Table of Contents

Illustrations

Oil Cooler Cover and Oil Filter Base

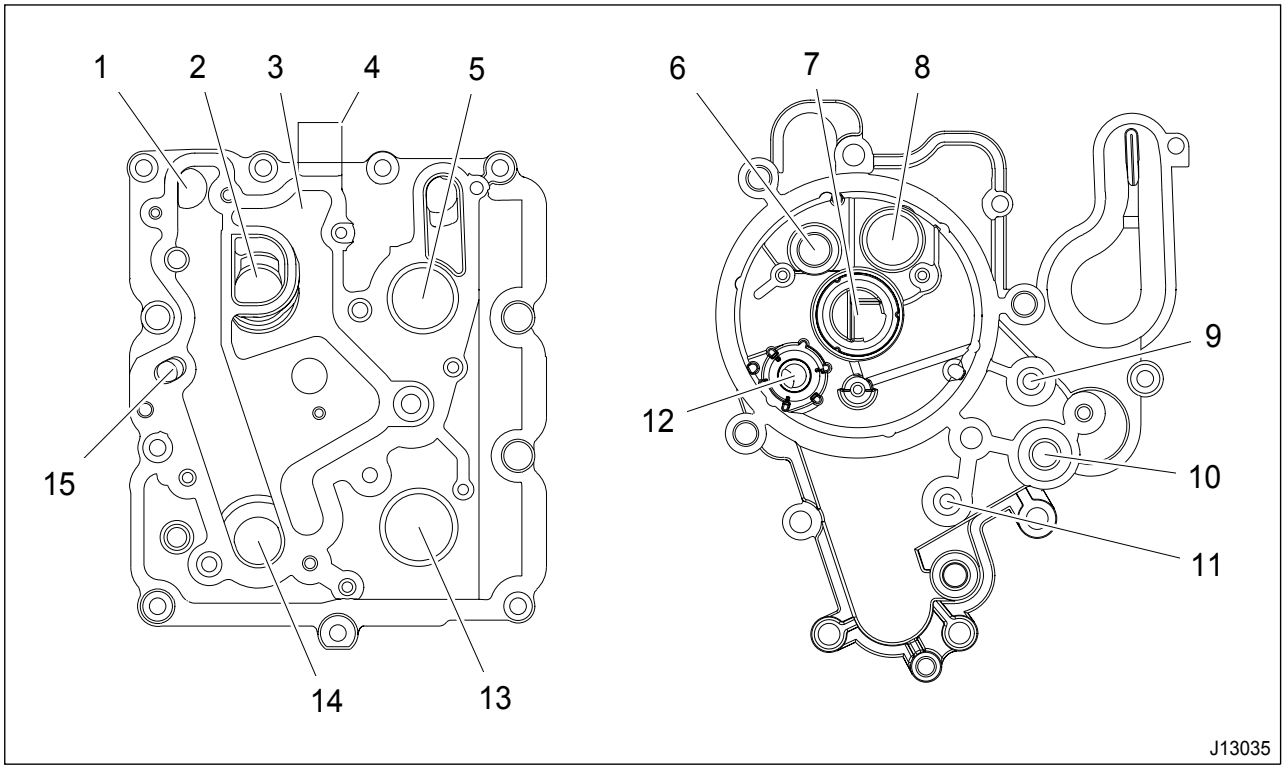

Figure 233 Oil cooler cover and oil filter base

1. Unfiltered oil flow from pump
2. Oil cooler outlet (oil)
3. Filtered oil to reservoir
4. Oil pressure test port fitting
5. Coolant inlet
6. Oil cooler bypass valve
7. Filtered oil to crankcase galleries and other components
8. Unfiltered oil inlet
9. Oil temperature sensor port
10. Dual turbocharger oil supply port
11. Oil pressure sensor port
12. Oil filter drain to sump
13. Coolant outlet
14. Oil cooler inlet (oil)
15. Oil drain to sump

Oil Cooler Cover and Filter Housing

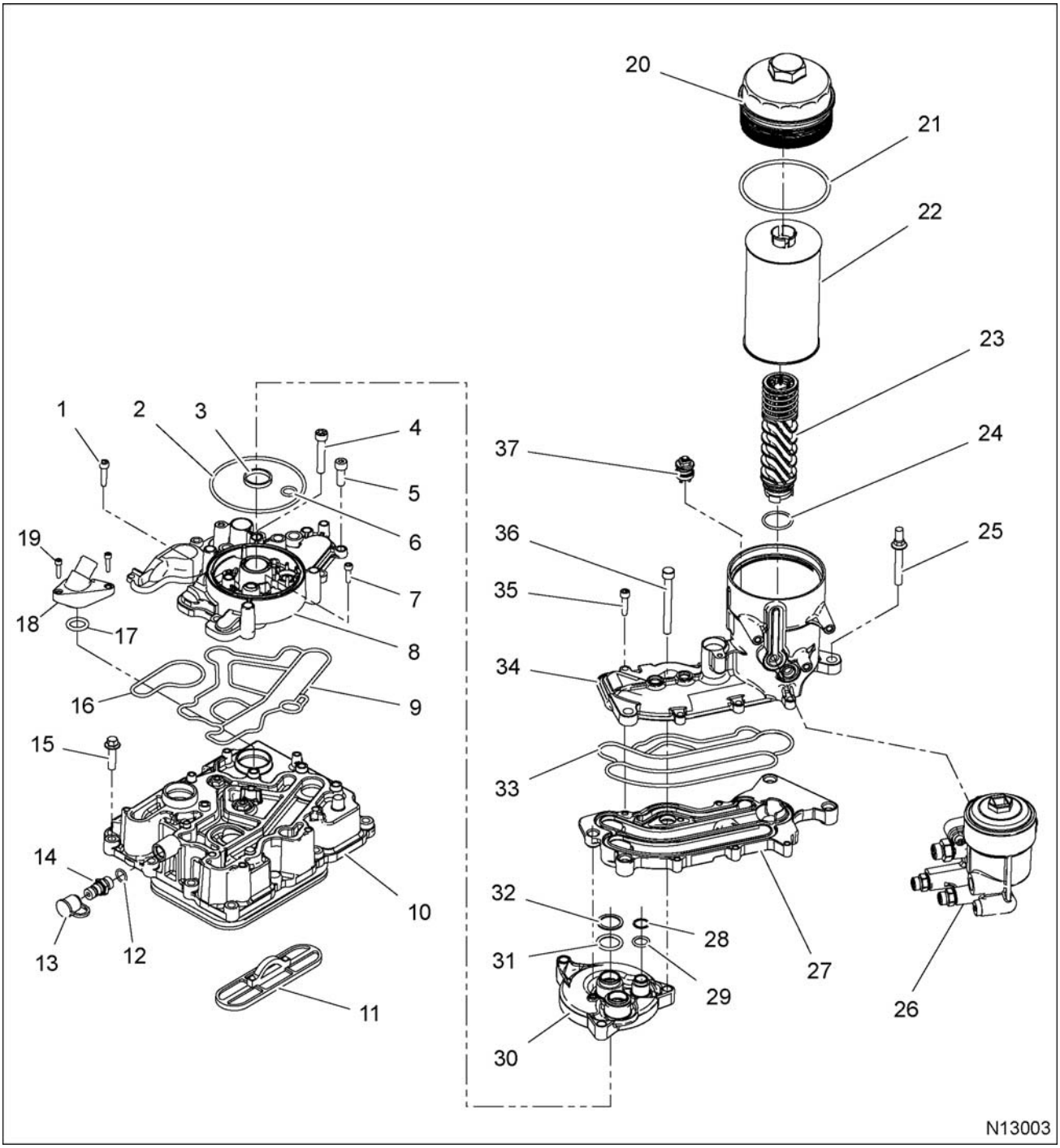

Figure 234 Oil cooler cover and filter housing assembly

1. Thread forming screw, M6 x 25 (3)
2. Viton O-ring, size #241
3. Return tube gasket
4. Bolt, M8 x 45 (Torx®)
5. Screw, M8 x 23 (6)
6. Viton O-ring, size #112
7. Screw, M5 x 18 (2)
8. Oil filter base assembly
9. Oil filter base gasket
10. Oil cooler cover assembly
11. High-pressure pump inlet strainer
12. O-ring, size #906
13. Dust cap
14. Diagnostic port
15. Bolt, M8 x 30 (10)
16. Coolant inlet gasket
17. O-ring
18. EGR coolant supply elbow
19. M6 screw
20. Oil filter cap
21. Oil filter cap seal
22. Oil filter element
23. Latching return tube
24. Viton O-ring, size #122
25. M8 x 55 x 16 stud bolt (2)
26. Fuel filter housing (see Fuel System section)
27. Oil filter base
28. Viton O-ring, size #113
29. O-ring retaining washer
30. Oil filter adapter
31. Viton O-ring, size #212 (2)
32. O-ring retaining washer (2)
33. Oil filter assembly gasket
34. Oil filter housing
35. Screw, M6 x 25 (6)
36. M8 x 75 bolt (3)
37. Oil drain valve assembly

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 removing components.

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

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

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.

Oil Filter Housing Assembly

1. Remove the air intake duct and turbocharger oil supply tube assembly. See “Dual Stage Turbocharger Assembly”.
2. Remove the secondary fuel filter assembly. See “Fuel Systems”.

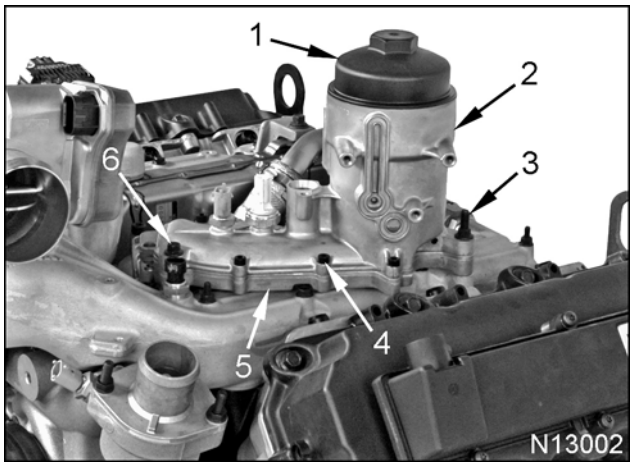

Figure 235 Oil filter housing and base

1. Oil filter cap
2. Oil filter housing
3. M8 x 50 x 16 stud bolt (2)
4. M6 x 25 screw (6)
5. Oil filter base
6. M8 x 55 bolt

3. Loosen oil filter cap and allow oil to drain through filter housing.
4. Remove the oil filter cap and oil filter. Discard O-ring gasket on cap.

CAUTION: To prevent engine damage, do not remove latching return tube unless oil filter housing and oil filter base have been separated.

5. Remove M8 x 55 bolt securing the oil filter housing assembly to the oil filter adapter.
6. Remove the two M8 x 50 x 16 stud bolts securing the oil filter housing to the intake manifold.
7. Pull up and remove oil filter housing assembly from engine. Discard O-rings.
8. Remove six M6 x 25 screws securing the oil filter housing to the oil filter base. Remove and discard oil filter assembly gasket.

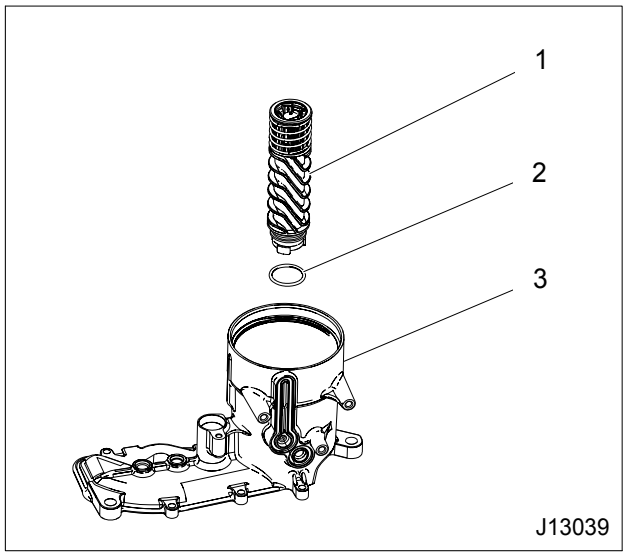

Figure 236 Latching return tube assembly

1. Latching return tube
2. Viton O-ring seal, size #122
3. Oil filter housing

9. Remove the oil filter latching return tube by pushing down and rotating tube counter-clockwise 120°, then lift tube straight up. Remove O-ring seal and discard.

Oil Cooler Cover

1. Remove the intake manifold. See “Manifolds and Exhaust Gas Recirculation (EGR)”.

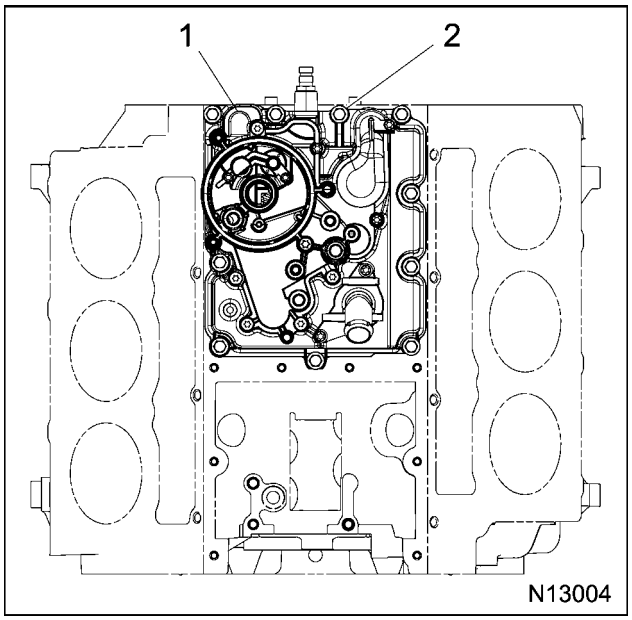

Figure 237 Oil cooler assembly

1. Oil cooler assembly with oil filter base
2. M8 x 30 bolt (10)

CAUTION: To prevent engine damage, always replace the oil cooler cover assembly after a catastrophic engine failure. Debris cannot be removed from the oil cooler.

2. Remove ten M8 x 30 oil cooler cover assembly mounting bolts.

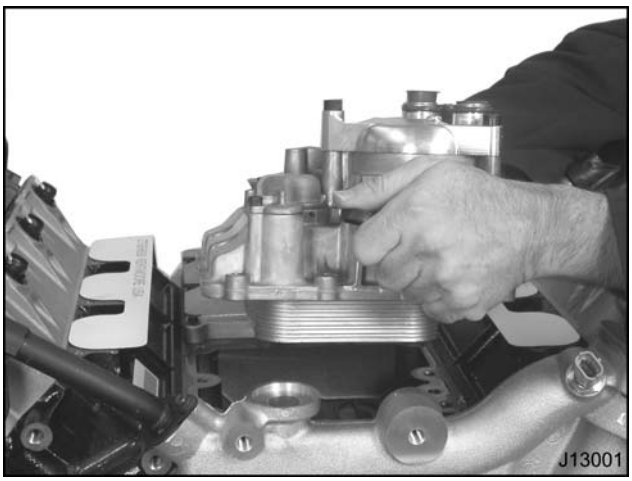

Figure 238 Oil cooler module removal

3. Remove oil cooler assembly from crankcase.

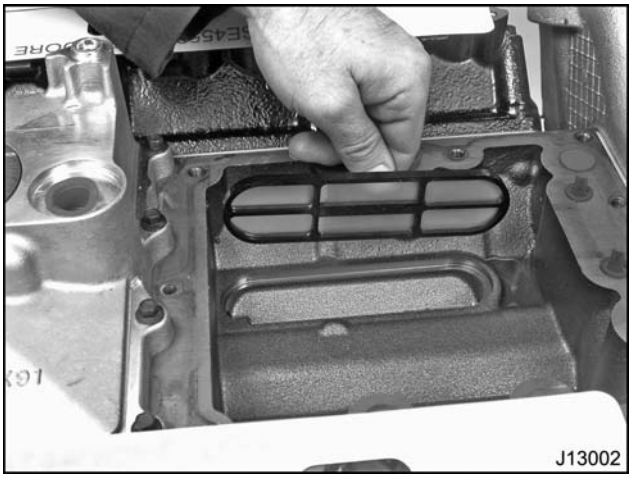

Figure 239 High-pressure oil pump inlet strainer

4. Remove pump inlet strainer from oil reservoir and clean or discard.
5. Remove remaining oil from reservoir.

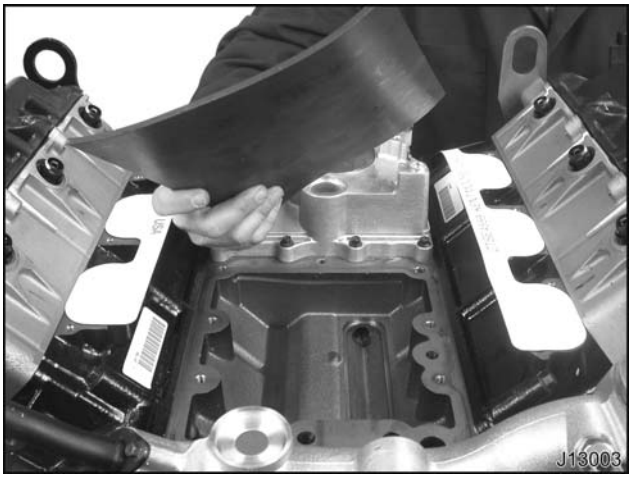

Figure 240 Oil reservoir magnetic cover installation

6. Install oil reservoir Magnetic Covers (page 206).

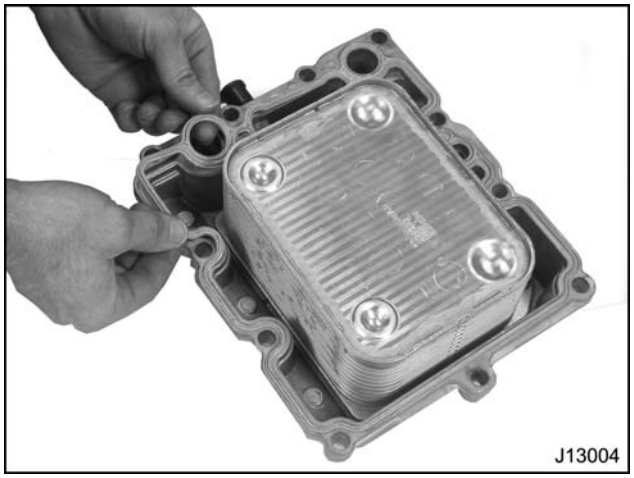

Figure 241 Oil cooler cover gasket removal

7. Remove oil cooler cover gasket and discard.

Oil Filter Base Disassembly

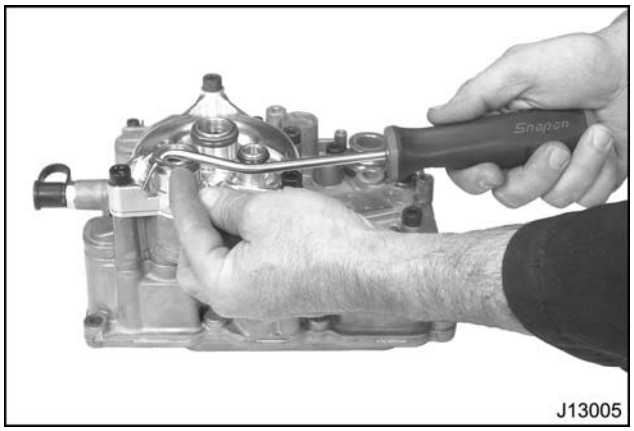

Figure 242 Oil filter adapter O-ring removal

1. Remove and discard all three oil filter base assembly O-rings on top.
2. Remove the three M8 x 75 bolts securing the oil filter adapter.

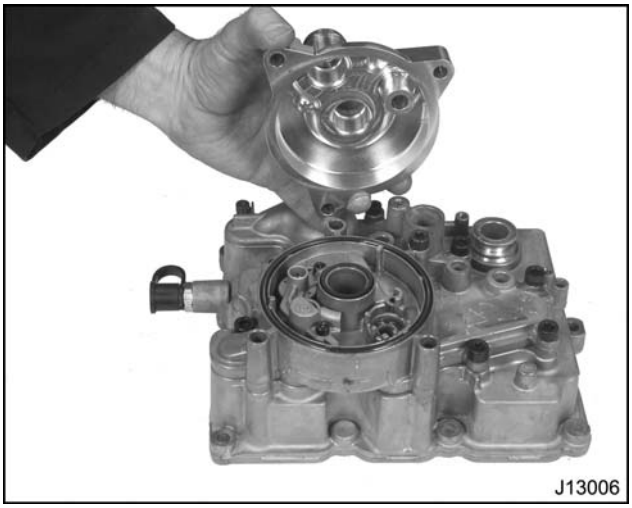

Figure 243 Oil filter adapter removal

3. Remove the oil filter adapter and discard three O-ring seals.

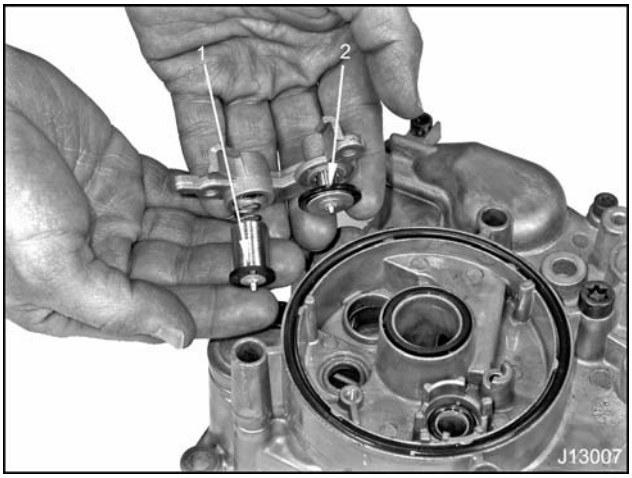

Figure 244 Oil bypass / filter inlet guide valve assembly

1. Oil cooler bypass valve washer seal
2. Oil filter inlet washer seal

NOTE: Remove oil bypass assembly only if you suspect problems.

4. Remove two M5 x 18 screws and remove the oil bypass / filter inlet guide valve.

NOTE: Do not remove the oil filter base until oil cooler pressure test has been performed.

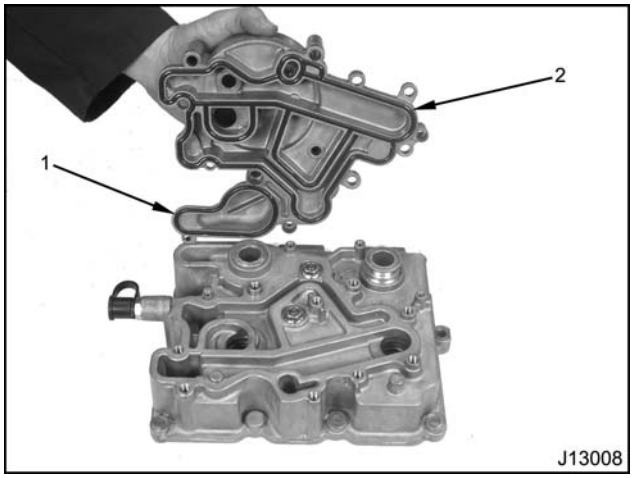

Figure 245 Oil filter base removal

1. Coolant inlet gasket
2. Oil filter base gasket

5. Remove oil filter base assembly from oil cooler cover assembly. Remove and discard oil and coolant gaskets.

Cleaning, Inspection, and Testing

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

Oil Cooler Cover and Oil Filter Base

1. Drain and flush oil cooler cover, oil filter base, and housing to remove any internal residue.
2. Dry all components thoroughly with filtered compressed air.

Oil Cooler Pressure Test

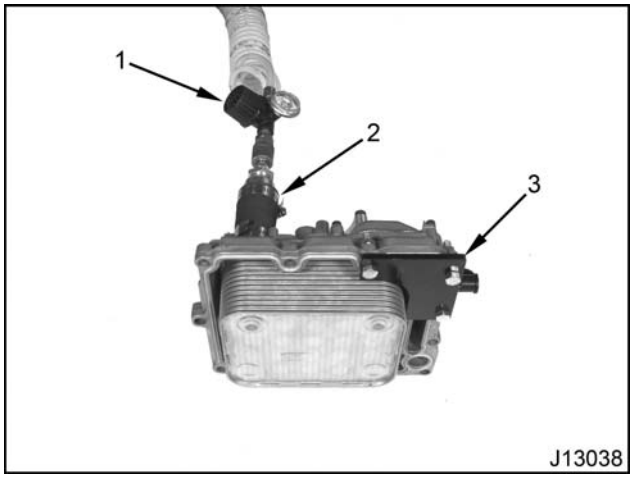

Figure 246 Oil cooler air pressure leakage test

1. Air pressure regulator
2. Air adapter (make locally)
3. Test plate

NOTE: If oil cooler is leaking, replace the oil cooler assembly. There are no serviceable parts for this unit.

NOTE: The oil filter base must be installed on the oil cooler cover assembly before pressure testing.

1. Fabricate an air adapter with the following items:
   - Rubber hose
   - Reducer bushing (hose to fitting)
   - Shop air fitting (male)
   - Two clamps
2. Fasten Oil Cooler Pressure Test Plate (page 206) to oil cooler assembly.
3. Install air pressure regulator to EGR cooler coolant outlet port (air adapter).
4. Apply 207 kPa (30 psi) of air pressure.
5. Spray a soapy water solution around oil cooler and oil filter base.

CAUTION: To prevent engine damage, do not submerge the oil cooler in water. Submerging can allow water into oil passages.

6. If leaking, bubbles will be present. Replace leaking component or seal.
7. Remove soapy water residue and blow off with filtered compressed air.

Installation

Oil Filter Base

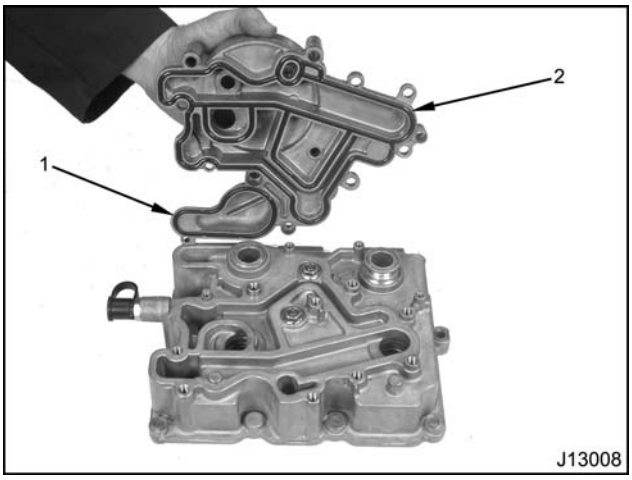

Figure 247 Oil filter base assembly gaskets

1. Coolant inlet gasket
2. Oil filter base gasket

1. Install new oil filter base gasket and coolant inlet gasket onto oil filter base assembly.

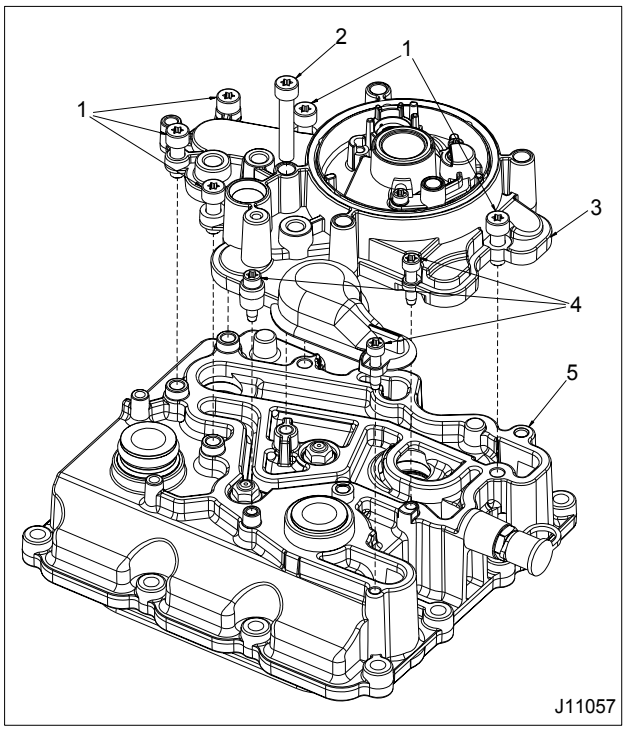

Figure 248 Oil filter base and oil cooler cover

1. Screw, M8 X 23 (5)
2. Bolt, M8 X 45 (Torx®)
3. Oil filter base assembly
4. Screw, M6 X 25 (6)
5. Oil cooler cover assembly

2. Install oil filter base onto oil cooler cover assembly.
3. Install all oil filter base assembly bolts and screws. Tighten to special torque (page 206).
4. Do oil cooler pressure test.

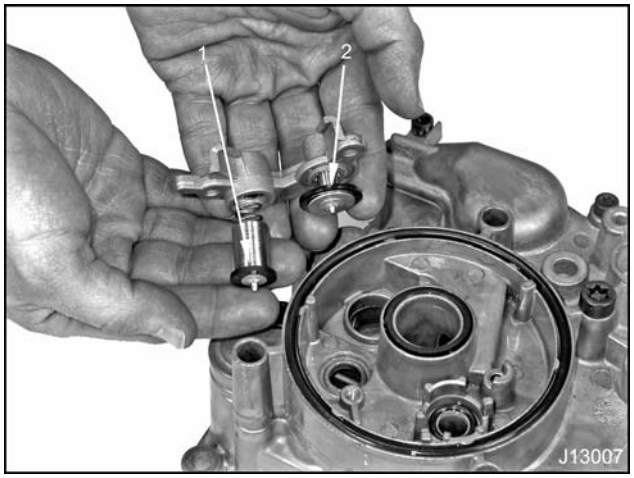

Figure 249 Oil bypass / filter inlet guide valve assembly

1. Oil cooler bypass valve washer seal
2. Oil filter inlet washer seal

5. If removed, install a new oil bypass / filter inlet guide valve and two screws.

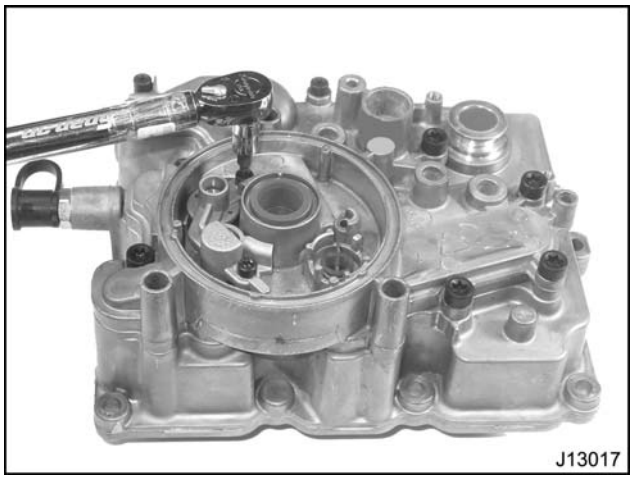

Figure 250 Oil bypass / filter inlet guide screws

6. Tighten the oil bypass / filter inlet guide screws (M5 x 18) to special torque (page 206).

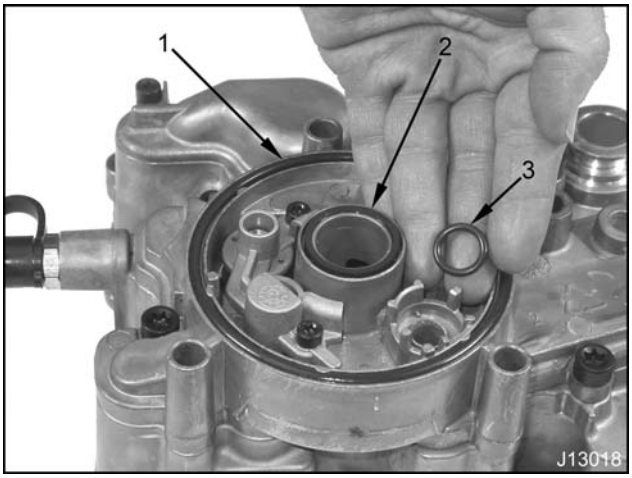

Figure 251 Oil filter base O-rings

1. O-ring, size #241
2. Return tube gasket
3. O-ring, size #112

7. Install two oil adapter O-rings and return tube gasket.

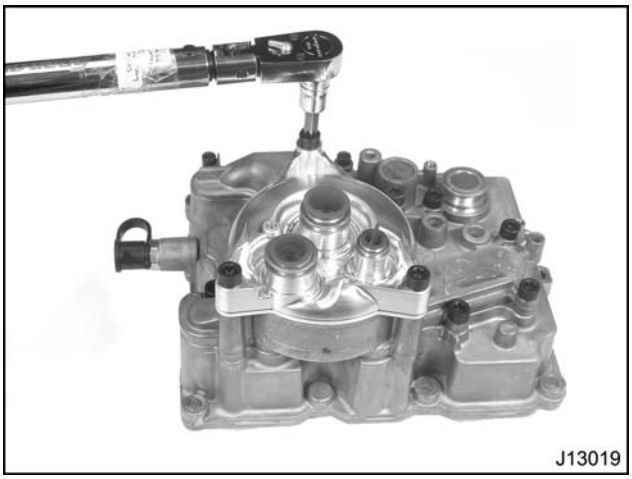

Figure 252 Oil adapter assembly bolts

8. Install oil adapter assembly onto oil filter base assembly. Tighten three Torx® socket screws (M8 x 75) to standard torque (page 400).

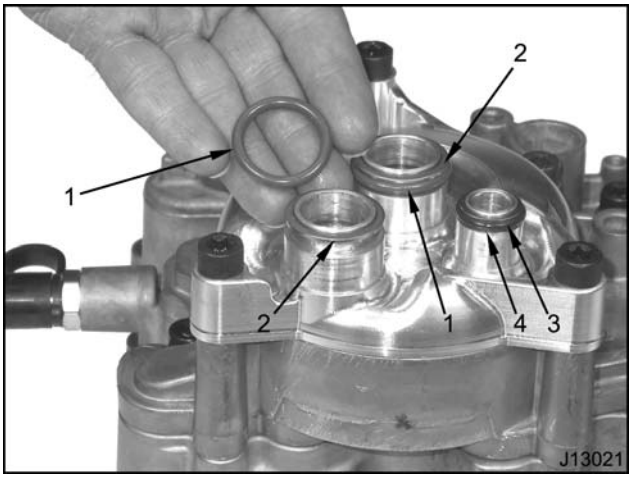

Figure 253 Oil filter adapter O-rings

1. O-ring, size #212 (position below retainer washer)
2. O-ring retainer washer (position above O-ring)
3. O-ring retainer washer (position above O-ring)
4. O-ring, size #113 (position below retainer washer)

9. Install a new set of O-rings onto the oil filter adapter.

Oil Cooler Cover

1. Remove Magnetic Covers from oil reservoir.

Figure 254 Pump inlet strainer

2. Install a new or clean pump inlet strainer in the oil reservoir.

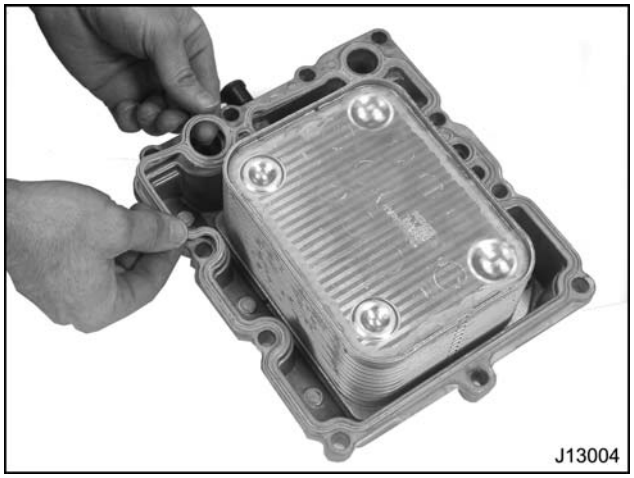

Figure 255 Oil cooler cover gasket

3. Install a new reservoir cover gasket on the oil cooler cover.

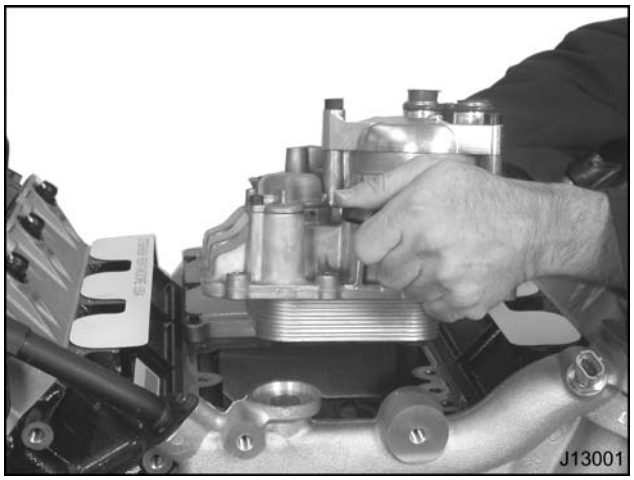

Figure 256 Oil cooler cover assembly installation

4. Install oil cooler assembly onto crankcase.

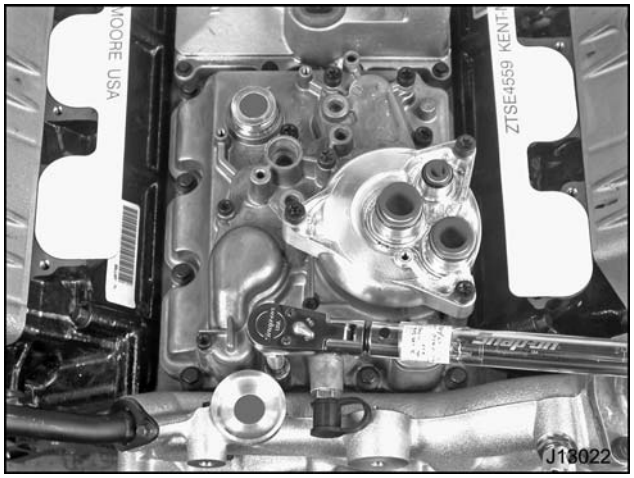

Figure 257 Oil cooler cover assembly bolts

5. Install ten M8 x 30 oil cooler cover assembly mounting bolts and tighten to standard torque (page 400).
6. Lubricate three O-ring seals on top of the oil filter adapter with clean engine oil.

Oil Filter Base and Housing

1. Install intake manifold. See “Manifolds and Exhaust Gas Recirculation (EGR)”.

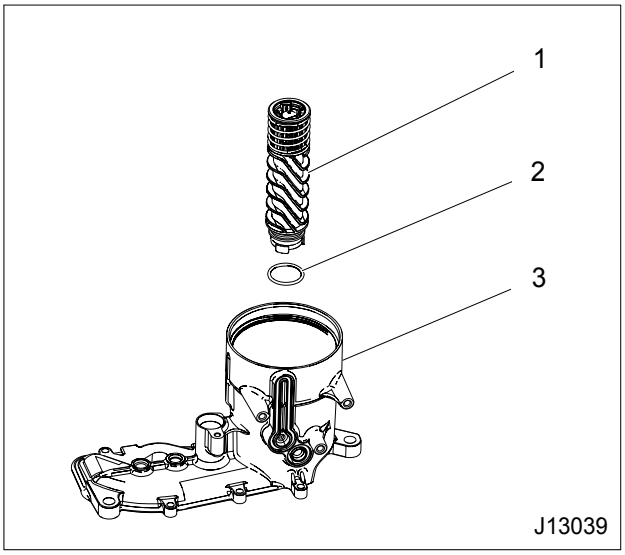

Figure 258 Latching return tube

1. Latching return tube
2. Latching return tube gasket
3. Oil filter housing

2. Lubricate a new latching return tube gasket with clean engine oil and install onto latching return tube.
3. Install latching return tube by pushing down and twisting tube 120° clockwise until latched.

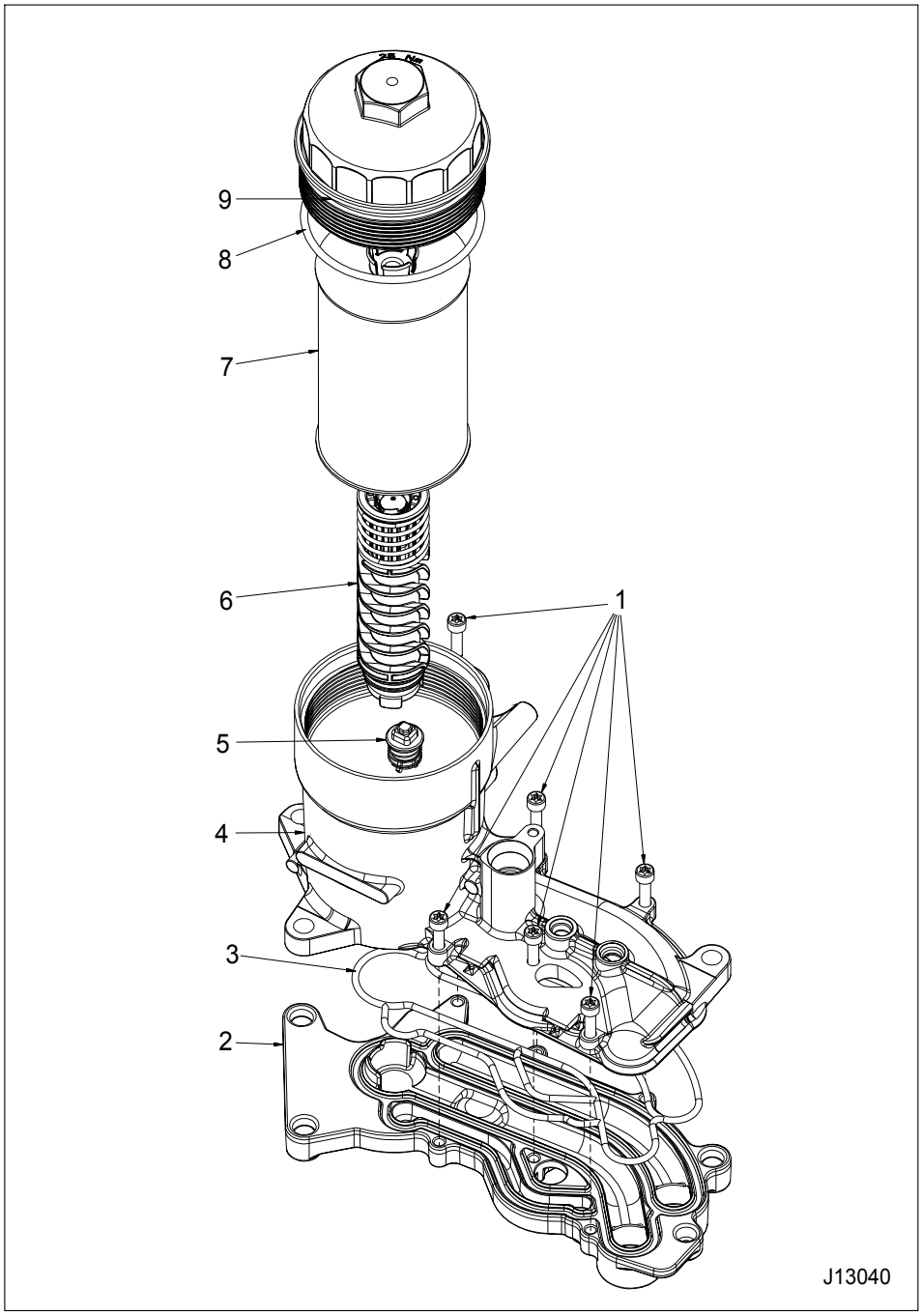

Figure 259 Oil filter base and housing

1. Screw, (M6 x 25)
2. Oil filter base
3. Oil filter housing gasket
4. Oil filter housing
5. Oil drain valve assembly
6. Latching return tube assembly
7. Oil filter element
8. Oil filter cap seal
9. Oil filter cap

4. Install a new oil filter housing gasket between the housing and base.
5. Install six M6 x 25 oil filter housing mounting screws and tighten to special torque (page 206).

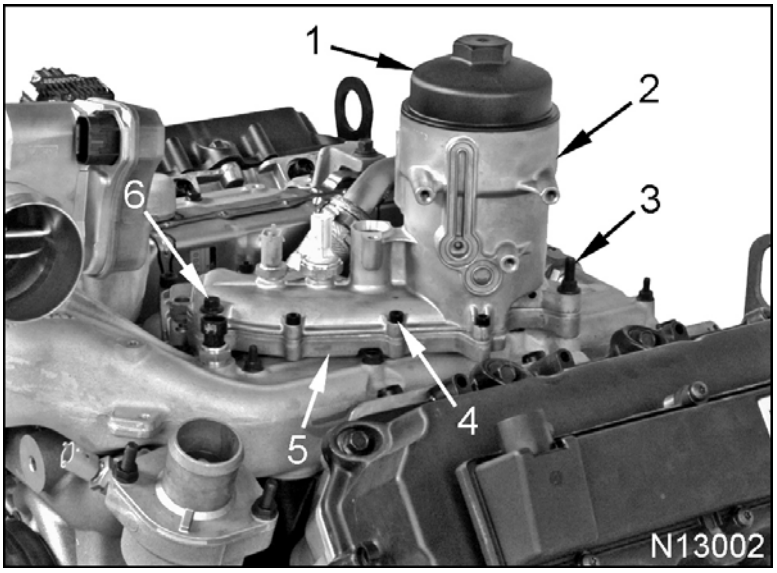

Figure 260 Oil filter housing assembly

1. Oil filter cap
2. Oil filter housing
3. M8 x 50 x 16 stud bolt (2)
4. M6 x 25 screw (6)
5. Oil filter base
6. M8 x 55 bolt

6. Install oil filter housing assembly onto oil filter adapter and intake manifold.
7. Install M8 x 55 bolt and two M8 x 50 x 16 stud bolts. Tighten bolts to standard torque (page 400).
8. Install a new O-ring on the oil filter cap and lubricate with clean engine oil.
9. Install oil filter and cap as a combined unit. Tighten cap to special torque (page 206).

CAUTION: To prevent engine damage, add the correct viscosity oil to the engine before starting. See *Engine Operation and Maintenance Manual*.

Specifications

Oil Cooler	
Type	Full-flow: oil, coolant
Location	Engine valley (forward)
Oil Filter	
Type	Cartridge, full flow - disposable
Filter bypass location	Oil filter return tube assembly

Special Torque

Oil filter base assembly screws (M6 x 25)	10 N·m (85 lbf·in)
Oil filter base assembly bolt (M8 x 45)	11 N·m (97 lbf·in)
Oil filter base assembly screws (M8 x 23)	23 N·m (17 lbf·ft)
Oil bypass / filter inlet guide valve screws (M5 x 18)	7 N·m (62 lbf·in)
Oil filter housing mounting screws (M6 x 25)	15 N·m (132 lbf·in)
Diagnostic port	16 N·m (144 lbf·in)
EGR coolant supply elbow, M6 screw	9.7 N·m (85 lbf·in)
Oil filter cap	25 N·m (18 lbf·ft)

Special Service Tools

Magnetic Covers	ZTSE4557
Oil Cooler Pressure Test Plate	ZTSE4525

Table of Contents

Exploded Views

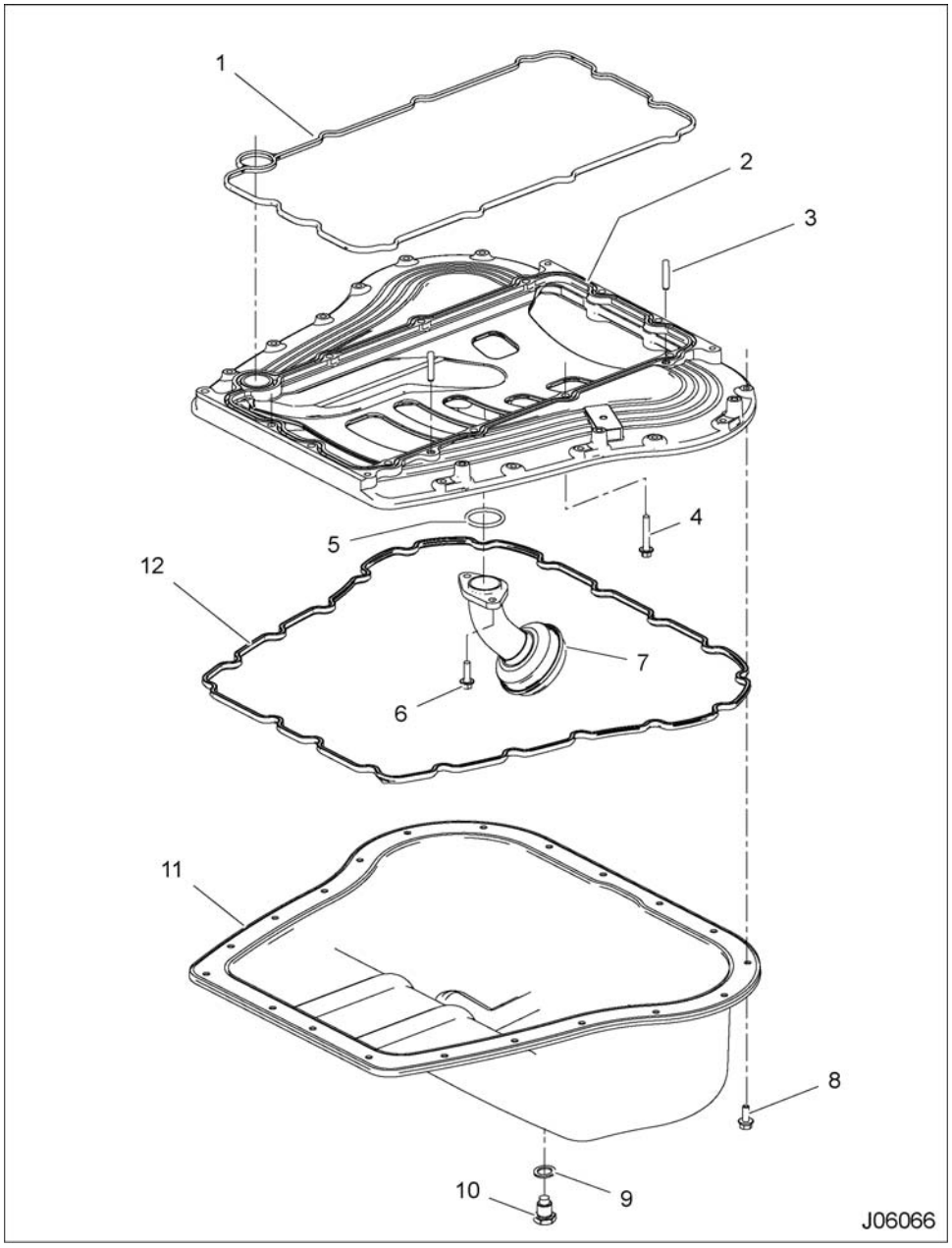

Figure 261 Lube oil pan and related components (CityStar™)

1. Upper oil pan gasket
2. Upper oil pan assembly
3. Dowel pin (2)
4. Upper oil pan bolts (Figure 268)
5. Oil pickup tube O-ring
6. Bolt, M6 x 20 (2)
7. Oil pickup tube assembly
8. Lower oil pan bolts (Figure 263)
9. Drain plug gasket
10. Drain plug
11. Lower oil pan
12. Lower oil pan gasket

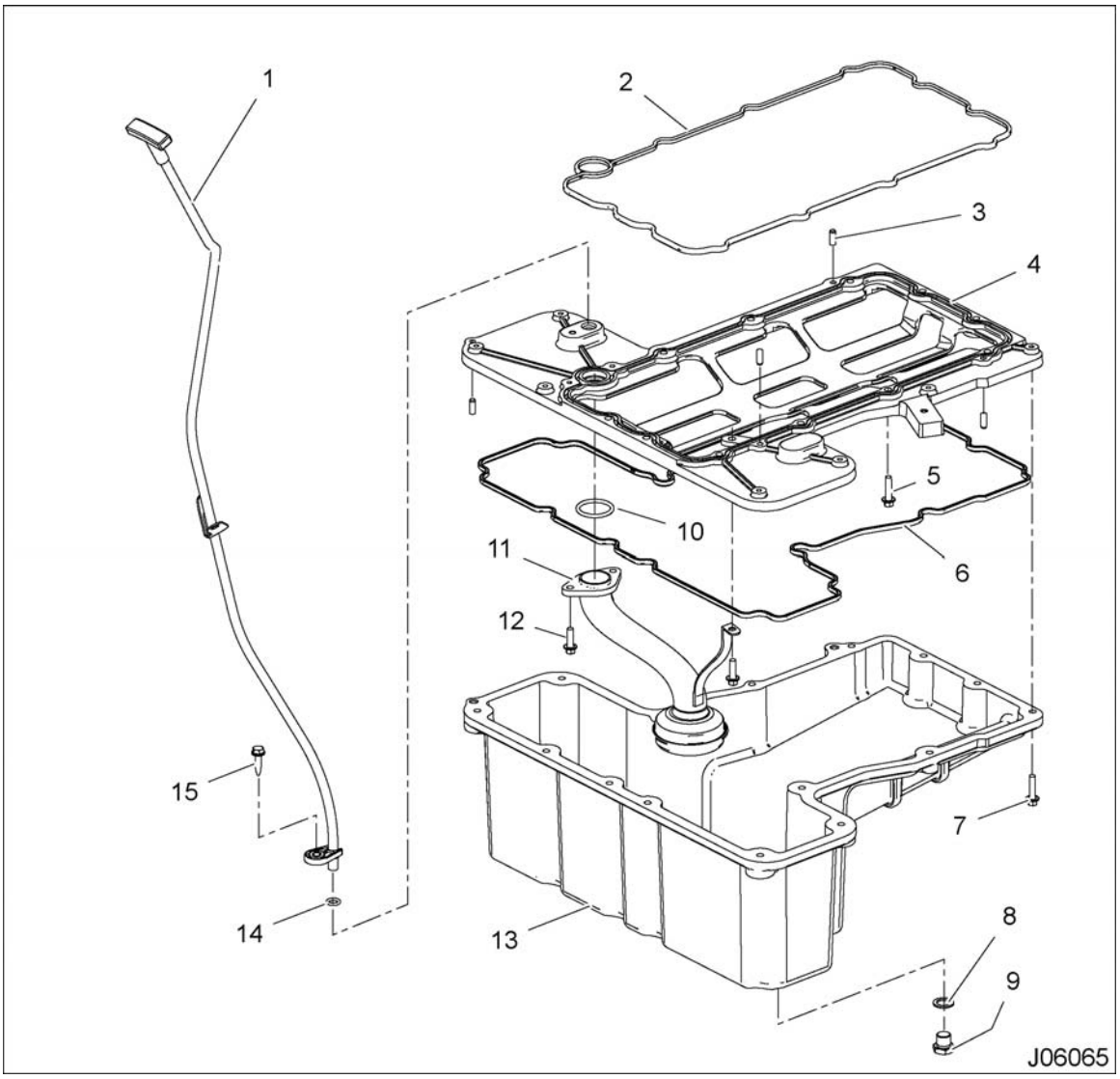

Figure 262 Lube oil pan and related components (stripped chassis)

1. Oil level gauge and tube assembly (gauge blade removed for clarity)
2. Upper oil pan gasket
3. Dowel pin (4)
4. Upper oil pan assembly
5. Bolts (Figure 269)
6. Lower oil pan gasket
7. Bolts (Figure 265)
8. Drain plug gasket
9. Drain plug
10. Oil pickup tube O-ring
11. Oil pickup tube assembly
12. Bolt - patch type, M6 x 25 (3)
13. Lower oil pan
14. Oil level gauge tube seal
15. Bolt, M6 x 20

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 removing components.

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

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.

Lower Oil Pan

1. Remove safety guards, shields, and covers.

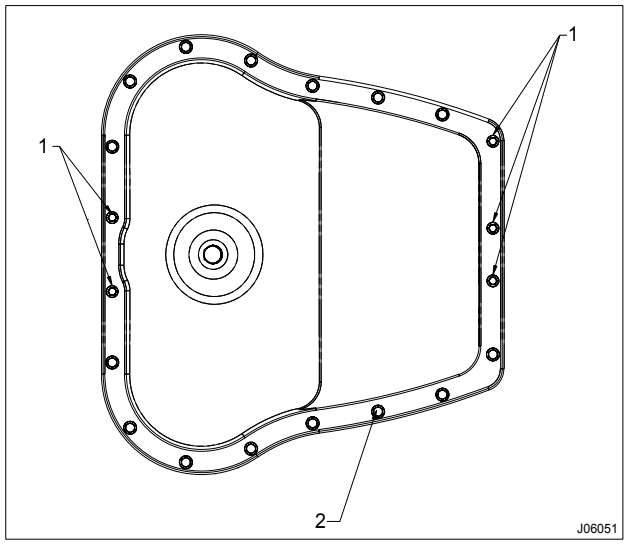

Figure 263 Lower oil pan bolt locations (CityStar™)

1. M6 x 35 bolt (5)
2. M6 x 16 bolt (15)

Figure 264 Lower oil pan mounting bolts

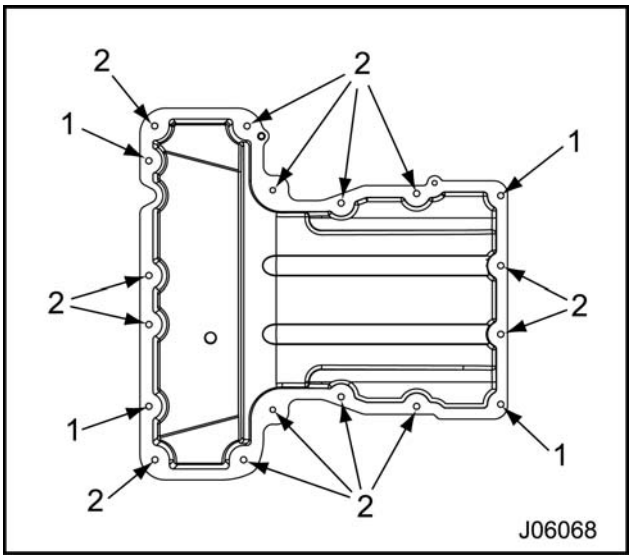

Figure 265 Lower oil pan bolt locations (stripped chassis)

1. M6 x 25 bolt (4)
2. M6 x 35 bolt (14)

2. CityStar™ - Remove five lower oil pan mounting bolts (M6 x 35) and 15 lower oil pan mounting bolts (M6 x 16).

   Stripped chassis - Remove four lower oil pan mounting bolts (M6 x 25) and 14 lower oil pan mounting bolts (M6 x 35).

Figure 266 Lower oil pan removal (typical)

3. Remove the lower oil pan.

Oil Pickup Tube

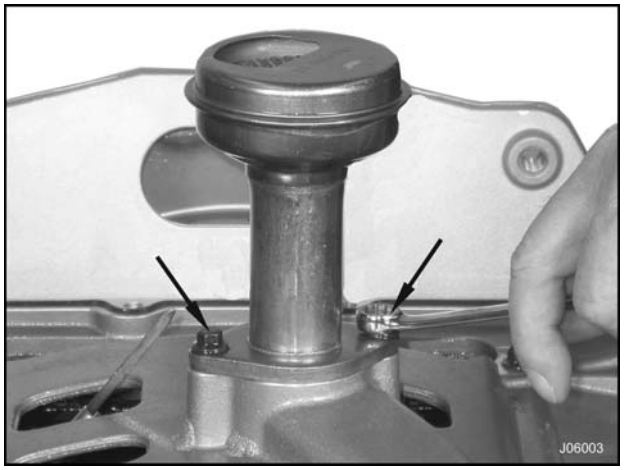

Figure 267 Oil pickup tube removal (typical)

1. CityStar™ - Remove two oil pickup tube mounting bolts (M6 x 20) and oil pickup tube.

   Stripped chassis - Remove three oil pickup tube mounting bolts (M6 x 25 - patch type) and oil pickup tube.

2. Remove and discard the oil pickup tube O-ring.

Upper Oil Pan

Figure 268 Upper oil pan mounting bolts (CityStar™)

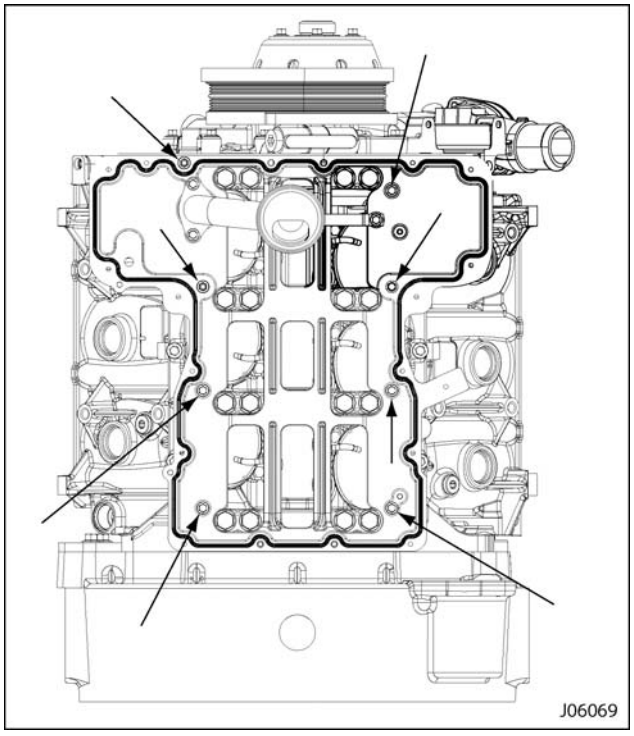

Figure 269 Upper oil pan mounting bolts (stripped chassis)

1. CityStar™ - Remove seven upper oil pan mounting bolts (M6 x 25).

   Stripped chassis - Remove eight upper oil pan mounting bolts (M6 x 25).

2. Remove upper oil pan.

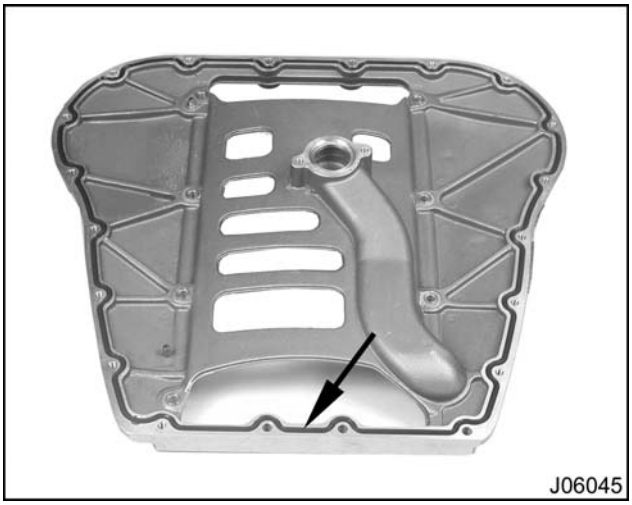

Figure 270 Lower oil pan gasket (lower face) (typical)

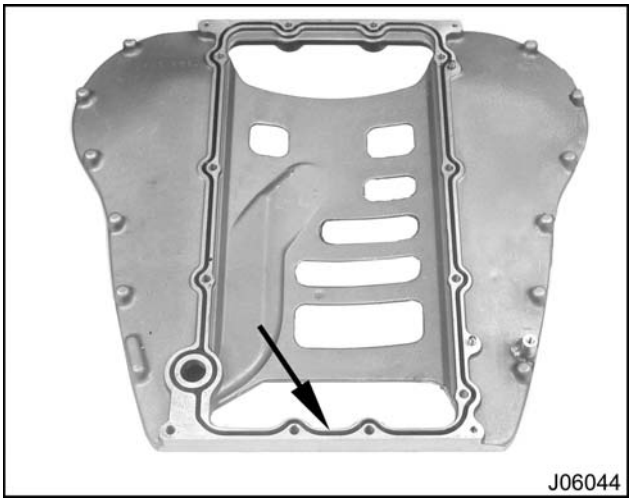

Figure 271 Upper oil pan gasket (upper face) (typical)

3. Remove and discard gasket from each face of upper oil pan.

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).

Lower Oil Pan

1. Inspect bottom of oil pan for metallic debris or other evidence of engine damage. Investigate any abnormalities as required.
2. Clean oil pan with a suitable solvent.
3. Dry with filtered compressed air.
4. Look for warping, dents, and cracking. Replace the oil pan if necessary.

Oil Pickup Tube

1. Clean tube in a suitable solvent.
2. Dry with filtered compressed air.
3. Inspect the oil pickup tube assembly for cracking. Replace if necessary.

Upper Oil Pan

1. Clean oil pan in a suitable solvent.
2. Dry with filtered compressed air.
3. Inspect for signs of warping or cracking. Replace if necessary.

Installation

Upper Oil Pan

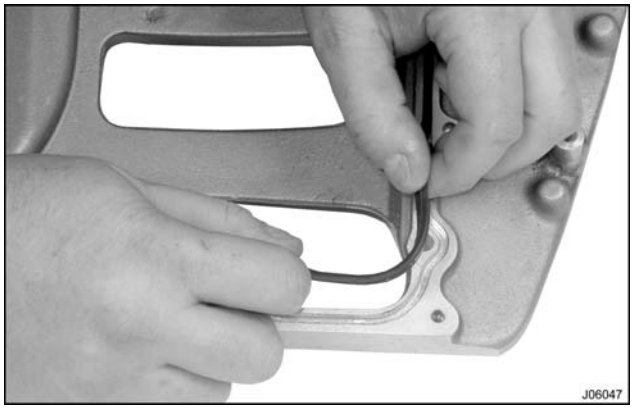

Figure 272 Upper oil pan gasket installation (upper face) (typical)

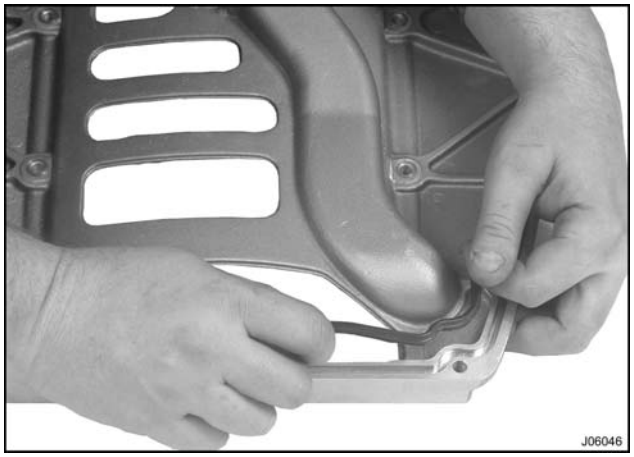

Figure 273 Upper oil pan gasket installation (lower face) (typical)

1. Install a new gasket for each face on the upper oil pan gasket.

Figure 274 Upper oil pan mounting bolts (CityStar™)

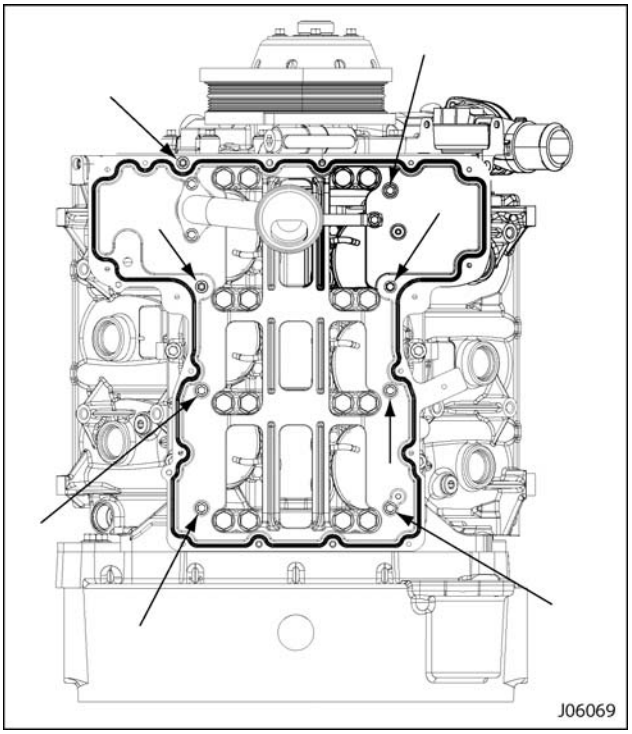

Figure 275 Upper oil pan mounting bolts (stripped chassis)

2. CityStar™ – Install upper oil pan and seven mounting bolts (M6 x 25).

   Stripped chassis — Install upper oil pan and eight mounting bolts (M6 x 25).

   Tighten bolts to the standard torque (page 400).

Oil Pickup Tube

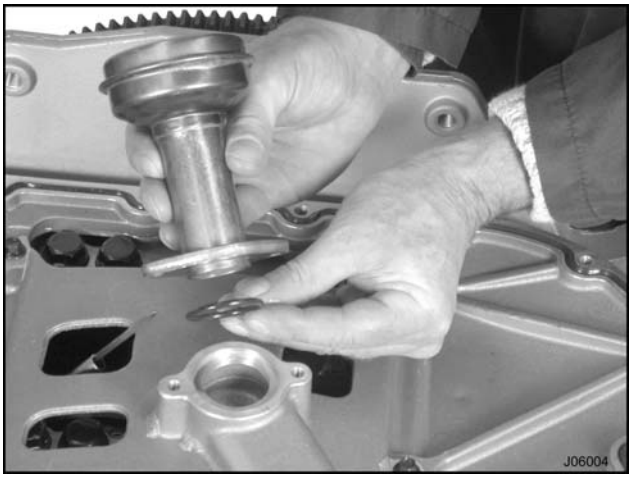

Figure 276 Oil pickup tube O-ring (typical)

1. Lubricate a new O-ring with clean engine oil and install onto oil pickup tube.
2. CityStar™ - Install oil pickup tube and two mounting bolts (M6 x 25). Tighten bolts to standard torque (page 400).

   Stripped chassis - Do the following:

   - Clean threads of three mounting bolts (M6 x 25 - patch type) with suitable solvent.
   - Apply Loctite® #242 (obtain locally) to threads.
   - Install oil pickup tube and three mounting bolts.
   - Tighten bolts to standard torque (page 400).

Lower Oil Pan

Figure 277 Lower oil pan installation (typical)

1. Place lower oil pan onto upper oil pan mating surface.

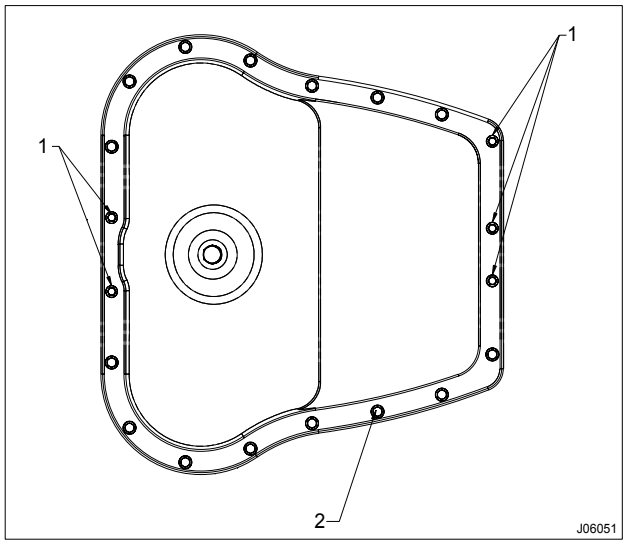

Figure 278 Lower oil pan bolt locations (CityStar™)

1. Five bolts (M6 x 35)
2. 15 bolts (M6 x 16)

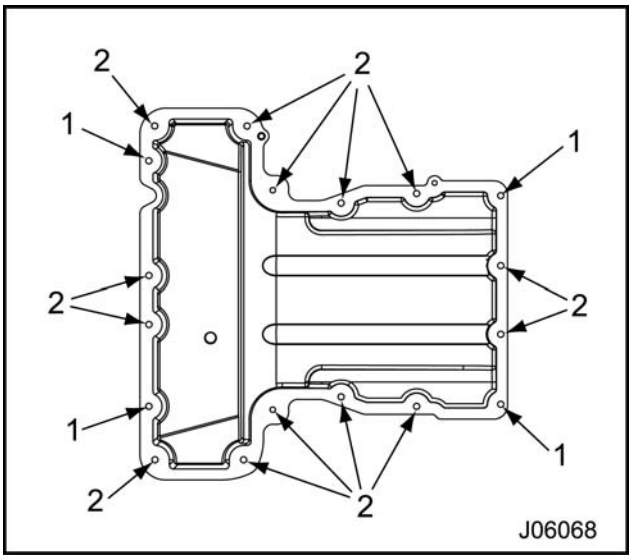

Figure 279 Lower oil pan bolt locations (stripped chassis)

1. Four bolts (M6 x 25)
2. 14 bolts (M6 x 35)

2. CityStar™ – Install five lower oil pan mounting bolts (M6 x 35) and 15 lower oil pan mounting bolts (M6 x 16).

   Stripped chassis — Install four lower oil pan mounting bolts (M6 x 25) and 14 lower oil pan mounting bolts (M6 x 35).

   Tighten all bolts to standard torque (page 400)

3. Remove tools, parts and equipment.

   a. Reinstall all safety guards, shields, and covers after servicing engine.

   b. Make sure all tools, covers, loose parts and service equipment are removed from engine area after all work is done.

Table of Contents

Exploded View

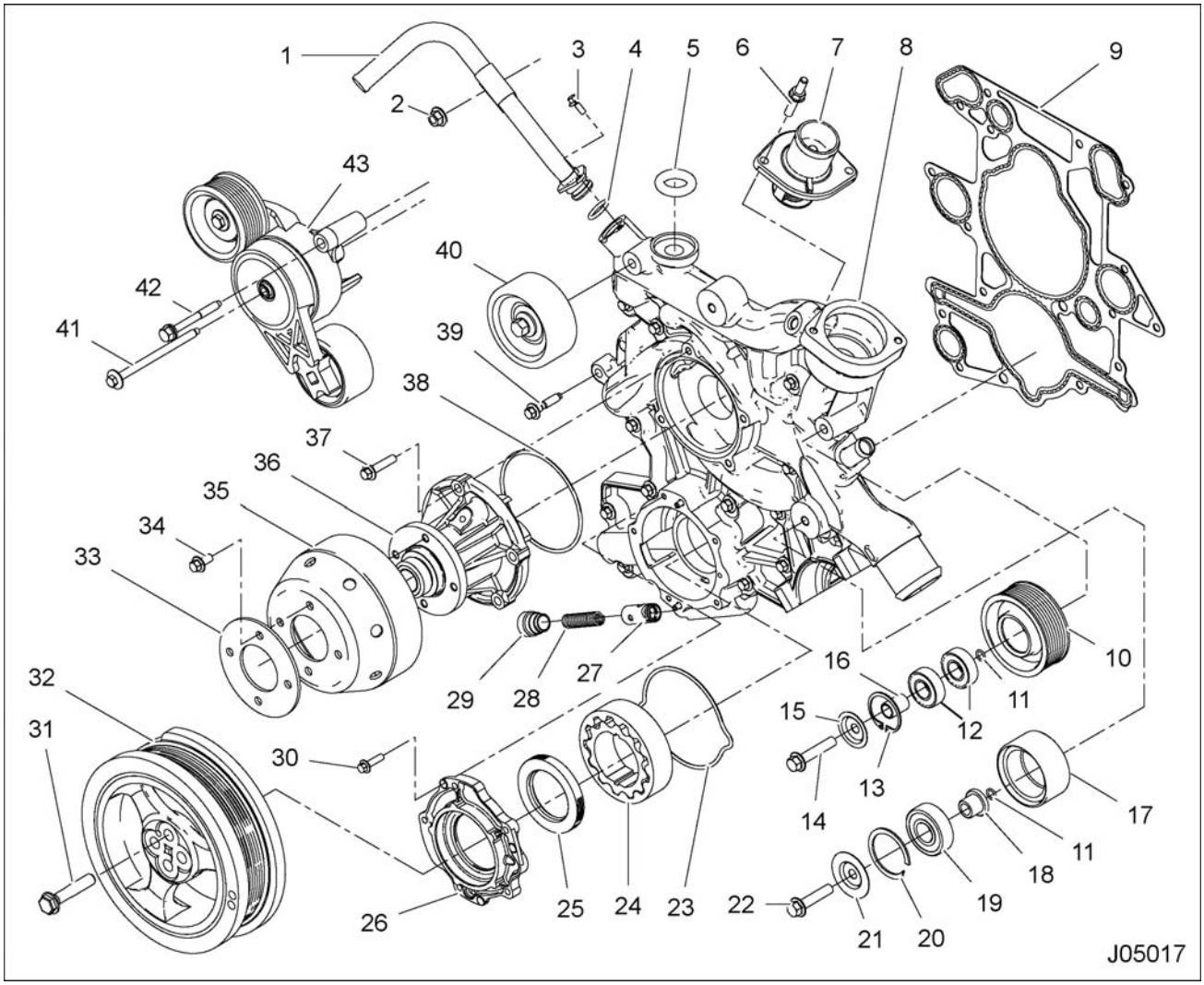

Figure 280 Front cover components

1. Heater feed tube assembly
2. Nut, M10
3. Bolt, M6 x 14
4. O-ring seal
5. Front cover O-ring seal
6. Stud bolt, M8 x 30 x 19 (2)
7. Thermostat assembly
8. Front cover assembly
9. Front cover gasket
10. 8-groove idler pulley
11. O-ring, size #904
12. Ball bearing assembly
13. Retaining ring
14. Bolt, M10 x 50
15. Dust cover
16. Spacer
17. Smooth idler pulley assembly
18. Spacer
19. Ball bearing assembly
20. Retaining ring
21. Dust cover
22. Bolt, M10 x 45
23. Gerotor cover seal
24. Gerotor oil pump assembly
25. Front crankshaft oil seal
26. Gerotor cover assembly
27. Oil pressure regulating valve
28. Spring
29. End pressure regulator plug with O-ring
30. Bolt, M6 x 25 (5)
31. Bolt, M12 x 59 (4)
32. Vibration damper
33. Reinforcement ring
34. Bolt, M8 x 16 (4)
35. Water pump / fan drive pulley
36. Water pump assembly
37. Bolt, M8 x 30 (4)
38. O-ring, size #242
39. Bolt, M8 x 35 (17)
40. Smooth idler pulley assembly
41. Bolt, M8 x 115
42. Bolt, M8 x 72
43. Belt tensioner assembly

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, make sure engine has cooled before removing components.

WARNING: To prevent personal injury or death, do not open pressurized Freon® lines.

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, 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.

Vibration Damper

1. Before removing vibration damper, measure damper runout as follows:

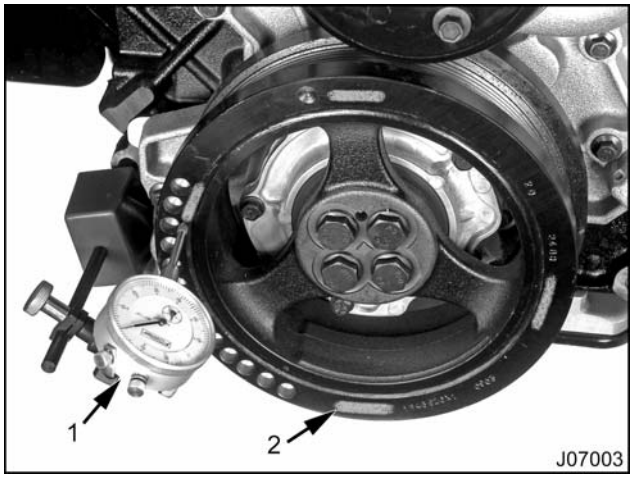

Figure 281 Check vibration damper runout

1. Dial indicator with magnetic base
2. Paint removed, four points (90° apart)

   a. Remove paint from face of vibration damper at four points approximately 90° apart.

   b. Attach a dial indicator with magnetic base (page 239) to front of crankcase. Position indicator tip onto an unpainted surface.

   c. Pry crankshaft forward and zero the dial indicator. This becomes the baseline.

      NOTE: Pry only in one direction to eliminate possible error induced by crankshaft end play.

   d. Turn crankshaft 90°. Pry crankshaft forward and record reading.

   e. Repeat at each unpainted surface. If run out exceeds specification (page 238), replace vibration damper.

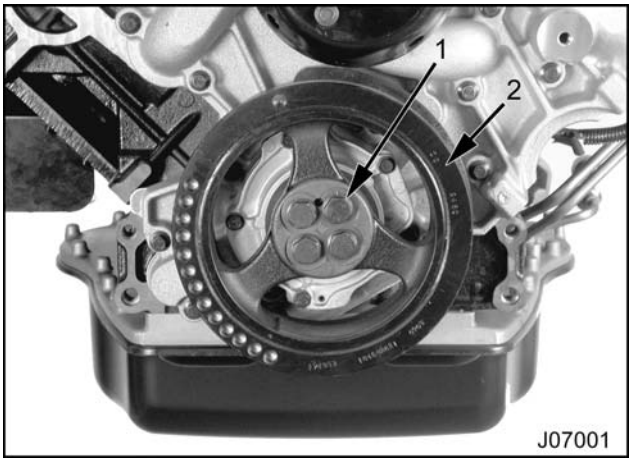

Figure 282 Vibration damper mounting bolts

1. Bolt, M12 x 59 (4)
2. Vibration damper

WARNING: To prevent personal injury or death, support the vibration damper during mounting bolt removal. The damper can easily slide off the end of the crankshaft.

2. Remove and discard the four bolts (M12 x 59) that secure vibration damper to crankshaft. The vibration damper retaining bolts are not reusable.
3. Remove vibration damper from crankshaft.

CAUTION: To prevent engine damage, do not immerse damper in petroleum based solvents. Damage to rubber damping element may result.

Front Oil Seal and Wear Sleeve

NOTE: International® MaxxForce™ 5 is not equipped with a wear sleeve during factory production. Wear sleeves are available with an oil seal service kit.

NOTE: If removing only the seal, do steps 1 through 3. Otherwise, remove seal and wear sleeve by doing steps 1 through 4.

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

1. Drill two holes 180° apart in the front oil seal.

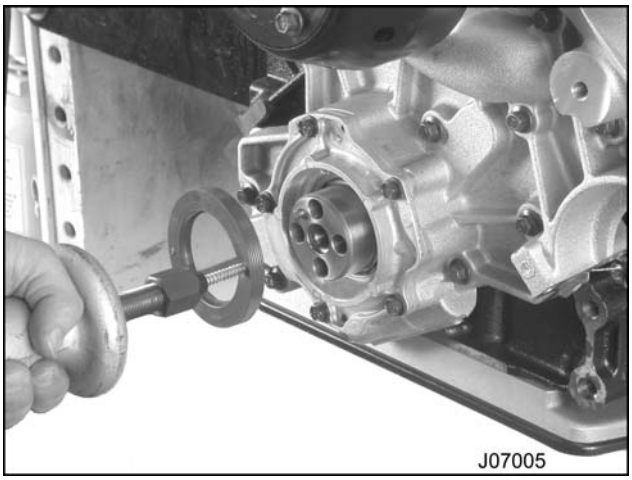

Figure 283 Front seal removal

2. Thread a slide hammer with an appropriately sized screw in one of the two holes.
3. Slide hammer until one side of the seal begins to pull out the gerotor cover. Move the slide hammer to the other hole and repeat until the front oil seal is removed completely.

NOTE: The following steps are only necessary if the engine is equipped with a front wear sleeve. Wear sleeves are only available in oil seal service kits.

4. Install the Front Wear Sleeve Remover. See Special Service Tools (page 239). Do the following steps:

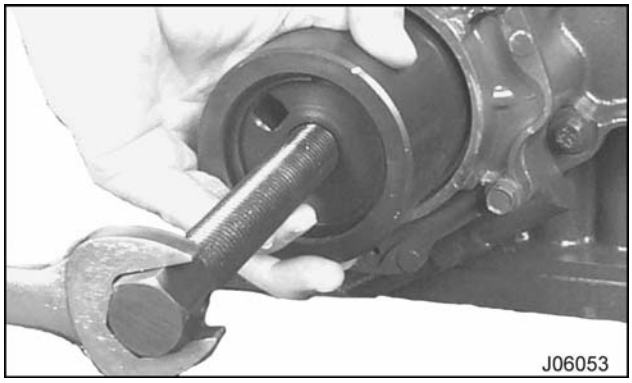

Figure 284 Front Wear Sleeve Remover

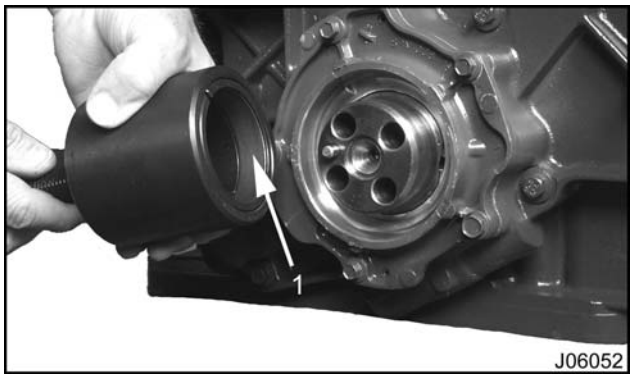

Figure 285 Front wear sleeve removed

1. Front wear sleeve

   a. Install the tool's two half shell ridges behind the front wear sleeve.
   b. Place the threaded shaft and pulling flange inside the two shells while holding the shells together.
   c. Place the shell collar over the two shells.
   d. Thread the shaft up to the crankshaft, and apply tension to the two half shells. Remove the wear sleeve.

Gerotor Oil Pump

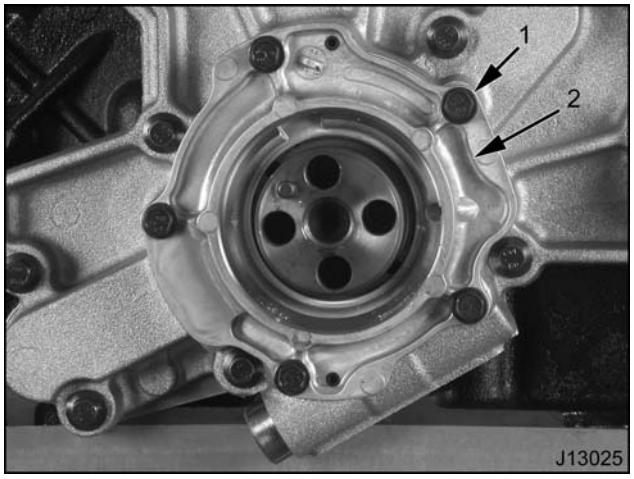

Figure 286 Gerotor oil pump cover mounting bolts

1. Gerotor oil pump cover mounting bolts (5)
2. Gerotor oil pump cover

1. Remove five gerotor oil pump cover mounting bolts (M6 x 25).
2. Carefully remove cover to expose gerotor.

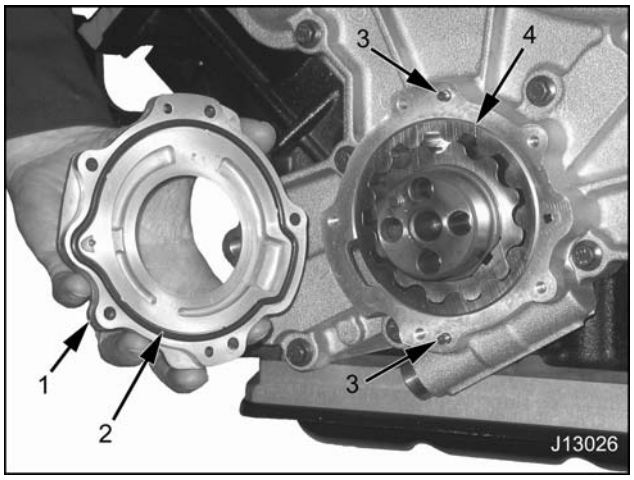

Figure 287 Gerotor oil pump

1. Gerotor cover
2. O-ring
3. Dowel (2)
4. Gerotor assembly

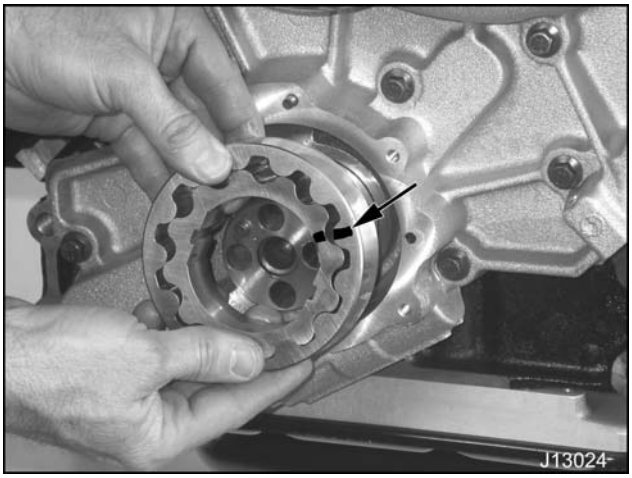

Figure 288 Gerotor orientation marking

3. Using a permanent marker, mark the forward side of each gerotor for proper reassembly and orientation.

CAUTION: To prevent engine damage, do not use paint to identify internal components or their orientation. Use permanent markers only.

4. Remove gerotor gear set from housing.

Water Pump

NOTE: If removing the front cover, the water pump and thermostat do not need to be removed, however the water pump / fan drive pulley must be removed for access to some front cover bolts.

Figure 289 Water pump / fan drive pulley removal

NOTE: If not using pneumatic tools, use a holding device to lock the fan drive pulley when removing bolts.

1. Remove four bolts (M8 x 12) securing the pulley to the water pump and remove pulley.

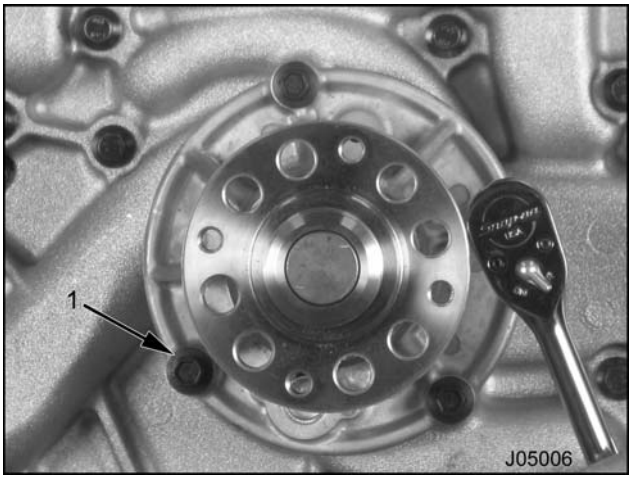

Figure 290 Water pump assembly

1. M8 x 30 bolt (4)

2. Remove four M8 x 30 bolts securing water pump assembly to front cover.
3. Remove and discard water pump O-ring.

Thermostat

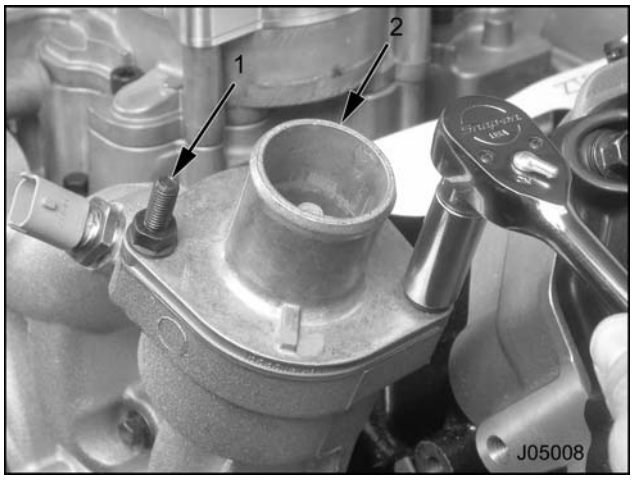

Figure 291 Thermostat assembly

1. Stud bolt, M8 x 30 x 19 (2)
2. Coolant outlet side of front cover (left side)

1. Remove two stud bolts (M8 x 30 x 19) that secure thermostat assembly to left side of front cover.
2. Remove thermostat assembly from front cover. Remove and discard O-ring.

Front Cover

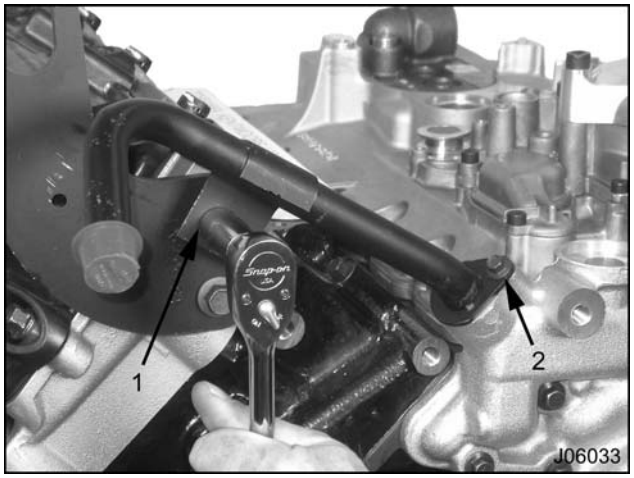

Figure 292 Heater feed tube assembly

1. Nut, M10
2. Bolt, M6 x 14

1. Remove bolt (M6 x 14) securing heater feed tube to front cover. Loosen nut (M10) at lifting eye bracket and slide heater feed tube from front cover. Remove and discard O-ring seal.

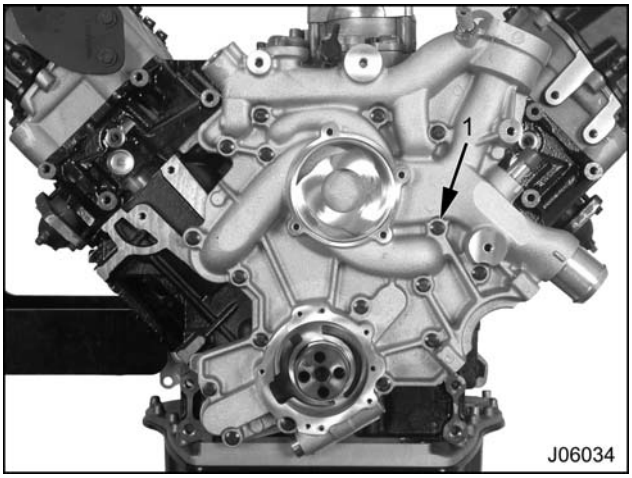

Figure 293 Front cover retaining bolts

1. Bolt, M8 x 35 (17)

CAUTION: To prevent engine damage, cut sealant where crankcase and lower crankcase meet, when removing the front cover gasket. Failure to adequately cut sealant before removing front cover and front cover gasket, can cause gasket between upper crankcase and lower crankcase to pull out. Engine removal and disassembly will be required to replace the crankcase gasket.

2. Remove 17 M8 x 35 bolts from the front cover.

3. Two conditions can occur when removing the front cover. Use the appropriate procedure listed below.

   a. Condition 1: Front cover and front cover gasket are stuck together.

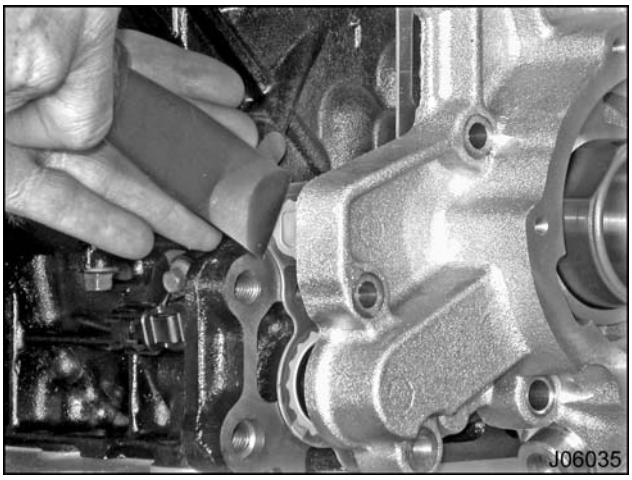

Figure 294 Cutting sealant between front cover and front cover gasket (condition 1)

Use a thin blade scraper to cut sealant between the front cover and front cover gasket. Remove front cover and follow Condition 2 instructions.

   b. Condition 2: Front cover gasket and lower crankcase gasket are stuck together.

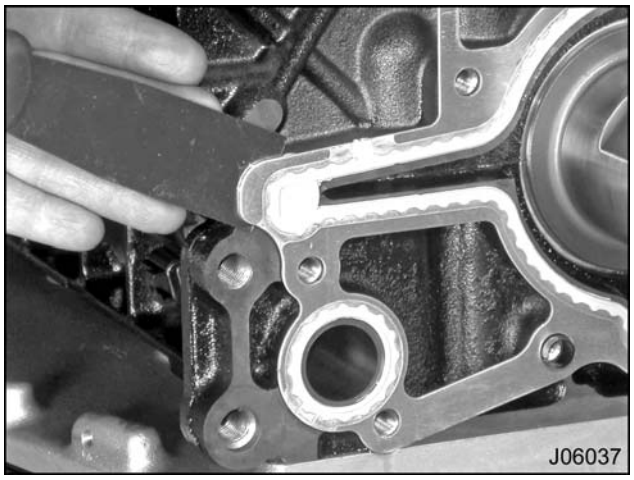

Figure 295 Cutting sealant between front cover gasket and upper / lower crankcase joint (condition 2)

Use a thin blade scraper to cut sealant where crankcase, lower crankcase and front cover gasket meet. Cut the front cover gasket loose and discard.

Cleaning, Inspection, and Testing

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

Front Cover

1. Wash components thoroughly in a suitable cleaning solvent.
2. Dry with filtered compressed air.
3. Inspect front cover for cracks.
4. Replace front cover if cracked.

Water Pump

Inspect water pump for leaks, cracks, bearing failure, and problems with the shaft seal. Replace as necessary.

Vibration Damper

CAUTION: To prevent engine damage, do not immerse damper in petroleum based solvents. Damage to rubber damping element may result.

1. Clean vibration damper with soap, water, and a soft parts brush. Dry with filtered compressed air.
2. Inspect vibration damper rubber compound for cracking, bulging or separation. See rubber bulging maximum (page 238) specification. Replace as necessary.

Thermostat

WARNING: To prevent personal injury or death, wear heat resistant gloves and appropriate eye protection during thermostat operation check.

CAUTION: To prevent engine damage, when servicing thermostat, make sure the thermostat opens fully at the specified temperature to avoid engine overheating.

NOTE: Only genuine International® thermostats ensure proper coolant flow and positive sealing for proper engine cooling.

Check thermostat operation as follows:

1. Manually open thermostat enough to insert a nylon ribbon under the valve seat. Suspend the thermostat in a container so the thermostat does not touch the bottom of the container.

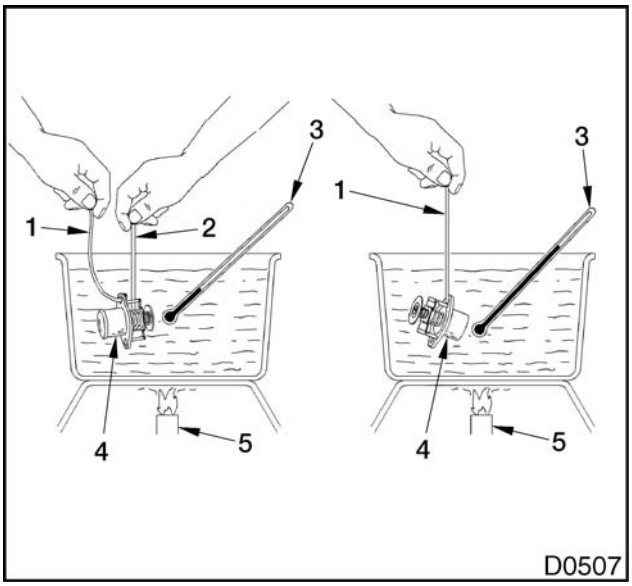

Figure 296 Test thermostat operation

1. Suspension line
2. Ribbon
3. Thermometer
4. Thermostat
5. Heat source

2. Heat 50/50 ethylene glycol and water filled container to the approximate normal operating temperature of the thermostat.
3. Observe thermometer and record temperature thermostat drops from nylon ribbon. This is the point where normal operating temperature begins.
4. Continue to heat ethylene glycol and water to the full-open temperature (page 238) of the thermostat and observe thermometer and movement of thermostat sleeve.
5. Remove thermostat from container with suspension line and let cool.
6. Inspect seat area for pitting and foreign deposits. Replace thermostat if it is damaged or does not operate correctly.

Gerotor Oil Pump

Wash all parts thoroughly in a suitable solvent. Dry with filtered compressed air.

1. Lay front cover assembly on workbench.
2. Inspect gerotors and housing for nicks, burrs or scoring.
3. Replace any damaged components.

   NOTE: The inner and outer gerotors are a matched set and cannot be replaced individually.

   - When installing new gerotors, correct orientation is not required.
   - When installing old gerotors, correct orientation is required.
4. Place inner and outer gerotors in oil pump housing.

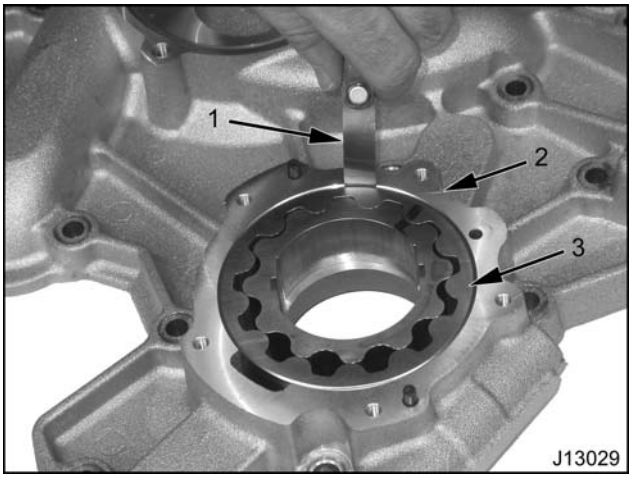

Figure 297 Inspect gerotors for wear

1. Feeler gauge
2. Front cover assembly
3. Outer gerotor

5. Use a feeler gauge to inspect for wear by checking the radial clearance (page 238) between outer gerotor and oil pump housing.

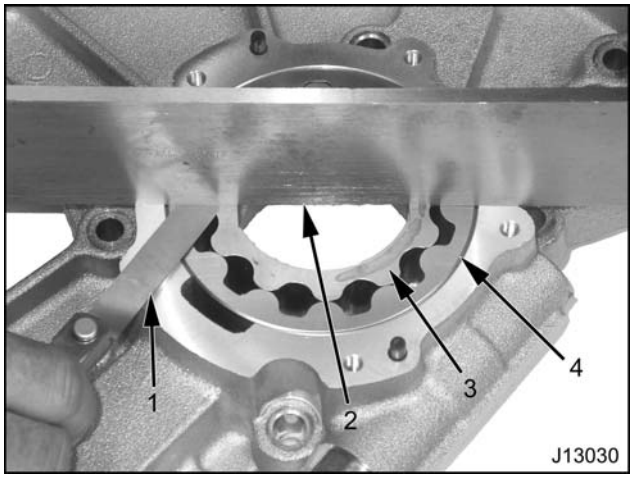

Figure 298 Check oil pump end clearance

1. Feeler gauge
2. Straightedge
3. Inner gerotor
4. Outer gerotor

6. Check oil pump end clearance as follows:
   a. With the gerotors in place in the front cover, place straightedge across housing.
   b. Insert feeler gauge under straightedge at inner and outer gerotors. Compare end clearance with Specifications (page 238).
   c. If measurements are not within specifications, replace both gerotors (as a set).

7. Use a 12 mm internal hex wrench to remove oil pressure regulator.

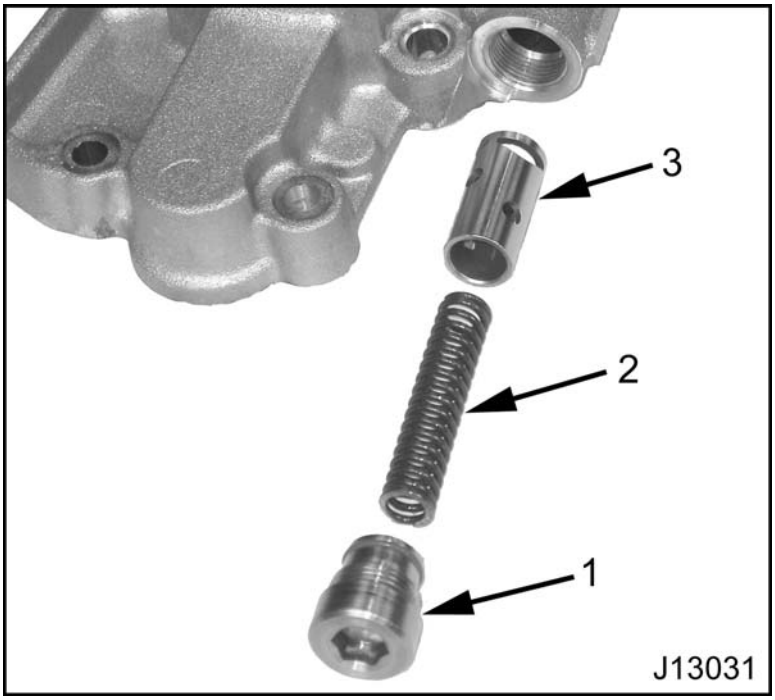

Figure 299 Oil pressure regulator components

1. End cap and O-ring
2. Oil pressure bypass spring
3. Piston poppet

8. Inspect oil pressure regulator piston poppet (steel) for binding and sticking due to debris or severe piston poppet scoring. Check for a broken oil pressure bypass spring. The spring should normally be the only potential cause of any malfunction in this assembly. Replace as necessary.
9. Check regulator bore (aluminum) for severe piston poppet scoring. It should not be expected to experience any significant dimensional wear. Refer to Specifications (page 238). Replace as necessary.
10. Install a new O-ring on the end cap.
11. Install regulator components and tighten end cap to special torque (page 238).

Installation

Front Cover

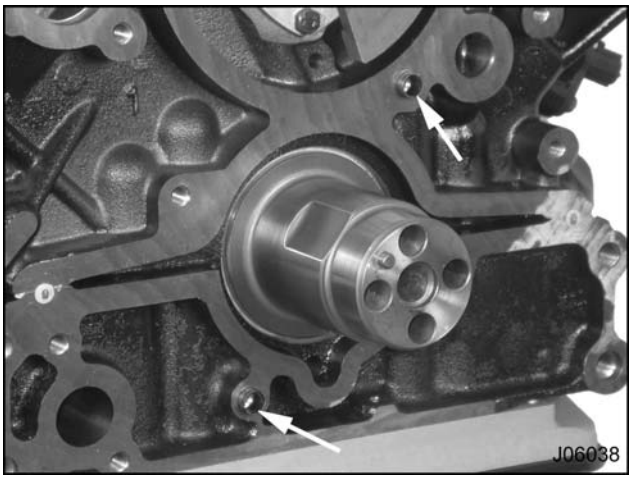

Figure 300 Front cover crankcase dowels

1. If removed, install front cover crankcase dowels.

NOTE: Dowels may become lodged in front cover. Remove dowels and install in crankcase. If dowels are bent, replace with new ones.

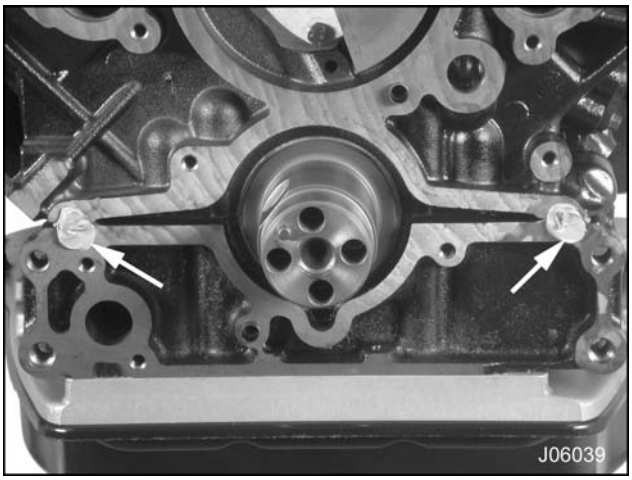

Figure 301 Locations for Liquid Gasket (RTV) application

CAUTION: To prevent engine damage, install and torque gasket and cover within five minutes of applying Liquid Gasket (RTV).

2. Apply Liquid Gasket (RTV) (page 239) to joining surfaces of crankcase and lower crankcase.
3. Install a new front cover gasket on the crankcase.

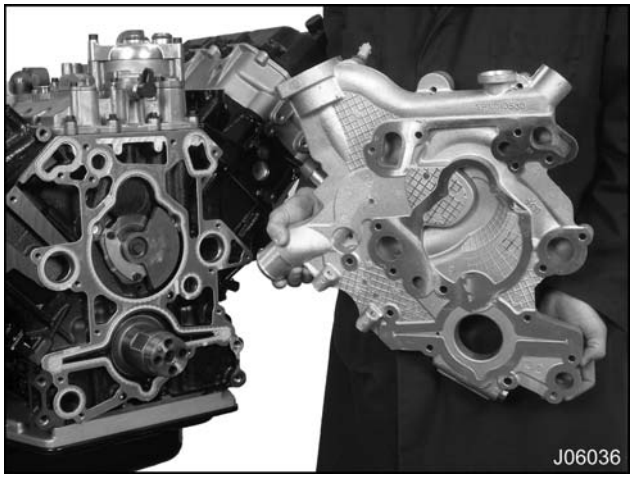

Figure 302 Front cover and gasket

4. Align front cover with crankcase dowels.

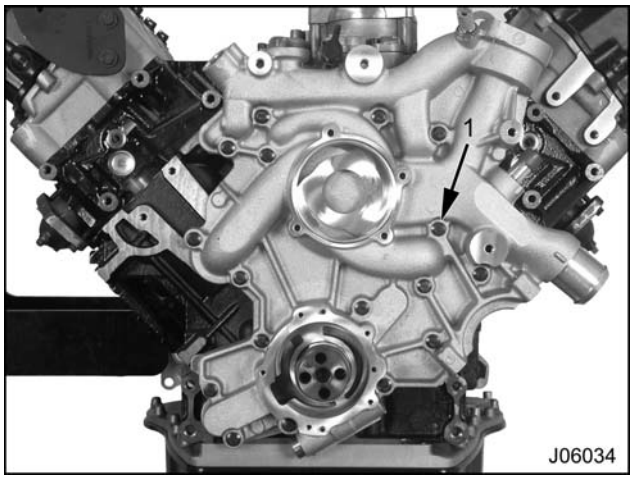

Figure 303 Front cover module retaining bolts

1. Bolt, M8 x 35 (17)

5. Install seventeen M8 x 35 bolts and finger tighten.
6. Tighten seventeen M8 x 35 bolts to special torque (page 238).

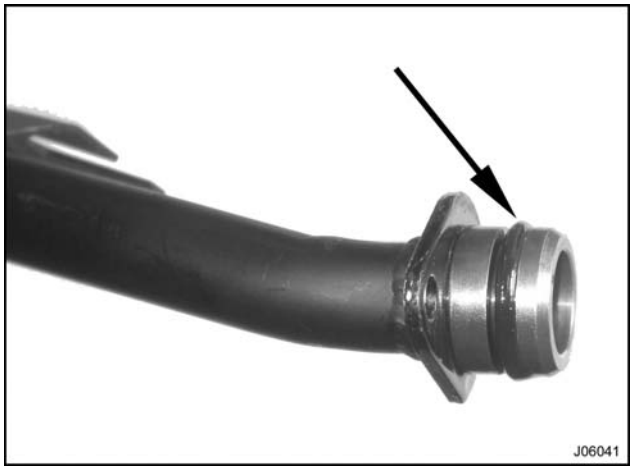

Figure 304 Heater feed tube O-ring

7. Lubricate a new heater feed tube O-ring with the recommended coolant.

CAUTION: To prevent engine damage, do not lubricate heater feed tube O-ring with engine oil. Oil produces swelling of O-ring, resulting in leakage.

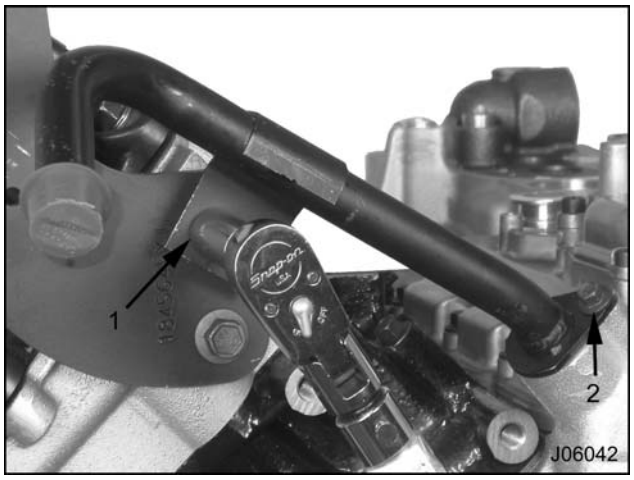

Figure 305 Heater feed tube assembly

1. Nut, M10
2. Bolt, M6 x 14

8. Install heater feed tube into front cover while aligning bracket slot with stud at lifting eye. Install bolt (M6 x 14) into front cover and tighten to standard torque (page 400). Tighten nut to special torque (page 238).

Thermostat

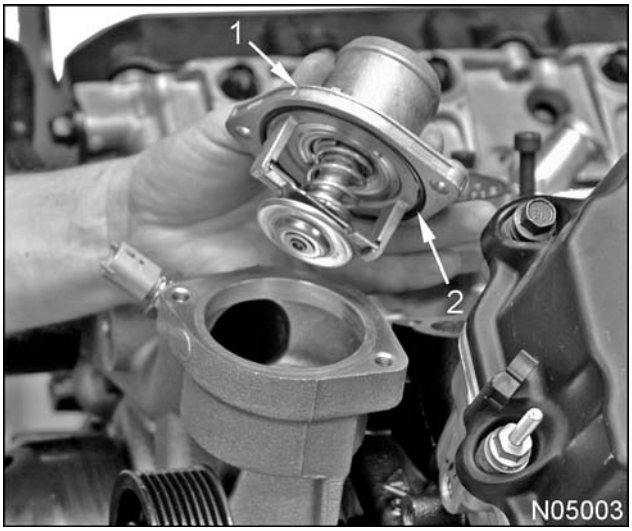

Figure 306 Thermostat assembly

1. Thermostat assembly
2. Thermostat O-ring seal

1. Install a new O-ring seal onto thermostat assembly.
2. Install thermostat assembly on front cover coolant outlet. Secure with two mounting stud bolts (M8 x 30 x 19) and tighten to special torque (page 238).

Water Pump

1. Install a new water pump O-ring onto the front cover assembly.

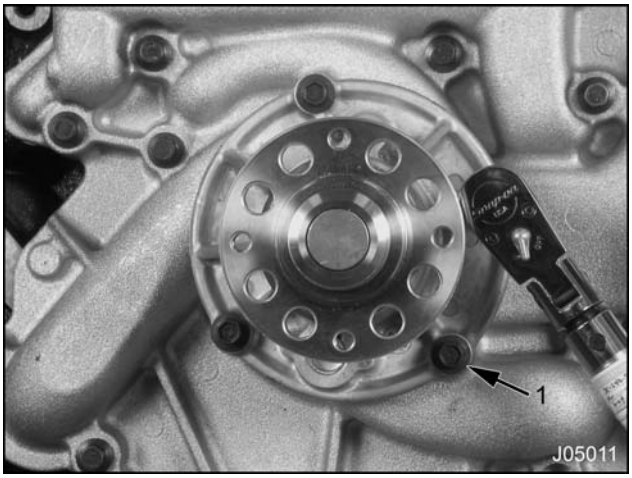

Figure 307 Water pump assembly installation

1. M8 x 30 bolt (4)

2. Install water pump assembly on front cover over the new O-ring and secure with four M8 x 30 bolts. Tighten bolts to special torque (page 238).

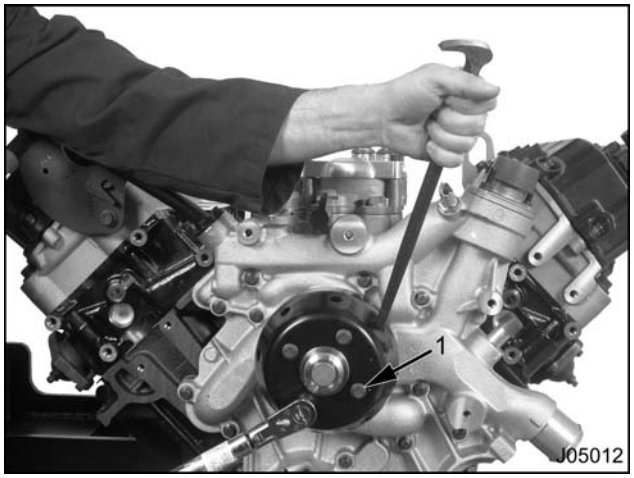

Figure 308 Water pump / fan drive pulley installation

1. Water pump / fan drive pulley mounting bolts

3. Install water pump / fan drive pulley with four bolts (M8 x 12) and tighten to special torque (page 238).

Gerotor Oil Pump

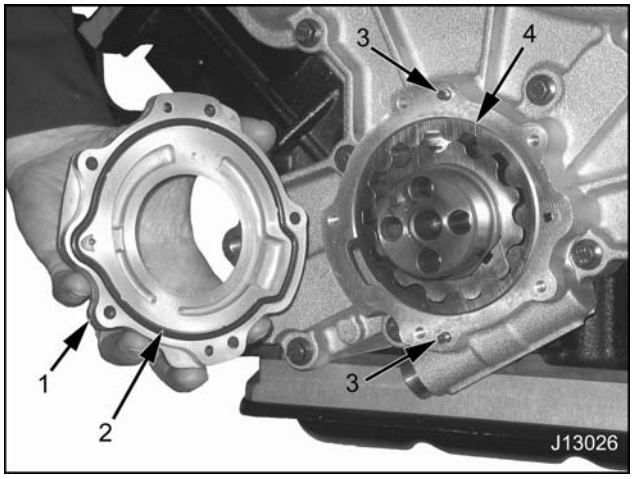

Figure 309 Gerotor oil pump

1. Gerotor oil pump cover
2. O-ring
3. Dowel pins (2)
4. Gerotor assembly

CAUTION: To prevent engine damage, when installing used oil pump rotors, make sure oil pump inner and outer rotors rotate in the same direction as before removal. See marks added during removal for proper rotor orientation.

1. Lubricate inner gear with lithium assembly grease and install on crankshaft. Lubricate outer gear with lithium assembly grease and mesh with inner gear rotor in oil pump housing. Wipe off excess assembly grease.

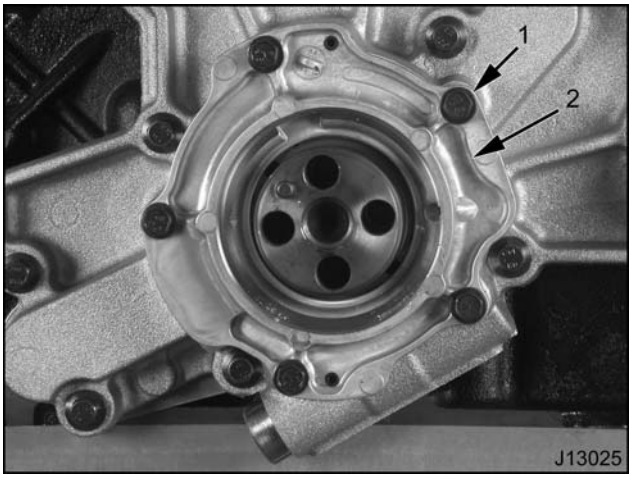

Figure 310 Gerotor oil pump housing

1. Gerotor oil pump cover retaining bolts, M6 x 25 (5)
2. Gerotor oil pump cover

2. Align dowel pins and install oil pump cover on front cover. Install five retaining bolts (M6 x 25) to oil pump cover. Tighten bolts to special torque (page 238).

Front Oil Seal and Wear Sleeve

NOTE: A wear sleeve is not installed during engine production. The wear sleeve is required for rebuild and is supplied with the front oil seal as a service part only.

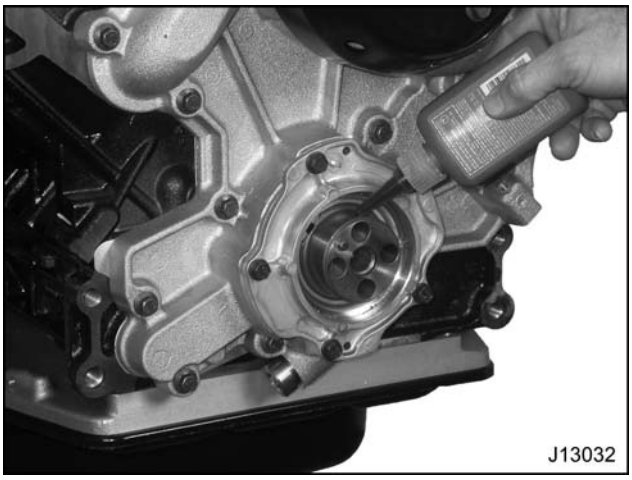

Figure 311 Loctite® Hydraulic Sealant application to crankshaft

1. Remove oil from front of crankshaft with a suitable solvent and clean rag.

   Place a 360° bead of Loctite® Hydraulic Sealant (page 239) on the leading edge of the crankshaft prior to wear sleeve installation.

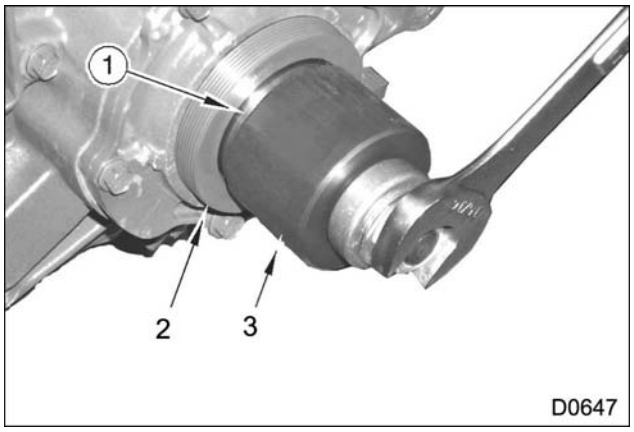

Figure 312 Front oil seal and wear sleeve installation

1. Wear sleeve
2. Front oil seal
3. Front Oil Seal/Wear Sleeve Installer

2. Install the oil seal and wear sleeve into the oil pump cover using Front Seal / Wear Sleeve Installer (page 239).
3. Install the seal and sleeve until the tool bottoms out (correct depth).

Vibration Damper

1. Align vibration damper with dowel pin located on the front of the crankshaft.

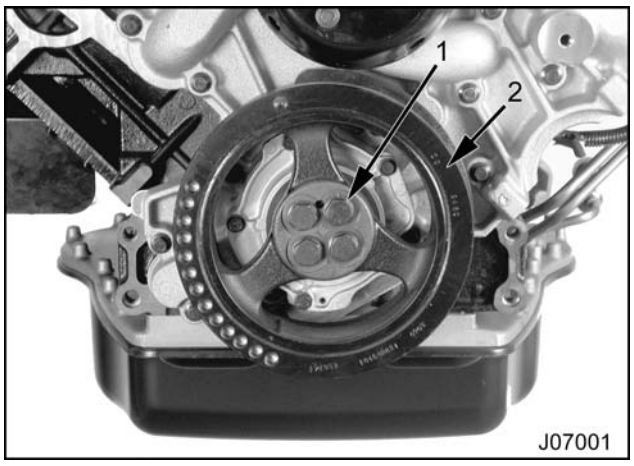

Figure 313 Vibration damper mounting bolts

1. Mounting bolts, M12 x 59 (4)
2. Vibration damper

WARNING: To prevent personal injury or death, always install four new vibration damper bolts when installing the vibration damper.

2. Install four new bolts (M12 x 59) to secure vibration damper onto crankshaft.

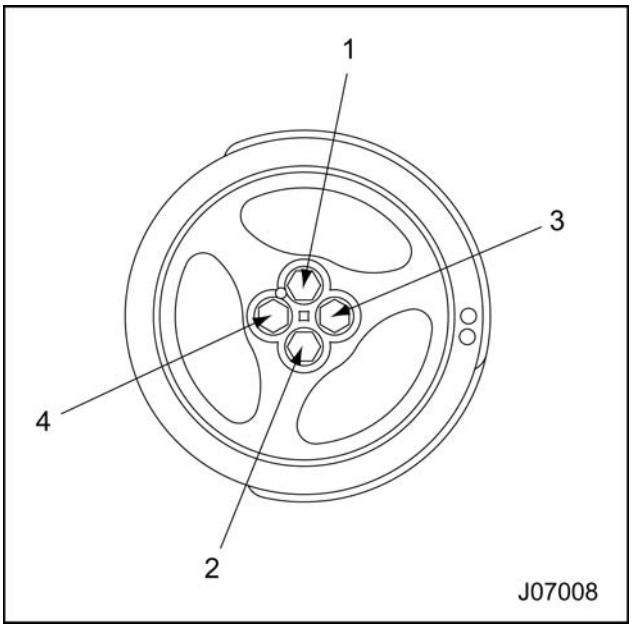

Figure 314 Vibration damper torque sequence

3. Tighten vibration damper bolts to special torque (page 238) using the above sequence.

NOTE: Refer to Accessories Drive Belt Routing (Figure 540) for idler pulley and accessory location and identification.

4. Remove tools, parts and equipment.
   a. Install all safety guards, shields and covers after servicing the engine.
   b. Make sure all tools, loose parts and service equipment are removed from the engine area after all work is done.

Specifications

Vibration Damper	
Face runout (maximum)	0.635 mm (0.025 in)
Rubber bulging (maximum)	1.5 mm (0.060 in)
Lubricating Oil Pump and Pressure Regulator	
Type	Gerotor
Drive	Crankshaft
Location	Gerotor oil pump housing (front cover)
Oil Pressure:	
• Engine oil pressure, low idle (min. @ 110 °C (230 °F) oil temp.)	69 kPa (10 psi)
• Engine oil pressure, high idle (min. @ 110 °C (230 °F) oil temp.)	276 kPa (40 psi)
• Oil pump discharge pressure (2,500 rpm)	483 to 621 kPa (70 to 90 psi)
Oil pump end clearance (inner and outer rotor to housing)	0.025 to 0.095 mm (0.001 to 0.004 in)
Oil pump radial clearance (between outer rotor and housing)	0.15 to 0.28 mm (0.006 to 0.011 in)
Oil pressure regulator bore	18.81 ± 0.02 mm (0.741 ± 0.001)
Thermostat	
Type	Balanced pressure, wax pellet
Full open temperature, >10 mm (0.394 in) stroke	104 °C (219 °F)

Special Torque

Water pump / fan drive pulley bolts, M8 x 12	36 N·m (26 lbf·ft)
Front cover bolts, M8 x 35	24 N·m (18 lbf·ft)
Nut (heater feed to lifting eye), M10	41 N·m (35 lbf·ft)
Oil pressure regulator end cap	27 N·m (240 lbf·in)
Gerotor oil pump cover bolts, M6 x 25	13 N·m (110 lbf·in)
Thermostat stud bolts, M8 x 30 x 19	22 N·m (200 lbf·in)
Vibration damper mounting bolts, M12 x 59	New bolts only: 68 N·m (50 lbf·ft) + 90° rotation
Water pump mounting bolts, M8 x 30	23 N·m (17 lbf·ft)

Special Service Tools

Dial indicator with magnetic base	Obtain locally
Fan Hub Wrench (2 inch)	ZTSE43972
Fan Wrench (pulley bolts)	ZTSE4587
Front Seal / Wear Sleeve Installer	ZTSE4680
Front Wear Sleeve Remover	ZTSE4517
Liquid Gasket (RTV) (6 oz. tube)	1830858C1
Loctite® Hydraulic Sealant	Obtain locally

Table of Contents

Exploded Views

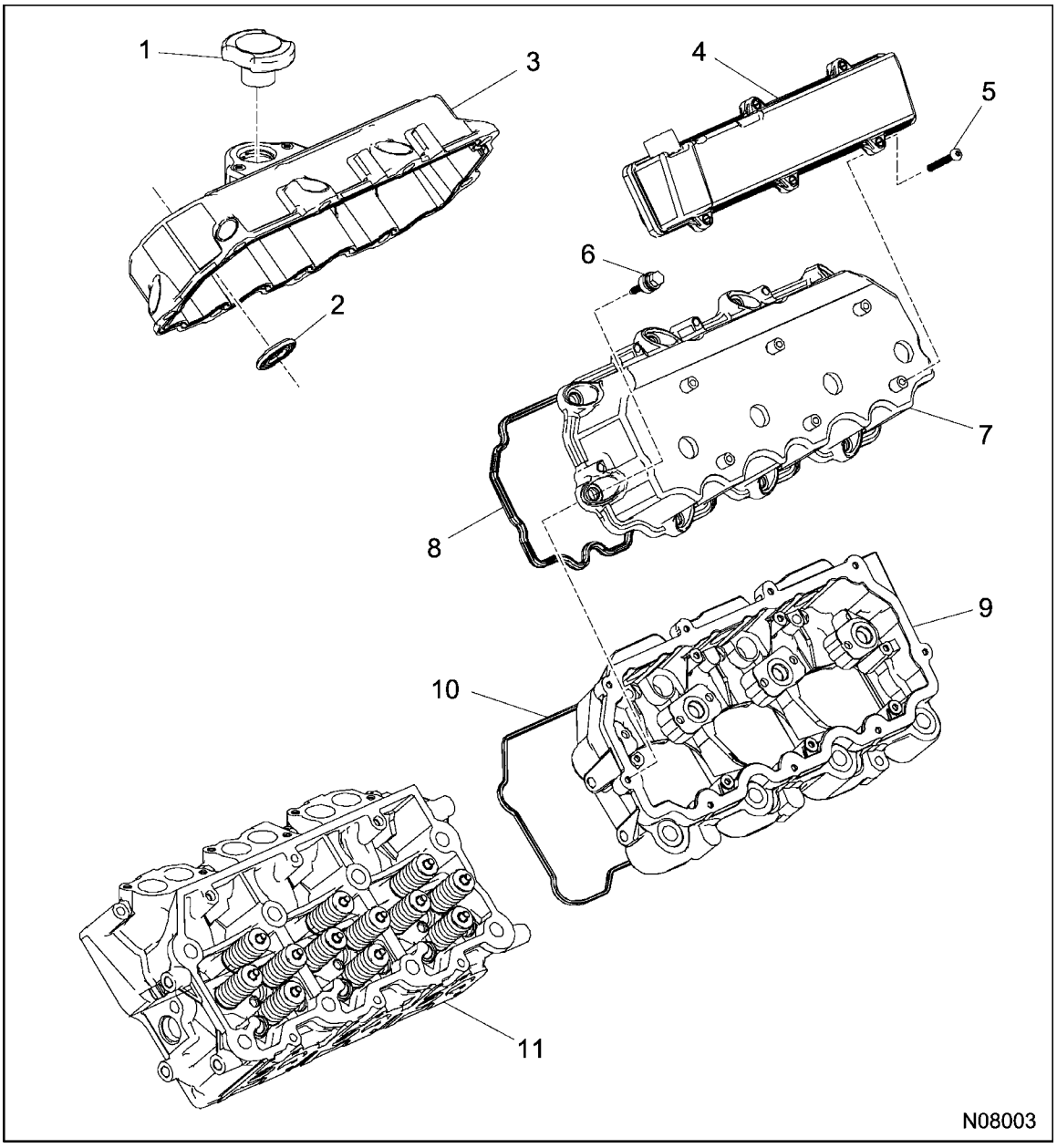

Figure 315 Cylinder head, rocker arm carrier, valve covers, and crankcase breather

1. Oil fill cap
2. ICP sensor seal
3. Valve cover (right side)
4. Crankcase breather housing assembly
5. Bolt, M6 x 43 (6)
6. Valve cover bolt (18)
7. Valve cover (left side)
8. Valve cover gasket (2)
9. Rocker arm carrier (2)
10. Rocker arm carrier gasket (2)
11. Cylinder head assembly (2)

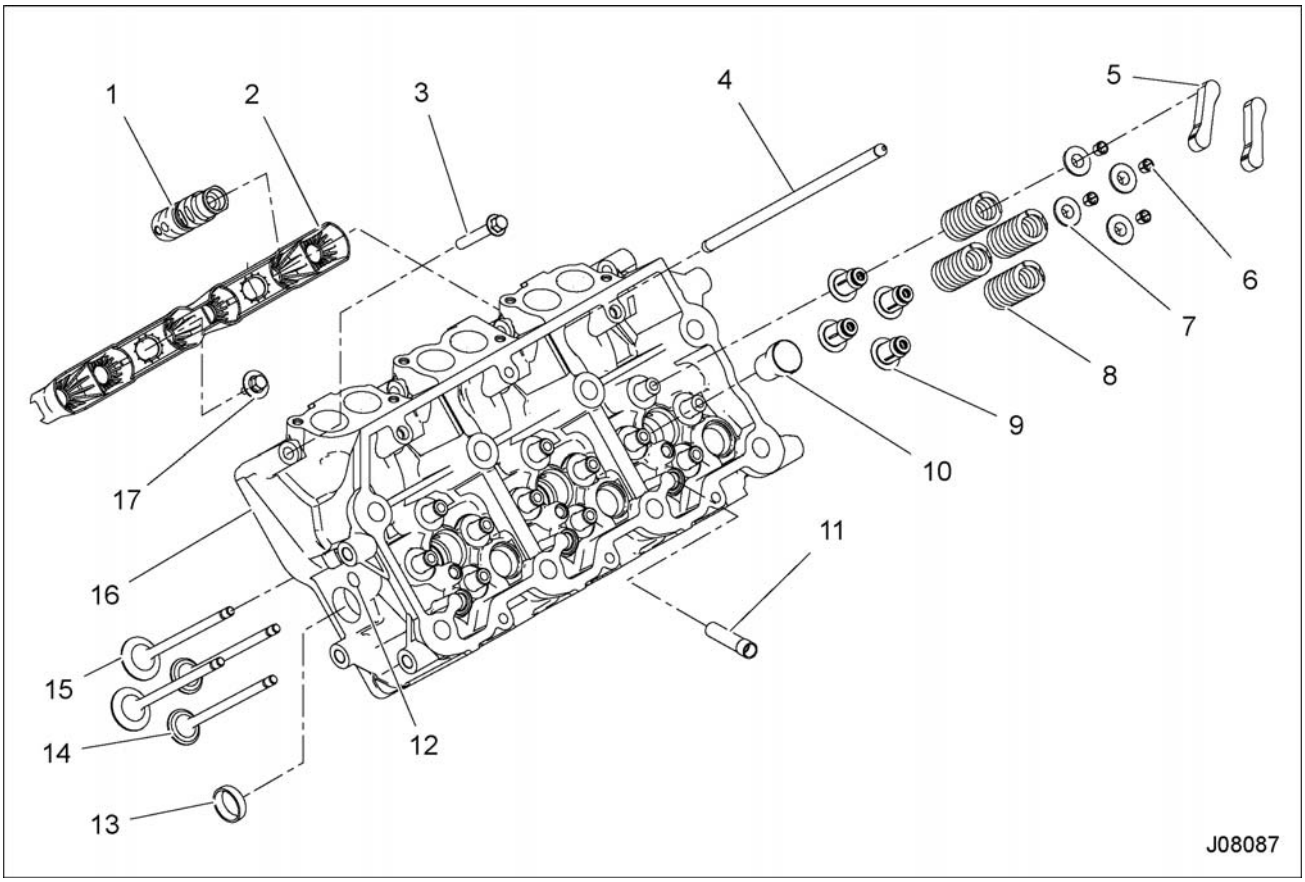

Figure 316 Cylinder head and valve train components

1. Hydraulic cam follower (12)
2. Cam follower guide (2)
3. Bolt, M8 x 70 (8)
4. Push rod (12)
5. Valve bridges (12)
6. Valve retainer keys (48)
7. Valve spring retainer (24)
8. Valve spring (24)
9. Valve stem oil seal (24)
10. Fuel injector sleeve (6)
11. Glow plug sleeve (6)
12. Fuel rail port
13. Core plug (10)
14. Exhaust valves (12)
15. Intake valves (12)
16. Cylinder head (2)
17. Bolt/washer (2)

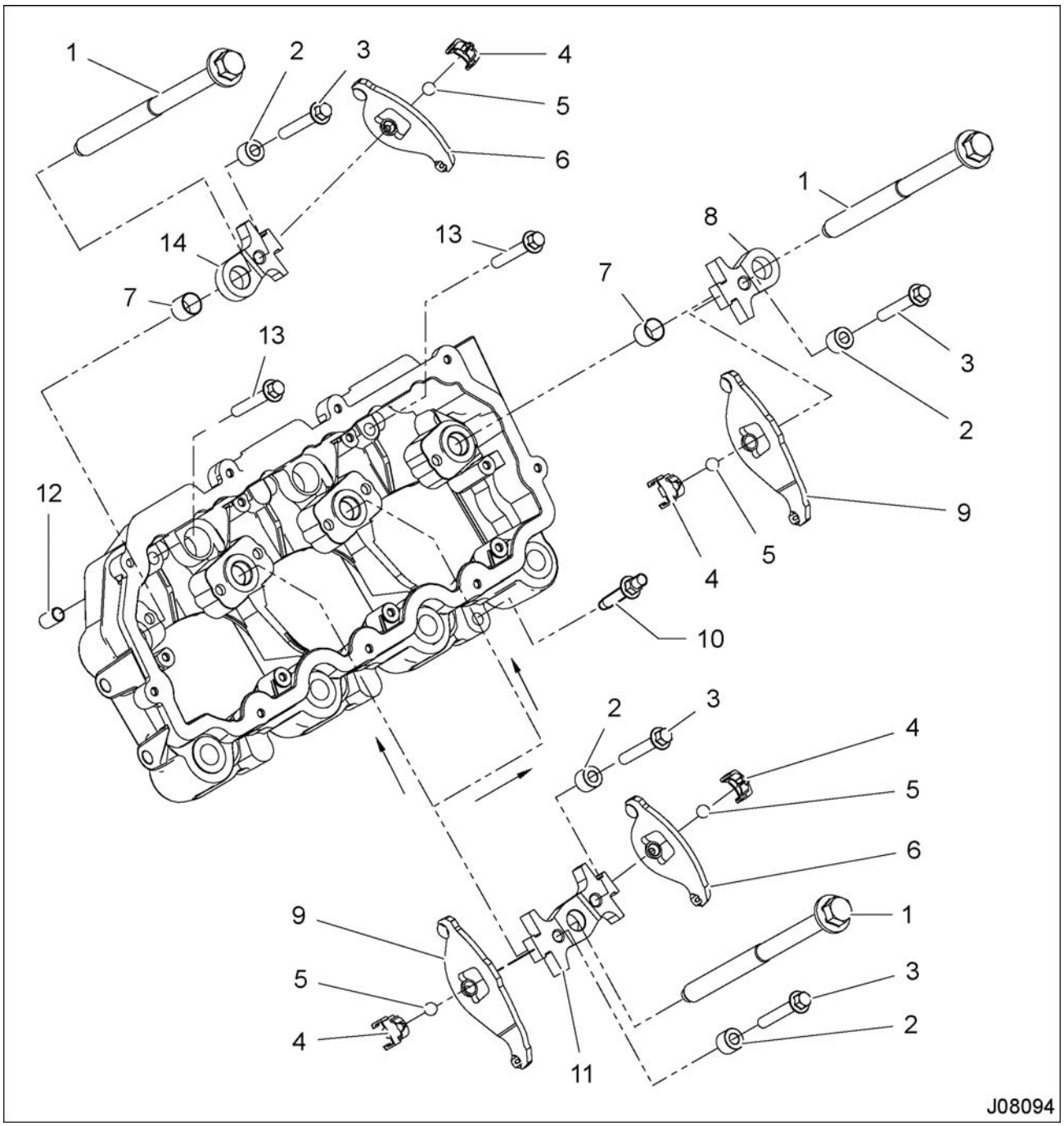

Figure 317 Rocker arm carrier components

1. Head bolt, M14 x 193 (16)
2. Fulcrum bolt spacer (12)
3. Bolt, M8 X 45 (12)
4. Rocker arm clip (12)
5. Ball, ⅜ chrome (12)
6. Rocker arm (intake) (6)
7. Dowel sleeve (end fulcrums only) (4)
8. Fulcrum plate (exhaust) (2)
9. Rocker arm (exhaust) (6)
10. Self tapping bolt stud, M10 x 30 x M8 x 10 (CityStar™ only)
11. Fulcrum plate (dual) (4)
12. Dowel sleeve bushing (4)
13. Bolt, M8 X 50 (4)
14. Fulcrum plate (intake) (2)

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, 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.

Crankcase Breather Housing

NOTE: Remove the crankcase breather only if necessary. The left valve cover may be removed without removing the crankcase breather housing.

1. Remove the crankcase breather hose from the crankcase breather housing.

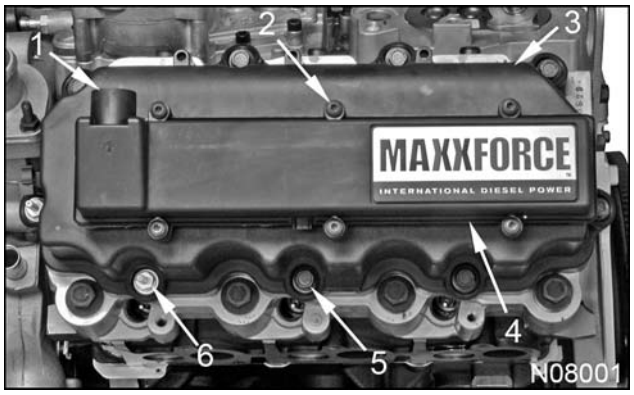

Figure 318 Crankcase breather and left valve cover

1. Crankcase breather hose connection
2. M6 x 43 breather bolt (6)
3. Left valve cover
4. Crankcase breather
5. Valve cover bolt assembly (7)
6. Valve cover stud bolt assembly (2)

2. Remove six M6 x 43 bolts securing crankcase breather to the left valve cover.

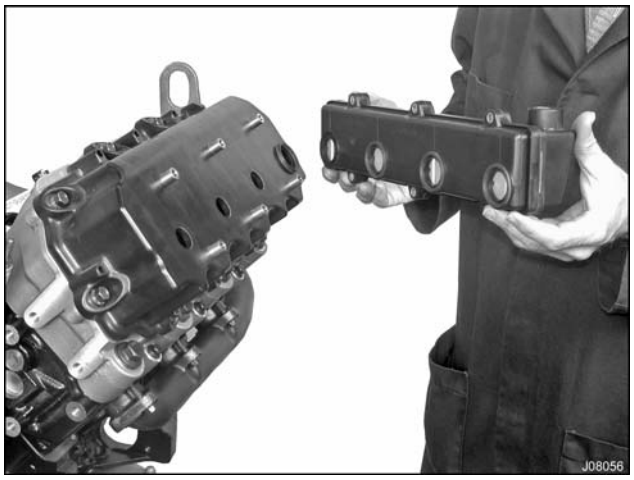

Figure 319 Crankcase breather removal

3. Remove crankcase breather from valve cover.
4. Remove four breather opening seals.

NOTE: The breather and seals are supplied as a service kit. Seals are not available separately.

Valve Covers

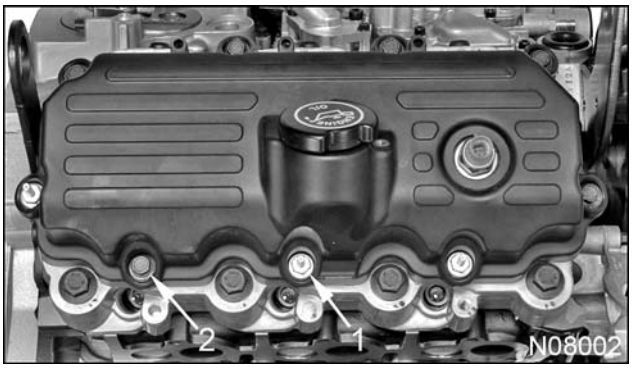

Figure 320 Valve cover mounting bolts – right

1. Valve cover stud bolt assembly (3)
2. Valve cover bolt assembly (6)

1. Loosen six valve cover bolts and three valve cover stud bolts securing right valve cover to the right cylinder head.
2. Remove the right valve cover.
3. Loosen seven valve cover bolts and two valve cover stud bolts securing left valve cover to the left cylinder head.
4. Remove the left valve cover.

Rocker Arm Carrier

1. Remove the right and left high-pressure oil rails. See “High-pressure Oil System”.
2. Remove the fuel injectors. See “Fuel System”.

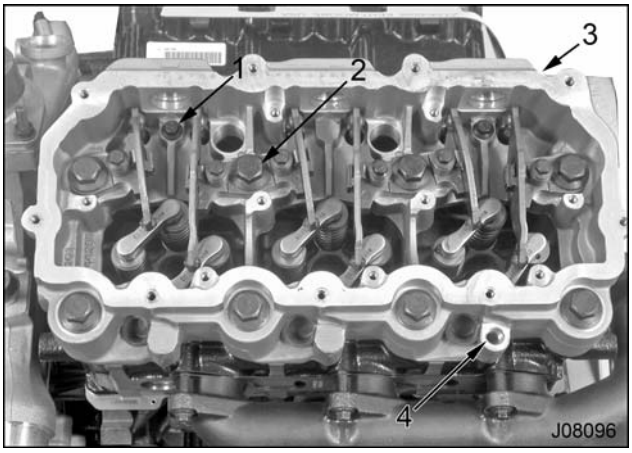

Figure 321 Rocker arm carrier assembly

1. Rocker arm carrier mounting bolts (2)
2. Cylinder head bolts (8)
3. Rocker arm carrier assembly
4. Hole for mounting stud

3. Remove two rocker arm carrier bolts (M8 x 50) and eight cylinder head bolts (M14 x 193) using a circular pattern to loosen. Begin with the outer bolts and loosen bolts moving inward. Discard cylinder head bolts.

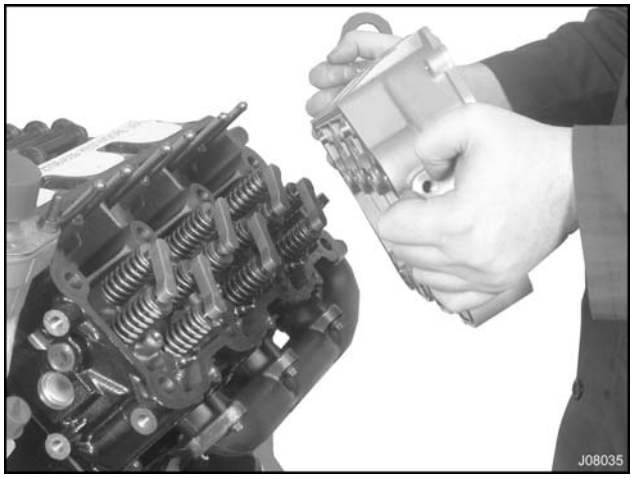

Figure 322 Rocker arm carrier removal

4. Lift rocker arm carrier assembly from cylinder head and set aside for disassembly, cleaning, inspection, and assembly.

Valve Bridges and Push Rods

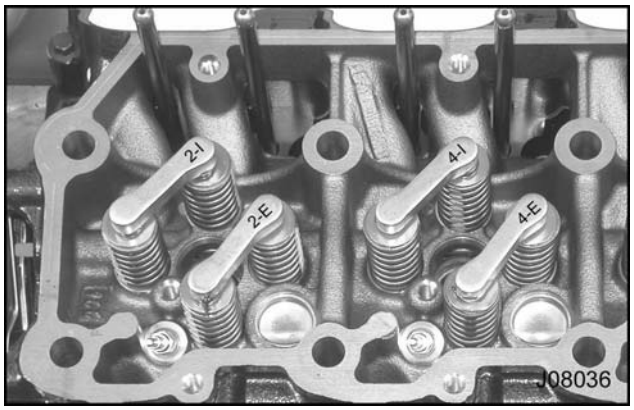

Figure 323 Valve bridge identification (left cylinder head)

CAUTION: To prevent engine damage, use permanent marker to identify internal components and their orientation. Do not use paint or temporary markers.

1. Identify each valve bridge with its respective valve set so they can be installed in their original locations.

   Example: **2 - I**

   - Cylinder number **2** as counted from the front of engine
   - **I** = Intake, **E** = Exhaust

2. Remove valve bridge by lifting bridge straight up.

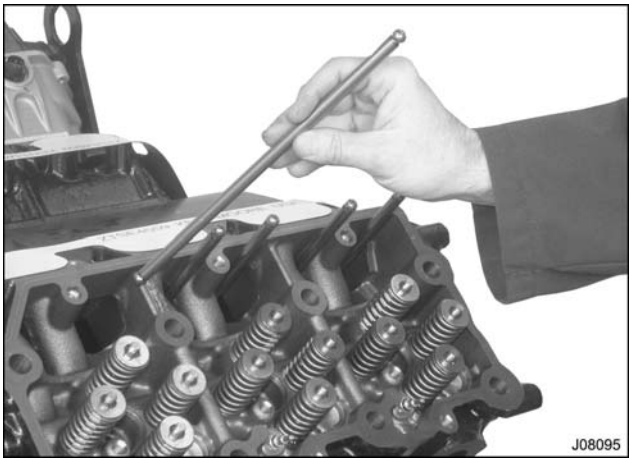

Figure 324 Push rod removal

3. Remove and identify all push rods so that they may be returned to their original positions during installation.

Cylinder Heads

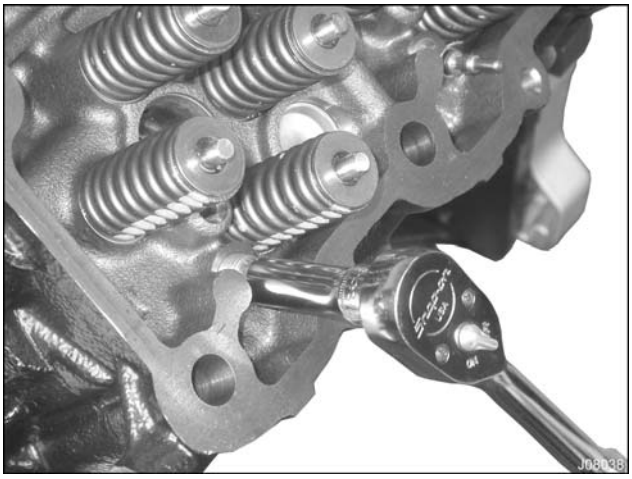

Figure 325 Glow plug removal

1. Remove six glow plugs.
2. Remove two inboard bolts (M8 x 50) along upper edge of cylinder head.

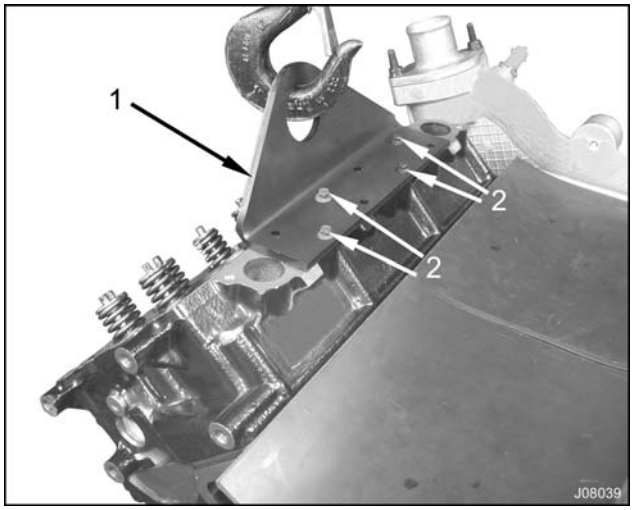

Figure 326 Cylinder Head Lifting Bracket

1. Cylinder Head Lifting Bracket
2. Lifting bracket mounting bolts (4)

WARNING: To prevent personal injury or death, mount cylinder head lifting bracket on the center of the cylinder head. Make sure lifting hook has a safety latch.

3. Install Cylinder Head Lifting Bracket (page 281) on the cylinder head using four lifting bracket mounting bolts. Locate bracket in center of head.

   NOTE: The lifting bracket allows the cylinder head to lift squarely from the crankcase.

4. Attach a lifting hoist hook or suitable lifting sling to lifting bracket.

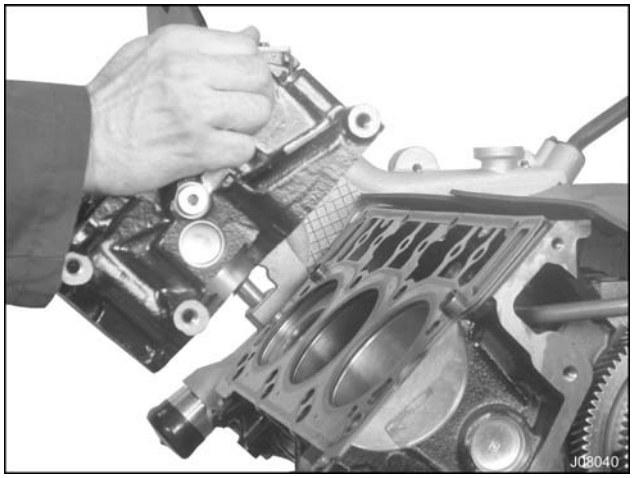

Figure 327 Cylinder head removal from crankcase

5. Lift cylinder head from the crankcase. Be careful not to damage cylinder head locating spring dowel pins. Place cylinder head on suitable surface, using caution not to scratch cylinder head surface.

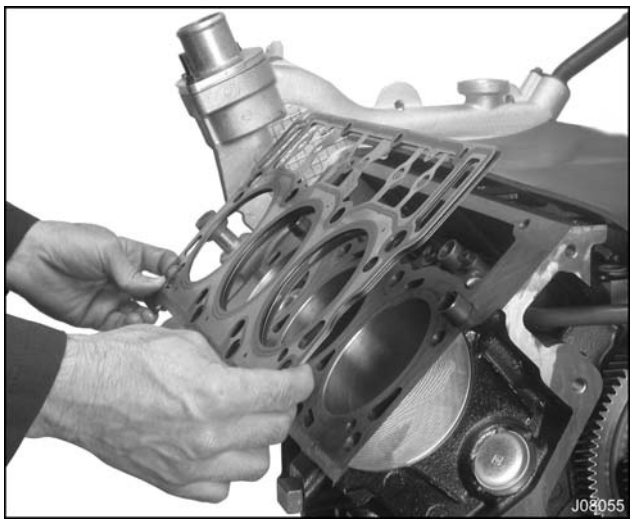

Figure 328 Cylinder head gasket removal

6. Remove and discard the cylinder head gasket.

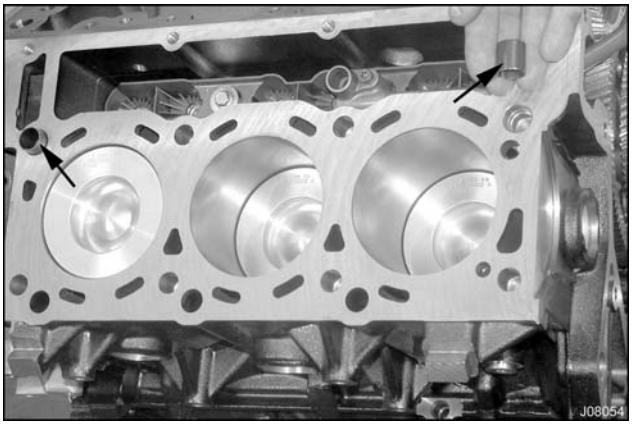

Figure 329 Cylinder head spring dowel pins

NOTE: Inspect cylinder head spring dowel pins. If pins are loose, damaged or missing, replace with new.

Hydraulic Cam Followers

NOTE: As a general rule, hydraulic cam followers should not be serviced when they are functioning satisfactorily and operate quietly.

NOTE: If it is necessary to remove the cam followers, the rear cover, high-pressure oil pump cover, and branch tube assembly must be removed. See “Rear Cover” and “High-pressure Oil System”.

CAUTION: To prevent engine damage, keep cam followers in the order they were removed. Install all cam followers back in their original positions.

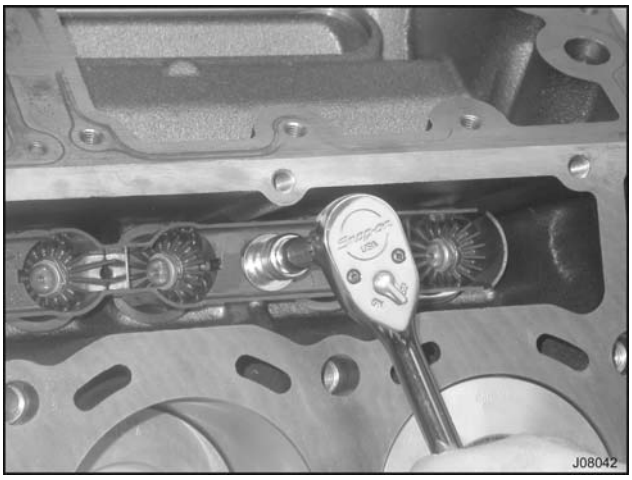

Figure 330 Roller follower guide bolt / washer removal

NOTE: Be careful when removing the mounting bolt / washer assembly used to secure roller follower guide to crankcase. These are small parts which can easily fall into the crankcase during removal.

1. Remove one bolt and washer (M6 x 12) assembly from forward guide hole and lift out guide and roller lifters.

NOTE: Identify location and orientation of each cam follower and guide during disassembly.

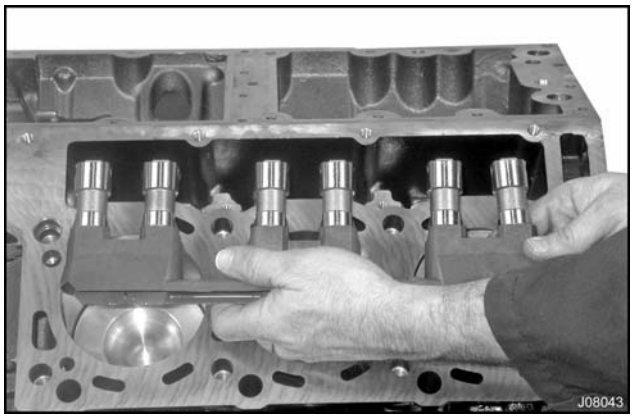

Figure 331 Cam followers and roller follower guide removal

2. Remove cam followers and roller follower guide by lifting the guide straight up. Some followers may need to be removed individually using hand tools.

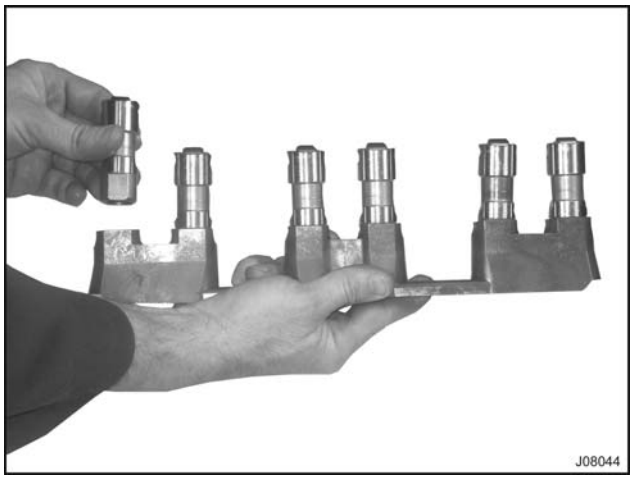

Figure 332 Cam follower removal from guide

3. Remove individual cam followers from roller follower guide.

Cleaning, Inspection, and Tests

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

Cylinder Head and Valve Train Components

Cleaning

1. With valves installed to protect seats, remove deposits and gasket material from valve heads and gasket surface with a scraper and wire brush. Be careful not to damage cylinder head gasket surface.
2. Use a suitable solvent to remove dirt, grease, and other deposits from parts removed.
3. Clean all bolt holes and be sure gasket surfaces, oil returns, and coolant passages are clean. After a thorough rinsing with hot water, blow out passages with filtered compressed air.
4. Wash all bolts and hardware (except head bolts, these must be replaced) with a suitable solvent and dry thoroughly.

NOTE: Clean crankcase threads are essential. Dirt or damaged threads may cause binding and false torque readings.

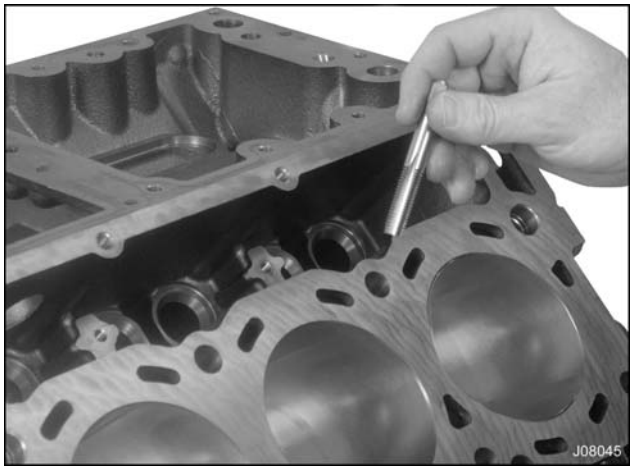

Figure 333 Crankcase cylinder head bolt hole cleaning

5. Use a Head Bolt Bottoming Tap (page 281) to clean each tapped hole in crankcase top deck. Remove debris with filtered compressed air.

CAUTION: To prevent engine damage, install new head bolts when installing the cylinder head.

6. Thoroughly clean each push rod using a suitable solvent and dry with filtered compressed air.

Cylinder Head Inspection

NOTE: Cylinder head condition must be evaluated by inspecting for thickness, warping, cracks, and valve leakage.

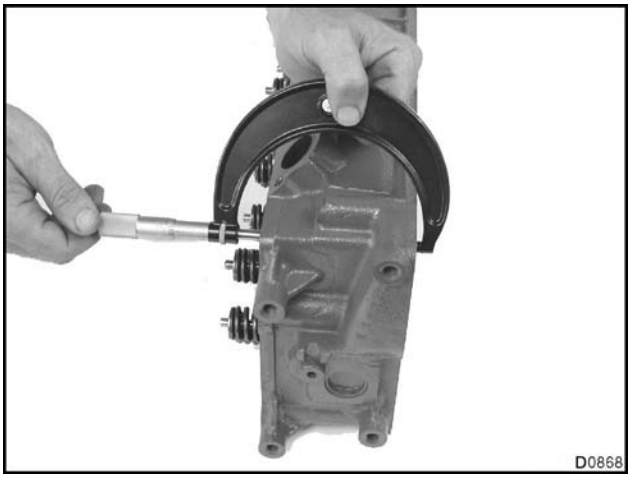

Figure 334 Cylinder head thickness measurement

1. To determine if cylinder head has been resurfaced previously, use a 3-4 inch micrometer to measure cylinder head deck thickness at four corner locations. If overall cylinder head thickness (deck-to-deck) specification is not met, replace cylinder head. See Specifications (page 280).

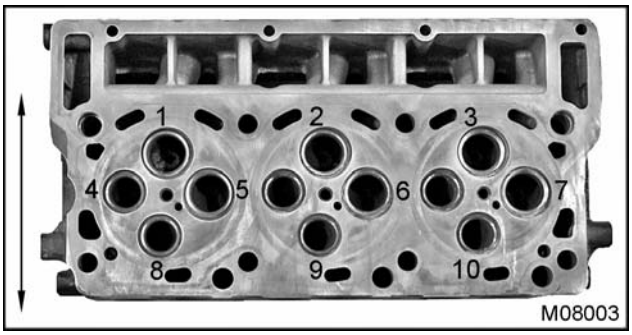

Figure 335 Inspection points for cylinder head flatness check

NOTE: It is not necessary to remove the valves to do the cylinder head flatness check.

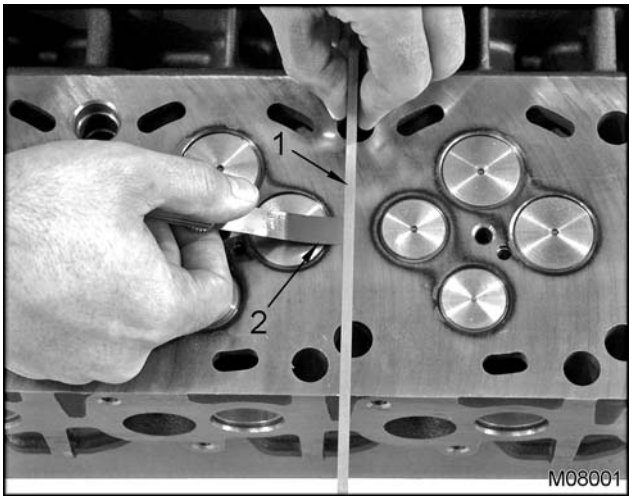

Figure 336 Cylinder head flatness measurement

1. Straightedge
2. Feeler gauge

2. Use a straightedge (page 281) and 0.051 mm (0.002 in) feeler gauge to check cylinder head gasket surface for flatness. Position straightedge only in the direction of the double ended arrow line shown above. Check cylinder head flatness at each point 1 through 10. If the feeler gauge passes through the gap between the cylinder head and straight edge easily, replace that cylinder head.

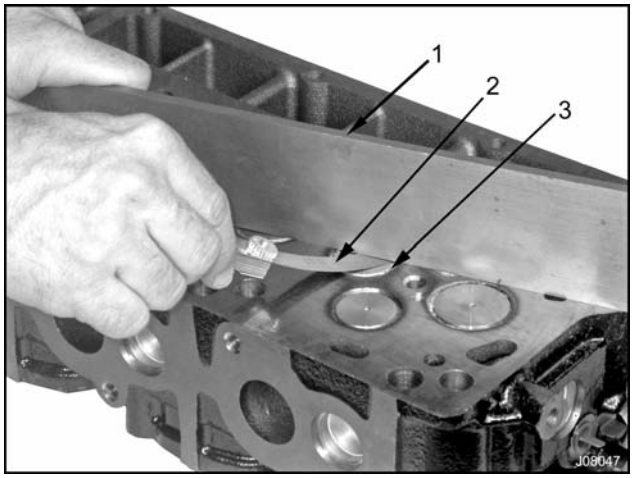

Figure 337 Checking valve recession

1. Straightedge
2. Feeler gauge
3. Valve head

3. Before removing valves, check valve head recession (relative to deck) as follows:
   a. Place a straightedge across each valve.
   b. Place a feeler gauge between straightedge and valve head. Record valve recession clearance.
   c. If out of specification, replace valve. Perform step 2 over again, and if specifications are still not met, replace cylinder head. See Specifications (page 280).

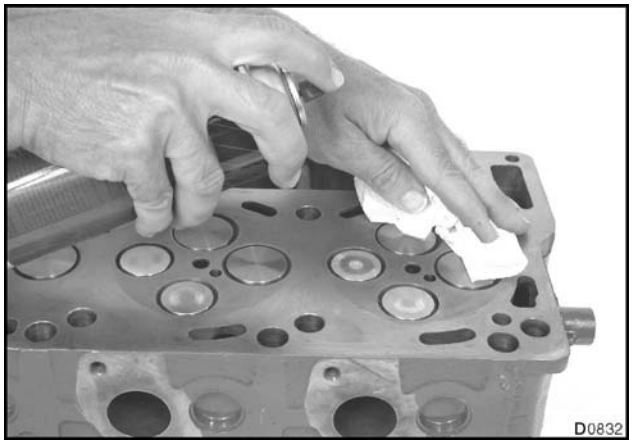

Figure 338 Spraying cleaner on cylinder head

4. Inspect for cracks in the cylinder head using the Dye Penetrant Kit (page 281).

   a. Spray cleaner on gasket surface of cylinder head and wipe dry.

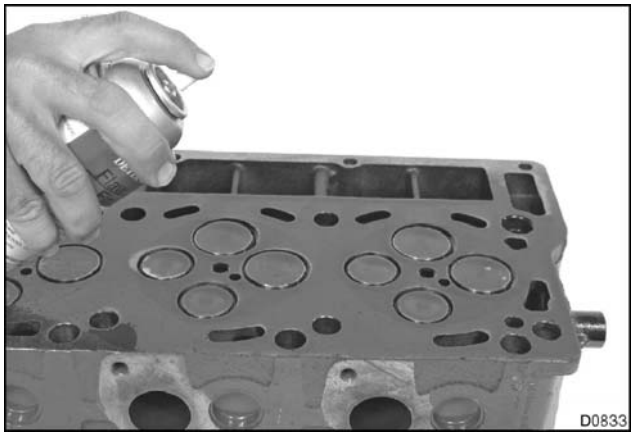

Figure 339 Spraying Dye Penetrant onto cylinder head

   b. Spray dye penetrant onto gasket surface of cylinder head. Allow dye to remain on surface from 1 to 30 minutes.

   c. Wipe dye off cylinder head surface.

      NOTE: Dye will remain in any cracks during this 'wipe off' step.

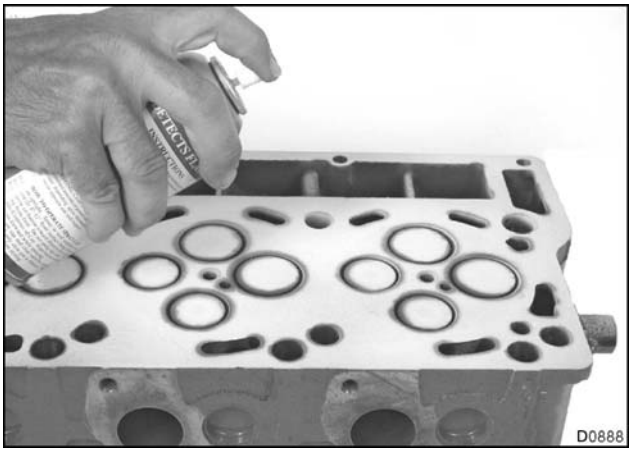

Figure 340 Spraying developer onto cylinder head

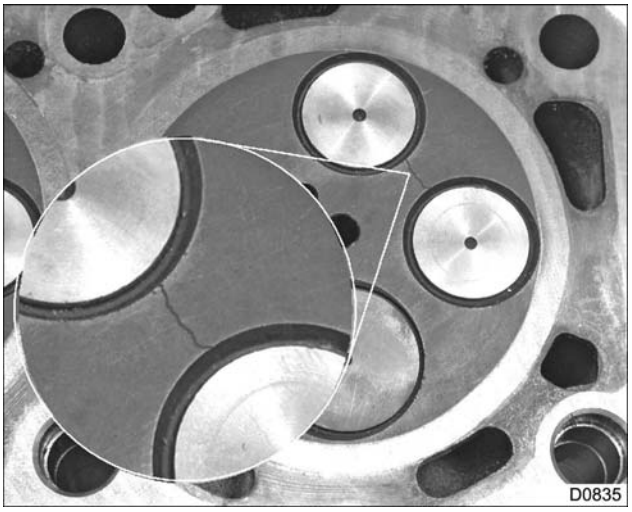

Figure 341 Cylinder head crack between intake and exhaust valves

   d. Spray developer on gasket surface of cylinder head and let dry for 5 to 15 minutes. Cracks will show up as purple lines against white developer.

   e. Replace cylinder head if cracks are present.

5. Check for valve leakage using mineral spirits as follows:

   a. Position cylinder head on wooden blocks with gasket surface facing down.

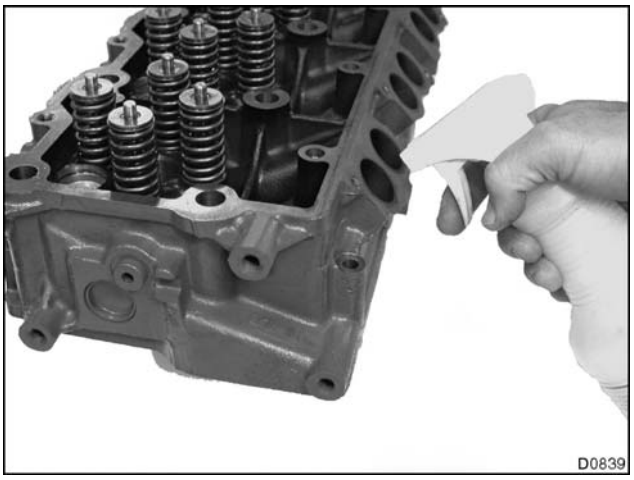

Figure 342 Squirting ports with mineral spirits

   b. Squirt mineral spirits in intake and exhaust ports.

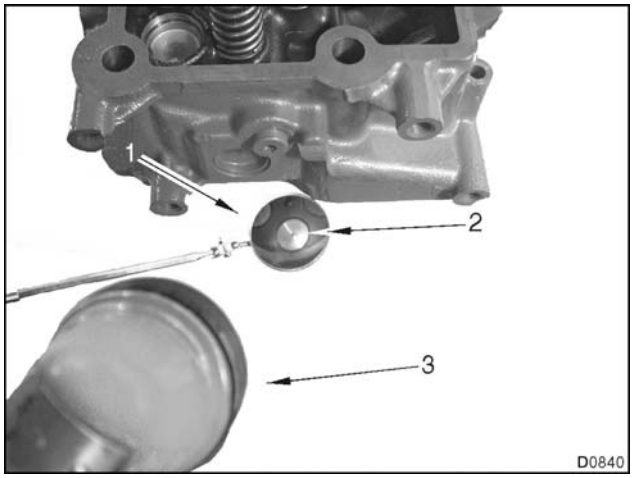

Figure 343 Inspecting for leaks

1. Inspection mirror
2. Reflection of valve
3. Flashlight

   c. Wait five minutes. Use an inspection mirror to inspect valve seat area for leakage of mineral spirits.

      NOTE: There should be no leakage. Valve seat reconditioning is not required if the cylinder head passes the mineral spirits test.

   d. If leakage is observed, the valves require reconditioning.

Removing Valves from Cylinder Head

NOTE: Valve removal is only required if replacing valves or reconditioning valve seats. Valve seat reconditioning is not required if the cylinder head passes the mineral spirits test, see Cleaning, Inspections, and Tests.

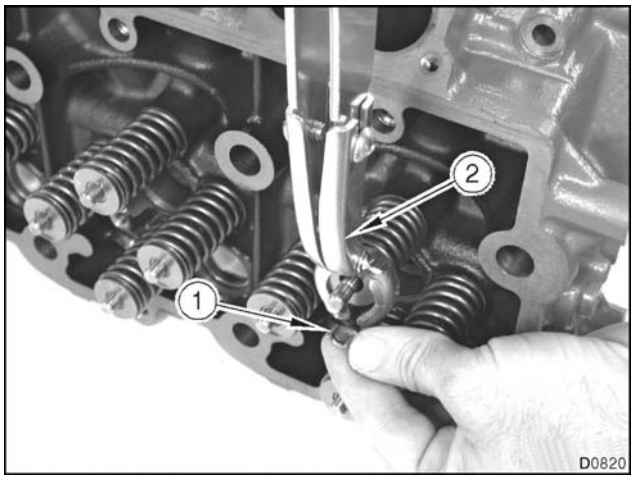

Figure 344 Removing the valve retainer keys

1. Valve retainer keys
2. Valve Spring Compressor

1. Use the Valve Spring Compressor to compress valve springs. Remove valve retainer keys. A small magnet is useful for this procedure. See Special Service Tools (page 281).

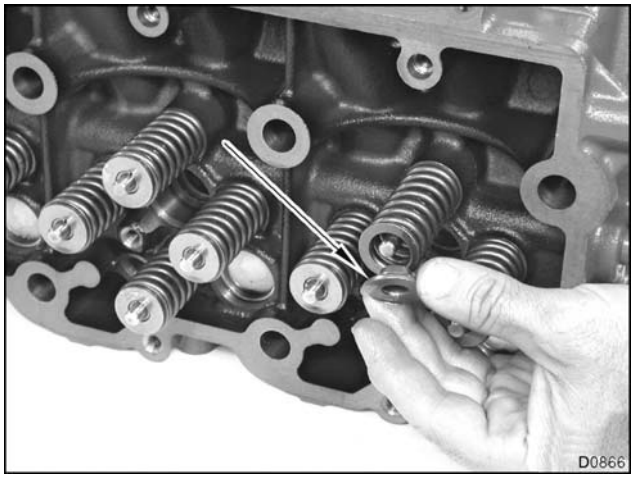

Figure 345 Valve spring retainer

2. Remove valve spring retainers.
3. Remove valve springs from cylinder head.

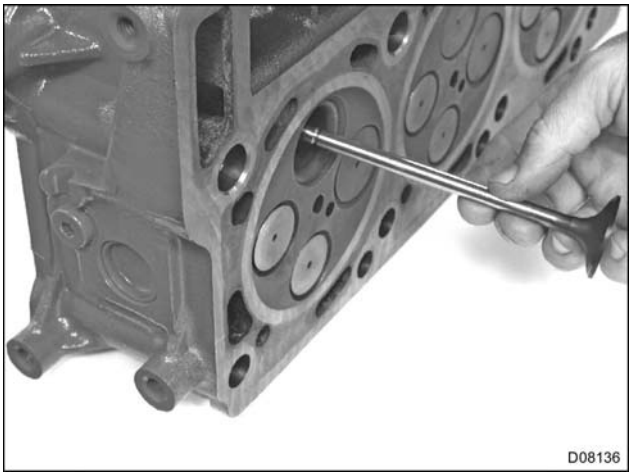

Figure 346 Removing valves from cylinder head

4. Remove valves from cylinder head.

Figure 347 Removing valve stem oil seal

5. Remove valve stem oil seals and discard. Valve stem seals are not reusable. Pliers will be necessary to get seal off end of the valve stem guide.

Cylinder Head Inspection – Valves Removed

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

1. Pressure testing the cylinder head will reveal cracks in ports or sleeve leakage which cannot be observed using dye penetrant. Pressure test the cylinder head as follows:

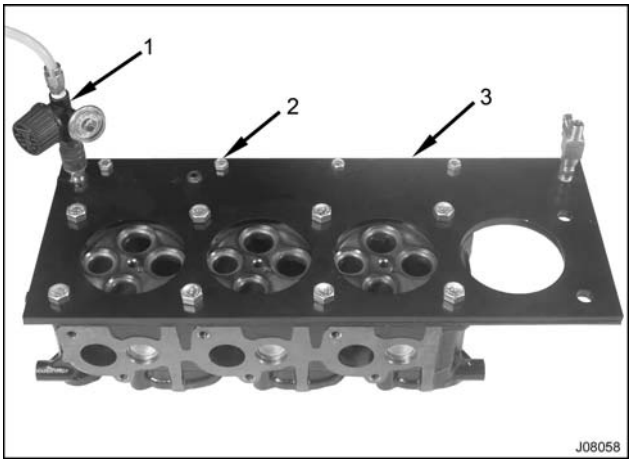

Figure 348 Cylinder Head Test Plate

1. Pressure gauge and regulator
2. Mounting bolts (12 total)
3. Pressure test plate

   a. Fasten the Cylinder Head Pressure Test Plate tool, with rubber gasket attached, to gasket side of cylinder head. Secure plate using eight (M14) bolts and four (M8) bolts. See Special Service Tools (page 281).

   b. Install pressure test regulator and gauge assembly to cylinder head test plate.

   c. Immerse cylinder head in water. Apply air pressure and adjust to 124 to 138 kPa (18 to 20 psi) and inspect for leaks at the following places. If any leaks are observed replace the cylinder head:

      - Ports
      - Upper cylinder head deck
      - Lower cylinder head deck
      - Injector sleeve area
      - Glow plug sleeve area

2. With the valves removed from the cylinder head, clean all valve guides using a nylon brush, soap and water. Blow out any residue with filtered compressed air.
3. Position an inspection light at the bottom of the valve guide bores and examine the walls for burning or cracking. Replace the cylinder head as necessary.

Figure 349 Measuring the small hole gauge (valve guide ID)

4. Measure each valve guide by using a 0-1 inch outside micrometer.

   a. Record each valve guide inner diameter so valve-to-guide running clearance may be determined.

   b. If valve guide inner diameter exceeds specifications, replace cylinder head. See Specifications (page 280).

5. Clean valve seat area using suitable solvent, prior to visual inspection.
6. Inspect the exhaust valve seats for burned or cracked conditions. If any of these conditions exist, replace cylinder head.

Push Rods

1. Inspect each push rod for wear and deposits which may restrict the flow of oil into the rocker arm assemblies. Replace push rods as required.

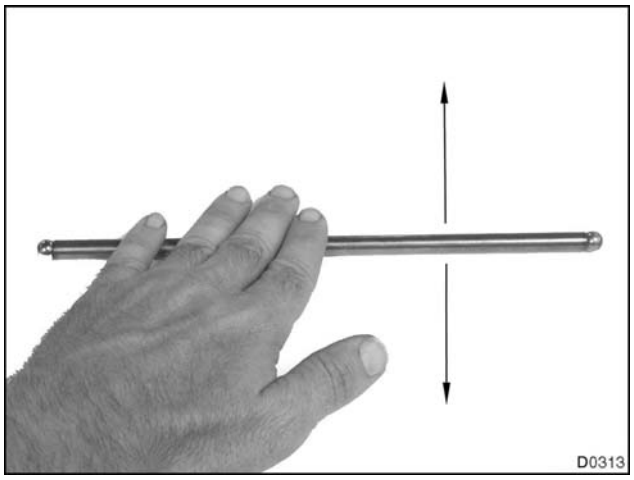

Figure 350 Checking for push rod straightness

2. Check all push rods for straightness by rolling them on a straight flat surface. If a push rod is not straight, replace as necessary. See Specifications (page 280).

Valves

1. Remove carbon deposits from valve stems and valve heads.
2. Inspect each valve, replacing any that show excessive burn marks, warping, scuffing, bending, or valve tip spalling.

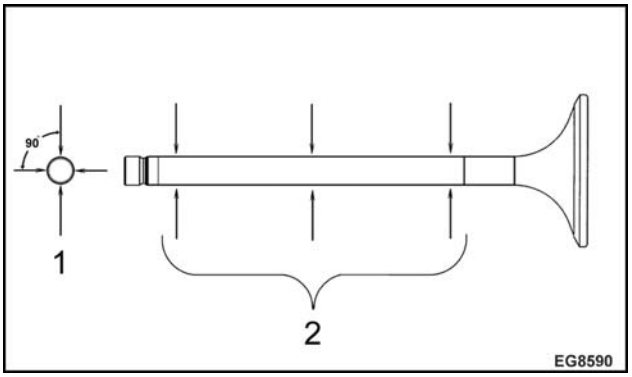

Figure 351 Valve stem measurement points

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

3. Measure each valve stem diameter for wear using a 0-1 inch micrometer. Measure valves at three locations 90° apart and record readings. Replace valves not within minimum stem diameter specification (page 280).

NOTE: The intake valve has a larger diameter head.

4. Using the valve guide inside diameters measured earlier and the valve stem diameter measurements just recorded, determine valve stem-to-guide running clearance. Replace valve or cylinder head as required. See Specifications (page 280).

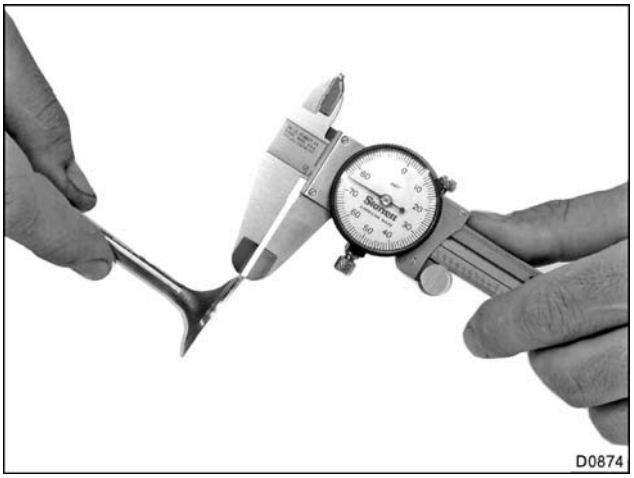

Figure 352 Measuring the valve face

5. Measure the valve face margin at four locations (90° apart) using a dial caliper.

CAUTION: To prevent engine damage, the minimum valve face margin must be maintained across the entire valve face. An insufficient margin will not provide proper heat dissipation and lead to valve warping or breakage. Intake and exhaust valve margins are different. Replace valve if the margin is less than the specified minimum. See Specifications (page 280).

NOTE: If valves and seats are in a serviceable condition, they may be re-faced to the specified angles. See Specifications (page 280).

Valve Springs

1. Clean all valve springs in a suitable solvent.
2. Inspect valve springs for rust, pitting, distortion, and cracks. If any of these conditions exist, replace the valve spring.

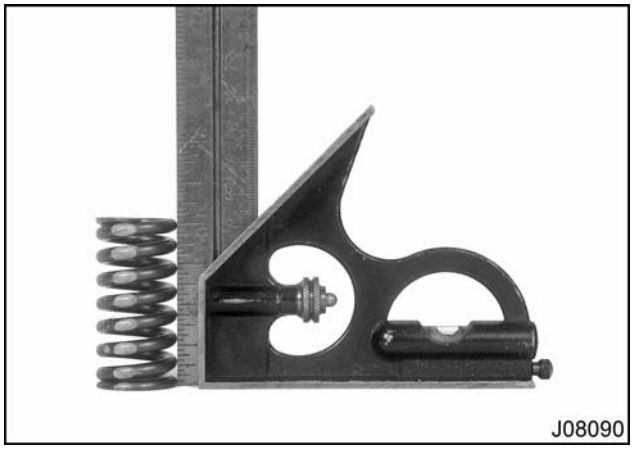

Figure 353 Check the squareness of each valve spring

3. Inspect valve spring ends to verify they are square. Square ends prevent lateral loads on valve stem. Replace springs as required.

Figure 354 Check valve spring free length

4. Measure valve spring tension using Valve Spring Tester (page 281). Replace any springs as required.
   a. Measure valve spring free length. See Specifications (page 280).

Figure 355 Measuring valve spring length under load

   b. Apply the appropriate test loads to each spring and determine whether test length is achieved. See Specifications (page 280).

Valve Spring Retainer Keys

1. Clean all valve spring retainer keys with a suitable cleaning solvent.
2. Inspect the inside and outside of the valve spring retainer keys for wear. Replace any worn valve spring keys as required.

Fuel Injector Sleeve Removal

NOTE: Fuel injector sleeve removal is only required if leaks were found during pressure test or the inner surface is nicked or scratched.

CAUTION: To prevent engine damage, (if replacing fuel injector sleeves in chassis), coat bottom of the injector sleeve with a dab of grease prior to cutting threads. The grease will prevent small metal chips from entering combustion chamber.

NOTE: The fuel injector sleeve is made of stainless steel. Lubrication of the Injector Sleeve Remover (thread tap) is required.

1. Lubricate Injector Sleeve Remover (thread tap) (page 281) with clean engine oil.

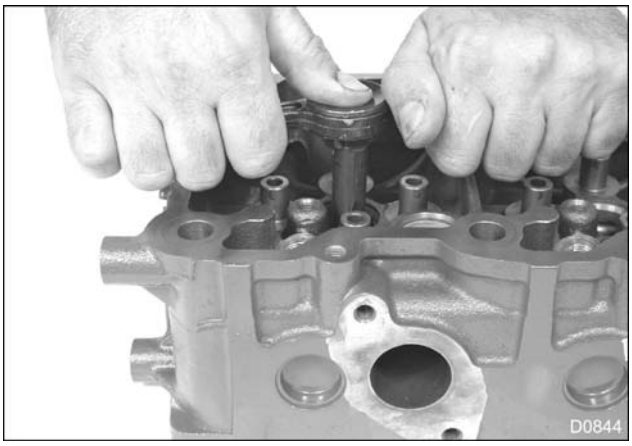

Figure 356 Cutting threads in fuel injector sleeve

2. Thread Injector Sleeve Remover (thread tap) into fuel injector sleeve. Cut threads at least ¾ inch deep to accommodate the Injector Sleeve Remover.

Figure 357 Injector Sleeve Remover and slide hammer

3. Install Injector Sleeve Remover (page 281) (slide hammer adapter) into the cut threads of the fuel injector sleeve and tighten.
4. Thread slide hammer into Injector Sleeve Remover.

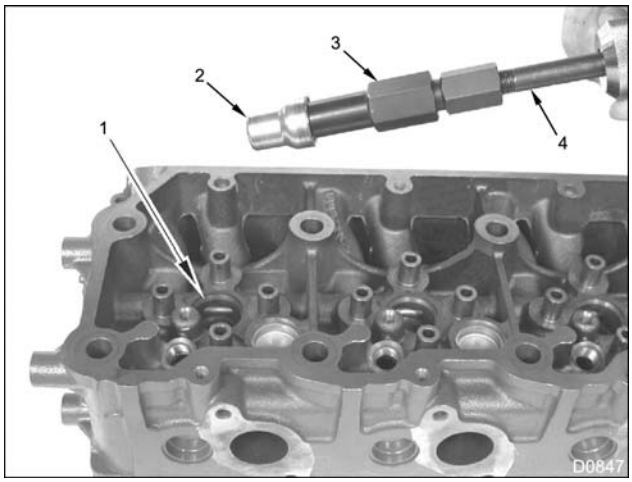

Figure 358 Fuel injector sleeve removed

1. Fuel injector bore
2. Fuel injector sleeve
3. Injector Sleeve Remover
4. Slide hammer

5. Using the slide hammer, remove fuel injector sleeve and discard.

Fuel Injector Sleeve Bore and Gallery

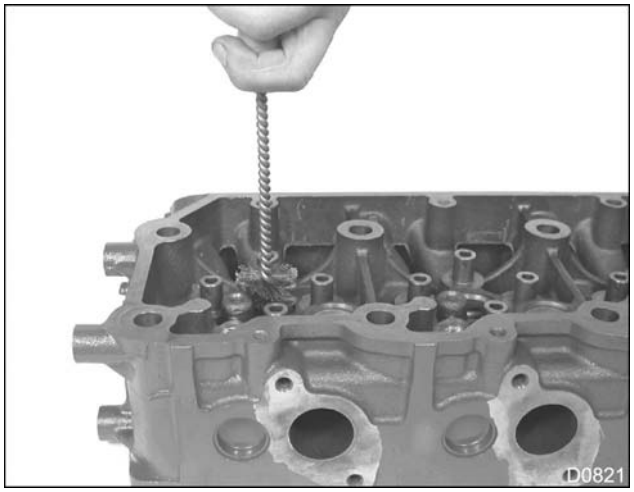

Figure 359 Cleaning the injector bore

1. Use Injector Sleeve Brush to remove deposits and hardened sealant from injector bore. See Special Service Tools (page 281).
2. Remove fuel rail plug assembly (M12).

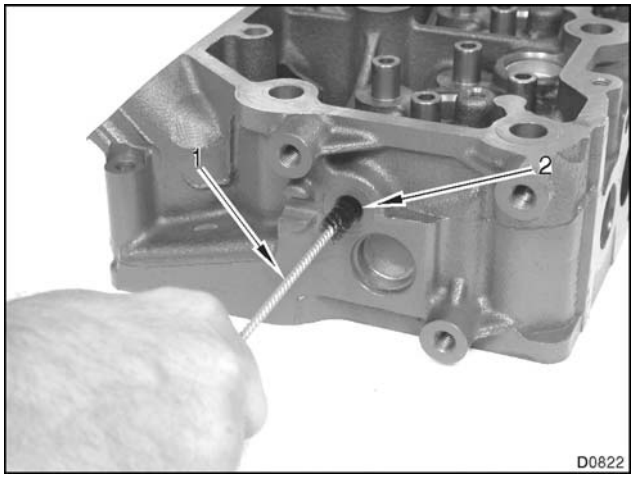

Figure 360 Cleaning the fuel gallery

1. Fuel Gallery Cleaning Brush
2. Fuel gallery port

3. Clean the fuel gallery with the Fuel Gallery Cleaning Brush. See Special Service Tools (page 281).

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

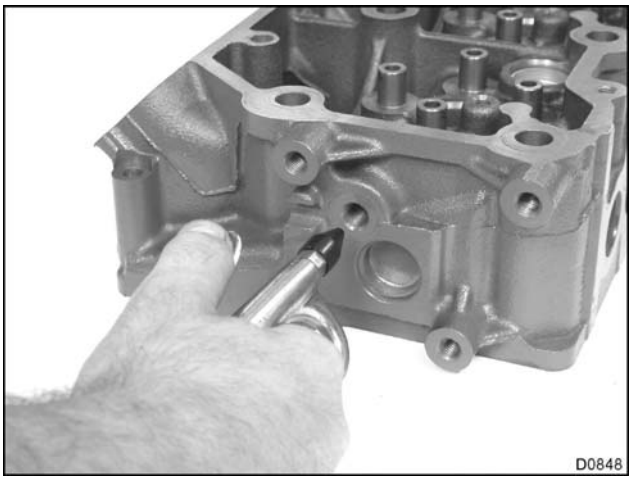

Figure 361 Blowing out fuel gallery

4. Using filtered compressed air, clean out all debris from fuel gallery port.
5. Install the fuel rail plug assembly and tighten to the special torque (page 281).

Fuel Injector Sleeve Replacement

1. Verify injector bore is completely clean and dry.
2. Place fuel injector sleeve onto Injector Sleeve Installer. See Special Service Tools (page 281).

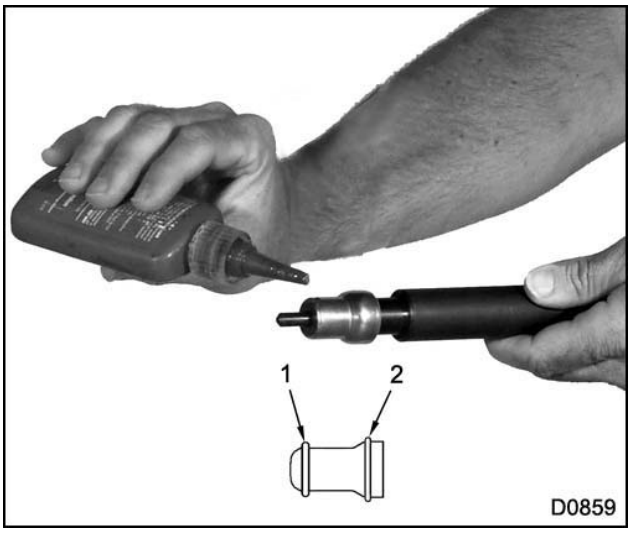

Figure 362 Applying Loctite® #620 sealant to fuel injector sleeve

1. Wall (end)
2. Upper wall (top)

3. Apply Loctite® #620 sealant to fuel injector sleeve. See Special Service Tools (page 281).

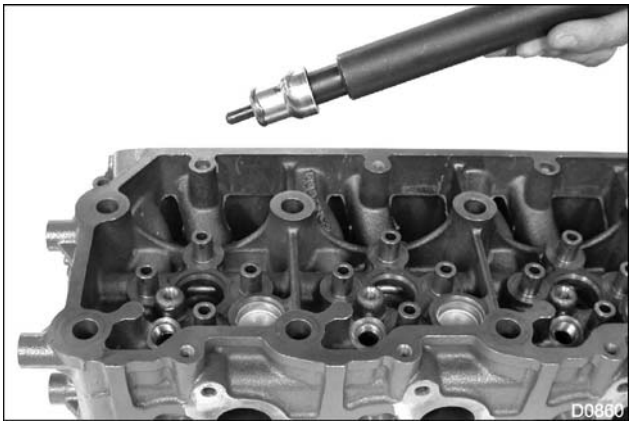

Figure 363 Installing fuel injector sleeve

4. Carefully center the fuel injector sleeve in the injector bore.

Figure 364 Installing fuel injector sleeve into bore

5. Drive Injector Sleeve Installer with new sleeve into fuel injector bore until sleeve bottoms. If any Loctite® #620 sealant gets into the inside of the injector sleeve, it must be cleaned out before it begins to harden.
6. Inspect the inside surface of the installed fuel injector sleeve. If nicks and scratches are evident, replace the fuel injector sleeve again. Make sure the installation tool is not causing damage. Use a different installation tool if necessary.

Glow Plug Sleeve Removal

CAUTION: To prevent engine damage, (if replacing glow plug sleeves in chassis), place a small dab of grease into the bottom of the glow plug sleeve prior to cutting threads. The grease will prevent small metal chips from entering the combustion chamber.

NOTE: Glow plug sleeve removal is not required unless the sleeve is leaking or the inner surface is nicked or scratched. See Cleaning, Inspection and Tests in this section to determine if sleeve replacement is required.

NOTE: The glow plug sleeve is made of stainless steel. Lubrication of the Glow Plug Sleeve Remover (thread tap) is required, otherwise excessive force will be necessary.

1. Lubricate Glow Plug Sleeve Remover (page 281) (thread tap) with clean engine oil.

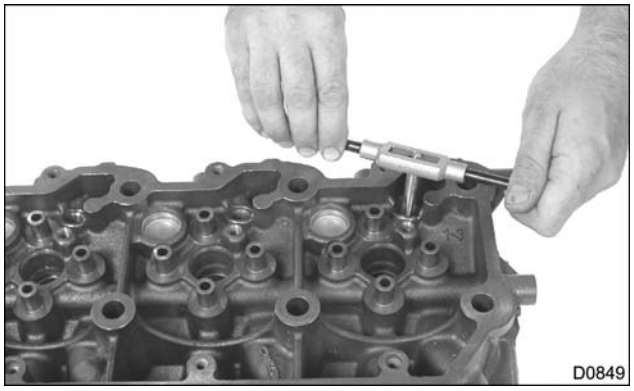

Figure 365 Glow Plug Sleeve Remover (thread tap) installation

2. Install Glow Plug Sleeve Remover (thread tap) to cut threads in the glow plug sleeve. Cut threads at least ½ inch deep to accommodate Glow Plug Sleeve Remover (bolt and sleeve adapter).

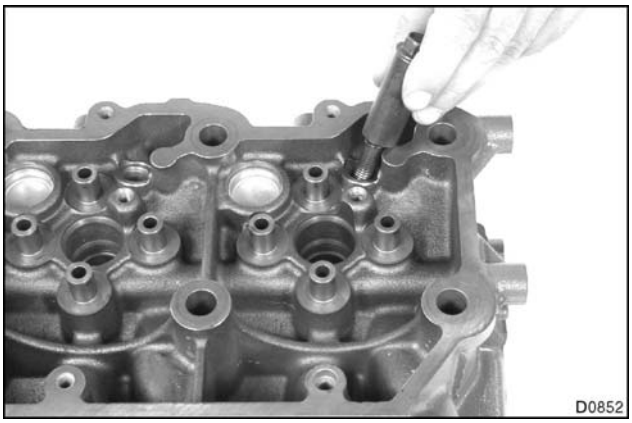

Figure 366 Installing the Glow Plug Sleeve Remover

3. Thread Glow Plug Sleeve Remover (bolt and sleeve adapter) into glow plug sleeve. See Special Service Tools (page 281).
4. Using a wrench, tighten the bolt in the remover until the glow plug sleeve adapter is extracted.
5. Remove glow plug sleeve and discard.

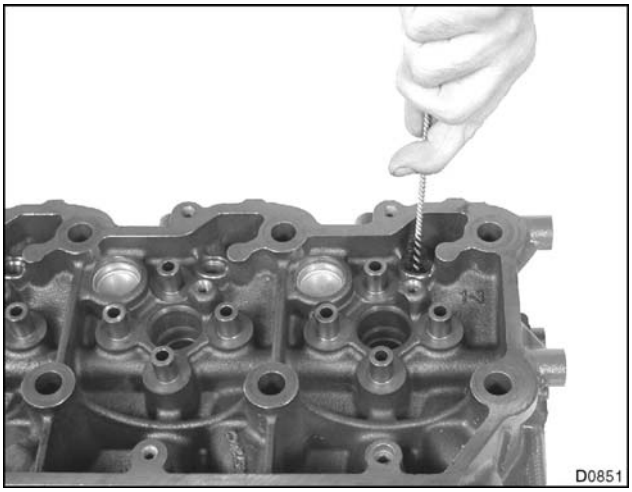

Figure 367 Glow plug bore cleaning

6. Clean glow plug bore with Glow Plug Sleeve Brush (page 281).

Glow Plug Sleeve Replacement

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

NOTE: Be certain that the glow plug recess was cleaned out with the Glow Plug Sleeve Brush, rinsed with a suitable cleaning solution, and blown out with shop air.

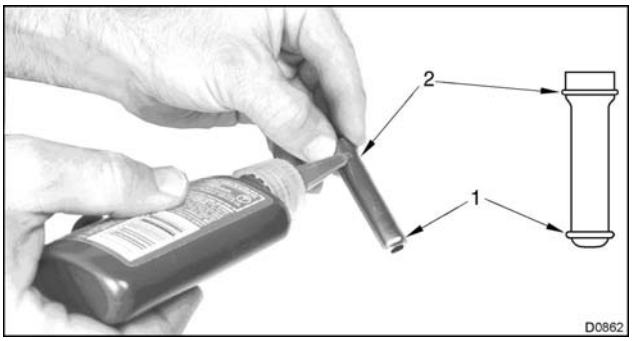

Figure 368 Applying Loctite® #620 sealant to sleeve locations

1. Wall (end)
2. Upper wall (top)

1. Apply Loctite® #620 sealant to the wall and upper wall on the glow plug sleeve. See Special Service Tools (page 281).

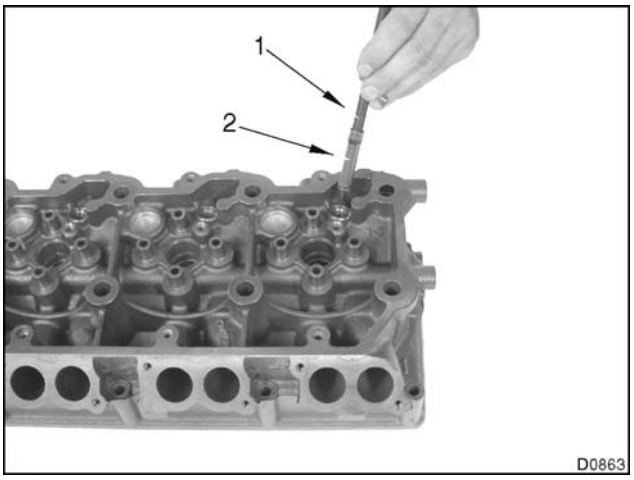

Figure 369 Glow plug sleeve installation

1. Glow Plug Sleeve Installer
2. Glow plug sleeve

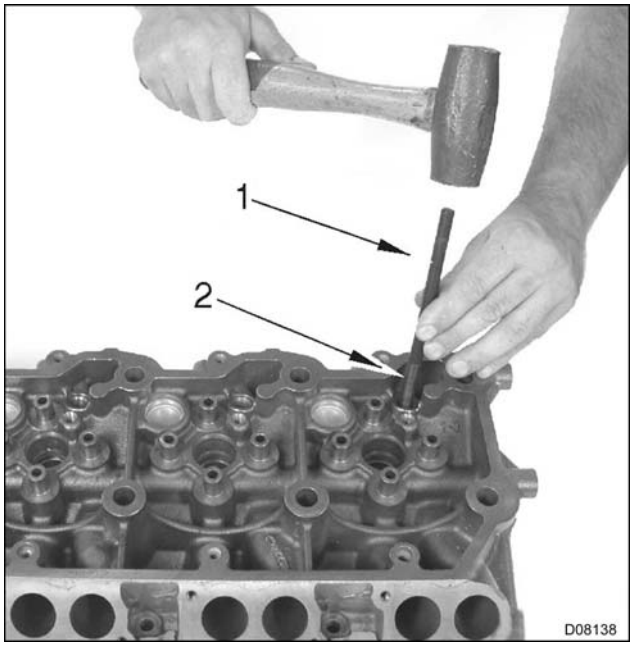

Figure 370 Installing glow plug sleeve into place

1. Glow plug installation tool
2. Glow plug sleeve

2. Install glow plug sleeve in cylinder head with the Glow Plug Sleeve Installer. Continue to tap the installer until the sleeve bottoms. See Special Service Tools (page 281).
3. Clean glow plug sleeve after installation with a nylon brush and solvent. Make sure Loctite® sealant is cleaned out before it hardens.
4. Inspect the inside surface of the installed glow plug sleeve. If nicks and scratches are evident, replace the glow plug sleeve again. Make sure the installation tool is not causing damage. Use a different installation tool if necessary.

Valve Installation

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

Clean valve faces and seats with a suitable cleaning solvent to remove all dirt or foreign material. Blow dry all new and used components using filtered compressed air.

NOTE: Guides must be clean! Use a valve guide brush to clean guides.

1. Dry valve guides with filtered compressed air.
2. Lubricate inside diameter of new valve stem seal and inside diameter of valve guide with clean engine oil. Install stem seal over valve guide until it stops.

NOTE: Valve seal will not seat completely over valve guide by hand. Seals can be seated using a suitable deep socket and rubber mallet to provide a positive contact with machined base.

3. Lubricate valve stem with clean engine oil and insert valve into cylinder head.

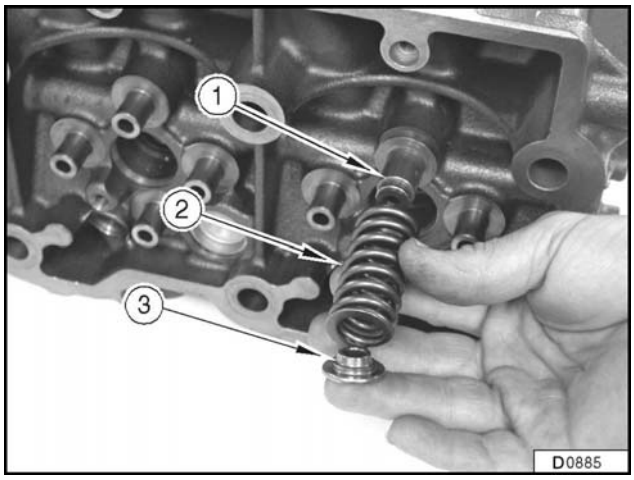

Figure 371 Valve seal, spring, and retainer

1. Valve seal
2. Valve spring
3. Valve retainer

4. Place valve spring over valve stem seal.
5. Install valve spring retainer on top of spring.

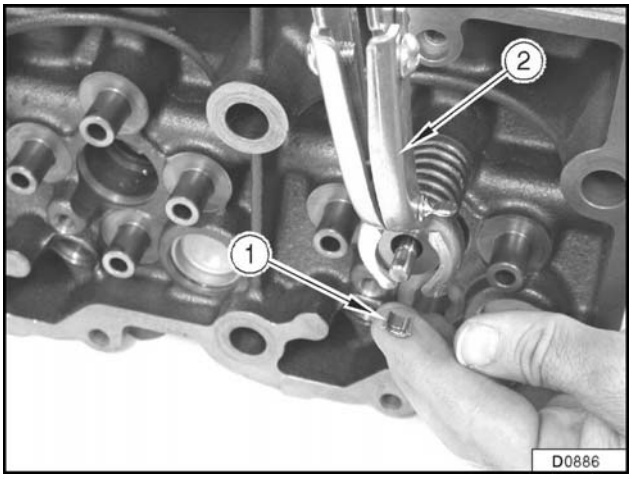

Figure 372 Valve retainer keys installation

1. Valve retainer key
2. Valve spring compressor

CAUTION: To prevent engine damage, make sure when the valve spring compressor is released, the inside bead of each valve retainer key locks into the key groove of the valve stem.

6. Compress valve spring with Valve Spring Compressor (page 281), install two valve stem keys, and release spring compressor.
7. After valve replacement, measure valve head recession (page 280) and compare to specifications.

Rocker Arm Carrier

Rocker Arm and Fulcrum Disassembly

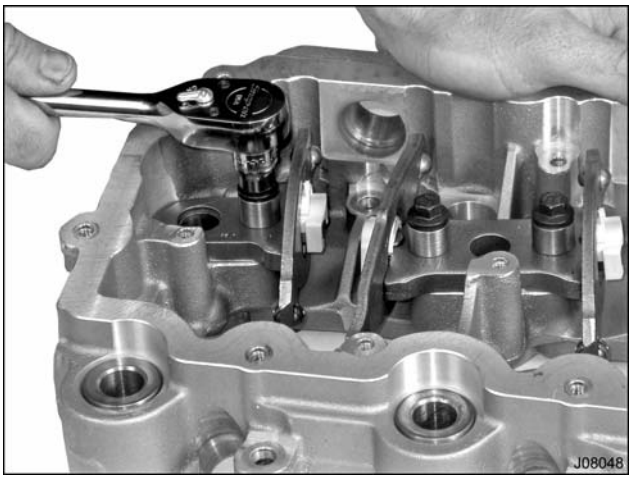

Figure 373 Removing the rocker arm fulcrum bolt

1. Remove six bolts (M8 x 45) and fulcrum bolt spacer holding all the rocker arm fulcrums to the rocker arm carrier. Remove fulcrums and rocker arms as assemblies.

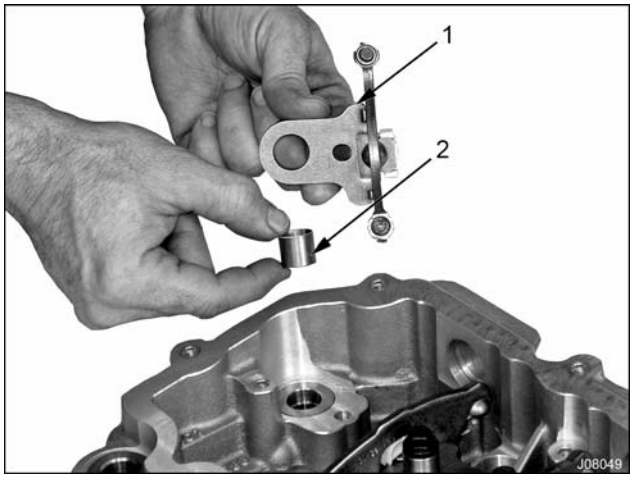

Figure 374 Removing the end fulcrum plate and fulcrum bolt spacer

1. End fulcrum plate
2. Fulcrum bolt spacer

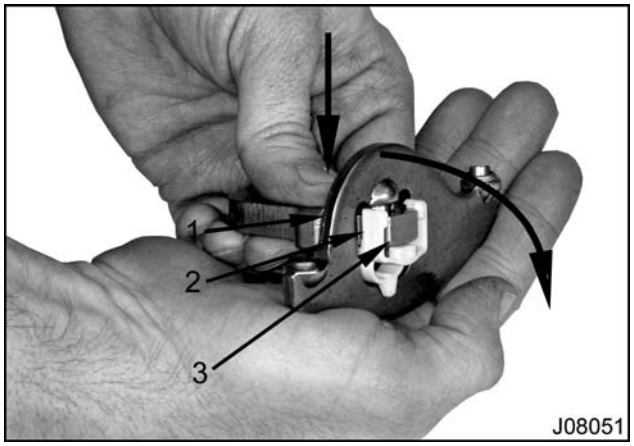

Figure 375 Compressing the rocker arm clip

1. Rocker arm
2. Rocker arm clip
3. Fulcrum plate

NOTE: Disassembly and assembly of dual and single rocker arm fulcrum plates are similar.

2. To disassemble the rocker arm from the fulcrum plate; hold rocker arm and fulcrum plate upside down in the palm of your hand. Push down on fulcrum plate against rocker arm (relieving force on ball) while simultaneously pushing rocker away from ball and fulcrum plate.

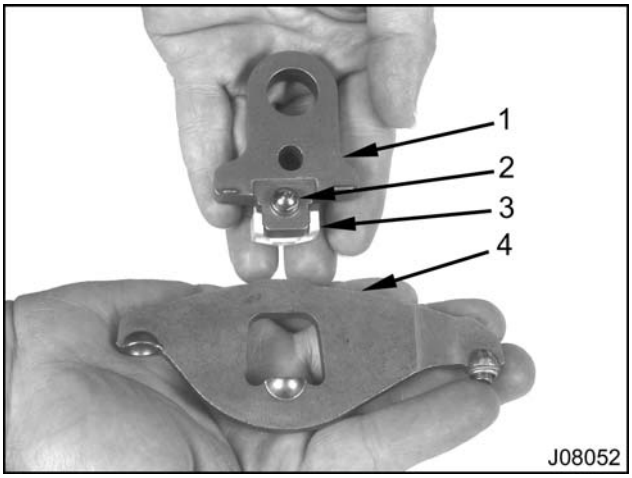

Figure 376 Removing the rocker arm

1. Fulcrum plate
2. Rocker arm ball
3. Rocker arm clip
4. Rocker arm

3. Move the rocker off the ball, keeping the ball in the detent of the fulcrum plate.

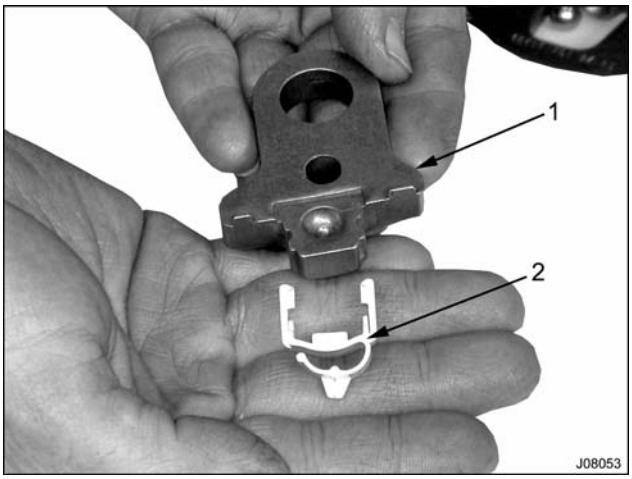

Figure 377 Removing the rocker arm clip

1. Fulcrum plate
2. Rocker arm clip

4. Remove and discard the rocker arm clip.

Cleaning and Inspection

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

1. Clean all parts with a suitable solvent. Use filtered compressed air to dry parts.
2. Inspect each rocker arm pivot foot and corresponding valve bridge for pitting or scuffing. Inspect each rocker arm ball and socket for scuffing. Replace rocker arms and valve bridges as required.
3. Inspect rocker arm post ball socket for excessive wear. Inspect bolts for thread damage. Replace worn components as required.

Rocker Arm and Fulcrum Assembly

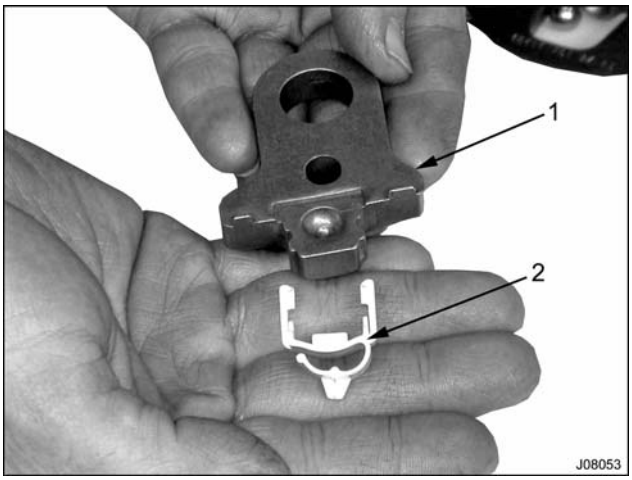

Figure 378 Installing a new rocker arm clip

1. Fulcrum plate
2. Rocker arm clip

NOTE: Disassembly and assembly of dual and single rocker arm fulcrum plates are similar.

1. Install a new rocker arm clip onto the fulcrum plate.

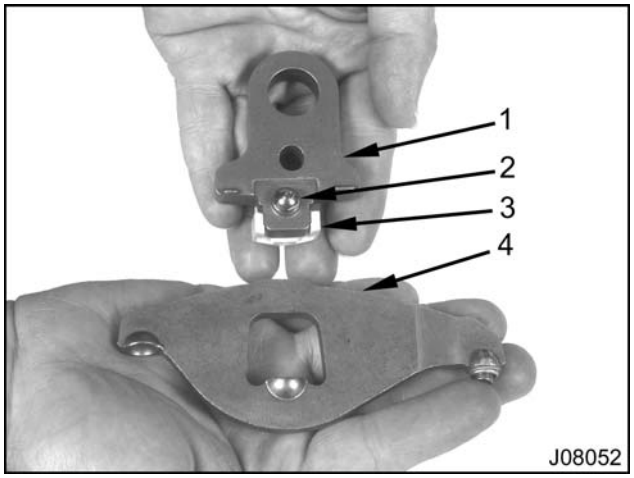

Figure 379 Installing the rocker arm ball

1. Fulcrum plate
2. Rocker arm ball
3. Rocker arm clip
4. Rocker arm

2. Insert the ball onto the fulcrum plate detent. Hold rocker arm upside down in your palm.

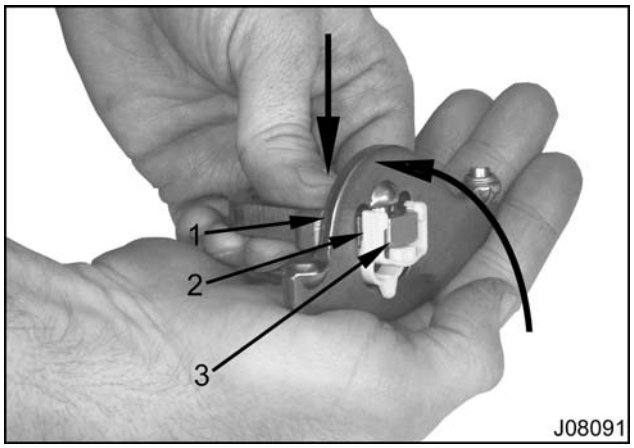

Figure 380 Installing the rocker arm clip

1. Rocker arm
2. Rocker arm clip
3. Fulcrum plate

3. Press lower part of the rocker arm against the rocker arm clip, push up with your palm and push the upper part of the rocker arm over the rocker arm ball. Check for freedom of movement of rocker arm on the fulcrum plate.

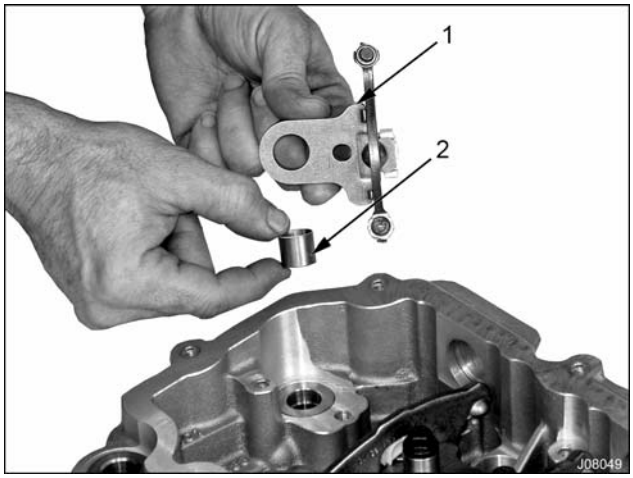

Figure 381 Installing the end fulcrum and fulcrum bolt spacer

1. Fulcrum plate
2. Fulcrum bolt spacer

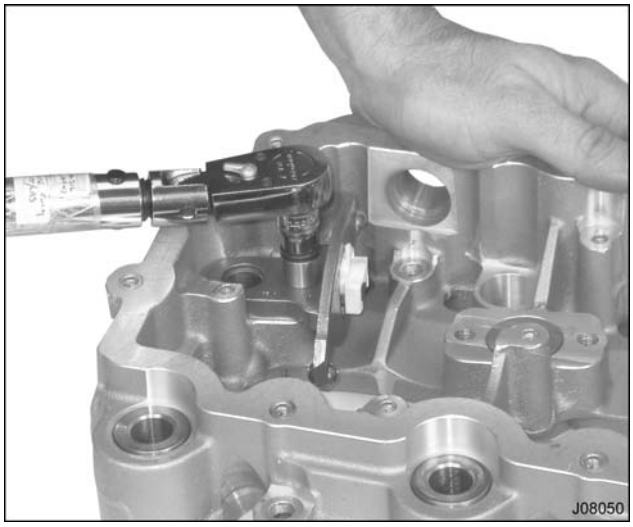

Figure 382 Installing an end rocker fulcrum plate

4. Position each assembled end rocker fulcrum plate (intake or exhaust) with a fulcrum bolt spacer onto rocker carrier assembly. Orient **E** and **I** fulcrum stamping face up. Install bolt (M8 x 45) into each fulcrum and tighten to the special torque (page 281).
5. Position each assembled dual fulcrum plate with two fulcrum bolt spacers onto rocker carrier assembly. Orient **E** and **I** stamping face up. Install two bolts (M8 x 45) into each fulcrum and tighten to the special torque.

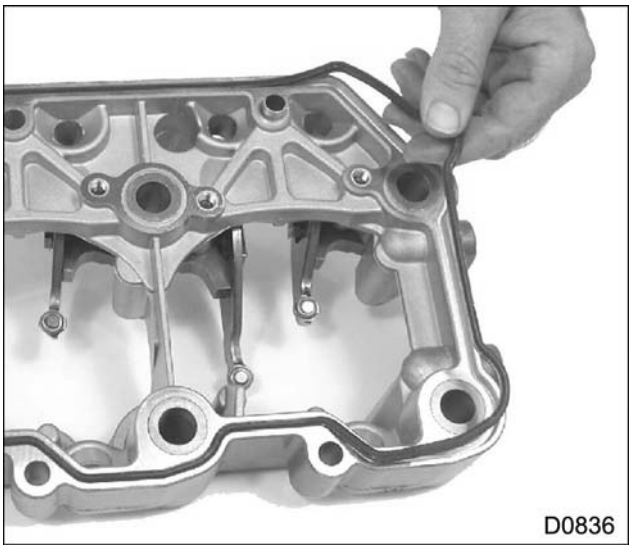

Figure 383 Installing the cylinder head to rocker arm carrier gasket

6. Install a new cylinder head to rocker arm carrier gasket.

Installation

Hydraulic Cam Follower

1. Clean hydraulic cam followers and roller follower guide. Use care to maintain roller follower location and orientation.

NOTE: Verify correct location and orientation of each reused cam follower and guide during reassembly.

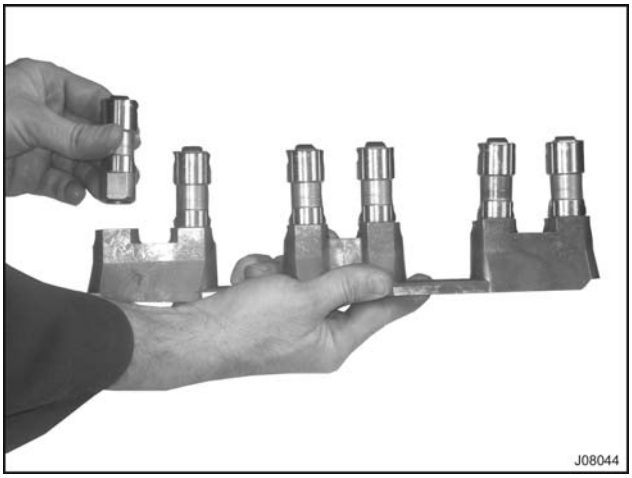

Figure 384 Installing a cam follower in guide

2. Lubricate and place each hydraulic cam follower into its respective roller follower guide.

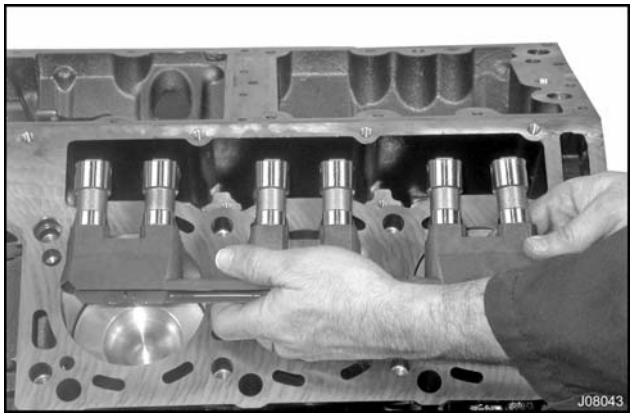

Figure 385 Installing the cam followers and guide into crankcase

3. Lubricate cam followers with clean engine oil and install them into their respective bores.
4. Install one M6 x 12 bolt and washer assembly with roller follower guide (forward guide hole only) and tighten to the standard torque (page 400).

Cylinder Heads

CAUTION: To prevent engine damage, be sure cylinder head is free of debris or a good seal between the cylinder head and gasket will not be possible; leading to oil, coolant, and compression leakage. Do not apply sealant to head gasket surfaces.

CAUTION: To prevent engine damage, threads in crankcase bolt holes must be clean and blown dry with filtered compressed air. Dirt or oil left in holes may cause binding and false torque reading during assembly.

1. If not performed already, clean all cylinder head bolt holes with a Head Bolt Bottoming Tap (page 281) and remove debris with filtered compressed air.

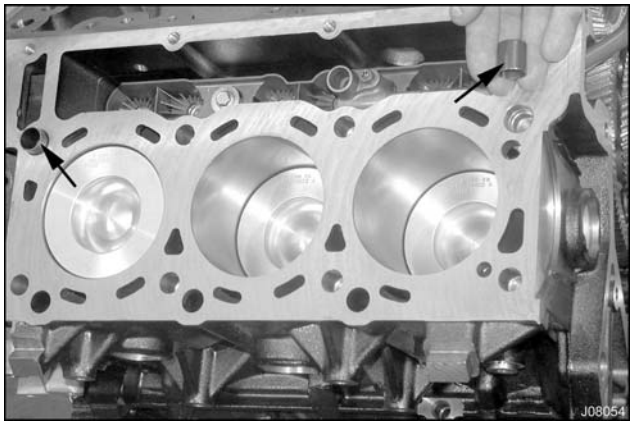

Figure 386 Cylinder head spring dowel pins

2. Make sure two cylinder head spring dowel pins are installed (one at front and one at rear of crankcase).

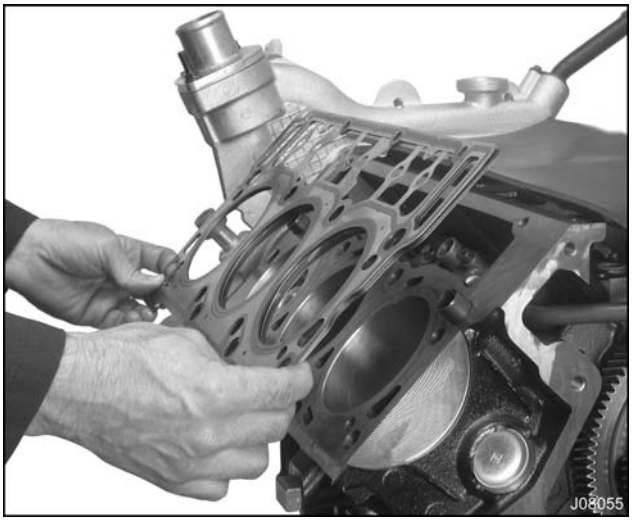

Figure 387 Cylinder head gasket installation

CAUTION: To prevent engine damage, install a new cylinder head gasket with part number facing up. Verify top four bolt holes and cylinder head gasket push rod holes are all aligned.

NOTE: Use care to avoid scratching blue compound on cylinder head gaskets.

3. Install new cylinder head gasket over spring dowel pins and onto crankcase.

Figure 388 Guide pin installation

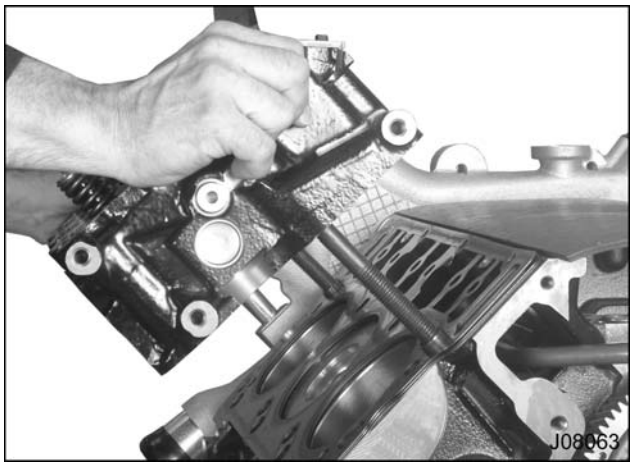

Figure 389 Cylinder head installation onto crankcase

4. Install cylinder head installation guide pins (make locally).

NOTE: Cam followers cannot be removed or replaced when cylinder head is bolted to the crankcase. Be sure to complete any required work to cam followers before installing cylinder head.

5. Install Cylinder Head Lifting Bracket (page 281) in center of cylinder head (if removed). Tighten bracket mounting bolts.

CAUTION: To prevent engine damage, do not drop cylinder head on gasket or slide it across gasket. Either action will damage cylinder head gasket and spring dowel pins, resulting in leakage.

6. Attach hoist hook or lifting sling to lifting bracket. Raise cylinder head and align with guide pins, previously installed in crankcase.
7. Lower cylinder head onto head gasket.
8. Install two outer bolts (M8 x 70) across top of cylinder head. Run threads down until finger tight.
9. Install two inner bolts (M8 x 70) across the top of the cylinder head. Run threads down until finger tight.
10. Remove hoist and cylinder head lifting bracket.

Valve Bridges and Push Rods

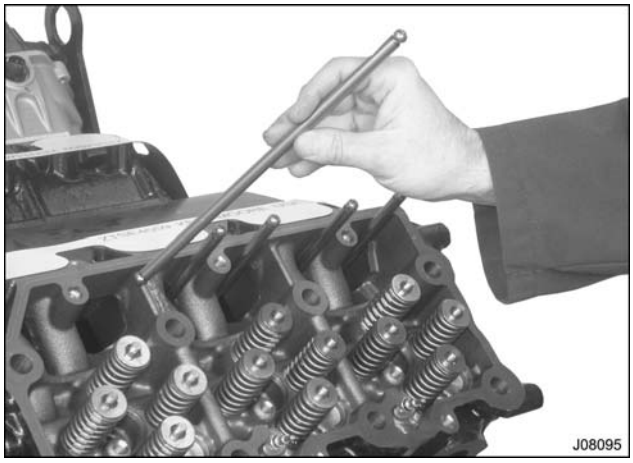

Figure 390 Installing push rod

NOTE: Copper ball on end of each push rod must be installed into rocker arm socket.

1. Apply clean engine oil to each end of push rods and insert into previously marked positions.
2. Coat the end of each valve stem with clean engine oil.

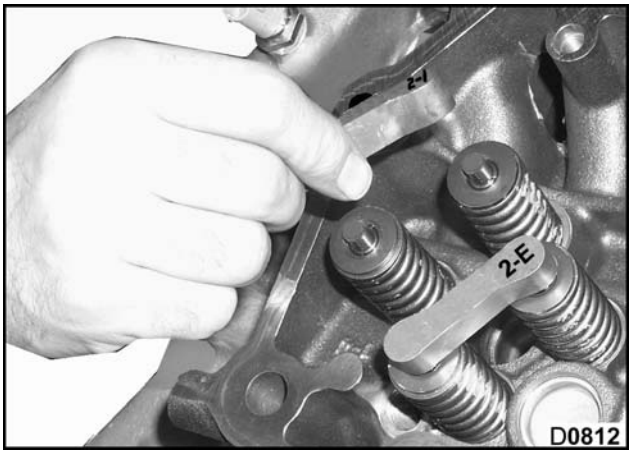

Figure 391 Installing the valve bridges

3. Place each of the previously marked valve bridges onto their respective valve stems.

CAUTION: To prevent engine damage, make sure the push rods are seated in the hydraulic roller follower sockets before installing the rocker arm carrier assembly.

Rocker Arm Carrier

1. Install dowels in cylinder head.

   NOTE: Dowels may still be attached to the cylinder head.

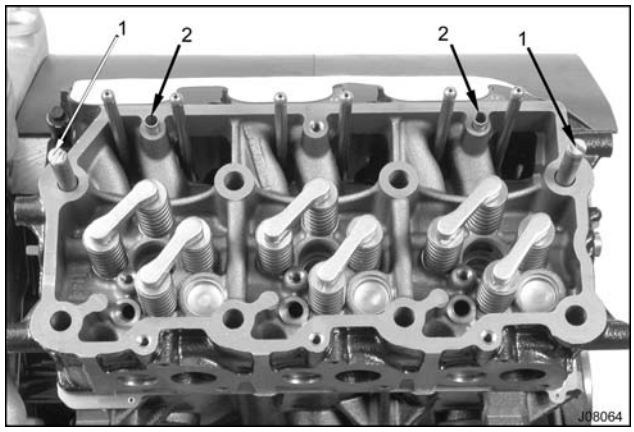

Figure 392 Alignment guides and dowels in place

1. Alignment guides
2. Dowels

2. Install cylinder head and rocker carrier alignment guides (make locally) in position shown prior to installing rocker arm carrier.
3. Rotate the crankshaft until damper locating dowel hole is in the six o'clock position. This positions all pistons below TDC so the valves do not contact the pistons when tightening the rocker arm assemblies.
4. Apply engine oil to the top center of each valve bridge.

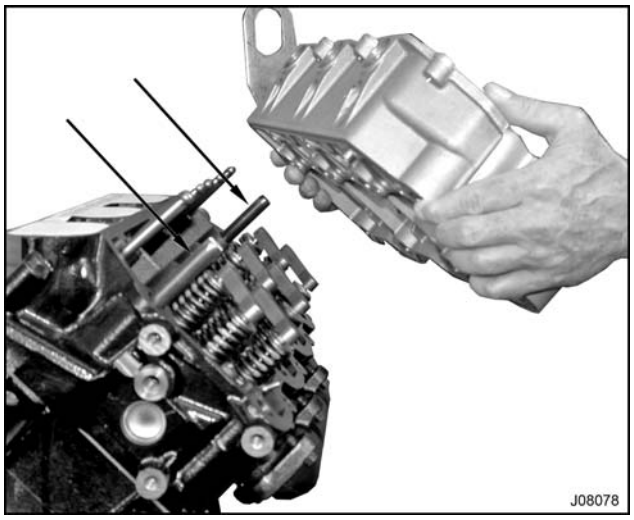

Figure 393 Installing the rocker arm carrier assembly

5. Place rocker arm carrier onto guides.
6. Remove guides and install two rocker carrier bolts (M8 x 50). Tighten each bolt alternately while observing rocker carrier, dowel sleeve bushings and cylinder head for signs of misalignment. Tighten bolts to the standard torque (page 400).

Cylinder Head Bolt Torque Sequence

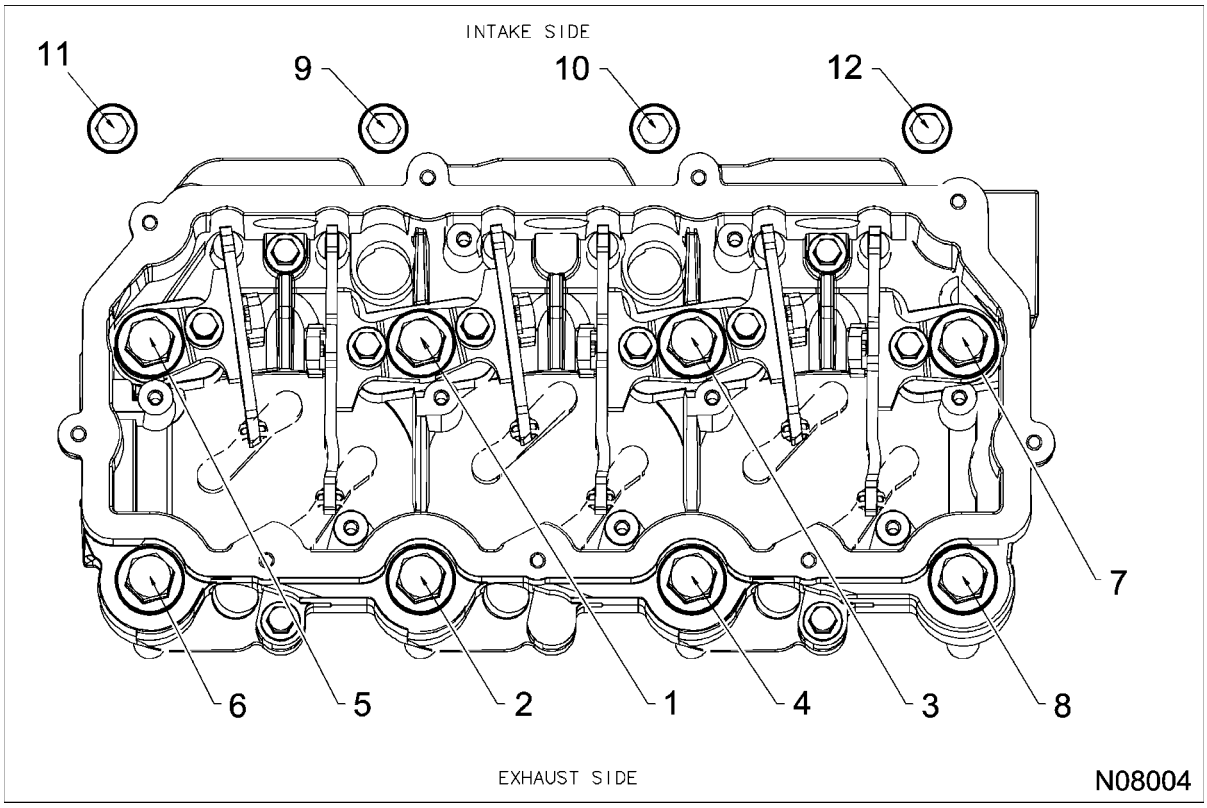

Figure 394 Cylinder head bolt torque sequence

CAUTION: To prevent engine damage, use a permanent ink marker to identify head bolt torque orientation. Do not use paint or other temporary marking.

CAUTION: To prevent engine damage, check to make sure all push rods have been seated in their respective rocker arm pivot recesses.

CAUTION: To prevent engine damage, all M14 x 193 head bolts must be replaced when installing cylinder head. Lubricate bolt threads, flanges, and mating surfaces with a light coat of clean engine oil. Too much oil will cause hydrostatic lock and give an incorrect torque reading. Do not use anti-seize compound, grease, or any other lubricant on cylinder head bolt threads.

1. Lightly lubricate new M14 x 193 cylinder head bolts with clean engine oil.
2. Install eight M14 head bolts in the head and finger tighten.
3. Tighten M14 bolts 1 through 8 in sequence to 88 N·m (65 lbf·ft).
4. Tighten M14 bolts 1, 3, 5, and 7 in sequence to 116 N·m (85 lbf·ft).
5. Tighten M14 bolts 2, 4, 6, and 8 in sequence to 116 N·m (85 lbf·ft).
6. Tighten M14 bolts 1 through 8 in sequence clockwise 90 degrees.
7. Tighten M14 bolts 1 through 8 in sequence a second time clockwise 90 degrees.
8. Tighten M 14 bolts 1 through 8 in sequence a third time clockwise 90 degrees.
9. Tighten M8 x 70 bolts 9 through 12 in sequence to 24 N·m (18 lbf·ft).
10. Tighten M8 x 70 bolts 9 through 12 in sequence to 31 N·m (23 lbf·ft).

Glow Plugs

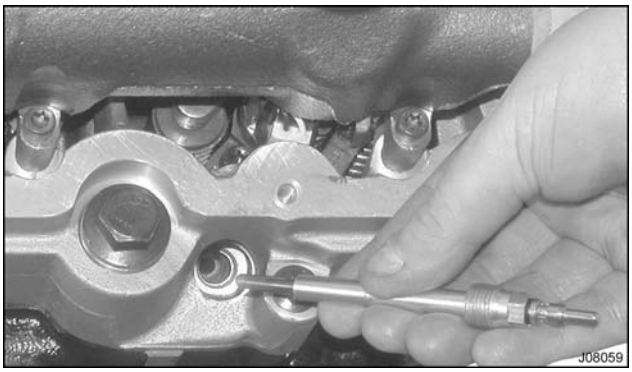

Figure 395 Glow plug

1. Install six glow plugs in the cylinder heads.
2. Tighten glow plugs to the special torque (page 281).

Valve Covers

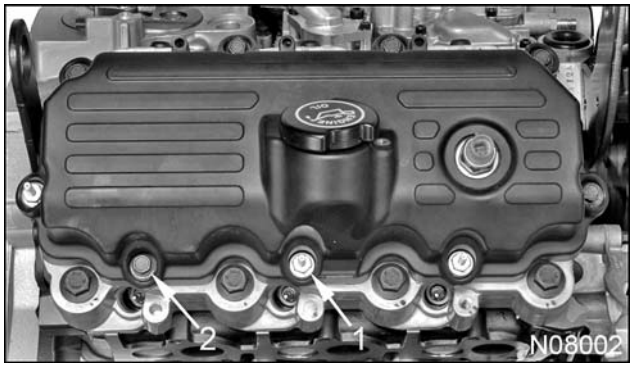

Figure 396 Valve cover mounting bolts – right

1. Valve cover stud bolt assembly (3)
2. Valve cover bolt assembly (6)

CAUTION: To prevent engine damage, do not use air tools to install valve covers.

1. Install valve cover gasket and right valve cover onto right rocker arm carrier.
2. Tighten six valve cover bolts and three valve cover stud bolts to special torque (page 281).
3. Install valve cover gasket and left valve cover onto left rocker arm carrier.
4. Tighten seven valve cover bolts and two valve cover stud bolts to special torque.
5. If removed, install lifting eyes on the rear of each rocker arm carrier and one on the left front carrier. Tighten bolts to special torque.

Crankcase Breather Assembly

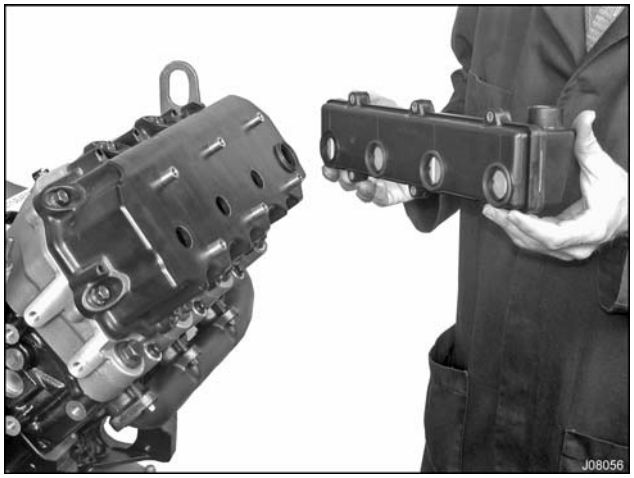

Figure 397 Crankcase breather installation

1. Install four breather cover opening seals onto crankcase breather.

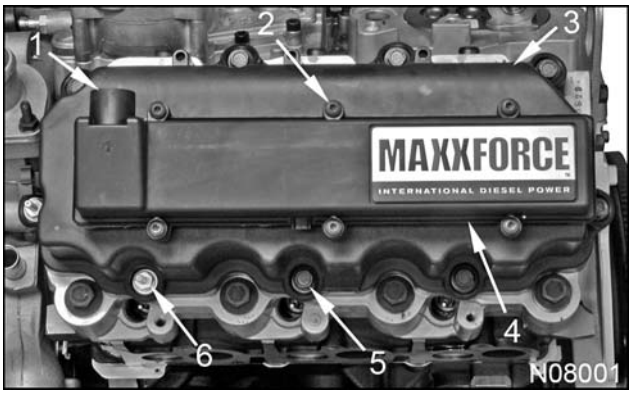

Figure 398 Crankcase breather and left valve cover

1. Crankcase breather hose connection
2. M6 x 43 breather bolt (6)
3. Left valve cover
4. Crankcase breather
5. Valve cover bolt assembly (7)
6. Valve cover stud bolt assembly (2)

2. Install the crankcase breather onto the left valve cover.
3. Install and finger tighten six M6 x 43 breather bolts.
4. Tighten M6 x 43 bolts to special torque (page 281).
5. Remove tools, parts and equipment.
   a. Reinstall all safety guards, shields and covers after servicing the engine.
   b. Make sure all tools, loose parts, and service equipment are removed from the engine area after all work is done.

Specifications

Valve Specifications	
Face to stem runout (T.I.R. max.)	0.038 mm (0.0015 in)
Stem to guide clearance (max. allowable before replacement)	0.140 mm (0.0055 in)
Valve stem diameter	6.947 to 6.965 mm (0.2735 to 0.2742 in)
Exhaust valve face angle	37.5°
Intake valve face angle	30.0°
Exhaust valve margin (minimum)	1.35 mm (0.053 in)
Intake valve margin (minimum)	1.40 mm (0.055 in)

Valve Spring Specifications	
Free length	51.96 mm (2.045 in)
Compressed* (first test)	46.30 mm @ 340 ± 17 N (1.82 in @ 76.5 ± 3.8 lbf)
Compressed* (second test)	38.30 mm @ 850 ± 43 N (1.51 in @ 191.1 ± 9.7 lbf)

* Spring must be compressed to a solid height before checking test loads.

Cylinder Head Specifications	
Gasket surface flatness (maximum)	0.051 mm (0.002 in) per check point
Overall thickness of cylinder head (deck-to-deck)	95 mm (3.74 in)
Valve guide bore runout	0.05 mm (0.002 in)
Valve guide inside diameter	7.003 to 7.029 mm (0.276 to 0.277 in)
Valve guide taper (maximum)	0.10 mm (0.004 in)
Valve head recession relative to deck (surface of cylinder head)	0.32 to 0.68 mm (0.0126 to 0.0268 in)
Valve seat angle (exhaust)	37.5°
Valve seat angle (intake)	30.0°
Valve seat runout (T.I.R. max.)	0.035 mm (0.0014 in)
Valve seat width (exhaust)	1.48 to 2.24 mm (0.058 to 0.088 in)
Valve seat width (intake)	1.80 to 2.56 mm (0.071 to 0.101 in)
Push rod runout (maximum)	0.25 mm (0.01 in)

Special Torque

Cylinder head bolt torque and sequence	See Cylinder Head Bolt Torque Sequence(page 277)
Crankcase breather bolts (M6 x 43)	11 N·m (96 lbf·in)
Feeler gauge	Obtain locally
Fuel rail plug, M12	36 N·m (27 lbf·ft)
Glow plugs	18 N·m (159 lbf·in)
Lifting eye, front (M10 x 30)	41 N·m (30 lbf·ft)
Lifting eye, rear (M10 x 35)	41 N·m (30 lbf·ft)
Rocker arm fulcrum plate (M8 x 45)	31 N·m (23 lbf·ft)
Valve cover bolt assemblies (M6)	9 N·m (84 lbf·in)

Special Service Tools

Cylinder Head Lifting Bracket	ZTSE4661
Cylinder Head Pressure Test Plate	ZTSE4534
Dye Penetrant Kit	PT-7191
Feeler gauge	Obtain locally
Fuel Gallery Cleaning Brush	ZTSE4541
Glow Plug Sleeve Brush (nylon)	ZTSE4533
Glow Plug Sleeve Installer	ZTSE4532
Glow Plug Sleeve Remover (consists of: tap, bolt and adapter)	ZTSE4531
Glow Plug Sleeve Seat Wire Brush	ZTSE4589
Head Bolt Bottoming Tap	ZTSE4508
Injector Sleeve Brush	ZTSE43041
Injector Sleeve Flat Bottom Brush	ZTSE43042
Injector Sleeve Installer	ZTSE4529
Injector Sleeve Remover (consists of: tap and adapter)	ZTSE4528
Loctite® #620	Obtain locally
Magnetic Covers (Cylinder Head Intake Ports)	ZTSE4559
Slide Hammer Kit	ZTSE4398A
Straightedge	Obtain locally
Valve Guide Gauge Tool	ZTSE4577
Valve Spring Compressor	ZTSE1846
Valve spring tester	Obtain locally