belt and fan belt. Set the belts aside.
3. Remove the belt tensioner from the front of the engine.

4.3.2 Installation of Front Idler and Tensioner Support

Installation steps are as follows:

1. Install the front idler on to the cylinder block. Tighten the mounting bolts to 60 N·m (44 lb·ft).
2. Release the tension on the main belt tensioner and install the main drive belt. Release the tension on the fan belt tensioner and install the fan belt.
3. Connect the batteries.

4.4 THERMOSTAT

Perform the following procedures for removal and installation of the thermostat.

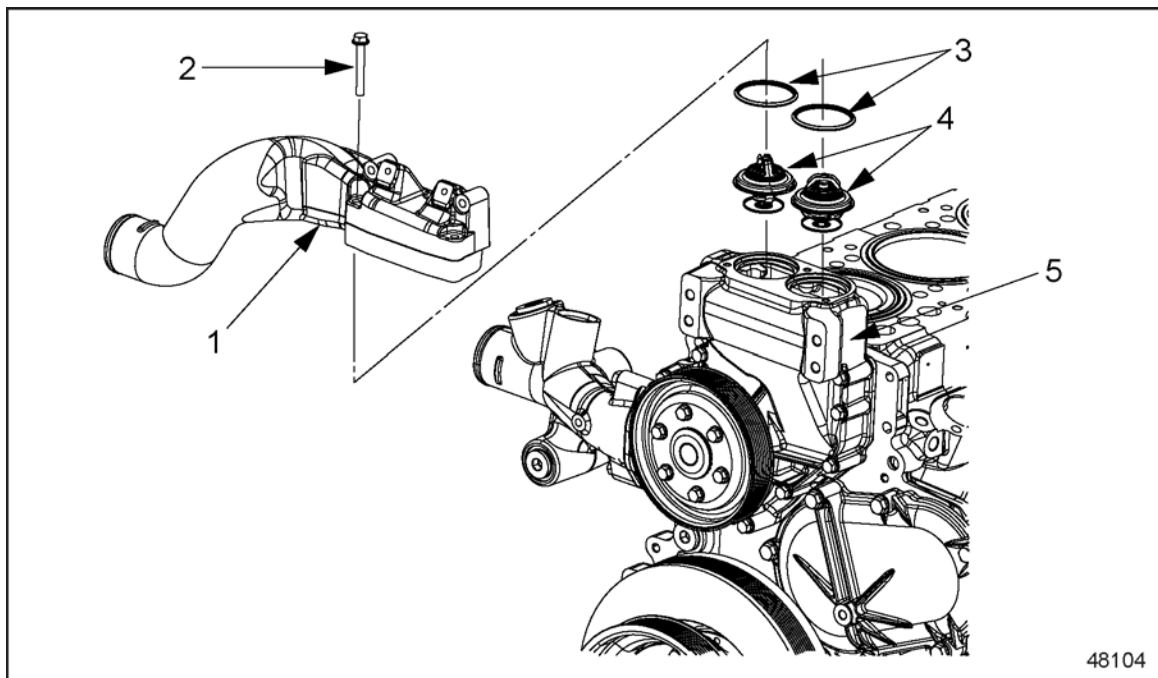
4.4.1 Removal of Thermostat

Removal steps are as follows:

! WARNING:
HOT COOLANT

To avoid scalding from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Wear adequate protective clothing (face shield, rubber gloves, apron, and boots). Remove the cap slowly to relieve pressure.

1. Drain the coolant from the engine. Refer to section 4.1.1.
2. Remove the upper coolant tube from the thermostat housing. See Figure 4-10.



- | | |
|-----------------------------|-------------------------|
| 1. Upper Thermostat Housing | 4. Thermostat |
| 2. Mounting Bolt | 5. Coolant Pump Housing |
| 3. Seal-Ring | |

Figure 4-10 Thermostat

3. Remove the mounting screws attaching the thermostat housing to the coolant pump housing. Remove the thermostat housing.

NOTE:

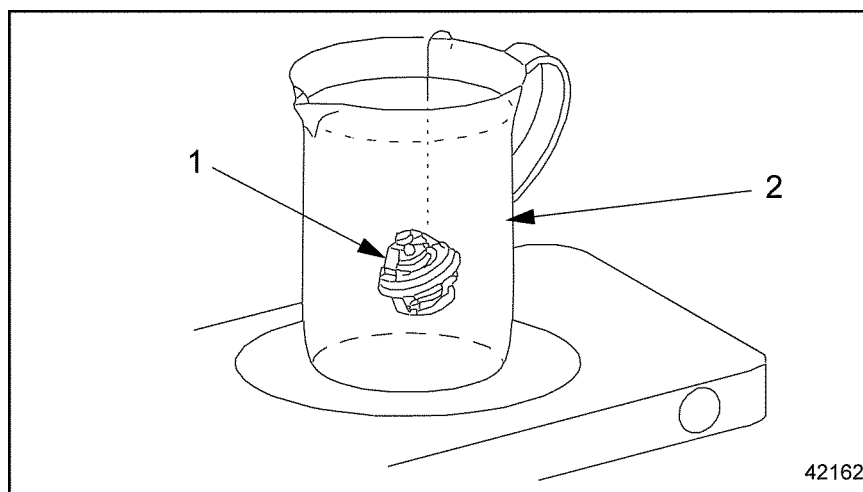
Catch any coolant that runs out of the upper coolant tube or coolant pump housing.

4. Remove the thermostats and seal rings from the coolant pump housing. Discard the seal rings.
5. Check both thermostats for proper operation. For detailed procedures, refer to section 4.4.1.1. Replace any thermostat that fails one or more tests.

4.4.1.1 Checking of Thermostat

Checking steps are as follows:

1. Remove the thermostat from the coolant pump housing. Refer to section 4.4.1.
2. Hang the thermostat by a wire inside a container filled with water. See Figure 4-11.



1. Thermostat

2. Container

Figure 4-11 Heat the Thermostat

NOTE:

To allow the thermostat to heat evenly, make sure it is not touching the sides of the container.

NOTICE:

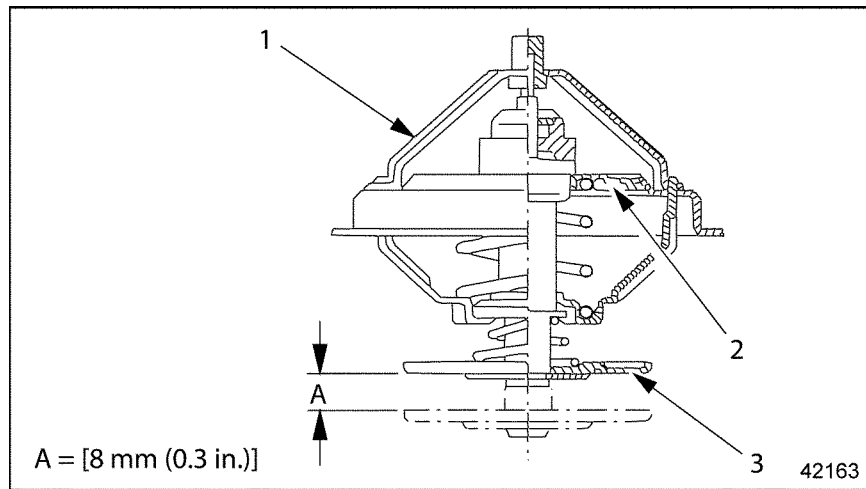
To prevent damage to the thermostat or heating container, do not ever use a welding torch or soldering gun as a source of heat.

3. Heat the water with a suitable heating element. Stir the water occasionally to help equalize the temperature.

**WARNING:****PERSONAL INJURY**

To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

- [a] Measure the water temperature. As the temperature climbs to around 75°C (167°F), slow the rate of heating down to about 1-2°C (2-3°F) per minute.
 - [b] In about five minutes, the main valve should begin to open.
4. Continue to heat the water at this rate for about six to eight minutes until it reaches the opening temperature of the main valve. If the main valve is not completely open, replace the thermostat. See Figure 4-12.



1. Thermostat

2. Main Valve

3. Short Circuit Valve

Figure 4-12 Thermostat Lift

5. Check all the test values for the main valve listed in Table 4-5. If any of the values is not met, replace the thermostat.

Description	Temperature °C (°F)	Distance mm (in.)
Main Valve Starts To Open	81-85 (177-185)	—
Main Valve Fully Open	95 (203)	—
Main Valve Minimum Lift	—	8 (0.3)
Short Circuit Valve Fully Closed	92° (198)	—
Short Circuit Valve Minimum Lift	—	6-7.5 mm (0.24-0.295 in.)

Table 4-5 Thermostat Test Values

- [a] At the temperature of 85°C (185°F), check that the main valve has started to open.
 - [b] At the opening temperature of 95°C (203°F), check that the main valve is fully open.
 - [c] Check the minimum lift of the main valve at the opening temperature.
6. Check all the test values for the short circuit valve listed in Table 4-5. If any of the values is not met, replace the thermostat.
 - [a] At the temperature of 92°C (198°F), check that the short circuit valve is fully closed.
 - [b] Check the minimum lift of the short circuit valve at the closing temperature.
 7. Install the original or replacement thermostat(s), as necessary, the upper coolant hose inlet, and seal ring(s) on the coolant pump, as removed.
 8. Fill the engine with coolant, as removed, and check for leaks and proper operation.

4.4.2 Installation of Thermostat

Installation steps are as follows:

1. Install a new seal ring on each thermostat.
2. Install the original and/or replacement thermostats.
3. Install the thermostat housing. Install the mounting bolts attaching the thermostat housing to the coolant pump housing. Tighten each mounting bolt to 25 N·m (18 lb·ft). See Figure 4-10.
4. Install the upper coolant tube on the thermostat housing. Tighten the hose clamp until firm.
5. Fill the engine with coolant, and check for leaks and proper operation. Refer to section 4.1.1.

4.5 ENGINE COOLANT TEMPERATURE SENSOR

The coolant temperature sensor is located on the left side of the cylinder block behind the engine harness, between unit pumps #2 and #3.

4.5.1 Removal of Engine Coolant Temperature Sensor

Removal steps are as follows:

WARNING:

HOT COOLANT

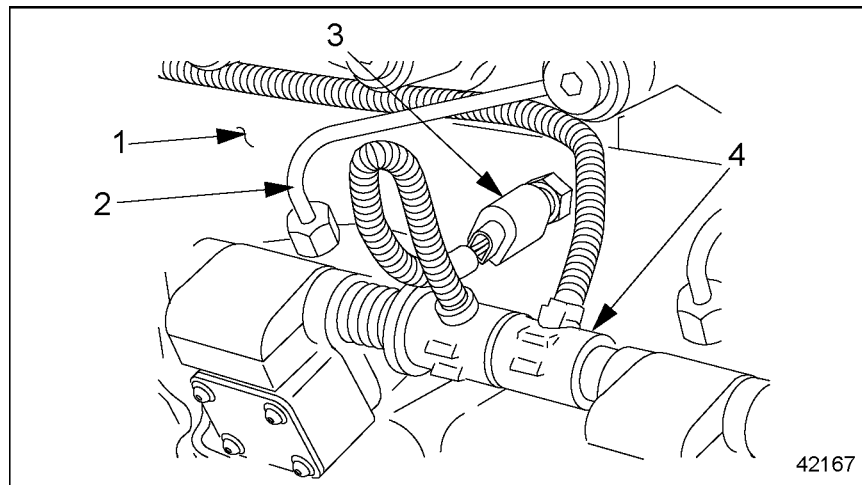
To avoid scalding from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Wear adequate protective clothing (face shield, rubber gloves, apron, and boots). Remove the cap slowly to relieve pressure.

1. Drain some coolant from the engine.

NOTE:

It is not necessary to drain all the coolant from the engine to do this procedure. Enough has to be drained to prevent coolant from leaking out while the sensor is being changed.

2. Remove the engine trim panel from the left side of the engine. Refer to section 1.1.1.
3. Locate the Engine Coolant Temperature Sensor behind the engine harness, between unit pumps #2 and #3. See Figure 4-13.



1. Cylinder Block

2. High-Pressure Fuel Line

3. Engine Coolant Temperature Sensor

4. Engine Harness

Figure 4-13 Engine Coolant Temperature Sensor Location

4. Remove the electrical connector from the Engine Coolant Temperature Sensor.
5. Unscrew the Engine Coolant Temperature Sensor from the wall of the cylinder block.

4.5.2 Installation of Engine Coolant Temperature Sensor

Installation steps are as follows:

1. Install the new sensor into the hole in the cylinder block, as removed. Torque the sensor to 30 Nm (22 lb-ft)
2. Connect the electrical connector to the Engine Coolant Temperature Sensor. Make sure the connection is secure.
3. Install the engine trim panel. Refer to section 1.1.2.
4. Fill the engine with the required amount of coolant, and check for leaks and proper operation.

4.6 CYLINDER HEAD COOLANT VENT LINE

Perform the following procedures for removal and installation of the cylinder head coolant vent line.

4.6.1 Removal of Cylinder Head Coolant Vent Line

Remove as follows:

1. Drain the cooling system.
2. Remove air cleaner assembly.
3. Remove the radiator support bracket from the top of the EGR cooler bracket and radiator.
4. Disconnect the coolant vent line located on top of the EGR cooler by removing the banjo bolt and seal rings. Discard the seal rings.
5. Remove the bolt securing the air compressor suction supply bracket to the EGR cooler bracket. See Figure 4-14.

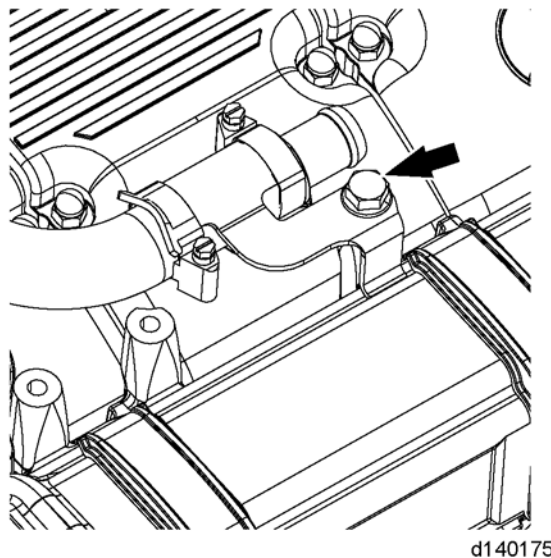


Figure 4-14 **Air Compressor Suction Supply Bracket**

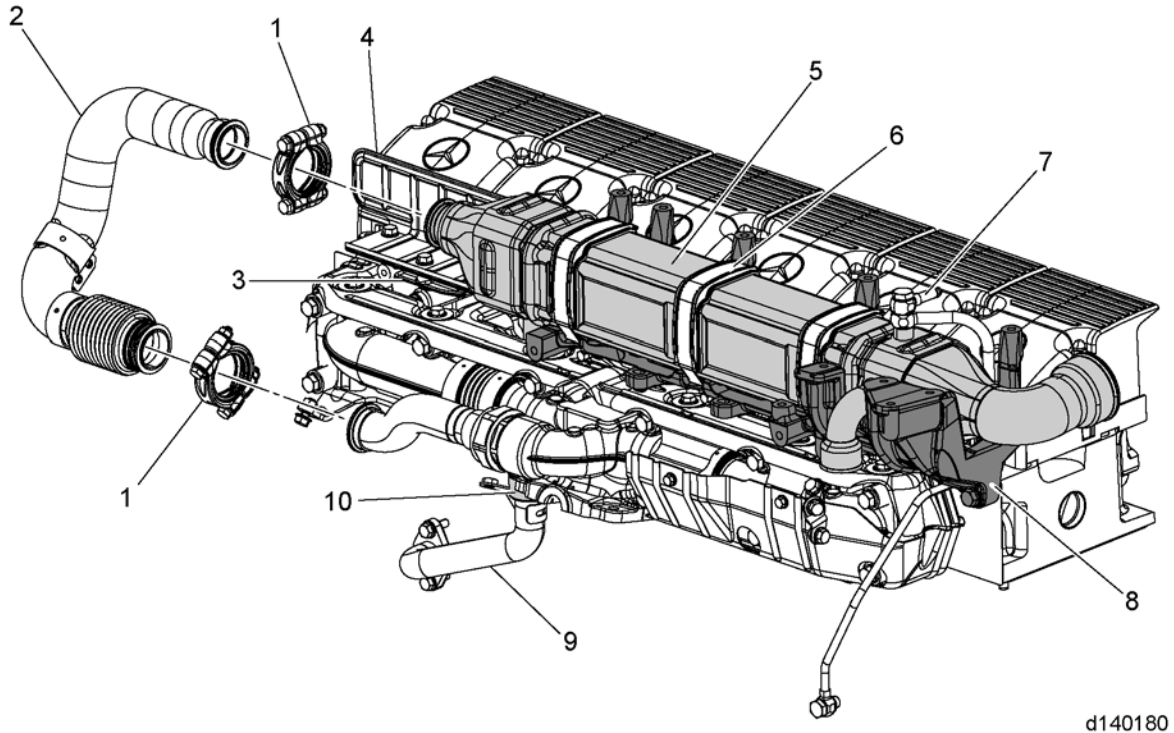
6. Remove the two bolts securing the turbocharger inlet elbow to the EGR cooler bracket. Rotate the turbocharger inlet elbow away from the engine.

NOTE:

Do not remove the turbocharger air inlet elbow.

7. Remove the clamp halves securing the exhaust gas inlet pipe to the EGR cooler and to the center pipe of the exhaust manifold. Remove the exhaust gas inlet pipe.

8. Remove the EGR cooler gas outlet pipe. Refer to section 8.2.1 "Removal of EGR Cooler Gas Outlet Pipe."
9. Remove the EGR control valve. Refer to section 8.7.1 "Removal of EGR Control Valve."
10. Remove the EGR cooler straps. See Figure 4-15.
11. Disconnect the upper coolant inlet pipe from the lower coolant inlet pipe. See Figure 4-15.



- | | |
|--------------------------------|---------------------------------|
| 1. Clamp | 6. EGR Cooler Straps |
| 2. Exhaust Gas Inlet Pipe | 7. Coolant Vent Line Connection |
| 3. Exhaust Heat Shield Bracket | 8. EGR Cooler Bracket |
| 4. Exhaust Heat Shield | 9. Lower Coolant Pipe |
| 5. EGR Cooler | 10. Upper Coolant Pipe |

Figure 4-15 EGR Cooler

12. Pull the EGR cooler straight up from the EGR cooler support bracket. See Figure 4-15.

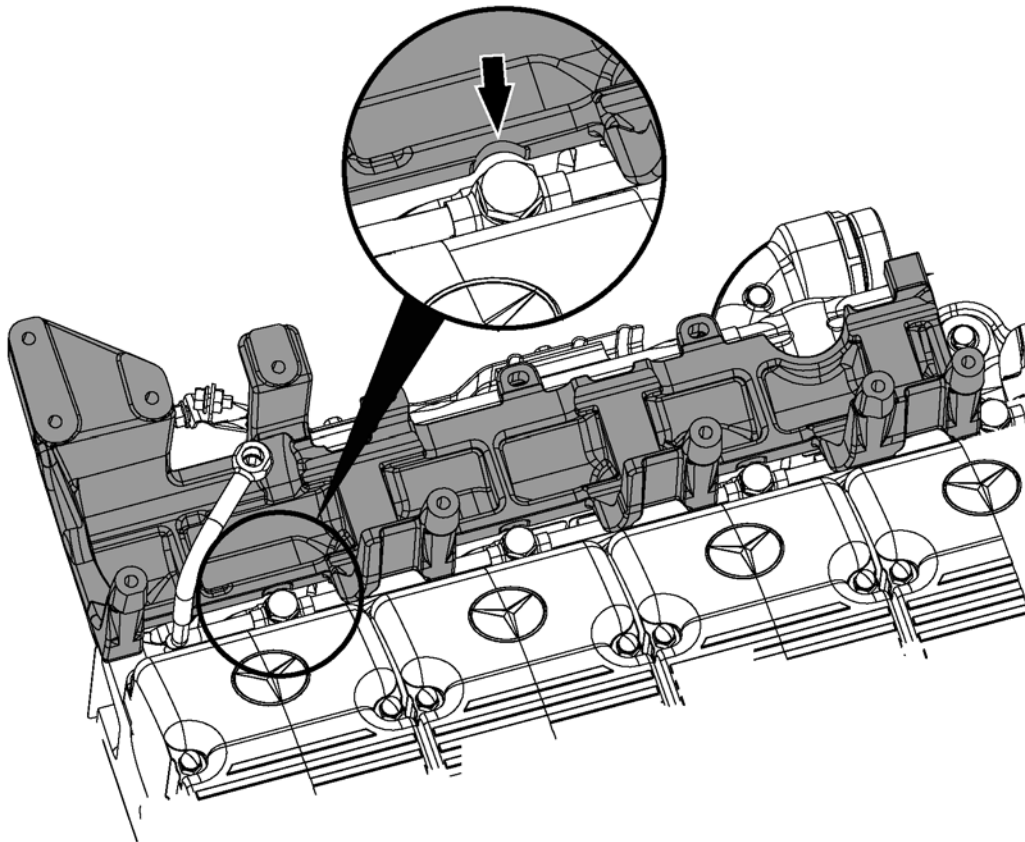
**CAUTION:****EYE INJURY**

To avoid injury from flying debris, wear a face shield or goggles.

NOTE:

Remove only enough material to allow a socket to fit on the banjo bolts.

13. Using a die grinder or other suitable device, remove material from the EGR cooler support bracket as shown in Figure 4-16. Do not remove cylinder head covers before this modification.

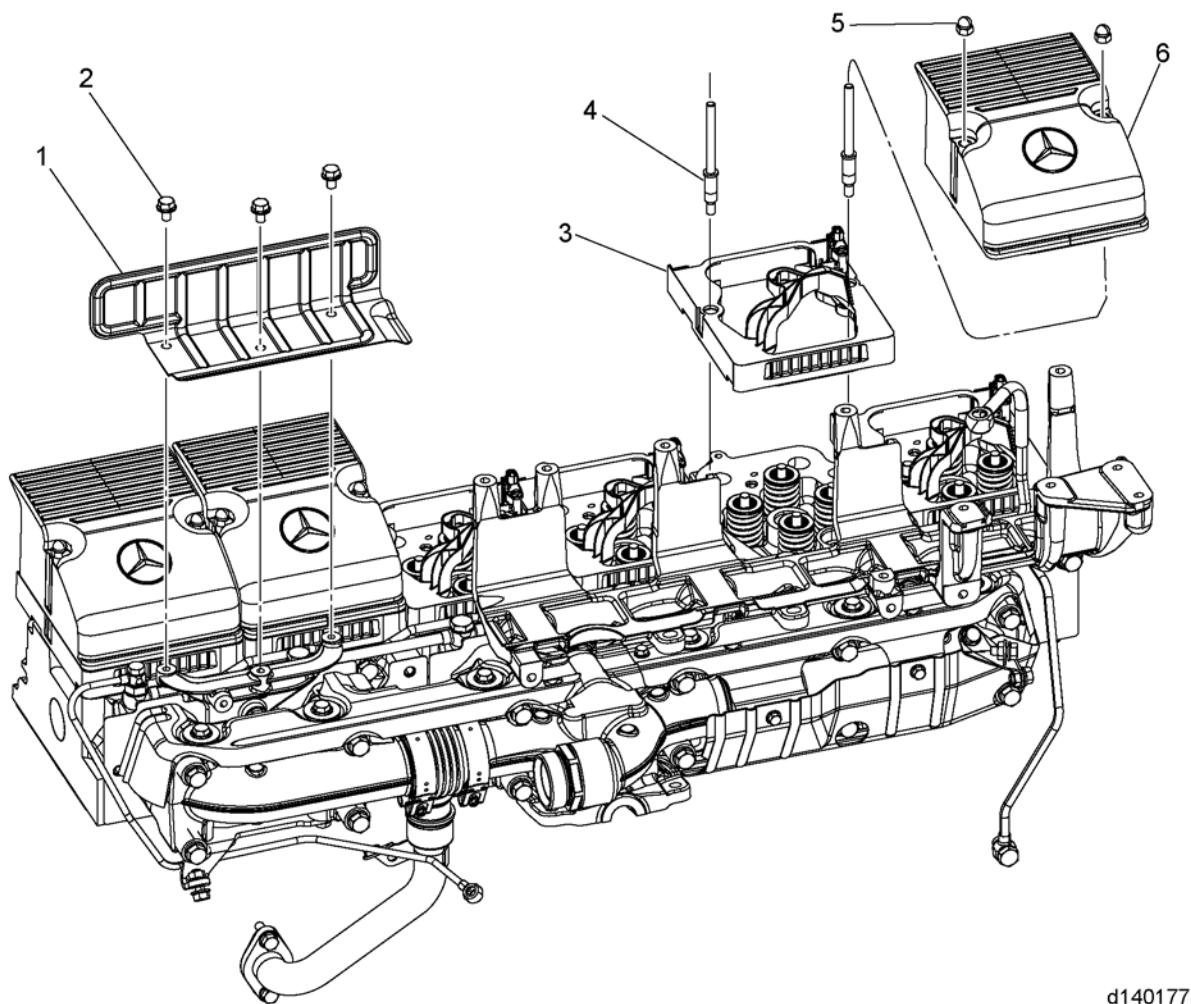


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Figure 4-16 EGR Cooler Support Bracket

14. Remove shavings and clean cylinder head area, taking care not to allow metal shavings into any part of the engine.
15. Remove the cylinder head covers from cylinders 1-4. Refer to section 1.2.1 "Removal of Cylinder Head Cover."

16. Remove the injector harness adaptor frames from cylinders 1-4. Refer to section 2.5.1 "Removal of Fuel Injector Harness Adaptor Frame."
17. Remove exhaust heat shield. See Figure 4-17.

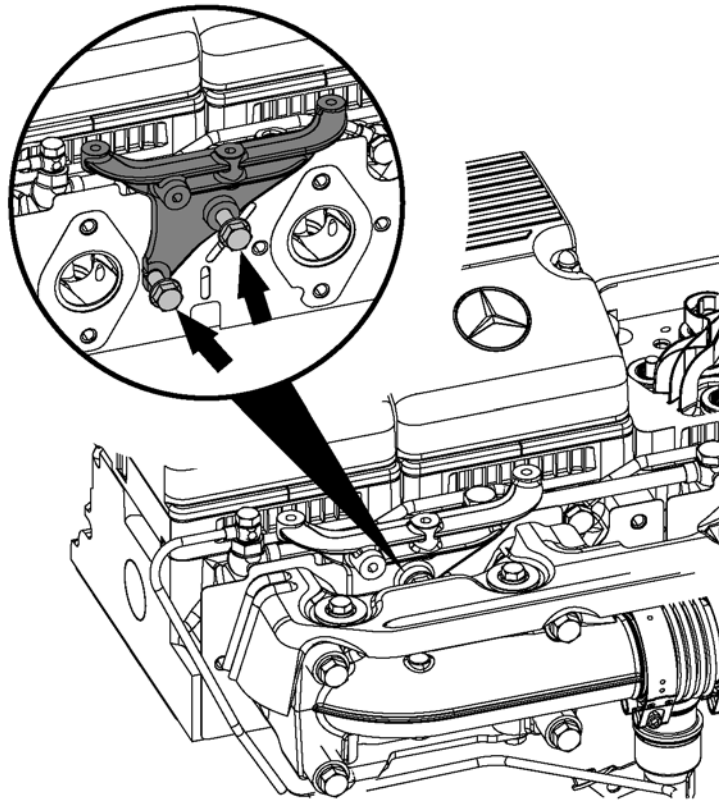


- | | |
|-----------------------------------|--|
| 1. Exhaust Manifold Heat Shield | 4. Injector Harness Adaptor Frame/Cylinder Head cover Mounting Studs |
| 2. Heat Shield Mounting Bolts | 5. Cylinder Head Cover Cap Nuts |
| 3. Injector Harness Adaptor Frame | 6. Cylinder Head Cover |

Figure 4-17 Exhaust Manifold Heat Shield

NOTE:

The lower exhaust mounting bolt cannot be fully removed with the exhaust manifold installed. Loosen the bolt enough to provide clearance for the coolant vent line to be removed. See Figure 4-18.

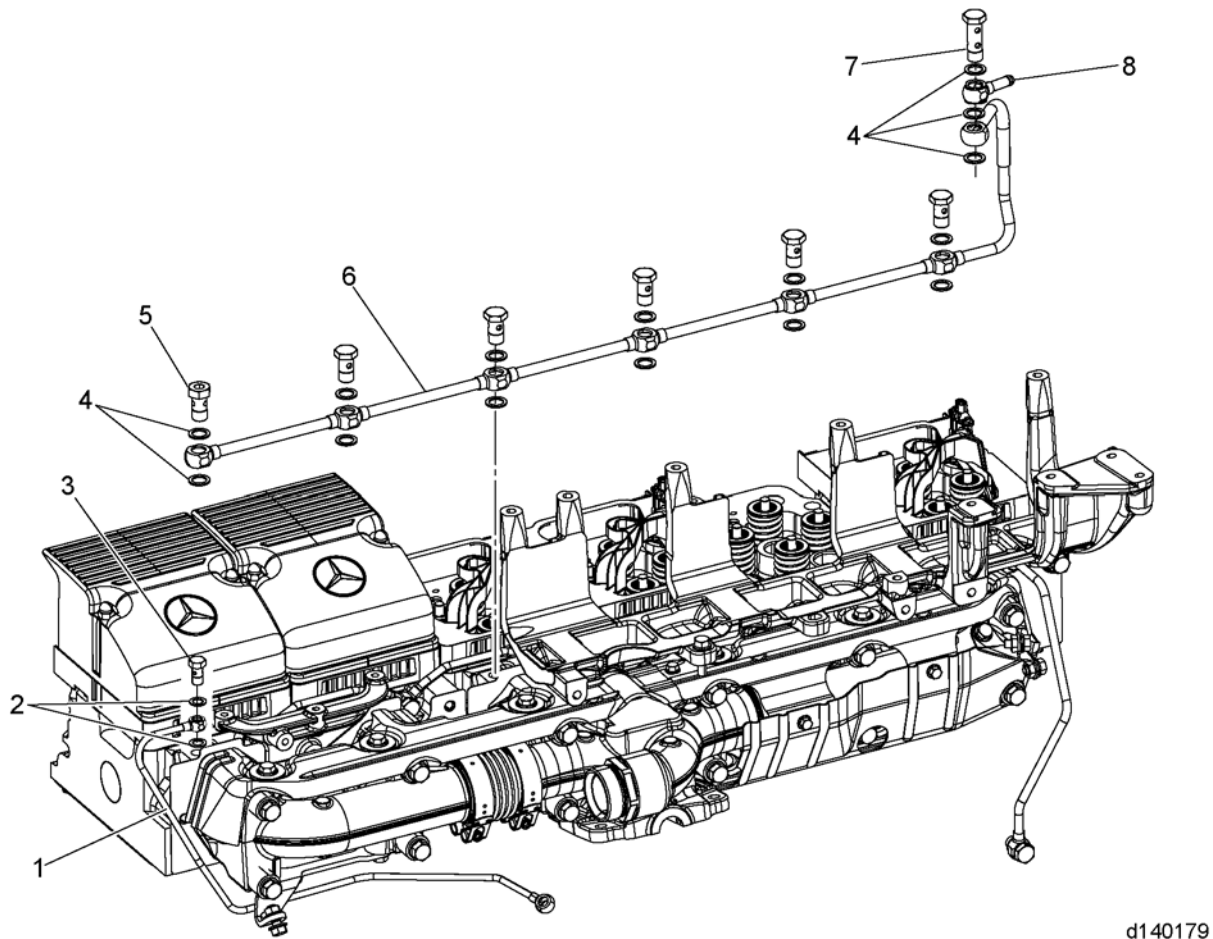


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Figure 4-18 Lower Heat Shield Bracket and Mounting Bolt

18. Remove the doser injector coolant line banjo bolt and seal rings from the #6 cylinder head connection. Discard seal rings.
19. Remove the six banjo bolts retaining the cylinder head coolant vent line.

20. Remove the cylinder head coolant vent line. Discard seal rings. See Figure 4-19.



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- | | |
|---|--|
| 1. Doser Injector Coolant Line | 5. Coolant Vent Line Banjo Bolt (6 qty.) |
| 2. Doser Injector Coolant Line Seal Rings | 6. Coolant Vent Line |
| 3. Doser Injector Coolant Line Banjo Bolt | 7. Coolant Vent Line Banjo Bolt |
| 4. Coolant Vent Line Seal Rings (15 qty.) | 8. Banjo Union |

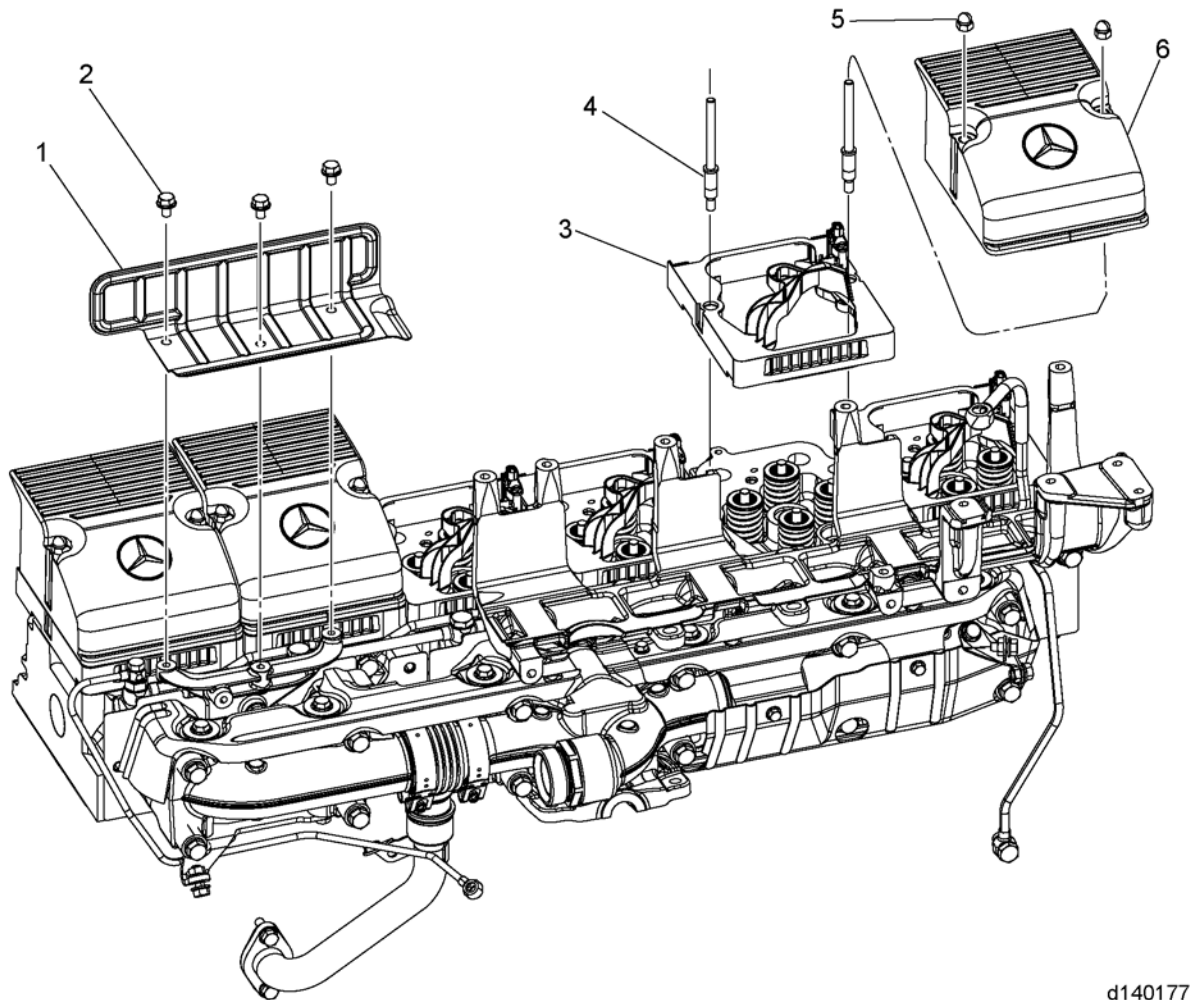
Figure 4-19 Coolant Vent Line

4.6.2 Installation of Cylinder Head Coolant Vent Line

Install as follows:

1. Install the cylinder head coolant vent line using new seal rings. Torque the six banjo bolts to 35 N·m (26 lb·ft).
2. Install the doser injector coolant line to the #6 cylinder head connection using new seal rings. Torque the banjo bolt to 16-20 N·m (12-15 lb·ft).

3. Install the exhaust heat shield. Torque heat shield bolts to 25 N·m (18 lb·ft). See Figure 4-20.



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- | | |
|-----------------------------------|--|
| 1. Exhaust Manifold Heat Shield | 4. Injector Harness Adaptor Frame/Cylinder Head cover Mounting Studs |
| 2. Heat Shield Mounting Bolts | 5. Cylinder Head Cover Cap Nuts |
| 3. Injector Harness Adaptor Frame | 6. Cylinder Head Cover |

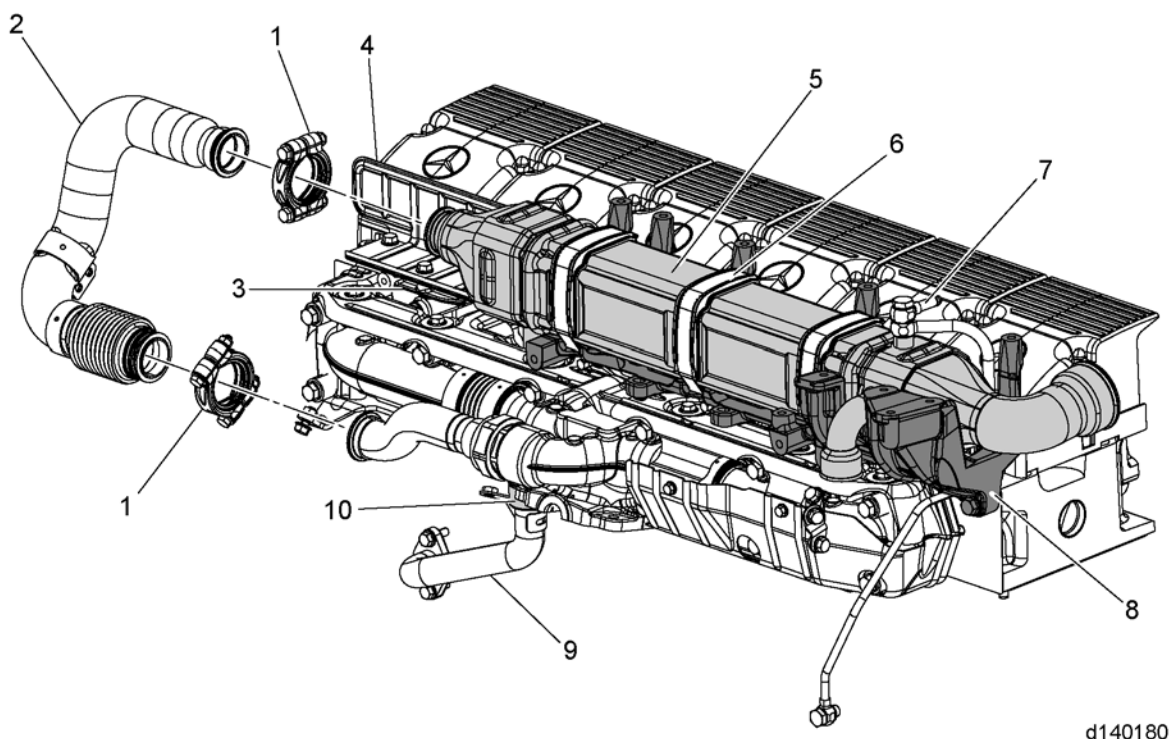
Figure 4-20 Exhaust Manifold Heat Shield

4. Install the injector harness adaptor frames for cylinders 1-4. Refer to section 2.5.2 "Installation of Fuel Injector Harness Adaptor Frame."
5. Install the cylinder head covers for cylinders 1-4. Refer to section 1.2.2 "Installation of Cylinder Head Cover."
6. Coat the EGR cooler coolant inlet and outlet connector pipes with International Product Corporation Rubber Lubricant Emulsion (P-80). See Figure 4-21.

NOTICE:

During installation, ensure that the EGR cooler coolant pipes are seated correctly with the connector pipes. Improperly seated pipes will leak causing engine damage.

7. Install the EGR cooler. Secure the EGR cooler to the bracket with clamps. Torque the clamps to 10 N·m (7 lb·ft). See Figure 4-21.



- | | |
|--------------------------------|---------------------------------|
| 1. Clamp | 6. EGR Cooler Straps |
| 2. Exhaust Gas Inlet Pipe | 7. Coolant Vent Line Connection |
| 3. Exhaust Heat Shield Bracket | 8. EGR Cooler Bracket |
| 4. Exhaust Heat Shield | 9. Lower Coolant Pipe |
| 5. EGR Cooler | 10. Upper Coolant Pipe |

Figure 4-21 EGR Cooler

8. Rotate the turbocharger inlet elbow back into the correct position and secure the support bracket with two bolts. Torque the bolts to 35 N·m (26 lb·ft).
9. Properly align the coolant pipe and small support bracket to the water pump. Torque the bolts to 35 N·m (26 lb·ft).

10. Install the inlet gas pipe to EGR cooler and center pipe of exhaust manifold and secure with clamp halves. Torque clamp bolts to 25 N·m (18 lb·ft).
11. Install the EGR control valve. Refer to section 8.7.2 "Installation of Installation of EGR Control Valve."
12. Install the EGR cooler gas outlet pipe. Refer to section 8.2.2 "Installation of EGR Cooler Gas Outlet Pipe."
13. Install the coolant vent line to the top of the EGR cooler and secure with banjo bolts and washers. Torque banjo bolt to 25 N·m (18 lb·ft).
14. Install the air compressor suction pipe to the mounting bracket and secure with one M10 bolt. Torque the bolt to 35 N·m (26 lb·ft). See Figure 4-22.

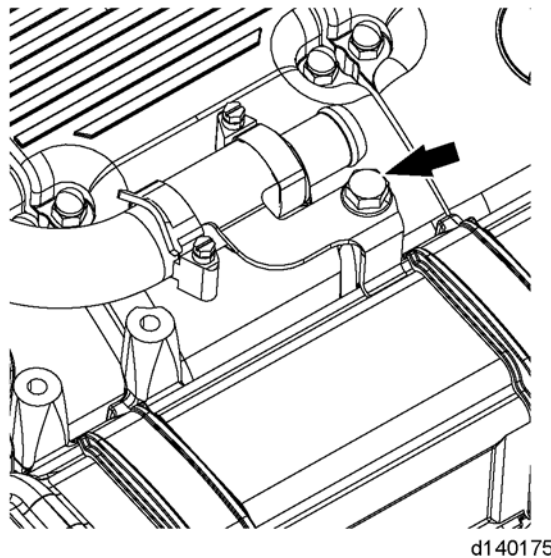


Figure 4-22 Air Compressor Suction Supply Bracket

15. Install the radiator support bracket from the top of the EGR cooler bracket and radiator.
16. Refill engine with coolant.

4.A ADDITIONAL INFORMATION

Description	Page
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Coolant Pump	4-37
Thermostat	4-38
Coolant Sensor	4-38

SPECIFICATIONS

This section contains the specifications for servicing the engine.

Cooling System Overview

The coolant specifications are listed in Table 4-6. Listed in Table 4-7 are the cooling system capacity figures. The coolant mixing ratio is listed in Table 4-8.

Type of Coolant	Requirement
Fully -Formulated Ethylene Glycol*	TMC RP-329 Type "A"
Water plus Corrosion Inhibitors	Temperature must not fall below 0°C (32°F)

*Preferred coolant

Table 4-6 Coolant Specifications

Description	Capacity L (qts)
Engine Coolant Capacity (all vehicles)	
Engine capacity*	30.0 (31.7)
Century Class and Columbia Cooling System Capacity	
Total capacity†	57.4 (60.7)
Antifreeze quantity at 50 percent	28.7 (30.3)
Antifreeze quantity at 55 percent	31.6 (33.4)
Sterling A-Line and L-Line Cooling System Capacity	
Total capacity	53.8 (56.8)
Antifreeze quantity at 50 percent	26.9 (28.4)
Antifreeze quantity at 55 percent	29.6 (31.3)
FL112 Cooling System Capacity	
Total capacity	42.0 (44.4)
Antifreeze quantity at 50 percent	21.0 (22.2)
Antifreeze quantity at 55 percent	23.1 (24.4)

* Does not include capacity of cooling system.

†With 1200 sq. in. radiator.

Table 4-7 Cooling System Capacity

Antifreeze Protection Down to °C (°F)	Water Percentage by Volume	Corrosion-Inhibiting Antifreeze Percentage by Volume
-37 (-34)	50	50
-45 (-49)	40	Maximum 60

Table 4-8 Coolant Mixing Ratio

Coolant Pump

The torque values for the cooling system are listed in Table 4-9. The wear dimensions for the coolant pump assembly are listed in Table 4-10. Listed in Table 4-11 is the critical dimension for the coolant pump assembly.

Fastener	Torque Nm (lb-ft)
Coolant Pump Inlet Pipe Mounting Bolts	50 (37)
Coolant Pump Mounting Bolts	30 (22)
Coolant Pump Pulley Mounting Bolts	25 (18)
Front Idler and Tensioner Support Mounting Bolts	60 (44)
Thermostat Housing Mounting Bolts	25 (18)

Table 4-9 Cooling System Torque Values

Description	Dimensions, mm (in.)
Drive Shaft Diameter (at the hub)	25.048 - 25.061 (0.9861 - 0.9867)
Hub Inside Diameter	24.995 - 25.008 (0.9841 - 0.9846)
Bearing Outside Diameter	54.981 - 54.994 (2.1646 - 2.1651)
Bearing Housing Diameter	54.930 - 54.960 (2.1626 - 2.1638)
Drive Shaft Diameter (at the impeller)	15.045 - 15.056 (0.5923 - 0.5928)
Impeller Inside Diameter	15.000 - 15.018 (0.5906 - 0.5913)
Impeller Outside Diameter	124 - 125 (4.88 - 4.92)
Impeller - Maximum Out-of-Round	0.15 (0.0059)

Table 4-10 Coolant Pump Assembly Wear Dimensions

Description	Dimensions mm (in.)
Gap between the Impeller and the Coolant Pump Housing	0.6 - 1.0 (0.023 - 0.039)

Table 4-11 Critical Dimension for Coolant Pump Assembly

Thermostat

The thermostat test values are listed in Table 4-12.

Description	Temperature °C (°F)	Distance mm (in.)
Main Valve Starts To Open	(81-85 (178-185))	—
Main Valve Fully Open	95 (203)	—
Main Valve Minimum Lift	—	8 (0.3)
Short Circuit Valve Fully Closed	92 (198)	—
Short Circuit Valve Minimum Lift	—	6-7.5 (0.24-0.295)

Table 4-12 Thermostat Test Values

Coolant Sensor

The sensor torque value is listed in Table 4-13.

Description	Torque, N·m (lb·ft)
Engine Coolant Temperature Sensor to the Engine Block	30 (22)

Table 4-13 Torque Value

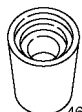
Tool	Description	Usage	Part Number
 46802	Coolant Pump Bearing Drift	Used to install the water pump seal in the housing.	J-35988-19
 46801	Installer, Water Pump Bearing	Used to install bearing in water pump housing.	J-45388
 47316	Water Pump Hub/Rotor Installer	Used to install the water pump impeller.	J-46179

Table 4-14 Special Tools

5 FUEL, LUBRICATING OIL, AND COOLANT

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5.1 FUEL	5-3
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5.3 COOLANT	5-7
5.A ADDITIONAL INFORMATION	5-13

5.1 FUEL

Detroit Diesel MBE 4000 engines for 2007 must be operated on Ultra-Low Sulfur Diesel (ULSD) fuel with 15 ppm sulfur content or less, based on ASTM D2622 test procedures. Grades such as marine diesel fuel, heating oil, and others are not acceptable and will cause the diesel particulate filter to prematurely plug with ash.

Fuel additives are not required. Using fuel additives may affect your warranty.

NOTICE:
Fuel added from drums or cans could be contaminated. This could lead to malfunctions in the fuel system. Always filter the fuel before adding it to the tank.

5.1.1 Flow Improvers

The effectiveness of flow improvers is not guaranteed with all fuels. Comply with the product manufacturer's recommendations. Any authorized dealer can provide information on approved flow improvers.

5.1.2 Biodiesel

Biodiesel fuels meeting ASTM D 6751 specification, prior to blending can be mixed up to 5% maximum by volume in petroleum diesel fuel. Detroit Diesel highly recommends biodiesel fuels made from soybean or rapeseed oil through the proper transesterification reaction process. Other feedstock source of biodiesel fuels such as animal fat and used cooking oils are not recommended by Detroit Diesel. The resulting mixture must meet ASTM D 975 specification. More information is available in the Detroit Diesel publication *Lubricating Oil, Fuel, and Filters* (7SE270).

Failures attributed to the use of biodiesel fuel will not be covered by Detroit Diesel product warranty. Also, any engine performance problem related to the use of biodiesel fuel would not be recognized nor considered Detroit Diesel's responsibility.

5.1.3 Used Lubricating Oil

Do not use fuel blended with used lubricating oil. Detroit Diesel specifically prohibits the use of used lubricating oil in diesel fuel. Used lubricating oil contains combustion acids and particulate materials which can severely erode fuel injector components, resulting in loss of power and increased exhaust emissions along with causing the diesel particulate filter to prematurely plug with ash. In addition, the use of drained lubricating oil will increase maintenance requirements due to filter plugging and combustion deposits.

5.1.4 Kerosene

Do not use kerosene mixed in the fuel.

NOTICE:

Kerosene added to the diesel fuel for cold weather applications is not recommended by Detroit Diesel. Kerosene in the fuel will shorten the longevity of the Aftertreatment System and impact the EPA emission regulations.

5.1.5 Winter Grade Diesel Fuel for Cold Weather

At low outside temperatures, paraffin may separate from the diesel and affect its ability to flow freely.

Avoid breakdowns caused by this problem (for example, blocked filters) by using cold-resistant winter-grade diesel fuel with improved low-temperature flow characteristics. In most cases, winter-grade fuel can be used without problems at cold outside temperatures.

If using summer-grade fuel or a less cold-resistant winter grade, a flow improver or kerosene can be added. The amount needed depends on the outside temperature.

**WARNING:****FIRE**

To avoid increased risk of a fuel fire, do not mix gasoline and diesel fuel.

NOTICE:

Do not add gasoline to diesel fuel or engine damage will result.

Flow improver or petroleum spirit must be mixed with diesel fuel before its flow characteristics have been adversely affected by paraffin separation. If changes have already been caused by paraffin separation, they can be corrected only by heating the entire fuel system. Do not add anything to cold-resistant winter-grade diesel fuels. The fuel's low-temperature flow characteristics could actually deteriorate with additives.

5.2 LUBRICATING OIL

The engine is delivered from the factory filled with an approved engine oil.

NOTICE:
The use of non-approved engine oils could affect warranty rights, and cause engine damage.

To ensure long and trouble-free service, it is important to select oil of the correct viscosity and service designation. Only multigrade oils of American Petroleum Institute (API) service designation CJ-4 should be used in 2007 MBE 4000 engines. Look for the service mark printed on the oil container. See Figure 5-1.

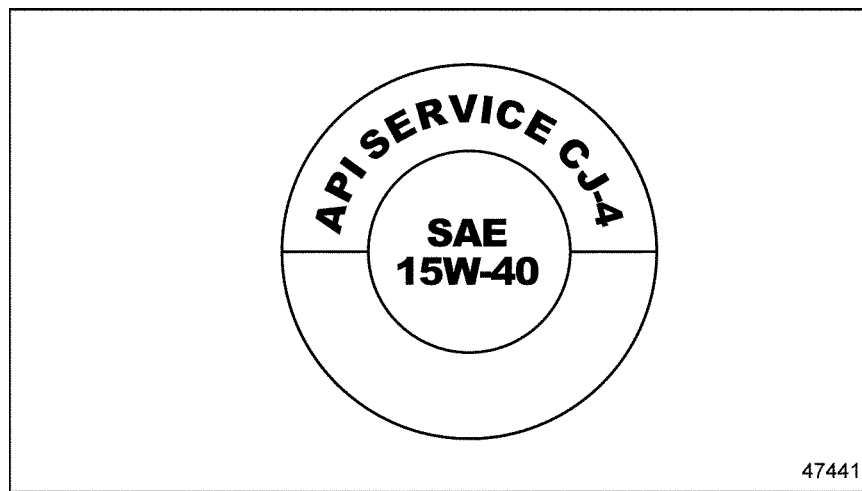


Figure 5-1 API Lubricant Service Mark

When maintenance work is performed, record engine oil changes including details of the brand used, the quality category, and the Society of Automotive Engineers (SAE) viscosity rating of the oil. When topping off, use only engine oils of the correct API designation and SAE rating.

5.2.1 Synthetic Oils

Synthetic oil may be used in MBE 4000 engines, provided they are of the correct API designation and viscosity, as required for non-synthetic oil.

Synthetic oil offers improved low-temperature flow properties and high-temperature resistance to oxidation. However, it is generally more costly than non-synthetic oil.

Review carefully the product information published by the synthetic oil manufacturer. Performance additive systems often respond differently in synthetic oil. Use of synthetic oil does not change the recommended oil change service interval.

5.2.2 Low Viscosity Engine Oil for Cold Weather

When changing the engine oil, estimate the interval before your next oil change. Choose an oil from the SAE viscosity class which corresponds to the outside temperatures anticipated during this period of operation. See Figure 5-2.

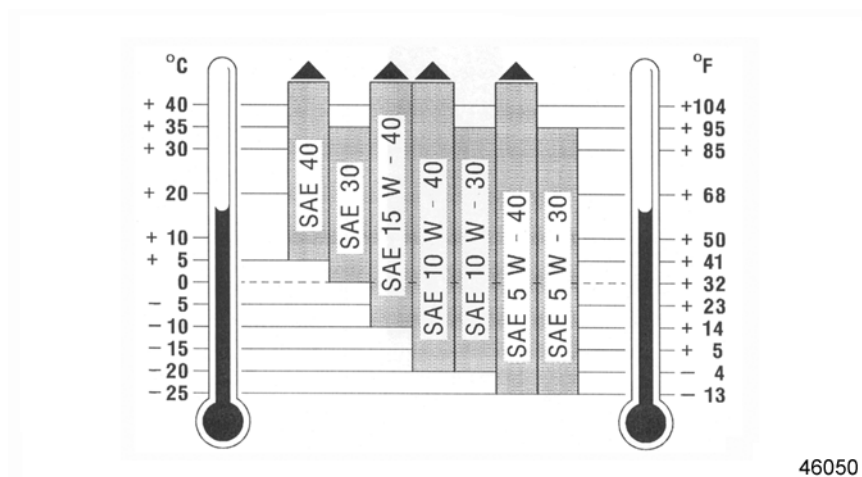


Figure 5-2 Engine Oil Temperature Ranges

5.3 COOLANT

Coolant is a mixture of water and antifreeze. Under normal conditions, it is a mixture of 50 percent water and 50 percent antifreeze, but under extreme cold weather conditions, as much as 60 percent antifreeze can be added. For reasons of anticorrosion protection and to raise the boiling point, the coolant must remain in the cooling system all year round.

Regardless of mileage, replace the coolant every two years since the degree of corrosion protection gradually drops with time.

5.3.1 Fully Formulated Antifreeze

Antifreeze approved for use in the MBE 4000 engine is a mixture of glycol compound (ethylene glycol), and corrosion inhibitors. Antifreeze containing glycol compounds and corrosion inhibitors is known as fully-formulated antifreeze.

NOTE:

Do not use propylene glycol.

Fully-formulated antifreeze has the following properties:

- ☐ It protects the radiator and engine from freezing.
- ☐ It provides protection against corrosion and cavitation for all components in the cooling system.
- ☐ It raises the boiling point of the coolant. This slows the rate of evaporation, avoiding coolant loss at high temperatures.

5.3.2 Water

Water containing no additives is not suitable as a coolant, even if no antifreeze protection is needed.

The water used in the coolant must comply with certain requirements, which are not always satisfied by drinking water. If water quality is inadequate, the water must undergo suitable treatment.

NOTICE:

In some areas, tap water can contain high levels of dissolved chlorides, sulfates, magnesium, and calcium, causing scale deposits, sludge deposits and/or corrosion. These deposits can damage the coolant pump and allow the engine to overheat.

The following types of water are preferred for use in coolant:

- ☐ Distilled water
- ☐ Water purified by reverse osmosis
- ☐ De-ionized water

5.3.2.1 Coolant Specifications and Concentration

To avoid damage to the cooling system, use only an approved corrosion-inhibiting antifreeze. Approved antifreeze must be fully-formulated and comply with the requirements of the Truck Maintenance Council (TMC). Coolant specifications are listed in Table 5-1.

Type of Coolant	Requirement
Fully-Formulated Ethylene Glycol	TMC RP-329 Type "A"
Water plus Corrosion Inhibitors	Temperature Must Not Fall Below 0°C (32°F)

Table 5-1 Coolant Specifications

When topping off the cooling system after a drop in the coolant level, the concentration of corrosion-inhibiting antifreeze in the coolant must be 50 percent by volume. This affords protection down to a temperature of -37°C (-34°F). The cooling mixing ratio is listed in Table 5-2.

NOTE:

If the concentration is too low, there is risk of corrosion/cavitation in the cooling system.

Do not increase the proportion (mixing ratio) of corrosion-inhibiting antifreeze beyond 60 percent by volume (this gives the maximum antifreeze protection). Further increases in the mixing ratio would reduce the level of antifreeze protection and adversely affect the coolant's ability to dissipate heat.

Antifreeze Protection Down to °C (°F)	Water % by Volume	Corrosion - Inhibiting Antifreeze % by Volume
-37 (-34)	50	50
-52 (-62)	40	The cooling mix ratio is Max. 60

Table 5-2 Coolant Mixing Ratio

5.3.3 Supplemental Coolant Additives for Fully Formulated Coolant

The concentrations of some inhibitors will gradually deplete during normal engine operation. Supplemental Coolant Additives (SCAs) replenish the protection for cooling system components. The coolant must be maintained with the proper concentration of SCA. Detroit Diesel **POWER COOL®** maintenance SCAs are recommended.

NOTICE:

Failure to properly maintain coolant with SCA can result in damage to the cooling system and its related components. Conversely, over-concentration of SCA inhibitor can result in poor heat transfer, leading to engine damage. Always maintain concentrations at recommended levels. Do not use traditional SCAs with NOAT coolant.

The proper application of SCA will provide:

- ☐ pH control
- ☐ Restored inhibitor levels to prevent corrosion
- ☐ Water-softening to deter formation of mineral deposits
- ☐ Cavitation protection to protect wet sleeve cylinder liners

5.3.4 Recycled Antifreeze

Recycled antifreeze that complies with TMC RP-329 Type “A” (for ethylene glycol) is approved for use in MBE 4000 engines. The antifreeze must be recycled by distillation, reverse osmosis, or ion exchange.

Other recycled antifreeze, especially any antifreeze recycled by means of filtration processes, is not approved.

5.3.5 Corrosion Inhibitors

Corrosion inhibitors are very important in maintaining engine life. All corrosion inhibitors protect against corrosion caused by acid, and cavitation of wet cylinder liners. SCAs also protect against mineral deposits.

The concentrations of some inhibitors will gradually diminish during normal engine operation. To protect the engine, nitrite concentration must be checked at regular intervals, and inhibitors added as necessary. The intervals are longer if Nitrated Organic Acid Technology (NOAT) Inhibitors are used.

NOTICE:

Always maintain inhibitor at the recommended level. Failure to properly maintain coolant with SCA can result in damage to the cooling system and related components. Over-concentration of SCA inhibitor can result in poor heating transfer and lead to engine damage.

NOTICE:

Do not mix types of corrosion inhibitors. Do not add additional inhibitors to new, fully-formulated antifreeze, or coolant

NOTICE:

containing new, fully-formulated antifreeze. This can cause deposits or dropout in the cooling system.

The following types of corrosion inhibitors are approved for use in MBE 4000 engines:

- ☐ Supplemental Coolant Additives (SCAs)
- ☐ Nitrated Organic Acid Technology (NOAT) Inhibitors

Corrosion inhibitors are very important in maintaining engine life. All corrosion inhibitors protect against corrosion caused by acid, and cavitation of wet cylinder liners. SCAs also protect against mineral deposits.

The concentrations of some inhibitors will gradually diminish during normal engine operation. To protect the engine, nitrite concentration must be checked at regular intervals, and inhibitors added as necessary. The intervals are longer if NOAT inhibitors are used.

NOTICE:

Always maintain inhibitor at the recommended level. Failure to properly maintain coolant with SCA can result in damage to the cooling system and related components. Over-concentration of SCA inhibitor can result in poor heating transfer and lead to engine damage.

The following types of inhibitor must not be used in MBE 4000 engines:

- ☐ Soluble oil additives cause poor heat transfer and lead to engine damage.
- ☐ Chromate additives can lead to the build-up of "green slime" (chromium dioxide) in the engine, leading to engine damage.

5.3.5.1 Dropout

Excessive amounts of some corrosion inhibitors can cause a gel or crystalline deposit that reduces both heat transfer and coolant flow. This deposit is called "dropout."

Dropout takes the color of the coolant when wet, but becomes a white or gray powder when dry. It can pick up solid particles in the coolant and become gritty. It will cause premature wear of the coolant pump seals and other components of the cooling system.

The wet gel can be removed using an alkaline (non-acid) cleaner containing either sodium nitrite or sodium tetraborate.

If the gel is allowed to dry, it is necessary to disassemble the engine and clean it with a caustic solution, or physically clean the individual components.

5.3.6 Non-Approved Coolants

The following types of coolant are not approved for use in MBE 4000 engines:

- ❑ Antifreeze or coolant containing phosphate can cause dropout, overheating, and damage to coolant pump seals.
- ❑ Automotive coolants offer no protection against liner pitting, and generally contain high levels of phosphate and silicate.
- ❑ Antifreeze based on methyl alcohol can damage the non-metallic components of the cooling system. They are not suitable for use with diesel engines because of their low boiling point.
- ❑ Antifreeze based on methoxy propanol is not compatible with the fluoroelastomer seals used in the cooling system.
- ❑ Glycol-based Heating Ventilation Air Conditioning (HVAC) coolants contain phosphates which can deposit on hot internal engine surfaces and reduce heat transfer.

5.3.7 Disposal

Coolants are biologically degradable substances.

When disposing of used coolant, comply with local legal requirements and waste water regulations.

Consult the local water supply authorities to determine the best method of disposal.

A modern engine coolant has complex tasks to perform. Do not allow any form of "reprocessing" which consists only of mechanical purification.

5.A ADDITIONAL INFORMATION

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SPECIFICATIONS

This section contains the specifications for servicing the engine.

Coolant

Listed in Table 5-3 are the coolant specifications. The coolant mixing ratio is listed in Table 5-4.

Type of Coolant	Requirement
Fully-Formulated Ethylene Glycol	TMC RP-329 Type "A"
Water plus Corrosion Inhibitors	Temperature Must Not Fall Below 0°C (32°F)

Table 5-3 Coolant Specifications

Antifreeze Protection Down to °C (°F)	Water % by Volume	Corrosion - Inhibiting Antifreeze % by Volume
-37 (-34)	50	50
-52 (-62)	40	The cooling mix ratio is Max. 60

Table 5-4 Coolant Mixing Ratio

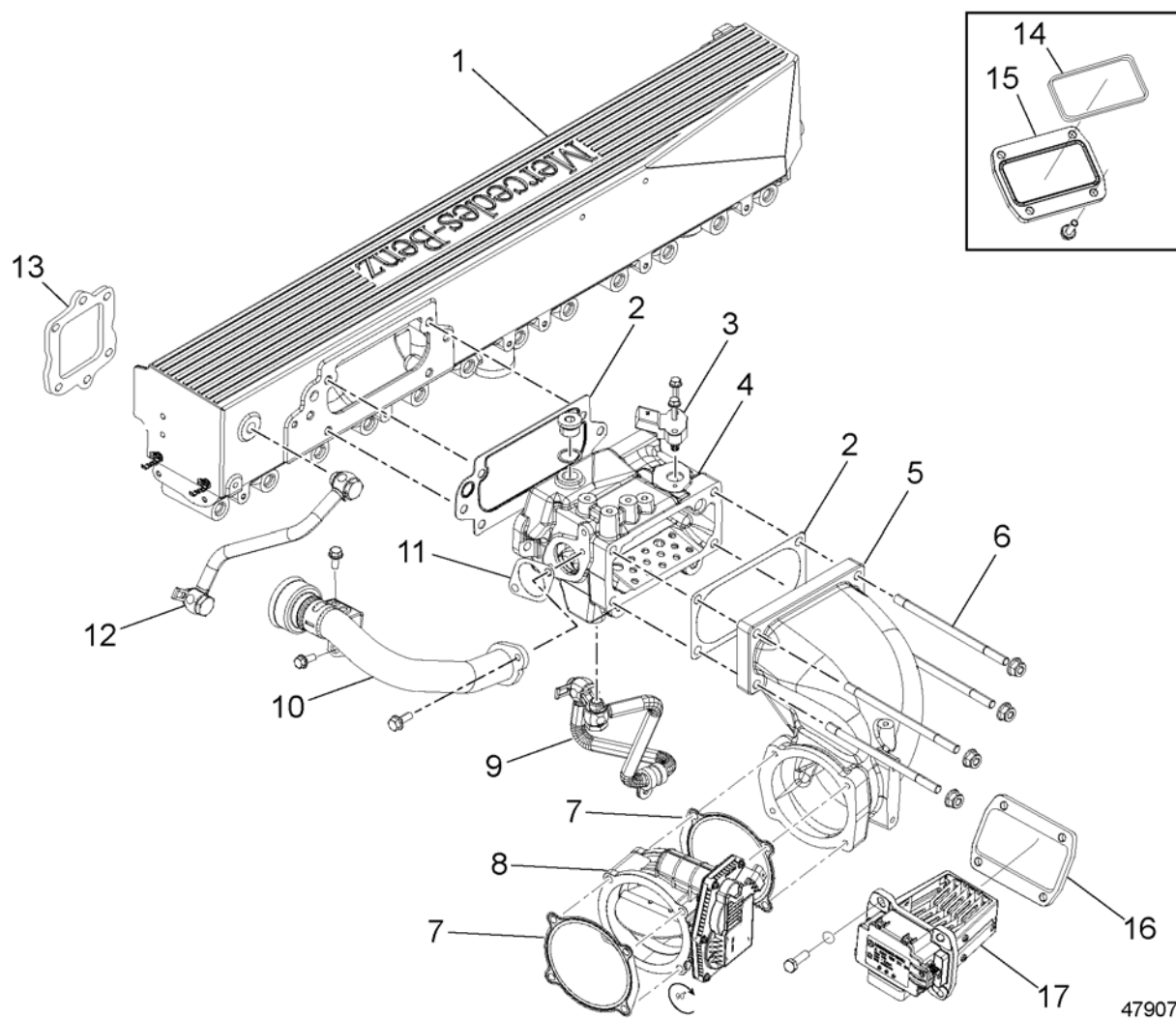
6 AIR INTAKE SYSTEM

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6.3 GAS MIXER HOUSING	6-10
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6.1 AIR INTAKE ELBOW AND GRID HEATER

Perform the following procedures for the removal and installation of the air intake elbow and if equipped, grid heater:

For the air intake manifold and related components, see Figure 6-1.



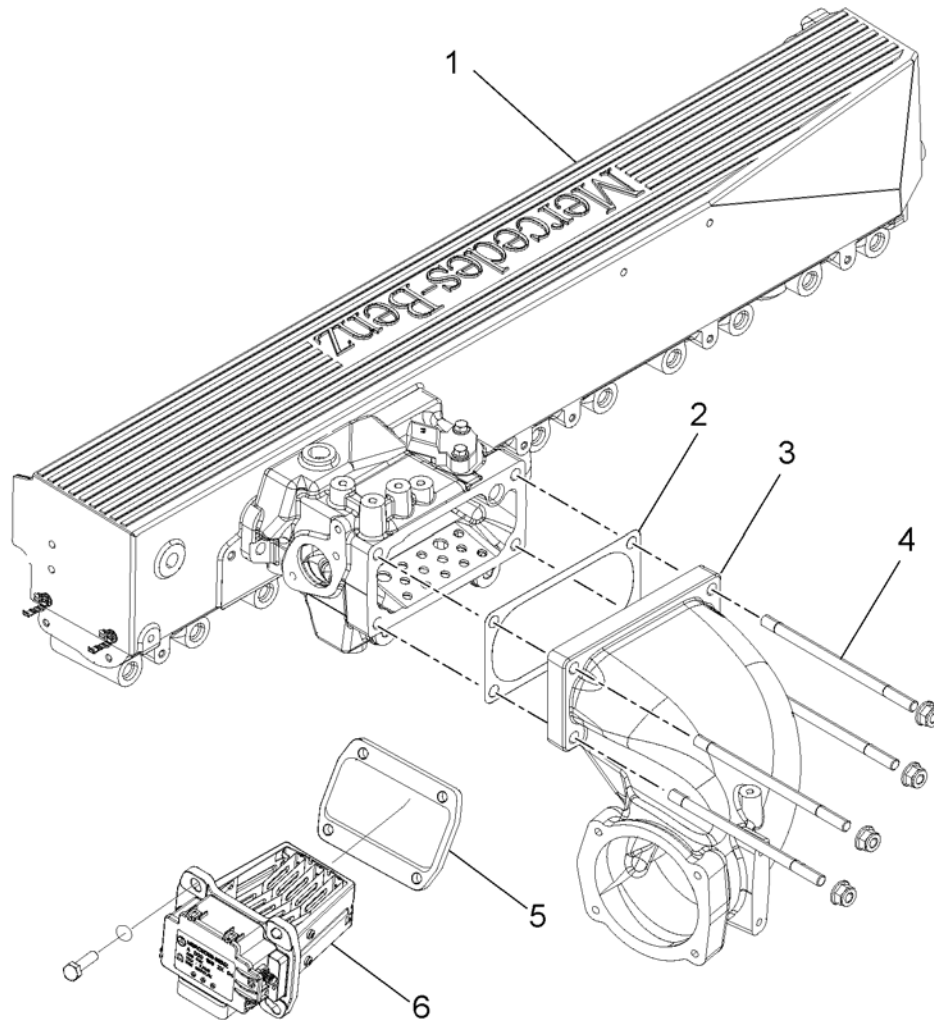
- | | |
|--------------------------------------|-----------------------------------|
| 1. Air Intake Manifold | 9. Coolant Feed Line |
| 2. Gasket | 10. EGR Gas Outlet Pipe |
| 3. Air Temperature / Pressure Sensor | 11. Gasket |
| 4. Gas Mixer Housing | 12. Coolant Return Line |
| 5. Air Inlet Elbow | 13. Gasket |
| 6. Studs & Nuts (4 qty.) | 14. Seal Ring (w/o grid heater) |
| 7. Gasket | 15. Cover Plate (w/o grid heater) |
| 8. Intake Air Throttle Valve | 16. Gasket |
| | 17. Hi-tech Grid Heater |

Figure 6-1 Air Intake Elbow and Grid Heater

6.1.1 Removal of Air Intake Elbow and Grid Heater

Removal steps are as follows:

1. Remove the intake throttle valve and adaptor. Refer to section 6.2.1.



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|------------------------|--------------------------|
| 1. Air Intake Manifold | 4. Studs & nuts (4 qty.) |
| 2. Gasket | 5. Gasket |
| 3. Air Inlet Elbow | 6. Grid Heater |

Figure 6-2 Air Intake Elbow

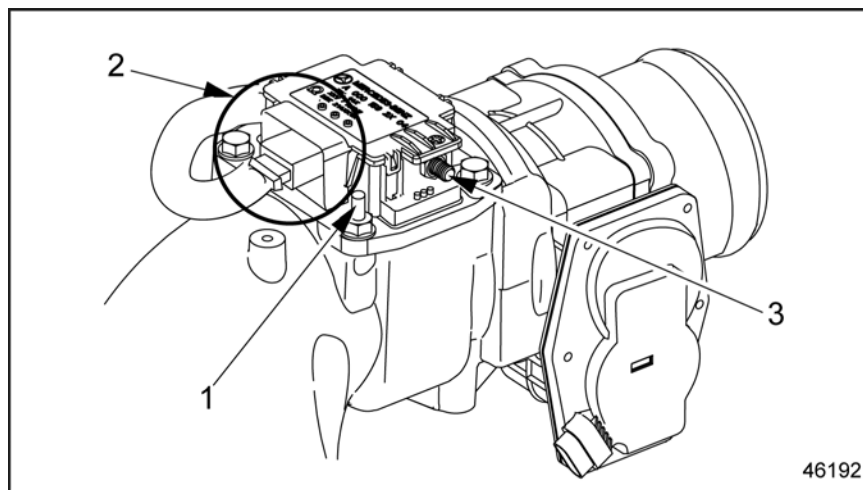
2. Remove four nuts securing the air intake elbow to the EGR gas mixer. See Figure 6-2.
3. Remove bolt securing support bracket to the air inlet elbow. See Figure 6-2.
4. Remove the bolt, spacer and two isolators securing the support bracket to the alternator bracket. See Figure 6-2.

5. Remove the elbow and metal gasket from gas mixer housing. See Figure 6-2.
6. Disconnect the harness connector and electrical connection on the grid heater.
7. Remove four bolts and washers securing the grid heater to the air inlet elbow. Remove the grid heater and gasket. Discard the gasket. See Figure 6-2.
8. If necessary, remove the cover plate and seal ring from the air intake elbow by removing four bolts. Discard seal ring. See Figure 6-2.

6.1.2 Installation of Air Intake Elbow and Grid Heater

Installation steps are as follows:

1. If removed, install the cover plate and seal ring on the air intake elbow and secure with four bolts (M8 x 25mm). Torque the bolts to 25 N·m (18 lb·ft). See Figure 6-2.
2. Install the grid heater and gasket and secure with four bolts and washers. Torque the bolts to 25 N·m (18 lb·ft). See Figure 6-2.
3. Connect the harness connector and electrical connections on the grid heater. Torque the nut for the battery supply connection to a maximum of 25 N·m (18 lb·ft). See Figure 6-3.



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|--|---------------------------|
| 1. Battery Ground | 3. Battery Supply (+12 V) |
| 2. Connector to MCM (part of engine harness) | |

Figure 6-3 Grid Heater Electrical Connections

4. Install the air intake elbow and metal gasket on the EGR gas mixer and secure with four locking nuts (M10). Torque the nuts to 25 N·m (18 lb·ft). See Figure 6-2.
5. Loosely secure the support bracket to the air intake elbow with a bolt (M10 x 25 mm). See Figure 6-2.
6. Secure the support bracket to the alternator bracket with two isolators, spacer and bolt (M10 x 35 mm). Torque the bolts to 60 N·m (44 lb·ft). See Figure 6-2.

7. Install the intake throttle valve and adaptor. Refer to section 6.2.2.

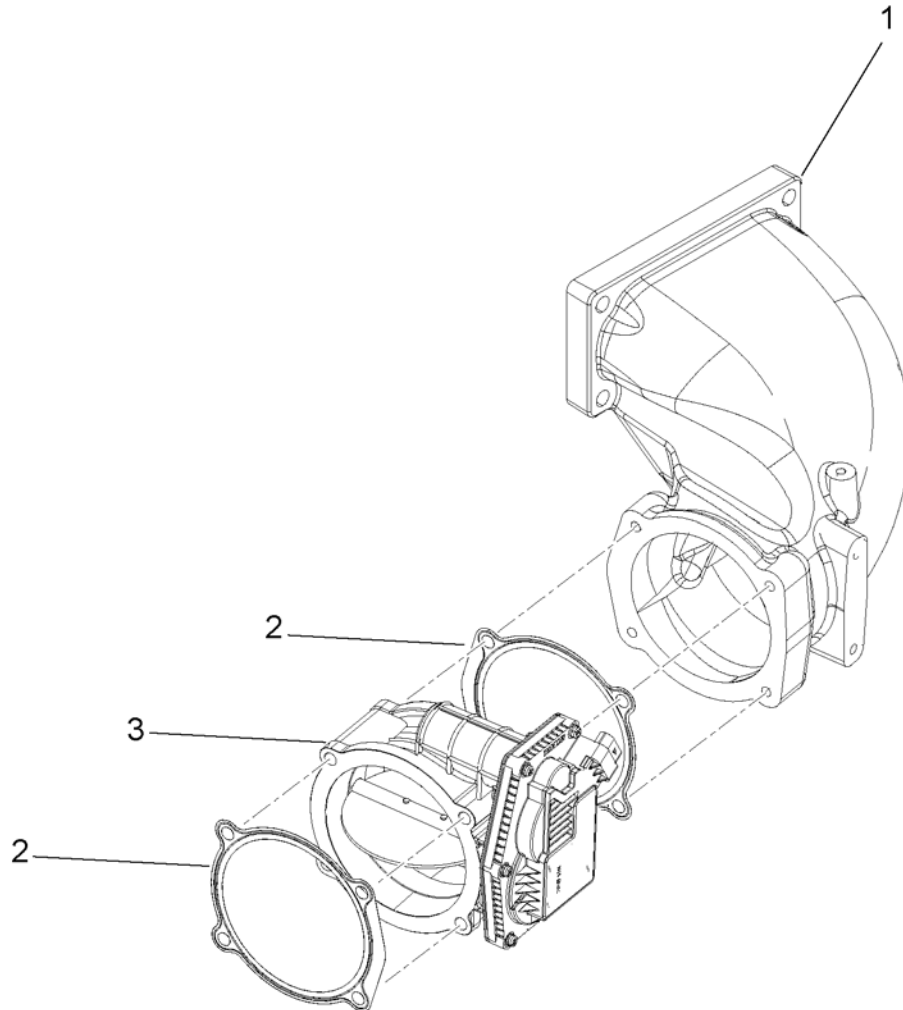
6.2 INTAKE THROTTLE VALVE AND ADAPTOR

Perform the following procedures for the removal and installation of the intake throttle valve.

6.2.1 Removal of Intake Throttle Valve and Adaptor

Removal steps are as follows:

1. Disconnect the hose connection from the charge air cooler to the intake throttle adaptor.



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1. Air Inlet Elbow

3. Air Intake Throttle Valve

2. Gaskets

Figure 6-4 Air Intake Throttle Valve and Adaptor

2. Disconnect the electrical connector at the intake throttle valve. See Figure 6-4.

3. Remove four hex socket-head bolts and remove the intake throttle valve and adaptor and two gaskets from the air intake elbow. Discard gaskets.

6.2.2 Installation of Intake Throttle Valve and Adaptor

Installation steps are as follows:

1. Secure the intake throttle valve, two gaskets and the adaptor to the air intake elbow with four hex socket-head bolts (M8 x 90 mm). Torque the bolts to 25 N·m (18 lb·ft). See Figure 6-4.
2. Connect the electrical connector to the intake throttle valve.

6.3 GAS MIXER HOUSING

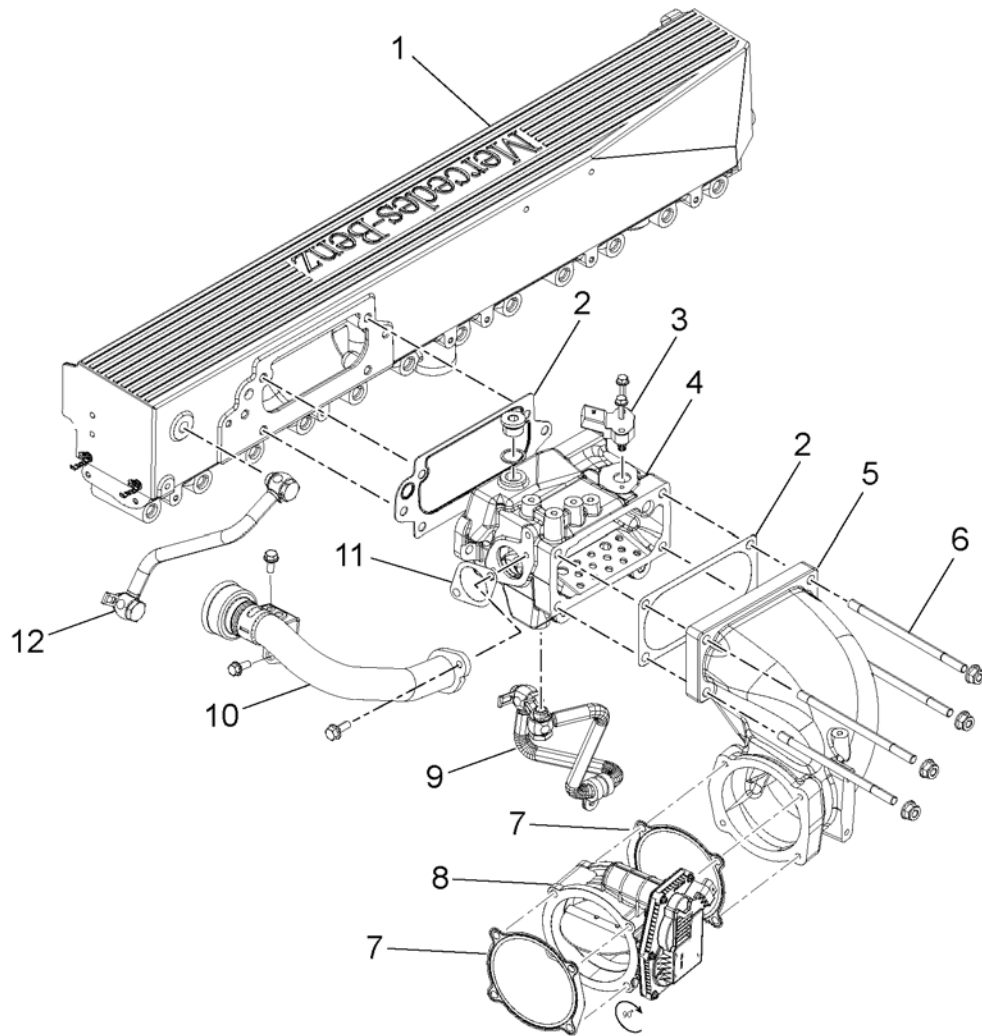
Perform the following procedures for removal and installation of the gas mixer housing.

6.3.1 Removal of Gas Mixer Housing

Removal steps are as follows:

1. Disconnect the hose connection from the charge air cooler to the intake throttle adaptor.
2. If equipped with a grid heater disconnect the electrical connections and harness connector.
3. Disconnect the electrical connector from the intake air temperature/pressure sensor on the mixer housing.
4. Disconnect the electrical connector from the air intake throttle valve.
5. Remove fuel primer pump.
6. For engines equipped with the Extreme Cold Climate (EC2) Package, remove the coolant feed line from the intake throttle valve.

7. Remove the bolt, spacer and two isolators securing the support bracket to the alternator bracket. See Figure 6-5.



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|--------------------------------------|---------------------------------|
| 1. Air Intake Manifold | 7. Gasket |
| 2. Gasket | 8. Intake Air Throttle Valve |
| 3. Air Temperature / Pressure Sensor | 9. Coolant Feed Line (w/EC2) |
| 4. Gas Mixer Housing | 10. EGR Gas Outlet Pipe |
| 5. Air Inlet Elbow | 11. Gasket |
| 6. Studs & Nuts (4 qty.) | 12. Coolant Return Line (w/EC2) |

Figure 6-5 Gas Mixer Housing

8. Remove four locking nuts securing the gasket and air intake elbow to the gas mixer housing. Remove the elbow, throttle valve and adaptor as an assembly. Discard the gasket. See Figure 6-5.

9. Remove two bolts mounting the EGR gas outlet pipe to the gas mixer housing. See Figure 6-5.
10. Remove two bolts (M8 x 16mm) attaching the mounting bracket on the EGR gas outlet pipe to the air intake manifold. Move pipe away from mixer housing. See Figure 6-5.
11. Remove two bolts (Extreme Cold Climate EC2 - M10 x 25mm) (Non EC2 - M8 x 25mm) attaching the mixer housing to the air intake manifold and remove the housing and gasket. Discard the gasket. See Figure 6-5.
12. If necessary, remove the mixer tube and gasket from the mixer housing. See Figure 6-5.

6.3.2 Installation of Gas Mixer Housing

Installation steps are as follows:

1. Install a new gasket and position the gas mixer housing over the four studs on the air intake manifold. Secure the housing to the manifold with two bolts. See Figure 6-5.
 - [a] Extreme Cold Climate (EC2) M10 x 25mm, torque the bolts to 60 N·m (44 lb·ft).
 - [b] Non-EC2 M8 x 25mm, torque the bolts to 25 N·m (18 lb·ft).
2. Attach the EGR gas outlet pipe and gasket to the mixer housing with two bolts. Torque the bolts to 35 N·m (26 lb·ft). See Figure 6-5.
3. Install two bolts (M8 x 16mm) and secure the mounting bracket on the EGR gas outlet pipe to the air intake manifold. Torque the bolts to 25 N·m (18 lb·ft). See Figure 6-5.
4. Install the gasket, elbow, throttle valve and adaptor as an assembly over the four studs on the air intake manifold. Secure the assembly to the air intake manifold with four locking nuts. Torque the nuts to 50 N·m (37 lb·ft). See Figure 6-5.
5. For engines equipped with the Extreme Cold Climate (EC2) Package, install the coolant feed line to the intake throttle valve.
6. Connect the electrical connector to the air intake throttle valve.
7. Connect the electrical connector to the intake air temperature/pressure sensor on the top of the mixer housing.
8. If equipped with a grid heater connect harness connector and electrical connections.
9. Connect the charge air hose connection to the intake throttle adaptor. Tighten the clamps securely.

6.4 AIR INTAKE MANIFOLD

Perform the following procedures for removal and installation of the air intake manifold.

6.4.1 Removal of Air Intake Manifold

Removal steps are as follows:

 WARNING: PERSONAL INJURY
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Apply the parking brakes, shut down the engine, and chock the rear tires. Tilt the hood.
2. Remove the hose clamps at the air compressor, air intake manifold and EGR cooler securing the air compressor air inlet tube to brackets.
3. Remove the gas mixer housing. Refer to section 6.3.1.
4. Remove front, two side, and one rear engine trim cover and mounting frames. Refer to section 1.1.1.
5. Disconnect the oil separator from the air intake manifold by loosening the upper hose clamp.
6. Disconnect the hose at the crankcase breather pipe hose at the rear of the air intake manifold by squeezing the clamp and pulling outward.
7. Remove the banjo bolt and two washers securing the electrostatic oil separator drain hose to the bottom of the air intake manifold. Discard the washers.
8. Remove twelve special bolts and washers and remove the air intake manifold and gaskets. Discard washers and gaskets.
9. Remove the intake air temperature/pressure sensor from the gas mixer housing. Refer to section 6.6.1.

6.4.2 Installation of Air Intake Manifold

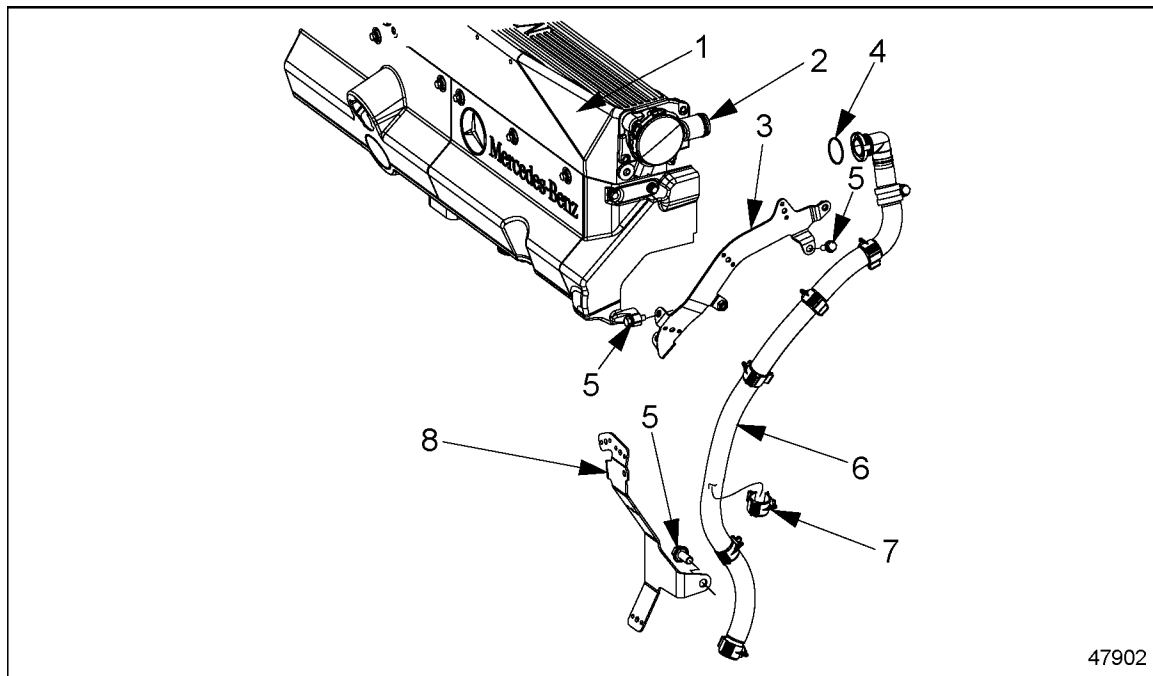
Installation steps are as follows:

1. Install new gaskets on the air intake manifold and secure the manifold to the cylinder head with twelve special bolts (M8 x 100 mm) and new washers. Torque the bolts to 33 N·m (24 lb·ft).
2. Connect the electrostatic oil separator return line to the bottom of the air intake manifold with banjo bolt and new washers. Torque the banjo bolt to 35 N·m (26 lb·ft).

3. Install the intake air temperature/pressure sensor in the gas mixer housing. Refer to section 6.6.2.
4. Connect the electrical connector to the air temperature sensor on the gas mixer housing.
5. Install the EGR gas mixer housing. Refer to section 8.7.2.
6. Install the engine trim cover side panels. Refer to section 1.1.2.
7. Lower the hood and remove the chocks from the rear tires.

6.4.3 Removal of Crankcase Breather Pipe

Removal steps are as follows:



- | | |
|--------------------------------|-----------------------------|
| 1. Air Intake Manifold | 5. Bolts (qty 3) |
| 2. Electrostatic Oil Separator | 6. Crankcase Breather Pipe |
| 3. Bracket (Upper) | 7. Retaining Clamps (qty 6) |
| 4. Seal Ring | 8. Bracket (Lower) |

Figure 6-6 Crankcase Breather Pipe

1. Remove the crankcase breather pipe from the electrostatic oil separator by compressing the band at the connection and pulling outward. Remove and discard the seal ring on the separator. See Figure 6-6.
2. Remove the bolt and nut at clamp and release pipe from hose bracket, then remove the pipe. See Figure 6-6.

6.4.4 Installation of Crankcase Breather Pipe

Installation steps are as follows:

1. Install a new seal ring on the electrostatic oil separator, then connect the breather pipe to the separator by snapping into place. See Figure 6-6.
2. Secure the crankcase breather pipe with the hose bracket and a bolt (M8 x 25) and nut at the clamp. Torque the bolt and nut to 25 N·m (18 lb·ft). See Figure 6-6.

6.5 ELECTROSTATIC OIL SEPARATOR, CRANKCASE SEPARATOR, AND OIL SEPARATOR DRAIN LINE

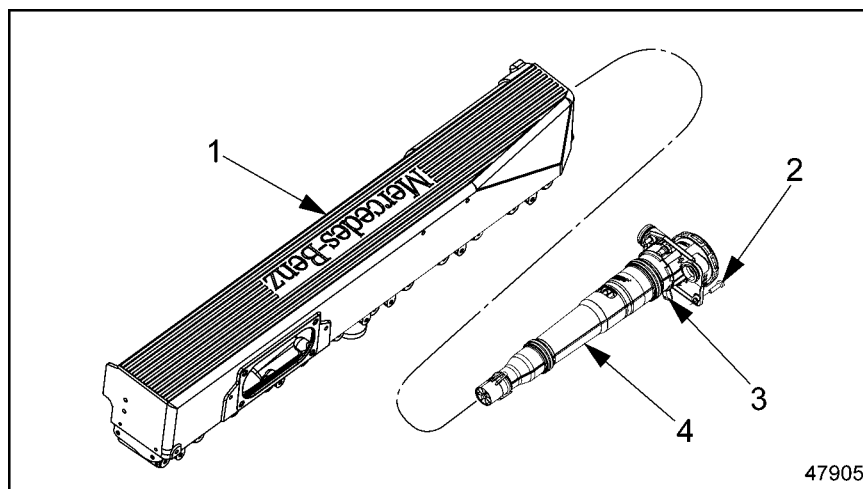
Removal the Electrostatic Oil Separator as follows:

6.5.1 Removal of Electrostatic Oil Separator

Removal steps are as follows:

NOTE:

The electrostatic oil separator is housed inside the air intake manifold.



1. Air Intake Manifold

2. Screws (qty 2)

3. Electrical Connection

4. Electrostatic Oil Separator

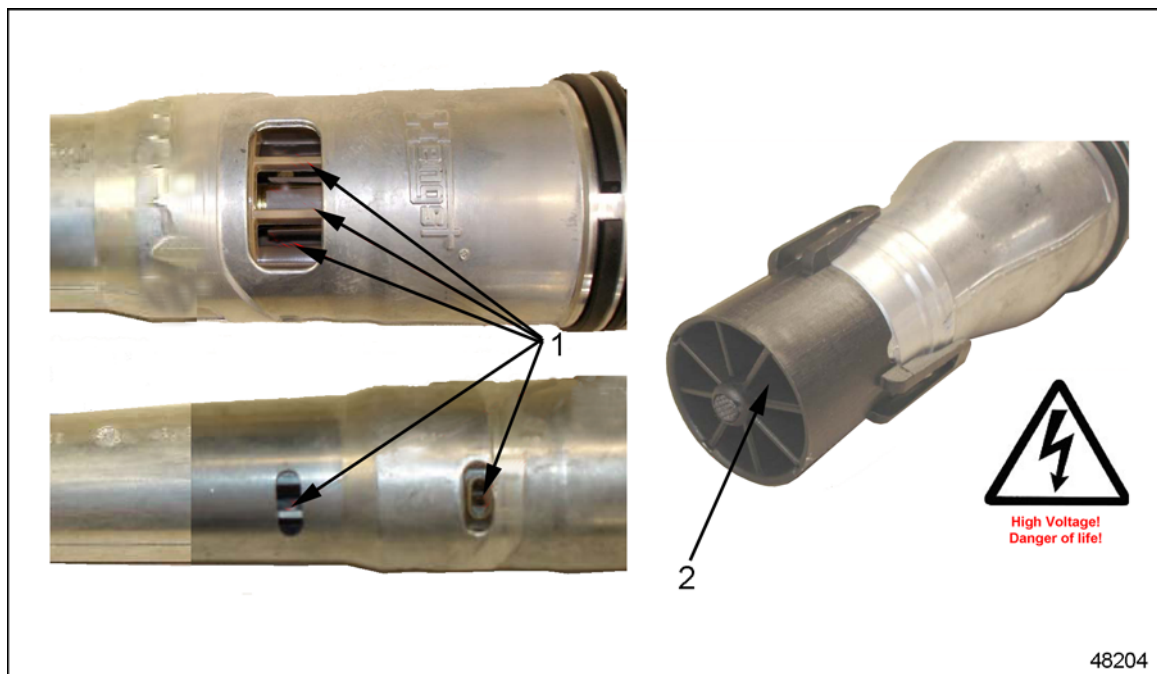
Figure 6-7 Electrostatic Oil Separator

1. Remove the rear trim cover and disconnect the electrical connector to the Electrostatic Oil Separator. See Figure 6-7.
2. Disconnect the crankcase breather pipe from the electrostatic oil separator by compressing the band at the connection and pulling outward.

**WARNING:****Electrical Shock Hazard**

High voltage can remain inside the Electrostatic Oil Separator after removal. Wait 30 minutes after turning off the ignition before removing the separator. Never touch parts through ventilation openings or impeller opening with finger or conductive items (e.g. screwdriver or wire). High voltage can remain inside the Electrostatic Oil Separator for up to 12 hours after the ignition is turned off.

3. Remove two bolts securing the oil separator to the air intake manifold. Carefully pry the end cover and oil separator from the air intake manifold and remove separator. See Figure 6-7.
4. Never touch parts through the ventilation openings or impeller end with fingers or conductive items e.g. screwdriver or wire. The separator can contain high voltage for up to 12 hours. See Figure 6-8.



1. Ventilation Openings

2. Impeller Opening

Figure 6-8 Electrostatic Oil Separator Electrical Shock Hazard

5. Inspect the two isolator rings and seal rings on the electrostatic oil separator. Discard the isolators and seal rings if damaged.
6. Remove the seal ring from the pressure regulator valve and discard the seal ring.

6.5.2 Installation of Electrostatic Oil Separator

Perform the following to install the Electrostatic Oil Separator.

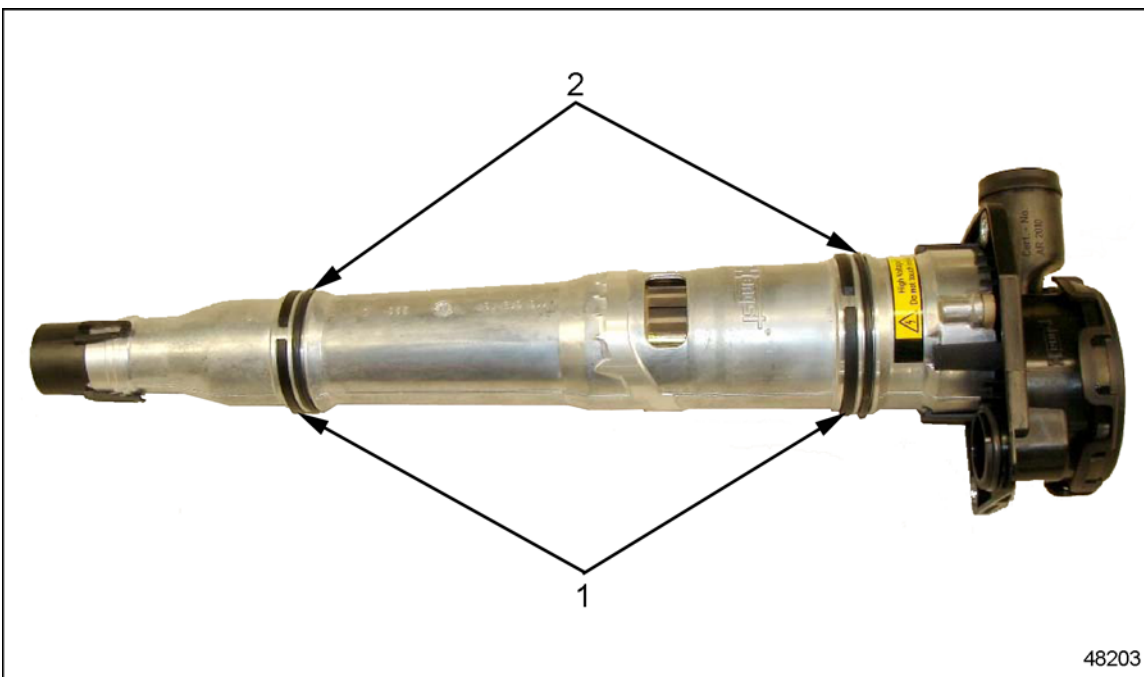


WARNING:

Electrical Shock Hazard

High voltage can remain inside the Electrostatic Oil Separator after removal. Wait 30 minutes after turning off the ignition before removing the separator. Never touch parts through ventilation openings or impeller opening with finger or conductive items (e.g. screwdriver or wire). High voltage can remain inside the Electrostatic Oil Separator for up to 12 hours after the ignition is turned off.

1. If damaged, install new isolator spacers and seal rings on the Electrostatic Oil Separator. Lightly coat the isolator spacers and seal rings with clean engine oil prior to installing in the air intake manifold. See Figure 6-9.



1. Isolator Spacers

2. Seal Rings

Figure 6-9 Electrostatic Oil Separator Isolator Spacers and Seal Rings

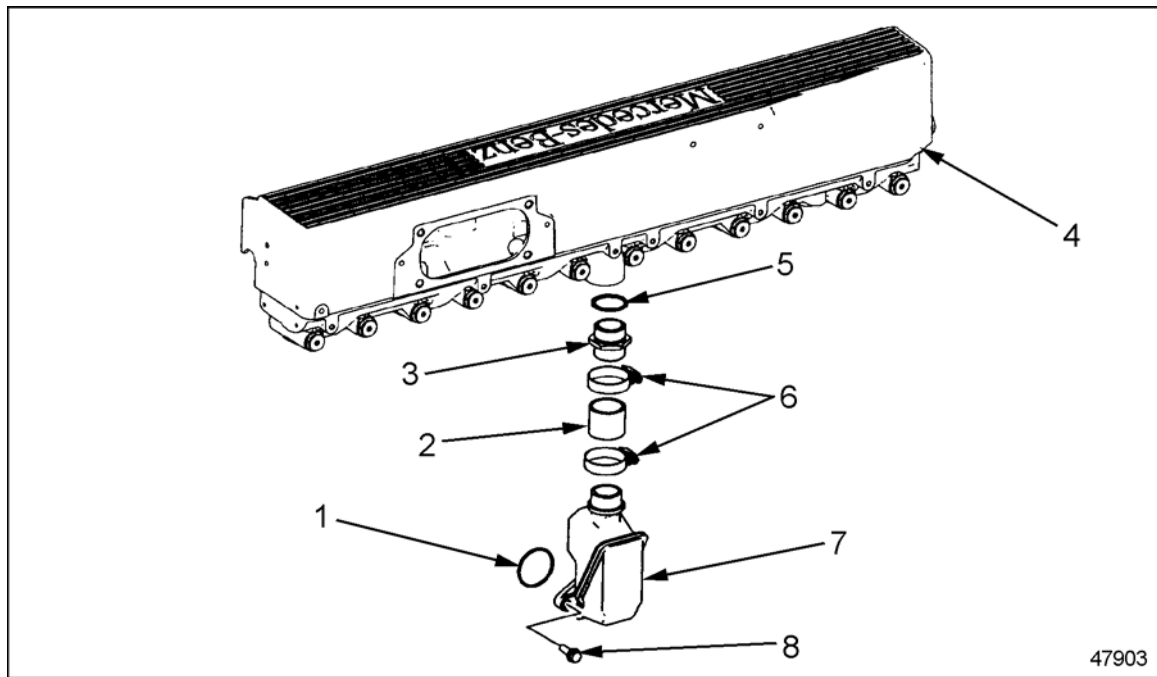
2. Install a new seal ring on pressure regulator valve. See Figure 6-7.
3. If removed, install the oil separator into the housing in the air intake manifold and secure with two screws (M6 x 20 mm). Torque the screws to 10 N·m (7 lb·ft). See Figure 6-7.

4. Connect the electrical connector to the Electrostatic Oil Separator.
5. Install the rear engine trim cover and secure with two bolts (M6 x 18 mm). Torque the bolts to 12 N·m (9 lb·ft).
6. Install the crankcase breather pipe. Refer to section 6.4.4.

6.5.3 Removal of Crankcase Separator

Removal steps are as follows:

1. Remove the rear side trim cover.



1. Seal Ring

4. Air Intake Manifold

7. Oil Preseparator

2. Hose

5. Seal Ring

8. Bolt

3. Connector Fitting

6. Clamps

Figure 6-10 Oil Separator

2. Loosen hose clamp on the bottom of the air intake manifold and crankcase separator. See Figure 6-10.

**WARNING:****Electrical Shock Hazard**

High voltage can remain inside the Electrostatic Oil Separator after removal. Wait 30 minutes after turning off the ignition before removing the separator. Never touch parts through ventilation openings or impeller opening with finger or conductive items (e.g. screwdriver or wire). High voltage can remain inside the Electrostatic Oil Separator for up to 12 hours after the ignition is turned off.

3. Remove two bolts securing the separator to the side of the cylinder block. See Figure 6-10.
4. Remove the separator and seal ring. Discard the seal ring. See Figure 6-10.
5. If necessary, remove the hose and clamp from the crankcase pre-separation. Inspect the hose and replace if damaged.
6. If necessary, remove the connector fitting and seal ring from the bottom of the air intake manifold. Discard the seal ring. See Figure 6-10.

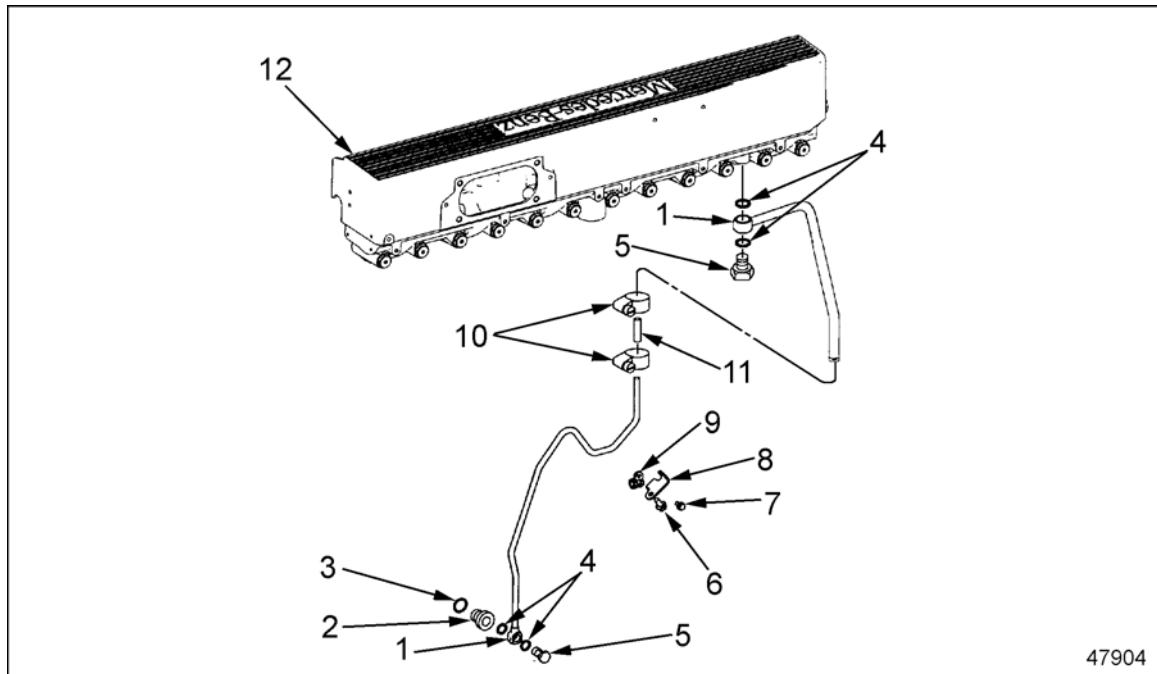
6.5.4 Installation of Crankcase Separator

Installation steps are as follows:

1. If removed, install the hose and clamp on the crankcase pre-separation. See Figure 6-10.
2. Install a new seal ring on the crankcase separator. See Figure 6-10.
3. Attach the separator to the side of the cylinder block by sliding into hose on the bottom of the air intake manifold and secure with two bolts (M8 x 15 mm). Torque the bolts to 25 N·m (18 lb·ft). Tighten the clamp securely. See Figure 6-10.
4. Install the rear side trim cover and secure with three bolts (M8 x 18mm). Torque the bolts to 12 N·m (9 lb·ft).

6.5.5 Removal of Oil Separator Drain Line

Removal steps are as follows:



- | | | |
|--------------------|---------------|-------------------------|
| 1. Banjo Fitting | 5. Banjo Bolt | 9. Clamp |
| 2. Adaptor Fitting | 6. Bolt | 10. Hose Clamps |
| 3. Seal Ring | 7. Screw | 11. Hose |
| 4. Washers | 8. Bracket | 12. Air Intake Manifold |

Figure 6-11 Oil Separator Drain Line

1. Remove the banjo bolt and washers securing the crankcase breather drain line to the bottom rear of the air intake manifold. Discard washers. See Figure 6-11.
2. Remove the banjo bolt and washers securing the oil separator drain line to the side of the oil pan and remove the line. Discard the washer. See Figure 6-11.
3. Pull the oil drain line upward and remove two hose clamps and hose from the drain tube. Remove the upper and lower drain tube line. See Figure 6-11.
4. If necessary, adaptor fitting and seal ring. Discard seal ring. See Figure 6-11.

6.5.6 Installation of Oil Separator Drain Line

Installation steps are as follows:

1. If removed, install drain line adaptor fitting and new seal ring in the side of the cylinder block. Torque the fitting to 25 N·m (18 lb·ft). See Figure 6-11.

2. Install hose and clamp on lower oil separator drain tube line. Slide the lower drain tube up from the bottom of the block between the trim cover frame between cylinders five and six. See Figure 6-11.
3. While holding lower oil drain line up install a hose clamp over the hose, then insert the upper line into the hose. The upper banjo fitting should face outward and the lower fitting should be parallel with the cylinder block. Tighten the hose clamps securely.
4. Secure lower end of the oil separator drain line to the oil pan with a banjo bolt and new washers. Torque the banjo bolt to 50 N·m (37 lb·ft). See Figure 6-11.
5. Secure the upper end of the oil separator drain line to the bottom rear of the air intake manifold with a banjo bolt and new washers. Torque the banjo bolt to 35 N·m (26 lb·ft). See Figure 6-11.

6.6 INTAKE AIR TEMPERATURE/PRESSURE SENSOR

The following sections support the intake air temperature and pressure sensor.

6.6.1 Intake Air Temperature/Pressure Sensor Removal

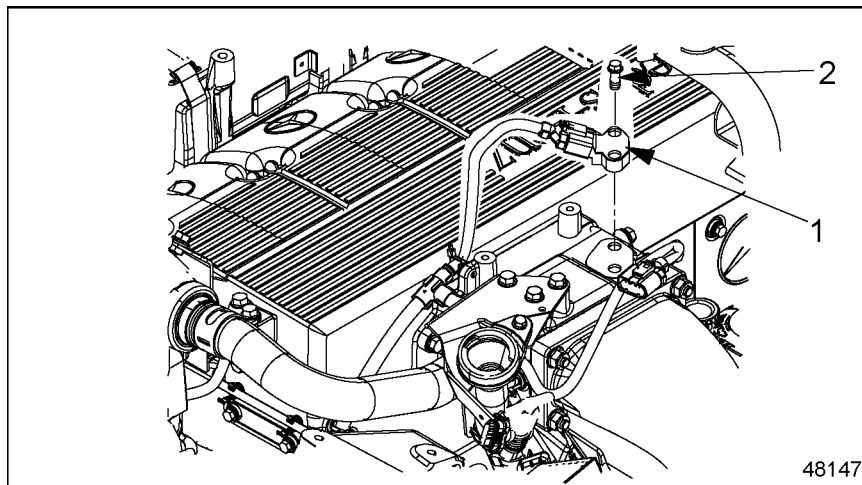
Removal steps are as follows:

NOTE:

The intake air temperature/pressure sensor is located on top of the EGR gas mixer housing.

 WARNING:
PERSONAL INJURY
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Apply the parking brakes, shut down the engine, and chock the rear tires. Tilt the hood.



1. Bolts

2. Intake Air Temperature/Pressure Sensor

Figure 6-12 Intake Air Pressure/Temperature Sensor

2. Disconnect the electrical connector to the sensor located on top of the gas mixer housing. See Figure 6-12.
3. Remove the screws attaching the intake manifold pressure/temperature sensor, then remove the sensor from the EGR gas mixer housing. See Figure 6-12.

6.6.2 Installation of Intake Air Pressure/Temperature Sensor

Installation steps are as follows:

1. Install the intake air temperature/pressure sensor in the EGR mixer housing and secure with two screws. Tighten the screws to 10 N·m (7 lb·ft). See Figure 6-12.
2. Connect the electrical connector to the sensor. See Figure 6-12.
3. Lower the hood and remove the chocks from the rear tires.



WARNING: **ENGINE EXHAUST**

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

NOTICE:

Whenever the intake air temperature/pressure sensor is replaced the air mass flow of the engine must be re-calibrated to ensure proper engine EGR and smoke control operation.

4. Start and run the engine.
5. Connect DDDL® 7.0 and turn the ignition to the "ON" position, code SPN 132 FMI 13 (Air Mass Adaptation Required) will appear. To clear the code run the Air Mass Adaptation service routine.
6. If any other codes appear, refer to the MBE 4000 DDEC VI Troubleshooting Guide.
7. Shut down the engine.

6.7 TURBOCHARGER

The following sections support the turbocharger.

6.7.1 Inspection of Turbocharger

Inspection steps are as follows:

1. Chock the rear tires and lift the hood.

 WARNING: ENGINE EXHAUST
To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

2. Place the transmission in neutral and start the engine.

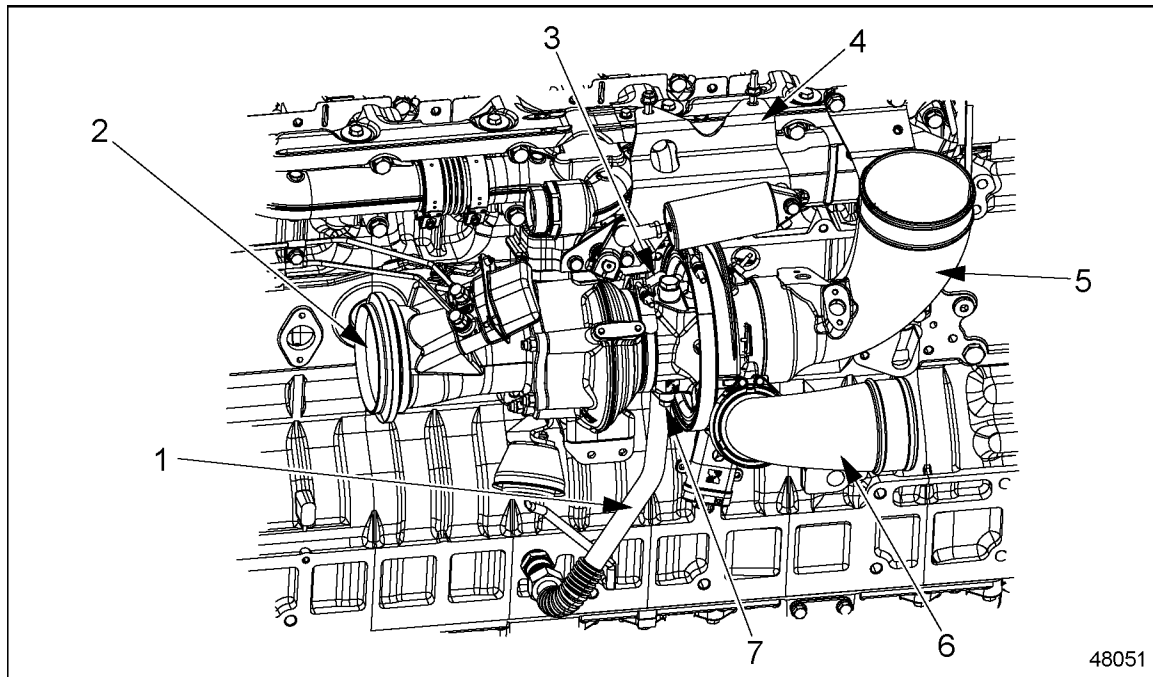
 WARNING: PERSONAL INJURY
To avoid injury, use care when working around moving belts and rotating parts on the engine.

3. Check the turbocharger for unusual noises and excessive vibration.

NOTE:

Unusual noises and excessive vibration can be caused by damage to the turbocharger wheels, or by leaks in the charge-air piping.

4. Visually check the turbocharger outlet pipe and air cleaner elbow for leaks. See Figure 6-13.



- | | |
|--------------------|------------------------------|
| 1. Oil Return Line | 5. Air Cleaner Inlet |
| 2. Exhaust Housing | 6. Turbocharger Outlet Pipe |
| 3. Oil Supply Line | 7. Return Line Mounting Bolt |
| 4. Bracket | |

Figure 6-13 Turbocharger Components

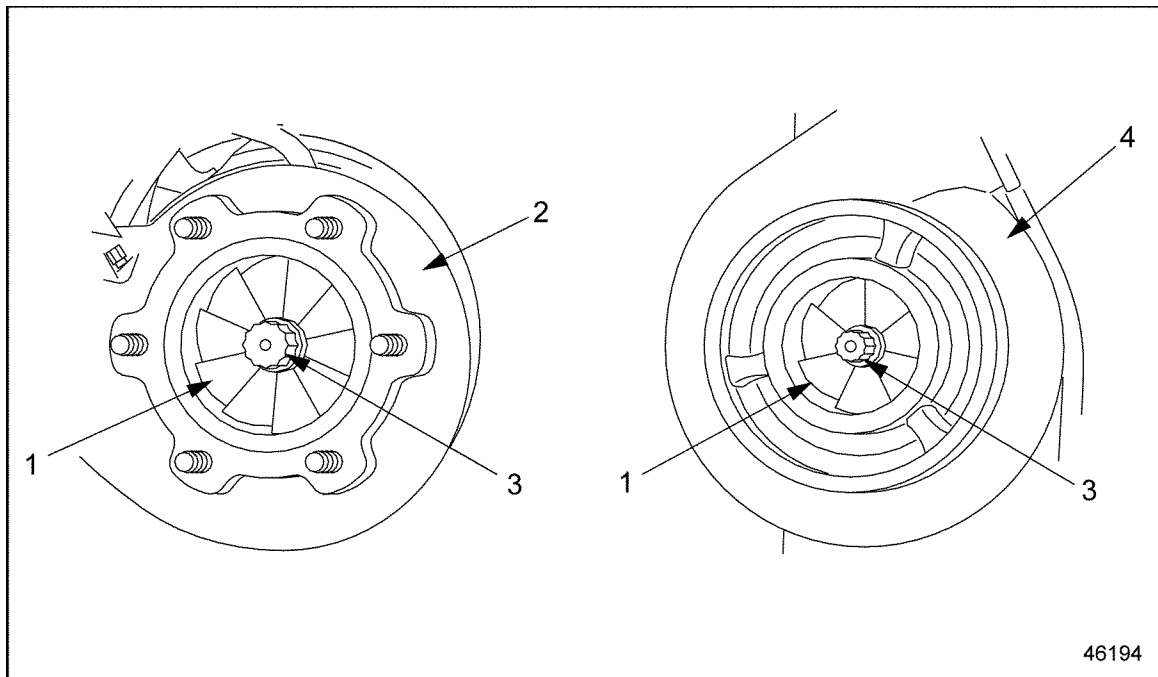
5. Check the charge air piping for leaks. To find leaks, coat the outside of the pipe with a thin film of soapy water.
6. Check the exhaust system for leaks. To find leaks, check for color changes to the pipe caused by heating around the leak area.
7. Shut down the engine.

6.7.1.1 Checking Turbocharger Radial and Axial Play

Checking steps are as follows:

1. Disconnect the air line from the exhaust brake cylinder.
2. Remove the exhaust housing to expose the turbine wheel. Refer to section 7.2.1 and see Figure 6-13.
3. Remove the air cleaner inlet pipe to expose the compressor wheel. See Figure 6-13.

4. Check the turbine wheel and compressor wheel for damage to the blades caused by dirt, debris, and other foreign matter in the turbocharger air system. See Figure 6-14 for the turbine wheel and compressor wheel.



- | | |
|--------------------|-----------------------|
| 1. Blade | 3. Rotor Shaft |
| 2. Turbine Housing | 4. Compressor Housing |

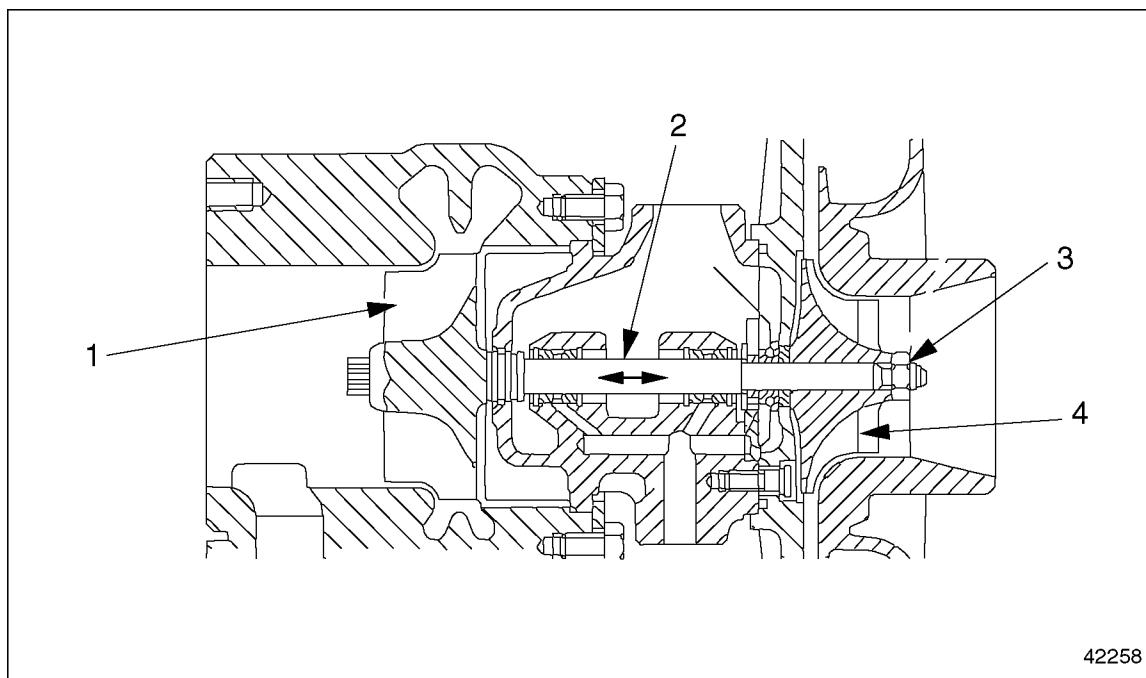
Figure 6-14 Turbine Wheel and Compressor Wheel

- [a] If wheel blades are worn at the leading edges, ripped, cut, or bent backwards, replace the turbocharger. Refer to section 6.7.2.
- [b] Clean the exhaust manifold and the entire turbocharger air system.
5. Check the turning smoothness and uniformity of the rotor shaft.
 - [a] Turn the shaft alternately, in both clockwise and counterclockwise directions, until it is clear of carbonized oil.
 - [b] Turn the nut on the end of the rotor shaft. Check that the shaft does not bind in some places and spin in others (smoothness).
 - [c] Turn the nut on the end of the rotor shaft. Check that the same amount of turn on the nut always causes the same amount of turn on each wheel (uniformity).

6. Check the axial play of the rotor shaft. See Figure 6-15.

NOTE:

Move the shaft in the direction shown by the arrows.



1. Turbine Wheel

3. Rotor Nut

2. Rotor Shaft

4. Compressor Wheel

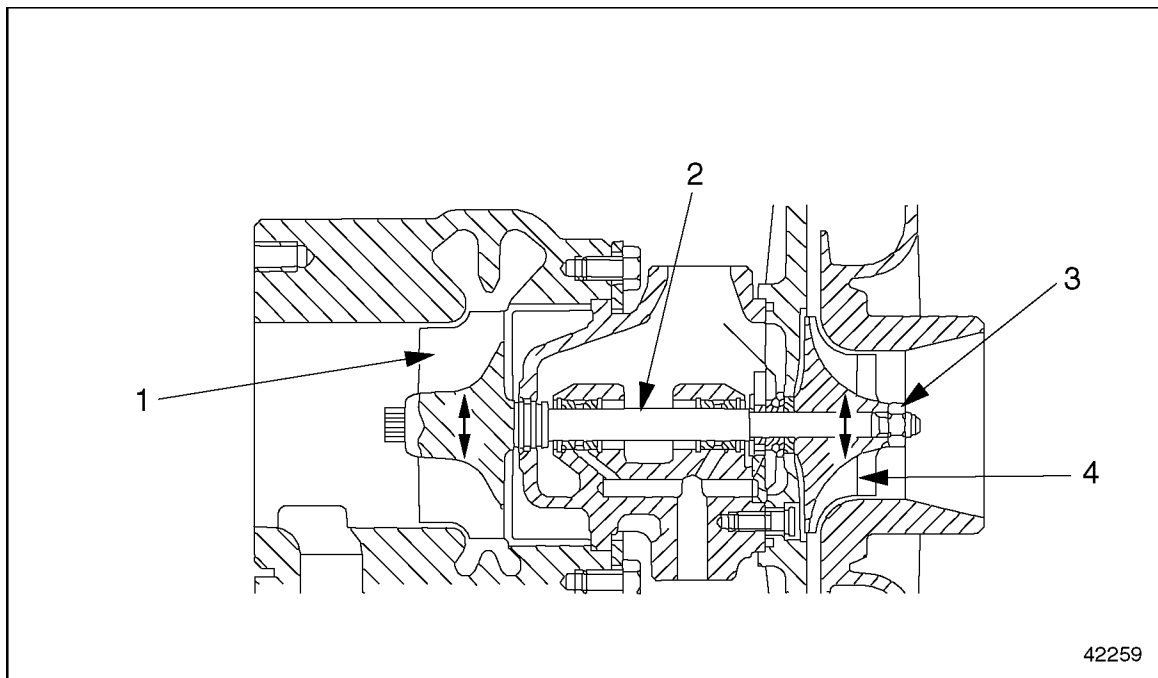
Figure 6-15 Turbocharger Axial Play

- [a] Move the rotor shaft from end to end and check for friction between the wheels and the turbo housing. Neither turbine wheel nor compressor wheel should rub against the housing.
- [b] If there is friction or contact with either side of the housing, replace the turbocharger. Refer to section 6.7.2.

7. Check the radial play of the rotor shaft. See Figure 6-16.

NOTE:

Move the shaft in the direction shown by the arrows.



1. Turbine Wheel

3. Rotor Nut

2. Rotor Shaft

4. Compressor Wheel

Figure 6-16 Turbocharger Radial Play

- [a] Move the rotor shaft from side to side and check for friction between the wheels and the turbo housing. Neither turbo wheel nor compressor wheel should rub against the housing.
- [b] If there is friction or contact with either side of the housing, replace the turbocharger. Refer to section 6.7.2.
8. Install the air cleaner inlet pipe.
9. Install the exhaust brake valve housing on the turbocharger. Refer to section 7.2.2.
10. Lower the hood and remove the chocks from the rear tires.

6.7.2 Removal of Turbocharger

Removal steps are as follows:

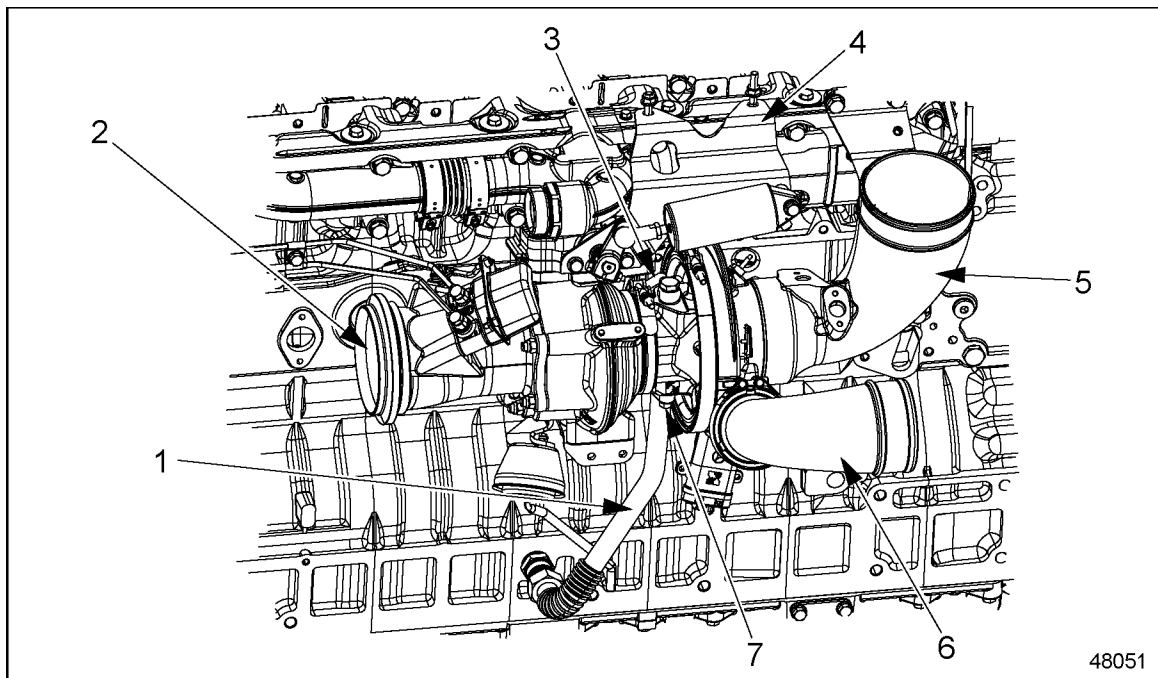


WARNING:
PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Apply the parking brakes, shut down the engine, and chock the rear tires. Tilt the hood.
2. To gain access to the turbocharger, remove the air cleaner.
3. Disconnect the exhaust pipe from the exhaust housing on the turbocharger.
4. Disconnect the air line from the brake gate actuator.
5. Drain the coolant.
6. Disconnect the coolant in and out lines to the Fuel Doser Valve by removing the banjo bolts and washers. Discard the washers.
7. Disconnect the fuel pressure line to the Fuel Doser Valve.
8. Disconnect the line to the actuator on the exhaust brake housing and remove housing from the turbocharger.

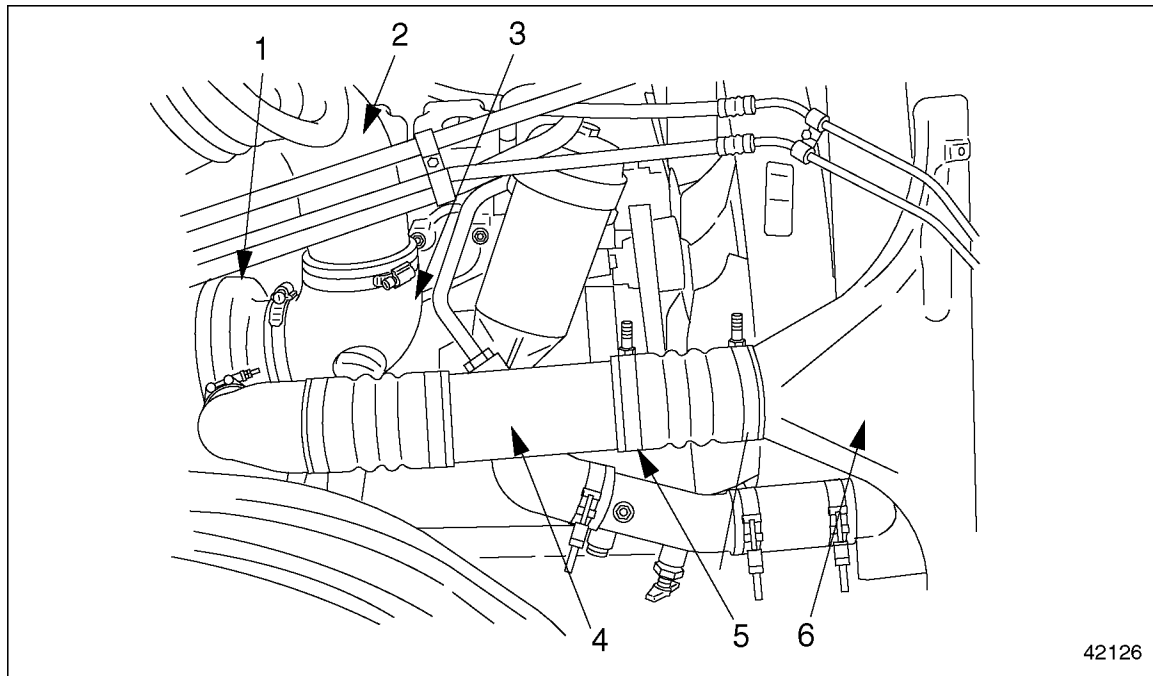
9. Disconnect the turbocharger outlet pipe from the turbocharger housing. See Figure 6-17.



- | | |
|--------------------|------------------------------|
| 1. Oil Return Line | 5. Air Cleaner Inlet |
| 2. Exhaust Housing | 6. Turbocharger Outlet Pipe |
| 3. Oil Supply Line | 7. Return Line Mounting Bolt |
| 4. Bracket | |

Figure 6-17 **Turbocharger Air Outlet**

10. Disconnect the air intake elbow from the turbocharger. See Figure 6-18.



- | | |
|---------------------|-----------------------------|
| 1. Turbocharger | 4. Turbocharger Outlet Line |
| 2. Air Cleaner Pipe | 5. Constant-Torque Clamp |
| 3. Air Intake Elbow | 6. Charge Air Cooler |

Figure 6-18 Turbocharger Air Intake

11. Remove the oil return line from the turbocharger and the cylinder block.
 - [a] Remove the two bolts attaching the oil return line to the bottom of the turbocharger. Discard the gasket.
 - [b] Disconnect the fitting attaching the oil return line to the cylinder block.
12. Remove the oil supply line from the turbocharger and the cylinder block.
 - [a] Remove the two bolts attaching the oil supply line to the turbocharger. Discard the gasket.
 - [b] Remove the banjo bolt attaching the oil supply line to the cylinder block. Discard the two seal rings.
13. Remove the nuts that attach the turbocharger to the exhaust manifold center section and discard nuts. Remove the turbocharger and exhaust housing.
14. If necessary, remove the exhaust housing from the turbocharger and discard nuts.
15. Remove two studs from the turbocharger.

6.7.3 Installation of Turbocharger

Installation steps are as follows:

1. Inspect the turbo inlet hose, turbocharger outlet pipe, and the oil supply and return lines for restrictions or foreign objects.
2. Using new nuts, install the exhaust housing on the turbocharger (if removed). Torque the nuts 50 N·m (37 lb·ft).
3. Install the two removed studs into the turbocharger. Torque the studs to 50 N·m (37 lb·ft).
4. Install the turbocharger on the exhaust manifold center section.
 - [a] Coat four new prevailing torque locknuts with a light coating of high temperature grease.
 - [b] Make sure that the mating surfaces of the turbocharger and the exhaust manifold are clean and free of damage.
 - [c] Position the turbocharger over the mounting studs on the exhaust manifold.
 - [d] Install the four nuts and torque to 50 N·m (37 lb·ft).
5. Attach the oil return line to the turbocharger and the cylinder block.
 - [a] Install a new gasket where the end flange of the return line meets the turbocharger.
 - [b] Install the mounting bolts through the holes in the end flange. Torque the bolts to 25 N·m (18 lb·ft).
 - [c] Connect the return line fitting to the side of the engine block. Torque the line fitting to 50 N·m (37 lb·ft).
6. Fill the bearing housing with clean engine oil through the oil inlet port. Turn the turbocharger wheel several times to coat the bearings with oil.

NOTE:

If the turbocharger wheel cannot be spun freely by hand or if there is any indication of rubbing or scraping, determine the reason before starting the engine. One cause of wheel rubbing is a misaligned turbocharger housing.

7. Connect the oil supply line to the turbocharger.
 - [a] Install a new gasket where the end flange of the supply line meets the turbocharger.
 - [b] Install the mounting bolts through the holes in the end flange and the heat shield bracket. Tighten the bolts to 25 N·m (18 lb·ft).
 - [c] Install two new seal rings on the banjo fitting at the other end of the supply line.
 - [d] Install the banjo bolt attaching the supply line to the cylinder block. Tighten the bolt to 35 N·m (26 lb·ft).
8. Connect the coolant lines to the Doser Block Assembly with banjo bolts and new washers. Torque the banjo bolts to 25–30N·m (18–22 lb·ft).
9. Attach the air intake elbow to the turbocharger. Tighten the clamp to 10 N·m (89 lb·in.).

10. Attach the turbocharger outlet pipe to the turbocharger. Tighten the clamp to 10 N·m (89 lb·in.).
11. Connect the exhaust pipe to the exhaust brake valve housing. Tighten the v-band clamp securely.
12. Install the air line on the exhaust brake cylinder, as removed. Tighten fitting nut securely.
13. Install the air cleaner.



WARNING:
ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

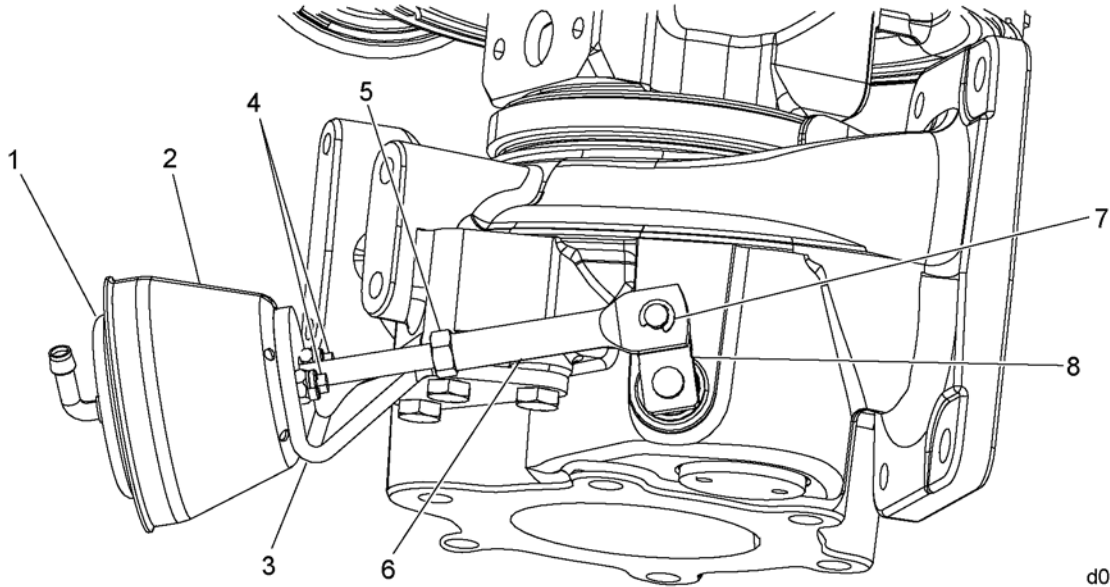
14. Start the engine and allow it to run at idle speed for three to four minutes before accelerating.
15. Check for oil leaks. Correct any leaks found.
16. Lower the hood and remove the chocks from the rear tires.

6.8 WASTEGATE ACTUATOR

The following explains the removal and installation of the wastegate actuator.

6.8.1 Removal of Wastegate Actuator

Remove as follows:



d090037

- | | |
|-----------------------|-------------------------------|
| 1. Wastegate Actuator | 5. Adjusting Rod Jam Nut (M8) |
| 2. Heat Shield | 6. Adjusting Rod |
| 3. Actuator Bracket | 7. E-Clip |
| 4. Hex Nuts (M6) | 8. Wastegate Swing-Arm |

Figure 6-19 Turbocharger Actuator Components

Removal is as follows:

NOTE:

This procedure utilizes the vehicle compressed air system. For removal, installation, and adjustment, ensure the system maintains minimum 90 psi.

1. Shut off the engine, apply the parking brake, chock the wheels, and perform any other applicable safety steps.
2. Remove the turbocharger. Refer to section 6.7.2.
3. Loosen the jam nut on the wastegate adjusting rod.
4. Remove the two nuts securing the actuator to the actuator bracket.
5. Remove and discard the E-clip holding the adjusting rod onto the actuator swing-arm pin.

6. Remove the adjusting rod and jam nut from the actuator swing-arm pin.

NOTE:

There is significant tension on the actuator rod and swing arm. Take care not to damage the swing arm pin when removing the adjusting rod.

7. Remove the adjusting rod and jam nut from the actuator rod.
8. Remove the actuator and heat shield from the mounting bracket.

6.8.2 Verification of Wastegate Actuator Operation

With the actuator disconnected from the turbocharger, it is possible to verify proper operation of the wastegate actuator. Due to the internal preload of the actuator return spring, movement of the actuator rod may not be seen at low pressures.

1. Connect regulated shop air to the wastegate actuator.
2. Slowly increase the regulated air pressure from 0 to 45 psi (0 to 300 kPa).
3. Verify that the wastegate actuator rod moves from the fully relaxed position to the fully extended position.
4. Using a soapy water solution, spray the wastegate actuator and check for leaks. No bubbles should be seen around the actuator body.
5. Slowly reduce air pressure from 45 to 0 psi (300 to 0 kPa).
6. Verify that the wastegate actuator rod moves from the fully extended position to the fully relaxed position.

6.8.3 Installation and Adjustment of Wastegate Actuator

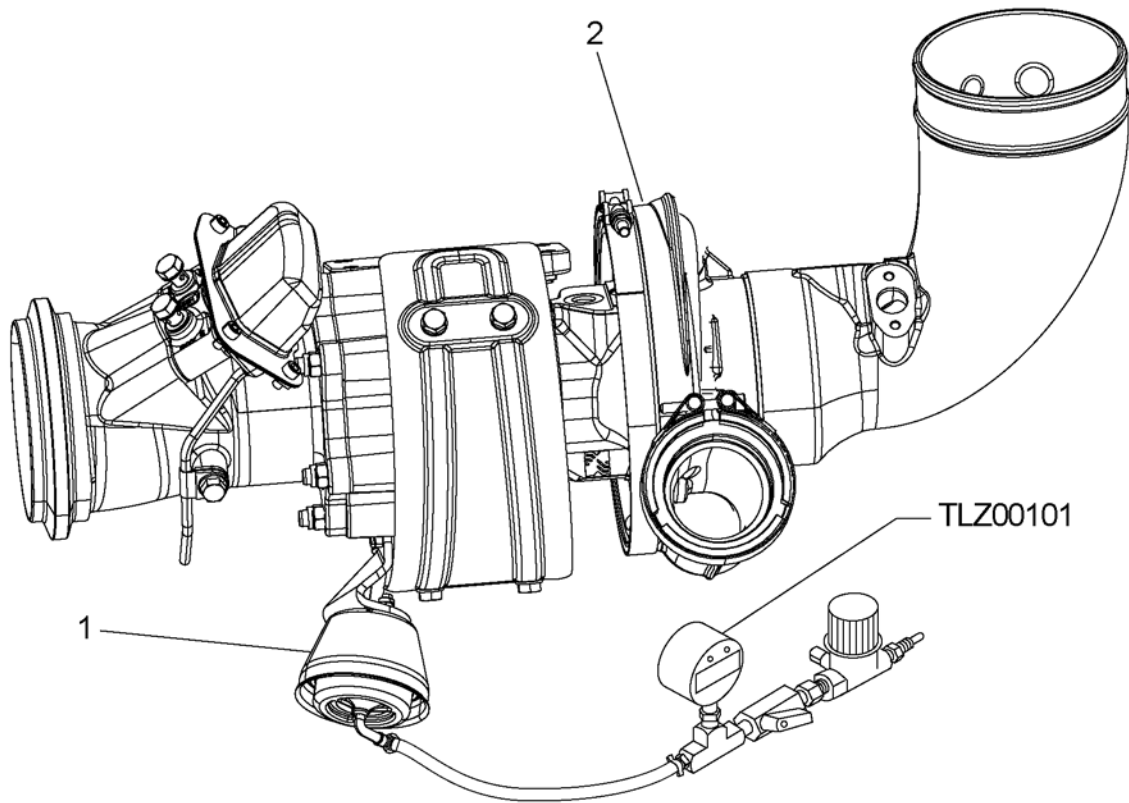
Installation is as follows:

NOTE:

Proper installation and adjustment of the wastegate actuator requires the use of a highly accurate digital air pressure gauge, TLZ00101 or equivalent.

1. With the adjusting rod and jam nut removed from the actuator rod, install the heat shield on the new wastegate actuator, and then install the wastegate actuator to the actuator bracket. Tighten nuts to 12 N·m (9 lb·ft).
2. Thread the jam nut and adjusting rod onto the actuator rod; do not tighten.
3. Attach regulated shop air to the digital pressure/regulator setup.
4. Adjust the regulator output knob until airflow stops.
5. Turn the digital pressure gauge (TLZ00101 or equivalent) on and set to “zero.”
6. Attach the digital pressure/regulator hose to the wastegate actuator port.

7. Connect the new wastegate actuator to a regulated air supply as shown in Figure 6-20. Secure all air hose connections, ensuring there are no leaks.



d090041

1. Wastegate Actuator

2. Turbocharger

Figure 6-20 Proper Setup of Regulated Air for Calibration

8. SLOWLY adjust the air regulator output to 26.1 psi (180 kPa).

9. With the wastegate in the fully closed position, adjust the free length of the adjusting rod by rotating it, so that the adjusting rod hole lines up with the wastegate swing-arm pin.

NOTE:

It is critical that the swing-arm remains in the closed position and the actuator rod is not moved in or out of the actuator during the adjustment. If the rod is moved in or out, it will slowly return to the correct position and must be readjusted. See Figure 6-21.

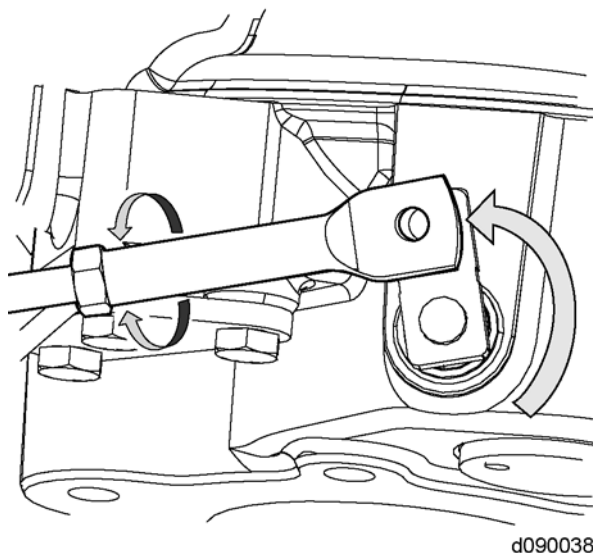
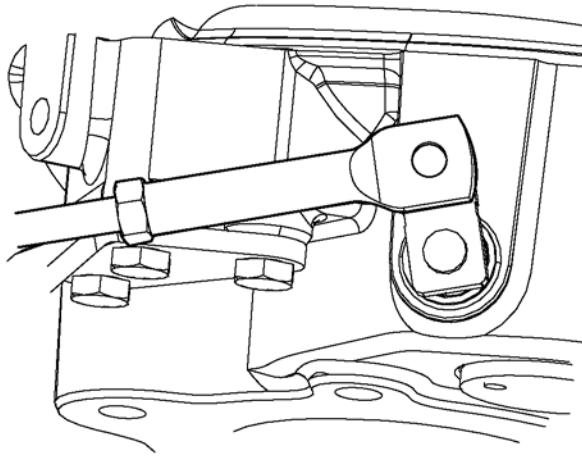


Figure 6-21 **Wastegate Swing-Arm in Closed Position**

10. Install the adjusting rod on the wastegate swing-arm pin. With the wastegate swing-arm in the fully closed position and the adjusting rod length properly set, the adjusting rod should be perfectly aligned with the swing-arm pin, see Figure 6-22. The adjusting rod should slip over the wastegate swing-arm pin nearly effortlessly when properly adjusted.



d090039

Figure 6-22 **Proper Adjusting Rod Length**

11. Install replacement E-clip onto the wastegate lever pin.
12. Tighten the jam nut on the wastegate actuator adjusting rod, taking care not to rotate the actuator shaft. Torque jam nut to 5 N·m (4 lb·ft).
13. Disconnect regulated air supply.
14. Install the turbocharger. Refer to section 6.7.3.
15. Verify the repair.

6.A Additional Information

Description	Page
SPECIFICATIONS	6-41
Charge Air Cooler	6-41
Air Intake Manifold	6-42
Turbocharger	6-43

SPECIFICATIONS

This section contains the specifications for servicing the engine.

Charge Air Cooler

The torque values for the charge air cooler are listed in Table 6-1.

Description	Torque N·m (lb·ft) *
Charge Air Cooler Mounting Bolts (to radiator strut)	25 (18)
Charge Air Inlet Hose Clamps	10 (7)
Charge Air Inlet Pipe Mounting Bolts	60 (44)
Charge Air Manifold Mounting Bolts	33 (24)
Fuel Line Banjo Bolt	50 (37)
Manual Priming Pump Banjo Bolt	50 (37)
Radiator Strut Mounting Bolts (to engine)	50 (37)
Turbo Outlet Hose Clamps	10 (7)
Turbo Outlet Pipe Mounting Bolts (to bracket)	50 (37)

* = unless otherwise noted

Table 6-1 Torque Values for Charge Air Cooler

Air Intake Manifold

The torque values for the air intake manifold are listed in Table 6-2.

Description	Torque N·m (lb·ft)
Grid Heater Cover Plate on Air Intake Elbow	25 (18)
Grid Heater to Air Intake Elbow	25 (18)
Air Intake Elbow to Mixer Housing Nuts	25 (18)
Support Bracket to Air Intake Manifold Bolt	60 (44)
Support Bracket to Alternator Bracket	60 (44)
Intake Throttle Valve & Adaptor to Air Intake Elbow	25 (18)
Gas Mixer Housing to Air Intake Manifold	25 (18)
EGR Gas Outlet Pipe to Mixer Housing	35 (26)
Mixer Housing Studs to Air Intake Manifold	25 (18)
Nuts - Air Intake Elbow to Mixer Housing Studs	25 (18)
Air Intake Manifold Bolts to Cylinder Head	33 (24)
Bolts to Air Intake Temperature/Pressure Sensor to Mixer Housing	10 (7)
Bolts to Crankcase Breather Pipe Mounting Bracket	25 (18)
Screws - Electrostatic Oil Separator to Air Intake Manifold	10 (7)
Rear Trim Cover Bolts	12 (9)
Oil Pre-Separator to Cylinder Block	25 (18)
Oil Separator Drain Line Adaptor to Cylinder Block	25 (18)
Banjo Bolt - Oil Separator Drain Line to Cylinder Block	35 (26)
Banjo Bolt - Oil Separator Drain Line to Bottom of Air Intake Manifold	35 (26)

Table 6-2 Torque Values for Air Intake Manifold

Turbocharger

The torque values for the turbocharger are listed in Table 6-3.

Description	Torque N·m (lb·ft)
Exhaust Brake Valve Housing to Turbocharger	50 (37)
Heat Shield Mounting Bolts	25 (18)
Turbocharger to Exhaust Manifold	50 (37)
Turbocharger Oil Return Line Mounting Bolts	25 (18)
Turbocharger Oil Supply Line Banjo Bolts	35 (26)
Turbocharger Oil Supply Line Mounting Bolts	25 (18)
Turbocharger Oil Return Line Fitting	50 (37)
Turbocharger Oil Return Line Banjo Bolt	120 (89)
Studs (Exhaust Manifold to Turbocharger)	50 (37)

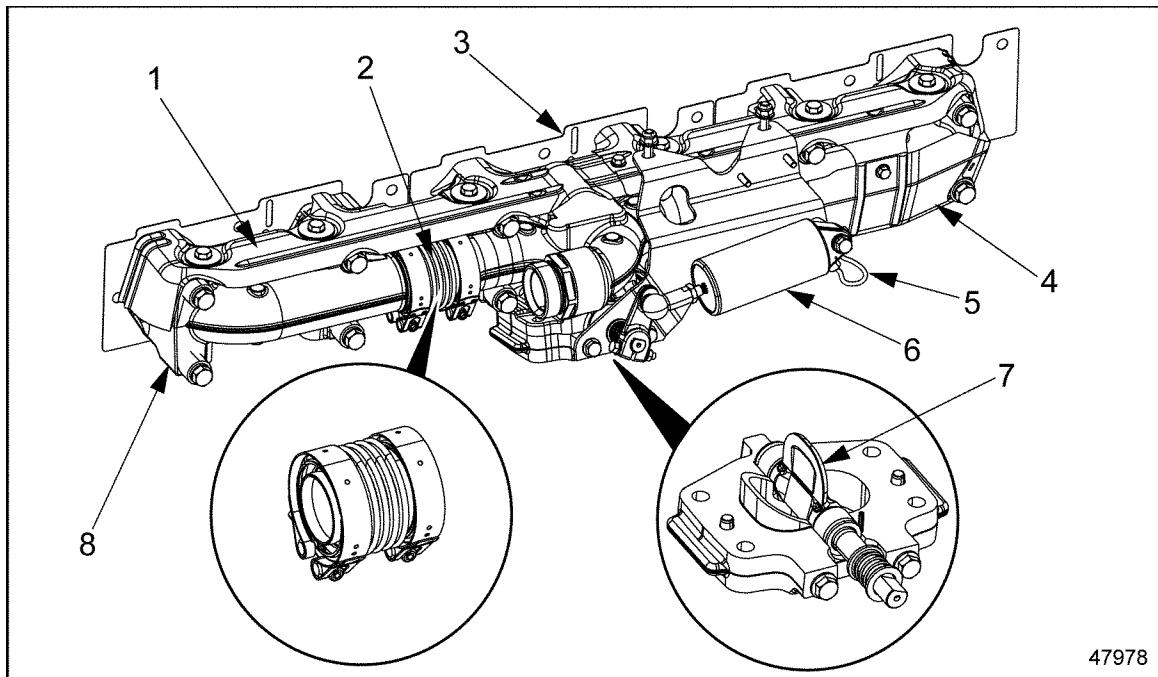
Table 6-3 Turbocharger Torque Values

7 EXHAUST SYSTEM

Section	Page
7.1 EXHAUST MANIFOLD ASSEMBLY	7-3
7.2 BRAKE GATE	7-11
7.3 ELECTRONIC PROPORTIONAL VALVE	7-26
7.A ADDITIONAL INFORMATION	7-29

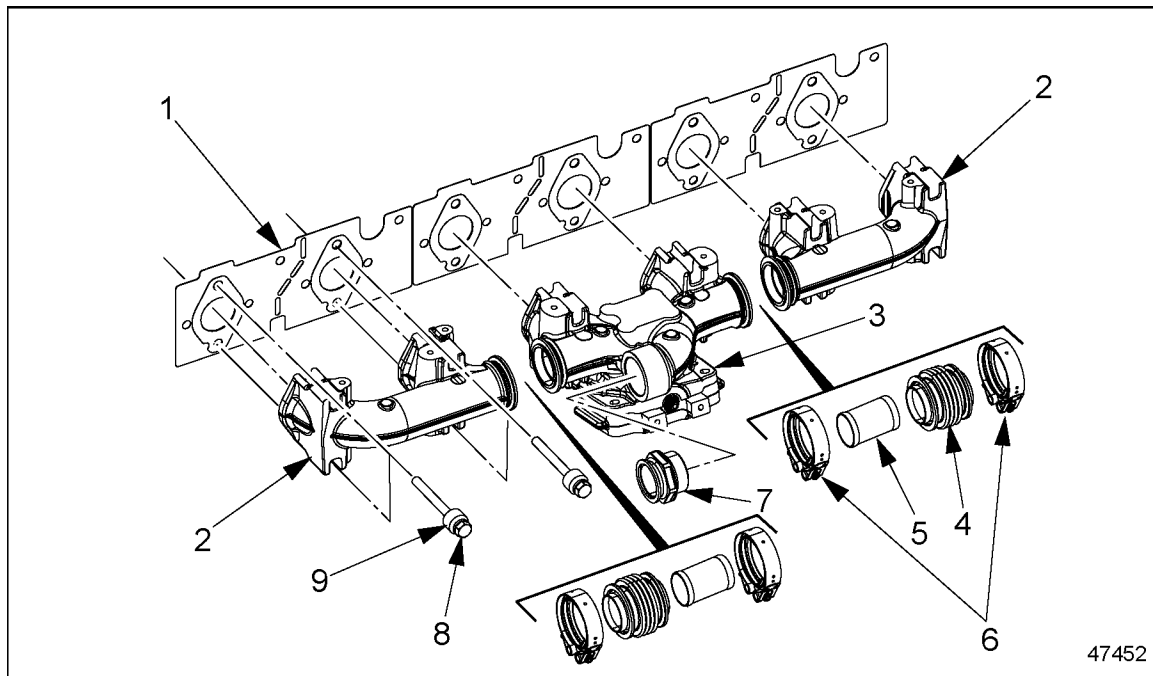
7.1 EXHAUST MANIFOLD ASSEMBLY

The exhaust manifold is a three-piece manifold. The manifold assembly is assembled apart from the cylinder heads, then the entire assembly is installed to the heads. For exhaust manifold components and location see Figure 7-1 and see Figure 7-2.



- | | |
|--------------------------------------|-----------------------------------|
| 1. Upper Heat Shield | 5. Air Supply Line |
| 2. Exhaust Manifold Bellow Connector | 6. Engine Brake Actuator Cylinder |
| 3. Exhaust Manifold Gaskets (qty 3) | 7. Engine Brake Flap Plate |
| 4. Lower Heat Shield | 8. Exhaust Manifold Assembly |

Figure 7-1 Exhaust Manifold Assembly and Components (View 1)



- | | |
|-------------------------------------|--------------------|
| 1. Exhaust Manifold Gaskets (qty 3) | 6. V-Band Clamp |
| 2. Exhaust Manifold End Piece | 7. Adaptor |
| 3. Exhaust Manifold Center Piece | 8. Bolt (qty 12) |
| 4. Bellows | 9. Spacer (qty 12) |
| 5. Sleeve | |

Figure 7-2 Exhaust Manifold Assembly and Components (View 2)

7.1.1 Removal of Exhaust Manifold

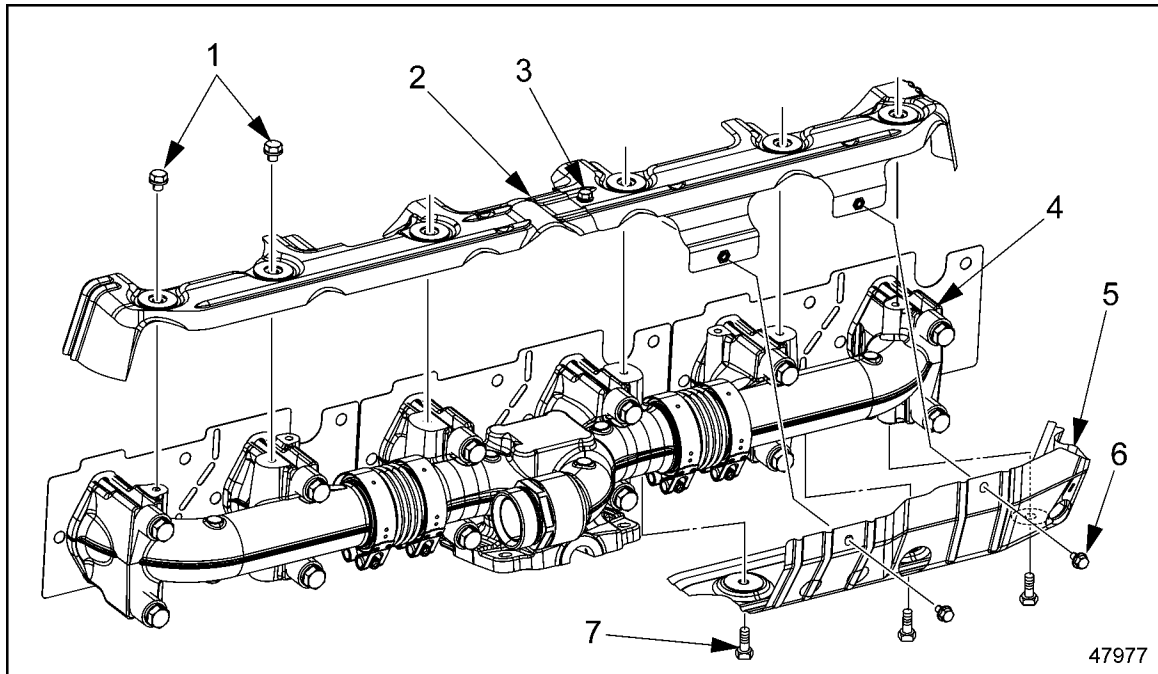
Removal steps are as follows:

NOTE:

The EGR cooler and cooler bracket remain installed on the engine when the exhaust manifold assembly is removed.

1. Remove the turbocharger. Refer to section 6.7.2.
2. Remove the EGR gas inlet pipe. Refer to section 8.1.1.
3. Remove the three bolts attaching the lower heat shield to the bottom of the exhaust manifold. See Figure 7-3.
4. Remove the two bolts attaching the lower heat shield to the upper heat shield. Remove the lower heat shield.

5. Remove the two side bolts attaching the upper and lower heat shields together and remove the lower heat shield. See Figure 7-3.



- | | |
|--|-----------------------------------|
| 1. Bolts (Upper Heat Shield) | 5. Lower Heat Shield |
| 2. Upper Heat Shield | 6. Bolts (Lower Heat Shield-qty2) |
| 3. Bolt (Attaching Two Upper Heat Shields) | 7. Bolts (Lower Heat Shield-qty3) |
| 4. Exhaust Manifold | |

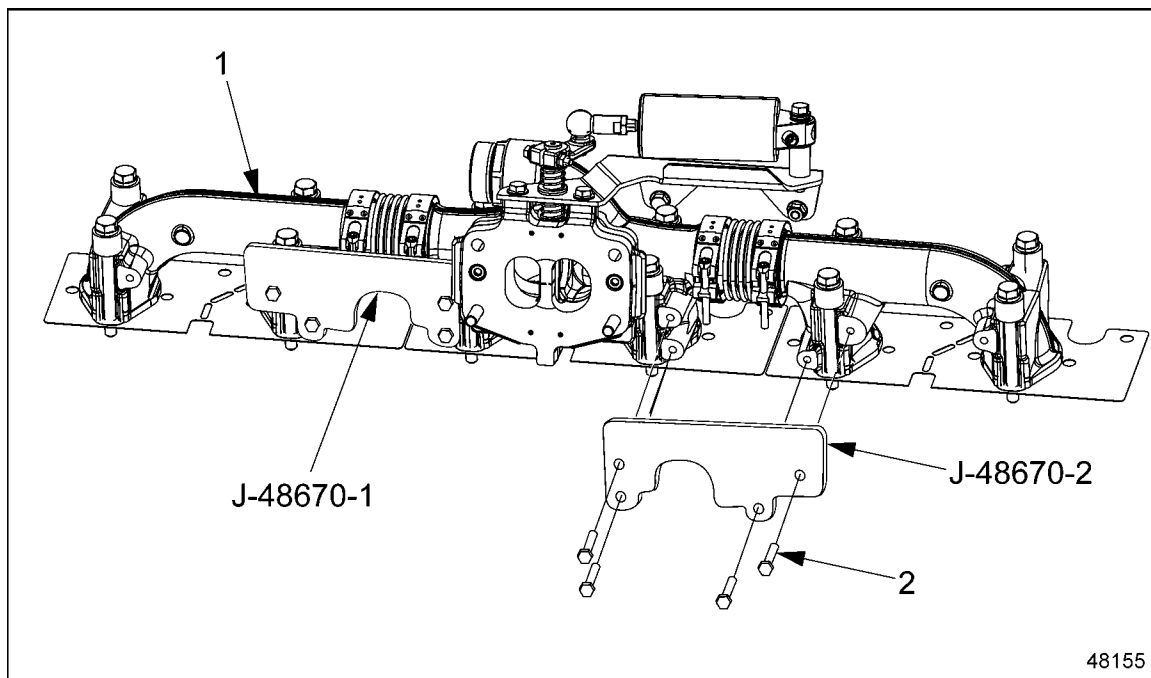
Figure 7-3 Exhaust Manifold Heat Shields

NOTE:

The upper heat shield remains in place at this time.

6. Disconnect the air line at the exhaust brake actuator cylinder. See Figure 7-1.

7. Position and secure two exhaust manifold alignment plates (J-48670-1 and J-48670-2) to the lower side of the exhaust manifold. See Figure 7-4.

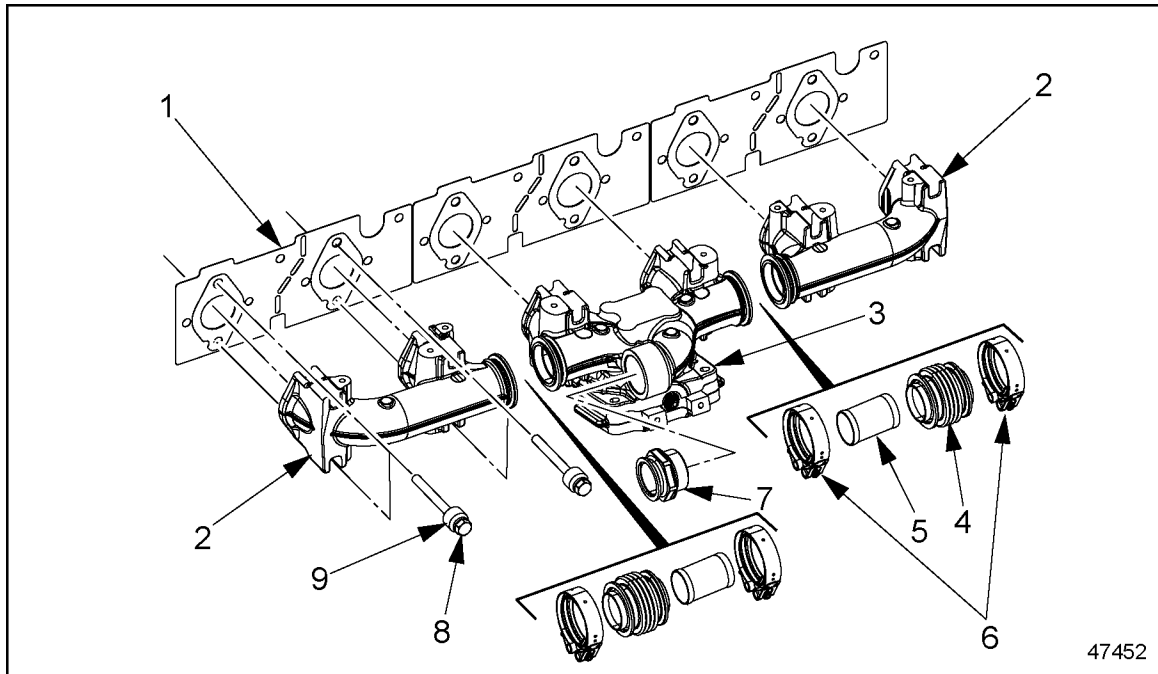


1. Exhaust Manifold Assembly

Figure 7-4 **Installation of J-48670-1 and J-48670-2**

8. Loosen two bolts securing the exhaust manifold center to the EGR cooler bracket.

9. Remove the twelve bolts and spacers securing the three piece exhaust manifold assembly to the cylinder heads. See Figure 7-5.



- | | |
|--|---------------------|
| 1. Exhaust Manifold Gaskets (qty 3) | 6. V-Band Clamps |
| 2. Exhaust Manifold End Pieces | 7. Adaptor |
| 3. Exhaust Manifold Center Piece with Engine Brake, Bottom Plate, Brake Components | 8. Bolts (qty 12) |
| 4. Bellows | 9. Spacers (qty 12) |
| 5. Sleeve | |

Figure 7-5 Exhaust Manifold Components

10. Remove the exhaust manifold assembly as a unit from the engine and place it on a workbench.
11. Remove the six mounting bolts from the upper heat shield. Remove the upper heat shield.
12. Remove the bolts securing J-48670-1 and J-48670-2 to the engine.
13. Remove the V-band clamps securing the two end exhaust manifold sections to the center exhaust manifold section. Remove the two end sections.
14. Remove the sleeves from the exhaust manifold. See Figure 7-5.
15. Visually inspect the sleeves and bellow connectors for damage. Replace components as necessary.

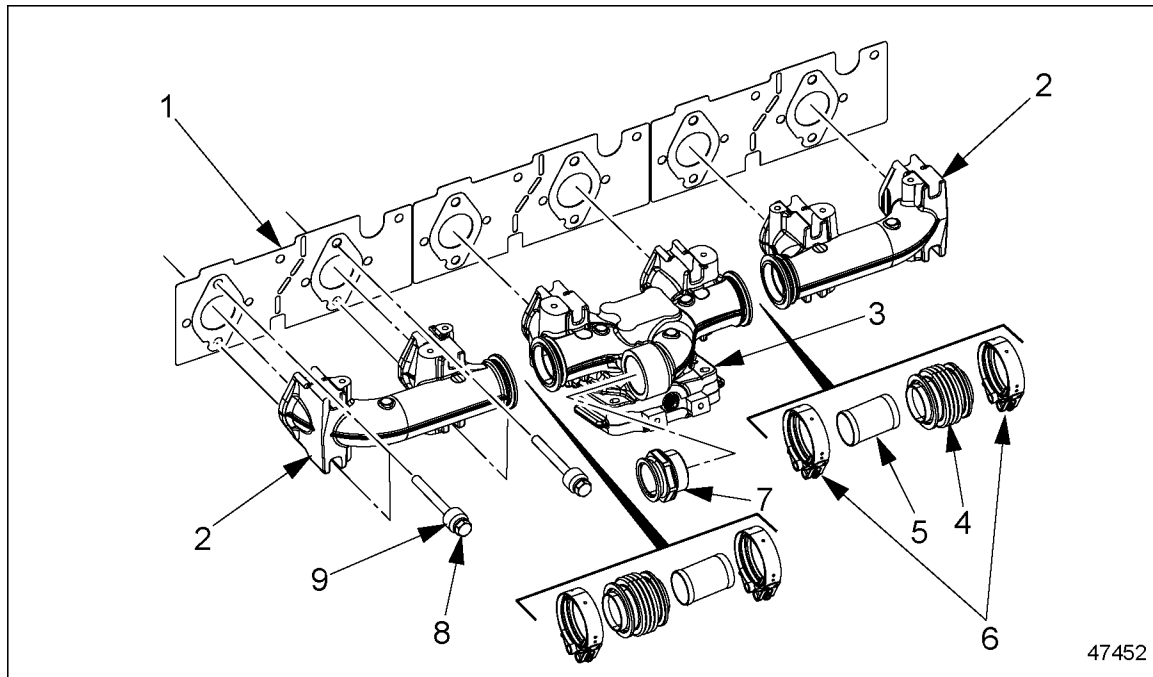
7.1.2 Installation of Exhaust Manifold Assembly

Installation steps are as follows:

NOTICE:

To ensure proper installation of the exhaust manifold assembly and to avoid exhaust gas leaks during engine operation, new exhaust manifold gaskets must be installed.

1. Install the exhaust manifold gaskets to cylinder heads and secure using the lower exhaust manifold bolts. See Figure 7-6.



- | | |
|---|---------------------|
| 1. Exhaust Manifold Gaskets (qty 3) | 6. V-Band Clamps |
| 2. Exhaust Manifold End Pieces (qty 2) | 7. Adaptor |
| 3. Exhaust Manifold Center Piece (engine brake installed) | 8. Bolts (qty 12) |
| 4. Bellows | 9. Spacers (qty 12) |
| 5. Sleeves | |

Figure 7-6 Exhaust Manifold Assembly

NOTE:

Ensure that only one quarter of the bolt threads are threaded inside the cylinder heads. During installation, the exhaust manifold bolts will act as guide studs to support the exhaust manifold assembly.

2. Install the EGR cooler support bracket. Torque bolts to 50 N·m (37 lb·ft).

3. Install a sleeve into each exhaust manifold end piece.

NOTE:

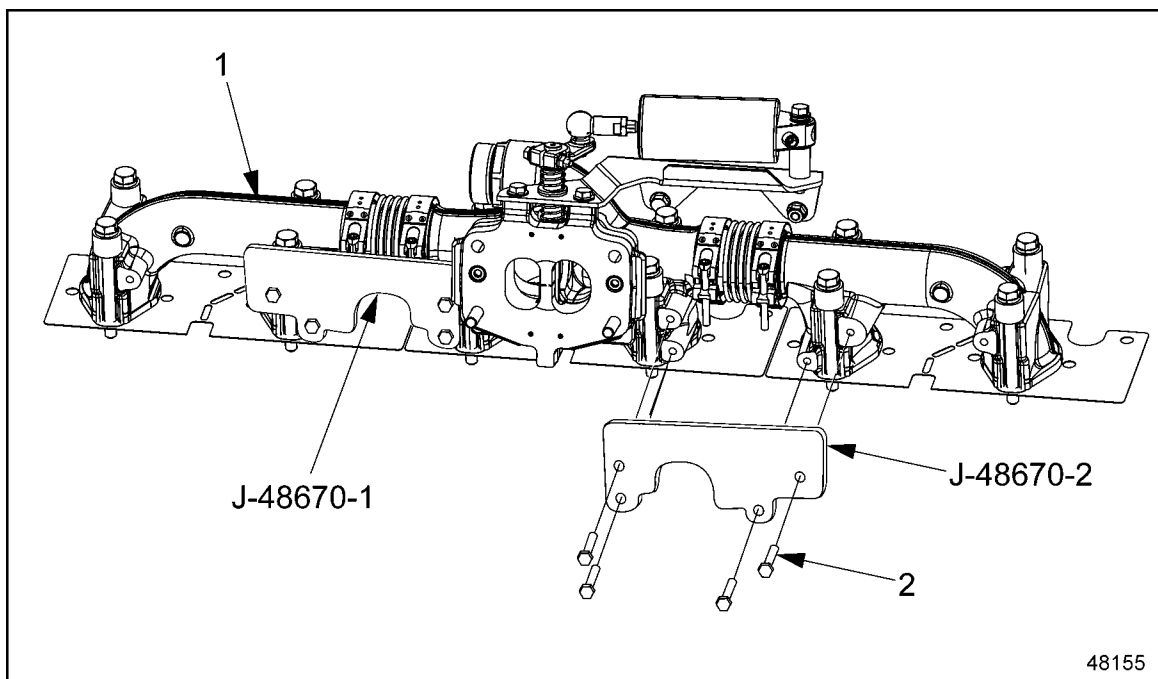
The sleeve should be aligned linear with the exhaust manifold end pieces. If necessary, tap the sleeve with a rubber mallet to properly position the sleeve.

4. Position the exhaust manifold end pieces and center piece machined face down on a flat work surface.
5. Install a bellow connector to each end piece.
6. Install two V-clamps to each bellow and hand-tighten.

NOTE:

Do not torque the V-clamps and ensure that the clamps are positioned head-end up and 90° to the workbench.

7. Install the exhaust manifold end pieces to the exhaust manifold center piece. Torque the V-clamp bolts to 8 N·m (6 lb·ft).
8. Install the alignment plates (J-48670-1 and J-48670-2) to exhaust manifold and secure with bolts. See Figure 7-7. Torque bolts to 20 N·m (15 lb·ft).



1. Exhaust Manifold Assembly

2. Bolts

Figure 7-7 Exhaust Manifold Alignment Plates

NOTICE:

To avoid exhaust gas leaks during engine operation, ensure that the exhaust manifold end pieces are parallel with the exhaust manifold center piece.

9. Using a suitable straight edge, place the straight edge along the length of the top machined surface of the exhaust manifold. If not aligned properly, adjust the sections as necessary.

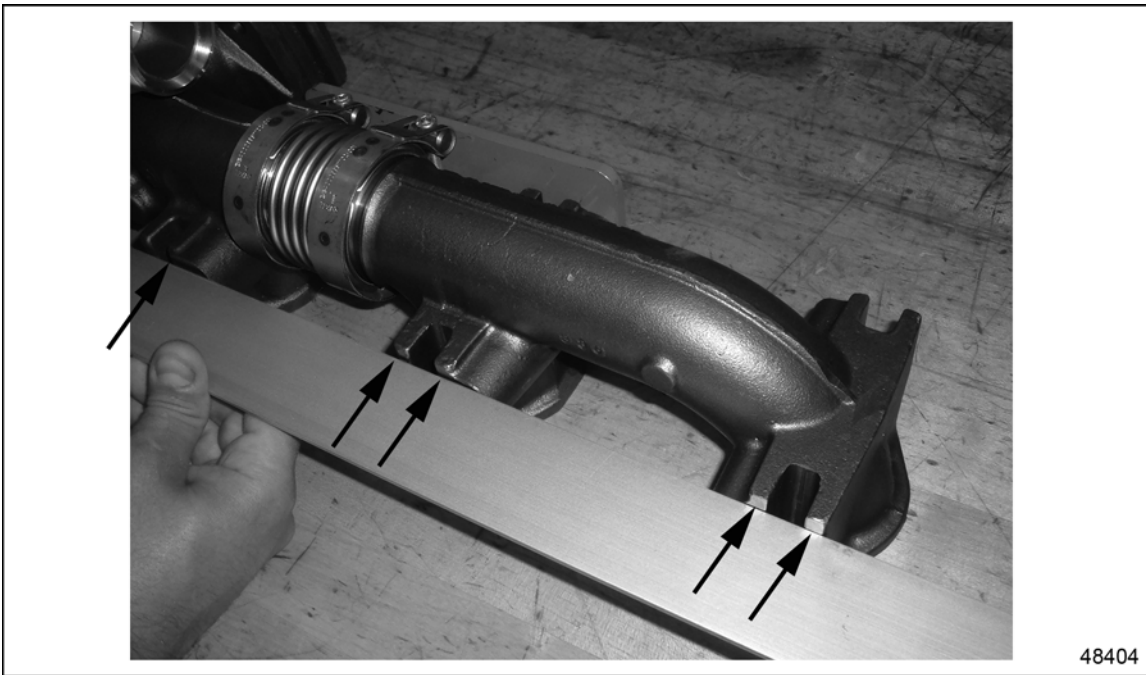


Figure 7-8 Exhaust Manifold Alignment Check

10. Install the upper heat shields to the exhaust manifold assembly and secure with six M8 x 12 mm bolts. Torque bolts to 25 N·m (18 lb·ft).
11. Install the exhaust manifold assembly to the cylinder heads and secure with bolts. Using a crisscross sequence, torque the 12 mounting bolts to 50 N·m (37 lb·ft) plus an additional 90°.
12. Remove the alignment plates J-48670.
13. Install the lower heat shields with bolts. Torque bolts to 25 N·m (18 lb·ft).

7.2 BRAKE GATE

Engine braking is controlled by a pneumatically-operated exhaust brake gate located in the center exhaust manifold and by a hydraulic constant throttle valve system.

7.2.1 Removal of Brake Gate Actuator Cylinder and Bracket

Removal steps are as follows:

1. Disconnect the batteries.



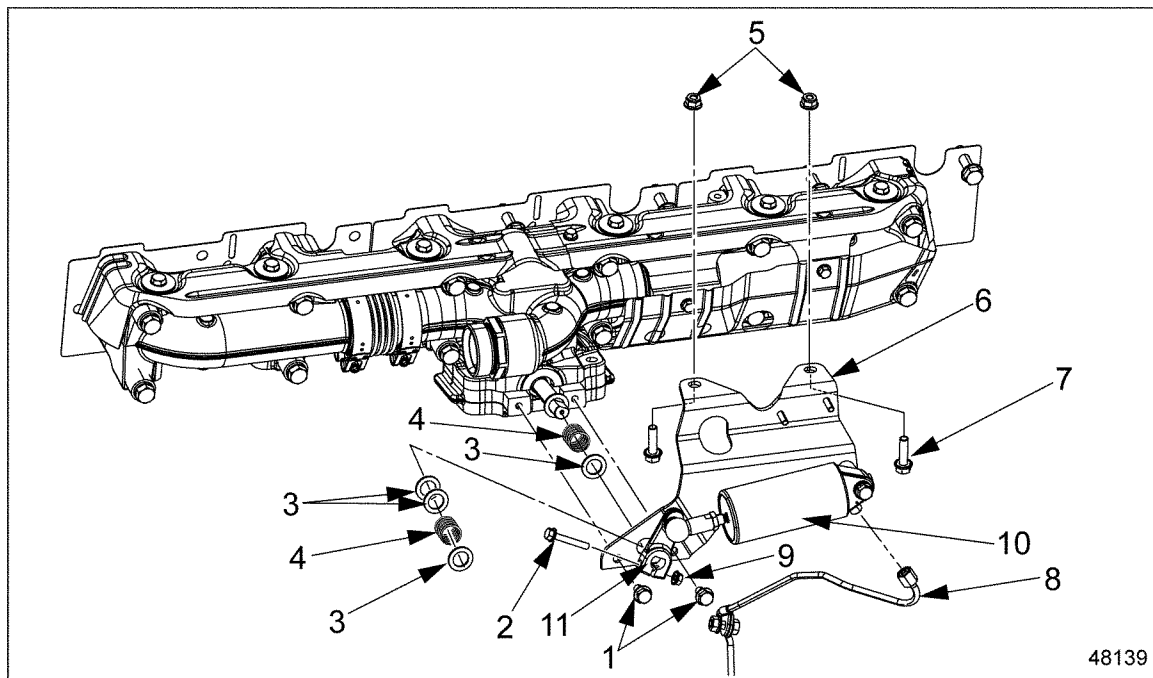
WARNING:

PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

2. Chock the rear tires and tilt the hood.

3. To gain access to the exhaust brake gate, remove the air cleaner.



- | | | |
|------------|---------------------------|----------------------------------|
| 1. Bolts | 5. Bracket Mounting Nuts | 9. Nut |
| 2. Bolt | 6. Actuator Bracket | 10. Brake Gate Actuator Cylinder |
| 3. Washers | 7. Bracket Mounting Bolts | 11. Lever |
| 4. Spring | 8. Actuator Air Line | |

Figure 7-9 Brake Gate Actuator Cylinder and Bracket

4. Remove the brake gate actuator cylinder and bracket as an assembly as follows:
- [a] Disconnect the air supply line to the brake gate. See Figure 7-9.
 - [b] Remove the retaining clip connecting the ball socket to the actuator cylinder. Pry the ball socket from the ball fitting.
 - [c] Disconnect the lever at the exhaust brake gate by removing the bolt and nut. See Figure 7-9.

- [d] Remove three washers and one spring from the assembly. See Figure 7-10.

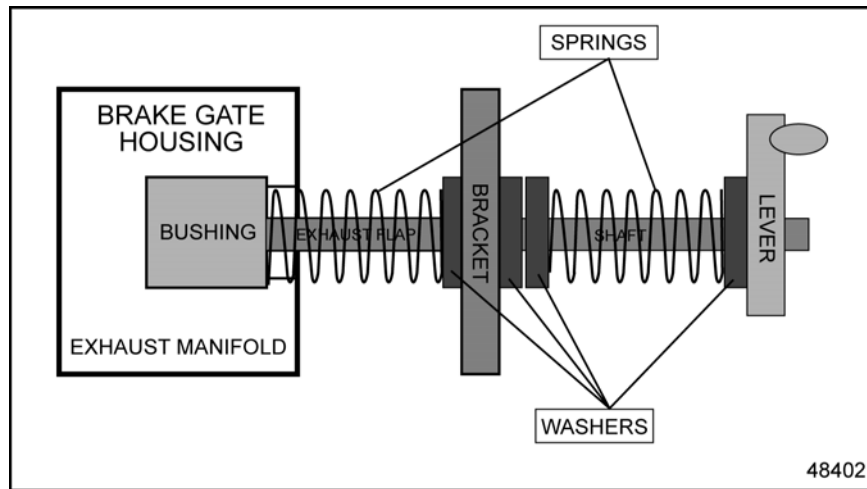


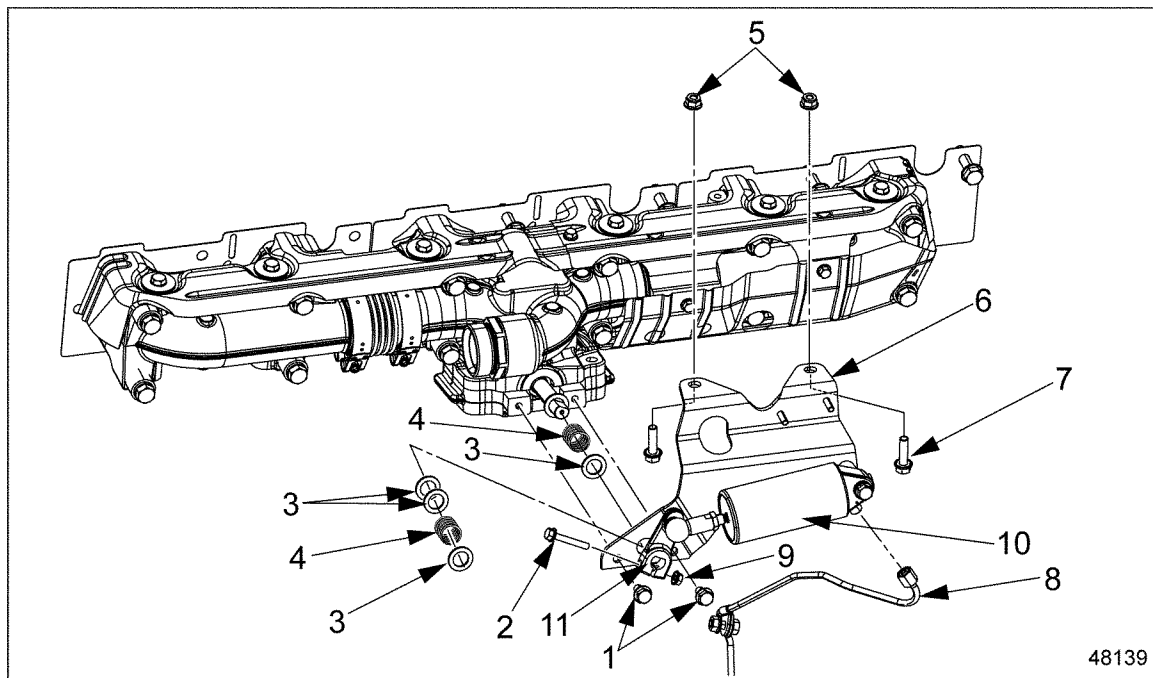
Figure 7-10 Brake Gate Lever Assembly

- [e] Remove the two bolts securing the bracket and actuator cylinder to the brake gate housing. See Figure 7-9.
- [f] Remove the two bolts and nuts securing the bracket at the top and remove the assembly. Remove the one remaining spring and washer from the shaft. See Figure 7-9.

7.2.2 Installation of Brake Gate Actuator Cylinder and Bracket

Installation steps are as follows:

1. Install a spring and washer onto the brake gate shaft. See Figure 7-11.



- | | | |
|------------|---------------------------|----------------------------------|
| 1. Bolts | 5. Bracket Mounting Nuts | 9. Nut |
| 2. Bolt | 6. Actuator Bracket | 10. Brake Gate Actuator Cylinder |
| 3. Washers | 7. Bracket Mounting Bolts | 11. Lever |
| 4. Spring | 8. Actuator Air Line | |

Figure 7-11 Brake Gate Actuator Cylinder and Bracket

2. Install the bracket assembly onto the shaft and secure the bracket with two bolts. Torque the bolts to 25 N·m (18 lb·ft).
3. Install the actuator bracket to the EGR cooler and secure using two bolts and bracket mounting nuts. Torque the bolts to 25 N·m (18 lb·ft).

4. Install two washers, a spring, a washer, and the lever onto the brake gate shaft. Secure the lever with a bolt and nut. Torque the bolt to 11N·m (8 lb·ft) and an additional 90 degrees. See Figure 7-12 for an assembled lever assembly.

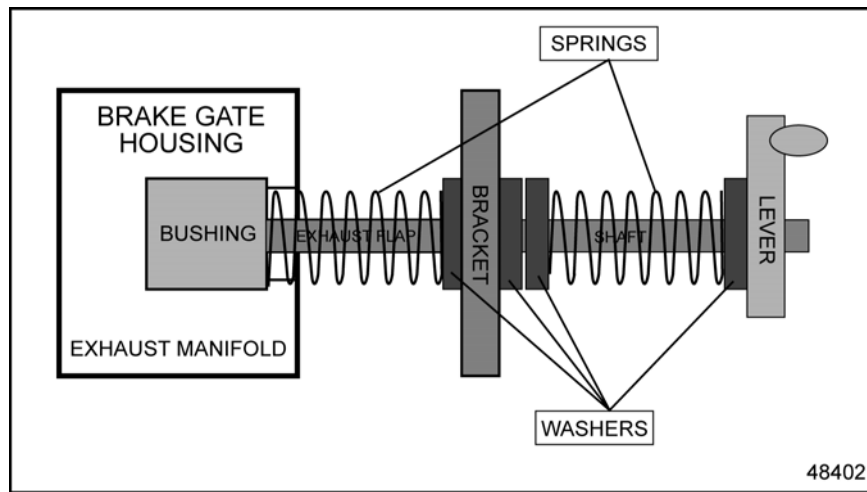


Figure 7-12 Brake Gate Lever Assembly

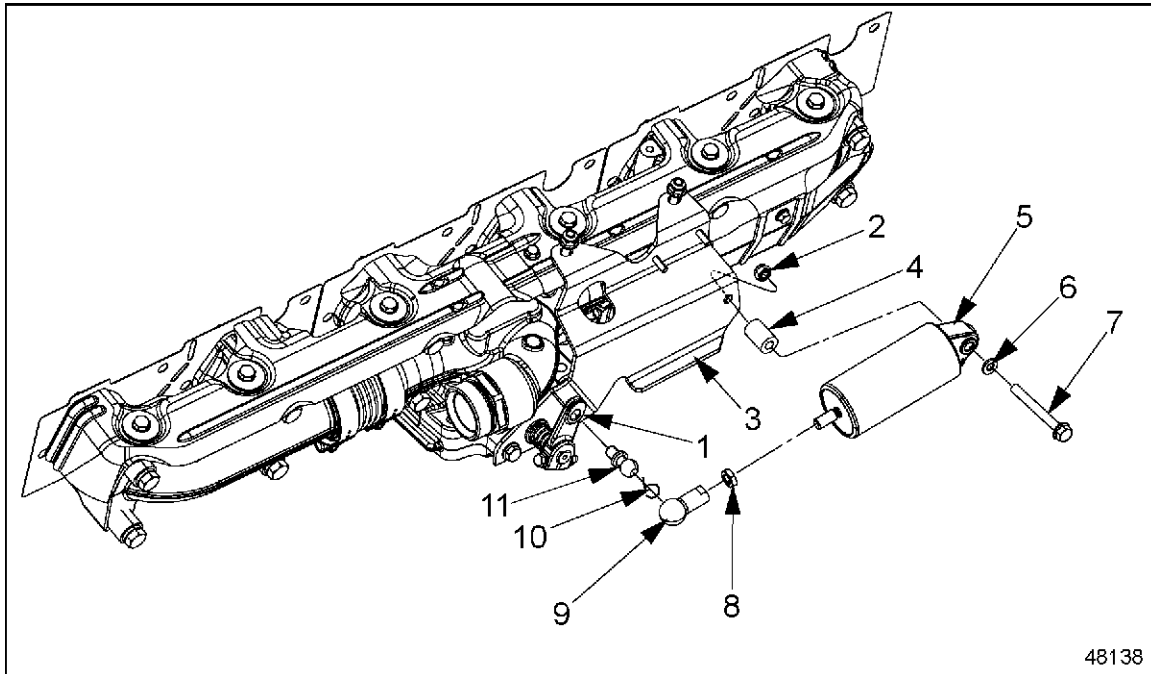
5. Install the actuator cylinder ball socket to the lever and secure using a retaining clip.
6. Connect the actuator air line to the actuator cylinder. See Figure 7-11.
7. Install the air cleaner.
8. Connect the battery cables, lower the hood, and remove the chocks from the rear wheels.

7.2.3 Removal of Brake Gate Actuator Cylinder

Removal steps are as follows:

1. Disconnect the air supply line to the brake gate actuator.

2. Remove the retaining clip securing the ball socket to the ball fitting. Pry the ball socket from the ball fitting. See Figure 7-13.



- | | | |
|------------------------------|---------------------------------|--------------------|
| 1. Lever | 5. Brake Gate Actuator Cylinder | 9. Ball Socket |
| 2. Nut | 6. Washer | 10. Retaining clip |
| 3. Actuator Mounting Bracket | 7. Bolt | 11. Ball Fitting |
| 4. Spacer | 8. Nut | |

Figure 7-13 Brake Gate Actuator Cylinder and Related Components

3. Remove the bolt, washer, spacer, and nut securing the brake gate actuator cylinder to the mounting bracket and remove the actuator. See Figure 7-13.

7.2.4 Installation of Brake Gate Actuator

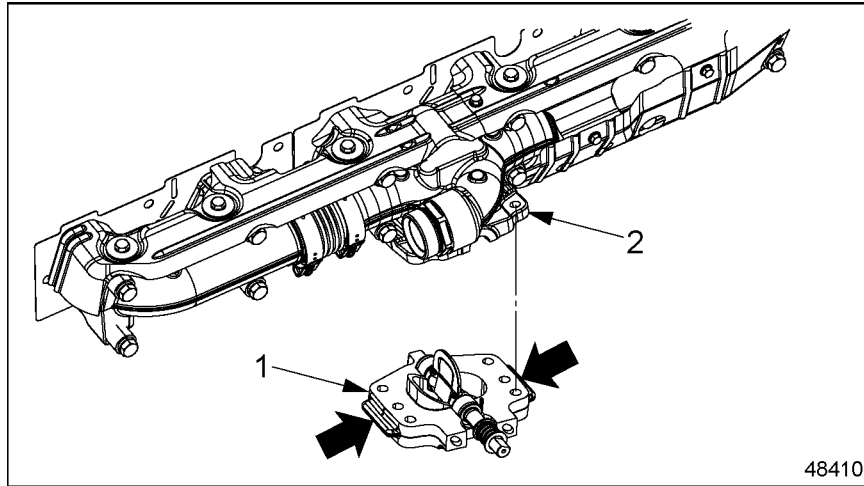
Installation steps are as follows:

1. If removed, connect the actuator lever to the brake gate and secure with bolt and nut. Torque the bolt and nut to 11 N·m (8 lb·ft) and an additional 90 degrees.
2. Attach the brake gate actuator to the mounting bracket with a bolt, washer, spacer and nut. Torque the actuator bolt, and nut on the mounting bracket to 25 N·m (18 lb·ft). See Figure 7-13.
3. Connect the air supply line to the actuator. Tighten the fitting securely.

7.2.5 Removal of Brake Gate

Removal steps are as follows:

1. Remove the brake gate actuator cylinder and bracket. Refer to section 7.2.1.
2. Remove the turbocharger. Refer to section 6.7.2.
3. Remove the brake gate assembly from the center exhaust manifold by using a drift and hammer on the ears of the brake gate cover plate and tap alternating from side to side (see arrows in figure). See Figure 7-14.



1. Brake Gate Assembly

2. Exhaust Manifold Center Section

Figure 7-14 Brake Gate

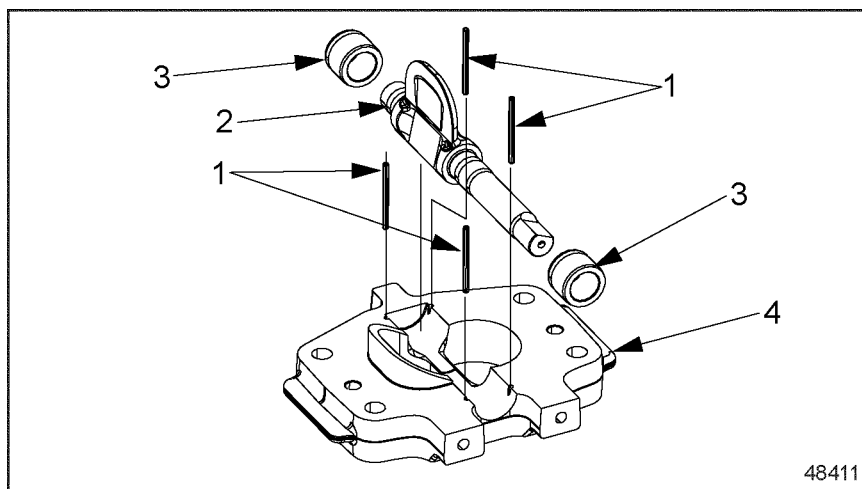
NOTICE:

To avoid roll pin damage, slowly remove the brake gate assembly during disassembly.

4. Remove the brake gate assembly and the roll pins from the plate. See Figure 7-15.

NOTE:

Some brake gates were built with a two roll pin design.



1. Roll Pins

2. Shaft

3. Bearings

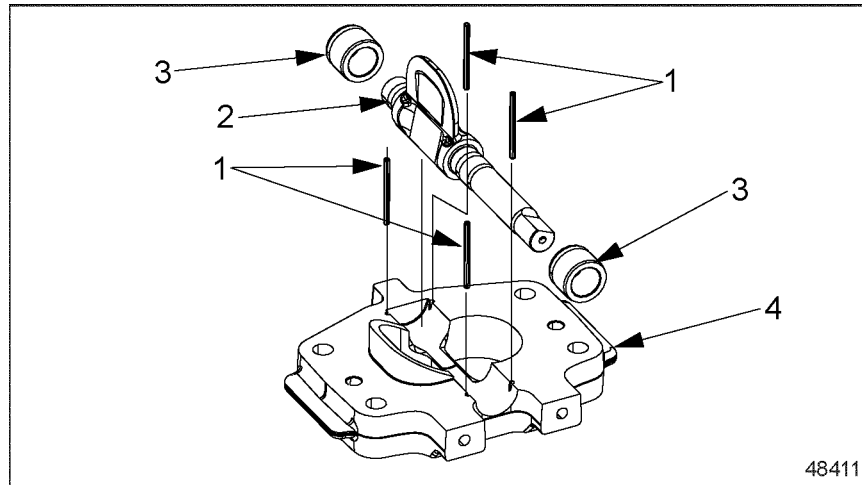
4. Housing Plate

Figure 7-15 **Brake Gate Assembly**

7.2.5.1 Repair of Brake Gate

Repair steps are as follows:

1. Remove the brake gate shaft and two bushings from the brake gate plate. See Figure 7-16.



1. Roll Pins

2. Shaft

3. Bearings

4. Housing Plate

Figure 7-16 Brake Gate Assembly

2. Position the brake gate assembly on top of an open vise with the flat flange (turbocharger side) facing upwards. Using a small diameter (approximately 2.5 mm) pin drift, drive the alignment roll pins from their bores and discard the pins.
3. Clean the brake gate housing and inspect for cracks or gouges on the mounting faces. If damaged, replace the brake gate assembly.
4. Clean the brake shaft and bushing. Visually check components for wear, free rotation, and axial play.
 - [a] If components are damaged, replace components as necessary.
 - [b] If components are not damaged, reuse components and go to step 5.
5. Position the brake gate housing on top of an open vise with the flat flange facing upwards. Using a small diameter (approximately 2.5 mm) pin drift, drive new alignment roll pins into the plate until they are 1.0 mm (0.039 in.) below the face of the plate.
6. Install the bushings on each end of the brake gate shaft. Position shaft and bushings so the grooves in each bushing are aligned with the two small roll pins. See Figure 7-16.
7. Install the brake gate and shaft. Refer to section 7.2.6.

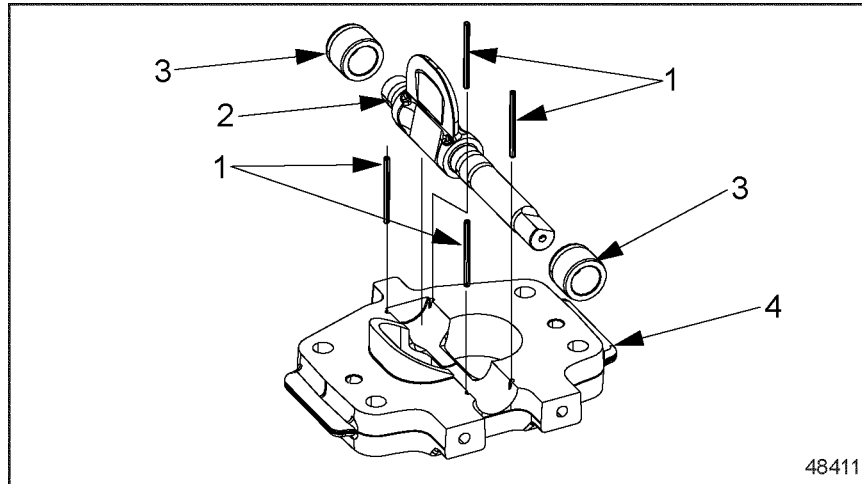
7.2.6 Installation of Brake Gate

Install the brake gate as follows:

1. Clean both sides of the brake gate with a suitable solvent. Also clean the sealing surfaces of the exhaust manifold and turbocharger mounting flanges, using a suitable solvent and Scotch pads.
2. If removed, install two studs into the rear bores of the exhaust manifold center section. Torque the two studs to 50 N·m (37 lb·ft).
3. Install two dowel pins into the exhaust manifold center section. See Figure 7-17.

NOTE:

Some brake gates were built with a two roll pin design.



1. Roll Pins

2. Shaft

3. Bearings

4. Housing Plate

Figure 7-17 Brake Gate Assembly

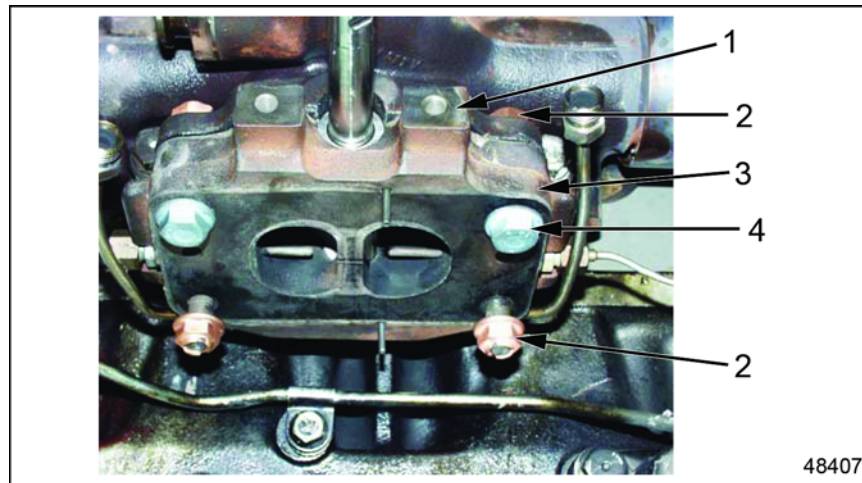
4. Coat the mounting flange area of the center exhaust manifold section with heavy duty anti-seize compound. Take care not to get compound in the area of the bushing bores and roll pin bores.
5. Align the brake gate assembly with the two dowel pins on the exhaust manifold.

NOTICE:

To avoid roll pin damage, ensure the brake gate assembly is properly seated against the center section of the exhaust manifold.

6. Install the brake gate assembly to the exhaust manifold and secure using two nuts onto the rear studs and two bolts and nuts through the front holes. Hand tighten the nuts in a

crosswise pattern to ensure the brake gate assembly is seated properly against the center section of the exhaust manifold. See Figure 7-18.



1. Exhaust Manifold Flange

2. Nut (qty 4)

3. Housing Plate

4. Bolt (qty 2)

Figure 7-18 Brake Gate Assembly

7. Using a soft head hammer, tap the roll pins until they are properly seated in the plate housing. See Figure 7-19.

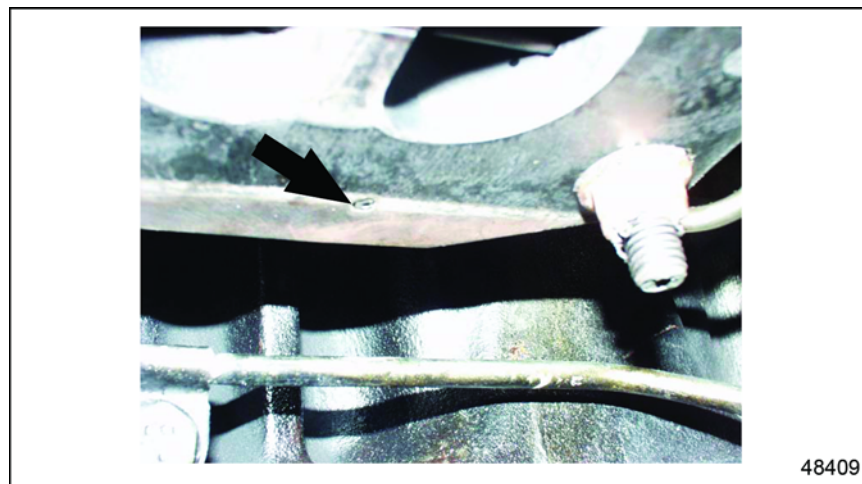
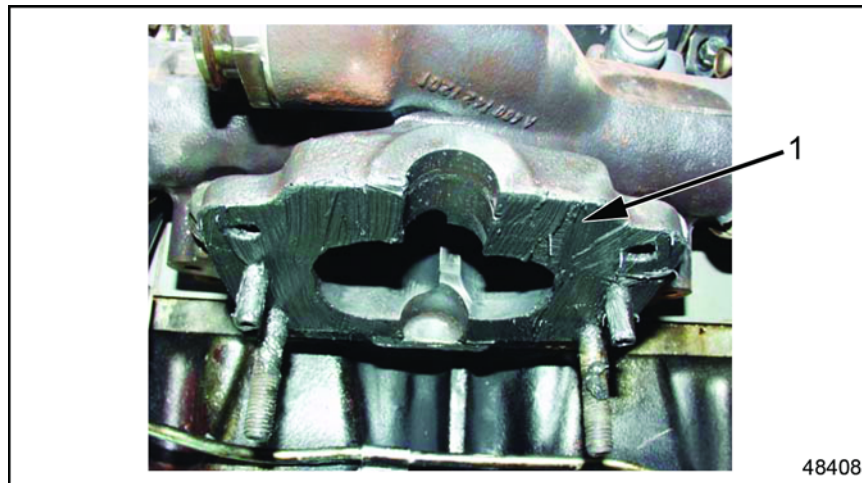


Figure 7-19 Roll Pin

8. Remove the two nuts from the rear studs and the two nuts and bolts from the front holes.

9. Apply a light coating of heavy duty anti-seize compound to the turbocharger housing mounting flange. See Figure 7-20.



1. Exhaust Manifold Mounting Flange

Figure 7-20 **Turbocharger Mounting Flange**

10. Install the turbocharger to the housing plate and secure using two nuts. See Figure 7-21.

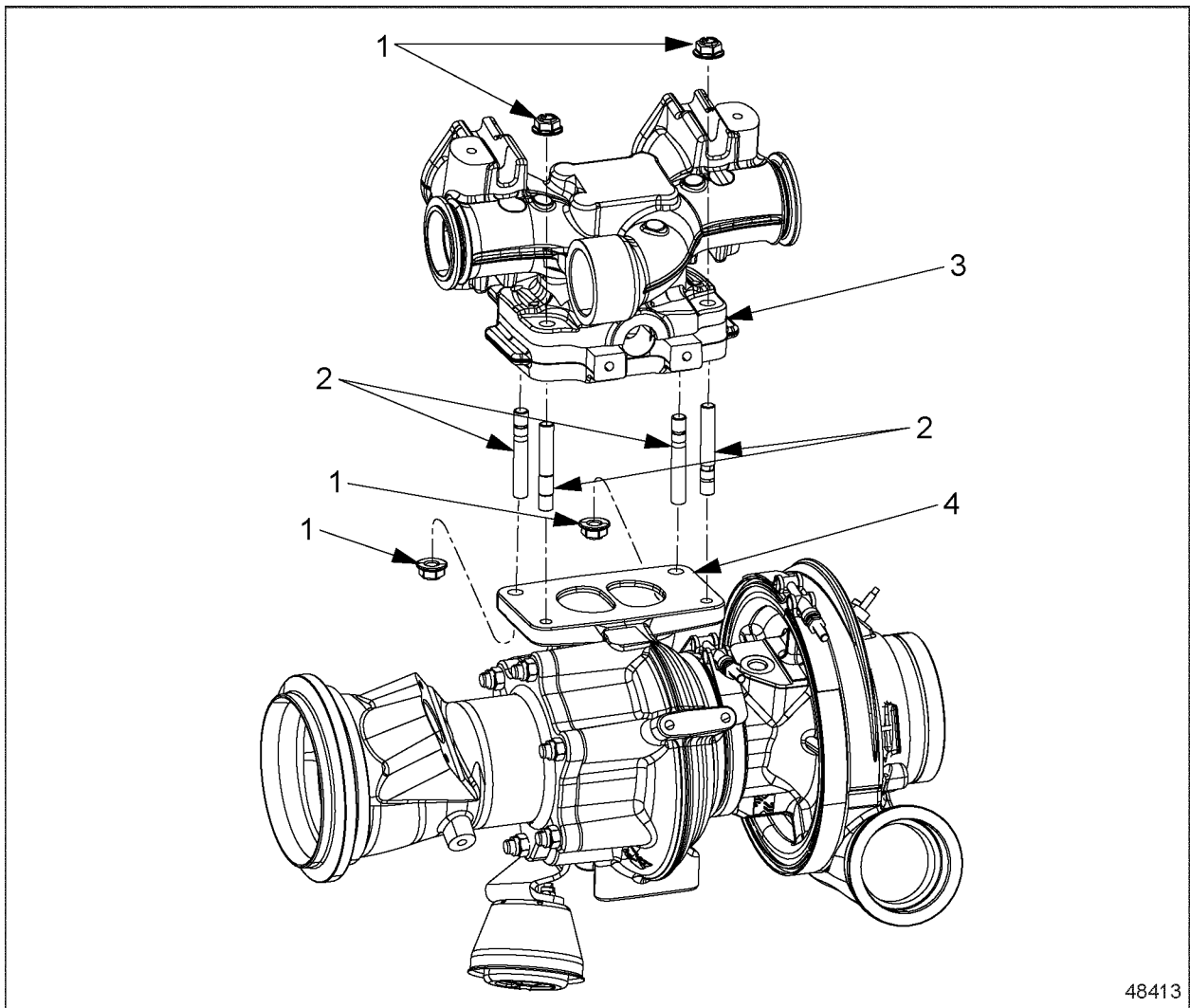
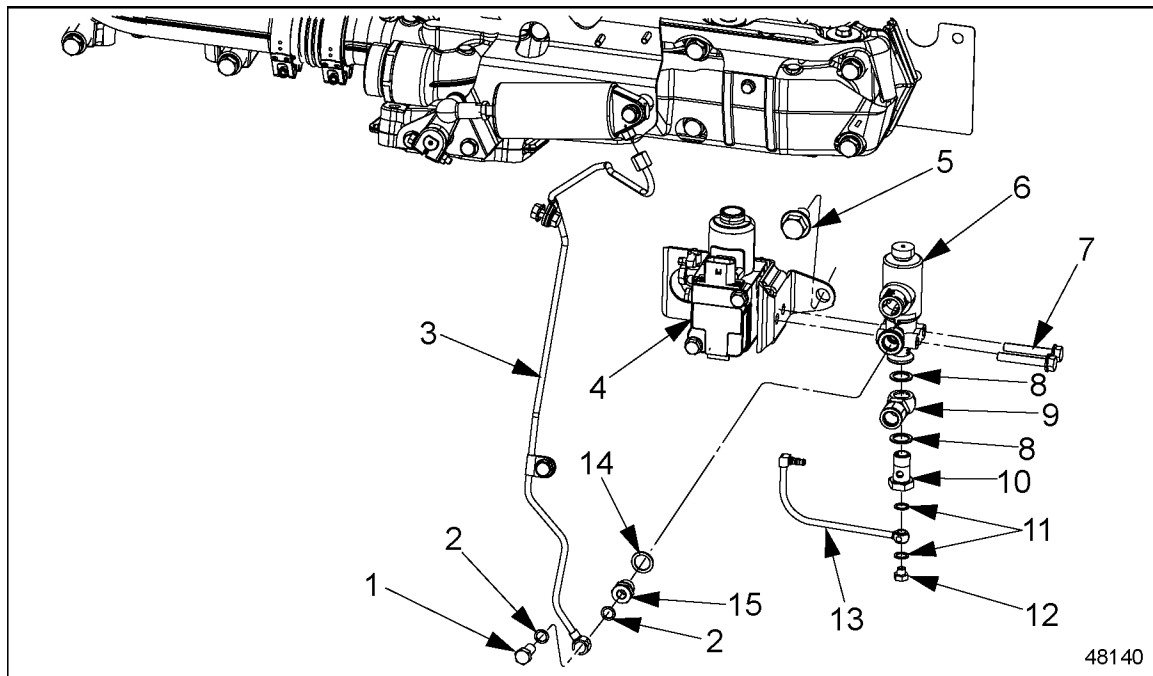


Figure 7-21 Securing the Turbocharger to the Housing Plate (Step one)

11. Install two nuts to the exhaust manifold center housing studs. See Figure 7-21.
12. Hand tighten the nuts using a criss-cross pattern. Torque the nuts to 50 N·m (37 lb·ft).
13. Refer to section 6.7.3 to complete the turbocharger installation.
14. Install the brake gate actuator and bracket. Refer to section 7.2.2.

7.2.7 Removal of Brake Gate Solenoid

Remove the brake gate solenoid as follows:



- | | | |
|----------------------|------------------------|---------------------|
| 1. Banjo Bolt | 6. Brake Gate Solenoid | 11. Washers |
| 2. Washers | 7. Bolts | 12. Banjo Bolt |
| 3. Actuator Air Line | 8. Washers | 13. Air Line |
| 4. EPV | 9. Banjo Fitting | 14. Washer |
| 5. Bolt | 10. Adaptor Fitting | 15. Adaptor Fitting |

Figure 7-22 Brake Gate Solenoid

1. Disconnect the harness connector at the brake gate solenoid.
2. Remove the banjo bolt and washer attaching the actuator air line to the side of the solenoid. Discard the washers. See Figure 7-22.
3. Remove the adaptor fitting and washer from the side of the solenoid. Discard the washer.
4. Remove the banjo bolt and washers from the air line on the bottom of the exhaust brake gate solenoid. Discard the washers. See Figure 7-22.
5. Remove the adaptor fitting, banjo fitting and washers from the bottom of the solenoid. Discard the washers.
6. Remove the two bolts securing the brake gate solenoid to the mounting bracket and remove the solenoid. See Figure 7-22.

7.2.8 Installation of Brake Gate Solenoid

Installation steps are as follows:

1. Secure the brake gate solenoid to the mounting bracket with two bolts. Torque the bolts to 25 N·m (18 lb·ft). See Figure 7-22.
2. Install the adaptor fitting and new washer in the side of the solenoid. Torque the adaptor fitting to 15 N·m (11 lb·ft). See Figure 7-22.
3. Connect the air supply line to the side of the brake gate solenoid with banjo bolt and new washers. Torque the banjo bolt to 15 N·m (11 lb·ft). See Figure 7-22.
4. Attach the air line to the bottom of the exhaust brake gate solenoid with adaptor fitting and new washers. Torque the adaptor fitting to 50N·m (37 lb·ft). See Figure 7-22.
5. Attach the air line to the bottom of the exhaust brake gate solenoid with the banjo bolt and new washers. Torque the banjo bolt to 15 N·m (11 lb·ft). See Figure 7-22.
6. Connect the harness connector at the exhaust brake gate solenoid.

7.3 ELECTRONIC PROPORTIONAL VALVE

The following sections describe the removal and installation of the Electronic Proportional Valve (EPV).

7.3.1 Removal of Electronic Proportional Valve

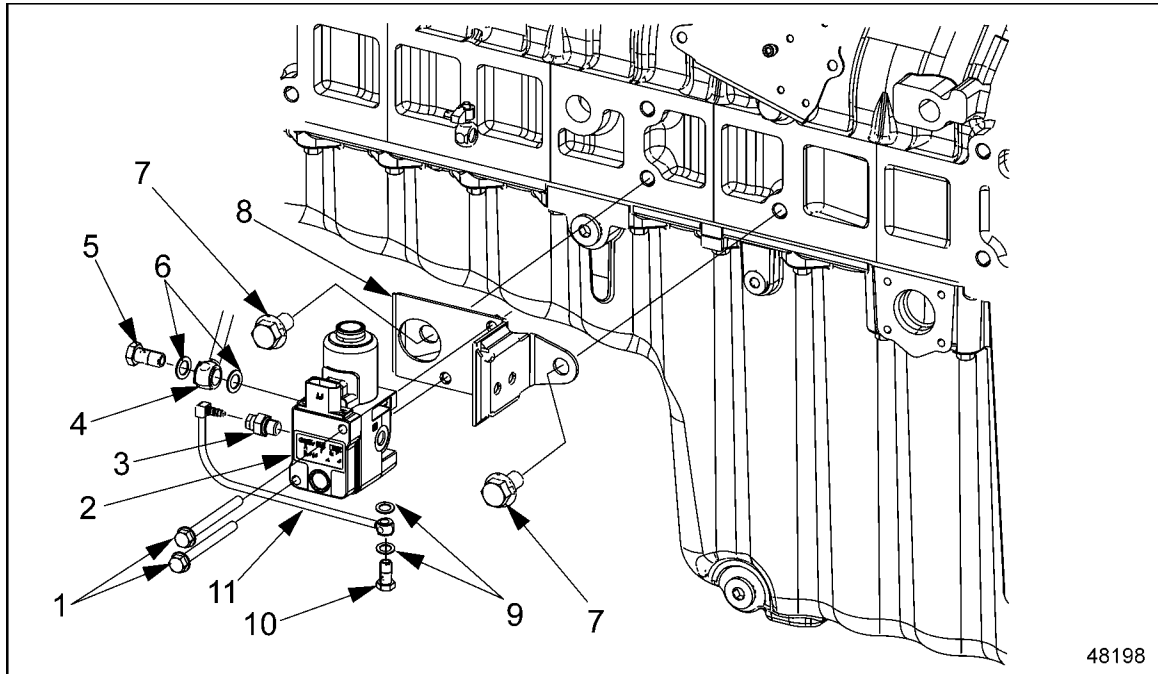
Removal steps are as follows:

1. Disconnect wiring harness from the EPV.

**WARNING:****PERSONAL INJURY**

To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles.

2. Disconnect the compressed air pipe between inlet connection installed at the EPV and brake gate actuator. See Figure 7-23.



- | | |
|--|-------------------------------|
| 1. Bolts | 7. EPV Mounting Bracket Bolts |
| 2. EPV (Electronic Proportional Valve) | 8. EPV Mounting Bracket |
| 3. Connector Fitting | 9. Washers |
| 4. Wastegate Actuator Line | 10. Banjo Bolt |
| 5. Banjo Bolt | 11. Brake Gate Solenoid Line |
| 6. Washers | |

Figure 7-23 Electronic Proportional Valve

3. Remove the brake gate solenoid. Refer to section 7.2.7.
4. Disconnect the inlet and outlet connections at EPV pressure regulating valve.
5. Remove the threaded connector, banjo fitting and washers. Discard washers. See Figure 7-23.
6. Remove the two bolts securing the EPV valve to the mounting bracket. See Figure 7-23.
7. Remove the two bolts that hold the EPV mounting bracket to the block.

7.3.2 Installation of Electronic Proportional Valve

Installation steps are as follows:

1. Install the EPV mounting bracket to the block with two bolts. Torque the bolts to 100 N·m (74 lb·ft). See Figure 7-23.
2. Mount the EPV to the mounting bracket using two bolts. Torque the bolts to 25 N·m (18 lb·ft). See Figure 7-23.
3. Install the threaded connector to the side of the EPV. Torque the threaded connector to 50 N·m (37 lb·ft). See Figure 7-23.

NOTICE:
Avoid friction on compressed air pipe traveling under the EPV or potential damage to engine could result.

4. Install the brake gate solenoid. Refer to section 7.2.8.
5. Install the brake gate solenoid line to the EPV and brake gate actuator solenoid. Torque the small banjo bolt to 15 N·m (11 lb·ft). See Figure 7-23.
6. Connect the wastegate line to the EPV with banjo bolt and new washers. Torque the banjo bolt to 25 N·m (18 lb·ft).
7. Connect the wiring harness connector to the EPV and exhaust brake gate solenoid.

7.A ADDITIONAL INFORMATION

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SPECIFICATIONS

This section contains the specifications for servicing the engine.

Exhaust Manifold

The torque values for the turbocharger and the exhaust manifold are listed in Table 7-1.

Description	Torque N·m (lb·ft)
Turbocharger to Exhaust Manifold Nuts	50 (37)
Exhaust Manifold Mounting Bolts	50 (37) + 90°

Table 7-1 Turbocharger and Exhaust Manifold Torque Values

Exhaust Brake Assembly

The exhaust brake assembly specifications are listed in Table 7-2.

Description	Specifications in mm (in.)
End Play (axial play) of Exhaust Brake Shaft	0.4-0.7 (0.016-0.028)
Radial Play of Exhaust Brake Shaft	0.200-0.263 (0.008-0.010)
Distance between the two Projecting Bushings,	84.2 (3.31)
Projection of the Rear Bushing into the Brake Valve Housing	2.6 (0.10)

Table 7-2 Exhaust Brake Assembly Specifications

Protectant Material	Approved Brand
Anti-seize	International Product Corporation Rubber Lubricant Emulsion (P-80)

Table 7-3 Approved Sealants

Torque Values

The torque values for components in this chapter are listed in Table 7-4.

Description	Torque N·m (lb·ft) unless otherwise noted
Bolts — Exhaust Manifold Alignment Plate	20 (15)
Clamps — Exhaust Manifold Connector	8 (6)
Exhaust Manifold Heat Shield Bolts	25 (18)
Exhaust Manifold Bolts	50 (37) + 90°
Brake Gate Lever Bolt	11 (8)
Actuator Bracket Bolts to Brake Gate Housing	20 (15)
Brake Gate Actuator Bolt to Mounting Bracket	20 (15)
Brake Gate Solenoid to Mounting Bracket Bolts	25 (18)
Adaptor Fitting — to Side of Brake Gate Solenoid	15 (11)
Air Line Banjo Bolt to Side of Brake Gate Solenoid	15 (11)
Small Banjo Bolt to Threaded Connection on Bottom of Brake Gate Solenoid	15 (11)
Adaptor Fitting on Bottom of Brake Gate Solenoid	50 (37)
EPV to Mounting Bracket Bolts	25 (18)
EPV Bracket to Cylinder Block Bolts	100 (74)

Table 7-4 Torque Values

Special Tools

The special tools used within this chapter are listed in Table 7-5.

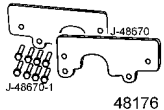
Tool	Description	Usage	Part Number
 J-48670 J-48670-1 48176	Exhaust Manifold Alignment Plates	Used to assemble the 3-piece exhaust manifold prior to installation	J-48670

Table 7-5 Special Tools

8 EXHAUST GAS RECIRCULATION COMPONENTS

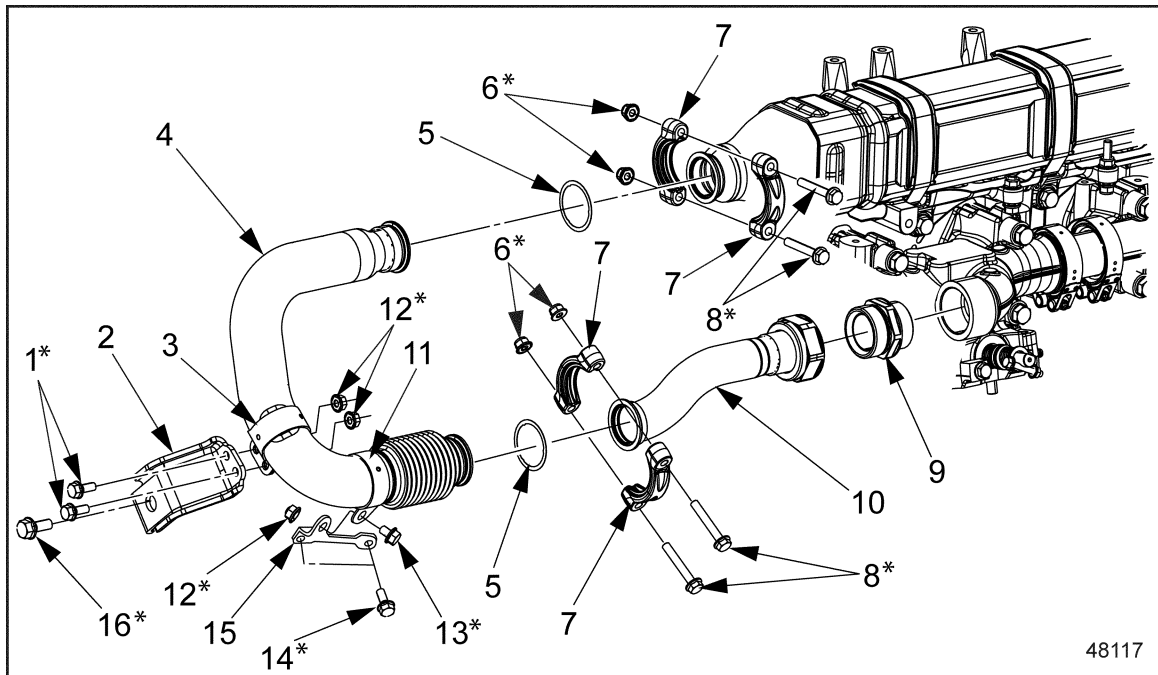
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8.1 EGR GAS INLET PIPE

The following sections cover the removal and installation of the Exhaust Gas Recirculation (EGR) gas inlet pipe.

8.1.1 Removal of EGR Gas Inlet Pipe

Removal steps are as follows:



- | | |
|-------------------------------------|--|
| 1. Bolts | 9. Insert |
| 2. Rear Mounting Bracket | 10. EGR Gas Inlet Pipe from Exhaust Manifold |
| 3. Clamp | 11. Clamp |
| 4. EGR Gas Inlet Pipe to EGR Cooler | 12. Flanged Nut * |
| 5. Seal | 13. Bolt |
| 6. Flanged Nut * | 14. Bolt |
| 7. Clamp Halves | 15. Bracket |
| 8. Bolts | 16. Bolt |

* Use high temperature resistant hardware only

Figure 8-1 EGR Gas Inlet Pipe and Related Components

1. Remove the two bolts from the clamp securing the gas inlet pipe to the mounting bracket at the rear of the engine. See Figure 8-1.
2. Loosen the bolt securing the rear mounting bracket to the rear engine lifting bracket. See Figure 8-1.

3. Remove the bolt from the clamp (near bellows) securing the EGR gas inlet pipe to mounting bracket attached below the rear exhaust manifold. See Figure 8-1.
4. Loosen the two bolts securing the mounting bracket to the exhaust manifold.
5. Remove the two bolts and the two nuts from the clamp halves securing the two components of the EGR gas inlet pipe to the exhaust manifold. See Figure 8-1.
6. Remove the two bolts and the two nuts from the clamp halves securing the EGR gas inlet pipe to the EGR cooler and remove the pipe and two gaskets attached to the EGR cooler. Discard the gaskets. See Figure 8-1.
7. Loosen the nut securing the EGR gas inlet pipe to the threaded insert on the exhaust manifold and remove the gas inlet pipe. See Figure 8-1.

8.1.1.1 Inspection of Insert

Inspection steps are as follows:

1. Clean the insert threads using a wire brush.
2. Visually inspect the insert threads for wear and cracks.
 - [a] If the threads are not damaged, refer to section 8.1.2.
 - [b] If the threads are damaged replace the insert, refer to section 7.1.1 for replacement procedure.

NOTE:

When the insert has been replaced, refer to section 8.1.2.

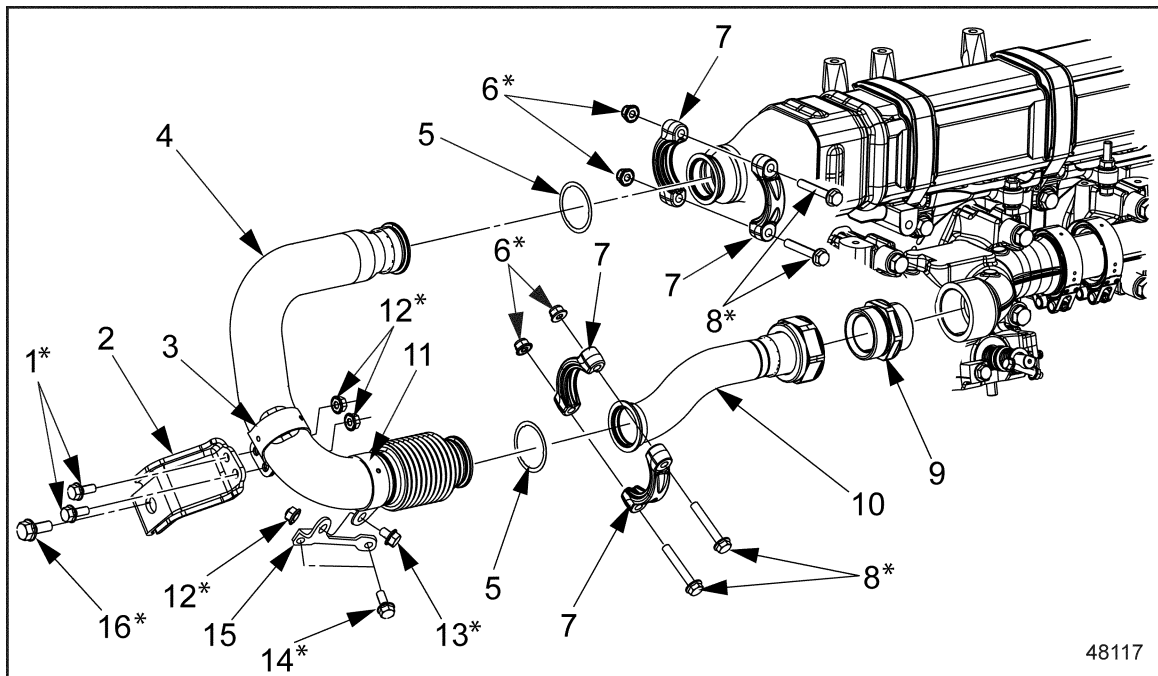
8.1.2 Installation of EGR Gas Inlet Pipe

Installation steps are as follows:

1. If removed, install rear mounting bracket. See Figure 8-2.

NOTE:

Do not torque bolt.



- | | |
|-------------------------------------|--|
| 1. Bolts | 9. Insert |
| 2. Rear Mounting Bracket | 10. EGR Gas Inlet Pipe from Exhaust Manifold |
| 3. Clamp | 11. Clamp |
| 4. EGR Gas Inlet Pipe to EGR Cooler | 12. Flanged Nut * |
| 5. Seal | 13. Bolt |
| 6. Flanged Nut * | 14. Bolt |
| 7. Clamp Halves | 15. Bracket |
| 8. Bolts | 16. Bolt |

* Use high temperature resistant hardware only

Figure 8-2 EGR Gas Inlet Pipe and Related Components

2. If removed, install exhaust mounting bracket. See Figure 8-2

NOTE:

Do not torque bolts.

3. Install EGR gas inlet pipe to the EGR cooler and secure using clamp halves, bolts, and flanged nuts. See Figure 8-2.

NOTE:

Do not torque bolts.

4. Install EGR gas inlet pipe to the exhaust manifold and secure using clamp halves, flanged nuts, and bolts. See Figure 8-2.
5. Secure clamp (11) using bolt and flanged nut. See Figure 8-2.
6. Secure clamp (3) using flanged nuts and bolts. See Figure 8-2.
7. Torque mounting bracket flange nuts to 50 N·m (37 lb·ft).
8. Torque clamp halves flange nuts to 25 N·m (18 lb·ft).

NOTICE:
To ensure to not damage the bellows when applying torque to the inlet pipe nut, secure the inner clamp half of the inner clamp and the rear exhaust manifold from rotating. Placing a 13 mm (0.5 in.) spacer block between the gas inlet pipe and the exhaust manifold will ensure the part is located correctly during installation.

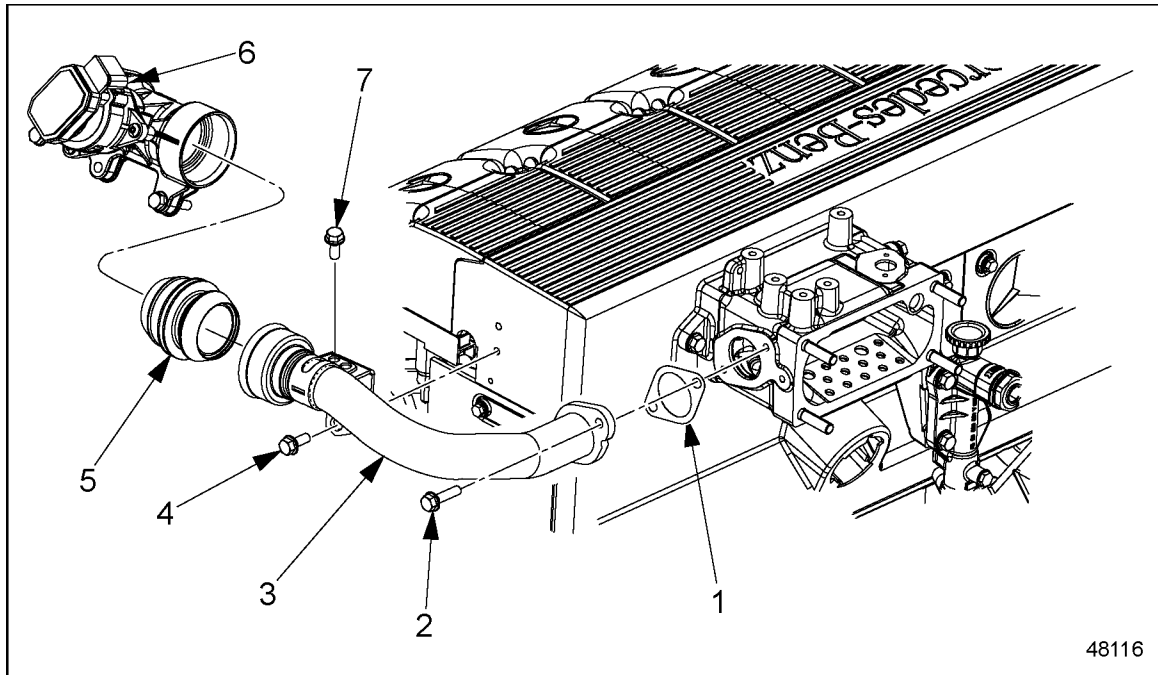
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|--|
| To ensure to not damage the bellows when applying torque to the inlet pipe nut, secure the inner clamp half of the inner clamp and the rear exhaust manifold from rotating. Placing a 13 mm (0.5 in.) spacer block between the gas inlet pipe and the exhaust manifold will ensure the part is located correctly during installation. |
|--|
9. Torque EGR gas inlet pipe nut to 150N·m (110 lb·ft) / +10 N·m (7 lb·ft).
 10. Torque bolts (14) to 25 N·m (18 lb·ft).
 11. Torque bolts (13) to 25 N·m (18 lb·ft).
 12. Torque bolts (16) to 50 N·m (37 lb·ft).
 13. Torque bolts (1) to 25 N·m (18 lb·ft).

8.2 EGR COOLER GAS OUTLET PIPE

The following sections cover the removal and installation of the EGR gas outlet pipe.

8.2.1 Removal of EGR Cooler Gas Outlet Pipe

Removal steps are as follows:



- | | |
|-------------------------------|-------------------|
| 1. Gasket | 5. Connector Pipe |
| 2. Bolts (qty 2) | 6. EGR Valve |
| 3. EGR Cooler Gas Outlet Pipe | 7. Bolts (qty 2) |
| 4. Bolt (qty 2) | |

Figure 8-3 EGR Cooler Gas Outlet Pipe

1. Remove two bolts mounting the EGR gas outlet pipe to the gas mixer housing. See Figure 8-3.
2. Remove two bolts (M8 x 16mm) attaching the mounting bracket on the EGR gas outlet pipe to the air intake manifold and move the pipe away from mixer housing. See Figure 8-3.

NOTE:

Visually inspect the pipe for damage and replace if necessary

8.2.2 Installation of EGR Cooler Gas Outlet Pipe

Installation steps are as follows:

1. Apply a light coating of International Product Corporation Rubber Lubricant Emulsion (P-80) to the rubber insert and install the gas outlet pipe into the connector fitting on the EGR control valve. See Figure 8-3.
2. Attach the gas outlet pipe to EGR gas mixer housing using a new metal gasket and two bolts (M8 x 16 mm). Torque the bolts to 25 N·m (18 lb·ft). See Figure 8-3.
3. Position support bracket in place for gas outlet pipe. Install support bracket using three bolts (M8 x 16 mm). Torque the bolts to 25 N·m (18 lb·ft). See Figure 8-3.

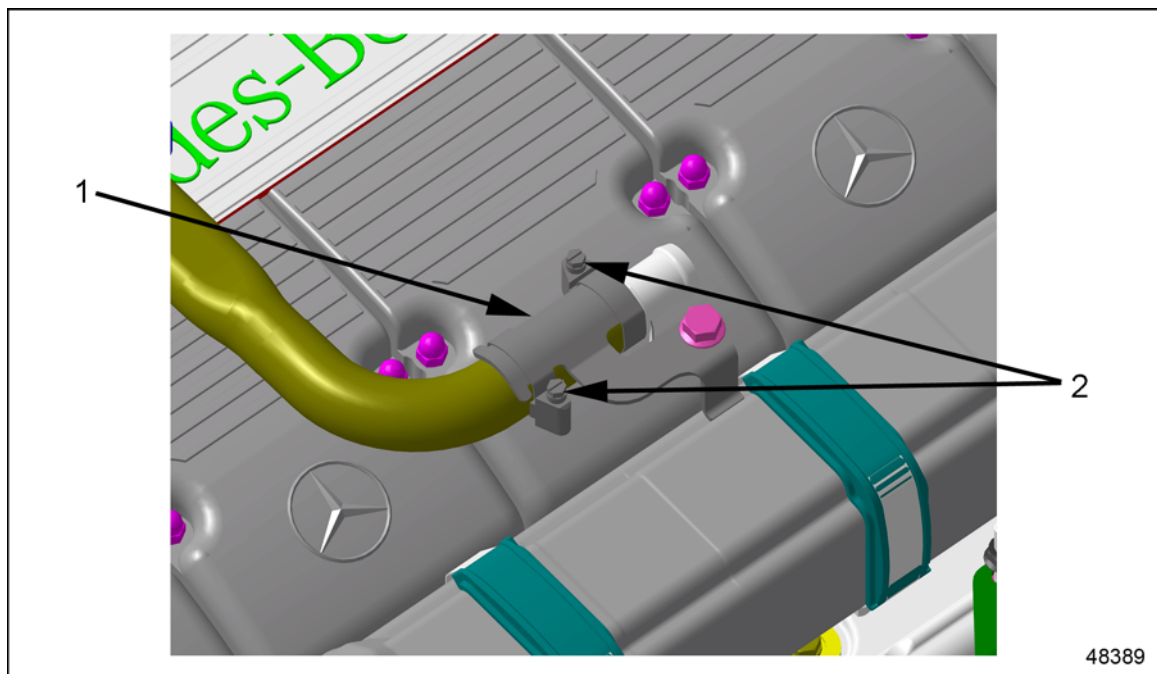
8.3 EGR COOLER AND SUPPORT BRACKET

The primary purpose of the EGR cooler is to cool the engine exhaust gases.

8.3.1 Removal of EGR Cooler

Removal steps are as follows:

1. Drain the cooling system.
2. Disconnect the coolant vent line located on top of the EGR cooler by removing the banjo bolt and two washers. Discard the washers.
3. Remove the bolts securing the air compressor suction supply bracket to the EGR cooler. See Figure 8-4.



1. Air Compressor Suction Supply Bracket

2. Bolts

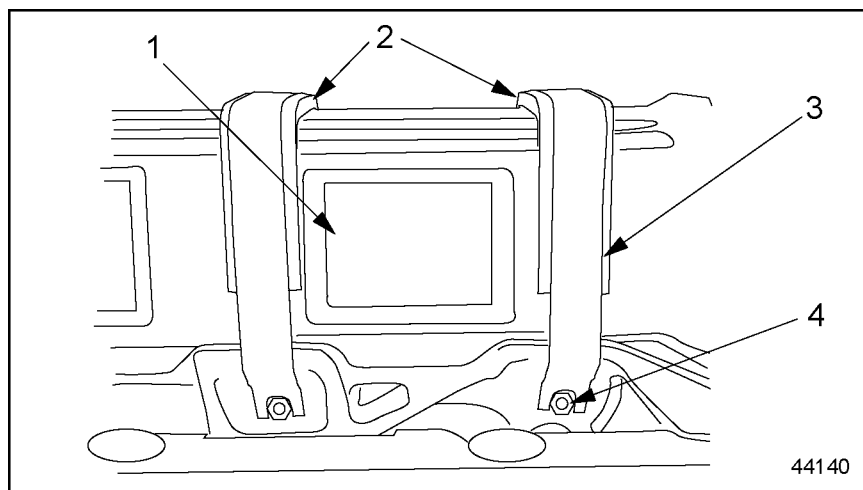
Figure 8-4 Air Compressor Suction Supply Bracket

4. Remove the four bolts securing the air inlet bracket. Rotate the turbocharger inlet elbow away from the engine.

NOTE:

Do not remove the air inlet elbow.

5. Remove the clamp halves securing the exhaust gas inlet pipe to the EGR cooler
6. Remove the EGR cooler gas outlet pipe. Refer to section 8.2.1.
7. Remove the EGR control valve. Refer to section 8.7.1.
8. Remove the EGR cooler straps. See Figure 8-5.

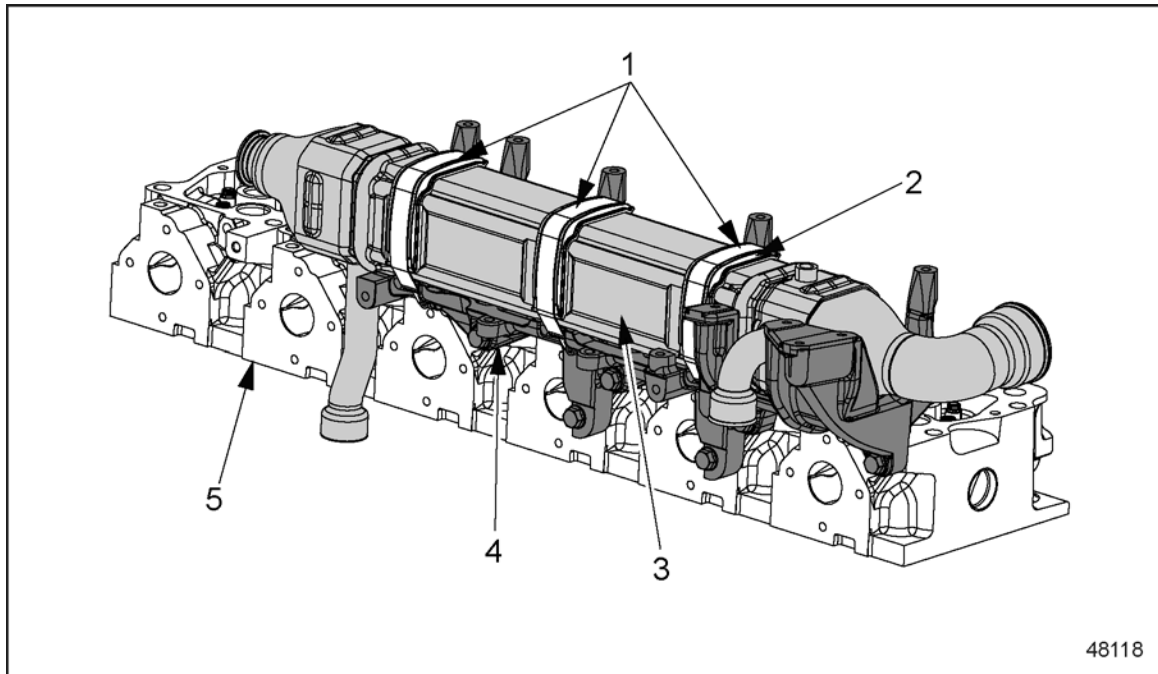


1. EGR Cooler
2. Clamping Pieces (3)

3. Clamps (3 Qty.)
4. Clamp Bolts

Figure 8-5 **Clamps on the Cooler**

9. Pull the EGR cooler straight up from the EGR cooler support bracket. Place the EGR cooler on a workbench. See Figure 8-6.



- | | |
|----------------------|-------------------------------|
| 1. EGR Cooler Clamps | 4. EGR Cooler Support Bracket |
| 2. Clamp Pieces | 5. Cylinder Heads |
| 3. EGR Cooler | |

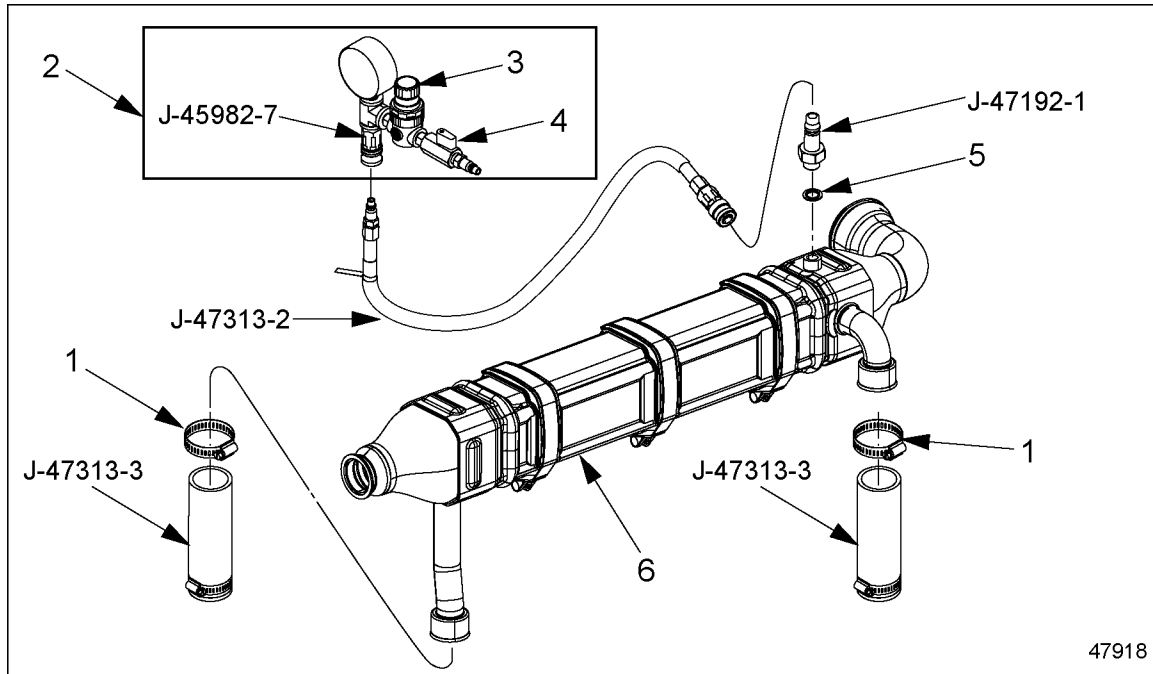
Figure 8-6 EGR Cooler

10. Remove the six mounting bolts from the EGR cooler support and remove the support bracket from cylinder heads.

8.3.1.1 Testing of EGR Cooler Leak

Testing steps are as follows:

1. Install air supply fitting (J-47192-1, part of toolset (J-47192)) and seal washer in the EGR cooler at the vent line port. See Figure 8-7.
2. Attach the two plugs (J-47313-3, part of toolset (J-47192)) to the coolant inlet and outlet tubes on the EGR cooler and secure the plugs with hose clamps. Tighten the clamps securely. See Figure 8-7 for details.



- | | |
|--------------------|-------------------|
| 1. Hose Clamp | 4. Shut-off Valve |
| 2. Regulator Valve | 5. Seal Washer |
| 3. Regulator Knob | 6. EGR Cooler |

Figure 8-7 EGR Cooler Test Set-Up

3. Connect the pressure hose (J-47313-2, part of toolset (J-47192)) to regulator and gauge (J-45982-7, part of toolset J-45982) to the EGR cooler vent line. See Figure 8-7.
4. Check and ensure the shutoff valve is in the OFF position.
5. Set the regulator to zero pressure by pulling upward on the adjusting knob and turning in a counterclockwise direction until it stops.
6. Connect a shop air supply to the pressure regulator and open the shutoff valve.

**WARNING:****EYE INJURY**

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 276 kPa (40 psi) air pressure.

7. Adjust the system pressure by pulling the adjusting knob upward and turning clockwise until a pressure is set to 90 kPa (13 psi).

NOTE:

Do not connect the pressure hose (J-47313-2) to the air supply fitting (J-47192-1) on the EGR cooler until the pressure has been adjusted to 90 kPa (13 psi).

8. Once the pressure has been set to 90 kPa (13 psi), connect the pressure hose to the vent line fitting on the cooler.

**WARNING:****BURNS**

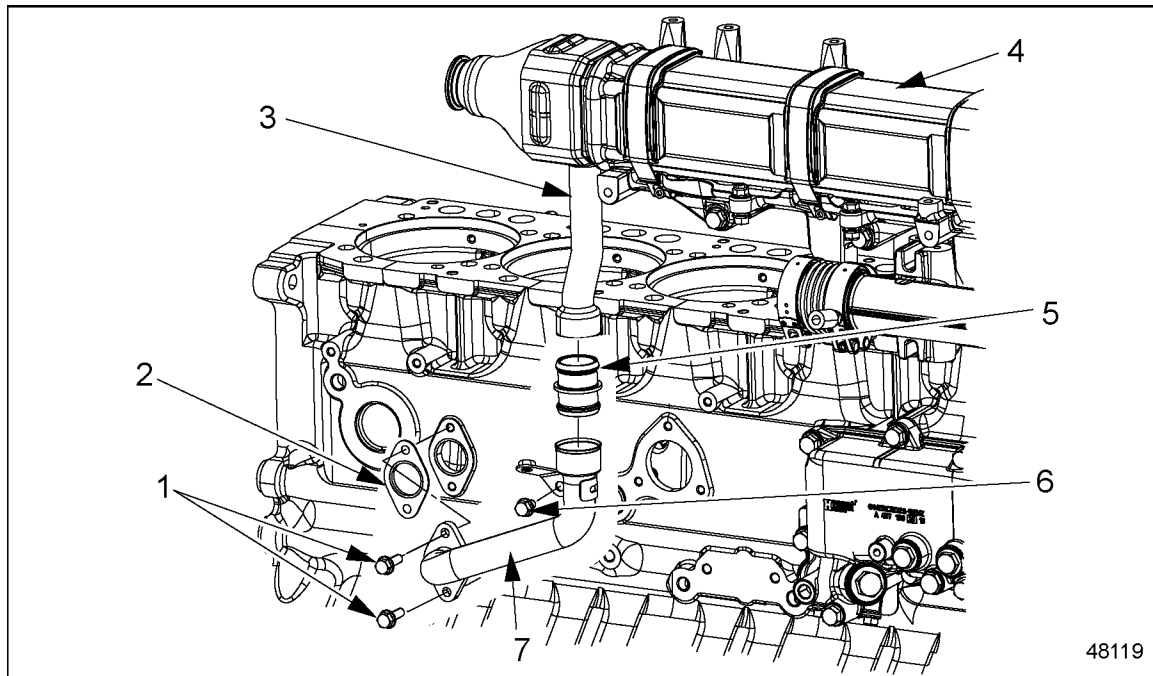
To avoid injury from burning, use lifting tools and heat-resistant gloves when handling heated components.

9. Submerge the EGR cooler completely in a hot water tank. Tip one end of the cooler up so that air bubbles will quickly escape.
10. Leave the EGR cooler submerged for five minutes.
11. If a steady stream of small air bubbles will come out of the highest end of the EGR cooler the cooler is faulty and must be replaced.
12. Turn OFF the regulator valve, remove the shop air supply, and slowly turn ON the regulator valve to relieve the residual pressure from the EGR cooler.
13. Remove the EGR cooler test kit components from the EGR cooler.

8.3.2 Installation of EGR Cooler

Installation steps are as follows:

1. Coat the connector pipe on the EGR cooler outlet pipe with International Product Corporation Rubber Lubricant Emulsion (P-80) and insert the connector pipe and outlet pipe into the coolant inlet pipe on the water pump. See Figure 8-8.

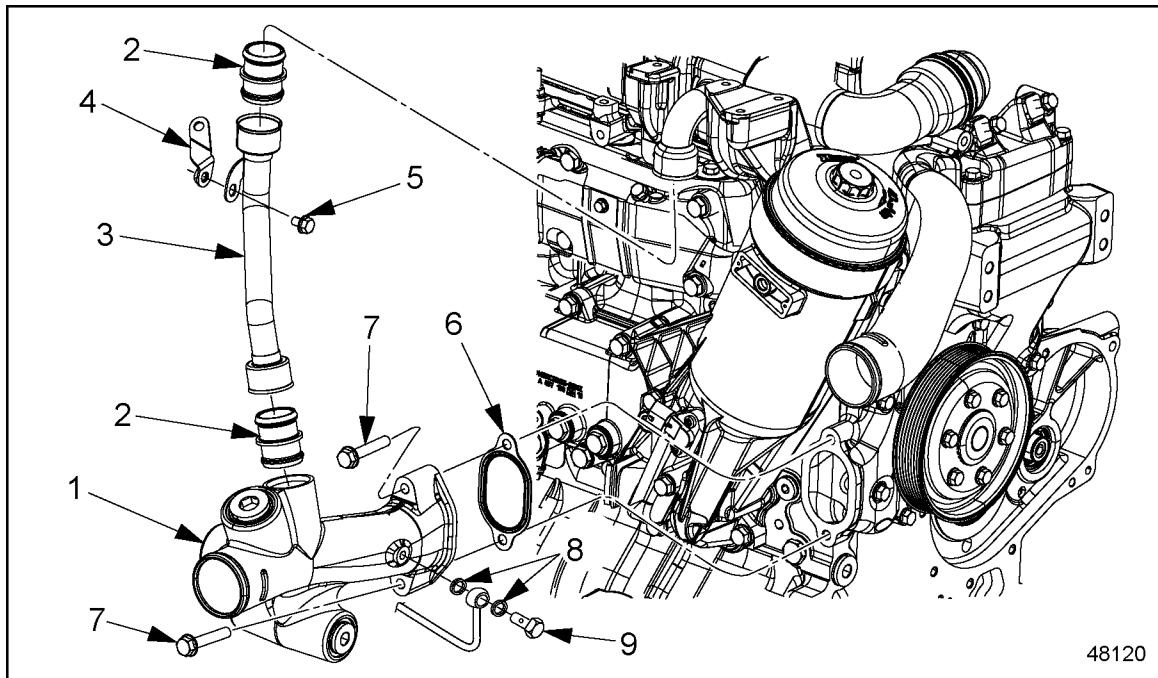


- | | |
|-----------------------------|-----------------------------|
| 1. Bolts | 5. Connector Pipe |
| 2. Gasket | 6. Bolt |
| 3. Upper Coolant Inlet Pipe | 7. Lower Coolant Inlet Pipe |
| 4. EGR Cooler | |

Figure 8-8 **Coolant Inlet Pipe**

2. If removed, install a new gasket and the EGR coolant inlet pipe to the cylinder block and secure with two bolts. Torque bolts to 35 N·m (26 lb·ft). See Figure 8-8.

3. Coat the rubber on the connecting pipe with International Product Corporation Rubber Lubricant Emulsion (P-80) and insert the pipe into the EGR cooler coolant return tube. See Figure 8-9.



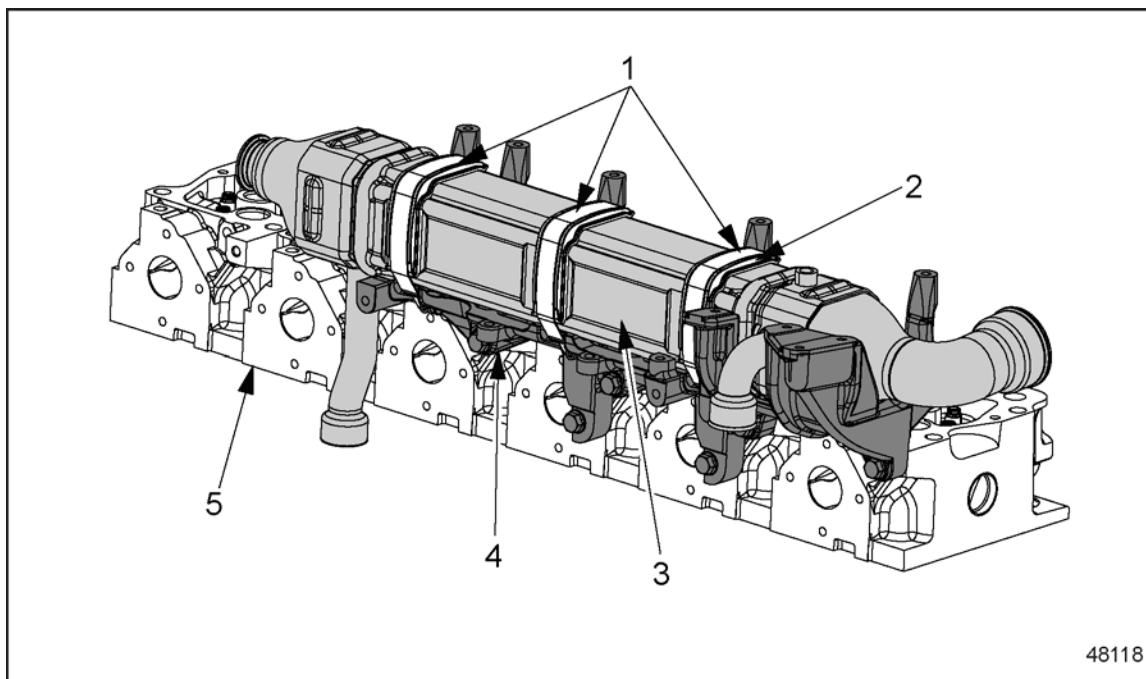
- | | |
|----------------------------|---------------|
| 1. Water Pump Inlet Pipe | 6. Gasket |
| 2. Connector Pipes | 7. Bolts |
| 3. EGR Coolant Return Pipe | 8. Washers |
| 4. Bracket | 9. Banjo Bolt |
| 5. Bolt | |

Figure 8-9 EGR Coolant Return Tube

NOTICE:

During installation, ensure that the EGR cooler water pipes are seated correctly with the connector pipes. Improperly seated pipes will leak causing engine damage.

4. Install the EGR to the EGR cooler support bracket. Secure the EGR cooler to the bracket with clamps. Torque the clamps to 10 N·m (7 lb·ft). See Figure 8-10.



- | | |
|----------------------|-------------------------------|
| 1. EGR Cooler Clamps | 4. EGR Cooler Support Bracket |
| 2. Clamp Pieces | 5. Cylinder Heads |
| 3. EGR Cooler | |

Figure 8-10 EGR Cooler

5. Reconnect the turbocharger inlet elbow and secure the support bracket with two bolts. Torque the bolts to 35 N·m (26 lb·ft).
6. Properly align the coolant pipe and small support bracket to the water pump. Torque the bolts to 35 N·m (26 lb·ft).
7. Install the inlet gas pipe to EGR cooler and secure with clamp halves. Torque clamp bolts to 25 N·m (18 lb·ft).
8. Install the air compressor suction pipe to the mounting bracket and secure with one M10 bolt. Torque the bolt to 35 N·m (26 lb·ft).
9. Install the EGR control valve. Refer to section 8.7.2.
10. Install the EGR cooler gas outlet pipe. Refer to section 8.2.2.

11. Install the coolant vent line to the top of the EGR cooler and secure with banjo bolts and washers. Torque banjo bolt to 25 N·m (18 lb·ft).
12. Refill engine with coolant.

8.3.3 Removal of EGR Cooler Support Bracket

Removal steps are as follows:

1. Disconnect the fuel line and two coolant lines from Doser Block Assembly at the turbocharger.
2. Disconnect the two coolant lines from Doser Block Assembly at the turbocharger by removing banjo bolts and washers. Discard the washers.
3. Remove the turbocharger. Refer to section 6.7.2.
4. Remove the exhaust manifold. Refer to section 7.1.1.
5. Remove the EGR cooler. Refer to section 8.3.1.
6. Remove the EGR cooler support bracket from the side of the cylinder heads. by removing six M10 x 40 mm bolts.

8.3.4 Installation of EGR Cooler Support Bracket

Installation steps are as follows:

NOTE:

Exhaust manifold gaskets will have to be installed before the EGR cooler support bracket can be installed. Refer to section 7.1.2.

1. Install the exhaust manifold guide studs into the cylinder heads 1 through 4 and mount two exhaust manifold gaskets.
2. Attach the EGR cooler support bracket to the side of the cylinder heads and secure with six bolts (M10 x 40 mm). Remove guide studs and torque the bolts to 50 N·m (36 lb·ft).
3. Install the turbocharger. Refer to section 6.7.3.
4. Install the exhaust manifold. Refer to section 7.1.2.
5. Install the EGR cooler. Refer to section 8.3.2.

8.4 EGR COOLER HEAT SHIELD AND MOUNTING BRACKET

The following sections cover EGR cooler heat shield and mounting bracket removal and installation.

8.4.1 Removal of EGR Cooler Heat Shield and Mounting Bracket

Removal steps are as follows:

1. Remove three bolts M8 x 12 securing the heat shield to mounting bracket and remove shield.
2. Remove the bolt to the bracket securing the EGR gas inlet pipe to the mounting bracket.
3. Remove bolt M10 x 20 mm securing the bracket to the cylinder head and remove bracket.

8.4.2 Installation of EGR Cooler Heat Shield and Mounting Bracket

Installation steps are as follows:

1. Install bolt M10 x 20 mm and secure the mounting bracket to the cylinder head . Torque the bolt to 35 N·m (26 lb·ft).
2. Using three bolts M8 x 12 secure the heat shield to mounting bracket. Torque the bolt to 25 N·m (18 lb·ft).
3. Install the bolt in the bracket and secure the EGR gas inlet pipe to the mounting bracket. Torque the bolt to 25 N·m (18 lb·ft).

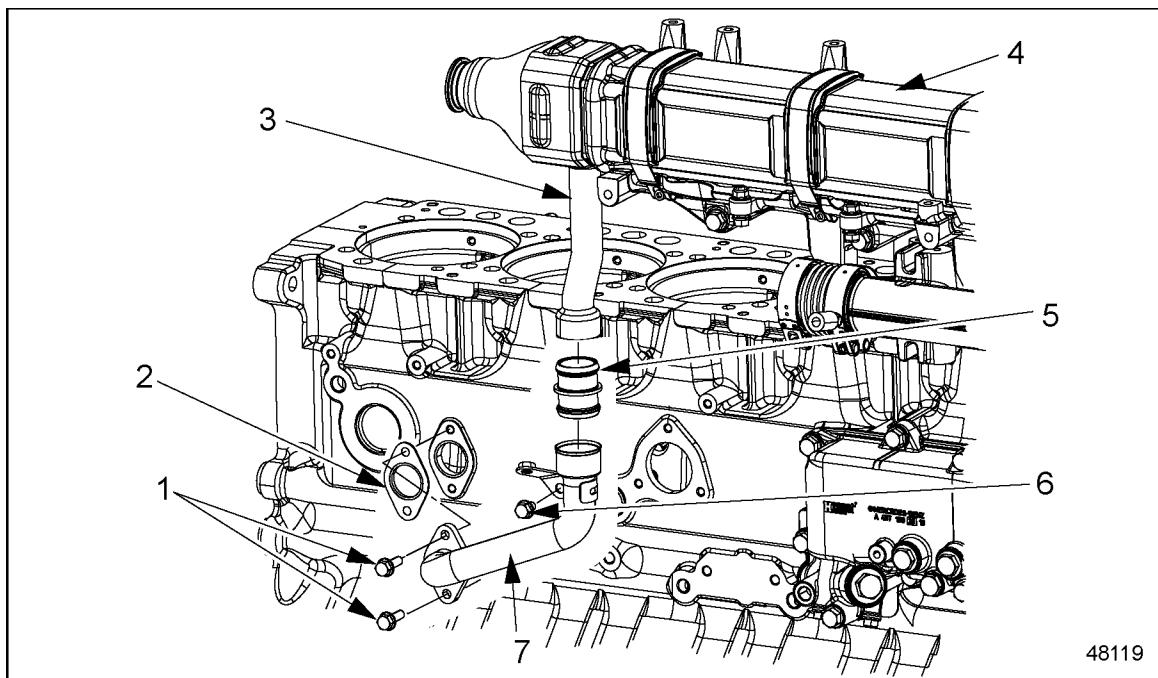
8.5 EGR COOLER COOLANT INLET TUBE

Exhaust gas cooling is accomplished by the flow of exhaust gases through the EGR cooler tubes.

8.5.1 Removal of EGR Cooler Coolant Inlet Tube

Removal steps are as follows:

1. Drain the engine coolant.
2. Remove the two bolts mounting the lower coolant inlet pipe to the block and remove the bracket bolt, just below the connector pipe, which attaches the lower coolant inlet pipe to the block. Remove gasket and discard. See Figure 8-11.



- | | |
|-----------------------------|-----------------------------|
| 1. Bolts | 5. Connector Pipe |
| 2. Gasket | 6. Bolt |
| 3. Upper Coolant Inlet Pipe | 7. Lower Coolant Inlet Pipe |
| 4. EGR Cooler | |

Figure 8-11 Coolant Inlet Pipe

3. Pull down on the lower coolant inlet pipe to loosen it from the EGR cooler pipe. Remove the pipe and connector pipe. See Figure 8-11.

NOTE:

Have a container nearby to drain any unused coolant from the inlet pipes.

8.5.2 Installation of EGR Cooler Coolant Inlet Tube

Installation steps are as follows:

1. Coat the connector pipe on the EGR cooler inlet pipe with International Product Corporation Rubber Lubricant Emulsion (P-80) and insert the connector pipe and inlet pipe into the EGR cooler. See Figure 8-11.
2. Secure the EGR coolant inlet pipe to the side of the cylinder block with two bolts and new gasket. Torque the bolts to 35 N·m (26 lb·ft). See Figure 8-11.
3. Install the removed coolant.

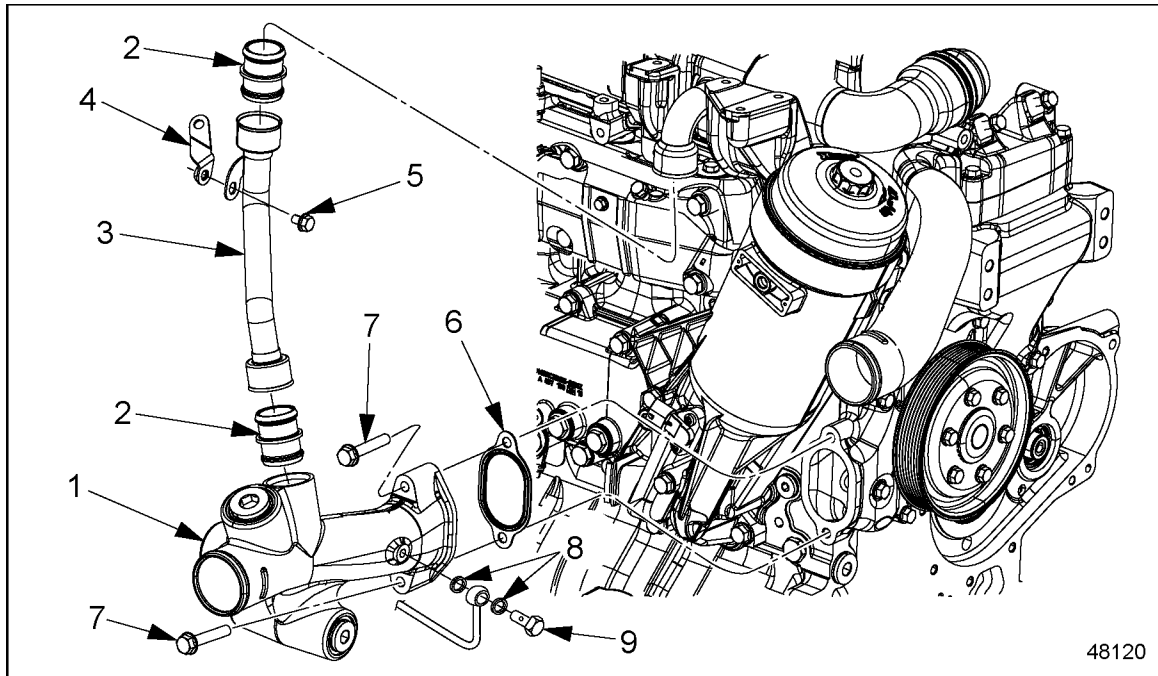
8.6 EGR COOLER COOLANT RETURN TUBE

Exhaust gas cooling is accomplished by the flow of exhaust gases through the EGR cooler tubes.

8.6.1 Removal of EGR Cooler Coolant Return Tube

Removal steps are as follows:

1. Drain the engine coolant.



- | | |
|---------------------------|---------------|
| 1. Water Pump Inlet Pipe | 6. Gasket |
| 2. Connector Pipes | 7. Bolts |
| 3. EGR Cooler Return Pipe | 8. Washers |
| 4. Bracket | 9. Banjo Bolt |
| 5. Bolt | |

Figure 8-12 EGR Cooler Coolant Return Tube

2. Remove the hose connections at the water pump inlet pipe to the water pump.
3. Remove the banjo bolt and two washers from the line on the water pump inlet pipe. Discard the washers. See Figure 8-12.
4. Remove two bolts securing the water pump inlet pipe and gasket and pull downward and remove EGR cooler coolant return tube. Discard the gasket. See Figure 8-12.
5. Remove the bolt from the clamp attaching the EGR cooler coolant return tube to the turbocharger air inlet elbow and remove tube from the EGR cooler. See Figure 8-12.

6. Remove the two connector pipes from the return tube. Inspect pipes, if damaged replace. See Figure 8-12.

8.6.2 Installation of EGR Cooler Coolant Return Tube

Installation steps are as follows:

1. Coat the two connector pipes with International Product Corporation Rubber Lubricant Emulsion (P-80) and insert them in the EGR cooler coolant return tube. See Figure 8-12.
2. Insert the EGR cooler coolant return tube into the EGR cooler.
3. Insert the water pump inlet pipe into the connector pipe and secure water inlet pipe and gasket to the water pump with two bolts. Torque the bolts to 50 N·m (37 lb·ft). See Figure 8-12.
4. Install the bolt in the clamp and attach the EGR cooler coolant return tube and bracket to the turbocharger air inlet elbow. Torque the bolts to 35 N·m (26 lb·ft). See Figure 8-12.
5. Install the banjo bolt and two new washers and secure line on the water pump inlet pipe. Torque the banjo bolt to 60–70 N·m (44–52 lb·ft). See Figure 8-12.
6. Install the hose connections at the water pump inlet pipe. Tighten the connections securely. See Figure 8-12.

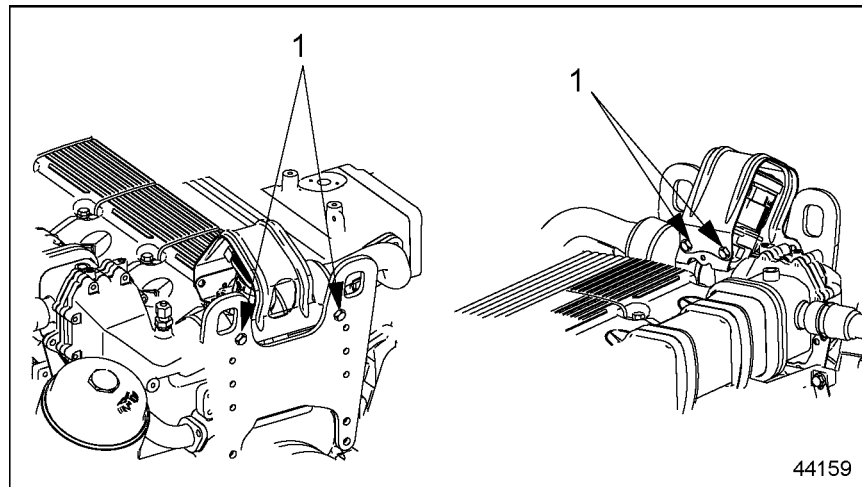
8.7 EGR CONTROL VALVE

The EGR control valve controls the quantity of exhaust gas returning back to the intake manifold.

8.7.1 Removal of EGR Control Valve

Removal steps are as follows:

1. Remove the EGR gas outlet pipe. Refer to section 8.2.1.
2. Remove the EGR control valve cover by removing the mounting bolts at the front lifter bracket and the rear of the EGR valve. See Figure 8-13.



1. EGR Control Valve Cover Mounting Bolts

Figure 8-13 EGR Control Valve Cover

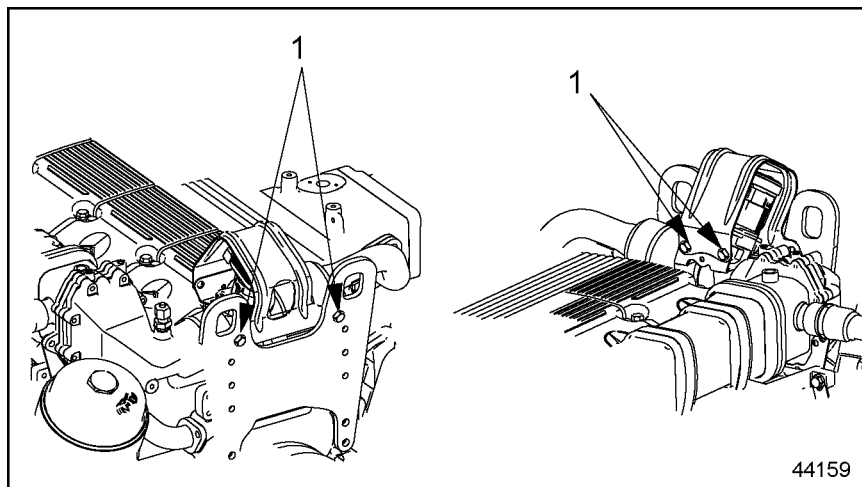
3. Remove connector pipe from the EGR control valve.
4. Disconnect wiring harness connector from the EGR valve.
5. Remove the four bolts attaching the EGR control valve to the thermostat housing.
6. Pull the EGR control valve out of the EGR cooler.
7. Remove connector pipe from the EGR cooler or EGR control valve.

8.7.2 Installation of Installation of EGR Control Valve

Installation steps are as follows:

1. Coat the rubber of the connector pipe with International Product Corporation Rubber Lubricant Emulsion (P-80) and insert the connector pipe into the EGR cooler.
2. Coat the connector pipe with International Product Corporation Rubber Lubricant Emulsion (P-80) and insert the EGR control valve onto the connector pipe.

3. Install four bolts and secure the EGR control valve to the thermostat housing. Torque the bolts to 25 N·m (18 lb·ft).



1. EGR Control Valve Cover Mounting Bolts

Figure 8-14 EGR Control Valve Cover

4. Secure the EGR control valve cover by installing the mounting bolts at the front lifter bracket and the rear of the EGR valve. Torque the bolts to 25 N·m (18 lb·ft).
5. Connect the electrical connector to the EGR control valve.
6. Install the EGR gas outlet pipe. Refer to section 8.2.2.

8.A ADDITIONAL INFORMATION

Description	Page
SPECIFICATIONS	8-25
Torque Values	8-26
Protectant Materials	8-27
Special Tools	8-27

SPECIFICATIONS

This section contains the specifications for servicing the engine.

Torque Values

The torque values for components in this chapter are listed in Table 8-1.

Description	Torque N·m (lb·ft) unless otherwise noted
EGR Cooler Gas Inlet Pipe Clamp Bolts (rear of engine)	18 (13)
EGR Cooler Gas Inlet Pipe Mounting Bracket (at rear of block) Bolt	25 (18)
EGR Cooler Gas Inlet Pipe Clamp (near bellows) Bolt	25 (18)
EGR Cooler Gas Outlet Pipe Mounting Bracket to Air Intake Manifold Bolt	25 (18)
EGR Cooler Gas Outlet Pipe Mounting Bracket to Clamp Bolts	25 (18)
EGR Cooler Mounting Clamp Bolts	10 (7)
EGR Control Valve to Thermostat Housing Bolts	25 (18)
Coolant Vent Line Banjo Bolt at EGR Cooler	25 (18)
EGR Cooler Support Bracket to Cylinder Head Bolts	50 (37)
EGR Cooler Heat Shield Mounting Bracket to Cylinder Head (M10) Bolt	35 (26)
EGR Cooler Heat Shield (M8) Bolts to Mounting Bracket	25 (18)
EGR Cooler Coolant Return Tube Clamp to Air Inlet Housing Bolt	25 (18)
Water Inlet Pipe to Water Pump Bolts	50 (37)
Banjo Bolt on Water Pump Inlet Pipe	60–70 (44–52)
EGR Cooler Coolant Return Tube to Cylinder Block Bolts	35 (26)
EGR Cooler Coolant Return Tube Clamp to Cylinder Block Bolt	25 (18)
EGR Control Valve Cover Bolts	25 (18)
Gas Mixer Housing Studs	25 (18)
EGR Gas Outlet Pipe to Mixer Housing Bolts	25 (18)
EGR Gas Outlet Pipe Mounting Bracket Bolts	25 (18)
Gas Mixer Housing (stud) Nuts	60 (44)

Table 8-1 Torque Values

Protectant Materials

The approved protectant materials used in this chapter are listed in Table 8-2.

Protectant Material	Approved Brand
Anti-seize	International Product Corporation Rubber Lubricant Emulsion (P-80)

Table 8-2 Approved Sealants

Special Tools

The special tools used within this chapter are listed in Table 8-3.

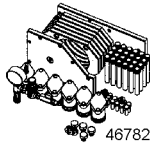
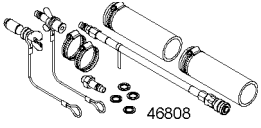
Tool	Description	Usage	Part Number
 46782	Head and Block Leak Tester	Used to pressure test the cylinder head and cylinder block for leaks.	J-45982
 46808	EGR Cooler Leak Test Kit	Used to pressure test the EGR cooler for leaks.	J-47192

Table 8-3 Special Tools

9 ELECTRICAL EQUIPMENT

Section	Page
9.1 DRIVE BELTS	9-3
9.2 ALTERNATOR/AIR CONDITIONING COMPRESSOR BRACKET	9-12
9.A ADDITIONAL INFORMATION	9-15

9.1 DRIVE BELTS

There are two v-ribbed drive belts on the MBE 4000 engine:

- The main drive poly-vee belt — (nine ribs)
- The fan poly-vee belt — (eight ribs)

The main drive poly-vee belt has nine ribs and drives the alternator, coolant pump and other accessories. The fan poly-vee belt has eight ribs.

NOTE:

Before removing and installing a poly-vee belt, check belt function and make sure to install the correct belt.

There are three idler pulleys on the MBE 4000 engine, one on the fan poly-vee belt and two on the main drive poly-vee belt.

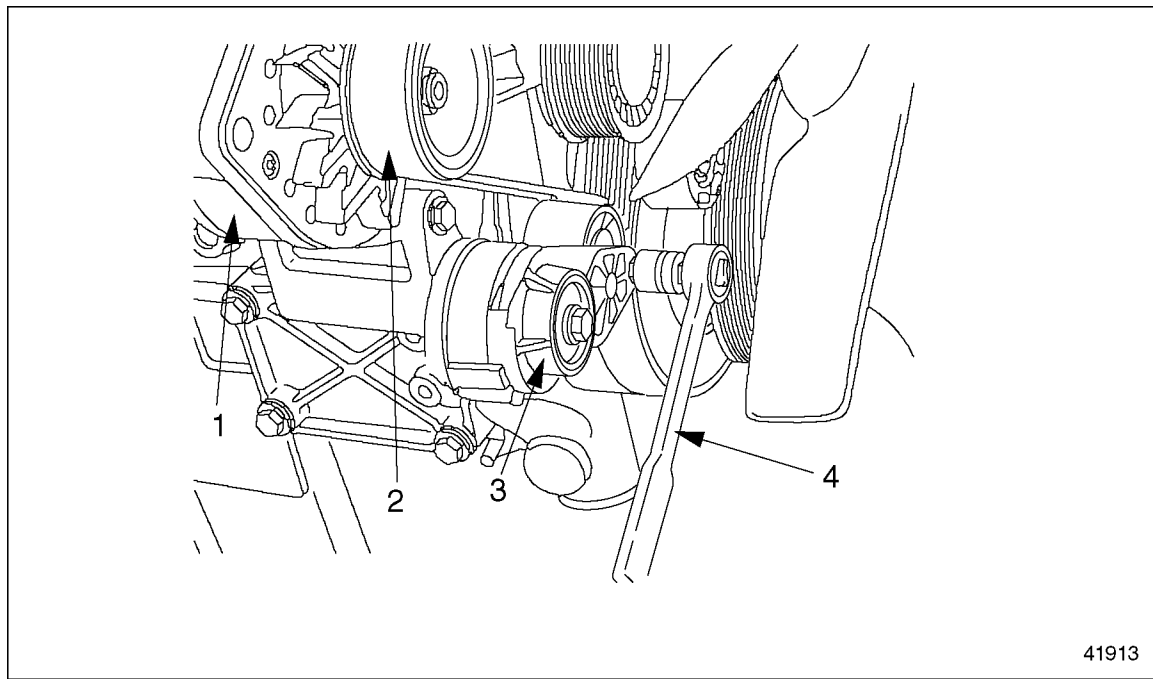
9.1.1 Removal of Main Drive Belt

Removal steps are as follows:

NOTE:

There are two poly-vee drive belts on the MBE 4000 engine. Be sure to remove and install the correct belt(s).

1. Disconnect the batteries.
2. Release the tension on the main drive poly-vee belt. See Figure 9-1.

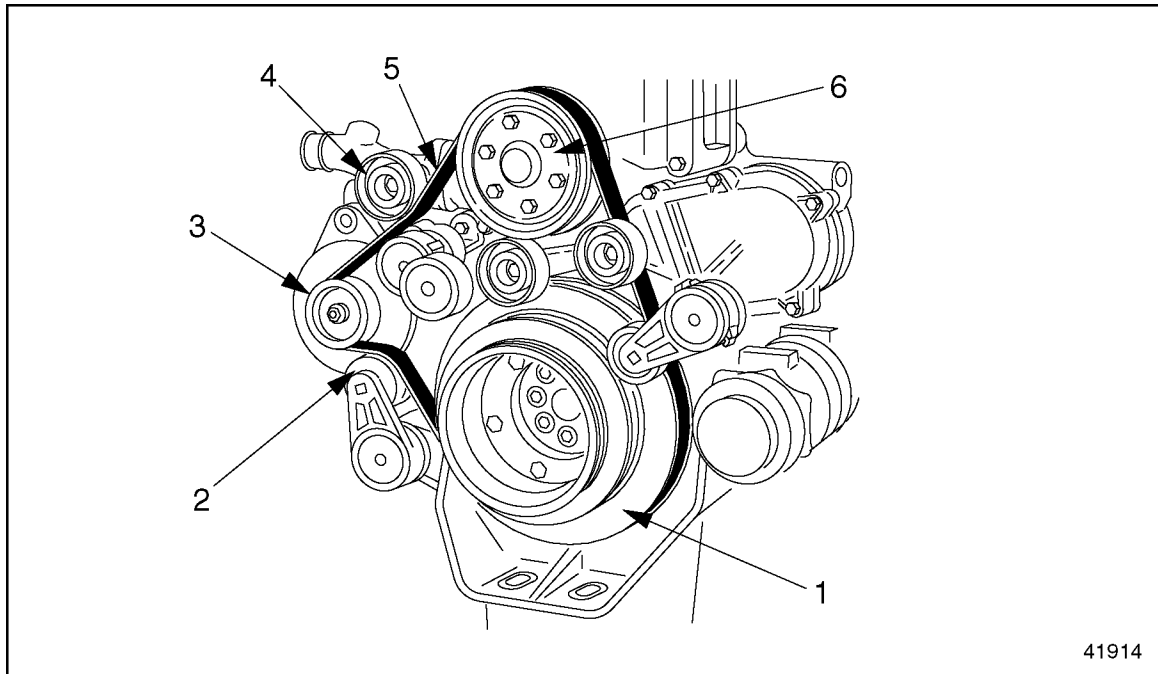


- | | |
|-----------------------------|-------------------|
| 1. Alternator | 3. Belt Tensioner |
| 2. Main Drive Poly-Vee Belt | 4. Socket Wrench |

Figure 9-1 Releasing Belt Tension

- [a] Place a socket wrench on the tensioner pulley bolt.
- [b] Pull the socket wrench (rotate the tensioner pulley clockwise) to remove the tension from the poly-vee belt.
- [c] Hold the tensioner pulley in this position for the next step.

3. Remove the drive poly-vee belt from the alternator, coolant-pump, AC compressor and idler pulleys. Be careful not to kink, stretch, or otherwise damage the belt. See Figure 9-2.



- | | |
|----------------------|-----------------------------|
| 1. Vibration Damper | 4. Idler Pulley |
| 2. Tensioner Pulley | 5. Main Drive Poly-Vee Belt |
| 3. Alternator Pulley | 6. Coolant Pump Pulley |

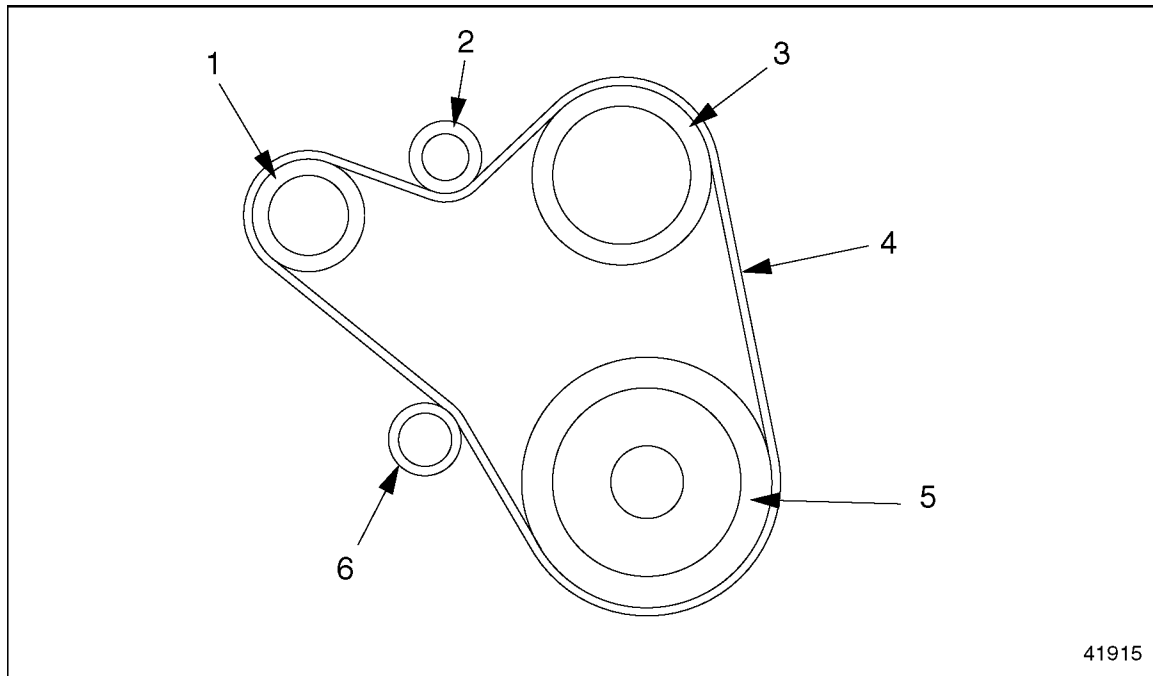
Figure 9-2 Main Drive Poly-Vee Belt

4. Release the tensioner pulley.
5. Inspect the drive poly-vee belt for nicks, wear, or other damage. Replace the belt if necessary.
6. Inspect the following parts and replace any that are damaged or worn:
 - ☐ Vibration damper
 - ☐ Alternator pulley
 - ☐ Coolant-pump pulley
 - ☐ Belt tensioner
 - ☐ Tensioner pulley
 - ☐ Idler pulley

9.1.2 Installation of Main Drive Belt

Installation steps are as follows:

1. Fit the main drive poly-vee belt on the belt pulleys. Be careful not to kink, stretch, or otherwise damage the belt. For correct routing, see Figure 9-3. Do not fit the belt onto the tensioner pulley yet.



- | | |
|------------------------|-----------------------------|
| 1. Alternator Pulley | 4. Main Drive Poly-Vee Belt |
| 2. Idler Pulley | 5. Vibration Damper |
| 3. Coolant Pump Pulley | 6. Tensioner Pulley |

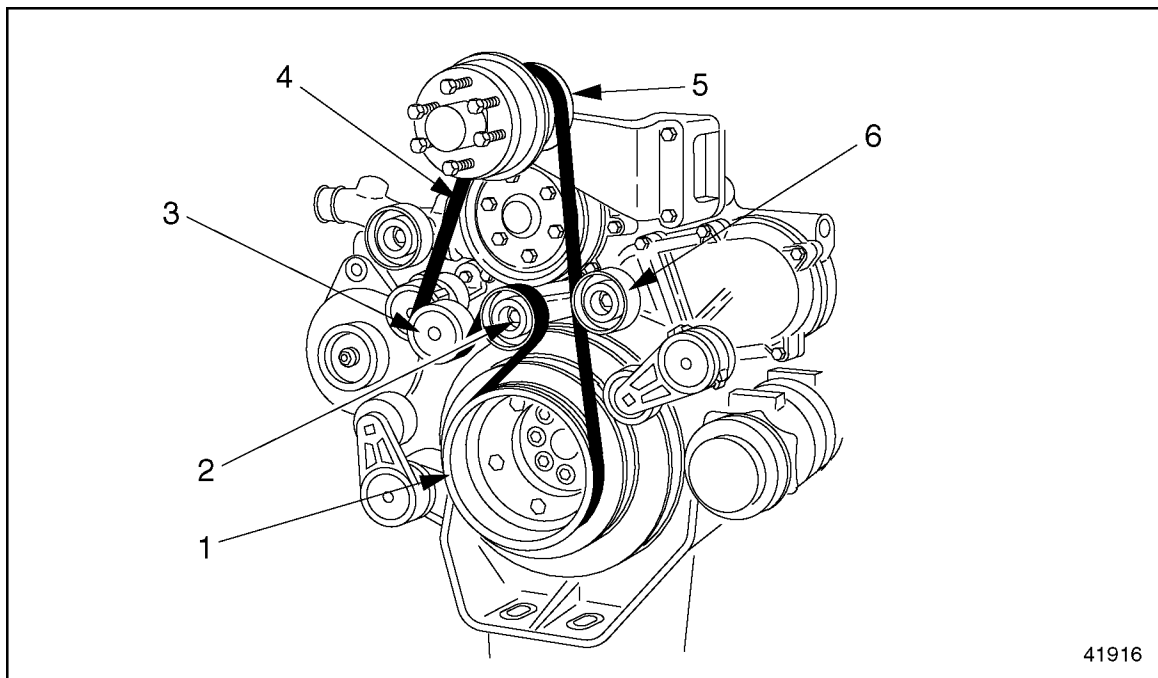
Figure 9-3 Main Drive Poly-Vee Belt Routing

2. Using a socket wrench (rotate the tensioner pulley counterclockwise) to remove the tension from the tensioner on the main drive poly-vee belt. See Figure 9-1.
3. Make sure the poly-vee belt is correctly positioned for the tensioner pulley.
4. Restore the tension on the poly-vee belt.
 - [a] Release the tension on the socket wrench to return the tensioner pulley to its original position.
 - [b] Remove the socket-wrench bit from the pulley bolt.
5. Check the main drive poly-vee belt to make sure it is in the correct position and properly aligned on the pulleys.
6. Connect the batteries.

9.1.3 Removal of Fan Belt

Removal steps are as follows:

1. Disconnect the batteries.
2. Release the tension on the fan drive poly-vee belt. See Figure 9-1.
 - [a] Place a socket wrench on the tensioner pulley bolt.
 - [b] Pull the socket wrench (rotate the tensioner pulley clockwise) to remove the tension from the belt.
 - [c] Hold the tensioner pulley in this position for the next step.
3. Remove the drive poly-vee belt from the fan and vibration damper pulley. Be careful not to kink, stretch, or otherwise damage the belt. See Figure 9-4.



- | | |
|-----------------------|----------------------|
| 1. Crankshaft Pulley | 4. Fan Poly-Vee Belt |
| 2. Idler Pulley #1 | 5. Fan Pulley |
| 3. Fan Belt Tensioner | 6. Idler Pulley #2 |

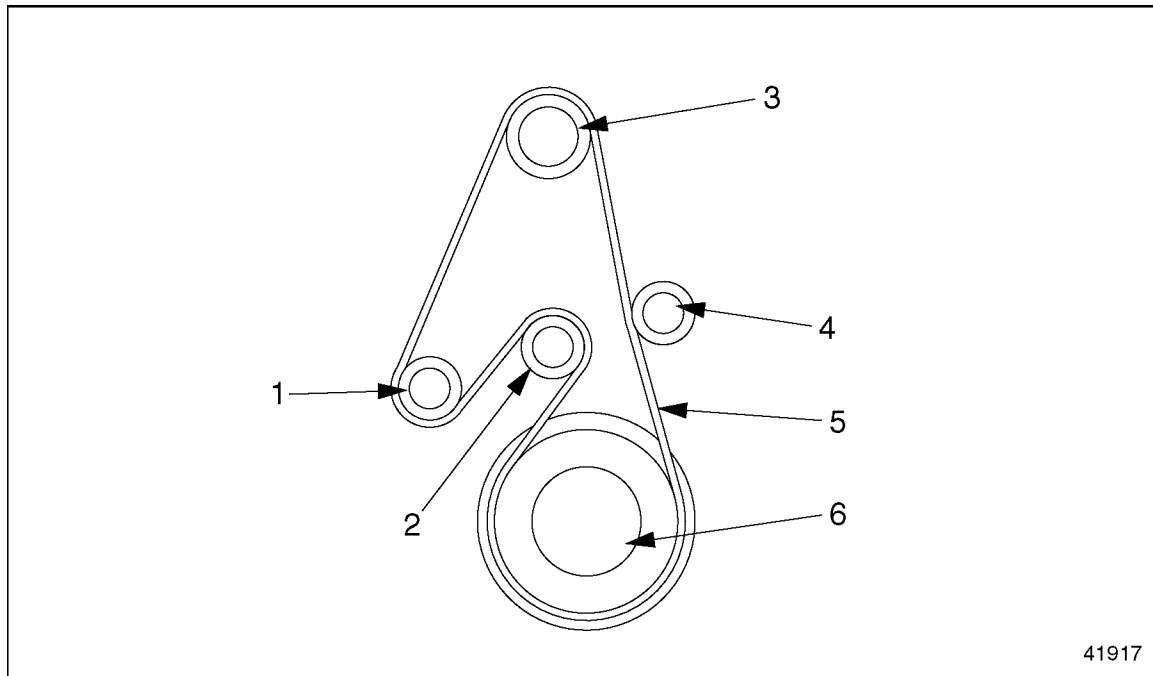
Figure 9-4 Fan Poly-Vee Belt

4. Release the fan belt tensioner.
5. Inspect the fan poly-vee belt for nicks, wear, or other damage. Replace the belt if necessary.
6. Inspect the vibration damper pulley, the fan pulley, and the belt tensioner. Replace any that are damaged or worn:

9.1.4 Installation of Fan Belt

Installation steps are as follows:

1. Fit the fan drive poly-vee belt on the belt pulleys. Be careful not to kink, stretch, or otherwise damage the belt. For correct routing, see Figure 9-5. Do not fit the belt onto the tensioner pulley yet.



1. Tensioner Pulley

5. Fan Poly-Vee Belt

3. Fan Pulley

6. Crankshaft Pulley

Figure 9-5 Fan Poly-Vee Belt Routing

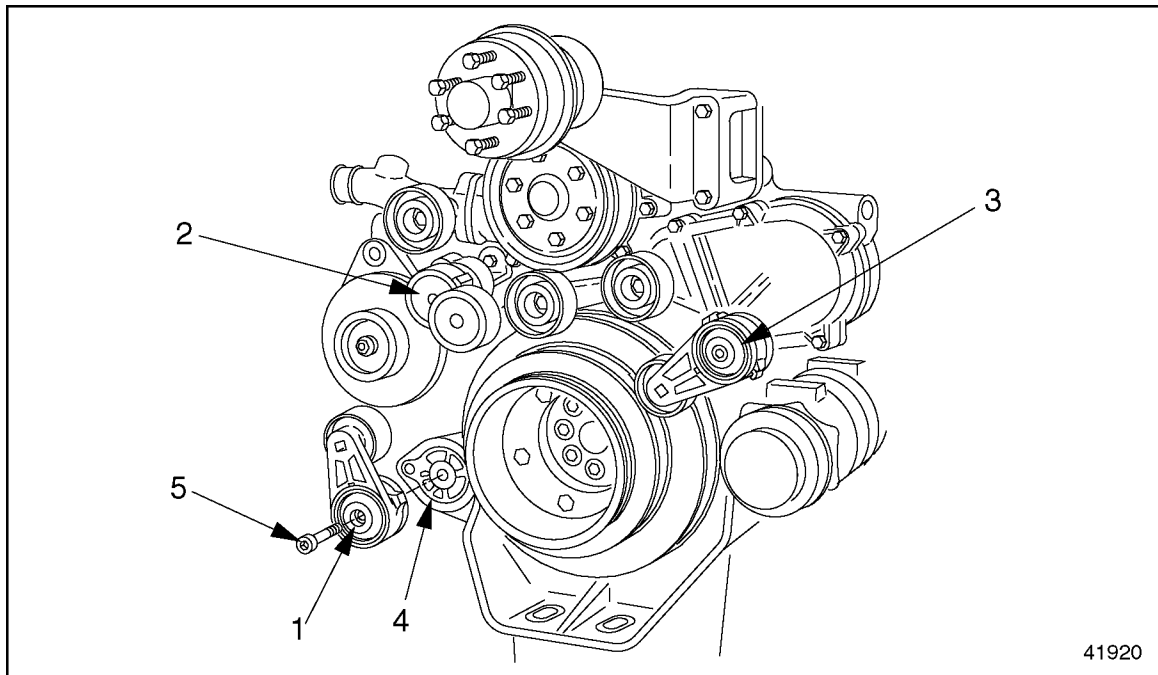
2. Using a socket wrench (rotate the tensioner pulley clockwise) to remove the tension from the tensioner on the fan belt. See Figure 9-1.
3. Make sure the belt is correctly positioned for the tensioner pulley.
4. Restore the tension on the belt.
 - [a] Release the tension on the socket wrench to return the tensioner pulley to its original position.
 - [b] Remove the socket-wrench bit from the pulley bolt.
5. Check the fan belt to make sure it is in the correct position and properly aligned on the pulleys.
6. Connect the batteries.

9.1.5 Removal of Belt Tensioner

Removal steps are as follows:

NOTE:

This procedure works for all belt tensioners. See Figure 9-6 to identify the correct belt tensioner.



- | | |
|----------------------------------|------------------------------|
| 1. Main Drive Belt Tensioner | 4. Mounting Pad |
| 2. Fan Belt Tensioner | 5. Socket-Head Mounting Bolt |
| 3. A/C Compressor Belt Tensioner | |

Figure 9-6 Belt Tensioners



WARNING:

PERSONAL INJURY

To avoid injury to hands and fingers from the spring-loaded auto belt tensioner violently snapping back, do not cut the belt to remove it.

1. Release the tension on the main drive belt (alternator, and AC compressor) and move belt away from tensioner.
2. Release the tensioner.
3. Remove the mounting bolt that fastens the belt tensioner and tensioner pulley to the cylinder block.

4. Remove the belt tensioner and tensioner pulley from the mounting pad on the cylinder block.

9.1.6 Installation of Belt Tensioner

Installation steps are as follows:

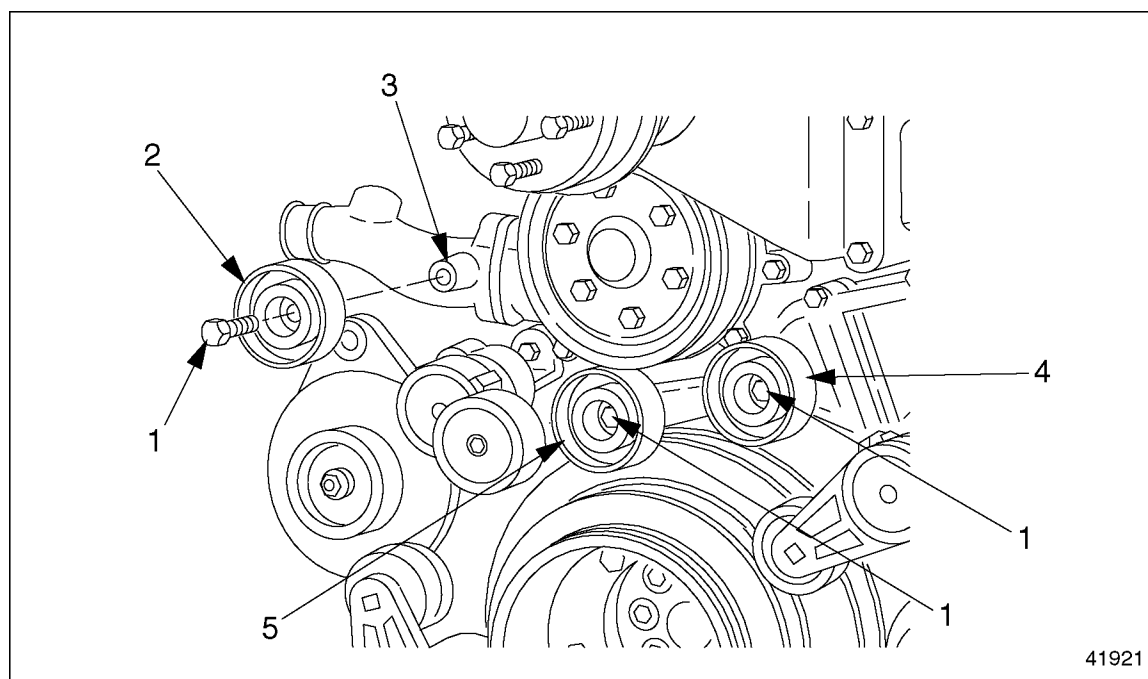
1. Align the guide pins on the belt tensioner with the holes in the mounting pad.
2. Position the belt tensioner to the mounting pad and secure in place with the mounting bolt. Tighten the bolt to 50 N·m (37 lb·ft).
3. Release the belt tensioner to allow the belt to be installed. Refer to section 9.1.2.
4. Install the drive belt on the pulleys, as removed.
5. Restore the tension on the drive belt.

9.1.7 Removal of Idler Pulley

Removal steps are as follows:

NOTE:

This procedure works for all idler pulleys. To identify the correct pulley, see Figure 9-7.



- | | |
|---------------------------------|------------------------|
| 1. Mounting Bolt | 4. Fan Idler Pulley #2 |
| 2. Main Drive Belt Idler Pulley | 5. Fan Idler Pulley #1 |
| 3. Coolant Pump Inlet Pipe | |

Figure 9-7 Idler Pulleys

1. Release the tension on the main drive belt (alternator, coolant-pump, and/or AC compressor), as required. Refer to section 9.1.1 for detailed instructions.
2. With belt tension relaxed, remove the belt from contact with the idler pulley.
3. Release the tensioning pulley.
4. Remove the cover from the idler pulley.
5. Remove the socket-head bolt fastening the pulley to the mounting pad.
6. Remove the pulley from the mounting pad.

9.1.8 Installation of Idler Pulley

Installation steps are as follows:

1. Position the pulley on the mounting pad, as removed.
2. Secure the pulley with the socket-head bolt. Tighten the bolt 45 N·m (33 lb·ft).
3. Release the tension on the belt tensioner. Refer to section 9.1.1 for detailed instructions.
4. Position the belt around the new pulley.
5. When the belt is in place, restore the tension on the drive belt. Refer to section 9.1.1 for detailed instructions.
6. Install the idler pulley cover.

9.2 ALTERNATOR/AIR CONDITIONING COMPRESSOR BRACKET

The alternator/air conditioning compressor bracket is located at the front left side of the engine and is used to mount the alternator and the air conditioning compressor.

9.2.1 Removal Alternator/Air Conditioning Compressor Bracket

Removal steps are as follows:

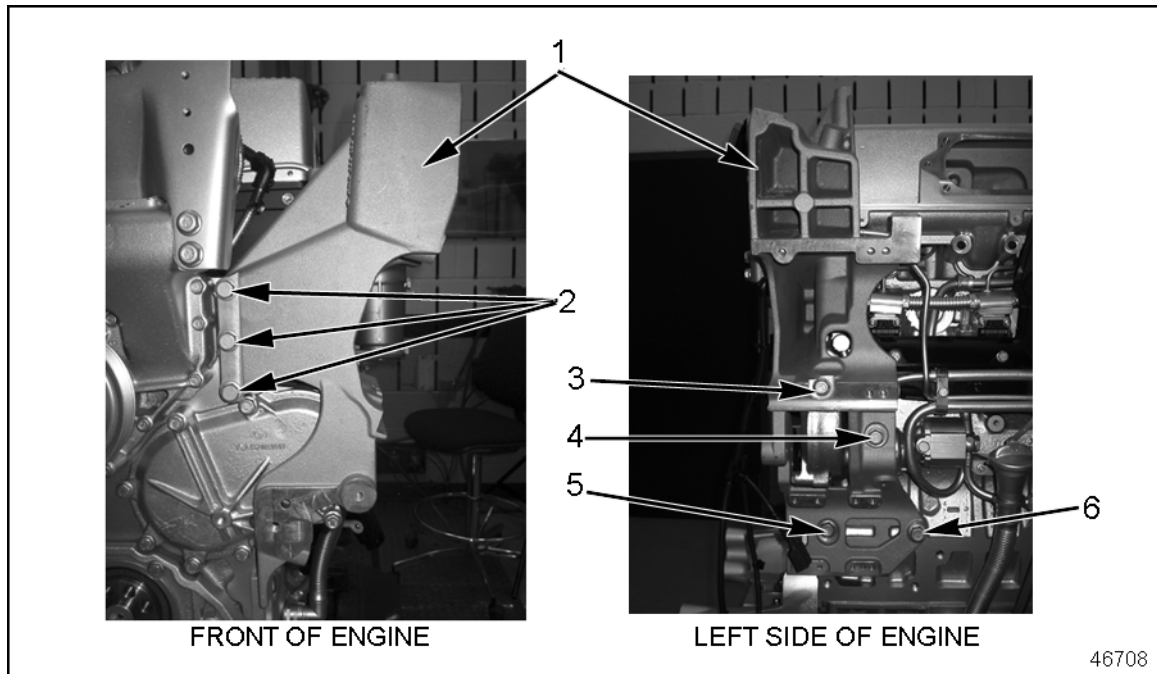
1. Disconnect the electrical connections at the alternator.
2. Remove the main drive poly-vee belt. Refer to section 9.1.1.
3. Disconnect the electrical connections and remove the air conditioning compressor. Refer to OEM guidelines.
4. Remove bolts securing the alternator to the mounting bracket and remove the alternator.
5. Remove the bolts securing the air conditioning compressor to the bracket.
6. Remove three bolts from the front of the bracket.
7. Remove four bolts from the side of the bracket and remove the bracket.

9.2.2 Installation of Alternator/Air Conditioning Compressor Bracket

Install the alternator/air conditioning compressor bracket as follows:

1. Loosely install three bolts (M12 x 45 mm) in the front of the alternator/air conditioning compressor bracket to the front left side the cylinder block to secure the bracket. See Figure 9-8.
2. Loosely install two bolts (M12 x 30 mm and M12 x 35 mm) in the upper holes of the bracket. See Figure 9-8.

3. Install two bolts (a M14 x 25 mm and M14 x 35 mm) in the lower holes in the bracket. Torque the bolts to 125 N·m (92 lb·ft). See Figure 9-8.



- | | |
|---|---------------------|
| 1. Alternator/Air Conditioning Compressor Bracket | 4. Bolt M12 x 35 mm |
| 2. Front Mounting Bolts M12 x 45 mm (3) | 5. Bolt M14 x 35 mm |
| 3. Bolt M12 x 30 mm | 6. Bolt M14 x 25 mm |

Figure 9-8 Alternator Air Conditioning Compressor Bracket Mounting Bolts

4. Torque the M14 bolts to 125 N·m (92 lb·ft) and torque the three front M12 bolts to 80 N·m (59 lb·ft).
5. Secure the air conditioning compressor to the bracket. Refer to OEM guidelines.
6. Secure the alternator to the bracket with bolts. Refer to OEM guidelines.
7. Install the main drive poly-vee belt. Refer to section 9.1.2.
8. Connect the electrical connector to the alternator.

9.A ADDITIONAL INFORMATION

Description	Page
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Drive Belt	9-15

SPECIFICATIONS

This section contains the specifications for servicing the engine.

Drive Belt

The torque values for the drive poly-vee belts are listed in Table 9-1.

Description	Torque N·m (lb·ft)
Socket-Head Mounting Bolt Belt Tensioner	50 (37)
Idler Pulley, Mounting Bolt	45 (33)

Table 9-1 Drive Belts Torque Values

10 POWER TAKE-OFF

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10.1 FRONT POWER TAKE-OFF	10-3
10.2 REAR ENGINE POWER TAKE-OFF	10-7

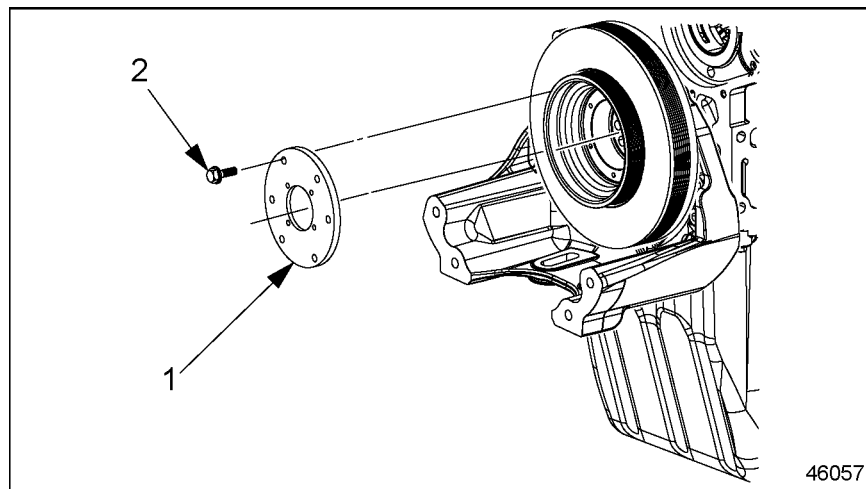
10.1 FRONT POWER TAKE-OFF

A Front Power Take-Off (FEPTO) accessory drive is an available engine option. The drive provides continuous live power anytime the engine is operating. The FEPTO is adaptable to a Spicer 1350/1410 drive shaft.

10.1.1 Removal of FEPTO Components

Removal steps are as follows:

1. Remove the bolts securing the drive shaft to the FEPTO and remove the shaft.
2. Remove the drive belts from their pulleys as installed.
3. To gain access to the vibration damper, remove the lower mounting bolts from the bottom of the front fairing/bumper.

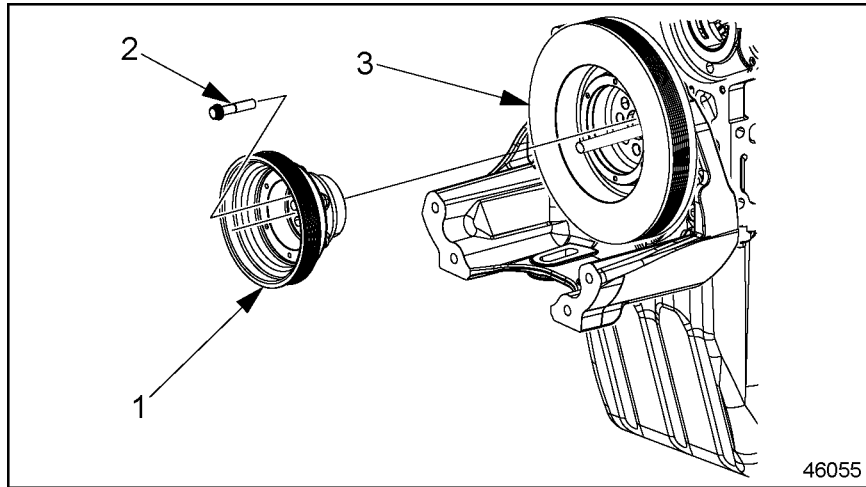


1. Bolts

2. Plate (Hub)

Figure 10-1 FEPTO Hub Plate

4. Remove six bolts M10 x 30 mm securing the plate (hub) to the intermediate pulley and remove plate. See Figure 10-1.



- | | |
|---------------------------|---------------------|
| 1. Intermediate Pulley | 3. Vibration Damper |
| 2. Vibration Damper Bolts | |

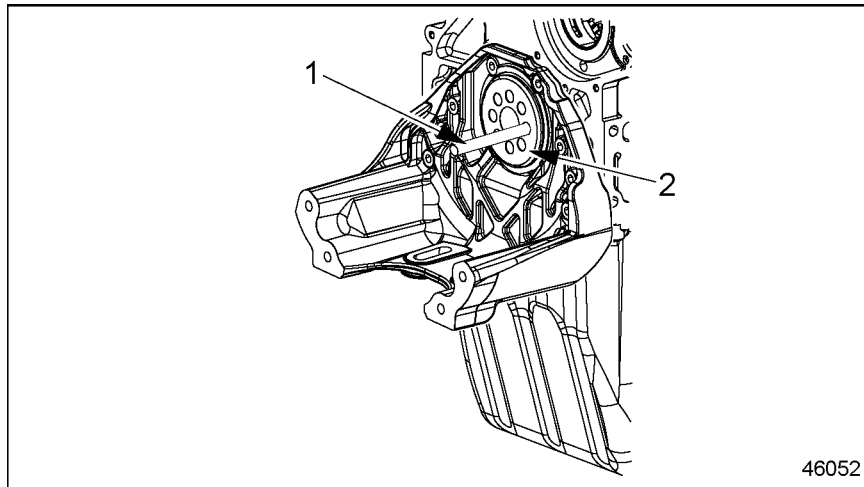
Figure 10-2 FEPTO Intermediate Pulley

5. Remove two M16 x 76 mm bolts securing the intermediate pulley to the front of the crankshaft and install two guide pins (J-46172). See Figure 10-2.
6. Remove the remaining six bolt securing the intermediate pulley and remove the pulley.
7. Remove the vibration damper from the engine.

10.1.2 Installation of FEPTO Components

Installation steps are as follows:

1. Install guide pins. (J-46172) into the front of the crankshaft. See Figure 10-3.

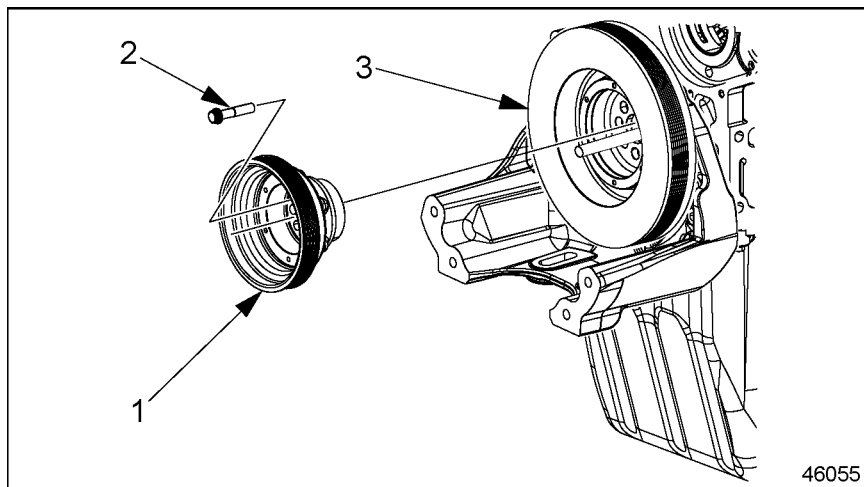


1. Guide Pins (J-46172)

2. Oil Deflector

Figure 10-3 Guide Pin

2. Install the oil deflector and vibration damper over the guide pins. Ensure the rim on the deflector is facing the engine. See Figure 10-3.



1. Intermediate Pulley

3. Vibration Damper

Figure 10-4 Vibration Damper and Pulley

3. Install the intermediate pulley over the guide pins. See Figure 10-4.
4. Install eight M16 x 76 mm mounting bolts and secure the intermediate pulley and the vibration damper, Torque the bolts in a criss-cross pattern to 200 N·m (148 lb·ft). Ensure all bolts have been tighten.
5. Remove the guide pins from the front of the crankshaft.

6. Install the FEPTO plate (hub) and secure with six bolts. Torque bolts in a criss-cross pattern to 60 N·m (45 lb·ft). See Figure 10-5.

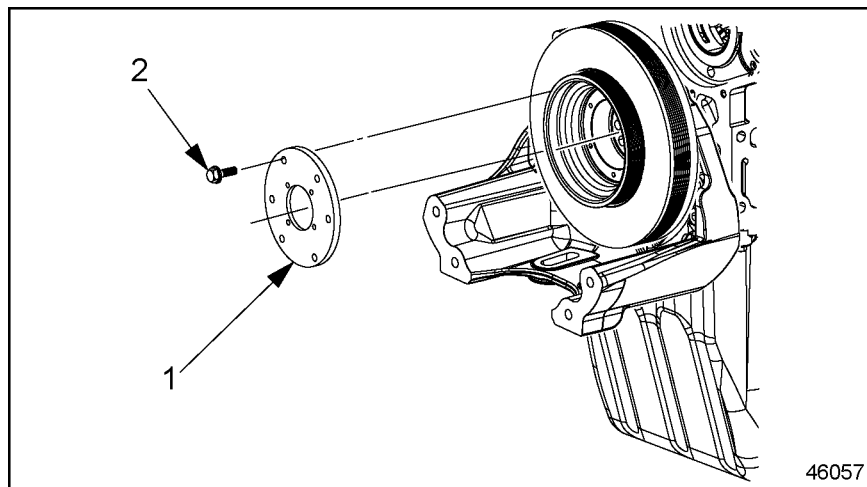


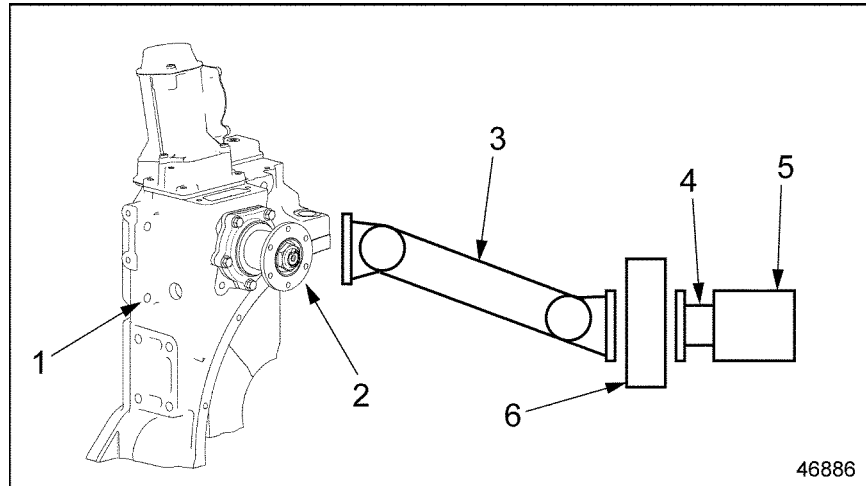
Figure 10-5 **FEPTO Hub Plate**

7. Install the drive belts on their pulleys, as removed. Refer to section 9.1.2 and section 9.1.4.
8. Install the lower mounting bolts of the front fairing/bumper, as removed.

10.2 REAR ENGINE POWER TAKE-OFF

A Rear Engine Power Take-Off (REPTO) accessory drive is available as an option on the MBE 4000 engine. The drive provides continuous live power anytime the engine is operating. The REPTO is driven by the camshaft gear and is an integral part of a unique SAE#1 flywheel housing.

All REPTO installations require a torsional damper coupling (P/N: 906 250 00 01) installed at the flange of the driven unit (e.g. hydraulic pump). The torsional coupling is a rubber element design to reduce the unwanted stresses reaching the engine. The torsional coupling is available as a service part from Detroit Diesel Corporation. See Figure 10-6.



- | | |
|---------------------|-----------------------|
| 1. Flywheel Housing | 4. Flange |
| 2. REPTO Unit | 5. Driven Unit |
| 3. Cardan Shaft | 6. Torsional Coupling |

Figure 10-6 MBE 4000 REPTO Connection Illustration

10.2.1 Inspection of Torsional Coupling

NOTE:

The torsional coupling must be replaced during normal engine overhaul, contact the Customer Support Center for further details.

Inspection steps are as follows:

1. Visually inspect the outer case of the torsional coupling for dents and bulges.
 - [a] If damage was detected, replace the with a new torsional coupling.
 - [b] If no damage was detected, reuse the torsional coupling and go to step 2.
2. Inspect the rubber element of the torsional coupling for bulges and cracking.
 - [a] If damage was detected, replace with a new torsional coupling.
 - [b] If no damage was detected, reuse the torsional coupling and go to step 3.
3. Inspect the rubber element teeth for wear. See Figure 10-7.

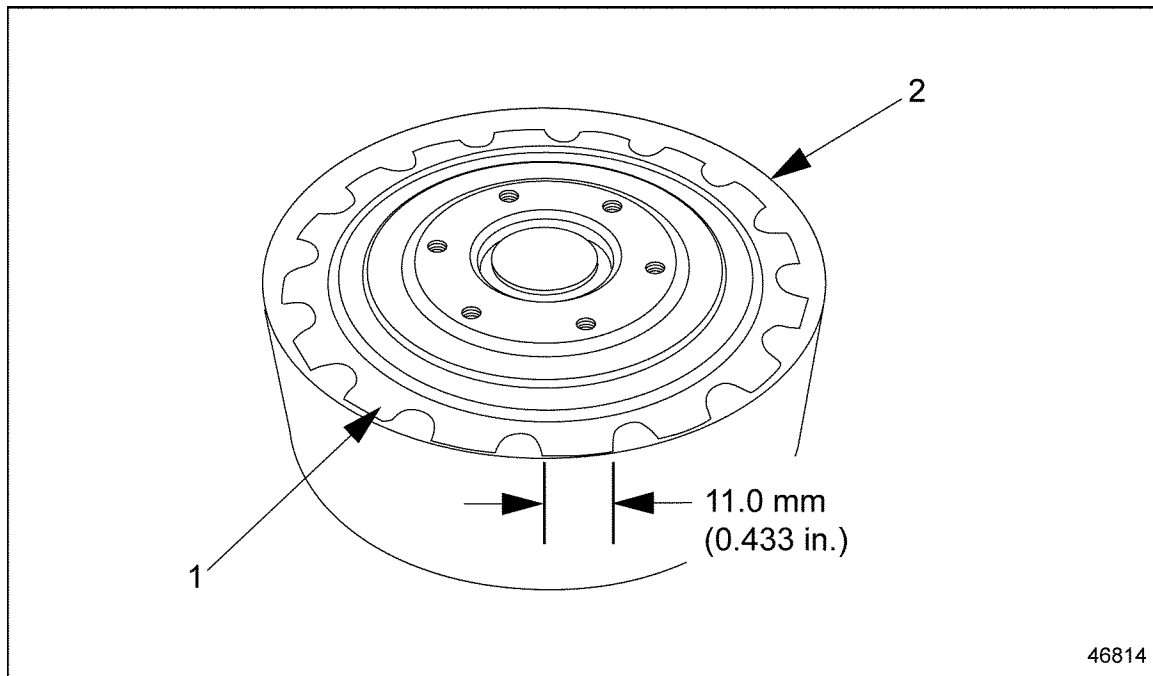


Figure 10-7 Torsional Coupling

- [a] If the rubber element teeth are worn less than one-half of the original length 11.0 mm (0.433 in.), replace with a new torsional coupling.
- [b] If no damage was detected, reuse the torsional coupling.

11 SPECIAL EQUIPMENT

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11.2 AIR COMPRESSOR	11-5
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11.1 AIR COMPRESSOR FLANGE

The air compressor flange is attached to the air compressor housing. Perform the following procedures for removal and installation of the air compressor flange and O-ring.

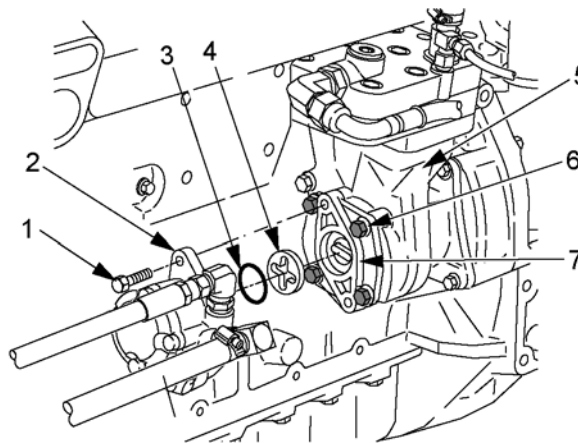
11.1.1 Removal of Air Compressor Flange

Remove as follows:

1. Shut off engine and apply the parking brake, chock the wheels, disconnect vehicle battery power, and perform any other applicable safety steps.
2. Remove the two bolts attaching the power steering pump to the air compressor.

NOTE:

Do not remove the power steering lines. Tie up the lines and move the pump out of the way.



d130028

- | | |
|--------------------------------------|---------------------------------|
| 1. Power Steering Pump Mounting Bolt | 5. Air Compressor Housing |
| 2. Power Steering Pump | 6. Air Compressor Mounting Bolt |
| 3. O-ring | 7. Air Compressor Flange |
| 4. Cross Plate | |

Figure 11-1 Air Compressor

3. Remove the cross plate between the compressor and the power steering pump.
4. Discard the O-ring between the power steering pump and the air compressor.

NOTICE:

When removing the flange, make sure not to damage the crankshaft journal or crankshaft bearing.

5. Remove the four bolts attaching the air compressor flange to the air compressor housing.
6. Discard O-ring between the air compressor flange and air compressor housing.
7. Inspect air compressor flange, bearing, and O-ring surfaces for damage. Replace if necessary.

11.1.2 Installation of Air Compressor Flange

Installation steps are as follows:

1. Install the new O-ring between the air compressor flange and air compressor housing.

NOTICE:

Make sure to not damage the crankshaft journal or crankshaft bearing while installing.

2. Install the air compressor flange using the four bolts. Torque to 30 N·m (22 lb·ft).

NOTE:

Use grease to hold the cross plate in place while installing the power steering pump.

3. Install the cross plate.

NOTICE:

Make sure not to damage the bolt threads when installing the power steering pump to the air compressor.

4. Install the two bolts attaching the power steering pump to the air compressor. Torque to 40 N·m (30 lb·ft).

11.2 AIR COMPRESSOR

The air compressor, with a power-steering pump attached, is driven by a gear on the camshaft. Perform the following procedures for removal and installation of the air compressor.

11.2.1 Removal of Air Compressor

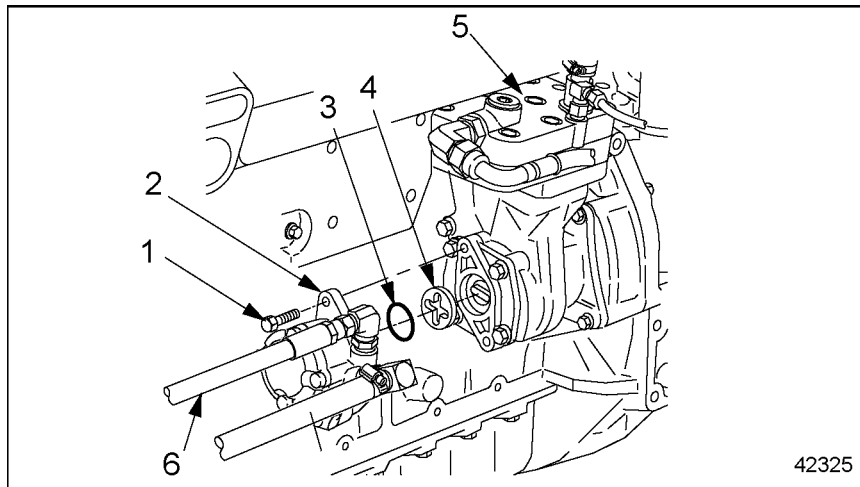
Removal steps are as follows:

WARNING:

HOT COOLANT

To avoid scalding from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Wear adequate protective clothing (face shield, rubber gloves, apron, and boots). Remove the cap slowly to relieve pressure.

1. Drain the coolant.
2. Remove the two bolts attaching the power steering pump to the air compressor. See Figure 11-2.



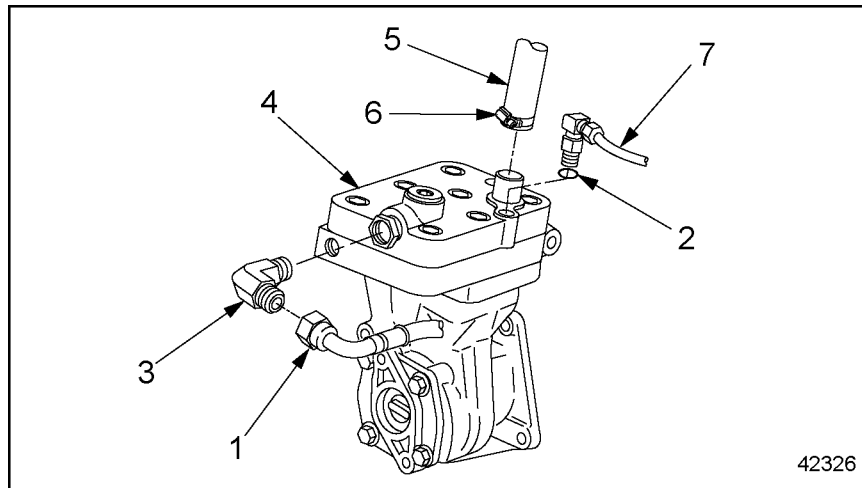
- | | |
|------------------------|--------------------|
| 1. Mounting Bolt | 4. Cross Plate |
| 2. Power Steering Pump | 5. Air Compressor |
| 3. O-ring | 6. Hydraulic Lines |

Figure 11-2 Power Steering Pump

NOTE:

Do not remove the power steering lines. Tie up the lines and move the pump out of the way.

3. Remove the cross plate between the compressor and the power steering pump.
4. Remove the three air lines. See Figure 11-3.



- | | |
|-----------------------|----------------------|
| 1. Discharge Air Line | 5. Intake Air Line |
| 2. O-ring | 6. Hose Clamp |
| 3. 90° Elbow | 7. Unloader Air Line |
| 4. Air Compressor | |

Figure 11-3 Air Line Attachments

 WARNING:
PERSONAL INJURY
To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles.

- [a] Remove the discharge (compressed air) line and the 90° elbow. Check inside the discharge line for carbon deposits. If deposits are found, replace the discharge line.

NOTE:

The 90° elbow on the discharge line must be removed to allow removal of the engine trim cover.

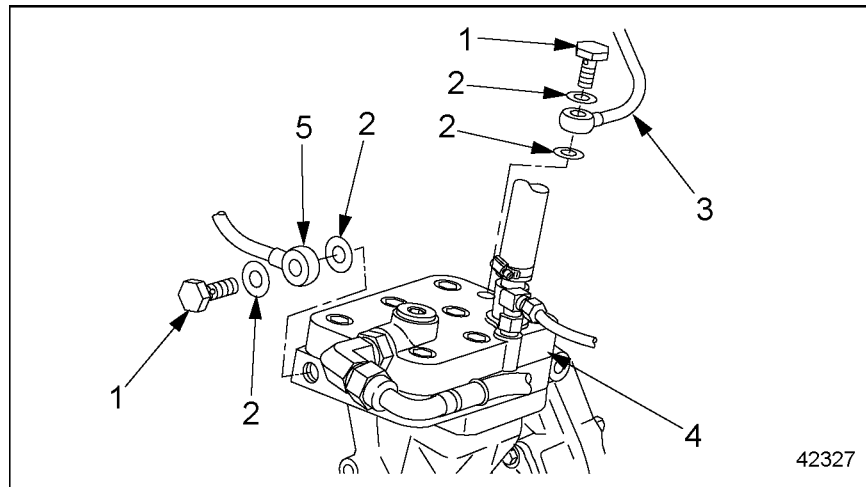
- [b] Remove the unloader line. Check the fittings for damage and replace if necessary.
- [c] Loosen the hose clamp and remove the intake (suction) air line.

5. Remove the engine trim cover. Refer to section 1.1.1.

NOTE:

The bottom of the engine trim cover overhangs the coolant delivery line fasteners, making them difficult to remove.

6. Remove the coolant delivery line and coolant return line. Discard the seal rings. See Figure 11-4.

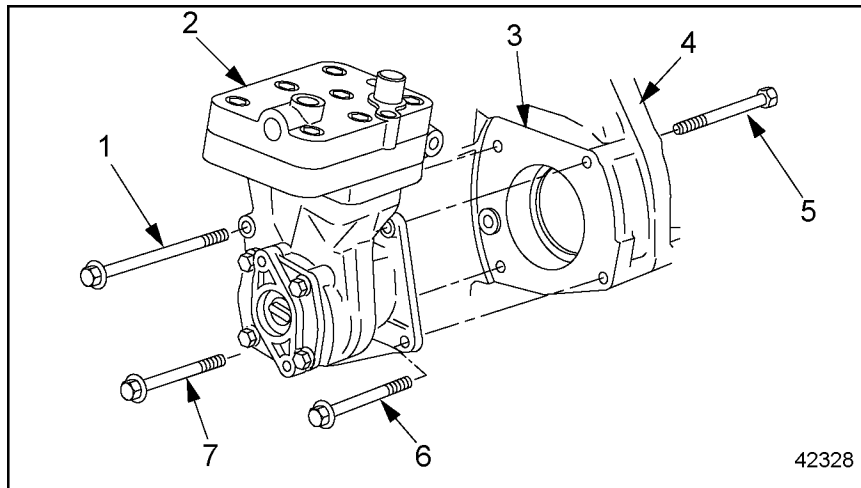


1. Hollow-Core Banjo Bolt
2. Seal Ring
3. Coolant Delivery Line

4. Air Compressor
5. Coolant Return Line

Figure 11-4 **Air Compressor Coolant Lines**

7. Remove the four mounting bolts attaching the air compressor to the crankcase. See Figure 11-5.



- | | |
|--------------------------------|---------------------------------|
| 1. Inboard Upper Mounting Bolt | 5. Outboard Upper Mounting Bolt |
| 2. Air Compressor | 6. Outboard Lower Mounting Bolt |
| 3. Cylinder Block | 7. Inboard Lower Mounting Bolt |
| 4. Flywheel Housing | |

Figure 11-5 Air Compressor Mounting

NOTE:

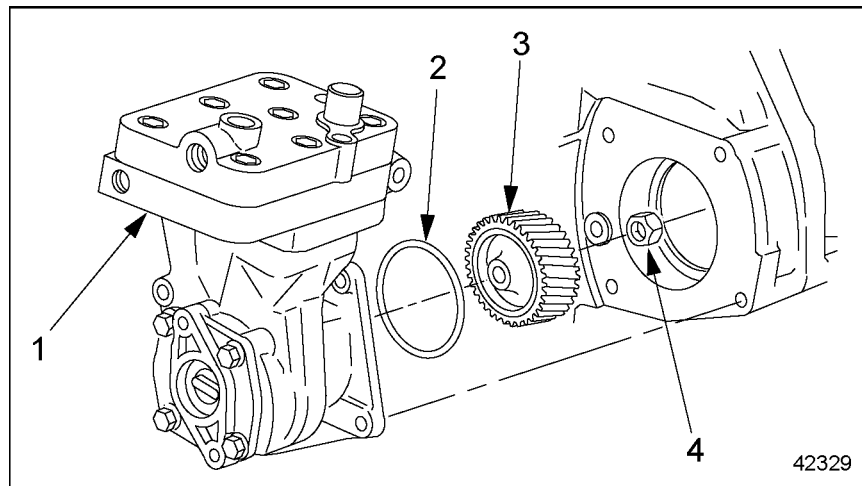
The mounting bolts are of different lengths. The outboard upper mounting bolt is removed from the rear.

8. Slide the drive gear away from the flywheel. Catch any oil that runs out and dispose of it properly.

11.2.1.1 Inspection of Air Compressor

Inspection steps are as follows:

1. Inspect the O-rings on the fittings at the air system ports and replace if necessary. If the O-rings are damaged, replace the fittings also.
2. Replace the O-ring between the power steering pump and the air compressor.
3. Install the locking device (J-46177) on the driveshaft end of the air compressor. This locks the driveshaft to allow removal of the drive nut.
4. Remove the drive gear from the air compressor.
 - [a] Place the air compressor and locking device (J-46177) in a vise. Make sure the locking device is tightly secured and cannot slip or slide out of the vise.
 - [b] Using an impact wrench, remove the drive nut from the drive gear.
 - [c] Remove the locking device (J-46177) from the air compressor and the vise.
 - [d] Remove the drive gear from the air compressor with a gear puller, if necessary.
 - [e] Discard the O-ring on the driveshaft end of the air compressor.
5. Inspect the drive gear for worn or broken teeth, spalling, and corrosion. Replace the drive gear if necessary.
6. Install the drive gear, drive nut, and a new O-ring on the driveshaft end of the air compressor. Tighten the drive nut 290 N·m (214 lb·ft). See Figure 11-6.



1. Air Compressor

2. O-ring

3. Drive Gear

4. Drive Nut

Figure 11-6 Air Compressor Drive Gear

7. Release the air compressor from the vise.

11.2.2 Installation of Air Compressor

Installation steps are as follows:

1. Install the air compressor.
2. Install the four air compressor mounting bolts. Tighten each bolt 60 N·m (44 lb·ft). See Figure 11-5.

NOTE:

Be sure the correct mounting bolt is mounted at each location. The outboard upper mounting bolt is installed from the rear.

3. Install the two coolant lines.
 - [a] Replace the seal rings on the coolant lines.
 - [b] Install the coolant delivery line at the rear of the air compressor. Tighten the hollow-core banjo bolt 30 N·m (22 lb·ft).
 - [c] Install the coolant return line at the front of the air compressor. Tighten the hollow-core banjo bolt 30 N·m (22 lb·ft).
4. Install the engine trim cover. Refer to section 1.1.2.
5. Install the three air lines. See Figure 11-3.
 - [a] Install the discharge line and the 90° elbow. Make sure the O-ring is properly installed on the fitting.
 - [b] Install the uploader line. Make sure the O-ring is properly installed on the fitting.
 - [c] Tighten the fittings 80 N·m (60 lb·ft).
 - [d] Install the intake air line and tighten the hose clamp.
6. Install the cross plate. Use grease to hold it in place while installing the power steering pump.
7. Install the two bolts attaching the power steering pump to the air compressor. Tighten the bolts 40 N·m (30 lb·ft).
8. Fill the radiator with coolant.

11.A ADDITIONAL INFORMATION

Description	Page
SPECIFICATIONS	11-11
Air Compressor	11-11

SPECIFICATIONS

This section contains the specifications for servicing the engine.

Air Compressor

The torque values for the air compressor are listed in Table 11-1. The air governor torque values are listed in Table 11-2.

Description	Torque N·m (lb·ft)
Air Compressor Mounting Bolts	60 (44)
Discharge Line Fitting	80 (60)
Coolant Line Banjo Bolts	30 (22)
Drive Nut	290 (214)
Power Steering Pump Mounting Bolts	40 (30)

Table 11-1 Air Compressor Torque Values

Description	Torque N·m (lb·ft)
Air Governor Mounting Bolt, M8	25 (18)

Table 11-2 Air Governor Torque Values

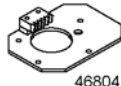
Tool	Description	Usage	Part Number
 46804	Air Compressor Locking Device	Used to lock the drive shaft on the air compressor.	J-46177

Table 11-3 Special Tools

12 OPERATION AND VERIFICATION

Section	Page
12.1 PREPARATION FOR A FIRST TIME START	12-3
12.2 STARTING THE ENGINE	12-8
12.3 RUNNING THE ENGINE	12-11
12.4 STOPPING THE ENGINE	12-13
12.A ADDITIONAL INFORMATION	12-15

12.1 PREPARATION FOR A FIRST TIME START

NOTE:

Before starting the engine, do all the recommended pretrip inspections and daily maintenance. Check the engine oil and fuel levels, and drain contaminants from the fuel/water separator (optional).

NOTE:

If you drain the fuel/water separator completely, you may have to prime the fuel system.

Read the appropriate chapters in the driver's manual for detailed information on instruments, gauges, and controls. Be sure you are familiar with all of the instruments, gauges and controls which are needed to operate the engine.

Note especially the location and function of the following:

- ☐ Oil pressure gauge
- ☐ Low oil pressure warning light
- ☐ Coolant temperature gauge
- ☐ High coolant temperature warning light
- ☐ Water in fuel warning light
- ☐ Tachometer
- ☐ Air restriction indicator

When you start the engine, and while you are driving, watch for any signs of engine problems. If the engine overheats, uses excessive fuel or lubricating oil, vibrates, misfires, makes unusual noises, or shows an unusual loss of power, turn the engine off as soon as possible and determine the cause of the problem. Frequently, engine damage may be avoided by a quick response to early indications of problems.

12.1.1 Checking the Batteries

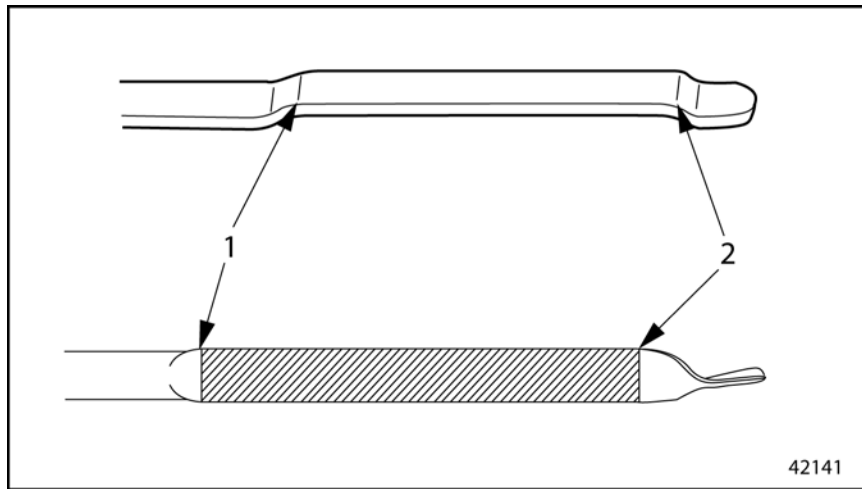
Use only batteries that have been correctly filled and serviced. To provide corrosion protection, apply pumpable dielectric grease, part number 48-02349-000, liberally to the terminal pads. Approved suppliers are listed in Table 12-1.

Manufacturer	Lubricant or Part Number
Shell Oil Co.	No. 71032; No. 71306
Texaco, Inc.	No. 955
Quaker State	No. NYK-77

Table 12-1 Approved Electrical Lubricants

12.1.2 Checking the Oil Level

1. Check the oil level using the oil dipstick. See Figure 12-1.

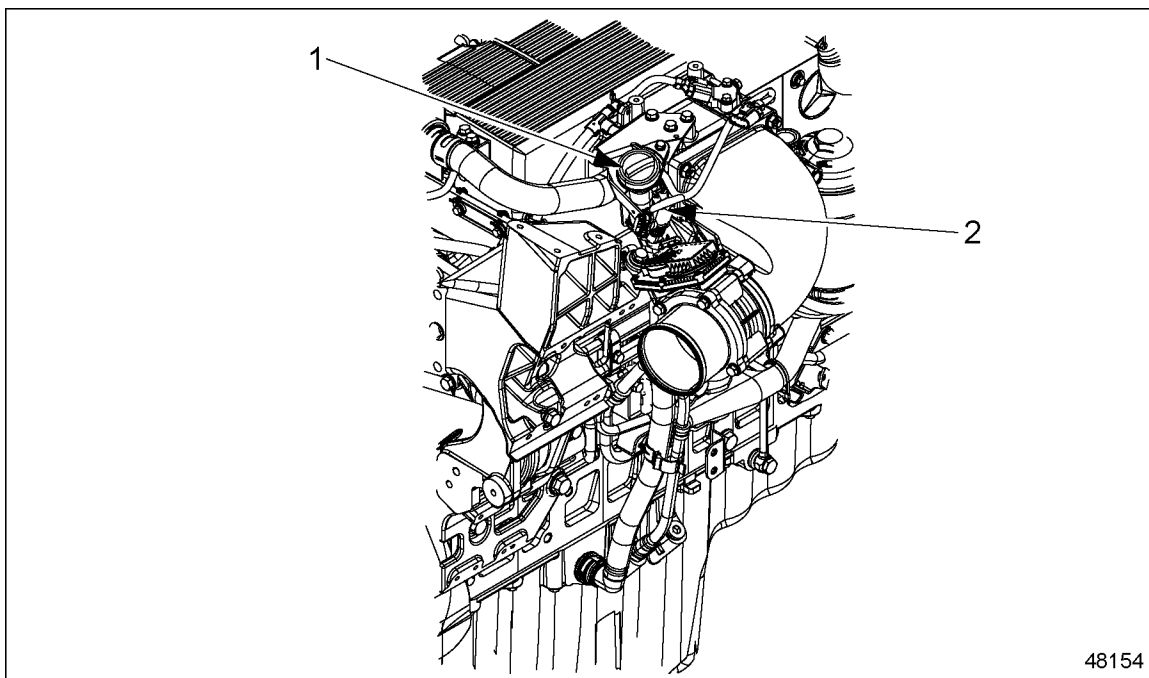


1. Maximum Fill Level

2. Minimum Fill Level

Figure 12-1 Oil Dipstick

2. If necessary, top off by filling engine oil through the oil fill cap until the maximum fill level on the oil dipstick has been reached. See Figure 12-2.



1. Oil Fill Cap

2. Oil Dipstick

Figure 12-2 Oil Fill Cap

12.1.3 Checking the Coolant Level (Cold Check)

Check coolant level as follows:

1. Ensure that all coolant plugs in the bottom of the radiator and on the radiator outlet pipe are secure and tight.
2. Check the coolant level. The cooling system is correctly filled when the coolant is between the maximum and minimum marks on the surge tank.

12.1.4 Adding Fuel

When adding fuel, pay attention to the following:

- ☐ Add winter or summer grade fuel according to the season of the year. Refer to publication *Engine Requirements – Lubricating Oil, Fuel and Filters*, (7SE270), available from authorized Detroit Diesel distributors.
- ☐ Work in the cleanest conditions possible.
- ☐ Prevent water from entering the fuel tank.

12.1.5 Priming the Fuel System

Prime the fuel system as follows:

NOTICE:
Correct torque on the high-pressure lines is critical. Incorrect torques could result in leaks or lack of power due to restricted fuel flow.

1. Make sure that all high-pressure lines have been tightened to 35–37 N·m (26–27 lb·ft) and all banjo bolts to 45-50 N·m (33-37 lb·ft).



2. If equipped with a hand pump on the fuel/water separator, work the hand pump until resistance is felt.

3. Use the diesel fuel system primer (J-47912) to prime the fuel system See figure 12-3

NOTE:

There should be a strong resistance in the hand pump caused by the pressure build-up within the system.

NOTE:

DDC does not recommend opening the high-pressure lines and bleeding the air from the fuel system while cranking the engine.

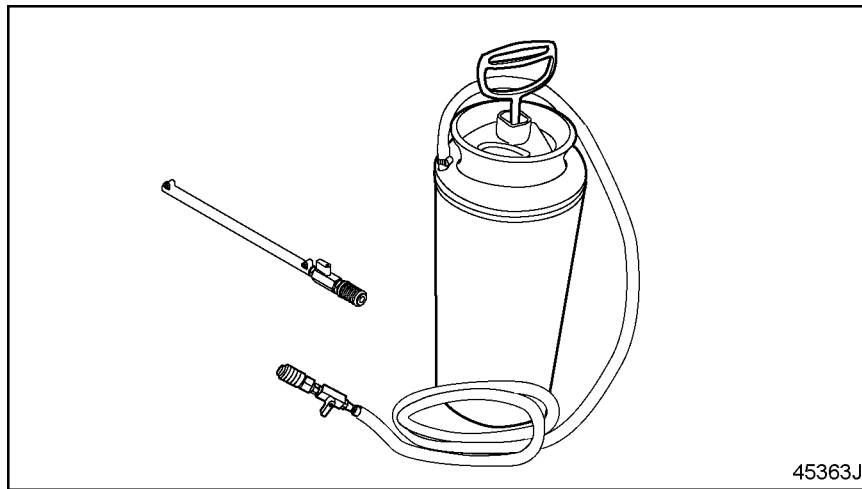
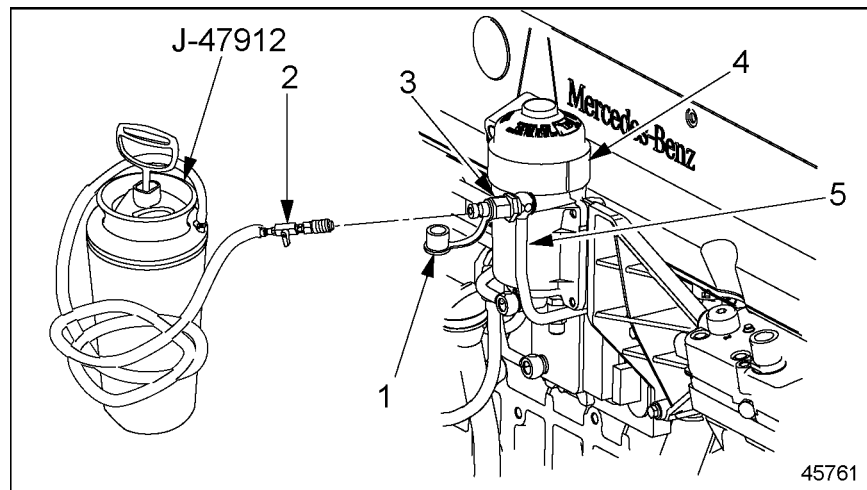


Figure 12-3 Diesel Fuel System Primer Tool J-47912

4. Fill the fuel system primer three-fourths full with fuel oil.

5. Remove the dust cover from the priming valve and connect the line from the primer tank to the priming valve on the secondary fuel filter. Close the valve on the priming line. See Figure 12-4



- | | | |
|-------------|--------------------------|-----------------------|
| 1. Dust Cap | 3. Priming Nipple Valve | 5. Fuel Delivery line |
| 2. Valve | 4. Secondary Fuel Filter | |

Figure 12-4 Priming the Fuel Filter

6. Pump the primer tank numerous times to build up pressure.
7. Open the valve on the priming line and wait 60 seconds for system to fill.
8. Crank the engine for 30 seconds at a time, but *no longer*. Before cranking the engine again, wait at least two minutes. The engine should start within four 30-second attempts.
9. Once the engine starts and runs smoothly, close the valve and disconnect the priming line from the priming nipple valve on the secondary fuel filter. Install the dust cap on the priming nipple valve.
10. Slowly release the pressure on the diesel fuel system primer (J-47912) by slightly turning the pumping handle counter-clockwise.
11. With the engine running, check the fuel filter for leaks. Repair any leaks found.
12. Shut down the engine.

12.2 STARTING THE ENGINE

Before operating the engine, do the work described under "Preparation for a First Time Start." Start the engine as follows:

NOTICE:

Never attempt to start any Mercedes-Benz electronic engine using ether or any other starting fluid. Serious engine damage could result.

NOTE:

As a safety function, the electronic engine control system allows the engine to start only if the transmission is in neutral.

**WARNING:****PERSONAL INJURY**

To avoid injury when working near or on an operating engine, remove loose items of clothing and jewelry. Tie back or contain long hair that could be caught in any moving part causing injury.

1. Turn on the ignition switch.
2. With the accelerator pedal in the idle position, start the engine.
3. Check the engine for leaks.
 - [a] Check all hoses, hose clamps, and pipe unions on the engine for tightness. Shut down the engine and tighten them if necessary.
 - [b] Check the oil feed and return lines at the turbocharger for tightness. Shut down the engine and tighten them if necessary.
4. Shut down the engine.
5. Approximately five minutes after shutdown, check the engine oil level. If necessary, add oil up to the maximum fill level on the oil dipstick.
6. Check all the mounting fasteners on the engine for tightness.

12.2.1 Checking the Coolant Level (Hot Check)

Check the coolant levels as follows:

1. Allow the engine to run for approximately five minutes at a moderate speed.



WARNING:

HOT COOLANT

To avoid scalding from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Wear adequate protective clothing (face shield, rubber gloves, apron, and boots). Remove the cap slowly to relieve pressure.

2. Then, with the coolant temperature above 50°C (122°F), recheck the coolant level.
3. Add more coolant if necessary. Open the heater valves before adding coolant.
4. Do not close the heater valves until the engine has been run briefly and the coolant level again checked and corrected as necessary.

12.2.2 Starting an Engine That Has Not Been Run for a Long Time

Before starting an engine which has not been run for a long time, certain special work must be carried out.

NOTE:

At outside temperatures below -20°C (-4°F), a coolant preheater is recommended.



WARNING:

PERSONAL INJURY

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Chock the tires, place the transmission in neutral, and set the parking brake.
2. Turn on the ignition switch and start the engine



WARNING:
ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

3. If the engine doesn't start after 20 seconds, stop. Try again after waiting about one minute.

NOTICE:

Do not rev the engine if the oil pressure gauge indicates no oil pressure. To avoid engine damage, shut down the engine if no oil pressure appears within approximately ten seconds. Check to determine the cause of the problem.

4. Monitor the oil pressure gauge immediately after starting the engine.

NOTE:

Do not place the engine under full load until it reaches operating temperature.

12.3 RUNNING THE ENGINE

The following sections cover normal operations:

12.3.1 Battery Charge

The battery charge indicator light must go out once the engine starts.

If the indicator light comes on while the engine is running, do the following:

1. Shut down the engine.
2. Check the poly-vee belt for tightness.



WARNING:

FIRE

To avoid injury from fire, keep all potential ignition sources away from diesel fuel, including open flames, sparks, and electrical resistance heating elements. Do not smoke when refueling.

3. Do a load test on the batteries. Charge or replace the batteries as needed.
4. If necessary, visit the nearest authorized dealer to have the alternator voltage and output checked.

12.3.2 Oil Pressure

When the engine has reached its normal operating temperature, the engine oil pressure must not drop below the following values:

- 250 kPa (36 psi) at rated speed
- 50 kPa (7 psi) at idling speed

If oil pressure drops below these values, stop the engine and determine the cause.

12.3.3 Excessive Idling

Never allow the engine to idle for more than 30 minutes. Excessive idling can cause oil to leak from the turbocharger.

12.3.4 Changing the Idle Speed

The rpm range of the MBE 4000 engine is 600 to 850 rpm if the parameters in the VCU are set to the default range.

Change the idling speed as follows:

1. Turn the cruise control switch to the OFF position.

2. To increase the idle speed, push the "Resume" switch until the idle is fast enough.
3. To decrease the idle speed, push the "Decel" switch until the idle is slow enough.

12.3.5 Emergency Running Mode

The engine is equipped with the electronic engine control system, which monitors the engine as it is running.

As soon as a fault is detected, it is evaluated and one of the following measures is initiated.

NOTICE:
To prevent possible serious engine damage, have any faults corrected without delay by an authorized dealer.

- In conjunction with any dashboard or instrument panel display, the code for the electronic control unit reporting the fault can be read immediately on the display.
- Complete fault codes are transmitted and can be read using DDDL® 7.0 or latest version.
- If the fault is serious enough to impair normal operation, the electronic engine system switches over to emergency running mode. When in emergency running mode, the engine operates at a constant 1300 rpm. This allows you to move the vehicle to a service location.

For fault codes and their meanings, see the *DDEC VI MBE 4000 Troubleshooting Guide* (6SE568).

12.4 STOPPING THE ENGINE

If the engine has been running at full output or the coolant temperature has been high, allow the engine to idle for one to two minutes without load.

Then turn off the ignition switch.

If any the following occur, shut down the engine immediately.

- ☐ The oil pressure swings back and forth or falls sharply.
- ☐ Engine power and rpm fall, even though the accelerator pedal remains steady.
- ☐ The exhaust pipe gives off heavy smoke.
- ☐ The coolant and/or oil temperature climb abnormally.
- ☐ Abnormal sounds suddenly occur in the engine or turbocharger.

12.4.1 Shutting Down After Hard Operation

After hard operation, do the following:

NOTICE:
After hard operation, allow the engine to idle for one to two minutes without load. Shutting down the engine without idling may cause damage to the turbocharger.

1. If the engine has been running at full output or the coolant temperature has been high, allow the engine to idle for one to two minutes without load.
2. Turn off the ignition switch and shut down the engine.

12.A ADDITIONAL INFORMATION

Description	Page
SPECIAL TOOLS	12-15

SPECIAL TOOLS

The special tools used within the chapter are listed in Table 12-2.

Tool	Description	Usage	Part Number
	Diesel Fuel System Primer	Used to prime the fuel system.	J-47912

Table 12-2 Special Tools

13 ENGINE TUNE-UP

Section	Page
13.1 CHECKING THE VALVE LASH	13-3
13.2 ADJUSTING THE VALVE LASH	13-9
13.A ADDITIONAL INFORMATION	13-11

13.1 CHECKING THE VALVE LASH

Checking steps are as follows:

NOTE:

Adjust the valve lash when the engine is cold. Wait at least 30 minutes after shutdown, even if the engine ran only a short time.

Select a method for adjusting the valves. There are two acceptable methods for adjusting the valves, prior to checking the valve lash:

- In order, according to the timing sequence used for fuel injection (see Method One—Adjust Each Cylinder in Firing Order);
- By type of valve, depending on crankshaft position (see Method Two—Adjust All Valves Using Two Crankshaft Positions). See Figure 13-1 for the cylinder and valve layout on MBE 4000 engines.

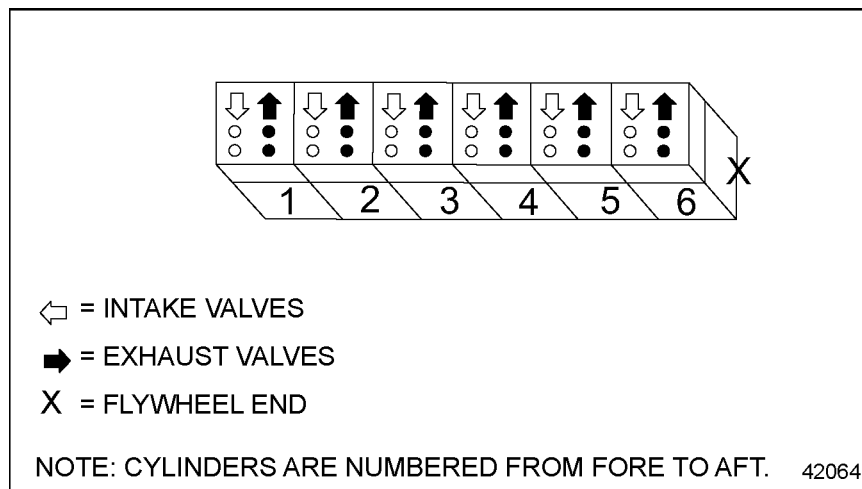


Figure 13-1 **Cylinder and Valve Layout**

13.1.1 Method One — Adjust Each Cylinder in Firing Order

Method one allows you to adjust each cylinder in the order in which fuel is injected. The crankshaft must be repositioned after each cylinder is adjusted as listed in Table 13-1.

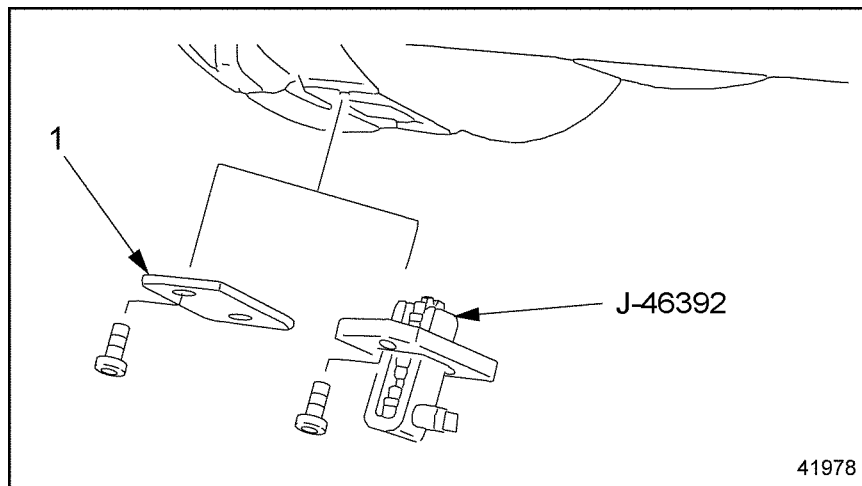
Engine	Crank-shaft Po-sition	Cylinders	Cylinders	Cylinders	Cylinders	Cylinders	Cylinders
MBE 4000	Ignition TDC	1	5	3	6	2	4
MBE 4000	Valve Overlap	6	2	4	1	5	3

Table 13-1 Valve Adjustment (Method One)

NOTE:

Clean each cylinder head cover before removing it.

1. Remove the cylinder head covers. Refer to section 1.2.1.
2. Remove the inspection cover on the flywheel housing.
3. Install the engine barring tool (J-46392) into the inspection hole on the flywheel housing. See Figure 13-2.



1. Inspection Cover

Figure 13-2 Placement of Engine Barring Tool

4. For each cylinder, use the engine barring tool (J-46392) to turn over the crankshaft until the piston is exactly at top dead center (TDC) in the compression stroke. The valves must be closed and it must be possible to turn the pushrods without effort.

NOTE:

When the piston in cylinder #1 is at ignition TDC, the valves of cylinder #6 will overlap, meaning that both intake and exhaust valves are partially open, and show no measurable play when tested with a feeler gauge.

5. Check each valve and adjust it (if necessary), using the procedures under the heading "Adjusting Valve Lash."
6. For each valve, measure the valve lash with an angled feeler gauge between the rocker arm and valve bridge. It should be possible to pull the feeler gauge through with light resistance.

Valve Type	Adjust to: mm (inches)
Intake	0.40 mm (0.016 in.)
Exhaust	0.60 mm (0.024 in.)

Table 13-2 Valve Lash Checking and Adjustment

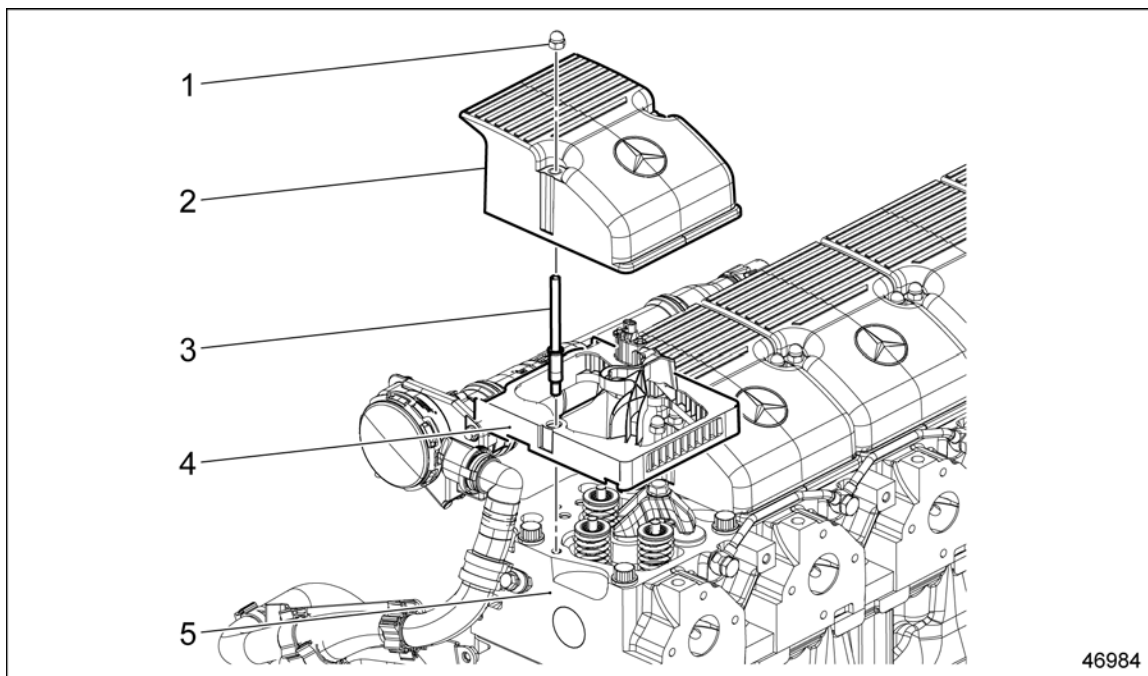
13.1.2 Method Two — Adjust All Valves Using Two Crankshaft Positions

Method two allows you to adjust all the valves using just two crankshaft positions.

NOTE:

Clean each cylinder head cover before removing it.

1. Remove the cylinder head covers. See Figure 13-3. Refer to section 1.2.1.



- | | |
|------------------------|------------------|
| 1. Nut | 4. Bridge |
| 2. Cylinder Head Cover | 5. Cylinder Head |
| 3. Stud | |

Figure 13-3 **Cylinder Head Cover and Related Components**

2. Remove the inspection cover on the flywheel housing.

3. Attach the engine barring tool (J-46392) into the inspection hole on the flywheel housing. See Figure 13-4.

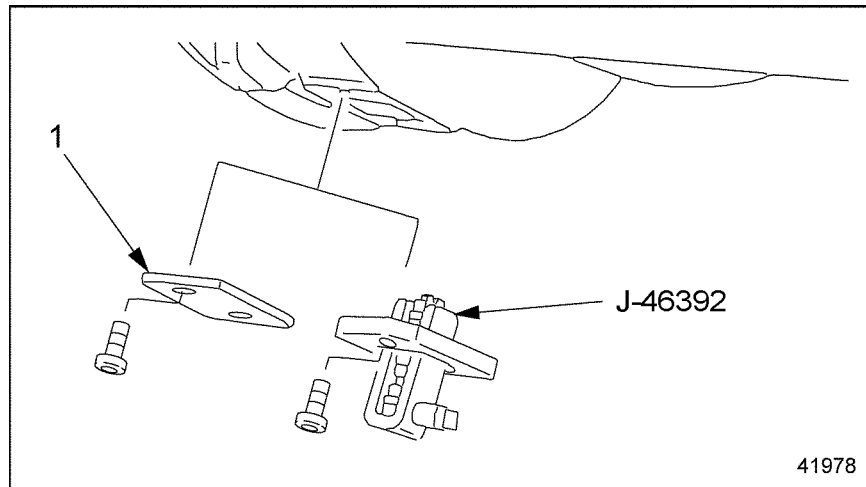


Figure 13-4 **Placement of Engine Barring Tool**

4. Using the engine barring tool (J-46392), turn the crankshaft until cylinder #1 is at the ignition TDC position (all valves are closed) and cylinder #6 is at the valve overlap position (all valves are open).

NOTE:

When the piston in cylinder #1 or #6 is at ignition TDC, there will be a small beveled alignment mark visible through the inspection hole. See Figure 13-5.

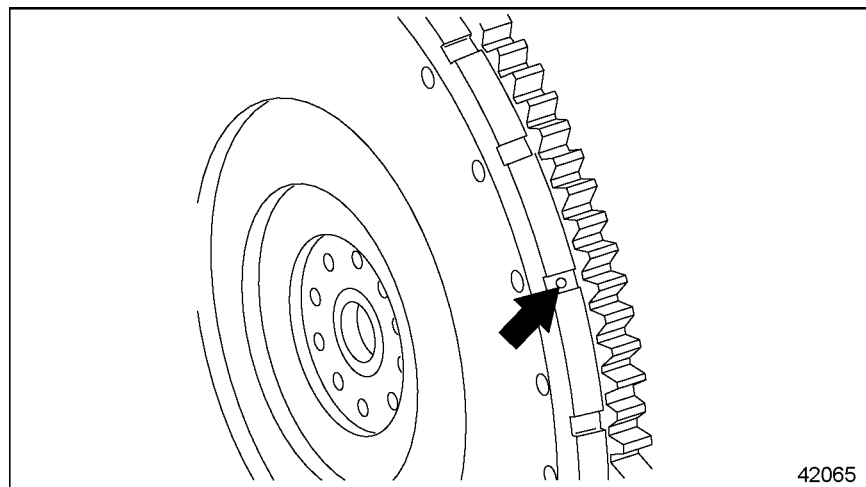


Figure 13-5 **Flywheel Alignment Mark**

5. Check the valves in the "Ignition TDC" row listed in Table 13-3, and adjust them (if necessary), using the procedures under the headings "Checking Valve Lash" and "Adjusting Valve Lash."

Engine	Cylinder #1 Crankshaft Position	Cylinder Valves/Types*	Cylinder Valves/Types*	Cylinder Valves/Types*	Cylinder Valves/Types*	Cylinder Valves/Types*	Cylinder Valves/Types*
		1	2	3	4	5	6
MBE 4000	Ignition TDC	I/E	I	E	I	E	—
MBE 4000	Valve Overlap	—	E	I	E	I	I/E

* I= Intake Valve and E= Exhaust Valve

Table 13-3 Valve Adjustment (Method Two)

6. Using the engine barring tool (J-46392), turn the crankshaft until cylinder #6 is at the ignition TDC position (all valves are closed) and cylinder #1 is at the valve overlap position (all valves are open).
7. Using the same procedure, check the valves in the "Valve Overlap" row listed in Table 13-3 and adjust them (if necessary), using the procedures under the headings "Checking Valve Lash" and "Adjusting Valve Lash."
8. For each valve, measure the valve lash with a feeler gauge between the rocker arm and valve bridge. It should be possible to pull the feeler gauge through with light resistance.

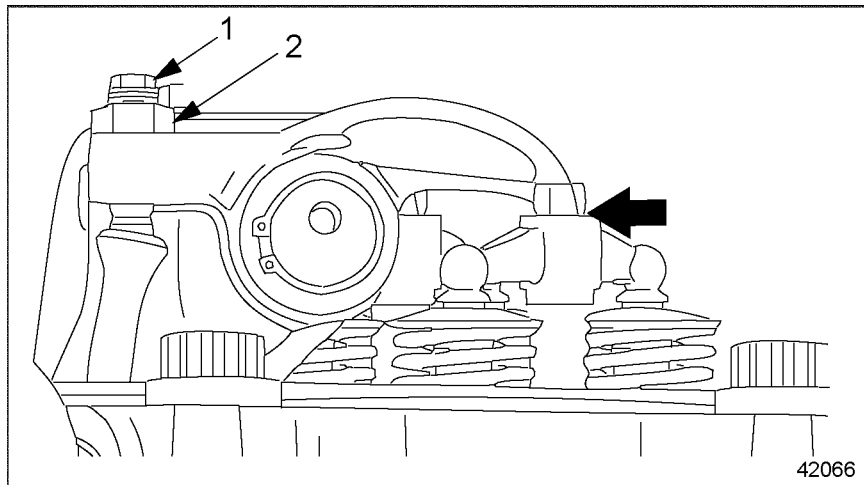
Valve Type	Adjust to: mm (inches)
Intake	0.40 mm (0.016 in.)
Exhaust	0.60 mm (0.024 in.)

Table 13-4 Valve Lash Checking and Adjustment

13.2 ADJUSTING THE VALVE LASH

Adjustment steps are as follows:

1. If adjustment is needed, unscrew the locknut. See Figure 13-6. Turn the adjusting screw until the valve lash is correct. Use the exact settings given in the "Adjust To" column listed in Table 13-4.



1. Adjusting Screw

2. Locknut

Figure 13-6 **Valve Lash Adjustment**

NOTE:

When adjusting the valves, adjust to the exact setting. Use the range only for checking adjustment.

2. Tighten the locknut 50 N·m (37 lb·ft).
3. Check the valve lash again. Adjust again if necessary.
4. Install the cylinder head covers. Refer to section 1.2.2.
5. Remove the engine barring tool (J-46392) from the inspection hole in the flywheel housing.
6. Replace the end cover on the inspection hole and tighten the bolts 25 N·m (18 lb·ft).

13.A ADDITIONAL INFORMATION

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SPECIAL TOOLS

The special tools used within the chapter are listed in Table 13-5.

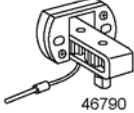
Tool	Description	Usage	Part Number
	Engine Barring Tool	Used to lock or rotate the engine flywheel.	J-46392

Table 13-5

14 PREVENTIVE MAINTENANCE

Section	Page
14.1 SCHEDULED INTERVALS	14-3

14.1 SCHEDULED INTERVALS

When performed on a regular basis, changing the engine oil and filters is the least costly way of obtaining safe and reliable vehicle operation. Added benefits and savings occur when you check that the valves, fuel injectors, and oil and cooling circuits are in good working order during oil changes.

The maintenance section of this manual explains when you should change your oil and what to look for when checking for wear or damage.

All service intervals and maintenance operations are based on the parts and accessories expressly approved for your engine.

The scope and frequency of maintenance work are determined by the engine's operating conditions: severe duty, short haul, or long haul.

Evidence of regular maintenance is essential if a warranty claim has to be submitted.

If optional equipment is installed, be sure to comply with the maintenance requirements for these extra items.

NOTE:

If the engine is stored for more than 18 months, the oil must be changed before the engine can be brought into service.

14.1.1 Maintenance Schedule Types

There are three types of maintenance schedule. To determine which schedule to use, find the distance traveled by the vehicle in a year, regardless of vehicle type.

- **Severe Service** - Severe Service applies to vehicles that annually travel up to 10,000 km (6000 miles) or that operate under severe conditions. Examples of Severe Service usage include: operation on extremely poor roads or where there is heavy dust accumulation; constant exposure to extreme hot, cold, salt-air, or other extreme climates; frequent short-distance travel; construction-site operation; city operation (fire truck, garbage truck); or farm operation.
- **Short Haul** - Short Haul applies to vehicles that annually travel up to 100,000 km (60,000 miles) and operate under normal conditions. Examples of Short-Haul usage are: operation primarily in cities and densely populated areas; local transport with infrequent freeway travel; or high percentage of stop-and-go travel.
- **Long Haul** - Long Haul (over-the-road transport) is for vehicles that annually travel more than 100,000 km (60,000 miles), with minimal city or stop-and-go operation. Examples of Long-Haul usage are: regional delivery that is mostly freeway miles; interstate transport; or any road operation with high annual mileage.

14.1.1.1 Maintenance Intervals

The three different schedules of vehicle usage severe, short haul, and long haul. For each schedule, the appropriate distance interval (in miles and kilometers) is given for performing and repeating each maintenance operation.

The descriptions of all maintenance operations, indicating all maintenance operation sets at which each operation must be performed are listed in tables. Listed in Table 14-1 are the intervals by engine hours which gives an engine hours conversion for applications that may require service intervals based on hours and not mileage. The intervals are based on a collaboration of field and fleet data. For a more accurate analyst of when fluids should be changed, such as engine oil, refer to publication *Engine Requirements – Lubricating Oil, Fuel and Filters*, (7SE270), available from authorized Detroit Diesel distributors. Listed in Table 14-2 is Severe Service. Listed in Table 14-3 is Short-Haul. Listed in Table 14-4 is Long-Haul.

These maintenance interval tables show which maintenance operation must be performed at the actual distances (in km or miles) for each maintenance operation. The schedule of actual distances is based on the intervals given in the Maintenance Schedule Table.

Procedure	Severe (hrs)	Short-Haul (hrs)	Long-Haul (hrs)
Engine Oil and Filter	300	500 — or 6 months	—
Fuel Filter	600	—	—
Valve Lash Adjustment	600 then every 1200	—	—

Table 14-1 Maintenance Intervals by Engine Hours

Miles (X 1000)	10	12	20	24	30	36	40	48	50	60	70	72
Km (X 1000)	17	19	32	38	50	57	68	77	84	100	113	116
Item	Procedure											
1. Lubricating Oil/Filter	R	—	R	—	R	—	R	—	R	R	R	—
2. Cooling System	Intervals are based on type of coolant used as listed in Table 14-7, Coolant Maintenance Intervals.											
3. Valve Lash Checking and Adjustment	First adjustment at 20,000 mi. (32,000 Km) and then every 40,000 mi. (68,000 Km)											
4. Drive Belts	I	—	I	—	I	—	I	—	I	I	I	—
5. Fuel/Water Separator	Inspect at every fuel fill. Replace when fuel level is at top of filter.											
6. Fuel Filters	—	R	—	R	—	R	—	R	—	R	—	R
7. Air System	I	—	I	—	I	—	I	—	I	I	—	—
8. Exhaust System	I	—	I	—	I	—	I	—	I	I	I	—
9. Air Compressor	I	—	I	—	I	—	I	—	I	I	I	—
10. Aftertreatment Device	Inspect same as exhaust system interval, ash removal at 450,000 Miles (724,000 Km)											
11. Vibration Damper	Replace at major overhaul or earlier if dented or leaking.											
12. REPTO torsional damper checking	10,000 mi. (16,000 Km) or 300 hours or 1 year, whichever comes first.											

I – Inspect, service, test, correct or replace as necessary.

R – Replace.

Table 14-2 Maintenance Intervals (Severe Service)

Miles (X 1000)	15	30	45	60	75	90	105	120	135	150	165	180
Km (X 1000)	25	50	75	100	125	150	169	193	217	241	266	290
Item	Procedure											
1. Lubricating Oil/Filter	R	R	R	R	R	R	R	R	R	R	R	R
2. Cooling System	Intervals are based on type of coolant used as listed in Table 14-7, Coolant Maintenance Intervals.											
3. Valve Lash Checking and Adjustment	First adjustment at 30,000 mi. (50,000 Km) and then every 60,000 mi. (100,000 Km)											
4. Drive Belts	I	I	I	I	I	I	I	I	I	I	I	I
5. Fuel/Water Separator	Inspect at every fuel fill. Replace when fuel level is at top of filter.											
6. Fuel Filters	—	R	—	R	—	R	—	R	—	R	—	R
7. Air System	I	I	I	I	I	I	I	I	I	I	I	I
8. Exhaust System	I	I	I	I	I	I	I	I	I	I	I	I
9. Air Compressor	I	I	I	I	I	I	I	I	I	I	I	I
10. Aftertreatment Device	Inspect same as exhaust system interval, ash removal at 450,000 Miles (724,000 Km)											
11. Vibration Damper	Replace at major overhaul or earlier if dented or leaking.											
12. REPTO torsional damper checking	First inspection at 60,000 mi. (100,000 Km) or 3000 hours and then every 30,000 mi (50,000 Km) or 1500 hours.											

I – Inspect, service, test, correct or replace as necessary.

R – Replace.

Table 14-3 Maintenance Intervals (Short Haul)

Miles (X 1000)	15	30	45	60	75	90	105	120	135	150	165	180
Km (X 1000)	25	50	75	100	125	150	169	193	217	241	266	290
Item	Procedure											
1. Lubricating Oil/Filter	R	R	R	R	R	R	R	R	R	R	R	R
2. Cooling System	Intervals are based on type of coolant used as listed in Table 14-7, Coolant Maintenance Intervals.											
3. Valve Lash Checking and Adjustment	First adjustment at 30,000 mi. (50,000 Km) and then every 60,000 mi. (100,000 Km)											
4. Drive Belts	I	I	I	I	I	I	I	I	I	I	I	I
5. Fuel/Water Separator	Inspect at every fuel fill. Replace when fuel level is at top of filter.											
6. Fuel Filters	—	R	—	R	—	R	—	R	—	R	—	R
7. Air System	I	I	I	I	I	I	I	I	I	I	I	I
8. Exhaust System	I	I	I	I	I	I	I	I	I	I	I	I
9. Air Compressor	I	I	I	I	I	I	I	I	I	I	I	I
10. Aftertreatment Device	Inspect same as exhaust system interval, ash removal at 450,000 Miles (724,000 Km)											
11. Vibration Damper	Replace at major overhaul or earlier if dented or leaking.											
12. REPTO torsional damper checking	First inspection at 60,000 mi. (100,000 Km) or 3000 hours and then every 30,000 mi (50,000 Km) or 1500 hours.											

I – Inspect, service, test, correct or replace as necessary.

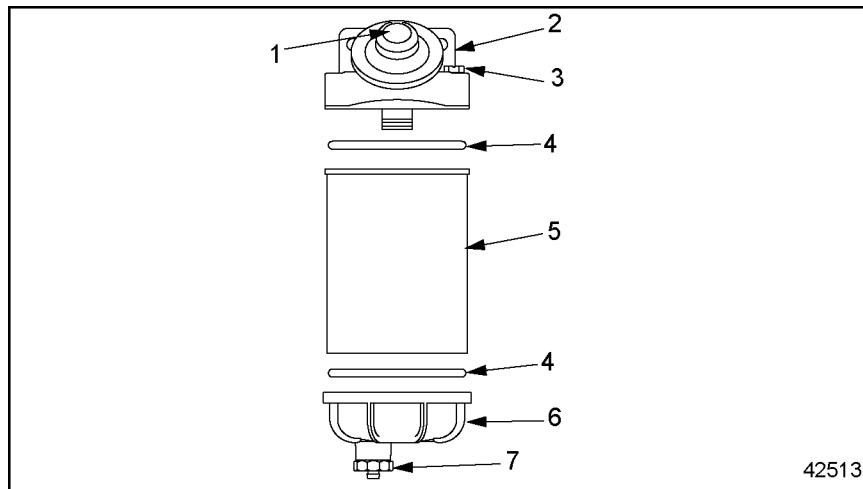
R – Replace.

Table 14-4 Maintenance Intervals for Schedule III, Long Haul

14.1.2 Fuel/Water Separator Pre-Filter Element Cleaning

Clean the pre-filter element as follows:

1. Loosen the bleed screw. See Figure 14-1.



- | | |
|-------------------|-----------------------|
| 1. Hand Pump | 5. Pre-Filter Element |
| 2. Separator Head | 6. Sight Bowl |
| 3. Bleed Screw | 7. Drain Plug |
| 4. O-ring | |

Figure 14-1 Fuel /Water Separator

2. Unscrew the drain plug and drain the fuel in the pre-filter.
3. Twist off the sight bowl and remove the filter element from the separator head.
4. Separate the sight bowl from the filter element. Clean the sight bowl. Discard the old filter element and both O-rings.
5. Replace the filter element and O-rings.
6. Assemble the sight bowl and the pre-filter element.
 - [a] Lubricate one O-ring with a light coating of engine oil.
 - [b] Insert the lubricated O-ring into the sight bowl.
 - [c] Screw the pre-filter element and sight bowl together.
7. Assemble the pre-filter element and the separator head.
 - [a] Lubricate the other O-ring with a light coating of engine oil.
 - [b] Insert the lubricated O-ring into the open end of the pre-filter element.
 - [c] Screw the pre-filter element onto the separator head and tighten firmly, using hands only.

NOTE:

Do not use tools to tighten the pre-filter element.

8. Insert the filter element into the pre-filter housing and screw the cap onto the housing. Tighten the cap 25 N·m (18 lb·ft).
9. Tighten the drain plug.
10. Prime the fuel system. Refer to section 12.1.5.

14.1.3 Removal of Fuel Filter

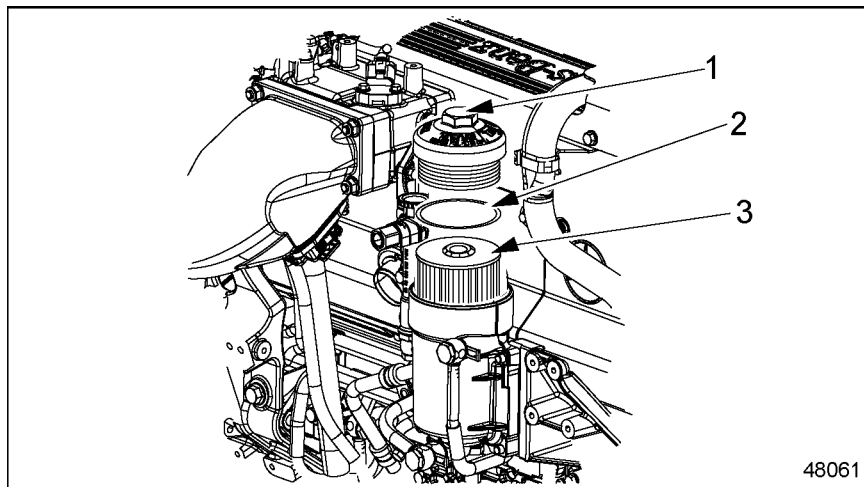
Removal steps are as follows:

WARNING:

FIRE

To avoid injury from fire, keep all potential ignition sources away from diesel fuel, including open flames, sparks, and electrical resistance heating elements. Do not smoke when refueling.

1. Disconnect the batteries.
2. Open the fuel tank fill cap to release pressure in the fuel system. Replace and tighten the cap.
3. Clean the outside of the fuel filter housing.
4. Using a 36-mm socket, unscrew the cap on the main fuel filter housing. Remove the cap and lift the filter element a short distance within the filter housing allowing the fuel to drain off the filter. Allow the fuel to drain off the filter into the housing.



1. Filter Housing Cap
2. O-ring

3. Fuel Filter Element

Figure 14-2 Fuel Filter



WARNING:
PERSONAL INJURY

To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles.

5. Remove the filter element from the cap and clean the fuel filter cap. Discard the filter element and the O-ring from the cap

NOTE:

Catch any fuel that runs out of the filter housing or fuel return line.

14.1.4 Installation of Fuel Filter

Installation steps are as follows:

1. Lubricate the filter element rubber seal with a light coating of fuel oil and insert it into the filter housing. Push down and rotate the filter element while installing to ensure it is seated properly at the base of the housing.
2. Fill fuel filter housing with clean fuel oil.

NOTE:

Note: A properly seated filter element will hold the fuel in the filter housing and prevent it from draining back to the tank. If the fuel does not stay in the housing the element is not seated properly, repeat steps 1 and 2.

3. Install a new O-ring on the filter cap and screw the cap onto the filter housing. Tighten the cap to 25 N·m (18 lb·ft).
4. Work the fuel pump until resistance is felt.

NOTE:

There should be a strong resistance in the hand pump, caused by the pressure build-up within the fuel system.

5. Connect the batteries.
6. Crank the engine for 30 seconds at a time, but no longer. Before cranking the engine again, wait at least two minutes. The engine should start within four 30-second attempts.

**WARNING:****ENGINE EXHAUST**

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

7. Once the engine starts allow it to idle for at least one minute or until idle is smooth before applying the throttle. Check the fuel filter housing for leaks.

NOTICE:

To avoid engine damage, never open the high pressure fuel lines to bleed off trapped air.

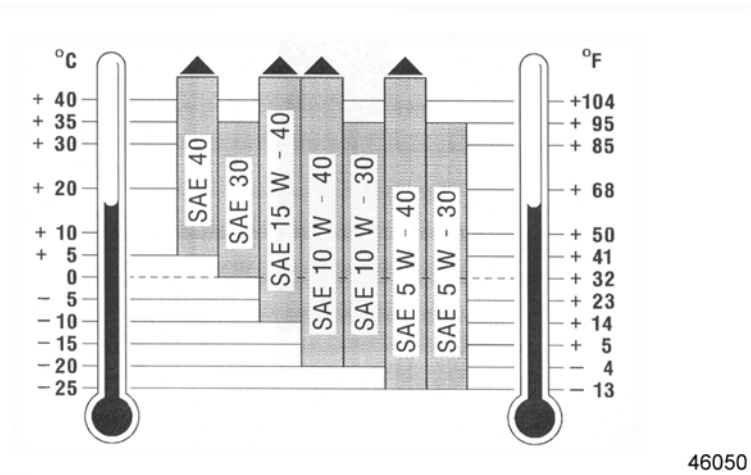
8. If the engine will not start and run smoothly, prime the fuel system.

14.1.5 Engine Oil and Filter Changing

Select the SAE class (viscosity) on the basis of the average air temperature for the season. See Figure 14-3.

NOTE:

Too strict adherence to the SAE classes will result in frequent oil changes. For this reason, view the temperature ranges for the various SAE classes as guidelines that can be exceeded for a short time.



46050

Figure 14-3 Engine Oil Temperature Ranges

Use approved multigrade oils to extend the temperature range.

To ensure the engine is protected and the oil stays clean until the next oil change, use only oils of API classification CJ-4.

Drain oil as follows:

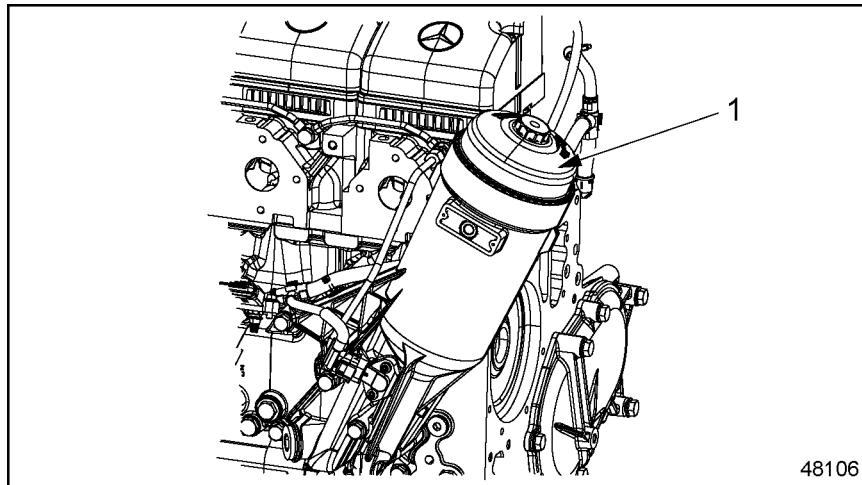
! WARNING: PERSONAL INJURY
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Chock the tires, place the transmission in neutral, and set the parking brake.

NOTE:

Change the engine oil only when the engine is at a temperature of approximately 60°C (140°F).

2. Using a 36-mm socket, unscrew the oil filter cap. See Figure 14-4.



1. Oil Filter Cap

Figure 14-4 **Oil Filter Cap**

! WARNING: FIRE
To avoid injury from fire, keep open flames, sparks, electrical resistance heating elements, or other potential ignition sources away when draining lubrication oil. Do not smoke when draining lubricating oil.

3. Drain the oil.
 - [a] Place a suitable receptacle beneath the oil drain plug on the underside of the oil pan.

- [b] Carefully unscrew the oil drain plug on the oil pan and allow the oil to drain out.
- [c] Discard the O-ring on the oil drain plug.

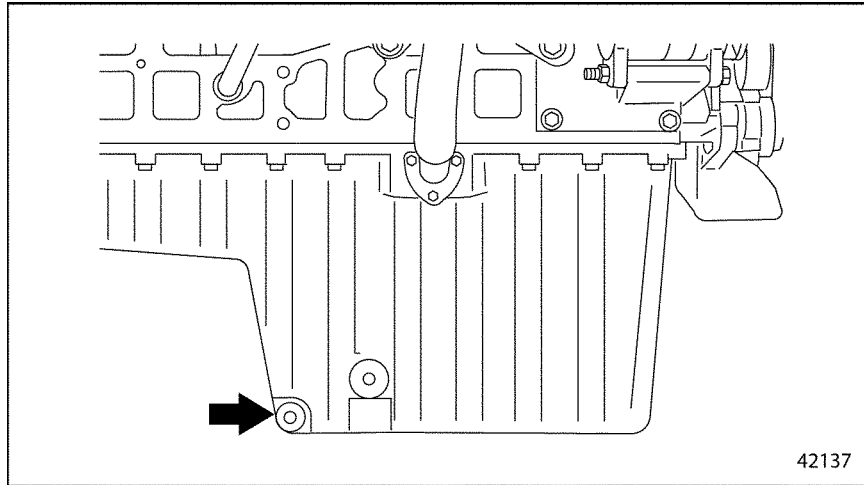
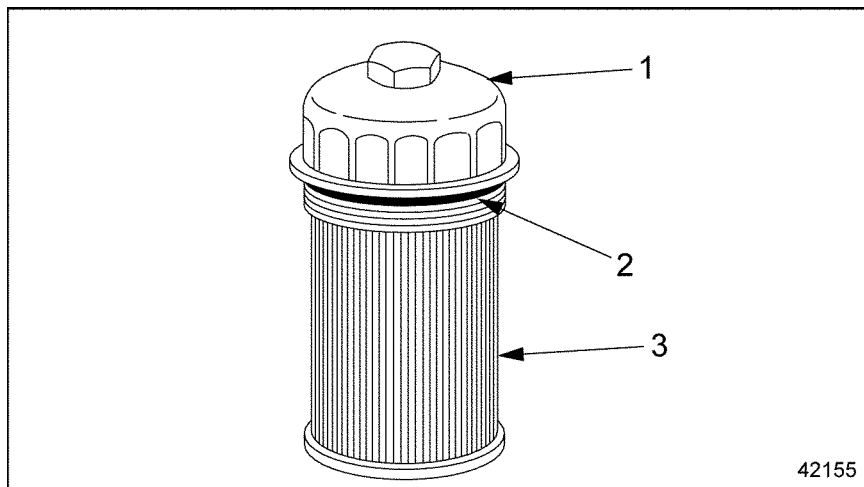


Figure 14-5 Engine Oil Drain Plug

4. Remove both the filter cap and the filter element. To release the filter element, twist the lower edge of the filter element to the side. See Figure 14-6.



- 1. Cap
- 2. O-ring

3. Filter Element

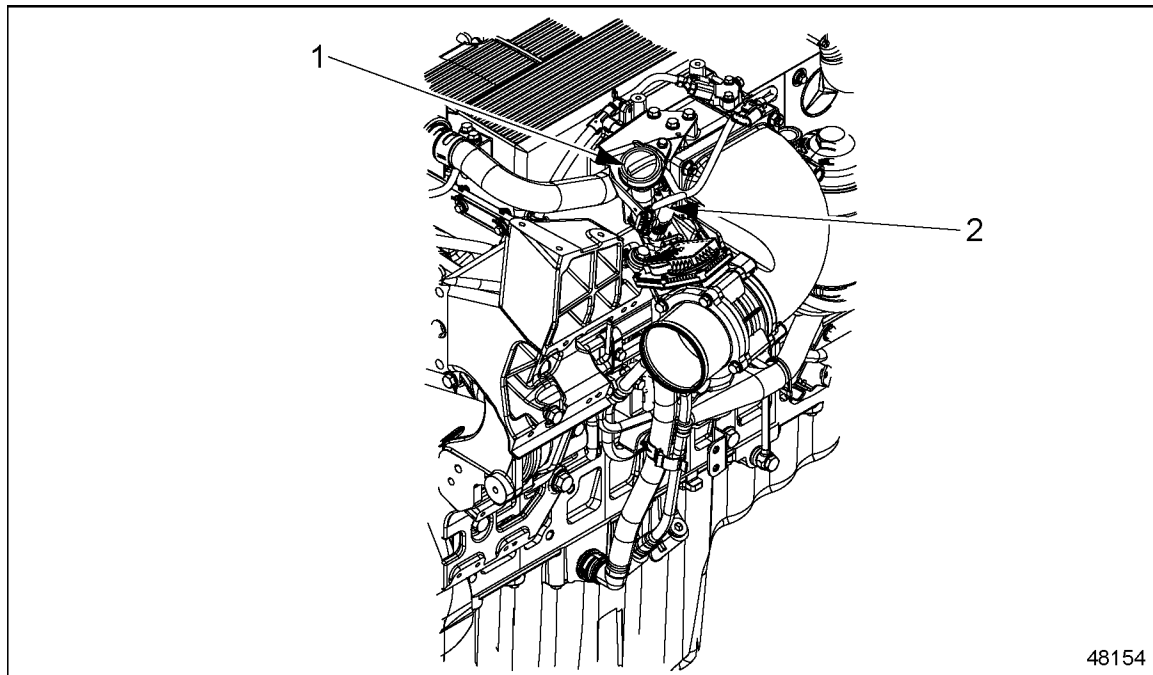
Figure 14-6 Cap with Oil Filter Element

NOTICE:

To prevent damage to the filter housing, ensure that no foreign objects get inside it. Do not wipe clean the filter housing.

5. Replace the O-ring on the cap. See Figure 14-6.

6. Install the new filter into the cap. Make sure the filter element is securely in place.
7. Screw the cap onto the oil filter housing. Tighten the cap 45 N·m (33 lb·ft).
8. Install the oil drain plug, using a new O-ring. Tighten the plug 80 N·m (60 lb·ft).
9. Add new engine oil through the oil fill, see Figure 14-7, until the maximum fill level on the oil dipstick has been reached. Engine fill capacity is 42.0 L (44.4 qts).



1. Oil Fill Cap

2. Oil Dipstick

Figure 14-7 Oil Fill

WARNING:
ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

10. Start the engine with the accelerator pedal in the idle position. Monitor the oil pressure gauge.

NOTICE:

Keep the engine running at idling speed until an oil pressure reading is obtained. If no oil pressure is shown after approximately 10 seconds, stop the engine and determine the cause. Failure to do so could result in engine damage.

11. Check the filter and oil drain plug for signs of leakage.
12. Stop the engine. Check the oil level again after approximately five minutes. If necessary, add oil up to the maximum fill level on the oil dipstick.

14.1.6 Coolant Concentration and Inhibitor Level Checking

Check the coolant concentration as follows:

**WARNING:****HOT COOLANT**

To avoid scalding from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Wear adequate protective clothing (face shield, rubber gloves, apron, and boots). Remove the cap slowly to relieve pressure.

NOTE:

Check and correct the coolant level only when the coolant temperature is below 50°C (122°F).

1. Open the cap on the surge tank slowly, to allow excess pressure to escape. Set the cap aside.
2. Before adding coolant, use a suitable tester to check the concentration of corrosion-inhibiting antifreeze. If the concentration is lower than 50 percent by volume, drain coolant/add antifreeze until the concentration is correct. The coolant mixing ratio is listed in Table 14-5.

Antifreeze Protection Down to °C (°F)	Water Percentage by Volume	Corrosion-Inhibiting Antifreeze Percentage by Volume
-37 (-34)	50	50
-52(-62)	40	Maximum 60*

*Concentrations of 60 percent affords the maximum antifreeze protection. Higher concentrations adversely affect heat dissipation.

Table 14-5 Coolant Mixing Ratio

NOTE:

When topping off, use only a pre-prepared coolant mixture containing a 50 percent concentration by volume of corrosion-inhibiting antifreeze.

NOTICE:

If the concentration of antifreeze is too low, there is a risk of corrosion or cavitation in the cooling system.

3. Check the coolant level and add more coolant if necessary.

14.1.7 Coolant Inhibitor Test Intervals

Coolant inhibitor level should be checked at the intervals listed in Table 14-6.

If topping off is needed, add coolant which is identical to the initial fill coolant.

Check the nitrite concentration at regular intervals as listed in Table 14-6 with a Detroit Diesel *POWER Trac*® 3-Way Test Strip. Nitrite levels must be within 800–2400 PPM. Additional SCA must be added to the coolant when it becomes depleted, as indicated by a nitrite concentration of 800 PPM or less. If the nitrite concentration is greater than 800 PPM, do not add additional SCA. If the nitrite concentration is above 2400 PPM, the system is over-inhibited and should be partially drained and filled with a 50/50 mix of water and EG or PG.

NOTE:

Drain intervals listed in Table 14-6 are dependent on proper maintenance.

Service Application	Inhibitor Test Interval
Long Haul — Highway Truck & Motor Coach — operates more than 60,000 miles (100,000 kilometers) per year	20,000 Miles (32,000 km)
Sort Haul — City Transit — operates up to 60,000 miles (100,000 kilometers) per year	6,000 Miles (9,600 km) or three months, whichever comes first
Severe Service — Fire Truck or Crash/Rescue Vehicle — operates up to 6000 miles (9,600 kilometers) or under severe conditions	6,000 Miles (9,600 km) or three months, whichever comes first

Table 14-6 Required Coolant Inhibitor Test Intervals

Coolant	Interval ¹	Action
Antifreeze / Water + SCA Inhibitor (DDC <i>Power Cool</i>)	20,000 Miles (32,000 km) or 3 Months*	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
	300,000 Miles (480,000 km)	Drain and clean system. Refill with new coolant.
Ethylene Glycol / Water + SCA Inhibitor or Propylene Glycol / Water + SCA Inhibitor	20,000 Miles (32,000 km) or 3 Months*	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
	300,000 Miles (480,000 km)	Drain and clean system. Refill with new coolant.
Ethylene Glycol / Water + OAT Inhibitor or Propylene Glycol / Water + OAT Inhibitor	Test at 1 Year.	—
	300,000 Miles (480,000 km) or 2 Years*	Add <i>Power Cool Plus Extender</i>
	600,000 Miles (960,000 km)	Drain and clean system. Replace with new coolant.
Water Only + SCA Inhibitor	20,000 Miles (32,000 km) or 3 Months*	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
	300,000 Miles (480,000 km)	Drain and clean system. Replace with new coolant.
Water Only + OAT Coolant	300,000 Miles (480,000 km) or 2 Years*	Add <i>Power Cool Plus Extender</i>
	600,000 Miles (960,000 km)	Clean and drain. Replace with new coolant.

¹ based on application. Drain interval dependent on proper maintenance.

Table 14-7 Coolant Maintenance Intervals

14.1.8 Inhibitor Level Checking

Use Detroit Diesel *POWER Trac*® 3-way Coolant Test Strips to measure nitrite and glycol concentrations. Cavitation/corrosion protection is indicated on the strip by the level of nitrite concentration. Freeze/boil-over protection is determined by glycol concentration.

Check the inhibitor level as follows:

 WARNING: HOT COOLANT
To avoid scalding from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Wear adequate protective clothing (face shield, rubber gloves, apron, and boots). Remove the cap slowly to relieve pressure.

1. Dip the test strip into the coolant for one second, then remove it. Shake the strip vigorously to remove excess liquid.
2. Immediately compare the end pad to the color chart on the container to determine the glycol concentration.
3. Sixty seconds (one minute) after dipping, compare the nitrite pad to the color chart on the container to determine the nitrite concentration.
4. If the additive indicator (middle pad) shows any color change, this indicates the presence of an unauthorized inhibitor.
5. If any problems exist, change the coolant.
6. After each use, replace and tighten the cap on the test strip container. Discard any test strips that have turned light pink or tan in color.
7. Close and tighten the cap on the surge tank.

A factory coolant analysis program is available through authorized Detroit Diesel service outlets.

14.1.9 Coolant Flushing and Changing

Flush and change the coolant as follows:

**WARNING:****HOT COOLANT**

To avoid scalding from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Wear adequate protective clothing (face shield, rubber gloves, apron, and boots). Remove the cap slowly to relieve pressure.

1. Open the cap on the surge tank slowly, to allow excess pressure to escape. Set the cap aside.
2. Open the water regulating valve for the heating system.
3. Drain the coolant from the engine. The coolant system capacity is listed in Table 14-8.

System	Description	Capacity L (qts)
Engine Coolant Capacity (all vehicles)	Engine capacity*	30.0 (31.7)
Century Class and Columbia Cooling System Capacity	Total capacity†	57.4 (60.7)
	Antifreeze quantity at 50%	57.4 (60.7)
	Antifreeze quantity at 60%	34.4 (36.4)
Sterling A-Line and L-Line Cooling System Capacity	Total capacity	53.8 (56.8)
	Antifreeze quantity at 50%	26.9 (28.4)
	Antifreeze quantity at 60%	32.3 (34.1)
FL112 Cooling System Capacity	Total capacity	42.0 (44.4)
	Antifreeze quantity at 50%	21.0 (22.2)
	Antifreeze quantity at 60%	25.2 (26.6)

*Does not include capacity of cooling system.

†With 1200 sq. in. radiator.

Table 14-8 Coolant Capacity

- [a] Place a receptacle underneath the coolant drain plug. Choose one that is large enough to hold the expected quantity of coolant.

NOTE:

Make sure the coolant can flow unobstructed into the receptacle.

- [b] Open the coolant drain plug on the bottom of the radiator.

NOTICE:

When flushing the radiator, do not apply more than 140 kPa (20 psi) air pressure. Excessive pressure can damage the radiator or heater core.

4. Flush the radiator.
 - [a] Attach a flushing gun nozzle to the radiator outlet.
 - [b] Run water in until the radiator is full.
 - [c] Apply no more than 140 kPa (20 psi) air pressure intermittently to help dislodge sediment buildup in the core.
5. Drain the radiator, and flush the radiator until clean water flows from the radiator. Remove the flushing gun.
6. When the coolant has drained, install the coolant drain plug on the radiator.
7. Add coolant in the specified concentration until the maximum mark on the surge tank is reached. The coolant system capacity is listed in Table 14-8.

**WARNING:
ENGINE EXHAUST**

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

8. Start the engine and run it for about one minute at varying speeds to release air pockets in the cooling system. Make sure the heater valve is still open. Check the coolant level and add more coolant if necessary.
9. Shut down the engine.
10. Close and tighten the cap on the surge tank.

14.1.10 Cooling System Inspecting

Inspect the cooling system as follows:

**WARNING:****HOT COOLANT**

To avoid scalding from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Wear adequate protective clothing (face shield, rubber gloves, apron, and boots). Remove the cap slowly to relieve pressure.

NOTE:

Before doing this inspection, make sure to do either maintenance operation "Coolant Concentration Checking," or maintenance operation "Coolant Flushing and Changing."

1. Inspect the radiator, the condenser, the coolant pump, the engine oil cooler, the freeze plugs, and the heat exchanger for damage and leaks.
2. Check all pipes and hoses in the cooling system for damage and leaks. Make sure all pipes and hoses are properly positioned to avoid chafing, and are securely fastened.
3. Check the outside of the radiator and condenser for blockage by dirt or debris. Make sure the fins are not damaged, and straighten them if necessary.

15 ENGINE STORAGE

Section	Page
15.1 PREPARING ENGINE FOR STORAGE	15-3

15.1 PREPARING ENGINE FOR STORAGE

It will be necessary to remove all rust or corrosion completely from any exposed part before applying rust preventive compound. Therefore, it is recommended that the engine be processed for storage as soon as possible after removal from operation.

The engine should be stored in a building that is dry and can be heated during the winter months. Moisture-absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

15.1.1 Cleaning the Engine

Please follow the equipment manufacturer's operating instructions for using high-pressure cleaning equipment.

Information on suitable cleaning and protective products is available from any authorized dealer.

NOTICE:
To prevent damage to engine components during the cleaning process, keep the water moving at all times. Never direct water onto electrical components, plug connectors, seals or flexible hoses.

Comply with the minimum working distance between the high-pressure nozzle and the surface being cleaned:

- ☐ Approximately 700 mm (28 in.) for circular pattern jets
- ☐ Approximately 300 mm (12 in.) for 25-degree flat jets and dirt cutters

15.1.2 Cleaning the Cooling System

Clean the cooling system as follows:

NOTE:

Collect the used coolant, cleaning solutions, and washing liquids. Dispose of them in accordance with applicable laws regarding the protection of the environment.

NOTICE:

Clean at moderate pressures only; otherwise the fins of the radiator grille could be damaged.

**WARNING:****EYE INJURY**

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 276 kPa (40 psi) air pressure.

1. Remove debris (dust, insects, etc.) from the fins of the radiator grille by blowing them through with compressed air or spraying them out with water. Work from the rear of the radiator (in the opposite direction of the normal cooling air flow).
2. Drain the coolant when the engine is cold. For detailed procedures, see the vehicle/chassis maintenance manual.
3. If the heat, ventilation, and air conditioning (HVAC) unit is connected to the cooling system, open the regulating valves all the way.

15.1.3 Degreasing the Cooling System

Degrease the cooling system as follows:

1. Fill the cooling system with a 5% solution (1.6 ounces per quart of water—50 grams per liter) of a mildly alkaline cleaning agent, such as sodium carbonate.

**WARNING:****ENGINE EXHAUST**

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

2. Run the engine at moderate speed until the thermostat starts to open, at an operating temperature of approximately 80°C (176°F). Then run it for about five minutes longer. Shut down the engine and allow it to cool to approximately 50°C (122°F).
3. Drain all the cleaning solution.
4. Flush the cleaning solution from the cooling system.
 - [a] Immediately after draining the cleaning solution, flush the system with clean water.
 - [b] Once the clean water has drained, fill the system again with clean water.
 - [c] Run the engine. Allow the engine to warm up to approximately 80°C (176°F), and then run it about five minutes longer.

[d] Drain the hot water.

5. Fill the cooling system with new coolant. For detailed procedures, see the vehicle/chassis maintenance manual. For types of coolant, refer to the coolant selections guide, *Coolant Requirements for Engine Cooling Systems (7SE298)*.

15.1.4 Storage

Required protective measures for the MBE 4000 engine depend on the following:

- ☐ The length of time that the engine will be out of service
- ☐ The climate and conditions where the engine is stored

After cleaning, engines should, whenever possible, be placed in a dry, well-ventilated place.

In all cases, protect the engine against direct exposure to moisture (rain/splash water).

If the engine is to be out of service for 12 months or less, anticorrosion measures are not necessary, provided that the place of storage are dry and well-ventilated as described above.

If the engine is to be out of service for over 12 months, or under extraordinary storage or transportation conditions, then special protective measures are necessary.

15.1.5 Temporary Storage (30 Days or Less)

To protect the engine for a temporary period of time (30 days or less), follow this procedure:

1. With the engine at ambient temperature and cool to the touch, drain engine crankcase oil into a suitable container. Dispose of the oil in an environmentally friendly manner, according to state and/or federal EPA recommendations.
2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil.
3. Fill the fuel tank with the recommended grade of fuel oil. Operate the engine for two (2) minutes at 1200 rpm and no load. **Do not drain the fuel system or the crankcase after this run.**
4. Check the air cleaner and service it, if necessary.
5. If freezing weather is expected during the storage period, check the antifreeze/coolant for required freeze and inhibitor protection. Add antifreeze solution to the cooling system as necessary.

NOTE:

If an antifreeze solution is not required during storage, flush the cooling system with a good soluble oil (3% – 5% by volume) rust inhibitor to prevent rusting of the outside diameter of the cylinder liners.

**WARNING:****EYE INJURY**

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 276 kPa (40 psi) air pressure.

6. Clean the exterior of the engine (except electrical parts) with fuel oil and dry with compressed air.
7. Seal all engine openings. The material used must be waterproof, vaporproof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

An engine prepared in this manner can be returned to service in a short time by removing the seals at the engine openings and by checking the engine coolant, fuel oil, lubricating oil and transmission oil levels.

15.1.6 Extended Storage (More than 30 Days)

To prepare an engine for extended storage (more than 30 days), follow this procedure:

1. Drain the cooling system and flush with clean, soft water. Refill with clean, soft water and add a rust inhibitor to the cooling system.
2. Circulate the coolant by operating the engine until normal operating temperature is reached.
3. Stop the engine.
4. With the engine at ambient temperature and cool to the touch, drain the engine crankcase oil into a suitable container. Remove the oil filters. Dispose of the oil and filters in an environmentally friendly manner, according to state and/or federal EPA recommendations. Replace the drain plug and tighten to 80 N·m (59 lb-ft) torque.
5. Install new lubricating oil filters. Fill the crankcase to the proper level with Tectyl® 930A preservative lubricating oil or an equivalent 30-weight preservative lubricating oil meeting Mil-L-21260C, Grade 2 Specification.
6. Drain the fuel tank. Refill with enough clean No. 1 diesel fuel or pure kerosene to permit the engine to operate for about ten (10) minutes. If draining the fuel tank is not convenient, use a separate, portable supply of recommended fuel.

NOTE:

If engines are stored where condensation of water in the fuel tank may be a problem, additives containing methyl carbitol or butyl cellusolve may be added to the fuel. Follow manufacturer's instructions for treatment. Where biological contamination of fuel may be a problem, add a biocide such as Biobor® JF (or equivalent) to the fuel. When using a biocide, follow the manufacturer's concentration recommendations and observe all cautions and warnings.

7. Drain the fuel system and remove the fuel filters. Dispose of used filters in an environmentally responsible manner, according to state and/or federal EPA recommendations. Fill the new filters with No. 1 diesel fuel or pure kerosene and install on the engine.
8. Operate the engine for five (5) minutes to circulate the clean fuel throughout the engine. Be sure the engine fuel system is full.
9. Stop the engine and allow to cool. Then disconnect the fuel return line and the inlet line at the primary filter and securely plug both to retain the fuel in the engine.
10. **Transmission:** Follow the manufacturer's recommendations for prolonged storage.
11. **Power Take-Off:** If equipped, follow manufacturer's recommendations for prolonged storage.

NOTICE:
Failure to properly seal off the turbocharger air inlet and exhaust outlet openings before engine storage may permit air drafts to circulate through the turbocharger and rotate the turbine/compressor shaft without an adequate flow of lubricating oil to the center housing bearings. This can result in severe bearing damage.

12. **Turbocharger:** Since turbocharger bearings are pressure lubricated through the external oil line leading from the oil filter adaptor while the engine is operating, no further attention is required. However, the turbocharger air inlet and turbine exhaust outlet connection should be sealed off with moisture-resistant tape.
13. Apply a non-friction rust preventive compound to all exposed engine parts. If convenient, apply the rust preventive compound to the engine flywheel. If not, disengage the clutch mechanism to prevent the clutch disc from sticking to the flywheel.

NOTE:

Do not apply oil, grease or any wax-base compound to the flywheel. The cast iron will absorb these substances, which can "sweat" out during operation and cause the clutch to slip.

14. Drain the engine cooling system.
15. Drain the preservative oil from the engine crankcase. Reinstall and torque the oil drain plug to 80 N·m (59 lb-ft).
16. Remove and clean the battery and battery cables with a baking soda-water solution and rinse with fresh water. Do not allow the soda solution to enter the battery. Add distilled water to the electrolyte (if necessary) and fully charge the battery. Store the battery in a cool (never below 0° C or 32° F) dry place. Keep the battery fully charged and check the level and specific gravity of the electrolyte regularly.
17. Insert heavy paper strips between the pulleys and drive belts to prevent sticking.

18. Seal all engine openings, including the exhaust outlet, with moisture-resistant tape. Use cardboard, plywood or metal covers where practical.
19. Clean and dry the exterior painted surfaces of the engine and spray with a suitable liquid automobile body wax, a synthetic resin varnish, or a rust preventive compound.
20. Protect the engine with a good weather-resistant tarpaulin and store it under cover, preferably in a dry building which can be heated during the winter months.

Outdoor storage of the engine is not recommended. If units must be kept out of doors, follow the preparation and storage instructions already given. Protect units with quality, weather-resistant tarpaulins (or other suitable covers) arranged to provide for air circulation.

NOTICE:

Do not use plastic sheeting for outdoor storage. Plastic is fine for indoor storage. When used outdoors, however, enough moisture can condense on the inside of the plastic to rust ferrous metal surfaces and pit aluminum surfaces. If a unit is stored outside for any extended period of time, severe corrosion damage can result.

The stored engine should be inspected periodically. If there are any indications of rust or corrosion, corrective steps must be taken to prevent damage to the engine parts. Perform a complete inspection at the end of one year and apply additional treatment as required.

15.1.7 Procedure for Restoring to Service an Engine that Has Been in Extended Storage

If an engine has been in extended storage, prepare it for service as follows:

1. Remove the covers and tape from all the openings of the engine, fuel tank and electrical equipment. Do not overlook the exhaust outlet.
2. Remove the plugs from the inlet and outlet fuel lines and reconnect the lines to their proper positions.
3. Wash the exterior of the engine with fuel oil to remove the rust preventive. **Do not wash electrical components.**
4. Remove the rust preventive from the flywheel. Flush any soluble oil rust inhibitor (if used) in the cooling system.
5. Remove the paper strips from between the pulleys and drive belts.
6. Fill the crankcase to the proper level with the required grade of lubricating oil. Use a pressure lubricator to insure all bearings and rocker shafts are lubricated.
7. Fill the fuel tank with the required fuel.
8. Close all drain cocks and fill the engine cooling system with clean, soft water and required inhibitors. If the engine is to be exposed to freezing temperatures, install genuine Detroit Diesel **Power Cool** antifreeze or an equivalent ethylene glycol-base or propylene

glycol-base antifreeze solution which provides required freeze, boil over, and inhibitor protection.

9. Install and connect the battery. Make sure the average specific gravity of the battery is 1.260 or higher. Charge the battery, if necessary.
10. Service the air cleaner, if required.
11. **Transmission:** Follow the manufacturer's recommendations covering the return of the transmission to service.
12. **Power Take-Off:** If equipped, follow the manufacturer's recommendations covering the return of the power take-off to service.
13. **Turbocharger:** Remove the covers from the turbocharger air inlet and turbine outlet connections. Reconnect piping as required. Prelube the turbocharger center bearing housing.



WARNING:

ENGINE EXHAUST

To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

14. After all preparations are completed, start the engine.

NOTE:

The small amount of rust preventive which remains in the fuel system will cause smoky exhaust for a few minutes.

NOTE:

Before subjecting the engine to a load or high speed, allow it to reach normal operating temperature. Then check for trouble codes.

15.1.8 Extended Storage (More Than 12 months)

To prepare an engine for extended storage (more than 12 months), follow this procedure:

1. Drain the cooling system.
2. Flush with clean, soft water.
3. Refill with clean, soft water and add a rust inhibitor to the cooling system. Refer to section 14.1.9.
4. Circulate the coolant by operating the engine until normal operating temperature is reached.
5. Stop the engine.
6. Install new lubricating oil filters. Refer to section 14.1.5.

7. Fill the crankcase to the proper level with Tectyl® 390A preservative lubricating oil or an equivalent 30-weight preservative lubricating oil meeting MIL-L-21260C, Grade 2 specification.
8. Drain the fuel tank.
9. Refill with enough clean No. 1 diesel fuel or pure kerosene to permit the engine to operate for about ten minutes. If it is not convenient to refill the fuel tank, use a separate, portable supply of recommended fuel.

NOTE:

If engines in vehicles are stored where condensation of water in the fuel tank may be a problem, supplemental additives containing methyl carbitol or butyl cellusolve are effective. Follow the manufacturer's instructions for their use. The use of isopropyl alcohol is no longer recommended due to its negative effect of fuel lubricity.

NOTE:

In environments where microbe growth is a problem, a fungicide such as Biobor® JF (or equivalent) may be used. Microbial activity may be confirmed with commercially available test kits. Follow the manufacturer's instructions for treatment. Avoid the use of fungicides containing halogenated compounds, since these may cause fuel system corrosion.

10. Drain the fuel system.
11. Replace the fuel filters. Refer to section 14.1.2 and Refer to section 14.1.3.

 WARNING:
ENGINE EXHAUST
To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

12. Operate the engine for five minutes to circulate the clean fuel oil throughout the engine. Ensure the engine fuel system is full.
13. Disconnect the fuel return line and the inlet line at the primary filter and securely plug both lines to retain the fuel in the engine.
14. Service the air cleaner.
15. To prepare the transmission, power take-off and turbocharger:
 - [a] Follow OEM recommendations for prolonged storage to store the transmission.
 - [b] Follow OEM recommendations for prolonged storage to store the power take-off.
 - [c] Since turbocharger bearings are pressure lubricated through the external oil line leading from the oil filter adaptor while the engine is operating, no further attention is required; however, the turbocharger air inlet and turbine outlet connections should be sealed off with moisture resistant tape.

NOTICE:

Do not apply oil, grease, or any wax base compound to the flywheel. The case iron will absorb these substances, which can sweat out during operation and cause the clutch to slip.

16. Apply a non-friction rust preventive compound to all exposed engine parts. If convenient, apply the rust preventive compound to the engine flywheel. If not, disengage the clutch mechanism to prevent the clutch disc from sticking to the flywheel.

NOTICE:

Incomplete draining of the water pump may result in rusting of the impeller to the pump body during extended engine storage, especially if inadequate inhibitor was used in the remaining coolant. Damage from freezing temperatures may occur if the coolant remaining in the engine has insufficient antifreeze to prevent it from freezing and expanding. To ensure complete pump drainage, always remove the drain plug from the bottom of the pump before extended storage. If a coolant filter/inhibitor system hose is attached to the bottom of the pump, disconnect the hose and allow the pump to drain completely. Open the drain cock at the bottom of the filter. Do not reinstall the pump drain plug or filter hose or retighten the filter drain plug until the engine is put back into service.

17. Drain the engine cooling system.
18. Drain the preservative oil from the engine crankcase.
19. Remove and clean the battery and battery cables with a baking soda–water solution and rinse with fresh water. Do not allow the baking soda solution to enter the battery.
20. Add distilled water to the electrolyte (if necessary) and fully charge the battery.

NOTICE:

To avoid possible battery damage caused by freezing, never store a battery in a place below 0°C (32°F).

21. Store the battery in a cool, dry place. Keep the battery fully charged and check the level and specific gravity of the electrolyte regularly.
22. Insert heavy paper strips between the pulleys and drive belts to prevent sticking.
23. Seal all engine openings including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood, or metal covers where practical.
24. Clean and dry the exterior painted surfaces of the engine and spray with a suitable liquid automobile body wax, a synthetic resin varnish, or a rust–preventive compound.

25. Protect the engine with a good weather-resistant tarpaulin and store it under cover, preferably in a dry building which can be heated during the winter months.

NOTE:

Plastic may be used for indoor storage.

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