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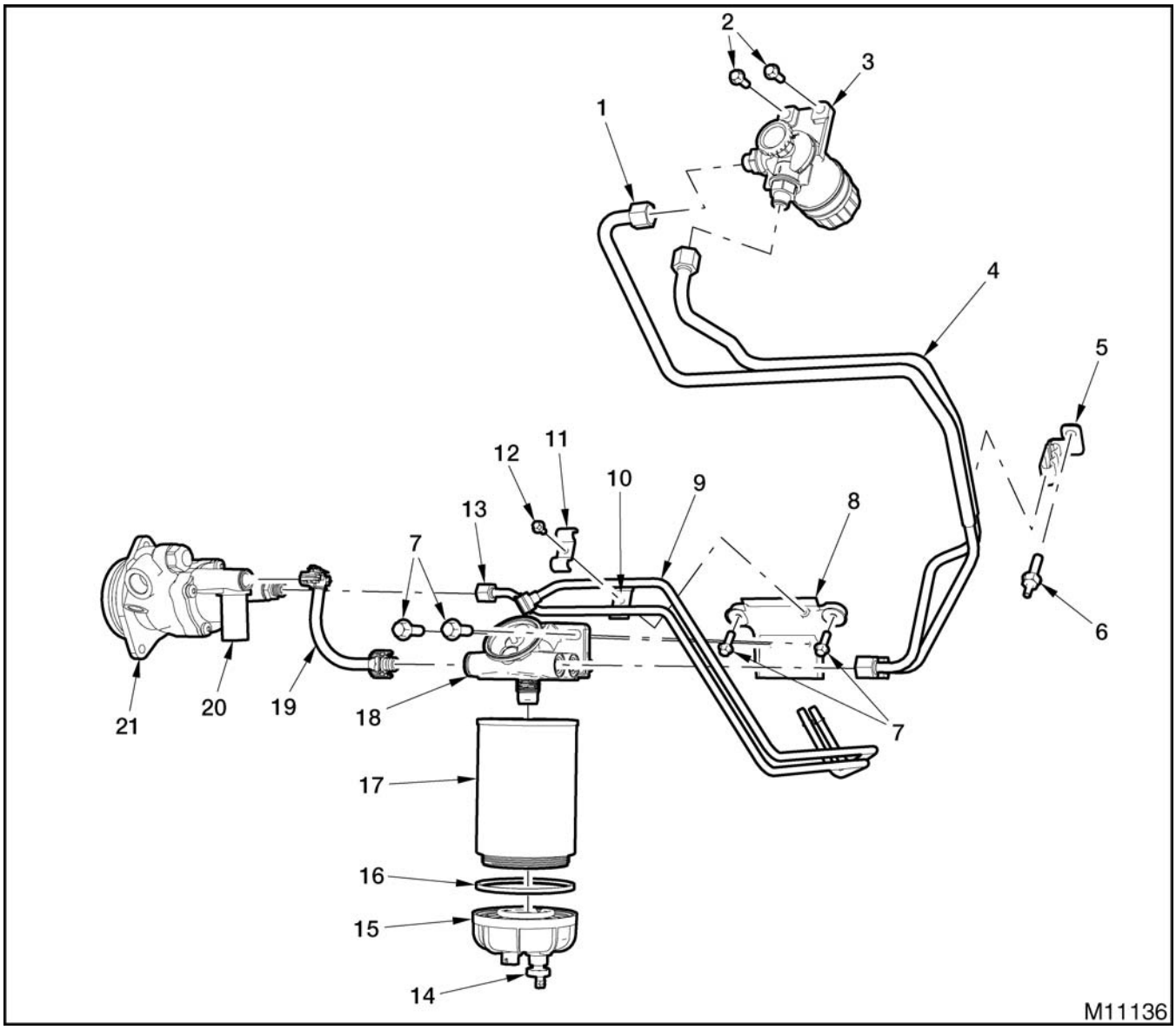

Figure 190 Primary fuel filter assembly and tubing

1. Fuel return from primer pump tube assembly
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6. M8 x 30 stud bolt
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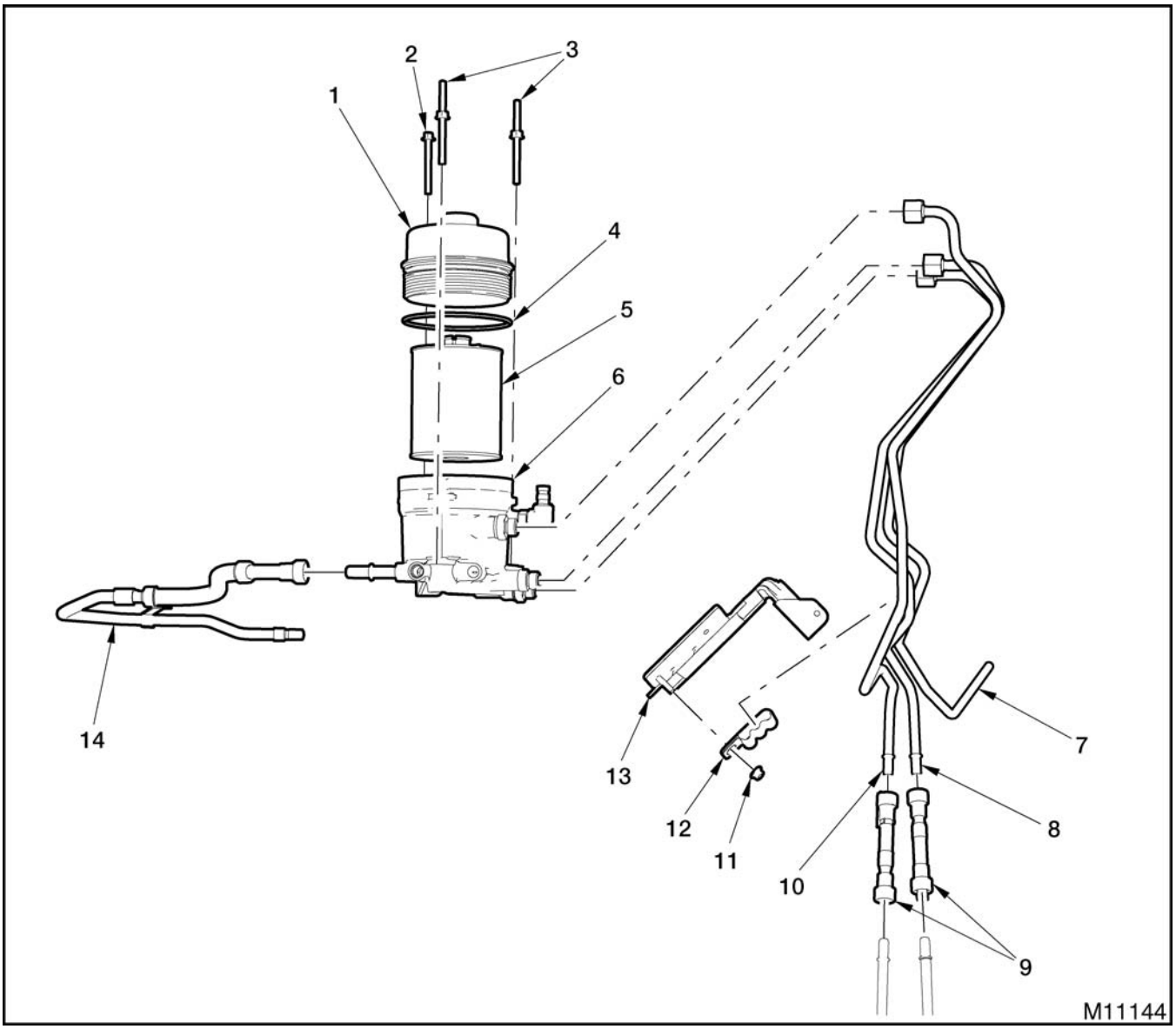

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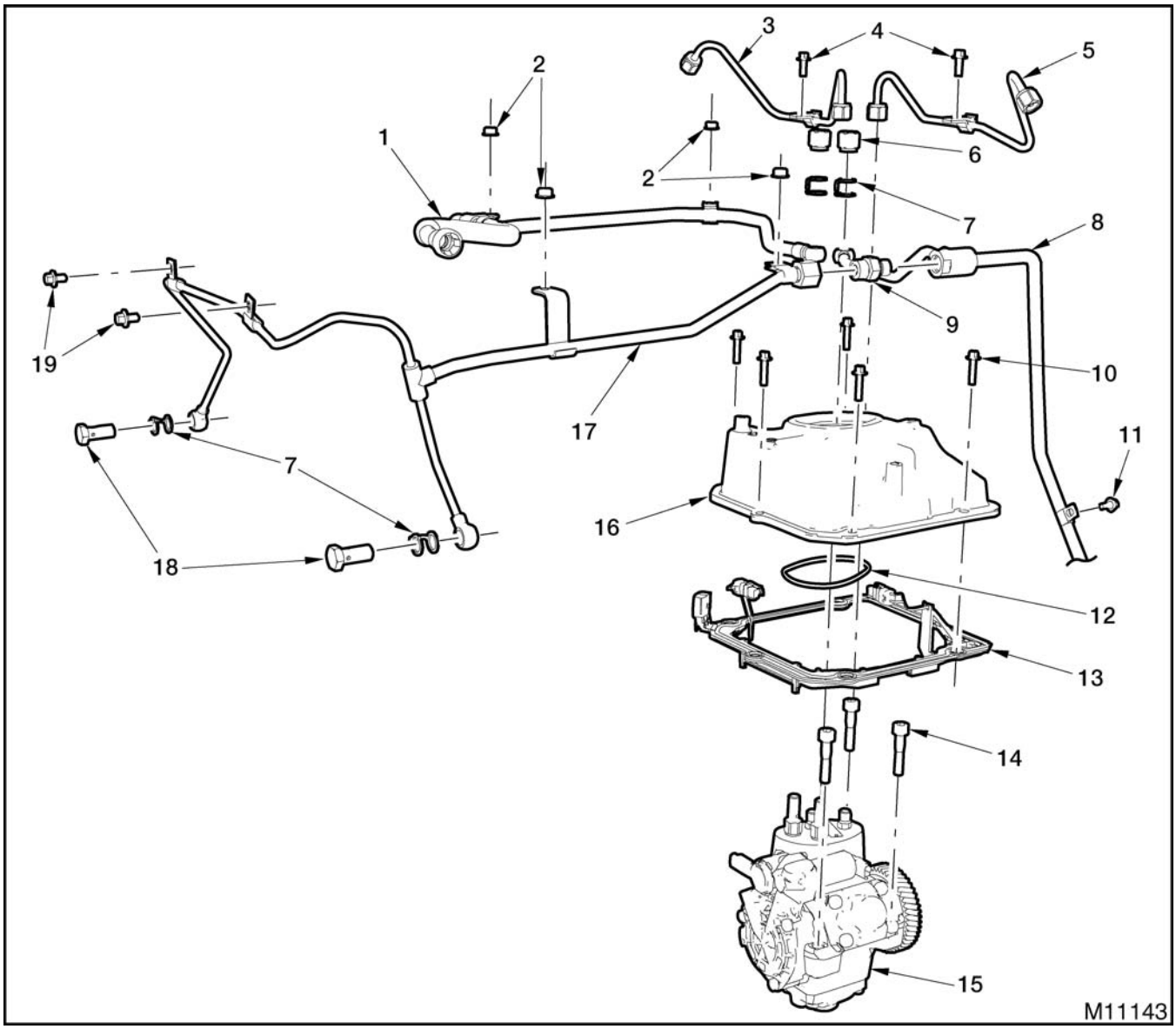

Figure 192 High-pressure Fuel Pump (HPFP) assembly and tubing

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3. Pump right tube assembly
4. M6 x 16 bolt (2)
5. Pump left tube assembly
6. M12 cap nut (2)
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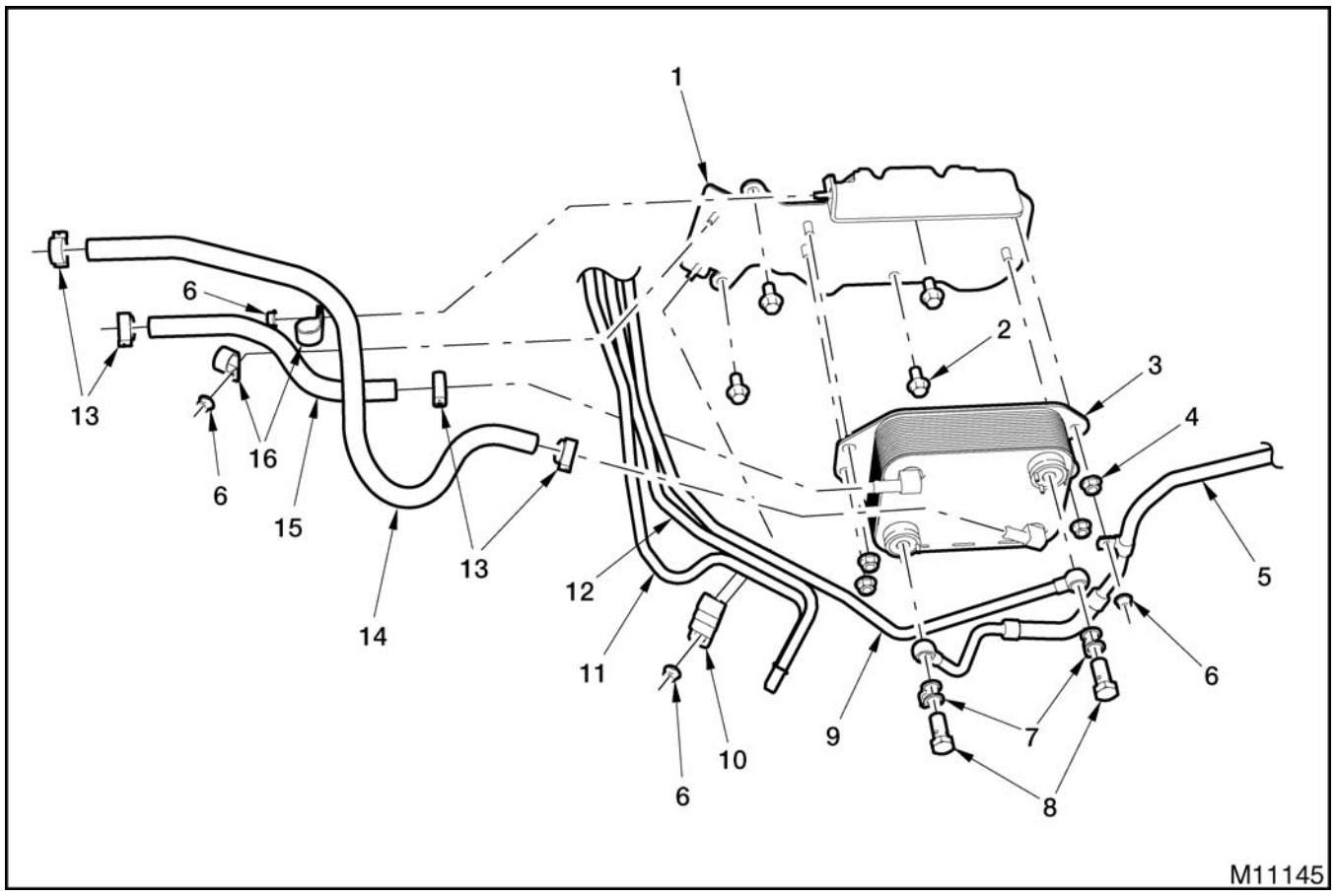

Figure 193 Fuel cooler assembly

1. Cooler support bracket assembly
2. M10 x 20 bolt (4)
3. Fuel cooler assembly
4. M8 nut (4)
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6. M6 nut (4)
7. Dual M12 banjo washer (2)
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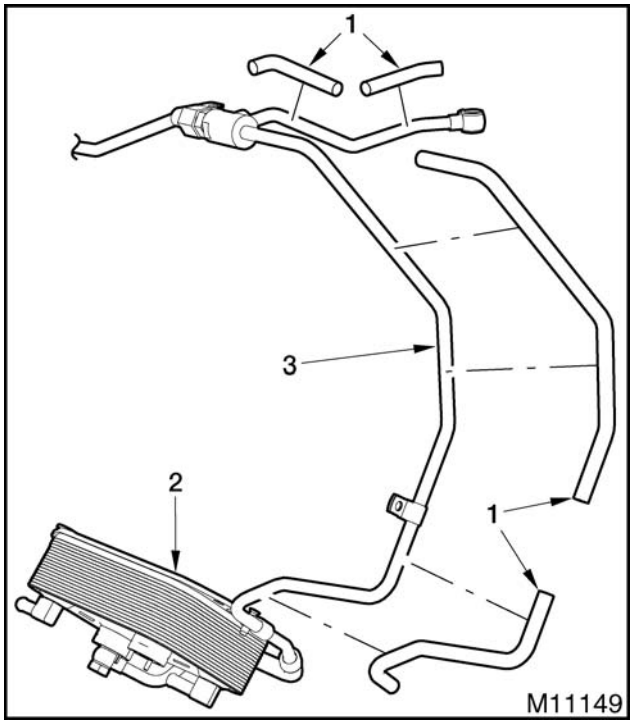

Figure 194 Fuel line sleeve — High-pressure pump to cooler tube assembly

1. Fuel line sleeve (4)
2. Fuel cooler assembly
3. High-pressure pump to cooler tube assembly

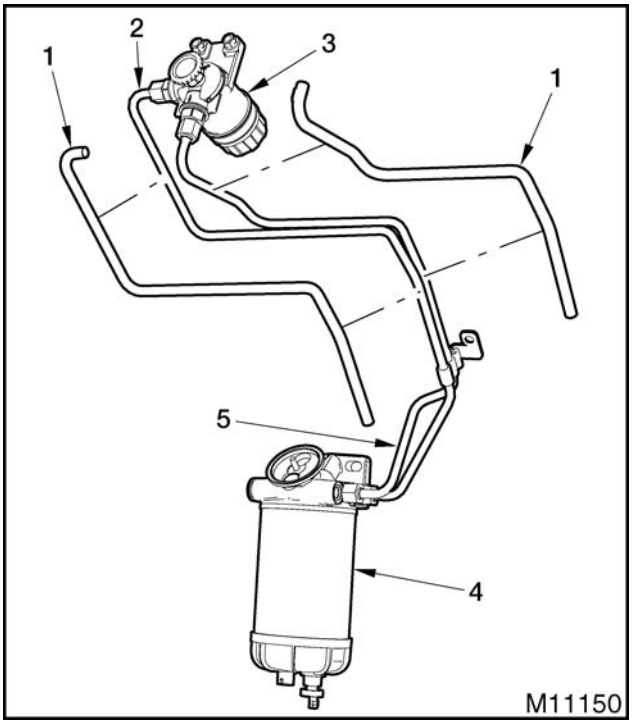

Figure 195 Fuel line sleeve — Primer pump tubes

1. Fuel line sleeve (2)
2. Fuel return from primer pump tube assembly
3. Fuel primer pump assembly
4. Primary fuel filter assembly
5. Fuel supply to primer pump tube 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 the transmission to park or neutral, set the parking brake, and block the wheels before doing diagnostic or service procedures.

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

WARNING: To prevent personal injury or death, remove the ground cable from the negative terminal of the main battery before disconnecting or connecting electrical components. Always connect the ground cable last.

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 according to applicable regulations. Never put engine fluids in the trash, on the ground, in sewers or bodies of water.

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

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

- Engine Electrical
- Exhaust Gas Recirculating (EGR) System
- Variable Geometry Turbocharger (VGT)
- Air Compressor and Power Steering/Fuel Pump

Fuel Prescreen Element

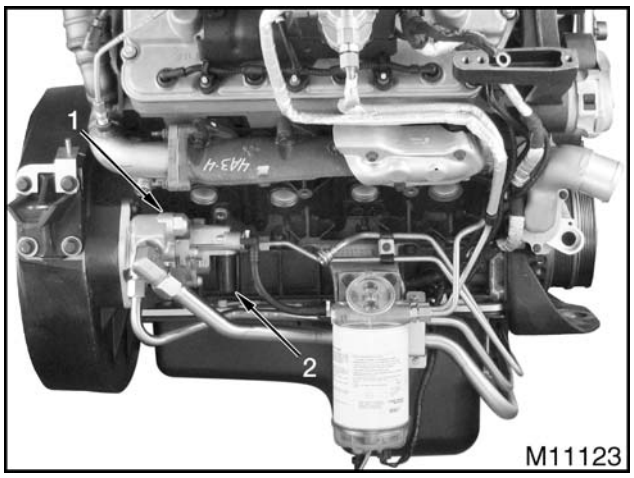

Figure 196 Removal of prescreen element

1. Gear driven fuel pump assembly
2. Prescreen bowl

WARNING: To prevent personal injury or death, dispose of fuel in a container marked DIESEL FUEL, according to applicable regulations.

1. Place a suitable container under prescreen bowl to catch draining fuel.
2. Use a 30 mm box end wrench to remove prescreen bowl from power steering/fuel pump.
3. Clean prescreen element after inspection, or replace if damaged.

Primary Fuel Filter Element

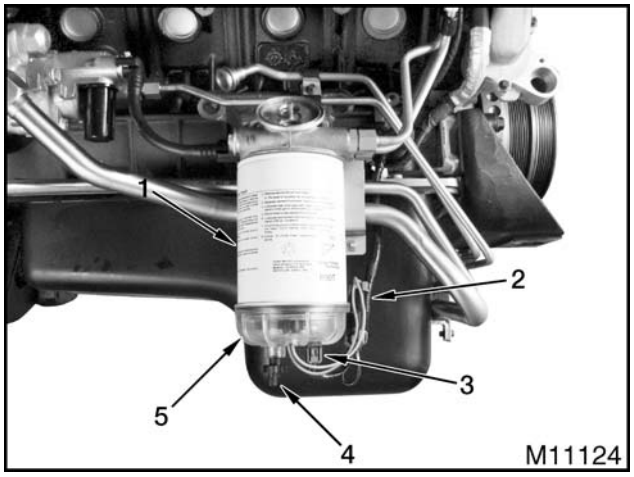

Figure 197 Primary filter element assembly

1. Primary filter element assembly
2. Fuel heater electrical connector
3. Water in Fuel (WIF) sensor electrical connector
4. Fuel drain valve
5. Bowl assembly with fuel heater/probe

1. Disconnect fuel heater electrical connector.
2. Disconnect WIF sensor electrical connector.

WARNING: To prevent personal injury or death, dispose of fuel in a container marked DIESEL FUEL, according to applicable regulations.

3. Place a suitable container under bowl assembly to catch draining fuel.
4. Turn fuel drain valve counterclockwise to drain fuel.
5. Rotate bowl assembly clockwise and remove from filter element. Use an oil filter wrench if necessary.

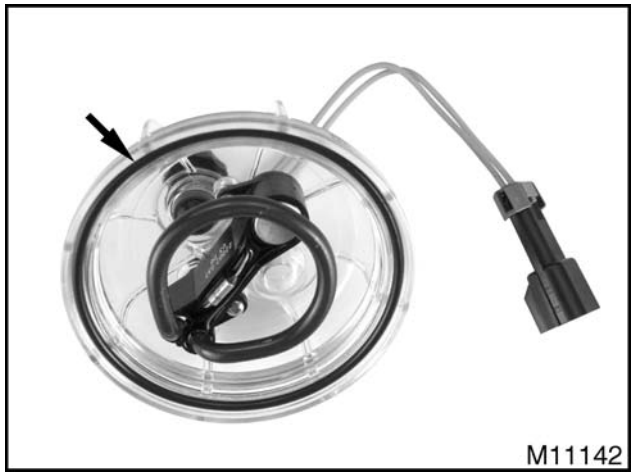

Figure 198 Element and bowl primary filter seal

6. Remove and discard bowl primary filter seal.
7. Remove primary filter element assembly. Use an oil filter wrench if necessary.

Secondary Fuel Filter Element

Figure 199 Fuel filter cap

1. Remove fuel filter cap by turning it counterclockwise.
2. Remove and discard fuel filter cap O-ring.
3. Lift fuel filter element from fuel filter housing.

Primary Fuel Filter Assembly and Tubing

WARNING: To prevent personal injury or death, dispose of fuel in a container marked DIESEL FUEL, according to applicable regulations.

1. Place a suitable container under bowl assembly to catch draining fuel.

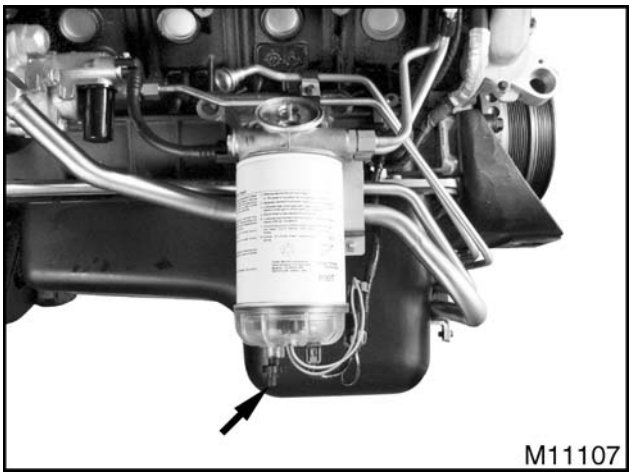

Figure 200 Fuel drain valve

2. Turn fuel drain valve counterclockwise to drain fuel.

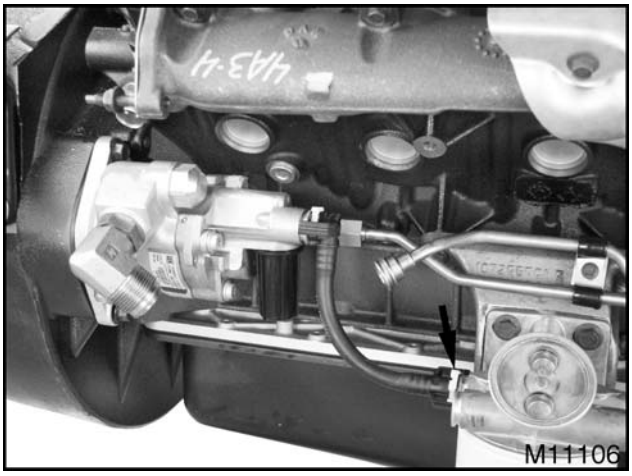

Figure 201 Primary fuel filter to pump tube assembly

3. Push tab to release fitting, and disconnect primary fuel filter to pump tube assembly.

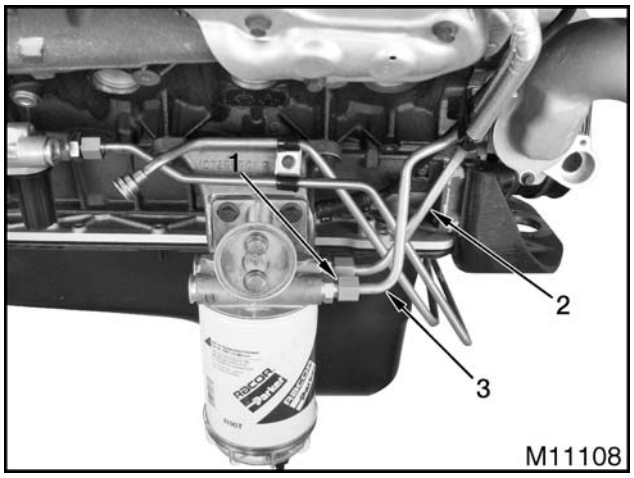

Figure 202 Primer pump tubes connection

1. 3/8” O-ring face seal nut (2)
2. Fuel return from primer pump tube assembly
3. Fuel supply to primer pump tube assembly

4. Loosen 3/8” O-ring face seal nut on fuel return from primer pump tube assembly.
5. Loosen 3/8” O-ring face seal nut on fuel supply to primer pump tube assembly.
6. Disconnect fuel supply to primer pump tube assembly and fuel return from primer pump tube assembly.
7. Cover ports and ends of tubes with Fuel System Caps ZTSE4710 (page 159). If plastic caps are not available, cover openings with tape.

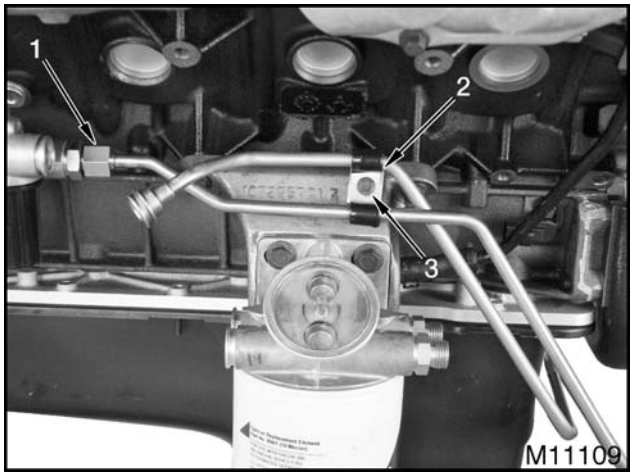

Figure 203 Primary filter bracket support clamp

1. 3/8” O-ring face seal nut
2. Saddle clamp
3. M6 x 12 bolt

8. Remove M6 x 12 bolt.
9. Remove saddle clamp and flat clamp.
10. Loosen 3/8” O-ring face seal nut and disconnect fuel supply tube assembly.

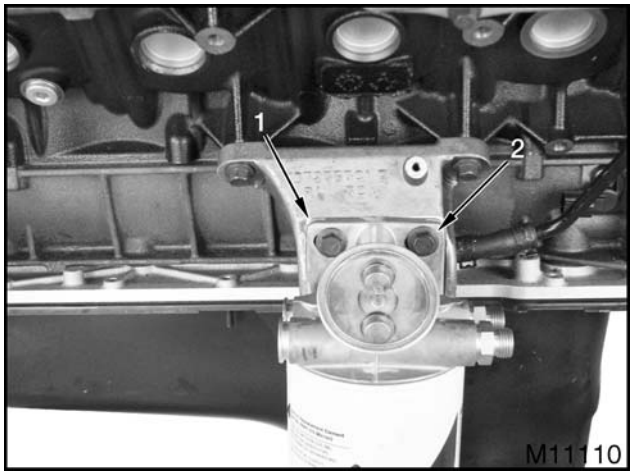

Figure 204 Fuel filter primary header to primary filter bracket support bolts

1. Fuel filter primary header
2. M10 x 30 bolt (2)

11. Remove two M10 x 30 bolts and fuel filter primary header.

Figure 205 Fuel filter primary header O-rings

12. Remove and discard two O-rings.

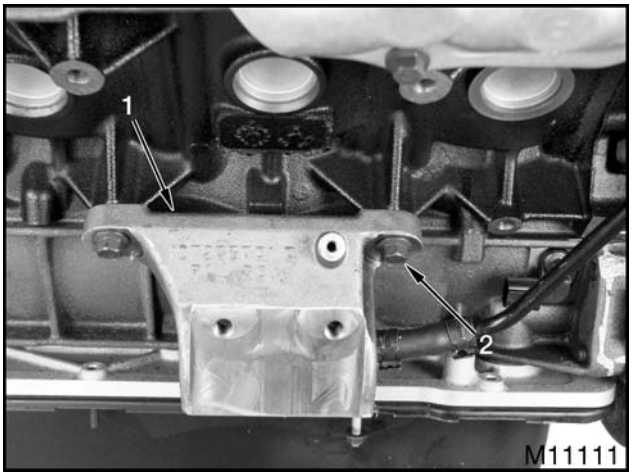

Figure 206 Primary filter bracket support bolts

1. Primary filter bracket support
2. M10 x 30 bolt (2)

13. Remove two M10 x 30 bolts and primary filter bracket support.

Fuel Primer Pump Assembly and Tubing

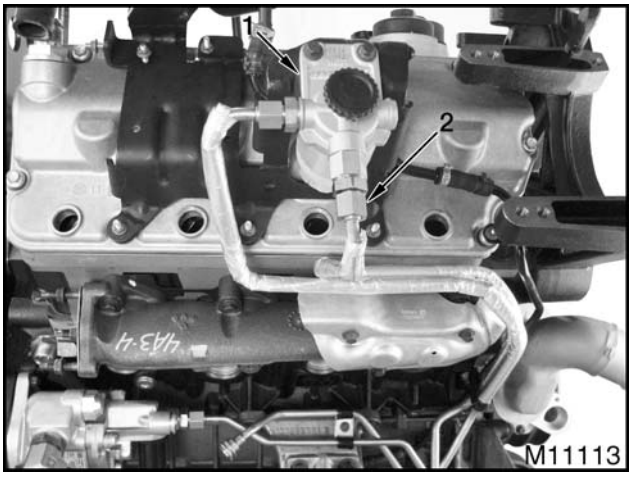

Figure 207 Fuel primer pump assembly tube connections

1. Fuel primer pump assembly
2. 3/8” O-ring face seal nut (2)

1. Loosen two 3/8” O-ring face seal nuts.
2. Disconnect fuel supply to primer pump tube assembly and fuel return from primer pump tube assembly.
3. Cover ports and ends of tubes with Fuel System Caps ZTSE4710 (page 159). If plastic caps are not available, cover openings with tape.

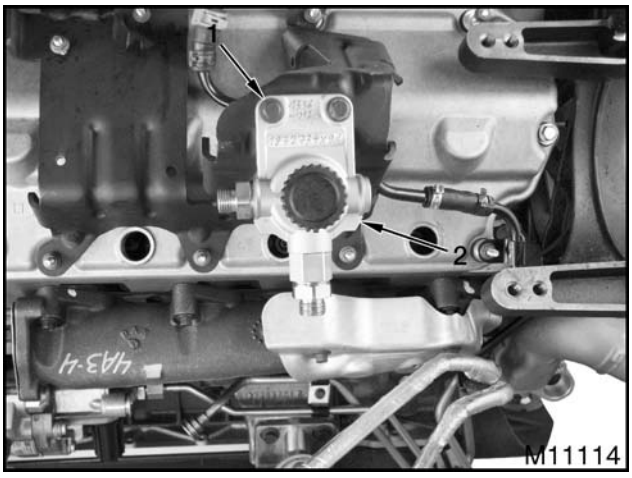

Figure 208 Fuel primer pump assembly bolts

1. M8 x 30 bolt (2)
2. Fuel primer pump assembly

4. Remove two M8 x 30 bolts and fuel primer pump assembly.

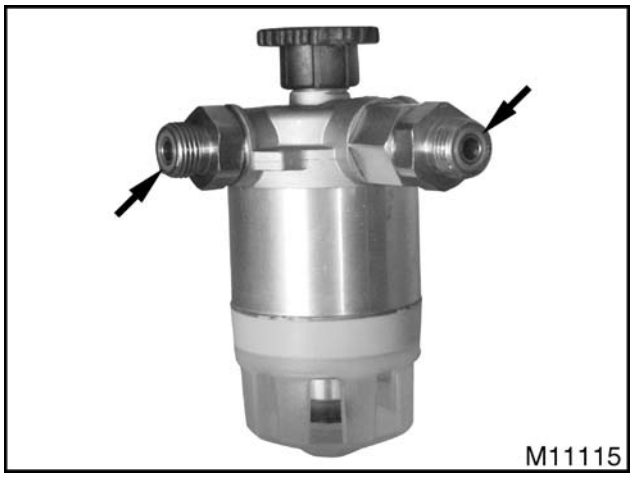

Figure 209 Fuel primer pump assembly O-rings

5. Remove and discard two O-rings.

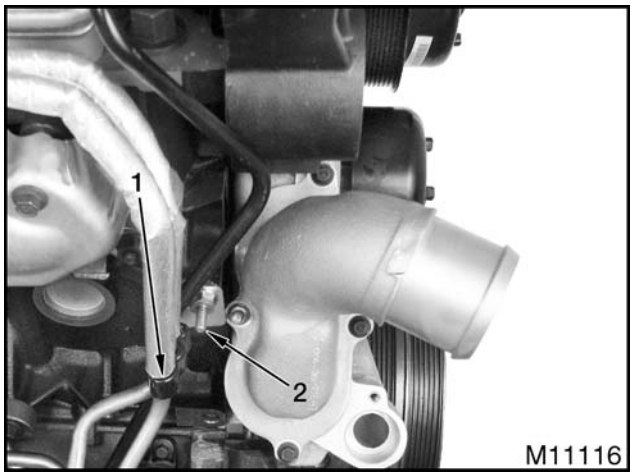

Figure 210 Triple tube clamp

1. Triple tube clamp
2. M8 x 30 stud bolt

6. Remove M8 x 30 stud bolt.
7. Remove triple tube clamp.
8. Remove fuel return from primer pump tube assembly.
9. Remove fuel supply to primer pump tube assembly.

Secondary Fuel Filter and Tubing

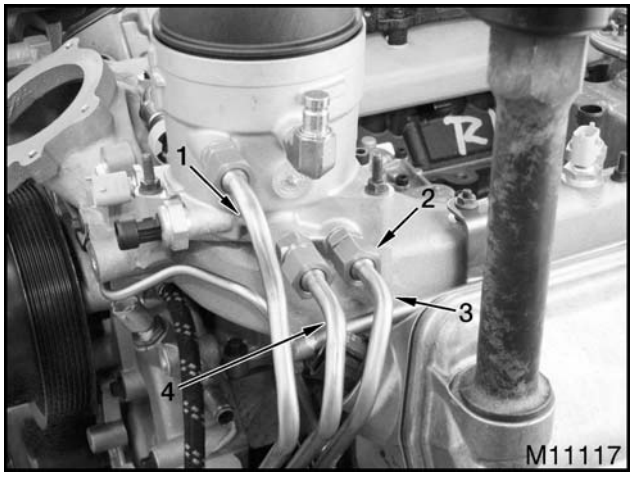

Figure 211 Fuel supply and return tubing

1. Fuel supply to filter tube assembly
2. 3/8” O-ring face seal nut (3)
3. Fuel cooler to filter tube assembly
4. Fuel return to tank tube assembly

WARNING: To prevent personal injury or death, dispose of fuel in a container marked DIESEL FUEL, according to applicable regulations.

1. Place a suitable container under tube connections to catch draining fuel.
2. Loosen three 3/8” O-ring face seal nuts.
3. Disconnect fuel supply to filter tube assembly.
4. Disconnect fuel cooler to filter tube assembly.
5. Disconnect fuel return to tank tube assembly.
6. Cover ports and ends of tubes with Fuel System Caps ZTSE4710 (page 159). If plastic caps are not available, cover openings with tape.

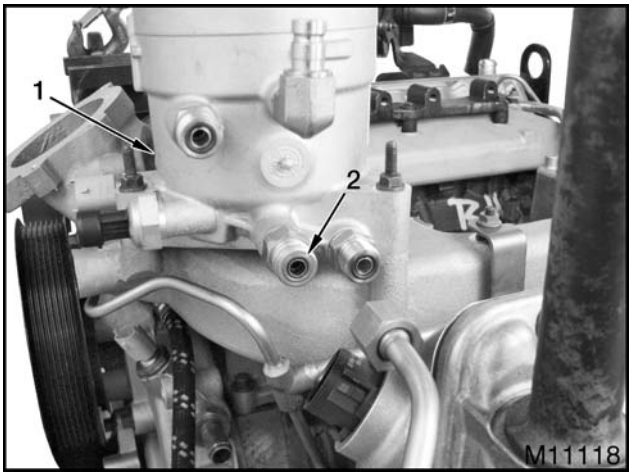

Figure 212 Fuel filter housing O-rings

1. Fuel filter housing
2. O-ring (3)

7. Remove and discard three O-rings.

Figure 213 Filter to pump tube assembly connection

1. Filter to pump tube assembly
2. Fitting release ring

8. Pull fitting release ring toward tube to release fitting lock, and disconnect filter to pump tube assembly from fuel filter housing.
9. Cover port on fuel filter housing and end of filter to pump tube assembly with Fuel System Caps ZTSE4710 (page 159). If plastic caps are not available, cover openings with tape.

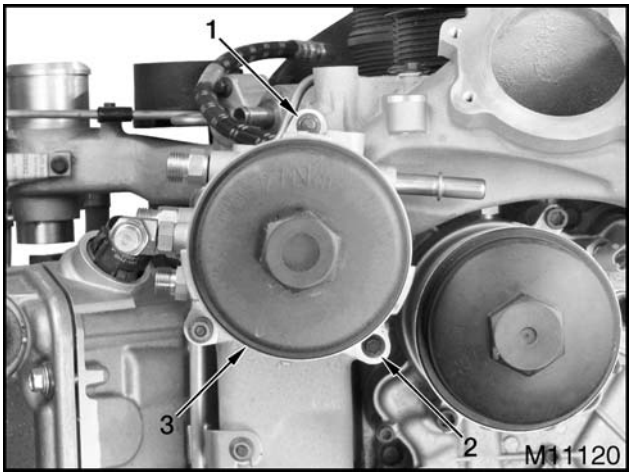

Figure 214 Secondary fuel filter assembly bolts

1. M6 x 45 stud bolt (2)
2. M6 x 45 bolt
3. Secondary fuel filter assembly

10. Remove two M6 x 45 stud bolts and M6 x 45 bolt.
11. Remove secondary fuel filter assembly.

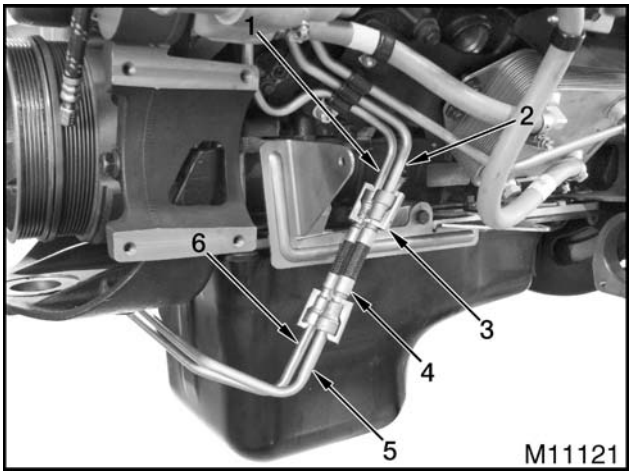

Figure 215 Fuel supply and return tube connections

1. Fuel supply to filter tube
2. Fuel return to tank tube assembly
3. 3/8” redundant clip (4)
4. 3/8” hose assembly (2)
5. Fuel return tube assembly
6. Fuel supply tube assembly

12. Remove four 3/8” redundant clips.
13. Use a spring lock coupling disconnect tool (page 159) to disconnect and remove fuel return tube assembly and fuel supply tube assembly from 3/8” hose assemblies.
14. Use a spring lock coupling disconnect tool (page 159) to disconnect and remove 3/8” hose assemblies from fuel return to tank tube assembly and fuel supply to filter tube.

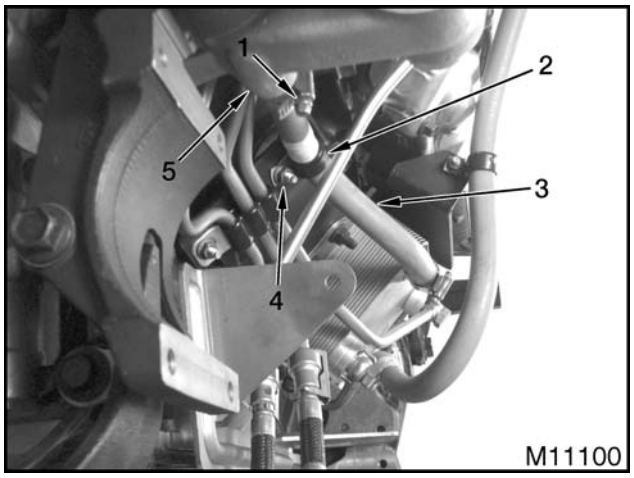

Figure 216 Coolant out from fuel cooler hose

1. Hose clamp
2. Clamp
3. Coolant out from fuel cooler hose
4. M6 nut
5. Front crankcase cover

15. Remove M6 nut and release clamp.

WARNING: To prevent personal injury or death, make sure the engine has cooled before draining coolant.

16. Place a suitable container under coolant out hose to catch draining coolant.
17. Loosen hose clamp and disconnect coolant out hose from front crankcase cover fitting.

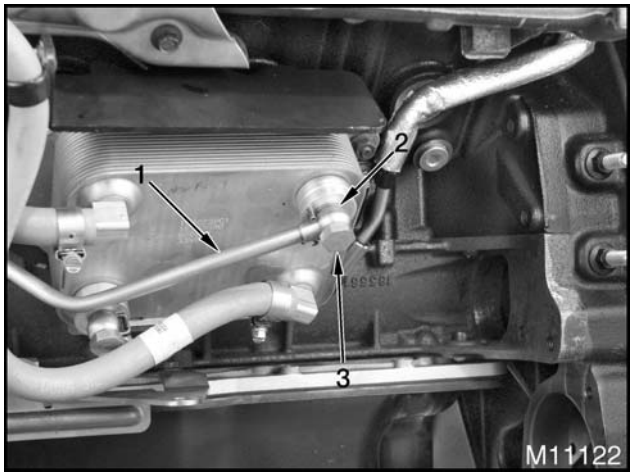

Figure 217 Fuel cooler to filter tube assembly connection

1. Fuel cooler to filter tube assembly
2. Dual M12 banjo washer
3. M12 banjo bolt

18. Remove M12 banjo bolt and disconnect fuel cooler to filter tube assembly.
19. Remove and discard dual M12 banjo washer.
20. Cover fuel cooler port and end of fuel cooler to filter tube with Fuel System Caps ZTSE4710 (page 159). If plastic caps are not available, cover openings with tape.

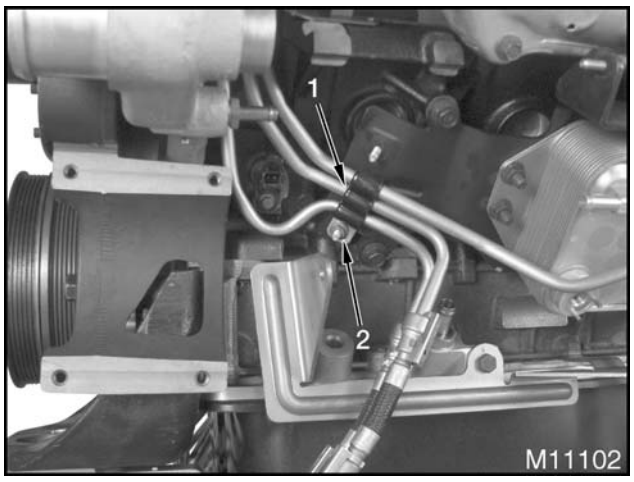

Figure 218 Triple tube clamp

1. Triple tube clamp
2. M6 nut

21. Remove M6 nut.
22. Remove triple tube clamp.
23. Remove fuel cooler to filter tube assembly.
24. Remove fuel return to tank tube assembly.
25. Remove fuel supply to filter tube assembly.

High-pressure Fuel Pump (HPFP) Assembly and Tubing

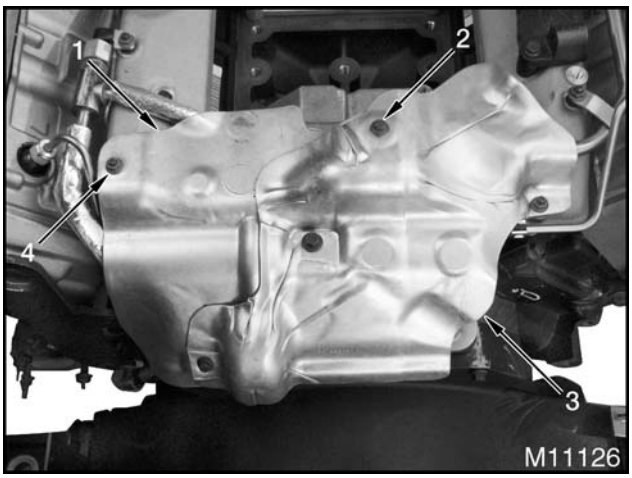

Figure 219 Heat shields

1. Left heat shield
2. M6 x 12 bolt (3)
3. Right heat shield
4. M6 nut (2)

1. Remove three M6 x 12 heat shield bolts.
2. Remove two M6 heat shield nuts.
3. Remove right and left heat shields.

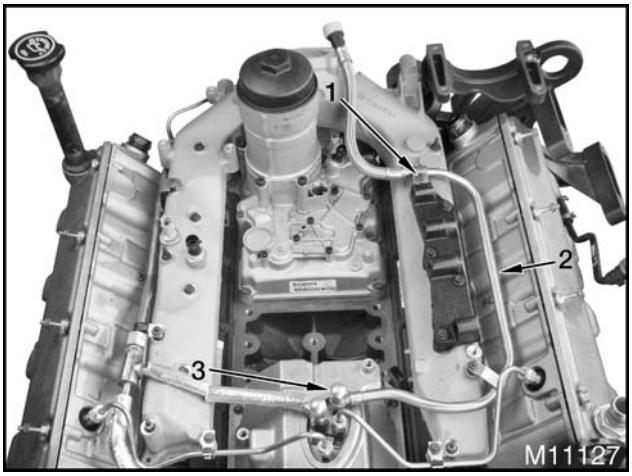

Figure 220 Filter to pump tube assembly

1. M6 nut (2)
2. Filter to pump tube assembly
3. M12 cap nut

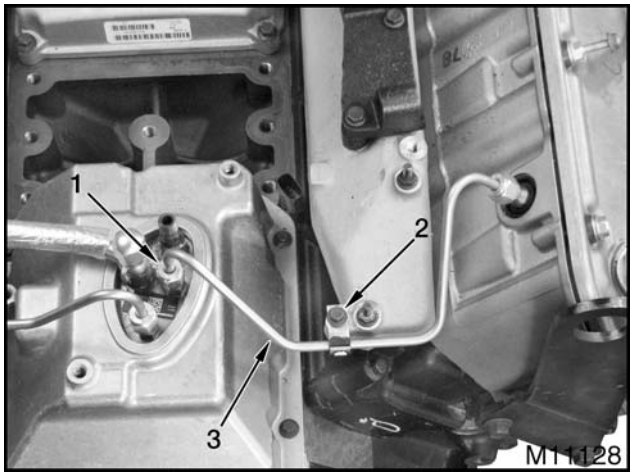

Figure 221 Pump right tube assembly

1. Tube nut (2)
2. M6 x 16 bolt
3. Pump right tube assembly

4. Remove two M6 nuts.
5. Remove M12 cap nut.
6. Remove filter to pump tube assembly.
7. Remove and discard dual M12 banjo washer from filter to pump tube assembly.
8. Cover fuel pump port and end of filter to pump tube with Fuel System Caps ZTSE4710 (page 159). If plastic caps are not available, cover openings with tape.
9. Loosen two tube nuts.
10. Remove M6 x 16 bolt.

WARNING: To prevent personal injury or death, whenever any fuel line (tubing) in the high-pressure fuel system is removed, it must be replaced with new.

11. Remove and discard pump right tube assembly.
12. Cover fuel pump and fuel rail ports with Fuel System Caps ZTSE4710 (page 159). If plastic caps are not available, cover openings with tape.

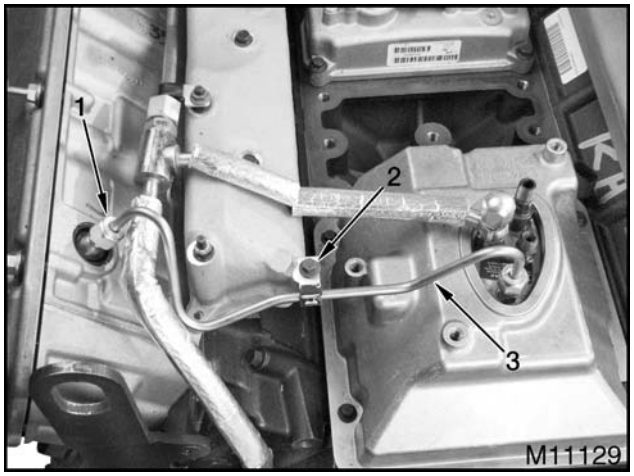

Figure 222 Pump left tube assembly

1. Tube nut (2)
2. M6 x 16 bolt
3. Pump left tube assembly

13. Loosen two tube nuts.
14. Remove M6 x 16 bolt.

WARNING: To prevent personal injury or death, whenever any fuel line (tubing) in the high-pressure fuel system is removed, it must be replaced with new.

15. Remove and discard pump left tube assembly.
16. Cover fuel pump and fuel rail ports with Fuel System Caps ZTSE4710 (page 159). If plastic caps are not available, cover openings with tape.

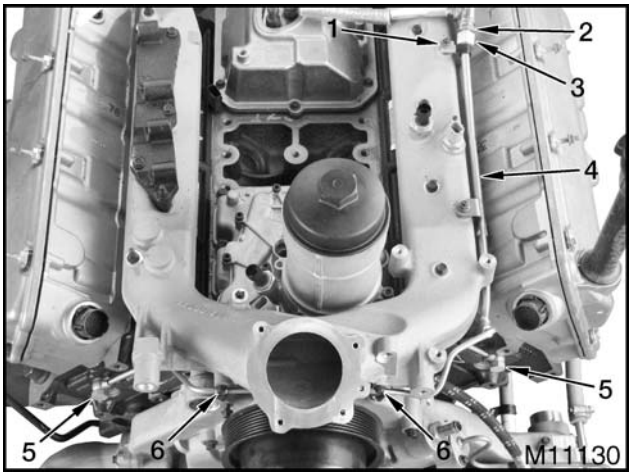

Figure 223 Injector return tube assembly

1. M6 nut (2)
2. Injector leak off check valve
3. 3/8” O-ring face seal nut
4. Injector return tube assembly
5. M12 banjo bolt (2)
6. M6 x 10 bolt (2)

17. Use a wrench to hold injector leak off check valve in place, and loosen 3/8” O-ring face seal nut.
18. Remove two M12 banjo bolts.
19. Remove and discard two dual M12 banjo washers.
20. Remove two M6 x 10 bolts.
21. Remove two M6 nuts.
22. Remove injector return tube assembly.
23. Cover ports and ends of tube with Fuel System Caps ZTSE4710 (page 159). If plastic caps are not available, cover openings with tape.

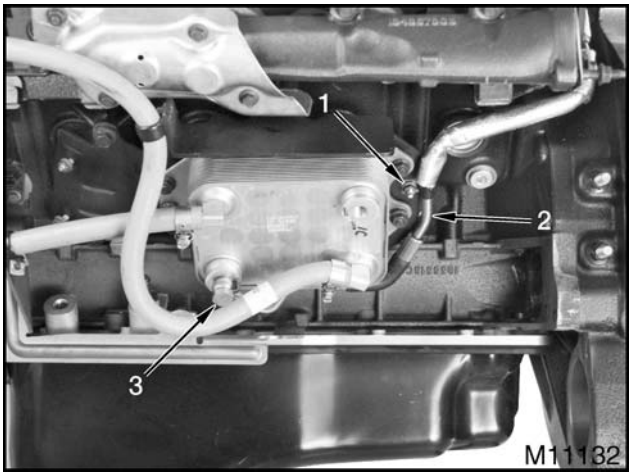

Figure 224 High-pressure pump to cooler tube assembly — lower connection

1. M6 nut (2)
2. High-pressure pump to cooler tube assembly
3. M12 banjo bolt

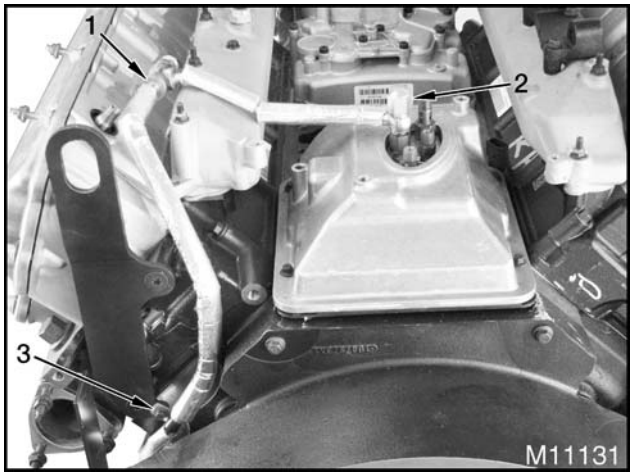

Figure 225 High-pressure pump to cooler tube assembly — upper connection

1. High-pressure pump to cooler tube assembly
2. M12 cap nut
3. M6 x 12 bolt

24. Remove M12 banjo bolt.
25. Remove and discard dual M12 banjo washer from high-pressure pump to cooler tube assembly.
26. Cover fuel cooler port and end of tube with Fuel System Caps ZTSE4710 (page 159). If plastic caps are not available, cover openings with tape.
27. Remove M6 high-pressure pump to cooler tube assembly clamp nut.
28. Remove M12 cap nut.
29. Remove M6 x 12 high-pressure pump to cooler tube assembly clamp bolt.
30. Remove high-pressure pump to cooler tube assembly.
31. Remove and discard dual M12 banjo washer from high-pressure pump to cooler tube assembly.
32. Cover fuel pump port and ends of tube with Fuel System Caps ZTSE4710 (page 159). If plastic caps are not available, cover openings with tape.

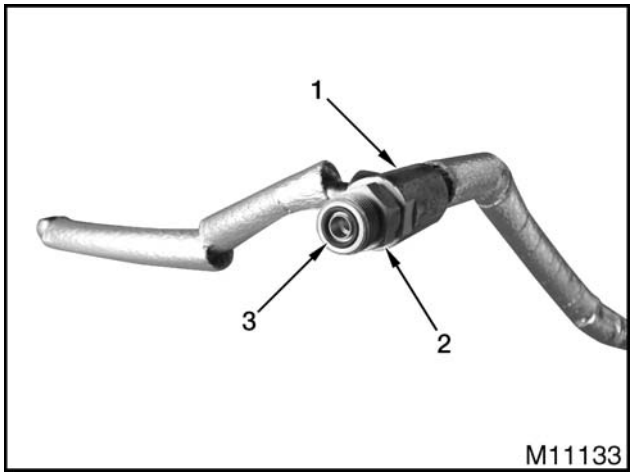

Figure 226 Injector leak off check valve

1. High-pressure pump to cooler tube assembly
2. Injector leak off check valve
3. O-ring

33. Use a wrench to hold high-pressure pump to cooler tube assembly, and remove injector leak off check valve.
34. Remove and discard O-ring.

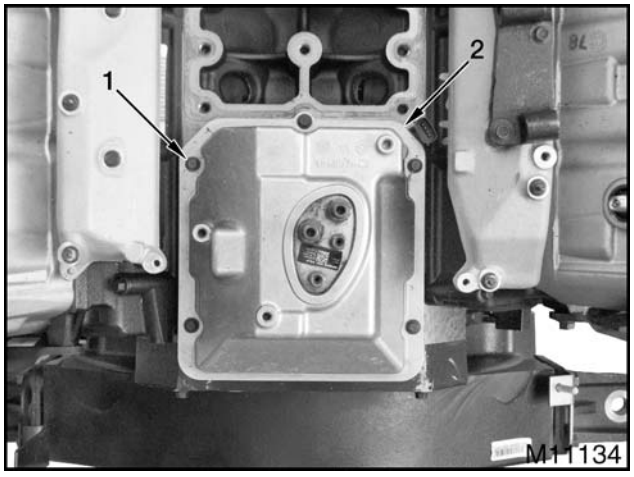

Figure 227 Fuel pump cover bolts

1. M6 x 25 bolt (5)
2. Fuel pump cover

35. Remove five M6 x 25 bolts and fuel pump cover.

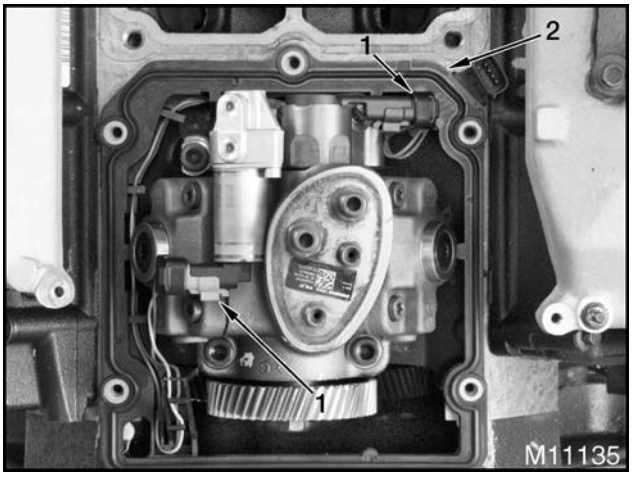

Figure 228 Pump cover gasket with connectors

1. Electrical connector (2)
2. Pump cover gasket with connectors

36. Disconnect two electrical connectors.
37. Remove and discard pump cover gasket with connectors.

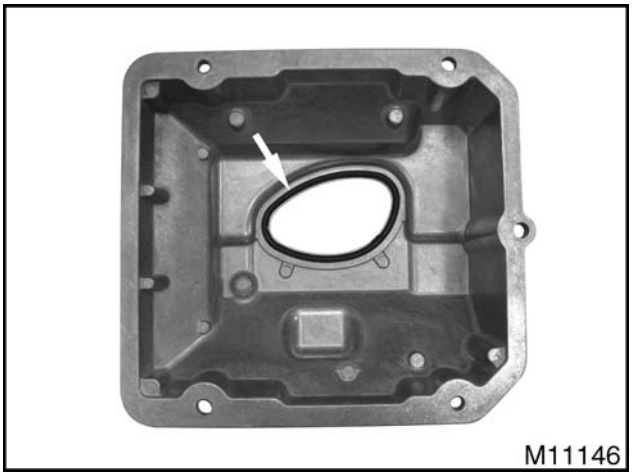

Figure 229 Pump cover gasket

38. Remove and discard pump cover gasket.

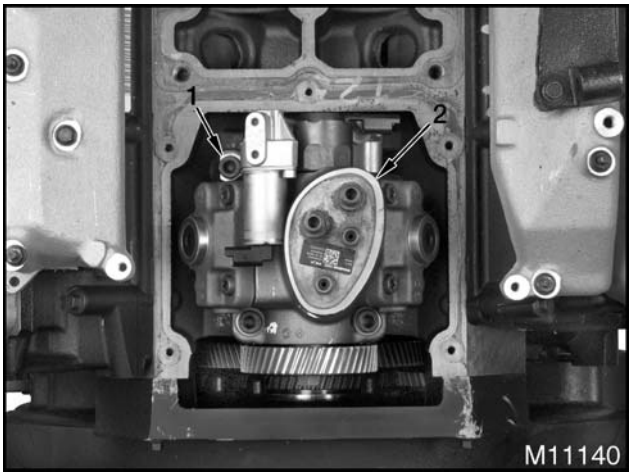

Figure 230 HPFP assembly

1. M10 x 55 bolt (3)
2. HPFP assembly

NOTE: Care must be taken to not drop the bolts into the crankcase.

39. Remove three M10 x 55 bolts and HPFP assembly.

Fuel Cooler Assembly

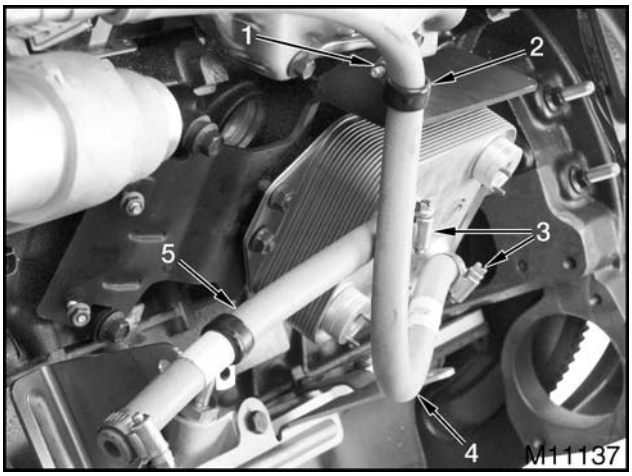

Figure 231 Fuel cooler assembly coolant hoses

1. M6 nut
2. Clamp
3. Hose clamp (2)
4. Coolant-in hose
5. Coolant-out from fuel cooler hose

1. Remove M6 nut and clamp.
2. Loosen two hose clamps.
3. Disconnect coolant-in hose and coolant-out hose from fuel cooler assembly.

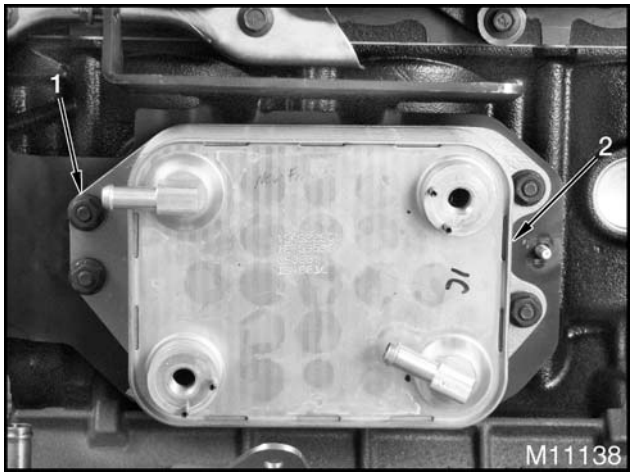

Figure 232 Fuel cooler assembly nuts

1. M8 nut (4)
2. Fuel cooler assembly

4. Remove four M8 nuts.
5. Remove fuel cooler assembly.

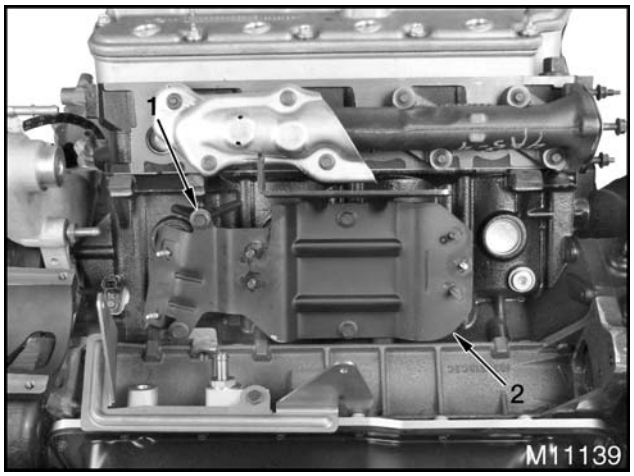

Figure 233 Cooler support bracket assembly

1. M10 x 20 bolt (4)
2. Cooler support bracket assembly

6. Remove four M10 x 20 bolts and cooler support bracket assembly.

Fuel Injectors and Fuel Rail to Injectors Tube Assemblies

NOTE: See Fuel Injector and Rail Assemblies (page 215) for removal procedures.

Inspection

1. Inspect fuel tubes for damage. Replace if necessary.
2. Inspect fuel line sleeves for damage. Replace if necessary.

Installation

Fuel Injectors and Fuel Rail to Injectors Tube Assemblies

NOTE: See Fuel Injector and Rail Assemblies (page 242) for installation procedures.

Fuel Cooler Assembly

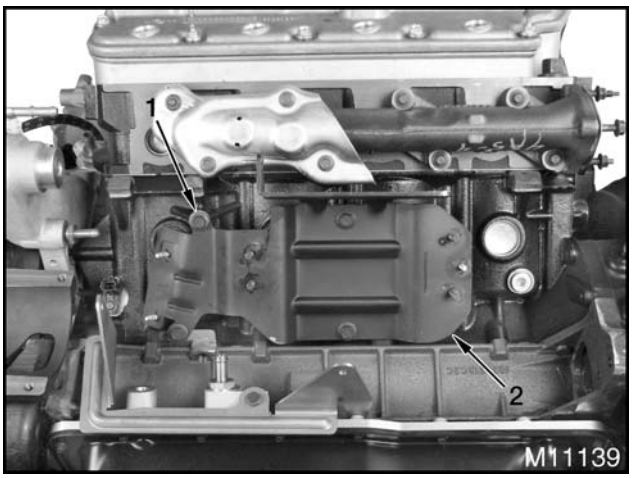

Figure 234 Cooler support bracket assembly

1. M10 x 20 bolt (4)
2. Cooler support bracket assembly

1. Install cooler support bracket assembly and four M10 x 20 bolts.
2. Tighten bolts to standard torque (page 369).

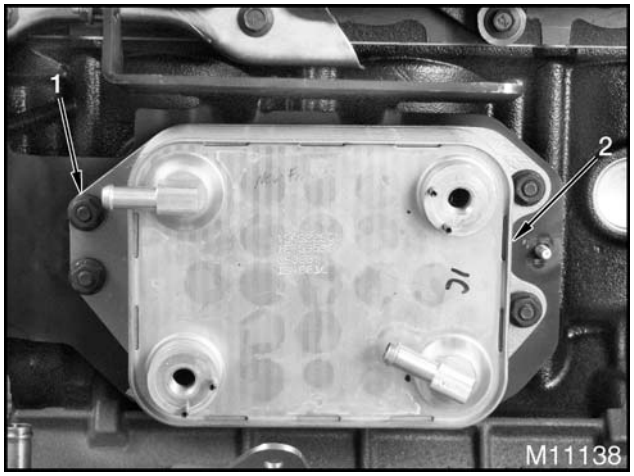

Figure 235 Fuel cooler assembly nuts

1. M8 nut (4)
2. Fuel cooler assembly

3. Install fuel cooler assembly and four M8 nuts.
4. Tighten nuts to standard torque (page 369).

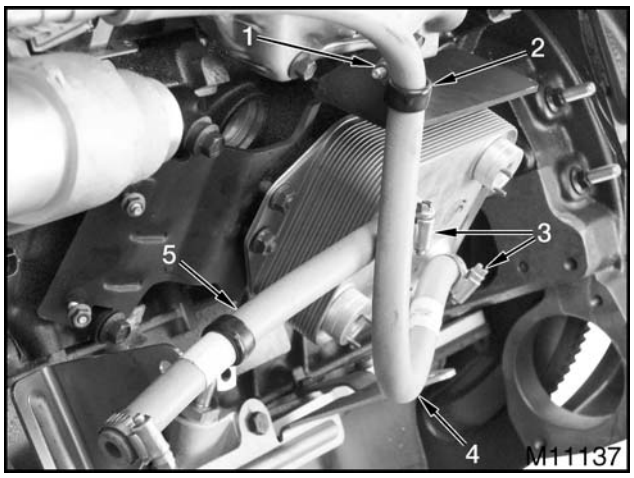

Figure 236 Fuel cooler assembly coolant hoses

1. M6 nut
2. Clamp
3. Hose clamp (2)
4. Coolant-in hose
5. Coolant-out from fuel cooler hose

5. Connect coolant-in hose and coolant-out hose to fuel cooler assembly. Do not tighten hose clamps at this time.

6. Install clamp and M6 nut. Do not tighten at this time.
7. Position coolant-in hose to maintain approximately 25.4 mm (1.0 in) clearance to exhaust manifold heat shield.
8. Tighten M6 clamp nut to standard torque (page 369).
9. Tighten two hose clamps to special torque (page 159).

High-pressure Fuel Pump (HPFP) Assembly and Tubing

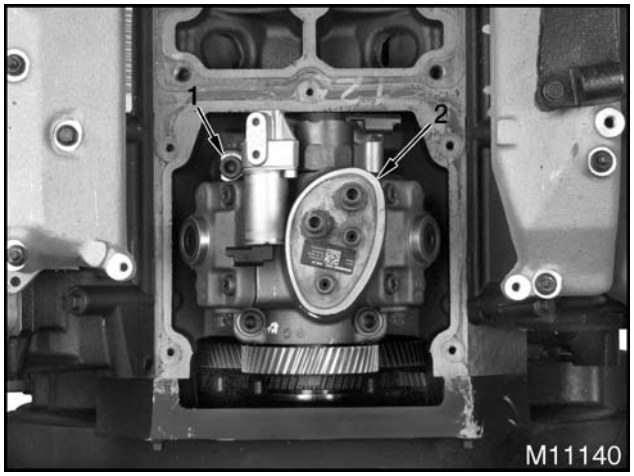

Figure 237 HPFP assembly

1. M10 x 55 bolt (3)
2. HPFP assembly

NOTE: Care must be taken to not drop the bolts into the crankcase.

1. Lower HPFP assembly into crankcase and secure with three M10 x 55 bolts. Tighten bolts to special torque (page 159).

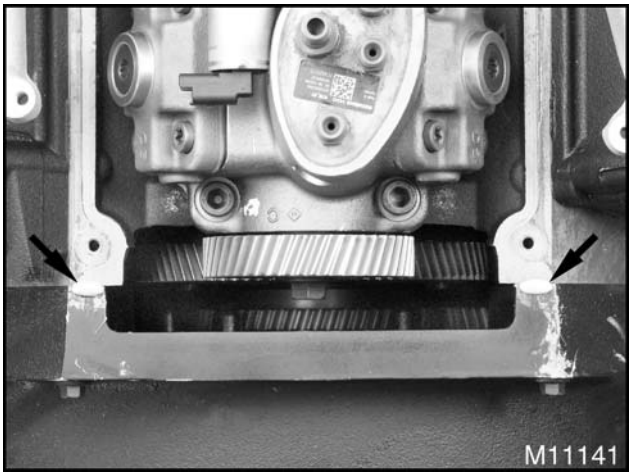

Figure 238 Liquid Gasket (RTV) application

2. Apply Liquid Gasket (RTV) (page 159) to joining surfaces of crankcase and crankcase rear cover assembly.

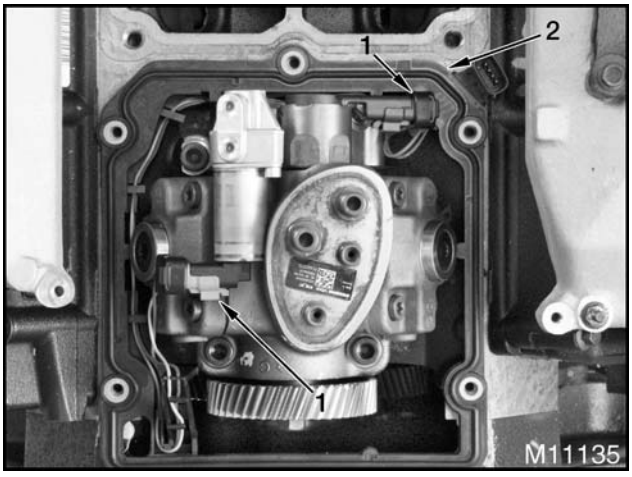

Figure 239 Pump cover gasket with connectors

1. Electrical connector (2)
2. Pump cover gasket with connectors

3. Install a new pump cover gasket with connectors and connect the two electrical connectors.

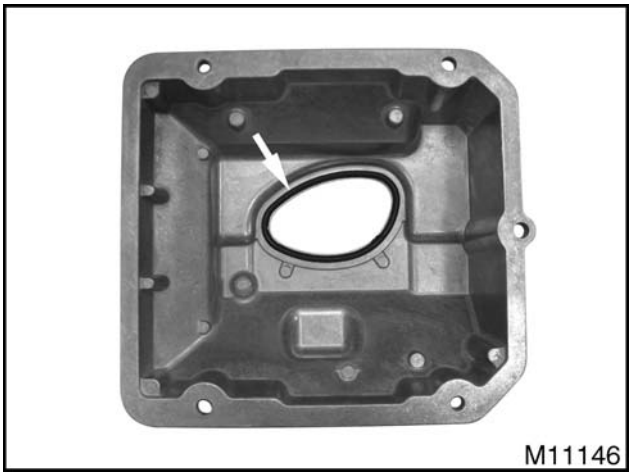

Figure 240 Pump cover gasket

4. Install a new pump cover gasket.

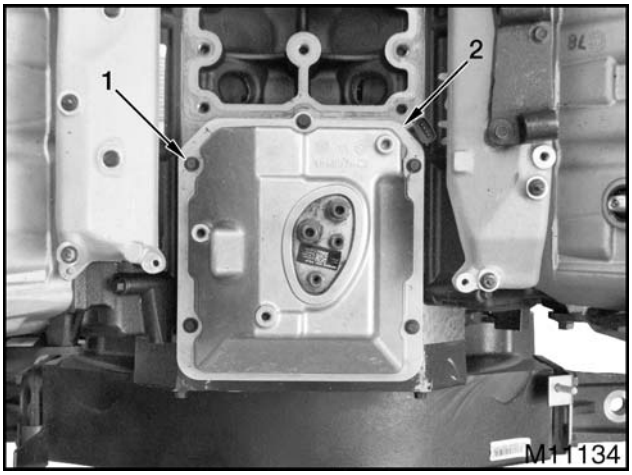

Figure 241 Fuel pump cover bolts

1. M6 x 25 bolt (5)
2. Fuel pump cover

5. Install fuel pump cover and five M6 x 25 bolts. Tighten bolts to special torque (page 159).

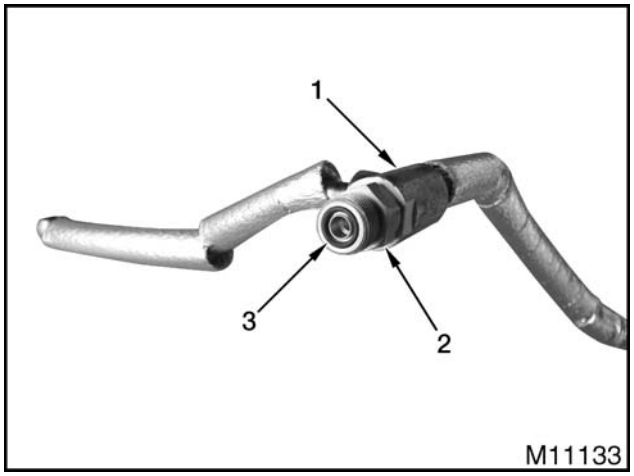

Figure 242 Injector leak off check valve

1. High-pressure pump to cooler tube assembly
2. Injector leak off check valve
3. O-ring

6. Install a new O-ring on injector leak off check valve.
7. Install injector leak off check valve on high-pressure pump to cooler tube assembly.
8. Use a wrench to hold high-pressure pump to cooler tube assembly, and tighten injector leak off check valve to special torque (page 159).

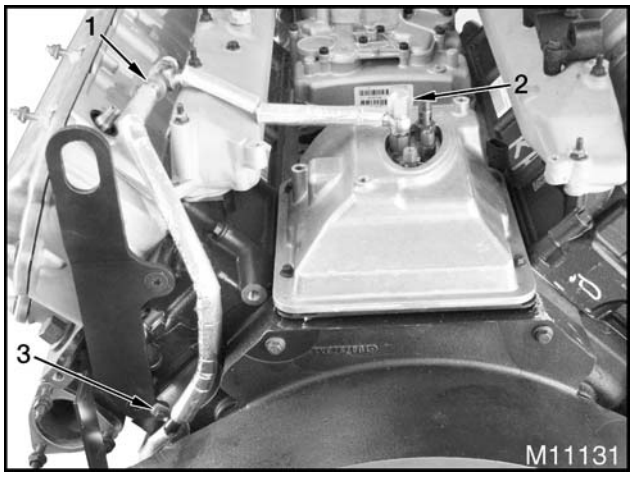

Figure 243 High-pressure pump to cooler tube assembly — upper connection

1. High-pressure pump to cooler tube assembly
2. M12 cap nut
3. M6 x 12 bolt

9. Install a new dual M12 banjo washer on high-pressure pump to cooler tube assembly fitting connecting to HPFP assembly.
10. Install high-pressure pump to cooler tube assembly.
11. Install M6 x 12 high-pressure pump to cooler tube assembly clamp bolt. Tighten bolt to standard torque (page 369).
12. Install M12 cap nut. Tighten cap nut to special torque (page 159).

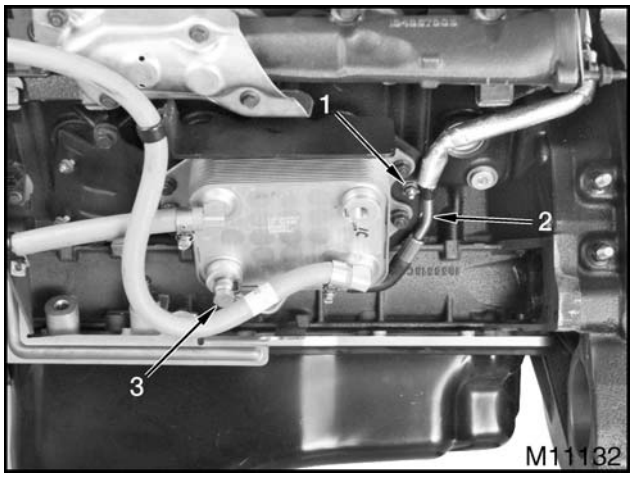

Figure 244 High-pressure pump to cooler tube assembly — lower connection

1. M6 nut (2)
2. High-pressure pump to cooler tube assembly
3. M12 banjo bolt

13. Install M6 clamp nut. Tighten nut to standard torque (page 369).
14. Install a new dual M12 banjo washer on high-pressure pump to cooler tube assembly.
15. Install M12 banjo bolt. Tighten banjo bolt to special torque (page 159).

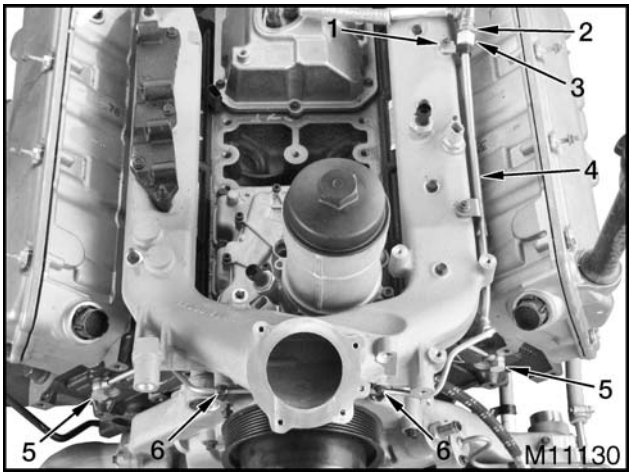

Figure 245 Injector return tube assembly

1. M6 nut (2)
2. Injector leak off check valve
3. 3/8” O-ring face seal nut
4. Injector return tube assembly
5. M12 banjo bolt (2)
6. M6 x 10 bolt (2)

16. Install injector return tube assembly.
17. Loosely install two M6 nuts and two M6 x 10 bolts. Do not tighten at this time.
18. Hand start and seat 3/8” O-ring face seal nut onto injector leak off check valve.

NOTE: When using a crowfoot extension make sure to adjust the torque settings as necessary to compensate for any length added to the torque wrench. See Appendix B - Torques (page 370).

19. Use a wrench to hold injector leak off check valve and, with a crowfoot torque wrench, tighten 3/8” O-ring face seal nut to special torque (page 159).
20. Install two new dual M12 banjo washers on injector return tube assembly.
21. Install two M12 banjo bolts. Tighten banjo bolts to special torque (page 159).
22. Tighten two M6 x 10 bolts to standard torque (page 369).
23. Tighten two M6 nuts to standard torque (page 369).

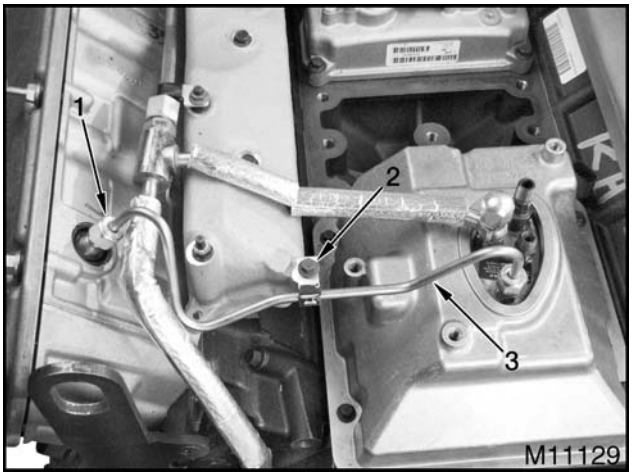

Figure 246 Pump left tube assembly

1. Tube nut (2)
2. M6 x 16 bolt
3. Pump left tube assembly

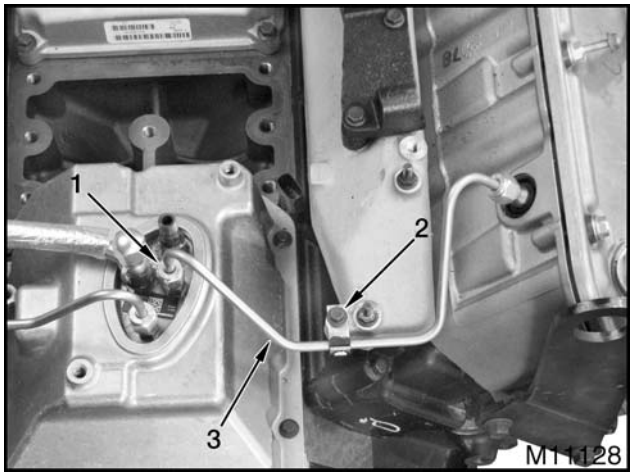

Figure 247 Pump right tube assembly

1. Tube nut (2)
2. M6 x 16 bolt
3. Pump right tube assembly

WARNING: To prevent personal injury or death, whenever any fuel line (tubing) in the high-pressure fuel system is removed, it must be replaced with new.

24. Position new pump left tube assembly between HPFP assembly and left fuel rail.

NOTE: Support pump left tube assembly while hand tightening nuts to assure proper assembly of joints.

NOTE: When using a crowfoot extension make sure to adjust the torque settings as necessary to compensate for any length added to the torque wrench. See Appendix B - Torques (page 370).

25. Hand start and seat tube assembly nuts onto mating connections, then tighten with a crowfoot torque wrench as follows:
    a. Torque to 2 N·m (18 lbf·in).
    b. Torque to 16 N·m (142 lbf·in).
    c. Tighten nuts an additional 60°.
26. Install M6 x 16 bolt. Tighten bolt to standard torque (page 369).

WARNING: To prevent personal injury or death, whenever any fuel line (tubing) in the high-pressure fuel system is removed, it must be replaced with new.

27. Position new pump right tube assembly between HPFP assembly and right fuel rail.

NOTE: Support pump right tube assembly while hand tightening nuts to assure proper assembly of joints.

NOTE: When using a crowfoot extension make sure to adjust the torque settings as necessary to compensate for any length added to the torque wrench. See Appendix B - Torques (page 370).

28. Hand start and seat tube assembly nuts onto mating connections, then tighten with a crowfoot torque wrench as follows:
    a. Torque to 2 N·m (18 lbf·in).
    b. Torque to 16 N·m (142 lbf·in).
    c. Tighten nuts an additional 60°.
29. Install M6 x 16 bolt. Tighten bolt to standard torque (page 369).

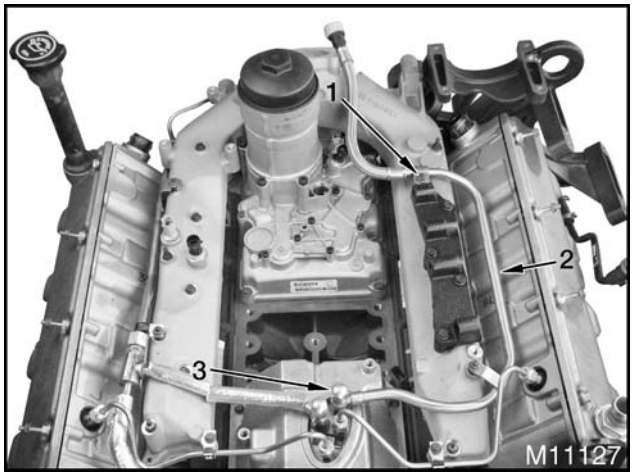

Figure 248 Filter to pump tube assembly

1. M6 nut (2)
2. Filter to pump tube assembly
3. M12 cap nut

30. Install a new dual M12 banjo washer on filter to pump tube assembly.
31. Position filter to pump tube assembly onto engine.
32. Install two M6 nuts. Tighten nuts to standard torque (page 369).
33. Install M12 cap nut. Tighten cap nut to special torque (page 159).

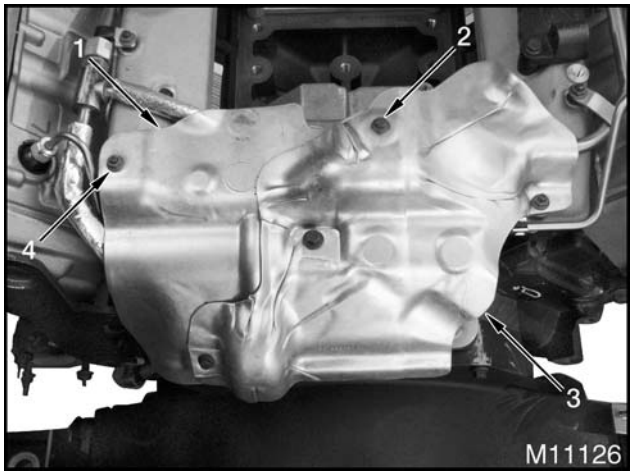

Figure 249 Heat shields

1. Left heat shield
2. M6 x 12 bolt (3)
3. Right heat shield
4. M6 nut (2)

34. Install left heat shield.
35. Install right heat shield.
36. Install three M6 x 12 heat shield bolts. Tighten bolts to standard torque (page 369).
37. Install two M6 heat shield nuts. Tighten nuts to standard torque (page 369).

Secondary Fuel Filter and Tubing

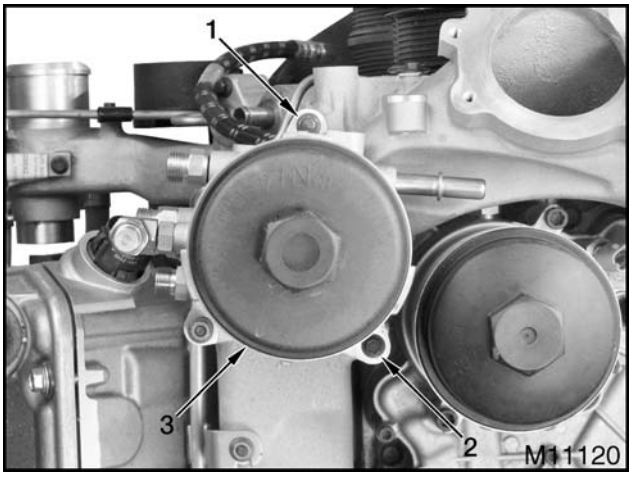

Figure 250 Secondary fuel filter assembly bolts

1. M6 x 45 stud bolt (2)
2. M6 x 45 bolt
3. Secondary fuel filter assembly

1. Install secondary fuel filter assembly.
2. Install two M6 x 45 stud bolts. Tighten stud bolts to standard torque (page 369).
3. Install M6 x 45 bolt. Tighten bolt to standard torque (page 369).

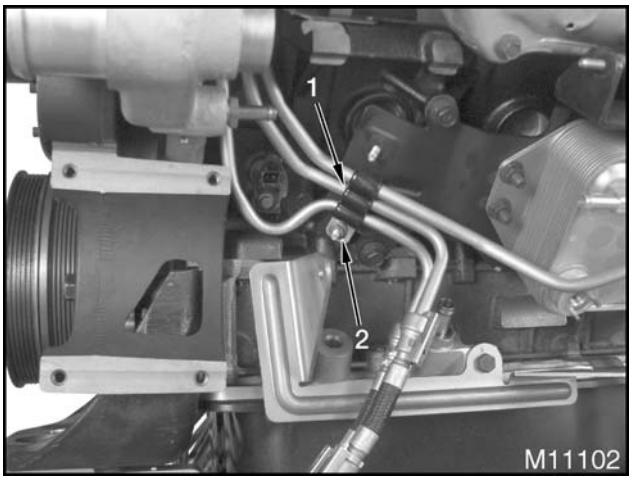

Figure 251 Triple tube clamp

1. Triple tube clamp
2. M6 nut

4. Install fuel supply to filter tube assembly, fuel cooler to filter tube assembly, and fuel return to tank tube assembly. Secure tubes with triple tube clamp.
5. Loosely install M6 nut. Do not tighten at this time.

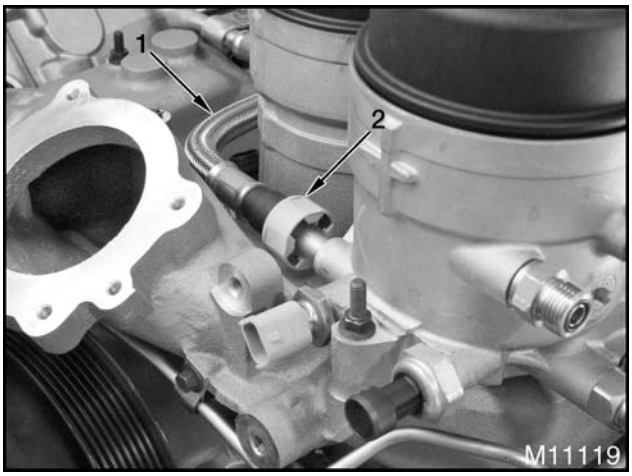

Figure 252 Filter to pump tube assembly connection

1. Filter to pump tube assembly
2. Fitting release ring

6. Connect filter to pump tube assembly, and push tube toward fuel filter housing to lock fitting.

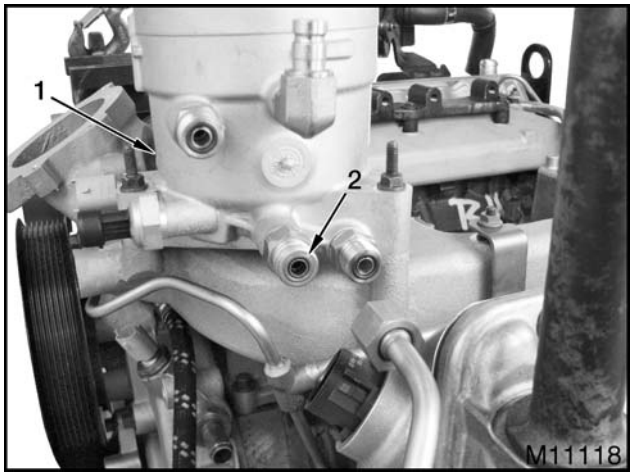

Figure 253 Fuel filter housing O-rings

1. Fuel filter housing
2. O-ring (3)

7. Install three new O-rings on fuel filter housing fittings.

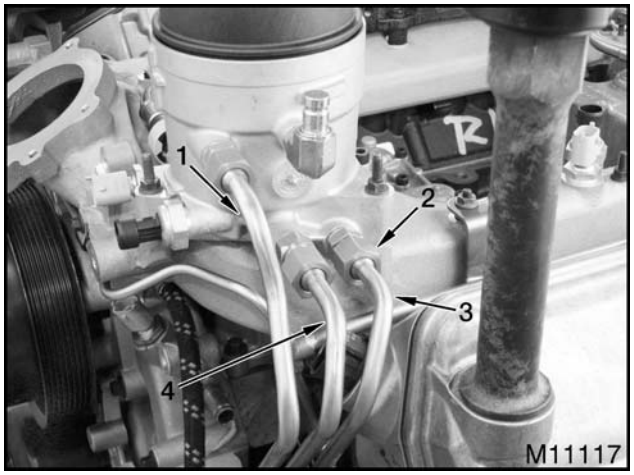

Figure 254 Fuel supply and return tubing

1. Fuel supply to filter tube assembly
2. 3/8” O-ring face seal nuts
3. Fuel cooler to filter tube assembly
4. Fuel return to tank tube assembly

NOTE: When using a crowfoot extension make sure to adjust the torque settings as necessary to compensate for any length added to the torque wrench. See Appendix B - Torques (page 370).

8. Connect fuel cooler to filter tube assembly, fuel supply to filter tube assembly, and fuel return to tank tube assembly to fuel filter housing fittings. Secure tubes with 3/8” O-ring face seal nuts. Tighten nuts to special torque (page 159).
9. Tighten M6 triple tube clamp nut to standard torque (page 369).

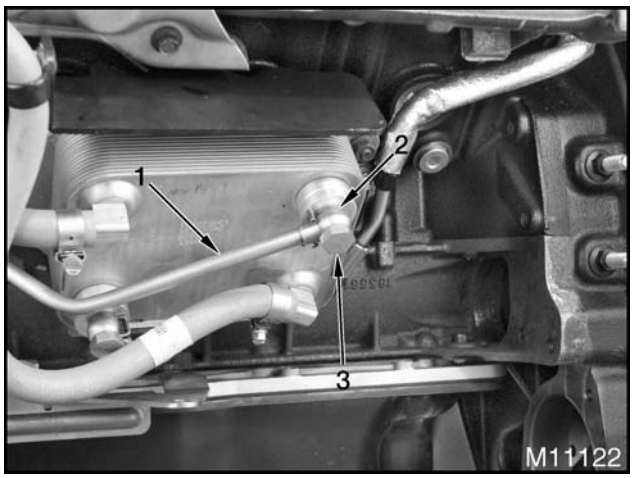

Figure 255 Fuel cooler to filter tube assembly connection

1. Fuel cooler to filter tube assembly
2. Dual M12 banjo washer
3. M12 banjo bolt

10. Install a new dual M12 banjo washer on fuel cooler to filter tube assembly.
11. Secure fuel cooler to filter tube assembly with M12 banjo bolt. Tighten banjo bolt to special torque (page 159).

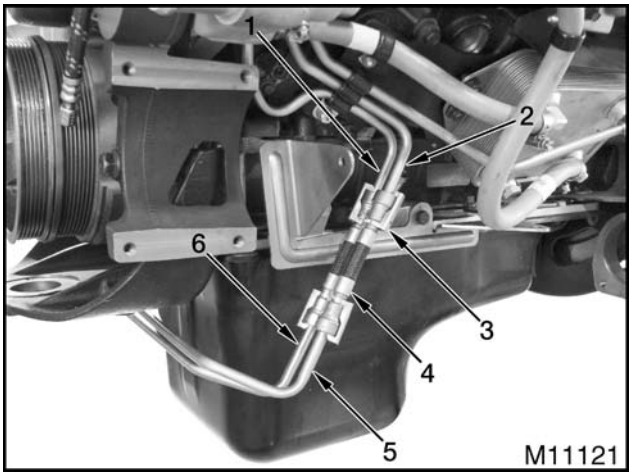

Figure 256 Fuel supply and return tube connections

1. Fuel supply to filter tube
2. Fuel return to tank tube assembly
3. 3/8” redundant clip (4)
4. 3/8” hose assembly (2)
5. Fuel return tube assembly
6. Fuel supply tube assembly

12. Connect 3/8” hose assemblies to fuel return to tank tube assembly and fuel supply to filter tube assembly and push together until audible click is heard.
13. Connect fuel return tube assembly and fuel supply tube assembly to 3/8” hose assemblies, and push together until audible click is heard.
14. Install four 3/8” redundant clips.

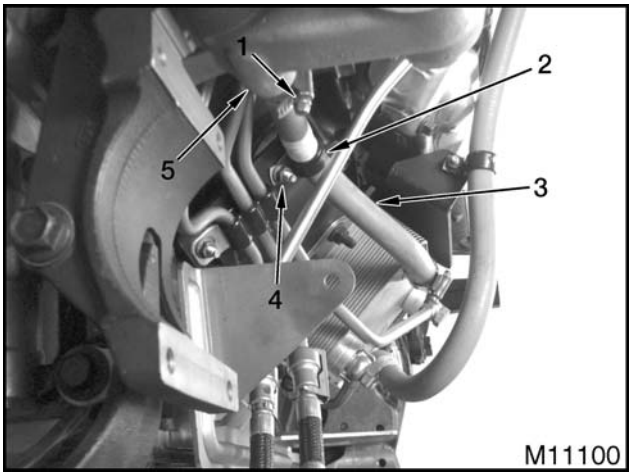

Figure 257 Coolant out from fuel cooler hose

1. Hose clamp
2. Clamp
3. Coolant out from fuel cooler hose
4. M6 nut
5. Front crankcase cover

15. Connect coolant out hose to front crankcase cover fitting and secure with hose clamp. Tighten hose clamp to special torque (page 159).
16. Install clamp and M6 nut. Tighten nut to standard torque (page 369).

Fuel Primer Pump Assembly and Tubing

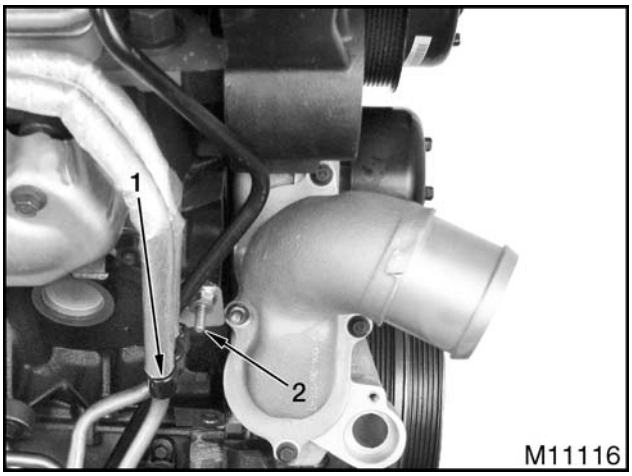

Figure 258 Triple tube clamp

1. Triple tube clamp
2. M8 x 30 stud bolt

1. Install fuel return from primer tube assembly and fuel supply to primer tube assembly in triple tube clamp.
2. Install fuel primer tubes and triple tube clamp on breather drain steel tube.
3. Secure triple tube clamp with M8 x 30 stud bolt. Do not tighten stud bolt at this time.

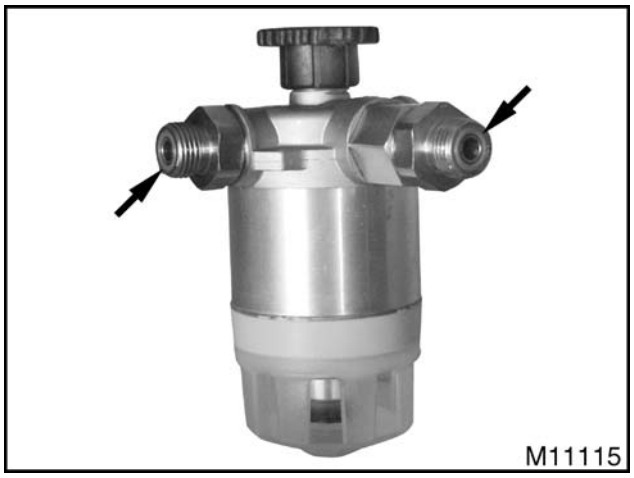

Figure 259 Fuel primer pump assembly O-rings

4. Install two new O-rings onto fuel primer pump assembly.

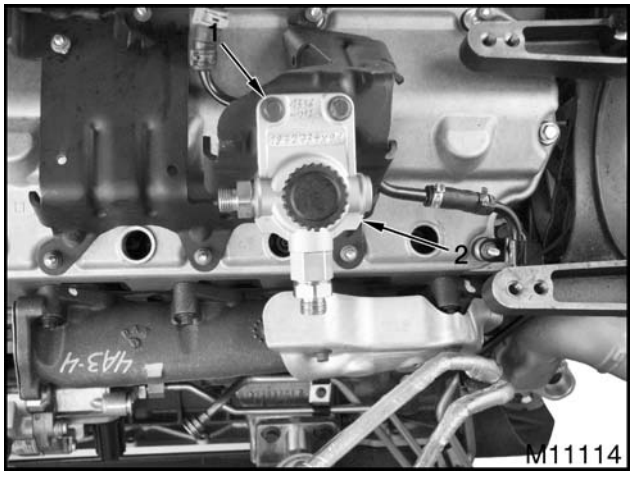

Figure 260 Fuel primer pump assembly bolts

1. M8 x 30 bolt (2)
2. Fuel primer pump assembly

5. Install fuel primer pump assembly and two M8 x 30 bolts. Tighten bolts to standard torque (page 369).

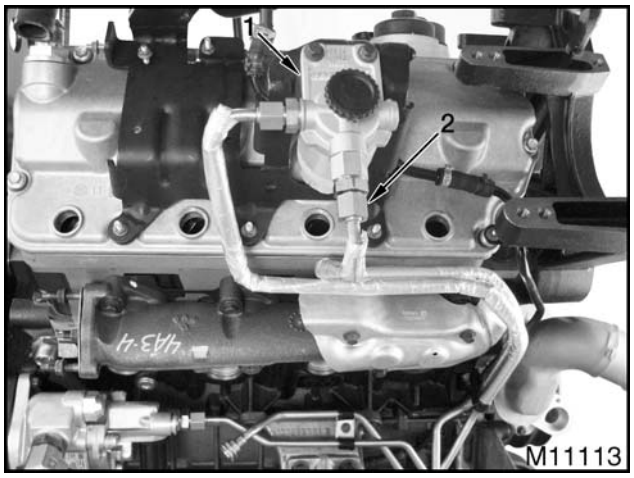

Figure 261 Fuel primer pump assembly tube connections

1. Fuel primer pump assembly
2. 3/8” O-ring face seal nut (2)

NOTE: When using a crowfoot extension make sure to adjust the torque settings as necessary to compensate for any length added to the torque wrench. See Appendix B - Torques (page 370).

6. Connect fuel supply to primer pump tube assembly and fuel return from primer pump tube assembly, and secure with two 3/8” O-ring face seal nuts. Tighten nuts to special torque (page 159).
7. Tighten M8 x 30 triple tube clamp stud bolt to standard torque (page 369).

Primary Fuel Filter Assembly and Tubing

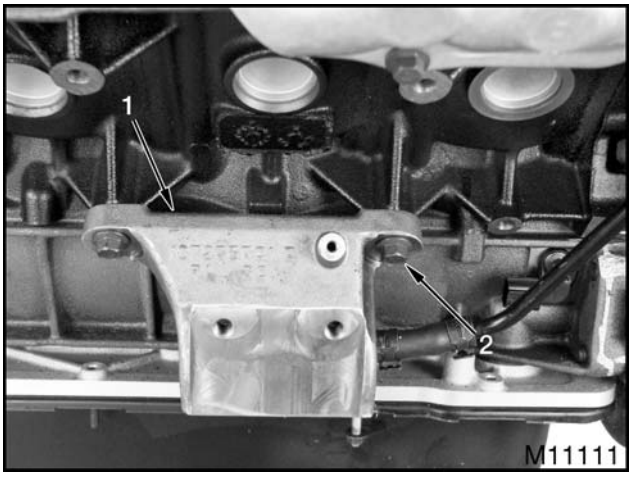

Figure 262 Primary filter bracket support bolts

1. Primary filter bracket support
2. M10 x 30 bolt (2)

1. Install primary filter bracket support and two M10 x 30 bolts. Tighten bolts to standard torque (page 369).

Figure 263 Fuel filter primary header O-rings

2. Install two new O-rings onto fuel filter primary header.

Figure 264 Fuel filter primary header to filter bracket support bolts

1. Fuel filter primary header
2. M10 x 30 bolt (2)

3. Install fuel filter primary header and two M10 x 30 bolts. Tighten bolts to standard torque (page 369).

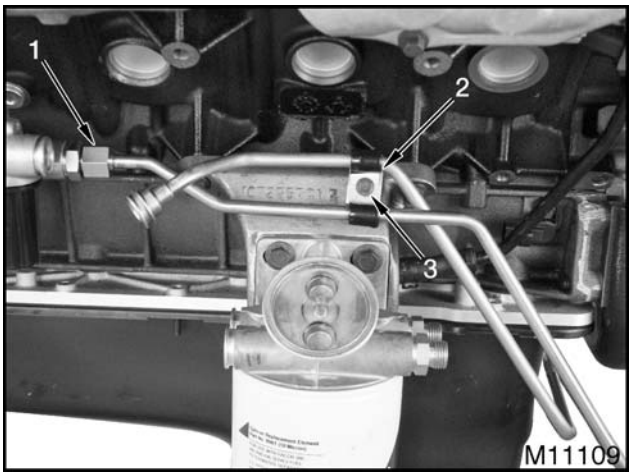

Figure 265 Primary filter bracket support clamp

1. 3/8” O-ring face seal nut
2. Saddle clamp
3. M6 x 12 bolt

NOTE: When using a crowfoot extension make sure to adjust the torque settings as necessary to compensate for any length added to the torque wrench. See Appendix B - Torques (page 370).

4. Connect fuel supply tube assembly to power steering/fuel pump and secure with 3/8” O-ring face seal nut. Tighten nut to special torque (page 159).

NOTE: Position and hold the fuel return tube assembly into flat clamp while tightening the bolt.

5. Install flat clamp and saddle clamp, and secure with M6 x 12 bolt. Tighten bolt to standard torque (page 369).

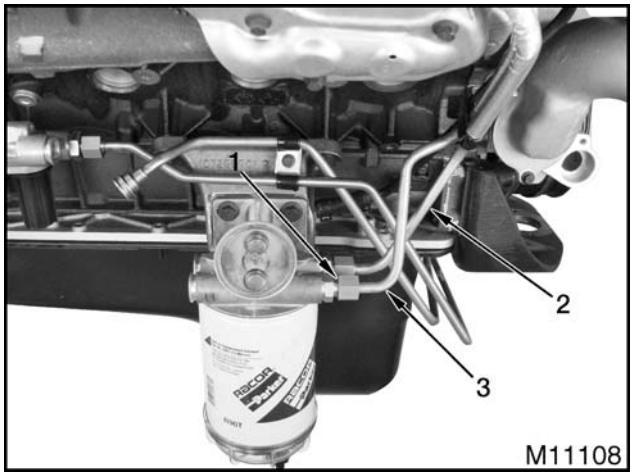

Figure 266 Primer pump tubes connection

1. 3/8” O-ring face seal nut (2)
2. Fuel return from primer pump tube assembly
3. Fuel supply to primer pump tube assembly

NOTE: When using a crowfoot extension make sure to adjust the torque settings as necessary to compensate for any length added to the torque wrench. See Appendix B - Torques (page 370).

6. Connect fuel return from primer pump tube assembly and fuel supply to primer pump tube assembly, and secure with two 3/8” O-ring face seal nuts. Tighten nuts to special torque (page 159).

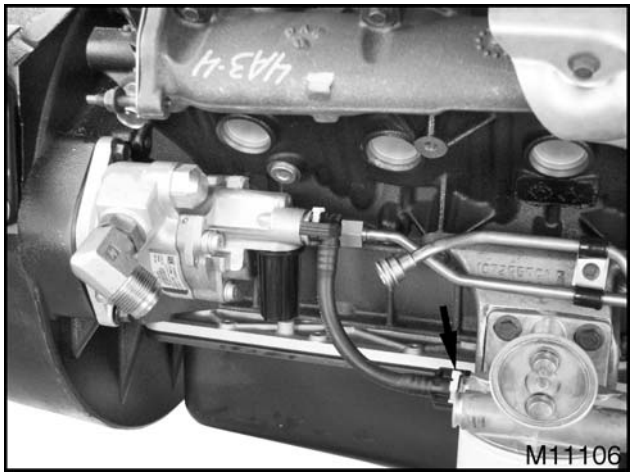

Figure 267 Primary filter to pump tube assembly

7. Push primary filter to pump tube assembly fitting into primary fuel filter. Make sure quick connector is locked in place.

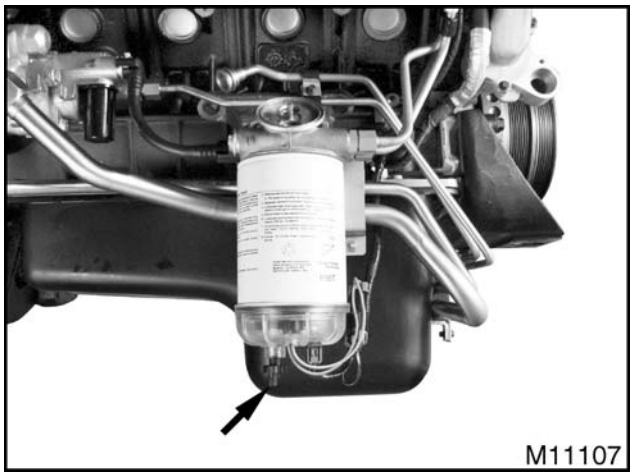

Figure 268 Fuel drain valve

8. Close fuel drain valve by turning it clockwise.

Secondary Fuel Filter Element

1. Install a new fuel filter element in fuel filter housing.

CAUTION: To prevent engine damage, do not add fuel to the fuel filter housing; this can add contaminants to the fuel.

2. Install a new O-ring on fuel filter cap.

CAUTION: To prevent engine damage, the fuel filter element must be installed in the fuel filter housing.

NOTE: The engine will not run if the filter element is not installed. The installed filter element opens a check valve in the center of the stand pipe, allowing fuel to flow.

3. Install fuel filter cap and tighten to special torque (page 159).

Primary Fuel Filter Element

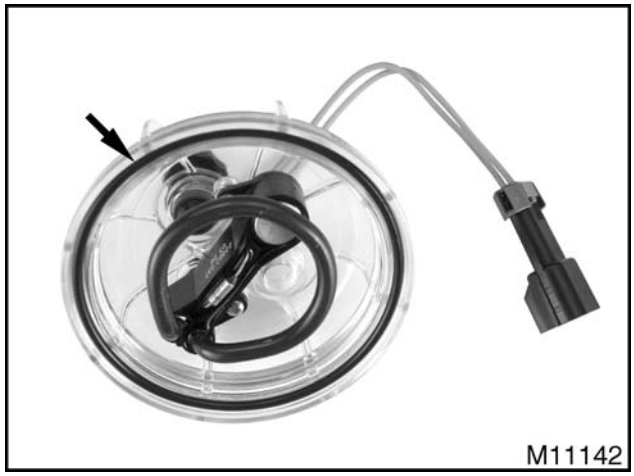

Figure 269 Element and bowl primary filter seal

1. Install a new bowl primary filter seal onto bowl assembly.

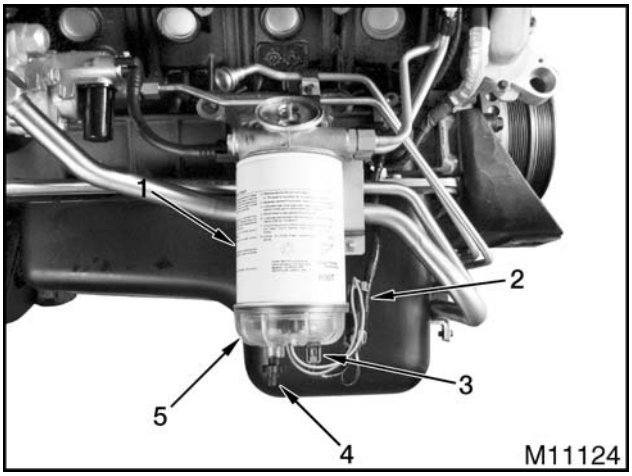

Figure 270 Primary filter element assembly

1. Primary filter element assembly
2. Fuel heater electrical connector
3. Water in Fuel (WIF) sensor electrical connector
4. Fuel drain valve
5. Bowl assembly with fuel heater/probe

2. Install a new primary filter element assembly and hand tighten firmly.
3. Install bowl assembly and hand tighten firmly.
4. Close fuel drain valve by turning it clockwise.
5. Connect fuel heater electrical connector.
6. Connect WIF sensor electrical connector.

Fuel Prescreen Element

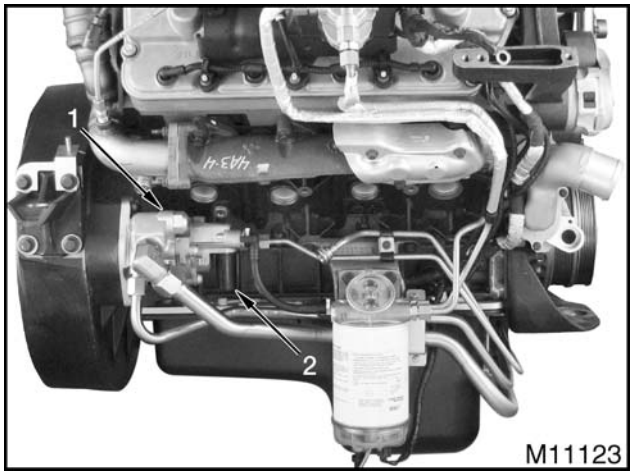

Figure 271 Removal of prescreen element

1. Gear driven fuel pump assembly
2. Prescreen bowl

1. Place a clean or a new prescreen element in prescreen bowl.
2. Coat new O-ring and prescreen bowl with diesel fuel.
3. Install prescreen bowl onto power steering/fuel pump. Hand tighten, then snug prescreen bowl with a 30 mm box end wrench.

Specifications

Table 12 Fuel Filter

Fuel Filter	
Primary fuel filter type	10 micron with water separation
Secondary fuel filter type	4 micron with water separation
Normal fuel pressure (after secondary fuel filter)	48 - 69 kPa (7 - 10 psi)

Special Torque

Table 13 Fuel System Components

High-pressure Fuel Pump (HPFP) assembly bolts	61 N·m (45 lbf·ft)
Pump right tube assembly nuts	See tightening step in procedure.
Pump left tube assembly nuts	See tightening step in procedure.
Fuel pump cover bolts	13 N·m (116 lbf·in)
Injector leak off check valve	45 N·m (33 lbf·ft)
High-pressure pump to cooler tube assembly cap nut	38 N·m (28 lbf·ft)
Banjo bolts	38 N·m (28 lbf·ft)
Filter to pump tube assembly cap nut	38 N·m (28 lbf·ft)
Hose clamps	3 N·m (26 lbf·in)
3/8” O-ring face seal nuts	41 N·m (30 lbf·ft)
Fuel filter cap (secondary)	27 N·m (20 lbf·ft)

Special Service Tools

Table 14 Fuel System

Description	Tool Number
Fuel System Caps	ZTSE4710
Spring lock coupling disconnect tool	Obtain locally
Liquid Gasket (RTV) (6 oz. tube)	1830858C1

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Exploded Views

Exhaust Manifolds

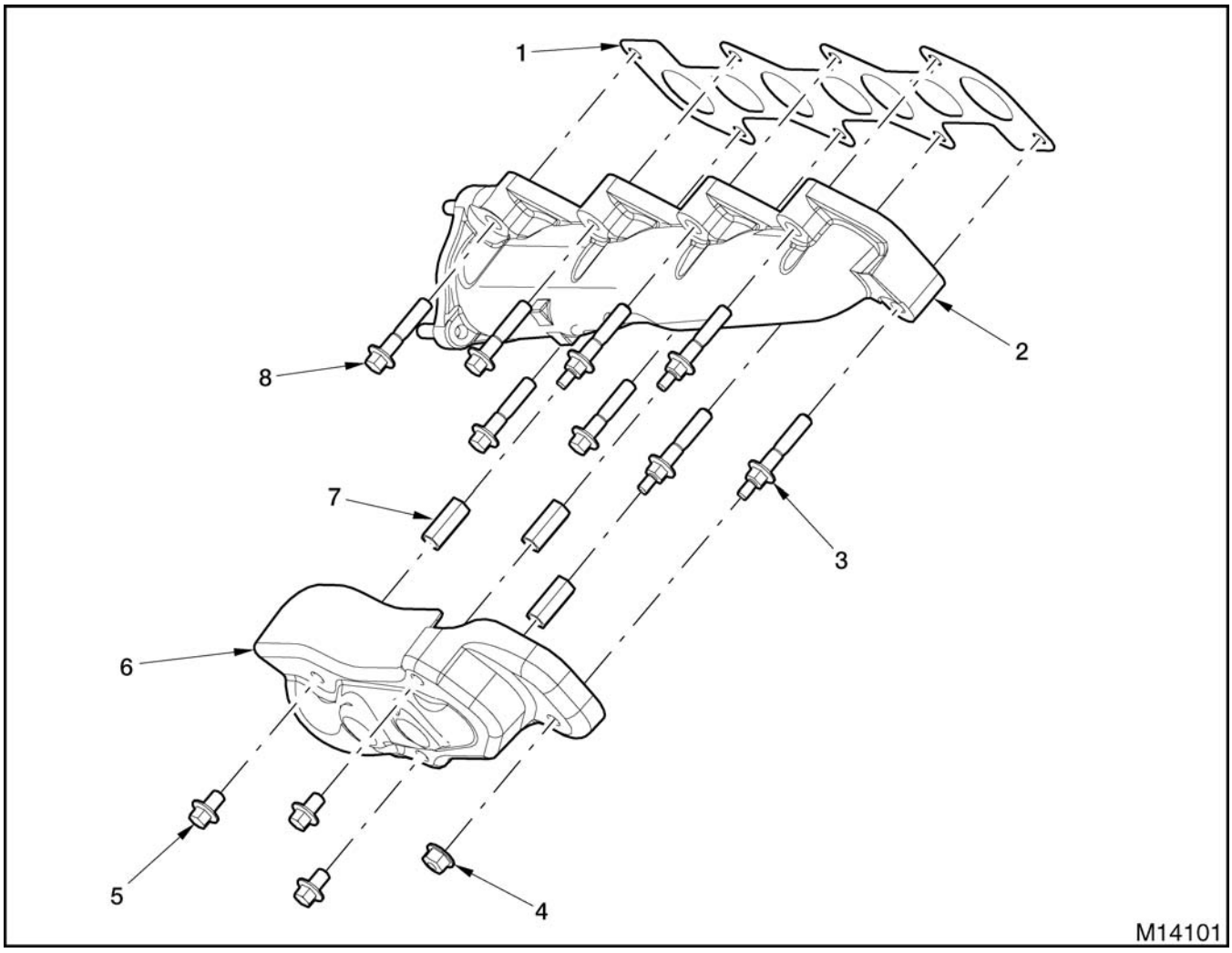

Figure 272 Left exhaust manifold (right side similar)

1. Exhaust manifold gasket
2. Left exhaust manifold
3. M8 x 40 stud bolt (4)
4. M8 nut
5. M8 x 12 bolt (3)
6. Heat shield
7. Heat shield threaded spacer (3)
8. M8 x 40 bolt (4)

Intake Manifold

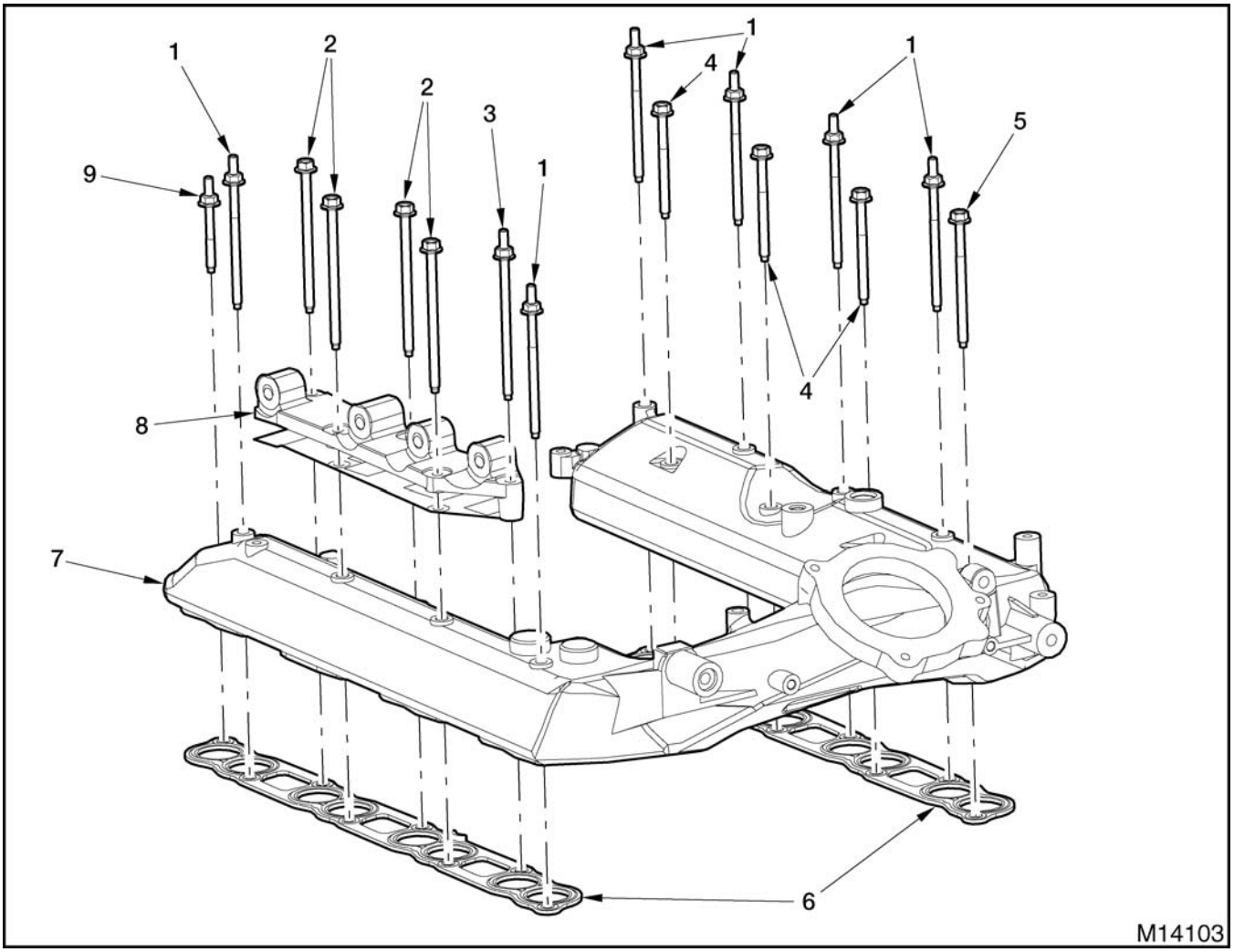

Figure 273 Intake manifold

1. M6 x 87 stud bolt (6)
2. M6 x 95 bolt (4)
3. M6 x 95 stud bolt
4. M6 x 70 bolt (3)
5. M6 x 87 bolt
6. Intake manifold gasket (2)
7. Intake manifold
8. Exhaust Gas Recirculating (EGR) cooler lower bracket
9. M6 x 47 stud bolt

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 the engine has cooled before removing components.

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

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

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

- Engine Electrical
- Exhaust Gas Recirculating (EGR) System
- Variable Geometry Turbocharger (VGT)
- Air Compressor and Power Steering/Fuel Pump
- Fuel System

Exhaust Manifolds

CAUTION: To prevent engine damage, do not reuse exhaust manifold bolts and stud bolts.

Left Exhaust Manifold

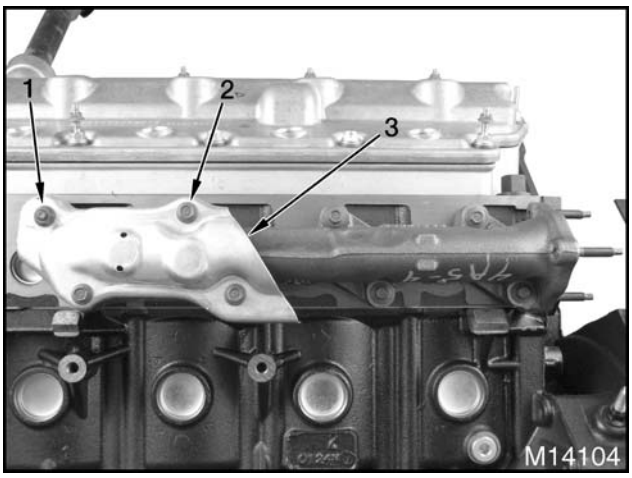

Figure 274 Left exhaust manifold heat shield

1. M8 nut
2. M8 x 12 bolt (3)
3. Heat shield

1. Remove and discard three M8 x 12 heat shield bolts and M8 heat shield nut.
2. Remove left exhaust manifold heat shield.

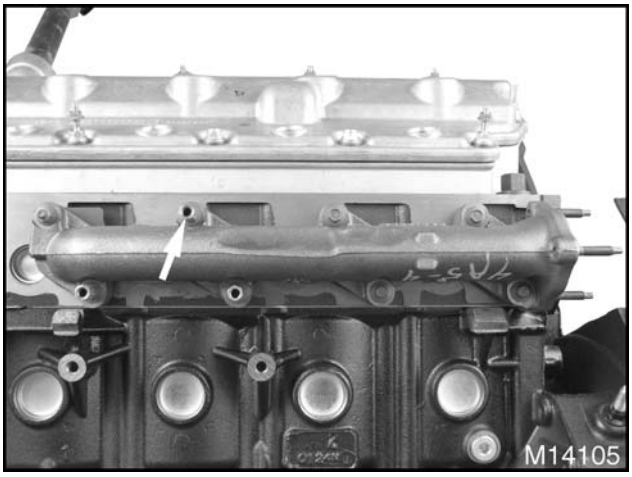

Figure 275 Left exhaust manifold heat shield spacers

3. Remove three left exhaust manifold heat shield threaded spacers.

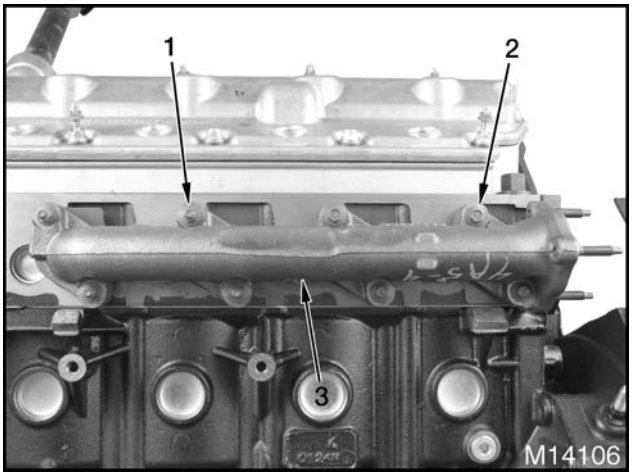

Figure 276 Left exhaust manifold

1. M8 x 40 stud bolt (4)
2. M8 x 40 bolt (4)
3. Left exhaust manifold

4. Remove and discard four M8 x 40 exhaust manifold bolts and four M8 x 40 exhaust manifold stud bolts.
5. Remove left exhaust manifold and discard gasket.

Right Exhaust Manifold

Figure 277 Right exhaust manifold heat shield

1. M8 x 12 bolt (3)
2. M8 nut
3. Heat shield

1. Remove and discard three M8 x 12 heat shield bolts and M8 heat shield nut.
2. Remove right exhaust manifold heat shield.

Figure 278 Right exhaust manifold heat shield spacers

3. Remove three right exhaust manifold heat shield threaded spacers.

Figure 279 Right exhaust manifold

1. M8 x 40 bolt (4)
2. M8 x 40 stud bolt (4)
3. Right exhaust manifold

4. Remove and discard four M8 x 40 exhaust manifold bolts and four M8 x 40 exhaust manifold stud bolts.

5. Remove right exhaust manifold and discard gasket.

Intake Manifold

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

CAUTION: To prevent engine damage, cover the exposed portion of the engine and blow out or vacuum dirt and debris under the intake manifold. This prevents dirt and debris from entering the intake ports when the manifold is removed.

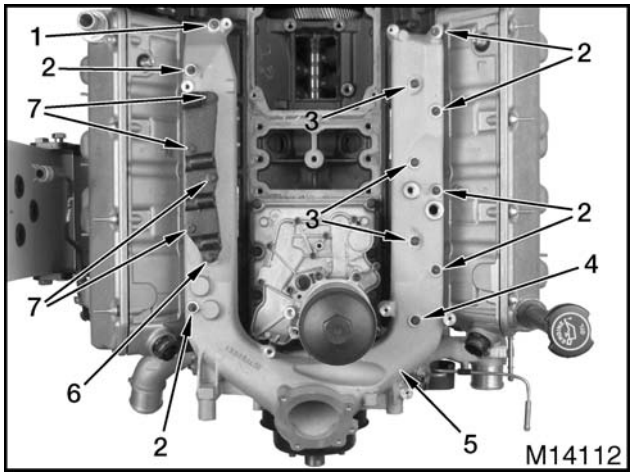

Figure 280 Intake manifold bolts

1. M6 x 47 stud bolt
2. M6 x 87 stud bolt (6)
3. M6 x 70 bolt (3)
4. M6 x 87 bolt
5. Intake manifold
6. M6 x 95 stud bolt
7. M6 x 95 bolt (4)

1. Remove eight intake manifold stud bolts and eight intake manifold bolts.
2. Remove Exhaust Gas Recirculating (EGR) cooler lower bracket.
3. Remove intake manifold by lifting straight up. Discard gaskets.
4. Place intake port covers ZTSE4559 (page 173) over cylinder head intake ports.

Cleaning, Inspection, and Testing

Intake and Exhaust Manifolds

Intake and exhaust manifolds are one piece castings and may be cleaned with steam or suitable non-caustic solvents.

Manifold Warp Test for Exhaust Manifolds

1. Use a straightedge and feeler gauge to check seating surface flatness for right and left exhaust manifolds.
2. Check for flatness – across left and right and diagonally. See specifications (page 173).
3. If specifications are not met, do not resurface exhaust manifold, replace exhaust manifold.

Installation

Intake Manifold

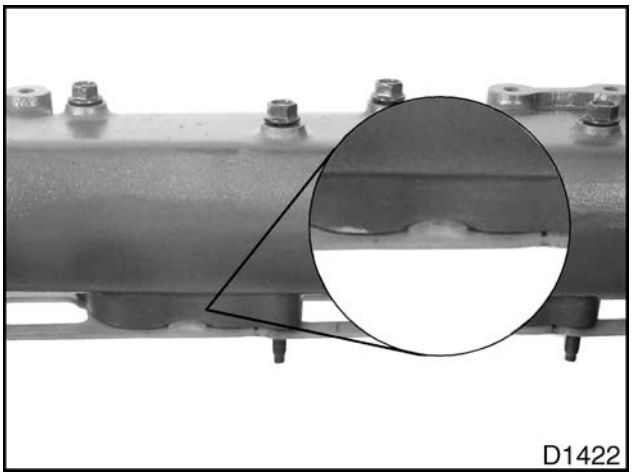

Figure 281 Intake manifold gasket with centering tab

1. Position a new intake manifold gasket on each side of intake manifold and install two bolts through each side to hold gaskets. Make sure centering tabs are facing up in the manifold, while positioned inboard toward engine valley.
2. Remove intake port covers ZTSE4559 (page 173) from cylinder head intake ports.
3. Position intake manifold on cylinder heads.
4. Install Exhaust Gas Recirculating (EGR) cooler lower bracket.

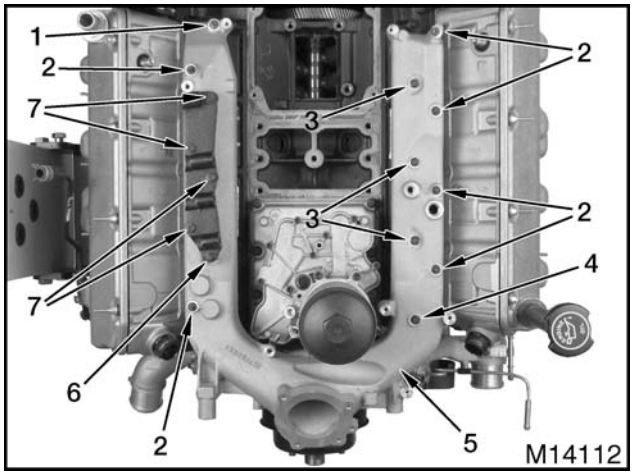

Figure 282 Intake manifold bolts

1. M6 x 47 stud bolt
2. M6 x 87 stud bolt (6)
3. M6 x 70 bolt (3)
4. M6 x 87 bolt
5. Intake manifold
6. M6 x 95 stud bolt
7. M6 x 95 bolt (4)

5. Loosely install eight intake manifold stud bolts and eight intake manifold bolts.

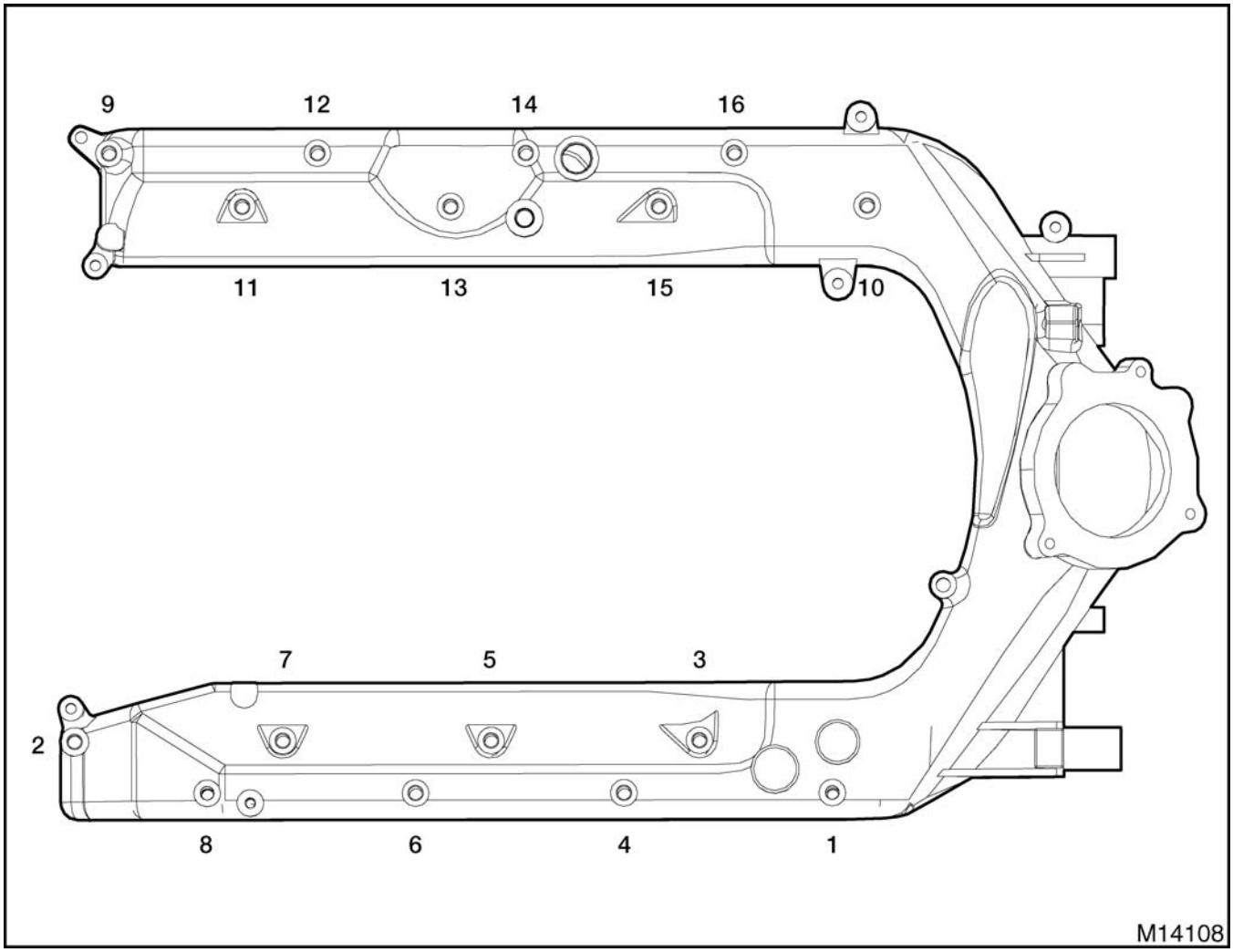

Figure 283 Torque sequence for intake manifold mounting bolts

6. Tighten intake manifold bolts and intake manifold stud bolts to special torque (page 173), following sequence (Figure 283).

Exhaust Manifolds

CAUTION: To prevent engine damage, hand torque all nuts and bolts of the exhaust manifolds. The exhaust manifold hardware has a special high-temperature coating which will be damaged by air tools.

CAUTION: To prevent engine damage, do not reuse exhaust manifold bolts or stud bolts.

NOTE: Do not apply anti-seize compound to threads.

Right Exhaust Manifold

Figure 284 Right exhaust manifold

1. M8 x 40 bolt (4)
2. M8 x 40 stud bolt (4)
3. Right exhaust manifold

1. Position a new gasket and install right exhaust manifold.

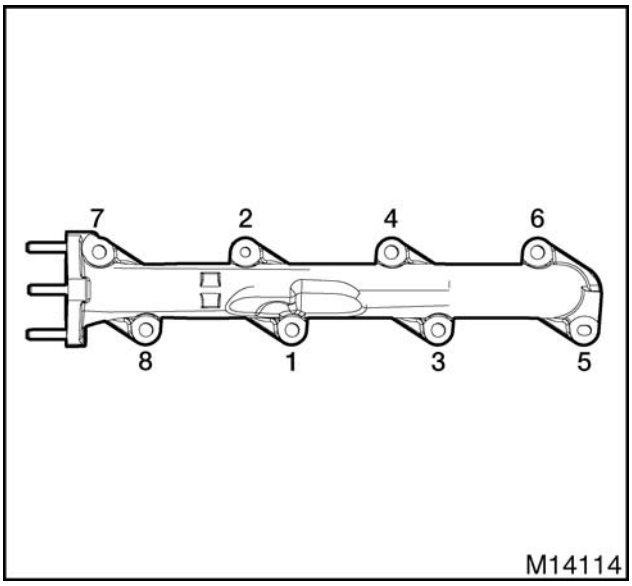

Figure 285 Torque sequence for right exhaust manifold mounting bolts

CAUTION: To prevent engine damage, align exhaust manifold gasket with exhaust manifold before tightening bolts and stud bolts to the specified torque value.

NOTE: Tighten bolts and stud bolts to special torque, then retighten using same sequence to seat manifold.

2. Install four new M8 x 40 exhaust manifold bolts and four new M8 x 40 exhaust manifold stud bolts. Tighten bolts and stud bolts to special torque (page 173) following sequence (Figure 285). Retighten bolts and stud bolts to special torque (page 173) using same sequence (Figure 285).

Figure 286 Right exhaust manifold heat shield spacers

3. Install three right exhaust manifold heat shield threaded spacers. Tighten spacers to special torque (page 173).

Figure 287 Right exhaust manifold heat shield

1. M8 x 12 bolt (3)
2. M8 nut
3. Heat shield

4. Install right exhaust manifold heat shield.
5. Install three new M8 x 12 heat shield bolts and a new M8 heat shield nut. Tighten bolts and nut to special torque (page 173).

Left Exhaust Manifold

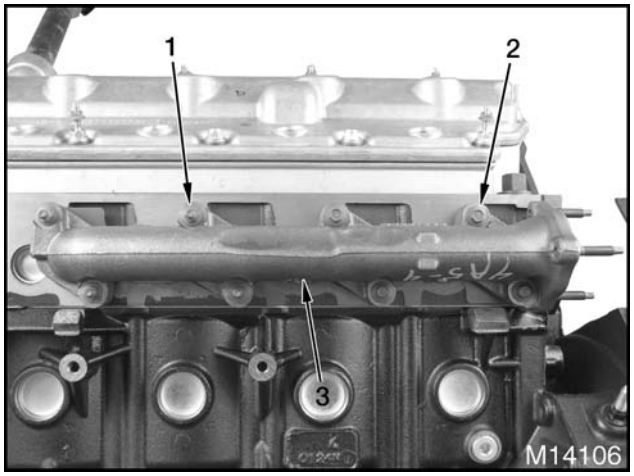

Figure 288 Left exhaust manifold

1. M8 x 40 stud bolt (4)
2. M8 x 40 bolt (4)
3. Left exhaust manifold

1. Position a new gasket and install left exhaust manifold.

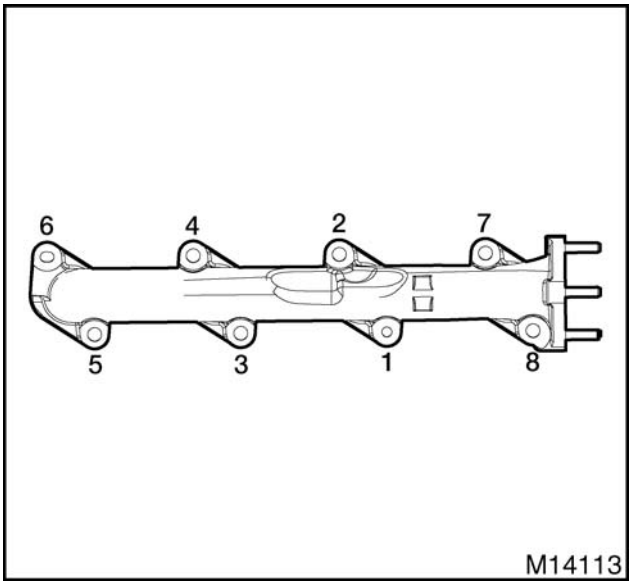

Figure 289 Torque sequence for left exhaust manifold mounting bolts

CAUTION: To prevent engine damage, align exhaust manifold gasket with exhaust manifold before tightening bolts and stud bolts to the specified torque value.

NOTE: Tighten bolts to special torque, then re-tighten using same sequence to seat manifold.

2. Install four new M8 x 40 exhaust manifold bolts and four new M8 x 40 exhaust manifold stud bolts. Tighten bolts and stud bolts to special torque (page 173) following sequence (Figure 289). Retighten bolts and stud bolts to special torque (page 173) using same sequence (Figure 289).

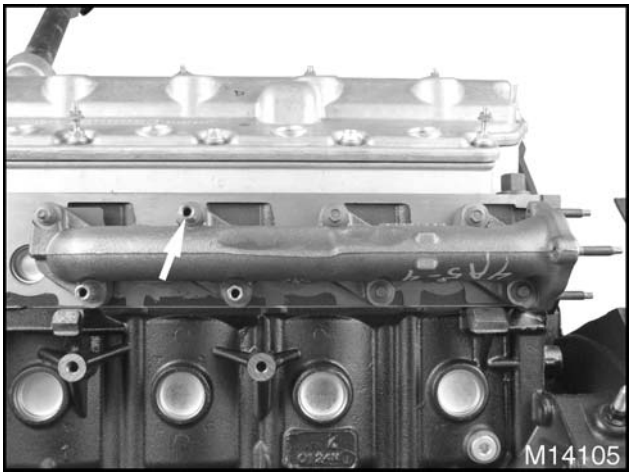

Figure 290 Left exhaust manifold heat shield spacers

3. Install three left exhaust manifold heat shield threaded spacers. Tighten spacers to special torque (page 173).

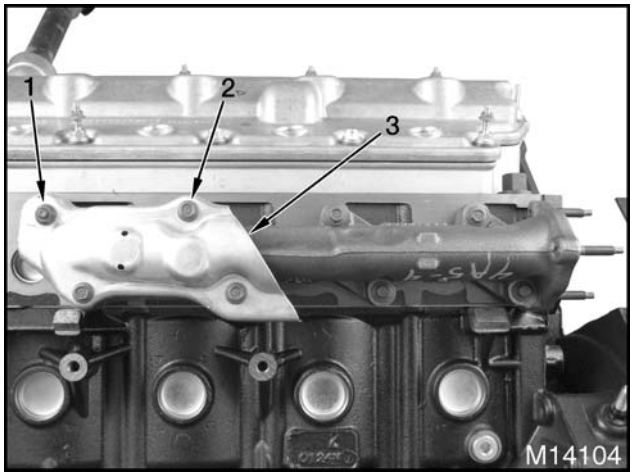

Figure 291 Left exhaust manifold heat shield

1. M8 nut
2. M8 x 12 bolt (3)
3. Heat shield

4. Install left exhaust manifold heat shield.
5. Install three new M8 x 12 heat shield bolts and a new M8 heat shield nut. Tighten bolts and nut to special torque (page 173).

Specifications

Table 15 Intake, Inlet, and Exhaust Manifolds

Exhaust Manifold	
Maximum allowable warpage	0.08 mm (0.003 in)

Special Torque

Table 16 Intake, Inlet, and Exhaust Manifolds

Intake manifold bolts and stud bolts (use special torque sequence)	11 N·m (100 lbf·in)
Exhaust manifold heat shield nuts, bolts, and spacers	30 N·m (22 lbf·ft)
Exhaust manifold bolts and stud bolts (use special torque sequence)	30 N·m (22 lbf·ft)

Special Service Tools

Table 17 Intake, Inlet, and Exhaust Manifolds

Description	Tool Number
Feeler Gauge	Obtain locally
Straightedge	Obtain locally
Intake port covers (cylinder heads)	ZTSE4559

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Exploded Views

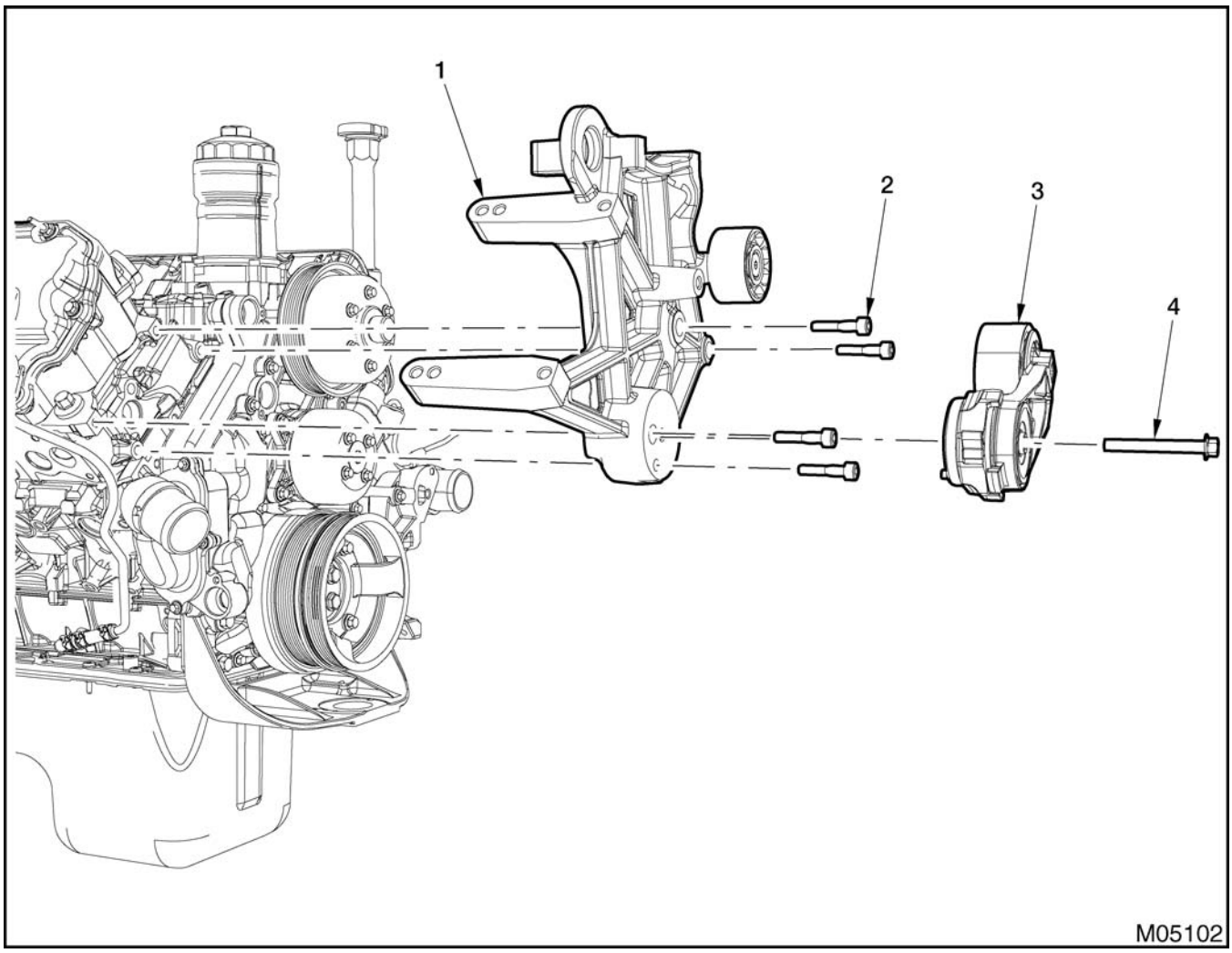

Figure 292 Alternator and Freon® mounting bracket

1. Alternator and Freon® mounting bracket
2. M10 x 45 cap screw (4)
3. Belt tensioner
4. M10 x 80 bolt

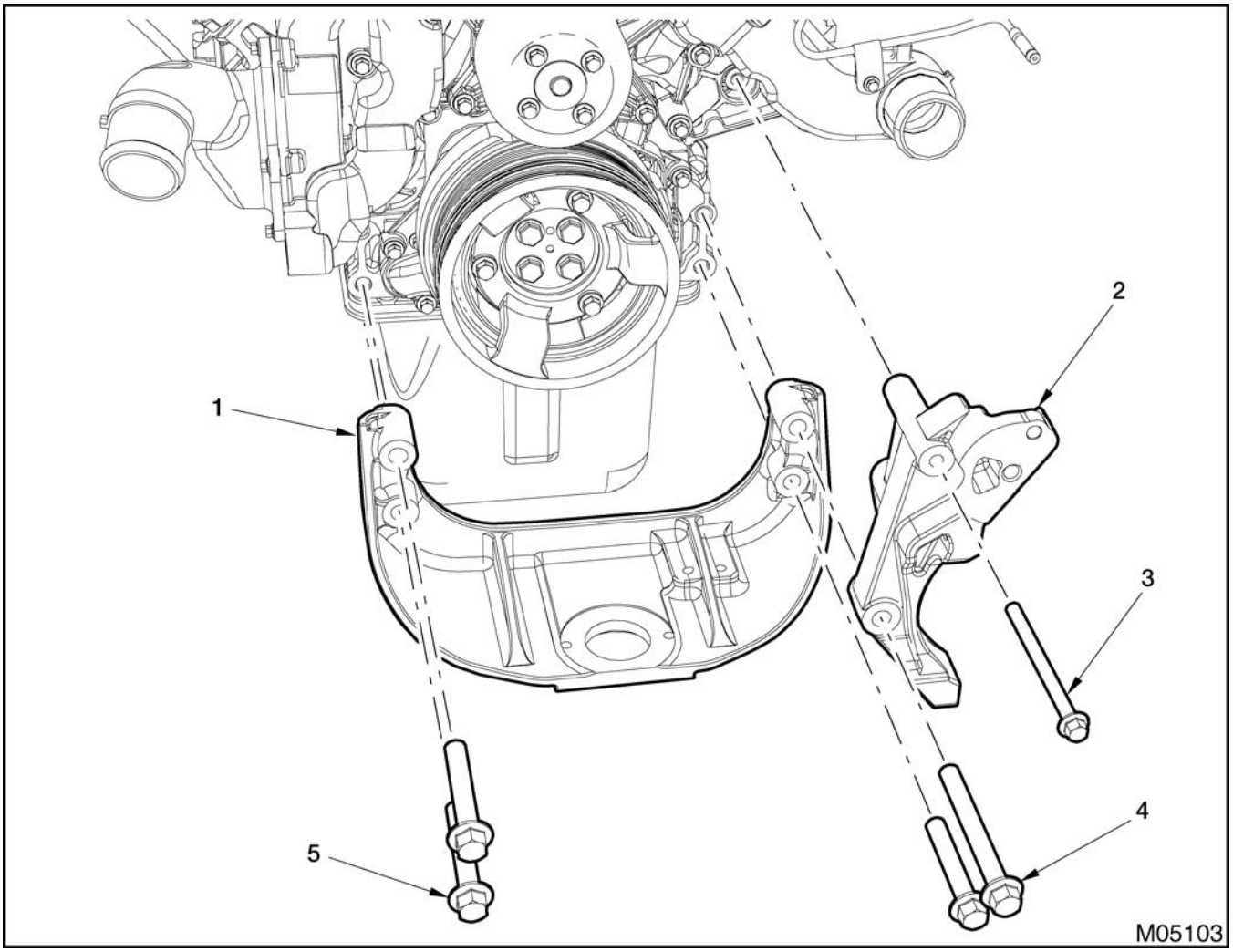

Figure 293 Front engine mount bracket

1. Front engine mount bracket
2. Auxiliary accessory mounting bracket (if equipped)
3. M8 x 100 bolt (if equipped)
4. M12 x 110 bolt (if equipped)
5. M12 x 70 bolt (3 if equipped with auxiliary accessory mounting bracket, 4 without)

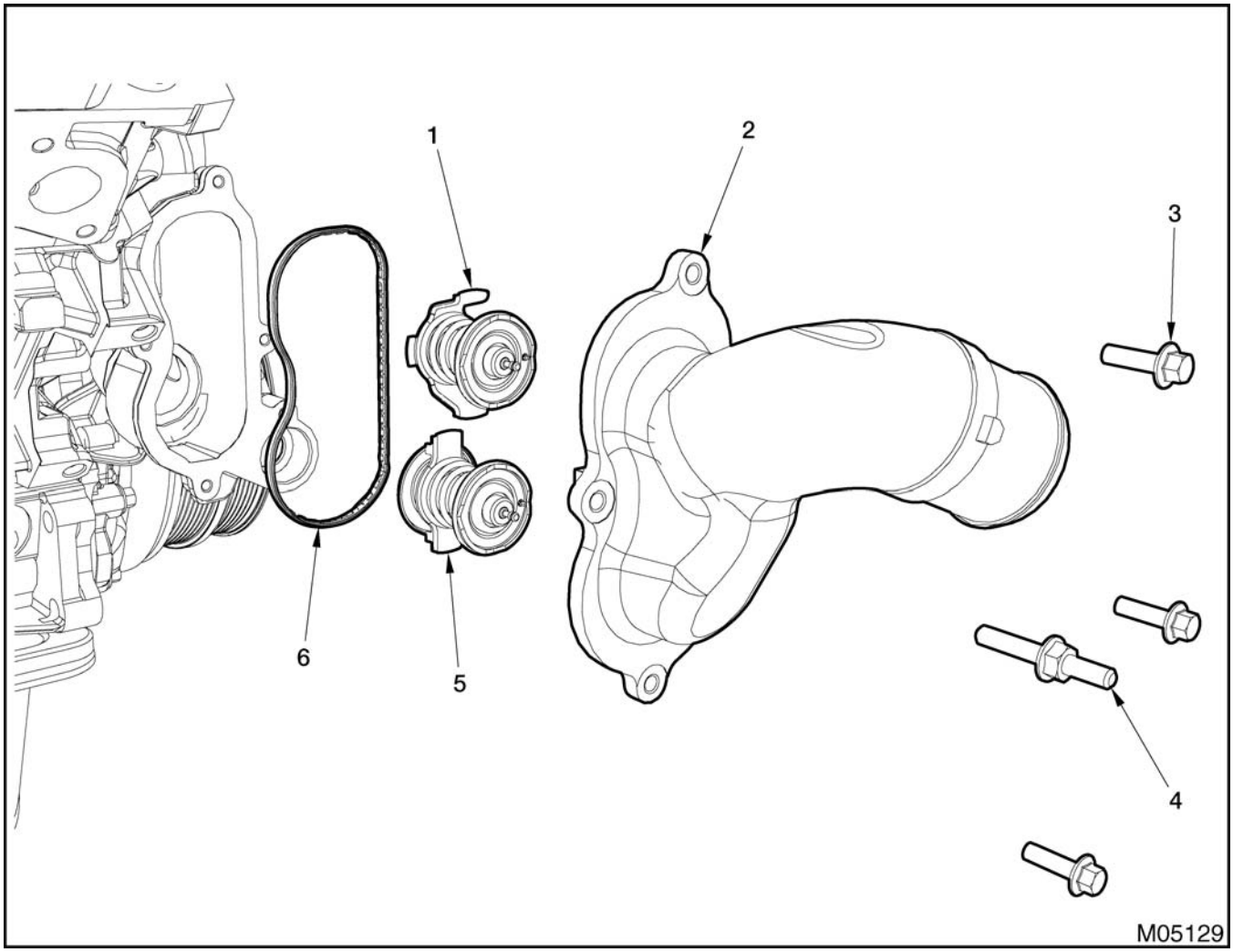

Figure 294 Thermostat assemblies and housing

1. Thermostat assembly without bypass
2. Thermostat housing
3. M6 x 20 bolt (3)
4. M6 x 25 stud bolt
5. Thermostat assembly with bypass
6. Thermostat cover gasket

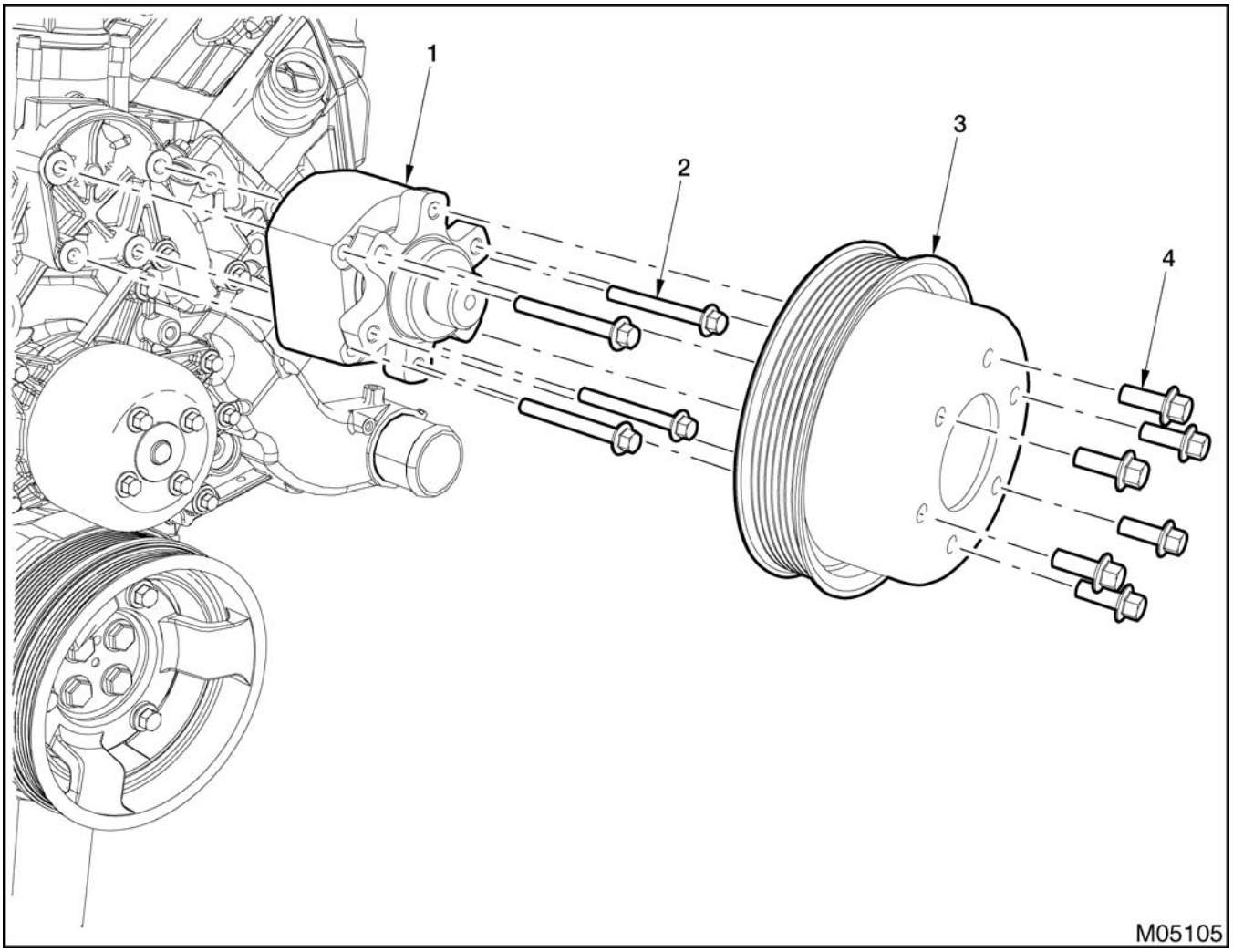

Figure 295 Fan drive

1. Fan and pulley mounting hub
2. M8 x 65 bolt (4)
3. Fan pulley
4. M8 x 20 bolt (6)

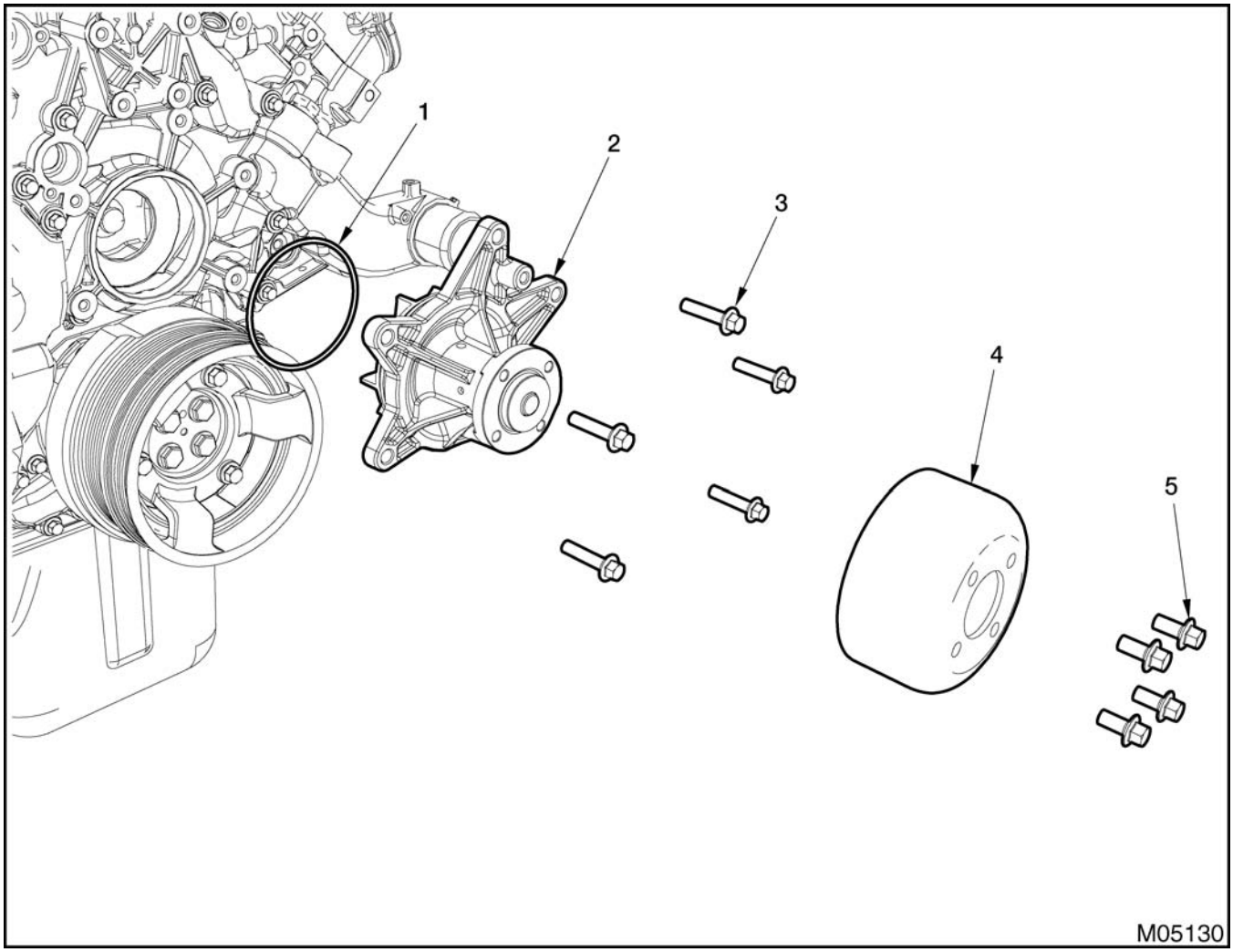

Figure 296 Water pump assembly

1. Water pump assembly gasket
2. Water pump assembly
3. M8 x 35 bolt (5)
4. Water pump pulley
5. M8 x 16 bolt (4)

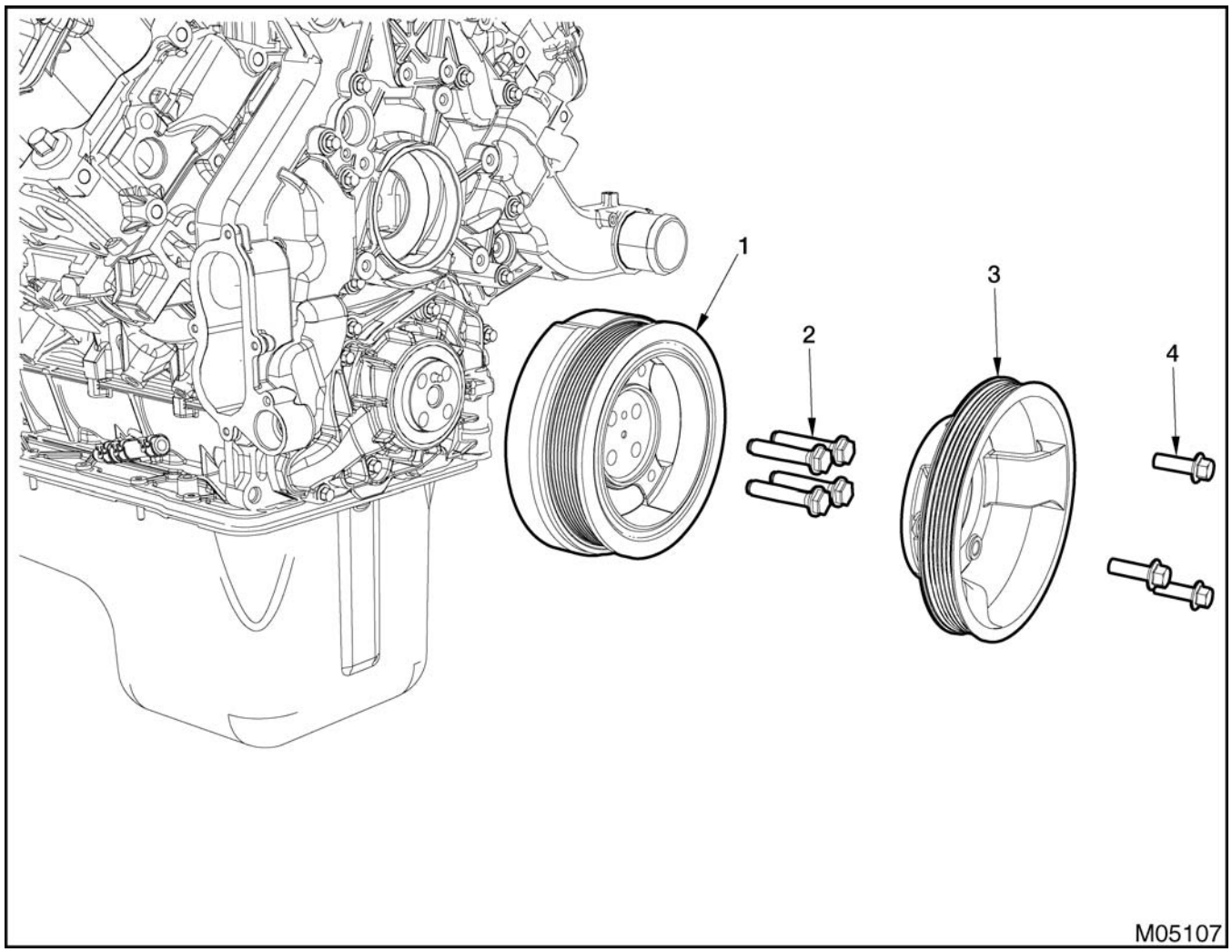

Figure 297 Vibration damper

1. Vibration damper
2. M12 x 59 bolt (4)
3. Front Power Takeoff (PTO) pulley (if equipped)
4. M10 x 30 bolt (3, if equipped with front PTO pulley)

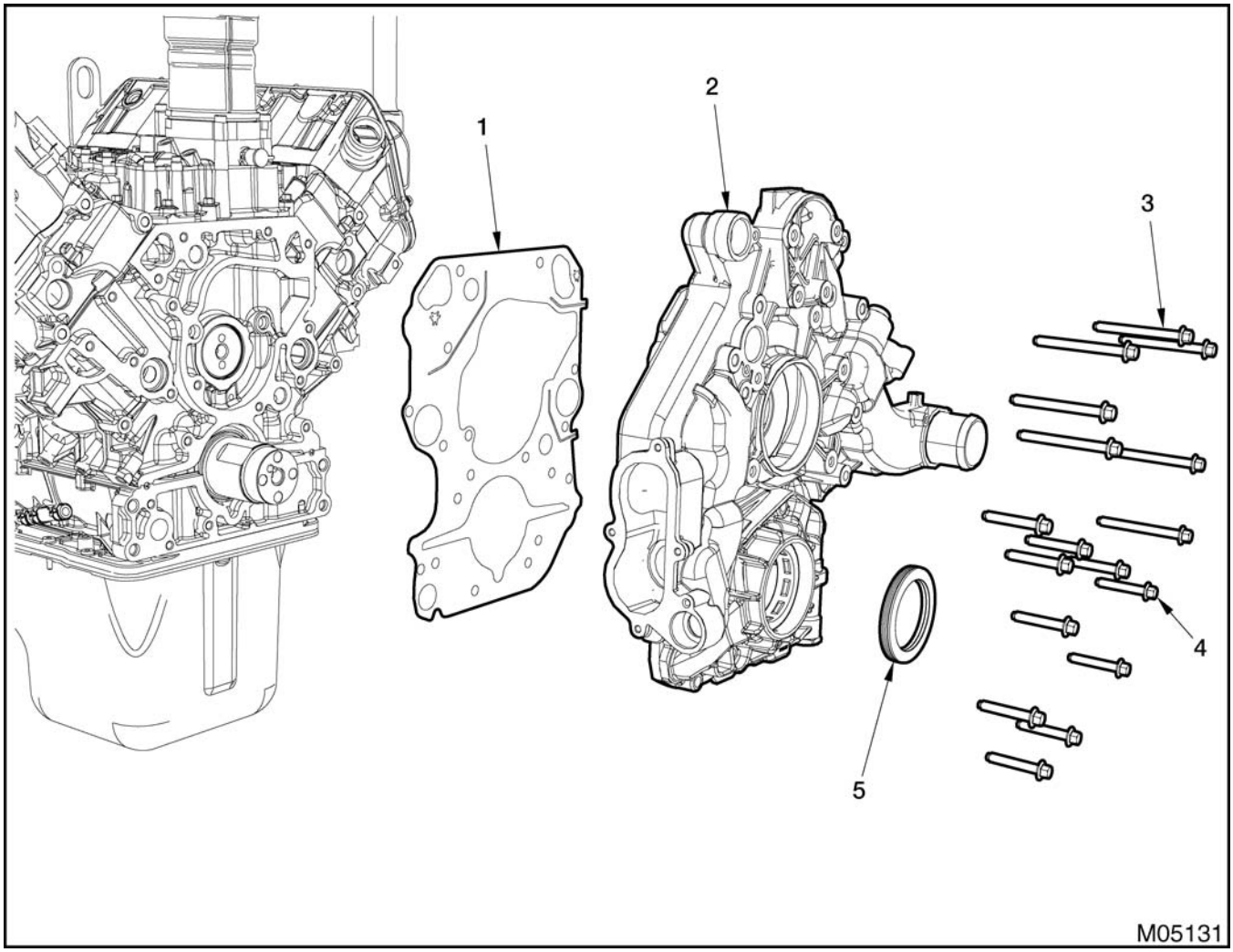

Figure 298 Front crankcase cover

1. Front cover gasket
2. Front crankcase cover
3. M8 x 75 bolt (7)
4. M8 x 45 bolt (10)
5. Front cover oil seal

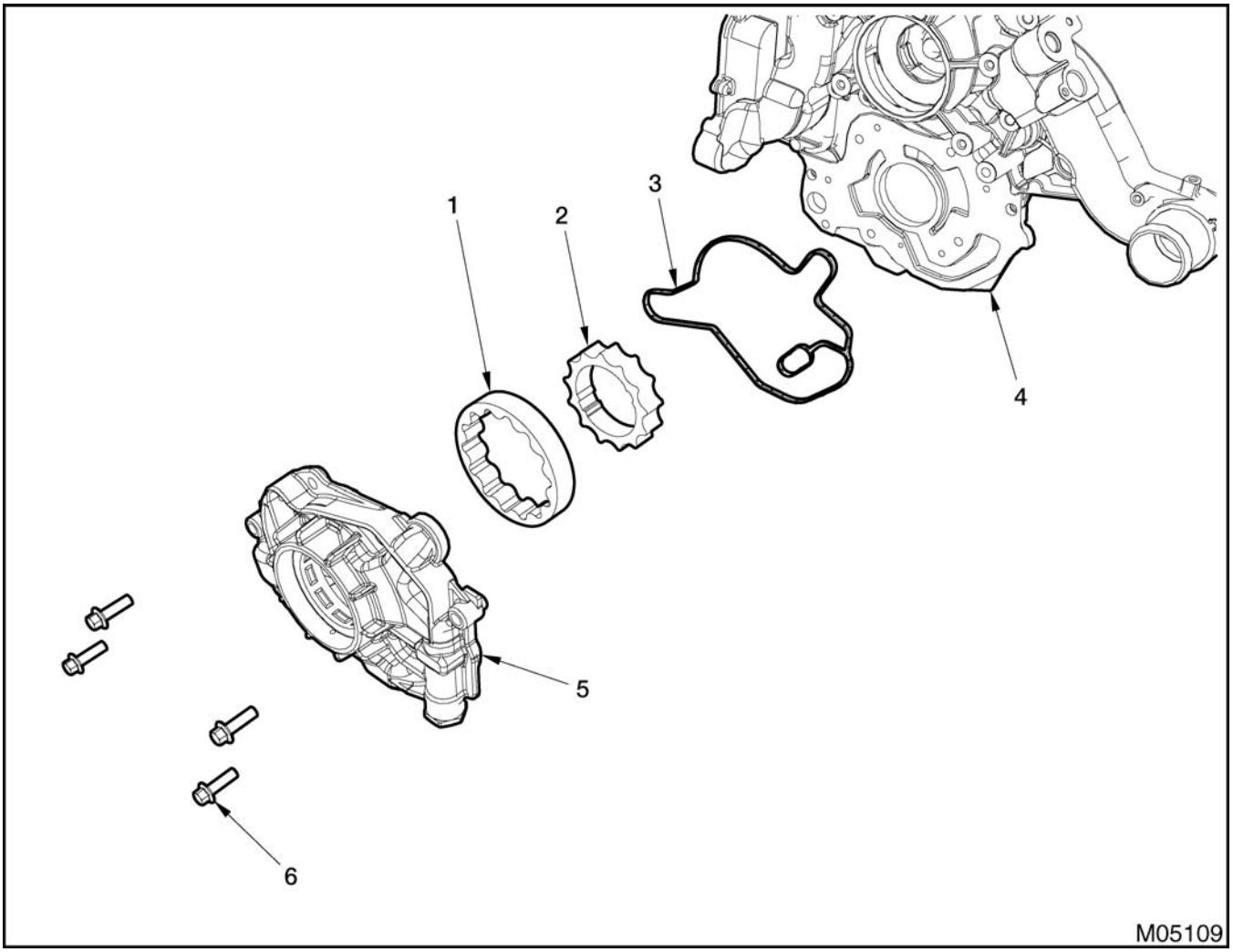

Figure 299 Oil pump assembly

1. Outer oil pump gerotor
2. Inner oil pump gerotor
3. Oil pump housing gasket
4. Front crankcase cover
5. Oil pump housing assembly
6. M8 x 25 bolt (4)

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 the engine has cooled before removing components.

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

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

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

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

Alternator and Freon® Mounting Bracket

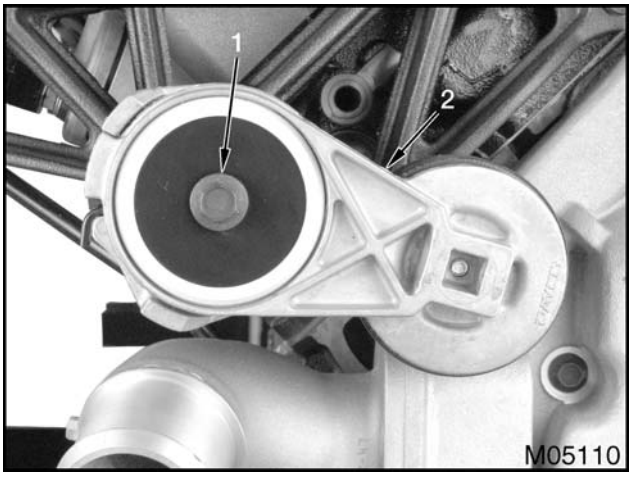

Figure 300 Belt tensioner

1. M10 x 80 bolt
2. Belt tensioner

CAUTION: To prevent engine damage, do not twist the belt tensioner; damage to the locating pin may occur, resulting in improper alignment of the belt tensioner.

1. Remove M10 x 80 bolt and belt tensioner.

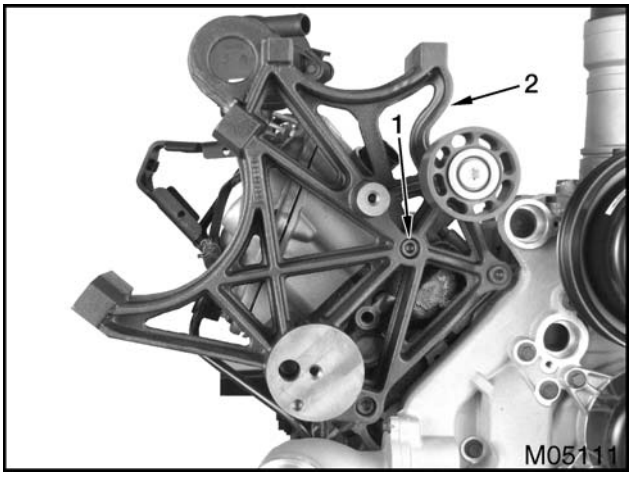

Figure 301 Alternator and Freon® mounting bracket

1. M10 x 45 cap screw (4)
2. Alternator and Freon® mounting bracket

2. Remove four M10 x 45 cap screws and alternator and Freon® mounting bracket.

Front Engine Mount Bracket

NOTE: For engines that are not equipped with auxiliary accessory mounting bracket, the front engine mount bracket is secured by four M12 x 70 bolts.

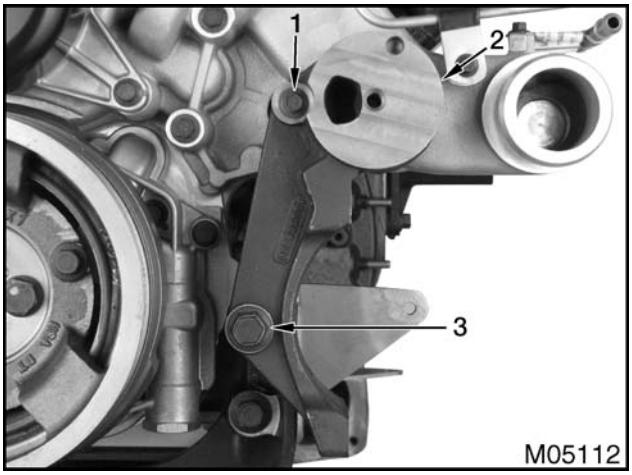

Figure 302 Auxiliary accessory mounting bracket (if equipped)

1. M8 x 100 bolt
2. Auxiliary accessory mounting bracket
3. M12 x 110 bolt

1. Remove M8 x 100 bolt.
2. Remove M12 x 110 bolt.
3. Remove auxiliary accessory mounting bracket.

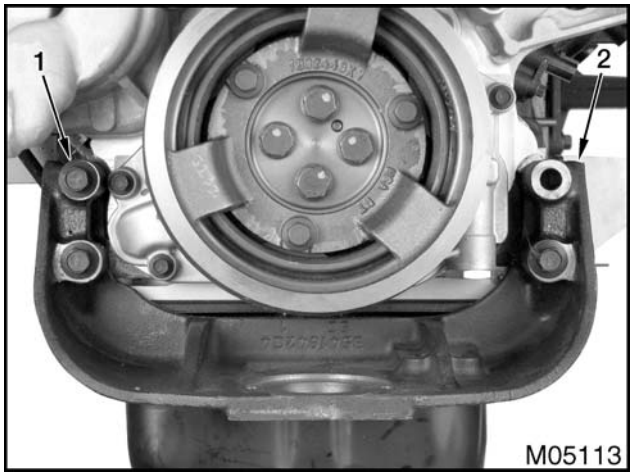

Figure 303 Front engine mount bracket

1. M12 x 70 bolt (3)
2. Front engine mount bracket

4. Remove three M12 x 70 bolts and front engine mount bracket.

Thermostat Assemblies and Housing

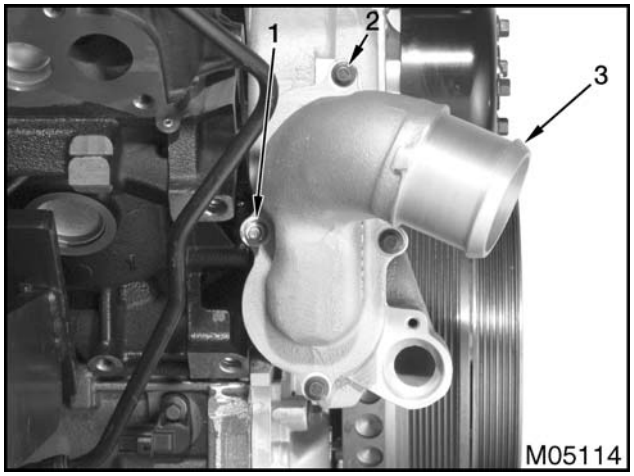

Figure 304 Thermostat housing

1. M6 x 25 stud bolt
2. M6 x 20 bolt (3)
3. Thermostat housing

1. Remove M6 x 25 stud bolt and three M6 x 20 bolts.
2. Remove thermostat housing from front crankcase cover and discard gasket.

NOTE: The thermostat assembly with bypass is the lower thermostat, and has a valve to seal against the orifice in the front crankcase cover.

3. Remove two thermostat assemblies from thermostat housing.

Fan Drive

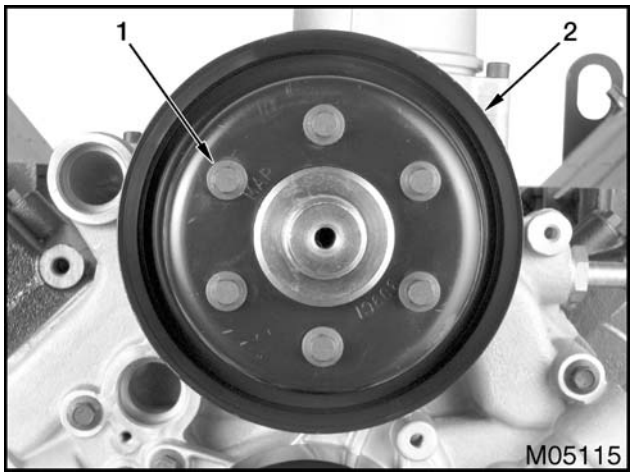

Figure 305 Fan pulley

1. M8 x 20 bolt (6)
2. Fan pulley

NOTE: If not using an impact wrench, use a holding device to lock fan pulley when removing bolts.

1. Remove six M8 x 20 bolts and fan pulley.

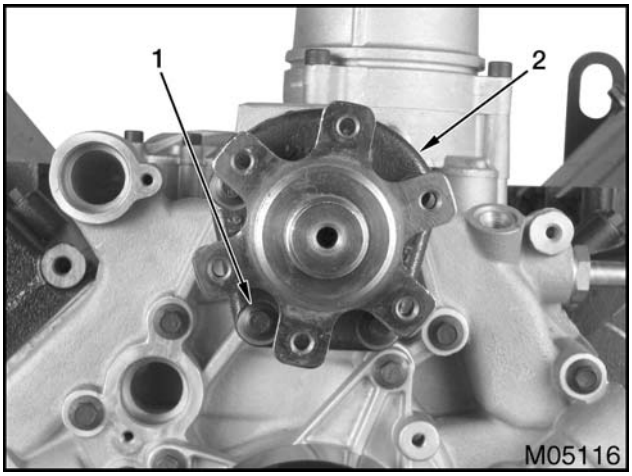

Figure 306 Fan and pulley mounting hub

1. M8 x 65 bolt (4)
2. Fan and pulley mounting hub

2. Remove four M8 x 65 bolts and fan and pulley mounting hub.

Water Pump Assembly

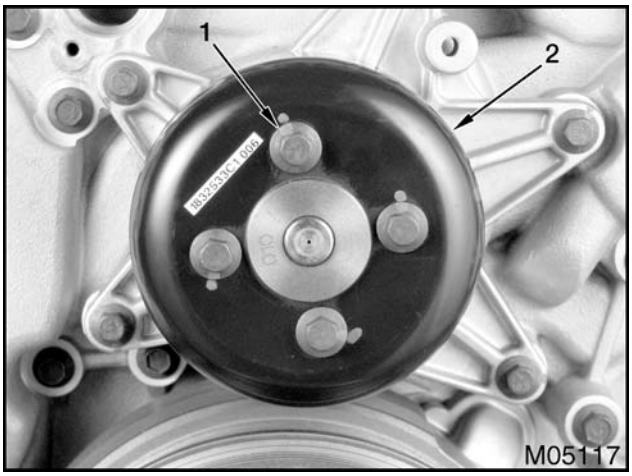

Figure 307 Water pump pulley

1. M8 x 16 bolt (4)
2. Water pump pulley

NOTE: If not using an impact wrench, use a holding device to lock water pump pulley when removing bolts.

1. Remove four M8 x 16 bolts and water pump pulley.

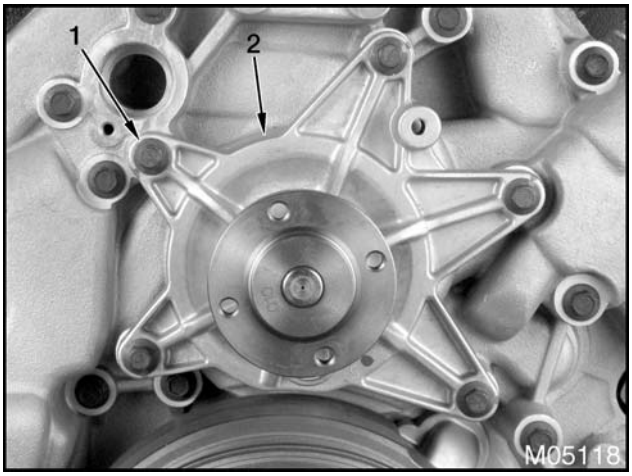

Figure 308 Water pump assembly

1. M8 x 35 bolt (5)
2. Water pump assembly

2. Remove five M8 x 35 bolts.

CAUTION: To prevent engine damage, do not drop water pump impeller or hit impeller with hard objects.

3. Remove water pump assembly and discard gasket.

Vibration Damper

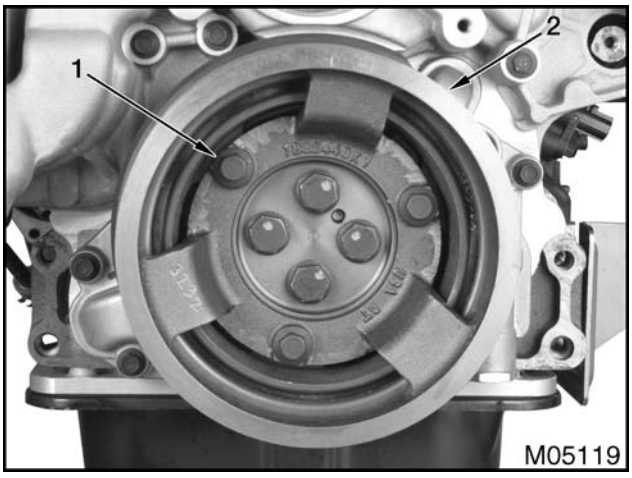

Figure 309 Front Power Takeoff (PTO) pulley (if equipped)

1. M10 x 30 bolt (3)
2. Front PTO pulley

1. Remove three M10 x 30 bolts and front PTO pulley (if equipped).

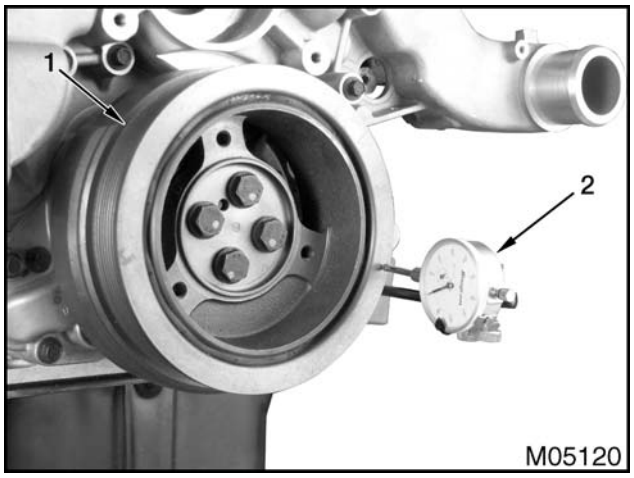

Figure 310 Vibration damper runout

1. Vibration damper
2. Dial indicator

NOTE: When prying crankshaft forward, use a block of wood between the prybar and front crankcase cover.

2. Before removing vibration damper, inspect vibration damper for runout as follows:

   a. Attach dial indicator with magnetic base (page 203) to front of crankcase. Position indicator point on vibration damper front surface.

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

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

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

   d. Repeat at each surface every 90°. If runout exceeds specification (page 202), replace vibration damper.

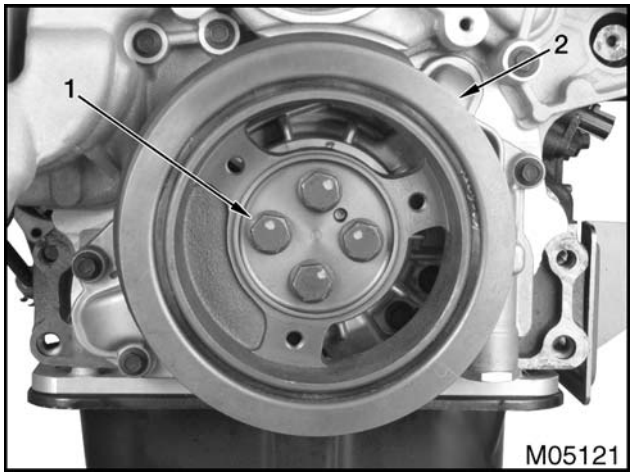

Figure 311 Vibration damper

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

WARNING: To prevent personal injury or death, support the vibration damper when removing bolts. The damper can easily slide off the end of the crankshaft.

NOTE: The vibration damper retaining bolts are not reusable.

3. Remove and discard four M12 x 59 bolts.

CAUTION: To prevent engine damage, do not immerse damper in petroleum based solvents. This can damage the rubber damper element.

4. Remove vibration damper.

Front Oil Seal and Wear Sleeve

NOTE: The International ® MaxxForce™ 7 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, perform steps 1 through 3. Otherwise, remove seal and wear sleeve using steps 1 through 4.

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

1. With an awl and hammer, punch two holes 180° apart in front oil seal.

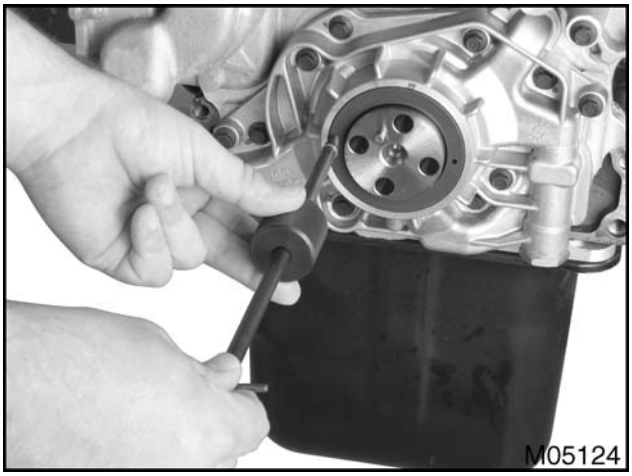

Figure 312 Front oil seal removal

2. Thread a slide hammer (page 203) with correct size screw in one of the two holes.
3. Slide hammer until one side of seal begins to pull out of oil pump housing assembly. Move slide hammer to other hole and repeat until front oil seal is removed completely.

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

4. Complete following steps to install front wear sleeve remover ZTSE4517 (page 203):

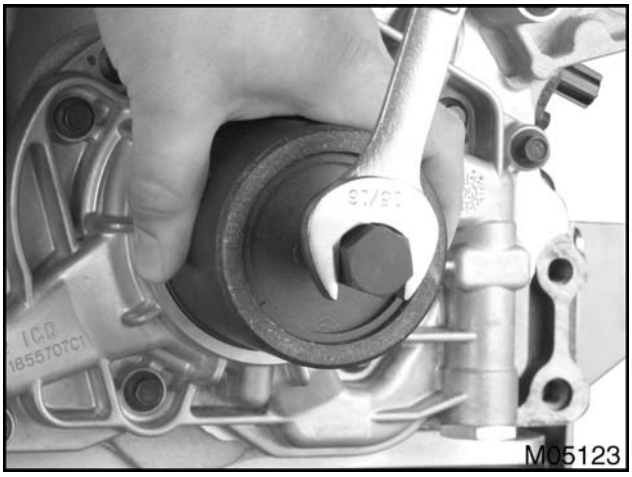

Figure 313 Removal of front wear sleeve

a. Install two half shell ridges of tool behind front wear sleeve.

b. Place threaded shaft and pulling flange inside two shells while holding shells together.

c. Slide outer collar of tool around two half shells.

d. Thread shaft up to crankshaft, and turn shaft to remove wear sleeve.

Front Crankcase Cover

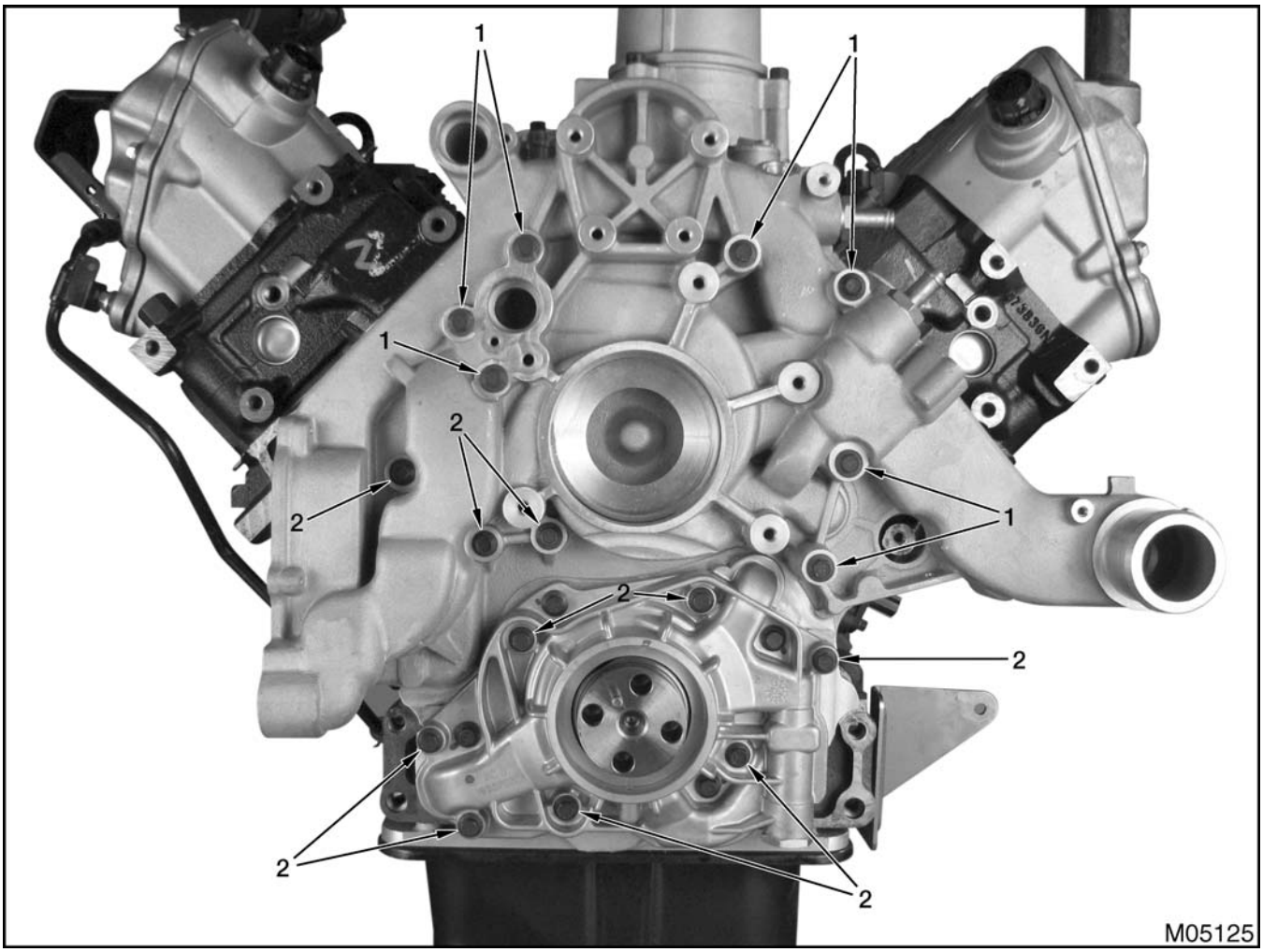

Figure 314 Front crankcase cover bolts

1. M8 x 75 bolt (7)
2. M8 x 45 bolt (10)

WARNING: To prevent personal injury or death, use a suitable lifting device and get help when removing, lowering, and installing the front cover.

CAUTION: Do not remove four M8 x 25 oil pump housing assembly bolts at this time. Damage to oil pump may result.

NOTE: Support front cover while removing bolts.

1. Remove seven M8 x 75 bolts and 10 M8 x 45 bolts.

CAUTION: To prevent engine damage, cut protruding sealant from the joint of the crankcase and lower crankcase before removing the front cover gasket. If the sealant is not cut, the seal between the crankcase and lower crankcase may fail. Complete engine removal and disassembly is required to install a new crankcase gasket.

2. Remove front crankcase cover and discard gasket.

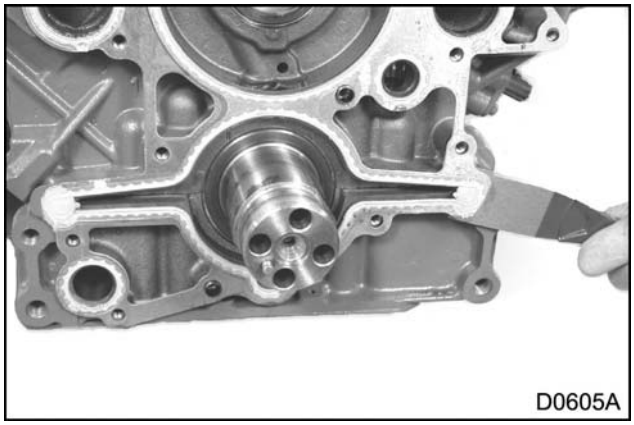

Figure 315 Sealant between crankcase and lower crankcase joint

3. Use a thin blade scraper to cut sealant where crankcase and lower crankcase meet.

Oil Pump Housing Assembly

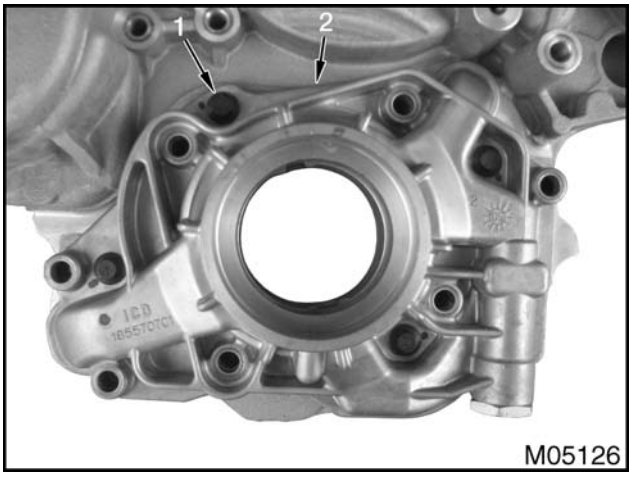

Figure 316 Oil pump housing assembly

1. M8 x 25 bolt (4)
2. Oil pump housing assembly

1. Remove four M8 x 25 bolts.

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

2. Remove oil pump housing assembly and discard gasket.
3. Use a permanent marker to mark the front of each gerotor for correct reassembly orientation.

Cleaning, Inspection, and Testing

Vibration Damper

CAUTION: To prevent engine damage, do not immerse damper in petroleum based solvents. This can damage the rubber damper element.

1. Clean vibration damper with soap, water, and a soft parts brush.

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

2. Dry damper with filtered compressed air.
3. Inspect vibration damper rubber compound for bulging (page 202). If bulging exceeds specification, replace vibration damper.
4. Inspect vibration damper rubber compound for cracks or separation. Replace vibration damper if necessary.

Oil Gerotor Pump

1. Wash all parts thoroughly in a suitable solvent.

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

2. Dry with filtered compressed air.
3. Lay oil pump housing assembly on workbench.
4. Inspect inner and outer oil pump gerotors and oil pump housing assembly for nicks, burrs or scoring.
5. Replace any damaged components.

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

   NOTE: If installing new inner and outer oil pump gerotors, correct orientation is not necessary. If installing old inner and outer oil pump gerotors, correct orientation is necessary.

6. Place inner and outer oil pump gerotors in oil pump housing assembly.

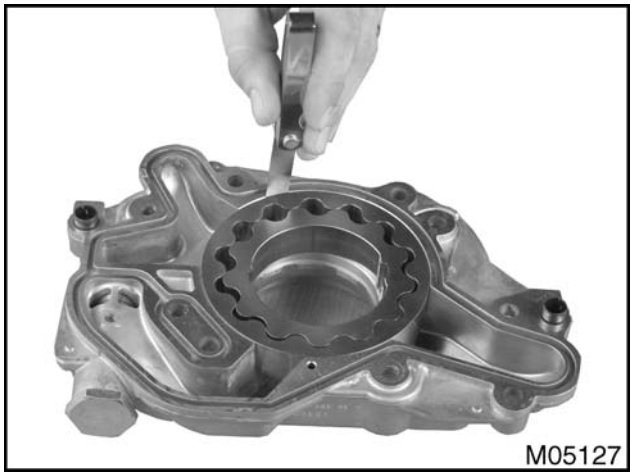

Figure 317 Outer oil pump gerotor inspection

7. Use a feeler gauge (page 203) to inspect for wear by checking radial clearance between outer oil pump gerotor and oil pump housing assembly.

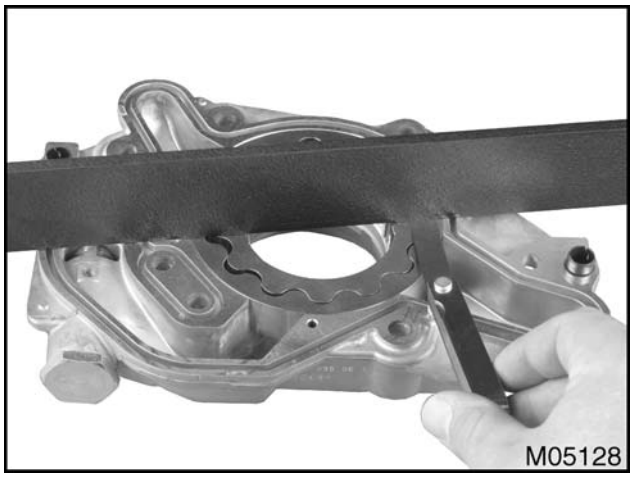

Figure 318 End clearance check for oil pump

8. Check oil pump end clearance as follows:
   a. With inner and outer oil pump gerotors in place in oil pump housing assembly, put straightedge across housing assembly.
   b. Insert feeler gauge under straightedge at inner and outer oil pump gerotors. Compare end clearance with specifications (page 202).
   c. If measurements are not within specifications, replace both inner and outer oil pump gerotors as a set.

9. Remove oil pressure regulator.

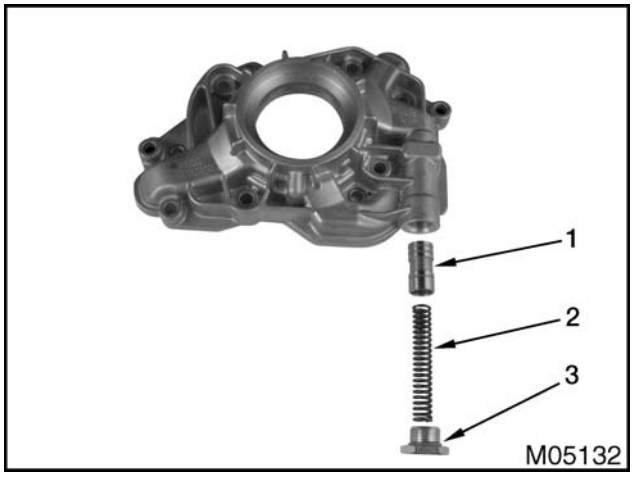

Figure 319 Oil pressure regulator components

1. Piston relief
2. Spring relief valve
3. Cap relief valve and seal relief valve retainer

10. Inspect oil pressure regulator components and bore for wear. Replace if necessary.

Front Crankcase Cover and Water Pump Assembly

1. Wash front crankcase cover and water pump assembly thoroughly in a suitable cleaning solvent.

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

2. Dry with filtered compressed air.
3. Inspect front crankcase cover for cracks. Replace if necessary.
4. Inspect water pump assembly for leaks, cracks, bearing failure, and problems with bearings or shaft seal. Replace if necessary.

Thermostat Assembly

WARNING: To prevent personal injury or death, wear heat protective gloves and appropriate eye protection when checking operation of thermostat.

CAUTION: To prevent engine damage, when testing the thermostat, make sure the thermostat assembly opens fully at the specified temperature.

Check operation of thermostat assemblies as follows:

1. Manually open thermostat enough to insert a nylon ribbon under valve seat.

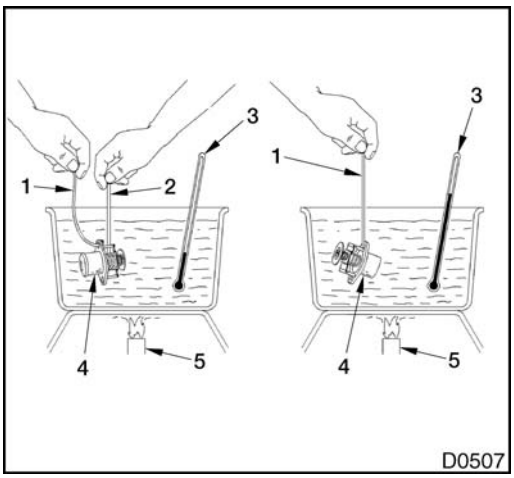

Figure 320 Thermostat operation test

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

2. Suspend thermostat assembly in a container so thermostat assembly does not touch bottom of container.
3. Heat water filled container to approximate start-to-open temperature of thermostat assembly. See Specifications for temperature (page 202).
4. Check thermometer and record temperature as soon as thermostat assembly drops from nylon ribbon. This is the start-to-open temperature.
5. Continue to heat water to full-open temperature of the thermostat assembly. See Specifications

(page 202). Check for movement of thermostat assembly valve.

6. While sleeve is off its seat, remove thermostat assembly from container and inspect seat area for pitting and foreign deposits.
7. If thermostat assembly is damaged or operates incorrectly, replace thermostat assembly.

Installation

Oil Pump Housing Assembly

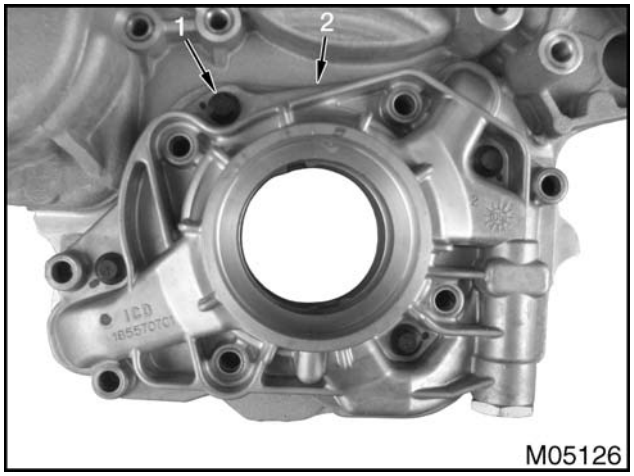

Figure 321 Oil pump housing assembly

1. M8 x 25 bolt (4)
2. Oil pump housing assembly

NOTE: If installing new inner and outer oil pump gerotors, correct orientation is not necessary. If installing old inner and outer oil pump gerotors, correct orientation is necessary.

1. Install inner and outer oil pump gerotors.
2. Position a new gasket and install oil pump housing assembly.
3. Install four M8 x 25 bolts and tighten to special torque (page 203).

Front Crankcase Cover

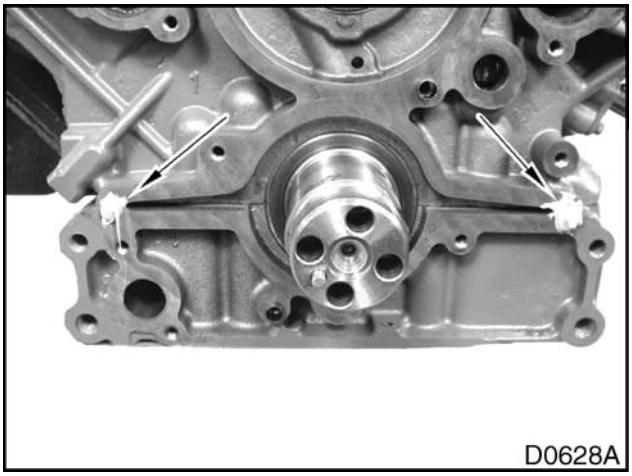

Figure 322 Liquid gasket applications

CAUTION: To prevent engine damage, install gasket and cover within 5 minutes of Liquid Gasket (RTV) application to inhibit the formation of a skin and ensure a leak proof joint.

1. Apply Liquid Gasket (RTV) (page 203) to joining surfaces of upper crankcase and lower crankcase assemblies.
2. Position a new front cover gasket on crankcase.

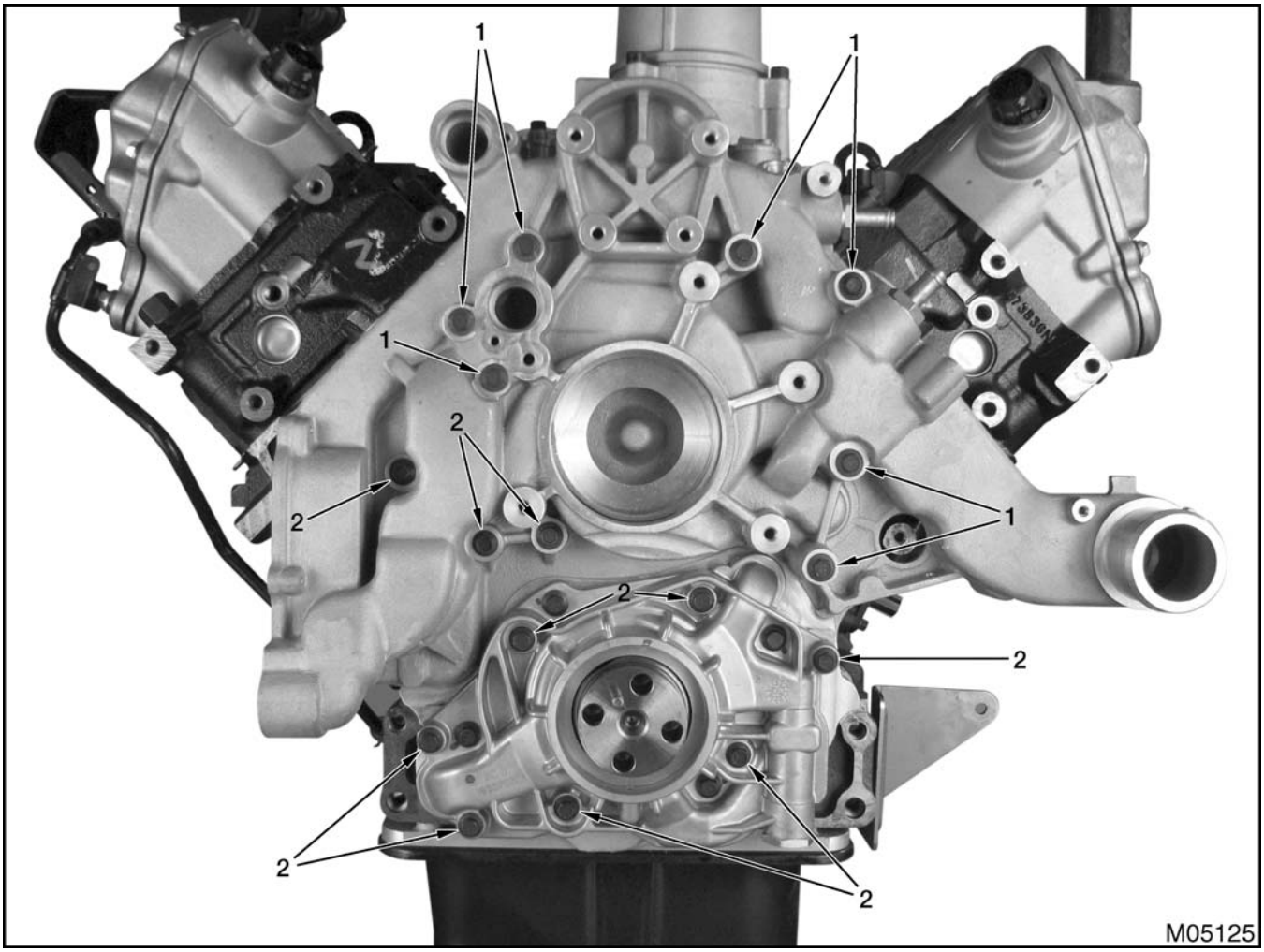

Figure 323 Front crankcase cover bolts

1. M8 x 75 bolt (7)
2. M8 x 45 bolt (10)

WARNING: To prevent personal injury or death, use a suitable lifting device and get help when removing, lowering, and installing the front cover.

NOTE: Install front crankcase cover with oil pump assembly in place for proper gerotor alignment.

NOTE: It may be necessary to manually turn oil pump gerotors, so they index onto crankshaft correctly.

NOTE: Support front crankcase cover while installing bolts.

3. Install front crankcase cover.
4. Install seven M8 x 75 bolts and 10 M8 x 45 bolts. Tighten bolts to special torque (page 203).

Front Oil Seal and Wear Sleeve

NOTE: The International ® MaxxForce™ 7 is not equipped with a wear sleeve during factory production. Wear sleeves are available with an oil seal service kit.

1. Put a 360° bead of hydraulic sealant such as Loctite® 569 (page 203) or equivalent on leading edge of crankshaft before wear sleeve installation.

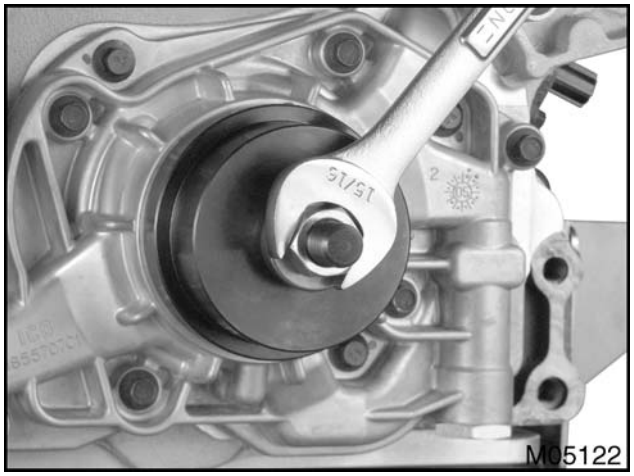

Figure 324 Front oil seal and wear sleeve

CAUTION: To prevent engine damage, do not separate wear sleeve from new oil seal; this damages seal.

2. Use front seal/wear sleeve installer ZTSE4516 (page 203), to drive oil seal and wear sleeve assembly into oil pump housing assembly.

Vibration Damper

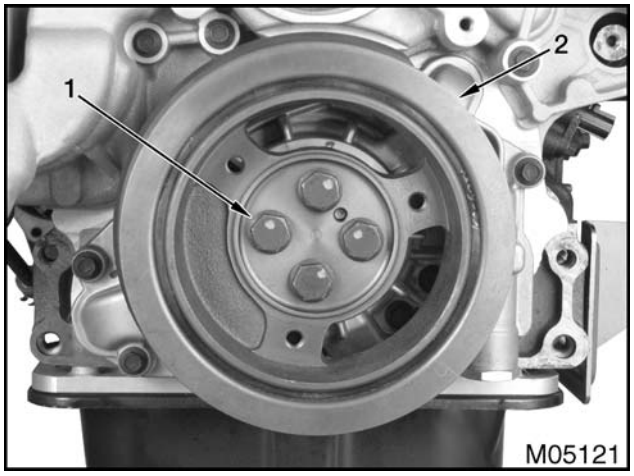

Figure 325 Vibration damper

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

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

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

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

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

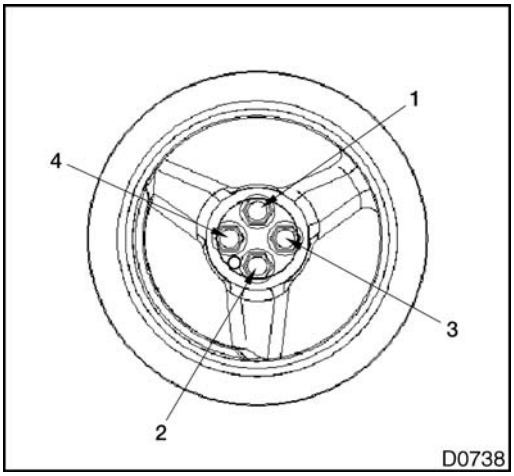

Figure 326 Torque sequence for vibration damper bolts

3. Vibration damper bolt torque sequence:
   a. Tighten each bolt to special torque (page 203) using above sequence.
   b. Rotate each bolt an additional 90° using above sequence.

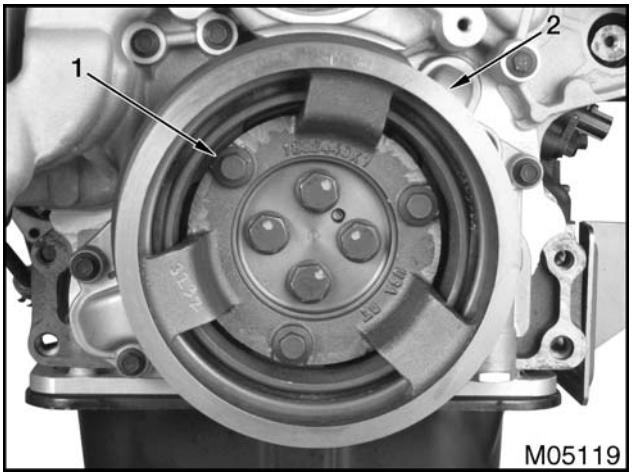

Figure 327 Front Power Takeoff (PTO) pulley (if equipped)

1. M10 x 30 bolt (3)
2. Front PTO pulley

4. Install front PTO pulley (if equipped).
5. Install three M10 x 30 bolts and tighten to special torque (page 203).

Water Pump Assembly

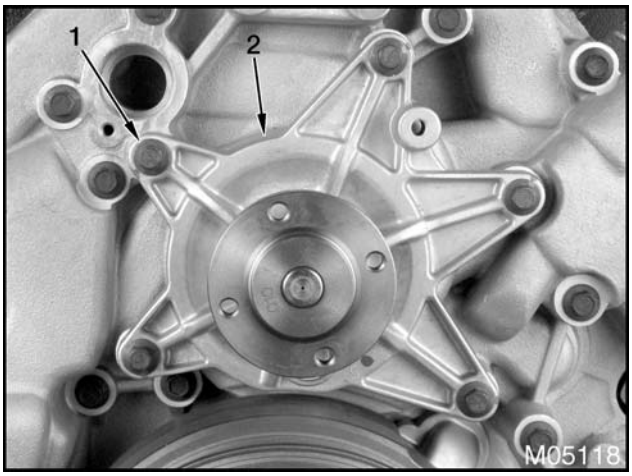

Figure 328 Water pump assembly

1. M8 x 35 bolt (5)
2. Water pump assembly

CAUTION: To prevent engine damage, do not drop water pump impeller or hit impeller with hard objects.

1. Position a new gasket and install water pump assembly.
2. Install five M8 x 35 bolts and tighten to special torque (page 203).

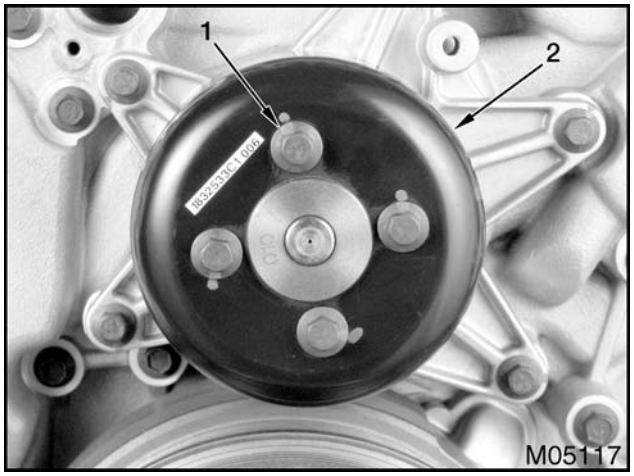

Figure 329 Water pump pulley

1. M8 x 16 bolt (4)
2. Water pump pulley

3. Install water pump pulley.

NOTE: Use a holding device to lock water pump pulley when installing bolts.

4. Install four M8 x 16 bolts and tighten to standard torque (page 369).

Fan Drive

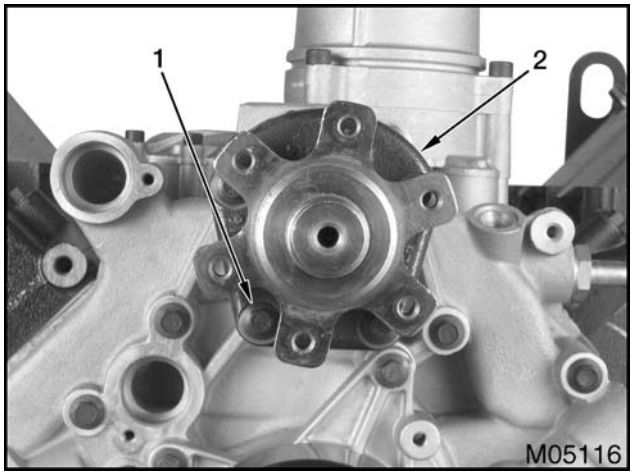

Figure 330 Fan and pulley mounting hub

1. M8 x 65 bolt (4)
2. Fan and pulley mounting hub

1. Install fan and pulley mounting hub.
2. Install four M8 x 65 bolts and tighten to special torque (page 203).

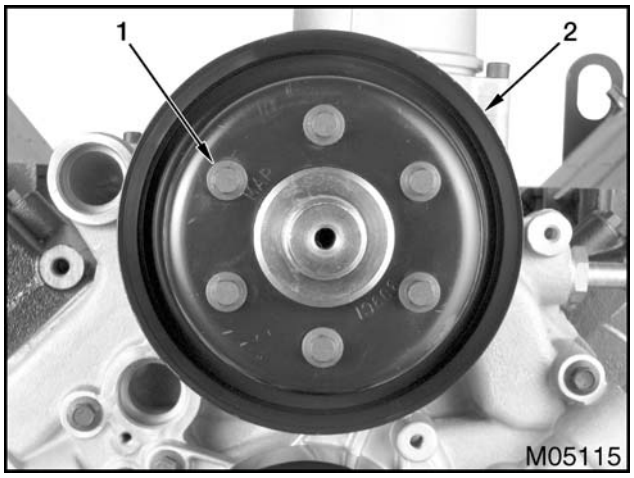

Figure 331 Fan pulley

1. M8 x 20 bolt (6)
2. Fan pulley

3. Install fan pulley.

NOTE: Use a holding device to lock fan pulley when installing bolts.

4. Install six M8 x 20 bolts and tighten to special torque (page 203).

Thermostat Assemblies and Housing

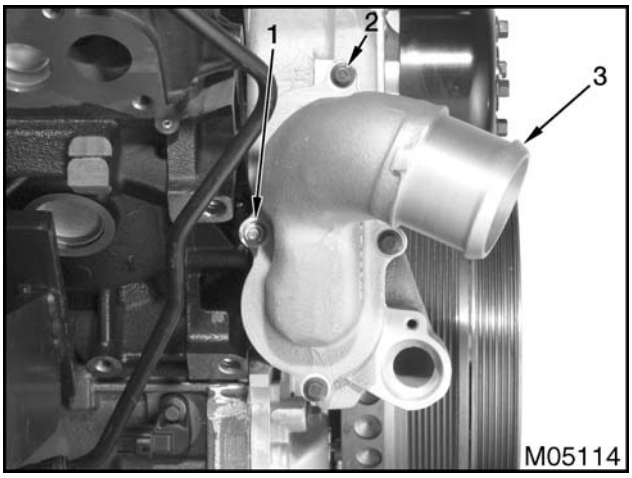

Figure 332 Thermostat housing

1. M6 x 25 stud bolt
2. M6 x 20 bolt (3)
3. Thermostat housing

NOTE: The thermostat assembly with bypass is the lower thermostat, and has a valve to seal against the orifice in the front crankcase cover.

1. Install two thermostat assemblies to thermostat housing. Verify correct position.
2. Position a new gasket and install thermostat housing.
3. Install M6 x 25 stud bolt and three M6 x 20 bolts. Tighten to special torque (page 203).

Front Engine Mount Bracket

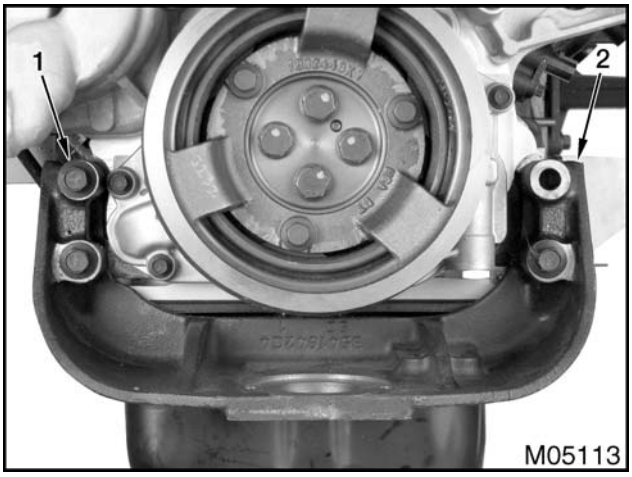

Figure 333 Front engine mount bracket

1. M12 x 70 bolt (3)
2. Front engine mount bracket

1. Install front engine mount bracket.

NOTE: For engines that are not equipped with auxiliary accessory mounting bracket, the front engine mount bracket is secured by four M12 x 70 bolts.

2. Install three M12 x 70 bolts and tighten to special torque (page 203).

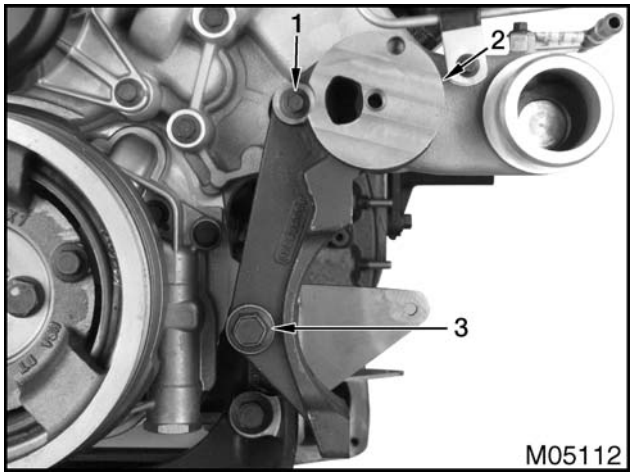

Figure 334 Auxiliary accessory mounting bracket (if equipped)

1. M8 x 100 bolt
2. Auxiliary accessory mounting bracket
3. M12 x 110 bolt

3. Install auxiliary accessory mounting bracket.
4. Install M8 x 100 bolt and tighten to standard torque (page 369).
5. Install M12 x 110 bolt (front engine mount bracket) and tighten to special torque (page 203).

Alternator and Freon® Mounting Bracket

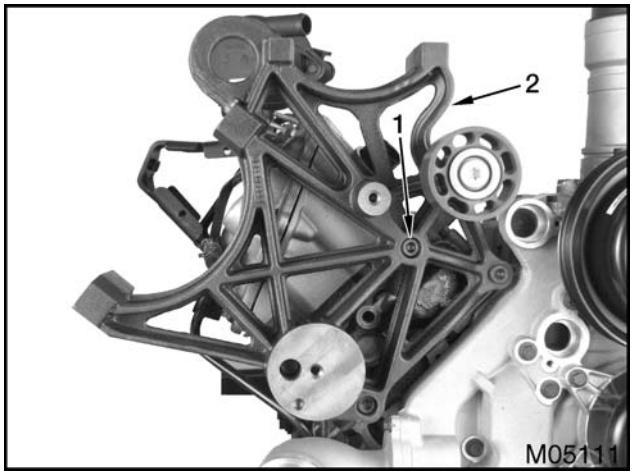

Figure 335 Alternator and Freon® mounting bracket

1. M10 x 45 cap screw (4)
2. Alternator and Freon® mounting bracket

1. Install alternator and Freon® mounting bracket.
2. Install four M10 x 45 cap screws and tighten to special torque (page 203).
3. Install belt tensioner.
4. Install M10 x 80 bolt and tighten to special torque (page 203).

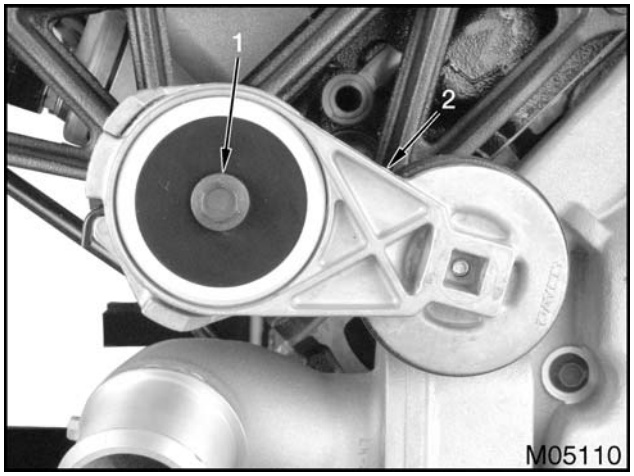

Figure 336 Belt tensioner

1. M10 x 80 bolt
2. Belt tensioner

Specifications

Table 18 Front Cover, Cooling System, and Related Components

Vibration Damper	
Face runout (maximum)	0.635 mm (0.025 in)
Rubber bulging (maximum)	1.5 mm (0.060 in)
Lubricating Oil Pump	
Type	Gerotor
Drive	Crankshaft
Location	Oil pump housing assembly
Pressure Regulating Valve:	
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)
End clearance (inner and outer oil pump gerotor to oil pump housing assembly)	0.025 to 0.095 mm (0.001 to 0.004 in)
Radial clearance (between outer oil pump gerotor and oil pump housing assembly)	0.15 to 0.28 mm (0.006 to 0.011 in)
Thermostat Assembly With Bypass	
Type	Balanced pressure, wax pellet
Minimum recommended coolant operating temperature	71° C (160° F)
Start-to-open temperature, 0.20 mm (0.009 in) stroke	92 to 96° C (198 to 205° F)
Full-open temperature, 10 mm (0.394 in) stroke	106° C (222.8° F)
Thermostat Assembly Without Bypass	
Type	Balanced pressure, wax pellet
Minimum recommended coolant operating temperature	71° C (160° F)
Start-to-open temperature, 0.20 mm (0.009 in) stroke	86.7 to 91° C (188 to 196° F)
Full-open temperature, 10 mm (0.394 in) stroke	104° C (219.1° F)

Special Torque

Table 19 Front Cover, Cooling System, and Related Components

Alternator and Freon® mounting bracket cap screws	72 N·m (53 lbf·ft)
Belt tensioner bolt	61 N·m (45 lbf·ft)
Fan and pulley mounting hub bolts	31 N·m (23 lbf·ft)
Fan pulley bolts	31 N·m (23 lbf·ft)
Front crankcase cover bolts	31 N·m (23 lbf·ft)
Front engine mount bracket bolts	107 N·m (79 lbf·ft)
Oil pump housing assembly bolts	22 N·m (16 lbf·ft)
Front Power Takeoff (PTO) pulley bolts	61 N·m (45 lbf·ft)
Thermostat housing stud bolt and bolts	13 N·m (115 lbf·in)
Vibration damper bolts	68 N·m (50 lbf·ft) + 90° rotation
Water pump assembly bolts	31 N·m (23 lbf·ft)

Special Service Tools

Table 20 Front Cover, Cooling System, and Related Components

Description	Tool Number
Dial indicator with magnetic base	Obtain locally
Feeler gauge	Obtain locally
Front seal/wear sleeve installer	ZTSE4516
Front wear sleeve remover	ZTSE4517
Liquid Gasket (RTV) (6 oz. tube)	1830858C1
Loctite® 569 hydraulic sealant or equivalent	Obtain locally
Slide hammer	Obtain locally
Straightedge	Obtain locally

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Exploded Views

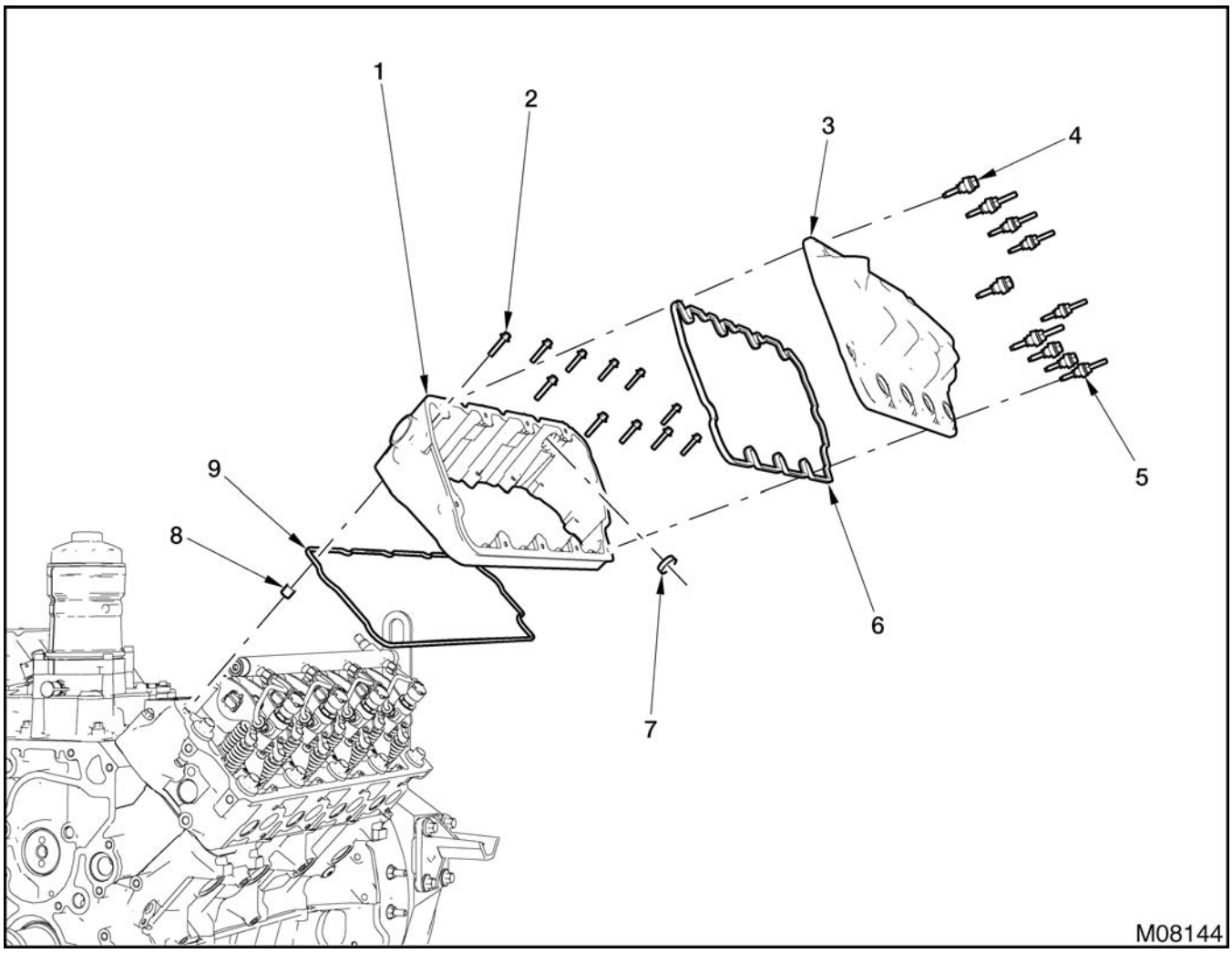

Figure 337 Valve cover and valve cover base assemblies (typical)

1. Valve cover base
2. M6 x 30 bolt (11)
3. Valve cover
4. Valve cover bolt assembly (left valve cover 4) (right valve cover 3)
5. Valve cover stud bolt assembly (left valve cover 6) (right valve cover 7)
6. Valve cover gasket
7. Fuel supply line seal
8. Slotted spring dowel pin
9. Valve cover base gasket

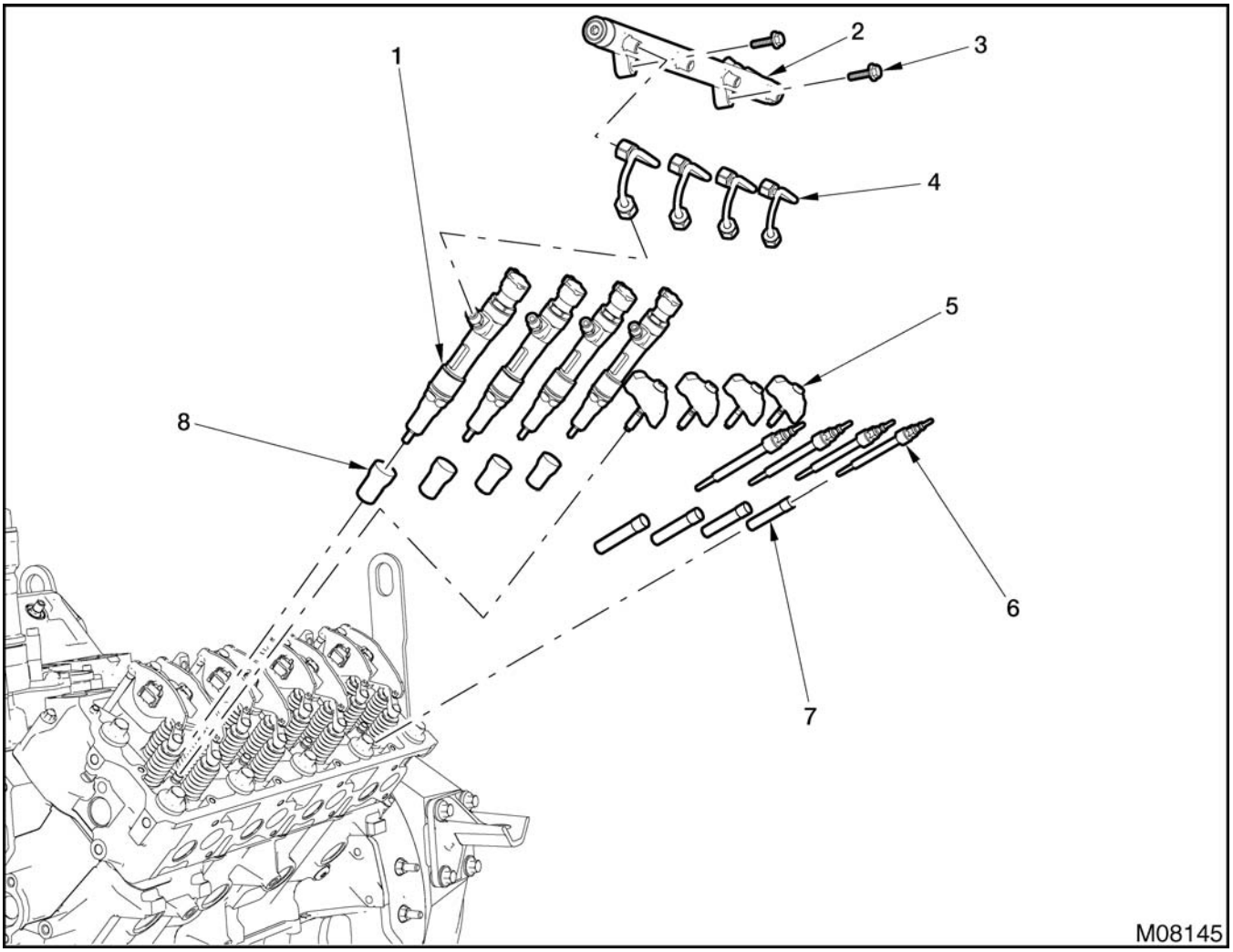

Figure 338 Fuel injectors and glow plugs (typical)

1. Fuel injector assembly (4)
2. Rail assembly
3. M8 x 30 bolt (2)
4. Fuel rail to injector tube assembly (4)
5. Injector hold down clamp assembly (4)
6. Glow plug (4)
7. Glow plug sleeve (4)
8. Injector sleeve (4)

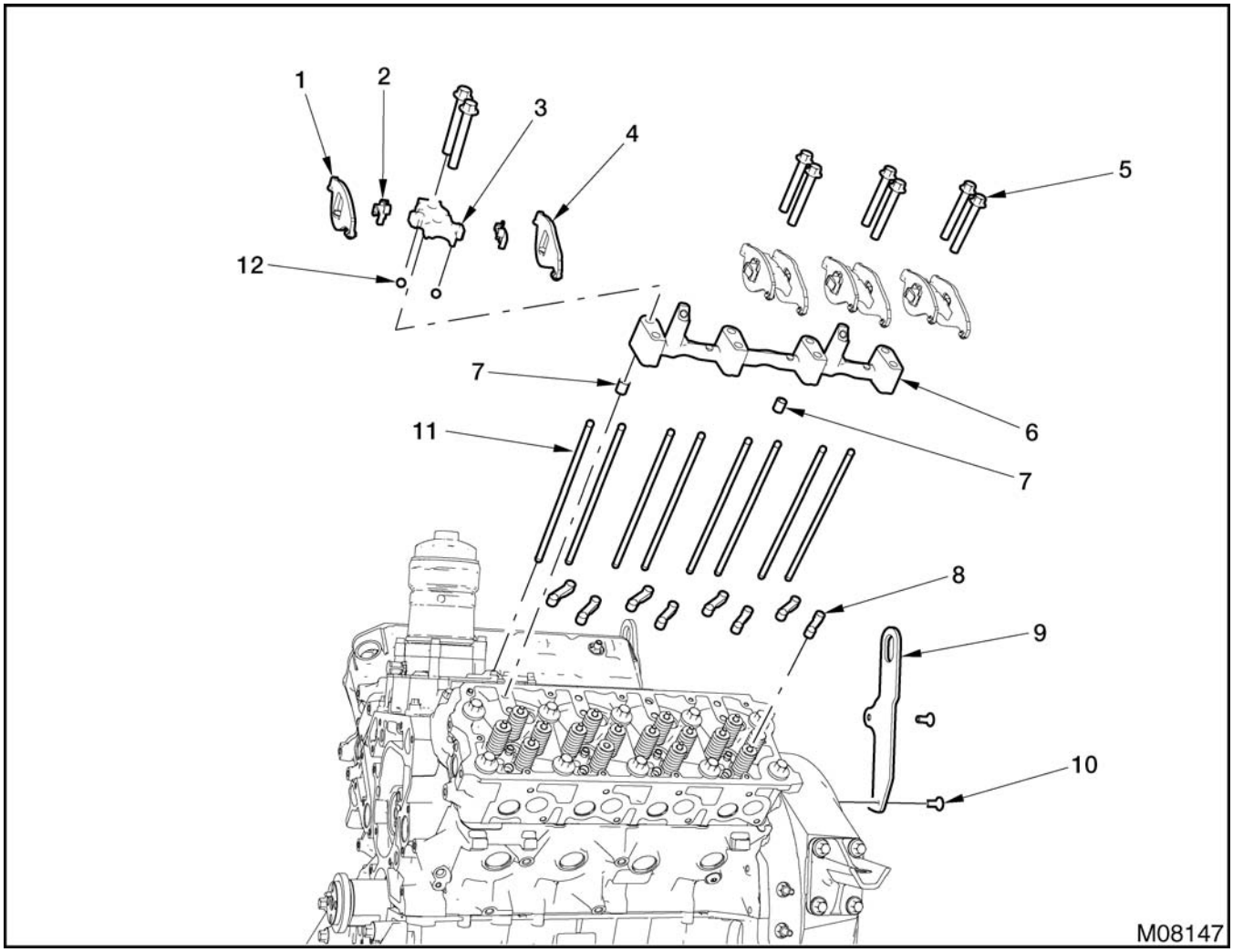

Figure 339 Rocker arm support components (typical)

1. Intake rocker arm assembly (4)
2. Rocker arm clip (8)
3. Dual rocker fulcrum plate (4)
4. Exhaust rocker arm assembly (4)
5. M10 x 70 bolt (8)
6. Rocker arm support
7. Dowel sleeve bushing (2)
8. Valve bridge (8)
9. Lifting eye
10. Flat countersunk screw (2) (left cylinder head)/ M10 x 25 bolt (2) (right cylinder head)
11. Push rod assembly (8)
12. 3/8” pivot ball (8)

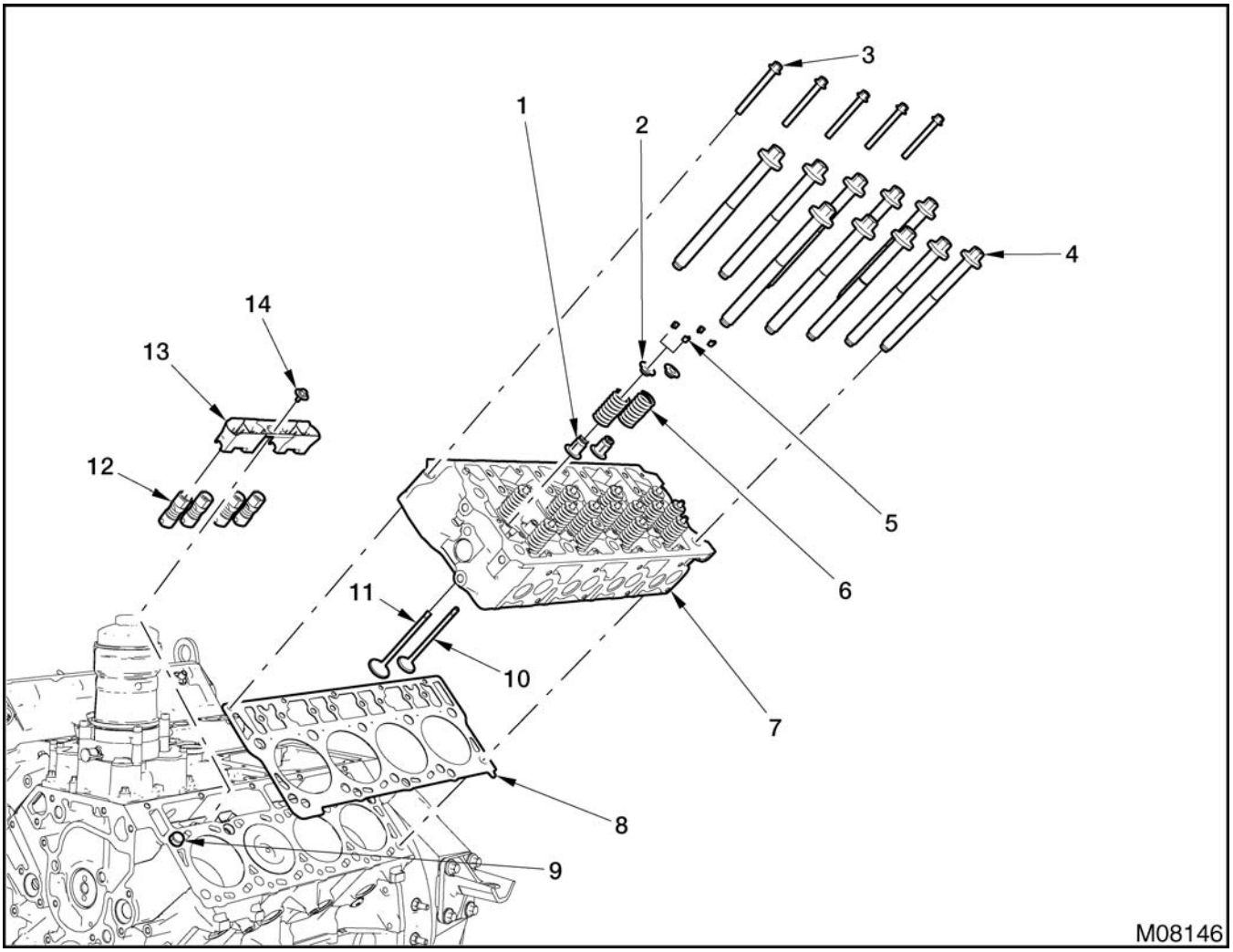

Figure 340 Cylinder head components (typical)

1. Valve seal assembly (16)
2. Valve spring retainer (16)
3. M8 x 70 bolt (5)
4. Cylinder head bolt (10)
5. Valve stem key (32)
6. Valve spring (16)
7. Cylinder head assembly
8. Cylinder head gasket
9. Spring dowel pin (2)
10. Exhaust valve (8)
11. Intake valve (8)
12. Roller hydraulic cam follower (8)
13. Roller follower guide (2)
14. Lifter guide bolt with washer assembly (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 the transmission to park or neutral, set the parking brake, and block the wheels before doing diagnostic or service procedures.

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

WARNING: To prevent personal injury or death, remove the ground cable from the negative terminal of the main battery before disconnecting or connecting electrical components. Always connect the ground cable last.

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 according to applicable regulations. Never put engine fluids in the trash, on the ground, in sewers or bodies of water.

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

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

- Engine Electrical
- Exhaust Gas Recirculating (EGR) System
- Variable Geometry Turbocharger (VGT)
- Air Compressor and Power Steering/Fuel Pump
- Fuel System
- Intake and Exhaust Manifolds

Valve Covers and Related Components

Breather Assembly and Components

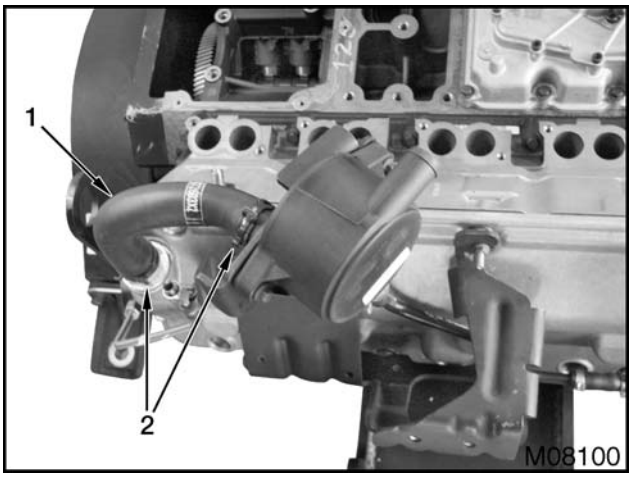

Figure 341 Breather inlet hose

1. Breather inlet hose
2. Clamp (2)

1. Release two clamps and remove breather inlet hose.

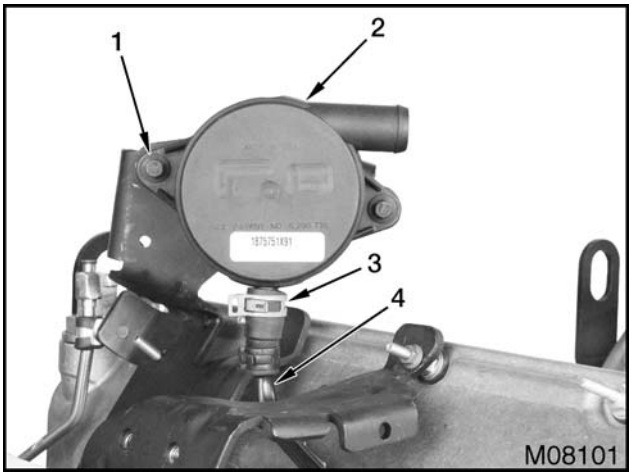

Figure 342 Breather assembly

1. M8 x 35 bolt (2)
2. Breather assembly
3. 1/2” preload clamp
4. Breather oil drain assembly

2. Remove two M8 x 35 bolts.
3. Release clamp and remove breather assembly.

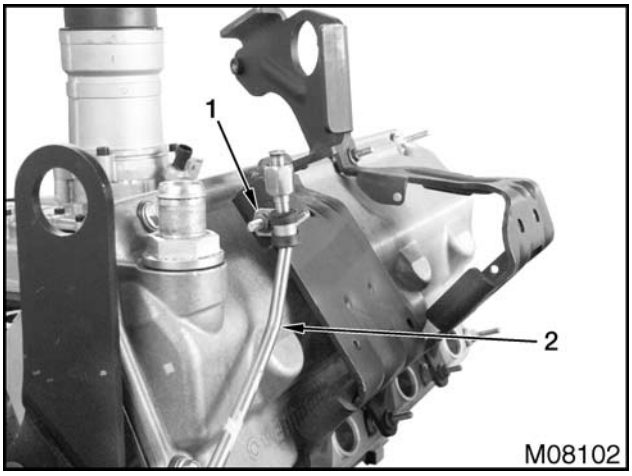

Figure 343 Exhaust Back Pressure (EBP) tube assembly

1. M6 nut
2. EBP tube assembly

4. Remove M6 nut.
5. Remove EBP tube assembly.

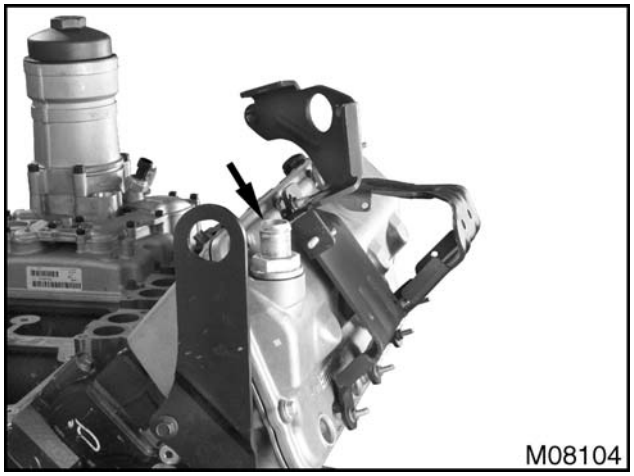

Figure 344 Breather inlet adapter

6. Remove breather inlet adapter.

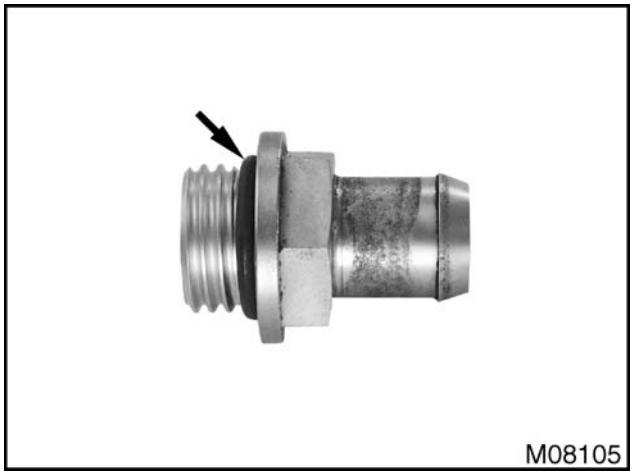

Figure 345 Breather inlet adapter O-ring seal

7. Remove and discard O-ring seal.

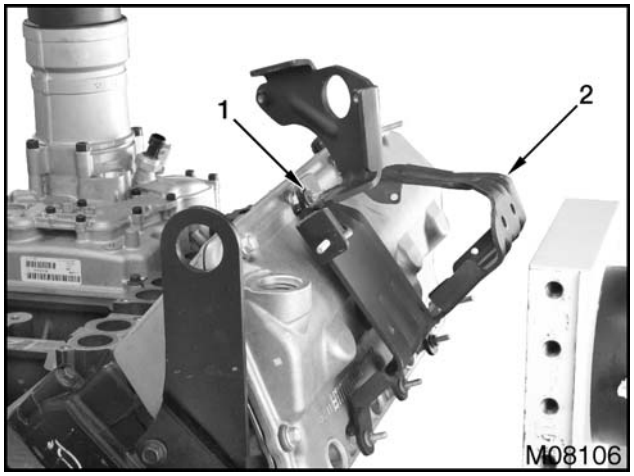

Figure 346 Breather support

1. M6 nut (4)
2. Breather support

8. Remove four M6 breather support nuts.
9. Remove breather support.

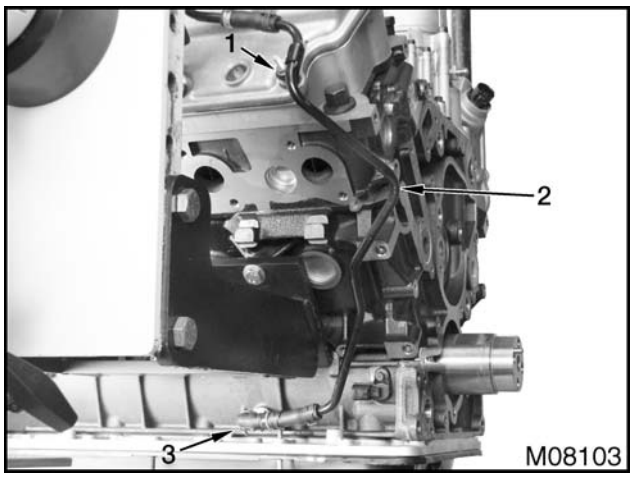

Figure 347 Breather oil drain assembly

1. M6 nut
2. Breather oil drain assembly
3. 3/8” preload clamp

10. Remove M6 breather oil drain assembly nut.
11. Release clamp and remove breather oil drain assembly.

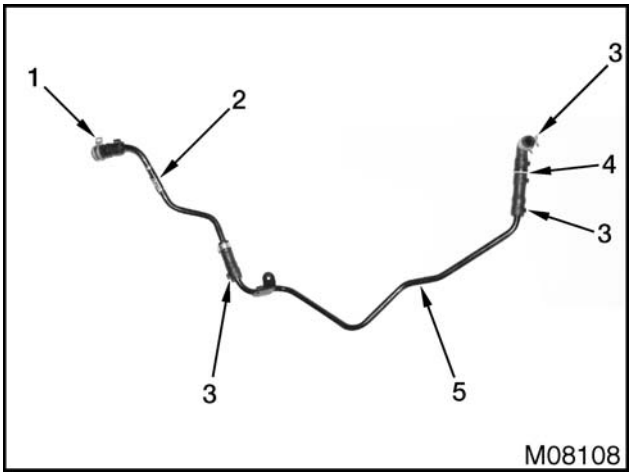

Figure 348 Breather oil drain assembly components

1. 1/2” preload clamp
2. Nylon tube assembly
3. 3/8” preload clamp (3)
4. Check valve assembly
5. Steel tube

12. Release and position aside three 3/8” preload clamps.
13. Disconnect and remove nylon tube, steel tube, and check valve.

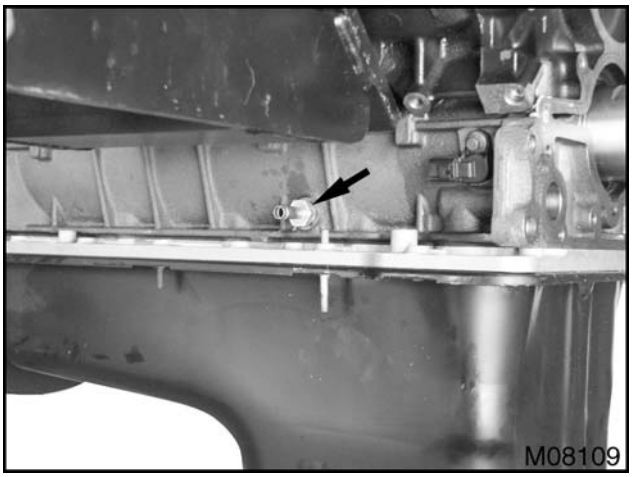

Figure 349 Breather oil drain assembly to crankcase M12 fitting

14. Remove M12 fitting.

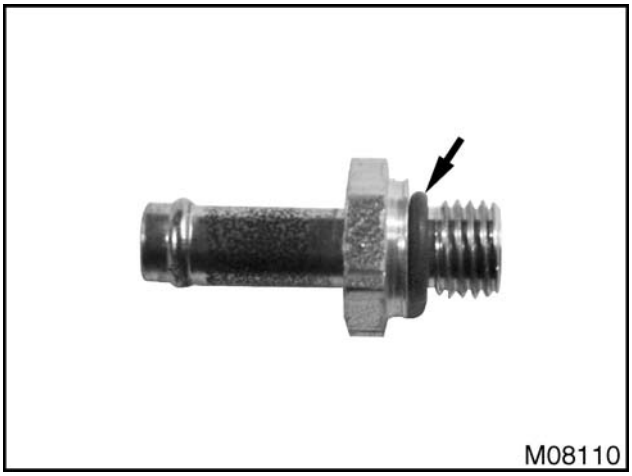

Figure 350 M12 fitting O-ring seal

15. Remove and discard O-ring seal.

Left Valve Cover

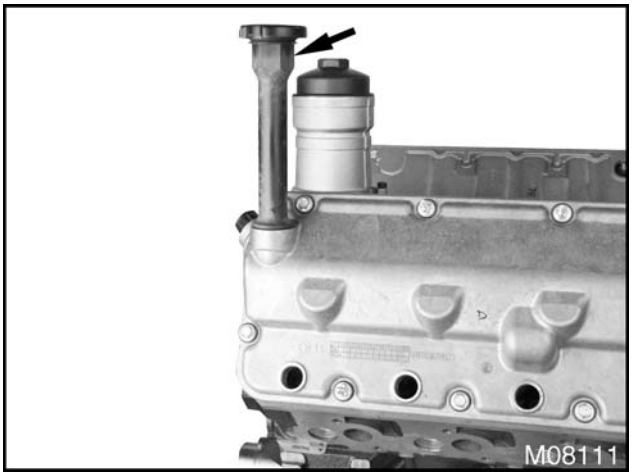

Figure 351 Oil fill extension

1. Remove oil fill extension.

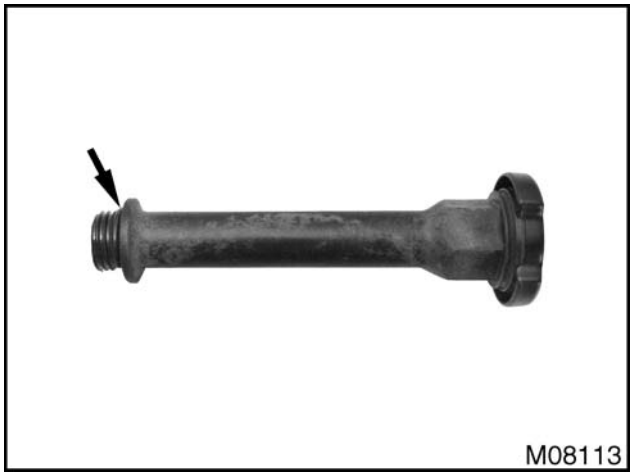

Figure 352 Oil fill extension O-ring seal

2. Remove and discard oil fill extension O-ring seal.

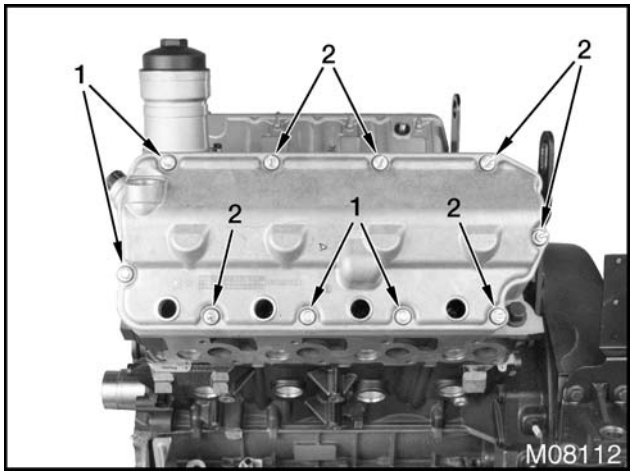

Figure 353 Left valve cover bolt and stud bolt assemblies

1. Valve cover bolt assembly (4)
2. Valve cover stud bolt assembly (6)

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

3. Remove four valve cover bolt assemblies and six valve cover stud bolt assemblies.
4. Remove left valve cover.
5. Remove and discard left valve cover gasket.

Right Valve Cover

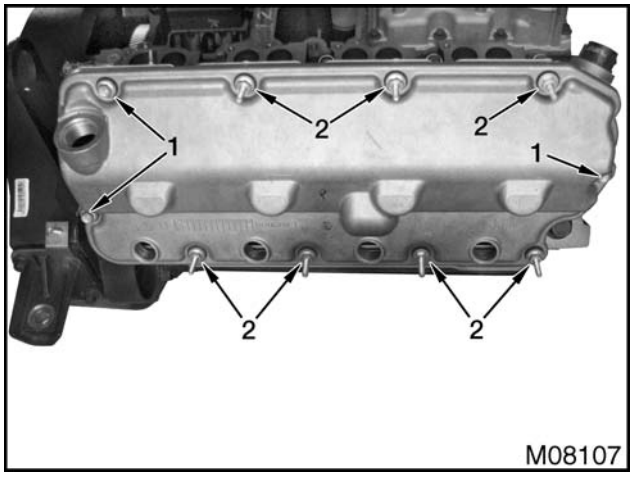

Figure 354 Right valve cover bolt and stud bolt assemblies

1. Valve cover bolt assembly (3)
2. Valve cover stud bolt assembly (7)

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

1. Remove three valve cover bolt assemblies and seven valve cover stud bolt assemblies.
2. Remove right valve cover.
3. Remove and discard right valve cover gasket.

Fuel Injector and Rail Assemblies

1. Remove Under Valve Cover (UVC) harness (page 64).

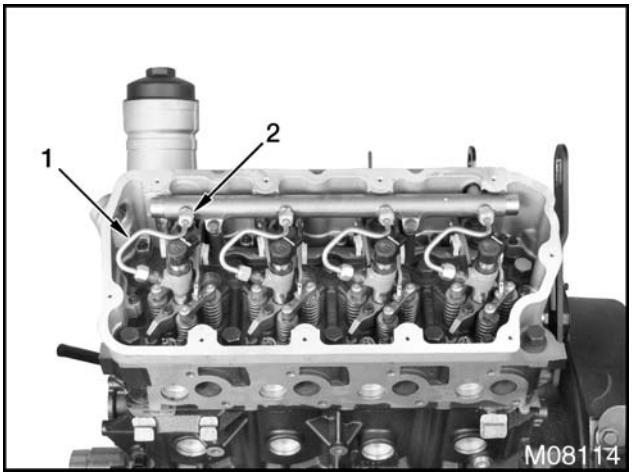

Figure 355 Fuel rail to injector tube assemblies (typical)

1. Fuel rail to injector tube assembly (4)
2. Tube nut (8)

⚠ WARNING: To prevent personal injury or death, whenever any fuel line (tubing) in the high-pressure fuel system is removed, it must be replaced with new.

2. Use a wrench to hold fuel injector fittings and loosen four tube nuts from fuel injectors.
3. Loosen four tube nuts on fuel rail. Remove and discard four fuel rail to injector tube assemblies.
4. Cover fuel rail inlet and outlet ports with Fuel System Caps ZTSE4710 (page 251).
5. Cover fuel injector ports with Fuel System Caps ZTSE4710 (page 251).

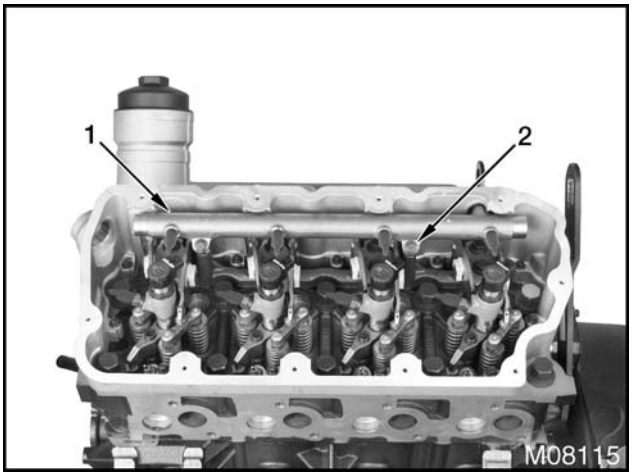

Figure 356 Rail assembly (typical)

1. Rail assembly
2. M8 x 30 bolt (2)

6. Remove two M8 x 30 bolts.
7. Remove rail assembly.

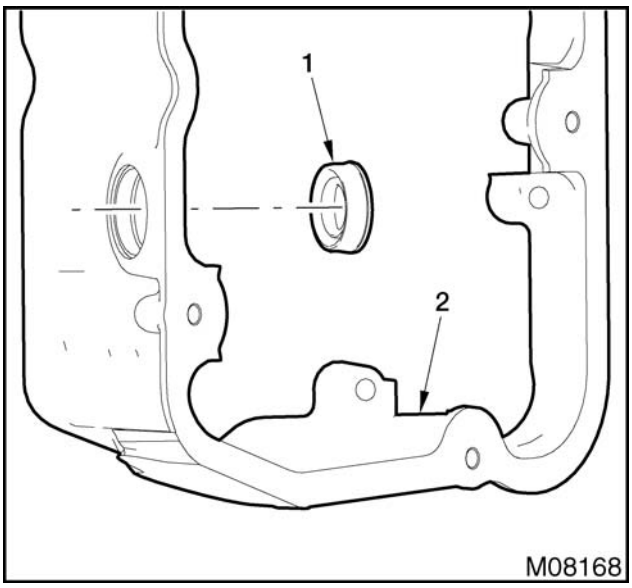

Figure 357 Fuel supply line seal removal (typical)

1. Fuel supply line seal
2. Valve cover base

8. Remove fuel supply line seal by pressing it with a proper size socket toward the inside of the valve cover base. Discard fuel supply line seal.

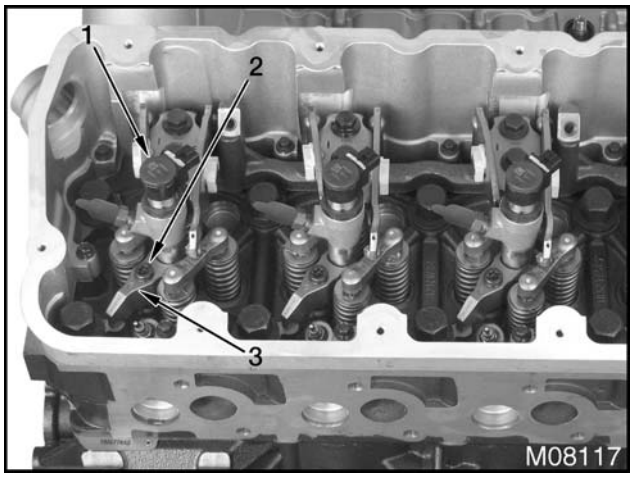

Figure 358 Fuel injector assembly (typical)

1. Fuel injector assembly (4)
2. Injector clamp bolt (4)
3. Injector hold down clamp (4)

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

CAUTION: To prevent engine damage, do not use power tools.

9. Loosen injector clamp bolt to extract fuel injector assembly from cylinder head.
10. Remove fuel injector assembly from cylinder head by lifting fuel injector assembly and injector hold down clamp assembly straight up and out.

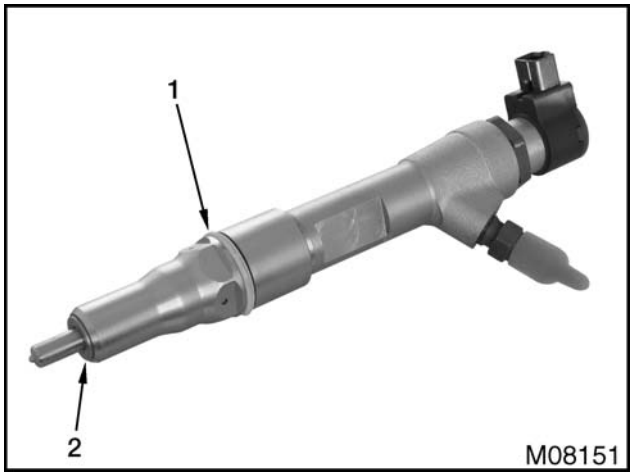

Figure 359 Fuel injector seal and combustion gasket (typical)

1. Fuel injector seal
2. Combustion gasket

CAUTION: To prevent engine damage, install new fuel injector seal and combustion gasket if a fuel injector is removed.

NOTE: Observe combustion gasket orientation at removal and be sure to install the new combustion gasket with the same orientation. If the combustion gasket remains stuck inside the fuel injector sleeve, remove it carefully so the original orientation can be noted. As a reference in establishing its orientation, the combustion gasket has a groove on one side and a rolled edge on the opposite side.

11. Using a small hand tool, remove and discard combustion gasket. Wipe injector nozzle with a lint free cloth.

CAUTION: To prevent engine damage, do not clean fuel injectors with solvents or brake cleaner.

12. Clean injector tip with Fuel Injector Tip Cleaning Brush ZTSE4301 (page 251).
13. Remove and discard old fuel injector seal.
14. Insert fuel injector assembly in Injector Cup ZTSE4709 (page 251), and place in Fuel Injector Rack Holder ZTSE4299B (page 251).

Glow Plugs

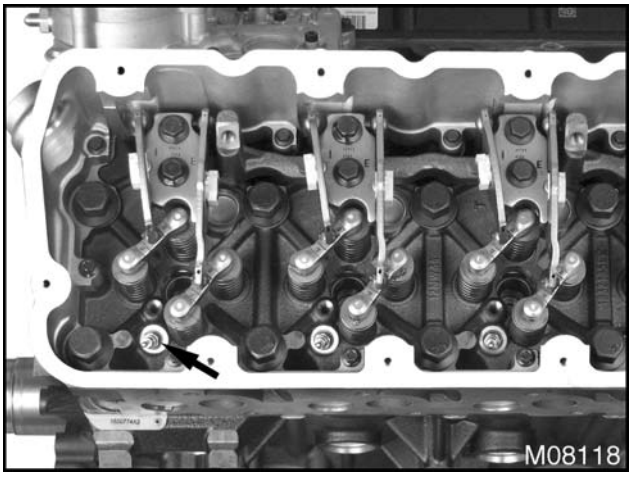

Figure 360 Glow plugs (typical)

Remove four glow plugs.

Valve Cover Base

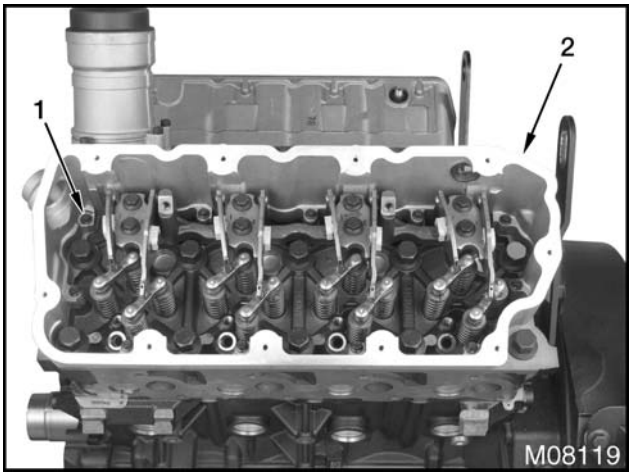

Figure 361 Valve cover base assembly (typical)

1. M6 x 30 bolt (11)
2. Valve cover base assembly

1. Remove 11 M6 x 30 bolts.
2. Remove valve cover base assembly.

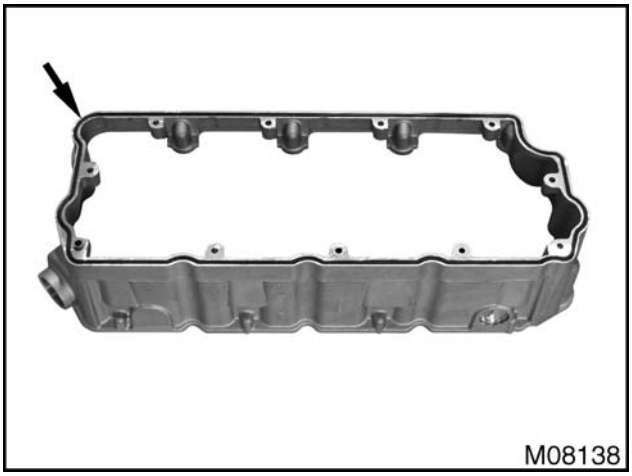

Figure 362 Valve cover base gasket (typical)

3. Remove and discard valve cover base gasket.

Rocker Arm Support, Push Rods, and Valve Bridges

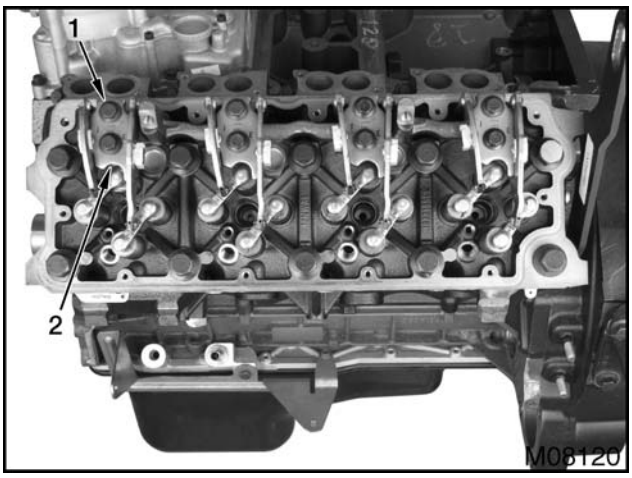

Figure 363 Dual rocker fulcrum plates (typical)

1. M10 x 70 bolt (8)
2. Dual fulcrum plate assembly (4)

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

1. Mark dual rocker fulcrum plates so they can be installed in their original location.
2. Remove eight M10 x 70 bolts and four dual fulcrum plate assemblies.

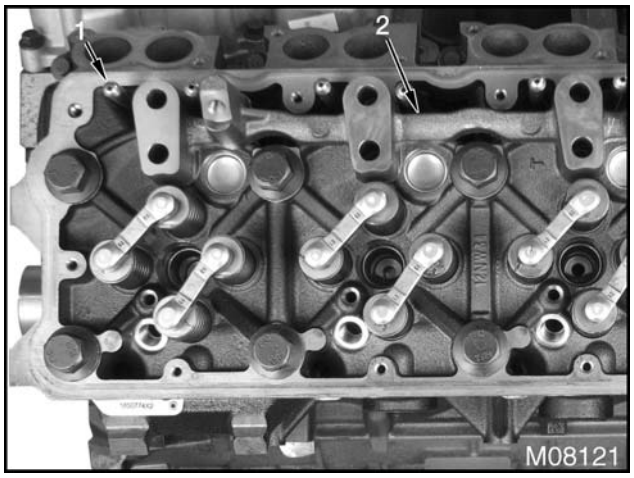

Figure 364 Push rod assemblies and rocker arm support (typical)

1. Push rod assembly (8)
2. Rocker arm support

3. Remove rocker arm support.

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

CAUTION: To prevent engine damage, keep cam followers and push rods in the order removed and install in original order.

4. Remove and identify each push rod 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

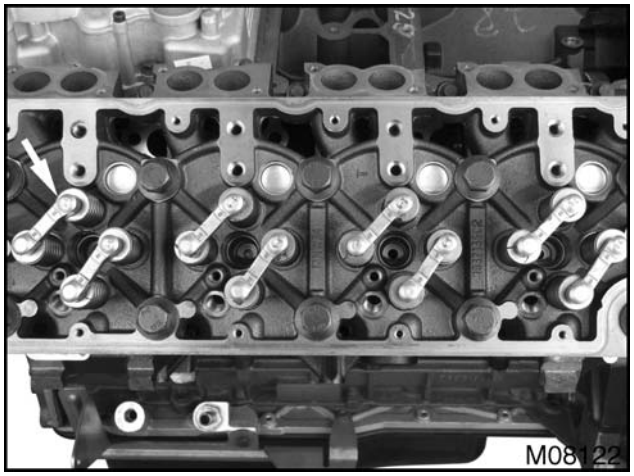

Figure 365 Valve bridge (typical)

NOTE: Identify each valve bridge and corresponding valve set so they can be installed in their original locations.

5. Remove eight valve bridges.

Cylinder Heads

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

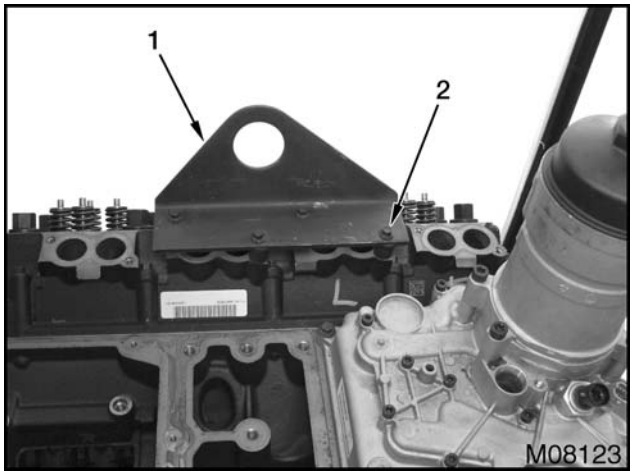

Figure 366 Cylinder Head Lifting Bracket ZTSE4535

1. Cylinder Head Lifting Bracket ZTSE4535
2. Lifting bracket mounting bolt (4)

NOTE: The lifting bracket allows each cylinder head to be removed squarely from the crankcase.

1. Position Cylinder Head Lifting Bracket ZTSE4535 (page 251) on cylinder head over the center two cylinders, install and tighten four lifting bracket mounting bolts.
2. Attach a lifting hoist hook or suitable lifting sling to lifting bracket.

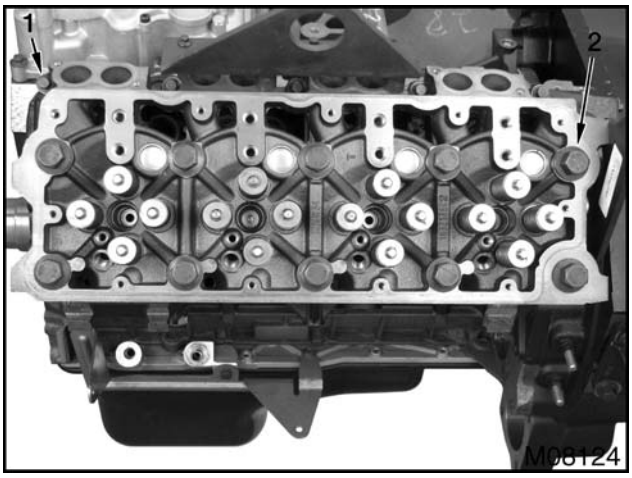

Figure 367 Cylinder head bolts (typical)

1. M8 x 70 bolt (5)
2. Cylinder head bolt (10)

3. Using a circular pattern loosen, remove, and discard ten cylinder head bolts. Begin with the outer bolts and move inward.
4. Remove five M8 x 70 bolts.
5. Lift cylinder head from crankcase.

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

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

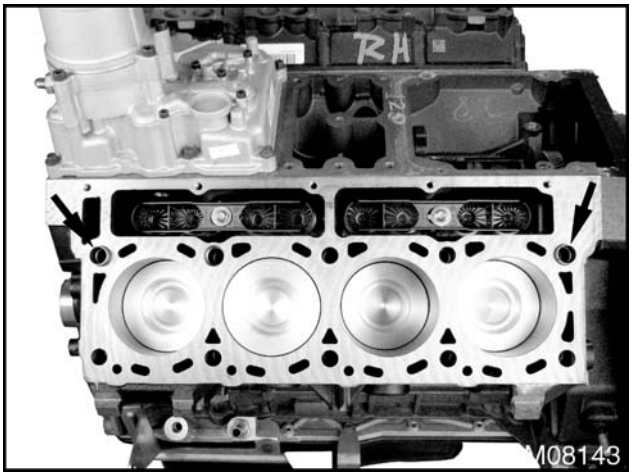

Figure 368 Cylinder head spring dowel pins in crankcase (typical)

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

Roller Hydraulic Cam Followers

NOTE: If the valve train operates quietly and hydraulic cam followers function properly, do not service cam followers.

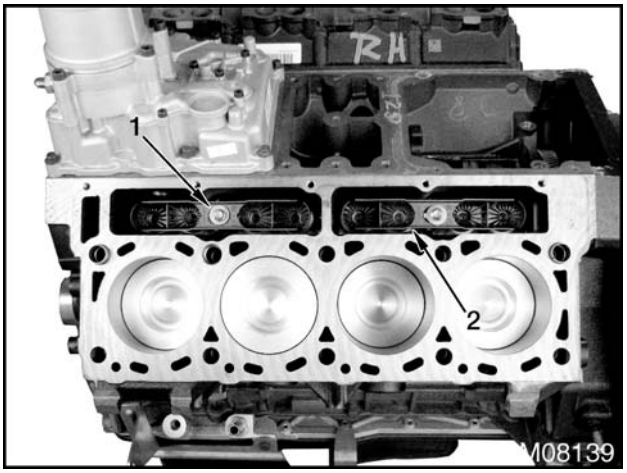

Figure 369 Cam follower and guide assemblies (typical)

1. Lifter guide bolt with washer assembly (2)
2. Cam follower and guide assembly (2)

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

CAUTION: To prevent engine damage, keep cam followers and push rods in the order removed and install in original order.

NOTE: To remove the cam followers lift the guide straight up. A hand tool may be required.

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

1. Remove two lifter guide bolt with washer assemblies and two cam follower and guide assemblies.

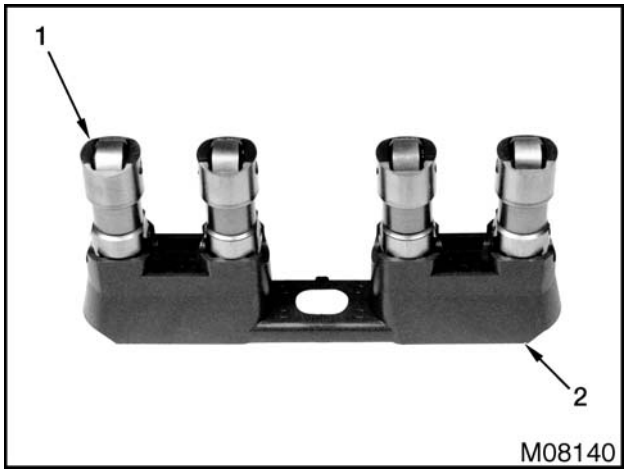

Figure 370 Roller hydraulic cam followers (typical)

1. Roller hydraulic cam follower (4)
2. Roller follower guide

NOTE: Identify and note the position of each roller hydraulic cam follower based on the orientation of its lubrication hole. The roller hydraulic cam followers must be installed in their original position.

2. Remove four roller hydraulic cam followers from roller follower guide.

Valves

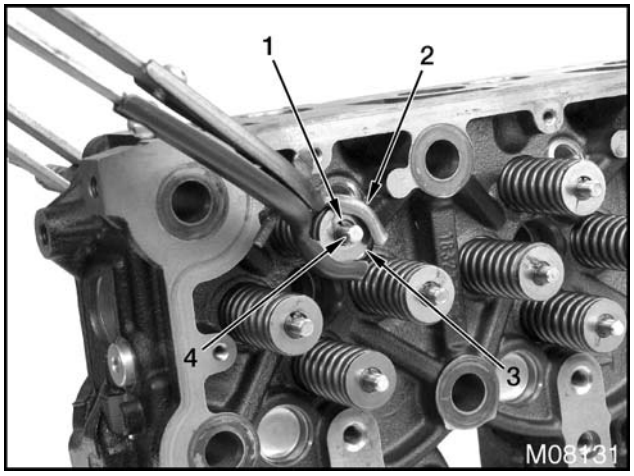

Figure 371 Valve spring compression (typical)

1. Valve stem key (2)
2. C Type Valve Spring Compressor ZTSE1846
3. Valve spring retainer
4. Valve

NOTE: A small magnet is useful to remove the valve stem keys.

1. Compress valve springs with C Type Valve Spring Compressor ZTSE1846 (page 251), and remove two valve stem keys.
2. Release valve spring compressor and remove valve spring retainer and valve spring.
3. Remove valve from cylinder head.

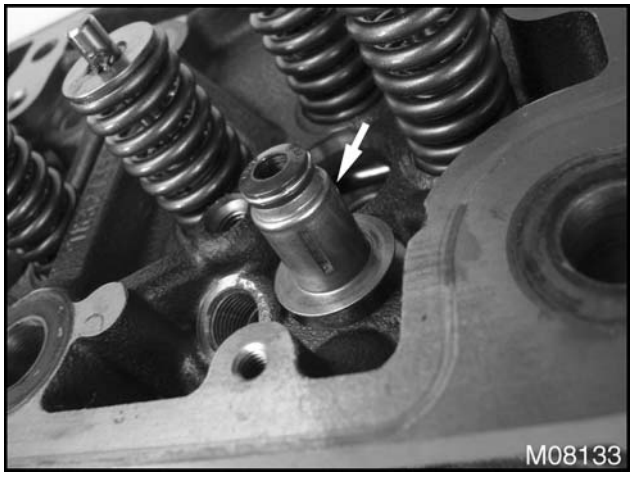

Figure 372 Valve seal assembly (typical)

NOTE: Valve seal assemblies are not reusable. Use pliers to remove valve seal assembly from end of valve stem guide.

4. Remove and discard valve seal assembly.

Fuel Injector Sleeves

CAUTION: To prevent engine damage, if replacing fuel injector sleeves in chassis, install a small plug in the bottom of the injector sleeve before cutting threads. This will keep small metal chips out of the combustion chamber.

NOTE: Fuel injector sleeve removal is not required unless sleeve is damaged.

NOTE: Use Injector Sleeve Remover ZTSE4732 (page 251) to remove injector sleeves.

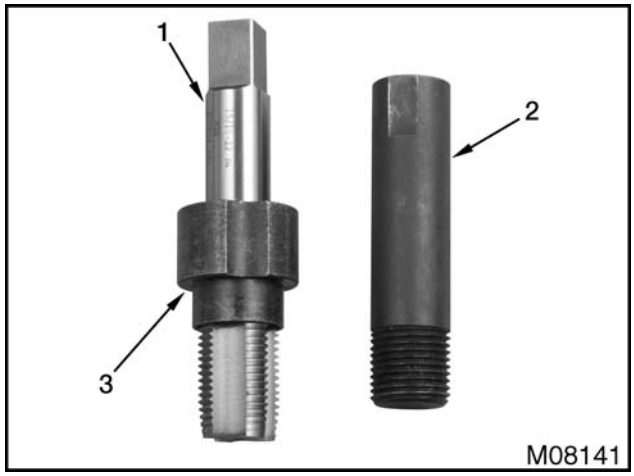

Figure 373 Injector Sleeve Remover ZTSE4732

1. Thread tap
2. Injector sleeve remover
3. Thread tap guide collar

NOTE: The fuel injector sleeve is made of stainless steel. Lubrication of the thread tap is required.

1. Lubricate thread tap.

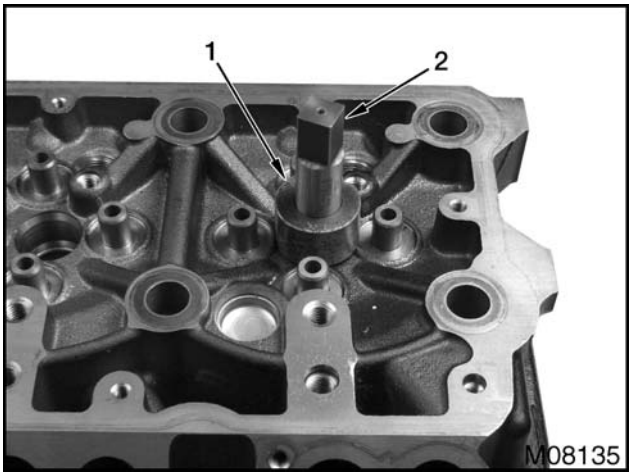

Figure 374 Thread tap guide collar installed (typical)

1. Thread tap guide collar
2. Thread tap

2. Insert thread tap into fuel injector sleeve and install thread tap guide collar on thread tap.
3. Cut at least 19 mm (0.75 in) deep threads to accommodate injector sleeve remover.

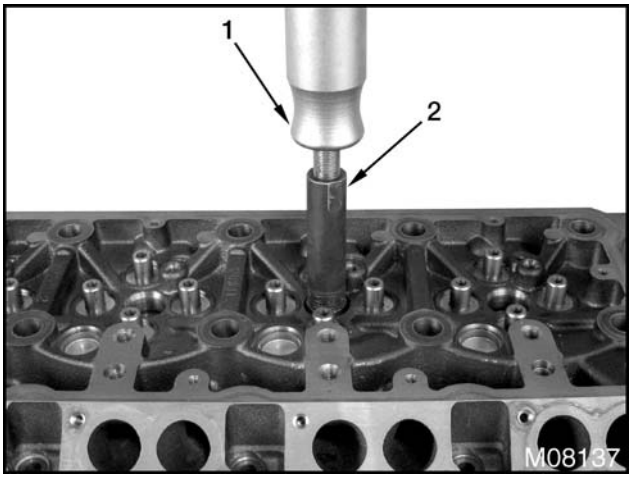

Figure 375 Injector sleeve remover installed (typical)

1. Slide hammer
2. Injector sleeve remover

4. Install and tighten injector sleeve remover in fuel injector sleeve.
5. Thread Slide Hammer ZTSE4398 (page 251) in injector sleeve remover.
6. Remove and discard fuel injector sleeve.

Glow Plug Sleeves

CAUTION: To prevent engine damage, if replacing glow plug sleeves in chassis, put a small plug in the bottom of the glow plug sleeve before cutting threads. The plug will prevent small metal chips from entering the combustion chamber.

NOTE: Glow plug sleeve removal is not required unless sleeves are damaged.

NOTE: Use Glow Plug Sleeve Remover ZTSE4531 (page 251) to remove glow plug sleeves.

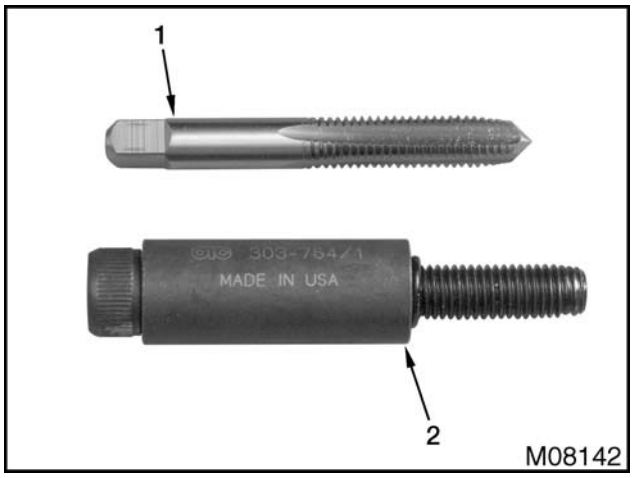

Figure 376 Glow Plug Sleeve Remover ZTSE4531

1. Thread tap
2. Glow plug sleeve remover

NOTE: The glow plug sleeve is made of stainless steel. Lubrication of the thread tap is required.

1. Lubricate thread tap.

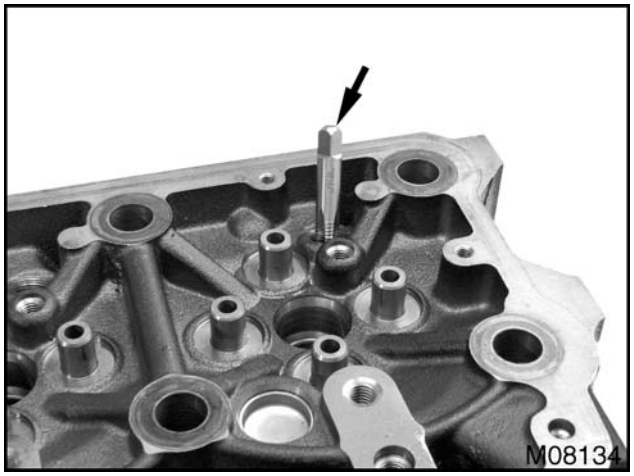

Figure 377 Glow plug sleeve tap (typical)

2. Insert thread tap into glow plug sleeve.
3. Cut at least 19 mm (0.75 in) deep threads to accommodate glow plug sleeve remover.

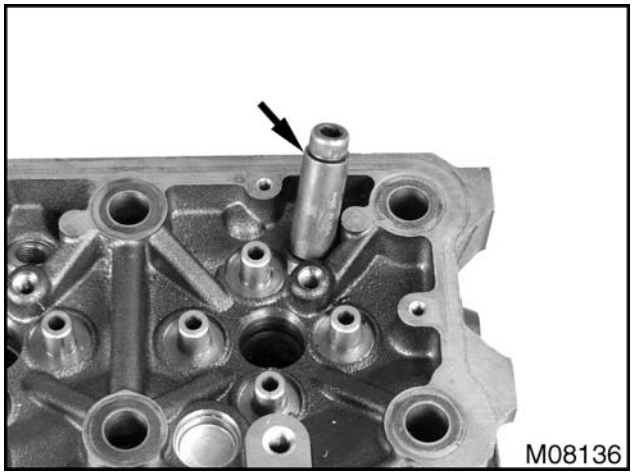

Figure 378 Glow Plug Sleeve Remover ZTSE4531 installed

4. Thread Glow Plug Sleeve Remover ZTSE4531 into glow plug sleeve and tighten bolt until sleeve is extracted.
5. Remove and discard glow plug sleeve.

Dual Fulcrum Plate Assemblies

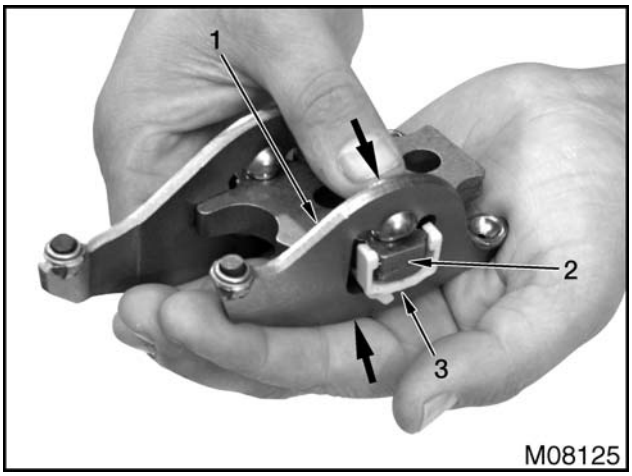

Figure 379 Separation of rocker arm assembly from dual rocker fulcrum plate (typical)

1. Rocker arm assembly
2. Dual rocker fulcrum plate
3. Rocker arm clip

1. Place dual fulcrum plate assembly upside down in your palm.
2. Push up on rocker arm assembly with palm and forward on dual rocker fulcrum plate with thumb of opposite hand.

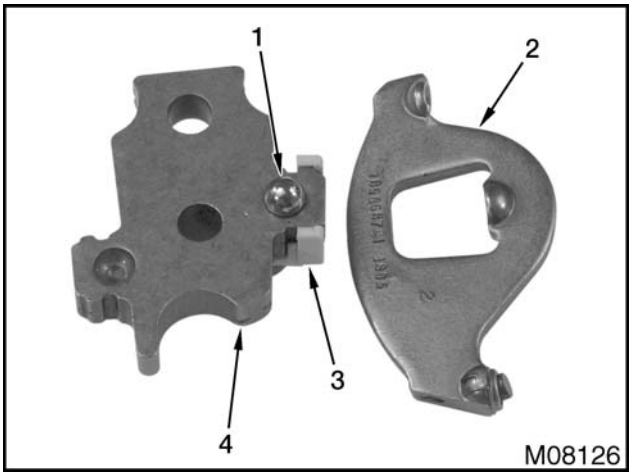

Figure 380 Rocker arm assembly separated (typical)

1. 3/8” pivot ball
2. Rocker arm assembly
3. Rocker arm clip
4. Dual rocker fulcrum plate

3. Remove rocker arm assembly and 3/8” pivot ball.

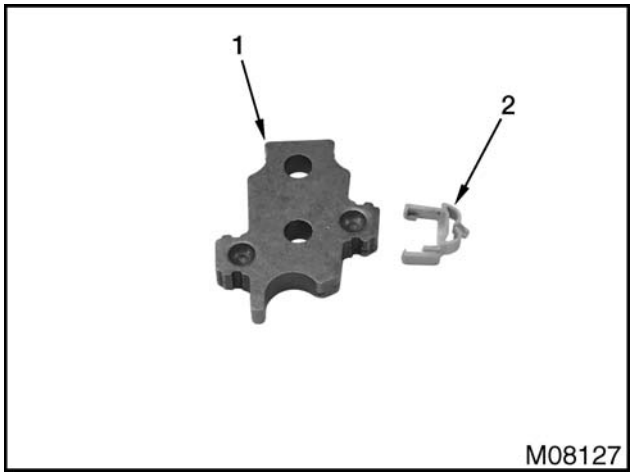

Figure 381 Rocker arm clip removed (typical)

1. Dual rocker fulcrum plate
2. Rocker arm clip

4. Remove and discard rocker arm clip.

Cleaning, Inspection, and Testing

Cylinder Head and Crankcase Components

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

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

1. With valves installed to protect seats, use a scraper and wire brush to remove deposits and gasket material from valve heads and gasket surface.
2. Use a suitable solvent to remove dirt, grease, and deposits from removed parts.
3. Clean all bolt holes. Make sure gasket surfaces, oil return, and coolant passages are clean. After rinsing thoroughly with hot water, dry with filtered compressed air.
4. Clean all bolts (except head bolts) with a suitable solvent and dry thoroughly. New head bolts must be installed.

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

5. Clean crankcase threads with compressed air.

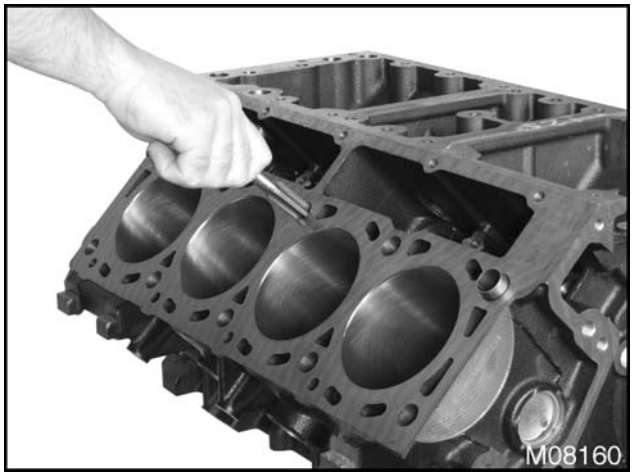

Figure 382 Cylinder Head Bolt Tap ZTSE4744

6. Use Cylinder Head Bolt Tap ZTSE4744 (page 251) to clean each tapped hole in crankcase top deck. Remove debris with filtered compressed air.
7. Thoroughly clean push rods with a suitable solvent. Dry with filtered compressed air.

Cylinder Head Inspection – Valves Installed

NOTE: Inspect cylinder head for thickness, warping, cracks, and valve leakage.

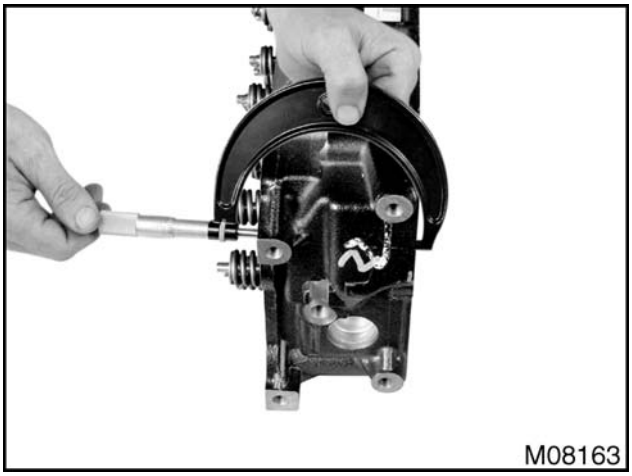

Figure 383 Measurement of cylinder head thickness

1. To determine if cylinder head has been resurfaced previously, use a 3-4 inch micrometer to measure deck thickness of cylinder head at four corner locations. If overall cylinder head thickness (deck-to-deck) specification (page 249) is not met, install new cylinder head.

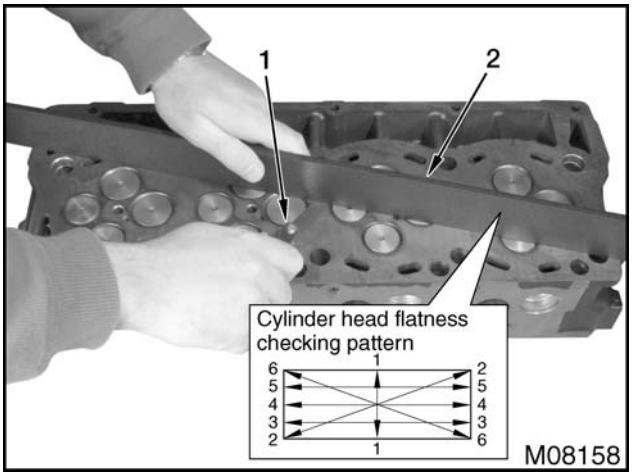

Figure 384 Check for gasket surface flatness

1. Feeler gauge
2. Straightedge

2. Use a straightedge and feeler gauge to check gasket surface of cylinder head for flatness. Check for flatness horizontally, diagonally, and transversely. If specifications (page 249) are not met, install new cylinder head.

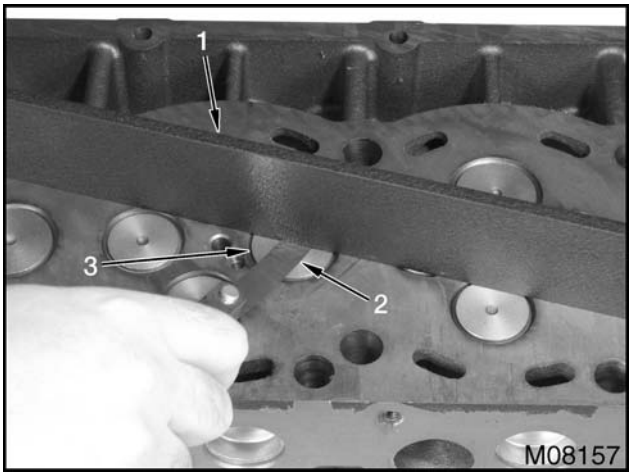

Figure 385 Checking valve head recession

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.
   c. If out of specification (page 249), replace valve. Repeat step 2 with new valve, and if specifications are still not met, replace cylinder head.
4. Use the Dye Penetrant Kit PT-7191 (page 251), to inspect for cracks in cylinder head

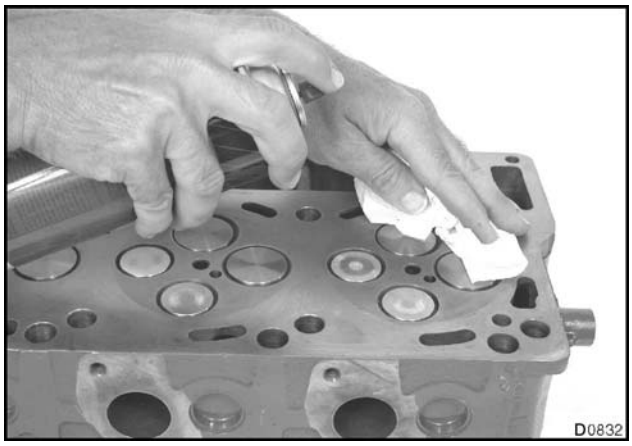

Figure 386 Cleaner sprayed on cylinder head (typical)

5. Spray cleaner on lower deck (gasket surface) of cylinder head and wipe dry.

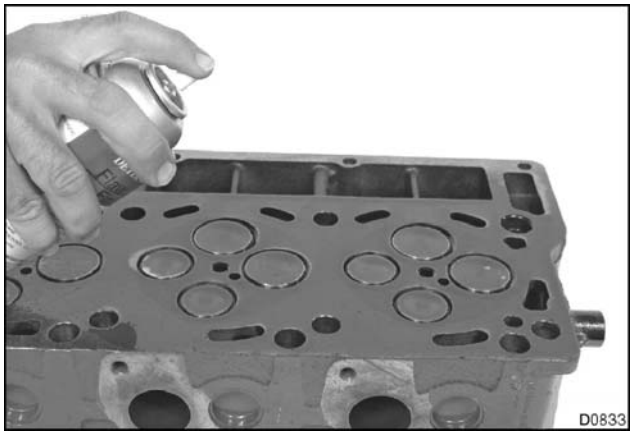

Figure 387 Dye penetrant sprayed on cylinder head (typical)

6. Spray dye penetrant on lower deck (gasket surface) of cylinder head and let dry for 5 to 15 minutes.

7. Wipe dye off cylinder head surface.

   NOTE: Dye will remain in cracks.

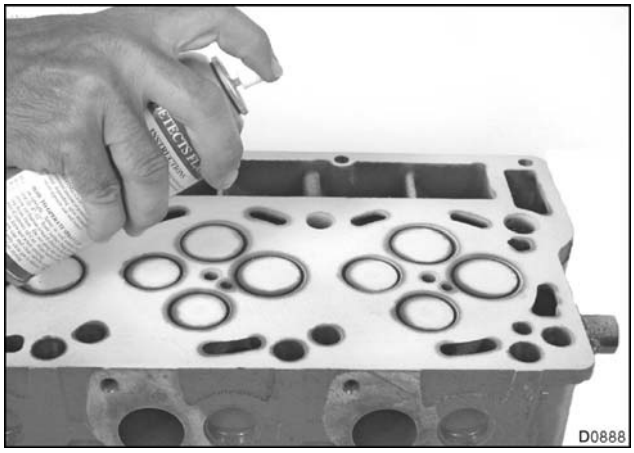

Figure 388 Spraying developer onto cylinder head (typical)

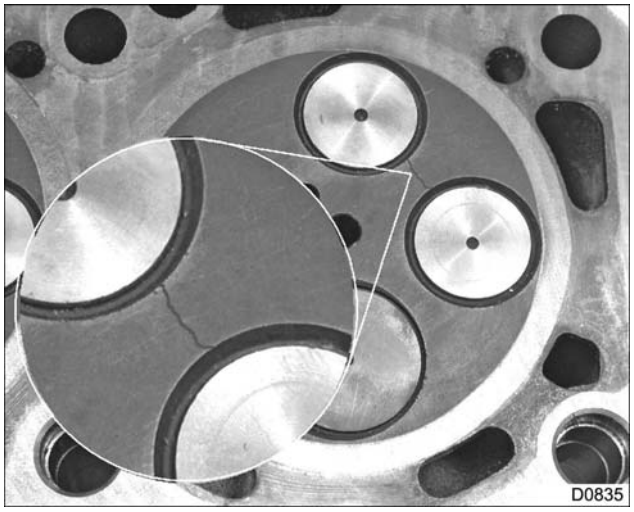

Figure 389 Cylinder head crack between intake and exhaust valves (typical)

8. Spray developer on lower deck (gasket surface) of cylinder head and let dry for 5 to 15 minutes. Cracks show up as purple lines against white developer.

CAUTION: To prevent engine damage, install a new cylinder head if cylinder head is cracked.

9. Position cylinder head on wooden blocks with gasket surface facing down and spray mineral spirits into intake and exhaust ports.

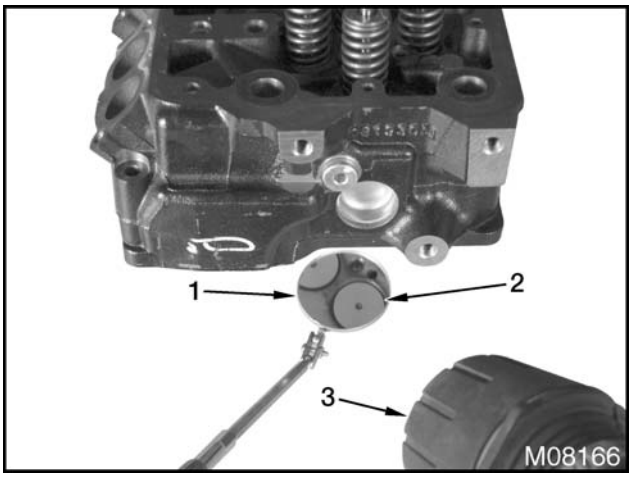

Figure 390 Leak inspection

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

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

NOTE: Valve seats must not leak. Valve replacement is not required if the cylinder head passes the mineral spirits test. If valve seats leak, install new valves. See Valves (page 221).

Cylinder Head Inspection – Valves Removed

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

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

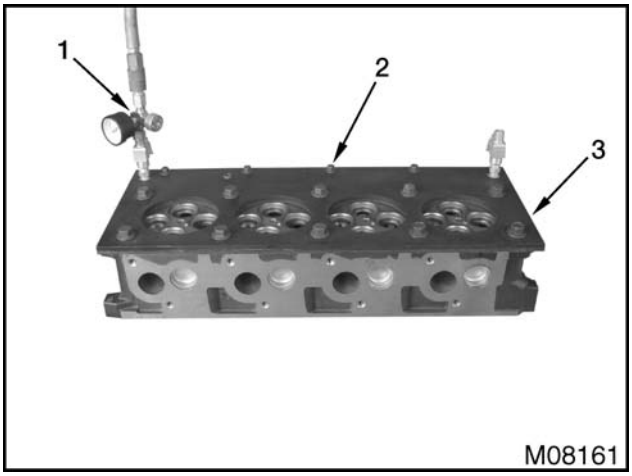

Figure 391 Cylinder Head Pressure Test Plate ZTSE4534

1. Pressure test regulator and gauge assembly
2. Mounting bolts (15)
3. Cylinder Head Pressure Test Plate ZTSE4534

2. Fasten Cylinder Head Pressure Test Plate ZTSE4534 (page 251) with rubber gasket attached to gasket side of cylinder head. Secure plate with ten M14 and five M8 mounting bolts.
3. Install pressure test regulator and gauge assembly to Cylinder Head Pressure Test Plate ZTSE4534 (page 251).
4. Immerse cylinder head in water. Apply air pressure and adjust to 124 to 138 kPa (18 to 20 psi) and inspect for leaks in the following places.
   - Ports
   - Upper cylinder head deck
   - Lower cylinder head deck
   - Nozzle sleeve area
   - Glow plug sleeve area
5. If leaks are observed, install a new cylinder head.
6. Clean all valve guides using a nylon brush, soap and water. Blow out any residue with filtered compressed air.
7. Position an inspection light at the bottom of the valve guide bores and examine the walls for burning or cracking. Replace cylinder head, if necessary.

Figure 392 Measurement of Small Hole Gauge (valve guide ID)

8. Measure each valve guide using a Valve Guide Gauge Tool ZTSE4577 (page 251) and a 0-1 inch micrometer.

NOTE: If valve guide inside diameter exceeds specifications (page 249), install a new cylinder head.

9. Measure the valve guides within 0.64 mm (0.025 in) of each end and 90° from the crankshaft center line. Record the readings in order to determine the valve-to-guide running clearance.
10. Using valve guide inside diameter and valve stem diameter measurements, determine valve stem-to-guide running clearance. See Specifications (page 249). Replace valve if necessary.
11. Clean valve seat area using suitable solvent, before inspection.
12. Inspect exhaust valve seats for burned or cracked conditions. If any of these conditions exist, replace cylinder head.
13. Using a dial caliper, measure valve seat width. See Specifications (page 249). Replace cylinder head if necessary.

Push Rods

1. Inspect push rods for wear and deposits that may restrict oil flow into rocker arm assemblies. Replace push rod if necessary.

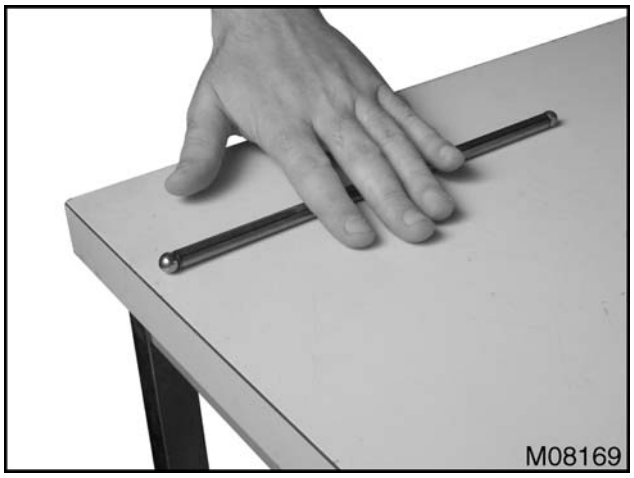

Figure 393 Push rod runout

2. Roll push rod on a flat surface to check runout. If a push rod is not straight, see Specifications (page 249) for runout. If specifications are exceeded, replace push rod.

Valves

1. Use a wire brush to remove all carbon from valve stems and heads.
2. Inspect each valve. Replace valves having burn marks, warping, scuffing, bending or valve tip spalling.
3. Measure each valve stem diameter for wear using a 0-1 inch micrometer. Measure valves at three locations 90° apart. Replace valves with stem diameter less than minimum valve stem diameter specification. See Specifications (page 249).

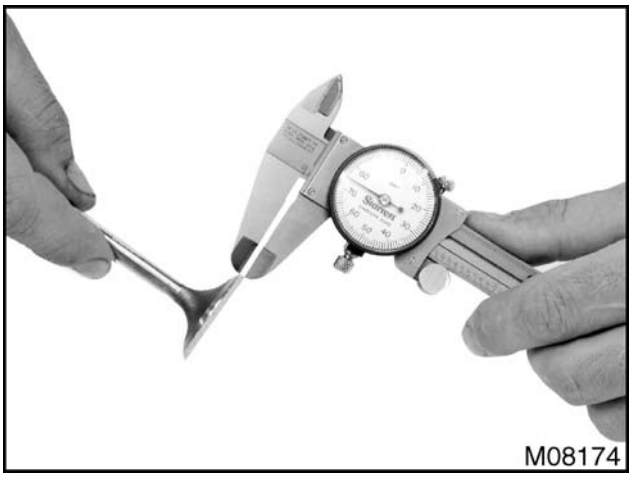

Figure 394 Measurement of valve face margin

CAUTION: To prevent engine damage, maintain a minimum valve face margin across the entire valve face. An insufficient margin will not provide correct heat dissipation, leading to valve warping or breakage. Replace valve if margin is less than specification. See Specifications (page 249).

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

Valve Springs

CAUTION: To prevent engine damage, do not wire brush or grind valve springs. This can cause fatigue cracks and spring failure.

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

Figure 395 Flatness check of valve spring

3. Inspect to verify valve spring ends are flat and square to prevent lateral loads on valve stem. Replace valve springs if necessary.
4. Measure valve spring tension using a Valve Spring Tester ZTSE2241 (page 251).

Figure 396 Measurement of valve spring free length under load

5. Apply correct test loads to each spring and determine whether specified heights are achieved. See Specifications (page 249). Replace valve springs if necessary.

Valve Stem Keys

1. Clean all valve stem keys with a suitable cleaning solvent.
2. Inspect inside and outside of valve stem keys for wear. Replace worn valve stem keys, if necessary.

Fuel Injector Sleeve Bore and Gallery

1. Use Injector Sleeve Brushes ZTSE4751 (page 251) in fuel injector bore to remove deposits and hardened sealant.
2. Remove fuel rail plug assembly.

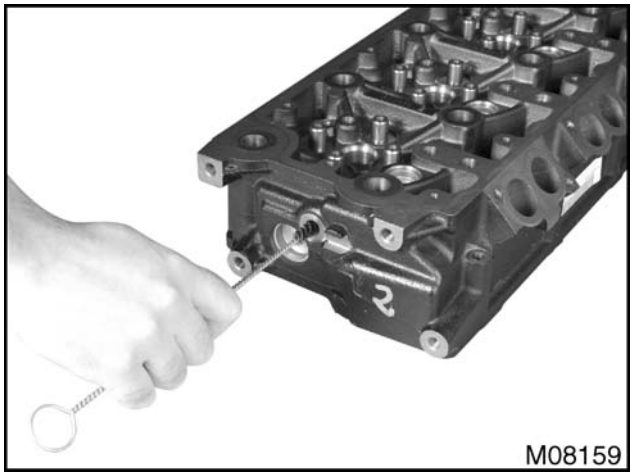

Figure 397 Fuel gallery

3. Clean fuel gallery with Fuel Gallery Cleaning Brush ZTSE4541 (page 251).

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

4. Use filtered compressed air to clean out debris from fuel gallery port.
5. Install a new seal on fuel rail plug.
6. Install fuel rail plug assembly and tighten to special torque (page 250).

Glow Plug Sleeve Bore

Clean glow plug bore with Glow Plug Sleeve Seat Wire Brush ZTSE4589 (page 251).

Dual Rocker Fulcrums

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

1. Clean parts with a suitable solvent. Use filtered compressed air to dry parts.
2. Inspect each rocker arm pivot foot for excessive wear, and corresponding valve bridge for pitting or scuffing. Replace rocker arm assemblies and valve bridges, if necessary.
3. Inspect each 3/8” pivot ball and rocker arm socket for scuffing. Replace 3/8” pivot ball and rocker arm, if necessary.
4. Inspect fulcrum plate ball socket for excessive wear. Inspect bolts for thread damage. Replace worn components, if necessary.

Installation

Dual Fulcrum Plate Assemblies

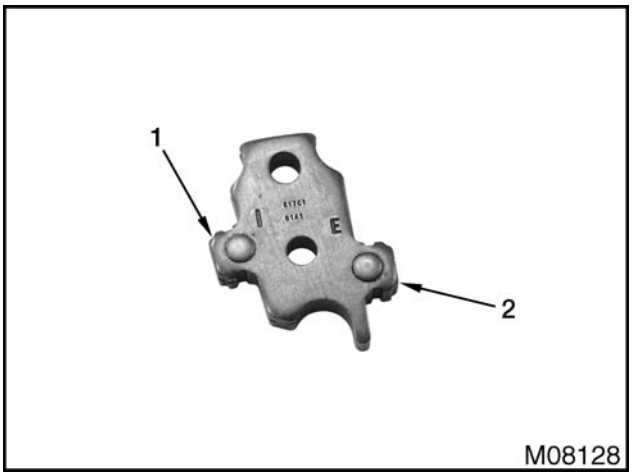

Figure 398 Dual rocker fulcrum plate (typical)

1. Intake end
2. Exhaust end

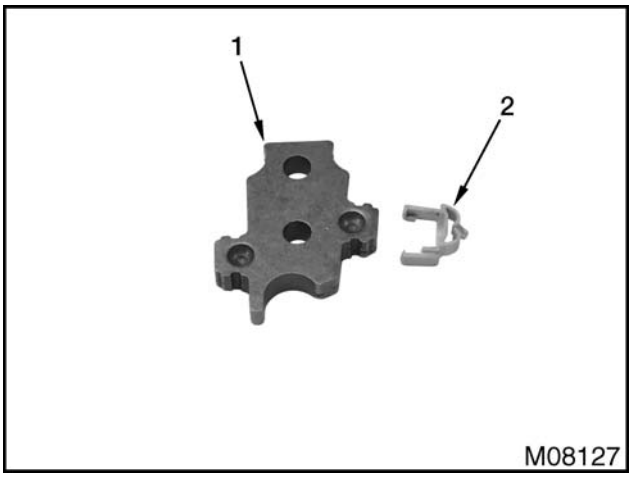

Figure 399 Rocker arm clip (typical)

1. Dual rocker fulcrum plate
2. Rocker arm clip

1. Install a new rocker arm clip on both sides of dual rocker fulcrum plate.

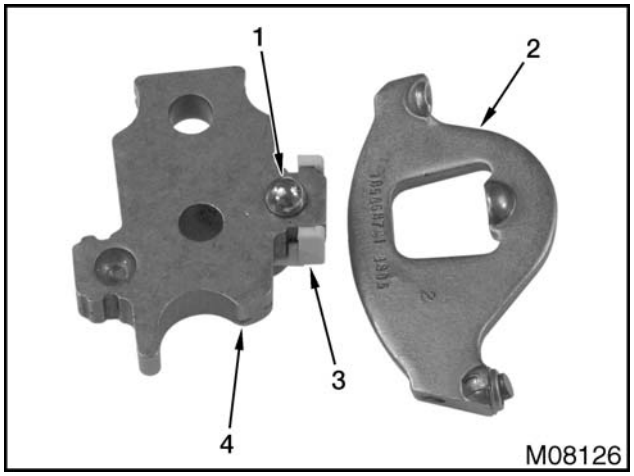

Figure 400 Rocker arm assembly installation (typical)

1. 3/8” pivot ball
2. Rocker arm assembly
3. Rocker arm clip
4. Dual rocker fulcrum plate

2. Apply a small amount of lithium grease (page 251) to dual rocker fulcrum plate pockets.
3. Insert 3/8” pivot ball in dual rocker fulcrum plate pockets.

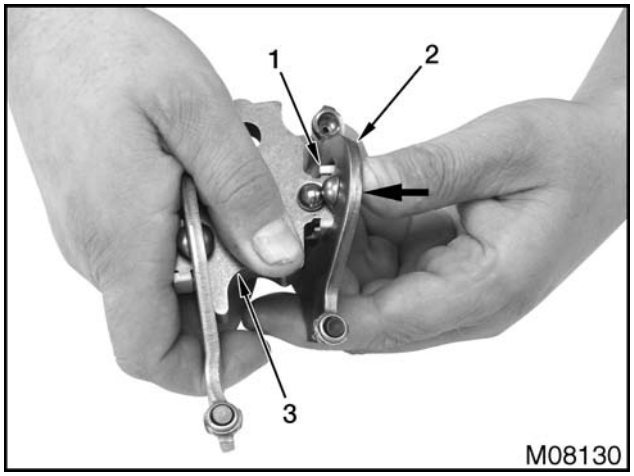

Figure 401 Installation of rocker arm (typical)

1. Rocker arm clip
2. Rocker arm assembly
3. Dual rocker fulcrum plate

4. Position lower part of rocker arm assembly under rocker arm clip and push it upward. Use thumb to push upper part of rocker arm assembly over 3/8" pivot ball.
5. Check for freedom of movement of rocker arm on dual rocker fulcrum plate.
6. Repeat steps 1–4 for the other rocker arm on the dual rocker fulcrum plate.

Glow Plug Sleeves

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

NOTE: Make sure the glow plug recess was cleaned out with the Glow Plug Sleeve Seat Wire Brush ZTSE4589 (page 251), rinsed with a suitable cleaning solution, and dried with compressed air.

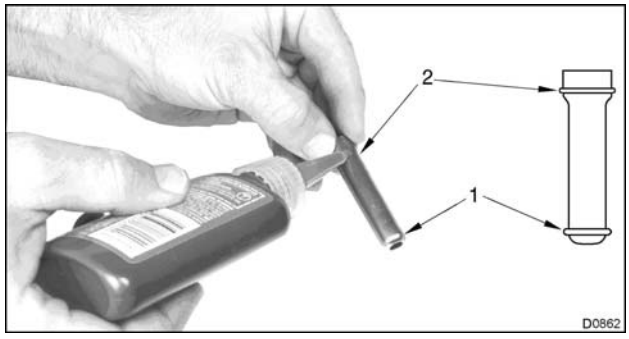

Figure 402 Application of Loctite® 620 Retaining Compound to glow plug sleeve

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

1. Apply Loctite® 620 Retaining Compound (page 251) to the wall and upper wall on glow plug sleeve.

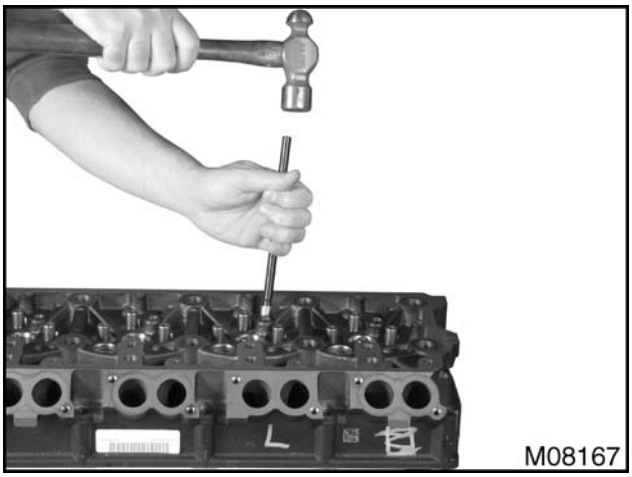

Figure 403 Glow Plug Sleeve Installer ZTSE4532

2. Install glow plug sleeve in cylinder head with Glow Plug Sleeve Installer ZTSE4532 (page 251). Continue to tap the Glow Plug Sleeve Installer until the glow plug sleeve bottoms out in the recess.
3. Clean glow plug sleeve with Glow Plug Sleeve Brush (nylon) ZTSE4533 (page 251) and solvent. Make sure liquid gasket 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

that the installation tool is not causing such damage. Use a different installation tool if necessary.

Fuel Injector Sleeves

NOTE: Verify injector bore is completely clean and dry.

1. Place new fuel injector sleeve on Injector Sleeve Installer ZTSE4733 (page 251).

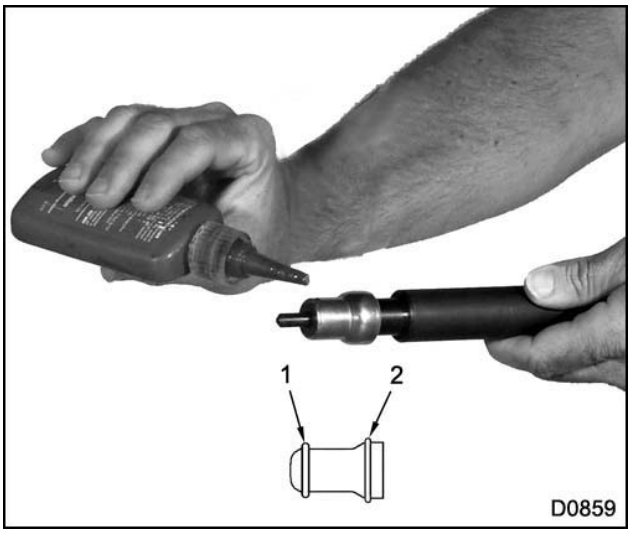

Figure 404 Application of Loctite® 620 Retaining Compound to fuel injector sleeve

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

2. Apply Loctite® 620 Retaining Compound (page 251) to fuel injector sleeve.
3. Center fuel injector sleeve into injector bore.

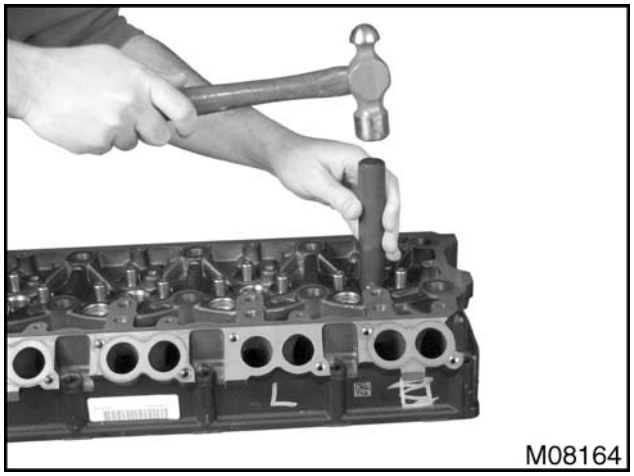

Figure 405 Installation of fuel injector sleeve into injector bore

4. Use a hammer to drive Injector Sleeve Installer ZTSE4733 (page 251) with fuel injector sleeve in fuel injector bore until the sleeve bottoms. If any liquid gasket gets inside injector sleeve, it must be cleaned out before it hardens.
5. Inspect the inside surface of the installed fuel injector sleeve. If nicks and scratches are evident, replace the fuel injector sleeve again. Make sure that the installation tool is not causing such damage. Use a different installation tool if necessary.

CAUTION: To prevent engine damage, insert a clean paper towel inside injector sleeve to keep foreign material out.

6. Cover injector sleeve.

Valves

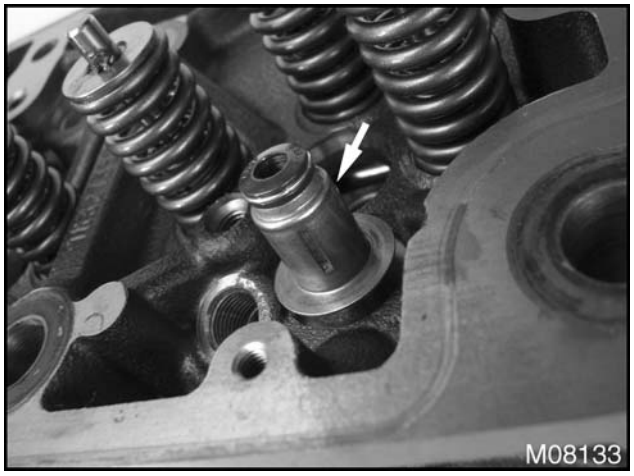

Figure 406 Valve seal assembly (typical)

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

1. Lubricate inside of new valve seal assembly with clean engine oil and install on valve guide.
2. Lubricate valve stem with clean engine oil and insert valve in cylinder head.
3. Install valve spring over valve seal.
4. Install valve spring retainer on top of valve spring.

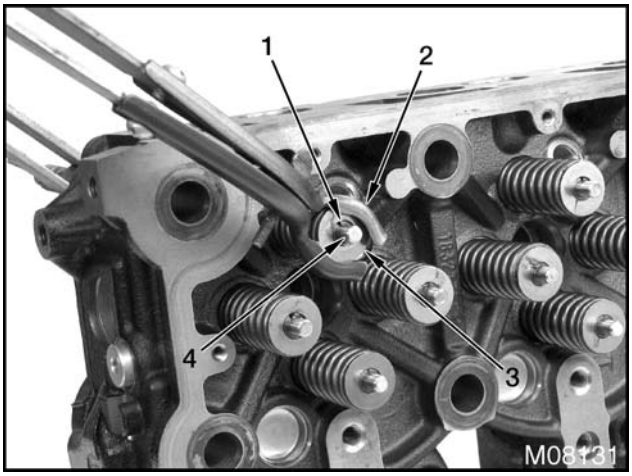

Figure 407 Valve spring compression (typical)

1. Valve stem key (2)
2. C Type Valve Spring Compressor ZTSE1846
3. Valve spring retainer
4. Valve

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

5. Compress valve spring with C Type Valve Spring Compressor ZTSE1846 (page 251), install two valve stem keys, and release spring compressor.
6. After valve replacement, measure valve head recession relative to deck to confirm reconditioning. See Specifications (page 249).

Roller Hydraulic Cam Followers

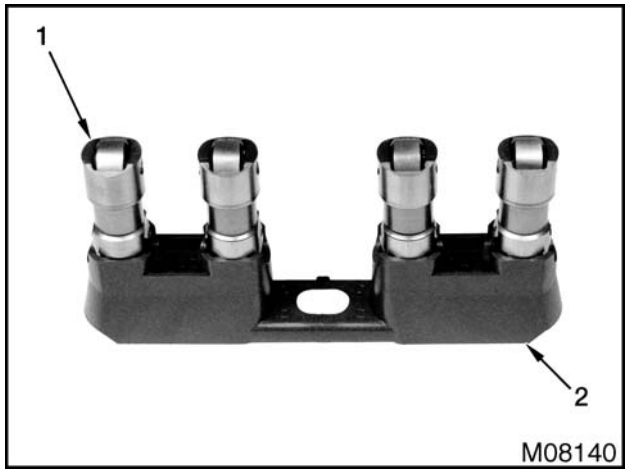

Figure 408 Roller hydraulic cam followers (typical)

1. Roller hydraulic cam follower (4)
2. Roller follower guide

CAUTION: To prevent engine damage, keep cam followers and push rods in the order removed and install in original order.

NOTE: Place rollers hydraulic cam followers in roller follower guides with the lubrication holes oriented as noted during removal.

1. Lubricate and place each roller hydraulic cam follower in its respective roller follower guide.

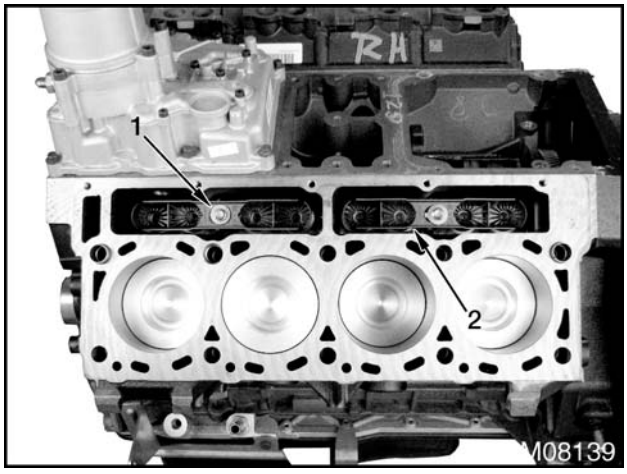

Figure 409 Cam follower and guide assemblies (typical)

1. Lifter guide bolt with washer assembly (2)
2. Cam follower and guide assembly (2)

2. Lubricate roller hydraulic cam followers with clean engine oil and install cam followers and guide assemblies in correct location.
3. Install two lifter guide bolt with washer assemblies. Tighten bolts to special torque (page 250).

Cylinder Heads

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

1. For left cylinder head, install lifting eye and two flat countersunk screws. Tighten screws to special torque (page 250).
2. For right cylinder head, install lifting eye and two M10 x 25 bolts. Tighten bolts to special torque (page 250).

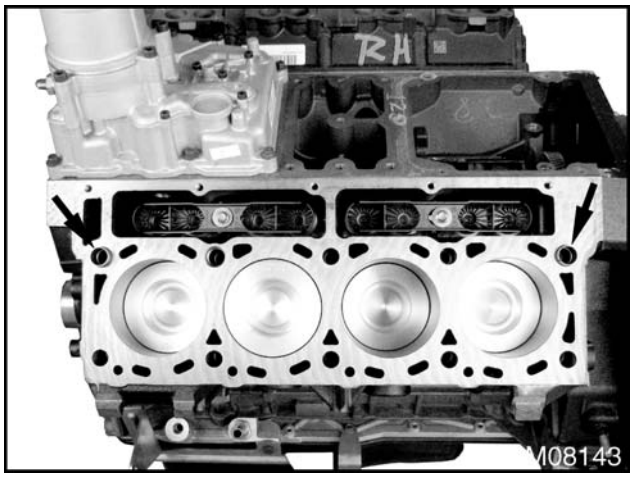

Figure 410 Cylinder head spring dowel pins in crankcase (typical)

3. Install two spring dowel pins in upper crankcase assembly.

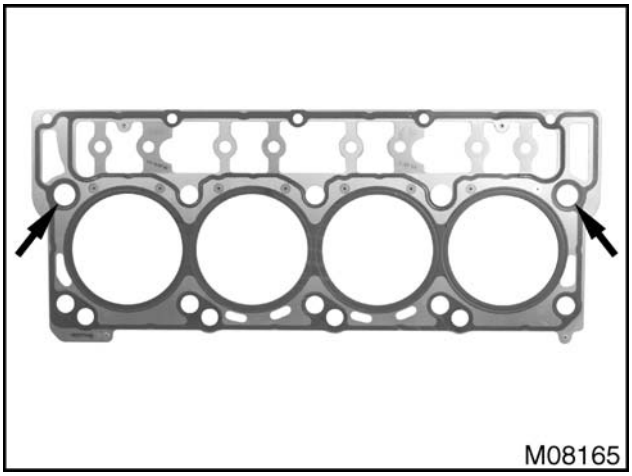

Figure 411 Clearance holes for spring dowel pins (typical)

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

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

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

CAUTION: To prevent engine damage, install a new cylinder head gasket with part number facing up.

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

4. Align a new cylinder head gasket with spring dowel pins and press to install.

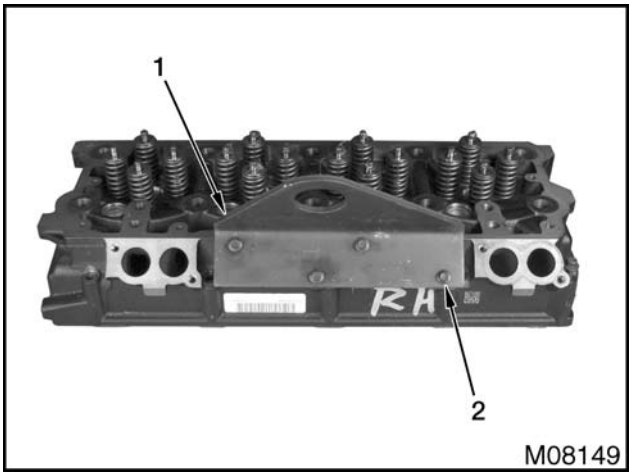

Figure 412 Installation of cylinder head lifting bracket (typical)

1. Cylinder Head Lifting Bracket ZTSE4535
2. Lifting bracket mounting bolt (4)

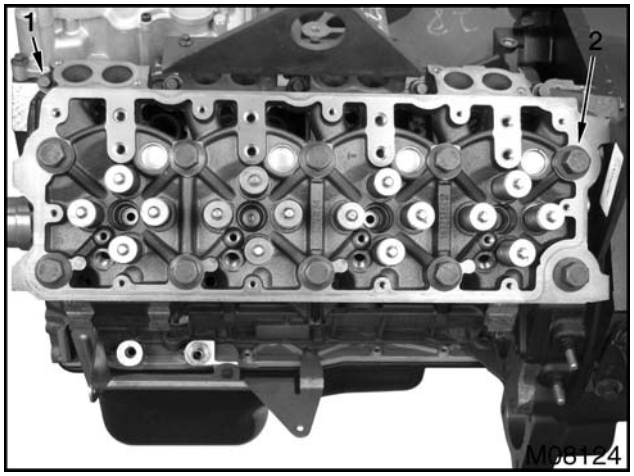

Figure 413 Cylinder head bolts (typical)

1. M8 x 70 bolt (5)
2. Cylinder head bolt (10)

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

5. Install Cylinder Head Lifting Bracket ZTSE4535 (page 251) and four bolts on center of cylinder head (if removed). Tighten lifting bracket mounting bolts.

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

6. Attach lifting hoist hook or lifting sling to lifting bracket. Raise cylinder head and align with dowel sleeves previously installed in crankcase.
7. Lower cylinder head on crankcase.

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

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

8. Install and finger tighten 10 cylinder head bolts and five M8 x 70 bolts.
9. Remove four lifting bracket bolts and cylinder head lifting bracket.

CAUTION: To prevent engine damage, use only permanent ink markers to identify bolt torque orientation.

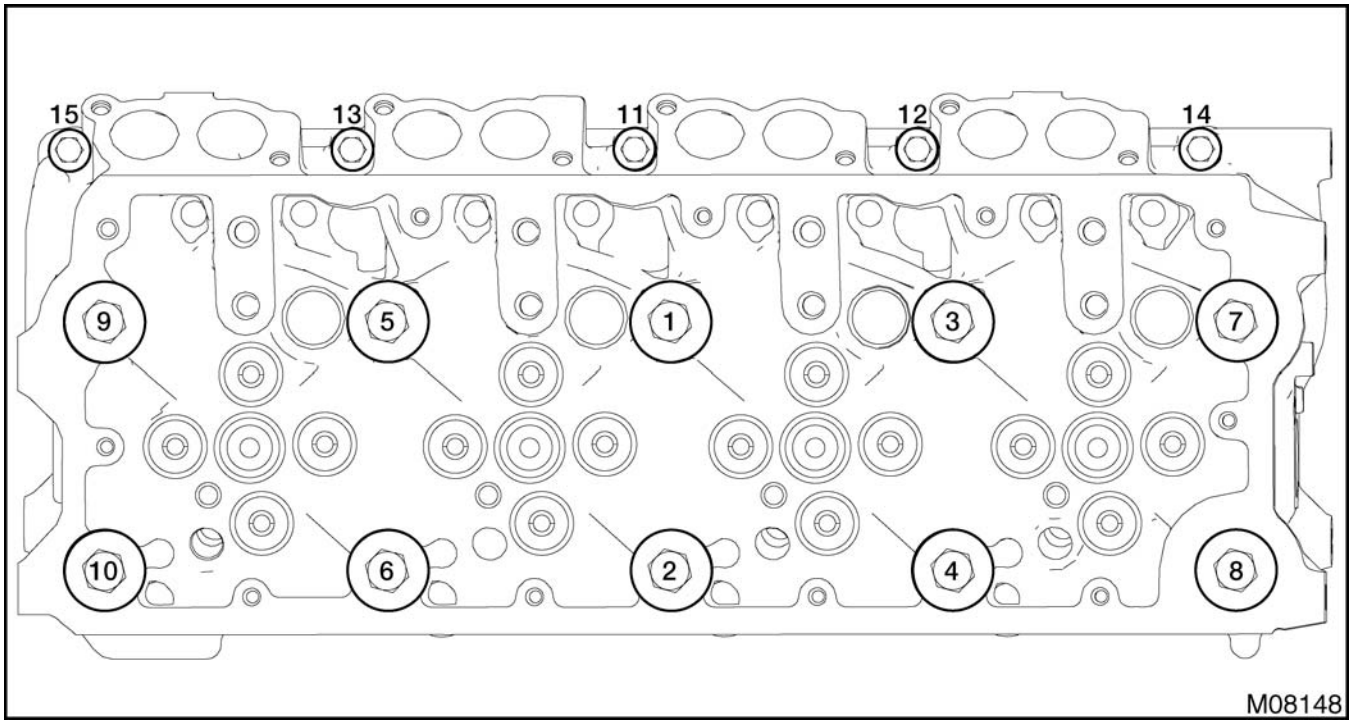

Figure 414 Cylinder head bolts tightening sequence

NOTE: For proper cylinder head surface seating and sealing, follow the correct tightening sequence.

10. Tighten the cylinder head bolts according to the following steps:
    1. Tighten cylinder head bolts numbered 1 through 10 to 95 N·m (70 lbf·ft) in numerical sequence.
    2. Loosen cylinder head bolts numbered 1 through 10 in numerical sequence.
    3. Tighten cylinder head bolts numbered 1 through 10 to 156 N·m (115 lbf·ft) in numerical sequence.
    4. Rotate cylinder head bolts numbered 1 through 10 an additional 90° (1/4 turn) clockwise in numerical sequence.
    5. Rotate cylinder head bolts numbered 1 through 10 another 90° (1/4 turn) clockwise in numerical sequence.
    6. Tighten M8 x 70 cylinder head bolts numbered 11 through 15 to 24 N·m (18 lbf·ft).
    7. Tighten M8 x 70 cylinder head bolts numbered 11 through 15 to 31 N·m (23 lbf·ft).

Rocker Arm Supports, Push Rods, and Valve Bridges

1. Apply lithium grease (page 251) to valve stem tips and to valve bridge pockets.

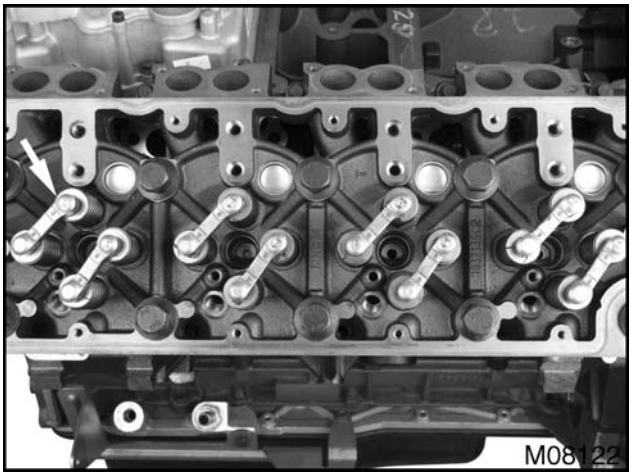

Figure 415 Valve bridge (typical)

2. Place each of the previously marked valve bridges on their respective valve stems.

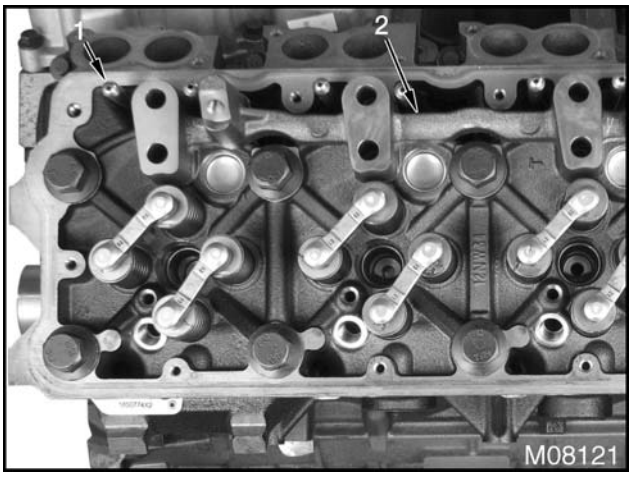

Figure 416 Push rod assemblies and rocker arm support (typical)

1. Push rod assembly (8)
2. Rocker arm support

3. Install rocker arm support.

CAUTION: To prevent engine damage, keep cam followers and push rods in the order removed and install in original order.

CAUTION: To prevent engine damage, seat push rods in the hydraulic roller follower sockets.

4. Apply clean engine oil to end of each push rod and install to original locations with the copper finish end on top.

NOTE: Rotate crankshaft and observe the intake push rod at number 3 cylinder. Cylinder number 1 is in firing position when intake push rod at cylinder number 3 indicates cam lift, and the crankshaft damper dowel pin is at the 10:30 position.

5. Position crankshaft so that cylinder number 1 is at Top Dead Center (TDC) and in firing position.

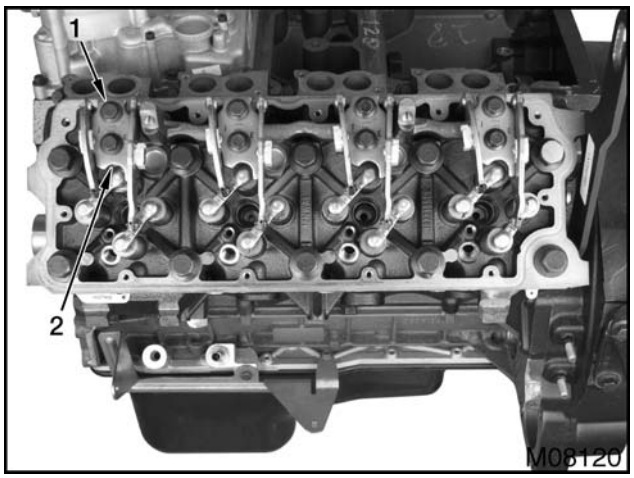

Figure 417 Dual rocker fulcrum plates (typical)

1. M10 x 70 bolt (8)
2. Dual fulcrum plate assembly (4)

CAUTION: To prevent engine damage, make sure push rods have seated in the rocker arm pocket.

6. Install dual fulcrum plate assemblies for cylinder numbers 1, 2, 7, and 8.
7. Install and tighten M10 x 70 bolts for cylinder numbers 1, 2, 7, and 8 as follows:
    1. Hand tighten all bolts.
    2. Make sure that pivot foot is centered on valve bridge.
    3. Tighten inboard (upper) bolts to 61 N·m (45 lbf·ft).
    4. Tighten outboard (lower) bolts to 61 N·m (45 lbf·ft).

5. Make sure that pivot foot is centered on valve bridge. If pivot foot is not centered on valve bridge, remove and reinstall dual fulcrum plate assembly in question.

NOTE: Rotate crankshaft and observe the intake push rod at number 8 cylinder. Cylinder number 4 is in firing position when intake push rod at cylinder number 8 indicates cam lift, and the crankshaft damper dowel pin is at the 10:30 position.

8. Rotate crankshaft 360° (full turn) so that cylinder number 4 is in firing position.

CAUTION: To prevent engine damage, make sure push rods have seated in the rocker arm pocket.

9. Install dual fulcrum plate assemblies for cylinder numbers 3, 4, 5, and 6.
10. Install and tighten M10 x 70 bolts for cylinder numbers 3, 4, 5, and 6 as follows:
    1. Hand tighten all bolts.
    2. Make sure that pivot foot is centered on valve bridge.
    3. Tighten inboard (upper) bolts to 61 N·m (45 lbf·ft).
    4. Tighten outboard (lower) bolts to 61 N·m (45 lbf·ft).
    5. Make sure that pivot foot is centered on valve bridge. If pivot foot is not centered on valve bridge, remove and reinstall dual fulcrum plate assembly in question.

Valve Cover Base

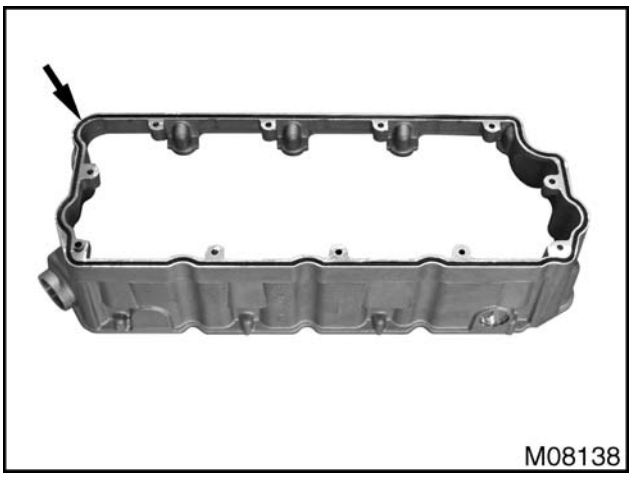

Figure 418 Valve cover base gasket (typical)

1. Install a new valve cover base gasket.

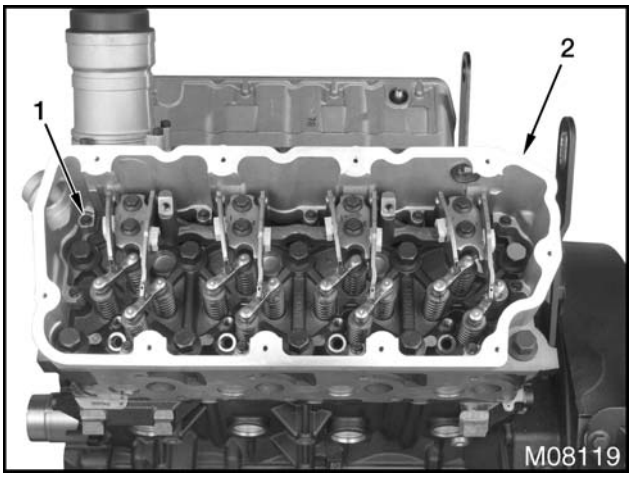

Figure 419 Valve cover base assembly (typical)

1. M6 x 30 bolt (11)
2. Valve cover base assembly

2. Install valve cover base assembly and 11 M6 x 30 bolts. Tighten bolts to special torque (page 250).

Glow Plugs

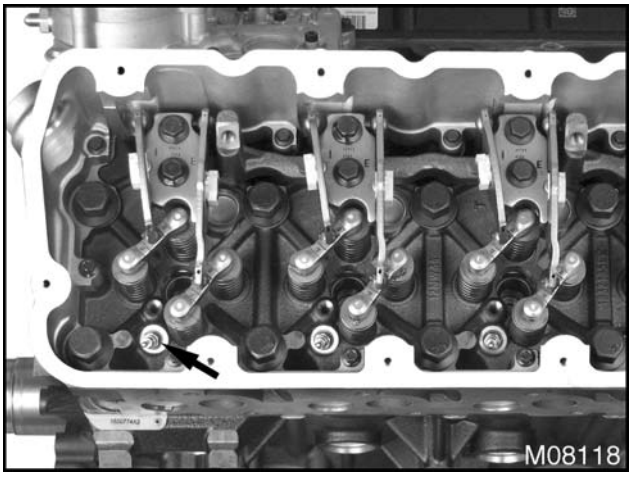

Figure 420 Glow plugs (typical)

Install four glow plugs. Tighten glow plugs to special torque (page 250).

Fuel Injector and Rail Assemblies

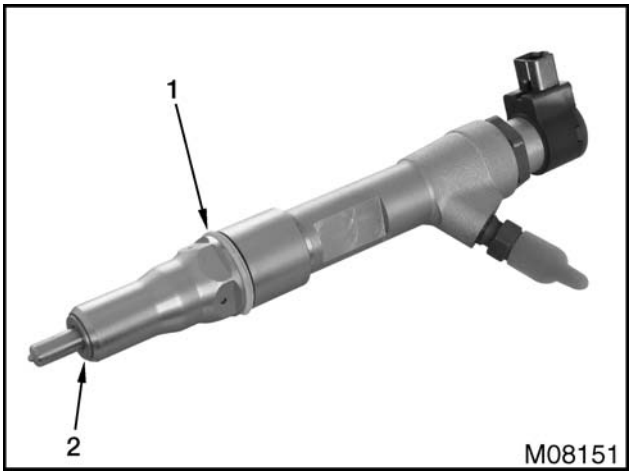

Figure 421 Fuel injector seal and combustion gasket (typical)

1. Fuel injector seal
2. Combustion gasket

CAUTION: To prevent engine damage, install new fuel injector seal and combustion gasket if a fuel injector is removed.

NOTE: Make sure to install new combustion gasket oriented as noted during removal.

1. Install a new combustion gasket onto injector tip.
2. To seat gasket, push on gasket with a deep socket.
3. Remove and discard old fuel injector seal.
4. Install a new fuel injector seal. Lubricate fuel injector seal with clean engine oil.

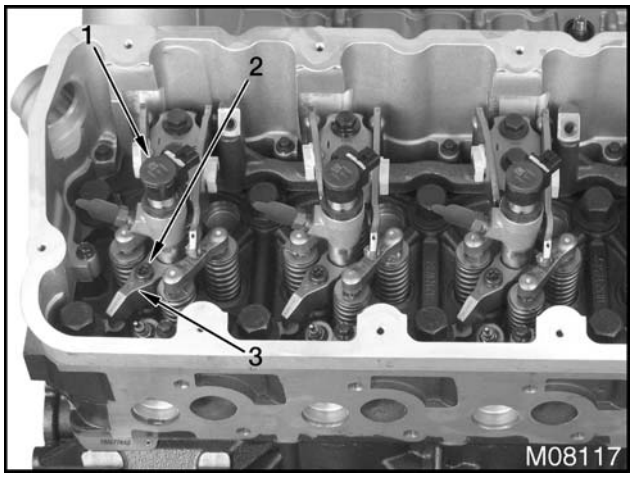

Figure 422 Fuel injector assembly (typical)

1. Fuel injector assembly (4)
2. Injector clamp bolt (4)
3. Injector hold down clamp (4)

CAUTION: To prevent engine damage, do not use power tools.

5. Install fuel injector assembly by lowering fuel injector and injector hold down clamp assembly as one unit into injector bore.

NOTE: Injectors must be fully seated, but moveable, for installation of fuel rail to injector tube assemblies.

6. Hand start clamp bolts. Pre-tighten injector clamp bolts to 2 N·m (18 lbf·in).
7. Apply a water based rubber lubricant, such as P-80® Rubber Lubricant or equivalent (page 251), to outer and inner diameters of fuel supply line seal.

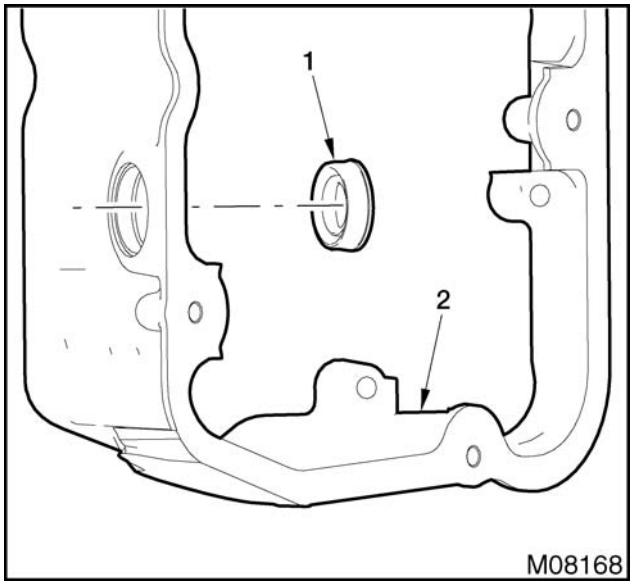

Figure 423 Fuel supply line seal installation (typical)

1. Fuel supply line seal
2. Valve cover base

8. Install a new fuel supply line seal by pressing it with a proper size socket toward the outside of the valve cover base.

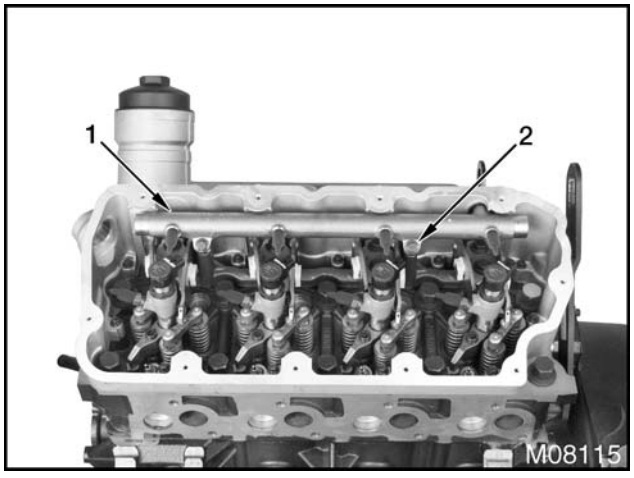

Figure 424 Rail assembly (typical)

1. Rail assembly
2. M8 x 30 bolt (2)

NOTE: Rail assembly must be fully seated but moveable for installation of fuel rail to injector tube assemblies.

9. Install rail assembly and two M8 x 30 bolts. Hand tighten bolts.
10. Remove all Fuel System Caps ZTSE4710 (page 251) from fuel rail and fuel injector assemblies.

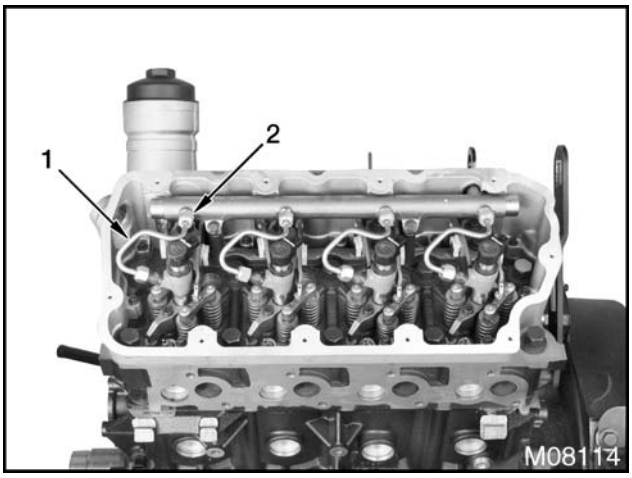

Figure 425 Fuel rail to injector tube assemblies (typical)

1. Fuel rail to injector tube assembly (4)
2. Tube nut (8)

WARNING: To prevent personal injury or death, whenever any fuel line (tubing) in the high-pressure fuel system is removed, it must be replaced with new.

11. Position four new fuel rail to injector tube assemblies between fuel injector assemblies and rail assembly.

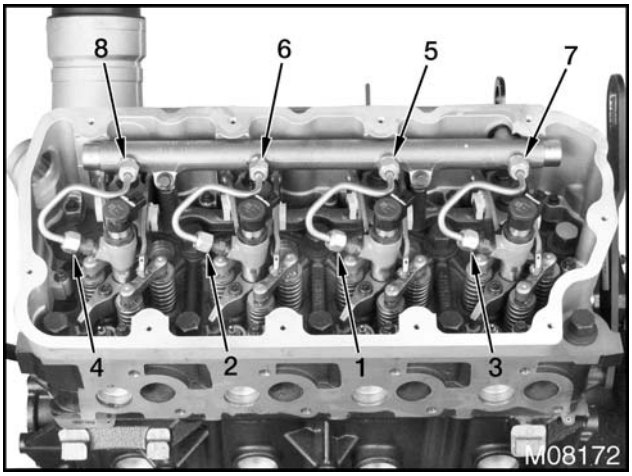

Figure 426 Fuel rail to injector tube assemblies tightening sequence (typical)

NOTE: Hold fuel rail to injector tube assemblies while hand tightening nuts to assure proper assembly of joints.

NOTE: When using a crowfoot extension make sure to adjust the torque settings as necessary to compensate for any length added to the torque wrench. See Appendix B - Torques (page 370).

12. Fully hand start and seat nuts onto mating connections of all fuel tubes, then pre-tighten with a crowfoot torque wrench following sequence shown in (Figure 426) to 2 N·m (18 lbf·in).
13. Tighten injector clamp bolts to 38 N·m (28 lbf·ft).
14. Tighten two M8 x 30 rail assembly bolts to 31 N·m (23 lbf·ft).
15. Using a crowfoot torque wrench and a second wrench to hold the fuel injector fittings, continue to tighten fuel rail to injector tube assembly nuts following sequence shown in (Figure 426). Tighten four nuts on the fuel injector assemblies first, then four nuts on the rail assembly as follows:
    a. Tighten nuts to 16 N·m (142 lbf·in).
    b. Tighten nuts an additional 60°.
16. Install Under Valve Cover (UVC) harness (page 66).

Valve Covers and Related Components

Right Valve Cover

1. Install a new valve cover gasket.

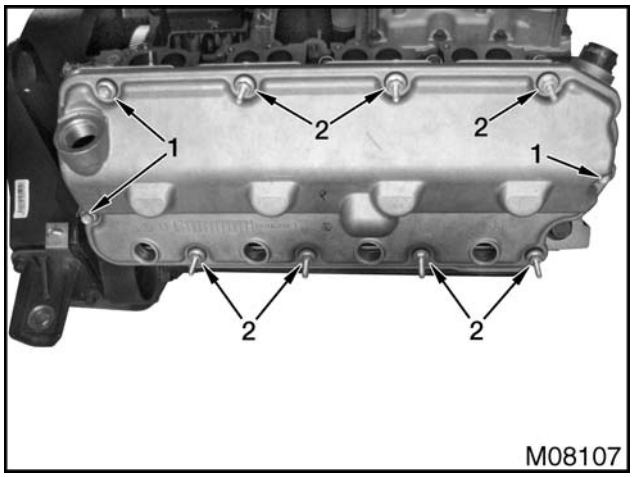

Figure 427 Right valve cover bolt and stud bolt assemblies

1. Valve cover bolt assembly (3)
2. Valve cover stud bolt assembly (7)

2. Position right valve cover on valve cover base assembly.

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

3. Install three valve cover bolt assemblies and seven valve cover stud bolt assemblies. Tighten bolts and stud bolts to special torque (page 250).

Left Valve Cover

1. Install a new valve cover gasket.

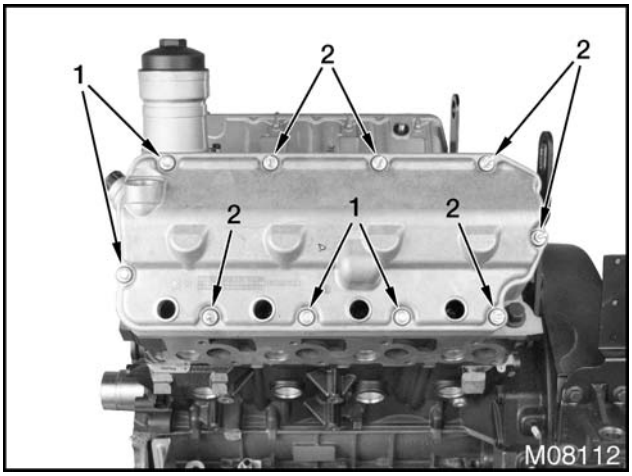

Figure 428 Left valve cover bolt and stud bolt assemblies

1. Valve cover bolt assembly (4)
2. Valve cover stud bolt assembly (6)

2. Position left valve cover on valve cover base.

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

3. Install four valve cover bolt assemblies and six valve cover stud bolt assemblies. Tighten bolts and stud bolts to special torque (page 250).

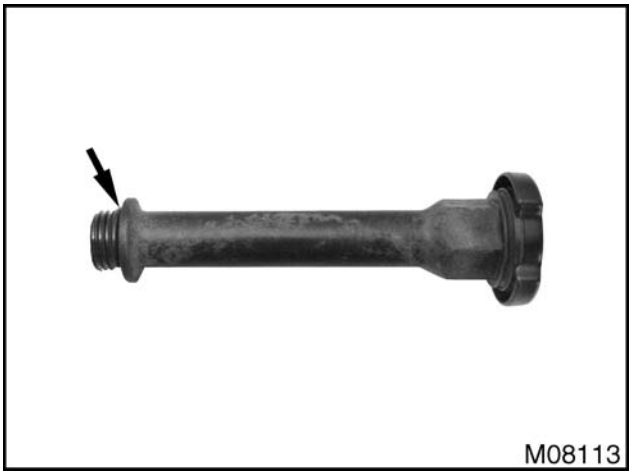

Figure 429 Oil fill extension O-ring seal

4. Install a new oil fill extension O-ring seal. Lubricate O-ring seal with clean engine oil.

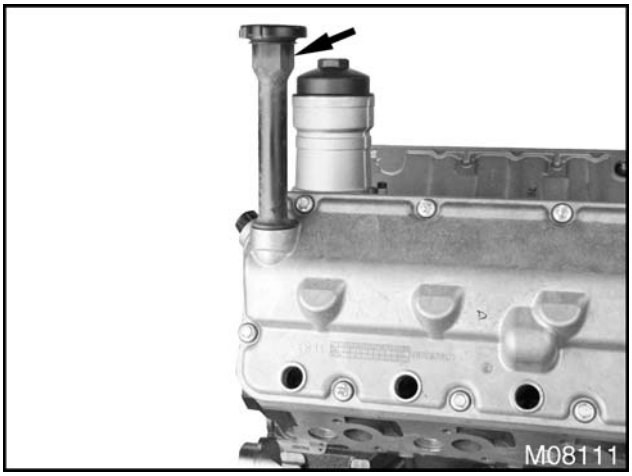

Figure 430 Oil fill extension

5. Install oil fill extension. Tighten to special torque (page 250).

Breather Assembly and Components

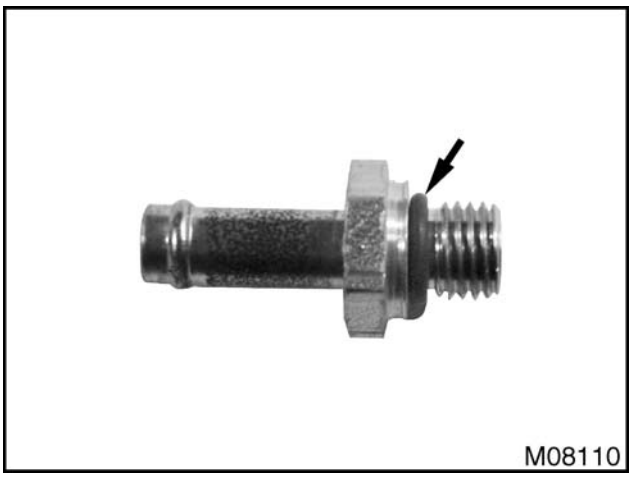

Figure 431 M12 fitting O-ring seal

1. Install a new breather oil drain assembly to crankcase M12 fitting O-ring seal.

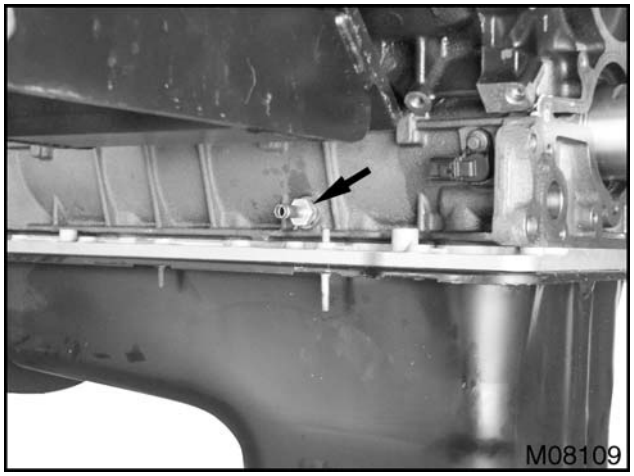

Figure 432 Breather oil drain assembly to crankcase M12 fitting

2. Install M12 fitting. Tighten fitting to special torque (page 250).

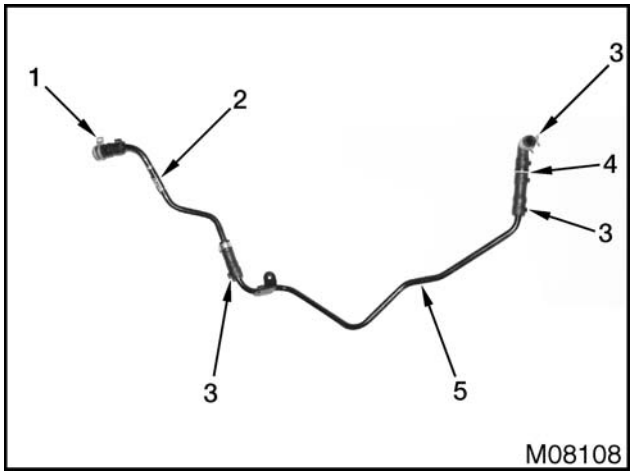

Figure 433 Breather oil drain assembly components

1. 1/2” preload clamp
2. Nylon tube assembly
3. 3/8” preload clamp (3)
4. Check valve assembly
5. Steel tube

3. Connect steel tube to 3/8” hose on nylon tube assembly and secure with a 3/8” preload clamp.
4. Connect steel tube to check valve assembly and secure with a 3/8” preload clamp.

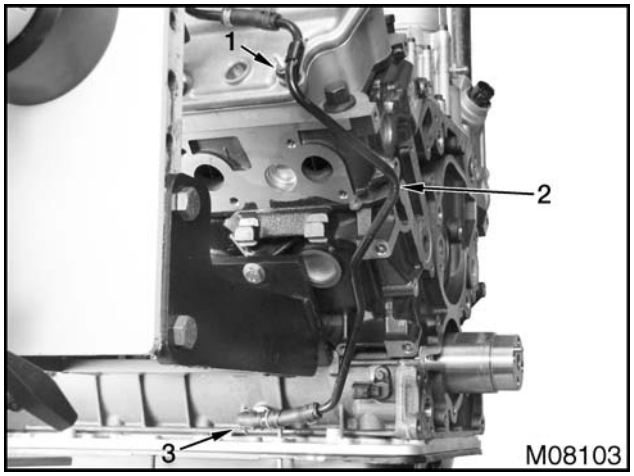

Figure 434 Breather oil drain assembly

1. M6 nut
2. Breather oil drain assembly
3. 3/8” preload clamp

5. Connect breather oil drain assembly to M12 fitting and secure with clamp.
6. Install M6 nut at breather oil drain assembly clamp, and tighten to standard torque (page 369).

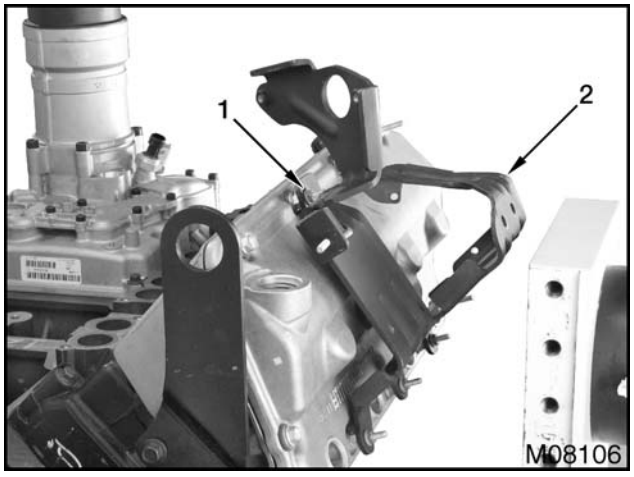

Figure 435 Breather support

1. M6 nut (4)
2. Breather support

7. Install breather support and four M6 nuts. Tighten nuts to special torque (page 250).

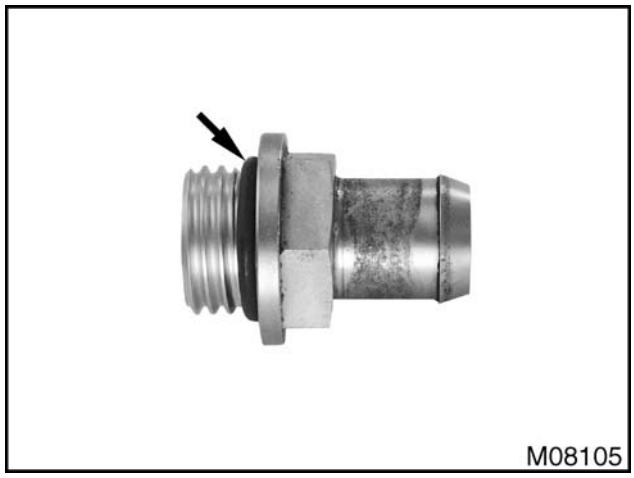

Figure 436 Breather inlet adapter O-ring seal

8. Install a new O-ring seal on breather inlet adapter. Lubricate O-ring seal with clean engine oil.

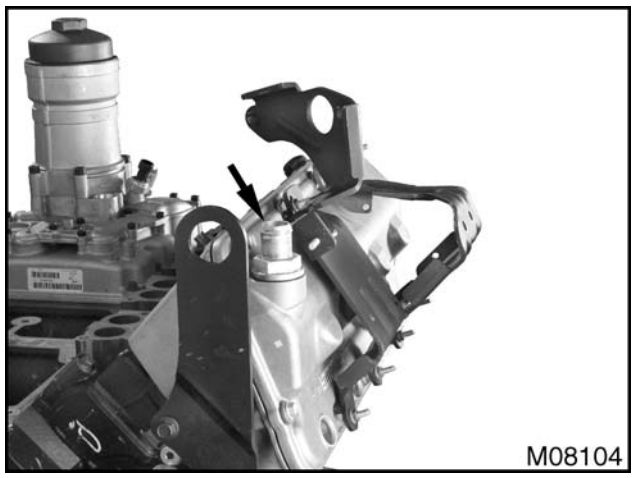

Figure 437 Breather inlet adapter

9. Install breather inlet adapter. Tighten to special torque (page 250).

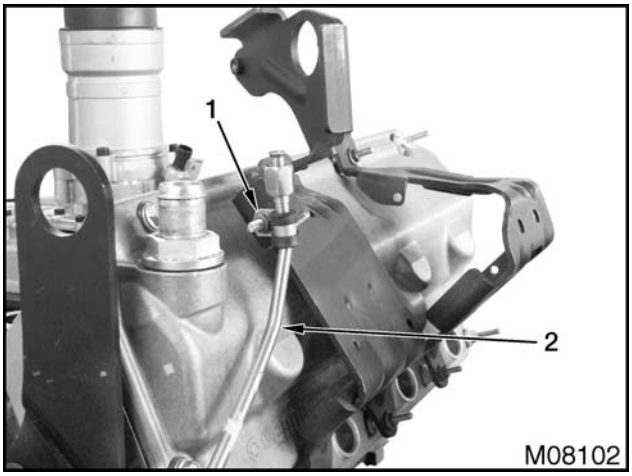

Figure 438 Exhaust Back Pressure (EBP) tube assembly

1. M6 nut
2. EBP tube assembly

10. Install EBP tube assembly and M6 nut. Tighten nut to special torque (page 250).

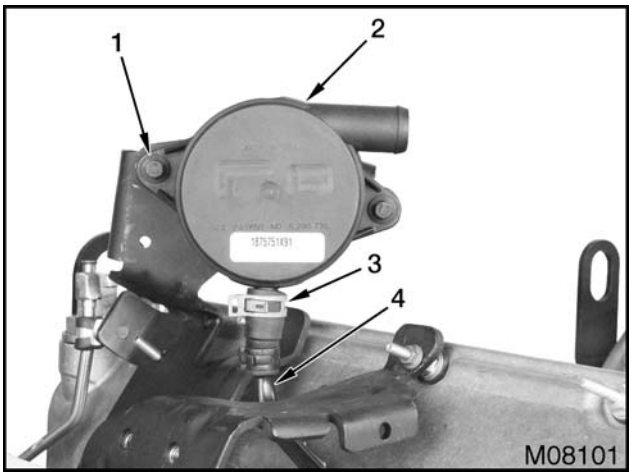

Figure 439 Breather assembly bolts

1. M8 x 35 bolt (2)
2. Breather assembly
3. 1/2” preload clamp
4. Breather oil drain assembly

11. Connect breather assembly to breather oil drain assembly and secure with clamp.
12. Install two M8 x 35 bolts and tighten to standard torque (page 369).

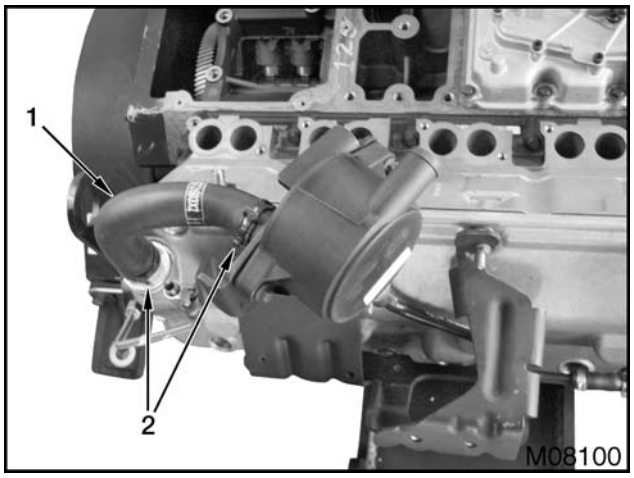

Figure 440 Breather inlet hose

1. Breather inlet hose
2. Clamp (2)

13. Install breather inlet hose and two clamps.

Specifications

Table 21 Cylinder Head and Valve Train

Exhaust Valves	
Stem diameter	6.946 to 6.964 mm (0.2735 to 0.2742 in)
Stem to guide running clearance (max. allowable before replacement) diametrically	0.1846 mm (0.00727 in)
Valve face angle from center line	50.5 – 50.75°
Valve margin (minimum)	1.53 mm (0.060 in)
Valve recession in head	0.37 – 0.73 mm (0.0146 – 0.0287 in)
Intake Valves	
Stem diameter	6.946 to 6.964 mm (0.2735 to 0.2742 in)
Stem to guide running clearance (max. allowable before replacement)	0.1846 mm (0.00727 in)
Valve face angle from center line	53.0 – 53.25°
Valve margin (minimum)	1.40 mm (0.055 in)
Valve recession in head	0.37 – 0.73 mm (0.0146 – 0.0287 in)
Cylinder Heads	
Valve guide inside diameter	7.003 to 7.029 mm (0.276 to 0.277 in)
Valve guide bore runout	0.06 mm (0.00236 in)
Valve guide taper (maximum)	0.10 mm (0.004 in)
Valve seat width (intake)	1.80 to 2.56 mm (0.071 to 0.101 in)
Valve seat width (exhaust)	1.48 to 2.24 mm (0.058 to 0.088 in)
Valve seat angle (intake) from center line of valve guide	52.5 – 52.75°
Valve seat angle (exhaust) from center line of valve guide	50.0 – 50.25°
Gasket surface flatness	0.025 mm per 25 x 25 mm Maximum 0.10 mm (0.004 in) per total surface area
Overall thickness of cylinder head (deck-to-deck)	95 ± 0.48 mm (3.74 ± 0.018 in)
Valve Spring:	
Solid height	36.1 mm (1.42 in)
Compressed*	46.50 mm @ 340 ± 17 N (1.83 in @ 76.5 ± 3.8 lbf)
Compressed*	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.

Table 21 Cylinder Head and Valve Train (cont.)

Push Rods	
Runout (maximum)	0.5 mm (0.02 in)

Special Torque

Table 22 Cylinder Head and Valve Train

Lifting eye flat countersunk screws (left cylinder head)	41 N·m (30 lbf·ft)
Lifting eye bolts (right cylinder head)	61 N·m (45 lbf·ft)
Breather inlet adapter	14 N·m (124 lbf·in)
Exhaust Back Pressure (EBP) tube assembly nut	9 N·m (80 lbf·in)
Cylinder head bolt	See tightening steps in procedure
Injector clamp bolt	See tightening steps in procedure
Dual fulcrum plate assembly bolts	See tightening steps in procedure
Rail assembly bolts	See tightening steps in procedure
Fuel rail to injector tubes	See tightening steps in procedure
Glow plugs	18 N·m (159 lbf·in)
Breather oil drain assembly to crankcase M12 fitting	25 N·m (18 lbf·ft)
Breather support nuts	13 N·m (115 lbf·in)
Valve cover bolt and stud bolt assemblies	9 N·m (80 lbf·in)
Oil fill extension	14 N·m (126 lbf·in)
Lifter guide bolts with washer assembly	13 N·m (115 lbf·in)
Valve cover base assembly bolts	13 N·m (115 lbf·in)
Fuel rail plug assembly	27 N·m (20 lbf·ft)

Special Service Tools

Table 23 Cylinder Head and Valve Train

Description	Tool Number
Cylinder Head Bolt Tap	ZTSE4744
Cylinder Head Lifting Bracket	ZTSE4535
Cylinder Head Pressure Test Plate	ZTSE4534
Dye Penetrant Kit	PT-7191
Fuel Gallery Cleaning Brush	ZTSE4541
Injector Cup	ZTSE4709
Fuel Injector Rack Holder	ZTSE4299B
Fuel Injector Tip Cleaning Brush	ZTSE4301
Fuel System Caps	ZTSE4710
Glow Plug Sleeve Brush (nylon)	ZTSE4533
Glow Plug Sleeve Installer	ZTSE4532
Glow Plug Sleeve Remover	ZTSE4531
Glow Plug Sleeve Seat Wire Brush	ZTSE4589
Injector Sleeve Brushes	ZTSE4751
Injector Sleeve Installer	ZTSE4733
Injector Sleeve Remover	ZTSE4732
Lithium Grease	Obtain locally
Loctite® 620 Retaining Compound	Obtain locally
P-80® Rubber Lubricant or equivalent	Obtain locally
Slide Hammer Kit	ZTSE4398
Straightedge	Obtain locally
Valve Guide Gauge Tool	ZTSE4577
C Type Valve Spring Compressor	ZTSE1846
Valve Spring Tester	ZTSE2241
Dial Caliper	Obtain locally
Feeler Gauge	Obtain locally
Pressure Test Regulator and Gauge	Obtain locally
0-1 inch Micrometer	Obtain locally
3-4 inch Micrometer	Obtain locally
Inspection Mirror	Obtain locally