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Illustrations

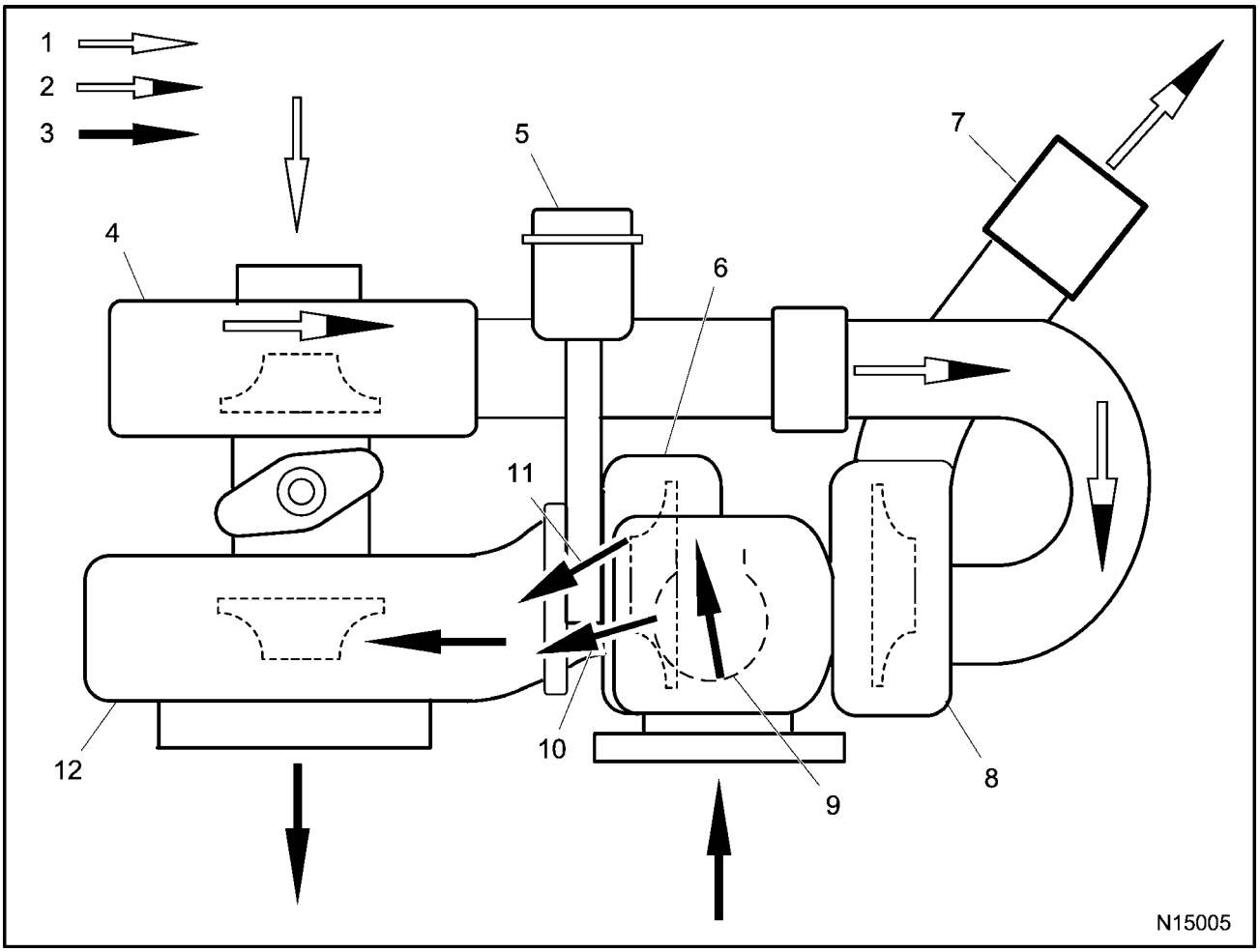

Figure 126 Dual stage turbocharger flow and components

1. Inlet air flow
2. Compressed air flow
3. Exhaust flow
4. Low-pressure compressor
5. Pneumatic actuator
6. High-pressure turbine
7. High-pressure turbocharger air outlet
8. High-pressure compressor
9. Turbocharger bypass valve
10. Exhaust flow with bypass valve open
11. Normal exhaust flow with bypass valve closed
12. Low-pressure turbine

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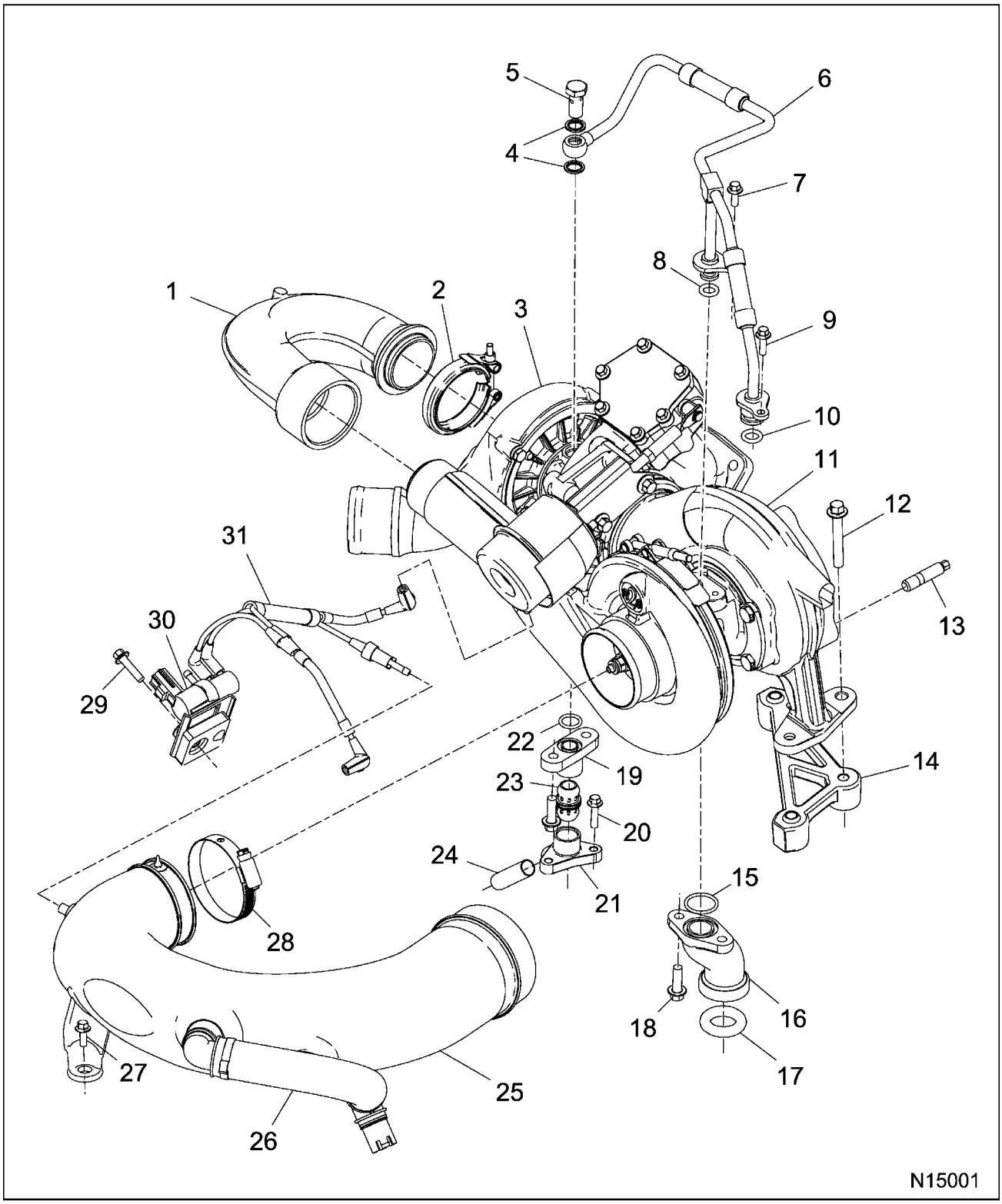

Figure 127 Dual stage turbocharger assembly

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1. Crossover tube
2. V-band clamp
3. High-pressure compressor
4. M12 bonded seal type B washer
5. M12 Bango bolt
6. Turbocharger oil supply tube assembly
7. M6 x 16 bolt
8. Turbo SPL seal
9. M6 x 20 bolt
10. O-ring seal
11. Low-pressure turbine
12. M8 x 55 bolt (3)
13. M10 x 25 high-temp locking stud (3)
14. Turbocharger spacer
15. O-ring
16. Low-pressure turbocharger oil drain tube
17. Turbocharger oil drain O-ring
18. M8 x 25 bolt (2)
19. High-pressure turbocharger oil drain upper adaptor
20. M6 x 25 bolt (2)
21. High-pressure turbocharger oil drain lower housing
22. O-ring
23. High-pressure turbocharger oil drain tube
24. High-pressure turbocharger oil drain housing tube
25. Air inlet duct assembly
26. Crankcase breather hose assembly
27. M6 x 16 bolt
28. Turbocharger worm gear clamp
29. M6 x 30 bolt
30. Boost Control Solenoid (BCS) assembly
31. BCS tube harness assembly

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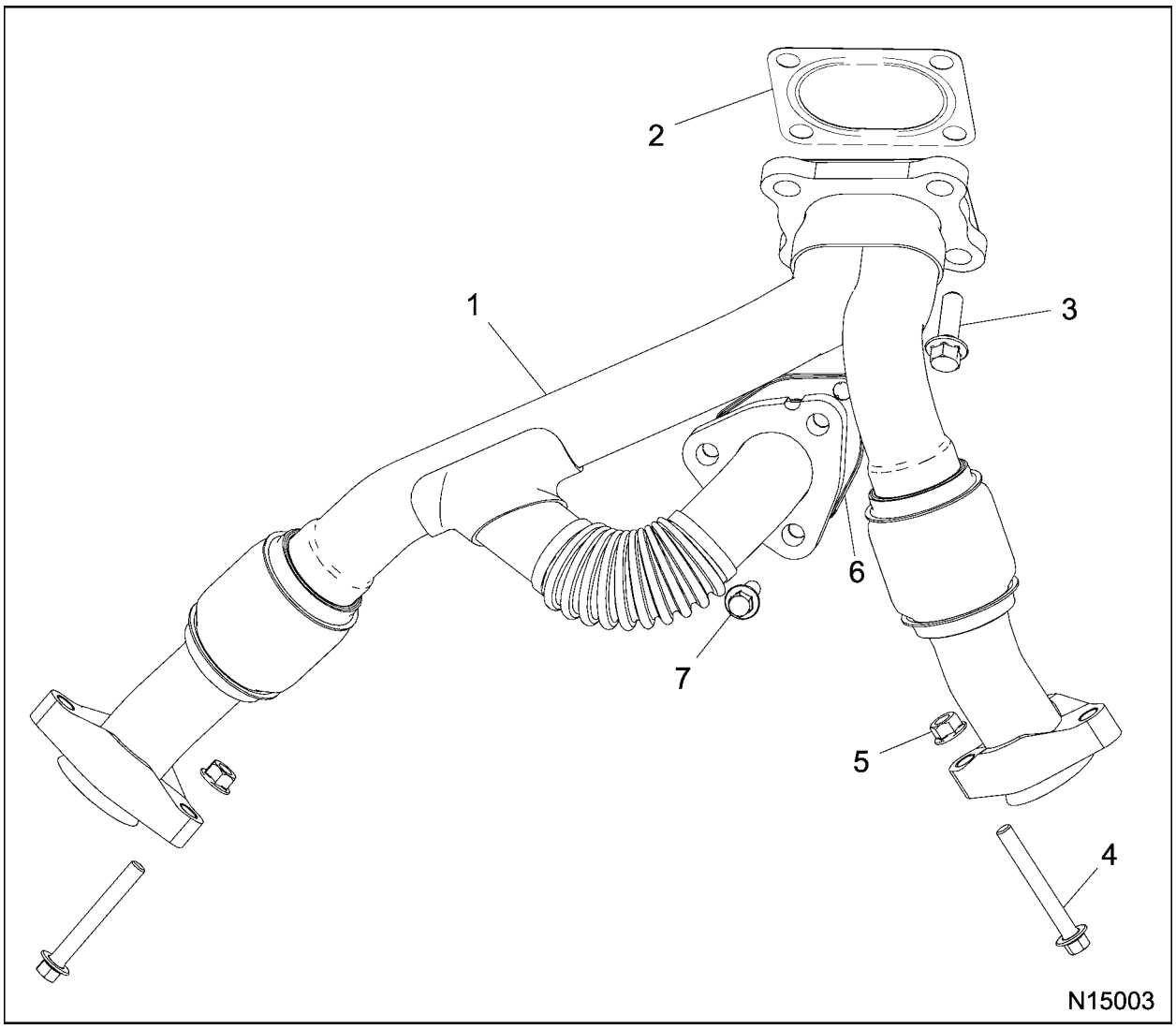

Figure 128 Exhaust tube assembly

1. Exhaust tube assembly
2. Turbocharger inlet gasket
3. M10 x 30 high temp bolt (4)
4. M8 x 50 exhaust flange bolt (4)
5. M8 nut (4)
6. Exhaust gasket
7. M8 x 27 high temp bolt (3)

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Removal

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, allow engine to cool before working with components.

WARNING: To prevent personal injury or death, disconnect ground (-) cable from battery before doing service or diagnostic procedures.

WARNING: To prevent personal injury or death, inspect turbocharger with engine off, and turbocharger not spinning. Turbocharger components may be extremely hot. Turbocharger wheels are very sharp and spin at high speeds.

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.

GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a threat to the environment. Recycle or dispose of engine fluids and filters according to applicable regulations. Never put engine fluids in the trash, on the ground, in sewers or bodies of water.

Air Inlet Duct

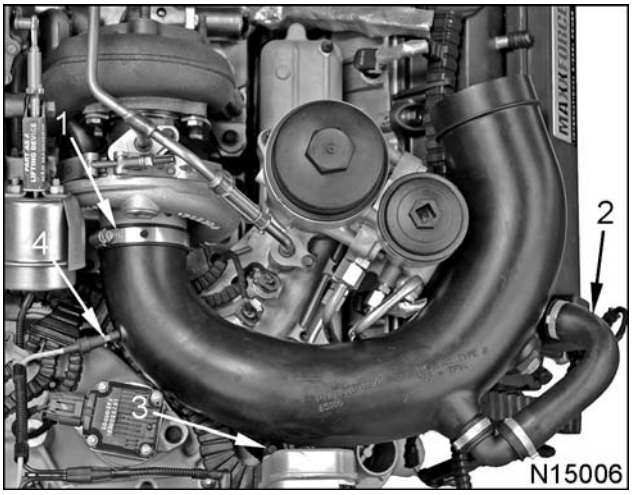

Figure 129 Air inlet duct assembly

1. Worm gear clamp
2. Crankcase breather hose
3. M6 x 16 bolt
4. Boost Control Solenoid (BCS) tubing

1. Remove the BCS tubing from the air inlet duct and pneumatic actuator.
2. Remove the M6 x 16 bolt holding the air inlet duct to the intake manifold.
3. Remove the air inlet duct crankcase breather hose from the crankcase breather on the left valve cover.
4. Loosen the worm gear clamp and remove the air inlet duct.

NOTE: See Boost Control Solenoid (BCS) Assembly (page 76) for BCS removal.

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Oil Supply Line

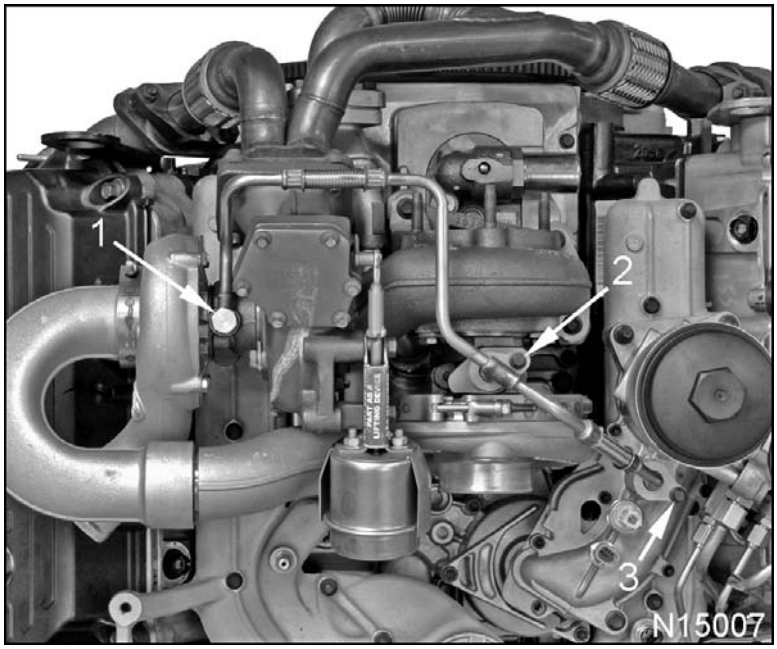

Figure 130 Turbocharger oil supply line

1. M12 Bango bolt and seal washers
2. M6 x 16 bolt
3. M6 x 20 bolt

1. Remove M12 banjo bolt and seal washers from the high-pressure turbocharger. Discard seal washers.
2. Remove M6 x 16 bolt from the low-pressure turbocharger.
3. Remove M6 x 20 bolt from the oil filter housing.
4. Pull up and remove the oil supply line.
5. Remove and discard two oil supply line O-rings.
6. Cap oil ports to prevent foreign material from entering.

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Exhaust Tubing

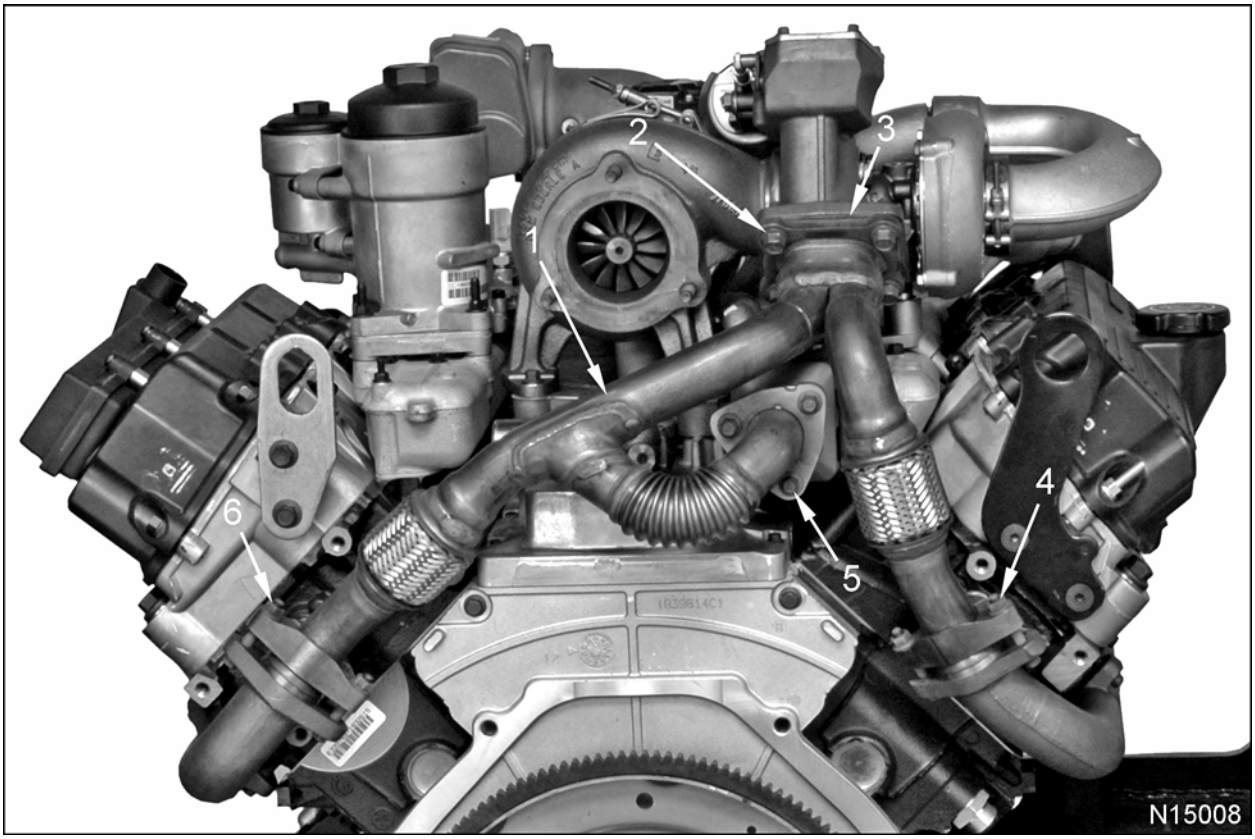

Figure 131 Exhaust tube assembly

1. Exhaust tube assembly
2. M10 x 30 high temp bolts (4)
3. Turbocharger inlet gasket
4. M8 x 50 bolts and M8 nuts (2)
5. M8 x 27 bolts (3)
6. M8 x 50 bolts and M8 nuts (2)

1. Remove two M8 x 50 bolts and nuts securing the exhaust tube assembly to the left exhaust manifold.
2. Remove two M8 x 50 bolts and nuts securing the exhaust tube assembly to the right exhaust manifold.
3. Remove the three M8 x 27 bolts securing the exhaust tube assembly to the EGR cooler.
4. Remove four M10 x 30 bolts securing the exhaust tube assembly to the turbocharger.
5. Remove and discard the turbocharger inlet gasket and EGR cooler exhaust gasket.
6. Remove turbocharger exhaust tube assembly.
7. Use protective caps to cover all openings. See Cap Kit (all) Special Service Tools (page 124). If plastic caps are not available, cover openings with tape.

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Dual Turbocharger Assembly

Figure 132 Turbocharger mounting bolts

1. M8 x 55 bolt (3)
2. Turbocharger spacer

1. Remove three M8 x 55 turbocharger mounting bolts.
2. Lift up and remove turbocharger assembly from engine.

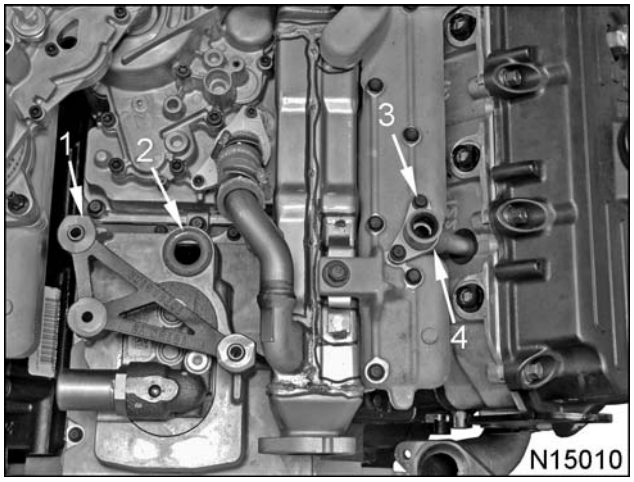

Figure 133 Turbocharger spacer, O-ring, and drain housing

1. Turbocharger spacer
2. Low-pressure turbocharger oil drain tube O-ring
3. M6 x 25 bolt (2)
4. High-pressure turbocharger oil drain lower housing assembly

3. Remove the turbocharger spacer and low-pressure turbocharger oil drain tube O-ring from the high-pressure oil pump cover. Discard O-ring.
4. Remove two M6 x 25 bolts and remove the high-pressure turbocharger oil drain lower housing assembly.

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Disassembly of Dual Turbocharger

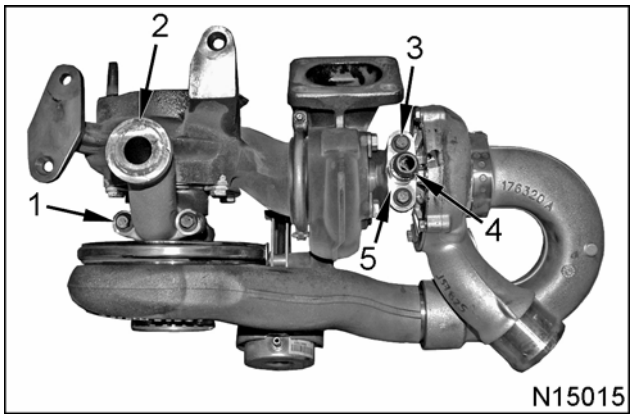

Figure 134 Dual turbocharger assembly (bottom view)

1. M8 x 25 bolt (2)
2. Low-pressure turbocharger oil drain tube
3. M8 x 25 bolt (2)
4. High-pressure turbocharger oil drain tube
5. High-pressure turbocharger oil drain upper adaptor

1. Remove two M8 x 25 bolts and remove the low-pressure turbocharger oil drain tube. Discard tube O-ring.
2. Remove the high-pressure turbocharger oil drain tube.
3. Remove two M8 x 25 bolts and remove the high-pressure turbocharger oil drain upper adaptor. Discard O-ring.

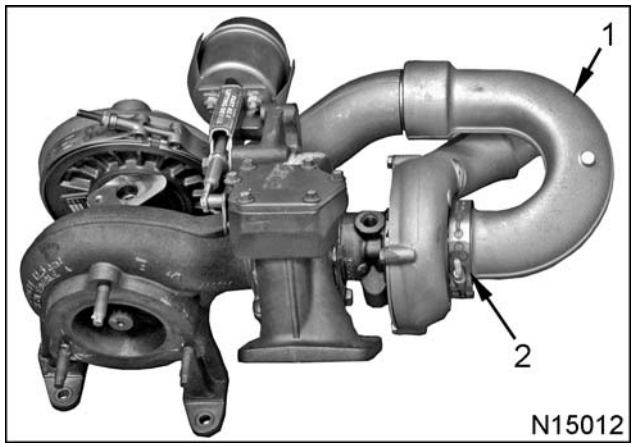

Figure 135 Turbocharger assembly crossover tube

1. Crossover tube
2. V-band clamp

4. Loosen the crossover tube V-band clamp.
5. Pull out and remove the crossover tube.

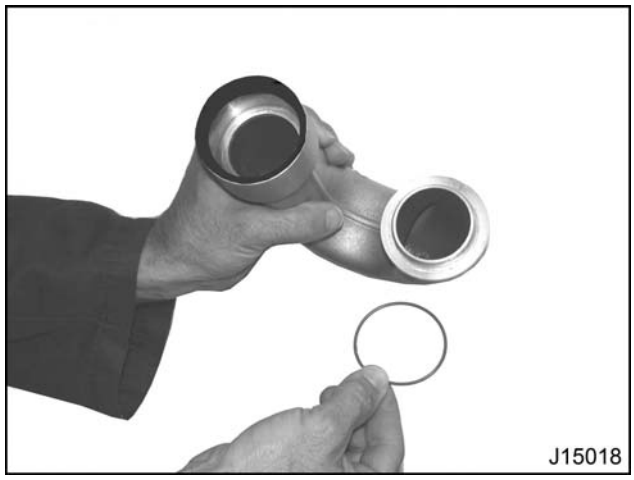

Figure 136 Crossover tube O-ring seal

6. Remove and discard the crossover tube O-ring seal.

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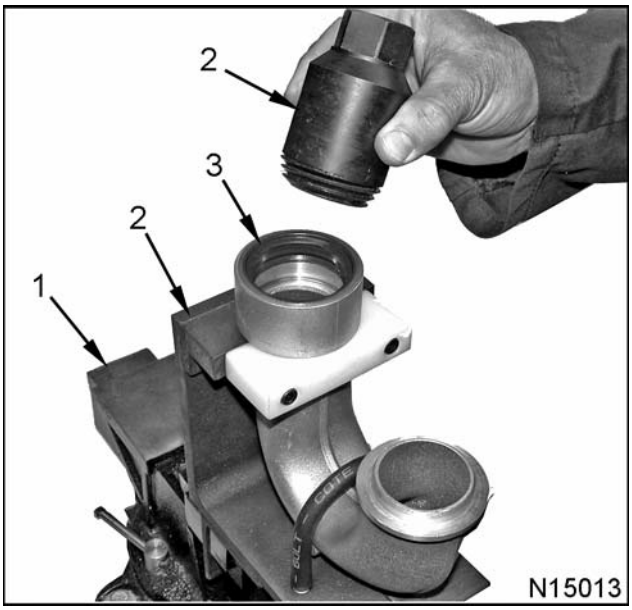

Figure 137 Crossover tube seal

1. Vise
2. Turbo Crossover Tube Seal Remover / Installer
3. Crossover tube seal

7. Place Turbo Crossover Tube Seal Remover / Installer (page 124) holding fixture into vise and clamp securely.
8. Place crossover tube into holding fixture and clamp securely.
9. Install the Turbo Crossover Tube Seal Remover / Installer into the crossover tube seal.

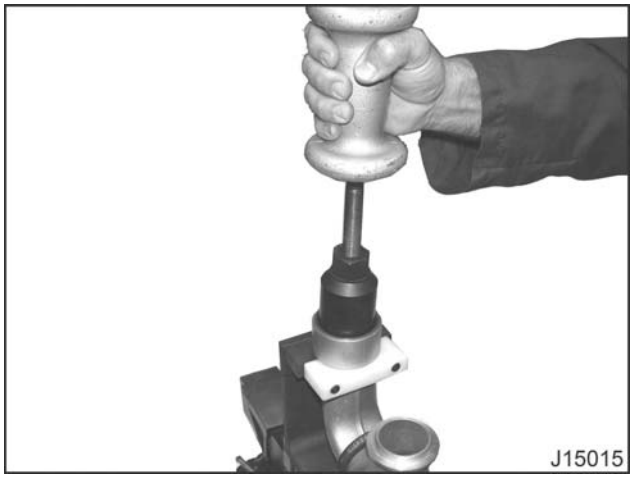

Figure 138 Crossover tube seal removal

10. Install a Slide Hammer on the Turbo Crossover Tube Seal Remover / Installer.
11. Pull the crossover tube seal out and discard.

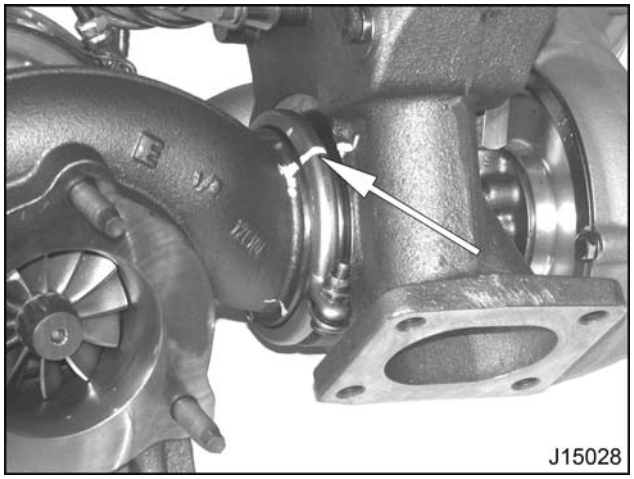

Figure 139 Turbine housing alignment marks

12. Using a permanent marker, place alignment marks over both high and low-pressure turbochargers and the turbine mating V-band clamp.
13. Remove the turbine mating V-band clamp.

NOTE: The Pneumatic actuator is not serviceable.

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Cleaning and Inspection

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

NOTE: Do not use caustic solutions to clean turbocharger or related components.

Turbocharger

Clean turbocharger assembly and bracket with a suitable solvent and nylon brush. Dry with filtered compressed air.

Related Components

1. Rinse the inside of the oil supply tube with parts cleaning solvent. Remove all solvent from inside tube.
2. Clean turbocharger mounting bracket, exhaust piping, and oil drain tubing with parts cleaning solvent.

Disassembly Inspection

If the turbocharger does not meet the following requirements, it must be replaced:

Visual and Mechanical Inspection

NOTE: Replace turbocharger if any impeller or turbine blades are bent. Do not attempt to straighten blades.

Compressor impeller and turbine wheel deposits can be caused by the following:

- High air inlet restriction allows oil to transfer from the turbocharger center housing, resulting in oil deposits. Excessive oil consumption can result in turbine wheel carbon deposits. Replace turbocharger if turbine wheel deposits can not be cleaned off.
- Engine over fueling can cause excessive temperatures which can cause aluminum components to melt.

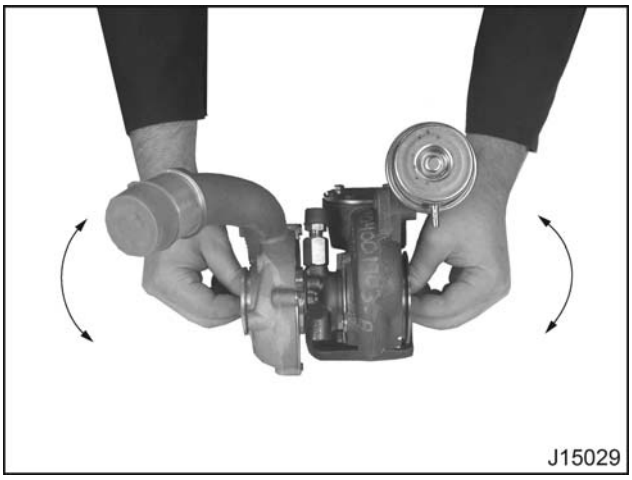

Figure 140 Turbocharger wheel rotation inspection

1. Each turbocharger shaft must spin freely when turned by hand. Inspect turbine and compressor housing for evidence of wheel rubbing, blade erosion, bending, or breakage. Replace turbocharger assembly if any of these conditions are found.
2. Perform same steps on adjacent turbocharger.
3. Inspect oil supply line for kinks, clogs, restrictions.
4. Inspect oil drain tubes for clogs, restrictions, and other defects.

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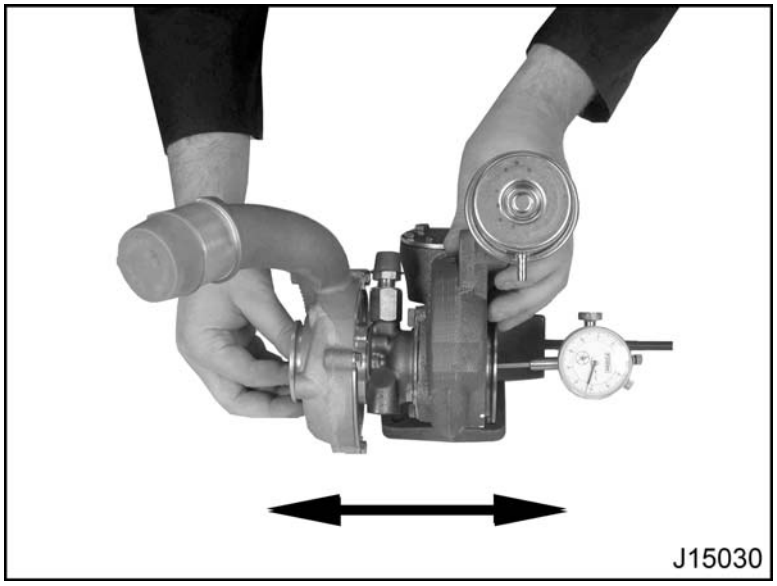

Figure 141 Checking axial end play

5. With turbocharger in a stable position, place tip of a dial indicator with magnetic base (page 124) onto end of shaft (turbine side).
   a. Push shaft in either direction and hold in position.
   b. Zero dial indicator face and needle.
   c. Pull shaft in opposite direction and record measured distance on dial face.
   d. If measurement exceeds Specifications (page 124), turbocharger assembly must be replaced.
6. Perform the previous steps on adjacent turbocharger.

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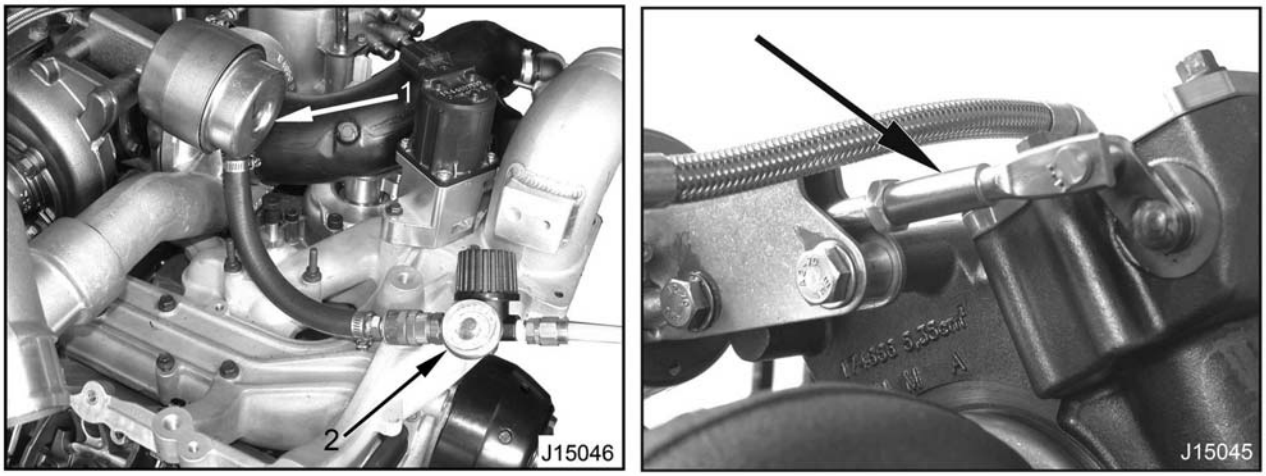

Figure 142 Left – boost control test setup, Right – actuator rod

1. Boost control diaphragm
2. Shop air pressure regulator

7. Proceed with the following steps to inspect the boost control actuator:
   a. Remove tubing from boost control diaphragm.
   b. Connect shop air and pressure regulator to the boost control diaphragm.

      CAUTION: To prevent engine damage, do not exceed 207 kPa (30 psi) to the boost control diaphragm.

   c. Slowly regulate shop air to approximately 103 kPa (15 psi) and observe the actuator arm. It should begin to move at this pressure.
   d. If the actuator rod does not begin to move at 103 kPa (15 psi) or if diaphragm is leaking, replace the dual turbocharger assembly.

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Installation

NOTE: Apply a light coat of clean engine oil on bolt threads and under bolt head when installing used nuts and bolts.

Assembly of Dual Turbocharger

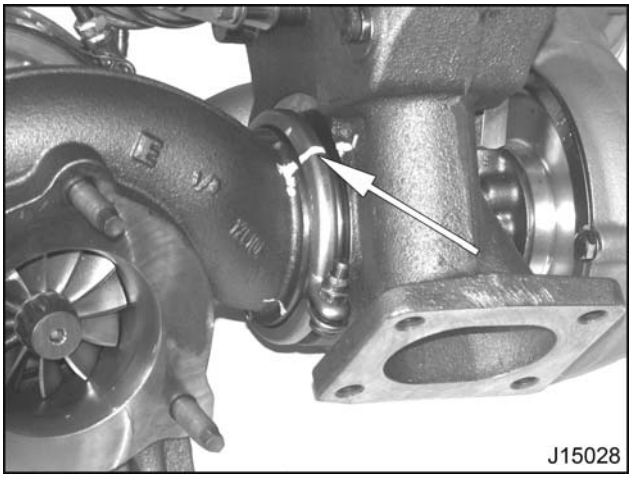

Figure 143 Turbine housing alignment marks

1. Install the high-pressure turbine housing on the low-pressure turbine housing and loosely install the V-band clamp. Align turbine housing marks. Do not tighten V-band clamp at this time.

Figure 144 Crossover tube seal installation

2. Secure Turbo Crossover Tube Seal Remover / Installer (page 124) holding fixture into a bench vise.
3. Install crossover tube into holding fixture and tighten clamps.
4. Position seal onto crossover tube and drive seal into crossover tube until seal is seated, using Turbo Crossover Tube Seal Remover / Installer.

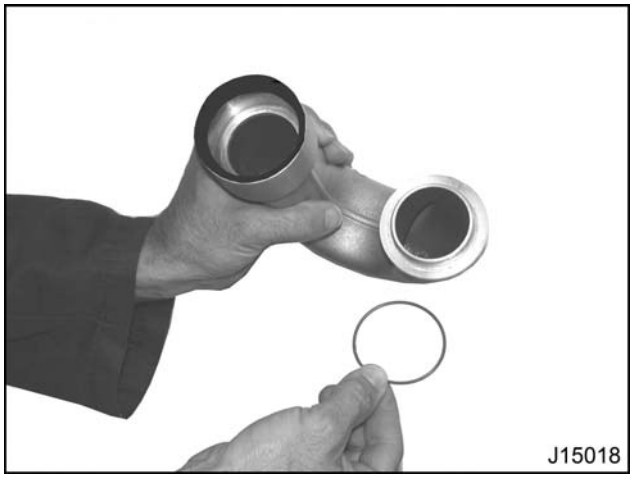

Figure 145 Small crossover seal

5. Install a new O-ring seal onto short end of crossover tube.

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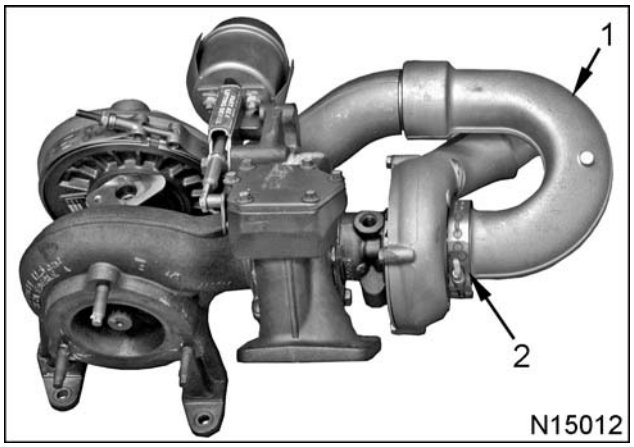

Figure 146 Turbocharger crossover tube

1. Crossover tube
2. V-band clamp

6. Install the V-band clamp onto the crossover tube.
7. Install crossover tube onto turbocharger assembly. A slight twisting motion may be necessary to start the long end of tube.

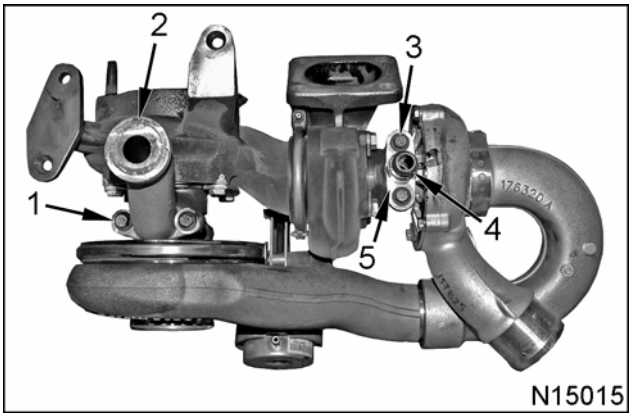

Figure 147 Turbocharger oil drain tubes

1. M8 x 25 bolt (2)
2. Low-pressure turbocharger oil drain tube
3. M8 x 25 bolt (2)
4. High-pressure turbocharger oil drain tube
5. High-pressure turbocharger oil drain upper adaptor

CAUTION: To prevent engine damage, do not pinch O-rings when installing turbocharger oil drain tubes.

8. Install a new O-ring on the low-pressure turbocharger oil drain tube and high-pressure oil drain upper adaptor. Lubricate O-rings with clean engine oil.
9. Install the low-pressure oil drain tube and finger tighten two M8 x 25 bolts.
10. Install the high-pressure oil drain upper adaptor and finger tighten two M8 x 25 bolts.
11. Tighten four M8 x 25 bolts to standard torque (page 400).

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Dual Turbocharger

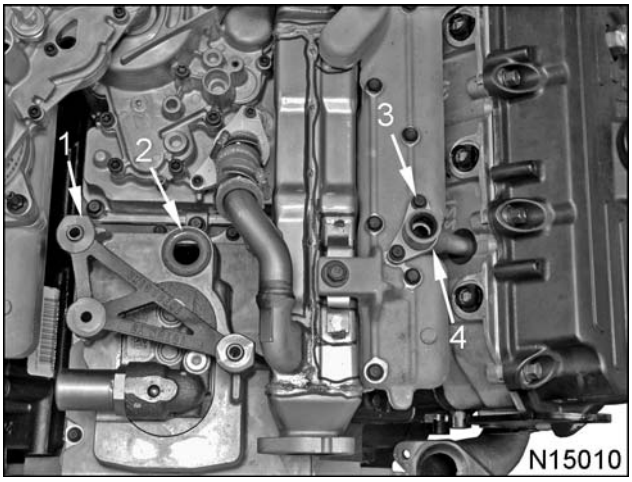

Figure 148 Turbocharger spacer, O-ring, and drain housing

1. Turbocharger spacer
2. Low-pressure turbocharger oil drain tube O-ring
3. M6 x 25 bolt (2)
4. High-pressure turbocharger oil drain lower housing assembly

1. Install a new low-pressure oil drain tube O-ring and lubricate with clean engine oil.
2. Install the high-pressure oil drain lower housing and tighten two M6 x 25 bolts to standard torque (page 400).
3. Install high-pressure turbocharger oil drain tube (Figure 147) on the high-pressure oil drain lower housing assembly.
4. Install the turbocharger spacer on the high-pressure oil pump cover.

Figure 149 Turbocharger mounting bolts

1. M8 x 55 bolt (3)
2. Turbocharger spacer

5. Carefully install the dual turbocharger assembly on the engine. Align the high-pressure oil drain tube into oil drain housing.
6. Install three M8 x 55 bolts and finger tighten.

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Exhaust Tubing

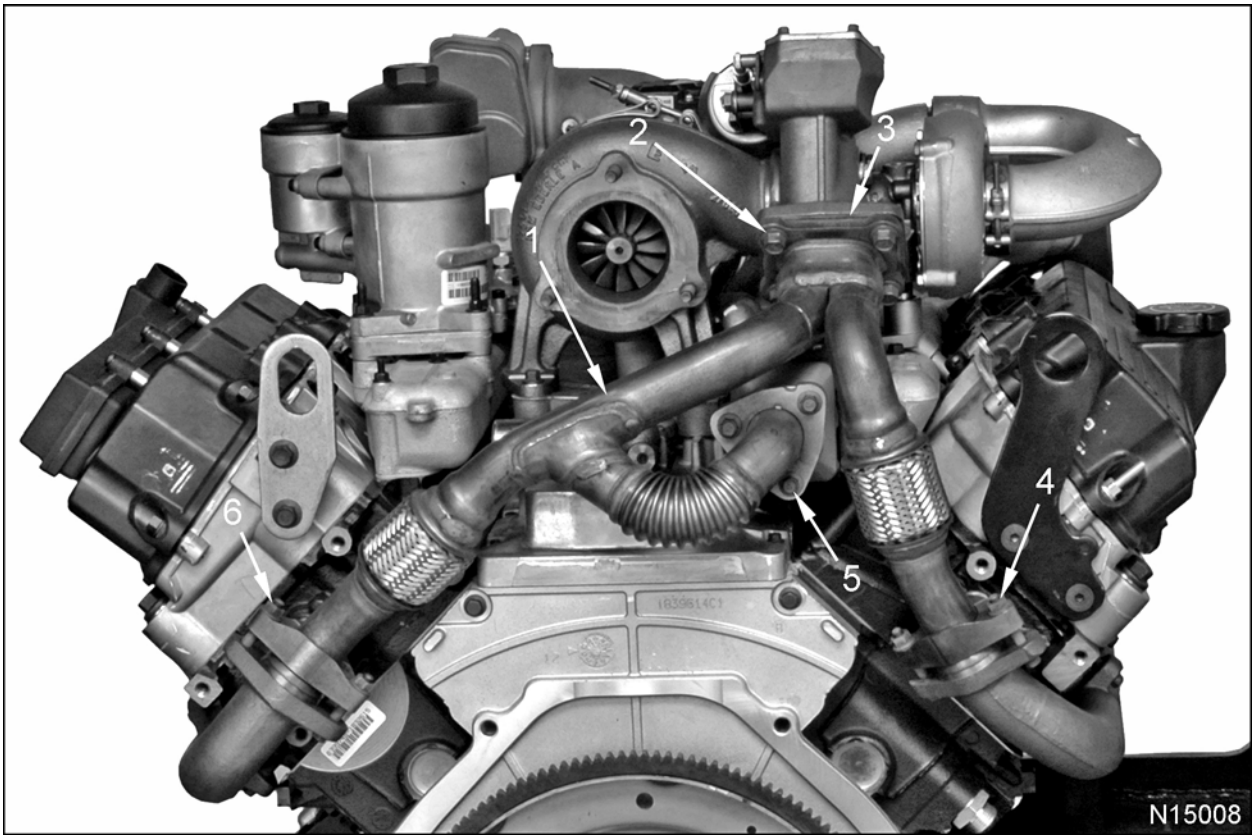

Figure 150 Exhaust tube assembly

1. Exhaust tube assembly
2. M10 x 30 high temp bolts (4)
3. Turbocharger inlet gasket
4. M8 x 50 bolts and M8 nuts (2)
5. M8 x 27 bolts (3)
6. M8 x 50 bolts and M8 nuts (2)

1. Apply anti-seize to four M10 x 30 and three M8 x 27 bolts.
2. Apply a light coat of clean engine oil to four M8 x 50 bolts and M8 nuts.
3. Install the exhaust tube assembly on the engine and install a new turbocharger inlet gasket between the turbocharger assembly and the exhaust tube assembly.
4. Install four M10 x 30 high temp bolts securing the exhaust tube assembly to the turbocharger and finger tighten bolts.
5. Install a new exhaust gasket between the EGR cooler and the exhaust tubing. Install three M8 x 27 bolts finger tight.
6. Install two M8 x 50 bolts and nuts securing the exhaust tube assembly to the right exhaust manifold and finger tighten bolts
7. Install two M8 x 50 bolts and nuts securing the exhaust tube assembly to the left exhaust manifold and finger tighten bolts

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Turbocharger and Exhaust Tube Torque Sequence

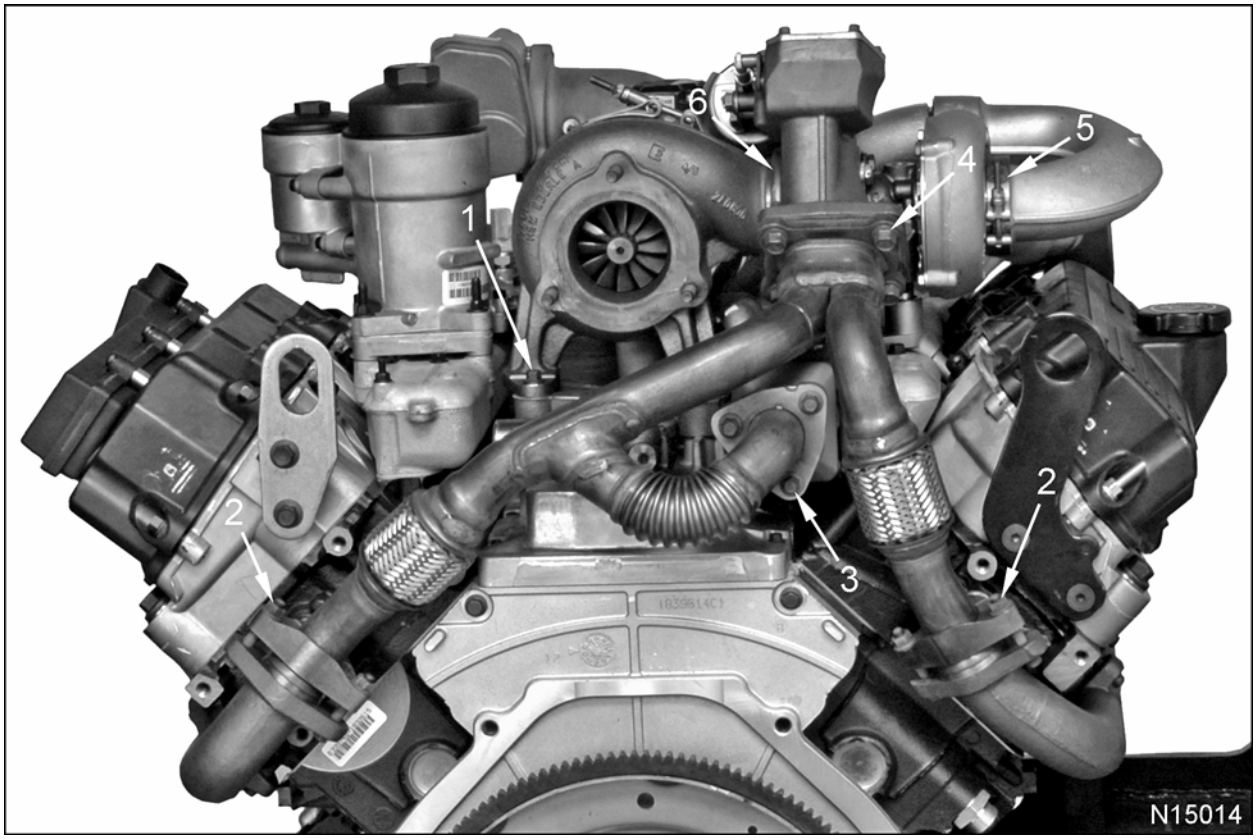

Figure 151 Exhaust tube assembly

1. M8 x 55 bolt (3)
2. M8 x 50 bolts and M8 nuts (4)
3. M8 x 27 bolt (3)
4. M10 x 30 high temp bolts (4)
5. V-band clamp (crossover tube)
6. Turbine V-band clamp

1. Tighten three M8 x 55 turbocharger mounting bolts to standard torque (page 400).
2. Tighten two M8 x 50 bolts and nuts securing the exhaust tube assembly to each exhaust manifold in the following order:
   A. Tighten M8 x 50 bolts and nuts to 10.3 N·m (91 lbf·in).
   B. Tighten M8 x 50 bolts and nuts to 20.6 N·m (183 lbf·in).
   C. Tighten M8 x 50 bolts and nuts to 31 N·m (23 lbf·ft).
3. Tighten three M8 x 27 bolts securing the exhaust tube assembly to the EGR cooler to standard torque.
4. Tighten four M10 x 30 high temp bolts securing the exhaust tube assembly to the turbocharger to standard torque.
5. Tighten the crossover tube V-band clamp to special torque (page 124).
6. Verify alignment marks are together, then tighten the turbine V-band clamp to special torque.

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Oil Supply Line

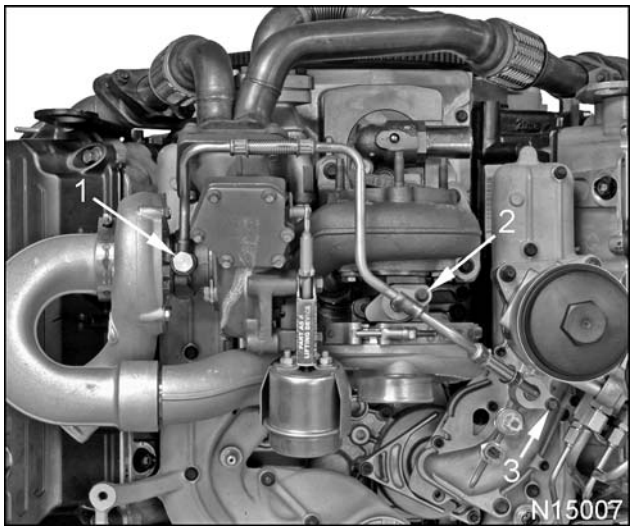

Figure 152 Turbocharger oil supply line

1. M12 Bango bolt and seal washers
2. M6 x 16 bolt
3. M6 x 20 bolt

1. Lubricate oil inlet hole of each turbocharger assembly with clean engine oil, spinning compressor wheel several times to allow oil to reach bearings. Refill oil inlet hole prior to installing oil supply line.
2. Install two new O-ring seals on the oil supply line.
3. Uncap oil ports and install turbocharger oil supply line into oil filter housing and low-pressure turbocharger.
4. Install M6 x 20 and M6 x 16 bolts and tighten to standard torque (page 400).
5. Install M12 banjo bolt and two new seal washers into the high-pressure turbocharger.
6. Tighten M12 banjo bolt to special torque (page 124).

Air Inlet Duct

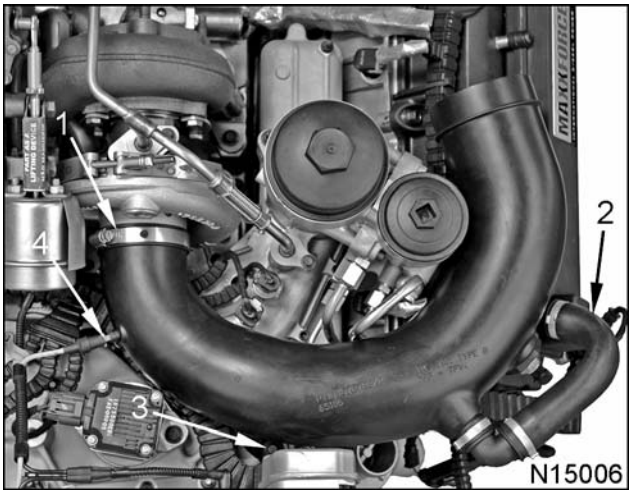

Figure 153 Air inlet duct assembly

1. Worm gear clamp
2. Crankcase breather hose
3. M6 x 16 bolt
4. Boost Control Solenoid (BCS) tubing

1. Install air inlet duct onto the turbocharger.
2. Install the crankcase breather hose to the crankcase breather on the left valve cover.
3. Install the M6 x 16 bolt and tighten to the standard torque (page 400).
4. Tighten worm gear clamp to special torque (page 124).
5. Install BCS tubing.

NOTE: See Boost Control Solenoid (BCS) Assembly (page 91) for BCS installation.

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Specifications

Maximum turbine shaft axial end play (LP turbocharger)	0.091 mm (0.0036 in)
Maximum turbine shaft radial shaft movement (clearance) (LP turbocharger)	0.5 mm (0.02 in)
Maximum turbine shaft axial end play (HP turbocharger)	0.091 mm (0.0036 in)
Maximum turbine shaft radial shaft movement (clearance) (HP turbocharger)	0.5 mm (0.02 in)

Special Torque

Air inlet duct worm gear clamp	5 N·m (48 lbf·in)
Bango bolt, M12	24 N·m (18 lbf·ft)
Boost Control Solenoid mounting bolt, M6 x 30	9 N·m (79 lbf·in)
Exhaust tubing to exhaust manifold, M8 x 50	See Turbocharger and Exhaust Tube Torque Sequence (page 122).
Low-pressure turbine exhaust outlet studs	22 N·m (16 lbf·ft)
V-band clamp (crossover tube)	7 N·m (62 lbf·in)
V-band clamp (turbine mating)	10 N·m (88 lbf·in)

Special Service Tools

Cap Kit (all)	ZTSE4610
Dial indicator with magnetic base	Obtain locally
Intake Guard	ZTSE4293
Turbo Crossover Tube Seal Remover / Installer	ZTSE4676
Slide Hammer	ZTSE4398A

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Exploded Views

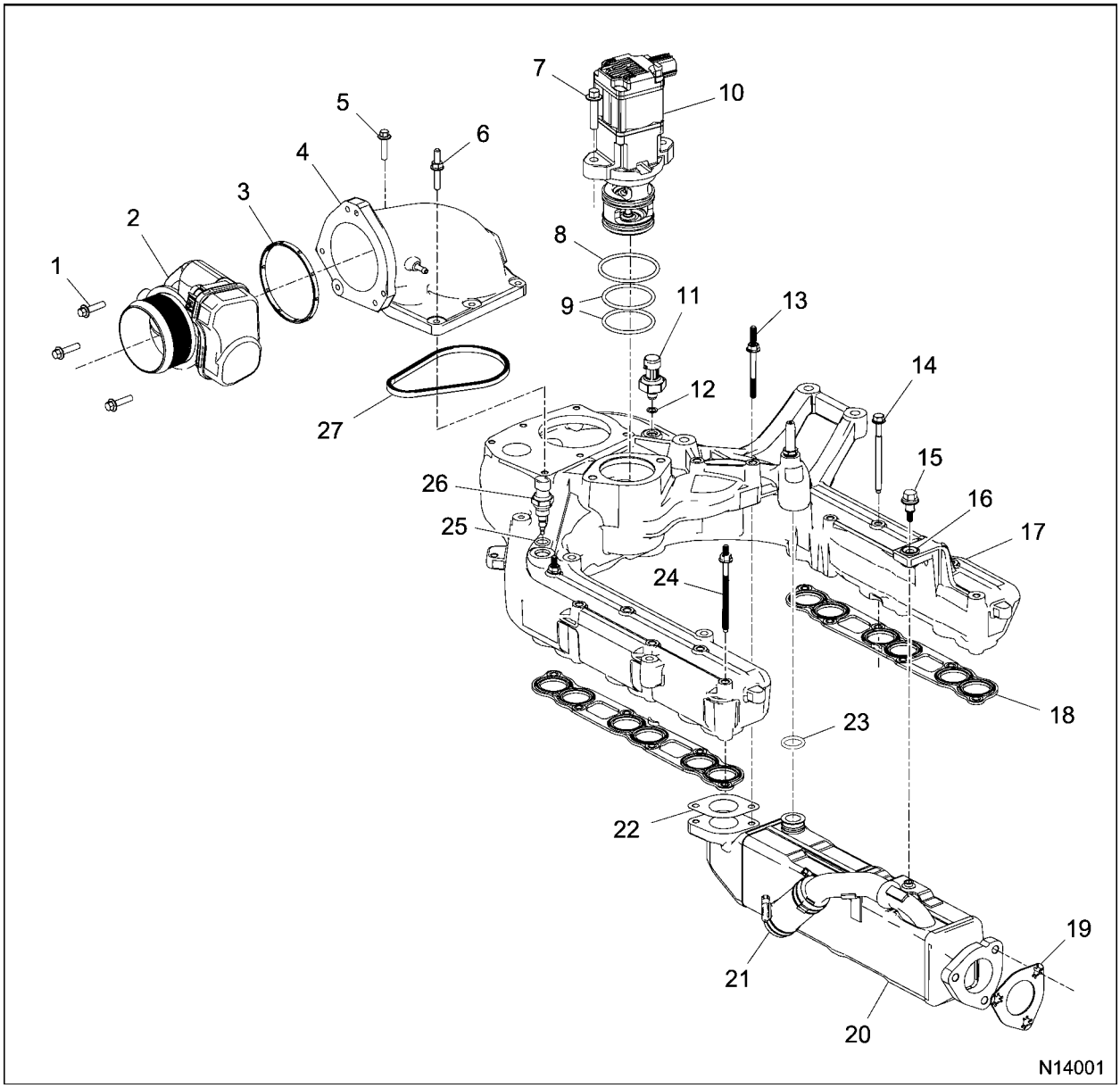

Figure 154 Intake manifold and EGR components

1. M6 x 25 bolt
2. Intake throttle assembly
3. Intake throttle gasket
4. Intake elbow assembly
5. M6 x 25 bolt (5)
6. M6 x 25 stud bolt
7. M8 x 35 bolt (2)
8. EGR valve seal
9. O-ring seal
10. EGR valve assembly
11. Manifold Air Pressure sensor
12. O-ring
13. M6 x 55 x 20 stud bolt (2)
14. M6 x 80 bolt (10)
15. M6 x 25 EGR cooler mounting bolt
16. EGR cooler insulator
17. Intake manifold
18. Intake manifold gasket (2)
19. Exhaust gasket
20. EGR cooler
21. Coolant hose assembly with clamps
22. EGR cooler to manifold gasket
23. O-ring seal
24. M6 x 80 stud bolt (2)
25. O-ring
26. MAT sensor
27. Intake elbow seal

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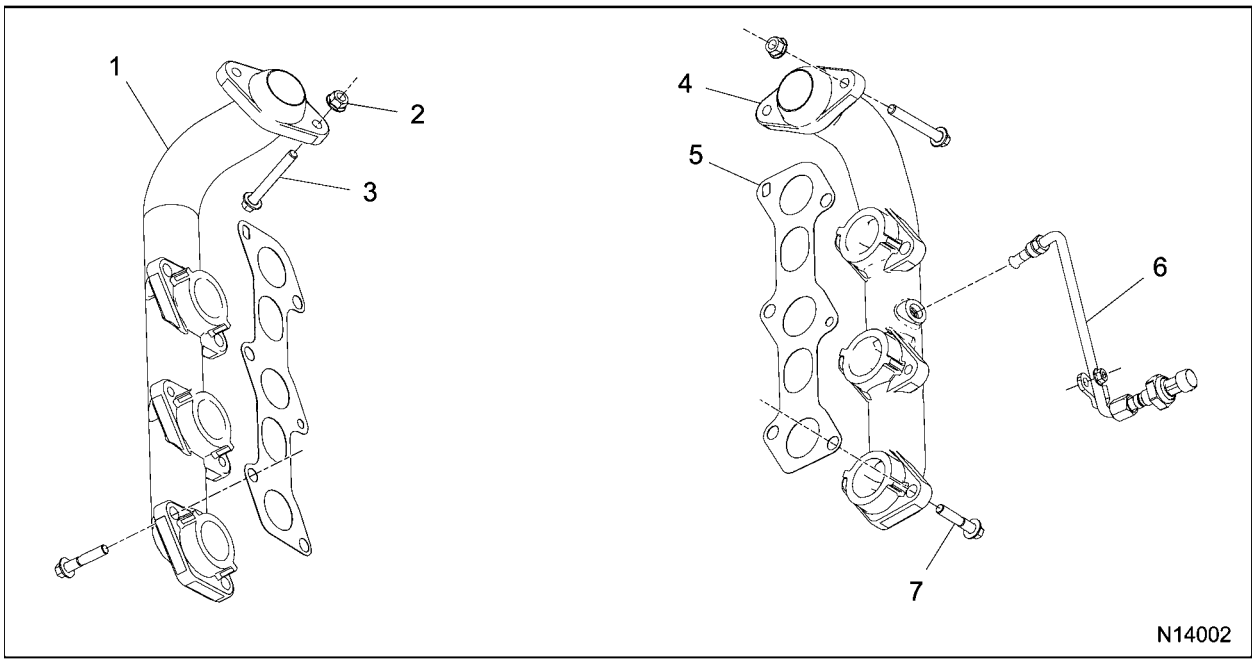

Figure 155 Exhaust manifolds and Exhaust Back Pressure (EBP) sensor

1. Right exhaust manifold
2. M8 nut (4)
3. M8 x 50 exhaust flange bolt (4)
4. Left exhaust manifold
5. Exhaust manifold gasket (2)
6. Exhaust Back Pressure (EBP) sensor assembly
7. M8 x 40 bolt (12)

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Removal

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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, 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, allow engine to cool before working with components.

WARNING: To prevent personal injury or death, disconnect the main battery negative terminal before disconnecting or connecting electrical 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.

GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a threat to the environment. Recycle or dispose of engine fluids and filters according to applicable regulations. Never put engine fluids in the trash, on the ground, in sewers or bodies of water.

Intake Throttle Assembly

1. Disconnect sensor harness connector from the intake throttle assembly.

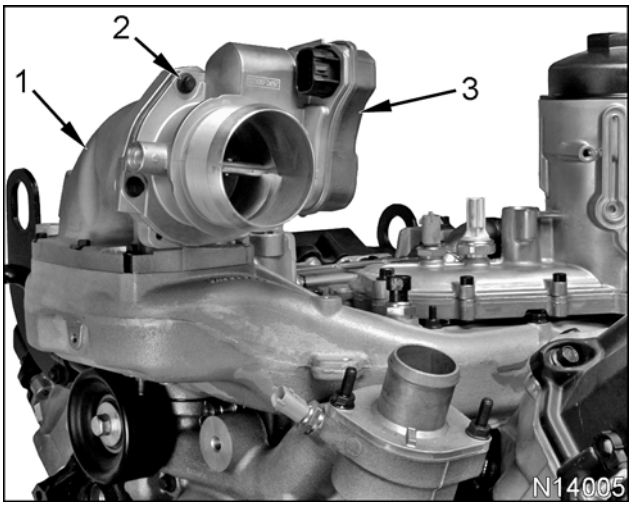

Figure 156 Intake throttle assembly

1. Intake elbow
2. M6 x 25 bolt (3)
3. Intake throttle assembly

2. Remove three M6 x 25 bolts securing the intake throttle assembly to the intake elbow and remove throttle assembly.
3. Remove and discard intake throttle gasket.

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Exhaust Manifolds

1. Remove turbocharger exhaust tube assembly. See “Dual Stage Turbocharger Assembly”.
2. Disconnect Exhaust Back Pressure (EBP) sensor connector.

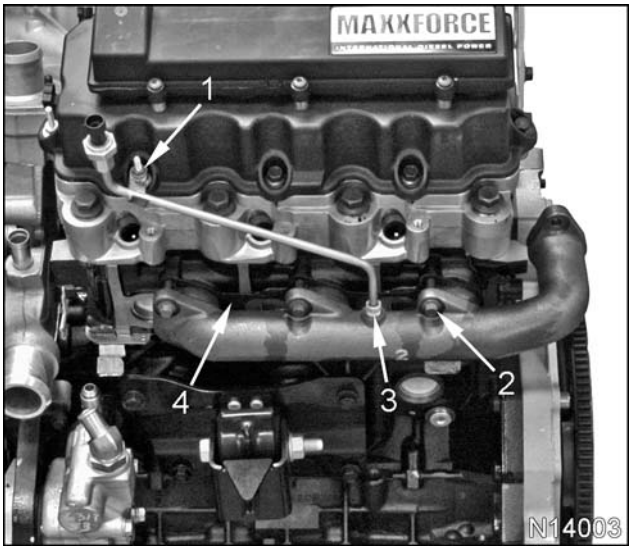

Figure 157 Left exhaust manifold and Exhaust Back Pressure (EBP) tube

1. M6 nut
2. M8 x 40 bolt (6)
3. EBP tube nut
4. Exhaust manifold gasket

3. Remove M6 nut from left valve cover stud bolt.
4. Remove EBP tubing nut from the left exhaust manifold and remove EBP tube assembly.
5. Remove six M8 x 40 bolts securing the left exhaust manifold to the left cylinder head. Discard six M8 x 40 bolts and exhaust manifold gasket.

Figure 158 Right exhaust manifold

1. Exhaust manifold gasket
2. M8 x 40 bolt (6)

6. Remove six M8 x 40 bolts securing the right exhaust manifold to the right cylinder head. Discard six M8 x 40 bolts and exhaust manifold gasket.

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Exhaust Gas Recirculation (EGR) Valve

1. Disconnect EGR valve sensor harness connector.

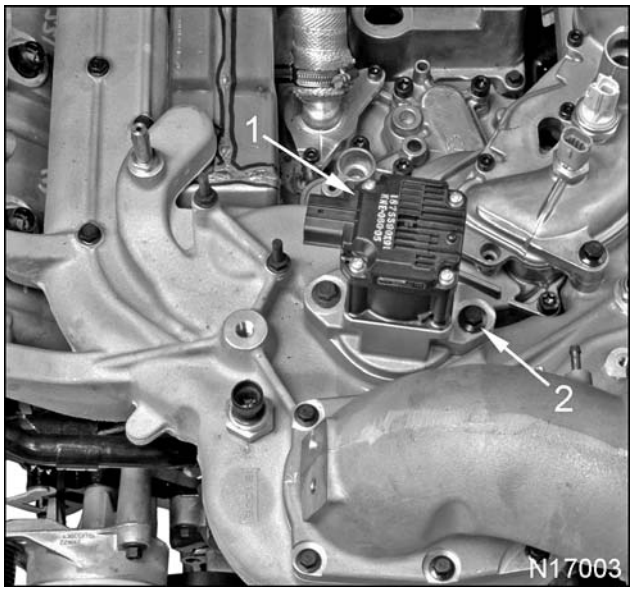

Figure 159 EGR valve

1. EGR valve
2. M8 x 35 bolt (2)

2. Remove two M8 x 35 bolts.

CAUTION: To prevent engine damage, when removing or installing the EGR valve, vacuum or remove loose carbon deposits and debris from inside the intake manifold.

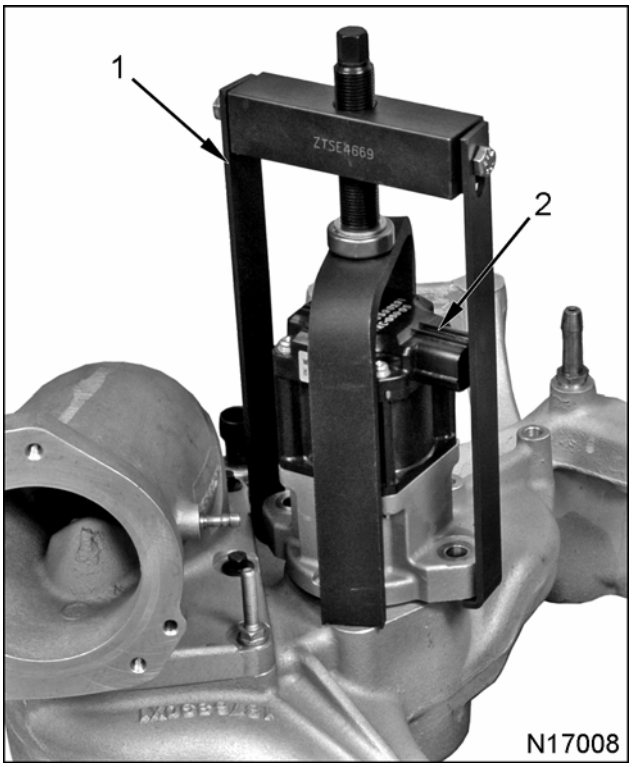

Figure 160 EGR valve removal

1. EGR Valve Puller
2. EGR Valve

3. Turn the EGR valve.
4. Position the EGR Valve Puller (page 142) support legs over the EGR bolt holes in the intake manifold.
5. Install arm pins under the EGR valve bolt holes and attach other end to puller beam.
6. Turn puller shaft counter-clockwise to remove EGR valve.
7. Remove and discard EGR valve seal and two O-rings seals.
8. Vacuum out any debris from inside the intake manifold.

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Intake Manifold and EGR Cooler Assembly

1. Remove the turbocharger air intake duct, oil supply line, exhaust tube assembly, and dual turbocharger assembly. See “Dual Stage Turbocharger Assembly”.
2. Remove the secondary fuel filter assembly. See “Fuel Systems”.
3. Remove the oil filter housing assembly. See “Oil Cooler and Filter Housing”.

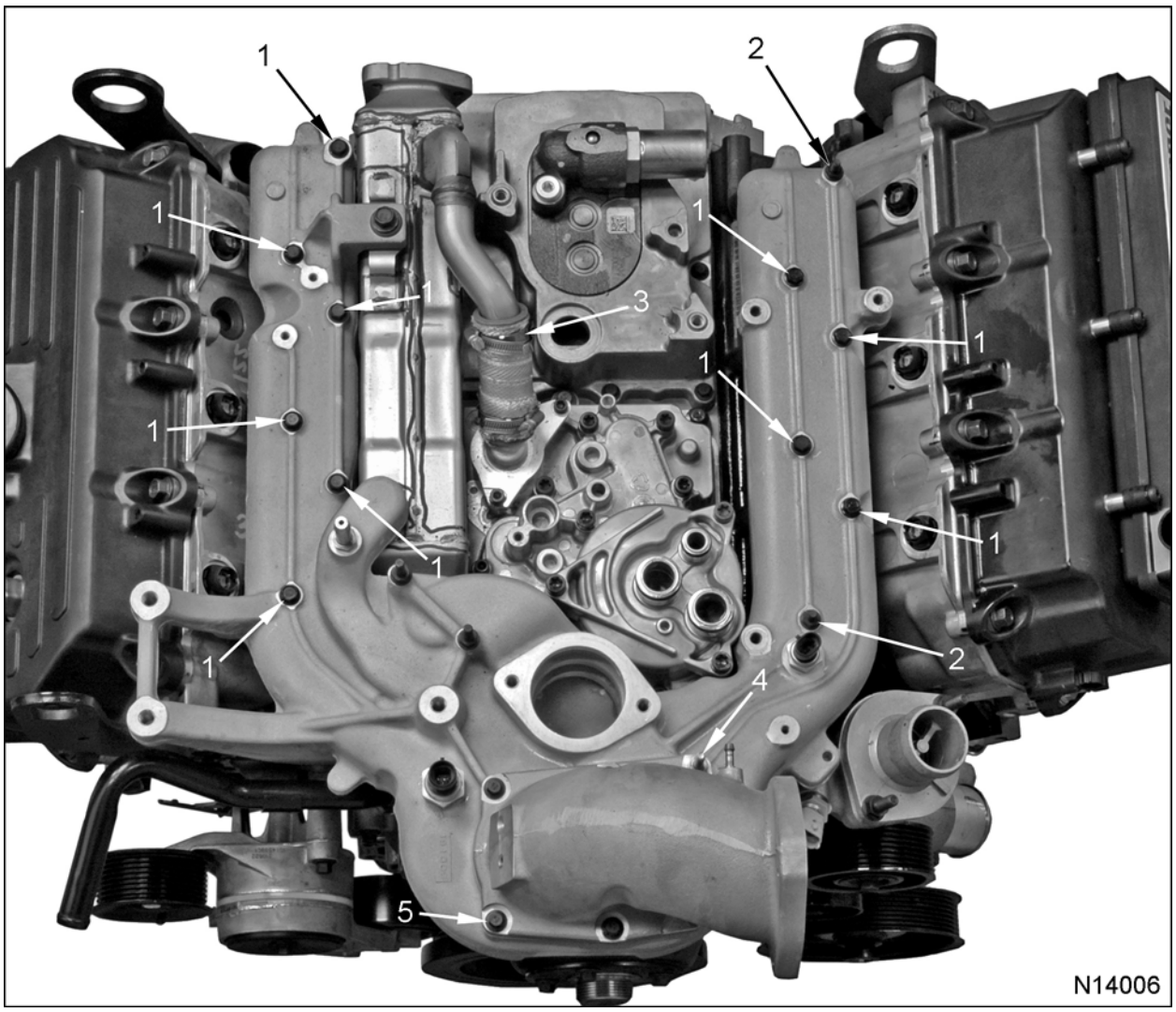

Figure 161 Intake manifold and intake elbow

1. M6 x 80 bolt (10)
2. M6 x 80 x 10 stud bolt (2)
3. Hose clamp (2)
4. M6 x 25 x 25 stud bolt
5. M6 x 25 bolt (5)

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

CAUTION: To prevent engine damage, blow out or vacuum any dirt and debris from around and under the intake manifold. This minimizes the chances something could fall in the cylinder head intake ports.

4. If required, remove M6 x 25 x 25 stud bolt, five M6 x 25 bolts, intake elbow and gasket.
5. Vacuum or blow out dirt and debris from around the intake manifold.
6. Remove two M6 x 80 x 10 stud bolts and ten M6 x 80 bolts.
7. Loosen two EGR coolant hose clamps.

NOTE: The EGR cooler should remain attached to the intake manifold.

8. Lift intake manifold and EGR cooler assembly up and off engine.
9. Carefully remove dirt and debris from around mating surfaces of intake ports, making sure debris does not fall into intake ports.
10. Use a borescope to inspect the inside of intake ports. Remove objects and debris from intake ports. Use a magnet to remove metal objects or fragments.
11. Install Magnetic Covers for Cylinder Head Intake Ports (page 142).

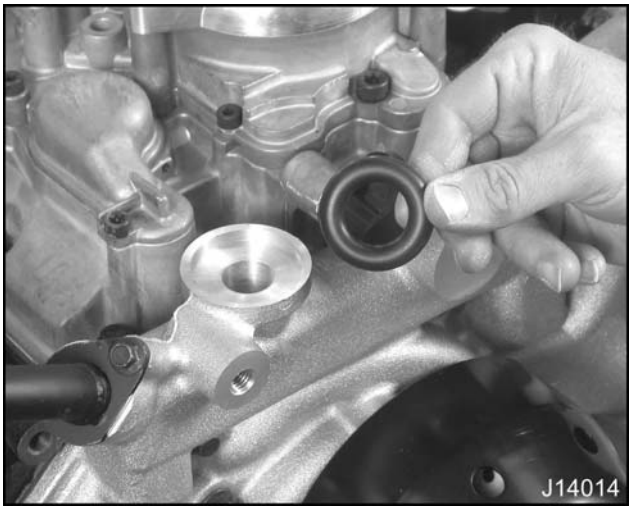

Figure 162 Front cover O-ring seal

12. Remove and discard the front cover O-ring seal.

Exhaust Gas Recirculation (EGR) Cooler

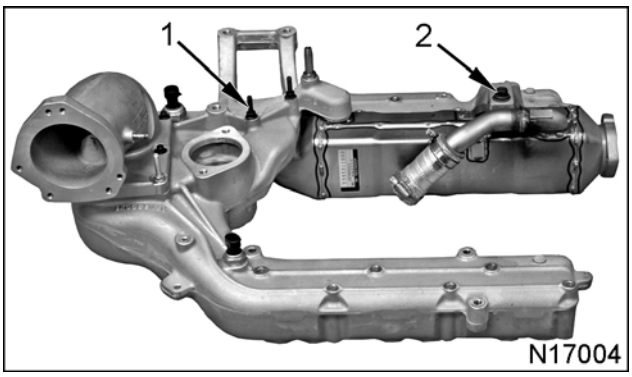

Figure 163 EGR cooler retaining bolts

1. M6 x 55 x 20 stud bolt (2)
2. M6 x 25 EGR cooler mounting bolt and EGR cooler insulator

1. Remove M6 x 25 EGR cooler mounting bolt and two M6 x 55 x 20 stud bolts securing the EGR cooler to the intake manifold.
2. Remove EGR cooler from the intake manifold and discard O-ring seal, cooler to manifold gasket, and EGR cooler insulator.

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Cleaning, Inspection and Test

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

Exhaust Manifold Warpage Test

1. Clean machined surfaces of exhaust manifolds and mating surfaces of cylinder heads.
2. Install exhaust manifolds onto cylinder heads without gasket.
3. Tighten bolts using Exhaust manifold torque sequence (page 140).

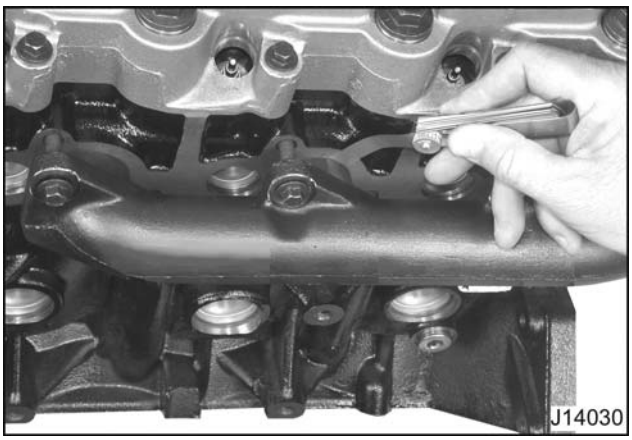

Figure 164 Exhaust manifold warpage measurement

4. Check each exhaust manifold port by trying to pass a 0.003 inch Feeler gauge (page 142) between the exhaust manifold and cylinder head. If the feeler gauge passes through the gap, replace that manifold.
5. Remove exhaust manifolds.

Exhaust Gas Recirculation (EGR) Valve

1. Clean gasket mating surfaces of EGR valve assembly and remove carbon deposits.
2. Check EGR valve assembly pintle shaft and carriage for misalignment.

NOTE: For EGR valve electrical inspections see EGES-395 *Engine Diagnostics Manual*.

Exhaust Gas Recirculation (EGR) Cooler

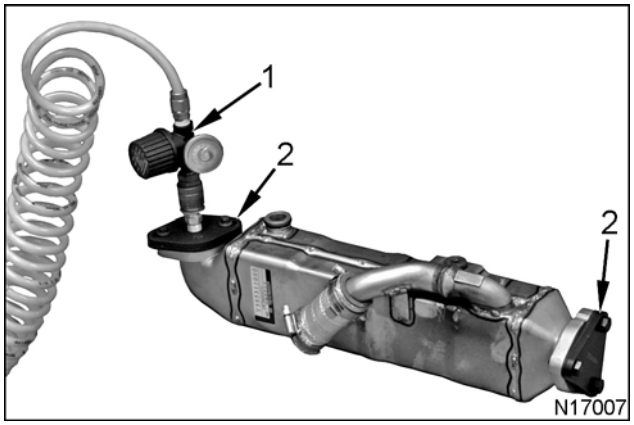

Figure 165 EGR Cooler Pressure Test Plates

1. Air pressure regulator assembly
2. EGR Cooler Pressure Test Plates

1. Install EGR Cooler Pressure Plates (page 142) to each end of the EGR cooler assembly.
2. Attach an air pressure regulator to the EGR cooler. Connect to air supply and adjust air pressure to approximately 172 to 207 kPa (25 to 30 psi).
3. Submerge EGR cooler in water. Inspect for air bubbles coming from coolant passages. Replace EGR cooler if leaking.

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Intake Manifold

The Intake manifold may be cleaned with steam or a suitable non-caustic solvent.

Clean the EGR O-ring contact areas in the intake manifold with Injector Sleeve Brush (page 142). Make sure carbon above and below O-ring contact areas is free enough to be vacuumed from the intake manifold.

1. Clean machined surfaces of intake manifold and mating surfaces of cylinder heads.
2. Install intake manifold onto cylinder heads without gasket.
3. Tighten bolts to special torque (page 142) using intake manifold torque sequence (Figure 171) .
4. Check each intake manifold port by trying to pass a 0.003 inch feeler gauge (page 142) between the intake manifold and the cylinder head. If the feeler gauge passes through the gap, replace the manifold. Remove intake manifold from engine.

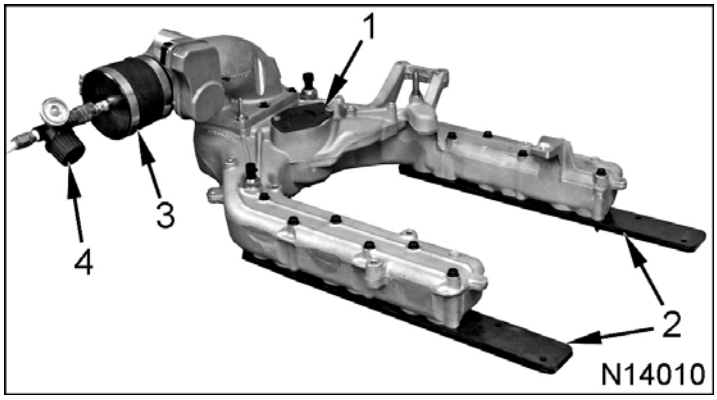

Figure 166 Intake manifold pressure test

1. Intake Manifold Pressure Test Plug
2. Intake Manifold Pressure Test Plates
3. Intake Manifold Pressure Test Cap
4. Air pressure regulator

5. Install Intake Manifold Pressure Test Plates (page 142).
6. Install Intake Manifold Pressure Test Plug (page 142) in EGR valve opening.
7. Install Intake Manifold Pressure Test Cap (page 142) onto air intake throttle.

CAUTION: To prevent engine damage, do not pressurize intake manifold over 206 kPa (30 psi).

8. Pressurize intake manifold to 172 to 206 kPa (25 to 30 psi) using regulated filtered air supply. Submerge the intake manifold assembly in water. Inspect for leaks in the intake plenum, EGR and coolant passages. Replace intake manifold if necessary.
9. Inspect intake manifold gasket seal beads for defects. Replace if necessary.

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Installation

NOTE: Apply a light coat of clean engine oil on bolt threads and under bolt head when installing used nuts and bolts.

Exhaust Gas Recirculation (EGR) Cooler

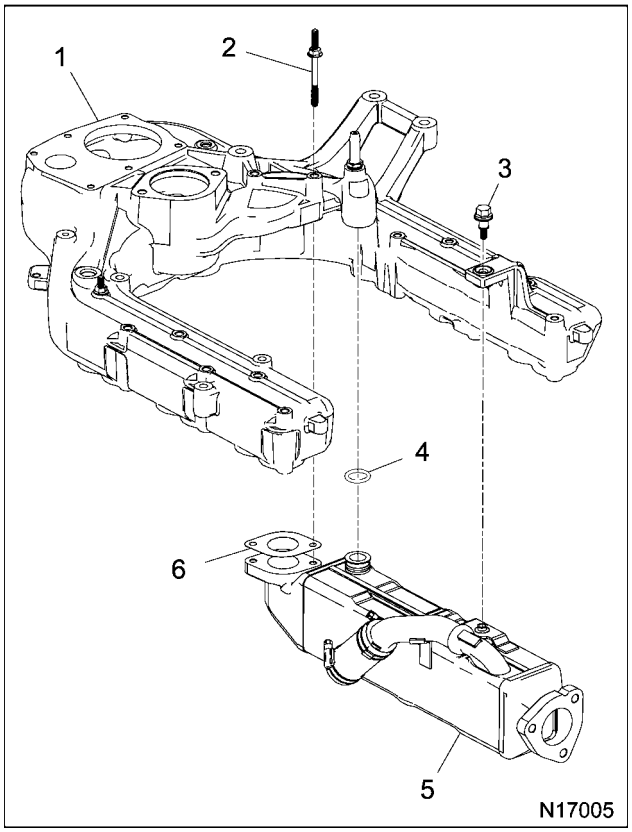

Figure 167 EGR cooler retaining bolts and gasket

1. Intake manifold
2. M6 x 55 x 20 stud bolt (2)
3. M6 x 25 EGR cooler mounting bolt
4. O-ring seal
5. EGR cooler
6. EGR cooler to manifold gasket

1. Install a new O-ring seal and EGR cooler insulators on the EGR cooler.
2. Install a new EGR cooler to manifold gasket and install two M6 x 55 x 20 stud bolts through the intake manifold and into the EGR cooler. Finger tighten bolts.
3. Install M6 x 25 EGR cooler mounting bolt and finger tighten.
4. Tighten M6 x 25 EGR cooler mounting bolt and two M6 x 55 x 20 stud bolts to special torque (page 142).

Intake Manifold and EGR Cooler Assembly

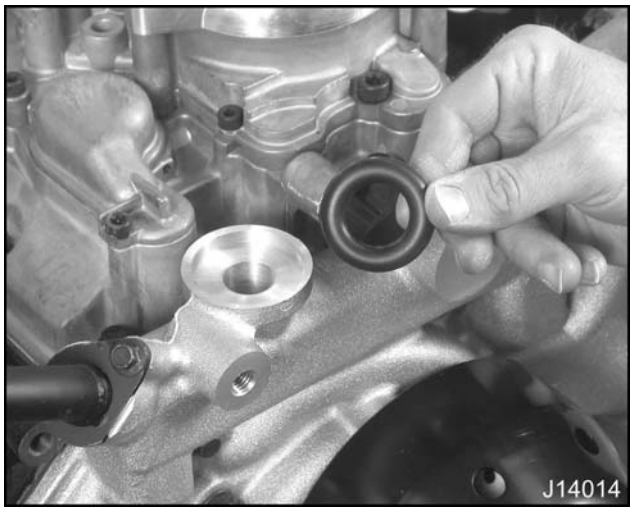

Figure 168 Front cover O-ring seal

1. Install a new front cover O-ring seal between the intake manifold and front cover assembly.

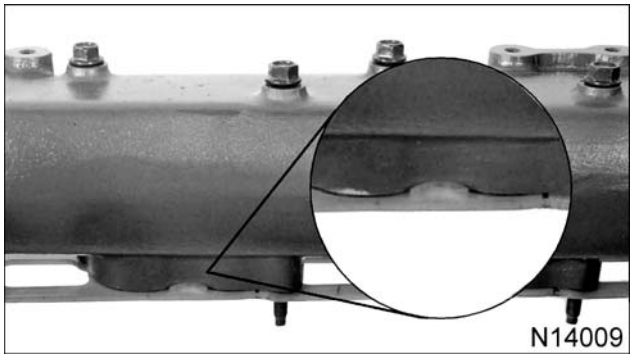

Figure 169 Intake manifold gasket with centering tab

2. Install a new gasket on each side of the intake manifold and run a few bolts through to hold gasket in place. Make sure centering tabs are facing up towards the manifold, while positioned inboard toward engine valley.

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3. Remove Magnetic Covers from cylinder head intake ports.
4. Before installing the intake manifold, use a borescope to make sure intake ports are free of objects and debris. Use a magnet to remove metal objects or fragments.
5. Install intake manifold and EGR cooler assembly onto cylinder heads.

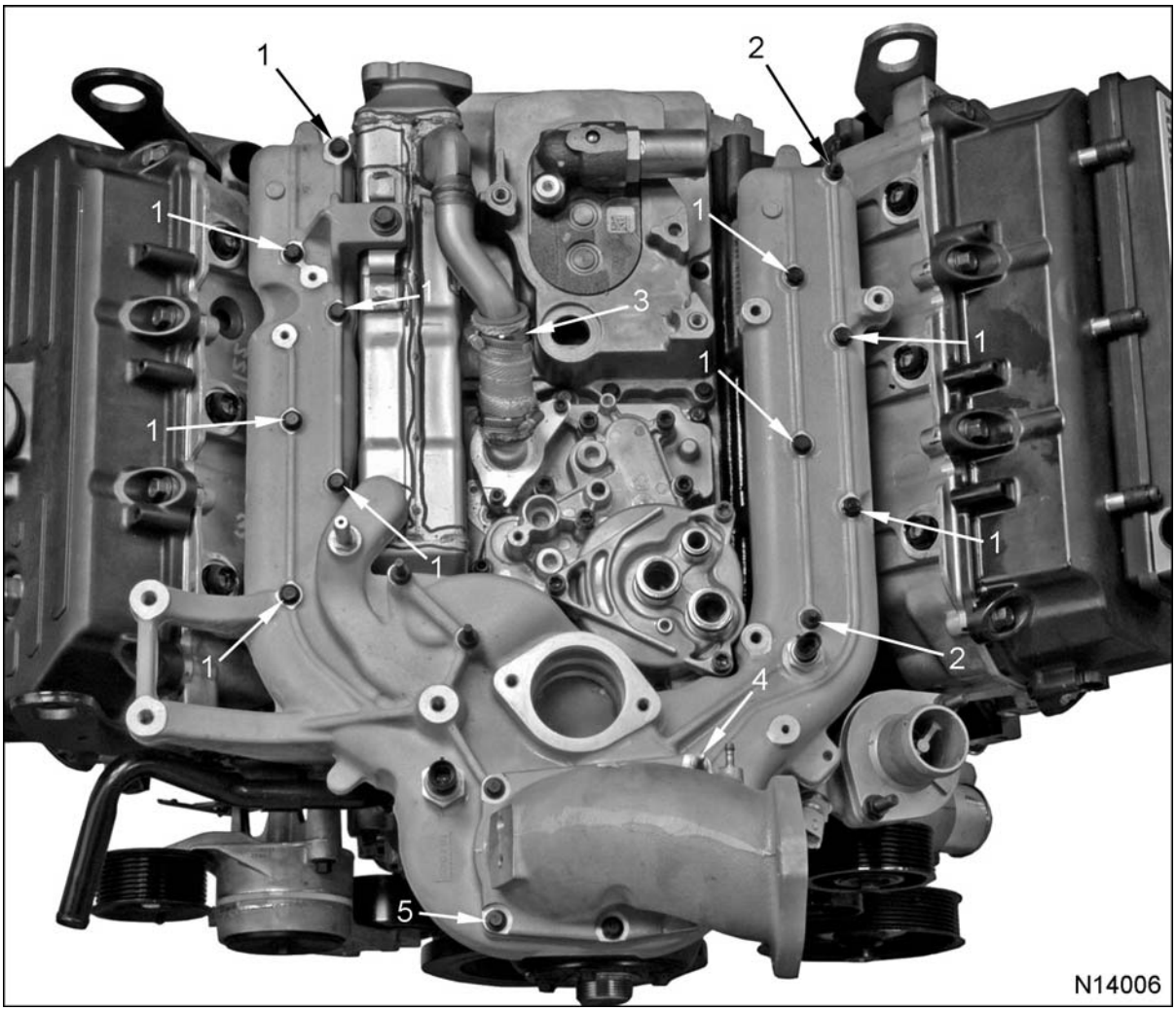

Figure 170 Intake manifold bolts

1. M6 x 80 bolt (10)
2. M6 x 80 x 10 stud bolt (2)
3. Hose clamp (2)
4. M6 x 25 x 25 stud bolt
5. M6 x 25 bolt (5)

6. Install ten M6 x 80 bolts and two M6 x 80 x 10 stud bolts finger tight.
7. Install intake elbow, new elbow seal, M6 x 25 x 25 stud bolt, and five M6 x 25 bolts. Tighten bolts and stud bolt to standard torque (page 400).

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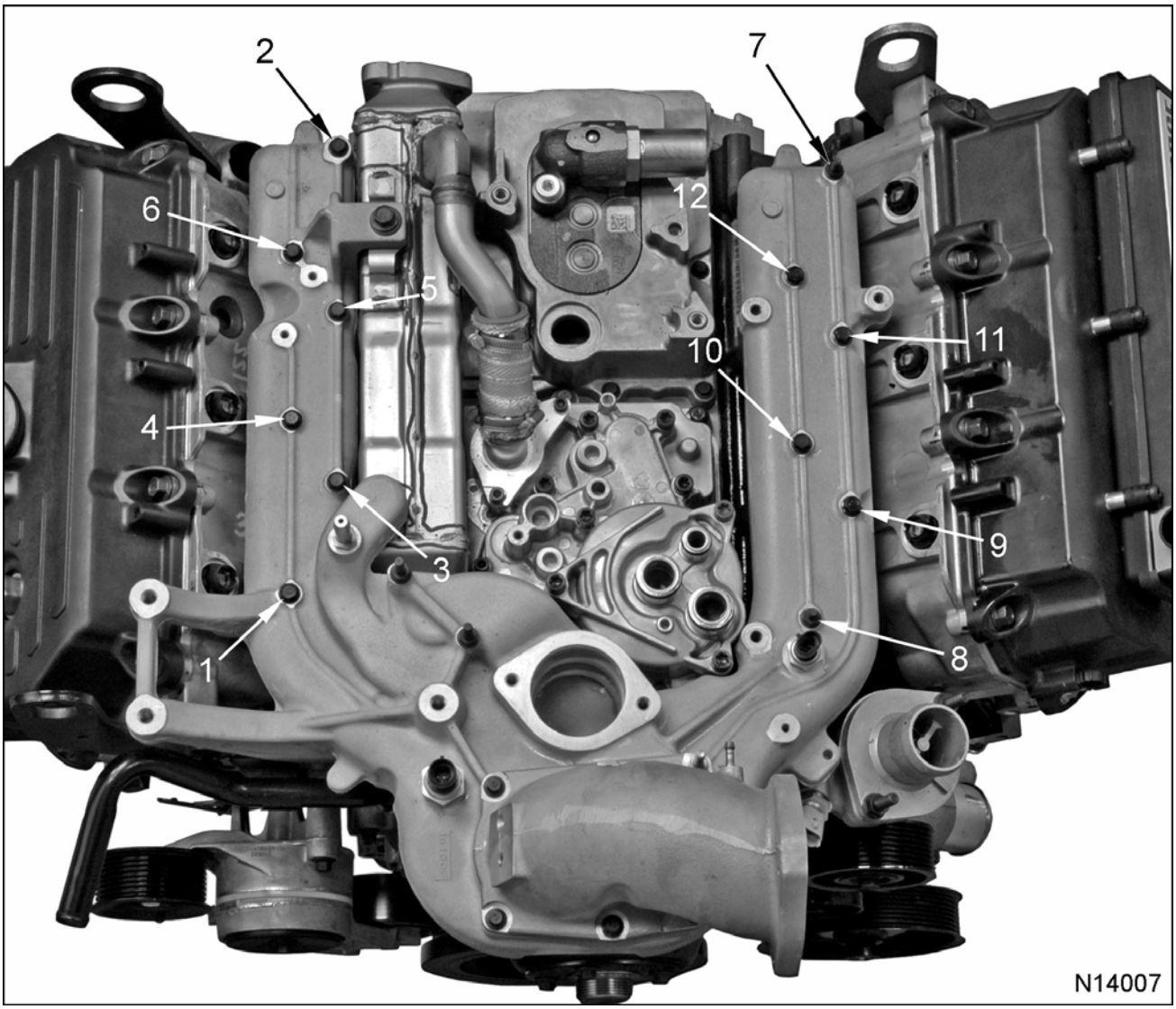

Figure 171 Intake manifold bolt torque sequence

8. Tighten twelve intake manifold bolts to special torque (page 142) and in the proper sequence shown above.

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Exhaust Gas Recirculation (EGR) Valve

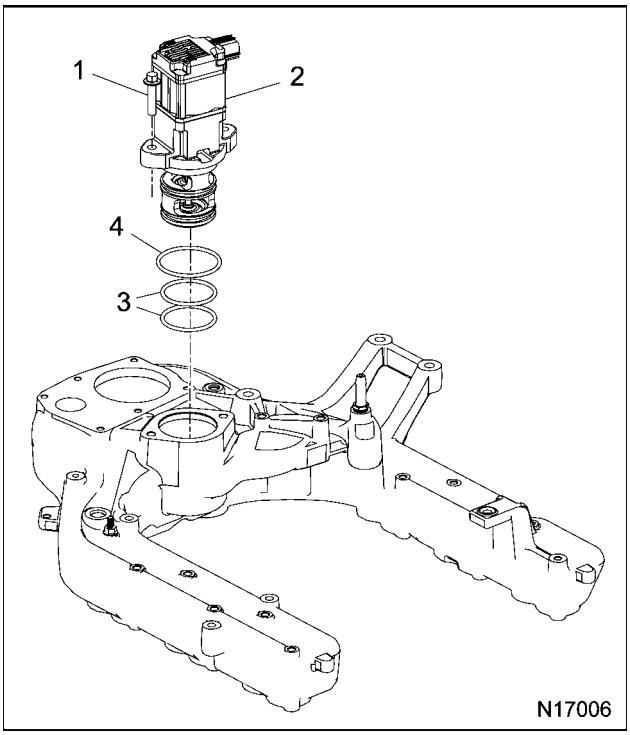

Figure 172 EGR valve and seals

1. M8 x 35 bolt (2)
2. EGR valve
3. O-ring seal
4. EGR valve seal

CAUTION: To prevent engine damage, completely seat the EGR valve in the intake manifold before installing bolts.

1. Install EGR valve seal onto the EGR valve.
2. Install two smaller O-rings seals onto the EGR valve.
3. Install the EGR valve into the intake manifold. Seat EGR valve into the intake manifold using only hand pressure.
4. Install two M8 x 35 bolts and tighten, alternating between both bolts to standard torque (page 400).

Intake Throttle Assembly

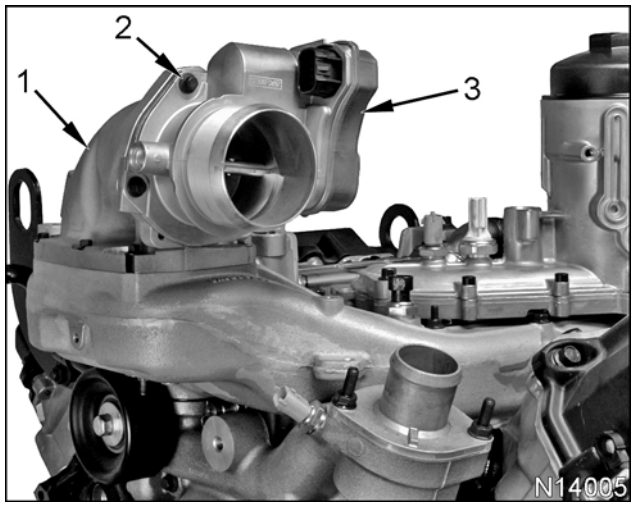

Figure 173 Intake throttle assembly

1. Intake elbow
2. M6 x 25 bolt (3)
3. Intake throttle assembly

1. Install a new intake throttle gasket on the intake throttle assembly.
2. Install three M6 x 25 bolts securing the intake throttle assembly to the intake elbow.
3. Tighten M6 x 25 bolts to standard torque (page 400).

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Exhaust Manifolds

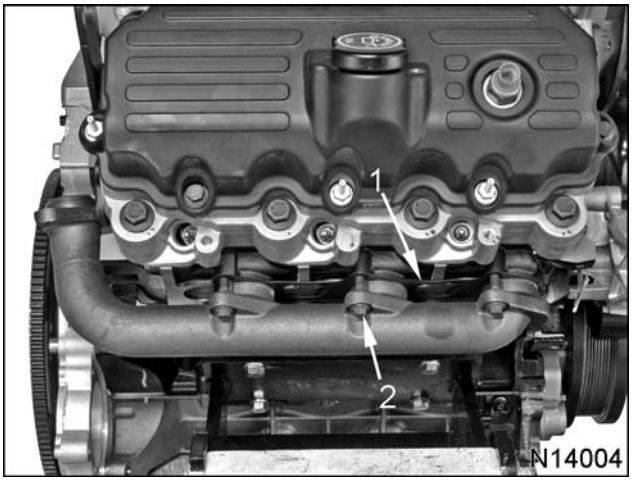

Figure 174 Right exhaust manifold

1. Exhaust manifold gasket
2. M8 x 40 bolt (6)

1. Apply anti-seize to six new M8 x 40 bolts.
2. Install a new exhaust manifold gasket on the right exhaust manifold.
3. Install the right exhaust manifold and install one new M8 x 40 bolt starting with the center top bolt hole. The hole diameter is smaller, allowing alignment of remaining bolts.
4. Install remaining new M8 x 40 bolts through the exhaust manifold and gasket.

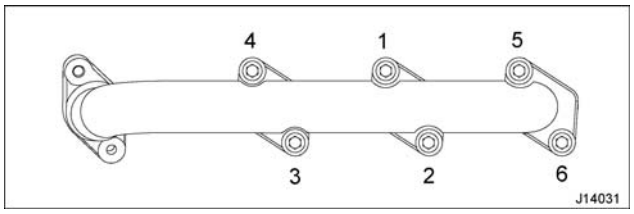

Figure 175 Exhaust manifold torque sequence – right

5. Tighten right exhaust manifold bolts to 19 N·m (14 lbf·ft) using the above torque sequence.
6. Tighten right exhaust manifold bolts to 38 N·m (28 lbf·ft) using the above torque sequence.

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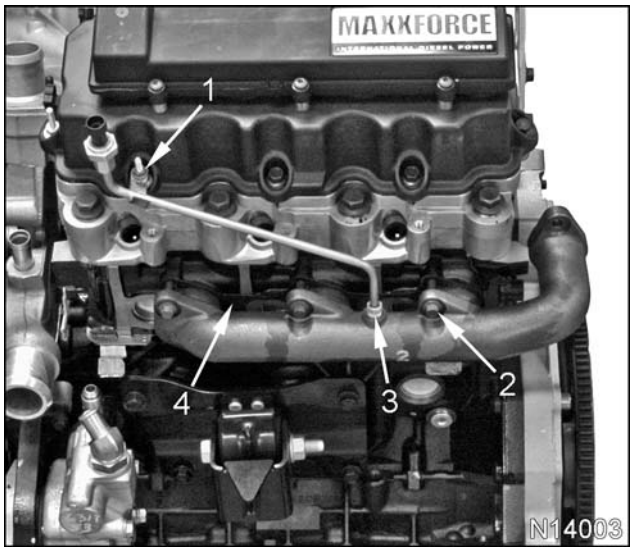

Figure 176 Left exhaust manifold and Exhaust Back Pressure (EBP) tube

1. M6 nut
2. M8 x 40 bolt (6)
3. EBP tube nut
4. Exhaust manifold gasket

7. Apply anti-seize to six new M8 x 40 bolts.
8. Install a new exhaust manifold gasket onto the left exhaust manifold.
9. Install the left exhaust manifold and install one new M8 x 40 bolt starting with the center top bolt hole.
10. Install remaining new M8 x 40 bolts through the exhaust manifold and gasket.

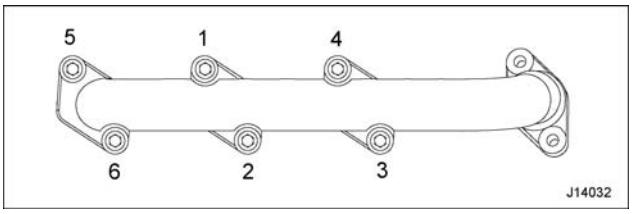

Figure 177 Exhaust manifold torque sequence – left

11. Tighten left exhaust manifold bolts to 19 N·m (14 lbf·ft) using the above torque sequence.
12. Tighten left exhaust manifold bolts to 38 N·m (28 lbf·ft) using the above torque sequence.
13. Install EBP tube assembly on left valve cover stud bolt and left exhaust manifold and finger tighten EBP tube nut.
14. Install M6 nut on valve cover stud bolt and tighten to standard torque (page 400).
15. Tighten EBP tube nut.

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Specifications

Exhaust Manifolds	
Maximum allowable warpage	0.08 mm (0.003 in)
Intake Manifold	
Maximum allowable warpage	0.08 mm (0.003 in)

Special Torque

Coolant deaeration fitting	10 N·m (90 lbf·in)
EGR cooler mounting bolt assembly, M6 x 25	11 N·m (97 lbf·in)
EGR cooler to manifold stud bolts, M6 x 55 x 20	11 N·m (97 lbf·in)
Exhaust manifold bolts, M8 x 40[1]	See Exhaust Manifolds (page 140) torque sequence
Intake manifold bolts, M6 bolts and stud bolts	11 N·m (97 lbf·in) See intake manifold bolt torque sequence (page 136)

[1] Apply anti-seize compound to bolt threads before assembly

Special Service Tools

Anti-seize compound	Obtain locally
Cap Kit (all)	ZTSE4610
EGR Cooler Pressure Test Plates	ZTSE4707
EGR Valve Puller	ZTSE4669
Feeler gauge	Obtain locally
Injector Sleeve Brush Set	ZTSE4304
Intake Manifold Pressure Test Plates	ZTSE4527
Intake Manifold Pressure Test Plug	ZTSE4888
Intake Manifold Pressure Test Cap	ZTSE4682
Magnetic Covers for Cylinder Head Intake Ports	ZTSE4559

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Illustrations

High-pressure Oil System Components

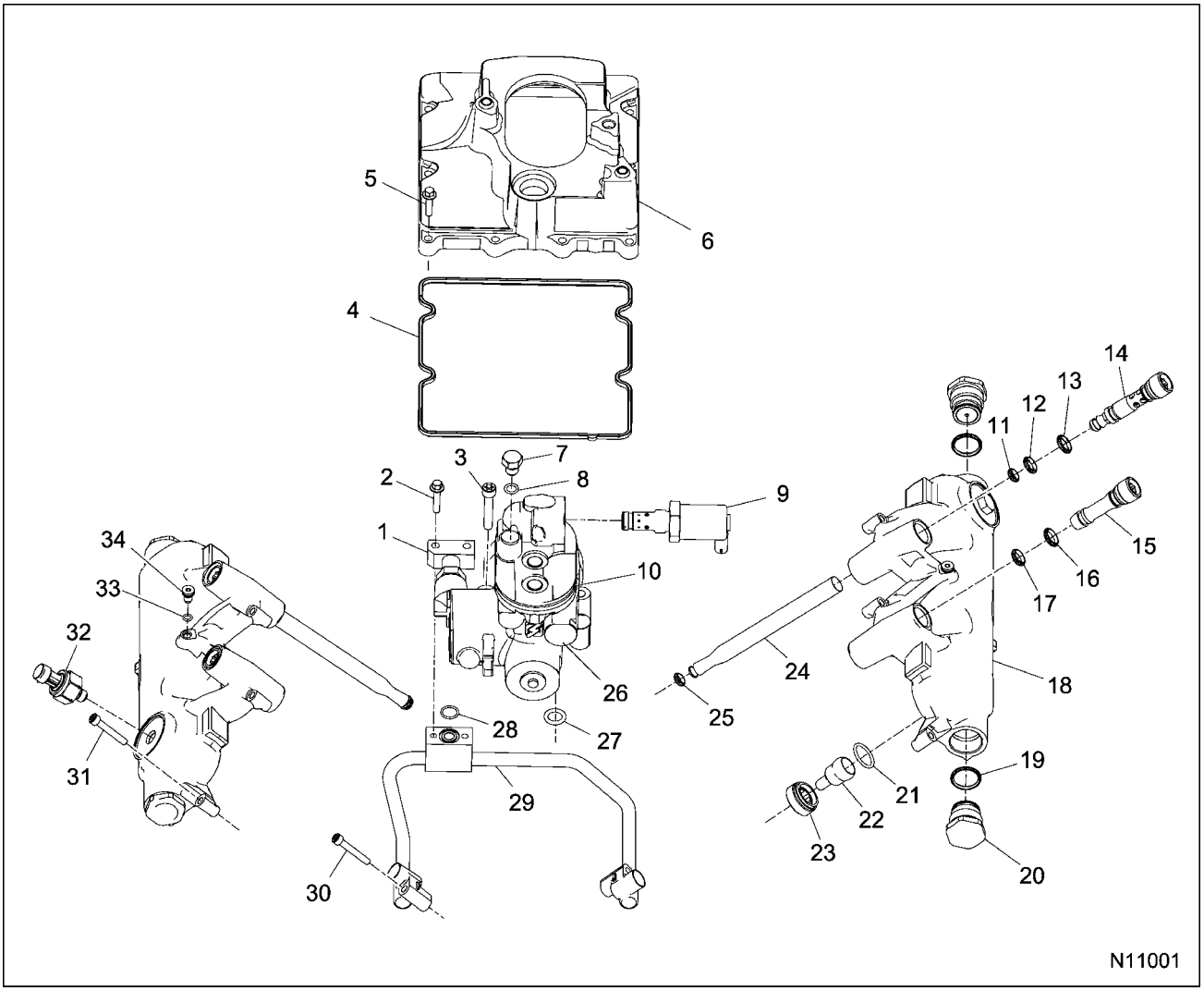

Figure 178 High-pressure oil system

1. Branch tube adaptor
2. M6 x 30 bolt (2)
3. M8 x 45 bolt (3)
4. Hydraulic pump cover gasket
5. M6 x 25 bolt (8)
6. Hydraulic pump cover
7. High-pressure pump plug, M12
8. O-ring seal
9. Injection Pressure Regulator (IPR) valve
10. Pump O-ring
11. D-ring seal (8.22 mm I.D.)
12. D-ring seal (11.7 mm I.D.)
13. D-ring seal (13.3 mm I.D.)
14. Case-to-head tube plug assembly (with check valve)
15. Rail port plug
16. D-ring seal (13.3 mm I.D.)
17. D-ring seal (11.7 mm I.D.)
18. High-pressure oil rail (2)
19. D-ring seal
20. Rail end plug (4)
21. O-ring seal
22. Single ball tube
23. Internal hex ferrule
24. Case-to-head tube
25. D-ring seal (8.22 mm I.D.)
26. High-pressure oil pump assembly
27. O-ring seal, #207
28. O-ring seal, #16
29. Branch tube assembly, brazed
30. M6 x 40 bolt (2)
31. M6 x 40 bolt (14)
32. Injection Control Pressure (ICP) sensor assembly
33. O-ring seal
34. Prime port plug, M8

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High-pressure Oil Flow Schematic

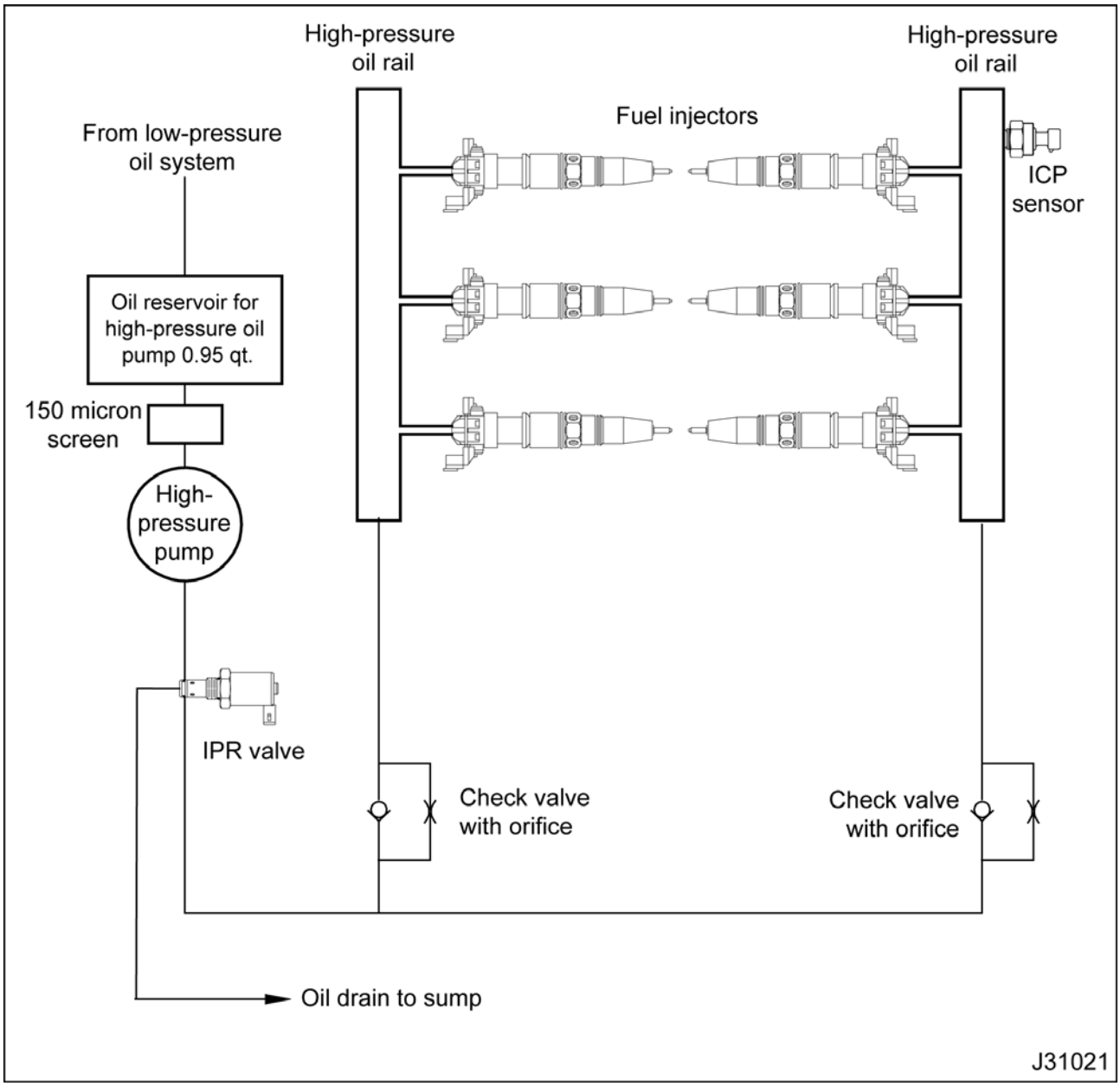

Figure 179 High-pressure oil flow

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Removal

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, disconnect the main battery negative terminal before disconnecting or connecting electrical 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.

GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a threat to the environment. Recycle or dispose of engine fluids and filters according to applicable regulations. Never put engine fluids in the trash, on the ground, in sewers or bodies of water.

NOTE: If removing only the high-pressure oil pump, it is not necessary to remove the branch tube assembly, rear cover, or cylinder heads.

High-pressure Oil Rail

1. Remove valve covers. See “Cylinder Head and Valve Train”.

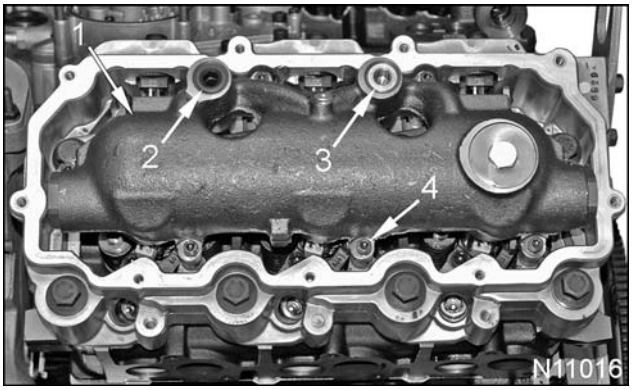

Figure 180 High-pressure oil rail (left)

1. High-pressure oil rail (left)
2. Rail port plug
3. Case-to-head tube plug
4. M6 x 40 bolt (7)

CAUTION: To prevent engine damage, replace case-to-head tubes and rail port plugs if removed. D-ring seals are not replaceable. Inspect each D-ring carefully for cuts, abrasions, and twisting. Never use a tube with any of these problems.

NOTE: It is not necessary to remove the rail port plug when removing the oil rail assemblies. Only remove the rail port plug if it is leaking.

2. Remove case-to-head tube plug assemblies with a 10 mm hex bit socket or wrench. Discard case-to-head tube because seals are not serviceable.

NOTE: On occasion, the case-to-head tube (lower) will come out along with the case-to-head plug. If this occurs, discard entire case-to-head tube assembly. Refer to case-to-head tube assembly (Figure 182).

3. Loosen and remove seven M6 x 40 bolts securing the oil rail assembly to the rocker arm carrier.

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4. Lift oil rail assembly straight away from injectors and case-to-head tube assembly. Allow oil to drain back to the sump or other suitable container.

CAUTION: To prevent engine damage, do not remove the 1¼ x 20 UNF oil rail end plugs or single ball tubes. Service parts are not available to support these components.

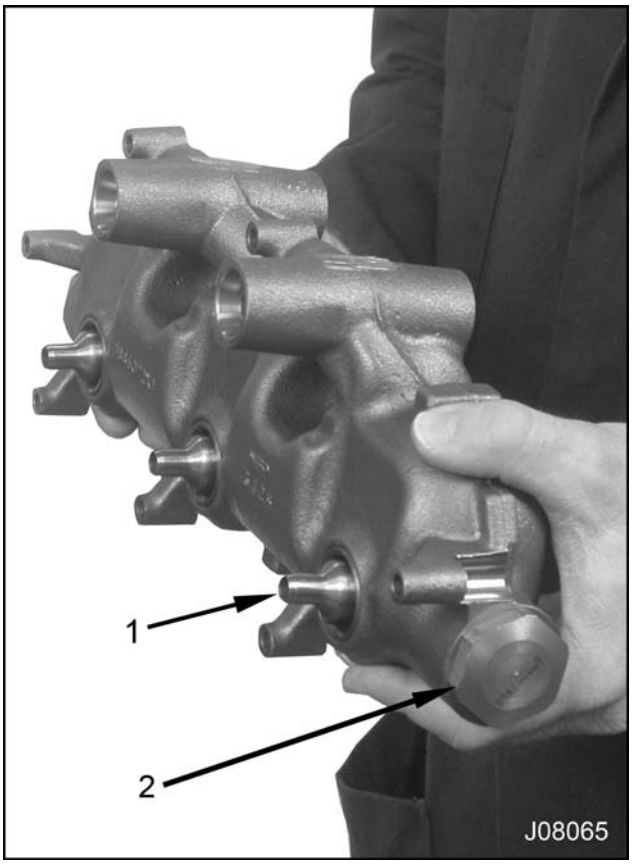

Figure 181 Non-serviceable oil rail components

1. Single ball tube (3)
2. Oil rail end plug (2)

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Case-to-head Tubes

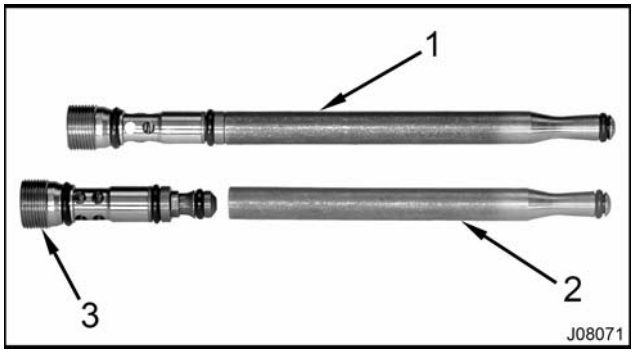

Figure 182 Case-to-head tube assembly

1. Assembled case-to-head tube
2. Case-to-head tube (lower)
3. Case-to-head tube plug

CAUTION: To prevent engine damage, replace case-to-head tubes and rail port plugs if removed. D-ring seals are not replaceable. Inspect each D-ring carefully for cuts, abrasions, and twisting. Never use a tube with any of these problems.

NOTE: The procedure for removing the case-to-head tube assembly is the same for both sides of the engine.

1. If the case-to-head tube came out with the case-to-head plug before high-pressure rail removal, the following step will be unnecessary.

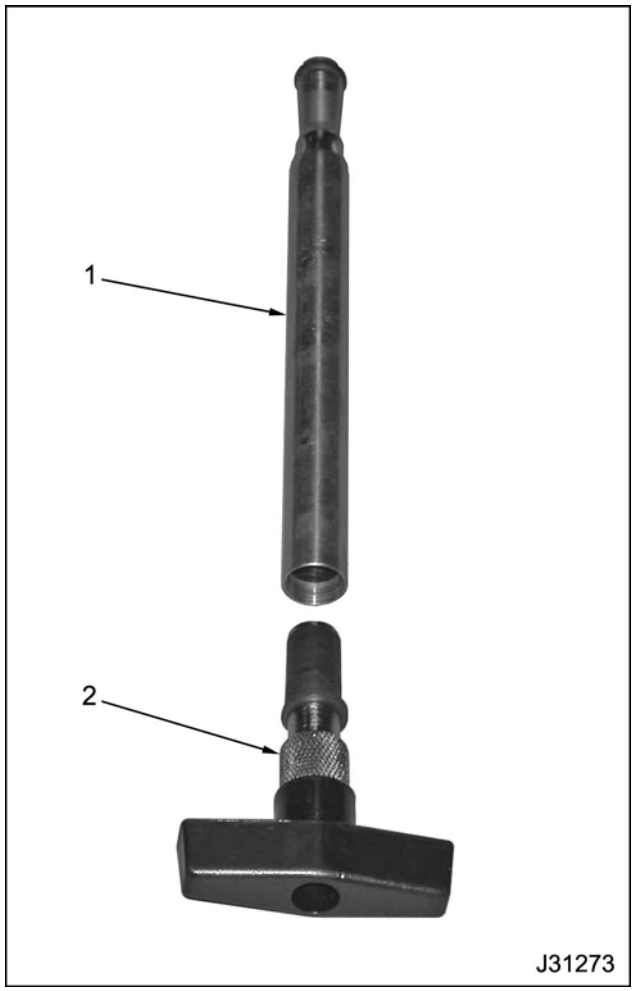

Figure 183 Case-to-head Tube Removal Tool

1. Case-to-head tube (lower)
2. Case-To-Head Tube Removal Tool

2. Push the Case-to-head Tube Removal Tool (page 159) into the case-to-head tube and tighten T-handle until a positive lock is felt. Pull out tube and discard.

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Injection Pressure Regulator (IPR) Valve

1. Cut zip tie and remove IPR harness connector heat shield.

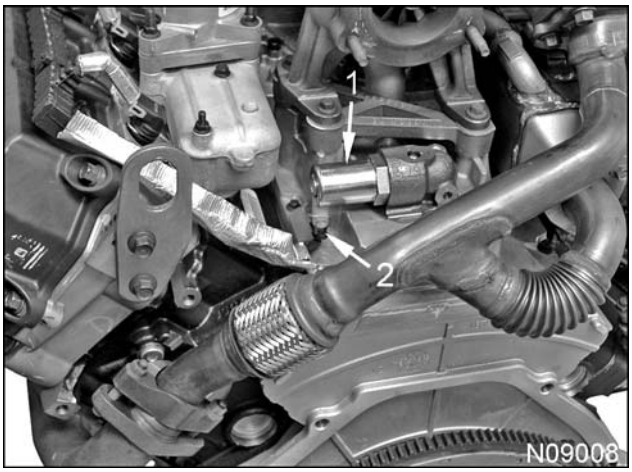

Figure 184 IPR valve and harness connector (connector heat shield removed)

1. IPR valve
2. IPR harness connector with wire retainer

2. Release the IPR valve harness connector wire retainer or tabs and pull 2-pin connector off the IPR valve.

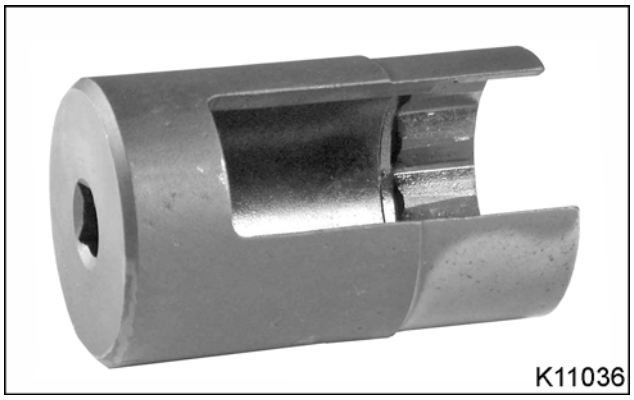

Figure 185 IPR Removal / Installation Tool

3. Remove IPR valve from the high-pressure oil pump with IPR Removal / Installation Tool (page 159).
4. Remove and discard IPR valve O-rings.

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High-pressure Oil Pump Cover

1. Remove the dual turbocharger assembly. See “Dual Turbocharger Assembly”.
2. Remove the intake manifold and EGR cooler assembly. See “Manifolds and Exhaust Gas Recirculation (EGR)”.

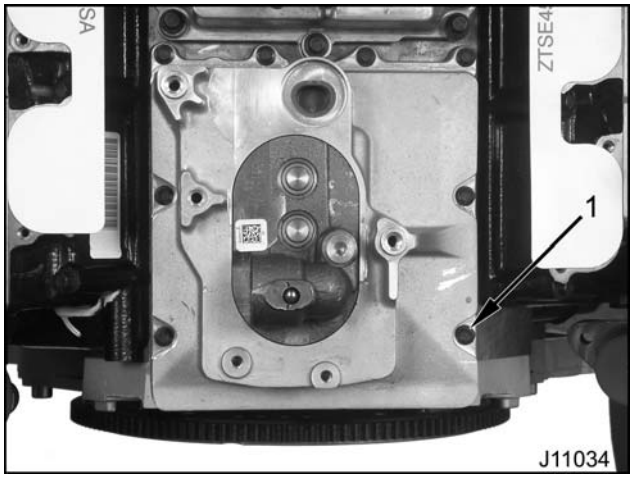

Figure 186 High-pressure oil pump cover

1. M6 x 25 bolt (8)

3. Remove eight M6 x 25 bolts from the high-pressure oil pump cover.

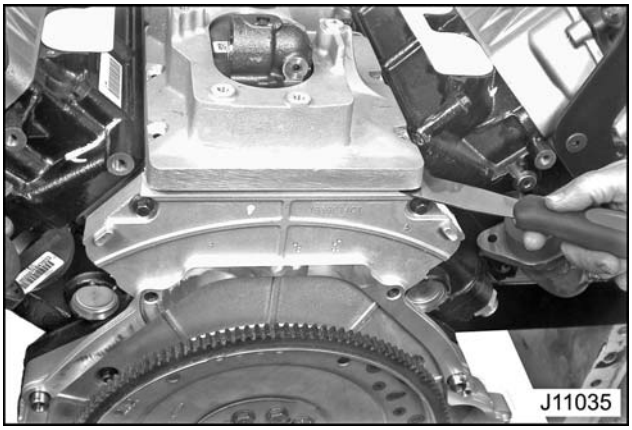

Figure 187 High-pressure oil pump cover sealant separation

CAUTION: To prevent engine damage, cut Liquid Gasket (RTV) before lifting up high-pressure cover. The rear cover gasket could be pulled up and out, requiring removal of the rear cover to replace gasket.

4. Use a thin gasket scraper to separate the sealant bond between crankcase, rear cover, and high-pressure oil pump cover.
5. After cutting sealant, lift the high-pressure oil pump cover straight up to clear pump gear.
6. Remove and discard the high-pressure pump cover gasket seal.

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High-pressure Oil Pump and Branch Tube Assembly

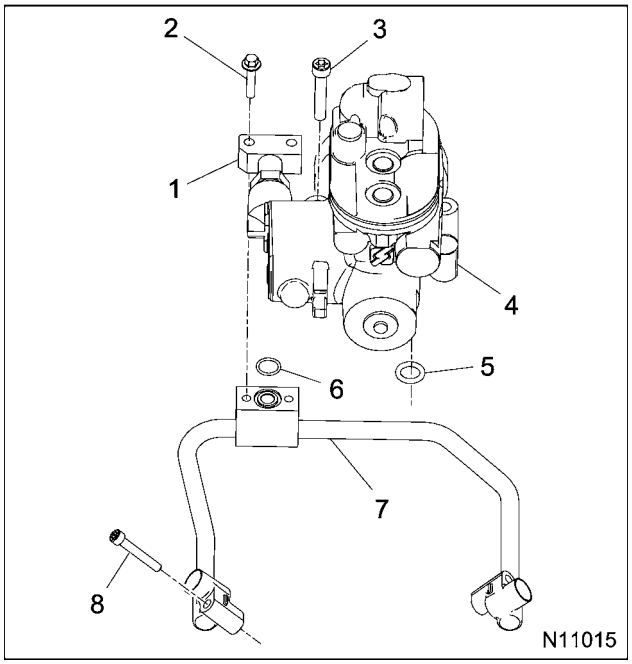

Figure 188 High-pressure oil pump and branch tube

1. Branch tube adaptor
2. M6 x 30 bolt (2)
3. M8 x 45 bolt (3)
4. High-pressure oil pump
5. O-ring seal (pump inlet)
6. O-ring seal (branch tube)
7. Branch tube assembly
8. M6 x 40 bolt (2)

CAUTION: To prevent engine damage, do not drop bolts into engine. Bolts are not captured within the branch tube or high-pressure oil pump.

1. Remove two M6 x 30 bolts securing the branch tube adapter to the branch tube.
2. Remove three M8 x 45 bolts securing the high-pressure oil pump to the crankcase.
3. Remove the high-pressure oil pump assembly.
4. Remove and discard the high-pressure oil pump inlet and branch tube adapter O-rings. Cap off oil holes.

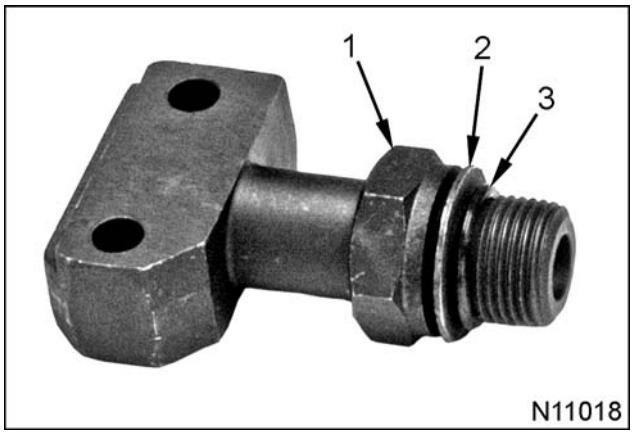

Figure 189 Branch tube adapter

1. Jam nut
2. Seal ring
3. O-ring

5. Loosen branch tube adapter jam nut and remove branch tube adapter from the high-pressure oil pump. Discard O-ring
6. Remove the rear cover. See “Rear Cover and Flywheel”.

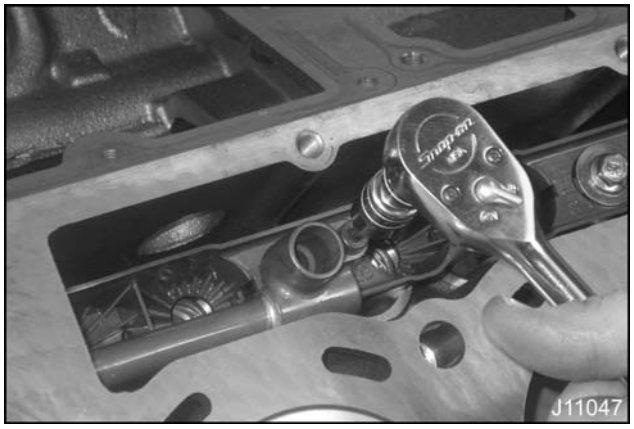

Figure 190 Branch tube bolt removal

7. Remove M6 x 40 bolt from each side of the branch tube assembly and remove branch tube assembly.

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Cleaning and Inspection

High-pressure Oil Pump Cover

1. Clean any old sealant residue from pump cover, crankcase, and rear cover mating surfaces.
2. Inspect the high-pressure oil pump cover, crankcase, and rear cover sealing surfaces for dirt, raised metal, cracking or other indications of seal failure. Correct as required.
3. Clean and inspect the IPR valve.
   a. Inspect the O-ring sealing surfaces for dirt, raised metal or other indications of seal failure. Correct as required.
   b. Inspect electrical connectors.
   c. Inspect valve openings for dirt or debris, investigate causes and correct as required.

High-pressure Oil Pump (Perform if Oil Pump was Removed)

NOTE: The high-pressure oil pump and gear are not serviceable independently. The pump and gear must be replaced as an assembly.

1. Clean and inspect the pump-to-cover O-ring sealing surface for dirt, raised metal or other indications of seal failure. Correct any defects as required.
2. Clean and inspect the branch tube adapter O-ring groove for dirt, raised metal or other indications of seal failure. Correct any defects as required.
3. Clean and inspect the branch tube adapter sealing surfaces for dirt, raised metal or other indications of seating seal failure. Correct any defects as required.
4. Clean and inspect the high-pressure oil pump inlet O-ring groove for dirt, raised metal or other indication of seal failure. Correct any defects as required.

Branch Tube

1. Clean and inspect the branch tube assembly end blocks for debris, galling or other damage indicating evidence of misalignment. Replace the branch tube assembly as required.
2. Inspect branch tube adapter bores, the outside of the adapter connection and the inside of the pump connection for debris, galling or other damage indicating misalignment or defects. Replace adapter as required.
3. Clean and inspect the brazed joints for cracks or other indications of joint failure. Replace branch tube assembly as required.
4. Clean and inspect the branch tube adapter (if high-pressure oil pump assembly was not removed) O-ring groove for dirt, raised metal or other indications of seal failure. Correct any defects as required.

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Installation

High-pressure Oil Pump and Branch Tube Assembly

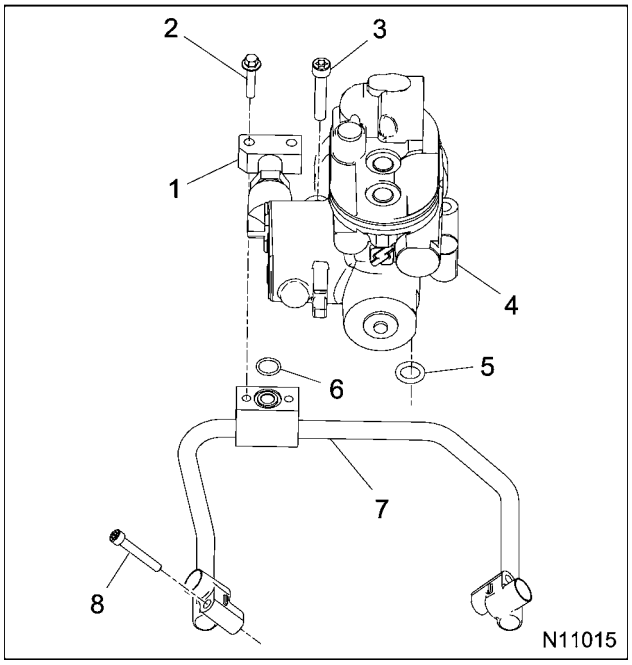

Figure 191 High-pressure oil pump and branch tube

1. Branch tube adaptor
2. M6 x 30 bolt (2)
3. M8 x 45 bolt (3)
4. High-pressure oil pump
5. O-ring seal (pump inlet)
6. O-ring seal (branch tube)
7. Branch tube assembly
8. M6 x 40 bolt (2)

CAUTION: To prevent engine damage, do not drop bolts into crankcase. Bolts are not captured within the branch tube or oil pump.

1. Install branch tube assembly into crankcase.
2. Install two M6 x 40 branch tube mounting bolts through the right and left sides of the branch tube assembly and finger tighten.

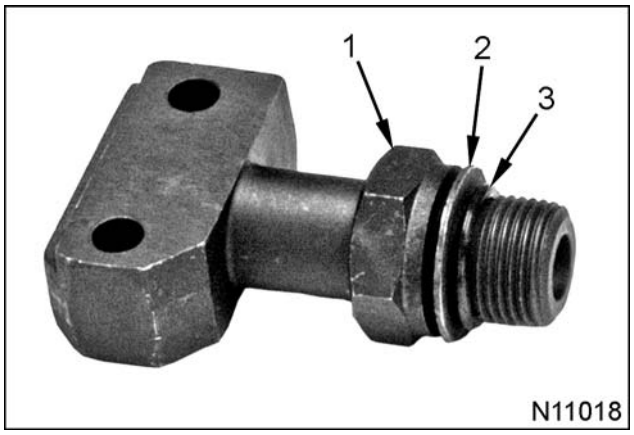

Figure 192 Branch tube adapter

1. Jam nut
2. Seal ring
3. O-ring

3. Rotate jam nut to the base of the branch tube adaptor.
4. Install a new branch tube adaptor O-ring and lubricate with clean engine oil.
5. Thread the branch tube adapter into the high-pressure oil pump. Do not tighten jam nut at this time. Oil outlet hole must face down.

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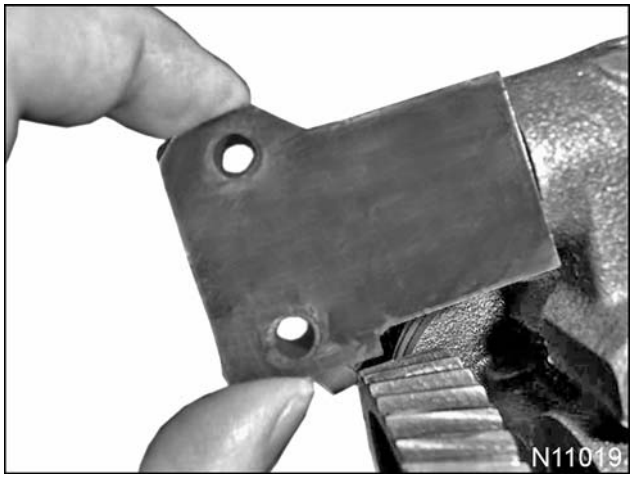

Figure 193 Branch Tube Adaptor Installation Depth Gauge

CAUTION: To prevent engine damage, branch tube adaptor must be installed at the correct depth to prevent high-pressure oil leaks.

6. Check branch tube adaptor installed depth by placing Branch Tube Adaptor Installation Depth Gauge (page 159) on the high-pressure oil pump and aligning gauge holes with branch tube adaptor holes. Install branch tube adaptor at depth that best aligns gauge and adaptor holes.

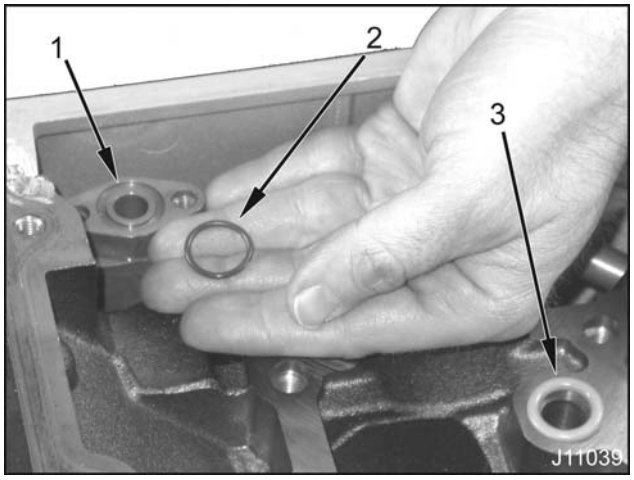

Figure 194 High-pressure oil pump inlet and branch tube adapter O-rings

1. Branch tube adapter O-ring seal recess
2. Branch tube adapter O-ring seal
3. High-pressure oil pump inlet O-ring seal, #207

7. Lubricate and install a new O-ring into the branch tube assembly O-ring recess and into the high-pressure oil pump inlet recess.

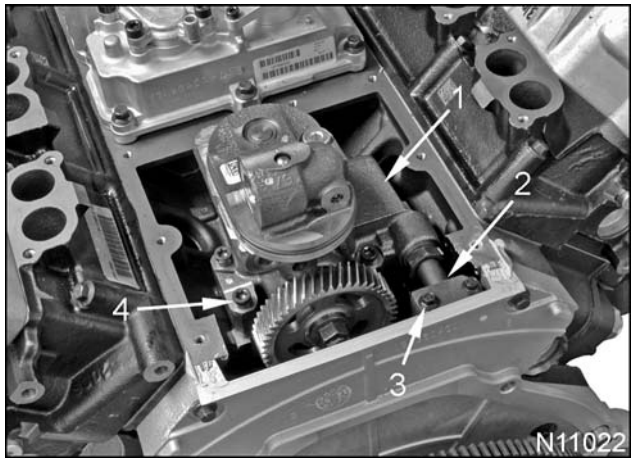

Figure 195 High-pressure oil pump and branch tube adaptor

1. High-pressure oil pump
2. Branch tube adaptor
3. M6 x 30 bolt (2)
4. M8 x 45 Torx bolt (3)

8. Install the high-pressure oil pump and branch tube adapter assembly. Branch tube adaptor oil outlet hole must face down.
9. Install three M8 x 45 bolts securing the high-pressure oil pump to the crankcase and finger tighten.
10. Align the branch tube adaptor and branch tube holes and install two M6 x 30 bolts into the branch tube finger tight.
11. Tighten three M8 x 45 bolts securing the high-pressure oil pump to the crankcase to standard torque (page 400).

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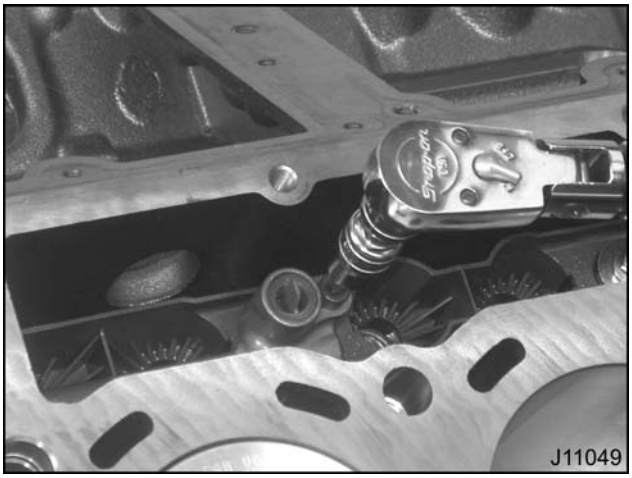

Figure 196 Branch tube assembly mounting bolt installation (right)

12. Tighten two M6 x 40 bolts securing the branch tube assembly to the crankcase to standard torque (page 400).

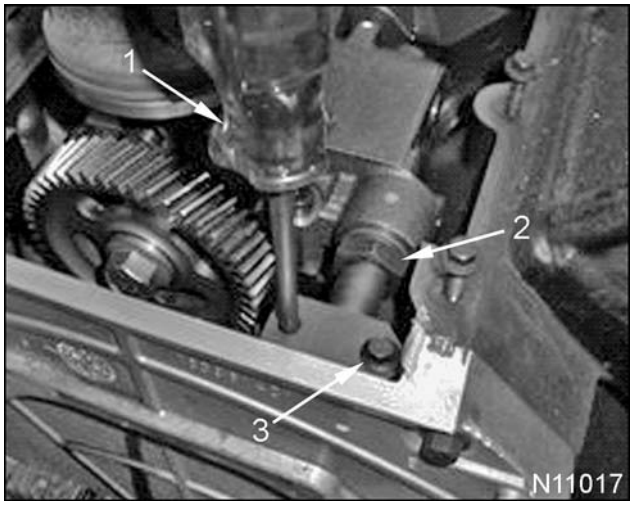

Figure 197 Branch tube adaptor and Anti-rotation Handle

1. Anti-rotation Handle
2. Branch tube adaptor jam nut
3. M6 x 30 bolt (2)

CAUTION: To prevent engine damage, use only Anti-rotation Handle to provide counter-torque for branch tube adaptor while tightening jam nut. Other tools will damage branch tube threads and cause high-pressure oil leaks.

13. Remove the left M6 x 30 bolt and insert the Anti-rotation Handle (page 159) into the branch tube assembly.
14. Provide proper counter-torque on Anti-rotation Handle while tightening branch tube adaptor jam nut with a 15/16 inch, 12-point (flare nut) crowfoot to special torque (page 159).
15. Remove Anti-rotation Handle and install left M6 x 30 bolt in the branch tube adaptor. Tighten two M6 x 30 bolts to standard torque (page 400).

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High-pressure Oil Pump Cover

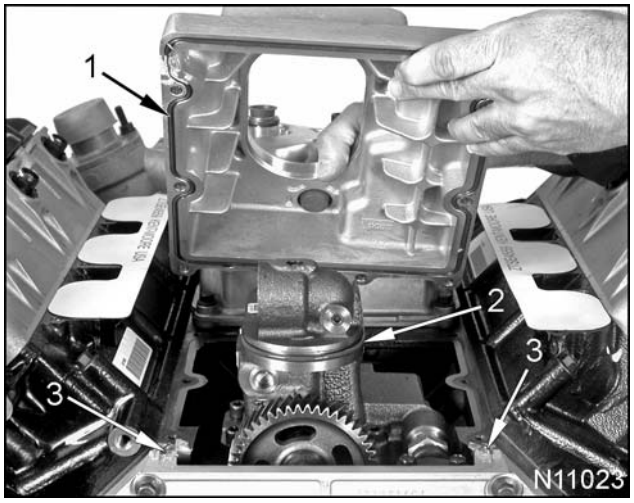

Figure 198 High-pressure oil pump seals

1. Hydraulic pump cover gasket
2. Pump O-ring
3. Liquid Gasket (RTV) application location (2)

1. Install a new pump O-ring in the high-pressure oil pump-to-cover recess. Lubricate O-ring with clean engine oil.
2. Apply Liquid Gasket (RTV) (page 159) to two locations where rear cover, high-pressure pump cover, and crankcase join.
3. Install a new hydraulic pump cover gasket in the recess of the high-pressure oil pump cover.

CAUTION: To prevent engine damage, the high-pressure oil pump cover must be firmly seated onto the high-pressure oil pump O-ring by hand to prevent cracking the pump cover.

4. Apply even pressure to seat the high-pressure oil pump cover on the high-pressure pump O-ring.
5. Install eight M6 x 25 mounting bolts and tighten to standard torque (page 400).

Injection Pressure Regulator (IPR) Valve

1. Install new O-rings on the IPR valve.
2. Install IPR valve into the high-pressure oil pump with IPR Removal / Installation Tool (page 159).
3. Tighten IPR valve to special torque (page 159).

Figure 199 IPR valve and harness connector (connector heat shield removed)

1. IPR valve
2. IPR harness connector

4. Install engine sensor harness on IPR valve.
5. Install IPR valve heat shield and secure with a zip tie.

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High-pressure Oil Rail

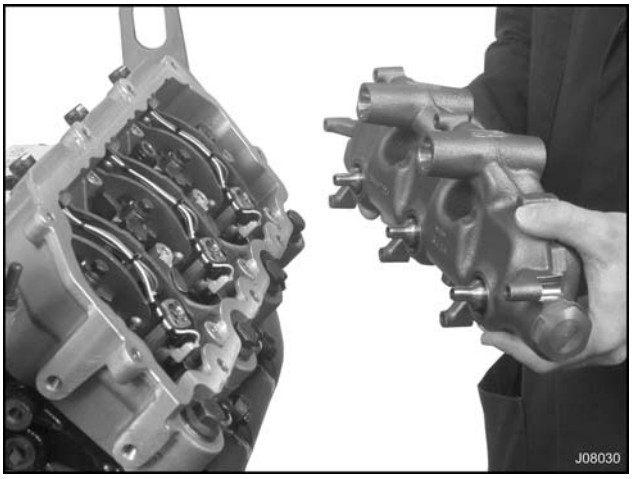

Figure 200 Align oil rail assembly to injector oil inlets

1. Using both hands, align the oil rail assembly with the oil inlets of each fuel injector. Push down evenly until oil rail assembly is firmly seated.
2. Install oil rail assembly M6 x 40 bolts finger tight.

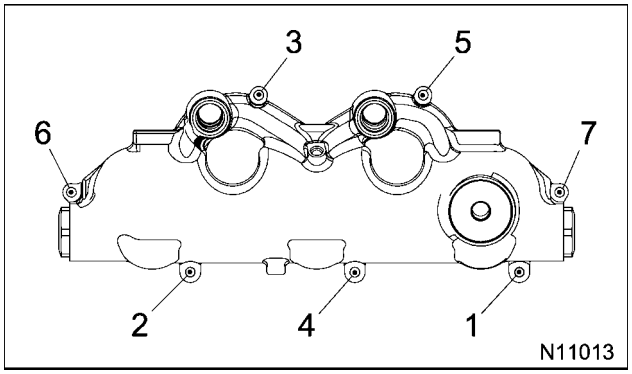

Figure 201 Oil rail torque sequence

3. Tighten M6 x 40 bolts to standard torque (page 400) in the above sequence.

Case-to-Head Tubes

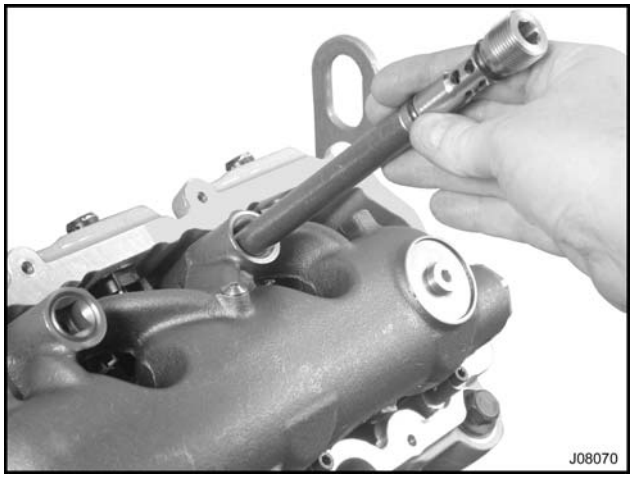

Figure 202 Case-to-head tube assembly installation

CAUTION: To prevent engine damage, replace case-to-head tubes and rail port plugs if removed. D-ring seals are not replaceable. Inspect each D-ring carefully for cuts, abrasions, and twisting. Never use a tube with any of these problems.

1. Lubricate the D-rings on the case-to-head tube assembly with clean engine oil and install through oil rail and into the branch tube.

NOTE: Oil rail must be completely torqued before installing case-to-head tube.

2. Tighten case-to-head tube assembly to special torque (page 159).

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Specifications

Injection Control Pressure (ICP) sensor operating pressure range	0 to 30 MPa (0 to 4,350 psi)
Injection Pressure Regulator (IPR) valve relief pressure	31 MPa (4,500 psi)
IPR valve maximum pressure	38 MPa (5,500 psi)

Special Torque

Branch tube adaptor jam nut	72 N·m (53 lbf·ft)
Case-to-head tube and rail port plug	82 N·m (60 lbf·ft)
Injection Pressure Regulator (IPR)	50 N·m (37 lbf·ft)
Prime port plug, M8	8 N·m (71 lbf·in)
High-pressure pump plug, M12	35 N·m (26 lbf·ft)

Special Service Tools

Anti-rotation Handle (branch tube adaptor)	ZTSE4876-1
Branch Tube Adaptor Installation Depth Gauge	ZTSE4876-2
Case-to-head Tube Removal Tool	ZTSE4694
IPR Removal / Installation Tool	ZTSE4666
Liquid Gasket (RTV, 6 oz. tube)	1830858C1
15/16 inch, 12-point (flare nut) crowfoot	Obtain locally

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Illustrations

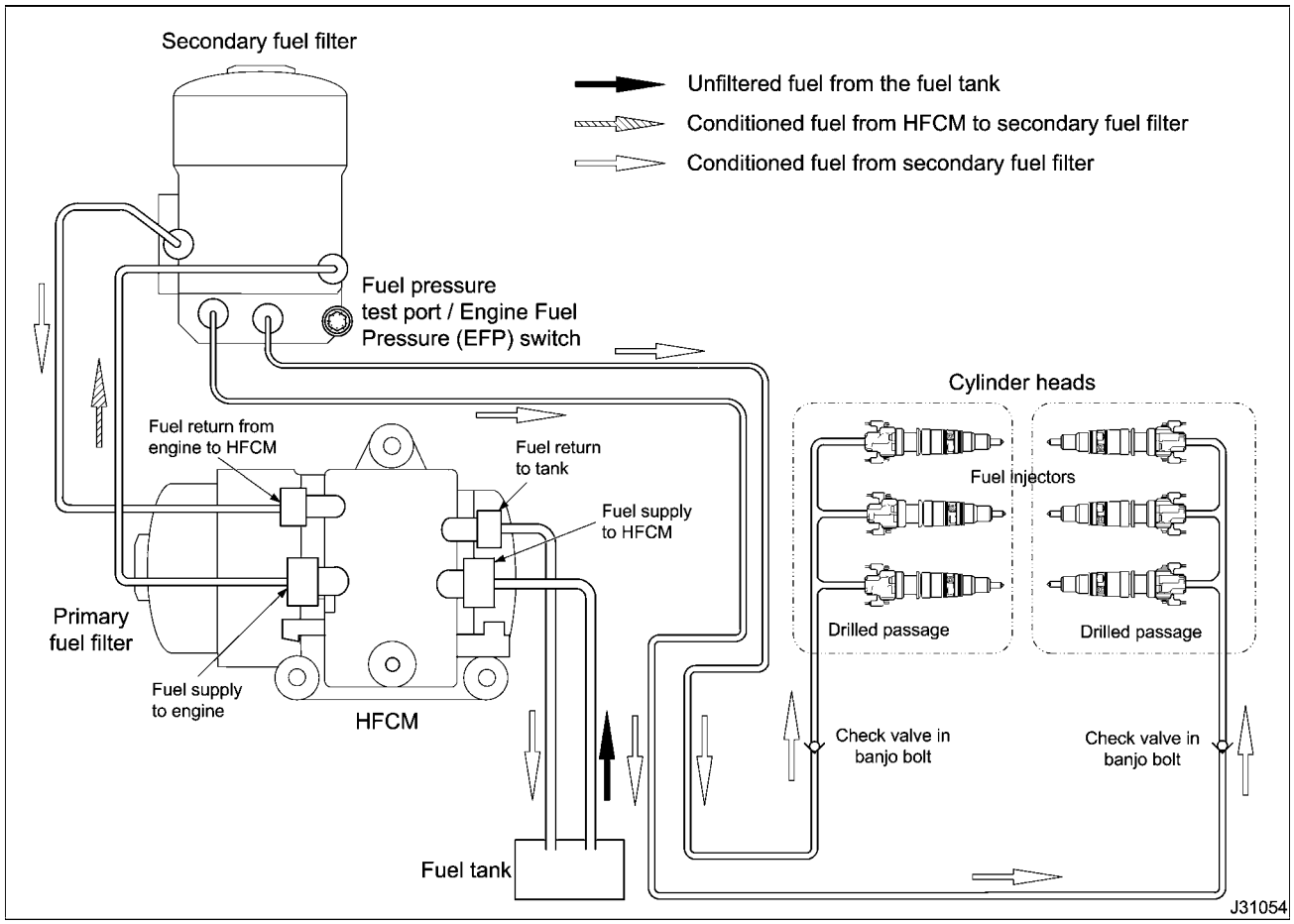

Figure 203 Fuel system flow and components

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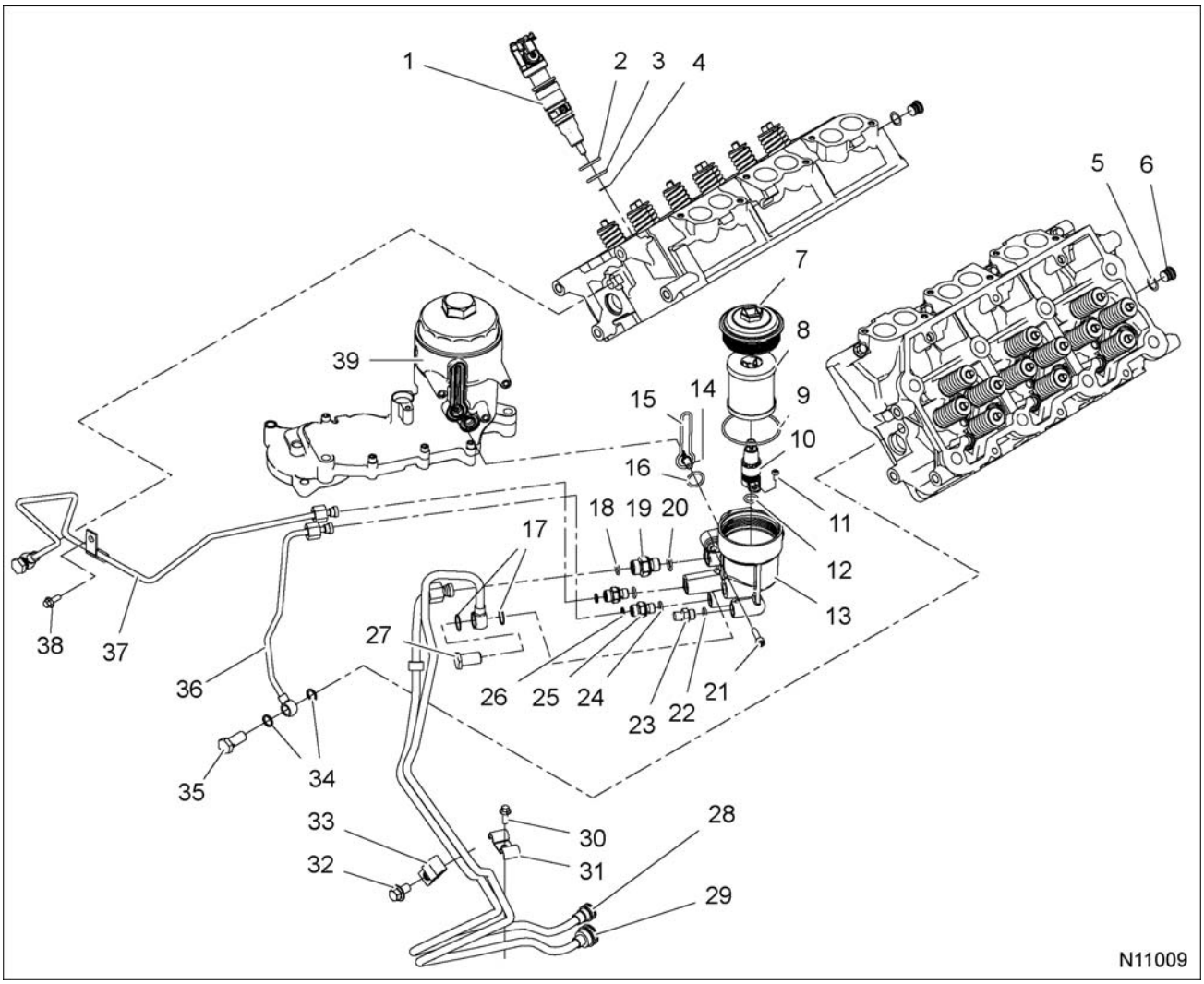

Figure 204 Fuel System Components (engine)

1. Fuel injector assembly (6)
2. Upper fuel seal
3. Lower fuel seal
4. Injector nozzle gasket
5. Viton seal (2)
6. Fuel plug, M12 (2)
7. Fuel filter cap
8. Secondary fuel filter element
9. O-ring, size #146
10. Fuel return tube (stand pipe)
11. Screw, 8/32 x 3/8 in (2)
12. O-ring, size #112
13. Secondary fuel filter housing
14. Fuel pressure regulator
15. Pressure regulator cover seal
16. O-ring seal, size #115
17. Copper washer (2)
18. O-ring seal, size #012
19. Fuel outlet fitting, M16
20. O-ring seal
21. Screw, M6 x 25 (3)
22. O-ring seal
23. Engine Fuel Pressure (EFP) switch
24. O-ring seal (2)
25. M12 fuel outlet fitting (2)
26. O-ring seal, size #011 (2)
27. Hollow screw
28. Fuel return to HFCM tube
29. Fuel supply to secondary filter tube
30. M6 x 16 bolt
31. Saddle clamp
32. M10 x 16 bolt
33. Dual tube clamp
34. Copper washers (4)
35. M12 Banjo bolt with check valve (2)
36. Fuel supply line, left cylinder head
37. Fuel filter to right cylinder head tube
38. M6 x 16 bolt
39. Oil filter housing assembly

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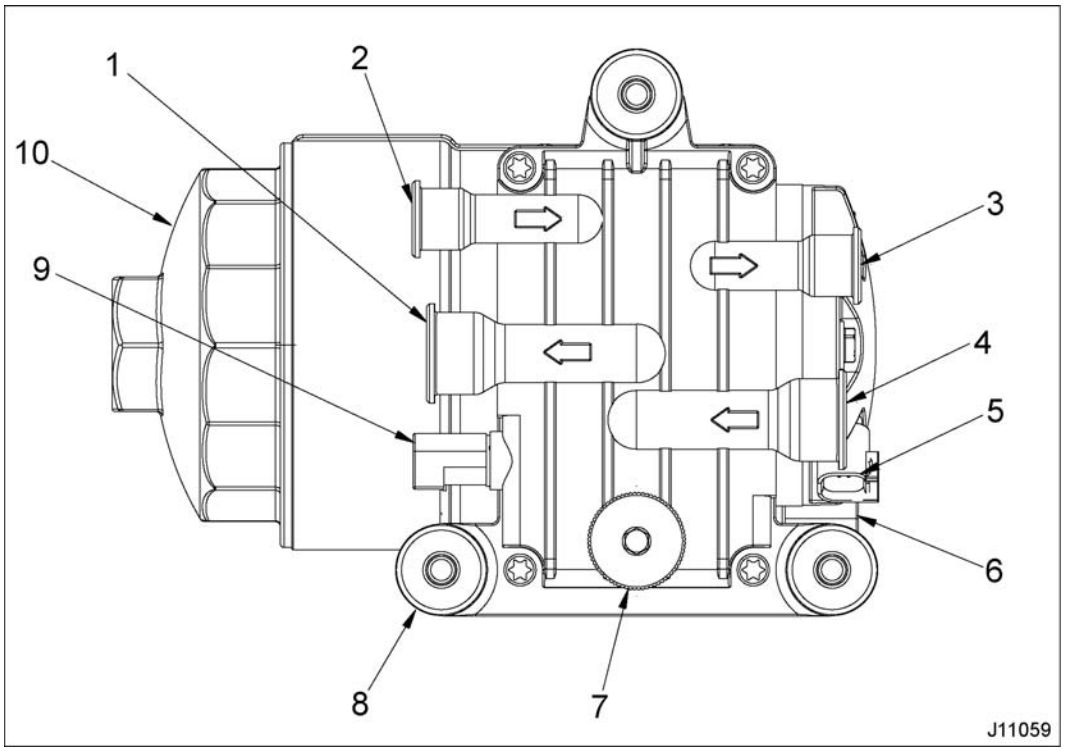

Figure 205 Horizontal Fuel Conditioning Module (HFCM) (chassis mounted)

1. Fuel supply port to engine
2. Fuel return port from engine
3. Fuel return port to tank
4. Fuel supply port to HFCM
5. Electric fuel pump connection
6. Water In Fuel (WIF) electrical connection
7. Water drain plug
8. Mounting grommet (3)
9. Fuel heater electrical connection
10. Primary filter element cap

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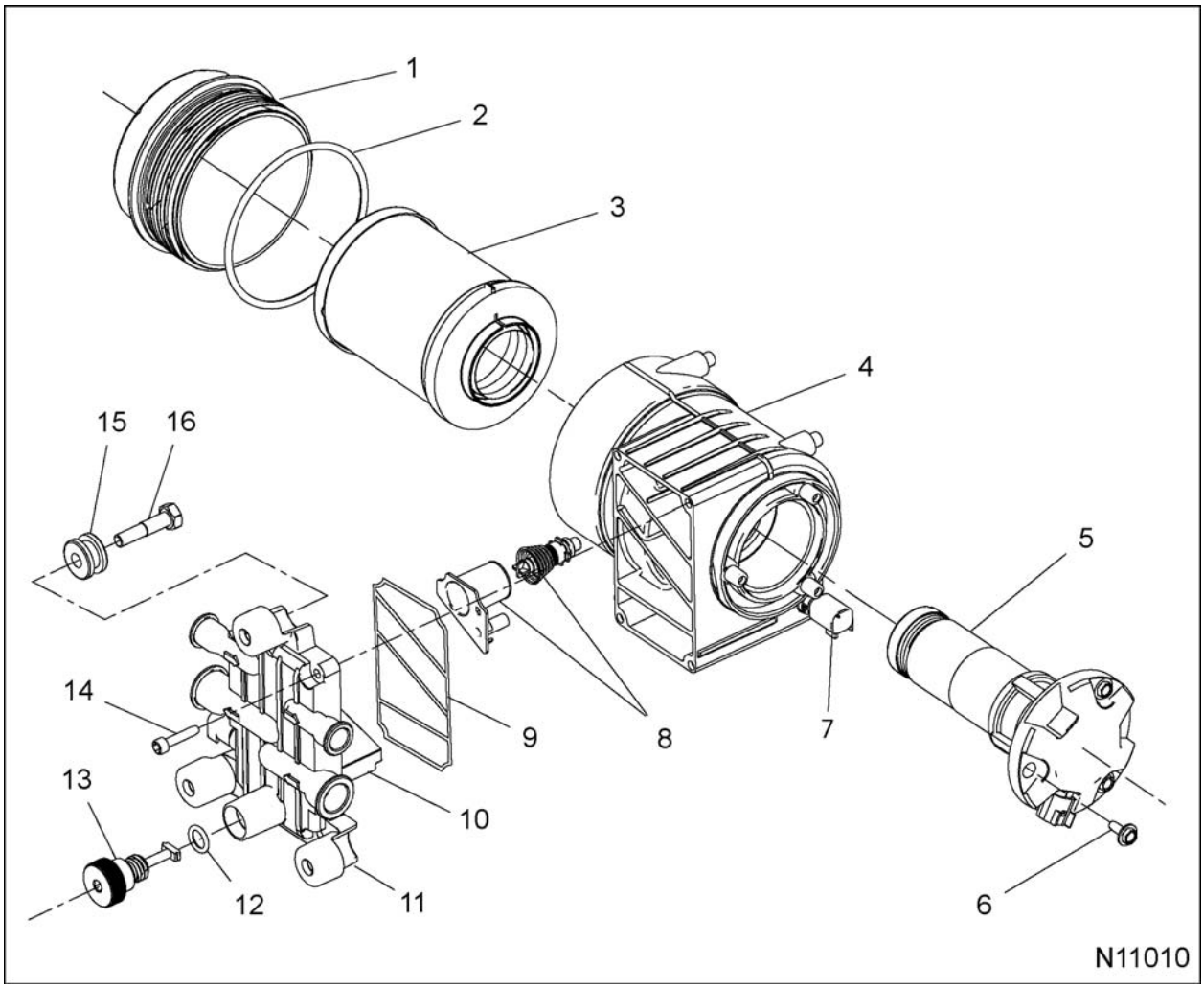

Figure 206 HFCM

1. Primary filter element cap
2. Cap O-ring seal
3. Primary fuel filter element
4. Primary fuel filter housing
5. Electric fuel pump
6. Self-tapping screw, #10 (3)
7. Water In Fuel (WIF) sensor
8. Thermo recirculating valve assembly
9. Cover plate gasket
10. Fuel heater
11. Cover plate
12. O-ring seal
13. Water drain plug
14. M5 x 23 screw (4)
15. Mounting grommet (3)
16. M8 x 40 bolt with shoulder (3)

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Periodic Service

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, do not turn ignition "KEY ON" during any phase of fuel system disassembly. Turning on the ignition key could pump fuel to disconnected tubing, resulting in fire.

WARNING: To prevent personal injury or death, disconnect the main battery negative terminal before disconnecting or connecting electrical 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.

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

GOVERNMENT REGULATION: Dispose of fuel according to applicable regulations in a correct container clearly marked DIESEL FUEL.

GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a threat to the environment. Recycle or dispose of engine fluids and filters according to applicable regulations. Never put engine fluids in the trash, on the ground, in sewers or bodies of water.

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Primary Fuel Filter Element

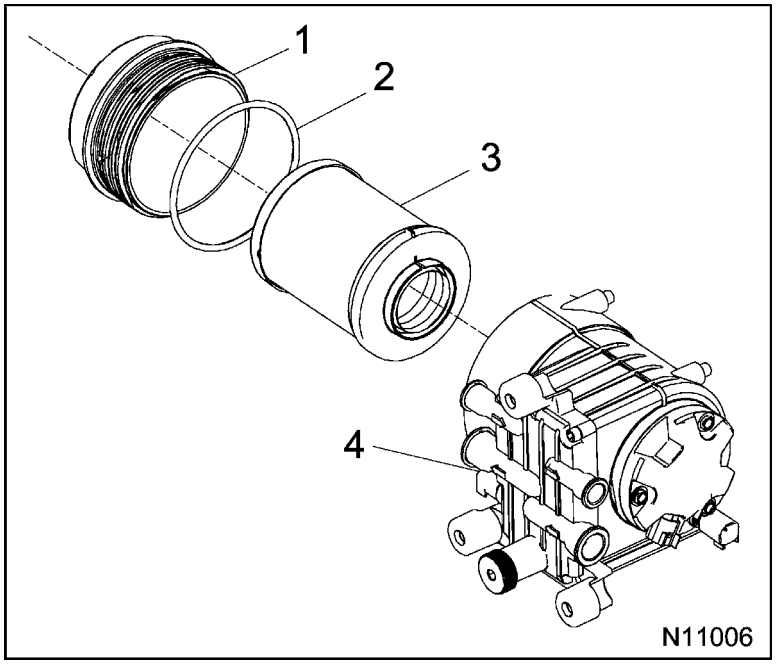

Figure 207 Primary fuel filter (chassis mounted)

1. Primary fuel filter element cap
2. Cap O-ring seal
3. Primary fuel filter element
4. Horizontal Fuel Conditioning Module (HFCM)

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

1. Collect fuel in a correct container clearly marked DIESEL FUEL. Loosen water drain plug and drain HFCM.
2. Remove primary fuel filter element cap from HFCM.
3. Remove and discard cap O-ring seal.
4. Pull fuel filter out of HFCM and dispose of filter element properly.
5. Clean seal areas and install a new cap O-ring seal on fuel filter cap.
6. Clean out debris from inside the HFCM.
7. Install a new primary fuel filter element in the HFCM.
8. Lubricate fuel filter cap threads and new O-ring with clean diesel fuel.
9. Tighten primary fuel filter cap to special torque (page 186).
10. Install a new O-ring on the water drain plug. Install and tighten drain plug.
11. When all fuel system components are installed and tight, turn key on and check for fuel leaks. If fuel is leaking turn off engine and repair leaks.

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Secondary Fuel Filter Element

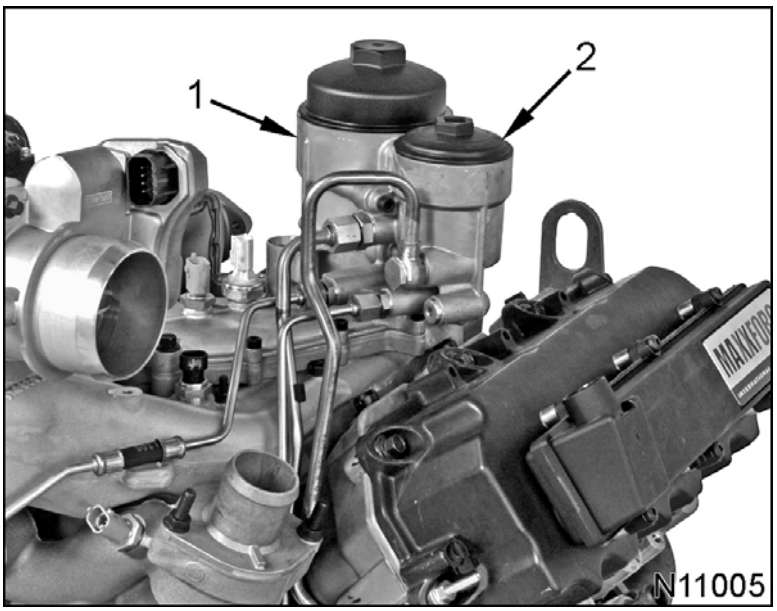

Figure 208 Secondary fuel filter assembly

1. Oil filter housing assembly
2. Secondary fuel filter cap

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

NOTE: Engine will not run without the secondary fuel filter element installed properly. When installed properly the secondary fuel filter element pushes down the fuel return tube, allowing fuel to flow into the filter housing.

1. Remove fuel filter cap from the secondary fuel filter housing.
2. Remove and discard fuel filter cap O-ring.
3. Pull fuel filter up and out of fuel filter housing and dispose of filter element properly.
4. Clean seal areas and install a new O-ring on fuel filter cap.
5. Clean out debris from inside the secondary fuel filter housing.
6. Install a new fuel filter element in the secondary fuel filter housing. Rotate filter element slightly until filter engages the return tube assembly and can be moved up and down against spring pressure.
7. Lubricate fuel filter cap threads and new O-ring with clean diesel fuel.
8. Tighten secondary fuel filter cap to special torque (page 186).
9. When all fuel system components are installed and tight, turn key on and check for fuel leaks. If fuel is leaking turn off engine and repair leaks.

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Removal

Fuel System Tubing

1. Remove the air inlet duct. See “Dual Turbocharger Assembly”.

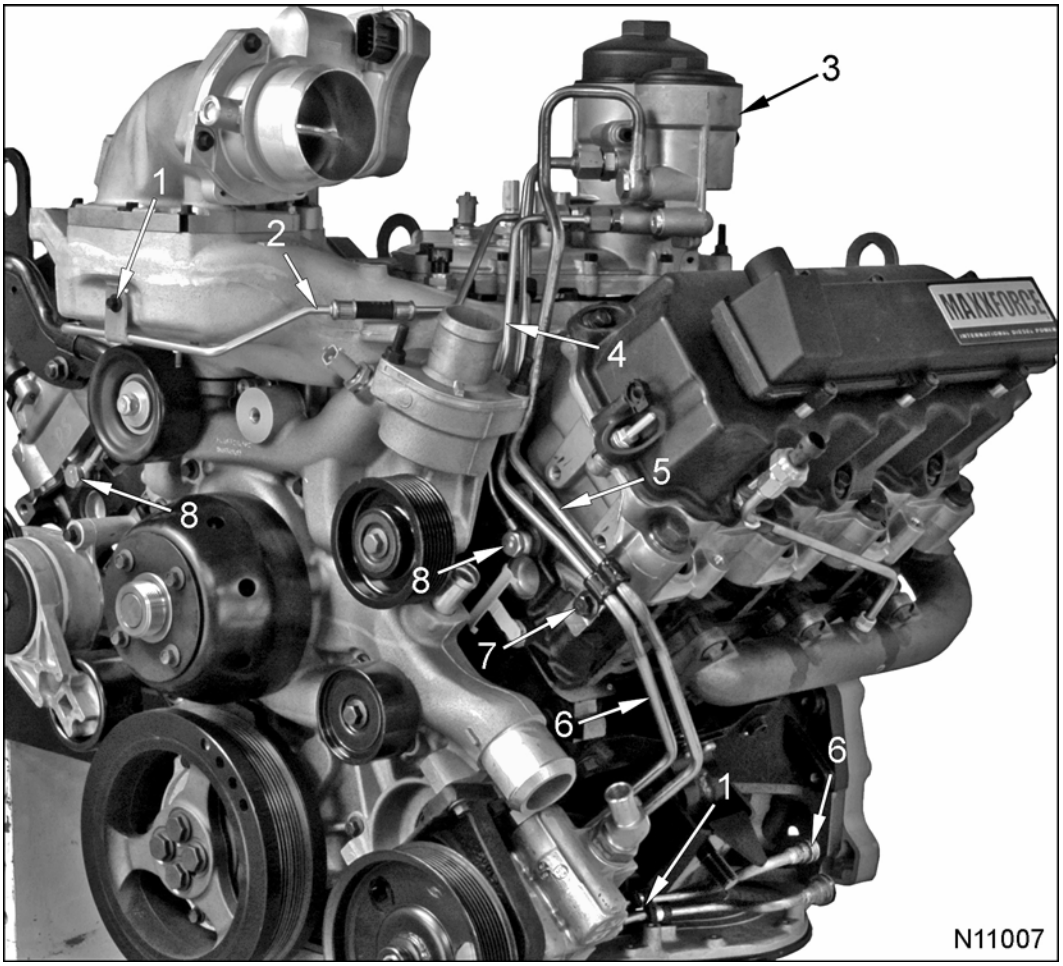

Figure 209 Fuel system tubing and connections

1. M6 x 16 bolt (2)
2. Fuel filter to right cylinder head tube
3. Secondary fuel filter housing
4. Fuel filter to left cylinder head tube
5. Fuel supply to filter tube
6. Fuel return to tank tube
7. M10 x 16 bolt
8. M12 banjo bolt with check valve (2)

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

2. Place a suitable container under the secondary fuel filter housing to catch draining fuel.
3. Remove the Engine Fuel Pressure (EFP) switch, installed in the bottom of secondary fuel filter housing.
4. Remove secondary fuel filter cap to allow air into filter housing so fuel will drain.
5. After fuel has drained, install EFP switch into filter housing and tighten to special torque (page 186).

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6. Remove M6 x 16 bolt securing the fuel return and fuel supply tubes to the oil pan.
7. Remove M10 x 16 bolt securing the fuel return and fuel supply tubes to the left cylinder head.
8. Remove M6 x 16 bolt securing the right fuel supply tube to the intake manifold.
9. Remove each M12 banjo bolt securing right and left fuel supply tubes to each cylinder head. Discard copper washers.

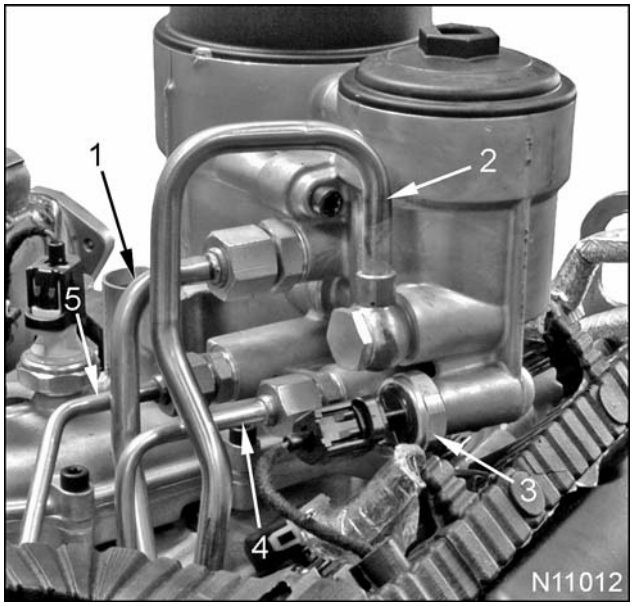

Figure 210 Secondary fuel filter tubes and housing

1. Fuel return to HFCM tube
2. Fuel supply to filter tube
3. Engine Fuel Pressure (EFP) switch
4. Fuel filter to left cylinder head tube
5. Fuel filter to right cylinder head tube

10. Remove hollow screw from fuel supply to filter tube and discard copper washers.
11. Disconnect fuel return to HFCM tube from fuel filter housing. Discard fitting O-ring.
12. Disconnect fuel filter to left and right cylinder head tubes from fuel filter housing. Discard fitting O-rings.
13. Remove fuel tubes from engine.
14. Cap all open ports on the secondary fuel filter housing using the Cap Kit (all) (page 187).

Secondary Fuel Filter Assembly

1. Remove three M6 x 25 screws and remove the secondary fuel filter assembly from the oil filter assembly.

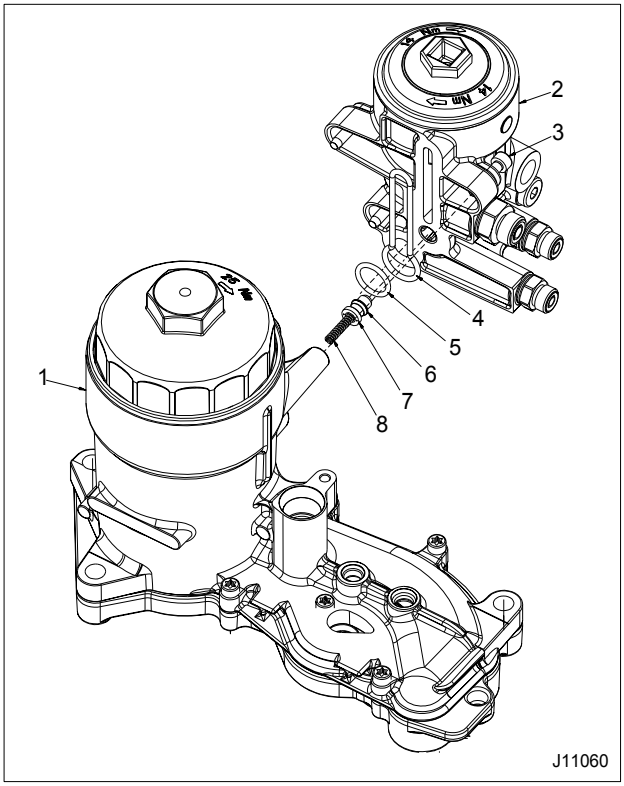

Figure 211 Fuel pressure regulator poppet assembly

1. Oil filter assembly
2. Secondary fuel filter housing
3. M6 x 25 screw (3)
4. Pressure regulator cover gasket
5. Viton O-ring, size #115
6. Poppet gasket seal
7. Brass poppet
8. Pressure regulator valve spring

2. Removing the secondary fuel filter assembly exposes the fuel pressure regulator poppet components. Remove these parts for later inspection.

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Horizontal Fuel Conditioning Module (HFCM)

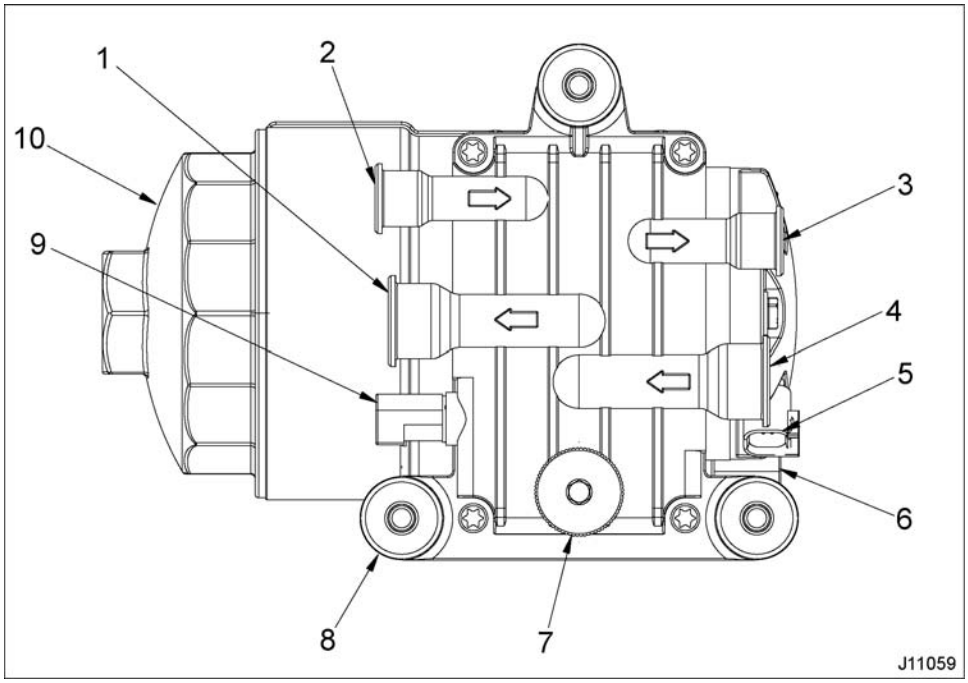

Figure 212 HFCM (chassis mounted)

1. Fuel supply port to engine
2. Fuel return port from engine
3. Fuel return port to tank
4. Fuel supply port to HFCM
5. Electric fuel pump connection
6. Water In Fuel (WIF) electrical connection
7. Water drain plug
8. Mounting grommet (3)
9. Fuel heater electrical connection
10. Primary filter element cap

For CityStar™ applications, the HFCM is mounted on the driver's side vehicle frame rail.

For stripped chassis applications, the HFCM is mounted on a bracket attached to the transmission housing on the passenger side.

1. Place a container under the HFCM to drain fuel and any accumulated water.
2. Rotate water drain plug to release fuel pressure and drain HFCM.
3. Disconnect fuel pump, fuel heater, and Water In Fuel (WIF) electrical connectors.
4. Press in retaining clips to release fuel hoses from HFCM housing.
5. Disconnect fuel hoses and discard fuel hose retaining clips
6. Remove three M8 mounting nuts and remove HFCM from chassis.

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Fuel Injector Assemblies

1. Remove valve covers. See “Cylinder Head and Valve Train”.
2. Remove high-pressure oil manifolds. See “High-pressure Oil System”.

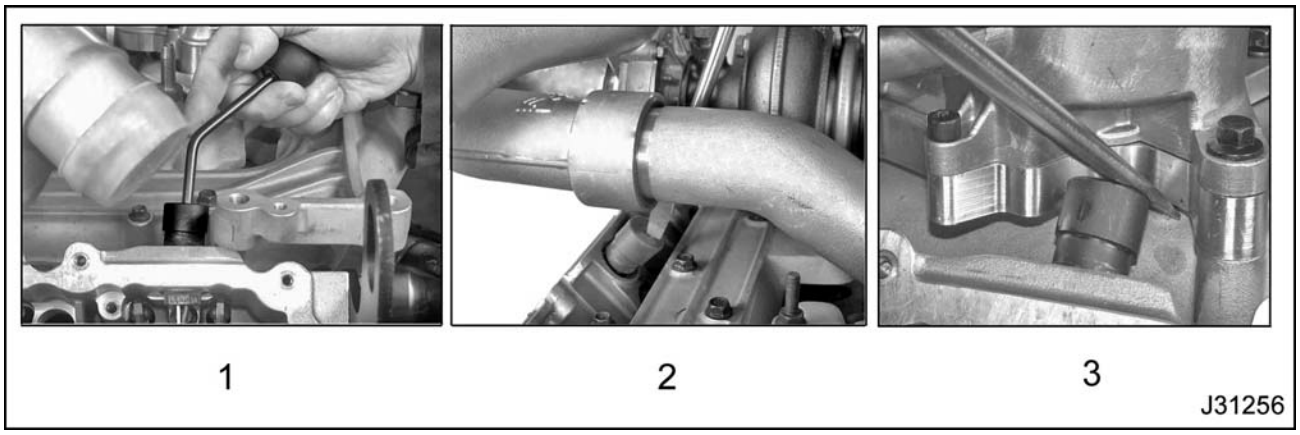

Figure 213 Releasing the injector connector from rocker arm carrier

1. Injector Connector Remover tool with handle (cylinders 1, 2, 6)
2. Injector Connector Remover tool without handle (cylinders 3, 5)
3. Injector Connector Remover tool without handle (cylinder 4)

NOTE: Injector connector removal procedures are based on the engine being out-of-chassis.

NOTE: There is no need to drain fuel rail when removing an injector.

3. Disconnect injector harness from the injector connector.
4. Release injector connectors using Injector Connector Remover (page 187).

NOTE: On some connectors remove the tool handle, fit the remover portion onto connector and use a screwdriver or other tool to push down and release connector.

5. Push down on the injector connector to release it from the rocker arm carrier.

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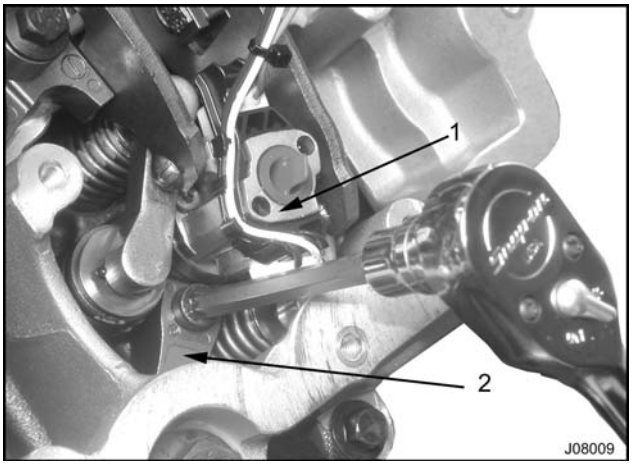

Figure 214 Fuel injector hold down clamp removal

1. Fuel injector assembly
2. Fuel injector hold down clamp

NOTE: Fuel injectors are self extracting and come out of injector bores as injector hold down clamp bolt is loosened.

6. Loosen each fuel injector hold down clamp bolt using a T45 Torx bit socket (page 187).

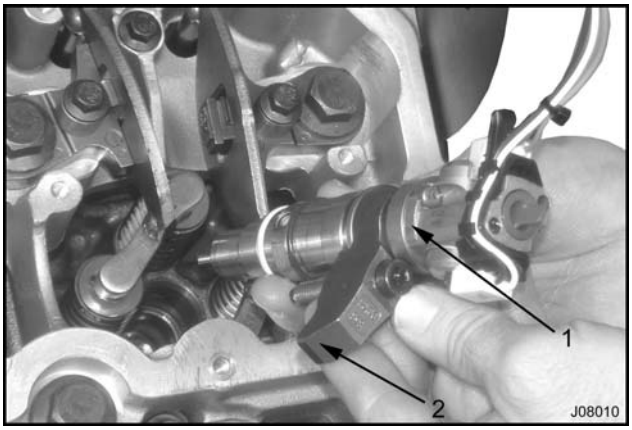

Figure 215 Fuel injector removal from cylinder head

1. Fuel injector assembly
2. Fuel injector hold down clamp assembly

7. Remove fuel injector from cylinder head bore by lifting injector and hold down clamp assembly up and out.

CAUTION: To prevent engine damage, do not clean injectors with parts solvent or other chemicals.

8. Remove and discard injector upper and lower O-rings and nozzle gasket with a non-metalic hand tool.

NOTE: If nozzle gasket is missing from any injector removed, look for gasket at the bottom of its injector bore. Remove and discard all nozzle gaskets.

CAUTION: To prevent engine damage, when injectors are removed from the engine, place injectors in a closeable container, cover with clean engine oil, and close container.

9. Remove each fuel injector assembly, place in a closeable container, cover with clean engine oil, and close container.

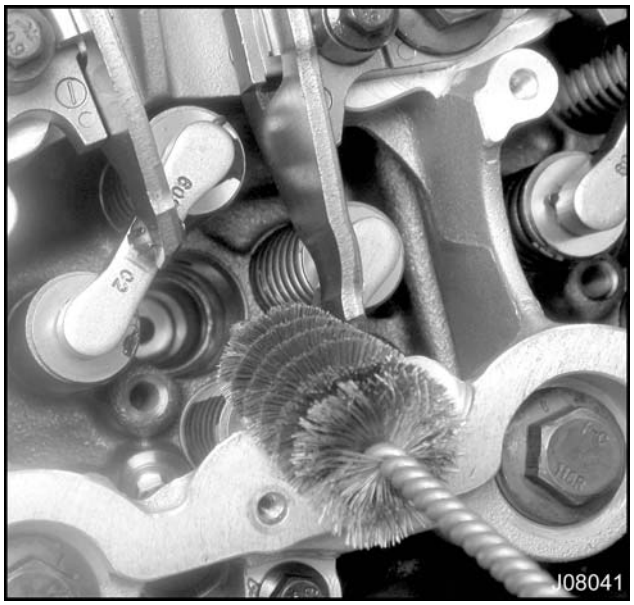

Figure 216 Injector Sleeve Brush

10. If removing or replacing any of the injectors and not the sleeves, clean injector sleeve with Injector Sleeve Brush (page 187).

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Disassembly

Secondary Fuel Filter Assembly

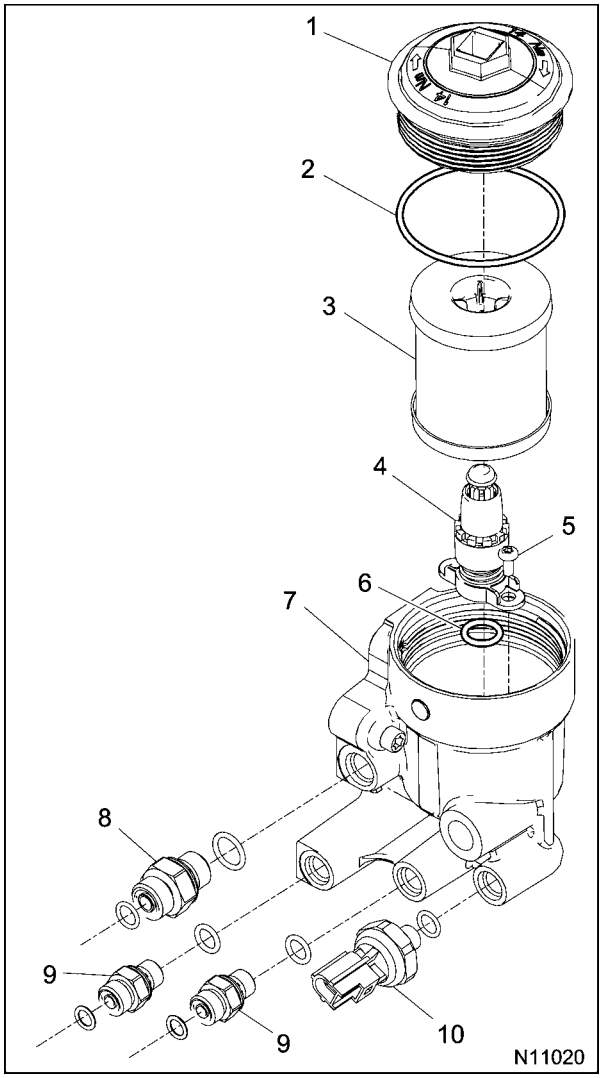

Figure 217 Secondary fuel filter assembly

1. Fuel filter cap
2. O-ring seal
3. Fuel filter element
4. Fuel return tube assembly
5. Screw, 8/32 x 3/8 in (2)
6. Viton O-ring, size #112
7. Secondary fuel filter housing
8. M16 fuel return fitting
9. M12 left and right cylinder head fuel tube assembly fitting (2)
10. Engine Fuel Pressure (EFP) switch

1. Loosen fuel filter cap and discard O-ring seal.
2. Before removing fuel filter element, depress filter to verify spring loaded fuel return tube moves freely.
3. Pull up secondary fuel filter element and discard.
4. Remove two 8/32 x 3/8 screws and remove the fuel return tube assembly. Discard O-ring.
5. Remove M16 and M12 fittings and discard O-rings.
6. Unplug EFP switch harness connector and remove EFP. Discard switch O-ring.

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Horizontal Fuel Conditioning Module (HFCM)

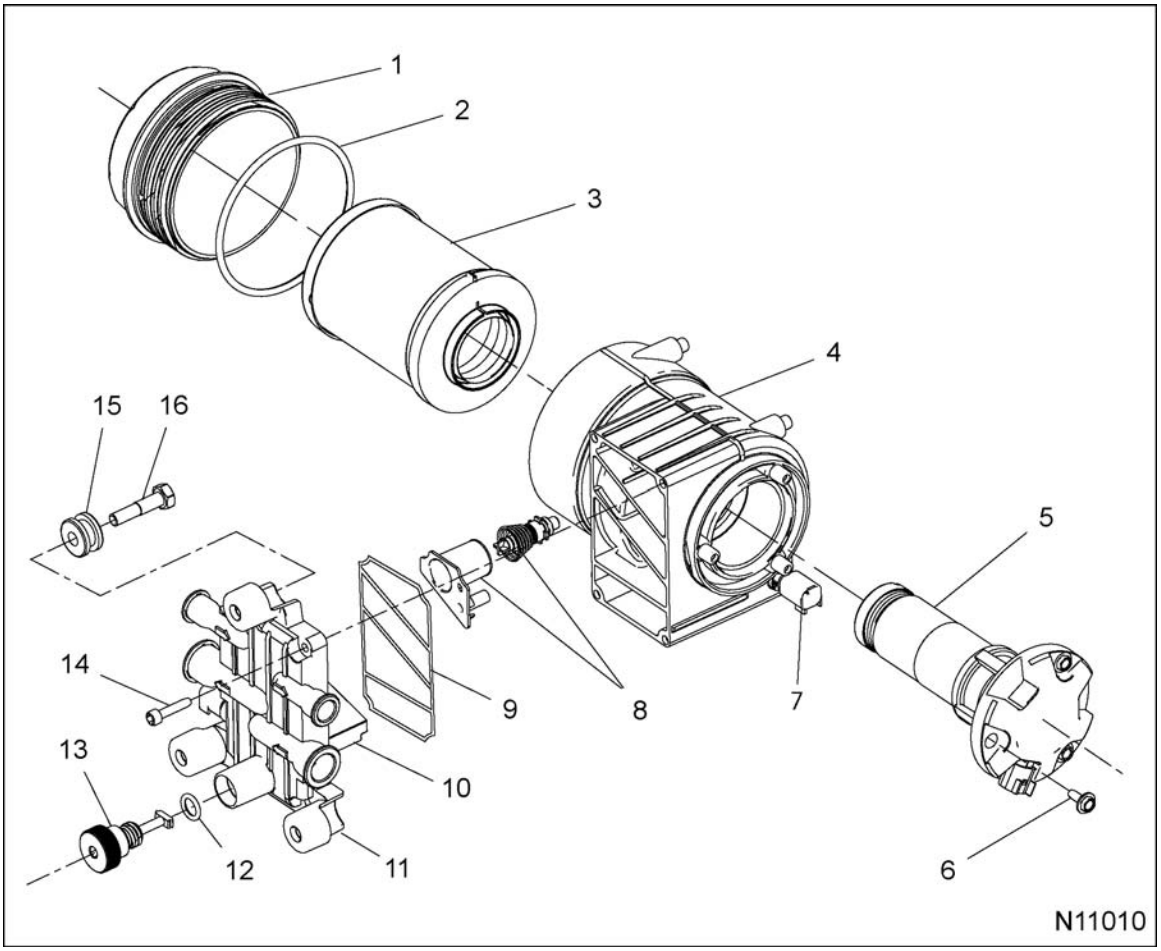

Figure 218 HFCM

1. Primary filter element cap
2. Cap O-ring seal
3. Primary fuel filter element
4. Primary fuel filter housing
5. Electric fuel pump
6. Self-tapping screw, #10 (3)
7. WIF sensor
8. Thermo recirculating valve assembly
9. Cover plate gasket
10. Fuel heater
11. Cover plate
12. O-ring seal
13. Water drain plug
14. M5 x 23 screw (4)
15. Mounting grommet (3)
16. M8 x 40 bolt with shoulder (3)

1. Remove the water drain plug assembly and discard O-ring.
2. Remove the primary filter cap and discard O-ring seal.
3. Remove primary fuel filter element and dispose of properly.
4. Remove four M5 x 23 cover plate screws and remove cover plate. Discard cover plate gasket.
5. Remove fuel heater from the cover plate.
6. Remove the thermo recirculating valve assembly from the primary fuel filter housing.
7. Remove three (#10 self-tapping) fuel pump screws and remove fuel pump. Discard O-rings.

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Cleaning and Inspection

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

1. Inspect fuel lines for kinks, chaffing or other signs of damage. Replace fuel lines if necessary.

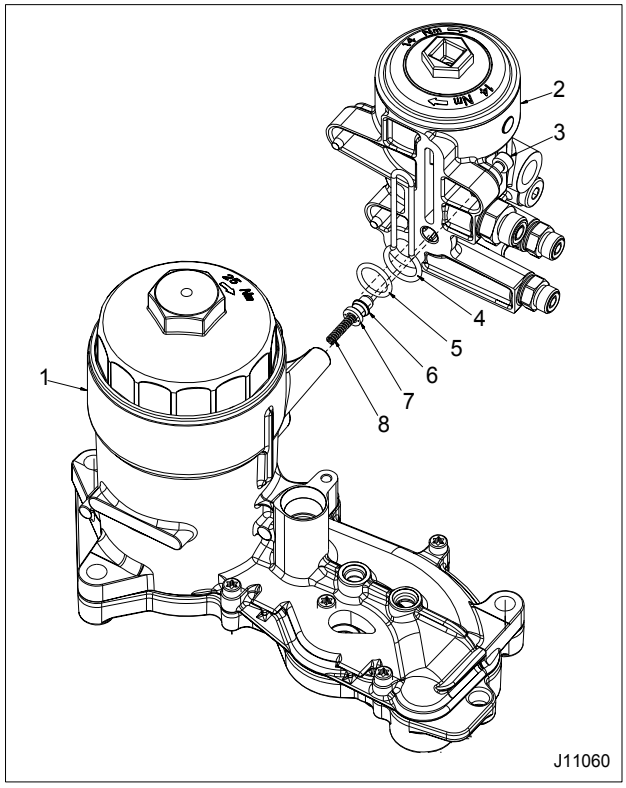

Figure 219 Fuel pressure regulator poppet assembly

1. Oil filter assembly
2. Secondary fuel filter housing
3. M6 x 25 screw (3)
4. Pressure regulator cover gasket
5. Viton O-ring, size #115
6. Poppet gasket seal
7. Brass poppet
8. Pressure regulator valve spring

2. Check poppet valve and spring for signs of misalignment. Inspect poppet gasket seal for signs of uneven seating with the fuel filter housing.
3. Check the fuel return tube assembly (Figure 217) for broken or cracked pieces.
4. Clean out any accumulated sediment in the bottom of the secondary fuel filter housing and HFCM housing.
5. Wash all fuel filter components in a suitable solvent and dry with filtered compressed air.

NOTE: See EGES-395 *Diagnostic Manual* for further inspection and repair of fuel system components.

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Assembly

Horizontal Fuel Conditioning Module (HFCM)

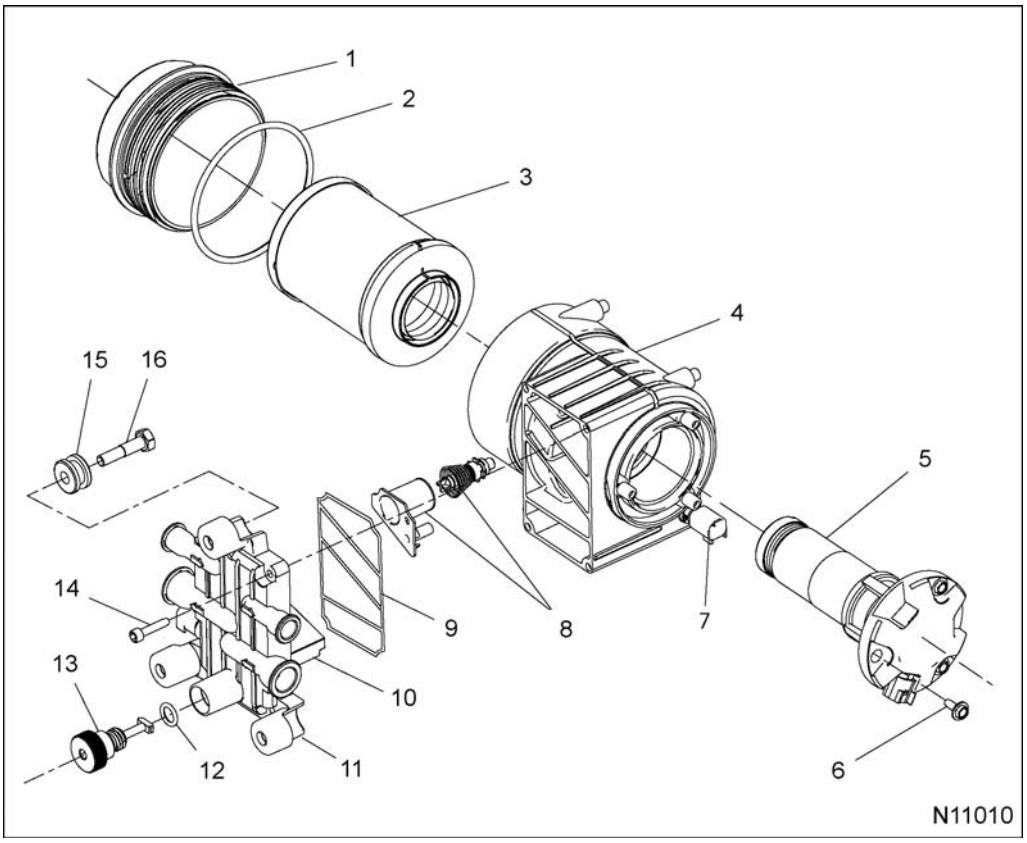

Figure 220 HFCM

1. Primary filter element cap
2. Cap O-ring seal
3. Primary fuel filter element
4. Primary fuel filter housing
5. Electric fuel pump
6. Self-tapping screw, #10 (3)
7. WIF sensor
8. Thermo recirculating valve assembly
9. Cover plate gasket
10. Fuel heater
11. Cover plate
12. O-ring seal
13. Water drain plug
14. M5 x 23 screw (4)
15. Mounting grommet (3)
16. M8 x 40 bolt with shoulder (3)

1. Install the thermo recirculating valve assembly into the primary fuel filter housing.
2. Install the fuel heater into the cover plate.
3. Install cover plate gasket onto cover plate.
4. Install cover plate onto filter housing and install four M5 x 23 screws. Tighten screws to special torque (page 186).
5. Install new O-rings onto the fuel pump and lubricate with clean diesel fuel.
6. Install fuel pump assembly into fuel filter housing.
7. Install three (#10 self-tapping) screws and tighten to special torque.
8. Install primary filter element into HFCM.
9. Install a new O-ring on the primary filter cap and lubricate O-ring with clean diesel fuel.
10. Install filter cap onto HFCM and tighten to special torque.
11. Install a new O-ring on water drain plug. Install and tighten plug.

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Secondary Fuel Filter Assembly

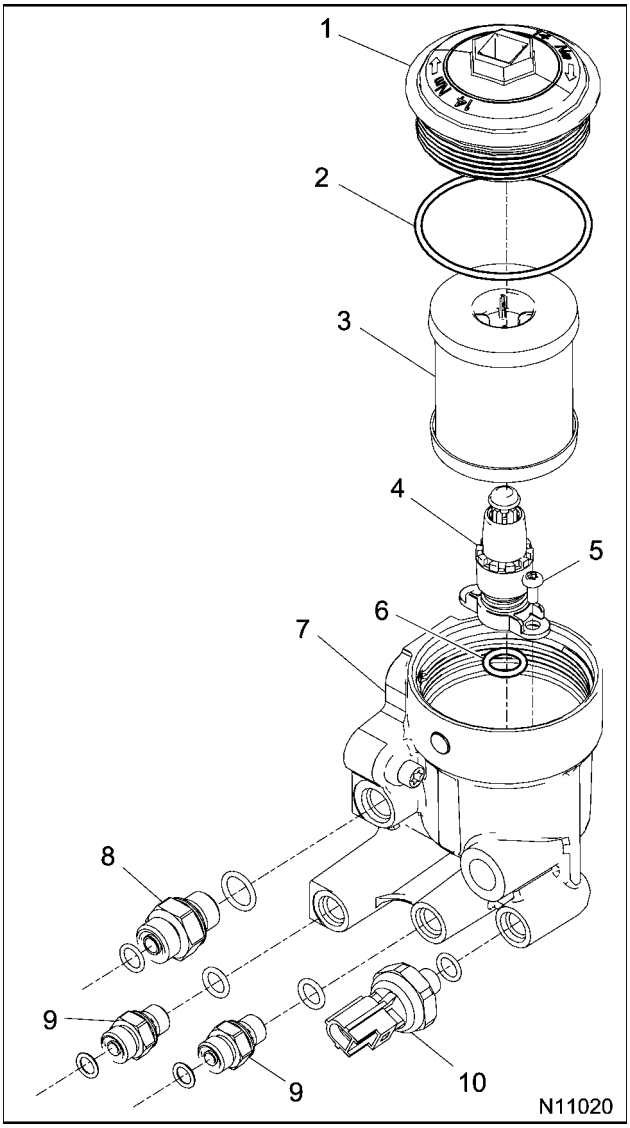

Figure 221 Secondary fuel filter assembly

1. Fuel filter cap
2. O-ring seal
3. Fuel filter element
4. Fuel return tube assembly
5. Screw, 8/32 x 3/8 in (2)
6. Viton O-ring, size #112
7. Secondary fuel filter housing
8. M16 fuel return fitting
9. M12 left and right cylinder head fuel tube assembly fitting (2)
10. Engine Fuel Pressure (EFP) switch

NOTE: The engine will not run without the secondary fuel filter element. When installed properly the secondary fuel filter element pushes down the fuel return tube which opens a valve, allowing fuel to flow into the filter housing.

1. Install a new O-ring gasket into the base of the fuel filter housing.
2. Install return tube assembly over O-ring and secure with two 8/32 x 3/8 in. screws. Tighten screws to special torque (page 186).
3. Install fuel filter element over return tube. Rotate element slightly until filter engages teeth and can be moved up and down against spring pressure.
4. Apply a coating of clean diesel fuel to a new O-ring and install onto fuel filter cap. Thread fuel filter cap onto filter housing and tighten to special torque.
5. Install new O-rings onto M12 and M16 fittings and install in fuel filter housing. Tighten fittings to special torque.

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Installation

Fuel Injector Assemblies

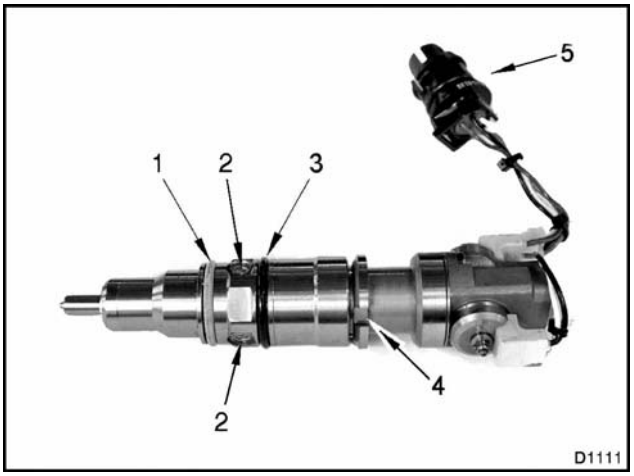

Figure 222 Fuel injector

1. O-ring, lower (white Teflon® coating) (smaller diameter)
2. Fuel inlet screens (3)
3. O-ring, upper (black Teflon® coating) (larger diameter)
4. Clamp alignment slot
5. O-ring, harness connector (dark blue)

CAUTION: To prevent engine damage, replace external O-rings and copper nozzle gasket each time the fuel injector is removed.

1. Install a new Teflon® coated (white) O-ring (smaller diameter) in the lower recess just below the fuel screens.
2. Install a new Teflon® coated (black) O-ring (larger diameter) in the recess just above the fuel inlet screens.
3. Lubricate upper and lower O-rings with clean engine oil.

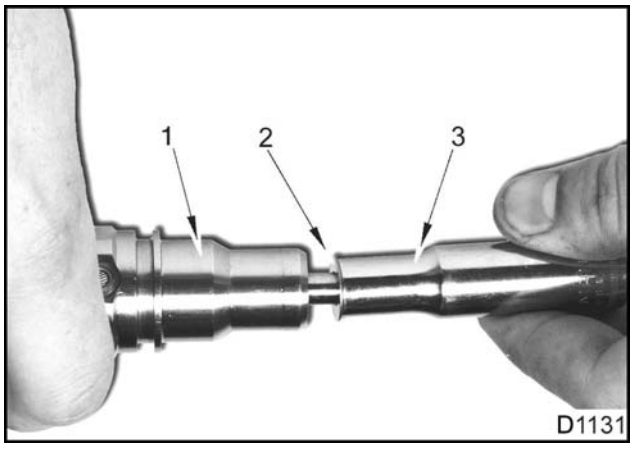

Figure 223 Fuel injector copper nozzle gasket installation

1. Injector (nozzle end)
2. Gasket (copper)
3. Deep socket

NOTE: The copper gasket may be installed in either direction.

4. Install a new copper gasket on the tip of the fuel injector nozzle. Push gasket on with a deep socket.

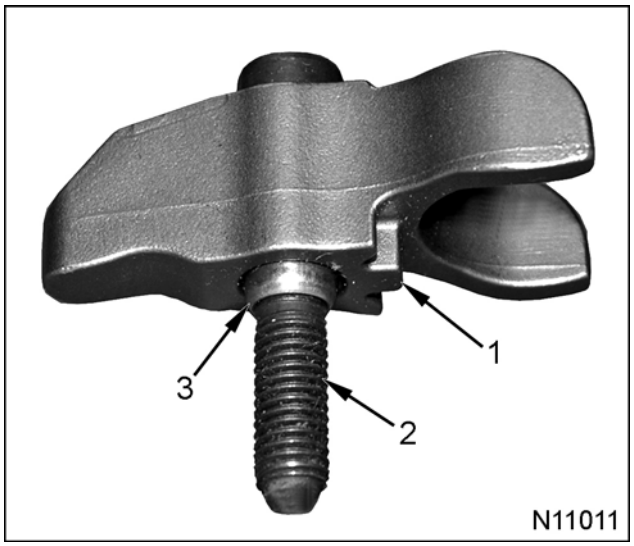

Figure 224 Injector hold down clamp assembly

1. Clamp alignment index
2. M8 x 45 bolt
3. Retainer

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5. Align slot in injector assembly with the injector hold down clamp alignment index.

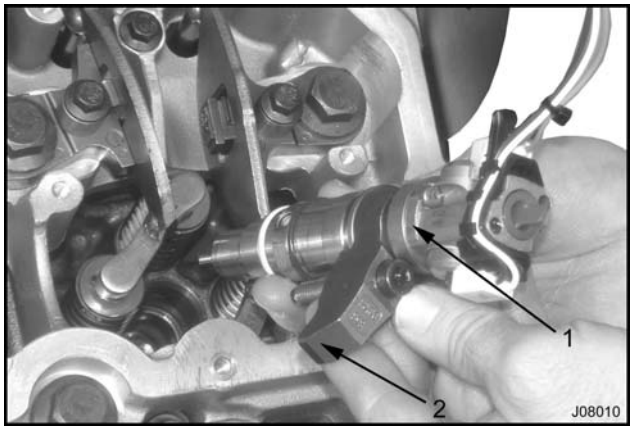

Figure 225 Fuel injector installation

1. Fuel injector
2. Fuel injector hold down clamp assembly

CAUTION: To prevent engine damage, do not use air tools to install fuel injectors. Use caution not to scratch fuel injector surfaces.

6. Install fuel injector and injector hold down clamp assembly into injector bore as one unit.
7. Install fuel injector hold down clamp assembly using a T45 Torx bit socket (page 187) . Do not use power tools to install injectors.
8. Tighten fuel injector hold down clamp bolt to special torque (page 186).

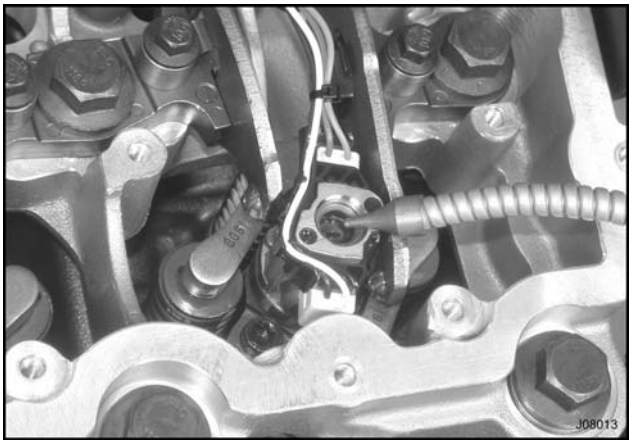

Figure 226 Top D-ring lubrication

9. Lubricate the D-ring in the top of the injector oil inlet with clean engine oil.

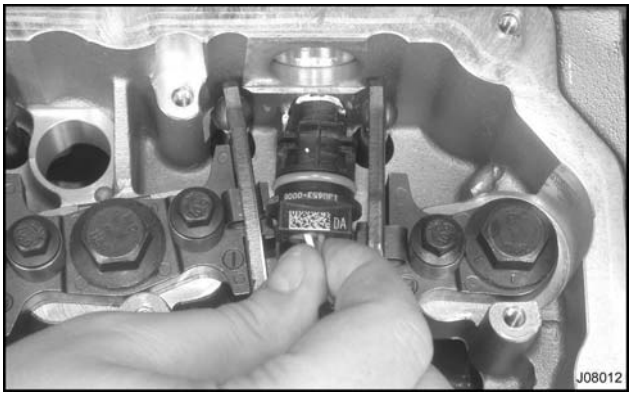

Figure 227 Injector harness connector installation

10. Lubricate injector harness connector O-ring with clean engine oil and install connector into rocker arm carrier by pushing connector straight in until it snaps into place. Identification marks should face up.

CAUTION: To prevent engine damage, be sure injector wiring is clear of moving parts.

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Horizontal Fuel Conditioning Module (HFCM)

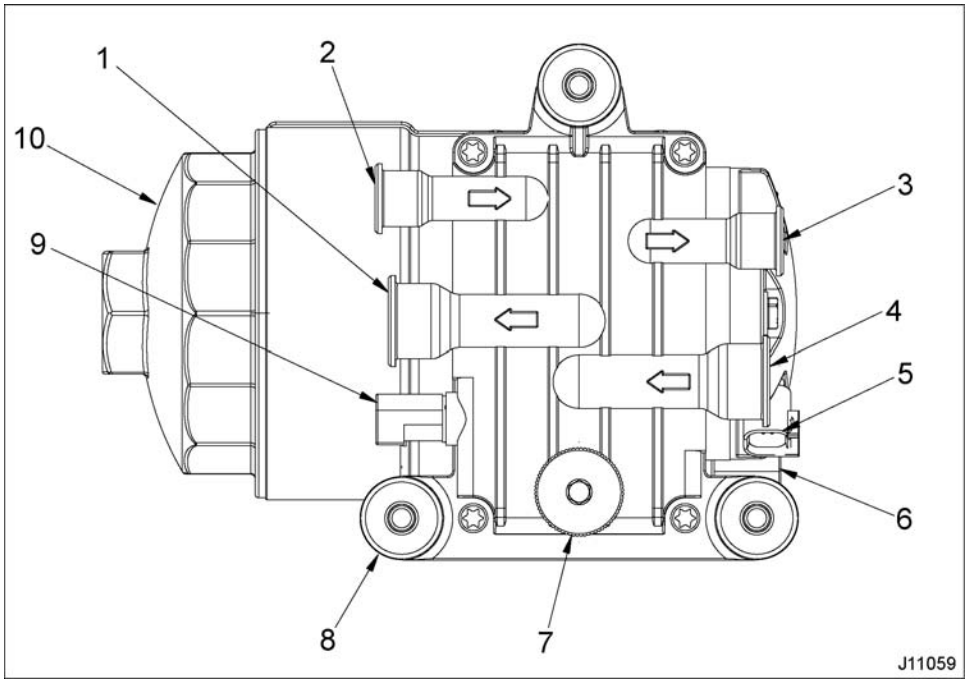

Figure 228 HFCM (chassis mounted)

1. Fuel supply port to engine
2. Fuel return port from engine
3. Fuel return port to tank
4. Fuel supply port to HFCM
5. Electric fuel pump connection
6. WIF electrical connection
7. Water drain plug
8. Mounting grommet (3)
9. Fuel heater electrical connection
10. Primary filter element cap

1. CityStar™ – Install HFCM to chassis rail. Thread three M8 mounting nuts onto mounting M8 x 40 bolts and tighten to special torque (page 186).

   Stripped chassis – Install HFCM to transmission housing mounting bracket. Thread three M8 mounting nuts onto M8 x 40 mounting bolts and tighten to special torque (page 186).
2. Install new retaining clips onto fuel hoses.
3. Install fuel hoses onto HFCM cover plate.
4. Connect the WIF, fuel heater, and fuel pump electrical connectors.
5. Close water drain plug.

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Secondary Fuel Filter Assembly

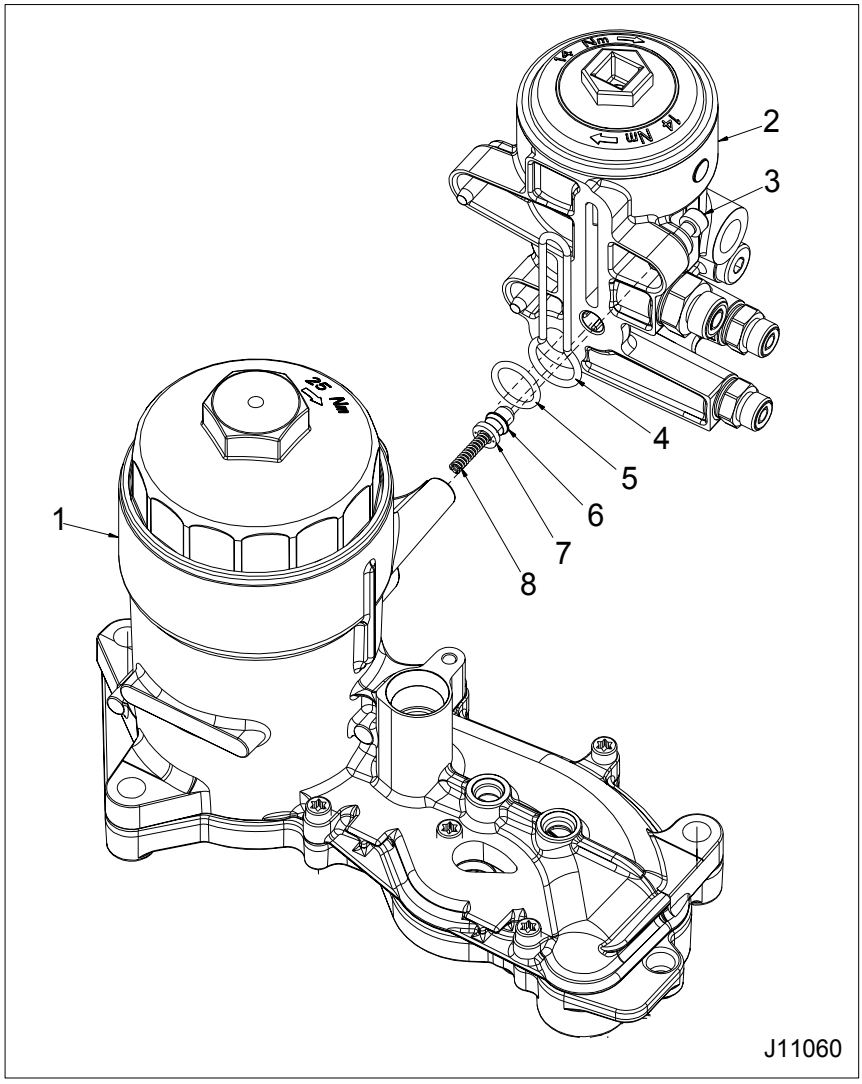

Figure 229 Fuel pressure regulator poppet assembly

1. Oil filter assembly
2. Secondary fuel filter housing
3. Screw, M6 x 25 (3)
4. Pressure regulator cover gasket
5. Viton O-ring, size #115
6. Poppet gasket seal
7. Brass poppet
8. Pressure regulator valve spring

1. Install a new pressure regulator cover gasket and new O-ring into the fuel filter housing.
2. Make sure brass poppet has a new gasket seal on it before placing assembly into fuel filter housing. Brass poppet goes in first, spring is oriented toward oil filter side.
3. Install three M6 x 25 screws through the fuel filter housing and into the oil filter assembly. Thread screws in evenly, watching the alignment of gasket, O-ring and poppet spring.
4. Tighten Three M6 x 25 screws to special torque (page 186).

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Fuel System Tubing

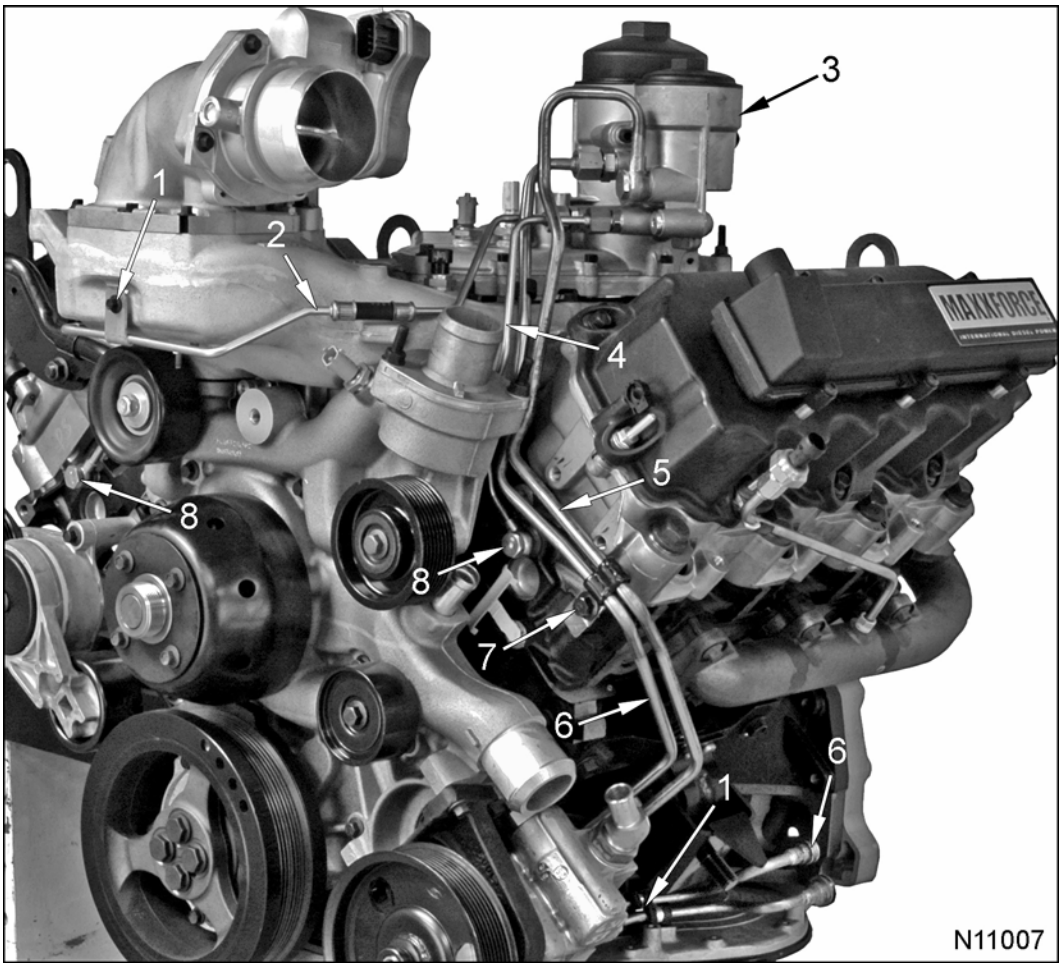

Figure 230 Fuel system tubing and connections

1. M6 x 16 bolt (2)
2. Fuel filter to right cylinder head tube
3. Secondary fuel filter housing
4. Fuel filter to left cylinder head tube
5. Fuel supply to filter tube
6. Fuel return to HFCM tube
7. M10 x 16 bolt
8. M12 banjo bolt with check valve (2)

NOTE: Install all fuel tube fittings and anchor clamps finger tight before tightening any to final torque.

1. Position the “fuel filter to right cylinder head tube” on the engine.
2. Install a new copper washer on an M12 banjo bolt and install bolt through the “fuel filter to right cylinder head tube”. Install second copper washer on banjo bolt and install bolt into front of right cylinder head and finger tighten.
3. Position “fuel filter to left cylinder head tube”, “fuel supply to filter tube”, and “fuel return to HFCM tube” on the engine.
4. Install a new copper washer on M12 banjo bolt and install bolt through the “fuel filter to left cylinder head tube”. Install second copper washer on banjo bolt and install bolt into front of left cylinder head and finger tighten.

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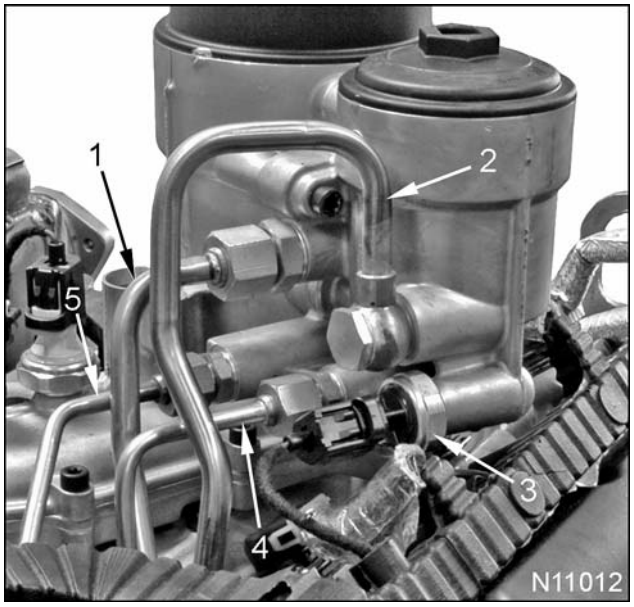

Figure 231 Secondary fuel filter tubes and housing

1. Fuel return to HFCM tube
2. Fuel supply to filter tube
3. Engine Fuel Pressure (EFP) switch
4. Fuel filter to left cylinder head tube
5. Fuel filter to right cylinder head tube

5. Connect left and right cylinder head fuel tubes to the fuel filter assembly and finger tighten.
6. Connect the “fuel return to HFCM tube” to the fuel filter assembly and finger tighten.
7. Install a new copper washer on the “fuel supply to filter tube” hollow screw and install screw through tube. Install second copper washer on hollow screw and install screw into the fuel filter assembly and finger tighten.
8. Install M6 x 16 bolt to secure fuel return and supply tubes to the oil pan and finger tighten.
9. Install M10 x 16 bolt to secure fuel return and supply tubes to the left cylinder head and finger tighten.
10. Install M6 x 16 bolt to secure “fuel filter to right cylinder head tube” to the intake manifold” and finger tighten.

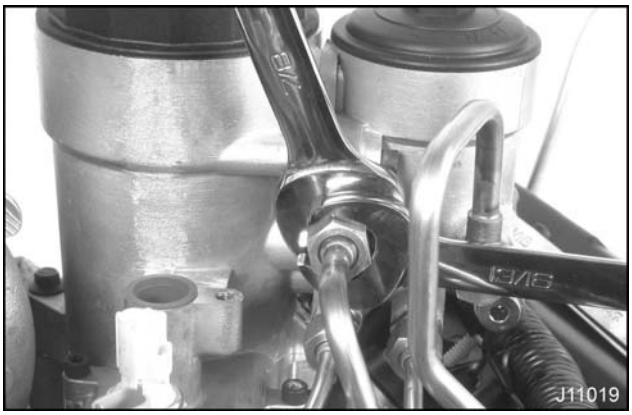

Figure 232 Tightening wrench and backup wrench

11. Using a backup wrench, tighten right and left cylinder head fuel tubes and fuel return to tank tube to special torque (page 186).
12. Tighten fuel supply to filter tube hollow screw to special torque.
13. Tighten right and left fuel supply tube banjo bolts to special torque.
14. Tighten M10 x 16 and two M6 x 16 bolts to standard torque (page 400).

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Specifications

Horizontal Fuel Conditioning Module (HFCM)	
Electric heater	150 W
Filter efficiency	10 micron
Rated flow capacity	98 L/hr (26 gph @ 60 psi)
Secondary Fuel Filter	
Filter efficiency	4 micron
Maximum fuel pressure in secondary filter	400 kPa (58 psi @ 35 gph)
Valve unseating pressure	310 ± 28 kPa (45 ± 4 psi)
Injection Pressure Regulator (IPR) valve	
Operating temperature range	-40 °C to 220 °C (-40 °F to 428 °F)
Maximum operating pressure	28 MPa (4,061 psi)

Special Torque

Banjo bolt, 12 mm (fuel supply tube to each cylinder head)	38 N·m (28 lbf·ft)
Engine Fuel Pressure (EFP) switch	14 N·m (124 lbf·in)
Fuel injector hold down clamp bolt	35 N·m (26 lbf·ft)
Fuel supply hollow screw, M14	35 N·m (26 lbf·ft)
Fuel pump mounting screws, self tapping #10	5 N·m (44 lbf·in)
Fuel return fitting, M16	46 N·m (34 lbf·ft)
Fuel return to HFCM tube fitting	25 N·m (19 lbf·ft)
Fuel return tube assembly mounting screws, 8/32 x 3/8	2-3 N·m (20-25 lbf·in)
HFCM cover plate screws, M5 x 23	5 N·m (44 lbf·in)
HFCM housing mounting nuts (M8)	15 N·m (132 lbf·in)
Left and right cylinder head supply tube fittings at filter, M12	25 N·m (18 lbf·ft)
Plug assembly, M12 (rear of cylinder head)	36 N·m (27 lbf·ft)
Primary fuel filter cap	25 N·m (18 lbf·ft)
Secondary Fuel filter cap	14 N·m (124 lbf·in)
Secondary fuel filter housing mounting screws, M6 x 25	10 N·m (88 lbf·in)

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Special Service Tools

Cap Kit (all)	ZTSE4610
T45 Torx bit socket	Obtain locally
Fuel Injector Tip Cleaning Brush	ZTSE4301
Injector Connector Remover	ZTSE4650
Injector Sleeve Brush Set	ZTSE4304
Turbocharger Inlet Guard	ZTSE4293

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