

## **ENGINE SERVICE MANUAL**

### **MaxxForce® 15L Diesel Engine**

**Navistar, Inc.**

2701 Navistar Drive, Lisle, IL 60532 USA

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## Engine Identification

### Engine Serial Number

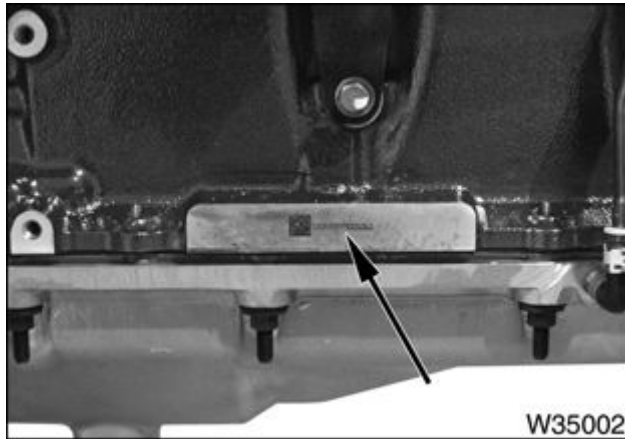


Figure 1 Engine serial number location

The engine serial number is located on the lower left side of the crankcase above the oil pan flange.

### Engine Serial Number Example

152HM2YXXXXXX

### Engine Serial Number Codes

- 15.2** – Engine displacement
- H** – Diesel, turbocharged, Charge Air Cooler (CAC) and electronically controlled
- M2** – Motor truck
- Y** – United States, Huntsville
- 7 digit suffix** – Engine serial number sequence

### Engine Emission Label

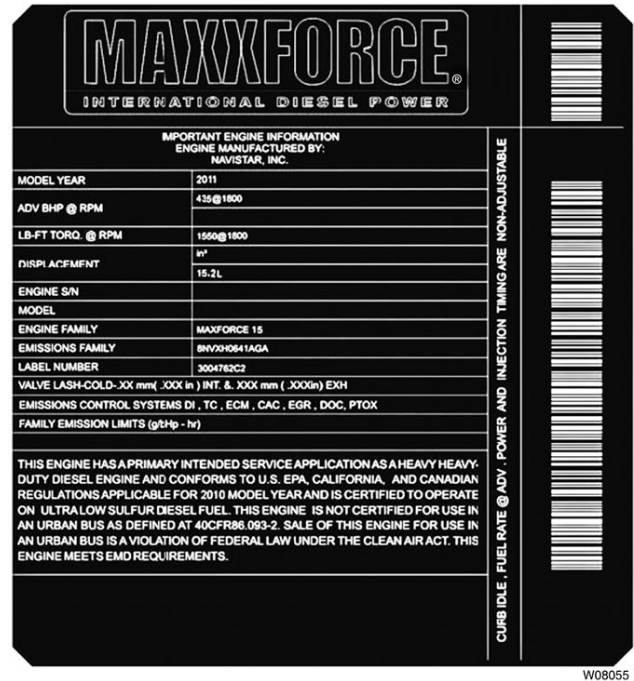


Figure 2 U.S. Environmental Protection Agency (EPA) exhaust emission label (example)

The U.S. Environmental Protection Agency (EPA) exhaust emission label is on top of the valve cover (front left side). The EPA label typically includes the following:

- Model year
- Engine family, model, and displacement
- Advertised brake horsepower and torque rating
- Emission family and control systems
- Valve lash specifications
- Engine serial number
- EPA, EURO, OBD and reserved fields for specific applications

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cylinder head. The intake manifold is an integral part of the cylinder head casting.

If the EGR control valve is closed, only filtered intake air flows through the ETV, mixing duct, and into the intake manifold.

During cold weather, the Cold Start Fuel Igniter (CSFI) rapidly heats the intake air by injecting and igniting small quantities of fuel into the mixing duct.

After combustion, gases exit through the cylinder head exhaust valves and ports. The exhaust gas is forced through the exhaust manifold where, depending on the EGR valve assembly position, is split between the EGR system and the exit path through the high-pressure turbocharger and low-pressure turbocharger.

The exhaust gases flow from the low-pressure turbocharger through the vehicle aftertreatment system to the exhaust tail pipe.

## **Air Management Components**

### **Turbochargers**

The MaxxForce® 15 engine is equipped with an electronically controlled, pneumatically actuated two stage turbocharging system. This system provides high levels of charge air pressure to improve engine performance and help reduce emissions. Because of its ability to generate very high charge air pressure levels, the system is fitted with an air control valve to control over-boost and surging conditions. The air control valve is supplied compressed air from the vehicle air supply tank. The compressed air flow to the wastegate actuator is electronically controlled by the air control valve based on the Pulse Width Modulated (PWM) signal supplied by the Engine Control Module (ECM). The high and low-pressure turbochargers are installed as an assembly on the exhaust manifold, on the right side of the engine.

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supplies high-pressure fuel to a pressure pipe rail, which feeds the injectors through individual tubes. Unused fuel from injectors is returned to the tank through a passage around the quill tubes in the cylinder head. The low-pressure fuel pump and high-pressure pump are assembled as one gear driven unit on the engine.

The fuel system is controlled by the ECM, various sensors, and the Fuel Pressure Control Valve (FPCV) located in the high-pressure pump.

In addition to providing high-pressure fuel to the injectors, the fuel system also provides low-pressure filtered fuel to the aftertreatment and cold start assist systems.

### DSI and Fuel Doser

In the aftertreatment system, filtered fuel from the fuel filter at supply pressure is delivered to the DSI assembly. The DSI assembly supplies precise amounts of fuel to the fuel doser.

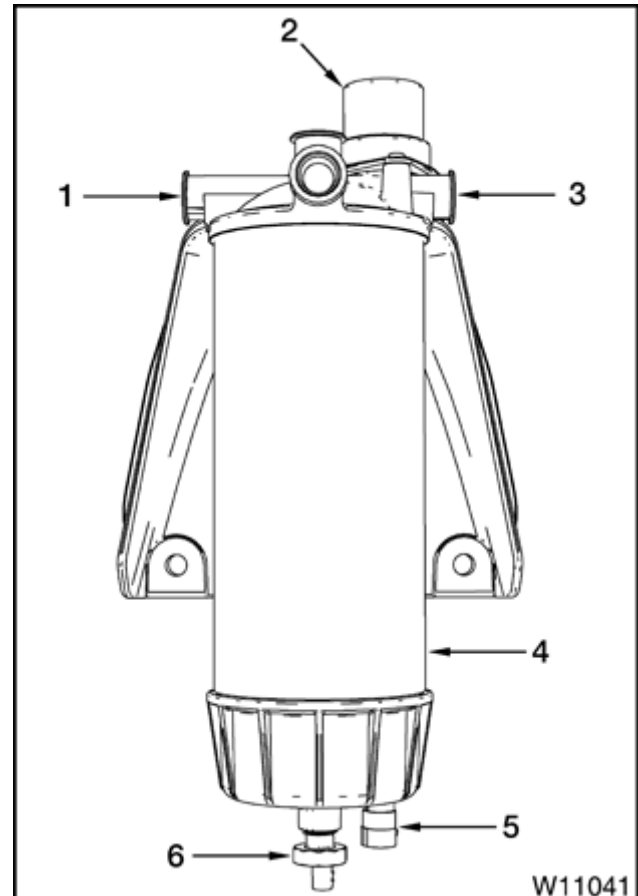
### Cold Start System

During cold weather, fuel is delivered to the Cold Start Fuel Igniter (CSFI) through the Cold Start Fuel Solenoid (CSFS). The CSFI then heats the intake air by injecting and igniting small quantities of fuel into the mixing duct.

### Fuel Filter and Housing

An orifice and an additional regulator located within the fuel filter housing work together to reduce fuel pressure to 10 psi for the cold start system solenoid. Supply system pressure is regulated by a pressure regulator valve located in the supply pump. Excess fuel relieved to achieve the pressure reduction is returned back to the fuel pump. The maximum system pressure is regulated to 1 300 kPa (189 psi).

### Chassis Mounted Components

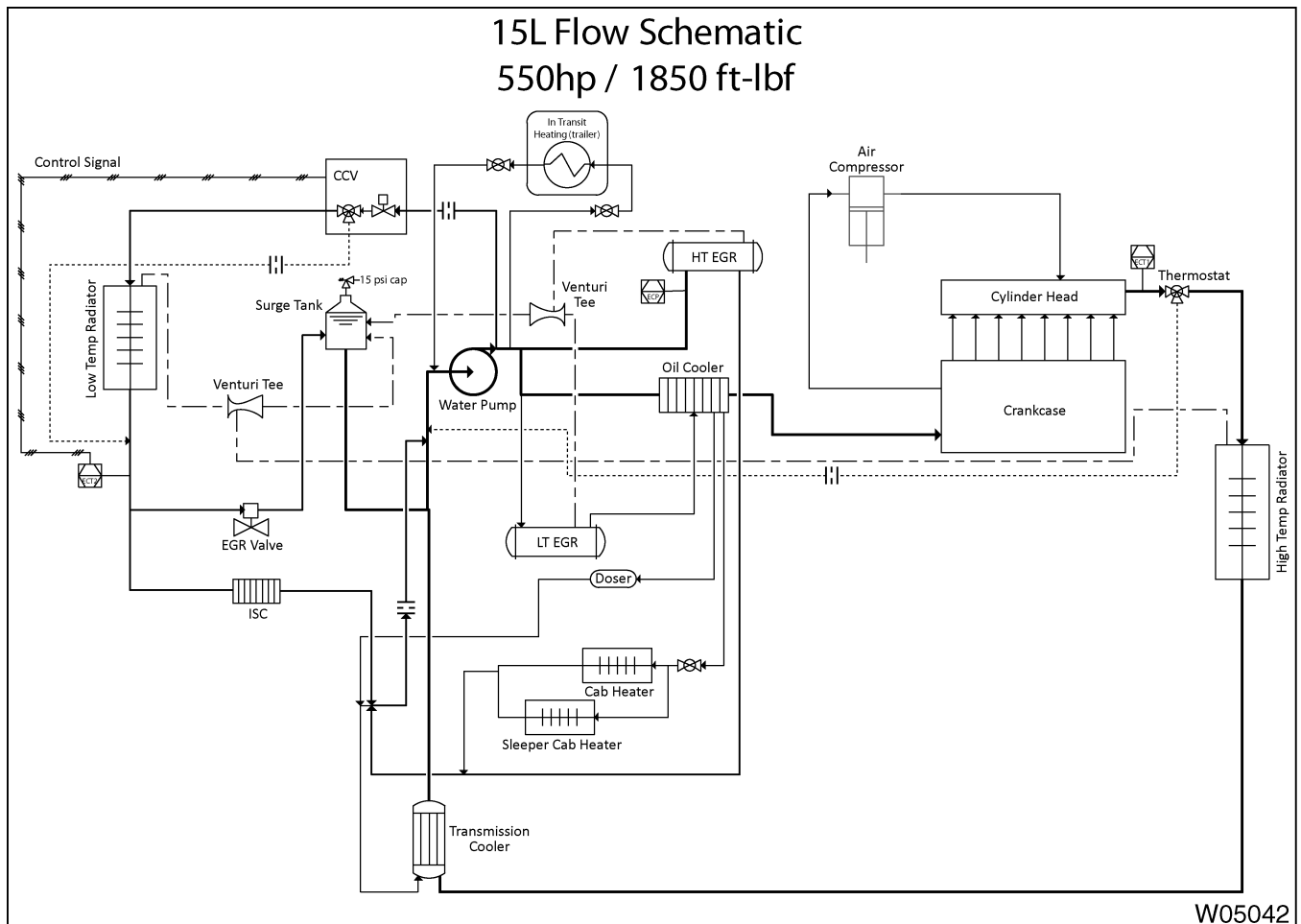


**Figure 16 Racor® fuel filter assembly**

1. Fuel outlet
2. Fuel primer pump assembly
3. Fuel inlet from tank
4. Fuel filter water separator assembly
5. Water In Fuel (WIF) sensor
6. Drain valve

### Fuel Filter and Water Separator Assembly

The Racor® fuel filter/water separator assembly is standard equipment. There is also an optional Davco® fuel filter water separator available depending on customer needs.



**Figure 24 Cooling system flow (automatic transmission)**

The water pump is located on the front cover and draws coolant from the radiator through the coolant inlet at the lower right side of the engine. The water pump pushes coolant to the oil cooler through a passage in the front cover.

Coolant flows to the crankcase and through the water jacket from rear to front. This coolant flows around the cylinder liners to absorb heat from combustion. The coolant may also pass through an optional engine coolant heater.

Coolant flows through the cylinder head water jackets towards the thermostat cavity at the front of the cylinder head. Depending on coolant temperature, the thermostat can direct into two directions to exit the cylinder head.

When the thermostat is closed, coolant is directed through the bypass port, crankcase and front cover, and into the water pump.

When the thermostat is open, the bypass port is blocked, and coolant is directed from the engine into the radiator. Coolant passes through the radiator and is cooled by moving air from the radiator fan. The coolant returns to the engine first through the transmission cooler, then through the engine water inlet pipe.

The air compressor is cooled with engine coolant supplied by a hose from the left side of the crankcase. Coolant passes through the air compressor cylinder head and returns through a hose back into the crankcase through the engine water inlet pipe.

The fuel doser is also cooled with engine coolant supplied by the oil cooler module. Coolant passes

**RAM**

RAM stores temporary information for current engine conditions. Temporary information in RAM is lost when the ignition switch is turned to OFF or power to control module is interrupted. RAM information includes the following:

- Engine temperature
- Engine rpm
- Accelerator pedal position

**Actuator Control**

The ECM controls the actuators by applying a low level signal (low side driver) or a high level signal (high side driver). When switched on, both drivers complete a ground or power circuit to an actuator.

Actuators are controlled in one of the following ways, depending upon type of actuator:

- Pulse Width Modulated (PWM)
- Switched on or off
- CAN messages

**Actuators**

The ECM controls engine operation with the following:

- Coolant Flow Valve (CFV)
- Coolant Mixer Valve (CMV)
- Exhaust Gas Recirculation (EGR) valve
- Air control valves (TC1WC and TC2WC)
- Cold Start Fuel Solenoid (CSFS)
- Cold Start Relay (CSR)
- Engine Throttle Valve (ETV)
- Fuel Pressure Control Valve (FPCV)

**Coolant Flow Valve and Coolant Mixer Valve**

The Coolant Flow Valve (CFV) controls the maximum pressure in the LTR and the Coolant Mixer Valve (CMV) regulates the temperature of the coolant by directing the coolant either through the Low Temperature Radiator (LTR) or through an internal bypass. Both valves are controlled by the ECM.

The CFV and CMV are part of the Coolant Control Valve (CCV) assembly which is mounted on the lower right side of the engine.

**Exhaust Gas Recirculation (EGR) Valve Assembly**

The EGR valve assembly controls the flow of exhaust gases entering the EGR cooler assembly.

The EGR valve operates on a Pulse Width Modulated (PWM) voltage signal from the ECM. The ECM will then regulate the duty cycle of the PWM voltage signal to the EGR valve assembly actuator to open or close the valve as required.

A sensor within the EGR valve provides feedback to the ECM on the valve position. A fault code will be set if the ECM detects an error.

The EGR valve assembly is mounted on the rear of the EGR cooler assembly, on the right side of the engine.

**Air Control Valve**

The air control valve controls the wastegate actuator on the high-pressure turbocharger.

The air control valve either applies air pressure to the wastegate actuator, or vents system pressure to the atmosphere in response to commands from the ECM.

The air control valve is mounted on a bracket on the right side of the engine, below the secondary EGR cooler.

**Cold Start Relay (CSR)**

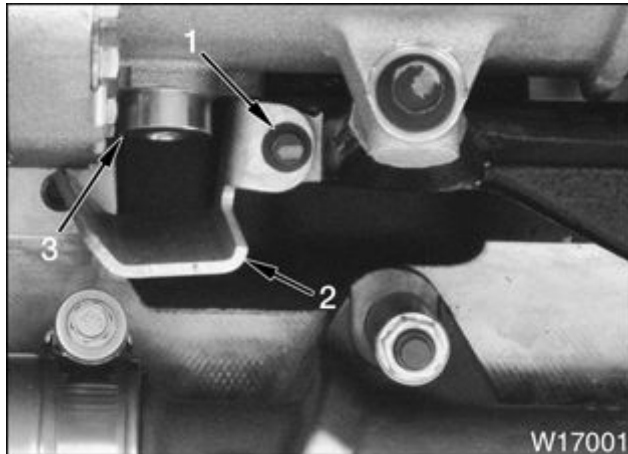
The cold start assist system aids cold engine starting by warming the incoming air supply during cranking and initial idling.

The CSR is a solid state relay that is pulse width modulated by the ECM to energize the CSFI. The CSFI is case grounded to the ETV assembly. The total time that the CSR energizes the CSFI is dependent on engine coolant temperature.

**Cold Start Fuel Solenoid (CSFS)**

The CSFS valve controls the fuel flow to the CSFI during cold start assist operation.

When the cold start assist is required, the ECM provides voltage to open the CSFS valve during cranking and initial idling.



**Figure 36 Low Temperature EGR cooler assembly M18 O-ring boss plug**

1. M6 x 12 hex flange bolt
2. EGRC coolant drain guide
3. M18 O-ring boss plug

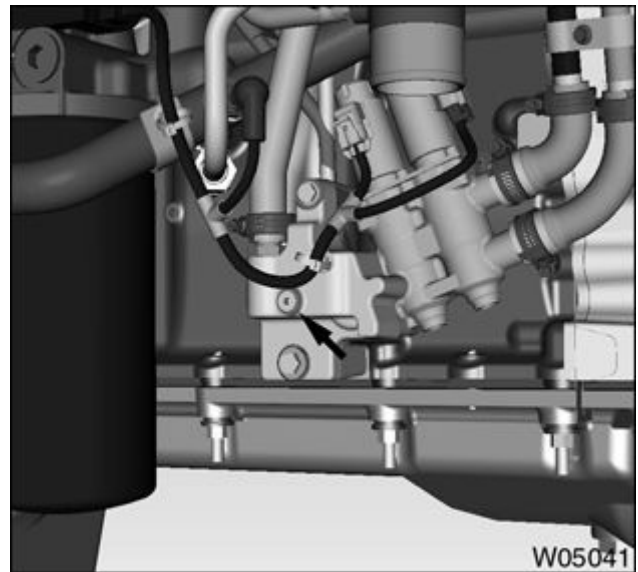
**⚠ WARNING:** To prevent personal injury or death, allow engine to cool before draining coolant.

18. Place coolant drain pan under the low temperature EGR cooler assembly.

**CAUTION:** To prevent engine damage, the EGRC coolant drain guide must be installed during reassembly before running the engine. The EGRC coolant drain guide also acts as a heat shield and provides protection from heat damage to the M18 O-ring boss plug O-ring.

19. Remove M6 x 12 hex flange bolt and the EGRC coolant drain guide.
20. Remove M18 O-ring boss plug from the bottom of the EGR cooler assembly.
21. Remove and discard M18 O-ring boss plug O-ring.
22. Install new O-ring on the M18 O-ring boss plug.
23. After coolant has drained, install M18 O-ring boss plug in the EGR cooler assembly.

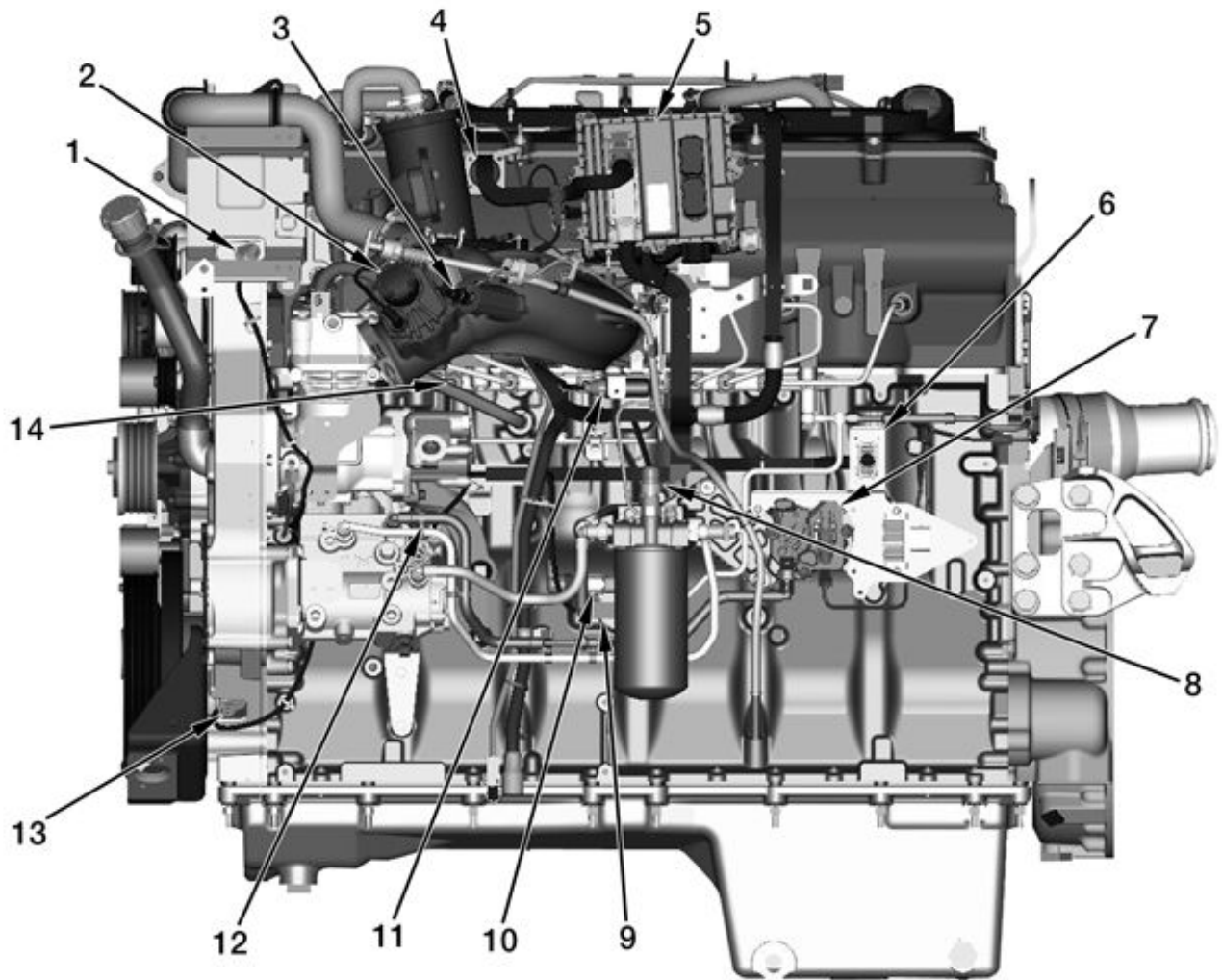
24. Tighten M18 O-ring boss plug to special torque (page 61).
25. Recycle or dispose of engine coolant according to applicable regulations.
26. During reassembly, install the EGRC coolant drain guide and M6 x 12 hex flange bolt. Tighten M6 x 12 hex flange bolt to standard torque (page 561).



**Figure 37 Coolant adapter plug assembly**

**⚠ WARNING:** To prevent personal injury or death, allow engine to cool before draining coolant.

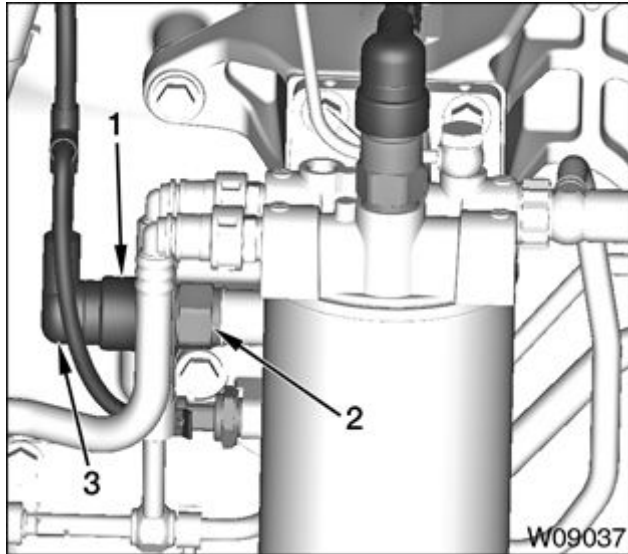
27. Place coolant drain pan under the coolant adapter.
28. Remove plug assembly and allow coolant to drain.
29. Install new O-ring on plug assembly.
30. Install plug assembly and tighten to special torque (page 61).
31. Recycle or dispose of engine coolant according to applicable regulations.



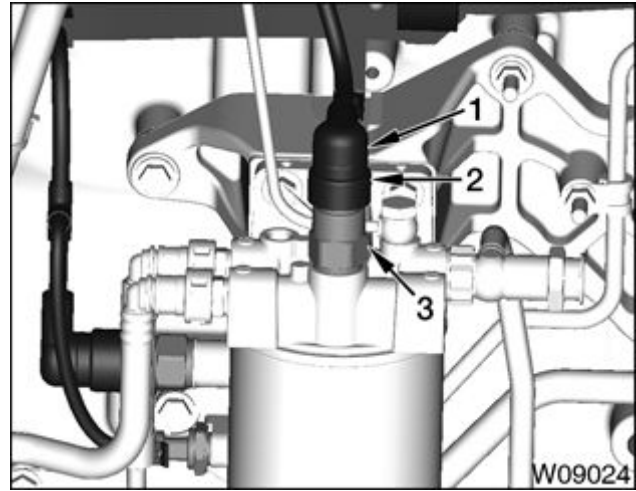
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**Figure 44 Electronic components – left**

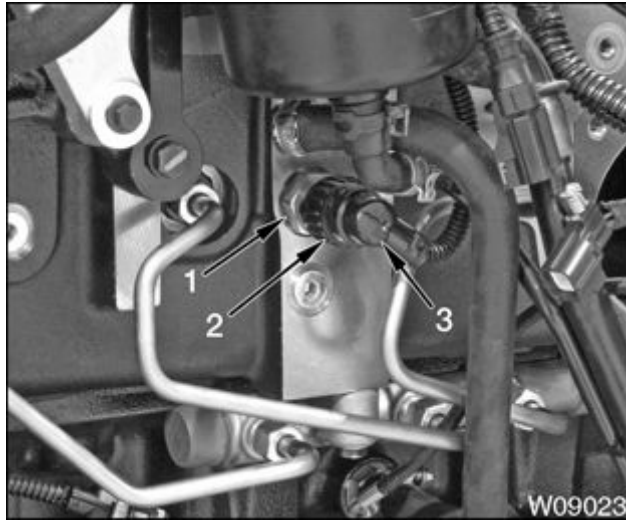
- |   |   |  |
|---|---|--|
| 1. Camshaft Position (CMP) sensor (behind alternator) | 7. Down Stream Injection (DSI) assembly | 11. Cold Start Fuel Solenoid (CSFS)          |
| 2. Engine throttle valve assembly                     | 8. Fuel Delivery Pressure (FDP) sensor  | 12. Injection Pressure Regulator (IPR) valve |
| 3. Cold Start Fuel Igniter (CSFI)                     | 9. Crankcase Pressure (CCP) sensor      | 13. Crankshaft Position (CKP) sensor         |
| 4. Engine injector harness assembly                   | 10. Engine Oil Pressure (EOP) sensor    | 14. Fuel Rail Pressure (FRP) sensor          |
| 5. Engine Control Module (ECM)                        |   |  |
| 6. Body harness interconnect                          |   |  |

**Engine Oil Pressure (EOP) Sensor****Figure 68 EOP sensor**

1. Locking collar
  2. Engine Oil Pressure (EOP) sensor
  3. Electrical connector
1. Turn EOP sensor electrical connector locking collar 90° counterclockwise.
  2. Disconnect electrical connector from EOP sensor installed in oil pressure sensor support behind fuel filter assembly.
  3. Remove EOP sensor and discard 18.7 x 26.0 x 1.5 seal ring.
  4. Cover exposed oil pressure sensor support opening using Disposable Air and Fuel Caps (page 110).

**Fuel Delivery Pressure (FDP) Sensor****Figure 69 FDP sensor**

1. Electrical connector
  2. Locking collar
  3. Fuel Delivery Pressure (FDP) sensor
1. Turn FDP sensor electrical connector locking collar 90° counterclockwise.
  2. Disconnect electrical connector from FDP sensor installed on top of fuel filter assembly.
  3. Remove FDP sensor and discard 16.7 x 24 seal ring.
  4. Cover exposed fuel filter assembly opening using Disposable Air and Fuel Caps (page 110).

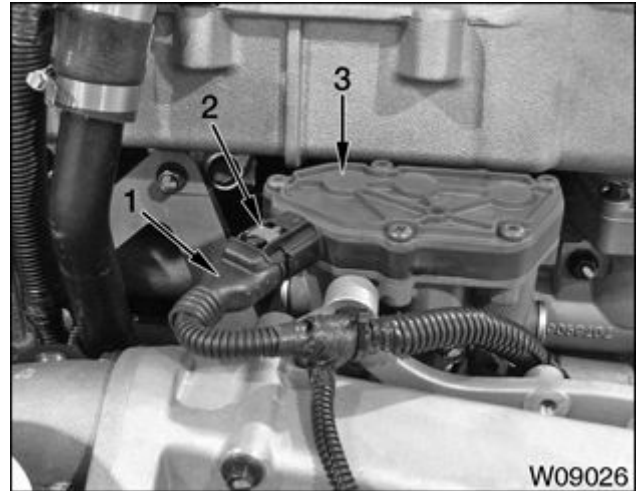
**Intake Manifold Temperature (IMT) Sensor****Figure 88** IMT sensor

1. Intake Manifold Temperature (IMT) sensor
2. Locking collar
3. Electrical connector

**NOTE:** This engine is equipped with several temperature sensors of similar physical construction. If removing or replacing a temperature sensor, observe and record the part number identification embossed on the hex face of the sensor body. Replace only with a temperature sensor of the same part number.

1. Turn IMT sensor electrical connector locking collar 90° counterclockwise.
2. Disconnect electrical connector from IMT sensor installed on cylinder head below breather filter assembly.

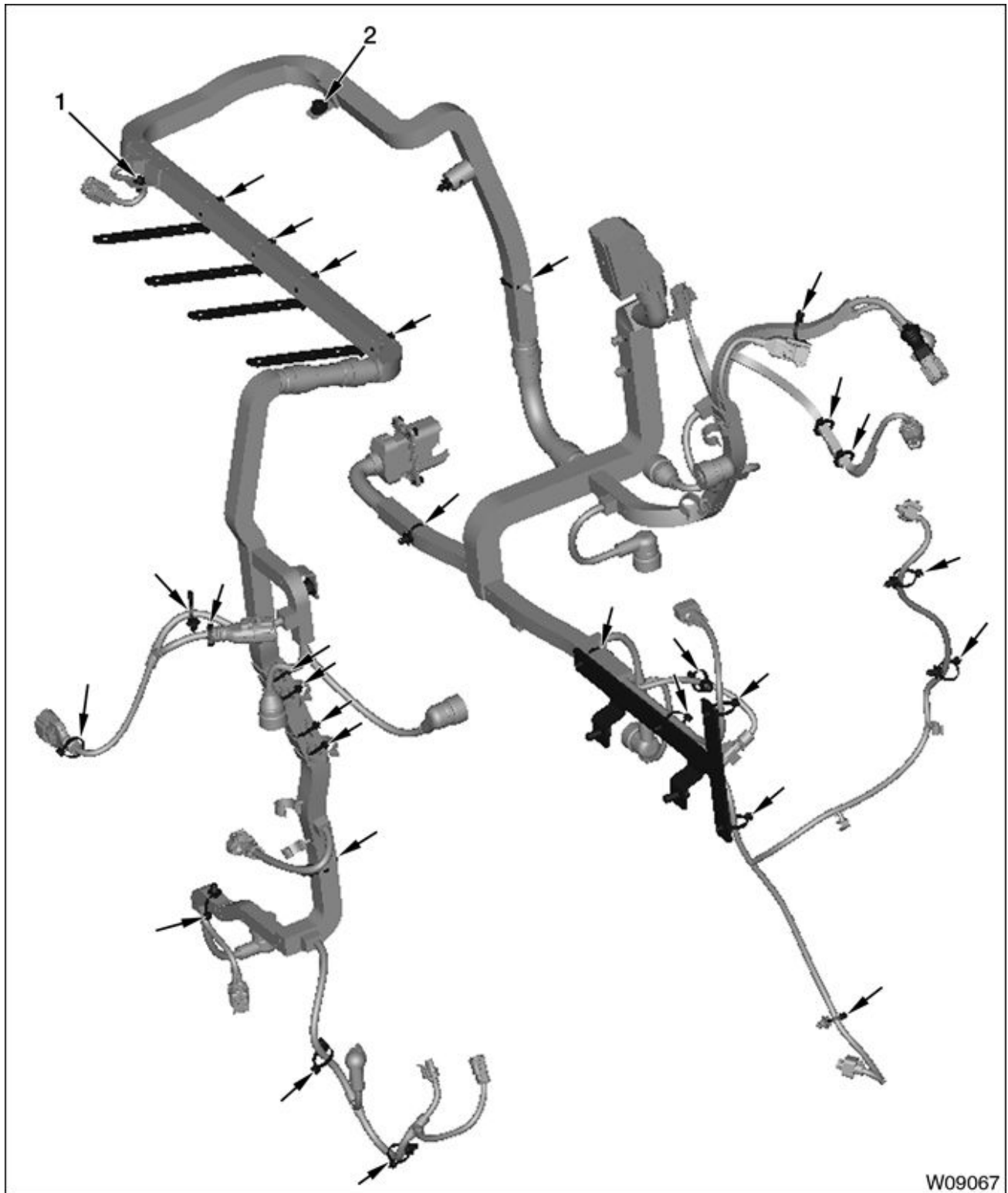
3. Remove IMT sensor and discard 16.7 x 24 seal ring.

**Air Control Valve Connector****Figure 89** Air control valve

1. Electrical connector
2. Red locking tab
3. Air control valve

1. Pull out red locking tab on electrical connector.
2. Press release lever and disconnect electrical connector from air control valve installed at right front of engine below front of EGR cooler assembly.

**NOTE:** For removal of air control valve, see Air Control Valve (page 150).

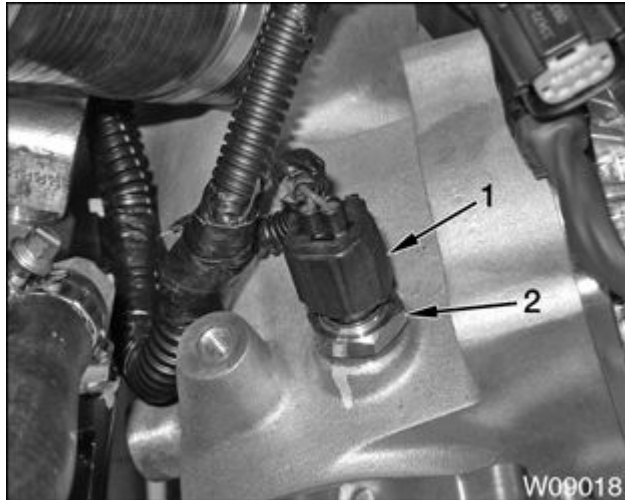


**Figure 104 Engine sensor harness assembly fasteners and tie strap locations**

1. M6 x 12 hex flange bolt
2. 5/16-18 hex nut

### Charge Air Cooler Outlet Temperature (CACOT) Sensor

1. Lubricate new O-ring with P-80® rubber lubricant or equivalent (page 110) and install on CACOT sensor.



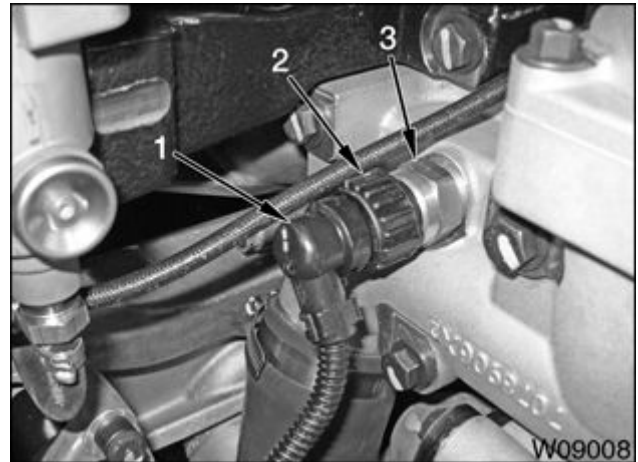
**Figure 123 CACOT sensor**

1. Electrical connector
  2. Charge Air Cooler Outlet Temperature (CACOT) sensor
2. Install CACOT sensor on engine throttle valve assembly and tighten to special torque (page 110).
  3. Connect electrical connector by pushing in until the release lever clicks into place (click may be heard or felt).

### Engine Coolant Temperature 1 (ECT1) Sensor

**NOTE:** This engine is equipped with several temperature sensors of similar physical construction. Install a temperature sensor of the same part number as the one removed. Part number identification is embossed on the hex face of the sensor body.

1. Install new 16.7 x 24 seal ring on ECT1 sensor.



**Figure 124 ECT1 sensor**

1. Electrical connector
  2. Locking collar
  3. Engine Coolant Temperature 1 (ECT1) sensor
2. Install ECT1 sensor on thermostat housing and tighten to special torque (page 110).
  3. Connect electrical connector and turn locking collar 90° clockwise.

## Installation

### Cold Start Fuel Igniter (CSFI)

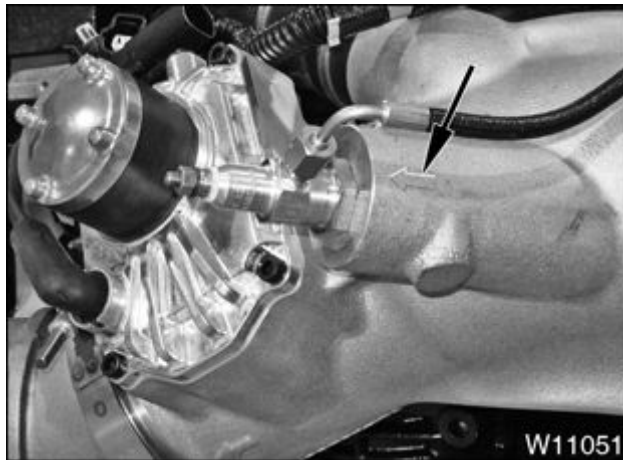


Figure 137 Alignment mark

**NOTE:** Use the alignment mark embossed on engine throttle valve assembly to properly orient both the Cold Start Fuel Igniter (CSFI) and connecting solenoid to injector tube.

1. Loosely install CSFI. Position CSFI so solenoid to injector tube connection is oriented with the alignment mark on engine throttle valve assembly.

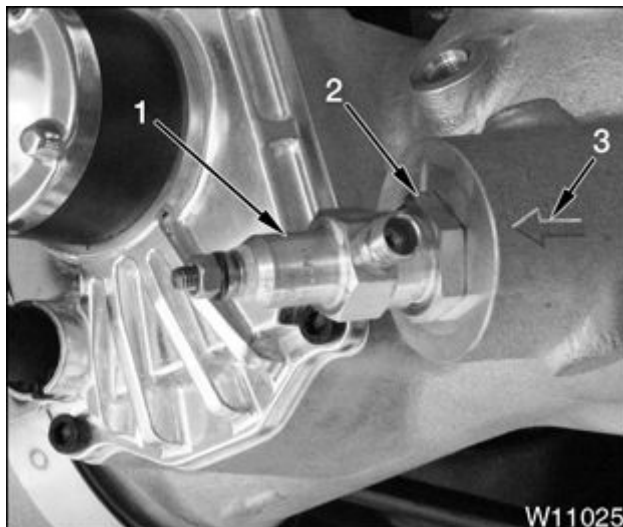


Figure 138 CSFI

1. Cold Start Fuel Igniter (CSFI)
2. CSFI locking nut (part of CSFI)
3. Alignment mark

2. If solenoid to injector tube was removed, keep CSFI loosely installed. Tighten CSFI to final torque only after installing solenoid to injector tube and ensuring proper CSFI to tube alignment. See Solenoid to Injector Tube (page 118) for installation of solenoid to injector tube.
3. Connect solenoid to injector tube nut onto loosely installed CSFI. Tighten solenoid to injector tube nut to special torque (page 121).
4. Hold CSFI with backup wrench to maintain proper orientation. Tighten CSFI locking nut to special torque (page 121).

### Cold Start Fuel Solenoid (CSFS)

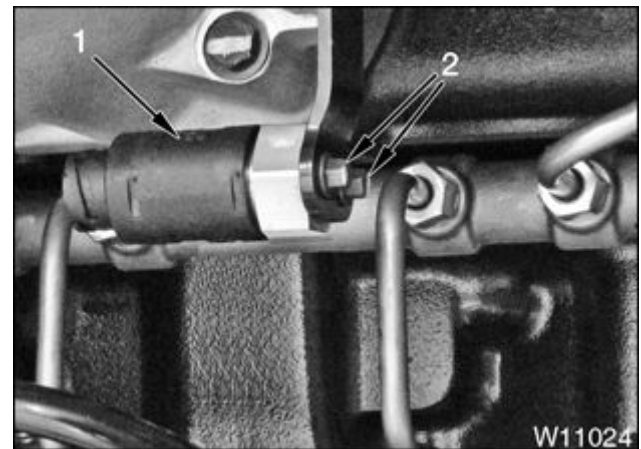


Figure 139 CSFS

1. Cold Start Fuel Solenoid (CSFS)
2. M6 x 12 hex flange bolt (2)

Install two M6 x 12 hex flange bolts and CSFS. Tighten bolts to special torque (page 121).

## Removal



**GOVERNMENT REGULATION:** Engine fluids (oil, fuel, and coolant) may be a hazard to human health and the environment. Handle all fluids and other contaminated materials (e.g. filters, rags) in accordance with applicable regulations. Recycle or dispose of engine fluids, filters, and other contaminated materials according to applicable regulations.

**! WARNING:** To prevent personal injury or death, read all safety instructions in the “Safety Information” section of this manual.

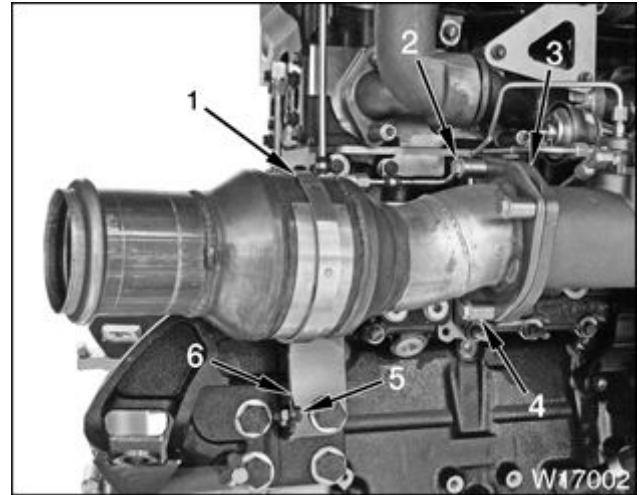
**! WARNING:** To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

**! WARNING:** To prevent personal injury or death, make sure that the engine has cooled before removing components.

**! WARNING:** To prevent personal injury or death, do not let engine fluids stay on your skin. Clean skin and nails using hand cleaner and wash with soap and water. Wash or discard clothing and rags contaminated with engine fluids.

**! WARNING:** To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

## Pre-Diesel Oxidation Catalyst (PDOC)



**Figure 148 PDOC tube assembly**

1. Clamp (PDOC)
2. M10 x 50 hex bolt (3)
3. Engine brake gasket
4. 11 ID x 20 OD x 24L spacer (3)
5. M10 x 20 hex bolt (3)
6. PDOC support assembly

1. Remove three M10 x 20 hex bolts from PDOC support assembly.
2. Remove three M10 x 50 hex bolts and three 11 ID x 20 OD x 24L spacers. Remove PDOC from turbocharger outlet. Discard engine brake gasket.
3. If required, loosen PDOC clamp and remove PDOC from PDOC support assembly.

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**Special Torque**

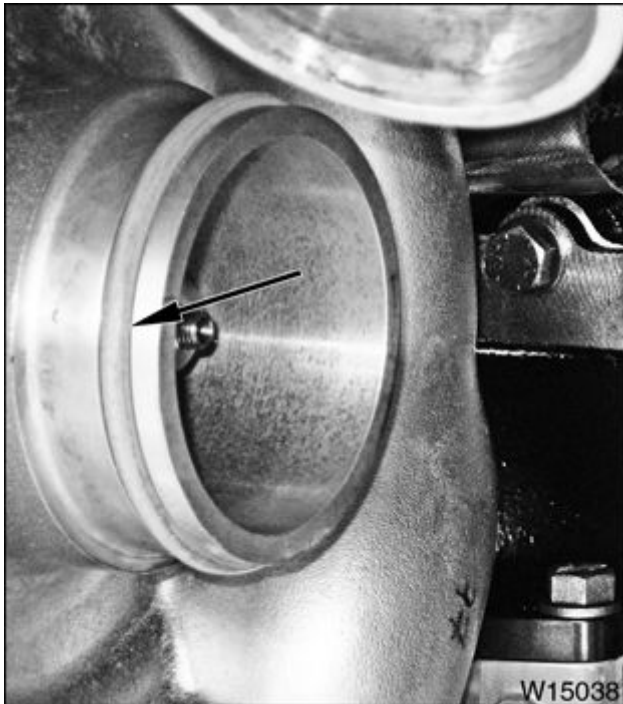
M8 x 45 bolts (fuel doser)	Step 1: 11 N·m (8 lbf·ft) Step 2: 24 N·m (18 lbf·ft)
M10 x 20 hex bolts (PDOC support assembly)	62 N·m (45 lbf·ft)
M10 x 5/16 tube fitting	31 N·m (23 lbf·ft)
Clamp (PDOC)	31 N·m (23 lbf·ft)
Coolant supply tube fitting nuts	20 N·m (15 lbf·ft)
Doser coolant return tube assembly nut	20 N·m (15 lbf·ft)
Doser coolant supply tube assembly nuts	20 N·m (15 lbf·ft)
Doser fuel from valve tube nuts	24 N·m (18 lbf·ft)
Doser fuel to injector tube nuts	24 N·m (18 lbf·ft)
Injector unit feed tube fittings	20 N·m (15 lbf·ft)
Tube fitting (90 degree elbow) jam nut	20 N·m (15 lbf·ft)

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**Special Service Tools**

Description	Tool Number
Fuel Line Disconnect Tool	ZTSE4773

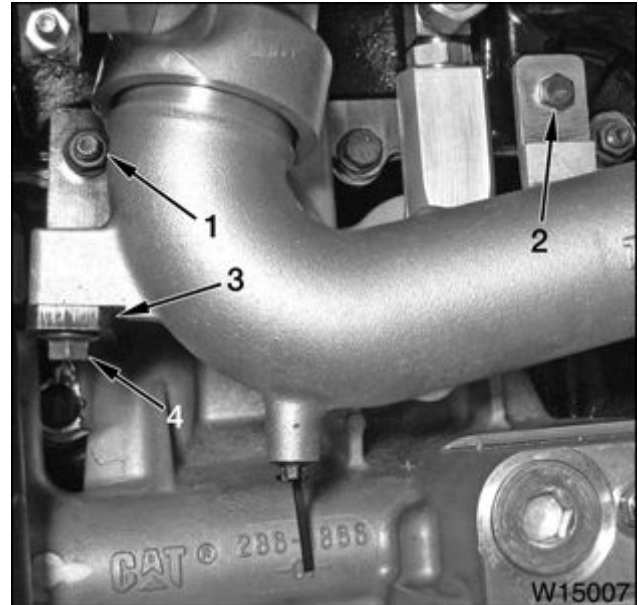
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**Figure 181 LP turbocharger inlet O-ring (size 337)**

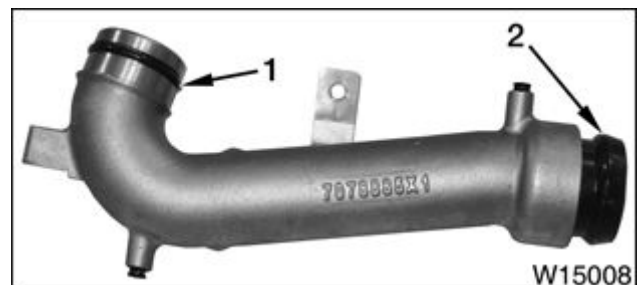
3. Remove and discard O-ring (size 337) from low-pressure turbocharger compressor inlet.

### Turbocharger to Intercooler Tube



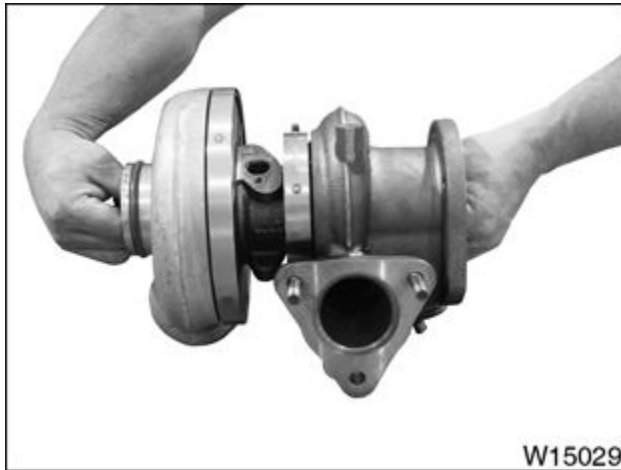
**Figure 182 Turbocharger to ISC tube**

1. 3/8-16 nut
  2. 5/16-18 x 1 bolt
  3. Turbocharger to intercooler tube support
  4. M10 x 30 bolt
1. Remove 3/8-16 nut, 5/16-18 x 1 bolt, and M10 x 30 bolt. Remove turbocharger to ISC tube and turbocharger to intercooler tube support.



**Figure 183 Turbocharger to ISC tube seals**

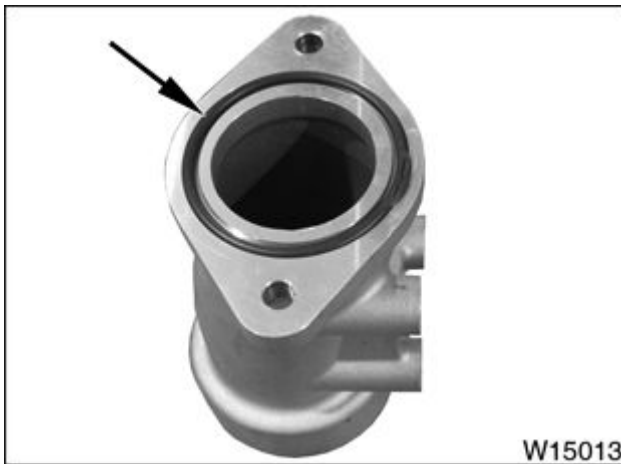
1. O-ring (size 329)
  2. 72.2 x 60 tube seal
2. Remove and discard O-ring (size 329).
  3. Remove and discard 72.2 x 60 tube seal.



**Figure 206 Free rotation of turbocharger assembly shaft (typical)**

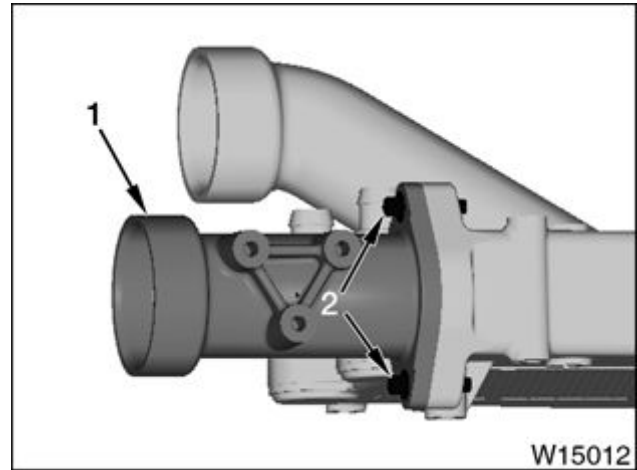
4. Turn turbine shafts by hand and check for wheel rub in each housing. The wheels must rotate freely. If there is any rubbing or interference, replace turbocharger.

**Turbocharger Interstage Cooler Assembly (ISC) Pressure Test**



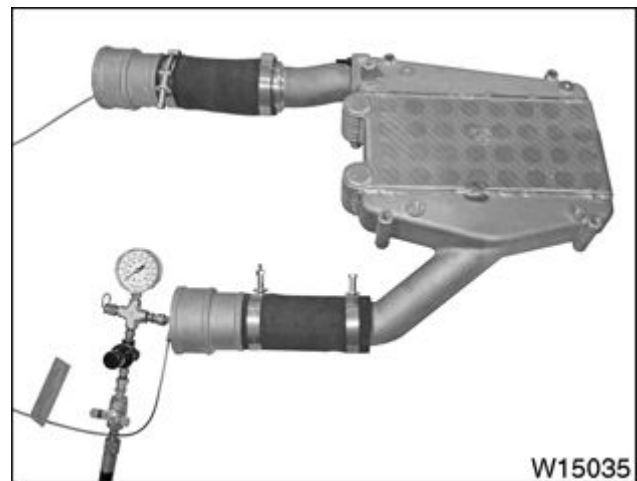
**Figure 207 ISC outlet tube 2-230 3.53 x 63.09 O-ring**

1. Place a new 2-230 3.53 x 63.09 O-ring in groove on ISC outlet tube.



**Figure 208 ISC outlet tube**

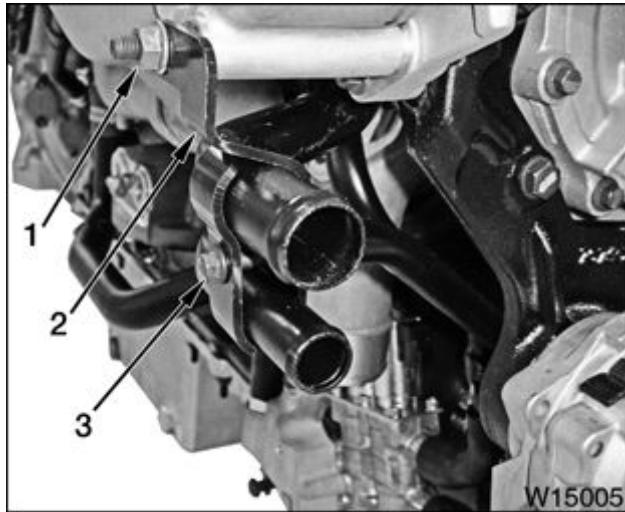
1. ISC outlet tube
  2. M8 x 35 hex flange bolt (2)
2. Install ISC outlet tube on ISC. Install M8 x 35 hex flange bolts. Tighten bolts to standard torque (page 561).



**Figure 209 ISC pressure test setup**

3. Attach Charge Air Cooler Tester Kit (page 170) to ISC using instructions supplied with tool and three inch couplers and clamps (obtain locally).

**⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).**

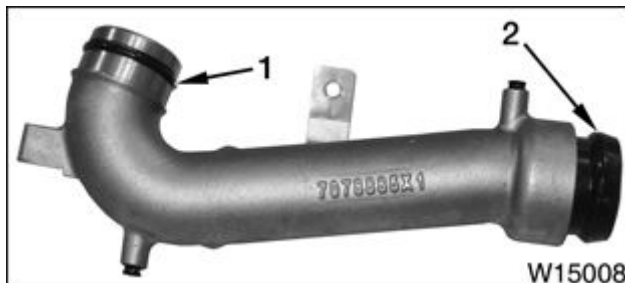


**Figure 231 CAC coolant pipe bracket**

1. M8 hex flange nut
2. EGR tube support assembly
3. M6 x 35 hex flange bolt

11. Position CAC coolant pipe bracket on M8 x 100 x 18 stud bolt and install M8 hex flange nut. Tighten nut to standard torque (page 561).
12. Install M6 x 35 bolt. Tighten bolt to standard torque (page 561).

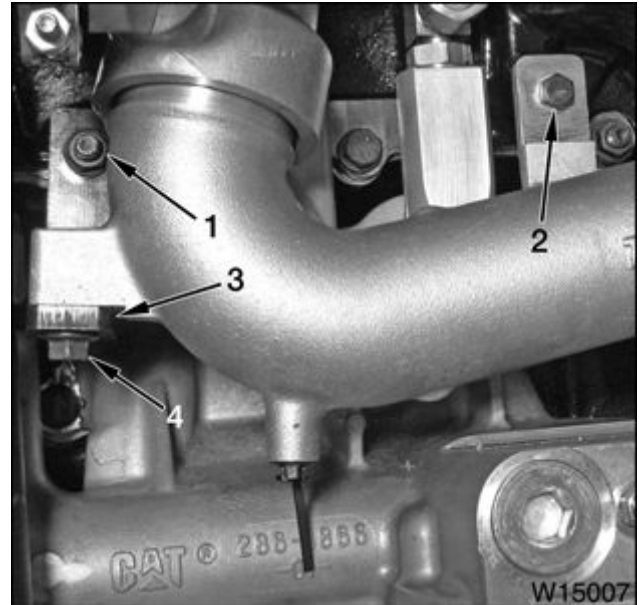
**Turbocharger to Intercooler Tube**



**Figure 232 Turbocharger to ISC tube seals**

1. O-ring (size 329)
2. 72.2 x 60 tube seal

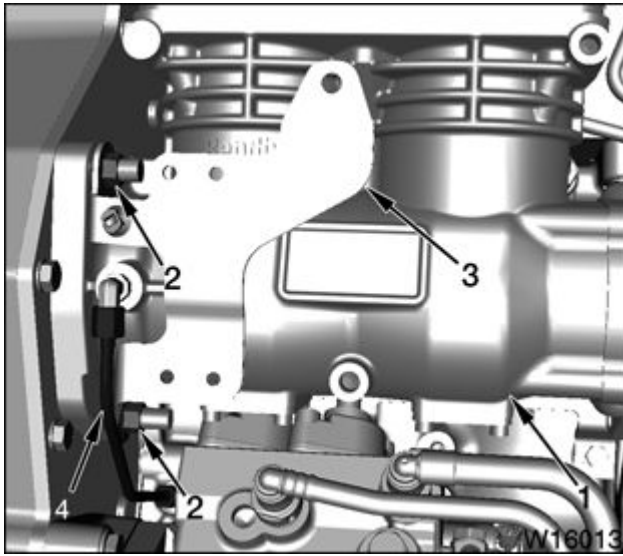
1. Install new intake O-ring (size 329). Lubricate O-ring with P-80® rubber lubricant or equivalent (page 170).
2. Install new 72.2 x 60 tube seal using Interstage Cooler Pipe to High-Pressure Turbo Extension Tube Seal Installer (page 170). Lubricate tube seal with P-80® rubber lubricant or equivalent (page 170) to ease installation.



**Figure 233 Turbocharger to ISC tube**

1. 3/8-16 nut
2. 5/16-18 x 1 bolt
3. Turbocharger to intercooler tube support
4. M10 x 30 bolt

3. Install turbocharger to intercooler tube into ISC and then into outlet of low-pressure turbocharger.
4. Install turbocharger to intercooler tube support. Install 3/8-16 nut finger tight.
5. Install 5/16-18 x 1 bolt. Tighten 5/16-18 x 1 bolt and 3/8-16 nut to standard torque (page 562).
6. Install M10 x 30 bolt. Tighten M10 x 30 bolt to standard torque (page 561)



**Figure 245 Air compressor/harness support (typical)**

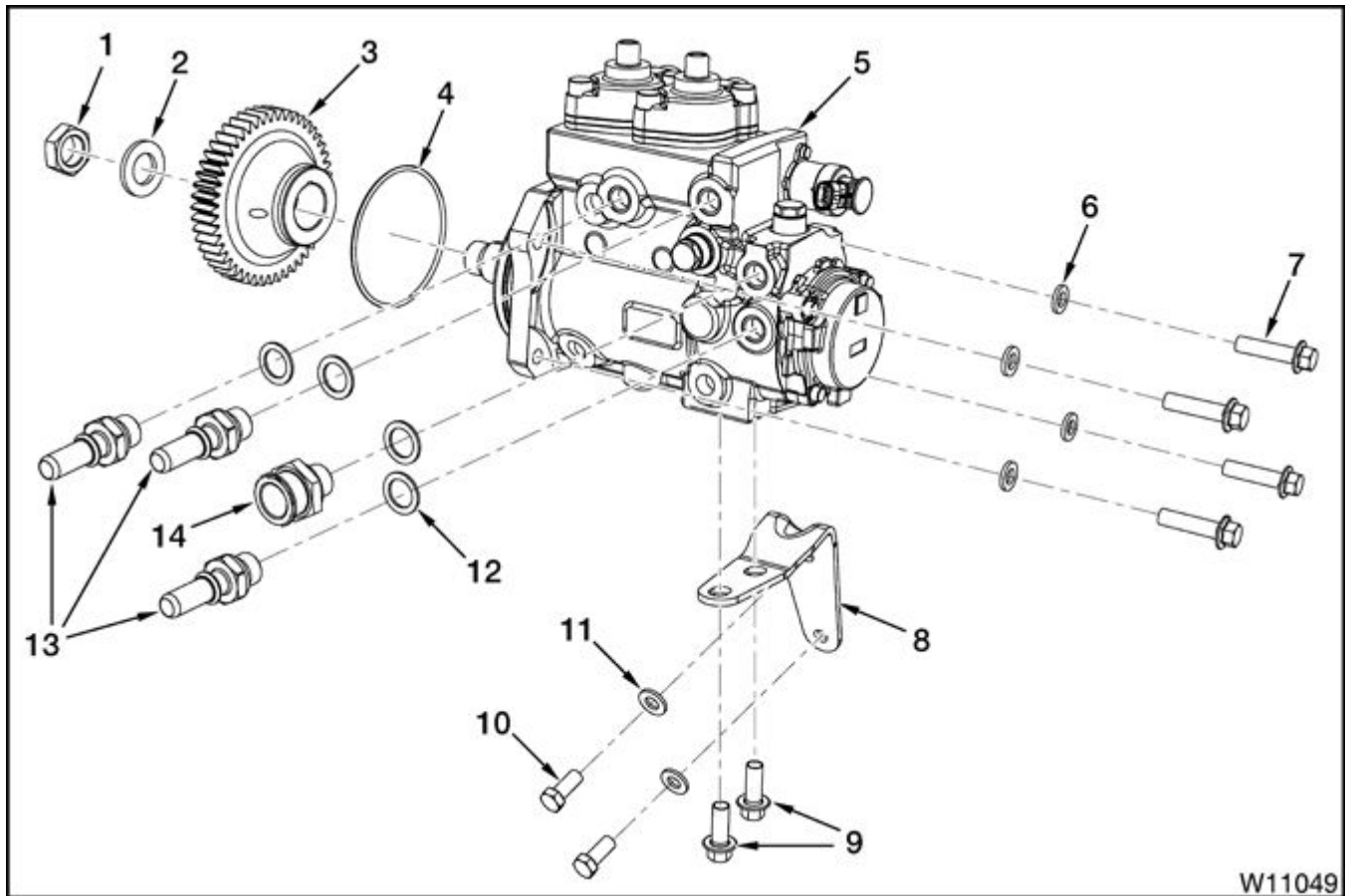
1. Air compressor
  2. 1/2–13 hex flange nut (3) (one behind compressor, not shown)
  3. Harness support
  4. Air compressor oil inlet tube assembly
3. Disconnect air compressor oil inlet tube assembly tube nut from connection on side of air compressor.

4. While supporting the air compressor, remove (2) 1/2–13 hex flange nuts securing harness support on outside of air compressor.
5. While continuing to support the air compressor, remove remaining 1/2–13 hex flange nut securing air compressor to the rear of the front cover plate (on back side of compressor).
6. Remove air compressor from studs.
7. Remove and discard seal.

## Cleaning

### All Components

1. Cover coolant, fluid and air openings to ensure dirt does not enter air compressor and power steering pump.
2. Clean foreign material from gasket surfaces of air compressor. Use a scraper to remove gasket from gasket surfaces.
3. Use only hot water to clean all hoses and tubes.



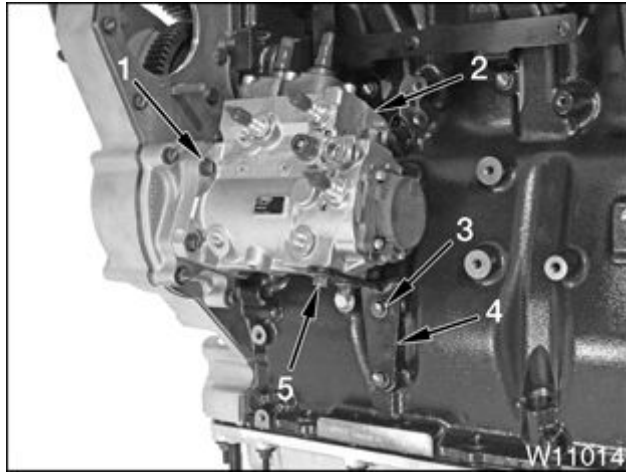
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Figure 257 High-pressure fuel pump

- |                            |                                    |   |
|----------------------------|------------------------------------|---|
| 1. M24 hex jam nut         | 6. Plain washer (4)                | 11. 3/8 hardened washer (2)               |
| 2. M25 x 44 x 4 washer     | 7. M10 x 40 hex flange bolt (4)    | 12. 16.7 x 24 ring seals (4)              |
| 3. High-pressure pump gear | 8. High-pressure pump support      | 13. M16 x 1.5 quick connect connector (3) |
| 4. 100 x 3.349 O-ring      | 9. M12 x 30 hex flange bolt (2)    | 14. M16 x 1.5 female connector            |
| 5. High-pressure fuel pump | 10. 3/8-16 x 7/8 hex head bolt (2) |   |

## Installation

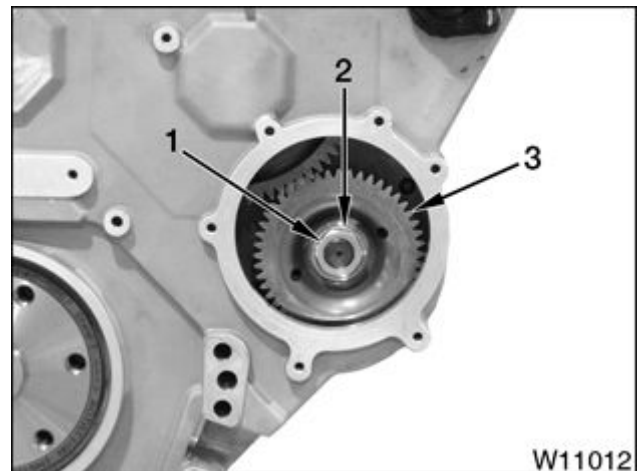
### High-Pressure Fuel Pump



**Figure 276 High-pressure fuel pump**

1. M10 x 40 hex flange bolt and plain washer (4 ea)
  2. M16 x 1.5 quick connect connector (3)
  3. M16 x 1.5 female connector
  4. High-pressure fuel pump
  5. 3/8-16 x 7/8 hex head bolt and 3/8 hardened washer (2 ea)
  6. High-pressure pump support
  7. M12 x 30 hex flange bolt (2)
1. If removed, install three M16 x 1.5 quick connect connectors and the M16 x 1.5 female connector with four new 16.7 x 24 ring seals on high-pressure fuel pump. Tighten the M16 x 1.5 quick connect connectors and the M16 x 1.5 female connector to special torque (page 204).
  2. Install a new 100 x 3.349 O-ring on front of high-pressure fuel pump. Ensure the O-ring is properly seated in the respective groove before tightening the bolts.
  3. Install two High-Pressure Pump Alignment Studs (page 204) in the high-pressure pump adapter.
  4. Position the high-pressure fuel pump on the High-Pressure Pump Alignment Studs (page 204) through the engine front cover.
  5. Clean oil residue from bolt threads with non-chlorinated solvent. Apply Loctite® 242 (page 204) to threads on M10 x 40 hex flange bolts.

6. Install two plain washers and two M10 x 40 hex flange bolts. Tighten hex flange bolts to standard torque (page 561).
7. Remove two High-Pressure Pump Alignment Studs (page 204) from the high-pressure pump adapter.
8. Install two plain washers and two M10 x 40 hex flange bolts. Tighten hex flange bolts to standard torque (page 561).
9. Clean oil residue from bolt threads with non-chlorinated solvent. Apply Loctite® 242 (page 204) to threads on 3/8 -16 x 7/8 bolts and M12 x 30 hex flange bolts.
10. Position the high-pressure pump support and install two 3/8 hardened washers, two 3/8-16 x 7/8 hex head bolts and two M12 x 30 hex flange bolts. Tighten the two 3/8-16 x 7/8 hex head bolts and two M12 x 30 hex flange bolts to special torque (page 204).



**Figure 277 High-pressure pump gear**

1. M24 hex jam nut
  2. M25 x 44 x 4 washer
  3. High-pressure pump gear
11. Position high-pressure pump gear on the high-pressure fuel pump shaft.
  12. Install M25 x 44 x 4 washer and M24 hex jam nut. Tighten M24 hex jam nut to special torque (page 204).
  13. Lubricate the high-pressure pump gear with 90 W gear oil (page 204).

Exploded Views

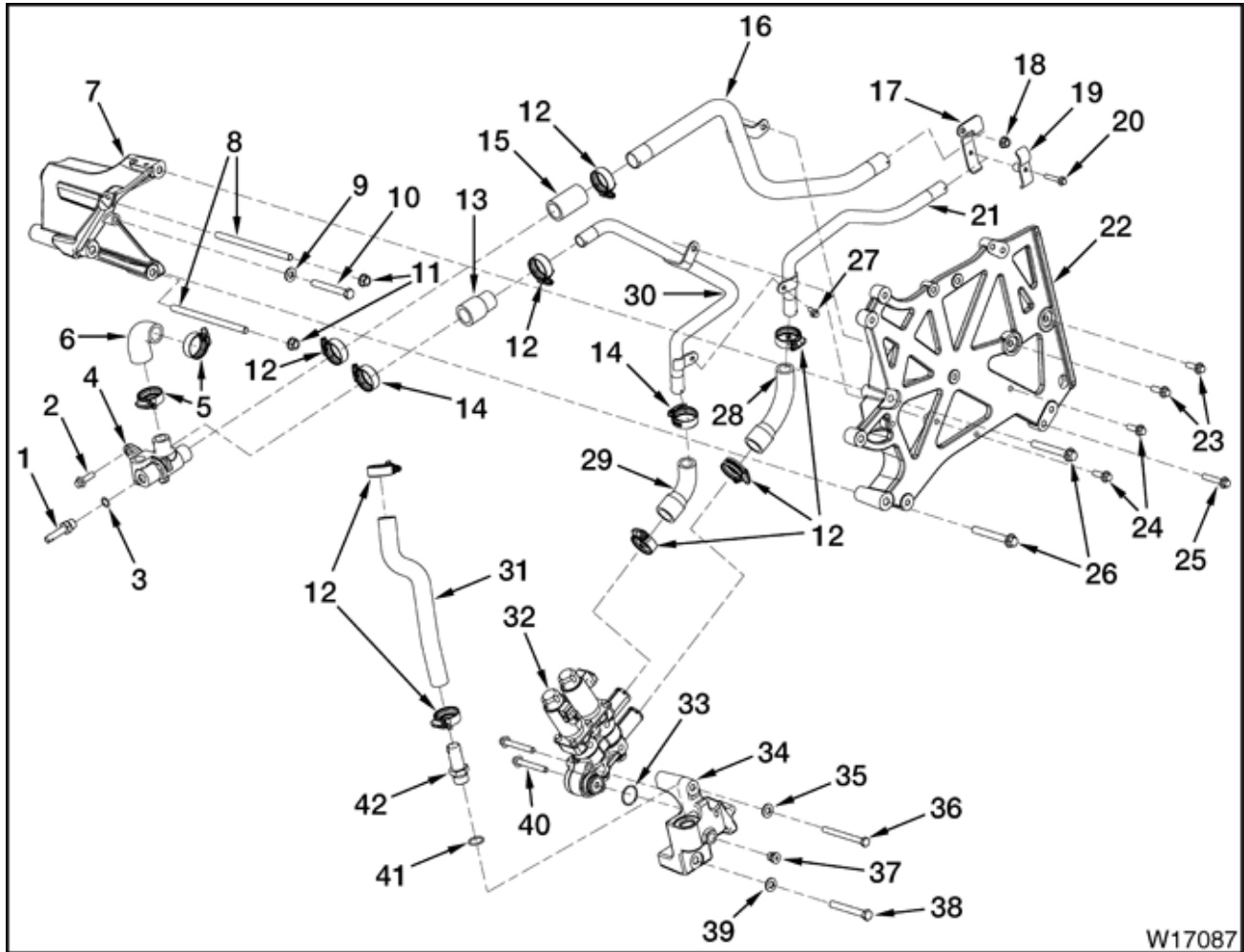
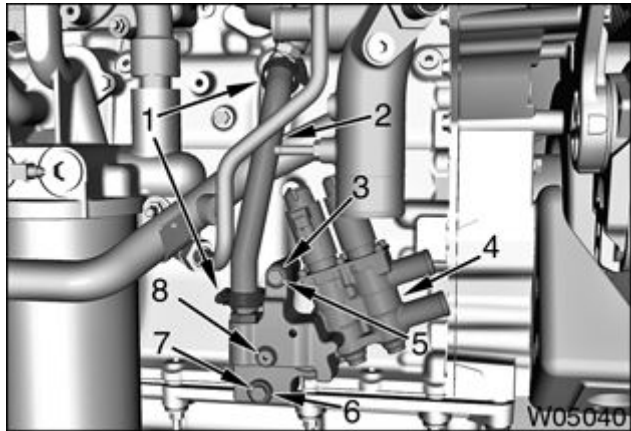


Figure 290 Interstage Cooler (ISC) support and coolant lines

- |                                       |                                      |  |
|---------------------------------------|--------------------------------------|--|
| 1. Hose fitting                       | 16. ISC coolant supply tube assembly | 30. CCV LTR bypass tube assembly         |
| 2. M8 x 25 hex flange bolt            | 17. EGR tube support assembly        | 31. CCV coolant supply hose assembly     |
| 3. O-ring                             | 18. M8 hex flange nut                | 32. Coolant Control Valve (CCV) assembly |
| 4. Coolant manifold                   | 19. EGR tube clamp                   | 33. O-ring (26 x 2.0)                    |
| 5. SAE 16 clamp (2)                   | 20. M6 x 35 hex flange bolt          | 34. Coolant adapter                      |
| 6. HPCAC supply and return hose       | 21. CCV LTR supply tube assembly     | 35. 8.8 x 17 x 1.6 washer                |
| 7. Intercooler support (inner)        | 22. Intercooler support (outer)      | 36. 5/16-18 x 3 1/2 hex bolt             |
| 8. 3/8-16 x 6 1/2 taper lock stud (2) | 23. M8 x 25 hex flange bolt (2)      | 37. Plug assembly                        |
| 9. 3/8 hardened washer                | 24. M8 x 30 hex flange bolt (2)      | 38. 3/8-16 x 3 hex bolt                  |
| 10. 3/8-16 x 3 hex bolt               | 25. M8 x 45 hex flange bolt          | 39. 10.2 x 18.5 hardened washer          |
| 11. 3/8-16 hex flange nut (2)         | 26. M8 x 80 hex flange bolt (2)      | 40. M8 x 60 hex flange bolt (2)          |
| 12. SAE 15/16 left clip clamp (8)     | 27. M6 x 16 hex flange bolt          | 41. O-ring (3-910)                       |
| 13. Adapter hose                      | 28. 3/4 to 1 inch elbow hose (lower) | 42. Hose fitting                         |
| 14. SAE 16 clamp (2)                  | 29. 3/4 to 1 inch elbow hose (upper) |  |
| 15. 24.6 x 52 coolant hose            |                                      |  |

**Coolant Control Valve (CCV) Assembly and Coolant Adapter**

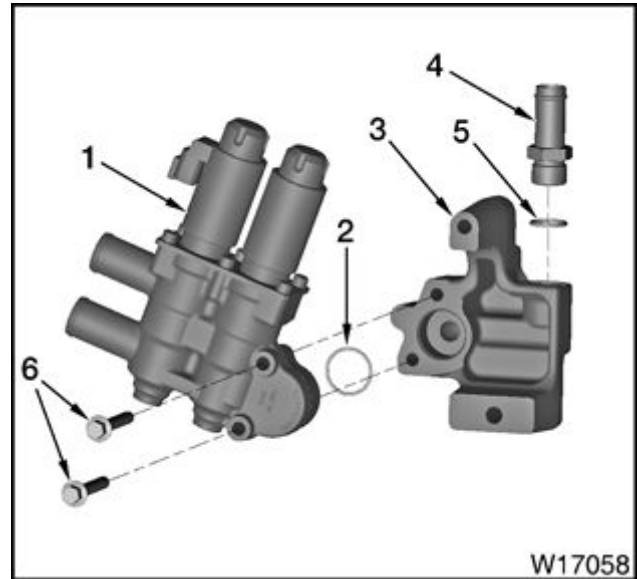


**Figure 300 CCV assembly and coolant adapter**

1. SAE 15/16 left clip clamp (2)
2. CCV supply hose assembly
3. 8.8 x 17 x 1.6 washer
4. CCV assembly
5. 5/16-18 x 3 1/2 hex bolt
6. 10.2 x 18.5 x 5 hardened washer
7. 3/8-16 x 3 hex bolt
8. Plug assembly

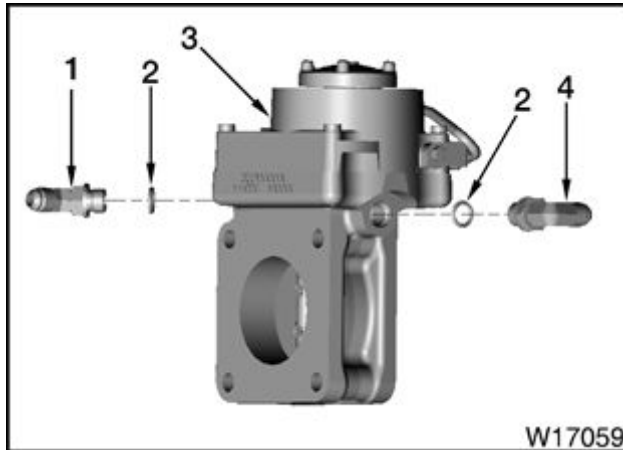
1. Loosen upper SAE 15/16 left clip clamp.
2. Remove 5/16-18 x 3 1/2 hex bolt and 8.8 x 17 x 1.6 washer.
3. Remove 3/8-16 x 3 hex bolt with 10.2 x 18.5 x 5 hardened washer.
4. Remove CCV and coolant adapter with CCV supply hose assembly.

5. If necessary, loosen remaining SAE 15/16 left clip clamp and remove CCV supply hose assembly.



**Figure 301 CCV assembly and coolant adapter (exploded view)**

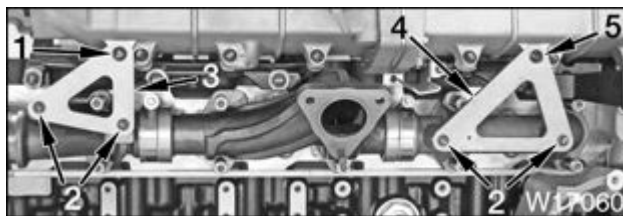
1. CCV assembly
  2. O-ring (26 x 2.0)
  3. Coolant adapter
  4. Hose fitting
  5. O-ring (3-910)
  6. M8 x 60 hex flange bolt (2)
6. Remove two M8 x 60 hex flange bolts and separate coolant adapter from CCV assembly. Remove and discard O-ring (26 x 2.0).



**Figure 322 EGR valve assembly and coolant fittings**

1. Fitting (45 degree)
  2. O-ring (M14) (2)
  3. EGR valve assembly
  4. M14 37 degree flare fitting (90 degree)
6. If required, remove two fitting (45 degree) from EGR valve assembly. Remove and discard O-ring (M14).
  7. If required, remove M14 37 degree flare fitting (90 degree) from EGR valve assembly. Remove and discard O-ring (M14).

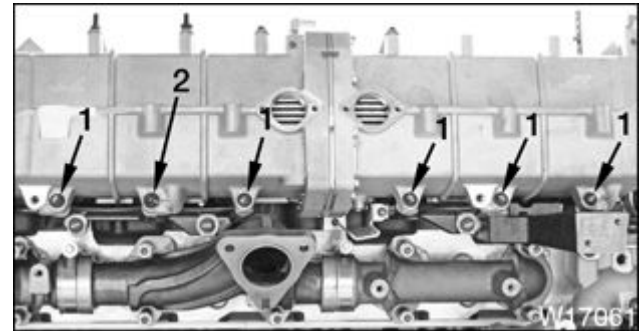
**EGR Cooler Assembly**



**Figure 323 EGR cooler supports**

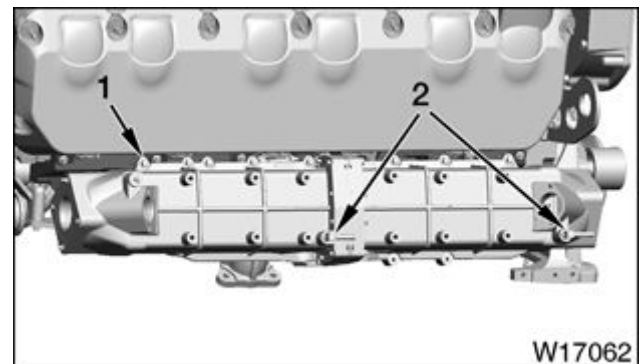
1. M10 x 30 hex flange bolt
  2. M8 x 27 high temp bolt (4)
  3. EGR cooler support (rear)
  4. EGR cooler support (front)
  5. M10 x 20 x 35 hex flange stud bolt
1. Remove M10 x 30 hex flange bolt and two M8 x 27 high temp bolts at EGR cooler support (rear). Remove EGR cooler support (rear).

2. Remove M10 x 20 x 35 hex flange stud bolt and two M8 x 27 high temp bolts at EGR cooler support (front). Remove EGR cooler support (front).



**Figure 324 EGR cooler assembly lower bolts**

1. M10 x 45 hex flange bolt (5)
  2. M10 x 45 stud bolt
3. Remove five M10 x 45 hex flange bolts and M10 x 45 stud bolt from bottom of EGR cooler assembly.



**Figure 325 EGR cooler assembly upper bolts**

1. M8 x 45 hex flange bolts (6)
  2. M10 90 degree 3/8 hose fitting (2)
4. If required, remove two M10 90 degree 3/8 hose fittings from EGR cooler.
  5. With help from an assistant or using EGR Cooler Lifting Tool (page 255) and hoist, hold EGR cooler assembly to prevent it from falling and remove six M8 x 45 hex flange bolts. Lift EGR cooler assembly from engine.



0000045726

**Figure 342 Air Pressure Regulator Assembly adjustment knob**

8. Release the air pressure from EGR cooler assembly by rotating the adjustment knob on the Air Pressure Regulator Assembly clockwise until the air pressure gauge reads 0 kPa (0 psi).
9. Verify air pressure reads 0 kPa (0 psi). Close valve on Air Pressure Regulator Assembly.



0000045721

**Figure 343 Shop air hose removal**

10. Disconnect shop air from Air Pressure Regulator Assembly.

**NOTE:** Do not disassemble Safety Relief Valve or Air Pressure Regulator Assembly from Test Plugs with O-ring.

11. Remove Test Plug with O-ring from upper coolant passage of the LT EGR cooler and install it to the upper coolant passage of the HT EGR cooler. Tighten two M8 hex bolts to 13.6 N·m (120 lbf·in).
12. Remove Test Plug with O-ring from lower coolant passage of the LT EGR cooler and install it to the lower coolant passage of the HT EGR cooler. Tighten two M8 hex bolts to 13.6 N·m (120 lbf·in).
13. Repeat steps 3 through 10 to leak test the HT EGR cooler.

#### Tool Removal

1. Remove M10 Plugs with O-ring from EGR cooler assembly deaeration ports. Store for reuse.
2. If necessary, install two M10 90-degree 3/8 hose fittings with O-rings in EGR cooler assembly deaeration ports. Tighten to 8 N·m (71 lbf·in).

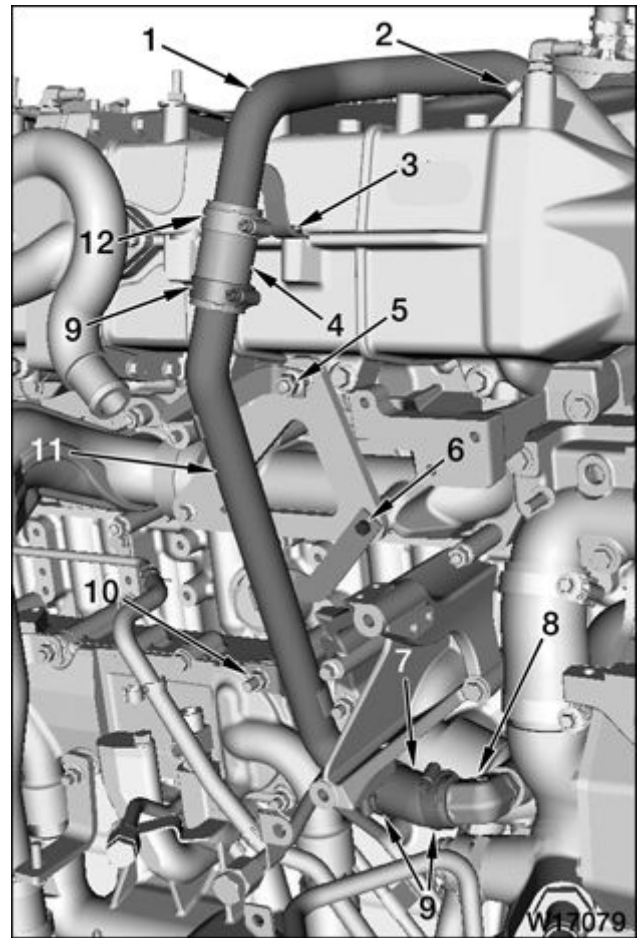
6. Install 3/8–16 hex flange nut at oil cooler module and M8 hex flange nut at upper bracket on EGR coolant tube assembly. Tighten nuts to standard torque (page 561).
7. Place 8.8 x 16 x 2 hardened washer (under bracket) on stud of EGR cooler.
8. Install EGR coolant tube assembly (rear), clamps, and adapter hose. Tighten two M8 x 20 hex flange bolts and M8 hex flange nut to standard torque (page 561).
9. Tighten clamps to special torque (page 255).

**EGR Coolant Tube Assembly (front) and EGR2 Coolant Supply Tube Assembly**



**Figure 366 EGR coolant tube assembly O-ring seal (2-221)**

1. Install a new O-ring seal (2-221) on EGR coolant tube assembly (front)



**Figure 367 EGR coolant tube assembly (front)**

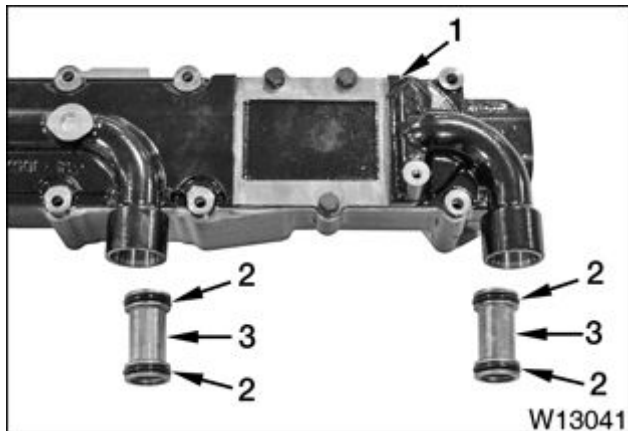
1. EGR coolant tube assembly (front)
  2. M8 x 25 hex flange bolt (2)
  3. M6 x 12 hex flange bolt
  4. SAE 24 left clip clamp
  5. 31.75 x 69 coolant hose
  6. SAE 24 clamp (3)
  7. M10 hex flange nut
  8. EGR2 coolant supply tube assembly
  9. 1 1/4 inch formed hose
  10. 90 degree fitting assembly (on water pump outlet pipe)
2. Lubricate with P-80® rubber lubricant or equivalent (page 255) and install a new O-ring on 90 degree fitting assembly and install fitting. Do not tighten fitting nut at this time.
  3. Assemble EGR coolant tube assembly (front) to EGR2 coolant supply tube assembly with 31.75

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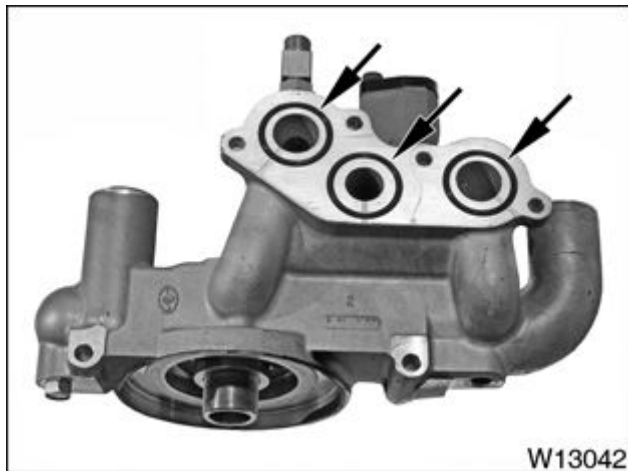
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**Figure 387 Connecting tubes**

1. Engine oil cooler assembly
2. O-ring (4)
3. Tube (2)

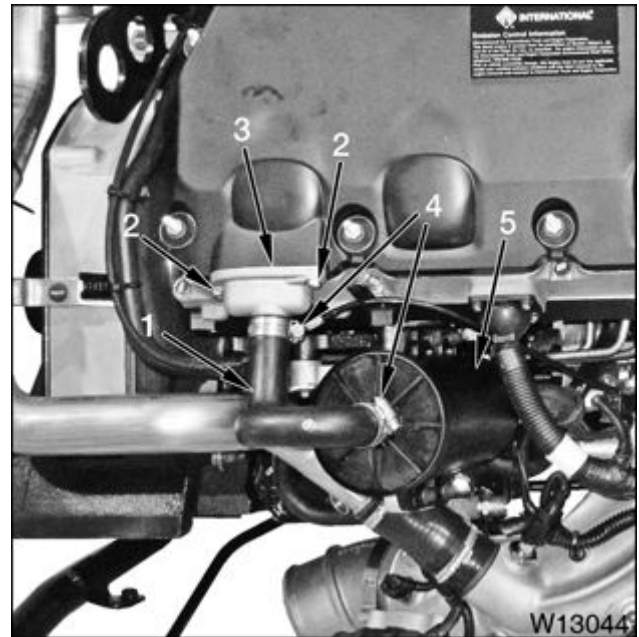
23. Remove two tubes. Remove and discard four O-rings



**Figure 388 Oil filter base assembly O-rings**

24. Remove and discard three O-rings from back side of oil filter base assembly.

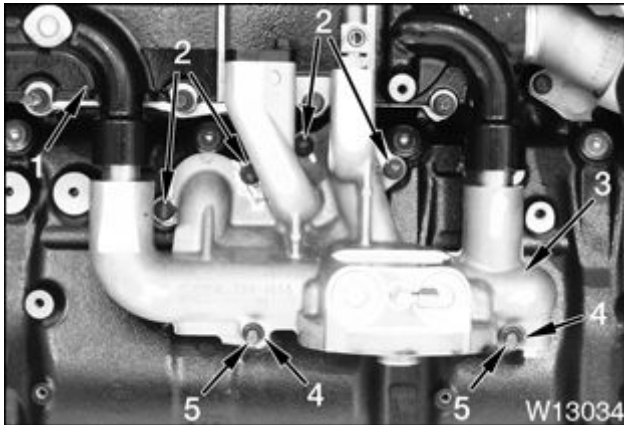
### Breather Tube and Valve Cover Adapter



**Figure 389 Breather tube and valve cover adapter**

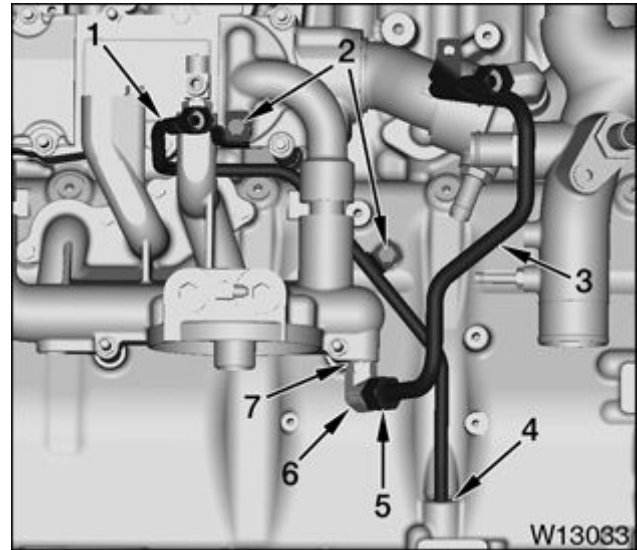
1. Breather tube
2. 1/4 x 20 x 0.875 hex bolt (2) and 7.2 x 14.5 hardened washer (2)
3. Valve cover adapter
4. CTB 1 dia clamp (2)
5. Breather filter assembly

1. Loosen two CTB 1 dia clamps.
2. Disconnect end of breather tube from valve cover adapter.
3. Disconnect other end of breather tube from breather filter assembly and remove breather tube.
4. Remove two 1/4 x 20 x 0.875 hex bolts and two 7.2 x 14.5 hardened washers.
5. Remove valve cover adapter.



**Figure 408 Oil filter base assembly**

1. Engine oil cooler assembly
  2. 3/8–16 x 1.125 hex bolt (4) and 10.2 x 18.5 hardened washer (4)
  3. Oil filter base assembly
  4. 3/8–16 hex flange nut (2)
  5. 3/8–16 x 4 taperlock stud (2)
13. Install two 3/8–16 x 4 taperlock studs. Tighten studs until they bottom out to standard torque (page 562).
  14. Install two 3/8–16 hex flange nuts and tighten to standard torque (page 562).
  15. Install four 10.2 x 18.5 hardened washers and four 3/8–16 x 1.125 hex bolts. Tighten bolts to standard torque (page 562).



**Figure 409 Oil supply tube assembly and oil drain tube assembly**

1. Oil drain tube assembly
  2. 3/8-16 x 1/2 bolt (2)
  3. Oil supply tube assembly
  4. O-ring
  5. O-ring seal
  6. 90 degree elbow assembly
  7. O-ring seal
16. Install new O-ring on bottom of oil drain tube assembly. Lubricate O-ring with P-80® rubber lubricant or equivalent (page 279). Install oil drain tube assembly in crankcase. Install two 3/8-16 x 1/2 bolts. Tighten bolts to standard torque (page 562).
  17. If removed, lubricate O-ring and O-ring seal with P-80® rubber lubricant or equivalent (page 279) and install O-ring and O-ring seal onto 90 degree elbow assembly. Install 90 degree elbow assembly into oil filter base assembly hand tight.
  18. Position oil supply tube assembly on engine.
  19. Hand tighten oil supply tube assembly connection to 90 degree elbow assembly.
  20. Using back up wrench, tighten 90 degree elbow assembly jam nut to special torque (page 279).
  21. Using back up wrench, tighten oil supply tube assembly nut to special torque (page 279).

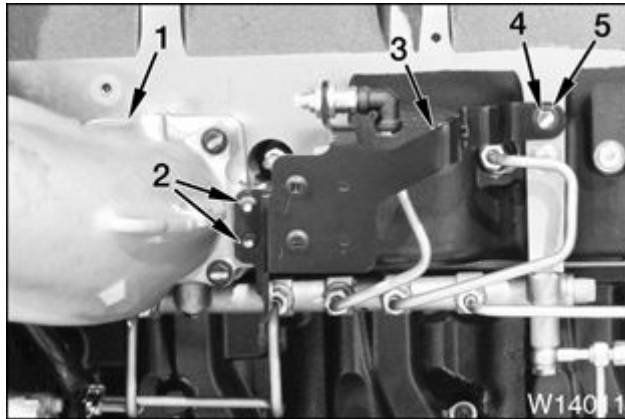
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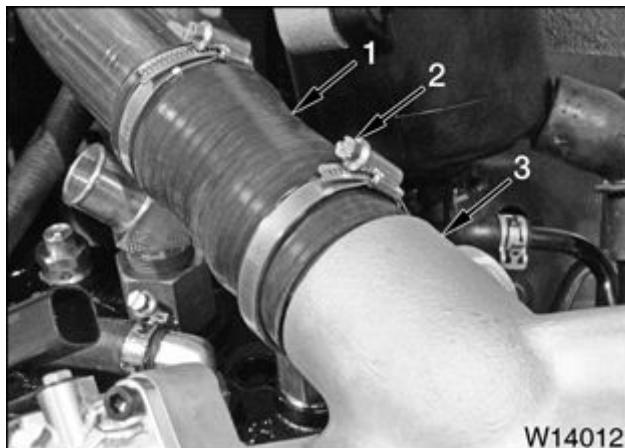


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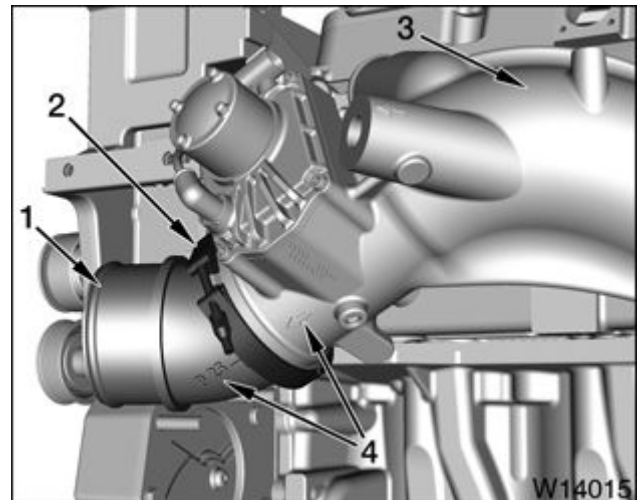
**Air Inlet****Figure 420 ECM harness support**

1. Engine throttle valve assembly
  2. M6 x 30 hex flange bolt (2)
  3. ECM harness support
  4. 3/8-16 x 1 hex bolt
  5. 3/8 hardened washer
1. If not previously removed, remove ECM harness support.
    - a. Remove two M6 x 30 hex flange bolts.
    - b. Remove 3/8-16 x 1 hex bolt and 3/8 hardened washer.
    - c. Remove ECM harness support.

**Figure 421 EGR supply hose**

1. EGR supply hose
2. Clamp (EGR supply hose)
3. Engine throttle valve assembly

2. If not previously disconnected, disconnect EGR supply hose from engine throttle valve assembly.
  - a. Loosen EGR supply hose clamp at engine throttle valve assembly.
  - b. Slide back clamp and disconnect EGR supply hose from engine throttle valve assembly.

**Figure 422 Intake throttle elbow**

1. Intake throttle elbow
  2. Intake throttle clamp
  3. Engine throttle valve assembly
  4. Alignment marks
3. Remove intake throttle clamp fastening intake throttle elbow to engine throttle valve assembly.
  4. Remove intake throttle elbow.
  5. Remove and discard intake throttle elbow O-ring.

Exploded Views

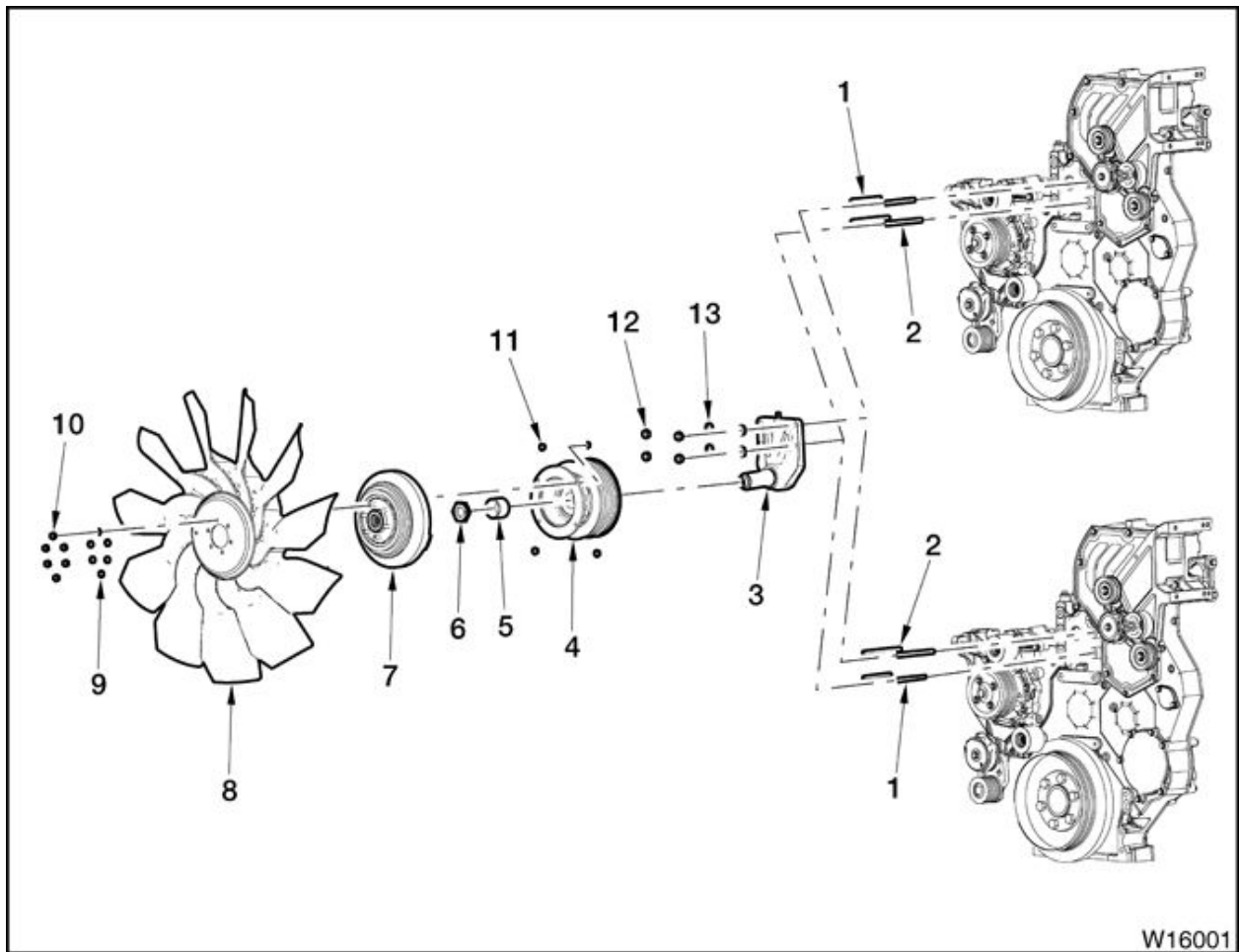
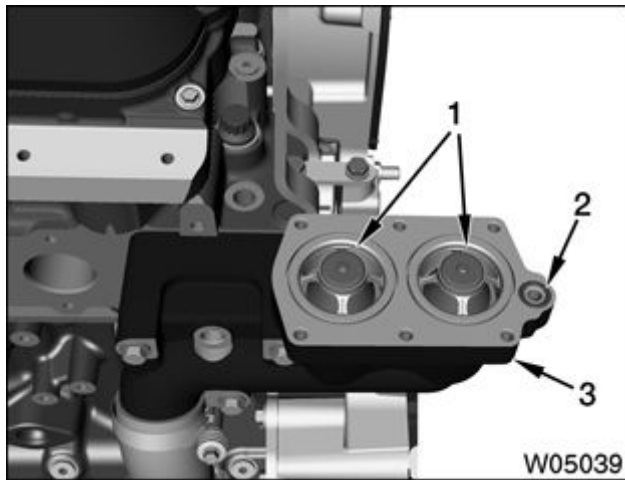


Figure 438 High and low mount fan drive system (Typical)

- |                                      |                        |                                     |
|--------------------------------------|------------------------|-------------------------------------|
| 1. 1/2-13 x 2.72 taperlock stud (2)  | 6. Nut assembly        | 11. M8 hex flange nut (4)           |
| 2. 1/2-13 x 5 5/8 taperlock stud (2) | 7. Fan clutch          | 12. 1/2-13 hex nut (4)              |
| 3. Horton® fan bracket               | 8. Fan                 | 13. 13.5 x 25.5 hardened washer (4) |
| 4. Pulley                            | 9. 3/8 lock washer (6) |                                     |
| 5. Spacer                            | 10. 3/8-24 nut (6)     |                                     |



**Figure 451 Thermostat**

1. Thermostat
2. O-ring
3. Thermostat housing

3. Remove and discard O-ring.
4. Remove and discard the thermostats from thermostat housing assembly.

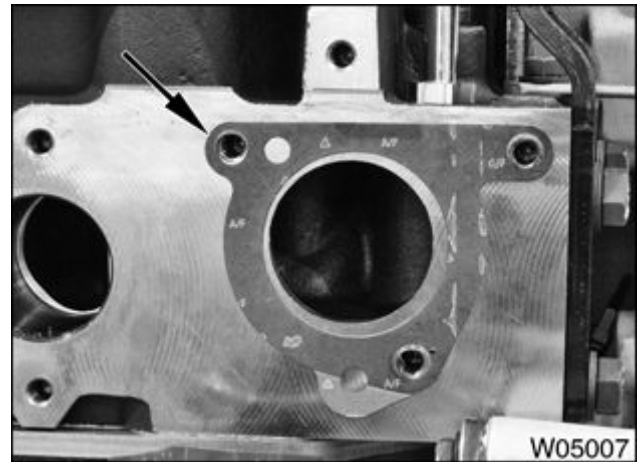


**Figure 452 Thermostat housing**

1. 3/8–16 x 4.25 hex flange bolt (3)
2. Thermostat housing
3. Water pump inlet hose
4. Hose clamp (2)

5. Loosen two hose clamps.
6. Remove three 3/8–16 x 4.25 hex flange bolts.

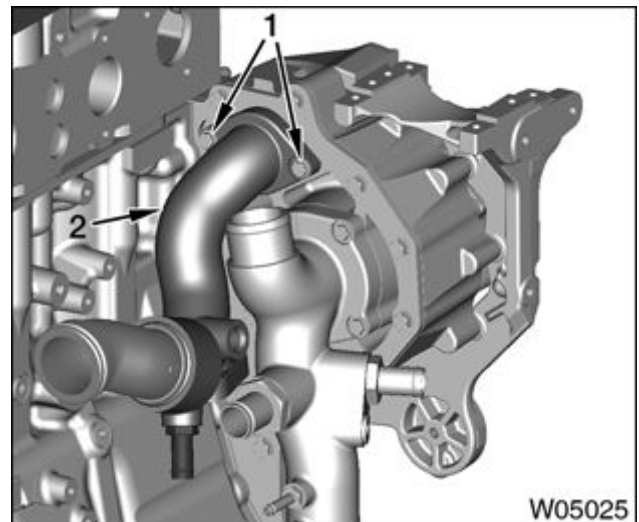
7. Remove the thermostat housing.
8. Remove the water pump inlet hose.



**Figure 453 Regulator cover gasket**

9. Remove and discard regulator cover gasket.

**Water Pump Inlet and Water Outlet Pipe**

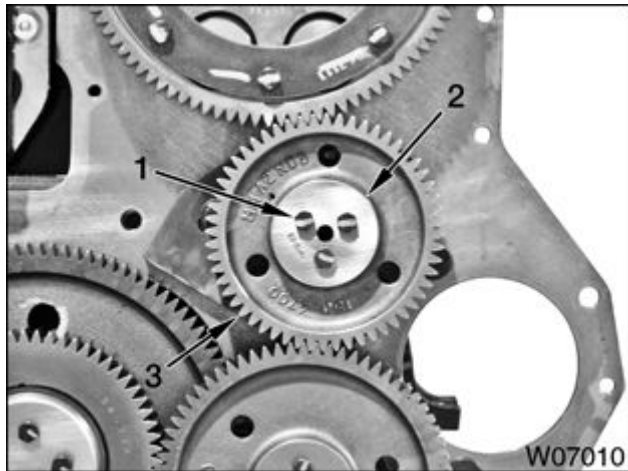


**Figure 454 Water outlet pipe**

1. 5/16–18 x 1 1/2 hex flange bolt (2)
2. Water outlet pipe

1. Remove two 5/16–18 x 1 1/2 hex flange bolts and the water outlet pipe assembly.

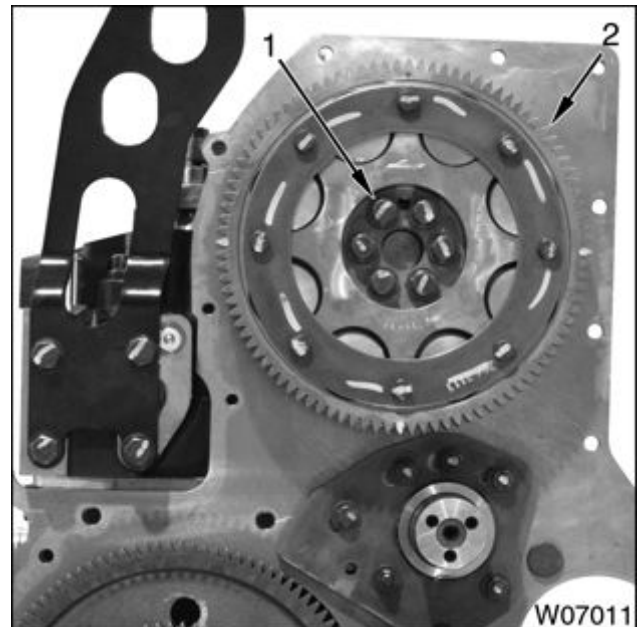
timing mark is in the 12 o'clock position. The Timing Pin (page 349) will slide into a hole in the flywheel when the timing marks align.



**Figure 480 56-teeth gear assembly**

1. 5/16–18 x 0.875 hex locking bolt (3)
2. Bushing flange
3. 56-teeth gear assembly

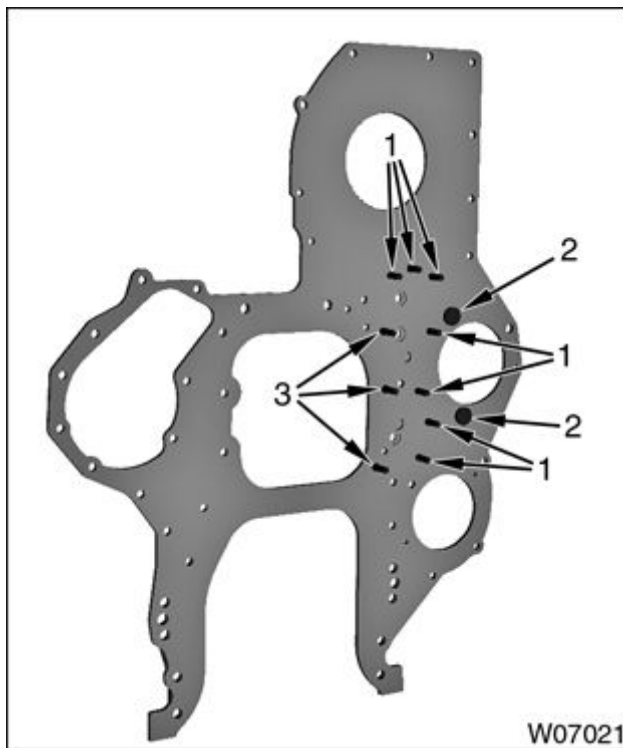
10. Remove three 5/16–18 x 0.875 hex locking bolts and the bushing flange.
11. Remove the 56-teeth gear assembly.



**Figure 481 Camshaft timing gear assembly**

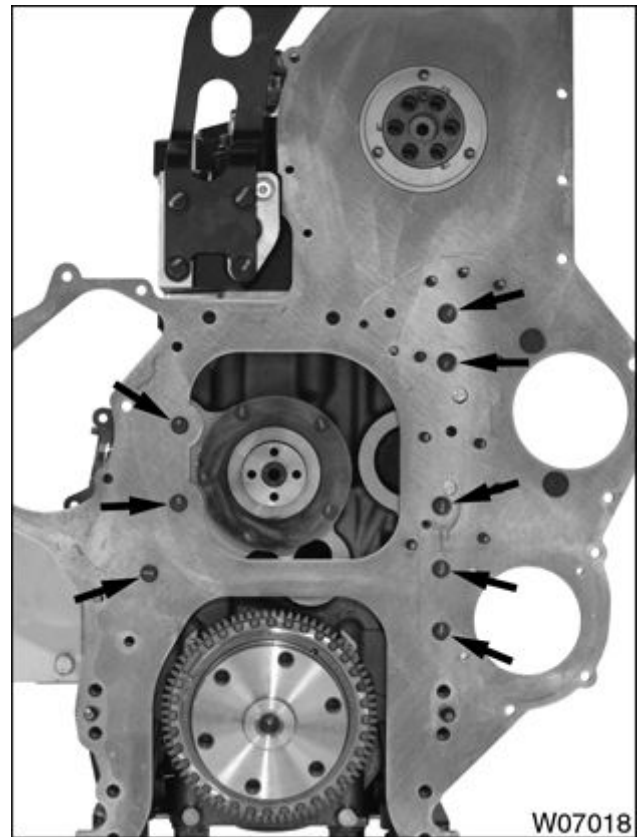
1. 5/8–11 x 3, 12 point socket head bolt (6)
2. Camshaft gear assembly

12. Using a 5/8 inch 12 point socket, remove six 5/8–11 x 3, 12 point socket head bolts.
13. Remove the camshaft gear assembly.



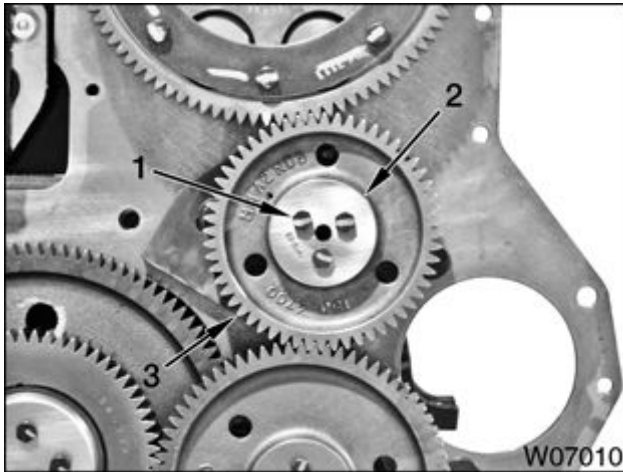
**Figure 498 Front cover plate stud locations**

1. Self clinching stud with 10.85 x 19.3 x 1.27 mm THK washer (small) (7)
  2. Self clinching stud with sealing washer (large) (2)
  3. Self clinching stud (small) (3)
7. If any large self clinching stud was removed, install the sealing washer on the large self clinching stud.
  8. If any small self clinching stud was removed, install a new 10.85 x 19.3 x 1.27 mm THK washer on the small self clinching stud.
  9. If any self clinching stud was removed, press in the self clinching stud.



**Figure 499 Front cover plate 3/8-16 x 1 hex flange bolts**

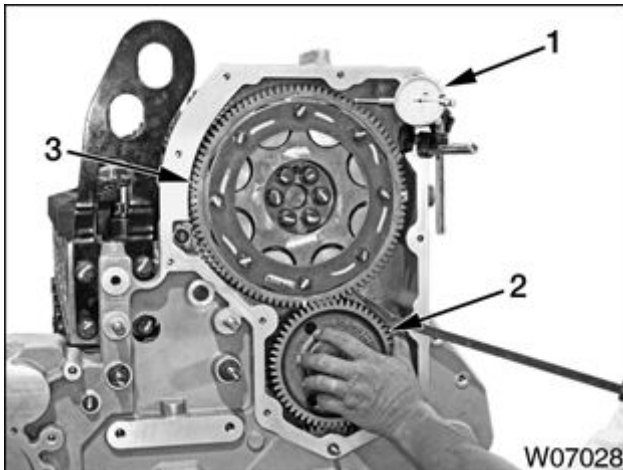
10. Apply Loctite® 242 (page 349) to threads on eight 3/8-16 x 1 thread locking hex flange bolts.
11. Position front cover plate and install eight 3/8-16 x 1 thread locking hex flange bolts. Tighten the eight 3/8-16 x 1 thread locking hex flange bolts in two stages to special torque:
  - a. Tighten the eight 3/8-16 x 1 thread locking hex flange bolts to 56 N·m (41 lbf·ft).
  - b. Retighten the eight 3/8-16 x 1 thread locking hex flange bolts to 56 N·m (41 lbf·ft).



**Figure 524 56-teeth gear assembly**

1. 5/16–18 x 0.875 hex locking bolt (3)
2. Bushing flange
3. 56-teeth gear assembly

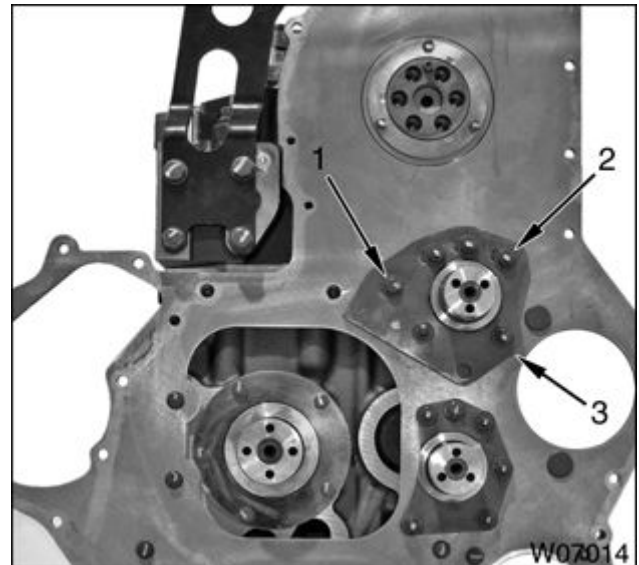
6. Position the 56-teeth gear assembly on the 56-teeth gear support shaft.
7. Position the bushing flange and install three 5/16–18 x 0.875 hex locking bolts. Tighten the 5/16–18 x 0.875 hex locking bolts to standard torque (page 562).



**Figure 525 Idler gear backlash check**

1. Dial indicator and bracket
2. 56-teeth gear assembly
3. Camshaft gear assembly

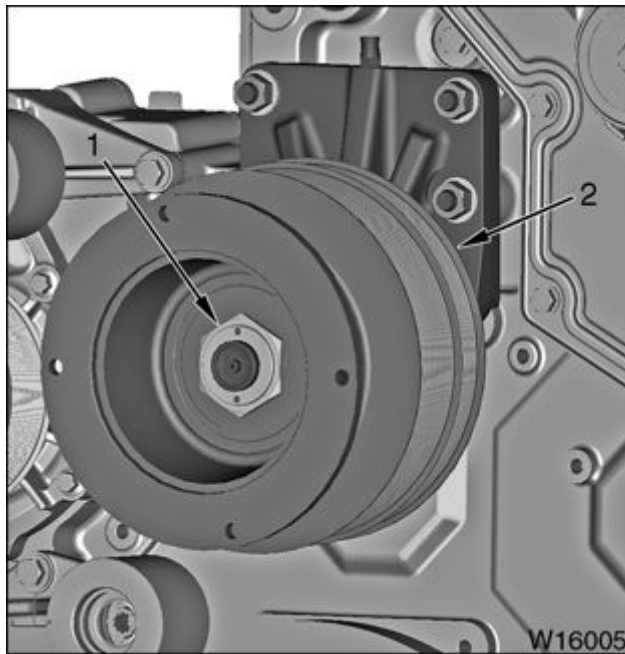
8. Using a dial indicator and bracket (page 349), measure the backlash between the 56-teeth gear assembly and the camshaft gear assembly while the 56-teeth gear assembly is held stationary.
9. If idler gear backlash is outside Specifications (page 348):
  - a. Remove the 56-teeth gear assembly.
  - b. Loosen the 3/8–16 x 1.5 hex flange locking bolt and five 3/8–16 hex flange nuts.
  - c. Repeat steps 1–8 until a correct backlash reading is achieved.
10. Remove the 56-teeth gear assembly.



**Figure 526 56-teeth gear support assembly**

1. 3/8–16 x 1.5 hex flange locking bolt
2. 3/8–16 hex flange nut (5)
3. 56-teeth gear support assembly

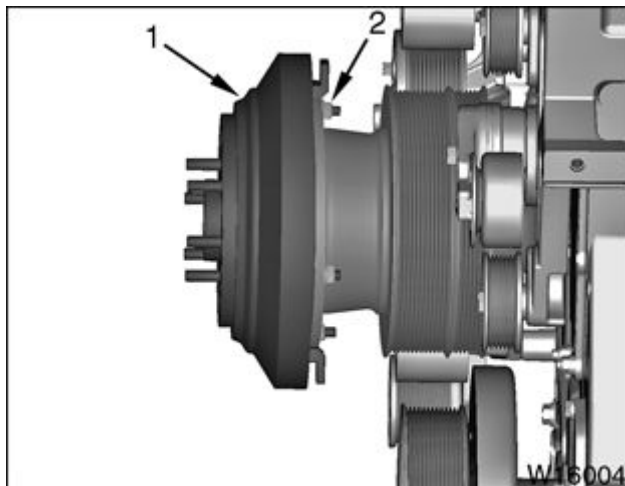
11. Remove the 3/8–16 x 1.5 hex flange locking bolt.
12. Apply Loctite® 242 (page 349) to threads on 3/8–16 x 1.5 hex flange locking bolt.
13. Reinstall and tighten the 3/8–16 x 1.5 hex flange locking bolt to special torque (page 348).
14. Remove one 3/8–16 hex flange nut.
15. Apply Loctite® 242 (page 349) to threads on self clinching stud.



**Figure 548 Fan pulley**

1. Nut assembly
2. Pulley

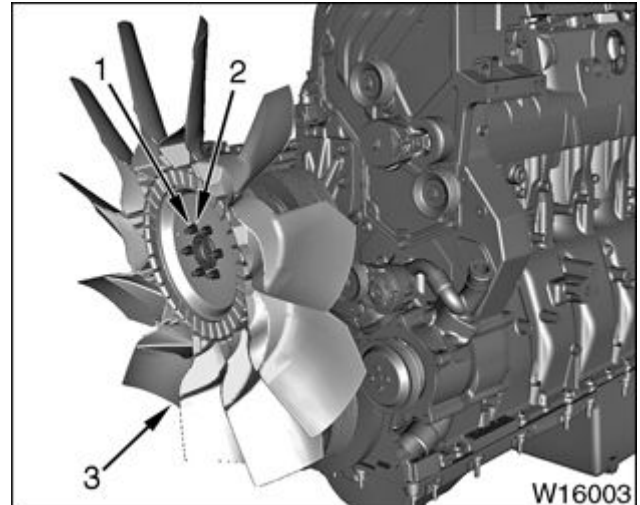
6. Install the spacer (Figure 438) (item 5) and the pulley.
7. Install the nut assembly. Tighten nut assembly to special torque (page 348).



**Figure 549 Fan clutch**

1. Fan clutch
2. M8 hex flange nut (4)

8. Install the fan clutch and four M8 hex flange nuts. Tighten M8 hex flange nuts to special torque (page 348).



**Figure 550 Fan**

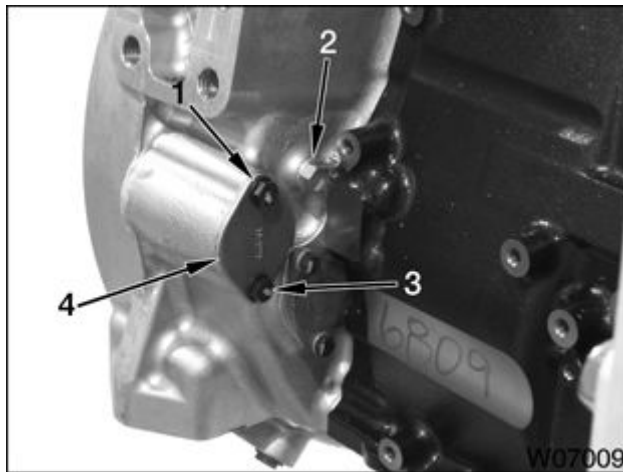
1. 3/8–24 hex nut (6)
2. 3/8 lock washer (6)
3. Fan

9. Install the fan blade.
10. Install six 3/8 lock washers and six 3/8–24 hex nuts. Tighten six 3/8–24 hex nuts to special torque (page 348).

**NOTE:** There are two holes in the front surface of the flywheel used to pin (lock in place) the engine. Each of these flywheel holes are in alignment with a port at either the left or right front of the flywheel housing assembly. The two flywheel lock holes are at different distances from the center of the flywheel, so only one of the flywheel holes is engaged at each port location. Installing the timing pin in either port will lock the flywheel at TDC compression of cylinder 1 or 6. Engine brake lash adjustment is performed on cylinders 1, 3, and 5 when cylinder 1 is at TDC compression and on cylinders 2, 4, and 6 when cylinder 6 is at TDC compression. Either port location may be used for the engine brake lash adjustment. It is suggested to use the right side locking port as that location is next to the tool port used to rotate the engine.

**Table 1**

Crank Angle for TDC Compression	Cam Angle	Brake Lash Adjustment at:
#1 TDC = 0 degrees	#1 TDC = 0 degrees	Cylinders: 1, 3, and 5
#6 TDC = 360 degrees	#6 TDC = 180 degrees	Cylinders: 2, 4, and 6



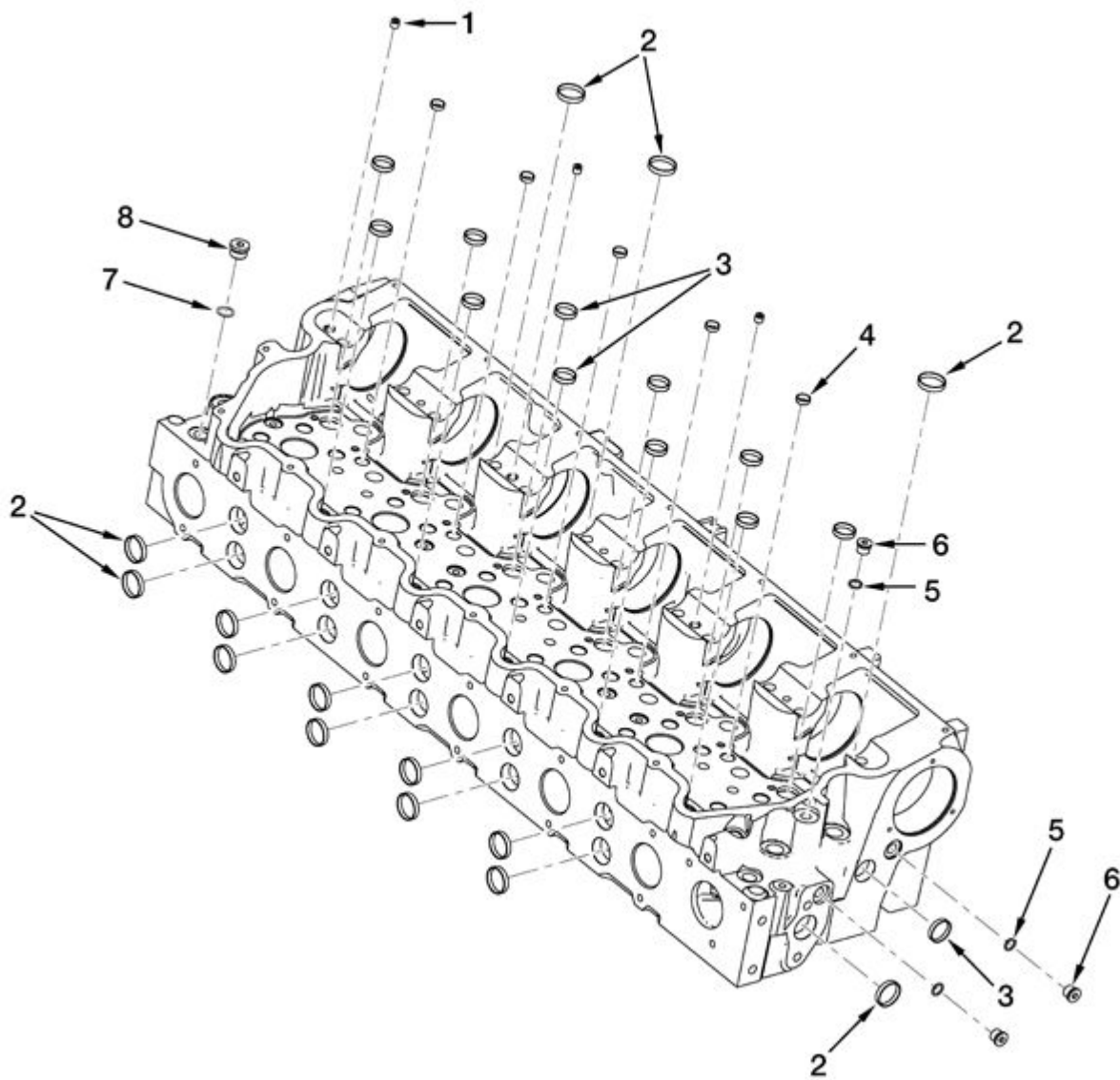
**Figure 555 Flywheel locking port and rotation tool guide (right side)**

1. 3/8–16 x 3 hex flange bolt
2. Plug (right flywheel locking port)
3. 3/8–16 x 1 hex flange bolt
4. Plate (rotation tool guide)

1. Using Engine Rotation Tool (page 368) and Timing Pin (page 368), lock flywheel in position to perform engine brake lash adjustment.
  - a. Remove 3/8–16 x 3 hex flange bolt, 3/8–16 x 1 hex flange bolt, and plate (rotation tool guide). Discard plate seal.
  - b. Install engine rotation tool through opening that was covered by the plate.
  - c. Remove plug from flywheel locking port.
  - d. Install timing pin into flywheel locking port.
  - e. Using 1/2 inch drive ratchet, rotate engine rotation tool in the direction of normal engine rotation (counterclockwise as viewed from the flywheel end of the engine looking forward). The timing pin is under constant spring tension and will engage the appropriate hole in the flywheel when the crankshaft is at correct top dead center (TDC) position.
2. Determine which cylinder (1 or 6) is currently at TDC compression. At cylinder 1 position, attempt to move the exhaust and intake rocker arm assemblies by hand. If both rocker arm assemblies (exhaust and intake) are in free float and can be moved by hand, then cylinder 1 is at TDC compression. If the rocker arm assemblies cannot be moved and the valves are slightly open, then cylinder 1 is on the exhaust stroke and companion cylinder 6 is at TDC compression.
3. Engine brake lash adjustment is performed on cylinders 1, 3, and 5 when cylinder 1 is at TDC compression and on cylinders 2, 4, and 6 when cylinder 6 is at TDC compression (Table 1).
 

**CAUTION:** To prevent engine damage, back out slave piston lash adjusters. If slave piston lash adjusters are not backed out, binding between exhaust rockers and slave piston may occur during lash adjustment.
4. On appropriate cylinders, loosen slave piston lash adjuster jam nut and back out slave piston lash adjuster using 5/32 hex key wrench (page 368) so that slave piston is not in contact with exhaust rocker arm.

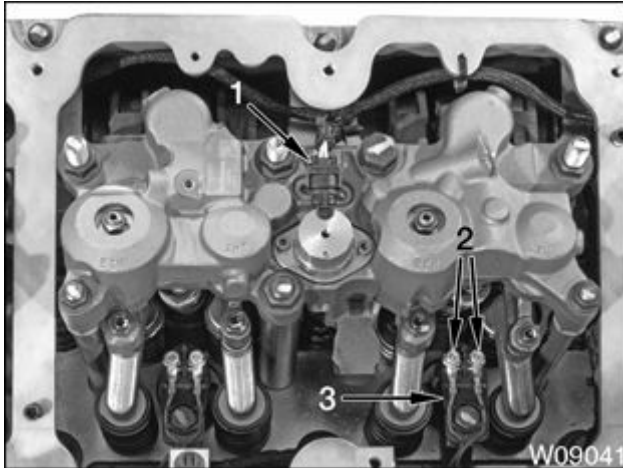
11. Perform lash adjustment on each installed valve brake actuator assembly. See Engine Brake Lash Adjustment (page 356).
-



W08011

**Figure 582 Front, top and RH cup plugs and O-ring boss plugs**

- |                                |                                       |                                     |
|--------------------------------|---------------------------------------|-------------------------------------|
| 1. 10 mm pipe plug (3)         | 4. Cup plug (22 mm) (5)               | 6. O-ring boss plug (9/16 – 18) (3) |
| 2. Cup plug (1 - 7/32 in) (14) | 5. O-ring (9/16 O-ring boss plug) (3) | 7. Ring seal (3/4 O-ring boss plug) |
| 3. Cup plug (1 in) (12)        |                                       | 8. O-ring boss plug 3/4 - 16)       |

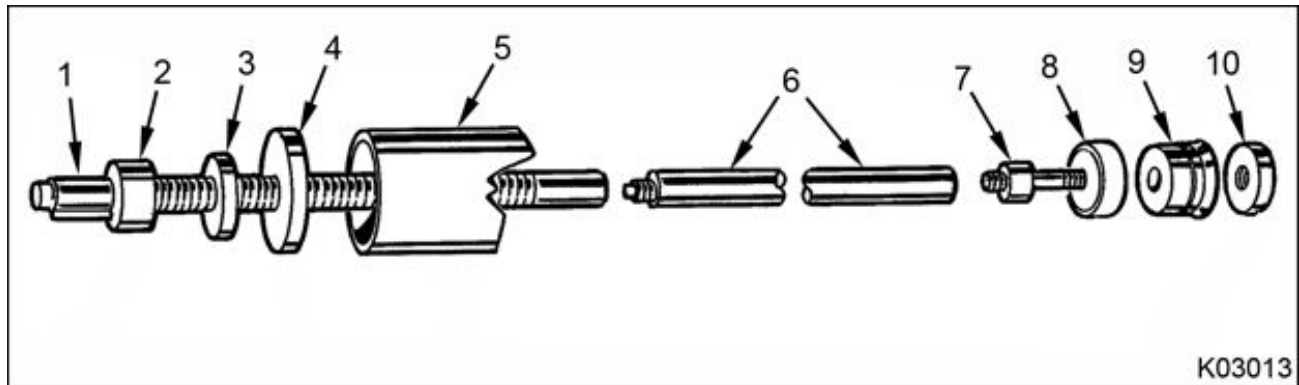
**Valve Cover Base**

**Figure 592 Under valve cover (UVC) harness connections (typical)**

1. Engine brake electrical connector (3)
2. Injector harness nut (12)
3. Fuel injector connector bracket (6)

**NOTE:** The injector harness nuts are part of the under valve cover (UVC) harness and cannot be separated.

1. Disconnect three engine brake electrical connectors and twelve injector harness nuts.
2. Remove six fuel injector connector brackets from the fuel injector clamp bolt.



**Figure 618 Cam Bushing Installation and Removal Tools**

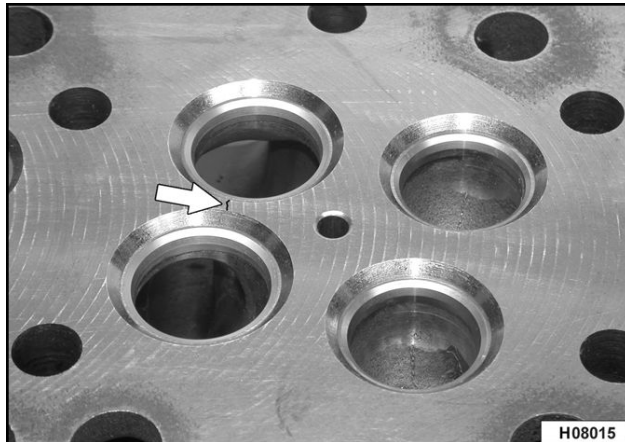
- |                   |  |                |
|-------------------|--|----------------|
| 1. Puller screw   | 6. Extension tube                      | 10. Backup nut |
| 2. Pulling nut    | 7. Puller screw extension              |                |
| 3. Thrust bearing | 8. Camshaft bearing (not part of tool) |                |
| 4. Pulling plate  | 9. Expanding collet                    |                |
| 5. Pulling spacer |  |                |

2. Install the expanding collet into the rear (number 7 bearing) camshaft bearing from rear of engine.
3. Place the puller screw extension through expanding collet (from front of engine). Install backup nut on puller screw extension and tighten backup nut until collet expands into camshaft bearing.
4. Assemble the Cam Bushing Installer (page 427) and install extension tube onto the puller screw extension.
5. Hold the end of the puller screw with a wrench and tighten the pulling nut against the thrust bearing and pulling plate until the camshaft bearing is removed.
6. Working from the rear of the engine and removing the next rearmost camshaft bearing, repeat steps 1 through 4 for the remaining six camshaft bearings.

**NOTE:** Make sure pulling spacer is squarely mounted on the cylinder head before tightening pulling nut.

### Cylinder Head

**CAUTION:** To prevent engine damage, remove injectors before removing cylinder head.



**Figure 642 Crack in cylinder head (example)**

**NOTE:** Any cracks will show up as purple lines against the white developer. If any cracks are present, replace cylinder head.

## Installation

### Cylinder Head

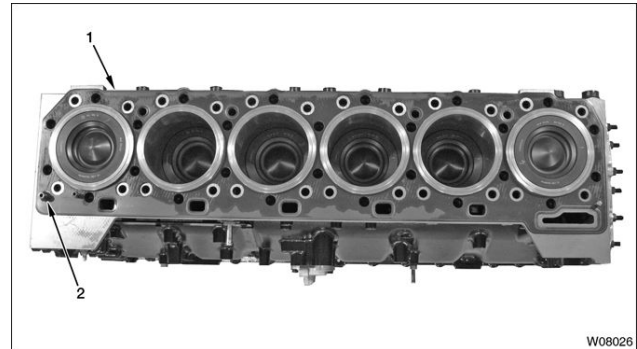
**⚠ WARNING:** To prevent personal injury or death, wear safety glasses with side shields to protect eyes. Limit compressed air pressure to 207 kPa (30 psi).

**CAUTION:** To prevent engine damage, do not use chlorinated solvents on bolts or crankcase tapped holes. Parts should be clean, dry, and free of any chemicals other than engine oil.

**CAUTION:** To prevent engine damage, clean and blow dry threads in the crankcase bolt holes with filtered compressed air. Dirt or oil in holes may cause binding or an incorrect torque reading.

**CAUTION:** To prevent engine damage, remove debris from cylinder head. If debris is not removed, a faulty seal between the cylinder head and gasket will cause oil, coolant, and compression leaks. Do not apply sealant to head gasket surfaces.

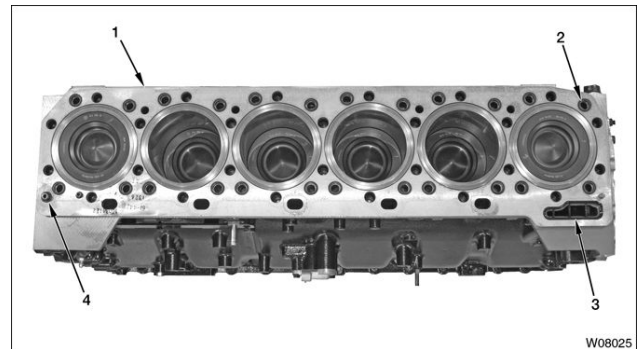
1. If removed, install three dowel pins into top of crankcase. See Crankcase Dowel Pins, Plugs and Fittings (page 516).



**Figure 643 Spacer plate gasket installation**

1. Spacer plate gasket
2. O-ring

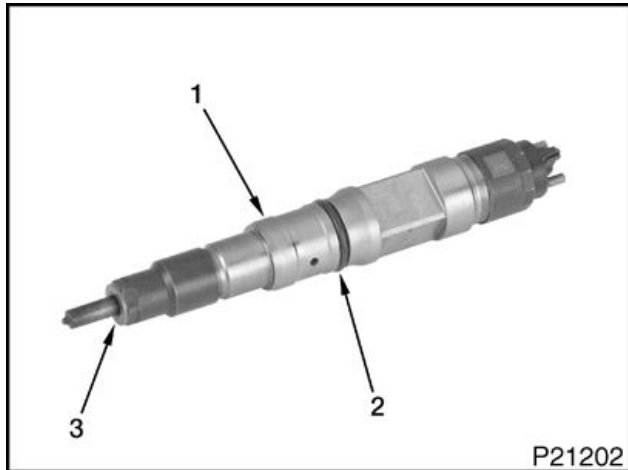
2. Install the O-ring on the front dowel pin.
3. Install a new spacer plate gasket.



**Figure 644 Spacer plate installation**

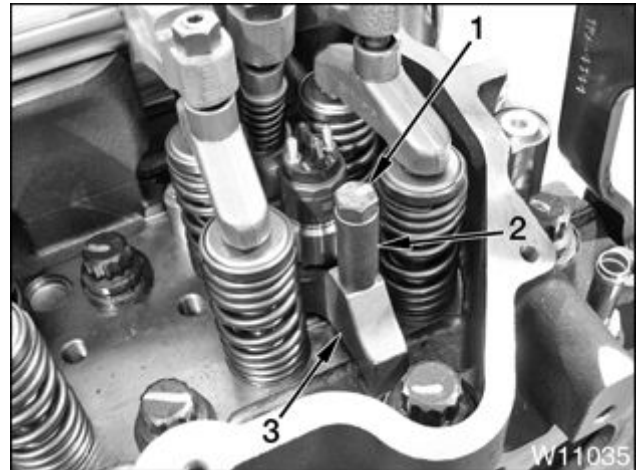
1. Spacer plate
2. Seal ring (24)
3. Coolant passage insert assembly (used as an oil drain passage in this application)
4. O-ring

4. Select the appropriate spacer plate thickness. See Cylinder Sleeve Protrusion Measurement (page 488).
5. Install the spacer plate.
6. Install the O-ring on the front dowel pin.
7. Install twenty four seal rings and the coolant passage insert assembly.



**Figure 669 Injector seals (typical)**

1. Injector
2. O-ring
3. Combustion gasket



**Figure 670 Injector clamp (typical)**

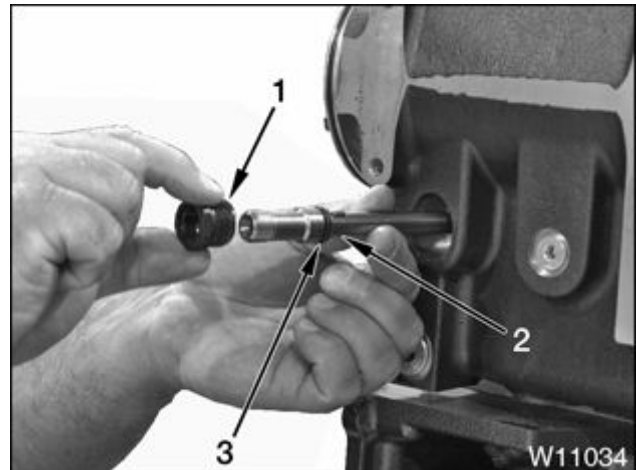
1. 3/8 - 16 X 4 hex bolt (6)
2. 9.8 X 15.85 X 37.6 spacer (6)
3. Injector clamp (6)

1. Remove and discard O-ring from each fuel injector.
2. Install a new O-ring on each fuel injector. Lubricate O-ring with clean engine oil.
3. Install a new combustion gasket on each fuel injector.
4. Remove Disposable Air and Fuel Caps (page 427) from cylinder head injector bore.

**CAUTION:** To prevent engine damage, align injector correctly with cylinder head so injector tube inlet port aligns with pressure pipe holes in cylinder head; do not twist injector when inserting injector into cylinder head.

5. Install injectors so injector tube inlet port aligns with pressure pipe holes in cylinder head.

6. Install six injector clamps, six 9.8 X 15.85 X 37.6 spacers, and six 3/8 - 16 X 4 hex bolts. Tighten 3/8 - 16 X 4 hex bolts to 36 N·m (24 lbf·ft) to seat the injector.
7. Back off 3/8 - 16 X 4 hex bolts, just until loose enough to allow injectors to move freely.



**Figure 671 High-pressure connector (typical)**

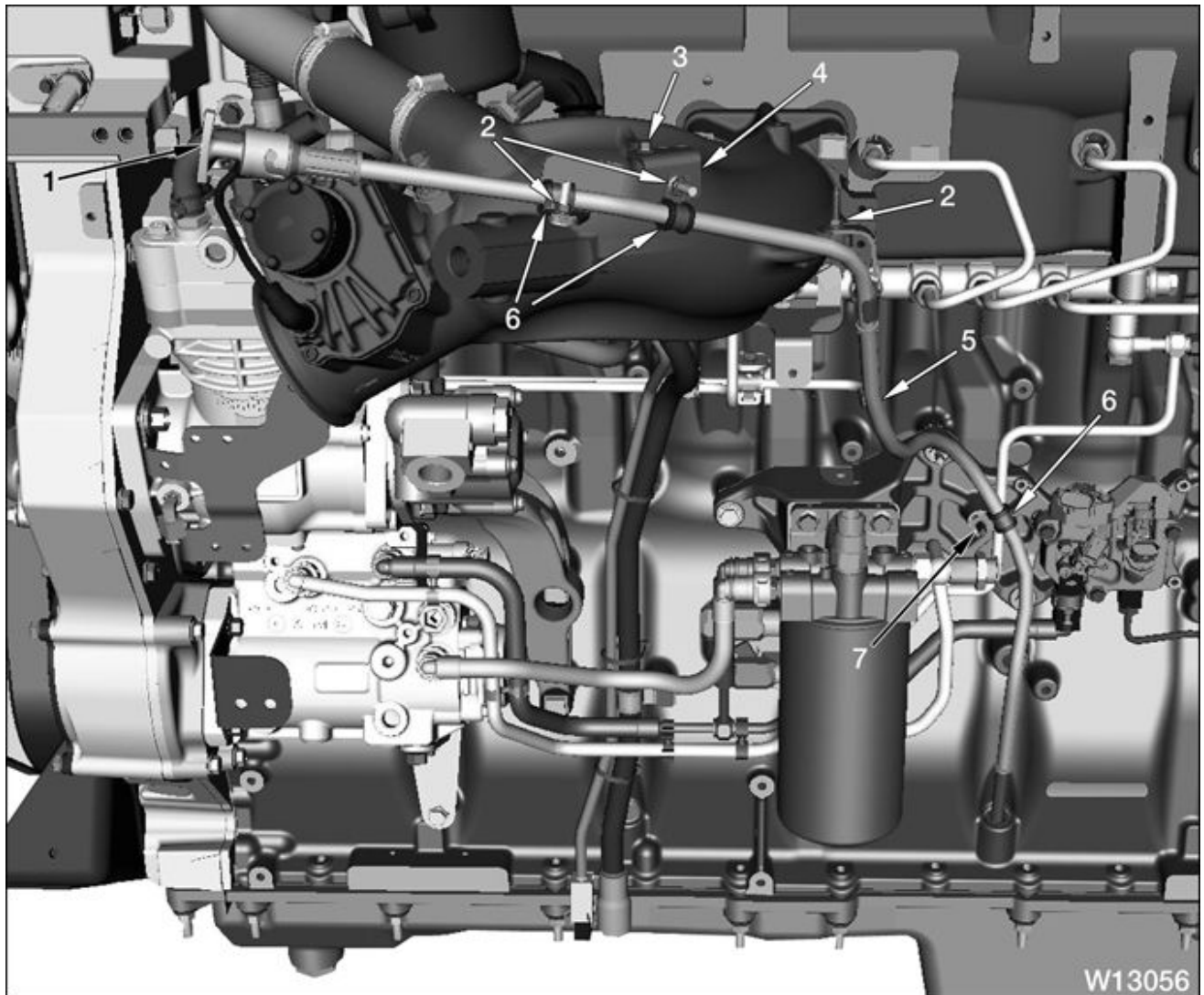
1. High-pressure connector retaining nut (6)
2. High-pressure connector body (6)
3. 13.5 X 3 O-ring (6)

---

**Special Service Tools**

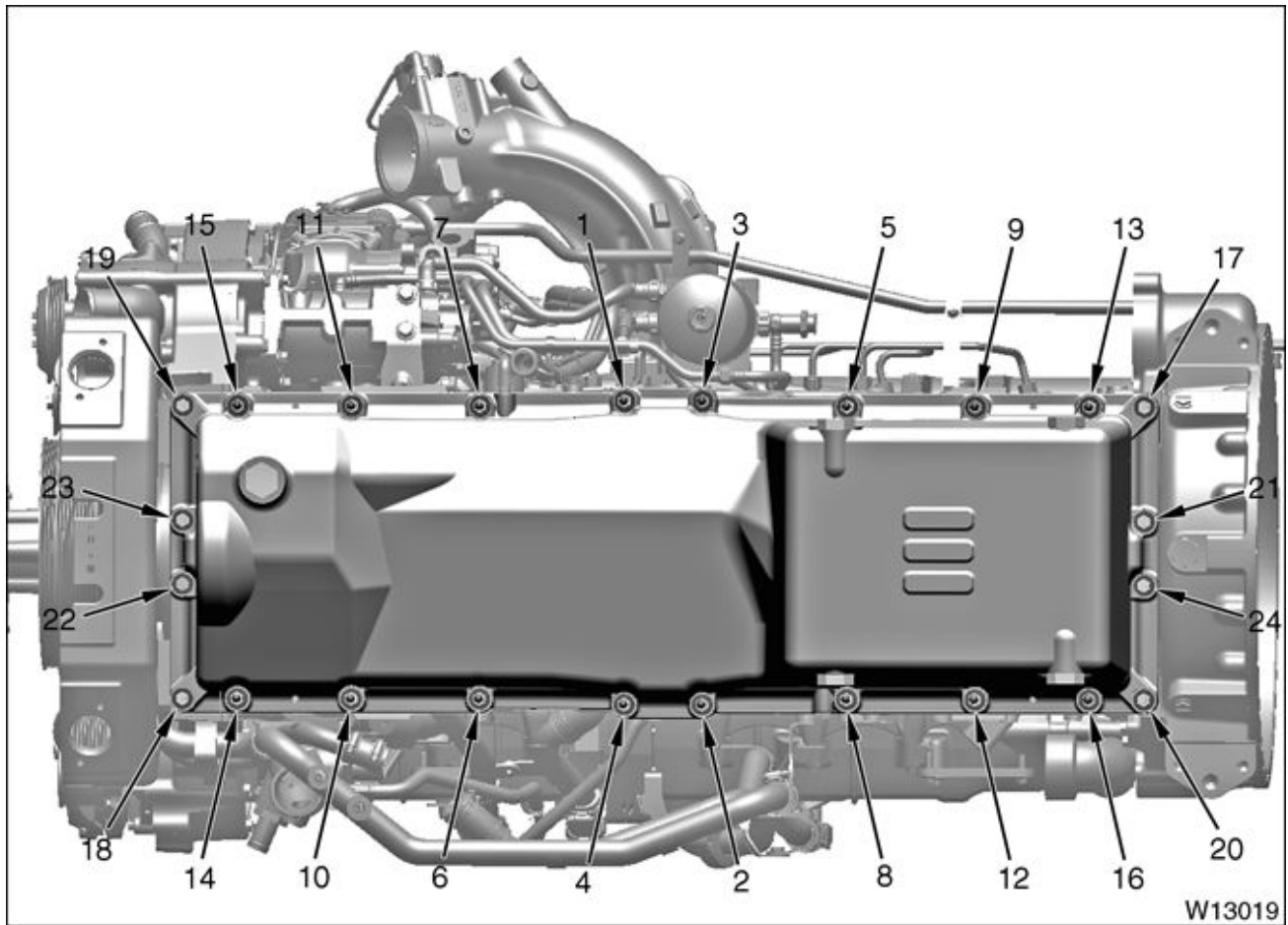
Description	Tool Number
1–2 inch Micrometer	Obtain locally
2–3 inch Micrometer	Obtain locally
3–4 inch Micrometer	Obtain locally
3/4 inch 12 point socket	Obtain locally
6–7 inch Micrometer	Obtain locally
Camshaft Remover/Installer	ZTSE6103
Cam Bushing Installer (used for both installation and removal)	ZTSE6113
Cylinder Head Lifting Brackets	ZTSE6106
Dye penetrant kit	Obtain locally
Disposable Air and Fuel Caps	ZTSE4891
Engine Rotation Tool	ZTSE6112
Feeler gauge set	Obtain locally
Fuel Injector Tip Cleaning Brush	ZTSE4301
Fuel Injector Cups and Rack	ZTSE4299B
Head and Main Bolt Bottoming Tap Kit (3/4 x 16 and 7/8 x 14 taps)	ZTSE6117
High-Pressure Connector Installer/Remover	ZTSE6115
Injector Removal Kit	ZTSE6102
Injector Sleeve Brushes	ZTSE4751
Lash Gauge	ZTSE6076–7
Loctite® 120541 Core Plug Sealant	Obtain locally
Loctite® 242	Obtain locally
Molykote paste lubricant 6V-4876	Obtain locally
P-80® rubber lubricant or equivalent	Obtain locally
Pressure regulator	Obtain locally
Rocker Arm Lifting Bracket Assembly	ZTSE6122
Slide Hammer Kit	ZTSE1879
Straight edge	Obtain locally
Telescoping gauge set	Obtain locally
Timing Pin	ZTSE6108
V-bolcks	Obtain locally

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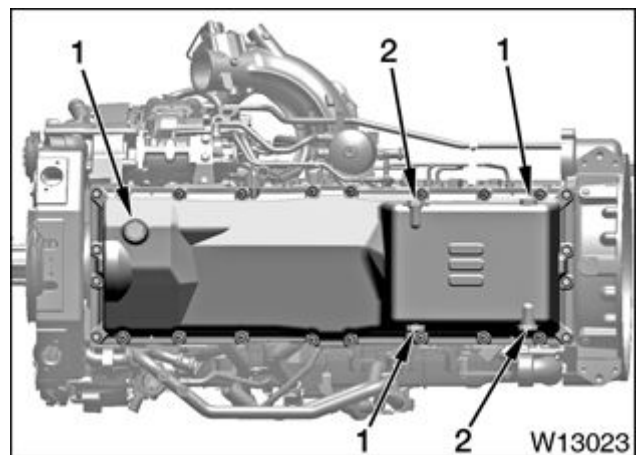
**Figure 687 Oil level gauge tube assembly (late production)**

- |                             |                                  |                  |
|-----------------------------|----------------------------------|------------------|
| 1. Oil level gauge assembly | 4. Oil level gauge support       | 7. M8 x 1.25 nut |
| 2. M6 nut                   | 5. Oil level gauge tube assembly |                  |
| 3. M6 x 12 bolt             | 6. Cushioned clamp               |                  |
2. Remove M6 x 12 bolt and M8 x 1.25 nut. Slide oil level gauge tube assembly out of crankcase as an assembly.
  3. If required, remove cushioned clamp, oil level gauge support, and O-ring from oil level gauge tube.



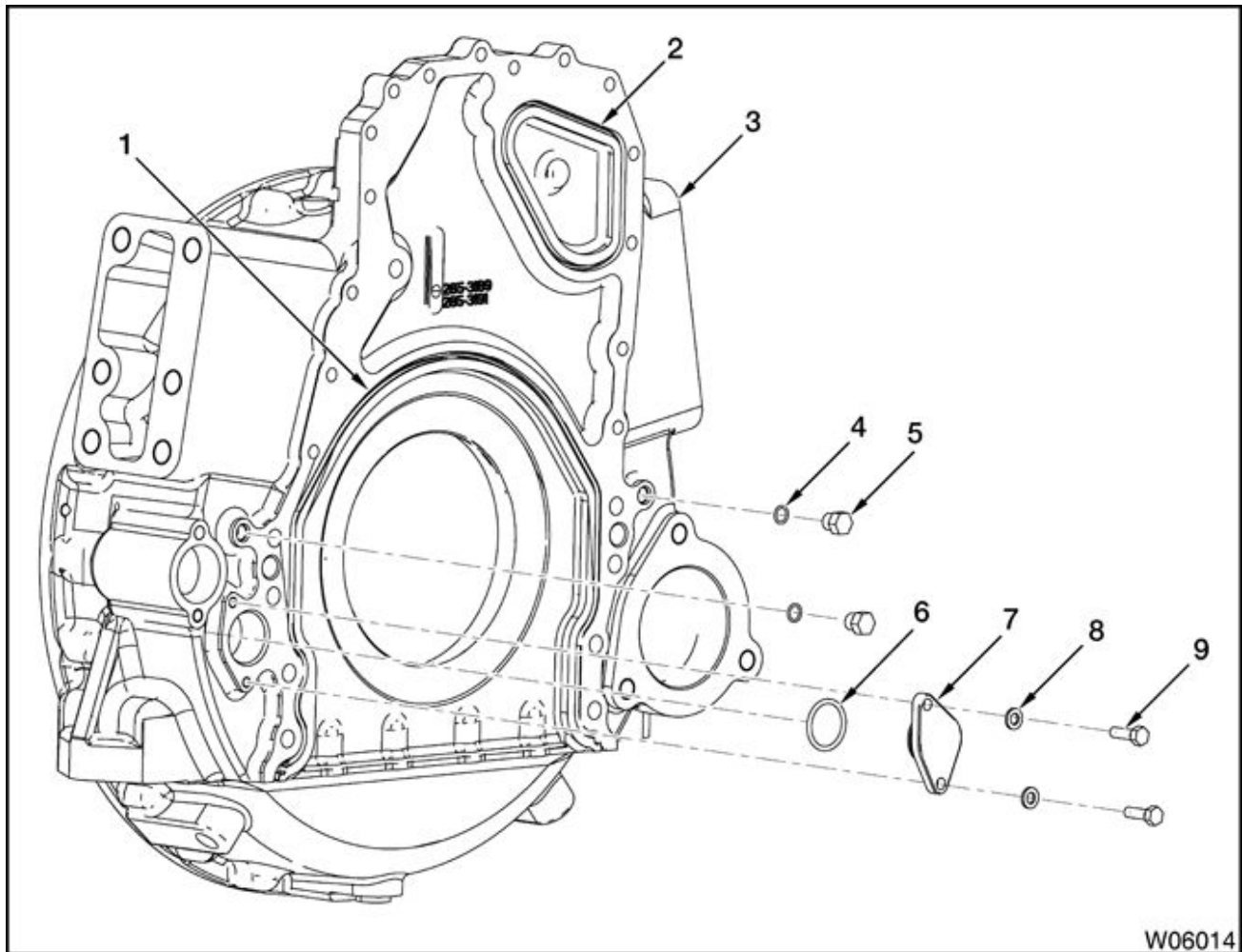
**Figure 706** Oil pan stud bolt tightening sequence

6. Install 24 10.2 x 25.5 x 2.5 washers and 24 3/8–16 x 2 x 3/4 stud bolts at each mounting hole location. Tighten stud bolts to 25 N·m (220 lbf·in) in the sequence shown.



**Figure 707** Oil drain plugs

1. 1 1/8–12 oil drain plug
2. 1 5/16–12 oil drain plug



**Figure 714 Flywheel housing (engine side)**

- |                            |               |                                   |
|----------------------------|---------------|-----------------------------------|
| 1. Flywheel housing gasket | 4. O-ring (2) | 7. Access cover                   |
| 2. Flywheel housing gasket | 5. Plug (2)   | 8. 8.8 x 16.2 hardened washer (2) |
| 3. Flywheel housing        | 6. O-ring     | 9. 5/16-18 x 1 bolt (2)           |

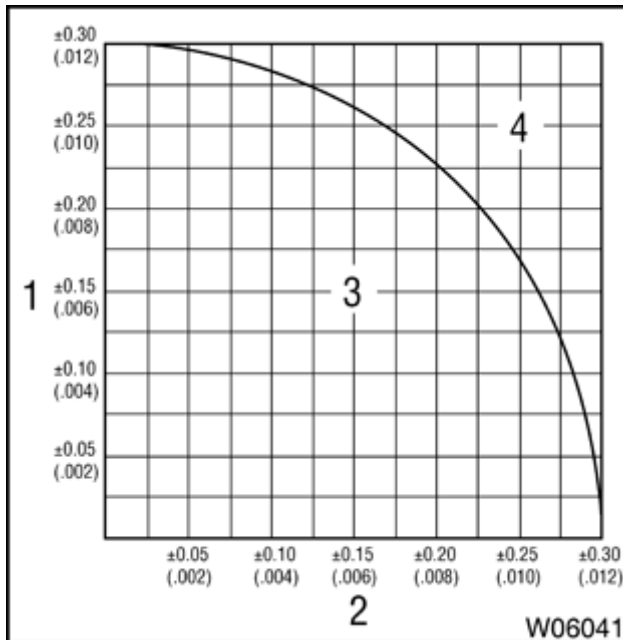


Figure 734 Flywheel housing bore runout graph

1. Total vertical eccentricity (mm (inch))
2. Total horizontal eccentricity (mm (inch))
3. Acceptable value
4. Unacceptable value

15. Using graph, find intersection of eccentricity lines (vertical and horizontal).
16. If point of intersection is in "Acceptable" range, bore is in alignment. If point of intersection is in "Unacceptable" range, flywheel housing must be changed.

**Recondition**

**Flywheel Assembly**

**NOTE:** Flywheel assemblies used with manual transmissions may be resurfaced to correct minor wear and scoring. If flywheel assembly meets following requirements it can be resurfaced.

**! WARNING:** To prevent personal injury or death, do not machine flywheel assembly beyond minimum thickness specified for resurfacing.

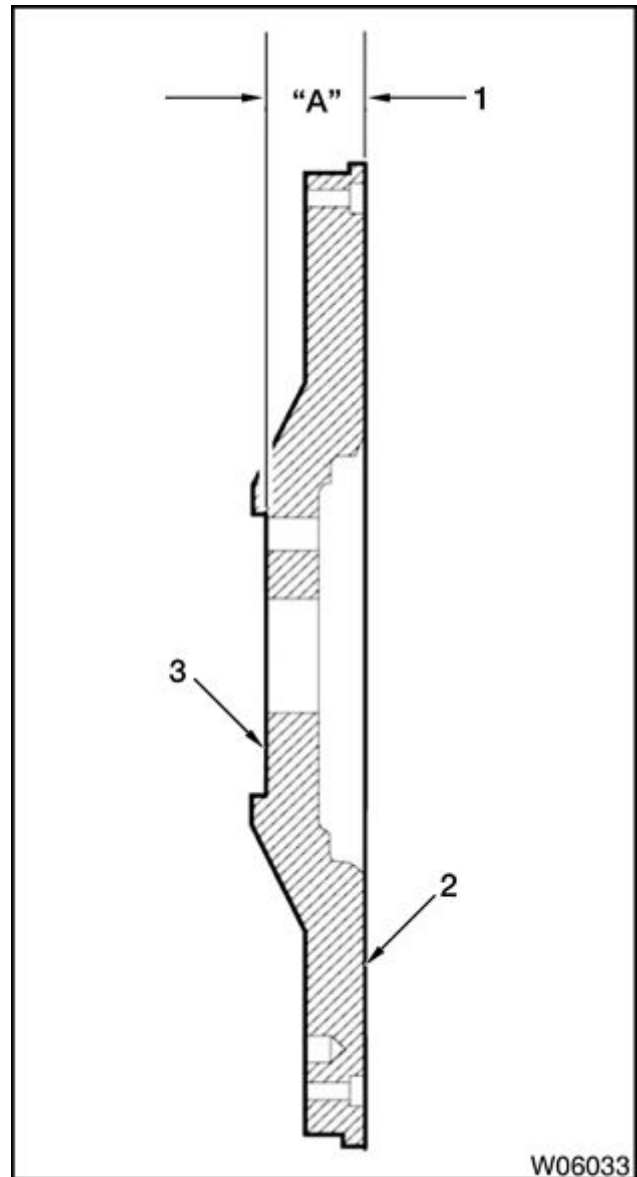


Figure 735 Flywheel assembly surface dimension (typical)

1. Flywheel assembly thickness (dimension "A")
2. Clutch disc mounting face
3. Crankshaft flange mounting face

**NOTE:** Flywheel assembly resurfacing information is provided for guidance only. Navistar Inc. assumes no responsibility either for results of any work performed in accordance with this information or for ability of service personnel to detect cracks.

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### Connecting Rod Bore Check

**CAUTION:** To prevent engine damage, do not use air powered tools to install connecting rod bolts; this can seize rod bolts.

1. Lubricate used connecting rod M11 x 84 12 point bolts with clean engine oil. Assemble cap to connecting rod without bearing shell. Tighten bolts to special torque (page 497).



**Figure 765** Measurement of connecting rod bore

2. Using a telescoping gauge (page 497) and a 3–4 inch micrometer (page 497), measure connecting rod bearing bore diameter in three locations. If connecting rod bearing bore diameter does not meet specification (page 496), replace connecting rod.
3. After all connecting rod bores are inspected, disassemble connecting rods and discard used M11 x 84 12 point bolts.
4. With connecting rod cap removed, inspect surface finish of connecting rod bearing bore. Bore must be smooth and free of scoring, nicks, or burrs. Replace connecting rod as necessary.

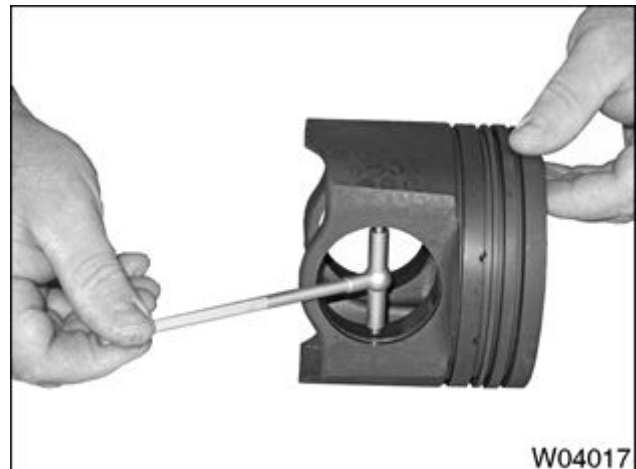
### Piston Pin Inspection

1. Inspect piston pins for scoring or wear. Replace as necessary.



**Figure 766** Piston pin wear

2. Using a 2–3 inch micrometer (page 497), measure piston pin outside diameter at two locations 90° apart.
3. Measure center area and each end of pin. If outside diameter of any piston pin is less than minimum specification (page 496), replace piston pin.



**Figure 767** Inside diameter measurement of piston pin bore

4. Using a telescoping gauge (page 497) and 2–3 inch micrometer (page 497), measure each piston pin bore inside diameter at two locations 90° apart. If piston pin bore inside diameter is not within specification (page 496), replace piston.

---

**Special Torque**

M11 x 84 12 point bolts (connecting rod bolts)	Initial	70 ± 4 N·m (52 ± 3 lbf·ft)
	Final	additional 60° (1/6 turn)
Cylinder sleeve projection hold-down bolts		Step 1: Tighten all to 95 N·m (70 lbf·ft)
		Step 2: Retighten all to 95 N·m (70 lbf·ft)

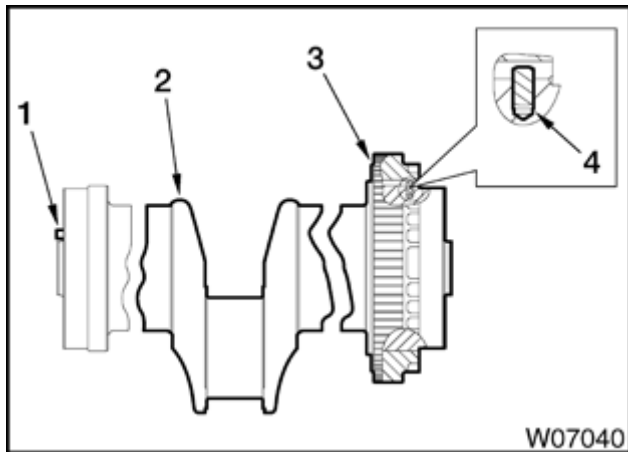
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**Special Service Tools**

Description	Tool Number
2–3 inch micrometer	Obtain locally
3–4 inch micrometer	Obtain locally
4–5 inch micrometer	Obtain locally
12 Point 14 mm socket	Obtain locally
Cylinder Sleeve Puller	ZTSE2536
Dial bore gauge	Obtain locally
Dial Indicator with Base	Part of ZTSE2515A
Feeler gauge	Obtain locally
P-80® Rubber lubricant or equivalent	Obtain locally
Piston Cope (ring compressor)	ZTSE6118
Piston Gauge Pin (3.4 mm (0.1338 in.))	Obtain locally
Piston ring expansion pliers	Obtain locally
Telescoping gauge set	Obtain locally

---

8. If required, using Gear remover (page 527), remove the crankshaft gear from crankshaft.

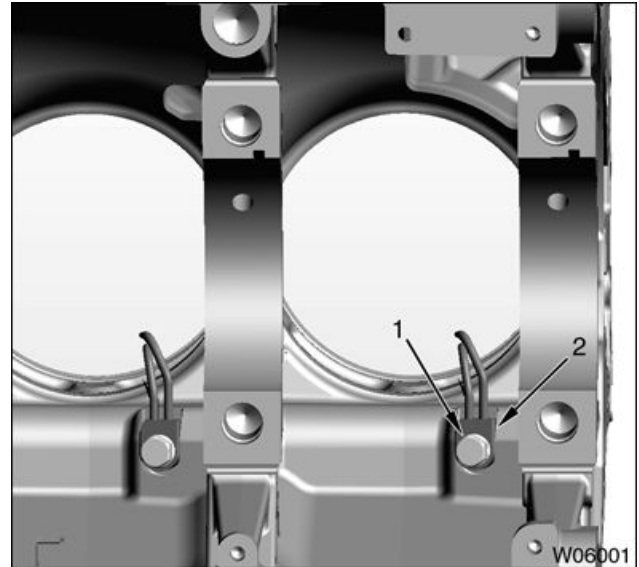


**Figure 789 Crankshaft gear dowel**

1. Crankshaft rear dowel pin (9.55 X 19.1 mm)
2. Crankshaft
3. Crankshaft gear
4. Crankshaft gear dowel pin (0.25 X 0.5 mm)

9. If required, remove the crankshaft front dowel pin and crankshaft rear dowel pin from crankshaft.

### Piston Cooling Jet

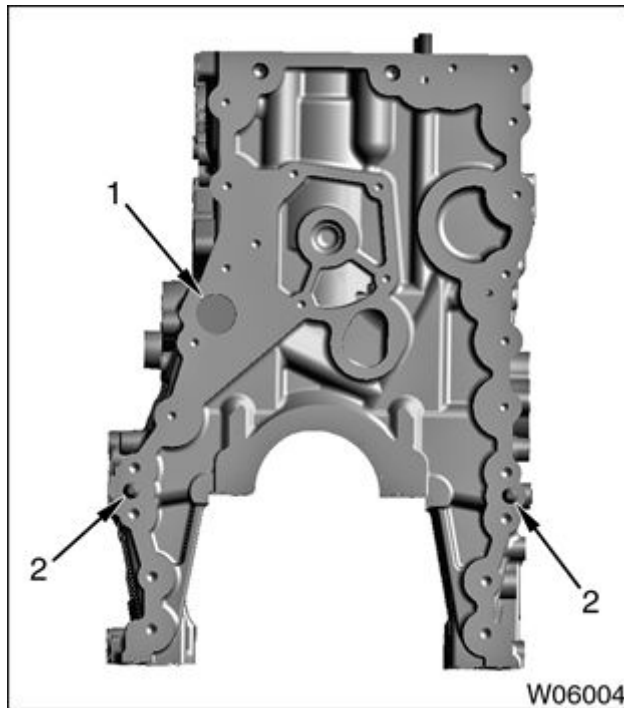


**Figure 790 Piston cooling jet (typical)**

1. Cooling jet bolt (6)
2. Piston cooling jet (6)

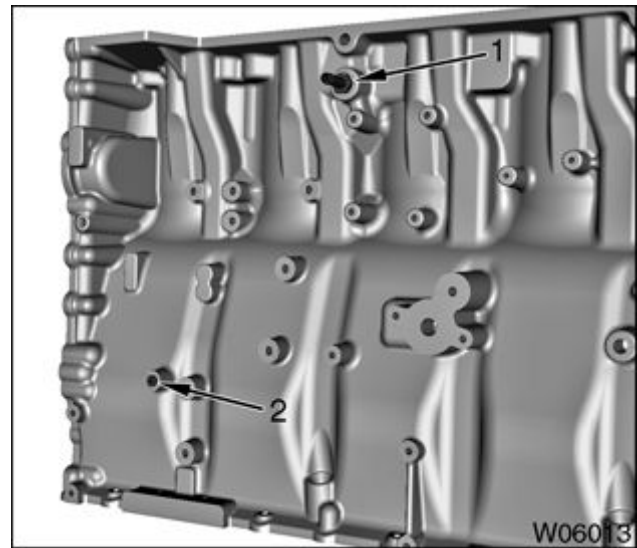
**CAUTION:** To prevent engine damage, do not bend the piston cooling jets because the piston cooling jets are precision aligned with a coolant passage in the pistons and will not function properly if bent.

1. Remove six cooling jet bolts and six piston cooling jets.



**Figure 805 Front crankcase**

1. Plug with o-ring
  2. Dowel pin (15.88 X 50 mm solid) (2)
9. Lubricate new O-ring and front crankcase plug bore with clean engine oil.
  10. Install lubricated O-ring into the plug ring groove.
  11. Install plug into the front of the crankcase to depth specified (page 526).
  12. Install two dowel pins (15.88 X 50 mm solid) to specified (page 526) protrusion.
  13. Measure the protrusion of the dowels and make sure the protrusion is within specification (page 526).



**Figure 806 Left side crankcase**

1. Hose fitting (3/4–16) with o-ring
  2. O-ring boss plug (7/16–20)
14. Install a new O-ring on the 3/4–16 hose fitting.
  15. Install 3/4–16 hose fitting into left side of crankcase as shown. Tighten 3/4–16 hose fitting to special torque (page 526).
  16. Install a new O-ring on the O-ring boss plug (7/16–20).
  17. Install O-ring boss plug (7/16–20) into left side of crankcase as shown. Tighten O-ring boss plug (7/16–20) to special torque (page 526).

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**Special Service Tools**

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<b>Description</b>	<b>Tool Number</b>
1/2 x 20 in. tap	Obtain locally
29/64 <sup>th</sup> drill bit	Obtain locally
3–4 inch micrometer	Obtain locally
4–5 inch micrometer	Obtain locally
5–6 inch micrometer	Obtain locally
Dial bore gauge	Obtain locally
Dial indicator with magnetic base	Obtain locally
Gear remover	Obtain locally
Head and Main Bolt Bottoming Tap Kit (3/4 x 16 and 7/8 x 14 taps)	ZTSE6117
Heat insulated gloves	Obtain locally
Heavy duty strap	Obtain locally
Hot plate	Obtain locally
Infrared thermometer (thermo gun)	Obtain locally
Loctite® 609	Obtain locally
Plastigage®	Obtain locally
P-80® Rubber lubricant or equivalent	Obtain locally
Slide Hammer Kit	ZTSE1879

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**Voltage ignition** – Voltage supplied by the ignition switch when the key is ON.

**Washcoat** – A layer of alumina applied to the substrate in a monolith-type converter.

**Water In Fuel (WIF) sensor** – A switch sensor that measures the amount of water in the fuel.

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**Exhaust Gas Recirculation (EGR) System**

90 degree fitting assembly (on water pump outlet pipe)	58 N·m (43 lbf·ft)
Clamp (EGR supply hose)	4 N·m (2 lbf·ft)
EGRV coolant return tube nut	26 N·m (19 lbf·ft)
EGRV coolant supply tube nut	26 N·m (19 lbf·ft)
Fitting (45 degree on EGR valve)	35 N·m (26 lbf·ft)
1 3/16-12 x 1 1/4 inch hose elbow lock nut (90 degree on rear of oil cooler)	250 N·m (184 lbf·ft)
Hose fitting (on coolant adapter)	48 N·m (35 lbf·ft)
M8 x 27 high temp bolt	24 N·m (18 lbf·ft)
M8 hex flange lock nut	8.2 N·m (72 lbf·in)
M10 x 130 high temp bolt	48 N·m (35 lbf·ft)
M10 90 degree 3/8 hose fitting (nut)	8 N·m (71 lbf·in)
M14 37 degree flare fitting (90 degree) (on EGR valve)	35 N·m (26 lbf·ft)
M18 plug assembly	24 N·m (18 lbf·ft)
SAE 15/16 left clip clamp	Step 1: 5.8 N·m (51 lbf·in) Wait 5 seconds Step 2: 5.8 N·m (51 lbf·in)
SAE 24 clamp	Step 1: 8.3 N·m (73 lbf·in) Wait 5 seconds Step 2: 8.3 N·m (73 lbf·in)
SAE 24 left clip clamp	Step 1: 8.3 N·m (73 lbf·in) Wait 5 seconds Step 2: 8.3 N·m (73 lbf·in)

**Oil Cooler, Filter Housing and Crankcase Ventilation**

3/8-16 x 4 3/4 stud	35 N·m (26 lbf·ft)
3/8-16 x 5 1/8 taperlock stud	35 N·m (26 lbf·ft)
3/8-16 x 5 1/2 stud	35 N·m (26 lbf·ft)
3/8-16 x 6 1/2 taperlock stud	35 N·m (26 lbf·ft)
7/16-20 STR to 3/8 fitting	23 N·m (17 lbf·ft)
90 degree elbow assembly jam nut (oil filter base assembly)	28 N·m (20 lbf·ft)
O-ring boss plug (7/8-14)	100 N·m (74 lbf·ft)
O-ring boss plug (1 3/16-12)	100 N·m (74 lbf·ft)
O-ring boss plug (1 5/16-12)	100 N·m (74 lbf·ft)
Oil supply tube assembly nut	28 N·m (21 lbf·ft)

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**Front Cover, High Mount Fan Drive, Cooling System, and Related Components**

<b>Description</b>	<b>Tool Number</b>
90 weight gear oil	Obtain locally
100 °C (212 °F) thermo-melt crayon	Obtain locally
Abrasive cutting disk	Obtain locally
Dial indicator and bracket	Obtain locally
Engine Rotation Tool	ZTSE6112
Front and Rear Crankshaft Seal Installer	ZTSE6119
Idler Assembly Adjuster	ZTSE6116
Infrared thermometer (thermo gun)	Obtain locally
Heat insulated gloves	Obtain locally
Hot plate	Obtain locally
Loctite® 242	Obtain locally
P-80® rubber lubricant or equivalent	Obtain locally
Propane torch	Obtain locally
Rubber mallet	Obtain locally
Slide Hammer Kit	ZTSE1879
Timing Pin	ZTSE6108

**Engine Brake**

<b>Description</b>	<b>Tool Number</b>
5/32 hex key wrench	Obtain locally
Engine Rotation Tool	ZTSE6112
Lash gauge 0.686 mm (0.027 in.)	Obtain locally
Timing Pin	ZTSE6108

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