DDC-SVC-MAN-0034 2008

EPA07 DD15
Workshop Manual

DETROIT DIESEL

DEMAND PERFORMANCE℠

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CALIFORNIA
Proposition 65 Warning

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

CALIFORNIA
Engine Idle Limiting Standard Notice

Vehicles with engines certified by the State of California are equipped with software features making them compliant with the California Engine Idle Regulations. In order to meet this regulation, the engine control strategy is generally configured to automatically shut down the engine after five minutes of continuous idle operation. This shutdown feature is not an engine malfunction and is required to meet the California emission regulations.

ABSTRACT

This manual provides instruction for servicing the on-highway applications of the Detroit Diesel DD15.

Specifically a basic overview of each major component and system along with recommendations for removal, cleaning, inspection criteria for replacement, repair and installation and mechanical troubleshooting are contained in this manual.

EPA07 DD15 troubleshooting concerns are contained in the EPA07 DD15 Troubleshooting Guide, DDC-SVC-MAN-0029.

ENGINE EXHAUST

Consider the following before servicing engines.

WARNING:

PERSONAL INJURY

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

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

REVISION NOTIFICATION

Modifications to this manual are announced in the form of Service Information Bulletins.

TABLE OF CONTENTS

GENERAL INFORMATION

Section **Page**

SCOPE AND USE OF THIS MANUAL

This manual contains complete instructions on operation, adjustment (tune-up), preventive maintenance, and repair (including complete overhaul) for the DD15 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 DD15 Engines, and apply to all engine models.

This manual is divided into numbered sections. Section one covers the engine (less major assemblies). The following 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.

CLEARANCE OF NEW PARTS AND WEAR LIMITS

New parts clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" must be qualified by the judgement of personnel responsible for installing new parts. For additional information, refer to Inspection the section entitled "Inspection" within this section.

THE FOUR CYCLE PRINCIPLE FOR DIESEL ENGINES

The diesel engine is an internal combustion engine, in which the energy of burning fuel is converted into energy to work the cylinder of the engine. In the diesel engine, air alone is compressed in the cylinder, raising its temperature significantly. After the air has been compressed, a charge of fuel is sprayed into the cylinder and ignition is accomplished by the heat of compression. The four piston strokes of the cycle occur in the following order: intake, compression, power and exhaust.

Intake Stroke

During the intake stroke, the piston travels downward, the intake valves are open, and the exhaust valves are closed. The down stroke of the piston facilitates air from the intake manifold to enter the cylinder through the open intake valve. The turbocharger, by increasing the air pressure in the engine intake manifold, assures a full charge of air is available for the cylinder.

The intake charge consists of air only with no fuel mixture.

Compression Stroke

At the end of the intake stroke, the intake valves close and the piston starts upward on the compression stroke. The exhaust valves remain closed.

At the end of the compression stroke, the air in the combustion chamber has been compressed by the piston to occupy a space about one-seventeenth as great in volume as it occupied at the beginning of the stroke. Thus, the compression ratio is 18.1

Compressing the air into a small space causes the temperature of that air to rise. During the last part of the compression stroke and the early part of the power stroke, a small metered charge of fuel is injected into the combustion chamber.

Almost immediately after the fuel charge is injected into the combustion chamber, the fuel is ignited by the hot air and starts to burn, beginning the power stroke.

Power Stroke

During the power stroke, the piston travels downward and all intake and exhaust valves are closed.

As the fuel is added and burns, the gases get hotter, the pressure increases, pushing the piston downward and adding to crankshaft rotation.

Exhaust Stroke

During the exhaust stroke, the intake valves are closed; the exhaust valves are open, and the piston is on its up stroke.

The burned gases are forced out of the combustion chamber through the open exhaust valve port by the upward travel of the piston.

From the preceding description, it is apparent that the proper operation of the engine depends upon the two separate functions: first, compression for ignition, and second, that fuel be measured and injected into the compressed air in the cylinder in the proper quantity and at the proper time.

GENERAL DESCRIPTION

The DD15 Engine described in this manual is a four-stroke cycle, high speed, diesel engine.

It uses an inline cast iron block and has a cast iron cylinder head that contains a duel overhead camshaft. The camshafts actuates all the valves (two intake, two exhaust per cylinder), and operates the fuel injectors. The vertically aligned gear train, located at the rear end of the engine in a gear case, contains drive gears for the lubricating oil pump, crankshaft, camshafts, air compressor drive, fuel pump drive, water pump and alternator accessory drives.

Full pressure lubrication is supplied to all main, connecting, camshaft and rocker assembly bearings and to other moving parts. The oil spray nozzles spray engine oil continuously below the piston crowns to ensure that they are cooled. A gear-type pump draws oil from the oil pan through a screen and delivers it to the oil coolant module. The engine oil is first fed through the oil/water heat exchanger located on the oil coolant module. During the cold start phase of the engine the oil/water heat exchanger will rapidly warm the oil. After the warm-up phase of the engine the oil/water heat exchanger will cool the engine oil. Once the engine oil has passed through the oil/water heat exchanger it then goes to the oil filter. In the oil filter part of the engine oil (about 90%) flows through the filter element and is cleaned. The rest of the oil (about 10%) goes into the oil centrifuge. The engine oil cleaned in the centrifuge and flows unpressurized back into the oil pan. Part of the oil goes to the camshaft frame where it feeds the camshaft bearings and rocker assemblies. The remainder of the oil goes to the main bearings and connecting rod bearings via the drilled oil passages in the crankshaft. The turbocharger is supplied with engine oil by an external oil line. Return flow of the engine oil by return ducts and return holes in the cylinder head and cylinder block and back to the oil pan.

Coolant is circulated through the engine by a centrifugal-type water pump. The cooling system, including the radiator, is a closed system. Heat is removed from the coolant by the radiator. Control of the engine temperature is accomplished by thermostats that regulate the flow of the coolant within the cooling system.

The fuel supply ensures that the fuel required for combustion is available under all operating conditions in the sufficient quantity, at the correct time and at the required pressure. Fuel to the individual cylinders is supplied via the Amplified Pressure Common Rail System (APCRS) which is supplied by the fuel low pressure circuit with fuel. The fuel low pressure circuit ensures that the fuel is cleaned and is provided in the sufficient quantities and at the required pressure to the APCRS

Air is supplied by the turbocharger to the intake manifold and into the engine cylinders after passing through an air-to-air charge air cooler mounted ahead of the cooling system radiator. The charge air cooler cools the pressurized intake air charge coming from the turbocharger before it enters the intake manifold.

Engine starting is provided by an electric motor energized by a storage battery. A battery charging alternator, with a suitable voltage regulator, serves to keep the battery charged.

The DD15 Engine was designed to be electronically controlled. The Detroit Diesel Electronic Control (DDEC) system has evolved with the product.

DDEC VI

The DDEC VI Motor Control Unit (MCM) receives electronic inputs from sensors on the engine and vehicle, and uses the information to control engine operation. It computes fuel timing and fuel quantity based upon predetermined calibration tables in its memory. DDEC VI provides an indication of engine and vehicle malfunctions. The Motor Control Unit (MCM) continually monitors the DDEC VI system.

Any faults that occur are stored as codes in the MCM's memory. A DDDL® can be used to read the codes.

GENERAL SPECIFICATIONS

The general specifications for the DD15 Engine are listed in Table 1.

Filling Capacities are listed in Table 2.

Piston specifications are listed in Table 3.

Piston pin specifications are listed in Table 4.

Fuel system specifications are listed in Table 5.

Crankshaft bearing specifications are listed in Table 6.

Connecting rod specifications are listed in Table 7.

Connecting rod bearing specifications are listed in Table 8.

Cylinder block specifications are listed in Table 9.

See see Figure 1 for the cylinder designation and firing order.

General Specifications	14L Family
Total Displacement (L)	14.8
Number of Cylinders	6
Valve Control	DOHC
Number of Valves per Cylinder (Intake/Exhaust)	2/2
Idle Speed	560 (rpm)
Output	382 - 478 (kW)
Combustion Pressure max.	250 (bar)
Compression Ratio	18:0
Stroke	163 (mm)
Hub Bore Ratio	1.17

Table 1 Specifications for the DD15 Engine

Initial Filling Capacity of Oil Pan	44.5 l (47.02 qt)
Oil Pan Capacity	40 l (42.27 qt)
Oil Capacity of Oil Coolant Module	4.5 l (4.755 qt)

Table 2 Filling Capacity

Diameter	139 mm (5.472 in.)
Total Height	124.5 mm (4.902 in.)
Compression Height	83.5 mm (3.287 in.)
Shank Length	54.5 mm (2.146 in.)

Table 3 Piston Specifications

Inside Diameter	23 mm (0.9055 in.)
Outside Diameter	62 mm (2.441 in.)
Length	92 mm (3.622 in)

Table 4 Piston Pin Specifications

Rail Pressure max.	900 bar
Injection Pressure max.	2200 bar

Table 5 Fuel System Specifications

Diameter	120 mm (4.724 in.)
Width	39.5 mm (1.555 in)

Table 6 Crankshaft Bearing Specifications

Length	276 mm (10.87 in.)

Table 7 Connecting Rod Specifications

Diameter	100 mm (3.937 in.)
Width	39.5 mm (1.555 in.)

Table 8 Connecting Rod Bearing Specifications

Cylinder Diameter (mm)	139 mm (5.472 in.)
Cylinder Clearance (mm)	173 mm (6.811 in.)

Table 9 Cylinder Block Specifications

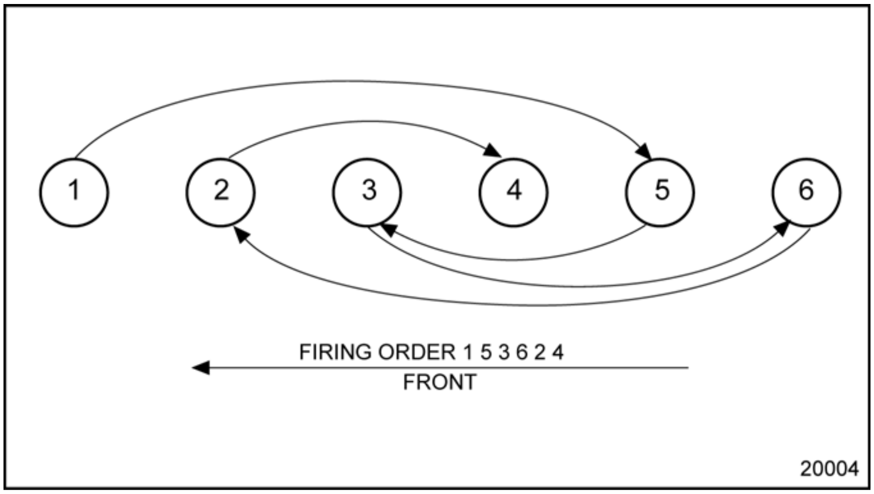


Figure 1 Cylinder Designation and Firing Order

ENGINE MODEL, SERIAL NUMBER

The engine serial and model numbers are stamped on the left side cylinder block. Serial number will be laser engraved at the front left side of the engine block.

Figure 2 Serial Number Location

REPLACING AND REPAIRING

In many cases, a technician is justified in replacing parts with new material rather than attempting repair. However, there are times when a slight amount of reworking or reconditioning may save a customer considerable added expense. Exchange assemblies such as injectors, fuel pumps, water pumps and turbochargers are desirable service items.

Various factors such as the type of operation of the engine, hours in service and the next overhaul period must be considered when determining whether new parts are installed or used parts are reconditioned to provide trouble-free operation.

For convenience and logical order in disassembly and assembly, the various subassemblies and other related parts mounted on the cylinder block will be treated as separate items in the various sections of the manual.

DISASSEMBLY

A technician can be severely injured if caught in pulleys, belts or the fan of an engine that is accidentally started. To avoid such a misfortune, take the following precautions before starting to work on an engine.

WARNING:

PERSONAL INJURY

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

WARNING:

PERSONAL INJURY

To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles. Bleed the air from the air starter system before disconnecting the air supply hose.

Before any major disassembly, the engine must be drained of lubricating oil, coolant and fuel.

To perform a major overhaul or other extensive repairs, the complete engine assembly, after removal from the engine base and drive mechanism, should be mounted on an engine overhaul stand; then the various subassemblies should be removed from the engine. When only a few items need replacement, it is not always necessary to mount the engine on an overhaul stand.

Parts removed from an individual engine should be kept together so they will be available for inspection and assembly. Those items having machined faces, which might be easily damaged by steel or concrete, should be stored on suitable wooden racks or blocks, or a parts dolly.

CLEANING

Before removing any of the subassemblies from the engine (but after removal of the electrical equipment), the exterior of the engine should be thoroughly cleaned.

NOTICE:
The DD15 Engine is equipped with various sensors and other electronic components which may be damaged if subjected to the high temperatures in a solvent tank. Do not immerse any electrical components in a solvent tank. Care should be taken to ensure that all electronic components are removed from the various engine assemblies before they are immersed in a solvent tank. Refer to section2 for a description of these components.

Then, after each subassembly is removed and disassembled, the individual parts should be cleaned. Thorough cleaning of each part is absolutely necessary before it can be satisfactorily inspected. Various items of equipment needed for general cleaning are listed below.

The cleaning procedure used for all ordinary cast iron parts is the same as the following cylinder block cleaning procedure. Any special cleaning procedures will be mentioned when required.

Remove cylinder liners before putting the block in cleaning or descaling baths, to avoid trapping cleaning agents in block liner seating bores.

After stripping and before removing the cylinder block from the overhaul stand for cleaning and inspection, install the two metric eye bolts into head bolt holes at each end of the cylinder block.

Remove all oil and water gallery and weep hole plugs to allow the cleaning solution to enter the inside of the oil and water passages.

1. Using two metric eye bolts installed in the head bolt holes at opposite ends of the block, and with a suitable lifting device and spreader bar, immerse and agitate the block in a hot bath of a commercial, heavy-duty alkaline solution.
2. Wash the block in hot water or steam clean it to remove the alkaline solution.
3. If the water jackets are heavily scaled, proceed as follows:
   - [a] Agitate the block in a bath of inhibited phosphoric acid.
   - [b] Allow the block to remain in the acid bath until the bubbling action stops (approximately 30 minutes).
   - [c] Lift the block, drain it and immerse it again in the same acid solution for 10 more minutes. Repeat until all scale is removed from the water jacket area.
   - [d] Rinse the block in clear, hot water to remove the acid solution.
   - [e] Neutralize the acid that may cling to the casting by immersing the block in an alkaline bath.
   - [f] Wash the block in clean water or steam clean it.

WARNING:

EYE INJURY

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

4. Dry the cylinder block with compressed air.

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. Blow out all of the bolt holes and passages with compressed air.

NOTE:
The above cleaning procedure may be used on all ordinary cast iron and steel parts for the engine. Aluminum parts, such as flywheel housing, air intake manifold, oil filter adaptor and the camshaft gear access cover should NOT be cleaned in this manner. Mention will be made of special procedures when necessary.

6. Be certain that all water passages and oil galleries have been thoroughly cleaned. After the cylinder block has been thoroughly cleaned and dried, install weep hole plugs and precoated pipe plugs. Install new cup plugs using a coating of good grade non-hardening sealant such as Loctite® 620 or equivalent.

Loctite® is a registered trademark of The Loctite Corporation.

Steam Cleaning

A steam cleaner is a necessary item in a large shop and is useful for removing heavy accumulations of grease and dirt from the exterior of the engine and its subassemblies.

Solvent Tank Cleaning

A tank of sufficient size to accommodate the largest part that will require cleaning (usually the cylinder block) should be provided and provisions made for heating the cleaning solution.

WARNING:

PERSONAL INJURY

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

Fill the tank with a commercial heavy-duty solvent, that is heated to 52°C (125°F). Lower large parts directly into the tank with a hoist. Place small parts in a wire mesh basket and lower them into the tank. Immerse the parts long enough to loosen all of the grease and dirt.

Aluminum or plastic parts such as the flywheel housing, fuel pump drive, air intake manifold, oil filter adaptor, camshaft gear access cover, oil pan or rocker covers, should not be cleaned in this manner.

Rinsing Bath

Provide another tank of similar size containing hot water for rinsing the parts.

Drying

Parts may be dried with compressed air.

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.

The heat from the hot tanks will quite frequently complete drying of the parts without the use of compressed air.

Rust Preventive

If parts are not to be used immediately after cleaning, dip them in a suitable rust preventive compound. The rust preventive compound should be removed before installing the parts in an engine.

Gasket Removal

The gasket used on numerous mating surface joints in the DD15 Engine results in a very thin film that must be removed from both surfaces prior to reassembly. As many of the surfaces are aluminum and/or dimensionally critical, conventional scraping methods, or the use of emery cloth for removing the gasket is not recommended.

Four-inch, 3M Scotch-Brite® Surface Conditioning Discs, used with an electric or air powered hand drill (with a speed of 15,000-18,000 r/min), have proven successful in removing the gasket without damaging the mating surfaces of engine parts. See Figure 3.

Scotch-Brite® is a registered trademark of the 3M Corporation.

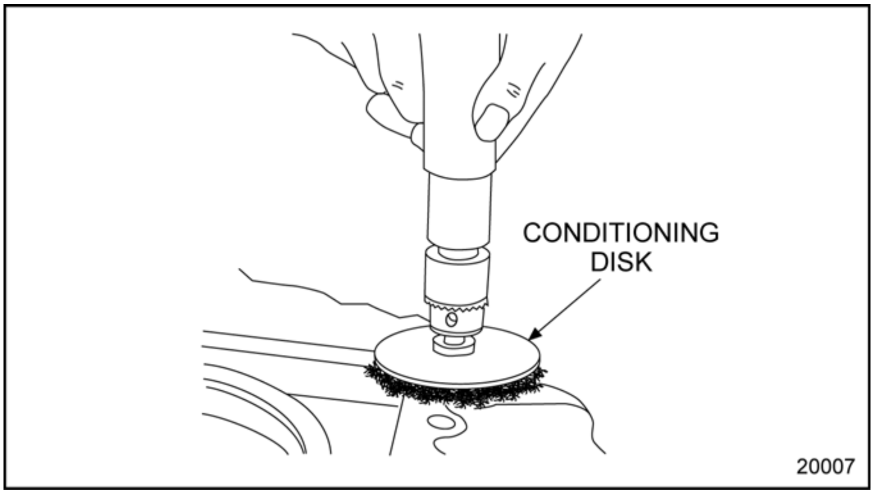


Figure 3 Gasket Removal

A coarse pad, is suitable for steel surfaces. A medium pad is recommended for aluminum surfaces. The pads are easily interchangeable. See Figure 4.

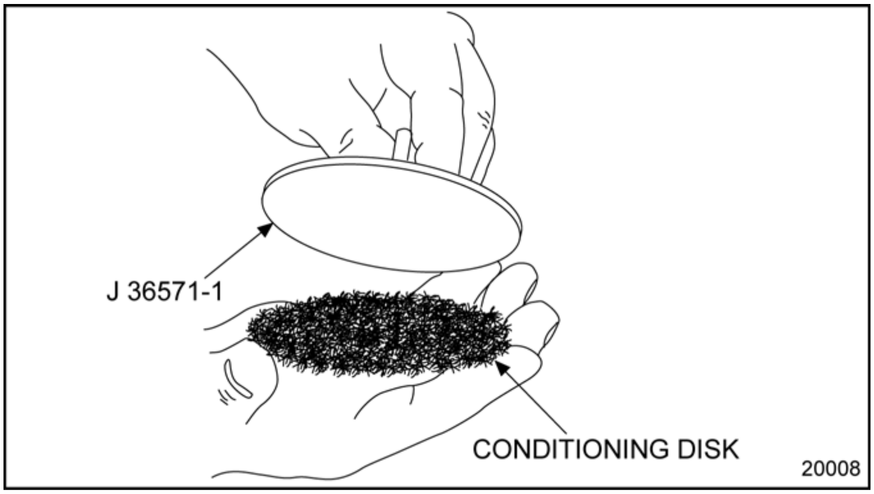


Figure 4 Scotch-Brite Surface Conditioning Disc Installation

Inspection

The purpose of parts inspection is to determine which parts can be used and which must be replaced. Although the engine overhaul specifications given throughout the text will aid in determining which parts should be replaced, considerable judgment must be exercised by the inspector. The guiding factors in determining the usability of worn parts, that are otherwise in good condition, is the clearance between the mating parts and the rate of wear on each of the parts. If it is determined that the rate of wear will maintain the clearances within the specified maximum allowable until the next overhaul period, the reinstallation of used parts may be justified. Rate of wear of a part is determined by dividing the amount the part has worn by the hours it has operated

Many service replacement parts are available in various undersize or oversize as well as standard sizes. Also, service kits for reconditioning certain parts and service sets that include all of the parts necessary to complete a particular repair job are available.

A complete discussion of the proper methods of precision measuring and inspection are outside the scope of this manual. However, every shop should be equipped with standard gages, such as dial bore gages, dial indicators, and inside and outside micrometers.

In addition to measuring the used parts after cleaning, the parts should be carefully inspected for cracks, scoring, chipping and other detrimental conditions.

SAFETY PRECAUTIONS

The following safety measures are essential when working on the DD15 Engine.

Exhaust (Start/Run Engine)

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

WARNING:

PERSONAL INJURY

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

WARNING:

PERSONAL INJURY

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

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

Stands

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

Glasses

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

WARNING:

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.

Welding

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

WARNING:

PERSONAL INJURY

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

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

WARNING:

FIRE

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

NOTICE:

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

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

Work Place

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

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

After servicing or adjusting the engine:

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

Clothing

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

WARNING:

PERSONAL INJURY

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

- Rings
- Wrist watches
- Loose fitting clothing

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

Power Tools

Do not use defective portable power tools.

WARNING:

ELECTRICAL SHOCK

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

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

Air

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

WARNING:

EYE INJURY

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

Fluids and Pressure

Be extremely careful when dealing with fluids under pressure.

WARNING:

PERSONAL INJURY

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

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

Fuel

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

WARNING:

FIRE

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

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

WARNING:

GASOLINE VAPOR IGNITION

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

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

CAUTION:

PERSONAL INJURY

To avoid injury from fuel spills, do not overfill the fuel tank.

WARNING:

FIRE

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

Batteries

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

WARNING:

Battery Explosion and Acid Burn

To avoid injury from battery explosion or contact with battery acid, work in a well ventilated area, wear protective clothing, and avoid sparks or flames near the battery. If you come in contact with battery acid:

- **Flush your skin with water.**
- **Apply baking soda or lime to help neutralize the acid.**
- **Flush your eyes with water.**
- **Get medical attention immediately.**

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

WARNING:

PERSONAL INJURY

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

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

CAUTION:

Electrical Shock

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

Use care when connecting battery cables to avoid electrical shock.

Fire

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

Cleaning Agent

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

WARNING:

PERSONAL INJURY

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

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

Working on a Running Engine

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

CAUTION:

PERSONAL INJURY

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

WARNING:

PERSONAL INJURY

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

Turbocharger Compressor Inlet Shield

A turbocharger compressor inlet shield, is available and must be used anytime the engine is operated with the air inlet piping removed. The shield helps to prevent foreign objects from entering and damaging the turbocharger and will prevent the mechanic from accidentally touching the turbocharger impeller. The use of this shield does NOT preclude any other safety practices contained in this manual.

WARNING:

PERSONAL INJURY

To avoid injury from contact with rotating parts when an engine is operating with the air inlet piping removed, install an air inlet screen shield over the turbocharger air inlet. The shield prevents contact with rotating parts.

Use of this shield does NOT preclude any other safety practices contained in this manual.

FLUOROELASTOMER (VITON) CAUTION

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

WARNING:

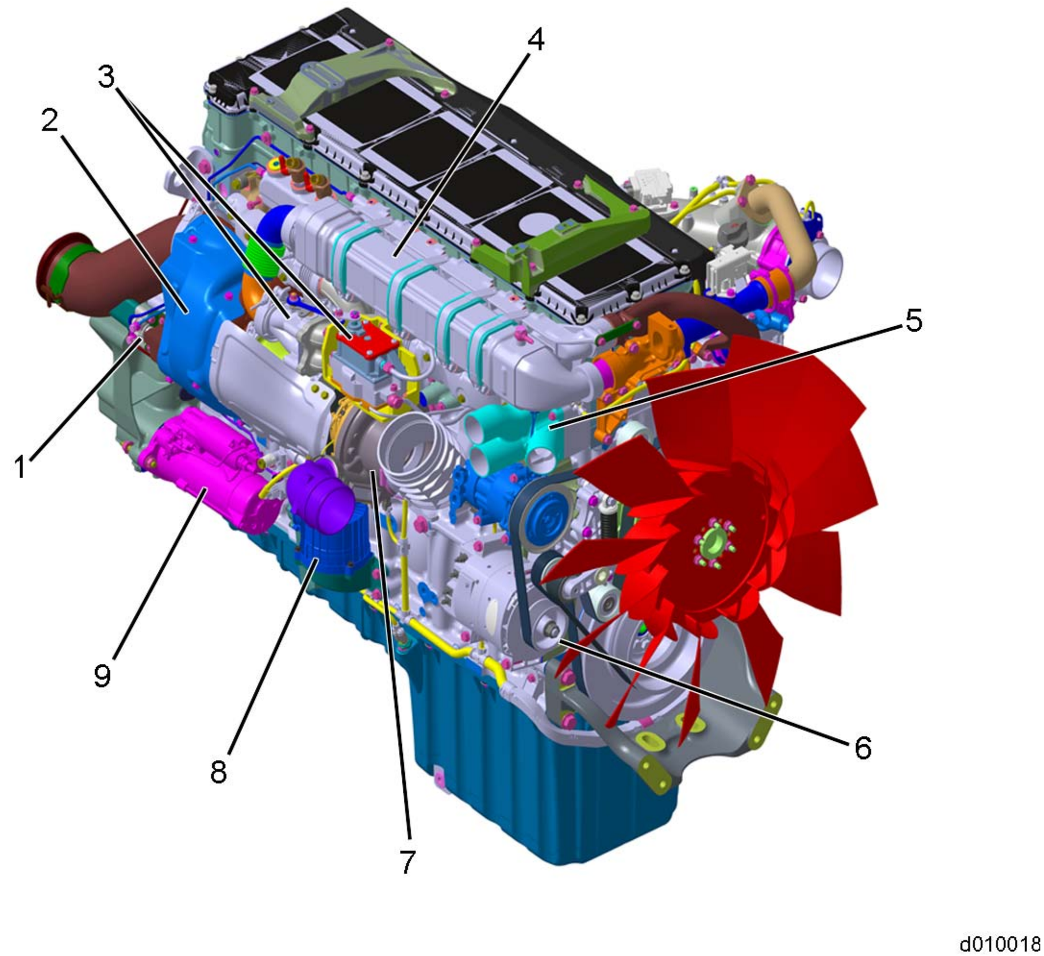
CHEMICAL BURNS

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.

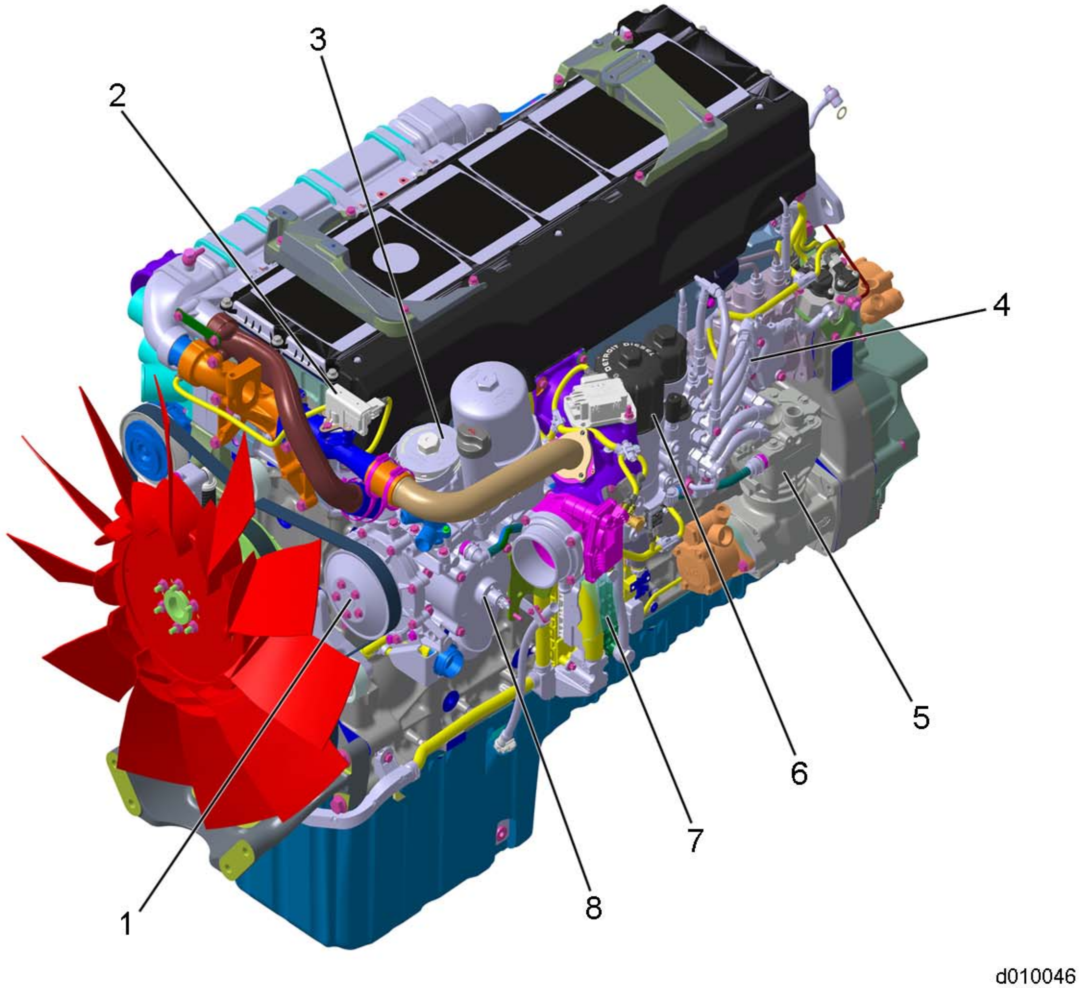
DD15 ENGINE VIEWS

Engine views for the EPA07 DD15 Engine.



1. Fuel Doser Valve
2. Turbocompound
3. Exhaust Gas Recirculation (EGR) Valve/Actuator
4. EGR Cooler
5. Thermostat
6. A/C Freon Compressor
7. Turbocharger
8. Crankcase Breather
9. Starter

Figure 5 14.8L DD15 Engine Right Side View



1. Water Pump
2. Delta P Sensor
3. Oil Coolant Module
4. Fuel System
5. Single Air Compressor
6. Fuel Module
7. Motor Control Module
8. Thermostat

Figure 6 14.8L DD15 Engine Left Side View

ENGLISH TO METRIC CONVERSION

Listed in Table 10 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/s^2)
Inch/second^2 (in./sec^2)	0.0254	Meter/second^2 (m/s^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 Pressure	By	To get equivalent number of:
Inches of water (in. H_2 O)	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 x 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 10 English to Metric Conversion Table

DECIMAL AND METRIC EQUIVALENTS

Listed in Table 11are 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 11 Conversion Chart-Customary and Metric Units

SPECIFICATIONS

This section contains fastener torque specifications and pipe plug torque specifications.

Torque Specifications - Fasteners

The proper bolt and nut torque is dependent on its size. Standard (non-metric) nut and bolt torque specifications are . Listed in Table 12 The proper torque specifications for metric nuts and bolts are .Listed in Table 13.

Nut and Bolt Size, mm	280M or Better Torque, N·m	280M or Better Torque, lb·ft
No.10-24	5-7	4-5
1/4 in.-20	9-12	7-9
1/4 in.-28	11-14	8-10
5/16 in.-18	18-23	13-17
5/16 in.-24	20-26	15-19
3/8 in.-16	41-47	30-35
3/8 in.-24	47-53	35-39
7/16 in.-14	62-68	46-50
7/16 in.-20	77-83	57-61
1/2 in.-13	96-102	71-75
1/2 in.-20	112-126	83-93
9/16 in.-12	122-136	90-100
9/16 in.-18	145-159	107-117
5/8 in.-11	186-199	137-147
5/8 in.-18	228-241	168-178
3/4 in.-10	325-339	240-250
3/4 in.-16	393-407	290-300
7/8 in.-9	556-569	410-420
7/8 in.-14	644-657	475-485
1 in.-8	789-799	580-590
1 in.-14	928-942	685-695

Table 12 Standard (Non-metric) Fastener Torque Specifications

Nut and Bolt Size, mm	Property Class 10.9 Torque, N·m	Property Class 10.9 Torque, lb·ft
M6 X 1.0	13-16	10-12
M8 X 1.25	30-38	22-28
M10 X 1.5	58-73	43-54
M12 X 1.75	101-126	75-93
M14 X 2.0	160-200	118-148
M16 X 2.0	245-306	181-226
M20 X 2.5	478-598	353-441

Table 13 Class 10.9 Torque Specifications for Metric Fasteners

Torque Specification - Pipe Plugs

Standard pipe plug torque specifications supporting the DD15 Engine are . listed in Table 14.

*Pipe Plug Size, NPTF	Torque Specifications, N·m	Torque Specifications, lb·ft
1/8 in.	14-18	10-13
1/4 in.	19-24	14-18
3/8 in.	24-31	18-23
1/2 in.	31-39	23-29
3/4 in.	45-56	33-41
1 in.	101-126	75-93
1-1/4 in.	129-161	95-119
1-1/2 in.	149-187	110-138

*Use sealant such as Pipe Plug Sealant with Teflon®, PT-7271 (Loctite® 592), or equivalent on all uncoated pipe plugs.

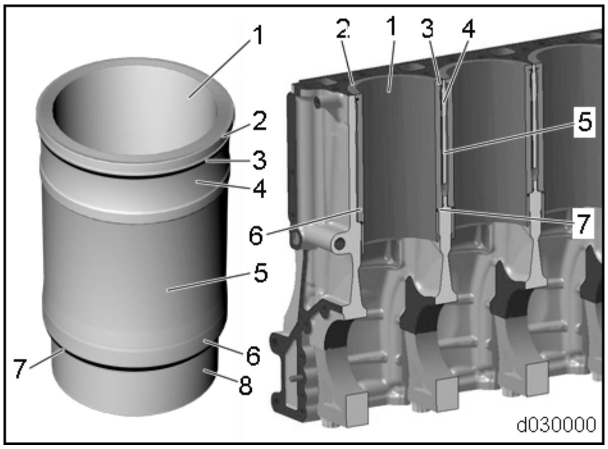
Table 14 Standard Pipe Plug Torque Specifications

1 ENGINE

1.1 CYLINDER BLOCK AND CYLINDER LINER

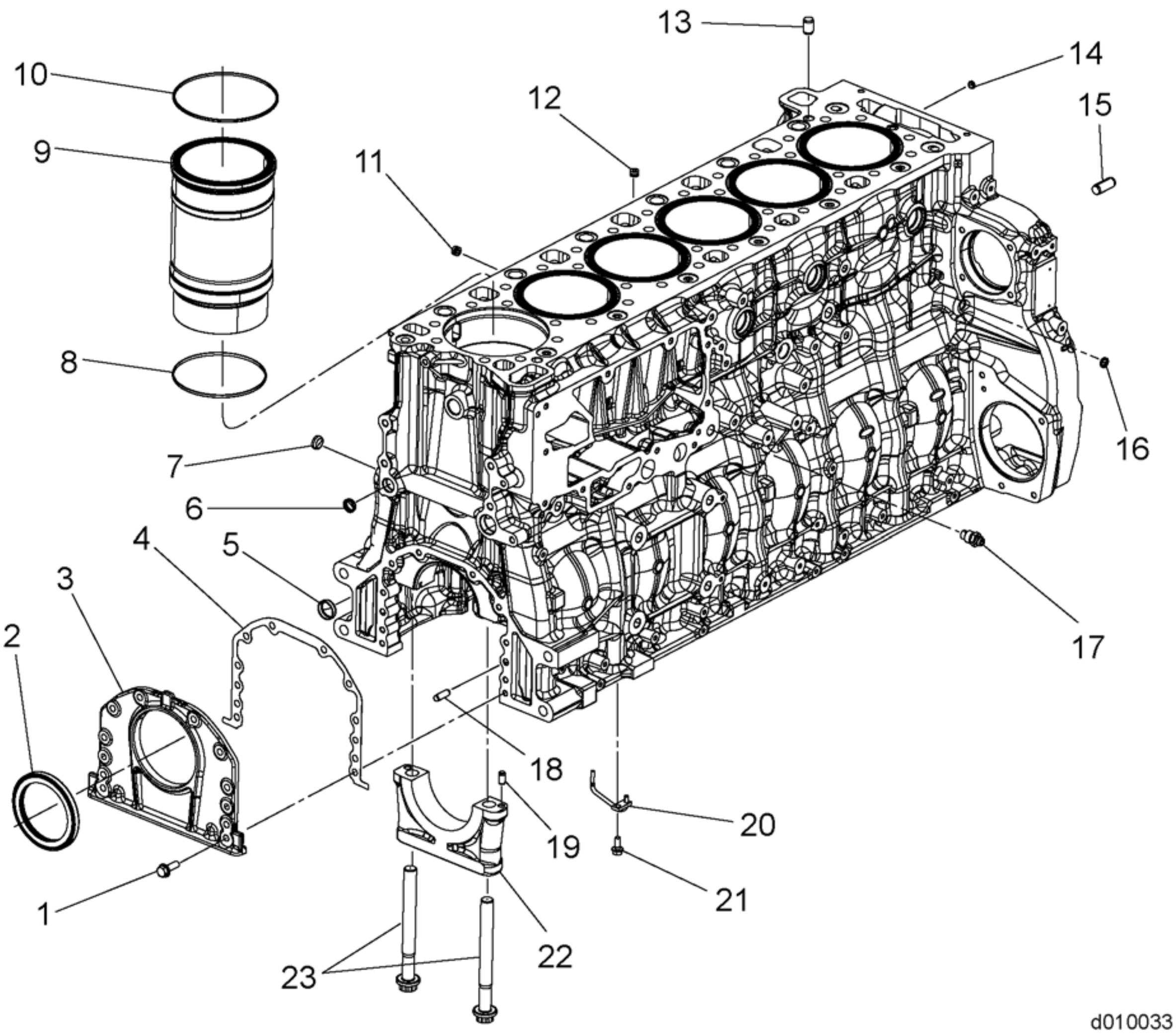
The cylinder block is the basic engine structure, establishing and maintaining the alignment of all engine working parts. The cylinder block is made from a iron material. High strength and low noise are features of this cylinder block, this is a result of the vertical and horizontal reinforcements and the design of the oil return ducts.

The cylinder liners (1) are designed as "bottom stop" cylinder liners which means that the cylinder liners (1) are installed with a lower collar (6) in the cylinder block. This design allows for a shorter distance between cylinders and a more compact design for the cylinder block. Each cylinder liner (1) has 2 sealing rings: the upper sealing ring (3), sealed by the upper coolant jacket (4) to the cylinder head the lower sealing ring (7), is sealed by the lower coolant jacket (5) to the cylinder block bore.



1. Cylinder Liner
2. Top of Cylinder Liner
3. Upper Sealing Ring
4. Upper Coolant Jacket
5. Lower Coolant Jacket
6. Lower Collar
7. Lower Sealing Ring
8. Bottom of Cylinder Liner

Figure 1-1 Cylinder Liner



1. Bolt, Front Cover to Cylinder Block
2. Sealing Ring, Front Crankshaft Sealing
3. Front Cover
4. Gasket, Front Cover to Cylinder Block
5. Expansion Plug, Front Oil Duct Intake
6. Expansion Plug, Front Oil Duct Outlet
7. Expansion Plug, Connector Front Oil Duct Outlet
8. Bottom Cylinder Liner Seal Ring
9. Cylinder Liner
10. Top Cylinder Liner Seal Ring
11. Expansion Plug, Connector Crankcase Ventilation
12. Plug
13. Pin
14. Expansion Plug, Cooling Water Duct
15. Pin
16. Expansion Plug
17. Connector Pipe
18. Pin, Front Cover
19. Dowel Pin, Crankshaft Bearing Cap
20. Piston Oil Spray Nozzle
21. Bolt, Oil Spray Nozzle
22. Main Bearing Cap
23. Bolt, Crankshaft Bearing Cap to Cylinder Block.

Figure 1-2 Cylinder Block, Cylinder Liners and Related Parts

The cylinder bores are a integral part of the block casting, but are in the form of replaceable, wet type.

The cylinder block has 1.5 mm counterbores machined on top for the cylinder head to cylinder block sealing surface. The lubrication and coolant holes in the cylinder block supply the cylinder head with oil and coolant. This allows for a superior sealing pressure between the gasket, cylinder head and cylinder block.

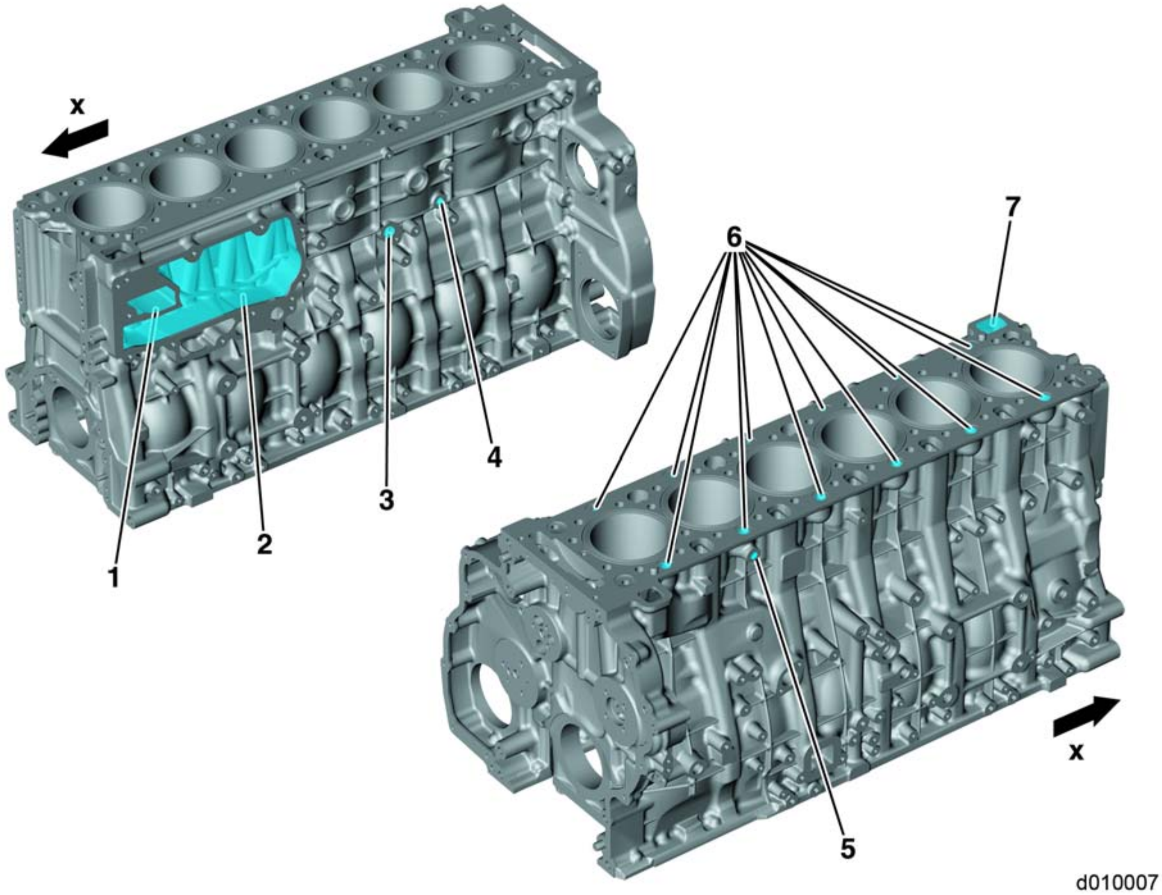
The following components are installed to the cylinder block:

Right Side

- Turbocompound
- Starter

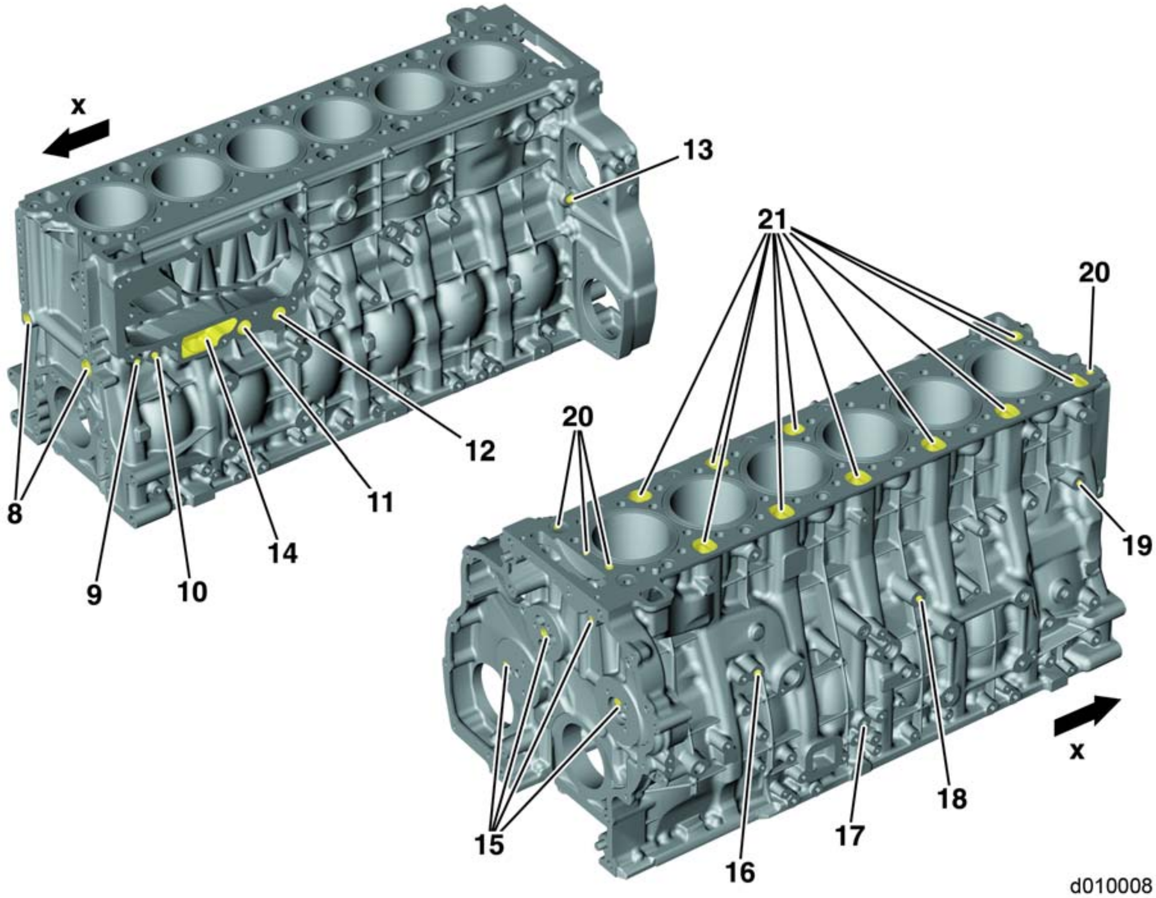
Left Side

- Oil Module
- Motor Control Module (MCM)
- Fuel Filter Module
- Fuel System High Pressure Pump
- Air Compressor



1. Coolant Return for Cylinder Head Coolant Manifold
2. Coolant Feed for Oil Water Heat Exchanger
3. Coolant Connection for Fuel Heat Exchanger
4. Coolant Connection for Air Compressor
5. Coolant Connection for EGR Cooler
6. Coolant Transfer Hole to Cylinder Head
7. Coolant Return from Cylinder Head
x. Front of Engine

Figure 1-3 Cylinder Block



8. Oil Holes

9. Connection for Oil Pressure Sensor

10. Connection for Engine Oil Temperature Sensor

11. Oil Return Connection from Oil Water Heat Exchanger

12. Oil Feed Connection to Oil Water Heat Exchanger

13. Oil Holes

14.Oil Return for Oil Filter Change

15. Holes for Feed Gear Drive

16. Connection for Oil Feed to Axial Power Turbine

17. Oil Feed Connection for Cylinder Block Ventilation

18. Oil Feed Connection Turbocharger

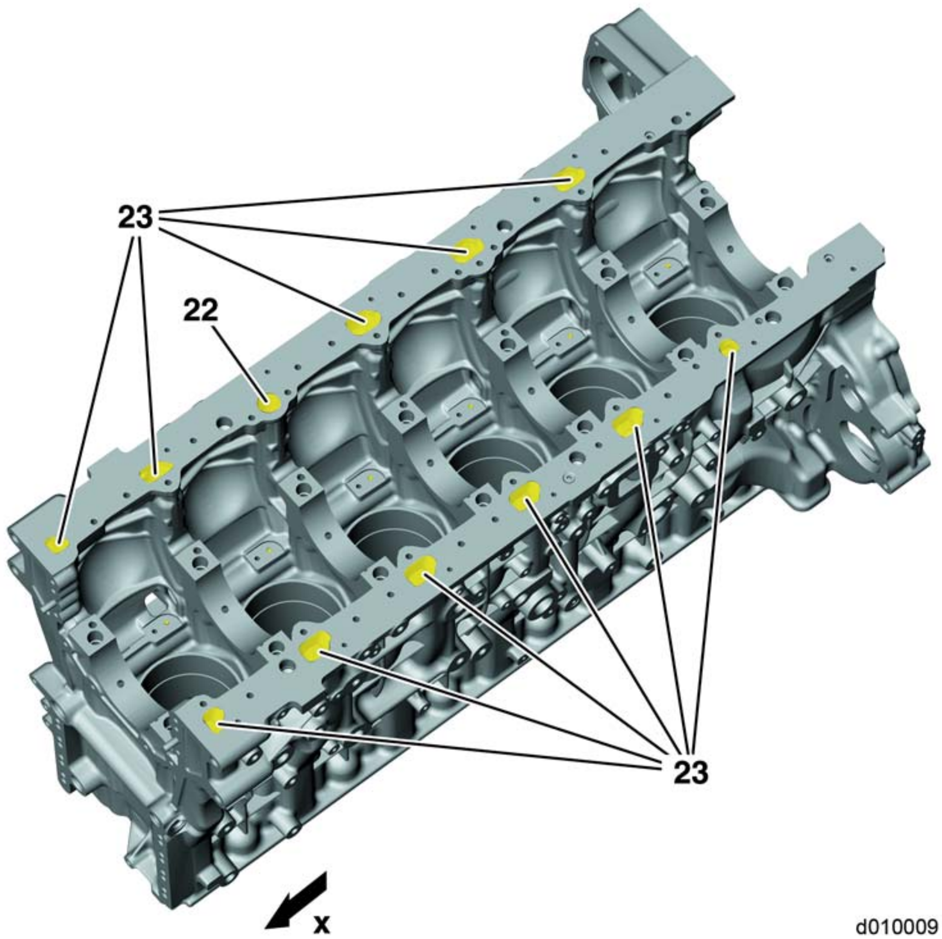
19. Oil Holes

20. Oil Transfer Holes to the Cylinder Head

21. Oil Return from Cylinder Head

x. Front of Engine

Figure 1-4 Cylinder Block

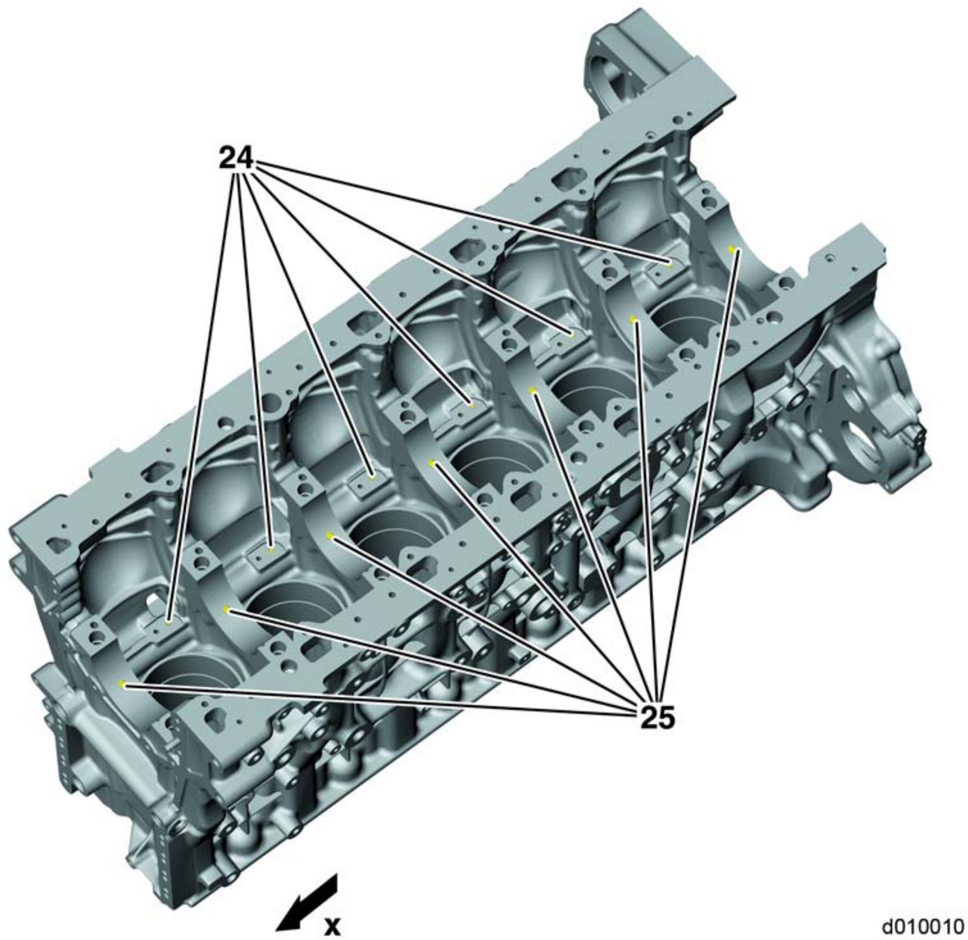


22. Oil Feed Bore

23. Oil Return to Oil Pan

x. Front of Engine

Figure 1-5 Bottom of Cylinder Block Oil Hole Location



24. Oil Feed Hole for Oil Spray Nozzles
25. Oil Feed Hole for Main Bearing and Connecting Rod Bearing

x. Front of Engine

Figure 1-6 Bottom of Cylinder Block Oil Hole Location

1.1.1 Removal and Disassembly of Engine from the Vehicle

Before mounting an engine on an overhaul stand, it must be disconnected from the transmission. Details for removing an engine will vary from one application to another. However, the following steps will be necessary, regardless of application:

1. Steam clean the engine.
2. Disconnect the battery cable(s) from the battery(s).
3. Drain the radiator system. Refer to OEM guide lines.
4. Drain the cooling system refer to section 12.4.
5. Drain the lubricating oil. Refer to section 12.3.1.

6. Remove two fuel lines from the high pressure fuel pump and cylinder head. Refer to section 2.4.
7. Disconnect the lines on the fuel filter module.
8. Remove the air cleaner ducting as necessary for engine removal. Refer to OEM guidelines.
9. Remove the charge air cooler ducting from the turbocharger and intake manifold.
10. Disconnect the exhaust piping from the turbocharger.
11. Remove DDEC VI components. Refer to section 2.10.
12. Disconnect wiring from the cranking motor and remove cranking motor. Refer to section 9.1.
13. Disconnect the alternator and other electrical equipment, as necessary. Refer to section 9.2.
14. Remove air compressor and air lines, as necessary. Refer to section 10.1.
15. Disconnect and remove the coolant hoses.
16. Remove the charge air cooler, radiator, fan guard and other cooling system related parts as necessary to remove the engine.
17. Connect a suitable lifting device to the engine using all three lifting brackets (two at the rear and one at the front).
18. Remove the engine mounting bolts.

DANGER:

FALLING ENGINE

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

19. Lift the engine from its mounts using a suitable lifting device.

WARNING:

FALLING ENGINE

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

20. Separate the engine from the transmission.
21. Remove the fuel filter module. Refer to section 2.8.

22. Remove high pressure pump. Refer to section 2.4.
23. Use engine overhaul stand (J–29109) for support when stripping a engine cylinder block.
24. Rotate it in either direction and lock it into position.
25. For DDEC VI remove the inlet and outlet fuel lines connected to the Motor Control Module (MCM). Refer to section 2.10.
26. Remove any electrical components, accessories, connectors or wiring looms from the engine.
27. With the engine mounted on the overhaul stand, remove all of any remaining subassemblies and parts from the cylinder block.
    [a] Remove the rocker cover. Refer to section 1.9.
    [b] Remove the engine lifter brackets. Refer to section 1.6.
    [c] Remove the crankshaft pulley. Refer to section 1.10.
    [d] Remove the crankshaft and vibration damper. Refer to section1.10.
    [e] Remove the flywheel. Refer to section 1.11.
    [f] Remove flywheel housing. Refer to section 1.12.
    [g] Remove idler gears. Refer to section 1.15.
    [h] Remove camshaft housing. Refer to section 1.5.
    [i] Remove the cylinder head. Refer to section 1.2.
    [j] Remove the oil pan. Refer to section3.2.
    [k] Remove the piston and connecting rod assembly. Refer to section 1.13.
    [l] Remove cylinder liners. Refer to section 1.14.
    [m] Remove the crankshaft. Refer to section 1.10.

NOTICE:
Before removing main bearing caps, be sure each is stamped or punch-marked in numerical order, beginning with No. 1 at the front, to ensure installation in their original position. Mark all caps on the oil cooler side (left side) of the engine to prevent reversal at assembly. Failure to mark numerical order may result in the caps being put back in incorrect order, improper crankshaft support and severe crankshaft or bearing damage or both.

    [n] Remove the crankshaft main bearings. Refer to section 1.10.

1.1.2 Cleaning the Cylinder Block

Before removing cylinder liners for block cleaning, the liner bores should be gaged to determine whether liner replacement is necessary.

Remove cylinder liners with the cylinder liner removal tool (J–45876) before putting the block in cleaning or descaling baths, to avoid trapping cleaning agents in block liner seating bores.

Clean the cylinder block as follows:

1. Remove all oil and water gallery and weep hole plugs to allow the cleaning solution to enter the inside of the oil and water passages. On current block, remove bolt-on plate or piston-cooling oil spray nozzle at the base of each cylinder bore.
2. Immerse and agitate the block in a hot bath of a commercial, heavy-duty alkaline solution.
3. Wash the block in hot water or steam clean it to remove the alkaline solution.
4. If the water jackets are heavily scaled, proceed as follows:
   [a] Immerse and agitate the block in a bath of inhibited phosphoric acid.
   [b] Allow the block to remain in the acid bath until the bubbling action stops (approximately 30 minutes).
   [c] Lift the block, drain it and immerse it again in the same acid solution for 10 more minutes. Repeat until all scale is removed from the water jacket area.
   [d] Rinse the block in clear, hot water to remove the acid solution.
   [e] Neutralize the acid that may cling to the casting by immersing the block in an alkaline bath.
   [f] Wash the block in clean water or steam clean it.

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. Dry the cylinder block with compressed air. Blow out all of the bolt holes and passages with compressed air.

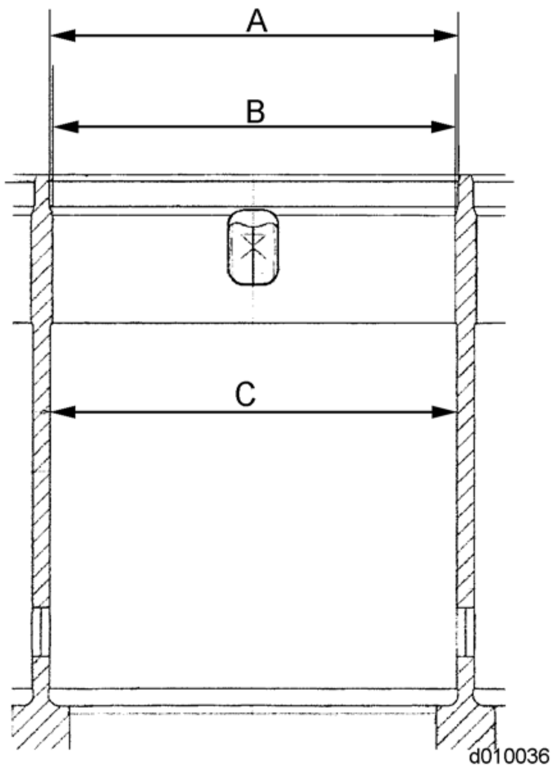
NOTE:
The above cleaning procedure may be used on all ordinary cast iron and steel parts for the engine. Aluminum parts, such as flywheel housing, air intake manifold, oil filter adaptor and the camshaft gear access cover should NOT be cleaned in this manner. Mention will be made of special procedures when necessary.

6. Be certain that all water passages and oil galleries have been thoroughly cleaned and dried. Install new cup plugs using a coating of good grade non-hardening sealant such as Loctite® 620 or equivalent."

1.1.2.1 Inspection of the Cylinder Block

Perform the following for cylinder block inspection:

1. Remove the cylinder liners and check to determine whether liner replacement is necessary.
2. Measure the bore of each cylinder with cylinder bore gage (J–5347–B) which has a dial indicator calibrated in 0.0001 in. increments.
3. Measure cylinder block bore, at the positions on axis 90 degrees apart. If the diameter does not exceed the dimensions , the block may be reused.



A. Ø 167

B. Ø 164.4

C. Ø 166

Figure 1-7 Cylinder Block Bore Diameters

NOTE:
The above measurements are average gage readings at each position. Also, the out-of-round must not exceed 0.0254 mm (0.001 in.).

Location	Diameter, mm	Diameter, in.
A	167	6.575
B	164.4	6.4
C	166	6.535

Table 1-1 Acceptable Cylinder Bore Diameters

1.1.2.2 Inspection of Main Bearing Bores

Perform the following steps for main bearing bore inspection:

1. Install the main bearing caps in their original positions. Lubricate the cap bolt threads and head contact surfaces with a small quantity of clean engine oil

NOTE:
The following torque sequence is for the 14.8L engine only.See Figure 1-8.

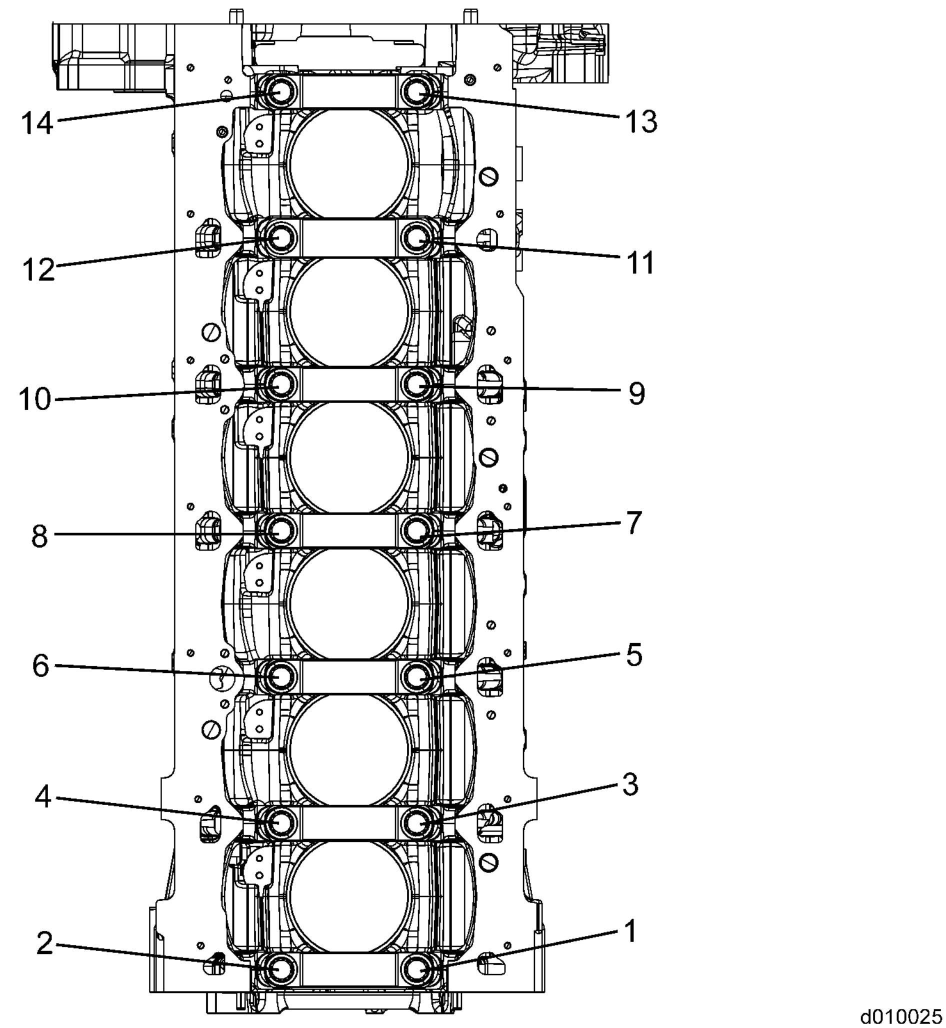


Figure 1-8 Main Bearing Cap Torque Sequence

2. Install the main cap bolts and torque bolts to 50 N·m (37 lb·ft).
3. Torque the main cap bolts again to 140 N·m (103 lb·ft).
4. Final torque the main cap bolts to 300 N·m (221 lb·ft).
5. Torque turn the bolts 90° and again torque turn the bolts 90°.

6. Measure the main bearing bores using dial bore gage which has a dial indicator calibrated in 0.0001 in. increments. Set the cylinder bore gage on zero in master setting fixture.

The bore diameter specifications is 127 mm (5 in.) to 127.025 mm (5.001 in.). Line boring is also necessary when a bearing cap must be replaced due to breakage or spun-bearing damage.

NOTE:
Dial bore master setting fixture should be used to zero the cylinder bore gage.

1.1.2.3 General Inspection

Check all machined surfaces for nicks or burrs that could affect the fit of mating parts. Clean up as necessary by stoning. Also inspect all tapped holes for thread damage and retap or install helical thread inserts as necessary. Replace any loose or damaged dowel pins.

1.1.2.4 Rust Prevention

After inspection, if the cylinder block is not to be used immediately, spray the machined surfaces with engine oil.

NOTICE:
Castings free of grease or oil will rust when exposed to the atmosphere. Rust on machined surfaces may result in leakage.

If the block is to be stored for an extended period of time, spray or dip it in a polar-type rust preventive such as "Tectyl® 502-C" from Valvoline Oil Company (or equivalent).

Tectyl® is a registered trademark of Ashland Oil, Inc.

1.1.3 Reassembly of Cylinder Block

After the cylinder block has been cleaned and inspected, assemble the engine as follows:

WARNING:

EYE INJURY

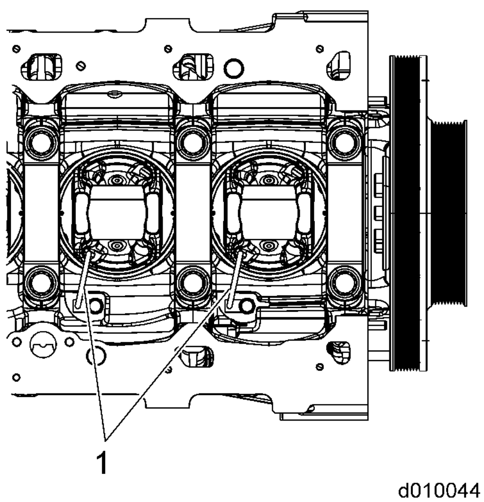
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 276 kPa (40 psi) air pressure.

1. Before a reconditioned or new service replacement cylinder block is used, steam clean it to remove the rust preventive and blow out the oil galleries with compressed air.
2. If a new service replacement block is used, stamp the engine serial number and model number on the pad provided on the front left side of the block.
3. Also stamp the position numbers on the main bearing caps and the position of the No. 1 bearing on the cooler side of the oil pan mounting flange of the block.
4. Install the main bearing caps in their original positions.

NOTICE:
Always check to make sure cooling nozzles are open and aligned after piston installation. An obstructed, misaligned, bent, or damaged nozzle may not provide proper piston cooling. A loosened nozzle may cause a loss of main gallery oil pressure. In either case, piston overheating or lack of adequate lubrication may result in severe engine damage.

NOTICE
When installed ensure the spray nozzles are aligned.

5. If removed install oil spray nozzles. Torque plate nozzle retaining bolts to 30 N·m (22 lb·ft).See Figure 1-9.



1. Oil Spray Nozzle Location

Figure 1-9 Oil Spray Nozzle Location

6. Install all of the required cup plugs. Use a good grade of non-hardening sealant such as Loctite® 620 (or equivalent). Apply a thin coat of sealant just inside the chamfer where the plug is to be installed and install using cup plug installation tool set (J–35653).
7. With the engine mounted on the overhaul stand, install all of any remaining subassemblies and parts on the cylinder block.
   [a] Install the crankshaft main bearings. Refer to section 1.10.
   [b] Install the crankshaft. Refer to section 1.10.
   [c] Install the cylinder liner. Refer to section 1.1.

[d] Install the piston and connecting rod assembly.1.13.

[e] Install the gear train. Refer to section 1.15.

[f] Install the flywheel housing.Refer to section 1.12.

[g] Install the oil pan. Refer to section3.2.

[h] Install the flywheel. Refer to section 1.11.

[i] Install the cylinder head. Refer to section 1.2.

[j] Install camshaft housing. Refer to section 1.5.

[k] Install the crankshaft vibration damper. Refer to section 1.10.

[l] Install the crankshaft pulley. Refer to section 1.10.

[m] Install the engine lifter brackets. Refer to section 1.6.

[n] Install the rocker cover. Refer to section 1.9.

[o] Install any electrical components, accessories, connectors or wiring looms that were removed during disassembly.

[p] Install the Motor Control Module (MCM). Refer to section 2.10.

[q] Install a suitable lifting device to the engine.1.6.

WARNING:

FALLING ENGINE

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

[r] Remove the engine from the overhaul stand.

[s] Prime engine lubrication system.

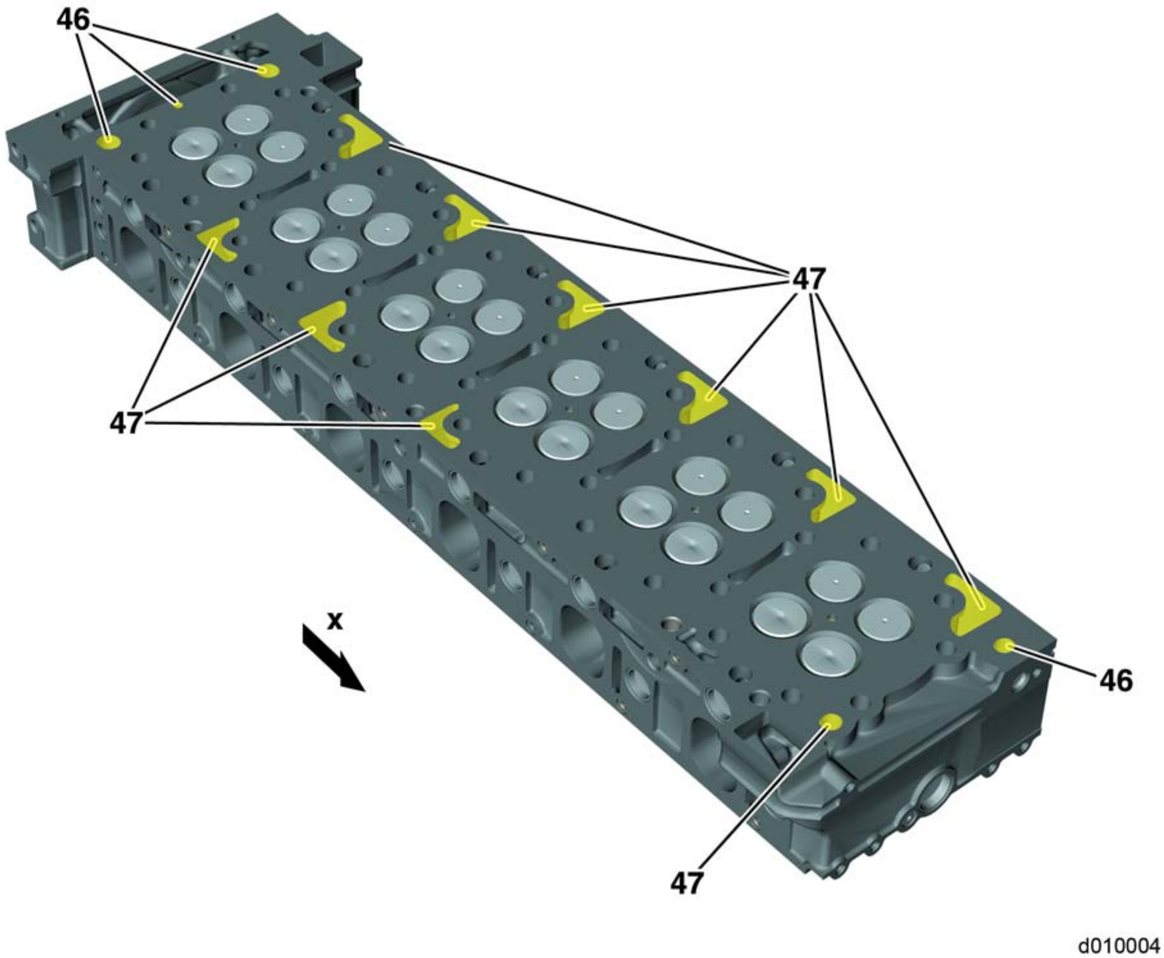
Transfer the engine to a suitable engine dynamometer test stand. Operate the engine on a dynamometer following the Run-in procedure.

Install the engine in the equipment from which it was removed.

1.2 CYLINDER HEAD

The cylinder head has been designed with a compacted graphic iron material. There are two intake and exhaust valves per cylinder. To ensure the correct bolts are used when installing the cylinder head, the bolt thread size 16 is stamped on the head of the bolt. All bolts must be tightened in the correct sequence. The valve train assembly needs to be removed in order to access the cylinder head bolts.

The cylinder head has a split coolant jacket, the coolant flows around the cylinder to the inlet side of the head and then to the exhaust side. The advantage is coolant flows to the injectors and the valve seat rings in the lower cooling level (51) of the cylinder head. The coolant then flows around in the upper level (50) of the cylinder head and cools the valve guides. This design offers a very even and highly effective cooling system.

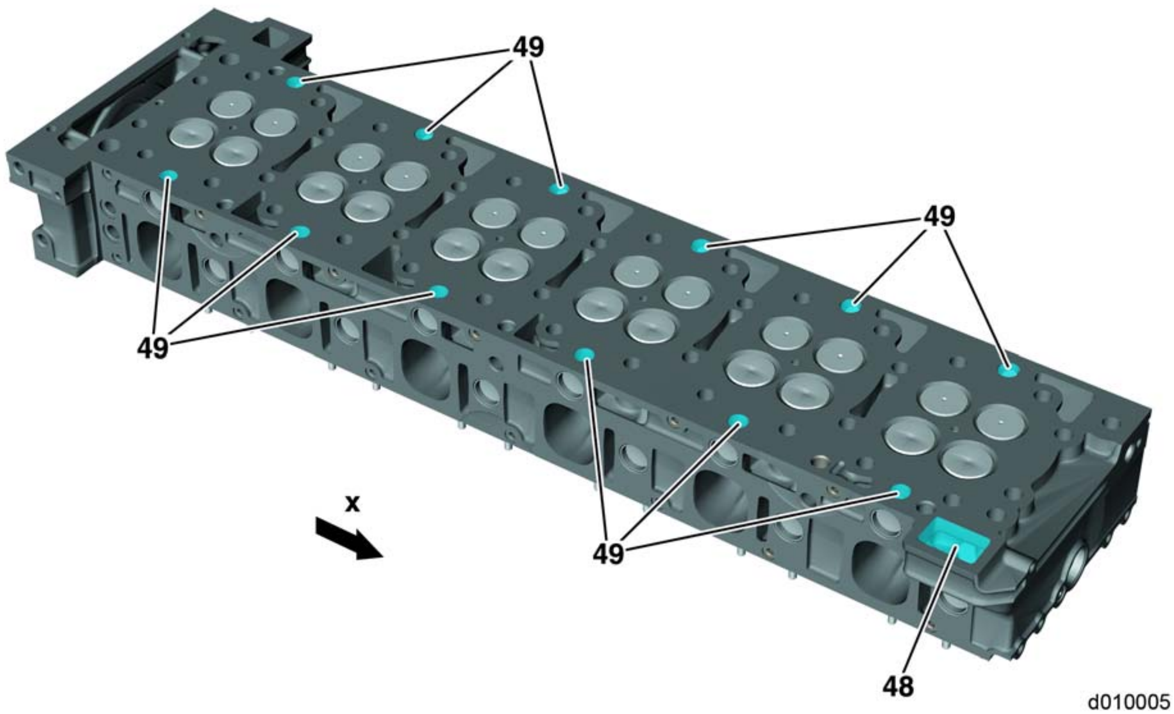


46. Oil Transfer Holes from Cylinder Block to Cylinder Head

47. Oil Return Openings or Oil Return Holes From Cylinder Head to Cylinder Block

x. Front of Engine

Figure 1-10 Oil Hole Location

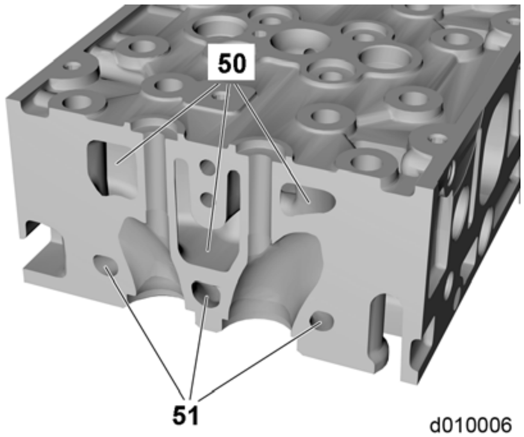


48. Water Return Openings from Cylinder Head to Cylinder Block

49. Water Transfer Holes from Cylinder Block to Cylinder Head

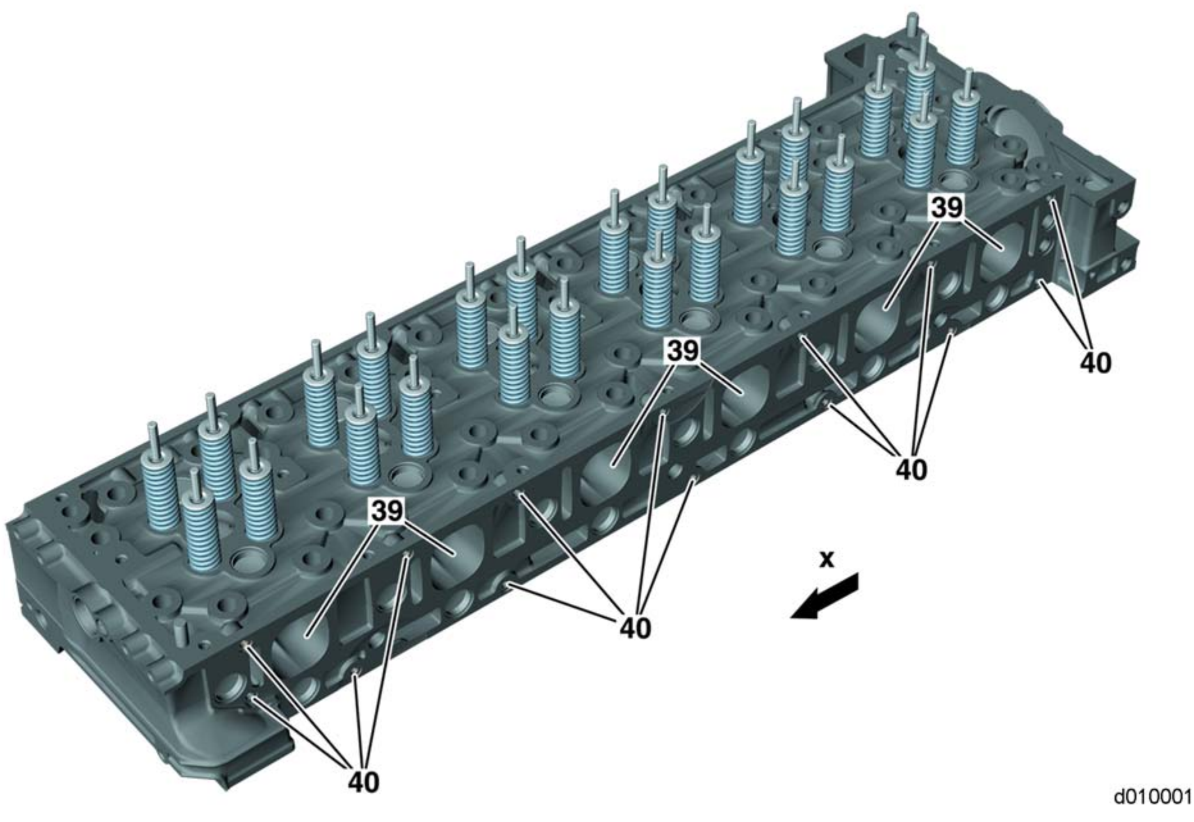
x. Front of Engine

Figure 1-11 Water Hole Location



50. Upper Cooling Level
51. Lower Cooling Level

Figure 1-12 Cooling Levels



39. Inlet Ducts
40. Holes for Installing the Intake Manifold
x. Front of Engine

Figure 1-13 Cylinder Head Inlet Duct Location

1.2.1 Removal of the Cylinder Head

Because optional and accessory equipment varies with the engine application, this procedure covers only the basic engine. If the engine is equipped with accessories that affect cylinder head removal, note the mounting details of each to assure correct installation at reassembly.

Remove the cylinder head as follows:

1. Steam clean the engine.
2. Disconnect the batteries.
3. Drain the fuel system.
4. Drain the oil.
5. Drain the coolant.
6. Remove the turbocharger inlet pipe.
7. Remove rocker cover.
8. Remove intake air temperature sensor.
9. Disconnect coolant temperature sensor harness.
10. Remove injector feed lines from fuel rail.
11. Remove low pressure return and high pressure rail lines.
12. Remove amplification, needle pressure limiting valve (PLV) lines
13. Disconnect injector harness from injectors and Engine Brake solenoid.
14. Remove the injectors.
15. Remove intake elbow, mixer pipe and venturi.
16. Remove the rocker arm shafts.
17. Loosen dose coolant lines at the water manifold and exhaust gas recirculation (EGR) vent line.
18. Remove the intake and exhaust camshafts.
19. Remove the camshaft frame.
20. Remove EGR actuator coolant line block to actuator.
21. Disconnect EGR linkage from actuator.
22. Disconnect EGR actuator connector and remove heat shield.
23. Remove EGR hot pipe.

NOTE:
Before removing the four bolts securing the turbocharger to the exhaust manifold ensure the turbocharger and axial power turbine are supported.

24. Remove the turbocharger flange bolts.

25. Using the appropriate tool remove the 40 bolts securing the cylinder head to the cylinder block.
26. Using a suitable lifting device, remove the cylinder head from the cylinder block.
27. Remove and discard the metallic gasket from the cylinder block.

1.2.2 Cleaning of the Cylinder Head

Clean the cylinder head as follows:

1. Keep parts segregated according to original position to assure proper reassembly, if parts are to be reused.
2. Remove all plugs.
3. Steam clean the cylinder head once it has been stripped.
4. Clean the head in a descaling bath.
5. Clean the valves, springs, and rocker shafts in fuel oil and blow dry with compressed air.
6. Clean the rocker arm assemblies.

1.2.3 Assembly of Cylinder Head

Assembly the cylinder head 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.

NOTICE:

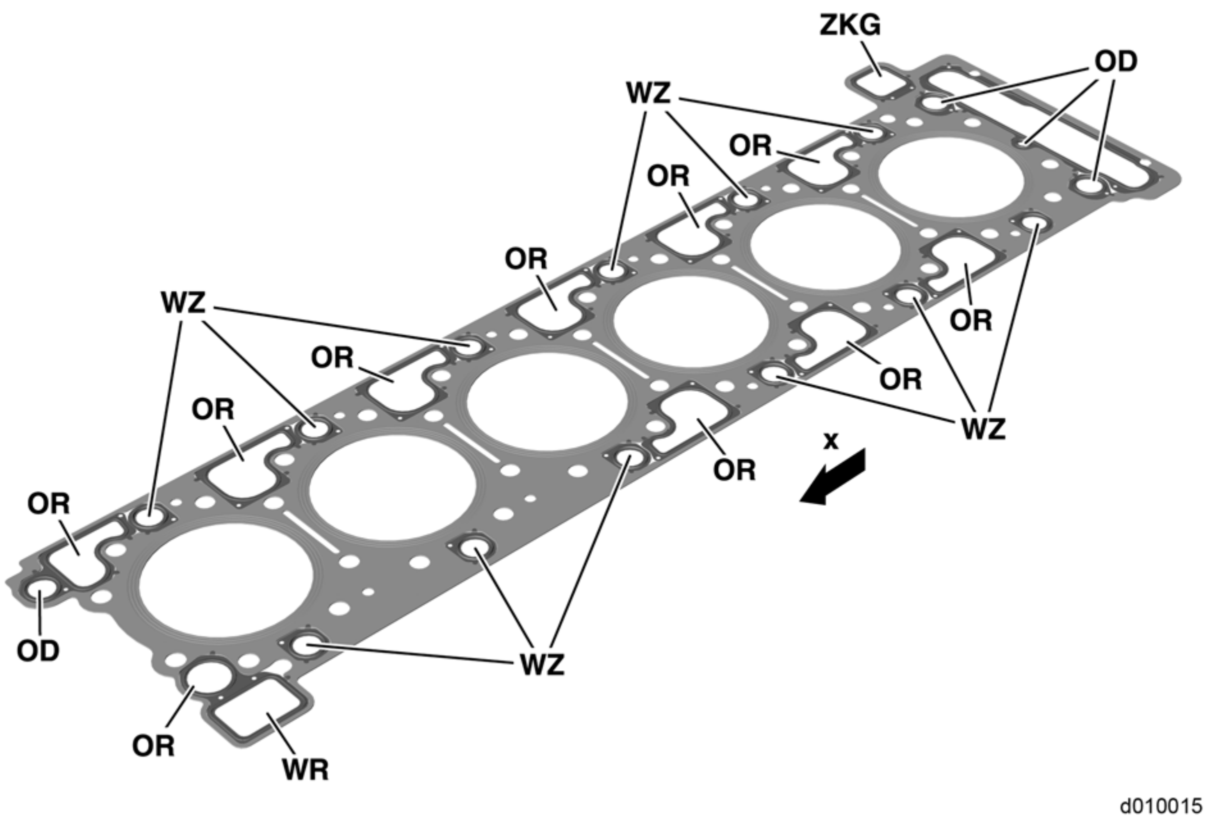
If the cylinder head is to be replaced, the new head must be thoroughly cleaned before installation to remove all rust and preventive compound, especially from the fuel and oil galleries. This can be done by immersion in a bath of fuel oil or mineral-spirits-based solvent and scrubbing out all openings with a soft bristle brush. When clean, blow the head dry with compressed air.

1. Install all of the required cup plugs using a good grade of non-hardening sealant, such as Loctite® 620 or equivalent, on the cup plugs. Use cup plug installation tool set (J–35653).
2. Ensure that all cup plugs on the front face of the cylinder head are flush or below the surface.
3. Install valve guides and seats, valves, valve stem seals, valve springs and keepers.

1.2.4 Installation of the Cylinder Head

Install the cylinder head as follows:

1. Ensure piston domes and the cylinder head and cylinder block firedeck surfaces are clean and free of foreign matter. Inspect the head bolt holes in both block and head for the presence of oil, water, dirt, or damaged threads, clean or retap as necessary.
2. Verify that the cylinder liner protrusion heights are all the same prior to installing the cylinder head.
3. Install cylinder head guide studs.
4. Position a new cylinder head gasket onto engine block. See Figure 1-14.



OD .Engine Oil Feed Hole

OR. Engine Oil Return Opening

WZ. Coolant Feed Hole

WR. Coolant Return Opening

ZKG. Opening for Blow-by Duct to Crankcase Vent

Figure 1-14 Cylinder Head Gasket

5. Install four lift hooks onto cylinder head.
6. Lift the cylinder head into position using an appropriate lifting device. Lower into place over the guide studs and dowel pins until it is seated on the engine block.

7. Remove the guide studs.
8. Remove the lifting hooks from the cylinder head.
9. Coat the threads and underside of bolt head with clean engine oil before installation.
10. Install the 40 cylinder head bolts into the cylinder head.
11. Torque the bolts to 50 N·m (37 ft·lb) and torque bolts to 250 N·m (184 ft·lb) with a 2 x 90° torque turn. See Figure 1-15 for torque sequence.
12. Torque bolts 39 and 40 to 60 N·m (44 ft·lb).

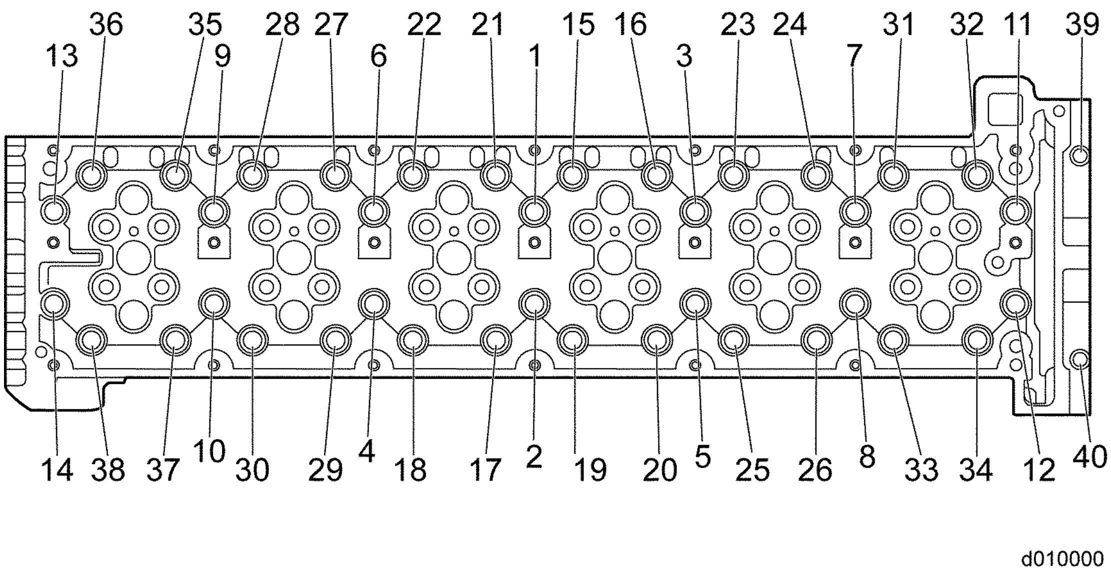


Figure 1-15 Cylinder Head Torque Sequence

13. Install rocker assembly.
14. Set the valve lash and engine brake.Refer to section 1.16.
15. Install any components that were removed and fill with required fluids as recommended. Refer to OEM guidelines.
16. Fill the cooling and lubrication systems.

WARNING:

ENGINE EXHAUST

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

17. Start the engine and check for fuel, coolant or oil leaks.
18. Shut down the engine.

1.3 VALVES

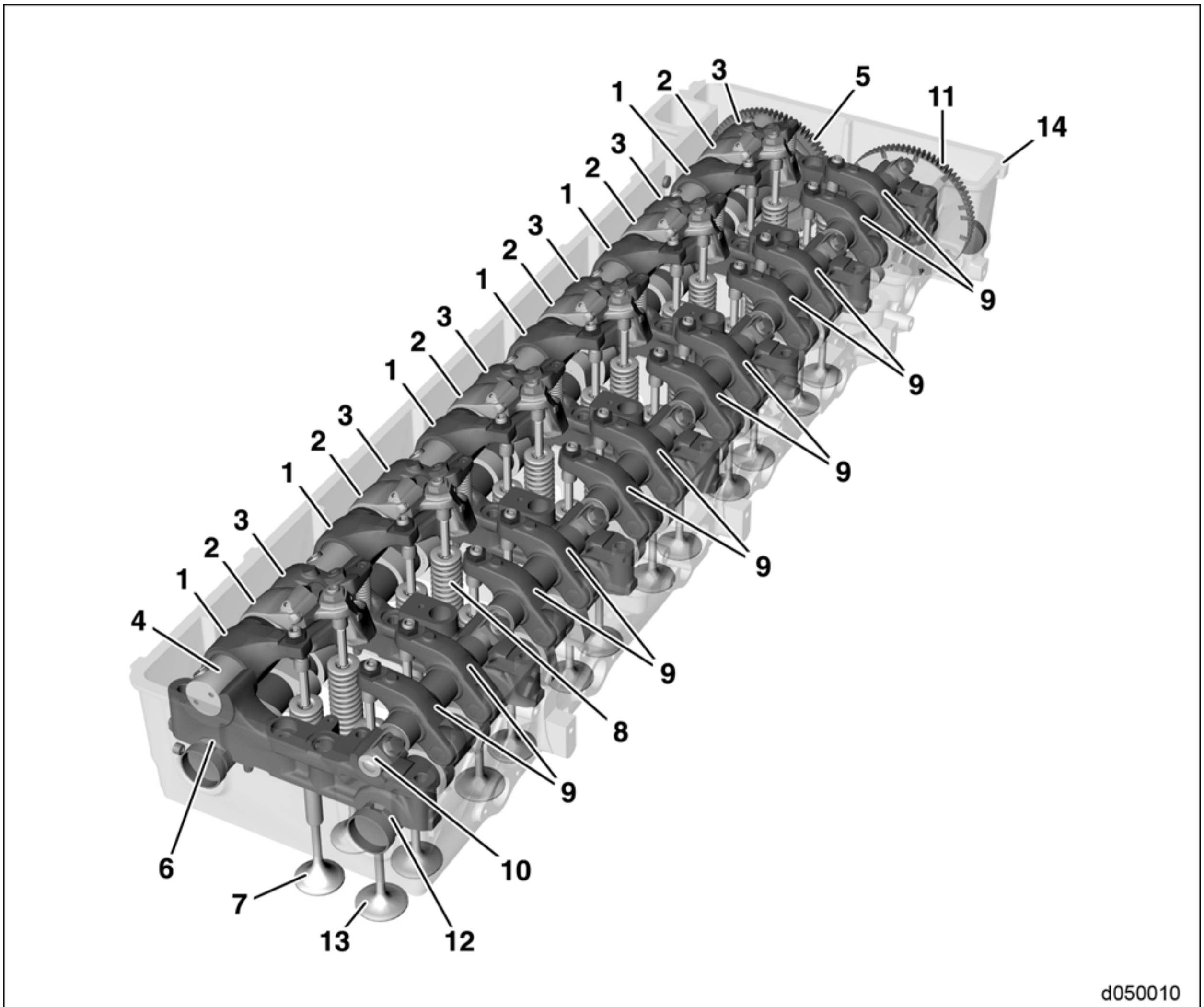
There are four valves per cylinder, two for each intake and exhaust.

Valves are made of heat-treated alloys, with heads and stems precision ground. Stem ends are hardened to minimize wear in contact with the valve rocker buttons.

All valves are retained by valve spring caps and two-piece tapered valve locks.

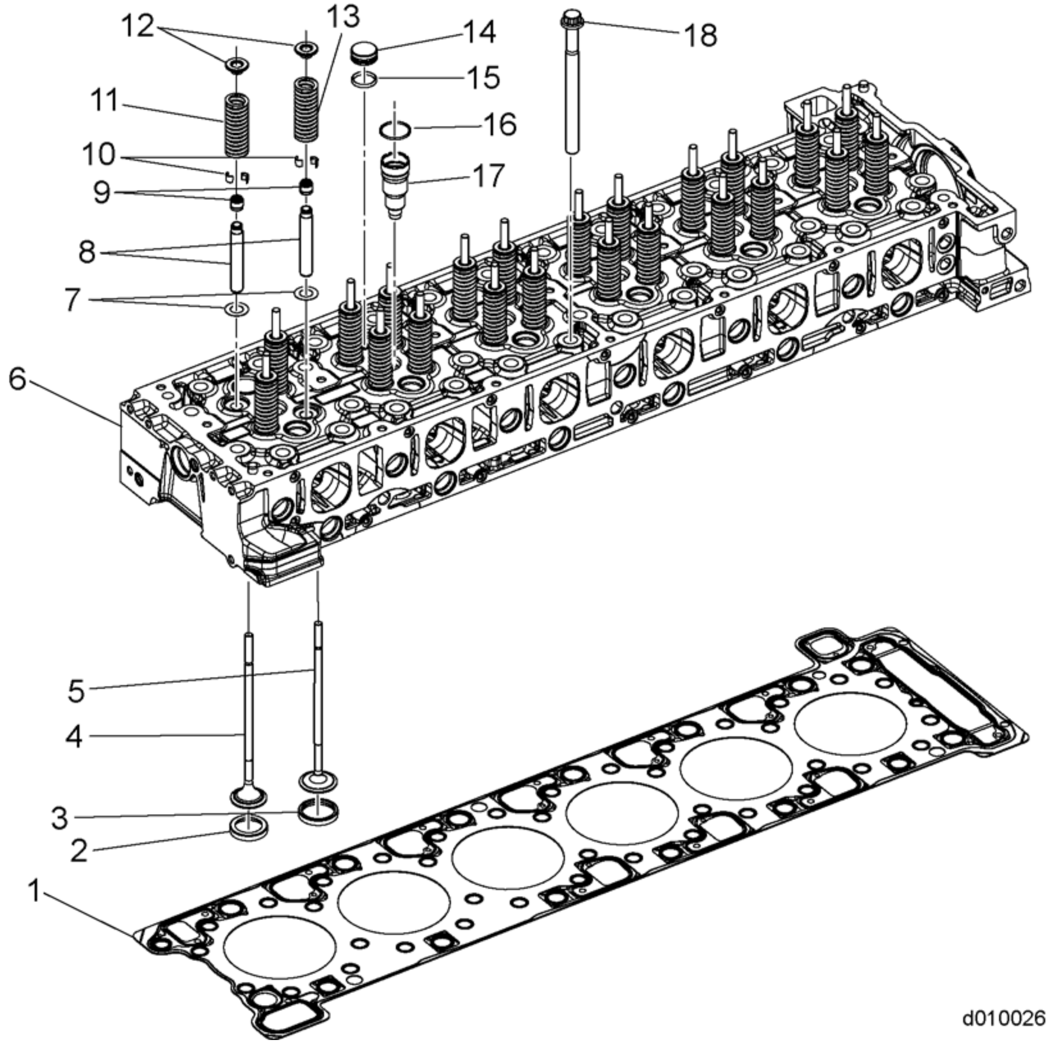
Valve stem oil seals, installed on both intake and exhaust valves, provide controlled valve stem lubrication while limiting oil consumption.

The exhaust valves use an nickel based alloy and are identified by a smaller dimple on the combustion face. The intake valves are an iron based alloy and are identified from the exhaust valve by a larger dimple on the combustion face.



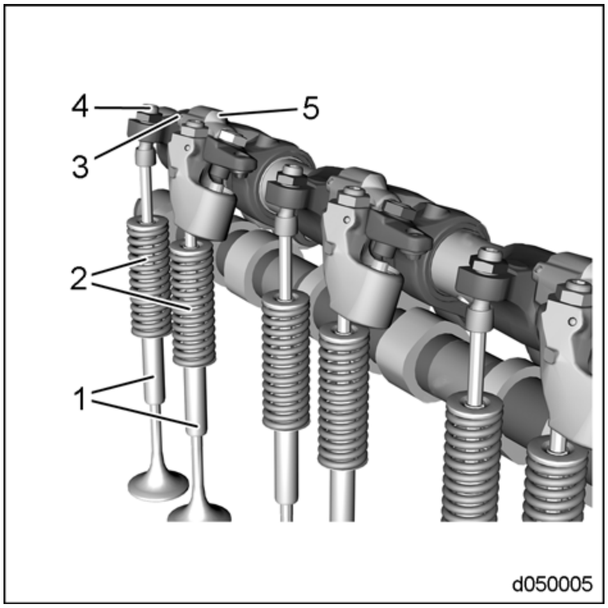
1. Exhaust Rocker Arm
2. Exhaust Rocker Arm with Hydroelement
3. Brake Rocker Arm
4. Exhaust Rocker Arm Shaft
5. Drive Gear for Exhaust Camshaft
6. Exhaust Camshaft
7. Valve
8. Valve Spring
9. Intake Rocker Arm
10. Intake Rocker Arm Shaft
11. Drive Gear for Intake Camshaft
12. Intake Camshaft
13. Intake Valve
14. Camshaft Frame

Figure 1-16 Valves Rocker Arms and Related Parts



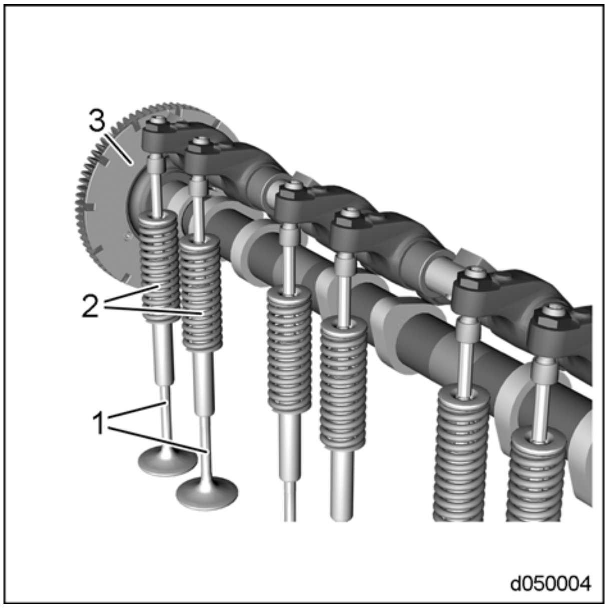
1. Cylinder Head Gasket
2. Exhaust Valve Seat Ring
3.Intake Valve Seat Ring
4. Exhaust Valve
5. Intake Valve
6. Cylinder Head
7. Washer
8. Valve Guide
9. Seal Holder
10. Valve Keeper
11. Exhaust Valve Spring
12. Spring Retainer
13. Intake Valve Spring
14. Water Jacket Cover Plug
15. Water Jacket Seal Ring Plug
16.Water Protection Sleeve Seal Ring
17.Injector Cup
18. Cylinder Head-to-Cylinder Block Bolt

Figure 1-17 Valves and Related Parts



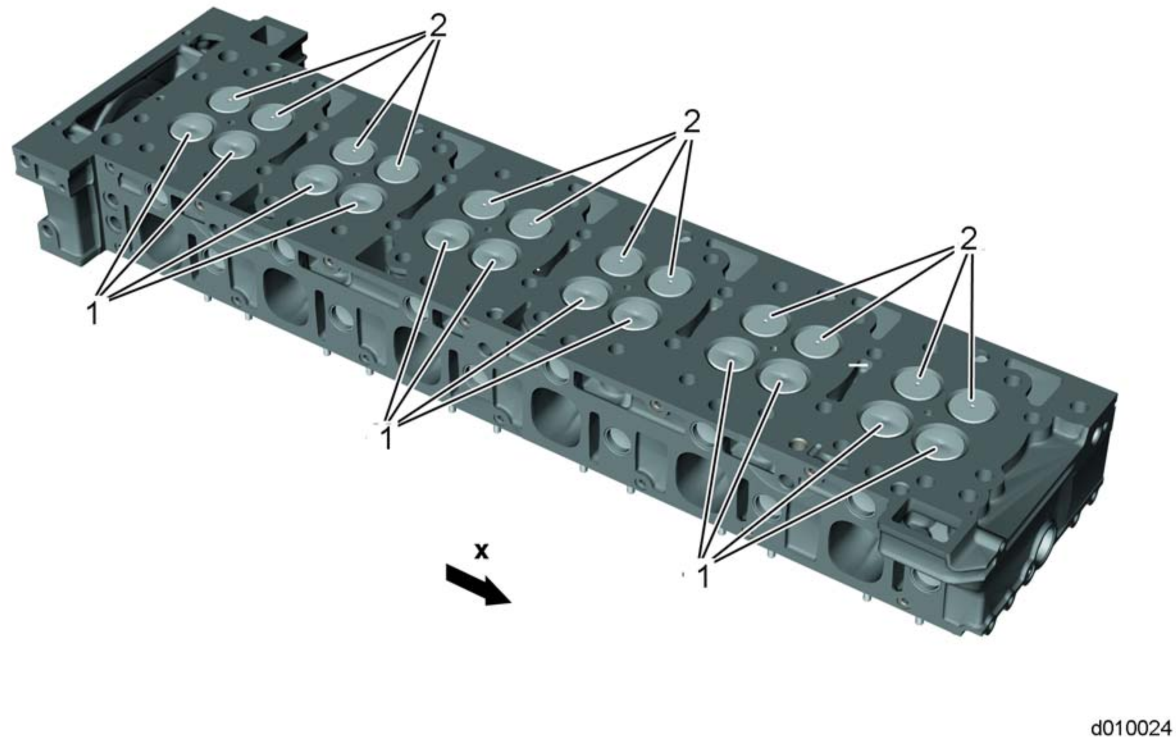
1. Exhaust Valve
2. Valve Springs
3. Exhaust Rocker Arm
4. Adjusting Element for adjusting the Valve Clearance
5. Exhaust Rocker Arm with Actuator

Figure 1-18 Exhaust Valve Assembly



1. Intake Valves
2. Valve Springs
3. Drive Gear and Timing Wheel for Intake Camshaft

Figure 1-19 Intake Valve Assembly



1.Inlet Valves

2. Exhaust Valves

x. Front of Engine

Figure 1-20 Intake and Exhaust Valve Location

1.3.1 Removal and Cleaning of Valve Spring (Cylinder Head Installed)

Remove and clean as follows:

1. Steam clean the engine.
2. Drain the fuel system.
3. Remove the rocker cover.
4. Remove the rocker arm assemblies.
5. Remove the intake and exhaust camshafts.
6. Remove the camshaft frame.

NOTE:
Fuel must be removed from the cylinder head fuel galleries prior to removing the injectors.

7. Remove the injector from the appropriate cylinder.
8. Bar the engine over until the cylinder is at top-dead-center (TDC).

9. Position the spring compressor cage portion of the valve spring compressor (J–47406) directly over the valve spring to be compressed. Engage the dowel of the cage in the closest slot of the valve spring compressor handle.

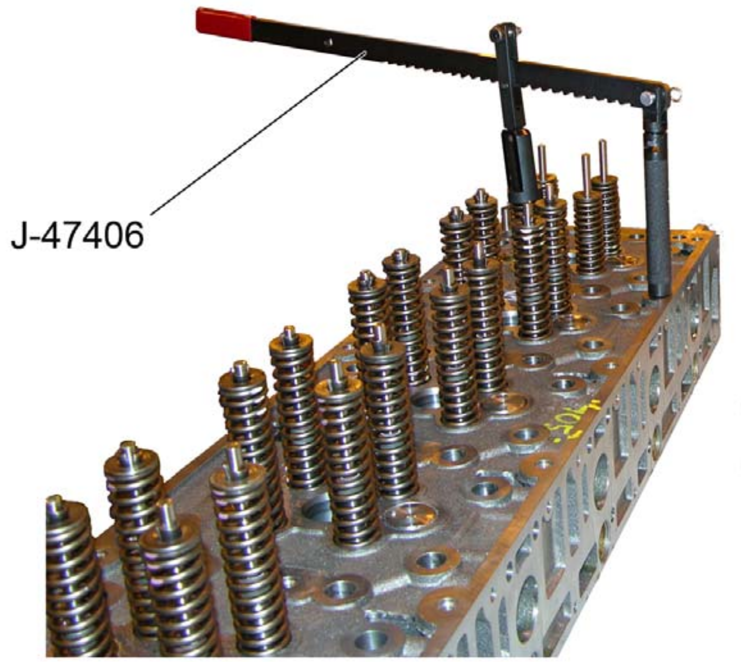


Figure 1-21 Valve Spring Compressor

NOTICE:
Do not contact the valve with the compressor tool.

10. Compress the valve spring and remove the valve locks using a small magnet to prevent the locks from falling into the cylinder head oil return galleries.
11. Release the spring and remove the valve cap and valve spring. If the valve stem oil seal is to be replaced, remove the seal and discard it.
12. On the other three valves it may be necessary to repeat these steps for cylinders being worked on.

NOTE:
All valve spring or seal removal and replacement must be completed for each cylinder being serviced while the piston is at top-dead-center, before turning the crankshaft to work on another cylinder.

1.3.2 Removal and Cleaning of the Valve Spring (Cylinder Head Removed)

With the cylinder head assembly removed from the engine, remove the valve springs as follows:

1. Remove the valve locks using valve spring compressor (J–47406) compress each valve spring.
2. Release the spring and remove the valve, valve cap and valve spring.
3. Remove the valve stem oil seal and discard the seal.
4. Remove the valve spring seat.
5. As parts are removed, mark or segregate them according to their original position for possible reuse.

1.3.2.1 Cleaning of Valves and Related Parts

Clean the valves and parts 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. Using proper eye protection, clean all of the disassembled parts with fuel oil and dry with compressed air.
2. Clean the carbon from the valve stems and wash the valves with fuel oil.
3. Clean the valve guide bore to remove all gum and carbon deposits use bore brush (J–5437) (or equivalent) for this procedure.

1.3.2.2 Inspection of Valve

The valve stems must be free from scratches or scuff marks, and, the valve faces must be free from ridges or cracks. Some pitting of the valve face is normal, and is acceptable as long as no leak paths are evident. If leak paths exist, reface the valves or install new valves. If the valve heads are warped or the valve stem is bent, replace the valves. See Figures 1-22 and 1-23.

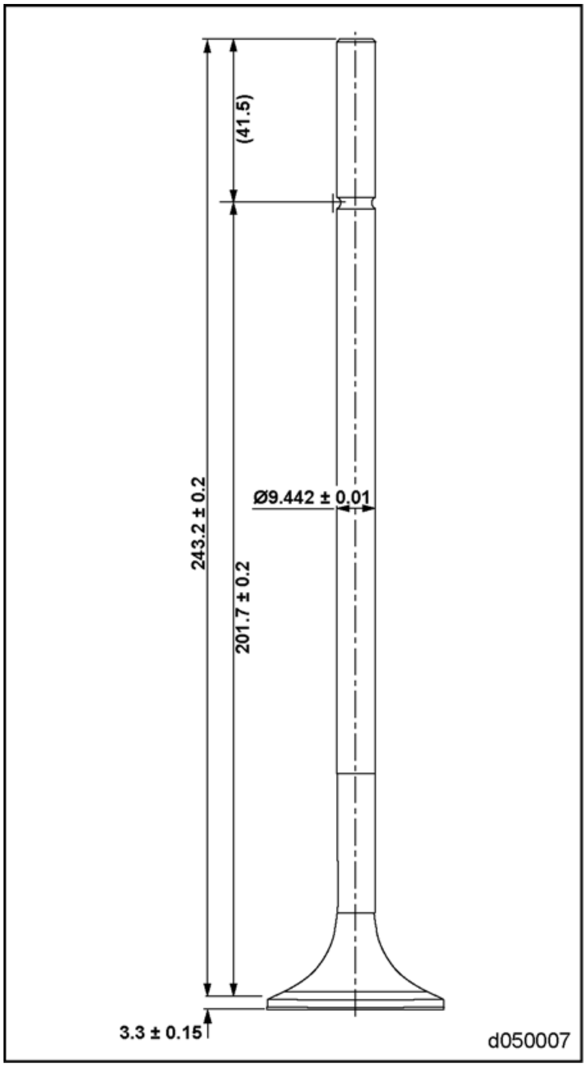


Figure 1-22 Exhaust Valve

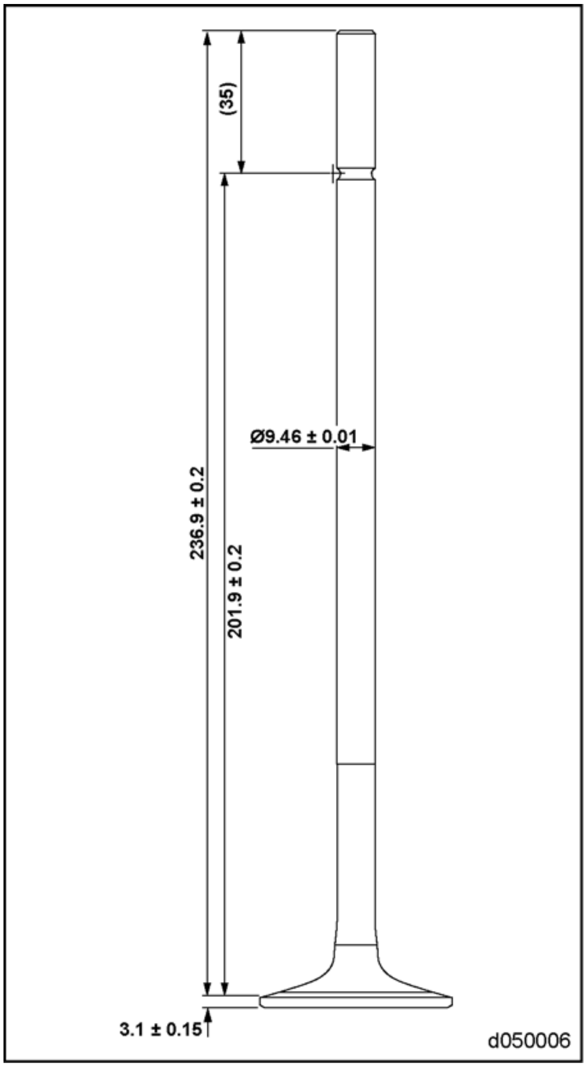


Figure 1-23 Intake Valve

1.3.2.3 Inspection of Valve Springs

Inspect the valve springs and replace any that are pitted or cracked. The entire spring should be inspected. When a broken spring is replaced, the spring retainer and valve locks for that valve and spring should also be replaced.

1.3.3 Installation of Valve, Spring, Seal and Valve Cap

Install as follows:

1. Position the cylinder head on a work bench. Lubricate the valve stems with clean engine lubricating oil and slide them into their respective valve guides and against the valve seats. If reusing valves, install them to their original positions.
2. Install the valve spring seat over the valve guide. Install the valve stem oil seals using valve stem oil seal installation tools.
3. Install the cap over the valve stem.

NOTICE:
Ensure all valve spring seats have been installed before the valve stem seal is installed.

4. The valve stem oil seal may be installed with or without oil. Push the seal over the protector.
5. Push the seal down on the valve stem using the seal installer (J–47490).
6. When the installer tool contacts the cylinder head, the seal is correctly positioned. Be sure the installer is square against the cylinder head. Remove the seal installer and protector cap.
7. Install the valve spring and retainer. If reusing parts, install them to their original positions.
8. Using the valve spring compressor tool (J–47406), compress the valve spring only as much as required to install the valve locks. After installing the valve locks, rap the end of the valve stem sharply with a plastic mallet to seat the valve locks.

NOTE:
Always install new valve stem locks when installing valves.

NOTE:
Be sure the valve cap is properly centered and aligned to avoid scoring the valve stem. Do not compress the spring any more than necessary to install the locks, to avoid damaging the oil seal.

9. After all of the valves are installed, check the spring opening pressure on each valve using a spring load gage.

10. Note the gage reading when the valve just starts to unseat.
11. Install a new cylinder head gasket to the cylinder block.
12. Using an appropriate lifting device, install the cylinder head onto the cylinder block.
13. Install the camshaft frame, camshaft and rocker arm assemblies. Lightly lubricate the overhead assemblies with clean engine oil.
14. Lash the valves and engine brake. Refer to section 1.16.
15. Install any other components that were removed.
16. Fill the engine crankcase with the proper lubricant.
17. Fill the fuel system.
18. Close any drain cocks that were opened and fill the cooling system. Purge the air from the system using the vent in the thermostat housing. Complete filling of the cooling system is essential for proper engine operation.

WARNING:

ENGINE EXHAUST

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

19. Start the engine and check for leaks.

1.4 CAMSHAFT GEAR AND ROCKER SHAFT ASSEMBLIES

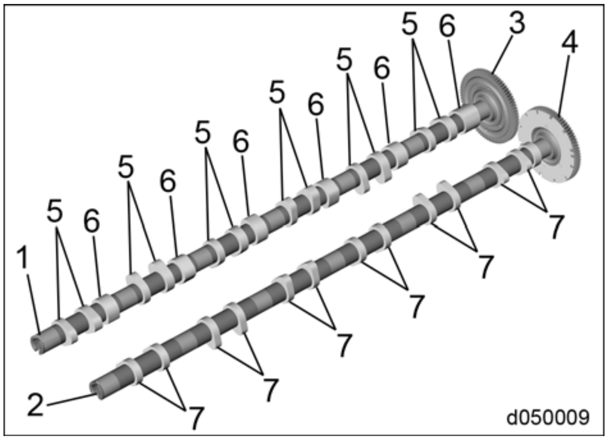
The exhaust camshaft (1) and the intake camshaft (2) are driven by the gear drive for the exhaust camshaft (3) and the gear drive for the intake camshaft by the pinion gear drive.

There are two intake lobes (7) on the intake camshaft (2) per cylinder. The corresponding intake valves are opened by the intake lobes (7) and the intake rocker arm spindle.

There are two exhaust lobes (5) and a brake lobe (6) on the exhaust camshaft (1) per cylinder.

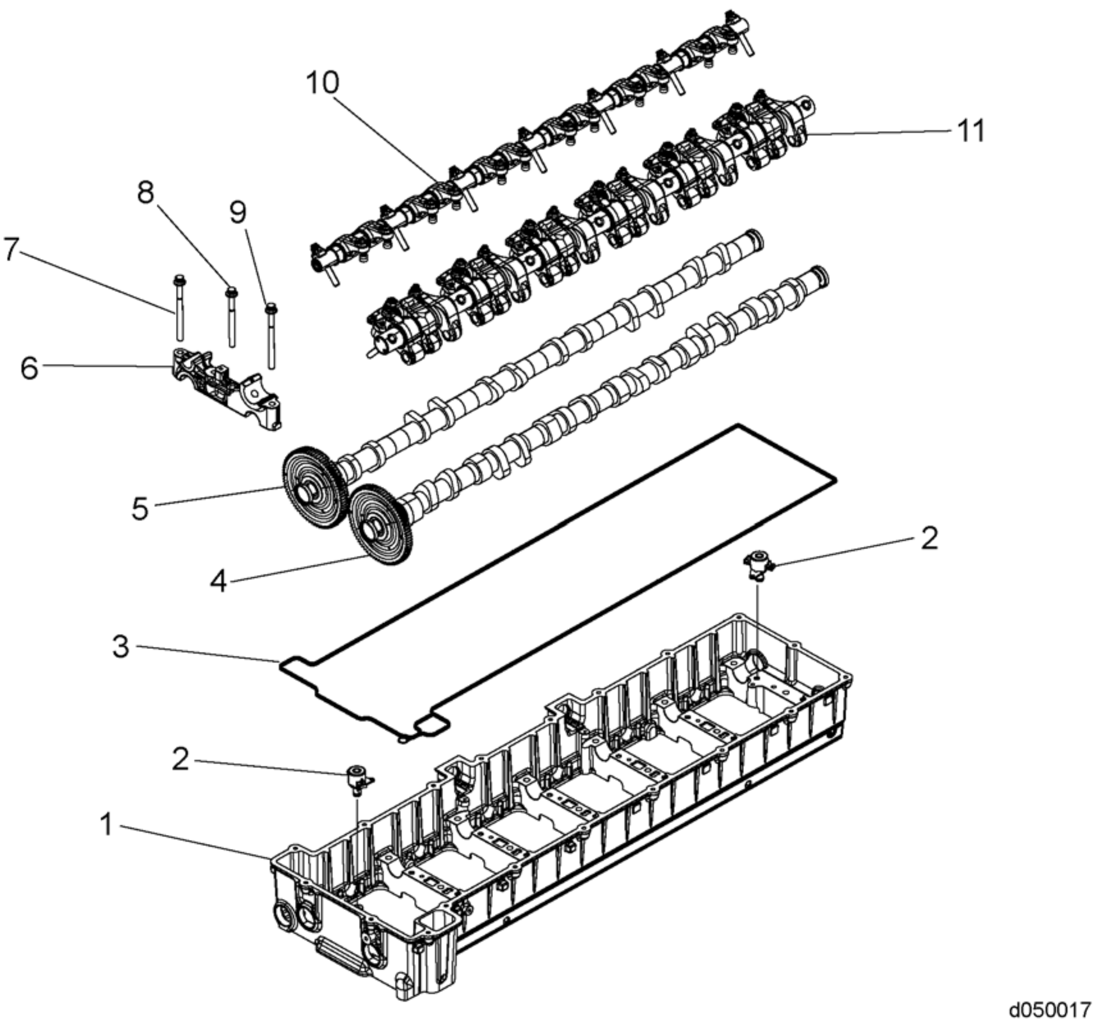
The exhaust valves are opened by the exhaust lobes (5) and the exhaust rocker arm on the exhaust rocker arm spindle.

For an activated engine brake one exhaust valve is opened per cylinder by the brake cam (6), after the beginning and before the end of the compression cycle.



1. Exhaust Camshaft
2. Intake Camshaft
3. Drive Gear for Exhaust Camshaft
4. Drive Gear for Intake Camshaft
5. Exhaust Cam
6. Brake Cam
7. Intake Cam

Figure 1-24 Camshaft and Gears



1. Camshaft Housing
2. Engine Brake Solenoid
3. Gasket
4. Exhaust Camshaft and Gear
5. Intake Camshaft and Gear
6. Main Bearing Bracket
7. Bolt 120 mm
8. Bolt 63 mm
9. Bolt 108 mm
10. Intake Rocker Arm
11. Exhaust Rocker Are

Figure 1-25 Camshaft Housing and Related Parts

1.4.1 Camshaft Gear and Rocker Shaft Assembly Removal

Remove as follows:

1. Remove pipe, air cleaner and turbocharger inlet hose.

2. Remove air cleaner housing.
3. Remove eight bolts from turbocharger air cleaner bracket and remove bracket.
4. Steam clean the engine.
5. Remove nineteen bolts from valve rocker cover and remove valve cover.
6. Loosen the seven bolts securing the intake rocker shaft to the camshaft caps.
7. Using rocker arm lifter spacer tool W470589004000 remove the intake rocker shaft assembly. See Figure 1-26.
8. Loosen the seven bolts securing the exhaust rocker shaft to the camshaft cap.
9. Using rocker arm lifter spacer tool W470589004000 remove the exhaust rocker shaft assembly from the camshaft cap. See Figure 1-26.

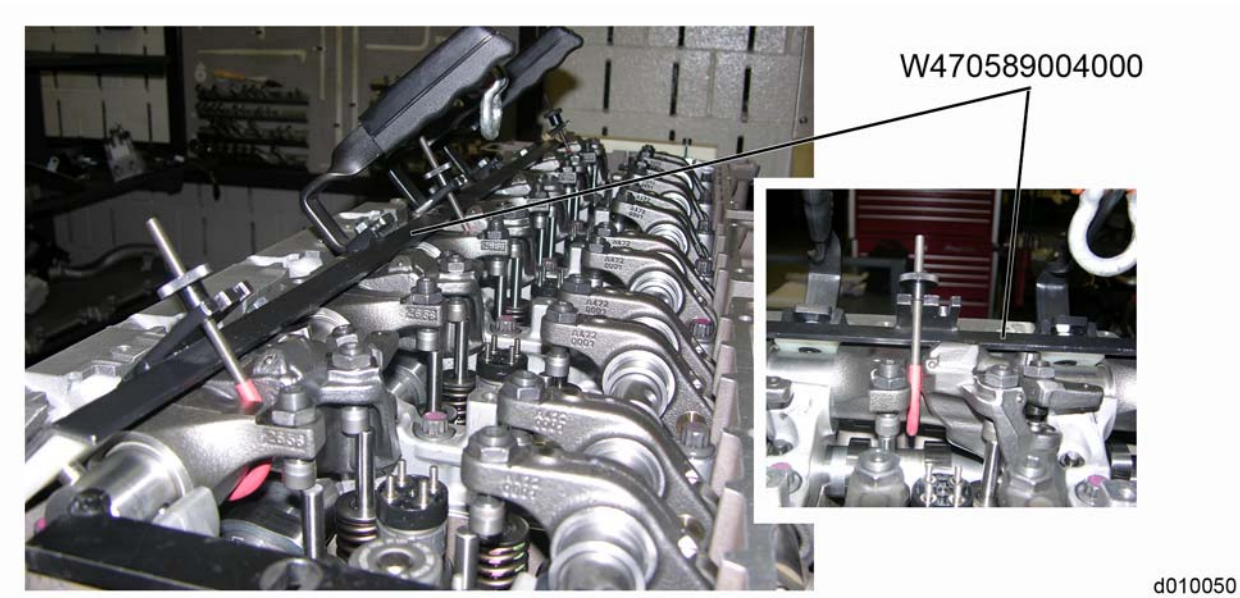


Figure 1-26 Tool W470589004000

NOTE:
The engine brake solenoids do not have to be removed unless damaged.

10. Remove the remaining bolts from the camshaft caps and remove with J–48883.
11. Remove the intake and exhaust camshaft assemblies from the camshaft housing.

1.4.1.1 Inspection of the Camshaft Gear and Rocker Shaft Assemblies

Inspect the camshaft gear and rocker shaft assemblies for damage; replace if necessary.

1.4.2 Installation of the Camshaft Gear and Rocker Shaft Assemblies

Install as follows:

1. Rotate engine to top dead center and install timing tools. Refer to section 1.15.
2. Lubricate the lower camshaft bearing surfaces and camshaft journals before installation of the camshafts. Install the exhaust and intake camshaft gear assemblies onto camshaft housing brackets.

NOTICE
The camshaft caps are numbered and need to be installed correctly.

3. Oil the journals install the seven camshaft caps onto intake and exhaust camshafts.
4. The first and seventh camshaft caps hold the engine brake solenoid to camshaft cap. Replace the O-rings on the solenoid prior to reinstallation. Install the engine brake solenoid.

NOTE:
There are 28 bolts installing the overhead assemblies, 14 120 mm (M10) bolts, seven 108 mm (M10) bolts and seven 63 mm (M8).

5. Install the 28 bolts to camshaft cap brackets and finger tighten. See Figure 1-28.
6. Torque fourteen 120 mm M10 camshaft cap bolts and seven 108 mm M10 bolts torque to 20 N·m (15 lb·ft) then torque to 50 - 55 N·m (37 - 40 lb·ft). Using torque sequence shown in Figure 1-27.
7. Torque the seven 63 mm M8 bolts to 30 N·m (22 lb·ft) using the torque sequence shown in Figure 1-27.

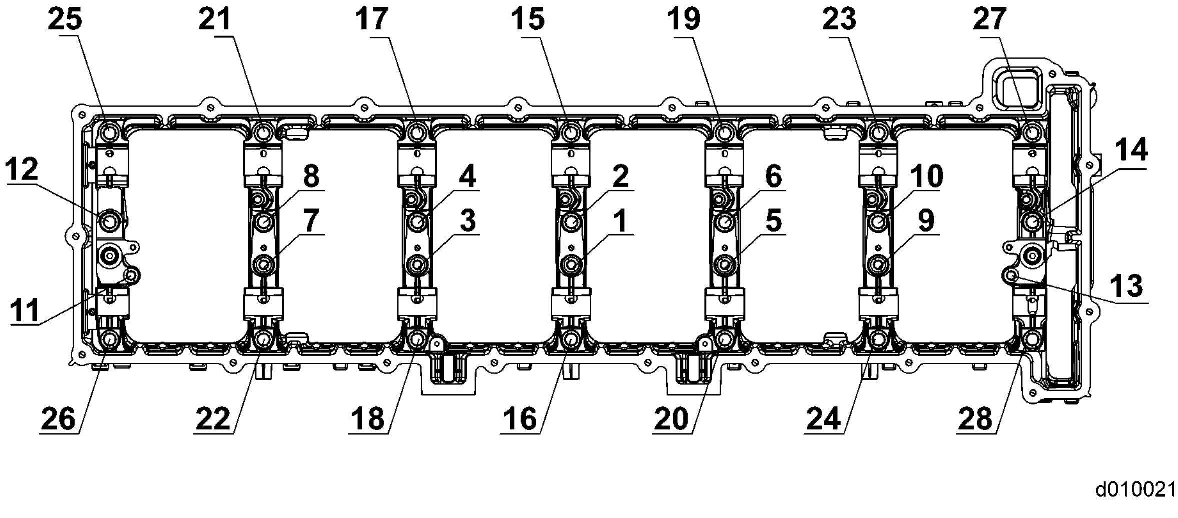


Figure 1-27 Camshaft Bolt Torque Sequence

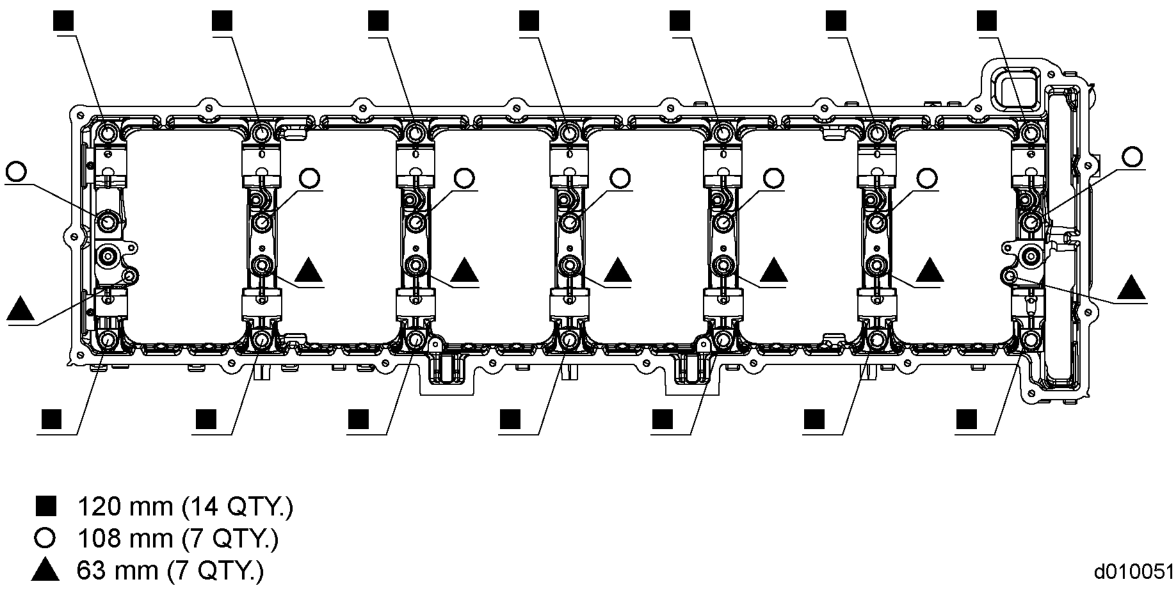


Figure 1-28 Bolt Size and Location

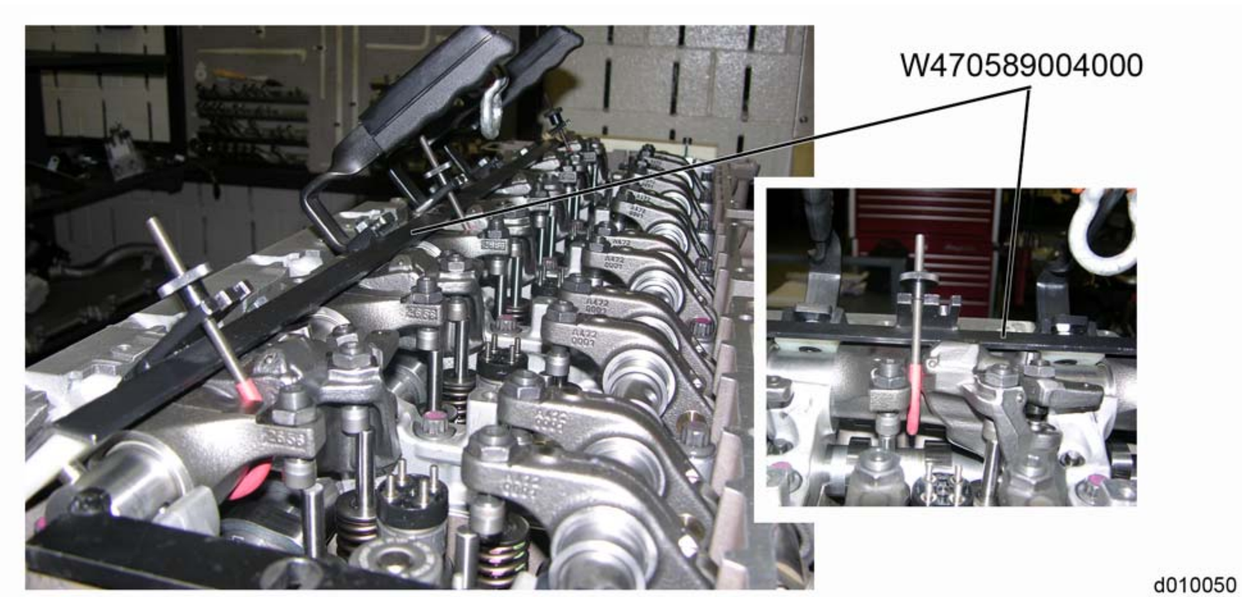
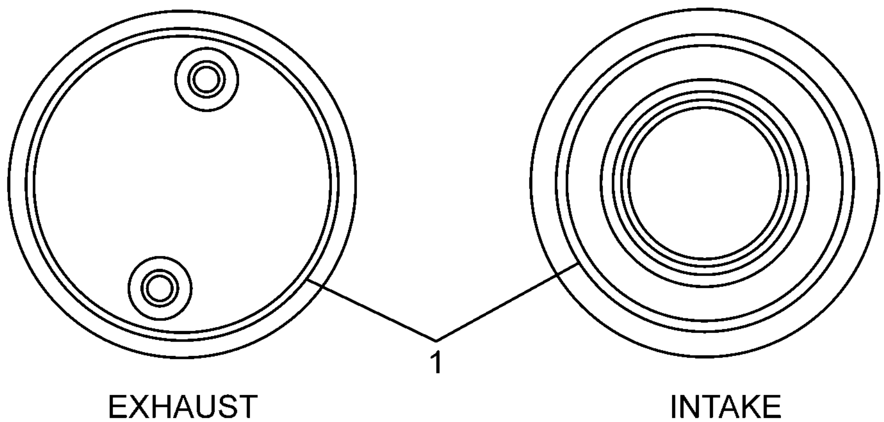


Figure 1-29 Tool W470589004000

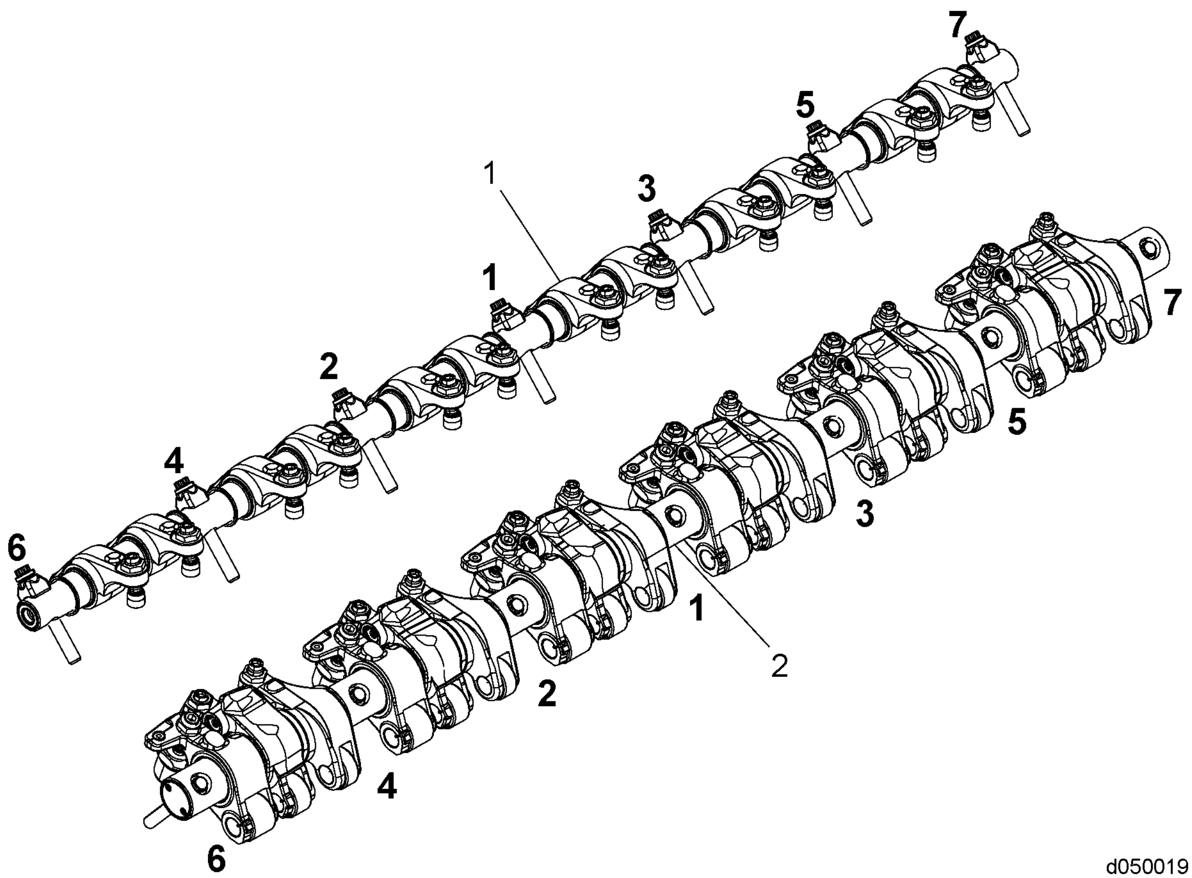
NOTICE:

The camshaft journal area is lubricated by oil that has to travel through the rocker shaft. If the rocker shaft is installed incorrectly, oil passages do not line up. This results in insufficient lubrication and damage to the camshaft journals. See Figure 1-30.



1. Marking Groove – faces rear of engine

Figure 1-30 Bolt Hole Location



1. Intake Rocker Shaft	2. Exhaust Rocker Shaft

Figure 1-31 Intake and Exhaust Rocker Shaft Torque Sequence

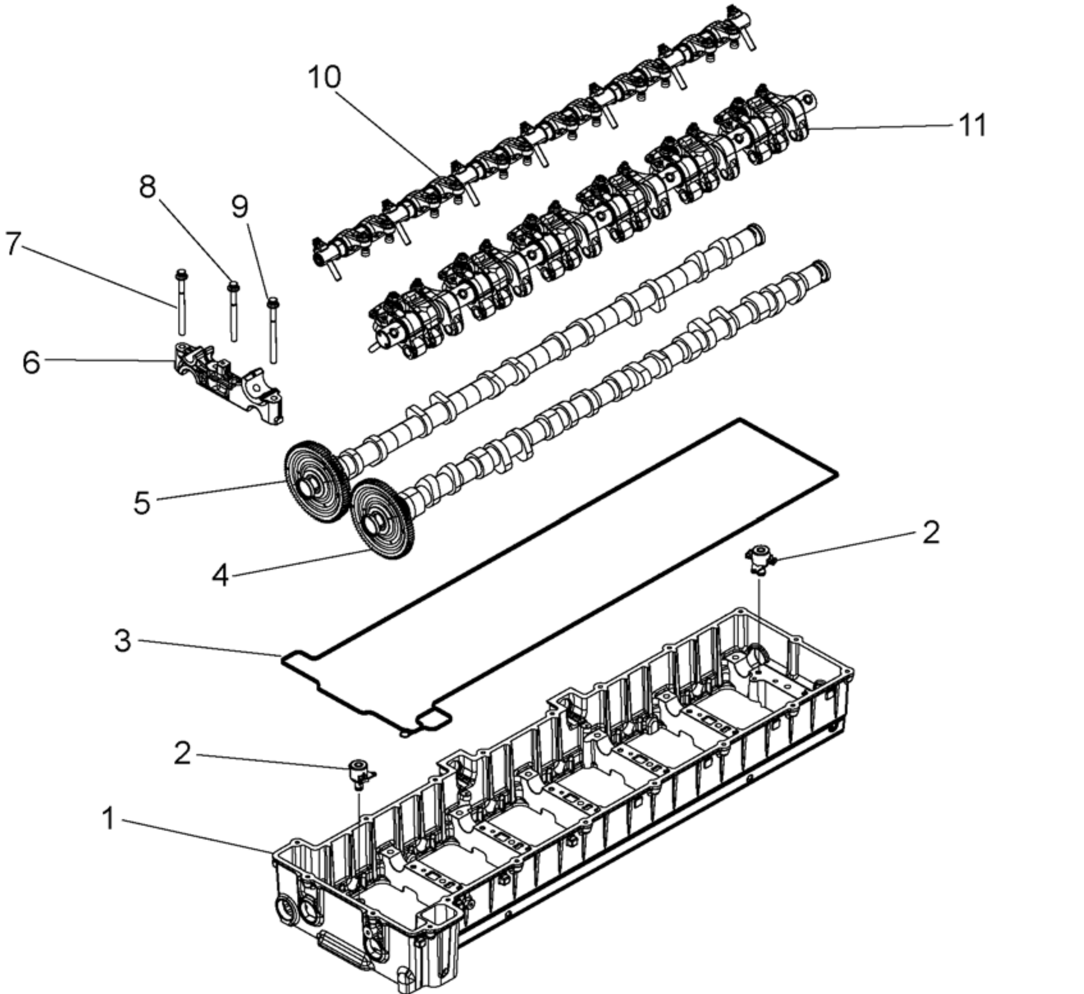
NOTICE:
Ensure when torquing the rocker shaft bolts that the bolts are torqued from the inside bolts outward in increments, before final torque . If the rocker shaft bolt is fully torqued without using the increment procedure the rocker shaft can break. See Figure 1-31.

8. Using tool W470589004000 install the assembled intake rocker arm assembly to the camshaft cap and secure with seven clamping blocks and bolts. Torque the bolts to 55 N·m (41 lb·ft) + 90° see Figure 1-29.
9. Using tool W470589004000 install the assembled exhaust rocker arm assembly to the camshaft cap. Torque the bolts to 55 N·m (41 lb·ft) + 90°. See Figure 1-29.
10. Install the injectors. Refer to section 2.2.
11. Lash the valves and engine brakes. Refer to section 1.16.
12. Install the rocker cover. Refer to section 1.9.

13. Install turbocharger air cleaner bracket with eight bolts.
14. Install air cleaner housing.
15. Install pipe, air cleaner and turbo inlet hose.

1.5 CAMSHAFT HOUSING

The camshaft housing houses the camshafts and valve train. It has internal oil passages to supply oil from the block to the camshaft and rocker bearings along with pressurized oil to the engine brake rockers via the engine brake solenoids through the exhaust shaft. The camshaft housing is made of aluminium material. See Figure 1-32.



1. Camshaft Housing
2. Engine Brake Solenoid
3. Gasket
4. Exhaust Camshaft and Gear
5. Intake Camshaft and Gear
6. Main Bearing Bracket
7. Bolt 120 mm
8. Bolt 63 mm
9. Bolt 108 mm
10. Intake Rocker Arm
11. Exhaust Rocker Arm

Figure 1-32 Camshaft Housing and Related Parts

1.5.1 Removal of the Camshaft Housing

Remove as follows:

1. Steam clean the engine.
2. Remove the rocker cover. Refer to section 1.9.
3. Disconnect the fuel injector harness from the camshaft housing.
4. Remove camshaft and rocker shaft assemblies. Refer to section 1.4.

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.

5. Disconnect the rail pressure sensor. Refer to section.
6. Disconnect camshaft position sensor. Refer to section 2.13.
7. Unclip camshaft sensor harness from camshaft housing.
8. Remove high pressure fuel line bracket.
9. Remove high pressure fuel lines from fuel rail to high pressure pump. Refer to section 2.4.
10. Remove high pressure fuel lines from fuel rail to injectors. Refer to section 2.4.
11. Remove fuel line from fuel rail to fuel filter module. Refer to section 2.4.
12. Remove bolt securing doser coolant line and P clip to camshaft housing. Refer to section 2.12.
13. Remove bolts securing camshaft housing to cylinder head. Refer to section 1.4.
14. Attach lifting device to camshaft housing and lift camshaft housing from cylinder head.

1.5.1.1 Inspection of Camshaft Housing

Inspect the camshaft housing as follows:

1. Inspect the camshaft journals for scoring or scratches, replace if damaged.
2. Inspect the camshaft caps for cracks, replace if damaged.
3. Inspect the camshaft housing for cracks and damage to the bolt hole threads in the housing, replace if damaged.
4. Inspect the camshaft housing sealing surfaces for damage. Inspect the following sealing surfaces for damage:

[a] The camshaft housing to rocker cover.

[b] The camshaft housing to cylinder head.

[c] The O-ring seal on the injector harness.

[d] The O-ring seal on the engine brake solenoids.

5. Inspect the rocker shaft installation surface located inside the camshaft housing for scoring or scratches.

1.5.2 Installation of the Camshaft Housing

Install as follows:

1. Install a new seal into the camshaft housing.
2. Using an appropriate lifting device install camshaft housing onto the cylinder head.
3. Install the camshaft assemblies into the camshaft housing. Refer to sections 1.4 and 1.4.2.
4. Place camshaft caps onto the camshaft assemblies and camshaft housing. Tap the bridges in proper position to the doweled holes.
5. The first and seventh camshaft caps hold the engine brake solenoid to camshaft cap. Replace the O-rings on the solenoid prior to reinstallation. Install the engine brake solenoid.

NOTE:
There are 28 bolts installing the overhead assemblies, 14 120 mm (M10) bolts, seven 108 mm (M10) bolts and seven 63 mm (M8).

6. Install the 28 bolts to camshaft housing and finger tighten.
7. Torque fourteen 120 mm M10 camshaft cap bolts and seven 108 mm M10 bolts and primary torque to 20 N·m (15 lb·ft) then torque to 50 - 55 N·m (37 - 40 lb·ft). Using torque sequence shown in figure 1-33.

8. Torque the seven 63 mm M8 bolts to 30 N·m (22 lb·ft) using the torque sequence shown in figure 1-33.

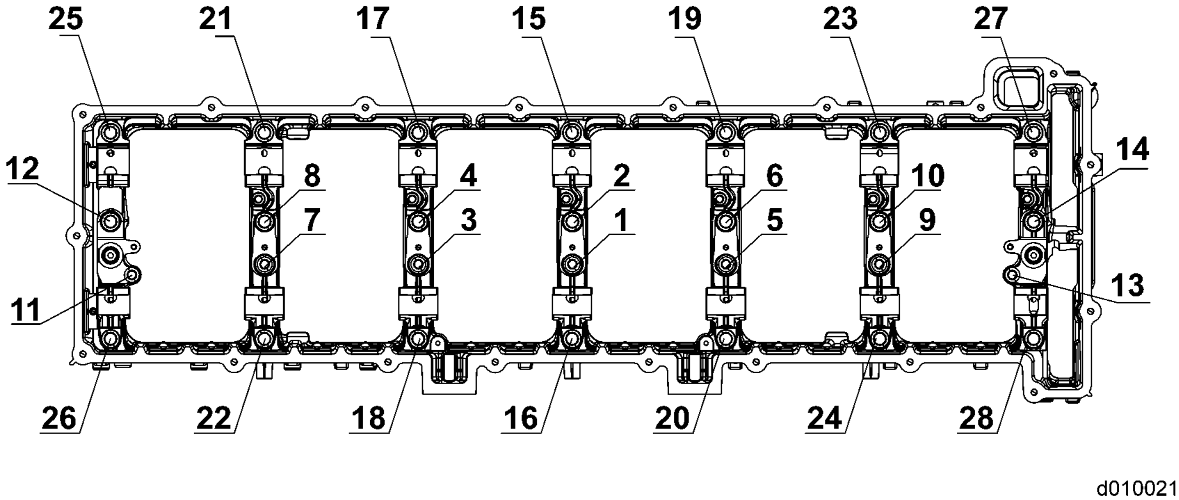


Figure 1-33 Camshaft Housing Torque Sequence

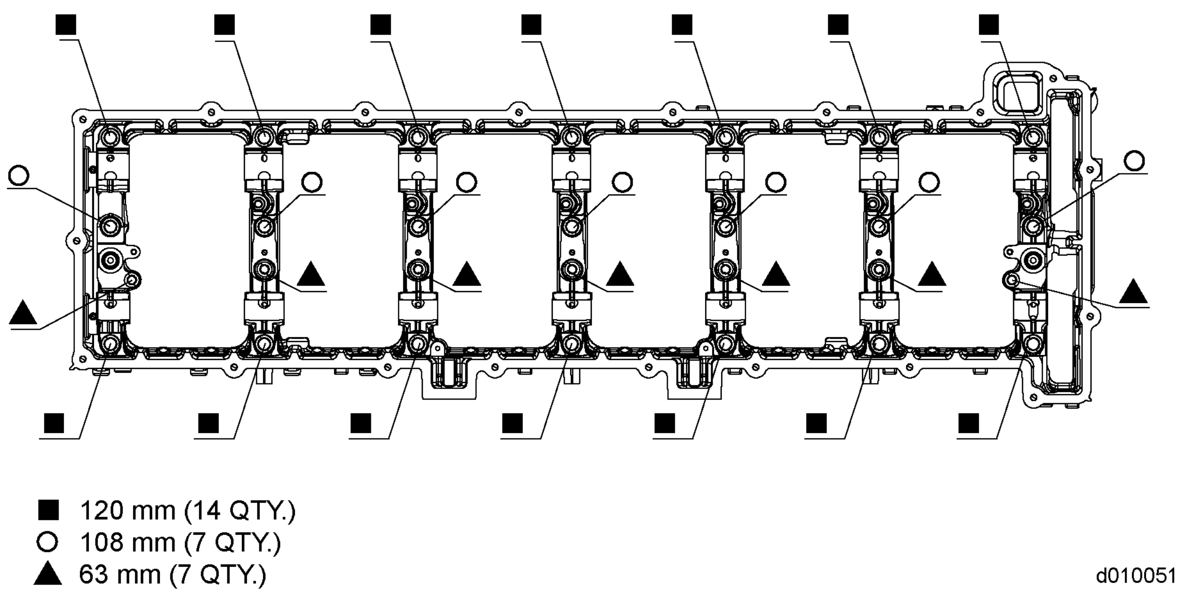


Figure 1-34 Bolt Size and Location

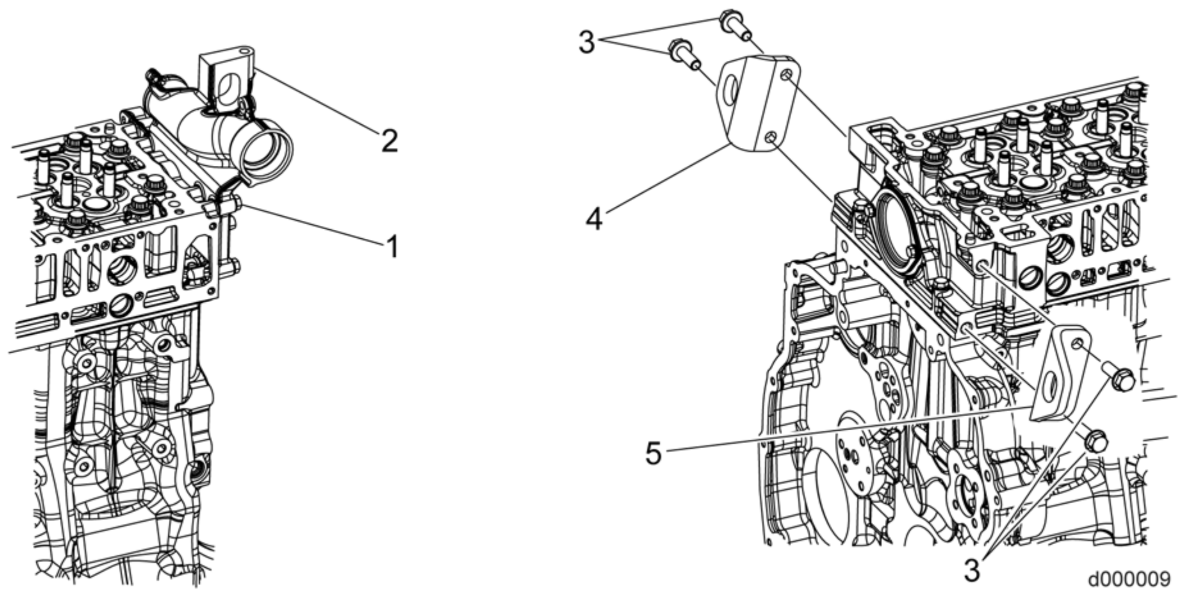
NOTICE:

Ensure when torquing the rocker shaft bolts that the bolts are torqued from the inside bolts outward in increments before final torque. If the rocker shaft bolt is fully torqued without using the increment procedure the shaft can break.

9. Using tool W470589004000 install the assembled intake rocker arm assembly to the camshaft cap and secure with seven clamping blocks and bolts. Torque the bolts to 55 N·m (41 lb·ft) + 90°.
10. Using tool W470589004000 install the assembled exhaust rocker arm assembly to the camshaft cap. Torque the bolts to 55 N·m (41 lb·ft) + 90°.
11. Set the valve lash and lash the engine brake. Refer to section 1.16.
12. Install high pressure fuel lines to fuel rail and high pressure pump. Refer to section 2.4.
13. Install high pressure fuel lines to fuel rail and injectors. Refer to section 2.4.
14. Install fuel line to fuel rail and fuel filter module. Refer to section 2.4.
15. Install the rocker cover. Refer to section 1.9.
16. Prime the fuel system.

1.6 ENGINE LIFTER BRACKETS

The lifter brackets are utilized when removing and replacing the engine. Two lifting brackets are located on the rear bolted to the cylinder head. The third lifter bracket is a crossover tube for the exhaust gas with a lifting eye built into it and is part of the exhaust gas recirculation system.See Figure 1-35.



1. Bolt
2. Exhaust Gas Recirculation Tube Crossover Tube Lifting Bracket
3. Rear Left Lifting Bracket
4. Rear Right Lifting Bracket

Figure 1-35 Lifting Bracket Location

> **CAUTION:**
>
> **To avoid injury from a falling engine, do not use a damaged lifter bracket when lifting the engine.**

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

1.6.1 Removal of the Engine Lifter Brackets

Remove the bolts securing the lifter brackets to the engine.

1.6.1.1 Inspection of the Engine Lifter Brackets

Inspect the lifter brackets for cracks bending or other damage. Replace the bracket if these conditions exist.

1.6.2 Installation of the Engine Lifter Brackets

Install the lifter brackets as follows:

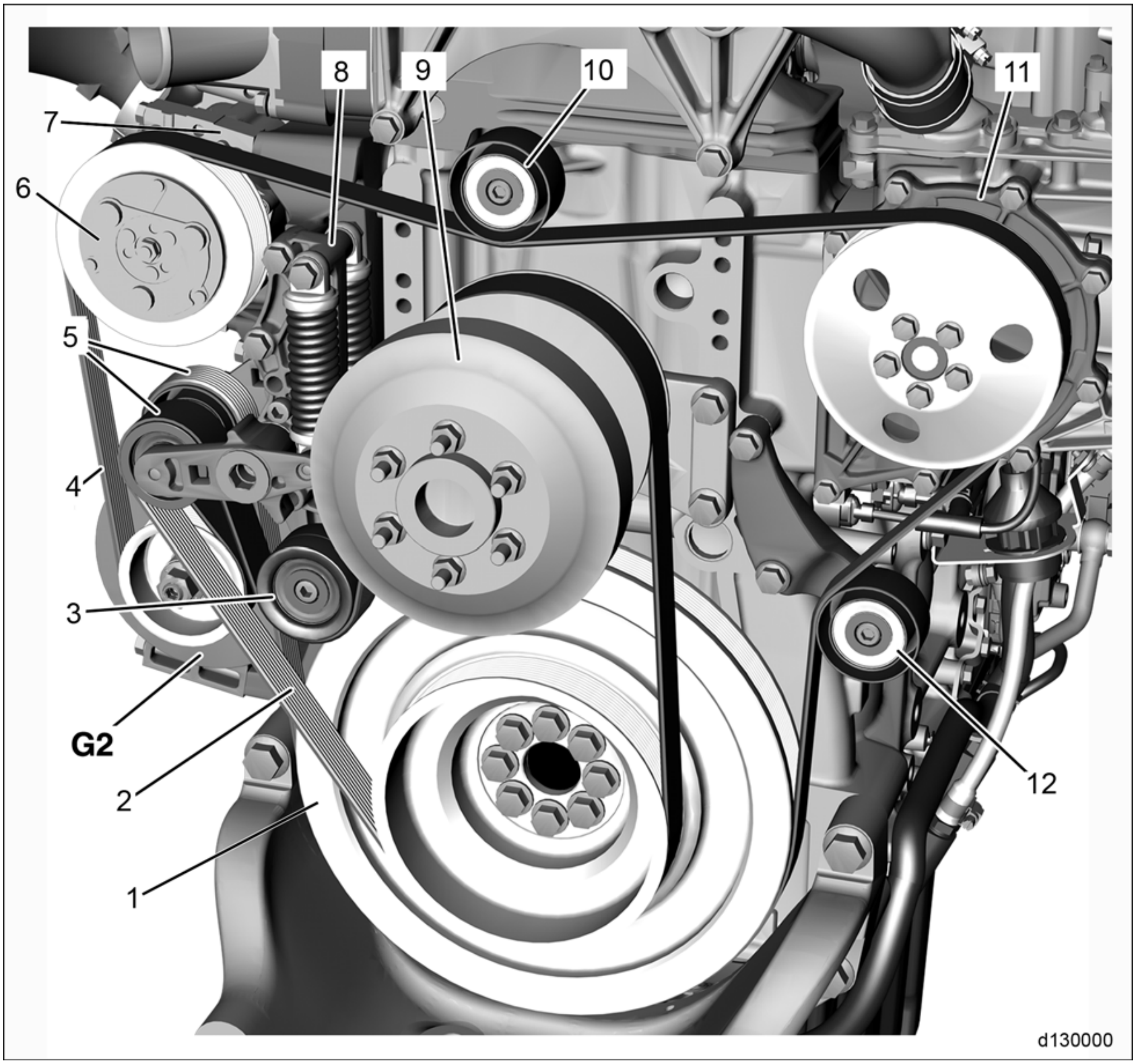
1. Install the two rear lifter brackets with four bolts to the cylinder head torque the bolts to 180 N·m (132 ft·lb).
2. Install a new press and seal connector onto EGR cooler and install front crossover tube lifting bracket onto EGR cooler.
3. Loosely install bolts to front crossover tube lifter bracket.
4. Install venturi pipe to front crossover tube lifter bracket with a new gasket and two bolts torque the bolt to 30 N·m (22 ft·lb).
5. Slide a new hose onto venturi pipe using soap and water for ease of installation.
6. Slide mixer tube onto hose with soap and water for ease of installation.
7. Install two clamps onto hose and tighten.
8. Install coolant delivery pipe to front crossover tube lifter bracket with two bolts torque bolts to 30 N·m (22 ft·lb).

1.7 BELT DRIVE TENSIONER SYSTEM

The engine uses two poly-V-belts. Since this type of belt is very flexible a number of major assemblies can be driven by one poly-V-belt. The alternator (G2), refrigerant compressor (6) and coolant pump (11) are driven by one poly-V-belt (4). The fan clutch (9) and the engine fan are driven by another poly-V-belt (2).

The belt tensioners (8) are firmly bolted onto the accessory bracket (7). The tensioning arms (SA, SB) with tensioner pulleys (5,12) are turned counterclockwise by the force of the springs to provide the required tension in the belts.

There is a square hole (V) in each tensioning arm (SA, SB) to install a 1/2 in. socket tool for removal and installation of the poly-V-belts. The outer poly-V-belt (2) must be removed before removing the inner poly-V-belt (4).



1. Crankcase Damper
2. Poly-v-Belt for the Fan
3. Pully
4. Poly-v-Belt for Driving the Alternator, Refrigerant Compressor and Coolant Pump
5. Tensioner Pulley
6. Refrigerant Compressor
7. Accessory Mounting Bracket
8. Belt Tensioner
9. Fan Clutch
10. Pulley and Spacer
11. Water Pump
12. Pulley

G2 Alternator

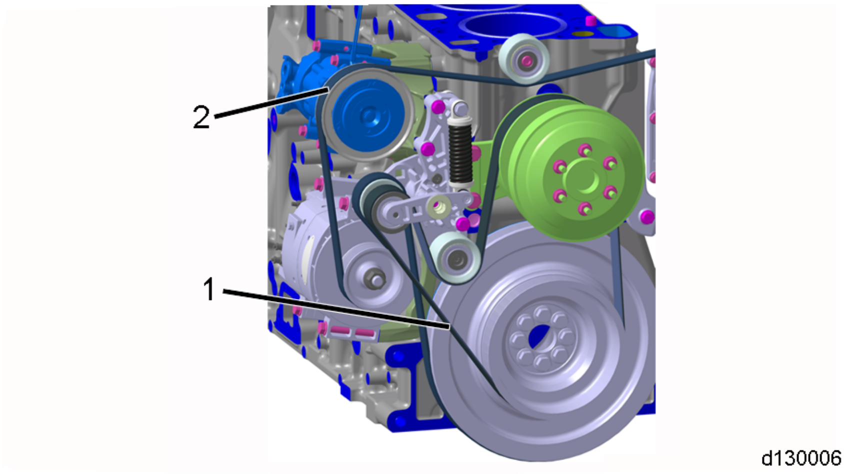
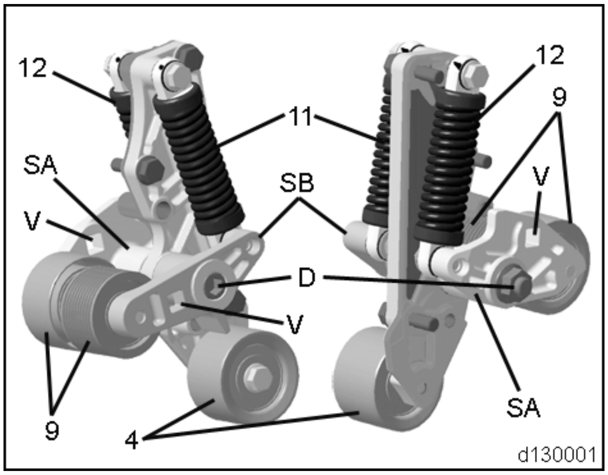


Figure 1-36 Poly-v-Belts

1. Poly-v-Belt for Driving the Fan
2. Poly-v-Belt for Driving the Alternator, Compressor and Coolant Pump



4. Pulley
9. Tensioner Pulley
11. Spring Damper
12. Spring Damper

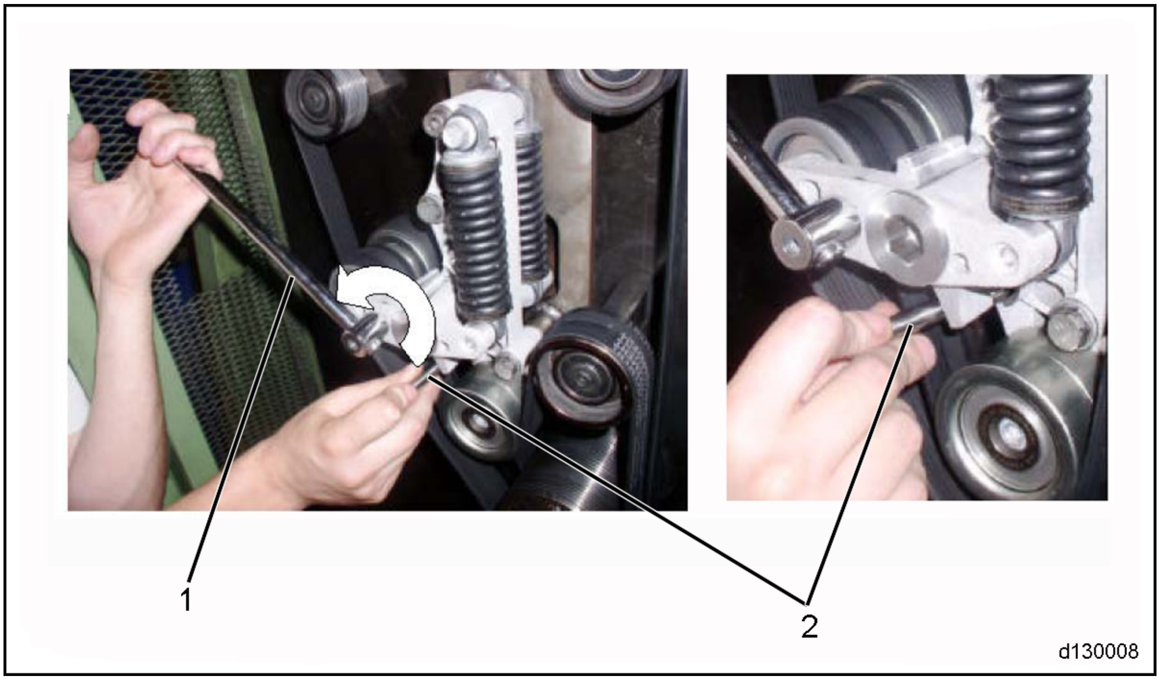
D.Pivot

SA. Tensioning Arm-for the poly-V-belt for the Fan

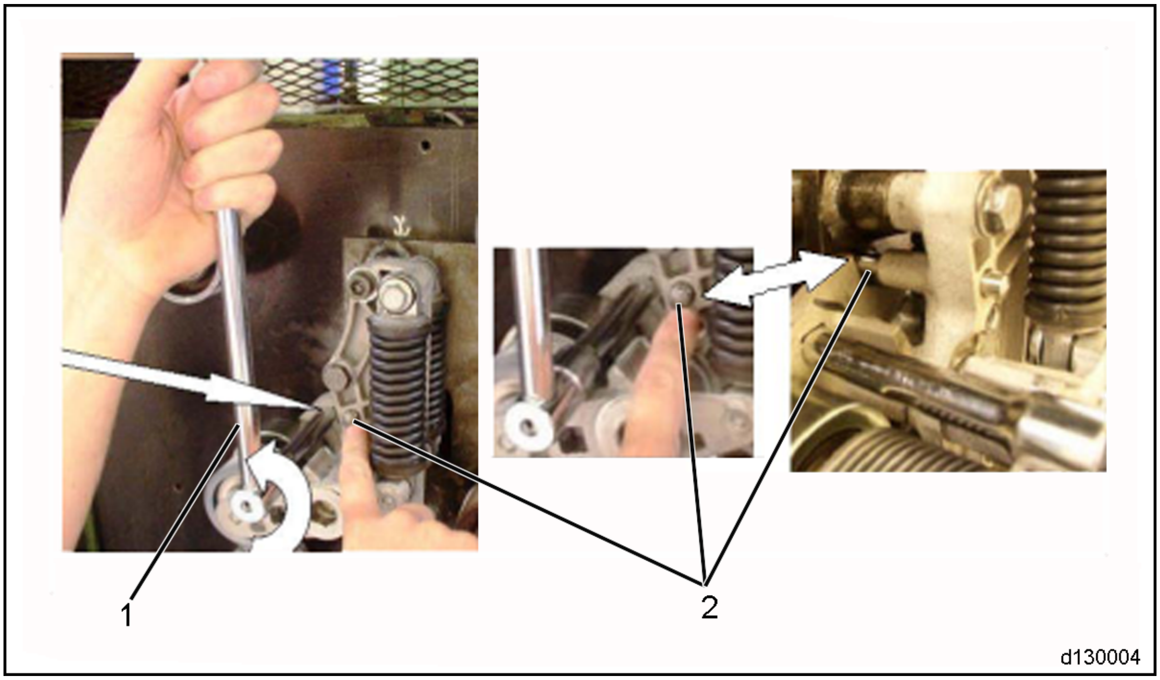
SB. Tensioning Arm for the poly-V-belt for Driving the Alternator, Refrigerant Compressor and Coolant Pump

V. Square Hole (1/2 in.)

Figure 1-37 Tensioning Device



1. Socket Wrench
2. Grooved Pulley Pin Location



1. Socket Wrench
2. Non-grooved Pulley Pin Location

1.7.1 Removal of the Poly-V-Belts

Remove as follows:

NOTE:
Ensure a 1/2 in. socket tool is used. Apply smooth pressure to tensioner. Jerking or sudden pressure could cause damage to tensioner.

NOTE:
Never pre-tension the non-grooved pulley idler arm before the grooved idler pulley arm is pre-tensioned.

NOTE:
Never turn the pulley idler arms clockwise.

NOTE:
When removing the poly-V-belts always remove the belt driving the fan first and then remove the belt driving the alternator, refrigerant compressor and coolant pump.

NOTE:
Do not use any type of cleaning solvent to the rubber parts on the tensioner.

1. Install a 1/2 in. socket tool into the square hole (V) on the grooved pulley idler arm.
2. Turn the grooved pulley idler arm counterclockwise. Maximum allowable torque is 90-100 N·m (66-73 ft·lb).
3. Insert pin No. TL# 677555–2 into the bracket hole in the idler arm.
4. Release the idler arm. The grooved pulley idler arm is now locked in a pre-tensioned position.
5. Remove the fan belt.
6. Install a 1/2 in. socket tool and a 125 mm (5 in.) extension into the square hole (V) on the non-grooved pulley idler arm.
7. Turn the non-grooved pulley idler arm counterclockwise. Maximum allowable torque is 90-100 N·m (66-73 ft·lb).

NOTE:
For ease of pin removal when inserting the second pin into the non-grooved idler arm bracket hole; do not insert pin completely into the bracket hole.

8. Insert pin TL# 677555–2 into the bracket hole in the non-grooved pulley idler arm.
9. Release the idler arm. The non-grooved pulley idler arm is now locked in a pre-tensioned position.
10. Remove the alternator, refrigerant compressor and coolant pump belt from the pulleys.

1.7.1.1 Inspection of the Poly-V-Belts

Inspect as follows:

Inspect the poly-V-belts for wear, cracking or tears. Refer to section 12 and see Figure 1-38.

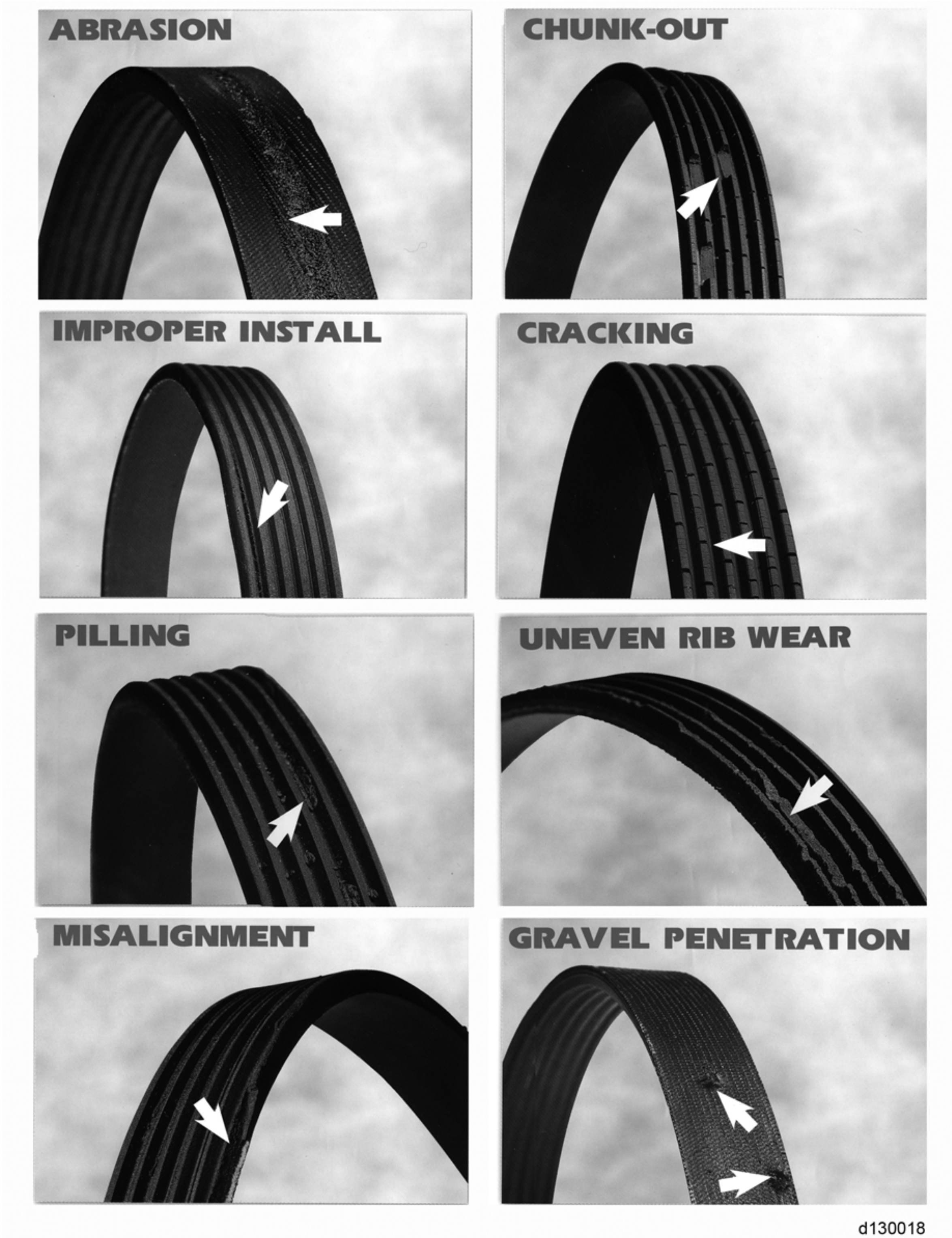


Figure 1-38 Poly-v-Belt Wear

1.7.2 Installation of the Poly-V-Belts

Install as follows:

NOTE:
If tensioners are pre-tensioned start at step 9.

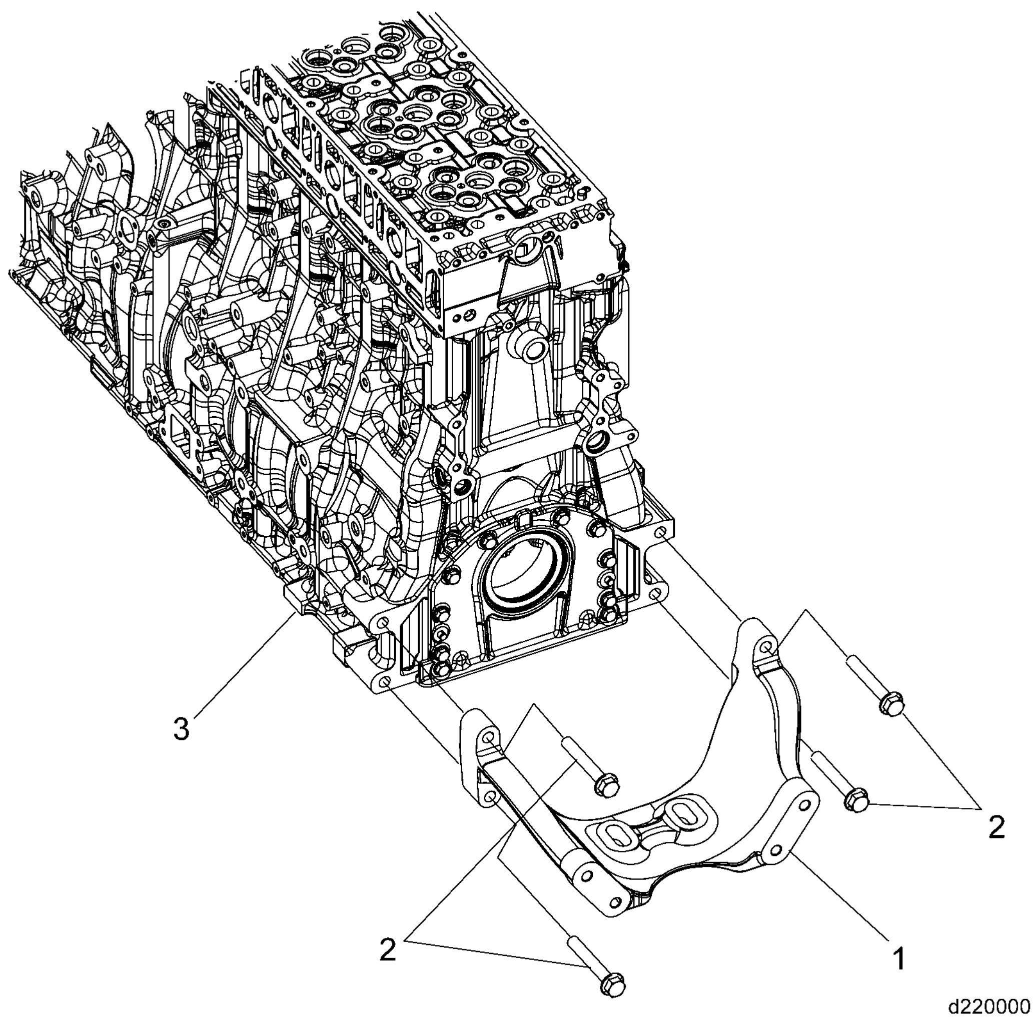
1. Install a 1/2 in. socket tool into the square hole (V) on the grooved pulley idler arm.
2. Turn the grooved pulley idler arm counterclockwise. Maximum allowable torque is 90-100 N·m (66-73 ft·lb).
3. Insert pin TL# 677555–2 into the bracket hole in the grooved pulley idler arm.
4. Release the idler arm. The grooved pulley idler arm is now locked in a pre-tensioned position.
5. Install a 1/2 in. socket tool with a 125 mm (5 in.) extension into the square hole in the non-grooved pulley idler arm bracket.

NOTE:
For ease of pin removal when inserting the second pin into the non-grooved pulley idler arm bracket hole; do not insert pin completely into hole.

6. Turn the non-grooved pulley idler arm counterclockwise. Maximum allowable torque is 90-100 N·m (66-73 ft·lb).
7. Insert pin TL# 677555–2 into the bracket hole on the non-grooved pulley idler arm.
8. Release the idler arm. The non-grooved pulley idler arm is now locked in a pre-tensioned position.
9. Install the poly-V-belts onto the pulleys.
10. Ensure the belts are properly installed on the pulleys.
11. Install a 1/2 in. socket tool with a 125 mm (5 in.) extension into the square hole (V) on the non-grooved idler arm.
12. Turn the non-grooved pulley idler arm counterclockwise until the pin holding the idler arm can be removed. Remove the pin.
13. Install a 1/2 in. socket tool into the square hole in the grooved pulley idler arm.
14. Turn the grooved pulley idler arm counterclockwise until the pin holding the grooved pulley idler arm can be removed. Remove the pin.

1.8 ENGINE MOUNTED RADIATOR SUPPORT

The engine mounted radiator support is mounted to the cylinder block with four bolts behind the crankshaft pulley and vibration damper.



1. Engine Mounted Radiator Support (EMR)
2. Bolts
3. Engine Block

Figure 1-39 Engine Mounted Radiator Support (EMR) and Related Parts

1.8.1 Removal of the Engine Mounted Radiator Support (EMR)

Remove as follows.

1. Drain the coolant
2. Remove charge air cooler (CAC) hoses.
3. Remove air cooling components refer to OEM guidelines.

4. Remove the four bolts securing the engine mounted radiator support and remove the EMR.See Figure 1-39.

1.8.1.1 Inspection of the Engine Mounted Radiator Support

Inspect the EMR for damage; replace as necessary.

1.8.2 Installation of the Engine Mounted Radiator Support

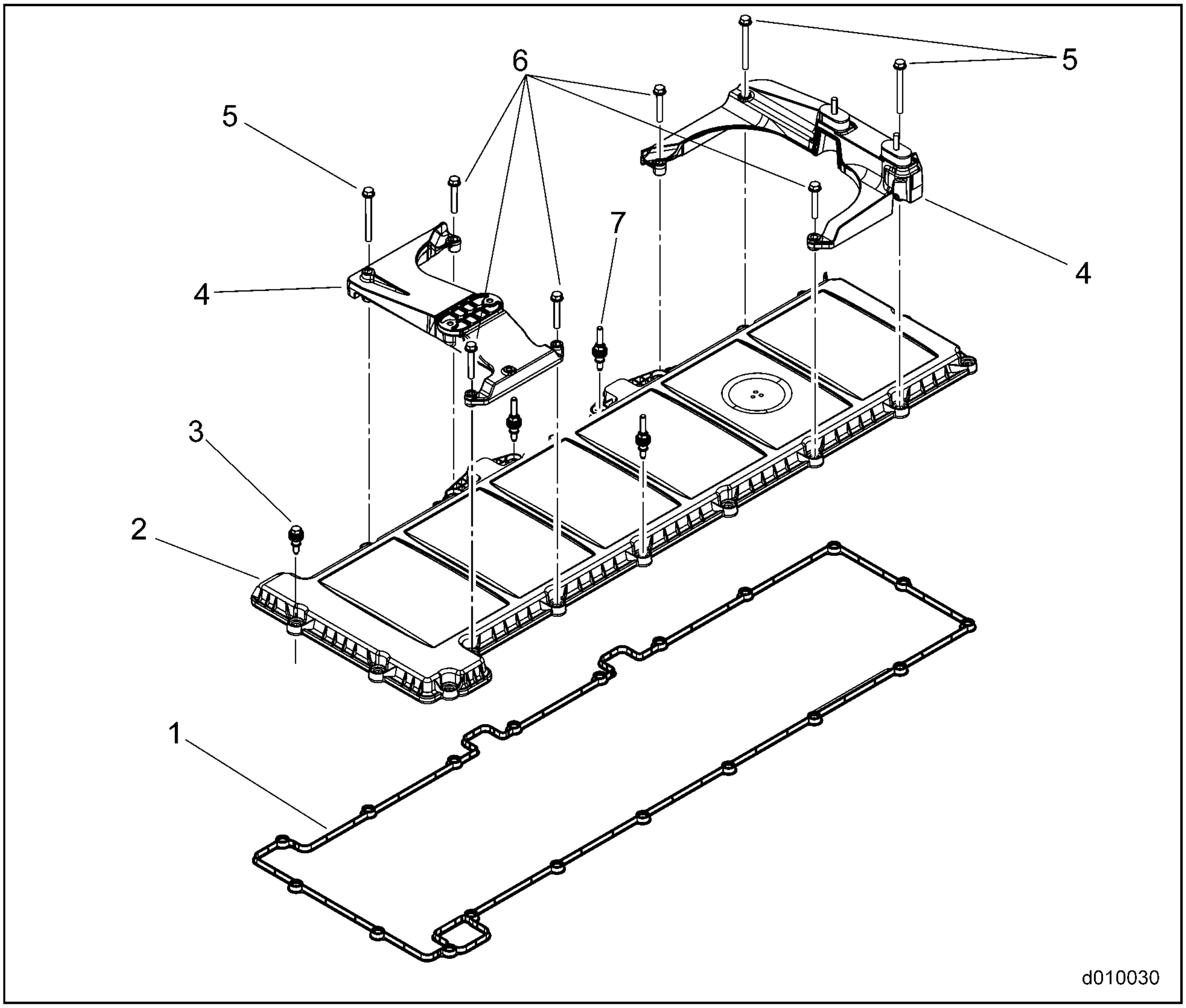
Install as follows:

1. Install the EMR to the cylinder block with four bolts torque bolts to 250 N·m (184 ft·lb).See Figure 1-39.
2. Install CAC hoses.
3. Install vibration damper and pulley assembly.
4. Fill with coolant to the appropriate levels.

1.9 ROCKER COVER

The rocker cover completely encloses the valve and injector operating mechanism on top of the camshaft frame, including the overhead camshaft and brake assemblies.

The rocker cover is an aluminum or plastic material using a elastomer seal. This seal prevents any lubricating oil from seeping out and will not allow water to enter the camshaft frame.



1. Gasket
2. Rocker Cover
3. Element
4. Air Cleaner Bracket
5. Bolt (3 QTY)
6. Bolt 5 Qty)
7. Stud

Figure 1-40 Rocker Cover and Related Parts

1.9.1 Removal of the Rocker Cover

Remove as follows:

1. Steam clean the engine.
2. Remove eight bolts from the two air filter housing brackets and remove housings from the rocker cover.
3. Remove the remaining eleven bolts from the rocker cover and remove rocker cover.
4. Remove rocker cover seal.

1.9.1.1 Inspection and Cleaning of the Rocker Cover

Inspect and clean as follows:

1. Clean cover in clean fuel oil.

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.

2. Blow dry with compressed air.
3. Check the rocker cover and seal for damage. Replace as necessary.
4. Inspect the bolts and isolators; replace if damaged.
5. Inspect the bolt holes for damage.

1.9.2 Installation of the Rocker Cover

Install as follows:

1. Install rocker cover seal into groove in rocker cover.
2. Install bolts and isolators into rocker cover.
3. Install rocker cover onto camshaft frame.
4. Finger tighten all eleven bolts; then torque the bolts to 20 N·m (14 ft·lb).
5. Install the two air filter housings onto the rocker cover and torque the eight bolts to 20 N·m (14 ft·lb).

WARNING:

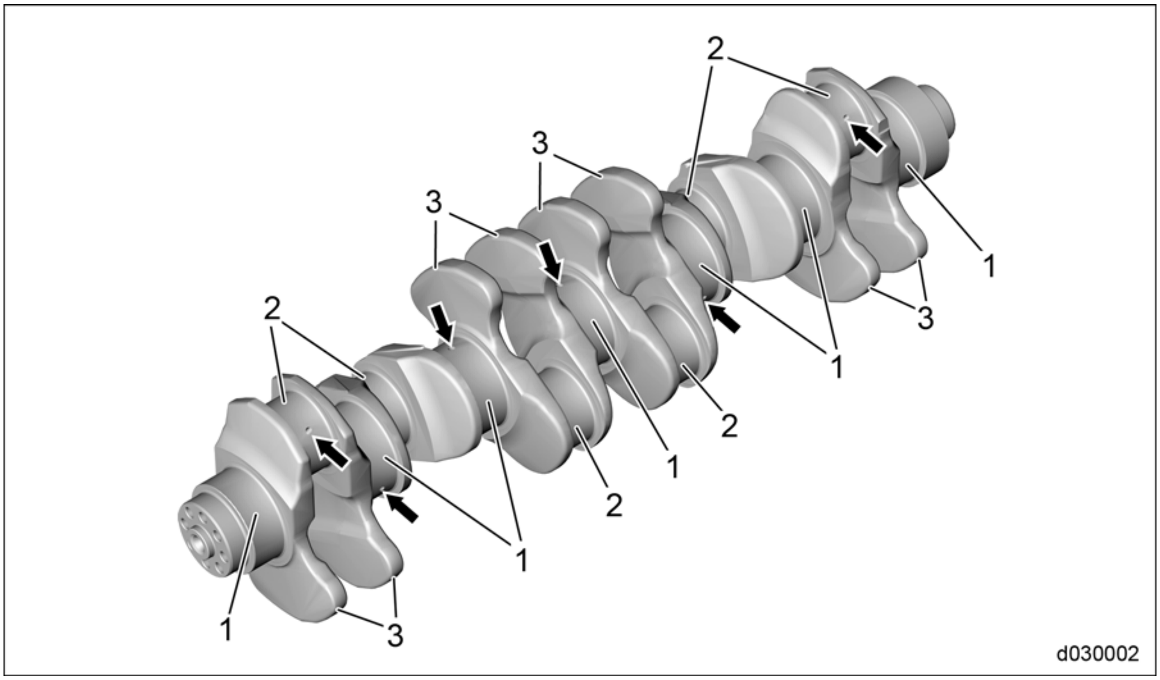
ENGINE EXHAUST

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.

1.10 CRANKSHAFT

The crankshaft is made out of induction-hardened steel. It is mounted with 7 crankshaft bearing journals (1) in the crankcase. In order to avoid vibrations counterweights (3) are cast onto the guide-ways. The crankshaft bearing journals (1) and connecting rod journals (2) are hardened in the boundary layer and ground. There are oil holes (arrow) located at the crankshaft bearing journal (1) and the connecting rod journal (2) over which the crankshaft bearing and connecting rod bearing are lubricated.

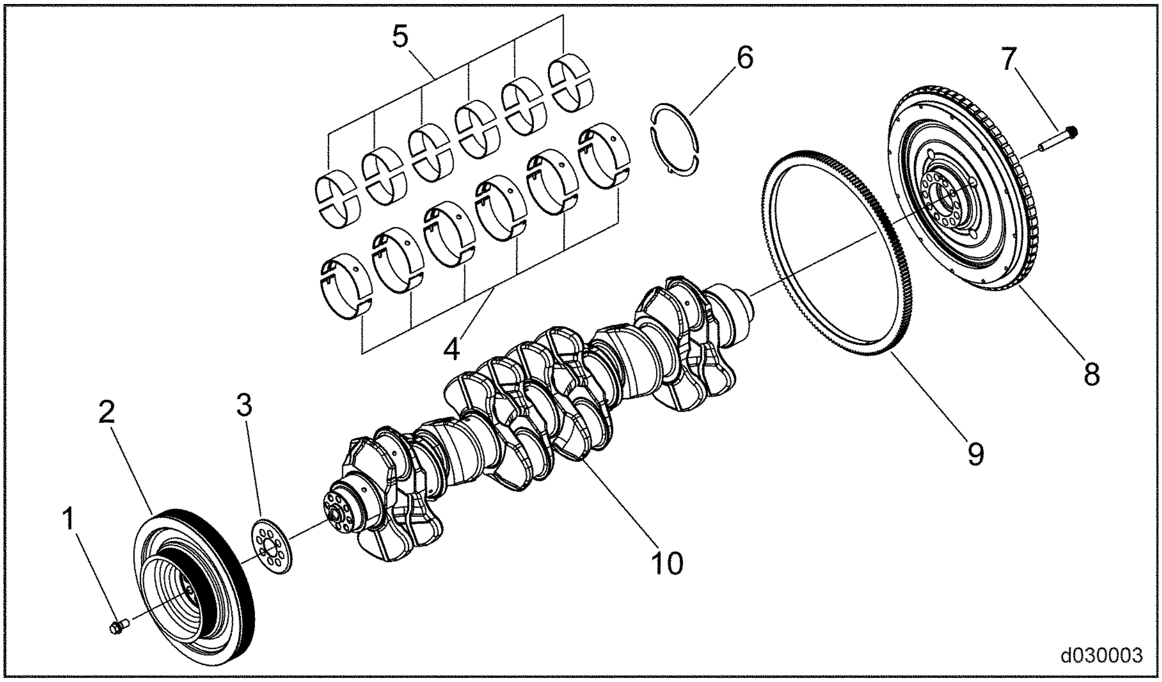


1. Crankshaft Bearing Journals
2. Connecting Rod Bearing Journals

3 Counterweights

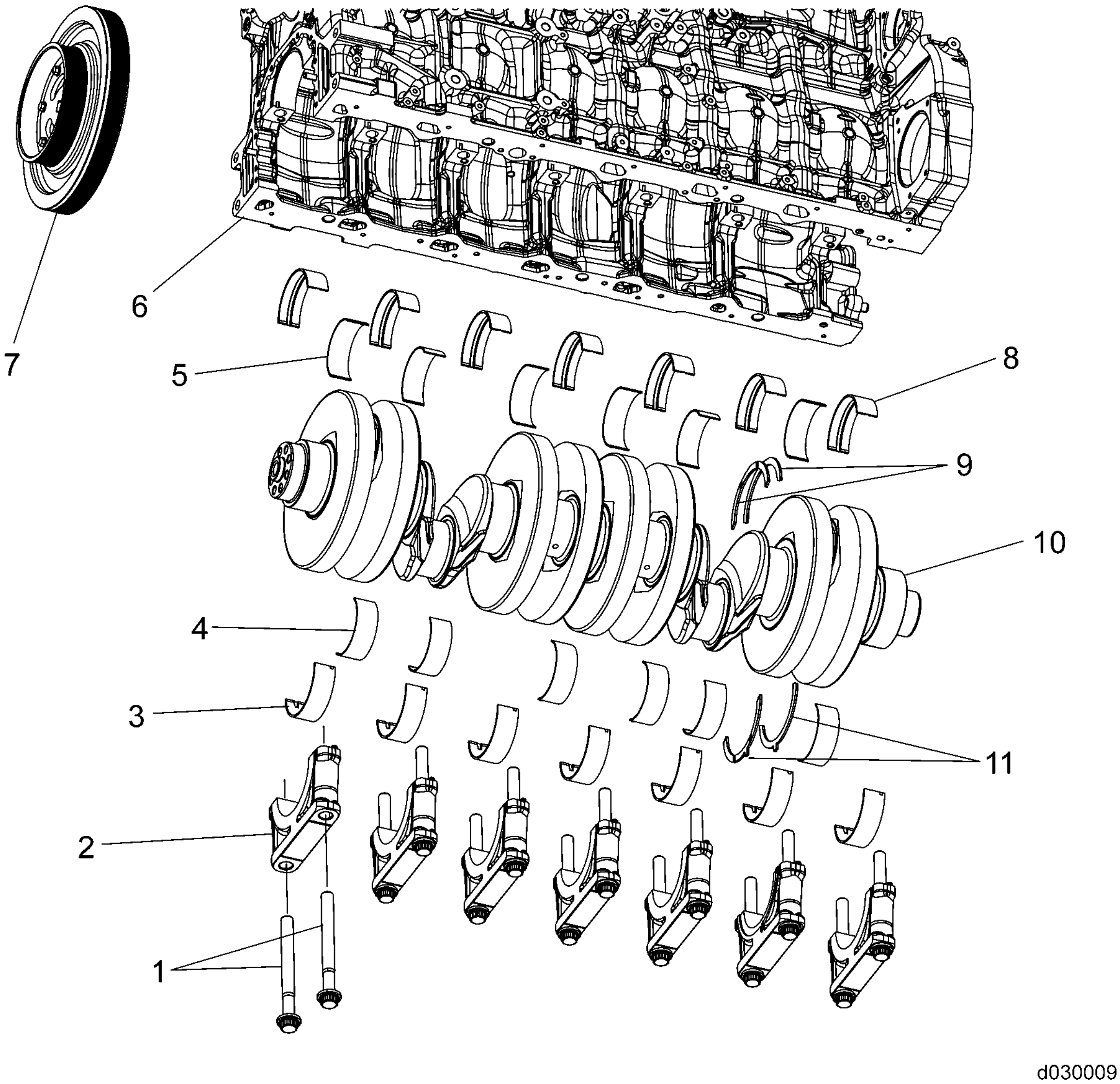
Arrows show the location of the oil passages

Figure 1-41 Crankshaft



1. Bolt
2. Vibration Damper
3. Cover Plate
4. Crankshaft Bearings
5. Connecting Rod Bearings
6. Thrust Washer
7. Bolt
8. Flywheel
9. Ring Gear
10. Crankshaft

Figure 1-42 Crankshaft and Related Parts



1. Bolt
2. Main Bearing Caps
3. Lower Crankshaft Bearing Shells
4. Lower Connecting Rod Bearing Shells
5. Upper Connecting Rod Bearing Shells
6. Engine Block
7. Vibration Damper
8. Upper Crankshaft Bearing Shells
9. Thrust Washer
10. Crankshaft
11. Thrust Washer

Figure 1-43 Crankshaft and Related Parts

1.10.1 Removal of the Crankshaft

When removal of the crankshaft becomes necessary, first remove the transmission, then proceed as follows:

1. Steam clean the exterior of the engine.
2. Drain the cooling system.
3. Drain the lubricating oil.
4. Attach suitable chain hoist and spreader bar with hooks to the three lifter brackets (one at the front and two at the rear). Remove all engine to base attaching bolts and remove the engine from its chassis.

WARNING:

FALLING ENGINE

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

5. Remove and inspect all of the accessories and assemblies with their attaching parts as necessary to permit the engine block adaptor, to be bolted to the intake (left) side of the cylinder block. Mount the engine to the overhaul stand (J–29109) with adaptor (J–35635–A). .
6. Remove the oil pan.
7. Remove the lubricating oil pump.
8. Remove the flywheel.
9. Remove flywheel housing,.

NOTICE:

Use care when removing the crankshaft pulley and vibration assembly. If the damper is allowed to fall, damage to the internal components of the damper may result.

10. Loosen and remove two of the crankshaft pulley retaining bolts and hardened washers 180 degrees apart and install two flywheel guide studs (J–36235) in their place. Then loosen and remove the remaining six pulley retaining bolts and hardened washers.
11. Remove the viscous crankshaft pulley vibration damper assembly.
12. Remove front seal housing.

13. Loosen and remove the main bearing cap bolts. Using J– 48884 remove the main bearing caps for inspection.

NOTE:
The main rod caps must be reinstalled to their respective main rods. The main bearing caps must be kept in sequence, so that they are installed to their original positions.

14. Remove the thrust washers from each side of the No. 6 main bearing cap.
15. Remove the crankshaft.

1.10.1.1 Inspection of the Crankshaft

Inspect 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 out the oil passages thoroughly with a stiff wire brush. Clean the crankshaft with fuel oil and dry it with compressed air.
2. If the crankshaft shows evidence of excessive overheating, replace the crankshaft since the heat treatment has probably been destroyed.
3. Check the crankshaft journal surfaces for score marks and other imperfections. If excessively scored, the journal surfaces must be reground.
4. Carefully, inspect the front end of the crankshaft in the area of the oil seal contact surface for evidence of a rough or grooved condition. Any imperfections of the oil seal contact surfaces will result in oil leakage at these points.
5. Check the crankshaft thrust surfaces for excessive wear or grooving. If excessively worn, the thrust surfaces must be reground.
6. Inspect the crankshaft gear.
7. Check the crankshaft journal run-out.
8. Check the journal alignment.
9. Check the journal measurements.
10. Inspect the crankshaft for cracks.
11. Check oil bearings for burrs.
12. Inspect the thrust washers.
13. Inspect the main cap bolt length. If the length exceeds 200.5 mm (7.89 in.) replace the bolt.

1.10.2 Installation of Crankshaft

Install the crankshaft using the following procedure:

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. Steam clean it to remove the rust preventive and blow out the oil passages with compressed air.
2. Install the upper main bearing shells in the block. If the old bearing shells are to be used again, install them in the same locations from which they were removed.

NOTE:
When a new or reground crankshaft is installed, ALL new main and connecting rod (upper and lower) bearing shells and new thrust washers must also be installed.

NOTE:
If the crankshaft surfaces were reground, it may be necessary to install oversize thrust washers on one or both sides of the No. 6 main journal.

3. Install the thrust washer upper halves in the counterbores on either side of the No. 6 bearing saddle. Coat the backs of the thrust washers (without oil grooves) with petroleum jelly and stick them in place with the oil-grooved sides facing away from the saddle.
4. Apply clean engine oil 360 degrees around all crankshaft bearing journals and install the crankshaft in place.
5. Install the main bearing shells in the main bearing caps as follows:
   [a] Align the tang on the lower main bearing shell with the groove in the main bearing cap. Install the bearing shell to the main bearing cap.

NOTE:
The main bearing caps are bored in position and stamped with position number. They must be installed in their original positions, with the marked (numbered) side of each cap toward the cooler (right) side of the cylinder block.

   [b] If the old bearing shells are to be used again, install them in the same bearing caps from which they were removed.

6. Install the main bearing caps together with lower bearing shells in place.
7. Apply a small quantity of clean engine oil to the bolt threads and underside of the bolt heads. Install the main bearing cap bolts and draw them up snug.

8. Torque all of the main bearing cap bolts to 50 N·m (36 lb·ft) 140 N·m (103 lb·ft) 300 N·m (221 lb·ft) 90° +90· torque turn.

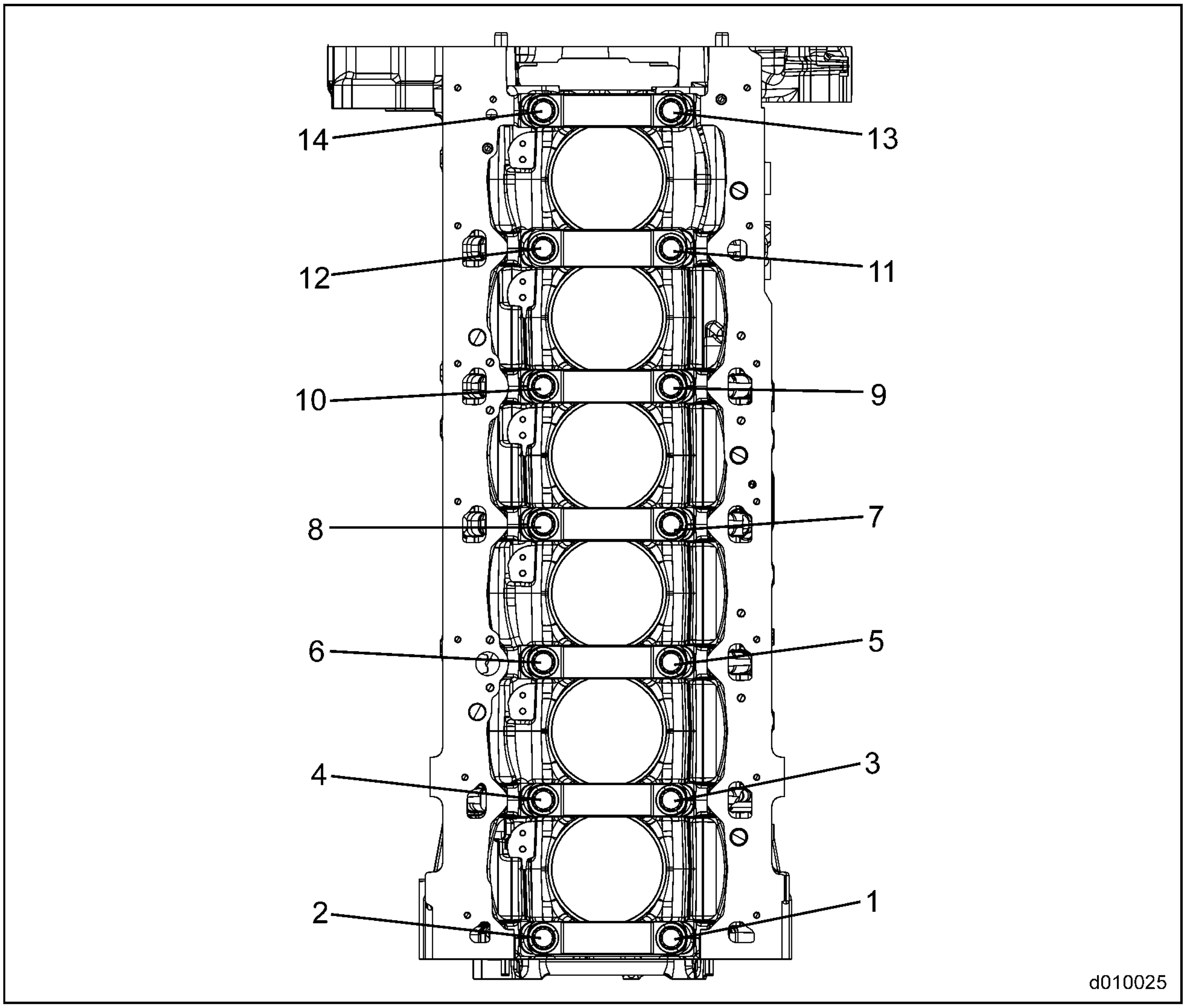


Figure 1-44 Main Bearing Cap Torque Sequence

NOTE:
If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

9. Check the crankshaft end by moving the crankshaft toward the gage with a small 304.8 mm (less than 12 in.) pry bar. Keep a constant pressure on the pry bar and zero the pointer on the dial indicator. Then, remove and insert the pry bar on the other side of the bearing cap. Force the crankshaft in the opposite direction and note the amount of end play on the dial. The end play should be 0.099-0.419 mm (0.0039 -0.0165 in.). Insufficient end play can be the result of a misaligned No. 6 main bearing, a misaligned upper thrust washer or a burr or dirt on the inner face of one or more of the thrust washers.

10. If removed install the piston and connecting rod assemblies. Torque the connecting rod cap bolts to 100 N·m + 90° + 90° torque turn.
11. If removed install the cylinder head.
12. If removed install the camshaft frame.
13. If removed install the gear train.
14. Install the flywheel housing.
15. Replace the rear crankshaft seal with new seal and sleeve assembly.
16. Install the flywheel.
17. Install the lubricating oil pump, inlet and outlet pipes.
18. Replace the front crankshaft seal with new seal and sleeve assembly.
19. Install the crankshaft pulley and vibration damper assembly.
20. Install the oil pan.
21. Use a chain hoist and spreader bar with hooks attached to the lifting brackets at each end of the engine and remove the engine from the overhaul stand.
22. Remove the overhaul stand adaptor plate from the engine block.
23. Install any accessories that were removed.
24. Install the engine to the equipment from which it was removed.
25. Fill the cooling system.
26. Fill the engine crankcase to correct operating level. Prime the system.
27. After replacing the main or connecting rod bearings or installing a new or reground crankshaft, operate the engine as outlined in the "Run-In Schedule."

1.11 FLYWHEEL

The flywheel is attached to the rear end of the crankshaft with twelve bolts. The bolt holes in the crankshaft and flywheel are equally spaced.

1.11.1 Removal and Cleaning of Flywheel

Precleaning is not necessary.

Remove as follows:

1. Remove the crankshaft position sensor.
2. Remove eleven of the twelve flywheel attaching bolts, leaving one bolt at the 12 o'clock position.
3. Install two flywheel guide studs (J–41672) through the flywheel and into the crankshaft at the 3 and 9 o'clock positions.
4. Attach the flywheel lifting tool (J–25026) or some other suitable lifting device, to the flywheel.
5. Attach a chain hoist to the lifting tool.
6. Loosen, but do not remove the last flywheel attaching bolt.
7. Lift lightly on flywheel using lifting device and remove last bolt.

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.

8. Remove flywheel.

1.11.1.1 Inspection of Flywheel

Inspect as follows:

1. Inspect the clutch contact base of the flywheel.
   [a] Check clutch contact base for scoring, wear, or cracks.
   [b] The flywheel may be refaced, if the clutch contact face is scored or worn.
   [c] The flywheel must be replaced, if the clutch contact face shows cracks.
2. Inspect the ring gear.
   [a] Check ring gear for excessively worn or damaged gear teeth.
   [b] If damaged gear teeth are detected, replace the ring gear.
3. Inspect crankshaft and flywheel contact surface.
   [a] Check the butt end of the crankshaft and flywheel contact surface for fretting, brinelling, or burrs.
   [b] Lightly stone the contact surface to remove any fretting, brinelling, or burrs.

1.11.2 Installation of Flywheel

Install as follows:

1. Install two flywheel guide studs (J–36235) into two of the tapped holes in the crankshaft at the 3 and 9 o'clock position.
2. Attach the flywheel lifting tool and, using a chain hoist, position the flywheel in the flywheel housing. Align the flywheel bolt holes with the crankshaft bolt holes.
3. Install the flywheel lock (J–36375–A).
4. Remove the flywheel lifting tool and guide studs.
5. Apply clean engine oil to the threads and to the bolt head contact area (underside) of the remaining bolts. The bolt threads must be completely filled with engine oil. Any excess must be wiped off.

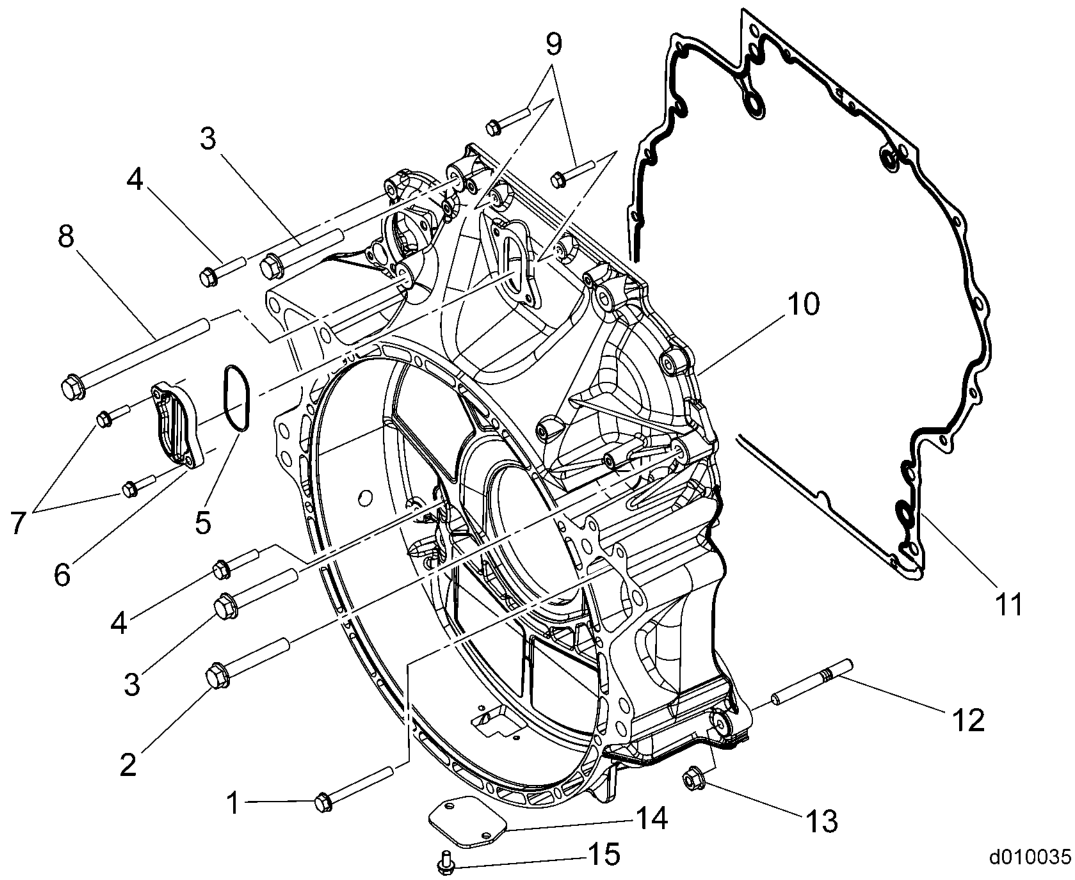
NOTE:
Clean engine oil must never be used between two surfaces where maximum friction is desired, as between the crankshaft and the flywheel.

6. Install the bolts and torque them to 200-220 N·m (147-162 lb·ft) 90° + 10 torque turn.

1.12 FLYWHEEL HOUSING

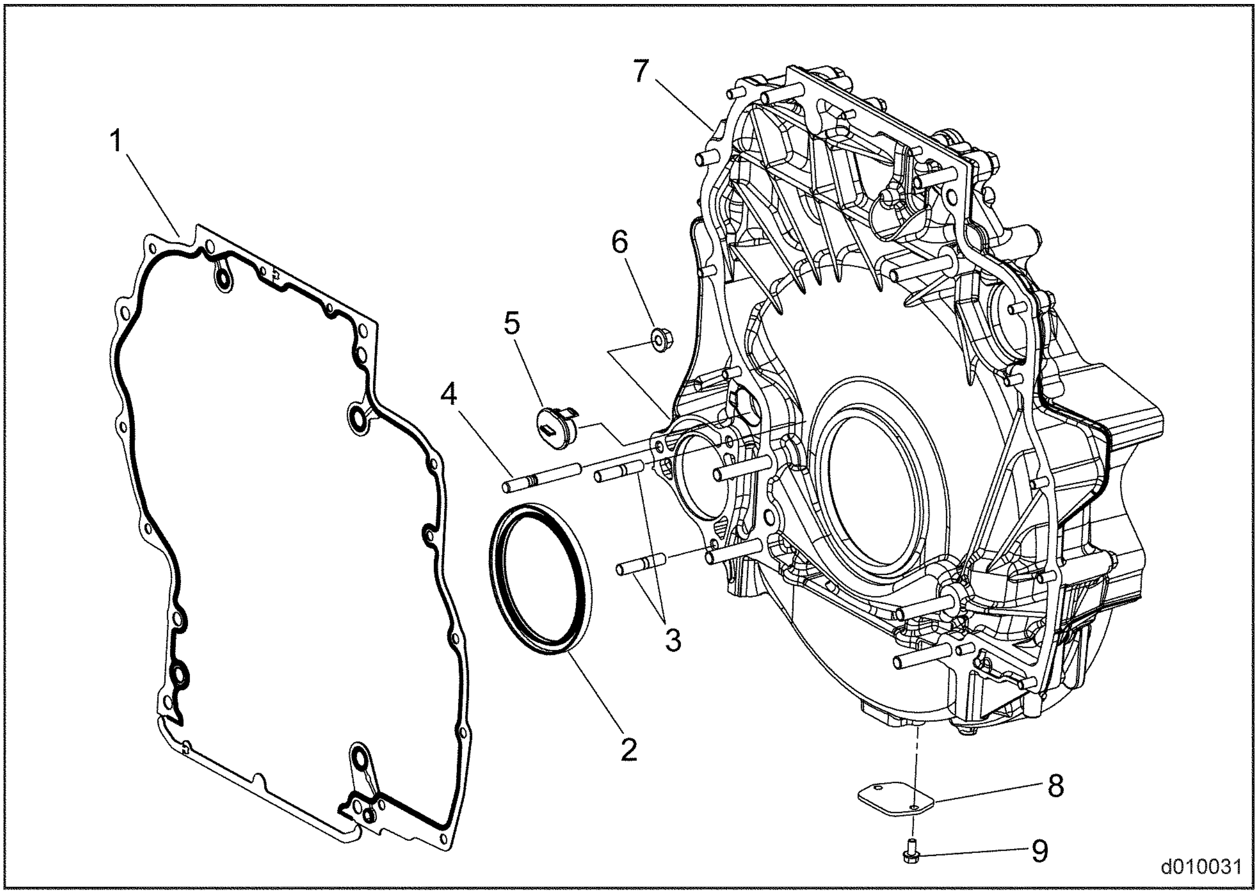
The flywheel housing is a one-piece aluminum casting mounted against the rear of the engine. It provides a cover for the gear drive, houses the flywheel. The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing.

The power steering pump can be attached to the flywheel housing when the vehicle when a two-cylinder compressor is used. On vehicles with a one-cylinder compressor, the power steering pump is mounted to the compressor and a cover is used. An engine barring or locking device can be attached at the opening on the bottom of the flywheel housing. This allows the engine to be barred or locked for maintenance or repair work.



1. Bolt M10 x 90 (3 Qty)
2. Bolt M14 x 1.5 x 70 (1 Qty)
3. Bolt M14 x 1.5 x 90 (6 Qty)
4. Bolt M10 x 45 (6 Qty)
5. Gasket (1 Qty)
6. Cover (1 Qty)
7. Bolt M8 x 30 (2 Qty)
8. Bolt M14 x 1.5 x 180 (1 Qty)
9. Bolt M8 x 45 (2 Qty)
10. Flywheel Housing
11. Gasket
12. Stud (Qty 1)
13. Nut M12-10 (Qty 1)
14. Cover
15. Bolt (Qty 2)

Figure 1-45 Front of Flywheel Housing and Related Parts



1. Gasket
2. Seal
3. Stud
4. Stud
5. Expansion Plug
6. Nut
7. Flywheel Housing
8. Cover
9. Bolt (2)

Figure 1-46 Rear of Flywheel Housing and Related Parts

1.12.1 Removal and Cleaning of Flywheel Housing

Precleaning is not necessary.

Remove as follows:

1. If the engine is removed from the vehicle, mount the engine on an overhaul stand.
2. Drain the engine oil and remove the oil pan. Refer to section 3.2.
3. Remove the flywheel. Refer to section 1.11.
4. Remove crank position sensor. Refer to section 2.16.
5. Remove two bolts securing exhaust pipe bracket to flywheel housing.
6. Remove clamp from exhaust pipe and axial power turbine and remove exhaust pipe.
7. Thread eye bolts into the tapped holes in the side of the flywheel housing.
8. To guide the flywheel housing until it clears the end of the crankshaft, thread two guide studs (J–43431) for 14 mm bolts, into the cylinder block.
9. Remove the remainder of the bolts that secure the flywheel housing to the engine block.
10. Attach a suitable lifting sling to the eye bolts and strike the front face of the housing alternately on each side with a soft hammer to loosen and work it off the dowel pins.
11. Remove and discard the crankshaft rear oil seal.
12. Remove and discard flywheel housing gasket.
13. Remove all sealing material from the flywheel housing. Refer to section, "Cleaning" in the "General Information" section at the beginning of this manual.

1.12.1.1 Inspection of Flywheel Housing and Rear Oil Seal Area of Crankshaft

Inspect as follows:

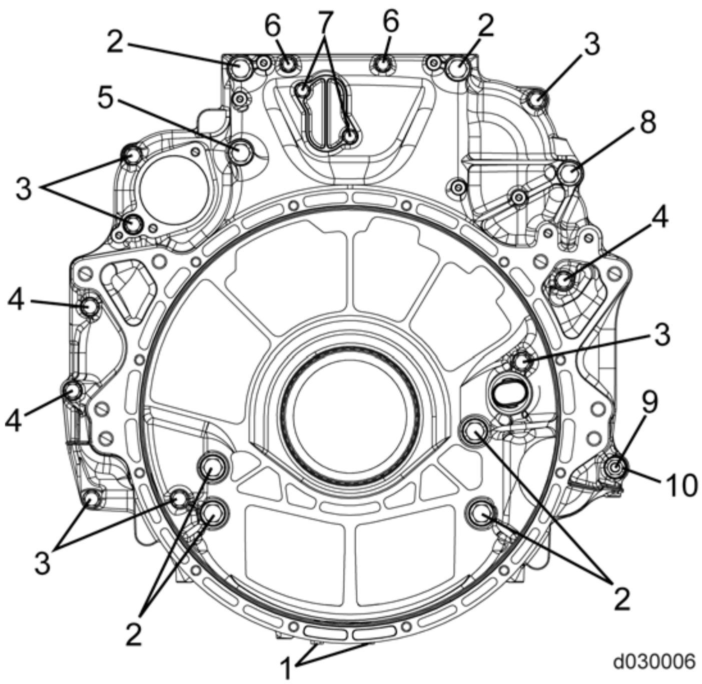
1. Inspect flywheel housing for cracks and any other damage.
   - [a] If sealing surface is damaged, repair with scotch brite disc.
   - [b] If cracked, repair is not possible; replace the part.
2. Inspect the flywheel where the rear oil seal makes contact.
   - [a] Check for groove in flywheel.
   - [b] If flywheel is grooved, install a wear sleeve over the crankshaft end. An oversized I D. rear oil seal must be used with the wear sleeve.

1.12.2 Installation of Flywheel Housing

Install as follows:

1. Thread two aligning studs (J–43431) for 14 mm bolts, into the cylinder block to guide the housing in place.
2. Install new gasket
3. Using lifting sling support the flywheel housing and position it onto the cylinder block.

4. Install all of the housing bolts in their proper location, finger-tighten them. See Figure 1-47.
5. Remove the pilot studs.
6. Torque the flywheel housing bolts using the torque found in figure 1-47. and the torque sequence found in figure 1-48.



1. Bolt, M8 x 16 (2 Qty) 30 N·m (22 lb·ft)
2. Bolt, M14 x 1.5 x 90 (6 Qty) 120 N·m (88 lb·ft)
3. Bolt, M10 x 45 (6 Qty) 60 N·m (44 lb·ft)
4. Bolt, M10 x 90 (3 Qty) 60 N·m (44 lb·ft)
5. Bolt, M14 x 1.5 x 180 (1 Qty) 120 N·m (88 lb·ft)
6. Bolt, M8 x 45 (2 Qty) 30 N·m (22 lb·ft)
7. Bolt, M8 x 30 (2 Qty) 30 N·m (22 lb·ft)
8. Bolt, M14 x 1.5 x 70 (1 Qty) 120 N·m (88 lb·ft)
9. Stud, (1 Qty)
10. Nut, M12-10 (1 Qty) 100 N·m (74 lb·ft)

Figure 1-47 Flywheel Housing Bolt and Torque Identification

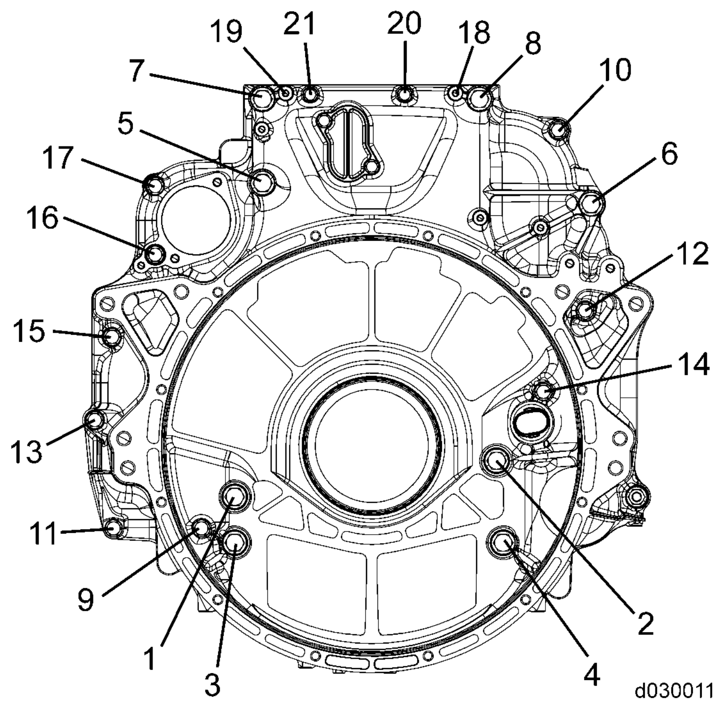


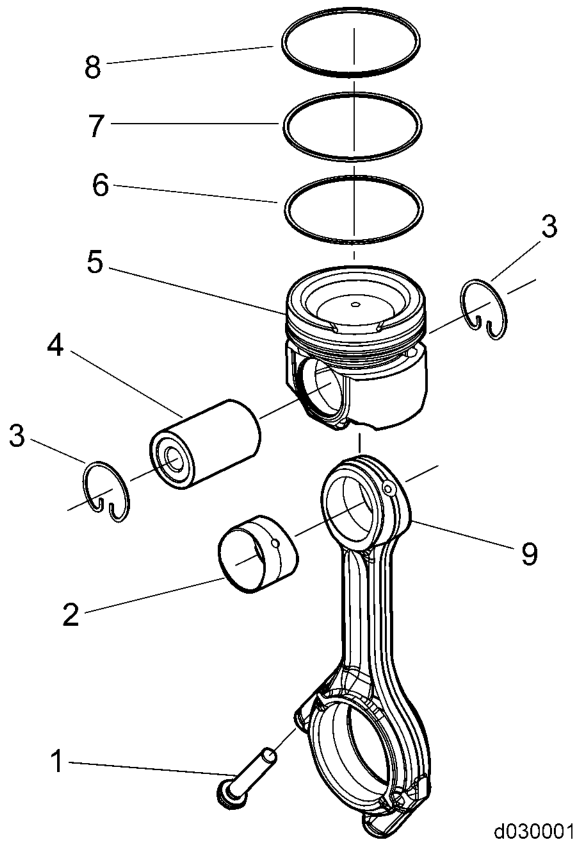
Figure 1-48 Flywheel Housing Torque Sequence

7. Install the crankshaft rear main oil seal.
8. Install the flywheel. Refer to section 1.11.
9. Install the exhaust pipe and bracket to the flywheel housing and axial power turbine. Install two bolts into the bracket and flywheel housing. Install a clamp onto the exhaust pipe and axial power turbine.
10. Install crankshaft position sensor to flywheel housing. Refer to section 2.16.
11. Install the oil pan; and refill the engine with new oil. Refer to section 3.2.

1.13 PISTON AND CONNECTING ROD ASSEMBLY

The connecting rods are forged from a high strength steel. A connecting rod bushing is pressed into the connecting rod eye .

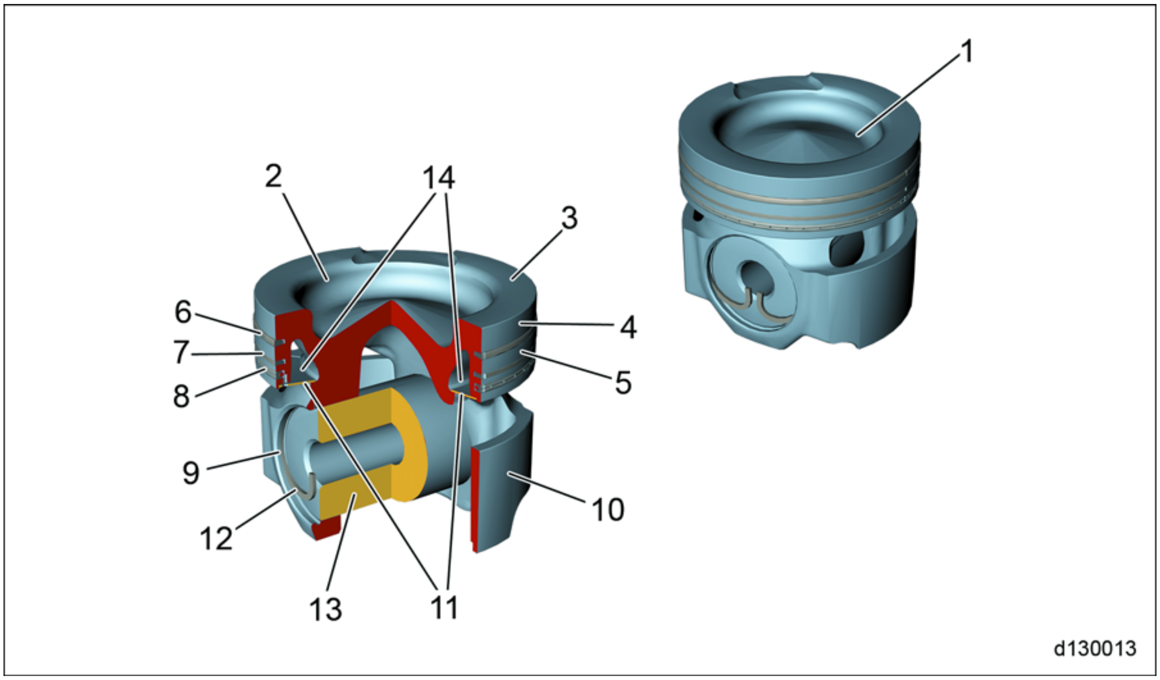
Since the piston and connecting rod assembly is one unit made of two separate components, the components will be addressed in separate sections.



1. Connecting Rod Bolt
2. Piston Pin Bushing
3. Retaining Ring
4. Piston Pin
5. Piston
6. Oil Control Ring
7. Compression Ring
8. Fire Ring
9. Connecting Rod

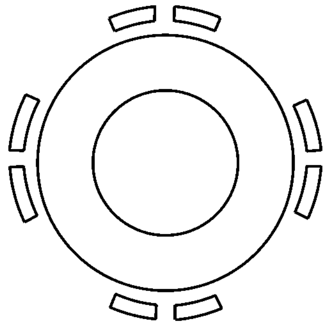
Figure 1-49 Piston and Connecting Rod Assembly

Each piston has a top fire ring (8) middle compression ring (7) and an oil control ring (6).



1. Piston
2.Piston Bowl
3. Piston Dome
4. Top Land
5. Second Land
6. Fire Ring
7. Compression Ring
8. Oil Control Ring
9. Piston Boss
10. Piston Skirt
11. Cover Plate
12.Retaining Clip
13. Piston Pin
14. Cooling Galley

Figure 1-50 Piston



A. Top Ring Gap

B. Oil Ring Gap

C. Second Ring Gap

D. Expander Gap

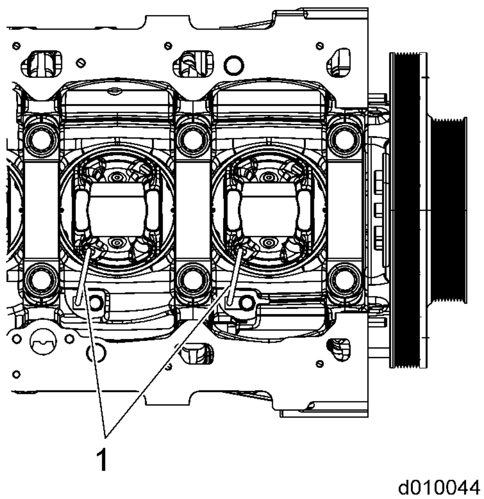
Figure 1-51 Piston Ring Gap

1.13.1 Removal and Cleaning of Piston and Connecting Rod

Remove the piston and connecting rod assembly as follows:

1. Drain the engine cooling system.
2. Drain the engine oil.
3. Remove the oil pan.
4. Remove the camshaft frame.
5. Remove the cylinder head and gasket.
6. Use Scotch Brite pads to remove any carbon deposits from the upper surface of the cylinder liner.

7. Remove the piston cooling nozzles from the base of the cylinder bores and discard the nozzles.



1. Spray nozzle

Figure 1-52 Piston Spray Nozzle Location

8. Position the crankshaft for the piston and connecting rod assembly to be removed at bottom dead center.
9. Remove the bearing cap and lower bearing shell from the connecting rod.

NOTICE
The connecting rod assembly is a cracked rod design. Ensure when the bearing cap is removed that it is placed on it's side. Damage to the bearing cap will occur if it is placed on end; the connecting rod assembly will need to be replaced if the cap is damaged.

10. Remove the piston and connecting rod assembly through the top of the cylinder liner.
11. Assemble the connecting rod bearing cap and lower bearing shell to the connecting rod after removal. If not already marked, match-mark the rod and cap (on the tang side) with the cylinder number from where they were removed.

NOTE:
When removed, the bearing cap and the bearing shell must be reinstalled on the original connecting rod before another connecting rod bearing cap is removed.

1.13.2 Disassembly of Piston and Connecting Rod Assembly

Piston assembly components should be segregated by cylinder and match-marked during disassembly to ensure they are assembled in the same position and orientation.

NOTICE:
Stamping cylinder numbers on the piston assembly will damage the components.

Disassemble piston and connecting rod assembly as follows:

1. Place the piston, dome down, on the table.
2. Using the required snap ring pliers, remove the circlip-type snap rings from the piston skirt.
3. Slide out the piston pin and remove the connecting rod from piston dome/skirt assembly.

1.13.2.1 Inspection of Piston and Connecting Rod Assembly

Inspect as follows:

1. Inspect the connecting rod and bearing cap for damage; replace as necessary.
2. Inspect the piston, pin and rings for damage; replace as necessary.

1.13.3 Assembly of Piston and Connecting Rod Assembly

Assemble as follows:

1. Position the piston dome on its rim.
2. Liberally lubricate the piston pin bore in the dome and connecting rod bearing cap with clean engine oil.
3. Using the required snap ring pliers, install one of the circlip-type snap rings into the recess in the piston. Orient the snap ring gap to either the 12 o'clock or 6 o'clock position.
4. Lubricate the pin with clean engine oil.
5. Position the end of the connecting rod inside the piston dome.
6. Install piston pin into the pin bores through the rod until it rests against the previously installed snap ring.
7. Using the required snap ring pliers, install the other circlip-type snap ring into the recess in the piston to lock the pin in place. Orient the snap ring gap to either the 12 o'clock or 6 o'clock position.

1.13.4 Installation of Piston and Connecting Rod Assembly

Install as follows:

1. If the rings have been removed, install them into the grooves of the dome and rotate 120° apart.
2. Allowable new ring end gaps are listed in Table 1-2.

Ring	Ring End Gap
Fire Ring	0.6 - 0.75 mm (0.02362 - 0.02953 in.)
Compression Ring	0.7 - 0.9 mm (0.02756 - 0.03543 in.)
Oil Control Ring	0.4 - 0.6 mm (0.01575 - 0.02362 in.)

Table 1-2 Allowable Ring End Gap

3. Add clean engine oil to a clean pan at least 305 mm (12 in.) in diameter, until the level reaches approximately 76 mm (3 in.).
4. Place the piston and connecting rod assembly into pan, with the dome of the piston on the bottom of the pan.
5. Coat the piston liberally with the engine oil, saturating the piston rings and lands.
6. Coat the inside diameter of the ring compression tool J–47386 with clean engine oil.
7. Clamp the ring compressor, with groove (pilot bore) of the compressor facing away from the connecting rod, around the dome and rings. See Figure 1-53.

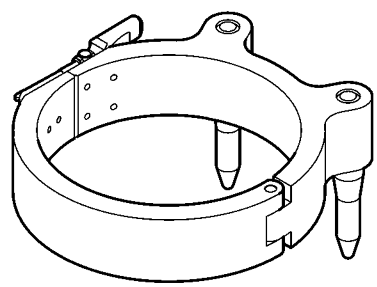


Figure 1-53 Piston Ring Compressor J–47386

8. Once the ring compressor is "clamped," ensure the piston can rotate freely. If rotation is hindered, remove the compressor and reposition the dome and rings, or inspect for ring damage.
9. Lubricate the inside of the cylinder liner with oil.
10. Position the throw of the crankshaft journal to bottom dead center for the cylinder being installed with the piston and connecting rod assembly.

NOTICE:
Failure to orient the piston connecting rod properly during piston installation may result in the bearing end of the rod striking the nozzle, causing damage to the nozzle or loosening it from the block. A damaged, bent, or loosened nozzle may cause a loss of main gallery pressure. In these cases piston overheating or lack of adequate lubrication may result in severe engine damage.

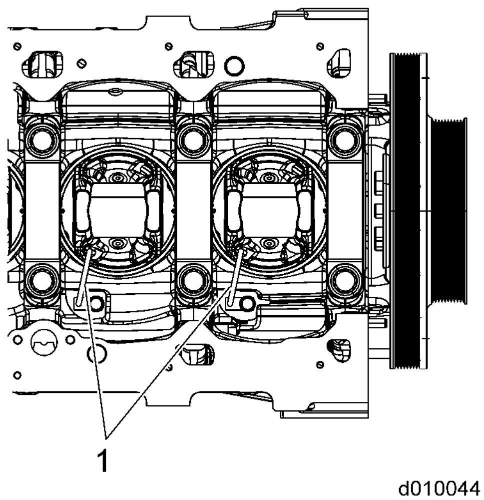
11. Ensure arrow on piston dome is pointing toward the front of the engine during installation and rod is properly oriented.
12. Align the ring compressor guide pins over the two bolt holes on the top of the cylinder block.

NOTICE:
DO NOT force the dome into the liner. Considerable force on the dome could scratch or otherwise damage the inside of the cylinder liner. Therefore, care must be taken during the installation of the dome to prevent damage.

13. Insert the ring compressor guide pins into the two bolt holes on the top of the block.
14. With care and moderate pressure, press the dome into the liner.
15. Remove the ring compressor.
16. Push or tap the piston and connecting rod within the liner until the upper rod bearing is firmly seated on the appropriate crankshaft journal.
17. Lubricate the lower bearing shell with clean engine oil.
18. Install the bearing cap. The number on the cap and rod must be on the same side.
19. Torque the connecting rod bolts alternately to 100 N·m + 90° + 90° torque turn.
20. Check connecting rod side clearance by moving the rod from crank cheek to crank cheek. If there is no clearance, check for proper bearing cap installation.
21. Install the remaining piston and rod assemblies in the same manner.

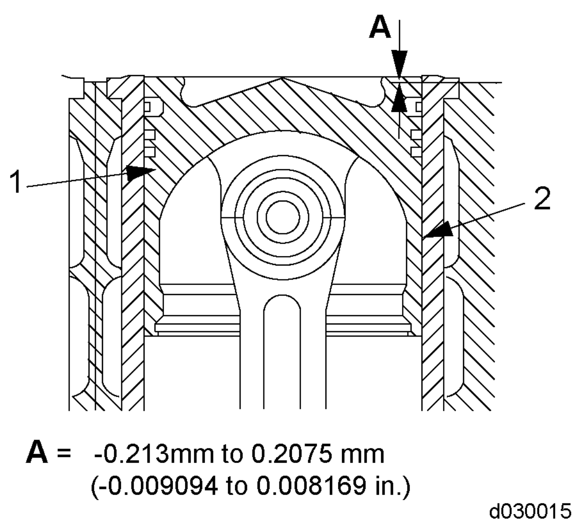
NOTICE:
Ensure when installing the piston spray nozzles that damage to the nozzles does not occur. Damaged oil spray nozzles could result in a loss of oil pressure and cause engine damage.

22. Install new piston spray nozzles at the base of the cylinder bores. Torque nozzle bolt to 30 N·m (22 lb·ft). See Figure 1-54.



1. Spray nozzle

Figure 1-54 Spray Nozzle Location



1. Piston
2. Cylinder Liner

Figure 1-55 Piston Protrusion at Top Dead Center

23. Using a dial gauge and holder, measure the piston protrusion relative to cylinder block top dead center at all the pistons. See Figure 1-55.

24. Allowable piston protrusion is -0.213 mm (-0.009094 in.) minimum and 0.2075 mm (0.008169 in.) maximum. See table 1-6. in additional information.
25. If piston protrusion is not between -0.213 mm (-0.009094 in.) minimum and 0.2075 mm (0.008169 in.) maximum replace the piston.
26. Install a new cylinder head gasket.
27. Install the cylinder head. Refer to section 1.2.
28. Install the lubricating oil pump inlet pipe and screen assembly, and the lubricating oil pump. Refer to section3.3.
29. Install the oil pan. Refer to section 3.2.
30. Complete any other engine assembly as necessary.
31. After the engine has been completely assembled, refill the crank block to the proper oil level on the dipstick.
32. Close the drain cocks and fill the engine with the recommended coolant.

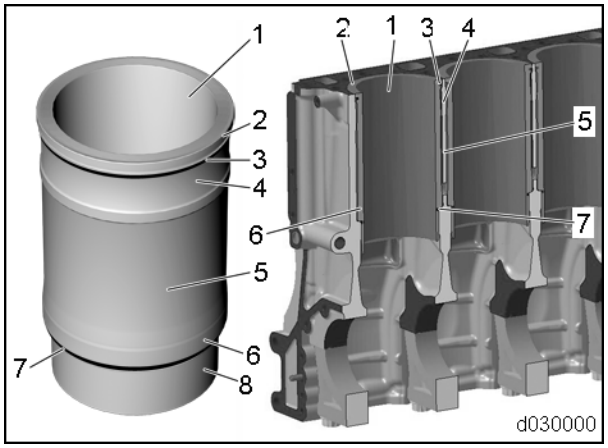
NOTE:

Coolant system maintenance is very important. Bleed off all the air from the system and top off.

33. Perform the following steps for verifying repairs made to the piston and connecting rod assembly:
    [a] If new parts such as pistons, rings, cylinder liners or bearings were installed, operate the engine on the run-in schedule.
    [b] If used parts such as pistons, rings, cylinder liners or bearings were installed verify proper piston and connecting rod assembly installation.

1.14 CYLINDER LINER

The cylinder liners (1) are designed as "bottom stop" cylinder liners which means that the cylinder liners (1) are installed with a lower collar (6) in the cylinder block. This design allows for a shorter distance between cylinders and a more compact design for the cylinder block. Each cylinder liner (1) has 2 sealing rings: the upper sealing ring (3), sealed by the upper coolant jacket (4) to the cylinder head the lower sealing ring (7), is sealed by the lower coolant jacket (5) to the cylinder block bore.



1. Cylinder Liner
2. Top of Cylinder Liner
3. Upper Sealing Ring
4. Upper Coolant Jacket
5. Lower Coolant Jacket
6. Lower Collar
7. Lower Sealing Ring
8. Bottom of Cylinder Liner

Figure 1-56 Cylinder Liner

1.14.1 Removal of the Cylinder Liner

Remove as follows:

NOTICE:
The proper method must be followed when removing the a cylinder liner. Damage to the liners and cylinder block may occur if the proper tool sand procedures are not used.

1. Remove the piston and connecting rod.Refer to section1.13.
2. Install cylinder liner remove tool J–45875 into cylinder liner.
3. Remove cylinder liner.

NOTE:
After removing the liners from the engine and prior to installation, always store them in an upright position until ready for use. Liner left on their side for any length of time

can become egg-shaped and distorted, making installation in cylinder bores difficult or impossible. If the cylinder liners are to be reused, they should be marked for cylinder location and engine orientation, a paint mark can be used to indicate the front of the engine so they may be installed to the same cylinder from which they were removed.

4. Remove the two seals from the cylinder liner and discard them.

1.14.1.1 Cleaning of the Cylinder Liner

Clean as follows:

NOTE:
If using degreasing solution to clean cylinder liner when finished an application of clean engine oil will need to be applied to protect the cylinder liner from corrosion.

1. If cleaning a new or used liner, use a clean cloth and clean engine oil.

CAUTION:

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

2. Dry the liner with compressed air.

NOTICE:

If the liners are to be installed at this time, oil them lightly with clean engine lubricating oil and store them upright in a clean, dry area. Do not let the liners rest on their sides and do not store anything on top of the liners.

3. Coat the bore of the liner with clean engine lubricating oil.
4. Allow the liner to sit for 10 minutes (to allow the oil to work into the surface finish).
5. Wipe the inside of the liner with , white paper towels.
6. If a dark residue appears on the towels, repeat the oiling and wiping procedure until residue no longer appears.

1.14.1.2 Inspection of Cylinder Liner

Inspect as follows:

1. Inspect the cylinder liner.
   [a] Check the cylinder liner for cracks or scoring.
   [b] If any of these are detected, replace with a new part.

NOTICE:
Cavitation is due to poor cooling system maintenance. If uncorrected, it will eventually make holes through the liner. This can result in combustion gases blowing water out of the radiator, oil in the coolant, or when the engine is stopped will allow water to flow into the cylinder and result in major engine damage due to water in the oil or hydraulic lockup.

[c] Check the cylinder liner for cavitation.

[d] If cavitation occurs replace the liner.

2. Inspect the outside diameter of the liner.

   [a] Check the liner for fretting.

   [b] If any fretting is found, remove it from the surface of the liner with a course, flat stone.

3. Inspect the liner flange.

   [a] Check the liner flange for cracks, smoothness and flatness on both the top and bottom surfaces.

   [b] If these are detected, replace with a new part.

4. Inspect the block bore and cylinder liner.

   [a] Measure the block bore refer to section 1.1.2.1 and the outside diameter of the liner.

   [b] If the liner does not meet specification, replace with a new part.

5. Inspect the cylinder liner.

   [a] Check the seal ring and crevice seal grooves for burrs or sharp edges.

   [b] If any are detected, smooth with an Scotch Brite.

   [c] Check for bowl polishing: if that is detected replace the cylinder liner.

1.14.2 Installation of the Cylinder Liner

Install as follows:

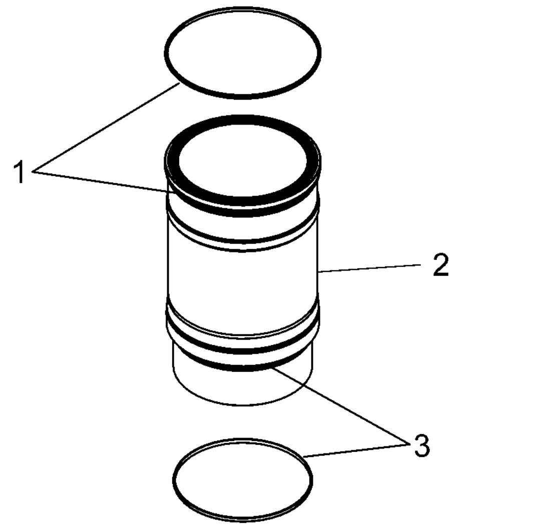
1. Wipe the inside and outside of the liner clean.

NOTE:
Thoroughly clean the cylinder block, liner, and counter bores to remove any foreign material. Foreign material in the cylinder liner counter bores can cause the liner to seat improperly.

2. Lubricate the seal rings with clean engine oil..

3. Install the two new seal rings onto the cylinder liner. See Figure 1-57.

NOTE:
Ensure when installed the seal rings are properly seated in the proper grooves.



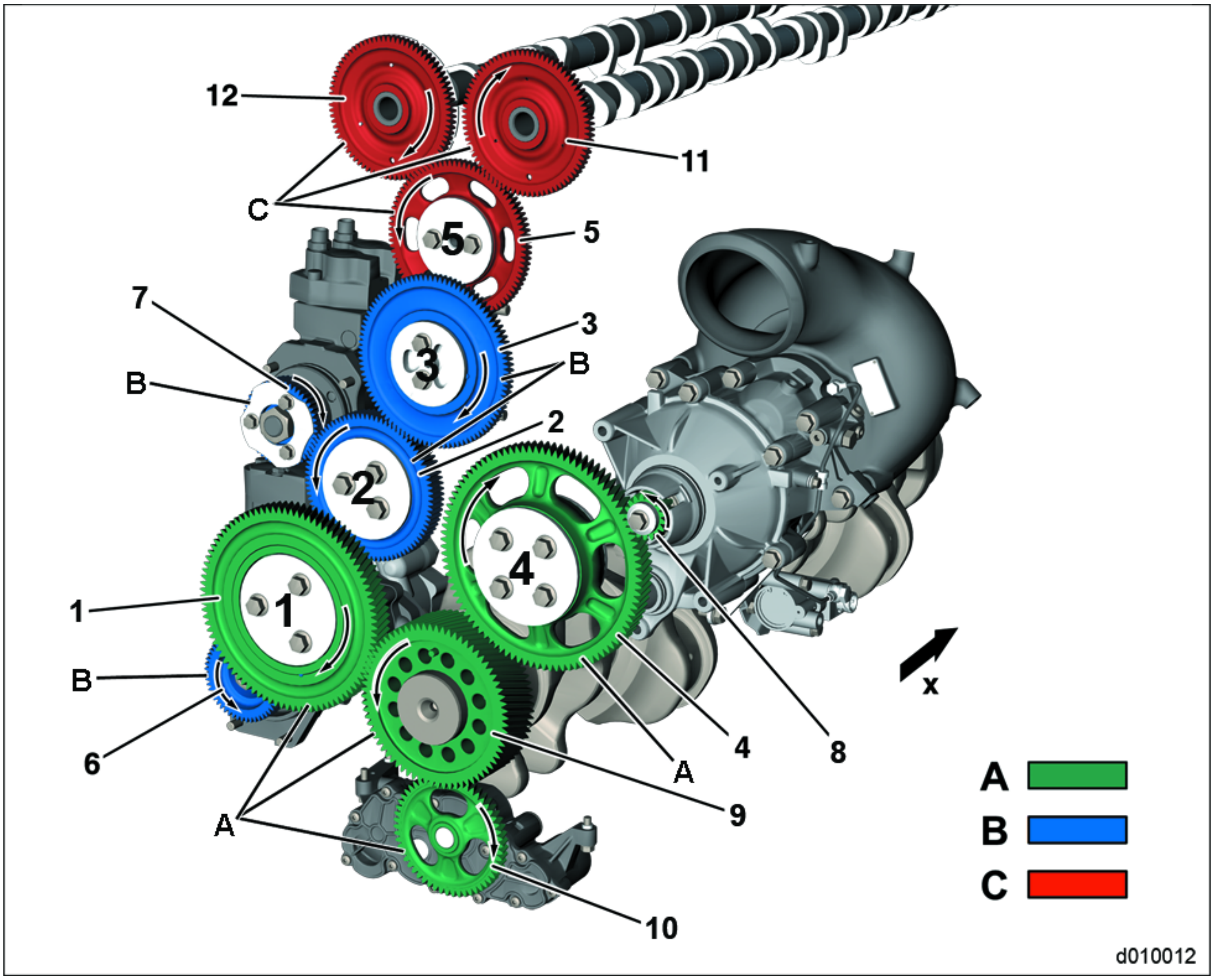
1. Top Cylinder Liner Seal Ring and Ring Location
2. Cylinder Liner
3. Bottom Cylinder Liner Seal Ring and Ring Location

Figure 1-57 Cylinder Liner and Seal Ring Location

4. Install cylinder liner in cylinder block bore using cylinder liner installation tool J–45875.
5. Seat the liner into the block using cylinder liner installation tool J–47407.
6. Install cylinder protrusion tool (J–47415) onto cylinder block. thread four cylinder head bolts through the tool and into a head bolt hole, Alternately torque the four bolts to 10 N·m (7.37 lb·ft).
7. Install a dial indicator.
8. Measure the distance from the top of the liner flange to the top of the block.
   [a] Allowable liner protrusion is 0.18-0.27 mm (0.007087-0.01063 in.).
   [b] If the liner protrusion exceeds the maximum allowable, remove the piston and connecting rod assembly and check for debris under the liner flange.
9. Remove the cylinder liner protrusion tool J–47415.

1.15 GEAR TRAIN AND ENGINE TIMING

The gear train is located at the rear of the engine. The gear train consists of intake and exhaust camshaft gears, idler gears No. 1, 2, 3, 4, and 5, crankshaft gear, oil pump gear, and the air compressor gear. See Figure 1-58.



1. Idler Gear No. 1
2. Idler Gear No. 2
3. Idler Gear No. 3
4. Idler Gear No. 4
5. Idler Gear No. 5
6 .Air Compressor Gear
7. Fuel Pump Gear
8. Axial Power Turbine
9. Crankshaft Gear
10. Oil Pump Gear
11. Camshaft Gear Exhaust
12. Camshaft Gear Intake

A. Level 1
B. Level 2
C. Level 3
x. To Front of Engine

Figure 1-58 Gear Train

Additional torque can be transmitted from the turbocompound to idler gear No. 4 and to the crankshaft.

The following components and major assemblies are driven by the crankshaft the oil pump gear, idler gear No.1, air compressor gear, idler gear No. 2, high pressure fuel pump gear, idler gear No.3, idler gear No. 5, camshaft gear, exhaust camshaft gear, intake gear and power steering pump . An additional torque is transmitted from the axial power turbine gear to idler gear No. 4 and to the crankshaft. Which adds an additional 260 N·m (192 ft·lb) of torque to the crankshaft.

The gear drives for the individual major assemblies and components are transferred on the following levels:

- Level 1 (A)
- Level 2 (B)
- Level 3 (C)

Level 1 (A) includes the drive gear for the crankshaft gear, idler gear No. 1, oil pump gear, idler gear No. 4 and axial power turbine gear. The gears for Level 1 (A) are helically geared.

Level 2 (B) includes idler gear No.2, idler gear No.3, high pressure fuel pump gear and air compressor gear. The gears for Level 2 (B) are straight toothed.

Level 3 (C) includes the drive gear for the camshaft gear exhaust, camshaft gear intake and the idler gear No.5. The gears for Level 3 (B) are straight toothed.

Gear train noise is an indication of excessive gear lash, chipped or burred gear teeth. Therefore, when noise develops in a gear train, the gear train needs to be inspected. A rattling noise usually indicates excessive gear lash. A whining noise indicates too little gear lash.

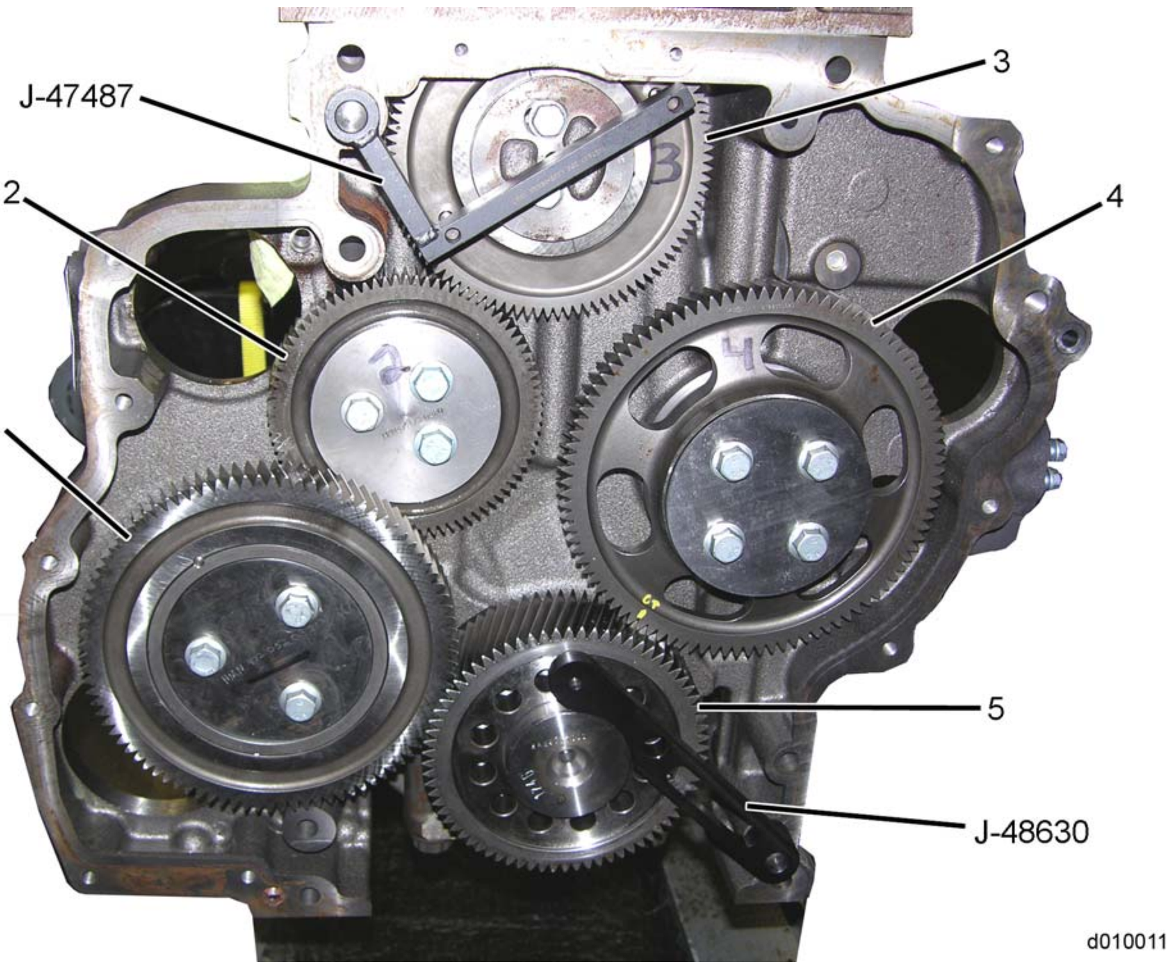
1.15.1 GEAR TRAIN TIMING

Time the gear train as follows:

NOTE:
Timing marks are etched on the exhaust and intake gears.

NOTE:
To ensure gear train remains in time do not remove timing tools until all the gears have been installed.

NOTE:
Coat the inside of the gears with clean oil before installation.



1. Idler Gear 1
2. Idler Gear 2
3. Idler Gear 3 with J-47487 Installed
4. Idler Gear 4
5. Crankshaft Gear with J-48630 Installed

Figure 1-59 Timing Tools Installed

1. Install timing tool W47058902400 into the holes at the front and rear of the camshaft frame and secure to the camshaft frame with two bolts on the front and one bolt for the rear timing tool.
2. Ensure timing marks on camshaft gear are at TDC for intake and exhaust gear.

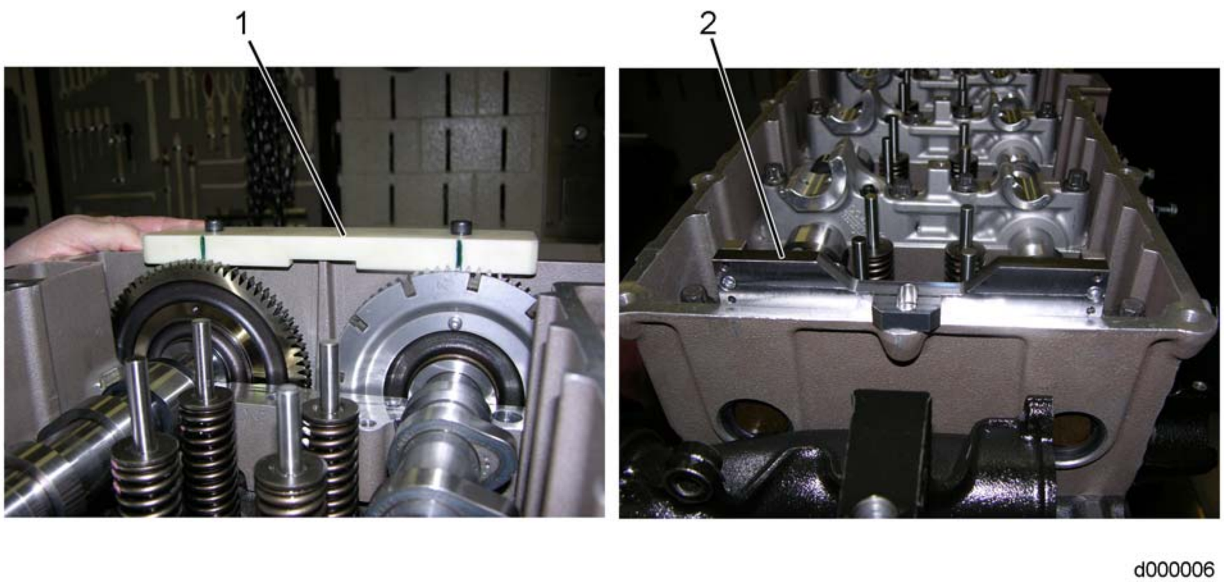


Figure 1-60 Timing Tools W47059024000

3. Rotate the engine to top dead center (TDC) on cylinder No. 1. Lock tool J-48630 into place with bolt.See Figure 1-61.

Figure 1-61 Timing Tool J–48630

4. Install timing tool J–47487 on idler gear No.3 see Figure 1-62.

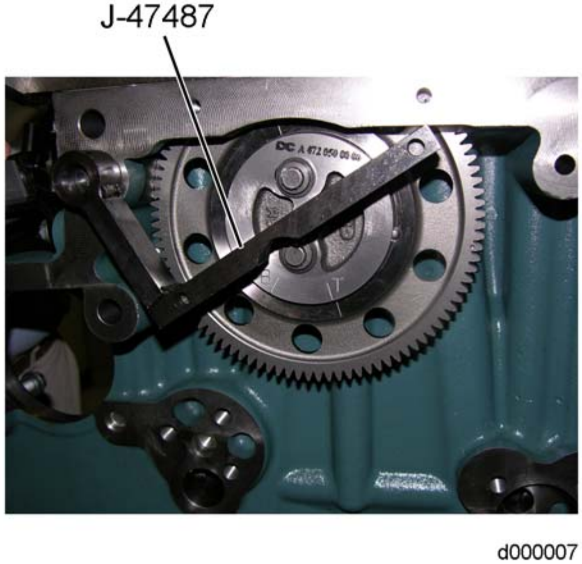


Figure 1-62 Timing Tool J–47487

NOTE:
Ensure Timing mark on spindle and gear for idler gear No. 3 align.

5. Install shoulder bolt J-47486 into No. 5 idler gear.
6. Install idler gear No. 3 and tool J–47487 onto cylinder block.
7. Install two bolts into idler No. 5 remove shoulder bolt J–47486 and finger tighten bolts.
8. Install two bolts into idler gear No. 3 and snug the bolts.

NOTE:
When idler gear No. 3 and timing tool J–47487 are installed to the gear case timing tool J–47487 should come off of the gear with ease. If the timing tool is not easily removed that is a indication the gears are not timed.

9. Check the gear lash between idler gear No. 3 and idler gear No. 5.
10. Install a dial indicator onto gear case and position the stem to rest between the teeth on idler gear No. 3, zero out the dial indicator.
11. Hold idler gear No. 5 with a screw driver.
12. The lash reading on the dial indicator should be 0.77 - 0.345 mm (0.003-0.013 in.).
13. Install spindle and idler gear No. 2 onto gear case with three bolts torque bolts to 100 N·m (73 ft·lb).

NOTE:
For ease of installation on idler gear No. 1 roll the gear into crankshaft gear.

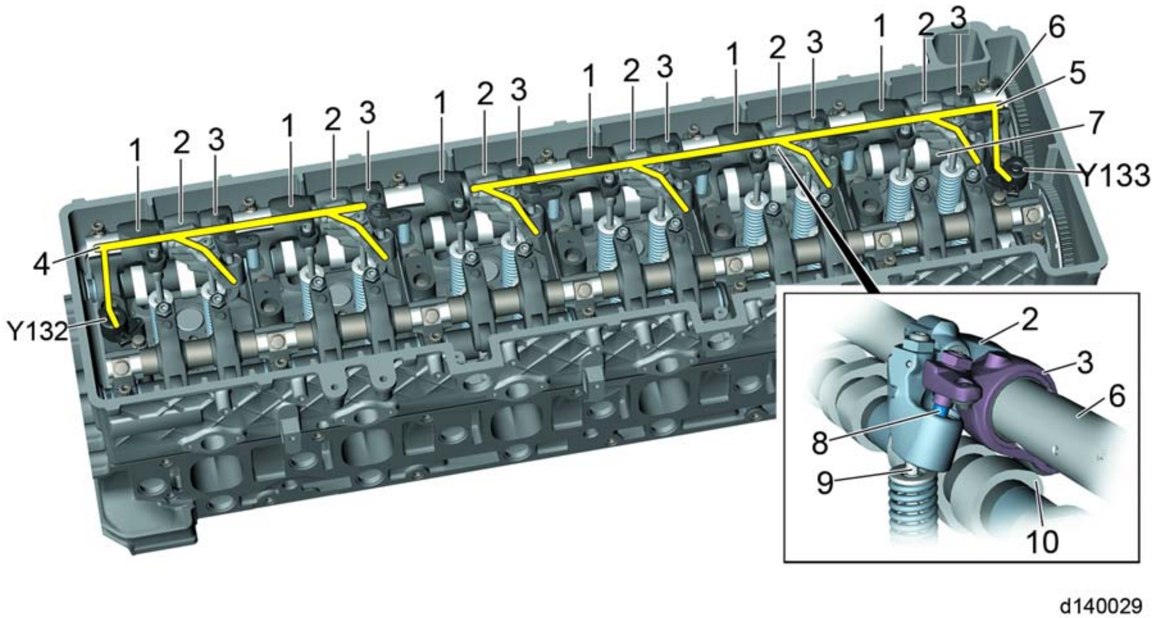
14. Install idler gear No. 1 and thrust washer onto gear case with three bolts. Torque the bolts to 100 N·m (73 ft·lb).
15. Install, idler gear No. 4 and spindle onto gear case with four bolts. Torque the bolts to 100 N·m (73 ft·lb).
16. Final torque idler gear No. 5 to 60 N·m (44 ft·lb).
17. Install timing verification tool W47058902400 into the holes in the in the rear of the camshaft frame. Verify camshaft gear timing marks are aligned with marks on the verification tool.
18. Remove timing tools from gears and camshaft frame.

1.16 ENGINE BRAKE

The engine brake is activated on the compression stroke. During the intake stroke one exhaust valve is opened on the cylinder. Hot gas flows into the cylinder, the compression pressure increases and the upward piston is braked. The engine brake system can only be activated in overrun mode. The driver can select one of 3 brake stages; in Brake Stage 1 the braking power of the cylinders 1 and 2 is used, in Brake Stage 2 the braking power of cylinders 3 to 6 is used and in Brake Stage 3 the braking power of all cylinders is used.

The engine brake system is enabled using the following components:

- Engine brake solenoid valve low (Y132)
- Engine brake solenoid valve medium (Y133)
- Six exhaust rocker arms with actuator (2)
- Six brake rocker arms (3) which are actuated by the brake cam lobes(10)
- Exhaust rocker arm axis (6) with an oil duct for lubricating the rocker arm and 2 additional oil ducts (oil duct for cylinders 1 and 2 (4) and oil duct for cylinders 3 to 6 (5)) for supplying pressurized oil to the exhaust rocker arm with actuator (2)
- Exhaust camshaft (7) with one brake cam lobe (10) per cylinder



1. Exhaust Rocker Arm
2. Exhaust rocker Arm with Actuator
3. Brake Rocker Arm
4. Oil Duct for Cylinders 1 and 2
5. Oil Duct for Cylinders 3 and 6
6. Exhaust Rocker Arm Shaft
7. Exhaust Camshaft
8. Piston
9. Outlet Valve
10. Brake Cam

Y132 Engine Brake Solenoid Valve Low

Y133 Engine Brake Solenoid Valve Medium

Figure 1-63 Engine Brake

1.16.1 Removal of the Engine Brake

Remove as follows:

1. Steam clean the engine.

NOTE:
Ensure the engine is at ambient temperature.

2. Disconnect the starting system.
3. Remove the rocker cover. Refer to section 1.9.
4. Disconnect the harness from engine brake solenoid (Y132 and 133).
5. Remove the engine brake solenoid.
6. Loosen the seven bolts securing the exhaust rocker arm (1) to the bridge.
7. Using rocker arm removal tool 470589004000 remove exhaust rocker assembly from the camshaft housing. See Figure 1-64.

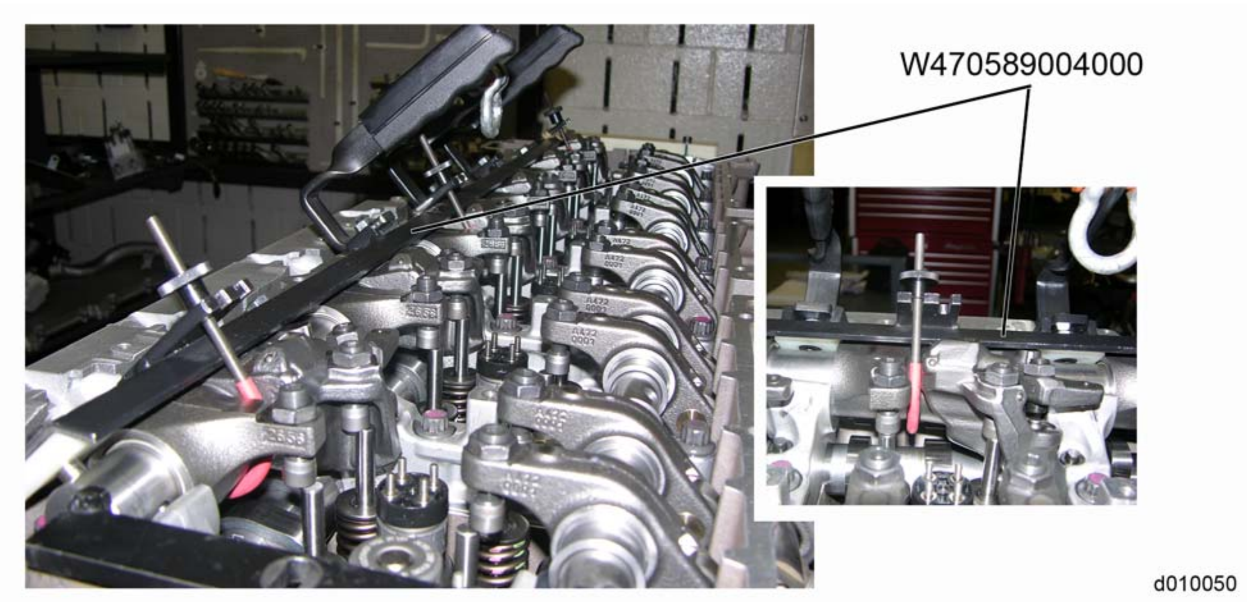


Figure 1-64 Tool W470589004000

1.16.1.1 Inspection of the Engine Brake

Inspect as follows

1. Inspect the exhaust rocker arm with actuator for damage or wear; replace if necessary.
2. Inspect the two engine brake solenoids for wear or damage; replace if necessary.
3. Inspect the brake rocker arm for wear or damage; replace if necessary.

1.16.2 Installation of the Engine Brake

Install as follows:

1. Install the exhaust rocker arm with actuator (2) and brake rocker arm (3) onto exhaust rocker shaft.
2. Install rocker arm assembly using installation tool W470589004000 onto rocker arm assembly and install assembly into camshaft housing. See Figure 1-65.

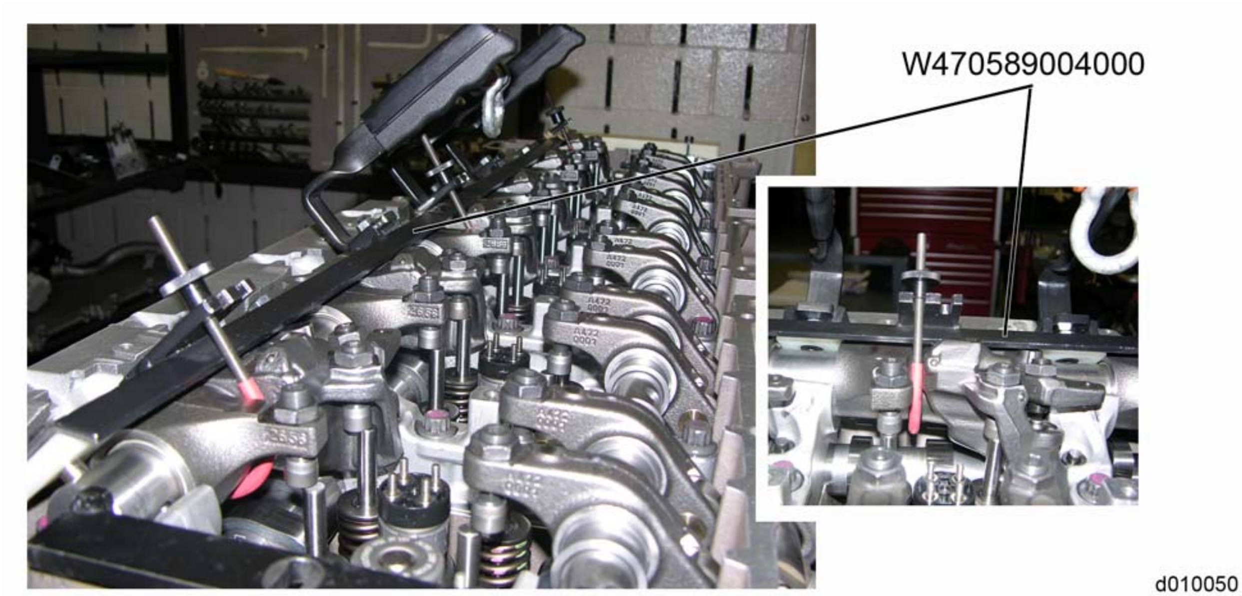
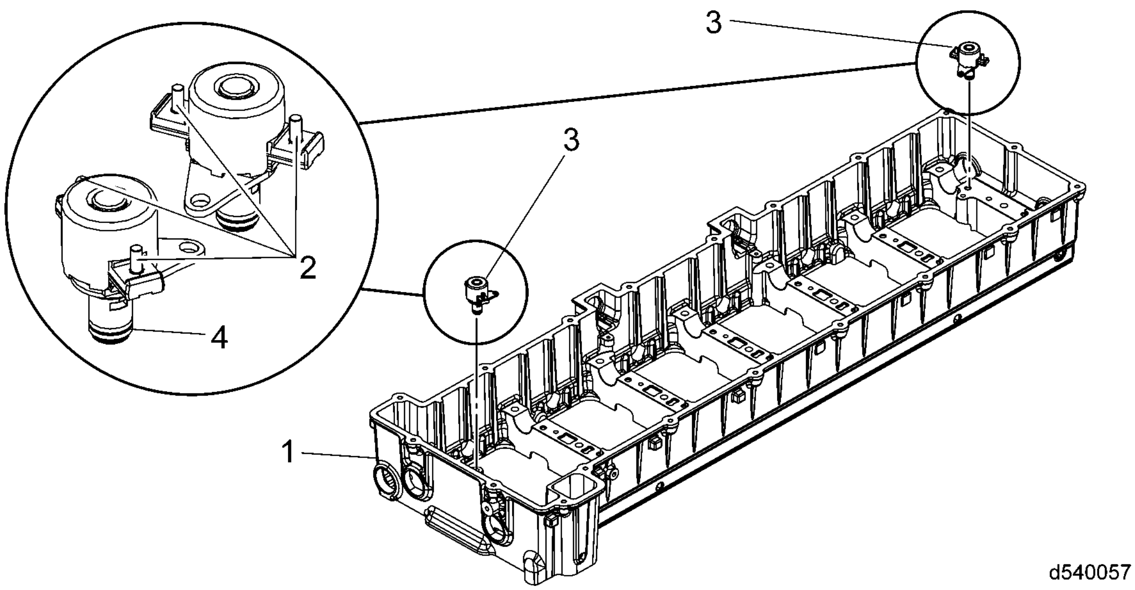


Figure 1-65 Tool W470589004000

3. Install seven bolts into the rocker shaft and bracket.
4. Tighten the seven bolts 55 N·m (41 lb·ft) 90° +10.

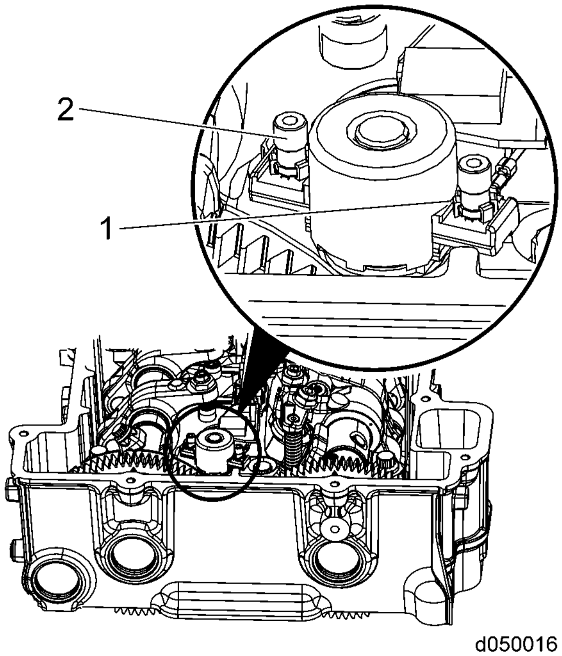
5. Install the two brake solenoids with new seal O-rings. See Figure 1-66.



1. Camshaft Housing
2. Engine Brake Solenoid Posts
3. Engine Brake Solenoids
4. Seal O-rings

Figure 1-66 Solenoid and Seal O-ring Location

NOTICE:
Ensure when tightening the terminal connector that the connector does not contact the solenoid housing. A short to all the injectors will occur if contact is made. See Figure 1-67.



1. Terminal Connector
2. Interference Point between the Solenoid and Connector

Figure 1-67 Location of Connector and Solenoid

6. Install injector harness contacts to solenoids.
7. Install rocker cover. Refer to section 1.9.

NOTE:
Anytime the engine brake lash is set the valve lash will need to be adjusted. Refer to section 1.16.2.1 refer to section 1.16.3.

1.16.2.1 Setting the Engine Brake Lash

Set the lash as follows:

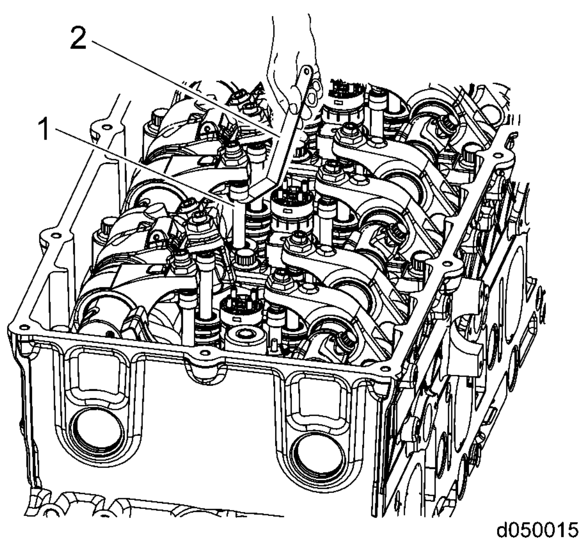
1. Set the lash on all the exhaust adjusting screws first (all the adjusting screws in direct contact with the exhaust valves).
2. Rotate the engine until a given cylinder is at maximum intake lift. When this is reached, the brake lash can be set on this cylinder

3. When the brake rocker arm is in contact with the exhaust valve, set the lash between the brake rocker arm adjusting screw and the actuator piston stem. Set the lash to 4.1 mm (0.1614 in.).
4. Lash the engine brakes in the following firing order; 1, 5, 3, 6, 2, and 4.
5. Torque the locknut valve adjusting screw to 50 N·m (37 lb·ft).

1.16.3 Valve Lash Adjustment

Adjust the valves as follows:

1. Steam clean the engine.
2. Disconnect the starting power for the engine.
3. Remove the rocker cover.
4. Bar the engine over until cylinder number one is at top dead center (TDC).



1. Feeler Gauge
2. Feeler Gauge Location between the Rocker Arm and Valve

Figure 1-68 Feeler Gauge Location

5. Lash intake valves one, two and four to 0.4 mm (0.016 in.). See Figure 1-68.
6. Lash exhaust valves one, three and five to 0.6 mm (0.024 in.). See Figure 1-68.
7. Rotate the engine 360° from the flywheel housing; until cylinder number six is at TDC; for a setting of 180° from the camshafts.
8. Lash intake valves three, five, and six to 0.4 mm (0.016 in.). See Figure 1-68.
9. Lash exhaust valves two, four and six to 0.6 mm (0.024 in.). See Figure 1-68.

10. Torque the locknut valve adjusting screw to 50 N·m (37 lb·ft).
11. Remove any tools used for this procedure.
12. Install the rocker cover.
13. Reconnect the battery power to the engine.

1.A ADDITIONAL INFORMATION

Description **Page**

SPECIFICATIONS

Specifications, clearances and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" in this chart lists the amount of wear or increase of clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the judgment of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work.

Specifications, New Clearances, and Wear Limits

These limits also apply to oversize and undersize parts.

Refer to the following tables to obtain specifications, new clearances, and wear limits for the DD15 Engine.

Component	Reference
14.8L piston and piston rings	Listed in Table 1-4
14.8L piston pin	Listed in Table 1-5
Idler Gear Specifications	Listed in Table 1-7
Idler Gear Axial Play	Listed in Table 1-8
Intake Valves	Listed in Table 1-9
Exhaust Valves	Listed in Table 1-10

Table 1-3 Engine Component Reference Table

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Piston Diameter	139 mm	-	–
Compression Rings	–	–	–
Gap Top Compression (fire ring)	0.60 mm	0.75 mm	–
Gap (No. 2 middle compression ring)	0.70 mm (0.028 in.)	0.90 mm (0.035 in.)	–
Oil Control Rings	–	–	–
Gap	0.40 mm	0.60 mm	–

Table 1-4 14.8L Piston and Piston Rings

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Piston Pin Outside Diameter	62 mm (2.44 in.)	–	–

Table 1-5 Piston Pin

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Piston Protrusion	-0.213 mm (-0.009094 in.)	0.2075 mm (0.008169 in.)	–

Table 1-6 Piston Protrusion

Engine Part (Standard Size, New)	Minimum	Maximum	
Backlash (crank gear idler 1)	0.039 mm	0.197 mm	–
Backlash (idler 1- idler 2)	0.042 mm	0.166 mm	–
Backlash (idler 2 - idler 3)	0.042 mm	0.166 mm	–
Backlash (idler3 - 5)	0.043 mm	0.165 mm	–
Backlash (idler 5 to camgear)	0.051 mm	0.257 mm	–
Backlash (crank gear- oil pump gear)	0.032 mm	0.388 mm	–
Backlash (crank gear- idler 4)	0.039 mm	0.197 mm	–
Backlash (idler 4 - turbocompound gear)	0.037 mm	0.143 mm	–
Backlash (crank gear oil pump gear)	0.032 mm	0.388 mm	–
Backlash (idler 2- High Pressure Fuel Pump gear)	0.041 mm	0.167 mm	–

Table 1-7 Idler Gear Specifications

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Idler 1 axial play	0.100 mm (0.003937 in.)	0.330 mm (0.01299 in.)	–
Idler 2 axial play	0.100 mm (0.003937 in.)	0.180 mm (0.007087 in.)	–
Idler 3 axial play	0.100 mm (0.003937 in.)	0.180 mm (0.007087 in.)	–
Idler 4 axial play	0.100 mm (0.003937 in.)	0.330 mm (0.01299 in.)	–
Idler 5 axial play	0.100 mm (0.003937 in.)	0.180 mm (0.007087 in.)	–

Table 1-8 Idler Gear Axial Play

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Stem Diameter	9.46 mm (0.3724 in.)	–	–
Valve Height	240.0 mm (9.449 in.)	–	–

Table 1-9 Intake Valves

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Stem Diameter	9.442 mm (0.3717 in.)	–	–
Valve Height	246.5 mm (9.70 in.)	–	–

Table 1-10 Exhaust Valves

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Block Bore: Diameter	164.4 mm (6.47 in.)	167 mm 6.57 in.	–

Table 1-11 Cylinder Block

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Outside Diameter Top of Liner)	— —	166.98 mm (6.57 in.)	–
Outside Diameter Bottom of Liner)	— —	149.04 mm (6.00 in.)	–

Table 1-12 Cylinder Liner

Engine Part (Standard Size, New)	
Fire Deck Flatness	0.02 mm over 150 mm distance and a maximum 0.05 mm (0.0007874 in over 5.906 in. and a maximum 0.001969 in.)

Table 1-13 Cylinder Head

2 FUEL SYSTEM

Section Page

2.1 FUEL SYSTEM OVERVIEW

The fuel supply ensures that the fuel required for combustion is available under all operating conditions in sufficient quantity, in the correct sequence and at the required pressure. Fuel to the individual cylinders is supplied from the Amplified Pressure Common Rail System. Fuel is supplied to the (APCRS) from the fuel low pressure circuit.

The fuel low pressure circuit ensures that the fuel is cleaned and is provided in sufficient quantities and at the required pressure to the APCRS. It consists of the following components:

- Fuel tank
- Fuel filter module with fuel prefilter , water separator and main filter
- Low pressure fuel pump which is located on the fuel high pressure pump
- Low Pressure Fuel Pump Outlet
- Low Pressure Fuel Pump Inlet
- High Pressure Fuel Pump Outlet
- High Pressure Fuel Pump Inlet
- High Pressure Fuel Pump Emergency Lubrication Line

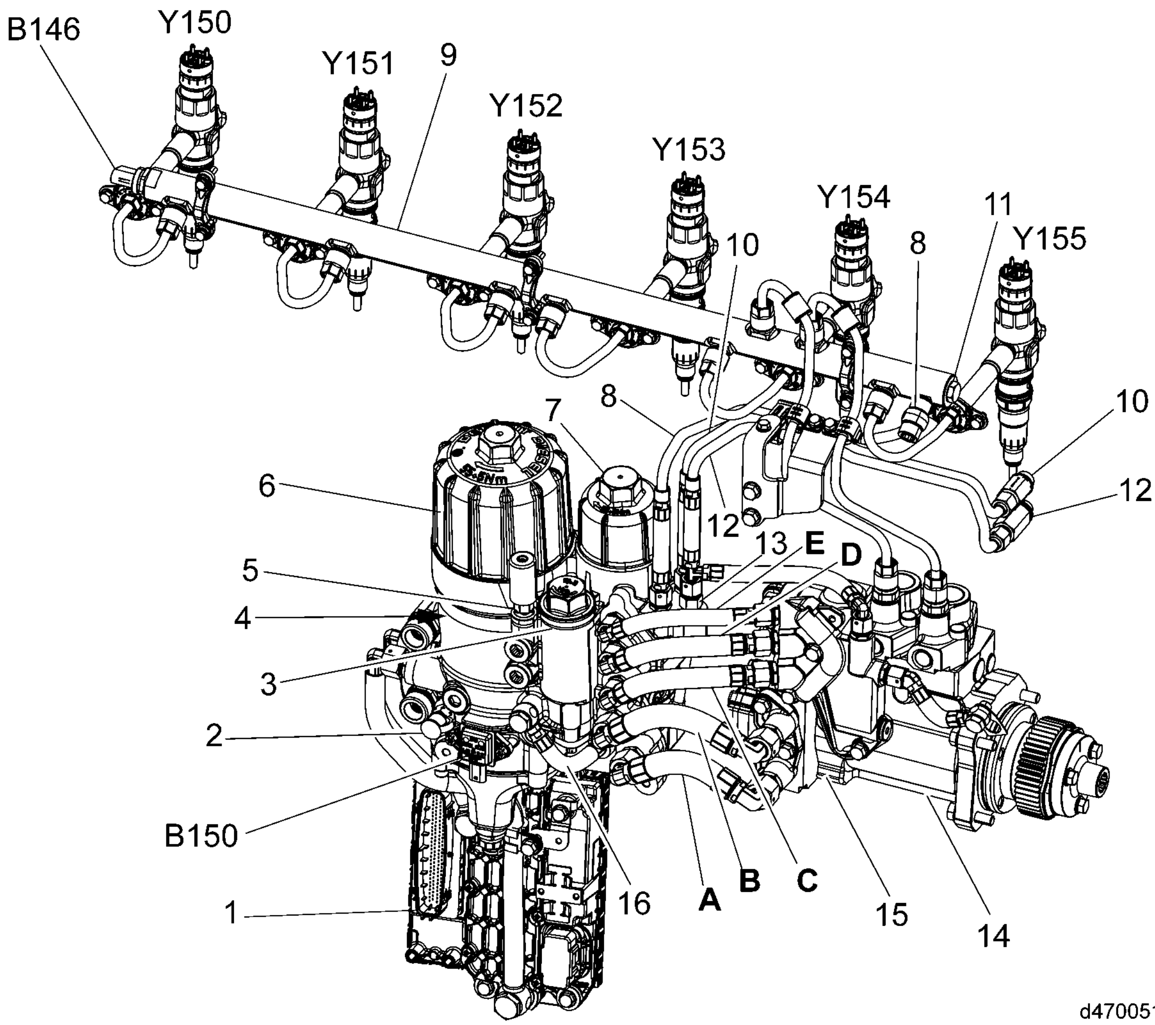
Amplified Pressure Common-Rail System (APCRS)

Fuel provided by the fuel low pressure circuit to the APCRS is injected into the cylinders in adequate quantities, in the correct sequence and at the correct pressure

The high pressure circuit of the APCRS consists of the following components:

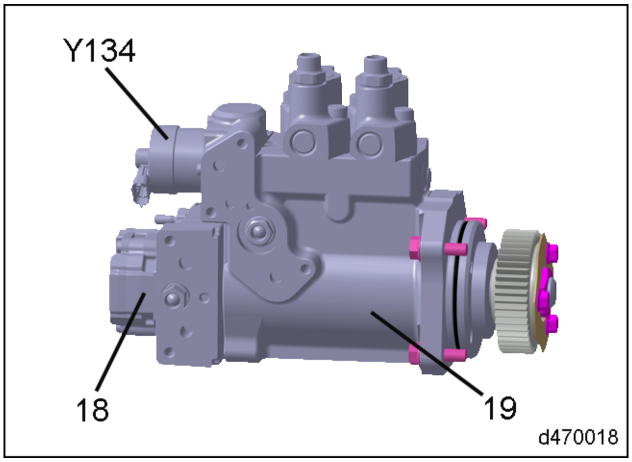
- Fuel High Pressure Pump
- Rail
- Pressure Limiting Valve
- Rail Pressure Sensor
- Quantity Control Valve
- Injector (cylinder 1) (Y150)
- Injector (cylinder 2) (Y151)
- Injector (cylinder 3) (Y152)
- Injector (cylinder 4) (Y153)
- Injector (cylinder 5) (Y154)
- Injector (cylinder 6) (Y155)

Excess fuel in the fuel high pressure circuit passes through the fuel return line (D), to the fuel return line pressure limiting valve (8) and two fuel return lines of the injectors (12) back into the fuel low pressure circuit.



1. MCM Heat Exchanger	13. Regulator
2. Priming Port	14. High Pressure Fuel Pump
3. Fuel Prefilter	15. Low Pressure Fuel Pump
4. Fuel Filter Module	16. Amplifier Return Line (External to Module)
5. Hand Primer Pump	B146. Rail Pressure Sensor
6. Water Separator	B150. Water Level Sensor
7. Final Filter	A. Low Pressure Fuel Pump Outlet
8. Fuel Return from Pressure Limiting Valve	B. Low Pressure Fuel Pump Inlet
9. Fuel Rail	C. High Pressure Fuel Pump Outlet
10. Fuel Return from Injectors Amplifiers	D. High Pressure Fuel Pump Inlet
11. Pressure Limiting Valve	E. High Pressure Fuel Pump Emergency Lubrication Line
12. Fuel Return for Injector Needle Valves	

Figure 2-1 Fuel Pump and Related Parts



18. Low Pressure Pump
19. High Pressure Pump

Y134. Quantity Control Valve

Figure 2-2 High Pressure Fuel Pump

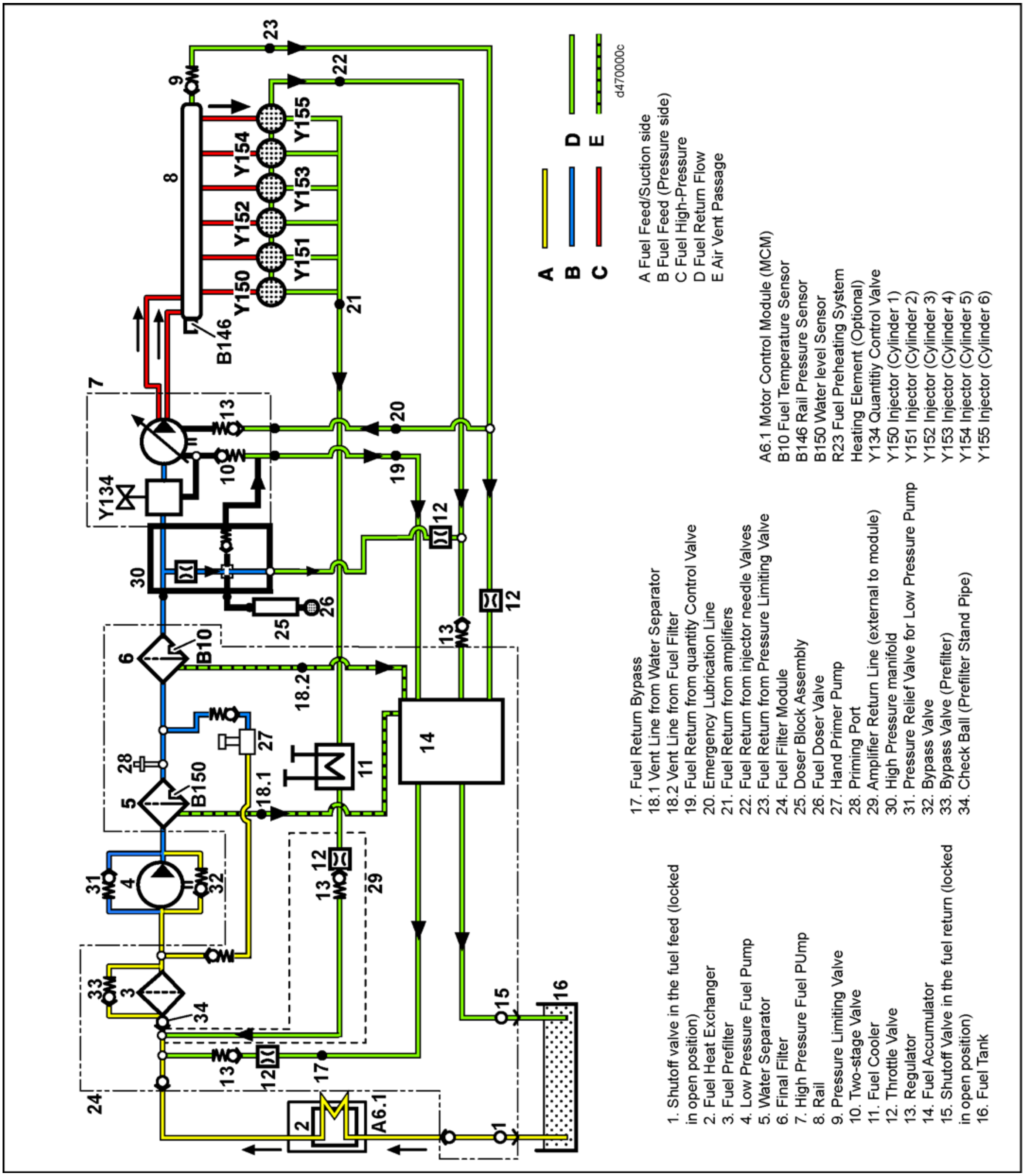


Figure 2-3 Fuel System

NOTICE:
Ensure debris does not contaminate the fuel system when servicing the fuel system components.

Before servicing the fuel system the following procedure must be followed:

1. Clean the engine, fuel system components and fuel lines.
2. If the fuel system must be drained; collect the fuel into a container.
3. Install plastic caps over any open fuel lines.
4. If the fuel system (low pressure circuit) is contaminated the lines from the tank to the filter module can be cleaned.
5. If the fuel system (high pressure circuit) is contaminated with chips the high pressure must be replaced with new lines.

2.2 COMMON RAIL INJECTOR

The injectors (Y150 to Y155) are installed with a injector clamp and bolt in the cylinder head and are located between the valves of the respective cylinder.

The injectors inject the fuel under high pressure into the cylinders. The injection timing point, injection period and the injection variants (e.g. with or without pressure converter) are established by the motor control module MCM.

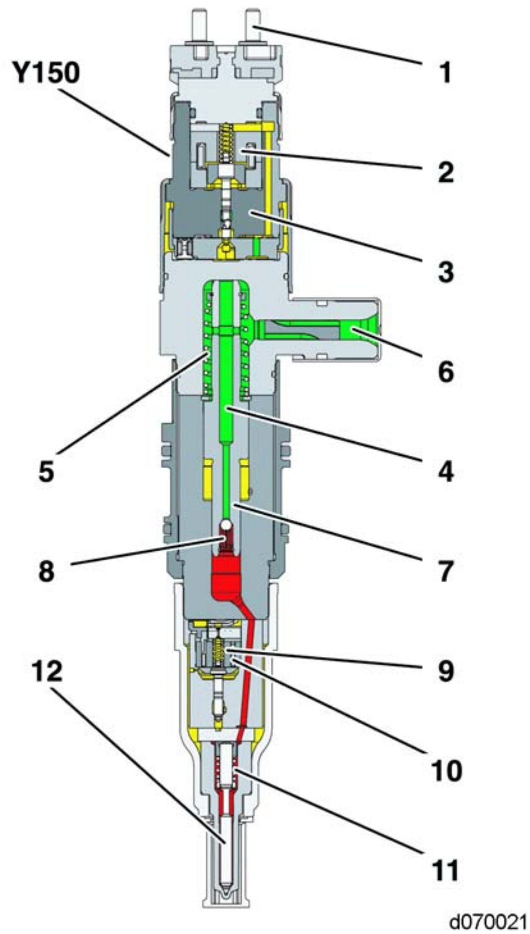
All injectors have a 7-digit code, the injector quantity compensation coding, which is located on the upper side of the injector. This code describes the quantity characterization of the injector. If an injector is replaced then this code must be reported to the motor control module (MCM).

The injectors have been designed with a pressure converter (7). If injection without a pressure converter (7) is used the injection pressure is determined by the rail pressure (about 900 bar). If injection with a pressure converter (7) is used the injection pressure of up to 2100 bar is generated in the injector.

Use of the pressure converter (7) offers the following advantages:

- Leaks in the high pressure area are reduced
- The pressure load of the high pressure pump, the rail, the high pressure lines as well as components in the injectors are reduced

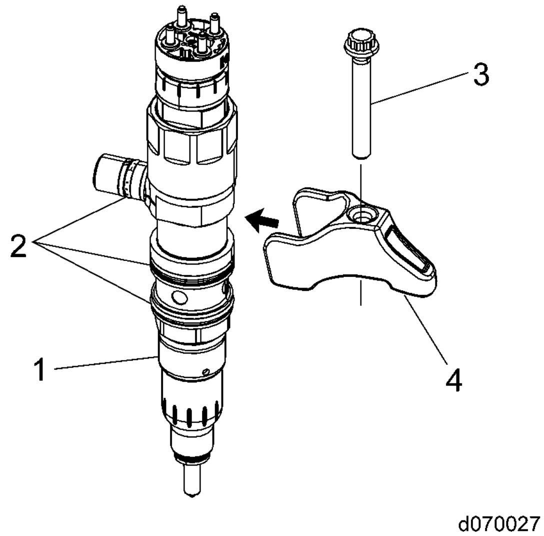
Every injector has a pressure converter control module (3) with a second solenoid valve. The pressure converter (7) will be actuated by the MCM when the MCM determines the operating condition of the engine.



1. Electrical Connector
2. Coil
3. Pressure Converter Control Module
4. Pressure Converter Piston
5. Return Spring
6. High Pressure Feed
7. Pressure Converter
8. Check Valve
9. Solenoid Valve
10. Coil
11. Spring
12. Injector Needle

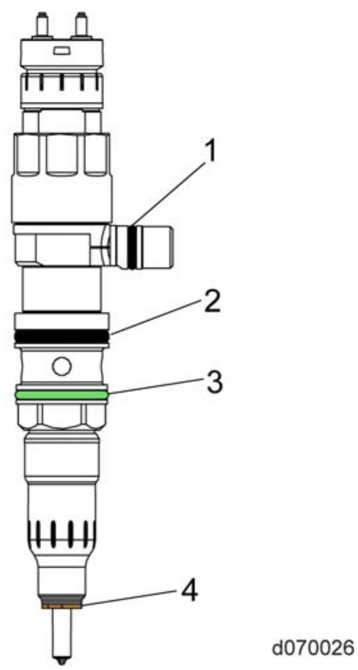
Y150 Injector (Cylinder 1)

Figure 2-4 Injector



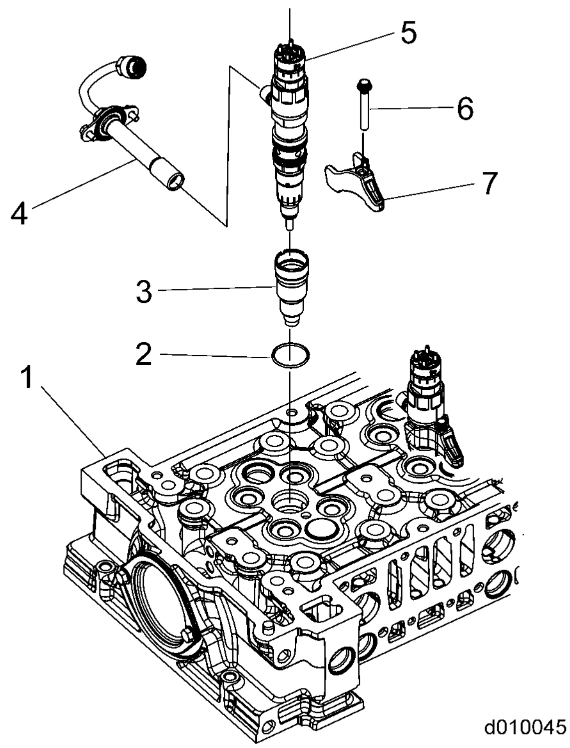
1. Injector
2. O-ring
3. Bolt
4. Clamp

Figure 2-5 Injector and Related Parts



1. Black Seal
2. Black Seal
3. Green Seal
4. Copper Washer

Figure 2-6 Injector Seals and Copper Washer



1. Cylinder Head
2. Seal
3. Injector Tube
4. High Pressure Lines
5. Injector
6. Bolt
7.
8. Clamp

Figure 2-7 Injector and Related Parts

2.2.1 Removal of the Injector

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.

1. Steam clean the engine.
2. Disconnect the batteries to prevent failure of the motor control motor (MCM).
3. Remove the rocker cover.

CAUTION:

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

4. Loosen the allen bolts holding the harness in place.
5. Disconnect the electrical contacts from the injectors.

NOTICE

Residual high pressure may be present within the circuit. Ensure the engine has been shut down for a minimum of ten minutes before servicing any component within the high pressure circuit.

6. Remove harness with the engine brake solenoids attached.
7. Disconnect 14 pin injector harness connector.
8. Remove spring clip holding the appropriate injector harness connector to camshaft frame and remove appropriate injector wiring harness.

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.

9. Disconnect high pressure line at the camshaft frame and fuel rail. Using fuel line tool J–48770.
10. Remove injector hold down bolt and clamp.
11. Lift the clamp and injector from its seat in the cylinder head using J-47391 injector removal tool.
12. Remove clamps from injectors (Y150 through Y155) and install a tip protector onto the injector nozzle (12).
13. Cover the injector hole to keep out foreign material.

NOTICE:
Avoid cleaning (wire brushing etc.) the injector tip spray holes to prevent damage and plugging.

14. Carefully remove carbon material from the injector exterior in the area where the tip joins the nut, using a clean rag soaked with clean diesel fuel.

2.2.1.1 Inspection of the Injector

Inspect the injector as follows:

NOTICE:
Injector O-ring seals, injector clamp bolt and the injector copper washer are considered one-use items and cannot be reused. Any time an injector is removed, the injector bolt, three injector O-ring seals and copper washer must be replaced with new parts. Failure to replace the O-ring seals copper washer and bolt can result in leakage.

1. Inspect the injector body for visible damage. Replace the injector if damaged.
2. Remove and discard the three injector O-rings and the copper washer.

2.2.2 Installation of the Injector

Install as follows:

NOTE:
Ensure fuel is removed from cylinder head.

1. If the fuel system is contaminated:
   [a] Drain the fuel tanks and refill with clean fuel.
   [b] Clean the fuel water/separator and replace the fuel filter module filters with new filters.
2. If the coolant system is contaminated with fuel, flush and reverse flush the system.
3. If the oil system is contaminated, change the engine oil and filters.

NOTICE:
Leftover fuel must be removed from the injector bore before injector installation.

NOTICE:
The injector tube bore should be cleaned and inspected for damage before installation of the injector.

4. Check to make sure the injector tube bore is thoroughly clean.
5. Remove injector nozzle tip protector.

NOTICE:
The copper washer must be installed with recess facing injector body. Incorrect installation can cause combustion gasses to enter the fuel system.

6. Install a new copper washer with lip facing down onto the injector.
7. Apply a thin coat of acid free grease or clean engine oil to the injector seal rings and install them in the injector nut ring grooves using J–48837. Make sure they are properly seated.
8. Install the injector and clamp as an assembly into its respective injector bore. Align the clamp over the bolt hole, install the new bolt into injector clamp and snug then release injector bolt.

NOTE:
If the high pressure lines leak after installation the lines need to be replaced.

9. Install high pressure line to the injectors (Y150 through Y155) finger tighten the cap nuts.

NOTE:
The injector may need to rotate slightly to allow connection to the injector line.

10. Torque the injector clamp bolts to 20 N·m (15 lb·ft) + 90°.
11. Using tool J–48770 torque the high pressure lines to the injector to 40 N·m (29 lb·ft).
12. Install spring clip holding injector harness connector to camshaft frame.
13. Connect 14 pin injector harness connector.
14. Record the injector calibration code from the name plate with the proper cylinder location and enter calibration codes using DDDL service routine. See Figure 2-8.

d470050

Figure 2-8 Injector Calibration Code Location

15. Install injector harness with engine brake solenoids installed and torque connections to 1 N·m (0.7376 lb·ft). Torque allen hold down screws to 10 N·m (7.376 lb·ft).
16. Install rocker cover and torque bolts in a cross pattern to 20 Nm (15 ft/lb).
17. Connect batteries.

2.3 FUEL INJECTOR TUBE

The bore in the cylinder head is for the fuel injector tube. The injector tube prevents coolant from contaminating the injector and maintains maximum cooling of the injector. The injector tube is a stainless steel tube screwed into the cylinder head. There is an O-ring installed in the cylinder head to create a water and fuel tight seal.

2.3.1 Removal of Fuel Injector Tube

Remove as follows:

NOTICE:
Engine coolant must be drained prior to injector tube removal.

1. Drain the engine coolant.
2. Remove injector harness.
3. Remove the injectors.
4. Install tool J-47388–8 into injector tube and align tool with slots in tube and turn counter clockwise to remove.
5. Remove injector tube; discard injector tube O-ring in cylinder head.

2.3.1.1 Inspection of the Injector Tube

Inspect as follows:

1. Inspect the injector tube for cracks or defects. If defective replace injector tube.
2. Clean injector tube threads with a fine wire brush, being careful not to abrade the cylinder head to injector tube sealing surface.
3. Clean the injector tube interior sealing surface, a chemical solvent maybe used for cleaning interior sealing surface.

2.3.2 Installation of Injector Tube

Install as follows:

1. Clean the injector bore of debris.

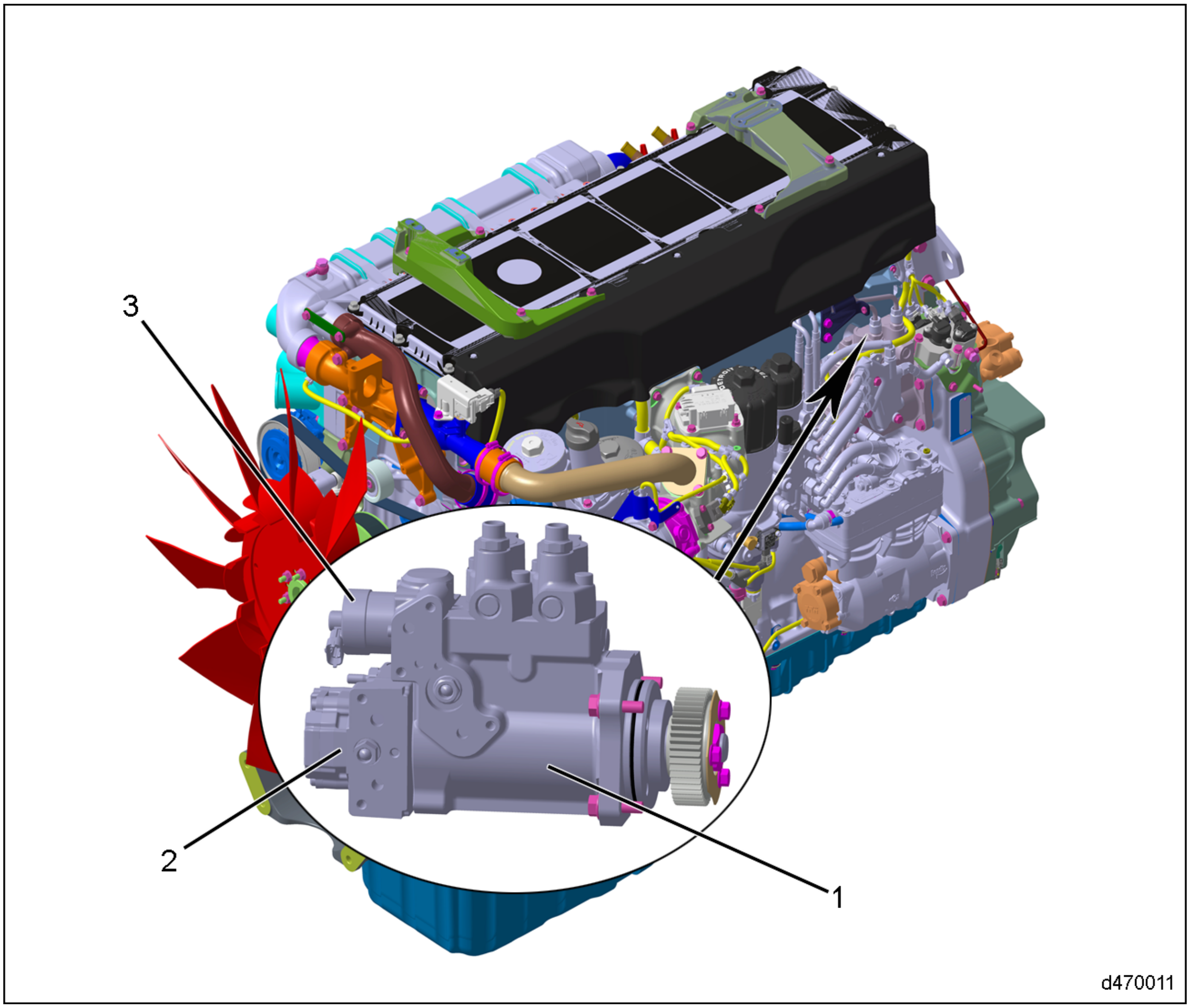
NOTICE
Take extra precautions when cleaning the injector bores to ensure that debris does not enter the fuel system. Do not use power tools to clean the injector bores, use J–47375 hand brush and a rag. Do not use compressed air to blowout debris in the bores.

NOTE:
Replace injector tube O-ring with a new O-ring when injector tube is removed or replaced.

2. Install O-ring in cylinder head, a small amount of silicone based O-ring lubrication will aid in the installation.
3. Coat the threads of the injector tube and tube sealing surface with a high temperature nickel based antiseize lubricant.
4. Install injector tube onto tool J–47388 and install into injector bore.
5. Torque injector tube to 45-49 N·m (33 -36 ft·lb).
6. Release torque approximately 180°.
7. Torque injector tube to 45-49N·m (33-36 ft·lb). If cylinder head has been removed ensure the tip of the tube is flush with the fire deck.
8. Install any components that were removed for this procedure.
9. Fill and pressure test the cooling system; check for leaks..

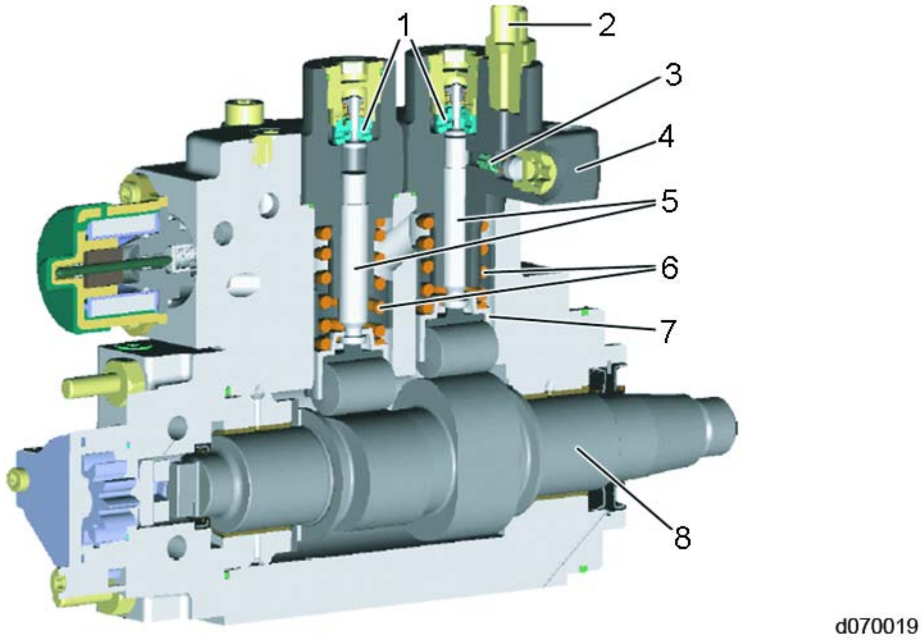
2.4 HIGH PRESSURE FUEL PUMP

The fuel pressure pump (1) is located at the rear on the left side of the cylinder block and is driven by the pinion gear drive. The high pressure pump supplies the fuel high pressure circuit with fuel and ensures that the fuel required for combustion is available in sufficient quantity and at the required pressure at the fuel injectors, under all conditions.



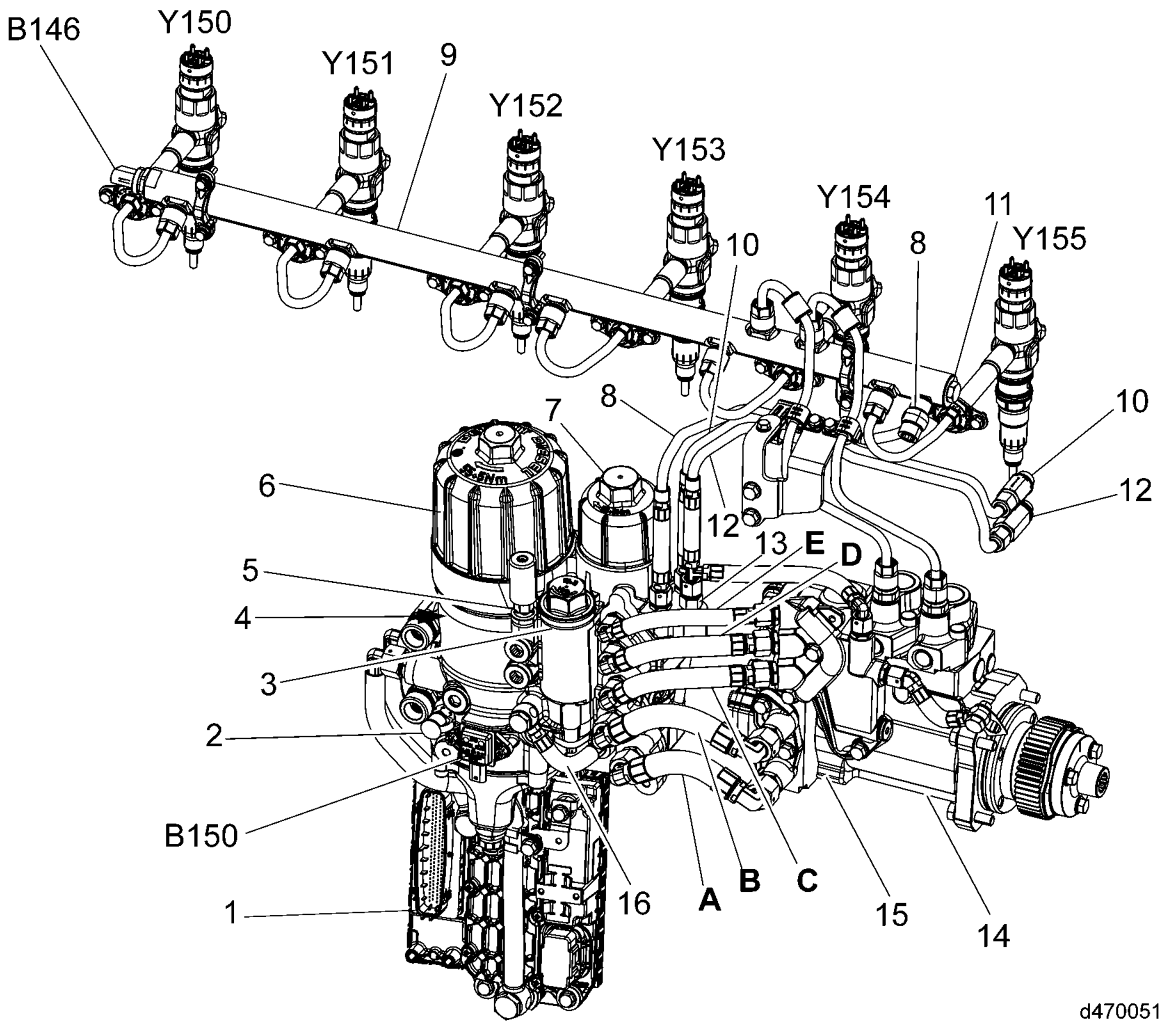
1. High Pressure Fuel Pump
2. Low Pressure Fuel Pump
3. Quantity Control Valve

Figure 2-9 High Pressure Fuel Pump



1. Intake Valve
2. High Pressure Connection
3. High Pressure Valve
4. High Pressure Pump Housing
5. High Pressure Piston
6. Compression Spring
7. Roller Tappet
8. Camshaft

Figure 2-10 Internal Components High Pressure Fuel Pump



1. MCM Heat Exchanger
2. Priming Port
3. Fuel Prefilter
4. Fuel Filter Module
5. Hand Primer Pump
6. Water Separator
7. Final Filter
8. Fuel Return from Pressure Limiting Valve
9. Fuel Rail
10. Fuel Return from Injectors Amplifiers
11. Pressure Limiting Valve
12. Fuel Return for Injector Needle Valves
13. Regulator
14. High Pressure Fuel Pump
15. Low Pressure Fuel Pump
16. Amplifier Return Line (External to Module)

B146. Rail Pressure Sensor
B150. Water Level Sensor
A. Low Pressure Fuel Pump Outlet
B. Low Pressure Fuel Pump Inlet
C. High Pressure Fuel Pump Outlet
D. High Pressure Fuel Pump Inlet
E. High Pressure Fuel Pump Emergency Lubrication Line

Figure 2-11 Fuel Pump and Related Parts

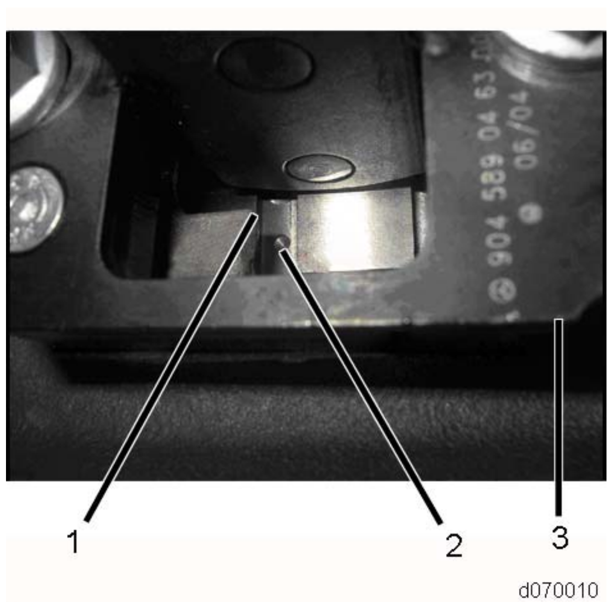
The camshaft for the fuel pressure pump is driven by the pinion gear drive. The fuel is compressed by two high pressure pistons and flows to the high pressure connection and corresponding high pressure lines to the rail. The two roller tappets on the double cams of the camshaft are pressed together by the two compression springs which are offset by 90°. Two power strokes occur for one camshaft revolution per high pressure piston . If the high pressure piston is in a downward movement, the fuel can flow to the corresponding intake valve into the clearance volume to the high pressure piston .

If the high pressure piston changes to an upward movement, the intake valve is closed by the compression pressure and the fuel is compressed until the high pressure valve opens a transfer duct between the high pressure compartment and the high pressure connection . The highly compressed fuel can now flow into the rail. If the high pressure piston changes to a downward movement, the transfer duct is closed by the spring-loaded high pressure valve and fuel can flow through the opened intake valve into the clearance volume.

2.4.1 Removal of the High Pressure Fuel Pump

Remove as follows:

1. Disconnect the batteries.
2. Drain the coolant system.
3. Install engine barring tool to the flywheel housing.
4. Rotate flywheel until the dot that is located inside tooth is aligned with the edge of pointer.



1. Edge of Pointer
2. Dot Located inside of Tooth
3. Barring Tool Location

5. Remove crank position sensor and install TDC tool W470589001500.

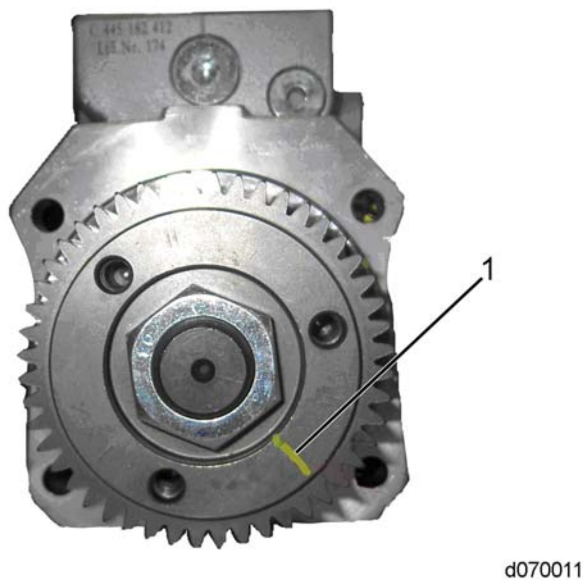
6. Remove coolant line from the module to air compressor.
7. Disconnect fuel supply line to the doser block assembly.
8. Disconnect the needle return line.
9. Disconnect amplifier return line.
10. Disconnect fuel lines from the fuel filter module on the manifold at the high pressure pump.
11. Remove fuel filter module. Refer to section2.8.
12. Remove two high pressure lines from the high pressure fuel pump to the fuel rail.
13. Remove upper and lower fuel manifolds from the high pressure fuel pump and discard the gaskets.
14. Disconnect electrical connector for the quantity control valve.
15. Remove two bolts securing the high pressure fuel pump bracket to engine block.
16. Remove two nuts securing high pressure fuel pump to bracket.
17. Remove four bolts securing high pressure fuel pump to cylinder block.
18. Remove high pressure fuel pump.

2.4.2 Installation of High Pressure Pump

Install as follows:

1. Ensure flywheel is positioned at top dead center (TDC) on cylinder number one.
2. Inspect the high pressure pump:
   [a] If driven gear has been installed from the factory, go to step 11.
   [b] If driven gear has been exchanged from the old pump or is installed new, go to step 3.
3. Install a new high pressure pump into holding fixture W470589014000. Remove locking tooth from the tool.
4. Install key way onto shaft using a brass hammer.
5. Install driven gear onto shaft.

6. Prior to installing the nut mark the gear with paint to show the location of the key way.

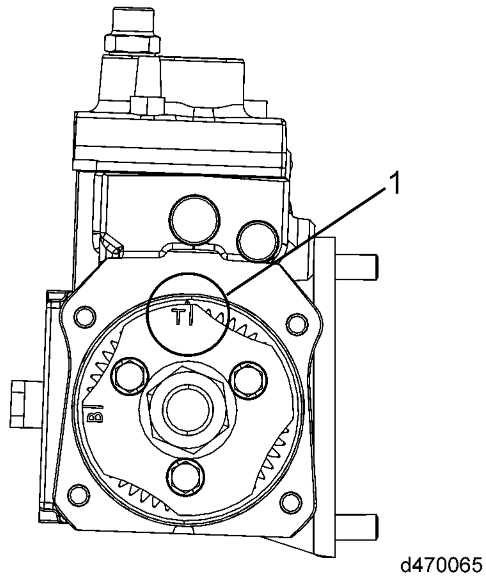


1. Paint Mark for Key Way

7. Install the nut and locking tooth for tool W470589014000 and using tool J–48669 torque to 250 N·m (184 ft·lb).
8. Position eyebrow plate over gear and align the hash mark on the plate to the paint mark on the gear.

1. Hash Mark Aligned with Key Way

9. Install three eyebrow mounting bolts and torque to 30 N·m (22 ft·lb).
10. If not installed; install the high pressure pump into holding fixture W470589014000. Remove the locking tooth from the tool.
11. Use a non marring strap wrench rotate the gear until the hash mark is at the twelve O'clock position. See Figure 2-12.



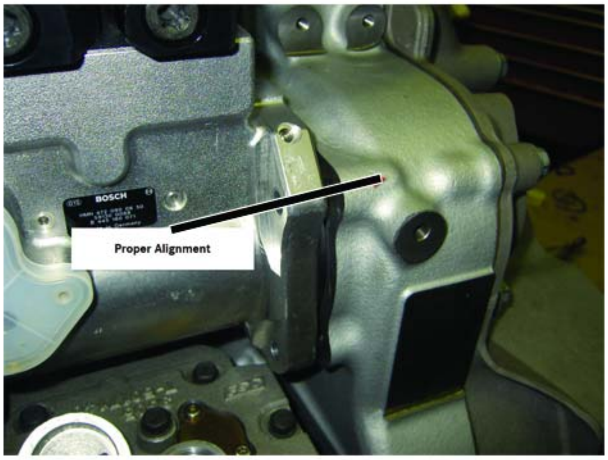
1. Mark at the Twelve O'clock Position

Figure 2-12 Time Plate at the Twelve O'clock Position

12. Remove strap from pump.
13. Install a new O-ring.
14. Install the high pressure pump.

NOTE:

The pump should slide into the flywheel housing without binding. The bolt hole on the pump housing should align very close with the mounting hole on the flywheel housing.



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1. Proper Alignment of the High Pressure Pump to the Flywheel Housing

NOTE:
If the high pressure pump binds when being installed or if there is misalignment in the bolt holes, remove pump and verify timing mark at the twelve O'clock position and reinstall. See Figure 2-13.

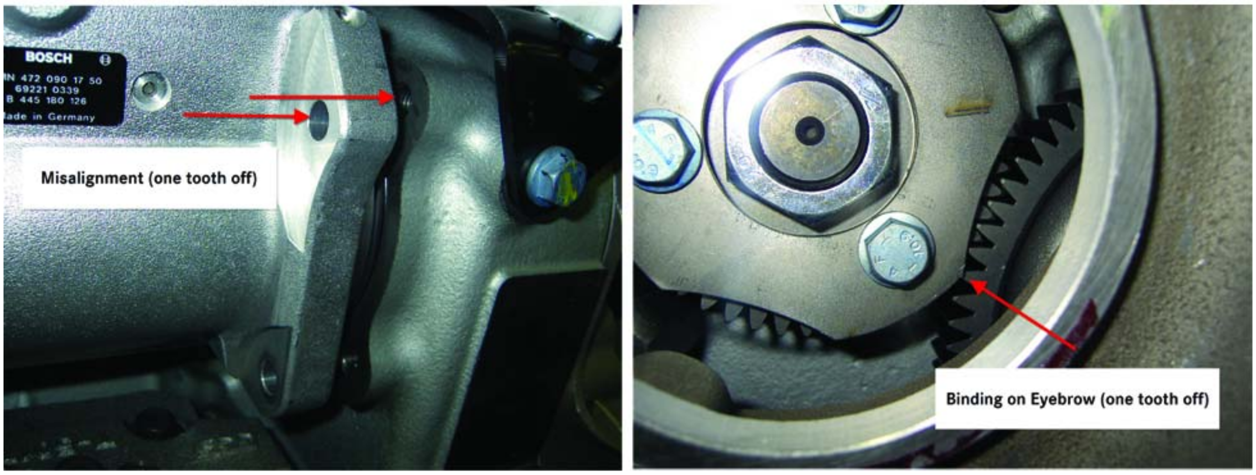

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Figure 2-13 Misalignment of the High Pressure Pump

NOTICE:
Ensure the correct bolt length is used when the high pressure pump is installed. If an incorrect bolt length (to long) is used the cup plugs installed in the cylinder block can be pushed out into the gear train causing severe damage to the gear train. The correct bolt length is 35 mm (1.37 in.).

15. Install four bolts securing the high pressure pump to the flywheel housing and torque to 60 N·m (44 ft·lb).
16. Install two nuts securing the high pressure fuel pump to bracket and torque to 30 N·m (22 ft·lb).
17. Install two bolts securing high pressure fuel pump bracket to block and torque to 100 N·m (74 ft·lb).
18. Install a new gasket and torque upper fuel manifold bolts of the high pressure fuel pump to 30 N·m (22 ft·lb).
19. Install a new gasket and torque lower fuel manifold bolts of the high pressure fuel pump to 30 N·m (22 ft·lb).
20. Connect quantity control valve connector.
21. Install the fuel lines on fuel filter module.
22. Torque the emergency lubrication line to 35 N·m (26 ft·lb).
23. Torque the fuel inlet for high pressure pump to 45 N·m (33 ft·lb).
24. Torque the fuel return for the high pressure pump to 45 N·m (33 ft·lb).
25. Torque the fuel inlet for the low pressure pump to 45 N·m (33 ft·lb).
26. Torque the fuel return for the low pressure pump to 45 N·m (33 ft·lb).
27. Install the banjo bolts. (Only version four).
28. Torque the amplifier return fitting at the fuel inlet for low pressure pump to 35 N·m (26 ft·lb).
29. Torque the needle return fitting at fuel inlet for high pressure pump to 35 N·m (26 ft·lb).
30. Torque the fuel supply line to doser block assembly 40 N·m (30 ft·lb).
31. Install two high pressure lines from the high pressure pump to the fuel rail and torque fittings to 40 N·m (30 ft·lb).
32. Install fuel filter module refer to section 2.8.
33. Install coolant line for air compressor.
34. Fill coolant system.
35. Prime system using fuel priming valve or hand primer.

WARNING:

ENGINE EXHAUST

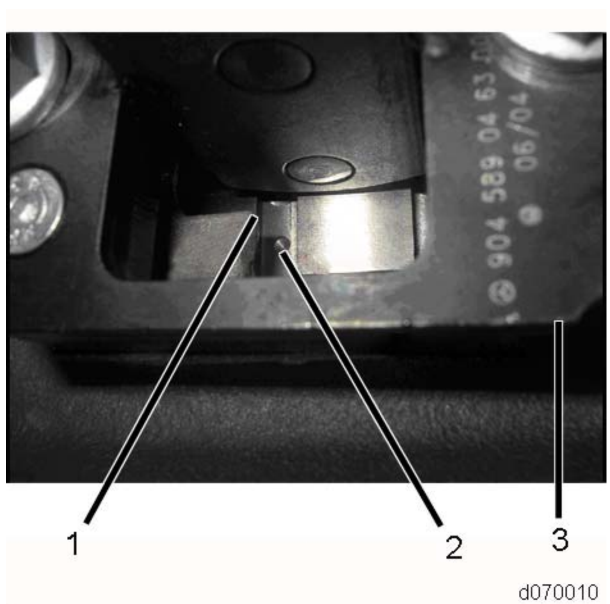
To avoid injury from inhaling engine exhaust, always operate the engine in a well-ventilated area. Engine exhaust is toxic.

36. Start and run the engine.
37. When the engine has reached operating temperature 140° F (60° C). Observe pump for any performance problems or leaks.

2.4.3 CHECK PUMP TIMING

Time the fuel pump as follows:

1. Disconnect the battery power.
2. Install engine barring tool J-46392 to flywheel housing.
3. Rotate the flywheel until the dot that is located inside the tooth is aligned with edge of pointer and install pin W470589001500. See Figure 2-14.



1. Edge of Pointer
2. Dot Located Inside of Tooth
3. Barring Tool Location

Figure 2-14 Engine at TDC

NOTE:
Cylinder No. 1 can be positioned on either the firing stroke or exhaust stroke. Both valves will be closed when cylinder number one is at TDC and the camshaft lobes will be positioned inward.

4. Remove rocker cover and ensure cylinder No. 1 is at top dead center (TDC) in the firing position.
   [a] If cylinder No. 1 is not at TDC firing position, rotate the engine one more revolution and position timing mark as shown in Figure 2-14.
5. Remove inspection cover located on flywheel housing.

NOTE:
All new pumps factory or service install will be timed at the twelve O'clock position.

6. Using a telescoping mirror check and ensure the hash mark is at the twelve O'clock position.
   [a] If the hash mark is not at twelve O'clock position; remove the pump and reinstall at the twelve O'clock position.
7. Using a telescoping mirror compare the radius of the eyebrow to the gear radius.
   [a] If the eyebrow radius intersects with the gear radius, the pump is out of time with the gear train. See Figure 2-15.

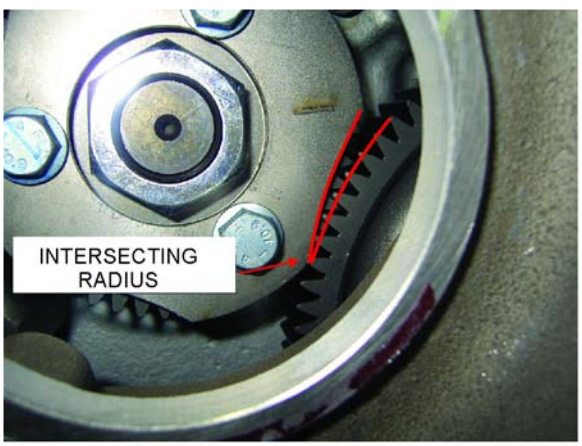


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Figure 2-15 Intersecting Radius (pump installed one tooth off)

   [b] Remove high pressure pump and inspect for damage.

[c] If no damage is found, reinstall pump at proper timing.

[d] If the eyebrow radius does not intersect with the gear radius, the pump is in time with the gear train. See Figure 2-16.

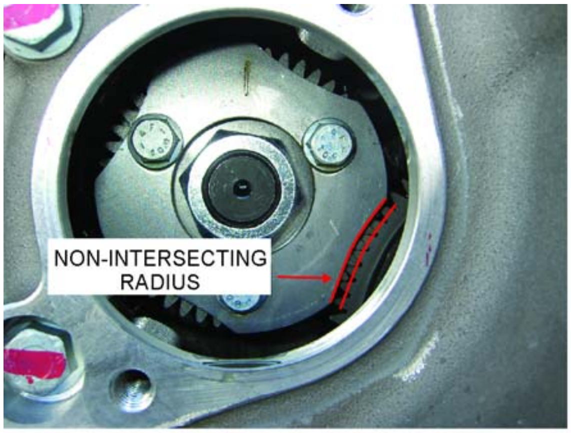

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Figure 2-16 Non Intersecting Radius

2.5 LOW PRESSURE FUEL PUMP

The low pressure fuel pump is mounted on the high pressure fuel pump. The fuel pump pulls fuel from the fuel tank through the fuel heat exchanger for the motor control module (MCM). The low pressure fuel pump is designed as a gear pump and is driven by the high pressure fuel pump. As soon as the engine starts and runs, the right gearwheel in the fuel pump is driven by the drive plate on the high pressure fuel pump camshaft. The fuel is suctioned by the rotational movement of both gearwheels and the design of the pump chamber.

2.5.1 Removal of the Low Pressure Pump

Remove as follows:

1. Disconnect batteries.
2. Drain fuel filter module by removing one of the fuel filters or by using the water in fuel drain.
3. Remove bottom two fuel lines from the fuel filter module to the high pressure pump.
4. Remove three bolts attaching the low pressure pump to the high pressure pump.
5. Remove low pressure pump.

2.5.1.1 Inspection and Cleaning of the Low Pressure Pump

Clean and Inspect as follows:

1. Clean housing around the high pressure fuel pump.
2. Inspect the “Oldham” coupling on the high pressure pump and replace high pressure pump if worn or damaged.

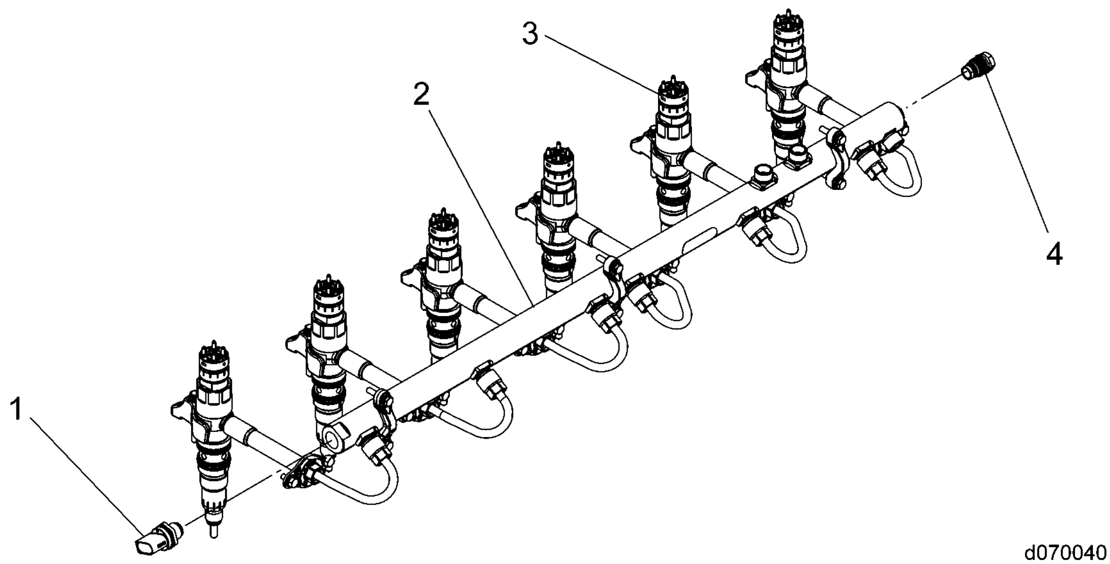
2.5.2 Installation of the Low Pressure Pump

Install as follows:

1. Install low pressure pump to the high pressure pump with new O-rings and torque bolts to 8 Nm (6 ft/lb).
2. Install bottom two fuel lines from the fuel filter module to the high pressure pump.
   [a] Fuel inlet for low pressure pump to 45 Nm (33 ft/lb).
   [b] Fuel return for low pressure pump to 45 Nm (33 ft/lb).
3. Connect batteries.
4. Prime system using fuel priming valve or hand primer.

2.6 FUEL RAIL

The fuel rail incorporates the fuel pressure sensor and pressure limiting valve. The fuel rail attaches to the camshaft frame with brackets. The fuel rail pressure sensor is installed at the front of the rail. The fuel is compressed by the by the high pressure fuel pump and is sent to the two high pressure lines and then to the fuel rail. The pressure in the rail is detected by the fuel rail pressure sensor, the pressure can be up to 900 bar. See Figure 2-17.



1. Fuel Rail Pressure Sensor
2. Fuel Rail
3. Injector
4. Pressure Limiting Valve

Figure 2-17 Fuel Rail and Related Parts

2.6.1 Removal of the Fuel Rail

Remove as follows:

1. Steam clean the engine. Refer to section .
2. Disconnect the batteries.
3. Drain the fuel system. Refer to section 12.5.13.

4. Disconnect the fuel rail pressure sensor connector from the harness.

NOTE:
When removed the fuel rail feed tubes need to be covered on the ends to ensure debris does not enter the tubes.

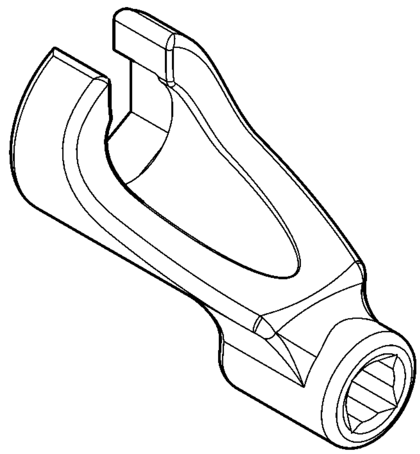


Figure 2-18 Fuel Line Removal Tool J48770

5. Remove injector feed tubes with tool J-48770.
6. Remove bracket from high pressure fuel lines.
7. Remove high pressure fuel lines from the high pressure pump and fuel rail with tool J-48770.
8. Remove pressure limiting valve return fuel line from fuel rail and fuel module.
9. Remove six bolts and three clamps connecting the fuel rail to the camshaft housing and remove fuel rail.

2.6.1.1 Inspection of Fuel Rail

Inspect as follows:

1. Inspect the bolts and clamps for damage and wear; replace as necessary.
2. Inspect the fuel rail for damage and wear; replace as necessary.
3. Inspect the fuel feed tubes for damage and wear; replace as necessary.
4. Inspect the feed tube seal located on the camshaft housing for damage; replace as necessary.

2.6.2 Installation of the Fuel Rail

Install as follows:

1. Install fuel rail to camshaft housing with three clamps and six bolts torque bolts to 10 N·m (7.376 lb·ft).
2. Remove covers from injector feed tubes.
3. Using tool J–48770 install injector feed tubes to fuel rail and the injectors torque to 40 N·m. (29.5 lb·ft).
4. Install high pressure fuel lines to the fuel rail and high pressure pump with tool J-48770 torque lines to 40 N·m (29.5 lb·ft).
5. Install pressure limiting valve fuel return line to fuel filter module and fuel rail with tool J-48770 torque to banjo bolt 35 N·m (25.81 lb·ft).
6. Install pressure limiting valve. Refer to section 2.7.
7. Install and connect rail pressure sensor to engine harness. Refer to section .
8. Install bracket to high pressure fuel lines.
9. Connect the batteries.

WARNING:

ENGINE EXHAUST

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

10. Prime the fuel system start the engine and check for leaks.

2.7 PRESSURE LIMITING VALVE (PLV)

The pressure limiting valve is a safety valve which limits the maximum rail pressure in the injection system to about 1100 bar.

2.7.1 Removal of the Pressure Limiting Valve

Remove as follows:

CAUTION:

EYE INJURY

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

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.

1. Place a small container below the pressure limiting valve to catch escaping fuel.
2. Remove the pressure limiting valve from the fuel rail

2.7.2 Installation of the Pressure Limiting Valve (PLV)

Install as follows:

1. Install the pressure limiting valve and torque to 95-105 N·m (70-77 ft·lb).
2. Prime the fuel system using fuel priming valve or hand primer.

WARNING:

ENGINE EXHAUST

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

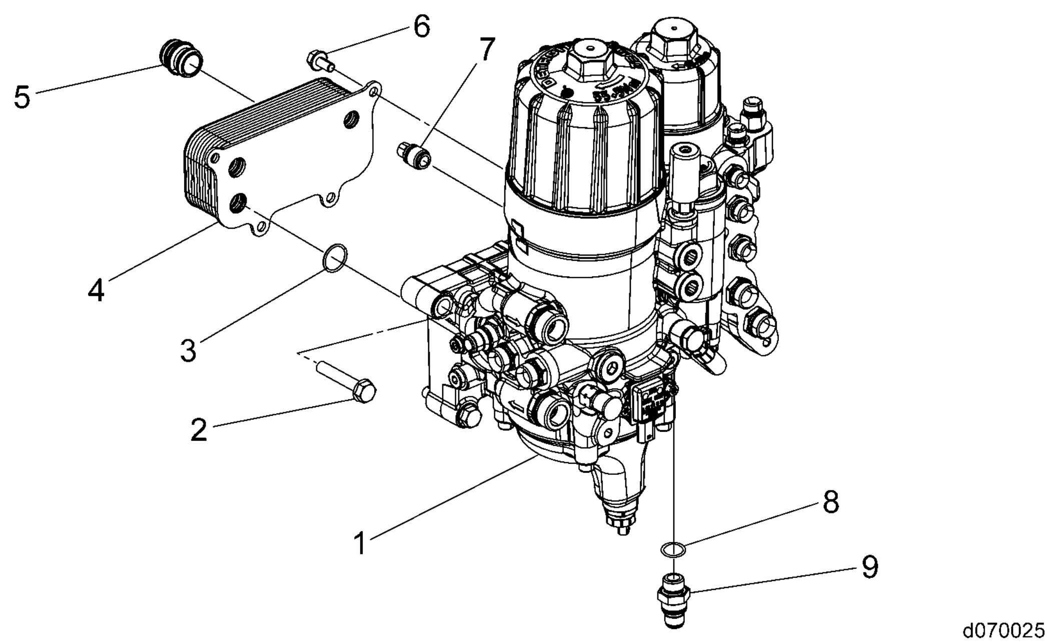
3. Start the engine and bring up to operating temperature over 60 C (140 F).

4. Check for fuel leaks.

2.8 FUEL FILTER MODULE

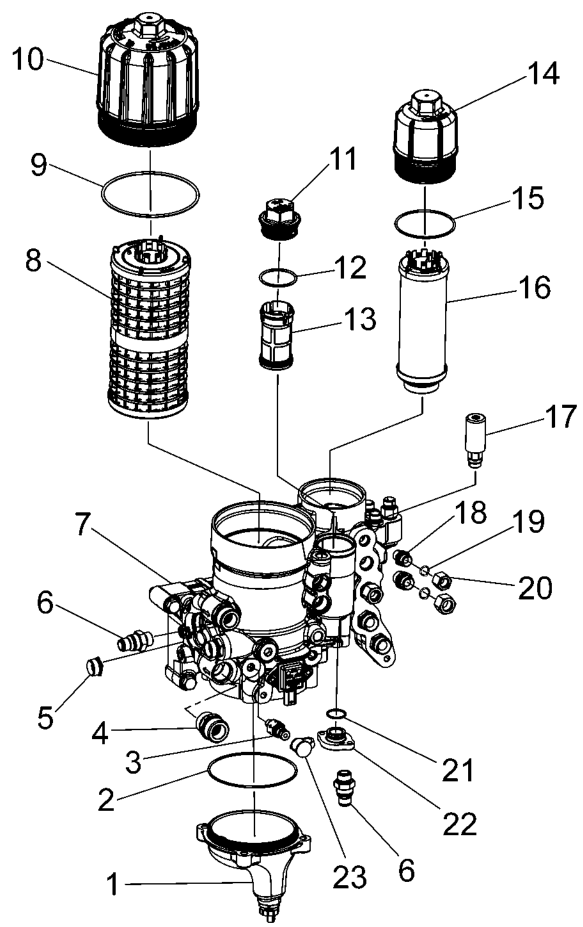
The fuel filter module is located on the left side of the engine block. The fuel filter module separates out the water in the fuel and filters out dirt particles in two stages. The fuel filter module consists of the following components:

- Fuel prefilter where large dirt particles are removed from the fuel.
- Water separator with water collector through which water in the fuel is separated.
- Final filter where small dirt particles are removed from the fuel.
- The fuel accumulator gathers fuel from all return lines and passes it through a bypass valve to either the fuel prefilter or to the fuel tank.
- The hand operated primer pump allows for priming the system when a filter is changed or when the fuel system is empty.
- The fuel priming valve can also be used after replacing a fuel filter or when the fuel system is empty.
- Assembly valves which prevents fuel from escaping when disassembling the fuel lines between the fuel tank and the fuel filter module.



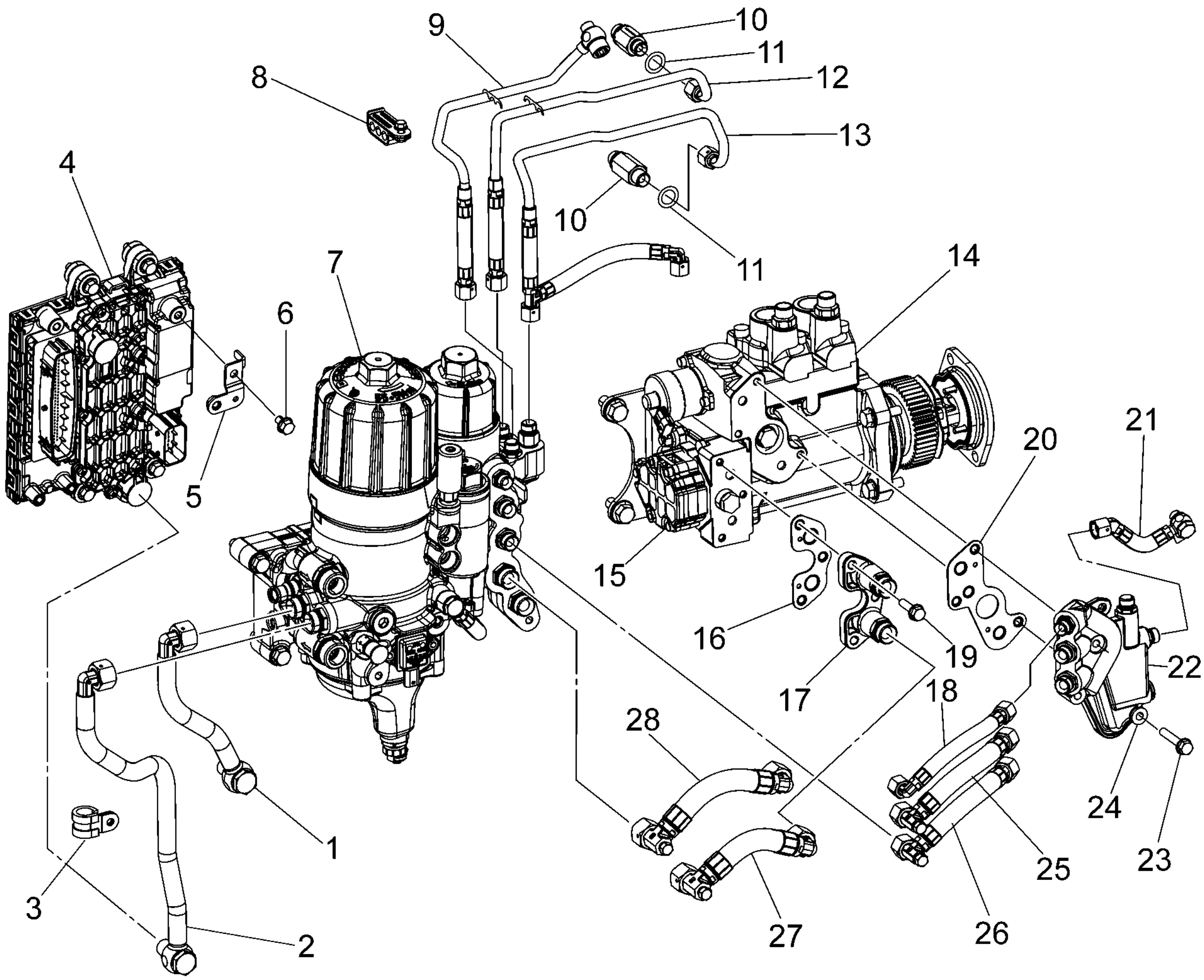
1. Fuel Filter Module
2. Bolt
3. O-ring
4. Fuel Cooler
5. Pipe
6. Bolt
7. Fitting
8. O-ring
9. Supply Fuel Temperature Sensor

Figure 2-19 Fuel Filter Module and Fuel Cooler



1. Filter Cap
2. Seal
3. Maintenance Valve
4. Valve
5. Fitting
6. Fitting
7. Fuel Filter Module
8. Water Separator/Coalescer
9. Seal
10. Filter Cap
11. Pre-filter
12. Seal
13. Pre-filter
14. Final Filter Cap
15. Seal
16. Final Filter
17. Manual Feed Pump
18. Fitting
19. Clip
20. Fitting
21. Heating Element
22. Seal
23. Cover
24. Protective Cap

Figure 2-20 Fuel Filter Module and Related Parts



1. MCM to Fuel Filter
2. Fuel Inlet to MCM
3. Clip
4. MCM
5. Bracket
6. Bolt
7. Fuel Filter Module
8. Damper
9. High Pressure Fuel Line
10. Connector
11. O-ring
12. Amplification Return Line
15. Low Pressure Fuel Pump
16. Gasket
17. Fuel Flange
18. Emergency Lubrication Line
19. Bolt
20. Gasket
21. Doser Fuel Supply Line
22. Fuel Flange
23. Bolt
24. Washer
25. Lower Pressure Feed to High Pressure Pump
26. Low Pressure Return from High Pressure Pump

13. Needle Return Line
14. High Pressure Fuel Pump
27. Low Pressure Supply to Fuel Filter Module
28. Suction Low Pressure Feed

Figure 2-21 Fuel Filter Module and Related Parts

2.8.1 Removal of Fuel Filter Module

Remove as follows:

1. Drain the coolant.
2. Disconnect and remove the coolant lines from the front and bottom of the module.
3. Drain fuel filter module by using air pressure.
4. Disconnect fuel feed and return lines (to tank) from the fuel filter module.
5. Disconnect remaining fuel lines.
6. Disconnect electrical connectors from sensors.
7. Remove line assemblies from high pressure fuel pump.
8. Remove the four bolts securing the fuel filter module to the cylinder block and remove fuel filter module from engine block..
9. Remove the fuel cooler O-ring seal from the engine block and discard.

2.8.2 Disassembly of the Fuel Filter Module

Disassemble as follows:

1. Remove the fuel cooler from the fuel filter module.
2. Remove the three filter covers using a 36 mm socket.
3. Pull the covers and filters straight up and out of the fuel filter module.
4. Remove the filters from the covers by applying a lateral force to the bottom of the filters. The filter will unsnap from the cover. Discard the filters.
5. Remove the seal rings from the covers and discard seal.

2.8.2.1 Inspection of the Fuel Filter Module

Inspect as follows:

1. Inspect the fuel filter module for cracks or damage ; replace if necessary.
2. Inspect fuel filter sensors; replace if necessary.
3. Inspect the fuel cooler for wear or damage; replace if necessary.
4. Inspect the fuel filter housing and cooler for debris and clean if necessary.

2.8.3 Assembly of the Fuel Filter Module

Assemble as follows:

1. Install new seal rings onto plastic caps and coat with clean engine oil.
2. Install the filters into the plastic caps by snapping the filter into the cap.

NOTE:
The prefilter has slots and the tabs should align with the slot in the plastic cap.

3. Install filters and caps into fuel filter module
4. Turn the cap counter clockwise until a clicking sound is made and then turn the cap clockwise and hand tighten.
5. Torque prefilter cap to 15-20 N·m (11-15 ft·lb).
6. Torque water separator and fuel filter caps to 50-60 N·m (37-44 ft·lb).
7. Install fuel cooler into fuel filter module.

2.8.4 Installation of the Fuel Filter Module

Install as follows:

1. Install a new coolant O-rings onto cylinder block.
2. Install guide studs.
3. Install fuel filter module using care not to damage coolant O-ring seal between cylinder block and fuel cooler.
4. Torque mounting bolts to 60 N·m (44 ft·lb).
5. Connect coolant lines.
6. Install bolt securing the air compressor coolant line to the fuel filter module and torque to 25 N·m (15 ft·lb).
7. Fill engine with coolant and pressure test system to check for a seal leak between fuel cooler and cylinder block.
8. Install fuel lines to fuel filter module and high pressure fuel pump.
9. Torque fuel lines to 25 N·m (18 ft·lb).
10. Connect the electrical connectors from sensors.
11. Prime fuel system and check for leaks.

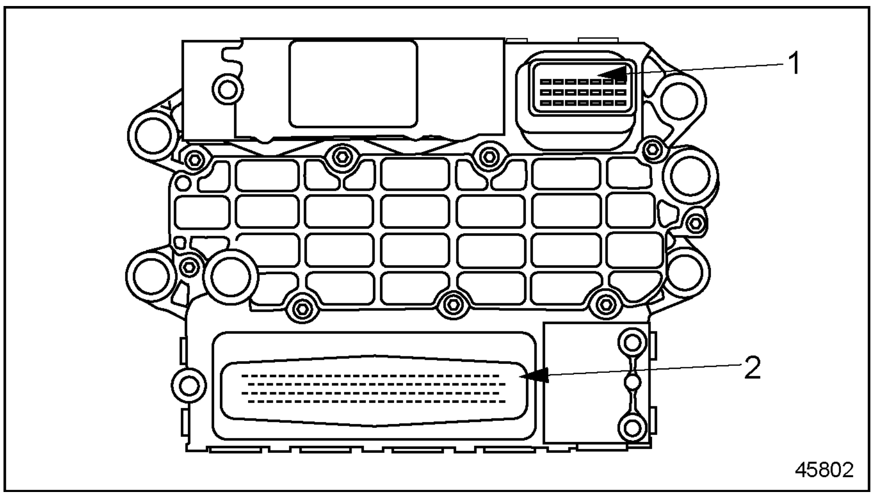
2.9 ELECTRONIC ENGINE CONTROL

The Detroit Diesel Electronic Control System (DDEC) controls fuel injection timing and output by the Common Rail Injector on the engine. The system also monitors several engine functions using electrical sensors which send electrical signals to the Motor Control Module (MCM). The MCM then computes the incoming data and determines the correct fuel output and timing for optimum power, fuel economy and emissions. The MCM also has the ability to display warnings or shut down the engine completely (depending on option selection) in the case of damaging engine conditions, such as low oil pressure, low coolant, or high oil temperature.

The DDEC system also has a cab-mounted control unit for vehicle engine management, the Common Powertrain Controller (CPC). The connection to the vehicle is made via a CAN interface which digitally transmits the nominal values (e.g. torque, engine speed specifications, etc.) and the actual values (e.g. engine speed, oil pressure, etc.).

The Exhaust Gas Recirculation (EGR) engines will use the sixth generation of the DDEC system, DDEC VI® Motor Control Module (MCM). See Figure 2-22.

The replacement of DDEC components is based on indicated diagnostic codes leading to faulty components. Check the *HDE Troubleshooting Guide, 6SE569.* for more complete information on diagnosis of components and system problems.



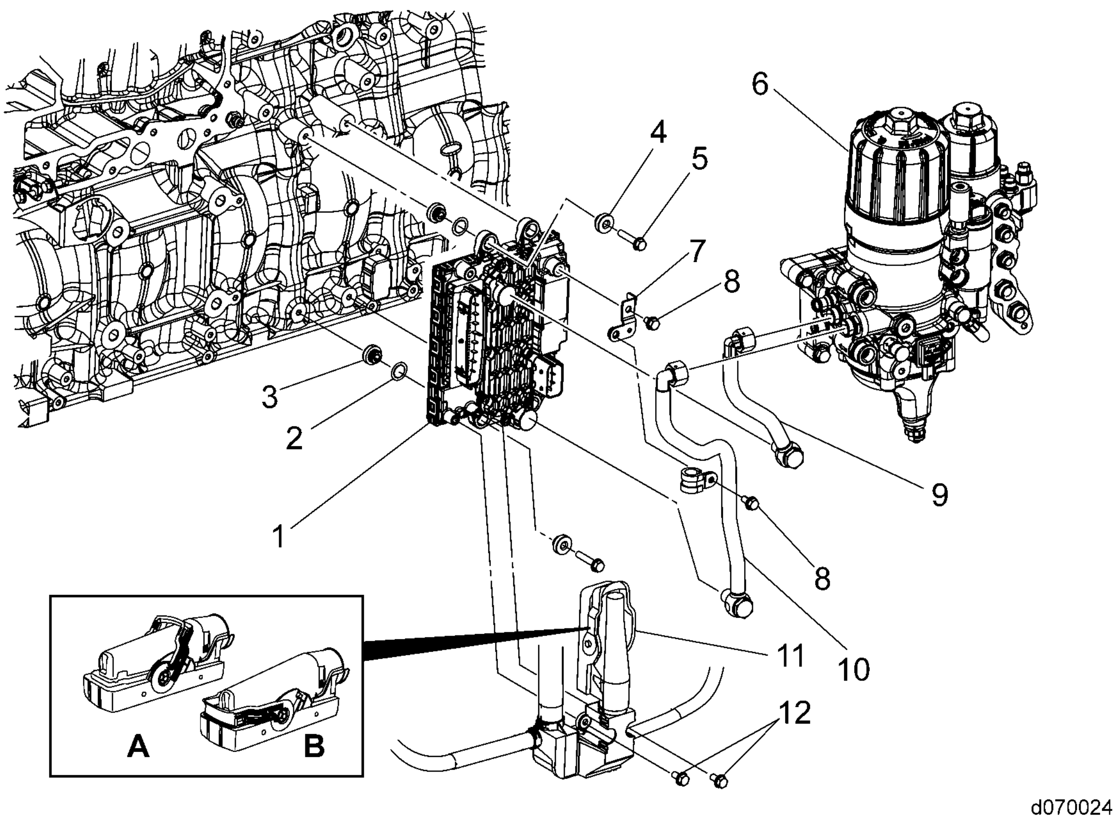
1. 21- pin (OEM Responsibility)
2. 120- pin (Detroit Diesel Responsibility)

Figure 2-22 DDEC VI Motor Control Module (MCM)

2.10 MOTOR CONTROL MODULE (MCM)

The Motor Control Module (MCM) is located on the left side of the cylinder block. The Motor Control Module (MCM) serves primarily as an interface between the electrical or electronic components located on the engine side and the Common Powertrain Controller (CPC) located on the vehicle side. Both control units are networked together with the Controller Area Network CAN. The MCM takes on a number of tasks; it controls and regulates processes for systems such as engine control or the Exhaust Gas Recirculation (EGR) system, and also monitors information for oil level in the engine.

The MCM also has the ability to display warnings or shut down the engine completely (depending on option selection) in the case of damaging engine conditions, such as low oil pressure, low coolant, or high oil temperature. See Figure 2-23



1. MCM
2. Seal
3. Isolator
4. Isolator
5. Bolt
6. Fuel Filter Module
7. Bracket
8. Bolt
9. MCM to Fuel Filter Module
10. Fuel Lines to MCM
11. Harness Connector
12. Bolts

A. Harness Unlatched

B. Harness Latched

Figure 2-23 Motor Control Module and Related Parts

The following is a summary of the tasks the MCM monitors:

- Exhaust gas recirculation (EGR)
- Intake air preheating system
- Turbocharger
- Diesel particulate filter (DPF)
- Instrument cluster
- Engine brake
- Amplified Pressure Common Rail System (APCRS)
- Thermal management

DDEC VI provides an indication of engine and vehicle malfunctions. The MCM continually monitors the DDEC VI system.

Any faults that occur are stored as codes. These codes can be accessed in any of three ways:

1. A DDDL® 7.0 for DDEC VI can be used to read the codes.
2. A personal computer (PC) connected to the Motor Control Module (MCM) through a translator device using SAE J1939 Data Link+, are used as the communication link, to Common Powertrain Controller (CPC) and CAN link to (MCM).
3. The Amber Warning Lamp (AWL) (check engine) or the Red Stop Lamp (RSL) is illuminated.
   - The AWL (check engine) (panel mounted yellow indicator light) illuminated diagnose condition as soon as convenient, lights are CPC controlled.
   - The RSL (panel mounted red indicator light) and AWL (check engine) illuminated, a major fault occurred and immediate attention required to avoid engine damage.
   - Automatic engine shutdown or rampdown is available as an option. A shutdown override switch is required to allow the vehicle to be moved to a safe location during automatic shutdown or rampdown.
   - The MCM tells the light when to activate.

2.10.1 Repair or Replacement of the Motor Control Module (MCM)

The MCM is a sealed, nonserviceable unit. Tag defective MCM for recore. Ship to Detroit Diesel Reman Central.

2.10.2 Removal of the Motor Control Module

Perform the following steps for MCM removal:

1. Release latch on harness connector to remove the 21 and 120 pin connectors from Motor Control Module (MCM).
2. Disconnect the vehicle battery power to prevent failure of the MCM.

NOTICE:
Ensure MCM is not contaminated with diesel fuel.

3. Drain the fuel system.
4. Disconnect two fuel lines from MCM.
5. Remove the line bracket.
6. Remove two harness retaining bolts.
7. Remove the four bolts holding the MCM to the engine, remove the MCM from engine.

2.10.2.1 Inspection of the Motor Control Module

Inspect the MCM as follows:

1. Inspect the MCM for damage and replace if required.
2. Inspect the ISO mounts for damage and replace if required.

2.10.3 Installation of the Motor Control Module

Perform the following steps for MCM installation:

NOTE:
If installing a new MCM; after installation program to proper settings using the programming station.

NOTE:
Do not ground the MCM housing. This can result in false codes being logged.

NOTICE:
Ensure the MCM metal housing does not come in contact with the chassis.

1. Mount the MCM to the engine.

NOTICE:
Ensure MCM is not contaminated with diesel fuel.

2. Install the MCM to the engine with four bolts and isolators. Torque the MCM-to-engine bolts to 34 N·m (25 lb·ft).

NOTICE:
Ensure the connectors are not contaminated with diesel fuel.

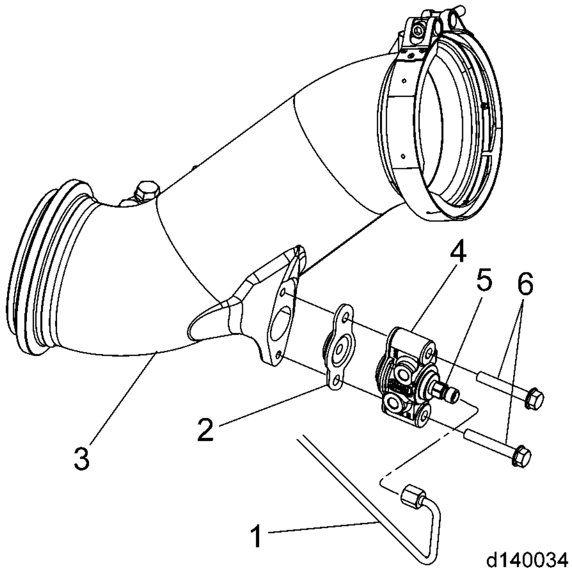
3. Connect the 21 and 120 pin engine harness connectors to the MCM close and lock latch on the connectors.
4. Install bracket onto fuel line; install bracket and line to MCM with two bolts.
5. Install the fuel line to the MCM and fuel filter module. Torque bolts to 55 N·m (40.57 lb·ft).
6. Install the fuel line to the fuel filter module and MCM.. Torque bolts to 55 N·m (40.57 lb·ft).
7. Reconnect vehicle battery power.
8. Turn the ignition to the "ON" position. Observe the DDDL 7.0 for any diagnostic code(s). If any code(s) are logged, refer to the *DDEC VI Troubleshooting Guide, 6SE569.*

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.

2.11 FUEL DOSER VALVE

The Fuel Doser Valve is mounted in an exhaust elbow that is mounted to the turbocharger. The fuel will atomize with the exhaust gas and combust across the Diesel Oxidation Catalyst (DOC).



1. Coolant Line
2. Gasket and Shield
3. Exhaust Pipe
4. Doser
5. Bolts

Figure 2-24 Doser Valve and Related Parts

2.11.1 Removal of the Fuel Doser Valve

Remove as follows:

1. Drain the coolant.
2. Disconnect dosing fuel line from injection nozzle.
3. Disconnect the lines for coolant in and coolant out.
4. Loosen two screws and remove fuel doser valve.

2.11.2 Installation of the Fuel Doser Valve

Install as follows:

1. Install fuel doser valve to exhaust elbow with two screws. Torque screws to 34 N·m (25 lb·ft).
2. Connect coolant in and out lines.
3. Connect dosing fuel line to injection nozzle.

4. Tighten all connections securely.

WARNING:

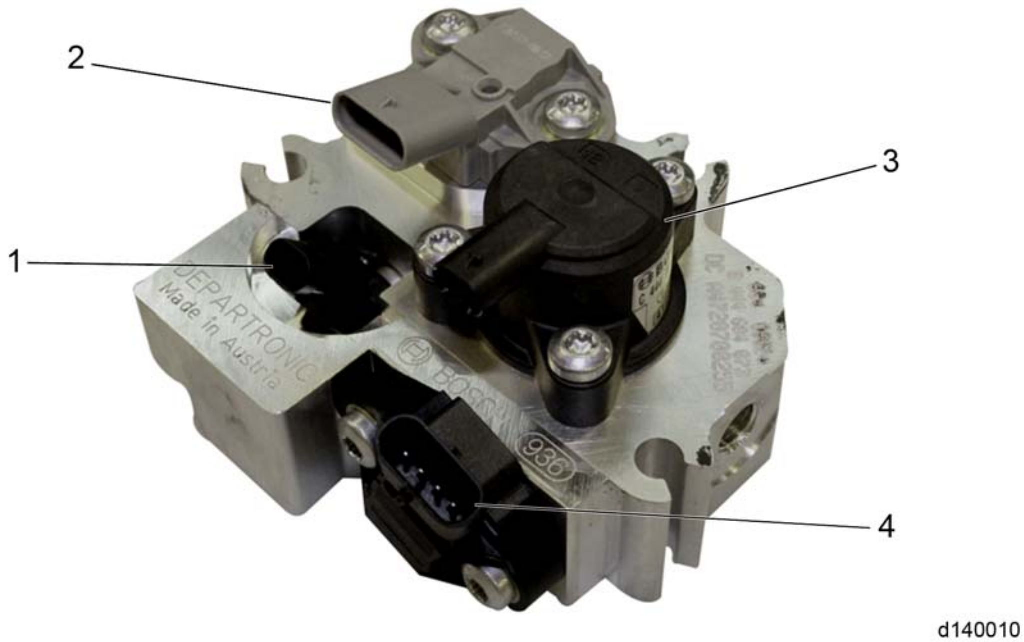
ENGINE EXHAUST

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

5. Fill coolant system.
6. Start engine.
7. Use the command purge function in DDDL 7.0.

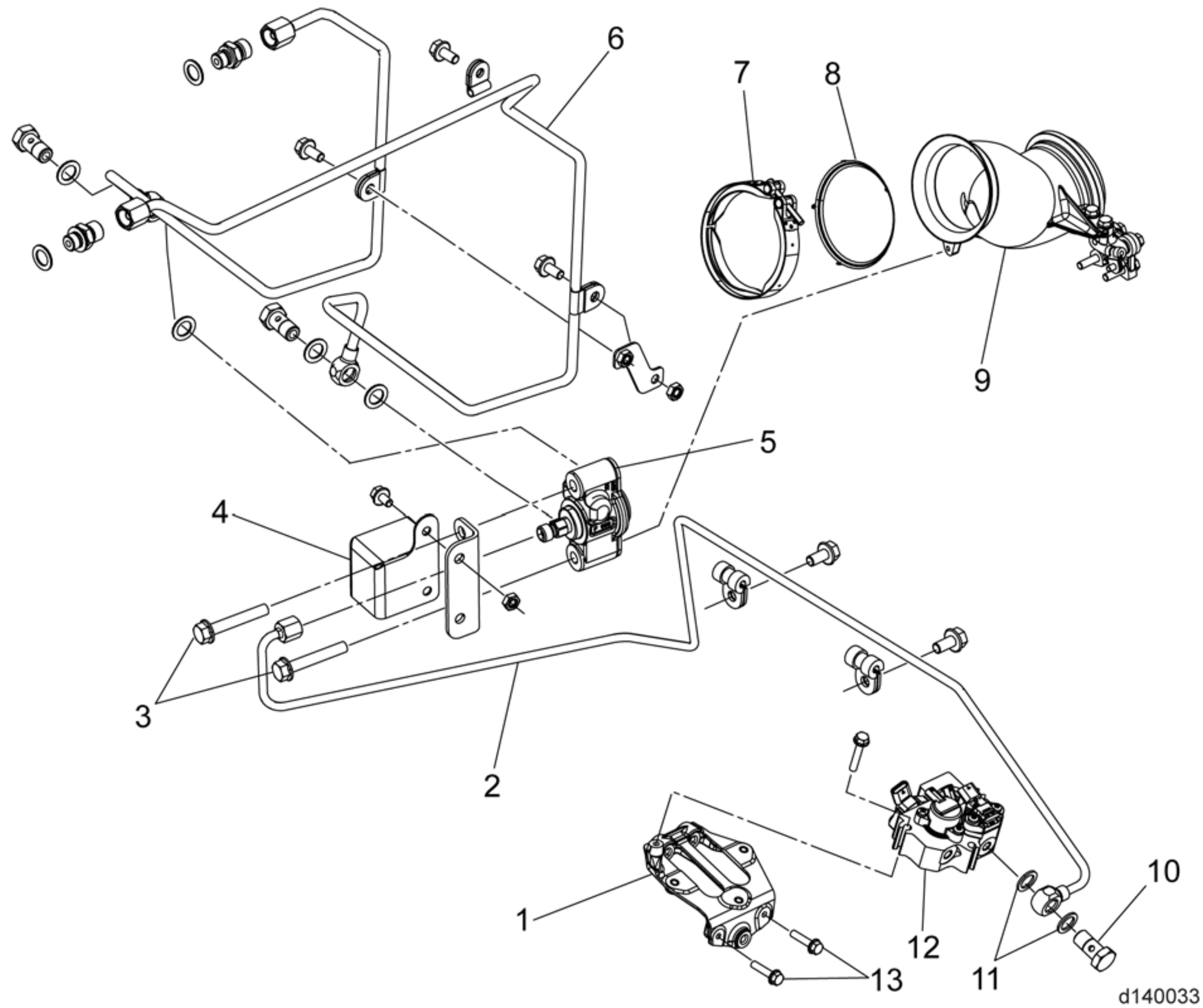
2.12 DOSER BLOCK ASSEMBLY

The Doser Block Assembly is designed with the fuel injector mounted in an elbow in the exhaust system and the Doser control mounted on the left side of the engine on top of the gear case. The diesel fuel pressure is regulated to the Doser where it is injected into the exhaust stream and circulated into the After-Treatment Device



1. Electronic Dosing Valve
2. Fuel Line Pressure Sensor
3. Fuel Cutoff Valve
4. Fuel Compensation Pressure Sensor

Figure 2-25 Doser Block Assembly



1. Doser Assembly Bracket
2. Fuel Line
3. Bolts
4. Doser Valve Bracket
5. Doser Valve
6. Fuel Line
7. Clamp
8. Gasket
9. Exhaust Elbow
10. Banjo Bolt
11. Washer
12. Doser Assembly
13. Bolt

Figure 2-26 Doser Block Assembly and Related Parts

2.12.1 Removal of the Doser Block Assembly

Remove as follows:

1. Steam clean the engine.
2. Place a drip pan under engine to collect fuel.

3. Disconnect the fuel inlet line from the junction block connecting the doser assembly to the high pressure fuel pump and fuel filter module.
4. Drain the fuel system.
5. Disconnect the fuel dosing line from the doser assembly.

NOTE:
Before unplugging the sensors note their positions.

6. Unplug connectors from Fuel Cutoff Valve (FCV) (3), Fuel Line Pressure Sensor (FLP) (2), Fuel Compensation Pressure Sensor (FCP) (4), and Electronic Dosing Valve (EDV) (1).
7. Loosen three bolts and remove the Doser Block Assembly

2.12.2 Installation of the Doser Block Assembly

Install as follows:

1. Install the Doser Block Assembly using three bolts; torque bolts to 32-36 N·m (24-27 lb·ft).
2. Plug in connectors to the FCV, FLP Sensor, FCP Sensor and EDV.
3. Connect dosing fuel line.
4. Connect fuel inlet line to the junction block connecting the doser block assembly to the high pressure fuel pump and fuel filter module.
5. Tighten all 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.

6. Start the engine.
7. Use the HC Doser command to run the purge function in DDDL 7.0 to purge all the air from the doser valve and line.

2.13 CAMSHAFT POSITION SENSOR

The camshaft position sensor is mounted on the camshaft frame near cylinder number six.

The camshaft position sensor sends a signal to the Motor Control Module (MCM) which senses engine rotation and the compression cycle of cylinder number one, engine speed or crankshaft position can then be determined. (If the crankshaft position sensor fails the engine reverts to limp home mode)

The camshaft position sensor is an active Hall sensor and is installed with a permanent magnet and a electronic analysis system.

The magnet generates a magnetic field. When the camshaft rotates fluctuations in the magnetic field occur due to the grooves in the camshaft sprocket. These fluctuations in the magnetic field are converted by the electronic analysis in the camshaft position sensor into signals and sent to the MCM which determines the compression cycle of cylinder number one.

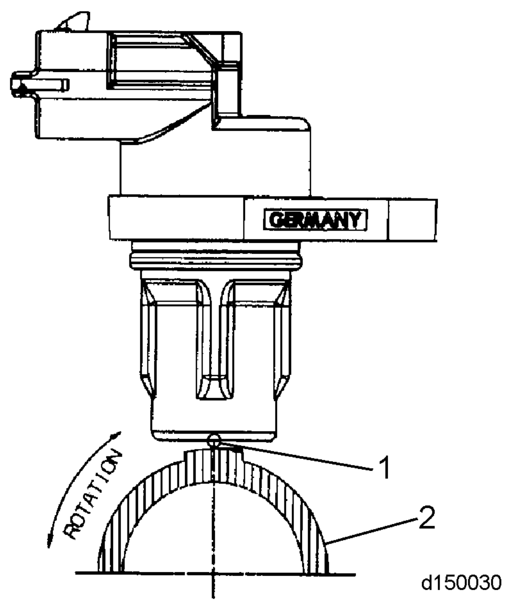


Figure 2-27 Camshaft Position Sensor

2.13.1 Removal of Camshaft Position Sensor

Remove as follows:

1. Remove harness connector from camshaft position sensor by pulling the gray tab on the connector up to unlock and remove harness connection.
2. Remove the bolt retaining the sensor to the camshaft frame.
3. Remove camshaft position sensor from camshaft frame.

2.13.2 Installation of Camshaft Position Sensor

Install as follows:

1. Lubricate the seal ring from the sensor with grease.
2. Install camshaft position sensor into camshaft frame.
3. Install the bolt to the sensor and camshaft frame and tighten.
4. Install harness connector to the camshaft position sensor and push gray tab down to lock connector to sensor.

2.14 COOLANT INLET TEMPERATURE SENSOR

The coolant inlet temperature sensor is mounted on the oil cooler module. The motor control module (MCM) receives a signal from the coolant inlet temperature sensor which senses the coolant temperature and alerts the driver if the coolant temperature is high.

2.14.1 Removal of the Coolant Inlet Temperature Sensor

Remove as follows:

1. Remove harness connector from coolant inlet temperature sensor by pulling up on the gray tab on the connector to unlock and remove harness connection.
2. Drain the coolant.
3. Using the appropriate hex tool unscrew coolant inlet sensor from oil coolant module.

2.14.2 Installation of the Coolant Inlet Temperature Sensor

Install as follows:

1. Using the appropriate hex tool install the coolant inlet temperature sensor and a new gasket to the oil cooler module.
2. Install harness connector to the coolant inlet temperature sensor by pushing the gray tab down to lock the connector to the sensor.
3. Fill the cooling system.

2.15 COOLANT OUTLET TEMPERATURE SENSOR

The coolant outlet temperature sensor is mounted on the front side of the water manifold between the camshaft frame exhaust gas recirculation (EGR) cooler. The motor control module (MCM) receives a signal from the coolant outlet temperature sensor and analyzes coolant temperature for functions such as engine protection, fan control and engine fueling.

2.15.1 Removal of Coolant Outlet Temperature Sensor

Remove as follows

1. Remove harness connector from coolant outlet sensor by pushing the gray tab on the connector up to unlock and remove harness connection.
2. Drain the coolant system.
3. Using the appropriate tool unscrew coolant outlet sensor from water manifold.

2.15.2 Installation of Coolant Outlet Temperature Sensor

Install as follows:

1. Using the appropriate tool install the coolant outlet temperature sensor and new gasket to the water manifold. Tighten to 35-45 N·m (26-33 lb·ft).
2. Install harness connector to the coolant outlet temperature sensor and push gray tab down to lock connector to sensor.
3. Fill the cooling system.

2.16 CRANKSHAFT POSITION SENSOR

The crankcase position sensor is mounted on the left side of the flywheel housing. The crankshaft position sensor sends a signal to the Motor Control Module (MCM) to determine rotational speed and crankshaft position.

2.16.1 Removal of the Crankshaft Position Sensor

Remove as follows:

1. Pull back on the gray tab to release harness connector from sensor.
2. Remove harness connection from sensor.
3. Remove one bolt from sensor and remove sensor from flywheel housing.

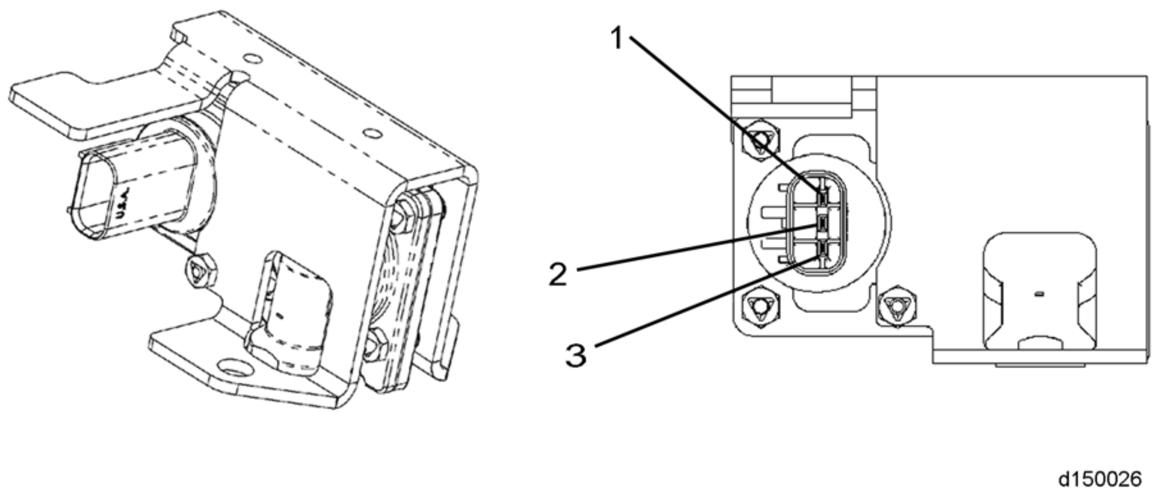
2.16.2 Installation on the Crankshaft Position Sensor

Install as follows:

1. Lubricate the seal ring from the sensor with grease.
2. Install the crankshaft position sensor to the flywheel housing with one bolt and tighten.
3. Install harness connection to sensor and push up on the gray tab to lock harness connector to sensor.
4. Turn the engine to the ON position. Observe DDDL for any diagnostic code(s).

2.17 DELTA P SENSOR

The Delta P sensor is mounted on the exhaust gas recirculation (EGR) delivery pipe. The motor control module (MCM) receives a signal from the delta p sensor which senses pressure and drop across the EGR venturi. The MCM uses this signal to calculate the EGR flow rate.



1. Output
2. Ground
3. Supply Voltage

Figure 2-28 Delta-P Sensor

2.17.1 Removal of the Delta P Sensor

Remove as follows:

1. Release harness connector on sensor by pushing the orange tab up to unlock the connector, depress the thumb tab and remove the harness connector .
2. Remove two bolts from Delta P sensor securing it to the exhaust gas recirculation (EGR) venturi pipe.

2.17.2 Installation of the Delta P Sensor

Install as follows:

1. Install the Delta P sensor to the EGR venturi pipe with two bolts and tighten.
2. Install harness connector to sensor and push orange tab down to lock harness connector to sensor.

2.18 FUEL RAIL PRESSURE SENSOR

The fuel rail pressure sensor is mounted on the front end of the fuel rail. The motor control module (MCM) receives signal from the fuel rail pressure sensor which senses if the fuel rail pressure is to high or to low.

2.18.1 Removal of the Fuel Rail Sensor

Remove as follows:

1. Remove connector.
2. Remove the fuel rail sensor using the appropriate wrench on the hex end of the fuel rail sensor and unscrew the sensor from the fuel rail.

2.18.2 Installation of the Fuel Rail Sensor

Install as follows:

1. Install the fuel rail sensor using the appropriate wrench on the hex end of the fuel rail sensor and screw the sensor to the fuel rail.
2. Install connector.

2.19 SUPPLY FUEL TEMPERATURE SENSOR

The supply fuel temperature sensor (B10) is located on the left side of the engine on the fuel filter module (1). The motor control module (MCM) receives a signal from the supply fuel temperature sensor to sense the temperature of the fuel for functions such as engine fueling.

2.19.1 Removal of the Supply Fuel Temperature Sensor

Remove as follows:

1. Drain the fuel filter module using the water drain valve located on the bottom of the fuel filter module.
2. Unseat the secondary lock on the electrical connector.
3. Push gray tab down and pull harness connector from sensor.
4. Using the appropriate wrench on the hex end of the supply fuel temperature sensor unscrew the sensor from the fuel filter module.

2.19.2 Installation of the Supply Fuel Temperature Sensor

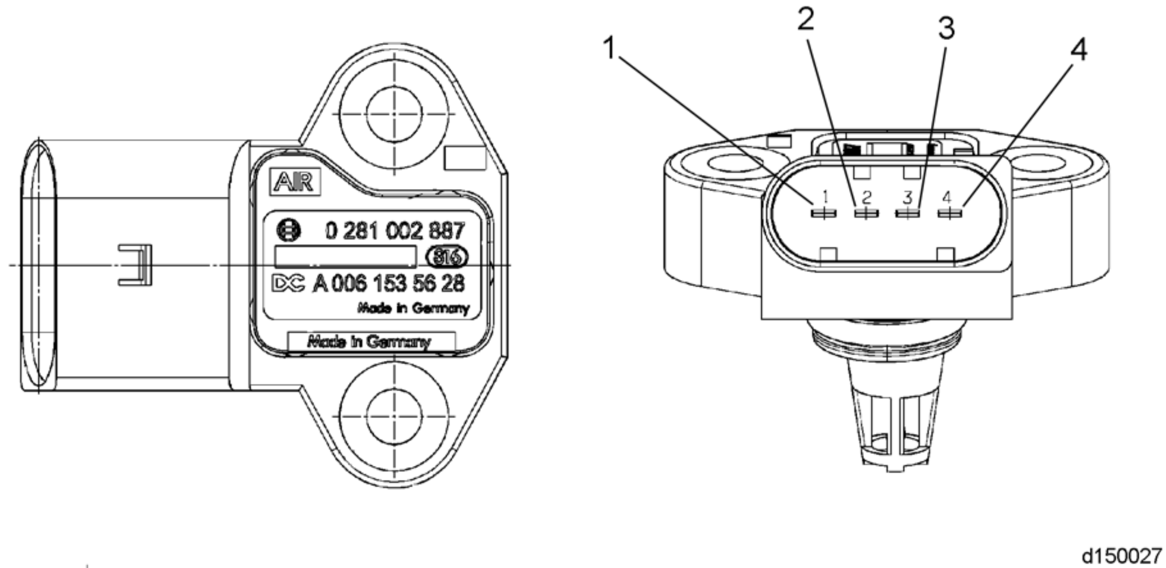
Install as follows:

1. Install the sensor and new gasket on the engine and using the appropriate wrench on the hex end of the sensor tighten the sensor. Torque sensor to 35-45 N·m (26-33 lb·ft).
2. Install harness connector onto sensor and push gray tab to the up position.
3. Seat secondary lock on the electrical connector.
4. Prime the fuel system using fuel priming valve or hand primer.

2.20 INTAKE MANIFOLD PRESSURE/TEMPERATURE SENSOR

The intake manifold pressure/temperature sensor is mounted to the top intake manifold on the left side of the engine.

The motor control module (MCM) determines the air pressure and air temperature of the air entering the engine from a signal received from the intake manifold pressure/temperature sensor .



1. Pin 1 = 0.5 v to 4.5v
2. Pin2 = =4.75v to 5.25v
3. NTC Output
4. Ground

Figure 2-29 Intake Manifold Pressure/Temperature Sensor

2.20.1 Removal of the Intake Manifold Pressure/Temperature Sensor

Remove as follows:

1. Release harness connection from sensor by pulling the gray tab up to unlock and remove harness connection from sensor.
2. Using the appropriate wrench on the hex end of the intake manifold pressure/temperature sensor unscrew the sensor from the intake manifold.

2.20.2 Installation of the Intake Manifold Pressure/Temperature Sensor

Install as follows:

1. Lubricate the seal ring from the sensor with grease.
2. Install the intake manifold pressure/temperature sensor to the intake manifold with the appropriate wrench on the hex end of the sensor.

3. Install the harness connection onto the sensor and push down on the gray tab to lock the harness onto sensor.

2.21 OIL PRESSURE SENSOR

The oil pressure sensor is mounted below the water pump in the cylinder block. The motor control module (MCM) receives a signal from the oil pressure sensor to ensure that the oil is at the correct pressure levels. Senses gallery oil pressure for functions such as engine protection.

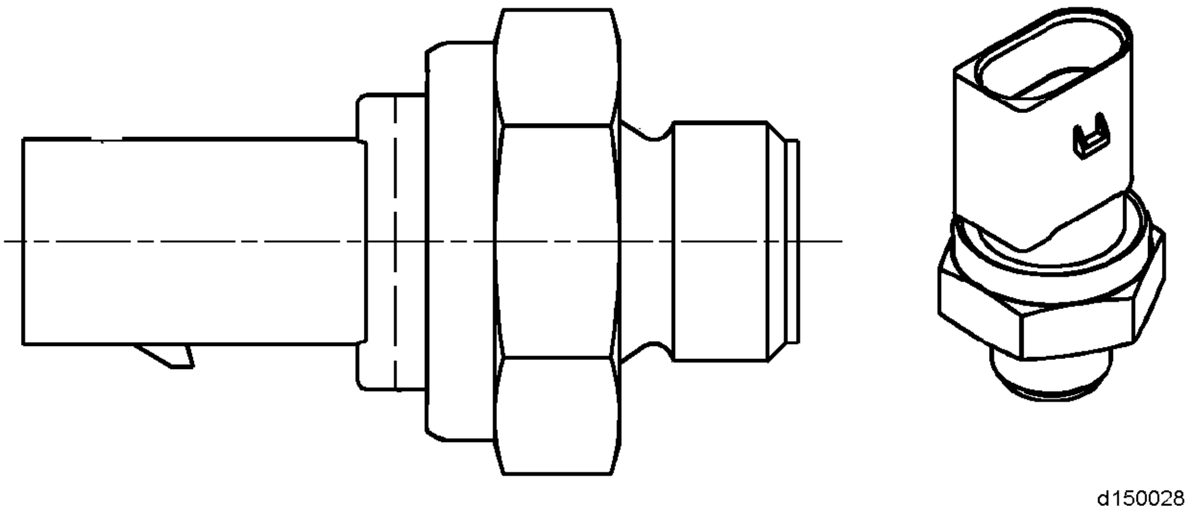


Figure 2-30 Oil Pressure Sensor

2.21.1 Removal of the Oil Pressure Sensor

Remove as follows:

1. Release harness connection from sensor by pushing the gray tab to unlock and remove harness connection from sensor.
2. Using the appropriate tool on the oil pressure sensor unscrew the sensor from the cylinder block.

2.21.2 Installation of the Oil Pressure Sensor

Install as follows:

1. Install the oil pressure sensor and new gasket to the cylinder block using the appropriate tool.
2. Install harness connector to oil pressure sensor and push the gray tab forward to lock the connector onto the sensor

2.22 OIL TEMPERATURE SENSOR

The oil temperature sensor is mounted below the water pump in the cylinder block. The motor control module (MCM) receives a signal from the oil temperature sensor to ensure that the oil temperature is at the correct temperature levels.

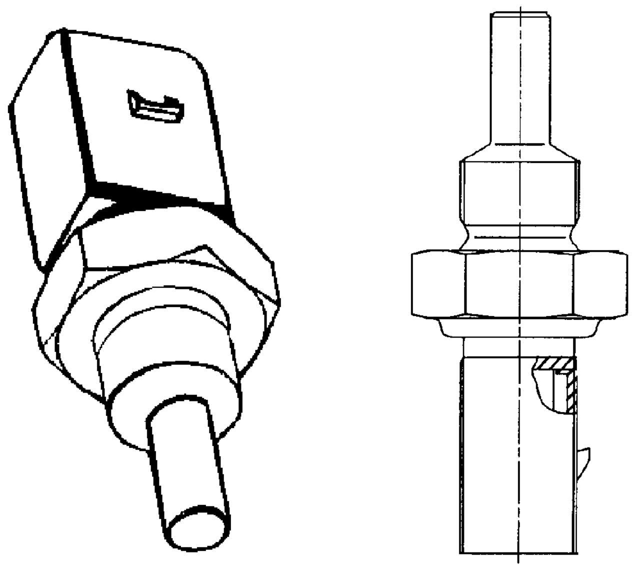


Figure 2-31 Oil Temperature Sensor

2.22.1 Removal of the Oil Temperature Sensor

Remove as follows:

1. Release harness connection from sensor by pushing the gray tab to unlock and remove harness connection from sensor.
2. Using the appropriate tool on the oil temperature sensor unscrew the sensor from the cylinder block.

2.22.2 Installation of the Oil Temperature Sensor

Install as follows:

1. Install the oil temperature sensor and new gasket to the cylinder block using the appropriate tool. Torque sensor to 35-45 N·m (26-33 lb·ft)
2. Install harness connector to oil temperature sensor and push the gray tab forward to lock the connector onto the sensor.

2.23 TURBO SPEED SENSOR

The turbo speed sensor is mounted in the center housing of the of the turbocharger. The motor control module (MCM) receives a signal from the turbo speed sensor to monitor turbocharger speed and prevent overspeed conditions.

NOTE:
The turbo speed sensor is used on certain DD15 engine models; check the engine to see if your engine requires the sensor.

NOTE:
The turbo speed sensor is used on applicable models.

2.23.1 Removal of the Turbo Speed Sensor

Remove as follows:

NOTE:
If the turbocharger speed sensor is difficult to access, removal of the turbocharger may be necessary.

1. Clean the center housing area around the base of the speed sensor.
2. Disconnect the sensor wire from the main harness.

NOTICE:
Ensure the turbocharger shaft is secured and not rotated when the turbocharger speed sensor is removed from the bearing spacer. Turning the shaft without the sensor in place can rotate the bearing spacer. If the sensor is not properly positioned in the opening of the bearing spacer, the sensor and turbocharger bearings will be damaged during sensor installation.

2.23.2 Installation of the Turbo Speed Sensor

Install as follows.

NOTE:
Ensure O-ring is located in sensor to prevent oil leaks.

1. Inspect the hole for the speed sensor and ensure the hole in the bearing spacer is aligned and the rotor shaft is visible.
2. Manually insert the turbocharger speed sensor into the hole of the center housing wall. Push the sensor until the sealing lip on the underside of the sensor seats against the flat on the center housing and the sensor is finger tight.
3. Turn the turbocharger rotor to ensure it spins freely with minimal resistance. If binding occurs, repeat speed sensor installation.

NOTICE:
Ensure the turbocharger rotor turns freely. If the shaft binds, the speed sensor is not aligned with the bearing spacer and damage can occur to the shaft and speed sensor.

4. Tighten the speed sensor.
5. Turn the turbocharger rotor to ensure it spins freely. If binding occurs it is not aligned properly. Refer to step 3.

2.24 TURBOCHARGER INLET TEMPERATURE SENSOR

The turbocharger inlet temperature sensor sends a signal to the motor control module (MCM) to monitor the inlet air to the turbocharger.

2.24.1 Removal of the Turbocharger Inlet Temperature Sensor

Remove as follows:

1. Release harness connector on sensor by pulling the gray tab to unlock the connector and remove harness connector from sensor.
2. Using the appropriate tool on the turbocharger inlet temperature sensor unscrew the sensor from the inlet pipe.

2.24.2 Installation of the Turbocharger Inlet Temperature Sensor

Install as follows:

1. Using the appropriate tool on the turbocharger inlet temperature sensor screw the sensor and new gasket into the air inlet pipe.
2. Install harness connector onto the turbocharger inlet temperature sensor and push the gray tab to lock harness connector to sensor.

2.25 WATER-IN-FUEL SENSOR

The water-in-fuel sensor is located on the left side of the engine mounted on the fuel filter module. The water level sensor determines the electrical resistance between the two sensor electrodes . If the water increases in the water separator up to the sensor electrodes the electrical resistance drops. This change of resistance is detected by the Motor Control Module (MCM) If a critical water level is reached, an indicator light on the sensor will illuminate and the driver is alerted to dry the fuel filter. Alerting the driver to drain the water from the fuel filter module

2.25.1 Removal of the Water-in-Fuel Sensor

Remove as follows:

1. Drain the fuel filter module using the water drain valve located on the bottom on the bottom of the fuel filter module.
2. Pull gray tab down and disconnect the harness connector from the water in fuel sensor.
3. Remove two screws from sensor and remove sensor.

2.25.2 Installation of the Water-in-Fuel Sensor

Install as follows:

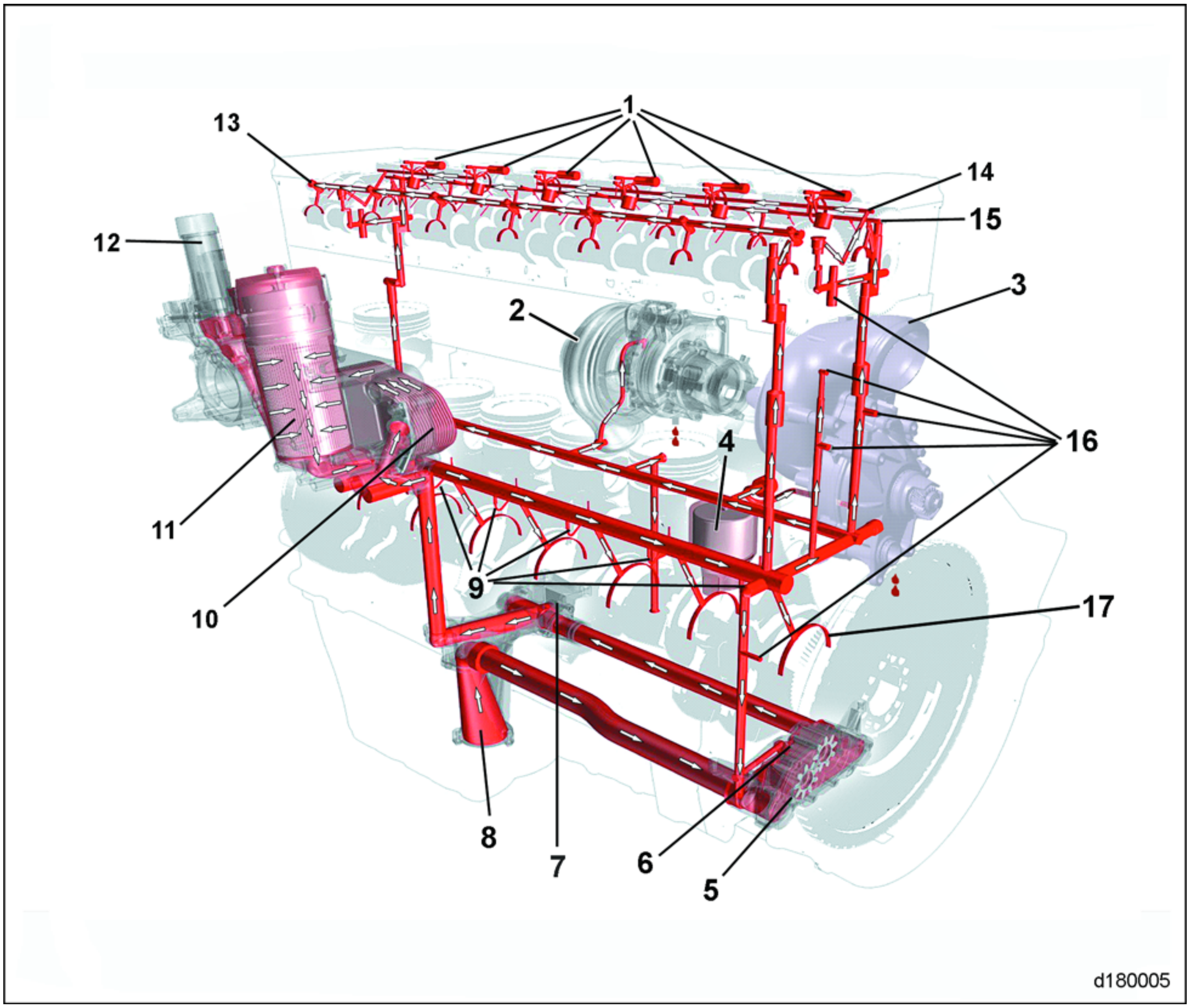
1. Lubricate the seal ring on the new sensor with clean fuel.
2. Install water in fuel sensor to fuel filter module.
3. Install two screws to the fuel in water sensor and fuel filter module and tighten bolts 9-13 N·m (6.5-9.5 ft·lb).
4. Install harness connector to sensor and push in the gray tab on the connector to lock harness connector.
5. Prime fuel system using fuel priming valve or hand primer.

3 LUBRICATION SYSTEM

Section **Page**

3.1 OVERVIEW OF THE LUBRICATION SYSTEM

A schematic of the lubrication system in the following illustration shows the oil flow to the engine components. See Figure 3-1.

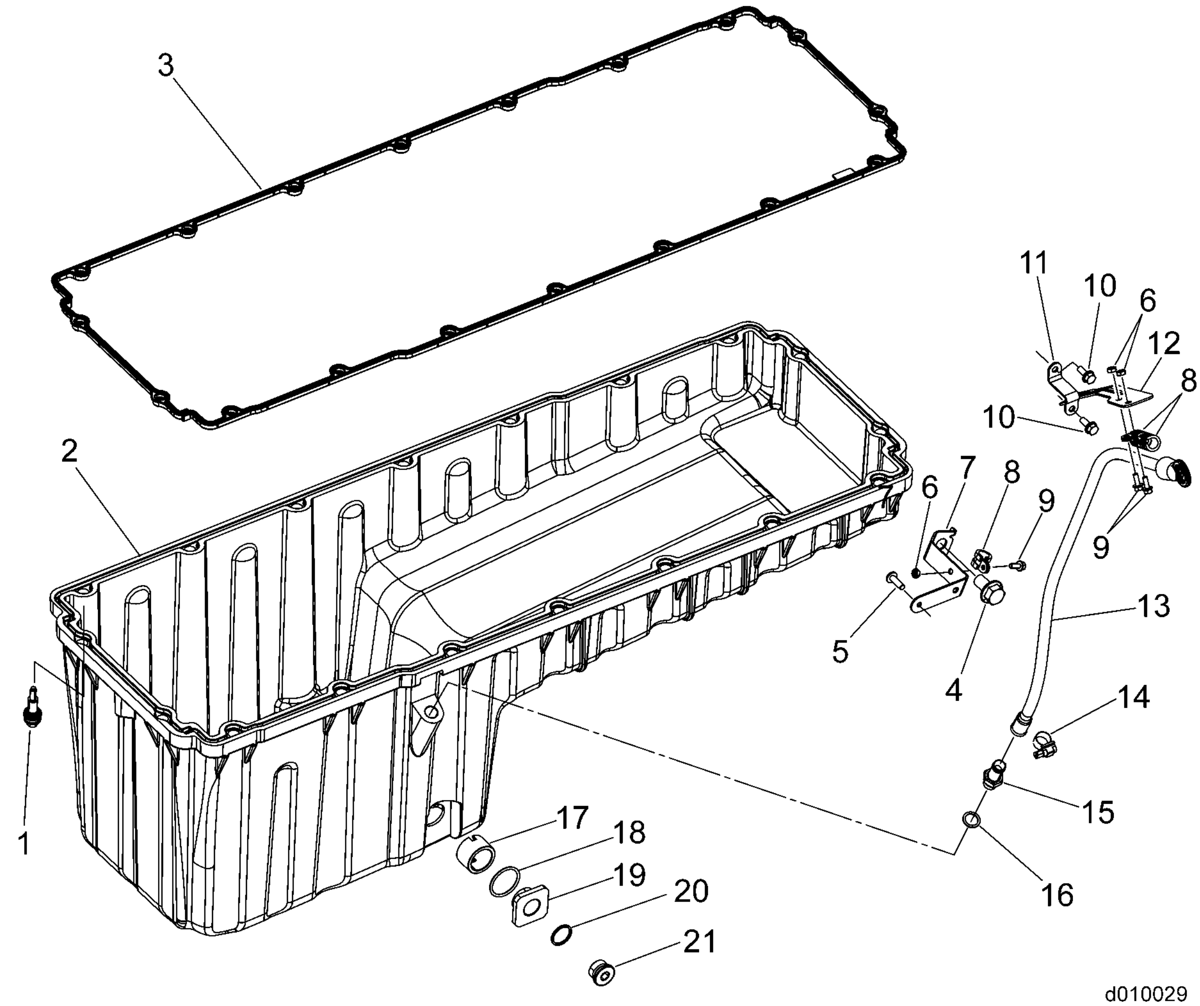


1. Engine Brake
2. Turbocharger
3. Axial Power Turbine
4. Crankcase Breather
5. Oil Pump
6. Pressure Valve
7. Backflow Valve
8. Suction Pipe
9. Oil Spray Nozzle
10. Oil Cooler and Housing
11. Oil Filter
12. Oil Refill
13. Intake Rocker Arm Spindle Supply
14. Engine Brake Supply
15. Exhaust Rocker Arm Spindle Supply
16. Gear Train Oil Supply
17. Main Bearing Supply

Figure 3-1 Oil Flow Schematic

3.2 OIL PAN

Depending on the manufacturer the oil pan (2) consists either of glass fiber reinforced plastic or aluminum. Sealing of the oil pan (2) takes place using a metal elastomer pre-formed gasket (3) for the aluminum pan and an elastomer for the plastic pan. The oil pan seal has high sealing reliability and noise reduction. The oil pan (2) holds 40 liters of engine oil. In order to determine the engine oil level there is a conventional oil dipstick. See Figure 3-2.



1. Bolt and Isolater
2. Oil Pan
3. Gasket
4. Bolt
5. Bolt
6. Nut
7. Bracket
8. Clamp
9. Bolt
10. Bolt
11. Bracket
12. Bracket
13. Dipstick Tube
14. Clamp
15. Adapter
16. Seal
17. Nut
18. Seal Ring
19. Nut
20. Seal Ring
21. Screw Plug

Figure 3-2 Oil Pan and Related Parts

3.2.1 Removal of the Oil Pan

Remove as follows:

1. Open the oil filter housing.
2. Remove the dipstick.
3. Loosen the dipstick tube on the oil pan.
4. Remove bolt at harness P-clamp on front center of oil pan.
5. Remove the drain plug and drain the engine oil.
6. Loosen the eighteen oil pan bolts. Bolts will remain installed to the pan.
7. Remove the oil pan taking care not to damage the oil pump inlet pipe and screen.
8. Remove the oil pan seal and check for damage.

3.2.1.1 Cleaning of the Oil Pan

Clean as follows:

1. Clean the oil pan and attaching hardware with clean fuel oil.

CAUTION:

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

2. Dry with compressed air.

NOTICE:

Do not use solvents to clean gaskets. Damage to the gasket will result.

3. Clean the surfaces of the cylinder block, and flywheel housing where they mate.

3.2.1.2 Inspection of the Oil Pan

Inspect as follows:

1. Check bolt assembly for dryness, or tears in isolator or damage to bolt or sleeve.
   [a] If isolator is damaged, replace with new part.
   [b] If isolator is not damaged, reuse the part.
2. Check oil pan for major dents, cracks and other damage.
   [a] If oil pan is damaged, replace with new part.

[b] If oil pan is not damaged, reuse the part.

3. Check seal for dryness, cracks or tears.
   [a] If seal is damaged replace with new part.
   [b] If seal is not damaged clean off excess Loctite®, clean seal with clean fuel oil, dry completely and reuse the part. Reapply Loctite 59-70 or equivalent to four corners squares in gasket.

3.2.2 Installation of the Oil Pan

Install as follows:

1. When a plastic pan is used insert the raised lip portion of the seal into the groove in the oil pan. Press down on the isolator seal and insert it completely around the oil pan. Be careful not to stretch or bunch the seal. For best results, install the seal at each corner, then at points half way between the corners. Continue in this manner, halving the distance and seating the seal.
2. For the aluminum pan the gasket is placed on top of the pan.
3. Install the eighteen oil pan bolt and sleeve assemblies.
4. Ensure the joint surfaces of the gear case and the cylinder block, is cleaned and there is no damage that could prevent sealing.
5. When an aluminum pan is used apply sealant to the four corners of the pan; where the block meets the gear cover and the front seal mount.
6. Install the oil pan assembly in position on the cylinder block.

7. Ensure that the seal has not been disturbed. Torque the eighteen oil pan bolt assemblies to 20 N·m, (15 lb·ft) using the proper sequence.

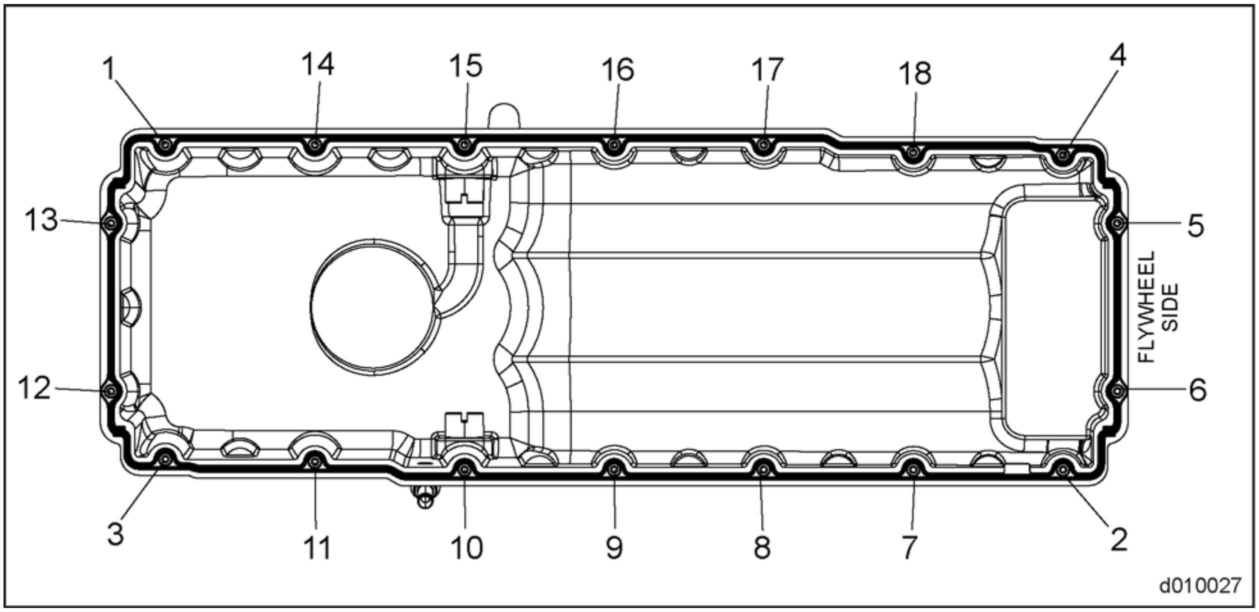


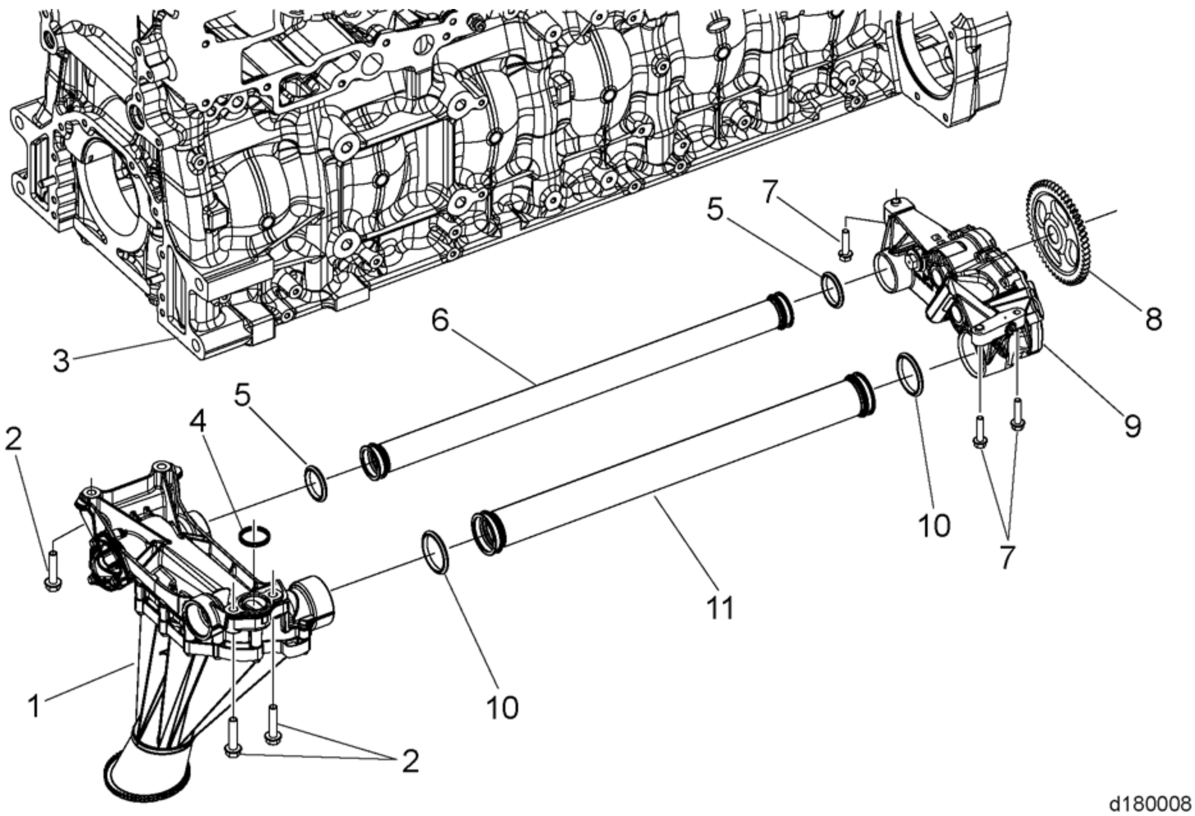
Figure 3-3 Oil Pan Torque Sequence

8. Install the oil pan drain plug and torque the plug to 45 N·m (33 lb·ft).
9. Install and tighten any other plugs that were removed from the oil pan.
10. Refill the crankcase with lubricating oil.

3.3 OIL PUMP

The oil pump supplies the oil circuit of the engine with engine oil. It ensures that engine oil is available under all operating conditions in adequate quantities and at the required pressure at the respective locations

The drive gear for the oil pump, which is driven by the crankshaft gear, drives the two impellers. The rotational movement of the impellers and the design of the pump chamber suctions the engine oil and delivers it to the oil outlet. The engine oil flows through oil strainer before it flows to the oil inlet and into the oil pump. The engine oil is delivered into the pressure line and then through the return flow check valve to the main oil duct, into the engine oil circuit. The pressure regulator valve regulates engine oil pressure. The pressure regulator valve has the oil pressure applied to it from the engine oil in the main oil duct. Excess engine oil is fed by the pressure regulator valve to the suction side according to the oil pressure in the main oil duct. This regulates the engine oil pressure and reduces the operating energy input of the oil pump. High pressures in the oil circuit are avoided using the safety valve. High pressure can occur in the cold start phase of the engine if the engine oil is not yet viscous. The safety valve opens at a pressure >10 bar and leads part of the engine oil back into oil pan. See Figure 3-4.



1. Oil Pump to Intake Manifold
2. Bolt, Suction Pipe to Cylinder Head
3. Cylinder Block
4. Gasket, Suction Pipe to Cylinder Block
5. Gasket, Pressure Pipe at Oil Pump and Oil Intake Manifold
6. Oil Line, Oil Pump to Oil Pressure Intake Manifold
7. Bolt, Oil Pump to Cylinder Block
8. Oil Pump Drive Gear
9. Oil Pump
10. Gasket, Intake Pipe at Oil Pump and Oil Intake Manifold
11. Oil Line, Oil Pump to Oil Intake Manifold

Figure 3-4 Oil Pump and Related Parts

3.3.1 Removal of the Oil Pump

Remove as follows:

1. Remove the oil pan refer to section 3.2.1.
2. Remove oil drain plug from the oil pan and drain the oil.
3. Remove the eighteen bolts and spacers securing the oil pan to the cylinder block and remove the oil pan from the cylinder block.
4. Remove the four bolts securing the oil manifold to the engine block.
5. Remove the oil suction pipe, pressure line and O-rings. Discard the O-rings.
6. Remove the three bolts securing the oil pump to the engine block and remove from the engine block.

3.3.1.1 Inspection of the Oil Pump

Inspect as follows:

CAUTION:

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

1. Wash all parts in clean fuel oil and dry them with compressed air.
2. Clean the suction and pressure pipe and screen in clean fuel oil and blow dry with compressed air.

3.3.2 Installation of the Oil Pump

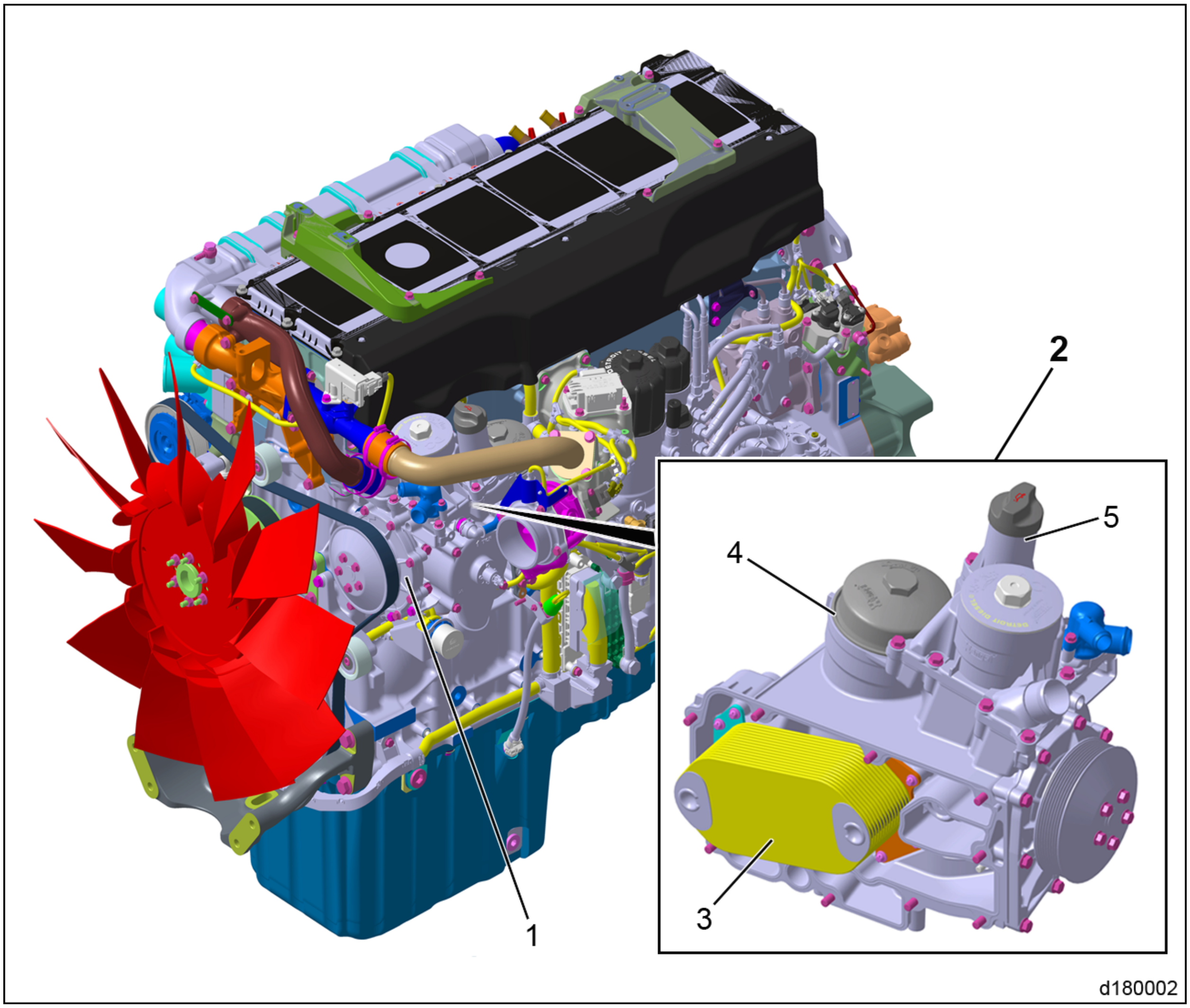
Install as follows:

1. Position the oil pump on the cylinder block so that the drive gear of the oil pump meshes with the crankshaft gear.
2. Install oil pump with three bolts. Torque the bolts to 30 N·m (22 ft·lb).
3. Install oil suction and Pressure pipes with new O-rings. Install new O-ring onto oil suction module.
4. Install four bolts and secure the oil manifold to the cylinder block. Torque the bolts to 60 N·m (44 ft·lb).
5. Install the oil pan. Refer to section 3.2.2.
6. Fill the crankcase to the proper level of oil, with the recommended oil.
7. Prime the lubrication system.

3.4 OIL COOLANT MODULE

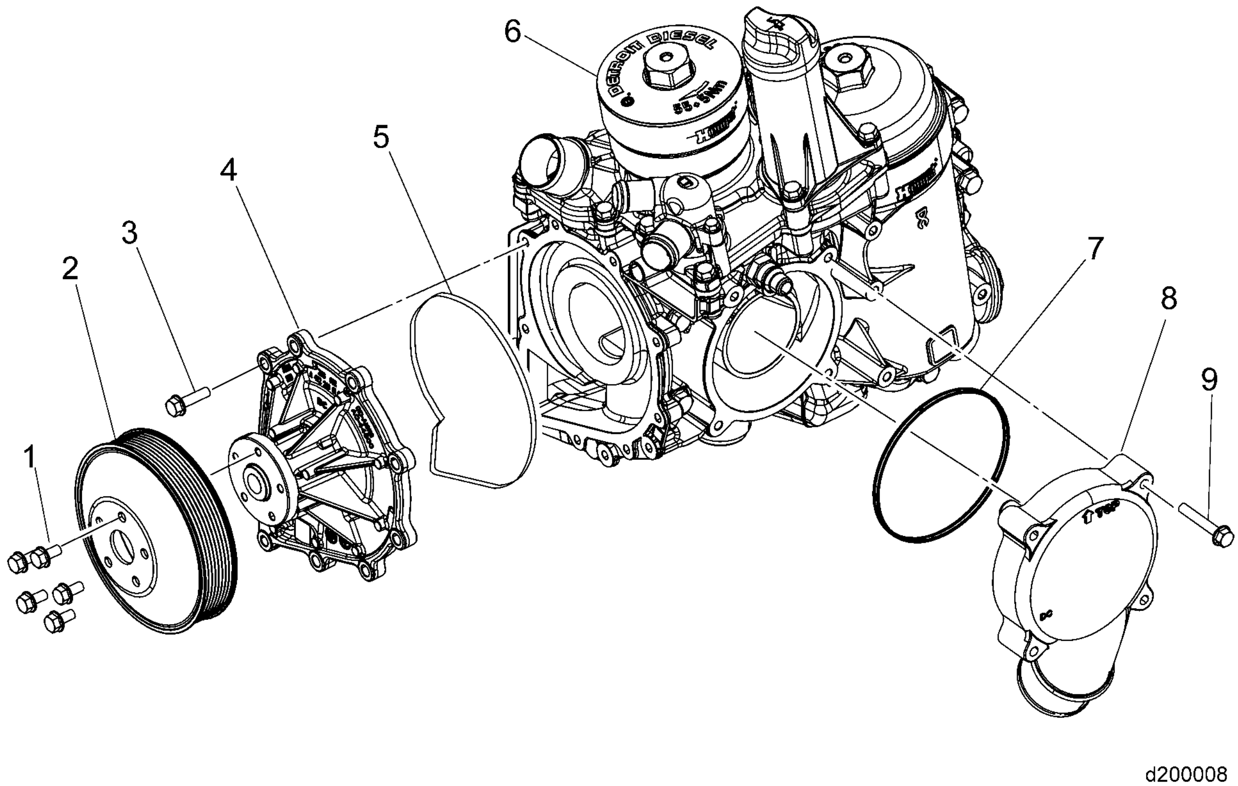
The oil filter unit is an integral part of the oil/coolant module which is located on the left side of the engine behind the coolant pump. The oil filter unit ensures filtering of the engine oil.

The engine oil flows through the oil/water heat exchanger and then to the main oil stream feed into the oil filter unit .Oil flows into the oil filter unit from outside of the oil coolant module through the oil filter element to the support dome where it is cleaned. The cleaned engine oil flows to the support dome and main oil flow drain back into the oil circuit.



1. Coolant Pump
2. Oil Coolant Module
3. Oil Water Heat Exchanger
4. Oil Filter Unit
5. Oil Fill

Figure 3-5 Oil Coolant Module Location



1. Bolt
2. Pulley
3. Bolt
4. Cover
5. Oil Cooler Module
6. Seal
7. Thermostat
8. Bolt

Figure 3-6 Oil Coolant Module and Related Parts

3.4.1 Removal of the Oil Coolant Module

Remove as follows:

1. Open the drain plug on the cylinder block located next to the oil coolant module and drain the coolant. Refer to section 12.4.
2. Remove the coolant delivery pipe refer to section5.1, mixer pipe refer to section, cold boost pipe and throttle valve assembly. refer to section5.4.
3. Remove heater hose from oil coolant module.
4. Disconnect coolant line from fuel module to oil coolant module.
5. Remove engine harness from sensor.
6. Disconnect harness from oil coolant module.

7. Remove the poly-V-belt from the water pump pulley. Refer to section 1.7.
8. Remove thermostat from oil coolant module.

NOTE:
Ensure any remaining coolant is drained from the oil coolant module and from the cylinder block to prevent coolant from contaminating the engine oil.

9. Remove the drain plug from the bottom of the oil coolant module and drain any remaining coolant from the oil coolant module.
10. Remove eleven bolts securing oil coolant module to engine block and remove oil coolant module.

3.4.2 Disassembly of the Oil Coolant Module

Disassemble as follows:

1. Using the appropriate wrench loosen the filter assembly and remove the unit consisting of the filter cover, and filter insert.
2. Unclip the filter insert from the filter cover by tilting it slightly and pulling.

3.4.3 Assembly of the Oil Coolant Module

Assemble as follows:

NOTE:
Before reinstalling, replace the O-ring on the filter cover with new a O-ring.

1. Place a new filter insert on the filter cover.
2. Install filter cover and torque to 55N·m (40 lb·ft).

3.4.4 Installation of the Oil Coolant Module

Install as follows:

1. Install thermostat to oil coolant module with four bolts torque to 20-25 N·m (15-19 lb·ft).
2. Install guide studs 677555–1 and 677555–2 into the cylinder block to assist in guiding the oil coolant module onto the cylinder block..
3. Install a new gasket.
4. Install the oil coolant module on to the guide studs and cylinder block.

5. Torque in the following sequence. See Figure 3-7.

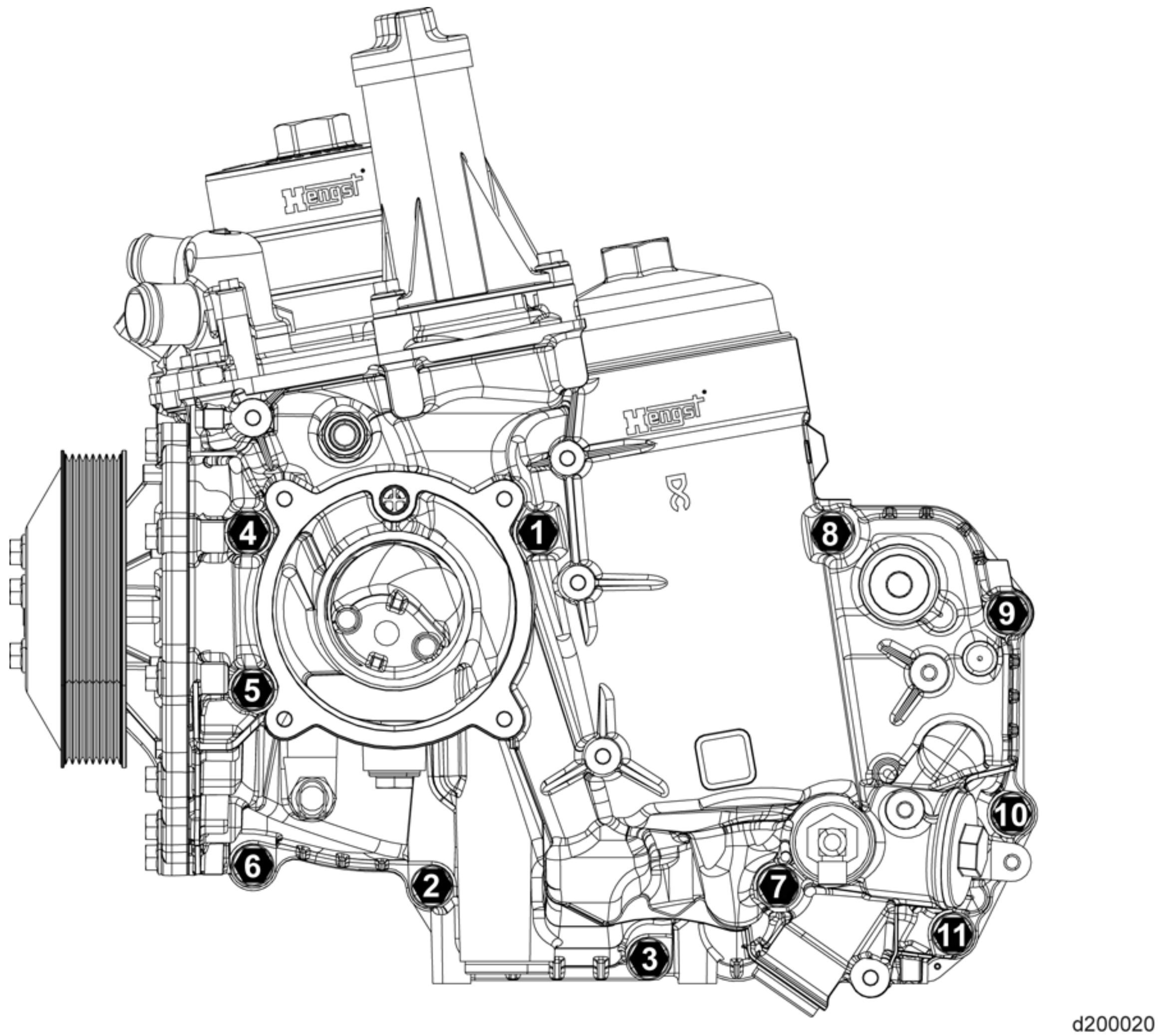


Figure 3-7 Oil Coolant Module Torque Sequence

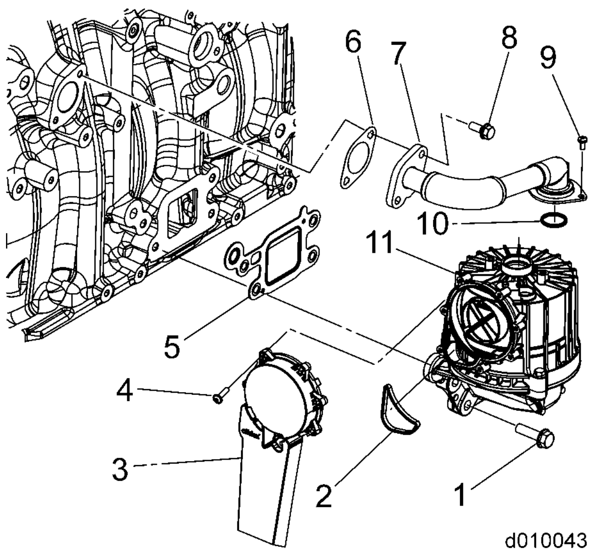
6. Install eleven bolts and torque to 10 N·m (7. 376 lb·ft). Final torque the bolts to 60-65 N·m (44-47 lb·ft).
7. Remove guide studs 677555–1 and 677555–2. Install the remaining two bolts into the oil cooler module. Torque the bolts to 10 N·m (7.376 lb·ft). Final torque the bolts to 60-65 N·m (44-47 lb·ft).
8. Install water pump if removed. Refer to section 7.4.
9. Install poly-V-belt to water pump pulley. Refer to section 1.7.
10. Install engine harness to the sensor.
11. Connect coolant line to fuel module and oil coolant module.
12. Install heater hose to oil coolant module.
13. If removed install coolant drain plug to the bottom of the oil coolant module and tighten.

14. If open close the drain plug on the cylinder block located next to the oil coolant module.
15. Install coolant delivery pipe and hose to oil coolant module and tighten the two hose clamps.
16. Install cold boost pipe to intake manifold refer to section 5.5.2.
17. Install mixer tube to cold boost pipe with three bolts refer to section 5.3
18. Install the intake throttle valve to cold boost pipe. Refer tp section 5.4.
19. Fill the coolant system.

3.5 CRANKCASE BREATHER

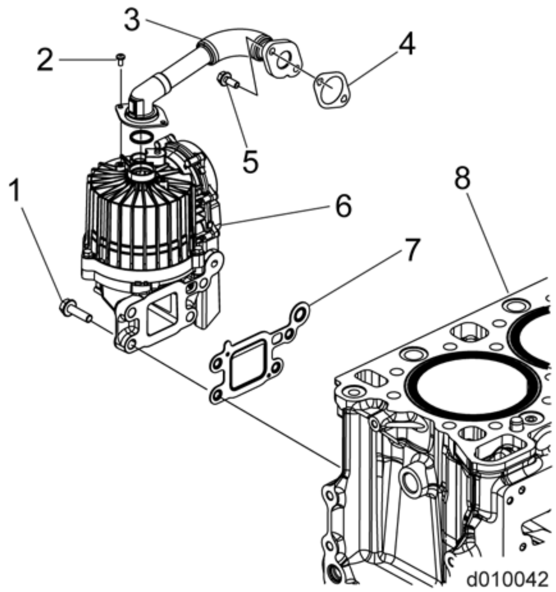
The crankcase breather is located below the 14.8L axial power turbine and the turbocharger , next to the starter on the right hand side of the cylinder block. The crankcase breather has the primary task of regulating the pressure in the crankcase as well as cleaning discharged blowby gases. The gases from the crankcase contain engine oil and large amounts of engine oil can lead to adverse effects upon the emission levels of the engine.

The blow-by-gas produced by the engine passes into the inlet for blow-by-gas in the housing of the crankcase breather. In the housing the blow-by-gas flows to the centrifuge. The centrifuge drive gear, which is driven by the engine oil pumped to the oil pressure duct , causes the centrifuge to turn. The centrifugal force that is created causes the blow-by-gas to be pushed against the inside wall of the housing. The engine oil contained in the blow-by-gas runs along the inside wall downwards and flows to the outlet for the engine oil that has been separated back into the oil pan. The cleaned blow-by-gas flows to the outlet for blow-by-gas to the atmosphere. The crankcase breather is maintenance free for the working life of the component.



1. Bolt
2. Gasket
3. Outlet Tube
4. Bolt
5. Gasket
6.
7. Inlet Tube
8. Bolt
9. Bolt
10. Seal
11. Crankcase Breather

Figure 3-8 Crankcase Breather and Related Parts



1. Bolt
2. Bolt
3. Inlet Tube
4. Gasket
5. Bolt
6. Crankcase Breather
7. Gasket
8. Cylinder Block

Figure 3-9 Crankcase Breather and Related Parts

3.5.1 Removal of the Crankcase Breather

Remove as follows:

1. Remove the two bolts and gasket from the breather pipe.
2. Remove the four bolts and gasket from the crankcase breather and remove crankcase breather from the cylinder block.

3.5.1.1 Inspection of the Crankcase Breather

Inspect as follows:

1. Clean the gasket surface of the engine block prior to installation of crankcase breather.
2. Inspect the tubes, clamps and hoses for wear or damage; replace if necessary.
3. Inspect the crankcase breather for cracks or damage; replace if necessary.

3.5.2 Installation of the Crankcase Breather

Install as follows:

1. Install the crankcase breather to the engine block with a new gasket and four bolts torque the bolts to 60 N·m (44 ft·lb).
2. Install the breather pipe and gasket to the engine block. Torque the two bolts to 30 N·m (22 ft·lb).

WARNING:

ENGINE EXHAUST

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

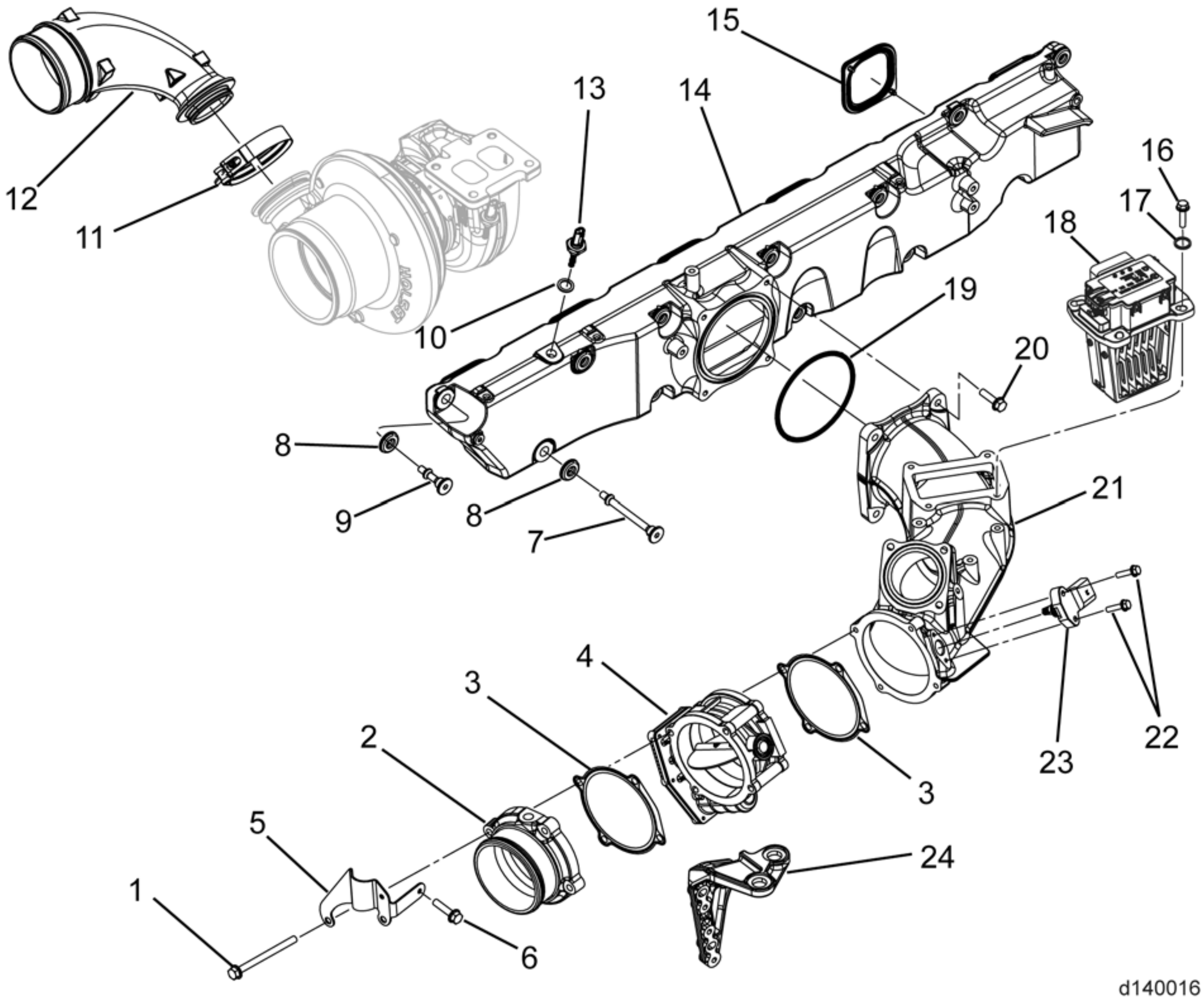
3. Start the engine and check for leaks.

4 AIR INTAKE SYSTEM

Section **Page**

4.1 AIR INTAKE MANIFOLD

On diesel engines, the intake charge air is routed to the individual cylinders of an intake manifold that is bolted to the cylinder head with ten bolts. The mating surface of the manifold and cylinder head is machined. The intake manifold is sealed to the cylinder head with six rubber and steel gaskets. If the manifold is removed, new gaskets must be installed to maintain seal under higher boost pressure. An intake manifold air temperature sensor are installed to the intake manifold. The Exhaust Gas Recirculation valve (EGR) mixer, intake throttle valve and adaptor are installed to the air inlet of the intake manifold. CAC ducting is installed on the intake throttle valve adaptor. There is a pressure sensor in the intake elbow and a temperature sensor in the imtake throttle adaptor.



1. Bolt	9. Bolt, Intake Manifold Elbow to Cylinder Head	17. Washer, Grid Heater to Cold Boost Pipe
2. Adaptor	10. Seal Ring Charge Air Sensor	18. Grid Heater
3. Gasket	11. Clamp, turbocharger outlet pipe	19. Gasket, Cold Boost Pipe
4. EGR Throttle Valve	12. Elbow, Turbo Outlet	20. Bolt, Cold Boost Pipe to Intake Manifold
5. Air Temperature Sensor Guard	13. Intake Manifold Sender Unit	21. Cold Boost Pipe
6. Bolt	14. Intake Manifold	22. Bolt, Combination Temperature and Pressure Sensor
7. Bolt, Intake Manifold Elbow-to Cylinder Head	15. Gasket	23. Charge Air Pressure Sensor
8. Gasket, Intake Manifold Elbow-to Cylinder Head	16. Bolt, Grid Heater to Cold Boost Pipe	24. Bracket to Oil Coolant Module

Figure 4-1 Air Intake Manifold and Related Parts

4.1.1 Removal of the Air Intake Manifold

Remove as follows:

1. Drain the cooling system.
2. Drain fuel module
3. Remove the exhaust gas recirculation (EGR) mixer pipe and delivery pipe.
4. Remove the fuel module.
5. Remove the oil coolant module.
6. Disconnect the high pressure fuel lines connected to the common rail and output side of the high pressure fuel pump.
7. Disconnect and remove the fuel line connected to the common rail and base of the fuel filter housing.
8. Disconnect and remove the air intake pressure sensor harness from the two air intake sensors.
9. Identify the bolt locations prior to removal of bolts.
10. Remove the twelve bolts, isolators and washers securing the air intake manifold to cylinder head.
11. Remove the air intake manifold and six gaskets from the cylinder head. Discard gaskets.

4.1.1.1 Cleaning of the Air Intake Manifold

Clean as follows:

1. Remove loose gasket material from the cylinder head and intake manifold mating surfaces.
2. Wash all of the parts in clean fuel oil.

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.

3. Blow dry with compressed air.

4.1.1.2 Inspection of the Intake Manifold

Inspect as follows:

1. Visually inspect the manifold for any cracks, dents or other damage. Pay particular attention to the bolt areas.

[a] If a crack is found, replace the intake manifold.

[b] If no cracks are found, reuse the intake manifold.

2. Inspect the manifold mating surface for imperfections that could affect its sealing to the cylinder head.

   [a] If the manifold mating surface has imperfections, replace the intake manifold.

   [b] If the manifold mating surface is not damaged, reuse part.

3. Check the mating ports for warpage, using a 0.5 mm (20 in.) long by 6 mm (1/4 in.) wide straight edge bar laying the bar across the manifold

   [a] If all port flange area measurements are less than 0.127 mm (0.005 in.), the manifold is reusable and can be reinstalled with new gaskets.

   [b] If the manifold does not meet this requirement the manifold *must* be replaced.

4.1.2 Installation of Air Intake Manifold

Install as follows:

1. Install intake manifold and gaskets to the cylinder head.
2. Install twelve bolts to intake manifold torque the bolts to 25 N·m (18 ft·lb).
3. Install oil cooler module.
4. Install fuel module.
5. Install fuel line bracket.
6. Install the high pressure fuel lines connected to the common rail and output side of the high pressure fuel pump..
7. Install the exhaust gas recirculation (EGR) mixer pipe and delivery pipe.
8. Fill the coolant system to the appropriate level.

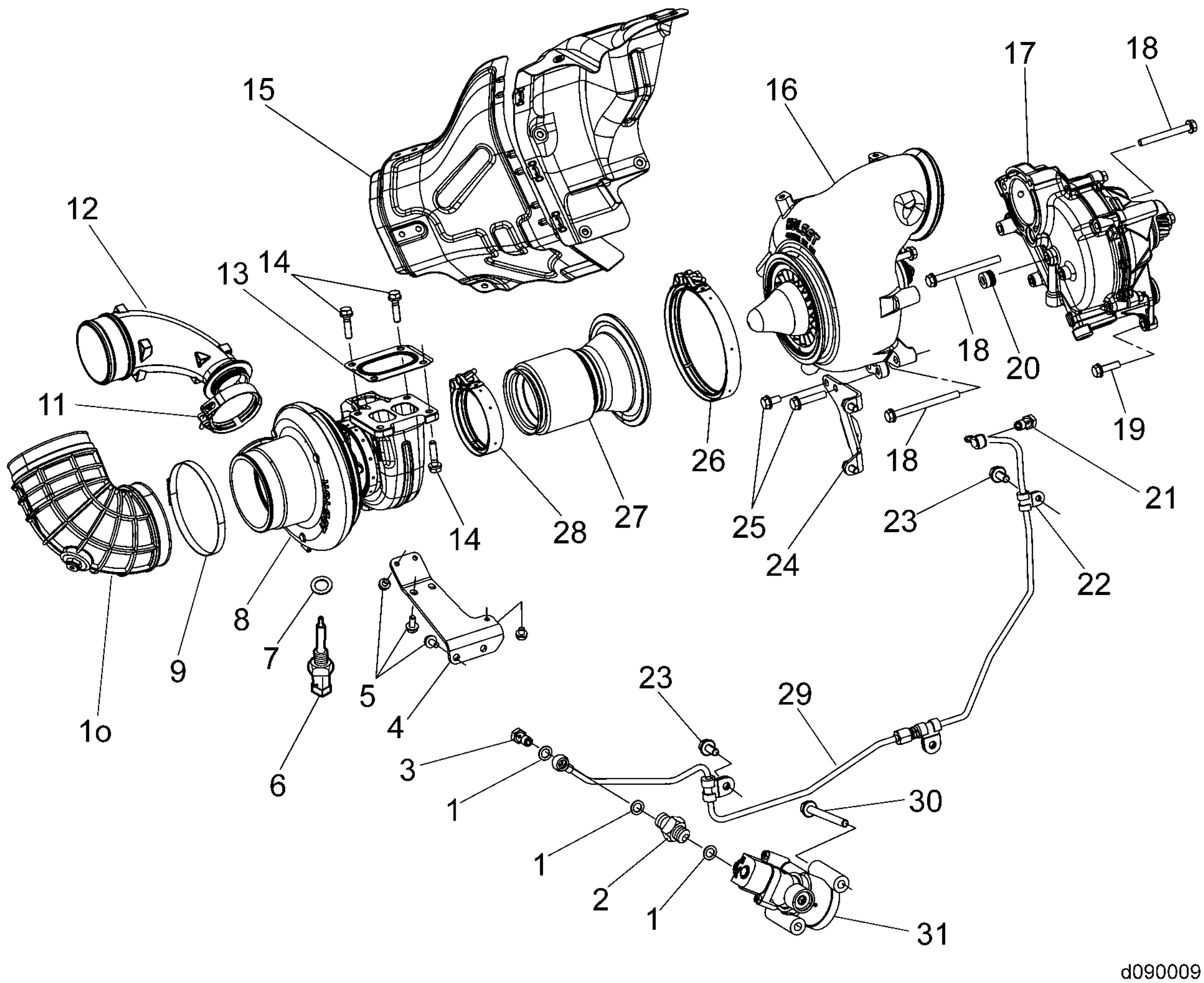
4.2 TURBOCHARGER

Compression of air in the turbocharger causes an air mass to flow into the combustion chamber. The turbocharger consists of a turbine and a compressor which are attached to a shaft). The exhaust gas flows to the turbine wheel and causes it to turn. This turning motion is transmitted to the shaft and the compressor impeller . The intake air from the air filter is compressed by the compressor impeller and flows over a charge air pipe to the charge air cooler. The compressed air is cooled in the charge air cooler, this permits a more dense charge of air to be delivered to the engine and the output of the engine is increased. The charge air then passes from charge air cooler into the charge air manifold cylinders.

The turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold.

The advantages are as follows:

- Increases the engine performance and torque
- Reduction of the fuel consumption compared to a similarly powered naturally aspirated engine
- Reduction of emissions



1. Washer
2. Connector
3. Banjo Bolt
4. Bracket
5. Bolts
6. Turbo Speed Sensor
7. O-ring
8. Turbocharger
9. Clamp
10. Exhaust Pipe
11. Clamp
12. Turbo Outlet Elbow
13. Gasket
14. Bolts
15. Heat Shield
16. Axial Power Turbine
17. Gear Box
18. Bolt
19. Bolt
20. Washer
21. Banjo Bolt
22. Clip
23. Bolt
24. Bracket
25. Bolt
26. Clamp
27. Interstage Duct
28. Clamp
29. Air Line
30. Bolt
31. Air Seal Pressure Regulator

Figure 4-2 Turbocharger and Related Parts

4.2.1 Removal and Cleaning of Turbocharger

Cleaning the turbocharger is necessary before removal.

WARNING:

PERSONAL INJURY

To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

WARNING:

PERSONAL INJURY

To avoid injury from contact with rotating parts when an engine is operating with the air inlet piping removed, install an air inlet screen shield over the turbocharger air inlet. The shield prevents contact with rotating parts.

Prior to removal, visually check for:

1. Missing or loose nuts and bolts.
2. Loose or damaged intake and exhaust ducting.
3. Damaged oil drain lines.
4. Cracked or deteriorating turbocharger housings.
5. External oil leakage or exhaust leaks.
6. Replace damaged parts with new parts.

To remove the turbocharger, perform the following:

NOTICE:

Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. If chunks of carbon are left on the blades, an unbalanced condition will exist and subsequent failure of the bearings will result if the turbocharger is operated. However, it is not necessary to disassemble the turbocharger to remove dirt or dust buildup.

1. Remove turbocharger heat shield.
2. Disconnect and remove the CAC ducting at the compressor housing, compressor outlet elbow and inlet air temperature connector.
3. Remove the turbo oil supply and drain line from the center housing.

4. Remove two bolts from center section and loosen two bolts in the engine block.
5. If turbocharger has a turbo speed sensor installed disconnect turbo speed sensor harness.
6. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.

NOTICE:
Turbocharger must be supported when removing the mounting bolts to avoid damage to the turbocharger.

7. Disconnect interstage duct marman clamps.
8. Remove the four bolts securing the turbocharger assembly to the exhaust manifold.
9. Separate turbocharger from exhaust manifold and interstage duct.
10. Lift the turbocharger assembly and inter stage duct away from the engine and place it on a bench
11. Cover the end of the oil supply line, the oil drain line, the air inlet and the exhaust outlet openings on the engine and turbocharger, to prevent the entry of foreign material.

WARNING: PERSONAL INJURY
To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

12. Clean the exterior of the turbocharger with a non-caustic cleaning solvent.

4.2.1.1 Inspection of Turbocharger

Inspect the turbocharger as follows, discarding any damaged parts:

NOTICE:
Never attempt to straighten compressor turbine wheel blades.

1. Visually check for nicked, crossed or stripped threads.
2. Visually check the turbine wheel housing and turbine wheel for signs of rubbing.
3. Visually check the compressor wheel for signs of rubbing or damage from foreign material. The wheel must be free of dirt and other foreign material.
4. Visually check the turbine and compressor housings for damage.
5. Visually check for excess bearing axial and radial clearances.
6. If light finger pressure causes contact between compressor or turbine wheel and respective housing replace turbocharger.

4.2.2 Installation of Turbocharger

Install as follows:

1. If removed install gear box.
2. If removed install the axial power turbine.
3. Install interstage duct onto turbo.
4. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
5. Remove any covers that were placed over the openings of the air inlet and exhaust outlet openings on the engine and turbocharger when the turbocharger was removed.
6. Remove any covers on the oil and coolant inlet and drain lines, and the oil and coolant inlet and drain openings on the turbocharger.
7. Place a gasket on turbine housing flange.
8. Place the turbocharger assembly into position on the exhaust manifold.

NOTICE:
The turbocharger must be supported after it has been installed to the exhaust manifold flange to avoid damage to the turbocharger.

9. Secure the turbocharger to the exhaust flange. Tighten the bolts just enough to hold the turbocharger in place.

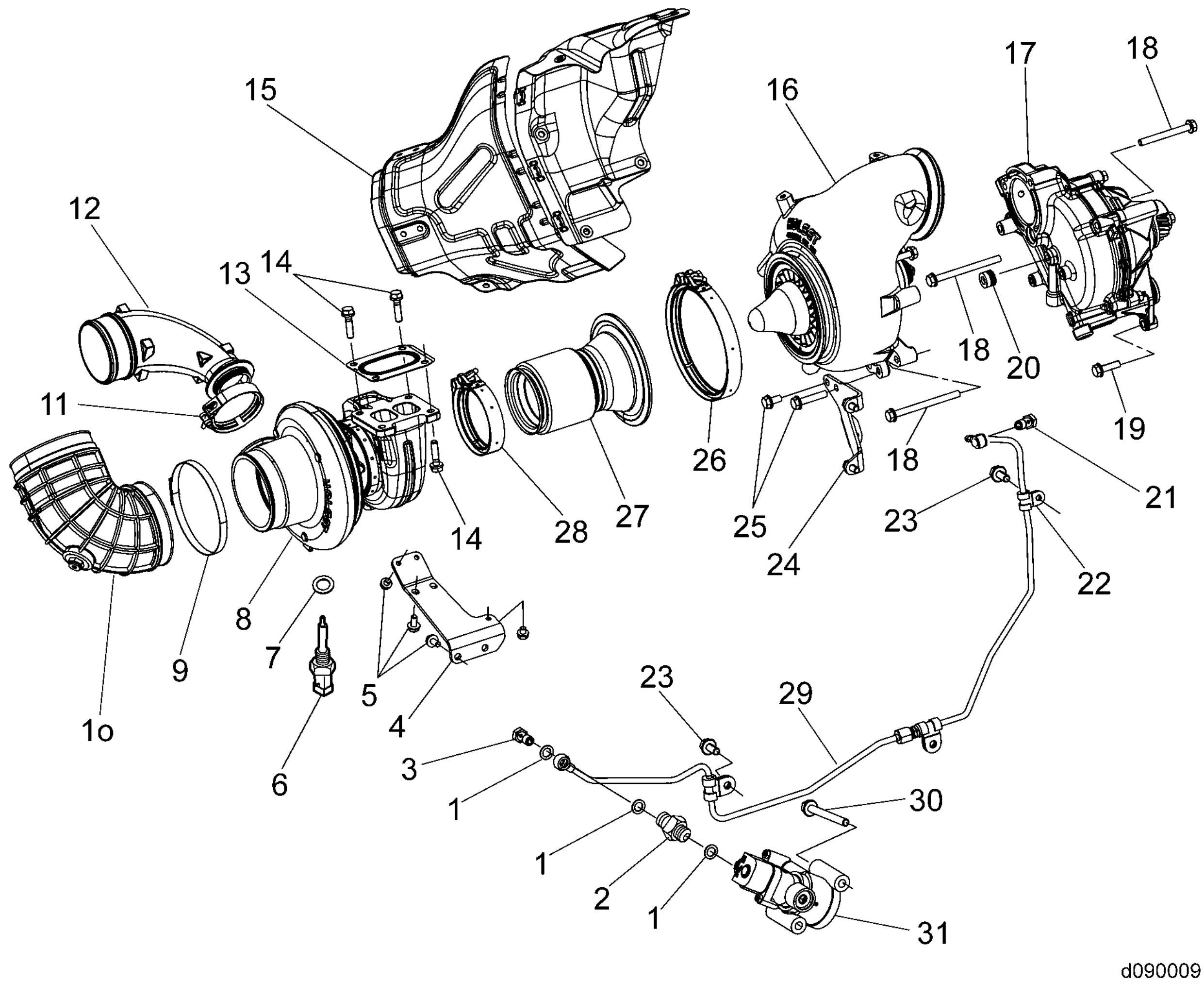
NOTE:
Do not use any type of lubricant on the inside of any air inlet hose or on the hose contact surfaces of the turbocharger compressor housing, CAC ducting or the intake manifold.

10. Torque the turbocharger to exhaust manifold bolts to 50 N·m (37 lb·ft).
11. Tighten the interstage duct to 12 mm (0.4724 in.).
12. Install the turbocharger oil drain line, using a new gasket and O-ring between the opening in the bottom side of the turbocharger center housing and the drain line that runs to the cylinder block. Torque the bolts to 30-38 N·m (22-28 lb·ft).
13. Install turbocharger oil supply line. Torque line to 30 N·m (22 lb·ft).
14. Connect turbocharger speed sensor plug.
15. Torque bracket bolts to 25 N·m (18 lb·ft).
16. Install heat shield.
17. Install compressor elbow and charge air compressor plumbing. Torque clamps to 6 N·m (4 lb·ft)..

4.3 AXIAL POWER TURBINE

The axial power turbine increases the efficiency and the economy of the engine by converting thermal energy, in the exhaust flow from the turbocharger into mechanical energy and delivers the resulting torque to the crankshaft. The rated speed of the turbine wheel of the axial power turbine device is about 50,000 rpm. The turbine wheel generates a torque in this range of about 10 Nm which is increased through various gear ratios of gears up to 260 Nm. The exhaust gas flows to the turbine wheel of the axial power turbine device and drives the wheel. The rotational movement created is transmitted to the shaft the small output gear and from the small output gear to the large output gear of the hydrodynamic clutch . The rotational speed is reduced because of the gear ratio between the output gear and drive gear and the torque increased. The impeller of the hydrodynamic clutch is connected to the housing of the hydrodynamic clutch to the drive gear and turns at the same rotational speed. The vanes on the impeller generate an oil flow in the hydrodynamic clutch which sets the turbine wheel of the hydrodynamic clutch into rotation and the output gear is driven over a shaft. The generated torque is transferred to the gear for the crankshaft via the intermediate gear and therefore to the crankshaft. It is therefore also possible to ensure via the hydrodynamic clutch that rotational speed matching takes place between the crankshaft and the axial power turbine-drive.

The axial power turbine device is connected to the engine oil circuit. The gears and the bearing are lubricated and cooled by the engine oil. The hydrodynamic clutch is supplied with engine oil by the hollow bearing shaft. One special aspect is the seal between the shaft and the exhaust turbine housing. The seal between these two components takes place by using two metal sealing rings which are pressed into their seat by compressed air. The pressure for pressing these sealing rings is reduced over the axial power turbine air seal pressure regulator valve to 0.5 bar which is actuated by the motor control module (MCM) as soon as the engine starts.



1. Washer	10. Exhaust Pipe	19. Bolt	28. Clamp
2. Connector	11. Clamp	20. Washer	29. Air Line
3. Banjo Bolt	12. Turbo Outlet Elbow	21. Banjo Bolt	30. Bolt
4. Bracket	13. Gasket	22. Clip	31. Air Seal Pressure Regulator
5. Bolts	14. Bolts	23. Bolt	
6. Turbo Speed Sensor	15. Heat Shield	24. Bracket	
7. O-ring	16. Axial Power Turbine	25. Bolt	
8. Turbocharger	17. Gear Box	26. Clamp	
9. Clamp	18. Bolt	27. Interstage Duct	

Figure 4-3 Axial Power Turbine and Related Parts

4.3.1 Removal of Axial Power Turbine

Remove as follows:

NOTICE:
Ensure turbocharger and axial power turbine are supported prior to removal.

1. Drain coolant.
2. Remove heat shields.
3. Remove exhaust pipe.
4. Remove exhaust gas recirculation (EGR) valve.
5. Remove turbocharger and interstage duct.
6. Remove clamp from turbo outlet elbow at elbow return..
7. Remove airline from air seal pressure regulator valve.
8. Remove four bolts securing gear box and axial power turbine.
9. Remove four bolts retaining the bracket to the axial power turbine and cylinder block and remove bracket.
10. Remove remaining bolts attaching turbine housing and gear box.
11. Separate turbine housing and gear box.

4.3.1.1 Inspection of the Axial Power Turbine

Inspect as follows:

1. Inspect axial power turbine for damage; replace if necessary.
2. Inspect for gear damage and turbine damage.

4.3.2 Installation of Axial Power Turbine

Install as follows:

1. If removed install gear box to cylinder block with four bolts. Torque bolts to 55 N·m +5 (41 lb·ft +5).

NOTICE:
When installing axial power turbine to gear box ensure gears are aligned by viewing through exhaust port and rotating impeller. Damage to gear box and axial power turbine will occur if not installed correctly.

2. Install axial power turbine O-ring and graphite seal..

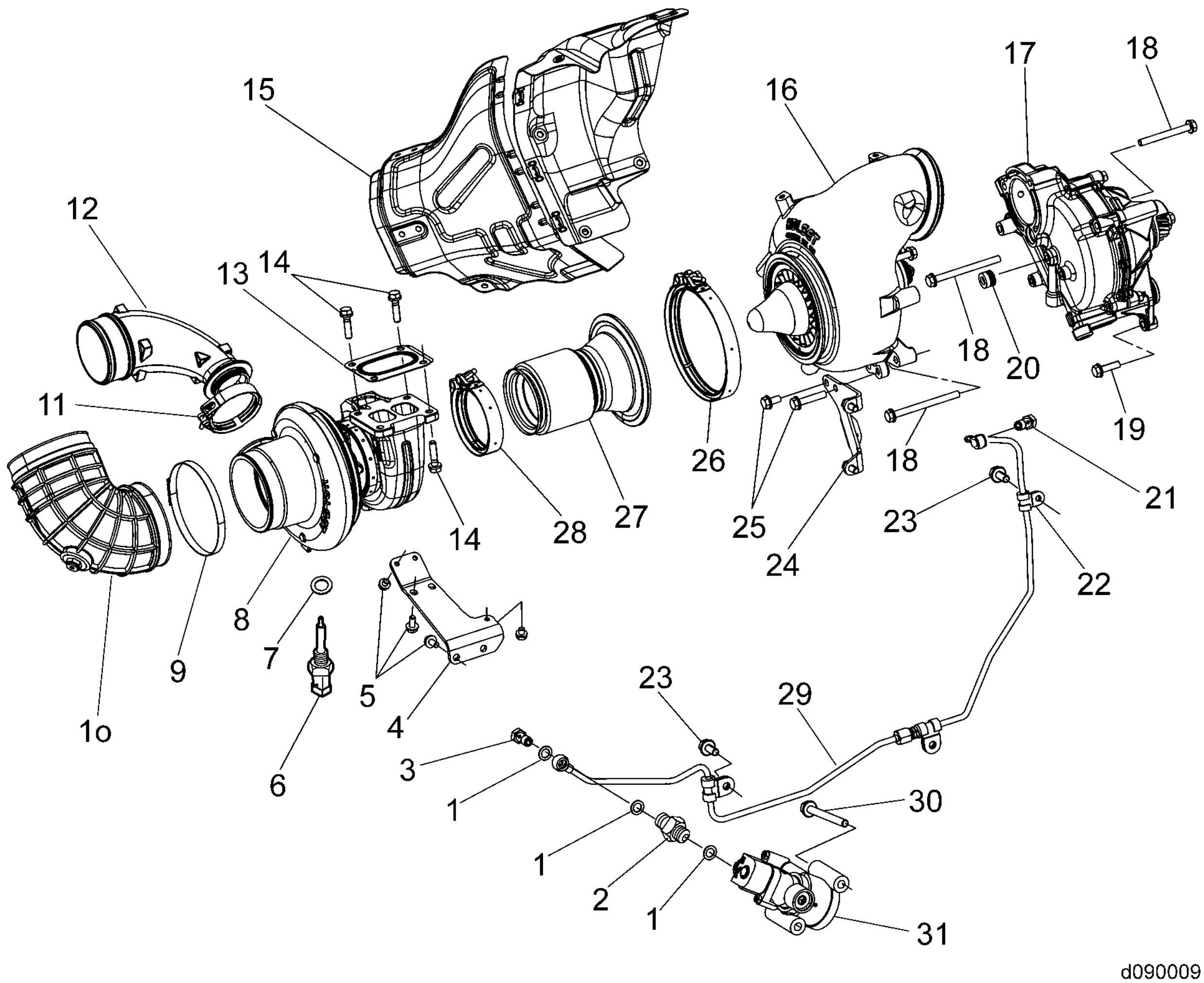
3. Lubricate collar and O-ring.
4. Install axial power turbine to gear box and bracket.
5. Install front bolt.
6. Install two bolts through bracket into axial power turbine and install two bolts through bracket into cylinder block. Install the remaining three bolts into axial power turbine.

NOTICE:
Ensure axial power turbine is aligned correctly before final torquing bolts to the gear box; damage to the O-ring and graphite seal may occur.

7. Torque the bolts to 55-60 N·m (41-44 lb·ft).
8. Install airline to axial power turbine from air seal pressure regulator valve.

4.4 GEAR BOX

The gear box is located on the right side of the engine between the turbocompound and cylinder block.



1. Washer	10. Exhaust Pipe	19. Bolt	28. Clamp
2. Connector	11. Clamp	20. Washer	29. Air Line
3. Banjo Bolt	12. Turbo Outlet Elbow	21. Banjo Bolt	30. Bolt
4. Bracket	13. Gasket	22. Clip	31. Air Seal Pressure Regulator
5. Bolts	14. Bolts	23. Bolt	
6. Turbo Speed Sensor	15. Heat Shield	24. Bracket	
7. O-ring	16. Axial Power Turbine	25. Bolt	
8. Turbocharger	17. Gear Box	26. Clamp	
9. Clamp	18. Bolt	27. Interstage Duct	

Figure 4-4 Gear Box and Related Parts

4.4.1 Removal of the Gear Box

Remove as follows:

1. Remove the turbocharger.
2. Remove the axial power turbine.
3. Remove the line from cylinder block to gear box.
4. Remove four bolts from the gear box and cylinder block and remove gear box.

4.4.1.1 Inspection of Gear Box

Inspect as follows:

1. Inspect the gear box for damage; replace if necessary.

4.4.2 Installation of the Turbocompound Gear Box

Install as follows:

NOTICE:
Ensure the gear box gear and idler gear located in the gear case housing are mesh. Failure to mesh gears correctly will cause damage.

1. Install the gear box to cylinder block, ensure the gears mesh together when installed.

NOTICE:
Ensure the correct bolt length is used when the gear box is installed. If an incorrect bolt length (too long) is used the cup plugs installed in the cylinder block can be pushed out into the gear train causing severe damage to the gear train. The correct bolt length for the bolt installed in the upper location near the cylinder block is 35 mm (1.37 in.). The correct length for the bolt located in the lower position of the gear box is 120 mm (4.72 in.).

2. Install four bolts into gear box and cylinder block and tighten.
3. Torque the four bolts to 55-60 N·m (41-44 ft·lb).
4. Install line to gear box and engine block.

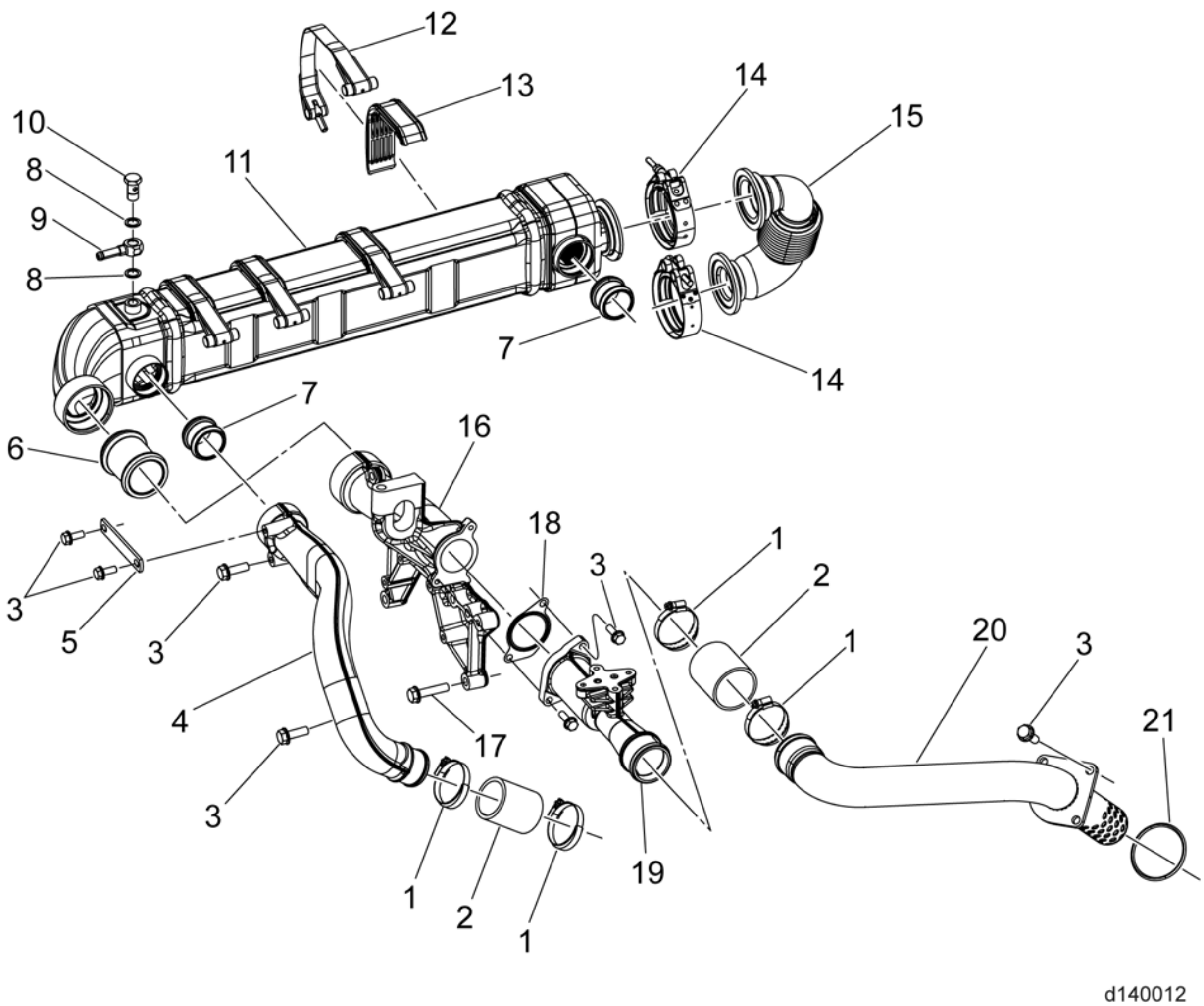
5 EXHAUST GAS RECIRCULATION (EGR) COMPONENTS

Section **Page**

5.1 EXHAUST GAS RECIRCULATION (EGR) COOLER

The exhaust gas recirculation cooler (EGR) is located on the right side of the engine over the turbocharger. The EGR cooler cools the exhaust gas from the exhaust manifold from 650° C (1202° F) down to 170° C (338° F.).

The exhaust gas is cooled by the flow of exhaust gases through the EGR cooler tubes. The hot exhaust gas flows to the valves actuated by the EGR valve actuator into the EGR cooler. The EGR cooler is part of the engine cooling system. The EGR cooler core transfers the heat removed from the exhaust gases to the engine coolant. The cooled exhaust gas is mixed in the mixer housing with charge air from the charge air cooler and flows to the intake manifold.



1. Clamp
2. Hose
3. Screw
4. Delivery Pipe, Coolant
5. Support
6. Connecting Tube
7. Connecting Tube
8. Seal Ring
9. Banjo Union
10. Banjo Bolt
11. Exhaust Gas Cooler
12. Strap
13. Shim
14. Clamp
15. Exhaust Pipe.
16. Exhaust Gas Crossover Tube/ Lifting Eye
17. Bolt
18. Gasket
19. Venturi
20. Mixer Pipe
21. Seal Ring

Figure 5-1 Exhaust Gas Recirculation Cooler and Related Parts

5.1.1 Removal of the EGR Cooler

Remove the EGR cooler as follows:

WARNING: **PERSONAL INJURY**
To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

1. Steam clean the engine.
2. Drain the engine coolant.
3. Remove the two clamps from exhaust pipe.
4. Remove exhaust pipe from EGR cooler and EGR valve.
5. Remove delivery pipe from ERG cooler and oil coolant module, remove two clamps from hose connecting delivery pipe to module.
6. Remove four bolts from EGR cooler straps and remove straps.
7. Remove retaining plate bolts at the front of the cooler.
8. Remove EGR cooler from water manifold.

5.1.2 Installation of the EGR Cooler

Install the EGR cooler as follows:

NOTICE:
Ensure items 6 and 7 connecting tubes see Figure 5-1 are lubricated with clean oil; if they are not lubricated the tubes cannot not be fully installed or the rubber can be cut.

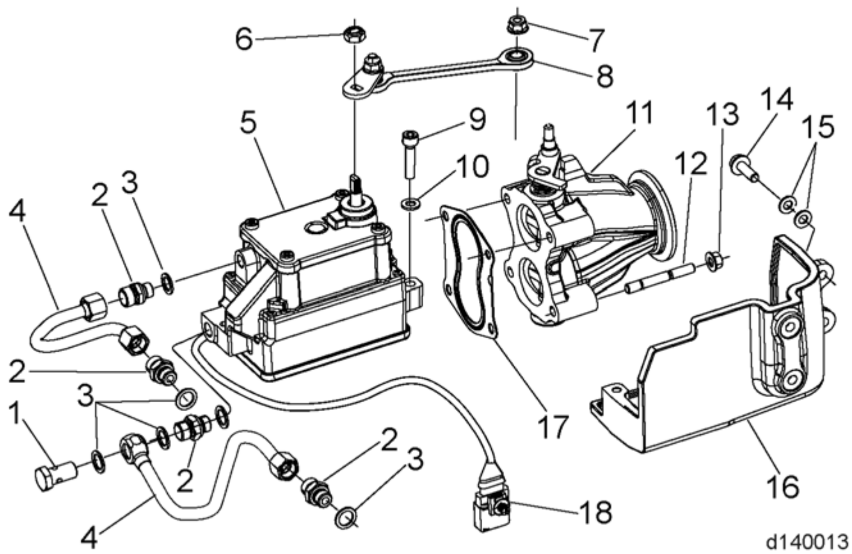
1. Install EGR cooler to the water manifold.
2. Install four EGR cooler straps and install strap bolts and tighten bolts to 20 N·m (14 lb·ft).
3. Install delivery pipe to ERG cooler and oil coolant module, install two clamps onto hose connecting delivery pipe to module. Tighten clamps.
4. Install exhaust pipe on EGR cooler and EGR valve with two clamps and tighten clamp bolts to 12 N·m (9 lb·ft).
5. Fill engine with coolant.

5.2 EXHAUST GAS RECIRCULATION (EGR) VALVE ACTUATOR

Exhaust Gas Recirculation (EGR) is controlled by an EGR valve and actuator . The EGR actuator opens and closes the valve to achieve the desired flow through the EGR cooler where high temperature gas is cooled then directed through a mixing pipe where it is mixed with air from the Charge Air Cooler (CAC) and directed to the cylinders.

The Motor Control Module (MCM) actuates the EGR valve with a pulse width modulated signal. A coil generates a magnetic field which activates and turns the valves on the EGR valve actuator.

The EGR valve actuator determines the position of the adjusting lever on the MCM for diagnostic purposes.



1. Screw
2. Fitting
3. Seal Ring
4. Line
5. EGR Valve Actuator
6 .Nut
7. Clamping Nut
8. Rod
9. Bolt
10. Washer
11. EGR Valve
12. Stud
13. Stud Nut
14. Bolt
15. Spacer Washer
16. Bracket
17. Gasket
18. Harness Plug

Figure 5-2 Exhaust Gas Recirculation Valve and Actuator

5.2.1 Removal of EGR Valve Actuator

Remove as follows:

NOTICE:
See Figure 5-2. Items numbers seven (nut) and eight (rod) must remain installed to the actuator linkage when removing or installing number six (nut) to avoid damage to the actuator valve gears

1. Remove one nut connecting actuator to linkage and remove linkage from EGR valve.
2. Remove coolant line from the actuator and cylinder block.
3. Remove coolant line from the actuator and water manifold.
4. Disconnect actuator sensor from sensor harness.
5. Remove three bolts and washers from actuator and remove actuator from bracket.
6. Remove four bolts and eight special thermal washers from actuator bracket and exhaust manifold and remove actuator bracket.

5.2.1.1 Inspection of the EGR Valve Actuator

Inspect the EGR valve /actuator and actuator bracket for damage and replace if necessary.

5.2.2 Installation of EGR Valve Actuator

Installation steps are as follows:

NOTICE:
If reusing the original actuator bracket bolts always apply a small amount of copper based anti-seize compound to the bolts. The original coating will burn off and that makes it necessary to reapply the anti-seize compound.

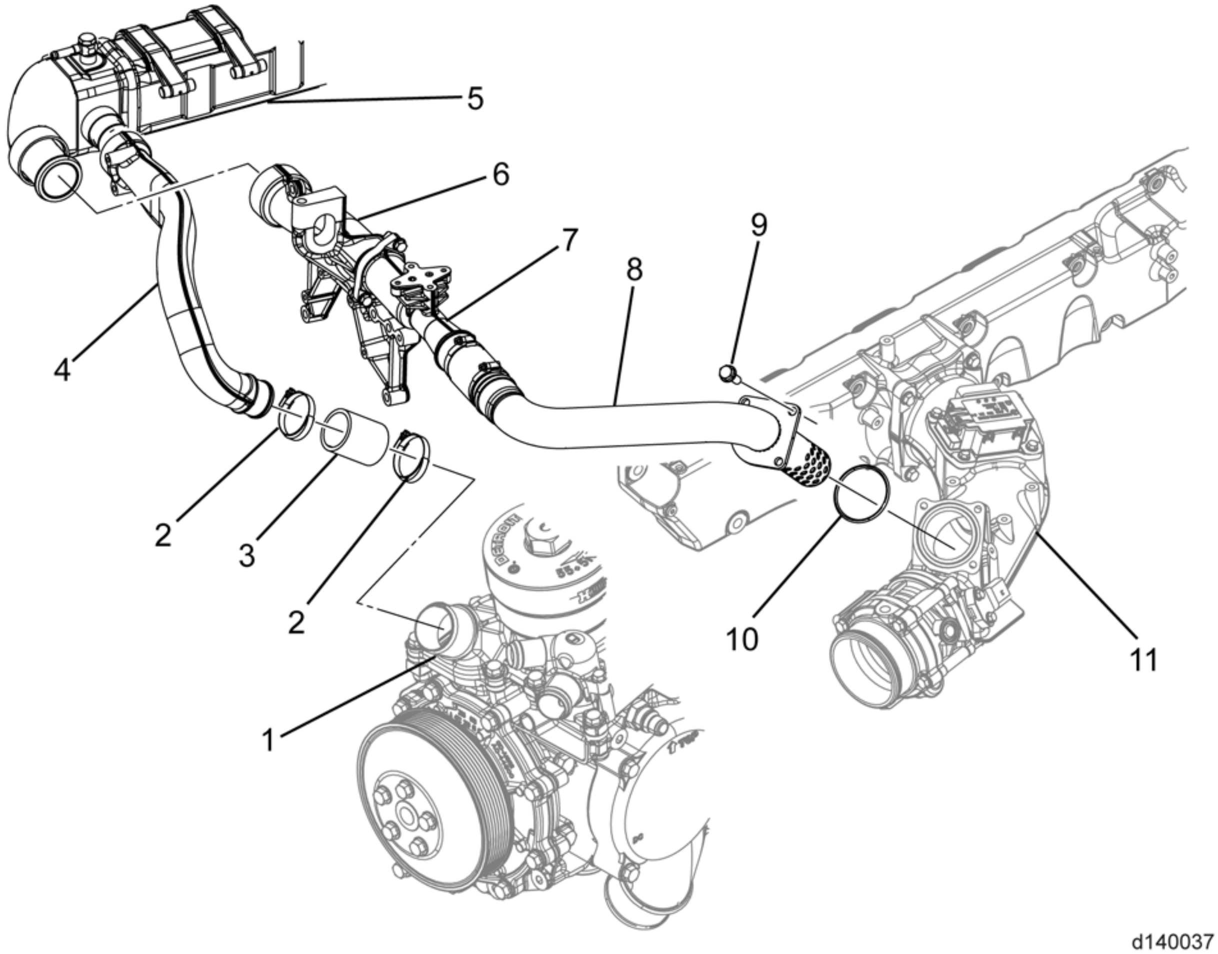
NOTICE:
Ensure the bracket and exhaust manifold are at ambient temperature when the actuator bracket bolts are torqued.

NOTICE:
See Figure 5-2. Items seven (nut) and eight (rod) must remain installed to the actuator linkage when removing or installing number six (nut) to avoid damage to the actuator valve gears

1. Install the actuator bracket to the exhaust manifold using four bolts and eight special thermal washers . Apply a small amount of copper based anti-seize compound to the bolts and torque the bolts for the bracket to exhaust manifold to 30 N·m (22 lb·ft).
2. Install actuator onto bracket using three bolts and washers. Torque bolts to 20 N·m (15 lb·ft).
3. Install linkage onto actuator and secure with one nut. Tighten nut to 25 N·m (18 lb·ft).
4. Install the coolant line to the actuator and fitting on cylinder block. Tighten coolant line to actuator to 25 N·m (18 lb·ft). Tighten coolant line to fitting on cylinder block 40 N·m (29 lb·ft).
5. Install the coolant line to the actuator and water manifold. Tighten coolant line to 35 N·m (26 lb·ft).
6. Connect actuator to engine harness.

5.3 MIXER TUBE

When the EGR valve is open, the exhaust gas is directed into the EGR cooler, through the mixer tube, and into the cold boost pipe. See Figure 5-3.



1. Oil Coolant Module
2. Clamp
3. Hose
4. Coolant Delivery Pipe
5. Exhaust Gas Recirculation Cooler (EGR)
6. Crossover Lifter Tube
7. Venturi
8. Mixer Tube
9. Bolt
10. Seal
11. Cold Boost Pipe

Figure 5-3 Mixer Tube and Related Parts

5.3.1 Removal of Mixer Tube

Removal steps are as follows:

NOTE:
Prior to performing the removal steps, ensure that the mixer tube is not hot.

WARNING:
PERSONAL INJURY
To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

NOTE:
The hose is a one use item.

1. Remove two hose clamps from hose on mixer tube and venturi. Discard the hose.
2. Remove hose and discard hose.
3. Remove three bolts securing mixer tube to cold boost pipe.
4. Remove mixer tube from cold boost pipe.

5.3.1.1 Inspection of Mixer Tube

Inspection steps are as follows:

1. Visually inspect the hose clamps for damage.
   [a] If the hose clamps are damaged, replace as necessary.
   [b] If the hose clamps are not damaged, reuse the component for assembly.
2. Visually inspect the mixer tube for damage.
   [a] If the mixer tube is damaged, replace as necessary.
   [b] If the mixer tube is not damaged, reuse.

5.3.2 Installation of Mixer tube

Installation steps are as follows:

NOTICE:
Before the hose is installed on the mixer tube ensure there are not any sharp edges present that can cut the hose liner.

NOTICE:
If hose clamps have been removed from mixer tube, they must be reinstalled prior to hose installation.

1. Install a new hose on the mixer tube.
2. Insert EGR cooler side of mixer tube hose into venturi and secure with two clamps.
3. Install mixer tube onto cold boost pipe with three bolts. Torque bolts to 30 N·m (22 lb·ft).

5.4 INTAKE THROTTLE VALVE AND ADAPTOR

The electronically actuated intake throttle valve restricts air flow to increase exhaust temperature to aid in particulate regeneration.

The throttle valve actuator is located on the cold boost pipe (charge air pipe) and is actuated by the motor control module (MCM) from a pulse width modulated signal.

The position of the throttle valve and the flow of exhaust gas through the cross-section in the throttle body are altered by the throttle valve actuator.

During regeneration of the diesel particulate filter (DPF), the throttle valve is partly closed by the throttle valve actuator . The air deficiency arising from this leads to an increase in the exhaust gas temperature which is necessary for regeneration of the DPF. To make a diagnosis, the electronics for the throttle valve actuator determines the position of the throttle valve at the MCM.

5.4.1 Removal of Intake Throttle Valve

Remove the intake throttle valve as follows:

1. Remove the clamp from CAC hose and remove hose from adaptor inlet.
2. Remove the four bolts securing adaptor and intake throttle valve to cold boost pipe (charge air pipe).
3. Remove the adaptor, intake throttle valve and two seals. Discard the two seals.

5.4.1.1 Inspection of Adaptor and Intake Throttle Valve

Inspect the intake throttle valve for damage and replace if necessary.

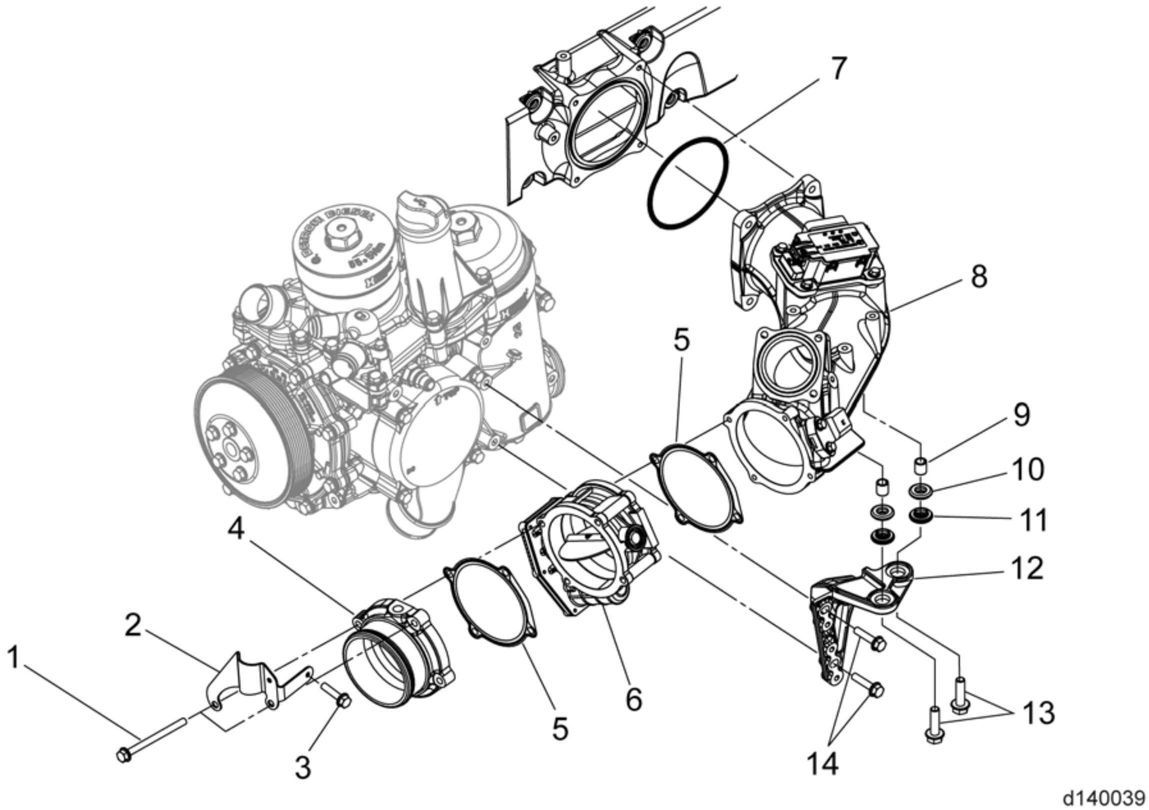
5.4.2 Installation of Adapter and Intake Throttle Valve

Install the adapter and intake throttle valve as follows:

1. Install the adaptor and gasket to the intake throttle valve with four bolts.
2. Install the throttle valve and gasket to the cold boost pipe (charge air pipe) with the four bolts previously installed. for the adaptor. Torque bolts to 30-38 N·m (22-28 lb·ft).

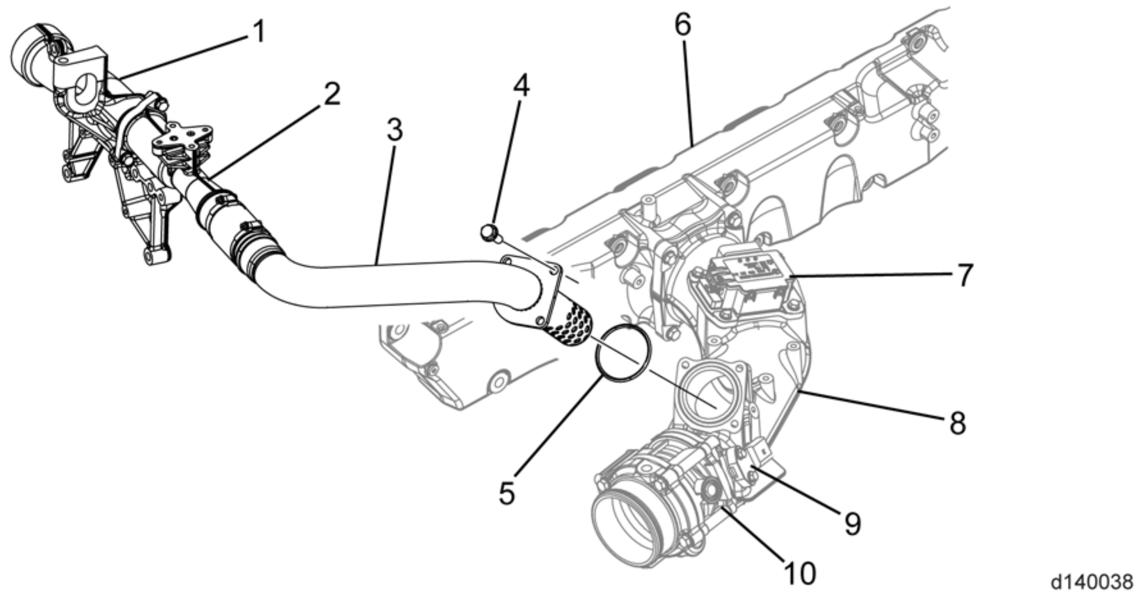
5.5 EXHAUST GAS RECIRCULATION COLD BOOST PIPE (CHARGE AIR PIPE)

The cold boost pipe (Charge Air Pipe) is installed onto the intake manifold and is a component of the EGR System. See Figure 5-5. and 5-4.



1. Bolt	8. Cold Boost Pipe
2. Bracket	9. Spacer
3. Bolt	10. Isolators
4. Adaptor	11. Clamp
5. Gasket	12. Bracket to Oil Coolant Module
6. EGR Throttle Valve	13. Bolt M10 x 35
7. Gasket	14. Bolt M10 x 35

Figure 5-4 Cold Boost Pipe and Related Parts



1. Exhaust Gas Recirculation (EGR) Crossover Tube
2. Venturi
3. Mixer Pipe
4. Bolt
5. Seal Ring
6. Charge Air Housing
7. Grid Heater
8. Cold Boost Pipe
9. Pressure/Temperature Sensor
10. EGR Throttle Valve

Figure 5-5 Cold Boost Pipe and Related Parts

5.5.1 Removal of the Cold Boost Pipe (Charge Air Pipe)

Remove the cold boost pipe (charge air pipe) as follows:

1. Remove mixer tube.
2. Disconnect sensor harness.
3. Remove CAC hose clamp at CAC.
4. Remove the four bolts securing the cold boost pipe to the intake manifold.
5. Remove two bolts at cold boost pipe bracket on oil module.
6. Remove the cold boost pipe.

5.5.1.1 Inspection of Cold Boost Pipe (Charge Air Pipe)

NOTICE:
If the cold boost pipe is damaged on the interior the pipe needs to be replaced.

Inspect the cold boost pipe for cracks, flange damage, blockage and leaks; replace if necessary.

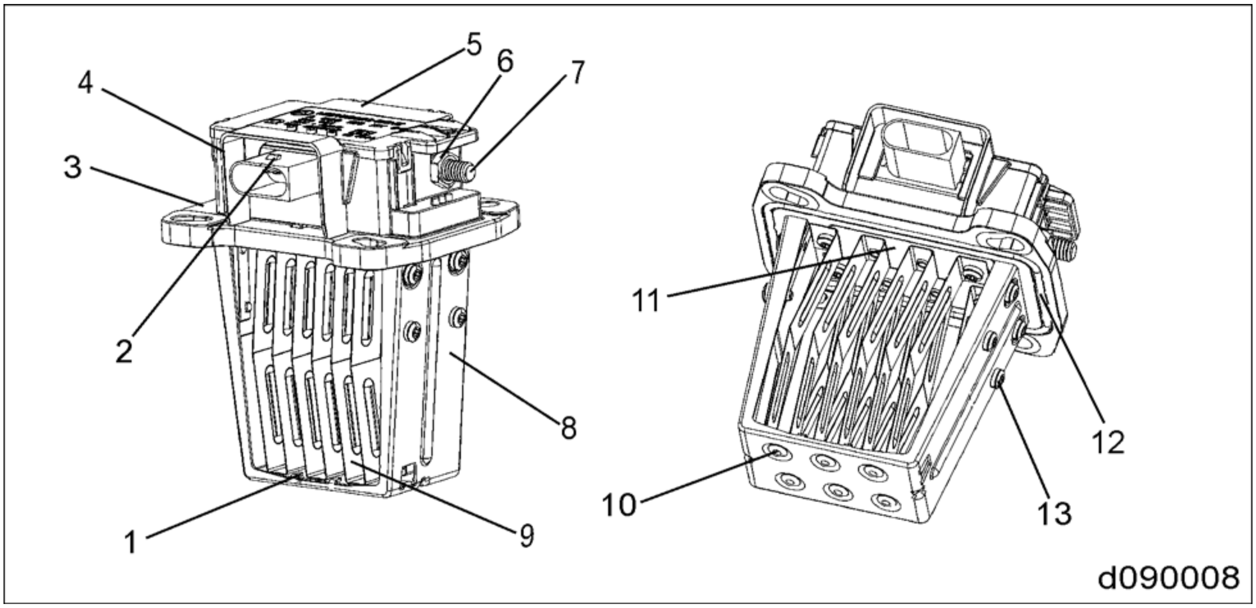
5.5.2 Installation of the Cold Boost Pipe (Charge Air Pipe)

Install the cold boost pipe as follows:

1. Install seal onto intake manifold.
2. Secure cold boost pipe to intake manifold with four bolts. Torque bolts to 30 N·m (22 lb·ft).
3. Attach support bracket to oil module with two bolts.
4. Install EGR mixer tube refer to section 5.3.2.
5. If removed install seal, intake throttle valve and adaptor onto cold boost pipe. Torque four bolts to 30-38 N·m (22-28 lb·ft).
6. Connect the sensor harness.

5.6 GRID HEATER

Senses the temperature from the grid heater and sends a signal to the motor control module (MCM).



1. Isolation Plate
2. Connector
3. Flange
4. Housing
5. Cover
6. Lock Nut
7. Stud Bolt
8. Retaining Frame
9. Heating Coil
10. Rivet
11. Isolation Plate
12. Seal
13. Pan Head Screw

Figure 5-6 Grid Heater and Related Parts

5.6.1 Removal of the Grid Heater

Remove as follows:

1. Disconnect the batteries.
2. Release harness connection from sensor by pulling the gray tab back to unlock and remove harness connection from sensor.
3. Disconnect power and ground wires.
4. Remove four bolts from the sensor securing it to the grid heater and remove.

5.6.2 Installation of the Grid Heater

Install as follows:

1. Install grid heater to cold boost pipe with four bolts tighten bolts.
2. Install harness connector to grid heater sensor and push the gray tab forward to lock the connector onto the sensor.
3. Connect power and ground wires.
4. Connect batteries.

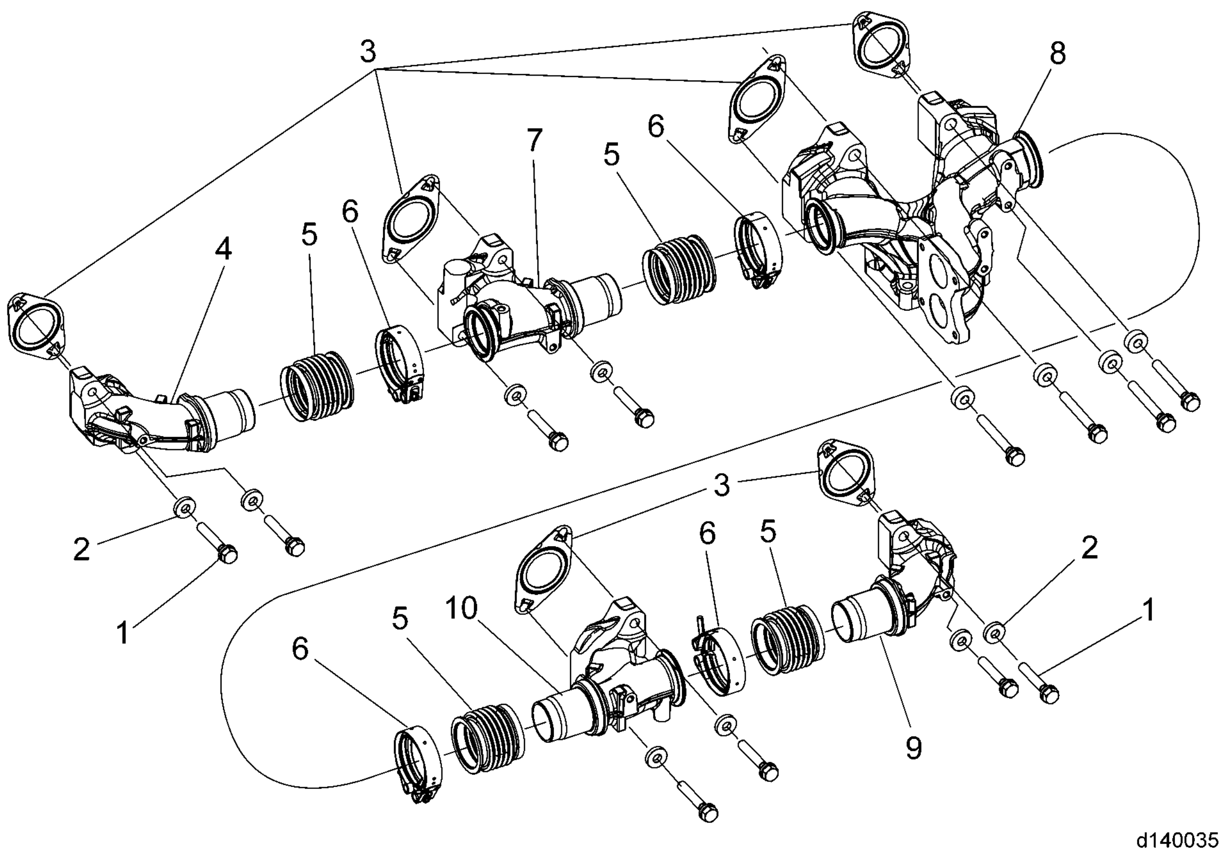
6 EXHAUST SYSTEM

Section **Page**

6.1 EXHAUST MANIFOLD

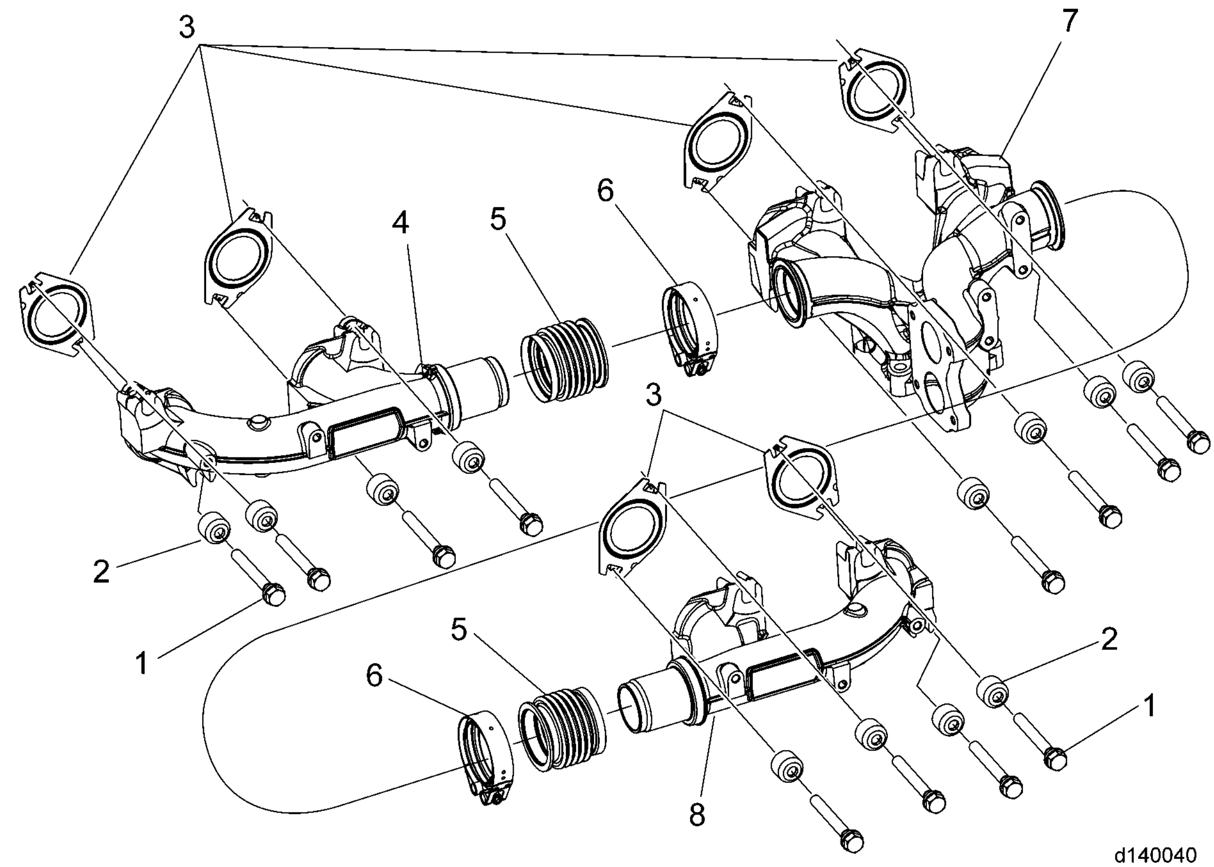
The exhaust manifold is a three piece design utilizing a bellows pipe connecting the front and rear exhaust manifold to the center exhaust manifold.

The exhaust manifold is made of a cast-iron material and has a bellows pipe clamped to each exhaust pipe section. The exhaust manifold is attached to the cylinder head with sixteen special alloy hardened bolts. The exhaust manifold outlet flange is bolted directly to the turbocharger turbine housing. Six gaskets are placed between the exhaust manifold and the cylinder head to prevent exhaust gas leaks. The center exhaust housing has a bellows pipe mounted and clamped to each end.



1. Mounting Bolt (Qty 12)
2. Washer (Qty 12)
3. Gasket (Qty 12)
4. Exhaust Manifold End Piece
5. Bellows
6. Clamp
7. Exhaust Manifold Middle (inner) Piece
8. Exhaust Center Piece
9. Exhaust Manifold End Piece
10. Exhaust Manifold Middle (inner) Piece

Figure 6-1 High Horsepower Exhaust Manifold



1. Mounting Bolt (12 Qty)
2. Washer (12 Qty)
3. Gasket (6 Qty)
4. Exhaust Manifold (Rear Piece)
5. Bellows (2 Qty)
6. Clamp (2 Qty)
7. Exhaust Manifold Center Piece
8. Exhaust Manifold Front Piece

Figure 6-2 Exhaust Manifold

6.1.1 Removal of the Exhaust Manifold

Remove as follows:

1. Drain coolant.
2. Remove the ten bolts from the axial power turbine heat shield and remove heat shield.
3. Remove the exhaust pipe from the exhaust gas recirculation (EGR) cooler and EGR valve.
4. Remove the EGR valve and actuator. Refer to section 5.2.
5. Remove the exhaust manifold heat shields.
6. Remove the turbocharger. Refer to section4.2.
7. Remove the sixteen bolts securing the front, rear and center exhaust housings to the cylinder head and remove exhaust manifolds as an assembly.

8. Remove and discard all exhaust manifold gaskets.

NOTE:
Exhaust manifold gaskets and bolts are not reusable components.

6.1.1.1 Inspection of Assembled Exhaust Manifold

Inspect as follows:

1. Visually inspect the exhaust manifold for cracks.
2. Visually inspect the exhaust manifold for excessive soot.
3. Visually inspect the center exhaust ports for wear and distortion.
4. Visually inspect the bolts; if bolts are stressed, stretched or damaged, replace bolts.
5. If any cracks, excessive soot, exhaust port wear and distortion are present refer to section 6.1.2 for disassembly instructions. If none are present, refer to section 6.1.3 for installation instructions.

6.1.2 Disassembly of the Exhaust Manifold

Disassemble as follows:

1. Remove two clamps from center exhaust manifold. Separate front and rear exhaust manifolds from center exhaust manifold.

6.1.2.1 Inspection of Disassembled Exhaust Manifold

Inspect as follows:

1. Visually inspect the rear exhaust manifold for excessive wear, replace rear exhaust manifold if necessary.
2. Visually inspect the front exhaust manifold for excessive wear, replace front exhaust manifold if necessary.
3. Visually inspect the center exhaust manifold for excessive wear, replace center exhaust manifold if necessary.
4. Visually inspect the bellows for damage; replace manifold assembly if damaged.
5. Visually inspect the studs and nuts on the center housing; replace if necessary.
6. Visually inspect the spacers and clamps; replace if necessary.
7. Clean the exhaust manifold refer to section 6.1.2.2.

6.1.2.2 Cleaning of the Exhaust Manifold

Clean as follows:

1. Remove any loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold and counterbores for the liner used with the inner tubes.
2. Clean the exhaust manifold exterior with a wire brush.

6.1.3 Installation of the Exhaust Manifold

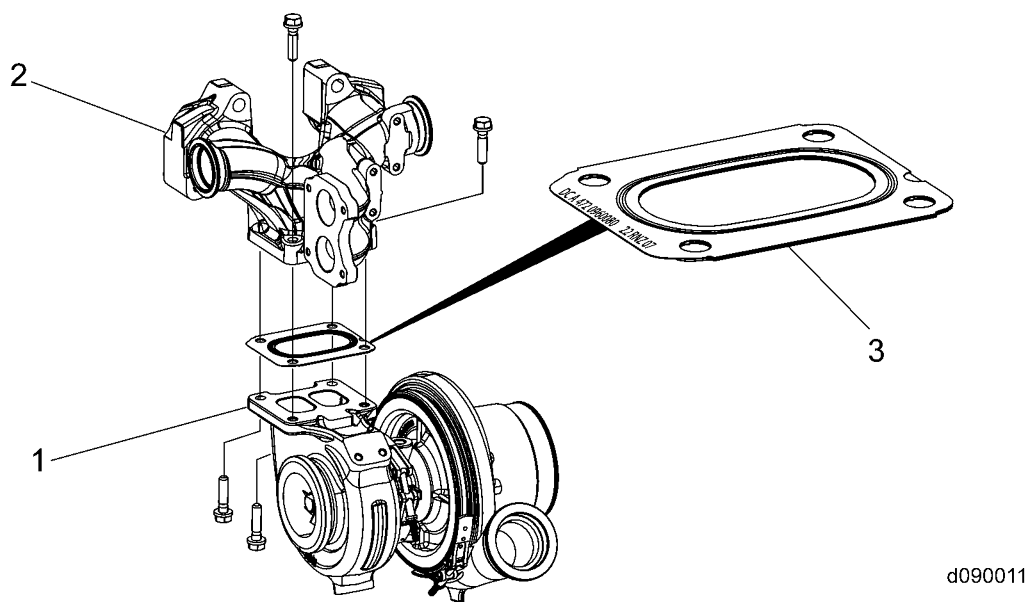
Install as follows:

1. Install the turbocharger. Refer to section 4.2.
2. Install six exhaust manifold guide studs into the cylinder head to hold the six exhaust manifold gaskets in the correct position and facilitate manifold installation.

NOTE:
The exhaust gasket can be positioned either way. Ensure the guide studs and gaskets are positioned correctly for the manifold being installed.

3. Install the exhaust gaskets.

NOTE:
The exhaust manifold gasket between the center housing and turbocharger must be installed with the part number facing up and to the rear of the engine. See Figure 6-3.



1. Turbocharger
2. Exhaust Manifold Center Housing
3. Gasket

Figure 6-3 Exhaust Manifold Center Housing to Turbocharger Gasket Installation

4. Install the gasket between the exhaust manifold center housing and turbocharger.

5. Install the assembled exhaust manifold to the guide studs.

NOTE:
Hand tighten exhaust bolts to avoid bending the bellows pipe.

6. Install mounting bolts. Torque mounting bolts to 20 N·m (15 lb·ft). The bolts should be tightened enough to hold the exhaust manifold assembly in place when the guide studs are removed.
7. Remove the guide studs, making sure the exhaust manifold has not moved.
8. Torque bolts to 40 N·m (29 lb·ft) using the proper tightening sequence.See Figure 6-4.

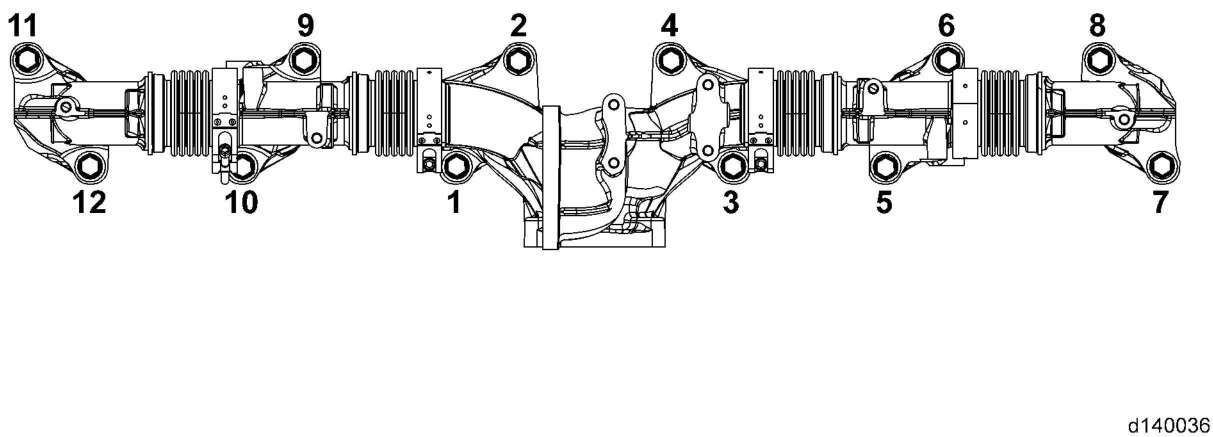


Figure 6-4 Exhaust Manifold Torque Sequence

9. Install the front and rear exhaust manifold heat shields and secure with six bolts.
10. Install the exhaust pipe to the EGR valve and EGR cooler with two clamps.
11. Install EGR valve and actuator. Refer to section 5.2.

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.

12. Install the axial power turbine heat shield with eight bolts.

WARNING:

PERSONAL INJURY

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

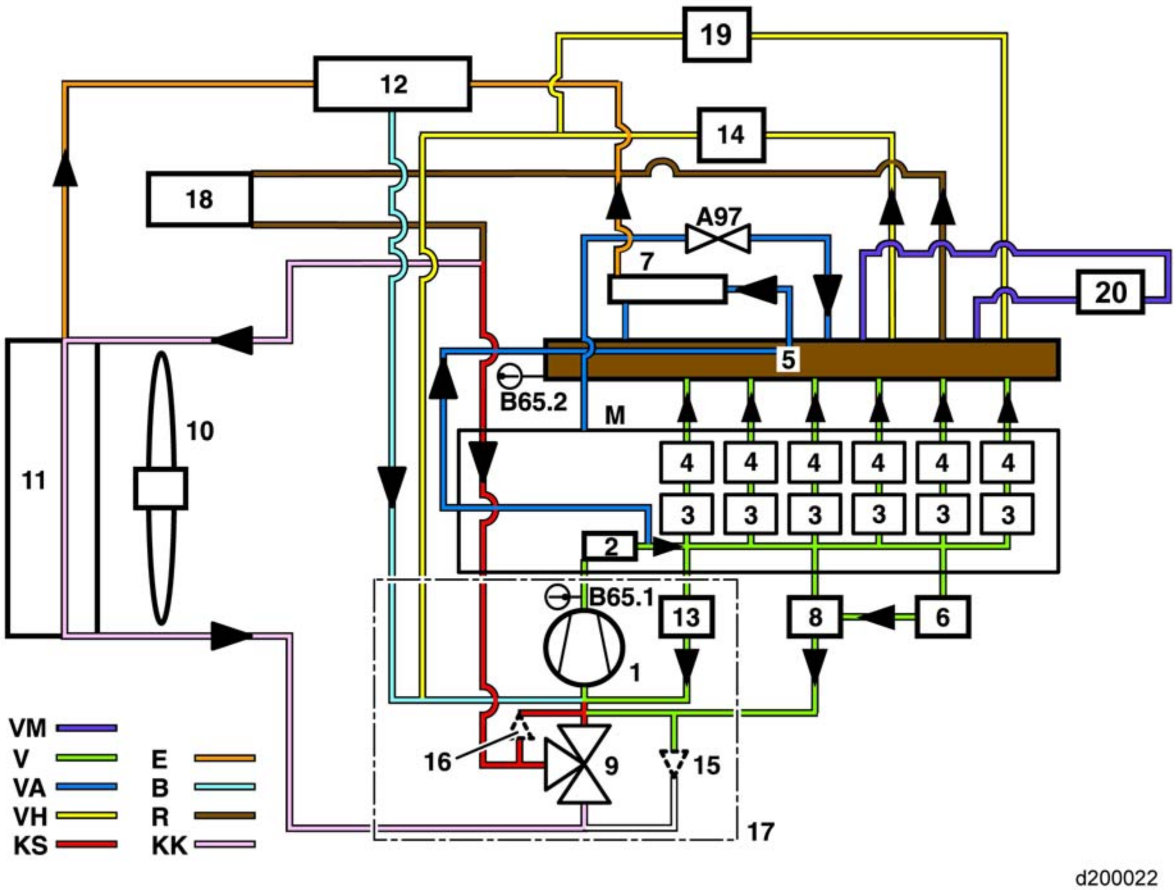
- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

13. Start the engine and check for exhaust leaks.
14. If exhaust gas leaks are detected, contact the Detroit Diesel Customer Support Center for further information (313–592–5800).

7 COOLING SYSTEM

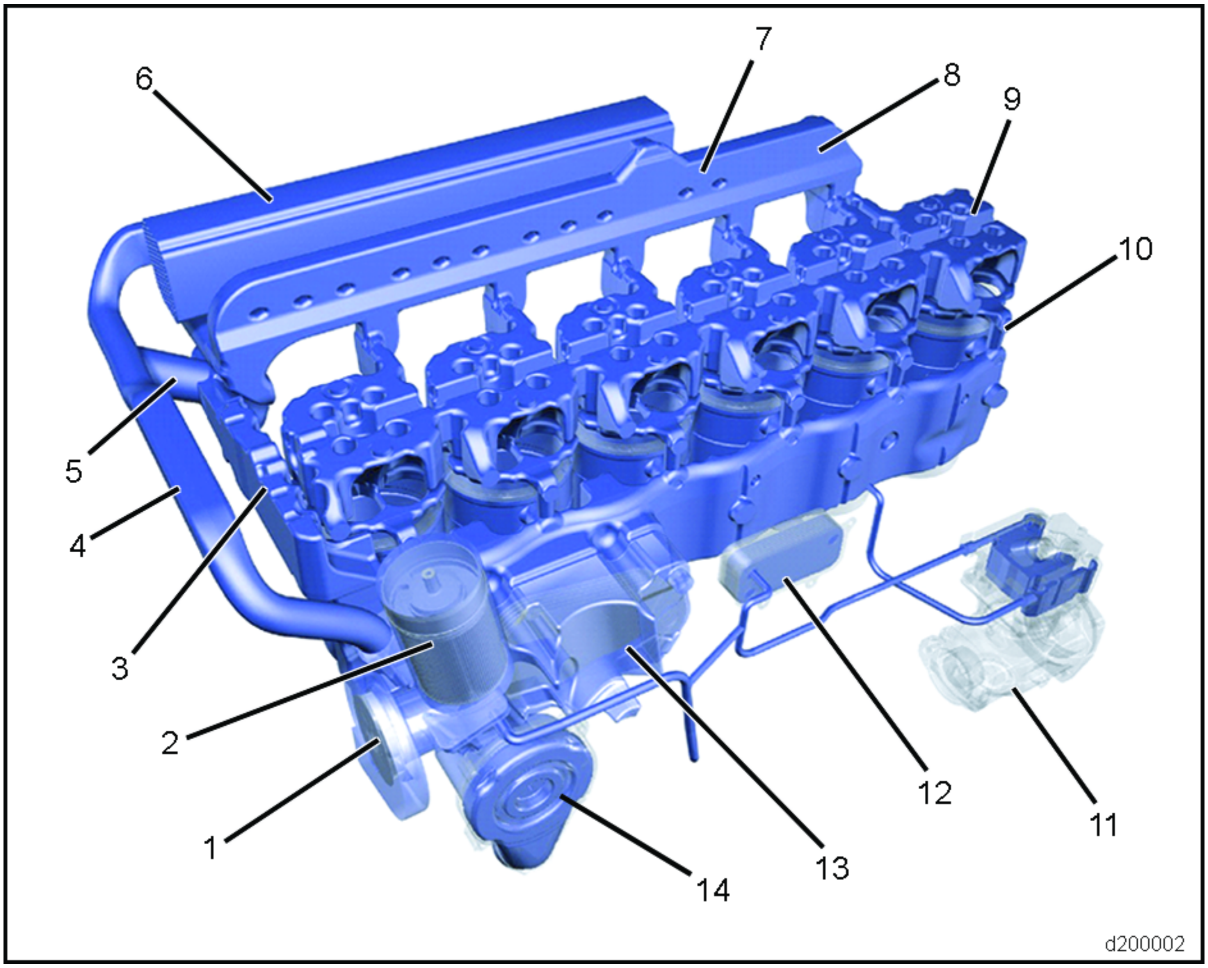
7.1 OVERVIEW OF THE COOLING SYSTEM

A schematic of the cooling system in the following illustration shows the coolant flow to the engine components.



1. Coolant Pump	10. Fan	19. Heat Exchanger	M. Engine
2. Oil Cooler	11. Radiator	20. Doser	R. Auto Trans Cooler Flow
3. Crankcase	12. Reservoir	A97. EGR Actuator	V. Coolant Feed
4.Cyl Head	13. Coolant Filter	B65. 1 Inlet Temp Sensor	VA.Clt EGR to Clr Actuator
5. Manifold	14. Heat Exchanger	B65. 2 Outlet Temp Sensor	VH. Clt Heat Exchanger
6. Compressor	15. Filling Valve	B. Coolant Fill Line	VM. Clt to Doser
7. EGR Cooler	16. Pressure Control Vlv	E. De-airation	
8. Fuel Cooler	17. Oil/Coolant Module	KK. Radiator Circuit	
9. Thermostat	18. Trans Cooler	KS. Bypass Line	

Figure 7-1 Cooling System



1. Water Pump
2. Coolant Filter
3. Short Circuit Line
4. Coolant Return Flow
5. Coolant Outlet to Cooler Circuit
6. Exhaust Gas Recirculation Cooler
7. Coolant Return Flow
8. Water Manifold
9. Cylinder Head
10. Cylinder Block
11. Air Compressor
12. Fuel Cooler
13. Oil/Water Heat Exchanger
14. Thermostat

Figure 7-2 Cooling System Components

7.2 THERMOSTAT

The coolant thermostat is located on the left side of the engine on the oil coolant module. The coolant thermostat regulates the coolant inlet temperature in a range from 88°C (190° F) to 95°C. (203°F)

The coolant thermostat consists of a thermostat with an integral thermostat. The coolant thermostat regulates the flow of coolant through the engine radiator and the temperature of the coolant in the coolant circuit.

The following benefits result from regulating the coolant at the inlet temperature of the engine:

- Reduced thermal cycling of the engine
- Operating temperature is reached faster
- Emissions are reduced
- Improved vehicle heating

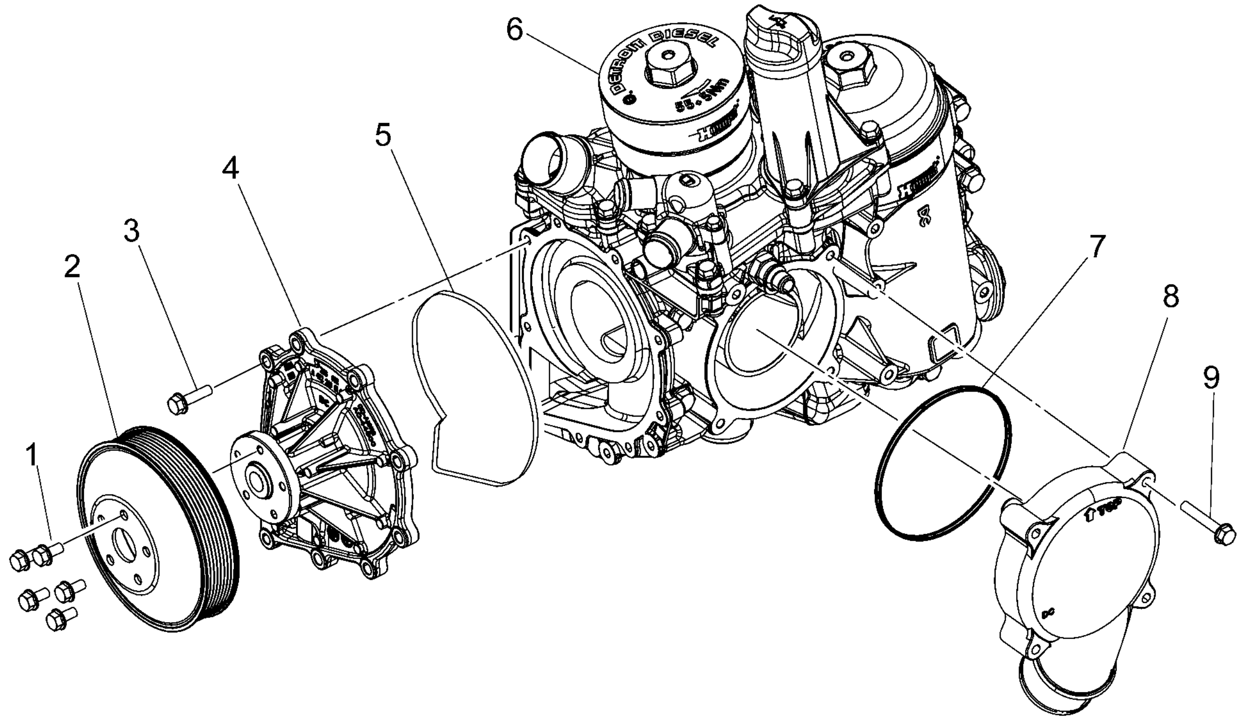
Operating statuses

The coolant from the radiator and the radiator bypass mix in the thermostat. The thermostat regulates the temperature of this mixed flow.

Three different operating conditions occur due to the coolant mixed flow temperature:

- **Bypass mode:** When the coolant mixed flow temperature is <88°C (190°F) the circulating thermostat is closed. The coolant circulates through the radiator bypass to the coolant thermostat . None of the flow passes through the radiator.
- **Mixed mode:** For a coolant mixed flow temperature of >88°C (190°F) to <95°C (203°F) the circulating thermostat opens partially and the coolant flows at the same time through the engine radiator and the radiator bypass to the coolant thermostat .
- **Radiator operation:** When the coolant inlet temperature >95°C (203°F) the circulating thermostat is completely open. The coolant flows through the radiator to the coolant thermostat. None of the flow passes through the radiator bypass.

Other minor coolant loops exist in addition to those described above. The flow through these loops are unaffected by the position of the coolant thermostat. These loops include the flow through the vehicle cab heater, vehicle bunk heater, the EGR actuator, and the doser.



1. Pulley to Water Pump Screw
2. Water Pump Pulley
3. Bolt
4. Water Pump
5. Seal
6. Oil Coolant Module
7. Seal
8. Thermostat
9. Bolt

Figure 7-3 Thermostat and Related Parts

7.2.1 Removal of Thermostat

Remove 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 cooling system so that the coolant is below the thermostat level. Remove the plug on the cylinder block below the oil coolant module to drain the remaining coolant from the oil coolant module.
2. Loosen hose clamp at the thermostat.
3. Remove the four thermostat housing-to-oil cooler module attaching bolts.
4. Remove the thermostat housing assembly from the oil coolant module and hose.
5. Remove and discard the thermostat housing seal.

7.2.1.1 Inspection of Thermostat

Inspect thermostat as follows:

1. Visually inspect all parts for wear or damage.
   [a] If wear or damage is found, replace parts.
   [b] If wear or damage is not found, reuse parts.
2. Visually inspect thermostat body seal for damage, cracks or nicks.
   [a] If any damage is noted, replace seal.
   [b] If no damage is found, reuse parts.

7.2.2 Installation of Thermostat and Seal

Install as follows:

1. Install new seal onto thermostat housing.
2. Install thermostat into hose and onto oil cooler module.
3. Torque four bolts to 30 N·m (22 ft·lb).
4. Tighten clamp at the hose.
5. Fill engine with coolant to the correct level.

WARNING:

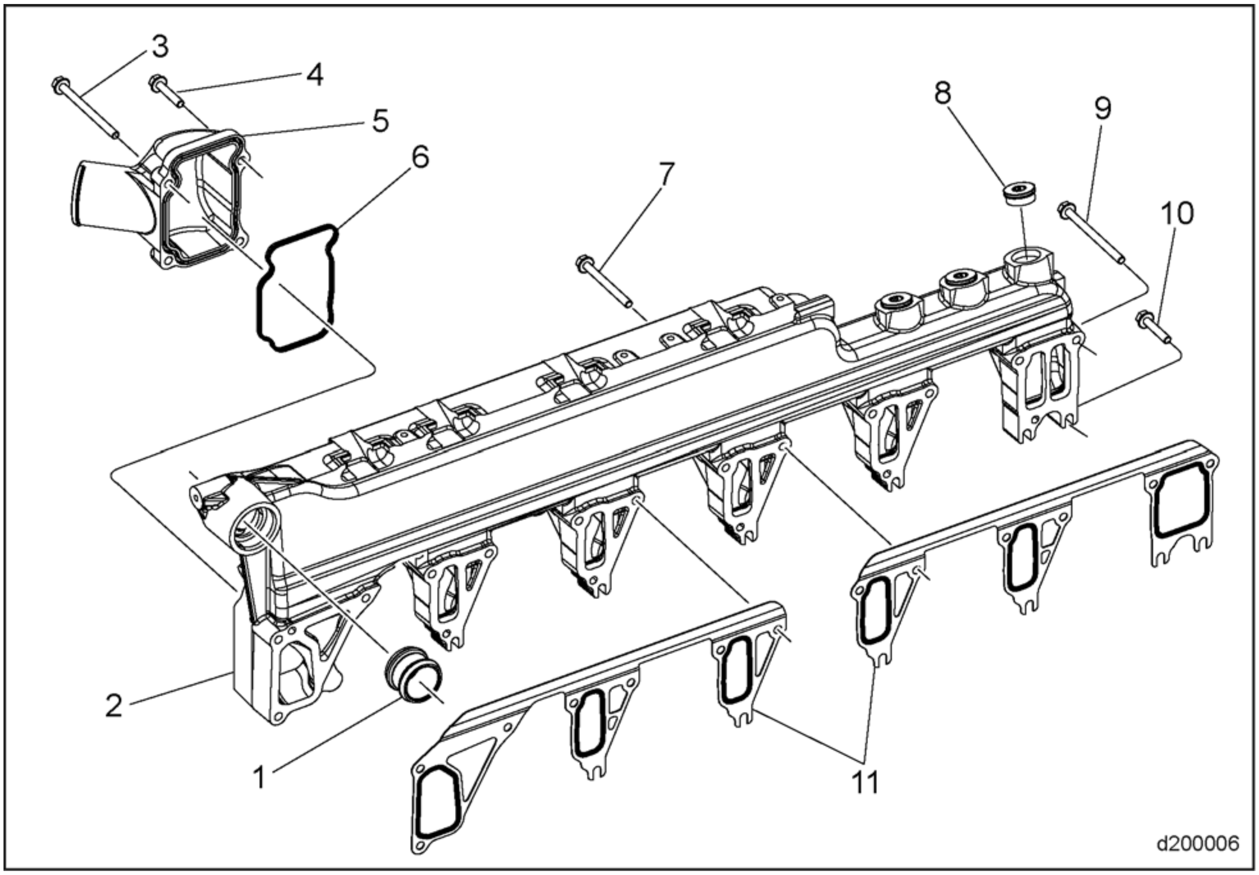
ENGINE EXHAUST

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.

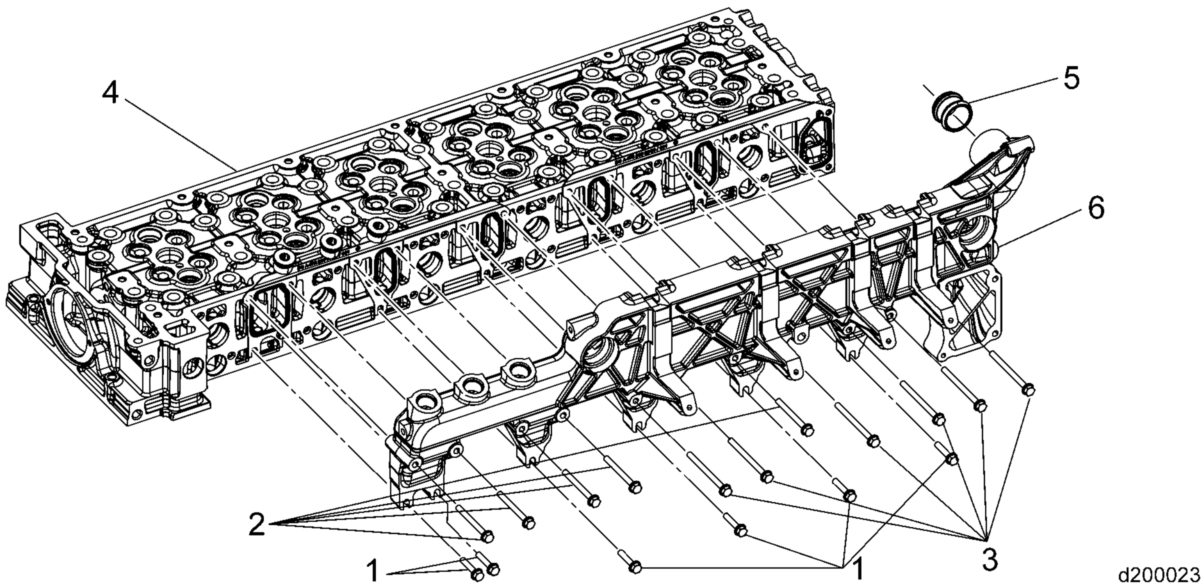
7.3 WATER MANIFOLD

Coolant flows from the cylinder head through an opening directly over exhaust port, enters the water manifold, which is attached to the cylinder head by a total of seventeen bolts including two that are shared with the coolant outlet connector. Two three port gaskets are used between the manifold and cylinder head.



1. Connecting Pipe
2. Water Manifold
3. Screw
4. Screw
5. Coolant Fitting
6. Gasket
7. Bolt
8.Plugt
9. Bolt
10. Bolt
11. Gasket

Figure 7-4 Water Manifold and Related Parts



1. Bolt M8 x 40 (6 qty)
2. Bolt M8 x 80 (5 qty)
3. Bolt M8 x 100 (6 qty)
4. Cylinder Head
5. Insert
6. Water Manifold

Figure 7-5 Water Manifold and Related Parts

7.3.1 Removal of the Water Manifold

Remove as follows:

1. Disconnect the batteries.
2. Drain the engine coolant.
3. Remove the air cleaner.
4. Remove the heat shields.
5. Remove the exhaust gas recirculation (EGR) pipe.
6. Disconnect Doser coolant lines.
7. Disconnect EGR cooler vent line.
8. Disconnect coolant temperature sensor outlet.
9. Remove EGR actuator coolant outlet line.
10. Remove upper radiator hose.
11. Remove coolant outlet elbow four bolts.
12. Remove eleven upper water manifold bolts.
13. Loosen six lower water manifold bolts.

14. Remove EGR cooler.
15. Remove water manifold.
16. Remove gaskets and discard gaskets.

7.3.1.1 Inspection and Cleaning of the Water Manifold

Clean and Inspect as follows:

1. Clean the water manifold.
2. Inspect the water manifold for damage or cracks; replace if necessary.

7.3.2 Installation of the Water Manifold

Install as follows:

NOTICE:
Ensure when installing item 1 connecting pipe is lubricated with clean oil; see Figure 7-4 ; if it is not lubricated the connecting tube cannot be fully installed and the rubber can be cut.

NOTICE:
Do not use sealant when installing water manifold to the cylinder head.

1. Install water manifold gaskets onto dowels on cylinder head.
2. Install water manifold onto gaskets and cylinder head.
3. Install six lower water manifold bolts.
4. Install eleven upper water manifold bolts. See Figure 7-6.

5. Torque the water manifolds bolts to 30 N·m 30 (22 lb·ft). See Figure 7-6.

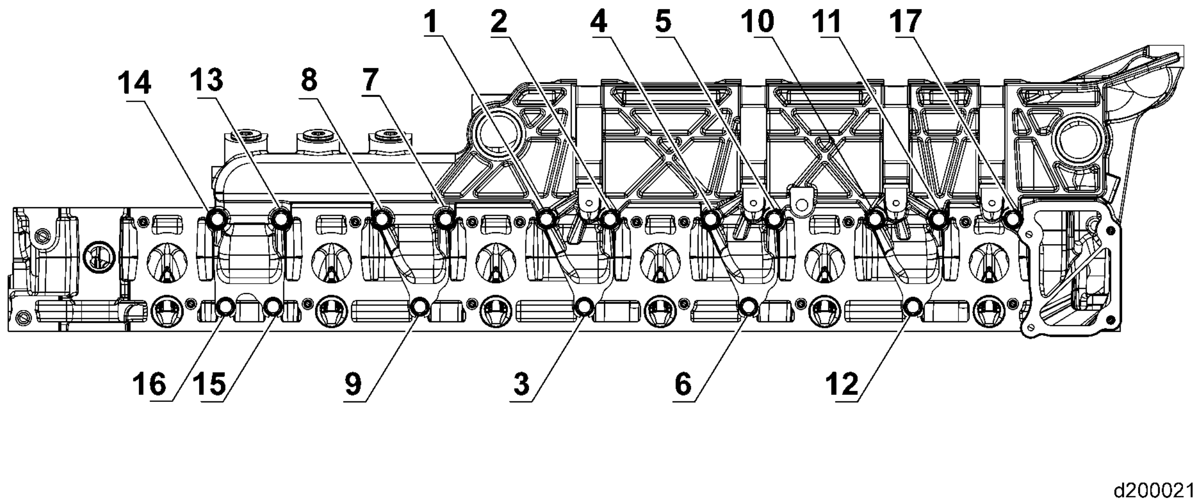


Figure 7-6 Water Manifold Torque Sequence

6. Install EGR cooler to water manifold.
7. Install coolant outlet elbow with four bolts.
8. Install upper radiator hose.
9. Install EGR actuator coolant outlet line.
10. Connect the coolant temperature sensor outlet.
11. Connect the EGR cooler vent line.
12. Connect Doser coolant lines.
13. Install the exhaust gas recirculation (EGR) pipe.
14. Install the heat shields.
15. Install the air cleaner.
16. Fill the coolant system.
17. Connect the batteries.

WARNING:

ENGINE EXHAUST

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

18. Start the engine and check for leaks.

7.4 WATER PUMP

The water pump is located on the left side of the engine; mounted on the front of the oil coolant module. The water pump circulates the coolant in the cooling circuit.

The water pump pulley is mounted to the water pump with five bolts .The water pump is driven by the poly-V-belt that is installed onto the water pump pulley. The rotary motion of the pulley is transmitted by the hub to the shaft . The shaft drives the impeller which causes the coolant to circulate in the coolant circuit.

The water pump has a large leakage reservoir in the aluminum housing which will contain minor water pump leaks.

7.4.1 Removal of the Water Pump

Remove as follows:

1. Drain the coolant.
2. Disconnect the batteries.
3. Loosen the five bolts securing the water pump pulley to the water pump.
4. Lock the belt tension device in the loose position and remove the accessory belt.
5. Remove the five bolts securing the coolant pulley to the water pump; and remove pulley from water pump.
6. Remove nine bolts from the water pump and remove from the oil coolant module.

7.4.1.1 Inspection of the Water Pump

Inspect as follows:

1. Inspect the poly-V-belt for damage or wear; replace if necessary;
2. Inspect the water pump pulley for damage and replace if necessary.
3. Inspect the water pump for damage and replace if necessary.

7.4.2 Installation of the Water Pump

Install as follows:

1. Install a new gasket to the water pump.
2. Install the water pump to the oil coolant module with nine bolts and torque to 30 N·m (22 lb·ft).
3. Install the water pump pulley to the water pump with five bolts finger tighten and install belt. Torque the bolts to 25 N·m (18 lb·ft).
4. Fill the coolant system.
5. Reconnect the batteries.

WARNING:

ENGINE EXHAUST

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

6. Start the engine and inspect for leaks.

8 FUEL LUBRICATING OIL AND COOLANT

Section **Page**

8.1 FUEL

The quality of fuel used is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels. The DD15 engine was designed to operate on most diesel fuels marketed today. In general, fuels meeting the properties of ASTM Designation D 975 (Grades 1–D and 2–D) have provided satisfactory performance. The ASTM D 975 specification, however, does not in itself adequately define the fuel characteristics necessary to assure fuel quality. Reference the Lubricating Oil, Fuel, and Filters publication 7SE270. This publication will provide information for optimum engine performance.

NOTICE:
Use only Ultra-Low Sulfur Diesel (ULSD) fuel (15 ppm sulfur content maxium), based on ASTM D2622 test procedure. Using fuel other than USLD will damage the Aftertreatment Device.

8.1.1 Fuel Lubricity

Fuels such as those containing kerosene and jet fuel and some low sulfur fuels have characteristics which cause operational concerns in the engine.

8.1.2 BIODIESEL FUELS

Biodiesel fuels are alkyl esters of long chain fatty acids derived from renewable resources. Detroit Diesel Corporation 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 DDC. Biodiesel fuels meeting ASTM D 6751 specification, prior to blending can be mixed up to 5% maximum by volume in petroleum diesel fuel. The resulting mixture must meet ASTM D 975 specification. 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 DDC's responsibility

8.1.3 Other Fuels

Lower density fuels, such as those found in the Lubricating Oil, Fuel, and Filters publication 7SE270 and "winter blended" diesel fuels, have a lower volumetric heat content than the standard 2-D fuel found in the Lubricating Oil, Fuel, and Filters publication 7SE270. Operating with these fuels will result in reduced engine output and reduced fuel mileage, compared to standard 2-D fuel. Reductions of 5% are not unusual and may be as high as 10%. A good rule of thumb is: The engine power is proportional to the heating value of the fuel.

Lower density fuels also tend to have lower viscosity and poor lubrication characteristics.

8.1.4 Fuel Cleanliness

Fuel should be clean and free of contamination. Storage tanks and stored fuel should be inspected regularly for dirt, water, or water-emulsion sludge, and cleaned if contaminated. Storage instability of the fuel can lead to the formation of varnish or sludge in the tank. The presence of these contaminants from storage instability must be resolved with the fuel supplier. If fuel is stored on site, the following is recommended:

NOTICE:
Do not use a fuel storage tank or lines made from galvanized steel. The fuel will react chemically with the galvanized coating to form powdery flakes that will quickly clog fuel filters and cause damage to the fuel pump and injectors.

- Keep the storage tank filler cap covered to prevent contamination by rain water.
- Keep the tank clean, especially around the filler cap and tap areas.
- Position the tank so that it tilts slightly toward the bottom drain. This will make it easier to drain accumulated water and sediment. Drain water off the bottom monthly
- Minimize condensation by keeping the tank reasonably filled at all times.
- After filling the fuel storage tank, wait a few hours before filling equipment tanks. This will allow contaminants to settle.

8.1.5 Cold Weather Operation

In cold weather, diesel fuel will form wax crystals that can restrict flow and clog filters. Fuel suppliers approach this problem several ways. Some blend 1–D and 2–D while others may use flow improving additives or winter blends. Good indicators of a fuel's low temperature operability are cloud point by ASTM D 2500 and cold filter plugging point by ASTM D 6371.

8.1.6 Prohibited Fuel Additives

Used Lubricating Oil: Detroit Diesel specifically prohibits the use of drained lubricating oil in diesel fuel. Used lubricating oil contains combustion acids and particulate materials which erode injector components, resulting in loss of power and increased exhaust emissions. In addition, the use of drained lubricating oil will increase maintenance requirements due to filter plugging and combustion deposits.

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

The addition of gasoline or ethanol to diesel fuel will create a serious fire hazard. The presence of gasoline in diesel fuel will reduce fuel cetane number and increase combustion temperatures. Tanks which contain such mixtures should be drained and cleaned as soon as possible.

8.1.7 Waste Oil Disposal and Re-refined Oils

With over one billion gallons of waste oil generated annually in the U.S. alone, disposal of waste oil has become a serious environmental concern. Re-refining waste oils provides an environmentally viable way of handling this material. Detroit Diesel favors the recycling of waste oil and permits the use of re-refined oils in all engine product lines, provided the re-refined oil meets the SAE Viscosity and API specifications previously mentioned.

WARNING:

FIRE

To avoid injury from combustion of heated lubricating-oil vapors, stop the engine immediately if an oil leak is detected.

WARNING:

FIRE

To avoid injury from fire, do not smoke or allow open flames when working on an operating engine.

WARNING:

FIRE

To avoid injury from fire from a buildup of volatile vapors, keep the engine area well ventilated during operation.

Consideration for the disposal of waste oil should begin when negotiating the purchase of new oil. Oil supplier selection criteria should include a proposal for handling waste oil. It is important to know exactly how the oil will be disposed of since it is the generator, not the hauler, that is ultimately responsible for its proper disposal.

8.2 LUBRICATING OIL

The selection of the proper lubricating oil is important for achieving the long and trouble-free service Detroit Diesel DD15 engines are designed to provide.

Labeling grades and classification of today's oil may not be sufficient as a method of lubricant selection. The proper lubricating oil was established based on Detroit Diesel 93K218 approved criteria. The current API Service Category CJ-4 forms the core of the 93K12 specification. However, additional requirements are added to the specification to assure adequate lubrication performance for newer emission controlled engines. Detroit Diesel works through API, Engine Manufacturers Association (EMA) and other trade organizations to develop quality oil which meets Detroit Diesel's requirements.

8.2.1 Lubricant Requirement

Lubricants meeting these Detroit Diesel recommended lubricant criteria have provided maximum engine life when used in conjunction with recommended oil drain and filter maintenance schedules. For the API symbol for this, see Figure 8-1.

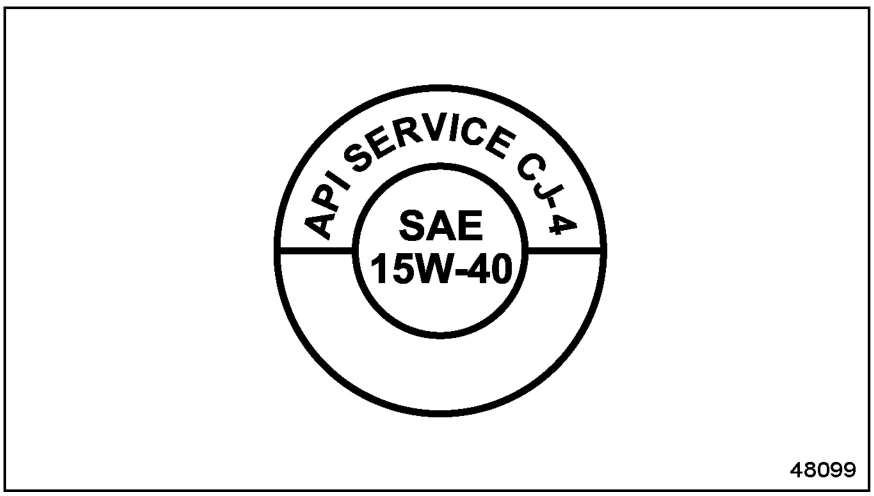


Figure 8-1 API Symbol

Lubricants meeting these criteria have provided maximum engine life when used in conjunction with specified oil drain and filter maintenance schedules. Only oils licensed by API may be used. Lubricants meeting API Service category CJ-4 are intended for use primarily with ultra low (15 ppm) sulfur fuel and may be used primarily in DD15 engines.

At ambient temperatures below -20°C (-4°F) when sufficient starter speed cannot be achieved with SAE 15W-40 oils, the use of 5W-XX oils, where XX is 30 or 40, may be used to improve startability provided they are DDC 93K218 approved and have demonstrated field performance in DDC engines. These oils must possess a HT/HS of 3.7 minimum.

8.2.2 Oil and Filter Change Intervals

The length of time an engine may operate before changing the oil and filter depends on the lubricant and fuel used, engine oil consumption, and operating cycle. The maximum interval the engine may operate before changing the oil and filter is listed in Table 8-1. Oil analysis may be used to determine whether this interval should be shorter, but should not be used to lengthen the interval.

Maintenance Item	Long Haul	Short Haul	Severe Duty
Engine Oil and Filter Change†	50,000 miles (80,000 km)	40,000 miles (64,000 km)	30,000 miles (48,000 km)

†Refer to publication “Lubricating Oil, Fuel, and Filters”, form 7SE270, available from authorized Detroit Diesel distributors.

Table 8-1 Maximum Oil Drain and Filter Change Intervals for DD15 Engine On-Highway Truck Applications using PGOS 93K218 Approved Oils with ULSD Fuel

Extending Oil Drain Intervals: Some oil companies may promote engine lubricants with a claimed useful life that would allow customers following certain maintenance and operating parameters to elect to extend oil drain intervals beyond the recommended periods. The ability of such lubricants to maintain their protective qualities over a longer period and the acceptability of maintenance and operating parameters must be established by the oil company and the customer. Claims for engine failure attributable to the inadequacy of the lubricant are not covered under the terms of the engine's limited warranty.

8.2.3 Statement of Policy on Supplemental Fuel and Lubricant Additives

The DD15 engine will operate satisfactorily on the commercial fuels and lubricants of good quality regularly provided by the petroleum industry through retail outlets.

Supplementary additives include all products marketed as fuel conditioner, smoke suppressants, masking agents, deodorants, tune-up compounds, top oils, break-in oils, graphitizers, and friction-reducing compounds. The regular and continued use of supplementary additives in fuels and lubricants is not recommended.

NOTE:
Detroit Diesel is not responsible for the cost of maintenance or repairs due to lack of required maintenance services performed or the failure to use fuel, oil, lubricants and coolant meeting Detroit Diesel -recommended specifications. Performance of required maintenance and use of proper fuel, oil, lubricants and coolant are the responsibility of the owner. See the OEM's guidelines for details.

8.2.4 Oil and Filter Selection

For oil and fuel filter part number information, refer to the DD15 engine Operators Guide (DDC-SVC-MAN-0003) and Lubricating Oil, Fuel and Filters Technicians Guide (7SE270).

8.2.5 Used Lubricating Oil Analysis Guidelines

These values indicate the need for an immediate oil change, but do not necessarily indicate internal engine problems requiring engine tear down. Characteristics relating to lubricating oil dilution should trigger corrective action to identify and find the source(s) of leaks, if the values listed in Table 8-2 are realized. Contact your DDC distributor or dealer regarding oil analysis services.

Characteristics	ASTM or Other Methods	Conditions Measured	Four-Stroke Cycle Engine Series
			DD15
Viscosity	D 445 DIN 51562	Engine & Oil	—
Kv100 °C, cSt., Min.	—	—	12.5 SAE 15W-40
Kv100 °C, cSt., Max.	—	—	21.9 SAE 15W-40
Soot, % Max.	E1131(TGA)†	Engine Combustion	4.5 (4.5)*
Pentane Insolubles, Max.	D 893 DIN 51565	Engine Combustion	1.0 (N/A)*
Total Base Number, Min.	D 4739	Oil	1/3 New Oil
Total Base Number, Min.	D 2896 ISO 3771		1/3 New Oil
Glycol, Max.	D 2982 DIN 51375	Engine	Negative
Water, Max.	D 1744	Engine	0.3%
Fuel Dilution, Max.	D 3524	Engine	7.1%
Iron, Max. §	D 5185	Engine Wear	200
Copper, Max. §	D 5185	Engine Wear	50
Lead, Max. §	D 5185	Engine Wear	10

* With API CJ-4 / CI-4 Plus Oil, 93K218 approved list

† Infrared spectroscopy (ASTM E168/DIN 51452)may also be used, provided it is calibrated to be equivalent to the TGA method.

The DD15 is a lead free engine. No meaningful amount of lead should be found in the oil.

D5185 Engine 100, d5188 Engine 150

§ These are general limits. Wear metal limits must be determined for specific application and oil used.

Table 8-2 Single Sample Used Oil Analysis Warning Limits

8.3 COOLANT

The coolant provides a medium for heat transfer and controls the internal temperature of the engine during operation. In an engine having proper coolant flow, some of the heat of combustion is conveyed through the cylinder walls and the cylinder head into the coolant. Without adequate coolant, normal heat transfer cannot take place within the engine, and engine temperature rapidly rises. Therefore, coolant must be carefully selected and properly maintained.

The following terms are used throughout this section and must be understood.

- Coolant - The fluid mixture circulating in the engine cooling system.
- IEG - Full strength (non-diluted) Inhibited Ethylene Glycol meeting applicable heavy-duty formulation specifications.
- IPG - Full strength (non-diluted) Inhibited Propylene Glycol meeting applicable heavy-duty formulation specifications.
- SCA - Supplemental Coolant Additives. Used to prevent corrosion, cavitation, and the formation of deposits.
- Initial fill - Any time the cooling system is empty, then filled with new coolant.
- Precharged IEG - Also referred to as a fully formulated IEG. Contains the proper amount of SCA. Additional SCA must not be used with a precharged IEG at initial fill.
- Precharged IPG - Also referred to as a fully formulated IPG. Contains the proper amount of SCA. Additional SCA must not be used with a precharged IPG at initial fill.
- Dropout - Sludge or deposit formation in or on cooling system components.

Using a coolant with the appropriate concentrations of SCA is one of the most important aspects of quality engine maintenance. To achieve the chemical balance needed to protect a cooling system, certain coolant basics must be understood.

This section provides the directions and information required to ensure cooling system protection for DD15 engines. These recommendations are general rules and reflect the current technology. Specific concerns not covered should be addressed to your local Detroit Diesel representative.

The coolant used in DD15 engines must meet the following basic requirements:

- Provide an adequate heat transfer medium.
- Protect against cavitation damage.
- Provide a corrosion/erosion-resistant environment.
- Prevent formation of scale or sludge deposits.
- Be compatible with cooling system components.
- Provide adequate freeze and boil protection.

A properly maintained coolant can be used up to the intervals listed in Table 8-14. At this time the cooling system must be drained, thoroughly cleaned and filled with approved coolant.

To achieve these requirements, coolants are mixtures of good quality water, SCA and often an IEG or IPG for freeze protection. The rest of this bulletin will describe the requirements and usage of the water, SCA, IEG, and IPG.

8.3.1 Water

Water is the best practical medium for heat transfer. However, water alone can cause corrosion and inherently contains minerals that can produce scale deposits on internal cooling system surfaces. Chlorides, sulfates, magnesium, and calcium dissolved in the water can cause scale deposits, and/or corrosion.

Distilled or deionized water is preferred to minimize the adverse effects of minerals in water are listed in Table 8-3. The maximum allowable limits for minerals in water are see Figure 8-2

Mineral	Limit - ppm	Limit - grains per gallon
Chlorides	40	2.5
Sulfates	100	5.8
Total dissolved solids	340	20
Total Hardness: Magnesium & Calcium	170	10

Table 8-3 Maximum Allowable Limits for Minerals in Water

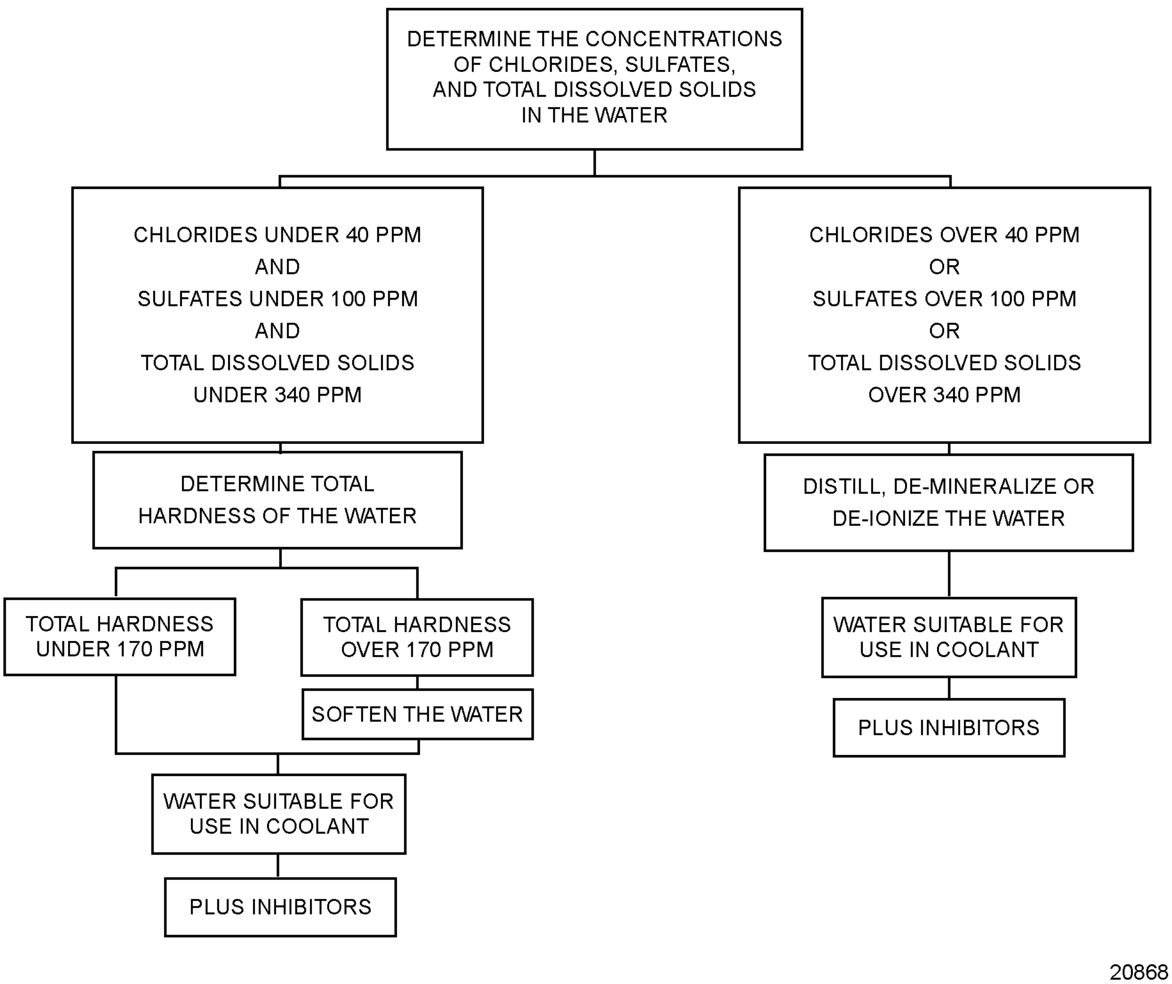


Figure 8-2 Water Evaluation Procedure

8.3.1.1 Antifreeze, Inhibited Ethylene Glycol

Ethylene glycol is used for freeze and boil protection of the coolant. IEG, commonly referred to as antifreeze, also contains chemicals that provide a limited protection against corrosion. The use of an IEG product with a low silicate formulation that meets either the ASTM D6210–A, ASTM D 4985 and TMC RP329 Type A requirements is recommended.

Power Cool - DDC Part Number	Size
23512138	1 gallon
23512139	55 gallons
23512140	bulk

Table 8-4 Power Cool Fully Formulated/Precharged IEG

Ethylene Glycol Volume %	Freezing Point		Boiling Point	
	° F	° C	° F	° C
0	32	0	212.0	100.0
10	24.2	4.3	212.6	100.2
20	14.9	– 9.5	215.1	101.7
25	9.3	– 12.6	216.7	102.5
30	3.0	– 16.1	218.2	103.4
35	– 4.3	– 20.2	219.8	104.3
40	– 13.1	– 25.0	221.4	105.2
45	–23.5	– 30.9	223.1	106.1
50	– 36.2	– 37.9	225.1	107.2
55	– 51.6	– 46.5	227.4	108.4
60	– 70.3	– 56.8	230.5	110.1
65	< – 70	< – 60	234.5	112.2
70	NA	NA	239.9	115.2
80	NA	NA	256.4	124.2
90	NA	NA	284.0	139.6
100	NA	NA	327.7	164.0

Table 8-5 Coolant Freezing and Boiling Temperatures vs. Inhibited Ethylene Glycol (IEG) Concentration (Sea Level)

8.3.2 Coolants Not Recommended

Methyl alcohol-based antifreeze should not be used in DD15 engines because of its effect on the non-metallic components of the cooling system and its low boiling point. Similarly, methoxy propanol-based antifreeze should not be used in DD15 engines because it is not compatible with fluoroelastomer seals found in the cooling system. Glycol-based coolants formulated for heating/ventilation/air conditioning (HVAC) should not be used in DD15 engines. These coolants generally contain high levels of phosphates, that can deposit on hot internal engine surfaces and reduce heat transfer.

8.3.3 Supplemental Coolant Additive

SCAs provide protection for the cooling system components. The coolant must have the proper concentration of SCAs. Detroit Diesel Maintenance products are recommended for use in DD15 engines.

NOTICE:
Excessive amounts of chemicals in the engine coolant can cause a gel-type or crystalline deposit that reduces heat transfer and coolant flow. The deposit, called dropout takes the color of the coolant when wet, but appears as a white powder when dry. It can pick up solid particles in the coolant and become gritty, causing excessive wear of water pump seals and other cooling system components. The wet gel can be removed by non-acid (alkali) type heavy-duty cleaner, Detroit Diesel Maintenance Product cleaner DD-2001 (sodium nitrite/sodium tetraborate). If the gel is allowed to dry, it is necessary to disassemble the engine and clean with a caustic solution or mechanically clean individual components.

The proper application of SCA will provide:

- A pH control to prevent corrosion.
- Water-softening to deter formation of mineral deposits.
- Cavitation protection to reduce the effects of cavitation.

The proper dosage for initial cooling system fill is listed in Table 8-6. Maintenance cooling system fill is listed in Table 8-7, initial coolant inhibitor element size requirements for IPG and IEG plus water coolant mixtures are listed in Table 8-8. Coolant inhibitor element size requirements, initial dosage for water-only systems, are listed in Table 8-9. The proper maintenance dosages are listed in Table 8-10.

Coolant	Coolant Element	Liquid *
Precharged IEG and Water	NONE	NONE
IEG and Water	Select Element listed in Table 8-8.	3% by volume, or 1 pint per 4 gallons
Water only	Select Element listed in Table 8-9.	6% by volume, or 1 quart per 4 gallons

*1 gallon = 3.785 L; 2 pints = 1 quart; 4 quarts = 1 gallon

Table 8-6 Initial Fill SCA Dosage

Coolant Element	Liquid *
Select element listed in Table 8-10.	0.6% by volume or 1 pint per 20 gallons

*1 gallon = 3.785 L; 8 pints = gallon

Table 8-7 Maintenance Fill SCA Dosage

Cooling System Capacity, L (Gallons)	Quantity	DDC Part Number
34-45 (9-12)	1	23508426
49-61 (13-16)	1	23507189

Table 8-8 Coolant Inhibitor Element Size Requirements-Initial Fill Dosage for IEG or IPG plus Water Coolant Mixtures

Cooling System Capacity L (Gallons)	SCA Element Quantity	Detroit Diesel SCA Element Part Number	Additional SCA Liquid Required
26 (7)	1	23508426	None
38 (10)	1	23507189	None
57 (15)	2	23508426	None

Table 8-9 Coolant Inhibitor Element Size Requirements-Initial Dosage for Water-Only System

Cooling System Capacity, L (Gallons)	Filter Quantity	Filter Part Number	Liquid Only Number of Pints
34-45 (9-12)	1	23507545	1/2 - 3/4
49-61 (13-16)	1	23507545	3/4 - 1

Table 8-10 Coolant Inhibitor Element Size Requirements-Maintenance Dosage for IEG, IPG, Precharged, and Water-Only Coolant Mixture

The concentration of SCA will gradually deplete during normal engine operation. Check the SCA concentration at the regular intervals listed in Table 8-11. Additional SCA must be added to the coolant when it becomes depleted below a specified level (listed in Table 8-12). Maintenance dosage of SCA must only be added if nitrite concentration is less than 900 ppm. If nitrite concentration is greater than 900 ppm, do not add additional SCA.

Service Application	Inhibitor Test Interval
On-highway Trucks and Motor Coaches	330,000 km (205,000 miles)
City Transit Coaches, Pick-up and Delivery, Short Trip, and Emergency Vehicles	9,600 km (6,000 miles) or three months, whichever comes first.

Table 8-11 Required Coolant Inhibitor Test Intervals

SCA	Minimum SCA ppm	Maximum SCA ppm
Boron (B)	1,000	1,500
Nitrite (NO_2)	900	3,200
Nitrates (NO_3)	0	1,000
Silicon (Si)	50	250
Phosphorus (P)	0	500
pH	8.0	11.0

Table 8-12 SCA Limits with ASTM D6210–A, ASTM-D 4985 and TMC RP329 TYPE A (50/50 Coolant/Water Mixture)

8.3.4 Soluble Oils

Soluble oil additives are not approved for use in the DD15 engine cooling systems. A small amount of oil adversely affects heat transfer. A 1.25% concentration of soluble oil increases the fire deck temperature 6%. A 2.50% concentration increases the fire deck temperature 15%.

8.3.5 Chromate

Chromate additives are not approved for use in the DD15 engine cooling systems. Chromate additives can form chromium hydroxide, commonly called green slime. This, in turn, can result in engine damage due to poor heat transfer. Cooling systems operated with chromate-inhibited coolant must be chemically cleaned with Power Cool 2015 cooling system cleaner and conditioner (or equivalent sulfamic acid/sodium carbonate cleaner) and flushed.

Some coolant filter elements with magnesium internal support plates have caused engine damage. The coolant dissolves the magnesium and deposits it on the hot zones of the engine where heat transfer is most critical. The use of elements with these plates is not approved.

8.3.6 Detroit Diesel Cooling System Maintenance Products

Detroit Diesel Maintenance Products with SCA are water-soluble chemical compounds. These products are available in coolant filter elements, liquid packages, and a fully formulated IEG.

8.3.7 Coolant Inhibitor Elements

Replaceable coolant inhibitor elements (spin-on canisters) are available in various sizes suitable for cooling systems of varying capacity. If a fully formulated IEG coolant *is not* used, a pre-charge element *must*be installed. Selection of the proper element size is vital when precharging the coolant system at initial fill. If a coolant inhibitor element is used, it is important to make sure that the coolant inlet/outlet valves on the element adaptor head are fully opened prior to filling the cooling system with coolant.

NOTE:
A fully formulated IEG must NOT have SCA added at initial fill.

The need for maintenance elements is determined by the results of the SCA concentration test performed at each cooling system service interval.

8.3.8 Supplemental Coolant Additive Test Procedures

Nitrite concentration is an indication of the SCA concentration in the coolant. Nitrite test kits and test strips are commercially available. The coolant must be tested for required inhibitor levels at the intervals listed in Table 8-11. SCA levels must be within the ranges listed in Table 8-12.

8.3.8.1 Liquid Supplemental Coolant Additive

Detroit Diesel Cooling System Maintenance Procedures SCA and Cleaners are available in liquid form and are listed in Table 8-13.

Product	Size *	DDC Part No.
Power Cool® 2000 - Liquid SCA	1 pint (12 per case)	23507858
Power Cool 2000 - Liquid SCA	half gallon (6 per case)	23507859
Power Cool 2000 - Liquid SCA	5 gallons	23507860
Power Cool 2000 - Liquid SCA	55 gallons	23507861
Power Cool 3000 † - Liquid SCA	1 pint (12 per case)	23507854
Power Cool 3000 † - Liquid SCA	half gallon (6 per case)	23507855
Power Cool 3000 † - Liquid SCA	5 gallons	23507856
Power Cool 3000 † - Liquid SCA	55 gallons	23507857
Power Cool 2001 ON-LINE CLEANER	half gallon (6 per case)	23507862
Power Cool 2001 ON-LINE CLEANER	5 gallons	23507863
Power Cool 2001 ON-LINE CLEANER	55 gallons	23507864
Power Cool 2015, Twin Pac, Dry Chemical Cleaner/Conditioner	2 per case	23507867

* 1 gallon = 3.785 L; 8 pints = gallon

† Power Cool 3000 is more compatible with hard water than Power Cool 2000. Use Power Cool on-line cleaner for light deposits. Use Power Cool dry chemical cleaner conditioner for heavy deposits or scale.

Table 8-13 Liquid SCA and Additional Coolant Treatment Products

8.3.8.2 Test Kit Procedures

Use Detroit Diesel Powertrac® 3-Way Coolant Test Strips (part number 23515917) to measure nitrite and glycol concentrations. Cavitation/corrosion protection is indicated on the strip by the level of nitrite concentration.

NOTICE:

Do not use Detroit Diesel **Power Cool**™ test strips to determine the inhibitor levels of coolant with non-DDC approved additive packages. Incompatible chemicals and variance in inhibitor levels in the additive packages may cause inaccurate interpretation of test strip readings. This can lead to under-inhibiting the coolant, which may result in cavitation erosion.

Freeze and boil over protection is determined by glycol concentration. 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 end pad (% glycol) to the color chart.
3. Sixty seconds (one minute) after dipping, compare the nitrite pad to the chart contained within the kit.

For best results make the tests while the coolant is between 10 - 60°C (50 - 140°F). Wait at least 60, but not longer than 75 seconds before reading the nitrite level. Promptly replace and tighten container cap after each use. Discard unused strips if they have turned light pink or tan.

A factory coolant analysis program is also available through authorized Detroit Diesel service outlets under part number 23508774.

8.3.9 Summary of Coolant Recommendations

Coolant recommendations may be summarized 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.

- Always maintain the engine coolant to meet Detroit Diesel specifications.

- Only use water that meets Detroit Diesel specifications. Distilled or deionized water is preferred
- The proper dosage of SCA must be included in the coolant at initial fill for all DD15 engines. This dosage can be either included in part or entirely in the IEG used, or it may need to be added. Dosage is also dependent on whether water or IEG is used. The user is urged to refer to the full text of this bulletin to determine the proper dosage. Mixing of different manufacturers' inhibitors (SCAs) could cause cooling system problems
- Maintain the SCA to the prescribed concentration. Test the nitrite concentration by using a titration kit or Detroit Diesel 3-Way Coolant Test Strips. Add SCA only if the nitrite concentration is below 900 ppm
- Do not use another manufacturer's test kit to measure the SCA concentration of Detroit Diesel Maintenance Products.
- Pre-mix coolant makeup solutions at the proper concentration before adding to the coolant system.
- Where antifreeze/boil over protection is required, use only ethylene glycol coolant (low silicate formulation) meeting ASTM D6210–A, ASTM D 4985 and TMC RP329 Type A.
- Always maintain proper coolant level.

- A properly maintained cooling system can be operated for up to intervals listed in Table 8-14. The cooling system must be thoroughly cleaned and the coolant replaced at these intervals.

Coolant	Interval - Whichever comes first	Action
Conventional Detroit Diesel *POWER COOL* Antifreeze/Water	32,000 km (20,000 miles) 3 Months, or 500 Hours	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
	480,000 km (300,000 miles) or 2 Years	Drain and clean system. Refill with new coolant.
EG Antifreeze/Water + Conventional Corrosion Inhibitor	32,000 km (20,000 miles) 3 Months, or 500 Hours	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
	480,000 km (300,000 miles) or 2 Years	Drain and clean system. Refill with new coolant.
PG Antifreeze/Water + Conventional Corrosion Inhibitor	32,000 km (20,000 miles) 3 Months, or 500 Hours	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
	Engine Overhaul	Drain and clean system. Refill with new coolant.
EG Antifreeze/Water + OAT Inhibitor	480,000 km (300,000 miles) 2 years or 10,000 Hours	Add *Power Cool* Plus Extender
	960,000 km (600,000 miles) 4 Years, or Engine Overhaul	Drain and clean system. Refill with new coolant.
PG Antifreeze/Water + OAT Inhibitor	480,000 km (300,000 miles) 2 Years, or 10,000 Hours	Add *Power Cool* Plus Extender
	960,000 km (600,000 miles) 4 Years, or Engine Overhaul	Drain and clean system. Refill with new coolant.
Water Only + Conventional Corrosion Inhibitor	32,000 km (20,000 miles) 3 Months, or 500 Hours	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
	Engine Overhaul	Drain and clean system. Refill with new coolant.
Water Only + OAT Inhibitor	480,000 km (300,000 miles) 2 Years, or 10,000 Hours	Add *Power Cool* Plus Extender
	960,000 km (600,000 miles), 4 Years, or Engine Overhaul	Drain and clean system. Refill with new coolant.

Table 8-14 Cooling System Cleaning Intervals

Do not use the following in Detroit Diesel engine cooling systems:

- Soluble oil
- Chromate SCA
- Methoxy propanol-base coolant
- Methyl alcohol-base coolant
- Sealer additives or coolant containing sealer additives
- HVAC coolant

9 ELECTRICAL EQUIPMENT

Section **Page**

9.1 CRANKING MOTOR

The cranking motor is bolted to the flywheel housing.

NOTICE:
To prevent excessive overrun and damage to the drive and armature windings, the switch should be opened immediately when the engine starts. A cranking period should not exceed 15 seconds without stopping to allow the motor to cool for at least 15 seconds.

When the cranking circuit is closed, a drive pinion on the armature shaft engages with the teeth on the engine flywheel ring gear to crank the engine. When the engine starts, it is necessary to disengage the drive pinion to prevent the armature from overspeeding and damaging the cranking motor. To accomplish this, the cranking motor is equipped with an over-running clutch within the drive pinion. The cranking motor drive pinion and the engine flywheel ring gear must be matched to provide positive engagement and to avoid clashing of the gear teeth.

A solenoid, mounted on the cranking motor housing, operates the over-running clutch drive by linkage and a shift lever. When the start switch is closed, the magnetic switch contacts close, and the solenoid windings are connected to the battery. The resulting plunger and shift lever movement causes the pinion to engage the engine flywheel ring gear and the solenoid main contacts to close, and the cranking takes place.

The cranking circuit may contain a key start switch or push switch (or both), a relay, magnetic switches, solenoids, oil pressure switch, fuel pressure switch, and other protective devices. For the complete cranking circuit, refer to the vehicle manufacturer's wiring diagram.

9.1.1 Repair of Cranking Motor

Refer to the OEM guidelines for cranking motor repair procedures.

9.1.2 Removal of Cranking Motor

Precleaning is not necessary.

Remove the cranking motor as follows:

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

1. Remove the ground strap or negative cable(s) from the battery(s).
2. Tag each lead to ensure correct connections when the cranking motor is reinstalled.

3. Disconnect the cranking motor cables and solenoid wiring.
4. Support the motor, and remove the three bolts which secure it to the flywheel housing.
5. Pull the motor out to remove it from the flywheel housing.

If the nose housing requires relocation, perform the following steps:

NOTICE:
The solenoid should not be located below the centerline of the cranking motor. Dust, oil, moisture and foreign material can collect and cause solenoid failure.

1. Remove the six socket-head screws (one short and five long) and six neoprene plugs from the unused holes if a twelve-hole mounting flange is used.
2. Turn the nose housing to the required position.
3. Install the six socket-head screws, with the short screw in the shallow hole nearest the solenoid and six neoprene plugs, if a twelve hole mounting flange is used.
4. Torque the screws to 18-23 N·m (13-17 lb·ft).

9.1.3 Installation of Cranking Motor

Install the cranking motor as follows:

WARNING:

ELECTRICAL SHOCK

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

1. Support the cranking motor, and install the three bolts that secure it to the flywheel housing.
2. Connect the cranking motor cables and the solenoid wiring.
3. Install the ground strap or negative cable(s) to the battery(s).
4. If an aluminum flywheel housing is used, torque the cranking motor attaching bolts to 187-209 N·m (138-154 lb·ft). If a cast iron flywheel housing is used, torque the cranking motor attaching bolts to 245-306 N·m (181-226 lb·ft).
5. If equipped with a 42 MT or 50 MT starting motor, install wiring terminal leads to the cranking motor and the solenoid switch.

NOTE:
Keep all of the electrical connections clean and tight.

6. Torque the smaller connections to 1.8-3.4 N·m (16-30 lb· in.). Torque the larger connections to 27-34 N·m (20-25 lb·ft).

9.2 ALTERNATOR

The battery charging alternator provides a source of electrical current for maintaining the storage battery in a charged condition and supplies sufficient current to carry any other electrical load requirements up to the rated capacity of the alternator.

The battery charging circuit consists of an alternator, with an integral voltage regulator, a battery(s) and the connecting wiring.

9.2.1 Repair of Alternator

Refer to the OEM guidelines for alternator repair procedures.

9.2.2 Removal of Alternator

Precleaning is not necessary.

Remove the alternator as follows:

WARNING:

ELECTRICAL SHOCK

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

1. Disconnect the cables at the batteries. Tag each lead to ensure correct connection when the alternator is reinstalled.
2. If the alternator has more than the output cable lead, disconnect all other leads from the alternator, and tag each one to ensure correct installation.
3. Remove the alternator output cable.
4. Remove the drive belts. Refer to section 1.7 for belt removal.

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.

5. Remove four bolts attaching the alternator to the bracket.

9.2.2.1 Inspection of Alternator

Refer to OEM guidelines for alternator inspection procedures.

9.2.3 Installation of Alternator

Install as follows:

1. Install alternator mounting bracket to the cylinder block, if it was removed. Torque the six mounting bolts to 80 N·m (59 lb·ft),
2. Position the alternator on the mounting bracket, and align the holes in the alternator mounting flanges with the holes in the bracket. Torque the six bolts to 40 N·m (29 lb·ft)
3. Install air conditioning compressor to mounting bracket torque the four bolts to 30 N·m (22 lb·ft).
4. Install the belt pulley and fan to alternator. Torque the nut to 80 N·m (59 ft·lb).

NOTICE:
Failure to properly orient the drive belt when installing it over the pulleys may result in belt damage at engine startup.

5. Install the belt(s) carefully over the pulleys on the crankshaft or alternator drive and the drive belt tensioner. refer to section 1.7. Ensure the pulleys are properly positioned before taking up slack.
6. Attach the wires and cables to the alternator. Ensure that each one is correctly installed in the location from which it was removed. Keep all connections clean and tight.

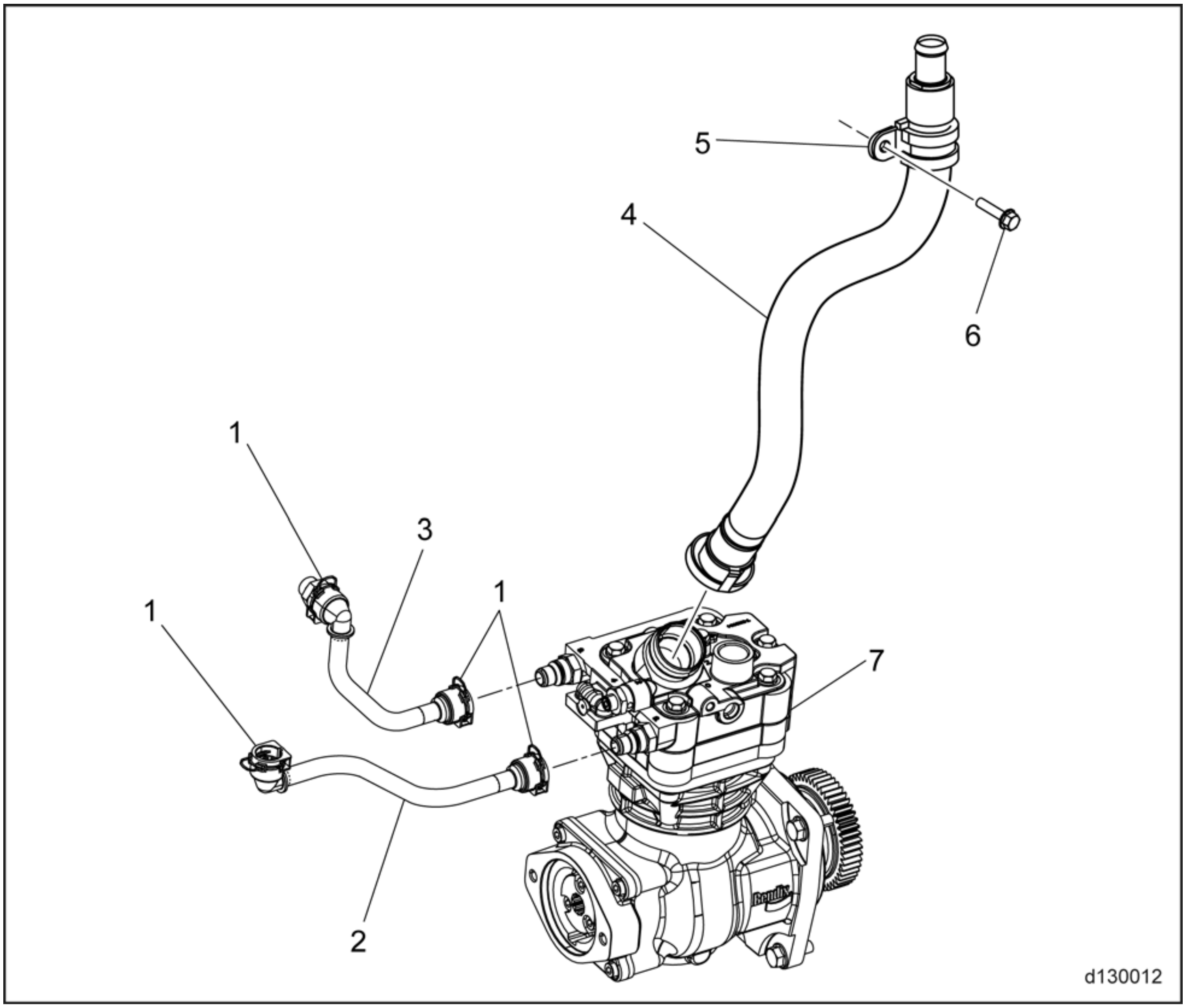
10 SPECIAL EQUIPMENT

10.1 AIR COMPRESSOR

The air compressor is mounted to the rear of the cylinder block on the left side of the engine.

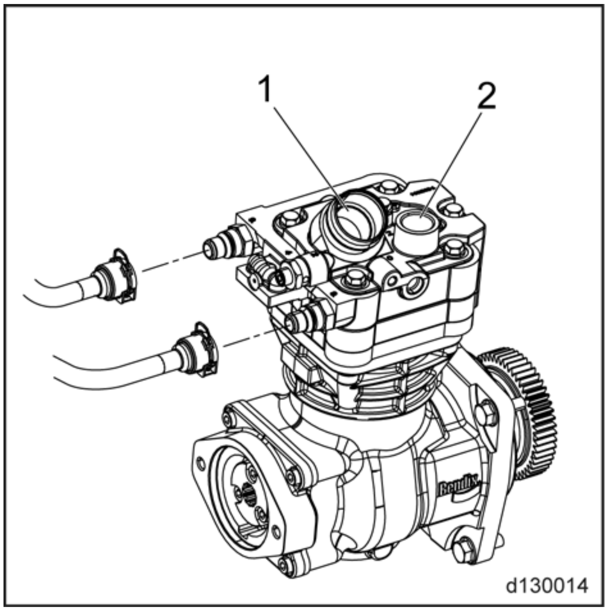
The engine provides a continuous supply of oil to the compressor. Oil is routed from the oil passage in the gear case to the compressor oil inlet. The air compressor is designed to permit direct installation of the compressor onto the gear case.

Detroit Diesel offers two sizes of air compressors. The single cylinder which has a displacement 360 cm^3 and the twin cylinder which has a displacement 650 cm^3. Both compressors are installed with an energy saving system (ESS) to save fuel.



1. Oil Ring Retainer
2. Coolant Return Line
3. Coolant Inlet Line
4. Intake Line
5. Clamp
6. Bolt
7. Single Cylinder Air Compressor

Figure 10-1 Air Compressor and Related Parts



1. Air Inlet
2. Air Outlet

Figure 10-2 Air Inlet and Outlet Locations

10.1.1 Replacement of Air Compressor

Detroit Diesel does not service the air compressor. Service of an air compressor should be referred to an authorized service center of the original equipment manufacturer.

10.1.2 Removal of Air Compressor

Remove as follows:

1. Disconnect the batteries.
2. Drain the coolant.

NOTICE:
Ensure the air pressure has been released from the air lines before removing the lines from the air compressor.

3. Relive air pressure from tanks
4. Disconnect the air lines to and from the compressor.
5. Disconnect and drain the coolant supply and return lines at the air compressor.
6. Remove the four bolts that secure the air compressor to the cylinder block..

NOTICE:
Do not contact the drive gear to the engine block during removal, damage to the seal surface will cause oil leaks.

7. Slide the air compressor forward to disengage the hub from the coupling.

10.1.2.1 Inspection of Air Compressor

Refer to OEM guidelines to determine if the air compressor needs to be repaired or replaced.

10.1.3 Installation of Air Compressor

Install the air compressor as follows:

1. Clean all foreign material from the mating surfaces of the air compressor and the block.
2. Using a new gasket and bolts previously removed, install the air compressor to its original location on the cylinder block.

NOTICE:
Ensure the correct bolt length is used when the air compressor is installed. If an incorrect bolt length (too long) is used the cup plugs installed in the cylinder block can be pushed out into the gear train causing severe damage to the gear train. The correct bolt length is 35 mm (1.37 in.).

3. Torque the four bolts to 60 N·m (44 lb·ft).

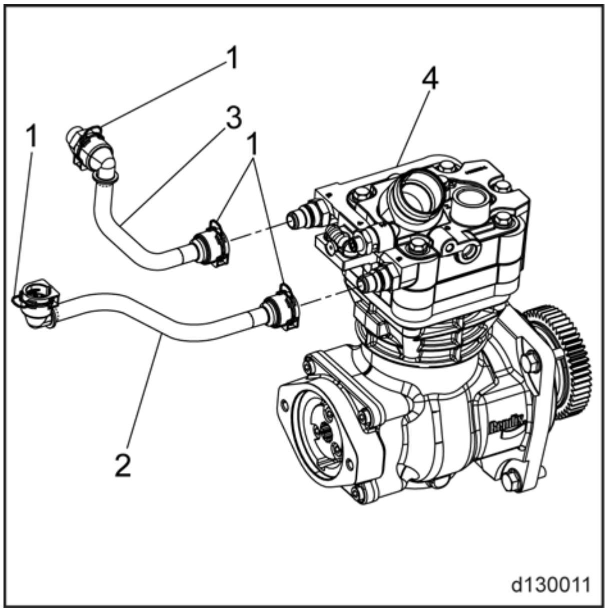
WARNING:

EYE INJURY

To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).

NOTICE:

Ensure when the air compressor coolant lines are installed that there is an O-ring and O-ring retainer installed on both ends of the coolant lines. Ensure that the air compressor retainer is installed on the coolant line and is pushed down to lock the lines on the inlet and outlet ports to the cylinder block, fuel filter module and air compressor. A leak will occur if the lines are incorrectly installed and the coolant line retainer is not engaged in the locked position. If the O-ring or coolant line retainer are missing or removed replace the coolant line. See Figure 10-3.



1.Air Compressor Coolant Line Retainer Location
2. Coolant Return Line
3. Coolant Inlet Line
4. Single Cylinder Air Compressor

Figure 10-3 Coolant Line Retainer Location

4. Install the hose clamps onto the hoses. Install the coolant supply and return lines and connect them to the air compressor.
5. Install the air lines to and from the compressor.
6. Fill the cooling system.

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.

11 ENGINE TUNE-UP PROCEDURES

Section **Page**

11.1 VALVE LASH ADJUSTMENTS

Accurate adjustment of clearance between intake and exhaust valves is important if maximum performance and economy are to be obtained.

The valve lash on the DD15 engine must be measured and if necessary, adjusted at the initial period listed in Table 11-1.

NOTE:
Anytime the valve lash is adjusted; the engine brake lash will need to be set also. Refer to section 11.1.1.

NOTICE:
Failure to measure valve clearances at the required initial period and make necessary adjustments may result in gradual degrading of engine performance and reduced fuel combustion efficiency.

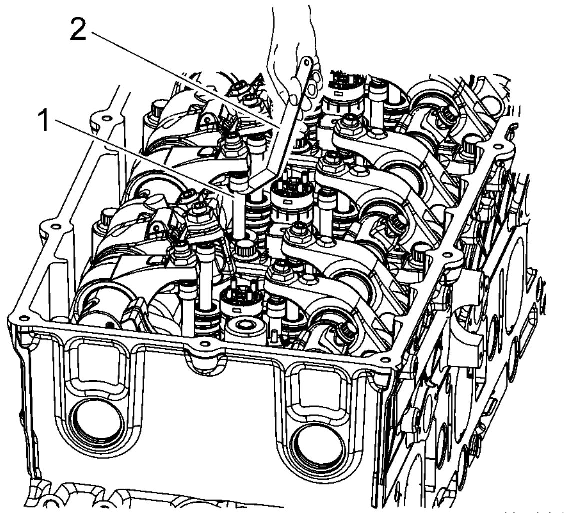
Initial Valve Lash and Measurement/Adjustment Period
Adjust at 100,000 km (60,000 mi), at 300,000 km (180,000 mi), and then every 300,000 km (180,000 mi)

Table 11-1 Measurement/Adjustment Period

Adjust the valves as follows:

1. Steam clean the engine.
2. Disconnect the starting power for the engine.
3. Remove the rocker cover.
4. Bar the engine over until cylinder number one is at top dead center (TDC).
5. Lash intake valves one, two and four to 0.4 mm (0.016 in.). See Figure 11-1.
6. Lash exhaust valves one, three and five to 0.6 mm (0.024 in.).See Figure 11-1.

7. Rotate the engine 360° from the flywheel housing; until cylinder number six is at TDC; for a setting of 180° from the camshafts.



1. Feeler Gauge
2. Feeler Gauge Location between Rocker Arm and Valve

Figure 11-1

8. Lash intake valves three, five, and six to 0.4 mm (0.016 in.). See Figure 11-1.
9. Lash exhaust valves two, four and six to 0.6 mm (0.024 in.). See Figure 11-1.
10. Torque the locknut valve adjusting screw to 50 N·m (37 lb·ft).
11. Remove any tools used for this procedure.
12. Install the rocker cover.
13. Reconnect the battery power to the engine.

11.1.1 Setting the Engine Brake Lash

Set the brake lash as follows:

1. Set the lash on all the exhaust adjusting screws first (all the adjusting screws in direct contact with the exhaust valves).
2. Rotate the engine until a given cylinder is at maximum intake lift. When this is reached, the brake lash can be set on this cylinder
3. When the brake rocker arm is in contact with the exhaust valve, set the lash between the brake rocker arm adjusting screw and the actuator piston stem. Set the lash to 4.1 mm (0.1614 in.).
4. Lash the engine brakes in the following firing order; 1, 5, 3, 6, 2, and 4.

5. Torque the locknut valve adjusting screw to 50 N·m (37 lb·ft).

12 PREVENTIVE MAINTENANCE

Section **Page**

12.1 MAINTENANCE OVERVIEW

The lubrication and preventive maintenance schedule is intended as a guide for establishing a preventive maintenance schedule. The suggestions and recommendations for preventive maintenance should be followed as closely as possible to obtain long life and best performance from the DD15 engine. The intervals indicated are time or miles of actual operation.

The time or mileage increments shown apply only to the maintenance function described. These functions should be coordinated with other regularly scheduled maintenance such as chassis lubrication.

12.2 DAILY MAINTENANCE

The following items need to be inspected, serviced, corrected or replaced on a daily basis, as necessary:

- Lubricating oil
- Fuel tank
- Fuel lines and flexible hoses
- Cooling system
- Turbocharger

12.2.1 Maintenance Schedule Applications

There are three types of maintenance schedules:

- Severe Service
- Short Haul
- Long Haul

NOTE:
Load factor and idle time values must be based on DDEC reports representative of the current service application.

12.2.1.1 Severe Service

Severe service applies to vehicles that annually travel up to 30,000 miles (48,000 kilometers) or that operate under severe conditions. Examples of Severe Service usage include: **idle time over 35%, load factor over 55%,** 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. **Only one of these conditions needs to be met to categorize an application as Severe Service.**

12.2.1.2 Short Haul

Short Haul service applies to vehicles that annually travel up to 60,000 miles (96,000 kilometers) or with a **load factor over 45%** 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.

12.2.1.3 Long Haul

Long Haul service (over-the-road transport) applies to vehicles that annually travel more than 60,000 miles (96,000 kilometers) with minimal city stop-and-go operation. Examples of Long Haul service are: Regional delivery that is mostly freeway mileage, interstate transport, and any road operation with high annual mileage.

12.3 MAINTENANCE OF VEHICLE ENGINES

The maintenance intervals are listed in Tables 12-1 , 12-2 and 12-3.

Miles/Km (X 1000)	25/ 40	35/ 55	50/ 80	70/ 110	75/ 120	100/ 160	105/ 165	125/ 200	140/ 220
Item	Procedure								
Lubricating Oil	R		R		R	R		R	
Lubricating Oil Filter	R		R		R	R		R	
Coolant	Intervals for the required coolant are listed in Table 12-5.								
Cooling System Filter						R			
Fuel Filters									
Prefilter		R		R			R		R
Coalescer (Water Separator)		R		R			R		R
Final Filter		R		R			R		R
Initial Valve Lash Adjustment	Adjust at 60,000 mi (100,000 km).								
Belts	I		I		I	I		R	
Air System	I		I		I	I		I	
Air Cleaner	I		I		I	I		I	
Exhaust System	I		I		I	I		I	
Aftertreatment Device	Inspect external hardware and connections every 6 months or 30,000 mi (50,000 km) Remove ash at 300,000 mi (480,000 km) or 9,000 hours, whichever comes first.								
Air Compressor	I		I		I	I		I	

R – Replace.

I – Inspect, service, correct, or replace as necessary.

Table 12-1 Severe Service Maintenance Intervals

Miles/Km (X 1000)	35/ 55	50/ 80	70/ 110	100/ 160	105/ 165	140/ 220	150/ 240	175/ 275	200/ 320
Item	Procedure								
Lubricating Oil	R		R		R	R		R	
Lubricating Oil Filter	R		R		R	R		R	
Coolant	Intervals for the required coolant are listed in Table 12-5.								
Cooling System Filter				R					R
Fuel Filters									
Prefilter		R		R			R		R
Coalescer (Water Separator)		R		R			R		R
Final Filter		R		R			R		R
Initial Valve Lash Adjustment	Adjust at 60,000 mi (100,000 km).								
Belts	I		I		I	I		R	
Air System	I		I		I	I		I	
Air Cleaner	I		I		I	I		I	
Exhaust System	I		I		I	I		I	
Aftertreatment Device	Inspect external hardware and connections every 6 months or 30,000 mi (50,000 km) Remove ash at 300,000 mi (480,000 km) or 9,000 hours, whichever comes first.								
Air Compressor	I		I		I	I		I	

R – Replace.

I – Inspect, service, correct, or replace as necessary.

Table 12-2 Short Haul Maintenance Intervals

Miles/Km (X 1000)	50/ 80	100/ 160	150/ 240	200/ 320	250/ 400	300/ 480
Item	Procedure					
Lubricating Oil	R	R	R	R	R	R
Lubricating Oil Filter	R	R	R	R	R	R
Coolant	Intervals for the required coolant are listed in Table 12-5.					
Cooling System Filter			R			R
Fuel Filters						
Prefilter	R	R	R	R	R	R
Coalescer (Water Separator)	R	R	R	R	R	R
Final Filter	R	R	R	R	R	R
Initial Valve Lash Adjustment	Adjust at 60,000 mi (100,000 km).					
Belts	I	I	I	I	I	R
Air System	I	I	I	I	I	I
Air Cleaner	I	I	I	I	I	I
Exhaust System	I	I	I	I	I	I
Aftertreatment Device	Inspect external hardware and connections every 6 months or 30,000 mi (50,000 km) Remove ash at 300,000 mi (480,000 km) or 9,000 hours, whichever comes first.					
Air Compressor	I	I	I	I	I	I

R – Replace.

I – Inspect, service, correct, or replace as necessary.

Table 12-3 Long Haul Maintenance Intervals

12.3.1 LUBRICATING OIL

Check the lubricating oil level with the engine stopped and the vehicle on level ground. If the engine has just been stopped and is warm, wait approximately ten minutes to allow the oil to drain back to the oil pan. Add the proper grade oil as recommended to maintain the correct oil level on the dipstick. See Figure 12-1.

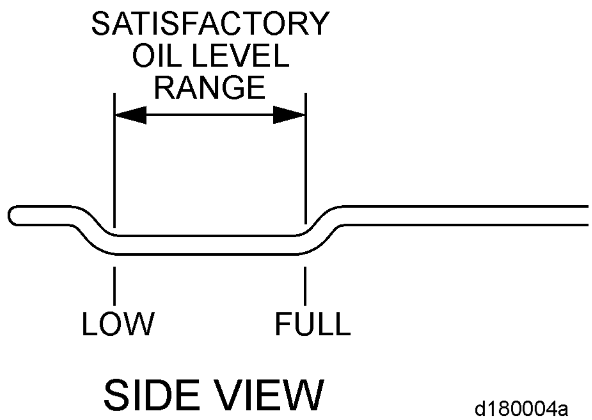


Figure 12-1 Dipstick Oil Level

NOTE:
Do not overfill. Oil may be blown out through the crankcase breather if the crankcase is overfilled.

Make a visual check for oil leaks around the oil coolant module and the external oil lines.

To ensure the engine is protected and the oil stays clean until the next oil change, use only oils of API classification CJ-4.

Change as follows:

1. Position the vehicle or equipment on level ground.
2. If the engine is cold, run it until it is warm.

NOTE:
Change the engine oil only when the engine is at a temperature of approximately 60°C (140°F).

3. Chock the tires, place the transmission in neutral and set the parking brake.
4. Remove drain plug on the bottom of oil pan and discard the plug seal. Drain lube oil into a suitable container. *Always dispose of used lubricating oil in an environmentally responsible manner, according to state and/or federal (EPA) recommendations.*

5. Using the appropriate wrench loosen the filter assembly cover and remove the unit consisting of the filter cover, rotor, intermediate cover and filter insert.
6. Unlatch the filter cover by turning it in the opposite direction to loosen cover.
7. Remove the rotor from the shaft by unlatching the clips.
8. Unclip the filter insert from the intermediate cover by tilting it slightly and pulling.

NOTE:
Before reinstalling, replace the O-rings on the intermediate cover and filter cover with new O-rings.

9. Place a new filter insert on the supporting dome in the base and mount intermediate cover.
10. Place a new rotor on the shaft and clip into place and install filter cover.
11. Install filter cover to oil cooler module and torque to 65 N·m + 10 N·m (48 lb·ft + 7 lb·ft).
12. Install the oil pan drain plug using a new O-ring. Tighten plug to 45 N·m (33 lb·ft).
13. Add clean engine oil through the oil fill located on the oil coolant module.
14. Check that the level on the oil dipstick has reached maximum fill level. Engine fill capacity is 45.0 l (47.5 qts).

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 with the accelerator pedal in the idle position. Monitor the oil pressure gauge.

NOTICE

Keep the engine running at idling speed until an oil pressure reading is obtained. If no oil pressure is shown after approximately 10 seconds, stop the engine and determine the cause. Failure to do so could result in engine damage.

16. Check the filter and oil drain plug for signs of leakage.
17. Stop the engine. Check the oil level again after approximately five minutes. If necessary add oil up to the maximum fill level on the oil dipstick.

12.4 COOLING SYSTEM

The cooling system must be *full* for proper operation of the engine.

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.

Check the coolant level daily and maintain it between the full and low marks on the surge tank. Add coolant as required, but do not overfill.

Make a daily visual check for cooling system leaks. Look for an accumulation of coolant when the engine is running and when it is stopped. Coolant leaks may be more apparent on a engine when it is cold.

The inhibitors in antifreeze solutions *must* be replenished with an approved corrosion inhibitor supplement when indicated by testing the coolant.

NOTICE:

Coolant *must* be inhibited with the recommended SCAs listed in this guide. **Failure to check and maintain SCA levels at required concentrations will result in severe damage (corrosion) to the engine cooling system and related components.**

The cooling system is protected by an SCA element. In addition, the engine can be equipped with a coolant filter/inhibitor system as an installed option or as an after-sale item.

A coolant system properly maintained and protected with supplemental coolant inhibitors can be operated up to the intervals listed. At these intervals the coolant *must* be drained and disposed of in an environmentally responsible manner according to state and/or federal (EPA) recommendations.

Install a new cooling system filter at a **maximum** of 90,000 miles (150,000 km).

The DD15 engine is equipped with a coolant filter. The coolant filter contains supplemental corrosion inhibitors.

Service the cooling system as follows:

1. Place the transmission in neutral, and set the parking brake.

WARNING:

HOT COOLANT

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

NOTE:
Change the coolant filter only after the vehicle has cooled and no residual pressure is present.

2. Clean outside of the coolant filter housing.

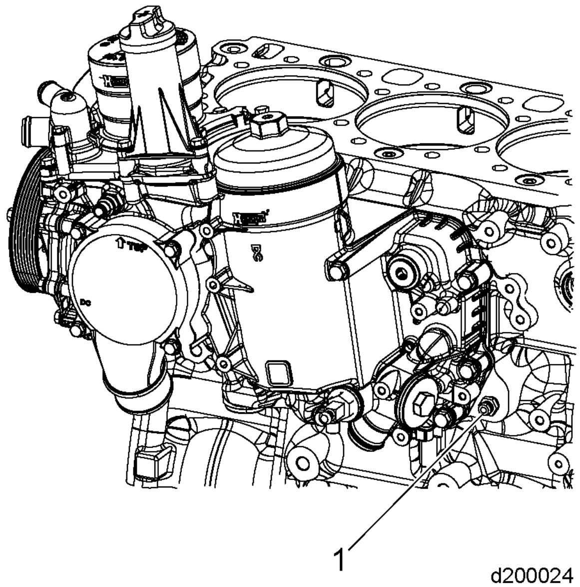
NOTICE:

Ensure when servicing the oil coolant module that coolant from module does not contaminate the lubrication system.

NOTE:
Use care to prevent foreign objects from entering the filter housing.

3. Using a 36-mm socket, unscrew cap and filter and allow the coolant to drain into the housing.
4. Remove the drain plug from the bottom of the oil coolant module and drain any remaining coolant from the oil coolant module into a suitable container.

5. Open the drain plug located on the left side of the engine block and attache a hose to the plug. See Figure 12-2.

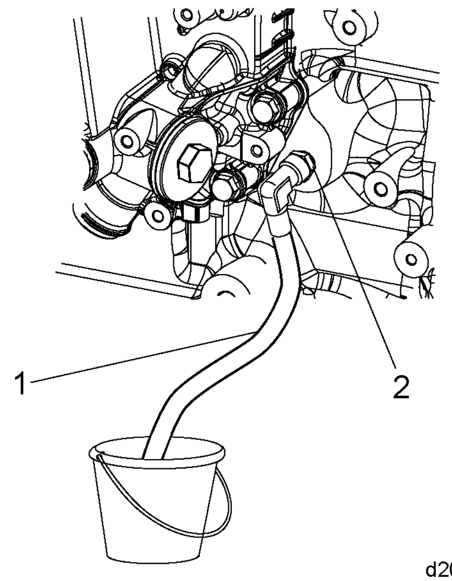


1. Coolant Drain Plug Location

Figure 12-2 Coolant Drain Location

NOTICE:
Coolant is a hazardous material and needs to be disposed in an environmentally responsible manner.

6. Collect the used antifreeze in a suitable container, and dispose of the solution in an environmentally responsible manner, according to state and federal (EPA) recommendations. See Figure 12-3.



1. Hose
2. Engine Block Drain Location

Figure 12-3 Coolant Drain Plug with Hose Attached

7. After draining, remove the oil coolant module assembly from the cylinder block housing.
8. Remove the filter from the plastic cap by placing the filter on a solid surface and apply pressure on the plastic cap at an angle.
9. Remove oil coolant filter O-ring and discard it. Lightly lubricate a new O-ring with clean engine oil and install it on the filter cap.
10. Check filter housing for any debris and remove if necessary.
11. Insert a new filter element into the cap.
12. Insert element and cap assembly into the housing. Torque the cap to 55-60 N·m (41-44 lb·ft).
13. Install oil coolant module refer to section 3.4.
14. Replace all drain plugs and close all drain valves.
15. Add coolant to the correct levels. Refer to section12.5.3.

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 engine with the accelerator pedal in the idle position. Monitor all gauges or indicator lamps.
17. Check the filter housings for signs of leakage.

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.

If the cooling system is contaminated, flush the cooling system as follows:

1. With the engine cool drain the coolant from the engine and radiator. Dispose of the coolant in an environmentally friendly manner, according to state and federal Environmental Protection Agency (EPA) recommendations.
2. Refill with soft clean water and a cleaning system compound listed in Table 12-4.

Coolant Type	Part Number	Description
On-Line Cleaner	200164	One Half Gallon Jug -6Per Case
	200105	5 Gallon Pail
	200155	55 Gallon Drum

Table 12-4 Power Cool® Cooling System Cleaners

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 operate it for 15 minutes after the thermostat has opened to thoroughly circulate the water.

4. Stop the engine and allow to cool. Drain the unit completely.

NOTICE:
If the engine is hot, fill slowly to prevent rapid cooling and distortion of the engine castings.

5. If the engine is hot, refill slowly with clean water and start the engine and operate for 15 minutes after the thermostats have opened.
6. Stop the engine and allow it to cool.
7. With engine cool, drain the cleaner residue form the cooling system.
8. Refill the cooling system. Refer to section .
9. Purge entrapped air by allowing the engine to warm-up without the pressure cap installed. With the transmission in neutral, increase engine speed above 1000 rpm. Add coolant as required.
10. Allow engine to cool.
11. Install the pressure cap after filling the coolant system to the required coolant level.

In addition to the cleaning procedure the cooling system should be checked periodically to keep the engine operating at peak efficiency.

Coolant	Interval	Action
Ethylene Glycol / Water + OAT Inhibitor	300,000 miles (48,000 km) or 10,000 hours	Add *POWER COOL* Plus extender.
	600,000 miles (960,000 km)	Drain and clean system. Refill with new coolant.
Ethylene Glycol / Water + SCA Inhibitor	20,000 miles (32,000 km) or 3 months	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
	300,000 miles (480,000 km)	Drain and clean system. Refill with new coolant.
Water Only + Conventional Corrosion Inhibitor	20,000 miles (32,000 km), 3 months, or 500 hours	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
	Engine Overhaul	Drain and clean system. Refill with new coolant.
Water Only + OAT Inhibitor	300,000 miles (480,000 km), 2 years, or 10,000 hours	Add *POWER COOL* Plus extender.
	600,000 miles (960,000 km), 4 years, or Engine Overhaul	Drain and clean system. Refill with new coolant.

Table 12-5 Coolant Maintenance Intervals

12.5 PREVENTIVE MAINTENANCE INTERVALS

This section describes the items listed in the maintenance interval tables.

The “Daily” instructions apply to routine or daily starting of the engine. They do not apply to a new engine or one that has been operated for a considerable period of time.

For new or stored engines, refer to the *EPA07 DD15 Engine Operator's Guide* (DDC-SVC-MAN-0003). Follow instructions under ***Preparations for Starting the Engine the First Time***.

12.5.1 Lubricating Oil

Check the oil level daily with the engine stopped using the oil dipstick. The dipstick has an operating range identified by two bends. If the oil meniscus is between the bends, then the oil range is adequate for engine operation.

NOTE:
The engine must be shut down for 60 minutes and on a level surface for an accurate oil level reading. Otherwise, the engine must be brought up to an operating temperature of 80°C (176°F), shut down, and allowed to sit for five minutes on a level surface. Failure to allow the oil to drain back properly as just described can result in a low oil level reading.

Add the proper grade of oil to maintain the satisfactory range on the dipstick.

NOTICE:
When adding lubricating oil, do not overfill. Oil may be blown out through the crankcase breather if the crankcase is overfilled.

All diesel engines are designed to use some oil, so the periodic addition of oil is normal.

NOTICE:
If the oil level is constantly above normal and excess oil has not been added to the crankcase, consult with an authorized Detroit Diesel service outlet for the cause. Fuel or coolant dilution of lubricating oil can result in serious engine damage.

API CJ–4 oils are recommended for use in the DD15 engine.

12.5.2 Lubricating Oil Filter

The DD15 engine is equipped with a single cartridge style oil filter that is part of the oil/coolant module. Incorporated into the housing is a drain back port which allows residual oil to be returned to the oil pan when the filter is removed. This design, including the cartridge style element, allows for a more environmental safe oil change.

WARNING:

PERSONAL INJURY

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

For maintenance intervals, please replace the oil filter using the schedule.

Make a visual check of all lubricating oil lines for wear and/or chafing. If any indication of wear is evident, replace the oil lines and correct the cause.

Check for oil leaks after starting the engine.

12.5.3 Cooling System

The cooling system must be *full* for proper operation of the engine.

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.

Check the coolant level daily and maintain it between the full and low marks on the surge tank. Add coolant as required, but do not overfill. Before adding coolant, listed in Table 12-5.

12.5.3.1 Coolant Level

Make a daily visual check for cooling system leaks. Look for an accumulation of coolant when the engine is running and when it is stopped. Coolant leaks may be more apparent on a engine when it is cold.

12.5.3.2 Coolant Inhibitors

The inhibitors in antifreeze solutions *must* be replenished with an approved corrosion inhibitor supplement when indicated by testing the coolant. for required test intervals, inhibitor levels, seeTable 12-5 for approved inhibitors.

NOTICE:

Coolant *must* be inhibited with the recommended SCAs listed in this guide. **Failure to check and maintain SCA levels at required concentrations will result in severe damage (corrosion) to the engine cooling system and related components.**

The cooling system is protected by an SCA element. In addition, the engine can be equipped with a coolant filter/inhibitor system as an installed option or as an after-sale item.

12.5.3.3 Coolant Drain Interval

A coolant system properly maintained and protected with supplemental coolant inhibitors can be operated up to the intervals listed. At these intervals the coolant *must* be drained and disposed of in an environmentally responsible manner according to state and/or federal (EPA) recommendations.

12.5.3.4 Radiator

The exterior of the radiator core should be inspected every 30,000 miles (50,000 km) or 12 months and cleaned, if necessary.

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.

Use a quality grease solvent, such as mineral spirits, and dry with compressed air. **Fuel oil, kerosene or gasoline should not be used.**

It may be necessary to clean the radiator more frequently if the engine is being operated in extremely dusty or dirty areas.

If the low coolant level sensor is installed in the top tank of the radiator, it should be tested for proper operation every 100,000 miles (160,000 km) or 12 months, whichever comes first. Authorized Detroit Diesel distributors are properly equipped to perform this service.

12.5.4 Cooling System Filter

Install a new cooling system filter at a **maximum** of 90,000 miles (150,000 km).

12.5.5 Fuel Filters

The DD15 engine is equipped with a prefilter that filters down to 100 micron, a coalescer that separates water, and a final filter which filters material from 3 to 5 microns. The final filter is 98% effective at filtering material at 5 microns. When servicing these elements, all three filters should be changed at the same time. All three elements are located within the fuel filter module located on the left side of the engine.

Located at the base of the fuel filter module is a water level sensor. When water level reaches a predetermined height, the LED indicators on the front of the sensor change from green to red. At this time, remove the water from the module by opening the water drain valve at the bottom of the module.

For maintenance intervals, please replace the fuel filters using the schedule.

NOTE:
Filter change intervals may be shortened to conform with established preventive maintenance schedules, but should never be extended.

12.5.6 Valve Lash Adjustment

Valve lash adjustment should be performed at the maintenance interval. The maintenance intervals are listed in Tables , , and .Proper valve lash clearance allows the engine to produce the best possible performance with the lowest emissions. Valve lash adjustments should be performed by an authorized Detroit Diesel maintenance or repair facility.

12.5.7 Belts

The DD15 engine is equipped with two engine belt tensioners so the belts are neither too tight nor too loose. Belts that are too tight impose extra loads on the crankshaft, fan, and/or alternator bearings shortening both belt and bearing life. A loose belt will slip and generate excessive heat that may cause damage to the belt and accessory drive components.

WARNING:
PERSONAL INJURY
To avoid injury from rotating belts and fans, do not remove and discard safety guards.

Inspect the belt tensioner for wear or damage. If necessary, replace tensioner.

12.5.7.1 Serpentine Belts

Two poly-V belts are used with DD15 Engine On-Highway Vehicle applications. One belt drives the fan hub and the other belt drives the remaining accessories. To provide proper running tension, the current DD15 engine uses an automatic fan hub belt tensioner and an accessory belt tensioner . Automatic belt tensioners require no adjustment.

12.5.7.2 Belt Replacement

Drive belts should be replaced every 2,000 hours or 300,000 miles (480,000 km).

12.5.8 Air System

All the connections in the air system should be checked to make sure they are tight and leak free. Check all hoses and ducting for punctures, deterioration, or other damage and replace, if necessary.

12.5.9 Air Cleaner

The DD15 engine is equipped with an engine-mounted air cleaner that is flat in design to accommodate various vehicle packages. The air cleaner element should be inspected every 50,000 miles (80,000 km) or more often if the engine is operating under severe dust conditions.

Replace the element, if necessary. Check the gaskets for deterioration and replace, if necessary. If the dry type air cleaner is equipped with an aspirator, check for aspirator damage or clogging. Clean, repair or replace, as necessary.

NOTICE:
Do not allow the air inlet restriction to exceed 20 in. H_2O (5.0 kPa) under any engine operating conditions. A clogged air cleaner element will cause excessive intake restriction and reduced air supply to the engine resulting in increased fuel consumption, inefficient engine operation, and reduced engine life.

Inspect the entire air system for leaks daily. Look especially for torn air inlet piping or boots and loose or damaged clamps. Have worn or damaged parts repaired or replaced, as required. Retighten loose connections.

12.5.9.1 Air Cleaner Replacement

Dry type air cleaner elements should be replaced when the maximum allowable air intake restriction has been reached. for additional information.

12.5.10 Exhaust System

Have the exhaust manifold retaining bolts and other connections checked for tightness. Have the exhaust pipe rain cap checked for proper operation, if so equipped.

12.5.11 Aftertreatment System

There is a need to periodically remove accumulated ash, derived from engine lubricating oil, from the Aftertreatment System (ATS). This ash does not oxidize in the filter during the regeneration process and must be removed through a cleaning procedure. All Detroit Diesel ATS-equipped engines will illuminate a dashboard warning lamp indicating the need for ash cleaning.

12.5.12 Air Compressor

The air compressor incorporates three of the major systems of a diesel engine (air, lubrication, and cooling). Proper inspection of air compressor would include inspecting for air, oil, and coolant leaks. Because the air compressor facilitates air, lubricating oil, and coolant flow, a failed air compressor could result in contamination between these three fluids. When failed, an air compressor can produce excessive crankcase pressure or allow an engine to ingest lubricating oil.

12.5.13 Fuel and Fuel Tank

Keep the fuel tank filled to reduce condensation.

Before adding fuel, refer to publication Engine Requirements–Lubricating Oil, Fuel and Filters (DDC–SVC–BRO–0001).

Refill the tank at the end of each day's operation to prevent condensation from contaminating the fuel. Condensation formed in a partially filled tank promotes the growth of microorganisms that can clog fuel filters and restrict fuel flow.

To prevent microbe growth, add a biocide to the fuel tank or primary fuel supply only as needed.

WARNING:

PERSONAL INJURY

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

NOTICE:

Never use galvanized steel fuel tanks, fittings, pipes, or supply lines. The fuel reacts chemically with the zinc coating to form powdery flakes that can quickly clog the fuel filters and damage the fuel pumps and injectors.

Open the drain at the bottom of the fuel tank every 30,000 miles (50,000 kilometers) to drain off any water and/or sediment.

Every 120,000 miles (200,000 kilometers) or 12 months tighten all fuel tank mountings and brackets. At the same time, check the seal in the fuel tank cap, the breather hole in the cap and the condition of the flexible fuel lines. Repair or replace the parts, as necessary.

12.5.14 Fuel Lines, Flexible Hoses

A prestart inspection of hoses and fuel lines is recommended.

12.5.14.1 Leaks

Make a visual check for fuel leaks at all engine-mounted fuel lines and connections, and at the fuel tank suction and return lines. Since fuel tanks are susceptible to road hazards, leaks in this area may best be detected by checking for an accumulation of fuel under the tank.

WARNING:

FIRE

To avoid injury from fire, contain and eliminate leaks of flammable fluids as they occur. Failure to eliminate leaks could result in fire.

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.

Leaks are not only detrimental to machine operation, but they can also result in added expense caused by the need to replace lost fluids.

12.5.14.2 Hoses and Fittings

Check hoses daily as part of the prestart inspection. Examine hoses for leaks, and check all fittings, clamps and ties carefully. Make sure hoses are not resting on or touching shafts, couplings, heated surfaces including exhaust manifolds, any sharp edges, or other obviously hazardous areas. Since all machinery vibrates and moves to a certain extent, clamps and ties can fatigue with age. To ensure continued proper support, inspect fasteners frequently and tighten or replace them as necessary. If fittings have loosened or cracked or if hoses have ruptured or worn through, take corrective action immediately.

12.5.14.3 Hose Service Life

A hose has a finite service life. With this in mind, all hoses should be thoroughly inspected at least every 500 operating hours (1,000 hours for fire-resistant fuel and lubricating oil hoses) and/or annually. Look for cover damage and/or indications of twisted, worn, crimped, brittle, cracked or leaking lines. Hoses with their outer cover worn through or with damaged metal reinforcements should be considered unfit for further service.

All hoses in and out of machinery should be replaced during major overhaul and/or after a maximum of five (5) years of service.

NOTE:
Fire-resistant fuel and lubricating oil hose assemblies do not require automatic replacement after five years of service or at major overhaul, but should be inspected carefully before being put back into service.

12.5.15 Turbocharger, Air-to-Air Charge Cooler, and Axial Power Turbine

Visually inspect the turbocharger and axial power turbine mountings, intake and exhaust ducting, and connections for leaks daily.

WARNING:

PERSONAL INJURY

To avoid injury from hot surfaces, wear protective gloves, or allow engine to cool before removing any component.

Check the lubricating oil inlet and outlet lines for leaks or restrictions to oil flow. Check for unusual noise or vibration and, if excessive, stop the engine and do not operate until the cause is determined.

Periodically inspect the air-to-air charge cooler for buildup of dirt, mud, etc. and wash off. Check the charge cooler, ductwork, and flexible connections for leaks and have repaired or replaced, as required.

12.5.16 Battery

Check the hydrometer “eye” of maintenance-free batteries for charge.

WARNING:

PERSONAL INJURY

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

If lead-acid or low-maintenance batteries are used, check the specific gravity of each cell every 150 operating hours. Check more frequently in warm weather due to the more rapid loss of water through evaporation.

Maintain the electrolyte level according to the battery manufacturer's recommendations, but *do not overfill.* Overfilling can cause poor battery performance or early failure.

Keep the terminal side of the battery clean. When necessary, wash with a solution of baking soda and water. Rinse with fresh water. Do not allow the soda solution to enter the cells.

Inspect the cables, clamps and hold-down brackets regularly. Clean and reapply a light coating of petroleum jelly when needed. Have corroded or damaged parts replaced.

If the engine is to be out of service for more than 30 days, remove the batteries and store in a cool, dry place. Keep batteries fully charged, if possible. Replace any battery that fails to hold a charge.

Periodically check battery connections for corrosion and tightness. If necessary, remove connections and wire brush any corrosion from terminals and cable ends. Replace damaged wiring.

12.5.17 Engine (Steam Clean)

Steam clean the engine and engine compartment every 60,000 miles (100,000 km) or 2,000 hours, whichever comes first.

NOTICE:

Do not apply steam or solvent directly to the battery-charging alternator, starting motor, DDEC components, sensors or other electrical components, as damage may result.

12.5.18 Battery-Charging Alternator

Precautions must be taken when working on or around the alternator. The diodes and transistors in the alternator circuit are very sensitive and can be easily destroyed.

To avoid equipment damage, pay attention to the following:

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.**

- Avoid grounding the output terminal. Grounding an alternator's output wire or terminal (which is always “hot,” regardless of whether or not the engine is running) and accidentally reversing the battery polarity will result in equipment damage.
- Do not reverse battery connections.
- Never disconnect the battery while the alternator is operating. Disconnecting the battery can result in damage to the battery diodes. In applications which have two (2) sets of batteries, switching from one set to the other while the engine is running will momentarily disconnect the batteries.

- If a booster battery is to be used, batteries must be connected correctly (negative to negative, positive to positive).
- Never use a fast charger with the batteries connected or as a booster for battery output.

For information on the alternator assembly, contact an authorized distributor, depending on manufacturer.

12.5.18.1 General Service Requirements – Alternators

Terminals should be checked for corrosion and loose connections and wiring inspected for damage and frayed insulation. Have wiring repaired or replaced, as required.

Check torque on alternator mounting bolts and bracketing every 30,000 miles (50,000 km). Retighten, if necessary.

12.5.19 Fan Hub

If the fan bearing hub assembly has a grease fitting, use a hand grease gun to lubricate the bearings with one shot of quality lithium-based, multipurpose grease every 120,000 miles (200,000 km).

Care should be taken not to overfill the bearing housing.

12.5.20 Vibration Damper

The viscous vibration damper should be inspected periodically and replaced if dented or leaking. Heat from normal engine operation may, over a period of time, cause the fluid within the damper to break down and lose its dampening properties. For this reason, the viscous vibration damper must be replaced at time of normal major engine overhaul, regardless of apparent condition.

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