EPA07 MBE 900 Service Manual - DDC-SVC-MAN-0034

DETROIT DIESEL

Generated on 10-13-2008

General Information

SCOPE AND USE OF THIS MANUAL

This manual contains complete instructions on operation, adjustments (including valve lash), preventive maintenance, and repair (including complete overhaul) for the MBE 900 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 900 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 900 engine described in this manual is a water–cooled, four–stroke, direct–injection diesel engine. Only a 6–cylinder inline model is available. Each has a separate electronic unit pump (EUP) with a short injection line to the injection nozzle, which is located in the center of the combustion chamber. The EUP(s) are attached to the crankcase and are driven from the camshaft. Each cylinder has two intake valves and one exhaust valve.

Engines with a horsepower rating of 190–250 have a single stage turbocharger and engines with a horsepower rating of 260–350 are equipped with a dual stage turbocharger.

Charge–air cooling and an exhaust gas turbocharger are standard equipment on all MBE 900 engines (wastegate turbochargers are optional).

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.

Engine braking is controlled by either a pneumatically–operated exhaust brake or an electronic actuated brake located on the turbocharger Engine braking is also controlled by an optional constant–throttle system.

The cylinder block has integrated oil and water channels. The single–piece cylinder head is made of cast iron. The cylinder head gasket is a three–layer, adjustment–free seal with Viton® sealing elements.

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

The crankshaft is precision–forged with seven main bearings , six of which have custom–forged counterweights, 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 EUP. The valves are controlled by mushroom tappets, pushrods, and rocker arms. The intake valves are opened and closed by a valve–guided bridge.

There is a force–feed lubricating oil circuit supplied by a rotary oil pump. This pump is positioned at the front of the crankcase and driven by gears from the crankshaft. The oil cooler is located near the front of the crankcase on the right–hand side near the turbocharger. The high-horsepower engines, 260 -330 BHP, are equipped with an oil centrifuge. In the centrifuge filters larger dirt particles are removed then returns the coarsely cleaned engine oil back into the oil pan. The use of the oil centrifuge prolongs the oil change interval.

The gear–type fuel pump is bolted to the front of the crankcase. 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 (optional).

The vehicle is cooled by a closed system using recirculated coolant; temperature is regulated automatically by two thermostats.

The alternator and water pump (and other accessories) are driven by a belt with an automatic belt tensioner. Electrical equipment includes a starter and an alternator.

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. 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 about the aftertreatment system refer to the Aftertreatment System Technician's Guide 7SE63.

ENGINE BRAKES - PNEUMATIC and SMART REMOTE ACTUATOR (SRA2)

The MBE 900 employs two types of engine brakes; the pneumatic actuated engine brake, which uses the air pressure created by the engines mounted air compressor, and the Smart Remote Actuator (SRA2), a solid state electronic actuator, controlled by the MCM. Either style is not used for engine braking, rather they are used only for controlling the position of the brake flap mounted on the turbocharger, which increases backpressure during the regeneration event, based on the temperature needed to sustain the regeneration operation.

The pneumatic operated engine brake uses air pressure from the engine driven air compressor, controlled by an engine mounted solenoid, to the brake flap actuator mounted between the turbocharger and the Aftertreatment Device. This is an on-off solenoid with no modulation or position feedback control. The air powered actuator operates the brake flap, for the thermal management during the regeneration process.

The second type of engine brake is used on engines that do not have the engine driven air compressor. In this operation, a CAN-operated electronic actuator is used to operate the brake flap. Liquid cooling of the actuator is required to protect the actuator electronics from heat conducted from the turbocharger, Again, this is only used during the regeneration process, to control the thermal management of the engine. During the regeneration process, the Smart Remote Actuator (SRA2) is used to control the operating and closing of the brake flap. The actuator is operated through a “learning: cycle the initial power up of the actuator, learning the end points of its travel. These points are used throughout the operation of the engine brake system. In the un-powered condition, the actuator will move to a default (open) position. A linkage system translates the rotary motion of the actuator to the brake flap.

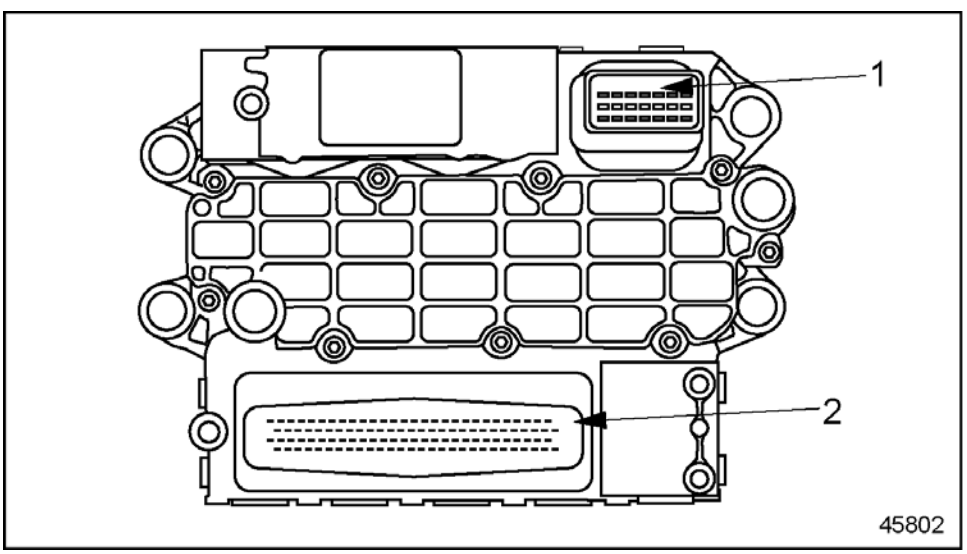
ELECTRONIC ENGINE CONTROL SYSTEM

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 (MCM)

The engine mounted MCM includes control logic to provide overall engine management. See Figure "Motor Control Module" . 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 electronic unit pumps are actuated accordingly through the solenoid valves.



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 (CPC)

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 "Common Powertrain Controller (CPC)" .

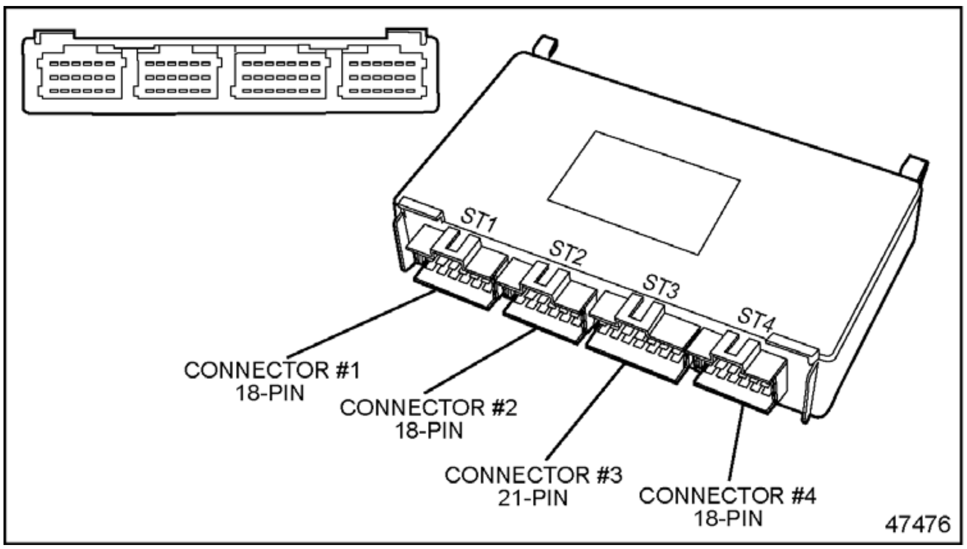


Figure 2. Common Powertrain Controller (CPC)

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 "CPC Dimensions" .

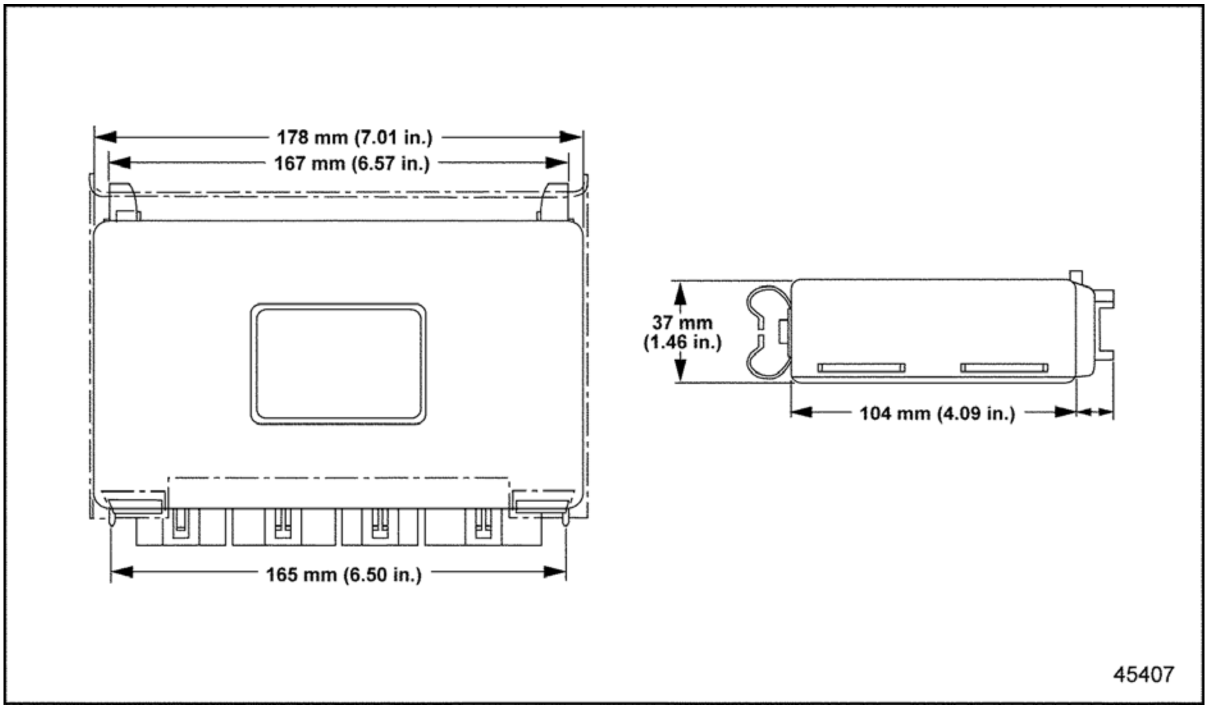


Figure 3. CPC Dimensions

The CPC receives data from the operator (accelerator pedal position, switches, various sensors) and other electronic control units.

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.

CPC to MCM - VEHICLE INTERFACE HARNESS (VIH)

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

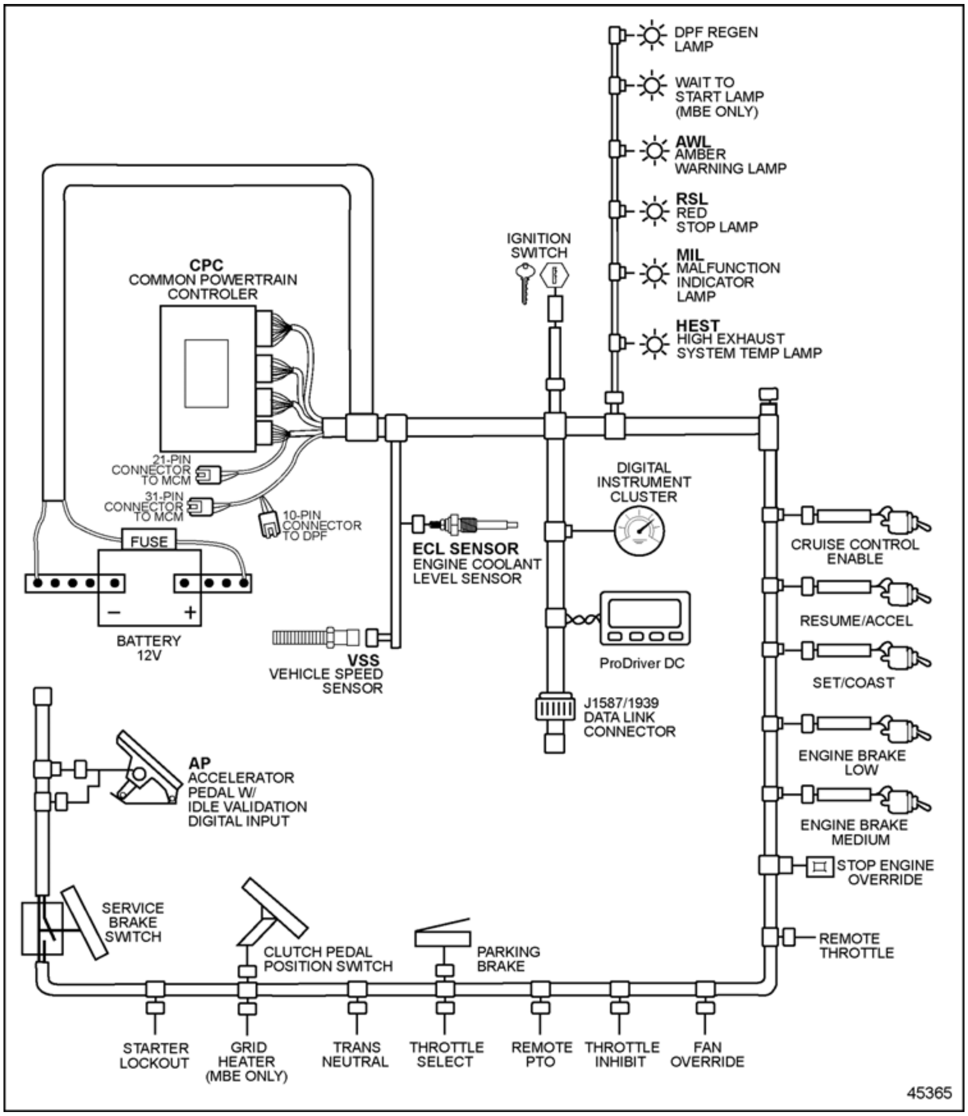


Figure 4. Vehicle Interface Harness

FACTORY INSTALLED SENSORS

The sensors integrated into the factory-installed Engine Harness are listed in Table "Function of Factory-installed Sensors" .

Sensor	Function
Camshaft Position Sensor (CMP Sensor)	Senses crankshaft position and engine speed for functions such as fuel control strategy.
Crankshaft Position Sensor (CKP Sensor)	Indicates a specific cylinder in the firing order.
DPF Inlet Pressure Sensor	Sensor measures pressure between the Diesel Oxidation Catalyst (DOC) and the Diesel Particulate Filter (DPF) in the aftertreatment assembly located in the exhaust system of the vehicle.
DPF Outlet Pressure Sensor	Sensor measures pressure on the outlet of the after-treatment device in the exhaust system of the vehicle. Located after the DPF that is within the aftertreatment device.

DPF Outlet Temperature Sensor	Temperature measured at the outlet of the after-treatment system that is installed within the exhaust system of the vehicle. It's located after the DPF that is within the aftertreatment unit.
DOC Inlet Temperature	DOC Temperature In - Temperature measured at the inlet of the after-treatment device in the exhaust system of the vehicle. Located before the DOC that is within the after-treatment device.
DOC Outlet Temperature	Temperature measured between the DOC and the DPF in the aftertreatment assembly located in the exhaust system of the vehicle.
EGR Delta Pressure Sensor EGR Delta P Sensor	Senses EGR pressure for EGR control.
EGR Temperature Sensor	Senses EGR exhaust temperature after EGR cooler. Used for EGR system diagnosis.
Engine Coolant Temperature Sensor (ECT Sensor)	Senses coolant temperature for functions such as engine protection, fan control and engine fueling.
Engine Oil Pressure Switch	Senses gallery oil pressure for functions such as engine protection.
Engine Oil Temperature Sensor (EOT Sensor)	Senses oil temperature for functions such as reducing variation in fuel injection and fan control.
Fuel Line Pressure Sensor	Senses fuel line pressure
Fuel Compensation Pressure Sensor	Compensates fuel line pressure
Intake Manifold Pressure Sensor (IMP Sensor)	Senses turbo boost for functions such as smoke control and engine protection.
Intake Manifold Temperature Sensor (IMT Sensor)	Senses boost temperature
Supply Fuel Temperature Sensor (SFT Sensor)	Senses fuel temperature for functions such as engine fueling.
Turbo Compressor Temperature Out Sensor	Senses turbo out air temperature.
Water-in-Fuel Sensor (MBE 900 only)	Detects water in the fuel filter that alerts the owner/driver that the fuel filter needs to be dried out.

Table 2. Function of Factory-installed Sensors

GENERAL DESCRIPTION OF MBE 900 EGR SYSTEM AND ENGINE VIEWS

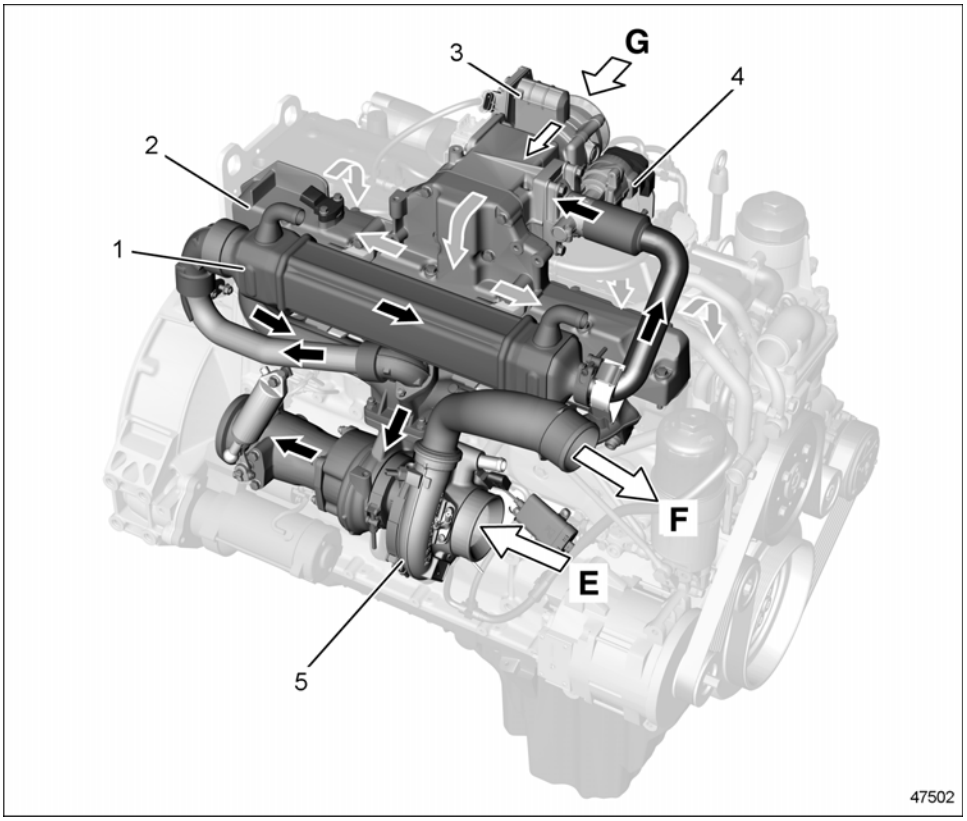
The purpose of the Exhaust Gas Recirculation (EGR) System is to reduce engine exhaust gas emissions in accordance with Environmental Protection Agency (EPA) regulations.

The EGR system consists of:

- Turbocharger
- EGR Cooler
- EGR Valve
- EGR Mixer

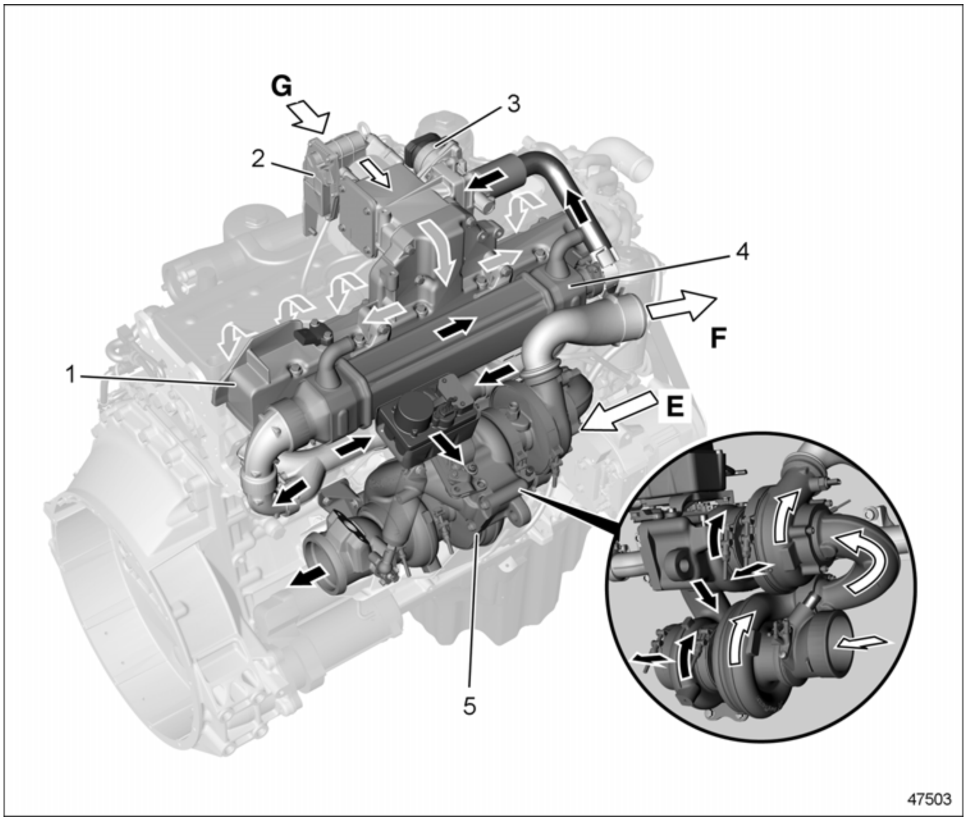
The MBE 900 engines for on-highway EPA 2007 regulation applications use a water cooled EGR system along with an Aftertreatment System to meet the emission standards. On engine model 926.961, the EGR is fed by all six cylinders. Engine model 926.960 uses an asymmetric turbocharger with two entries, and the EGR is fed from the first three cylinder, taken from a small entry. The exhaust with a maximum exhaust gas temperature of 730°C (1346°F) is cooled to a maximum of 150°C (302°F) in the EGR cooler. The cooled exhaust gases then pass through the EGR valve and added to the mixer. The addition of cooled exhaust gases back into the combustion airflow reduces the peak in cylinder combustion temperature. Less oxides of nitrogen (NOx) are produced at lower combustion temperatures.

The recycled exhaust gases are cooled before engine consumption in a single pass EGR cooler. See Figure "Air Flow Diagram (Single-Stage Turbocharger)" for engine air flow for the single-stage turbocharger and see Figure "Air Flow Diagram (Dual-Stage Turbocharger)" for engine air flow for the dual-stage turbocharger.



1. EGR Cooler	5. Single-Stage Turbocharger
2. Air Intake Manifold	E — Intake Air from Air Cleaner
3. Throttle Valve	F — Charge Air to the Charge Air Cooler
4. EGR Valve	G — Charge Air from the Charge Air Cooler

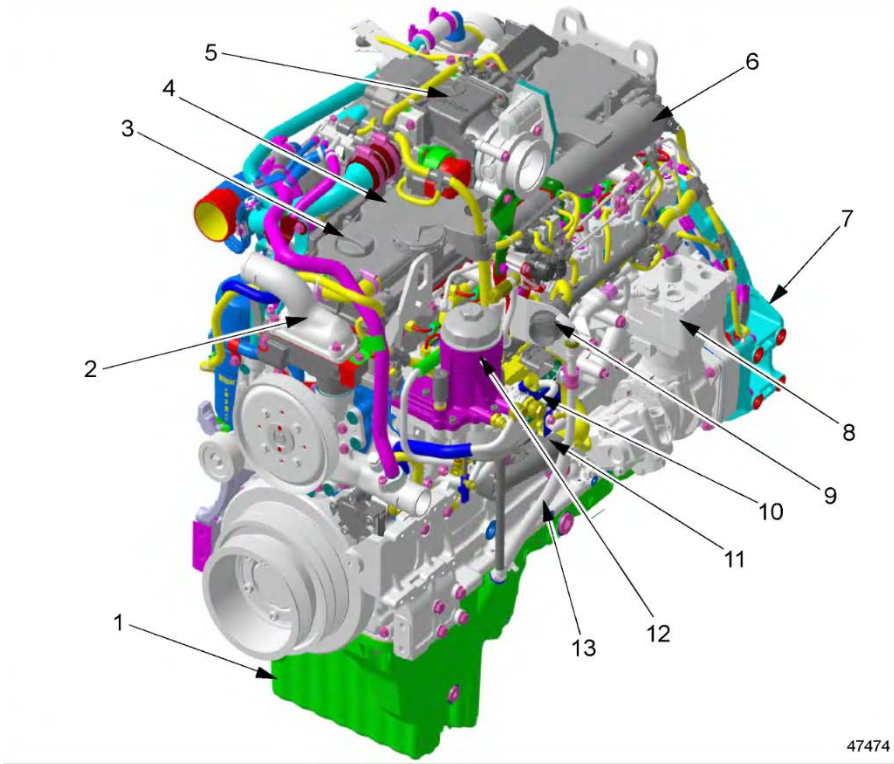
Figure 5. Air Flow Diagram (Single-Stage Turbocharger)



1. Air Intake Manifold	5. Dual-Stage Turbocharger
2. Throttle Valve	E — Intake Air from Air Cleaner
3. EGR Valve	F — Charge Air to the Charge Air Cooler
4. EGR Cooler	G — Charge Air from the Charge Air Cooler

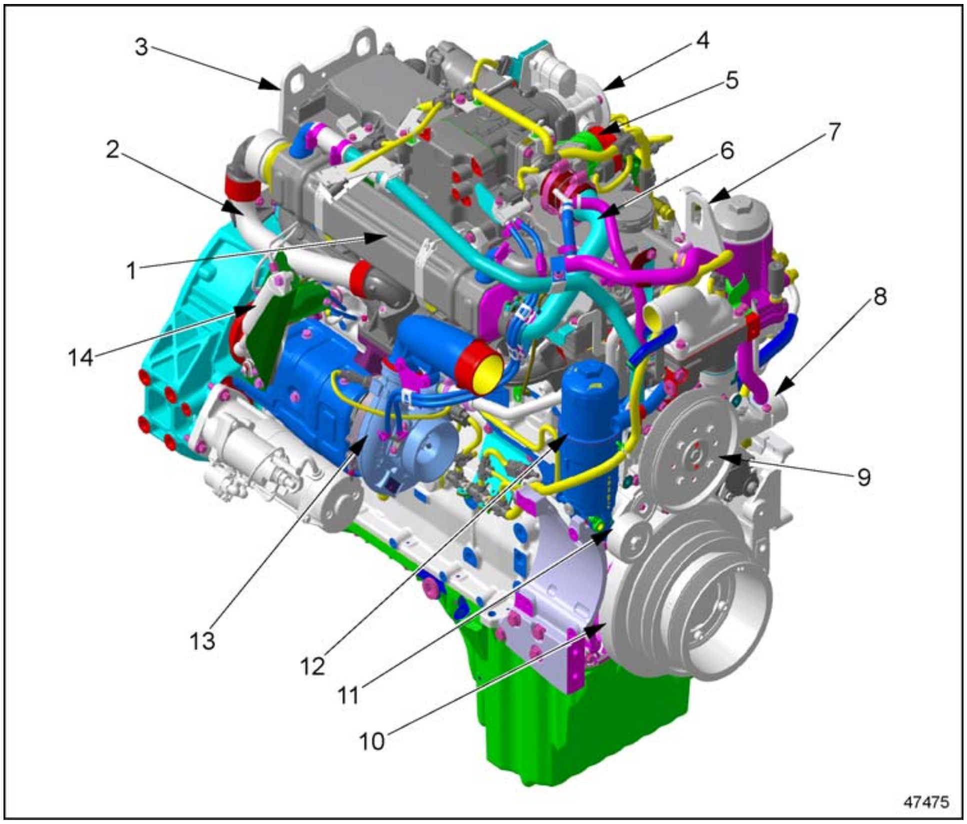
Figure 6. Air Flow Diagram (Dual-Stage Turbocharger)

See Figure "Left Side View of MBE 900 Engine (Single Stage Turbocharger) and Components" and see Figure "Right Side View of MBE 900 Engine (Single Stage Turbocharger) and Components" for the MBE 900 (Single-Stage Turbocharger) and component location. See Figure "Right Side View of MBE 900 Engine (Dual-Stage Turbocharger) and Components", and see figure "Left Side View of MBE 900 Engine (Dual-Stage Turbocharger) and Components" for the MBE 900 (Dual-Stage Turbocharger) and component location.



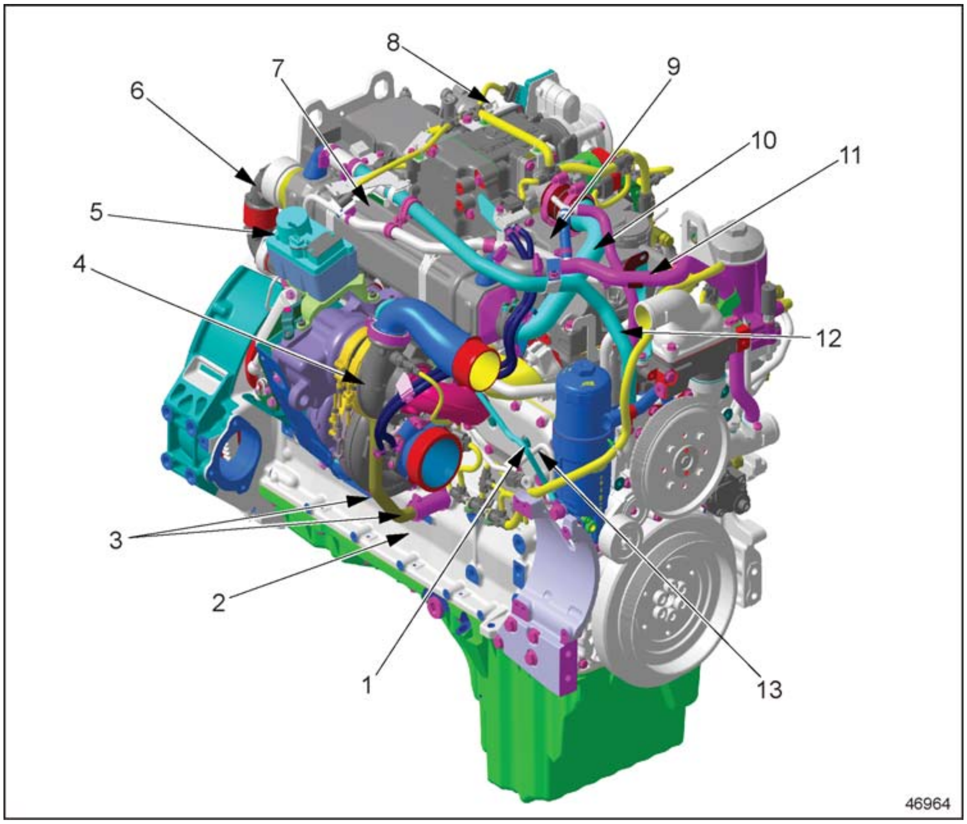
1. Oil Pan	8. Air Compressor
2. Thermostat Housing	9. 31–Pin Connector
3. Oil Fill Cap	10. Motor Control Module (MCM)
4. Cylinder Head Cover	11. 120–Pin Connector
5. EGR Mixer	12. Fuel Filter/Water Separator
6. Electrostatic Oil Separator	13. Oil Dipstick Tube
7. Flywheel Housing	

Figure 7. Left Side View of MBE 900 Engine (Single Stage Turbocharger) and Components



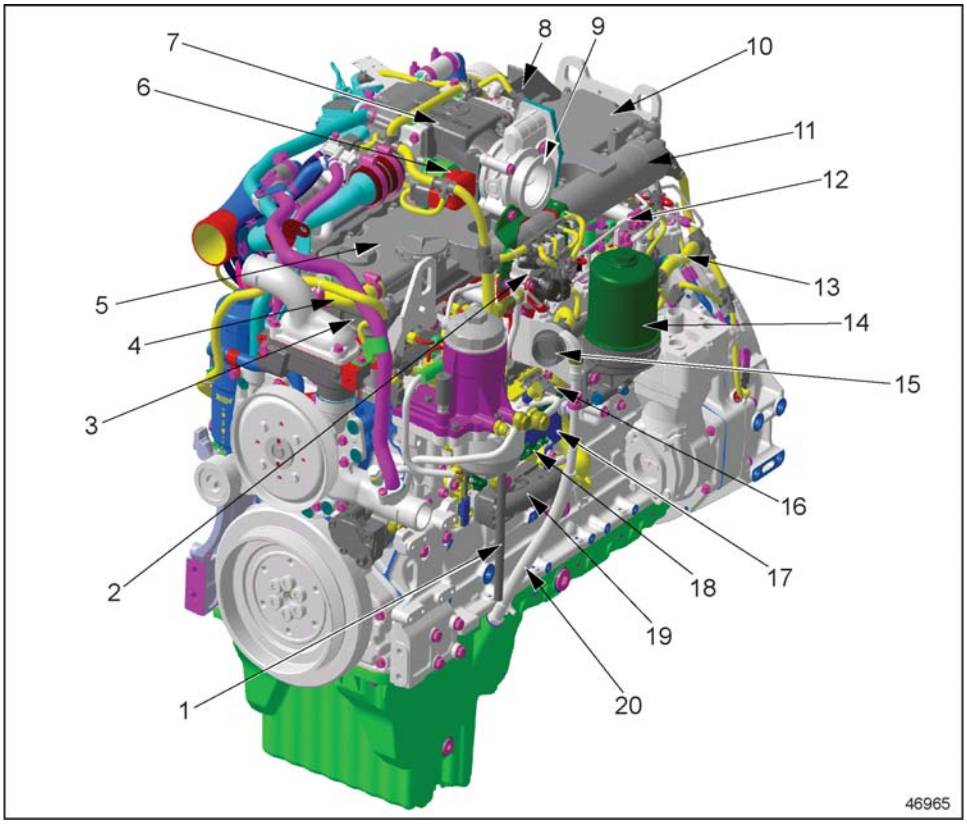
1. EGR Cooler	9. Fan Pulley
2. EGR Exhaust Elbow	10. Crankshaft Vibration Damper
3. Rear Lifting Bracket	11. Belt Tensioner
4. Air Intake Throttle Valve	12. Oil Filter
5. EGR Valve	13. Turbocharger (Single-Stage)
6. EGR Delivery Pipe	14. Exhaust Brake
7. Front Lifting Bracket	15. Pipe
8. Water Pump	

Figure 8. Right Side View of MBE 900 Engine (Single Stage Turbocharger) and Components



1. Oil Supply Line to Turbocharger	8. Grid Heater
2. Cylinder Block	9. Air Intake Manifold
3. Dual Turbo Oil Return to Block	10. EGR Delivery Pipe
4. Dual-Stage Turbocharger	11. EGR Cooler Coolant Return Tube
5. Wastegate Actuator	12. EGR Cooler Coolant Inlet Tube
6. Exhaust Elbow	13. Oil Supply Line to 2nd Turbocharger
7. EGR Cooler	

Figure 9. Right Side View of MBE 900 Engine (Dual-Stage Turbocharger) and Components



1. Drain Line for Water Separator	11. Electrostatic Oil Separator
2. Doser Block Assembly	12. Fuel Dosing Line
3. Rocker Arm Frame	13. Wire Harness
4. Fuel Injector (under cover)	14. Oil Centrifuge (260–350Horsepower models except motorcoach)
5. Breather Hose	15. 31–Pin Connector
6. EGR Valve	16. 21–Pin Connector
7. EGR Mixer Housing	17. Motor Control Module (MCM)
8. Air Intake Manifold	18. Fuel Heat Exchanger
9. Air Intake Throttle Valve	19. 120–Pin Connector
10. Cylinder Head Cover	20. Dipstick Tube

Figure 10. Left Side View of MBE 900 Engine (Dual-Stage Turbocharger) and Components

The general specifications for the MBE 900 EGR engines are listed in Table "General Technical Information for MBE 900 EGR Engines"

Descriptions	6–Cylinder EGR Engine
Engine Type	Vertical, inline cylinder block with turbocharger and charge–air cooler
Engine Length	1057 mm (41.6 in.)

Engine Width	862 mm (33.9 in.)
Engine Height	1138 mm (44.8 in.)
Cooling System	Liquid Circuit
Combustion Principle	4–Stroke direct–injection diesel
Number of Cylinders	6
Bore	106 mm (4.17 in.)
Stroke	136 mm (5.35 in.)
Displacement (total)	7.2 liters (439 in^3)
Compression Ratio	18:1
Starting Speed	Approximately 100 rpm
Direction of Engine Rotation (viewed from flywheel)	Counterclockwise
Starter	Electric Motor
Coolant Capacity of Engine (Does not include capacity of cooling system.)	Max. 12.5 liters (13.2 qt.)
Lubricating Oil Fill Capacity(In standard pan, including oil filter.)	Max. 29.0 liters (30.6 qt.)
Cold–Start Temperature Limit (Without starting aids and with battery 75 percent charged)	Down to –15°C (+5°F)
Engine "Dry" Weight — Single -Stage Turbocharger Engine "Dry" Weight — Dual -Stage Turbocharger	613 kg (1362 lb) 648 kg (1428 lb)
Valve Lash (with engine cool)	Intake = 0.40 mm (0.016 in.)
	Exhaust = 0.60 mm (0.024 in.)
Valve Lift (at maximum valve clearance)	Intake = 9.7 mm (0.38 in.)
	Exhaust = 10.7 mm (0.42 in.)
Engine Oil Pressure	At idle rpm = 50 kPa (7 psi)
	At maximum rpm = 250 kPa (36 psi)
Fuel Injectors	Minimum opening pressure = 24,500 kPa (3553 psi)
	Maximum opening pressure = 25,700 kPa (3727 psi)
Coolant Thermostat	Opening temperature = 81° to 85°C (178° to 185° F)
	Normal operating temperature = 95°C (203°F)

Table 9. General Technical Information for MBE 900 EGR Engines

IDENTIFICATION

This engine has an engine identification number and an emissions label.

Engine Identification Number

On the EPA07 MBE 900 engines, all locations show a 14–digit engine serial number with a specific numbering sequence developed as follows:

- The first 3 digits show the series of the engine, 926 for the 900 Series Engine.
- The second group is the specific model identifier for the engine.
    - 961 for the EPA07 single-turbocharger engine, up to 230 HP/620 lb·ft.
    - 963 for the EPA07 single-turbocharger engine, up to 250 HP/660 lb·ft.
- The third in the sequence is a plant identification code, “S” indicates Detroit and a “0” indicates a Mannheim produced engine.
- Prior to the 6 digit sequential serial number is a “0” acting as a place holder for future volume.
- The forth grouping in the sequence is the 6 digit sequential serial number.

The engine identification number is located on the following surfaces:

- Right rear side, top of engine block See Figure "Location of Engine Identification Numbers" .
- Top rear of engine rocker cover.
- Top front of engine rocker cover.
- Top of flywheel housing.

The etched identification number contains the type reference followed by a sequential manufacturing number. See Figure "Location of Engine Identification Numbers" .

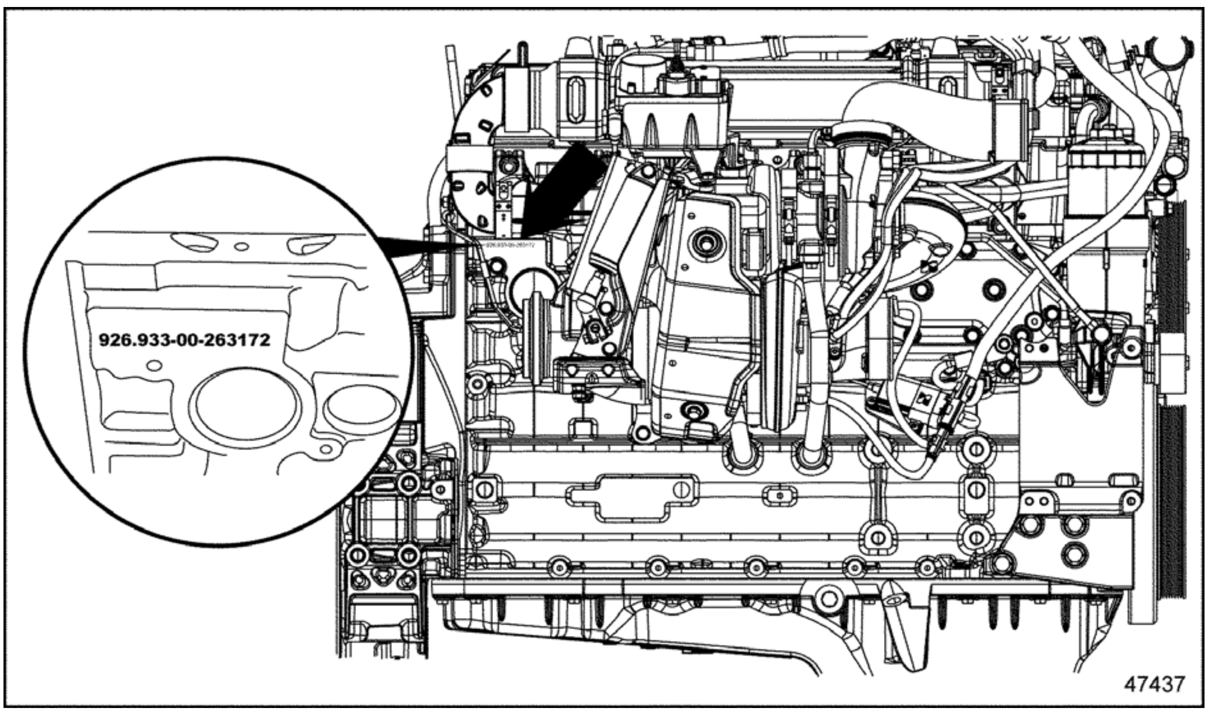
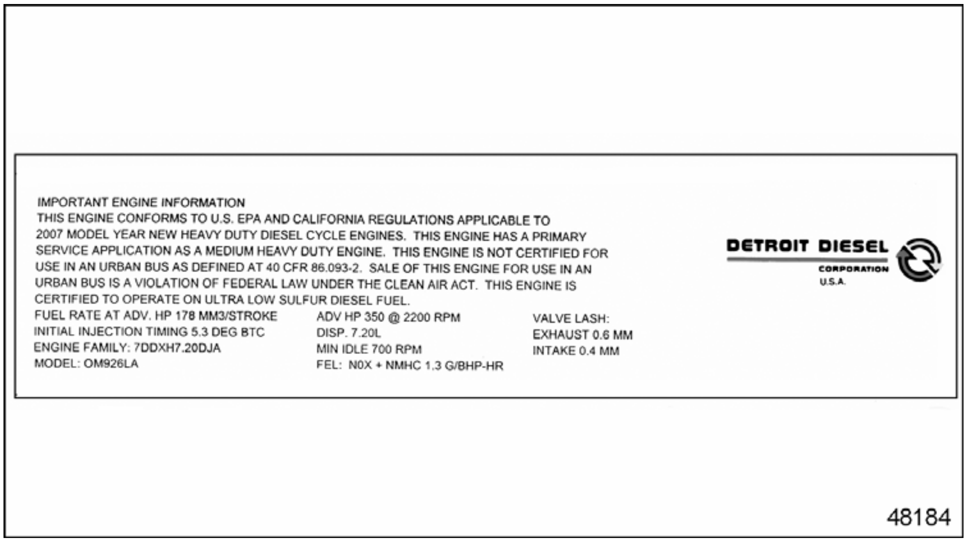


Figure 11. Location of Engine Identification Numbers

Emission Label

The MBE 900 EPA07 engine is built in accordance with sound technological principles and based on state–of–the–art technology. It complies with all United States Environmental Protection Agency (USEPA) and California Air Resources Board (CARB) emission standards. An emission label is attached to the cylinder head cover, as required by law. See Figure "Engine Emission Label — EPA07" for the emission label for the EPA07 EGR model label.


IMPORTANT ENGINE INFORMATION
THIS ENGINE CONFORMS TO U.S. EPA AND CALIFORNIA REGULATIONS APPLICABLE TO 2007 MODEL YEAR NEW HEAVY DUTY DIESEL CYCLE ENGINES. THIS ENGINE HAS A PRIMARY SERVICE APPLICATION AS A MEDIUM HEAVY DUTY ENGINE. THIS ENGINE IS NOT CERTIFIED FOR USE IN AN URBAN BUS AS DEFINED AT 40 CFR 86.093-2. SALE OF THIS ENGINE FOR USE IN AN URBAN BUS IS A VIOLATION OF FEDERAL LAW UNDER THE CLEAN AIR ACT. THIS ENGINE IS CERTIFIED TO OPERATE ON ULTRA LOW SULFUR DIESEL FUEL.

FUEL RATE AT ADV. HP 178 MM3/STROKE	ADV HP 350 @ 2200 RPM	VALVE LASH:
INITIAL INJECTION TIMING 5.3 DEG BTC	DISP. 7.20L	EXHAUST 0.6 MM
ENGINE FAMILY: 7DDXH7.20DJA	MIN IDLE 700 RPM	INTAKE 0.4 MM
MODEL: OM926LA	FEL: N0X + NMHC 1.3 G/BHP-HR	

DETROIT DIESEL CORPORATION U.S.A.

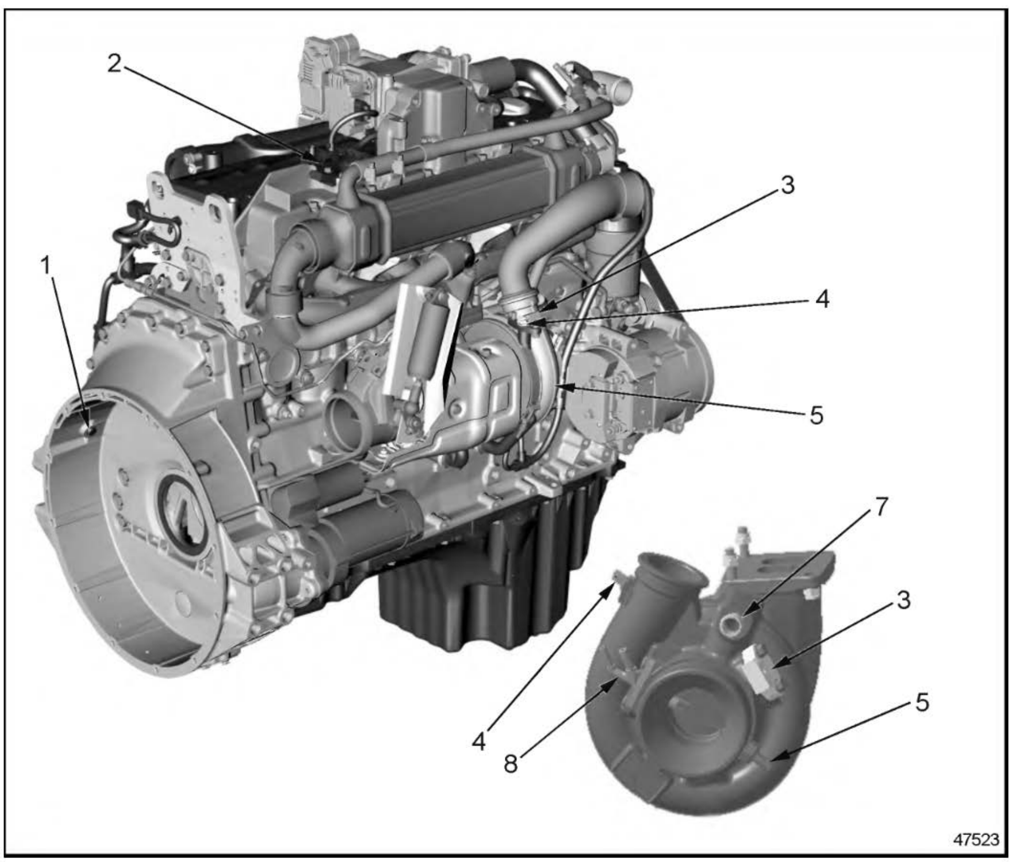
48184

Figure 12. Engine Emission Label — EPA07

Note: The horsepower rating on the emission label is for the highest engine rating and not necessarily the rating of your engine.

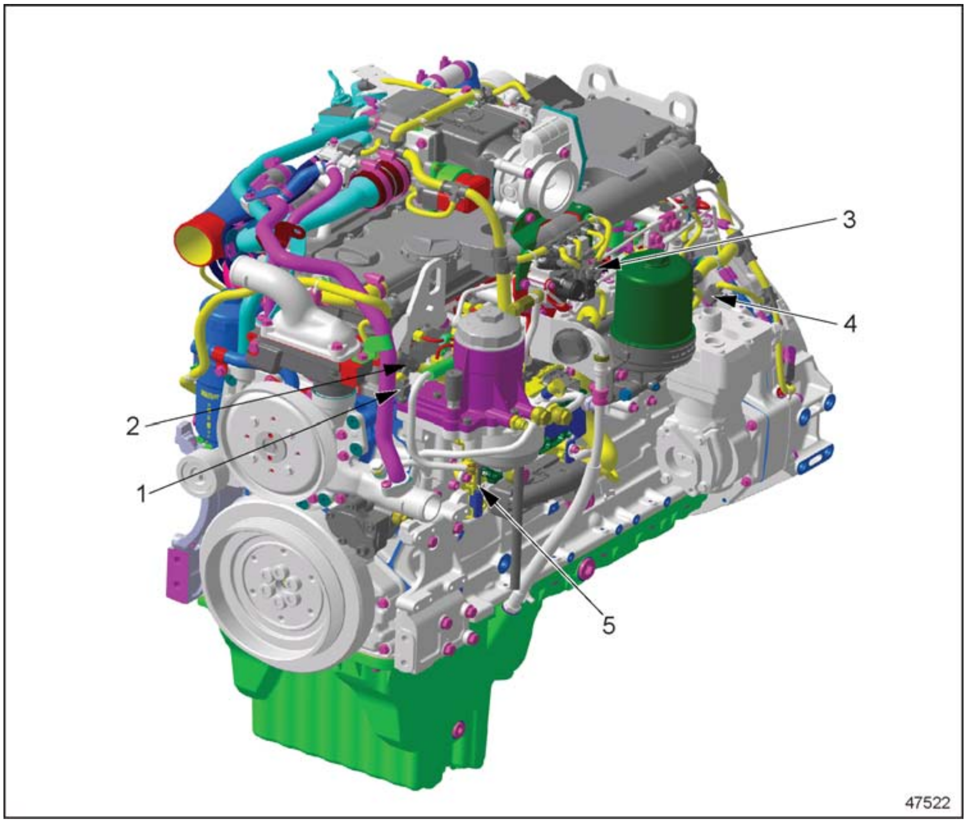
Sensor Locations

See Figure "Sensor Location on the Right Side of the MBE 900 EGR Engine" and see Figure "Sensor Location on the Left Side of the MBE 900 EGR Engine" for sensor locations for MBE 900 EGR engines.



1. Crankshaft Position (CKP) Sensor	5. Turbocharger Inlet Temperature Sensor
2. Air Intake Pressure/Temperature Sensor	6. Blow-by Return
3. Blow-by Return Insert	7. Delta P Air Inlet Fitting
4. Turbocharger Outlet Temperature Sensor	8. Delta P Insert

Figure 13. Sensor Location on the Right Side of the MBE 900 EGR Engine



1. Water-in-Fuel (WIF) Sensor (Optional)	4.Camshaft Position (CMP) Sensor
2. Fuel Temperature Sensor	5. Fuel Line Pressure Sensor
3. Coolant Temperature Sensor	

Figure 14. Sensor Location on the Left Side of the MBE 900 EGR Engine

SAFETY INSTRUCTIONS AND PRECAUTIONS

The following safety measures are essential when working on the MBE 900 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 a 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 or warranty will be jeopardized by the replacement part, procedure or tool selected.

Note: It is important to note that this manual contains various ” Dangers”, “Warnings”, 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 “Dangers”, “Warnings”, “Cautions” and “Notices” are not exhaustive, because it is impossible to warn personnel of all the possible hazardous consequences that might result from failure to follow these instructions.

Despite this, the engine may constitute a risk of damage to property or injury to persons under the following conditions:

- It is not used for its intended purpose.
- It is modified or converted in an incorrect manner.
- The safety instructions are disregarded.

Air

Cautions involving 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.

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.

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

WARNING:

PERSONAL INJURY

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

Clothing

Make sure that safe work clothing fits and is in good condition. Use work shoes that 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 rings, wrist watches, bracelets, necklaces and loose fitting clothing could catch on moving parts causing serious injury.

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.

Coolant System

Vehicle cooling systems are under pressure when at operating temperature. Allow engine to cool down before removing pressure control cap. Scalding may occur from expulsion of hot coolant if cap is removed without allowing system to cool. Wear adequate protective clothing (face shield, rubber gloves, apron and boots). Remove cap slowly to relieve pressure.

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.

WARNING:

PERSONAL INJURY

To avoid injury from scalding, drain the radiator when the engine and coolant are cool.

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.

CAUTION:

EXHAUST FUMES

To avoid injury or injury to bystanders from fumes, engine or vehicle fuel system service operations should be performed in a well ventilated area.

Fire

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

WARNING:

FIRE

To avoid injury from fire, keep a fire extinguisher near the grinding machine in case excessive heat should ignite the oil.

To avoid the risk of a potential fuel fire never mix gasoline and diesel fuel.

WARNING:

FIRE

To avoid increased risk of a fuel fire, do not mix gasoline and diesel fuel.

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.

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.

Flywheel

To avoid injury from a falling flywheel when removing the last bolt, hold flywheel against crankshaft or install guide studs.

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.

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.

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.

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.

CAUTION:

EYE INJURY

To avoid injury from flying debris, wear a face shield or goggles.

High Pressure Connections

To avoid injury from the sudden release of a high–pressure connection, wear a face shield or goggles.

WARNING:

PERSONAL INJURY

To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles.

Hot Components

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

WARNING:

BURNS

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

Items Under Tension

To avoid injury to hands and fingers from spring loaded belt tensioner snapping back, do not cut a belt to remove it.

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.

To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection.

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).

To avoid injury from an ejected EUP, do not completely loosen the mounting bolts if under tension, Rotate the crankshaft to relieve tension on the EUP then remove.

WARNING:

PERSONAL INJURY

To avoid injury from an ejected injector unit pump, do not completely loosen the mounting bolts until you have tested the spring tension. If the spring tension is at maximum and you remove the mounting cap screws, the pump will be ejected from the engine crankcase.

Lifting Devices

To avoid injury when lifting heavy objects be sure to use a proper lifting device. Never stand beneath a suspended load.

DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

DANGER:

FALLING COMPONENT

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

Liquid Nitrogen

To avoid injury from freezing or suffocation when using liquid nitrogen, wear a face shield and protective clothing in a well ventilated area.

WARNING:

FREEZING OR SUFFOCATION

To avoid injury from freezing or suffocation when using liquid nitrogen, wear a face shield and protective clothing and work in a well ventilated area.

Lubricating Oil

To avoid a potential fire, keep open flames, sparks, electrical resistance heating elements and other potential sources away when draining lubrication oil.

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.

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 and worn connectors 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.

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.

Thermostats

When removing thermostat from boiling water after testing use a lifting tool and wear heat–resistant gloves to avoid injury from scalding.

WARNING:

SCALDING

To avoid injury from scalding, use lifting tools and wear heat-resistant gloves when retrieving the thermostat from boiling water.

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 tanks and they must be chained to a cart.

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.

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:

WARNING:

PERSONAL INJURY

To avoid injury from slipping and falling, immediately clean up any spilled liquids.

- 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

ENGLISH TO METRIC CONVERSION

Listed in Table "English to Metric Conversion" are the English to metric conversions.

Multiply Length	By	To get equivalent number of:
Inch (in.)	25.4	Millimeters (mm)
Foot (ft)	0.3048	Meters (m)
Yard (yd)	0.9144	Meters (m)
Mile (mile)	1.609	Kilometers (km)
Multiply Area	By	To get equivalent number of:
$Inch^2$ ($in.^2$)	645.2	$Millimeters^2$ (mm^2)
$Inch^2$ ($in.^2$)	6.45	$Centimeters^2$ (cm^2)
$Foot^2$ (ft^2)	0.0929	$Meters^2$ (m^2)
$Yard^2$ (yd^2)	0.8361	$Meters^2$ (m^2)
Multiply Volume	By	To get equivalent number of:
$Inch^3$ ($in.^3$)	16387	$Millimeters^3$ (mm^3)
$Inch^3$ ($in.^3$)	16.387	$Centimeters^3$ (cm^3)

$Inch^3$ ($in.^3$)	0.0164	Liters (L)
Quart (qt)	0.9464	Liters (L)
Gallon (gal)	3.785	Liters (L)
$Yard^3$ (yd^3)	0.7646	$Meters^3$ (m^3)
Multiply Mass	By	To get equivalent number of:
Pound (lb)	0.4536	Kilograms (kg)
Ton (ton)	907.18	Kilograms (kg)
Ton (ton)	0.907	Tonne (t)
Multiply Force	By	To get equivalent number of:
Kilogram (kg)	9.807	Newtons (N)
Ounce (oz)	0.2780	Newtons (N)
Pound (lb)	4.448	Newtons (N)
Multiply Temperature	By	To get equivalent number of:
Degree Fahrenheit (°F)	(°F–32) ÷ 1.8	Degree Celsius (°C)
Multiply Acceleration	By	To get equivalent number of:
$Foot/second^2$ (ft/sec^2)	0.3048	$Meter/second^2$ (m/sec^2)
$Inch/second^2$ ($in./sec^2$)	0.0254	$Meter/second^2$ (m/sec^2)
Multiply Torque	By	To get equivalent number of:
Pound–inch (lb·in.)	0.11298	Newton–meters (N·m)
Pound–foot (lb·ft)	1.3558	Newton–meters (N·m)
Multiply Power	By	To get equivalent number of:
Horsepower (hp)	0.746	Kilowatts (kW)
Multiply Power	By	To get equivalent number of:
Inches of water (in. H_2 0)	0.2491	Kilopascals (kPa)
Pounds/square in. ($lb/in.^2$)	6.895	Kilopascals (kPa)
Multiply Energy or Work	By	To get equivalent number of:
British Thermal Unit (Btu)	1055	Joules (J)
Foot–pound (ft·lb)	1.3558	Joules (J)
kilowatt–hour (kW·hr)	3,600,000. or 3.6×10^6	Joules (J = one W/s)
Multiply Light	By	To get equivalent number of:
Foot candle (fc)	10.764	$Lumens/meter^2$ (lm/m^2)
Multiply Fuel Performance	By	To get equivalent number of:
Miles/gal (mile/gal)	0.4251	Kilometers/liter (km/L)
Gallons/mile (gal/mile)	2.3527	Liter/kilometer (L/km)
Multiply Velocity	By	To get equivalent number of:
Miles/hour (mile/hr)	1.6093	Kilometers/hour (km/hr)

Table 49. English to Metric Conversion

DECIMAL AND METRIC EQUIVALENTS

Listed in Table "Conversion Chart–Customary and Metric Units" are the decimal and metric equivalents.

Fractions of an inch	Decimal (in.)	Metric (mm)	Fractions of an inch	Decimal (in.)	Metric (mm)
1/64	0.015625	0.39688	33/64	0.515625	13.09687
1/32	0.03125	0.79375	17/32	0.53125	13.49375
3/64	0.046875	1.19062	35/64	0.546875	13.89062
1/16	0.0625	1.58750	9/16	0.5625	14.28750
5/64	0.078125	1.98437	37/64	0.578125	14.68437
3/32	0.09375	2.38125	19/32	0.59375	15.08125
7/64	0.109375	2.77812	39/64	0.609375	15.47812
1/8	0.125	3.175	5/8	0.625	15.87500
9/64	0.140625	3.57187	41/64	0.640625	16.27187
5/32	0.15625	3.96875	21/32	0.65625	16.66875
11/64	0.171875	4.36562	43/64	0.671875	17.06562
3/16	0.1875	4.76250	11/16	0.6875	17.46250
13/64	0.203125	5.15937	45/64	0.703125	17.85937
7/32	0.21875	5.55625	23/32	0.71875	18.25625
15/64	0.234375	5.95312	47/64	0.734375	18.65312
1/4	0.250	6.35000	3/4	0.750	19.05000
17/64	0.265625	6.74687	49/64	0.765625	19.44687
9/32	0.28125	7.14375	25/32	0.78125	19.84375
19/64	0.296875	7.54062	51/64	0.796875	20.24062
5/16	0.3125	7.93750	13/16	0.8125	20.63750
21/64	0.328125	8.33437	53/64	0.828125	21.03437
11/32	0.34375	8.73125	27/32	0.84375	21.43125
23/64	0.359375	9.12812	55/64	0.859375	21.82812
3/8	0.375	9.52500	7/8	0.875	22.22500
25/64	0.390625	9.92187	57/64	0.890625	22.62187
13/32	0.40625	10.31875	29/32	0.90625	23.01875
27/64	0.421875	10.71562	59/64	0.921875	23.41562
7/16	0.4375	11.11250	15/16	0.9375	23.81250
29/64	0.453125	11.50937	61/64	0.953125	24.20937
15/32	0.46875	11.90625	31/32	0.96875	24.60625
31/64	0.484375	12.30312	63/64	0.984375	25.00312
1/2	0.500	12.70000	1	1.00	25.40000

Table 50. Conversion Chart–Customary and Metric Units

TORQUE SPECIFICATIONS

Listed in Table "Torque Specifications" , , , , and are the torque specifications for the MBE 900 engine.

Torque Values for U.S. Customary Thread Fasteners with Lubricated* or Plated Threads†				
	Regular Hex, Torque:N·m (lb·ft)			

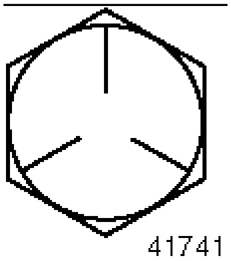
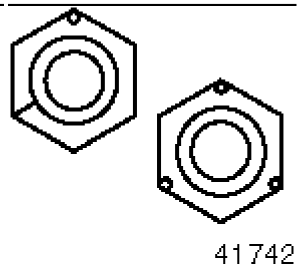
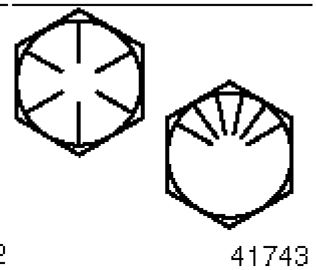
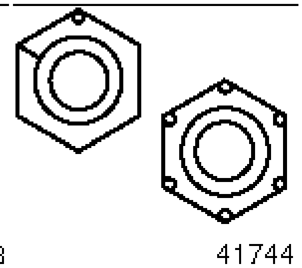
Thread Diameter–Pitch	Grade 5 Bolt	Grade 5 or B Nut	Grade 8 or 8.2 Bolt	Grade 8 or C Nut
				
1/4–20	9 (7)		11 (8)	
1/4–28	11 (8)		12 (9)	
5/16–18	20 (15)		22 (16)	
5/16–24	22 (16)		23 (17)	
3/8–16	35 (26)		38 (28)	
3/8–24	41 (30)		43 (32)	
7/16–14	57 (42)		61 (45)	
7/16–20	64 (47)		68 (50)	
1/2–13	87 (64)		92 (68)	
1/2–20	98 (72)		104 (77)	
9/16–12	125 (92)		133 (98)	
9/16–18	140 (103)		149 (110)	
5/8–11	173 (1283)		184 (136)	
5/8–18	197 (145)		209 (154)	
3/4–10	306 (226)		327 (241)	
3/4–16	343 (253)		365 (269)	
7/8–9	495 (365)		526 (3886)	
7/8–14	545 (402)		579 (427)	
1–8	—		789 (582)	
1–12	—		863 (637)	
1–14	—		883 (652)	

Table 51. Torque Specifications

** Coat all plated and non–plated fasteners with oil before installation.*
† Use these torque values if either the bolt or nut is lubricated or plated (zinc–phosphate conversion–coated, cadmium–plated, or waxed).

Torque Values for U.S. Customary Thread Fasteners with Lubricated* or Plated Threads†

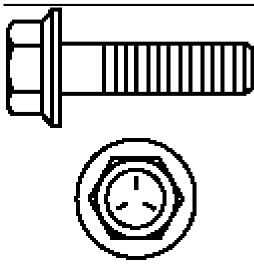
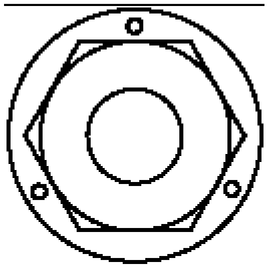
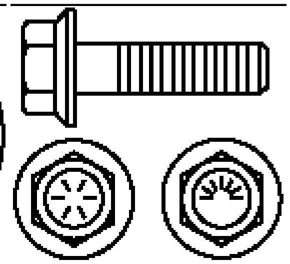
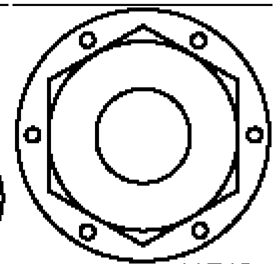
Thread Diameter–Pitch	Flanged, Torque:N·m (lb·ft)			
	Grade 5 Bolt	Grade B Nut	Grade 8 or C Nut	Grade G Nut
	 41745	 41746	 41747	 41748
1/4–20	8 (6)		14 (10)	
1/4–28	9 (7)		16 (12)	
5/16–18	18 (13)		28 (21)	
5/16–24	19 (14)		31 (23)	
3/8–16	31 (23)		50 (37)	
3/8–24	34 (25)		57 (42)	
7/16–14	47 (35)		81 (60)	
7/16–20	54 (40)		89 (66)	
1/2–13	75 (55)		123 (91)	
1/2–20	88 (65)		138 (102)	
9/16–12	108 (80)		176 (130)	
9/16–18	122 (90)		198 (146)	
5/8–11	149 (110)		244 (180)	
5/8–18	176 (130)		276 (204)	
3/4–10	271 (200)		434 (320)	
3/4–16	298 (220)		484 (357)	
7/8–9	434 (320)		698 (515)	
7/8–14	474 (350)		770 (568)	
1–8	—		—	
1–12	—		—	
1–14	—		—	

Table 52. Torque Specifications

** Coat all plated and non–plated fasteners with oil before installation.*

† Use these torque values if either the bolt or nut is lubricated or plated (zinc–phosphate conversion–coated, cadmium–plated, or waxed).

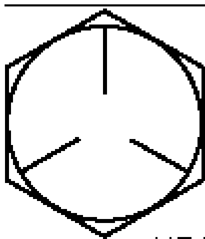
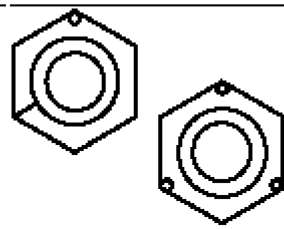
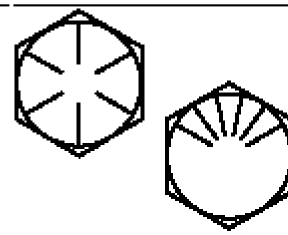
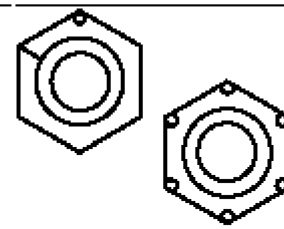
Torque Values for U.S. Customary Thread Fasteners with Dry (Non–lubricated)* or Plain (Non–plated) Threads†				
	Regular Hex, Torque:N·m (lb·ft)			
	Grade 5 Bolt	Grade 5 or B Nut	Grade 8 or 8.2 Bolt	Grade 8 or C Nut
Thread Diameter–Pitch	 41741	 41742	 41743	 41744
1/4–20	11 (8)		14 (10)	
1/4–28	12 (9)		16 (12)	
5/16–18	20 (15)		30 (22)	
5/16–24	23 (17)		34 (25)	
3/8–16	38 (28)		54 (40)	
3/8–24	42 (31)		61 (45)	
7/16–14	61 (451)		88 (65)	
7/16–20	68 (50)		95 (70)	
1/2–13	95 (70)		129 (95)	
1/2–20	102 (75)		95 (70)	
9/16–12	136 (100)		190 (140)	
9/16–18	149 (110)		210 (155)	
5/8–11	183 (135)		257 (190)	
5/8–18	210 (155)		291 (215)	
3/4–10	325 (240)		461 (340)	
3/4–16	366 (270)		515 (380)	
7/8–9	522 (385)		732 (540)	
7/8–14	576 (425)		813 (600)	
1–8	786 (580)		1111 (820)	
1–12	860 (635)		1220 (900)	
1–14	881 (650)		1240 (915)	

Table 53. Torque Specifications

** Threads may have residual oil, but will be dry to the touch.*
† Use one of the previous tables if either the male or female threads (bolt and nut) are plated or lubricated. Coat all plated and non–plated fasteners with oil before installation.

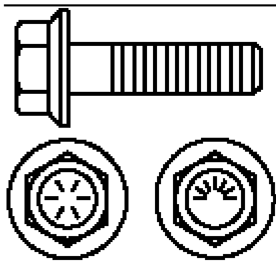
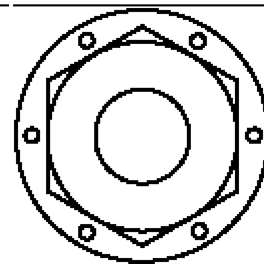
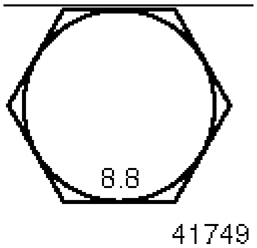
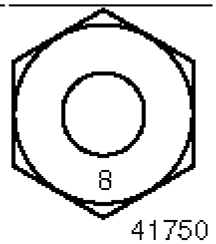
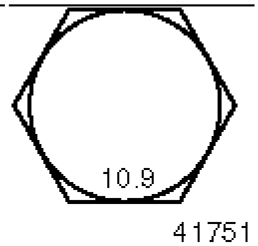
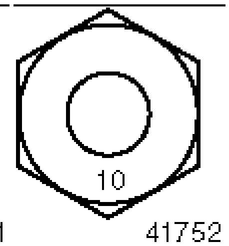
Torque Values for U.S. Customary Thread Fasteners with Dry (Non–lubricated)* or Plain (Non–plated) Threads†		
	Flanged, Torque:N·m (lb·ft)	
	Grade 8 or C Nut	Grade G Nut
Thread Diameter–Pitch	 41747	 41748
1/4–20	—	
1/4–28	—	
5/16–18	30 (22)	
5/16–24	—	
3/8–16	54 (40)	
3/8–24	—	
7/16–14	88 (65)	
7/16–20	—	
1/2–13	129 (95)	
1/2–20	—	
9/16–12	190 (140)	
9/16–18	—	
5/8–11	257 (190)	
5/8–18	—	
3/4–10	461 (340)	
3/4–16	—	
7/8–9	—	
7/8–14	—	
1–8	—	
1–12	—	
1–14	—	

Table 54. Torque Specifications

** Threads may have residual oil, but will be dry to the touch.*
† Use one of the previous tables if either the male or female threads (bolt and nut) are plated or lubricated. Coat all plated and non–plated fasteners with oil before installation.

Torque Values for Metric Thread Fasteners with Lubricated* or Plated Threads†				
	Grade 8.8 Bolt	Grade 8 Nut	Grade 10.9 Bolt	Grade 10 Nut
	Torque:N·m (lb·ft)			
Thread Diameter–Pitch				
M6	7 (5)		9 (7)	
M8	16 (12)		23 (17)	
M8 x 1	18 (13)		24 (18)	
M10	33 (24)		46 (34)	
M10 x 1.25	37 (27)		51 (38)	
M12	57 (42)		81 (61)	
M12 x 1.5	58 (43)		84 (62)	
M14	89 (66)		129 (95)	
M14 x 1.5	98 (72)		140 (103)	
M16	140 (103)		201 (148)	
M16 x 1.5	149 (110)		213 (157)	
M18	199 (147)		275 (203)	
M18 x 1.5	224 (165)		310 (229)	
M20	282 (208)		390 (288)	
M20 x 1.5	313 (213)		434 (320)	
M22	384 (283)		531 (392)	
M22 x 1.5	427 (315)		584 (431)	
M24	488 (360)		675 (498)	
M24 x 2	531 (392)		735 (542)	
M27	515 (527)		988 (729)	
M27 x 2	771 (569)		1068 (788)	
M30	969 (715)		1342 (990)	

M30 x 2	1074 (792)	1486 (1096)

Table 55. Torque Specifications

** Coat all plated and non–plated fasteners with oil before installation.*
† Use these torque values if either the bolt or nut is lubricated or plated (zinc–phosphate conversion–coated, cadmium–plated, or waxed).

ENGINE SPECIFICATIONS

The following information details engine specifications, engine features, power ratings, and provides information for further “Specification Sheets”.

Engine Specifications

Listed in Table "Engine Specifications" are the engine specifications.

Engine Specifications	
Configuration	Inline Six
Displacement	7.2 L (439 cu in.)
Bore	106 mm (4.17 in.)
Stroke	136 mm (5.35 in.)
Engine Weight	594 kg (1310 lbs.)
Electronics	DDEC VI
Compression Ratio	18:1

Table 56. Engine Specifications

Engine Features

The following list details some the major engine features.

- Fuel System
  - Primary and secondary filtration
  - Optional hand pump
  - Optional fuel-water separator and water-in fuel sensor
- Electrostatic Breather
  - Reduces oil consumption
  - Requires no maintenance
- Dual Stage Turbocharger
  - Maximizes throttle response and combustion efficiency
  - Enhanced engine performance at any engine speed
  - Standard feature on high-performance ratings
- SMART Fuel System
  - Enhanced engine performance and engine cleanliness
  - Multiple injections per engine cycle

2007 Power Ratings

EPA07 MBE 900 Standard Ratings

- 190 HP @ 2200 rpm / 520 lb-ft @1200 rpm
- 210 HP @ 2200 rpm / 520 lb-ft @1200 rpm
- 230 HP @ 2200 rpm / 620 lb-ft @1200 rpm
- 250 HP @ 2200 rpm / 660 lb-ft @1200 rpm

EPA07 MBE 900 High Performance Ratings

- 260 HP @ 2200 rpm / 800 lb-ft @1200 rpm
- 280 HP @ 2200 rpm / 800 lb-ft @1200 rpm
- 300 HP @ 2200 rpm / 860 lb-ft @1200 rpm
- 350 HP @ 2200 rpm / 860 lb-ft @1200 rpm

Specification Sheets

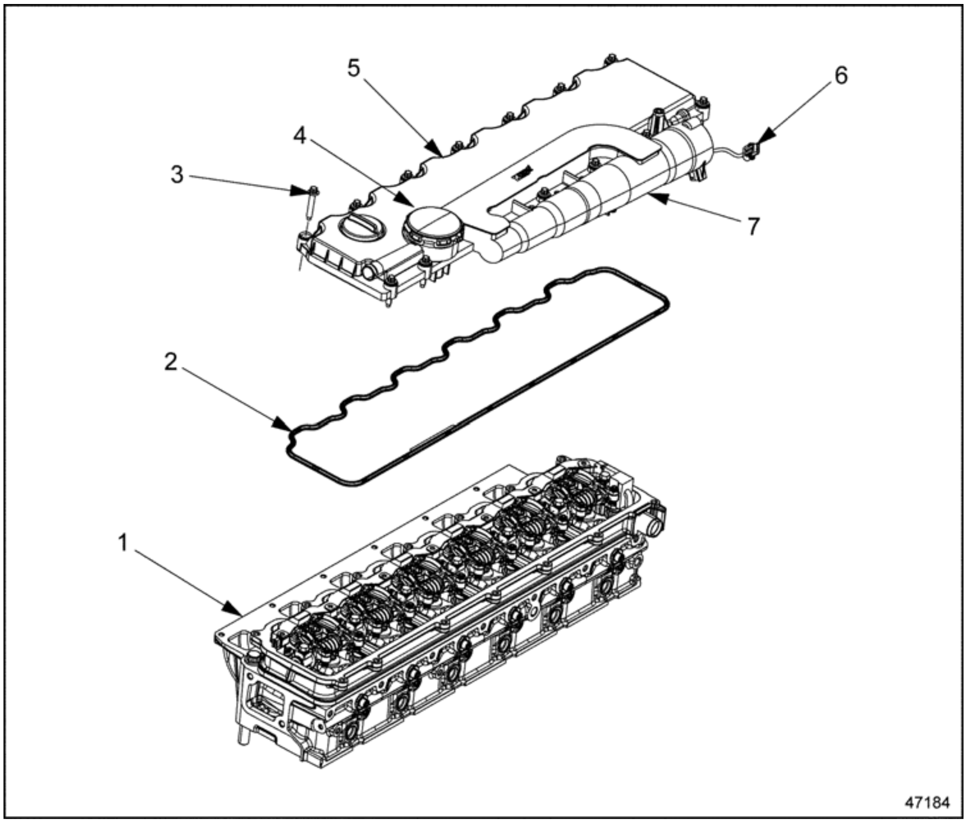
Listed in Table "Specification Sheet" is the URL for the EPA07 specification sheet.

Engine Type	Source
2007 MBE 900	Visit http://detroitdiesel.com/pdf/engines/2007_MBE900_specs.pdf

Table 57. Specification Sheet

Section 1.1
Cylinder Head Cover

See Figure "Cylinder Head Cover " for an exploded view of the cylinder head cover.



1. Cylinder Head	5. Cylinder Head Cover
2. Cylinder Head Cover Gasket	6. Electrostatic Oil Separator Electrical Connector
3. Bolt	7. Electrostatic Oil Separator
4. Crankcase Breather Valve	

Figure 1. Cylinder Head Cover

Section 1.1.1
Removal Cylinder Head Cover

Removal steps are as follows:

1. Disconnect electrical connection at the electrostatic oil separator. See Figure "Cylinder Head Cover " .
2. Disconnect the Delta P sensor hoses at the Delta P sensor.
3. Remove the EGR delivery pipe. Refer to "8.5.1 Removal of EGR Delivery Pipe" .
4. Remove the two lower bolts on the air intake throttle mounting bracket to the Doser Block Assembly.
5. Remove the intake throttle valve, air intake manifold, and EGR valve as an assembly by removing

the twelve bolts securing the intake manifold to the cylinder head..

6. Remove the preformed hose from cylinder head cover vent tube.
7. Remove the hose clamp securing the electrostatic oil separator drain line to the cylinder head cover.

   Note: The cylinder head cover gasket is reusable. Replace the gasket if damaged.

8. Remove the bolts securing the cylinder head cover to the cylinder head and remove cover assembly and gasket. Replace gasket if damaged.

Section 1.1.2
Installation of Cylinder Head Cover

Installation steps are as follows:

Note: The cylinder head cover gasket is reusable. Replace the gasket if damaged.

1. Install the gasket on cylinder head cover. See Figure "Cylinder Head Cover " .
2. Secure the cylinder head cover to the cylinder head with bolts. Torque the bolts, from the inside out starting in the center, to 20.0 N·m (14.8 lb·ft).
3. Install the air intake throttle, EGR valve, air intake manifold and new gaskets, as an assembly. Torque the twelve air intake manifold bolts to 25 N·m (18 lb·ft).
4. Install the two lower bolts on the air intake throttle mounting bracket to the Doser Block Assembly. Torque the bolts to 25 N·m (18 lb·ft).
5. Install four bolts and secure the air intake manifold to the charge air housing on the right side of engine. Torque the bolts to 25 N·m (18 lb·ft).
6. Install five bolts in the intake throttle support bracket and secure bracket and Doser Block Assembly. Torque the bolts to the bolts to 25 N·m (18 lb·ft).
7. Connect the electrical connections at the EGR valve, grid heater, and air intake throttle valve.
8. Install hose clamps and v-band clamp on EGR gas outlet pipe.
9. Secure Delta P hoses under spring clamps on the EGR delivery pipe.
10. For dual stage turbocharger, connect the electrical connection at the electrostatic oil separator and secure drain tube to the separator drain with hose clamp.
11. For single stage turbocharger, connect the electrical connector at the electrostatic oil separator.
12. Install hose clamps on the EGR gas outlet pipe and secure the pipe to the EGR cooler with a v-band clamp. Torque the clamp to 30 N·m (22 lb·ft). Tighten clamps securely.
13. Secure the electrostatic oil separator drain line to the cylinder head cover with hose clamp. Tighten the clamp securely.

Section 1.1.3
Removal of Crankcase Vent Tube

Removal steps are as follows:

1. Remove the preformed hose at the cylinder head cover by removing two clamps on hose.
2. If necessary, disconnect the vent tube at the lower turbocharger compressor inlet by removing hose and two clamps.
   a. Remove turbo elbow to gain access to bolt on tube bracket at oil cooler. For dual-stage turbochargers, refer to "6.6.2 Removal of Dual-stage Turbocharger " . Remove two Allen screws and retainers securing elbow to upper and lower turbocharger and remove elbow.

Discard seal rings.

b. Remove bolt on front bracket of the crankcase vent tube, on front right side of thermostat housing, by removing the charge air cooler inlet tube.

Section 1.1.4
Installation of Crankcase Vent Tube

Installation steps are as follows:

1. If removed, connect the vent tube at the lower turbocharger compressor inlet by installing hose and two clamps.
   a. Install bolt in front bracket of the crankcase vent tube and secure to front right side of thermostat housing. Torque bolt to 25 N·m (18 lb·ft). Install the charge air cooler coolant inlet tube.
   b. Install bolt at the oil cooler to secure the crankcase vent tube. Torque the bolt to 25 N·m (18 lb·ft).
   c. Install turbo elbow removed to gain access to bolt on tube bracket at oil cooler. Refer to "6.6.3 Installation of Dual-stage Turbocharger " . Install new seal rings on the turbocharger elbow and secure elbow to turbocharger with two Allen screws and retainers. Torque screws to 8 N·m (6 lb·ft).

Section 1.2
Electrostatic Oil Separator, and Drain Line

WARNING:

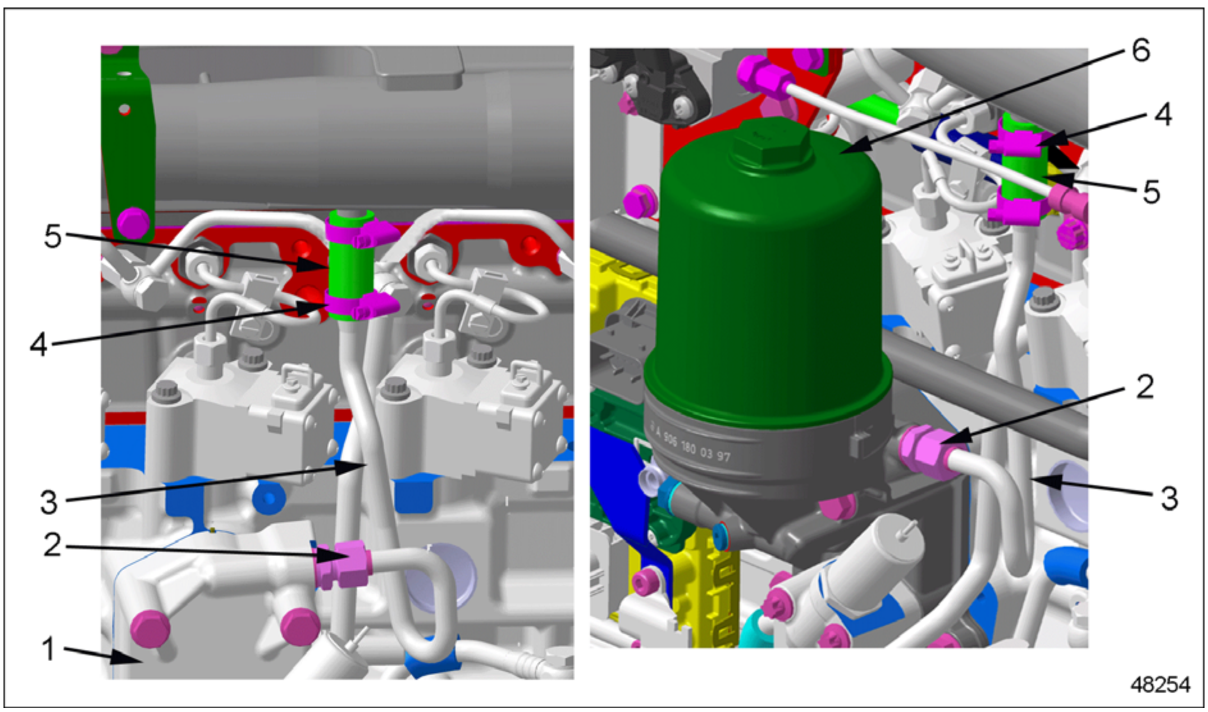
Electrical Shock Hazard

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.

The electrostatic oil separator is housed inside the cylinder head cover and is not serviceable If the separator is bad the complete cylinder head cover assembly must be replaced. Refer to "1.1.1 Removal Cylinder Head Cover" for the removal and refer to "1.1.2 Installation of Cylinder Head Cover" for the installation procedures.

Section 1.2.1
Removal of Electrostatic Oil Separator Drain Line

Removal steps are as follows:



1. Adaptor Cover	4. Hose Clamps
2. Fitting Nut	5. Hose

3. Drain Line	6. Oil Centrifuge

Figure 1. Electrostatic Oil Separator Drain Line

1. Remove the hose clamp and hose at the cylinder head cover, electrostatic oil separator drain. See Figure "Electrostatic Oil Separator Drain Line" .
2. Remove the fitting nut connecting the drain line to the adaptor cover or oil centrifuge and remove the drain line. See Figure "Electrostatic Oil Separator Drain Line" .
3. Remove the hose and clamp from the drain line.

Section 1.2.2
Installation of Electrostatic Oil Separator Drain Line

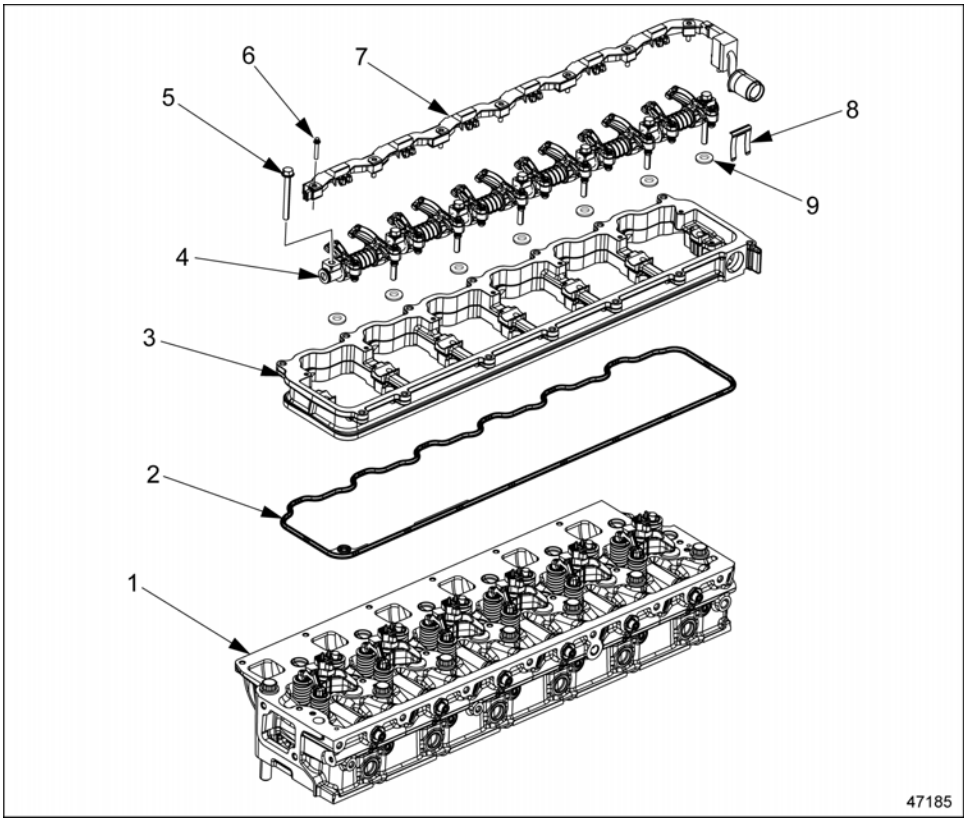
Installation steps are as follows:

1. Install the hose and clamp on the drain line and connect the hose and line to the drain on the electrostatic oil separator. See Figure "Electrostatic Oil Separator Drain Line" .
2. Secure the lower end of the drain line to the oil centrifuge or the adaptor cover with the fitting nut. Tighten the nut securely. See Figure "Electrostatic Oil Separator Drain Line" .
3. Tighten the hose clamp at the upper end of the drain line securely. See Figure "Electrostatic Oil Separator Drain Line" .

Section 1.3
Rocker Arm Frame

The rocker arm frame is die cast and houses the rocker shaft, rocker arms and the injector harness and frame.

See Figure "Rocker Arm Frame" for an exploded view of the rocker arm frame.



1. Cylinder Head	4. Rocker Arms and Shaft	7. Injector Harness and Frame
2. Rocker Arm Frame Gasket	5. Rocker Shaft Bolts	8. Retaining Clip
3. Rocker Arm Frame	6. Harness Screws	9. Washers (qty 7)

Figure 1. Rocker Arm Frame

Section 1.3.1
Removal of Rocker Arm Frame

Removal steps are as follows:

1. Remove the injector harness and frame. Refer to "2.6.1 Removal of Fuel Injector Harness and Frame" .
2. Remove the seven bolts securing the rocker arms and shaft to the cylinder head and remove. See Figure "Rocker Arm Frame" .
3. Remove the rocker arm frame and gasket from the cylinder head. See Figure "Rocker Arm

Frame" .

Note: The rocker arm frame gasket is reusable. Replace the gasket if damaged.

Section 1.3.2
Installation of Rocker Arm Frame

Installation steps are as follows:

Note: The rocker arm frame gasket is reusable. Replace the gasket if damaged.

NOTICE:

Make sure the rocker arms and rocker arm washers are secure during installation to avoid damage during assembly.

1. Install the rocker arm frame and gasket on the cylinder head. See Figure "Rocker Arm Frame" .
2. Install the rocker arm shaft and rocker arms in the rocker arm frame and secure with seven bolts. Torque the bolts to 30–36 N·m (22–27 lb·ft).
3. Adjust the valve lash. Refer to "13.2 Adjusting Valve Lash" .
4. Apply silicone to the injector harness to lubricate then install the injector harness and frame. Refer to "2.6.2 Installation of Fuel Injector Harness and Frame" .
5. Install the cylinder head cover. Refer to "1.1.2 Installation of Cylinder Head Cover" .

Section 1.4
Cylinder Head

The single–piece cylinder head is made of cast iron. The cylinder head gasket is a three–layer, adjustment–free seal with Viton sealing elements.

Section 1.4.1
Removal of Cylinder Head

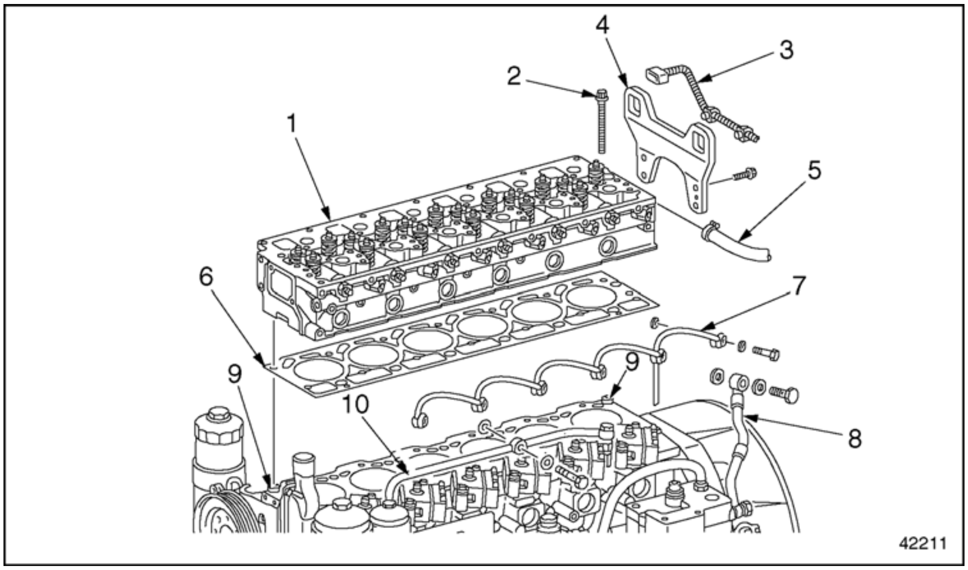
Removal steps are as follows:

WARNING:

PERSONAL INJURY

To avoid injury from scalding, drain the radiator when the engine and coolant are cool.

1. Drain the coolant from the radiator.
2. Remove the coolant delivery hoses from the surge tank.
3. Remove the coolant hose standoff bracket.
4. Remove the air cleaner, charge–air inlet, and turbocharger outlet pipes and hoses.
5. Remove the air cleaner assembly.
6. Remove the rocker arm frame. Refer to "1.3.1 Removal of Rocker Arm Frame"
7. Remove the air intake manifold and gasket. Refer to "6.4.1 Removal of Air Intake Manifold" .
8. Disconnect the turbocharger oil inlet line.
9. Remove the turbocharger. For the single-stage turbocharger, refer to "6.5.2 Removal of Single-stage Turbocharger" . For the dual-stage turbocharger, refer to "6.6.2 Removal of Dual-stage Turbocharger " .
10. For the single-stage turbocharger remove the exhaust manifold. Refer to "7.1.1 Removal of One-piece Exhaust Manifold" .
11. Remove the thermostat housing assembly. Refer to "4.4.1 Removal of Thermostat Housing" .
12. Remove the pushrods and mark the order of removal.
13. Remove the valve bridges. Mark the valve bridges in order of removal.
14. Remove the high pressure fuel line from the head and electronic unit pump (EUP). Refer to "2.3.1 Removal Of High Pressure Fuel Lines And Transfer Tubes" .
15. To prevent any dirt from entering, cover the openings in the EUP and the transfer-tube.
16. Remove the heater hose from the back of the cylinder head.
17. Remove the fuel return line. Refer to "2.23.1 Removal of Fuel Return Line" .
18. Remove the constant–throttle valve oil supply lines. Refer to "3.9.1 CTV Solenoid Oil Supply Line Removal" .
19. Disconnect the coolant delivery line from the cylinder head to the air compressor.
20. Remove the fuel injectors. Refer to "2.4.1 Removal of Fuel Injector" .
21. Using the head bolt impact socket (J–45390) , remove the cylinder head bolts.
22. Attach the cylinder head lifting device (J–46387) to the cylinder head and secure with two bolts.
23. Remove the cylinder head, see Figure "Cylinder Head and Related Components" , and set it on wooden blocks or on its side.



1. Cylinder Head	6. Cylinder Head Gasket
2. Cylinder Head Bolt	7. Constant Throttle Valve Oil Supply Line
3. Intake Manifold Pressure/Temperature Sensor	8. Coolant Delivery Line
4. Rear Lifting Bracket	9. Alignment Pin
5. Heater Hose	10. Fuel Return Line

Figure 1. Cylinder Head and Related Components

24. Remove the cylinder head gasket and discard.
25. Thoroughly clean the cylinder head and head mating surface of excess oil, grime, and paint chips.
26. With a straightedge, check the cylinder head surface for warpage. The cylinder head warpage limits are listed in Table "Head Warpage Limits" .

Descriptions mm (in.)	Limits mm (in.)
Over entire length	0.07 (0.003)
Over a length of 150 (6)	0.02 (0.001)

Table 3. Head Warpage Limits

27. With a straightedge, check the cylinder block mating surface for warpage. The cylinder block warpage is listed in Table "Cylinder Block Warpage Limits" .

Descriptions mm (in.)	Limits mm (in)
Over entire length	0.030 (0.0012)
Over a length of 150 (6)	0.015 (0.0006)

Table 4. Cylinder Block Warpage Limits

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

Inspection steps are as follows:

1. Measure cylinder–head overall height and variation of parallelism from top–to–bottom contact surfaces. See Figure "Measuring the Cylinder Head" . If the measurement is less than the permissible minimum height, replace the cylinder head.

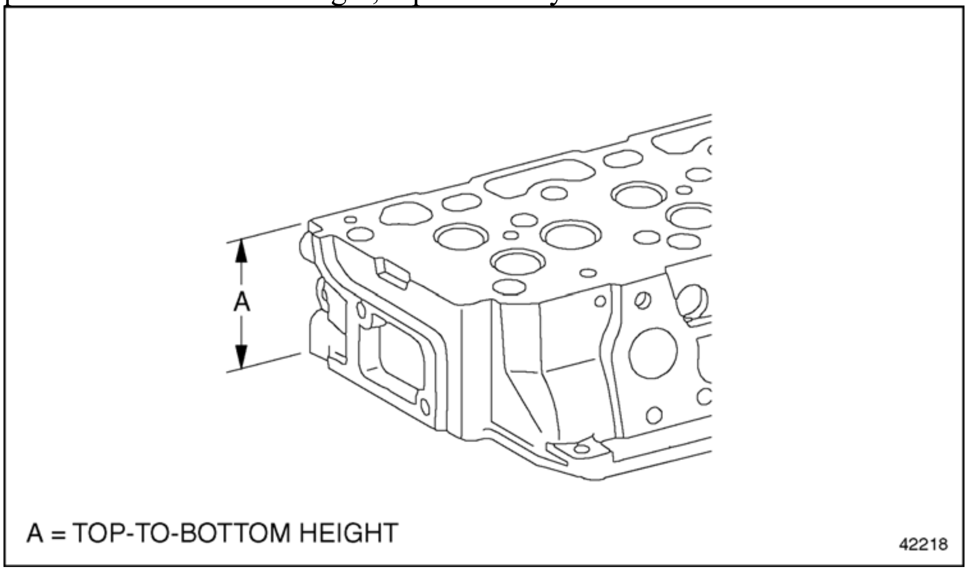


Figure 2. Measuring the Cylinder Head

2. Inspect the bottom contact surface of the cylinder head for the permissible difference of flatness in the longitudinal direction. The specifications for cylinder head height and mating surface warpage are listed in Table "Cylinder Head Height Specifications" and in Table "Cylinder Head Mating Surface Warpage" .

Height of Cylinder Head	Thickness “A” mm (in.)
When New	107.9 to 108.1 (4.25 to 4.26)
Minimum After Machining	106.9 (4.21)

Table 5. Cylinder Head Height Specifications

Maximum Lengthwise Head Mating Surface Warpage	Length mm (in.)
Over Entire Length	0.07 (0.003)
Over a Length of 150 (6)	0.02 (0.0008)

Table 6. Cylinder Head Mating Surface Warpage

Section 1.4.2
Installation of Cylinder Head

Installation steps are as follows:

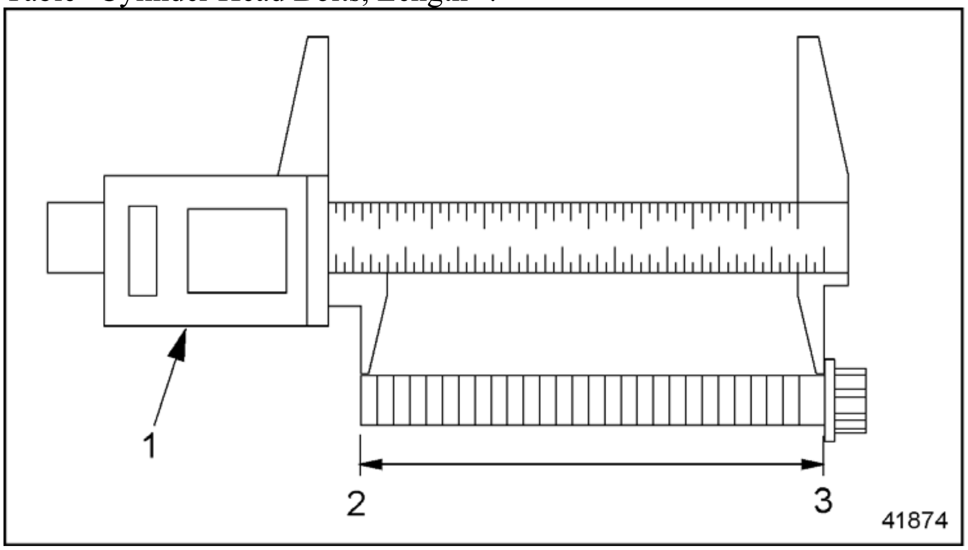
1. Install a new head gasket.

DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

2. Using an appropriate lifting device lower the cylinder head onto the cylinder block. Remove the cylinder head lifting device.
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 "Measuring Head Bolts" . The acceptable bolt length is listed in Table "Cylinder Head Bolts, Length" .



1. Dial Caliper	3. Bottom of Flange
2. End of Cylinder Head Bolt	

Figure 3. Measuring Head Bolts

Descriptions	Lengths mm (in.)
Shaft length when new	149.0 (5.87)
Maximum shaft length	151.0 (5.94)

Table 9. Cylinder Head Bolts, Length

4. Lubricate the cylinder head bolts with engine oil.
5. Using the head bolt impact socket (J–45390) , install the cylinder head bolts. The specific stages in the tightening sequence are listed in Table "Tightening Stages, Cylinder Head" . See Figure "Cylinder Head Bolt Tightening" for the torque sequence.

Size	Max. Shaft Length mm (in.)	Tightening Stage	Torque N·m (lb·ft)
M16	151.0 (5.94)	Stage 1	20 (15)
		Stage 2	70 (52)
		Stage 3	170 (125)
		Stage 4	280 (207)
		Stage 5	additional 90 degrees
		Stage 6	additional 90 degrees

Table 10. Tightening Stages, Cylinder Head

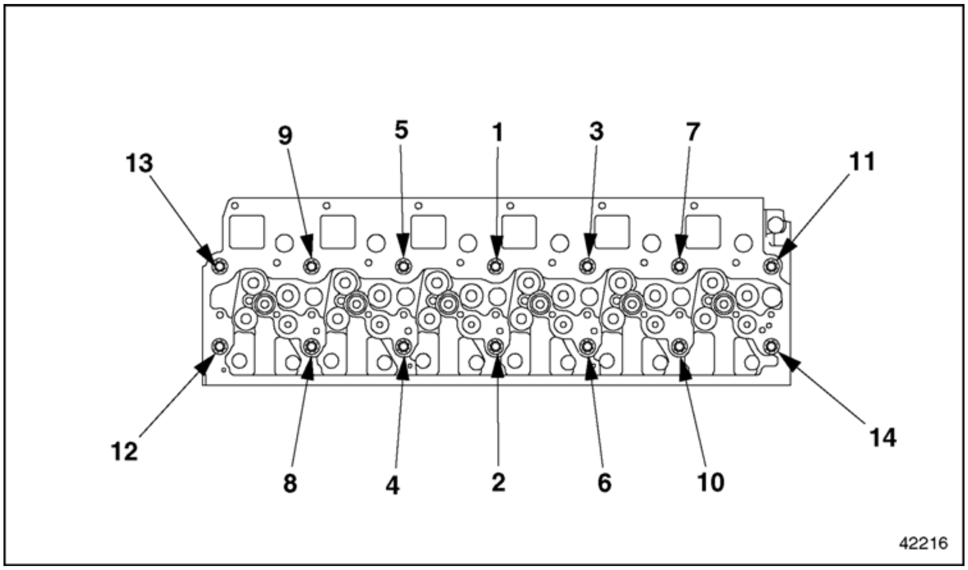


Figure 4. Cylinder Head Bolt Tightening

6. Install the CTV oil supply lines. Refer to "3.9.2 Installation of CTV Solenoid Oil Supply Line" .
7. Connect the coolant delivery line from the cylinder head to the air compressor.
8. Install the fuel return line. Refer to "2.23.2 Installation of Fuel Return Line" .
9. Install the heater hose to the back of the cylinder head.
10. Install the fuel injectors. Refer to "2.4.2 Installation of Fuel Injector" .

NOTICE:

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

11. Install the high-pressure fuel lines. Refer to "2.3.2 Installation of High Pressure Fuel Line" .
12. Install the exhaust manifold. For the one-piece exhaust manifold, refer to "7.1.2 Installation of One-piece Exhaust Manifold" . For the dual-stage turbocharger, refer to "7.1.4 Installation of Three-piece Exhaust Manifold" .
13. Using new gaskets, install the air intake manifold. Refer to "6.4.2 Installation of Air Intake Manifold" .
14. Lubricate the pushrods with a light coating of engine oil and install the pushrods, in the as–removed locations.
15. Install the valve bridges in the as–removed locations.
16. Install the rocker arm frame. Refer to "1.3.2 Installation of Rocker Arm Frame" .
17. Install the thermostat housing. Refer to "4.4.2 Installation of Thermostat Housing" .
18. Install the engine barring tool. Refer to "1.15.1 Installation of Engine Barring Tool" .
19. Adjust the valve lash. Refer to "13.2 Adjusting Valve Lash" .
20. Remove the engine barring tool.
21. Install the inspection hole end cover on the flywheel housing. Tighten the fasteners 25 N·m (18 lb·ft).
22. Install the air cleaner, charge–air inlet, and turbo outlet pipes and hoses.
23. Install the coolant delivery hoses that connect to the surge tank.
24. Check that the coolant drain plug is tight and not leaking.

25. Fill the radiator with coolant.
26. Install the cylinder head cover. Refer to "1.1.2 Installation of Cylinder Head Cover" .
27. Prime the fuel system. Refer to "12.1.5 Priming the Fuel System" .

WARNING:

ENGINE EXHAUST

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

28. Turn on the ignition key switch and run the engine. Observe the oil pressure gauge to verify the correct oil pressure. The minimum oil pressure reading at idle speed is listed in Table "Oil Pressure Readings" . Pay attention to the coolant temperature gauge, warning lights, fluid leaks, and any other signs of a problem.

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

Table 13. Oil Pressure Readings

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

Section 1.5
Engine Brake

The constant throttle valves are small valves which are built into the cylinder head. When the engine brake is switched on, the constant–throttle valves are put under pressure, which in turn opens the valves. The constant throttles are activated by engine oil pressure.

Section 1.5.1
Removal of Constant–Throttle Valve

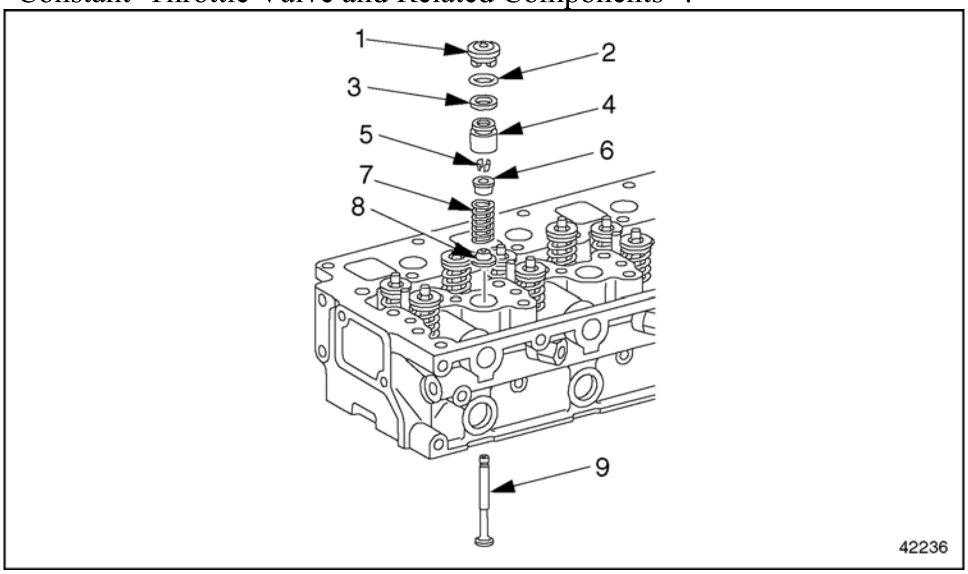
Removal steps are as follows:

1. Remove the cylinder head. Refer to "1.4.1 Removal of Cylinder Head" .

NOTICE:

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

2. Remove the fuel injector. For detailed procedures, refer to "2.4.1 Removal of Fuel Injector" .
3. From the top of the cylinder head, remove the constant throttle valve end cover. See Figure "Constant–Throttle Valve and Related Components" .

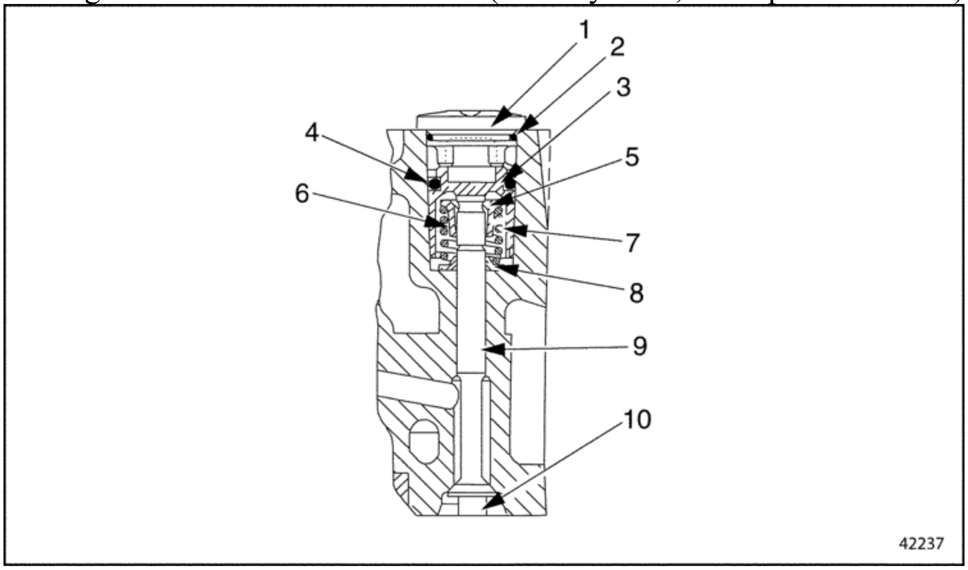


1. End Cover	4. Piston	7. Spring
2. O–ring	5. Collet	8. Spring Guide
3. Seal	6. Spring Retainer	9. Valve

Figure 1. Constant–Throttle Valve and Related Components

Note: Insert a spacer beneath the valve head to prevent the valve from opening while doing the rest of the removal procedures.

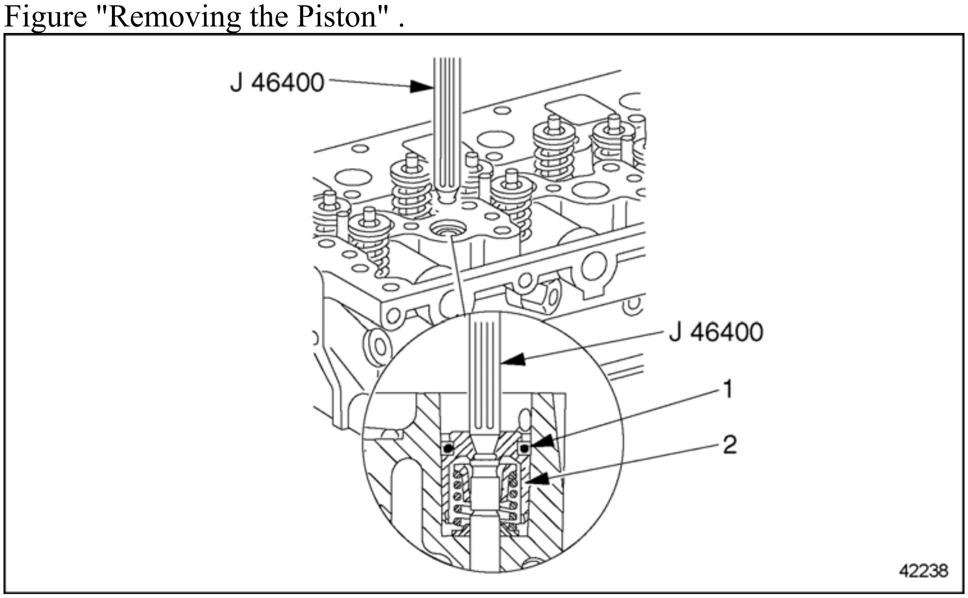
4. From the bottom of the cylinder head, insert a suitable spacer about 5.3 mm (0.21 in.) in height. See Figure "Constant–Throttle Valve (cutaway view, with spacer installed)" .



1. End Cover	5. Collet	9. Valve
2. O–ring	6. Spring Retainer	10. Spacer [5.3 mm (0.21 in.)]
3. Seal	7. Spring	
4. Piston	8. Spring Guide	

Figure 2. Constant–Throttle Valve (cutaway view, with spacer installed)

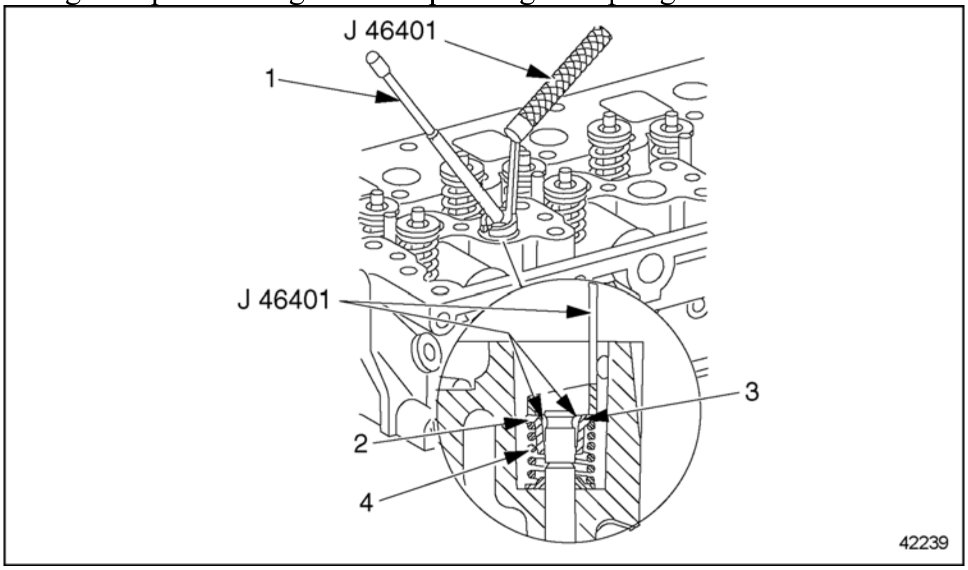
5. From the top of the cylinder head, insert the constant–throttle valve (CTV) piston remover (J–46400) into the valve bore until it contacts the piston. Pull the piston out of the valve bore. See Figure "Removing the Piston" .



1. Seal	2. Piston

Figure 3. Removing the Piston

6. Inspect the seal around the piston for damage and signs of wear. If necessary, replace the piston and seal.
7. Insert the CTV spring remover (J–46401) down onto the spring retainer. Remove the collets with a magnetic pin. See Figure "Compressing the Spring" .



1. Magnetic Pin	3. Spring Retainer
2. Collet	4. Spring

Figure 4. Compressing the Spring

8. Relieve the pressure on the spring. Remove the spring retainer, spring and spring guide. For ease of installation, mark the location of the spring retainer and spring guide with a paint pen.
9. From the bottom of the cylinder head, draw out the valve and spacer. For ease of installation, mark the location of the valve with a paint pen.
10. Do the same procedure for each valve.

Section 1.5.2
Installation of Constant–Throttle Valves

Installation steps are as follows:

1. Lubricate the valve stem with a light coating of engine oil. From the bottom of the cylinder head, push the valve, as marked on removal, into the valve bore. See Figure "Constant–Throttle Valve and Related Components" .

   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 5.3 mm (0.21 in.) in height. See Figure "Constant–Throttle Valve (cutaway view, with spacer installed)" .
3. From the top of the cylinder head, fit the spring guide, spring, and spring retainer, as marked on removal, onto the valve stem.
4. Push the spring down with the CTV spring remover (J–46401) and insert the collets into the spring retainer. Push until they lock into place.

5. Install the piston and seal, as removed. Be careful not to damage the seal on installation. See Figure "Removing the Piston" .
6. Remove the spacer from the bottom of the cylinder head.
7. Install a new O–ring on the end cover.
8. Install the end cover.
9. Install the fuel injector. For detailed procedures, refer to "2.4.2 Installation of Fuel Injector" .
10. Install the cylinder head. For detailed procedures, refer to "1.4.2 Installation of Cylinder Head" .
11. Perform the same procedure for each valve, as required.

Section 1.6
Front Radial Seal

The crankcase front radial seal is one of two seals used to retain the lubricating oil in the crankcase.

Section 1.6.1
Removal of Front Radial Seal

Removal steps are as follows:

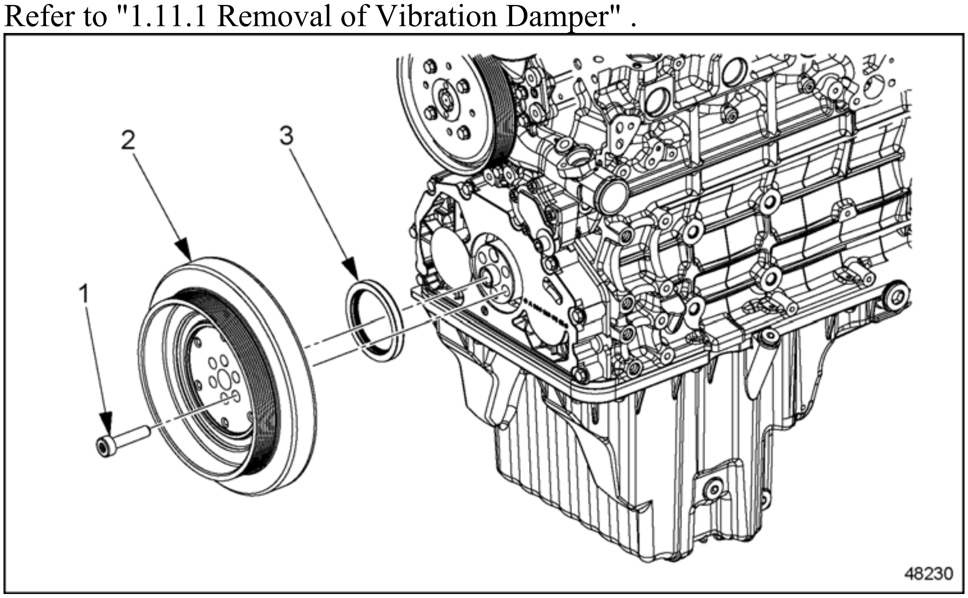
1. Park the vehicle on a level surface, set the parking brakes, and chock the tires.
2. Open the hood.

WARNING:

PERSONAL INJURY

To avoid injury from scalding, drain the radiator when the engine and coolant are cool.

3. Drain the radiator if necessary, to remove coolant system components for access to the seal.
4. Remove the upper and lower radiator hoses, and the radiator overflow hose if necessary, for access to seal.
5. Remove the fan shroud bolts.
6. Remove the fan.
7. Remove the fan clutch and the poly–V belt. Refer to "9.4 Belts — Drive"
   a. Move the fan shroud out of the way.
   b. Remove the poly–V belt. Refer to "9.4 Belts — Drive"
   c. Remove the fan clutch.
8. Remove the water pump pulley.
9. Remove the belt tensioner. Refer to "9.4 Belts — Drive"
10. Remove the vibration damper. See Figure "Front Radial Seal and Vibration Damper Location" . Refer to "1.11.1 Removal of Vibration Damper" .



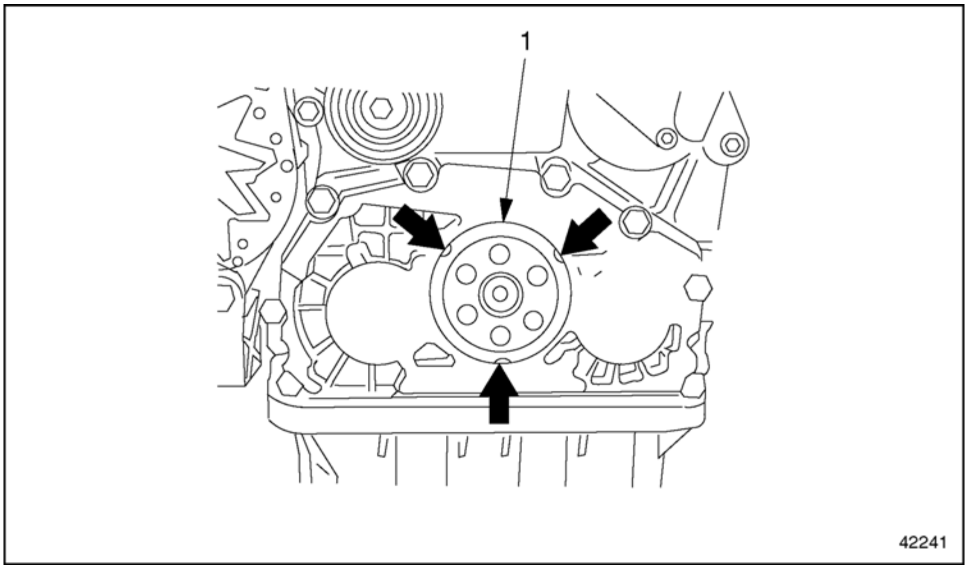
1. Bolts	2. Vibration Damper/Pulley	3. Front Radial Seal

Figure 1. Front Radial Seal and Vibration Damper Location

11. Attach the front seal puller (J–46383) to the front radial seal.

Note: Use a drill bit covered in grease to prevent metal shavings from entering the engine.

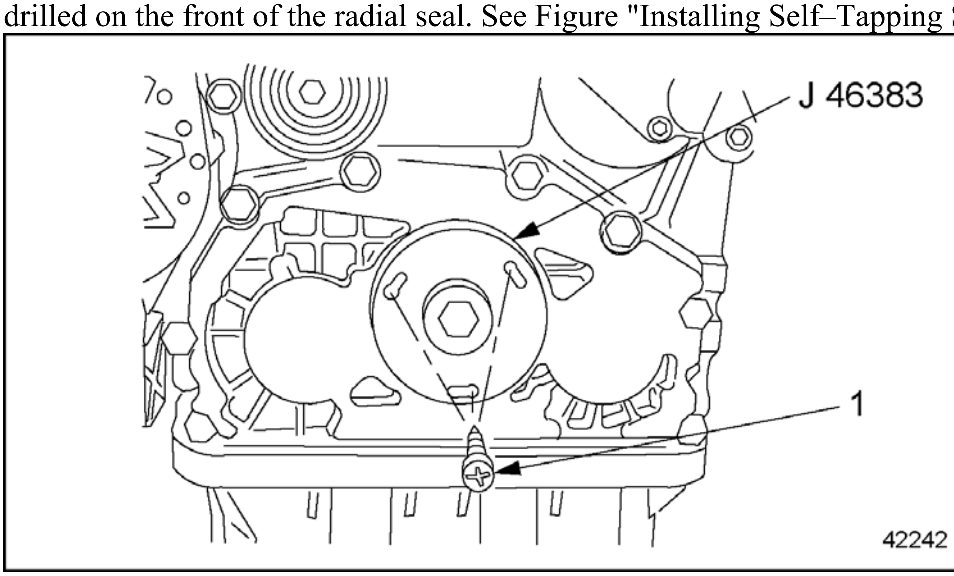
a. Using a drill bit covered in grease, drill three holes into the seal. To locate the holes, look for the indentations in the cover of the radial seal. See Figure "Indentations in the Radial Seal" .



1. Radial Seal

Figure 2. Indentations in the Radial Seal

b. Install three self–tapping screws through the front seal puller (J–46383) and into the holes drilled on the front of the radial seal. See Figure "Installing Self–Tapping Screws" .



1. Self–Tapping Screw (3 qty.)

Figure 3. Installing Self–Tapping Screws

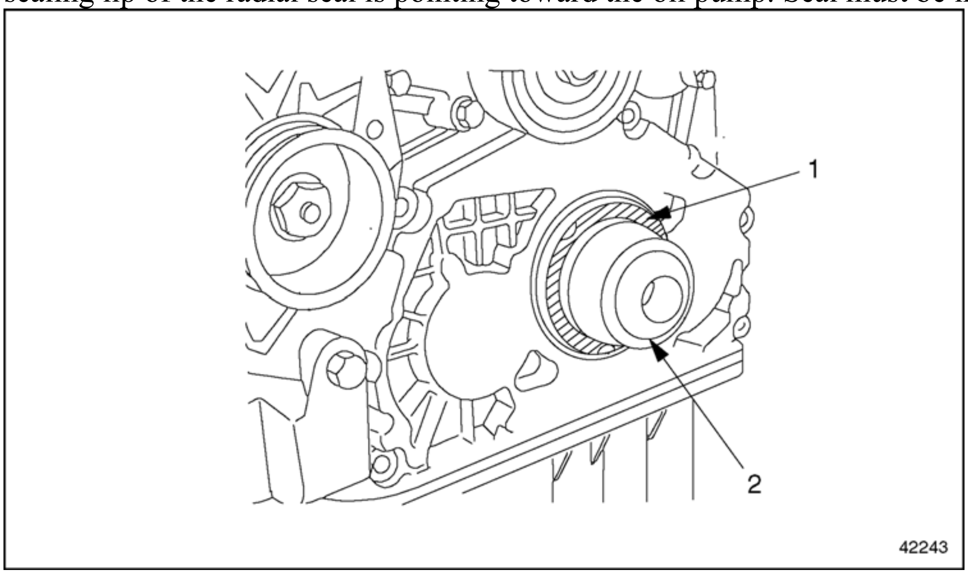
12. Turn the bolt in the center of the puller clockwise until the front radial seal is removed. Remove the seal from the tool.

Section 1.6.2
Installation of Front Radial Seal

Installation steps are as follows:

Note: Do not lubricate the radial seal.

1. Fit the guide sleeve of the front seal installer (J–46388) onto the crankshaft. Then push the new radial seal over the guide sleeve. See Figure "Installing the Front Radial Seal" . Make sure the sealing lip of the radial seal is pointing toward the oil pump. Seal must be installed dry.



1. Front Radial Seal	2. Sleeve Guide for Seal

Figure 4. Installing the Front Radial Seal

2. Put the front seal installer (J–46388) over the sleeve guide, and using a hammer, install the front seal. Make sure the seal is set back 1.5 mm (0.06 in.) from the face of the oil pump housing. See Figure "Correct Installation of the Radial Seal (cross–section view)" .

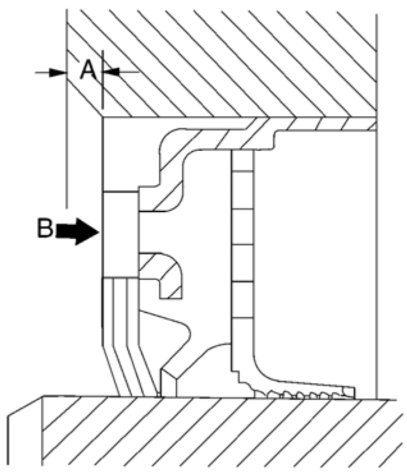


Figure 5. Correct Installation of the Radial Seal (cross–section view)

3. Install the vibration damper on the crankshaft. Tighten the M14 x 1.5 bolts in three stages. For detailed information, refer to "1.11.2 Installation of Vibration Damper" .
4. Install the belt tensioner. Refer to "9.4.2 Installation of Fan Belt" .
5. Install the water pump pulley and the fan clutch.
6. Install the poly–V belt. Refer to "9.4.2 Installation of Fan Belt" .
7. Move the fan shroud back into place. Install the fan and the fan shroud.
8. Install the upper and lower radiator hoses, and the radiator overflow hose.

WARNING:

ENGINE EXHAUST

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

9. Fill the system with coolant, then start the engine and check the coolant system for leaks.
10. Close the hood, and remove the chocks from the tires.

Section 1.7
Rear Radial Seal

The crankcase rear radial seal is one of two seals used to retain the lubricating oil in the crankcase.

Section 1.7.1
Removal of Rear Radial Seal

Removal steps are as follows:

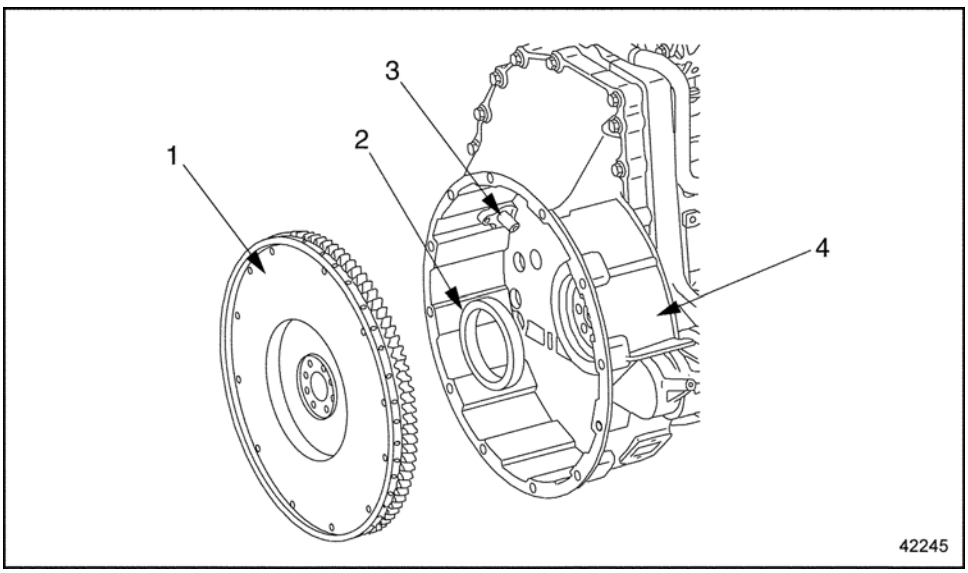
CAUTION:

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.

1. Remove the flywheel. See Figure "Rear Radial Seal Location" and refer to .

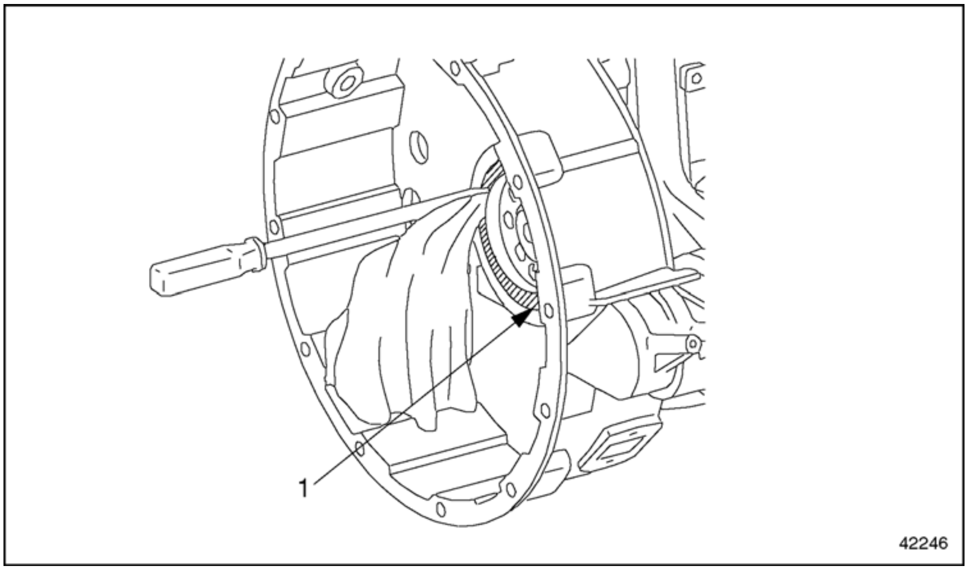
   Note: Make sure the crankshaft position sensor is not damaged during removal of flywheel.



1. Flywheel	3. Crankshaft Position Sensor
2. Rear Radial Seal	4. Flywheel Housing

Figure 1. Rear Radial Seal Location

2. Protect the crankshaft with a rag, then using a screwdriver, carefully pry out the radial seal. See Figure "Removing the Rear Radial Seal" .



1. Rear Radial Seal

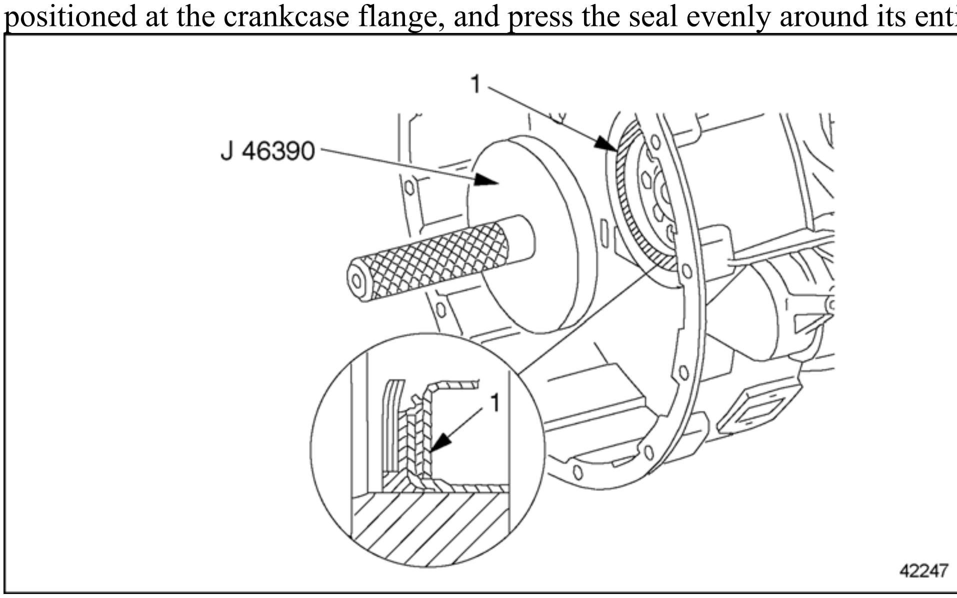
Figure 2. Removing the Rear Radial Seal

Section 1.7.2
Installation of Rear Radial Seal

Installation steps are as follows:

Note: Do not lubricate the radial seal.

1. Inspect the contact surface of the flywheel for damage and wear. If it is scored or worn, replace it.
2. Put the new radial seal in place, and using the rear seal installer (J–46390) , press the seal into position. See Figure "Installing the Rear Radial Seal" . Make sure the rear seal installer is positioned at the crankcase flange, and press the seal evenly around its entire circumference.



1. Rear Radial Seal

Figure 3. Installing the Rear Radial Seal

3. Check the sealing lip on the radial seal to make sure it is positioned correctly. See Figure "Installing the Rear Radial Seal" .

DANGER:

FALLING COMPONENT

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

4. Install the flywheel, using the location dowels for positioning. Refer to "1.12.2 Installation of Flywheel" .

   Note: Make sure the crankshaft position sensor is not damaged during installation.

5. Check the crankshaft position sensor for proper positioning.

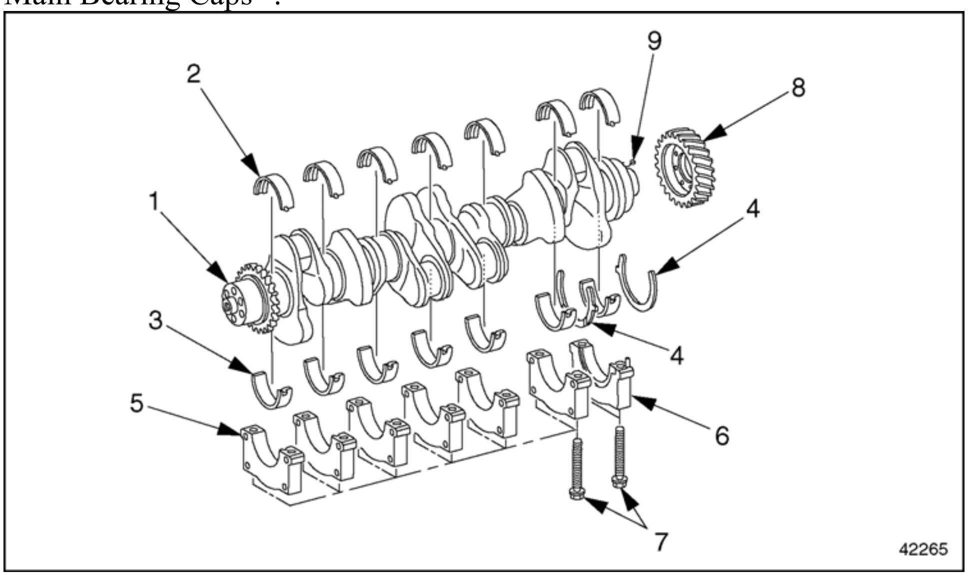
Section 1.8
Crankshaft

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

Section 1.8.1
Removal of Crankshaft

Removal steps are as follows:

1. Remove the engine from the vehicle.
2. Remove the cylinder head. Refer to "1.4.1 Removal of Cylinder Head" .
3. Remove the oil pan. Refer to "3.7.1 Removal of Oil Pan" .
4. Remove the flywheel housing.Refer to "1.16.1 Flywheel Housing Removal" .
5. Remove the oil pump. Refer to "3.3.1 Removal of Oil Pump" .
6. Remove the pistons. Refer to "1.17.1 Removal of Piston"
7. Remove the crankshaft gear from the crankshaft. See Figure "Crankshaft, Main Bearings, and Main Bearing Caps" .



1. Crankshaft	6. Main Bearing Cap for Thrust washer
2. Upper Bearing Shell	7. Main Bearing–Cap Bolt
3. Lower Bearing Shell	8. Crankshaft Gear
4. Thrust washer	9. Locating Pin
5. Main Bearing Caps	

Figure 1. Crankshaft, Main Bearings, and Main Bearing Caps

8. Mark the order of the main bearing caps, then remove the main bearing–cap bolts. Loosen the main bearing caps with a plastic hammer and remove them.

DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

9. Attach a suitable hoist to the crankshaft, using the existing mounting bolts for the flywheel and the vibration damper/belt pulley. Lift the crankshaft out of the crankcase.
10. Mark the upper bearing shells relative to their bearing caps, then remove them from the crankcase.
11. Check all parts for wear or damage. Measure the various crankshaft tolerances. Refer to "1.8.1.1 Measuring of Crankshaft" .

Section 1.8.1.1
Measuring of Crankshaft

Measurement steps are as follows:

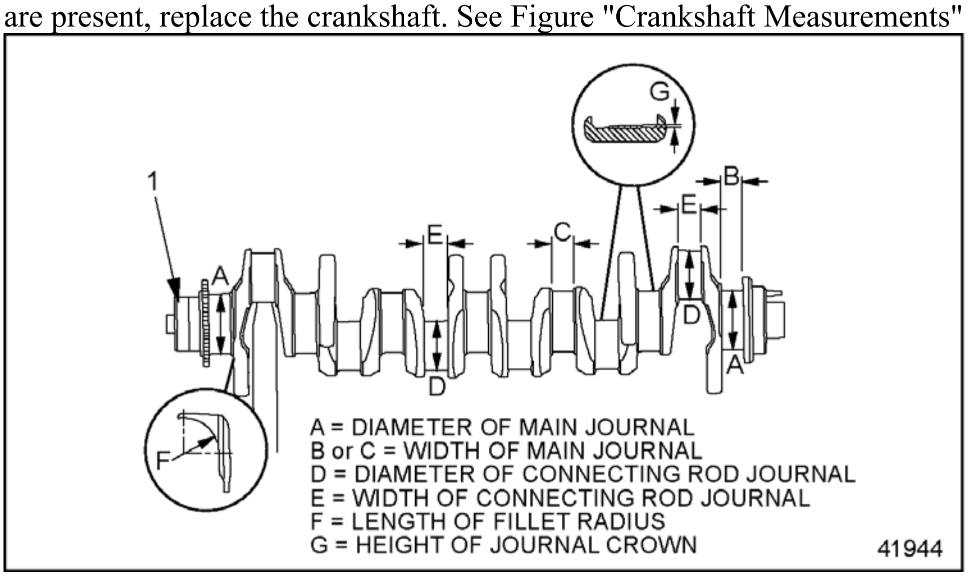
1. Remove the engine and install on an engine stand.

DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

2. Remove the crankshaft. Refer to "1.8.1 Removal of Crankshaft" .
3. Clean the crankshaft. Check the crankshaft flange at the front for wear.
4. Check the main bearing and connecting rod journals for damage and cracks. If damage or cracks are present, replace the crankshaft. See Figure "Crankshaft Measurements" .



1. Crankshaft

Figure 2. Crankshaft Measurements

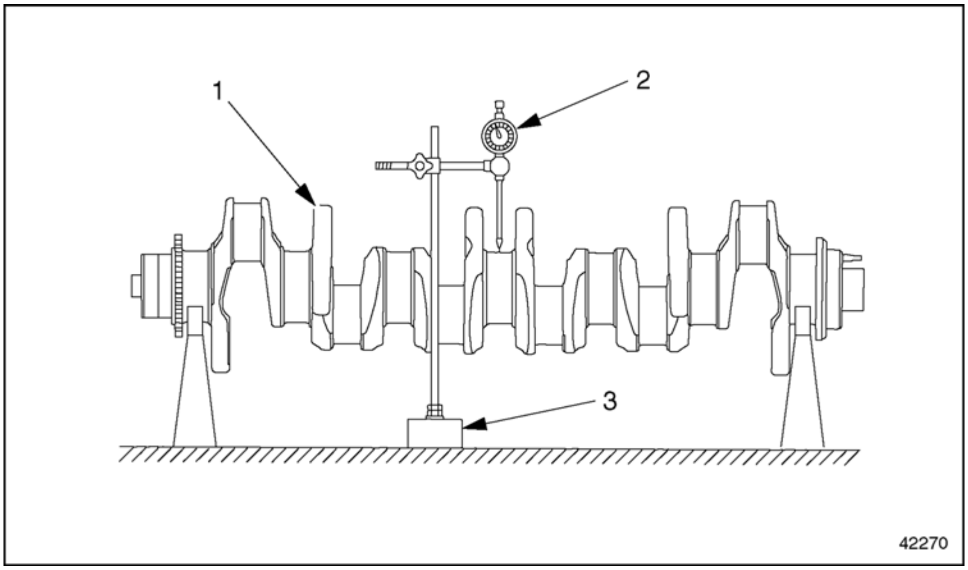
5. Using a hardness tester, test the hardness of the journals. Each journal must pass the hardness test at two thirds of its circumference. If it doesn't, either replace the crankshaft, or have it re–hardened.
   a. Place a base underneath the bearing journal to be tested.
   b. Test the hardness all the way around the journal circumference. The hardness should be a minimum of 52 HRC. The crankshaft specifications are listed in Table "Crankshaft Specifications" .

Descriptions	Specifications mm (in.)
Main and Connecting–Rod Bearing Journals Permissible Difference In Out–Of–Roundness	0.005 (0.0002)
Permissible Taper at Main Bearing Journals and Connecting–Rod Bearing Journals	0.005 (0.0002)
Fillet Radii of Main Bearing and Connecting–Rod Bearing Journals	2.5 to 3.0 (0.0984 to 0.1181)
Radial Runout Measured at Middle Main Journal*	0.15 (0.0059)
Lateral Runout (End Play) Measured at Thrust washer Bearing Journal	0.16–0.38 (0.006–0.015)
Crown of Main Bearing Journals and Connecting–Rod Journals	0.000 to 0.004 (0.000 to 0.0002)
Main Bearing and Connecting Rod Journal Hardness (Rockwell hardness)	52 HRC (min.)
Permissible Imbalance of Crankshaft†	30 gcm (0.4162 in.–ounce)

Table 5. Crankshaft Specifications

**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.

6. Using a dial gauge and holder, measure the radial runout of the crankshaft. Measure at the middle main bearing journal, with the crankshaft supported on the outer main bearing journals. See Figure "Measuring the Crankshaft Radial Runout" . The radial runout is listed in Table "Crankshaft Specifications" .



1. Crankshaft	3. Dial Gauge and Holder
2. Dial Gauge	

Figure 3. Measuring the Crankshaft Radial Runout

7. Measure the diameter of the main and connecting rod journals. Measure each journal at two points, offset at about 90 degrees. See Figure "Measuring the Crankshaft Journals" . The specifications are listed in Table "Crankshaft Repair Specifications" .

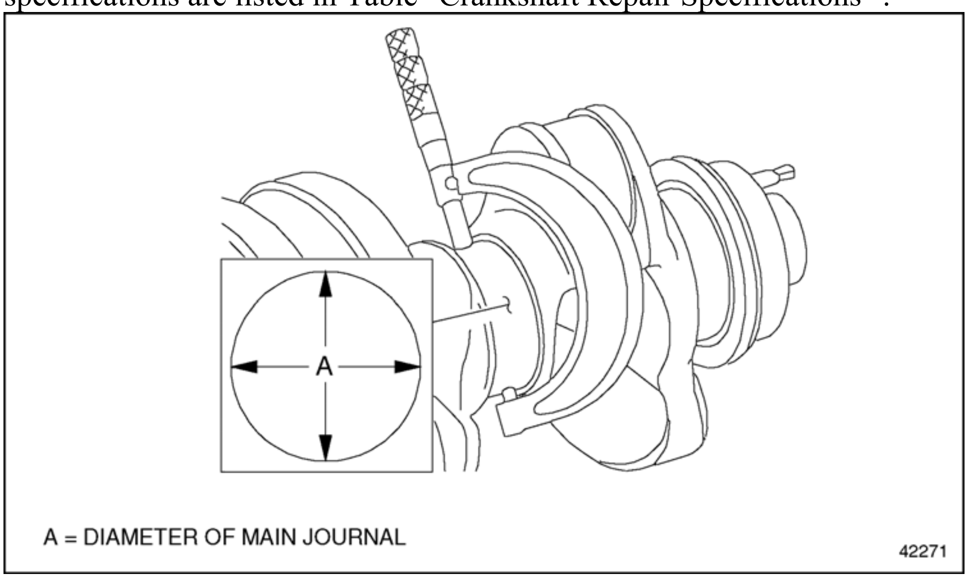


Figure 4. Measuring the Crankshaft Journals

Size mm (in.)	Main Bearing Journal Diameter mm (in.)	Main Bearing Journal Width mm (in.)	Thrustwasher Bearing Journal Width mm (in.)	Connecting–Rod Bearing Journal Diameter mm (in.)	Connecting–Rod Bearing Journal Width mm (in.)
		31.0–31.2			34.0–34.2

All Sizes	—	(1.220–1.228)	—	—	(1.339–1.346)
Standard	85.990–86.010 (3.3854–3.3862)	—	31.000–31.062 (1.2205–1.2229)	69.995–70.015 (2.7557–2.7565)	—
Undersize – 0.10 (0.004)	85.890–85.910 (3.3815–3.3823)	—	—	69.895–69.915 (2.7518–2.7526)	—
Undersize – 0.25 (0.010)	85.740–85.760 (3.3756–3.3764)	—	—	69.745–69.765 (2.7459–2.7466)	—
Undersize – 0.30 (0.012)	—	—	31.300–31.362 (1.2323–1.2347)	—	—
Undersize – 0.50 (0.020)	85.490–85.510 (3.3658–3.3665)	—	31.500–31.562 (1.2402–1.24256)	69.495–69.515 (2.7360–2.7368)	—
Undersize – 0.75 (0.030)	85.240–85.260 (3.3559–3.3567)	—	—	69.245–69.265 (2.7262–2.7270)	—
Undersize – 1.00 (0.040)	84.990–85.010 (3.3461–3.3469)	—	—	68.9950–69.015 (2.7163–2.7171)	—

Table 7. Crankshaft Repair Specifications

8. Measure the following dimensions on the crankshaft, see Figure "Crankshaft Measurements" and reference the specifications listed in Table "Crankshaft Specifications" and listed in Table "Crankshaft Repair Specifications" .
   - Thrust washer bearing journal width
   - Main bearing journal width
   - Connecting–rod journal width
   - Fillet radii of main and connecting–rod journals
   - Crown of main and connecting–rod journals
   - Out–of–roundness difference between the main and connecting–rod bearing journals
   - Imbalance of the crankshaft
   - Taper of main and connecting–rod bearing journals

Section 1.8.1.2
Positioning the Crankshaft Radially

Measure for radial position as follows:

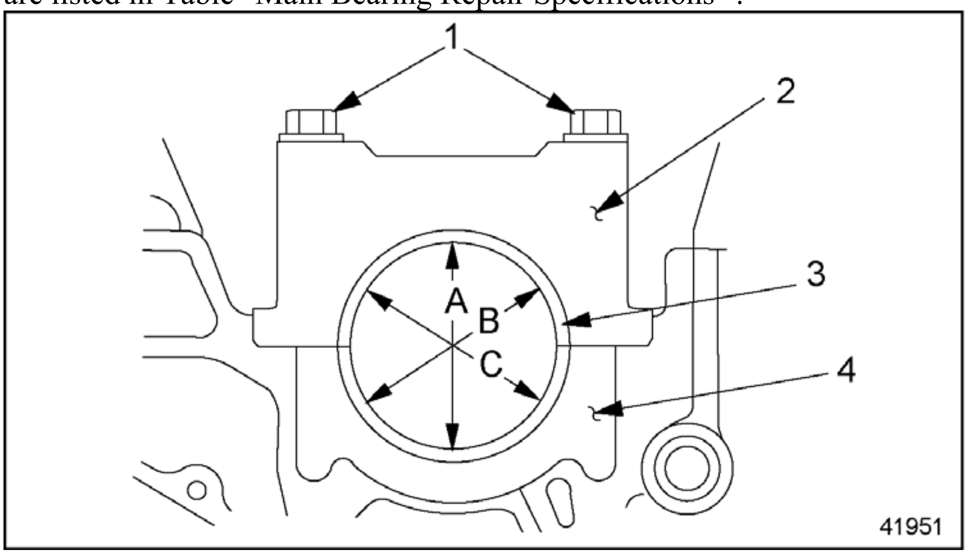
1. If not already done, remove the engine from the engine stand.

DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

2. If needed, remove the crankshaft from the engine, and remove the connecting rods and their bearings and the main bearing shells from the crankshaft. Refer to "1.8.1 Removal of Crankshaft" .
3. If needed, clean the bearing points of the crankshaft with a chamois.
4. Measure the main bearing journal. Refer to "1.8.1.1 Measuring of Crankshaft" .
5. Assemble the main bearing shells into the crankcase and the main bearing caps. Then install the main bearing caps. Refer to "1.8.2 Installation of Crankshaft" .
6. Using a dial gauge and calipers, measure the inside diameter of each of the main bearings. See Figure "Measuring the Inside Diameter of the Main Bearings" . The main bearing specifications are listed in Table "Main Bearing Repair Specifications" .



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

Figure 5. Measuring the Inside Diameter of the Main Bearings

Size mm (in.)	Main Bearing Inner Diameter mm (in.)
Standard	86.066 to 86.108 (3.388 to 3.390)
Undersize – 0.1 (0.0039)	85.966 to 86.008 (3.384 to 3.386)
Undersize – 0.25 (0.0098)	85.816 to 85.858 (3.379 to 3.380)

Undersize – 0.5 (0.0197)	85.566 to 85.608 (3.369 to 3.370)
Undersize – 0.75 (0.0295)	85.316 to 85.358 (3.359 to 3.361)
Undersize – 1.0 (0.0394)	85.066 to 85.108 (3.349 to 3.351)

Table 10. Main Bearing Repair Specifications

a. Measure vertically from the top to the bottom of the bore (see Figure "Measuring the Inside Diameter of the Main Bearings" , A).
b. Measure 30 degrees counterclockwise from the separation point of the bearing shells (see Figure "Measuring the Inside Diameter of the Main Bearings" , B).
c. Measure 30 degrees clockwise from the separation point of the bearing shells (see Figure "Measuring the Inside Diameter of the Main Bearings" , C).

7. If any one of the readings is not within tolerances, replace the main bearing shells as applicable.

   Note: New bearing shells are supplied ready for installation. Do not machine them.

8. Remove the bearing caps.

DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

9. Install the crankshaft into the cylinder block. Refer to "1.8.2 Installation of Crankshaft" .
10. Install the engine in the vehicle.

Section 1.8.2
Installation of Crankshaft

Installation steps are as follows:

WARNING:

EYE INJURY

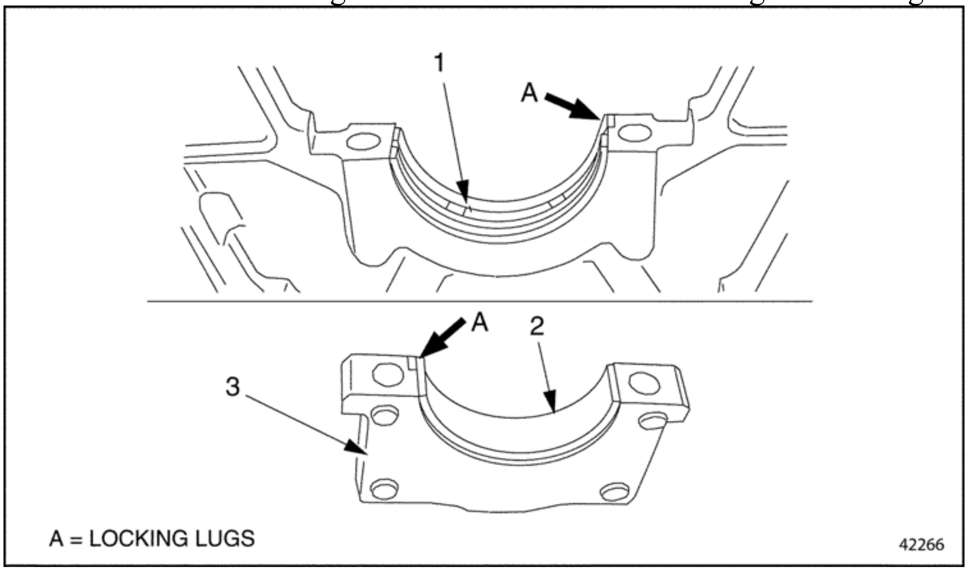
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 276 kPa (40 psi) air pressure.

1. 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. Check the main bearing and connecting rod journals for damage and cracks. If damage or cracks are present, replace the crankshaft.
3. Measure the crankshaft journals. Refer to "1.8.1.1 Measuring of Crankshaft" .
4. Lightly coat the bearing surfaces with clean engine oil.

NOTICE:

The oil holes of the upper bearing shells must be aligned with those of the crankcase. If these holes are not aligned, the bearings will not be sufficiently lubricated, and engine damage will result.

5. Install the upper bearing shells into the crankcase, in the same order they were removed.
6. Make sure the locking lugs of the bearing shells fit into the slots of the crankcase bores, and that the oil holes of the bearing shells and the crankcase are aligned. See Figure "Main Bearing" .



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

Figure 6. Main Bearing

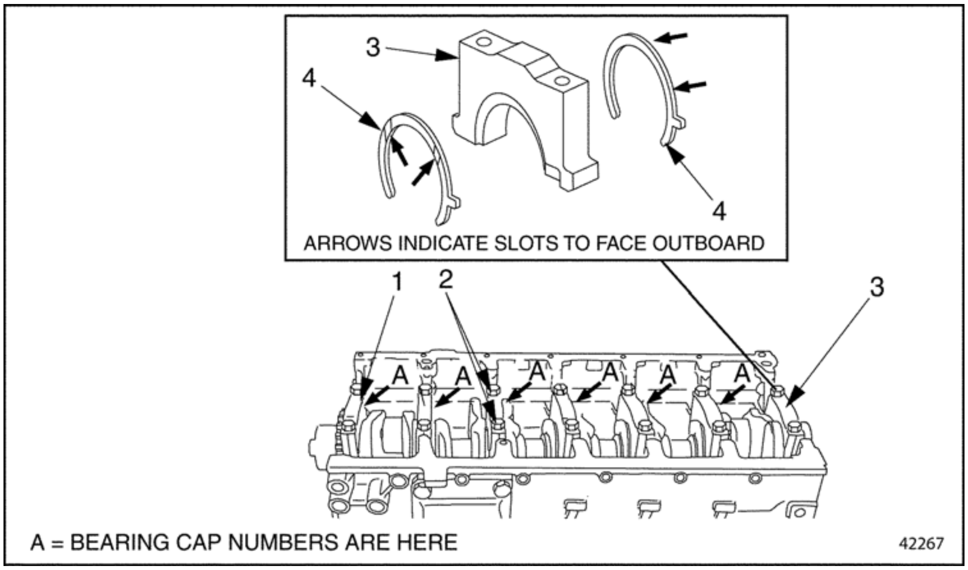
7. Install the lower bearing shells into main bearing caps, making sure the locking lugs are fully seated in the grooves of the bearing caps. See Figure "Main Bearing" .

DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

8. Using a suitable hoist, lower the crankshaft into the crankcase.
9. Position all the bearing caps (except the thrust washer bearing cap) with their bearing shells on the crankcase journals. All the bearing caps fit into the crankcase at the side (off–centered). Make sure the numbers on the bearing caps are in ascending order, starting from the front of the engine. See Figure "Main Bearing Cap Markings" .

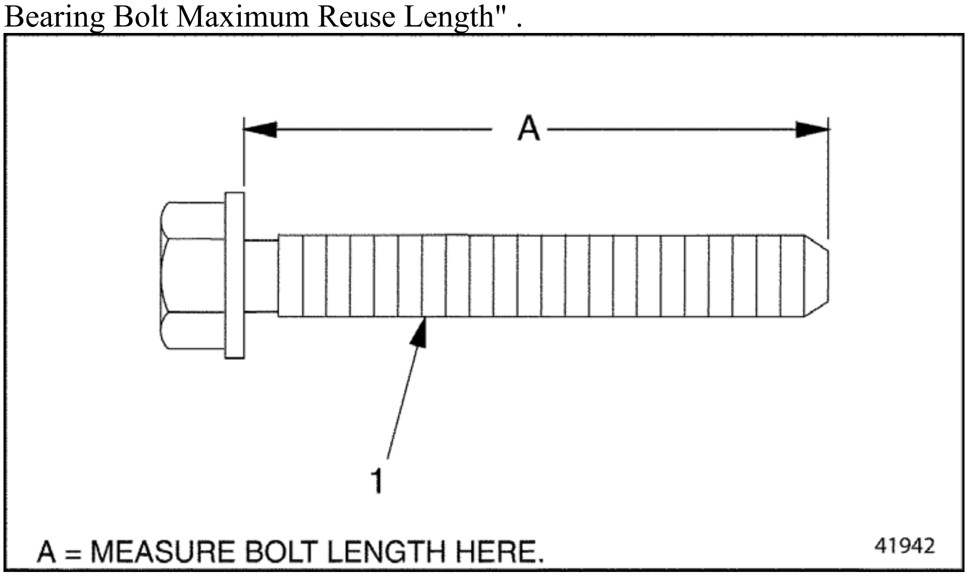


1. Bearing Caps	3. Thrust washer Bearing Cap
2. Bearing–Cap Bolts	4. Thrust washer (arrows indicate slots to face outboard)

Figure 7. Main Bearing Cap Markings

Note: The main bearing bolts have changed on some MBE 900 engines. Ensure that the correct length bolts are used when replacing.

10. Measure the shaft length of the main bearing–cap bolts. Replace any bolts that exceed the maximum shaft length. See Figure "Measuring a Main Bearing–Cap Bolt" and see Table "Main Bearing Bolt Maximum Reuse Length" .



1. Main Bearing–Cap Bolt

Figure 8. Measuring a Main Bearing–Cap Bolt

Size	Bolt Shaft Lengths (New) mm (in.)	Maximum Shaft Lengths mm (in.)

M14 x 2.0	114 (4.48)	116.0 (4.57)
	134 (5.28)	136.0 (5.35)

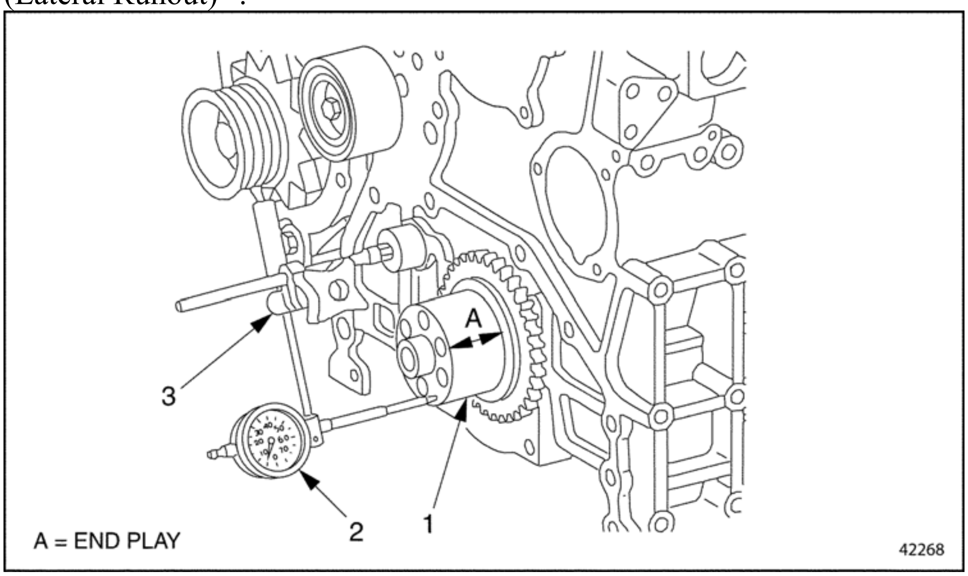
Table 18. Main Bearing Bolt Maximum Reuse Length

11. Put a light coat of oil on the main bearing–cap bolts. Install all the M14 main bearing–cap bolts. Tighten each one in four stages. The tightening stages are listed in Table "Tightening Stages, Main Bearing–Cap Bolts" .

Size	Max. Shaft Length mm (in.)	Tightening Stage	Torques N·m (lb·ft)
M14 x 2.0	116.0 (4.57) or 136.0 (5.35)	Stage 1	30 (22)
		Stage 2	80 (59)
		Stage 3	155 (114)
		Stage 4	additional 90 degrees

Table 19. Tightening Stages, Main Bearing–Cap Bolts

12. Install the thrust washers in the bearing cap, making sure the slots on the thrust washers are facing outboard. See Figure "Main Bearing Cap Markings" .
13. Install the thrust washer bearing cap. Tighten the bolts in stages to the same torque as the other bearing–cap bolts.
14. Measure the crankshaft end–play (lateral runout) at the thrust washer bearing journal. See Figure "Checking the Crankshaft End–Play (Lateral Runout)" .
    a. Set up a dial gauge and a dial gauge holder. See Figure "Checking the Crankshaft End–Play (Lateral Runout)" .



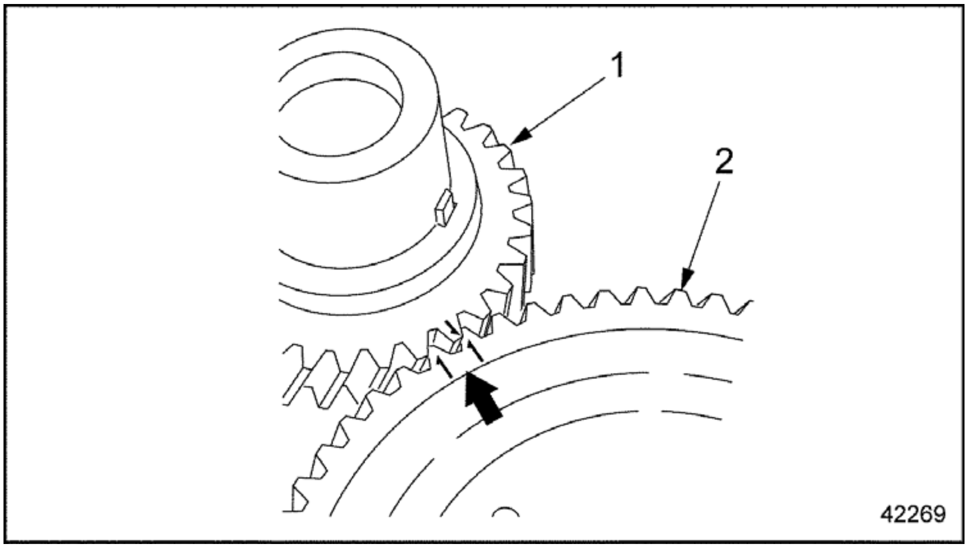
1. Crankshaft	3. Dial Gauge Holder
2. Dial Gauge	

Figure 9. Checking the Crankshaft End–Play (Lateral Runout)

    b. Move the crankshaft all the way forward by prying on one of the bearing caps, then zero out the dial gauge. See Figure "Checking the Crankshaft End–Play (Lateral Runout)" , A.
    c. Move the crankshaft all the way to the rear. Note the end–play on the dial gauge. See Figure "Checking the Crankshaft End–Play (Lateral Runout)" , A.

d. If the end–play is not 0.16 mm to 0.38 mm (0.006 in. to 0.015 in.), replace the thrust washers with those of the necessary thickness. Oversize thrust washers are available.

15. Attach the crankshaft gear to the crankshaft flange. Refer to "1.9.2 Installation of Crankshaft Gear" . Align the key on the crankshaft with the keyway in the gear. Make sure the mark "1" on the crankshaft gear is between the markings "1–1" on the camshaft gear. See Figure "Aligning the Marked Gear Teeth" .



1. Crankshaft Gear	2. Camshaft Gear

Figure 10. Aligning the Marked Gear Teeth

16. Install the pistons. Refer to "1.17.2 Installation of Piston" .
17. Install the oil pump. Refer to "3.3.2 Installation of Oil Pump" .
18. Install the oil pan. Refer to "3.7.2 Installation of Oil Pan" .

DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

19. Install the flywheel housing. Refer to "1.16.2 Installation of Flywheel Housing" .
20. Install the cylinder head. Refer to "1.4.2 Installation of Cylinder Head" .
21. Install the engine in the vehicle.

Section 1.9
Crankshaft Gear

The following sections describe crankshaft gear removal and installation.

Section 1.9.1
Removal of Crankshaft Gear

Removal steps are as follows:

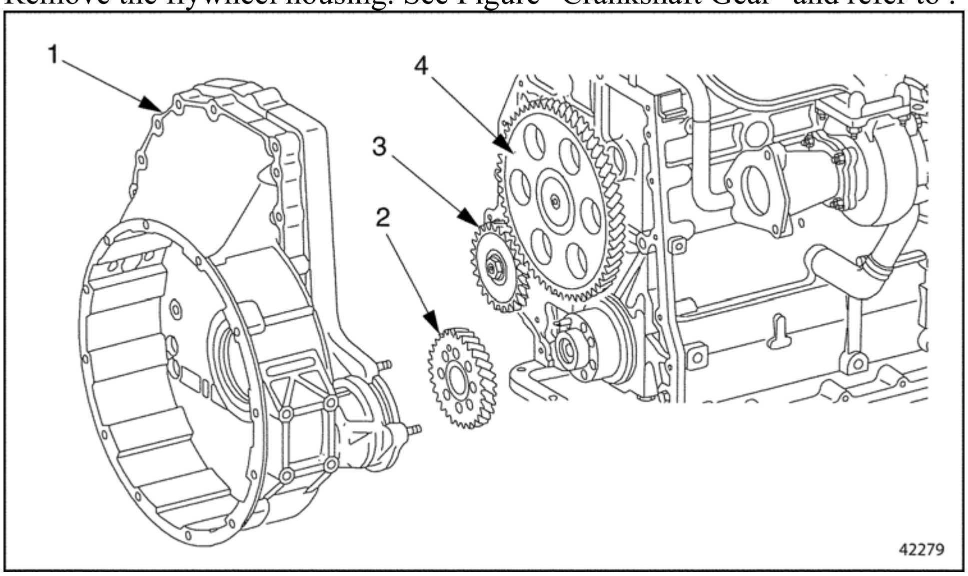
1. To remove the crankshaft gear, first remove the engine.

DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

2. Remove the flywheel housing. See Figure "Crankshaft Gear" and refer to .

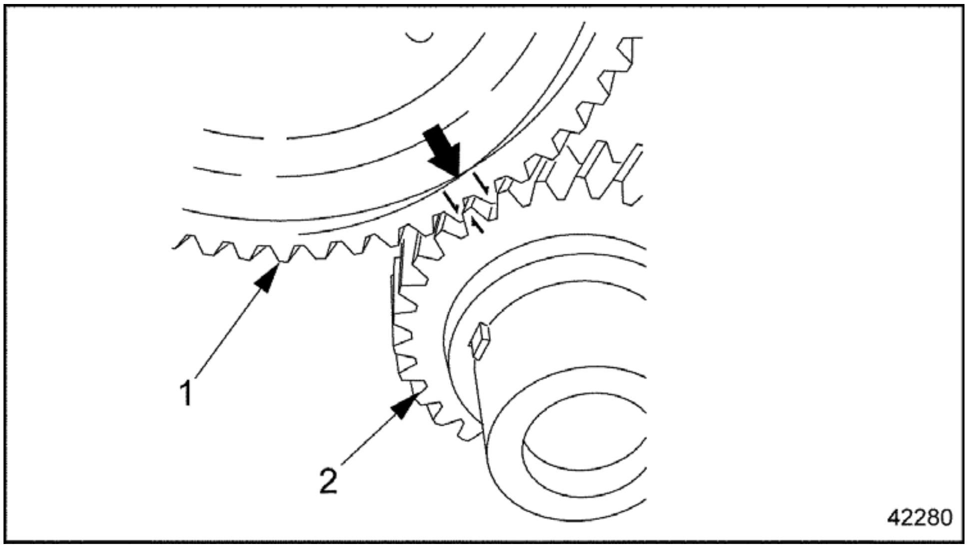


1. Flywheel Housing	3. Air Compressor Gear
2. Crankshaft Gear	4. Camshaft Gear

Figure 1. Crankshaft Gear

Note: Fasteners not shown.

3. Rotate the crankshaft until the "1" on the crankshaft gear is lined between the "1–1" mark on the camshaft gear. See Figure "Aligning the Camshaft and Crankshaft Gear Marks" .



1. Camshaft Gear	2. Crankshaft Gear

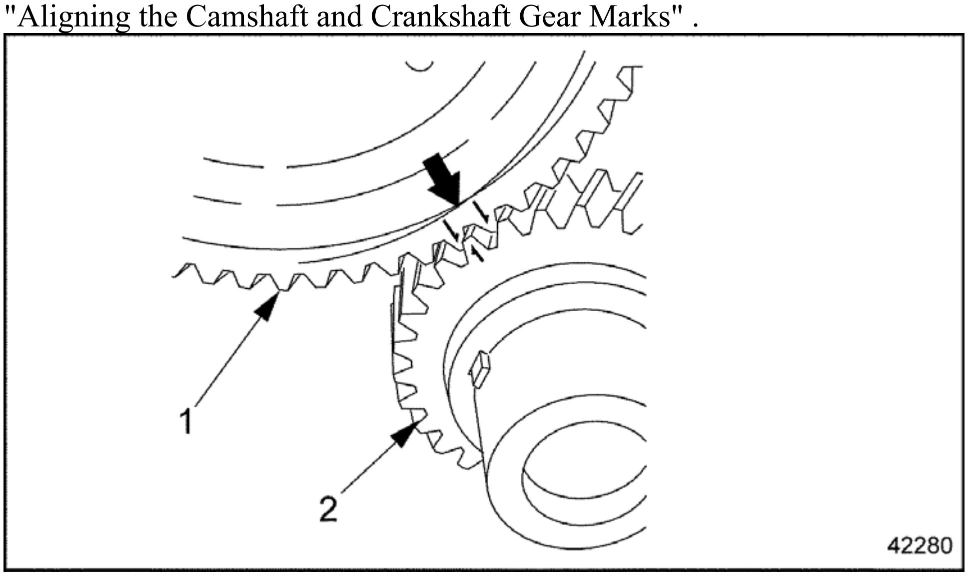
Figure 2. Aligning the Camshaft and Crankshaft Gear Marks

4. Pull the crankshaft gear off the end of the crankshaft.

Section 1.9.2
Installation of Crankshaft Gear

Installation steps are as follows:

1. Line up the keyway in the crankshaft gear with the key on the end of the crankshaft. Make sure the "1" mark on the crankshaft gear is between the "1–1" mark on the camshaft gear. See Figure "Aligning the Camshaft and Crankshaft Gear Marks" .



1. Camshaft Gear	2. Crankshaft Gear

Figure 3. Aligning the Camshaft and Crankshaft Gear Marks

2. Install the flywheel housing. Refer to "1.16.2 Installation of Flywheel Housing" .
3. Install the engine in the vehicle.

Section 1.10
Oil Pump Drive Gear

The drive gear for the oil pump must be replaced, not repaired.

Section 1.10.1
Removal of Oil Pump Drive Gear

Removal steps are as follows:

1. Remove the engine from the vehicle.

DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

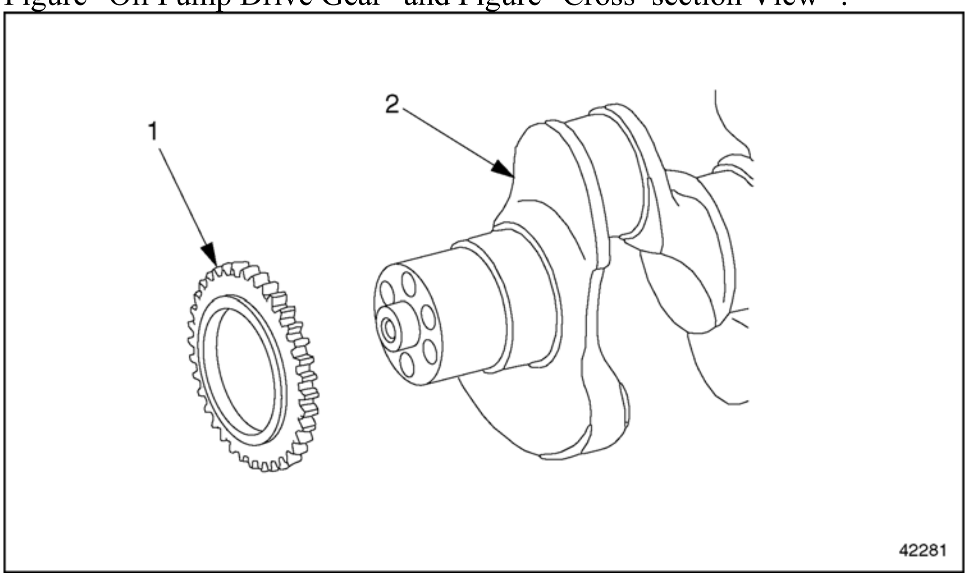
2. Remove the crankshaft from the engine. Refer to "1.8.1 Removal of Crankshaft" .

WARNING:

BURNS

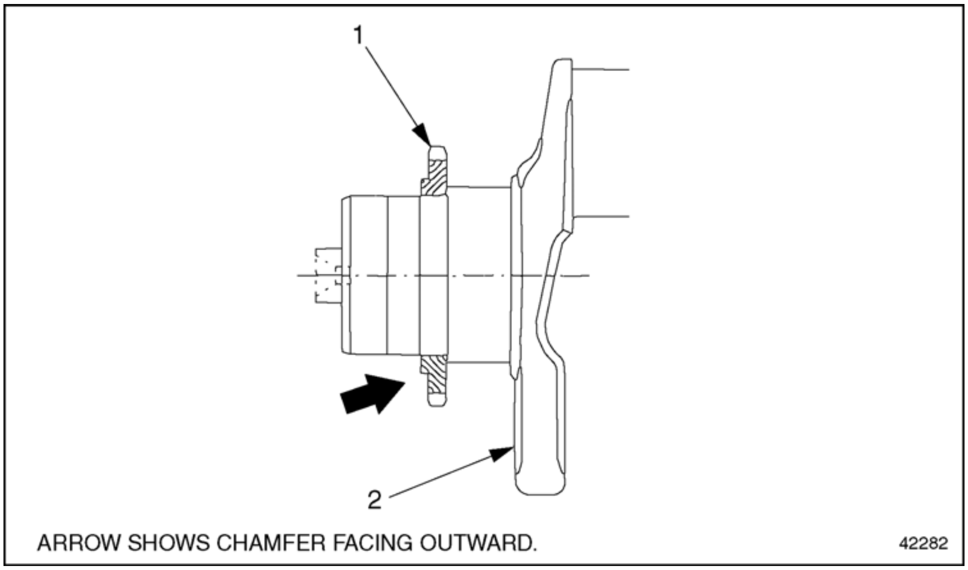
To avoid injury from burning, use lifting tools and heat-resistant gloves when handling heated components.

3. Heat the oil pump drive gear to 200°C (392°F).
4. Using a suitable puller, remove the oil pump drive gear from the front end of the crankshaft. See Figure "Oil Pump Drive Gear" and Figure "Cross–section View" .



1. Oil Pump Drive Gear	2. Crankshaft

Figure 1. Oil Pump Drive Gear



1. Oil Pump Drive Gear	2. Crankshaft

Figure 2. Cross–section View

Section 1.10.2
Oil Pump Drive Gear Installation

Install the new oil pump drive gear as follows:

WARNING:

BURNS

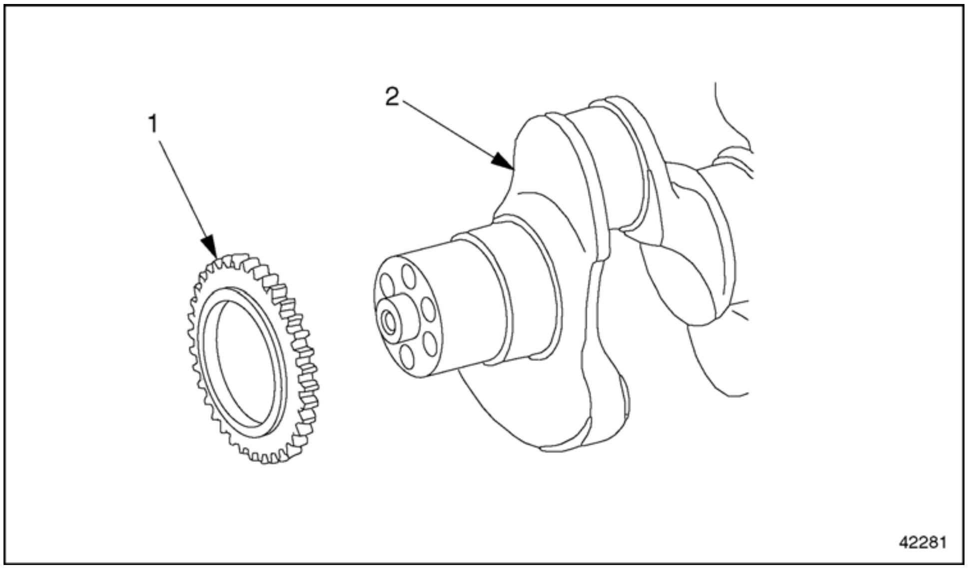
To avoid injury from burning, use lifting tools and heat-resistant gloves when handling heated components.

1. Heat the new oil pump drive gear to 200°C (392°F).
2. Press the gear onto the end of the crankshaft. Make sure the chamfer on the gear is facing outward. See Figure "Oil Pump Drive Gear" .

DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.



1. Oil Pump Drive Gear	2. Crankshaft

Figure 3. Oil Pump Drive Gear

3. Install the crankshaft. Refer to "1.8.2 Installation of Crankshaft" .
4. Install the engine in the vehicle.

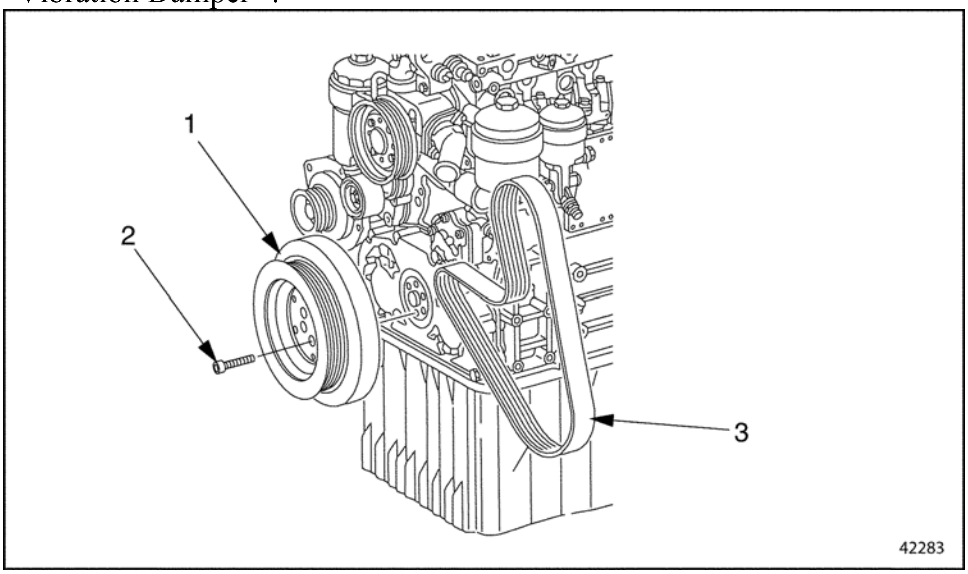
Section 1.11
Belt Pulley and Vibration Damper

The vibration damper reduces torsional vibrations to a safe value.

Section 1.11.1
Removal of Vibration Damper

Removal steps are as follows:

1. Remove the poly–V belt from the alternator, idler, A/C compressor, and coolant–pump pulleys, as installed.
2. Remove the end cover from the flywheel housing and install the engine barring tool (J–46392) . Refer to "1.15.1 Installation of Engine Barring Tool" .
3. Using the 16 mm (0.63 in.) flywheel and main pulley socket tool (J–46385) , remove the six multipoint socket–head bolts on the vibration damper. Remove the vibration damper. See Figure "Vibration Damper" .



1. Vibration Damper	3. Poly–V Belt
2. Bolt, M14 x 1.5 (6 qty.)	

Figure 1. Vibration Damper

4. Measure the shanks on the bolts. Replace the bolts if the shanks are stretched beyond the maximum length of 61.0 mm (2.40 in.).

Section 1.11.1.1
Vibration Damper Inspection

Inspect the vibration damper for damage. Replace the damper if the external surface is damaged, or if fluid leakage is apparent.

Section 1.11.2

Installation of Vibration Damper

Installation steps are as follows:

1. Lightly oil the threads and under the head of the bolt on six M14 x 1.5 bolts.
2. Install the vibration damper on the crankshaft. Tighten the six bolts in three stages. In each stage, use an alternating tightening sequence until all six bolts are tight. See Figure "Torque Tightening Sequence for Vibration Damper" . The tightening stages specifications are listed in Table "Tightening Stages, Vibration Damper Mounting Bolts" .

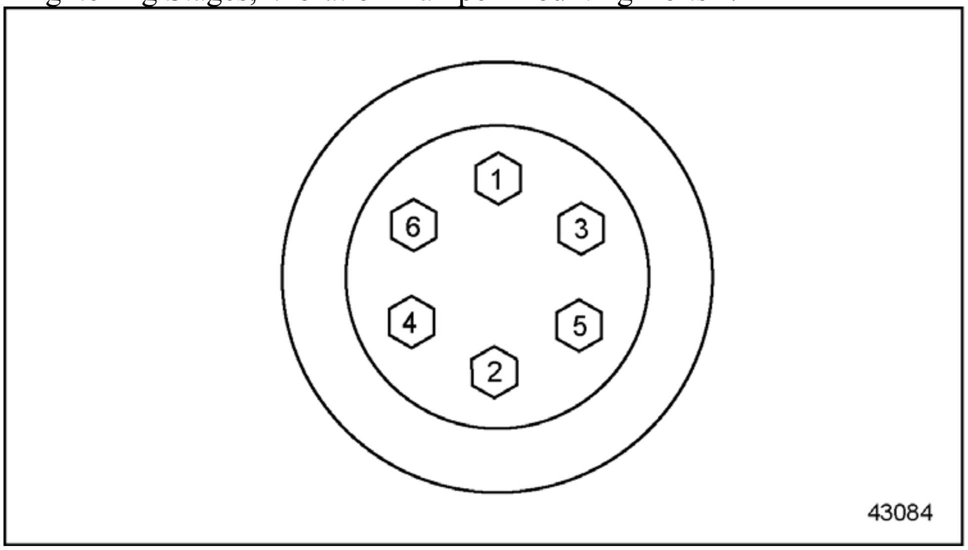


Figure 2. Torque Tightening Sequence for Vibration Damper

Maximum Shaft Length mm (in.)	Tightening Stage	Torques N·m (lb·ft)
61.0 (2.40)	Stage 1	50 (37)
	Stage 2	125 (92)
	Stage 3	additional 90 degrees

Table 2. Tightening Stages, Vibration Damper Mounting Bolts

3. Remove the engine barring tool (J–46392) from the flywheel housing and install the end cover. Refer to "1.15.2 Removal of Engine Barring Tool" . Tighten the end cover bolts 25 N·m (18 lb·ft).
4. Install the poly–V belt on the pulleys, as removed.

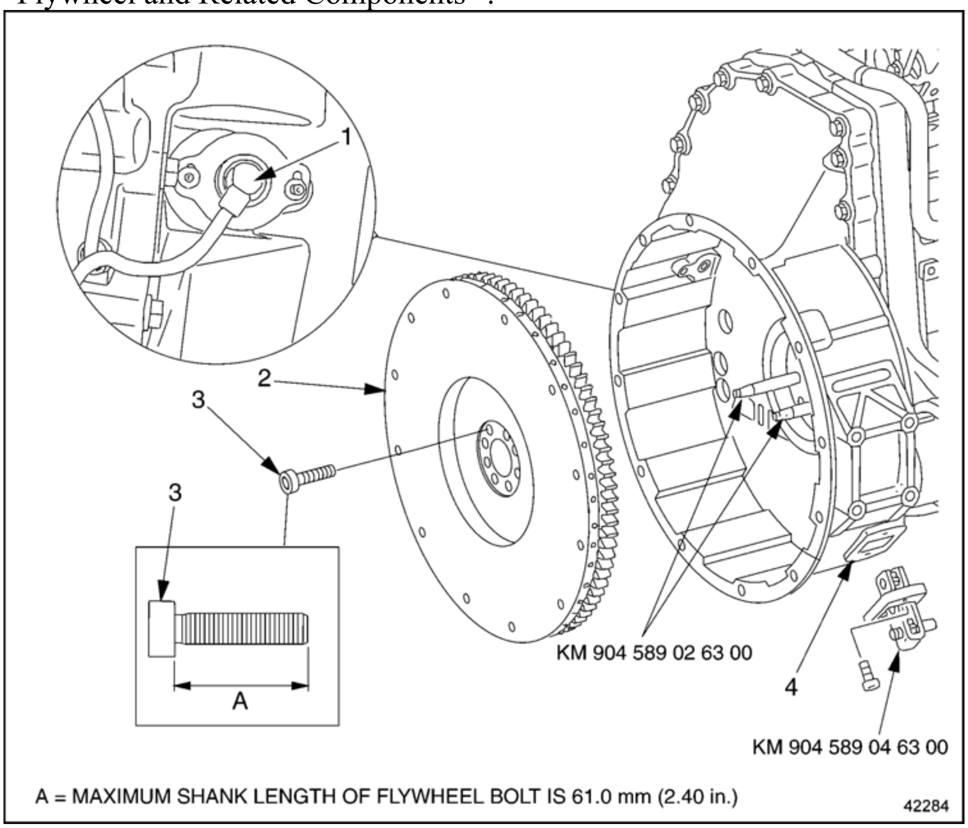
Section 1.12
Flywheel

The flywheel must be removed for service operations such as replacing the crankshaft radial oil seal, the crankshaft, or the flywheel housing.

Section 1.12.1
Removal of Flywheel

Removal steps are as follows:

1. Remove the transmission.
2. Remove the clutch from the flywheel.
3. Pull the crankshaft position sensor out of the flywheel housing about 8 mm (0.32 in.). See Figure "Flywheel and Related Components" .



1. Crankshaft Position Sensor	3. Bolt, M14 x 1.5 (8 qty.)
2. Flywheel	4. Flywheel Housing, End Cover Location

Figure 1. Flywheel and Related Components

4. Remove the end cover from the flywheel housing and install the engine barring tool (J–46392) . Tighten the bolts on the barring device 25 N·m (18 lb·ft). Refer to "1.15.1 Installation of Engine Barring Tool" . Insert the locking pin to block the device from rotating.
5. Using the 16 mm (0.63 in.) flywheel and main pulley socket tool (J–46385) , remove two flywheel

socket–head bolts from the flywheel, one from each side of the bolt circle.

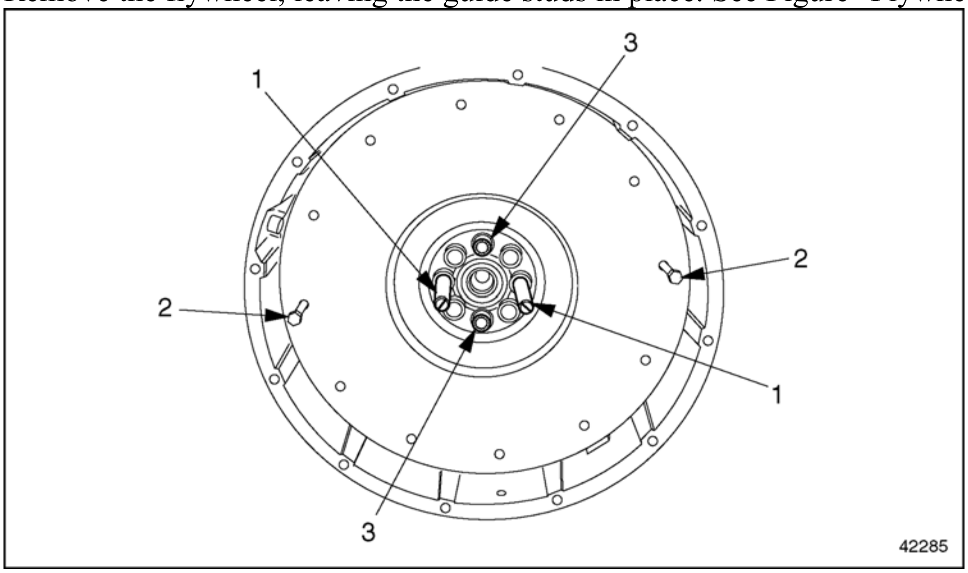
6. Install the two flywheel guide studs (J–46389) into the empty bolt holes in the center of the flywheel. See Figure "Flywheel and Related Components" .

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.

7. Remove the remaining six flywheel bolts.
8. Remove the engine barring tool (J–46392) . Refer to "1.15.2 Removal of Engine Barring Tool" .
9. Remove the flywheel, leaving the guide studs in place. See Figure "Flywheel" .



1. Flywheel Guide Stud	3. Flywheel Mounting Bolt
2. Bolt Used as Handle	

Figure 2. Flywheel

a. On opposite sides of the bolt circle, insert a clutch 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 61.0 mm (2.40 in.).

Section 1.12.1.1
Inspection of Flywheel

Inspection steps are as follows:

1. Thoroughly clean the flywheel and check the clutch surface for cracks, burned spots, or scoring.
2. Using an accurate straightedge and a feeler gauge, check the friction (clutch) surface for evenness. See Figure "Checking the Friction Surface for Evenness" . If the surface has areas that are too high or too low as Listed in Table "Flywheel Specifications" , machine the surface or replace the flywheel.

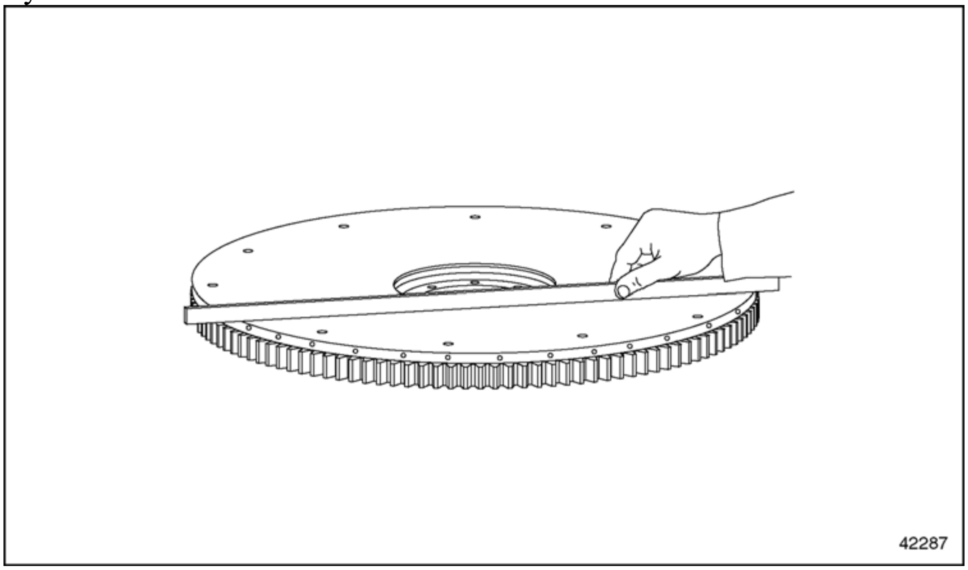


Figure 3. Checking the Friction Surface for Evenness

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

   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. The after–machining specifications are listed in Table "Flywheel Specifications" , Ref E.

4. Machine the flywheel friction surface, if required, to the specifications listed in Table "Flywheel Specifications" . See Figure "Machining the Flywheel Friction Surface" and see Figure "Flywheel Cross Section" . The surface finish (peak–to–valley height) after machining should be 16 µm (630 µin). A rougher surface finish will cause rapid clutch lining wear, while a smoother finish could cause difficulties in clutch disengagement.

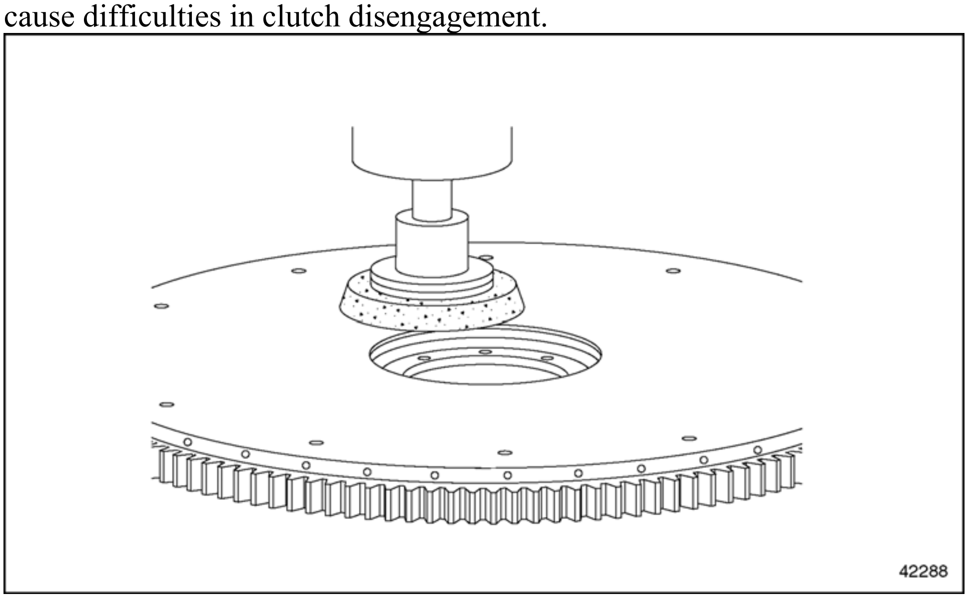
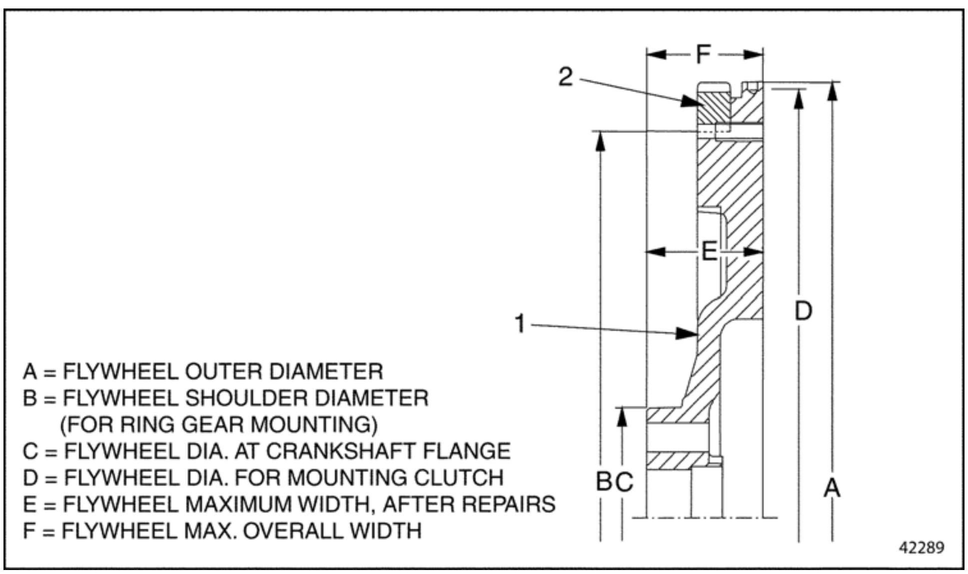


Figure 4. Machining the Flywheel Friction Surface

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

Descriptions	Specifications mm (in.)
Flywheel Outer Diameter (see Figure , Ref. A)	443 (17.4)
Flywheel Shoulder Diameter (for ring gear mounting – see Figure , Ref. B)	392.435–392.575 (15.4502–15.4557)
Flywheel Diameter at Crankshaft Flange (see Figure , Ref. C)	114.960–115.020 (4.5260–4.5283)
Flywheel Diameter for Mounting Clutch (see Figure , Ref. D)	435.000–435.063 (17.1260–17.1285)
Flywheel Minimum Width Between Friction Surface and Mounting Flange After Repairs (see Figure , Ref. E)	55 (2.17)
Flywheel Maximum Overall Width (see Figure , Ref. F)	56 (2.20)
Pitch Circle Diameter for Clutch	373.7 (14.71)
Peak–to–Valley Height (R_Z) of Clutch Friction Surface	16 µm (630 µin)
Flywheel Permissible Deviation From True (radial and lateral)	0.05 (0.002)

Table 4. Flywheel Specifications



1. Flywheel	2. Ring Gear

Figure 5. Flywheel Cross Section

5. Check the radial and lateral deviation from true of the flywheel. The deviation from true must not exceed 0.05 mm (0.002 inch).

Section 1.12.2
Installation of Flywheel

Installation steps are as follows:

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

DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

2. Align the flywheel with the location dowel on the crankshaft flange. Install the flywheel over the guide studs.
3. Install the engine barring tool (J–46392) in the flywheel housing and secure with two bolts. Insert the locating pin and make sure the tool gears do not rotate. Refer to "1.15.1 Installation of Engine Barring Tool" .
4. Lightly oil the threads on eight M14 x 1.5 multipoint socket–head bolts.
5. Tighten the eight bolts in three stages as listed in Table "Tightening Stages, Flywheel Mounting Bolts" . In each stage, use the torquing sequence in the next illustration (see Figure "Flywheel Torquing Sequence").

Size	Max. Shaft Length mm (in.)	Tightening Stage	Torques N·m (lb·ft)
M14 x 1.5	61.0 (2.40)	Stage 1	50 (37)
		Stage 2	125 (92)
		Stage 3	additional 90 degrees

Table 7. Tightening Stages, Flywheel Mounting Bolts

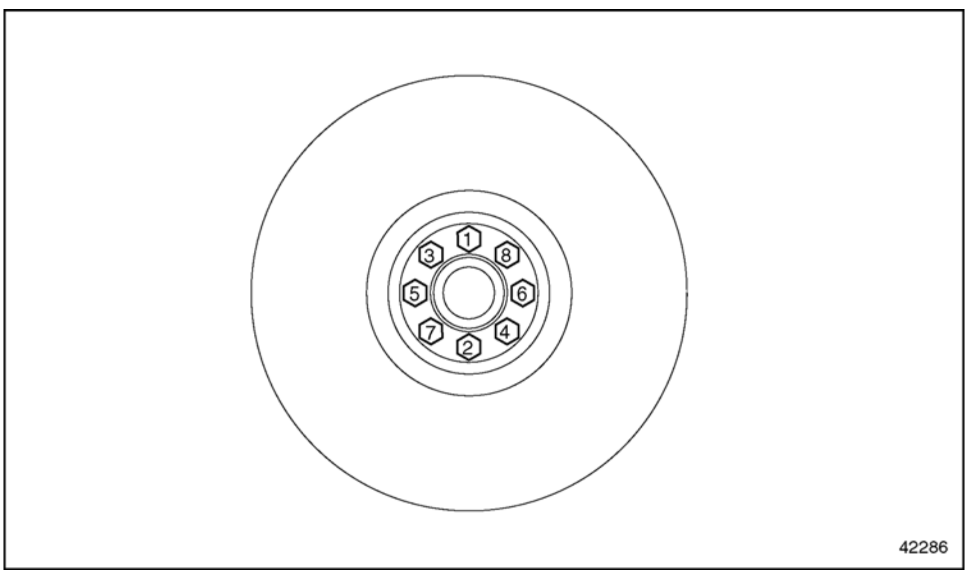


Figure 6. Flywheel Torquing Sequence

a. Install six bolts to hold the flywheel in position.

b. Remove the two guide studs and install the two remaining bolts in their place.
c. Tighten the bolts, in the correct torquing sequence, 50 N·m (37 lb·ft).
d. Repeat the torquing sequence to tighten the bolts 125 N·m (92 lb·ft).
e. Using the same torquing sequence, turn the flywheel bolts an additional 90 degrees.

6. Remove the engine barring tool. Install the end cover on the flywheel housing with two bolts. Tighten the bolts 25 N·m (18 lb·ft).
7. Push the crankshaft position sensor into the flywheel housing as far as the stop. Check the crankshaft position sensor for proper installation.
8. Install the clutch on the flywheel, then install the transmission.

Section 1.13
Flywheel Ring Gear

Replace the flywheel ring gear; do not repair it.

Section 1.13.1
Removal of Flywheel Ring Gear

Removal steps are as follows:

1. Remove the flywheel from the crankshaft flange. Refer to "1.12.1 Removal of Flywheel" .

> **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 "Heating the Ring Gear" .

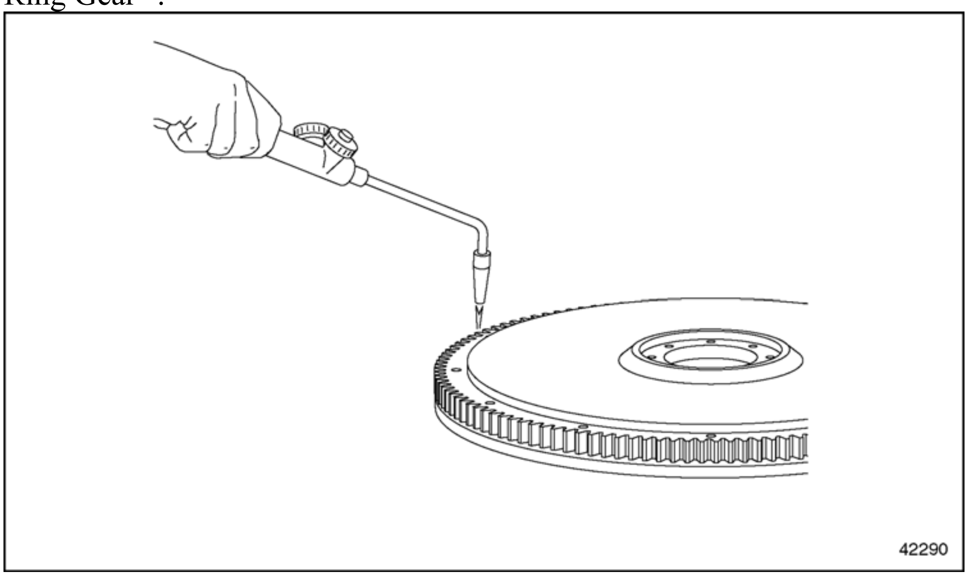
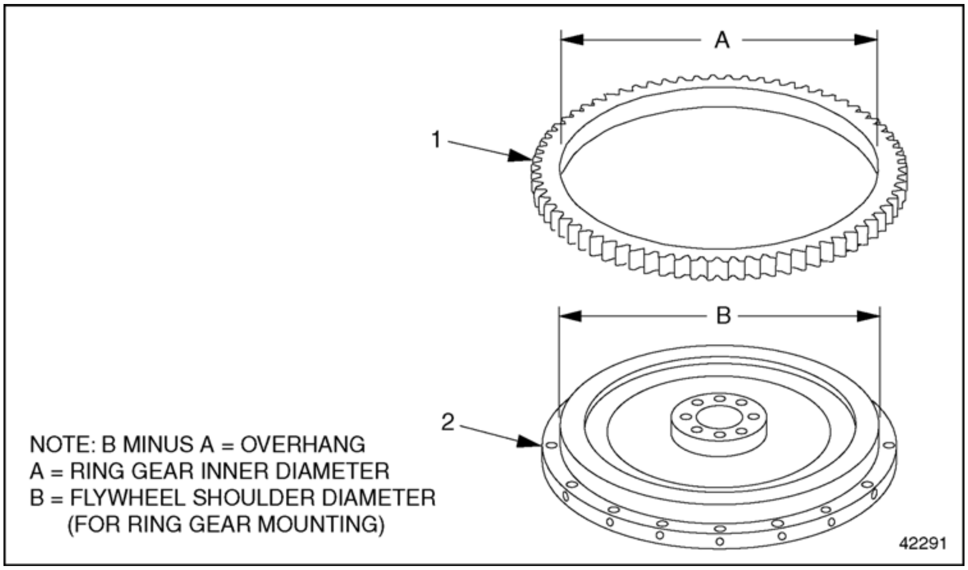


Figure 1. Heating the Ring Gear

Section 1.13.2
Installation of Flywheel Ring Gear

Installation steps are as follows:

1. Check the amount of overhang between the flywheel mounting shoulder and the ring gear. See Figure "Flywheel/Ring Gear Overhang Measurements" . The overhang must be within the permissible values listed in Table "Ring Gear Specifications" .



1. Ring Gear	2. Flywheel

Figure 2. Flywheel/Ring Gear Overhang Measurements

a. Measure the flywheel shoulder diameter (see Figure "Flywheel/Ring Gear Overhang Measurements" , B).
b. Measure the inner diameter of the new ring gear (see Figure "Flywheel/Ring Gear Overhang Measurements" , A).
c. Determine the amount of overhang by subtracting the ring gear inner diameter (see Figure "Flywheel/Ring Gear Overhang Measurements" , A) from the flywheel shoulder diameter (see Figure "Flywheel/Ring Gear Overhang Measurements" , B).
d. Make sure that the amount of overhang lies between 0.295 and 0.575 mm (0.0116 and 0.0226 in.).

WARNING:

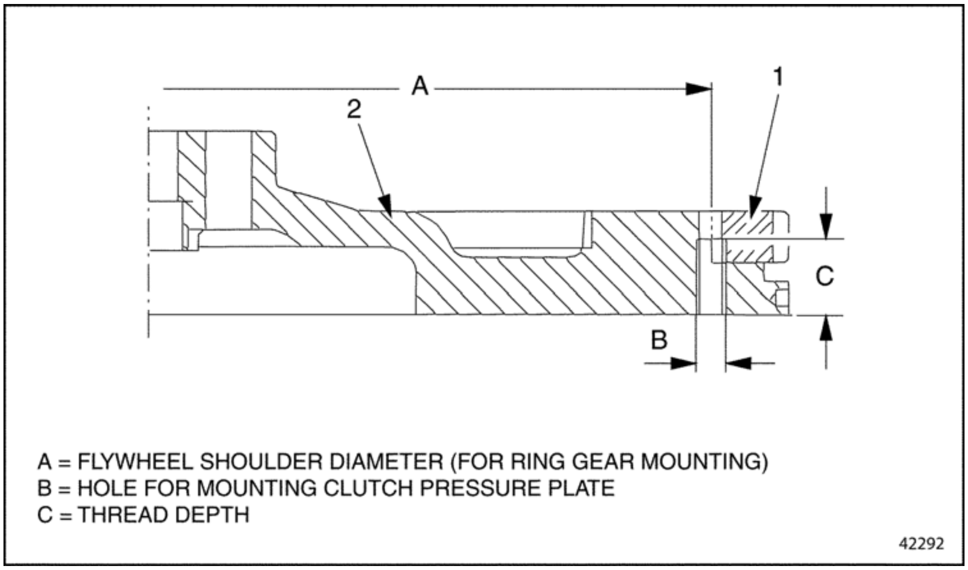
BURNS

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

2. Heat the new ring gear to 250 to 280°C (482 to 536°F).

   Note: When sufficiently heated, the metal should be a bright yellow annealing color.

3. Press the heated ring gear completely onto the mounting shoulder of the flywheel.
4. Tap the holes for the clutch mounting bolts. See Figure "Flywheel Cross Section" . The specifications are listed in Table "Ring Gear Specifications" .



1. Ring Gear	2. Flywheel

Figure 3. Flywheel Cross Section

Descriptions	Four– and Six–Cylinder Engines mm (in.)
Flywheel Shoulder Diameter (for ring gear mounting – see *Ref. A)*	392.435–392.575 (15.4502–15.4557)
Hole for Mounting Clutch Pressure Plate (see , Ref B)	3/8–16 UNC
Thread Depth (see , Ref C)	24 (15/16) minimum
Ring Gear Inner Diameter	392.000–392.140 (15.4331–15.4386)
Ring Gear/Flywheel Overhang	0.295–0.575 (0.0116–0.0226)
Ring Gear/Flywheel Permissible Radial Runout	0.5 (0.02)
Ring Gear Width	15.6–16.0 (0.614–0.630)
Ring Gear Fitting Temperature	250–280°C (482–536°F)

Table 5. Ring Gear Specifications

a. With the flywheel friction surface facing up (ring gear down), bore holes for the clutch mounting bolts.
b. Tap the bore holes with 3/8–16 UNC threads to a minimum depth of 24 mm (0.94 in.).

5. Check the ring gear/flywheel radial runout.

Note: With the ring gear pressed onto the flywheel, make sure the radial runout of the ring gear does not exceed 0.5 mm (0.02 in.).

6. Install the flywheel on the crankshaft flange. Refer to "1.12.2 Installation of Flywheel" .

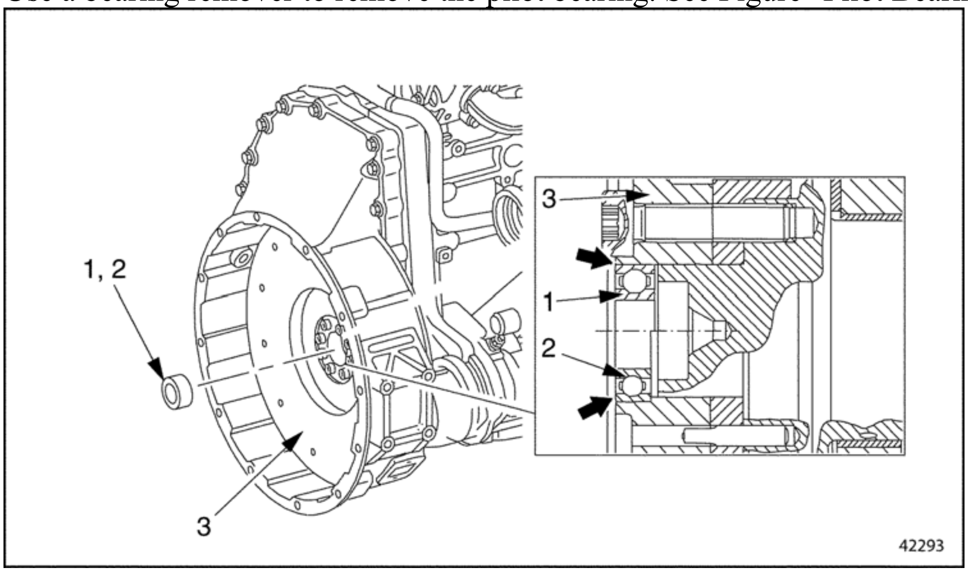
Section 1.14
Pilot Bearing

A special tool is required to remove the pilot bearing (OTC 7318) .

Section 1.14.1
Removal of Pilot Bearing

Removal steps are as follows:

1. Remove the transmission.
2. Remove the clutch from the flywheel.
3. Use a bearing remover to remove the pilot bearing. See Figure "Pilot Bearing" .



1. Pilot Bearing (25–mm ID)	3. Flywheel
2. Pilot Bearing (30–mm ID)	

Figure 1. Pilot Bearing

Section 1.14.2
Installation of Pilot Bearing

Installation steps are as follows:

1. Lubricate the new bearing with longlife grease.
2. Using a suitable driver and mallet, position the bearing on the crankshaft and drive it in the flywheel.
3. Install the clutch on the flywheel.
4. Install the transmission.

Section 1.15
Engine Barring Tool

The engine barring tool (J–46392) is used for two separate functions: locking the flywheel and rotating the crankshaft.

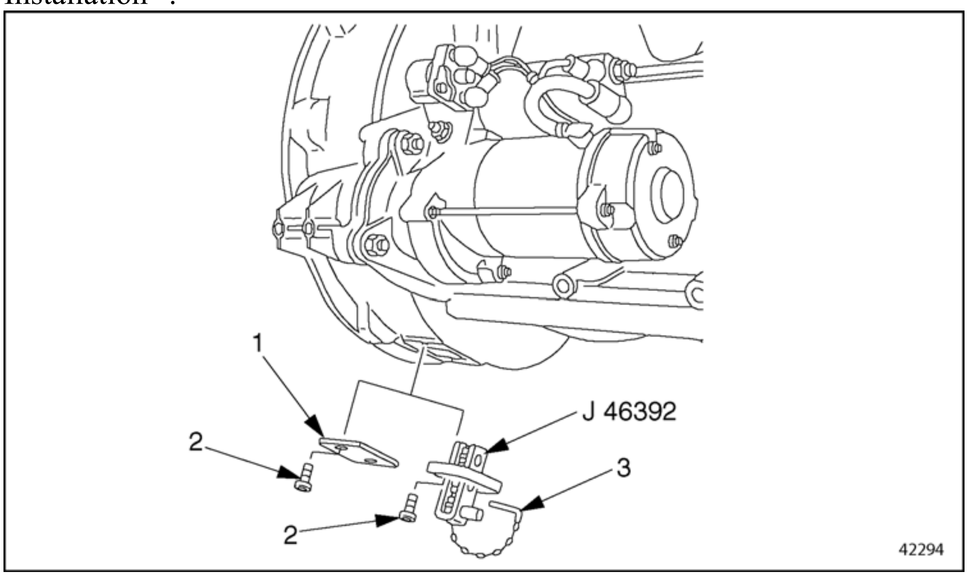
- With the locking pin inserted, the tool locks the flywheel ring gear to prevent rotation during removal and installation of the flywheel.
- Without the pin, the tool can be used with a wrench to turn the flywheel and crankshaft manually.

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.

Section 1.15.1
Installation of Engine Barring Tool

Installation steps are as follows:

1. Remove two bolts and the end cover from the flywheel housing. See Figure "Engine Barring Tool Installation" .



1. End Cover	3. Pin
2. Bolts (2 qty.)	

Figure 1. Engine Barring Tool Installation

2. Remove the pin from the barring tool.
3. Install the tool in the flywheel housing and secure with the two bolts from the end cover.
4. Insert the pin to lock the tool and block movement of the flywheel ring gear.

Section 1.15.2

Removal of Engine Barring Tool

Removal steps are as follows:

NOTICE:

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

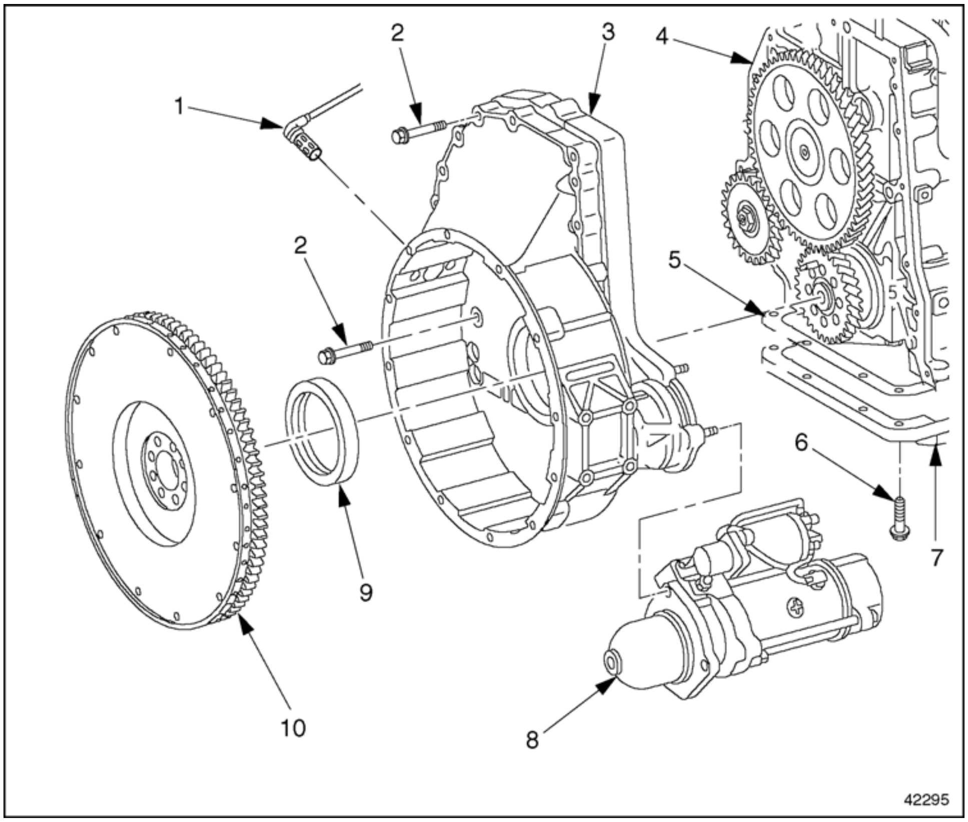
1. Remove two bolts and the barring tool from the flywheel housing. It is not necessary to remove the pin.
2. Install the end cover on the flywheel housing with the two bolts. Tighten the bolts 25 N·m (18 lb·ft).

Section 1.16
Flywheel Housing

The flywheel housing provides a cover for the flywheel. The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing.

Section 1.16.1
Flywheel Housing Removal

Remove the flywheel housing as follows:



1. Crankshaft Position Sensor	6. Oil Pan Bolt
2. Flywheel Housing Mounting Bolt	7. Oil Pan
3. Flywheel Housing	8. Starter
4. Rear of Crankcase	9. Radial Seal
5. Oil Pan Gasket	10. Flywheel

Figure 1. Flywheel Housing Assembly and Related Components

1. With the engine removed from the vehicle, remove the flywheel. Refer to "1.12.1 Removal of Flywheel" .
2. Remove any parts that are attached to the flywheel housing exterior. See Figure "Flywheel Housing Assembly and Related Components" .

3. Disconnect the electrical connection and remove the crankshaft position sensor from the flywheel housing.
4. Remove the oil pan and its gasket. See Figure "Flywheel Housing Assembly and Related Components" .
5. Remove the flywheel housing mounting bolts. Then remove the flywheel housing from the crankcase. See Figure "Flywheel Housing Assembly and Related Components" .

Section 1.16.1.1
Inspection of Flywheel Housing

Check the flywheel housing for damage. If necessary, replace it.

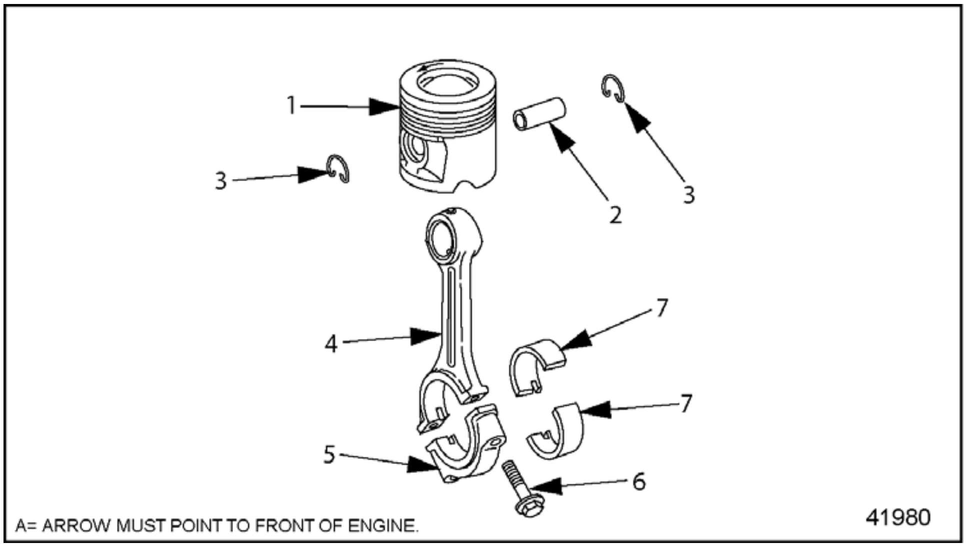
Section 1.16.2
Installation of Flywheel Housing

Installation steps are as follows:

1. Install a new rear radial seal. Refer to "1.7.2 Installation of Rear Radial Seal" .
2. Using a suitable scraper, such as a putty knife, clean the mating surfaces of the crankcase and the flywheel housing. Remove any dirt, grease, and all traces of old sealant.
3. Coat the mating surfaces of the timing cover and the crankcase with Loctite®574 sealant. Loctite® is a registered trademark of Loctite Corporation.
4. Put the flywheel housing onto the crankcase, making sure it clears the oil pan (if the pan is still installed) and the bolt holes line up. See Figure "Flywheel Housing Assembly and Related Components" .
5. Install the flywheel housing mounting bolts and tighten to 50 N·m (37 lb·ft). See Figure "Flywheel Housing Assembly and Related Components" .
6. Install the oil pan, using a new gasket. Tighten the oil pan bolts to 25 N·m (18 lb·ft). See Figure "Flywheel Housing Assembly and Related Components" .
7. Attach any parts that were removed from the flywheel housing exterior. See Figure "Flywheel Housing Assembly and Related Components" .
8. Install the flywheel. Refer to "1.12.2 Installation of Flywheel" .
9. Install the crankshaft position sensor in the flywheel housing and connect the electrical connector.
10. Install the engine in the vehicle.

Section 1.17
Pistons, Piston Rings, and Connecting Rods

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 following illustration shows the piston and connecting rod assembly in an exploded view. See Figure "Piston Assembly and Related Components" .



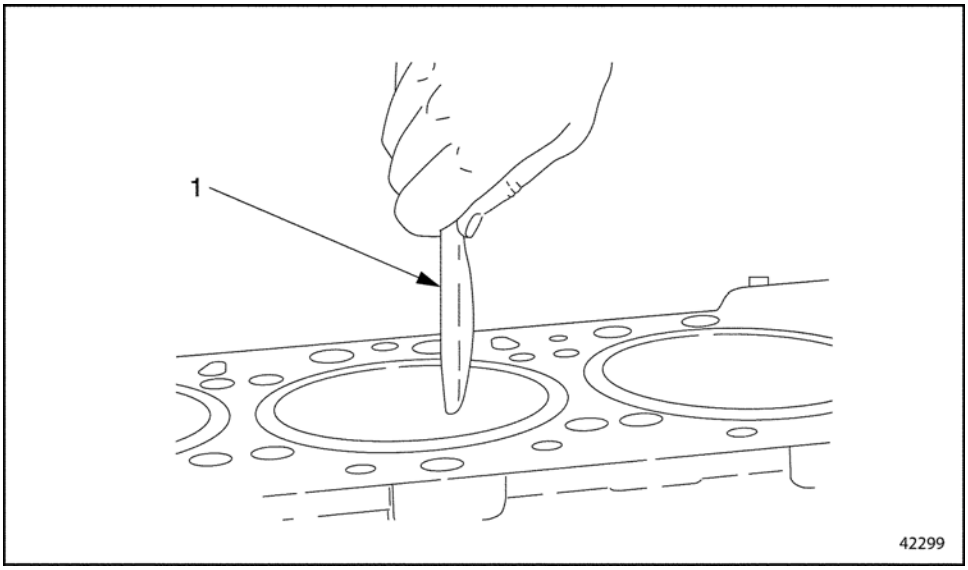
1. Piston and Rings	5. Connecting Rod Cap
2. Wrist Pin	6. Connecting Rod Stretch Bolt
3. Snap Ring	7. Bearing Halves
4. Connecting Rod	

Figure 1. Piston Assembly and Related Components

Section 1.17.1
Removal of Piston

Removal steps are as follows:

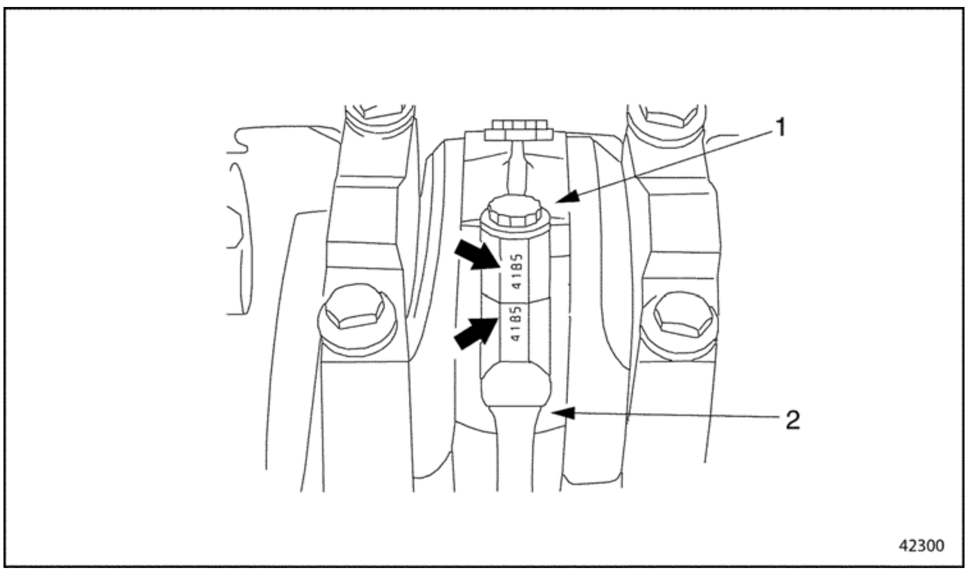
1. With the engine removed from the vehicle, remove the cylinder head and oil pan. Refer to and refer to .
2. Using a plastic scraping tool, carefully scrape off any combustion residues from the combustion area in the cylinder in order to avoid damage to the piston rings when the piston is removed. See Figure "Cleaning the Cylinder Liner" .



1. Plastic Scraping Tool

Figure 2. Cleaning the Cylinder Liner

Note: Be sure the connecting rods and the bearing caps are marked so that they can be matched for installation. See Figure "Checking Rod and Bearing Cap Markings" .



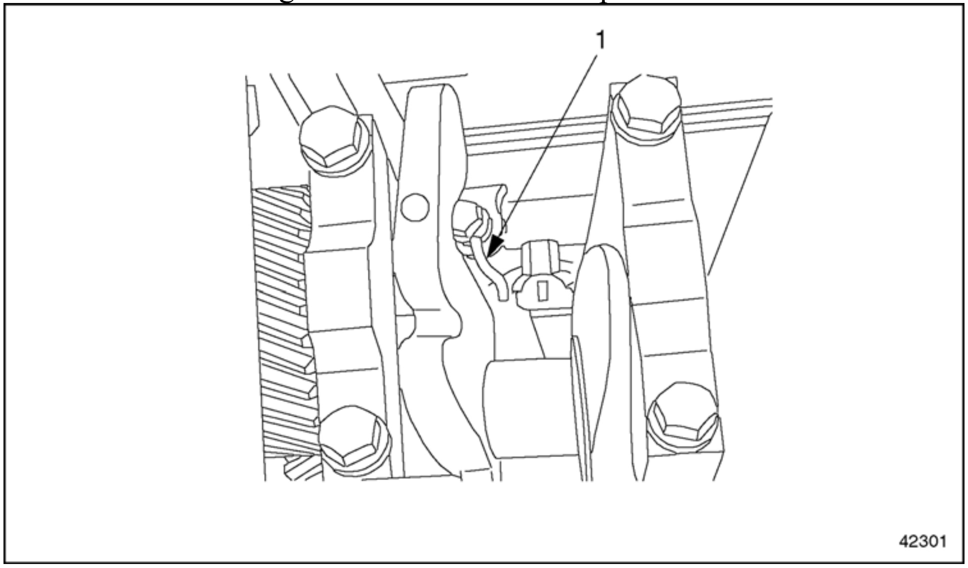
1. Bearing Cap	2. Connecting Rod

Figure 3. Checking Rod and Bearing Cap Markings

NOTICE:

Do not damage the oil spray nozzles. It is helpful to remove them before proceeding. Damaged oil spray nozzles could result in a loss of oil pressure and cause engine damage.

3. Being careful not to damage the oil spray nozzles (see Figure "Location of Oil Spray Nozzle"), remove the connecting rod stretch bolts and caps.



1. Oil Spray Nozzle

Figure 4. Location of Oil Spray Nozzle

4. Push the piston and connecting rod out of the cylinder, and remove it from the engine block.

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 cause rod cracking or breaking.

5. Secure the connecting rod in a vise with protective jaws.
6. Remove the wrist–pin snap rings. Push the wrist pin out and remove the piston from the connecting rod. At this time you may wish to remove and replace the piston rings. If so, refer to "1.17.3 Removal of Piston Ring" .

Section 1.17.1.1
Inspection of Connecting Rod

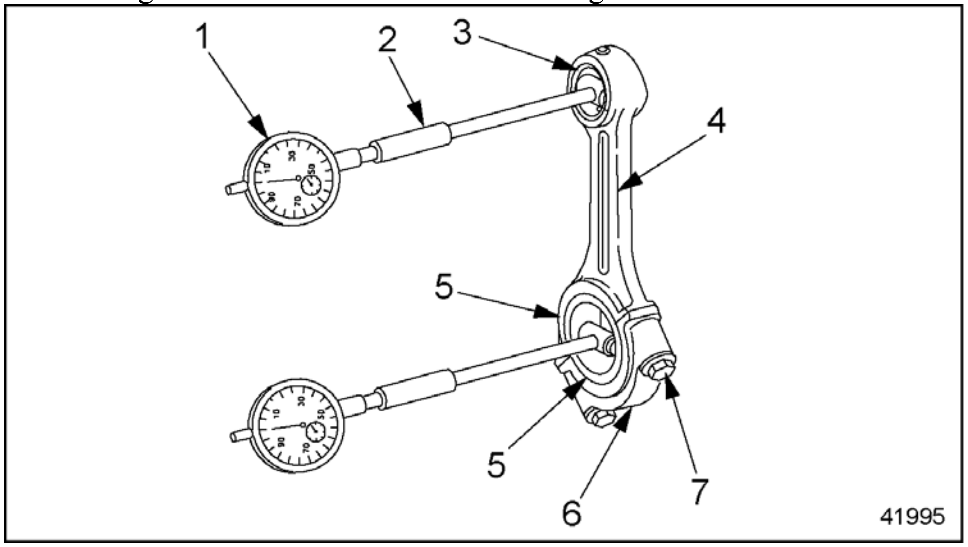
The following commercially available tools are required for this procedure:

- Caliper, internal measurement, 40 to 60 mm (1.57 to 2.36 in.)
- Caliper, internal measurement, 100 to 120 mm (3.94 to 4.72 in.)
- Micrometer, 50 to 75 mm (1.97 to 2.95 in.)
- Caliper gauge with dial indicator

Inspection steps are as follows:

1. Inspect the connecting rod for blue discoloration (indicates bearing overheat damage), scoring, notches, and cracks. If any of these conditions are found, replace the connecting rod.
2. Measure the inner diameter of the bushing in the small bore of the connecting rod. Use a caliper

(internal measurement, 40 to 60 mm (1.57 to 2.36 in.)), dial indicator, and holder. See Figure "Measuring Inner Diameters in the Connecting Rod" .



1. Dial Indicator	5. Bearing Shell (2 parts)
2. Holder, Dial Indicator	6. Bearing Cap
3. Bushing	7. Bolts (2 qty.)
4. Connecting Rod	

Figure 5. Measuring Inner Diameters in the Connecting Rod

3. If the inner diameter value exceeds the measure below, replace the connecting rod.
   - Single stage Turbocharger 42 mm (1.653 in.)
   - Dual Stage Turbocharger 44 mm (1.732 in.)

   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 dial indicator.

4. Inspect the connecting rod for twisting and dimensional tolerance. See Figure "Connecting Rod Measurements" . If any value exceeds those listed in Table "Connecting Rod Inspection Specifications" , replace the connecting rod. Do not attempt to straighten the rod.

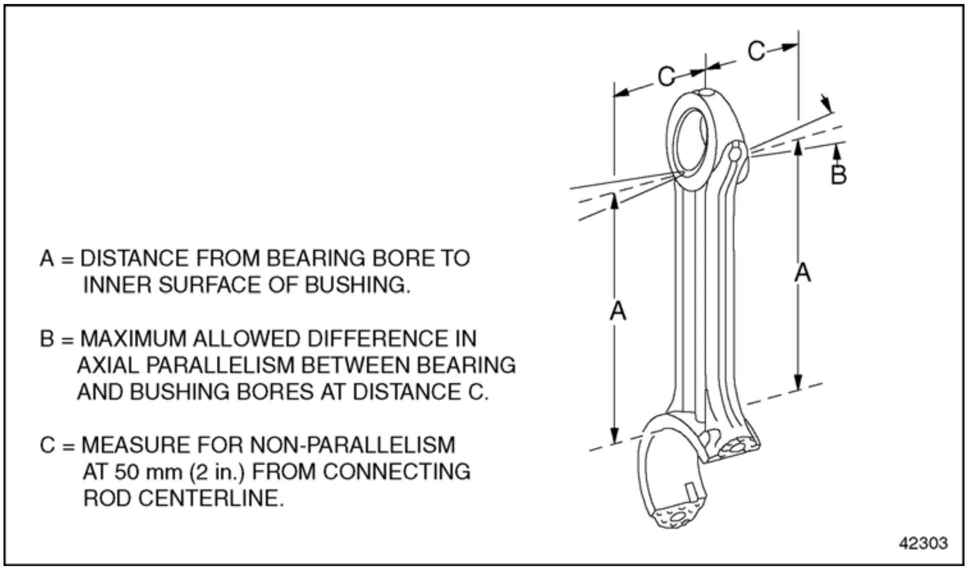


Figure 6. Connecting Rod Measurements

a. On each side of the connecting rod, measure the distance from the bearing bore (large bore) to the inner surface of the bushing. The measurement must be 157.445 to 157.510 mm (6.1986 to 6.2012 in).
b. Measure the difference in axial parallelism between the bearing bore and the inner surface of the bushing, at 50 mm (2.0 in.) from the connecting–rod centerline. The maximum allowed difference is 0.025 mm (0.0010 in.).

Descriptions	Dimensions, mm (in.)
Distance Between Connecting Rod Bearing Bore and Bushing Inner Surface	157.445–157.510 (6.1986–6.2012)
Maximum Difference in Axial Parallelism Between Bearing Bore and Bushing Inner Surface	0.025 (0.0010)
Distance from Connecting Rod Center Line for Measuring Parallelism	50 (2)
Bushing Inner Diameter	Single Stage Turbocharger 40.03–40.04 (1.575 –1.576) Dual Stage Turbocharger 42.03–42.04 (1.654 – 1.655)
Bearing Seat Inner Diameter with Bearing Shells Installed	
Standard	70.054–70.093 (2.7580–2.7596)
Repair Stage: Undersize 0.1 mm	69.954–69.993 (2.7541–2.7556)
Repair Stage: Undersize 0.25 mm	69.804–69.843 (2.7482–2.7497)
Repair Stage: Undersize 0.5 mm	69.554–69.593 (2.7383–2.7399)
Repair Stage: Undersize 0.75 mm	69.304–69.343 (2.7285–2.7300)
Repair Stage: Undersize 1.0 mm	69.054–69.093 (2.7187–2.7202)
Basic Bore Diameter for Connecting Rod Bearings	75.000–75.019 (2.9528–2.9535)
Connecting–Rod Bearing Play	

Radial	0.039–0.098 (0.0015–0.0039)
Axial (end play)	0.170–0.470 (0.0067–0.0185)
Permissible Out–of–Roundness of Basic Bores	
Bearing Bore	0.008 (0.0003)
Bushing Bore	0.006 (0.0002)
Connecting Rod Bolt	
Thread Diameter	M12 x 1.25
Shank Length When New	56.0 (2.20)
Maximum Shank Length	57.0 (2.24)

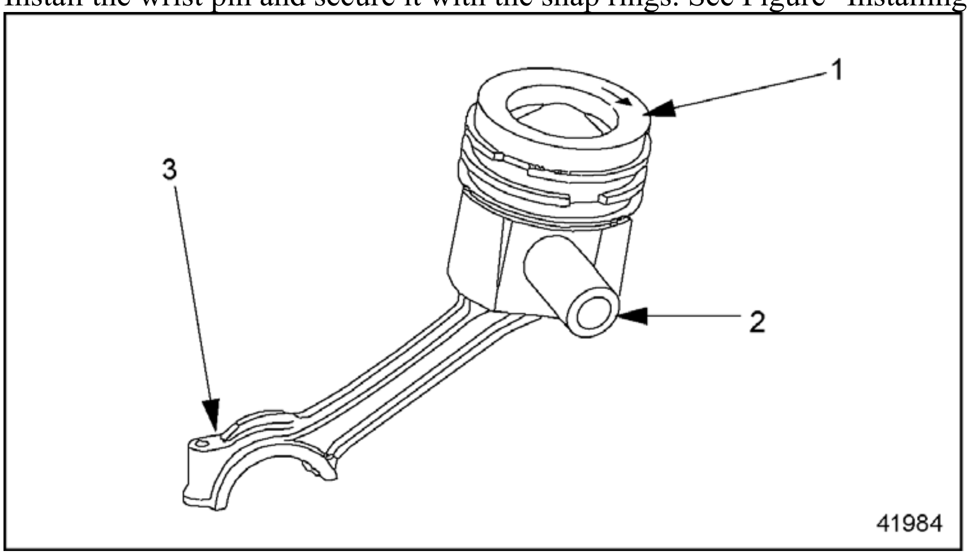
Table 8. Connecting Rod Inspection Specifications

Section 1.17.2
Installation of Piston

Installation steps are as follows:

Note: If the engine block deck height has been reduced, you must install pistons with a reduced height.

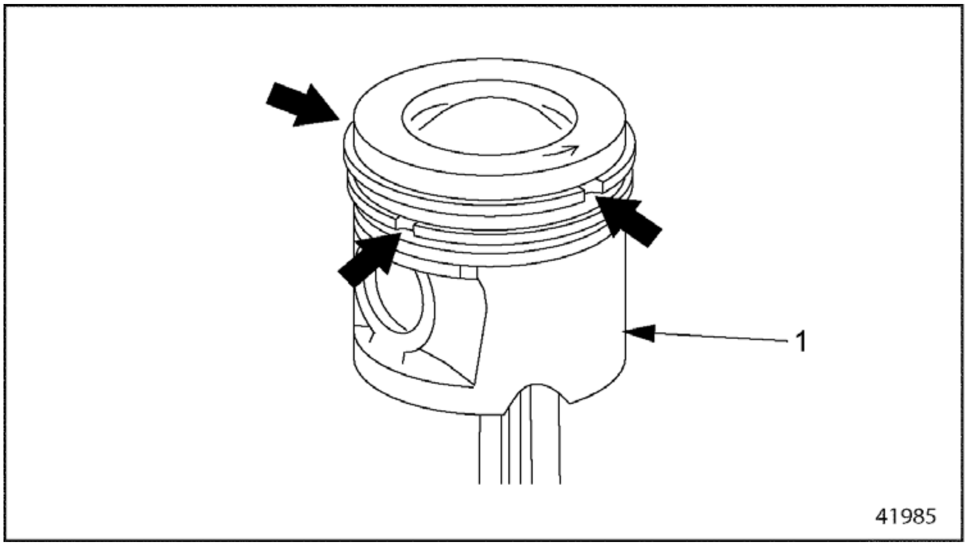
1. Position the connecting rod in the piston so that the far side of the rod contact surface (with the number on it) is on the right side (exhaust side) of the engine, and the arrow on the crown of the piston points toward the front of the engine.
2. Install the wrist pin and secure it with the snap rings. See Figure "Installing the Wrist Pin" .



1. Piston	3. Far Side of Connecting Rod
2. Wrist Pin	

Figure 7. Installing the Wrist Pin

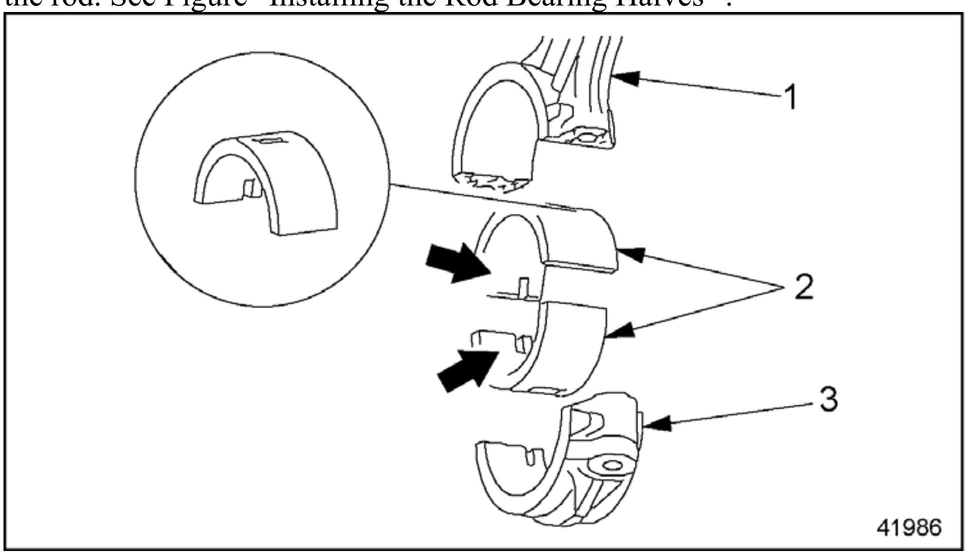
3. Coat the piston lightly with clean engine oil.
4. Install new piston rings. Refer to "1.17.4 Installation of Piston Ring" .
5. Offset the ring gaps alternately by 120 degrees. See Figure "Ring Gaps Offset 120 Degrees" .



1. Piston	

Figure 8. Ring Gaps Offset 120 Degrees

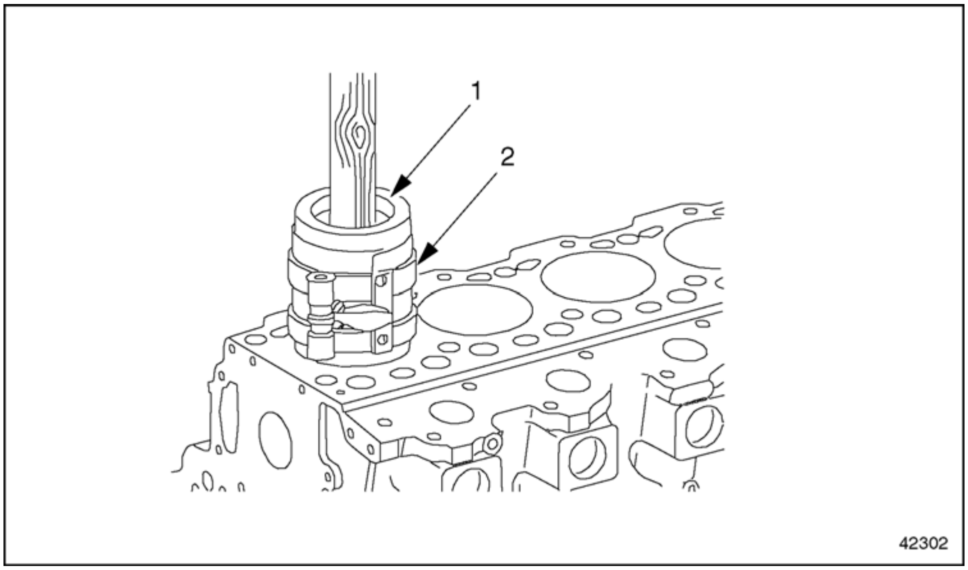
6. Position a ring compressor loosely over the piston. Tighten the ring compressor on the piston so that it can just slide over the piston.
7. Install the rod bearing half in the rod. Be sure that the bearing tang is fully seated in the groove of the rod. See Figure "Installing the Rod Bearing Halves" .



1. Connecting Rod	2. Bearing Halves	3. Connecting Rod Cap

Figure 9. Installing the Rod Bearing Halves

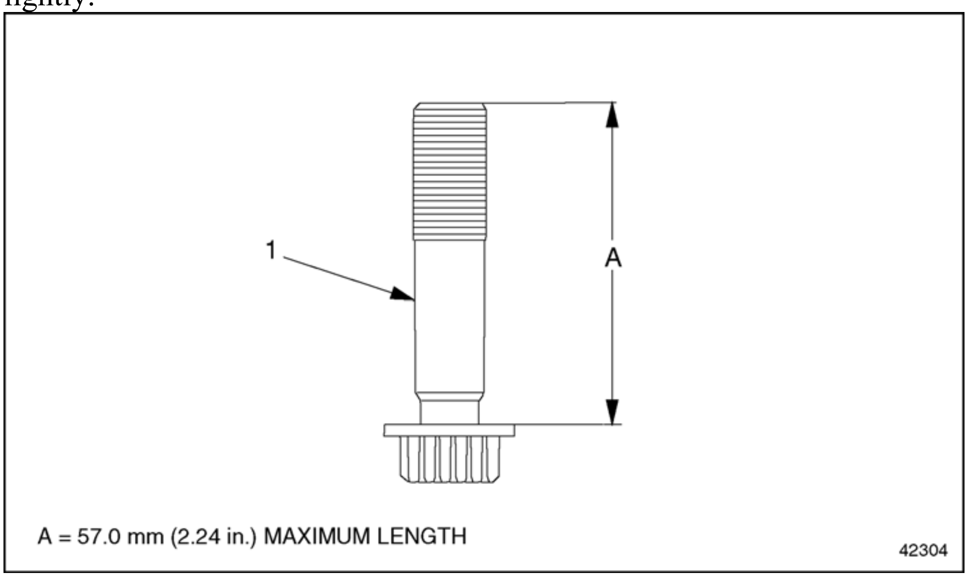
8. Coat the bearing surface lightly with clean engine oil.
9. With the piston arrow pointing toward the front of the engine, push the piston into the cylinder until the rod bearing rests on the crankshaft journal. See Figure "Piston Installation" . Be careful not to scratch the crankshaft journals with the connecting rod.



1. Piston	2 Ring Compressor

Figure 10. Piston Installation

10. Install the rod cap bearing half in the cap. Be sure that the bearing tang is fully seated in the groove of the cap. See Figure "Installing the Rod Bearing Halves" .
11. Coat the bearing surface lightly with clean engine oil.
12. Measure the connecting rod stretch bolts. Replace any bolts that exceed the maximum length of 57.0 mm (2.24 in.). See Figure "Measuring a Stretch Bolt" . Lubricate the stretch bolt threads lightly.

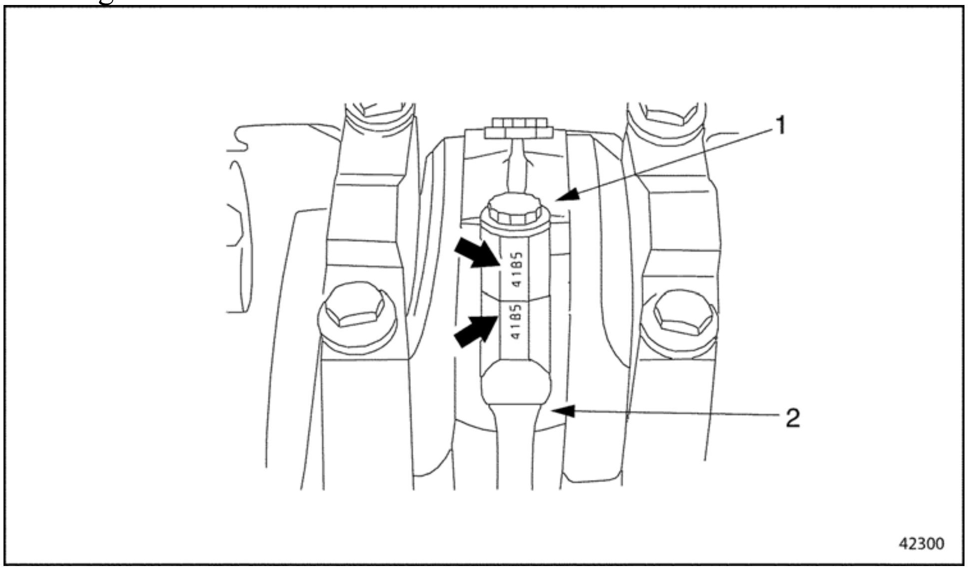


1. Shank

Figure 11. Measuring a Stretch Bolt

13. Install the connecting rod cap on the connecting rod and hand–tighten the stretch bolts. Be sure that the marks on the cap and the rod match. See Figure "Checking Rod and Bearing Cap

Markings" .



1. Bearing Cap	2. Connecting Rod

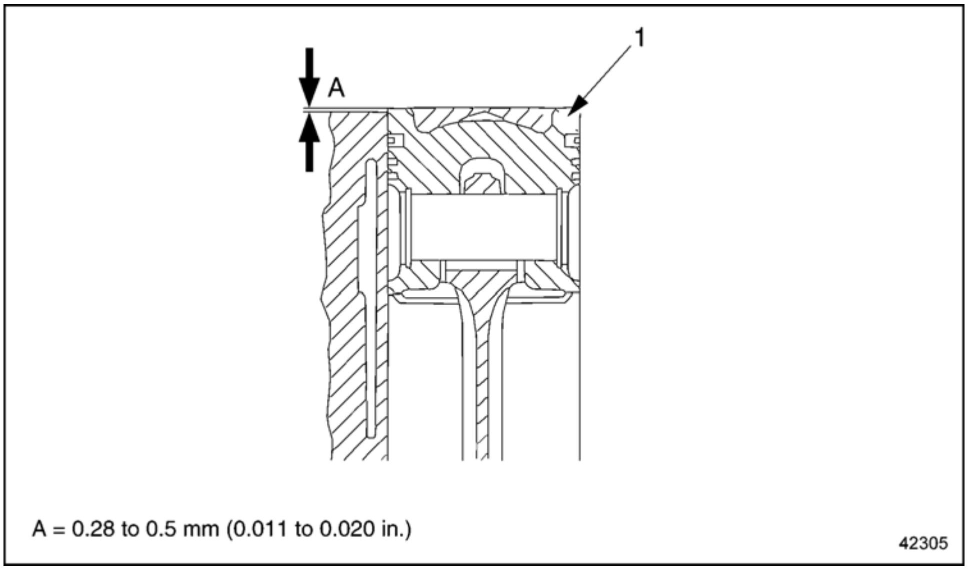
Figure 12. Checking Rod and Bearing Cap Markings

14. Tighten the connecting rod stretch bolts alternately. Tighten each one in turn to the first stage and then go on to the next stage as listed in Table "Tightening Stages, Connecting Rod Stretch Bolts" .

Max. Shaft Length mm (in.)	Tightening Stage	Torques N·m (lb·ft)
57.0 (2.24)	Stage 1	11 (8)
	Stage 2	45 (33)
	Stage 3	additional 90 degrees

Table 15. Tightening Stages, Connecting Rod Stretch Bolts

15. Rotate the crankshaft to make sure it turns freely.
16. Using a dial gauge and holder, measure the piston projection relative to the top of the crankcase at all the pistons. See Figure "Piston Projection at Top Dead Center" .



1. Piston

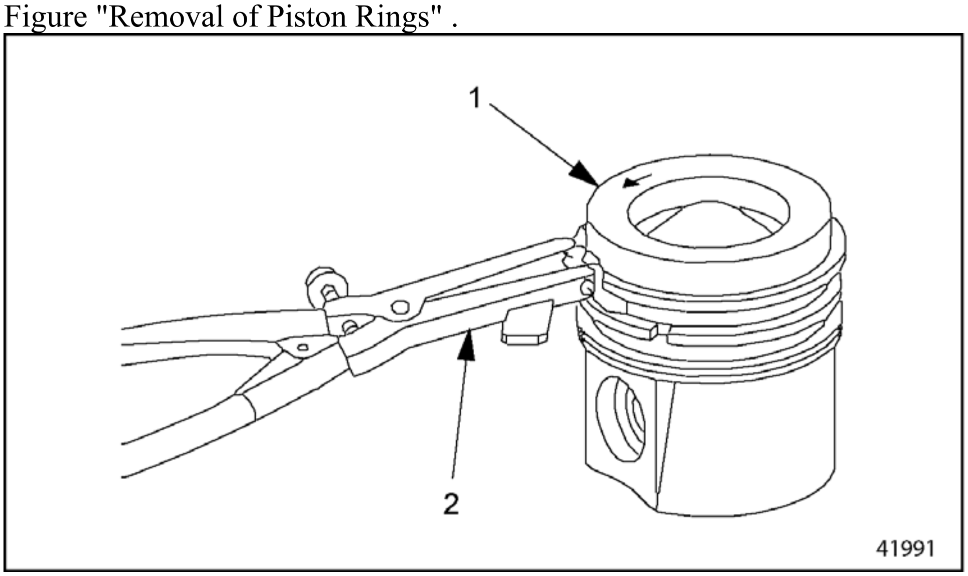
Figure 13. Piston Projection at Top Dead Center

17. If the piston projection dimensions are not correct, replace the piston.
18. Install the oil spray nozzles if they have been removed. Be sure they are seated and aligned correctly.
19. Install the cylinder head and the oil pan. Refer to "1.4.2 Installation of Cylinder Head" and refer to "3.7.2 Installation of Oil Pan" .

Section 1.17.3 Removal of Piston Ring

Removal steps are as follows:

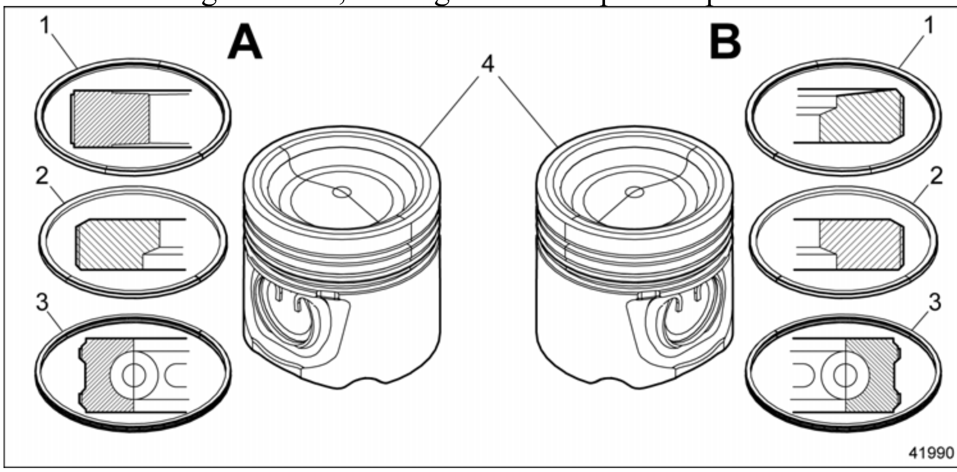
1. With the piston removed from the engine block, remove the rings, using suitable ring pliers. See Figure "Removal of Piston Rings" .



1. Piston	2. Ring Pliers

Figure 14. Removal of Piston Rings

2. Remove the rings in order, starting from the top of the piston down. See Figure " Piston Rings" .



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

Figure 15. Piston Rings

Section 1.17.3.1
Inspection of Piston and Piston Ring

Cleaning, inspecting, and measuring steps are as follows:

1. Clean all the carbon from the ring grooves.
2. Be sure the grooves are not damaged, and that there are no burrs or combustion residue in the grooves.
3. Before installing the new rings, check the end gap for the correct end gap measurements listed in Table "Piston Ring End–Gap Dimensions" .

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

Ring Designation	Groove	Gap When New mm (in.)	Maximum End Gap mm (in.)
Keystone	I	0.35 to 0.55 (0.014 to 0.022)	1.0 (.039)
Taper–Faced with Internal Angle	II	0.40 to 0.60 (0.016 to 0.024)	1.0 (.039)
Double–Chamfered Oil Control with Garter	III	0.25 to 0.50 (0.010 to	1.0 (.039)

Spring	0.020)

Table 19. Piston Ring End–Gap Dimensions

4. Place each ring squarely into the combustion area of a cylinder liner or cylinder, then measure the end gap, using a feeler gauge. See Figure "Checking the Ring End–Gap" .

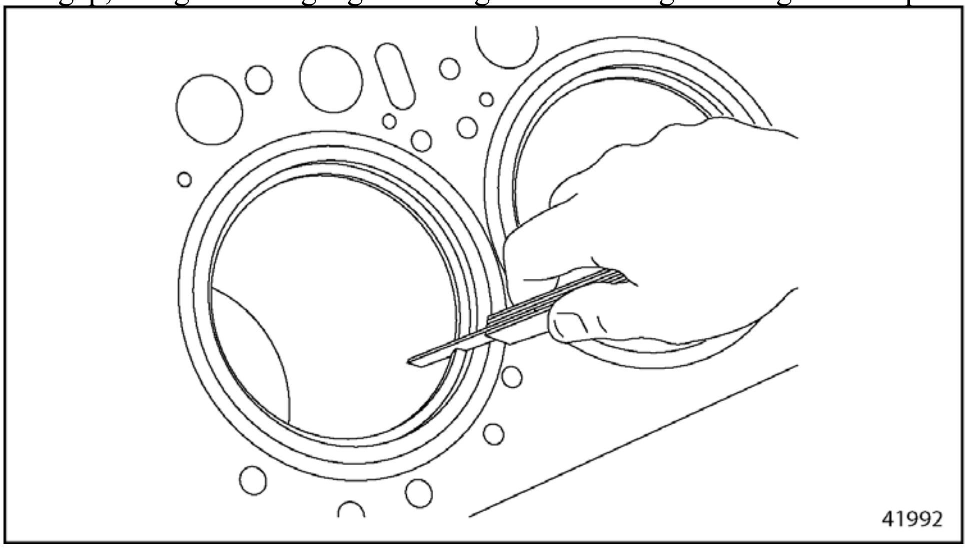


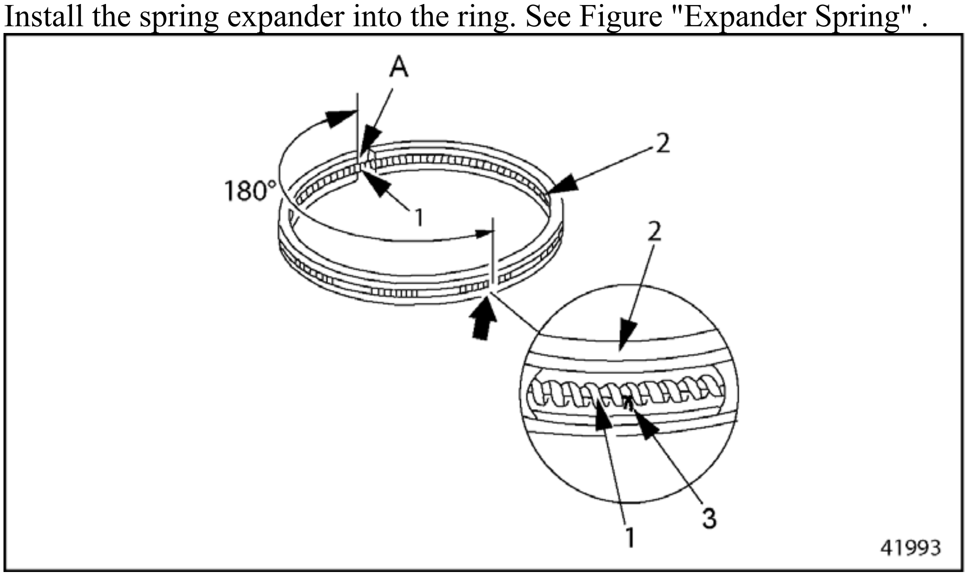
Figure 16. Checking the Ring End–Gap

5. Remove the spring expander from the third (lowest) ring, then measure its gap in the same way as the other two rings.

Section 1.17.4
Installation of Piston Ring

Installation steps are as follows:

1. Install the spring expander into the ring. See Figure "Expander Spring" .

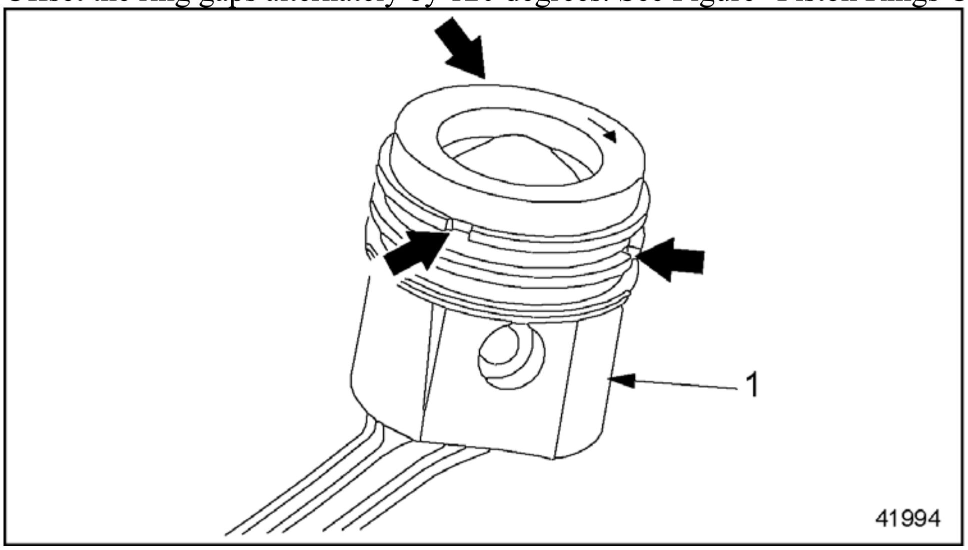


1. Expander Spring	3. Expander Spring Joint

2. Piston Ring

Figure 17. Expander Spring

2. Using ring pliers, install the rings. 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.
3. Offset the ring gaps alternately by 120 degrees. See Figure "Piston Rings Offset 120 Degrees" .



1. Piston

Figure 18. Piston Rings Offset 120 Degrees

Section 1.18
Connecting Rod Bearing

Do not try to repair the connecting rod bearings; replace them.

Section 1.18.1
Replacement of Bearing

Replacement steps are as follows:

1. Measure the bearing journal on the crankshaft with a micrometer at two points (vertical and horizontal) and note the measurements. See Figure "Measuring the Bearing Journal" .

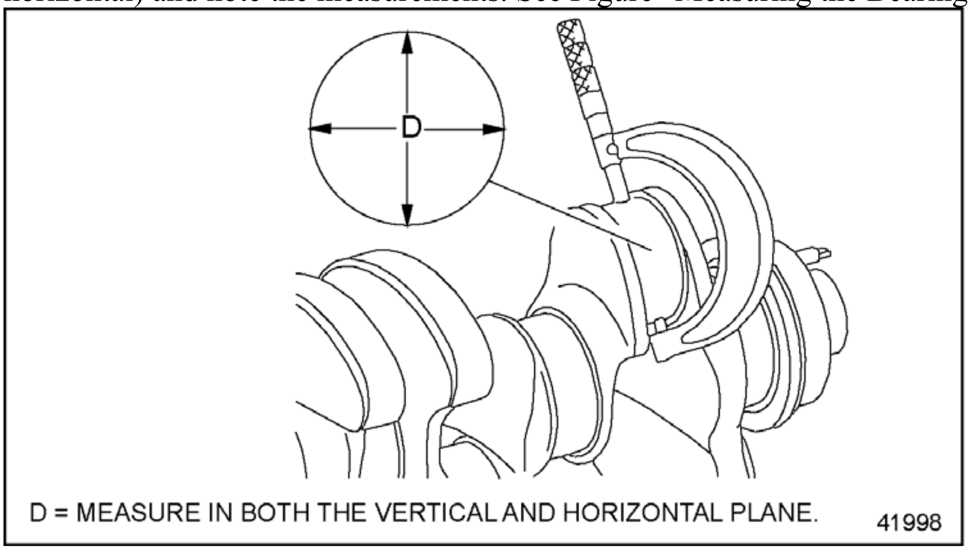


Figure 1. Measuring the Bearing Journal

2. Calculate the average (nominal) bearing–journal diameter from these two measurements, and determine the current repair stage from the specifications listed in Table "Bearing Journal Specifications" .

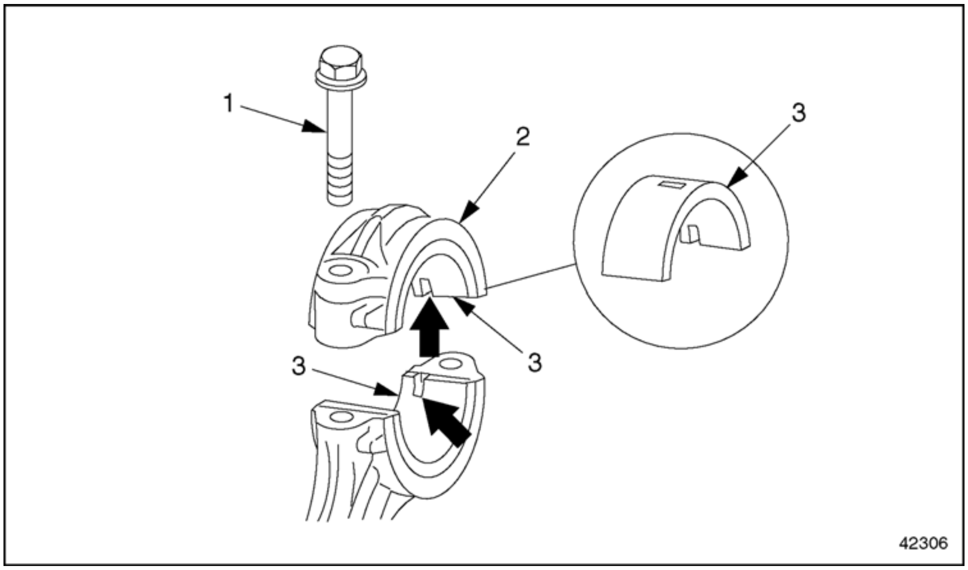
Repair Stage	Diameters mm (in.)
Standard	69.995–70.015 (2.7557–2.7565)
Undersize 0.1 mm	69.895–69.915 (2.7518–2.7526)
Undersize 0.25 mm	69.745–69.765 (2.7459–2.7467)
Undersize 0.5 mm	69.495–69.515 (2.7360–2.7368)
Undersize 0.75 mm	69.245–69.265 (2.7262–2.7270)
Undersize 1.0 mm	68.995–69.015 (2.7163–2.7171)

Table 1. Bearing Journal Specifications

3. If new bearings are required, select bearing shells that match the current repair stage of the bearing journal.

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

4. Clean the bearing contact surfaces on the connecting rod and bearing cap with a chamois.
5. Insert the bearing shells into the connecting rod and bearing cap. See Figure "Bearing Shell Placement" .



1. Bolt, Connecting Rod (2 qty.)	3. Bearing Shell (2 parts)
2. Bearing Cap	

Figure 2. Bearing Shell Placement

Note: The rod and cap require different bearing shells. Make sure the abbreviated part numbers on the shells correspond to the numbers on the rod and cap.

6. Be sure the locking lugs on the shells are completely seated in the slots in the rod and cap. See Figure "Bearing Shell Placement" , and see arrow locations.
7. Lightly oil the bearing surfaces, bolt threads, and contact surface of the bolt heads.
8. Being careful not to damage the mating surfaces, place the bearing cap on the connecting rod. Match the identifying marks on the cap with those on the rod. Make sure the numbers are on the same side.

Note: Never bolt the bearing cap tightly to the connecting rod without the bearing shells installed.

9. Install the bolts while pressing the bearing cap against the connecting rod. Tighten the bolts alternately as follows:
   a. Tighten the bolts 11 N·m (8 lb·ft).
   b. Tighten the bolts 45 N·m (33 lb·ft).
   c. Turn the bolts an additional 90 degrees.
10. Rotate the crankshaft to ensure there is no binding.

Section 1.19
Valves

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

Section 1.19.1
Inspection of Valve Lift

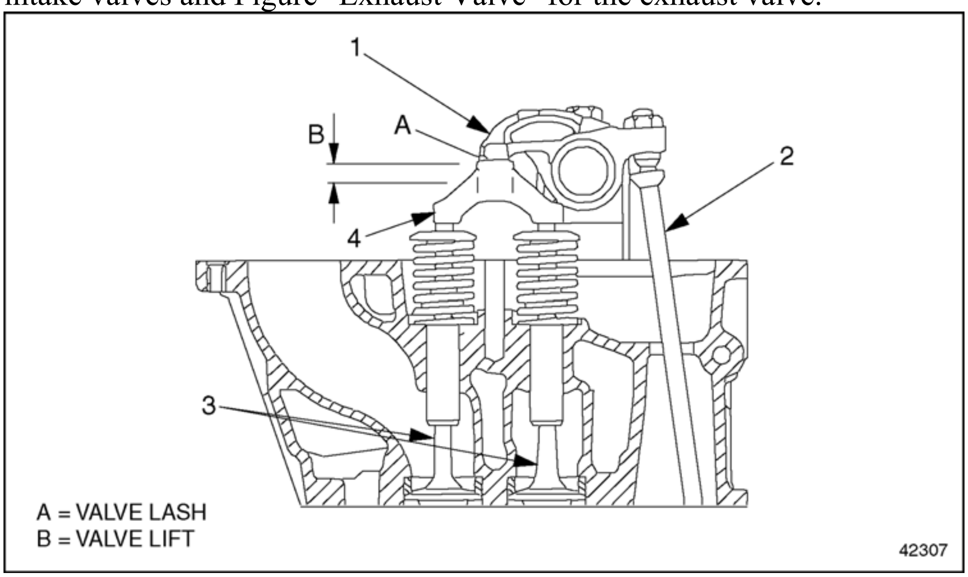
Note: Do this procedure to determine (without removing the camshaft) if the camshaft, or parts of the valve train, have suffered excessive wear. If the camshaft itself is suspect, check the lift on every valve.

Inspection steps are as follows:

1. Remove the cylinder head cover. Refer to "1.4.1 Removal of Cylinder Head" .
2. Remove the inspection cover on the flywheel housing and install the engine barring tool (J–46392) . Tighten the bolts on the barring device 25 N·m (18 lb·ft).

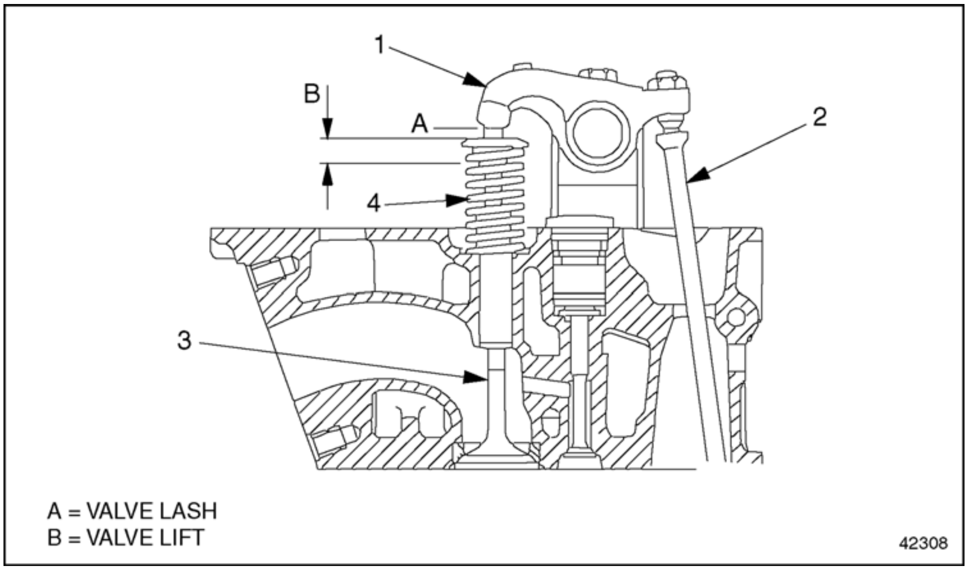
   Note: Check cylinders one at a time.

3. Select the first cylinder. Using the engine barring tool, turn the flywheel until the piston in that cylinder is at ignition top dead center (TDC).
4. Adjust the valve lash. Refer to "13.2 Adjusting Valve Lash" . See Figure "Intake Valves" for the intake valves and Figure "Exhaust Valve" for the exhaust valve.



1. Rocker Arm	2. Pushrod	3. Intake Valves	4. Valve Bridge

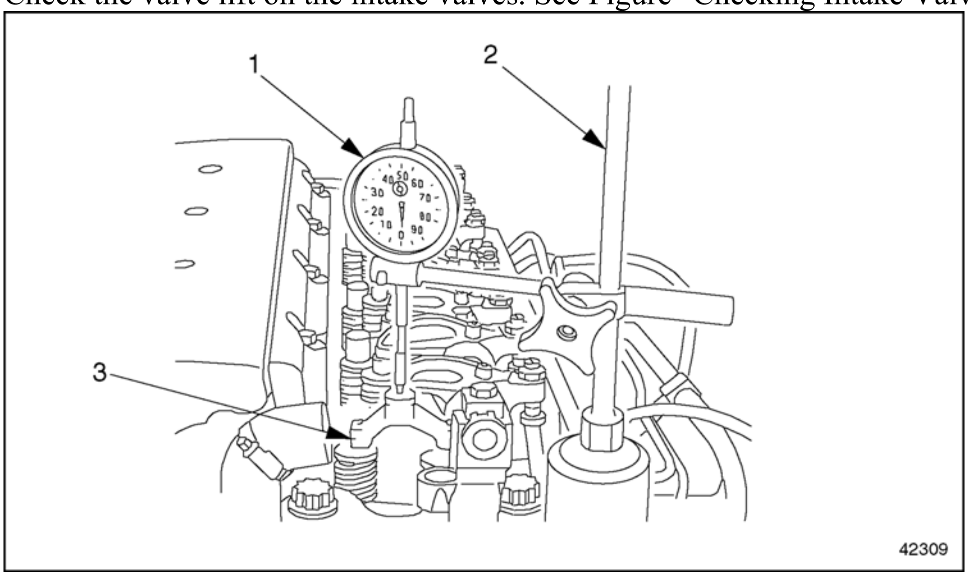
Figure 1. Intake Valves



1. Rocker Arm	2. Pushrod	3. Exhaust Valve	4. Valve Spring

Figure 2. Exhaust Valve

5. Check the valve lift on the intake valves. See Figure "Checking Intake Valve Lift" .



1. Dial Gage	3. Valve Bridge
2. Gage Holder	

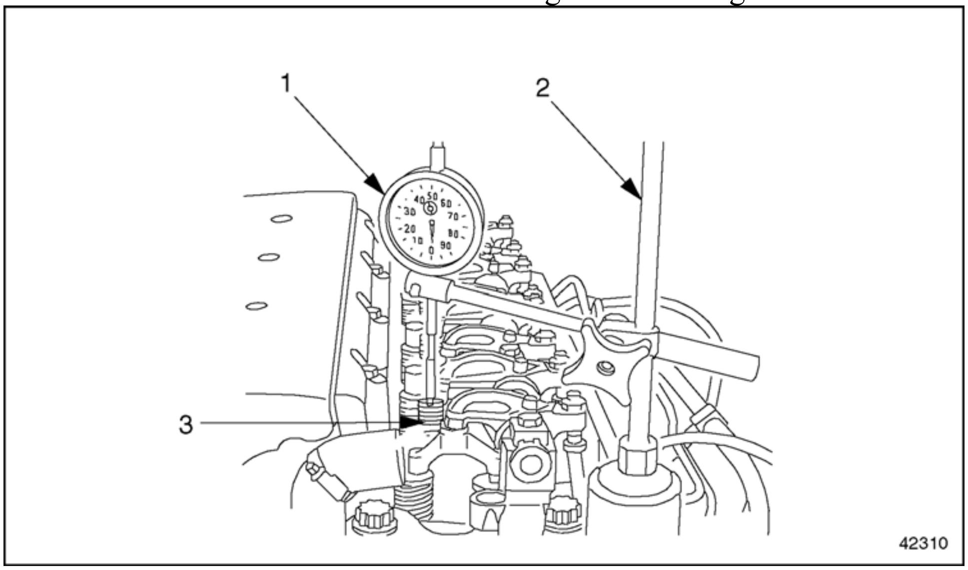
Figure 3. Checking Intake Valve Lift

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 inch) to provide adequate travel for checking the intake valve lift.
b. Set the scale on the dial gauge to zero.
c. Using the engine barring tool, 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.

d. When the valves are completely open, read off the value on the dial gauge. If the intake valve lift reaches at least 9.7 mm (0.38 in.) at its highest point, the intake valves are lifting properly. If the gauge reading fails to reach 9.7 mm (0.38 in.), be sure the valves were completely open. The dial gauge will show the highest reading when the valve is completely open. If the intake valve lift fails to reach 9.7 mm (0.38 in.) at its highest point, remove the camshaft and inspect it for wear.

6. Check the lift on the exhaust valve. See Figure "Checking Exhaust Valve Lift" .



1. Dial Gauge	3. Valve Spring
2. Gauge Holder	

Figure 4. Checking Exhaust Valve Lift

a. Turn the flywheel in a counterclockwise direction until the valve is 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 zero.
d. Using the engine barring tool, 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 valve is completely open, read off the value on the dial gauge. If the exhaust valve lift reaches at least 10.7 mm (0.42 in.) at its highest point, the exhaust valve is lifting properly. Check the next cylinder. If the gauge reading fails to reach 10.7 mm (0.42 in.), be sure the valves were completely open. The dial gauge will show the highest reading when the valve is completely open. If the exhaust valve lift fails to reach 10.7 mm (0.42 in.) at its highest point, remove the camshaft and inspect the cam lobes for wear.

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. 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).
10. Install the cylinder head cover. Refer to "1.1.2 Installation of Cylinder Head Cover" .

Section 1.19.2
Measuring Valve Recess

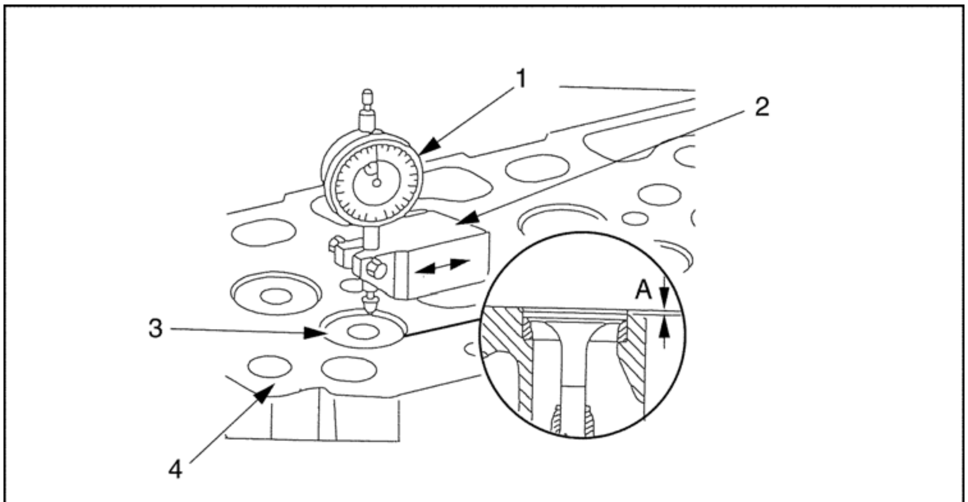
Measure valve recess as follows:

1. Remove the cylinder head from the engine. Refer to "1.4.1 Removal of Cylinder Head" .
2. Set up a dial gauge and dial gauge holder with a preload on the lower contact surface of the cylinder head.

   Note: Before doing this procedure, make sure the valve head is making contact with the valve seat. Remove any carbon buildup on the valve face.

3. Measure the valve recess from the cylinder head. See Figure "Measuring Valve Recess" .

   Note: The valve recess is the difference in height between the firedeck surface of the cylinder head and the valve head, when it is touching the valve seat.



1. Dial Gauge	3. Valve Head
2. Dial Gauge Holder	4. Firedeck Surface of Cylinder Head

Figure 5. Measuring Valve Recess

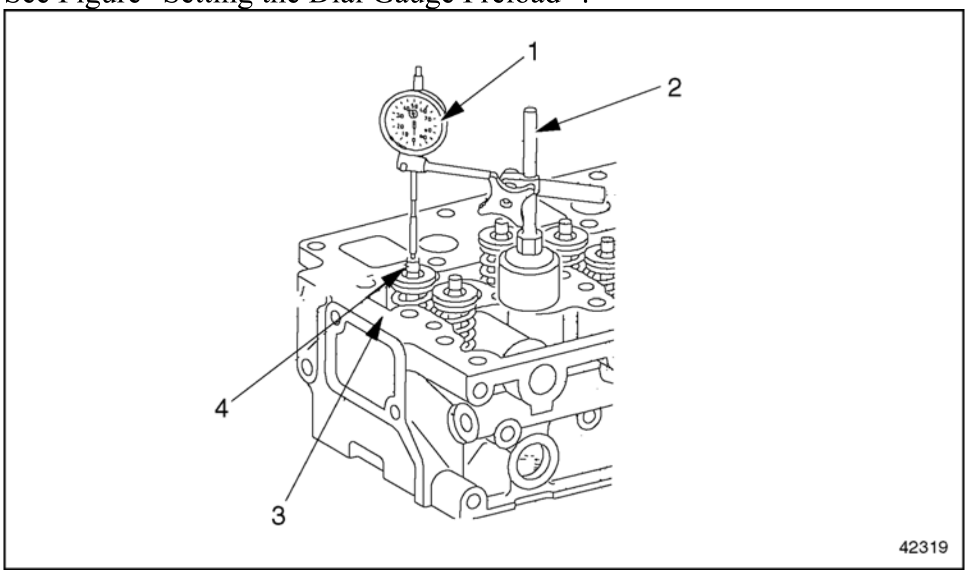
   a. Set the scale of the dial gauge to zero (0).
   b. Move the dial gauge enough so that its probe is touching the valve head.
   c. If the gauge reads between 1.1 and 1.5 mm (0.04 and 0.06 in.), the valve recess is within specifications. Go to step 5 . If the gauge reads less than 1.1 mm (0.04 in.), or more than 1.5 mm (0.06 in.), the valve recess is not within specifications. Go to step 4 .
4. If the measurement is not within specifications, inspect the valve head diameter for correct size and the valve seat inserts for height. Machine them if necessary. See Figure "Critical Dimensions,

Valve Stem and Head" . Inspection criteria and machining procedures are listed in Table "Valve Recess Specifications" .

Descriptions	Intake mm (in.)	Exhaust mm (in.)
Valve Head Diameter (C)	33.9–34.1 (1.33–1.34)	37.9–38.1 (1.49–1.50)
Valve Seat Height (D)	2.7–3.1 (0.106–0.122)	2.5–3.2 (0.098–0.126)
Valve Length (G)	125.65–126.95 (4.947–4.998)	152.5–152.9 (6.004–6.020)
Difference in Height Between the Two Intake Valves as Measured From the End of the Stem	0.20 (0.008)	N/A
Valve Recess from Cylinder Head	1.1–1.5 (0.04–0.06)	

Table 6. Valve Recess Specifications

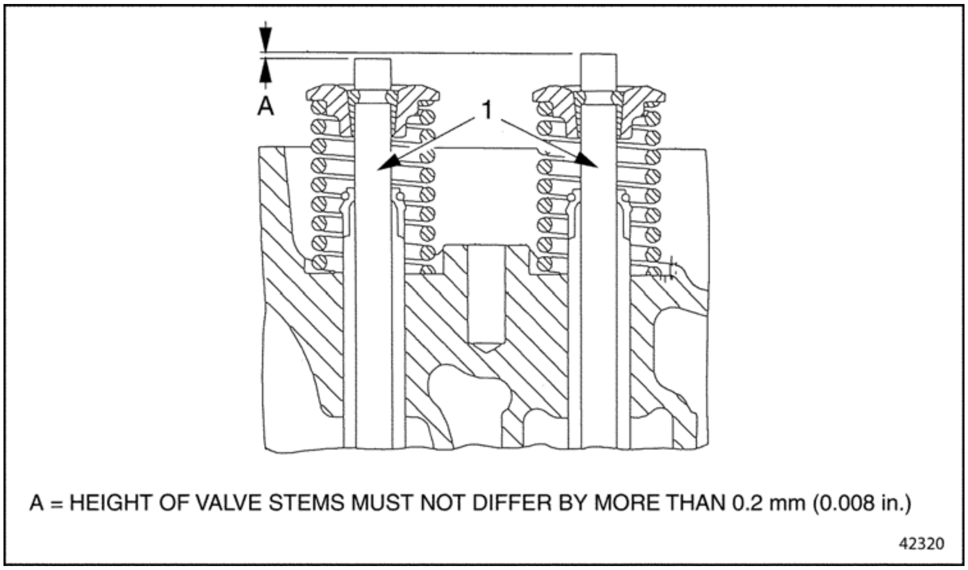
5. Move the dial gauge and dial gauge holder to the upper contact surface of the cylinder head. Set up the dial gauge and dial gauge holder with a preload on one of the two intake valve stem ends. See Figure "Setting the Dial Gauge Preload" .



1. Dial Gauge	3. Upper Contact Surface of Cylinder Head
2. Dial Gauge Holder	4. Valve Stem

Figure 6. Setting the Dial Gauge Preload

6. Measure the difference in height between the two intake valve stems. See Figure "Measuring the Intake Valve Stems" .



1. Intake Valve Stem

Figure 7. Measuring the Intake Valve Stems

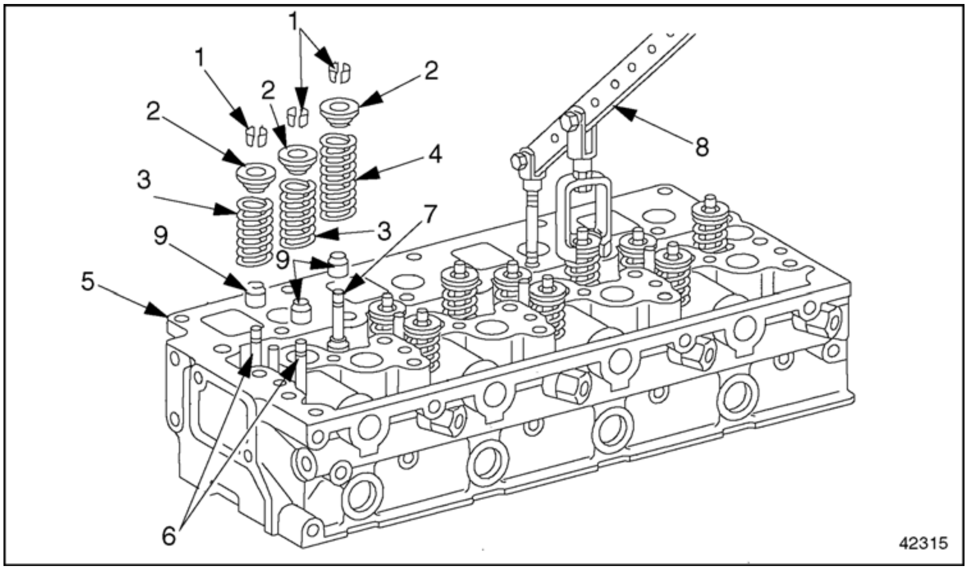
a. Set the scale of the dial gauge to zero (0).
b. Move the dial gauge over onto the end of the other valve stem.
c. If the gauge reads 0.2 mm (0.008 in.) or less, the difference in height of the valve stems is within specifications. Go to step 8 . If the gauge reads more than 0.2 mm (0.008 in.), the difference in height of the valve stems is not within specifications. Go to step 7 .

7. If the measurement is not within specifications, inspect the valve stems for length and valve seat inserts for height. Replace them if necessary. The inspection criteria is listed in Table "Valve Specifications" .
8. Install the cylinder head. Refer to "1.4.2 Installation of Cylinder Head" .

Section 1.19.3 Removal of Valve

Removal steps are as follows:

1. Remove the cylinder head from the engine. Refer to "1.4.1 Removal of Cylinder Head" . See Figure "Valves and Related Components" .



1. Valve Collet	6. Intake Valve
2. Valve Spring Retainer	7. Exhaust Valve
3. Intake Valve Spring	8. Valve Spring Adaptor/Remover
4. Exhaust Valve Spring	9. Valve Stem Seal
5. Cylinder Head	

Figure 8. Valves and Related Components

2. Remove the fuel injector. Refer to "2.4.1 Removal of Fuel Injector" .
3. Using a dial gauge and holder, measure the valve recess. Refer to "1.19.2 Measuring Valve Recess" .

   Note: To measure valve recess, refer to "1.19.2 Measuring Valve Recess" for instructions. If the measurement is not within tolerance, replace the valve or valve seat. Machine the valve seat inserts; refer to "1.20.1.1 Cleaning and Machining of Valve Seat Bore" for the procedures.

4. Attach the valve spring adaptor and remover (J–46399) to the cylinder head.
5. Using the adaptor/remover, press down on the valve spring retainer. Remove the collets with a magnetic pin.
6. Relieve the pressure on the adaptor/remover. Remove the valve spring retainer and the valve springs.
7. Remove the valves. Identify removed location on each valve.

   Note: Keep the valves in order for ease of installation.

8. Remove the valve stem seals.
9. Clean the valves thoroughly. Remove any traces of combustion residue.
10. Check the valves to see if they can be re–used. Replace the valves if the stem ends are damaged, if the valve grooves are deformed, or if the chrome surface of the shaft is not entirely intact. Always replace burned valves.
11. Check valve dimensions and concentricity. Replace all bent valves. The specifications are shown insee Figure "Critical Dimensions, Valve Stem and Head" and listed in Table "Valve

Specifications" .

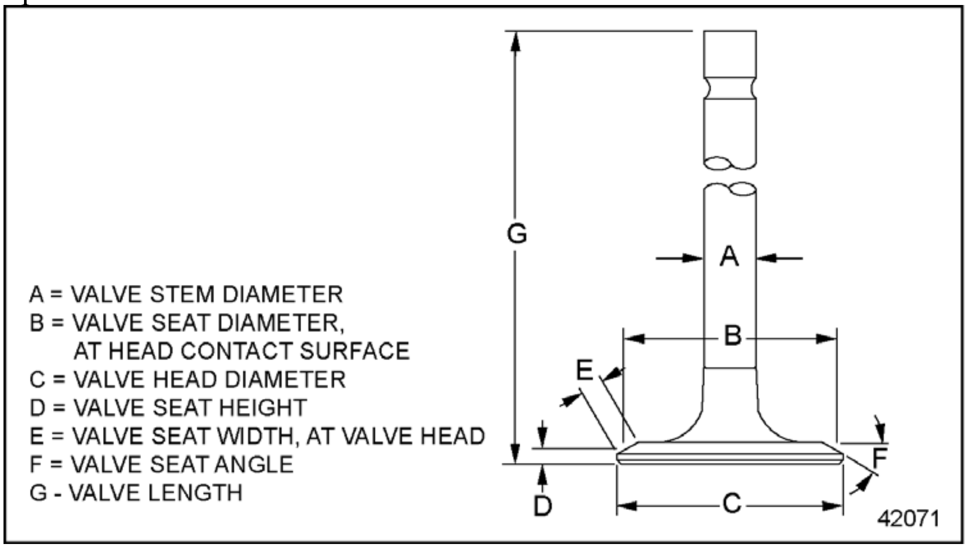


Figure 9. Critical Dimensions, Valve Stem and Head

Descriptions	Intake mm (in.)	Exhaust mm (in.)
Valve Stem Diameter (see Figure , Ref. A)	7.935–7.950 (0.3124–0.3130)	7.925–7.940 (0.3120–0.3126)
Valve Seat Diameter, at Head Mating Surface (see Figure , Ref. B)	31.0 (1.22)	36.0 (1.42)
Valve Head Diameter (see Figure , Ref. C)	33.9–34.1 (1.33–1.34)	37.9–38.1 (1.49–1.50)
Valve Seat Height—After Grinding (see Figure , Ref. D)	2.7–3.1 (0.106–0.122)	2.5–3.2 (0.098–0.126)
Valve Seat Width, at Valve Head (see Figure , Ref. E)	3.3–4.3 (0.130–0.169)	3.5–4.2 (0.138–0.165)
Valve Seat Angle (see Figure , Ref. F)	20 degrees	45 degrees
Valve Length (see Figure , Ref. G)	125.7–126.1 (4.948–4.965)	152.5–152.9 (6.004–6.020)
Valve Stem Clearance in Valve Guide	0.050–0.087 (0.0020–0.0034)	0.060–0.097 (0.0024–0.0038)
Maximum Eccentricity of Valve Seat to Stem	0.03 (0.0012)	
Valve Recess from Cylinder Head	1.1–1.5 (0.04–0.06)	

Table 10. Valve Specifications

a. Check dimensions A through G (see Figure "Critical Dimensions, Valve Stem and Head").
b. Check the concentricity of the valve seat to the valve stem.

   Note: Minor deviations in valve concentricity can be corrected by refacing the valves on a valve grinding machine. For instructions, refer to "1.19.3.1 Refacing of Valve" .

12. Inspect the valve guides for wear.
13. Inspect the valve springs. If damaged, replace the springs.

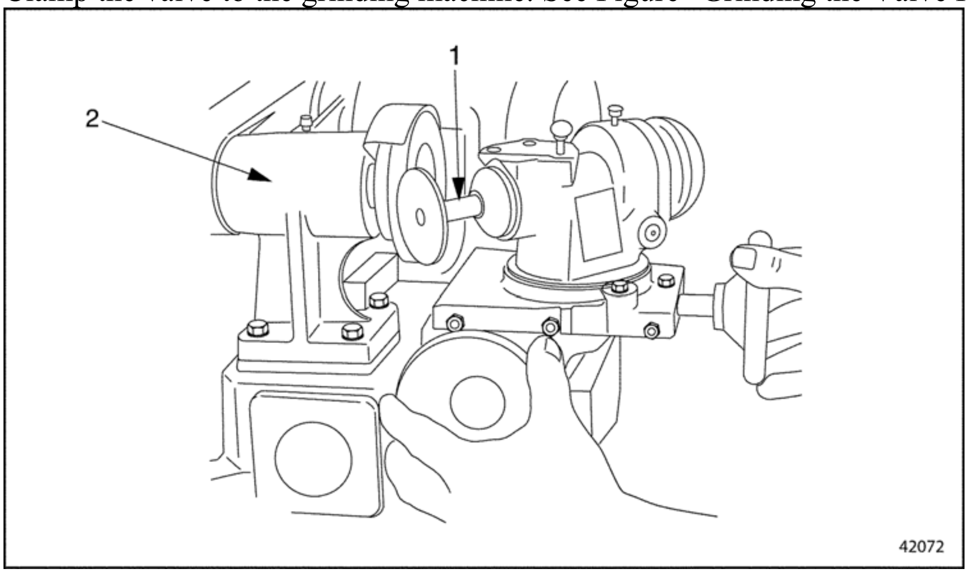
Section 1.19.3.1
Refacing of Valve

Refacing steps are as follows:

1. Clean the valves thoroughly. Remove any traces of combustion residue adhering to the valves.

   Note: To avoid vibration, which could disrupt the grinding process, clamp the valve to the grinding machine as close as possible to the valve head.

2. Clamp the valve to the grinding machine. See Figure "Grinding the Valve Head" .



1. Valve	2 Grinder

Figure 10. Grinding the Valve Head

3. Adjust the grinding angle on the machine scale to the correct value (20 degrees for intake valves, 45 degrees for exhaust valves). The valve grinding specifications are listed in Table "Valve Removal/Installation Specifications" .

Descriptions	Intake mm (in.)	Exhaust mm (in.)
Valve Stem Diameter (see Figure , Ref. A)	7.935–7.950 (0.3124–0.3130)	7.925–7.940 (0.3120–0.3126)
Valve Seat Diameter, at Head Mating Surface (see Figure , Ref. B)	31.0 (1.22)	36.0 (1.42)
Valve Head Diameter	33.9–34.1 (1.33–1.34)	37.9–38.1 (1.49–1.50)

(see Figure , Ref. C)		
Valve Seat Height—After Grinding (see Figure , Ref. D)	2.7–3.1 (0.106–0.122)	2.5–3.2 (0.098–0.126)
Valve Seat Width, at Valve Head (see Figure , Ref. E)	3.3–4.3 (0.130–0.169)	3.5–4.2 (0.138–0.165)
Valve Seat Angle (see Figure , Ref. F)	20 degrees	45 degrees
Valve Length (see Figure , Ref. G)	125.7–126.1 (4.948–4.965)	152.5–152.9 (6.004–6.020)
Valve Stem Hardness	54–60 HRC	
Maximum Eccentricity of Valve Seat to Stem	0.03 (0.0012)	

Table 12. Valve Removal/Installation Specifications

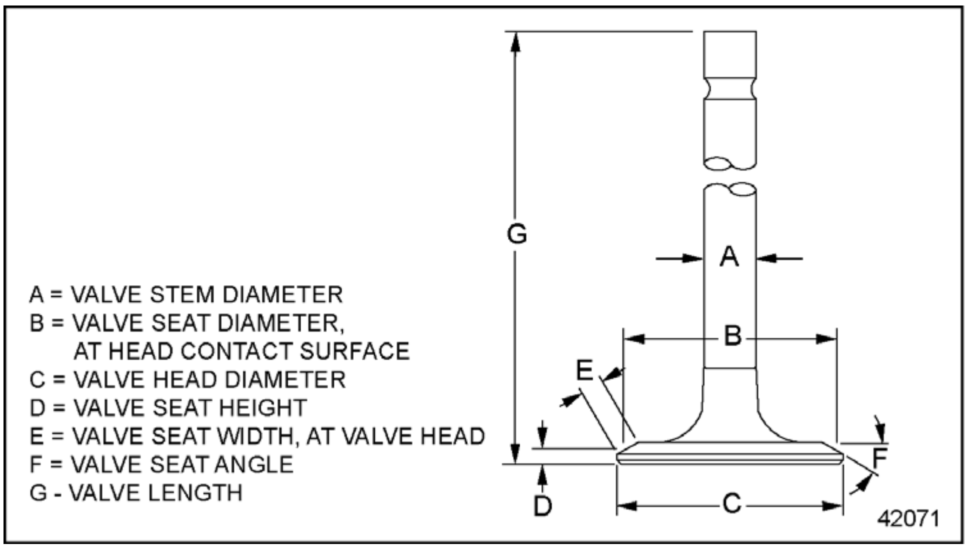


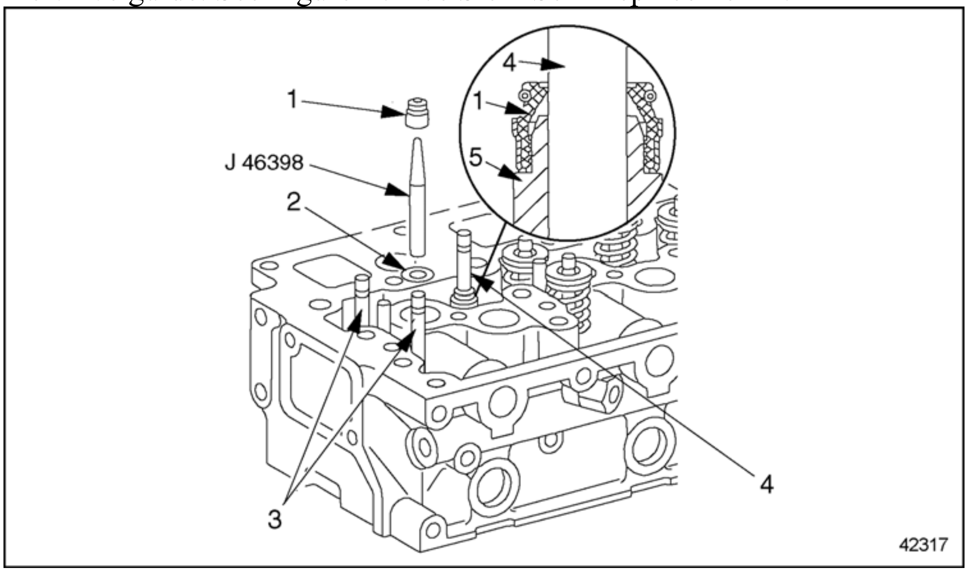
Figure 11. Critical Dimensions, Valve Stem and Head

4. Using the feed mechanism on the grinder, advance the valve slowly towards the grinding wheel, as it turns, until the seating surface of the valve comes in contact with the wheel.
5. Feed the valve gradually into the wheel until the entire circumference of the valve seat is smooth and free of chatter marks.
6. After this operation, check that each of the following critical dimensions are no smaller (shorter) than specified. See Figure "Critical Dimensions, Valve Stem and Head" for the critical dimensions listed in Table "Valve Removal/Installation Specifications" . The critical dimensions are:
   - Valve stem diameter (A)
   - Valve head diameter (C)
   - Valve seat width at the valve head (E)
   - Valve length (G)
   - Intake valve seat height, after grinding, (D) as it applies to valve seat diameter at the head mating surface (B)
   - Exhaust valve seat height, after grinding, (D) as it applies to valve seat diameter at the head mating surface (B)
   - Eccentricity of valve seat to valve stem
7. Release the valve from the clamp on the grinder.

Section 1.19.4
Installation of Valve

Installation steps are as follows:

1. Apply a light coating of engine oil on the valves. Then, install the valves.
2. Install new valve stem seals
   a. Lightly lubricate the valve stem and valve stem seal installer with clean engine oil.
   b. Push the valve stem seal installer (J–46398) over the valve stem until it makes contact with the valve guide. See Figure "Valve Stem Seal Replacement" .



1. Valve Stem Seal	4. Exhaust Valve
2. Supporting Washer	5. Valve Guide
3. Intake Valves	

Figure 12. Valve Stem Seal Replacement

   c. Install the new valve stem seal. Remove the valve stem seal installer.
3. Using the adaptor/remover, install the springs, spring retainers, and valve collets.
4. Check the valve stem clearance in the valve guide as listed in Table "Valve Specifications" .
5. Remove the adaptor/remover from the cylinder head.
6. Install the fuel injector.
7. Install the cylinder head. Refer to "1.4.2 Installation of Cylinder Head" .

Section 1.19.5
Replacement of Valve Stem Seal

Replacement steps are as follows:

DANGER:

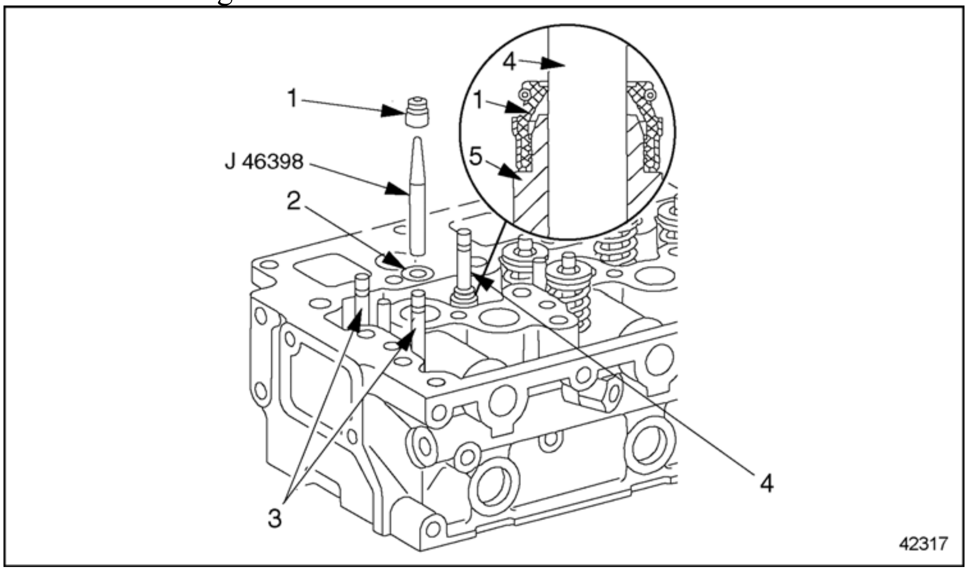
BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

1. Remove the cylinder head from the engine. Refer to "1.4.1 Removal of Cylinder Head" .

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

2. Remove the valve spring, valve collets, valve spring retainer, and valve stem seal. Do not remove the valve. See Figure "Valve Stem Seal" .



1. Valve Stem Seal	4. Exhaust Valve
2. Supporting Washer	5. Valve Guide
3. Intake Valves	

Figure 13. Valve Stem Seal

3. Lightly lubricate the valve stem and valve stem seal installer with clean engine oil.
4. Push the valve stem seal installer (J–46398) over the valve stem until it makes contact with the valve guide.
5. Install the new valve stem seal. Remove the valve stem seal installer.
6. Install the valve spring, valve spring retainer, and valve collets.
7. Repeat the procedure for the other valves.
8. Install the cylinder head. Refer to "1.4.2 Installation of Cylinder Head" .

Section 1.20
Valve Seats and Guides

Valve seat inserts can be replaced when worn to restore new engine performance. Valves are positioned and aligned by replaceable valve guides.

Section 1.20.1
Removal of Valve Seat Insert

Removal steps are as follows:

1. Remove the fuel injectors. Refer to "2.4.1 Removal of Fuel Injector" .
2. Remove the valves. Refer to "1.19.3 Removal of Valve" .
3. Clamp the cylinder head on a valve assembly stand.
4. Locate the point where the groove is to be ground.
   a. Using a measuring device such as calipers, measure the depth of the valve seat bore. See Figure "Valve Seat Critical Dimensions" . Listed in Table "General Specifications" are the specifications.

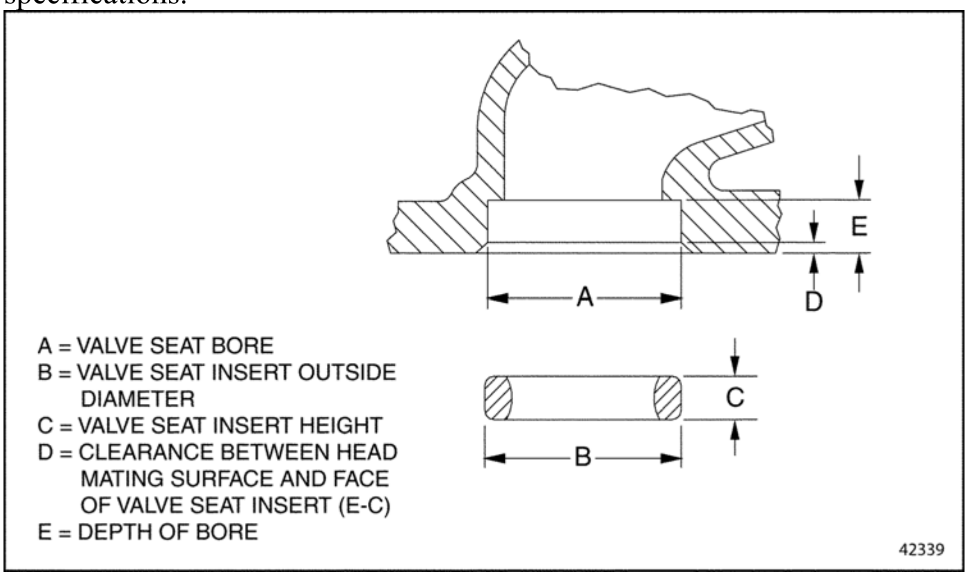


Figure 1. Valve Seat Critical Dimensions

Descriptions	Specifications mm (in.)
Valve Seat Interference Fit	0.045–0.080 (0.0018–0.0031)
Depth of Bore in Cylinder Head (see Figure "Valve Seat Critical Dimensions" , E)	11.4–11.6 (0.449–0.457)
Height of Valve Seat Insert (see Figure "Valve Seat Critical Dimensions" , C)	
Intake	7.6–7.7 (0.299–0.303)

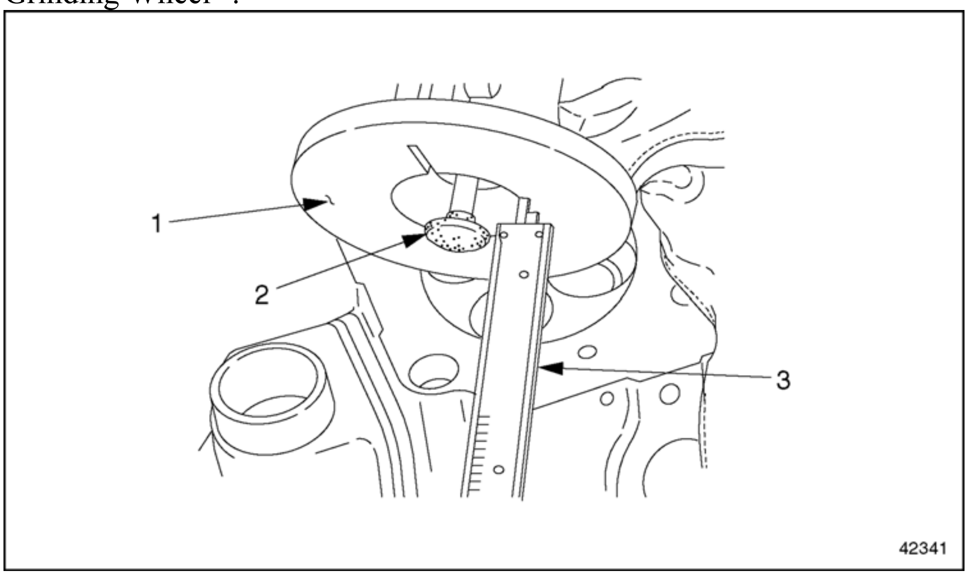
Exhaust	8.0–8.1 (0.315–0.319)
Clearance Between Head mating Surface and Valve Seat Insert Face (see Figure "Valve Seat Critical Dimensions" , D)	
Intake	3.7–4.0 (0.146–0.157)
Exhaust	3.3–3.6 (0.130–0.142)

Table 1. General Specifications

b. Measure the distance from the surface of the cylinder head to the point on the valve seat insert where the groove is to be ground.

Note: This point should be approximately 1.50 mm (0.060 in.) below any angular valve seating face on the valve seat insert.

5. Groove the valve seat insert for ease of removal.
   a. Install the grinder base on the grinder from the valve seat removal kit (PT–6390) . Adjust the grinding wheel to the proper height, 1.50 mm (0.060 in.). See Figure "Adjusting the Grinding Wheel" .



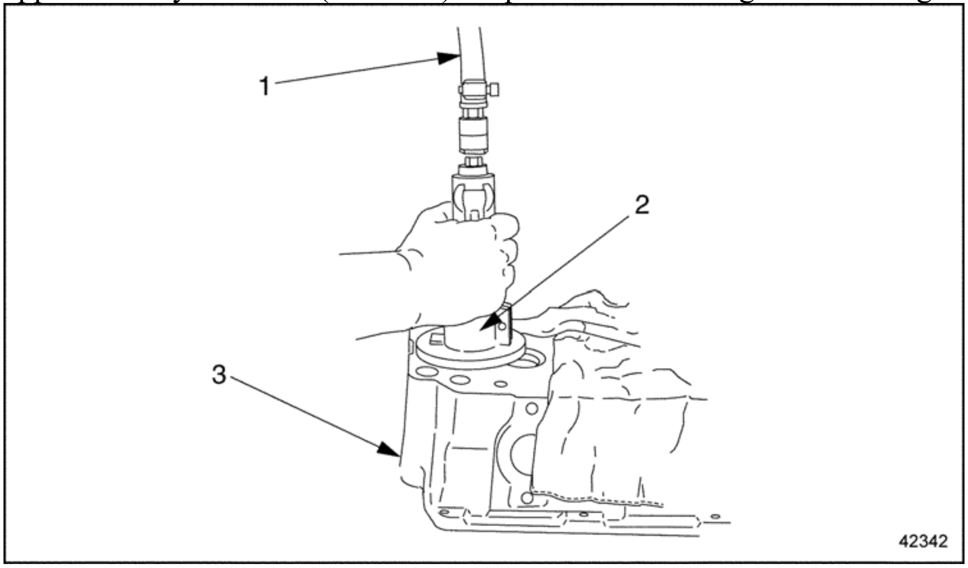
1. Grinder	3. Measuring Device
2. Grinding Wheel	

Figure 2. Adjusting the Grinding Wheel

b. Select the appropriate size grinding wheel from those included in the kit, based on the distance, as measured. Secure the grinder base to the grinding wheel by tightening the set screw.

Note: Two sizes of grinding wheels are available (1.250 in. diameter and 0.750 in. diameter). To make any wheel smaller, use the dressing stone included in the kit. The dressing stone can also be used to keep the wheels sharp, which increases cutting speed. When dressing a worn wheel, make the edge of the wheel just slightly wider than the width of the steps on the extractors.

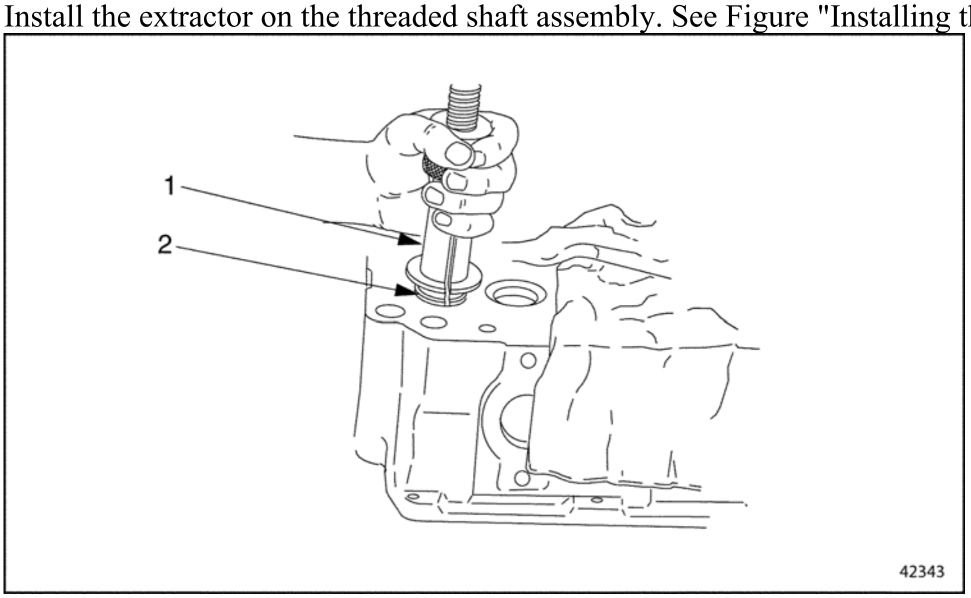
c. Grind a groove around the inside circumference of the valve seat insert. Make the groove approximately 0.75 mm (0.030 in.) deep on a side. See Figure "Grinding the Groove" .



1. Pressure Hose	3. Cylinder Head
2. Grinder	

Figure 3. Grinding the Groove

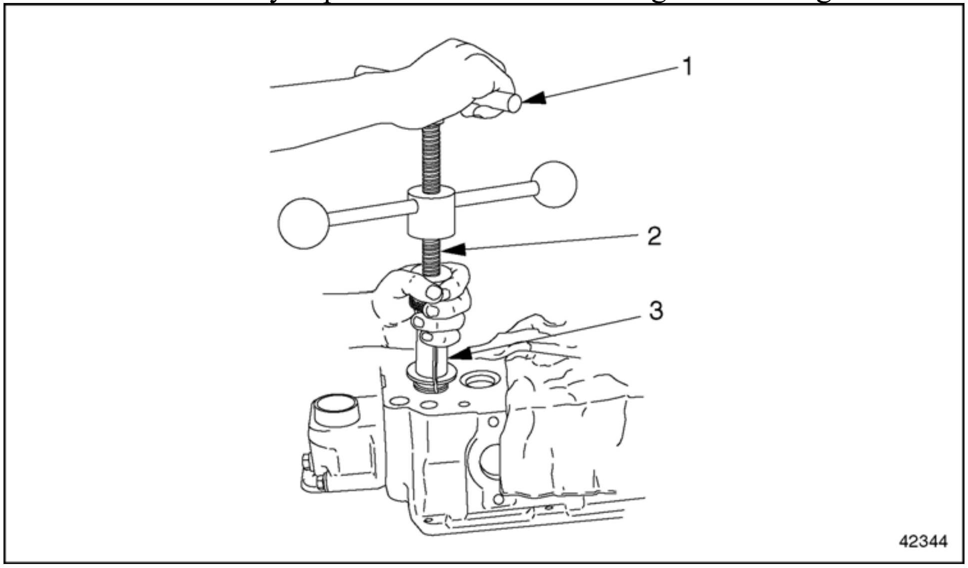
6. Assemble the valve seat remover, using the tools from the valve seat removal kit.
   a. Attach the crank handle onto the threaded shaft assembly.
   b. Select an extractor from the valve seat removal kit. Use the extractor with the largest step that will fit into the inside diameter of the valve seat insert.
   c. Install the extractor on the threaded shaft assembly. See Figure "Installing the Extractor" .



1. Extractor Shaft	2. Step

Figure 4. Installing the Extractor

d. Position the extractor step in the groove in the valve seat insert. Turn the T–handle on the threaded shaft to fully expand the extractor. See Figure "Turning the T–Handle" .

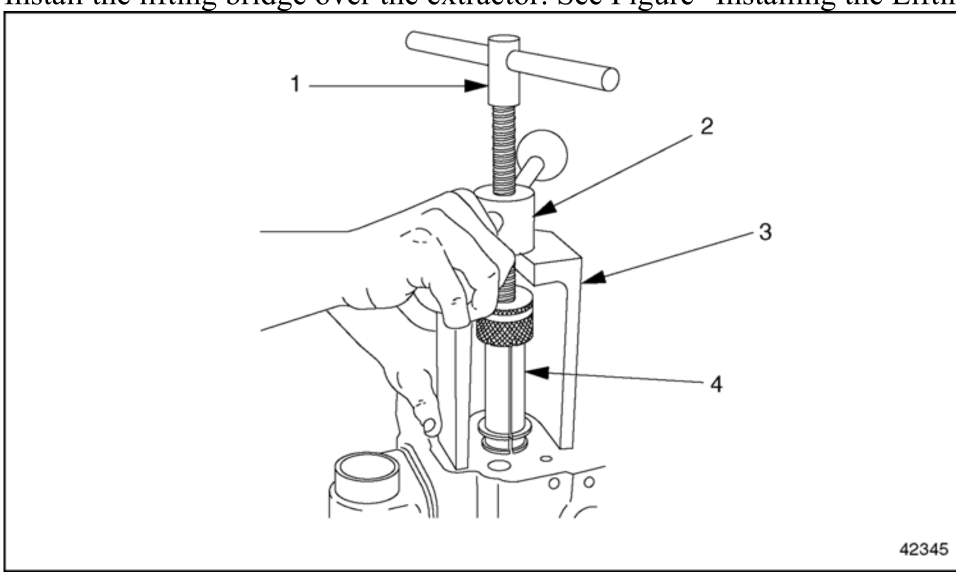


1. T–Handle	2. Threaded Shaft	3. Extractor

Figure 5. Turning the T–Handle

Note: Use only moderate force to expand the extractor.

e. Install the lifting bridge over the extractor. See Figure "Installing the Lifting Bridge" .



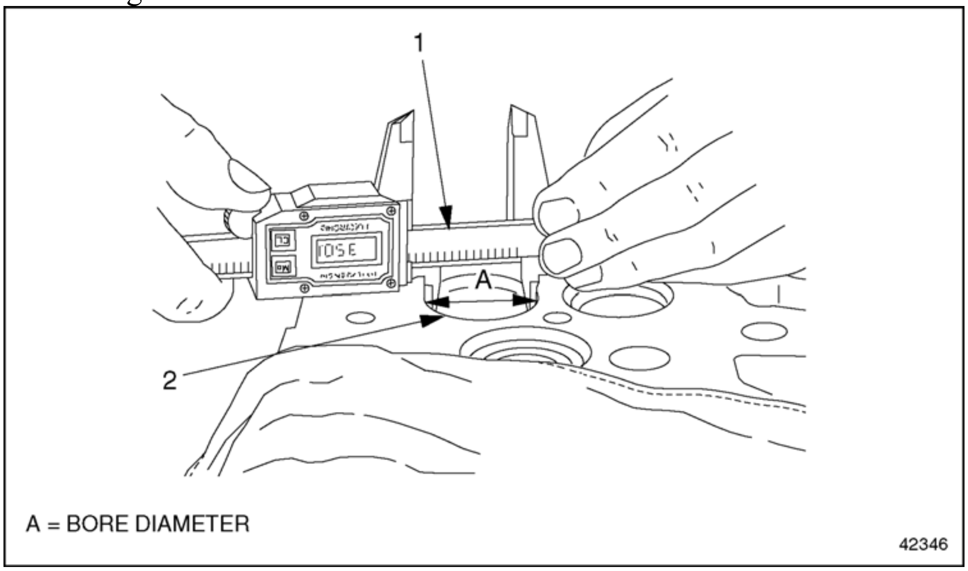
1. T–Handle	3. Lifting Bridge
2. Crank Handle	4. Extractor

Figure 6. Installing the Lifting Bridge

7. Remove the valve seat insert.
   a. Turn the crank handle to remove the insert from the valve seat bore.

b. To release the insert from the extractor, turn the T–handle on the threaded shaft.

8. Measure the valve seat bore. See Figure "Measuring the Valve Seat Bore" . If the bore is not within specifications, it must be machined to the next repair stage. Refer to "1.20.1.1 Cleaning and Machining of Valve Seat Bore" .



1. Measuring Device	2. Valve Seat Bore

Figure 7. Measuring the Valve Seat Bore

9. Repeat this procedure for each valve seat insert.

Section 1.20.1.1
Cleaning and Machining of Valve Seat Bore

Cleaning and machining steps are as follows:

1. Clean the valve seat bore and surrounding area of dirt, debris, and metal chips.
2. Insert the correct pilot into the valve guide. See Figure "Installing the Pilot in the Valve Guide" . Tighten the pilot in place.

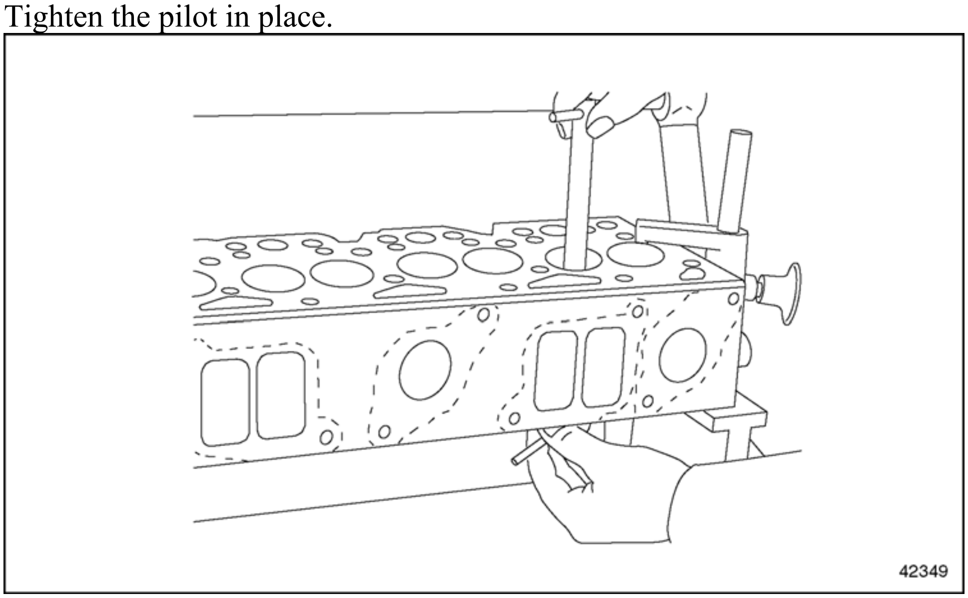


Figure 8. Installing the Pilot in the Valve Guide

NOTICE:

Install the machining tool carefully in order to avoid damage to the cutter or the head.

3. Install the machining tool.
    a. Coat the pilot lightly with oil.
    b. Position the machining tool over the pilot and move the machining tool in a horizontal direction until it is beyond the bore diameter.
    c. Push the machining tool down until the cutter rests on the head surface.
    d. Push the pilot shaft down until it rests on the pilot.
    e. Raise the machining tool until the cutter clears.
4. Set the cutting depth. The cutting depth should be equal to the depth of the bore. See Figure "Valve Seats Critical Dimensions" .

    Note: Dimensions A and B are listed in Table "Repair Stage Specifications" ; dimensions C, D, and E are listed in Table "General Specifications" .

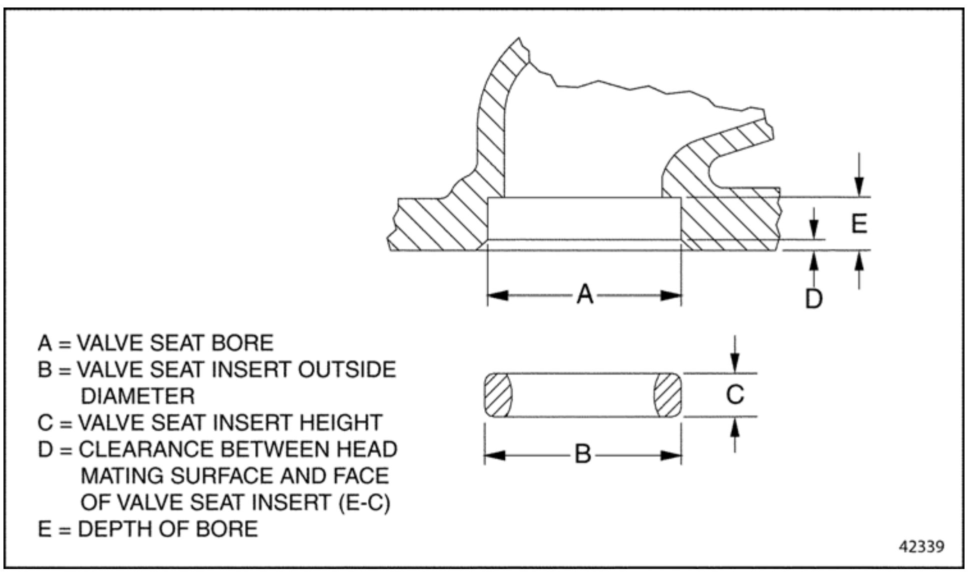
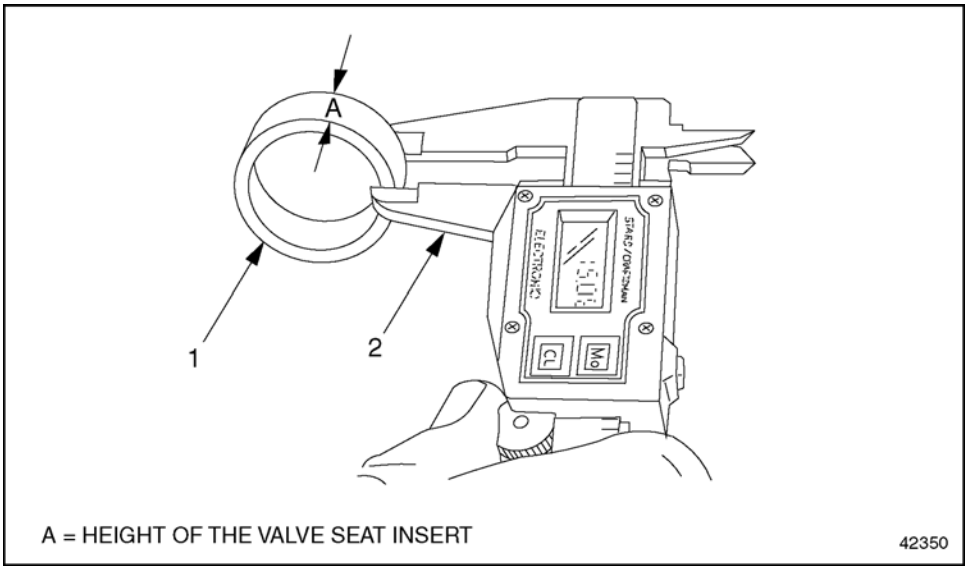


Figure 9. Valve Seats Critical Dimensions

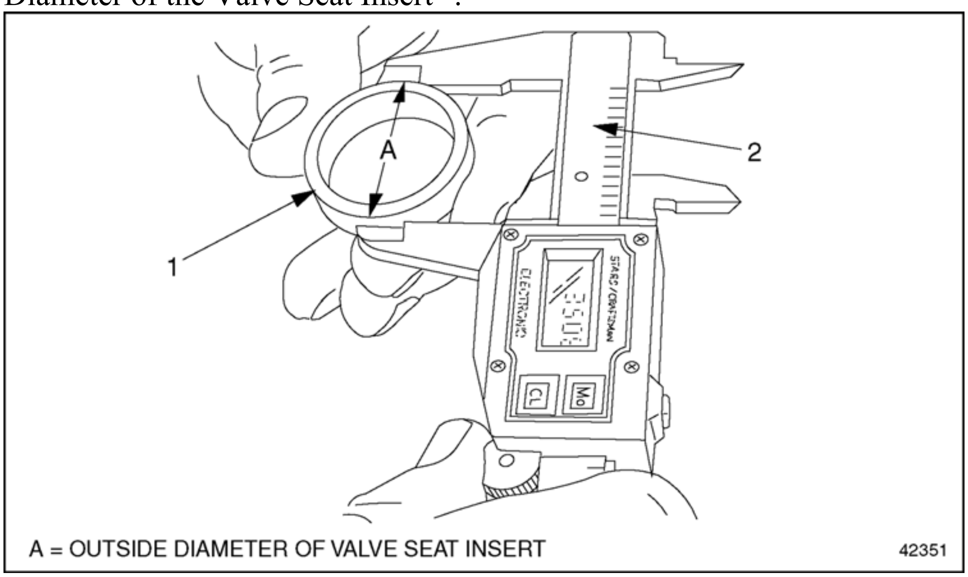
5. Measure the height of the valve seat insert. See Figure "Measuring the Height of the Valve Seat Insert" .



1. Valve Seat Insert	2. Measuring Device

Figure 10. Measuring the Height of the Valve Seat Insert

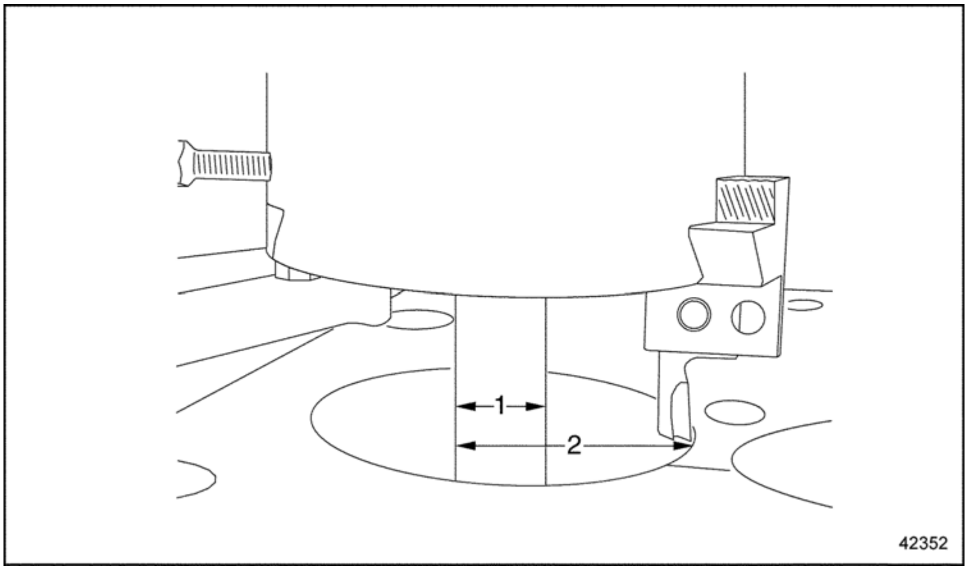
6. Measure the outside diameter of the valve seat insert. See Figure "Measuring the Outside Diameter of the Valve Seat Insert" .



1. Valve Seat Insert	2. Measuring Device

Figure 11. Measuring the Outside Diameter of the Valve Seat Insert

7. Calculate the machining adjustment. See Figure "Determining the Machining Adjustment" .



1. Pilot Shaft Diameter (P)	2. Machining Adjustment (M)

Figure 12. Determining the Machining Adjustment

a. Read the value for the valve seat basic bore (dimension "A" listed in Table "Repair Stage Specifications").

Repair Stage	Basic Bore in Cylinder Head (see Figure , A)		Outside Diameter of Valve Seat Insert (see Figure , B)	
	Intake mm (in.)	Exhaust mm (in.)	Intake mm (in.)	Exhaust mm (in.)
Standard	35.000–35.025 (1.378–1.379)	40.000–40.025 (1.575–1.576)	35.07–35.08 (1.3807–1.3811)	40.07–40.08 (1.5775–1.5779)
Standard I	35.300–35.325 (1.390–1.391)	40.300–40.325 (1.575–1.588)	35.37–35.38 (1.3925–1.3929)	40.37–40.38 (1.5893–1.589)
Stage I	35.500–35.525 (1.398–1.399)	40.500–40.525 (1.594–1.595)	35.57–35.58 (1.4004–1.4008)	40.57–40.58 (1.5972–1.5976)

Table 12. Repair Stage Specifications

Note: Choose the repair stage corresponding to the size of the outside diameter of the valve seat insert (dimension "B" listed in Table "Repair Stage Specifications"), as measured in the previous step.

b. Measure the diameter of the pilot (P). See Figure "Determining the Machining Adjustment" .
c. Add the diameter of the pilot to the valve seat bore and divide by two. Use this formula: M = (A + P)/2. Example: If the valve seat bore is 1.378 inches, and the diameter of the pilot is 0.573 inches, M = (1.378 + 0.573)/2 = 1.951/2 = 0.976 inches.

8. Set a micrometer to dimension "M" as calculated in the previous step. Lift the machining tool slightly and place the micrometer on the pilot. Set the cutter at dimension "M" and lock it in place.

   Note: For the first cut, it is recommended that the adjustment of the cutter be set at 0.1 mm (0.004 inch) less than the finished dimension (dimension "A" listed in Table "Repair Stage Specifications").

9. Machine the valve seat bore. Continue machining until the finished dimension is reached.
   a. Adjust the cutter as often as is necessary to reach the finished dimension.
   b. Without additional adjustment, turn the cutter through one more time.
10. Lift the machining tool slightly and machine the face of the valve seat bore. See Figure "Valve Seats Critical Dimensions" , D. Check the clearance between the head mating surface and the face of the valve seat insert. The specifications for intake and exhaust valves are listed in Table "General Specifications" .

Descriptions	Specifications mm (in.)
Valve Seat Interference Fit	0.045–0.80 (0.0018–0.0031)
Depth of Bore in Cylinder Head (see Figure "Valve Seats Critical Dimensions" , E)	11.4–11.6 (0.449–0.457)
Height of Valve Seat Insert (see Figure "Valve Seats Critical Dimensions" , C)	
Intake	7.6–7.7 (0.299–0.303)
Exhaust	8.0–8.1 (0.315–0.319)
Clearance Between Head mating Surface and Valve Seat Insert Face (see Figure "Valve Seats Critical Dimensions" , D)	
Intake	3.7–4.0 (0.146–0.157)
Exhaust	3.3–3.6 (0.130–0.142)

Table 13. General Specifications

11. Remove the cutting tool and measure the outside diameter of the valve seat insert. See Figure "Measuring the Outside Diameter of the Valve Seat Insert" . There must be an interference fit of 0.045 to 0.080 mm (0.0018 to 0.0031 in.) between the valve seat insert and the bore.
12. Install the valve seat inserts. Refer to "1.20.2 Installation of Valve Seat Insert" .

Section 1.20.2
Installation of Valve Seat Insert

Installation steps are as follows:

WARNING:

FREEZING OR SUFFOCATION

To avoid injury from freezing or suffocation when using liquid nitrogen, wear a face shield and protective clothing and work in a well ventilated area.

Note: Do not touch the insert with your bare hands. Handle the inserts with tweezers.

1. Place the valve seat inserts in liquid nitrogen. Allow the inserts to cool approximately 20 to 30 minutes.

   Note: Liquid nitrogen is commercially available.

WARNING:

BURNS

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

2. Heat the head to approximately 80°C (176°F) in a hot water tank. Remove the head from the hot water tank using an overhead hoist and place the head on a workbench or stand. Wear insulated gloves when handling the heated head.
3. Carefully remove the valve seat inserts from the liquid nitrogen and place the inserts in the bores of the heated head. See Figure "Positioning a Valve Seat Insert" .

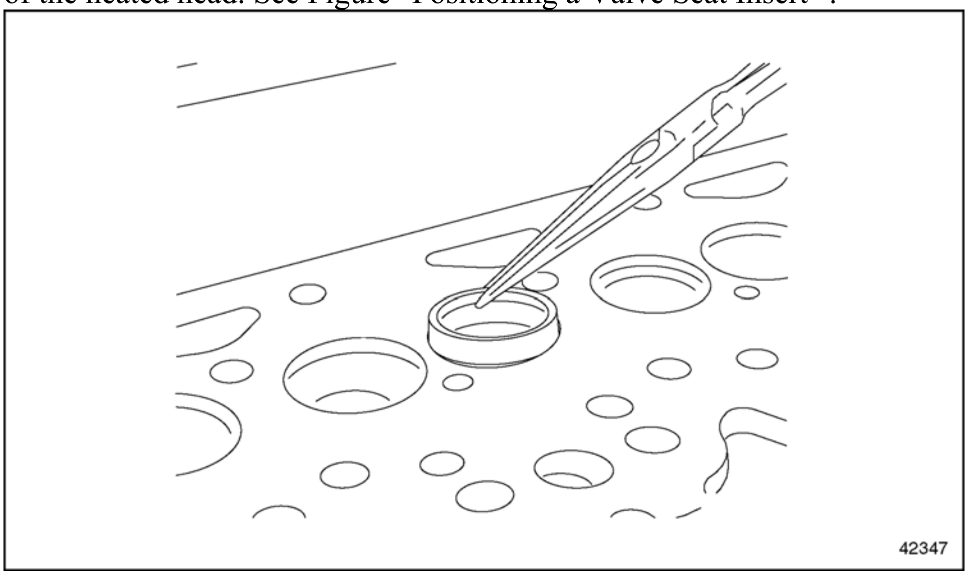


Figure 13. Positioning a Valve Seat Insert

4. Drive in each insert, using a suitable driver. See Figure "Driving a Valve Seat Insert Into Place" .

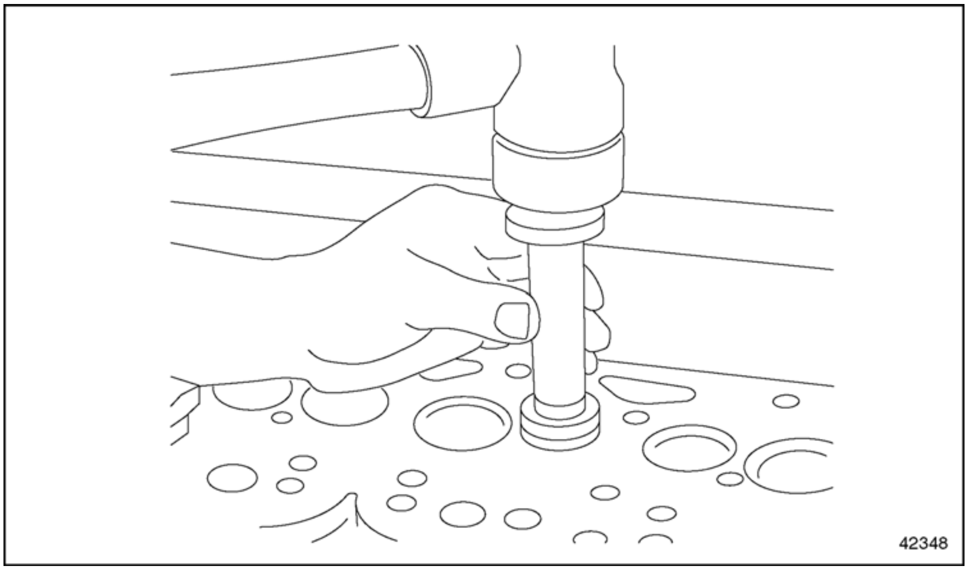


Figure 14. Driving a Valve Seat Insert Into Place

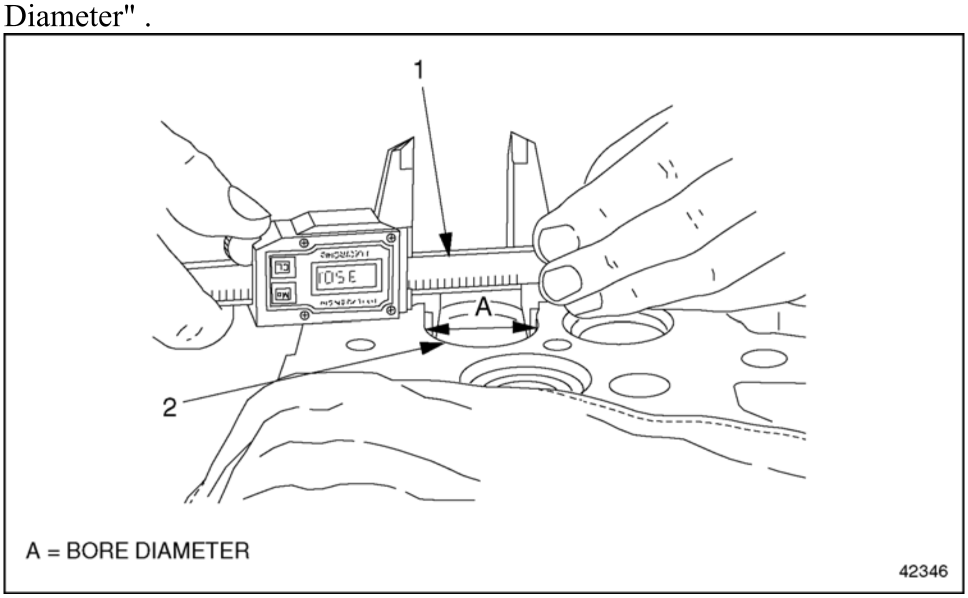
5. Machine the inserts to specifications. Refer to "1.20.2.1 Machining of Valve Seat Insert" .
6. Install the fuel injection nozzle holders. Refer to "2.4.2 Installation of Fuel Injector" .
7. Install the valves. Refer to "1.19.4 Installation of Valve" .

Section 1.20.2.1
Machining of Valve Seat Insert

Machining steps are as follows:

Note: Perform this operation with the valve guides installed.

1. Measure the outside diameter of the valve seat. See Figure "Measuring the Valve Seat Outside Diameter" .



1. Measuring Device	2. Valve Seat Bore

Figure 15. Measuring the Valve Seat Outside Diameter

Note: If the valve seats show only slight imprinting from the valves, the seats can be machined without replacing the valve seat inserts, as long as the maximum valve face recess does not exceed 1.5 mm (0.059 in.).

2. Insert the correct pilot into the valve guide. See Figure "Installing the Pilot in the Valve Guide" . Tighten the pilot in place.

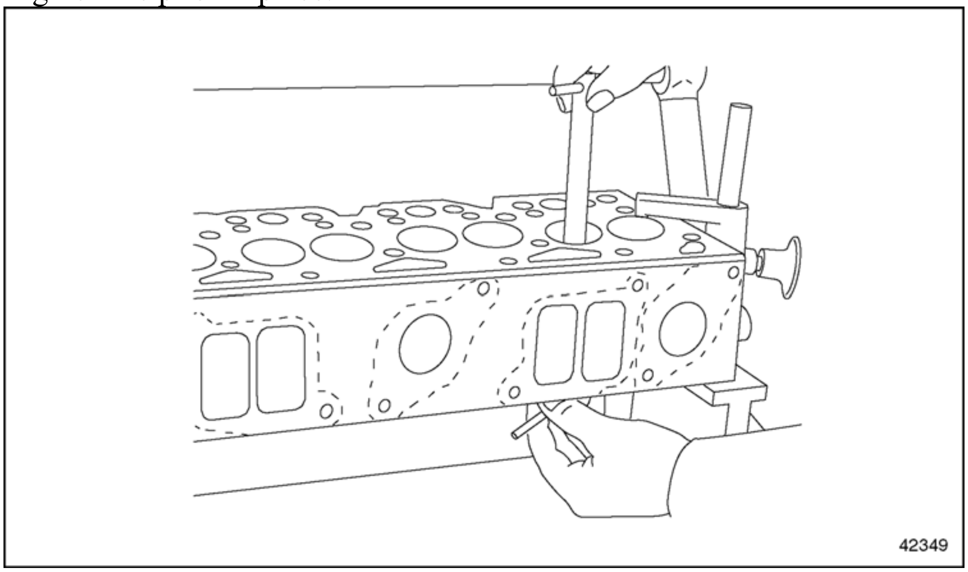


Figure 16. Installing the Pilot in the Valve Guide

3. Secure the machining tool on the support.

Note: Be sure that the machining tool is mounted with the correct angle adjustment of 20 degrees for the intake valve seat, or 45 degrees for the exhaust valve seat as listed in Table "Valve Seat Specifications" .

Descriptions	Intake mm (in.)	Exhaust mm (in.)
Valve Seat Angle (see Figure , A)	20 degrees	45 degrees
Valve Seat Width at Valve Seat Insert (see Figure , B)	1.5–2.5 (0.059–0.098)	1.8–3.0 (0.071–0.118)
Valve Seat Diameter at Insert (see Figure , C)	31.0 (1.22)	36.0 (1.42)
Machining Dimension (see Figure , E)	4.2–4.4 (0.165–0.173)	4.3–4.5 (0.169–0.177)

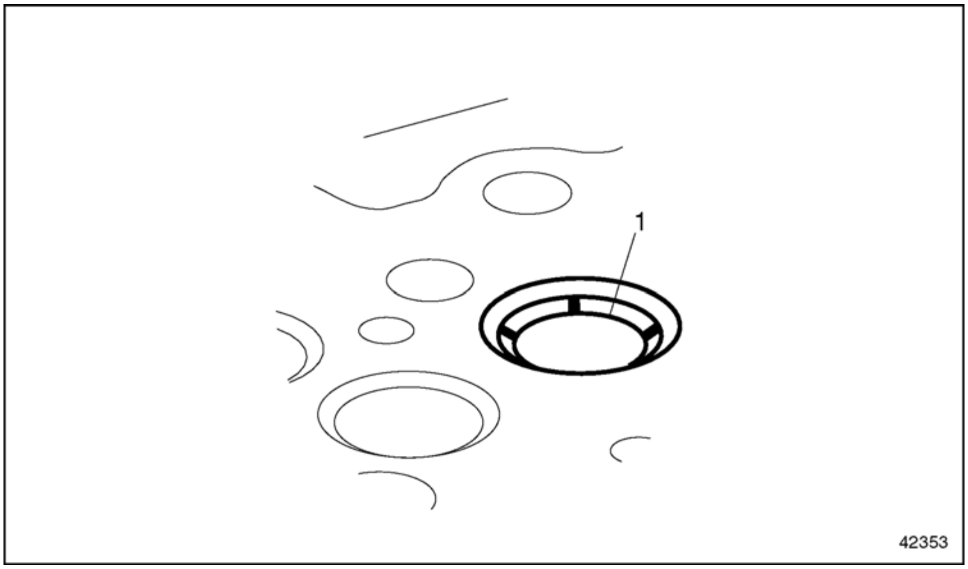
Table 17. Valve Seat Specifications

4. Coat the pilot lightly with oil. Insert the machining tool onto the pilot and press the tool down until the cutter rests on the cylinder head surface.
5. Position the machining tool over the pilot. Center the cutter over the valve seat insert.

NOTICE:

Do not allow the cutter to strike the cylinder head. This will damage the carbide metal tip of the cutting blade.

6. Lower the cutter until it is touching the middle of the valve seat insert.
7. Press the pilot shaft down until it seats on the pilot.
8. Using a marking pen, mark the valve seat insert every 120 degrees. See Figure "Mark the Valve Seat Insert" .



1. Valve Seat Insert

Figure 17. Mark the Valve Seat Insert

9. Set the cutter against the inner edge of the seat and lock it in place. Do not feed the tool beyond this setting yet.
10. Machine the valve seat insert along its inner edge. The cut in the metal will generally be uneven at this time. Adjust the cutter as often as necessary to meet the finished dimensions.
11. Repeat the machining procedure until the seat is thoroughly clean. Do not exceed the machining limits for the valve seat diameter and width (see Figure "Intake and Exhaust Valve Seat Cross Sections" , C and B) listed in Table "Valve Seat Specifications" . When the seat is clean, make one more full turn with the cutter without further adjustment.

    Note: If new valve seat inserts have been installed, be sure they meet the specifications listed in Table "Valve Seat Specifications" .

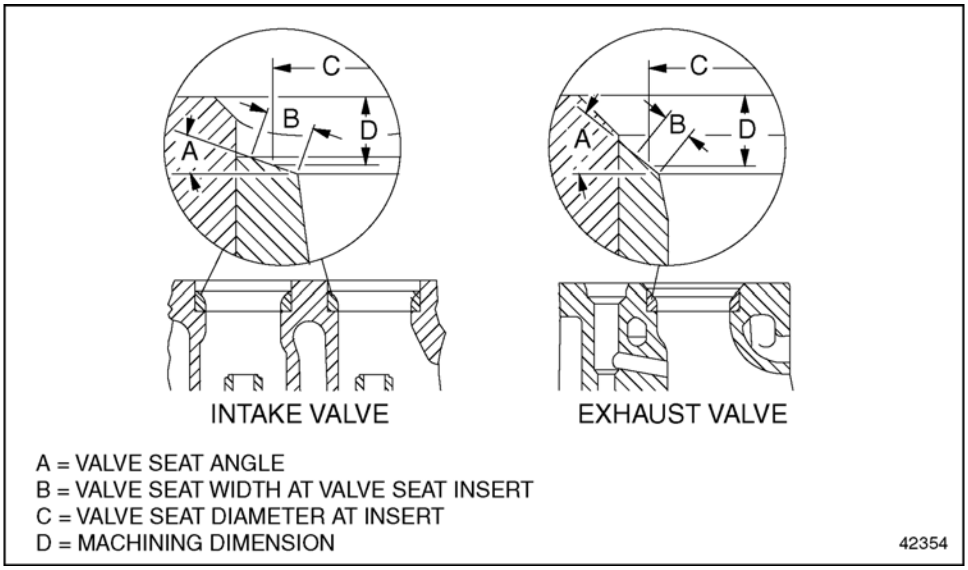


Figure 18. Intake and Exhaust Valve Seat Cross Sections

12. Machine the valve seat insert along its outer edge. The cut in the metal will generally be uneven at this time. Adjust the cutter as often as necessary to meet the finished dimensions.
13. Repeat the machining procedure until the seat is thoroughly clean. Do not exceed the machining limits for the valve seat diameter and width (see Figure "Intake and Exhaust Valve Seat Cross Sections" , C and B) listed in Table "Valve Seat Specifications" . When the seat is clean, make one more full turn with the cutter without further adjustment.

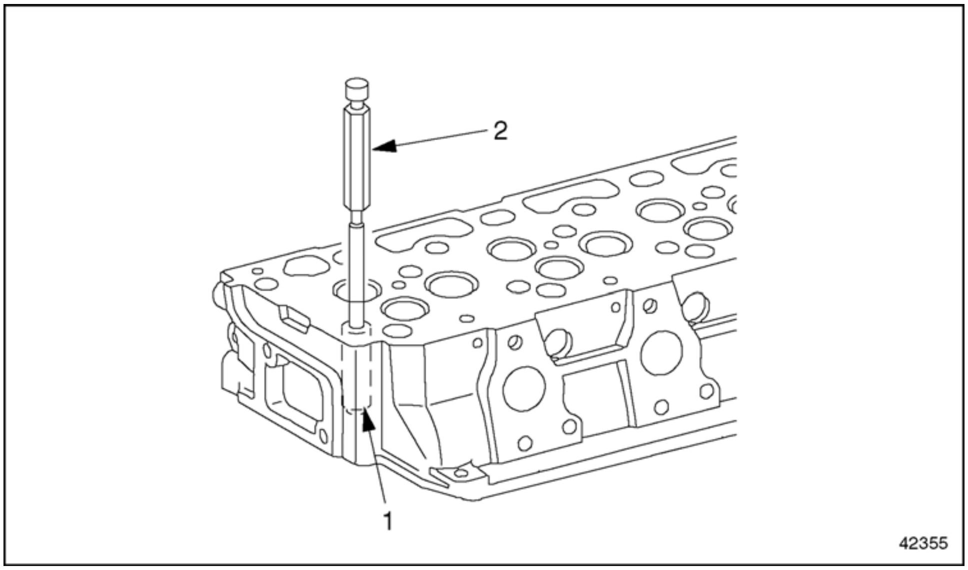
    Note: If new valve seat inserts have been installed, be sure they meet the specifications listed in Table "Valve Seat Specifications" .

14. Install the valves. Refer to "1.19.4 Installation of Valve" .
15. Install the cylinder head. Refer to "1.4.2 Installation of Cylinder Head" .

Section 1.20.3
Removal of Valve Guide

Removal steps are as follows:

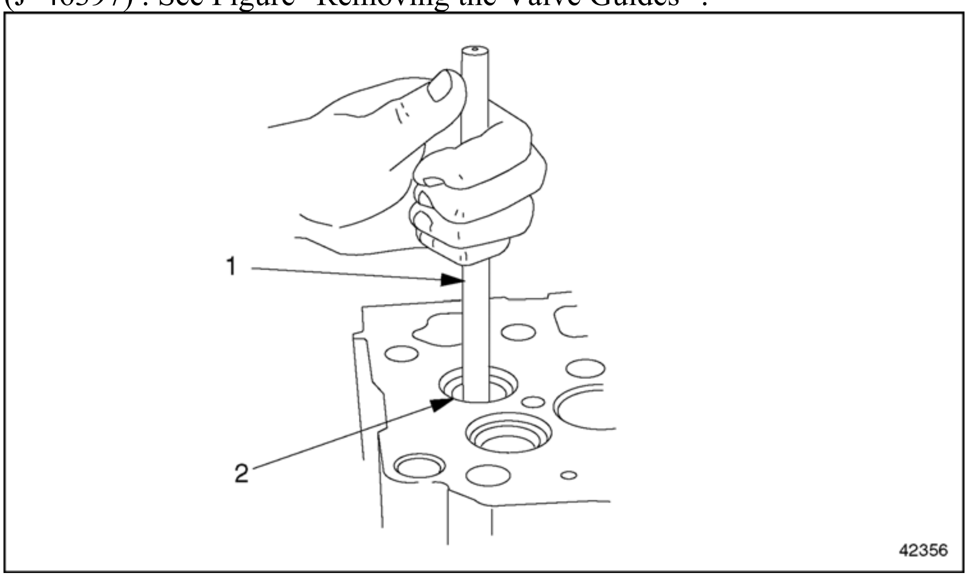
1. Remove the cylinder head. Refer to "1.4.1 Removal of Cylinder Head" .
2. Remove the valves. Refer to "1.19.3 Removal of Valve" .
3. Secure the cylinder head in a vise.
4. Using the go/no go gauge (J–46396) , try to insert it into the valve guide. The smaller diameter end of the gauge should fit into the guide. If the larger diameter end fits in either side of the guide, replace the guide. See Figure "Insert the Go/No Go Gauge" .



1. Valve Guide	2. Go/No Go Gauge

Figure 19. Insert the Go/No Go Gauge

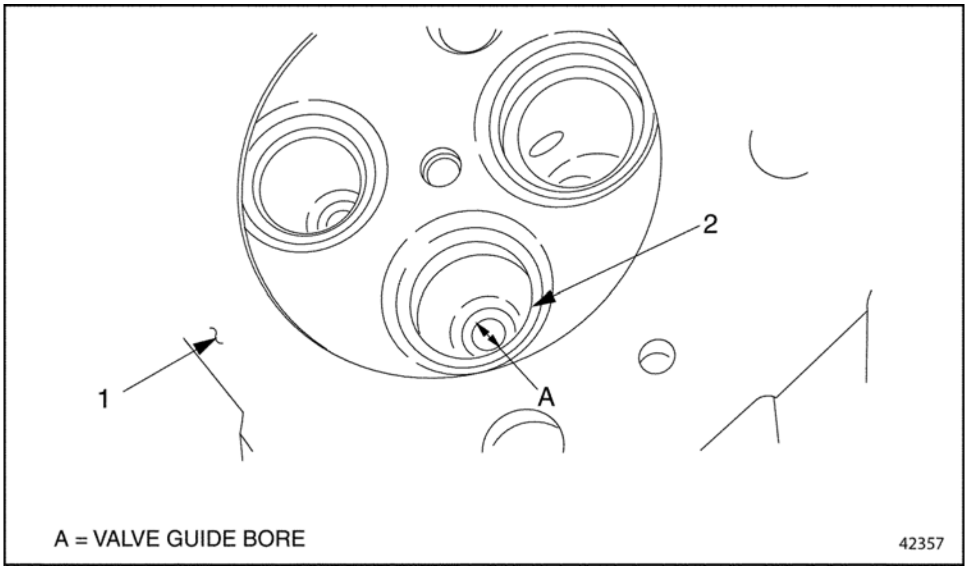
5. Drive the valve guides out of the head from the combustion side using the valve guide remover (J–46397) . See Figure "Removing the Valve Guides" .



1. Valve Guide Remover	2. Valve Bore

Figure 20. Removing the Valve Guides

6. Measure the valve guide bore in the cylinder head. See Figure "Measure the Valve Guide Bore" .

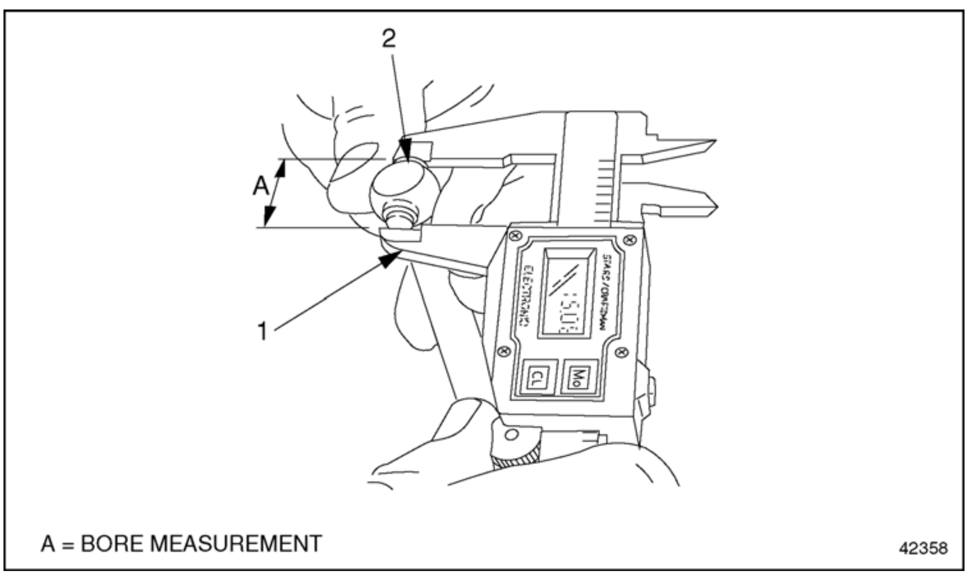


1. Cylinder Head	2. Valve Seat Insert

Figure 21. Measure the Valve Guide Bore

a. Insert the gauge into the bore and adjust it until the telescoping tips are firm against the walls of the bore.
b. Tighten the gauge.
c. Using a measuring device such as calipers or a micrometer, read the measurement off the tips of the gauge. See Figure "Reading the Bore Measurement" .

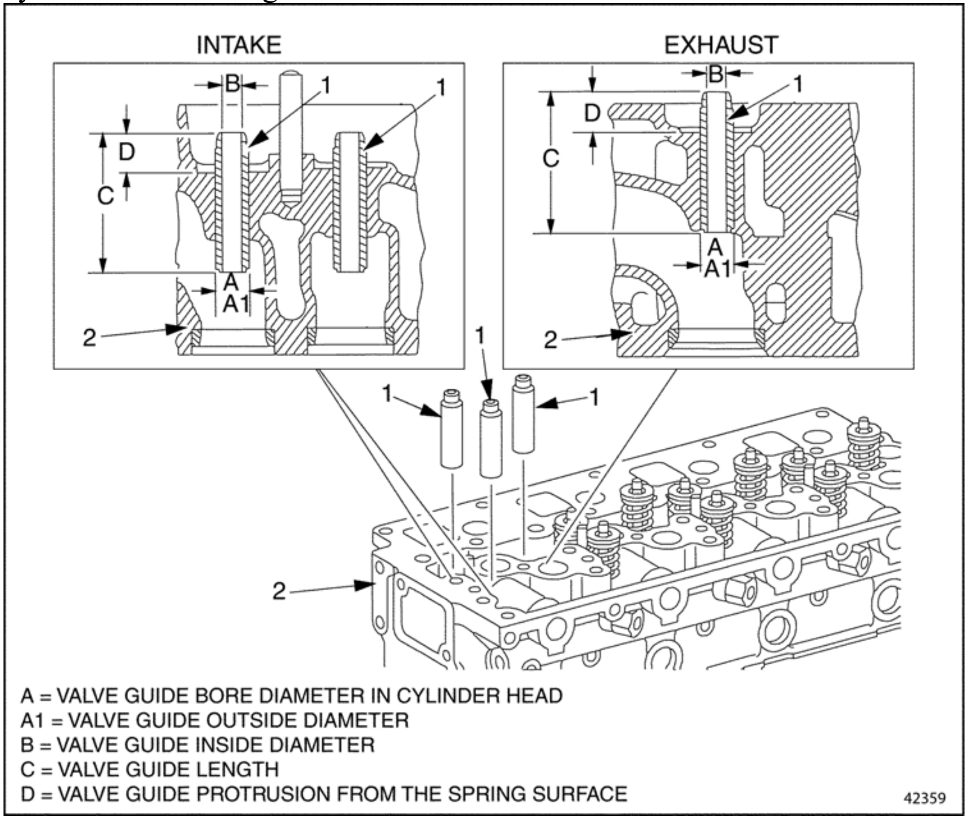
Note: Measure the telescoping bore gauge from tip to tip.



1. Measuring Device	2. Telescoping Bore Gauge

Figure 22. Reading the Bore Measurement

d. If the measurement is not within the specifications listed in Table "Repair Stage Specifications" and shown in see Figure "Cylinder Head Cross Section" , machine the cylinder head valve guide bore.



1. Valve Guide	2. Cylinder Head

Figure 23. Cylinder Head Cross Section

Repair Stage	Valve Guide Outside Diameter mm (in.) (see Figure , A1)	Bore in Cylinder Head mm (in.) (see Figure , A)
Standard	14.028–14.046 (0.552–0.553)	14.000–14.018 (0.551–0.552)
Standard I	14.228–14.246 (0.560–0.561)	14.200–14.218 (0.559–0.560)

Table 25. Repair Stage Specifications

Note: For standard bores, use the 14.0 mm (0.55 in.) reamer and ream the bore to the Standard specifications listed in Table "Repair Stage Specifications" . For oversize bores, use the 14.2 (0.56 in.) mm reamer and ream the bore to the Standard I specifications. Turn the reamer only in a clockwise direction.

7. Using the 14.0 or 14.2 mm (0.55 or 0.56 in.) reamer (J–46394) , ream the valve guide bore in the cylinder head. See Figure "Ream the Valve Guide Bore" .

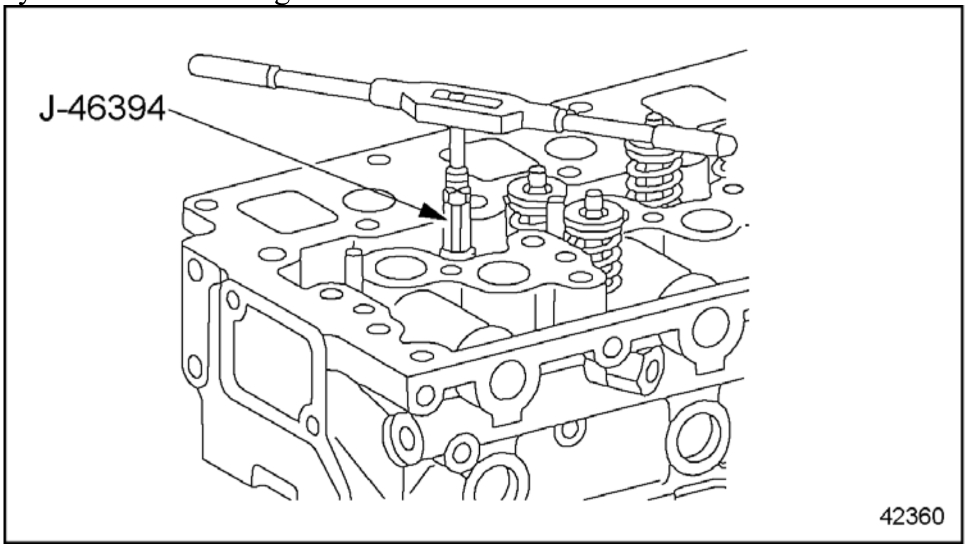


Figure 24. Ream the Valve Guide Bore

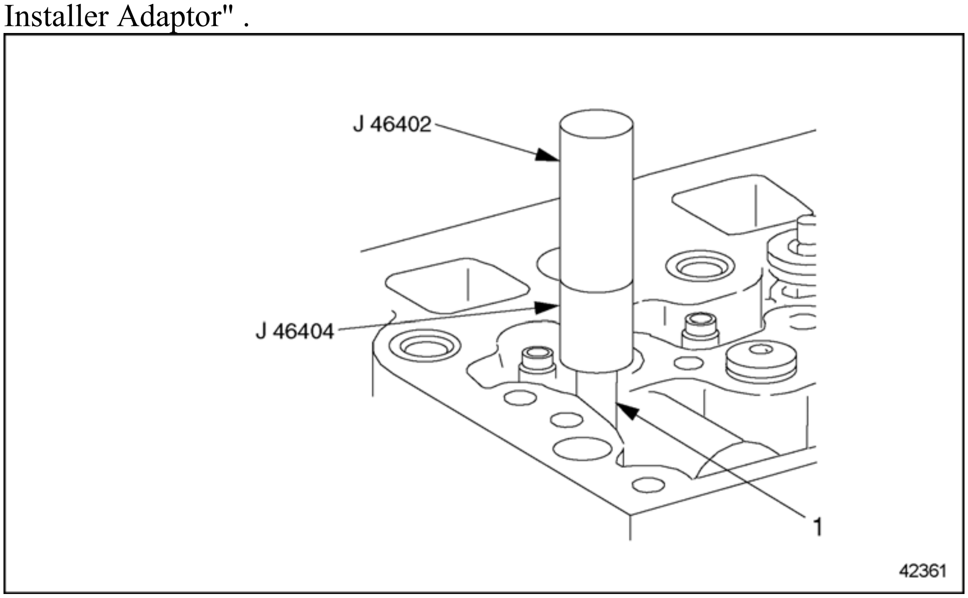
8. After reaming, clean the cylinder head to remove metal shavings.

Section 1.20.4
Installation of Valve Guide

Installation steps are as follows:

Note: Do not touch the valve guide with bare hands.

1. Place the valve guide in liquid nitrogen. Allow the valve guide to cool about 20 to 30 minutes.
2. Using pliers, remove the valve guide from the cooling box.
3. Fit the valve guide adapter (J–46404) onto the valve guide installer (J–46402) . See Figure "Guide Installer Adaptor" .

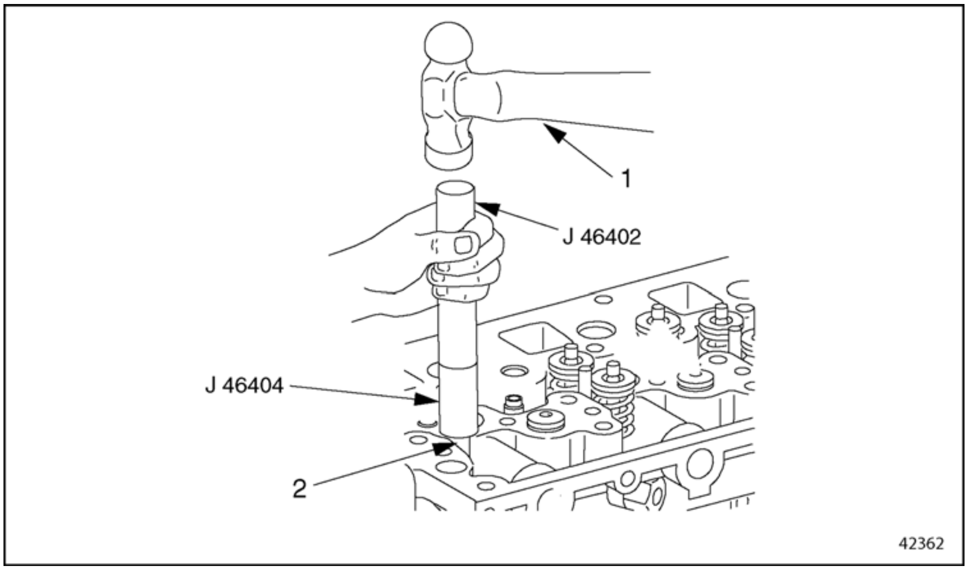


1. Valve Guide

Figure 25. Guide Installer Adaptor

Note: The guide installer adaptor has a different machined depth on each end. Use the end marked "14.5" for intake valve guides and "18.0" for exhaust valve guides.

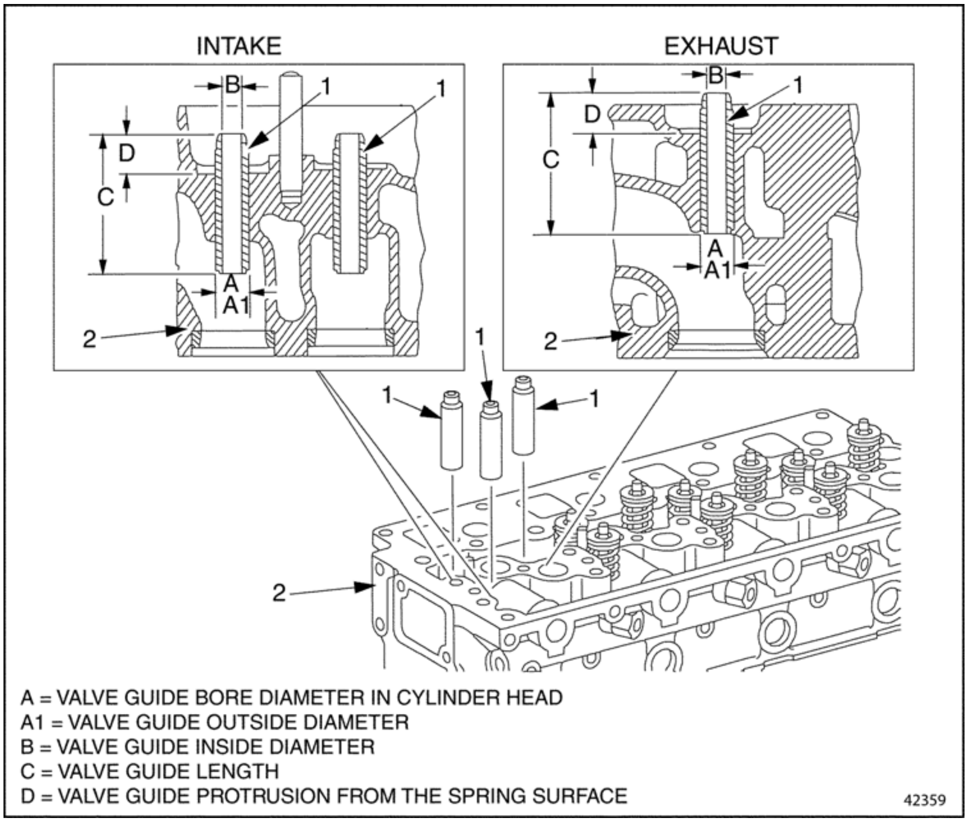
4. Coat the new valve guide with graphite oil and drive it into the bore using the valve guide installer (J–46402) and the guide installer adapter (J–46404) . See Figure "Driving the Valve Guide into the Bore" .



1. Hammer	2. Valve Guide

Figure 26. Driving the Valve Guide into the Bore

5. Check the valve guide protrusion from the spring surface (from the base relative to the top edge of the valve guide). See Figure "Cylinder Head Cross Section" , D. The valve guide protrusion specifications are listed in Table "Valve Guide Specifications" .



1. Valve Guide	2. Cylinder Head

Figure 27. Cylinder Head Cross Section

Descriptions	Specifications mm (in.)
Valve Guide Inside Diameter, Intake and Exhaust (see Figure "Cylinder Head Cross Section" , B)	8.000–8.022 (0.315–0.316)
Valve Guide Length, Intake and Exhaust (see Figure "Cylinder Head Cross Section" , C)	60.00–60.30 (2.36–2.37)
Valve Guide Protrusion from the Spring Surface (see Figure "Cylinder Head Cross Section" , D)	
Intake	13.7–14.5 (0.539–0.571)
Exhaust	17.2–18.0 (0.677–0.709)
Valve guide Overlap in Cylinder Head	0.010–0.046 (0.0004–0.0018)

Table 29. Valve Guide Specifications

6. Using the valve guide reamer (J–46395) , ream the inside diameter of the valve guide. See Figure "Cylinder Head Cross Section" , B. The inside diameter of the valve guide is listed in Table "Valve Guide Specifications" .

   Note: Turn the reamer only in a clockwise direction.

7. After reaming, clean the cylinder head to remove metal shavings.
8. Install the valves. Refer to "1.19.4 Installation of Valve" .
9. Install the cylinder head. Refer to "1.4.2 Installation of Cylinder Head" .

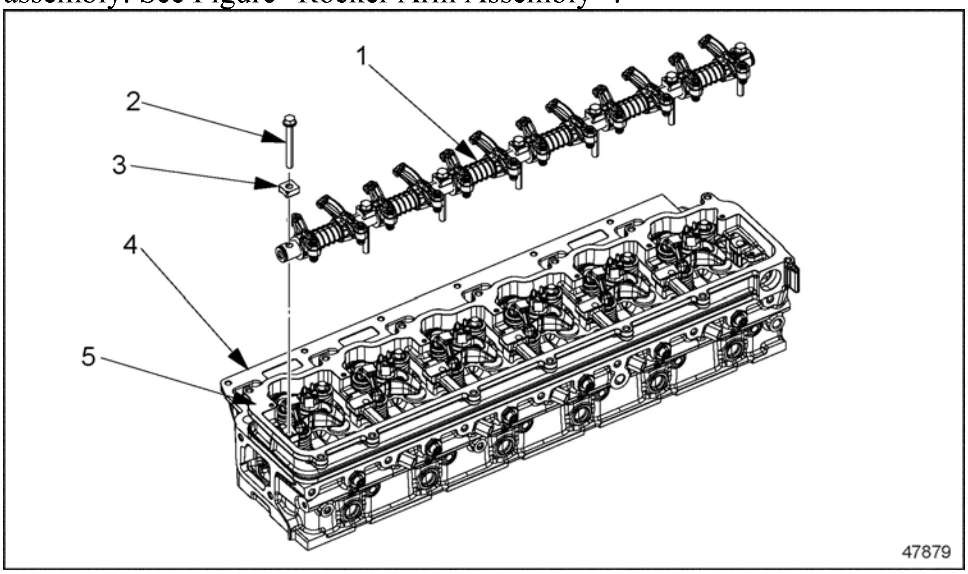
Section 1.21
Rocker Arms and Shaft

Perform the following procedures for removal and installation of the rocker arms.

Section 1.21.1
Removal of Rocker Arms and Shaft Assembly

Removal steps are as follows:

1. Remove the cylinder head cover. Refer to "1.1.1 Removal Cylinder Head Cover" .
2. Remove the seven rocker arm shaft bolts and the clamping pieces and remove the rocker arms and assembly. See Figure "Rocker Arm Assembly" .



1. Rocker Arms and Shaft Assembly	4. Cylinder Head
2. Rocker Shaft Bolts	5. Rocker Arm Frame
3. Clamping Piece	

Figure 1. Rocker Arm Assembly

3. Remove a cap from the end of the valve stem on each exhaust valve.
4. Remove the valve bridge from each set of intake valves.

Section 1.21.1.1
Inspection of Rocker Arm

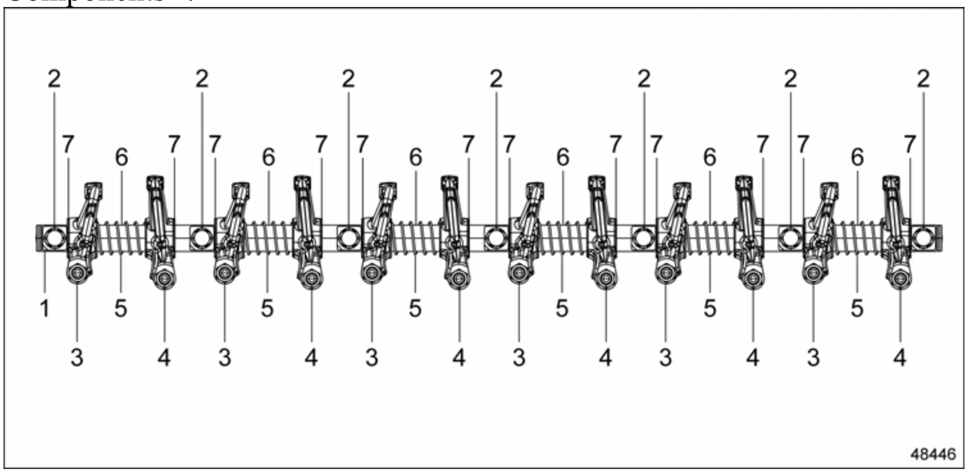
Inspection steps are as follows:

1. Inspect the rocker arm assembly for wear. If necessary, disassemble the rocker arm assembly and replace any worn parts.
2. Inspect the valve bridges for wear. If necessary, replace any worn valve bridge(s).

Section 1.21.2
Disassembly of Rocker Arm and Shaft

Disassembly steps are as follows:

1. Remove the rocker arm assembly from the cylinder head. Refer to "1.21.1 Removal of Rocker Arms and Shaft Assembly" .
2. Remove the spring clips from each end of the rocker arm shaft. See Figure "Rocker Arm Components" .



1. Spring Clip (front)	5. Spring
2. Clip and Bolt	6. Shaft
3. Intake Rocker Arm	7. Washer(s)
4. Exhaust Rocker Arm	

Figure 2. Rocker Arm Components

3. Remove the rocker arm brackets, rocker arms, washers, and springs from the rocker arm shaft. Keep all parts in order, as removed, for ease of assembly.
   a. Starting from one end of the shaft, remove the front (or rear) bracket and washer.
   b. Remove the first intake (exhaust) rocker arm.
   c. Remove the spring between the intake and the exhaust rocker arm.
   d. Remove the first exhaust (intake) rocker arm.
   e. Remove the first inside bracket and washers.
   f. Continue removing rocker arms, springs, brackets, and washers until done.
4. Inspect the parts of the rocker arm assembly for wear, and replace if necessary.

Section 1.21.2.1
Rocker Arm Bushing and Shaft Inspection

Inspect the disassembled rocker arm as follows:

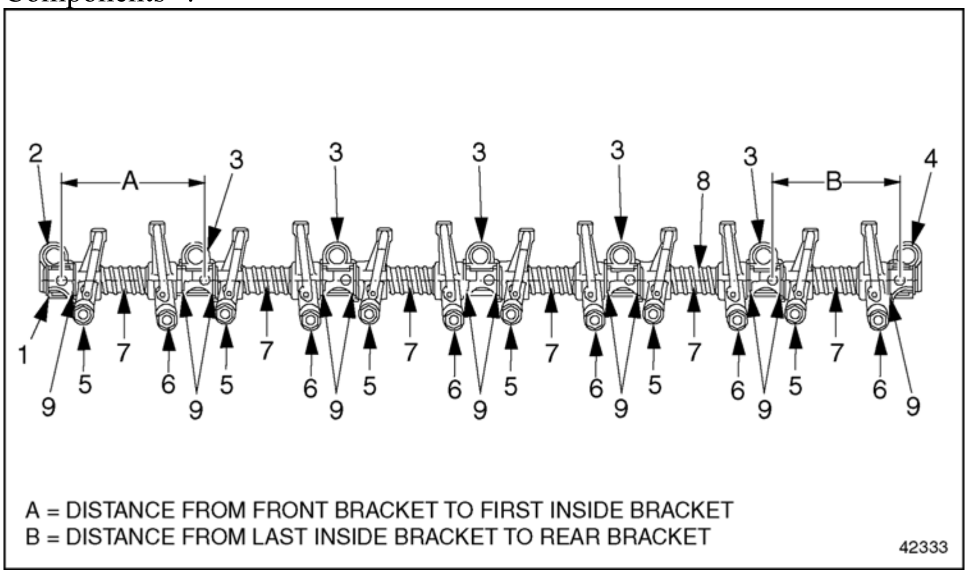
1. Inspect the inside diameter of the rocker arm bushing. Replace the rocker arm bushing if the inside diameter is smaller than 22.000 mm (0.8661 in.) or larger than 22.021 mm (0.8670 in.).
2. Inspect the diameter of the rocker arm shaft. Replace the rocker arm shaft if the diameter is smaller than 21.967 mm (0.8648 in.) or larger than 21.980 mm (0.8654 in.).

Section 1.21.3
Assembly of Rocker Arms and Shaft

Assembly steps are as follows:

Note: Be sure not to damage the washers during installation.

1. Install a spring clip on one end of the rocker arm shaft.
2. Install the rocker arm brackets, rocker arms, washers, and springs on the rocker arm shaft, starting from the closed end (with spring clip installed) and working towards the open end. Install all assembly components in order, as removed.
3. When installing the front and rear rocker arm brackets, pay close attention to the distance between the outer brackets and the inner brackets, as measured from hole to hole. See Figure "Rocker Arm Components" .



1. Spring Clip (front)	4. Rear Bracket	7. Spring
2. Front Bracket	5. Intake Rocker Arm	8. Shaft
3. Inside Bracket	6. Exhaust Rocker Arm	9. Washer(s)

Figure 3. Rocker Arm Components

Descriptions	Specifications mm (in.)
Bushing Inside Diameter (when installed)	22.00–22.021 (0.8661–0.8670)
Shaft Diameter	21.967–21.980 (0.8648–0.8654)
Rocker Arm Mounting Bolt Torque	30 N·m (22 lb·ft)
Distance from Front Bracket to First Inside Bracket (see Figure , A)	122 (4.80)
Distance from Last Inside Bracket to Rear Bracket (see Figure , *B)*	110 (4.33)

Table 4. Rocker Arm Specifications

a. The distance between the front bracket and the first inside bracket (Dimension "A") must equal 122 mm (4.80 in.).

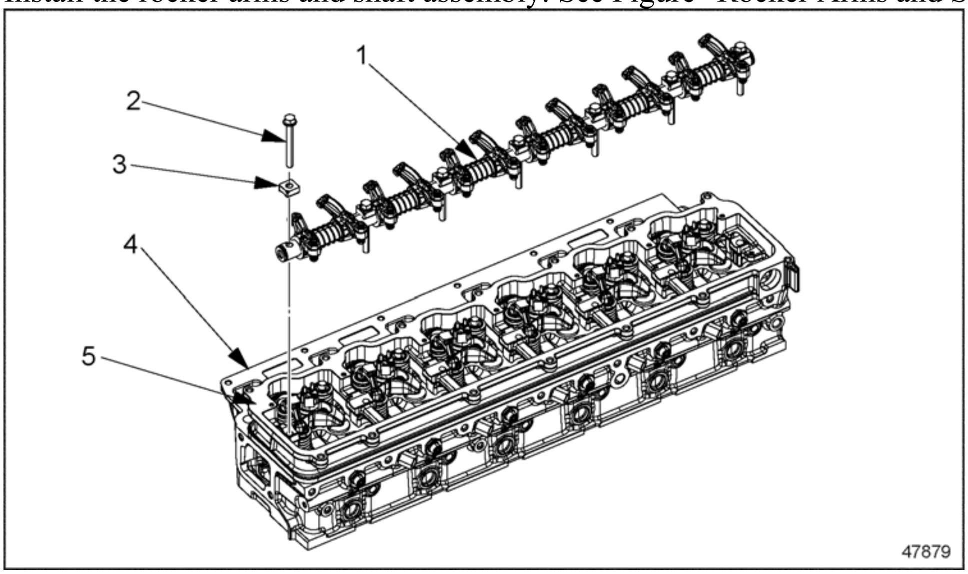
b. The distance between the last inside bracket and the rear bracket (Dimension "B") must equal 110 mm (4.33 in.).
4. When the assembly is complete, secure the assembly by installing a spring clip on the other end of the rocker arm shaft.
5. Install the rocker arm assembly on the cylinder head.

Section 1.21.4
Installation of Rocker Arms and Shaft Assembly

Installation steps are as follows:

Note: Secure rocker arms to each other to aid in installation. This will allow the rocker arm shaft and rocker arms to be installed safely without damage.

1. Install a valve bridge on each set of intake valves.
2. Install a cap on the end of each exhaust valve stem.
3. Inspect each pushrod to be sure it is correctly installed in its tappet.
4. Apply silicone to the injector harness connector then install into the injector frame.
5. Install the rocker arms and shaft assembly. See Figure "Rocker Arms and Shaft Mounting" .



1. Rocker Arms and Shaft	4. Cylinder Head
2. Rocker Shaft Bolts	5. Rocker Arm Frame
3. Clamping Pieces	

Figure 4. Rocker Arms and Shaft Mounting

a. Position the rocker arms and shaft assembly on the rocker arm frame while aligning the rocker arms with pushrods and valve bridges.
b. Install the seven clamping pieces and rocker shaft bolts in the shaft.
c. Tighten each mounting bolt to 30 N·m (22 lb·ft).

6. Adjust the valve lash. Refer to "13.2 Adjusting Valve Lash" .
7. Install the cylinder head cover. Refer to "1.1.2 Installation of Cylinder Head Cover" .

Section 1.22
Camshaft

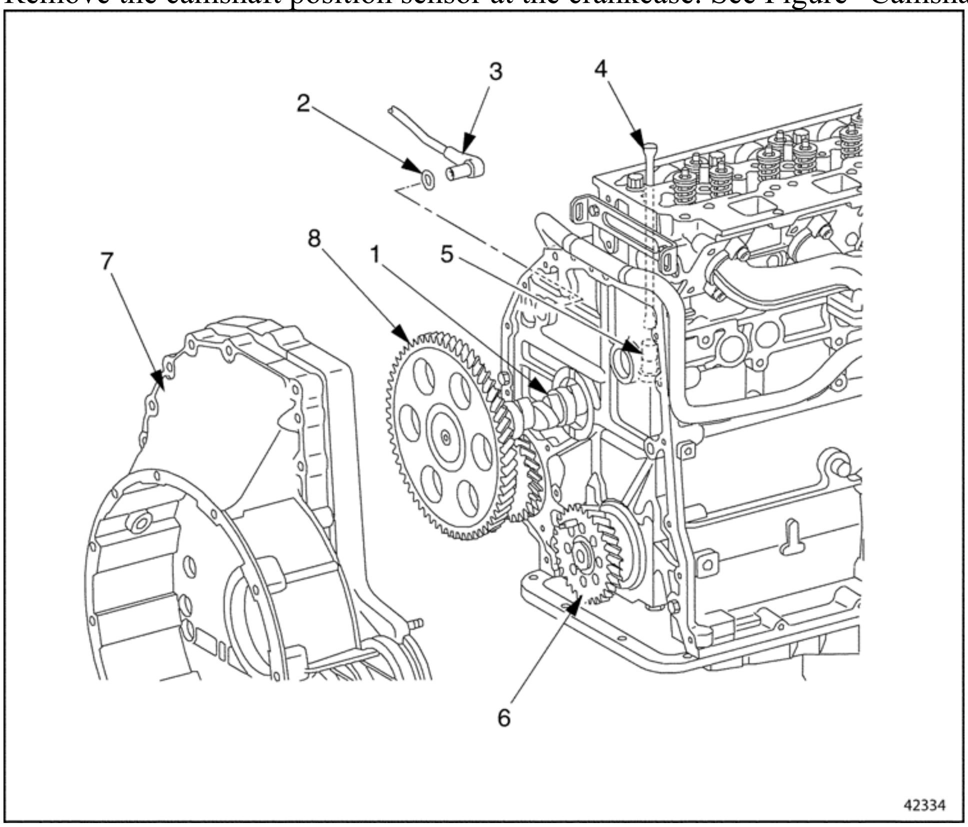
The camshaft is made of induction–hardened steel and has seven bearing journals. Each cylinder has cams for intake and exhaust valves and a electronic unit pump.

Section 1.22.1
Removal of Camshaft

Removal steps are as follows:

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

1. Drain the engine oil and coolant.
2. Remove the engine.
3. Remove the rocker arm assembly and pushrods. Refer to "1.21.1 Removal of Rocker Arms and Shaft Assembly" .
4. Remove the fuel pump. Refer to "2.18.1 Removal of Fuel Pump" .
5. Remove the EUP's. Refer to "2.2.1 Removal of Electronic Unit Pump" .
6. Remove the oil pan. Refer to "3.7.1 Removal of Oil Pan" .
7. Remove the camshaft position sensor at the crankcase. See Figure "Camshaft Assembly" .



1. Camshaft	5. Valve Tappet
2. O–ring	6. Crankshaft Gear

3. Camshaft Position Sensor	7. Flywheel Housing
4. Pushrod	8. Camshaft Gear

Figure 1. Camshaft Assembly

DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

8. Remove the flywheel housing. Refer to "1.16.1 Flywheel Housing Removal" .

NOTICE:

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

9. Attach the camshaft removal/installation tool (J–46403) to the front of the camshaft.

   Note: The following step may require two persons. The engine must be inverted (turned upside down) at this point in order to remove the camshaft.

10. Carefully remove the camshaft from the crankcase.
11. Pull the valve tappets out of the crankcase. Mark the valve tappets, in order, as removed.
12. Inspect the valve tappets. Refer to "1.22.1.1 Inspection of Camshaft"

Section 1.22.1.1
Inspection of Camshaft

Inspection steps are as follows:

1. Inspect the valve tappets. If damage or wear is present, replace the roller tappets.
   a. Inspect the valve tappet outer diameter, the specifications are listed in Table "Valve Tappet Specifications" .
   b. Inspect the valve tappet bore in the crankcase, the specifications are listed in Table "Valve Tappet Specifications" .

Descriptions	Specification mm (in.)
Valve Tappet Outer Diameter	
Standard	17.944–17.965 (0.7065–0.7073)
Oversize 0.25	18.194–18.215 (0.7163– 0.7171)
Valve Tappet Bore in Crankcase Diameter	
Standard	18.000–18.018 (0.7087–0.7094)
Oversize 0.25	18.250–18.268(0.7185–0.7192)

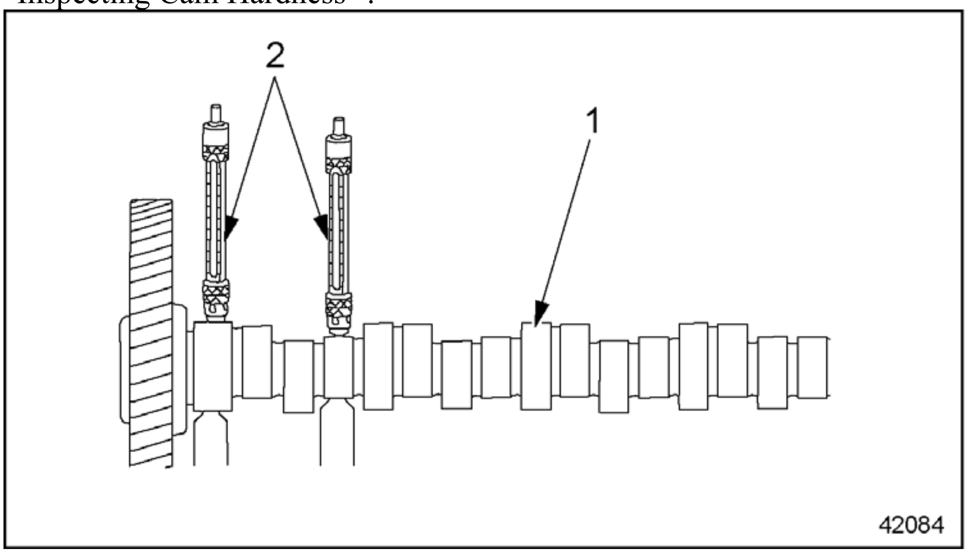
Table 4. Valve Tappet Specifications

Note: Be aware that in order to get a correct hardness reading, it is critical to place a hard base below the cam or bearing journal. Camshaft specifications are listed in Table "Camshaft Specifications" .

Descriptions	Value mm (in.)
Camshaft Radial Runout When Mounted on Outer Bearing Journals	
Timing Gear Seat Maximum	0.020 (0.0008)
Cam Base Circle Maximum	0.025 (0.0010)
All Bearing Points Maximum	0.030 (0.0012)
Cam Rise—Valve Lobes Over Base Circle Diameter	
Inlet Minimum	7.3 (0.3)
Exhaust Minimum	8.2 (0.32)
Cam Rise—Electronic Unit Pump Over Base Circle Diameter — Mininum	13.8 (0.54)
Hardness of Cams and Bearing Journals HRC	54–60 HRC

Table 5. Camshaft Specifications

2. Using a hardness tester, inspect the hardness of the cams and bearing journals at the camshaft. A hard base should be placed below the cam or bearing journal to be inspected. See Figure "Inspecting Cam Hardness" .

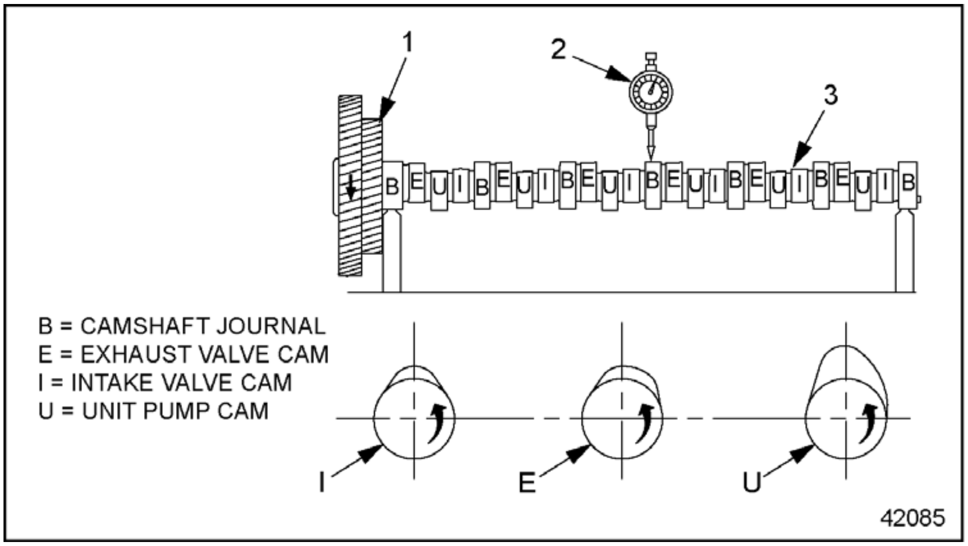


1. Camshaft	2. Hardness Tester

Figure 2. Inspecting Cam Hardness

Note: For all of the following steps, see Figure "Measuring the Cam Rise" .

3. Mount the camshaft at the outer bearing journals, indicated as B in the next illustration. See Figure "Measuring the Cam Rise" .



1. Camshaft Gear	3. Camshaft
2. Dial Gauge	

Figure 3. Measuring the Cam Rise

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

4. Measure the radial runout of the cam base circle or bearing points, shown as B. See Figure "Measuring the Cam Rise" .
5. Measure the cam rise of the inlet valve cams, shown as I. See Figure "Measuring the Cam Rise" .
6. Measure the cam rise of the exhaust valve cams, shown as E. See Figure "Measuring the Cam Rise" .
7. Measure the cam rise of the electronic unit pump valve cams, shown as U. See Figure "Measuring the Cam Rise" .
8. If in any of the preceding steps the camshaft does not meet specifications listed in Table "Camshaft Specifications" , replace it.

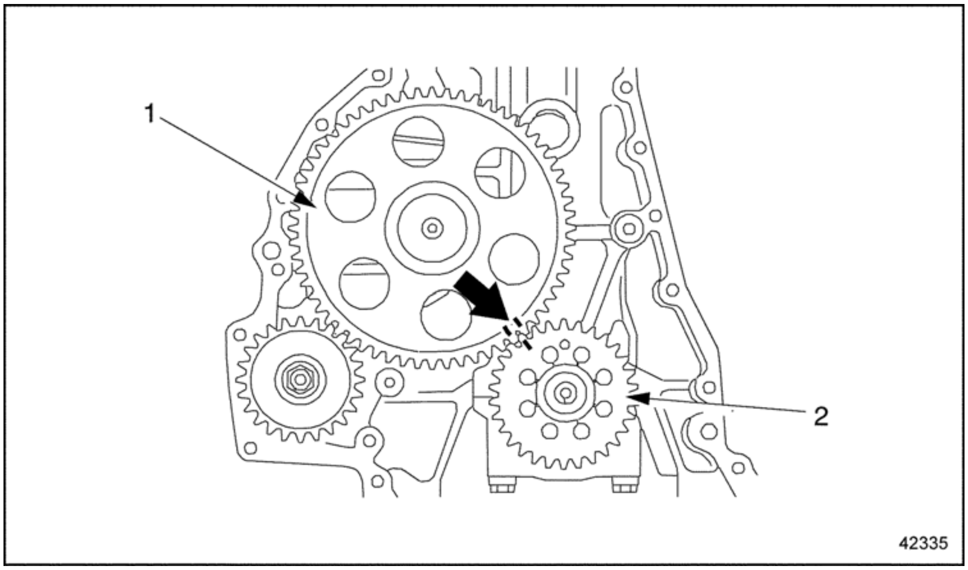
Section 1.22.2
Installation of Camshaft

Installation steps are as follows:

1. Install the valve tappets in the cylinder block, in locations, as removed. Put a light amount of lube oil on the tappets prior to installation.

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

2. Attach the camshaft removal/installation tool (J–46403) to the camshaft.
3. Carefully insert the camshaft into the cylinder block.



1. Camshaft Gear	2. Crankshaft Gear

Figure 4. Camshaft Alignment

4. Rotate the camshaft until the marking "1–1" on the camshaft gear is aligned with the marking "1" on the crankshaft gear. See Figure "Camshaft Alignment" .
5. Install the Flywheel housing. Refer to "1.16.2 Installation of Flywheel Housing" .
6. Install the camshaft position sensor at the cylinder block.
   a. Replace the O–ring.
   b. Carefully push in the sensor until it makes contact with the camshaft gear.
7. Install the oil pan. Refer to "3.7.2 Installation of Oil Pan" .
8. Install the EUP(s). Refer to "2.2.2 Installation of Electronic Unit Pump" .
9. Install the fuel pump. Refer to "2.18.2 Installation of Fuel Pump" .
10. Apply clean engine oil on the pushrods. Then, install the pushrods, and the rocker arm assembly. Refer to "1.21.4 Installation of Rocker Arms and Shaft Assembly" .
11. Install the engine in the vehicle.
12. Fill, pressurize, and attach the engine pre–oiler can.
13. Fill the engine with oil.

Additional Information

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 "Torque Values, Cylinder Head Cover" .

Description	Torque N·m (lb·ft)
Hexagon Socket Bolt	25 ±5 (15-22)

Table 1. Torque Values, Cylinder Head Cover

Cylinder Head

The cylinder head warpage limits are listed in Table "Head Warpage Limits" , and listed in Table "Cylinder Block Warpage Limits" (cylinder block). Cylinder head bolt length is listed in Table "Cylinder Head Bolts, Length" . The tightening stages are listed in Table "Tightening Stages, Exhaust Manifold Bolts" (exhaust manifold bolts) and listed in Table "Tightening Stages, Cylinder Head" (cylinder head bolts). Oil pressure readings are listed in Table "Oil Pressure Readings" . There are miscellaneous torque values listed in Table "Miscellaneous Torque Values" .

Descriptions mm (in.)	Limits mm (in.)
Over entire length	0.07 (0.003)
Over a length of 150 (6)	0.02 (0.001)

Table 2. Head Warpage Limits

Descriptions mm (in.)	Limits mm (in.)
Over entire length	0.030 (0.0012)
Over a length of 150 (6)	0.015 (0.0006)

Table 3. Cylinder Block Warpage Limits

Descriptions	Lengths mm (in.)
Shaft length when new	149.0 (5.87)
Maximum shaft length	151.0 (5.94)

Table 4. Cylinder Head Bolts, Length

Size	Maximum Shaft Length mm (in.)	Tightening Stage	Torques N·m (lb·ft)
M10	47.5 (1.87)	Stage 1	10 (7)
		Stage 2	55 (41)
		Stage 3	additional 90 degrees

Table 5. Tightening Stages, Exhaust Manifold Bolts

Size	Max. Shaft Length mm (in.)	Tightening Stage	Torques N·m (lb·ft)
M16	151.0 (5.94)	Stage 1	20 (15)
		Stage 2	70 (52)
		Stage 3	170 (125)
		Stage 4	280 (207)
		Stage 5	additional 90 degrees
		Stage 6	additional 90 degrees

Table 6. Tightening Stages, Cylinder Head

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

Table 7. Oil Pressure Readings

Descriptions	Torques N·m (lb·ft)
High–Pressure Fuel Injection Lines	25 (18)
Charge–Air Manifold Fasteners	25 (18)
Rocker Arm Mounting Bolts	30 (22)
Inspection Cover on Flywheel Housing	25 (18)
Protective Sleeve	45 (33)

Table 8. Miscellaneous Torque Values

Crankshaft

For the crankshaft specifications, see Figure "Cross–section View" . Crankshaft repair specifications are listed in Table "Crankshaft Repair Specifications" . The main bearing repair specifications are listed in Table "Main Bearing Repair Specifications" . The main bearing–cap tightening stages are listed in Table "Tightening Stages, Main Bearing–Cap Bolts" .

Descriptions	Specifications mm (in.)
Main and Connecting–Rod Bearing Journals Permissible Difference In Out–Of–Roundness	0.005 (0.0002)
Permissible Taper at Main Bearing Journals and Connecting–Rod Bearing Journals	0.005 (0.0002)
Fillet Radii of Main Bearing and Connecting–Rod Bearing Journals	2.5–3.0 (0.0984–0.1181)
Radial Runout Measured at Middle Main Journal*	0.15 (0.0059)
Lateral Runout (End Play) Measured at Thrust washer Bearing Journal	0.16–0.38 (0.006–0.015)
Crown of Main Bearing Journals and Connecting–Rod Journals	0.000– 0.004 (0.000 to 0.0002)
Main Bearing and Connecting Rod Journal Hardness (Rockwell hardness)	52 HRC
Permissible Imbalance of Crankshaft†	30 gcm (0.4162 in.–ounce)

Table 9. Crankshaft Specifications

**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.

Size mm (in.)	Main Bearing Journal Diameter mm (in.)	Main Bearing Journal Width mm (in.)	Thrustwasher Bearing Journal Width mm (in.)	Connecting–Rod Bearing Journal Diameter mm (in.)	Connecting–Rod Bearing Journal Width mm (in.)
All Sizes	—	31.0–31.2 (1.220–1.228)	—	—	34.0–34.2 (1.339–1.346)
Standard	85.990–86.010 (3.3854–3.3862)	—	31.000–31.062 (1.2205–1.2229)	69.995–70.015 (2.7557–2.7565)	—
Undersize – 0.10 (0.004)	85.890–85.910 (.3.3815–3.3823)	—	—	69.895–69.915 (2.7518–2.7526)	—
Undersize – 0.25 (0.010)	85.740–85.760 (3.3756–3.3764)	—	—	69.745–69.765 (2.7459–2.7466)	—
Undersize – 0.30 (0.012)	—	—	31.300–31.362 (1.2323–1.2347)	—	—
Undersize – 0.50 (0.020)	85.490–85.510 (3.3658–3.3665)	—	31.500–31.562 (1.2402–1.2426)	69.495–69.515 (2.7360–2.7368)	—
Undersize – 0.75 (0.030)	85.240–85.260 (3.3559–3.3567)	—	—	69.245–69.265 (2.7262–2.7270)	—
Undersize – 1.00 (0.040)	84.990–85.010 (3.3461–3.3469)	—	—	68.9950–69.015 (2.7163–2.7171)	—

Table 10. Crankshaft Repair Specifications

Size mm (in.)	Main Bearing Inner Diameter mm (in.)
Standard	86.066 to 86.108 (3.388 to 3.390)
Undersize – 0.1 (0.0039)	85.966 to 86.008 (3.384 to 3.386)
Undersize – 0.25 (0.0098)	85.816 to 85.858 (3.379 to 3.380)

Undersize – 0.5 (0.0197)	85.566 to 85.608 (3.369 to 3.370)
Undersize – 0.75 (0.0295)	85.316 to 85.358 (3.359 to 3.361)
Undersize – 1.0 (0.0394)	85.066 to 85.108 (3.349 to 3.351)

Table 11. Main Bearing Repair Specifications

Size	Max. Shaft Length mm (in.)	Tightening Stage	Torques N·m (lb·ft)
x 2.0	116.0 (4.57) or 136.0 (5.35)	Stage 1	30 (22)
		Stage 2	80 (59)
		Stage 3	155 (114)
		Stage 4	additional 90 degrees

Table 12. Tightening Stages, Main Bearing–Cap Bolts

Vibration Damper

The tightening stages for the vibration damper mounting bolts are listed in Table "Tightening Stages, Vibration Damper Mounting Bolts" .

Maximum Shank Length mm (in.)	Tightening Stage	Torques N·m (lb·ft)
61.0 (2.40)	Stage 1	50 (37)
	Stage 2	125 (92)
	Stage 3	additional 90 degrees

Table 13. Tightening Stages, Vibration Damper Mounting Bolts

Flywheel and Flywheel Housing

Flywheel specifications are listed in Table "Flywheel Specifications" . Ring Gear Specifications are listed in Table "Ring Gear Specifications" . The Flywheel Tightening Stages are listed in Table "Tightening Stages, Flywheel Mounting Bolts" .

Descriptions	Four and Six Cylinder Engines Specifications mm (in.)
Flywheel Outer Diameter	443 (17.4)
Flywheel Shoulder Diameter	392.435–392.575 (15.4502–15.4557)
Flywheel Diameter at Crankshaft Flange	114.960–115.020 (4.5260–4.5283)
Flywheel Diameter for Mounting Clutch	435.000–435.063 (17.1260–17.1285)
Flywheel Minimum Width Between Friction Surface and Mounting Flange After Repairs	55 (2.17)
Flywheel Maximum Overall Width	56 (2.20)
Pitch Circle Diameter for Clutch	373.7 (14.71)
Peak–to–Valley Height (R_z) of Clutch Friction Surface	16 µm (630 µin)
Flywheel Permissible Deviation From True (radial and lateral)	0.05 (0.002)

Descriptions	Four– and Six–Cylinder Engines mm (in.)
Flywheel Shoulder Diameter (for ring gear mounting)	392.435–392.575 (15.4502–15.4557)
Hole for Mounting Clutch Pressure Plate	3/8–16 UNC
Thread Depth	24 (15/16) minimum

Table 14. Flywheel Specifications

Ring Gear Inner Diameter	392.000–392.140 (15.4331–15.4386)
Ring Gear/Flywheel Overhang	0.295–0.575 (0.0116–0.0226)
Ring Gear/Flywheel Permissible Radial Runout	0.5 (0.02)
Ring Gear Width	15.6–16.0 (0.614–0.630)
Ring Gear Fitting Temperature	250–280°C (480–540°F)

Table 15. Ring Gear Specifications

Size	Max. Shank Length mm (in.)	Tightening Stage	Torques N·m (lb·ft)
M14 x 1.5	61.0 (2.40)	Stage 1	50 (37)
		Stage 2	125 (92)
		Stage 3	additional 90 degrees

Table 16. Tightening Stages, Flywheel Mounting Bolts

Pistons and Connecting Rods

The specification for piston protrusion specifications is listed in Table "Piston Protrusion Specifications" . The connecting rod stretch bolts tightening stages are listed in Table "Tightening Stages, Connecting Rod Stretch Bolts" . The piston ring end–gap dimensions are listed in Table "Piston Ring End–Gap Dimensions" . The connecting rod inspection specifications are listed in Table "Connecting Rod Inspection Specifications" . The bearing journal specifications are listed in Table "Bearing Journal Specifications" .

Description	mm (in.)
Piston Protrusion (from top dead center)	0.28 to 0.50 (0.011 to 0.020)

Table 17. Piston Protrusion Specifications

Size	Max. Shaft Length mm (in.)	Tightening Stage	Torques N·m (lb·ft)
M12 x 1.25	57.0 (2.24)	Stage 1	11 (8)
		Stage 2	45 (33)
		Stage 3	additional 90 degrees

Table 18. Tightening Stages, Connecting Rod Stretch Bolts

Ring Designation	Groove	Gap When New mm (in.)	Maximum End Gap mm (in.)
Keystone	I	0.35 to 0.55 (0.014 to 0.022)	1 (.039)
Taper–Faced with Internal Angle	II	0.40 to 0.60 (0.016 to 0.024)	1 (.039)
Double–Chamfered Oil Control with Garter Spring	III	0.25 to 0.50 (0.010 to 0.020)	1 (.039)

Table 19. Piston Ring End–Gap Dimensions

Descriptions	Dimensions, mm (in.)
Distance Between Connecting Rod Bearing Bore and Bushing Inner Surface	157.445–157.510 (6.1986–6.2012)
Maximum Difference in Axial Parallelism Between Bearing Bore and Bushing Inner Surface	0.025 (0.0010)
Distance from Connecting Rod Center Line for Measuring Parallelism	50 (2)
Bushing Inner Diameter	Single Stage Turbocharger 40.03–40.04 (1.575 –1.576) Dual Stage Turbocharger 42.03–42.04 (1.654 – 1.655)
Bearing Seat Inner Diameter with Bearing Shells Installed	
Standard	70.054–70.093 (2.7580–2.7596)
Repair Stage: Undersize 0.1 mm	69.954–69.993 (2.7541–2.7556)
Repair Stage: Undersize 0.25 mm	69.804–69.843 (2.7482–2.7497)
Repair Stage: Undersize 0.5 mm	69.554–69.593 (2.7383–2.7399)
Repair Stage: Undersize 0.75 mm	69.304–69.343 (2.7285–2.7300)
Repair Stage: Undersize 1.0 mm	69.054–69.093 (2.7187–2.7202)
Basic Bore Diameter for Connecting Rod Bearings	75.000–75.019 (2.9528–2.9535)
Connecting–Rod Bearing Play	
Radial	0.039–0.098 (0.0015–0.0039)
Axial (end play)	0.170–0.470 (0.0067–0.0185)
Permissible Out–of–Roundness of Basic Bores	
Bearing Bore	0.008 (0.0003)
Bushing Bore	0.006 (0.0002)
Connecting Rod Bolt	
Thread Diameter	M12 x 1.25
Shank Length When New	56.0 (2.20)
Maximum Shank Length	57.0 (2.24)

Table 20. Connecting Rod Inspection Specifications

Repair Stage	Diameter mm (in.)
Standard	69.995–70.015 (2.7557–2.7565)
Undersize 0.1 mm	69.895–69.915 (2.7518–2.7526)
Undersize 0.25 mm	69.745–69.765 (2.7459–2.7467)
Undersize 0.5 mm	69.495–69.515 (2.7360–2.7368)
Undersize 0.75 mm	69.245–69.265 (2.7262–2.7270)
Undersize 1.0 mm	68.995–69.015 (2.7163–2.7171)

Table 21. Bearing Journal Specifications

Valves

The general valve specifications are listed in Table "General Valve Specifications" . The valve lift specifications are listed in Table "Valve Lift Specifications" . The specifications for the valve seat bore machining are listed in Table "Valve Seat Bore Machining Repair Stage Specifications" . The general specifications for valve seats are listed in Table "Valve Seat General Specifications" .

Descriptions	Intake in. (mm)	Exhaust in. (mm)
Valve Stem Diameter	7.935–7.950 (0.3124–0.3130)	7.925–7.940 (0.3120–0.3126)
Valve Seat Diameter, at Head Mating Surface	31.0 (1.22)	36.0 (1.42)
Valve Head Diameter	33.9–34.1 (1.33–1.34)	37.9–38.1 (1.49–1.50)
Valve Seat Height—After Grinding	2.7–3.1 (0.106–0.122)	2.5–3.2 (0.098–0.126)
Valve Seat Width, at Valve Head	3.3–4.3 (0.130–0.169)	3.5–4.2 (0.138–0.165)
Valve Seat Angle	20 degrees	45 degrees
Valve Length	125.7–126.1 (4.948–4.998)	152.5–152.9 (6.004–6.020)
Valve Stem Hardness	54–60 HRC	
Maximum Concentricity of Valve Seat to Stem	0.03 (0.0012)	
Difference in Height Between the Two Intake Valves as Measured From the End of the Stem	0.20 (0.008)	N/A
Valve Standback from Cylinder Head	1.1–1.5 (0.04–0.08)	

Table 22. General Valve Specifications

Descriptions	Specifications mm (in.)
Specified Dial Gauge Preload for Checking Valve Lift	15 (0.60)
Valve Lift with Intake Valves Completely Open	at least 9.7 (0.38)
Valve Lift with Exhaust Valves Completely Open	at least 10.7 (0.42)
Inspection Cover Bolt Torque	25 N·m (18 lb·ft)

Table 23. Valve Lift Specifications

Repair Stage	Basic Bore in Cylinder Head		Outside Diameter of Valve Seat Insert	
	Intake mm (in.)	Exhaust mm (in.)	Intake mm (in.)	Exhaust mm (in.)
Standard	35.000–35.025 (1.378–1.379)	40.000–40.025 (1.575–1.576)	35.07–35.08 (1.3807–1.3811)	40.07–40.08 (1.5775–1.5779)
Standard I	35.300–35.325 (1.390–1.391)	40.300–40.325 (1.575–1.588)	35.37–35.38 (1.3925–1.3929)	40.37–40.38 (1.5893–1.589)
Stage I	35.500–35.525 (1.398–1.399)	40.500–40.525 (1.594–1.595)	35.57–35.58 (1.4004–1.4008)	40.57–40.58 (1.5972–1.5976)

Table 24. Valve Seat Bore Machining Repair Stage Specifications

Descriptions	Specifications mm (in.)

Valve Seat Interference Fit	0.045–0.080 (0.0018–0.0031)
Depth of Bore in Cylinder Head (see Figure , E)	11.4–11.6 (0.449–0.457)
Height of Valve Seat Insert (see Figure , C)	
Intake	7.6–7.7 (0.299–0.303)
Exhaust	8.0–8.1 (0.315–0.319)
Clearance Between Head mating Surface and Valve Seat Insert Face (see Figure , D)	
Intake	3.7–4.0 (0.146–0.157)
Exhaust	3.3–3.6 (0.130–0.142)

Table 25. Valve Seat General Specifications

Rocker Arm

Rocker arm specifications are listed in Table "Rocker Arm Specifications" .

Descriptions	Specifications mm (in.)
Bushing Inside Diameter (when installed)	22.00–22.021 (0.8661–0.8670)
Shaft Diameter	21.967–21.980 (0.8648–0.8654)
Rocker Arm Mounting Bolt Torque	30 N·m (22 lb ft)
Distance from Front Bracket to First Inside Bracket (see Figure , A)	122 (4.80)
Distance from Last Inside Bracket to Rear Bracket (see Figure , B)	110 (4.33)

Table 26. Rocker Arm Specifications

Camshaft

Camshaft specifications are listed in Table "Camshaft Specifications" . The valve tappet specifications are listed in Table "Valve Tappet Specifications" .

Descriptions	Specifications mm (in.)
Camshaft Radial Runout When Mounted on Outer Bearing Journals	
Timing Gear Seat Maximum	0.020 (0.0001)
Cam Base Circle Maximum	0.025 (0.0010)
All Bearing Points Maximum	0.030 (0.0012)
Cam Rise—Valve Lobes Over Base Circle Diameter	
Inlet Minimum	7.3 (0.3)
Exhaust Minimum	8.2 (0.32)
Cam Rise—Electronic Unit Pump Over Base Circle Diameter	
Minimum	13.8 (0.54)
Hardness of Cams and Bearing Journals HRC	54–60 HRC

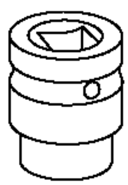
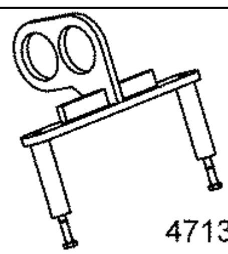
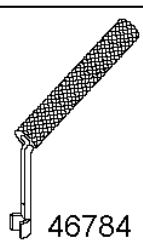
Table 27. Camshaft Specifications

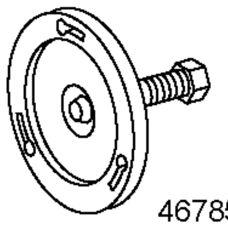
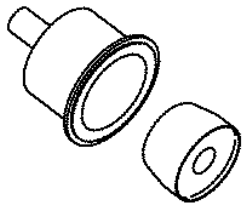
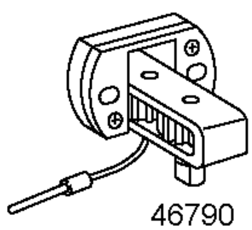
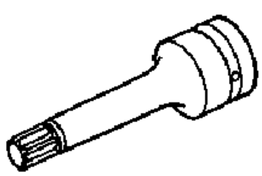
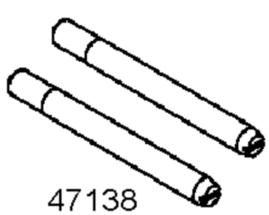
Descriptions	Specifications mm (in.)
Valve Tappet Outer Diameter	
Standard	17.944–17.965 (0.7065–0.7073)
Oversize 0.25mm	18.194–18.215 (0.7163– 0.7171)
Valve Tappet Bore in Crankcase Diameter	
Standard	18.000–18.018 (0.7087–0.7094)
Oversize 0.25mm	18.250–18.268 (0.7185–0.7192)

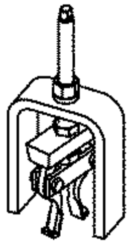
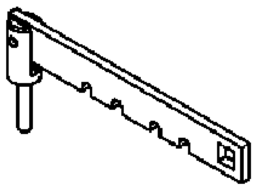
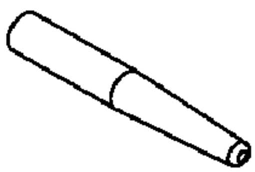
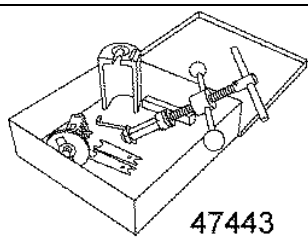
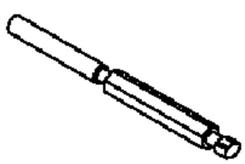
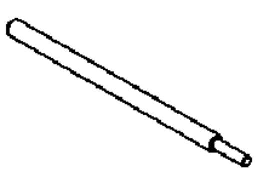
Table 28. Valve Tappet Specifications

Special Tools

The special tools used in this chapter are listed in Table "Special Tools" .

Tool	Description	Usage	Part Number
 46791	Head Bolt Impact Socket	Used to remove and install cylinder head bolts.	J–45390
 47133	Cylinder Head Lifting Device	Used to remove and install the cylinder head on the engine.	J–46387
 47135	Constant–Throttle Valve (CTV) Piston Remover	Used to remove the constant throttle valve piston.	J–46400
 46784	CTV Spring Remover	Used to remove constant throttle valve spring.	J–46401

 46785	Front Seal Puller	Used to remove the front crankshaft radial seal.	J–46383
 47130	Front Seal Installer	Used to install the front radial crankshaft seal.	J–46388
 47136	Rear Seal Installer	Used to install the rear radial crankshaft seal.	J–46390
 46790	Engine Barring Tool	Used to lock or rotate the engine flywheel.	J–46392
 47137	Flywheel and Main Pulley Socket Tool	Used to remove and install bolts in flywheel and vibration damper.	J–46385
 47138	Flywheel Guide Studs	Used when installing the flywheel on the crankshaft.	J–46389

 47139	Pilot Bearing Remover	Used to remove the pilot bearing from the crankshaft.	OTC 7318
 47140	Valve Spring Adaptor and Remover	Used to remove the valve springs from the cylinder head.	J–46399
 47141	Valve Stem Seal Installer	Used to install the valve stem seals.	J–46398
 47443	Valve Insert Removal Kit	Used to remove the valve insertts from the cylinder head.	PT–6390
 47143	Go/No Go Gauge	Used to measure the inside diameter of the valve guide.	J–46396
 47144	Valve Guide Remover	Used to remove the valve guides from the cylinder head.	J–46397
		Used to ream the cylinder head	

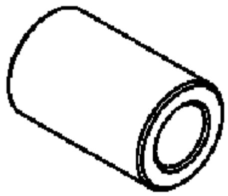
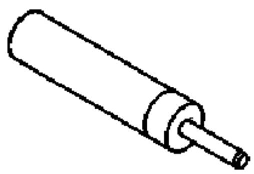
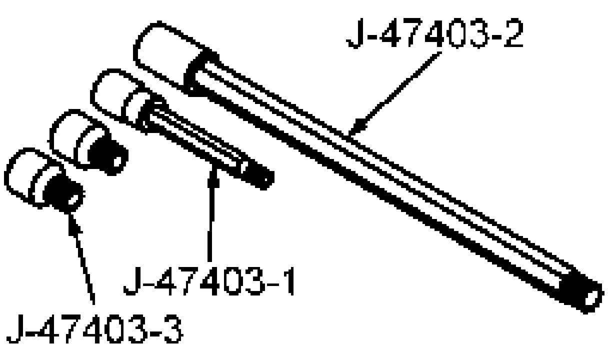
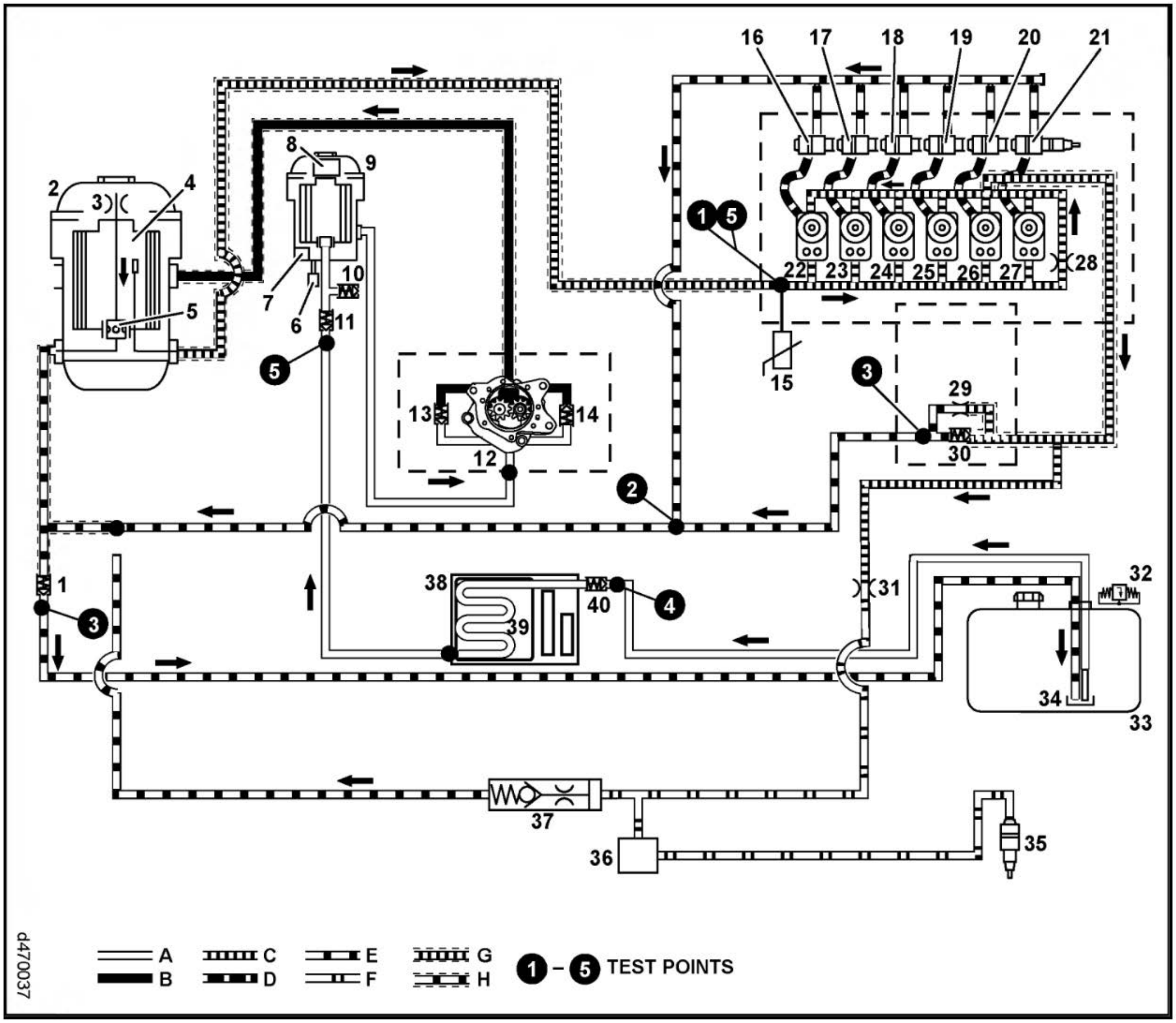
 47145	Reamer	for the outside diameter of the valve guide. 14.0 mm for standard size. 14.2 mm for oversize.	J–46394
 47146	Valve Guide Adapter	Used to set the valve guide depth in the cylinder head.	J–46404
 47147	Valve Guide Installer	Used to install the valve guides in the cylinder head.	J–46402
 47148	Valve Guide Reamer	Used to ream the inside diameter of the valve guide.	J–46395
 48183	Triple Square Drive Socket Set	Used to remove and install exhaust manifold bolts	J–47403

Table 29. Special Tools

Section 2.1
Fuel System Schematic

For the fuel system flow see Figure "Fuel System Schematic" .



1. Assembly Valve (fuel return)	25. Electronic Unit Pump 4
2. Main Fuel Filter	26. Electronic Unit Pump 5
3. Constant Vent	27. Electronic Unit Pump 6
4. Main Fuel Filter Element	28. Regulator – Electronic Unit Pumps (flow restrictor)
5. Drain Valve	29. Constant Vent
6. Water Separator Drain Valve	30. Overflow Valve
7. Water Level Sensor	31. Regulator – Doser Block (flow restrictor)
8. Fuel Pre-heating Element (optional)	32. Vent Valve

9. Fuel Pre Filter with Water Separator	33. Fuel Tank
10. Priming Valve	34. Fuel Screen
11. Assembly Valve	35. Fuel Doser Valve
12. Fuel Pump	36. Doser Block Assembly
13. Bypass Check Valve	37. Doser Block Pressure Regulator
14. Pressure Limiting Valve	38. Motor Control Module (MCM)
15. Supply Fuel Temperature Sensor	39. MCM Fuel Heat Exchanger
16. Injector Cylinder 1	40. Assembly Valve (fuel feed)
17. Injector Cylinder 2	A – Fuel Supply (suction side)
18. Injector Cylinder 3	B – Fuel Supply to Main Filter Element (pressure side - internal fuel gallery)
19. Injector Cylinder 4	C – Fuel Supply at Throttle Valve for Doser Block
20. Injector Cylinder 5	D – High Pressure Fuel to Injectors
21. Injector Cylinder 6	E – Fuel Return
22. Unit Pump 1	F – Fuel Supply to Doser Block Assembly
23. Unit Pump 2	G – Fuel Supply to EUP's (internal fuel gallery
24. Unit Pump 3	H – Fuel Return (internal to fuel filter housing)

Figure 1. Fuel System Schematic

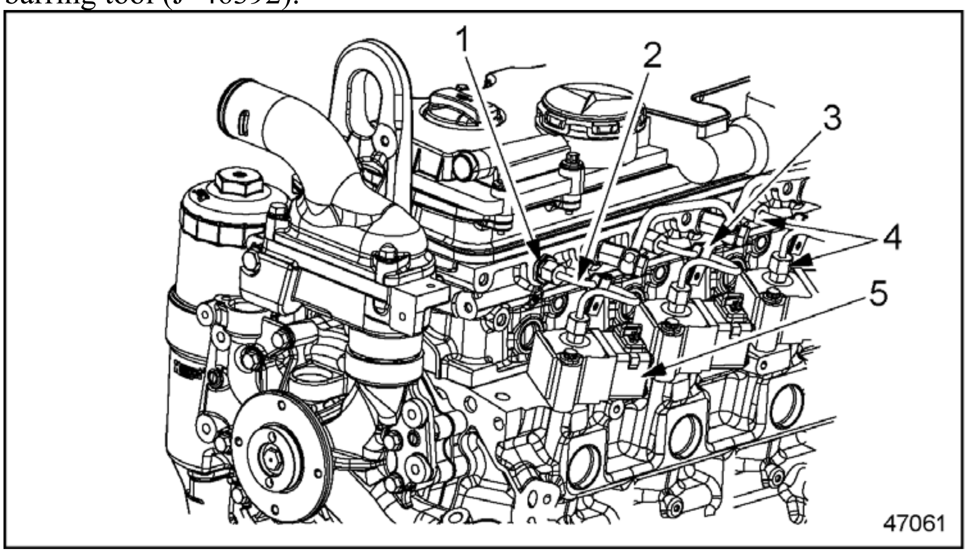
Section 2.2
Electronic Unit Pump

All MBE 900 engines are water–cooled, four–stroke, direct–injection diesel engines. The cylinders are arranged in line on models. Each has a separate fuel Electronic Unit Pump (EUP) with a short high pressure fuel line to the fuel injector, which is located in the center of the combustion chamber. The EUP's are attached to the engine block and are driven from the camshaft. Each cylinder has two intake valves and one exhaust valve.

Section 2.2.1
Removal of Electronic Unit Pump

Removal steps are as follows:

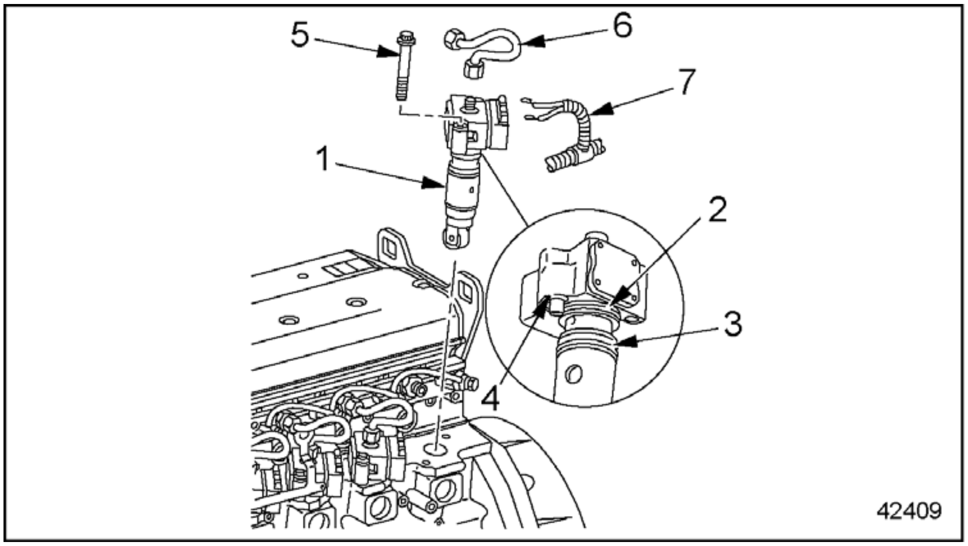
1. Remove the end cover from the lower right side of the flywheel housing, then attach the engine barring tool (J–46392).



1. Transfer-Tube Nut	4. Isolator Clamp
2. High Pressure Fuel Lines	5. Fuel Line Nuts
3. Electronic Unit Pump	

Figure 1. Electronic Unit Pump and High Pressure Fuel Lines

2. Remove the high pressure fuel line(s). See Figure "Electronic Unit Pump and High Pressure Fuel Lines" . Refer to "2.3.1 Removal Of High Pressure Fuel Lines And Transfer Tubes" .
3. Disconnect the engine wiring harness from each EUP to be removed. See Figure "Electronic Unit Pump" .



1. Electronic Unit Pump	5. Mounting Bolt
2. Black O–ring (large O–ring on EUP)	6. High Pressure Fuel Line
3. Green O–ring (small O–ring on EUP)	7. Engine Wiring Harness
4. O–ring (on head of EUP)	

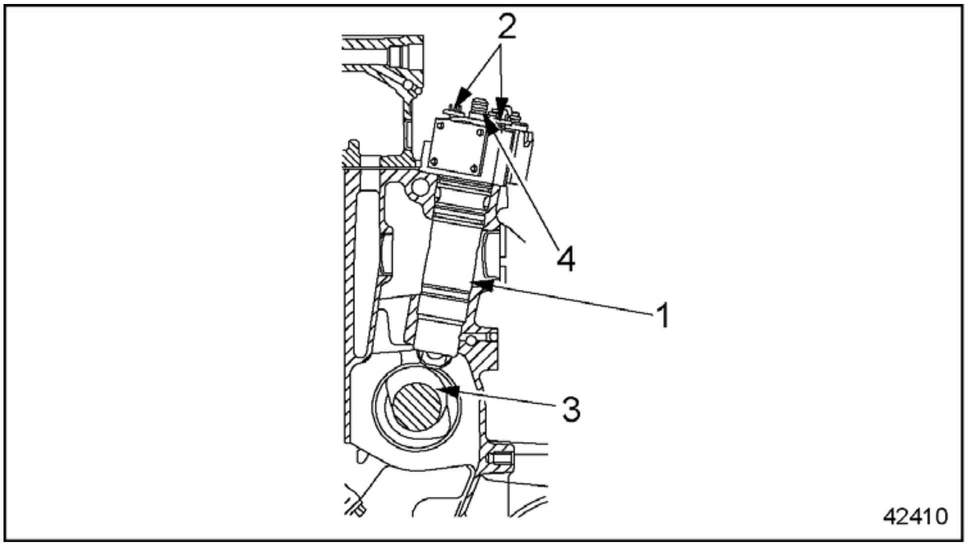
Figure 2. Electronic Unit Pump

WARNING:

PERSONAL INJURY

To avoid injury from an ejected injector unit pump, do not completely loosen the mounting bolts until you have tested the spring tension. If the spring tension is at maximum and you remove the mounting cap screws, the pump will be ejected from the engine crankcase.

4. Carefully loosen the EUP mounting bolts.
5. Check the spring tension on the EUP by pushing down on it. If you cannot push down on the injector pump manually, the spring tension is at the maximum. You must decrease the spring tension on the injector pump before removing it.
6. If the spring tension on the injector pump is at the maximum, go to the next step to reduce it; otherwise, go to step 8 for removing the mounting bolts.
7. Using the barring tool, rotate the crankshaft until the spring tension decreases enough to push the injector pump down manually.
8. Remove the mounting bolts from the EUP.
9. Using the barring tool, rotate the crankshaft until the camshaft lifts the EUP. See Figure "Electronic Unit Pump" .



1. Electronic Unit Pump	3. Camshaft
2. Mounting Bolts	4. Fuel Line Connection

Figure 3. Electronic Unit Pump

NOTICE:

If the electronic unit pump doesn't come out easily, do not try to pry it out. This will damage it. Use the electronic unit pump puller to remove it.

10. If the EUP doesn't come out easily, use the EUP puller (J–46375) to remove it.
    a. Thread the EUP puller onto the top of the EUP, where the high pressure fuel line was installed.
    b. Pull the EUP out by using the slide hammer on the EUP puller. Do not use excessive force that could damage the threads on the EUP fuel line connection.
11. Check the EUP for wear or damage. If any is found, replace the entire component. The EUP is not serviceable, except for the O–rings.

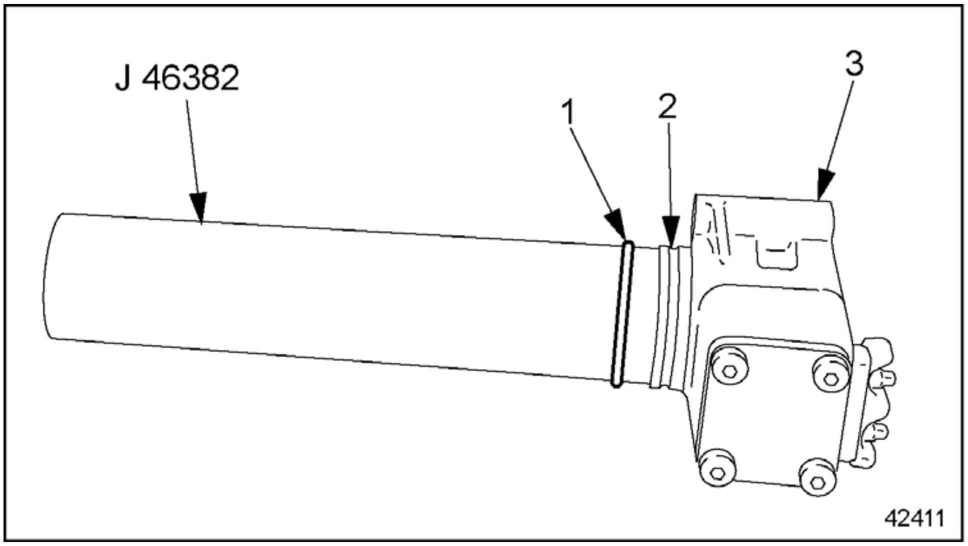
    Note: Replace all three O–rings.

12. Remove and discard all three O–rings: two on the EUP shaft, and one on the injector pump head. See Figure "Electronic Unit Pump" .
13. Repeat this procedure for each EUP that needs to be removed.

Section 2.2.2
Installation of Electronic Unit Pump

Installation steps are as follows:

1. Install a new pump head O–ring on the EUP head, as removed.
2. Lubricate the EUP bore in the cylinder block with grease.
3. Lubricate the new pump shaft O–rings with grease.
4. Install the black O–ring on the EUP shaft. See Figure "Black O–ring" .

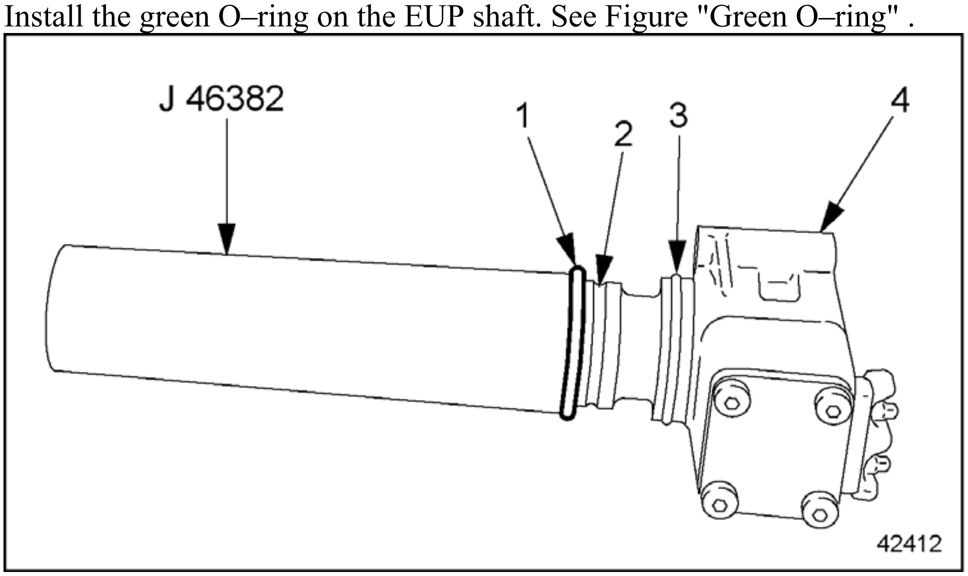


1. Black O–ring	3. Head of EUP
2. Seat for Black O–ring	

Figure 4. Black O–ring

   a. Insert the O–Ring installer (J–46382) over the injector pump shaft, leaving only the first groove in the shaft exposed.
   b. Slide the black O–ring (it is the larger of the two) over the installer and onto the first groove in the injector pump shaft.

5. Install the green O–ring on the EUP shaft. See Figure "Green O–ring" .



1. Green O–ring	3. Black O–ring (installed)
2. Seat for Green O–ring	4. Head of EUP

Figure 5. Green O–ring

   a. Back the O–ring installer out over the injector pump shaft, leaving the second groove in the shaft exposed.

   b. Slide the green O–ring (it is the smaller of the two) over the installer and onto the second groove in the injector pump shaft.
6. Insert the EUP into the mounting hole on the crankcase. Use the bolt mounting holes on the engine as a guide for positioning the injector pump. Push the injector pump in by hand. If it won't go in easily, rotate the crankshaft until the pump goes in easily.
7. Install the mounting bolts, and tighten 65 N·m (48 lb·ft).
8. Connect the high pressure fuel line(s). Refer to "2.3.2 Installation of High Pressure Fuel Line" .
9. Repeat this procedure for each EUP, as removed.
10. Connect the engine wiring harness to each EUP.
11. Prime the fuel system.

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 and check for leaks. Tighten connections as needed.

Section 2.3
High Pressure Fuel Lines and Transfer Tubes

The following section describes the removal and assembly of high pressure fuel lines 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.

Section 2.3.1
Removal Of High Pressure Fuel Lines And Transfer Tubes

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.

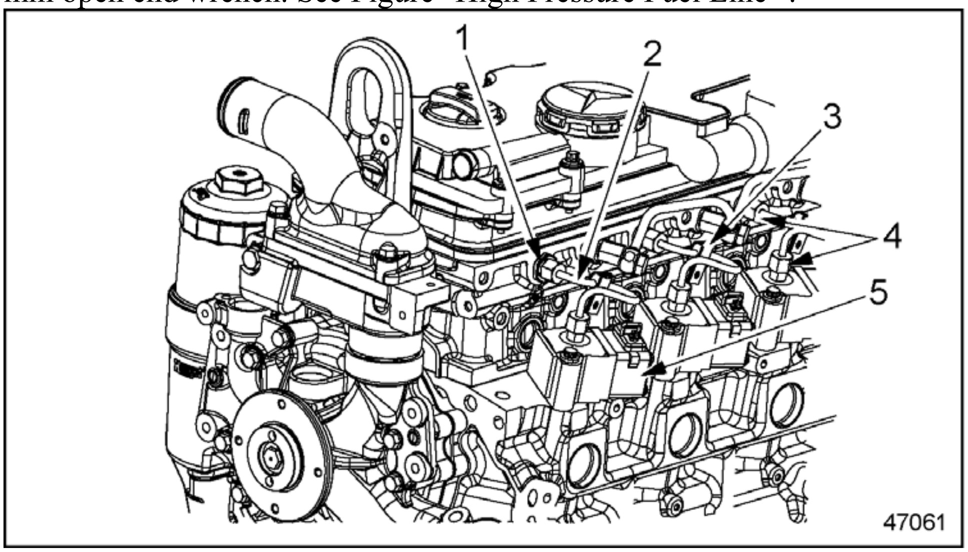
WARNING:

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 the cylinder head cover to improve access to the fuel lines.
2. Remove the engine lifting bracket to improve access to the fuel lines.
    a. Remove the left front lifting bracket by removing the three bolts securing the bracket to the cylinder head.
    b. If the application has a high mount fan, remove the three secondary mount bracket retention bolts on the cylinder head and the two bolts on the high mount fan bracket.
3. 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 "High Pressure Fuel Line" .



1. Transfer-Tube Nut	4. Fuel Lines Nuts
2. High Pressure Fuel Line	5. Electronic Unit Pump
3. Isolator Clip	

Figure 1. 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 injector line and transfer tube are one-time use items. Failure to install a new high pressure fuel injector line and transfer tube will cause fuel leaks and high pressure fuel injector line failures.

4. 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 electronic unit pump. Discard the high pressure fuel injector line. See Figure "High Pressure Fuel Line" .
5. Using a 24 mm fuel line wrench (J-45063 or J-47484) or a 24 mm socket, loosen the thrust nut on the transfer tube. Remove and discard the transfer tube and the O-ring. See Figure "High Pressure Fuel Line" .

Section 2.3.2
Installation of High Pressure Fuel Line

Installation steps are as follows:

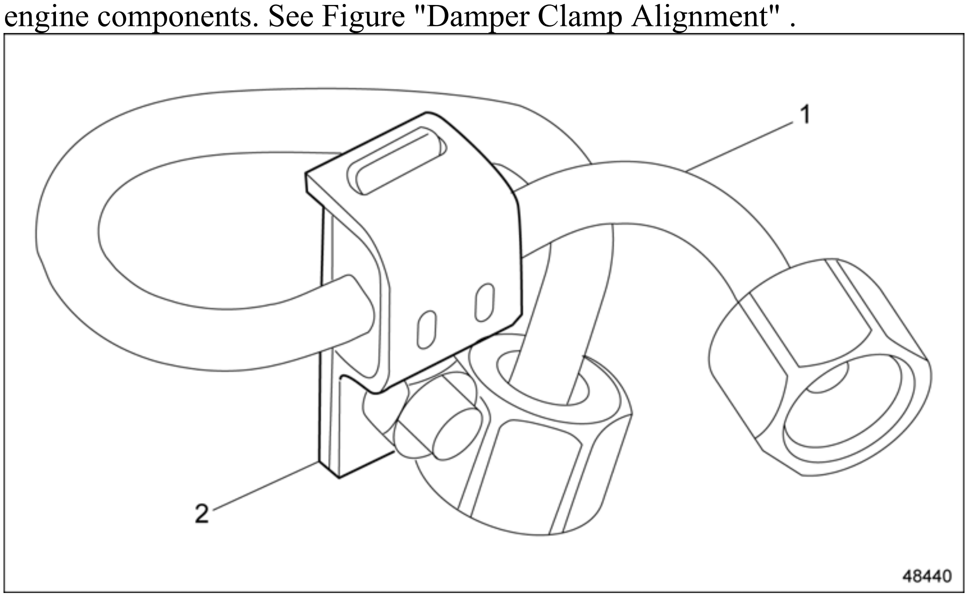
NOTICE:

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!

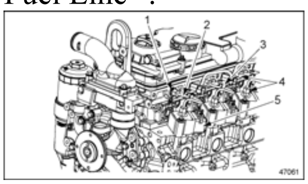
1. The new high pressure fuel line comes assembled with the damper clamp. Ensure that the damper clamp is aligned correctly on the high pressure fuel line and is not in contact with surrounding engine components. See Figure "Damper Clamp Alignment" .



1. High Pressure Fuel Line	2. Damper Clamp

Figure 2. Damper Clamp Alignment

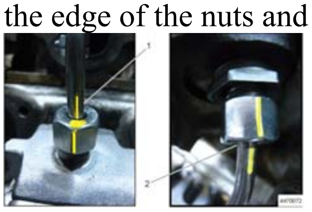
2. Apply a light coat of clean engine oil to the transfer tube O-ring and install the transfer tube into the cylinder head.
3. Using a 24 mm socket, torque the thrust nut to 45 N·m (33 lb·ft).
4. Align the new high pressure fuel injector line fittings to the transfer tube and unit pump. Ensure the fuel 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.
5. 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. 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 clamp is not touching any other fuel lines or other engine or vehicle components. See Figure "High Pressure Fuel Line" .



1. Transfer-Tube Nut	4. Fuel Lines Nuts
2. High Pressure Fuel Line	5. Electronic Unit Pump
3. Isolator Clip	

Figure 3. High Pressure Fuel Line

6. 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 4. Marking of High Pressure Fuel Injector Line and Nuts

7. 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. See Figure "Turning Fuel Line Nut 120 Degrees" .

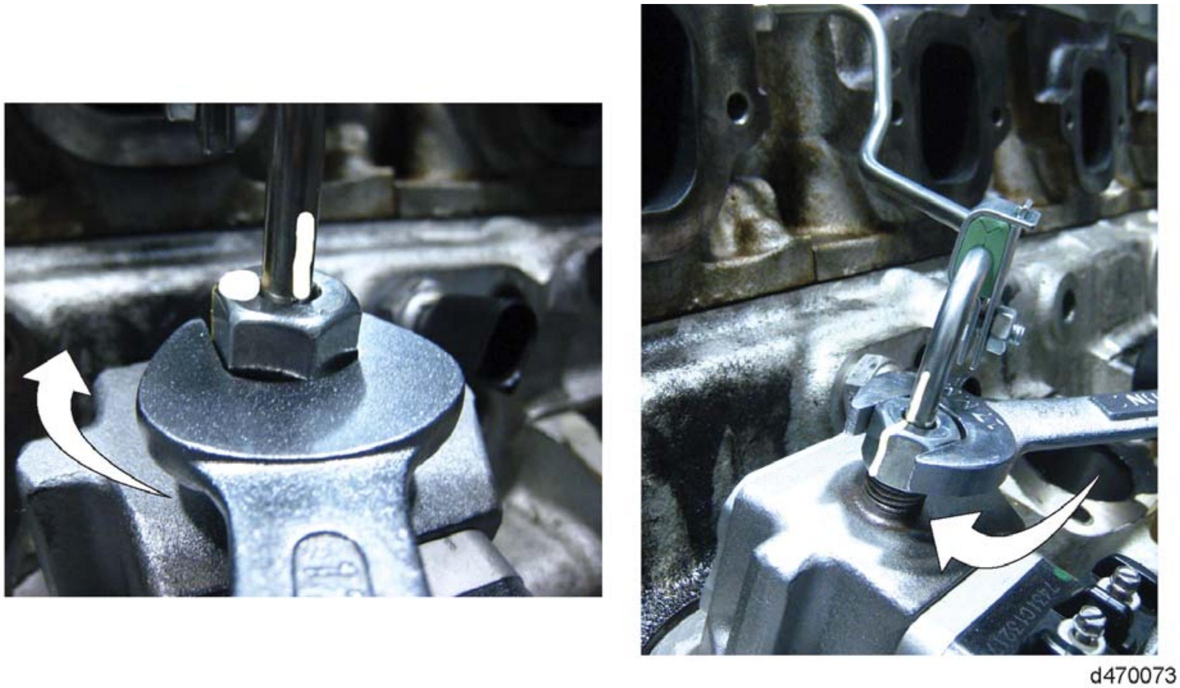


Figure 5. Turning Fuel Line Nut 120 Degrees

8. Using 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. See Figure "Turning Fuel Line Nut 120 Degrees" .

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).

9. Ensure that all six damper clamps on the high pressure fuel injector lines are installed correctly.
10. Install the engine lifting bracket.
    a. Install the left front lifting bracket and secure lifting bracket to cylinder head using original three bolts. Torque bolts to 50 N·m (37 lb·ft).
    b. On engine applications with a high mount fan, assemble the secondary mounting bracket using original three bolts on the side of the cylinder head and two bolts on the high mount fan bracket. Torque bolts to 50 N·m (37 lb·ft).
11. Install the cylinder head cover and any other remaining parts.
12. Prime the fuel system. Refer to "12.1.5 Priming the Fuel System" .

CAUTION:

EXHAUST FUMES

To avoid injury or injury to bystanders from fumes, engine or vehicle fuel system service operations should be performed in a well ventilated area.

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. Never loosen fuel line connections to bleed air from 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.

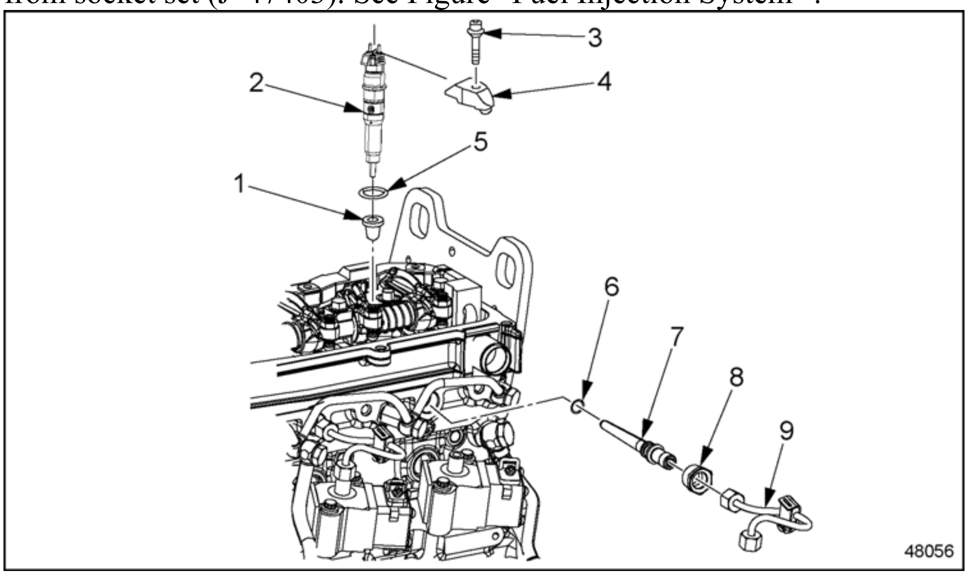
Section 2.4
Fuel Injector

The fuel injectors are electronically controlled nozzles capable of multiple injections per combustion cycle.

Section 2.4.1
Removal of Fuel Injector

Removal steps are as follows:

1. Remove cylinder head cover.
2. Remove the intake manifold.
3. Remove the transfer-tube and O–ring. Refer to "2.3.1 Removal Of High Pressure Fuel Lines And Transfer Tubes" .
4. Remove the fuel injector harness and frame. Refer to "2.6.1 Removal of Fuel Injector Harness and Frame" .
5. Remove rocker arms and shaft assembly. Refer to "1.21.1 Removal of Rocker Arms and Shaft Assembly" .
6. Remove the tensioning arm bolt and tensioning arm using the 8 mm triple square drive socket from socket set (J–47403). See Figure "Fuel Injection System" .

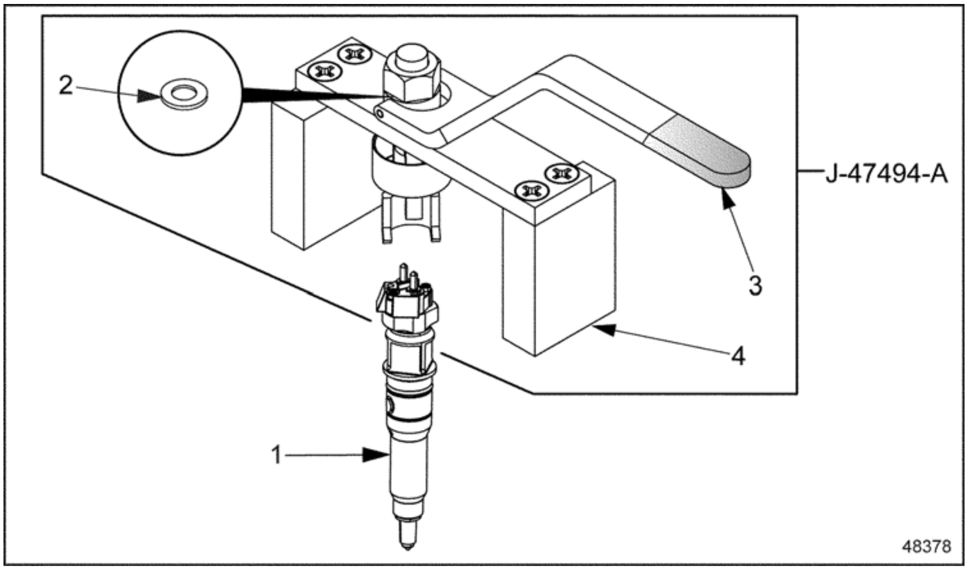


1. Heat Isolator	4. Tensioning Arm	7. Transfer-Tube
2. Fuel Injector	5. Fuel Injector O–ring	8. Thrust Bolt
3. Tensioning Arm Bolt	6. Transfer-Tube O–ring	9. High Pressure Fuel Line

Figure 1. Fuel Injection System

7. Position puller on injector with single arm of puller toward tensioning arm. See Figure "Injector Puller Tool" .

   Note: The double jaw faces toward the intake valves.



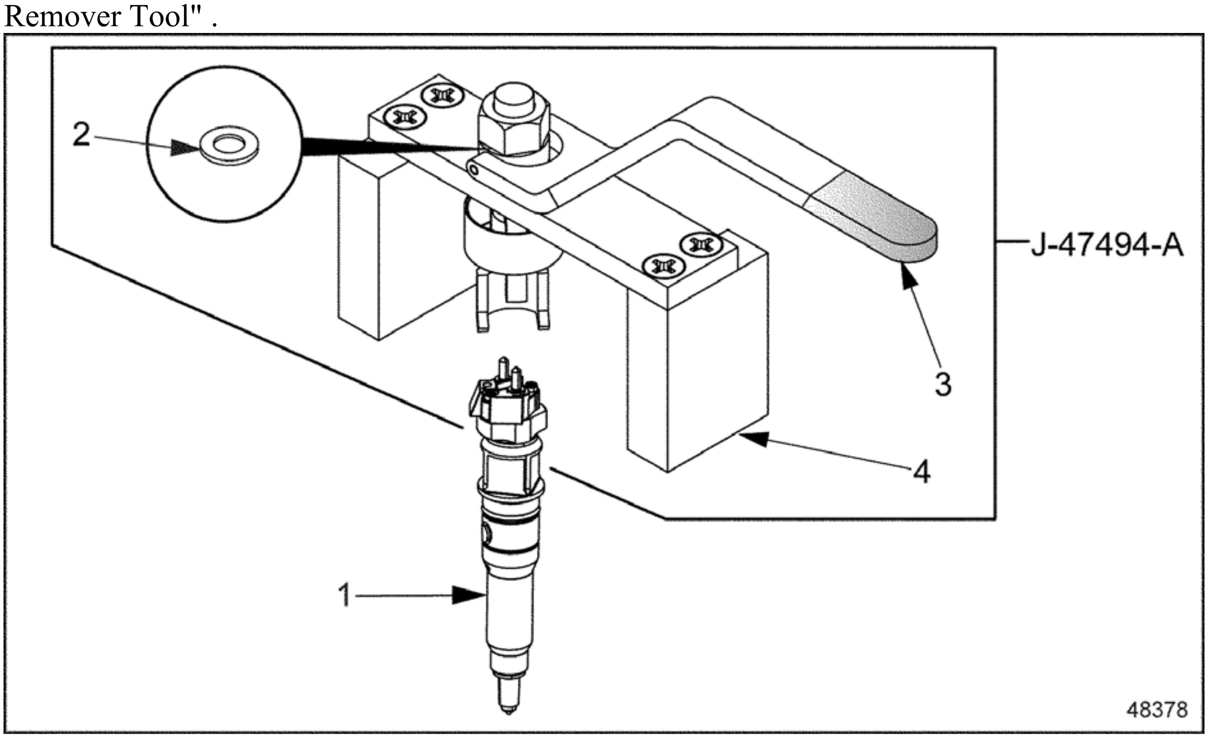
1. Fuel Injector	3. Lever
2. Washer	4. Bridge

Figure 2. Injector Puller Tool

8. Lower locking collar around puller.
9. Place bridge in place over threaded bolt of puller.
10. Place handle over bolt and secure using washer and nut.

    Note: Hand tighten nut, do not torque.

11. Lower the handle of (J47494-A) to raise the injector and tensioning arm. See Figure "Injector Remover Tool" .



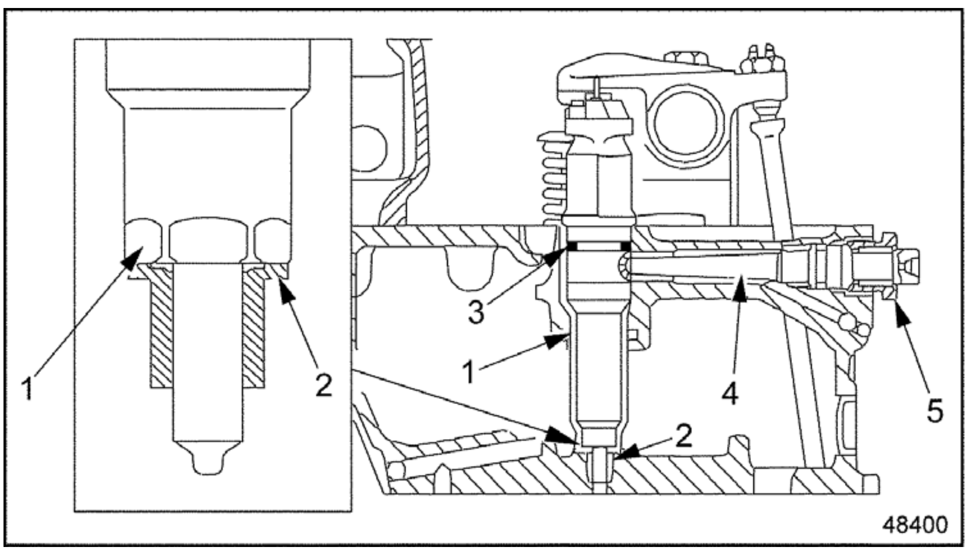
1. Fuel Injector	3. Lever
2. Washer	4. Bridge

Figure 3. Injector Remover Tool

Note: If there is not adequate clearance to use the handle as a lever, use the puller with a wrench to raise the puller.

12. Remove injector and tensioning arm.
13. Remove arm from injector.
14. Clean and remove any debris found in the protective sleeve. If the sleeve cannot be cleaned remove the protective sleeve, refer to "2.5.1 Removal of Protective Sleeve" . To replace the sleeve refer to "2.5.2 Installation of Protective Sleeve" .
15. Remove the heat isolator from the end of the fuel injector. Remove and discard the O-ring from the injector. See Figure "Heat Isolator Removal" .

Note: If the heat isolator remains in the cylinder head, go to step 16 .



1.Fuel Injector	4. Transfer-Tube
2. Heat Isolator	5. Thrust Bolt
3. O-ring	

Figure 4. Heat Isolator Removal

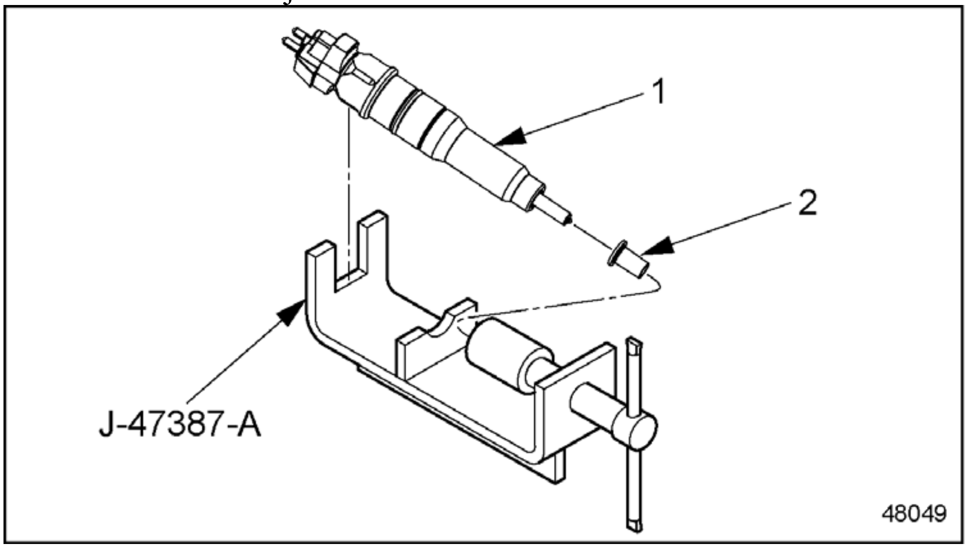
16. Install the end of the puller (J–46933) into the tip in the cylinder head. Turn the shaft of the tool to expand into the tip.
17. Use the slide hammer on the puller tool and remove and discard the heat isolator.
18. Inspect inside the protective sleeve for debris and clean if necessary. If the sleeve cannot be cleaned remove the protective sleeve, refer to "2.5.1 Removal of Protective Sleeve" , and to replace the sleeve refer to "2.5.2 Installation of Protective Sleeve" .

Section 2.4.2

Installation of Fuel Injector

Installation steps are as follows:

1. Lubricate the new O-ring with a light coat of engine oil (do not use a silicone base grease) and install it on the fuel injector.



1. Fuel Injector	2. Heat Isolator

Figure 5. Fuel Injector Heat Isolator

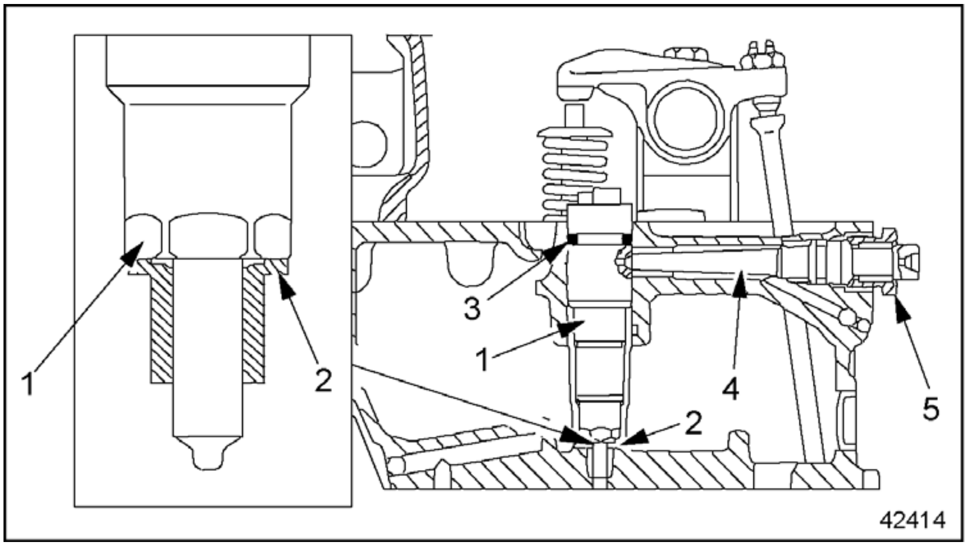
2. Using the injector heat isolator installer (J–47387–A), press the new heat isolator onto the fuel injector. See Figure "Fuel Injector Heat Isolator" .
   a. Place the heat isolator installation tool (J–47387–A) in a vise.
   b. Position the new heat isolator over the tip of the fuel injector.

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 in the installation tool and align the flats near the top of the injector with the slots in the installation tool.
   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 hole in the side of the fuel injector is installed correctly and is aligned properly with respect to the transfer-tube.



1. Fuel Injector	4. Transfer-Tube
2. Heat Isolator	5. Thrust Bolt
3. O-ring	

Figure 6. Fuel Injector and Related Components

3. Install the tensioning arm to the injector.
4. Install the fuel injector in the cylinder head with the hole in the side of the fuel injector facing toward the transfer-tube location. See Figure "Fuel Injector and Related Components" .

   Note: Ensure that the fuel injector is seated in the cylinder head.

5. Install the transfer-tube. Refer to "2.3.2 Installation of High Pressure Fuel Line" .
6. Install retaining bolt. Torque the retaining bolt to 30 N·m (22 lb·ft).
7. Install the high pressure fuel line. Refer to "2.3.2 Installation of High Pressure Fuel Line" .
8. Install the fuel injector harness and frame. Refer to "2.6.2 Installation of Fuel Injector Harness and Frame" .

Section 2.5
Protective Sleeve

The protective sleeve is located in the cylinder head.

Section 2.5.1
Removal of Protective Sleeve

Removal steps are as follows:

WARNING:

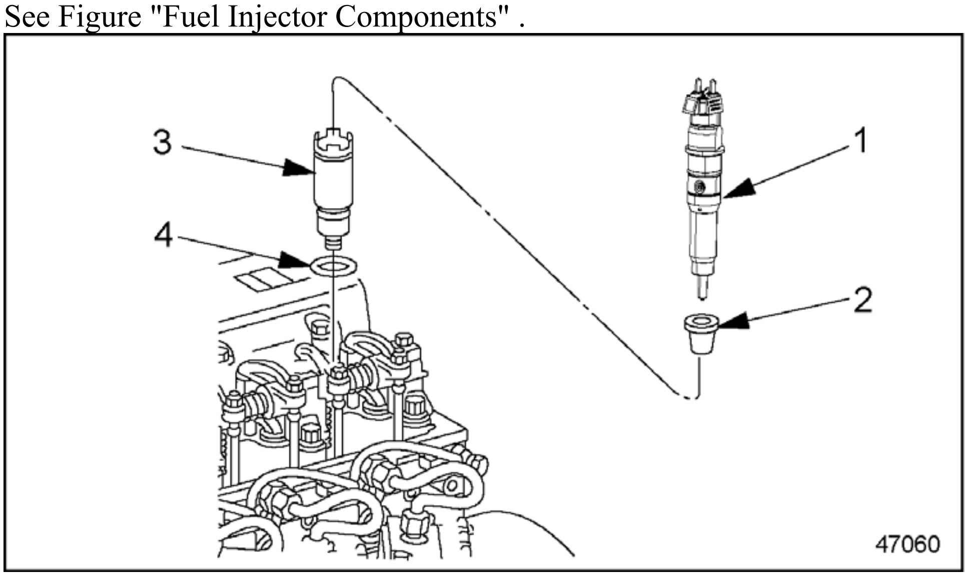
HOT COOLANT

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 it is clean, save it for later use.
2. Remove the fuel injector. Refer to "2.4.1 Removal of Fuel Injector" .

   Note: The injector sleeve puller kit (J–46381) comes with two sockets: a four-toothed socket and a rubber-ended socket.

3. Using the injector sleeve puller (J–46381), remove the protective sleeve from the cylinder head. See Figure "Fuel Injector Components" .



1. Fuel Injector	3. Protective Sleeve
2. Heat Isolator	4. O–ring

Figure 1. Fuel Injector Components

a. Insert the four-toothed socket into the protective sleeve. Make sure the teeth of the socket engage in the four openings on the protective sleeve.
b. Loosen the protective sleeve with a ratchet until the threads of the sleeve are disengaged from the cylinder head.
c. Replace the four-toothed socket on the protective sleeve puller with the rubber-ended socket. This is shown attached to the puller in the 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 and rotate the protective sleeve counterclockwise to remove it from the cylinder head.

4. Remove the O–ring from the cylinder head.

   Note: Replace the O–ring whenever the protective sleeve is removed.

Section 2.5.2
Installation of Protective Sleeve

Installation steps are as follows:

1. Clean the sealing surfaces of the protective sleeve and the cylinder head.
2. Install a new O–ring into the cylinder head. Coat the outside of the protective sleeve with acid–free grease. The grease will allow the protective sleeve to slide past the O–ring without damaging it.
3. Install the protective sleeve into the cylinder head. Tighten the protective sleeve 45 N·m (33 lb·ft).
4. Install the fuel injector. Refer to "2.4.2 Installation of Fuel Injector" .
5. Fill the cooling system with clean coolant.

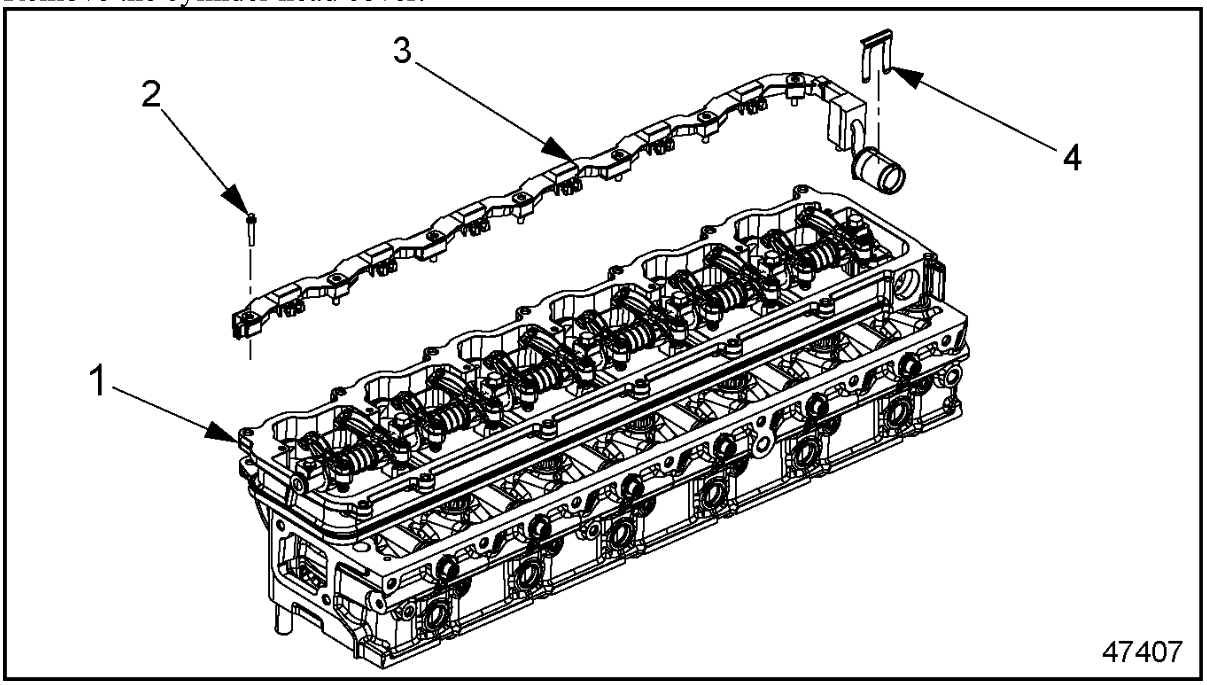
Section 2.6
Fuel Injector Harness and Frame

The following sections cover removal and installation of the Fuel Injector Harness and frame.

Section 2.6.1
Removal of Fuel Injector Harness and Frame

Remove steps are as follows:

1. Remove the cylinder head cover.



1. Rocker Arm Frame	3. Injector Harness and Frame
2. Screws	4. Retaining Clip

Figure 1. Fuel Injector Harness and Frame

2. Disconnect the fuel injector harness connector from the rocker arm frame by removing retainer clip at the rear of the frame. Push the connector through the hole in the rocker arm frame. See Figure "Fuel Injector Harness and Frame" .
3. Disconnect the fuel injector harness from each fuel injector by removing two captured nuts.
4. Remove eight screws securing the fuel injector harness and frame to the rocker arm frame and remove the harness and frame and screws. See Figure "Fuel Injector Harness and Frame" .

Section 2.6.2
Installation of Fuel Injector Harness and Frame

Installation steps are as follows:

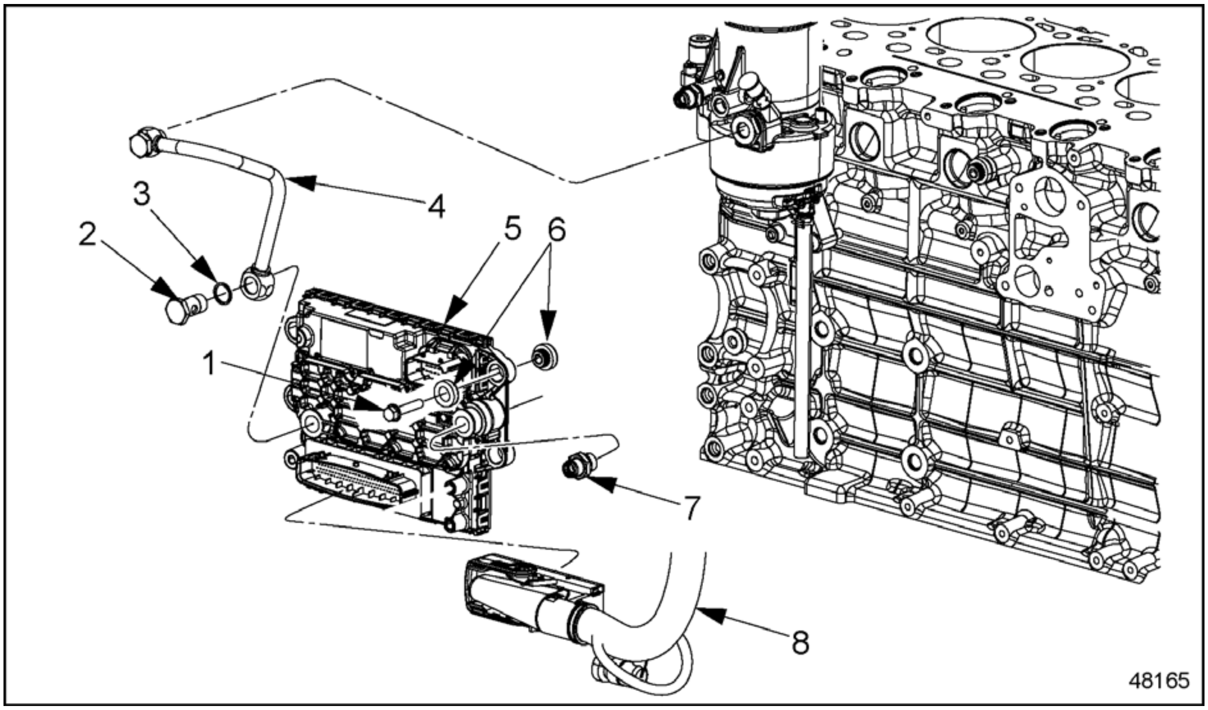
1. Install the injector harness and frame on the rocker arm frame and loosely secure with eight screws, then torque the screws to 7–9 N·m (5–7 lb·ft). See Figure "Fuel Injector Harness and Frame" .
2. Install the fuel injector harness connector through the hole at the rear of the rocker arm frame and secure with clip. See Figure "Fuel Injector Harness and Frame" .
3. Connect the fuel injector harness to each fuel injector and secure with captured nuts. Torque the nuts to 1.75 N·m (15 lb·in.)
4. Install the cylinder head cover.

Section 2.7 Motor Control Module

The MCM cannot be repaired, it must be replaced or reprogrammed.

Section 2.7.1 Removal of Motor Control Module

Remove the Motor Control Module (MCM) as follows:



1. Bolt (MCM Mounting)	5. MCM
2. Banjo Bolt (M18)	6. Isolators
3. copper-tin Washer	7. Connector Fitting (M18)
4. Fuel Line	8. 120–Pin MCM Connector

Figure 1. MCM and Related Parts

1. Disconnect the batteries.
2. Open the hood.
3. Disconnect and remove the 21 pin connector harness from the MCM.
4. Disconnect and remove the 120 pin connector harness from the MCM. See Figure "MCM and Related Parts" .
5. Remove the banjo bolts and washers securing the fuel line to the cooler plate on the MCM and at the fuel filter. Discard the washers. See Figure "MCM and Related Parts" .
6. Disconnect the fuel out line at the fitting on the MCM cooler and remove the line. If necessary, remove the fitting from the MCM.
7. Remove three bolts and six isolators securing the MCM to the cylinder block and remove the

MCM. See Figure "MCM and Related Parts" .

Note: Do not disassemble the MCM. It cannot be serviced.

Section 2.7.1.1
Inspection of Motor Control Module

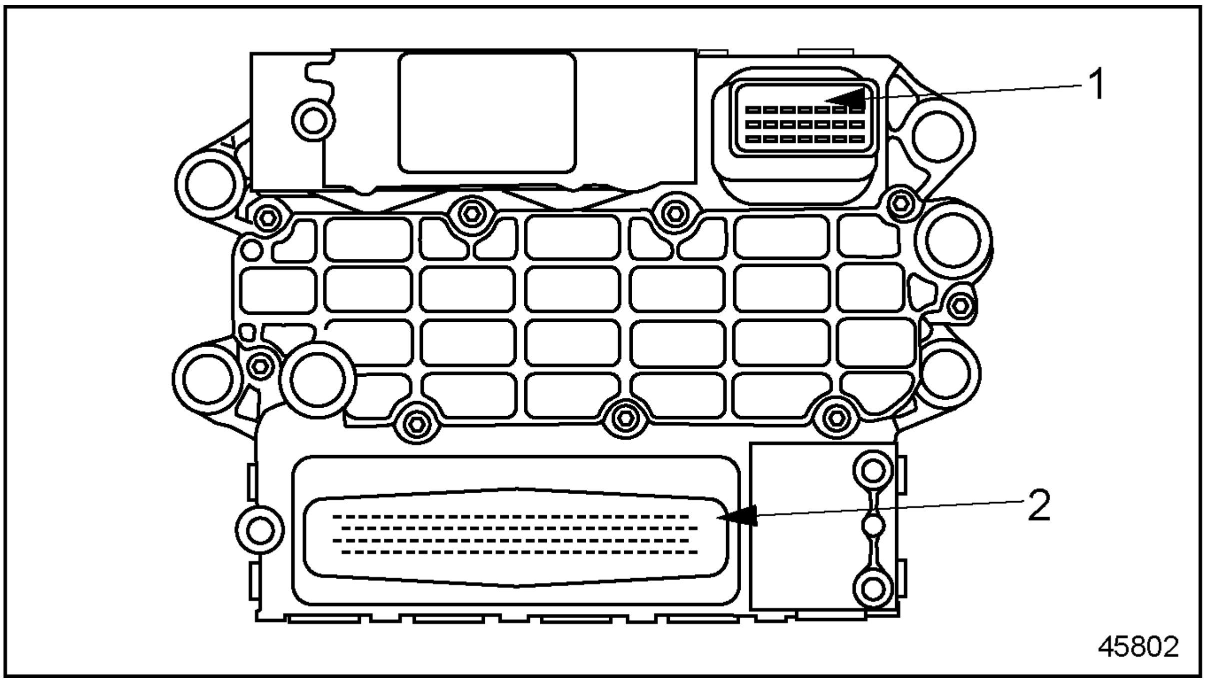
Inspection steps are as follows:

1. Inspect the MCM for damage and replace if necessary.
2. Inspect the isolator for damage and replace if necessary.

Section 2.7.2
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. 21–Pin Connector (Vehicle Harness)	2. 120–Pin Connector (Engine Harness)

Figure 2. Motor Control Module

NOTICE:

Ensure MCM and connectors are not contaminated with diesel fuel.

1. Secure the MCM to the left side of the cylinder block with three bolts and six new isolators.

Torque the bolts to 20–30 N·m (15–22 lb·ft). See Figure "MCM and Related Parts" .

2. Connect one end of fuel line to fuel cooler and the other end to the fuel filter. Secure the fuel line to the fuel filter with banjo bolt and two new copper-tin washers. Torque the banjo bolt to 55 N·m (40 lb·ft).
3. If removed, install the fitting in the MCM connector fitting. Torque to 55 N·m (40 lb·ft).See Figure "MCM and Related Parts" .
4. Attach bracket to the MCM with two bolts. Torque the bolts to 8–10 N·m (71–88 lb·in). See Figure "MCM and Related Parts" .
5. Connect the 21-pin connector harness to the MCM and lock in place. See Figure "Motor Control Module" .
6. Connect the 120-pin connector harness to the MCM and lock in place. See Figure "MCM and Related Parts" .

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 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.

7. Start and run the engine.
8. 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.
9. If any other codes appear, refer to the MBE 900 DDEC VI Troubleshooting Guide , 6SE580.

Section 2.8
Common Powertrain Controller

The Common Powertrain Controller (CPC) communicates between the MCM and other electronic control units installed on the vehicle over the J1587 datalink. See Figure "Common Powertrain Controller" . Within the CPC, sets of data for specific applications are stored. These include idle speed, maximum running speed, and speed limitation.

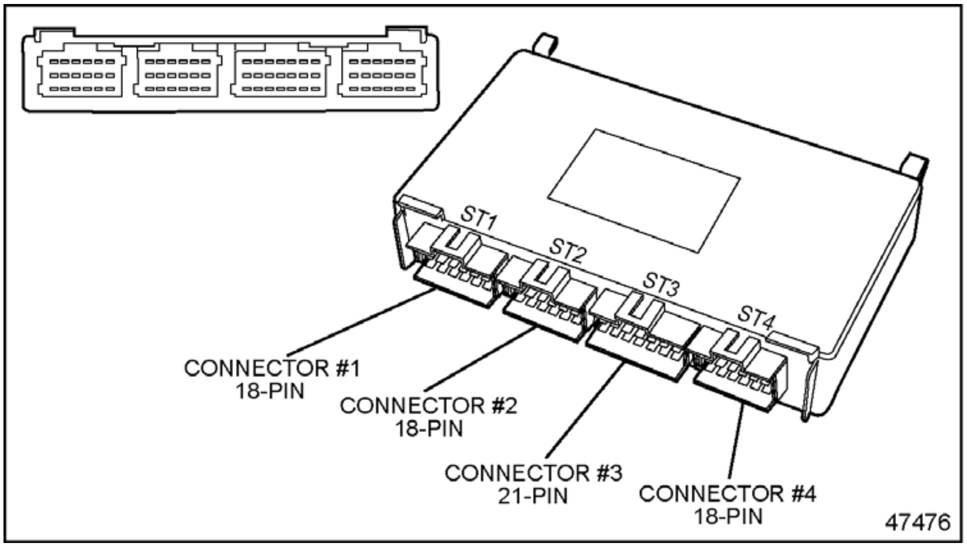


Figure 1. Common Powertrain Controller

The CPC receives data from the following sources:

- The operator (accelerator pedal position, engine brake switch)
- Other electronic control units (for example, the anti–lock brake system)
- The CPC control unit (data such as oil pressure and coolant temperature)

From this data, instructions are computed for controlling the engine and transmitted to the MCM via the proprietary datalink. The CPC controls various systems, for example, communications with the datalink, the engine brake, and the constant–throttle valves. If the engine control system detects a fault, the appropriate fault code is broadcast on the datalink and can be read using DDDL 7.0. When there is a fault, the code for the control unit reporting the fault can be read directly on the ICU display.

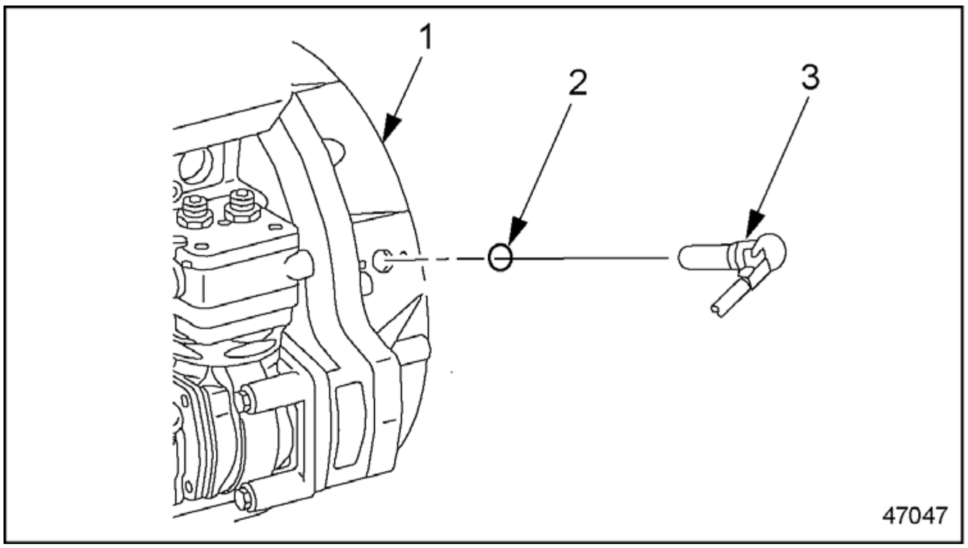
Section 2.9
Crankshaft Position Sensor

The Crankshaft Position (CKP) Sensor is located on the left side rear of the flywheel housing.

Section 2.9.1
Removal of Crankshaft Position Sensor

Removal steps are as follows:

1. Remove the electrical connector from the CKP sensor on the left side rear of the flywheel housing.
2. Pull the CKP Sensor from the flywheel housing. See Figure "Crankshaft Position Sensor Bracket Removal / Installation" .



1. Flywheel Housing	3. Crankshaft Position Sensor
2. O-ring	

Figure 1. Crankshaft Position Sensor Bracket Removal / Installation

Section 2.9.2
Installation of Crankshaft Position Sensor and Bracket

Installation steps are as follows:

1. Install the CKP Sensor by push it in until it bottoms on the flywheel housing. See Figure "Crankshaft Position Sensor Bracket Removal / Installation" .
2. Connect the electrical connector to the CKP Sensor.

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Section 2.10
Intake Manifold Pressure/Temperature Sensor

The Intake Manifold Pressure/Temperature Sensor is located in the top rear cover of the intake manifold.

Section 2.10.1
Removal of Intake Manifold Pressure/Temperature Sensor

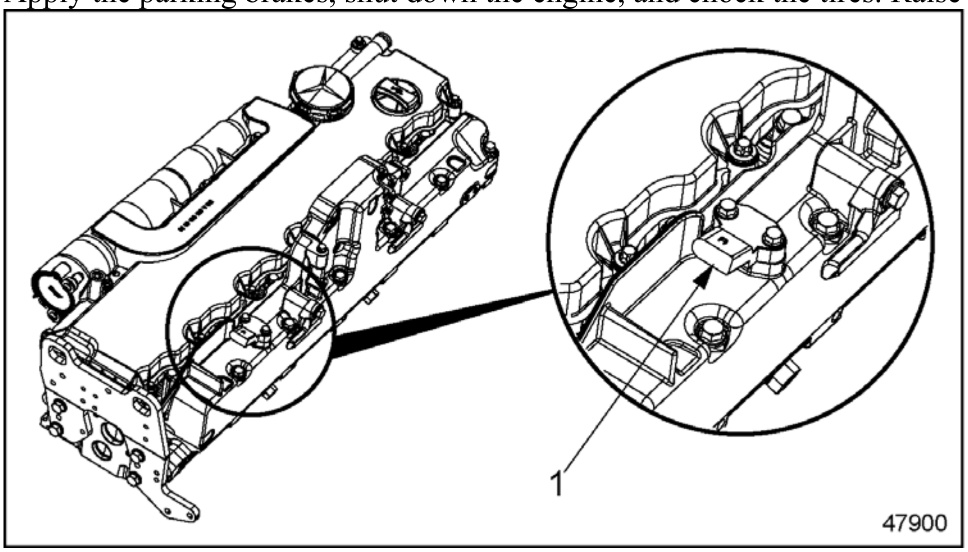
Removal steps are as follows:

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 tires. Raise the hood.



1. Intake Manifold Pressure and Temperature Sensor

Figure 1. Intake Manifold Pressure/Temperature Sensor

2. Disconnect the electrical wiring harness connector to the Intake Manifold Pressure/Temperature Sensor located on the top rear of the intake manifold. See Figure "Intake Manifold Pressure/Temperature Sensor" .
3. Remove the fasteners that attach the Intake Manifold Pressure/Temperature Sensor, then remove the sensor.

Section 2.10.2
Installation of Intake Manifold Pressure/Temperature Sensor

Installation steps are as follows:

1. Install the Intake Manifold Pressure/Temperature Sensor. Tighten the fasteners to 8–10 N·m (6–7 lb·ft).
2. Connect the harness electrical connector to the sensor.
3. Remove the chocks from the tires.

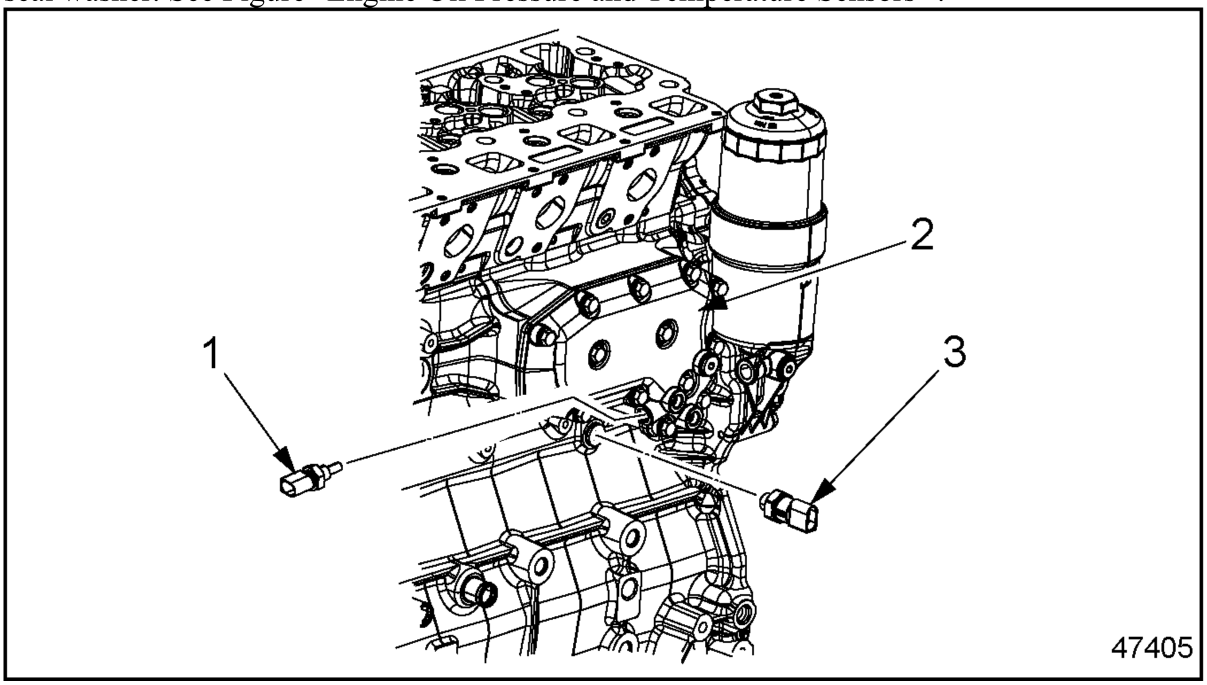
Section 2.11
Engine Oil Pressure Sensor

The Engine Oil Pressure (EOP) Sensor is located on the right front side of the cylinder block.

Section 2.11.1
Removal of Engine Oil Pressure Sensor

Removal steps are as follows:

1. Disconnect the wiring connector from the EOP Sensor.
2. Remove the EOP Sensor and seal washer from the right front side of the cylinder block. Discard seal washer. See Figure "Engine Oil Pressure and Temperature Sensors" .



1. Engine Oil Temperature Sensor	2. Engine Oil Cooler	3. Engine Oil Pressure Sensor

Figure 1. Engine Oil Pressure and Temperature Sensors

Section 2.11.2
Installation of Engine Oil Pressure Sensor

Installation steps are as follows:

1. Install the EOP Sensor and new seal washer in the right front side of the cylinder block. Torque the sensor to 50 N·m (37 lb·ft). See Figure "Engine Oil Pressure and Temperature Sensors" .
2. Connect the wiring harness to the EOP Sensor.

WARNING:

ENGINE EXHAUST

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

3. Start the engine. Check the gauge for the correct oil pressure and check for leaks.
4. Check and add engine oil as needed.

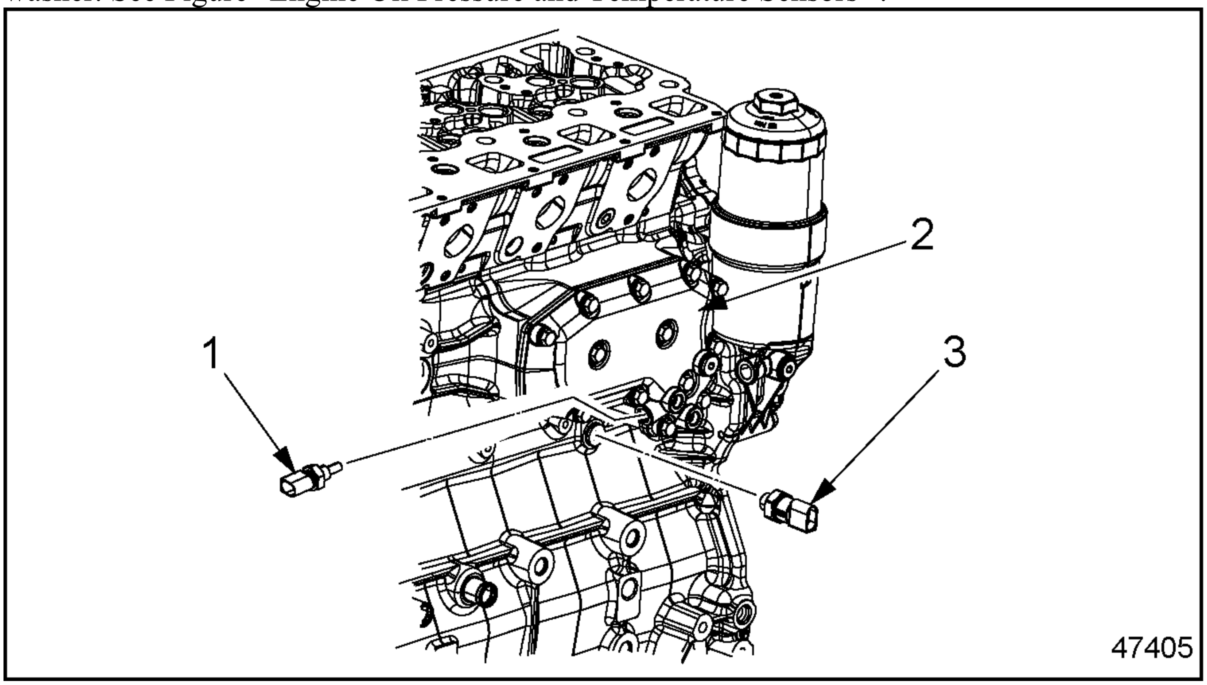
Section 2.12
Engine Oil Temperature Sensor

The Engine Oil Temperature (EOT) Sensor is located on the rear of the engine oil cooler.

Section 2.12.1
Removal of Engine Oil Temperature Sensor

Removal steps are as follows:

1. Disconnect the wiring connector from the EOT Sensor.
2. Remove the EOT Sensor and seal washer from the rear of the engine oil cooler. Discard seal washer. See Figure "Engine Oil Pressure and Temperature Sensors" .



1. Engine Oil Temperature Sensor	2. Engine Oil Cooler	3. Engine Oil Pressure sensor

Figure 1. Engine Oil Pressure and Temperature Sensors

Section 2.12.2
Installation of Engine Oil Temperature Sensor

Installation steps are as follows:

1. Install the EOT Sensor and new seal washer in the rear of the engine oil cooler. Torque the sensor to 45 N·m (33 lb·ft).
2. Connect the wiring harness to the EOT Sensor.

WARNING:

ENGINE EXHAUST

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

3. Start the engine and check for leaks.
4. Check and add engine oil as needed.

Section 2.13
Engine Coolant Temperature Sensor

The Engine Coolant Temperature sensor is located on the left–hand side of the thermostat housing, just below the lifting eye.

Section 2.13.1
Removal of Engine Coolant Temperature Sensor

Removal steps are as follows:

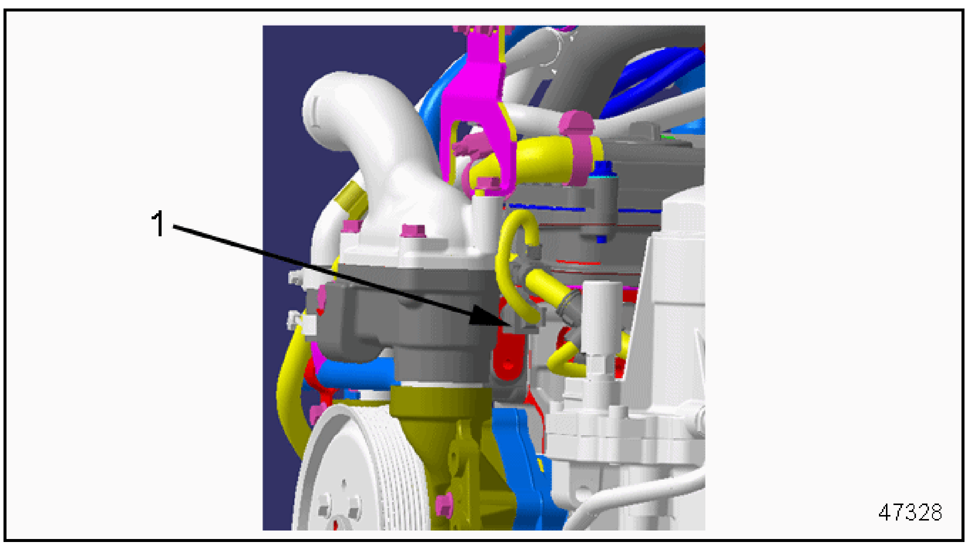
WARNING:

PERSONAL INJURY

To avoid injury from scalding, drain the radiator when the engine and coolant are cool.

1. Drain the coolant from the engine.
2. Remove the hose clamp attaching the (surge tank) coolant delivery hose to the front connector housing.

   Note: Collect any coolant that runs out of the hose.



1. Engine Coolant Temperature Sensor

Figure 1. Engine Coolant Temperature Sensor

3. Disconnect the electrical connector from the coolant temperature sensor located on the left–hand side of the thermostat housing, just below the front lifting eye. See Figure "Engine Coolant Temperature Sensor" .

4. Remove the ECT Sensor and seal washer from the connector housing. Discard the seal washer.

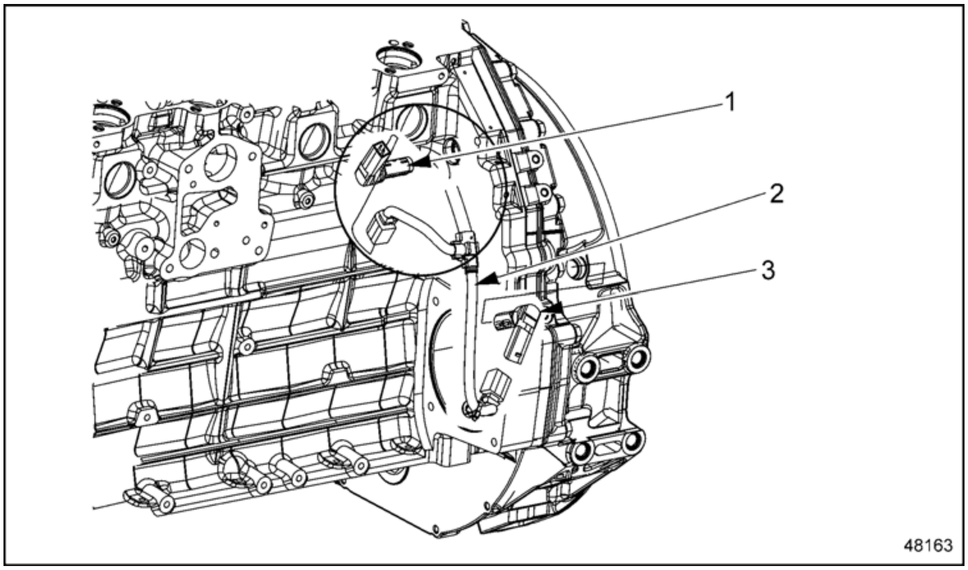
Section 2.13.2
Installation of Engine Coolant Temperature Sensor

Installation steps are as follows:

1. Install the ECT Sensor and new seal washer in the thermostat housing. Torque the sensor to 30 N·m (22 lb·ft). See Figure "Engine Coolant Temperature Sensor" .
2. Connect the electrical connector to the coolant temperature sensor.
3. Fill the engine with the removed coolant, and check for leaks and proper operation.

Section 2.14
Camshaft Position Sensor

The Camshaft Position (CMP) Sensor, is located at the left front side flywheel housing. It is located above the air compressor. See Figure "Location of Camshaft Position Sensor" .



1. Camshaft Position Sensor	3. Crankshaft Position Sensor (CKP)
2. Camshaft Position Sensor (CMP)	

Figure 1. Location of Camshaft Position Sensor

Section 2.14.1
Removal of Camshaft Position Sensor

Removal steps are as follows:

Note: If the air compressor is still attached to the engine, it may be necessary to remove the compressed air intake line before removing the Camshaft Position Sensor.

1. If necessary, remove the air compressor air intake line.
2. Pull out the CMP Sensor from the left front side flywheel housing. Remove and discard the O–ring.
3. If inoperable, discard the sensor.

Section 2.14.2
Installation of Camshaft Position Sensor

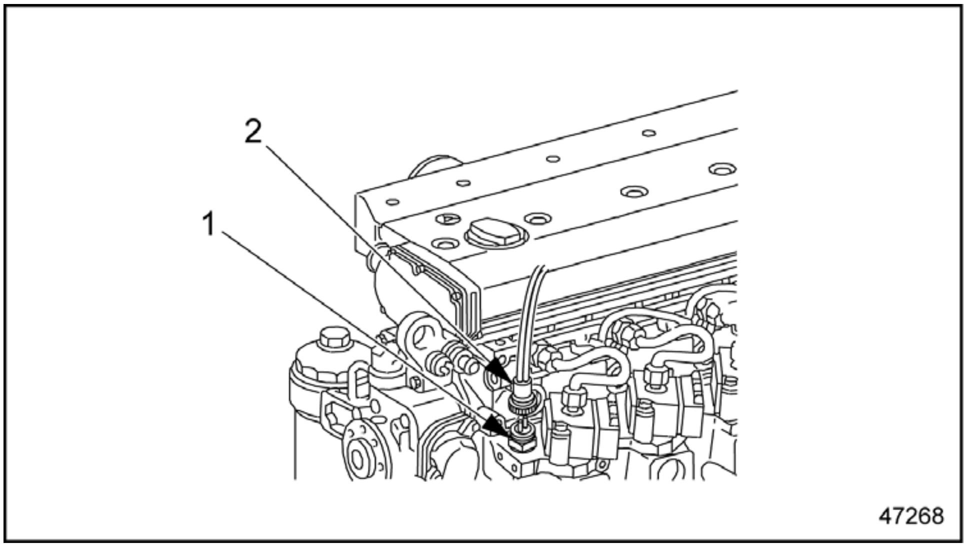
Installation steps are as follows:

1. Install a new O–ring on the CMP Sensor.
2. Push the CMP Sensor until it makes contact with the flywheel housing.

3. If the air compressor air intake line was removed, install it.

Section 2.15
Supply Fuel Temperature Sensor

The Supply Fuel Temperature Sensor is located on the front left side of the engine. See Figure "Location of Engine Supply Fuel Temperature Sensor" .



1. Supply Fuel Temperature Sensor	2. Wiring Harness Connector

Figure 1. Location of Engine Supply Fuel Temperature Sensor

Section 2.15.1
Removal of Supply Fuel Temperature Sensor

Removal steps are as follows:

1. Disconnect the wiring harness from the Supply Fuel Temperature Sensor. See Figure "Location of Engine Supply Fuel Temperature Sensor" .
2. Remove the Supply Fuel Temperature Sensor and copper sealing ring, if inoperable discard. See Figure "Location of Engine Supply Fuel Temperature Sensor" .

Section 2.15.2
Installation of Supply Fuel Temperature Sensor

Installation steps are as follows:

1. Install or mount the new Supply Fuel Temperature Sensor and seal ring. Torque the sensor to 25–35 N·m (18–26 lb·ft). See Figure "Location of Engine Supply Fuel Temperature Sensor" .
2. Connect the wiring harness to the sensor. See Figure "Location of Engine Supply Fuel Temperature Sensor" .

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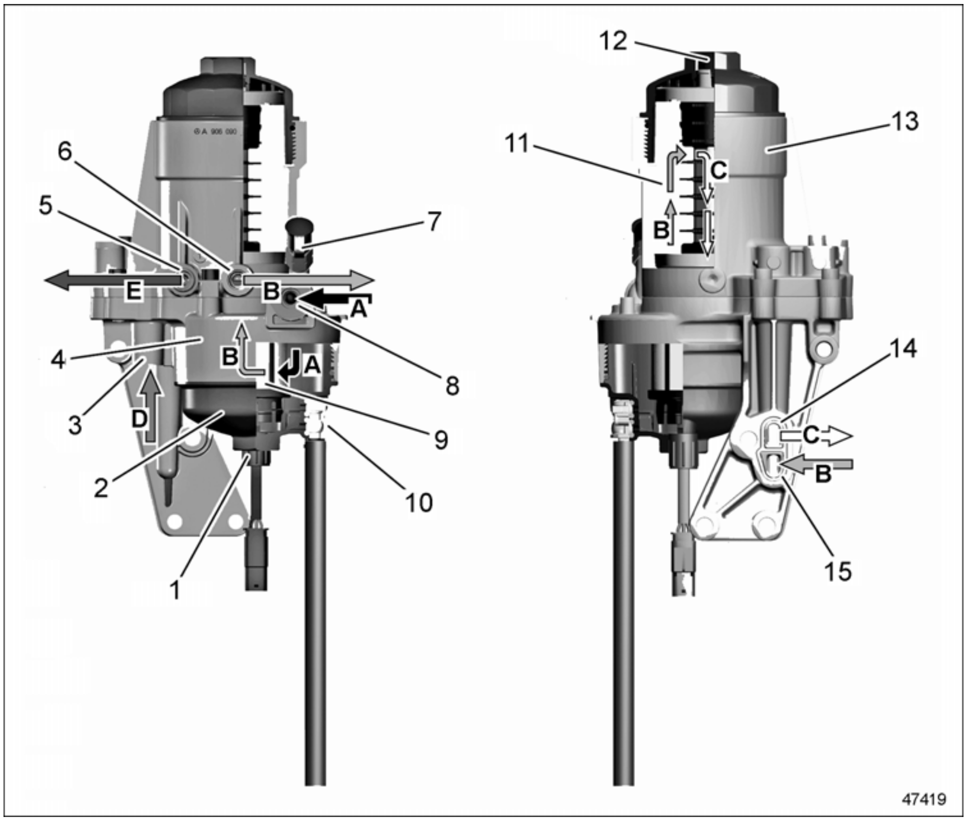
Section 2.16
Fuel Filter/Water Separator Filters

There is a primary filter and a secondary fuel filter in the fuel filter/water separator.

Section 2.16.1
Removal of Primary Fuel Filter

See Figure "Fuel Filter/Water Separator" for fuel filter/water separator components and fuel flows.



1. Water-In-Fuel Sensor (Optional)	9. Fuel Prefilter Insert
2. Water Collection Bowl	10. Drain Lever (Optional)
3. Main Fuel Filter Return Inlet	11. Main Fuel Filter Inlet
4. Fuel Prefilter with Water Separator (Optional)	12. Constant Vent in Main Fuel Filter
5. Main Fuel Filter Return Outlet	13. Main Fuel Filter
6. Outlet of Fuel Prefilter with Water Separator	14. Main Fuel Filter Outlet
7. Priming Valve	15. Main Fuel Filter Inlet
8. Inlet for Fuel Prefilter with Water Separator	A = Unfiltered Fuel
B = Prefiltered Fuel	D = Fuel Injector Leak Fuel
C = Cleaned Fuel	E = Fuel Return Line to Fuel Tank

Figure 1. Fuel Filter/Water Separator

Removal steps are as follows:

1. Shut down the vehicle.
2. Place the fuel drain hose in a collection container and open the drain lever. Once the fuel stops draining from the line, close the drain lever.
3. Disconnect the connector plug to the fuel pre-heater element. Remove the ground lead for the fuel pre-heater from the fuel filter/water separator housing.
4. Disconnect the harness Water-in-Fuel (WIF) sensor connector from the fuel filter/water separator housing. See Figure "Fuel Filter/Water Separator" .
5. Remove the water collection bowl from the filter housing using a 36 mm wrench or socket and remove bowl and seal ring. Discard seal ring. See Figure "Fuel Filter/Water Separator" .
6. Remove the primary filter element from the filter housing and discard the element. See Figure "Fuel Filter/Water Separator" .

Section 2.16.2
Installation of Primary Fuel Filter

Installation steps are as follows:

1. Install the new primary fuel filter, ensuring that the element is firmly seated against the filter housing.
2. Install a new seal ring on the fuel filter/water separator bowl and lubricate with clean engine oil. See Figure "Fuel Filter/Water Separator" .
3. Thread the bowl into the housing and tighten bowl to 25 N·m (18 lb·ft.).
4. Connect the connector plug to the fuel pre-heater element. Install the ground lead for the fuel pre-heater to the fuel filter/water separator housing.
5. Connect the WIF sensor harness connector to the fuel filter/water separator housing.
6. Ensure fuel drain lever is in closed position (counter-clockwise).
7. Use the hand primer on the fuel filter/water separator or the priming port and the Diesel Fuel System Primer (J–47912) to prime the fuel system for ease of starting.

Section 2.16.3
Removal of Secondary Fuel Filter

Removal steps are as follows:

1. Turn off the vehicle.
2. Remove the cover from the filter housing using a 36 mm wrench or socket and remove the cover and seal ring. Discard seal ring.
3. Remove the element from the cover and discard.

Section 2.16.4
Installation of Secondary Fuel Filter

Installation steps are as follows:

1. Insert a new element into the cover and lubricate the element seal (in the bottom end).
2. Install cover and element assembly into the housing and tighten the cover to 25 N·m (18 lb·ft).
3. Use the hand primer on the fuel filter/water separator or priming port with the Diesel Fuel System Primer (J–47912) to prime the fuel system for ease of starting.

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Section 2.17
Fuel Filter/Water Separator Housing

The following sections support the repair of the fuel filter separator housing.

Section 2.17.1
Removal of Fuel Filter/Water Separator Housing

Removal steps are as follows:

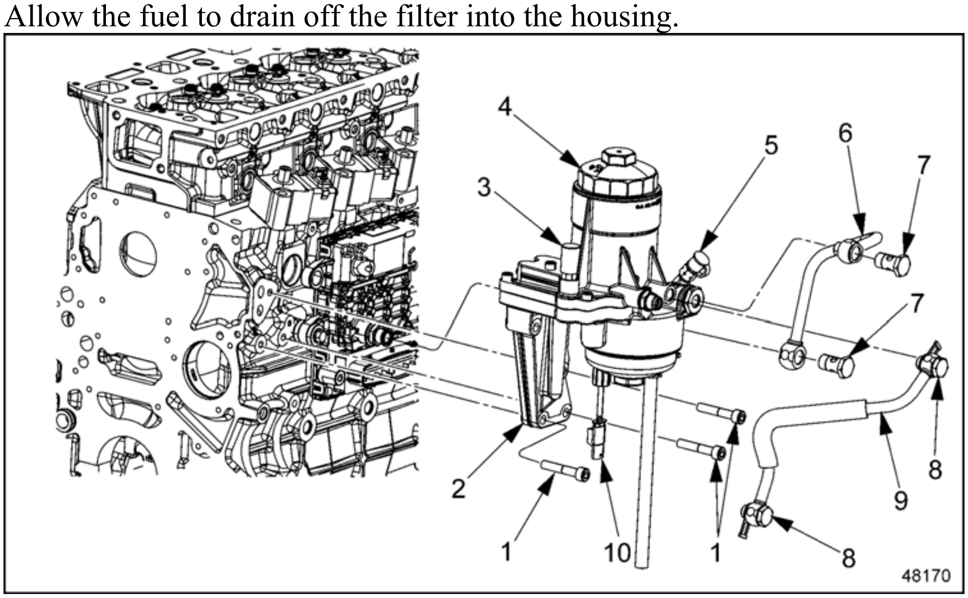
WARNING:

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. Open the fuel filler cap on the fuel tank to release pressure in the fuel system. Replace and tighten the cap.
2. Using a 36 mm socket wrench, unscrew the cap on the secondary fuel filter and pull both the cap and the filter element a short distance out of the filter housing. See Figure "Filter Housing" . Allow the fuel to drain off the filter into the housing.



1. Bolts	6. Fuel Out Line
2. Filter Assembly	7. Banjo Fitting

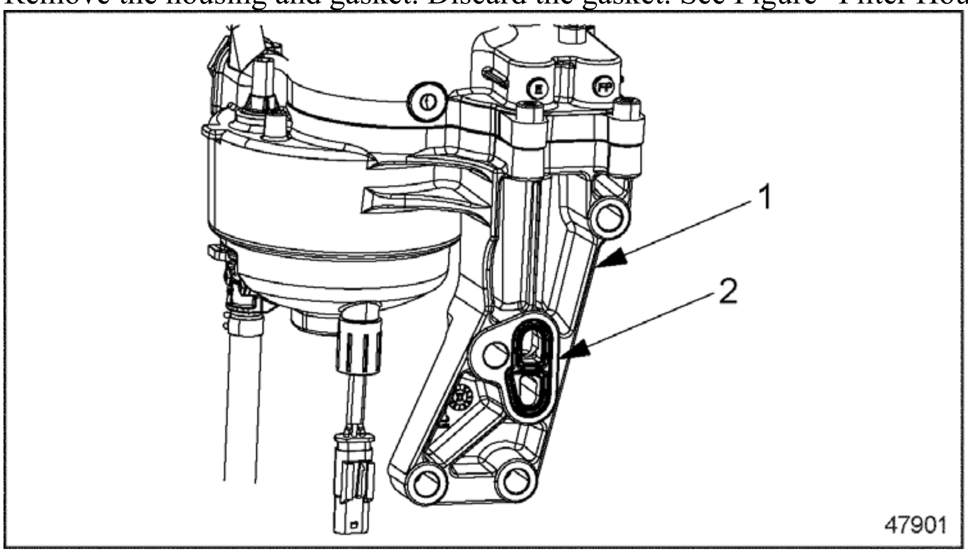
3. Hand Primer	8. Banjo Bolt
4. Filter Cap	9. Fuel In Line
5. Primer Port Fitting	10. WIF Connector

Figure 1. Filter Housing

3. Disconnect the water-in-fuel (WIF) sensor connector from the harness. See Figure "Filter Housing" .
4. Disconnect the connector plug to the fuel pre-heater element. Remove the ground lead for the fuel pre-heater from the fuel filter/water separator housing.
5. Remove the banjo bolts and washers on the feed and return lines. Discard the washers. See Figure "Filter Housing" .

   Note: Collect any fuel that runs out of the filter housing or assembly valves.

6. Remove the three socket-head hex bolts securing the filter housing to the crankcase. See Figure "Filter Housing" .
7. Remove the housing and gasket. Discard the gasket. See Figure "Filter Housing Gasket" .



1. Filter Housing	2. Gasket

Figure 2. Filter Housing Gasket

Section 2.17.2
Installation of Fuel Filter/Water Separator Housing

Installation steps are as follows:

1. Install a new gasket on the filter housing. See Figure "Filter Housing Gasket" .
2. Secure the filter housing to the crankcase with three socket-head hex bolts. Torque the mounting bolts to 50-55 Nm (37-41 lb·ft). See Figure "Filter Housing" .
3. Install the suction and delivery lines to the side of the filter and secure with banjo bolts and new copper-tin washers. Tighten the banjo bolts to 45 N·m (33 lb·ft). See Figure "Filter Housing" .

4. Install the assembly valves on the fuel filter housing, if removed.
5. Secure the fuel suction and return lines with banjo bolts and new washers. Tighten the banjo bolts to 40 N·m (30 lb·ft).
6. Check the filter element and O–ring on the main filter cap and replace if necessary. Always put the cartridge into the cap first, then screw the cap onto the filter housing. Tighten the cap to 25 N·m (18 lb·ft.).
7. Use the hand primer on the fuel filter/water separator or priming port with the Diesel Fuel System Primer (J–47912) to prime the fuel system for ease of starting.

Section 2.18
Fuel Pump

The gear–type fuel pump is bolted to the front of the cylinder block. The pump is driven from the forward end of the camshaft.

Section 2.18.1
Removal of Fuel Pump

Removal steps are as follows:

1. Release the tension on the serpentine belt. Remove the belt from the idler pulley.
2. Remove the crossover (cold air intake) hose that leads from the charge air cooler to the air inlet.
3. Remove the fan from the fan clutch and set it aside within the fan shroud.
4. On vehicles with air conditioning only, remove the idler pulley from the fuel pump.

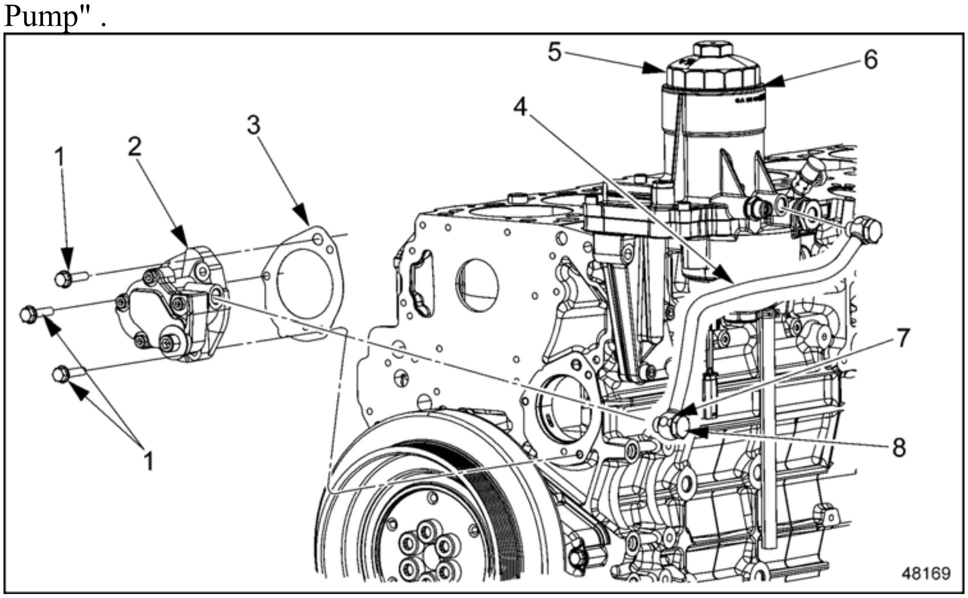
WARNING:

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.**

5. Using a 36–mm socket wrench insert, unscrew the cap on the main fuel filter. See Figure "Fuel Pump" .



1. Mounting Bolts (3 qty.)	5. Cap (Fuel Filter)

2. Fuel Pump	6. O–ring
3. Gasket	7. Washer
4. Fuel Line (Pump to Filter)	8. Banjo Bolt

Figure 1. Fuel Pump

6. Remove the fuel line from the fuel pump. Discard the washers on the banjo fitting.

   Note: Collect any fuel that runs out of the fuel pump or the fuel line.

7. Remove the fuel pump from the crankcase. Discard the gasket.

   Note: Collect any fuel that runs out of the fuel pump or the fuel line.

Section 2.18.2
Installation of Fuel Pump

Installation steps are as follows:

NOTICE:

When inserting the fuel pump into the crankcase, do not allow the driver on the fuel pump to rest on the camshaft dowel pin. This could cause damage to the pump.

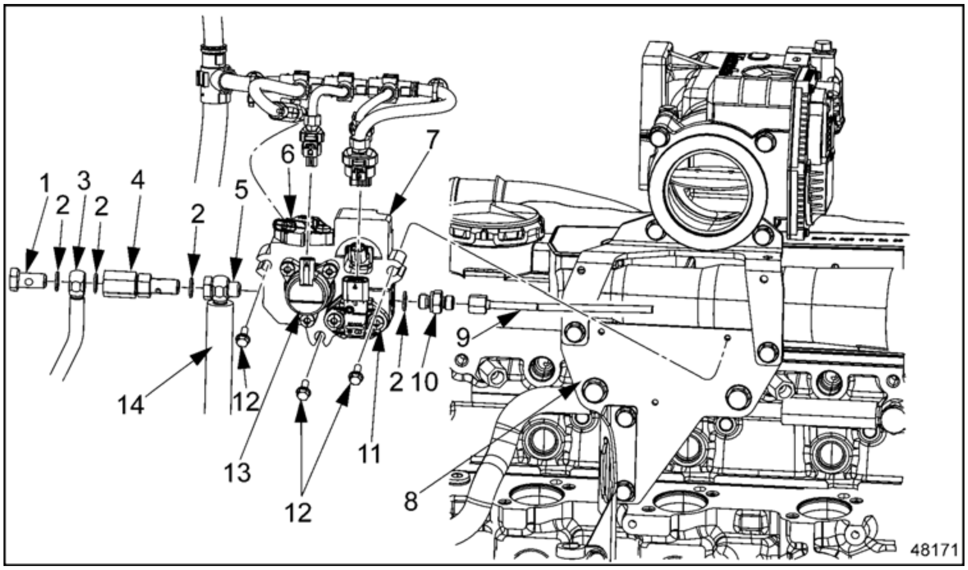
1. Install the fuel pump. Install a new gasket on the connection to the crankcase. Tighten the three mounting bolts to 25 N·m (18 lb·ft).
2. Install the fuel line, as removed. Install new copper-tin washers on the banjo fittings. Tighten the banjo bolts to 45 N·m (33 lb·ft).
3. On vehicles with air conditioning only, Install the idler pulley on the fuel pump. Tighten the idler pulley bolt to 75 N·m (55 lb·ft). On vehicles without air conditioning only, Tighten the cover bolt to 45 N·m (33 lb·ft).
4. Install the fan on the fan clutch, as removed.
5. Install the crossover (cold air intake) hose between the charge air cooler and the charge air inlet, as removed.
6. With the belt tension released, install the serpentine belt on the idler pulley. Restore the belt tension.
7. Prime the fuel system.

Section 2.19
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).

Section 2.19.1
Removal of Doser Block Assembly

Removal steps as are follows:



1. Banjo Bolt	9. Fuel Dosing Line
2. copper-tin Washers	10. Fuel Dosing Line Fitting
3. Fuel Supply Line	11. Fuel Line Pressure Sensor
4. Fuel Pressure Regulator	12. Bolts (Doser Block Mounting qty3)
6. Fuel Compensation Pressure Sensor	13. Fuel Cutoff Valve
7. Doser Block Assembly	14. Fuel Return Line
8. Bracket (Doser Block Mounting)	

Figure 1. Doser Block Assembly

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. See Figure "Doser Block Assembly" .
2. Disconnect the fitting to the dosing fuel line on the doser block assembly. See Figure "Doser Block Assembly" .
3. Remove the banjo bolt, fitting and washers connecting the fuel supply line to doser block assembly. Discard the washers. See Figure "Doser Block Assembly" .
4. Remove the three bolts securing the doser block assembly to the mounting bracket and remove the assembly. See Figure "Doser Block Assembly" .

Section 2.19.2
Installation of Doser Block Assembly

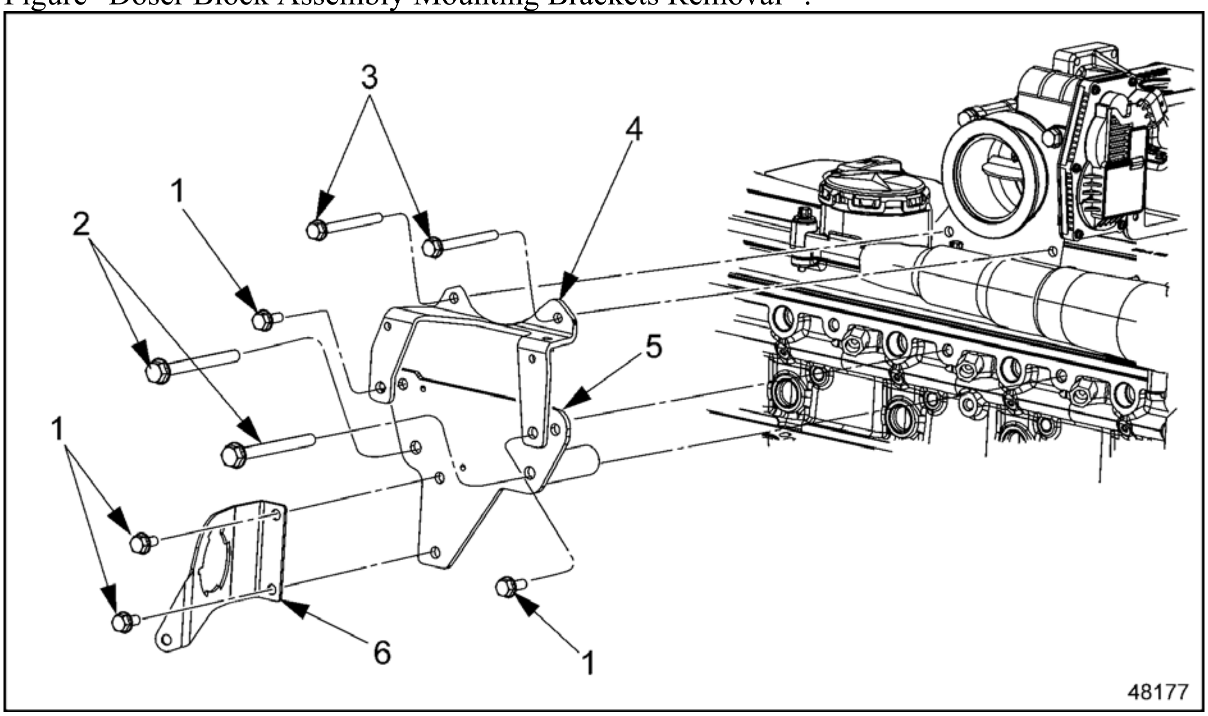
Installation steps are as follows:

1. Secure the doser block assembly to the mounting bracket with three bolts. Torque the bolts to 25 N·m (18 lb·ft). See Figure "Doser Block Assembly" .
2. Install the banjo bolt, fitting and new copper-tin washers and secure the fuel supply line to the doser block assembly. Torque the banjo bolt to 35 N·m (26 lb·ft). Install fuel pressure regulator valve. Torque to 35 N·m (26 lb·ft)See Figure "Doser Block Assembly" .
3. Connect the fitting to the dosing fuel line on the doser block assembly. Torque to 16-18 N·m (12-13 lb·ft).See Figure "Doser Block Assembly" .
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. See Figure "Doser Block Assembly" .

Section 2.19.3
Removal of Doser Block Assembly Mounting Brackets

Removal steps are as follows:

1. Remove the doser block assembly. Refer to "2.19.1 Removal of Doser Block Assembly" .
2. Remove the four bolts securing the upper mounting bracket to the air intake throttle valve. See Figure "Doser Block Assembly Mounting Brackets Removal" .



1. Bolts (31–pin Connector Bracket)	4. Bracket
2. Bolts (Doser Block Mounting Bracket)	5. Bracket (Doser Block Mounting)
3. Bolts	6. Bracket (31–pin Connector Mounting)

Figure 2. Doser Block Assembly Mounting Brackets Removal

3. Remove the three bolts securing the lower mounting bracket to the cylinder block and remove the bracket. See Figure "Doser Block Assembly Mounting Brackets Removal" .

Section 2.19.4
Installation of Doser Block Assembly Mounting Brackets

Installation steps are as follows:

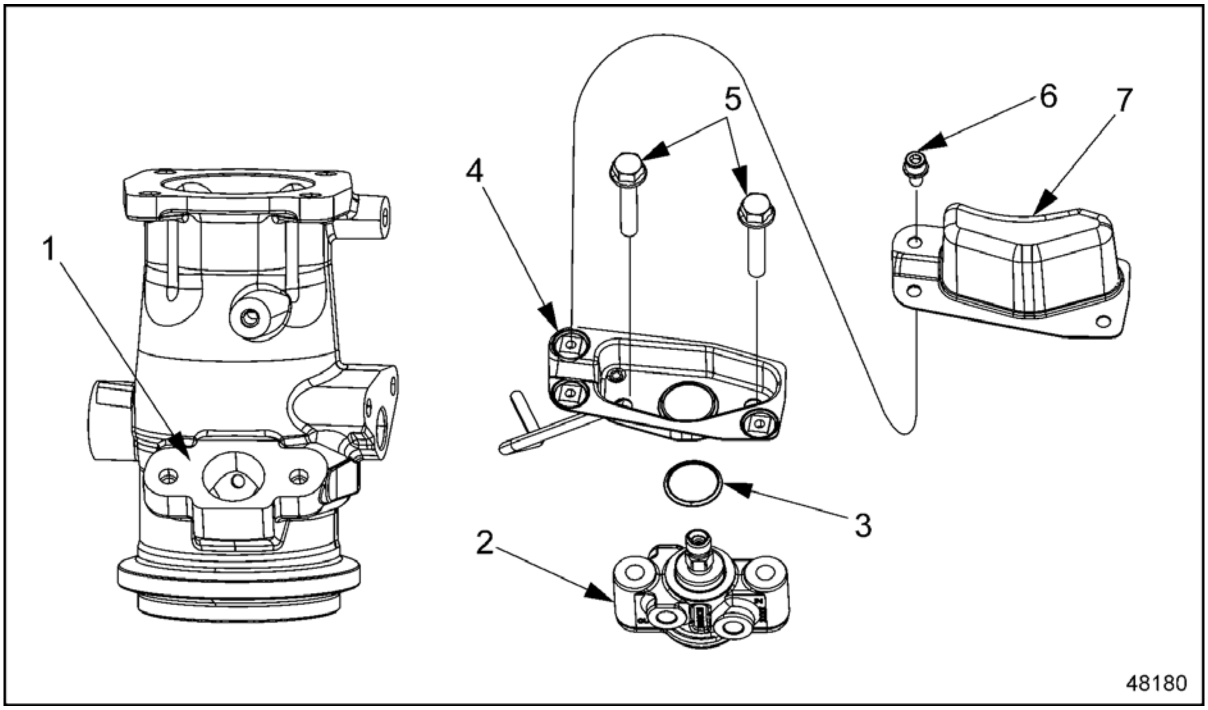
1. Secure the doser block lower mounting bracket to the cylinder block with two bolts. Torque the bolts to 45–55 N·m (33–40 lb·ft). See Figure "Doser Block Assembly Mounting Brackets Removal" .
2. Secure the doser block upper mounting bracket to the air intake throttle valve with four bolts. Torque the bolts to 20–30 N·m (15–22 lb·ft). See Figure "Doser Block Assembly Mounting Brackets Removal" .
3. Install the doser block assembly. Refer to "2.19.2 Installation of Doser Block Assembly" .

Section 2.20
Fuel Doser Valve

The Fuel Doser Valve (FDV) is part of the Aftertreatment System (ATS) and is used to inject fuel into the exhaust for the cleaning of the Diesel Particulate Filter (DPF).

Section 2.20.1
Removal of Fuel Doser Valve

Removal steps are as follows:



1. FDV Housing	5.Bolts (qty 2)
2. FDV	6. Torx Head Screws (qty 3)
3. O-ring	7. Upper FDV Spray Shield
4. Lower FDV Spray Shield and Drain	

Figure 1. Fuel Doser Valve

1. Drain the engine coolant.
2. Remove the three bolts securing the upper cover on the FDV and remove the cover. See Figure "Fuel Doser Valve" .
3. Disconnect the dosing fuel line from the FDV.
4. Remove the coolant in and out lines from the FDV.
5. Remove the two bolts securing the lower cover with drain and remove the cover. See Figure "Fuel Doser Valve" .
6. Remove the gasket and lower cover along with the FDV. Discard the gaskets.

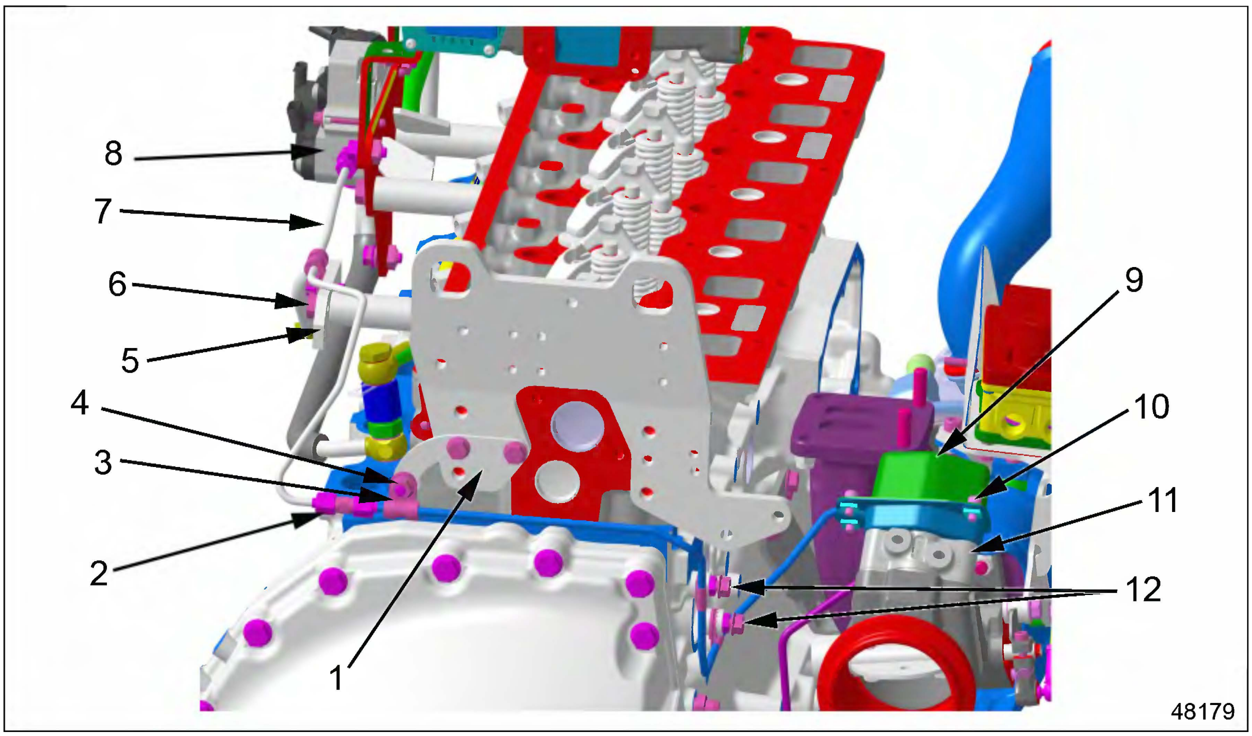
Section 2.20.2
Installation of Fuel Doser Valve

Installation steps are as follows:

1. Install the lower FDV spray shield and drain, new O-ring, and FDV, on the FDV housing and secure with two bolts. Torque the bolts to 20-30 Nm (15-22 lb·ft).
2. Connect the dosing fuel line to the FDV. Torque to 16-20 Nm (12-15 lb·ft).
3. Install the upper FDV spray shield to the lower FDV spray shield and drain on the FDV and secure with three screws. Torque the screws to 6-8 N·m (4-6 lb·ft).
4. Install the coolant inlet and outlet lines to the FDV. For single-stage turbocharger refer to "2.21.4 Installation of Single-Stage Fuel Doser Valve Coolant Lines" . For dual-stage turbocharger refer to "2.21.1 Removal of Dual-Stage Turbocharger Fuel Doser Valve Coolant Lines" .

Section 2.20.3
Removal of Dosing Fuel Line

Removal steps are as follows:



1. Fuel Dosing Line Mounting Bracket	7B. Fuel Dosing Line – Lower
2. Connector Fitting	8. Doser Block Assembly
3. Fuel Dosing Line Mounting Rubberized Clip (qty 2)	9. FDV Upper Cover (Spray Shield)
4. Bolt	10. Bolts (qty 3)
5. Fuel Dosing Line Side Mounting Bracket	11. FDV
6. Bolt	12. Bolts
7A. Fuel Dosing Line – Upper	13. Fuel Dosing Line (Non-Rubberized Clips (qty 2)

Figure 2. Dosing Fuel Line

1. Remove the three bolts securing the upper cover on the Fuel Dosing Valve (FDV) and remove the cover. See Figure "Dosing Fuel Line" .
2. Disconnect the dosing fuel line from the FDV. See Figure "Dosing Fuel Line" .
3. Remove the two bolts at clamps securing the dosing fuel line to the right side rear of the cylinder block. See Figure "Dosing Fuel Line" .
4. Remove the bolt and nut at the clamp securing the dosing fuel line to the bracket on the rear of the engine. If necessary, remove the bracket from the rear of the engine by removing the bolt attaching it to the cylinder block. See Figure "Dosing Fuel Line" .
5. Disconnect fitting at the connector union and remove that portion of the fuel line.
6. Remove the bolt and nut at the clamp securing the dosing fuel line to the bracket on the rear left side of the cylinder block. If necessary, remove the bracket from the side of the cylinder block by removing the attaching bolt. See Figure "Dosing Fuel Line" .
7. Disconnect the fitting connection at the dosing block assembly, located on the left side below the intake throttle valve, and remove that portion of the fuel line. See Figure "Dosing Fuel Line" .

Section 2.20.4
Installation of Dosing Fuel Line

Installation steps are as follows:

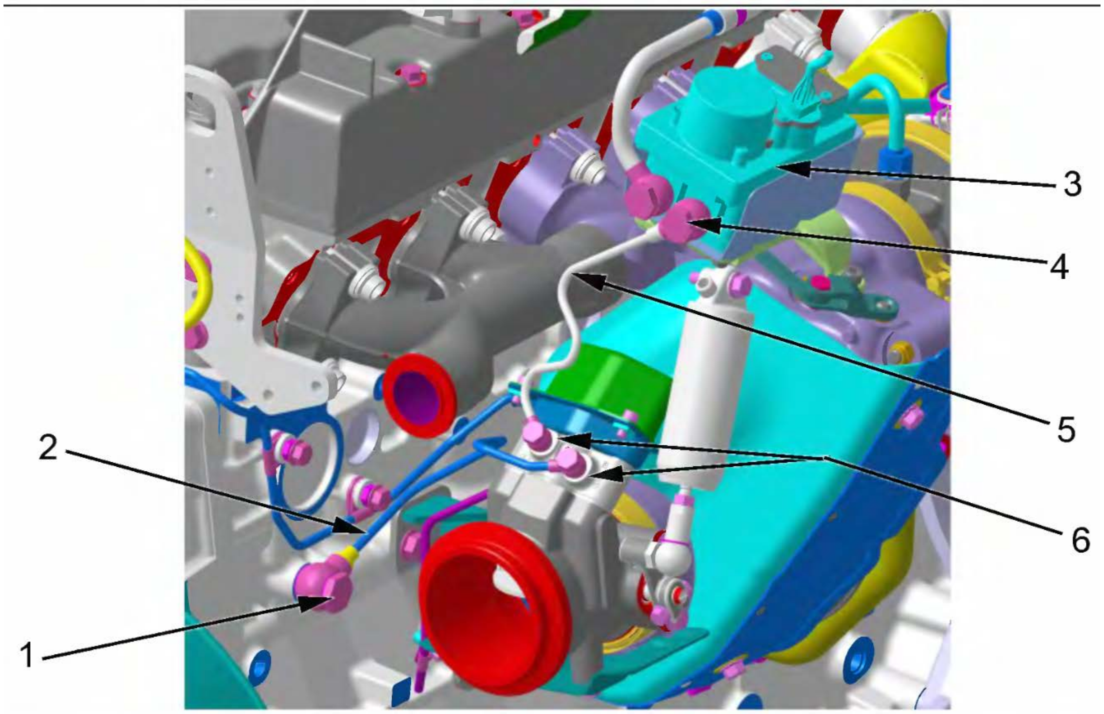
1. Loosely connect the dosing fuel line fitting connection to the doser block assembly. See Figure "Dosing Fuel Line" .
2. Connect the fuel dosing line to the FDV. Torque the fitting to 16-18 N·m (12-13 lb·ft). See Figure "Dosing Fuel Line" .
3. If removed, loosely attach the fuel line spacer and fuel line clip to the side of the cylinder block. Secure the fuel line to the bracket with a nut and bolt. Torque the nut and bolt to 20-30 N·m (15–22 lb·ft). See Figure "Dosing Fuel Line" .
4. If removed, loosely install the dosing fuel line mounting bracket to the rear of the cylinder block with a bolt. See Figure "Dosing Fuel Line" .
5. Connect the dosing fuel line to the connector union fitting on the fuel line going to the doser block assembly and connect the other end to the FDV. Tighten the fittings to 16-20 N·m (12–15 lb·ft). See Figure "Dosing Fuel Line" .
6. Secure the dosing fuel line to the mounting bracket at the rear of the cylinder block with a nut and bolt. Torque the nut and bolt to 20-30 N·m (15–22 lb·ft). See Figure "Dosing Fuel Line" .
7. Torque the bolt securing the dosing fuel line mounting bracket at the rear of the block to 20-30 N·m (15–22 lb·ft). See Figure "Dosing Fuel Line" .
8. Torque the bolt securing the fuel line mounting bracket on the left side of the block to 20-30 N·m (15–22 lb·ft).
9. Secure the upper cover of the FDV with three bolts. Torque the bolts to 6-8 N·m (53–71 lb·in). See Figure "Dosing Fuel Line" .

Section 2.21
Fuel Doser Valve Coolant Lines

The fuel doser valve is cooled by the engine coolant.

Section 2.21.1
Removal of Dual-Stage Turbocharger Fuel Doser Valve Coolant Lines

Removal steps are as follows:



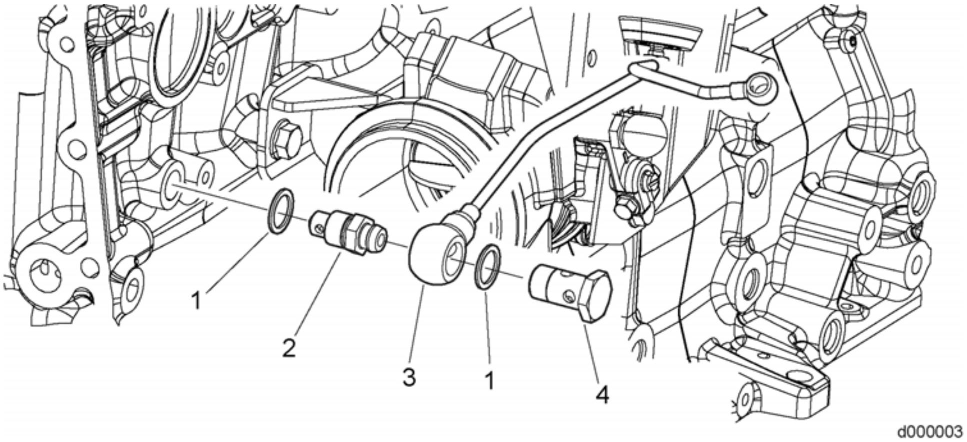
1. Banjo Bolt and Washers	3. Wastegate Actuator	5. FDV Coolant Outlet Line
2. FDV Coolant Inlet Line	4. Banjo Bolt and Washers	6. Banjo Bolts and Washers

Figure 1. Dual-Stage Fuel Doser Valve Coolant Lines

1. Remove the banjo bolts and washers attaching the FDV coolant outlet at the FDV and at the wastegate valve, remove the line and discard the washers. See Figure "Dual-Stage Fuel Doser Valve Coolant Lines" .
2. Remove the banjo bolts and washers securing the FDV coolant inlet line to the cylinder block and FDV. Remove the line and discard the washers. See Figure "Dual-Stage Fuel Doser Valve Coolant Lines" .

Section 2.21.2
Installation of Dual-Stage Turbocharger Fuel Doser Valve Coolant Lines

Installation steps are as follows:



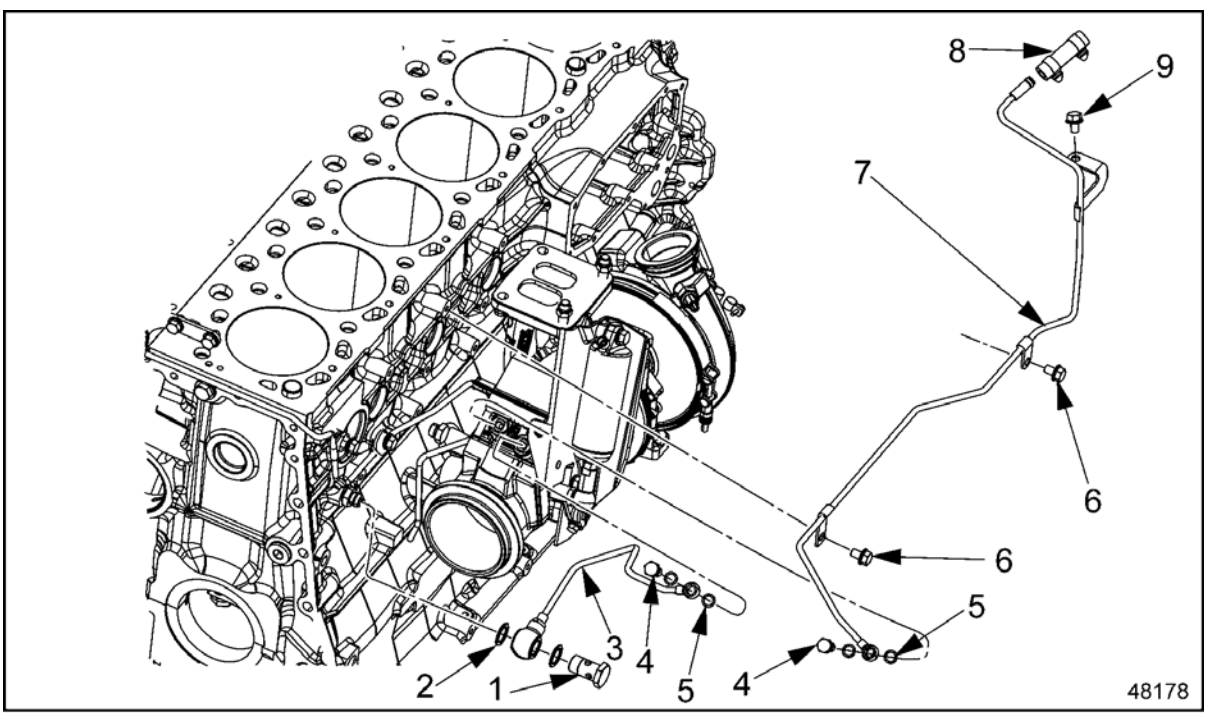
1. Washer	3. Banjo Bolt
2. Coolant	

Figure 2. Banjo Bolt At The Cylinder Block

1. Secure the FDV coolant outlet at the FDV and at the wastegate valve with banjo bolts and new washers. Torque the banjo bolt at the cylinder block to 40 – 45 N·m (30 – 33 lb·ft). Torque the banjo bolt at the FDV to 25 N·m (18 lb·ft). See Figure "Banjo Bolt At The Cylinder Block"
2. Secure the FDV coolant inlet line to the cylinder block and FDV with banjo bolts and two new washers. Torque the banjo bolt at the cylinder block to 13 – 17 N·m (10 – 12 lb·ft). Torque the banjo bolt at the FDV to 25 N·m (18 lb·ft). See Figure "Banjo Bolt At The Cylinder Block"

Section 2.21.3
Removal of Single-Stage Turbocharger Fuel Doser Valve Coolant Lines

Removal steps are as follows:



1. Banjo Bolt	6. Camp Bolts
2. Washers (qty 2)	7. FDV Coolant Outlet Line
3. FDV Coolant Inlet Line	8. Hose and Clamps
4. Banjo Bolt	9. Bolt
5. Washers (qty 2)	

Figure 3. Single-Stage Fuel Doser Valve Coolant Line

1. Remove the banjo bolts and washers attaching the FDV coolant inlet at the FDV and at the cylinder block. Discard washers. See Figure "Single-Stage Fuel Doser Valve Coolant Line" .
2. Remove the two bolts at clamps securing the FDV coolant outlet line to the cylinder block and bolt at bracket on line. See Figure "Single-Stage Fuel Doser Valve Coolant Line" .
3. Loosen the hose clamp from the hose at the EGR cooler coolant return pipe and remove the FDV coolant outlet line. See Figure "Single-Stage Fuel Doser Valve Coolant Line" .

Section 2.21.4
Installation of Single-Stage Fuel Doser Valve Coolant Lines

Installation steps are as follows:

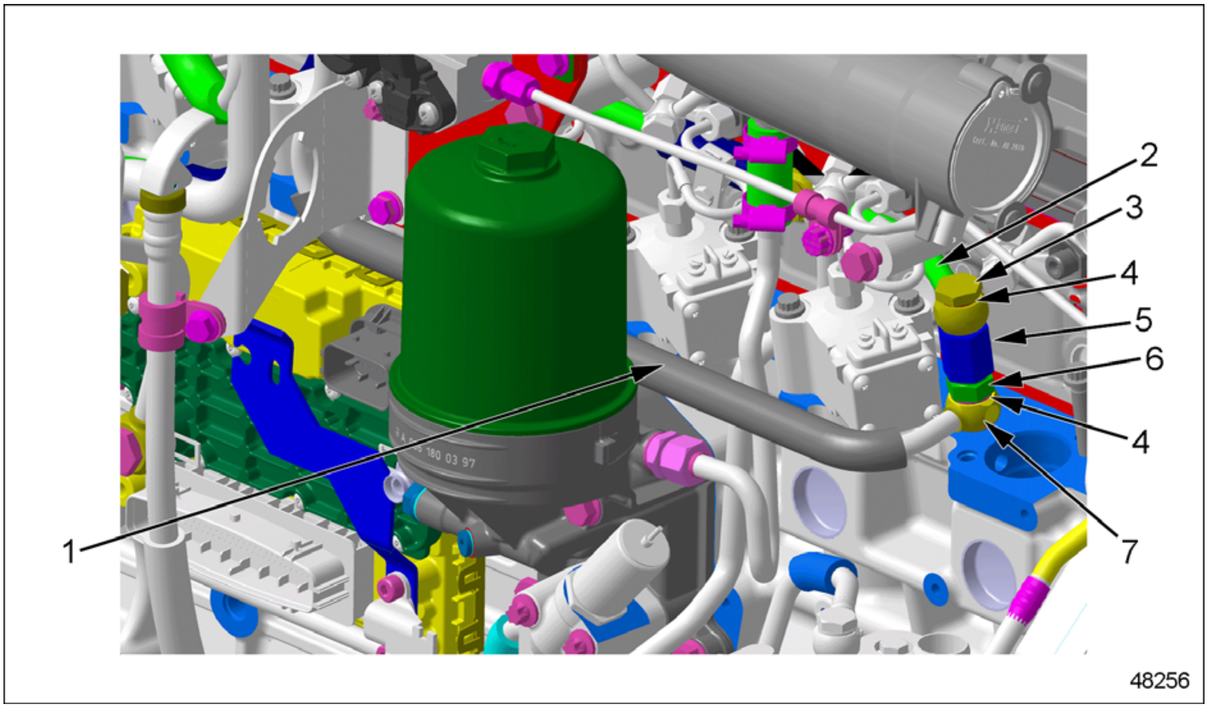
1. Loosely connect the FDV coolant inlet line to the FDV and cylinder block with banjo bolts and new washers. Torque the banjo bolt at the cylinder block to 40 - 45 N·m (29 – 33 lb·ft). Torque the banjo bolt at the FDV to 15–17 N·m (11–12 lb·ft). See Figure "Single-Stage Fuel Doser Valve Coolant Line" .
2. Connect the FDV coolant outlet line to the FDV banjo bolt and two new washers. Secure the two clamps on the coolant outlet line the cylinder with bolts. Torque the banjo bolt to 25 N·m (18 lb·ft). Torque the clamps bolts to 20 – 30 N·m (15 – 22 lb·ft). Attach the bracket to the charge air housing with bolt. Torque to 20 – 30 N·m (15 – 22 lb·ft).See Figure "Single-Stage Fuel Doser Valve Coolant Line" .
3. Connect the end of the FDV coolant outlet line to the EGR cooler coolant return pipe and secure hose with clamps. Tighten clamps to 2.0 – 2.5 N·m (18 – 22 lb·in). See Figure "Single-Stage Fuel Doser Valve Coolant Line" .

Section 2.22
Fuel Overflow Valve

Perform the following for the removal and installation of the fuel overflow valve.

Section 2.22.1
Removal of Fuel Overflow Valve

Removal steps are as follows:



1. Fuel Return Line	4. Washers	6. Banjo Fitting
2. Injector Fuel Return Line	5. Overflow Valve	7. Fuel Line to Doser Block Assembly
3. Banjo Bolt		

Figure 1. Fuel Overflow Valve

1. Remove the banjo bolt and washers securing the injector fuel return line to the overflow valve. See Figure "Fuel Overflow Valve" .
2. Use a wrench to hold the banjo fitting while removing the overflow valve from the fitting. See Figure "Fuel Overflow Valve" .

Section 2.22.2
Installation of Fuel Overflow Valve

Installation steps are as follows:

1. Install the overflow valve into the banjo fitting. Torque the overflow valve to 45 N·m (33 lb·ft).

See Figure "Fuel Overflow Valve" .

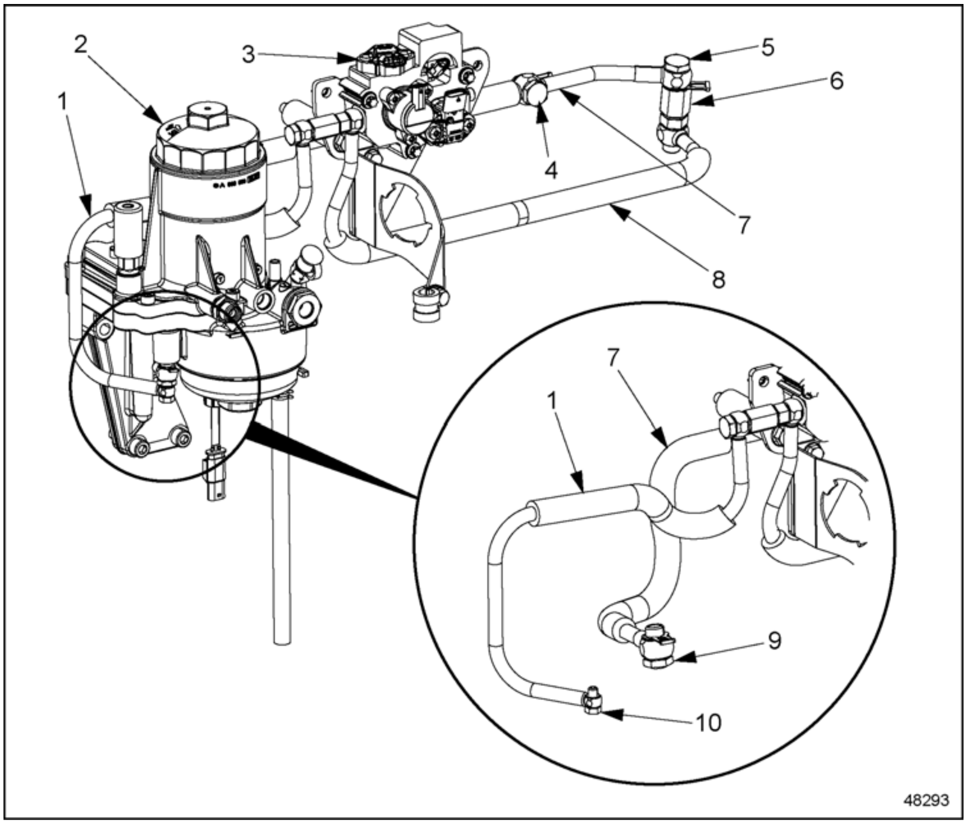
2. Secure the injector fuel return line to the overflow valve with a banjo bolt and new copper tin washers. Torque the banjo bolt to 45 N·m (33 lb·ft). See Figure "Fuel Overflow Valve" .

Section 2.23
Fuel Return Line

Perform the following for the removal and installation of the fuel return line.

Section 2.23.1
Removal of Fuel Return Line

Removal steps are as follows:



1. Fuel Return Line from Doser Block Assembly	6. Overflow Valve
2. Fuel Filter	7. Fuel Return Line
3. Doser Block Assembly	8. Fuel Return Line
4. Banjo Bolt	9. Adaptor Bolt
5. Banjo Bolt	10. Banjo Bolt

Figure 1. Fuel Return Line

1. Hold the overflow valve with a wrench and remove the banjo bolt and washers from the fuel return line. Discard the washers. See Figure "Fuel Return Line" .
2. Remove the banjo bolt and washers securing the fuel return line to the cylinder head. Discard the washers. See Figure "Fuel Return Line" .
3. Remove the banjo bolt and washers securing the fuel return line from the doser block assembly to

the bottom of the fuel filter. Discard the washers. See Figure "Fuel Return Line" .

4. Remove the adaptor bolt and washers securing the fuel return line to the bottom of the fuel filter. Remove the line and discard the washers. See Figure "Fuel Return Line" .

Section 2.23.2
Installation of Fuel Return Line

Installation steps are as follows:

1. Position the fuel return line behind the fuel filter and behind the EUP's.
2. Loosely secure the fuel return line to the cylinder head with a banjo bolt and copper - tin new washers. See Figure "Fuel Return Line" .
3. Loosely secure the fuel return line to the overflow valve with a banjo bolt and copper - tin new washers. See Figure "Fuel Return Line" .
4. Secure the fuel return line to the fuel filter with adaptor fitting and new copper-tin washers. Torque the adaptor fitting to 45 N·m (33 lb·ft). See Figure "Fuel Return Line" .
5. Torque the banjo bolt at the cylinder head to 45 N·m (33 lb·ft). See Figure "Fuel Return Line" .
6. While holding the overflow valve with a wrench, torque the banjo bolt to 45 N·m (33 lb·ft). See Figure "Fuel Return Line" .
7. Install the small banjo bolt and copper-tin washers securing the fuel return line from the doser block assembly to the bottom of the fuel filter if equipped. Torque the banjo bolt to 8 N·m (6 lb·ft). See Figure "Fuel Return Line" .

Additional Information

specifications

This section contains the specifications for servicing the engine.

Fuel Injectors

The fuel injection system torque values are listed in Table "Fuel Injection System Torque Values" .

Fastener Type	Torque N·m (lb·ft) unless otherwise noted
Electronic Unit Pump Mounting Bolt	65 (48)
Thrust Bolt	45 (33)
Tensioning Arm Bolt	35 (26)
Injector Harness Frame Screws	7–9 (5–7)
Fuel Injector Harness Nuts	1.75 (15 lb·in.)
MCM to Cylinder Block	20–30 (15–22)

Table 1. Fuel Injection System Torque Values

Fastener Type	Torque N·m (lb·ft) unless otherwise noted
Isolator Clamp to Bracket (High-Pressure Fuel Line)	8 (6)
High-Pressure Fuel Line Nuts (taper seat)	25–27 (18–20)
High-Pressure Fuel Line Nuts (ball seat)	35–37 (26–27)

Table 2. High Pressure Fuel Line Torque Values

Sensors

The sensor torques values are listed in Table "Sensor Torque Values" .

Fastener Type	Torque N·m (lb·ft) unless otherwise noted
Intake Manifold Pressure/Temperature Sensor	8–10 (6–7)
Engine Oil Pressure (EOP) Sensor	50 (37)
Engine Oil Temperature (EOT) Sensor	45 (33)
Engine Coolant Temperature (ECT) Sensor	30 (22)
Supply Fuel Temperature Sensor	30 (22)

Table 3. Sensor Torque Values

Fuel and Fuel Control

The fuel system torque values are Listed in Table "Fuel System Torque Values" . Listed in Table "Fuel Dosing System Torque Values" are the fuel dosing system torque values.

Fastener Type	Torque N·m (lb·ft) unless otherwise noted

Primary Fuel Filter Bowl	25 (221 lb·in.)
Secondary Fuel Filter Cover	25 (18)
Fuel Filter/Water Separator Housing to Cylinder Block	45 (33)
Fuel Suction and Delivery Line Banjo Bolts (Fuel Filter/Water separator)	40 (30)
Main Filter Cap (Fuel Filter/Water separator)	25 (18)
Fuel Pump Mounting Bolts	25 (18)
Pulley Mounting Bolt	75 (55)
Fuel Line Banjo Bolts (Fuel Pump)	45 (33)
Banjo Bolt — Fuel Return Line at Overflow Valve	45 (33)
Adaptor Fitting — On Bottom of Fuel Filter	45 (33)
Banjo Bolt — Fuel Return Line to Cylinder Head	45 (33)
Small Banjo Bolt — Fuel Line from FDV to Bottom of Fuel Filter	8 (6)

Table 4. Fuel System Torque Values

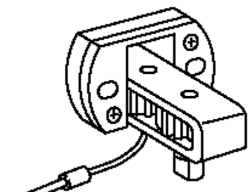
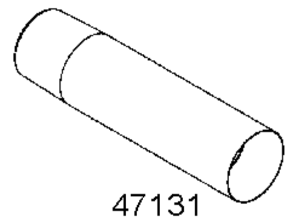
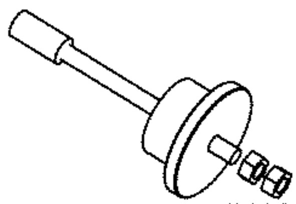
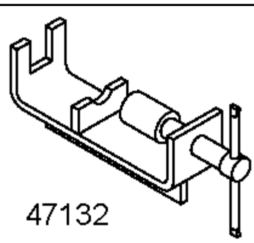
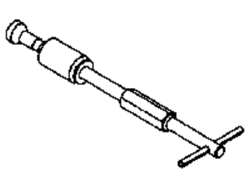
Fastener Type	Torque N·m (lb·ft)
Doser Block Assembly Mounting Bolts	8 (6)
Fuel Supply Line to Doser Block Assembly Banjo Bolt	45 (33)
Doser Block Assembly Mounting Bracket to Cylinder Block	50 (37)
Doser Block Assembly Upper Mounting Bracket to Air Intake Throttle Valve	25 (18)
Doser Shielding pot to Fuel Doser Valve Bolts	25 (18)
Doser Shielding Upper Cover to Lower Cover Bolts	6–8 (53 in – 71in)
Banjo Bolts to Coolant In and Out Lines on Fuel Doser Valve	25 (18)
Fuel Dosing Line Mounting Bracket and Spacer to Side of Cylinder Block, Nut and Bolt	40–45 (29–33)
Fuel Dosing Line to Mounting Bracket at Rear of Cylinder, Block Nut and Bolt	20–30 (15–22)
Fuel Dosing Line Clamp to Mounting Bracket to Rear of Cylinder Block Bolt	20–30 (15–22)
Fuel Dosing Line Clamp to Mounting Bracket to Side of Cylinder Block Bolt	20–30 (15–22)
Fuel Doser Valve Upper Cover to Valve Bolts	6–8 (53 in – 71in)
Fuel Doser Valve and Lower Cover to FDV Housing Bolts	20–30 (15–22)
Bolts — Left Front Engine Lifting Bracket	45–55 (33–40)
Bolts — Hi-mount Fan Secondary Mounting Bracket	45–55 (33–40)

Table 5. Fuel Dosing System Torque Values

Special Tools

The special tools used within this chapter are listed in Table "Special Tools" .

Tool	Description	Usage	Part Number
	Engine Barring Tool	Used to lock or rotate the engine flywheel.	J–46392

 46790			
 47131	Unit Pump O-ring Installer	Used to install O-rings on unit injection pump.	J–46382
 47129	Electronic Unit Pump Puller	Used to remove the electronic unit pump from the cylinder block.	J–46375
 46769	Injector Line Socket	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 Kit	Used to remove the injector protective sleeve from the cylinder head.	J–46381

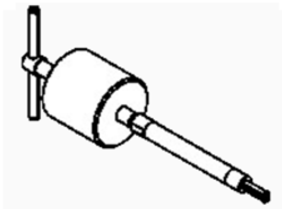
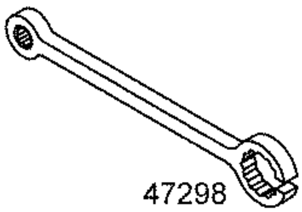
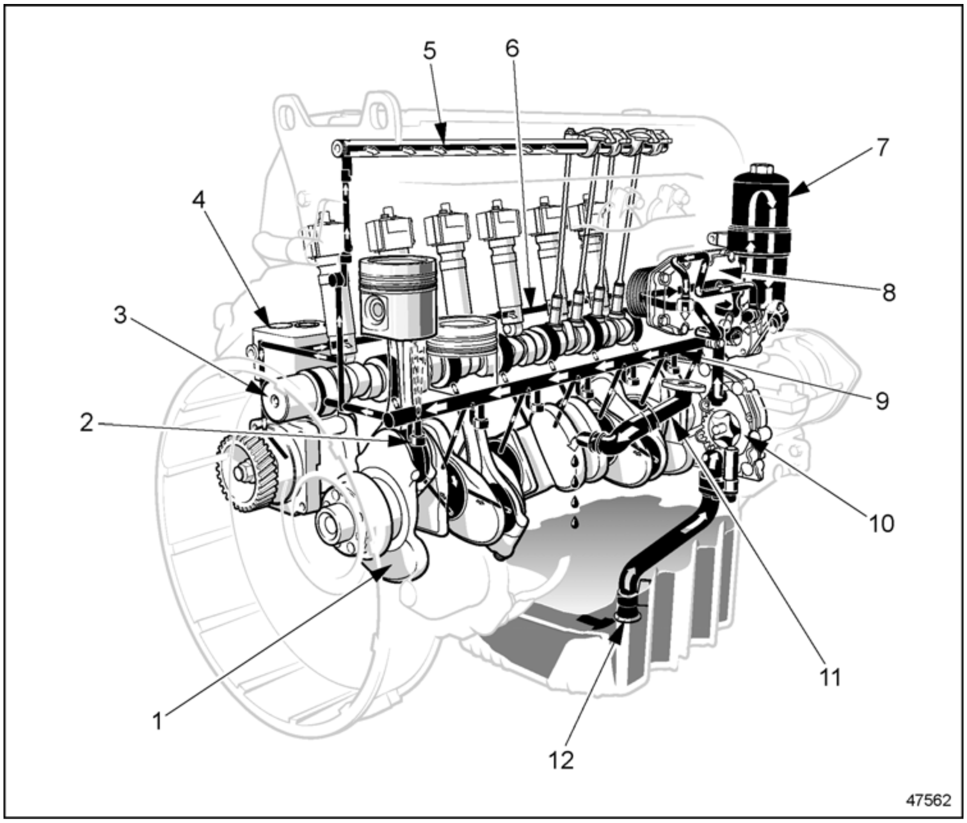
 46767	Injector Heat Isolator Remover	Used to remove a stuck fuel injector heat isolator from the cylinder head.	J–46933
 47298	Thrust Bolt Torque Wrench Adaptor	Used to torque the thrust bolt.	J–47484

Table 6. Special Tools

Section 3.1
Engine Oil Circuit

The MBE 900 engines have a force–feed lubricating oil circuit supplied by a rotary oil pump. See Figure "Engine Oil Flow Diagram" for the oil flow diagram of the engine.



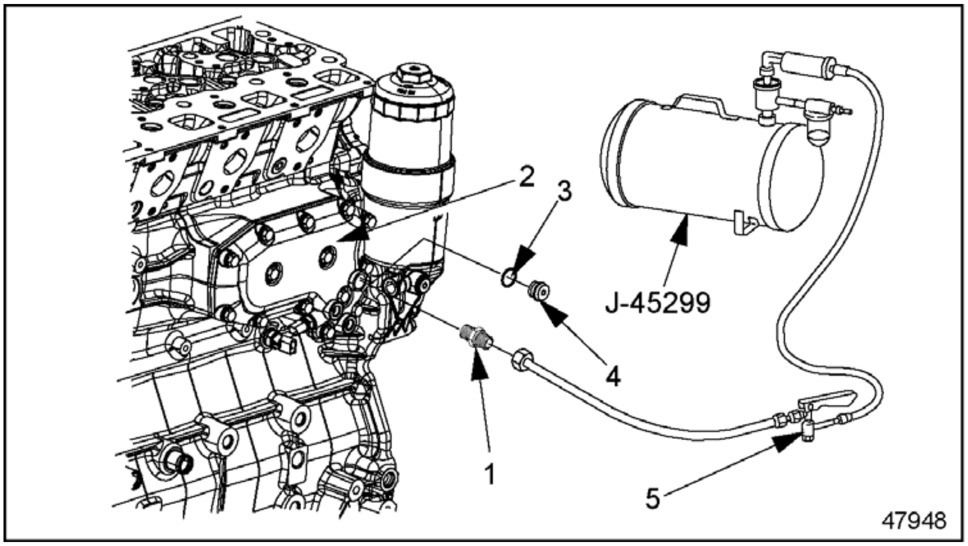
1. Crankshaft	7. Oil Filter
2. Piston Cooling Nozzle (cyl 6)	8. Oil Cooler
3. Camshaft	9. Main Oil Gallery
4. Air Compressor	10. Oil Pump
5. Rocker Arm Shaft	11. Oil Return from Turbocharger
6. Oil Gallery to Unit Pumps	12. Oil Pick-Up Tube

Figure 1. Engine Oil Flow Diagram

Section 3.1.1
Filling the Engine Oil Circuit

Fill the engine oil circuit as follows:

1. Remove the cylinder head cover. Refer to "1.1.1 Removal Cylinder Head Cover" .
2. Remove the Allen head screw plug from the oil cooler. See Figure "Filling the Engine Oil Circuit" .



1. Adaptor	4. Screw Plug
2. Oil Cooler	5. Shutoff Valve
3. Seal	

Figure 2. Filling the Engine Oil Circuit

3. Install adaptor from pre-oiler kit (J-45299) into the oil cooler housing and attach hose from oil primer. See Figure "Filling the Engine Oil Circuit" .
4. Pressurize the pre-oiler can (J–45299) to 303 kPa (44 psi), and then connect it to the oil cooler. See Figure "Filling the Engine Oil Circuit" .
5. Open the shutoff valve and check the oil at the rocker arms. When the oil flowing out at the rocker arms is free of bubbles, close the valve.
6. Disconnect the pre-oiler can. Remove the adaptor from the oil cooler housing and install the screw plug and a new seal in the oil cooler. Tighten the plug 20 N·m (15 lb·ft). See Figure "Filling the Engine Oil Circuit" .
7. Install the cylinder head cover. Refer to "1.1.2 Installation of 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.

8. Start the engine. Check the gauge for the correct oil pressure; check the lubrication system for leaks. Check the oil level and add if needed.

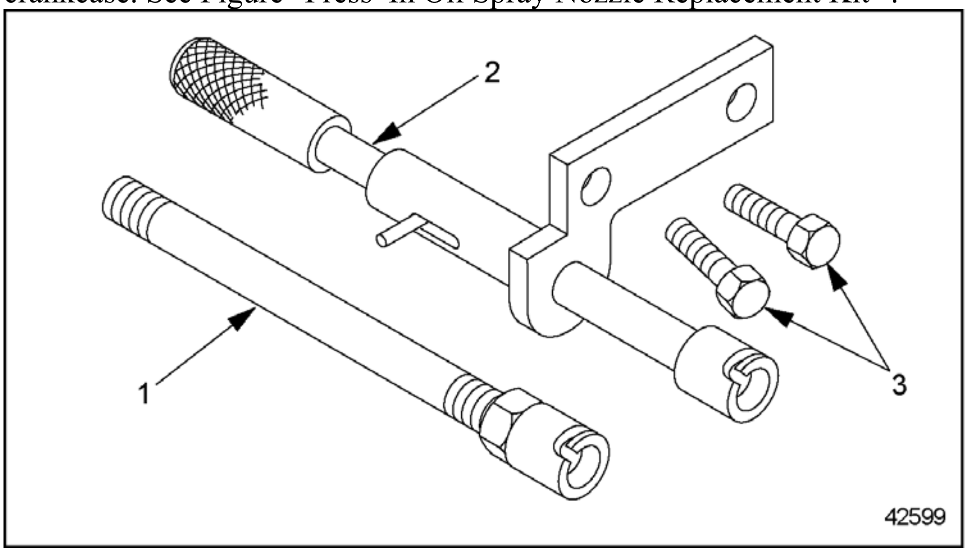
Section 3.2
Oil Spray Nozzle

If damaged, the oil spray nozzle must be replaced, not repaired.

Section 3.2.1
Removal of Press–In Oil Spray Nozzle

Removal steps are as follows:

1. Remove the engine from the vehicle.
2. Remove the oil pan. Refer to "3.7.1 Removal of Oil Pan" .
3. Remove the crankshaft. Refer to "1.8.1 Removal of Crankshaft" .
4. Use the oil spray nozzle replacement kit (J–44846) to remove and replace the oil spray nozzle. It contains a remover tool, an installer tool, and two hex bolts for mounting the installer to the crankcase. See Figure "Press–In Oil Spray Nozzle Replacement Kit" .



1. Remover Tool	3. Hex bolts (mount installer to crankcase)
2. Installer Tool	

Figure 1. Press–In Oil Spray Nozzle Replacement Kit

5. Attach the EUP puller (J–46375) to the threaded end of the remover tool (J–44846) . See Figure "Remover Assembly " .

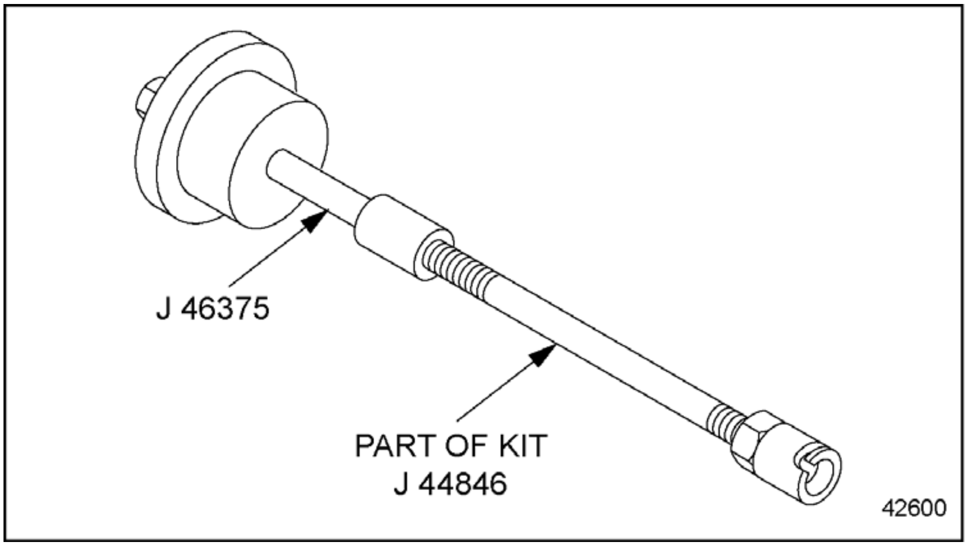


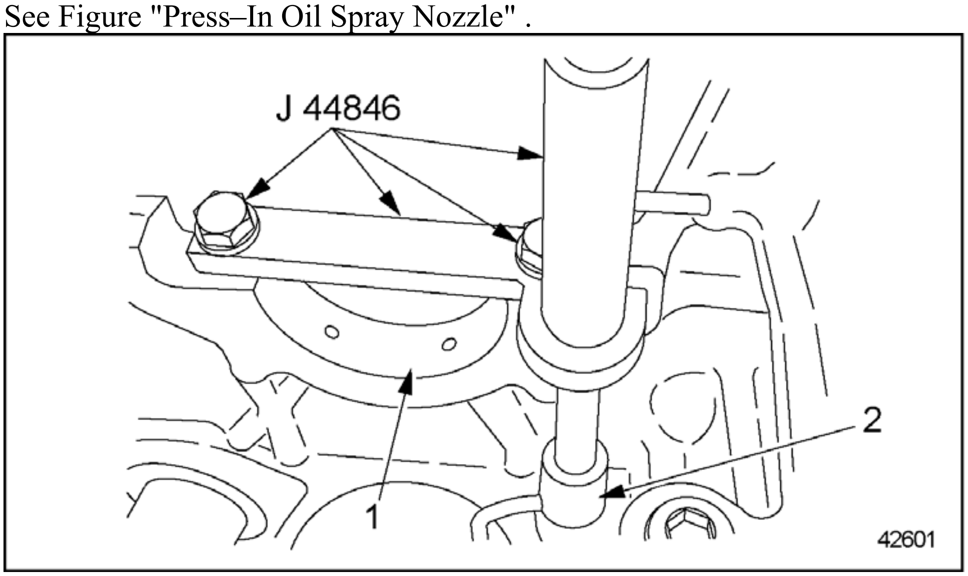
Figure 2. Remover Assembly

6. Using the remover assembly, remove the oil spray nozzle.
   a. Insert the slot in the end of the remover tool around the spray tube and turn it so the spray tube is locked in place.
   b. Operate the slide hammer on the impact extractor and remove the oil spray nozzle from the crankcase.
   c. Discard the old oil spray nozzle.

Section 3.2.2
Installation of Press–In Oil Spray Nozzle

Installation steps are as follows:

1. Insert a new oil spray nozzle into the slot in the end of the installer tool (J–44846) until the spray tube is locked in place.
2. Using the hex bolts provided in the kit, attach the hanger arm of the installer tool to the bolt holes in the crankcase where the bearing caps were installed. Tighten the hex bolts to 34 N·m (25 lb·ft). See Figure "Press–In Oil Spray Nozzle" .

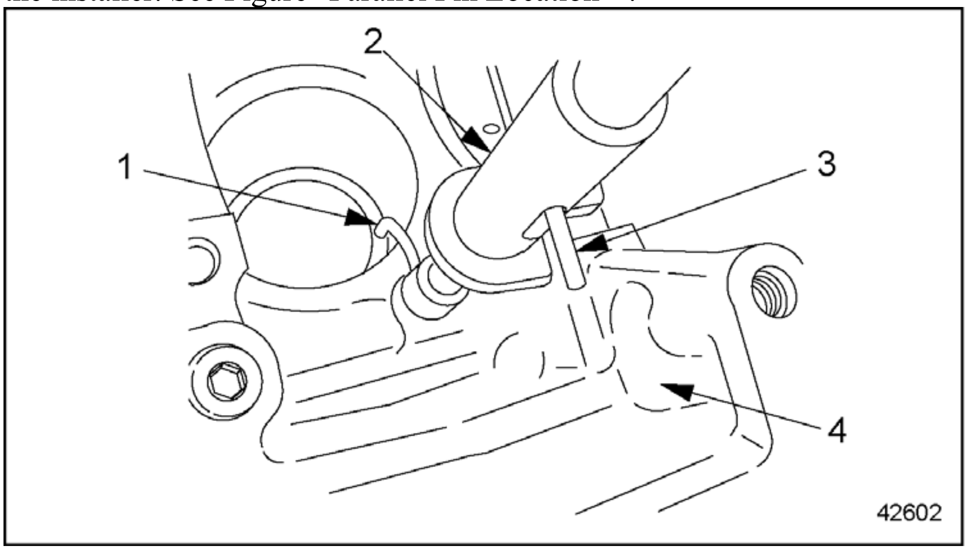


1. Main Bearing Race	2. Oil Spray Nozzle

Figure 3. Press–In Oil Spray Nozzle

Note: The oil spray nozzle must be vertical with respect to the crankcase when it is installed.

3. Install the oil spray nozzle in the crankcase, taking care to note the location of the parallel pin on the installer. See Figure "Parallel Pin Location " .



1. Oil Spray Nozzle	3. Parallel Pin
2. Installer Tool	4. Crankcase (cylinder block)

Figure 4. Parallel Pin Location

   a. Make sure the oil spray nozzle is correctly positioned in its hole in the crankcase.
   b. Check the location of the parallel pin to make sure the oil spray nozzle is vertical with respect to the crankcase.
   c. Using a hammer, hit the top of the installer until the oil spray nozzle is fully seated. The spray nozzle should be firmly in place.
   d. Remove the installer tool from the crankcase.
4. Do this procedure for each oil spray nozzle to be replaced.
5. Clean the oil passage holes in the crankcase main bearing race.
6. Install the crankshaft. Refer to "1.8.2 Installation of Crankshaft" .

NOTICE:

If the oil spray nozzle is not correctly positioned with respect to the piston, serious engine damage could result.

7. Turn the crankshaft and check, at each cylinder, the clearance between the piston and the oil spray nozzle.
8. Install the oil pan. Refer to "3.7.2 Installation of Oil Pan" .
9. Install the engine in the vehicle.

10. Fill the crankcase to the specified oil level. Do not overfill the crankcase.

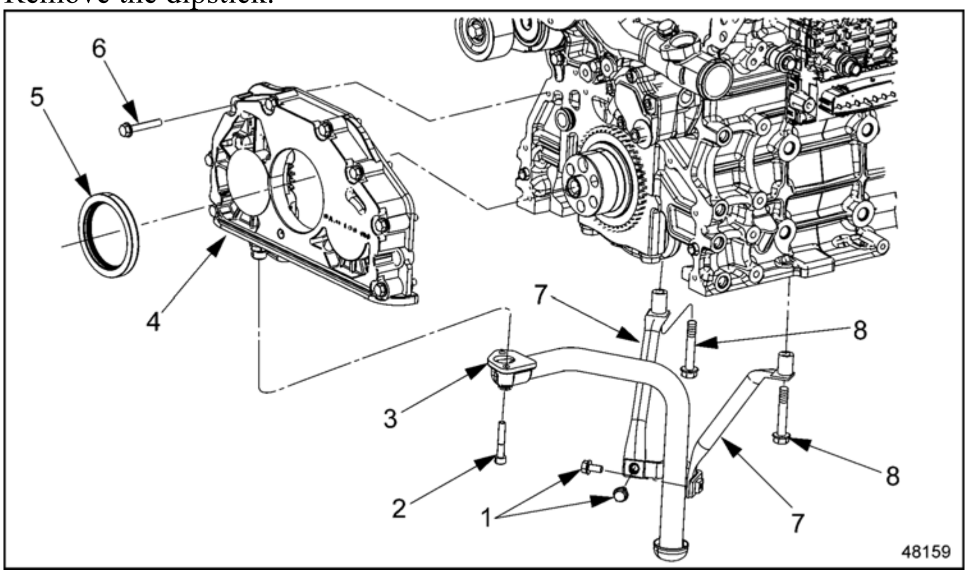
Section 3.3
Oil Pump

The rotary oil pump that supplies the force–feed lubricating oil circuit is positioned at the front of the cylinder block and driven by the crankshaft drive gear.

Section 3.3.1
Removal of Oil Pump

Removal steps are as follows:

1. Remove the vibration damper. Refer to "1.11.1 Removal of Vibration Damper" .
2. Remove the oil pan from the crankcase. Refer to "3.7.1 Removal of Oil Pan" .
3. Remove the dipstick.



1. Bolts (Bracket Mounting)	6. Bolts (Oil Pump Mounting)
2. Bolts (Suction Pipe to Oil Pump)	7. Bracket (Suction Pipe)
3. Suction Pipe	8. Bolts (Bracket to Block)
4. Oil Pump	9. Connection Fitting
5. Oil Seal	

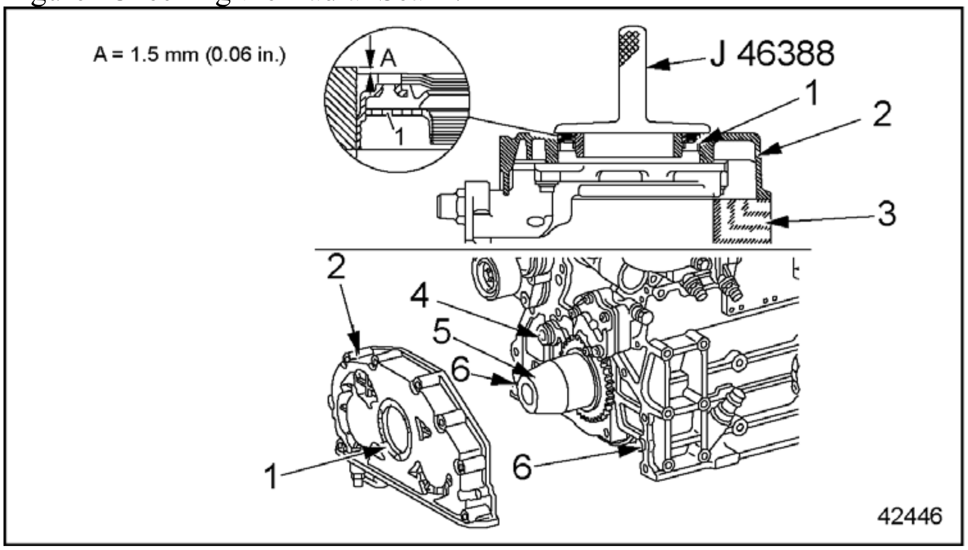
Figure 1. Oil Pump

4. Remove the suction pipe. See Figure "Oil Pump" .
5. Remove the oil pump using care not to damage the sealing surface. See Figure "Oil Pump" .
6. Remove the oil seal and the O–ring at the connection fitting. See Figure "Oil Pump" .
7. Thoroughly clean the contact surfaces of the oil pump.

Section 3.3.2
Installation of Oil Pump

Installation steps are as follows:

1. Lubricate a new O–ring with clean engine oil and install at the connection fitting. See Figure "Oil Pump" .
2. Using the front seal installer (J–46388) , press in the radial seal. Make sure the seal is evenly installed around the entire circumference of the oil pump. Check the setback of the seal. See Figure "Checking the Radial Seal" .



1. Radial Seal	4. Connection Fitting
2. Oil Pump	5. Guide Sleeve
3. Base	6. Dowel Pin

Figure 2. Checking the Radial Seal

3. Coat the contact surface between the block and the oil pump with Loctite® 574.
4. Position the front seal installer (J–46388) guide sleeve on the crankshaft flange and install the oil pump. Pay special attention to the dowel pin and the position of the drive gear. Tighten the oil pump to cylinder block bolts to 25 N·m (18 lb·ft). Remove the guide sleeve.

   Note: It may be necessary to rock the pump counterclockwise so the teeth of the gear can properly align with the crankshaft drive gear.

5. Install the suction pipe to the oil pump. Torque the bolts to 20–30 N·m (15–22 lb·ft). See Figure "Oil Pump" .
6. Install the suction pipe clamps to the support brackets and torque M8 bolts to 20–30 N·m (15–22 lb·ft).
7. Install the suction pipe support brackets to the bottom of the cylinder block. Torque the M10 support bracket bolts to 45–55 N·m (33–41 lb·ft).
8. Install the oil pan with a new gasket. Refer to "3.7.2 Installation of Oil Pan" .
9. Install the vibration damper. Refer to "1.11.2 Installation of Vibration Damper" .
10. Fill the engine with the correct amount and appropriate type of clean engine oil. Do not overfill.

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.
12. Check the engine oil level and add oil if necessary.

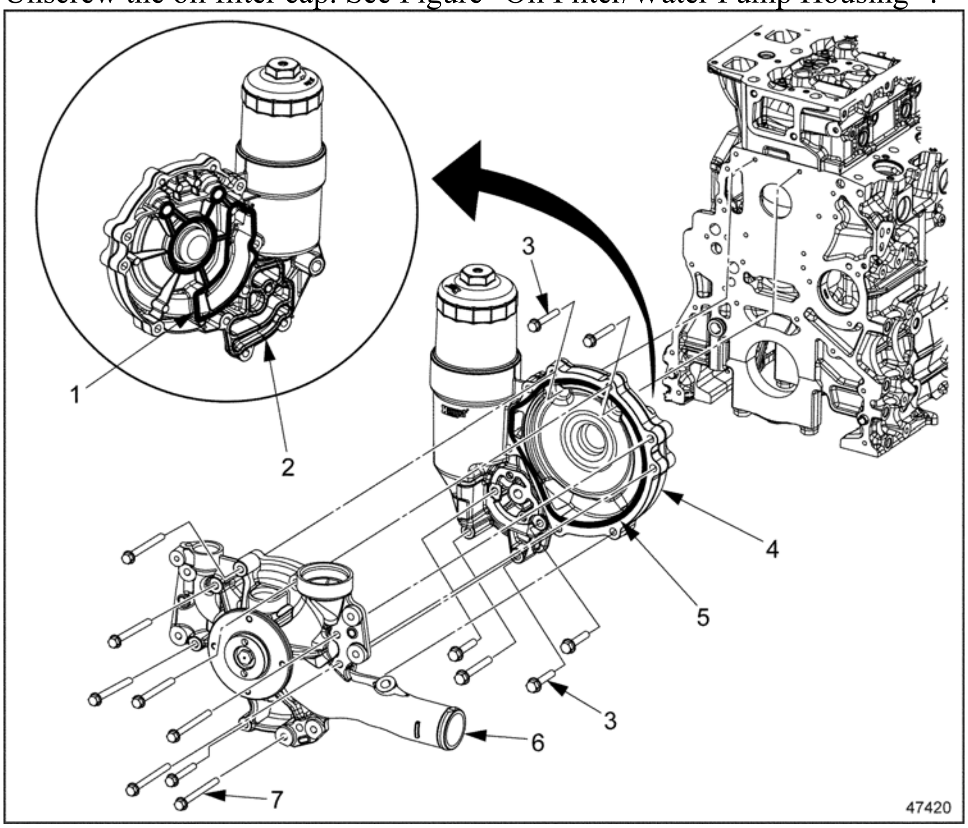
Section 3.4
Oil Filter Housing

Filters and their housing are an integral part of the fuel system.

Section 3.4.1
Removal of Oil Filter Housing

Removal steps are as follows:

1. Remove the poly–V belt. Refer to "9.4.3 Removal of Coolant Pump and Alternator Belt" . Remove the belt tensioner. Refer to "9.4.3 Removal of Coolant Pump and Alternator Belt" .
2. Unscrew the oil filter cap. See Figure "Oil Filter/Water Pump Housing" .



1. Oil Filter/Water Pump Housing Gasket (Rear)	5. Oil Filter/Water Pump Housing Gasket (Front)
2. Oil Filter Housing Gasket	6. Water Pump
3. Oil Filter/Water Pump Housing Mounting Bolts	7. Water Pump Mounting Bolts
4. Oil Filter/Water Pump Housing	

Figure 1. Oil Filter/Water Pump Housing

3. Disconnect the wiring harness from the oil pressure/temperature sensor.
4. Remove the water pump. Refer to "4.3.1 Removal of Water Pump" .

5. Remove the banjo bolt(s) and washers for the oil supply line(s) to the turbocharger(s) on the oil filter housing.
6. Remove the filter element and inspect it and the O–ring for damage. Replace only if necessary.
7. Remove bolts securing the oil filter housing to the crankcase and remove housing. Be prepared to collect any oil which runs out of the housing, and dispose of it properly. See Figure "Oil Filter/Water Pump Housing" .
8. Remove the two rear filter housing gaskets and discard. See Figure "Oil Filter/Water Pump Housing" .

Section 3.4.2
Installation of Oil Filter Housing

Installation steps are as follows:

1. Using a two new gaskets on the rear of the oil filter housing and secure to the crankcase. Torque the six bolts to 25 N·m (18 lb·ft). See Figure "Oil Filter/Water Pump Housing" .
2. Connect the turbocharger oil supply line(s) to the oil filter housing, secure with banjo bolt(s) and new washers. Torque the banjo bolt(s) 25 N·m (18 lb·ft).
3. Install the water pump. Refer to "4.3.2 Installation of Water Pump" .
4. Connect the wiring harness to the oil pressure/temperature sensor.
5. Install the oil filter element and cap. Using a 36–mm socket, tighten the cap 25 N·m (18 lb·ft).
6. Install the belt tensioner. Refer to "9.4.2 Installation of Fan Belt" .
7. Install the poly–V belt. Refer to "9.4.2 Installation of Fan Belt" .

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. Check the engine oil level and add oil if necessary.

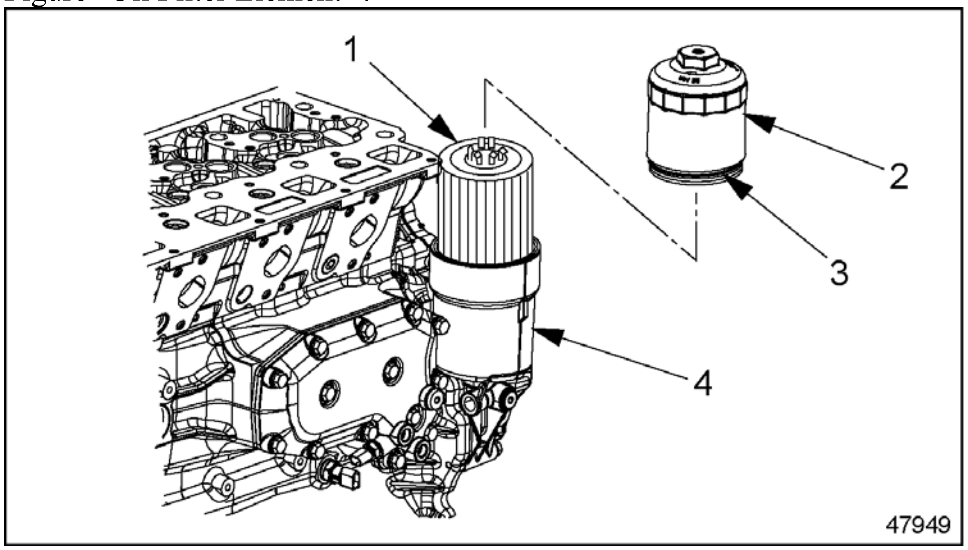
Section 3.5
Oil Filter Element

Replace the oil filter element. Filters and their housing are an integral part of the fuel system.

Section 3.5.1
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 "Oil Filter Element" .



1. Oil Filter Element	3. O-ring Seal
2. Oil Filter Cap	4. Oil Filter Housing

Figure 1. Oil Filter Element

2. Unscrew the cap and filter and allow the oil to drain into the housing. After draining, remove the assembly from the housing.

   Note: Use care to prevent foreign objects from entering the filter housing.

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 coat a new O–ring with engine oil and install it.
5. Insert a new filter element into the cap.
6. Install the element and cap assembly on the filter housing. Tighten the cap 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.

7. Start the engine and check for leaks.
8. Check the engine oil level and add oil if necessary.

Section 3.6
Oil Cooler

While performing its lubricating and cooling functions, the oil absorbs a considerable amount of heat, and this heat must be dissipated by an oil cooler.

Section 3.6.1
Removal of Oil Cooler

Removal steps are as follows:

WARNING:

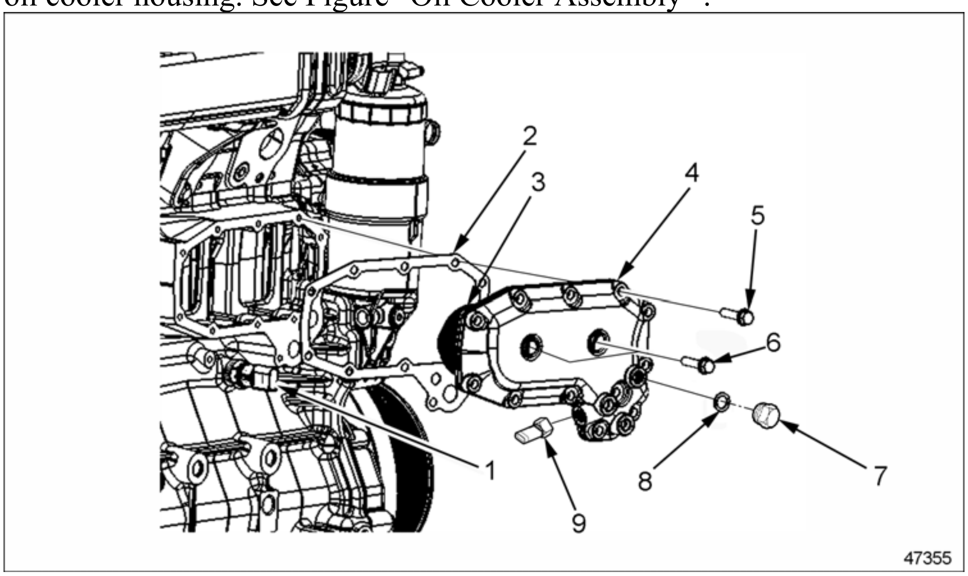
HOT COOLANT

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.

   Note: If the cooling system is rusty, it should be flushed.

2. Remove the vent tube at the turbocharger housing.
3. Disconnect the wiring connector from the oil temperature sensor and remove the sensor from the oil cooler housing. See Figure "Oil Cooler Assembly" .



1. Engine Oil Pressure Sensor	6. Element Bolts
2. Gasket	7. Screw Plug
3. Oil Cooler Element	8. Seal Washer

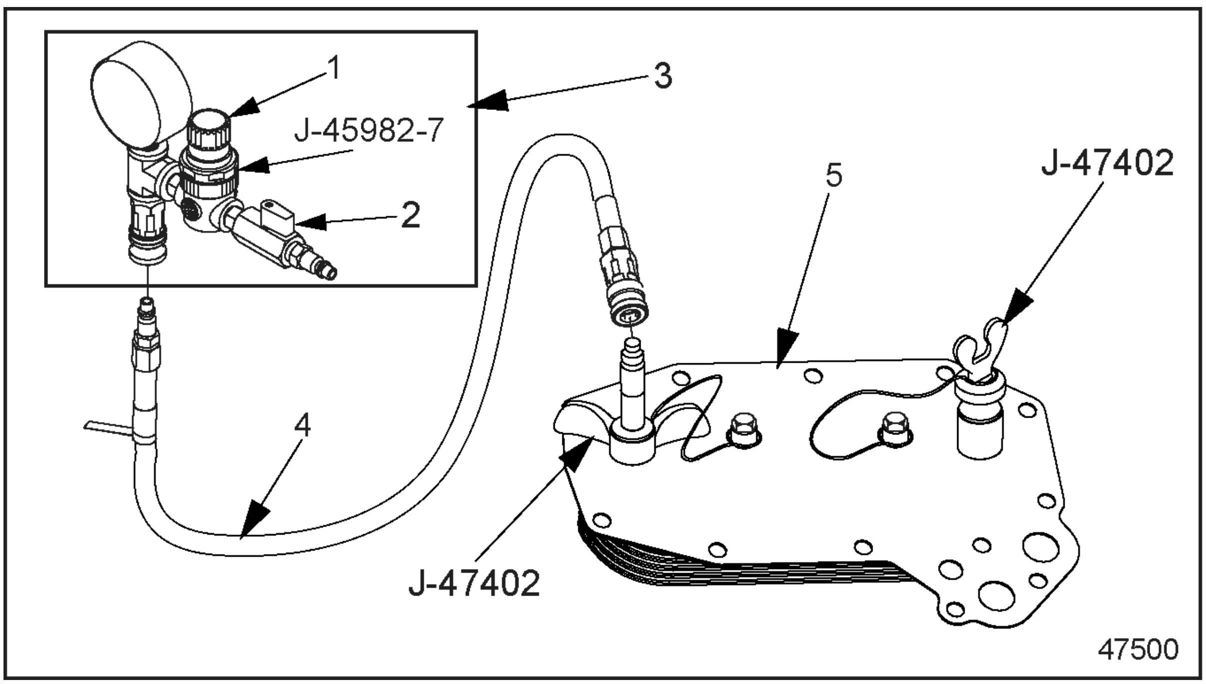
4. Engine Oil Cooler Cover	9. Engine Oil Temperature Sensor
5. Cooler Bolts	

Figure 1. Oil Cooler Assembly

4. Disconnect the oil pressure line at the top of the turbocharger.
5. Remove the banjo bolt and washers from the oil filter housing and remove the oil pressure line. Discard the washers.
6. Remove the seal plug and seal washer from the oil cooler and drain the oil into a suitable container. Discard the seal washer. See Figure "Oil Cooler Assembly" .
7. Remove the oil cooler cover and element and gasket from the cylinder block. Discard the gasket. See Figure "Oil Cooler Assembly" .
8. Remove the oil cooler element and gasket from the oil cooler cover. Discard the gasket.

Section 3.6.1.1
Testing of Oil Cooler Element Pressure

Pressure test the oil cooler element for leaks as follows:



1. Regulator Valve	4. Pressure Hose
2. Shutoff Valve	5. Oil Cooler Element
3. Regulator and Gauge	

Figure 2. Pressure Checking the Oil Cooler Element

1. Install the air supply test adapter to one of the oil passages. See Figure "Pressure Checking the Oil Cooler Element" .
2. Install test adapter plug to the opposite oil passage. See Figure "Pressure Checking the Oil Cooler

Element" .
3. Using the existing bolts from the oil cooler cover attach the safety straps. See Figure "Pressure Checking the Oil Cooler Element" .
4. Connect pressure hose to the pressure regulator (J-45982-7). See Figure "Pressure Checking the Oil Cooler Element" .
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 its 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 element 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.

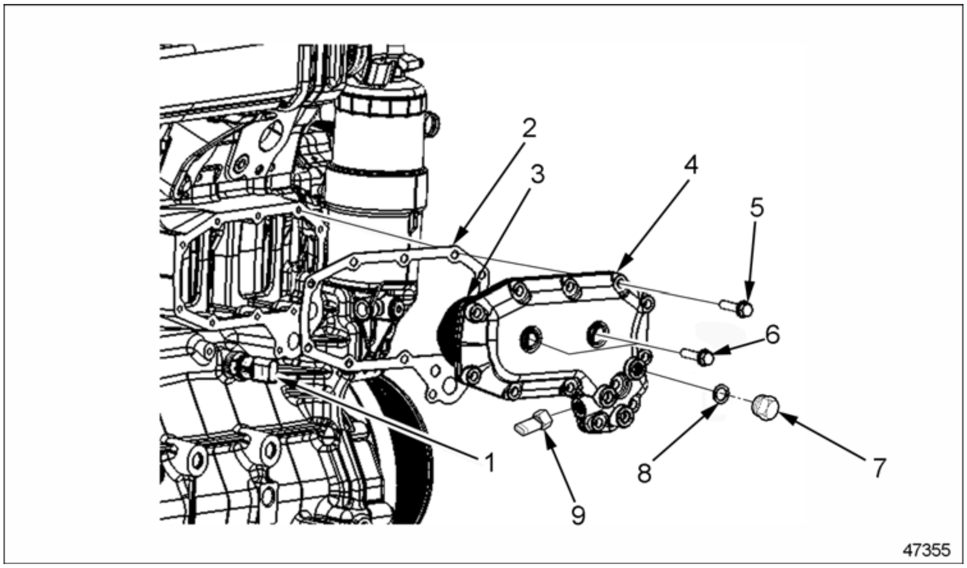
10. Submerge the oil cooler element completely in a hot water tank. Leave the element submerged for five minutes.
11. In the event of failed element, a steady stream of air bubbles will be noticed. Replace the oil cooler element.

    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.

Section 3.6.2
Installation of Oil Cooler

Installation steps are as follows:



1. Engine Oil Pressure Sensor	6. Element Bolts
2. Gasket	7. Screw Plug
3. Oil Cooler Element	8. Seal Washer
4. Engine Oil Cooler Cover	9. Engine Oil Temperature Sensor
5. Cooler Bolts	

Figure 3. Oil Cooler Assembly

1. Attach the oil cooler element and new element gasket to the housing cover. Do not tighten the housing cover bolt at this time.
2. Install the housing cover and element and a new gasket on the cylinder block. Tighten the mounting bolts to 25 N·m (18 lb·ft). See Figure "Oil Cooler Assembly" .
3. Tighten the housing cover to element bolts to 25 N·m (18 lb·ft). See Figure "Oil Cooler Assembly" .
4. Install the screw plug with a new seal in the cooler housing. Tighten the plug 20 N·m (15 lb·ft). See Figure "Oil Cooler Assembly" .
5. Attach the oil pressure line to the oil filter and the turbocharger:
   a. Secure the oil pressure line to the oil filter with the banjo bolt and new seal washers. Torque the banjo bolt to 25 N·m (18 lb·ft).
   b. Secure the oil pressure line to the top of the turbocharger. Tighten the fitting securely.
6. Install the oil temperature sensor in the cooler housing. Torque the sensor to 45 N·m (33 lb·ft).
7. Connect the wiring harness to the oil temperature sensor.
8. Install the vent tube at the turbocharger housing.
9. Install the oil filter cap. Replace the O–ring. Tighten the cap 25 N·m (18 lb·ft).
10. Fill the cooling system.
11. Check the engine oil level and add oil as necessary.

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 and check for leaks.

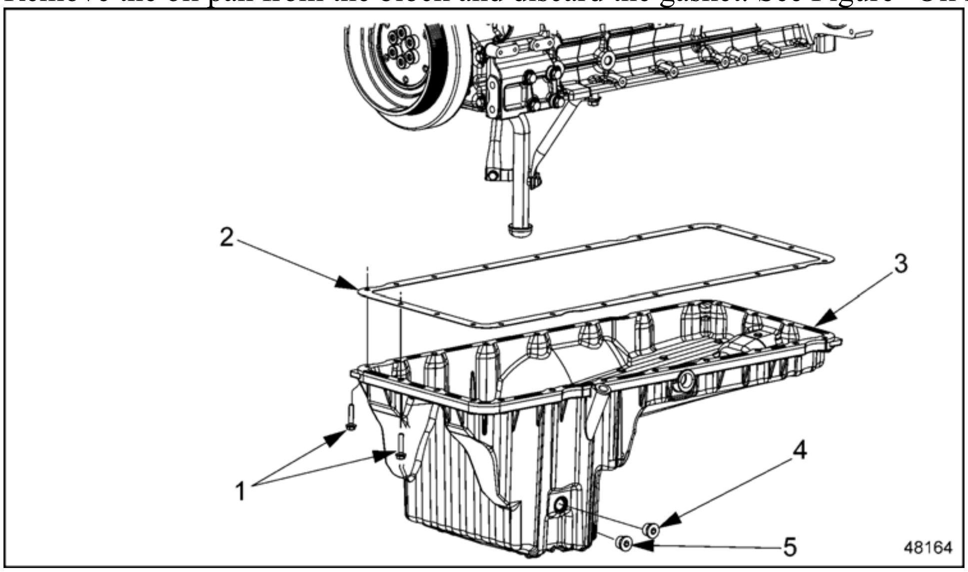
Section 3.7
Oil Pan

The procedure for removing the oil pan may vary with each installation.

Section 3.7.1
Removal of Oil Pan

Removal steps are as follows:

1. Drain the engine oil.
2. Remove the oil pan from the block and discard the gasket. See Figure "Oil Pan" .



1. Oil Pan Mounting Bolts	4. Plug
2. Oil Pan Gasket	5. Oil Pan Drain Plug
3. Oil Pan	

Figure 1. Oil Pan

3. Thoroughly clean the pan. Remove all traces of gasket material from the pan and from the block.

Section 3.7.2
Installation of Oil Pan

Installation steps are as follows:

1. Position a new gasket on the block.
2. Install the pan on the block and tighten the bolts 25 N·m (18 lb·ft).
3. Install the oil drain plug. Tighten the plug 65 N·m (48 lb·ft).
4. Fill the engine with engine oil. listed in Table

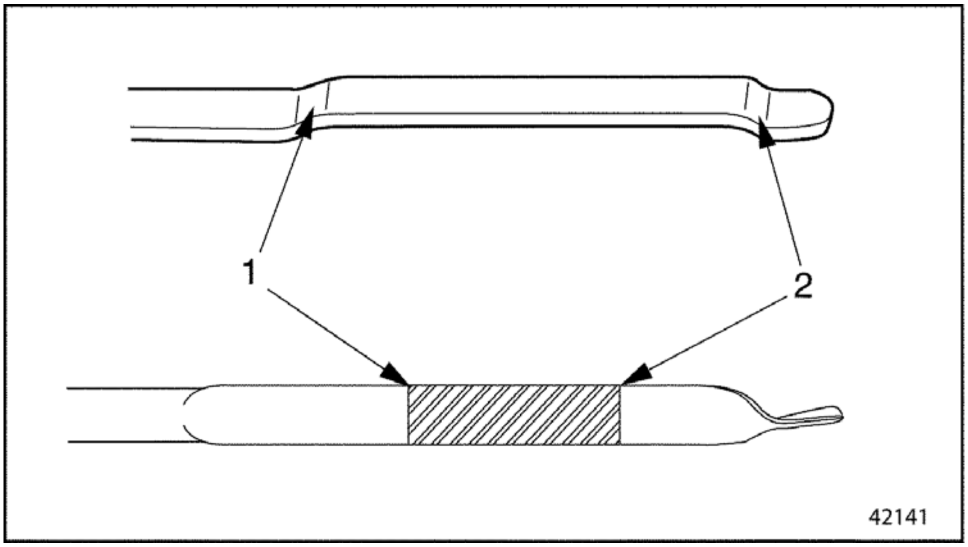
WARNING:

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 and check for leaks.
6. Shut down the engine. Check the oil level and add oil if necessary to bring within the range shown.See Figure "Oil Dipstick, Oil Level Range" .

   Note: Do not fill beyond the maximum fill level on the dipstick, since overfilling may result in high oil consumption. See Figure "Oil Dipstick, Oil Level Range" .



1. Maximum Fill Level	2. Minimum Fill Level

Figure 2. Oil Dipstick, Oil Level Range

7. Remove the dipstick from the guide tube. Note the dipstick has a positive locking device such as a lever or twist-lock design that must be disengaged before pulling the dipstick out of the guide tube.
8. Use a shop rag to wipe off the end of the dipstick.
9. Wait 15 seconds to allow any crankcase pressure to dissipate through the guide tube and let the oil level settle in the oil pan.
10. Reinstall the dipstick and make sure it is fully inserted into the guide tube.
11. Remove the dipstick and read the oil level. See Figure "Oil Dipstick, Oil Level Range" . The figure shows a comparison between the bends on the dipstick and a crosshatch pattern on a conventional dipstick. Note the exact area noted on the bends. For example, the “maximum” oil level will be at the BOTTOM of that bend. For the “minimum” oil level, it is noted at the TOP of the bend.
12. If the oil level is below the “minimum” bend, add oil to bring it up the “maximum” level. Do NOT fill beyond the maximum fill level on the dipstick, since overfilling may result in high oil

consumption and possible severe engine damage See Figure "Oil Dipstick, Oil Level Range" .

Section 3.8
Oil Centrifuge

See Figure "Oil Centrifuge and Related Components" for component location.

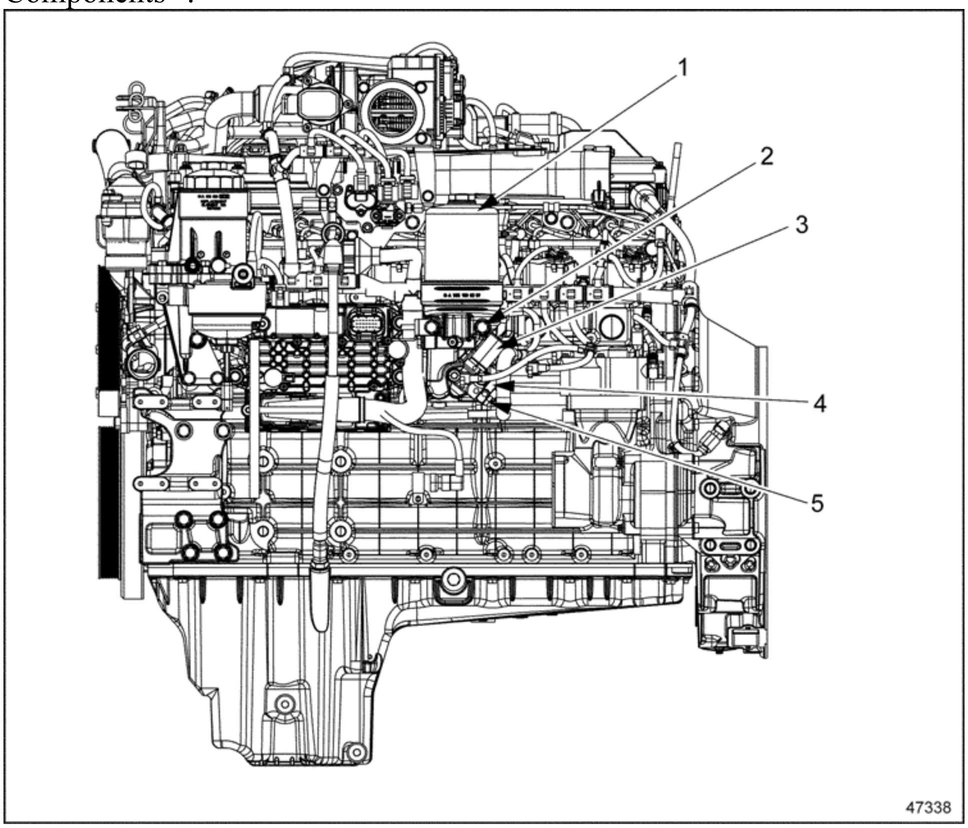
Note: The oil centrifuge is used on the high horsepower (260-330 BHP) MBE 900 model engines only.

Section 3.8.1
Removal of Oil Centrifuge

Removal steps are as follows:

Remove the oil centrifuge as follows:

1. Disconnect the CTV solenoid electrical plug connector. See Figure "Oil Centrifuge and Related Components" .



1. Oil Centrifuge	4. Constant Throttle Valve Oil Supply Line
2. Centrifuge Bolts	5. CTV Banjo Bolt and Washers
3. CTV Solenoid	

Figure 1. Oil Centrifuge and Related Components

2. Remove banjo bolt and washers from oil supply line at CTV solenoid. Discard washers. See Figure "Oil Centrifuge and Related Components" .

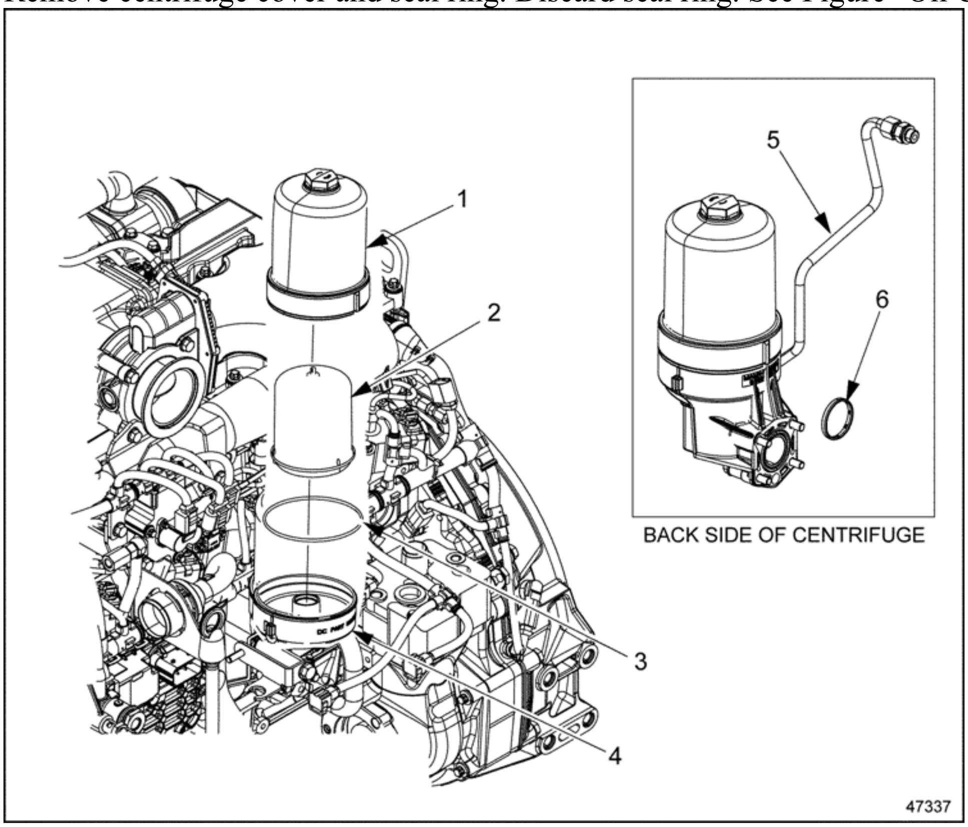
3. Remove two bolts and gasket from the CTV solenoid and remove the solenoid. Discard gasket.
4. Remove three bolts securing centrifuge to cylinder block and remove. Remove and discard seal ring on centrifuge.

Section 3.8.2
Disassembly of Oil Centrifuge

See Figure "Oil Centrifuge Assembly" for component location.

Removal steps are as follows:

1. Remove centrifuge cover and seal ring. Discard seal ring. See Figure "Oil Centrifuge Assembly" .



1. Centrifuge Cover	4. Oil Centrifuge Housing
2. Spinner Cartridge	5. CTV Oil Supply Line
3. Seal Ring	6. Seal Ring

Figure 2. Oil Centrifuge Assembly

2. Remove spinner cartridge from centrifuge housing and discard. See Figure "Oil Centrifuge Assembly" .

Section 3.8.3
Assembly of Oil Centrifuge

Assembly steps are as follows:

1. Install spinner cartridge in oil centrifuge housing. See Figure "Oil Centrifuge Assembly" .
2. Install oil centrifuge cover and new seal ring. Tighten the cover to 40 N·m (30 lb·ft).

Section 3.8.4
Installation of Oil Centrifuge

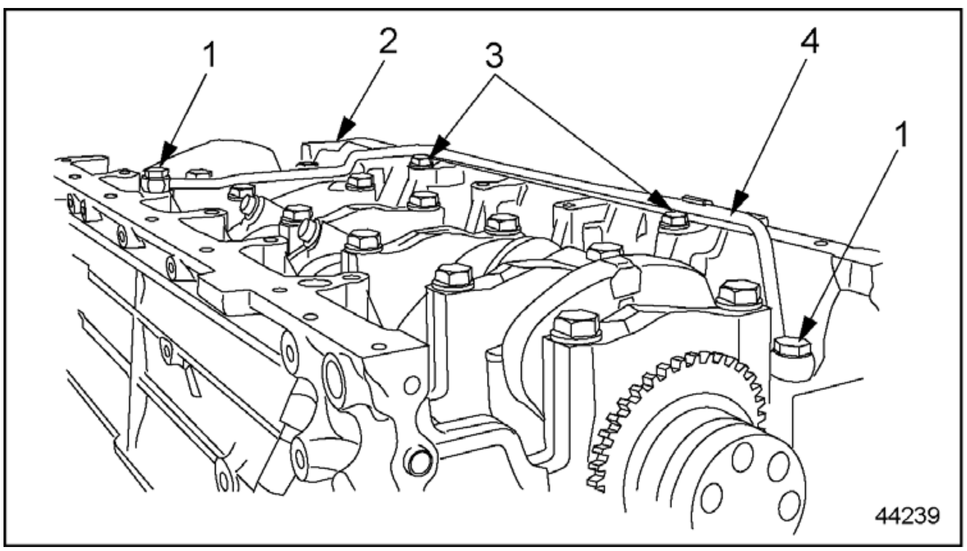
See Figure "Oil Centrifuge and Related Components" for component location.

Installation steps are as follows:

1. Install new seal ring on the oil centrifuge housing and secure to the cylinder block with four bolts. Tighten the bolts to 60–66 N·m (44–49 lb·ft). See Figure "Oil Centrifuge Assembly" .
2. Install the CTV solenoid to the centrifuge housing with two bolts. Tighten bolts to 31–35 N·m (23–26 lb·ft).
3. Install banjo bolt and two new washers and secure CTV oil supply line to the CTV solenoid. Tighten the banjo bolt to 25 N·m (18 lb·ft).
4. Connect the electrical connector plug to the CTV solenoid.

Section 3.8.5
Removal of Centrifuge Oil Supply Tube

See Figure "Centrifuge Oil Supply Tube and Related Components" for component location.



1.Banjo Bolts and Washers	3. Bolts
2.Cylinder Block	4. Centrifuge Oil Supply Tube

Figure 3. Centrifuge Oil Supply Tube and Related Components

Removal steps are as follows:

1. Remove oil pan. Refer to "3.7.1 Removal of Oil Pan" .
2. Remove two bolts at clips, attaching oil supply line to bottom of cylinder block.
3. Remove two banjo bolts and four washers securing oil supply line to cylinder block. Remove line

and discard washers.

Section 3.8.6
Installation of Centrifuge Oil Supply Tube

See Figure "Centrifuge Oil Supply Tube and Related Components" for component location.

Installation steps are as follows:

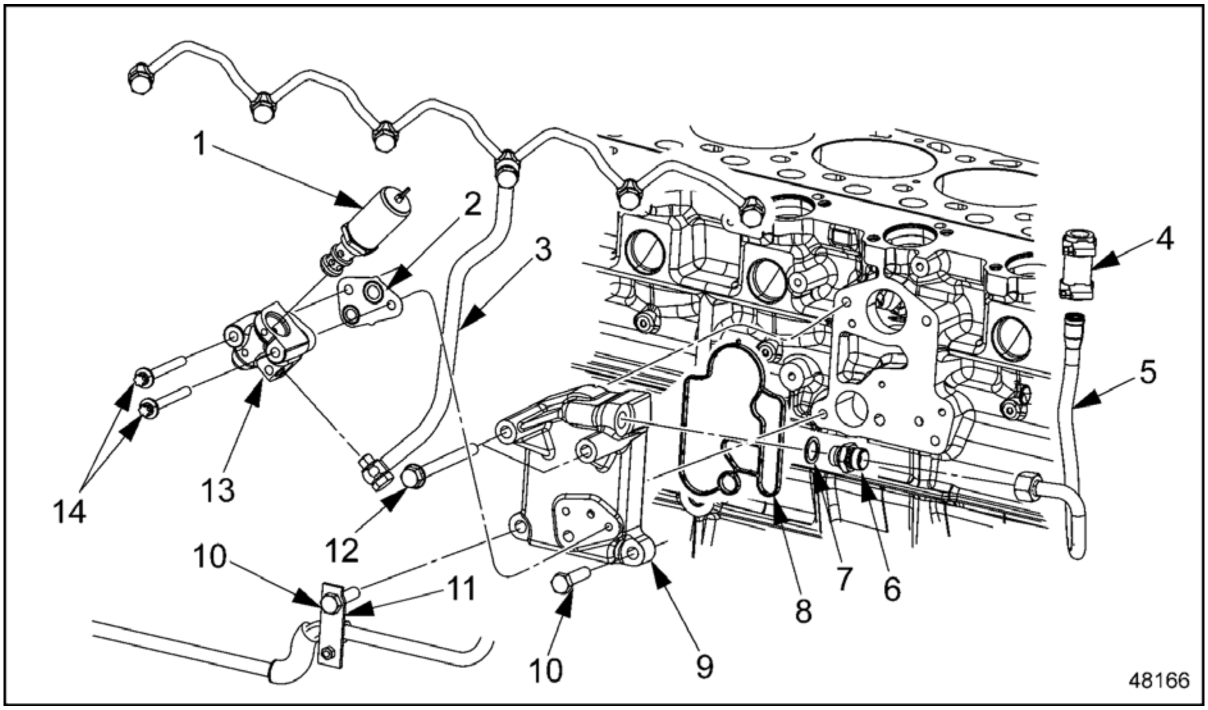
1. Install two banjo bolts and four new washers and attach centrifuge oil line to bottom of cylinder block. Tighten banjo bolts to 50 N·m (37 lb·ft).
2. Secure the centrifuge oil supply line to bottom of cylinder block with two bolts. Tighten bolts to 60–66 N·m (44–49 lb·ft).
3. Install oil pan.Refer to "3.7.2 Installation of Oil Pan" .

Section 3.9
Ctv Solenoid and Oil Supply Line

The following sections give instructions for CTV solenoid and oil supply line removal and installation.

Section 3.9.1
CTV Solenoid Oil Supply Line Removal

See Figure "CTV Solenoid and Oil Supply Line" for component location.



1. CTV Solenoid	8. Gasket
2. Gasket	9. CTV Mounting Plate
3. CTV Oil Supply Line to CTV	10. Bolts
4. Hose	11. Bracket
5. Electrostatic Oil Separator Drain Line	12. Bolts
6. Fitting	13. CTV Body
7. Washer	14. Bolts

Figure 1. CTV Solenoid and Oil Supply Line

Removal steps are as follows:

1. Remove banjo bolt and washers attaching the CTV solenoid oil supply line to the CTV solenoid. See Figure "CTV Solenoid and Oil Supply Line" .
2. Remove banjo bolt and two washers securing the CTV solenoid oil supply line to the cylinder head. Discard washers. See Figure "CTV Solenoid and Oil Supply Line" .

3. Remove five banjo bolts and washers securing the CTV oil supply line to the cylinder head. Discard the washers.
4. If necessary, remove the constant throttle fittings and seal rings at the cylinder head.

Section 3.9.2
Installation of CTV Solenoid Oil Supply Line

Installation steps are as follows:

1. If removed, install the constant throttle fittings and seal rings. Torque the fittings securely.
2. Secure the CTV oil supply line to the #5 cylinder head fitting with a banjo bolt and new washers. Torque the banjo bolts to 40–50 N·m (30–37 lb·ft). See Figure "CTV Solenoid and Oil Supply Line" .
3. Install banjo bolt and two new washers in the CTV solenoid oil supply line and attach to the CTV solenoid. Torque the banjo bolt to 40–50 N·m (30–37 lb·ft). See Figure "CTV Solenoid and Oil Supply Line" .
4. Install the remaining five banjo bolts and new washers and attach the oil supply line to the cylinder head fittings. Tighten the banjo bolts to 35 N·m (26 lb·ft). See Figure "CTV Solenoid and Oil Supply Line" .

Section 3.9.3
Removal of CTV Solenoid

Removal steps are as follows:

1. Disconnect the CTV solenoid electrical plug connector at the CTV.
2. Remove the CTV solenoid oil supply line. Refer to "3.9.1 CTV Solenoid Oil Supply Line Removal" .
3. Remove two bolts and gasket from CTV solenoid assembly and remove. Discard the gasket. See Figure "CTV Solenoid and Oil Supply Line" .
4. If necessary, remove the CTV mounting plate as follows: by removing four bolts. Remove plate and gasket. Discard gasket.
    a. Loosen hose clamp at the electrostatic oil separator drain and disconnect the drain line from the CTV mounting plate.
    b. If necessary remove the fitting and washer from the mounting plate. Discard the washer. See Figure "CTV Solenoid and Oil Supply Line" .
    c. Remove four bolts securing the CTV mounting plate to the cylinder block and remove plate and gasket. Discard gasket. See Figure "CTV Solenoid and Oil Supply Line" .

Section 3.9.4
Installation of CTV Solenoid

Installation steps are as follows:

1. If removed, install CTV mounting plate as follows:
    a. Attach the CTV mounting plate and new gasket and secure to the cylinder block with four bolts. Torque the bolts to 50 N·m (37 lb·ft). See Figure "CTV Solenoid and Oil Supply Line" .
    b. If removed, install fitting and new washer on mounting plate. Torque fitting to 25 N·m (18 lb·ft). See Figure "CTV Solenoid and Oil Supply Line" .

c. Install the electrostatic oil separator drain into the hose and secure the other end of the drain to the mounting plate fitting. Tighten the hose clamp and drain line fitting securely. See Figure "CTV Solenoid and Oil Supply Line" .

2. Install CTV solenoid and new gasket to the centrifuge housing or mounting plate and secure with two bolts. Tighten bolts to 31–35 N·m (23–26 lb·ft). See Figure "CTV Solenoid and Oil Supply Line" .
3. Install banjo bolt and two new washers and secure CTV oil supply line to the CTV solenoid. Tighten the banjo bolt to 35 N·m (26 lb·ft). See Figure "CTV Solenoid and Oil Supply Line" .
4. Connect the electrical connector plug to the CTV solenoid. See Figure "CTV Solenoid and Oil Supply Line" .

Additional Information

Specifications

The lubricating oil capacity is listed in Table "Lubricating Oil Capacity" .

Description	L (qt.)
Oil Fill Capacity*	29.5 (31)

Table 1. Lubricating Oil Capacity

** In standard pan, including oil filter.*

The torque values are listed in Table "Torque Values" .

Descriptions	N·m (lb·ft)
Oil Pump to Cylinder Block Bolts	25 (18)
Suction Pipe to Oil Pump Bolt	20–30 (15–22)
Suction Pipe Clamp to Bracket Bolts (M8)	20–30 (15–22)
Suction Pipe Bracket to Cylinder Block Bolts (M10)	45–55 (33–41)
Oil Filter Housing to Cylinder Block	25 (18)
Turbocharger Oil Supply Line Banjo Bolts	25 (18)
Oil Filter Cap	25 (18)
Oil Cooler Element to Cooler Housing Bolts	25 (18)
Oil Cooler Cover to Housing Bolts	25 (18)
Oil Temperature Sensor	45 (33)
Screw Plug to Oil–Water Heat Exchanger	20 (15)
Oil Pan Bolts (M8)	25 (18)
Oil Pan Drain Plug	65 (48)
Oil Centrifuge to Cylinder Block Bolts	60–66 (44–49)
CTV to Oil Centrifuge Bolts	31–35 (23–26)
Banjo Bolt on CTV	25 (18)
CTV Oil Line to Cylinder Head Banjo Bolt	35 (26)
Oil Centrifuge Cover Plate	28 (21)
Centrifuge Oil Supply Line Bottom of Cylinder Block Banjo Bolts	50 (37)
Centrifuge Oil Supply Line Bottom of Cylinder Block Mounting Bolts	60–66 (44–49)

Table 2. Torque Values

Special Tools

The special tools used in this chapter are listed in Table "Special Tools" .

Tool	Description	Usage	Part Number

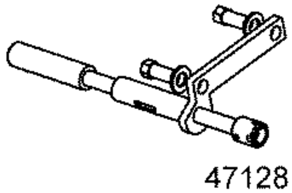
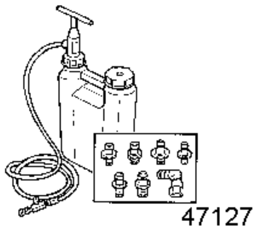
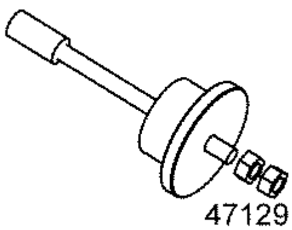
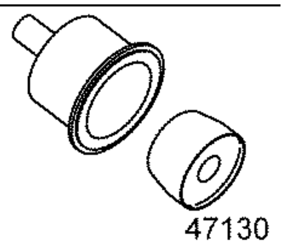
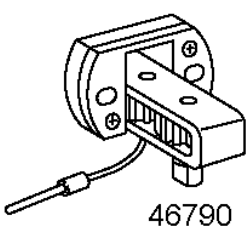
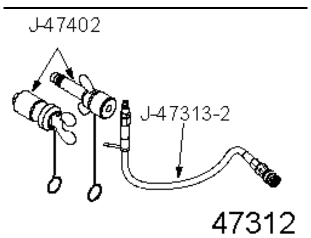
	Oil Spray Nozzle Replacement Kit	Used to install the piston oil spray nozzles in the cylinder block.	J–44846
	Pre–oiler Can	Used to pre-lub the engine oil system.	J–45299
	Electronic Unit Pump Puller	Puller used to pull the piston oil spray nozzle from the cylinder block.	J–46375
	Front Seal Installer	Used to install the front radial crankshaft seal.	J–46388
	Engine Barring Tool	Used to lock and rotate the engine flywheel.	J–46392
	Oil Cooler Leak Test Kit	Used to pressure test the oil cooler element.	J-47402

Table 3. Special Tools

Section 4.1
Coolant System Schematics

For the coolant system flows see Figure "Single-stage Turbocharger Coolant System Schematic" for single-stage turbocharger or see Figure "Dual-stage Turbocharger Coolant System Schematic" for dual-stage turbocharger engines.

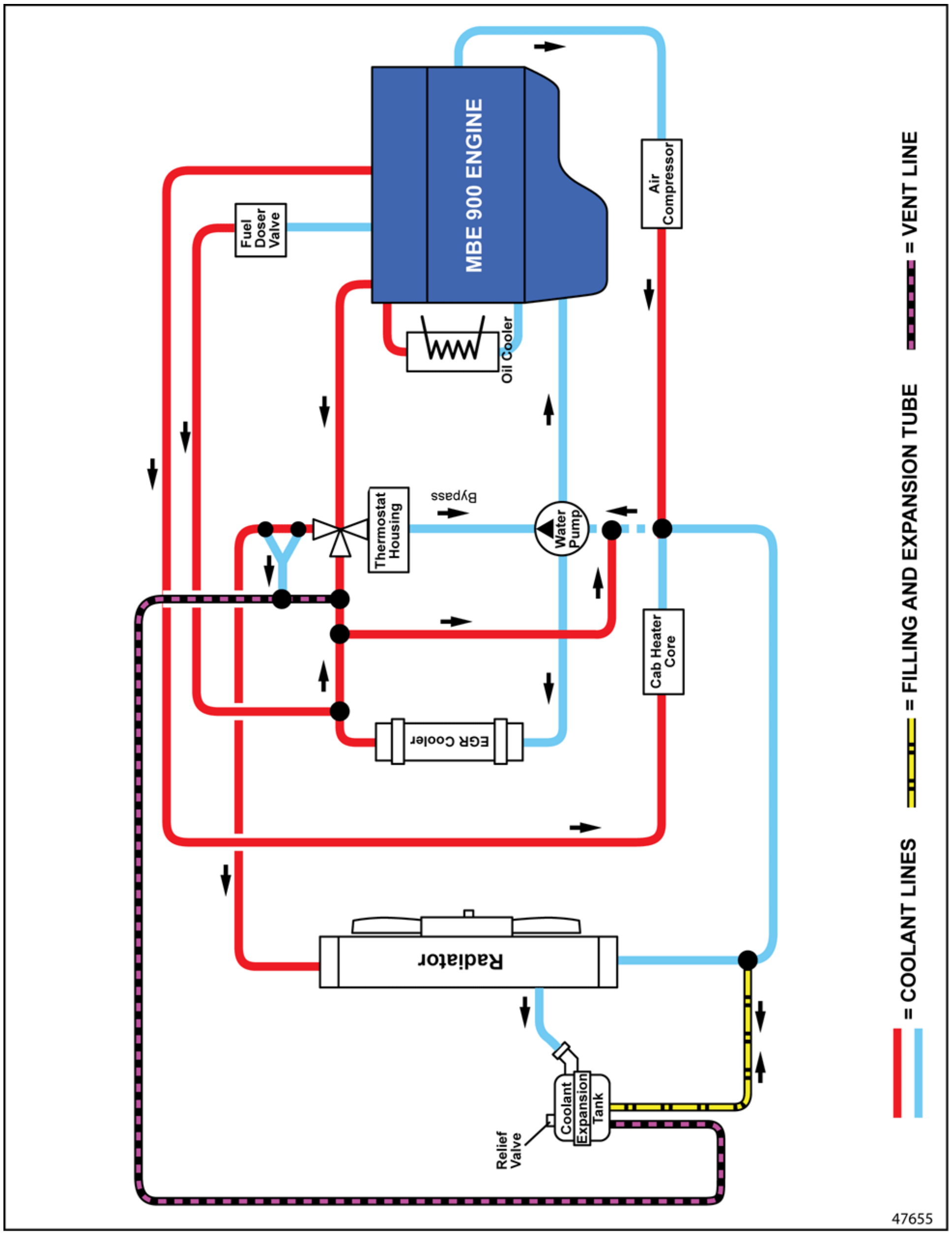


Figure 1. Single-stage Turbocharger Coolant System Schematic

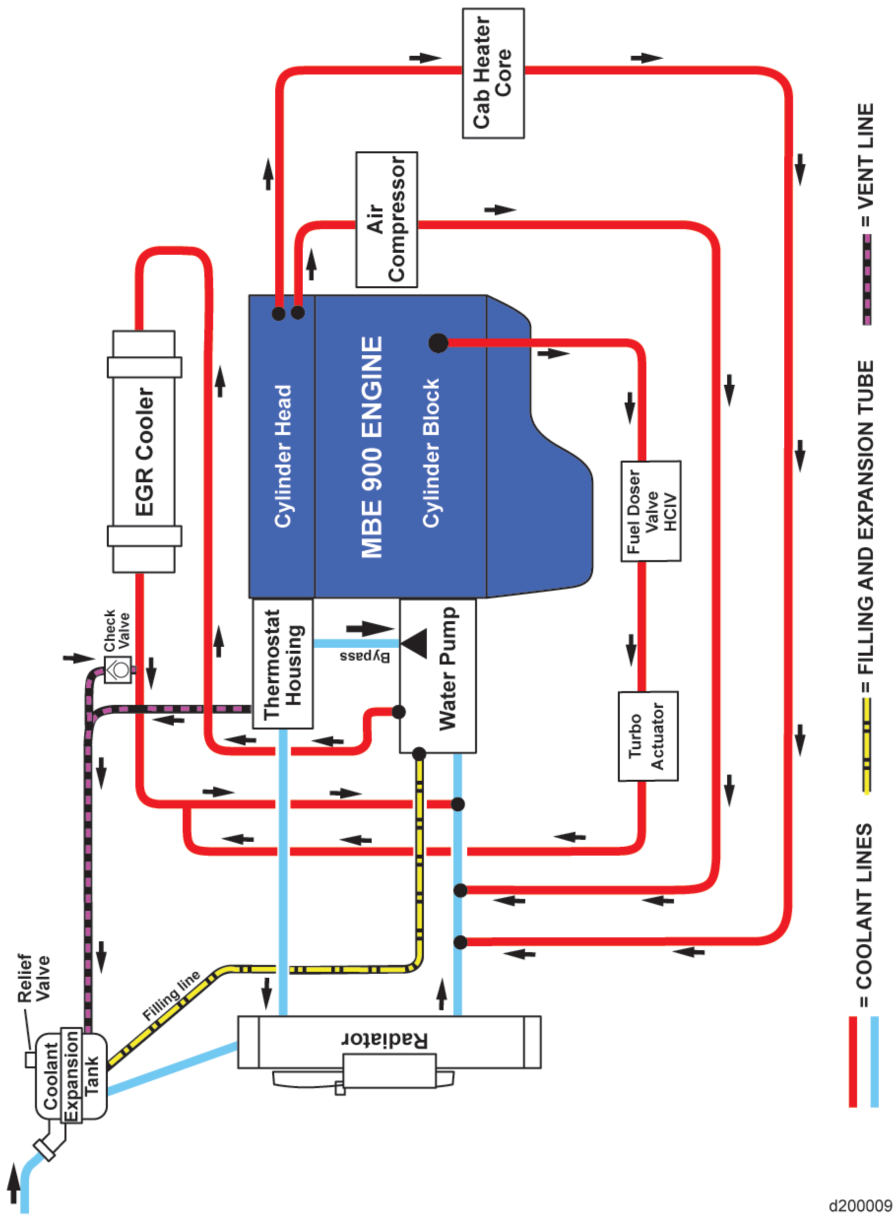


Figure 2. Dual-stage Turbocharger Coolant System Schematic

Section 4.2
Coolant Preheater

The following sections support the coolant preheater.

Section 4.2.1
Removal of Coolant Preheater

Removal steps are as follows:

WARNING:

PERSONAL INJURY

To avoid injury from scalding, drain the radiator when the engine and coolant are cool.

1. Drain the coolant from the radiator.

   WARNING:

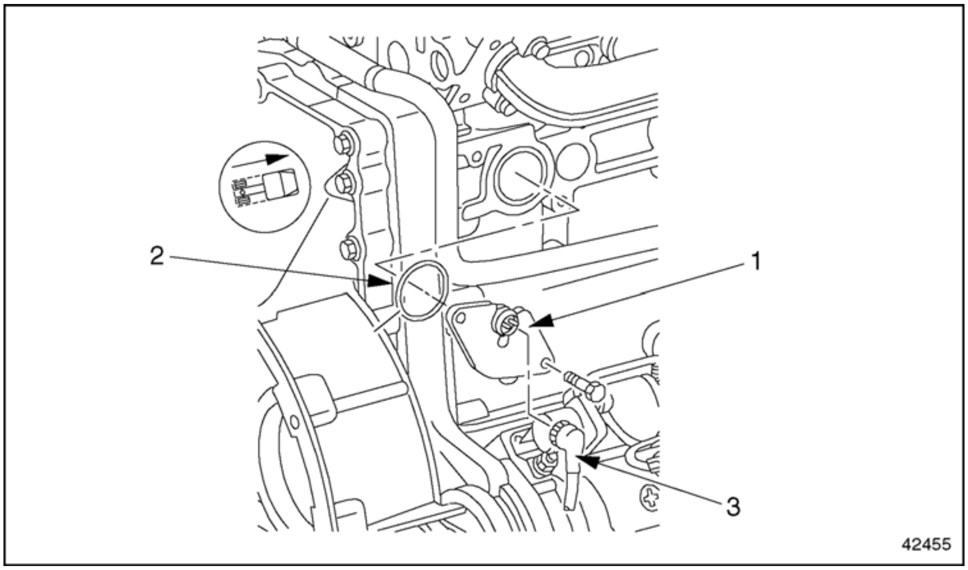
   HOT COOLANT

   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.

   a. Open the cap on the surge tank slowly, to allow excess pressure to escape.
   b. 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.

   c. Open the coolant drain plug on the bottom of the radiator.
2. Disconnect the electrical connector from the coolant pre–heater. See Figure "Coolant Preheater" .



1. Coolant Pre–heater	3. Electrical Connector
2. O–ring	

Figure 1. Coolant Preheater

3. Remove the two bolts securing the coolant pre–heater from the engine access hole. Remove and discard the O–ring. See Figure "Coolant Preheater" .

   Note: Collect any coolant that runs out of the access hole.

Section 4.2.2
Installation of Coolant Preheater

Installation steps are as follows:

1. Install a new O-ring on the coolant pre–heater and secure the pre-heater in the engine access hole with two bolts. Torque the bolt to 25 N·m (18 lb·ft). See Figure "Coolant Preheater" .
2. Connect the electrical connector to the coolant pre–heater. See Figure "Coolant Preheater" .
3. Fill the engine with the coolant. The cooling system capacity is listed in Table "Cooling System Capacity" .

Descriptions	L (qt.)
Total capacity	23 (24)
Antifreeze quantity at 50%	11.5 (12.0)
Antifreeze quantity at 55%	12.7 (13.4)

Table 4. Cooling System Capacity

   a. Tighten the coolant drain plug on the bottom of the radiator.
   b. Add coolant up to the maximum fill level on the surge tank.
4. 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, water pump, and surge tank for leaks.
c. Check the coolant level and add more coolant if necessary.

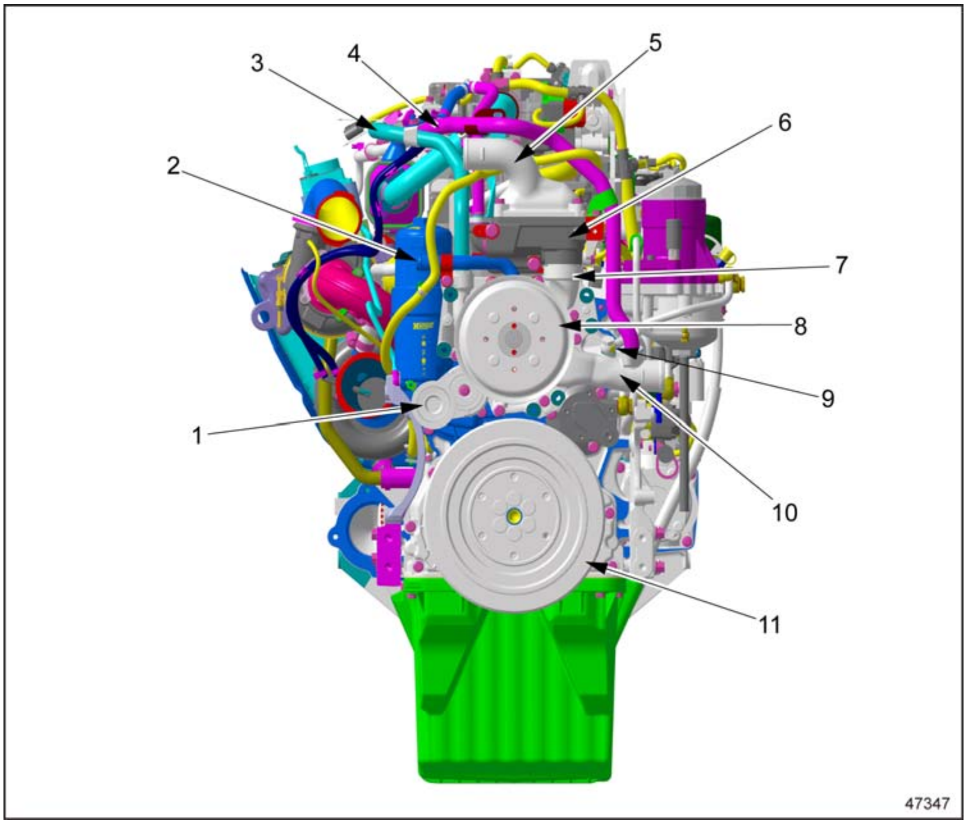
5. Shut down the engine.
6. Close and tighten the cap on the surge tank.

Section 4.3
Water Pump

The following sections support the water pump.

Section 4.3.1
Removal of Water Pump

Removal steps are as follows:



1. Belt Tensioner	7. Connector Tube
2. Filling – Expansion Tube	8. Pulley – Water Pump
3. EGR Cooler Coolant Inlet Tube	9. Banjo Bolt (Air Compressor Coolant Line)
4. EGR Cooler Coolant Return Tube	10. Water Pump
5. Upper Thermostat Housing	11. Crankshaft Vibration Damper
6. Lower Thermostat Housing	

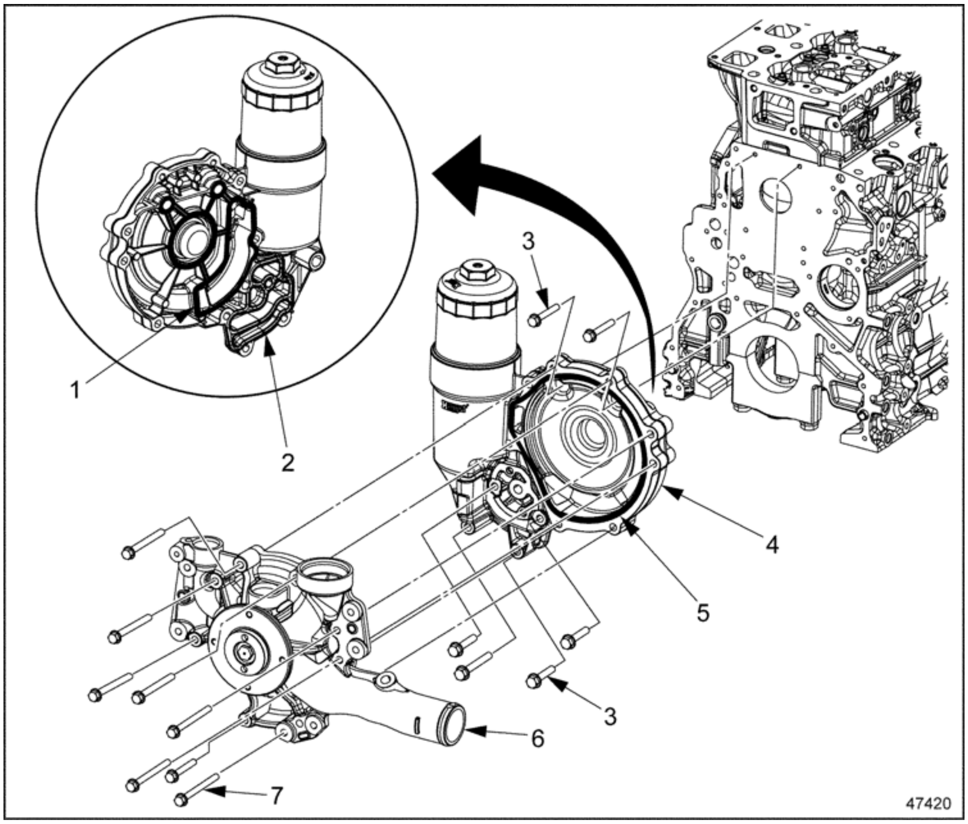
Figure 1. Water Pump and Related Components

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 engine coolant.
2. Release the tension on the poly–V belt tensioner and remove belt. See Figure "Water Pump and Related Components" .
3. Remove the fan shroud from the vehicle.
4. Remove the four bolts securing the fan and pulley to the coolant pump. See Figure "Water Pump and Related Components" .
5. Remove three bolts securing filling and expansion tube. Remove tube and discard seal ring.
6. Remove the banjo bolt and washers on the thermostat housing for the bleed line to the EGR coolant return line.
7. Remove EGR coolant inlet tube. Refer to "8.2.1 Removal of EGR Coolant Inlet Tube" .
8. Remove EGR coolant return tube. Refer to "8.3.1 Removal of EGR Coolant Return Tube" .
9. Remove banjo bolt and washers securing the vent line to the lower thermostat housing. Discard washers.
10. Disconnect coolant temperature sensor connector on thermostat housing. If required remove temperature sensor from housing.
11. Remove the bolts securing thermostat housing to the front of the engine and remove the housing and gasket. Discard gasket. See Figure "Water Pump and Related Components" .
12. Remove water connector tube from thermostat housing and discard the tube. See Figure "Water Pump and Related Components" .
13. Remove the banjo bolt and washers for the air compressor coolant line on the water pump. Discard washers. See Figure "Water Pump and Related Components" .
14. Remove hexagon socket–head bolt from belt tensioner and remove the tensioner.
15. Remove banjo bolt(s) and washers connecting the oil supply line(s) to the turbocharger(s) at the rear of oil filter housing. Discard washers.



1. Water Pump/Oil Filter Housing Gasket (Rear)	5. Water Pump/Oil Filter Housing Gasket (Front)
2. Oil Filter Housing Gasket	6. Water Pump
3. Water Pump/Oil Filter Housing Mounting Bolts	7. Water Pump Mounting Bolts
4. Water Pump/Oil Filter Housing	

Figure 2. Water Pump and Oil Filter Housing

16. Remove eight bolts securing water pump and seal ring to rear housing of water pump and remove. Discard seal ring. See Figure "Water Pump and Oil Filter Housing" .

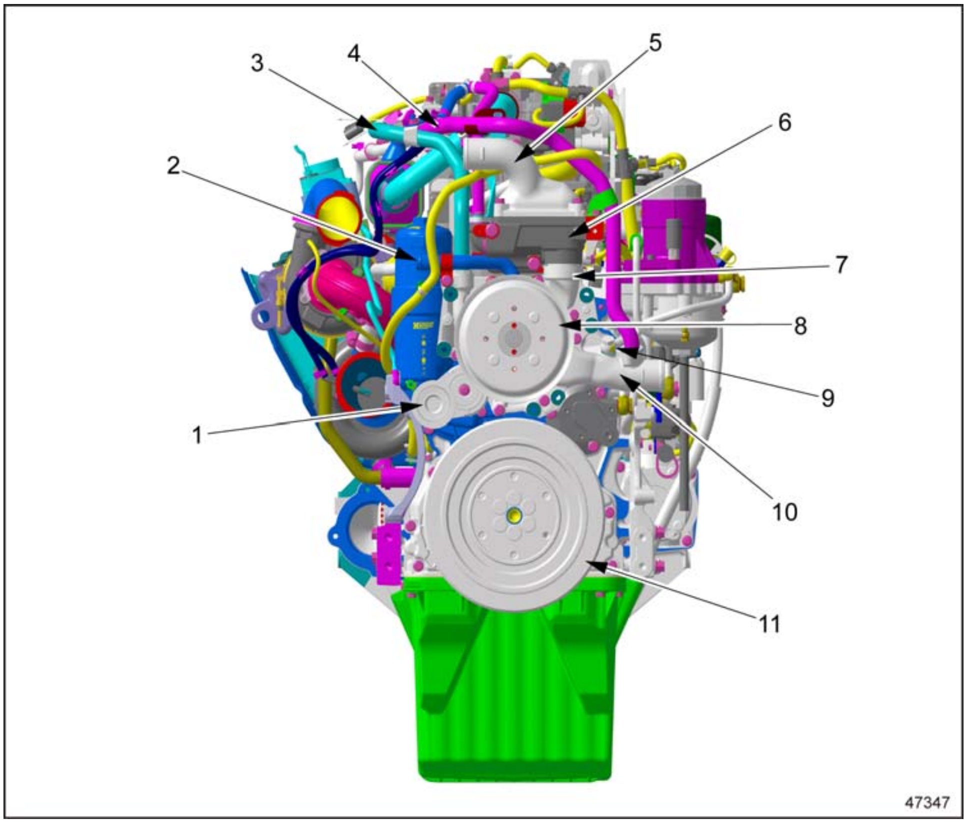
    Note: The oil filter is part of the rear water pump housing and must be removed as an assembly.

    Note: Only five bolts can be removed during the removal of the rear water pump housing and oil filter assembly due to interference with damper. Loosening the bolt near the damper completely will allow the removal of the assembly.

17. Unscrew the oil filter to allow oil in the canister to drain back into the engine prior to removing.
18. Remove six bolts securing water pump and oil filter assembly to the cylinder block. Discard two seals on rear of housing. See Figure "Water Pump and Oil Filter Housing" .

Section 4.3.2
Installation of Water Pump

See Figure "Water Pump and Related Components" for component location.



1. Belt Tensioner	7. Connector Tube
2. Filling and expansion Tube	8. Pulley.— Water Pump
3. EGR Cooler Coolant Inlet Tube	9. Banjo Bolt (Air Compressor Coolant Line)
4. EGR Cooler Coolant Return Tube	10. Water Pump
5. Upper Thermostat Housing	11. Vibration Damper
6. Lower Thermostat Housing	

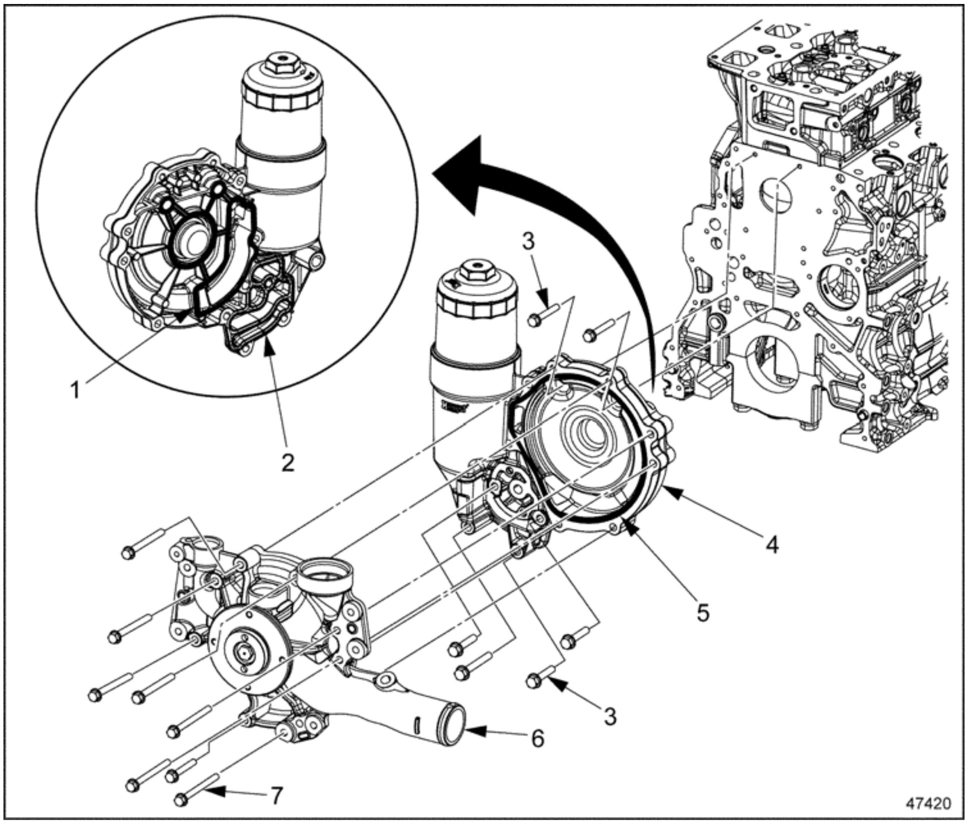
Figure 3. Water Pump and Related Components

Installation steps are as follows:

1. Install two new seals on rear of water pump and oil filter housing assembly. See Figure "Water Pump/Oil Filter Housing" .

   Note: One lower bolt, near the damper, must be installed in rear water pump and oil filter assembly prior to installation due to interference by damper.

   Note: The oil filter is part of the water pump housing and must installed as an assembly.



1.Oil Filter/Water Pump Housing Gasket (Rear)	5. Oil Filter/Water Pump Housing Gasket (Front)
2. Oil Filter Housing Gasket	6. Water Pump
3. Oil Filter/Water Pump Housing Mounting Bolts	7. Water Pump Mounting Bolts
4. Oil Filter/Water Pump Housing	

Figure 4. Water Pump/Oil Filter Housing

2. Secure the water pump housing/oil filter assembly to the cylinder block with six bolts. Tighten bolts to 31–35 N·m (23–26 lb·ft). See Figure "Water Pump/Oil Filter Housing" .

   Note: The belt tensioner has two locating pins on the rear that must align with corresponding holes in the cylinder block.

3. Install the hexagon socket–head bolt in the belt tensioner and secure to cylinder block. Tighten bolt to 50 N·m (37 lb·ft).
4. Install the banjo bolt and two new washers and secure water tube to the water pump.
5. Install a new seal ring on the filling and expansion tube (2) and secure tube to water pump with three bolts. Tighten bolts to 31–35 N·m (23–26 lb·ft). See Figure "Water Pump and Related Components" .
6. Install a new gasket and secure the thermostat housing to the water pump with three bolts. Tighten bolts to 31–35 N·m (23–26 lb·ft).
7. Connect temperature sensor electrical connector at thermostat housing.
8. Install the banjo bolt and two new washer and secure tube on rear of oil filter housing going to turbocharger.

9. Install EGR coolant return tube. Refer to "8.3.2 Installation of EGR Coolant Return Tube" .
10. Install EGR coolant inlet tube. Refer to "8.2.2 Installation of EGR Coolant Inlet Tube"
11. Install the fan and pulley on the coolant pump and secure with four bolts. Tighten bolts to 31–35 N·m (23–26 lb·ft). See Figure "Water Pump and Related Components" .
12. Release the belt tensioner. Route the poly–V belt around the fan pulley and restore belt tension.
13. Secure the fan shroud to the radiator. Tighten the fan shroud mounting bolts until firm.
14. Fill the engine with the removed coolant.

WARNING:

ENGINE EXHAUST

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

15. Start the engine and check for leaks and repair as necessary.

Section 4.4
Thermostat Housing

The following sections support the thermostat housing.

Section 4.4.1
Removal of Thermostat Housing

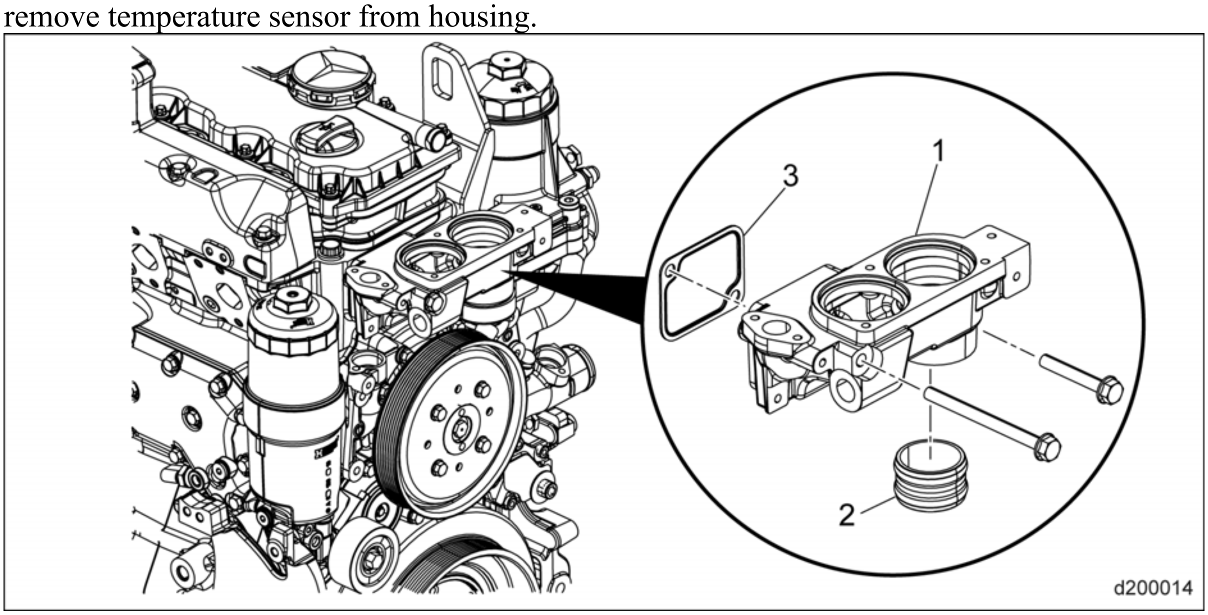
Removal steps are as follows:

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. Drain engine coolant.
2. Remove the fan shroud from the vehicle.
3. Release the tension on the poly–V belt and remove belt.
4. Remove the bolts securing the fan and pulley to the coolant pump and remove.
5. Remove three bolts securing the filling and expansion tube to the water pump. Remove tube and discard seal ring.
6. Remove the banjo bolt and washers on the thermostat housing for the bleed line to the EGR coolant return tube.
7. Remove EGR coolant return tube. Refer to "8.3.1 Removal of EGR Coolant Return Tube" .
8. Remove three bolts securing filling and expansion tube. Remove tube and discard seal ring.
9. Disconnect coolant temperature sensor connector from lower thermostat housing. If required remove temperature sensor from housing.



1. Lower Thermostat Housing	3. Gasket
2. Connector tube	

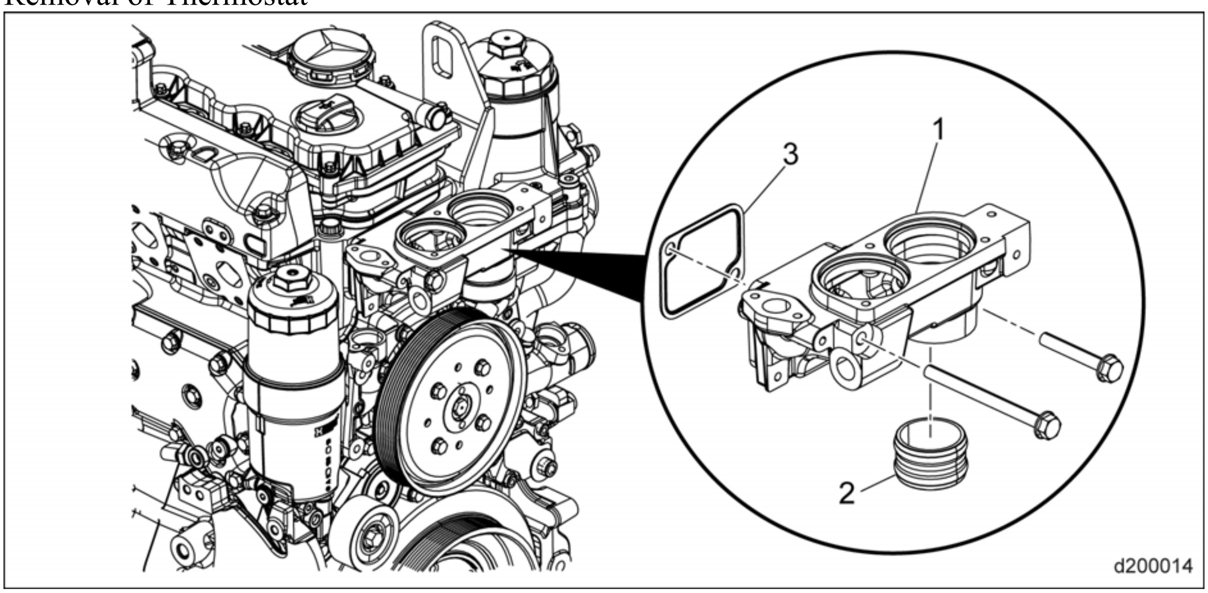
Figure 1. Thermostat Housing

10. Remove two bolts securing thermostat housing to the front of the engine and remove the housing.
11. Remove water connector tube from lower thermostat housing and discard tube. See Figure "Thermostat Housing" .
12. Remove three bolts securing upper thermostat housing to lower thermostat housing and remove. Refer to "4.5.1 Removal of Thermostat"
13. Remove the thermostat(s) and O–ring(s) from thermostat housing. Discard O–rings. Refer to "4.5.1 Removal of Thermostat"
14. Check the thermostat(s). Refer to "4.5.1.1 Testing of Thermostat"

Section 4.4.2
Installation of Thermostat Housing

Installation steps are as follows:

1. Install a new O–ring on each thermostat and install thermostats in lower housing. Refer to "4.5.1 Removal of Thermostat"



1. Lower Thermostat Housing	3. Gasket
2. Connector tube	

Figure 2. Thermostat Housing

2. Secure the thermostat upper housing to lower thermostat housing with two bolts. Tighten bolts to 17-23 Nm (13-17 lb·ft). Refer to "4.5.1 Removal of Thermostat"
3. Install a new water connector tube with seal in water pump. See Figure "Thermostat Housing" .
4. Position thermostat housing over connector tube and secure the thermostat housing to the water pump with two bolts. Tighten bolts to 31–35 N·m (23–26 lb·ft).

5. Secure coolant inlet tube at clamp on thermostat with bolt. Tighten bolts to 31–35 N·m (23–26 lb·ft).
6. If removed, install temperature sensor in thermostat housing.
7. Position thermostat housing over connector tube.
8. Connect temperature sensor electrical connector at thermostat housing.
9. Install EGR coolant return tube. Refer to "8.3.2 Installation of EGR Coolant Return Tube" .
10. Install the EGR coolant inlet tube. Refer to "8.2.2 Installation of EGR Coolant Inlet Tube" .
11. Install EGR delivery pipe. Refer to "8.5.2 Installation of EGR Delivery Pipe" .
12. Install the fan and water pump pulley to the water pump and secure with bolts. Tighten bolts to 18-22 Nm (13-16 lb·ft) .
13. Release the belt tensioner. Route the poly–V belt around the fan pulley and restore belt tension.
14. Secure the fan shroud to the radiator and tighten the fan shroud mounting bolts until firm.
15. Fill the engine with removed coolant.

WARNING:

ENGINE EXHAUST

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

16. Start the engine and check for leaks and repair as necessary.

Section 4.5
Thermostat

The vehicle is cooled by a closed system using recirculated coolant; temperature is regulated automatically by two thermostats.

Section 4.5.1
Removal of Thermostat

Removal steps are as follows:

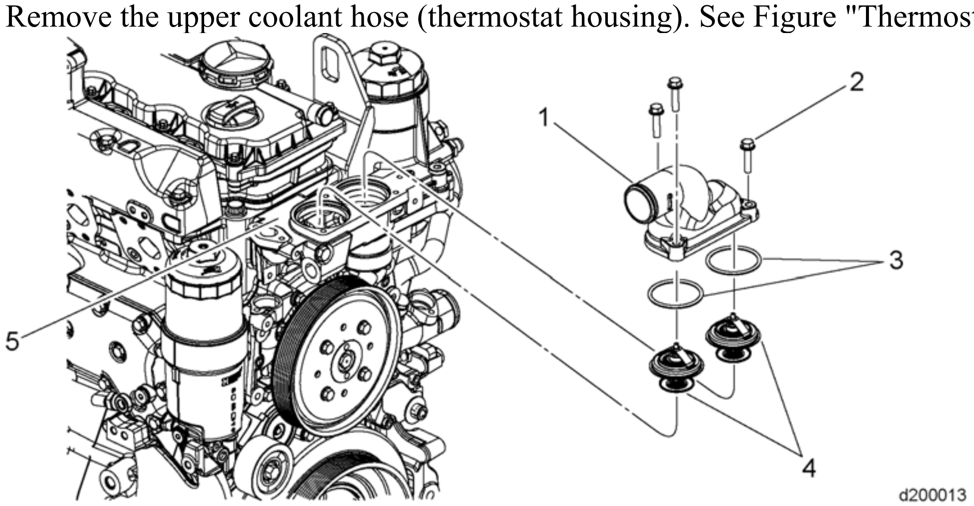
WARNING:

PERSONAL INJURY

To avoid injury from scalding, drain the radiator when the engine and coolant are cool.

Check the thermostat as follows:

1. Drain the coolant from the engine.
2. Remove the upper coolant hose (thermostat housing). See Figure "Thermostat" .



1. Upper Thermostat Housing	4. Thermostats
2. Bolts	5. Lower Thermostat Housing
3. O-rings	

Figure 1. Thermostat

a. Remove the hose clamp attaching the upper coolant hose to the inlet.
b. Remove three bolts securing the upper thermostat housing to lower thermostat housing.

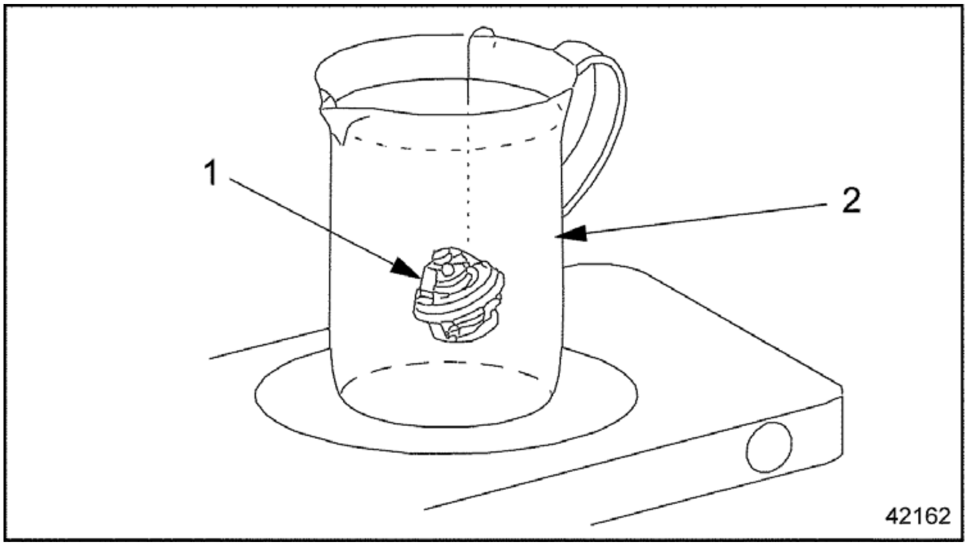
Note: Collect any coolant that runs out of the inlet or water pump.

3. Remove the thermostat(s) and O–ring(s) from the water pump. Discard the O–ring(s).
4. Check the thermostat(s) for proper operation. Refer to "4.5.1.1 Testing of Thermostat" . Replace any thermostat that fails one or more tests.

Section 4.5.1.1
Testing of Thermostat

Testing steps are as follows:

1. Hang the thermostat by a wire inside a container filled with water. See Figure "Heat the Thermostat" .



1. Thermostat	2. Container

Figure 2. 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.

2. Heat the water with a suitable heating element. Stir the water occasionally to help equalize the temperature.

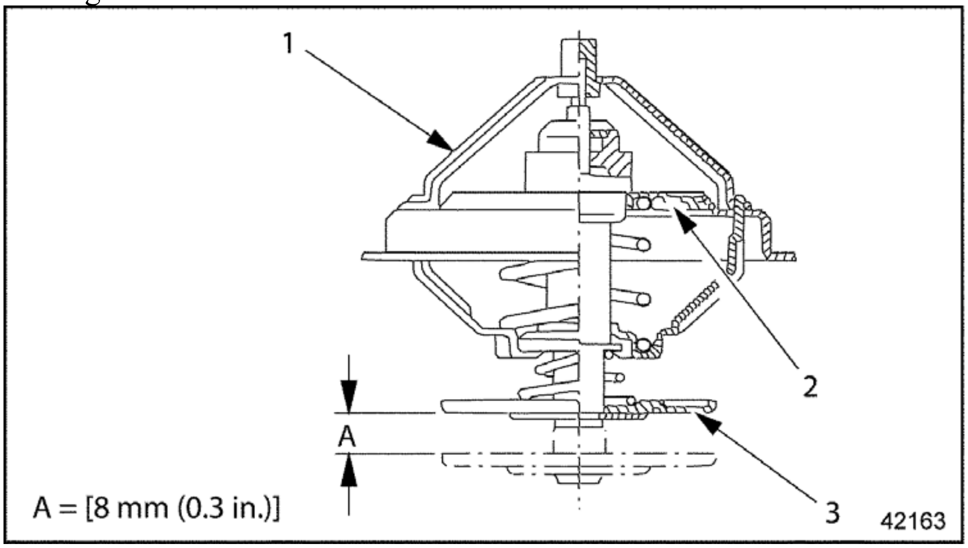
WARNING:

SCALDING

To avoid injury from scalding, use lifting tools and wear heat-resistant gloves when retrieving the thermostat from boiling water.

a. Measure the water temperature. As the temperature climbs to around 75°C (165°F), slow the rate of heating down to about 1 to 2°C (2 to 3°F) per minute.
b. In about five minutes, the main valve should begin to open.

3. 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 "Thermostat Valves" .



1. Thermostat	3. Short Circuit Valve
2. Main Valve	

Figure 3. Thermostat Valves

4. Check all the test values listed in Table "Thermostat Test Values" . If any of the values are not met, replace the thermostat.

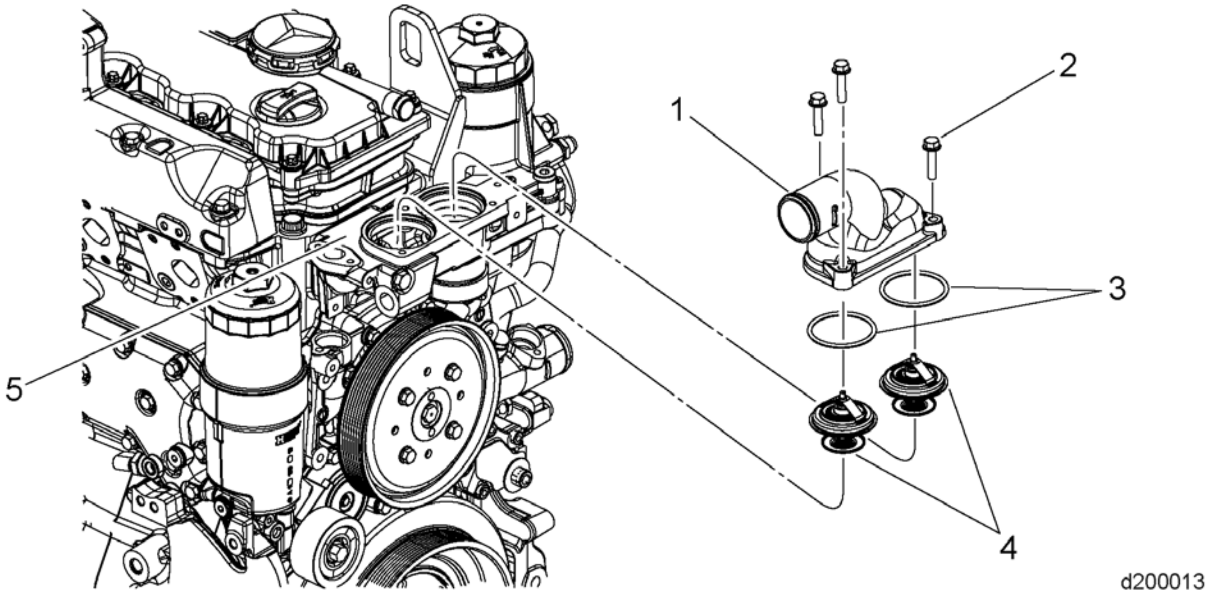
Descriptions	Temperatures °C (°F)	Distance mm (in.)
Main Valve Starts To Open	81 to 85 (178 to 185)	—
Short Circuit Valve Fully Closed	92 (198)	—
Main Valve Fully Open	95 (203)	—
Main Valve Minimum Lift (A)	—	8 (0.3)

Table 7. Thermostat Test Values

a. At the temperature of 85°C (185°F), check that the main valve has started to open.
b. At the temperature of 92°C (198°F), check that the short circuit valve is fully closed.
c. At the opening temperature of 95°C (203°F), check that the main valve is fully open.
d. Check the minimum lift of the main valve at the opening temperature.

Section 4.5.2
Installation of Thermostat

Installation steps are as follows:



1. Upper Thermostat Housing	4. Thermostats
2. Bolts	5. Lower Thermostat Housing
3. O-rings	

Figure 4. Thermostat

1. Install a new O–ring on each thermostat. See Figure "Thermostat" .
2. Install the original or replacement thermostat(s). See Figure "Thermostat"
3. Install the mounting bolts attaching the upper thermostat housing to lower thermostat housing. Tighten the bolts to 31–35 N·m (23–26 lb·ft). See Figure "Thermostat" .
4. Install the upper coolant hose to the thermostat housing and secure with hose clamp. Tighten clamp securely.
5. Fill the engine with the removed coolant.

WARNING:

ENGINE EXHAUST

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

6. Start the engine and check for leaks and repair as necessary.

Section 4.6
Coolant Fan

For the removal of the coolant fan, refer to the appropriate vehicle service manual.

Section 4.7
Belts and Tensioners

For the removal of the belts and tensioners, refer to the appropriate vehicle service manual.

Additional Information

SPECIFICATIONS

The engine cooling system capacity is listed in Table "Cooling System Capacity" See OEM literature for vehicle system fill capacity. .

Descriptions	L (qt.)
Engine capacity	12 (12.5)
Antifreeze quantity at 50%	11.5 (12.0)
Antifreeze quantity at 55%	12.7 (13.4)

Table 1. Cooling System Capacity

Listed in Table "Thermostat Test Values" are the thermostat test values.

Descriptions	Temperatures °C (°F)	Distance mm (in.)
Main Valve Starts To Open	81 to 85 (178 to 185)	—
Short Circuit Valve Fully Closed	92 (198)	—
Main Valve Fully Open	95 (203)	—
Main Valve Minimum Lift	—	8 (0.3)

Table 2. Thermostat Test Values

Section 5.1
Fuel

Detroit Diesel MBE 900 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. Ensure there is no water in the fuel.

Section 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.

Section 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.

Section 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.

Section 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 After-Treatment System and impact the EPA emission regulations.

Section 5.1.5
Winter–Grade Diesel Fuel for Cold Weather

At low outside temperatures, paraffin may separate from the diesel fuel 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 with caution. 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.

Section 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 900 engines. Look for the service mark printed on the oil container. See Figure "API Lubricant Service Mark" .

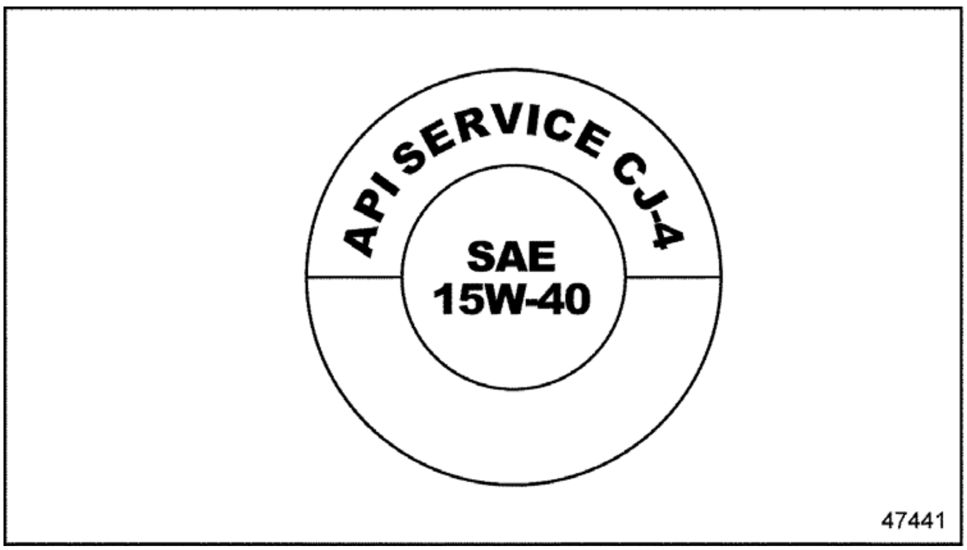


Figure 1. API Lubricant Service Mark

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.

Section 5.2.1
Synthetic Oils

Synthetic oil may be used in MBE 900 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.

Section 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 "Engine Oil Temperature Ranges" .

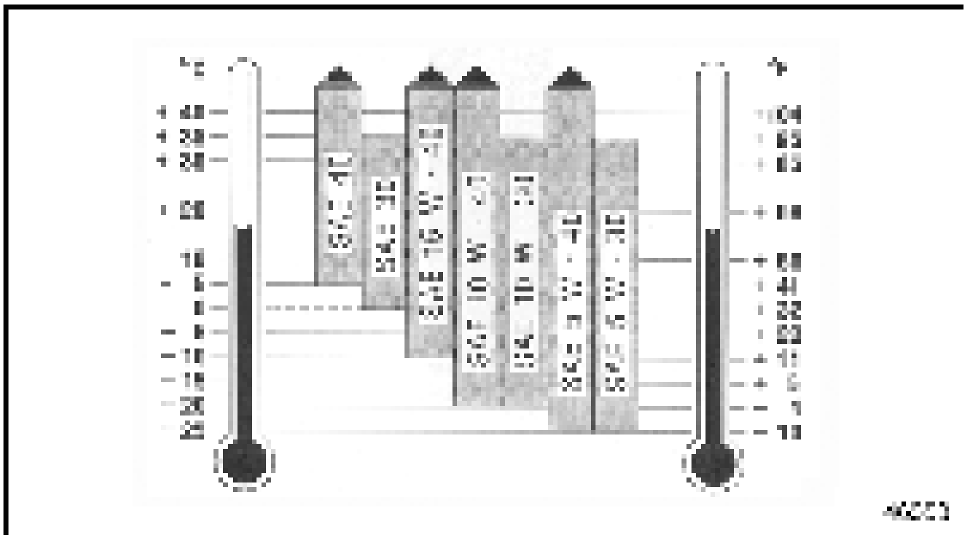


Figure 2. Engine Oil Temperature Ranges

Section 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. Mixtures above 60 percent may reduce cooling effectiveness and reduce heat transfer capability of the coolant. 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.

Section 5.3.1
Fully Formulated Antifreeze

Antifreeze approved for use in the MBE 900 engine is a mixture of ethylene glycol and corrosion inhibitors. Antifreeze containing ethylene glycol 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.

Section 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.

The following types of water are preferred for use in coolant:

- Distilled water
- Water purified by reverse osmosis
- De-ionized water

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.

Section 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 "Coolant Specifications" .

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 2. 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 "Coolant Mixing Ratio" .

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 3. Coolant Mixing Ratio

Section 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

Section 5.3.4
Recycled Antifreeze

Recycled antifreeze that complies with TMC RP-329 Type “A” (for ethylene glycol) is approved for use in MBE 900 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.

Section 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 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 900 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.

Section 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.

Section 5.3.6
Non-Approved Coolants

The following types of coolant are not approved for use in MBE 900 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.

Section 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.

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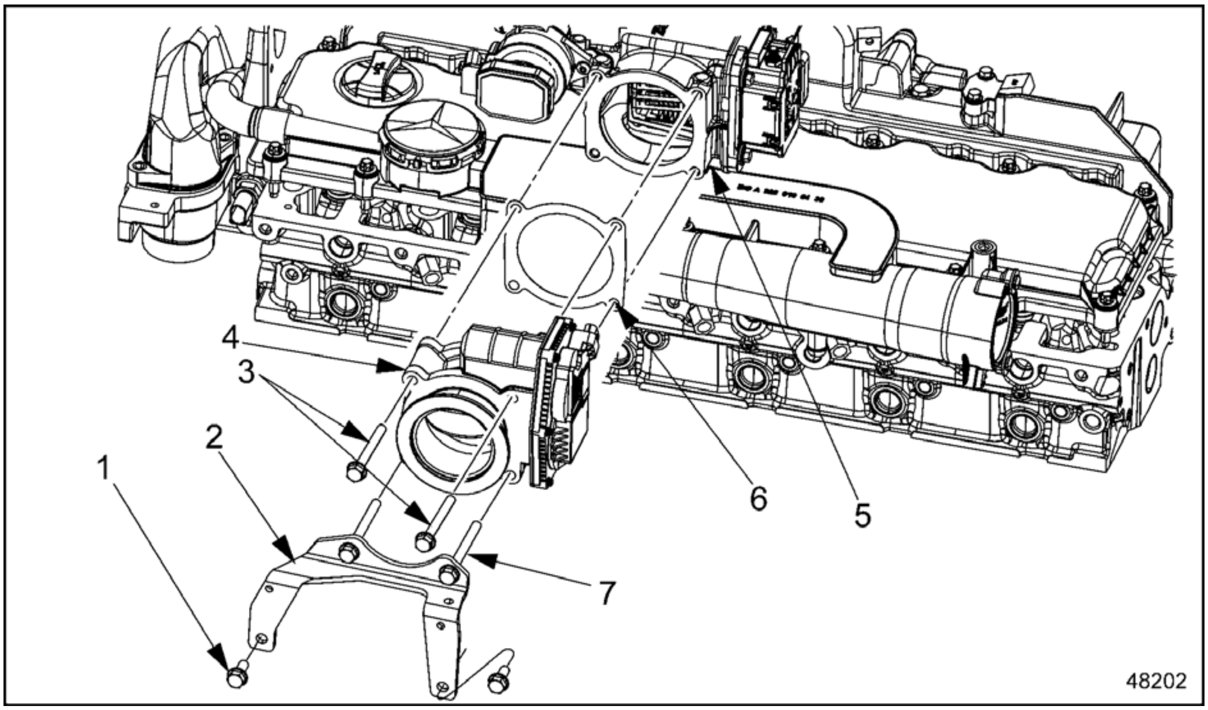
Section 6.1
Air Intake Throttle Valve

The following sections support the air intake throttle valve.

Section 6.1.1
Removal of Air Intake Throttle Valve

Removal steps are as follows:

1. Shut off electrical power with the ignition switch.
2. Disconnect the electrical connector at the intake throttle valve.
3. Remove the two lower bolts from the air intake throttle mounting bracket. See Figure "Air Intake Throttle Valve" .



1. Bolts (Qty 2)	5. Mixer Housing
2. Mounting Bracket	6. Gasket
3. Bolts (Qty 2)	7. Bolts (Qty 2)
4. Air Intake Throttle Valve	

Figure 1. Air Intake Throttle Valve

4. Remove the two upper bolts from the air intake throttle mounting bracket and remove the bracket. See Figure "Air Intake Throttle Valve" .
5. Remove the two upper bolts from the intake throttle and remove the air intake throttle. See Figure "Air Intake Throttle Valve" .

Section 6.1.2

Installation of Air Intake Throttle Valve

Installation steps are as follows:

1. Loosely install the air intake throttle valve to the mixer housing with two bolts in the upper holes.See Figure "Air Intake Throttle Valve" .

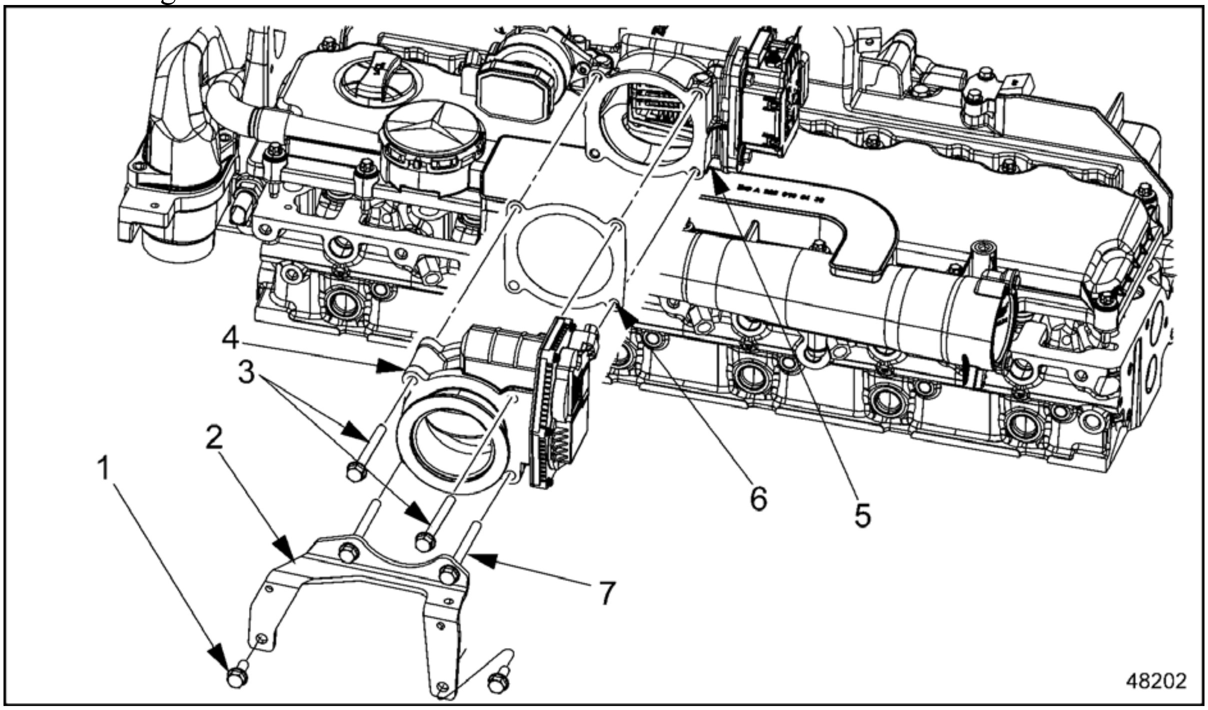


Figure 2. Air Intake Throttle Valve

2. Install two bolts and throttle valve mounting bracket in the lower two holes of the throttle valve.See Figure "Air Intake Throttle Valve" .
3. Install the two lower bolts in the throttle mounting bracket.See Figure "Air Intake Throttle Valve" .
4. Torque the throttle bracket and throttle valve bolts to 20-30 N·m (15-22 lb·ft).
5. Connect the electrical connector to the intake throttle valve. See Figure "Air Intake Throttle Valve" .

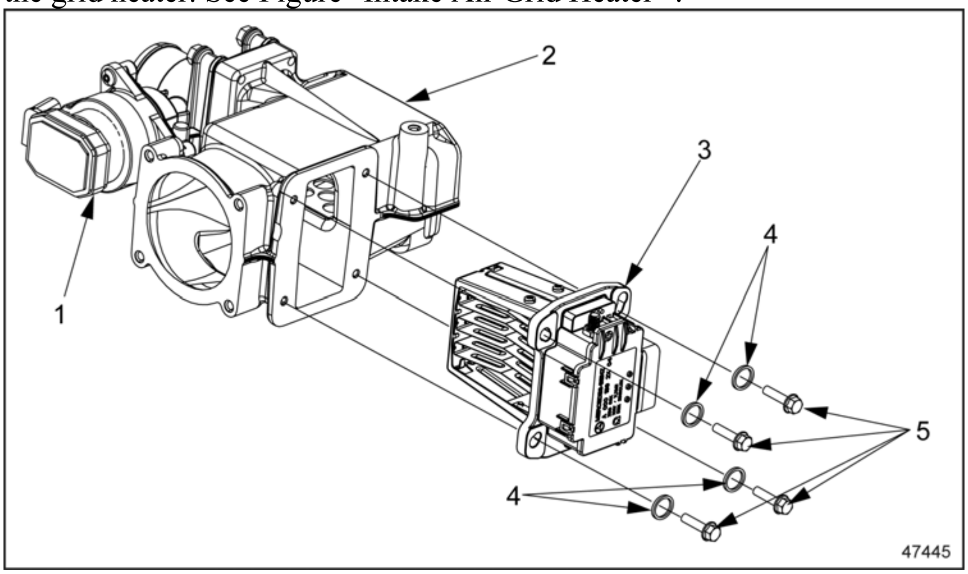
Section 6.2
Air Intake Grid Heater

Perform the following procedures for the removal and installation of the air intake grid heater.

Section 6.2.1
Removal of Air Intake Grid Heater

Removal steps are as follows:

1. Disconnect the battery cables.
2. Disconnect the harness connector and electrical connections at the grid heater.
3. Remove the four bolts securing the air intake grid heater to the air intake mixer housing. Remove the grid heater. See Figure "Intake Air Grid Heater" .



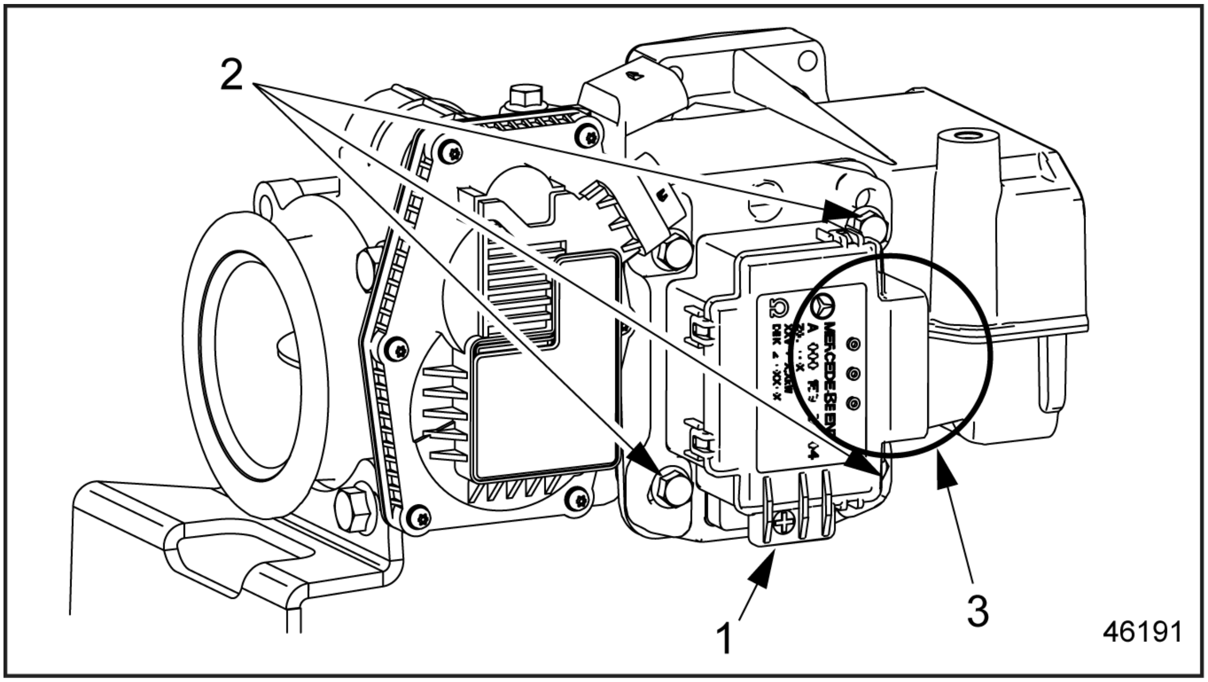
1. EGR Valve	4. Washers
2. Air Intake Mixer Housing	5. Bolts
3. Air Intake Grid Heater	

Figure 1. Intake Air Grid Heater

Section 6.2.2
Installation of Air Intake Grid Heater

Installation steps are as follows:

1. Insert the air intake grid heater in the air intake mixer housing and secure with four bolts and washers. Install the ground cable under one of the mounting bolts. Torque the bolts to 9 N·m (7 lb·ft) . See Figure "Intake Air Grid Heater" .



1. Battery Supply Stud (+12 V)	3. Connector to MCM (part of engine harness)
2. Possible Battery Ground Connection	

Figure 2. Grid Heater Electrical Connections

2. Connector 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 "Grid Heater Electrical Connections" .

   Note: Ensure that there is a flange nut on the stud seated against the grid heater housing and a flange nut securing the battery supply cable to the grid heater stud.

3. Connect the battery cables.

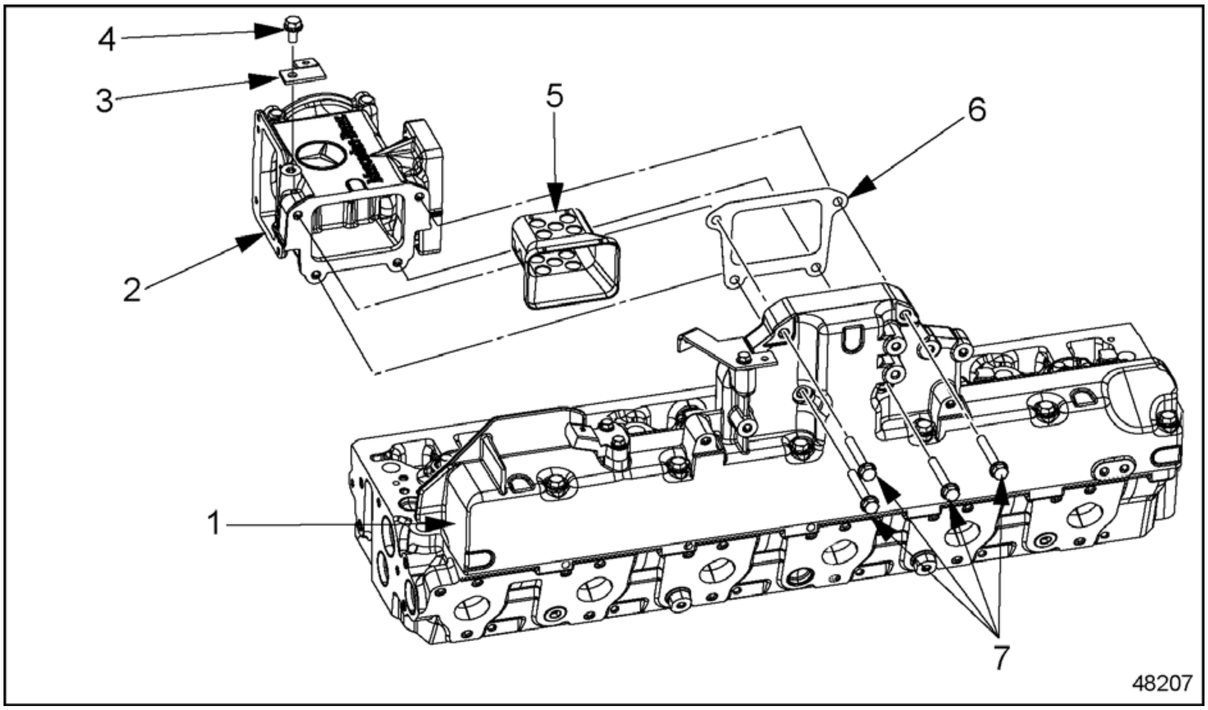
Section 6.3
Air Intake Mixer Housing

Perform the following procedures for the removal and installation of the air intake mixer housing.

Section 6.3.1
Removal of Air Intake Mixer Housing

Removal steps are as follows:

1. If installed, remove the air intake grid heater. Refer to "6.2.1 Removal of Air Intake Grid Heater" .
2. Remove the EGR valve. Refer to "8.4.1 Removal of EGR Valve Assembly" .
3. Remove the air intake throttle valve. Refer to "6.1.1 Removal of Air Intake Throttle Valve" .



1. Air Intake Manifold	5. Air Mixer
2. Air Mixer Housing	6. Gasket
3. Bracket	7. Bolts (qty 4)
4. Bolt	

Figure 1. Air Intake Mixer Housing

4. Remove the four bolts securing the air intake mixer housing and gasket to the air intake manifold and remove the housing. Discard the gasket. See Figure "Air Intake Mixer Housing" .

Section 6.3.2
Installation of Air Intake Mixer Housing

Installation steps are as follows:

1. Secure the air intake mixer housing and new gasket to the air intake manifold with four bolts. Torque the bolts to 20-30 N·m (15-22 lb·ft). See Figure "Air Intake Mixer Housing" .
2. Install the EGR valve. Refer to "8.4.2 EGR Valve Assembly Installation" .
3. Install the air intake throttle valve. Refer to "6.1.2 Installation of Air Intake Throttle Valve" .
4. Install the air intake grid heater. Refer to "6.2.2 Installation of Air Intake Grid Heater" .

Section 6.4
Air Intake Manifold

Perform the following procedures for the removal and installation of the intake manifold.

Section 6.4.1
Removal of Air Intake Manifold

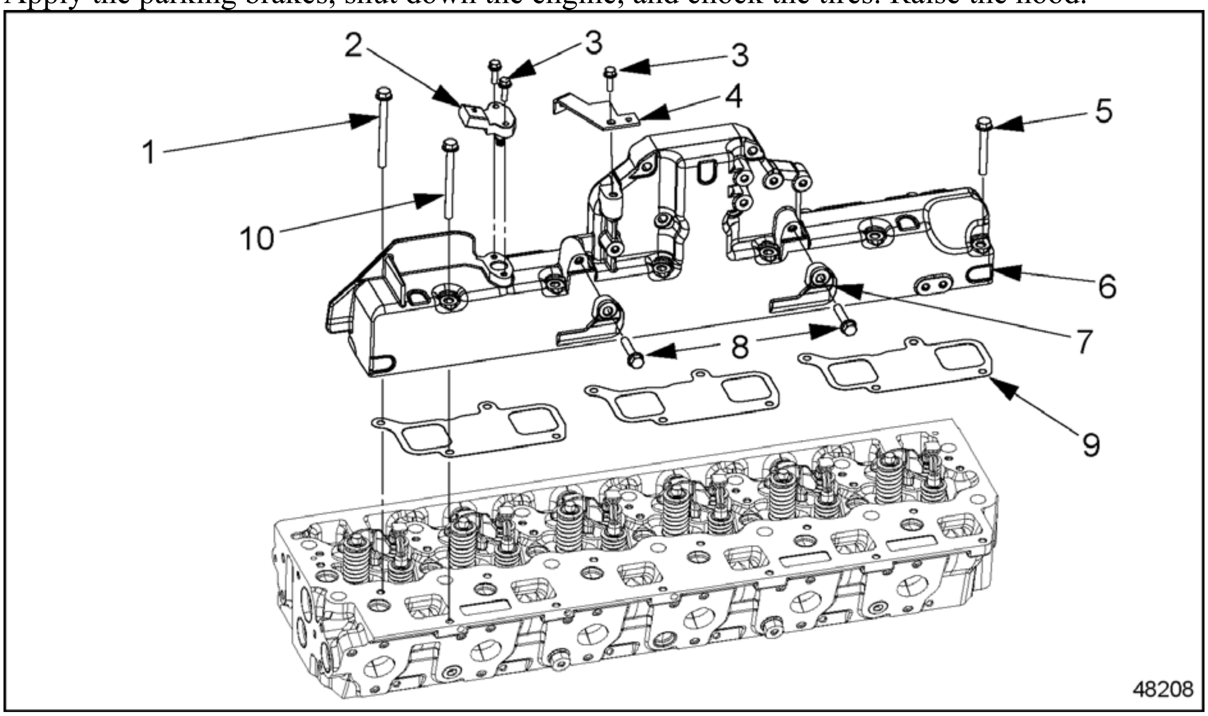
Removal steps area as follows:

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 tires. Raise the hood.



1. Bolts (qty 6)	6. Air Intake Manifold
2. Air Pressure Sensor	7. Upper EGR Cooler Brackets (qty 2)
3. Bolts	8. Bolts (qty 2)
4. Bracket	9. Gaskets (qty 3)
5. Bolt	10. Bolts (qty 5)

Figure 1. Intake Manifold

2. Remove the pipe clamp. Then, remove the intake manifold inlet pipe and O–ring from the intake manifold.
3. Disconnect the electrical wiring harness connector at the air intake temperature/pressure sensor on the top of the manifold.
4. Disconnect the electrical connector at the Delta P Sensor and remove the sensor from the air intake manifold.
5. Remove the EGR delivery pipe. Refer to "8.5.1 Removal of EGR Delivery Pipe" .
6. Remove the bolt at the clamp securing the air compressor air inlet tube to the air intake manifold.
7. Remove the two upper EGR cooler mounting brackets from the air intake manifold. See Figure "Intake Manifold" .
8. Remove the twelve intake manifold mounting bolts, then remove the intake manifold from the cylinder head. See Figure "Intake Manifold" .

Section 6.4.2
Installation of Air Intake Manifold

Installation steps are as follows:

1. Clean all mating surfaces, then place new manifold gaskets on the head.
2. Install the air intake manifold on the cylinder head and secure with twelve bolts. Tighten the mounting bolts 25 N·m (18 lb·ft), starting with the center bolt and then working outward to the end bolts. See Figure "Intake Manifold" .
3. Connect the electrical connector and install the cover on the sensor. See Figure "Intake Manifold" .
4. Remove the chocks from the tires.

Section 6.5
Single-Stage Turbocharger

The following sections support the repair of the single-stage turbocharger.

Section 6.5.1
Pre-Inspection of Single-stage Turbocharger

Pre-inspection steps are as follows:

1. Inspect the air induction system for loose connections. Check the ducts and lines for cracks, punctures, or corrosion.
2. Disconnect the exhaust pipe from the turbocharger turbine outlet and check the turbocharger wheel for damage.

   Note: A light may be useful for examining the turbocharger wheel blade tips inside the turbocharger housing. The surfaces requiring inspection can be viewed from the outlet of the turbocharger housing.

   a. If the turbocharger wheel rubs against the housing, or the turbocharger blades are damaged, replace the turbocharger. Refer to "6.5.2 Removal of Single-stage Turbocharger" .
   b. If the turbocharger wheel is not rubbing the housing and the blades are not damaged, go to step 3 .
3. Disconnect the air duct from the compressor air inlet and check the compressor wheel for damage.
   a. If the compressor wheel is damaged, or if the compressor wheel rubs against the housing, replace the turbocharger. Refer to "6.5.2 Removal of Single-stage Turbocharger" .
   b. If the compressor wheel is not damaged and the compressor wheel is not rubbing the housing, go to step 4 .
4. Inspect the entire turbocharger system for excessive oil.

   Note: A light film of oil is normal in the air inlet compressor area and exhaust duct tubes.

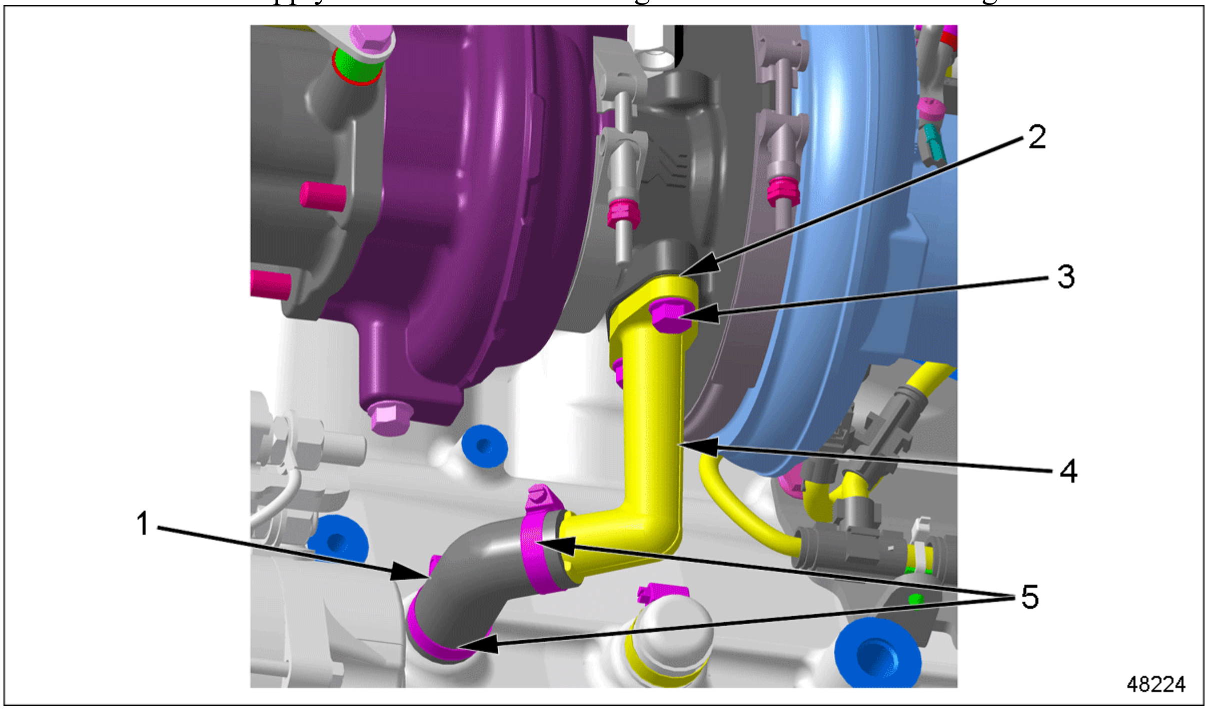
5. Check the oil supply and return lines for leaks
   a. If oil leaks are present, tighten all connections to the proper torque value. Listed in Table "Torque Values" are the necessary torque values and then go to step 6 .
   b. If no oil leaks are present, go to step 6 .
6. Install the air inlet and exhaust ducts, then tighten all connections.

Section 6.5.2
Removal of Single-stage Turbocharger

Removal steps are as follows:

1. Apply the parking brakes and chock the tires. Raise the hood.
2. Disconnect the air cleaner pipe from the turbocharger and the air filter housing. Refer to the appropriate vehicle service manual.
3. Disconnect the turbo compressor outlet pipe from the housing.
4. Remove the two hoses from the inlet air Delta P fitting on the turbocharger.
5. Disconnect the electrical connector to the turbocharger inlet pressure/temperature sensor.

6. Disconnect electrical connector to the turbocharger outlet temperature sensor.
7. Remove the blow-by return hose from the turbocharger.
8. Disconnect the oil supply line from the turbocharger and the oil filter housing.



1. Hose	4. Oil Drain
2. Gasket	5. Hose Clamps
3. Bolts	

Figure 1. Single-stage Turbocharger Oil Drain

9. Disconnect the oil return line from the turbocharger and discard gasket.
10. For engines equipped with a pneumatically actuated exhaust brake assembly remove the heat shield from the turbocharger and exhaust brake valve housing.
11. Remove the exhaust brake assembly from the turbocharger:
    a. For engines equipped with a pneumatic brake actuator refer to "7.2.6 Removal of Dual-stage Turbocharger Exhaust Brake Assembly" .
    b. For engines equipped with an electronic brake actuator, refer to "7.2.1 Removal of Single-stage Turbocharger with Electronic Wastegate Exhaust Brake Assembly" .
12. Remove the four nuts attaching the turbocharger to the exhaust manifold and remove the turbocharger. Discard the nuts.

Section 6.5.2.1
Inspection of Radial and Axial Play

Inspection steps are as follows:

1. Check radial play by rotating the shaft assembly by hand while applying equal side pressure to the compressor and turbocharger wheels.
    a. If there is wheel contact with either side of the housing, replace the turbocharger.
    b. If there is no wheel contact, go to step 2 .

2. Check axial play by rotating the shaft assembly while pushing it in one direction, then the opposite direction.
   a. If there is contact with either side of the housing, replace the turbocharger.
   b. If there is no contact with the housing, refer to "6.5.5 Installation of Single-stage Turbocharger " .

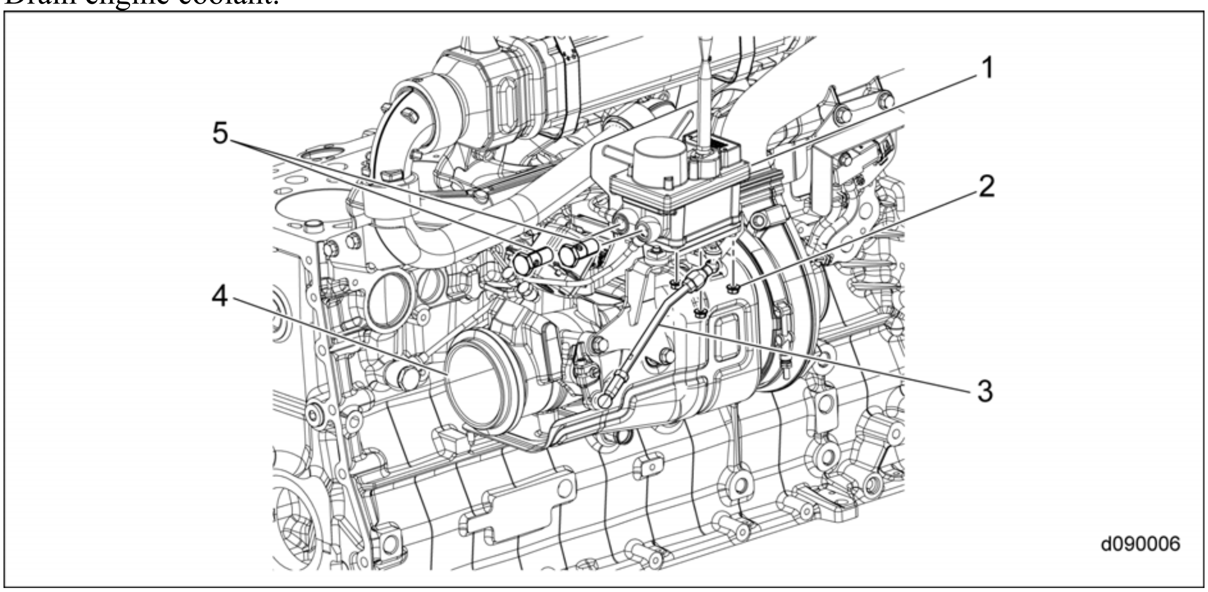
Section 6.5.3
Removal of Brake Actuator

Removal steps are as follows:

The SRA2 Actuator is a solid-state, CAN operated device. It is used as an electronic control for the engine brake flap for certain non-air compressor equipped applications and for a wastegate actuator.

There is no service internally in the electronic actuator. The only services for the SRA2 Actuator are the adjustment of the brake flap linkage, complete removal and replacement of the actuator, and servicing of the coolant lines.

1. Switch Ignition power off.
2. Drain engine coolant.



1. Brake Actuator	4. Engine Brake (flap)
2. Brake Actuator Mounting Nuts (qty 4)	5. Banjo Bolts (qty 2)
3. Brake Actuator Arm	

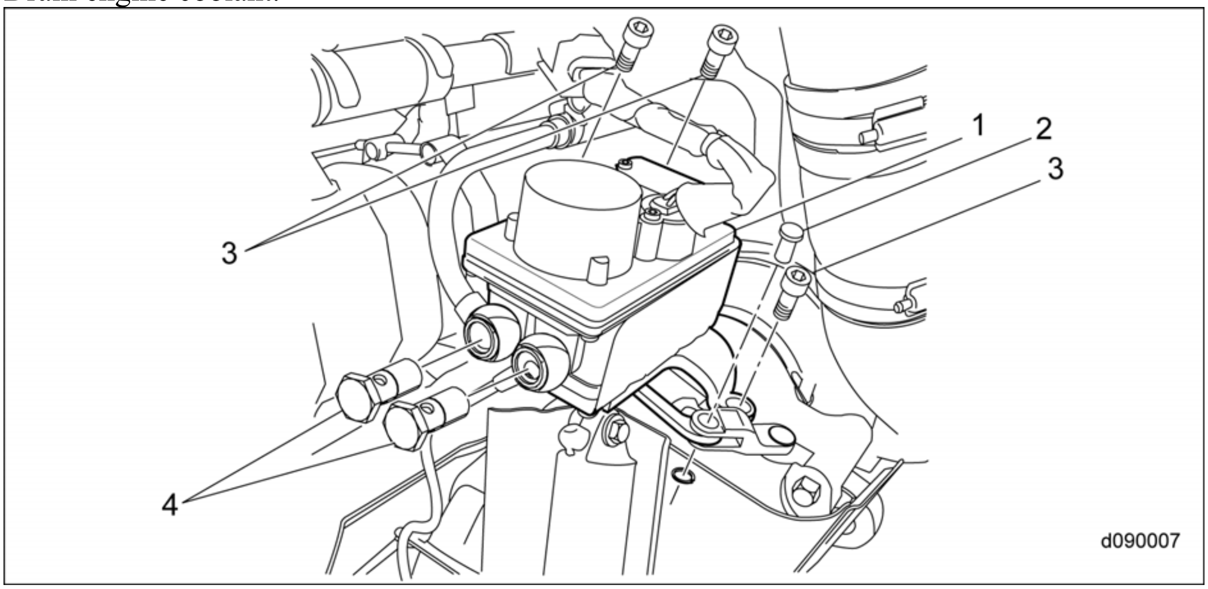
Figure 2. Brake Actuator

3. Remove coolant lines from actuator. See Figure "Brake Actuator" .
4. Disconnect wiring harness.
5. Remove clip to disconnect ball socket from actuator. See Figure "Brake Actuator"
6. Remove four nuts from underneath actuator bracket. See Figure "Brake Actuator"
7. Lift actuator from bracket.

Section 6.5.4
Removal of Wastegate Actuator

Removal steps are as follows:

1. Switch Ignition power off.
2. Drain engine coolant.



1. Wastegate Actuator	3. Wastegate Bolts (qty 3)
2. Actuator Lever Pin and Circlip	4. Coolant Line Banjo Bolts

Figure 3. Wastegate Actuator

3. Remove coolant lines banjo bolts from actuator. See Figure "Wastegate Actuator"
4. Disconnect wiring harness.
5. Remove circlip to disconnect wastegate arm from actuator lever. See Figure "Wastegate Actuator"
6. Remove 3 bolts attaching the bracket to the turbocharger. See Figure "Wastegate Actuator"
7. Remove four nuts from underneath actuator bracket.
8. Lift actuator from bracket.

Section 6.5.5
Installation of Single-stage Turbocharger

Installation steps are as follows:

1. Inspect the air cleaner pipe, turbo compressor outlet pipe, exhaust manifold, and the oil supply and return lines for restrictions or foreign objects.
2. Install the turbocharger on the exhaust manifold. Use new self-locking nuts to secure the turbocharger. Torque the nuts to 50 N·m (37 lb·ft).
3. Install the exhaust brake assembly to the turbocharger:
   a. For engines equipped with a pneumatic brake actuator, refer to "7.2.6 Removal of Dual-stage Turbocharger Exhaust Brake Assembly" .
   b. For engines equipped with an electronic brake actuator, refer to "7.2.1 Removal of Single-stage Turbocharger with Electronic Wastegate Exhaust Brake Assembly" .

4. Install the Fuel Doser Valve on the turbocharger. Refer to "2.20.1 Removal of Fuel Doser Valve" .
5. For engines equipped with a pneumatic brake actuator, attach the heat shield to the turbocharger and the exhaust brake valve housing. Torque the bolts to 25 N·m (18 lb·ft).
6. Using a new gasket, secure the oil return line to the turbocharger with two bolts. Torque the bolts to 25 N·m (18 lb·ft).
7. 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.
8. Refill the turbocharger oil inlet port and connect the oil supply line to the oil filter housing and secure with a banjo bolt and new washers. Torque the banjo bolt to 25 N·m (18 lb·ft).
9. Install the oil supply line fitting to the top of the turbocharger. Torque the fitting to 32-38 Nm (24-28 lb·ft).
10. Connect the engine exhaust brake air line. Torque the fitting to 15-19 N·m (11-14 lb·ft).
11. Connect the pipe between the exhaust brake valve housing and the exhaust pipe. Torque the V-band clamp to 10N·m (7 lb·ft).
12. Attach the turbocharger compressor outlet pipe to the turbocharger. Tighten the clamp firmly.
13. Attach the air cleaner pipe to the turbocharger.

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 and repair as necessary.

NOTICE:

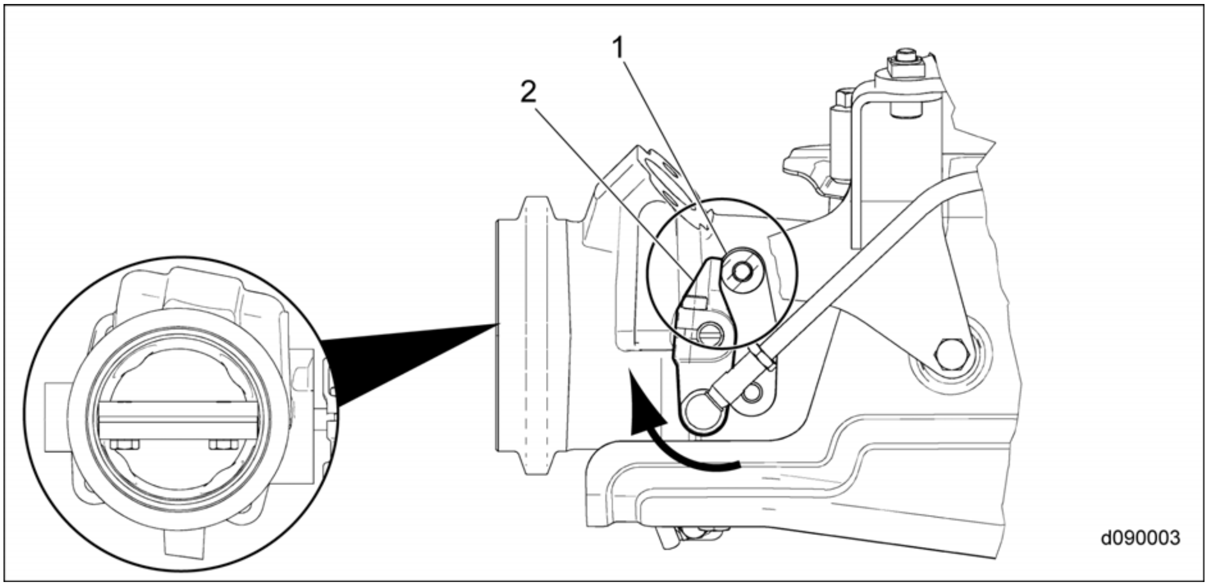
Whenever the turbocharger is replaced the air mass flow of the engine must be re-calibrated to ensure proper engine EGR and smoke control operation.

16. 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.
17. If any other codes appear, refer to the EPA07 MBE 900 DDEC VI Troubleshooting Guide , 6SE580.
18. Shut down the engine.

Section 6.5.6
Installation of Brake Actuator

Installation steps are as follows:

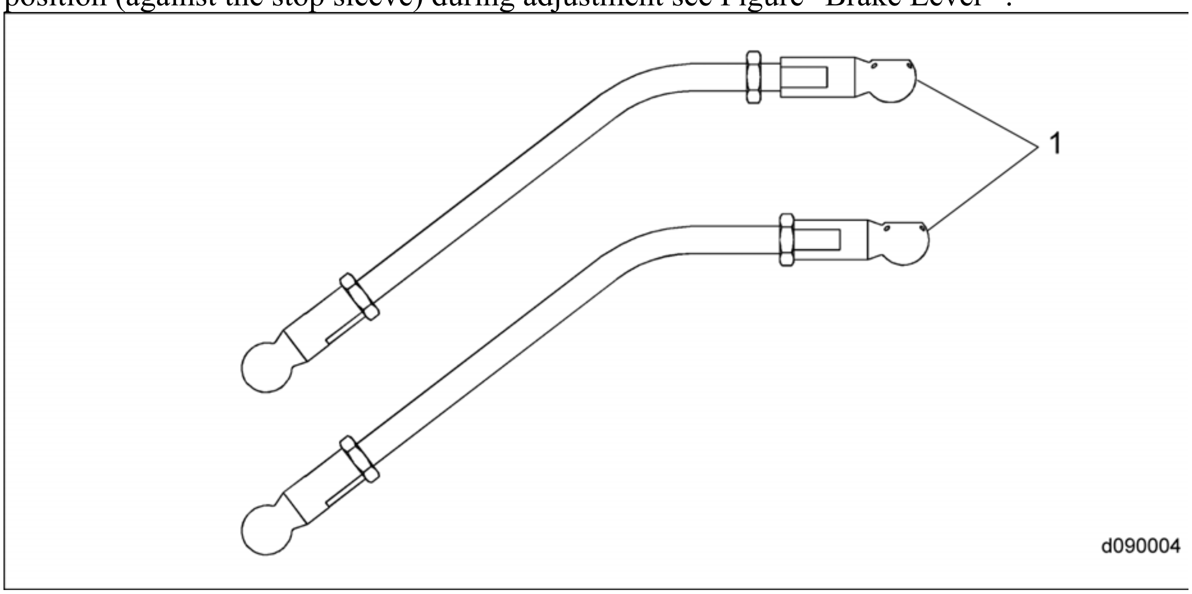
1. Adjust linkage as follows:



1. Stop Sleeve	2. Brake Actuator Lever

Figure 4. Brake Lever

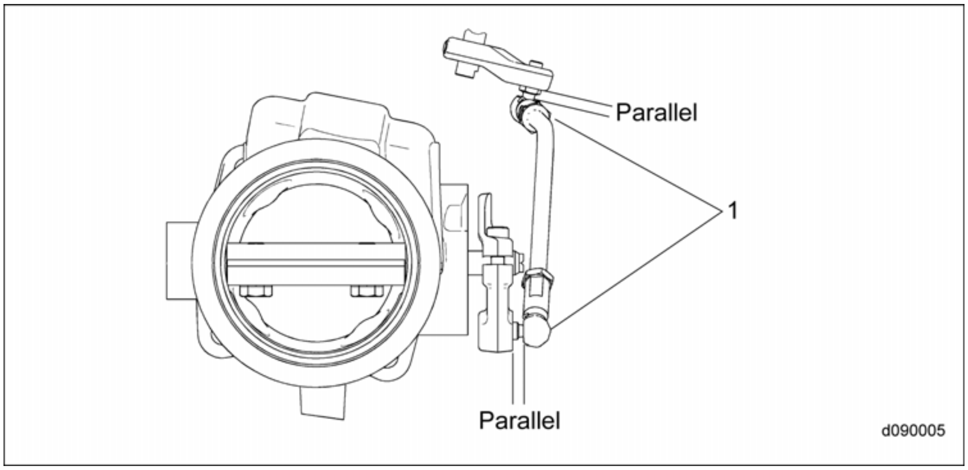
a. Align ball sockets with lever arms. It is important to keep the brake lever in the fully open position (against the stop sleeve) during adjustment see Figure "Brake Lever" .



1. Ball Sockets

Figure 5. Ball Socket

b. Screw ball socket out from initial position by 3 turns see Figure "Ball Socket" .
c. Tighten lock nuts.



1. Ball Sockets

Figure 6. Parallel Ball Sockets

   d. Position sockets parallel to lever arms and install clips see Figure "Parallel Ball Sockets" .
   e. Check for adequate clearance for linkage and brackets.
2. Install four nuts under bracket to secure actuator. Torque to 8Nm. See Figure "Brake Actuator"
3. Connect coolant lines to actuator. Torque to 35 +-5Nm. See Figure "Brake Actuator"
4. Connect wiring harness.
5. Fill engine with coolant. Refer to
6. Run DDL Routine for adaptive learning.

Section 6.5.7
Installation of Wastegate Actuator

Installation steps are as follows:

1. Attach actuator to bracket with 4 nuts. Torque to 8Nm.
2. Attach wastegate arm to actuator and turbocharger with circlips. See Figure "Wastegate Actuator"
3. Attach mounting bracket to turbocharger. Torque to XXnm. See Figure "Wastegate Actuator"
4. Connect wiring harness.
5. Connect coolant lines and torque banjo bolts to 35 +-5Nm. See Figure "Wastegate Actuator"
6. Fill engine with coolant. Refer to
7. Run DDL Routine for adaptive learning.

Section 6.6
Dual-Stage Turbocharger

The following sections support the repair of the dual-stage turbocharger.

Section 6.6.1
Pre-Inspection of Dual-stage Turbocharger

Pre-inspection steps are as follows:

1. Inspect the air induction system for loose connections. Check the ducts and lines for cracks, punctures, or corrosion.
2. Disconnect the exhaust pipe from the turbocharger turbine outlet and check the turbocharger wheel for damage.

   Note: A light may be useful for examining the turbocharger wheel blade tips inside the turbocharger housing. The surfaces requiring inspection can be viewed from the outlet of the turbocharger housing.

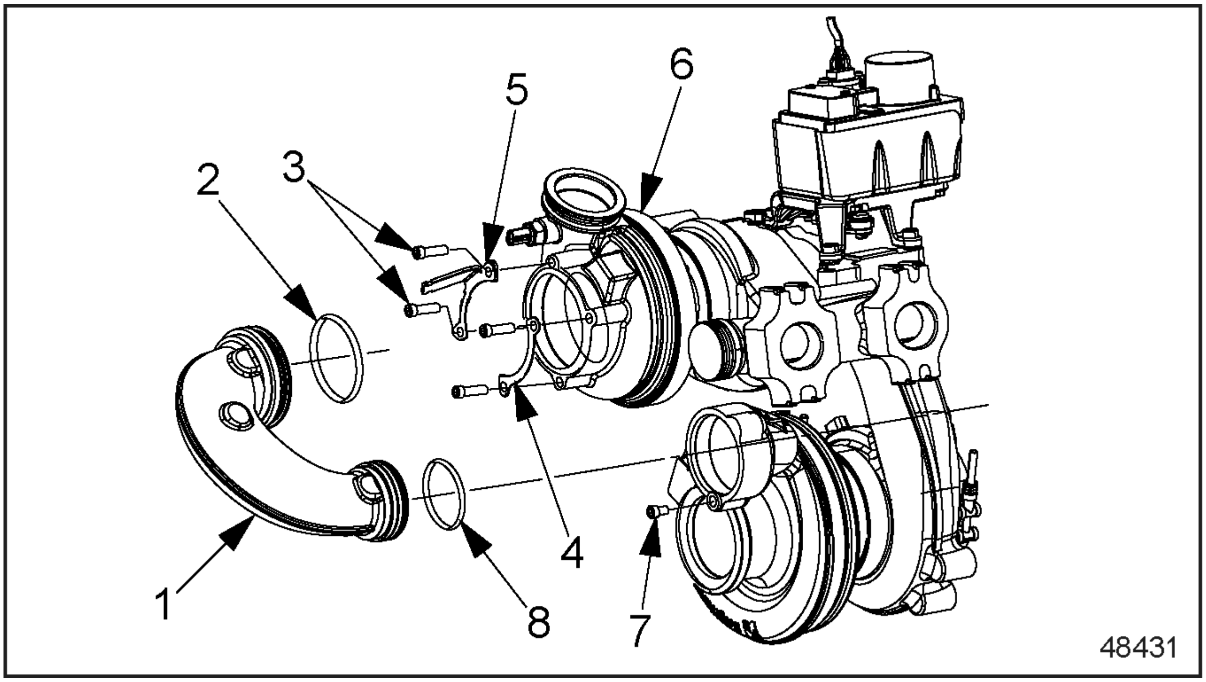
   a. If the turbocharger wheel rubs against the housing, or the turbocharger blades are damaged, replace the turbocharger. Refer to "6.6.2 Removal of Dual-stage Turbocharger " .
   b. If the turbocharger wheel is not rubbing the housing and the blades are not damaged, go to step 3 .
3. Disconnect the air duct from the compressor air inlet and check the compressor wheel for damage.
   a. If the compressor wheel is damaged, or if the compressor wheel rubs against the housing, replace the turbocharger. Refer to "6.6.2 Removal of Dual-stage Turbocharger " .
   b. If the compressor wheel is not damaged and the compressor wheel is not rubbing the housing, go to step 4 .
4. Inspect the entire turbocharger system for excessive oil.

   Note: A light film of oil is normal in the air inlet compressor area and exhaust duct tubes.

5. Check the oil supply and return lines for leaks
   a. If oil leaks are present, tighten all connections to the proper torque value. Listed in Table "Torque Values" are the necessary torque values and go to step 6 .
   b. If no oil leaks are present, go to step 6 .
6. Install the air inlet and exhaust ducts, then tighten all connections.

Section 6.6.2
Removal of Dual-stage Turbocharger

See Figure "Dual-stage Turbocharger and Components" for dual-stage turbocharger and component parts.

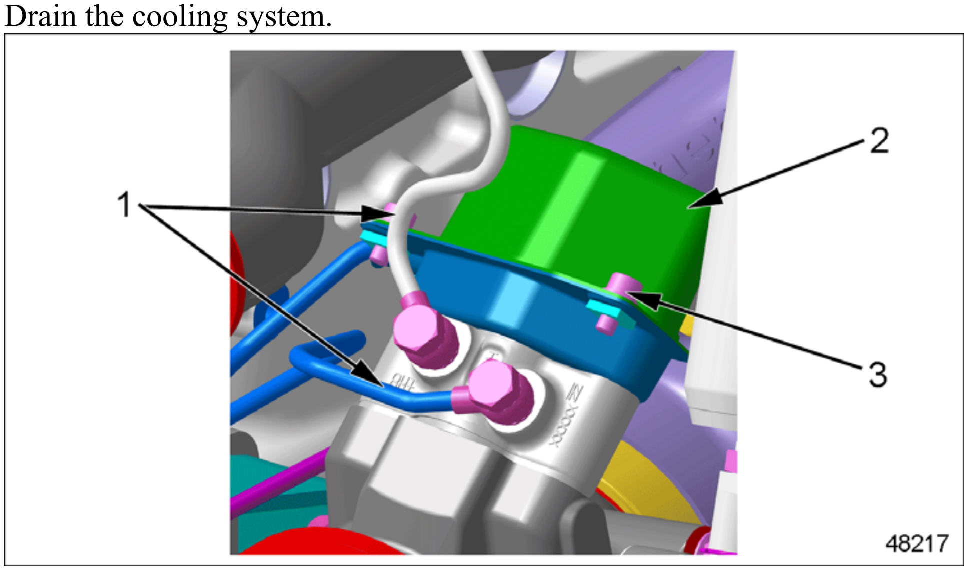


1. Elbow	5. Clamp Plate
2. O-Ring	6. Turbocharger - High-Pressure Stage
3. Screws (qty 4)	7. Screw
4. Clamp Plate	

Figure 1. Dual-stage Turbocharger and Components

Removal steps are as follows:

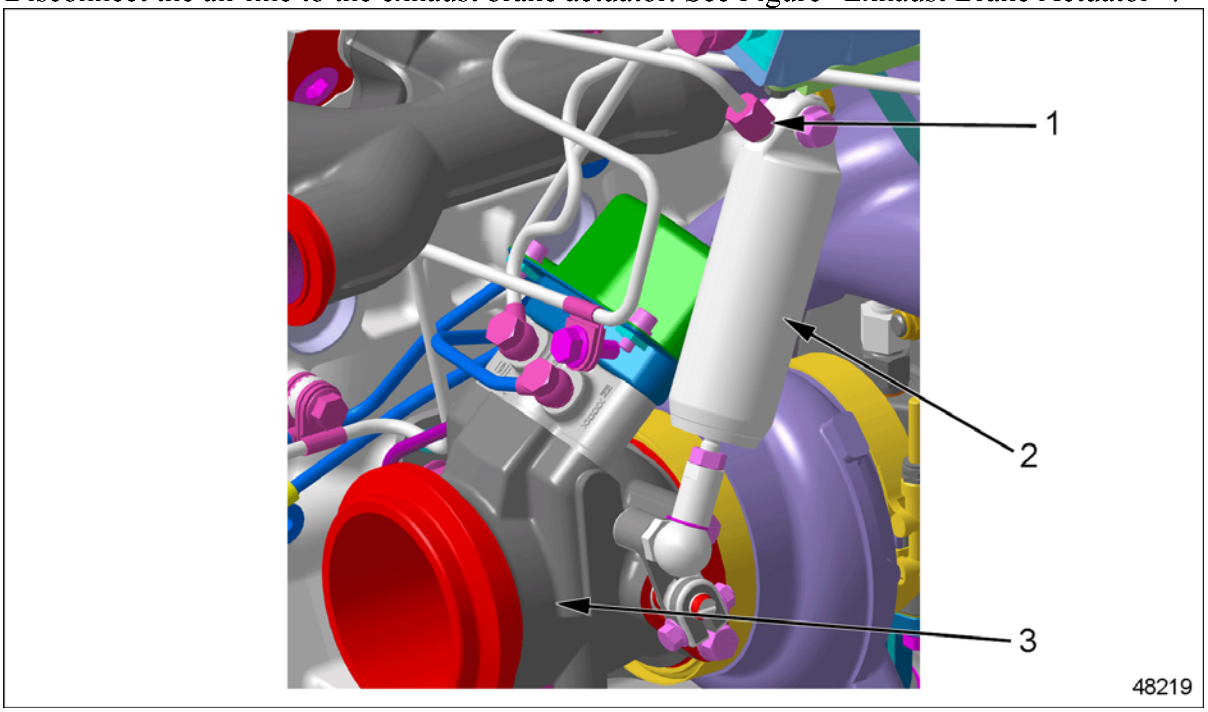
1. Drain the cooling system.



1. FDV Coolant Lines	3. Bolts (qty 3)
2. FDV Cover	

Figure 2. FDV Coolant Lines

2. Disconnect the coolant in and out lines on the Fuel Doser Valve by removing the banjo bolts and washers. Discard the washers. See Figure "FDV Coolant Lines" .
3. Remove the three bolts secure the upper cover to the Fuel Doser Valve (FDV) and remove. See Figure "FDV Coolant Lines" .
4. Disconnect the fuel dosing line from the FDV.
5. Disconnect the electrical harness connector to the turbocharger outlet temperature sensor on the turbocharger.
6. Disconnect the two Delta p hoses from the turbocharger by removing the clamps, if crimped clamps were used, discard the clamps. Remove the hoses from the spring clamps.
7. Disconnect the air line to the exhaust brake actuator. See Figure "Exhaust Brake Actuator" .

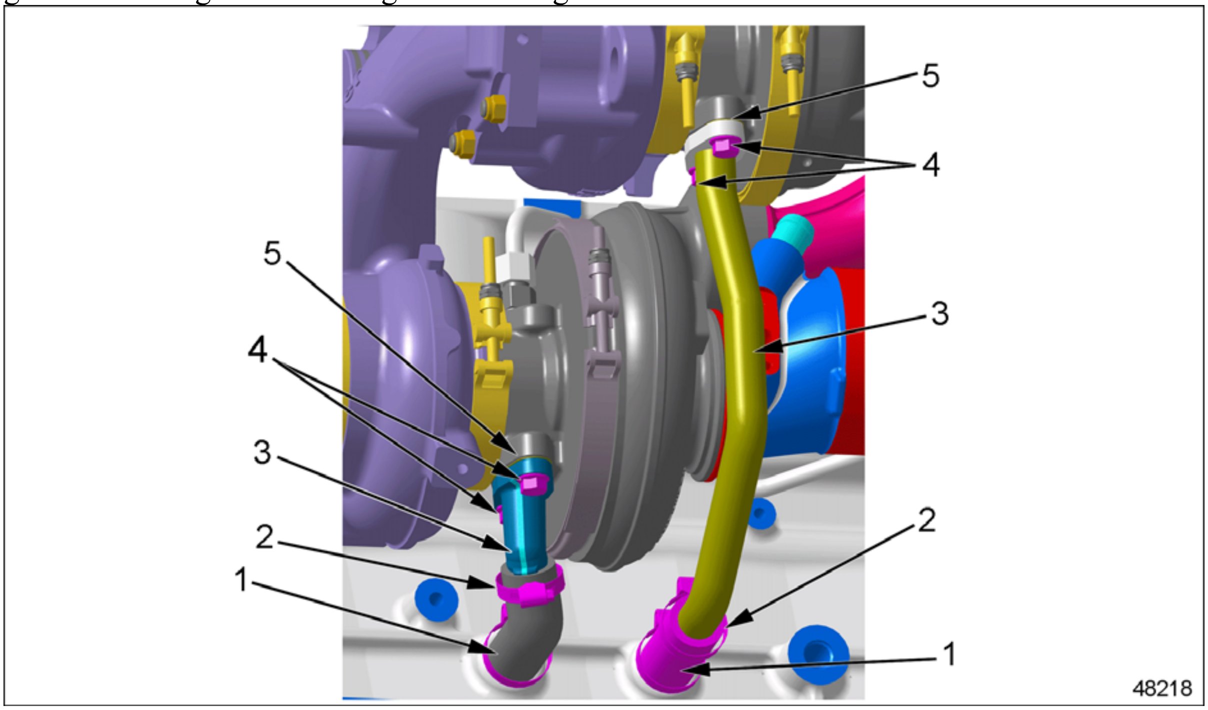


1. Brake Actuator Fitting Connection	3. Exhaust Brake Housing
2. Brake Actuator	

Figure 3. Exhaust Brake Actuator

8. Disconnect the air inlet connection at the lower compressor inlet housing.
9. Remove the crankcase vent hose at the compressor inlet housing by removing the clamp.
10. Disconnect the engine exhaust connection at the exhaust brake housing by removing the v-band clamp.
11. Disconnect the coolant in and out lines on the wastegate actuator by removing the banjo bolts and washers. Discard the washers.
12. Remove the engine exhaust brake assembly from the turbocharger by removing the v-band clamp on the brake housing.
13. Remove the turbocharger heat shield from the turbocharger by removing three bolts, two on the front and one on the side.
14. Disconnect each end of both turbocharger oil feed lines and remove. If necessary, remove the insulation covers from lines.

15. Remove both oil drain tubes and gaskets from the turbocharger and cylinder block. Discard gaskets. See Figure "Dual-stage Turbocharger Oil Drain Tubes" .



1. Hoses	4. Bolts
2. Hose Clamps	5. Gaskets
3. Oil Drains	

Figure 4. Dual-stage Turbocharger Oil Drain Tubes

16. Remove the two-piece EGR exhaust elbow. Refer to "8.6.3 Removal of Dual-Stage Turbocharger EGR Exhaust Elbow" . See Figure "Two-Piece EGR Exhaust Elbow" .
17. Remove and discard the Fey rings from the EGR exhaust elbows.
18. Remove the two Torx bolts securing Delta P Sensor fitting to the turbocharger and remove the sensor. Remove the O-ring from the sensor and discard.
19. Remove the EGR cooler. Refer to "8.1.3 Removal of Dual-stage Turbocharger EGR Cooler" .

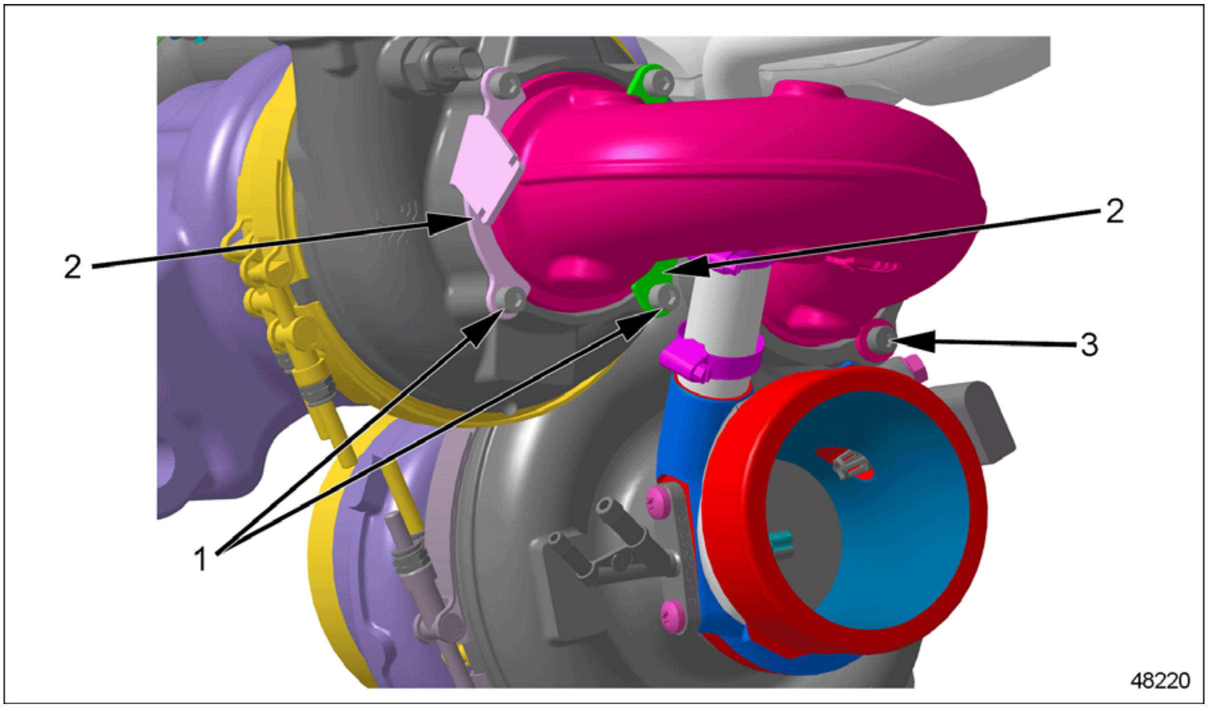
DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

20. Use a proper lifting device to hold the turbocharger assembly while removing the dual-stage turbocharger support bracket bolts.
21. Remove the socket-head cap screw from the lower turbocharger compressor inlet tube and remove the four hex-head cap screw and two retaining plates at the upper tube and remove tube. See Figure "Turbocharger Compressor Pipe" .

Note: In order to remove the bolts at the center exhaust manifold it is necessary to remove the turbocharger compressor pipe to gain access to the bolts.



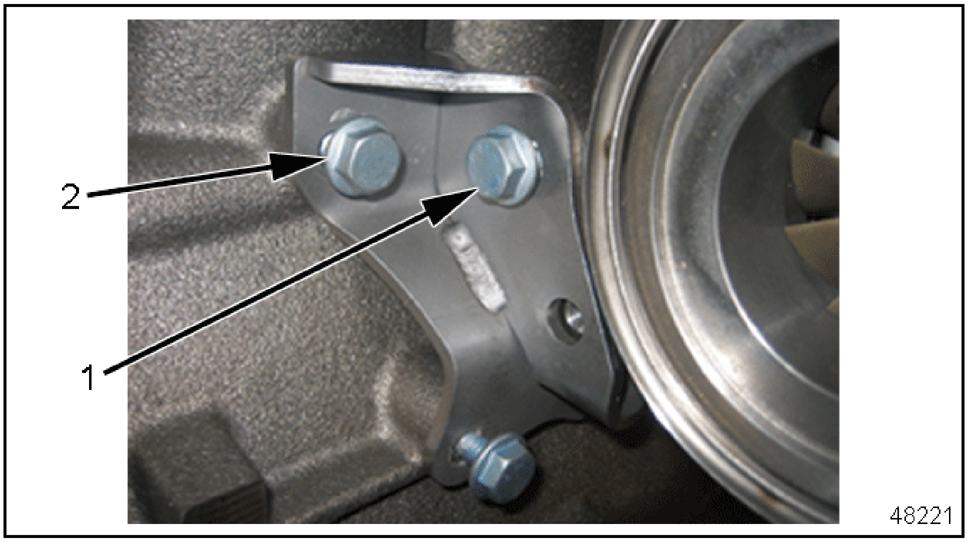
1. Hex-Head Cap Screws	3. Hex-Head Cap Screw
2. Retaining Plates	

Figure 5. Turbocharger Compressor Pipe

22. Remove the turbocharger and exhaust manifold as an assembly. Use the 12 mm socket from Triple Square Drive Socket Set (J-47403) to remove the exhaust manifold bolts.

    Note: Use the 12 mm short triple square drive socket (J-47403–3) to remove the upper exhaust manifold bolt near the turbocharger and the long socket for the remaining bolts.

23. Remove two bolts at the rear of the turbocharger securing the turbocharger to the support bracket at the cylinder block and remove the assembly. See Figure "Turbocharger (Dual-stage) to Block Mounting Bracket" .



1. Turbocharger to Mounting Bracket Bolts	2. Mounting Bracket to Cylinder Block Bolts

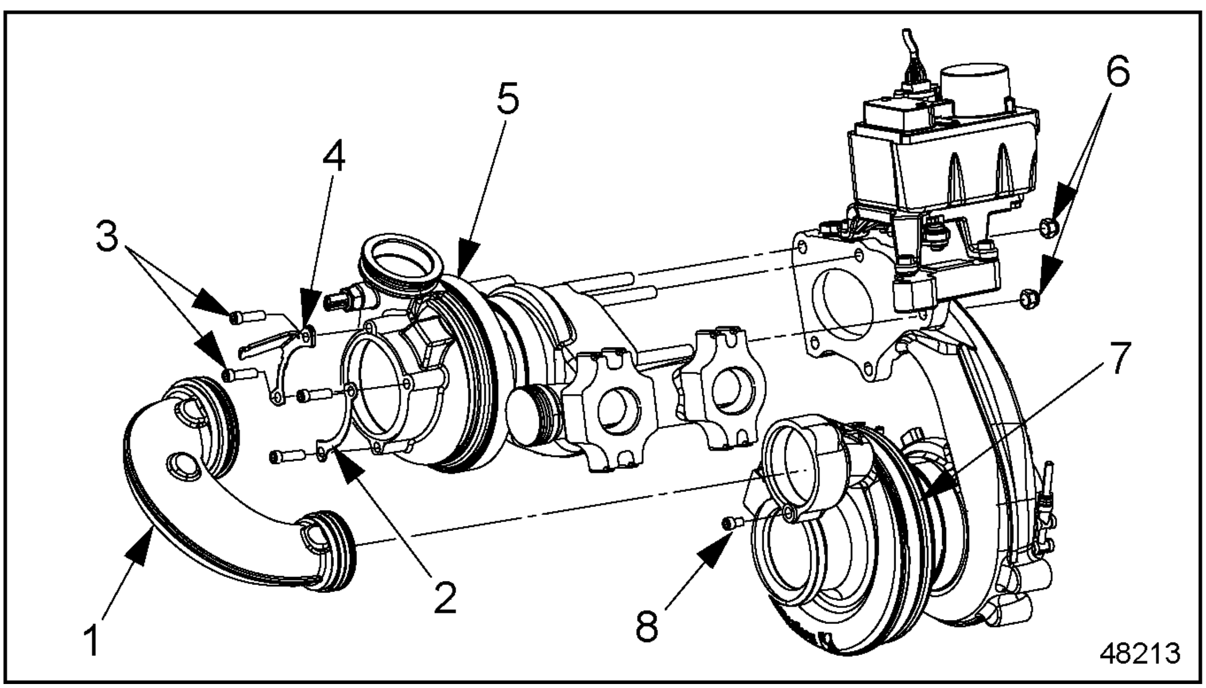
Figure 6. Turbocharger (Dual-stage) to Block Mounting Bracket

24. Remove both end exhaust manifolds from the turbocharger.
25. If required, remove the three bolts securing the turbocharger support bracket to the cylinder block and remove the bracket. See Figure "Turbocharger (Dual-stage) to Block Mounting Bracket" .
26. Cover the openings on the turbocharger to keep debris from entering.

Section 6.6.2.1
Inspection of Dual-stage Turbocharger

Inspection steps are as follows:

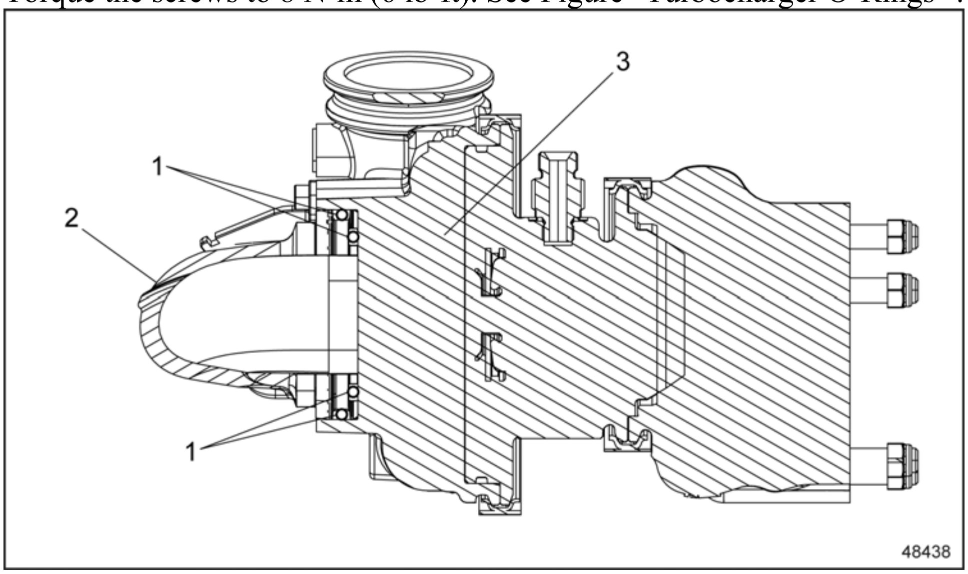
Note: The dual-stage turbocharger is serviced as an assembly only.



1. Elbow	5. Clamp Plate
2. Face Ring	6. Turbocharger -Assembly
3. Screws (qty 4)	7. Face Ring
4. Clamp Plate	

Figure 7. Dual-stage Turbocharger

1. Remove screw securing elbow to the low-pressure stage turbocharger. See Figure "Dual-stage Turbocharger" .
2. Remove four screws and two clamp plates securing the elbow to the high-pressure stage turbocharger and remove the elbow. See Figure "Dual-stage Turbocharger" .
3. Insert the elbow in the low-pressure stage and high-pressure stage of the dual-stage turbocharger and secure with two clamp plates and four screws at the high-pressure stage and one screw at the low-pressure stage. Ensure the two O-rings are installed correctly in the turbocharger housing. Torque the screws to 8 N·m (6 lb·ft). See Figure "Turbocharger O-Rings" .



1. O-Rings	3. Turbocharger Housing
2. Turbocharger Elbow	

Figure 8. Turbocharger O-Rings

4. Secure the elbow to the low-pressure stage turbocharger with a screw. Torque the screws to 8 N·m (6 lb·ft). See Figure "Dual-stage Turbocharger" .

Section 6.6.3
Installation of Dual-stage Turbocharger

Installation steps are as follows:

1. If removed, install the turbocharger support plate to the cylinder block with three bolts. See Figure "Turbocharger (Dual-stage) to Block Mounting Bracket" .
2. Install new fey rings (2 in each groove) BELLOWS on each end of turbocharger and center

exhaust manifold assembly.

3. Assemble two end exhaust manifolds V-BAND CLAMP to turbocharger and center exhaust manifold assembly.

DANGER:

BODILY INJURY

To avoid injury from a falling component, ensure a proper lifting device is used. Never stand beneath a suspended load.

4. Coat the threads of the exhaust manifold bolts with anti-seize compound. Install the exhaust manifold gaskets with the bridge down and the word “FRONT” outward and hold in place with bolts loosely installed in the lower positions only.
5. Use a proper lifting device to hold the turbocharger and exhaust manifold assembly and install the assembly over the lower exhaust bolts.
6. Loosely install the two bolts to secure the assembly to the turbocharger support bracket on the cylinder block. Torque the bolts to 50 N·m (37 lb·ft). See Figure "Turbocharger (Dual-stage) to Block Mounting Bracket" .
7. Use the 12 mm sockets from Triple Square Drive Socket Set (J-47403) to install the exhaust manifold bolts. Torque bolts in two stages as listed in Table "Exhaust Manifold Torque Procedure" .

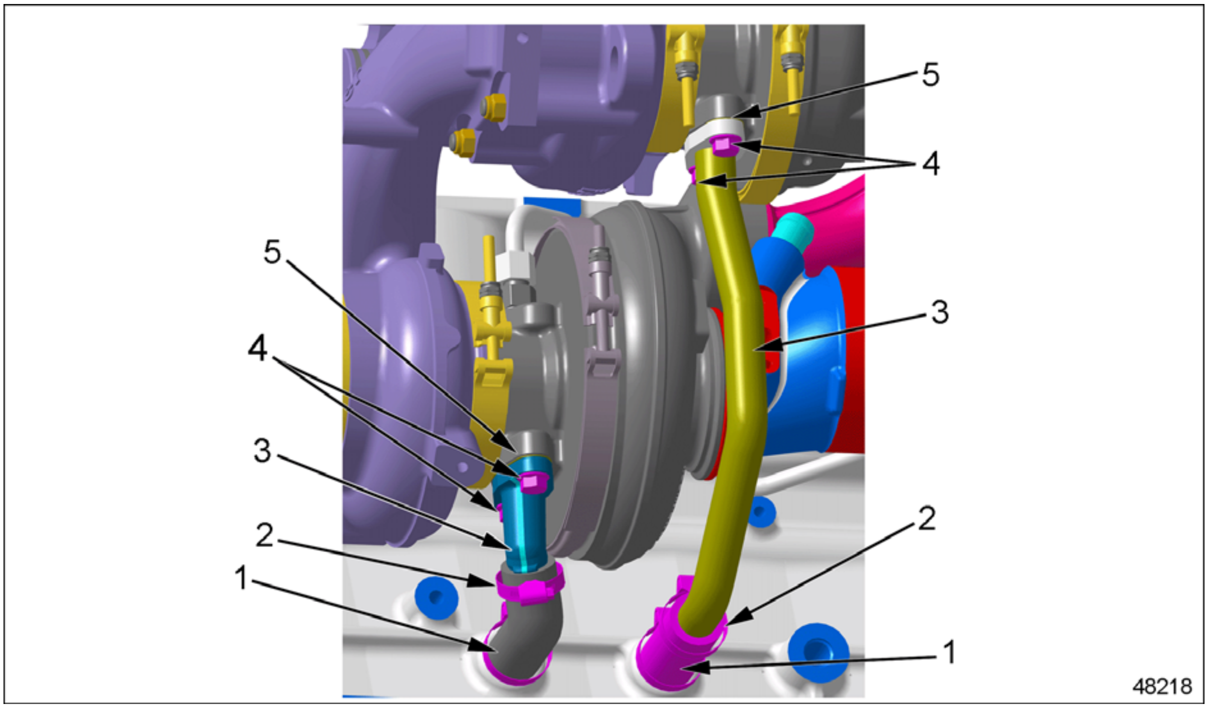
   Note: Install exhaust manifold gaskets with connector to the bottom and the word “FRONT” outward.

   Note: Use the 12 mm short triple square drive socket (J-47403–3) to torque the upper exhaust manifold bolt near the turbocharger and the longer socket for the remaining bolts.

Size	Maximum Shaft Length mm (in.)	Tightening Stage	Torque N·m (lb·ft)
M10	47.5 (1.87)	Stage 1	50 (37)
		Stage 2	additional 90 degrees

Table 11. Exhaust Manifold Torque Procedure

8. Torque the turbocharger to support bracket bolts to 50 N·m (37 lb·ft).



1. Hoses	4. Bolts
2. Hose Clamps	5. Gaskets
3. Oil Drains	

Figure 9. Dual-stage Turbocharger Oil Drain Tubes

9. Secure the two oil drain lines and new gaskets to the turbochargers with four bolts and connect the other end of the oil drain tubes to the oil pan drains with a hose and two clamps for each drain. Torque oil supply lines to 35 N·m (26 lb·ft) and torque the four bolts to 25 N·m (18 lb·ft). See Figure "Dual-stage Turbocharger Oil Drain Tubes" .
10. If removed, install insulation covers on turbocharger oil supply lines.
11. Loosely connect the two oil supply lines to the top of each turbocharger and connect other end of the lines to the bottom of the oil filter and secure with banjo bolts and washers. Tighten fitting connections securely and torque banjo bolts to 25 N·m (18 lb·ft).
12. Install the turbocharger heat shield and secure the shield with three bolts. Torque the bolts to 25 N·m (18 lb·ft).
13. Install the EGR cooler. Refer to "8.1.4 Installation of Dual-stage Turbocharger EGR Cooler" .
14. Secure the exhaust brake assembly to the turbocharger with v-band clamp. Torque the clamp to 5–7 N·m (4–5 lb·ft).
15. Connect the air line to the engine brake actuator. Tighten the fitting securely.
16. Connect the coolant in and out lines to the wastegate actuator with banjo bolts and new washers. Torque the banjo bolts to 40–50 N·m (30–37 lb·ft).
17. Connect the coolant in and out lines to the Fuel Doser Valve with banjo bolts and new washers. Torque the banjo bolts to 16-18 N·m (12-13 lb·ft).
18. Connect the fuel dosing line to the Fuel Doser Valve. Tighten the fitting securely.
19. Install the turbocharger outlet temperature sensor on the upper turbocharger. Torque the sensor to 35 N·m (26 lb·ft).
20. Connect the electrical harness connector to the turbocharger outlet temperature sensor on the turbocharger.

21. Install a new O-ring on the Delta P Sensor fitting and secure the fitting to the turbocharger with two bolts. Torque the bolts to 8–10 N·m (6–7 lb·ft).
22. Install the two Delta P hoses to the Delta P fitting on the turbocharger and secure with new clamps. If crimped type clamps were removed install hose type clamps and tighten clamps securely.
23. Add the removed coolant to the engine.
24. Attach the air cleaner pipe to the lower turbocharger compressor housing. Tighten connections securely.

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 and allow it to run at idle speed for three to four minutes before accelerating.
26. Check for oil leaks and repair as necessary.

NOTICE:

Whenever the turbocharger is replaced the air mass flow of the engine must be re-calibrated to ensure proper engine EGR and smoke control operation.

27. If the low-pressure stage of the turbocharger was replaced the Air Mass Adaptation service routine must be run. 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.
28. If any other codes appear, refer to the MBE 900 DDEC VI Troubleshooting Guide , 6SE580.
29. Shut down the engine.

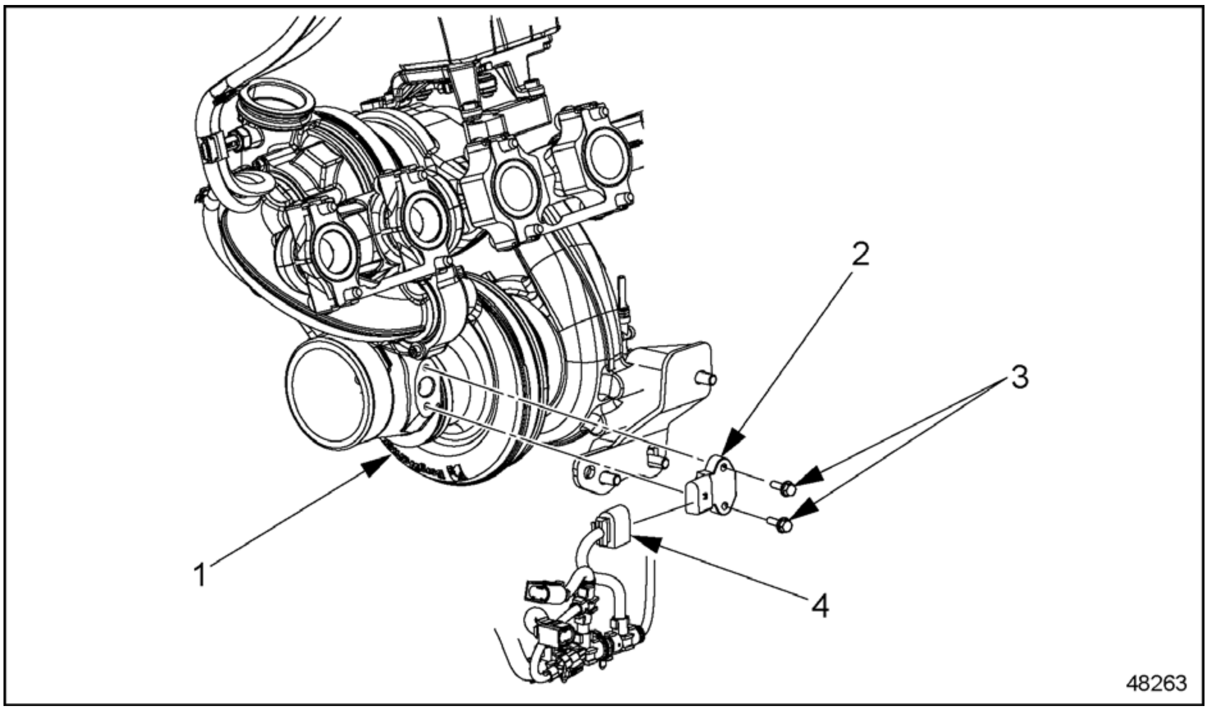
Section 6.7
Turbocharger Sensors

Below are the sensors found on the turbocharger:

- Turbocharger Pressure/Temperature Sensor (Dual-Stage Turbo)
- Turbocharger Inlet Pressure Sensor (Single-Stage Turbo)
- Turbocharger Outlet Temperature Sensor (Single-Stage Turbo)
- Inlet Air Delta P Sensor (Single-Stage Turbo)
- Inlet Air Delta P Sensor (Dual-Stage Turbo)
- Inlet Air Delta P Fitting (Systec Sensor)

Section 6.7.1
Removal of Dual-stage Turbocharger Pressure/Temperature Sensor

Removal steps are as follows:



1. Dual-Stage Turbocharger	3. Bolts (qty 2)
2. Pressure/Temperature Sensor	4. Wiring Harness

Figure 1. Dual-stage Turbocharger Pressure/Temperature Sensor

1. Disconnect the electrical connector from the turbocharger pressure/temperature sensor. See Figure "Dual-stage Turbocharger Pressure/Temperature Sensor" .
2. Remove the two screws securing the sensor to the turbocharger compressor housing and remove the sensor. See Figure "Dual-stage Turbocharger Pressure/Temperature Sensor" .

Section 6.7.2

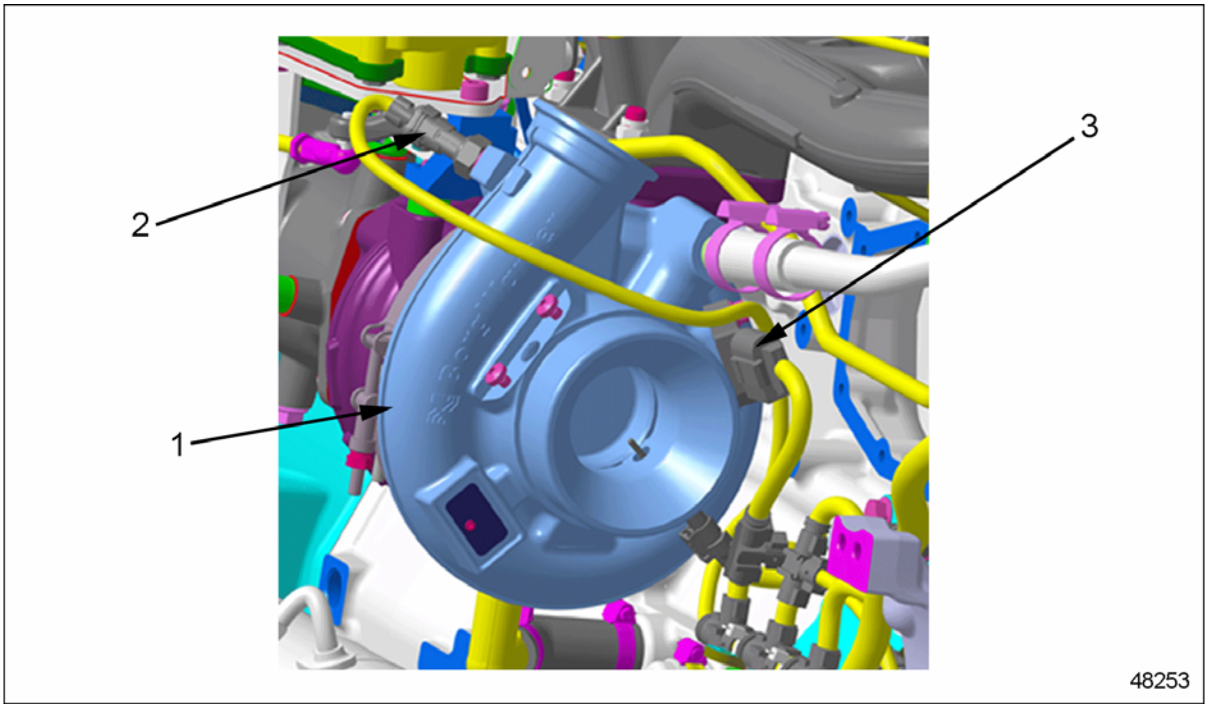
Installation of Dual-stage Turbocharger Pressure/Temperature Sensor

Installation steps are as follows:

1. Install the turbocharger pressure/temperature sensor in the turbocharger compressor housing and secure with two screws. Torque the screws to 9 N·m (7 lb·ft).
2. Connect the electrical connector to the turbocharger inlet pressure sensor.

Section 6.7.3
Removal of Single-stage Turbocharger Inlet Pressure Sensor

Removal steps are as follows:



1. Turbocharger	2. Turbocharger Inlet Pressure Sensor	3. Turbocharger Out Temperature Sensor

Figure 2. Turbocharge Inlet Pressure Sensor (Single-Stage Turbo) Removal/Installation

1. Disconnect the electrical connector from the turbocharger inlet pressure sensor. See Figure "Turbocharge Inlet Pressure Sensor (Single-Stage Turbo) Removal/Installation" .
2. Remove the two screws securing the sensor to the turbocharger compressor housing and remove the sensor. See Figure "Turbocharge Inlet Pressure Sensor (Single-Stage Turbo) Removal/Installation" .

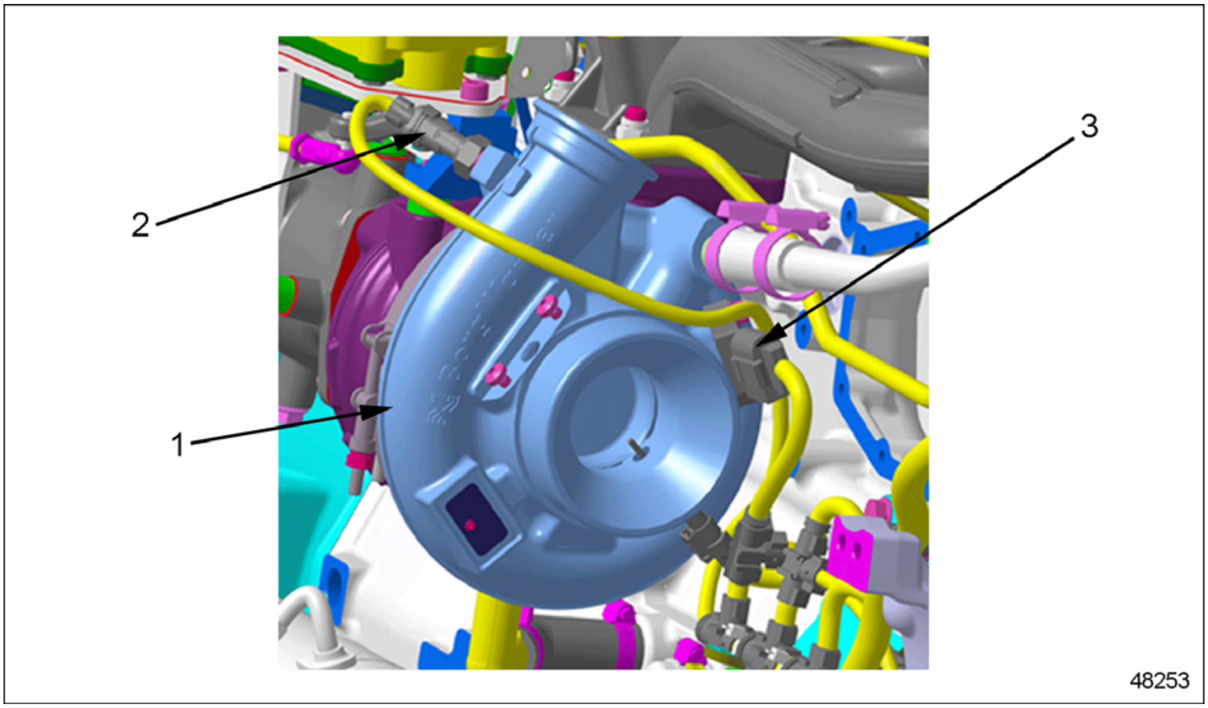
Section 6.7.4
Installation of Single-stage Turbocharger Inlet Pressure Sensor

Installation steps are as follows:

1. Install the turbocharger inlet pressure sensor in the turbocharger compressor housing and secure with two screws. Torque the screws to 9 N·m (7 lb·ft).
2. Connect the electrical connector to the turbocharger inlet pressure sensor.

Section 6.7.5
Removal of Single-stageTurbocharger Outlet Temperature Sensor

Removal steps are as follows:



1. Turbocharger	2. Turbocharger Inlet Pressure Sensor	3. Turbocharger Out Temperature Sensor

Figure 3. Turbocharger Outlet Temperature Sensor (Single-Stage Turbo) Removal/Installation

1. Disconnect the electrical connector from the turbocharger outlet temperature sensor. See Figure "Turbocharger Outlet Temperature Sensor (Single-Stage Turbo) Removal/Installation" .
2. Remove the screws securing the temperature sensor to the turbocharger compressor housing and remove the sensor. See Figure "Turbocharger Outlet Temperature Sensor (Single-Stage Turbo) Removal/Installation" .

Section 6.7.6
Installation of Single-stage Turbocharger Outlet Temperature Sensor

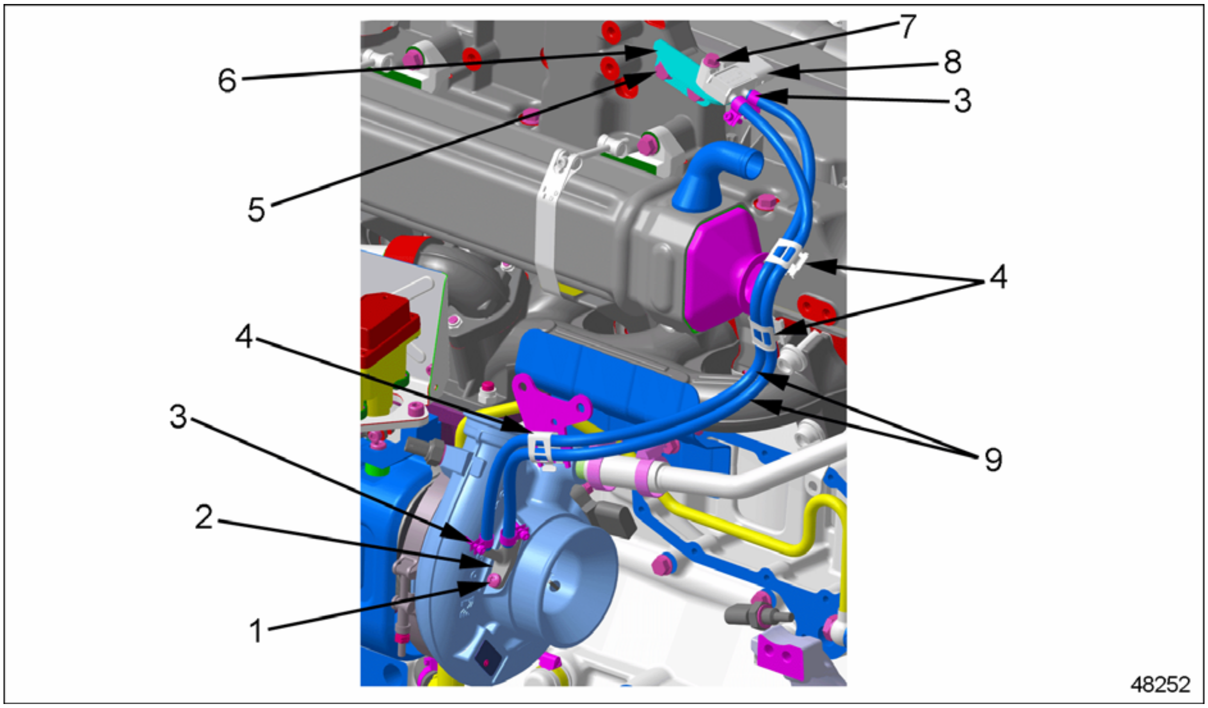
Installation steps are as follows:

1. Install the turbocharger outlet temperature sensor in the turbocharger compressor housing. Torque the sensor to to 35 N·m (26 lb·ft). See Figure "Turbocharger Outlet Temperature Sensor (Single-Stage Turbo) Removal/Installation" .
2. Connect the electrical connector to the turbocharger outlet temperature sensor. See Figure

"Turbocharger Outlet Temperature Sensor (Single-Stage Turbo) Removal/Installation" .

Section 6.7.7
Removal of Single-stage Turbocharger Inlet Air Delta P Sensor

Removal steps are as follows:



1. Bolts (qty 2)	4. Spring Clamps	7. Bolt
2. Delta P Fitting	5. Bolts (qty 2)	8. Delta P Sensor
3. Hose Clamps	6. Mounting Bracket – Delta P Sensor	9. Hoses (qty 2)

Figure 4. Inlet Air Delta P Sensor (Single-Stage Turbo) Removal/Installation

1. Disconnect the electrical connection at the Delta P Sensor box located on the right side of the air intake manifold.
2. Remove the hose clamps and disconnect the two Delta P pressure lines from the sensor on the air intake manifold. See Figure "Inlet Air Delta P Sensor (Single-Stage Turbo) Removal/Installation" .
3. Remove the bolt securing the sensor to the mounting bracket located on the right side of the intake manifold. See Figure "Inlet Air Delta P Sensor (Single-Stage Turbo) Removal/Installation" .
4. If necessary, remove the two bolts attaching the mounting bracket to the air intake manifold and remove the bracket. See Figure "Inlet Air Delta P Sensor (Single-Stage Turbo) Removal/Installation" .

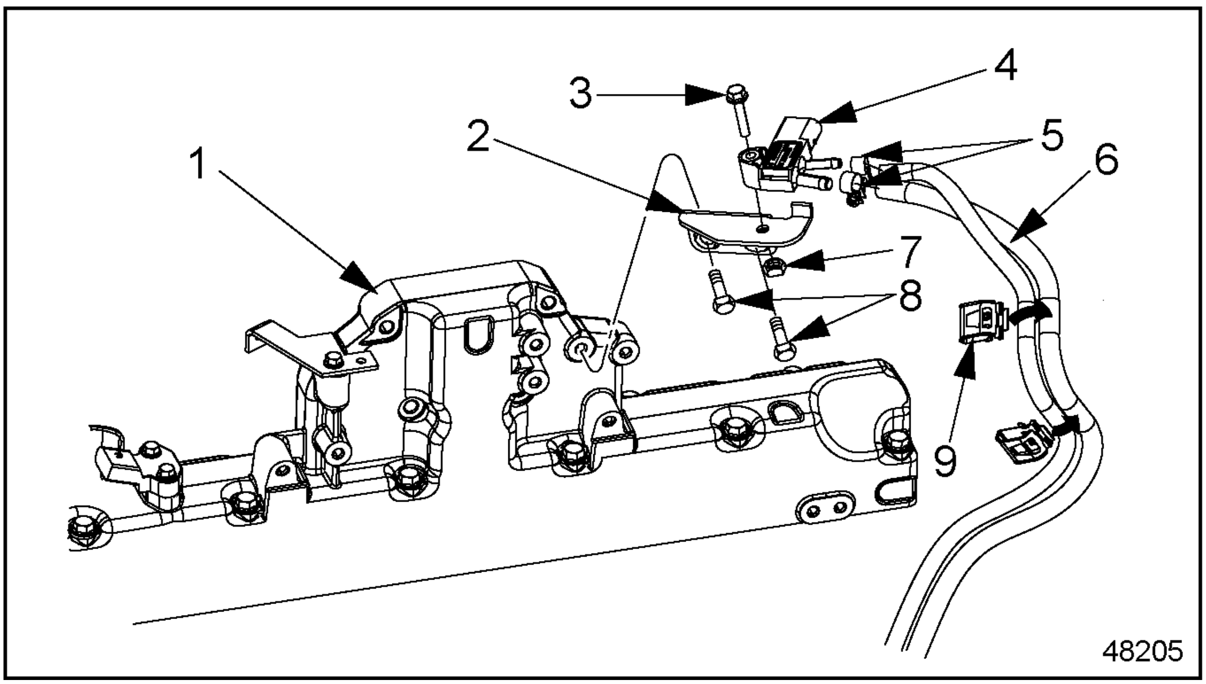
Section 6.7.8
Installation of Single-stage Turbocharger Inlet Air Delta P Sensor

Installation steps are as follows:

1. If removed, attach the Delta P Sensor mounting bracket to the side of the air intake manifold and secure with two bolts. Torque the bolts to 25 N·m (18 lb·ft). See Figure "Inlet Air Delta P Sensor (Single-Stage Turbo) Removal/Installation" .
2. Secure the Delta P Sensor to the air intake manifold with a bolt and nut. Torque the bolt and nut to 25 N·m (18 lb·ft). See Figure "Inlet Air Delta P Sensor (Single-Stage Turbo) Removal/Installation" .
3. Connect the two Delta P pressure lines to the Delta P Sensor and secure with hose clamps. Tighten clamps securely. See Figure "Inlet Air Delta P Sensor (Single-Stage Turbo) Removal/Installation" .
4. Connect the electrical harness connector to the Delta P Sensor. See Figure "Inlet Air Delta P Sensor (Single-Stage Turbo) Removal/Installation" .

Section 6.7.9
Removal of Dual-stage Turbocharger Inlet Air Delta P Sensor

Removal steps are as follows:



1. Air Intake Manifold	6. Hoses
2. .Bracket (Delta P Sensor)	7. Nut
3. Bolt	8. Bolts (qty 2)
4. Delta P Sensor	9. Spring Clips
5. Hose Clamps	

Figure 5. Dual-stage Inlet Air Delta P Sensor

1. Disconnect the electrical connection at the Delta P Sensor on the air intake manifold. See Figure "Dual-stage Inlet Air Delta P Sensor" .
2. Remove the hose clamps and disconnect the two Delta P pressure lines from the Delta P Sensor. See Figure "Dual-stage Inlet Air Delta P Sensor" .

3. Remove the bolt and nut securing the sensor to the mounting bracket located on the right side of the intake manifold. See Figure "Dual-stage Inlet Air Delta P Sensor" .
4. If necessary, remove the two bolts attaching the mounting bracket to the air intake manifold. See Figure "Dual-stage Inlet Air Delta P Sensor" .

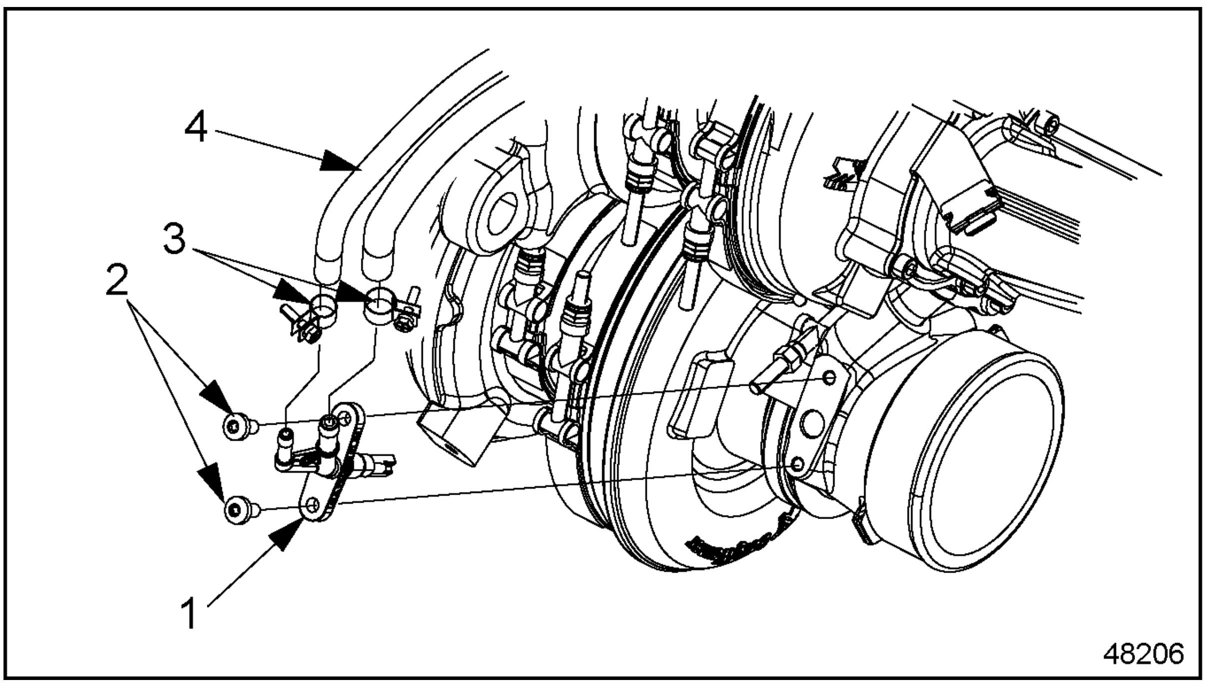
Section 6.7.10
Installation of Dual-stage Turbocharger Inlet Air Delta P Sensor

Installation steps are as follows:

1. If removed, attach the Delta P Sensor mounting bracket to the side of the air intake manifold and secure with two bolts. Torque the bolts to 25 N·m (18 lb·ft). See Figure "Dual-stage Inlet Air Delta P Sensor" .
2. Secure the Delta P Sensor to the mounting bracket with a bolt and nut. Torque the bolt and nut to 25 N·m (18 lb·ft). See Figure "Dual-stage Inlet Air Delta P Sensor" .
3. Connect the two Delta P pressure lines to the Delta P Sensor and secure with hose clamps. Tighten clamps securely. See Figure "Dual-stage Inlet Air Delta P Sensor" .
4. Connect the electrical harness connector to the Delta P Sensor. See Figure "Dual-stage Inlet Air Delta P Sensor" .

Section 6.7.11
Removal of Inlet Air Delta P Fitting

Removal steps are as follows:



1. Inlet Air Delta P Fitting	3. Hose Clamps
2. Screws (qty 2)	4. Hoses

Figure 6. Inlet Air Delta P Fitting

1. Disconnect and remove the two hoses at the Delta P fitting by removing the two hose clamps. See Figure "Inlet Air Delta P Fitting" .

NOTICE:

Use care when removing the inlet air Delta P fitting from the turbocharger so not to damage the tip of the fitting. If damaged, improper operation of the engine will result.

2. Remove the two screws securing the Delta P fitting to the turbocharger compressor housing and remove the fitting by pulling straight out. See Figure "Inlet Air Delta P Fitting" .
3. Inspect the O-ring on the Delta P fitting and replace if damaged. See Figure "Inlet Air Delta P Fitting" .

Section 6.7.12
Installation of Inlet Air Delta P Fitting

Installation steps are as follows:

1. Coat the seal ring on Delta P fitting with a light coat of lubricant. See Figure "Inlet Air Delta P Fitting" .
2. Install the Delta P fitting in the turbocharger compressor housing and secure with two screws. Torque the screws to to 8–10 N·m (6–7 lb·ft). See Figure "Inlet Air Delta P Fitting" .
3. Connect the two hoses to the Delta P fitting and secure the hoses with two clamps. Tighten the clamps securely.

WARNING:

ENGINE EXHAUST

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

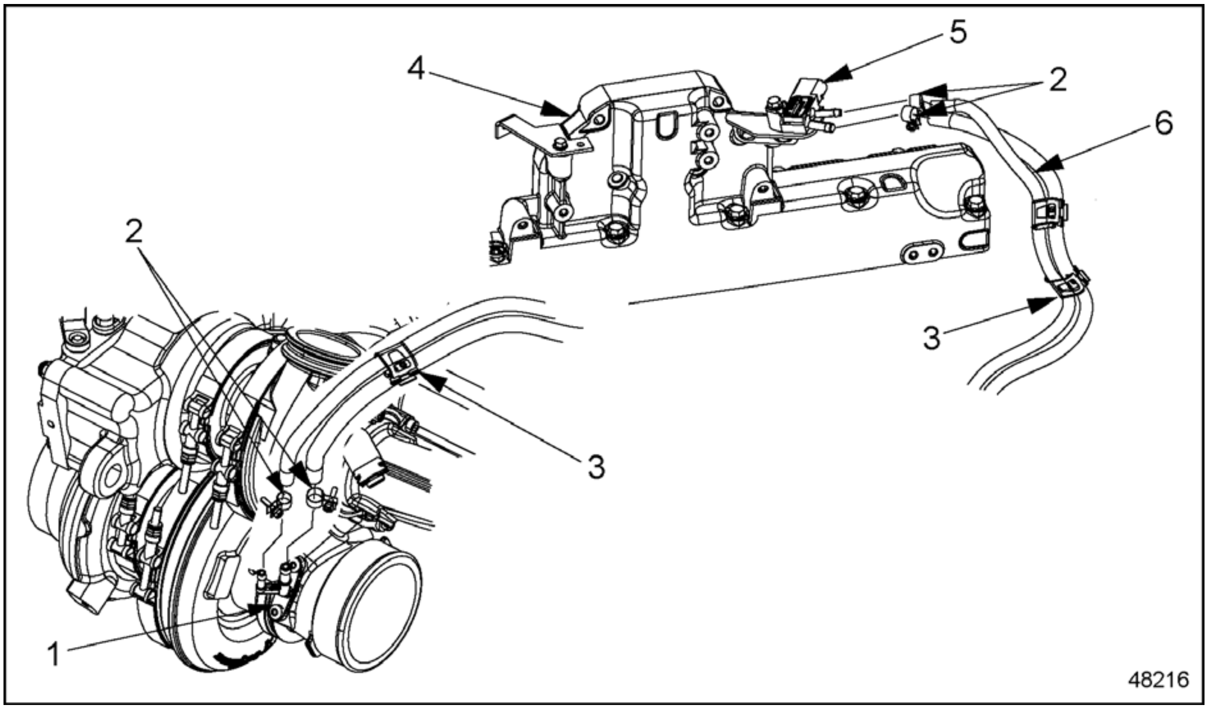
NOTICE:

Whenever the inlet air Delta P fitting is replaced the air mass flow of the engine must be re-calibrated to ensure proper engine EGR and smoke control operation.

4. Start 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 900 DDEC VI Troubleshooting Guide , 6SE580.
7. Shut down the engine.

Section 6.7.13
Removal of Delta P Sensor Hoses

Removal steps are as follows:



1. Delta P Fitting	4. Air Intake Manifold
2. Hose Clamps (qty 4)	5. Delta P Sensor
3. Spring Clamps	6. Hoses

Figure 7. Delta P Sensor Hoses

1. Remove the two hoses from under the spring clamps on the EGR delivery pipe. See Figure "Delta P Sensor Hoses" .
2. Remove the two hose clamps securing the hoses at the Delta P Sensor and Delta P Sensor fitting and remove the hoses. See Figure "Delta P Sensor Hoses" .

Section 6.7.14
Installation of Delta P Sensor Hoses

Installation steps are as follows:

1. Attach the two hoses to the Delta P Sensor and Delta P fitting with hose clamps. Tighten the hose clamps securely. See Figure "Delta P Sensor Hoses" .
2. Insert the two hoses under the spring clamps on the EGR delivery pipe. See Figure "Delta P Sensor Hoses" .

Additional Information

SPECIFICATIONS

The torque specifications are listed in Table "Torque Values" below.

Descriptions	Torque N·m (lb·ft)
Throttle Valve Mounting Bracket Bolts	20-30(15-22)
Grid Heater Battery Supply Connection	25 (18)
Grid Heater Ground Connection	8-12 (6-9)
Air Intake Mixer Housing Bolts to Intake Manifold	20-30 (15-22)
Air Intake Manifold Bolts to Cylinder Head	25 (18)
Turbocharger to Exhaust Manifold Nuts	50 (37)
Turbocharger Oil Return Bolts	25 (18)
Banjo Bolt — Turbo Oil Supply Line to Oil Filter Housing	25 (18)
Turbo Oil Supply Line Fitting (Top of Turbo)	32-38 (24-28)
Retaining Clamp Bolts — Turbo Elbow, Low-pressure Stage to Hi-pressure Stage	8 (6)
Bolts — Turbo Support Plate (Dual-stage Turbo)	50 (37)
Bolts — Turbo Heat Shield	25 (18)
V-band Clamp — Exhuast Brake Housing to Turbocharger	5-7 (4-5)
Banjo Bolts — Wastegate Actuator Coolant In and Out Lines	40-50 (30-37)
Banjo Bolts — FDV Coolant In and Out Lines	16-20 (12-15)
Turbocharger Outlet Temperature Sensor	35 (26)
Bolts — Delta P Sensor Fitting to Turbo	8-10 (6-7)
Screws — Pressure/Temperature Sensor (Dual-stage Turbo)	9 (7)
Screws — Inlet Pressure Sensor (Singlel-stage Turbo)	9 (7)
Turbocharger Outlet Temperature Sensor	35 (26)
Bolts — Delta P Sensor Mounting Bracket	25 (18)
Bolt and Nut — Delta P Sensor to Mounting Bracket	25 (18)
Screws — Delta p Fitting to Turbocharger	8-10 (6-7)

Table 1. Torque Values

Special Tools

The special tools used in this chapter are listed in Table "Special Tools" .

Tool	Description	Usage	Part Number
	Exhaust Manifold Socket Set	Used to remove, install and torque exhaust manifold bolts.	J–47403

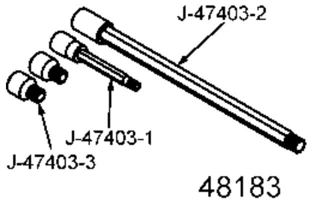


Table 2. Special Tools

Section 7.1
Exhaust Manifold

The exhaust manifold is a single piece manifold for the single-stage turbocharger. For the dual-stage turbocharger it is a three-piece manifold with the center manifold an integral part of the turbocharger. The three-piece manifold is assembled apart from the cylinder heads, then the entire manifold and turbocharger is installed on the cylinder head.

Section 7.1.1
Removal of One-piece Exhaust Manifold

Remove the one-piece exhaust manifold as follows:

1. Remove the turbocharger. Refer to "6.5.2 Removal of Single-stage Turbocharger" .
2. Remove the EGR exhaust elbow. Refer to "8.6.1 Removal of Single-Stage Turbocharger EGR Exhaust Elbow" .

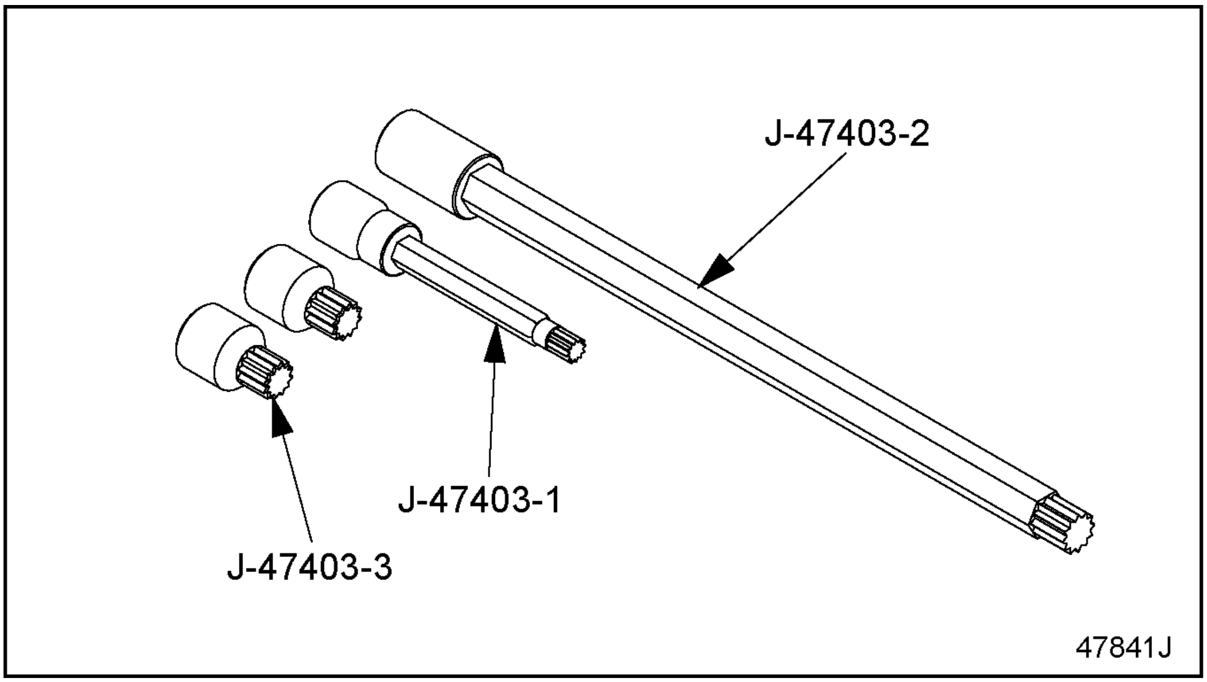
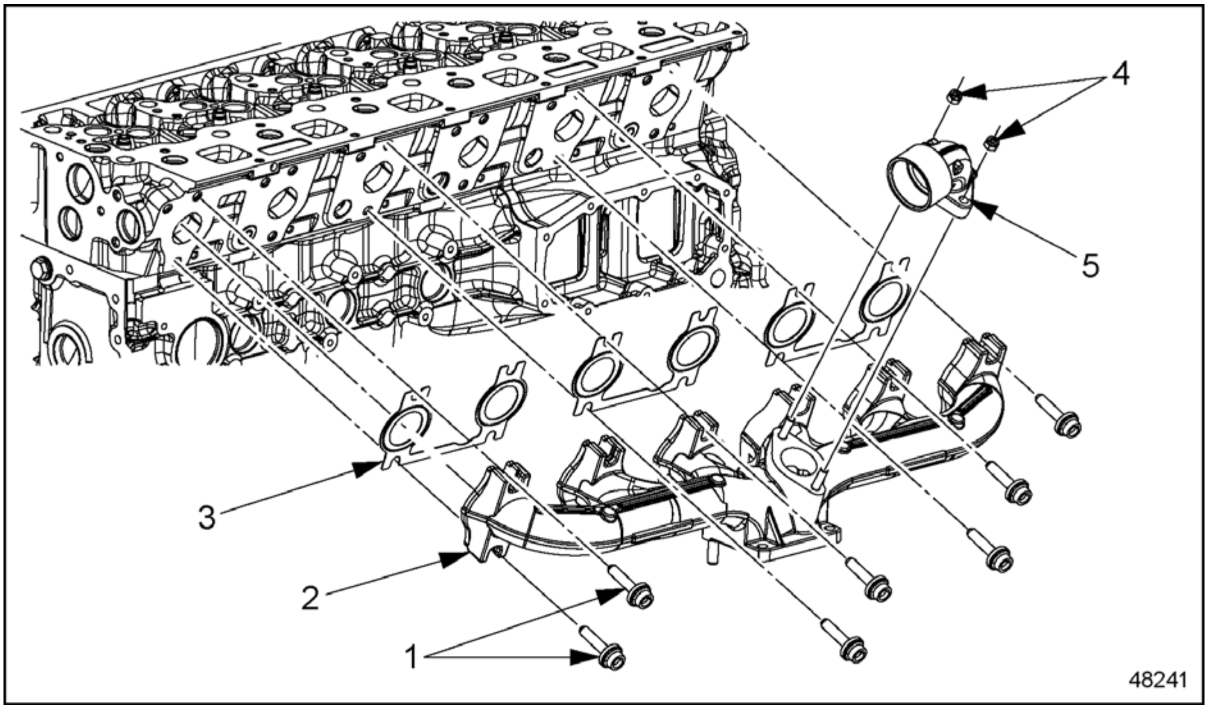


Figure 1. J-47403 Exhaust Manifold Socket Set

Note: In most cases, the long socket can be used. Use the shorter socket when necessary to gain access.

3. Using a the exhaust manifold socket set (J–46379) , remove the exhaust manifold from the engine. See Figure "One-piece Exhaust Manifold" .



1. Exhaust Manifold Mounting Bolts (qty 12)	4. Nuts (qty 2)
2. Exhaust Manifold	5. Exhaust Elbow
3. Gaskets (qty 3)	

Figure 2. One-piece Exhaust Manifold

4. Remove and discard the exhaust manifold gaskets. See Figure "One-piece Exhaust Manifold" .
5. Measure the shank length of the exhaust manifold bolts. If they exceed 47.5 mm (1.87 in.), replace the bolts.

Section 7.1.2
Installation of One-piece Exhaust Manifold

Installation steps are as follows:

1. Position the new gaskets on the engine exhaust ports.
2. Install the exhaust manifold on the engine. Using the exhaust manifold socket set (J–46379) , tighten the bolts in two stages as listed in Table "Tightening Stages for Exhaust Manifold Bolts and Cylinder Head" .

Size	Tightening Stage	Torque N·m (lb·ft)
M10	Stage 1	50 (37)
	Stage 2	additional 90 degrees

Table 2. Tightening Stages for Exhaust Manifold Bolts and Cylinder Head

Note: Clean the sealing surfaces of the exhaust manifold and cylinder head before installing.

3. Install the turbocharger onto the exhaust manifold. Refer to "6.5.5 Installation of Single-stage

Turbocharger " .

4. Install the exhaust brake assembly onto the turbocharger with four nuts. Refer to "7.2.9 Installation of Dual-stage Turbocharger Exhaust Brake Assembly" .
5. Connect the air line at the exhaust brake cylinder. Install the exhaust pipe at the exhaust brake valve housing.
6. Install the EGR exhaust elbow. Refer to "8.6.2 Installation of Single-Stage Turbocharger EGR Exhaust Elbow" .
7. Install the turbo compressor outlet pipe bracket.
8. Connect the air cleaner pipe at the turbocharger and 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.

9. Start the engine and ensure there is oil pressure. Shut down the engine and check for leaks.

Section 7.1.3
Removal of Three-piece Exhaust Manifold

Removal steps are as follows:

1. Disconnect the air cleaner pipe from the turbocharger.
2. Remove the turbocharger. Refer to "6.6.2 Removal of Dual-stage Turbocharger " .

Section 7.1.4
Installation of Three-piece Exhaust Manifold

Installation steps are as follows:

1. Install turbocharger and exhaust manifolds as an assembly. Refer to "6.6.3 Installation of Dual-stage Turbocharger " .
2. Connect the air cleaner pipe to the turbocharger.

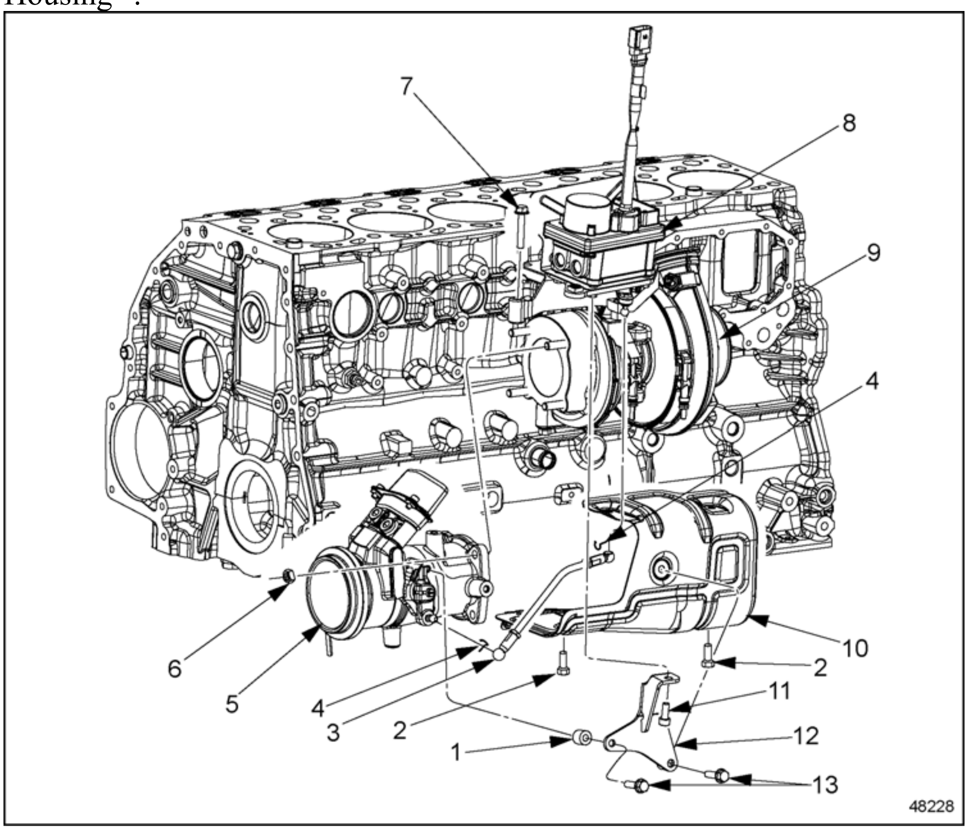
Section 7.2
Exhaust Brake Assembly

To increase braking performance, the engine can be equipped with an exhaust brake on the turbocharger in conjunction with constant–throttle valves on the cylinder head. The exhaust back-pressure is used by the exhaust brake to increase braking performance.

Section 7.2.1
Removal of Single-stage Turbocharger with Electronic Wastegate Exhaust Brake Assembly

Removal steps are as follows:

1. Disconnect the turbo compressor outlet pipe from the housing.
2. Drain the cooling system.
3. Remove the Fuel Doser Valve. Refer to "2.20.1 Removal of Fuel Doser Valve" .
4. Disconnect the exhaust pipe at the engine exhaust brake valve.
5. Remove the two retaining clips on the actuator rod connecting to the electronic brake actuator and exhaust brake housing and remove the rod. See Figure " Single-stage Turbocharger Exhaust Brake Housing" .



1. Spacer	8. Electronic Brake Actuator
2. Bolts — Heat Shield	9. Turbocharger — Single-stage
3. Actuator Rod	10. Heat Shield
4. Retaining Clips	11. Actuator Mounting Bracket Bolt

5. Exhaust Brake Housing	12. Actuator Mounting Bracket
6. Nuts	13. Actuator Mounting Bracket Bolts (qty 2)
7. Bolt	

Figure 1. Single-stage Turbocharger Exhaust Brake Housing

6. Remove the bolts and spacer securing the actuator mounting bracket to the exhaust brake housing, heat shield and actuator. Remove the bracket. See Figure " Single-stage Turbocharger Exhaust Brake Housing" .
7. Remove the nuts securing the exhaust brake housing to the turbocharger and remove housing. See Figure " Single-stage Turbocharger Exhaust Brake Housing" .
8. Remove the five hex head bolts that fasten the heat shield to the exhaust brake valve housing and turbocharger and remove the heat shield. See Figure "Single-stage Turbocharger Exhaust Brake Assembly" .
9. Loosen the clamp securing the exhaust pipe to the exhaust brake valve housing. Slide the exhaust pipe off the housing. See Figure "Single-stage Turbocharger Exhaust Brake Assembly" .

WARNING:

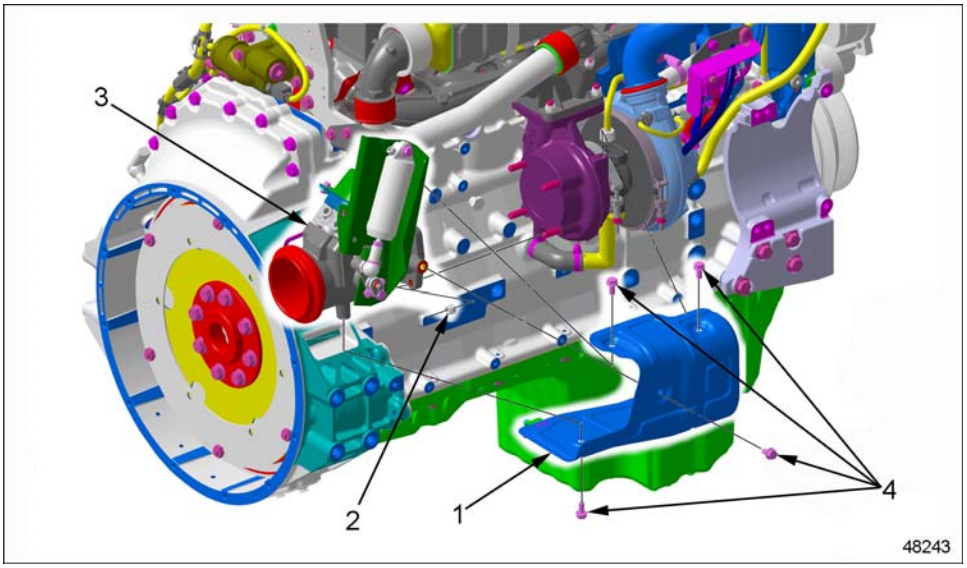
PERSONAL INJURY

To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles.

10. Disconnect the dosing fuel line from the fuel doser valve.
11. Remove four locknuts from the studs that secure the exhaust brake valve housing to the turbocharger and remove the housing. Discard the locknuts. See Figure "Single-stage Turbocharger Exhaust Brake Assembly" .
12. Remove the fuel doser valve from the exhaust brake housing. Refer to "2.20.1 Removal of Fuel Doser Valve" .

Section 7.2.2
Removal of Single-stage Turbocharger Exhaust Brake Assembly

Removal steps are as follows:



1. Heat Shield	3. Exhaust Brake Assembly
2. Nut (qty 4)	4. Heat Shield Mounting Bolts (qty 5)

Figure 2. Single-stage Turbocharger Exhaust Brake Assembly

1. Disconnect the turbo compressor outlet pipe from the housing.
2. Drain the cooling system.
3. Remove the Fuel Doser Valve. Refer to "2.20.1 Removal of Fuel Doser Valve" .
4. Disconnect the exhaust pipe at the engine exhaust brake valve.
5. Disconnect the air line at the exhaust brake actuator.
6. Remove the bolts securing the turbocharger heat shield to the turbocharger and remove the shield.
7. Remove the four nuts securing the exhaust brake assembly to the turbocharger and remove the assembly.

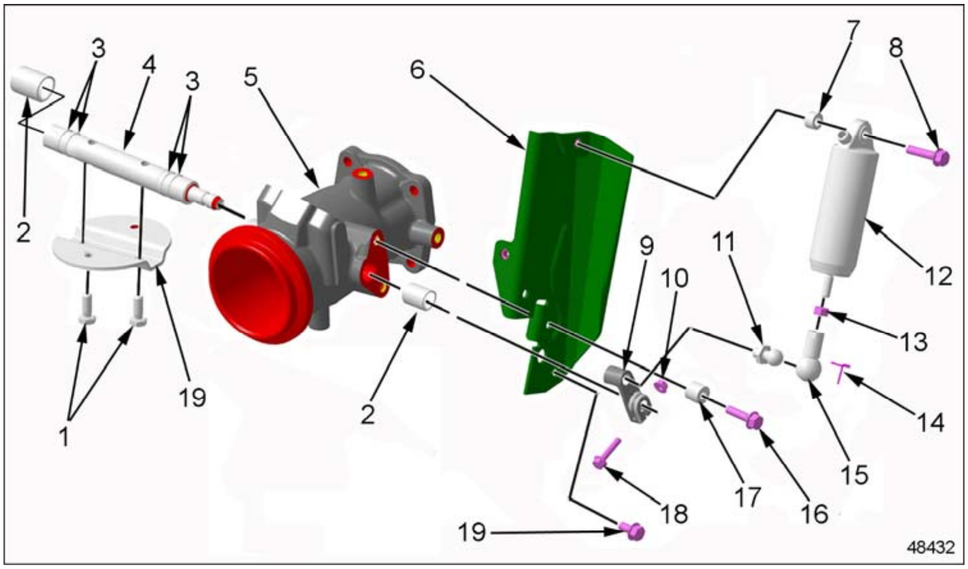
Section 7.2.3 Disassembly of Single-stage Turbocharger Exhaust Brake

Disassembly steps are as follows:

- Feeler Gauges, 0.3 - 0.5 mm (0.01 - 0.02 in.)
- Depth Slide Gauge, 0 - 200 mm (0 - 7.9 in.)

Disassemble the exhaust brake as follows:

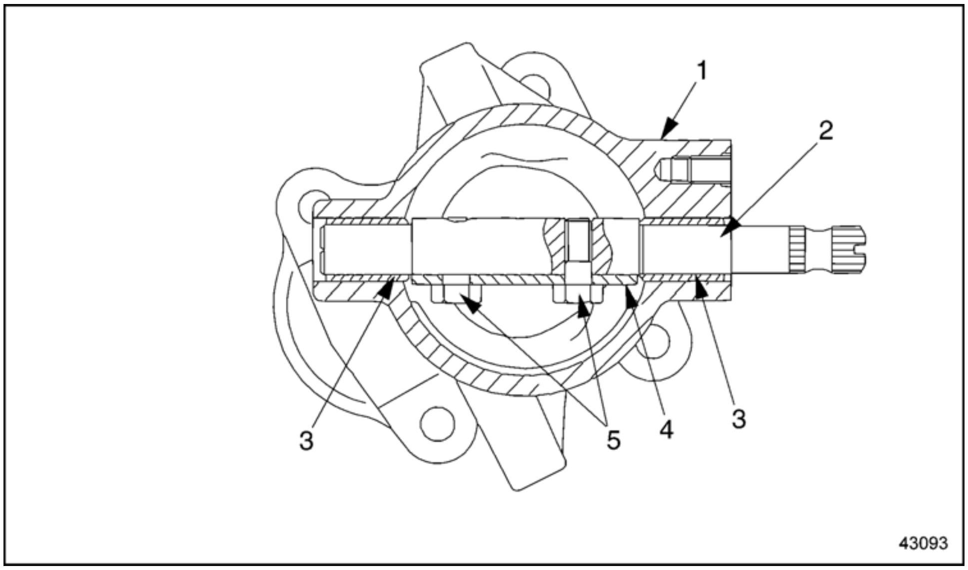
1. With the exhaust brake valve in the open position, loosen the locknut at the base of the ball socket. See Figure "Single-stage Turbocharger Exhaust Brake Assembly" .



1. Valve Mounting Bolt (qty 2)	11. Ball
2. Bushing (qty 2)	12. Exhaust Brake Actuator
3. Fey Rings	13. Nut
4. Shaft	14. Retaining Clip
5 .Exhaust Brake Housing	15. Ball Socket
6. Actuator Bracket	16. Bracket Mounting Bolt
7. Spacer	17. Spacer
8. Actuator Mounting Bolt	18. Lever Bolt
9. Lever	19. Bracket Mounting Bolt
10. Lever Nut	

Figure 3. Single-stage Turbocharger Exhaust Brake Assembly

2. Remove the exhaust brake actuator from the bracket. See Figure "Single-stage Turbocharger Exhaust Brake Assembly" .
   a. Remove the retaining clip at the ball socket.
   b. Remove the bolt and spacer securing the exhaust brake actuator to the mounting bracket.
   c. Remove the actuator ball socket from the lever. If necessary, remove the ball from the lever.
   d. Remove the exhaust brake actuator from the bracket.
3. Remove the lever. See Figure "Single-stage Turbocharger Exhaust Brake Assembly" .
   a. Loosen the hex nut on the lever bolt to release the clamping pressure on the exhaust brake shaft.
   b. Slide the lever off the shaft, taking care not to damage the splines on the shaft.
4. Remove the two bracket mounting bolts and one spacer securing the bracket to the exhaust brake housing and remove the bracket from the valve housing.
5. Remove the exhaust brake valve from the brake housing.
   a. Position the valve in the closed position.
   b. Using a socket wrench, remove the two valve mounting bolts securing the valve to the shaft. See Figure "Cross Sectional View of a Single-stage Turbocharger Exhaust Brake Valve" .



1. Exhaust Brake Valve Housing	4. Exhaust Brake Valve
2. Shaft	5. Valve Mounting Bolts
3. Bushing (2 qty.)	

Figure 4. Cross Sectional View of a Single-stage Turbocharger Exhaust Brake Valve

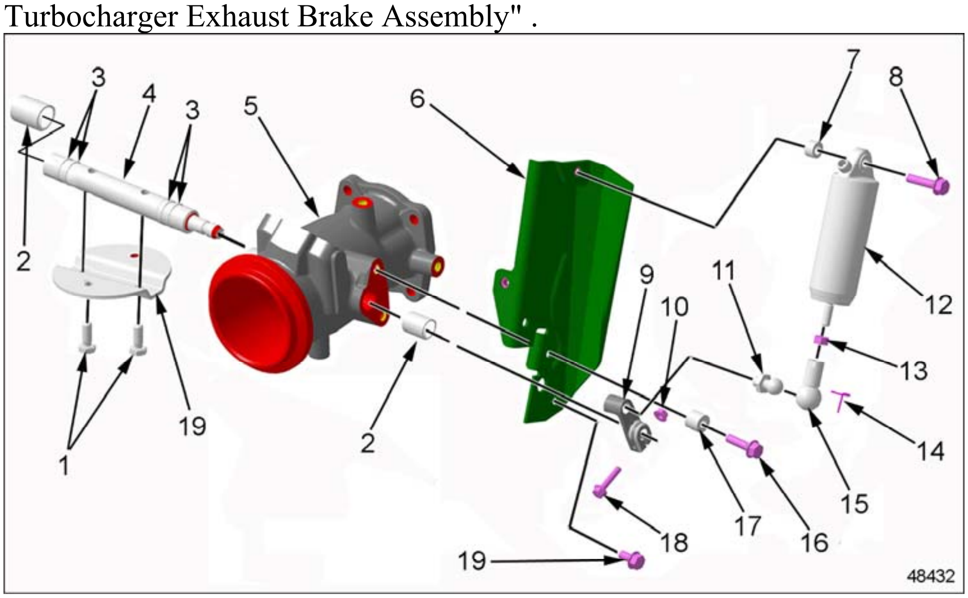
   c. Remove the valve through the large end of the valve housing.

6. Using a suitable drift, remove the shaft and the two bushings from the exhaust brake valve housing.

Section 7.2.4
Assembly of Single-stage Turbocharger Exhaust Brake Assembly

Assembly steps are as follows:

1. Install the bushing in the bracket side of the exhaust brake valve housing. See Figure "Single-stage Turbocharger Exhaust Brake Assembly" .

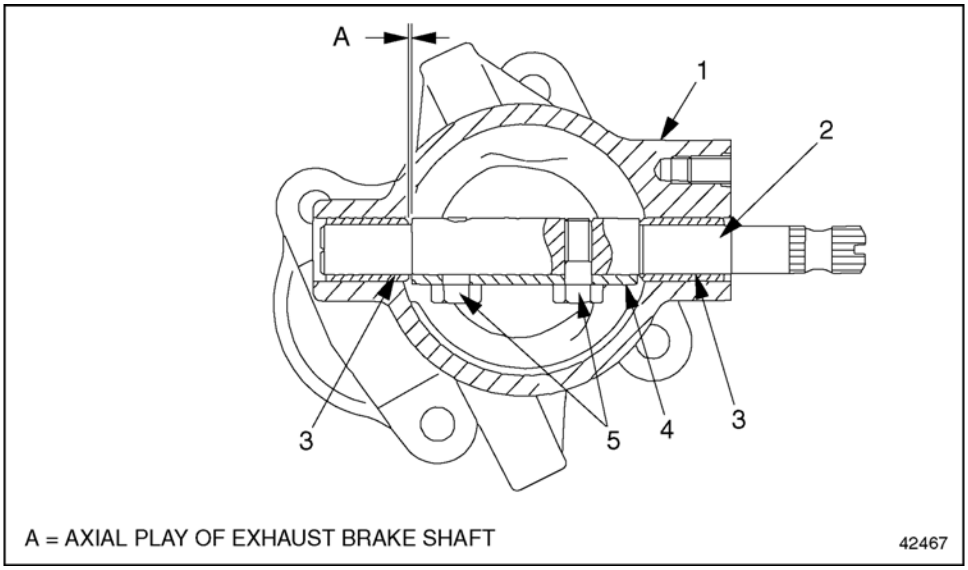


1. Valve Mounting Bolt (qty 2)	11. Ball
2. Bushing (qty 2)	12. Exhaust Brake Actuator
3. Fey Rings	13. Nut
4. Shaft	14. Retaining Clip
5 .Exhaust Brake Housing	15. Ball Socket
6. Actuator Bracket	16. Bracket Mounting Bolt
7. Spacer	17. Spacer
8. Actuator Mounting Bolt	18. Lever Bolt
9. Lever	19. Bracket Mounting Bolt
10. Lever Nut	

Figure 5. Single-stage Turbocharger Exhaust Brake Assembly

   a. Using a depth slide gauge, measure 3 mm (0.1 in.) inward on the inner contact surface of the bushing.
   b. Coat the leading (chamfered) edge of the bushing and the measured portion of the inner contact surface with bearing grease.
   c. Using a suitable drift, press in the bushing. Allow the bushing to protrude slightly outside the valve housing.

2. Insert the shaft into the valve housing and bushing. See Figure "Cross Sectional View of a Single-stage Turbocharger Exhaust Brake Valve" .
3. Install the second bushing in the other side of the valve housing.
   a. Using a depth slide gauge, measure 3 mm (0.1 in.) inward on the inner contact surface of the bushing.
   b. Coat the leading edge of the bushing and the measured portion of the inner contact surface with bearing grease.
   c. Using a suitable drift, press in the bushing. Allow the bushing to protrude slightly outside the valve housing.
4. Install the valve on the shaft. See Figure "Cross Sectional View of a Single-stage Turbocharger Exhaust Brake Valve" .
   a. Place the valve inside the valve housing.
   b. Rotate the shaft until the bolt holes are parallel with the direction of the exhaust flow.
   c. Apply anti-seize compound to the threads of the two valve mounting bolts.
   d. Place the valve against the shaft in the closed position (resting against the valve stop). Align the bolt holes in the valve and shaft.
   e. Install the two valve mounting bolts through the valve and into the shaft from the direction shown in see Figure "Single-stage Turbocharger Exhaust Brake Assembly" .
   f. Using a socket wrench, tighten the bolts 23 N·m (17 lb·ft).
5. Check the axial play of the shaft. See Figure "Cross Sectional View of a Single-stage Turbocharger Exhaust Brake Valve" .



1. Exhaust Brake Valve Housing	4. Exhaust Brake Valve
2. Shaft	5. Valve Mounting Bolts
3. Bushing (2 qty.)	

Figure 6. Cross Sectional View of a Single-stage Turbocharger Exhaust Brake Valve

   a. Center the shaft in the valve housing.
   b. Using a suitable drift, drive the bushings in evenly on both sides until the axial play is correct.
   c. Using a feeler gauge, check that the axial play of the shaft between the bushings is 0.3 - 0.5 mm (0.01 - 0.02 in.). Make sure the projection of the bushings inside the valve housing is the same on both sides.
6. Using a feeler gauge, check the outside edge (perimeter) of the closed valve to make sure it does not touch the housing at any point.
7. Install the bracket on the exhaust brake valve housing with the two bracket mounting bolts. Tighten the bolts 23 N·m (17 lb·ft). see Figure "Single-stage Turbocharger Exhaust Brake Assembly" .
8. Install the adjusting lever. See Figure "Single-stage Turbocharger Exhaust Brake Assembly" .
   a. Rotate the valve to the fully open position in the valve housing.
   b. Fit the adjusting lever on the splines of the shaft so the adjusting-lever stop rests against the bottom lip of the bracket.
9. Check the valve setting by rotating it to the closed position. The adjusting-lever stop must be about 1 mm (0.04 in.) below the lip of the bracket, not touching the bracket.
10. Install the exhaust brake cylinder on the bracket. see Figure "Single-stage Turbocharger Exhaust Brake Assembly" .
   a. Place a washer and the cylinder on the bracket pin. See Figure "Single-stage Turbocharger Exhaust Brake Assembly" . Install a washer and hex nut on the end of the bracket pin but do not tighten.
   b. With the valve open, turn the ball socket clockwise until the exhaust brake cylinder clearance is 1.0 - 2.0 mm (0.04 - 0.08 in.). Tighten the locknut against the ball socket.
   c. Install the retaining clip.
   d. Tighten the hex nut on the bracket pin.
11. Install the exhaust brake assembly on the turbocharger. Refer to "7.2.5 Installation of Single-stage

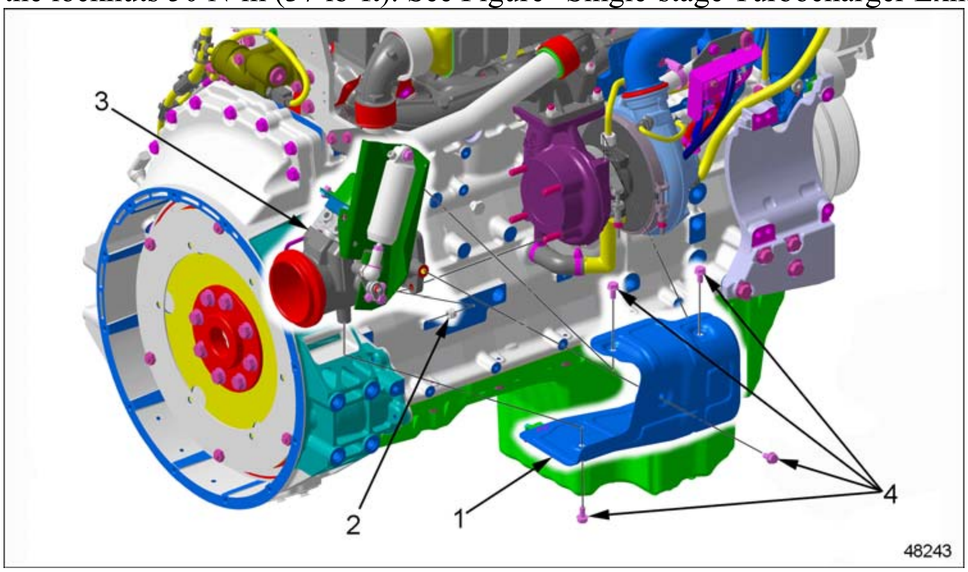
Turbocharger Exhaust Brake Assembly" .

Section 7.2.5
Installation of Single-stage Turbocharger Exhaust Brake Assembly

Installation steps are as follows:

Note: Four new prevailing torque locknuts are required for the installation of the exhaust brake assembly.

1. Clean the mating surfaces on the exhaust brake valve housing and the turbocharger.
2. Install the exhaust brake valve housing on the turbocharger by slipping the housing over the four turbocharger studs. Install four new prevailing torque locknuts on the turbocharger bolts. Tighten the locknuts 50 N·m (37 lb·ft). See Figure "Single-stage Turbocharger Exhaust Brake Assembly" .



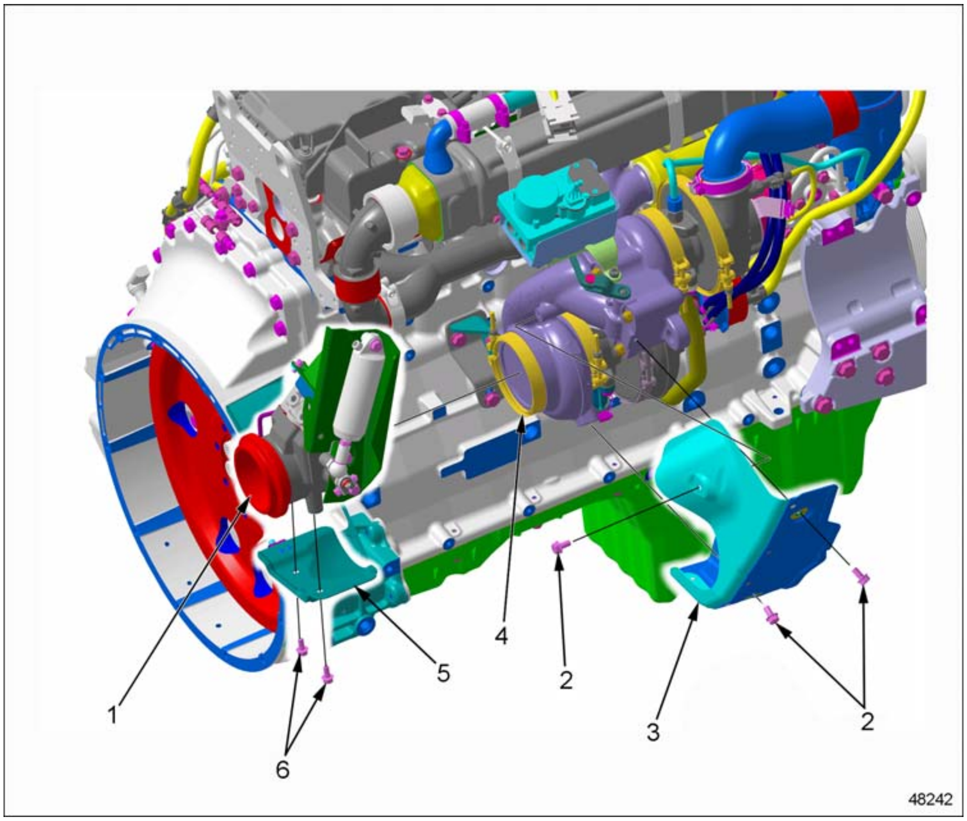
1. Heat Shield	3. Exhaust Brake Assembly
2. Nut (qty 4)	4. Heat Shield Mounting Bolts (qty 5)

Figure 7. Single-stage Turbocharger Exhaust Brake Assembly

3. Connect the compressed-air line to the exhaust brake cylinder. See Figure "Single-stage Turbocharger Exhaust Brake Assembly" .
4. Clean the sealing surfaces on the exhaust pipe and exhaust brake valve housing.
5. Slide the exhaust pipe and clamp over the end of the housing to the stop. Tighten the clamp.
6. Install the fuel doser valve on the exhaust brake housing. Refer to "2.20.2 Installation of Fuel Doser Valve" .
7. Install the heat shield on the exhaust brake valve housing and the turbocharger, using four hex head bolts. Torque the bolts to 20-25 N·m (15-18 lb·ft).

Section 7.2.6
Removal of Dual-stage Turbocharger Exhaust Brake Assembly

Removal steps are as follows:



1. Exhaust Brake Assembly	4. V-band Clamp
2. Bolts (qty 3)	5. Exhaust Brake Heat Shield
3. Turbocharger Heat Shield	6. Bolts

Figure 8. Dual-stage Turbocharger Exhaust Brake Assembly

1. Remove the three hex head bolts that secure the side heat shield to the turbocharger. Remove the heat shield. See Figure "Dual-stage Turbocharger Exhaust Brake Assembly" .
2. Remove two bolts securing the heat shield to the bottom of the exhaust brake housing and remove the shield. See Figure "Dual-stage Turbocharger Exhaust Brake Assembly" .
3. Loosen the clamp securing the exhaust pipe to the exhaust brake valve housing. Slide the exhaust pipe off the housing.

WARNING:

PERSONAL INJURY

To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles.

4. Unscrew the exhaust brake compressed–air line fitting from the exhaust brake cylinder.
5. Disconnect the dosing fuel line from the fuel doser valve.
6. If required, remove the FDV from the exhaust brake housing. Refer to "2.20.1 Removal of Fuel Doser Valve" .
7. Remove the v-band clamp that secures the exhaust brake valve housing to the turbocharger.

Remove the housing. See Figure "Dual-stage Turbocharger Exhaust Brake Assembly" .

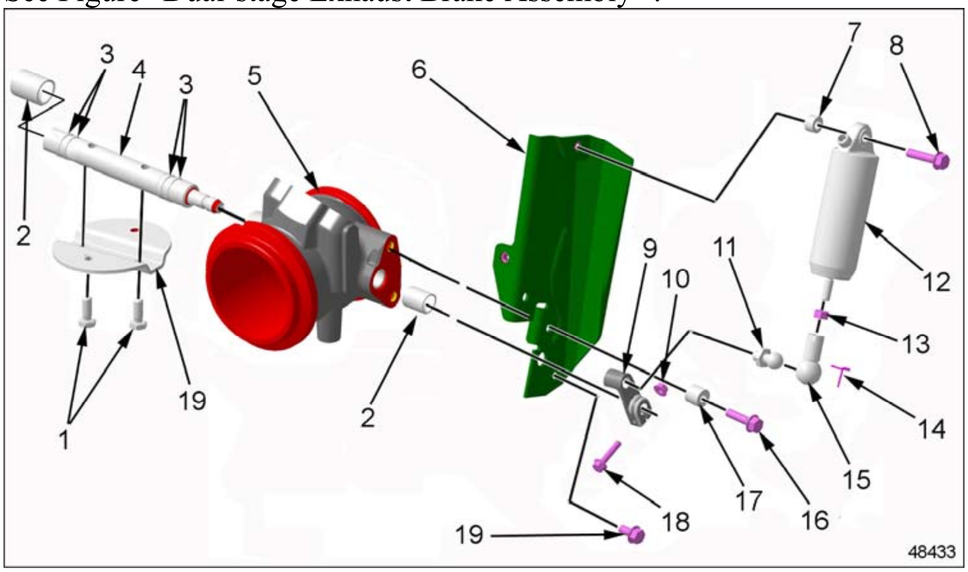
Section 7.2.7
Disassembly of Dual-stage Turbocharger Exhaust Brake

The following commercially available tools are required for this procedure:

- Feeler Gauges, 0.3 - 0.5 mm (0.01 - 0.02 in.)
- Depth Slide Gauge, 0 - 200 mm (0 - 7.9 in.)

Disassembly steps are as follows:

1. With the exhaust brake valve in the open position, loosen the locknut at the base of the ball socket. See Figure "Dual-stage Exhaust Brake Assembly" .



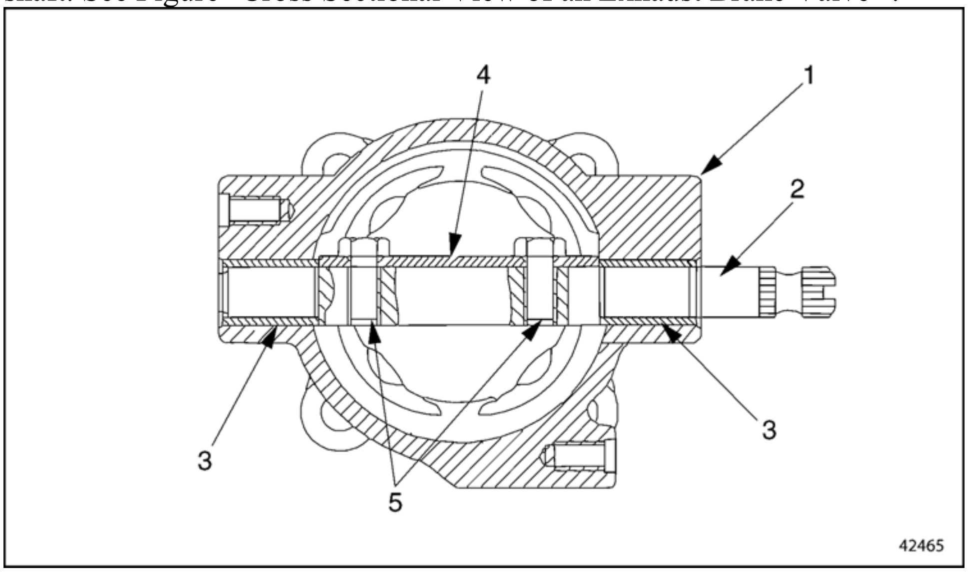
1. Valve Mounting Bolt (qty 2)	11. Ball
2. Bushing (qty 2)	12. Exhaust Brake Actuator
3. Fey Rings	13. Nut
4. Shaft	14. Retaining Clip
5. Exhaust Brake Housing	15. Ball Socket
6. Actuator Bracket	16. Bracket Mounting Bolt
7. Spacer	17. Spacer
8. Actuator Mounting Bolt	18. Lever Bolt
9. Lever	19. Bracket Mounting Bolt
10. Lever Nut	

Figure 9. Dual-stage Exhaust Brake Assembly

2. Remove the exhaust brake cylinder from the bracket. See the insert in Figure "Dual-stage Exhaust Brake Assembly" .
   a. Remove the locking clip.

b. Remove the exhaust brake actuator mounting bolt and spacer from the mounting bracket.
c. Remove the ball socket from the adjusting lever and remove the exhaust brake actuator.

3. Remove the adjusting lever. See the insert in Figure "Dual-stage Exhaust Brake Assembly" .
   a. Turn the adjusting lever to the closed position.
   b. Loosen the hex nut on the adjusting lever bolt to release the clamping pressure on the exhaust brake shaft.
   c. Slide the adjusting lever off the shaft, taking care not to damage the splines on the shaft.
4. Remove the two bracket mounting bolts that secure the bracket to the exhaust brake valve housing. Remove the bracket from the valve housing.
5. Take the exhaust brake valve out of the valve housing.
   a. Make sure the valve is closed.
   b. Using a socket wrench, remove the two valve mounting bolts that secure the valve to the shaft. See Figure "Cross Sectional View of an Exhaust Brake Valve" .



1. Exhaust Brake Valve Housing	4. Exhaust Brake Valve
2. Shaft	5. Valve Mounting Bolts
3. Bushing (2 qty.)	

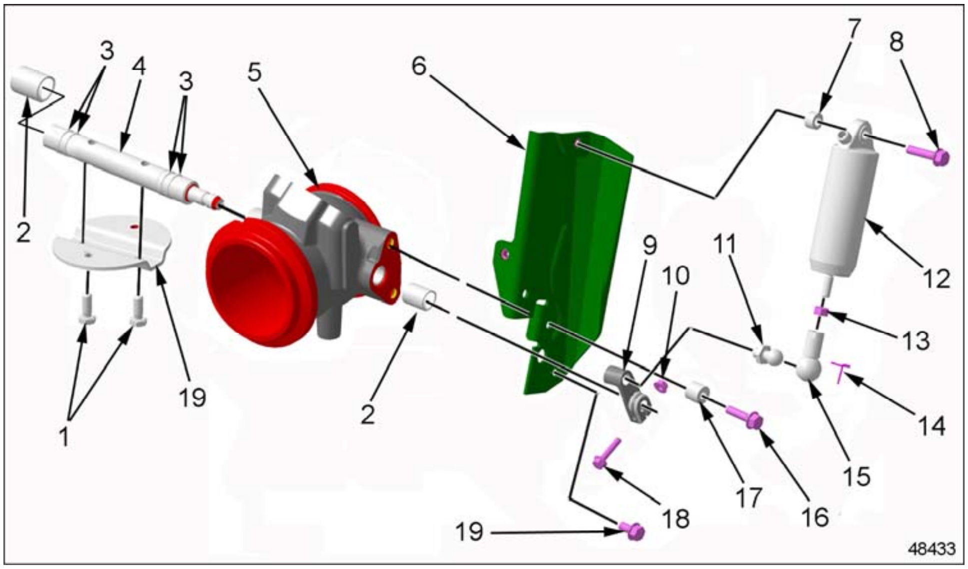
Figure 10. Cross Sectional View of an Exhaust Brake Valve

   c. Remove the valve through the large end of the valve housing.
6. Using a suitable drift, remove the shaft and the two bushings from the exhaust brake valve housing.

Section 7.2.8
Assembly of Dual-stage Turbocharger Exhaust Brake Assembly

Assembly steps are as follows:

1. Install the bushing in the bracket side of the exhaust brake valve housing. See Figure "Dual-stage Turbocharger Exhaust Brake Assembly" .

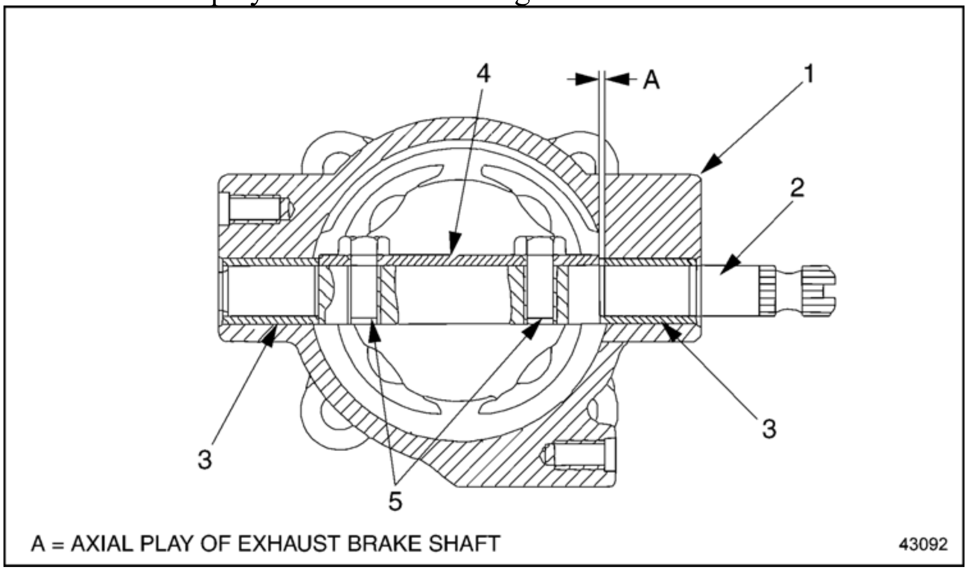


1. Valve Mounting Bolt (qty 2)	11. Ball
2. Bushing (qty 2)	12. Exhaust Brake Actuator
3. Fey Rings	13. Nut
4. Shaft	14. Retaining Clip
5 .Exhaust Brake Housing	15. Ball Socket
6. Actuator Bracket	16. Bracket Mounting Bolt
7. Spacer	17. Spacer
8. Actuator Mounting Bolt	18. Lever Bolt
9. Lever	19. Bracket Mounting Bolt
10. Lever Nut	

Figure 11. Dual-stage Turbocharger Exhaust Brake Assembly

   a. Using a depth slide gauge, measure 3 mm (0.1 in.) inward on the inner contact surface of the bushing.
   b. Coat the leading (chamfered) edge of the bushing and the measured portion of the inner contact surface with bearing grease.
   c. Using a suitable drift, press in the bushing. Allow the bushing to protrude slightly outside the valve housing.
2. Insert the shaft into the valve housing and bushing.
3. Install the second bushing in the opposite side of the valve housing.
   a. Using a depth slide gauge, measure 3 mm (0.1 in.) inward on the inner contact surface of the bushing.
   b. Coat the leading edge of the bushing and the measured portion of the inner contact surface with bearing grease.
   c. Using a suitable drift, press in the bushing. Allow the bushing to protrude slightly outside the valve housing
4. Install the valve on the shaft.
   a. Place the valve inside the valve housing.
   b. Rotate the shaft until the bolt holes are parallel with the direction of the exhaust flow.
   c. Apply anti–seize compound to the threads of the two valve mounting bolts.

    d. Place the valve against the shaft in the closed position (resting against the valve stop). Align the bolt holes in the valve and shaft.
    e. Install the two valve mounting bolts through the valve and into the shaft from the direction shown in Figure "Dual-stage Turbocharger Exhaust Brake Assembly" .
    f. Using a socket wrench, tighten the bolts 23 N·m (17 lb·ft).
5. Check the axial play of the shaft. See Figure "Cross Sectional View of an Exhaust Brake Valve" .



1. Exhaust Brake Valve Housing	4. Exhaust Brake Valve
2. Shaft	5. Valve Mounting Bolts
3. Bushing (2 qty.)	

Figure 12. Cross Sectional View of an Exhaust Brake Valve

    a. Center the shaft in the valve housing
    b. Using a suitable drift, drive the bushings in evenly on both sides until the axial play is correct.
    c. Using a feeler gauge, check that the axial play of the shaft between the bushings is 0.3 - 0.5 mm (0.01 - 0.02 in.). Make sure the projection of the bushings inside the valve housing is the same on both sides.
6. Using a feeler gauge, check the outside edge (perimeter) of the closed valve to make sure it does not touch the housing at any point.
7. Install the bracket on the exhaust brake valve housing with the two bracket mounting bolts. Tighten the bolts 23 N·m (17 lb·ft).
8. Install the adjusting lever. See Figure "Dual-stage Turbocharger Exhaust Brake Assembly" .
    a. Rotate the valve to the fully open position in the valve housing.
    b. Fit the adjusting lever on the splines of the shaft so the adjusting–lever stop rests against the bottom lip of the bracket.
9. Check the valve setting by rotating it to the closed position. The adjusting–lever stop must be approximately 1 mm (0.04 in.) below the lip of the bracket, not touching the bracket.
10. Install the exhaust brake cylinder on the bracket.
    a. Install the cylinder and a new cylinder mounting hex nut on the mounting stud but do not tighten. See Figure "Dual-stage Turbocharger Exhaust Brake Assembly" .
    b. With the valve open, turn the ball socket clockwise until the exhaust brake cylinder is pre–loaded at 1.0 - 2.0 mm (0.04 - 0.08 in.). Tighten the locknut against the ball socket.

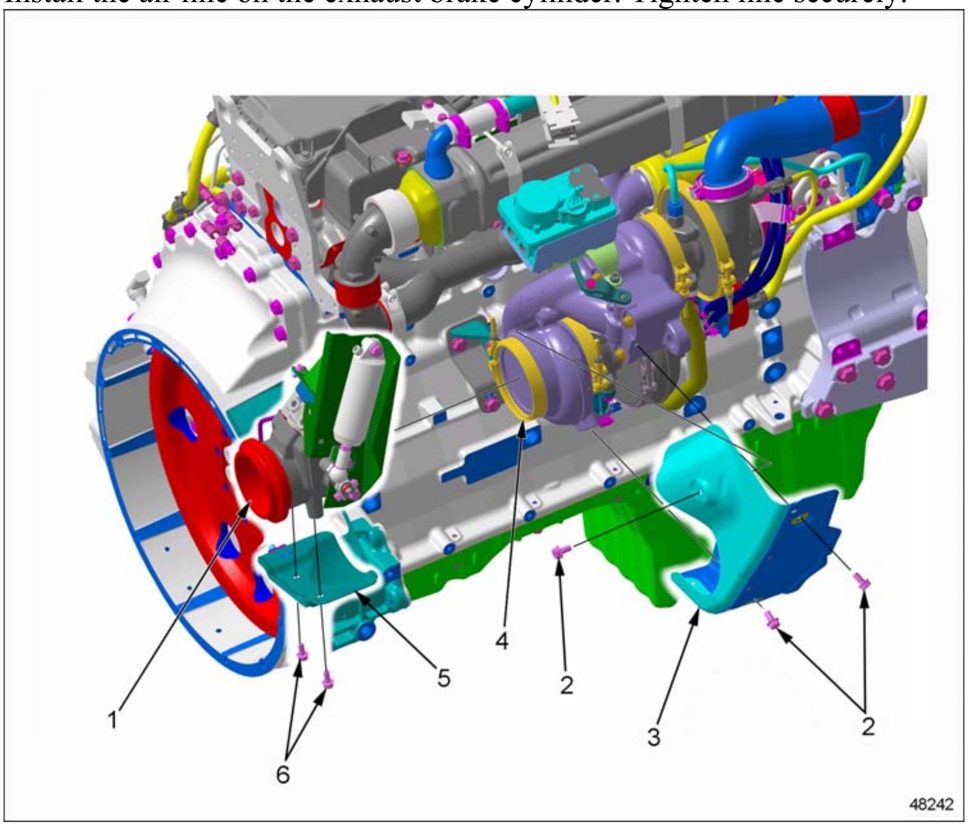
c. Install the locking element.
d. Tighten the cylinder mounting hex nut onto the mounting stud until firm.

11. Install the exhaust brake assembly. Refer to "7.2.9 Installation of Dual-stage Turbocharger Exhaust Brake Assembly" .

Section 7.2.9
Installation of Dual-stage Turbocharger Exhaust Brake Assembly

Installation steps are as follows:

1. If removed, install the fuel doser valve onto the exhaust brake housing. Refer to "2.20.2 Installation of Fuel Doser Valve" .
2. Clean the mating surfaces on the exhaust brake valve housing and the turbocharger.
3. Install the exhaust brake valve housing onto the turbocharger and secure with a v-band clamp. Tighten the clamp securely.
4. Install the air line on the exhaust brake cylinder. Tighten line securely.



1. Exhaust Brake Assembly	4. V-band Clamp
2. Bolts (qty 3)	5. Exhaust Brake Heat Shield
3. Turbocharger Heat Shield	6. Bolts

Figure 13. Dual-stage Exhaust Brake Assembly

5. Clean the sealing surfaces on the exhaust pipe and exhaust brake valve housing.
6. Slide the exhaust pipe and clamp over the end of the housing to the stop. Tighten the clamp securely.
7. Install the heat shield on the bottom of the exhaust brake valve housing with two bolts. Torque the

bolts to 20–25 N·m (15–18 lb·ft). See Figure "Dual-stage Exhaust Brake Assembly" .

8. Install the heat shield on the exhaust brake valve housing and the turbocharger, using four hex head bolts. Torque the bolts to 20–25 N·m (15–18 lb·ft).

Additional Information

Specifications

This section contains the specifications for the exhaust manifold and exhaust manifold brake assembly.

Exhaust Manifold

The specifications for the turbocharger are listed in Table "Turbocharger Torque Values" and listed in Table "Tightening Stages for Exhaust Manifold Bolts" are the specifications for the exhaust manifold.

Descriptions	Parts	Torque N·m (lb·ft)
Turbocharger to Exhaust Manifold Nuts	M10 Fastener	50 (37)
Turbocharger Oil Supply Line	M8 Bolt	40 (30)

Table 1. Turbocharger Torque Values

Size	Max. Shank Length mm (in.)	Tightening Stage	Torque N·m (lb·ft)
M10	47.5 (1.87)	Stage 1	50 (37)
		Stage 2	additional 90 degrees

Table 2. Tightening Stages for Exhaust Manifold Bolts

Exhaust Brake Assembly

Specifications for the exhaust brake assembly are listed in Table "Exhaust Brake Assembly Specifications" .

Descriptions	mm (in.)
Exhaust Brake Setting	180.3 (7.0984)
Exhaust Brake Preload	1.0–2.0 (0.04–0.08)
Shaft Axial Play Between Bushings	0.3–0.5 (0.01–0.02)

Table 3. Exhaust Brake Assembly Specifications

Special Tools

The special tools used in this section are listed in Table "Special Tools" .

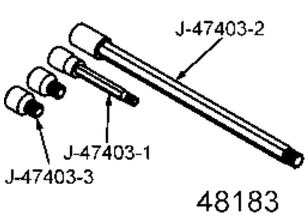
Tool	Description	Usage	Part Number
	Exhaust Manifold Socket Set	Used to remove, install and torque exhaust manifold bolts.	J–47403

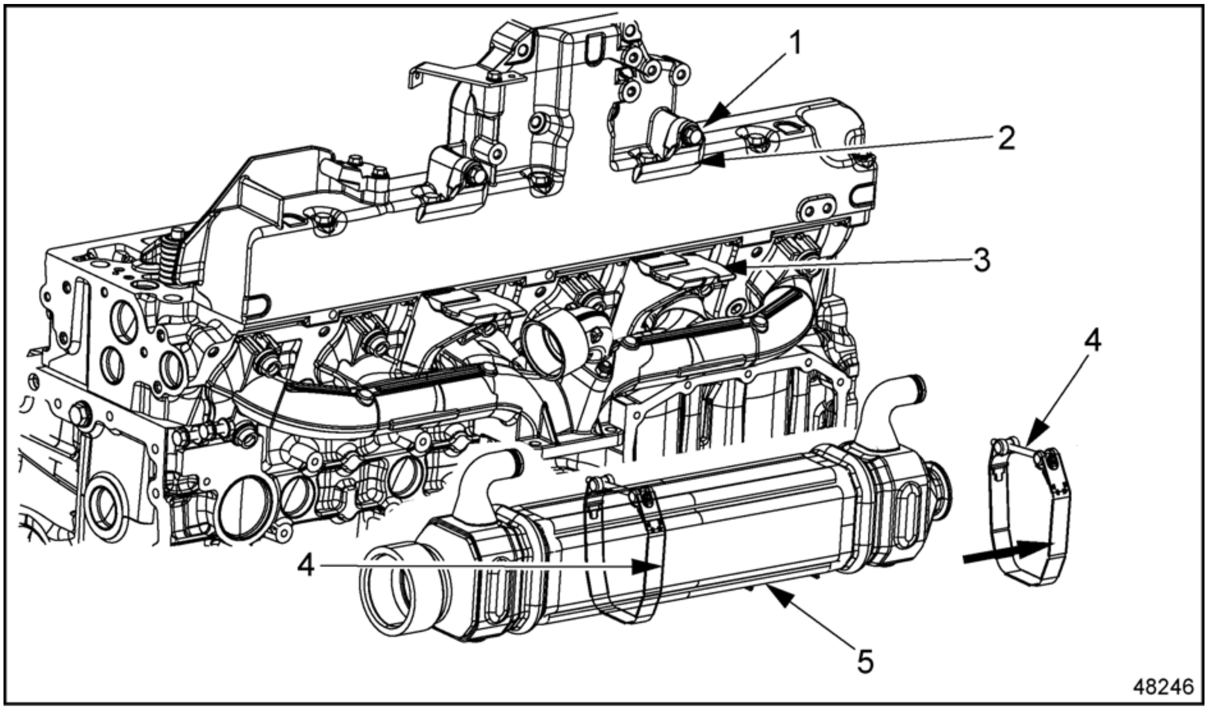
Table 4. Special Tools

Section 8.1
EGR Cooler and Mounting Bracket

The primary purpose of the Exhaust Gas Recirculation (EGR) cooler is to cool the engine exhaust gases.

Section 8.1.1
Removal of Single-stage Turbocharger EGR Cooler

Removal steps are as follows:



1. Bolts (qty 2)	4. Band Clamps (qty 2)
2. Upper Mounting Brackets	5. EGR Cooler
3. Lower Mounting Brackets	

Figure 1. Single-stage Turbocharger EGR Cooler

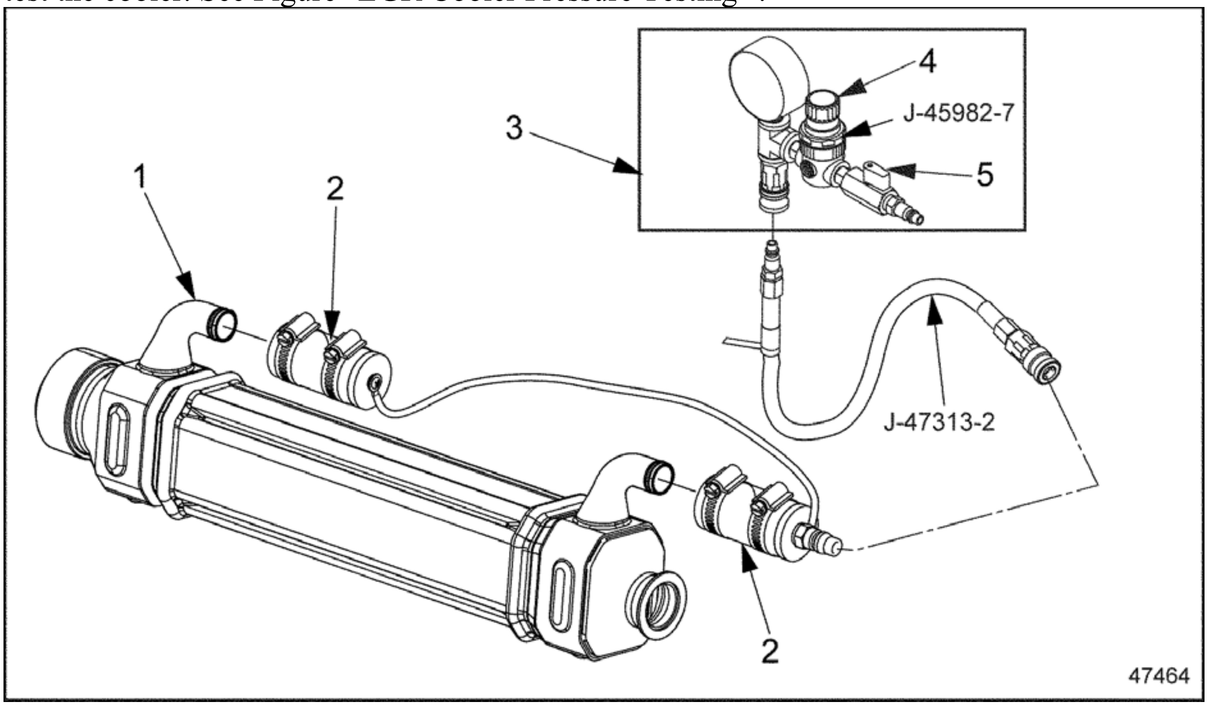
1. Remove the EGR coolant inlet tube. Refer to "8.2.1 Removal of EGR Coolant Inlet Tube" .
2. Remove the EGR coolant return tube. Refer to "8.3.1 Removal of EGR Coolant Return Tube" .
3. Remove the EGR delivery pipe. Refer to "8.5.1 Removal of EGR Delivery Pipe" .
4. Remove the EGR exhaust elbow. For the single-stage turbocharger refer to "8.6.1 Removal of Single-Stage Turbocharger EGR Exhaust Elbow" . For the dual-stage turbocharger refer to "8.6.3 Removal of Dual-Stage Turbocharger EGR Exhaust Elbow" .
5. Remove two band clamps securing the EGR cooler to the cooler brackets and remove the cooler.
6. If necessary, remove the EGR cooler mounting brackets:
    a. Remove the bolts securing the EGR cooler upper mounting brackets to the air intake manifold and remove the brackets. See Figure "Single-stage Turbocharger EGR Cooler" .
    b. Remove the bolts securing the EGR cooler upper mounting brackets to the air intake

manifold and remove the brackets. See Figure "Single-stage Turbocharger EGR Cooler" .
7. Pressure test the EGR cooler. Refer to "8.1.1.1 Pressure Testing of EGR Cooler" .

Section 8.1.1.1
Pressure Testing of EGR Cooler

Pressure testing steps are as follows:

1. Use the EGR cooler test kit (J–47192) and EGR cooler leak test adapters (J–47401) to pressure test the cooler. See Figure "EGR Cooler Pressure Testing" .



1. EGR Cooler	4. Regulator Valve
2. Adapters (J-47401)	5. Shut-off Valve
3. Regulator and Gauge	

Figure 2. EGR Cooler Pressure Testing

2. Install the air supply test adapter on one end of the EGR cooler coolant passage and secure with hose clamps. Tighten clamps securely.
3. Install the test adapter plug on the opposite end of the EGR cooler coolant passage and secure with hose clamps. Tighten clamps securely.
4. Connect pressure hose (J–47313–2, part of toolset J–47192) to pressure regulator (J–45982–7, part of toolset J–45987) .

WARNING:

EYE INJURY

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face

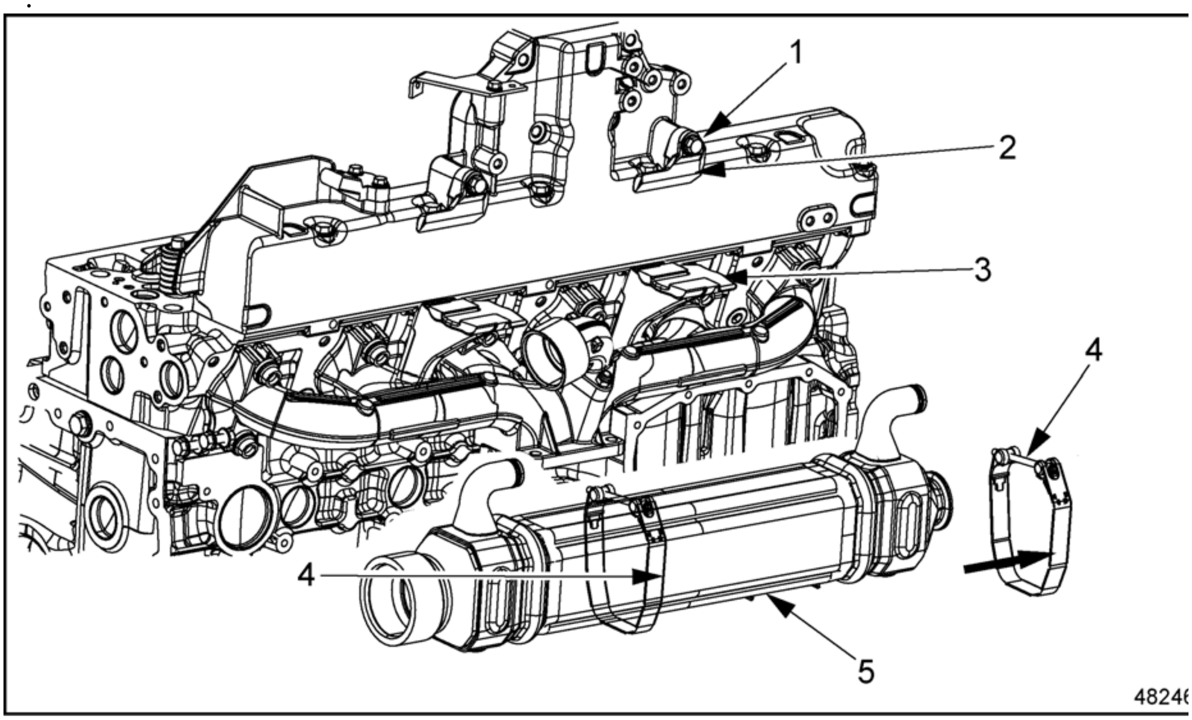
shield or safety goggles) and do not exceed 276 kPa (40 psi) air pressure.

5. Turn the shutoff valve to the OFF position (perpendicular to the valve) and connect the air supply hose to the pressure regulator.
6. Set the pressure regulator to zero by pulling upward on the adjusting knob and turning counter clockwise until it stops.
7. Turn the valve to the ON position (parallel with the valve).
8. Adjust the pressure by turning the knob clockwise until a pressure reading of 90 kPa (13 psi) is obtained.
9. Once the pressure regulator has been set, connect the pressure hose (J–47313–2, part of toolset J–47192) to the air supply fitting on the EGR cooler.
10. Submerge the EGR cooler completely into a hot water tank. Tip one end of the cooler upward so the air bubbles will escape.
11. Leave the cooler submerged for five minutes.
12. In the event of a failed cooler, a steady stream of small bubbles will come out of the highest end of the EGR cooler. Replace the cooler.
13. Remove the EGR cooler test components from the EGR cooler.

Section 8.1.2
Installation of Single-stage Turbocharger EGR Cooler

Installation steps are as follows:

1. If removed, install the EGR cooler mounting bracket:
   a. Secure the two EGR cooler upper mounting brackets to the air intake manifold with bolts. Torque the bolts to 25 N·m (18 lb·ft). See Figure "Single-stage Turbocharger EGR Cooler " .



1. Bolts (qty 2)	4. Band Clamps (qty 2)

2. Upper Mounting Brackets	5. EGR Cooler
3. Lower Mounting Brackets	

Figure 3. Single-stage Turbocharger EGR Cooler

   b. Secure the two EGR cooler lower mounting brackets to the cylinder head with bolts. Torque the bolts to 25 N·m (18 lb·ft). See Figure "Single-stage Turbocharger EGR Cooler " .

2. Loosely attach the EGR cooler to the EGR cooler support brackets with two band clamps. See Figure "Single-stage Turbocharger EGR Cooler " .
3. Install the EGR exhaust elbow. Refer to "8.6.2 Installation of Single-Stage Turbocharger EGR Exhaust Elbow" .
4. Install the EGR delivery pipe. Refer to "8.5.2 Installation of EGR Delivery Pipe" .
5. Install the EGR coolant inlet tube. Refer to "8.2.2 Installation of EGR Coolant Inlet Tube" .
6. Install the EGR coolant return tube. Refer to "8.3.1 Removal of EGR Coolant Return Tube" .
7. Fill engine with fresh coolant to the required level.

Section 8.1.3
Removal of Dual-stage Turbocharger EGR Cooler

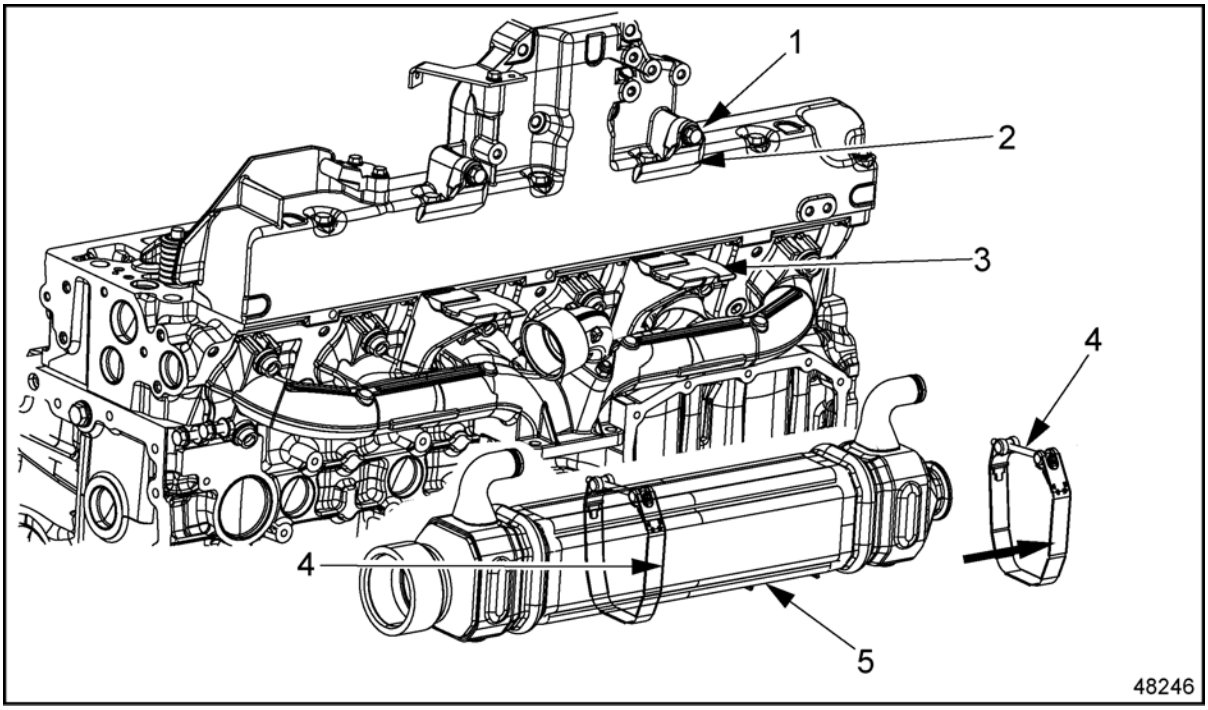
Removal steps are as follows

WARNING:

PERSONAL INJURY

To avoid injury from scalding, drain the radiator when the engine and coolant are cool.

1. Drain the coolant.



1. Bolts (qty 2)	4. Band Clamps (qty 2)
2. Upper Mounting Brackets	5. EGR Cooler
3. Lower Mounting Brackets	

Figure 4. Dual-stage Turbocharger EGR Cooler

2. Remove the EGR coolant return tube. Refer to "8.3.1 Removal of EGR Coolant Return Tube" .
3. Loosen the hose clamp at the hose on the delivery pipe to the EGR valve.
4. Remove the EGR delivery pipe. Refer to "8.5.1 Removal of EGR Delivery Pipe" .
5. Remove the EGR exhaust elbow. Refer to "8.6.3 Removal of Dual-Stage Turbocharger EGR Exhaust Elbow" .
6. Remove two band clamps securing the EGR cooler to the cooler brackets and remove the cooler.
7. If necessary, remove the EGR cooler mounting brackets:
   a. Remove the bolts securing the EGR cooler upper mounting brackets to the air intake manifold and remove the brackets. See Figure "Dual-stage Turbocharger EGR Cooler" .
   b. Remove the bolts securing the EGR cooler upper mounting brackets to the air intake manifold and remove the brackets. See Figure "Dual-stage Turbocharger EGR Cooler" .
8. Pressure test the EGR cooler. Refer to "8.1.1.1 Pressure Testing of EGR Cooler" .

Section 8.1.4
Installation of Dual-stage Turbocharger EGR Cooler

Installation steps are as follows:

1. If removed, install the EGR cooler mounting bracket:
   a. Secure the two EGR cooler upper mounting brackets to the air intake manifold with bolts. Torque the bolts to 25 N·m (18 lb·ft). See Figure "Dual-stage Turbocharger EGR Cooler" .
   b. Secure the two EGR cooler lower mounting brackets to the cylinder head with bolts. Torque the bolts to 25 N·m (18 lb·ft). See Figure "Dual-stage Turbocharger EGR Cooler" .

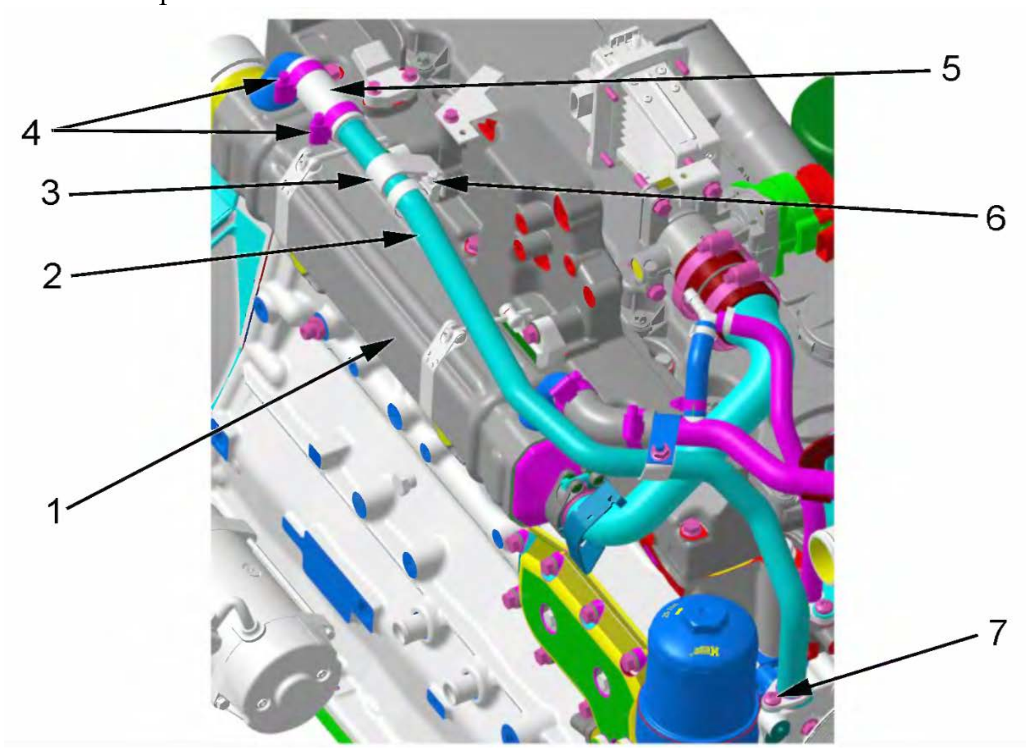
2. Loosely attach the EGR cooler to the EGR cooler support brackets with two band clamps. See Figure "Dual-stage Turbocharger EGR Cooler" .
3. Install the EGR exhaust elbow. Refer to "8.6.4 Installation of Dual-stage Turbocharger EGR Exhaust Elbow" .
4. Torque the EGR cooler band clamps to 6-8 Nm (4-6) lb·ft).
5. Install the EGR delivery pipe. Refer to "8.5.2 Installation of EGR Delivery Pipe" .
6. Install the EGR coolant inlet tube. Refer to "8.2.2 Installation of EGR Coolant Inlet Tube" .
7. Install the EGR coolant return tube. Refer to "8.3.2 Installation of EGR Coolant Return Tube" .
8. Fill engine with fresh coolant to the required level.

Section 8.2
EGR Coolant Inlet Tube

Exhaust gas cooling is accomplished by the flow of exhaust gases through the EGR cooler tubes.

Section 8.2.1
Removal of EGR Coolant Inlet Tube

Removal steps are as follows:



1. EGR Cooler	4. Hose Clamps (qty 2)	7. Bolt
2. Coolant Inlet Tube	5. Hose	
3. Retaining Bracket	6. Hose Clamp	

Figure 1. EGR Coolant Inlet Tube

WARNING:

PERSONAL INJURY

To avoid injury from scalding, drain the radiator when the engine and coolant are cool.

1. Drain the coolant.
2. Remove the coolant return tube. Refer to "8.3.1 Removal of EGR Coolant Return Tube" .
3. Remove the nut on the coolant inlet tube bracket attaching the inlet tube to the coolant return tube.

See Figure "EGR Coolant Inlet Tube" .

4. Remove the bolt securing the retaining clamp on the coolant inlet tube to the air intake manifold. See Figure "EGR Coolant Inlet Tube" .
5. Loosen the clamps and slide the hose, connecting the coolant inlet tube to the EGR cooler, onto the tube. See Figure "EGR Coolant Inlet Tube" .
6. Remove the bolt securing the EGR coolant inlet tube to the coolant pump housing. See Figure "EGR Coolant Inlet Tube" .
7. Remove the EGR coolant inlet tube and seal from the coolant pump housing and EGR cooler. Discard the seal. See Figure "EGR Coolant Inlet Tube" .

Section 8.2.2
Installation of EGR Coolant Inlet Tube

Installation steps are as follows:

1. Lubricate new coolant inlet tube seal with lubricant and install on inlet tube.
2. Inspect the coolant hose for damage and replace if required.
3. Install the hose and clamps on the coolant inlet tube and attach to the EGR cooler. See Figure "EGR Coolant Inlet Tube" .
4. Install the coolant inlet tube and new seal to the water pump housing. Tighten the bolt to 31–35 N·m (23–26 lb·ft). See Figure "EGR Coolant Inlet Tube" .
5. Secure the retaining clamp on the coolant inlet tube to the air intake manifold with a bolt. Torque the bolt to 25 N·m (18 lb·ft). Tighten the hose clamps securely. See Figure "EGR Coolant Inlet Tube" .
6. Install the EGR cooler coolant return tube. Refer to "8.3.2 Installation of EGR Coolant Return Tube" .
7. Fill engine with coolant to required level.

WARNING:

ENGINE EXHAUST

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

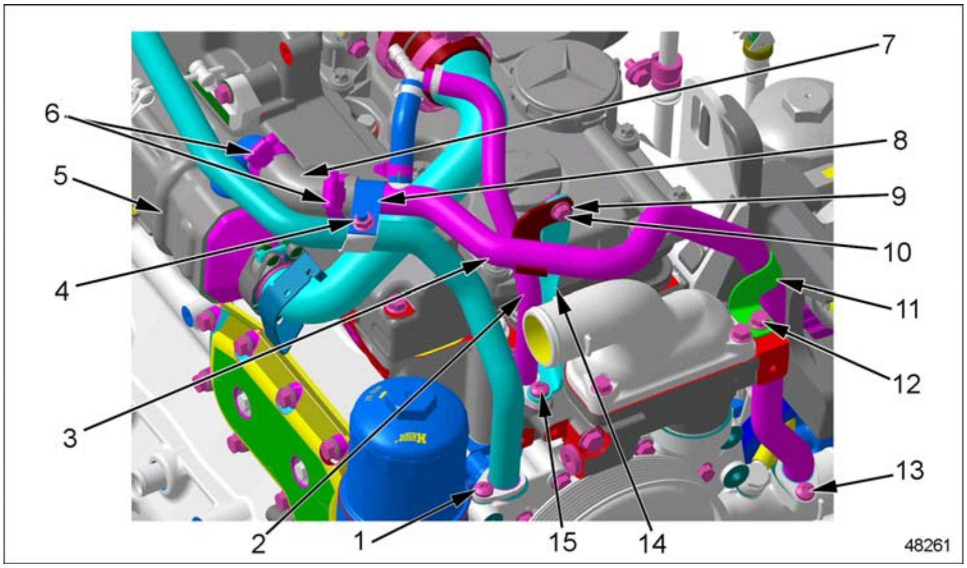
8. Start the engine and check for leaks, repair as necessary.

Section 8.3
EGR Coolant Return Tube

Exhaust gas cooling is accomplished by the flow of exhaust gases through the EGR cooler tubes.

Section 8.3.1
Removal of EGR Coolant Return Tube

Removal steps are as follows:



1. Bolt	6. Hose Clamps	11. Retaining Bracket
2. Vent Hose	7. Hose	12. Bolt
3. Coolant Return Tube	8. Retaining Bracket	13. Bolt
4. Nut	9. Bracket	14. Bracket
5. EGR Cooler	10. Bolt	15. Bolt

Figure 1. EGR Coolant Return Tube

WARNING:

PERSONAL INJURY

To avoid injury from scalding, drain the radiator when the engine and coolant are cool.

1. Drain the engine coolant.
2. Remove bolt from retaining bracket on coolant return tube at the left front of the thermostat housing. See Figure "EGR Coolant Return Tube" .
3. Remove nut from mounting bracket which secures the coolant inlet and outlet tubes together. See

Figure "EGR Coolant Return Tube" .

4. Remove bolt and nut securing coolant return tube bracket to mounting bracket on right side of thermostat housing. See Figure "EGR Coolant Return Tube" .
5. Loosen the clamps to the hose on the EGR cooler and coolant return tube. See Figure "EGR Coolant Return Tube" .
6. Remove the hose clamp attaching the coolant vent line to the EGR coolant return tube. See Figure "EGR Coolant Return Tube" .
7. Remove the two bolts attaching the vent line, adaptor and gasket from the thermostat housing. Discard the gasket. See Figure "EGR Coolant Return Tube" .
8. Remove bolt securing the coolant return tube to the coolant pump inlet and remove the tube. Remove the seal from the end of the tube and discard. See Figure "EGR Coolant Return Tube" .

Section 8.3.2
Installation of EGR Coolant Return Tube

Installation steps are as follows:

1. Inspect the coolant vent hose for any damage. Replace hose if necessary.
2. Install two bolts and new gasket and secure the vent line and adaptor to the thermostat housing. Torque the bolts to 25 N·m (18 lb·ft). See Figure "EGR Coolant Return Tube" .
3. Insert the hose on the end of the coolant return tube onto the EGR cooler and position mounting bracket over bolt on coolant inlet bracket and insert the other end, with new seal, into the coolant pump inlet connection with bolt. Torque the bolt to 25 N·m (18 lb·ft). Torque the nut to 25 N·m (18 lb·ft). See Figure "EGR Coolant Return Tube" .
4. Secure the coolant return tube bracket to the left side of the thermostat housing with a bolt. Torque the bolt to 25 N·m (18 lb·ft). See Figure "EGR Coolant Return Tube" .
5. Tighten the hose clamps at the EGR cooler securely.
6. Secure bolt and nut securing coolant return tube bracket to mounting bracket on right side of thermostat housing with a bolt and nut. Torque the bolt and nut to 25 N·m (18 lb·ft). See Figure "EGR Coolant Return Tube" .
7. Attach the coolant vent line to the EGR coolant return tube and secure with hose clamp. Tighten clamp securely.
8. Fill engine with coolant to required level.

WARNING:

ENGINE EXHAUST

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

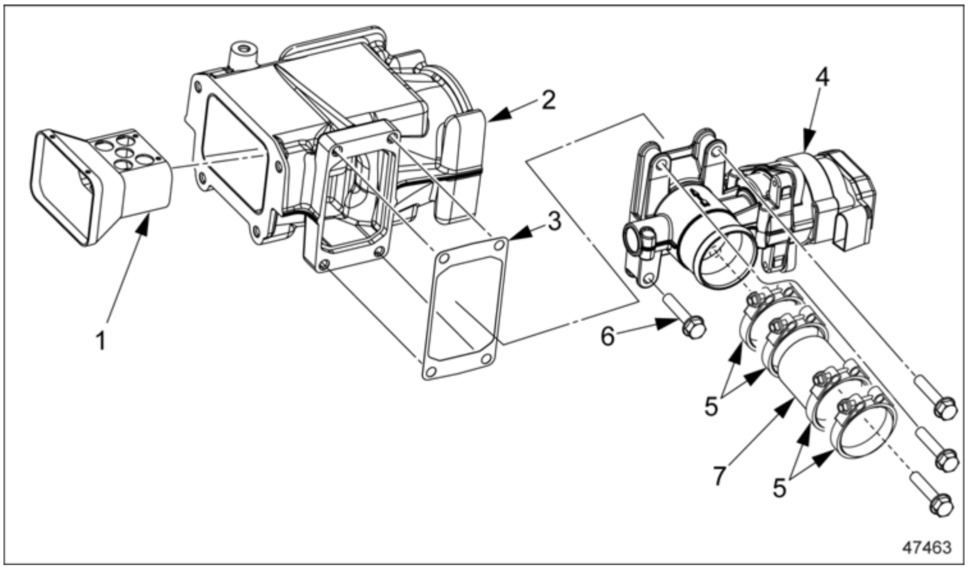
9. Start the engine and check for leaks, repair as necessary.

Section 8.4
EGR Valve Assembly

The EGR valve position is controlled by DDEC. The Motor Control Module (MCM) continuously monitors all engine operation modes and performs self diagnostic checks of RPM, load, altitude, air temperature, etc. and uses this information to determine the valve position.

Section 8.4.1
Removal of EGR Valve Assembly

Removal steps are as follows:



1. Air Mixer Insert	5. Hose Clamp (qty 4)
2. Air Intake Mixer Housing	6. Bolts
3. Gasket	7. Hose
4. EGR Valve Assembly	

Figure 1. EGR Valve Assembly Removal/Installation

1. Disconnect electrical connector from the EGR valve assembly.
2. Loosen the four hose clamps on the hose connecting the EGR valve to the EGR delivery pipe and slide the hose onto the pipe.
3. Remove four bolts securing the EGR valve and gasket to the mixer housing and remove the valve. Discard the gasket. See Figure "EGR Valve Assembly Removal/Installation" .

   Note: The EGR valve is not serviced and must be replaced as an assembly.

Section 8.4.2
EGR Valve Assembly Installation

Install the EGR valve assembly as follows (see Figure "EGR Valve Assembly Removal/Installation" for component location):

1. Using a new gasket, secure the EGR valve assembly to the mixer housing with four bolts . Torque the bolts to 31–35 N·m (23–26 lb·ft). See Figure "EGR Valve Assembly Removal/Installation" .
2. Install the four hose clamps on the hose and slide the hose onto the EGR delivery pipe. Torque clamps to 8 N·m (6 lb·ft).
3. Connect electrical connector to the EGR valve assembly.

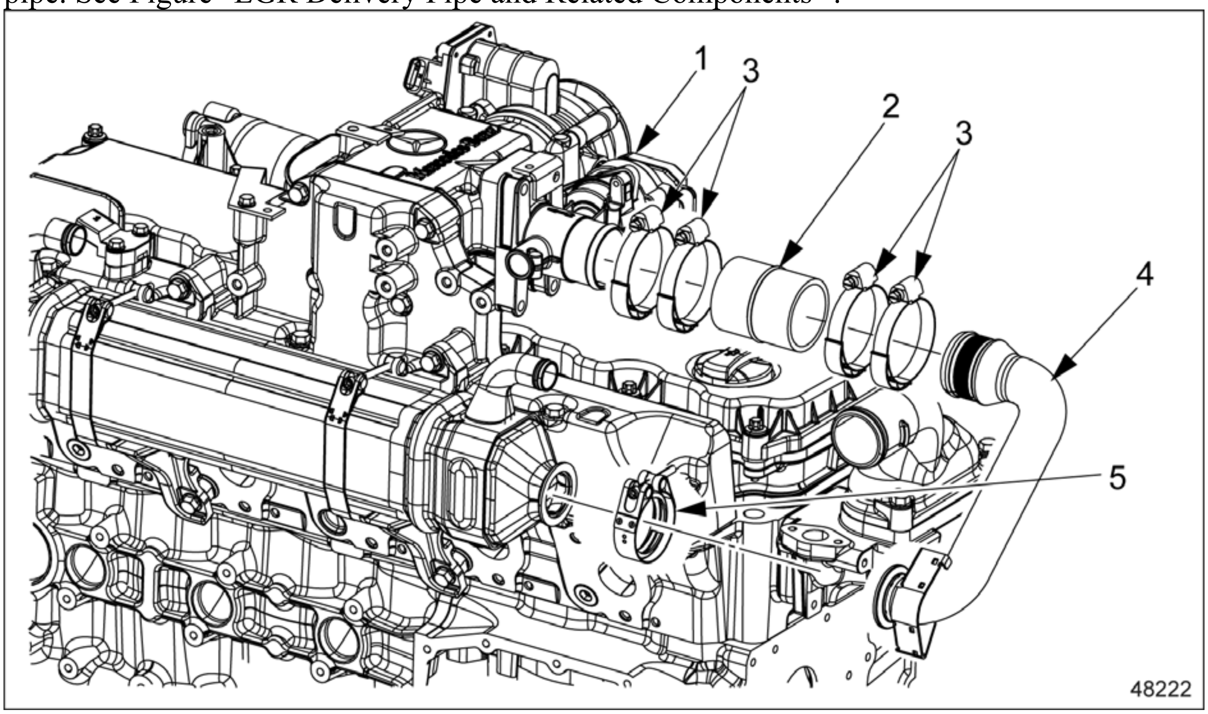
Section 8.5
EGR Delivery Pipe

When the EGR valve is open, the exhaust gas is directed into the EGR cooler, through the delivery pipe.

Section 8.5.1
Removal of EGR Delivery Pipe

Removal steps are as follows:

1. Remove the V-band clamp connecting the EGR delivery pipe to the EGR cooler.
2. Loosen the two hose clamps connecting the delivery pipe to hose and remove the EGR delivery pipe. See Figure "EGR Delivery Pipe and Related Components" .



1. EGR Valve	4. EGR Delivery Pipe
2. EGR Hose	5. V-band Clamp
3. Hose Clamps (qty 4)	

Figure 1. EGR Delivery Pipe and Related Components

3. Remove hose.

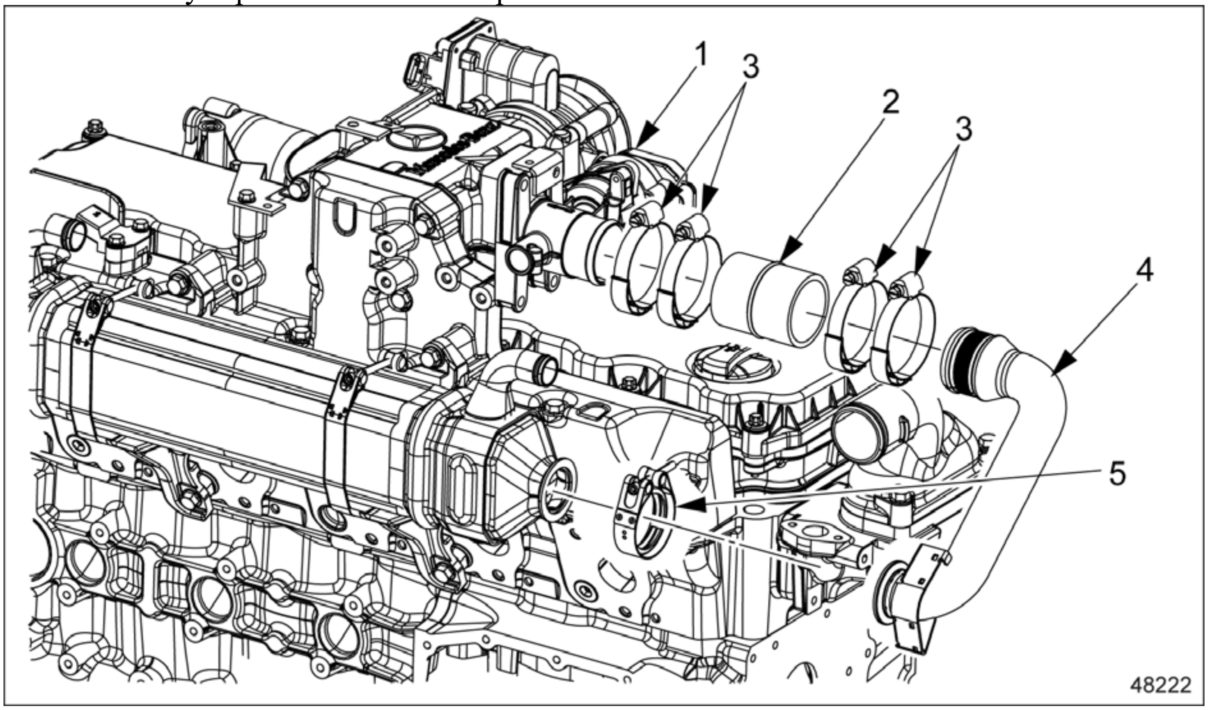
Section 8.5.2
Installation of EGR Delivery Pipe

Installation steps are as follows:

1. Inspect the hose on the EGR delivery pipe and replace if damaged. Secure the hose to EGR valve

using two clamps. Torque to 8 N·m (6 lb·ft).

2. Insert the EGR delivery pipe to the EGR cooler and secure using the V-band clamp. See Figure "EGR Delivery Pipe and Related Components" .



1. EGR Valve	4. EGR Delivery Pipe
2. EGR Hose	5. V-band Clamp
3. Hose Clamps (qty 4)	

Figure 2. EGR Delivery Pipe and Related Components

3. Secure the EGR delivery pipe to the hose and secure using two clamps. Torque to 8 N·m (6 lb·ft).
4. Torque the V-band clamp at the EGR cooler to 7-9 Nm (5-7 lb·ft).

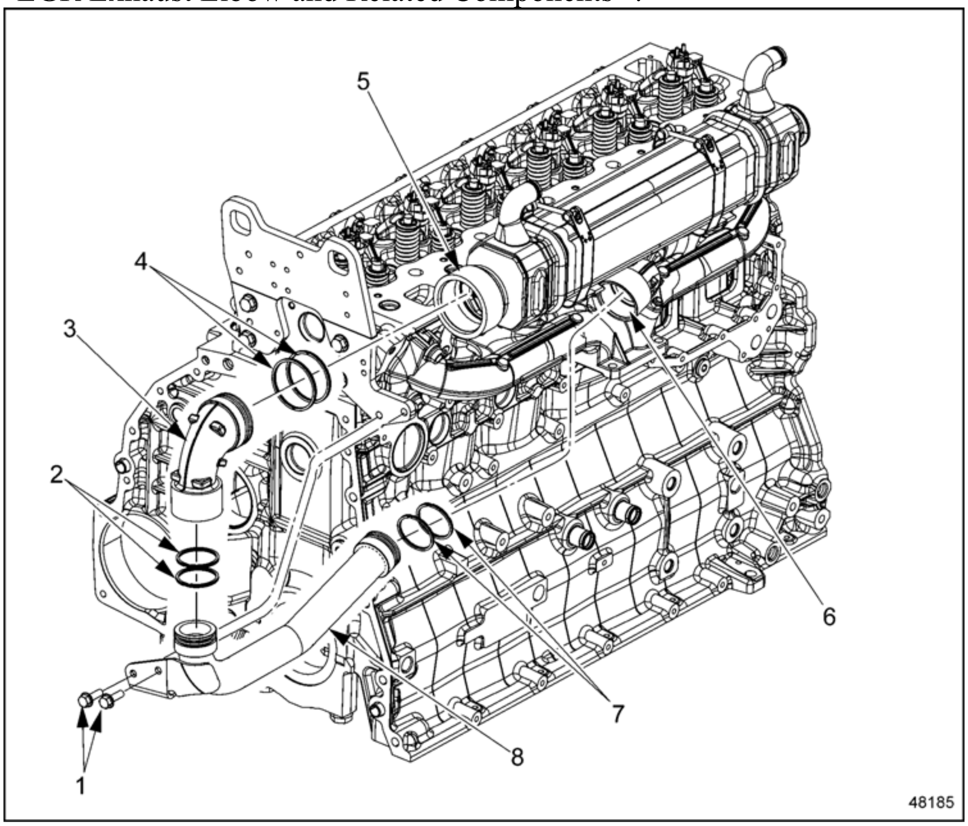
Section 8.6
EGR Exhaust Elbow

The following sections contain information on the removal and installation of the EGR exhaust elbow.

Section 8.6.1
Removal of Single-Stage Turbocharger EGR Exhaust Elbow

Removal steps are as follows:

1. Remove two bolts and nuts securing the EGR exhaust elbow to the rear lifting bracket. See Figure "EGR Exhaust Elbow and Related Components" .



1. Bolts	5. EGR Cooler
2. Fey Rings	6. Exhaust Manifold
3. EGR Exhaust Elbow	7. Fey Rings
4. Fey Rings	8. EGR Exhaust Pipe

Figure 1. EGR Exhaust Elbow and Related Components

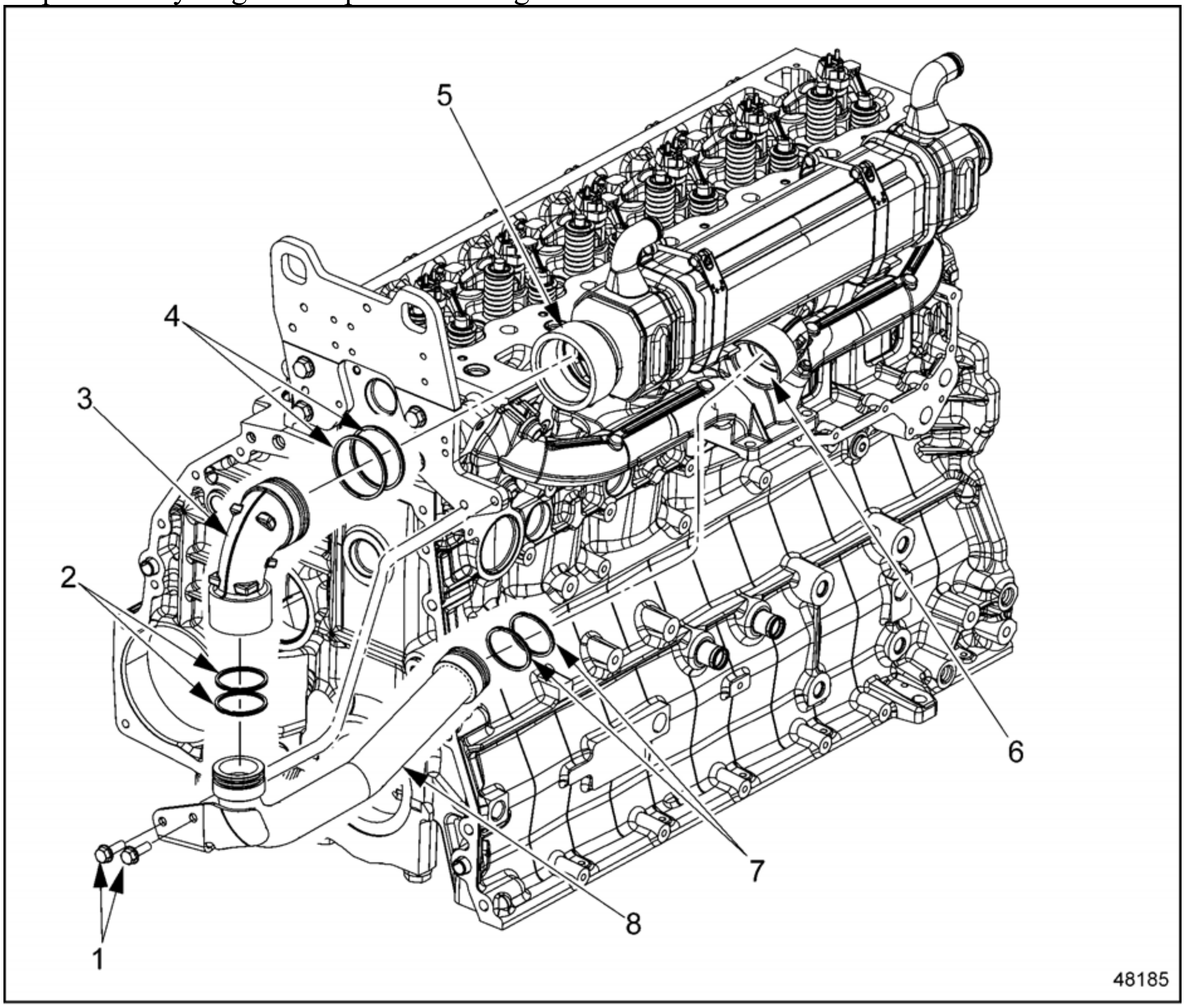
2. Remove the elbow and pipe from the rear of the EGR cooler and center exhaust manifold. Inspect seal rings. If damaged replace seal rings.
3. Separate the elbow from the pipe.

Section 8.6.2

Installation of Single-Stage Turbocharger EGR Exhaust Elbow

Installation steps are as follows:

1. Inspect the fey rings and replace if damaged. .



1. Bolts	5. EGR Cooler
2. Fey Rings	6. Exhaust Manifold
3. EGR Exhaust Elbow	7. Fey Rings
4. Fey Rings	8. EGR Exhaust Pipe

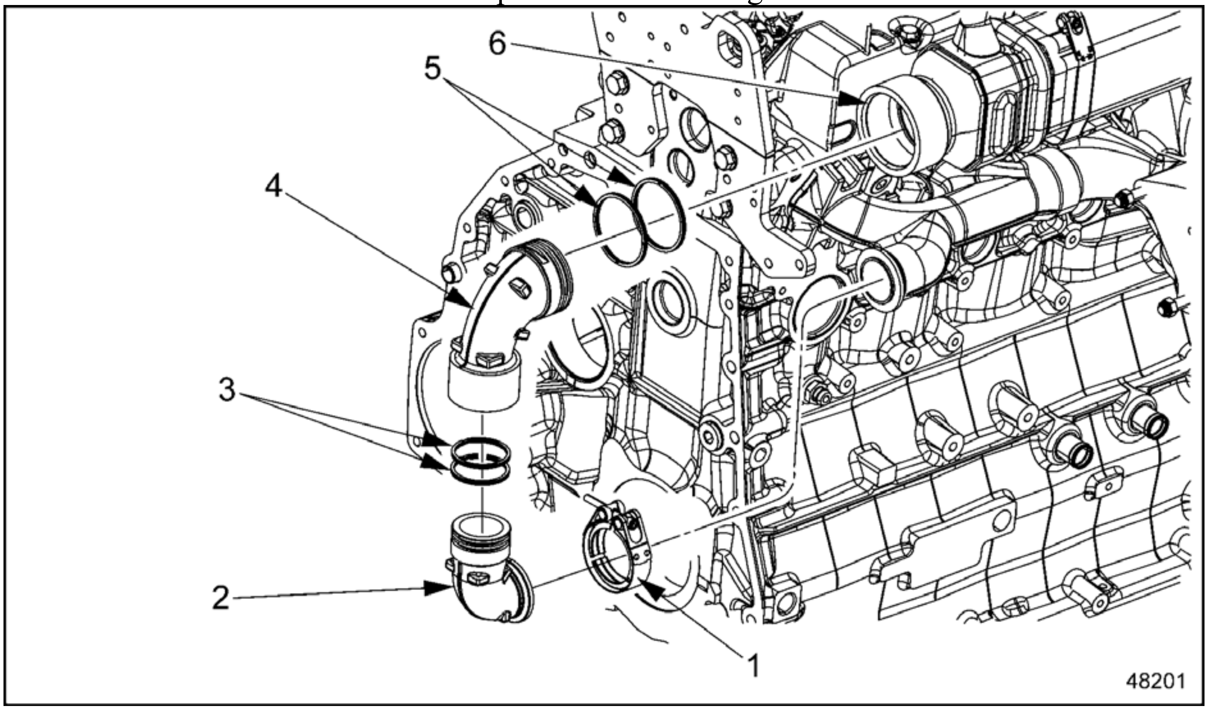
Figure 2. EGR Exhaust Elbow and Related Components

2. Install the fey rings (two in each groove) in the EGR exhaust elbow and pipe.
3. Install the elbow into the EGR exhaust pipe.
4. Install EGR exhaust elbow and pipe into the rear of the EGR cooler and center exhaust manifold.
5. Secure the EGR exhaust pipe to the rear lifting bracket with two bolts and nuts. Torque the bolts and nuts to 20–30 N·m (15–22 lb·ft).

Section 8.6.3
Removal of Dual-Stage Turbocharger EGR Exhaust Elbow

Removal steps are as follows:

1. Remove the V-band clamp securing the EGR exhaust elbow to the rear of the EGR cooler and rear exhaust manifold and remove the two-piece elbow. See Figure "Two-Piece EGR Exhaust Elbow" .



1. V-Band Clamp	4. EGR Exhaust Elbow to EGR Cooler
2. EGR Exhaust Elbow to Exhaust Manifold	5. Fey Rings
3. Fey Rings	6. EGR Cooler

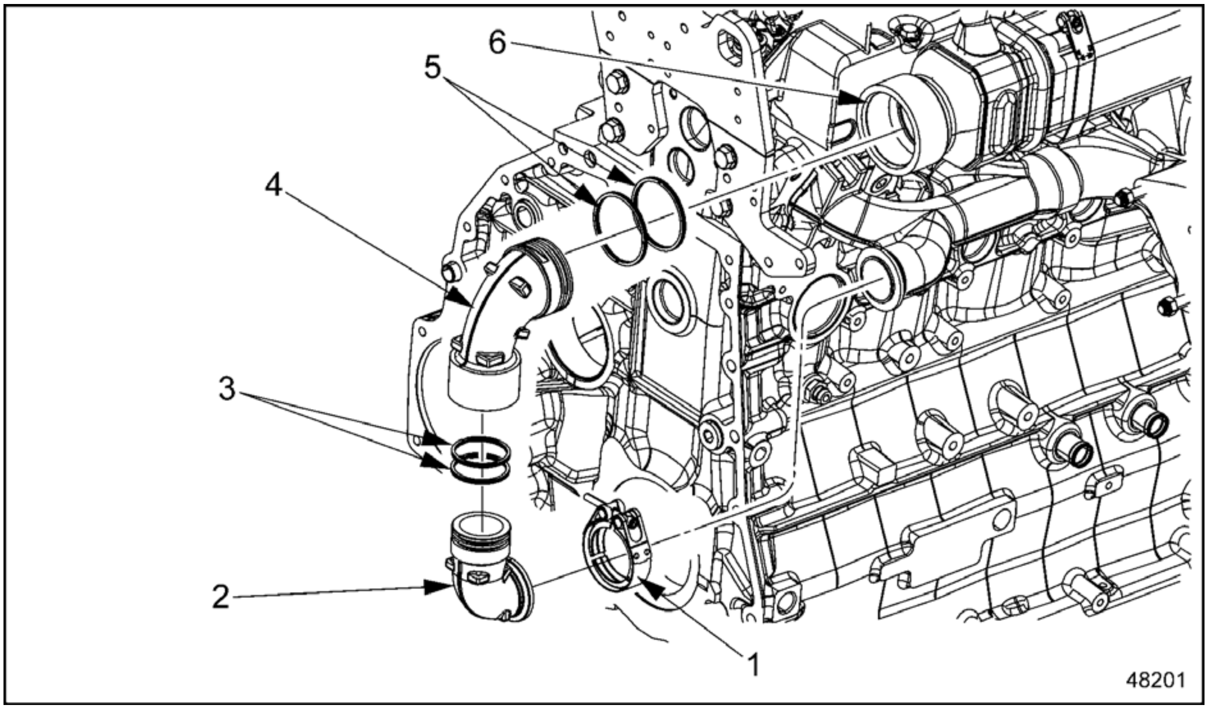
Figure 3. Two-Piece EGR Exhaust Elbow

2. Separate the elbows and inspect the fey rings. Discard rings if damaged. See Figure "Two-Piece EGR Exhaust Elbow" .

Section 8.6.4
Installation of Dual-stage Turbocharger EGR Exhaust Elbow

Installation steps are as follows:

1. Inspect the fey rings and replace if damaged. See Figure "Two-Piece EGR Exhaust Elbow" .



1. V-Band Clamp	4. EGR Exhaust Elbow to EGR Cooler
2. EGR Exhaust Elbow to Exhaust Manifold	5. Fey Rings
3. Fey Rings	6. EGR Cooler

Figure 4. Two-Piece EGR Exhaust Elbow

2. Install the fey rings (2 in each groove) on the EGR exhaust elbows.
3. Assemble the two exhaust elbows together.
4. Install the exhaust elbow into the rear of the EGR cooler and rear exhaust manifold. See Figure "Two-Piece EGR Exhaust Elbow" .
5. Secure the exhaust elbow to the exhaust manifold with the V-band clamp. Torque the clamp to 7-9 N·m (5-7 lb·ft). See Figure "Two-Piece EGR Exhaust Elbow" .

Additional Information

SPECIFICATIONS

Any specifications for special equipment are listed below.

EGR Components

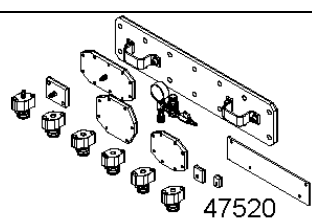
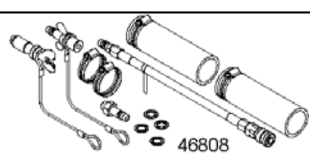
The specifications for the EGR components torque values are listed in Table "EGR Component Torque Values" .

Descriptions	Torque N·m (lb·ft)
EGR Exhaust Elbow to Rear Lifting Bracket Bolts	20–30 (15–21)
V-band Clamp — Exhaust Manifold to EGR Gas Outlet Pipe	7-9 (5-7)
V-band Clamp — EGR Cooler Mounting	7-9 (5-7)
V-band Clamp — EGR Valve	7-9 (5-7)
V-band Clamp — EGR Cooler Outlet Pipe	7-9 (5-7)
EGR Hose Clamps	8 (6)
Nut — Coolant Return Tube Bracket on Stud	25 (18)
Bolts — EGR Cooler mounting Bracket to Air Intake Manifold	25 (18)
Bolts — EGR Valve to Mixer Housing	31–35 (23–26)
Bolts — Coolant Inlet Tube to Water Pump	31–35 (23–26)
Bolts — Coolant Return Tube to Thermostat Housing	31–35 (23–26)

Table 1. EGR Component Torque Values

Special Tools

The special tools used in this section are listed in Table "Special Tools" .

Tool	Description	Usage	Part Number
	Cylinder Block Leak Test Kit	Use gage J-45982–7 from kit to pressure test the EGR cooler.	(J–45987)
	EGR Cooler Leak Test Kit	Used to pressure test the EGR cooler.	(J–47192)

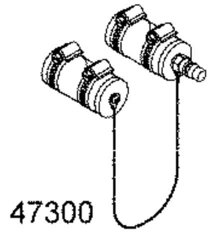
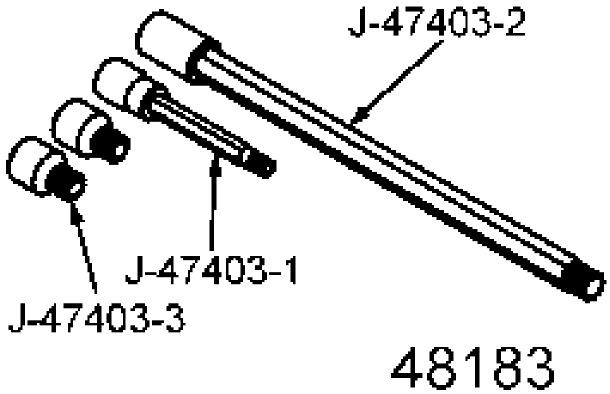
	EGR Cooler Leak Test Adapters	Used to pressure test the EGR cooler.	(J–47401)
	Exhaust Manifold Socket Set	Used to remove and install exhaust manifold bolts.	(J-47403)

Table 2. Special Tools

Section 9.1
Starter

For the removal and installation of the starter, refer to the appropriate vehicle service manual..

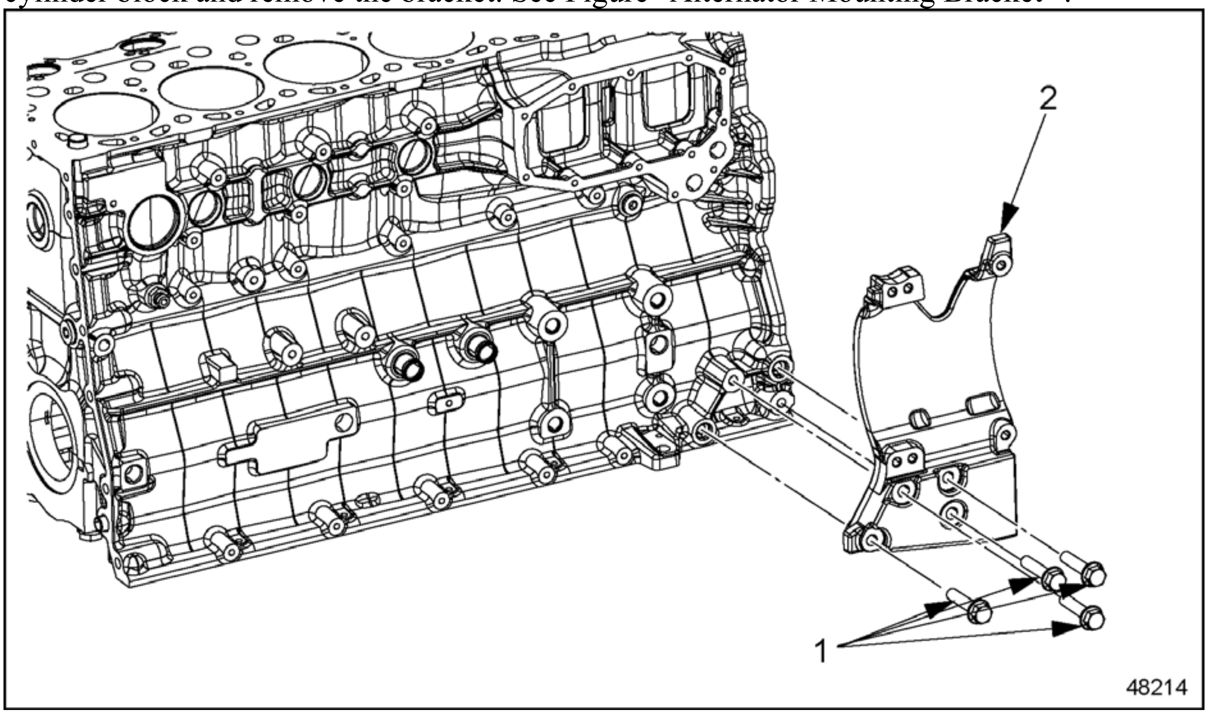
Section 9.2
Alternator

For removal and installation of the alternator, refer to the appropriate vehicle service manual.

Section 9.2.1
Removal of Alternator Mounting Bracket

Removal steps are as follows:

1. Remove the alternator. Refer to the appropriate vehicle service manual.
2. Remove the four bolts securing the alternator mounting bracket to the right front side of the cylinder block and remove the bracket. See Figure "Alternator Mounting Bracket" .



1. Mounting Bolts	2. Alternator Bracket

Figure 1. Alternator Mounting Bracket

Section 9.2.2
Installation of Alternator Mounting Bracket

Installation steps are as follows:

1. Secure the alternator mounting bracket to the right front side of the cylinder block with four bolts. Torque the bolts to 70–90 N·m (52–66 lb·ft). See Figure "Alternator Mounting Bracket" .

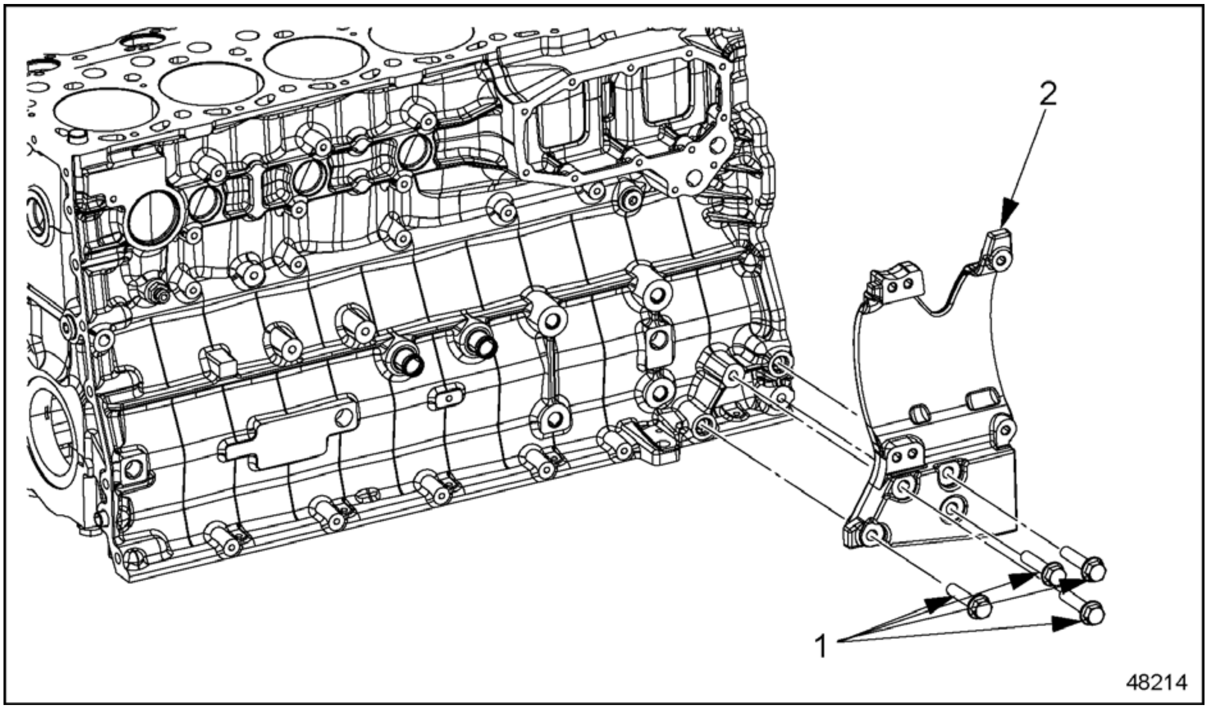


Figure 2. Alternator Mounting Bracket

2. Install the alternator. Refer to the appropriate vehicle service manual.

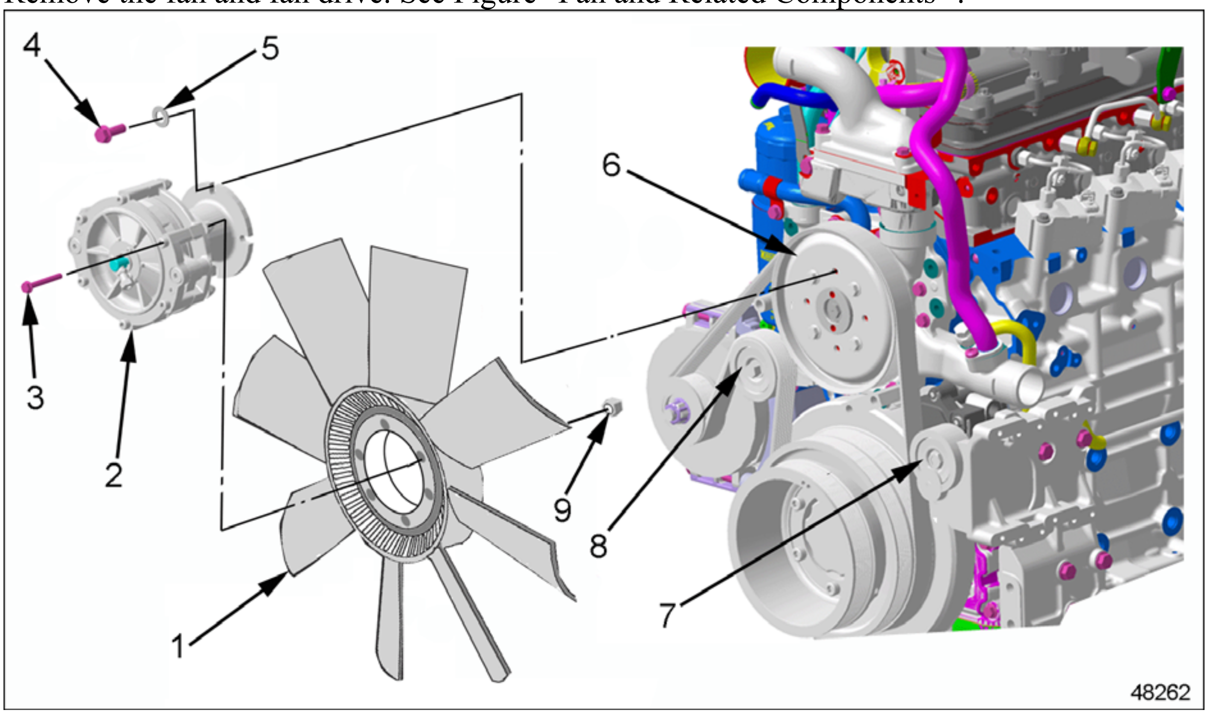
Section 9.3
Fan

The fan pulls cooling air through the radiator.

Section 9.3.1
Removal of Fan

Removal steps are as follows:

1. Disconnect the air line at the fan drive.
2. Remove four bolts and washers securing the fan and fan drive to the coolant pump pulley. Remove the fan and fan drive. See Figure "Fan and Related Components" .



1. Fan	4. Bolts (qty 4)	7. Idler Pulley
2. Fan Drive	5. Washers (qty 4)	8. Tensioner Pulley
3. Socket Head Cap Screws (qty 6)	6. Coolant Pump Pulley	9. Nuts (qty 6)

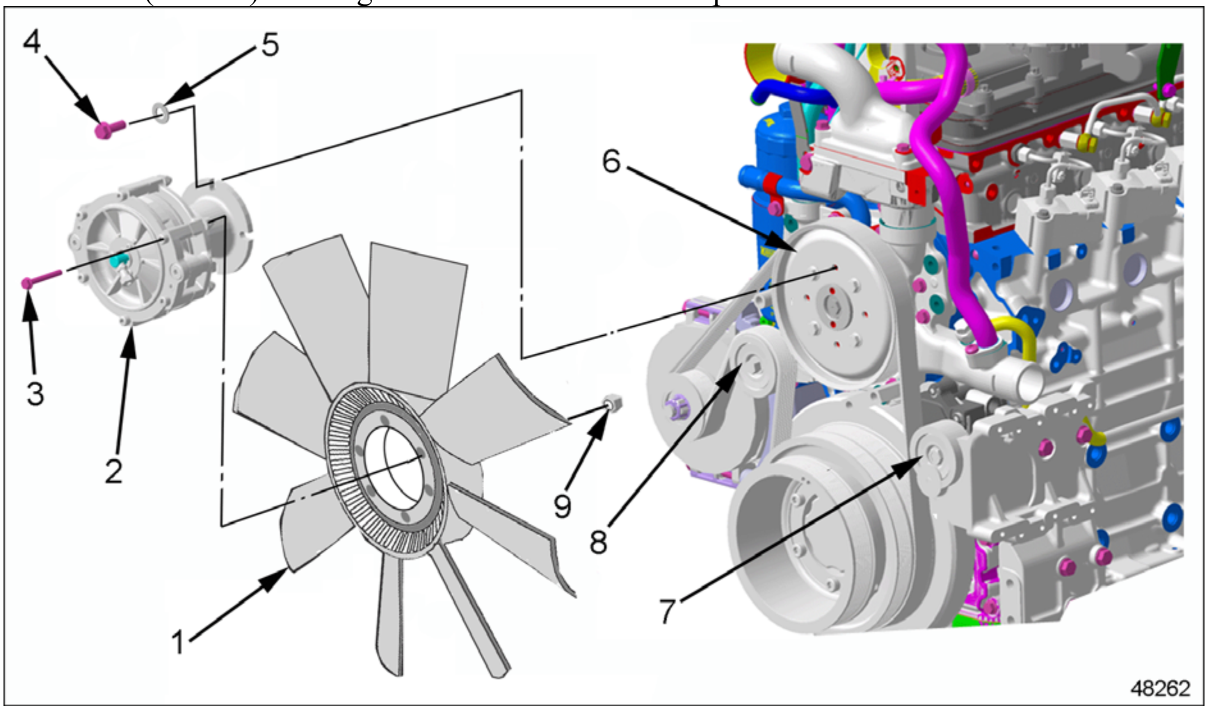
Figure 1. Fan and Related Components

3. Remove the six socket head cap screws and nuts securing the fan to the fan drive and remove the fan.

Section 9.3.2
Installation of Fan

Installation steps are as follows:

1. Secure the fan to the fan drive with six socket head cap screws and nuts. Torque the bolts and nuts to 20 N·m (18 lb·ft). See Figure "Fan and Related Components" .



1. Fan	4. Bolts (qty 4)	7. Idler Pulley
2. Fan Drive	5. Washers (qty 4)	8. Tensioner Pulley
3. Socket Head Cap Screws (qty 6)	6. Coolant Pump Pulley	9. Nuts (qty 6)

Figure 2. Fan and Related Components

2. Secure the fan and fan drive to the coolant pump pulley with four washers and bolts. Torque the bolts to 25 N·m (18 lb·ft). See Figure "Fan and Related Components" .
3. Connect the air line fitting to the fan drive.

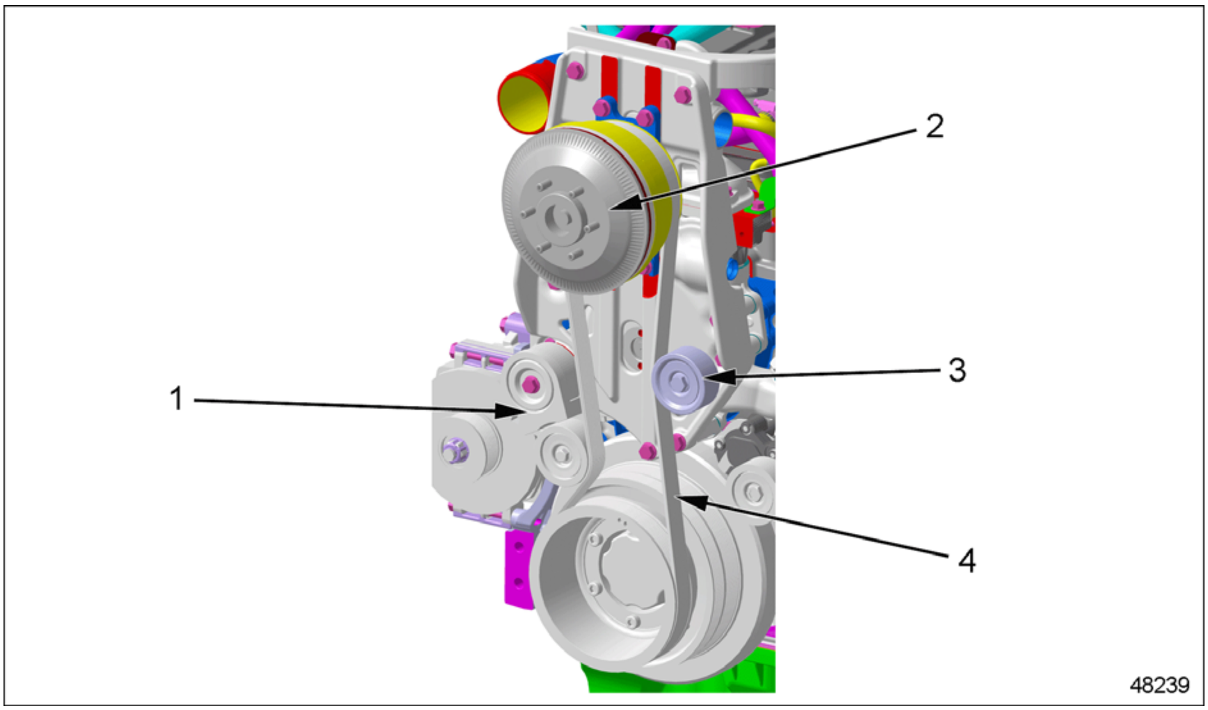
Section 9.4
Belts — Drive

The routing of the drive belts for the coolant pump, fan, alternator and air conditioning compressor(s) are shown in this section.

Section 9.4.1
Removal of Fan Belt

Removal steps are as follows:

1. Insert a T-handle with a 1/2 inch drive in the square hole in the belt tensioner.
2. Rotate the T-handle clockwise releasing tension from the belt on the fan pulley and vibration damper pulley. Remove the belt.
3. Remove the T-handle from the tensioner.
4. If necessary, remove the bolt securing the belt tensioner and remove the tensioner. See Figure "Fan Belt" .



1. Tensioner	3. Idler
2. Fan Pulley	4. Drive Belt

Figure 1. Fan Belt

5. If necessary, remove the bolt securing the idler assembly and remove the idler. See Figure "Fan Belt" .

Section 9.4.1.1
Inspection of Fan Belt and Related Components

Inspection steps are as follows:

1. Inspect the belt for nicks, wear, or other damage. Replace the belt if necessary.
2. Inspect the following parts and replace any that are damaged or worn.
    - Vibration Damper Pulley
    - Fan Pulley
    - Belt Tensioner
    - Idler Pulley

Section 9.4.2
Installation of Fan Belt

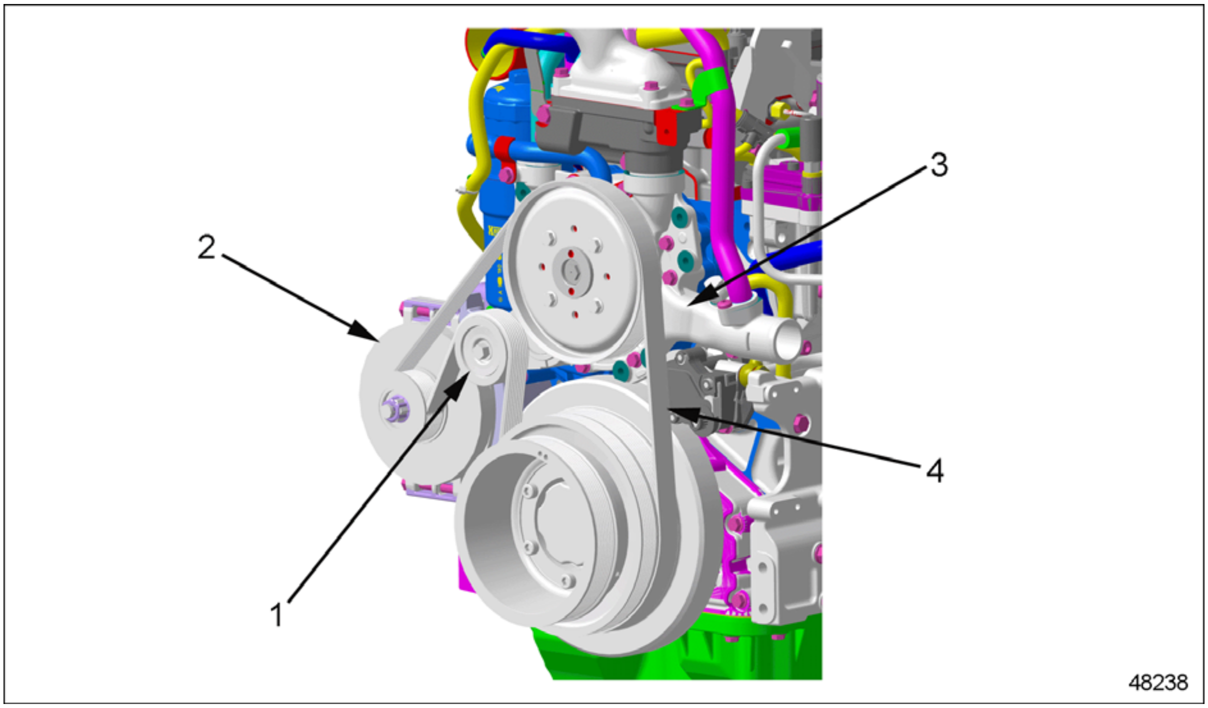
Installation steps are as follows:

1. If removed, secure the idler assembly with a bolt. Torque the bolt to 50 N·m (37 lb·ft). See Figure "Fan Belt" .
2. If removed, secure the belt tensioner assembly with a bolt. Torque the bolt to 50 N·m (37 lb·ft). See Figure "Fan Belt" .
3. Route the belt over the vibration damper pulley, behind the idler and onto the fan pulley. See Figure "Fan Belt" .
4. Insert a T-handle with a 1/2 inch drive in the square hole in the belt tensioner and rotate the T-handle clockwise to release tension , then install the belt in front of the tensioner and release the tensioner.
5. Remove the T-handle from the tensioner.
6. Check the drive belt to ensure it is in the correct position and properly aligned on the pulleys.

Section 9.4.3
Removal of Coolant Pump and Alternator Belt

Removal steps are as follows:

1. Remove the fan drive belt. Refer to "9.4.1 Removal of Fan Belt" .
2. Place a T-handle with a socket on the tensioning pulley bolt.
3. Rotate the T-handle counterclockwise releasing tension from the belt on the vibration damper pulley, coolant pump pulley and alternator pulley. Remove the belt. See Figure "Coolant Pump and Alternator Belt" .



1. Tensioner	3. Coolant Pump
2. Alternator	4. Drive Belt

Figure 2. Coolant Pump and Alternator Belt

4. Remove the T-handle from the tensioner.
5. If necessary, remove the bolt securing the tensioner assembly and remove the tensioner. See Figure "Coolant Pump and Alternator Belt" .

Section 9.4.3.1
Inspection of Coolant Pump and Alternator Belt

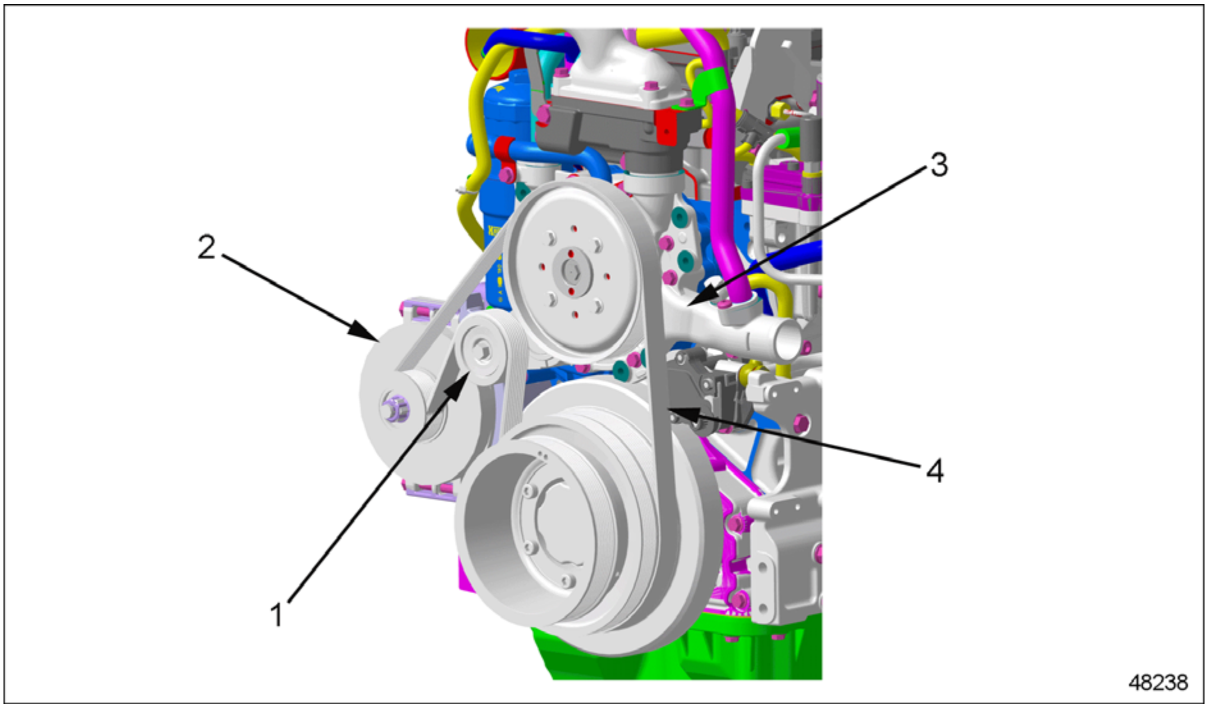
Inspection steps are as follows:

1. Inspect the belt for nicks, wear, or other damage. Replace the belt if necessary.
2. Inspect the following parts and replace any that are damaged or worn.
   - Vibration Damper Pulley
   - Coolant Pump Pulley
   - Alternator Pulley
   - Belt Tensioner

Section 9.4.4
Installation of Coolant Pump and Alternator Belt

Installation steps are as follows:

1. If removed, secure the tensioner assembly to the front of the engine with a bolt. Torque the bolt to 50 N·m (37 lb·ft). See Figure "Coolant Pump and Alternator Belt" .



1. Tensioner	3. Coolant Pump
2. Alternator	4. Drive Belt

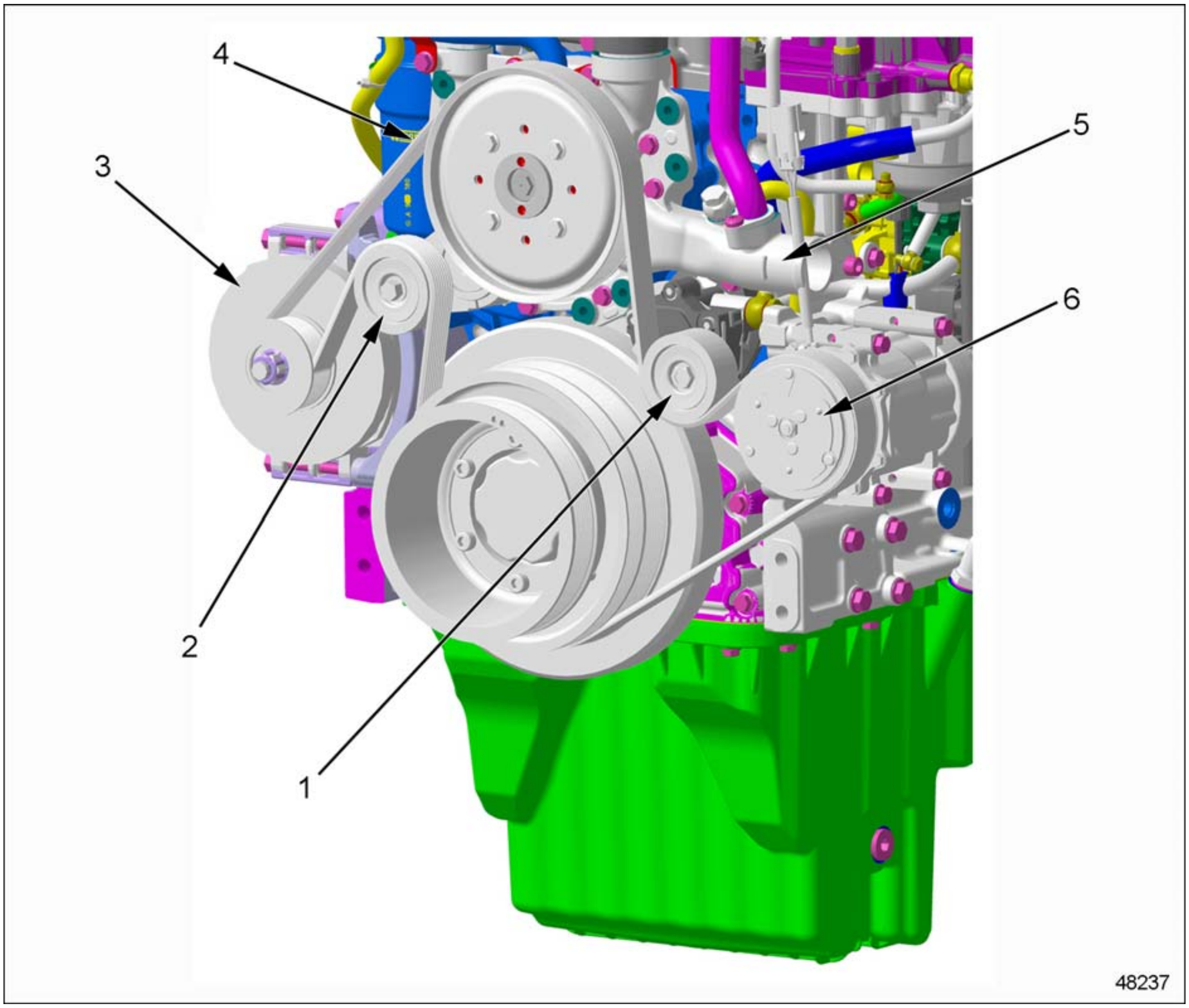
Figure 3. Coolant Pump and Alternator Belt

2. Install the belt over the vibration damper pulley, coolant pump pulley and in front of the tensioner. See Figure "Coolant Pump and Alternator Belt" .
3. Install and rotate the T-handle counterclockwise releasing tension from the tensioner and install the belt over the alternator pulley, then release the tension. See Figure "Coolant Pump and Alternator Belt" .
4. Remove the T-handle from the tensioner.
5. Check the drive belt to ensure it is in the correct position and properly aligned on the pulleys.
6. Install the fan drive belt. Refer to "9.4.2 Installation of Fan Belt" .

Section 9.4.5
Removal of Single Air Conditioning Belt

Removal steps are as follows:

1. Remove the fan drive belt. Refer to "9.4.1 Removal of Fan Belt" .
2. Place a T-handle with a socket on the tensioning pulley bolt.
3. Rotate the T-handle counterclockwise releasing tension from the belt on the vibration damper pulley, coolant pump pulley alternator pulley and air conditioner. Remove the belt. See Figure "Single Air Conditioning Belt" .



1. Idler Pulley	4. Drive Belt
2. Tensioner	5. Coolant Pump
3. Alternator	6. Air Conditioner

Figure 4. Single Air Conditioning Belt

4. Remove the T-handle from the tensioner.
5. If necessary, remove the bolt securing the tensioner assembly and remove the tensioner. See Figure "Single Air Conditioning Belt" .
6. If necessary, remove the bolt securing the idler pulley and remove the idler. See Figure "Single Air Conditioning Belt" .

Section 9.4.5.1
Inspection of Single Air Conditioning Belt

Inspection steps are as follows:

1. Inspect the belt for nicks, wear, or other damage. Replace the belt if necessary.
2. Inspect the following parts and replace any that are damaged or worn.
   - Vibration Damper Pulley

- Coolant Pump Pulley
- Alternator Pulley
- Air Conditioner Pulley
- Idler Puller
- Belt Tensioner

Section 9.4.6
Installation of Single Air Conditioning Belt

Installation steps are as follows:

1. If removed, secure the tensioner assembly to the front of the engine with a bolt. Torque the bolt to 50 N·m 37 lb·ft). See Figure "Single Air Conditioning Belt" .

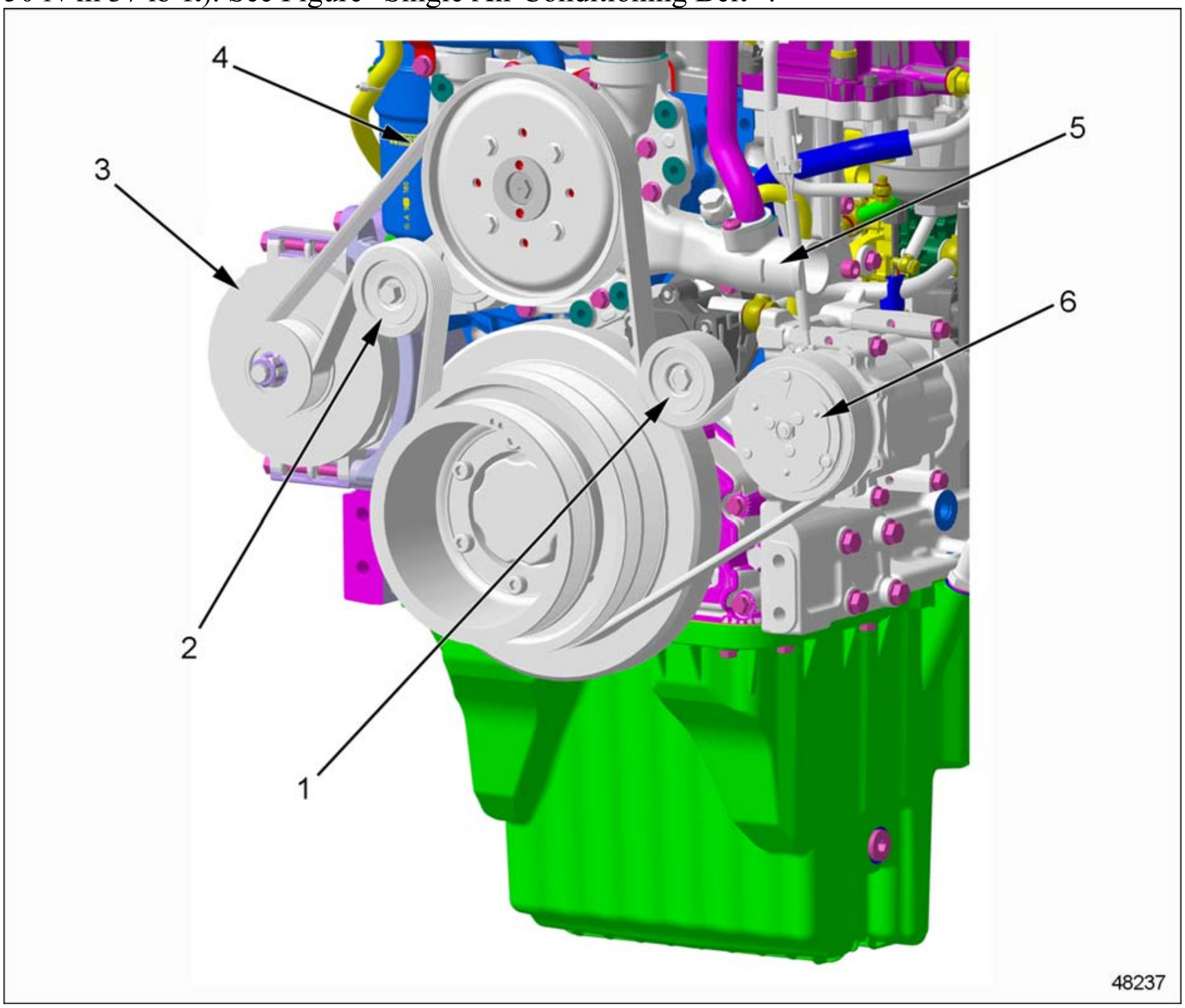


Figure 5. Single Air Conditioning Belt

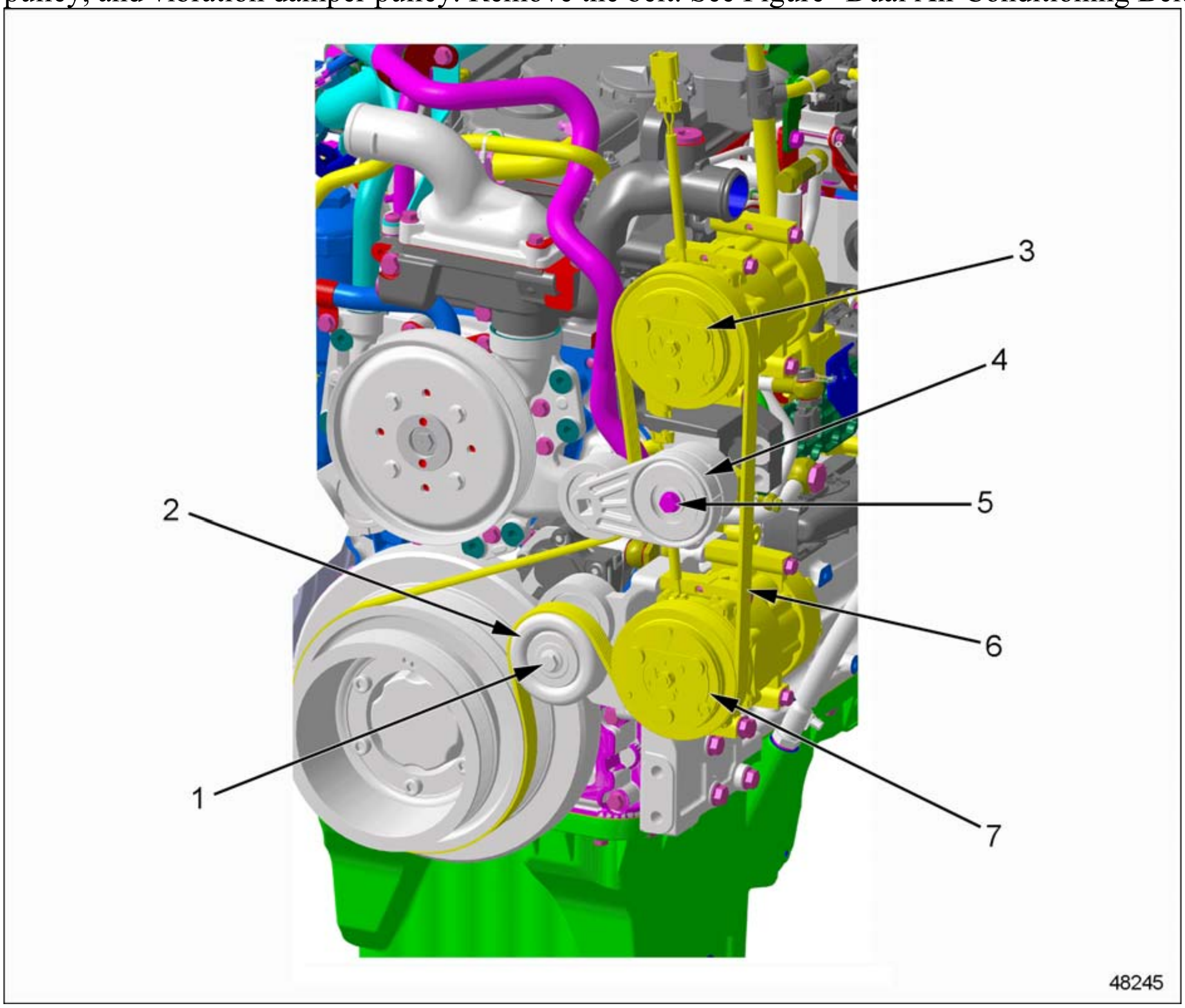
2. If removed, secure the idler assembly to the front of the engine with a bolt. Torque the bolt to 50 N·m (37 lb·ft). See Figure "Single Air Conditioning Belt" .
3. Install the belt over the vibration damper pulley, air conditioner, idler pulley, coolant pump pulley and in front of the tensioner. See Figure "Single Air Conditioning Belt" .
4. Install then rotate the T-handle counterclockwise releasing tension from the tensioner and install the belt over the alternator pulley, then release the tension. .

5. Remove the T-handle from the tensioner.
6. Check the drive belt to ensure it is in the correct position and properly aligned on the pulleys.
7. Install the fan drive belt. Refer to "9.4.2 Installation of Fan Belt" .

Section 9.4.7
Removal of Dual Air Conditioning Belt

Removal steps are as follows:

1. Remove the fan drive belt. Refer to "9.4.1 Removal of Fan Belt" .
2. Insert a T-handle with a 1/2 inch drive in the square hole in the belt tensioner.
3. Rotate the T-handle clockwise releasing tension from the belt on the two air conditioners, idler pulley, and vibration damper pulley. Remove the belt. See Figure "Dual Air Conditioning Belt" .



1. Bolt	5. Bolt
2. Idler Pulley	6. Drive Belt
3. Air Conditioner	7. Air Conditioner
4. Tensioner	

Figure 6. Dual Air Conditioning Belt

4. Remove the T-handle from the tensioner.
5. If necessary, remove the bolt securing the belt tensioner and remove the tensioner. See Figure "Dual Air Conditioning Belt" .
6. If necessary, remove the bolt securing the idler assembly and remove the idler. See Figure "Dual Air Conditioning Belt" .

Section 9.4.7.1
Inspection of Dual Air Conditioning Belt

Inspection steps are as follows:

1. Inspect the belt for nicks, wear, or other damage. Replace the belt if necessary.
2. Inspect the following parts and replace any that are damaged or worn.
   - Vibration Damper Pulley
   - Air Conditioner Pulleys
   - Belt Tensioner
   - Idler Pulley

Section 9.4.8
Installation of Dual Air Conditioning Belt

Installation steps are as follows:

1. If removed, secure the idler assembly with a bolt. Torque the bolt to 50 N·m (37 lb·ft). See Figure "Dual Air Conditioning Belt" .

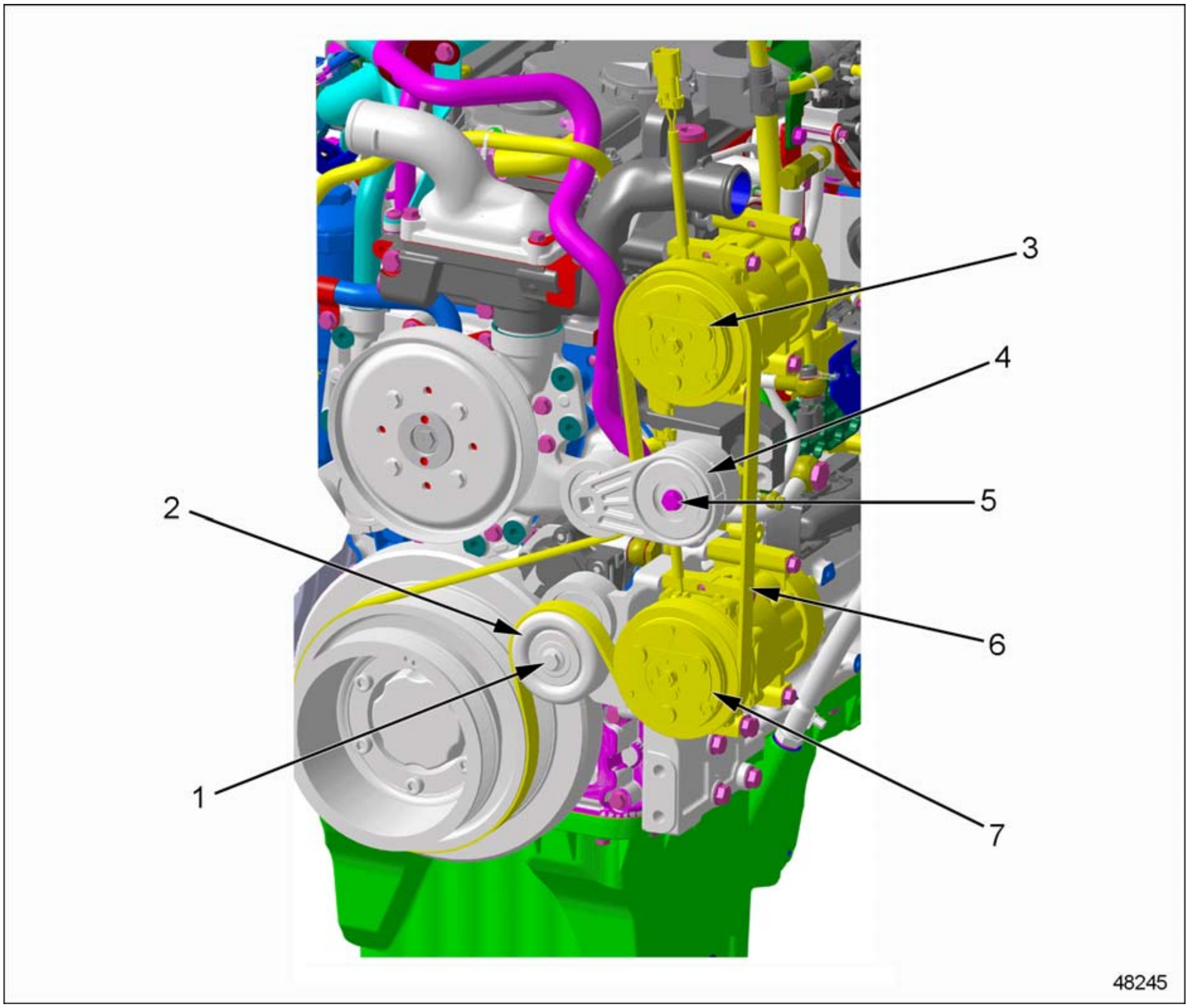


Figure 7. Dual Air Conditioning Belt

2. If removed, secure the belt tensioner assembly with a bolt. Torque the bolt to 50 N·m (37 lb·ft). See Figure "Dual Air Conditioning Belt" .
3. Route the belt over the vibration damper pulley, over the idler pulley and onto the two air conditioner fan pulleys. See Figure "Dual Air Conditioning Belt" .
4. Insert a T-handle with a 1/2 inch drive in the square hole in the belt tensioner and rotate the T-handle clockwise to release tension , then install the belt behind the tensioner and release the tensioner.
5. Remove the T-handle from the tensioner.
6. Check the drive belt to ensure it is in the correct position and properly aligned on the pulleys.
7. Install the fan drive belt. Refer to "9.4.2 Installation of Fan Belt" .

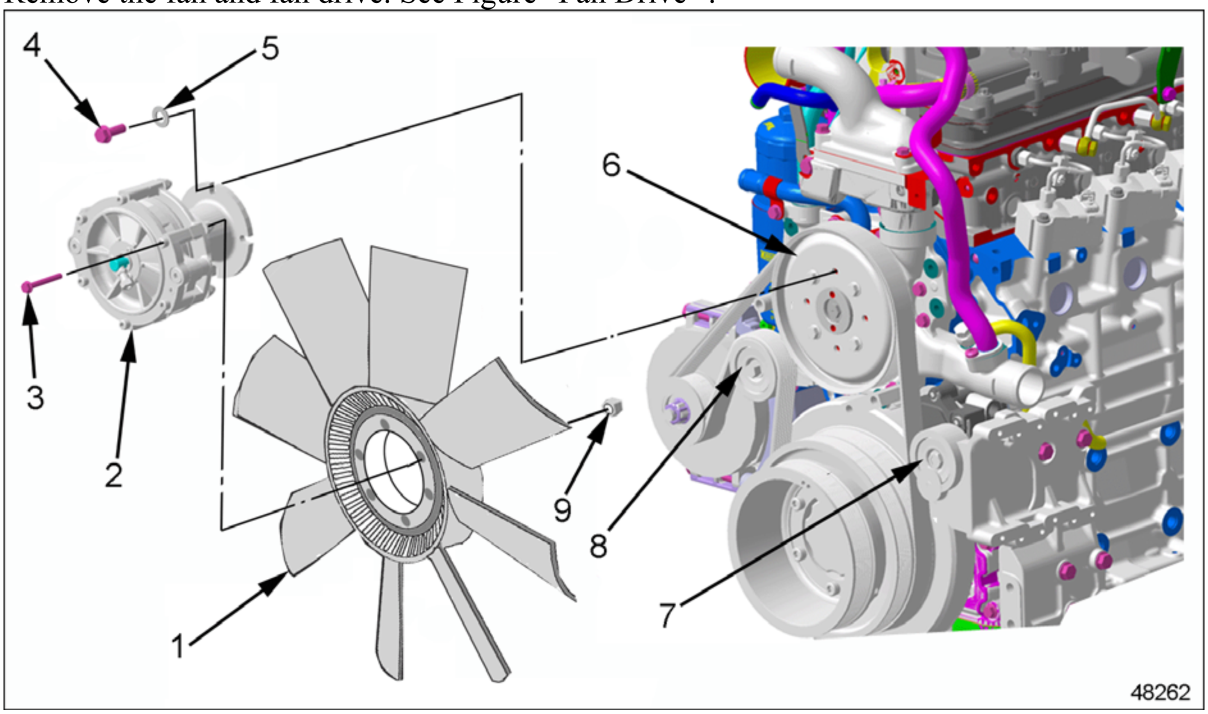
Section 9.5
Fan Drive

The following sections provide instructions for removal and installation of the fan drive.

Section 9.5.1
Removal of Fan Drive

Removal steps are as follows:

1. Disconnect the air line at the fan drive.
2. Remove four bolts and washers securing the fan and fan drive to the coolant pump pulley. Remove the fan and fan drive. See Figure "Fan Drive" .



1. Fan	4. Bolts (qty 4)	7. Idler Pulley
2. Fan Drive	5. Washers (qty 4)	8. Tensioner Pulley
3.Bolts (qty 6)	6. Coolant Pump Pulley	9. Nuts (qty 6)

Figure 1. Fan Drive

3. Remove the six socket head cap screws and nuts securing the fan to the fan drive and remove the fan. See Figure "Fan Drive" .
4. If necessary, remove the coolant pump drive belt as follows:
   a. Place a T-handle with a socket on the tensioning pulley bolt.
   b. Rotate the T-handle counterclockwise releasing tension from the belt on the vibration damper pulley, coolant pump pulley and alternator pulley. Remove the belt. See Figure "Coolant Pump and Alternator Belt" .
   c. Remove the T-handle from the tensioner.

d. If necessary, remove the bolt securing the tensioner assembly and remove the tensioner. See Figure "Coolant Pump and Alternator Belt" .

Section 9.5.1.1
Inspection of Fan Drive

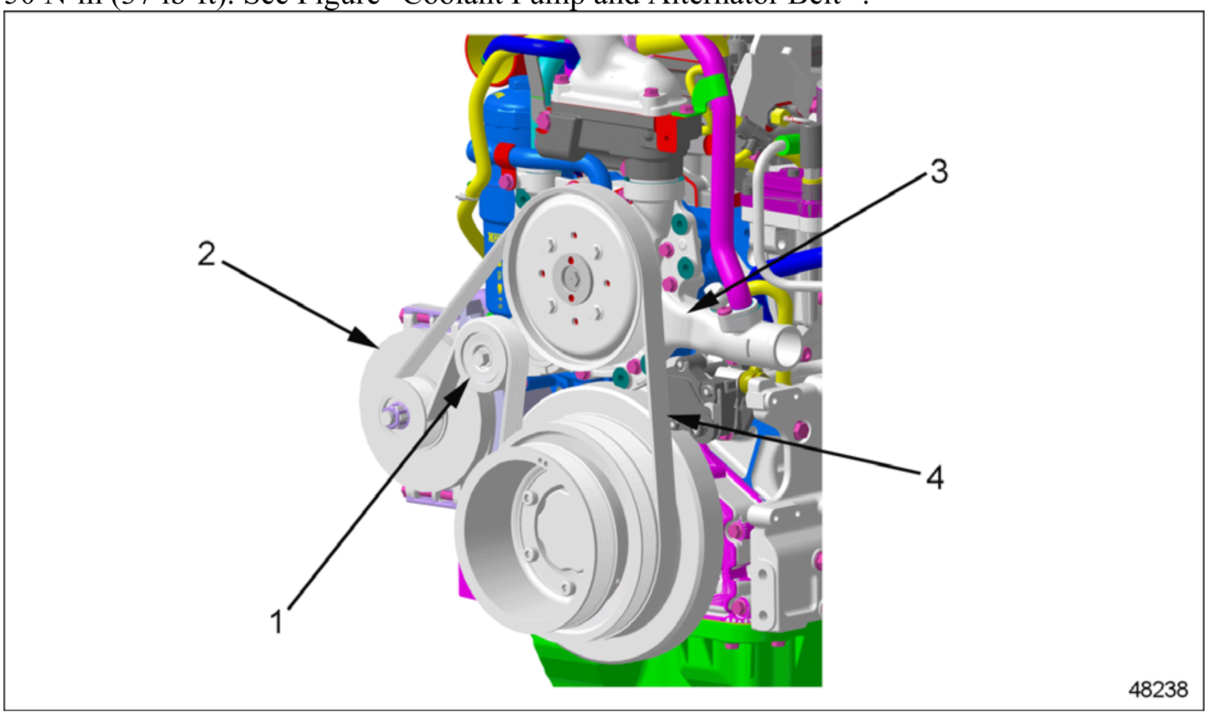
Inspection steps are as follows:

1. Inspect the belt for nicks, wear, or other damage. Replace the belt if necessary.
2. Inspect the following parts and replace any that are damaged or worn.
   - Vibration Damper Pulley
   - Coolant Pump Pulley
   - Belt Tensioner
   - Idler Pulley

Section 9.5.2
Installation of Fan Drive

Perform the following to install the fan drive.

1. If removed, secure the tensioner assembly to the front of the engine with a bolt. Torque the bolt to 50 N·m (37 lb·ft). See Figure "Coolant Pump and Alternator Belt" .



1. Tensioner	3. Coolant Pump
2. Alternator	4. Drive Belt

Figure 2. Coolant Pump and Alternator Belt

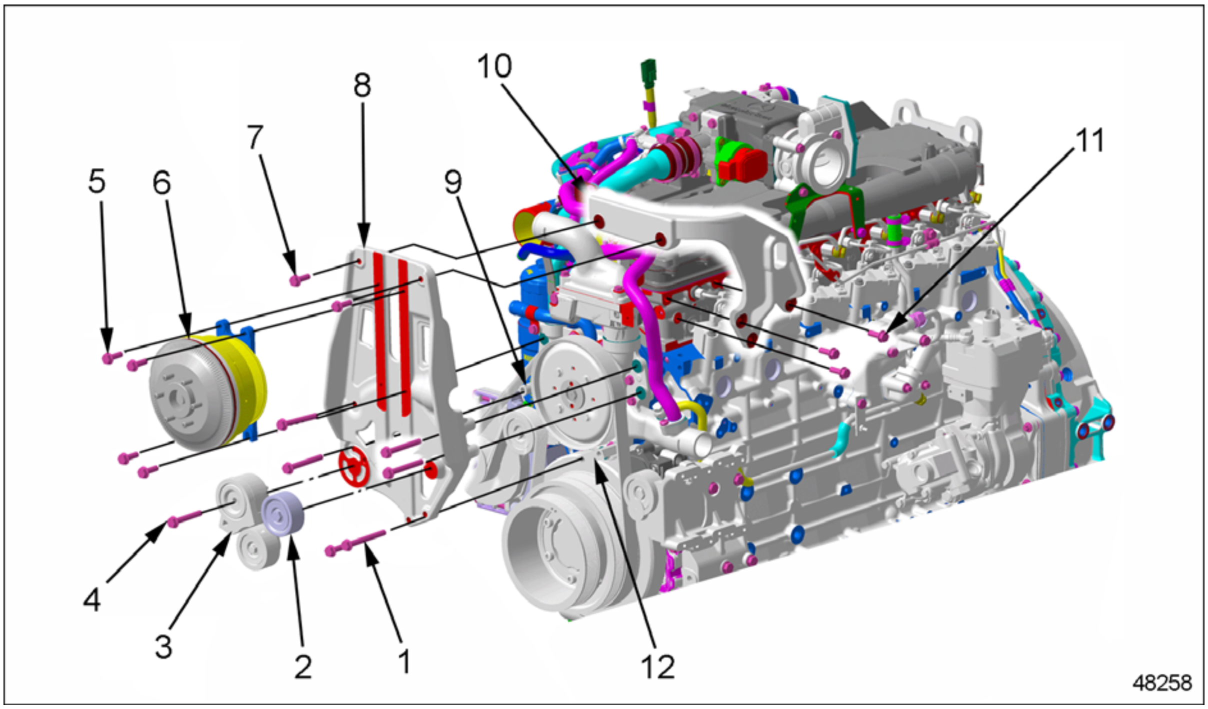
2. Install the belt over the vibration damper pulley, coolant pump pulley and in front of the tensioner. See Figure "Coolant Pump and Alternator Belt"

3. Install and rotate the T-handle counterclockwise releasing tension from the tensioner and install the belt over the alternator pulley, then release the tension. See Figure "Coolant Pump and Alternator Belt" .
4. Remove the T-handle from the tensioner.
5. Check the drive belt to ensure it is in the correct position and properly aligned on the pulleys.
6. Install the fan drive belt. Refer to "9.4.2 Installation of Fan Belt" .

Section 9.5.3
Removal of Hi-Mount Fan Drive and Brackets

Removal steps are as follows:

1. If necessary, remove the fan shroud. Refer to the appropriate vehicle service manual.
2. Remove the fan from the fan drive by removing six nuts.
3. Insert a T-handle with a 1/2 inch drive in the square hole in the belt tensioner.
4. Rotate the T-handle clockwise releasing tension from the belt on the fan drive, idler pulley, and vibration damper pulley. Remove the belt. See Figure "Hi-Mount Fan Drive and Mounting Brackets" .



1. Bolts (qty 2)	5. Bolts (qty 4)	9. Sleeve
2. Idler Pulley	6. Fan Drive	10. Secondary Mounting Bracket
3. Tensioner Pulley	7. Bolts (qty 2)	11. Bolts (qty 4)
4. Bolt	8. Hi-Mount Fan Bracket	12. Spacer

Figure 3. Hi-Mount Fan Drive and Mounting Brackets

5. Remove the T-handle from the tensioner.
6. Disconnect the air line at the fan drive.
7. Remove the four bolts attaching the fan drive to the mounting bracket and remove the drive. See Figure "Hi-Mount Fan Drive and Mounting Brackets" .

8. Remove the tensioner pulley from the mounting bracket.
9. Remove the idler pulley from the mounting bracket. See Figure "Hi-Mount Fan Drive and Mounting Brackets" .
10. Remove the bolts securing the mounting bracket to the coolant pump and secondary mounting bracket and remove the bracket, sleeve and spacer. See Figure "Hi-Mount Fan Drive and Mounting Brackets" .
11. Remove the three bolts securing the secondary mounting bracket to the cylinder head and remove the bracket. See Figure "Hi-Mount Fan Drive and Mounting Brackets" .

Section 9.5.3.1
Inspection of Hi-Mount Fan Drive and Mounting Brackets

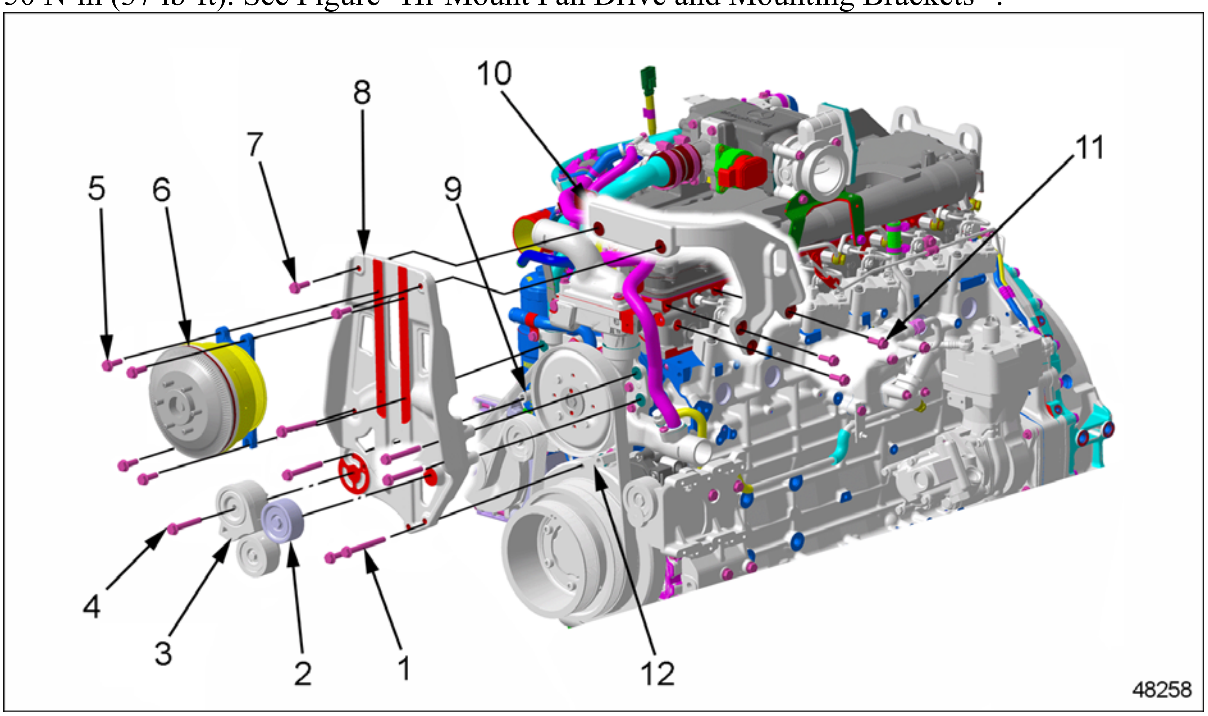
Inspection steps are as follows:

1. Inspect the belt for nicks, wear, or other damage. Replace the belt if necessary.
2. Inspect the following parts and replace any that are damaged or worn.
   - Vibration Damper Pulley
   - Fan Drive Pulley
   - Belt Tensioner
   - Idler Pulley

Section 9.5.4
Installation of Hi-Mount Fan Drive and Brackets

Installation steps are as follows:

1. Secure the secondary mounting bracket to the cylinder head with three bolts. Torque the bolts to 50 N·m (37 lb·ft). See Figure "Hi-Mount Fan Drive and Mounting Brackets" .



1. Bolts (qty 2)	5. Bolts (qty 4)	9. Sleeve
2. Idler Pulley	6. Fan Drive	10. Secondary Mounting Bracket

3. Tensioner Pulley	7. Bolts (qty 2)	11. Bolts (qty 4)
4. Bolt	8. Hi-Mount Fan Bracket	12. Spacer

Figure 4. Hi-Mount Fan Drive and Mounting Brackets

2. Secure the mounting bracket to the coolant pump and secondary mounting bracket with a sleeve, spacer and eight bolts. Torque the bolts to 50 N·m (37 lb·ft). See Figure "Hi-Mount Fan Drive and Mounting Brackets" .
3. Secure the idler pulley to the mounting bracket. Torque the bolt to 50 N·m (37 lb·ft). See Figure "Hi-Mount Fan Drive and Mounting Brackets" .
4. Secure the tensioner pulley to the mounting bracket. Torque the bolt to 50 N·m (37 lb·ft). See Figure "Hi-Mount Fan Drive and Mounting Brackets" .
5. Attach the fan drive to the mounting bracket and secure with four bolts. Torque the bolts to 25 N·m (18 lb·ft).
6. Install the fan belt over the vibration damper pulley, behind idler pulley, and over the fan drive.
7. Insert a T-handle with a 1/2 inch drive in the square hole in the belt tensioner.
8. Rotate the T-handle clockwise releasing tension and position the belt over the tensioner. Release the tension on the tensioner.
9. Remove the T-handle from the tensioner.
10. Install the fan on the fan drive and secure with six nuts. Torque the nuts to 20 N·m (15 lb·ft).
11. Connect the air line at the fan drive. Tighten the fitting securely.
12. If removed, install the fan shroud. Refer to the appropriate vehicle service manual.

Additional Information

Specifications

This sections contains the specifications for the alternator mounting bracket.

Torque Values

The torque values used in this chapter are listed in Table "Torque Values" .

Description	Torque N·m (lb·ft)
Alternator Mounting Bracket Bolts	70–90 (52–66)
Fan Belt Idler Bolt	50 (37)
Fan Belt Tensioner Bolt	50 (37)
Coolant Pump Tensioner Bolt	50 (37)
Coolant Pump Idler Bolt	50 (37)
Single AC Tensioner Bolt	50 (37)
AC Idler Bolt	50 (37)
Dual AC Tensioner Bolt	50 (37)
Dual AC Idler Bolt	50 (37)
Nuts — Fan on the Fan Drive	20 (15)
Bolts – Fan to Coolant Pump Pulley	25 (18)

Table 1. Torque Values

Section 10.1
Front Engine Power Take-Off

Refer to OEM guidelines for repair procedures.

Section 11.1
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.

Section 11.1.1
Removal of Air Compressor

Removal steps are as follows:

WARNING:

PERSONAL INJURY

To avoid injury from scalding, drain the radiator when the engine and coolant are cool.

1. Drain the coolant.
2. Remove the two bolts attaching the power steering pump to the air compressor. See Figure "Power Steering Pump" .

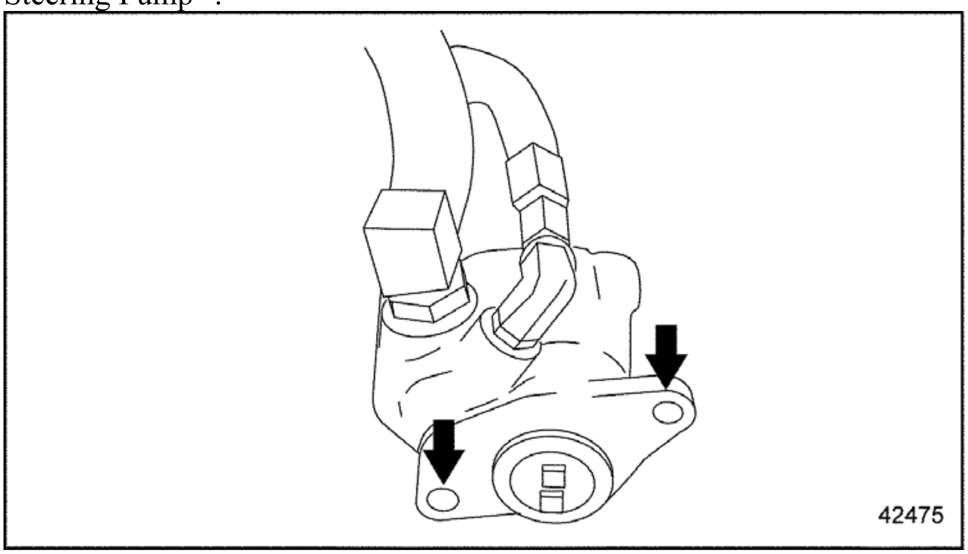
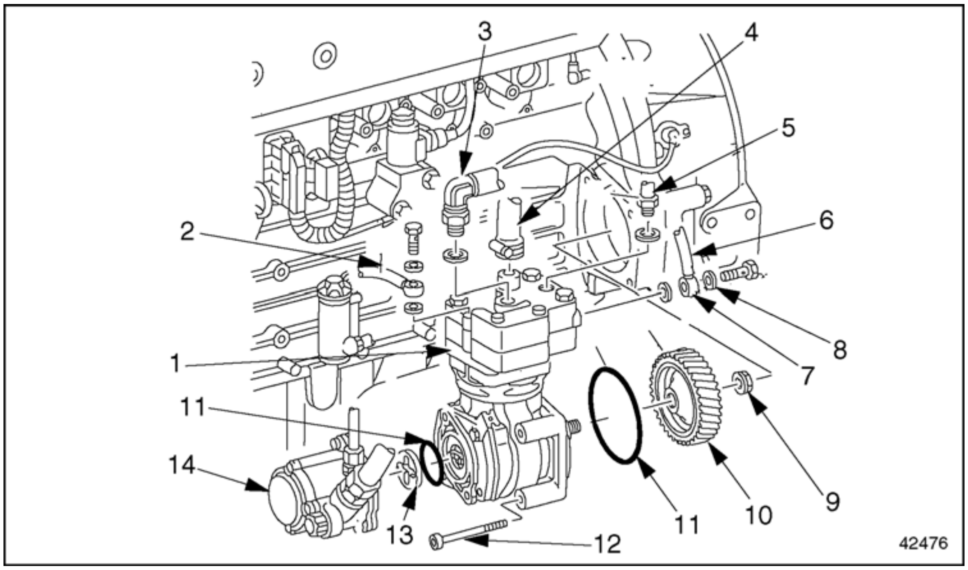


Figure 1. Power Steering Pump

Note: Do not remove the power steering lines. Tie up the lines and the pump out of the way.

3. Remove the cross plate between the compressor and the power steering pump. See Figure "Air Compressor Mounting" .



1. Air Compressor	8. Copper Washer (2)
2. Coolant Return Line	9. Drive Nut
3. Discharge Line (air)	10. Drive Gear
4. Intake Air Line	11. O–ring
5. Unloader Air Line	12. Mounting Bolt (4 qty.)
6. Coolant Delivery Line	13. Cross Plate
7. Banjo Fitting	14. Power Steering Pump

Figure 2. Air Compressor Mounting

4. Remove the coolant delivery line and coolant return line.

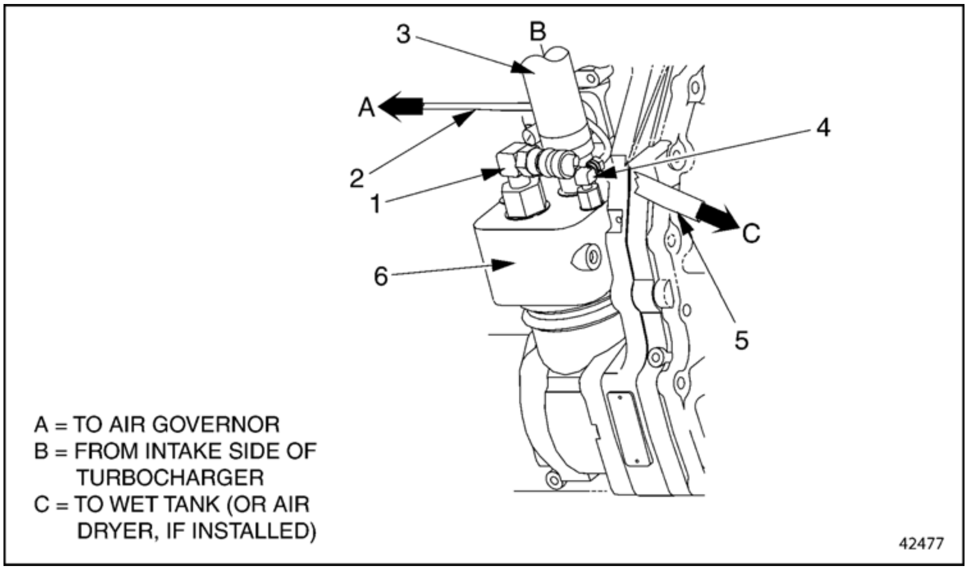
Note: The coolant delivery line is attached to the crankshaft position sensor wire with a tie strap. Cut the tie strap and remove the coolant delivery line.

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 three air lines. See Figure "Air Line Attachments" .



1. Discharge Port	4. Unloader Port
2. Unloader Air Line	5. Discharge Air Line
3. Intake Air Line	6. Air Compressor

Figure 3. Air Line Attachments

   a. Remove the discharge (compressed air) line. Check the fittings for damage and replace if necessary. Check inside the discharge line for carbon deposits. If deposits are found, replace the discharge line.
   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.
6. Remove the four mounting bolts attaching the air compressor to the cylinder block. See Figure "Air Compressor Mounting" .
7. Slide the drive gear away from the flywheel. Collect any oil that runs out and dispose of it properly.

Section 11.1.1.1
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, also replace the fittings.
2. Replace the O–ring between the power steering pump and the air compressor.
3. Install the locking device (J–46391) on the air compressor at the end of the drive shaft, where it connects to the power steering pump. This locks the drive shaft to allow removal of the drive nut. See Figure "Air Compressor Locking Device" .

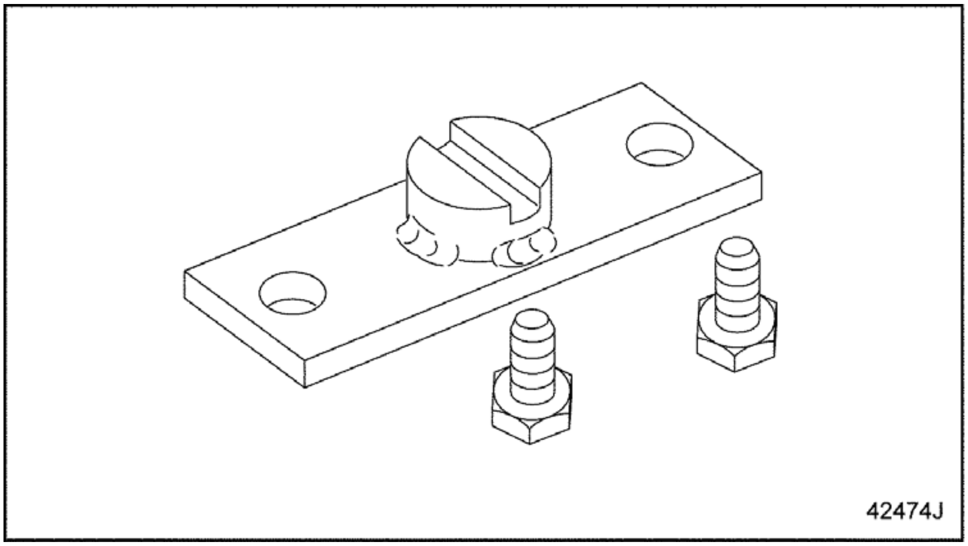
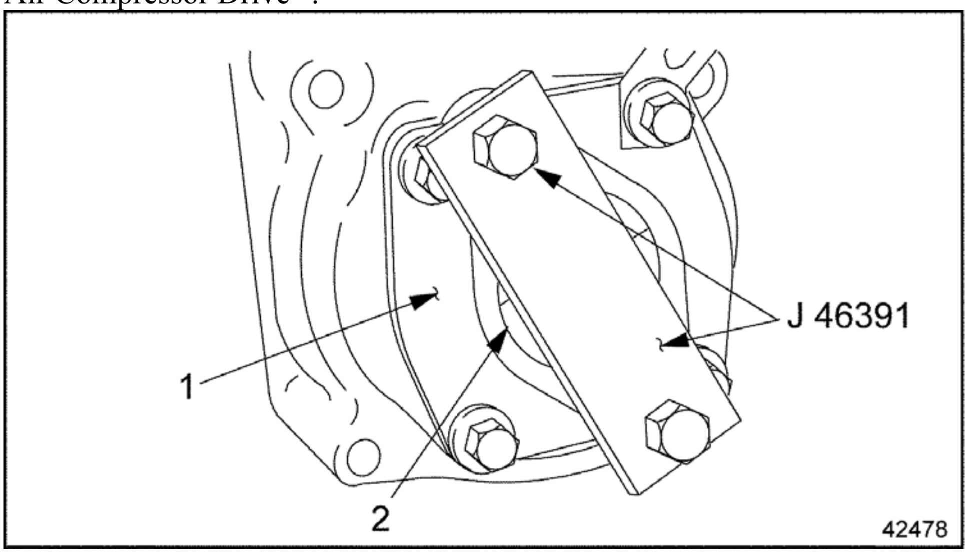


Figure 4. Air Compressor Locking Device

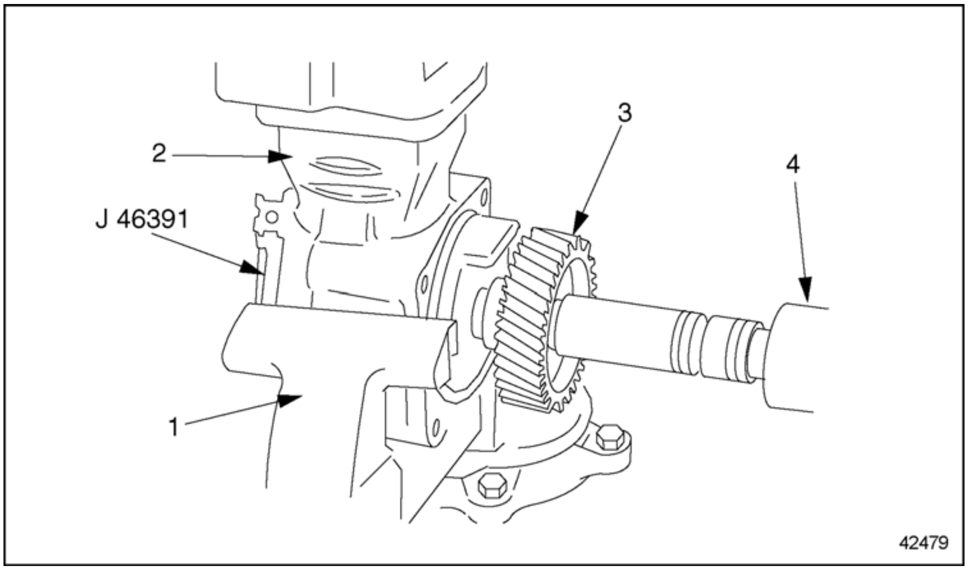
4. Install the two locking bolts on the locking device (J–46391 part of toolset J–44184) and tighten them until the air compressor drive is locked and incapable of movement. See Figure "Locking the Air Compressor Drive" .



1. Air Compressor	2. End of Drive Shaft

Figure 5. Locking the Air Compressor Drive

5. Remove the drive gear from the air compressor. See Figure "Pulling the Air Compressor Drive Gear" .



1. Vise	3. Drive Gear
2. Air Compressor	4. Impact Wrench

Figure 6. Pulling the Air Compressor Drive Gear

   a. Place the air compressor in a vise. Make sure it is tightly secured and cannot slip or slide out of the vise.
   b. Place an impact wrench on the drive gear nut and remove the drive nut.
   c. Remove the drive gear from the air compressor with a gear puller, if necessary.
6. Inspect the drive gear for worn or broken teeth, spalling, and corrosion. Replace the drive gear if necessary.
7. Install the drive gear and drive nut on the drive shaft of the air compressor. Tighten the drive nut 270 N·m (200 lb·ft).
8. Remove the locking device from the air compressor and release the air compressor from the vise.

Section 11.1.2 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 40 N·m (30 lb·ft).
3. Install the three air lines. See Figure "Air Line Attachments" .
   a. Install the discharge line. Make sure the O–ring is properly installed on the fitting. Tighten the fitting 100 N·m (74 lb·ft).
   b. Install the unloader line. Make sure the O–ring is properly installed on the fitting.
   c. Install the intake air line and tighten the hose clamp.
4. Install the two coolant lines.
   a. Pay particular attention to the coolant delivery line at the rear of the air compressor. It is difficult to line up the bolt and fitting correctly.

      Note: If necessary to line up the banjo bolt, loosen the coolant line that attaches to the rear of the engine.

Note: Attach the coolant delivery line to the crankshaft position sensor wire with a tie strap.

   b. Tighten the banjo bolts on the coolant delivery and return lines 40 N·m (30 lb·ft).

5. Install the cross plate. Use grease to hold it in place while installing the power steering pump.
6. Install the two bolts attaching the power steering pump to the air compressor. Tighten the bolts 35-40 N·m (26-30 lb·ft). See Figure "Power Steering Pump" .
7. Fill the radiator with coolant.

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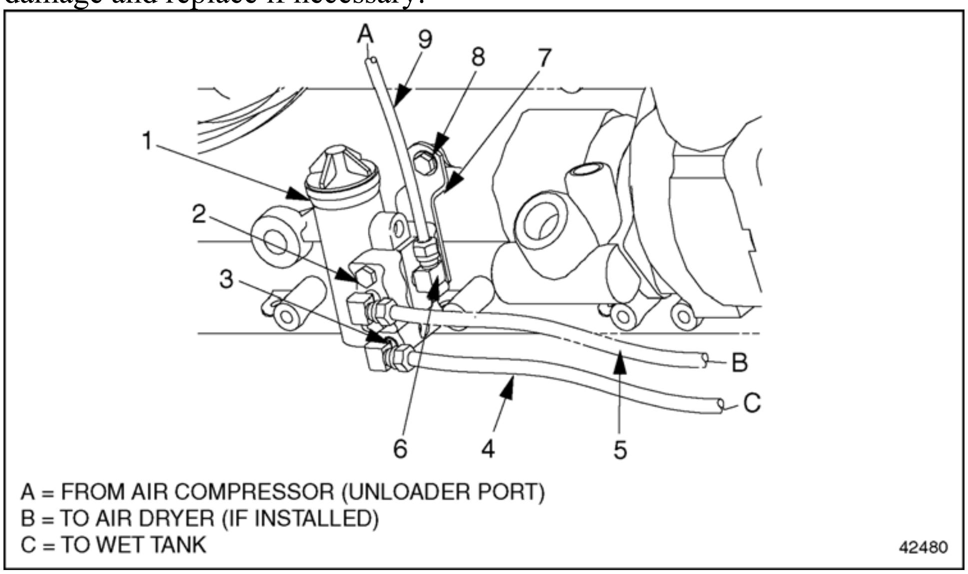
Section 11.2
Air Governor

The following sections describe the removal and installation of the air governor.

Section 11.2.1
Removal of Air Governor

Removal steps are as follows:

1. Release system air pressure.
2. Remove and mark the three air line fittings. See Figure "Air Governor" . Inspect all fittings for damage and replace if necessary.



1. Air Governor	6. Unloader Port, Air Compressor
2. Unloader Port, Air Dryer	7. Mounting Bracket
3. Reservoir Port	8. Mounting Bolt, M8
4. Supply Air Line	9. Unloader Air Line
5. Air Dryer Control Line	

Figure 1. Air Governor

3. Remove the mounting bolt and remove the mounting bracket from the vehicle, with the air governor attached.
4. Remove the two bolts holding the air governor to the mounting bracket.

Section 11.2.2
Installation of Air Governor

Installation steps are as follows:

1. Install the air governor on the mounting bracket, using the two bolts, as removed.
2. Install the mounting bracket, with the air governor attached, on the engine. Tighten the M8 mounting bolt 16 N·m (12 lb·ft).
3. Coat each air line fitting with pipe thread sealant at the air governor port.

   Note: Coat the surface between the fitting and port on the air governor. Do not put sealant on the surfaces between the fitting and the air line.

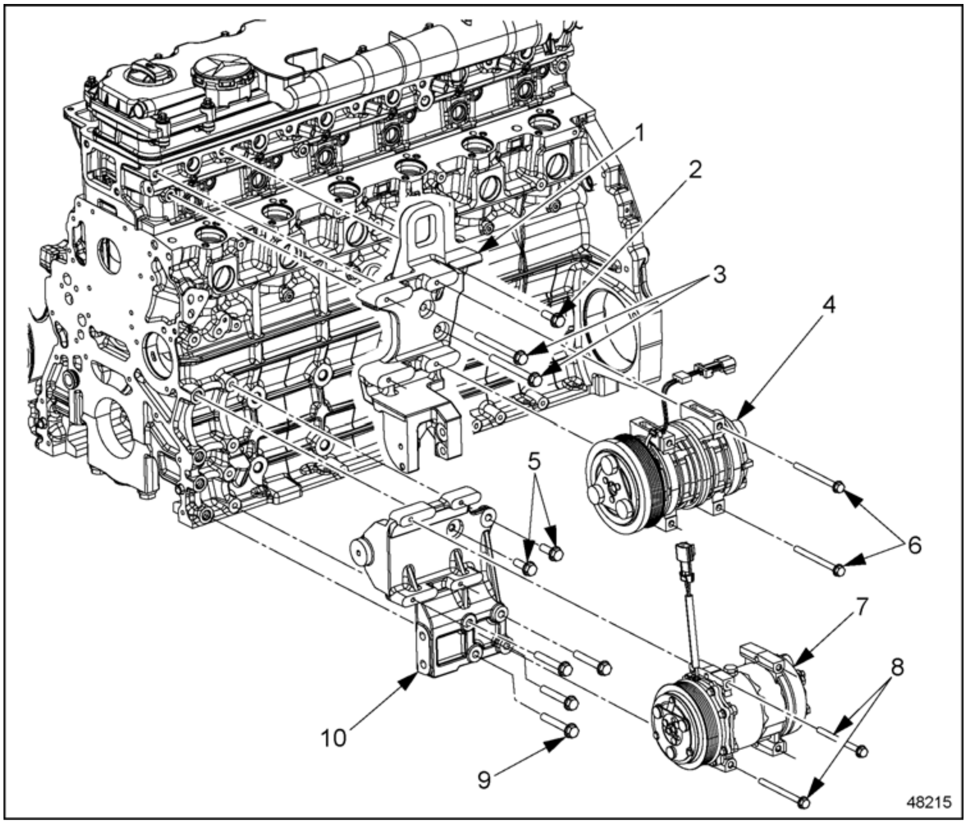
4. Install the three air line fittings, as removed. Make sure all fittings receive the proper torque, as listed in Table "Torque Values" .

Section 11.3
Air Conditioning Compressor(S)

Refer to the appropriate vehicle service manual to remove and install the air conditioning compressor.

Section 11.3.1
Removal of Air Conditioning Compressor Mounting Bracket

Removal steps are as follows:



1. Upper AC Mounting Bracket	6. Bolts (qty 4) Upper AC Mounting
2. Bolt (short)	7. Lower AC Compressor
3. Bolts (qty 2)	8. Bolts (qty 4) Lower AC Mounting
4. Upper AC	9. Bolts (qty 4) Lower Bracket Mounting
5. Bolts (short – lower mounting bracket)	10. Lower Bracket Mounting

Figure 1. Air Conditioning Compressor Mounting Bracket

1. Remove the Air Conditioning (AC) compressor(s). Refer to the appropriate vehicle service manual.
2. If equipped with dual AC compressors, remove the two long bolts and one short bolt securing the upper AC compressor mounting bracket to side of the cylinder heads and remove the upper bracket. See Figure "Air Conditioning Compressor Mounting Bracket" .

3. Remove two short bolts and four long bolts securing the lower AC compressor mounting bracket to the side of the cylinder block and remove the lower bracket. See Figure "Air Conditioning Compressor Mounting Bracket" .

Section 11.3.2
Installation of Air Conditioning Compressor Mounting Bracket

Installation steps are as follows:

1. Secure the lower AC compressor mounting bracket to the side of the cylinder block with two short bolts and four long bolts. Torque the bolts to 45–55 N·m (33–41 lb·ft). See Figure "Air Conditioning Compressor Mounting Bracket" .
2. Secure the upper AC compressor mounting bracket to the cylinder head with two long bolts and one short bolt. Torque the bolts to 45–55 N·m (33–41 lb·ft). See Figure "Air Conditioning Compressor Mounting Bracket" .
3. Install the air conditioning compressor(s). Refer to the appropriate vehicle service manual.

Additional Information

SPECIFICATIONS

Any specifications for special equipment are listed below.

Torque Values

The torque values for components in this chapter are listed in Table "Torque Values" .

Descriptions	Torque N·m (lb·ft)
Drive Nut	290 (214)
Air Compressor Mounting Bolts	60 (44)
Coolant Line Banjo Bolts	30 (22)
Discharge Line Fitting	80 (60)
Unloader Air Line Fitting	80 (60)
Power Steering Pump Mounting Bolts	40 (30)
Air Governor Mounting Bolts	16 (12)
AC Mounting Bracket Bolts	45–55 (33–41)

Table 1. Torque Values

Special Tools

The special tools used in this chapter are listed in Table "Special Tools" .

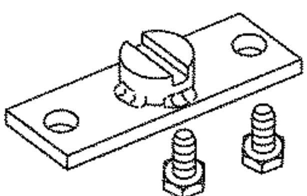
Tool	Description	Usage	Part Number
 47126	Air Compressor Locking Device	Used to lock the drive shaft on the air compressor.	(J–46391)

Table 2. Special Tools

Section 12.1
Preparation for a First Time Start

Note: Before starting the engine, do all the recommended pre–trip 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.

Note especially the location and function of the following:

- Oil Pressure Gauge
- Coolant Temperature Gauge
- Low Oil Pressure/High Coolant Temperature Warning Light
- Water In Fuel Warning Light
- Tachometer
- Air Restriction Indicator

When starting the engine, and while 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. Frequently, engine damage may be avoided by a quick response to early indications of problems.

Section 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 "Approved Electrical Lubricants" .

Manufacturers	Lubricants or Part Numbers
Shell® is a registered trademark of Shell Oil Corporation.	No. 71032; No. 71306
Texaco® is a registered trademark of Texaco, Inc.	No. 955
Quaker State® is a registered trademark of Quaker State Oil Refinery Company.	No. NYK–77

Table 1. Approved Electrical Lubricants

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.**

Section 12.1.2
Checking the Oil Level

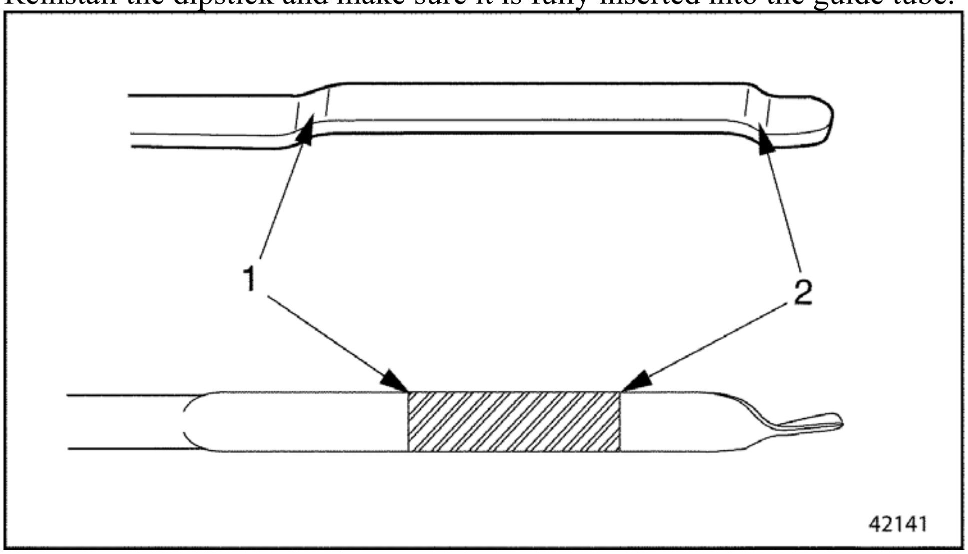
Check the oil level as follows:

WARNING:

PERSONAL INJURY

To avoid injury from slipping and falling, immediately clean up any spilled liquids.

1. Remove the dipstick from the guide tube. Note the dipstick has a positive locking device such as a lever or twist-lock design that must be disengaged before pulling the dipstick out of the guide tube.
2. Use a shop rag to wipe off the end of the dipstick.
3. Wait 15 seconds to allow any crankcase pressure to dissipate through the guide tube and let the oil level settle in the oil pan.
4. Reinstall the dipstick and make sure it is fully inserted into the guide tube.



1. Maximum Fill Level	2. Minimum Fill Level

Figure 1. Oil Dipstick

5. Remove the dipstick and read the oil level. See Figure "Oil Dipstick" . The figure shows a comparison between the bends on the dipstick and a crosshatch pattern on a conventional dipstick. Note the exact area noted on the bends. For example, the “maximum” oil level will be at the BOTTOM of that bend. For the “minimum” oil level, it is noted at the TOP of the bend.
6. If the oil level is below the “minimum” bend, add oil to bring it up the “maximum” level. Do

NOT fill beyond the maximum fill level on the dipstick, since overfilling may result in high oil consumption and possible severe engine damage

7. 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 "Oil Fill Cap" .

1. Oil Fill Cap

Figure 2. Oil Fill Cap

Section 12.1.3
Checking the Coolant Level (Cold Check)

Check engine 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.

Section 12.1.4
Adding Fuel

Note the following when adding fuel:

1. Add winter or summer grade fuel according to the season of the year.
2. Work in the cleanest conditions possible.
3. Prevent water from entering the fuel tank.

Section 12.1.5
Priming the Fuel System

Prime the fuel system as follows:

NOTICE:

The high pressure fuel lines are a one time use ONLY. If any service is done to the high pressure fuel lines they must be replaced with new. DO NOT open fuel system to release air during the priming procedure.

NOTICE:

Correct torque on the high pressure fuel 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 25 N·m (18 lb·ft) and all fuel banjo bolts to 40-50 N·m (30-37 lb·ft).
2. If equipped with a hand pump on the fuel/water separator, work the hand pump until a strong resistance is felt.

   Note: There should be a strong resistance in the hand pump, caused by the pressure build–up within the fuel system.

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 not equipped with a fuel/water separator with a hand pump, use the Diesel Fuel System Primer, (J–47912) to prime the fuel system. See Figure "Diesel Fuel System Primer J–47912" .

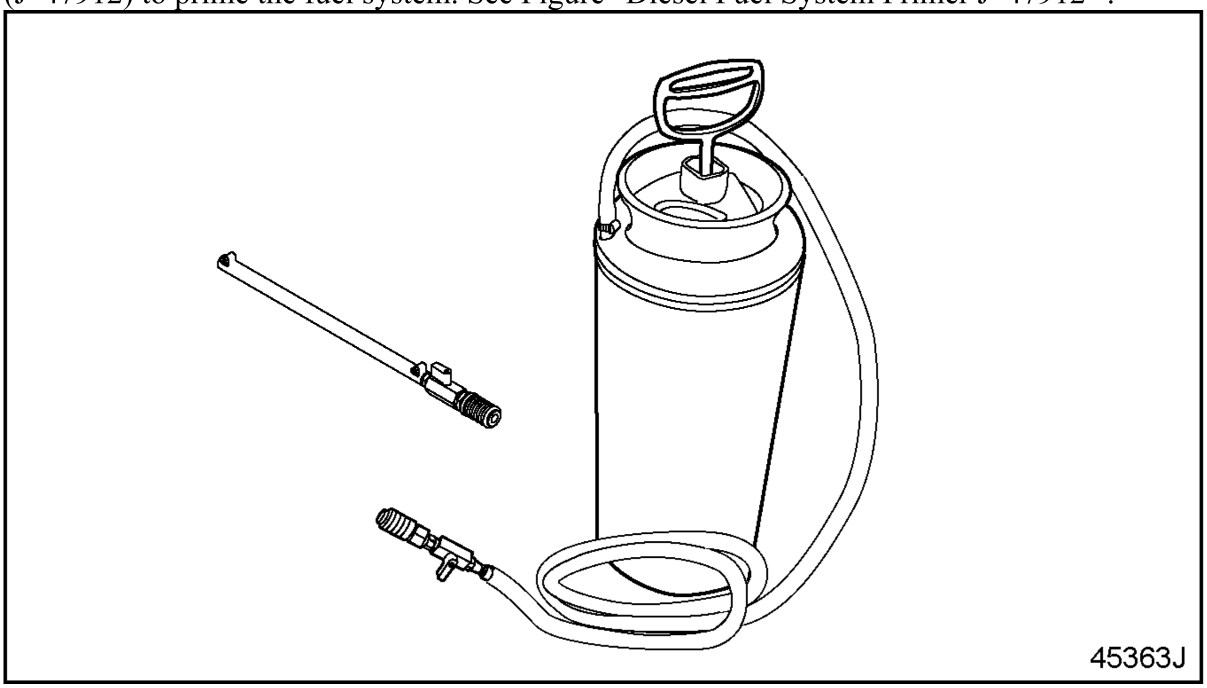


Figure 3. Diesel Fuel System Primer J–47912

4. Fill the fuel system primer three–fourth full with fuel oil.
5. Connect the line from the primer tank to priming valve on the primary fuel filter. Close the valve on the priming line. See Figure "Diesel Fuel System Primer J–47912" .
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, run for 30 seconds before closing the priming line valve.
10. After the engine starts and runs smoothly, remove the priming line from the primary fuel filter and install the dust cap on the priming fitting.
11. Slowly release the pressure on the fuel system primer, (J–47912) by turning the pumping handle slightly. See Figure "Diesel Fuel System Primer J–47912" .

Section 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:

Note: As a safety function, the electronic engine control system allows the engine to start only if the transmission is in neutral.

NOTICE:

Never attempt to start the MBE 900 engine using ether or any other starting fluid. Serious engine damage could result.

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:

ENGINE EXHAUST

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

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. Do not overfill.
6. Check all the mounting fasteners and belts on the engine for tightness.

Section 12.2.1
Checking the Coolant Level (Hot Check)

Check coolant level as follows:

1. Open the heater valves before adding coolant.

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. Allow the engine to run for approximately five minutes at a moderate speed. Allow the coolant temperature to reach 50°C (122°F).
3. Check the coolant level. Add more coolant if necessary.
4. Replace radiator cap.
5. Increase engine speed to 2200 rpm for one minute, then stop engine and carefully remove radiator cap, check the coolant level. Add more coolant if necessary.
6. Do not close the heater valves until the engine has been run briefly and the coolant level again checked and corrected as necessary.

Section 12.2.2
Starting an Engine That Has Not Been Run for an Extended Period of Time

Before starting an engine which has not been run for an extended period, certain special work must be carried out.

Note: At outside temperatures below 0°C (32°F), a coolant pre–heater 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.
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.

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Section 12.3
Running the Engine

The following sections cover normal operations:

Section 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–V belt for tightness.
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.

Section 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.

Section 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.

Section 12.3.4
Changing the Idle Speed

The rpm range of the MBE 900 engine is 600 rpm to 850 rpm if the parameters in the DDEC–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.

Section 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 900 Troubleshooting Guide (6SE580).

Section 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 key 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.

Section 12.4.1
Shutting Down After Hard Operation

After hard operation, do the following:

NOTICE:

After hard operation, 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. Shutting down the engine without idling may cause damage to the turbocharger.

Turn off the ignition switch and shut down the engine.

Additional Information

Special Tools

The special tools used within the chapter are listed in Listed in Table "Special Tools" .

Tool	Description	Usage	Part Number
 46805	Diesel Fuel System Primer	Used to prime the engine fuel system	J–47912

Table 1. Special Tools

Section 13.1
Checking of 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 valve lash. There are two acceptable methods for adjusting the valves, prior to checking the valve lash:

1. In order, according to the timing sequence used for fuel injection (see Method One—Adjust Each Cylinder in Firing Order);
2. By type of valve, depending on crankshaft position (see Method Two—Adjust All Valves Using Two Crankshaft Positions). See Figure "Cylinder and Valve Layout" for the cylinder and valve layout .

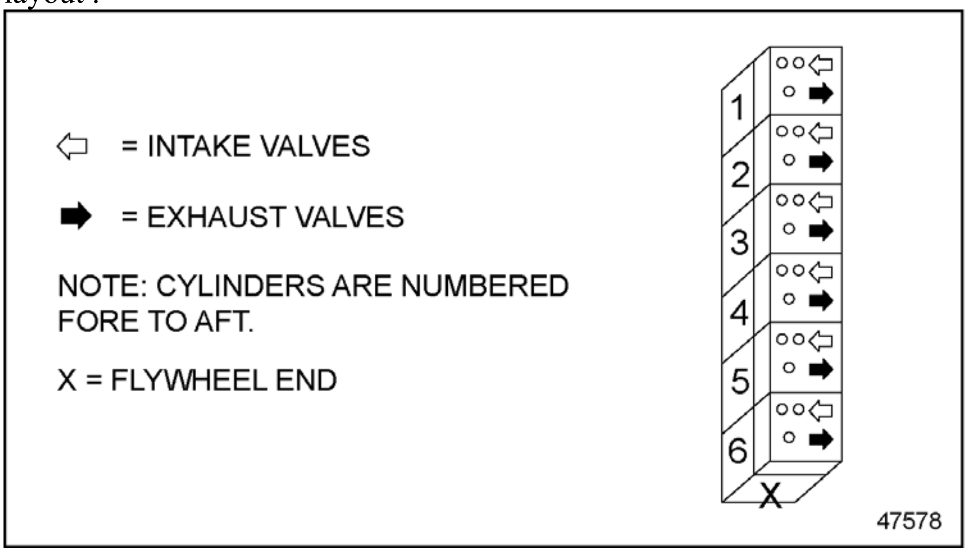


Figure 1. Cylinder and Valve Layout

Section 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 "Valve Adjustment (Method One)" .

Crankshaft Positions	Cylinders					
Ignition TDC	1	5	3	6	2	4
Valve Overlap	6	2	4	1	5	3

Table 1. Valve Adjustment (Method One)

Note: Clean the cylinder head cover before removing it.

1. Remove the cylinder head cover. Refer to "1.1.1 Removal Cylinder Head Cover" .
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. Refer to "1.15 Engine Barring Tool" . See Figure "Inspection Hole in the Flywheel Housing" .

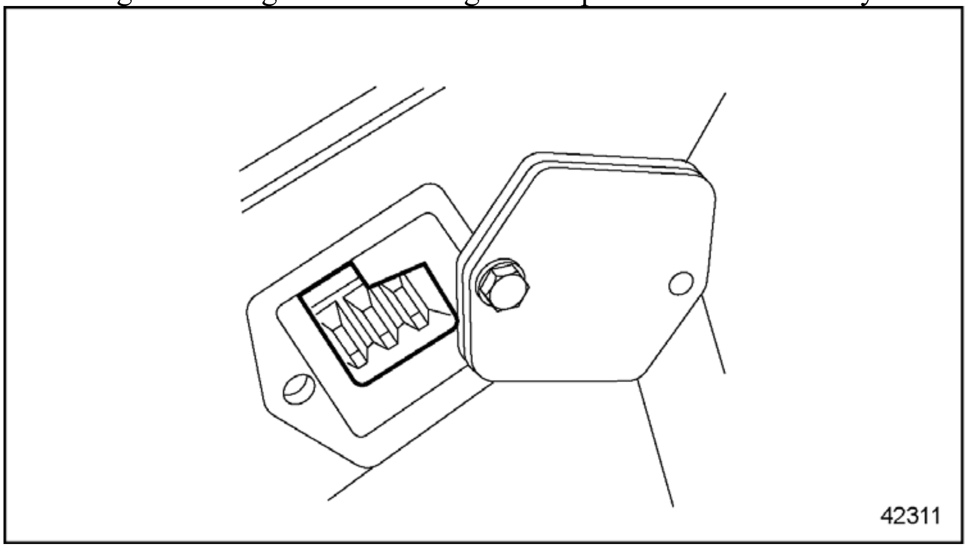


Figure 2. Inspection Hole in the Flywheel Housing

4. For each cylinder, use the cranking tool to rotate 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 if necessary, adjust it using the remaining steps.
6. For each valve, measure the valve lash with a feeler gauge between the rocker arm and valve stem (exhaust valve) or valve bridge (intake valve). It should be possible to pull the feeler gauge through with no more than light resistance.
7. If the value measured is within the range given in the "Check For" column listed in Table "Valve Lash Checking and Adjustment" , check the next valve.

Valve Types	Check for: mm (inches)	Adjust to: mm (inches)
Intake	0.30 to 0.60 (0.012 to 0.024)	0.40 (0.016)
Exhaust	0.50 to 0.80 (0.020 to 0.032)	0.60 (0.024)

Table 2. Valve Lash Checking and Adjustment

If the value measured is outside the range given in the "Check For" column listed in Table "Valve Lash Checking and Adjustment" , adjust the valve lash. Refer to "13.2 Adjusting Valve Lash" .

Section 13.1.2
Adjust All Valves Using Two Crankshaft Positions

Method two allows you to adjust all the valves using just two crankshaft positions.

Note: Clean the cylinder head cover before removing it.

1. Remove the cylinder head cover. Refer to "1.1.1 Removal Cylinder Head Cover" .
2. Remove the inspection cover on the flywheel housing.

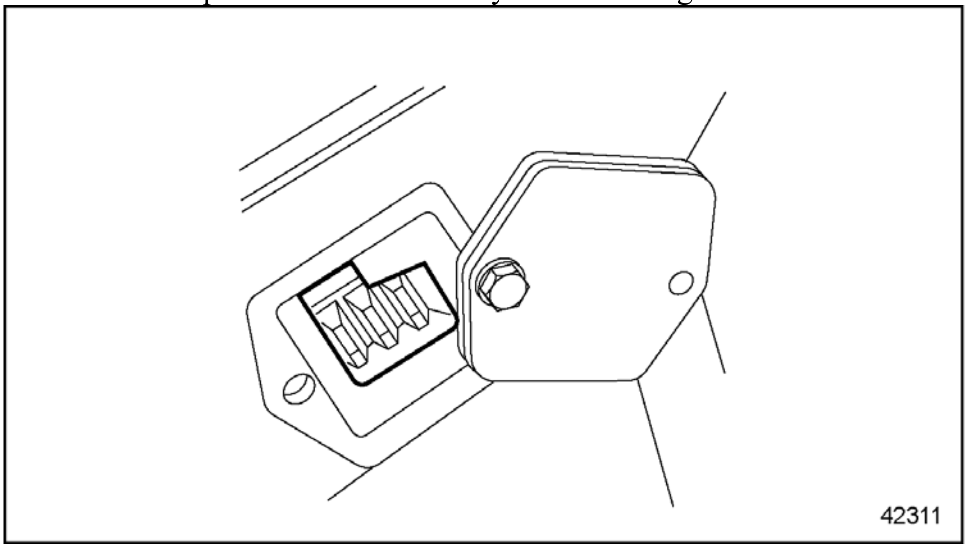


Figure 3. Inspection Hole in the Flywheel Housing

3. Install the engine barring tool (J–46392) into the inspection hole on the flywheel housing. Refer to "1.15 Engine Barring Tool" . See Figure "Inspection Hole in the Flywheel Housing" .
4. Using the cranking tool, rotate 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).
5. Check the valves in the "Ignition TDC" row listed in Table "Valve Adjustment (Method Two)" and adjust them (if necessary), using the remaining steps.

Cylinder #1 Crankshaft Position	Cylinders/Valve Types*					
	1	2	3	4	5	6
Ignition TDC	I/E	I	E	I	E	—
Valve Overlap	—	E	I	E	I	I/E

Table 3. Valve Adjustment (Method Two)

**NOTE: I = Intake Valve and E = Exhaust Valve*

6. Using the cranking tool, rotate 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 "Valve Adjustment (Method Two)" and adjust them (if necessary), using the remaining steps.
8. For each valve, measure the valve lash with a feeler gauge between the rocker arm and valve stem (exhaust valve) or valve bridge (intake valve). It should be possible to pull the feeler gauge through with no more than light resistance.
9. If the value measured is within the range given in the "Check For" column listed in Table "Valve Lash Checking and Adjustment" , check the next valve.

Valve Types	Check For: mm (inches)	Adjust to: mm (inches)
Intake	0.30 to 0.60 (0.012 to 0.024)	0.40 (0.016)
Exhaust	0.50 to 0.80 (0.020 to 0.032)	0.60 (0.024)

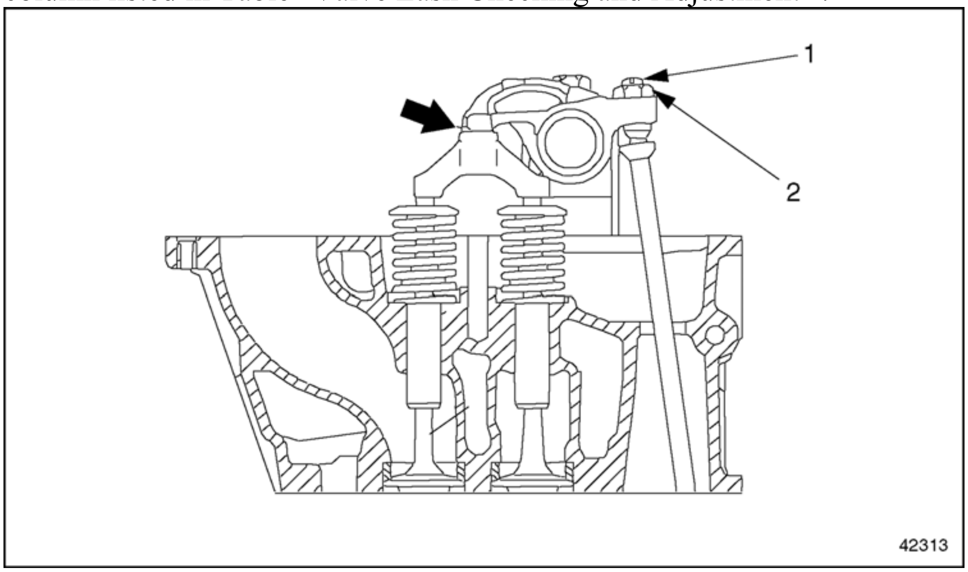
Table 4. Valve Lash Checking and Adjustment

If the value measured is outside the range given in the "Check For" column listed in Table "Valve Lash Checking and Adjustment" , adjust the valve lash.

Section 13.2
Adjusting Valve Lash

Adjust the valve lash as follows:

1. If adjustment is needed, unscrew the locknut. See Figure "Valve Lash Adjustment" . Turn the adjusting screw until the valve lash is correct. Use the exact settings given in the "Adjust To" column listed in Table "Valve Lash Checking and Adjustment" .



1. Adjusting Screw	2. Locknut

Figure 1. Valve Lash Adjustment

Note: When adjusting the valves, adjust to the exact setting. Use the range only for checking adjustment.

2. Tighten the locknut to 25 N·m (18 lb·ft).
3. Check the valve lash again. Adjust again if necessary.
4. Install the cylinder head cover. Refer to "1.1.2 Installation of Cylinder Head Cover" .
5. Remove the 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 to 25 N·m (18 lb·ft).

Additional Information

SPECIFICATIONS

This section contains the specifications for servicing the engine.

Special Tools

The special tools used in this chapter are listed in Table "Special Tools" .

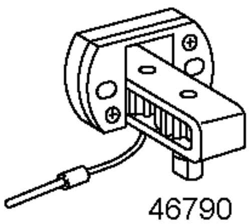
Tool	Description	Usage	Part Number
	Engine Barring Tool	Used to lock or rotate the engine flywheel.	J–46392

Table 1. Special Tools

Section 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.

Section 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 9,650 km (6,000 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 96,500 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 96,500 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.

Section 14.1.1.1
Maintenance Interval

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 "Maintenance Intervals by Engine Hours" 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 "Maintenance Intervals (Severe Service)" is Severe Service. Listed in Table "Maintenance Intervals (Short Haul)" is Short-Haul. Listed in Table "Maintenance Intervals (Long Haul)" is Long-Haul.

Procedure	Severe (hrs)	Short-Haul/(School Bus) (hrs)	Long-Haul (hrs)
Engine Oil and Filter	350	500 or 6 months	—
Fuel Filter	700	1000	—
Valve Lash Adjustment	1400	2500	—

Table 1. Maintenance Intervals by Engine Hours

	Miles (X 1000)	6	12	18	24	30	36	42	48	54	60	66	75
	Km (X 1000)	10	19	29	38	50	57	68	77	87	100	106	120
	Item	Procedure											
1.	Lubricating Oil/Filter & Oil Centrifuge*	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 "Coolant Maintenance Intervals" , Coolant Maintenance Intervals.											
3.	Valve Lash Checking & Adjustment†	Adjust every 24,000 mi. (38,000 Km)											
4.	Drive Belts	I	I	I	I	I	I	I	I	I	I	I	R
5.	Fuel/Water Separator	—	—	R	—	—	R	—	—	R	—	—	—
6.	Fuel Filters/Pre-Filters‡	—	—	R	—	—	R	—	—	R	—	—	—
7.	Air System	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	—
9	Air Compressor	I	I	I	I	I	I	I	I	I	I	I	—
10.	Aftertreatment Device	Inspect same as exhaust system interval, ash removal at 150,000 Miles (240,000 Km)											
11.	Vibration Damper	Replace at major overhaul or earlier if dented or leaking.											
12.	FEPTO	I	I	I	I	I	I	I	I	I	I	I	I

Table 2. Maintenance Intervals (Severe Service)

** Change lubricating oil/filter per above schedule or every 350 hours.*
† Adjust valve lash per above schedule or every 10,500 hours.
‡ Change fuel filter per above schedule or every 700 hours.
I – Inspect, service, test, correct or replace as necessary.
R – Replace.

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 & Oil Centrifuge	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 "Coolant Maintenance Intervals" , Coolant Maintenance Intervals.											
3. Valve Lash Checking and Adjustment	Adjust every 75,000 mi. (125,000 Km)											
4. Drive Belts	I	I	I	I	R	I	I	I	I	R	I	I
5. Fuel/Water Separator	—	R	—	R	—	R	—	R	—	R	—	R
6. Fuel Filters/Pre-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 150,000 Miles (240,000 Km)											
11. Vibration Damper	Replace at major overhaul or earlier if dented or leaking.											
12. FEPTO	—	—	—	I	—	I	—	I	—	I	—	I

Table 3. Maintenance Intervals (Short Haul)

I – Inspect, service, test, correct or replace as necessary.
R – Replace.

Miles (X 1000)	20	40	60	75	80	100	120	140	150	160	180	200	220	225
Km (X 1000)	32	64	97	121	129	161	193	225	241	257	290	322	354	362
Item	Procedure													
1. Lubricating Oil/Filter & Oil Centrifuge	R	R	R	—	R	R	R	R	—	R	R	R	R	—
2. Cooling System	Intervals are based on type of coolant used aslisted in Table "Coolant Maintenance Intervals" , Coolant Maintenance Intervals.													
3. Valve Lash Check and Adjustment	Adjust every 80,000 Mi. (129,000 Km)													
4. Drive Belts	I	I	I	R	I	I	I	I	R	I	I	I	I	R
5. Fuel/Water Separator	Follow manufacturer's recommendations.													
6. Fuel Filters	—	—	R	—	—	—	R	—	—	—	R	—	—	—
7. Air System	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	—
9. Air Compressor	I	I	I	—	I	I	I	I	—	I	I	I	I	—
10. Aftertreatment Device	Inspect same as exhaust system interval, ash removal at 150,000 Miles (240,000 Km)													
11. Vibration Damper	Inspect at oil changes. Replace at major overhaul or earlier if dented or leaking.													
12. FEPTO	—	—	—	—	I	—	I	—	—	I	—	I	—	—

Table 4. Maintenance Intervals (Long Haul)

I – Inspect, service, test, correct or replace as necessary.
R – Replace.

Section 14.1.2
Engine Oil and Filter

Select the SAE class (viscosity) on the basis of the average air temperature for the anticipated ambient temperature range that the engine will start and operate. See Figure "SAE Oil Viscosity Classes" .

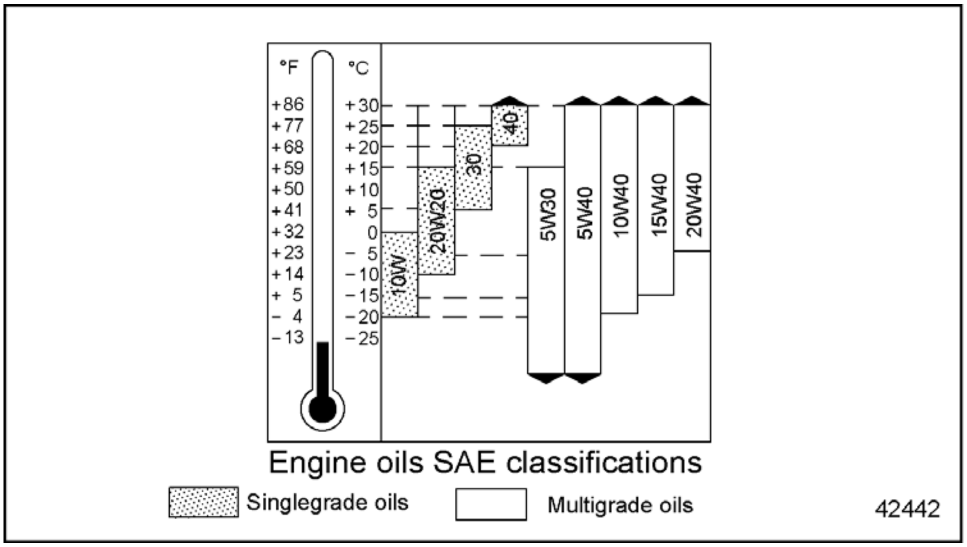


Figure 1. SAE Oil Viscosity Classes

To insure the engine is protected and the oil stays clean until the next oil change, use only oils of API classification CJ–4.

Note: SAE viscosity grade 15W–40 is the recommended oil grade.

Section 14.1.2.1
Primary Fuel/Water Separator Filter

To replace the primary fuel/water separator filter refer to "2.16.1 Removal of Primary Fuel Filter" and refer to "2.16.2 Installation of Primary Fuel Filter" .

Section 14.1.2.2
Secondary Fuel/Water Separator

To replace the secondary fuel/water separator filter refer to "2.16.3 Removal of Secondary Fuel Filter" and refer to "2.16.4 Installation of Secondary Fuel Filter" .

Section 14.1.3
Coolant Concentration Checking

Check 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.

1. Open the cap on the surge tank slowly, to allow excess pressure to escape. Set the cap aside.

   Note: Check and correct the coolant level only when the coolant temperature is below (50°C) 122°F.

2. Before adding coolant, use a suitable tester to check the concentration of corrosion–inhibiting antifreeze. If the concentration is lower than 50% by volume, add antifreeze until the concentration is correct. The coolant mixing ratio is listed in Table "Coolant Mixing Ratio" .

Antifreeze Protection Down to ° F (°C)	Water Percentage by Volume	Corrosion–Inhibiting Antifreeze Percentage by Volume
–34 (–37)	50	50
–49 (–45)	45	Maximum 55*

Table 6. Coolant Mixing Ratio

**Concentrations of more than 55% by volume should not be used, as this is the level which affords the maximum antifreeze protection, down to –49°F (–45°C). Higher concentrations adversely affect heat dissipation.*

NOTICE:

If the concentration of antifreeze is too low, there is a risk of corrosion or cavitation in the cooling system.

Note: When topping off, use only a prepared coolant mixture containing a 50% concentration by volume of corrosion–inhibiting antifreeze.

3. Check the coolant level and add more coolant if necessary.
4. Close the cap on the surge tank.

Section 14.1.4
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.

WARNING:

PERSONAL INJURY

To avoid injury from scalding, drain the radiator when the engine and coolant are cool.

2. Drain the coolant from the engine. Coolant system capacity is listed in Table "Coolant System Capacity" .

System	Descriptions	Capacity L (qt.)
Engine Coolant Capacity (all vehicles)	Engine capacity	12 (12.7)
Business Class Coolant System Capacity	Total capacity	23.7 (25)
	Antifreeze quantity at 50%	11.8 (12.5)
	Antifreeze quantity at 55%	13.1 (13.8)

Table 10. Coolant System Capacity

3. Flush 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.

   a. Attach a flushing nozzle to the radiator outlet.
   b. Run water in until the radiator is full.

   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.

   c. Apply no more than 140 kPa (20 psi) air pressure intermittently to help dislodge sediment buildup in the core.
4. Drain the radiator, and flush the radiator until clean water flows from the radiator. Remove the flushing device.
5. When the coolant has drained, install the coolant drain plug on the radiator.
6. Add coolant in the specified concentration until the maximum mark on the surge tank is reached. Coolant system capacity is listed in Table "Coolant System Capacity" .

WARNING:

ENGINE EXHAUST

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

7. 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.
8. Shut down the engine.
9. Add coolant if necessary.

Section 14.1.5
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.

1. Inspect the radiator, the condenser, the water 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.

Section 14.1.6
Coolant Inhibitor Test Intervals

The coolant inhibitor level should be checked at the intervals. Listed in Table "Required Coolant Inhibitor Test Intervals" .

Service Application	Inhibitor Test Interval
Long Haul — Highway Trucks and Motor Coaches — operates more than 60,000 miles (100,00 km) per year	20,000 Miles (32,000 Km)
Short Haul — City Transit — operates up to 60,000 miles (100,000 km) per year.	15,000 miles (25,000 Km)
Severe Service — Fire Truck or Crash/Rescue Vehicle — operates up to 6,000 miles (9,600 km) or under severe conditions.	6,000 Miles (9,600 Km) 300 hours or 1 year, whichever comes first

Table 15. Required Coolant Inhibitor Test Intervals

Check the nitrite concentration at the regular intervals listed in Table "Coolant Maintenance Intervals" with a Power Trac 3–Way Test Strip.

Coolant	Interval[1]	Action
Antifreeze / Water + SCA Inhibitor (DDC Power Cool)	20,000 Miles (32,000km) or 3 Months*	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
	300,000 Miles (480,000km)	Drain and clean system. Refill with new coolant.
Ethylene Glycol / Water + SCA Inhibitor or Propylene Glycol / Water + SCA Inhibitor	20,000 Miles (32,000km) or 3 Months*	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
	300,000 Miles (480,000km)	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 (480,000km) or 2 Years*	AddPower Cool Plus Extender
	600,000 Miles (960,000km)	Drain and clean system. Replace with new coolant.
Water Only + SCA Inhibitor	20,000 Miles (32,000km) or 3 Months*	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
	300,000 Miles (480,000km)	Drain and clean system. Replace with new coolant.
Water Only + OAT Coolant	300,000 Miles (480,000km) or 2 Years*	AddPower Cool Plus Extender
	600,000 Miles (960,000km)	Clean and drain. Replace with new coolant.

Table 16. Coolant Maintenance Intervals

[1] *Maintenance interval based on application. Drain interval dependent on proper maintenance.*

Section 14.1.7
Inhibitor Level Checking

Detroit Diesel Power Trac 3–Way Coolant Test Strips should be used to measure nitrite and glycol concentrations. Cavitation/corrosion is indicated on the strip by the level of nitrite concentration. Freeze/boil over protection is determined by glycol concentration.

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.

For best results make the test while the coolant is between 50° – 140° F (10.0° – 60° C). Wait at least 60, but not longer than 75, seconds before reading the nitrite level. Use the test strips as follows:

1. Dip the strip into coolant for one second. Remove and shake briskly to eliminate excess fluid.
2. Immediately compare the pad end (% glycol) to the color chart on the container.
3. Sixty seconds (one minute) after dipping, compare the nitrite pad to the color chart.
4. Color change of the additive indicator (middle pad) indicates the presence of inhibitor that is not approved by Detroit Diesel.
5. If any problems exist, change the coolant.
6. Promptly replace and tighten the test strip container cap after each use. Discard unused strips if they have turned light pink or tan.

A factory coolant analysis program is available through authorized Detroit Diesel service outlets.

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Section 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.

Section 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

Section 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).

WARNING:

PERSONAL INJURY

To avoid injury from scalding, drain the radiator when the engine and coolant are cool.

2. Drain the coolant when the engine is cold.
3. If the Heating Ventilation Air Conditioning (HVAC) unit is connected to the cooling system, open the regulating valves all the way.

Section 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).

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.

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.

Section 15.1.4
Storage

Required protective measures for the MBE 900 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 be placed in a dry, well–ventilated area.

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.

Section 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.

Section 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 65N·m (48 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 65N·m (48 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.

Section 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.

Section 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. Refer to "14.1.4 Coolant Flushing and Changing" .

3. Refill with clean, soft water and add a rust inhibitor to the cooling system. Refer to "5.3 Coolant" .
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 "3.5 Oil Filter Element" .
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. Remove the fuel filters. Refer to "2.16 Fuel Filter/Water Separator Filters" .
12. Install new filters with No. 1 diesel fuel or pure kerosene. Refer to "2.16 Fuel Filter/Water Separator Filters" .

WARNING:

ENGINE EXHAUST

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

13. Operate the engine for five minutes to circulate the clean fuel oil throughout the engine. Ensure the engine fuel system is full.
14. 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.
15. Service the air cleaner.
16. 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.

17. 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.

18. Drain the engine cooling system.
19. Drain the preservative oil from the engine crankcase.
20. 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.
21. 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).

22. Store the battery in a cool, dry place. Keep the battery fully charged and check the level and specific gravity of the electrolyte regularly.
23. Insert heavy paper strips between the pulleys and drive belts to prevent sticking.
24. Seal all engine openings including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood, or metal covers where practical.
25. 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.
26. 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.