ENGINE SERVICE MANUAL

2010 MaxxForce® 7

Navistar, Inc.

2701 Navistar Drive, Lisle, IL 60532 USA

0000002383
Revision 2
February 2014

Engine Identification

Engine Serial Number

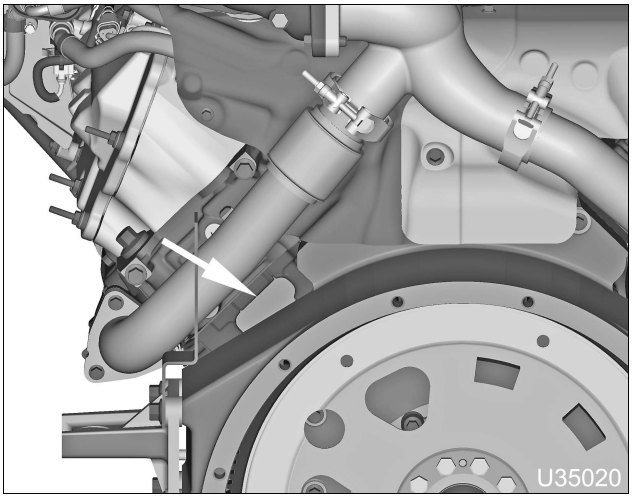

Figure 1 Engine Serial Number

The engine serial number is stamped on the crankcase pad, on the rear left side below the cylinder head.

Engine Serial Number Example

6.5HM2YXXXXXXX

6.5 – Engine family code
H – Diesel, turbocharged, air-intercooled and electronically controlled
M2 – Motor truck
Y – United States, Huntsville
7 digit suffix – Sequence number

Emission Label

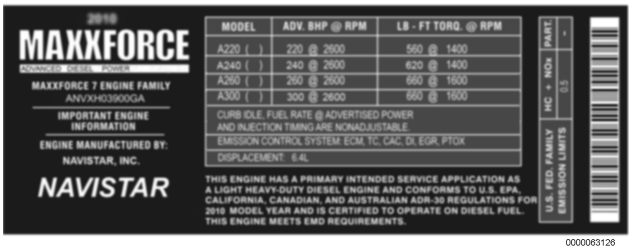

Figure 2 U.S. Environmental Protection Agency (EPA) Exhaust Emission Label (example)

The U.S. Environmental Protection Agency (EPA) exhaust emission label is on top of the EGR manifold mixer on the front of the engine. The label includes the following:

- Advertised brake horsepower ratings
- Engine model code
- Service applications
- Emission family and control systems
- Year the engine was certified to meet EPA emission standards

Engine Accessories

The following engine accessories may have manufacturers' labels or identification plates:

- Air compressor
- Air conditioning compressor
- Alternator
- Cooling fan clutch
- Power steering pump
- Starter motor

Labels or identification plates include information and specifications helpful to vehicle operators and technicians.

Air Flow

Air flows through the air filter assembly and enters the low-pressure turbocharger. Some vehicles are fitted with an optional Thermal Management Valve (TMV) between the air filter and the low-pressure turbocharger. The purpose of this valve is to enable engine braking and allow faster engine warm-ups. The compressor in the low-pressure turbocharger increases pressure, temperature, and density of the intake air before it enters the air crossover tube. From the air crossover tube assembly, air enters the high-pressure turbocharger. The high-pressure turbocharger compressor further increases the pressure, temperature, and density of the intake air. The high-pressure Turbocharger 1 Wastegate Control (TC1WC) solenoid and the TC1WC actuator control the output of the high-pressure turbocharger by adjusting the wastegate valve inside the turbocharger. From the high-pressure turbocharger, air enters the Charge Air Cooler (CAC). Cooled compressed air flows from the CAC through the ETV and Exhaust Gas Recirculation (EGR) mixer into the intake manifold.

If the EGR valve is open, some exhaust gas mixes with compressed intake air inside the EGR mixer and flows into the cylinders. If the EGR valve is closed, only compressed intake air flows into the cylinders.

After combustion, exhaust gas is forced through the exhaust manifolds to the EGR cooler and turbochargers. Some exhaust gas is cooled in the EGR cooler and flows through the EGR valve to the intake air stream. When exhaust gas mixes with air and fuel, it reduces the formation of Nitrogen Oxides (NO_X) engine emissions. The rest of the exhaust gas flows through the high-pressure turbocharger turbine and then through the low-pressure turbocharger turbine. The high-pressure turbine is on the same shaft as the high-pressure turbocharger compressor and compresses the mixture of filtered air. The low-pressure turbocharger turbine is on the same shaft as the low-pressure compressor. Some vehicles are fitted with an optional Thermal Management Valve (TMV) in the exhaust system between the low-pressure turbocharger and the DOC. The purpose of this valve is to enable engine braking and allow faster engine warm-ups.

The high-pressure TC1WC actuator is controlled by the Engine Control Module (ECM) and responds to engine loads. During heavy loads, increased exhaust flow turns the turbine wheel faster. This increased speed turns the compressor impeller faster and supplies greater boost pressure to the intake manifold. To prevent too much boost from building, the wastegate valve diverts exhaust away from the turbine wheel. Conversely, when engine load is light, the flow of exhaust decreases and less air is forced into the intake manifold. Therefore, the wastegate valve forces more exhaust towards the turbine wheel to compensate.

Charge Air Cooler (CAC)

Air from the dual stage turbocharger assembly passes through a network of heat exchanger tubes inside the CAC before entering the ETV. Outside air flows through the CAC and cools the charged air. Cooled intake air improves the fuel-to-air ratio during combustion. This results in improved emission control and power output.

Charge Air Cooler Outlet Temperature (CACOT) Sensor

The CACOT is a thermistor-style sensor that measures charged-air temperature entering the Engine Throttle Valve (ETV). As temperature increases, resistance drops, causing the voltage signal interpreted by the Engine Control Module (ECM) to vary. The ECM monitors this signal for Exhaust Gas Recirculation (EGR) system control and Charge Air Cooler (CAC) performance.

Fuel Volume Control Valve (FVCV)

The FVCV regulates the volume of flow sent to the HPFP. The FVCV is located in the HPFP assembly and is controlled by fuel rail pressure, via the ECM. The FVCV allows just sufficient quantity of fuel to be delivered to the HPFP depending on engine load, speed, injector quantity, fuel temperature, and number of injections per cycle.

Fuel Rail Pressure (FRP) Sensor

The FRP sensor monitors fuel pressure in the fuel rails and sends a signal to the ECM. The FRP sensor is installed in the right fuel rail. The FRP sensor harness is routed through the right Under Valve Cover (UVC) harness along with the fuel injector connections.

High-pressure Piezo Common Rail (HPCR) System

The HPFP pumps fuel through separate tubes to each fuel rail. Each fuel rail has four fuel tubes, one for each injector, that maintain constant pressure from the high-pressure pump to each injector.

The injectors are capable of five injections; two pre-injection, a main-injection, a post-injection, and a late post-injection. Pre-injection and post-injection reduce combustion noise, mechanical load, and exhaust emissions. The main-injection cycle injects and atomizes fuel in the combustion chambers for combustion. The late post-injection cycle adds fuel to the exhaust to regenerate the aftertreatment system.

Each injector has an actuator that opens or closes the injector nozzle holes. Charging the actuator opens the nozzle holes; discharging the actuator closes the nozzle holes. The ECM charges and discharges each actuator by energizing the appropriate high-side or low-side output. The low-side output supplies a return circuit for each actuator.

Return Fuel System

The return fuel system moves unused fuel from the fuel injectors to the fuel cooler. Excess fuel out of the FVCV and the FPCV mix with fuel from the fuel injectors on the way to the fuel cooler.

Operation and Function

The Engine Control Module (ECM) monitors and controls the engine to ensure maximum performance and adherence to emissions standards. The ECM has four primary functions:

- Provides reference voltage (VREF)
- Conditions input signals
- Processes and stores control strategies
- Controls actuators

Reference Voltage (VREF)

The ECM supplies a 5-volt VREF signal to input sensors in the electronic control system. By comparing the 5-volt VREF signal sent to the sensors with their respective returned signals, the ECM determines pressures, positions, and other variables important to engine and vehicle functions.

The ECM supplies three independent circuits for VREF:

- VREF supplies 5 volts to engine sensors
- VREF supplies 5 volts to vehicle aftertreatment
- VREF supplies 5 volts to fuel injector control

Signal Conditioner

The signal conditioner in the internal microprocessor converts analog signals to digital signals, squares up sine wave signals, or amplifies low-intensity signals to a level the ECM microprocessor can process.

Microprocessor

The ECM microprocessor stores operating instructions (control strategies) and value tables (calibration parameters). The ECM compares stored instructions and values with conditioned input values to determine the correct operating strategy for all engine operations.

Continuous calculations in the ECM occur at two different levels or speeds: Foreground and Background.

- Foreground calculations are faster than background calculations and are normally more critical for engine operation. Engine speed control is an example.
- Background calculations are normally variables that change at slower rates. Engine temperature is an example.

Suspect Parameter Numbers (SPN) and Fault Mode Indicators (FMI) are set by the microprocessor if inputs or conditions do not comply with expected values.

Diagnostic strategies are also programmed into the ECM. Some strategies monitor inputs continuously and command the necessary outputs for correct performance of the engine.

Microprocessor Memory

The ECM microprocessor includes Flash Memory and Random Access Memory (RAM).

Flash Memory

Flash memory is a nonvolatile form of memory that is electrically erasable and re-programmable. ROM (Read Only Memory) was used when the program (control strategy and calibration) was built into the physical silicon or was burnt in with a one time programming. In ROM, the program is fixed, and to change it you physically have to change the hardware. With Flash memory, you can keep reprogramming it. Flash memory is used to update vehicles in the field (over public CAN) with new calibrations, software bug fixes, or new features.

Flash memory includes the following:

- Vehicle configuration, modes of operation, and options
- Engine Family Rating Code (EFRC)
- Engine warning and protection modes

RAM

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

- Engine temperature
- Engine rpm
- Accelerator pedal position

Engine Preparation

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, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

WARNING: To prevent personal injury or death, make sure 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, make sure the engine is supported before removing mounting hardware.

NOTE: See manufacturer's instructions for specific directions on safe use of Engine Stand and Engine Stand Mounting Bracket.

Cleaning the Engine

1. Cap all engine openings to prevent water and degreasing agents from entering engine.
2. Cover exposed electrical connections and Engine Control Module (ECM), using plastic and duct tape.
3. Clean engine using an appropriate detergent mixed in the correct ratio and a hot pressure washer or similar cleaning equipment.

Draining Coolant and Engine Oil

NOTE: Before mounting engine on Engine Stand, do steps 1 through 11.

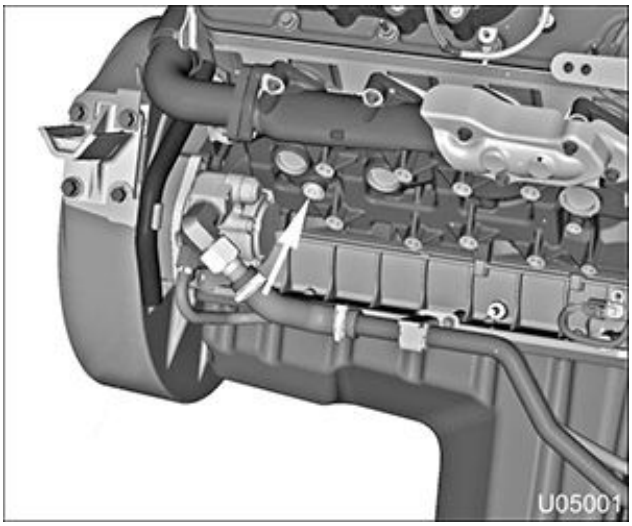

Figure 32 Coolant Drain Plug (Right side)

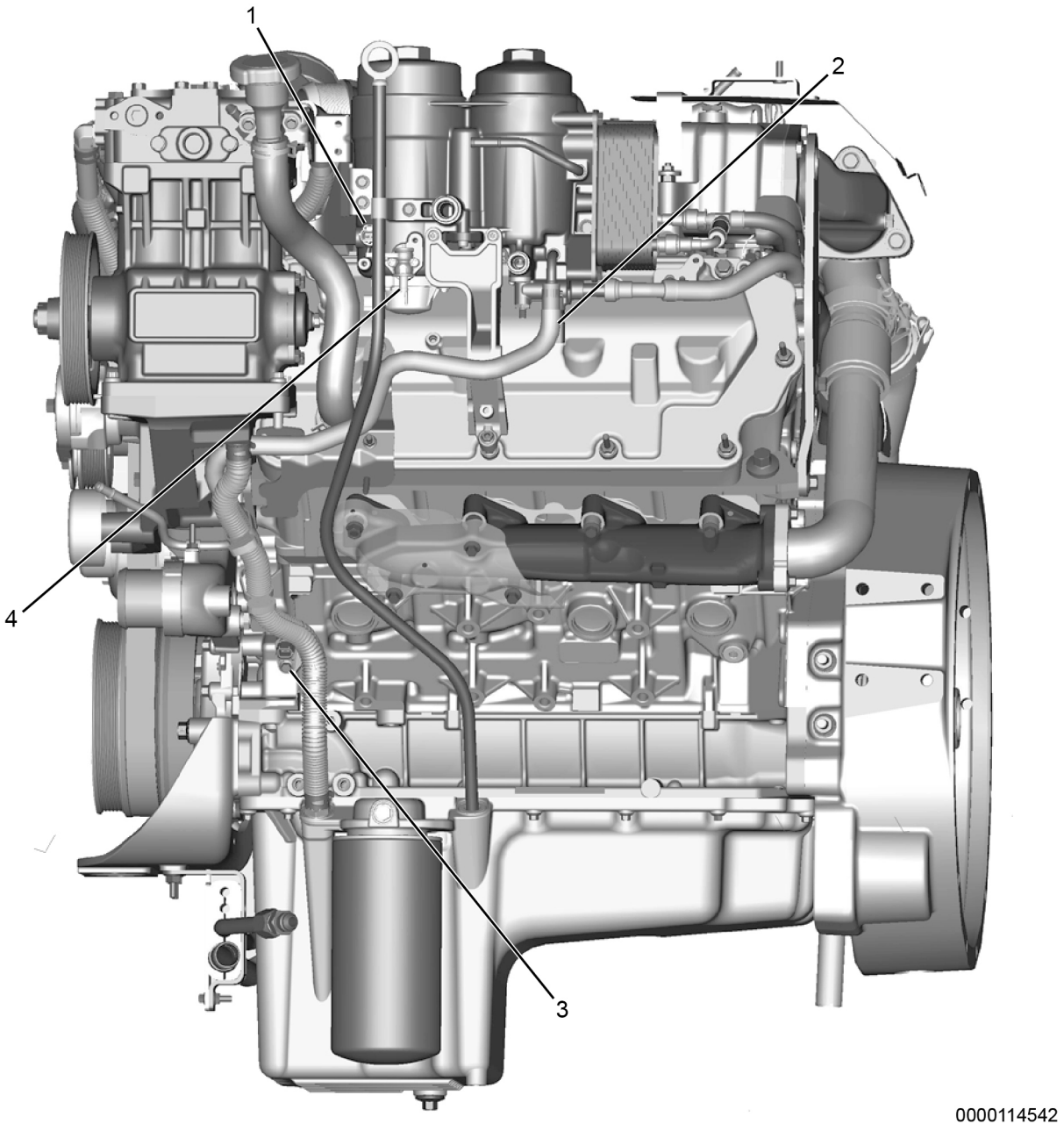

Figure 39 Electronic Components – Left

1. Water In Fuel (WIF) sensor
2. Engine Fuel Temperature (EFT) sensor
3. Camshaft Position (CMP) sensor
4. Fuel Pump

Intake Air Heater (IAH) Relay

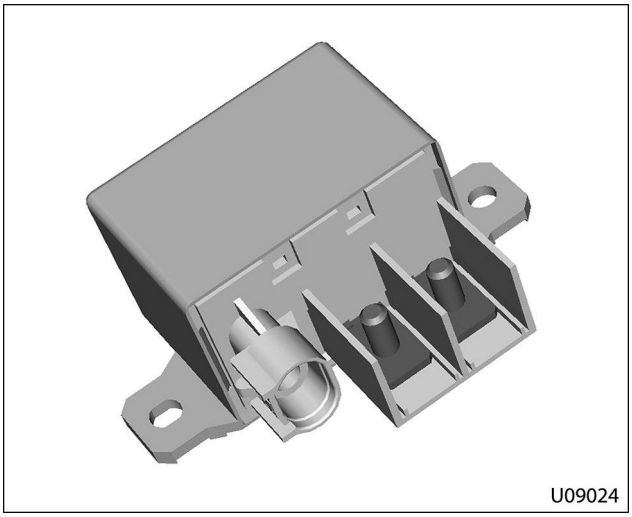

Figure 58 Intake Air Heater (IAH) Relay

The IAH relay delivers VBAT to the Intake Air Heater. The ECM activates the IAH by energizing the IAH relay while monitoring programmed conditions for engine coolant temperature, air inlet temperature, and atmospheric pressure. The ECM controls the WAIT TO START lamp and IAH relay separately.

The IAH relay is mounted to the relay support installed on top of the right valve cover.

Intake Manifold Pressure (IMP) Sensor

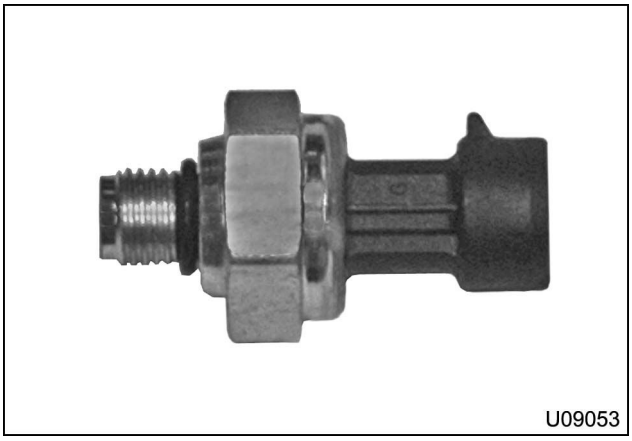

Figure 59 IMP Sensor

The IMP sensor is a variable capacitance sensor. The ECM monitors the IMP signal to determine intake manifold pressure (boost). This information is used to control the Exhaust Gas Recirculation (EGR) valve and determine fueling calculations.

The IMP sensor is installed (above the IMT sensor) in the top of the right valve cover and intake manifold base assembly, under the low-pressure turbocharger assembly.

Intake Manifold Temperature (IMT) Sensor

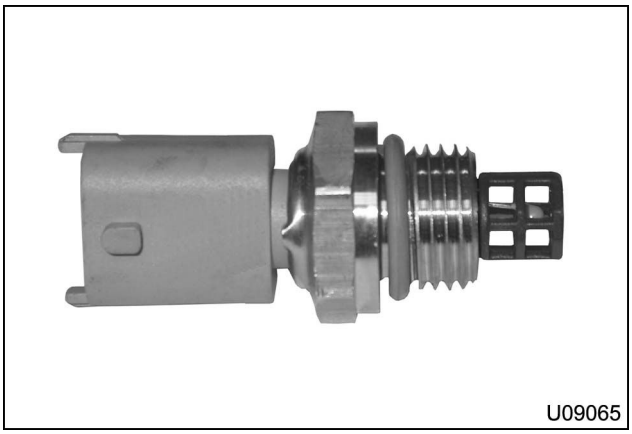

Figure 60 IMT Sensor

The IMT sensor is a thermistor sensor. The ECM monitors the IMT signal to control injector timing and fuel rate during cold starts. The ECM also uses the IMT signal to control Exhaust Gas Recirculation (EGR) valve position and intake throttle control.

The IMT sensor is installed (below the IMP sensor) in the top of the right valve cover and intake manifold base assembly, under the low-pressure turbocharger assembly.

Turbocharger 1 Compressor Outlet Temperature (TC1COT) Sensor

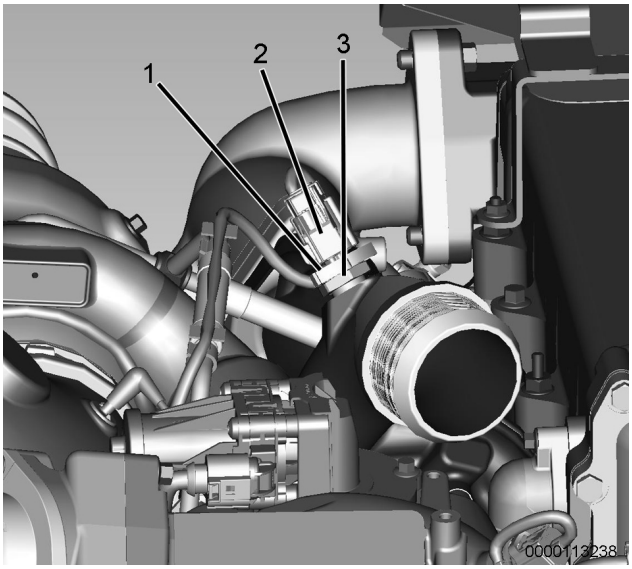

Figure 79 TC1COT Sensor

1. Clamp
2. 2-pin engine harness connector
3. TC1COT sensor

1. Open clamp on engine harness.
2. Pull out red CPA lock, press release tab on 2-pin engine harness connector, and pull connector from TC1COT sensor.
3. Remove TC1COT sensor from turbocharger 1 outlet.

Turbocharger 1 Wastegate Control (TC1WC) Solenoid

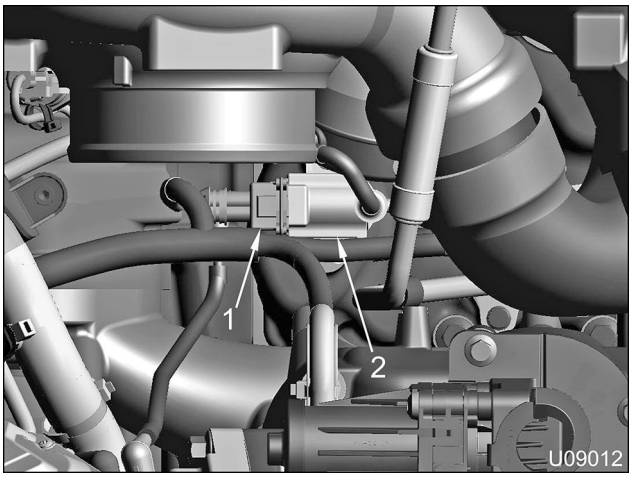

Figure 80 TC1WC Solenoid

1. 2-pin engine harness connector
2. TC1WC solenoid

NOTE: See Air Duct Assembly, Relief Tube Assembly, Wastegate Tube Assembly, and TC1WC Solenoid (page 156) for removal of TC1WC solenoid.

1. Remove air duct assembly.
2. Push down the metal clip on the 2-pin engine harness connector and disconnect connector from TC1WC solenoid.
3. Remove TC1WC solenoid.

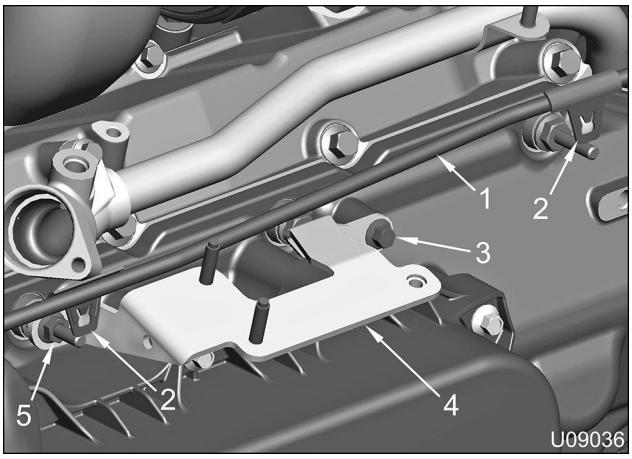

Figure 101 Relay Support

1. Jet pump tube assembly
2. Clip (2)
3. M6 x 14 bolt
4. Relay support
5. M6 nut

2. Pull out two clips on jet pump tube assembly and move up and away from stud bolts in valve cover.
3. Remove M6 x 14 bolt and M6 nut.
4. Remove relay support.

Fuel Rail Pressure (FRP) Sensor

NOTE: The FRP sensor is installed in the right fuel rail.

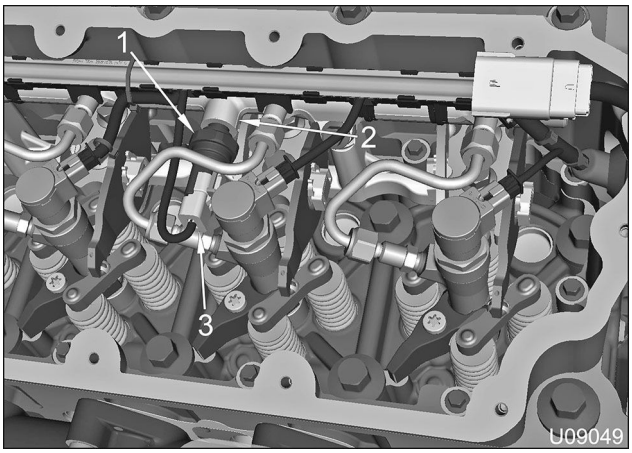

Figure 102 Fuel Rail Pressure (FRP) Sensor

1. Fuel Rail Pressure (FRP) sensor
2. Fuel rail
3. UVC Connector to FRP sensor (right harness only)

NOTE: See procedures in the "Cylinder Heads, Valve Covers, and Valve Train" section to remove the right valve cover (page 315).

1. Disconnect UVC Connector from FRP sensor, using Injector Connector Release Tool (page 111).
2. Remove FRP sensor from right fuel rail.
3. Remove and discard FRP sensor gasket from FRP sensor.

Under Valve Cover (UVC) Harnesses

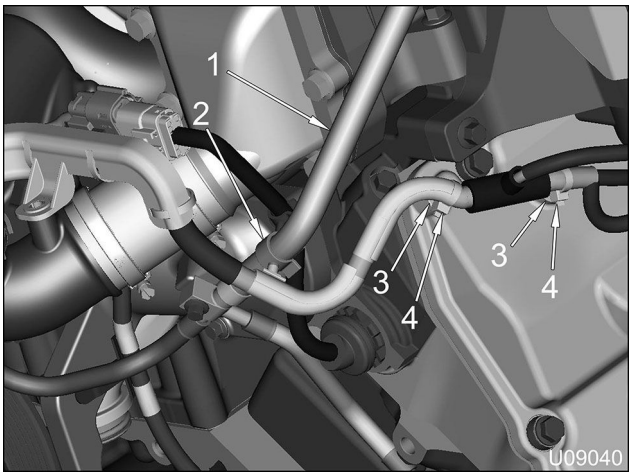

Figure 115 Engine Harness to Injector Hose Assembly and Tie Straps to Left Valve Cover

1. Injector hose assembly
2. Engine harness clip
3. Harness fir zip retainer (2)
4. Tie strap (2)

5. Connect engine harness clip to injector hose assembly.
6. Install two tie straps to secure engine harness to fir zip retainer in left valve cover.

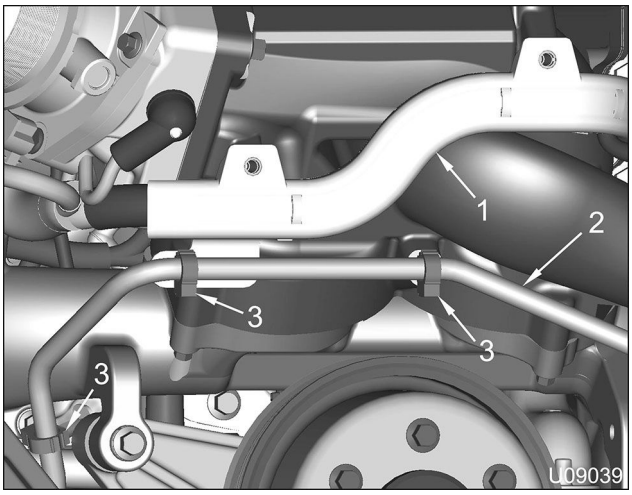

Figure 116 Harness Channel Shield

1. Harness channel shield
2. Injector hose assembly
3. .25 hose clip (3)

7. Engage hose clip to harness channel shield, manifold mixer, and bracket on heater supply tube.

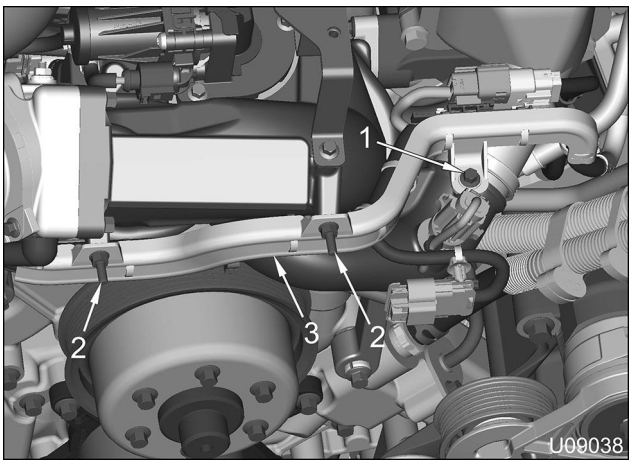

Figure 117 Harness Channel Shield Assembly (front)

1. M6 x 16 bolt
2. M6 x 16 stud bolt (2)
3. Harness channel shield

8. Install one M6 x 16 bolt and two M6 x 16 stud bolts to secure the harness channel shield to the manifold mixer.

1. See Intake Air Heater (page 134) for installation.
2. Install ring terminal of engine harness and nut onto stud bolt in the IAH. Tighten nut to standard torque (page 473).
3. Push boot onto engine harness connection.

Engine Throttle Valve (ETV)

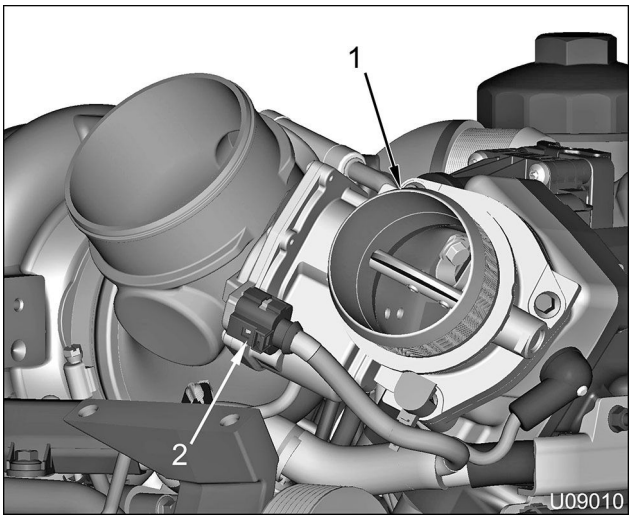

Figure 137 Engine Throttle Valve (ETV)

1. ETV
2. 6-pin engine harness connector

1. See Engine Throttle Valve (ETV) (page 135) for installation.
2. Connect 6-pin engine harness connector harness to ETV.

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, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

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.

NOTE: See the following sections for removal of components.

- Engine Electrical
- Dual Turbocharger
- Air Compressor and Power Steering Pump
- Fuel System

EGR Valve Assembly

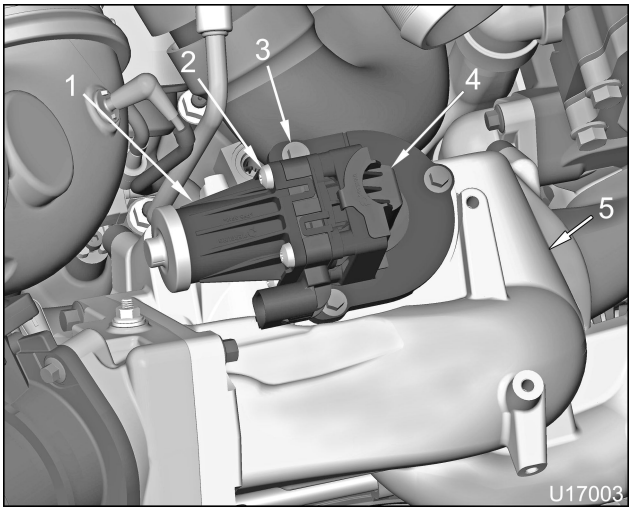

Figure 145 EGR Valve Assembly

1. DC motor
2. T-30 Torx screw (4)
3. M6 x 20 bolt (3)
4. Inspection cover
5. Manifold mixer

1. Remove inspection cover from EGR valve.
2. Remove four T-30 Torx screws from DC motor and remove DC motor from EGR valve.
3. Remove three M6 x 20 bolts that secure EGR valve assembly to manifold mixer.

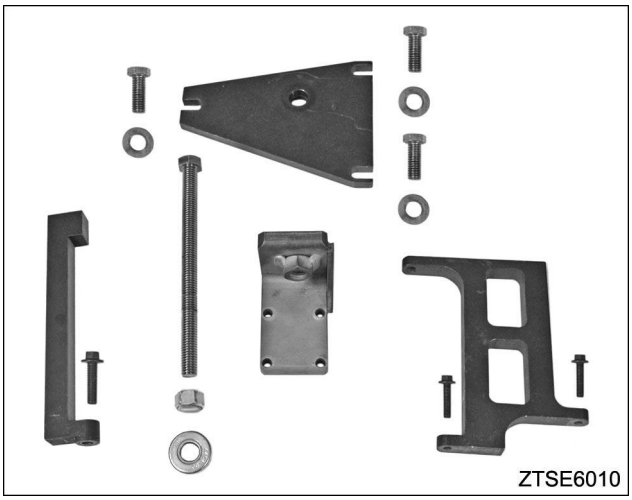

Figure 146 EGR Valve Puller

Cleaning, Inspection, and Testing

EGR System Components

NOTE: Do not remove EGR cooler end caps prior to inspection. Removing end caps will result in rejection of warranty claim.

1. Clean all gasket material and carbon deposits off of EGR cooler and exhaust manifold mating surfaces.
2. Clean gasket mating surfaces of EGR cooler and EGR valve elbow housing.
3. Clean gasket mating surfaces of EGR valve assembly and remove all carbon deposits, using EGR Valve Brush (page 140).
4. Clean all corrosion from ends of all EGR valve assembly coolant pipes and tubes.
5. Clean EGR coolant supply and EGR coolant return ports in front of front crankcase cover assembly.
6. Inspect all EGR system components for cracks and damage. Install new components if necessary.

Manifold Mixer

Clean manifold mixer with steam or suitable non-caustic solvents.

Clean contact areas of EGR O-ring in manifold mixer housing. Make sure carbon debris is removed above and below contact areas of manifold mixer.

EGR Cooler

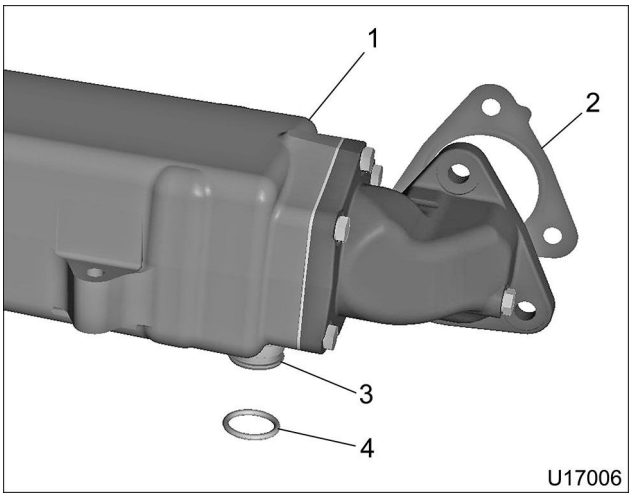

Figure 176 Coolant Gasket and O-ring Seal

1. EGR cooler
2. Turbocharger inlet gasket
3. O-ring seal nipple
4. O-ring seal

1. Lubricate new O-ring seal with P-80® Rubber Lubricant or equivalent (page 140). Install O-ring on nipple of EGR cooler.

Exhaust Tubes

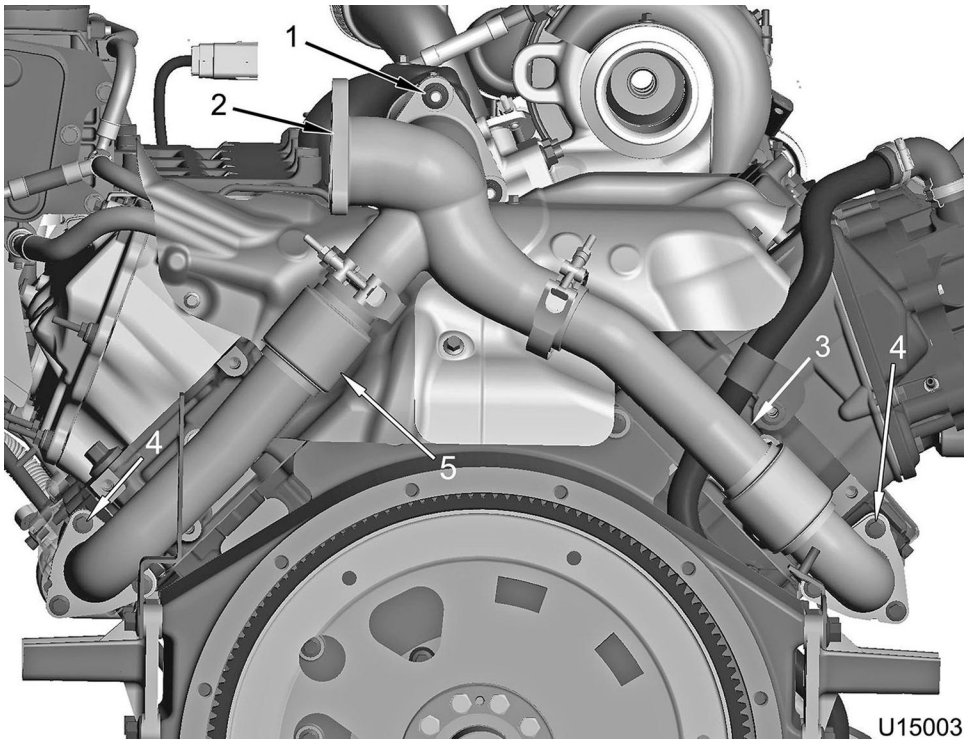

Figure 183 Exhaust Tubes

1. M10 nut (3)
2. Turbo exhaust inlet manifold
3. Right exhaust tube assembly
4. M8 x 27 bolt (6)
5. Left exhaust tube assembly

1. Remove three M10 nuts.
2. Remove three M8 x 27 bolts securing right exhaust tube assembly to right exhaust manifold.
3. Remove three M8 x 27 bolts securing left exhaust tube assembly to left exhaust manifold.
4. Remove turbocharger exhaust inlet manifold, right exhaust tube assembly, and left exhaust tube assembly – as a group.

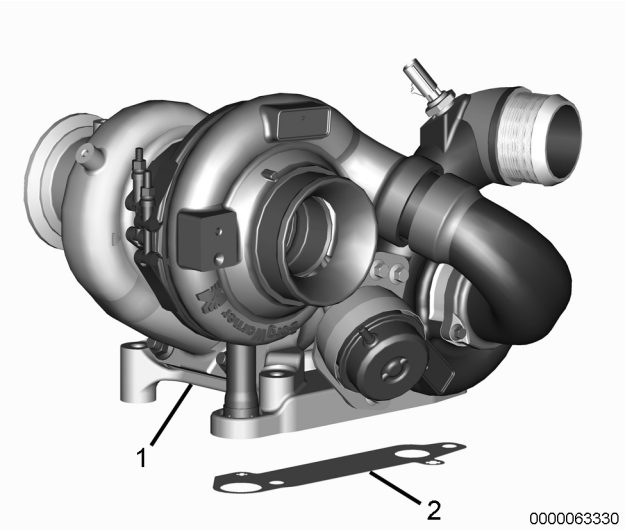

Figure 202 Dual Turbocharger and Turbocharger Oil Drain Gasket

1. Dual turbocharger
2. Turbocharger oil drain gasket

3. Remove dual turbocharger and discard turbocharger oil drain gasket.
4. Put turbocharger on a bench for additional disassembly.

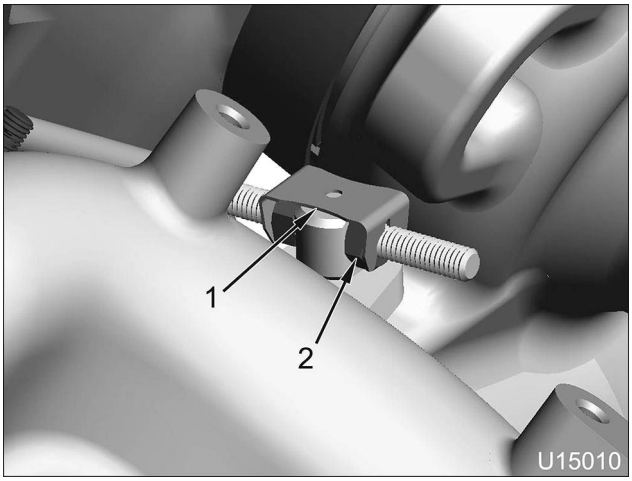

Figure 203 Wastegate Actuator Clip

1. Wastegate actuator clip
2. Nut (2)

5. Use flat head screw driver to pry off wastegate actuator clip covering actuator nuts.
6. Remove nut closest to rod end.

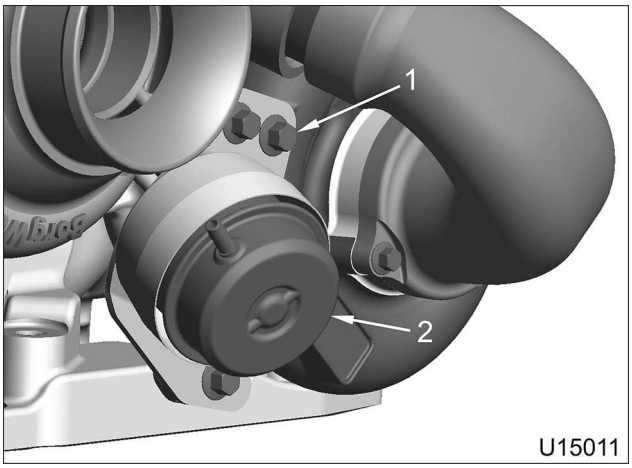

Figure 204 TC1WC Wastegate Actuator Bolts

1. M8 x 16 bolt (3)
2. TC1WC actuator

7. Remove three M8 x 16 bolts and TC1WC actuator.

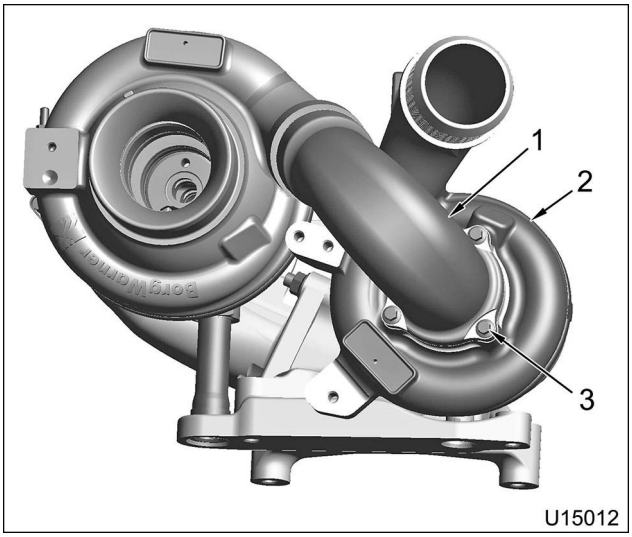

Figure 205 Crossover Tube

1. Crossover tube
2. High-pressure turbocharger assembly
3. M6 x 20 bolt (3)

8. Remove three M6 x 20 bolts from crossover tube flange.
9. Remove crossover tube.

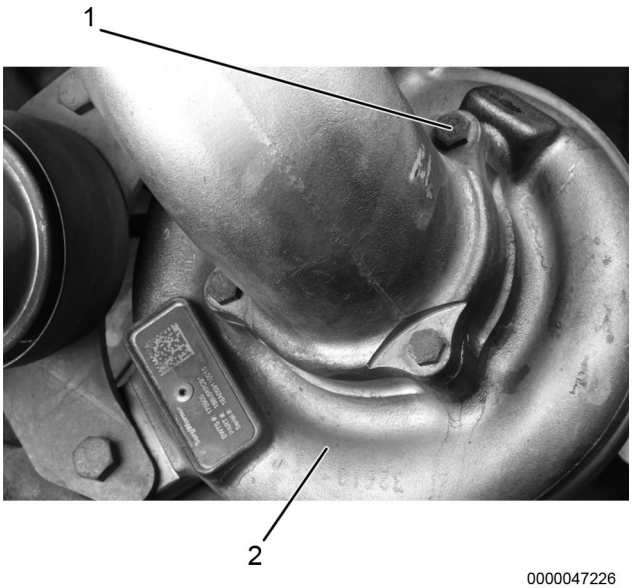

Figure 225 Crossover Tube Mounting

1. Bolt (3)
2. Turbocharger assembly

36. Install turbocharger crossover tube on turbocharger assembly with three bolts. Tighten bolts to 115 lb-in (13 N•m).

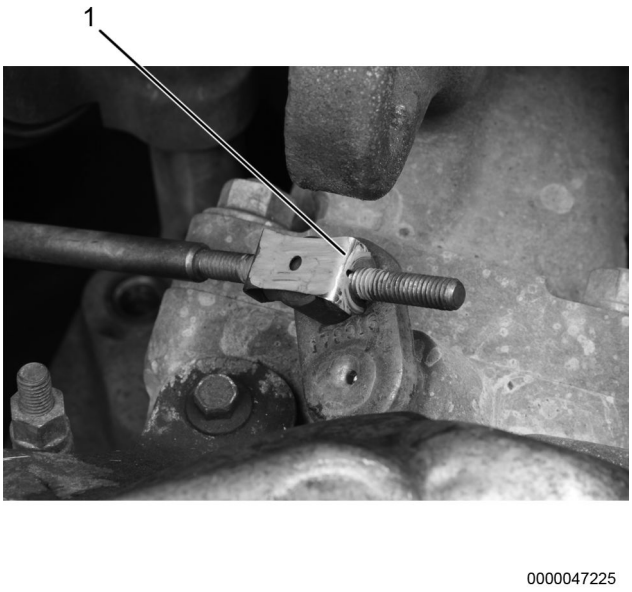

Figure 226 Wastegate Actuator Rod Assembly Clip

1. Wastegate actuator rod assembly clip

37. Adjust wastegate actuator assembly. Refer to (TC1WC Wastegate Actuator Set Procedure, page 169).
38. Install wastegate actuator rod assembly clip.

Check Free Rotation and Housing Rub

1. Place turbocharger assembly on a bench with the shaft in a horizontal position.

Dual Turbocharger Heat Shields

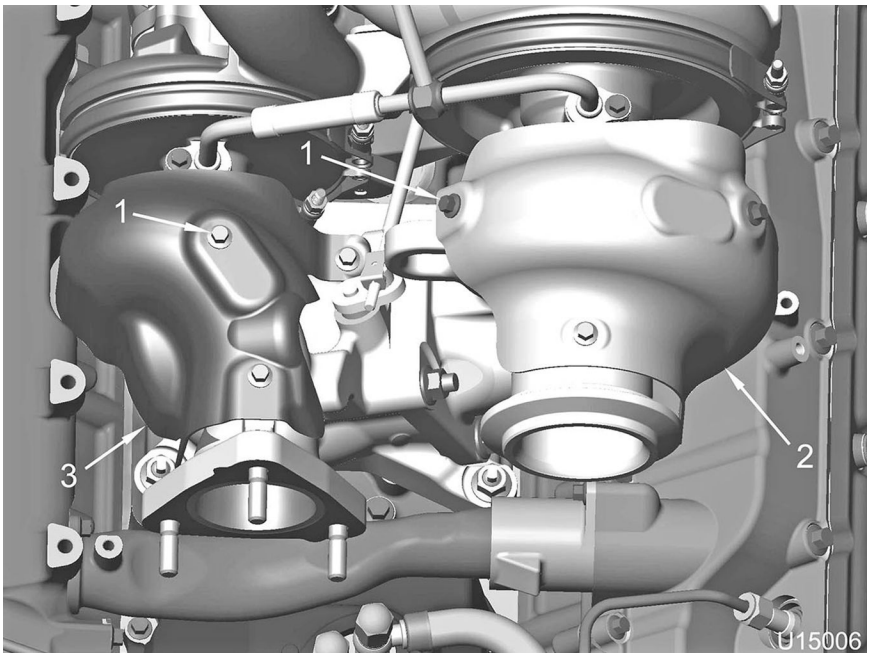

Figure 246 Dual Turbocharger Heat Shields

1. M6 x 10 bolt (6)
2. Low-pressure turbocharger heat shield
3. High-pressure turbocharger heat shield

1. Position high-pressure turbocharger heat shield.
2. Install three M6 x 10 bolts to secure high-pressure turbocharger heat shield. Tighten bolts to standard torque (page 473).
3. Position low-pressure turbocharger heat shield.
4. Install three M6 x 10 bolts to secure low-pressure turbocharger heat shield. Tighten bolts to standard torque (page 473).

Pump Cover Heat Shields

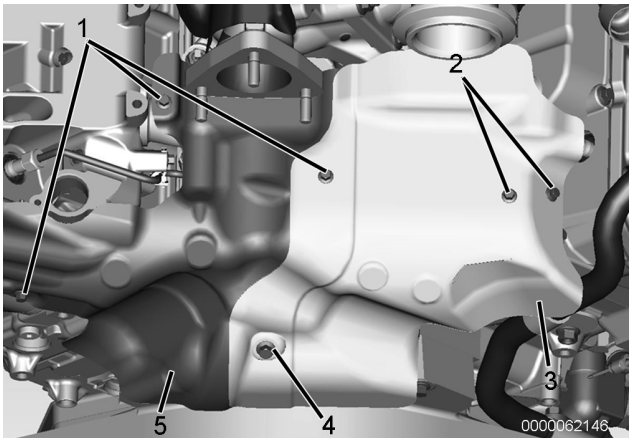

Figure 247 Pump Cover Heat Shields

1. M6 x 14 bolt (3)
2. M6 x 25 bolt (2)
3. Right pump cover heat shield
4. M8 x 12 bolt
5. Left pump cover heat shield

Exploded Views

Cleaning and Testing

All Components

1. Clean foreign material from gasket surfaces of air compressor and air compressor bracket. Use a scraper to remove gasket from gasket surfaces.

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

2. Wash air compressor bracket. Dry with filtered compressed air.
3. Wash power steering pump gear with a stiff brush and suitable solvent. Dry with filtered compressed air.

Power Steering Pump Idler Gear Backlash Measurement

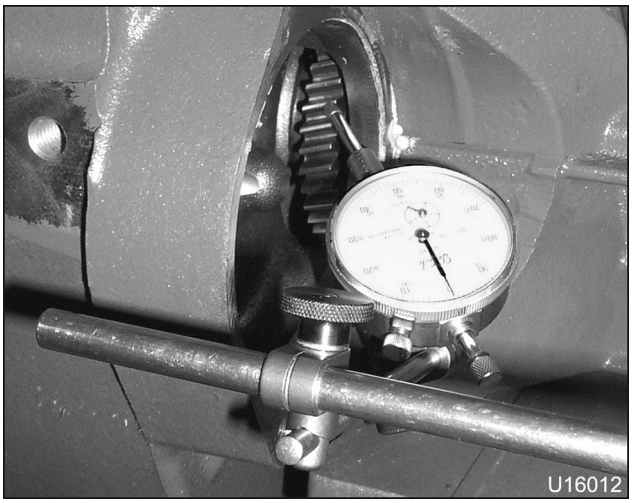

Figure 275 Power Steering Idler Gear Backlash

1. Attach dial indicator with magnetic base to crankcase rear cover.
2. Place indicator tip against power steering idler gear assembly.
3. Rotate gear by hand in one direction and zero the dial indicator.
4. Rock power steering idler gear assembly back and forth and verify that backlash reading is within specification (page 205).

Table of Contents

Pump to Cooler Hose and Filter to Pump Hose Assemblies

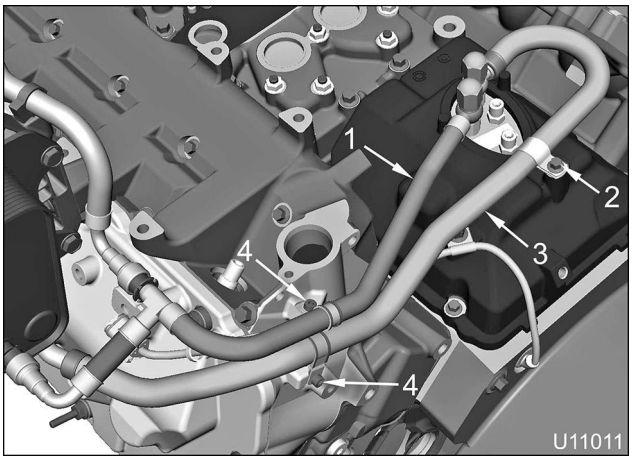

Figure 300 Pump to Cooler Hose and Filter to Pump Hose Assemblies

1. Pump to cooler hose assembly
2. M6 x 14 bolt
3. Filter to pump hose assembly
4. M5 x 12 socket head bolt (2)

1. Remove M6 x 14 bolt and M5 x 12 socket head bolt that secure filter to pump hose assembly.
2. Remove M5 x 12 socket head bolt that secures pump to cooler hose assembly.

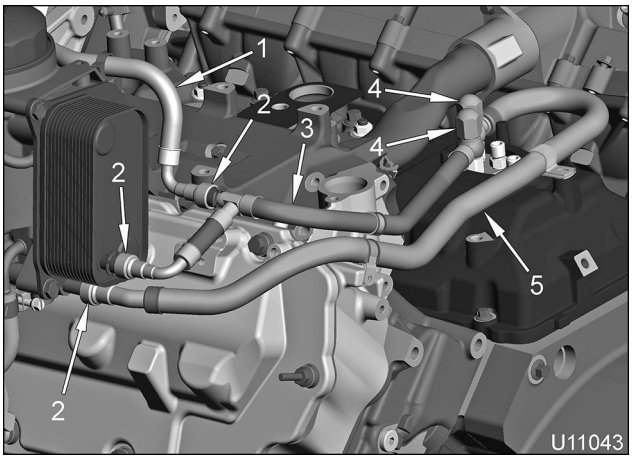

Figure 301 Quick Connectors and Cap Nuts

1. Injector return hose assembly
2. Quick connector
3. Pump to cooler hose assembly
4. M12 cap nut (2)
5. Filter to pump hose assembly

3. Loosen M12 cap nuts that secure the filter to pump hose assembly and pump to cooler hose assembly to the high-pressure fuel pump.

Fuel Coolant Supply Tube Assembly

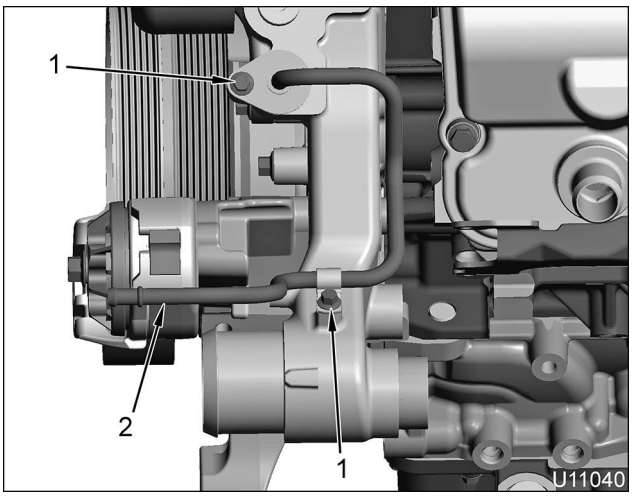

Figure 322 Fuel Coolant Supply Tube Assembly

1. M6 x 16 bolt (2)
2. Fuel coolant supply tube assembly

1. Remove two M6 x 16 bolts and fuel coolant supply tube assembly.

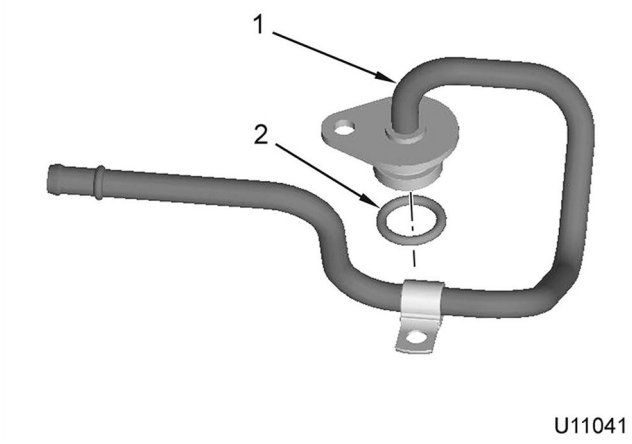

Figure 323 Fuel Coolant Supply Tube and O-ring Seal

1. Fuel coolant supply tube
2. O-ring seal

2. Remove O-ring seal from fuel coolant supply tube and discard O-ring seal.

Fuel Filter and Cooler Assembly

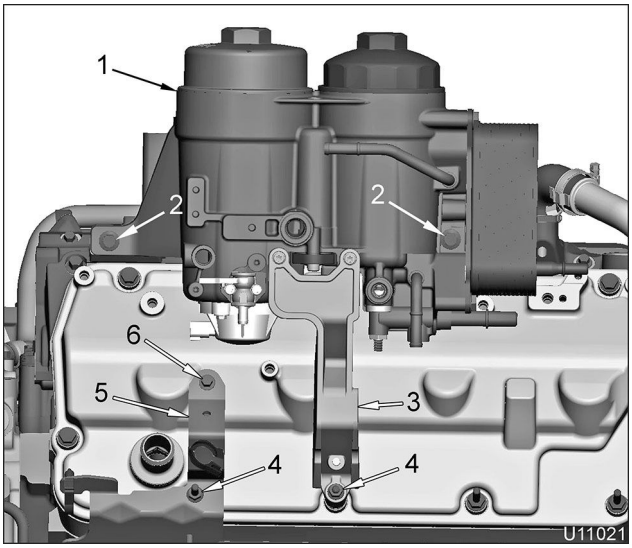

Figure 324 Fuel Filter and Cooler Assembly

1. Fuel filter cooler assembly
2. M8 x 35 bolt (2)
3. Filter cooler pump module support
4. M6 nut (2)
5. Hose bracket assembly
6. M6 x 20 bolt

1. Remove M6 nut from filter cooler pump module support.
2. Remove two M8 x 35 bolts that secure the fuel filter cooler assembly.
3. Remove fuel filter cooler assembly with filter cooler pump module support.
4. Remove M6 x 20 bolt, M6 nut, and hose bracket assembly.

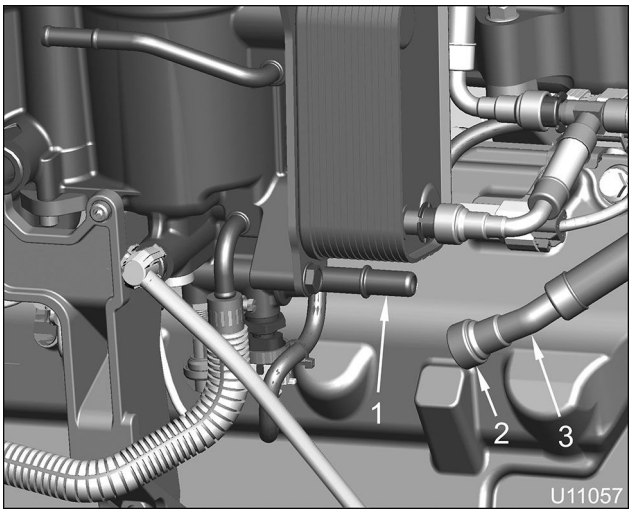

Figure 340 Quick Disconnect on Filter to Pump Hose Assembly

1. Clean outlet
2. 1/2 inch quick disconnect
3. Filter to pump hose assembly

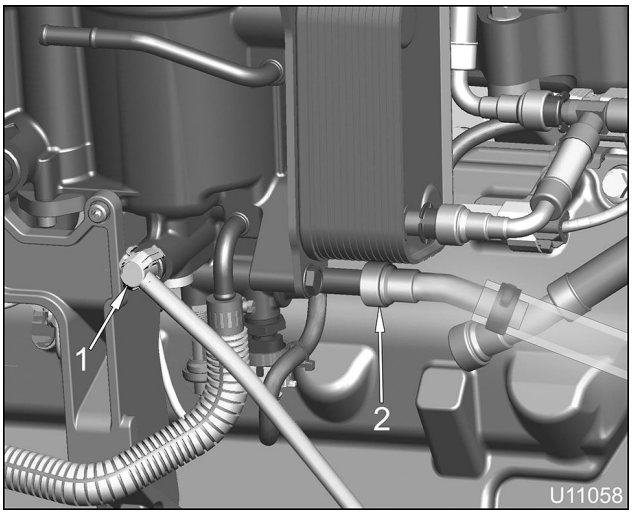

Figure 341 Fuel Filter Purge Line Connection to the Clean Outlet

1. Fuel Filter Purge Line
2. Return-to-tank hose

⚠ WARNING: To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked DIESEL FUEL.

3. Position a suitable container under the clean outlet on the fuel filter module housing, disconnect the 1/2 inch quick disconnect, and remove the filter to pump hose assembly. Cap the quick disconnect on the filter to pump hose assembly.
4. Attach Fuel Filter Purge Line to the clean outlet on the fuel filter module housing.
5. Connect the other end of the Fuel Filter Purge Line the Return Line attached to the 2.5 Gallon Clean Fuel Tank.
6. Restore electrical power to the system.
7. Remove the return-to-tank hose from fuel filter module housing.
8. Turn ignition key to ON for one Key-ON / Key-OFF sequence to energize the low pressure fuel pump.
   - Key - On for 15 seconds
   - Key - Off for 20 seconds

   Ensure that fuel is flowing into the 2.5 Gallon Clean Fuel Tank and check for leaks.

Oil Level Tube Assembly and Coolant Return Hose

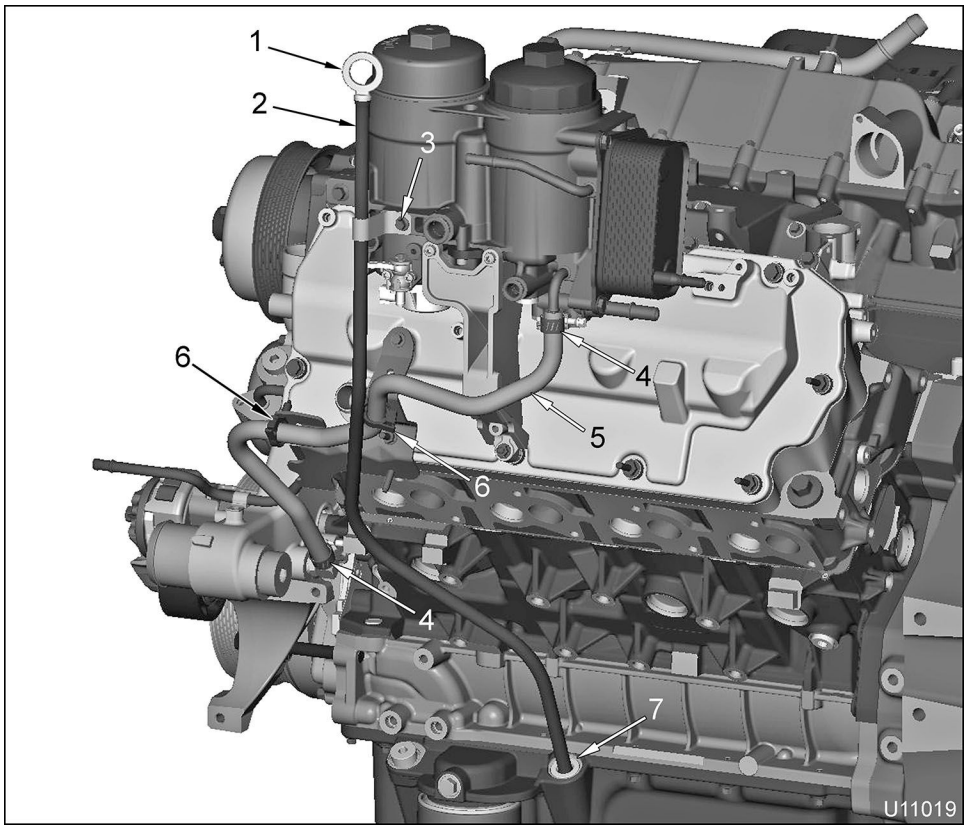

Figure 351 Oil Level Tube Assembly and Coolant Return Hose

1. Oil level gauge assembly
2. Oil level gauge tube with support
3. M6 x 16 bolt
4. Hose clamp (2)
5. Coolant return hose
6. Hose clip (2)
7. Oil level tube gauge gasket

1. Install coolant return hose, close hose clips, and tighten hose clamps to special torque (page 260).
2. Install new oil level tube gauge gasket.
3. Install M6 x 16 bolt to secure oil level gauge tube with support and tighten bolt to standard torque (page 473).
4. Install oil level gauge assembly.
5. Install oil fill support bracket and oil fill hose assembly (page 357).

High-Pressure Fuel Pump Assembly

NOTE: If the high-pressure fuel pump gear bolt was not removed, skip steps 1–4.

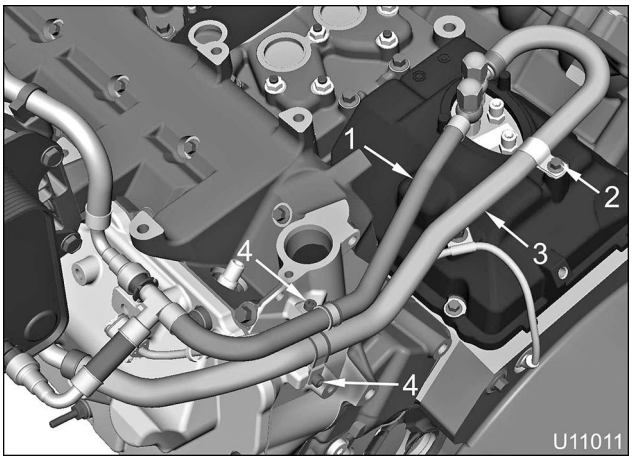

Figure 375 Pump to Cooler Hose and Filter to Pump Hose Assemblies

1. Pump to cooler hose assembly
2. M6 x 14 bolt
3. Filter to pump hose assembly
4. M5 x 12 socket head bolt (2)

9. Install M6 x 14 bolt and M5 x 12 socket head bolt to secure filter to pump hose assembly. Tighten M6 x 14 bolt and M5 x 12 socket head bolt to standard torque (page 473).
10. Install M5 x 12 socket head bolt to secures pump to cooler hose assembly. Tighten M5 x 12 socket head bolt to standard torque (page 473).
11. Tighten cap nuts, for filter to pump hose assembly and pump to cooler hose assembly, to special torque (page 260).

NOTE: See installation procedure for Balance Duct and Balance Tube Flange (page 361).

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: Failure to observe the following warning may cause property damage, personal injury, or death. To prevent personal injury or death, read all safety instructions in the "Safety Information" section of this manual.

WARNING: Failure to observe the following warning may cause property damage, personal injury, or death. 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: Failure to observe the following warning may cause property damage, personal injury, or death. To prevent personal injury or death, disconnect the main battery negative terminal before disconnecting or connecting electrical components.

WARNING: Failure to observe the following warning may cause property damage, personal injury, or death. To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

WARNING: Failure to observe the following warning may cause property damage, personal injury, or death. 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: Failure to observe the following warning may cause property damage, personal injury, or death. To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

NOTE: See the following service sections for information on removal of components prior to this section.

- **Engine Electrical**
- **Exhaust Gas Recirculation (EGR) System**
- **Air Compressor and Power Steering Pump**
- **Fuel System**

Alternator and Refrigerant Compressor Mounting Bracket

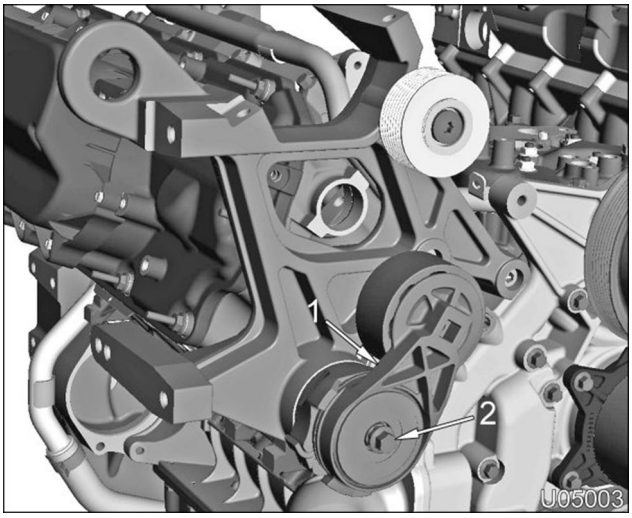

Figure 380 Belt Tensioner

1. Belt tensioner
2. M10 x 80 bolt

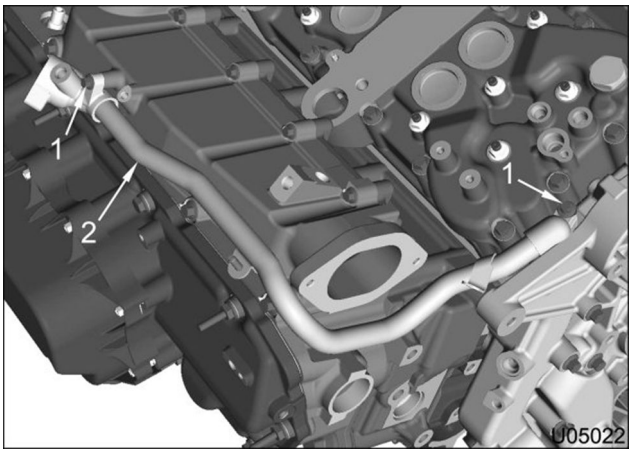

Figure 402 Heater Supply Tube Assembly

1. M6 x 25 bolt (2)
2. Heater supply tube assembly

6. Install two M6 x 25 bolts to secure heater supply tube assembly. Tighten bolts to standard torque (page 473).

Vibration Damper

1. See Vibration Damper Runout (page 274) for procedures.

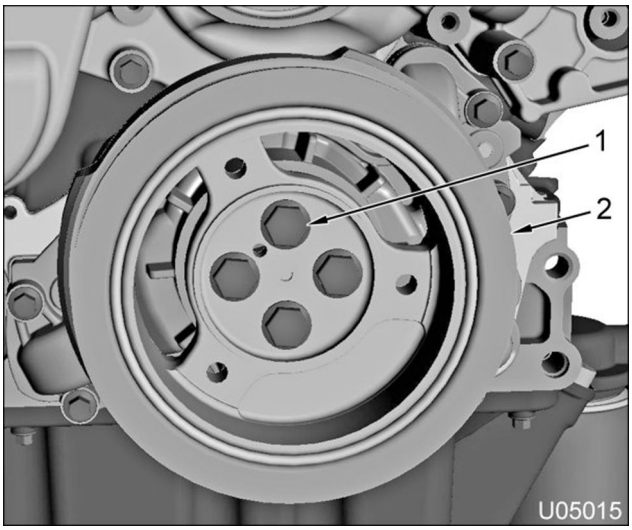

Figure 403 Vibration Damper

1. M12 x 59 bolt (4)
2. Vibration damper

WARNING: To prevent personal injury or death, install four new bolts to secure the vibration damper.

2. Align vibration damper with dowel pin on front of crankshaft.

NOTE: Do not use anti-seize compounds, grease or lubricants on mounting bolts. Each has an adverse effect on torque results.

3. Install four new M12 x 59 bolts to secure vibration damper on crankshaft.

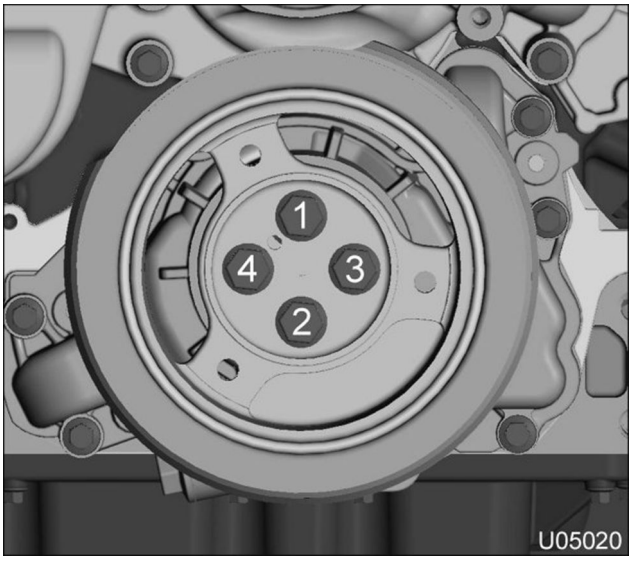

Figure 404 Torque Sequence for Vibration Damper Bolts

4. Tighten each bolt in torque sequence to special torque 68 N·m (50 lb·ft).
5. Rotate each bolt an additional 90° using torque sequence.

Exploded Views

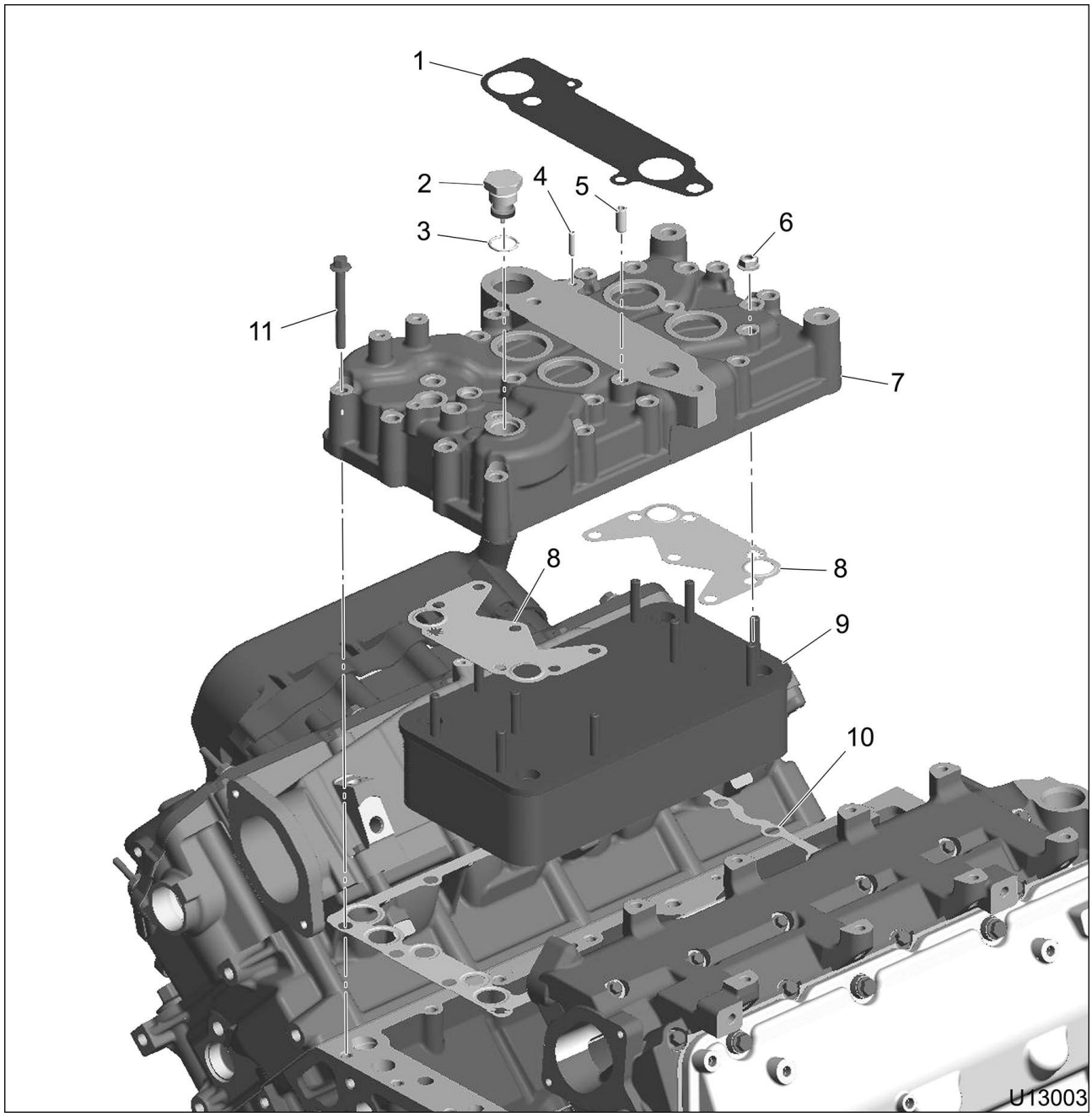

Figure 416 Oil Cooler Assembly

1. Turbo oil drain gasket
2. Oil cooler bypass valve assembly
3. Bypass valve cap seal
4. M5 x 20 slotted pin
5. M8 x 20 slotted pin
6. Serrated nut (10)
7. Oil cooler cover
8. Cooler to cover gasket (2)
9. Oil cooler
10. Cover to crankcase gasket
11. M8 x 70 bolt (12)

Oil Filter Assembly

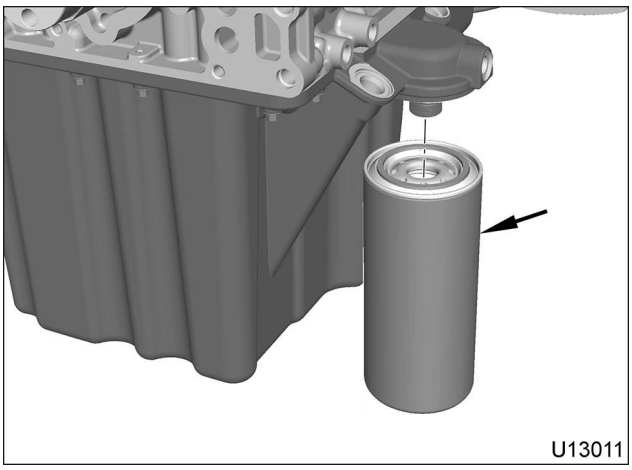

Figure 433 Oil Filter Assembly

1. Remove oil filter assembly.

Oil Pan

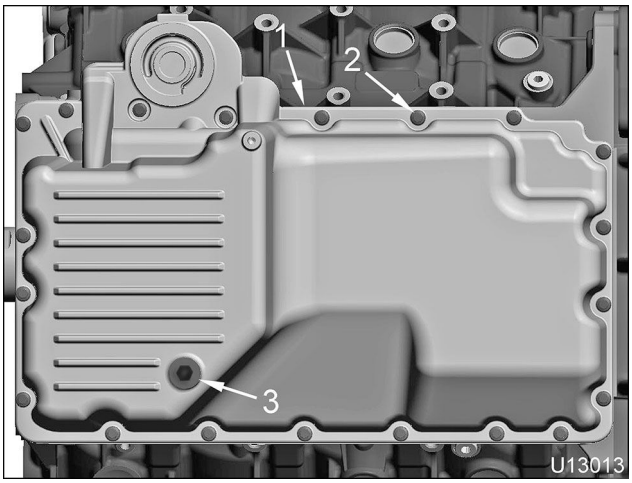

Figure 434 Oil Pan

1. Oil pan
2. M6 x 25 bolt (20)
3. Oil drain plug assembly

1. Remove twenty M6 x 25 bolts.
2. If not previously removed, remove oil drain plug assembly.

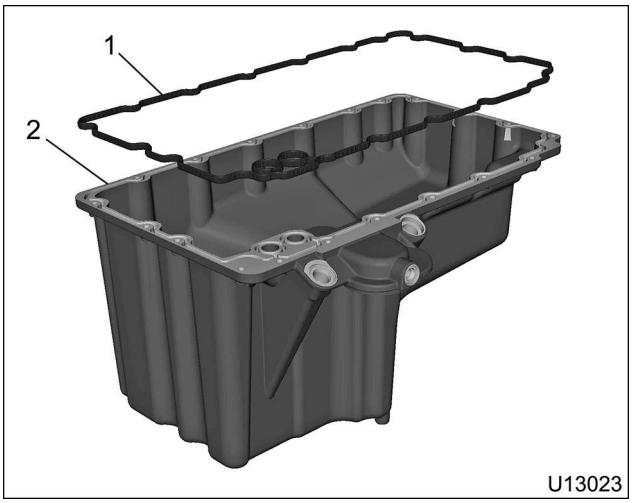

Figure 435 Oil Pan Gasket

1. Oil pan gasket
2. Oil pan

3. Remove oil pan and discard oil pan gasket.

Lube Oil Suction Tube

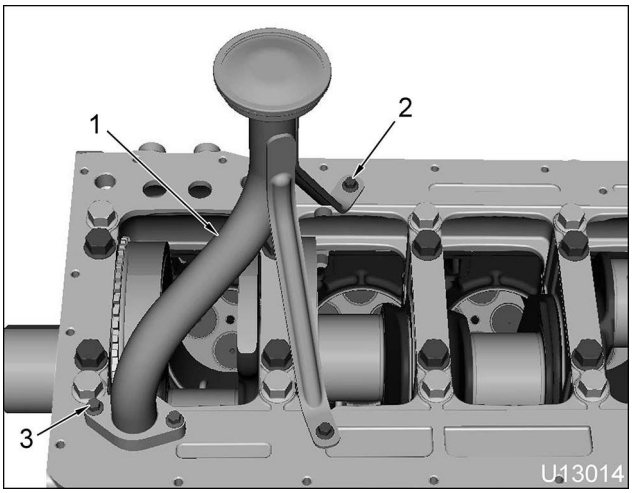

Figure 436 Lube Oil Suction Tube

1. Lube oil suction tube
2. M6 x 12 bolt (2)
3. M6 X 20 bolt (2)

1. Remove M6 x 12 bolts and M6 X 20 bolts.
2. Remove lube oil suction tube.

Specifications

Oil Pump Assembly	
Type	Gerotor
Drive	Crankshaft
Location	Oil pump housing assembly
Pressure Regulating Valve: Operates between 5.2 kPa - 6.0 kPa (75 psi - 87 psi)	
End clearance (inner and outer oil pump rotor to oil pump housing assembly)	0.025 to 0.095 mm (0.001 to 0.004 in)
Radial clearance (between outer oil pump rotor and oil pump housing assembly)	0.15 to 0.28 mm (0.006 to 0.011 in)

Oil Cooler Assembly	
Type	Full flow, fin
Location	Engine valley (front)

Oil Filter	
Type	Spin-on, full flow - disposable
Location	Oil pan mounted
Filter bypass location	Oil filter can

Special Torque

Oil cooler bypass valve assembly	71 N·m (52 lb·ft)
Oil cooler cover assembly serrated nuts	See assembly procedure for special torque sequence
Hex plug assembly (oil pan)	25 N·m (18 lb·ft)
Plug assembly, M18 (oil pan)	25 N·m (18 lb·ft)
Oil pan drain plug (M14)	44 N·m (32 lb·ft)
Oil filter adapter (oil pan)	55 N·m (40 lb·ft)
Oil pump housing plate screws, M8 x 25	17 N·m (150 lb·in)
Relief valve cap, oil pump	35 N·m (26 lb·ft)

Draft Tube Assembly

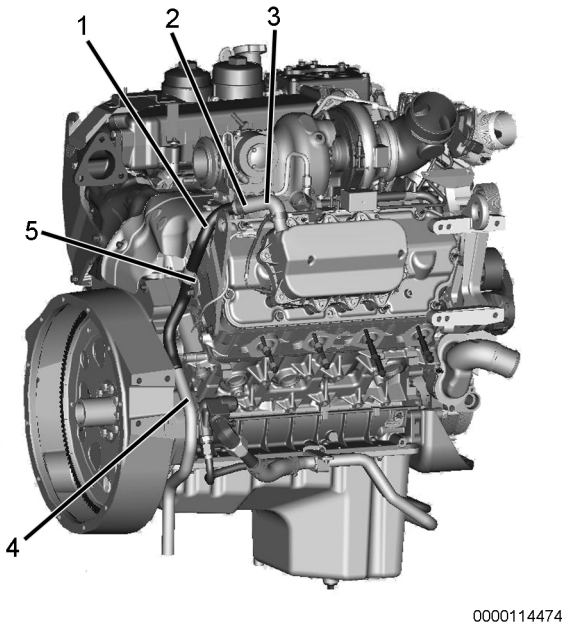

Figure 466 Draft Tube Assembly

1. Upper draft tube
2. 1” worm gear hose clamp (2)
3. 1” 90° elbow
4. Lower draft tube
5. M12 nut

NOTE: New lower draft tube assembly (7091588C1) will be non-serviceable.

1. Loosen worm gear hose clamp connecting 90° elbow to upper draft tube assembly.
2. Remove M12 nut securing upper draft tube assembly to rear crankcase cover.
3. Remove draft tube assembly.
4. Loosen worm gear hose clamp on 90° elbow to breather cover and remove elbow.
5. If necessary, remove worm gear hose clamps from elbow.

Lifting Eye and Jet Pump Tube Assembly

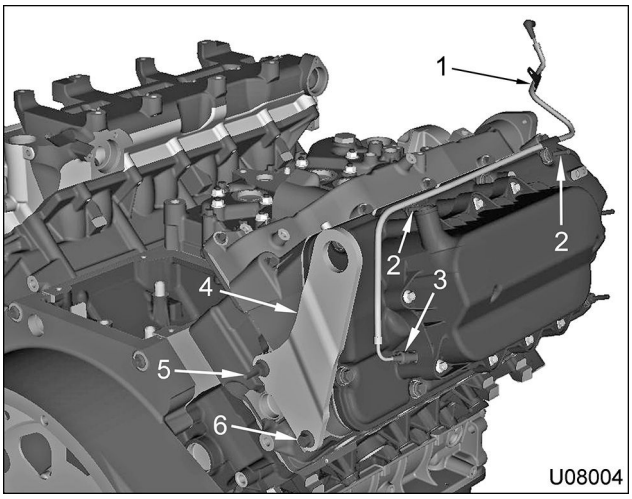

Figure 467 Lifting Eye and Jet Pump Tube Assembly

1. Jet pump tube assembly
2. Valve cover stud bolt assembly (2)
3. Nut
4. Lifting eye
5. M10 x 25 stud bolt
6. M10 x 25 bolt

1. Remove M10 x 25 stud bolt, M10 x 25 bolt, and lifting eye from cylinder head.
2. Disconnect nut on jet pump tube assembly from fitting in right valve cover.
3. Remove jet pump tube assembly from stud bolts in right valve cover, and discard jet pump tube assembly.

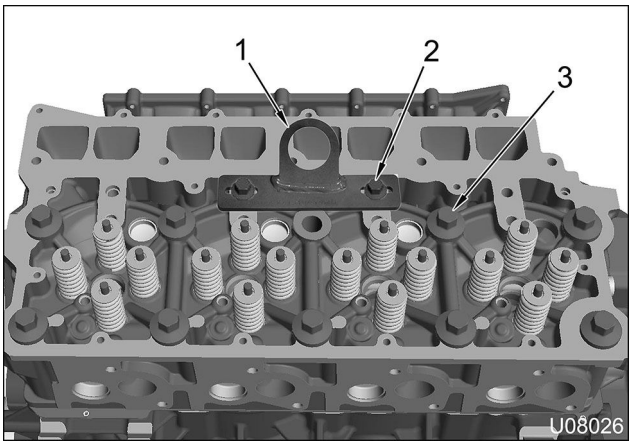

Figure 484 Installation of Cylinder Head Lifting Bracket and Removal Of Cylinder Head Bolts (typical)

1. Cylinder Head Lifting Bracket
2. M10 x 70 bolt (2)
3. M16 x 172 bolts (9)

2. Position Cylinder Head Lifting Bracket (page 365) on cylinder head over the center two threaded holes for the fulcrum plate assemblies and install two M10 x 70 bolts.
3. Tighten two M10 x 70 bolts to standard torque (page 473).
4. Attach a lifting hoist hook or suitable lifting sling to lifting bracket.
5. Using a circular pattern loosen, remove, and discard nine M16 x 172 cylinder head bolts. Begin with the outer bolts and move inward.
6. Lift cylinder head from crankcase.

CAUTION: To prevent engine damage, do not scratch gasket surface of cylinder head.

7. Place cylinder head on a protected surface.
8. Remove and discard cylinder head gasket.

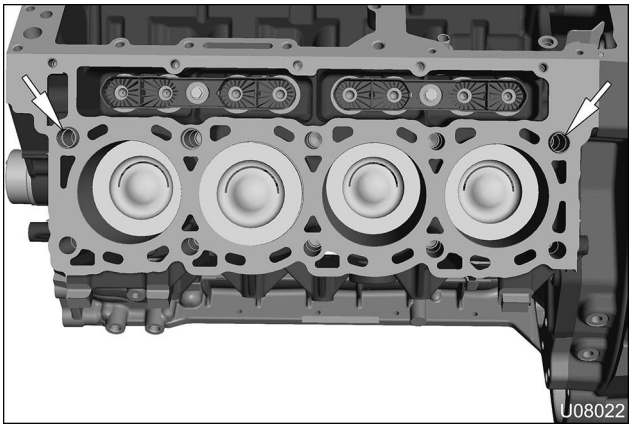

Figure 485 Cylinder Head Spring Dowel Pins (typical)

9. Remove two spring dowel pins.
10. For left cylinder head, remove two M10 x 25 bolts and lifting eye.

Valve Seats

1. Clean valve seat area using suitable solvent, before inspection.
2. Inspect exhaust valve seats for burned or cracked conditions. If any of these conditions exist, replace cylinder head.
3. Using a dial caliper (page 365), measure valve seat width. See Specifications (page 364). Replace cylinder head if necessary.

Valves

1. Use a wire brush to remove all carbon from valve stems and heads.
2. Inspect each valve. Replace valves having burn marks, warping, scuffing, bending or valve tip spalling.

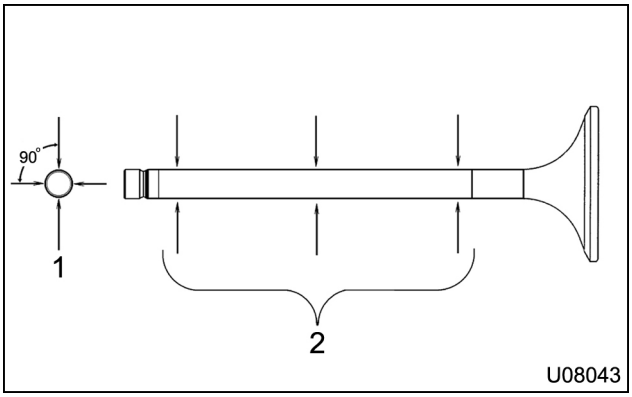

Figure 507 Valve Stem Diameter Measurements

1. Two measurements 90 degrees apart
2. Three valve stem diameter measurements locations

3. Measure valve stem diameter with a 0-1 inch micrometer (page 365) at three locations. At each location, take two measurements 90 degrees apart. Average the two measurements from each location.

   If the average of measurements at any of the three locations is not within valve stem diameter Specification (page 364), replace that valve.

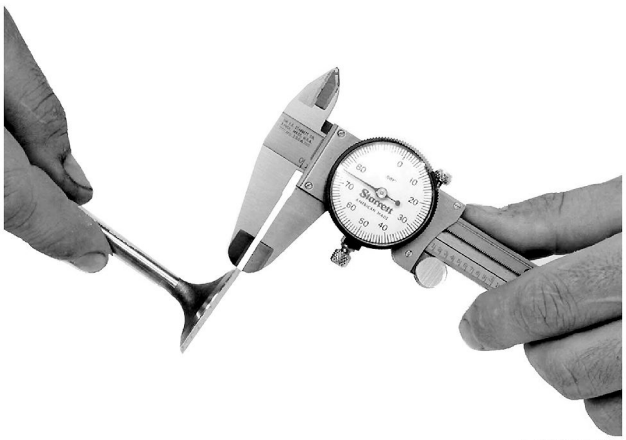

Figure 508 Measurement of Valve Face Margin

CAUTION: To prevent engine damage, maintain a minimum valve face margin across the entire valve face. An insufficient margin will not provide correct heat dissipation, leading to valve warping or breakage. Replace valve if margin is less than specification. See Specifications (page 364).

4. Use a dial caliper (page 365) to measure valve face margin at four locations (90° apart).

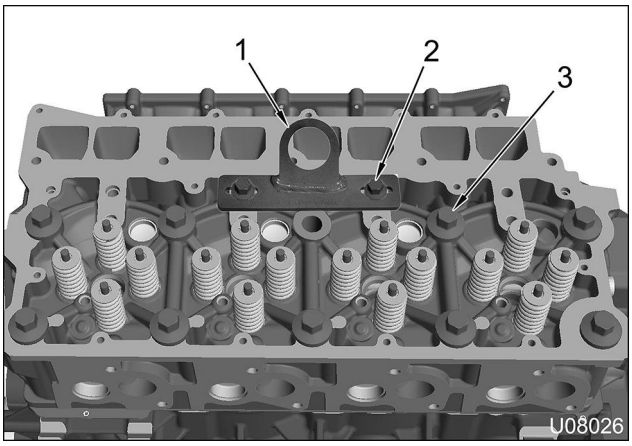

Figure 529 Cylinder Head Lifting Bracket (typical)

1. Cylinder Head Lifting Bracket
2. M10 x 70 bolt (2)
3. M16 x 172 bolt (9)

6. Remove two M10 x 70 bolts and the Cylinder Head Lifting Bracket.

CAUTION: To prevent engine damage, install new head bolts. Lightly lubricate new bolt threads and mating surfaces of bolt flanges with clean engine oil. Too much oil will cause hydrostatic lock and give incorrect torque reading.

CAUTION: To prevent engine damage, lubricate threads of new cylinder head bolts with clean engine oil. Do not use anti-seize compounds, grease, or other lubricants. This will cause an incorrect torque reading.

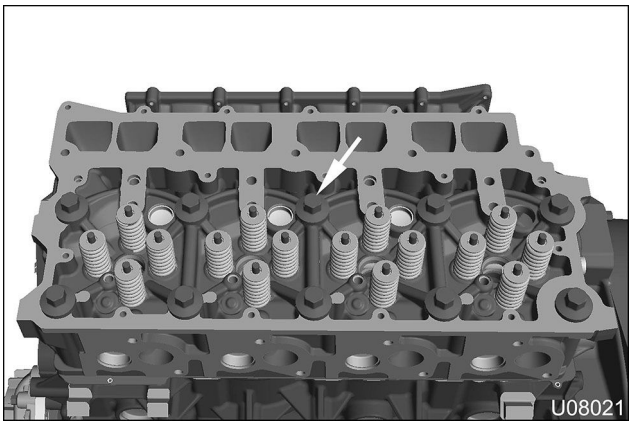

Figure 530 M16 x 172 Cylinder head bolt (10)

7. Lubricate 10 new cylinder head bolts with clean engine oil.
8. Install and hand tighten bolts.

Left Valve Cover

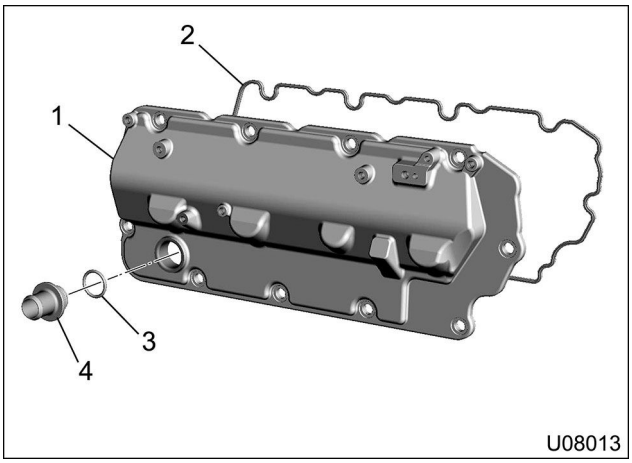

Figure 548 Oil Fill Tube and Valve Cover Gasket

1. Left valve cover
2. Valve cover gasket
3. Intake manifold O-ring
4. Oil fill tube

1. Install new intake manifold O-ring onto oil fill tube.
2. Install oil fill tube into left valve cover.
3. Install new left valve cover gasket.

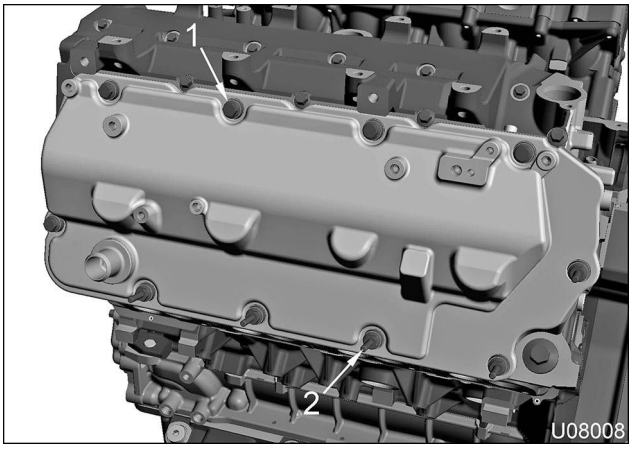

Figure 549 Left Valve Cover

1. Valve cover bolt assembly (5)
2. Valve cover stud bolt assembly (5)

4. Position left valve cover onto valve cover and intake manifold base.
5. Engage five valve cover bolt assemblies and five valve cover stud bolt assemblies. Tighten bolts and stud bolts to special torque (page 365).
6. Install oil fill support bracket and oil fill hose assembly onto fuel filter cooler assembly (page 357).

Oil Fill Tube Assembly

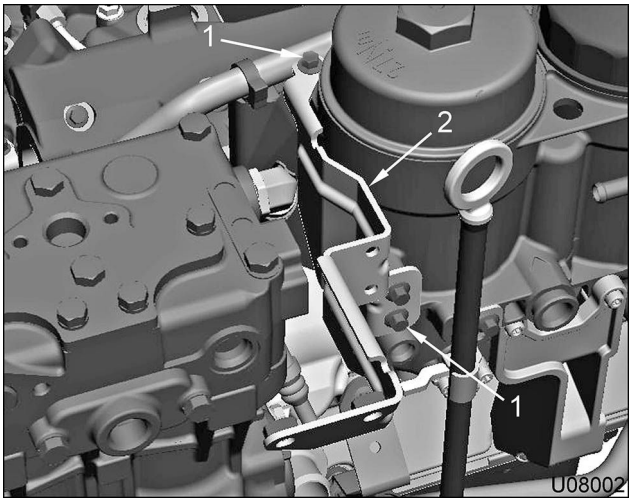

Figure 550 Oil Fill Support

1. M6 x 16 bolt (3)
2. Oil fill support

1. Install oil support bracket and install three M6 x 16 bolts to secure oil support bracket.
2. Tighten bolts to standard torque (page 473).

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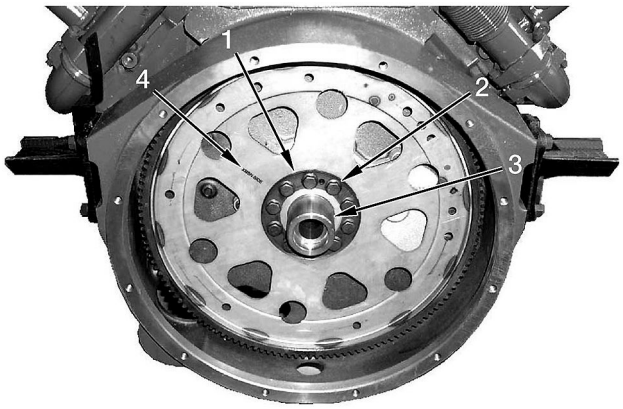
Flex Plate flywheel Assembly (Automatic Transmission)



M10124

Figure 575 Flex Plate Flywheel Assembly (Typical)

1. Reinforcement ring
2. M10 x 55 bolt (10)
3. Adapter hub
4. XMSN-SIDE stamp

1. Remove and discard 10 M10 x 55 bolts.

CAUTION: To prevent engine damage, carefully remove and store flywheel adapter or adapter hub. Damage to sealing surface of the adapter can cause a rear oil seal leak.

2. Remove reinforcement ring, flex plate flywheel assembly, and adapter hub.

Crankshaft Rear Oil Seal and Wear Sleeve

WARNING: To prevent personal injury or death, wear safety glasses with side shields when doing the following procedure.

1. Use an awl or 1/8 inch drill bit to make two small starter holes 180° apart in crankshaft rear oil seal.

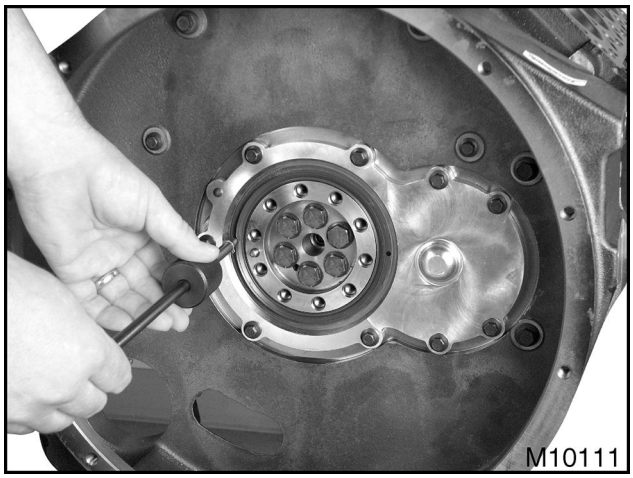


Figure 576 Crankshaft Rear Oil Seal Removal

2. Thread slide hammer (page 393) screw into one of the starter holes.
3. Remove seal evenly, by using a slide hammer on one side, and then alternate to other side.
4. Remove and discard crankshaft rear oil seal from crankshaft rear oil seal carrier.

5. Using a heat insulated glove, install crankshaft flange over guide pins and onto crankshaft, with dowel pin pointing at 12 o'clock position.
6. Remove guide pins and install six old M12 x 68 bolts. Tighten bolts alternately to seat crankshaft flange.
7. Check face runout of crankshaft flange, using dial indicator with magnetic base (page 393). If face runout exceeds specification (page 393), remove and reinstall crankshaft flange to ensure there is no trapped debris and crankshaft flange is seated against gear. If after reinstallation of crankshaft flange the face runout still exceeds specification, install new crankshaft flange.

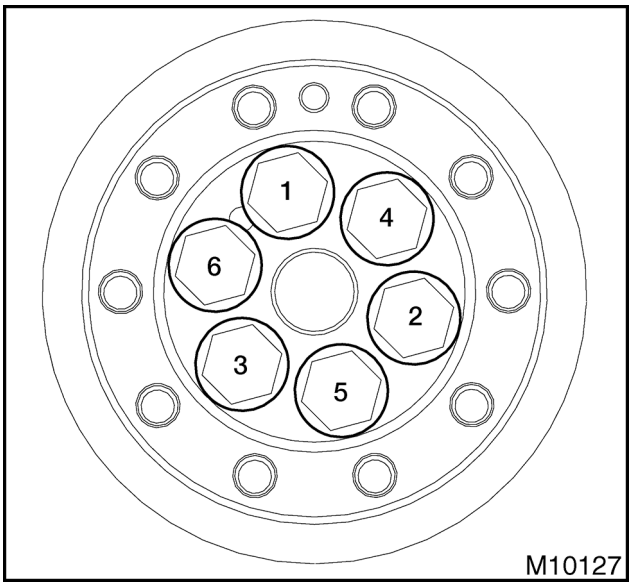


Figure 599 Crankshaft Flange Torque Sequence

CAUTION: To prevent engine damage, always install new crankshaft flange mounting bolts.

8. Remove and discard six old bolts. Lubricate underside of bolt heads on six new M12 x 68 bolts with clean engine oil and install bolts loosely. Tighten bolts as follows using above sequence:
   a. Tighten bolts to 41 N·m (30 lb·ft) using above sequence.
   b. Rotate bolts 90 degrees using above sequence.
   c. Rotate bolts an additional 90 degrees using above sequence.

Power Steering Idler Gear Assembly and Crankshaft Rear Oil Seal Carrier

CAUTION: To prevent engine damage, install gear with circular witness groove facing out.

1. Install power steering idler gear assembly on power steering idler shaft.
2. Verify correct gear orientation and gear tooth engagement.

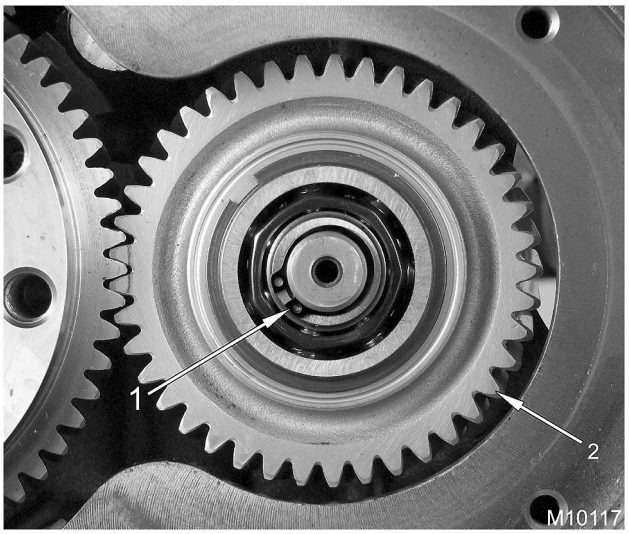


Figure 600 Power Steering Idler Gear Assembly

1. External retaining ring
2. Power steering idler gear assembly

WARNING: To prevent personal injury or death, wear safety glasses with side shields.

3. Install external retaining ring onto power steering idler shaft for power steering idler gear assembly.
4. Do Backlash Test for Power Steering Idler Gear Assembly (page 383).
5. Install new rear seal carrier gasket on crankshaft rear oil seal carrier.

Exploded View

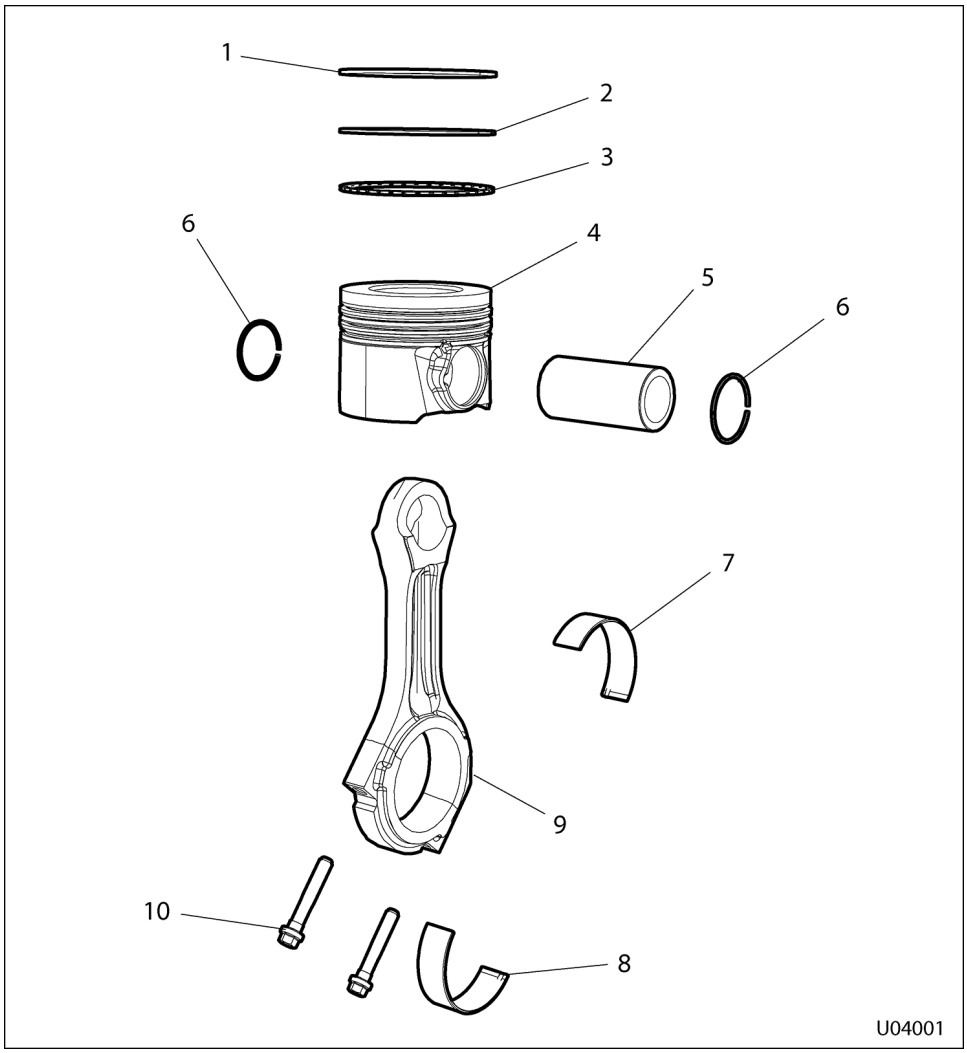


Figure 613 Piston, Piston Pin, and Connecting Rod

1. Top compression ring
2. Intermediate compression ring
3. Oil control ring
4. Piston
5. Piston pin with coating
6. Piston pin retainer ring (2)
7. Upper connecting rod bearing
8. Lower connecting rod bearing
9. Connecting rod assembly (rod and cap)
10. Connecting rod bolt (2)

Connecting Rod Bearing Fit Measurement

NOTE: Connecting rod bearings must fit tightly in the bore. When bearings are inserted into the connecting rod and cap, they protrude above parting line. This protrusion is required to achieve bearing crush. Bearing crush forces the ends inward at the parting line when a load is applied by tightening the bolts. Some flexibility may be lost in normal use, but bearing replacement is not required because of a nominal loss of flexibility. When assembly is drawn up tight, bearing is compressed, ensuring positive contact between backside of bearing and bore.

1. Lightly lubricate connecting rod bolt threads with clean engine oil. Assemble cap onto connecting rod with new bearings installed. Tighten connecting rod bolts to special torque (page 415).
2. Using a telescoping gauge (page 415), measure inside diameter of connecting rod bearing (big end) at two locations 90° apart. Average the two inside diameters.
3. Using a 2–3 inch micrometer (page 415), measure each crankshaft rod journal diameter.
4. Subtract crankshaft rod journal diameter from respective connecting rod bearing inside diameter to obtain connecting rod bearing running clearance. Repeat for each crankshaft rod journal and connecting rod.

CAUTION: To prevent engine damage, do not rework bearings or bearing caps to reduce journal-to-bearing running clearances. Grind or install a new crankshaft.

5. If connecting rod bearing running clearances exceed specifications (page 414) because of wear on crankshaft, replace or grind crankshaft and install under-size precision type bearings.

Piston Pin Inspection

NOTE: Some wear of the piston pin coating is normal. If there is evidence of material transfer on the piston pin, replace the piston pin, connecting rod, and piston.

1. Inspect piston pins for corrosion or wear. Replace as required.

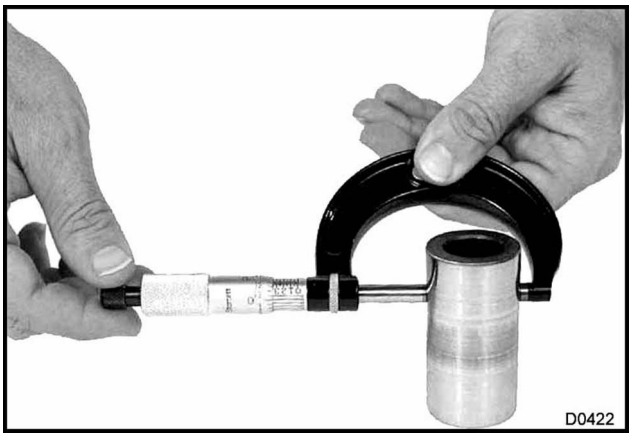


Figure 627 Piston Pin Diameter Measurement (typical)

2. Use a 1-2 inch micrometer (page 415) to measure piston pin outside diameter at two locations 90° apart. Measure each end of the pin.
3. Use a 2-3 inch micrometer to measure piston pin length.
4. If piston pin length or diameter are out of specifications (page 414), replace piston pin.

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Crankshaft End Play Measurement

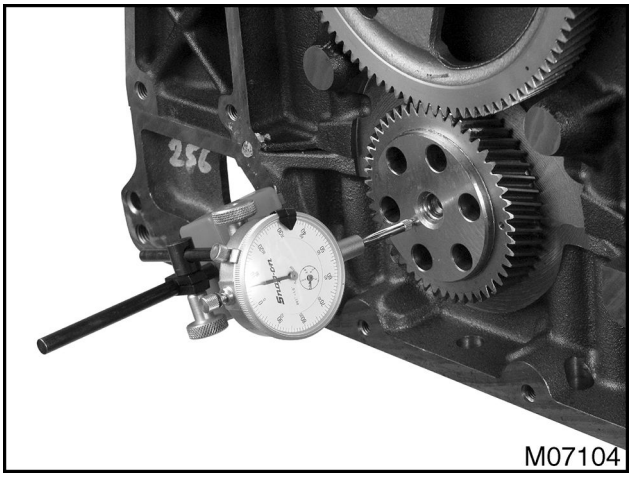

Figure 652 Crankshaft End Play

1. Mount dial indicator with magnetic base (page 486) on lower crankcase. Put indicator tip on end of crankshaft as shown.
2. Move crankshaft forward with pry bar and zero the dial indicator.
3. Move crankshaft back and forth while reading dial indicator. Compare dial indicator reading with Crankshaft end play specifications (page 441).
4. If end play exceeds maximum service specification, replace upper thrust bearing.

Crankcase Assembly

Crankcase Cleaning

NOTE: Thoroughly clean and inspect upper and lower crankcase assemblies before and after reconditioning.

1. Clean upper and lower crankcase assemblies in a chemical bath or hot tank. This removes all carbonized material and mineral deposits in coolant passages.

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

2. If a hot tank is not available, do the following steps:
   a. Use non-metallic stiff bristle brushes and scrapers to clean gasket material from machined surfaces of upper crankcase assembly.
   b. Clean cylinder bore with soap, water, and a stiff nylon brush.
   c. Clean upper and lower crankcase assemblies in solvent.
   d. Dry with filtered compressed air.

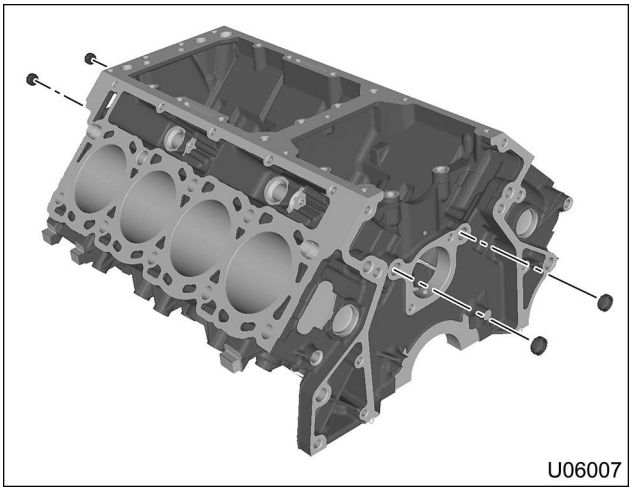

Figure 653 16-mm Cup Plugs (Oil Gallery)

3. Remove four 16 mm cup plugs from upper crankcase assembly (two in front and two in rear of main oil gallery), using a punch and hammer near edge of plug and striking with hammer. Discard plugs.

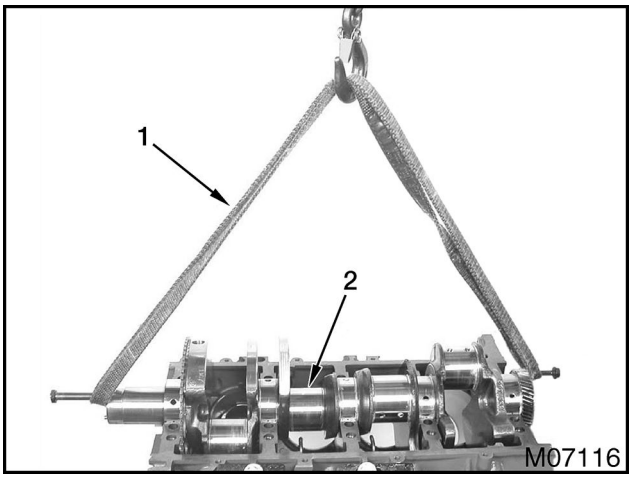

Figure 672 Lifting Sling

1. Lifting sling
2. Crankshaft assembly

WARNING: To prevent personal injury or death, use a correct size lifting sling and hoist with a safety latch on hook.

CAUTION: To prevent engine damage, do not drop or bend the crankshaft.

5. Install a bolt in each end of the crankshaft assembly (if removed). Attach hoist and lifting sling (page 486) around crankshaft bolts and carefully lower crankshaft onto five main bearings.

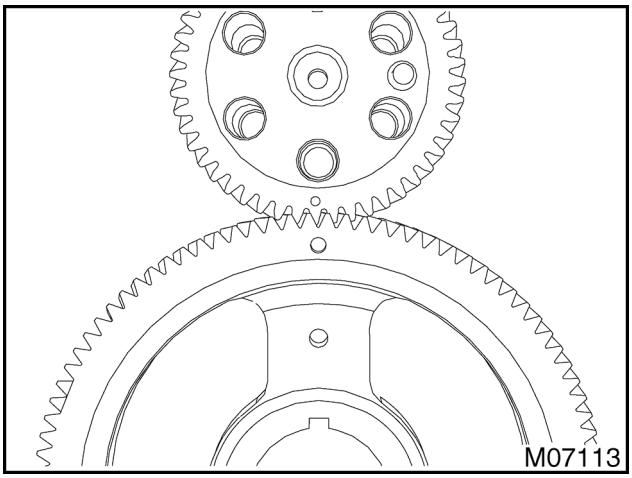

Figure 673 Crankshaft and Camshaft Timing Marks

6. Install crankshaft so timing mark on gear aligns with timing mark on camshaft gear.

Lower Crankcase Assembly

With acceptable bearing clearance as determined in Main Bearing Fit Check (page 431), install lower crankcase assembly as follows:

NOTE: When inserting main bearings, make sure oil is not between back side of bearing and lower crankcase assembly bearing saddles.

ICP – Injection Control Pressure
ICPR – Injection Control Pressure Regulator
ICG1 – Injector Control Group 1
ICG2 – Injector Control Group 2
ID – Inside Diameter
IGN – Ignition
ILO – Injector Leak Off
IMP – Intake Manifold Pressure
IMT – Intake Manifold Temperature
in – Inch
inHg – Inch of mercury
inH_2O – Inch of water
INJs – Injectors
IPR – Injection Pressure Regulator
IPR PWR – Injection Pressure Regulator Power
ISC – Interstage Cooler
ISIS – International Service Information System
IST – Idle Shutdown Timer
ITP – Internal Transfer Pump
J1939H – J1939 Data Link High
J1939L – J1939 Data Link Low
JCT – Junction (electrical)
kg – Kilogram
km – Kilometer
km/h – Kilometers per hour
km/l – Kilometers per liter
KOEO – Key On Engine-Off
KOER – Key On Engine-Running
kPa – Kilopascal
L – Liter
L/h – Liters per hour
L/m – Liters per minute
L/s – Liters per second
lb – Pound
lb – Pounds of force
lb/s – Pounds per second
lb ft – Pounds of force per foot
lb in – Pounds of force per inch
lbm – Pounds of mass
LSD – Low Sulfur Diesel
m – Meter
m/s – Meters per second
MAF – Mass Air Flow
MAF GND – Mass Air Flow Ground
MAG – Magnetic
MAP – Manifold Absolute Pressure
MAT – Manifold Air Temperature
mep – Mean effective pressure
mi – Mile
MIL – Malfunction Indicator Lamp
mm – Millimeter
mpg – Miles per gallon
mph – Miles per hour
MPR – Main Power Relay
MSDS – Material Safety Data Sheet
MSG – Micro Strain Gauge
MSM – Multiplex System Module
MY – Model Year
NC – Normally closed (electrical)
NETS – Navistar Electronics Technical Support
Nm – Newton meter
NO – Normally Open (electrical)
NO_X – Nitrogen Oxides
O2S – Oxygen Sensor
O2SH – Oxygen Sensor Heater
OAT – Organic Acid Technology
OCC – Output Circuit Check
OCP – Overcrank Protection
OD – Outside Diameter
OL – Over Limit
ORH – Out-of-Range High
ORL – Out-of-Range Low
OSHA – Occupational Safety and Health Administration
OWL – Oil/Water Lamp
PID – Parameter Identifier
P/N – Part Number
PDOC – Pre-Diesel Oxidation Catalyst
ppm – Parts per million
PROM – Programmable Read Only Memory
psi – Pounds per square inch
psia – Pounds per square inch absolute
psig – Pounds per square inch gauge
pt – Pint
PTO – Power Takeoff
PWM – Pulse Width Modulate
PWR – Power (voltage)
qt – Quart
RAM – Random Access Memory
RAPP – Remote Accelerator Pedal Position
RAS – Resume / Accelerate Switch (speed control)
REPTO – Rear Engine Power Takeoff
RFI – Radio Frequency Interference
rev – Revolution
rpm – Revolutions per minute
RPRE – Remote Preset Power Take Off
RSE – Radiator Shutter Enable
RVAR – Remote Variable
SAE – Society of Automotive Engineers®
SCA – Supplemental Cooling Additive
SCCS – Speed Control Command Switches
SCS – Speed Control Switch

Manifold Absolute Pressure (MAP) – Boost pressure in the manifold that is a result of the turbocharger.

Manifold Absolute Pressure (MAP) sensor – A variable capacitance sensor that measures boost pressure.

Manometer – A double-leg liquid-column gauge, or a single inclined gauge, used to measure the difference between two fluid pressures. Typically, a manometer records in inches of water.

Mass Airflow – The intake airflow in an engine.

Mass Airflow (MAF) sensor – The MAF sensor is used for closed loop control of the EGR valve and ITV. The ECM monitors the MAF signal so that the ECM can control the EGR and intake throttle systems.

Metering unit valve assembly – The Metering unit valve assembly provides a metered amount of fuel to the Aftertreatment Fuel Injector (AFI).

Microprocessor – An integrated circuit in a microcomputer that controls information flow.

Micro Strain Gauge (MSG) Sensor – A MSG sensor measures pressure. Pressure exerts force on a pressure vessel that stretches and compresses to change resistance of strain gauges bonded to the surface of the pressure vessel. Internal sensor electronics convert the changes in resistance to a ratiometric voltage output.

Nitrogen Oxides (NO_x) – Nitrogen oxides form by a reaction between nitrogen and oxygen at high temperatures and pressures in the combustion chamber.

Normally closed – Refers to a switch that remains closed when no control force is acting on it.

Normally open – Refers to a switch that remains open when no control force is acting on it.

Ohm (Ω) – The unit of electrical resistance. One ohm is the value of resistance through which a potential of one volt will maintain a current of one ampere. (SAE J1213 NOV82)

On demand test – A self-test the technician initiates using the EST that is run from a program in the software.

Output Circuit Check (OCC) – An on-demand test done during an Engine OFF self-test to check the continuity of selected actuators.

Output Shaft Speed (OSS) sensor – A sensor mounted to the rear of the transmission that supplies a vehicle speed signal to the ECM. The ECM uses this signal to control PTO, road speed limiting, and cruise control. Automatic transmissions use this signal for shift scheduling.

Oxides of Nitrogen (NOx) – Nitrogen oxides formed by a reaction between nitrogen and oxygen at high temperatures.

Oxygen Sensor (O2S) – A sensor that monitors oxygen levels in the exhaust.

Particulate matter – Particulate matter includes mostly burned particles of fuel and engine oil.

pH – A measure of the acidity or alkalinity of a solution.

Piezometer – An instrument for measuring fluid pressure.

Power – Power is a measure of the rate at which work (force x distance) is done during a specific time. Compare with Torque.

Power TakeOff (PTO) – Accessory output, usually from the transmission, used to power a hydraulic pump for a special auxiliary feature (garbage packing, lift equipment, etc).

Pre-DOC – Refers to exhaust gases that have not passed through the DOC.

Pulse Width Modulation (PWM) – Succession of digital electrical pulses, rather than an analog signal. Efficient method of providing power between fully on and fully off.

Radiator Shutter Enable (RSE) – A feature that uses various input signals to open or close radiator shutters by energizing or de-energizing a solenoid that controls an air or hydraulic cylinder.

Random Access Memory (RAM) – Computer memory that stores information. Information can be written to and read from RAM. Input information (current engine speed or temperature) can be stored in RAM to be compared to values stored in Read Only Memory (ROM). All memory in RAM is lost when the ignition switch is turned off.

Rated gross horsepower – Engine gross horsepower at rated speed as declared by the manufacturer. (SAE J1995 JUN90)

Top compression ring groove width (measured over 2.10 mm (0.083 in) gauge pins):	
Upper limit	96.541 mm (3.8008 in)
Replacement limit	96.341 mm (3.7929 in)
Ring groove (side clearance):	
Intermediate compression	0.050 to 0.096 mm (0.0020 to 0.0038 in)
Oil control	0.040 to 0.080 mm (0.00157 to 0.00315 in)
Piston height above crankcase deck (protrusion)	0.609 to 0.863 mm (0.0240 to 0.0340 in)
Piston skirt clearance	0.060 to 0.111 mm (0.0023 to 0.0044 in)
Piston Pins	
Length	74.6 to 75.0 mm (2.9371 to 2.9528 in)
Diameter	38.490 to 38.500 mm (1.5154 to 1.5158 in)
Piston pin clearance (at room temperature of 19 to 21°C [66 to 70°F]):	
Clearance in connecting rod (piston pin bore)	0.041 to 0.058 mm (0.0016 to 0.0023 in)
Clearance in piston (piston pin bore)	0.010 to 0.020 mm (0.0004 to 0.0008 in)
End clearance	0.84 mm (0.0331 in)
Piston Rings	
Ring diameter (standard):	98.2 mm (3.866 in)
Ring gap in bore:	
Top compression	0.29 to 0.55 mm (0.011 to 0.022 in)
Intermediate compression	0.67 to 0.82 mm (0.0264 to 0.0323 in)
Oil control	0.25 to 0.40 mm (0.010 to 0.016 in)

Fuel System

Banjo bolts, M12	25 N·m (18 lb-ft)
High-pressure pump cap nuts	25 N·m (18 lb-ft)
Diagnostic valve	13 N·m (115 lb-in)
Right high-pressure tube assembly nuts	See tightening steps in procedure.
Left high-pressure tube assembly nuts	See tightening steps in procedure.
Fuel cooler screws, M8 x 20	23 N·m (16 lb-ft)
Fuel housing cover screws, M5 x 18	7 N·m (62 lb-in)
High-pressure fuel pump gear bolt	78 N·m (57 lb-ft)
Fuel rail to injector tube fittings	See tightening steps in procedure
Injector clamp bolts	See tightening steps in procedure
Coolant return hose clamps	3 N·m (26 lb-in)
Primary fuel filter cap	50 N·m (37 lb-ft)
Secondary fuel filter cap	40 N·m (29 lb-ft)
Water drain retainer screws, M5 x18	7 N·m (62 lb-in)
WIF sensor	2 N·m (18 lb-in)
EFT sensor	18 N·m (159 lb-in)
FDP sensor	18 N·m (159 lb-in)

Front Cover, Cooling System, and Related Components

Vibration damper bolts	See Vibration Damper Installation Procedure

Oil Cooler, Oil pump, Oil Filter, and Oil Pan

Oil cooler bypass valve assembly	71 N·m (52 lb-ft)
Oil cooler cover assembly serrated nuts	See assembly procedure for special torque sequence
Hex plug assembly (oil pan)	25 N·m (18 lb-ft)
Plug assembly, M18 (oil pan)	25 N·m (18 lb-ft)
Oil pan drain plug (M14)	44 N·m (32 lb-ft)
Oil filter adapter (oil pan)	55 N·m (40 lb-ft)
Oil pump housing plate screws, M8 x 25	17 N·m (150 lb-in)
Relief valve cap, oil pump	35 N·m (26 lb-ft)