
Table of Contents

Component Removal.....	182
Preliminary Checks.....	182
Lower Crankcase.....	184
Crankshaft.....	185
Piston Cooling Tubes.....	185
Camshaft.....	186
Camshaft Bushings.....	187
Coolant Heater.....	187
Cleaning, Inspection, and Reconditioning.....	188
Crankcase Assembly.....	188
Cleaning the Crankcase.....	188
Inspecting the Crankcase.....	189
Cylinder Deglazing.....	189
Crankshaft.....	190
Piston Cooling Tubes.....	191
Camshaft.....	191
Measuring Camshaft Bushings.....	192
Coolant Heater.....	192
Component Reassembly.....	192
Camshaft Bushings.....	192
Camshaft.....	193
Piston Cooling Tubes.....	194
Crankshaft.....	194
Crankshaft and Timing.....	195
Lower Crankcase.....	195
Crankcase Sensors and Coolant Heater.....	197
Specifications.....	198
Special Torque.....	199
Special Service Tools.....	200

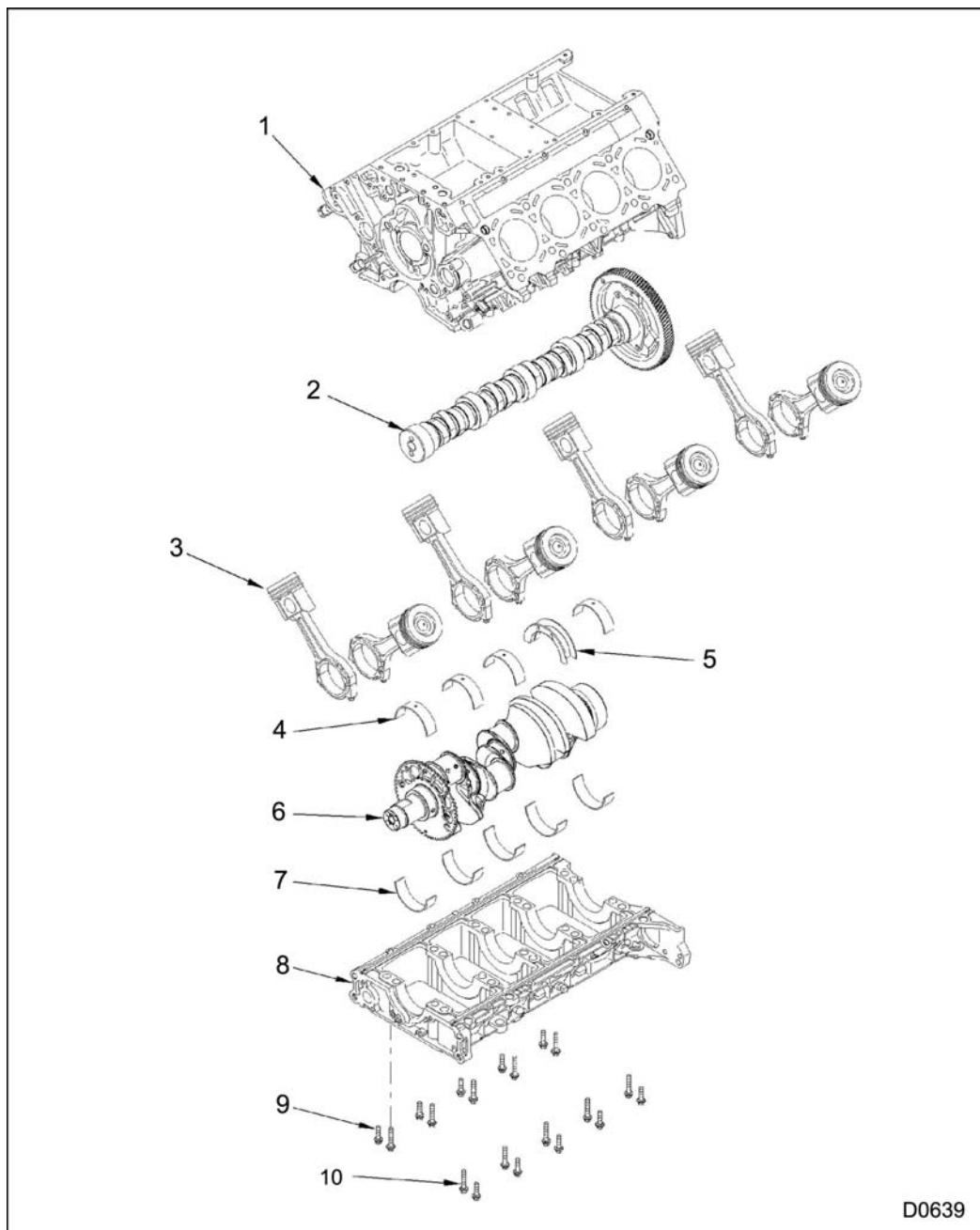


Figure 298 Crankcase and related parts

- | | | |
|---|---|--|
| 1. Crankcase assembly | 5. Crankshaft upper main thrust bearing (1) | 9. Main bearing bolt, M14 X 114 (10), outboard |
| 2. Camshaft assembly | 6. Crankshaft assembly | 10. Main bearing bolt, M14 X 127 (10), inboard |
| 3. Piston and connecting rod assembly (8) | 7. Crankshaft lower main bearing (5) | |
| 4. Crankshaft upper main bearing (4) | 8. Lower crankcase assembly | |

Component 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.

Before removing crankcase, crankshaft, bearings, camshaft, and bushings remove the following components:

- Flywheel and Rear Cover
See "Rear Cover, Flywheel, and Power Steering Drive Gear."
- Cylinder Heads
See "Cylinder Head and Valve Train."
- Intake Manifold and EGR
See "Manifolds and Exhaust Gas Recirculation (EGR)."
- Vibration Damper and Front Cover
See "Front Cover, Vibration Damper, and Gerotor Oil Pump."
- Turbocharger Assembly
See "VGT Electronically Controlled Turbocharger."
- Piston Assemblies
See "Pistons, Rings, and Connecting Rods."
- Upper and Lower Oil Pan
See "Oil Pan, Upper Oil pan, and Pickup Tube."

CAUTION: To prevent engine damage, do not remove the rear primary crankshaft flange bolts. If the flange is removed and reinstalled, engine vibration and premature wear of transmission components will occur.



Figure 299 Crankshaft flange bolt (6)

Preliminary Checks

NOTE: Before removing components, determine gear backlash (crankshaft gear to camshaft gear), camshaft end play, and crankshaft end play

1. Check and record camshaft gear-to-crankshaft gear backlash as follows :
 - a. Mount Dial Indicator with Magnetic Base (Table 23) on rear of engine.
 - b. Position dial indicator tip on a gear tooth and remove lash.
 - c. Zero the dial indicator.

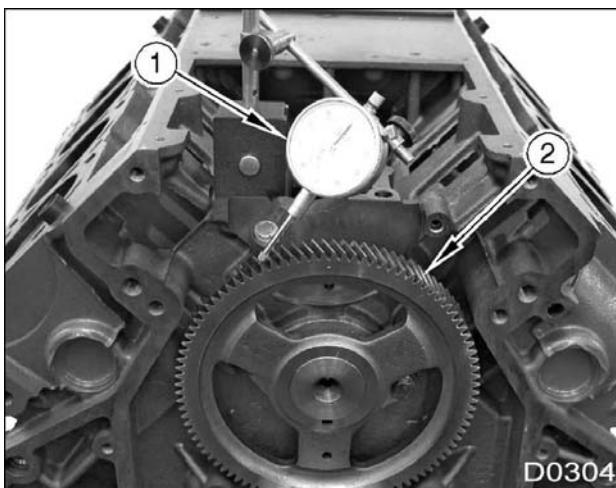


Figure 300 Gear backlash check (camshaft gear to crankshaft gear)

1. Dial Indicator with Magnetic Base
2. Camshaft gear
- d. Rotate gear by hand and read indicator. Record backlash.
- e. If backlash exceeds specified limits (Table 20), replace camshaft gear.
2. Reposition dial indicator and check camshaft end play as follows:
 - a. Push camshaft toward the front of the engine.
 - b. Zero the dial indicator.
 - c. Place a small pry bar between the camshaft gear and crankcase. Lightly pry camshaft forward. Compare dial indicator reading with specifications (Table 20).

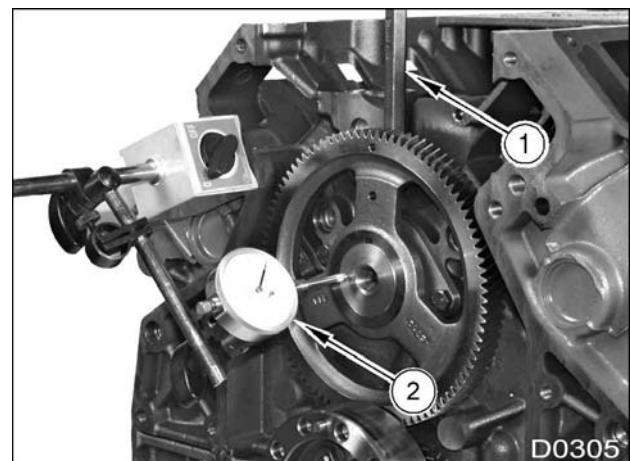


Figure 301 Camshaft end play

1. Pry bar
2. Dial Indicator with Magnetic Base
- d. If end play exceeds specified limits, replace camshaft thrust plate.
3. Check crankshaft end play as follows:
 - a. Mount dial indicator on crankcase with indicator tip on the end of crankshaft flange as shown.

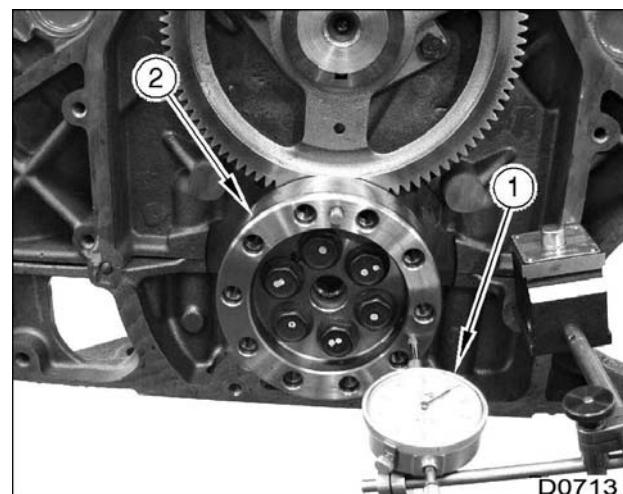


Figure 302 Crankshaft end play

1. Dial Indicator with Magnetic Base
2. Crankshaft flange
- b. Pry crankshaft forward with pry bar and zero the dial indicator.

- c. Pry crankshaft back and forth while reading dial indicator. Record end play.

Lower Crankcase

1. Remove the Crankshaft Position (CKP) sensor, located on the lower right front of the engine.

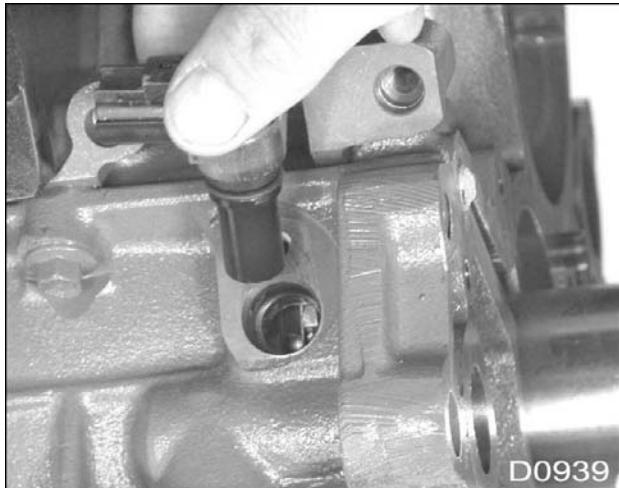


Figure 303 CKP position sensor

NOTE: Two different size bolts support the lower crankcase: inboard bolts (M14 x 127) and outboard bolts (M14 x 114).

2. Remove all 20 main bearing cap bolts.

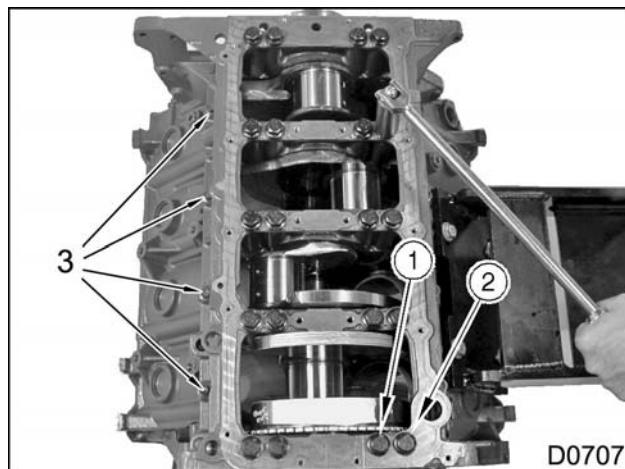


Figure 304 Removing main bearing bolts from lower crankcase

1. Inboard main bearing cap bolt (M14 x 127)
2. Outboard main bearing cap bolt (M14 x 114)
3. Outer lower crankcase bolt (M8 x 30) (8)
3. Remove four M8 x 30 bolts from each side of lower crankcase.
4. Carefully lift lower crankcase away from crankshaft.



Figure 305 Removing the lower crankcase assembly

1. Lower crankcase
2. Crankcase
5. Remove main bearing shells from lower crankcase by pushing them out of bearing saddles. Mark lower shells with bearing number

(1–5, beginning from the front) and place them aside for inspection.

bearings and put them with their respective lower bearings for proper inspection.

Crankshaft

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

1. Install a bolt in each end of crankshaft.
2. Attach lifting sling to crankshaft. Lift crankshaft straight up and out of crankcase.

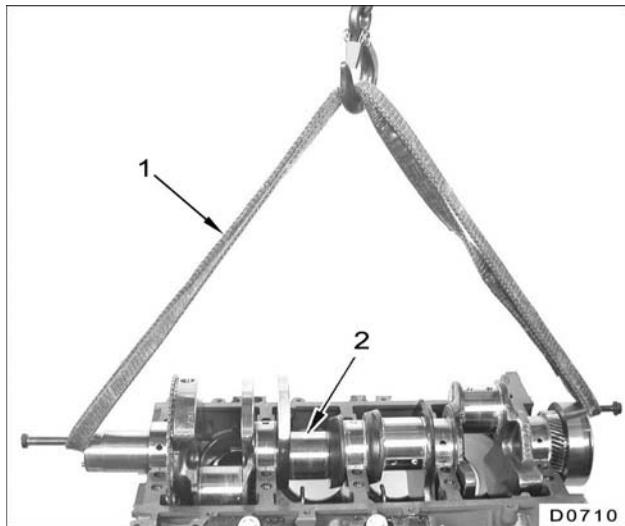


Figure 306 Lifting sling

1. Lifting sling
2. Crankshaft
3. Remove bearings from upper main bearing saddles by pushing them out. Mark upper

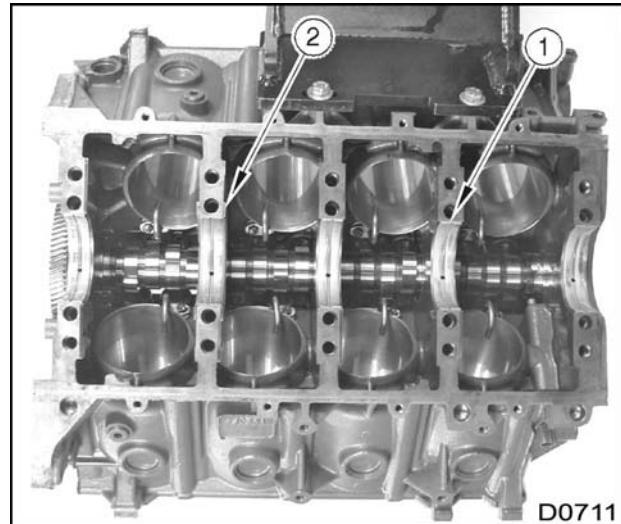


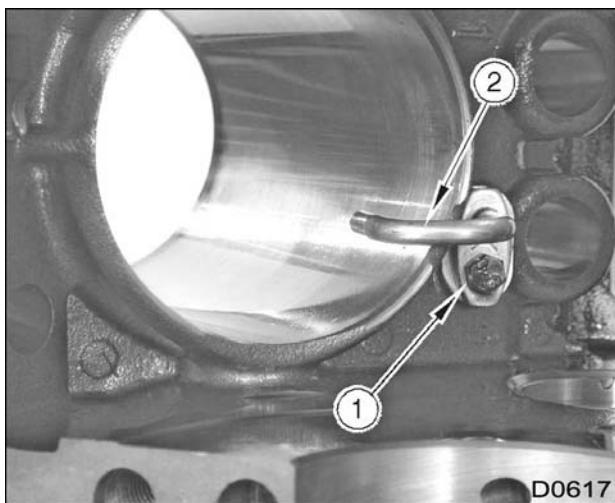
Figure 307 Main crankshaft upper bearings

1. Crankshaft upper bearing (4)
2. Crankshaft upper thrust bearing (1)

Piston Cooling Tubes

CAUTION: To prevent engine damage, the piston cooling tubes use a special patch type mounting bolt. Do not substitute.

Remove each piston cooling tube by removing its special patch type mounting bolt (M6 x 18). The bolts are reusable, only if you add Loctite® #242 (Table 23) to bolt threads upon reinstallation.

**Figure 308** Piston cooling tube

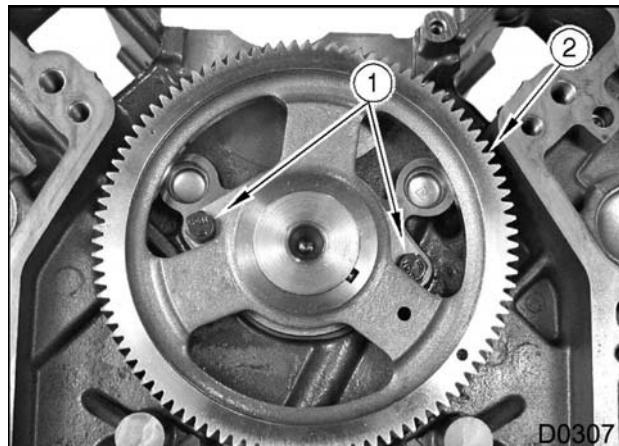
1. Piston cooling tube mounting bolt (patch type) (M6 x 18)
2. Piston cooling tube

Camshaft

1. Remove the Camshaft Position (CMP) sensor, from lower left front side of the engine.

**Figure 309** CMP sensor removal

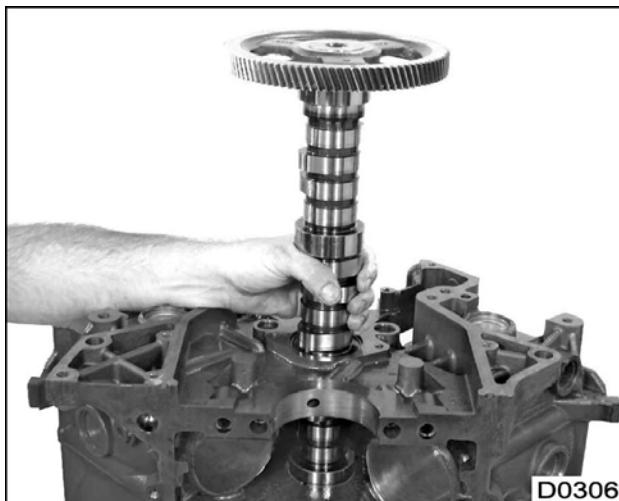
2. Remove two M8 x 16 mounting bolts from camshaft thrust plate.

**Figure 310** Mounting bolts for camshaft thrust plate

1. Camshaft thrust plate mounting bolts
2. Camshaft gear

NOTE: If the engine is mounted on a turn over stand, rotate engine face up, allowing for easy removal of camshaft assembly.

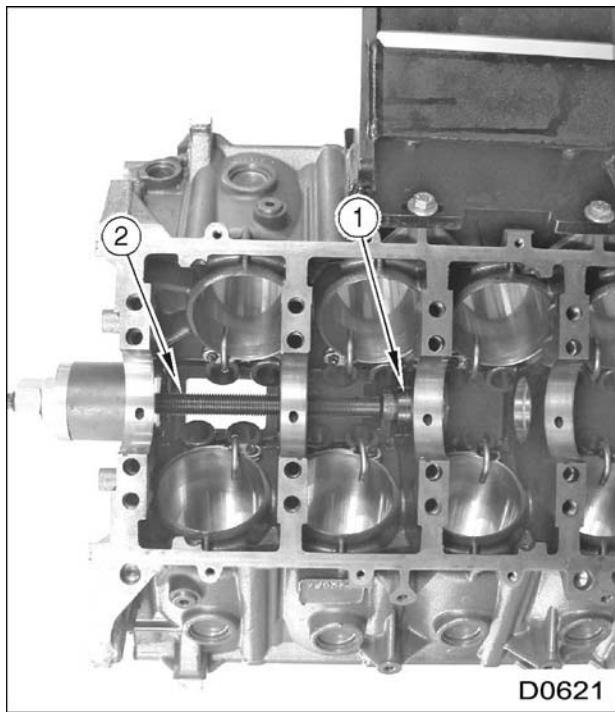
3. Remove camshaft from crankcase by lifting assembly straight up and out.

**Figure 311** Camshaft assembly

NOTE: The camshaft gear is assembled to the camshaft with a shrink fit and can be removed with a hydraulic press if required.

Camshaft Bushings

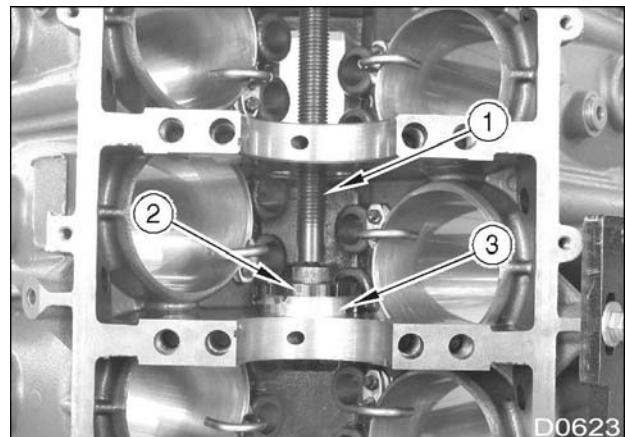
1. Determine necessity of replacing bushings based on running clearance (Measuring Camshaft Bushings, page 192).
2. Use existing camshaft bushing kit with Camshaft Bushing Remover/Installer (expanding collet) (Table 23) to remove all camshaft bushings. Install Camshaft Bushing Remover/Installer (collapsed) into camshaft bushing.
3. Assemble pulling screw into Camshaft Bushing Remover/Installer and tighten back-up nut until collet fits snug within camshaft bushing. To avoid nicks on bushings, be careful when inserting or removing threads of pulling screw.

**Figure 312 Camshaft bushing**

1. Camshaft Bushing Remover/Installer (expanding collet)
2. Pulling screw (from camshaft bushing kit)
4. Attach pulling plate, thrust bearing, and drive nut onto pulling screw. Tighten nut against thrust bearing and pulling plate. Continue to thread nut onto pulling screw until camshaft bushing is free from crankcase.

onto pulling screw until camshaft bushing is free from crankcase.

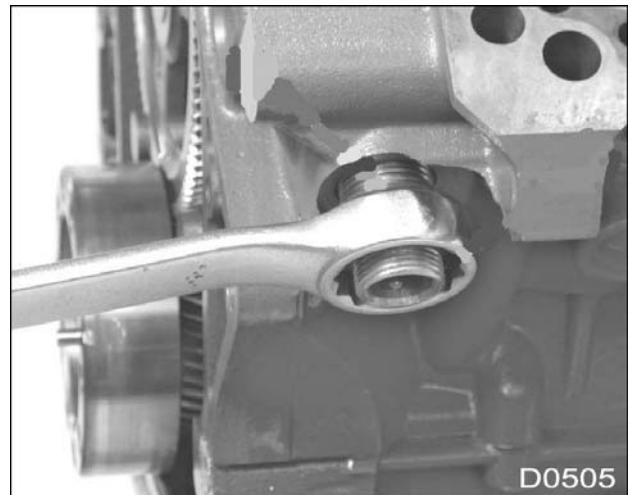
NOTE: Hold a wrench on the end of the pulling screw to prevent it from turning.

**Figure 313 Camshaft bushing**

1. Pulling screw
2. Camshaft Bushing Remover/Installer (expanding collet)
3. Camshaft bushing

Coolant Heater

Remove coolant heater from right rear side of engine block.

**Figure 314 Coolant heater removal**

Cleaning, Inspection, and Reconditioning

Crankcase Assembly

Cleaning the Crankcase

NOTE: Clean the crankcase in a chemical bath or hot tank. This removes all carbonized material and mineral deposits in coolant passages.

NOTE: Thoroughly clean and inspect crankcase before and after reconditioning.

1. Use nonmetallic brushes and scrapers to clean gasket material from machined surfaces of crankcase.
2. Clean cylinder bore with soap, water, and a nylon brush.
3. Clean lower crankcase in solvent. Dry with filtered compressed air. (page 3)



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

4. To remove main oil gallery cup plug (in rear of crankcase), use a punch and hammer near edge of plug and strike with a hammer. Remove plug from crankcase and discard. Clean main oil galleries with a Oil Gallery Cleaning Brush (Table 23).

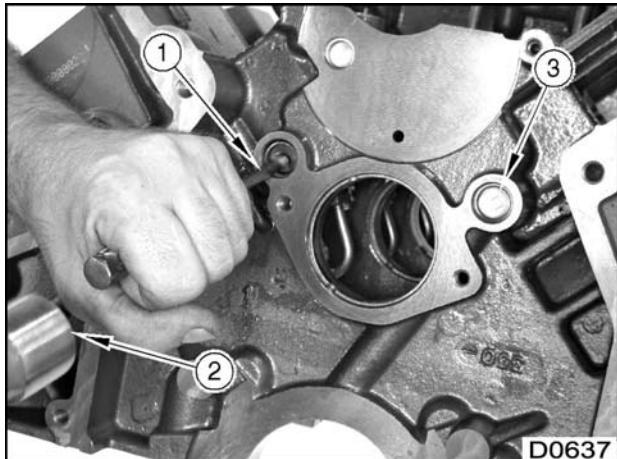
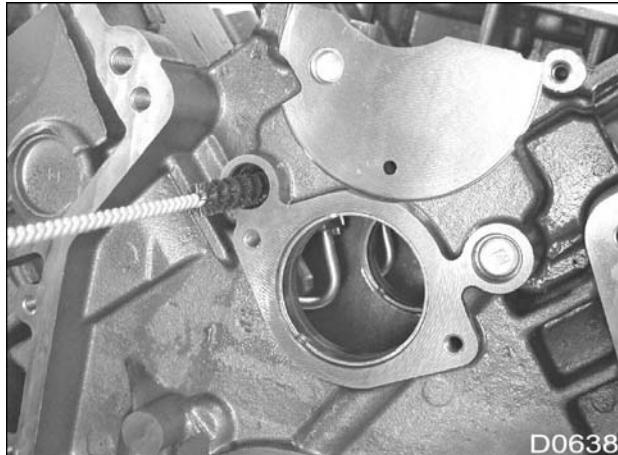


Figure 315 Removal of oil gallery cup plugs

1. Punch
2. Hammer
3. Oil gallery cup plug

5. Clean main galleries with an Oil Gallery Cleaning Brush (Table 23).



D0638

Figure 316 Oil Gallery Cleaning Brush

NOTE: Use Liquid Gasket (RTV) (Table 23) before installing main oil gallery core plugs.

6. Coat edges of new cup plugs with sealant. Use a Oil Gallery Plug Driver (Table 23) to install new cup plugs. The Oil Gallery Plug Driver installs cup plug to the proper depth. It should be flush with the crankcase surface to approximately 1.50 mm (0.060 in) below surface.

CAUTION: To prevent engine damage, threads in the crankcase bolt holes must be clean and blown dry with filtered compressed air.

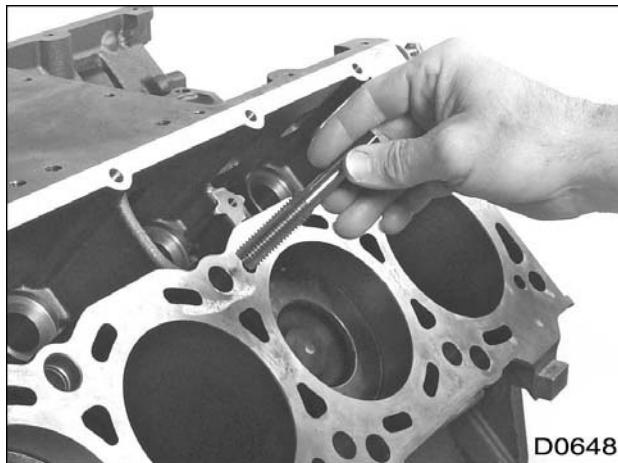


Figure 317 Head Bolt Bottoming Tap

- Clean all cylinder head bolt holes with a Head Bolt Bottoming Tap (Table 23). Blow out chips with filtered compressed air. (page 3)

Inspecting the Crankcase

- After cleaning, inspect crankcase for cracks, scoring, roughness or wear at cylinder bores.

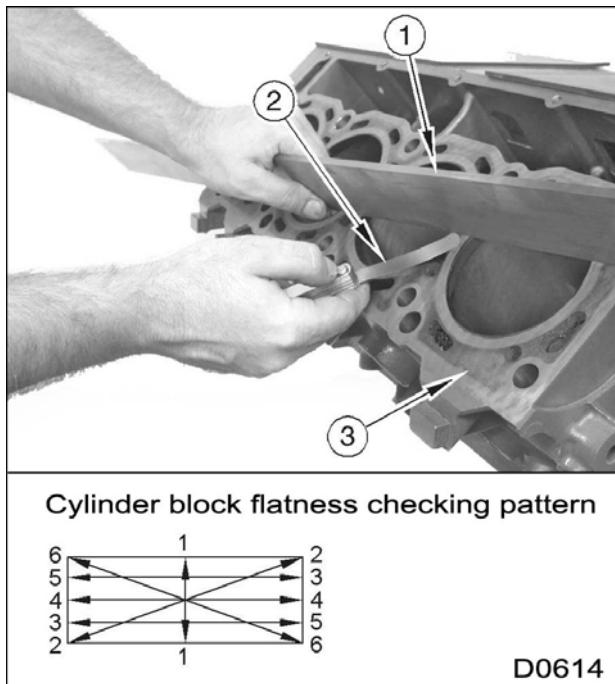


Figure 318 Flatness check for top surface of cylinder block

- Straightedge
- Feeler gauge
- Cylinder block top surface
- Use a Straightedge (Table 23) to check top surface of crankcase (top deck) for flatness. Insert a feeler gauge between Straightedge (Table 23) and crankcase head surface. If gap exceeds specifications (Table 20), crankcase must be replaced.
- If cylinder walls have minor surface damage, but are otherwise within out-of-round specifications,

CAUTION: Do not resurface the crankcase. Surface defects beyond those listed above are not correctable.

it may be possible to remove such damage by honing.

- Use a Cylinder Bore Gauge (Table 23) to check cylinder bore out-of-round conditions.
- Measure diameter of cylinder bore at top of piston ring travel. Be sure to measure at a right angle to the center line of crankshaft (dimension A). Record reading. Next, measure each bore so gauge reading coincides with center line of crankshaft (dimension B). Record reading.

The difference between readings from dimension A and dimension B is the out-of-round condition at the top of the cylinder bore. Repeat the same procedure at the bottom of ring travel to check for out-of-round condition.

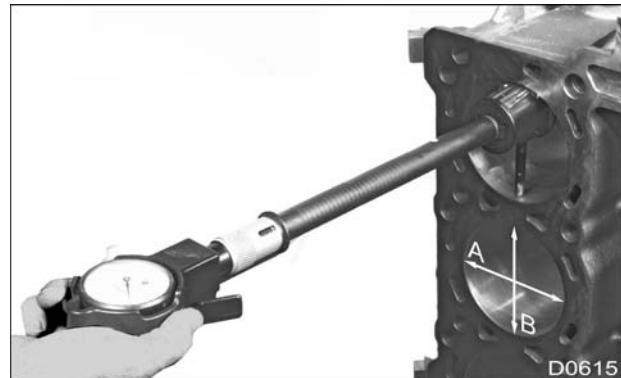


Figure 319 Out-of-round cylinder bore check

CAUTION: To prevent engine damage, if cylinder bores are deeply scored, out-of-round, or exceed specifications, all cylinders must be bored out to an oversize.

- If cylinder bore is within specifications (Table 20), standard size pistons and rings may be used. If cylinder bore is suitable for use without reconditioning, deglaze the cylinder bore before assembling. See Cylinder Deglazing in this section.

Cylinder Deglazing

NOTE: If cylinder bores are to be deglazed, all piston cooling tubes must be removed.

- Use a 4 inch Deglazing Hone (Table 23) to deglaze the cylinder bore. This silicone carbide-tipped nylon flexible brush quickly

- deglasses cylinder walls and produces a crosshatch pattern on the cylinder wall surface in a single operation. The brush contours itself to the cylinder wall and conditions wall surface without altering cylinder bore.
2. Spray both the cylinder to be deglazed and the Deglazing Hone brush with penetrating fluid or equivalent. This spray contains colloidal graphite and works well for this application.

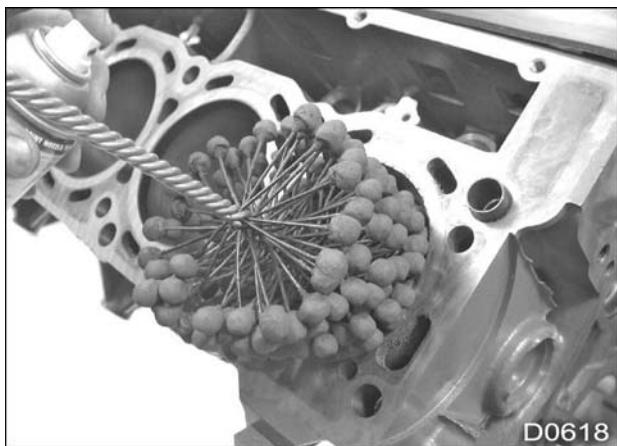


Figure 320 Deglazing Hone

3. Deglaze cylinder as follows:
 - a. Attach Deglazing Hone (Table 23) to a variable speed electric or air powered drill.

NOTE: 100-120 rpm and speed adjustment is required.

 - b. Deglaze cylinder wall for about 15 seconds. Stroke bore up and down at a rate of one complete up and down stroke per second.
 - c. Withdraw Deglazing Hone from cylinder bore while brush is rotating. Wipe portion of cylinder wall and inspect cross-hatch pattern.

NOTE: The crosshatch pattern left by the abrasive tool should be approximately 45°.

 - d. If pattern is "flatter" than required, increase up and down stroke speed or slow down drill rotation.
 - e. Continue deglazing cylinder bore for 10-15 seconds or 20-25 strokes.

- f. Wipe cylinder bore clean and inspect bore for proper 45° cross-hatch pattern.

4. After deglazing, thoroughly clean cylinder bores with soft bristle brush, soap and water. Dry with filtered compressed air (page 3). Lubricate bore with clean engine oil.

Crankshaft

Clean and inspect the crankshaft and main bearings as follows:

1. Clean crankshaft with a suitable solvent. Dry with compressed air. (page 3)
2. Use a stiff nylon brush to clean all internal oil passages of crankshaft. Loosen all accumulated dirt, sludge, and deposits. Flush oil passages with a suitable solvent.
3. Inspect crankshaft journals (main and connecting rod) for scratches, grooves, and scoring.
4. Inspect crankshaft main bearings for scratches, grooves, scoring, pitting, and inconsistent coloring.
5. Use a 3-4 inch micrometer to measure the diameter of each journal (main and connecting rod). Measure each journal at two points 90° apart. Move micrometer over entire width of journal (Table 20).



Figure 321 Measurement for crankshaft main journal



Figure 322 Measurement for crankshaft connecting rod journal

CAUTION: To prevent engine damage, crankshaft must be reground or replaced if journals exceed maximum out-of-round or taper specifications.

Piston Cooling Tubes

1. With the piston cooling tubes removed, run an appropriate size wire through the tube to ensure there is no blockage.
2. Use dry filtered compressed air to blow out any debris that remains from cleaning. (page 3)
3. Replace any cracked or bent tubes.

Camshaft

1. Inspect camshaft. If any lobes are scuffed, scored or cracked, replace camshaft.

NOTE: This engine uses hydraulic valve tappets with roller followers; therefore, a roller follower guide is needed to maintain correct orientation of roller to cam lobe. Normal clearance between the valve tappet roller and guide allows for slight tracking of roller across cam lobe.

Tracking of the roller is normal when the roller accelerates and decelerates during engine operation. Consequently, a typical wear pattern on cam lobes will exhibit tracks from side to side, have wide and narrow areas from the loading, and unloading of the follower. The wear pattern (tracking) is normal and the camshaft does not require replacement.

2. After inspection, evaluate camshaft main journal and lobe condition as follows:

NOTE: When measuring the camshaft with a micrometer, always take two measurements 90° apart.

- a. Use a 2-3 inch micrometer to measure camshaft bearing journal diameter. Record these measurements for later use in camshaft bushing inspection. If bearing journals are worn beyond limits, replace the camshaft.

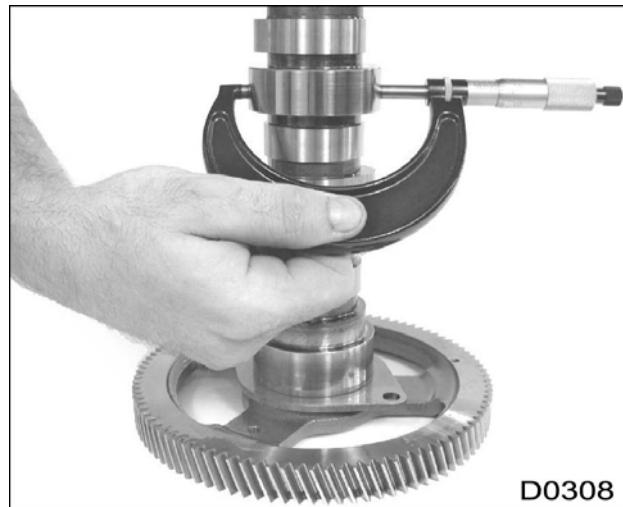


Figure 323 Measurement for camshaft bearing journal

- b. To check camshaft intake and exhaust lobes, measure across (A-C) and across (B-D). Subtract (B-D) from (A-C). This will give cam lobe lift. Replace camshaft when cam lobe wear exceeds specifications (Table 20).

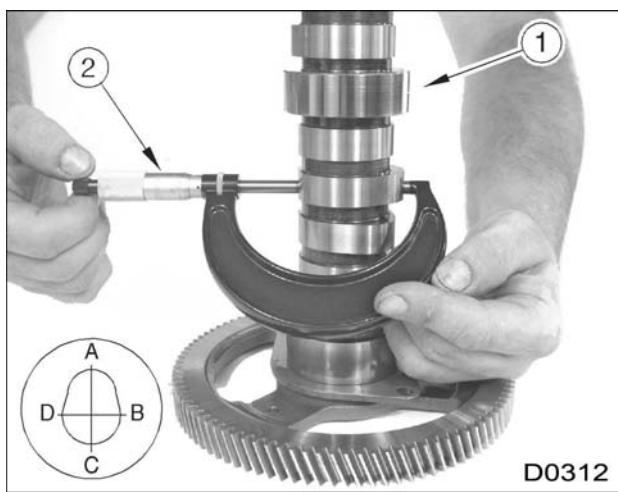


Figure 324 Measurement for camshaft intake and exhaust lobes

1. Camshaft assembly
2. Micrometer

3. Inspect thrust plate for wear, cracks or distortion. Use a micrometer to measure thrust plate thickness (Table 20). Replace thrust plate if worn or damaged.
4. Inspect camshaft drive gear for worn or damaged teeth.
5. Wash camshaft in cleaning solvent with a soft brush. Dry with filtered compressed air. (page 3)

Measuring Camshaft Bushings

Inspect the five camshaft bushings for wear and proper running clearance as follows:

1. Use a Telescoping Gauge (Table 23) and 2-3 inch micrometer to measure camshaft bushing inside diameters with bushings installed in crankcase. Record readings.

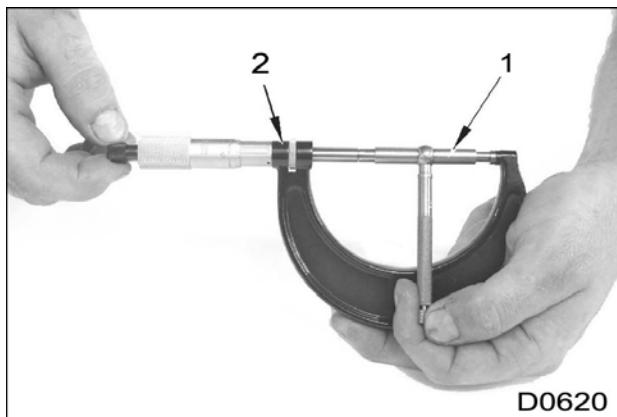


Figure 325 Measurement for inner diameter of camshaft bushing

1. Telescoping Gauge
2. Outside micrometer

2. To determine running clearance, subtract previous camshaft journal diameter readings from camshaft bushing inside diameter readings.
3. If maximum allowable running clearance is exceeded (Table 20), replace camshaft bushings. See camshaft bushing removal and installation procedures.
4. Inspect each bushing bore in crankcase for burrs or debris that could damage new bushings. Remove burrs and clean bores thoroughly before installing new camshaft bushings.

Coolant Heater

1. Inspect heater for continuity.
2. Check insulator at terminal for cracks.
3. Replace O-ring.

Component Reassembly

Camshaft Bushings

CAUTION: To prevent engine damage, use the correct Camshaft Bushing Remover/Installer.

1. Lubricate new camshaft bushings and crankcase bores with clean engine oil.
2. Slide a new bushing onto the Camshaft Bushing Remover/Installer (expanding collet) (Table 23).

Thread pulling screw, back-up nut, and Camshaft Bushing Remover/Installer together. Tighten expanding collet by turning back-up nut until bushing is securely held on tool.

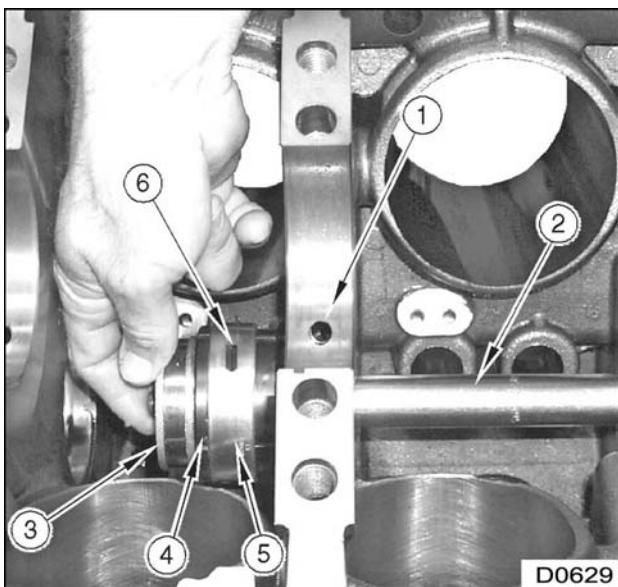


Figure 326 Installation of cam bushing

1. Oil supply hole
2. Pulling screw
3. Backup nut
4. Camshaft Bushing Remover/Installer (expanding collet)
5. Camshaft bushing
6. Camshaft bushing oil supply hole

CAUTION: To prevent engine damage and to ensure proper oil circulation through the crankcase, make certain that all camshaft bushing oil holes are aligned with the corresponding oil supply holes in the crankcase.

3. To aid in alignment of bushing and crankcase oil holes, use a marker to indicate oil hole location on back-up nut of installation tool. Repeat this step for each camshaft bushing.
4. Install all camshaft bushings through rear of crankcase. Pull bushings into place at rear of crankcase by turning pulling nut on pulling screw. Remove installer tool and inspect oil hole alignment.

Camshaft

1. Coat camshaft lobes and bushing journals with clean engine oil.
2. Position crankcase with rear of engine facing up on engine stand and carefully install camshaft assembly.

NOTE: Do not nick or scratch camshaft bushings with cam lobes.

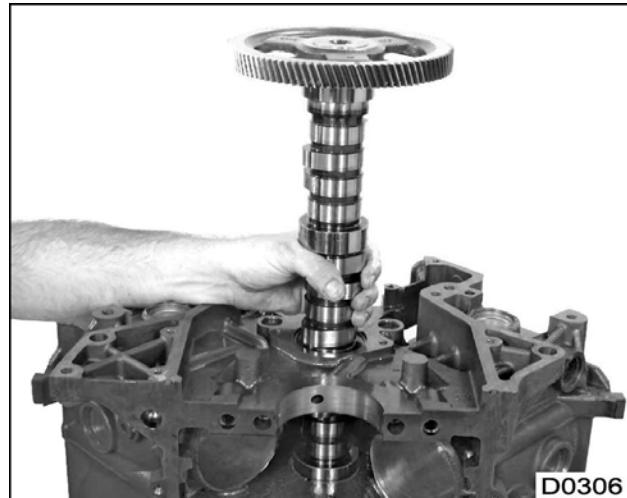


Figure 327 Camshaft assembly

3. Install two M8 x 16 camshaft thrust plate mounting bolts. Tighten bolts to the standard torque (General Torque Guidelines, page333).

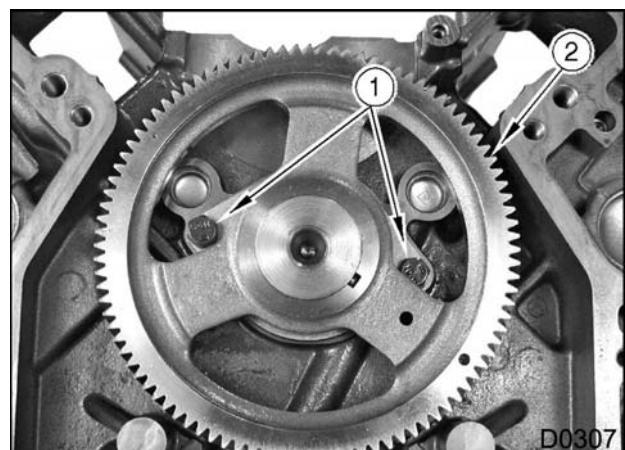


Figure 328 Camshaft thrust plate bolts installed

1. Camshaft thrust plate mounting bolt (M8 x 16)
2. Camshaft gear

- Confirm that camshaft end play is within specifications.

Piston Cooling Tubes

CAUTION: To prevent engine damage, the piston cooling tubes use a special patch type mounting bolt. Do not substitute.

NOTE: The bolt-on piston cooling tubes are self aligning.

- Place piston cooling tubes onto crankcase mounting pad.
- When installing the piston cooling tube bolts, use either:
 - Brand new piston cooling tube mounting bolts (patch type), or
 - Remove oil residue and apply Loctite® #242 (Table 23) to the threads of existing piston cooling tube mounting bolts (patch type).
- Install and tighten bolts to the standard torque (General Torque Guidelines, page333).

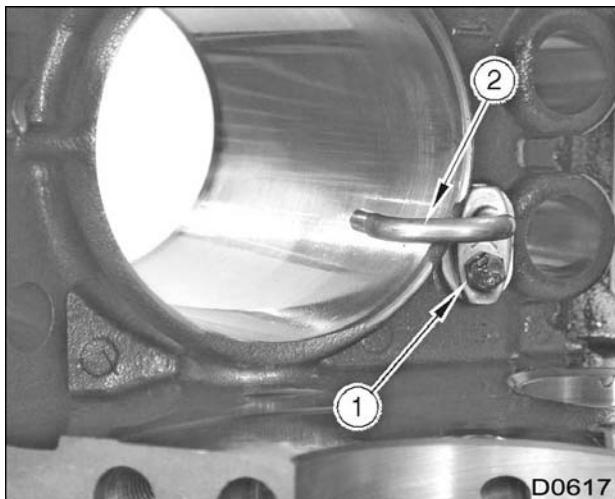


Figure 329 Piston cooling tube

- Piston cooling tube mounting bolt (patch type) (M6 x 18)
- Piston cooling tube

Crankshaft

NOTE: Make sure the crankshaft has been inspected per instructions found within this section prior to proceeding.

- Use a lint-free cloth to wipe the crankcase bearing supports free of oil.
- Inspect each bearing. Replace all bearings that are scored, chipped, or worn.

NOTE: When inserting main bearings into the crankcase, be sure that there is no oil between the backside of the bearing and the crankcase bearing saddles.

- Place upper main bearings into the crankcase. Make sure locking tabs on bearings are snapped into crankcase saddle and oil holes in bearings line up with oil holes in crankcase.

NOTE: Crankshaft thrust bearing is installed at the number 4 upper main bearing journal.

- Lubricate bearings with clean engine oil.

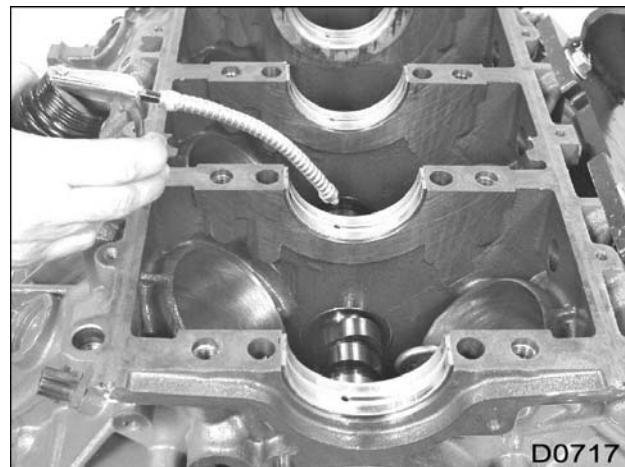


Figure 330 Upper main bearings lubrication

- Install crankshaft timing tool so index mark on camshaft gear is visible between alignment slot of timing tool.

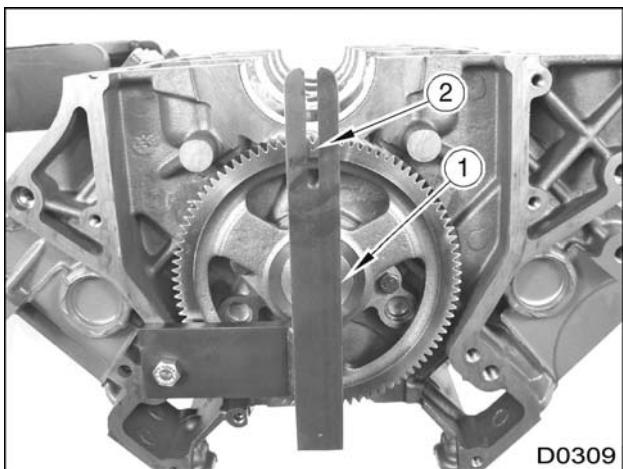


Figure 331 Crankshaft timing tool installed

1. Crankshaft timing tool
2. Camshaft index mark

WARNING: To prevent personal injury or death, use an appropriately sized lifting sling and hoist equipped with a safety latch on hook.

6. Place a bolt into each end the end the crankshaft. Attach hoist and lifting sling around crankshaft bolts and carefully lower it onto five main bearings.

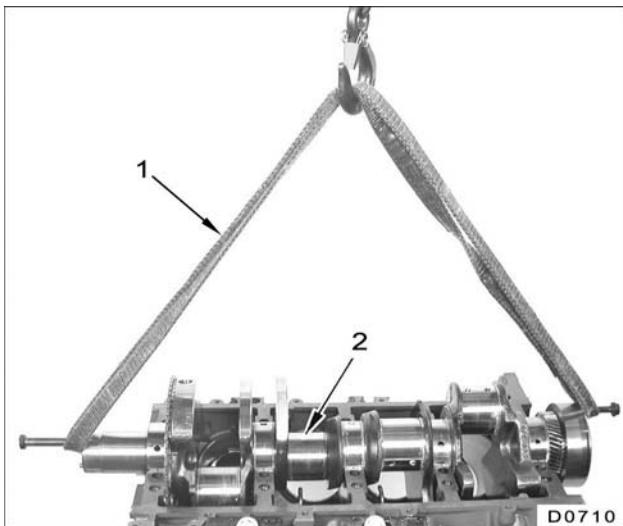


Figure 332 Lifting sling

1. Lifting sling
2. Crankshaft assembly

Crankshaft and Timing

Install crankshaft so alignment pin falls between crankshaft timing tool alignment slot.

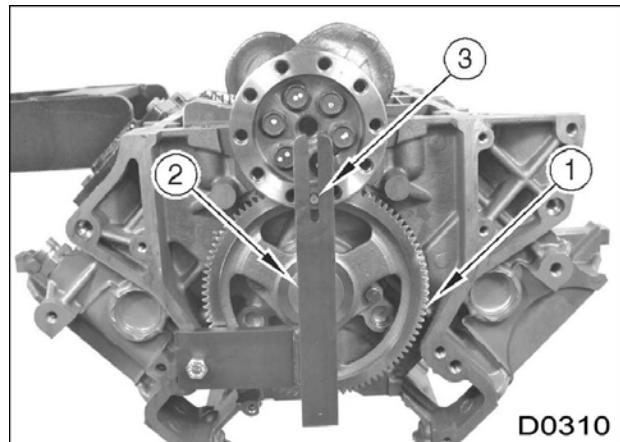


Figure 333 Crankshaft timing tool installed

1. Camshaft gear
2. Crankshaft timing tool
3. Crankshaft alignment pin

Lower Crankcase

With acceptable bearing clearance, install the lower crankcase as follows:

1. Install new lower crankcase seals.
2. Apply clean engine oil to lower bearing inserts, crankshaft journals and lower crankcase bolts.
- CAUTION:** To prevent engine damage, make sure that the longer main cap bolts (M14 x 2 x 127) are installed inboard and the shorter bolts (M14 x 2 x 114) are installed outboard.
3. Install all 20 lower crankcase main bearing mounting bolts. Tighten main cap bolts to special torque within the following sequence :
 - a. Torque bolts to 122 N·m (90 lbf·ft) in the numerical sequence.
 - b. Torque bolts again to 163 N·m (120 lbf·ft) in the numerical sequence.
 - c. Torque bolts finally to 231 N·m (170 lbf·ft) in the numerical sequence.

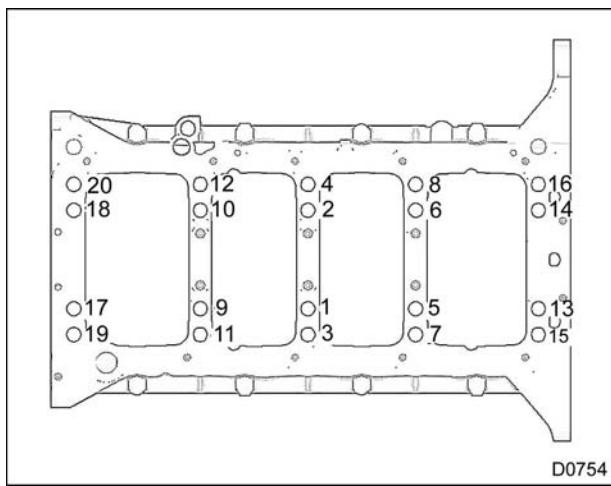


Figure 334 Torque sequence for main bearing mounting bolts to lower crankcase

4. Install eight M8 x 30 bolts around outside of lower crankcase. Tighten bolts to the standard torque (General Torque Guidelines, page 333) using the following sequence.

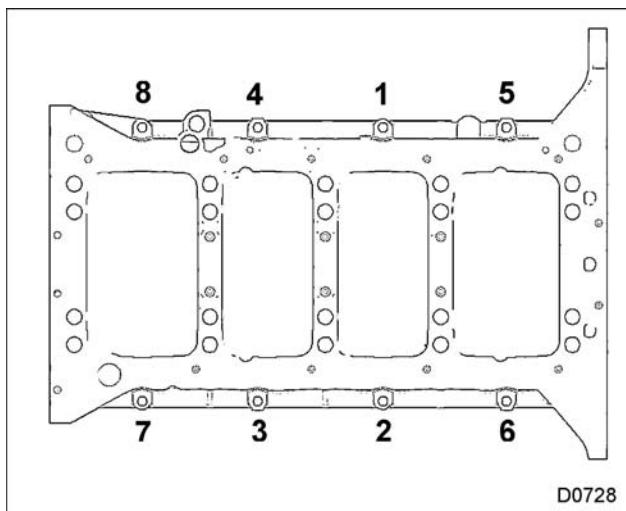


Figure 335 Tightening sequence for lower crankcase outer bolts (standard torque)

NOTE: Confirm that gear backlash between camshaft and crankshaft is within specifications.

5. Check and record camshaft gear to crankshaft gear backlash as follows :
 - a. Mount dial indicator on rear of engine.
 - b. Position dial indicator tip on a gear tooth and remove lash.
 - c. Zero the dial indicator.

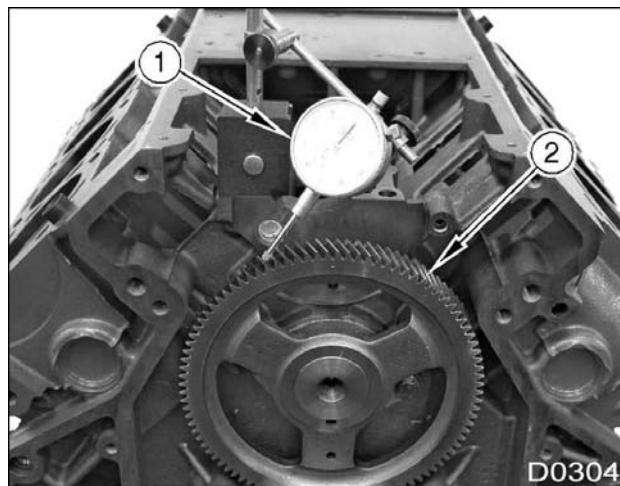
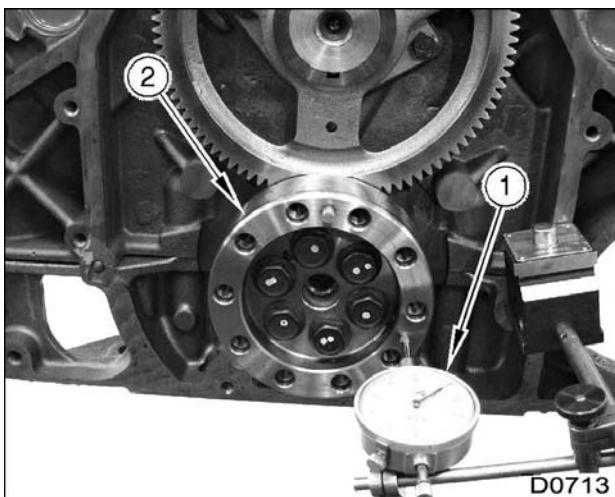


Figure 336 Gear backlash check (camshaft gear to crankshaft gear)

1. Dial indicator
2. Camshaft gear
- d. Rotate gear by hand and read indicator. Record backlash.
- e. If backlash exceeds specified limits (Table 20), replace camshaft gear.
6. Check crankshaft end play as follows:
 - a. Mount dial indicator on crankcase with indicator tip on the end of crankshaft flange as shown.

**Figure 337** End play check for crankshaft

1. Dial indicator
 2. Crankshaft flange
- b. Pry crankshaft forward with pry bar and zero the dial indicator.
 - c. Pry crankshaft back and forth while reading dial indicator. Record end play.

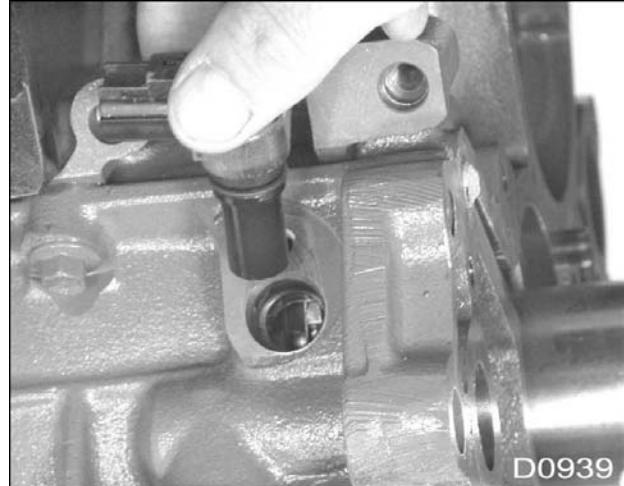
Crankcase Sensors and Coolant Heater

NOTE: See "Engine Electrical" section regarding O-rings for engine sensors (Camshaft Position (CMP) Sensor, page233).

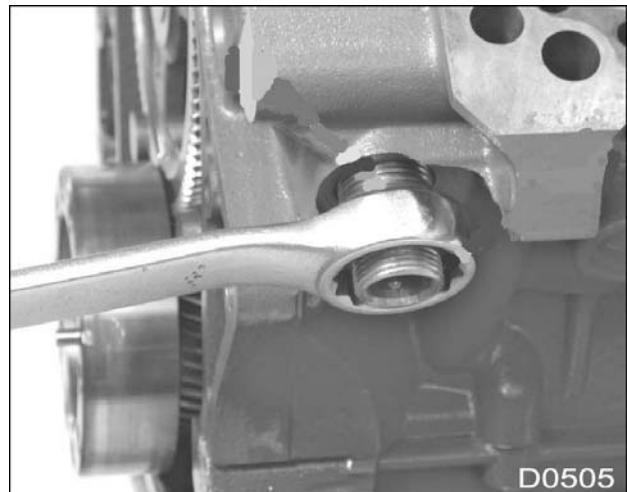
1. Install Camshaft Position (CMP) sensor. Tighten mounting bolt to the standard torque value (General Torque Guidelines, page333).

**Figure 338** CMP sensor installation

2. Install Crankshaft Position (CKP) sensor. Tighten mounting bolt to the standard torque (General Torque Guidelines, page333).

**Figure 339** Crankshaft Position (CKP) sensor installation

3. Lubricate a new O-ring and install onto the coolant heater. Install into engine block and tighten to the special torque (Table 22).

**Figure 340** Installation of coolant heating element

1. Coolant heating element
2. Coolant heater O-ring

Specifications**Table 20****Crankshaft**

Main Bearing Journal Diameter:

Standard size	80.9873 - 81.0127 mm (3.188 - 3.150 in)
0.254 mm (0.010 in) undersize	80.7333 - 80.7587 mm (3.178 - 3.140 in)
0.508 mm (0.020 in) undersize	80.4793 - 80.5047 mm (3.168 - 3.130 in)
0.762 mm (0.030 in) undersize	80.2253 - 80.2507 mm (3.158 - 3.120 in)
Main bearing thrust face maximum runout	0.051 mm (0.002 in)
Oil seal journal maximum runout	0.025 mm (0.001 in)
Vibration damper mounting area maximum runout	0.05 mm (0.002 in)
Flywheel mounting surface maximum runout	0.05 mm (0.002 in)
Main bearing to crankshaft running clearance	0.020 - 0.086 mm (0.0008 - 0.0034 in)
Connecting Rod Journal Diameter:	

Standard size	68.99 - 69.01 mm (2.716 - 2.717 in)
0.254 mm (0.010 in) undersize	68.73 - 68.75 mm (2.706 - 2.707 in)
0.508 mm (0.020 in) undersize	68.48 - 68.50 mm (2.696 - 2.697 in)
0.762 mm (0.030 in) undersize	68.23 - 68.25 mm (2.686 - 2.687 in)

Crankshaft end play (max.)

Camshaft	
Bearing journal diameter (all journals)	61.987 - 62.013 mm (2.440 - 2.441 in)
Bearing inside diameter	62.05 - 62.14 mm (2.443 - 2.446 in)
Journal/bushing running clearance	0.037 - 0.153 mm (0.0015 - 0.0060 in)
Camshaft end play	0.051 - 0.211 mm (0.002 - 0.008 in)
Camshaft gear backlash	0.179 - 0.315 mm (0.007 - 0.012 in)
Maximum permissible cam lobe wear	0.51 mm (0.02 in)
Camshaft thrust plate thickness	3.589 - 3.649 mm (0.1413 - 0.1436 in)
Camshaft lobe lift (max.):	
Intake	5.744 mm (0.2261 in)
Exhaust	5.832 mm (0.2296 in)
Valve timing no. 1 cylinder (top of lobe):	
Intake open	7.22° BTDC
Intake closed	34.66° ABDC
Exhaust open	45.12° BBDC
Exhaust closed	6.24° ATDC

Table 21

Crankcase	
Crankcase deck flatness	0.05 mm (0.002 in) / 150 mm ² (35 in ²) Total: 0.10 mm (0.004 in)
Crankcase main bearing bore diameter	85.99 - 86.01 mm (3.3854 - 3.3862 in)
Crankcase cam bearing bore diameter	65.98 - 66.02 mm (2.597 - 2.599 in)
Roller follower bore diameter	23.439 - 23.477 mm (0.9228 - 0.9243 in)
Roller follower outside diameter	23.391 - 23.411 mm (0.9209 - 0.9217 in)
Cylinder bore diameter	94.9905 - 95.0095 mm (3.7398 - 3.7405 in)
Cylinder bore maximum out-of-round	0.008 mm (0.0003 in)
Cylinder stroke	105 mm (4.13 in)
Main Bearings:	
Type	Precision replaceable
Material	Steel backed copper/lead
Number of main bearings	5
Thrust applied at	No. 4 main upper
Lower crankcase	Four bolts per main journal
Coolant heater element rating	1,000 watts, 120 volts

Special Torque

Table 22

Lower crankcase main bearing cap bolts	See tightening procedure and sequence (Figure 335)
Lower crankcase outer bolts (M8 x 30), standard torque	
Coolant heater element	41 N·m (30 lbf·ft)

Special Service Tools**Table 23**

Tool Number	Description
ZTSE2893A	Camshaft Bushing Kit
ZTSE4349	Deglazing Hone (4 inch)
ZTSE4489	Camshaft Bushing Remover/Installer (expanding collet)
ZTSE4508	Head Bolt Bottoming Tap
ZTSE4511	Oil Gallery Cleaning Brush
ZTSE4512	Oil Gallery Plug Driver
ZTSE4519	Crankshaft Timing Tool
ZTSE4520	Accessory Drive Gear Puller
Obtain locally	Straightedge
Obtain locally	Dial Indicator with Magnetic Base
Obtain locally	Telescoping Gauge Set
Obtain locally	Cylinder Bore Gauge
Obtain locally	Loctite® #242
Liquid Gasket (RTV) (6 oz. tube)	1830858C1

Table of Contents

Removal.....	205
Oil Filter Base Assembly.....	205
Oil Cooler Cover Assembly.....	207
Oil Cooler Disassembly.....	208
Cleaning, Inspection, and Testing.....	208
Oil Cooler Cover and Oil Filter Base Assemblies.....	208
Pump Inlet Strainer.....	208
Oil Cooler Leaks.....	208
Installation.....	209
Oil Cooler Cover Assembly.....	209
Oil Filter Base Assembly.....	209
Specifications.....	212
Special Torque.....	212
Special Service Tools.....	212

EGES235-2

Read all safety instructions in the "Safety Information" section of this manual before doing any procedures.

Follow all warnings, cautions, and notes.

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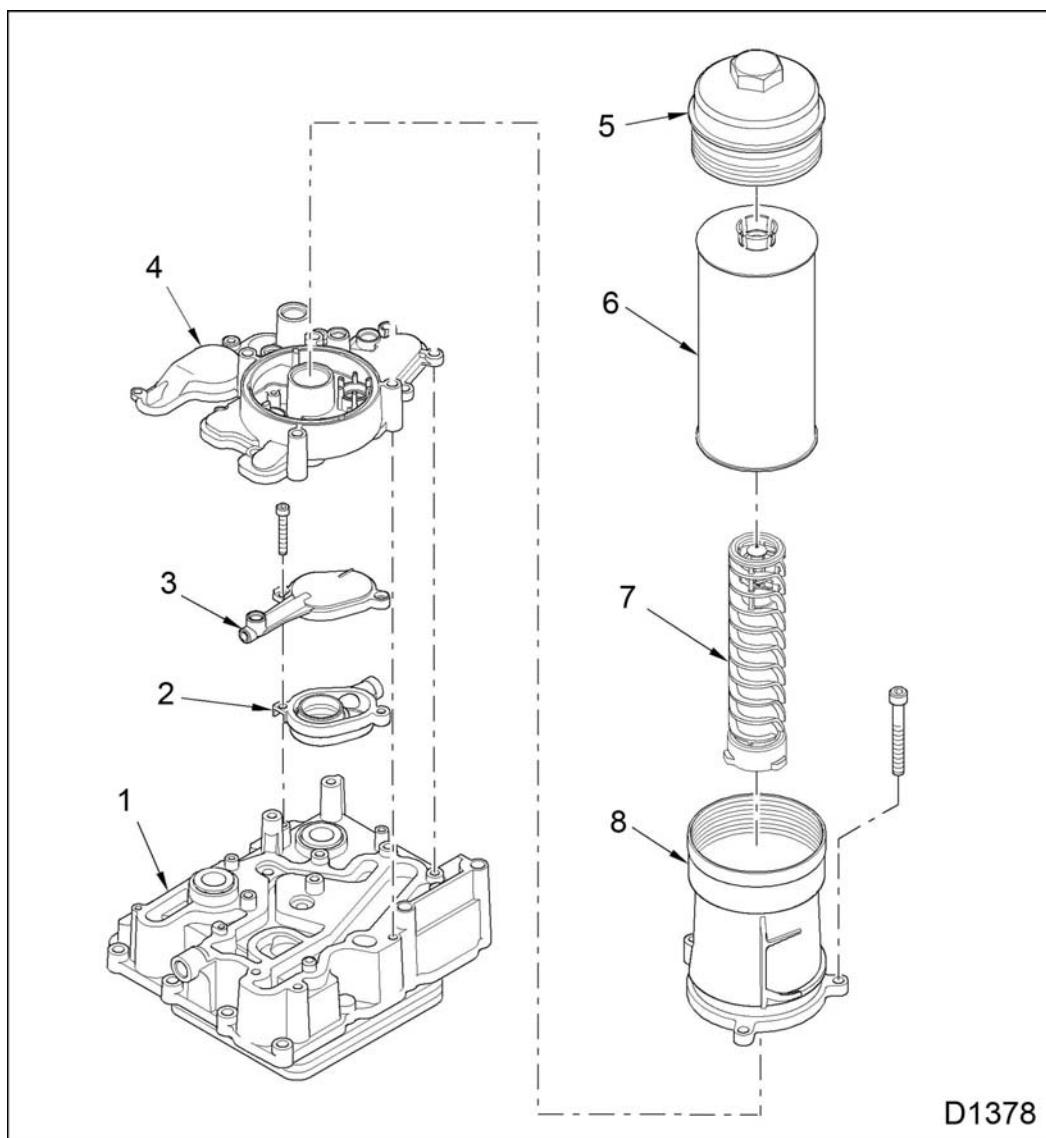


Figure 341 Oil cooler cover and filter housing assembly

- | | | |
|----------------------------------|------------------------------|---------------------------|
| 1. Oil cooler and cover assembly | 4. Oil filter base | 7. Oil filter return tube |
| 2. EGR coolant supply port | 5. Oil filter cap and O-ring | 8. Oil filter housing |
| 3. EGR coolant supply port cover | 6. Oil filter element | |

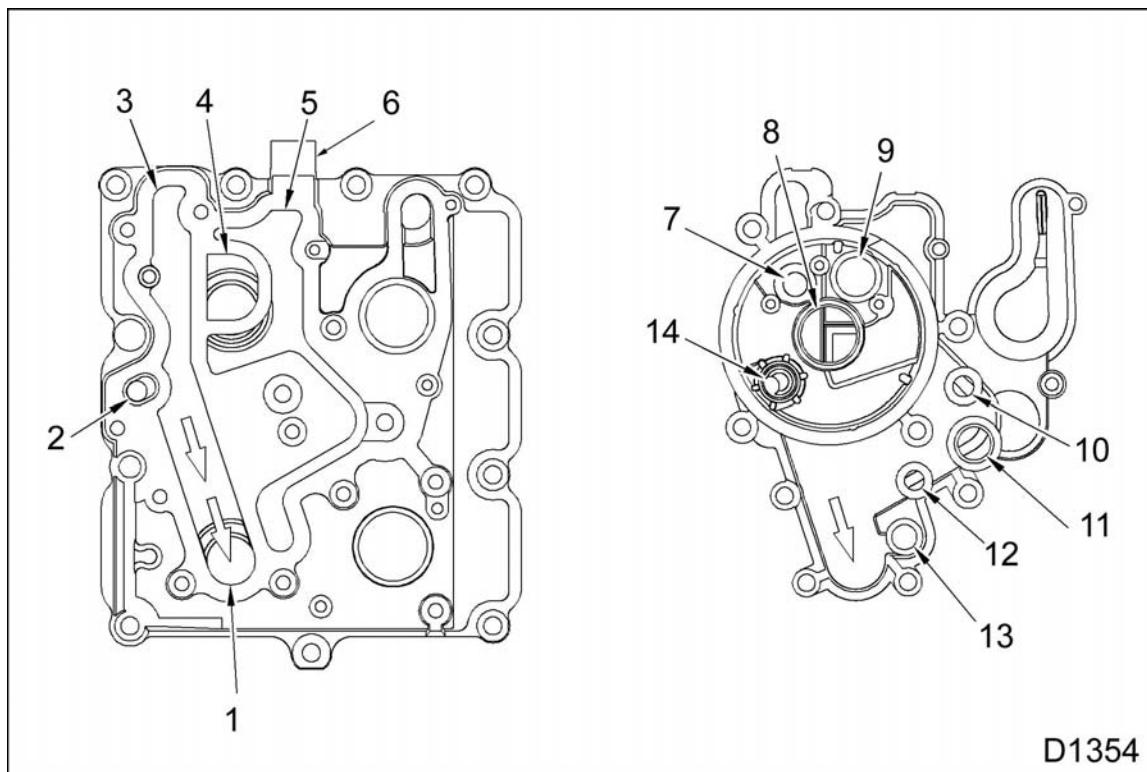


Figure 342 Oil cooler cover and oil filter base

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

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 service or diagnostic procedures.

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

Oil Filter Base Assembly



Figure 343 Oil filter cap

! WARNING: To prevent personal injury or death, do not allow engine fluids to stay on your skin. Clean skin and nails with hand cleaner and soap and water. Wash or dispose of clothing or rags containing engine fluids.

NOTE: Engine fluids (oil, fuel, and coolant) are a threat to the environment. Recycle or dispose of engine fluids according to local regulations. Never put engine fluids in the trash, on the ground, in sewers or other bodies of water.

1. Remove oil filter cap and filter element. Discard filter element and oil filter cap seal.

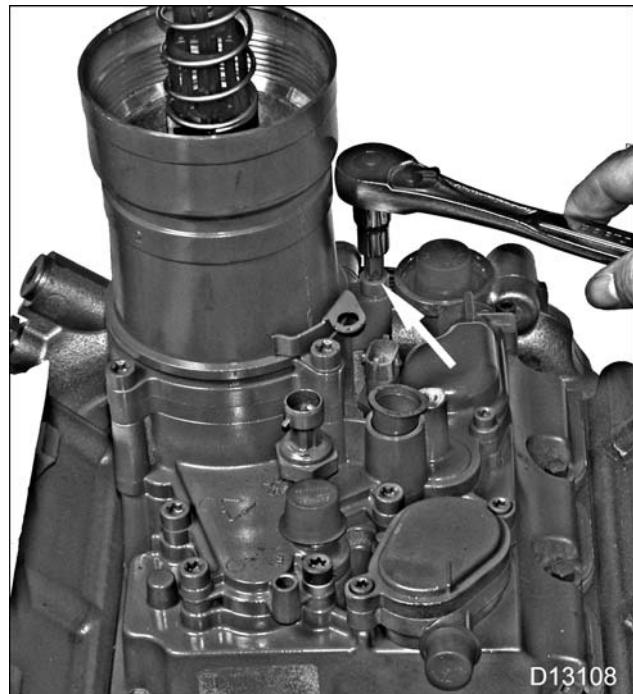


Figure 344 Oil filter housing mounting bolts (4)

2. Remove four M8 x 75 mounting bolts from the oil filter housing and remove housing. Discard the filter housing base seal.



Figure 345 Oil filter return tube

3. To remove the oil filter return tube, remove M5 x 18 lock screw and turn tube counterclockwise and lift up.
4. Remove and discard oil filter return tube gasket.

NOTE: Oil filter base does not have to be removed in order to remove the oil cooler assembly.



Figure 346 EGR cooler coolant supply port cover bolts

5. Remove EGR cooler coolant supply port cover bolts (2) and remove cover and discard seal.

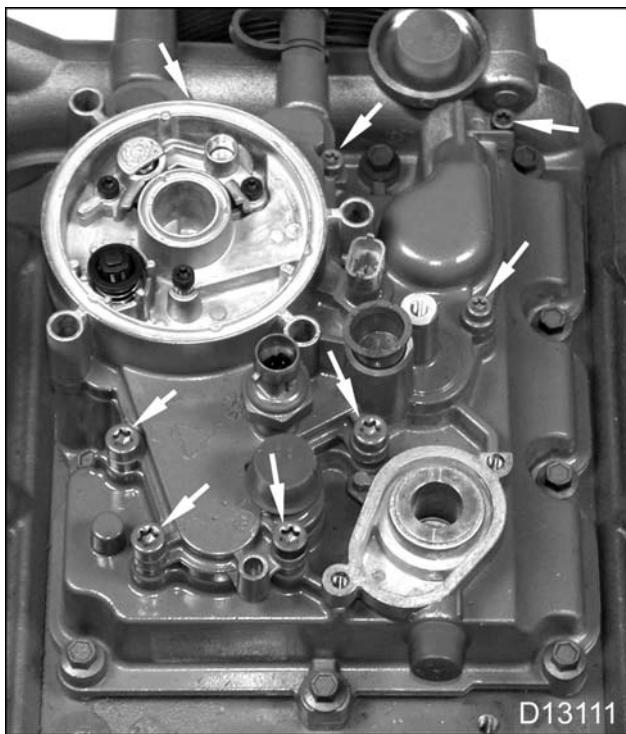


Figure 347 Oil filter base bolts

6. Remove eight mounting bolts from oil filter base assembly.

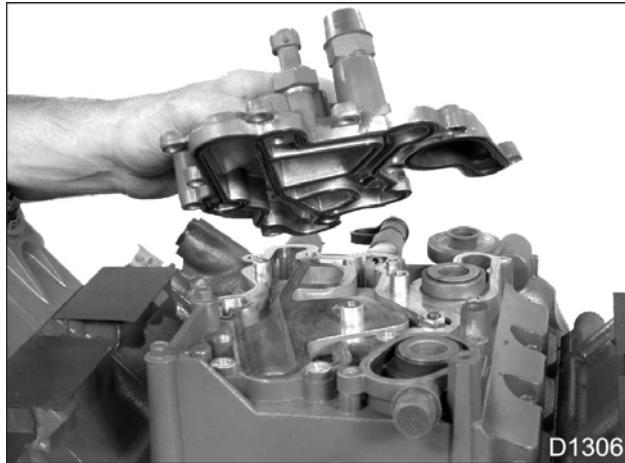


Figure 348 Removing oil filter base assembly

7. Lift oil filter base assembly off oil cooler cover assembly.
8. Remove and discard gasket.

Oil Cooler Cover Assembly

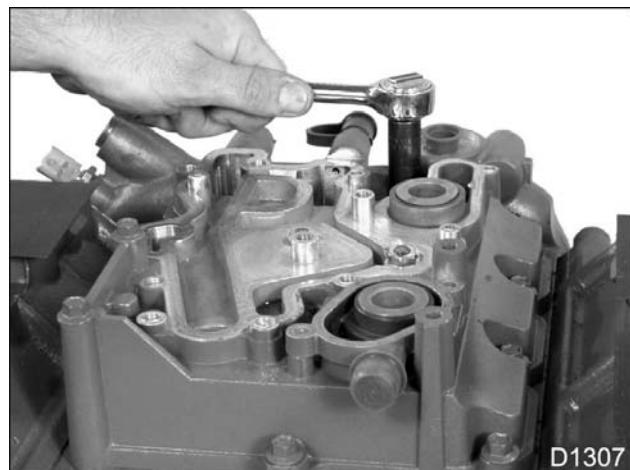


Figure 349 Mounting bolts for oil cooler cover assembly

1. Remove eight M8 x 30 and two M8 x 85 mounting bolts from oil cooler cover assembly.

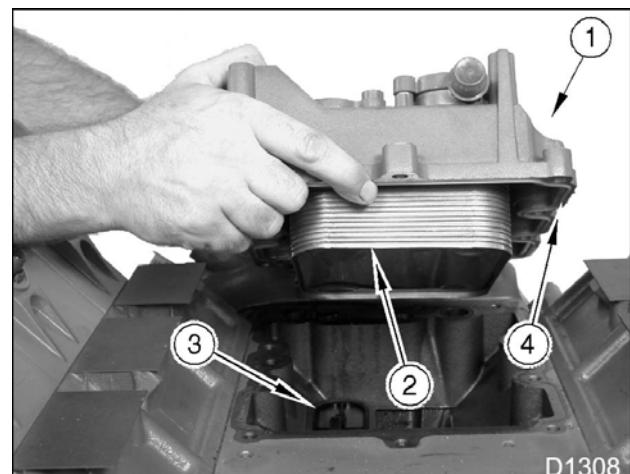


Figure 350 Oil cooler cover assembly

1. Oil cooler cover assembly
2. Oil cooler
3. Pump inlet strainer (150 micron)
4. Reservoir cover gasket
2. Remove oil cooler cover assembly from crankcase.
3. Remove and discard reservoir cover gasket.
4. Remove oil from reservoir.

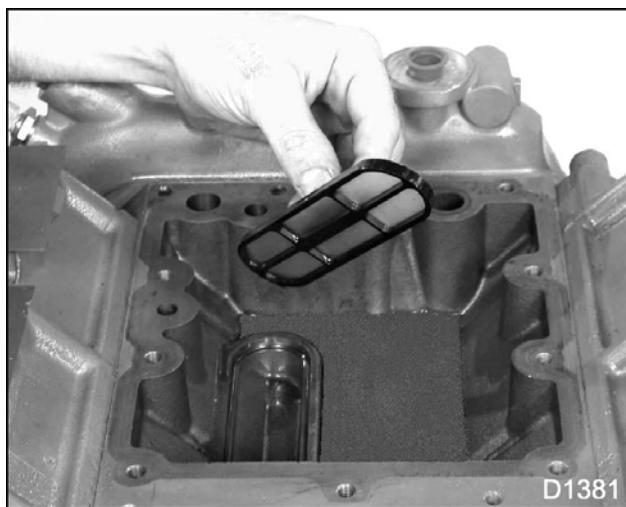


Figure 351 Pump inlet strainer

5. Remove pump inlet strainer from oil reservoir.

Oil Cooler Disassembly

CAUTION: If a catastrophic engine failure occurred, install a new oil cooler cover assembly and oil cooler. Debris cannot be removed from the oil cooler.

NOTE: Do the air pressure leakage test (Oil Cooler Leaks, page 208). If the oil cooler test indicates leakage, install new oil cooler cover assembly (w/oil cooler). Serviceable parts are not available.

Cleaning, Inspection, and Testing

Oil Cooler Cover and Oil Filter Base Assemblies

1. Drain and flush oil cooler cover, oil filter base, and housing to remove internal residue.
2. Dry all components thoroughly with filtered compressed air. (page 3)

Pump Inlet Strainer

1. Inspect the pump inlet strainer for tears or damage. Replace if necessary.

Oil Cooler Leaks

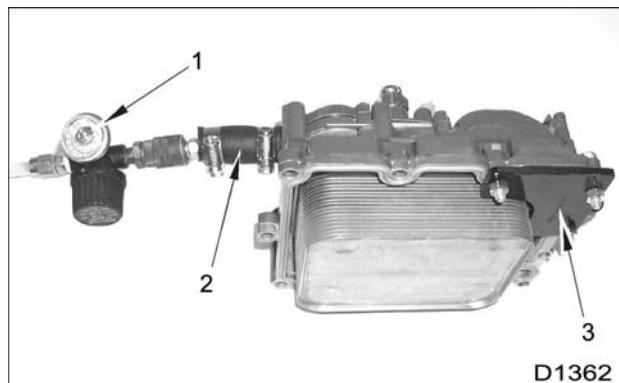


Figure 352 Air pressure leakage test

1. Air pressure regulator
2. Air adapter (make locally)
3. Oil Cooler Pressure Test Plate

NOTE: The oil filter base must be installed on the oil cooler cover assembly before a pressure test can done.

1. Fasten Oil Cooler Pressure Test Plate (Table 26) to oil cooler.
2. Install air pressure gauge to EGR cooler coolant outlet port.
3. Spray soapy water around the oil cooler and oil filter base.

CAUTION: To prevent engine damage, do not submerge into water. Submerging could allow water to be introduced into oil passages, causing engine damage during initial startup.

4. Apply 207 kPa (30 psi) of air pressure.
5. If leaking, bubbles will be present between the oil cooler and cover. Replace assembly as required.
6. Remove soapy water residue. Blow off with compressed air. (page 3)

Installation

Oil Cooler Cover Assembly

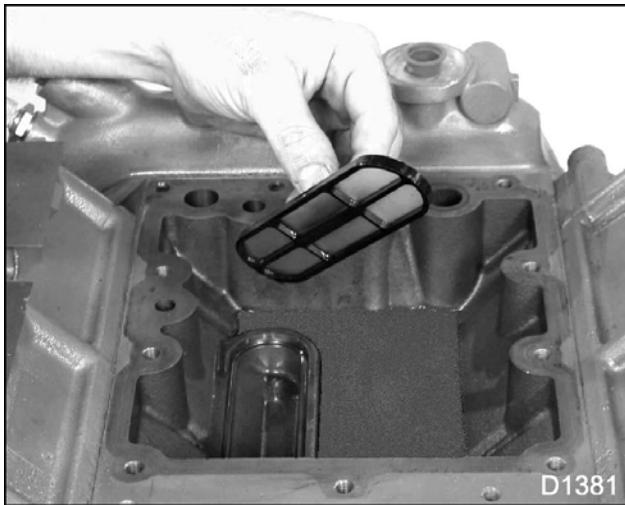


Figure 353 Pump inlet strainer (150 micron)

1. Install a clean pump inlet strainer to the oil reservoir.
2. Make sure dirt, sludge or debris does not restrict oil flow from crankcase to the hydraulic oil pump.
3. Add oil to correct level in oil reservoir.

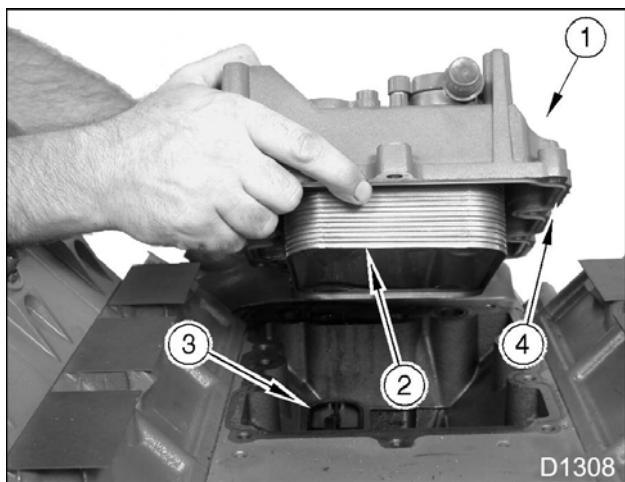


Figure 354 Oil cooler cover assembly

1. Oil cooler cover assembly
2. Oil cooler
3. Pump inlet strainer
4. Reservoir cover gasket

4. Install a new reservoir cover gasket onto the oil cooler cover assembly.
5. Lower oil cooler cover assembly onto engine crankcase.

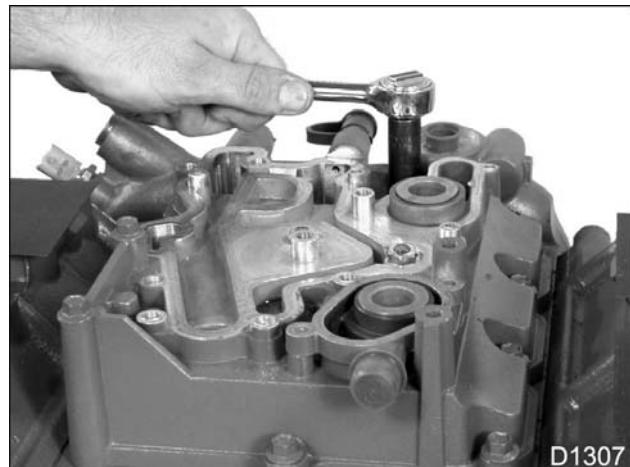


Figure 355 Mounting bolts for oil cooler cover assembly

6. Install eight M8 x 30, and two M8 x 85 mounting bolts into the oil cooler cover assembly. Tighten mounting bolts to the special torque (Table 25).

Oil Filter Base Assembly

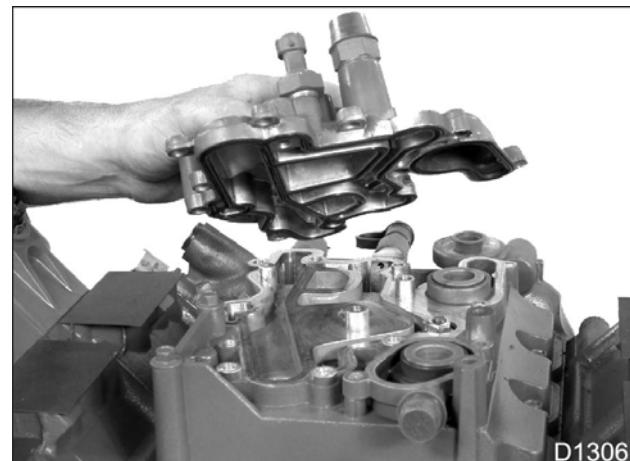


Figure 356 Oil filter base assembly

1. Install a new gasket set onto the oil filter base.

2. Install a new oil filter return tube gasket and filter housing to base seal. Coat gaskets and seals with clean engine oil.
3. Install oil filter base onto oil cooler cover assembly.

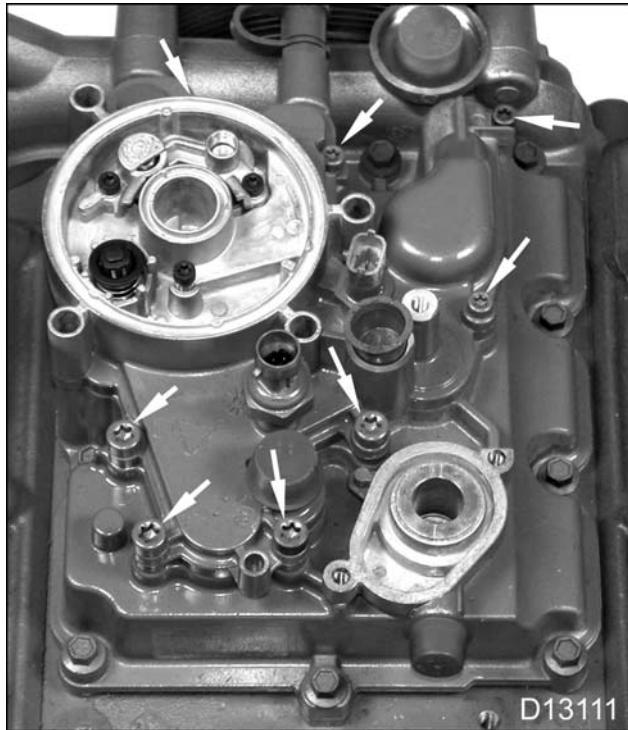


Figure 357 Installing oil filter base bolts

4. Install five M8 x 23 bolts, and three M6 x 25 bolts into the oil filter base assembly (Figure 357). Tighten all bolts to the special torque (Table 25).



Figure 358 EGR cooler coolant supply port cover bolts

5. Install a new seal on the EGR cooler coolant supply port cover and secure with two M6 x 25 bolts. Tighten bolts to the special torque (Table 25).

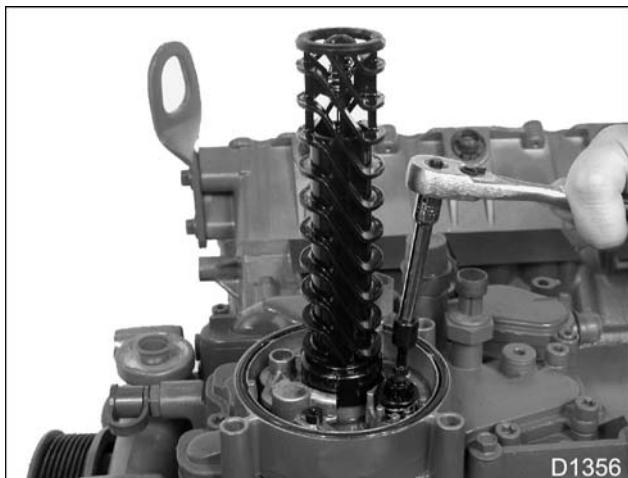


Figure 359 Oil filter return tube

6. Install oil filter return tube by pushing in and rotating clockwise to lock in place, while aligning

hold down tab with bolt hole in oil filter base. Tighten M5 x 18 lock screw to the special torque (Table 25).

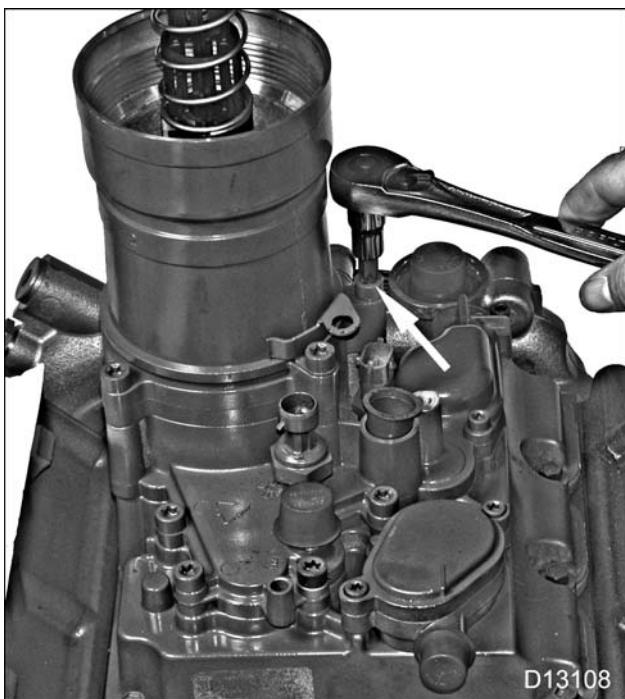


Figure 360 Oil filter housing mounting bolts

7. Install oil filter housing and four M8 x 75 mounting bolts. Tighten bolts to the standard torque. (General Torque Guidelines, page333)

8. Install oil filter onto cap with new seal and thread assembly into oil filter housing. Tighten cap to the special torque (Table 25).

CAUTION: To prevent engine damage, add oil to the engine before starting. See *Engine Operation and Maintenance Manual* for the engine oil and filter service interval. Correct maintenance will prolong service life.

Correct oil viscosity for diesel engines is important for satisfactory operation, especially in cold weather. Follow the chart in the *Engine Operation and Maintenance Manual* to determine which oil viscosity is best suited for the expected temperature range.

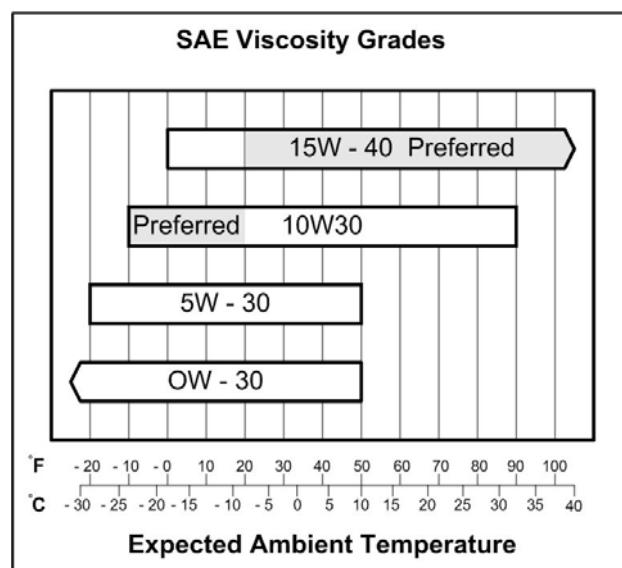


Figure 362 Lube Oil Recommendations



Figure 361 Oil filter and cap

9. Fill crankcase with oil. See *Operation and Maintenance Manual* for correct refill capacity or (Table 2).

NOTE: Engine fluids (oil, fuel, and coolant) are a threat to the environment. Recycle or dispose of engine fluids according to local regulations. Never put engine fluids in the trash, on the ground, in sewers or other bodies of water.

10. Start the engine and check for leaks. Fix leaks.
11. Shut down engine and check engine oil level. Add oil or drain oil as needed to bring oil level to the FULL mark on oil level gauge. Do not overfill past the FULL mark.

Specifications**Table 24**

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

Special Torque**Table 25**

EGR cooler coolant supply port cover (M6 x 25)	10 N·m (85 lbf-in)
Oil filter base bolts (M8 x 23)	23 N·m (17 lbf-ft)
Oil filter base bolts (M6 x 25)	10 N·m (85 lbf-in)
Lock screw (M5 x 18)	6.8 N·m (60 lbf-in)
Oil cooler mounting bolts (M8 x 30)	10 N·m (85 lbf-in)
Oil cooler mounting bolts (M8 x 85)	22 ± 2 N·m (17 ± 1 lbf-ft)
Oil filter return tube bolt	New base plate: 6 N·m (50 lbf-in) Reinstallation: 3 N·m (23 lbf-in)
Oil filter cap	25 N·m (18 lbf-ft)

Special Service Tools**Table 26**

Tool Number	Description
ZTSE4525	Oil Cooler Pressure Test Plate
ZTSE4557	Magnetic Cover

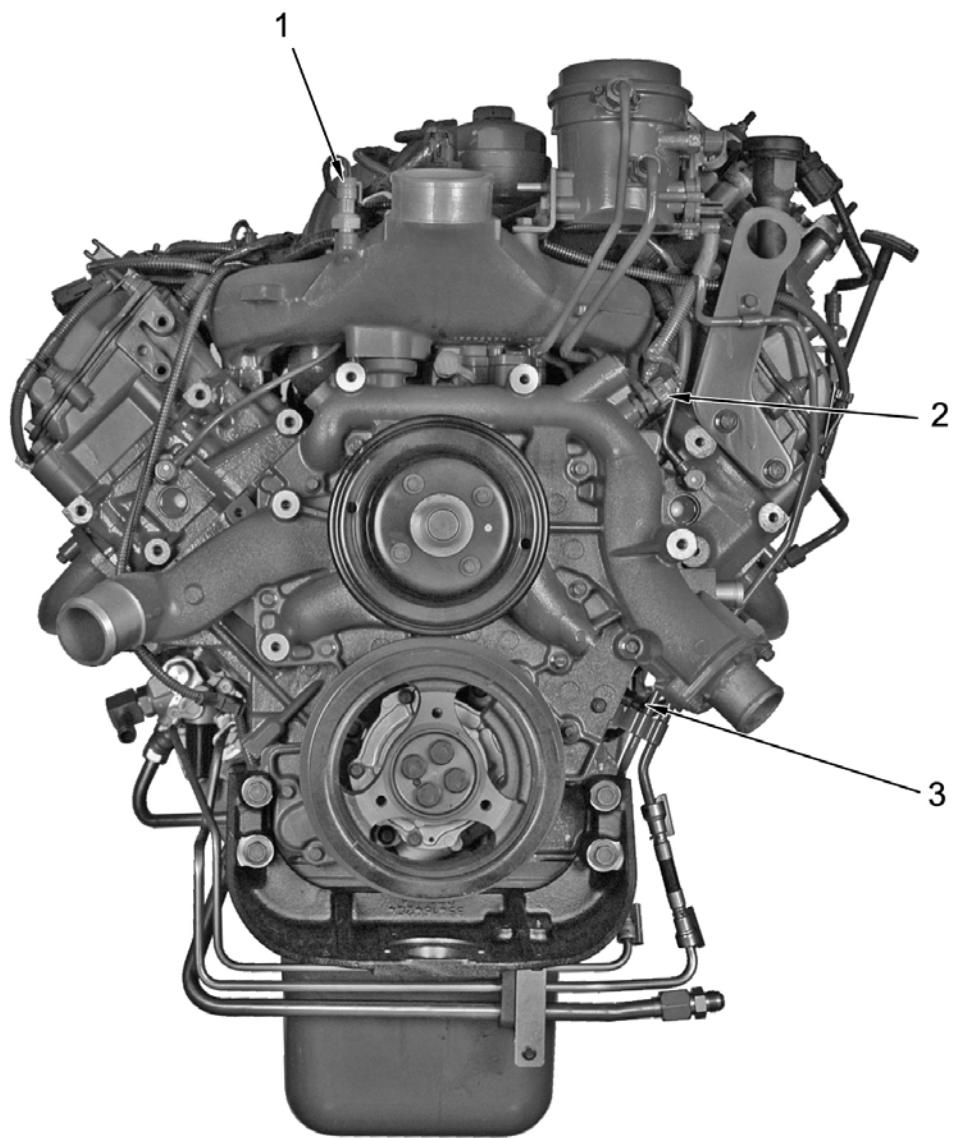
Table of Contents

Engine Electronic Components.....	215
Electronic Components – Front.....	215
Electronic Components – Left.....	216
Electronic Components – Rear.....	217
Electronic Components – Rear (detail).....	218
Electronic Components – Right.....	219
Electronic Components – Top.....	220
Engine Sensors and Valves.....	221
Crankshaft Position (CKP) Sensor.....	221
Camshaft Position (CMP) Sensor.....	221
Exhaust Back Pressure (EBP) Sensor.....	221
Engine Coolant Temperature (ECT) Sensor.....	222
Engine Oil Pressure (EOP) Sensor.....	222
Engine Oil Temperature (EOT) Sensor.....	222
Manifold Air Temperature (MAT) Sensor.....	222
Manifold Absolute Pressure (MAP) Sensor.....	223
Injection Control Pressure (ICP) Sensor.....	223
Injection Pressure Regulator (IPR) Valve.....	223
Variable Geometry Turbocharger (VGT) Control Valve.....	223
Exhaust Gas Recirculation (EGR) Valve	224
Removal.....	224
Crankshaft Position (CKP) Sensor.....	224
Camshaft Position (CMP) Sensor.....	225
Exhaust Back Pressure (EBP) Sensor.....	225
Engine Coolant Temperature (ECT) Sensor.....	225
Engine Oil Temperature (EOT) and Engine Oil Pressure (EOP) Sensors.....	226
Manifold Air Temperature (MAT) Sensor.....	226
Manifold Absolute Pressure (MAP) Sensor.....	226
Injection Control Pressure (ICP) Sensor and Injection Pressure Regulator (IPR) Valve.....	227
Variable Geometry Turbocharger (VGT) Control Valve.....	227
Exhaust Gas Recirculation (EGR) Valve.....	227
ECM and IDM Mounting Bracket.....	228
Main Engine Wiring Harness.....	230
Glow Plug Harness Busbar and Relay.....	230
Cleaning.....	231
Sensors.....	231
Glow Plug Harness Busbar.....	231
Inspection.....	231
Engine Sensors and Valves.....	231
ECM and IDM Assemblies	232
Main Engine Wiring Harness.....	232
Glow Plug Harness and Relay.....	232

Glow Plug Harness Busbar.....	232
Installation.....	233
Main Engine Wiring Harness.....	233
Crankshaft Position (CKP) Sensor.....	233
Camshaft Position (CMP) Sensor.....	233
Exhaust Back Pressure (EBP) Sensor.....	234
Engine Coolant Temperature (ECT) Sensor.....	234
Engine Oil Temperature (EOT) and Engine Oil Pressure (EOP) Sensors.....	234
Manifold Air Temperature (MAT) Sensor.....	235
Manifold Absolute Pressure (MAP) Sensor.....	235
Injection Control Pressure (ICP) Sensor and Injection Pressure Regulator (IPR) Valve.....	235
Variable Geometry Turbocharger (VGT) Assembly.....	236
Exhaust Gas Recirculation (EGR) Valve.....	236
Glow Plug Relay and Bracket.....	237
Glow Plug Harness Busbar.....	237
ECM and IDM Assemblies.....	237
Specifications.....	240
Special Torque.....	240
Special Service Tools.....	240

Engine Electronic Components

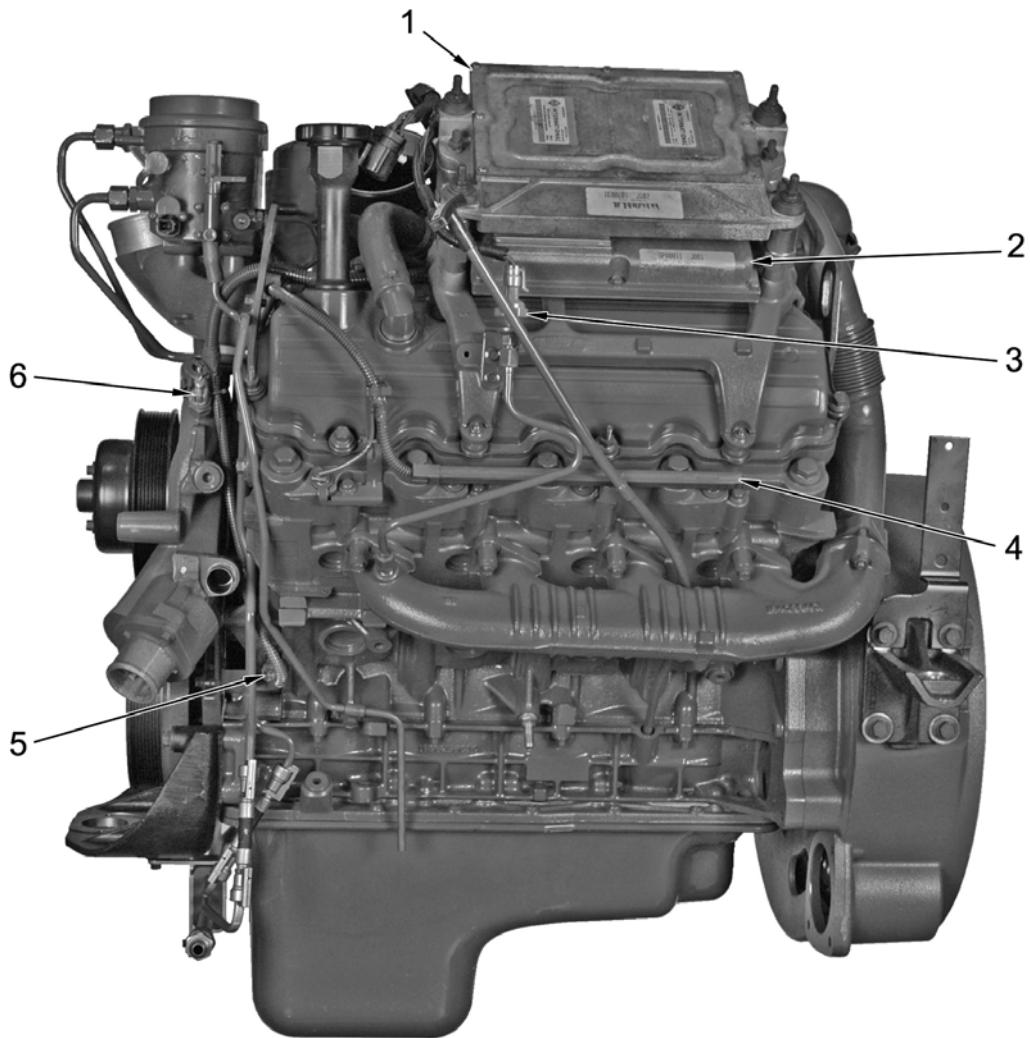
Electronic Components – Front



D31502

Figure 363 Electronic components – Front

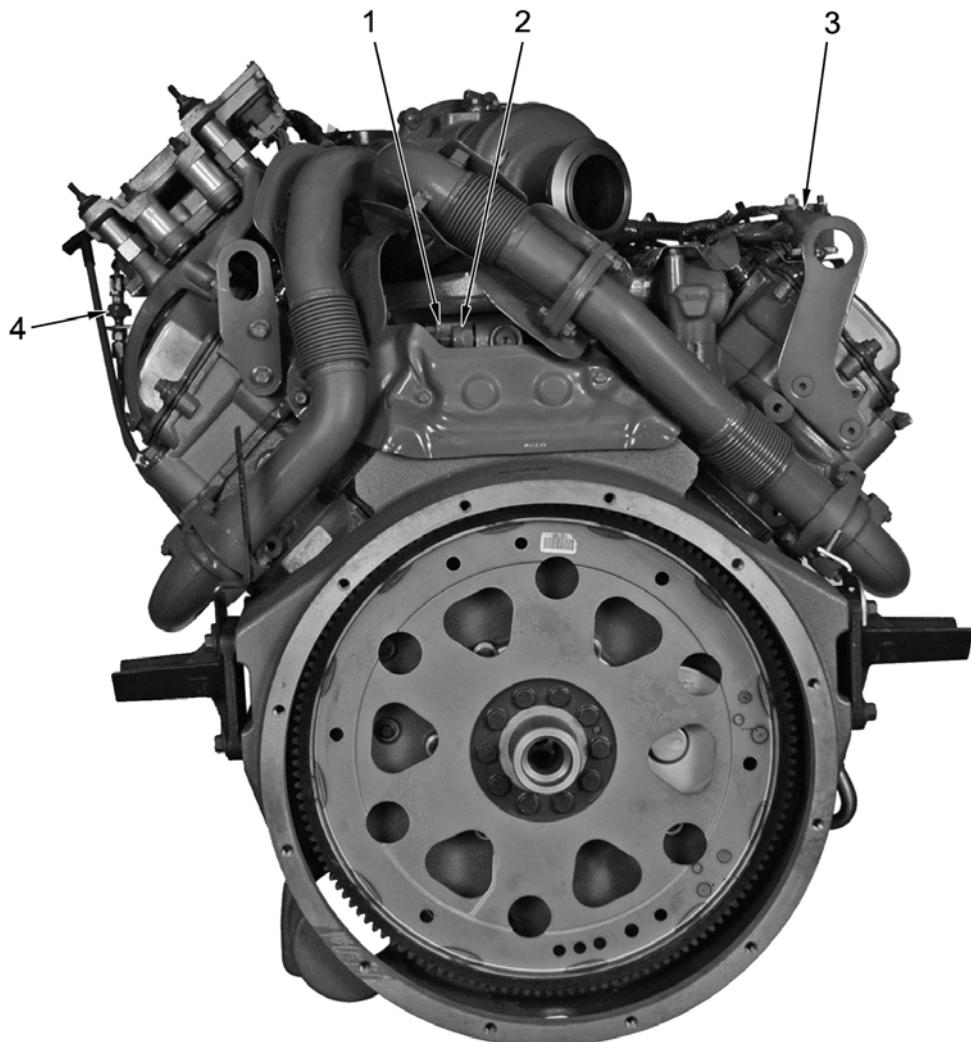
1. Manifold Absolute Pressure (MAP) sensor
2. Engine Coolant Temperature (ECT) sensor
3. Camshaft Position (CMP) sensor

Electronic Components – Left

D31485

Figure 364 Electronic components – Left

- | | | |
|------------------------------------|---------------------------------------|--|
| 1. Electronic control Module (ECM) | 3. Exhaust Back Pressure (EBP) sensor | 5. Camshaft Position (CMP) sensor |
| 2. Injector Driver Module (IDM) | 4. Glow plug harness rail | 6. Engine Coolant Temperature (ECT) sensor |

Electronic Components – Rear

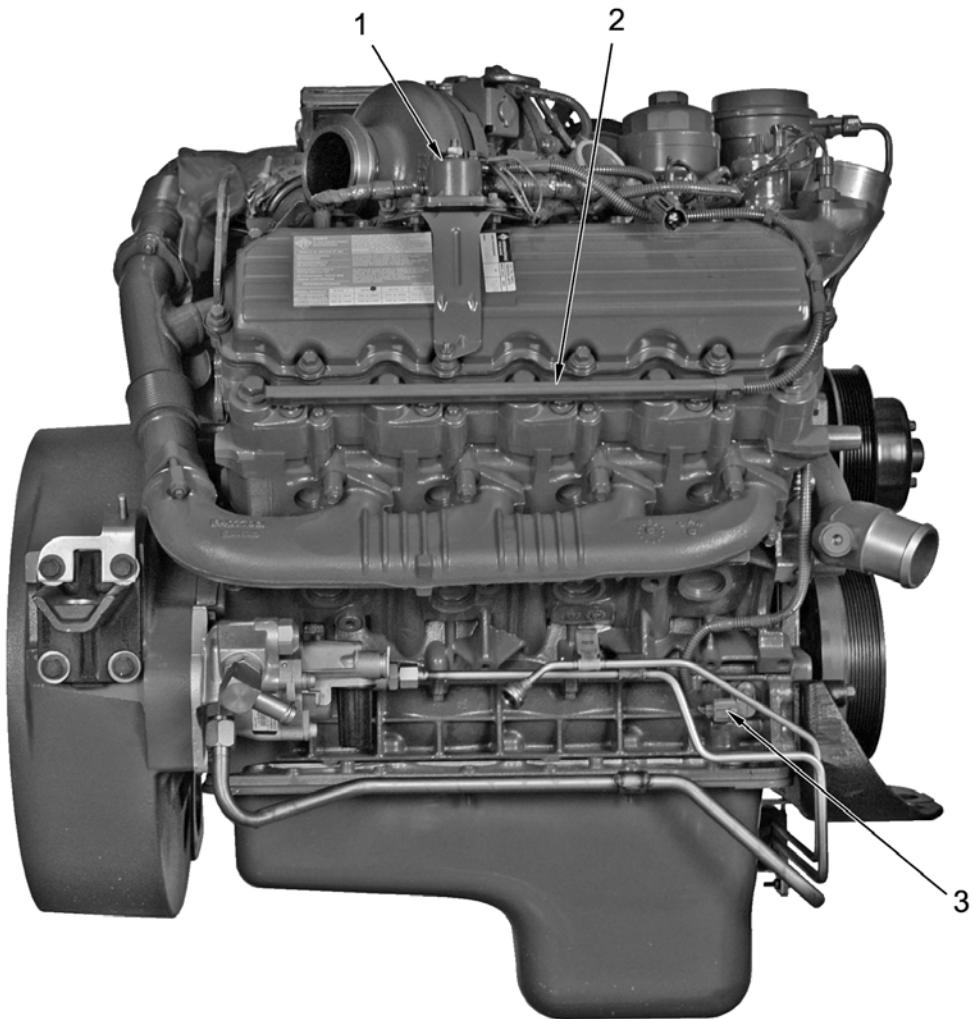
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Figure 365 Electronic components – Rear

1. Injection Pressure Regulator (IPR) valve
2. Injection Control Pressure (ICP) sensor
3. Glow plug relay
4. Exhaust Back Pressure (EBP) sensor

Electronic Components – Rear (detail)**Figure 366 Electronic components – Rear (detail)**

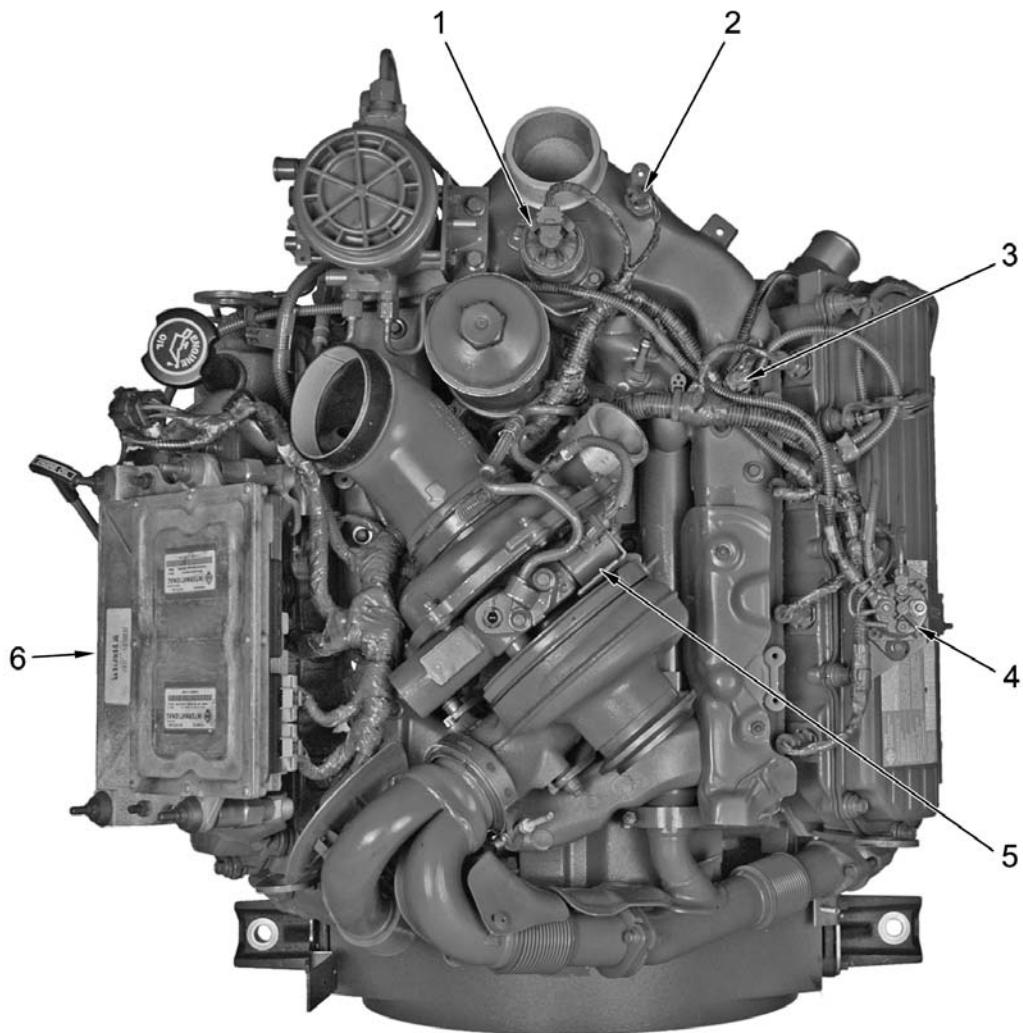
- | | |
|--|---|
| 1. Injection Pressure Regulator
(IPR) valve | 2. Injection Control Pressure (ICP)
sensor |
|--|---|

Electronic Components – Right

D31484

Figure 367 Electronic components – Right

- | | |
|---------------------------|------------------------------|
| 1. Glow plug relay | 3. Crankshaft Position (CKP) |
| 2. Glow plug harness rail | sensor |

Electronic Components – Top

D31483

Figure 368 Electronic components – Top

- | | | |
|--|--|---|
| 1. Exhaust Gas Recirculation (EGR) valve | 3. Manifold Air Temperature (MAT) sensor | 5. Variable Geometry Turbocharger (VGT) control valve |
| 2. Manifold Absolute Pressure (MAP) sensor | 4. Glow plug relay | 6. Electronic Control Module (ECM) |

Engine Sensors and Valves

NOTE: For information on diagnostics and troubleshooting, see the following publications:

- EGES-240 VT 365 *Engine Diagnostic Manual*
- EGED-245 VT 365 Hard Start/No Start Diagnostic Form
- EGED-250 VT 365 Engine Performance Diagnostic Form
- EGED-255 VT 365 Electronic Control System Diagnostic Form

Crankshaft Position (CKP) Sensor



Figure 369 CKP sensor

The CKP sensor, a magnetic pickup sensor, reads a timing disk on the crankshaft.

The CKP sensor provides the ECM with a signal that indicates crankshaft speed and position. As the crankshaft turns the CKP sensor reads a 60 tooth timing disk on the crankshaft. Teeth 59 and 60 are missing. By comparing the CKP signal with the CMP signal, the ECM calculates engine rpm and timing requirements.

The CKP is installed in the front right side of the lower crankcase.

NOTE: This short sensor measures crankshaft speed and position for INTERNATIONAL® VT 365 and VT 275 diesel engines; However, for INTERNATIONAL® DT 466, DT 570, and HT 570 diesel engines, this sensor measures camshaft speed and position, not crankshaft speed and position.

Camshaft Position (CMP) Sensor



Figure 370 CMP sensor

The CMP sensor, a magnetic pickup sensor, indicates camshaft speed and position.

The CMP sensor sends a pulsed signal to the ECM when a single peg on the camshaft rotates past the CMP sensor once during each revolution of the camshaft. The ECM calculates camshaft speed and position from CMP signal frequency.

The CMP sensor is installed in the front left side of the crankcase.

NOTE: This long sensor measures camshaft speed and position for INTERNATIONAL® VT 365 and VT 275 diesel engines; However, for INTERNATIONAL® DT 466, DT 570, and HT 570 diesel engines, this sensor measures crankshaft speed and position, not camshaft speed and position.

Exhaust Back Pressure (EBP) Sensor

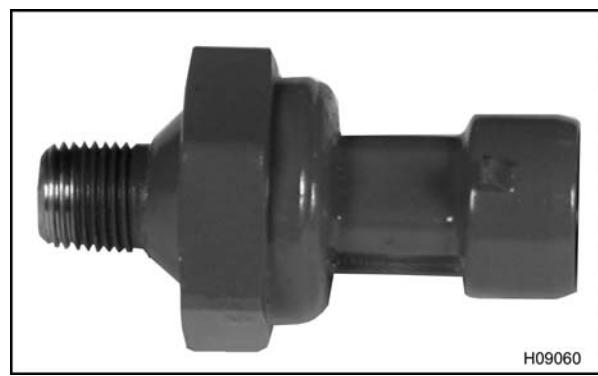


Figure 371 EBP sensor

The EBP sensor, a ceramic diaphragm sensor, measures exhaust back pressure before the turbocharger.

The EBP sensor provides feedback to the ECM for closed loop control of the VGT and for EGR position calculations.

The EBP sensor is mounted on a bracket on the left side of the engine below the ECM.

Engine Coolant Temperature (ECT) Sensor

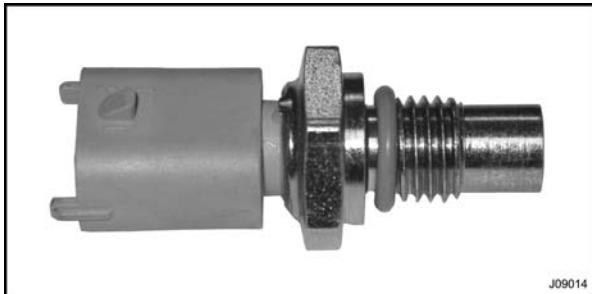


Figure 372 ECT sensor

The ECT sensor, a thermistor sensor, detects engine coolant temperature.

The ECT signal is monitored by the ECM for operation of the instrument panel temperature gauge, coolant temperature compensation, optional Engine Warning Protection System (EWPS), glow plugs, and the wait to start lamp. The ECM will use ECT sensor input as a backup, if EOT sensor values are out of range.

The ECT sensor is installed in the left side of the front cover.

Engine Oil Pressure (EOP) Sensor

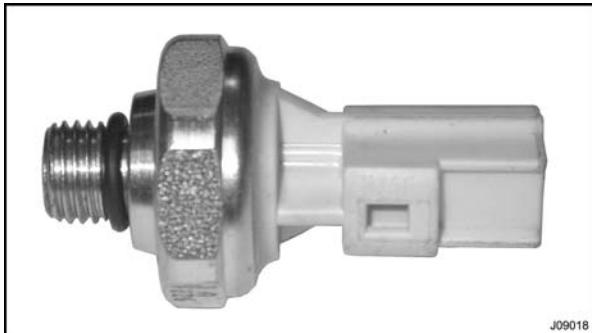


Figure 373 EOP sensor

The EOP sensor, a ceramic diaphragm sensor, detects engine oil pressure.

The EOP signal is monitored by the ECM for operation of the instrument panel pressure gauge and optional EWPS.

The EOP sensor is installed in the oil filter base.

Engine Oil Temperature (EOT) Sensor

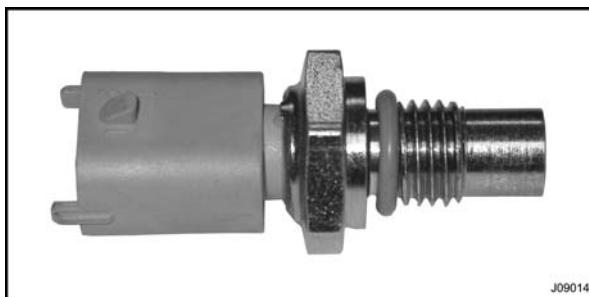


Figure 374 EOT sensor

The EOT sensor, a thermistor sensor, detects engine oil temperature.

The EOT signal is monitored by the ECM to control EGR, VGT, and for engine fueling calculations throughout the operating range of the engine. The EOT signal allows the ECM and IDM to compensate for differences in oil viscosity, due to temperature changes.

The EOT sensor is installed in the oil filter base.

Manifold Air Temperature (MAT) Sensor

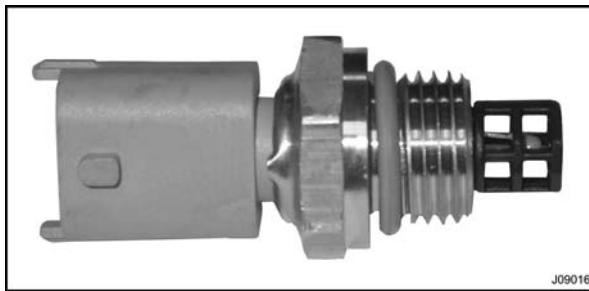


Figure 375 MAT sensor

The MAT sensor, a thermistor sensor, detects intake manifold air temperature.

The MAT signal is monitored by the ECM for EGR operation.

The MAT sensor is installed in the right front of the intake manifold.

Manifold Absolute Pressure (MAP) Sensor

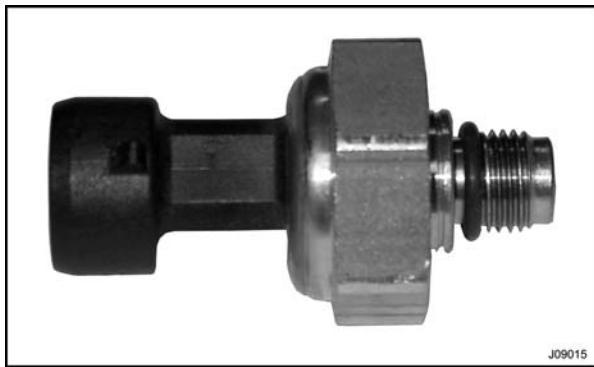


Figure 376 MAP sensor

The MAP sensor, a ceramic diaphragm sensor, detects intake manifold boost pressure.

The MAP signal is monitored by the ECM for EGR position and engine fueling calculations.

The MAP sensor is installed in the top front of the intake manifold.

Injection Control Pressure (ICP) Sensor



Figure 377 ICP sensor

The ICP sensor, a micro-strain gauge sensor, measures injection control pressure.

The ICP signal is monitored by the ECM for closed loop control of the IPR valve. The ICP signal is also used by the IDM for engine fueling calculations.

The ICP sensor is installed in the left rear side of the high-pressure oil pump.

Injection Pressure Regulator (IPR) Valve

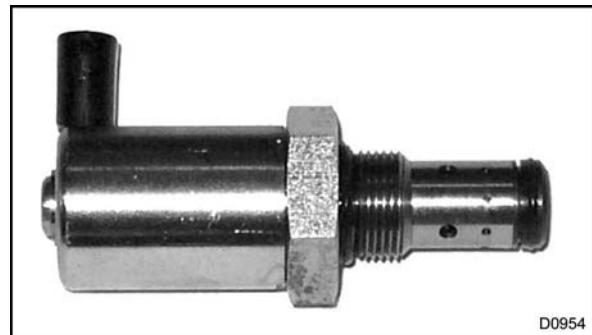


Figure 378 IPR valve

The IPR valve, a variable position Pulse Width Modulated (PWM) valve, regulates injection control pressure, which actuates the fuel injectors.

The IPR valve is controlled by the ground circuit in the ECM in response to ICP sensor input. Voltage is supplied through the ignition switch. The IPR valve includes a high pressure relief valve which releases excessive injection control pressure.

The IPR valve is installed in the left rear side of the high-pressure oil pump.

Variable Geometry Turbocharger (VGT) Control Valve

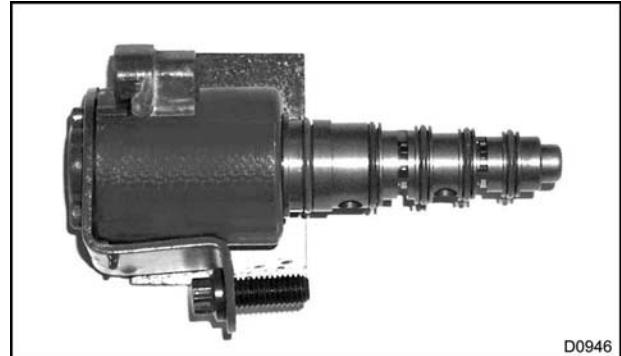


Figure 379 VGT control valve

The VGT control valve, a variable position duty cycle valve, controls turbocharger vane position.

The VGT valve is controlled by a pulse width modulated signal from the ECM in response to engine speed, required fuel quantity, boost, exhaust back pressure, and altitude. Engine lube oil pressure is used to control the movement of vanes, linked by a unison ring, within the turbine housing. Turbine exhaust gas flow and VGT boost are modified by vane position. The ground circuit is supplied directly from battery ground at all times.

The VGT control valve is installed in the top right side of the VGT.

Exhaust Gas Recirculation (EGR) Valve



Figure 380 EGR Valve

The EGR valve, an electromechanical valve, recirculates cooled exhaust gases into the intake air stream to reduce NOx emissions.

The EGR valve has two components: a valve with actuator (DC motor with micro-controller) and a position sensor to monitor valve movement. The EGR valve is controlled by the EGR Drive Module, which receives commands over the CAN2 link from the ECM. The ECM sends a desired EGR valve position signal in response to engine speed, required

fuel quantity, boost, exhaust back pressure, and altitude.

The EGR valve is installed in the front of the intake manifold behind the air inlet.

Removal

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

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

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

Crankshaft Position (CKP) Sensor

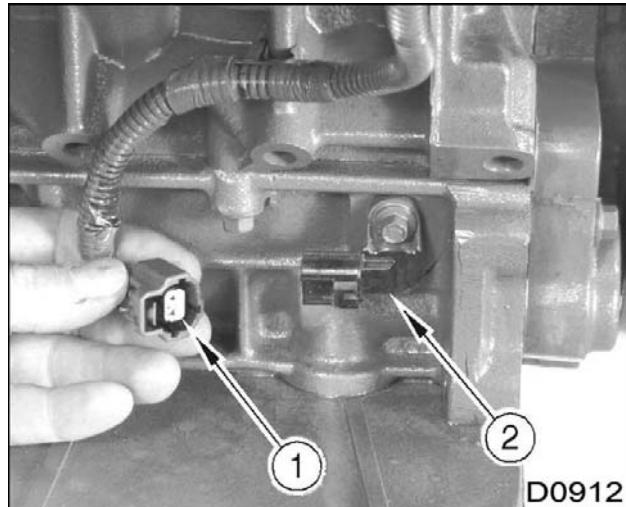


Figure 381 CKP sensor

1. Sensor connector
 2. CKP sensor
-
1. Disconnect 2-pin electrical connector from the CKP sensor installed in the front right side of the lower crankcase.

2. Remove the M6 x 14 retaining bolt from the CKP sensor.
3. Remove CKP sensor and discard O-ring.

Camshaft Position (CMP) Sensor

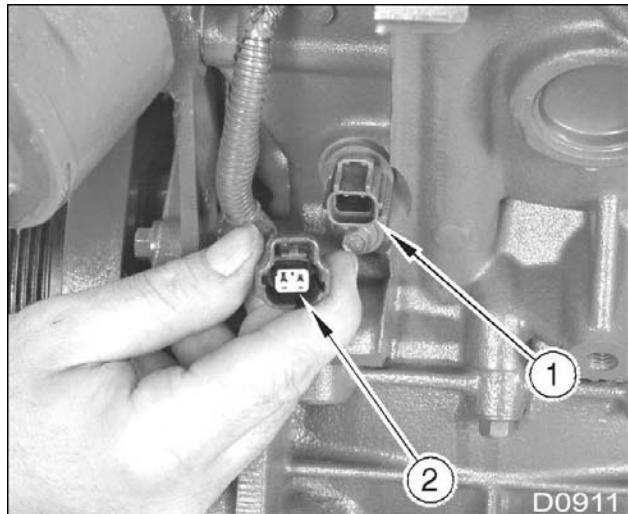


Figure 382 CMP Sensor

1. CMP sensor
2. Sensor connector

1. Disconnect the 2-pin engine harness connector from the CMP sensor installed in the front left side of the crankcase.
2. Remove the M6 x 14 retaining bolt from the CMP sensor.
3. Remove CMP sensor and discard both O-rings.

Exhaust Back Pressure (EBP) Sensor

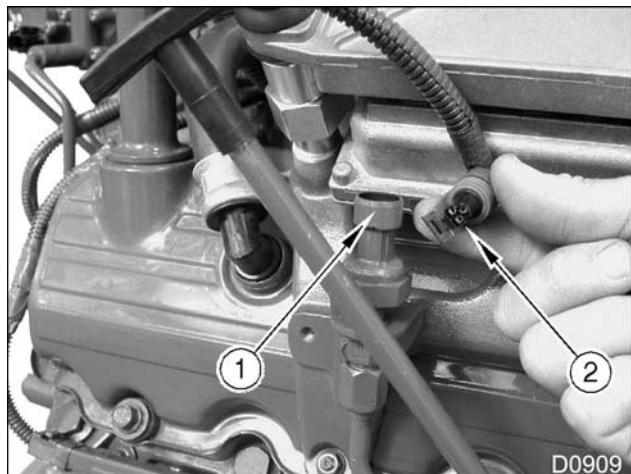


Figure 383 EBP sensor

1. EBP sensor
2. EBP sensor connector

1. Disconnect 3-pin electrical connector from EBP sensor mounted on a bracket on the left side of ECM / IDM bracket.
2. Unthread fitting on EBP tubing and remove EBP sensor.

Engine Coolant Temperature (ECT) Sensor

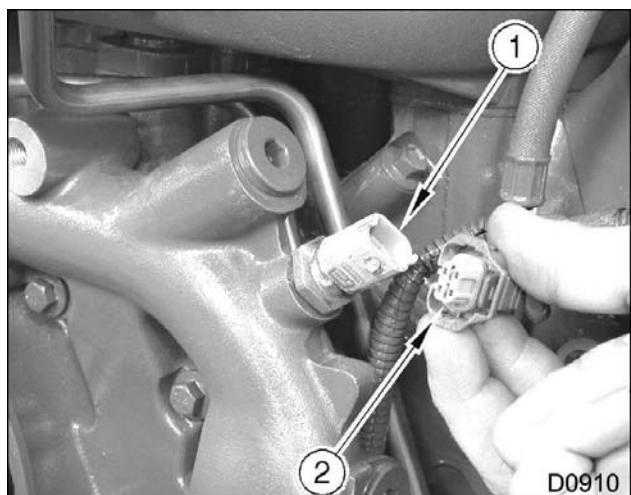


Figure 384 ECT sensor

1. ECT sensor
2. ECT sensor connector

1. Disconnect 2-pin electrical connector from the ECT sensor installed in the left side of the front cover.
2. Unscrew and remove ECT sensor. Discard O-ring.

Engine Oil Temperature (EOT) and Engine Oil Pressure (EOP) Sensors

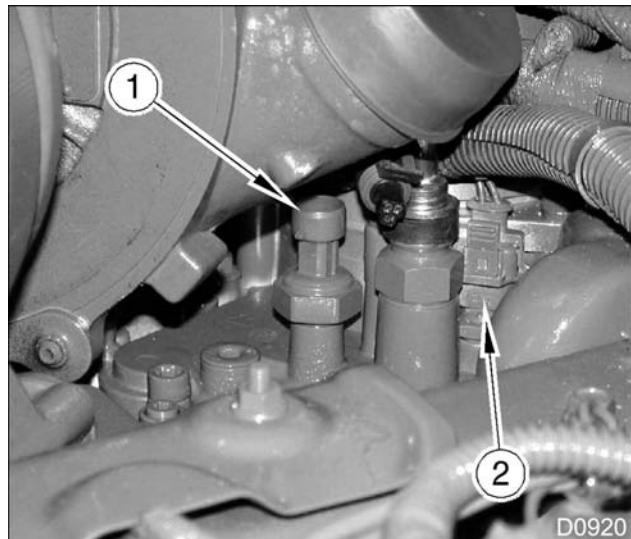


Figure 385 EOT and EOP sensors

1. EOP sensor
2. EOT sensor

1. Disconnect EOP and EOT electrical connectors from sensors installed in the oil filter base.
2. Unscrew and remove sensors. Discard O-rings.

Manifold Air Temperature (MAT) Sensor

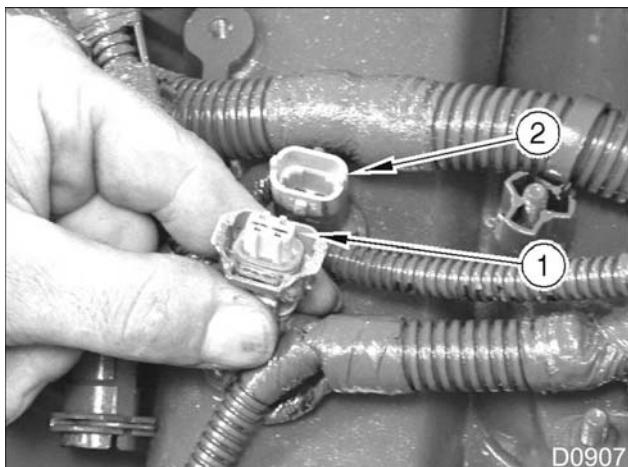


Figure 386 MAT sensor

1. MAT sensor connector
2. MAT sensor

1. Disconnect 2-pin electrical connector from the MAT sensor installed in the right side of intake manifold.
2. Unscrew and remove MAT sensor. Discard O-ring.

Manifold Absolute Pressure (MAP) Sensor

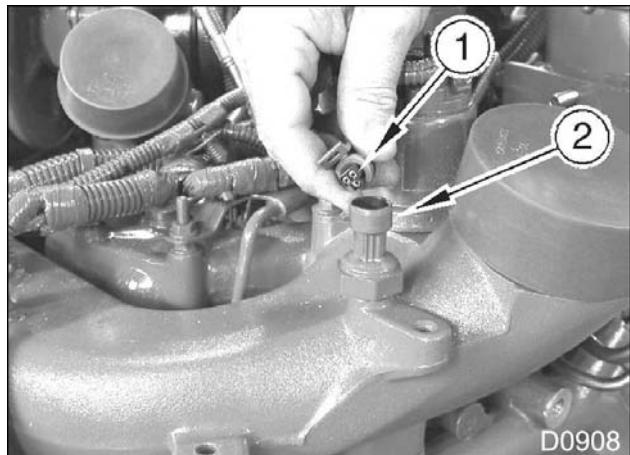


Figure 387 MAP sensor

1. MAP sensor connector
2. MAP sensor

1. Disconnect 3-pin electrical connector from the MAP sensor installed in the top front of the intake manifold.
2. Unscrew and remove MAP sensor. Discard O-ring.

Injection Control Pressure (ICP) Sensor and Injection Pressure Regulator (IPR) Valve

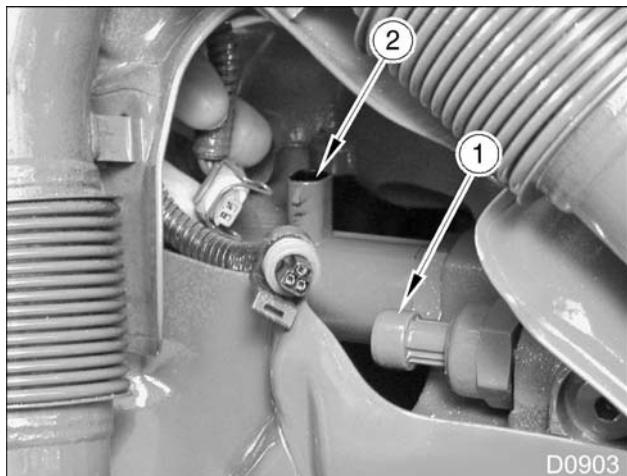


Figure 388 ICP sensor and IPR valve

1. 3-wire ICP sensor
2. 2-wire IPR valve

1. Disconnect ICP and IPR electrical connectors installed in the left side of the high pressure oil pump.
2. Unscrew and remove ICP sensor and IPR valve.
3. Remove and discard O-rings.

Variable Geometry Turbocharger (VGT) Control Valve

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

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

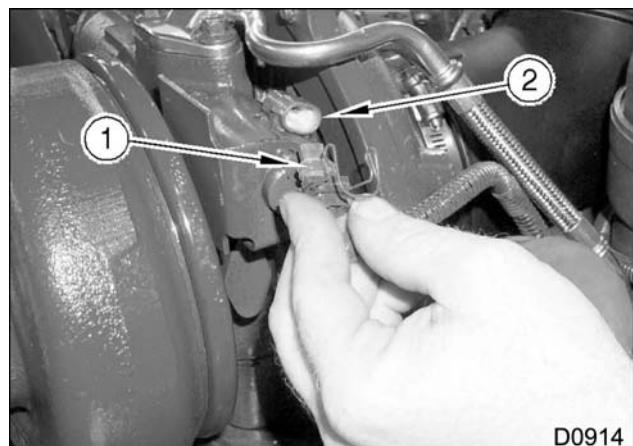


Figure 389 VGT Control Valve

1. VGT electrical connector
2. VGT harness connection

1. Disconnect VGT electrical connector installed in the top right side of the VGT assembly.
2. Remove M8 x 20 retaining bolt and bracket.
3. Pull VGT control valve straight out from center housing.

Exhaust Gas Recirculation (EGR) Valve

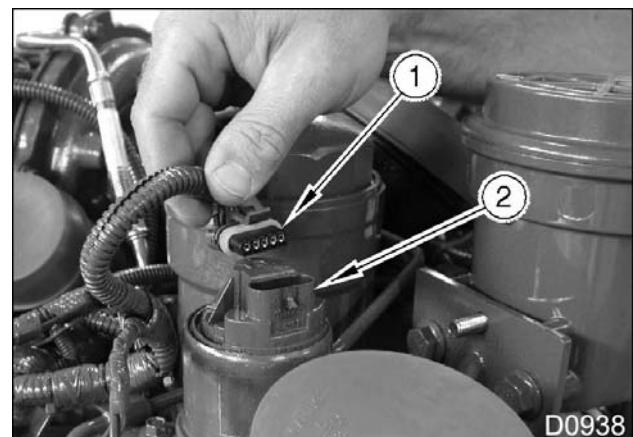


Figure 390 EGR valve

1. EGR valve electrical connector
2. EGR valve

1. Disconnect EGR valve electrical connector installed in the front top of the intake manifold.

2. Remove EGR valve (Exhaust Gas Recirculation Valve, page 70).
3. Remove and discard gasket and both O-rings.

CAUTION: To prevent engine damage, after removing the EGR valve only, vacuum loose carbon deposits and debris from inside the intake manifold.

ECM and IDM Mounting Bracket

WARNING: To prevent personal injury or death, disconnect the main negative battery terminal before removing or installing electrical components.

NOTE: The ECM and IDM can be removed without removing the mounting bracket.

1. Disconnect ground (-) cable from battery.

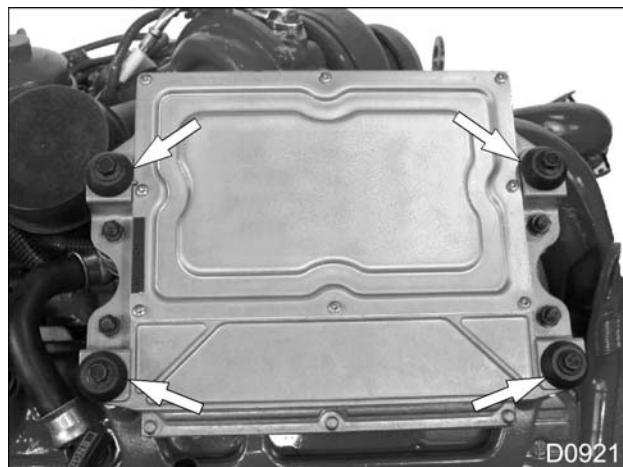


Figure 391 Mounting bolts for ECM and IDM assemblies

2. Remove four mounting bolts that secure ECM and IDM assemblies to mounting bracket.

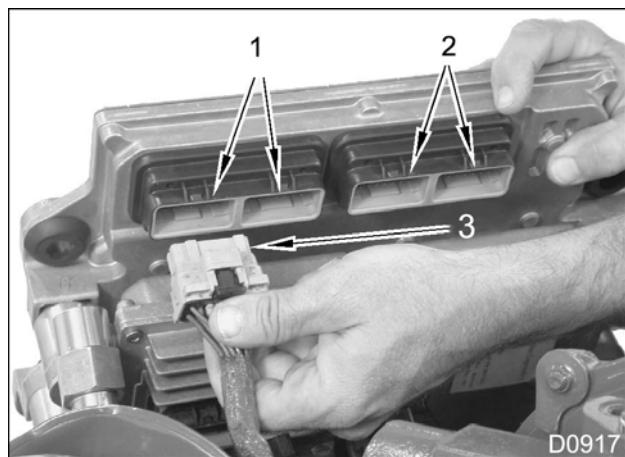


Figure 392 ECM harness connectors

1. ECM engine harness connection
2. ECM chassis harness connection
3. ECM engine harness connector (2)
3. Lift assembly and remove four ECM harness connections (two for engine and two for chassis).

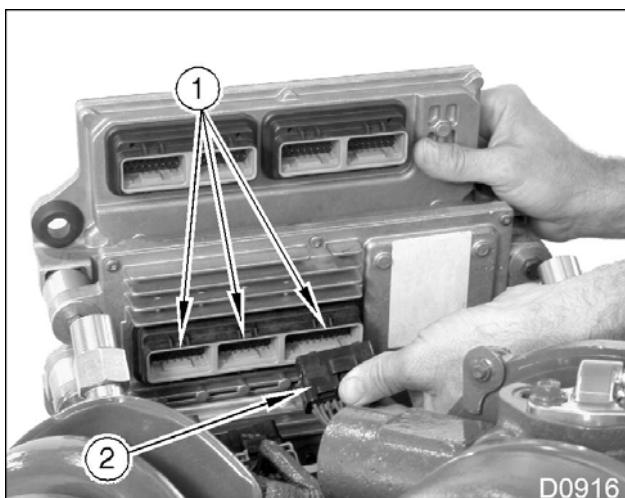


Figure 393 IDM harness connectors

1. IDM harness connection
2. IDM harness connector (3)
4. Remove three IDM harness connectors.

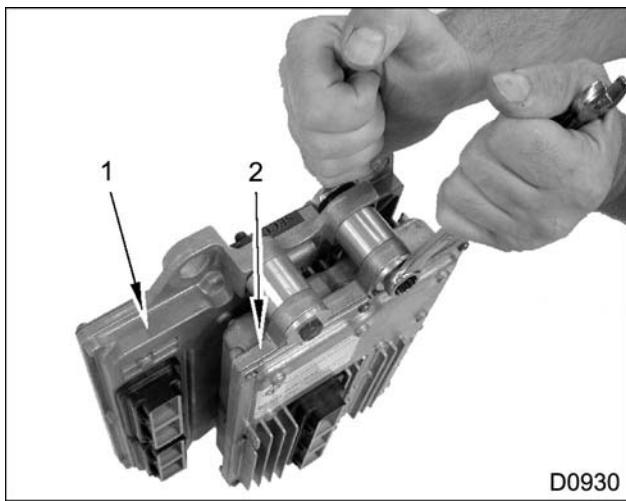


Figure 394 Separating the ECM and IDM

1. ECM
2. IDM

5. Separate ECM and IDM by removing four bolts and spacers.

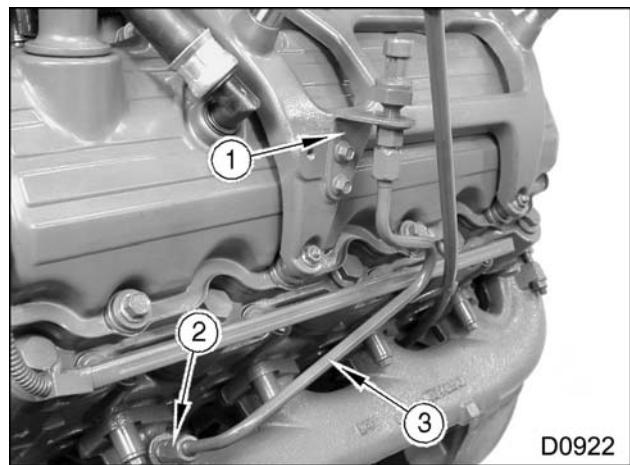


Figure 396 EBP sensor bracket and tubing

1. EBP sensor bracket
2. Tube fitting
3. Tube

7. Remove EBP sensor bracket and tubing to exhaust manifold.

NOTE: It is not necessary to remove the ECM and IDM bracket, if engine repairs are not necessary.

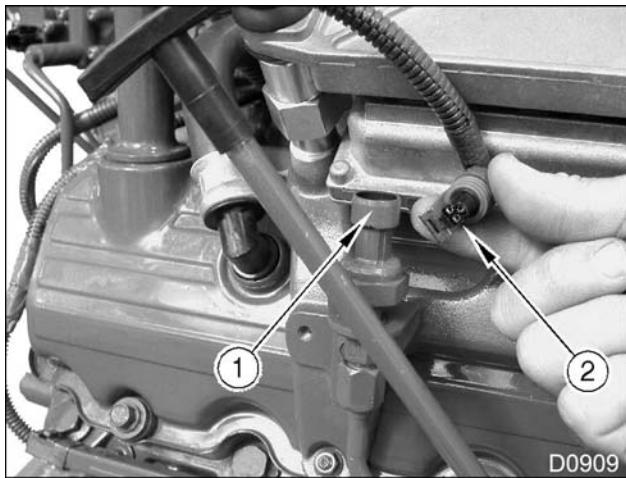


Figure 395 EBP sensor harness connector

1. EBP sensor
2. EBP sensor harness connector

6. Remove EBP sensor harness connector.

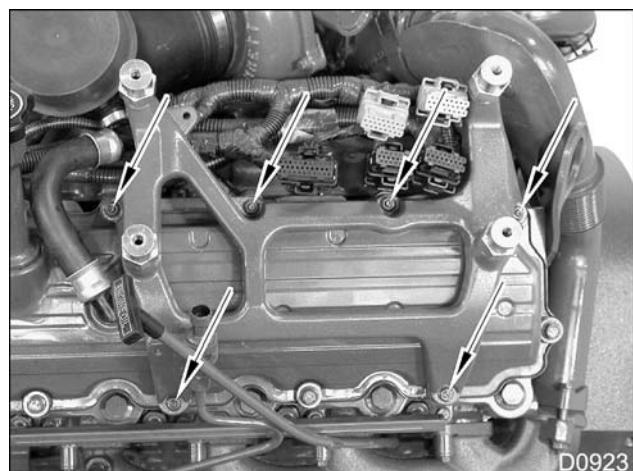


Figure 397 Bolts for ECM and IDM mounting bracket

8. Remove six nuts and ECM and IDM mounting bracket from engine.

Main Engine Wiring Harness

WARNING: To prevent personal injury or death, disconnect the main negative battery terminal before removing or installing any electrical components.

NOTE: The electrical harness does not need to be disconnected from the relay, unless the harness or relay is being replaced. Instead, the two relay mounting bolts or the three relay bracket bolts may be removed from the valve cover.

1. Disconnect ground (-) cable from battery.

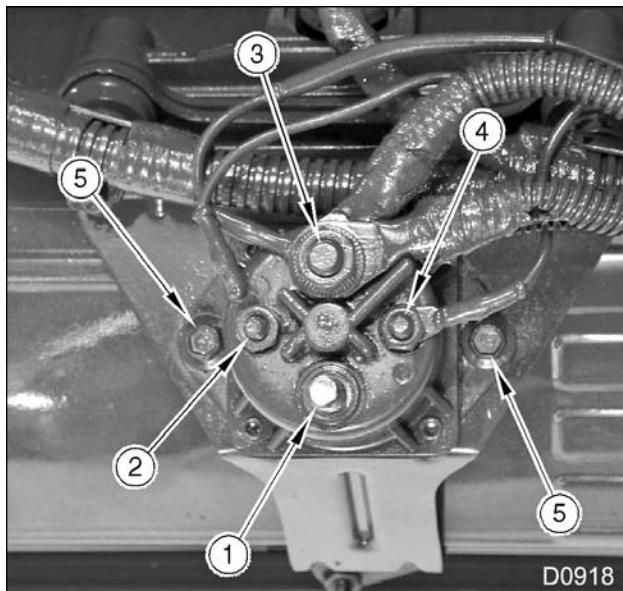


Figure 398 Glow plug relay terminals

1. To battery source
 2. To ECM (X1 connector)
 3. To ECM (w/ fusible link) (X1 connector), glow plug harness busbars
 4. To ground
 5. Mounting bolts (2)
-
2. Disconnect electrical connections from glow plug relay terminals.
 3. If not previously removed, remove ECM and IDM from mounting brackets (ECM and IDM Mounting Bracket, page 228).
 4. Disconnect main harness from sensors (Removal, page 224).

5. Remove wiring harness clamps that secure wiring harness to cylinder heads and front cover.
6. Disconnect electrical connectors from fuel injectors and glow plug harness busbars.
7. Remove ground wire attached at the left side rear of intake manifold.
8. Carefully lift main harness away from engine.

CAUTION: To prevent engine damage, do not tug on wiring harnesses while trying to remove them. If resistance is felt, find the source of resistance and free any connectors or clips that are caught before proceeding.

Glow Plug Harness Busbar and Relay

Glow Plug Harness Busbar

NOTE: To remove the left side glow plug harness busbar, the EBP sensor bracket and tubing must first be removed.

1. Disconnect ground (-) cable from battery.



Figure 399 Removing glow plug harness busbar

2. Remove left and right side glow plug harness busbars by placing a hand on each end of the busbar and pulling out.

Glow Plug Relay and Bracket

NOTE: If removing the valve cover, leave the glow plug relay attached to the bracket. Only remove the three nuts securing the bracket to the valve cover studs.

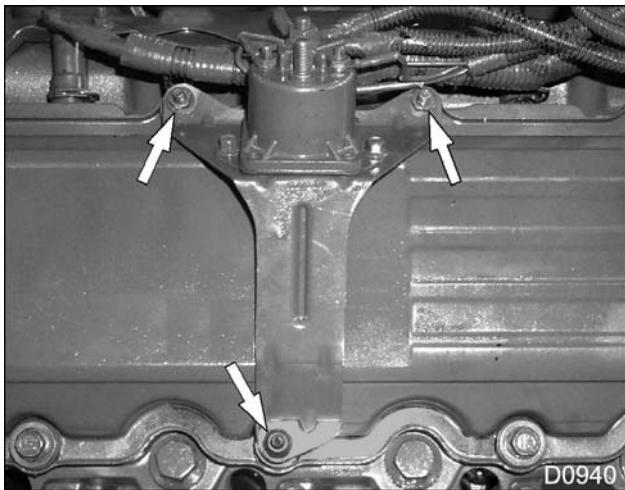


Figure 400 Glow plug relay bracket nuts

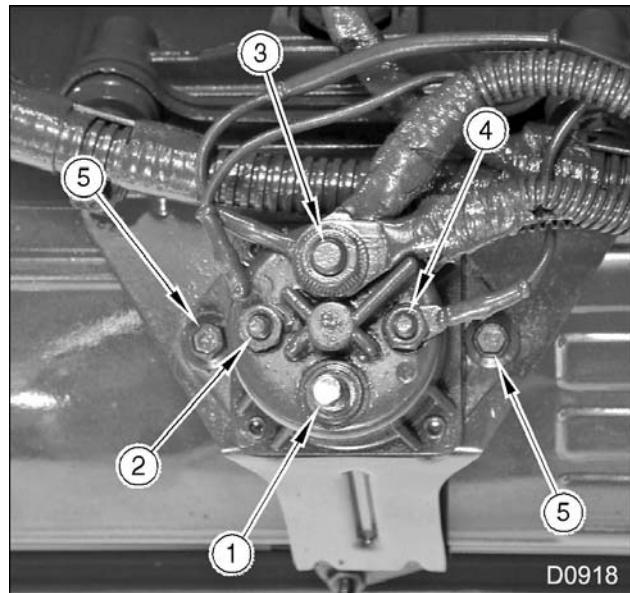


Figure 401 Glow plug relay terminals

3. Remove plastic glow plug relay terminal cover.
4. Disconnect battery lead from glow plug relay terminal.
5. Disconnect 12-V power wire, glow plug wire, and relay control harness connector.
6. Remove two glow plug relay mounting screws. Lift glow plug relay from engine.

1. To battery source
2. To ECM (X1 connector)
3. To ECM (w/ fusible link) (X1 connector), glow plug harness busbars
4. To ground
5. Mounting bolts (2)

Cleaning

Sensors

If sensors were removed, clean any sealants from sensor threads. Remove any scale or carbon build up.

If any orifices are plugged, replace sensors or valves as necessary.

Glow Plug Harness Busbar

Wipe down glow plug harness busbar with a shop towel. Do not use solvents.

Inspection

Engine Sensors and Valves

Inspect sensors and valves for physical damage such as bent pins, sensor body cracks, chaffing, and damaged or missing O-rings.

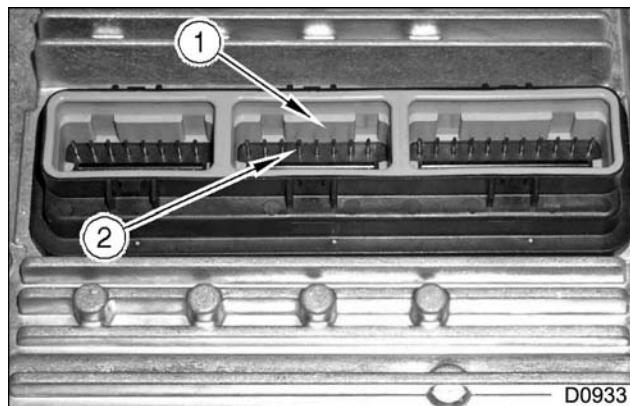
ECM and IDM Assemblies

Figure 402 ECM and IDM harness pin recesses (IDM shown)

1. Rubberized seal
2. Connector pins

1. Inspect rubber seal on harness connector and in ECM and IDM pin recesses.

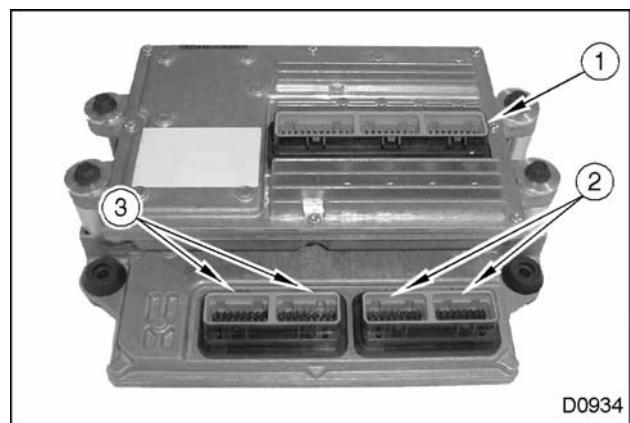


Figure 403 ECM and IDM connections

1. IDM connection
2. ECM engine connection
3. ECM chassis connection

2. Check for bent pins in ECM and IDM assemblies.

Main Engine Wiring Harness

1. Check all connector pins on sensors. If pins are bent or corroded, replace sensor.
2. Carefully inspect wiring harness for worn conduit, frayed insulation or heat damage on wires. Repair or replace as necessary.
3. Inspect each connector for the following conditions and replace if necessary:
 - Corroded connectors (green or gray) and white deposits on metal terminals.
 - Female connector sleeves spread open.
 - Terminals incorrectly latched into connector body or pushed back relative to other terminals in same connector.
 - Make sure that each connector has its ribbed seal in place.
4. Check engine wiring harness connectors, connector covers, seals, and cover shields for cracks, cuts, or worn areas. Replace if necessary.

Glow Plug Harness and Relay

NOTE: The glow plug relay is not repairable beyond being certain that all electrical connections to it are clean and tight.

Inspect base and relay housing for loose terminals, stripped threads, and cracks.

Glow Plug Harness Busbar

Inspect glow plug harness for defective or twisted O-rings, bent or misaligned harness busbar, and pin receptors that are spread open.

Installation

Main Engine Wiring Harness

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

NOTE: Make sure each connector has its ribbed seal in place before installing into sensor.

1. Install wiring harness onto engine and carefully align electrical connectors with sensors and valves (Figure 368).
2. Push each connector into its mating socket until locking tabs are fully latched (Camshaft Position (CMP) Sensor, page233).
3. Install wiring harness routing clips.

Crankshaft Position (CKP) Sensor

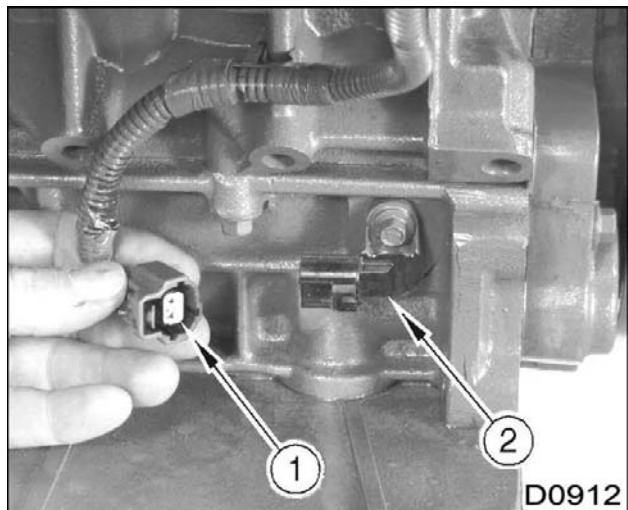


Figure 404 CKP sensor

1. CKP sensor connector
2. CKP sensor

1. Install new O-ring on CKP sensor.

2. Lubricate O-ring with clean engine oil and install CKP sensor into lower crankcase.
3. Secure sensor with M6 x 16 bolt and tighten bolt to the standard torque (General Torque Guidelines, page333).
4. Connect CKP sensor electrical connector to the sensor.

Camshaft Position (CMP) Sensor

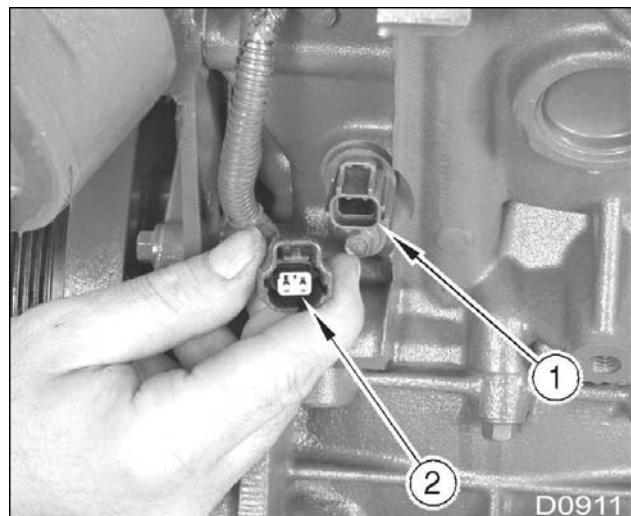
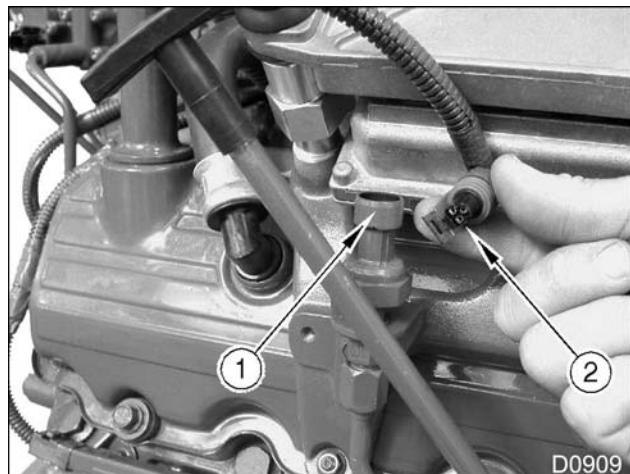


Figure 405 CMP sensor

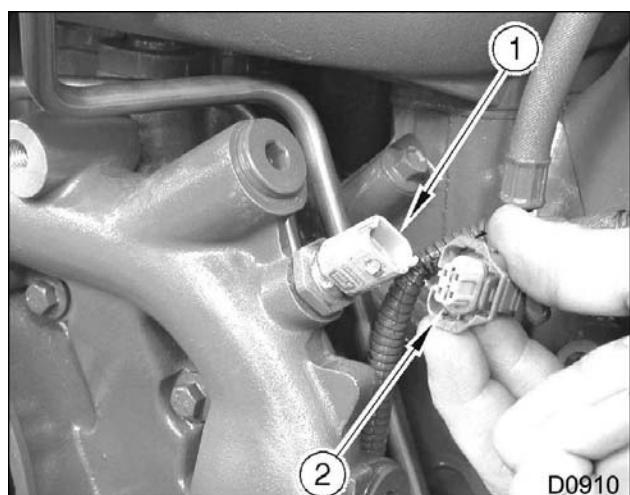
1. CMP sensor
2. CMP sensor connector

1. Install two new O-rings on CMP sensor.
2. Lubricate sensor O-rings with clean engine oil and install CMP sensor into crankcase.
3. Secure sensor with M6 x 16 bolt and tighten bolt to the standard torque (General Torque Guidelines, page333).
4. Connect CMP sensor electrical connector to the sensor.

Exhaust Back Pressure (EBP) Sensor**Figure 406 EBP sensor**

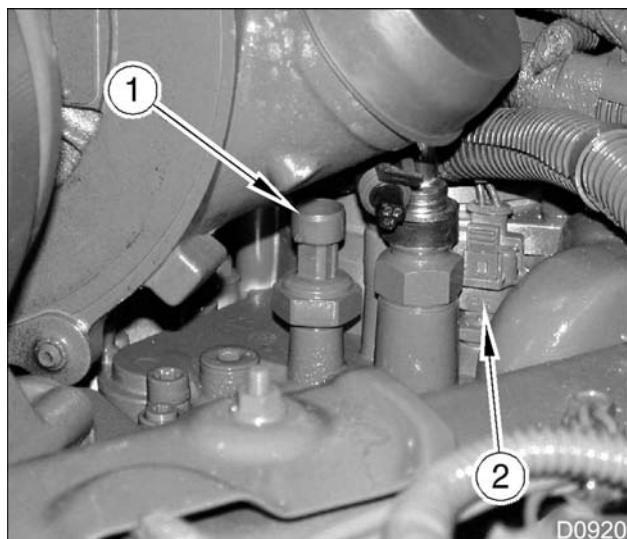
1. EBP sensor
2. EBP sensor electrical connector

1. Install EBP sensor into sensor bracket.
2. Thread EBP tube fitting onto sensor and tighten fitting to special torque (Table 28).
3. Connect EBP sensor electrical connector to the sensor.

Engine Coolant Temperature (ECT) Sensor**Figure 407 ECT sensor**

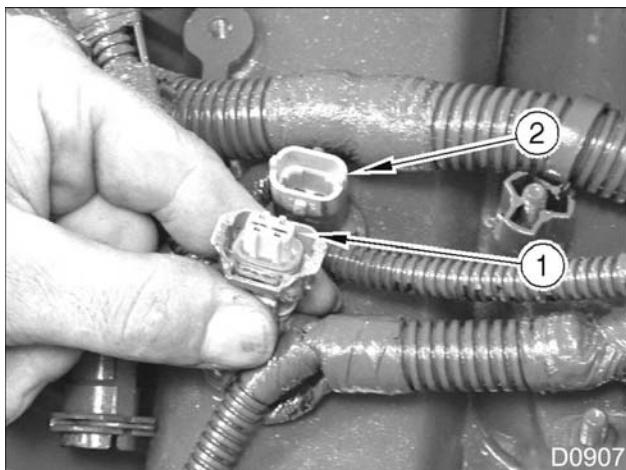
1. ECT sensor
2. ECT sensor electrical connector

1. Install new O-ring on ECT sensor.
2. Lubricate O-ring with clean engine oil.
3. Install ECT sensor into front cover and tighten sensor to special torque (Table 28).
4. Connect ECT sensor electrical connector to the sensor.

Engine Oil Temperature (EOT) and Engine Oil Pressure (EOP) Sensors**Figure 408 EOT and EOP sensors**

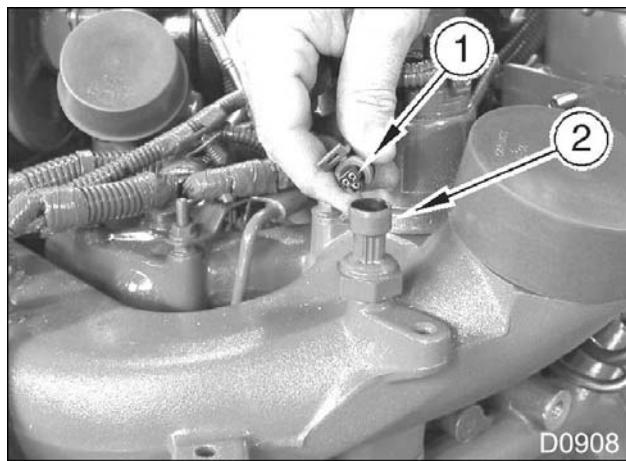
1. EOP sensor
2. EOT sensor

1. Install new O-rings on EOT and EOP sensors.
2. Lubricate EOT and EOP sensor O-rings with clean engine oil.
3. Install and tighten EOT sensor to the special torque (Table 28). Install and tighten EOP sensor to special torque (Table 28).
4. Connect sensor electrical connectors to sensors.

Manifold Air Temperature (MAT) Sensor**Figure 409** MAT sensor

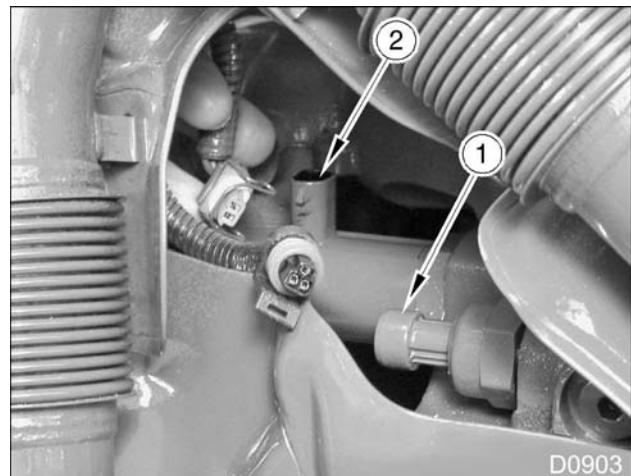
1. 2-wire connector
2. MAT sensor

1. Install new O-ring on MAT sensor.
2. Lubricate O-ring with clean engine oil.
3. Install MAT sensor and tighten sensor to special torque (Table 28).
4. Connect 2-wire connector to MAT sensor.

Manifold Absolute Pressure (MAP) Sensor**Figure 410** MAP sensor

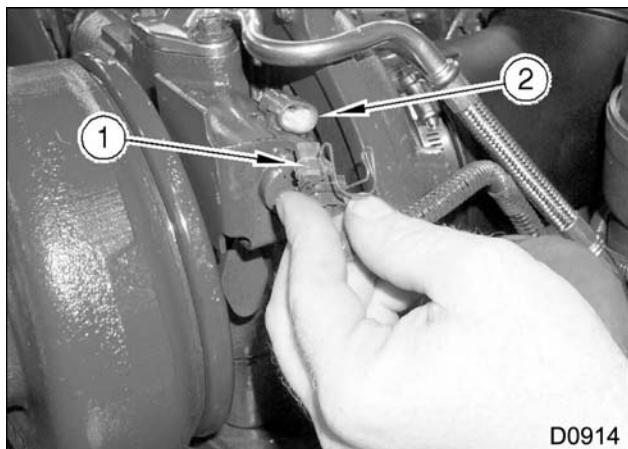
1. 3-wire connector
2. MAP sensor

1. Install a new O-ring on MAP sensor.
2. Lubricate O-ring with clean engine oil and install MAP sensor.
3. Tighten sensor to special torque (Table 28).
4. Connect 3-wire connector to MAP sensor.

Injection Control Pressure (ICP) Sensor and Injection Pressure Regulator (IPR) Valve**Figure 411** ICP sensor and IPR valve

1. 3-wire ICP sensor
2. 2-wire IPR valve

1. Install new O-rings on ICP sensor and IPR valve.
2. Lubricate O-rings with clean engine oil.
3. Install ICP sensor and IPR valve into hydraulic pump and torque sensor and valve to special torque (Table 28).
4. Connect electrical connectors to ICP sensor and IPR valve.

Variable Geometry Turbocharger (VGT) Assembly**Figure 412 VGT control Valve**

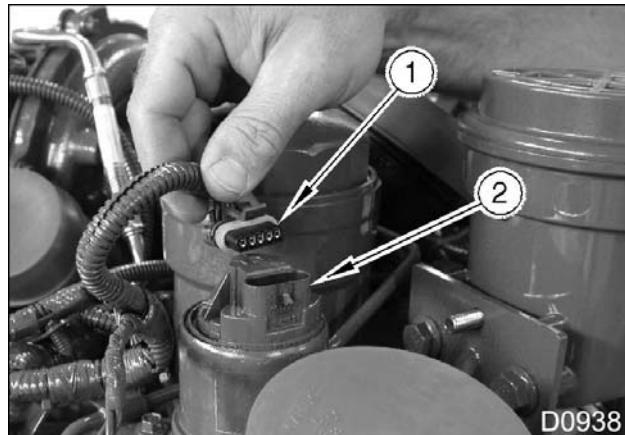
1. VGT electrical connector
2. VGT control valve connection

1. Install new O-rings on VGT control valve.
2. Lubricate O-rings with clean engine oil.

NOTE: Do not use the retaining bolt to draw the control valve into the housing. Push the control valve in by hand to seat securely, before installing bracket and bolt.

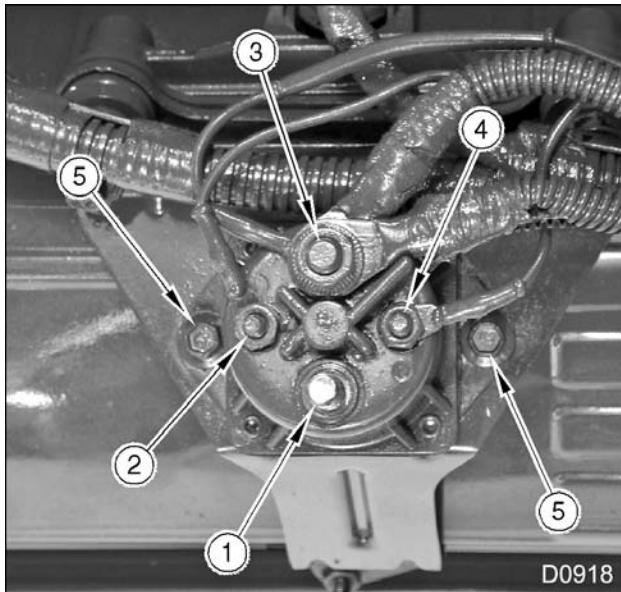
3. Install VGT control valve carefully to avoid twisting or cutting O-rings (Control Valve, page 59).
4. Install VGT control valve bracket and retaining bolt. Tighten bolt to standard torque. See General Torque Guidelines (Table 55).

5. Connect VGT electrical connector to VGT control valve connection.

Exhaust Gas Recirculation (EGR) Valve**Figure 413 EGR valve**

1. EGR valve electrical connector
2. EGR valve

1. Install new gasket and two new O-rings onto EGR valve.
2. Install EGR valve into intake manifold (Exhaust Gas Recirculation Valve, page 82).
3. Connect EGR valve electrical connector to valve.

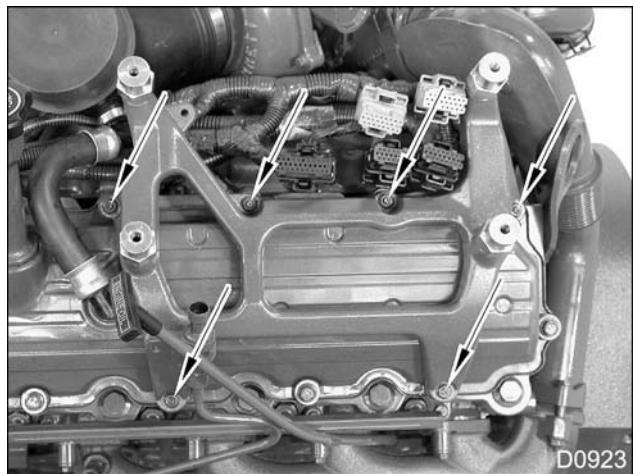
Glow Plug Relay and Bracket**Figure 414** Glow plug relay terminals

1. To battery source
2. To ECM (X1 connector)
3. To ECM (w/ fusible link) (X1 connector), glow plug harness busbars
4. To ground
5. Mounting bolts (2)

1. Install glow plug relay onto its bracket. Install and tighten two mounting bolts.
2. If removed, install bracket and three nuts to valve cover studs. Tighten nuts to the Special Torque Torque (Table 28).
3. Connect glow plug wire and 12-V power wire to top of glow plug relay. Tighten terminal nuts.
4. Connect wiring harness connector to glow plug relay.
5. Reconnect batteries.

Glow Plug Harness Busbar**Figure 415** Installing glow plug harness busbar

1. If necessary, replace O-rings on glow plug harness busbar.
2. Install left and right side glow plug harness busbars by placing a hand on each end and pushing evenly on each end until the busbar snaps into place. O-rings will be compressed at this time.

ECM and IDM Assemblies**Figure 416** Nuts for studded valve cover bolts

1. Install six mounting nuts on six studded valve cover bolts, to secure ECM and IDM bracket to engine.

2. Tighten mounting bracket nuts to standard torque (General Torque Guidelines, page333).

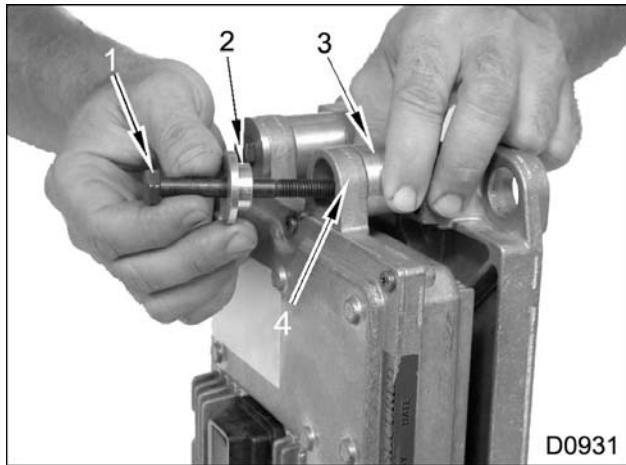


Figure 417 Spacers and bolts for ECM and IDM

1. M8 X 70 bolt
 2. Pilot
 3. Spacer
 4. IDM
-
3. To join ECM and IDM, install four M8 X 70 bolts through each component in the following order:
 - A. Pilot
 - B. IDM
 - C. Spacer
 - D. ECM

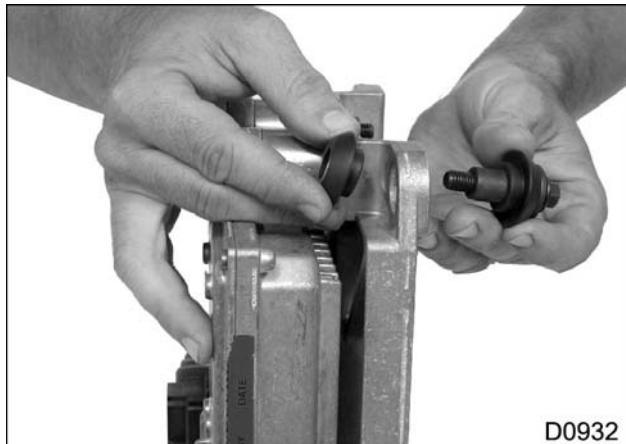


Figure 418 Bushing and grommets for vibration isolator

4. Install M6 X 25 bolts through vibration isolator grommets and bushings.

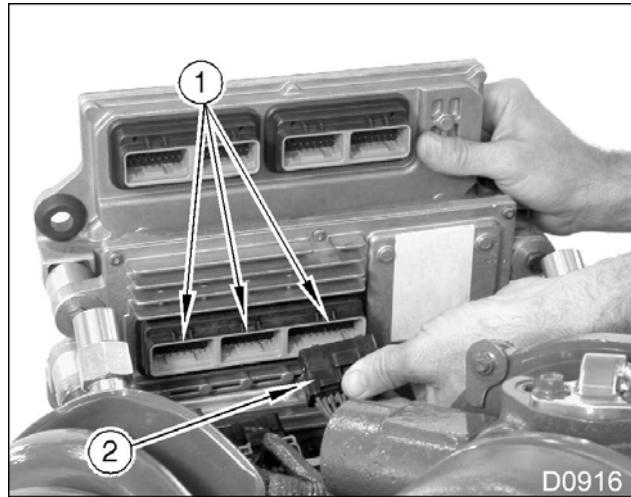


Figure 419 IDM harness connectors

1. IDM harness connection locations
2. IDM harness connector (3)

5. Install three IDM harness connectors.

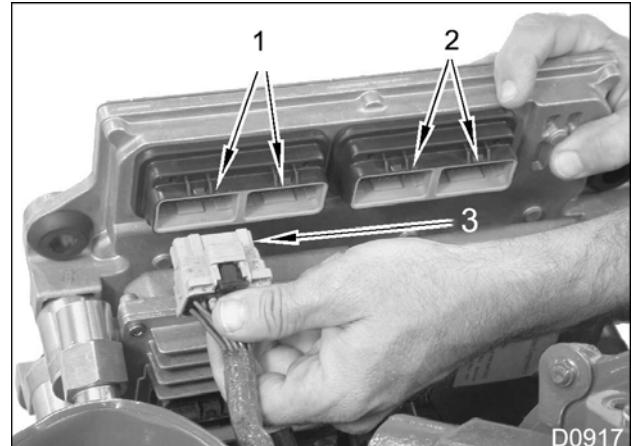


Figure 420 ECM harness connectors

1. ECM engine harness connection locations
2. ECM chassis harness connection locations
3. ECM engine harness connector (4)

6. Install four ECM harness connections (two for engine and two for chassis).

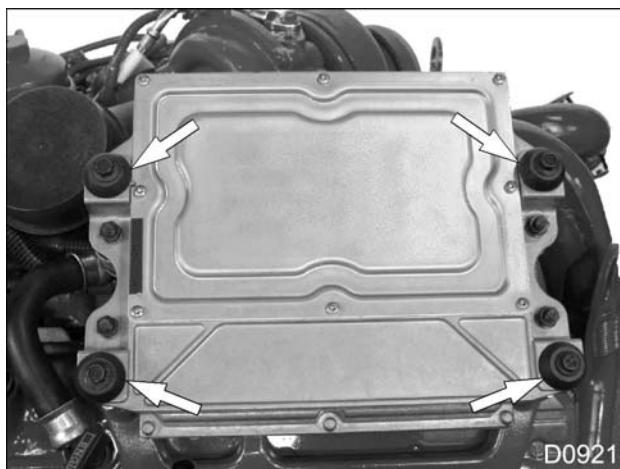


Figure 421 Installing ECM and IDM assemblies

7. Install ECM and IDM assemblies onto support bracket.
8. Tighten four M6 X 25 bolts to the standard torque (General Torque Guidelines, page333).

Specifications

Table 27

Glow Plugs	
Location	Cylinder Head
Quantity	8
Camshaft Position (CMP) Sensor	
Location	Crankcase (left side)
Crankshaft Position (CKP) Sensor	
Location	Lower crankcase (right side)
Operating actuator speed	15 to 2,000 rpm
Operating temperature	-40 °C to 130 °C (-40 °F to 266 °F)
Injection Pressure Regulator (IPR) Valve	
Operating temperature range	-40 °C to 125 °C (-40 °F to 257 °F)
Maximum operating pressure	20.7 MPa (3,000 psi)

Special Torque

Table 28

Exhaust Back Pressure (EBP) sensor	12 + 2/-3 N·m (108 ± 12 lbf-in)
Engine Coolant Temperature sensor (ECT)	12 ± 2 N·m (108 ± 12 lbf-in)
Engine Oil Temperature sensor (EOT)	12 ± 2 N·m (108 ± 12 lbf-in)
Engine Oil Pressure sensor (EOP)	12 ± 2 N·m (108 ± 12 lbf-in)
Glow plug relay nuts	19 N·m (168 lbf-in)
Injection Control Pressure (ICP) sensor	12 ± 2 N·m (108 ± 18 lbf-in)
Injection Pressure Regulator (IPR)	50 ± 5 N·m (37 ± 4 lbf-ft)
Manifold Absolute Pressure (MAP) sensor	12 ± 2 N·m (108 ± 12 lbf-in)
Manifold Air Temperature (MAT) sensor	18 + 2/-3 N·m (156 ± 24 lbf-in)

Special Service Tools

Table 29

Tool Number	Description
ZTSE4610	Cap Kit (All)