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Description

Front Cover Components

The front cover contains components relating to the cooling system, lube oil delivery, and drive belt support.

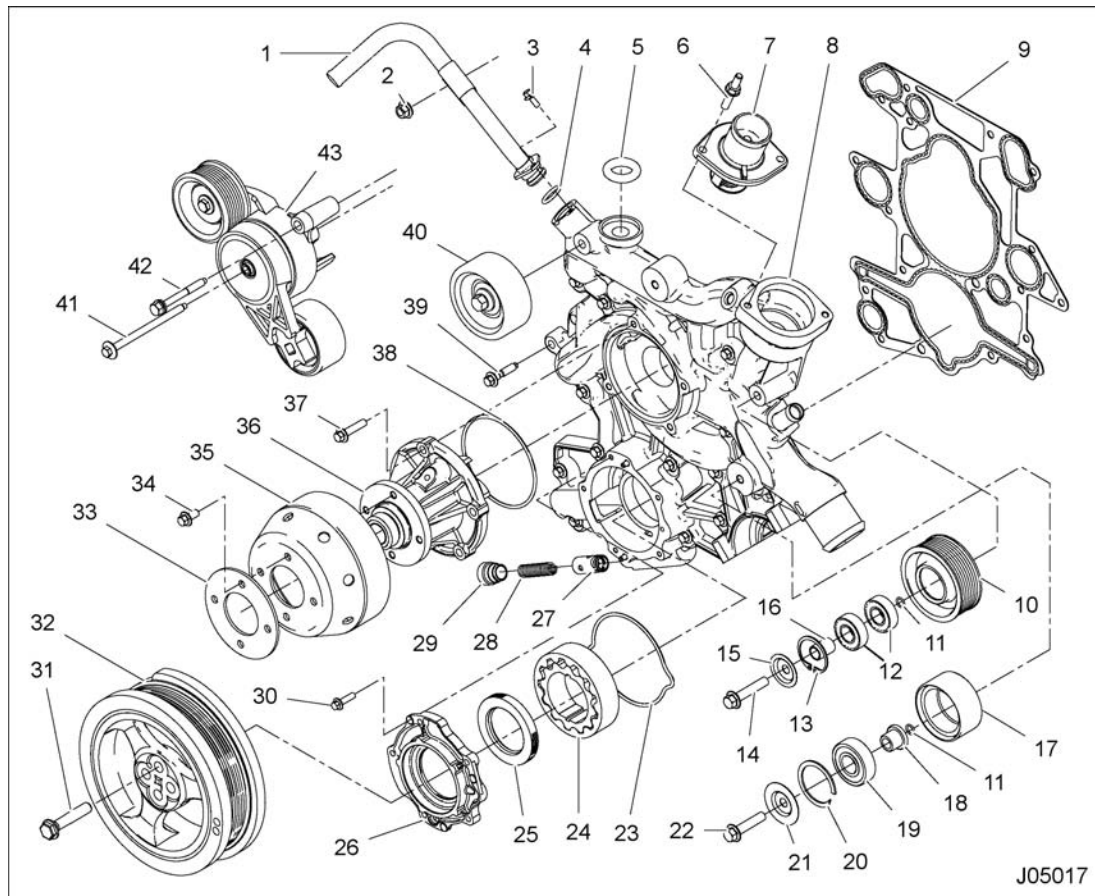


Figure 261 Front cover components

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

Removal

! WARNING: To avoid serious personal injury or possible death, make sure that the engine has cooled down sufficiently before attempting to remove any components. See "Safety Information (page 3)."

! WARNING: To avoid serious personal injury or possible death: Do not allow used engine fluids to stay on your skin. Clean your skin and nails with soap and water, or a good hand cleaner. Wash or properly throw away clothing or rags containing used engine fluids. Used engine fluids contain certain elements that may be unhealthy for skin and could even cause cancer. See "Safety Information (page 3)."

NOTE: Engine fluids, oil, fuel and coolant, can be a threat to the environment. Never dispose of engine fluids by putting them in the trash, pouring them on the ground, in the sewers, in streams or bodies of water.

Vibration Damper

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

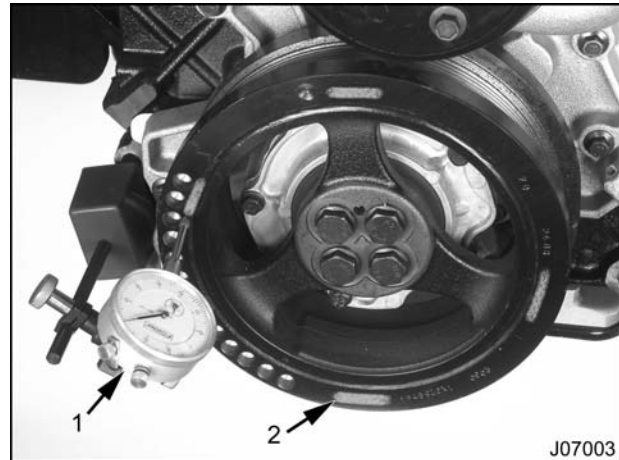


Figure 262 Check vibration damper runout

1. Dial indicator with magnetic base
 2. Paint removed, four points (90° apart)
 - a. Remove paint from face of vibration damper at four points approximately 90° apart.
 - b. Attach Dial Indicator with Magnetic Base to front of crankcase. See Special Service Tools (page 181). Position indicator tip onto an unpainted surface.
 - c. Pry crankshaft forward and zero the dial indicator. This becomes the baseline.
- NOTE:** Pry only in one direction to eliminate possible error induced by crankshaft end play.
- d. Turn crankshaft 90°. Pry crankshaft forward and record reading.
 - e. Repeat at each unpainted surface. If run out exceeds specification, replace vibration damper. See Specifications (page 180).

! WARNING: To prevent serious injury or possible death, support the vibration damper during mounting bolt removal. The damper can slide off the end of the crankshaft very easily. See "Safety Information (page 3)."



Figure 263 Vibration damper mounting bolts

1. Bolt, M12 x 59 (4)
 2. Vibration damper
2. Remove and discard the four bolts (M12 x 59) that secure vibration damper to crankshaft. The vibration damper retaining bolts are not reusable.
 3. Remove vibration damper from crankshaft.

Front Oil Seal and Wear Sleeve

NOTE: The International® VT 275 is not equipped with a wear sleeve during factory production. Wear sleeves are available with an oil seal service kit.

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



WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when metal impact tools to reduce the danger from flying debris. See "Safety Information (page 3)."

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



Figure 264 Drilling holes for the slide hammer

1. With a drill and bit, drill two holes 180° apart in the front oil seal.

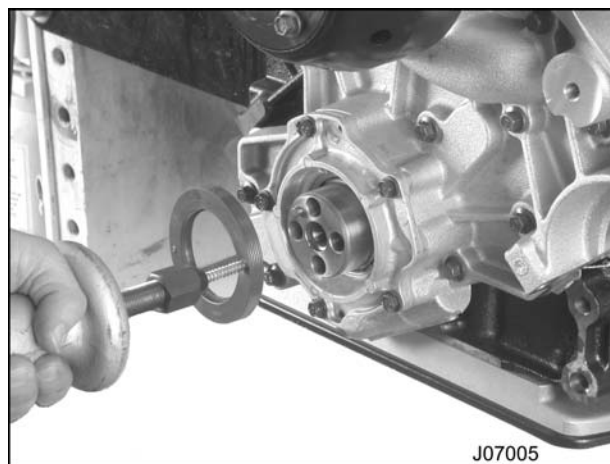


Figure 265 Removing the front seal

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

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

4. Install the Front Wear Sleeve Remover. See Special Service Tools (page 181). Do the following steps:

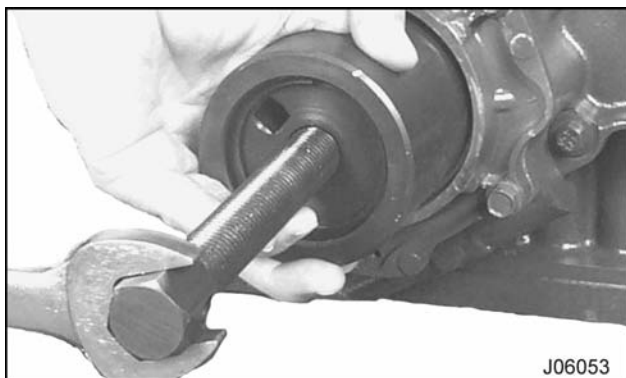


Figure 266 Front Wear Sleeve Remover

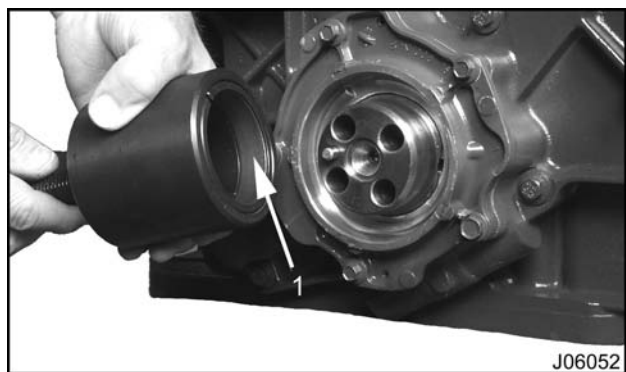


Figure 267 Front wear sleeve removed

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

Gerotor Oil Pump



Figure 268 Remove gerotor oil pump cover mounting bolts

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

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

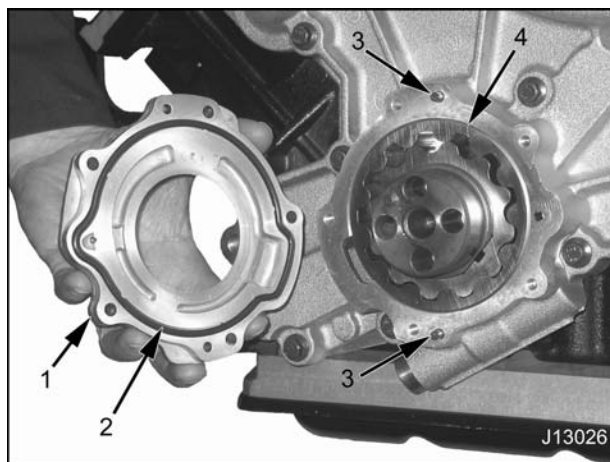


Figure 269 Gerotor components

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

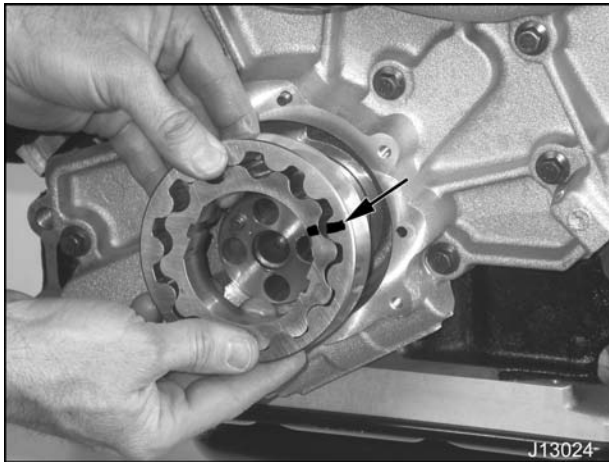


Figure 270 Gerotor orientation marking

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

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

4. Remove gerotor gear set from housing.

Water Pump

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



Figure 271 Removing the water pump / fan drive pulley

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

NOTE: If you are not using pneumatic tools, use a holding device to lock the fan drive pulley when removing bolts. See Special Service Tools (page 181).

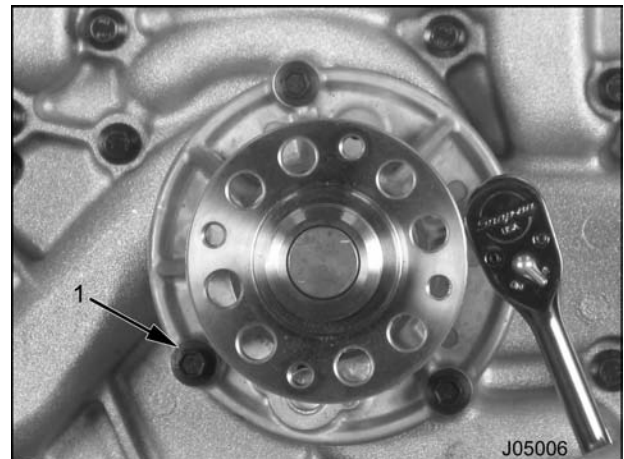


Figure 272 Removing water pump assembly

1. Bolt, M8 x 25 (4)
2. Remove four bolts (M8 x 25) that secure water pump assembly to front cover.

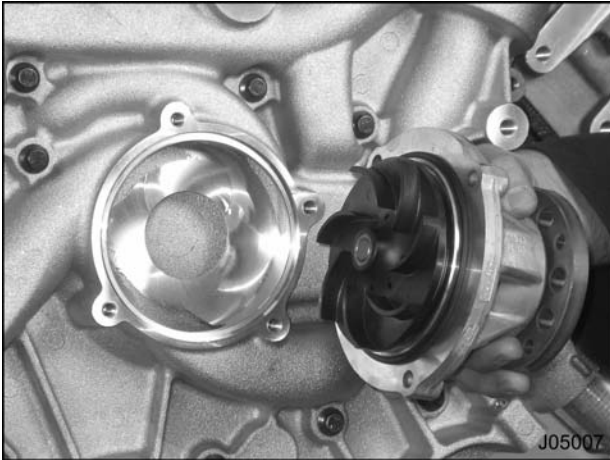


Figure 273 Water pump assembly

3. Remove and discard water pump O-ring.

Thermostat

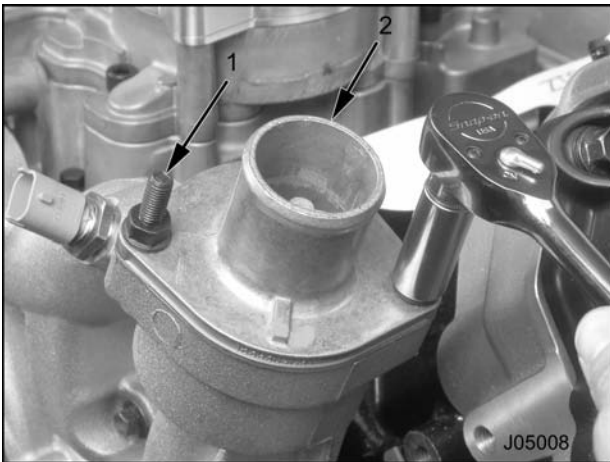


Figure 274 Thermostat assembly mounting studs

1. Stud bolt, M8 x 30 x 19 (2)
 2. Coolant outlet side of front cover (left side)
1. Remove two stud bolts (M8 x 30 x 19) that secure thermostat assembly to left side of front cover.

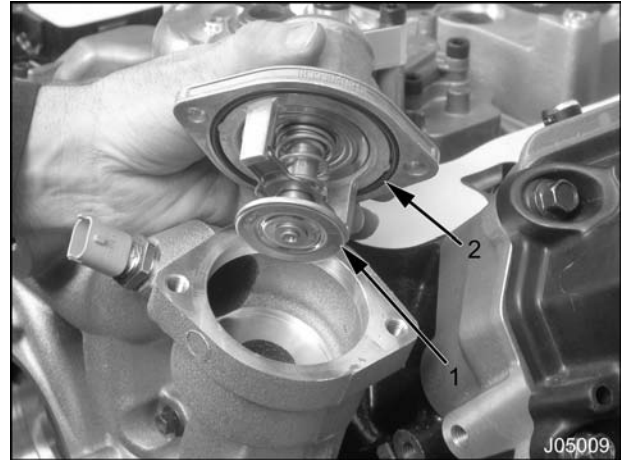


Figure 275 Removing the thermostat assembly

1. Thermostat assembly
 2. O-ring
2. Remove thermostat assembly from front cover. Remove and discard O-ring.

Front Cover

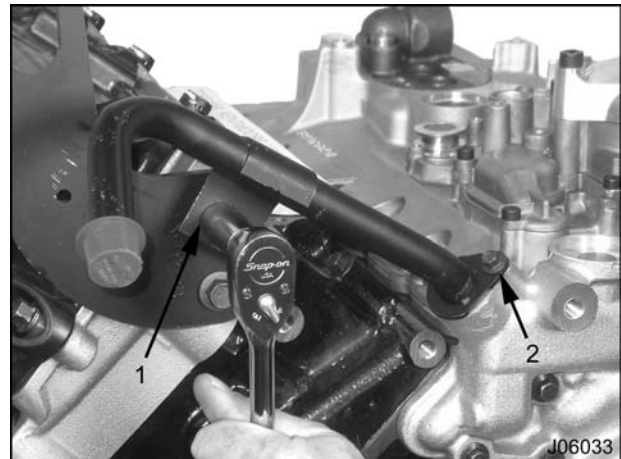


Figure 276 Removing the heater feed tube assembly hardware

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

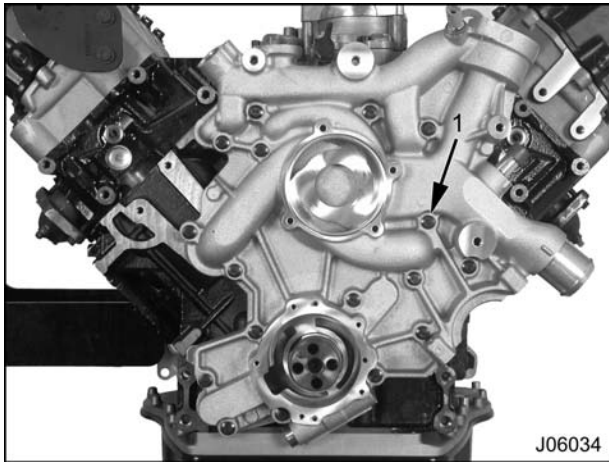


Figure 277 Front cover retaining bolts

1. Bolt, M8 x 35 (17)
2. Remove all 17 bolts (M8 X 35) from the front cover.

CAUTION: To prevent engine damage, cut the sealant where the crankcase and lower crankcase meet when removing the front cover gasket.

Note: Failure to adequately cut sealant prior to removing front cover and/or front cover gasket, could cause gasket between upper crankcase and lower crankcase to be pulled out. Complete engine removal and disassembly will be required to replace the crankcase gasket.

3. Two conditions can occur when removing the front cover. Use the appropriate procedure listed below.
 - a. Condition 1: Front cover and front cover gasket are stuck together.

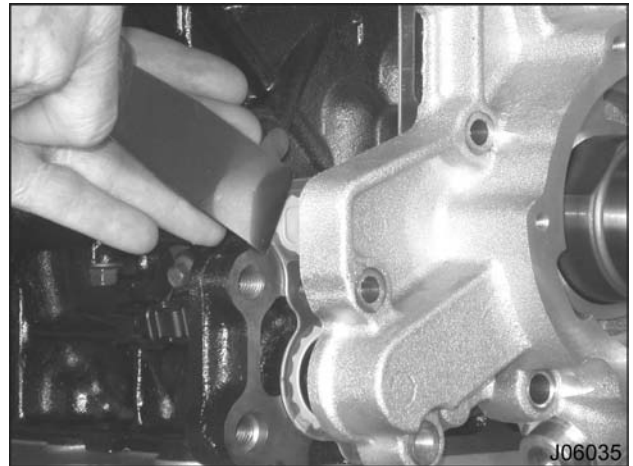
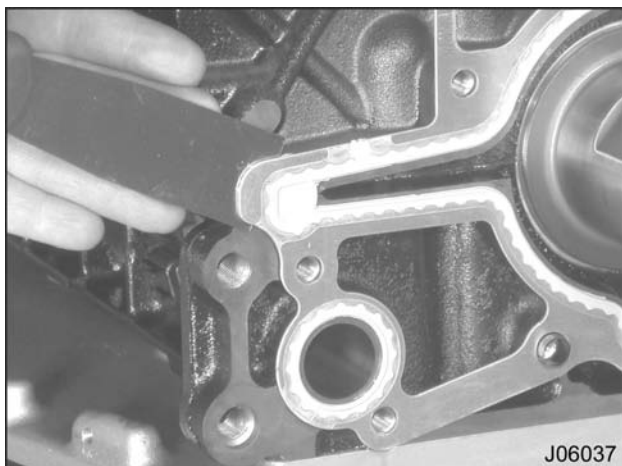


Figure 278 Cutting sealant between front cover and front cover gasket (condition 1)

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

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



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

Figure 279 Cutting sealant between front cover gasket and upper / lower crankcase joint (condition 2)

Cleaning, Inspection, and Testing

Vibration Damper

! WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using compressed air for cleaning to reduce the danger from flying debris. Limit the air pressure to 207 kPa (30 psi). See "Safety Information (page 3)."

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

Clean vibration damper with soap, water, and a soft parts brush. Dry with filtered compressed air.

Gerotor Oil Pump

! WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using compressed air for cleaning to reduce the danger from flying debris. Limit the air pressure to 207 kPa (30 psi). See "Safety Information (page 3)."

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

1. Lay front cover assembly on workbench.

2. Inspect gerotors and housing for nicks, burrs or scoring.
3. Replace any damaged components.

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

- When installing new gerotors, correct orientation is not required.
- When installing old gerotors, correct orientation is required.

4. Place inner and outer gerotors in oil pump housing.

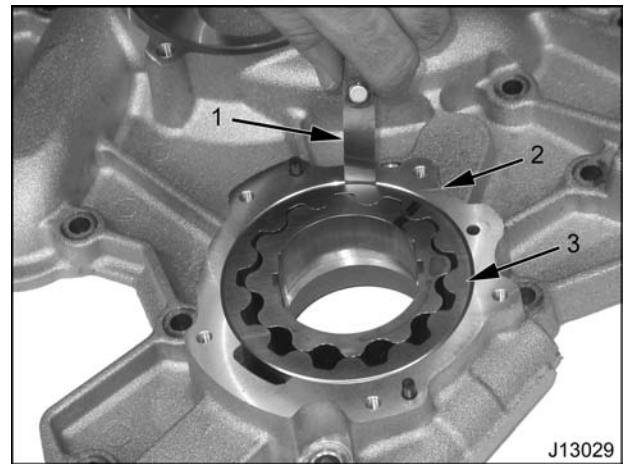


Figure 280 Inspect gerotors for wear

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

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

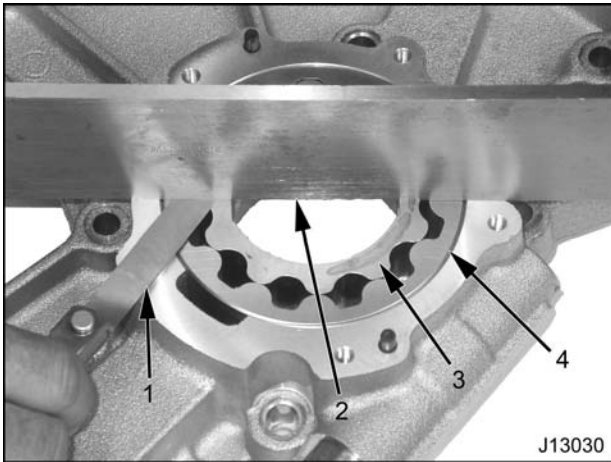


Figure 281 Check oil pump end clearance

1. Feeler gauge
 2. Straightedge
 3. Inner gerotor
 4. Outer gerotor
6. Check oil pump end clearance as follows:
 - a. With the gerotors in place in the front cover, place straightedge across housing.
 - b. Insert feeler gauge under straightedge at inner and outer gerotors. Compare end clearance with specifications. See Specifications (page 180).
 - c. If measurements are not within specifications, replace both gerotors (as a set).
 7. Use a 12 mm internal hex wrench to remove oil pressure regulator.

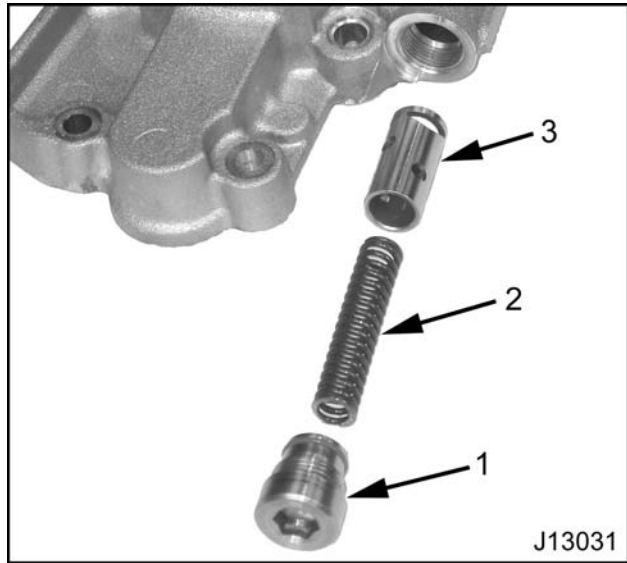


Figure 282 Oil pressure regulator components

1. End cap and O-ring
 2. Oil pressure bypass spring
 3. Piston poppet
8. Inspect oil pressure regulator piston poppet (steel) for binding / sticking due to debris or severe piston poppet scoring. Check for a broken oil pressure bypass spring. The spring should normally be the only potential cause of any malfunction in this assembly. Replace as necessary.
 9. Check regulator bore (aluminum) for severe piston poppet scoring. It should not be expected to experience any significant dimensional wear. Refer to Specifications (page 180). Replace as necessary.
 10. Install regulator components and tighten end cap to the Special Torque (page 180).

Front Cover and Water Pump



WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using compressed air for cleaning to reduce the danger from flying debris. Limit the air pressure to 207 kPa (30 psi). See "Safety Information (page 3)."

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

Thermostat



WARNING: To avoid serious personal injury or possible death, wear heat resistant gloves and appropriate eye protection during thermostat operation check. See "Safety Information (page 3)."

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

NOTE: Only genuine International® thermostats ensure proper coolant flow and positive sealing characteristics required to provide proper engine cooling.

Check thermostat operation as follows:

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

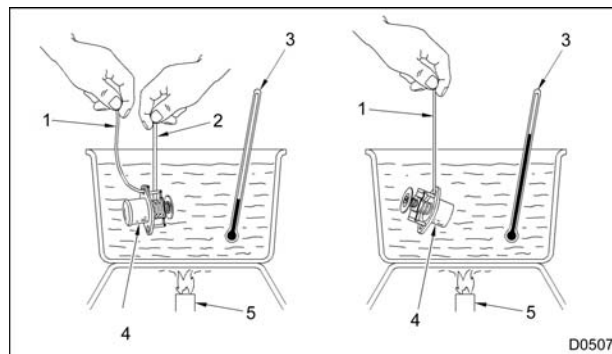


Figure 283 Test thermostat operation

1. Suspension line
 2. Ribbon
 3. Thermometer
 4. Thermostat
 5. Heat source
2. Heat the water filled container to the approximate normal operating temperature of the thermostat. See "Specifications" (page 180).
 3. Observe thermometer and record temperature as soon as thermostat drops from nylon ribbon. This is the point where the normal operating temperature begins.
 4. Continue to heat the water to the full-open temperature of the thermostat and observe thermometer and movement of thermostat sleeve.
 5. While sleeve is off its seat, use a hooked piece of wire to remove thermostat from container. Inspect seat area for pitting and foreign deposits.
 6. Replace thermostat if it is damaged or does not operate as described.

Vibration Damper

Inspect vibration damper rubber compound for evidence of cracking, bulging or separation. Replace as necessary.

Water Pump

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

Installation

Front Cover

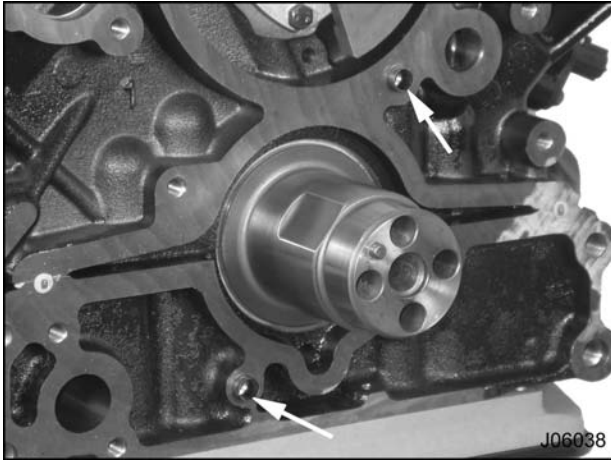


Figure 284 Front cover crankcase dowels

1. If removed, install front cover crankcase dowels.

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

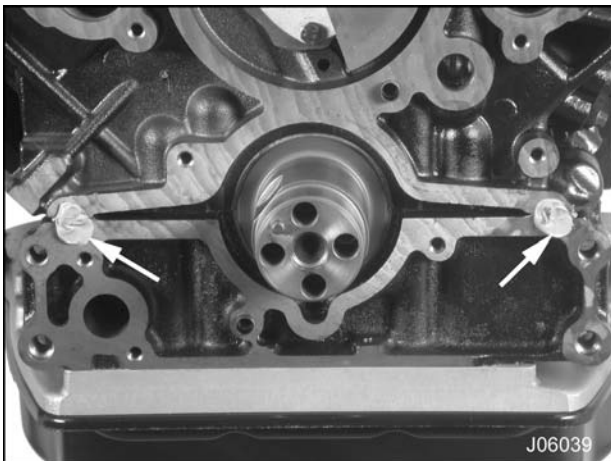


Figure 285 Locations for Liquid Gasket (RTV) application

2. Apply Liquid Gasket (RTV) to joining surfaces of crankcase and lower crankcase. See Special Service Tools (page 181).

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

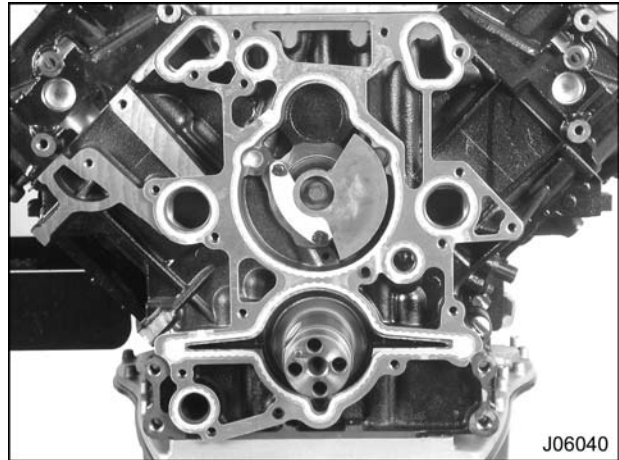


Figure 286 Front cover gasket installed

3. Position a new front cover gasket on the crankcase.

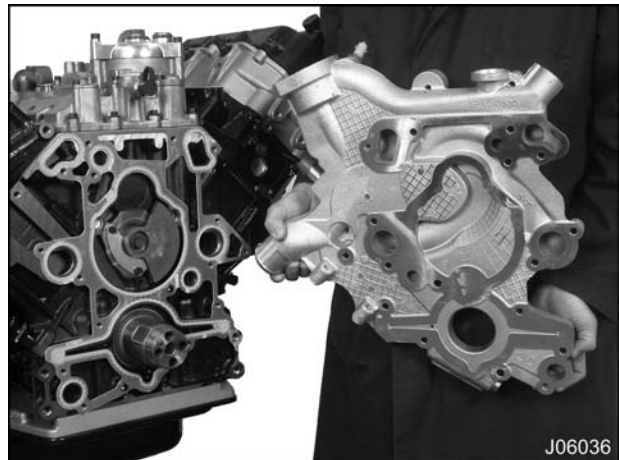


Figure 287 Installing the front cover

4. Align front cover with crankcase dowels.

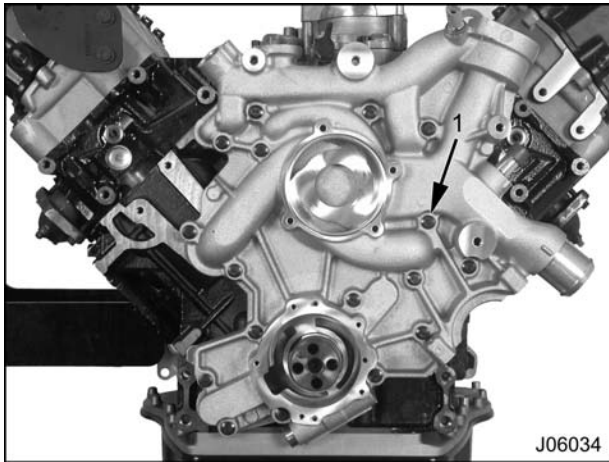


Figure 288 Front cover module retaining bolts

1. Bolt, M8 x 35 (17)
5. Fasten front cover assembly to crankcase with 17 bolts (M8 x 35) and tighten to the Special Torque (page 180).
6. If removed, install water pump onto front cover with new O-ring. See "Water Pump Installation" (page 176).

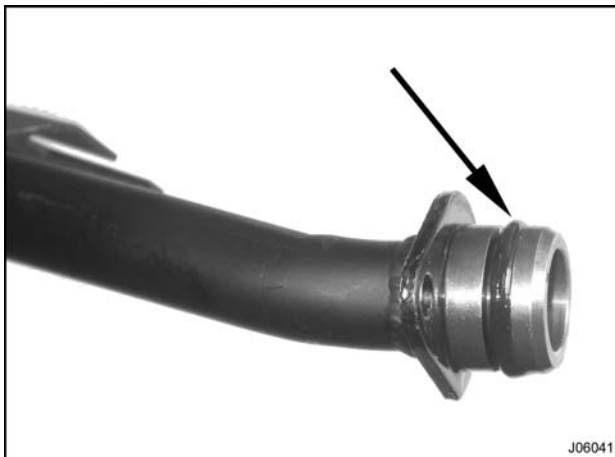


Figure 289 Heater feed tube O-ring

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

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

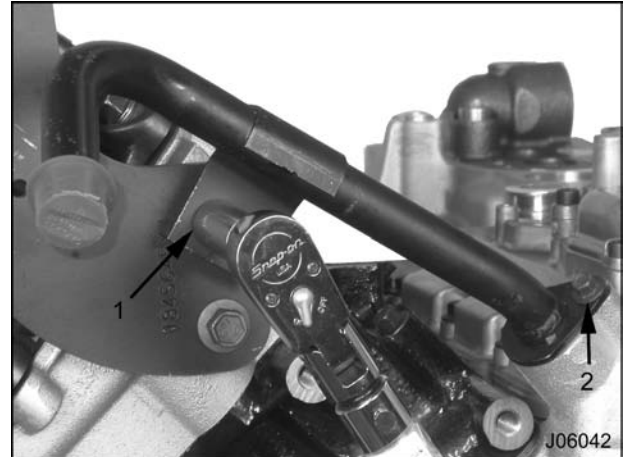
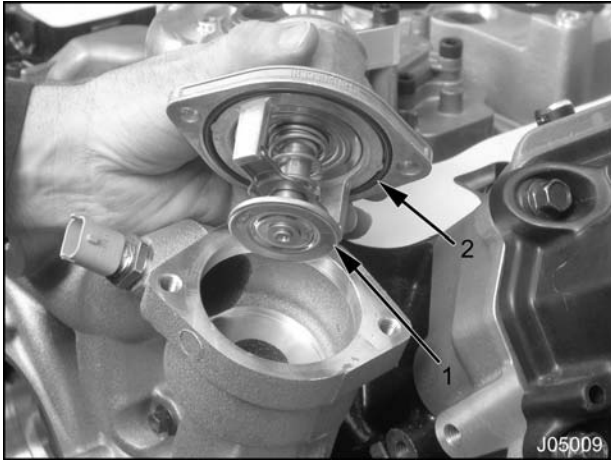


Figure 290 Torquing the heater feed tube assembly

1. Nut, M10
2. Bolt, M6 x 14
8. Install heater feed tube into front cover while aligning bracket slot with stud at lifting eye. Install bolt (M6 x 14) into front cover and tighten to the Standard Torque (page 405). Tighten nut to the Special Torque (page 180).

Thermostat**Figure 291 Installing the thermostat assembly**

1. Thermostat assembly
2. Thermostat O-ring seal

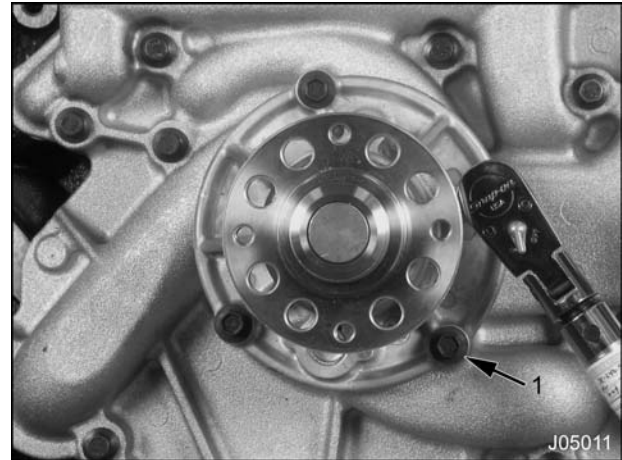
1. Place a new O-ring seal onto thermostat assembly.

**Figure 292 Torquing the thermostat assembly**

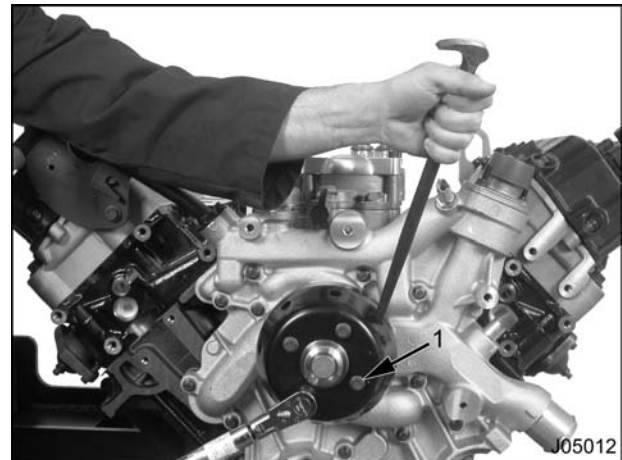
2. Install thermostat assembly on front cover coolant outlet. Secure with two mounting stud bolts (M8 x 30 x 19) and tighten to the Special Torque (page 180).

Water Pump

1. Place a new O-ring onto the front cover assembly. Use petroleum jelly to hold in place.

**Figure 293 Installing the water pump assembly**

1. Water pump assembly mounting bolts, M8 x 25 (4)
2. Install water pump assembly on front cover over the new O-ring and secure with four mounting bolts (M8 x 25). Tighten bolts to the Special Torque (page 180).

**Figure 294 Installing the water pump / fan drive pulley**

1. Water pump / fan drive pulley mounting bolts

3. Install water pump / fan drive pulley with four bolts (M8 x 12) and tighten to the Special Torque (page 180).

Gerotor Oil Pump

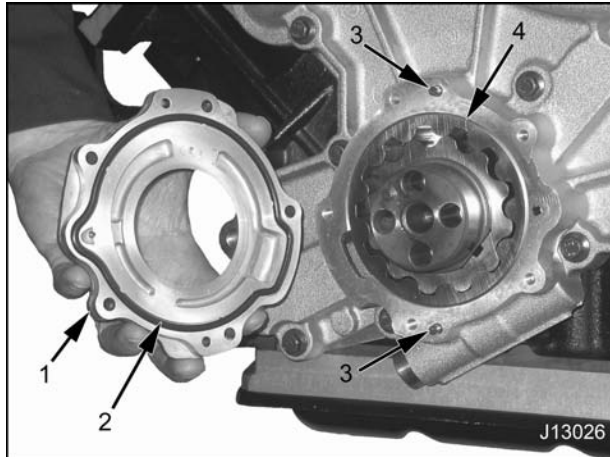


Figure 295 Installing the gerotor oil pump cover

1. Gerotor oil pump cover
 2. O-ring
 3. Dowel pins (2)
 4. Gerotor assembly
1. Lubricate inner gear with lithium assembly grease and install on crankshaft. Lubricate outer gear with lithium assembly grease and mesh with inner gear rotor in oil pump housing. Wipe off excess assembly grease.

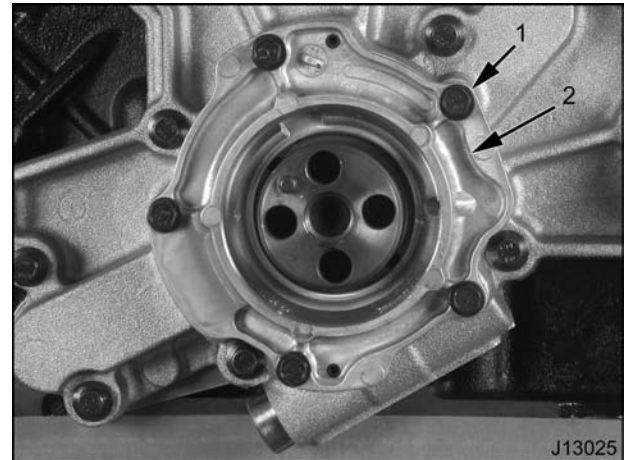


Figure 296 Gerotor oil pump housing

1. Gerotor oil pump cover retaining bolts, M6 x 25 (5)
 2. Gerotor oil pump cover
2. Align dowel pins and install oil pump cover on front cover. Install five retaining bolts (M6 x 25) to oil pump cover. Tighten bolts to the Special Torque (page 180).

Front Oil Seal and Wear Sleeve

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

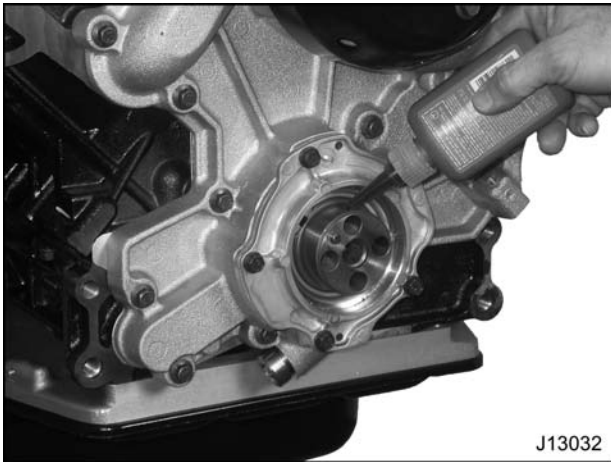


Figure 297 Adding Loctite® Hydraulic Sealant to crankshaft

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

Place a 360° bead of Loctite® Hydraulic Sealant on the leading edge of the crankshaft prior to wear sleeve installation. See Special Service Tools (page 181).

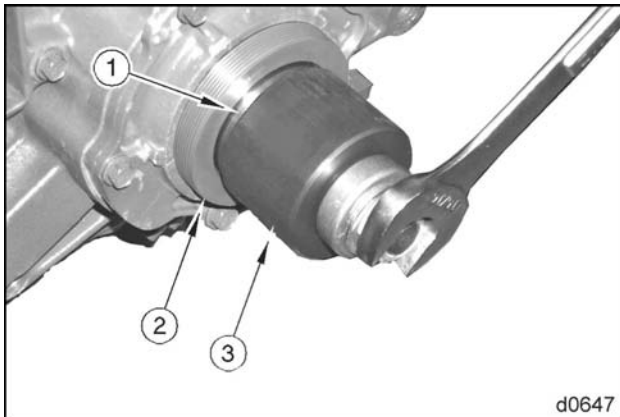


Figure 298 Installing the front oil seal and wear sleeve

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

2. Use the Front Seal / Wear Sleeve Installer to position the oil seal and wear sleeve combination into the oil pump cover. See Special Service Tools (page 181).
3. Install the seal and sleeve until the tool bottoms out (correct depth).

Vibration Damper

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

! WARNING: To avoid serious personal injury or possible death, you must always replace all four bolts with new ones when installing the vibration damper. See "Safety Information (page 3)."

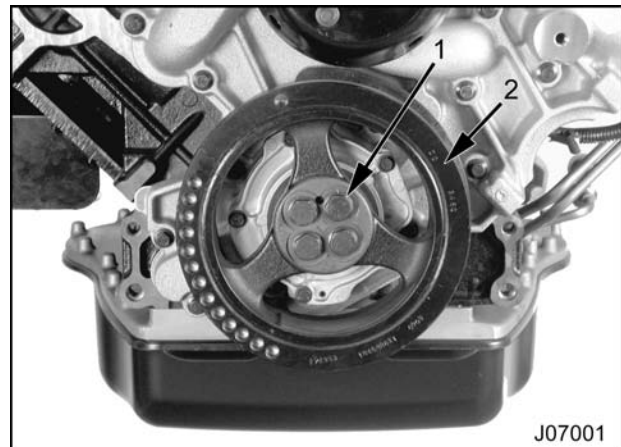


Figure 299 Vibration damper mounting bolts

1. Mounting bolts, M12 x 59 (4)
 2. Vibration damper
2. Install four new bolts (M12 x 59) to secure vibration damper onto crankshaft.

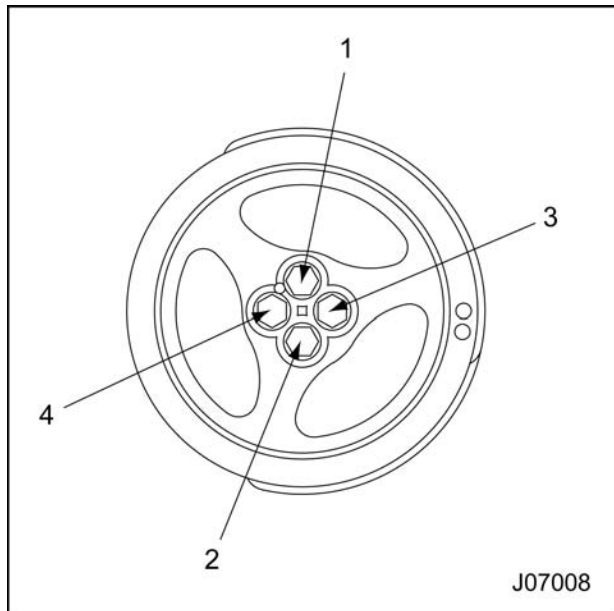


Figure 300 Vibration damper torque sequence

3. Tighten vibration damper bolts to the Special Torque (page 180) using the above sequence.

NOTE: Refer to Accessories Drive Belt Routing (Figure 636) for idler pulley and accessory location and identification.

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

Specifications

| Front Cover, Vibration Damper, and Gerotor Oil Pump | |
|---|---------------------------------------|
| Vibration Damper | |
| Face runout (maximum) | 0.635 mm (0.025 in) |
| Rubber bulging (maximum) | 1.5 mm (0.060 in) |
| Lubricating Oil Pump and Pressure Regulator | |
| Type | Gerotor |
| Drive | Crankshaft |
| Location | Gerotor oil pump housing |
| • 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 rotor to housing) | 0.025 to 0.095 mm (0.001 to 0.004 in) |
| Radial clearance (between outer rotor and housing) | 0.15 to 0.28 mm (0.006 to 0.011 in) |
| Pressure Regulating Valve: | |
| Plunger bore | 18.81 ± 0.02 mm (0.741 ± 0.001) |
| Thermostat | |
| Type | Balanced pressure, wax pellet |
| Normal operating temperature, >10 mm (0.394 in) stroke | 104°C (219°F) |

Special Torque

| Front Cover, Vibration Damper, and Gerotor Oil Pump | |
|---|---|
| Water pump / fan drive pulley | 36 N·m (26 lbf·ft) |
| Front cover module bolts | 24 N·m (18 lbf·ft) |
| Nut (heater feed to lifting eye) | 41 N·m (35 lbf·ft) |
| Oil pressure regulator end cap | 27 N·m (240 lbf·in) |
| Gerotor oil pump cover | 13 N·m (110 lbf·in) |
| Thermostat stud bolts | 22 N·m (200 lbf·in) |
| Vibration damper mounting bolts | New bolts only: 68 N·m (50 lbf·ft) + 90° rotation |
| Water pump mounting bolts | 23 N·m (17 lbf·ft) |

Special Service Tools

| Front Cover, Vibration Damper, and Gerotor Oil Pump | |
|---|----------------|
| Description | Tool Number |
| Dial Indicator with Magnetic Base | Obtain locally |
| Fan Hub Wrench (2 inch) | ZTSE43972 |
| Fan Wrench (pulley bolts) | ZTSE4587 |
| Front Seal / Wear Sleeve Installer | ZTSE4680 |
| Front Wear Sleeve Remover | ZTSE4517 |
| Liquid Gasket (RTV) (6 oz. tube) | 1830858C1 |
| Loctite® Hydraulic Sealant | Obtain locally |

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Description

Two different oil pan configurations exist depending on vehicle application.

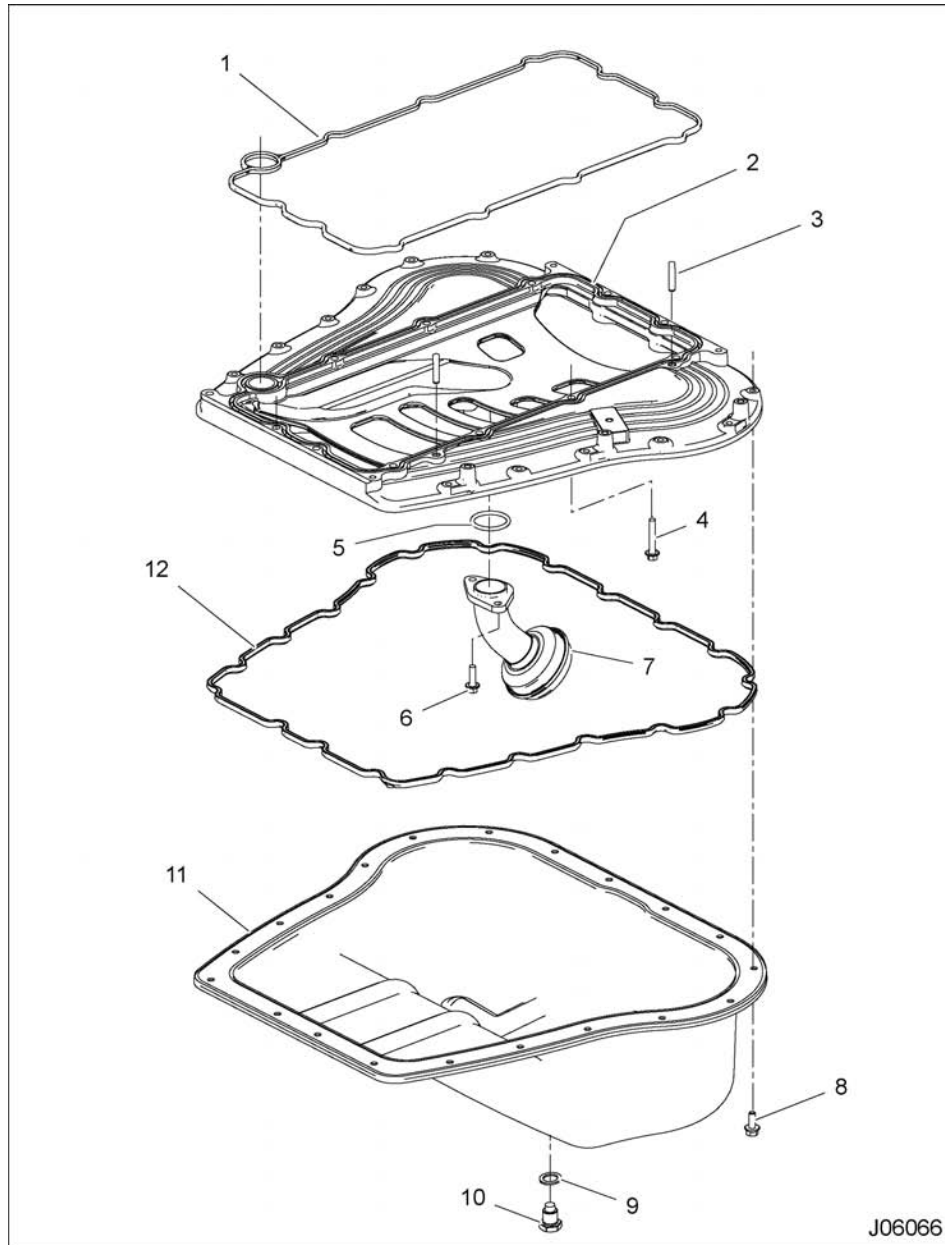


Figure 301 Lube oil pan and related components (CF)

- | | | |
|-------------------------------------|-------------------------------------|--------------------------|
| 1. Upper oil pan gasket | 5. Oil pickup tube O-ring | 9. Drain plug gasket |
| 2. Upper oil pan assembly | 6. Bolt, M6 x 20 (2) | 10. Drain plug |
| 3. Dowel pin (2) | 7. Oil pickup tube assembly | 11. Lower oil pan |
| 4. Upper oil pan bolts (Figure 309) | 8. Lower oil pan bolts (Figure 303) | 12. Lower oil pan gasket |

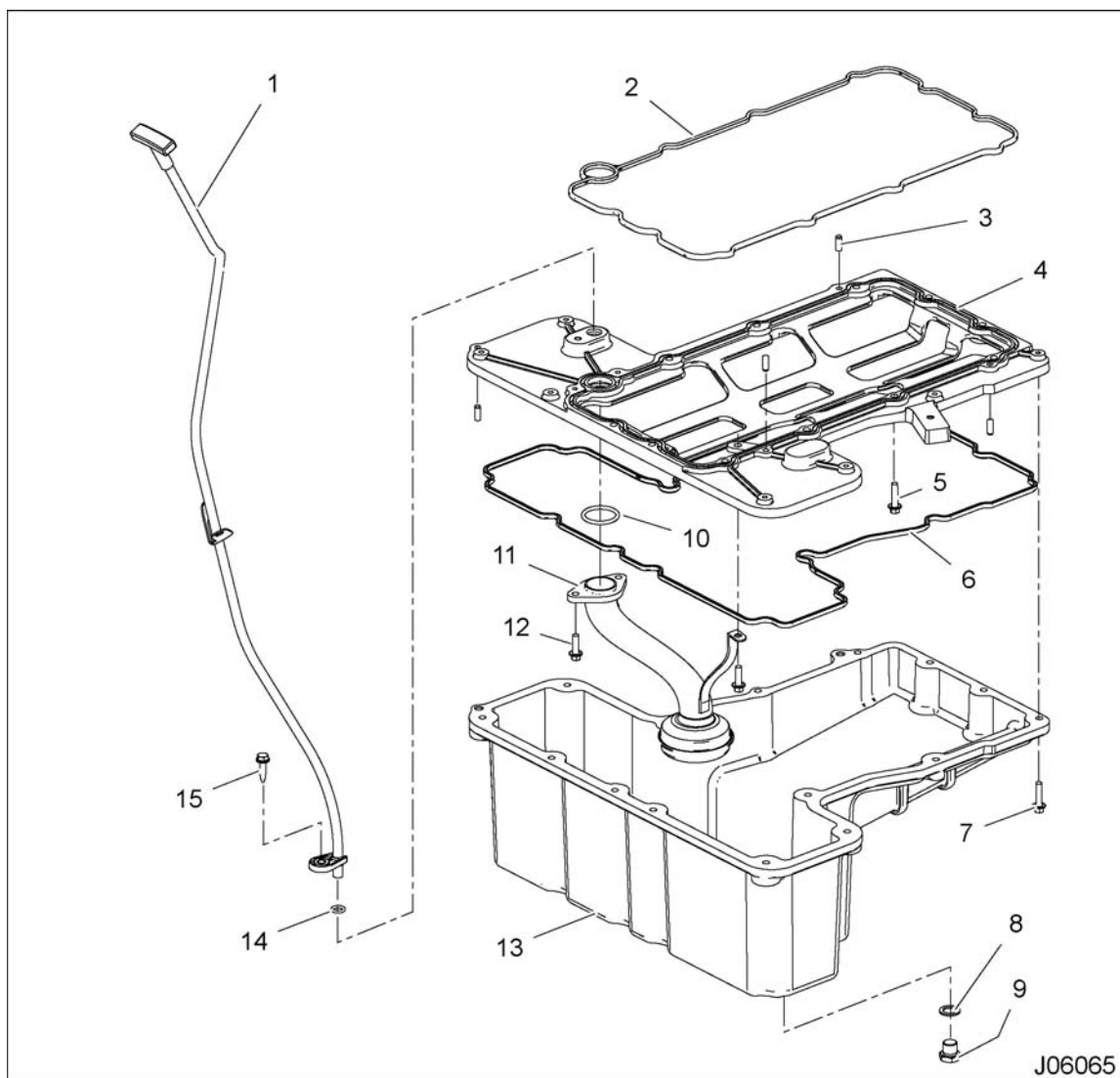


Figure 302 Lube oil pan and related components (stripped chassis)

- | | | |
|--|----------------------------|------------------------------------|
| 1. Oil level gauge and tube assembly (gauge blade removed for clarity) | 5. Bolts (Figure 310) | 11. Oil pickup tube assembly |
| 2. Upper oil pan gasket | 6. Lower oil pan gasket | 12. Bolt - patch type, M6 x 25 (3) |
| 3. Dowel pin (4) | 7. Bolts (Figure 305) | 13. Lower oil pan |
| 4. Upper oil pan assembly | 8. Drain plug gasket | 14. Oil level gauge tube seal |
| | 9. Drain plug | 15. Bolt, M6 x 20 |
| | 10. Oil pickup tube O-ring | |

Removal

! WARNING: To avoid serious personal injury or possible death, make sure that the engine has cooled down sufficiently before attempting to remove any components. See "Safety Information (page 3)."

! WARNING: To avoid serious personal injury or possible death: Do not allow used engine fluids to stay on your skin. Clean your skin and nails with soap and water, or a good hand cleaner. Wash or properly dispose of clothing or rags containing used engine fluids. Used engine fluids contain certain elements that may be unhealthy for skin and could even cause cancer. See "Safety Information (page 3)."

NOTE: Engine fluids can be a threat to the environment. Never dispose of engine fluids in the trash or pour them on the ground, in sewers, or in bodies of water.

Lower Oil Pan

1. Remove safety guards, shields, and covers.

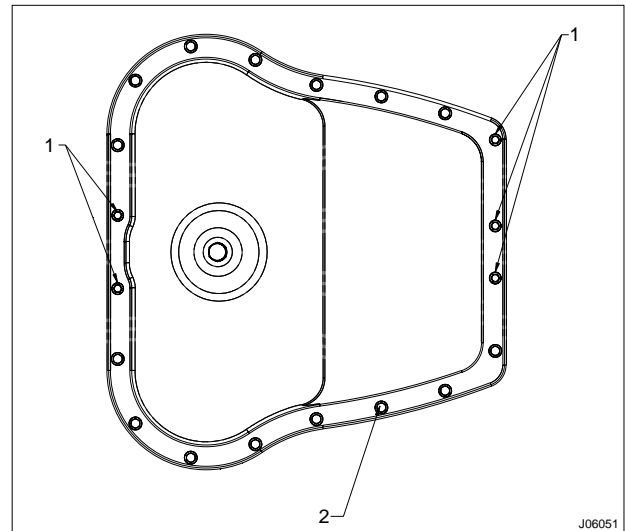


Figure 303 Lower oil pan bolt locations (CF)

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



Figure 304 Removing the lower oil pan mounting bolts

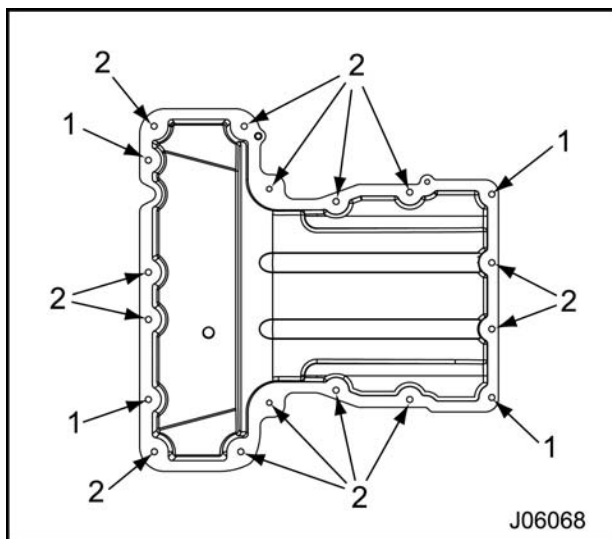


Figure 305 Lower oil pan bolt locations (stripped chassis)

1. Four bolts (M6 x 25)
 2. 14 bolts (M6 x 35)
2. CF - Remove five lower oil pan mounting bolts (M6 x 35) and 15 lower oil pan mounting bolts (M6 x 16).

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



Figure 306 Removing the lower oil pan (typical)

3. Remove the lower oil pan.

Oil Pickup Tube

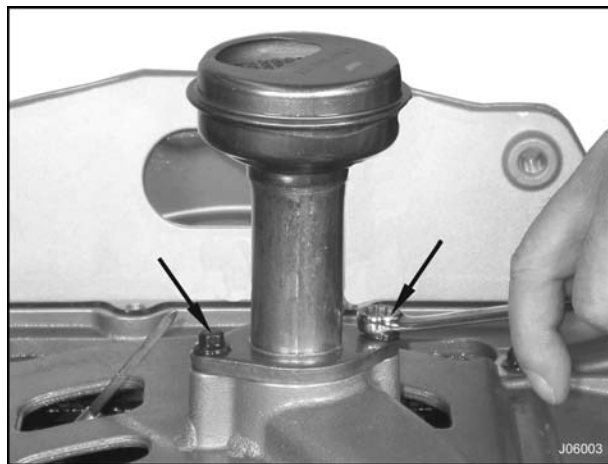


Figure 307 Removing the oil pickup tube (typical)

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

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



Figure 308 Removing the pickup tube O-ring (typical)

Upper Oil Pan



Figure 309 Upper oil pan mounting bolts (CF)

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

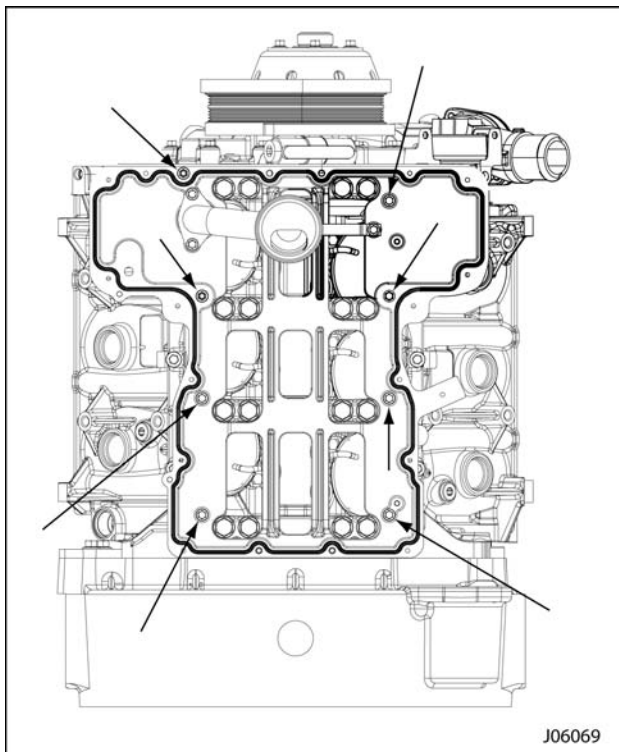


Figure 310 Upper oil pan mounting bolts (stripped chassis)

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

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

2. Remove upper oil pan.

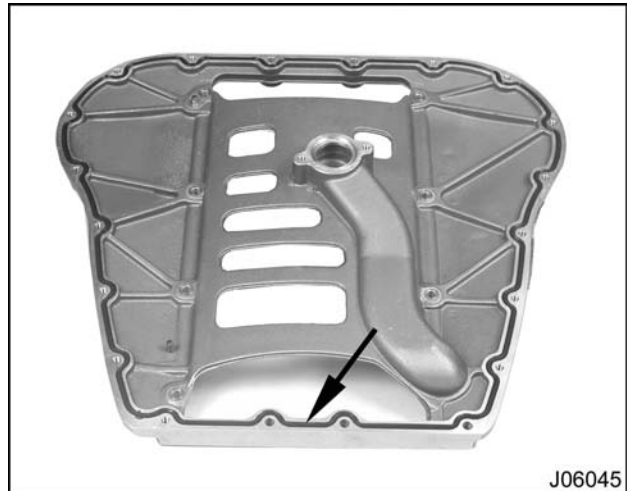


Figure 311 Lower oil pan gasket (lower face) (typical)

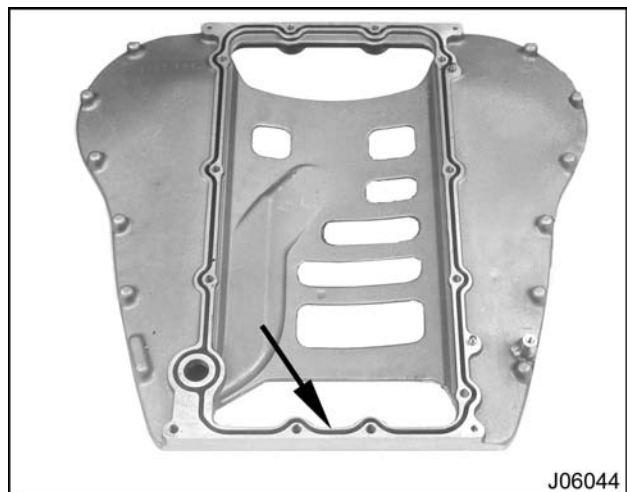


Figure 312 Upper oil pan gasket (upper face) (typical)

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

Cleaning and Inspection

Lower Oil Pan



WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using compressed air for cleaning to reduce the danger from flying debris. Limit the air pressure to 207 kPa (30 psi). See "Safety Information (page 3)."

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

Oil Pickup Tube



WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using compressed air for cleaning to reduce the danger from flying debris. Limit the air pressure to 207 kPa (30 psi). See "Safety Information (page 3)."

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

Upper Oil Pan



WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using compressed air for cleaning to reduce the danger from flying debris. Limit the air pressure to 207 kPa (30 psi). See "Safety Information (page 3)."

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

Installation

Upper Oil Pan

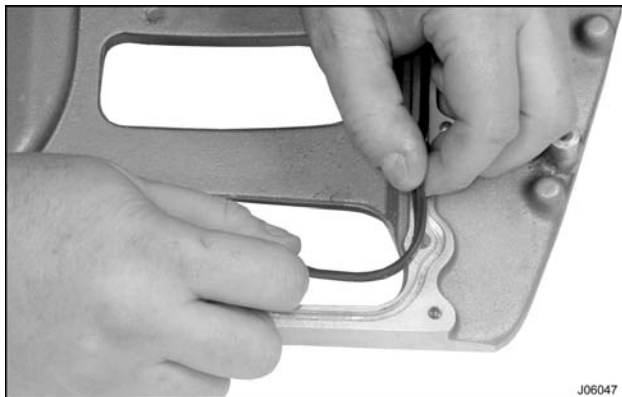


Figure 313 Installing a new upper oil pan gasket (upper face) (typical)

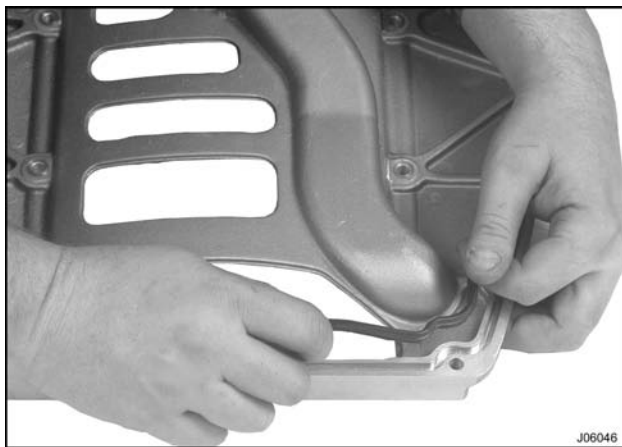


Figure 314 Installing a new upper oil pan gasket (lower face) (typical)

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



Figure 315 Upper oil pan mounting bolts (CF)

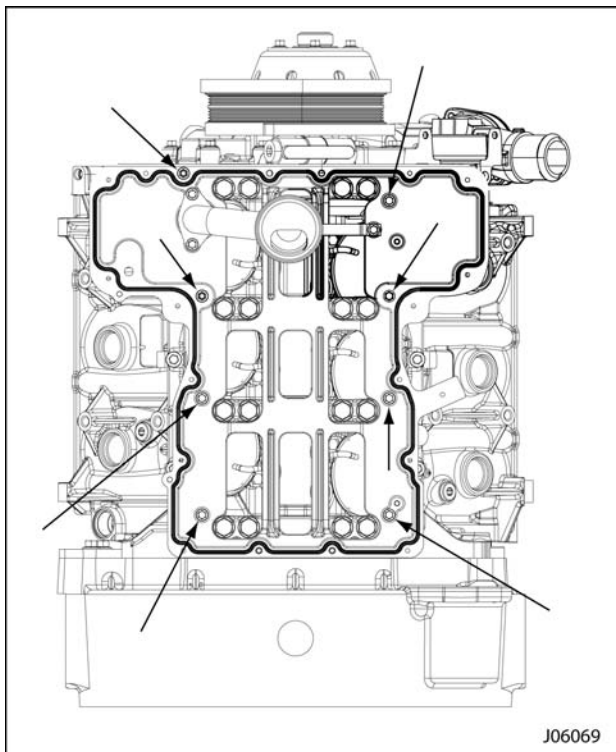
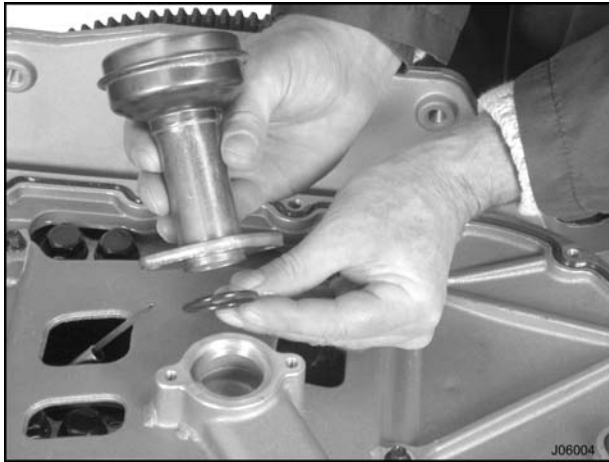


Figure 316 Upper oil pan mounting bolts (stripped chassis)

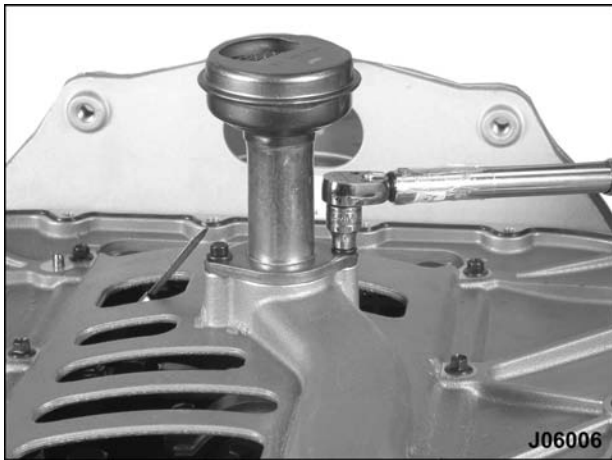
2. CF — Install upper oil pan and seven mounting bolts (M6 x 25).

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

Tighten bolts to the Standard Torque (page 405).

Oil Pickup Tube**Figure 317 Installing a new O-ring (typical)**

1. Lubricate a new O-ring with clean engine oil and install onto oil pickup tube.

**Figure 318 Torquing the oil pickup tube (CF)**

2. CF - Install oil pickup tube and two mounting bolts (M6 x 25). Tighten bolts to the Standard Torque (page 405).

Stripped chassis - Do the following:

- Clean threads of three mounting bolts (M6 x 25 - patch type) with suitable solvent.
- Apply Loctite® #242 (obtain locally) to threads.
- Install oil pickup tube and three mounting bolts.
- Tighten bolts to the Standard Torque (page 405).

Lower Oil Pan**Figure 319 Installing the lower oil pan onto engine (typical)**

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

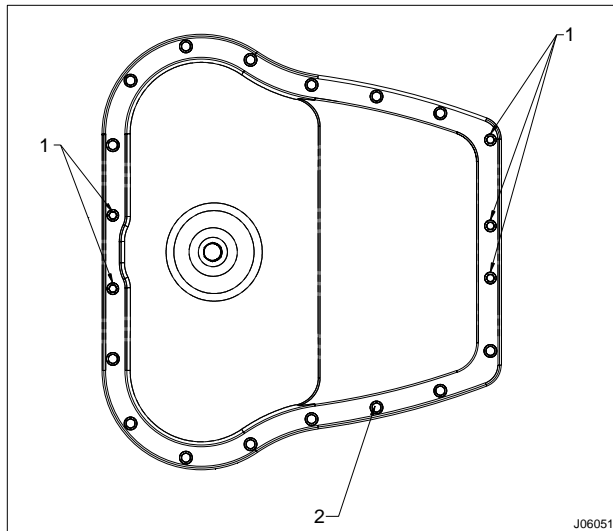


Figure 320 Lower oil pan bolt locations (CF)

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

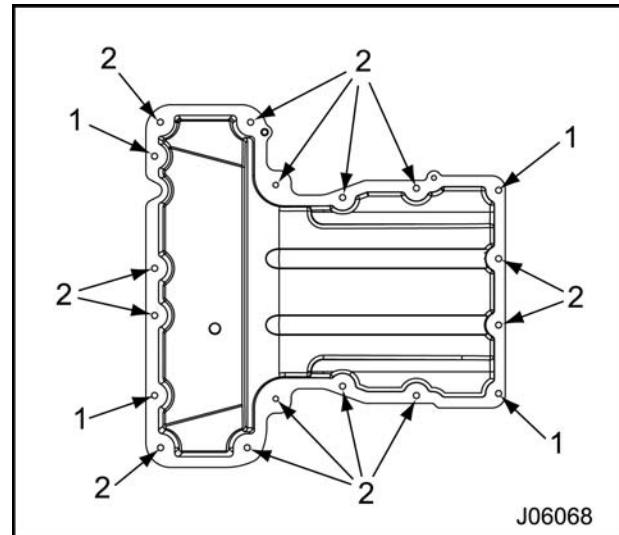


Figure 321 Lower oil pan bolt locations (stripped chassis)

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

2. CF — Install five lower oil pan mounting bolts (M6 x 35) and 15 lower oil pan mounting bolts (M6 x 16).

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

Tighten all bolts to the Standard Torque (page 405)

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

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Removal

! WARNING: To avoid serious personal injury or possible death, make sure that the engine has cooled down sufficiently before attempting to remove any components. See "Safety Information (page 3)."

! WARNING: To avoid serious personal injury or possible death: Do not allow used engine fluids to stay on your skin. Clean your skin and nails with soap and water, or a good hand cleaner. Wash or properly throw away clothing or rags containing used engine fluids. Used engine fluids contain certain elements that may be unhealthy for skin and could even cause cancer. See "Safety Information (page 3)."

NOTE: Engine fluids, oil, fuel, and coolant can be a threat to the environment. Never dispose of engine fluids by putting them in the trash, pouring them on the ground, in the sewers, in streams or bodies of water.

NOTE: Before removing pistons, rings and connecting rods, the following components must be removed first. See the appropriate section for removal procedure:

- Fuel filter and lines
- Dual turbocharger
- Intake manifold
- Cylinder heads
- Oil pans

Preliminary Checks

Piston Protrusion

NOTE: Prior to removing any piston and connecting rod assemblies, it is recommended that piston protrusion and connecting rod side clearance be evaluated. This will help identify bent or twisted connecting rods.



Figure 322 Checking piston protrusion

NOTE: Piston protrusion readings are performed at the 3 and 9 o'clock positions. Those positions are in line with the piston pin, removing the rocking movement of the piston at any other position of measurement.

1. Check piston protrusion above crankcase as follows:
 - a. Position a Dial Indicator with Magnetic Base close to the piston to be measured. See Special Service Tools (page 213).
 - b. Zero the dial indicator gauge on crankcase deck surface.
 - c. Position dial indicator tip over the piston head at the 3 o'clock position.
 - d. Bar the crankshaft around in the direction of normal rotation. This will raise the piston to its maximum outward protrusion at cylinder Top Dead Center (TDC). Read this maximum protrusion on dial indicator.
 - e. Record reading.
 - f. Reposition dial indicator tip on piston head at the 9 o'clock position.
 - g. Bar the crankshaft around in the direction of normal rotation to raise the piston to its maximum protrusion. Read the maximum protrusion (piston height above the crankcase) on the dial indicator.

- h. This will average the two readings. See Specifications (page 212). Replace piston and piston rod as required.

Connecting Rod Side Clearance

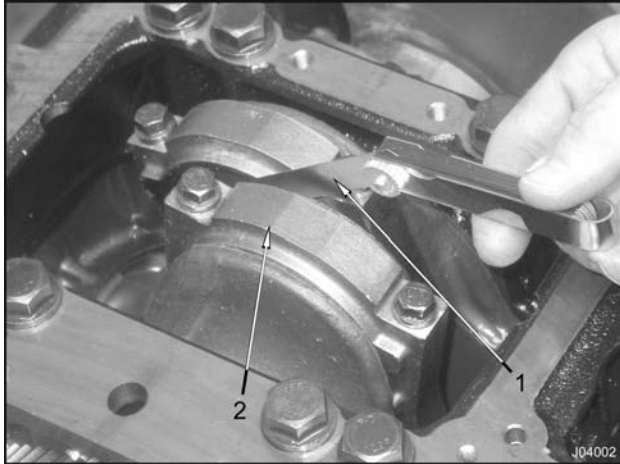


Figure 323 Checking connecting rod side clearance

1. Feeler gauge
 2. Connecting rod
1. Use a feeler gauge to check connecting rod side clearance as follows:
 - a. Pry apart a pair of connecting rods on a crankshaft rod journal. Insert largest possible feeler gauge between the connecting rods to check clearance.
 - b. Repeat for each pair of connecting rods on each crankshaft rod journal and compare with specification. See Specifications (page 212).

NOTE: Lack of clearance could indicate a damaged rod or a rod bearing out of position. Excessive clearance may require replacement of rods or crankshaft. Correct as required.

Removing Connecting Rod and Piston Assembly

CAUTION: To prevent engine damage, remove carbon ridge, if evident, prior to removing the rod and piston assemblies from the top of the cylinder bore. This reduces the chance of piston ring land damage during removal.

1. Use a razor knife or emery cloth to scrape carbon ridge from top of cylinder bore.
2. Rotate crankshaft to position journals for removal of connecting rod assemblies. Mark connecting rod locations.

CAUTION: To prevent engine damage, check connecting rod bolts for binding. If binding occurs, check thread condition carefully during inspection.

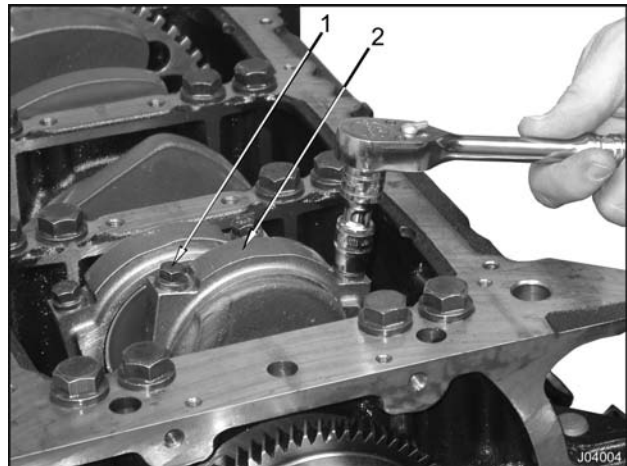


Figure 324 Removing connecting rod cap bolts

1. Connecting rod bolts (2 per rod cap)
 2. Connecting rod cap (6)
3. Remove two connecting rod bolts and connecting rod cap.

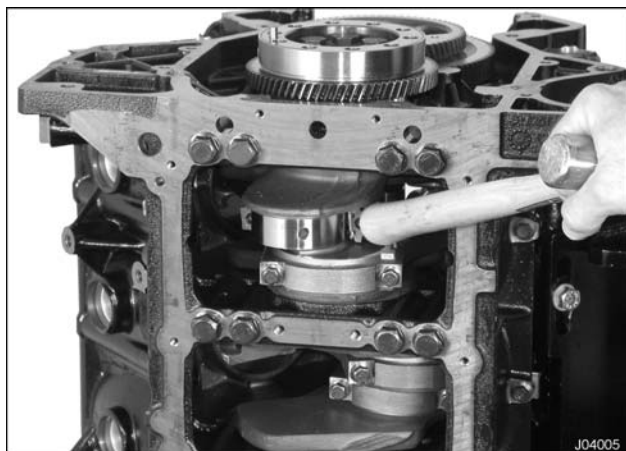


Figure 325 Removing the piston and connecting rod assembly

4. Remove piston and connecting rod assemblies from crankcase as follows:
 - a. Rotate engine to a vertical position.
 - b. Use a wooden or plastic handle of a hammer to push the piston and rod assembly from cylinder bore.
 - c. Once piston rings are free of cylinder bore, remove piston and connecting rod assembly from top crankcase.

CAUTION: To prevent engine damage, make sure each connecting rod and cap are stamped, marked, or tagged with the cylinder number.

This engine uses fractured connecting rods. Do not alter or damage the fractured mating surfaces of the rod and cap. A cap from one connecting rod is not interchangeable with any other connecting rod. The matching connecting rod and cap numbers have no significance other than indicating a matched set.

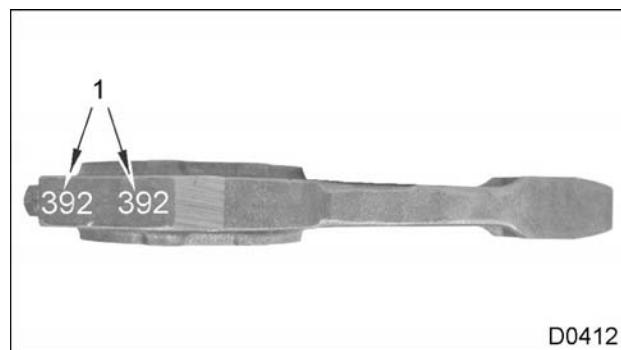


Figure 326 Matching cap and rod numbers

1. Matching numbers

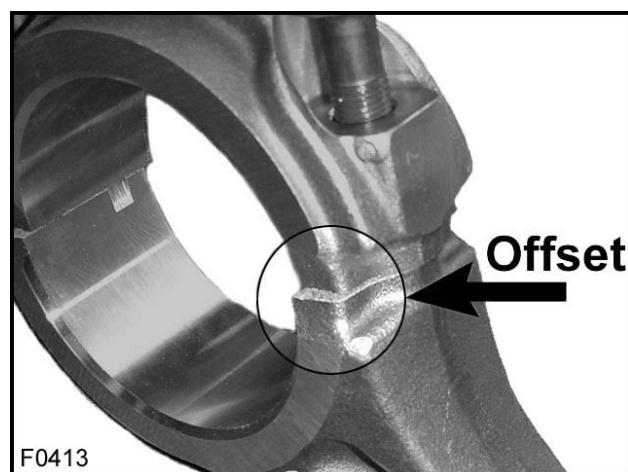


Figure 327 Offset for incorrect rod cap assembly

CAUTION: To prevent engine damage, make sure that connecting rods are installed with their caps in the right direction. If a rod cap is reversed during the assembly process, an obvious offset will be seen at the mating surfaces. If the connecting rod assembly is installed on the crankshaft in this manner, the connecting rod must be replaced. Also, check crank pin fillets for damage as such damage would require replacement of the crankshaft.

Piston Disassembly

! WARNING: To avoid serious personal injury or possible death, wear safety glasses when removing retaining rings. See "Safety Information (page 3)."

CAUTION: To prevent engine damage, mark the pistons with the cylinder number from which each was removed. Each piston must be reinstalled into its original cylinder bore, if the pistons are being reused.

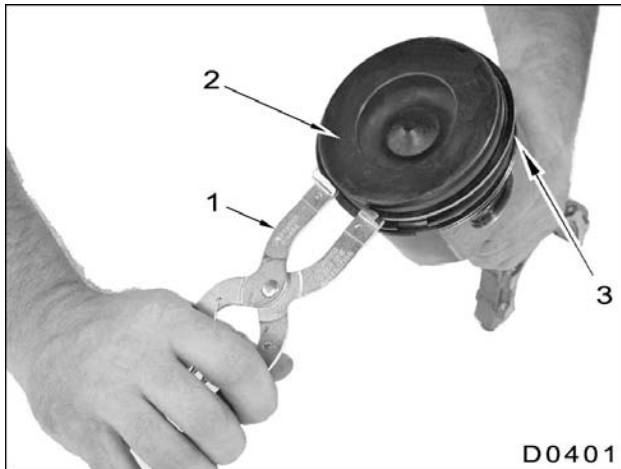


Figure 328 Removing the piston rings

1. Piston ring expansion pliers
2. Piston
3. Piston ring

1. Use Piston Ring Expansion Pliers to remove the piston rings. Remove top ring first, intermediate ring, and then finally the oil control ring. See Special Service Tools (page 213).



Figure 329 Removing the piston pin retaining ring

2. Separate connecting rod from piston as follows:
 - a. Use pliers to remove both piston pin retaining rings.
 - b. Remove piston pin from its bore by hand, and then separate connecting rod from piston.

Cleaning and Inspection

NOTE: Do not use a caustic solution or a wire brush for cleaning aluminum pistons. Do not use bead blast material on pistons.

1. Use a soap and water solution to clean aluminum pistons. Soak piston first, and then clean piston with a nonmetallic brush.
2. Clean all piston ring grooves thoroughly.
3. The following disassembled components may be cleaned using a suitable solvent:
 - Piston pins
 - Piston pin retainers
 - Connecting rods
4. Thoroughly clean all connecting rod bolt holes and threads.

Pistons

1. Inspect pistons for scuffed or scored skirts, cracked or worn ring lands, and cracked or scuffed pin bores. Replace any pistons showing such damage.

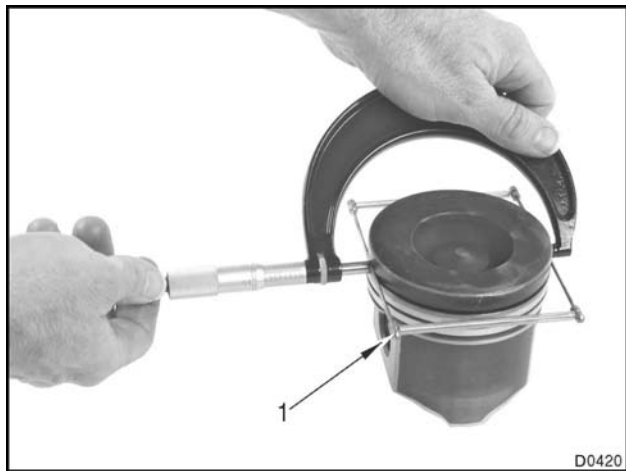


Figure 330 Measuring top compression ring groove

1. Piston gauge pins (0.082 in)
2. Check top compression ring groove for wear as follows:

NOTE: Top compression ring groove is a keystone design which requires measurement over gauge pins to determine ring groove wear.

- a. Install the Piston Gauge Pins (0.082 in) in the top ring groove. Piston gauge pins must be parallel. See Special Service Tools (page 213).
- b. Use a 3 - 4 inch outside micrometer to measure diameter over piston gauge pins. See Specifications (page 212).
- c. If measurement over the gauge pin is not within specifications, excessive piston groove wear exists. Replace piston. See Specifications (page 212).

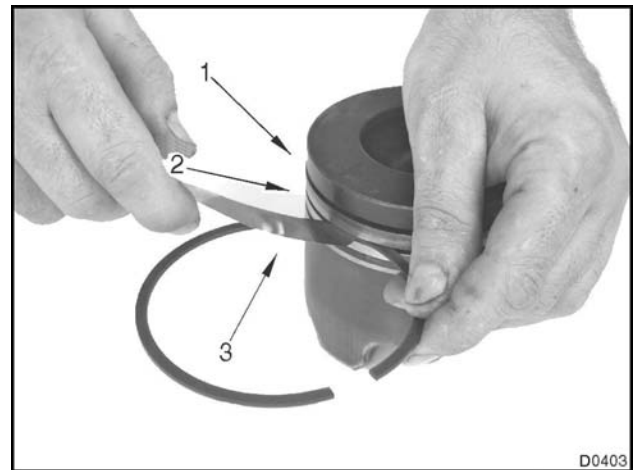


Figure 331 Checking ring groove clearance (intermediate ring shown)

1. Compression ring groove
2. Intermediate compression ring groove
3. Feeler gauge
3. Check side clearance of intermediate ring groove as follows:
 - a. Place outer edge of new ring in its respective ring groove.
 - b. Roll ring entirely around piston in its respective groove. Make sure ring is able to move freely in its groove.
 - c. Use a Feeler Gauge to check side clearance. Excessive side clearance indicates ring groove wear and requires

piston replacement. See Special Service Tools (page 213).

4. Check side clearance of oil control ring groove as follows:
 - a. Place outer edge of new ring in oil control ring groove.
 - b. Roll ring entirely around piston in its respective groove. Make sure ring is able to move freely in groove.
 - c. Use a feeler gauge to check side clearance of oil control ring in its respective groove. Excessive side clearance indicates ring groove wear and requires piston replacement. See Specifications (page 212).

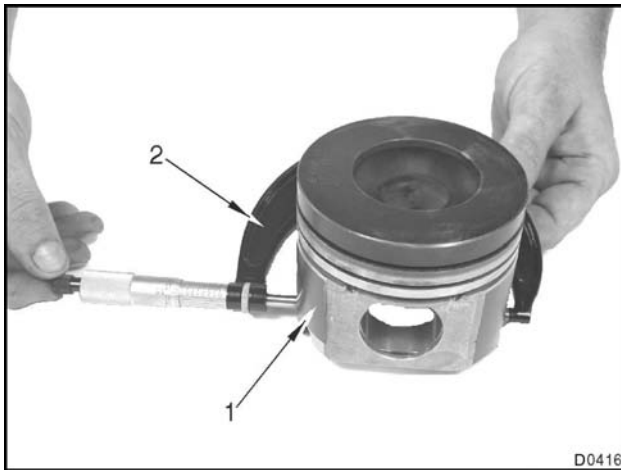


Figure 332 Measuring the piston skirt diameter

1. Piston skirt
 2. 3-4 inch micrometer
5. When considering piston replacement, check cylinder bore out-of-round specifications. See Specifications (page 212). Cylinder boring may be required. Such bore reconditioning will require oversize service pistons. Verify piston size by measuring skirt diameter under conditions indicated in the Specifications section of this manual. See Specifications (page 212).

NOTE: In addition to the standard size service piston, the following oversize pistons are available.

- 0.254 mm (0.010 in)
 - 0.508 mm (0.020 in)
 - 0.762 mm (0.030 in)
6. If cylinder walls have minor surface damage but are otherwise within specification (out of round), it may be possible to remove such damage by honing.

If cylinder bore is suitable for use without reconditioning, de-glaze bore using a glaze breaker brush, then reassemble. See Crankcase and Crankshaft section for the correct de-glazing procedure.

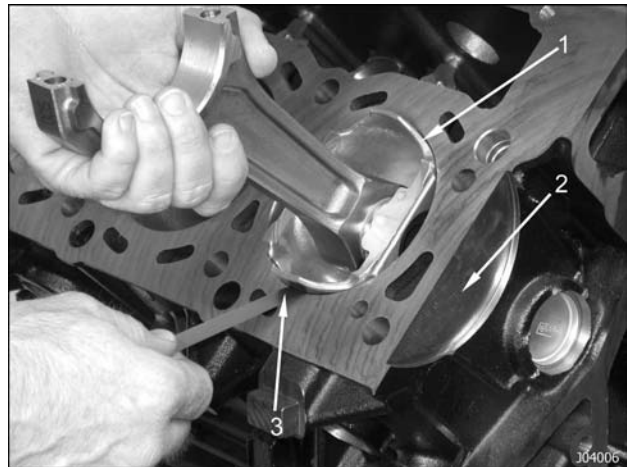


Figure 333 Checking the piston skirt clearance in cylinder bore

1. Piston
2. Crankcase
3. Feeler gauge

7. Check piston skirt clearance with a feeler gauge in the cylinder bore. Correct as required.

Piston Rings

NOTE: Faulty rings cannot always be detected by visual inspection. Therefore, whenever a piston is removed from a cylinder, replace the piston rings.

1. Inspect new piston rings for cleanliness.

2. Before installing new piston rings on piston, check gap for each ring as follows:
 - a. Push piston ring down into cylinder bore. Make sure the piston ring is square with cylinder wall. An inverted piston head can be used to push piston ring to desired location of measurement (usually at the top of the piston ring travel).
 - b. Use a feeler gauge to measure gap between ends of each piston ring.

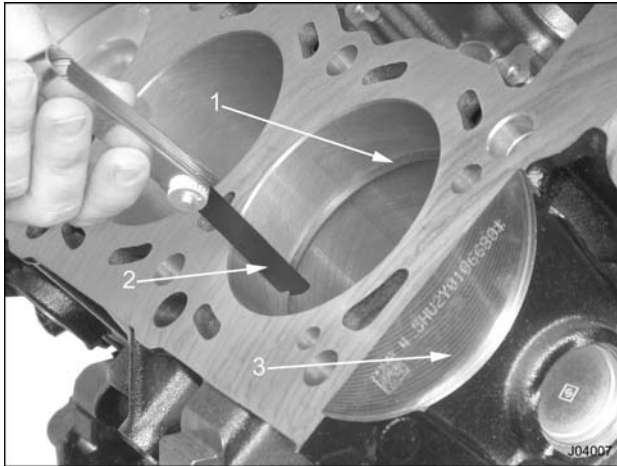


Figure 334 Checking the piston ring end gap clearance in cylinder bore

1. Piston ring
 2. Feeler gauge
 3. Crankcase
- c. If gap does not meet specifications, select another ring or recheck cylinder bore wear. See Specifications (page 212).

Connecting Rods

CAUTION: To prevent engine damage, the connecting rod cap fractured mating surfaces must be assembled onto the original connecting rod and in the original orientation (matching numbers must be adjacent to each other).

CAUTION: To prevent engine damage, keep the fractured mating surfaces clean and free of debris. Do not allow mating surfaces to rest on any other surface. Do not bump mating surfaces or drop the connecting rod or cap. This could cause wear and chipping of the fractured surface, resulting in improper mating during installation and possible engine damage.

1. Inspect connecting rod bolts for nicks or damage. Replace as required.
2. Inspect connecting rod and cap mating surfaces and bearing bore for any indication of damage. Bore must be smooth and free of scoring or nicks. Replace as required.

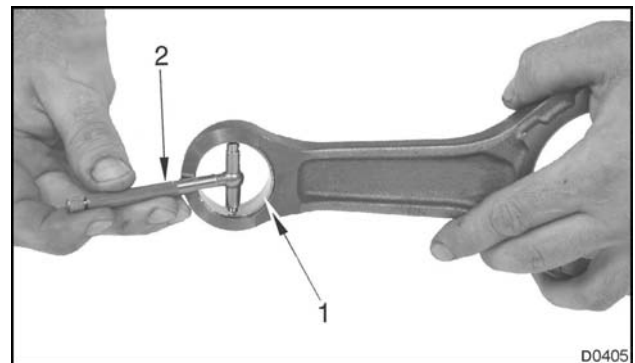


Figure 335 Measuring the inside diameter of piston pin bushing

1. Piston pin bushing
 2. Telescoping gauge
3. Inspect connecting rod piston pin bushing for wear as follows:
 - a. Using a Telescoping Gauge and a 1-2 inch micrometer, measure pin bore at two locations approximately 90° apart. Record the measurements. See Special Service Tools (page 213).
 - b. If inside diameter of piston pin bushing exceeds specification, replace connecting rod. See Specifications (page 212).

Connecting Rod Bore Out-of-Round and Taper Check

CAUTION: To prevent engine damage, check connecting rod bolts for binding. They should thread into connecting rod freely when lubricated with clean engine oil. If they do not, the connecting rod must be discarded. Connecting rod threads cannot be re-tapped if binding exists. Check thread condition carefully during inspection.

1. Lubricate connecting rod bolts with clean engine oil. Assemble cap to rod without bearing insert. Tighten bolts to Special Torque (page 213).

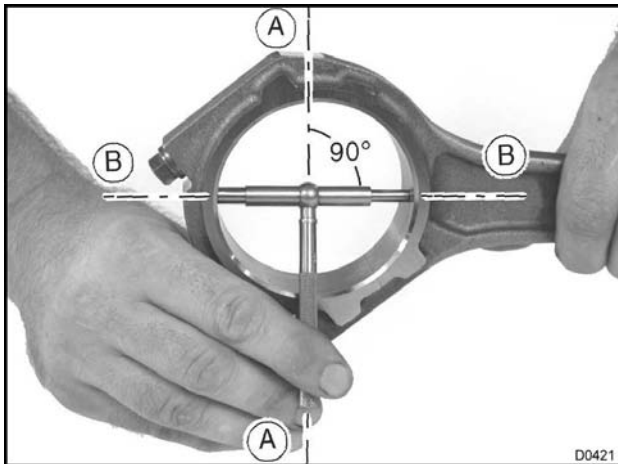


Figure 336 Measuring the connecting rod bearing bore for an out of round condition

2. Using a Telescoping Gauge, measure connecting rod at two locations, 90° apart. See Special Service Tools (page 213).

3. If the difference between dimension A and B exceeds out-of-round specifications, replace connecting rod. See Specifications (page 212).



Figure 337 Measuring connecting rod bore taper

4. Measure connecting rod taper as follows:
 - a. Insert a Telescoping Gauge near chamfer on either side. Record the readings. See Special Service Tools (page 213).
 - b. Measure inner diameter of connecting rod bearing bore near chamfer on other side. Record the readings.

The difference between the two readings is the connecting rod bore taper. If connecting rod bore taper exceeds specification, replace connecting rod. See Specifications (page 212).

5. With connecting rod cap removed, inspect surface finish of connecting rod bearing bore. Bore must be smooth and free of scoring, nicks or burrs. Replace as required.

Connecting Rod Bearing Fit Check

NOTE: Bearing shells must fit tightly in the bore. When bearing shells are inserted into the connecting rod and cap, they protrude above the parting line. This protrusion is required to achieve "bearing crush." Therefore connecting rod caps must be wiped clean prior to installation of the bearing shell.

Bearing shells across the open ends are slightly larger than the diameter of the connecting rod bore into which they are assembled. This condition is designed into the bearing shell, causing it to spread outward at the parting line when "bearing crush" load is applied by tightening the bolts. Some snap may be lost in normal use, but bearing replacement is not required because of a nominal loss of snap.

1. When the assembly is drawn up tight, the bearing is compressed, ensuring a positive contact between the backside of the bearing and the bore.
2. Lubricate connecting rod bolts with clean engine oil. Assemble cap to rod with new bearing shells installed. Tighten bolts alternately and evenly to the Special Torque (page 213).
3. Using a Telescoping Gauge, measure inside diameter of connecting rod bearing at two locations 90° apart. Average the two inside diameters. Record reading. See Special Service Tools (page 213).
4. Using a 2–3 inch micrometer, measure each crankshaft rod journal diameter. Record reading.
5. Subtract the crankshaft rod journal diameter from the respective connecting rod bearing inside diameter to obtain bearing-to-crankshaft running clearance. Repeat for each crankshaft rod journal.
6. If bearing-to-crankshaft running clearances exceed specifications because of wear on crankshaft, replace or grind crankshaft and

install undersize precision type bearing shells. See Specifications (page 212).

CAUTION: To prevent engine damage, do not attempt to reduce journal-to-bearing running clearances by reworking bearing cap, bearings, or both. Grind or replace the crankshaft only.

NOTE: Plastigage® measuring thread may be used as an alternate method of determining running clearance.

Piston Pin Inspection

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

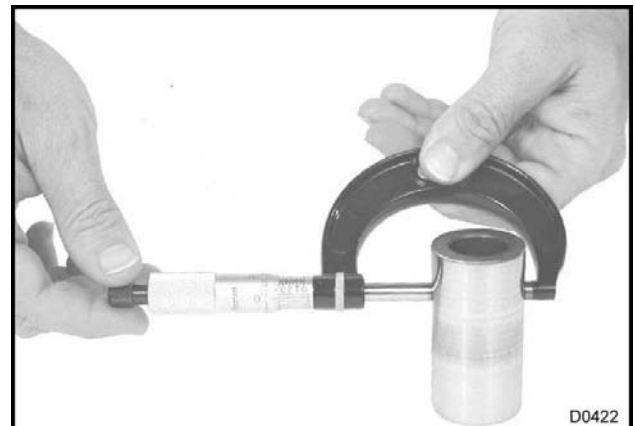


Figure 338 Checking for piston pin wear

2. Using a 1-2 inch micrometer, measure piston pin outside diameter at two locations 90° apart. Measure each end of the pin. Record the range of readings. If piston pin wear exceeds specifications, replace piston pin. See Specifications (page 212).



Figure 339 Measuring piston pin bore inside diameter

3. Using a 1-2 inch telescoping gauge and micrometer, measure each piston pin bore inside diameter, at two locations 90° apart. Record reading.
4. To check piston pin clearance, subtract piston pin outside diameter from piston pin bore inside diameter measurement. If clearance exceeds specifications, replace piston pin and check piston pin clearance using new piston pin. See Specifications (page 212).

Installation

Piston Assembly

! WARNING: To avoid serious personal injury or possible death, wear safety glasses when installing piston pin retaining rings. See "Safety Information (page 3)."

CAUTION: To prevent engine damage, make sure the connecting rod and piston are assembled correctly.

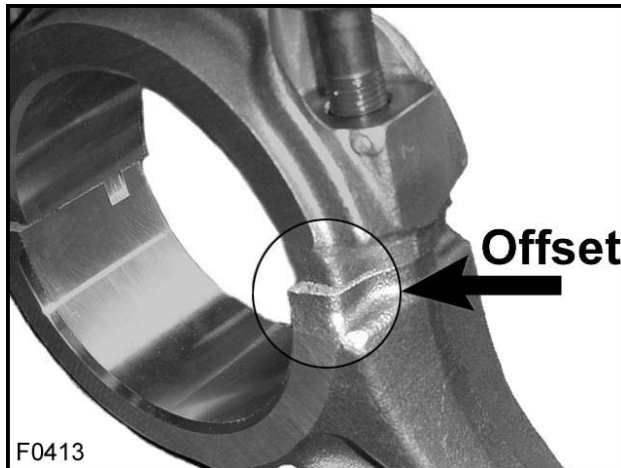


Figure 340 Offset for incorrect rod cap assembly

CAUTION: To prevent engine damage, the rod cap can only be correctly installed on the connecting rod if it is oriented in the correct direction. If the rod cap is reversed during assembly of the connecting rod, an obvious offset will be seen at the mating surfaces. If the connecting rod assembly is installed on the crankshaft in this manner, the connecting rod must be replaced. Also check the crank pin fillets for damage. Such damage will require replacement of the crankshaft.

Assemble the piston rings, piston, and connecting rod as follows:

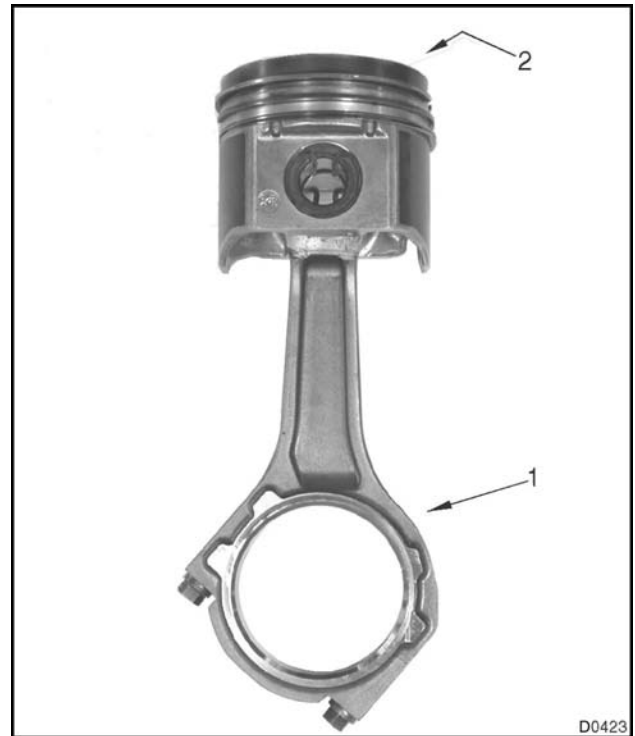


Figure 341 Proper position of installed connecting rod

1. Longer leg of connecting rod (cam side)
2. "CAM V8" stamped on cam side of piston crown

1. Connect piston to connecting rod as follows:
 - a. Lubricate connecting rod piston pin bore, piston pin bore, and piston pin with clean engine oil.
 - b. Orient the longer leg of the connecting rod with the side of the piston bearing the "CAM V8" stamped in its crown.



Figure 342 Installing the piston pin retaining ring

- c. Using pliers, install retaining ring at one end of piston pin bore.
- d. Slide piston pin through bored holes, stopping at installed retaining ring.
- e. Install second retaining ring.
- f. Check to see if the piston slides easily on piston pin from one snap ring to the other.

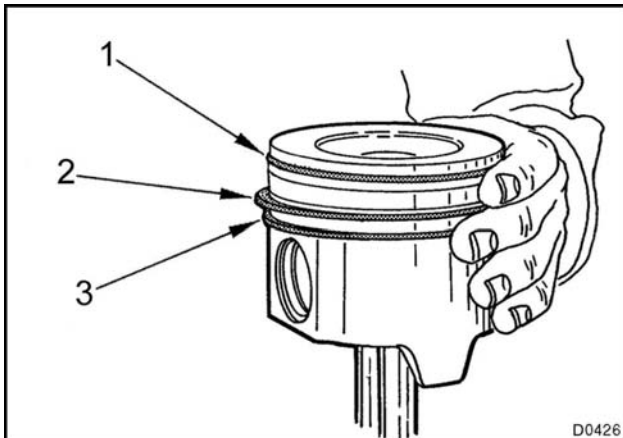


Figure 343 Piston ring locations

1. Top compression ring
2. Intermediate compression ring
3. Oil control ring

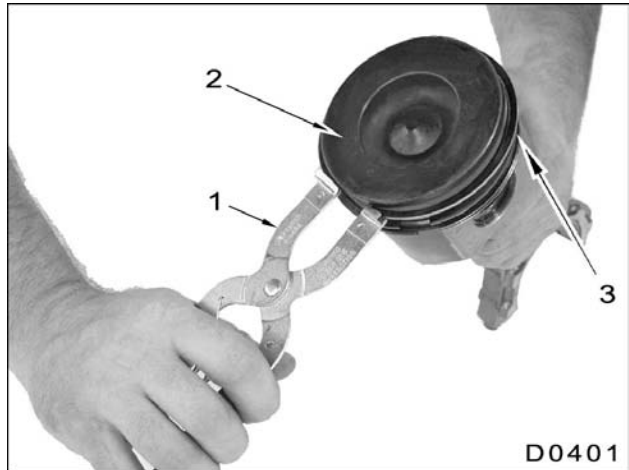


Figure 344 Installing the piston rings (typical)

1. Piston ring expansion pliers
 2. Piston
 3. Piston ring (top compression shown)
2. Using Piston Ring Expansion Pliers, install piston rings as follows: See Special Service Tools (page 213).
 - a. Install expansion spring component of two piece oil control ring into bottom piston groove.
 - b. Install oil scraper component of two piece oil control ring over expansion spring.

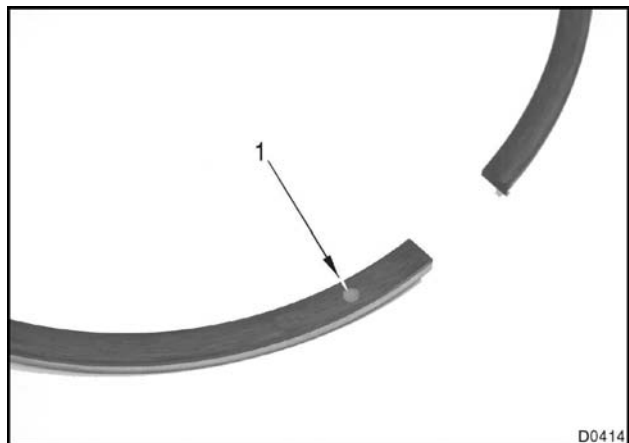


Figure 345 Piston ring identification marks (top ring shown)

1. Identification mark

CAUTION: To avoid engine damage, make sure the piston rings are installed correctly. Both intermediate and compression rings have the same identification markings. The intermediate ring has a square cross section and goes in the middle groove. The compression ring has a keystone cross section and goes in the top groove.

- c. Install intermediate ring (rectangular cross section) into middle piston groove. The intermediate ring is identified by one 'O' mark located on the top surface of ring. Make sure the ring is installed with identification mark facing up.
 - d. Install compression ring (keystone cross section) into top piston groove. The compression ring is identified by the 'O' mark located on the top surface of ring. Make sure the ring is installed with identification mark facing up.
3. Space ring gaps approximately 120° apart after ring installation.

Connecting Rod and Piston Installation

1. Turn crankshaft so that the number 1 connecting rod journal is at the bottom of its stroke.

NOTE: Before installing piston and connecting rod assembly, make sure all piston cooling tubes are in place.



Figure 346 Lubricating the piston and piston rings for installation

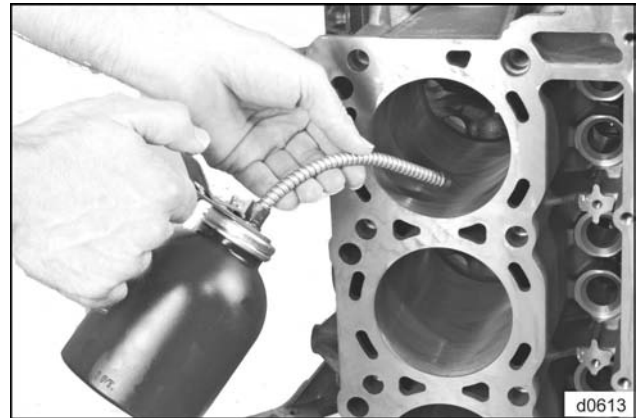


Figure 347 Lubricating the cylinder walls for piston installation

2. Coat piston and piston rings with clean engine oil. Coat cylinder walls, crankshaft journals, and piston cope with clean engine oil.

CAUTION: To prevent engine damage, the "CAM V8" stamped on top of the piston must be oriented towards the camshaft side of the crankcase, toward center of engine.

NOTE: The pistons are interchangeable between the VT 365 and VT 275 diesel engines. The initial VT 275 engine build used the same piston as the VT 365 engine. Therefore, a piston stamped with "CAM V8" on top is correct for both engines.



Figure 348 Piston rings compressed in piston cope

3. Place piston in Piston Ring Compressor (cope) to compress rings and ease the installation of piston / connecting rod assembly into the crankcase. See Special Service Tools (page 213).

NOTE: Make certain that connecting rod and cap bearing surfaces have been wiped clean of any oil or residue.

4. Install bearing shells in connecting rod and cap. Coat bearing shell in connecting rod with clean engine oil.
5. Carefully insert connecting rod and start piston into the top end of the cylinder bore until cope is against the top of the cylinder.

CAUTION: To prevent engine damage, use caution not to damage piston cooling tubes when installing connecting rod and piston assemblies.

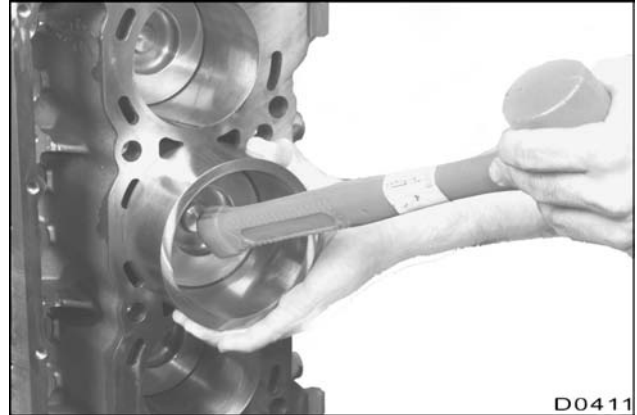


Figure 349 Installing the piston into the cylinder bore

6. Once piston and connecting rod assembly have been inserted in cylinder bore, use the handle (wood or plastic) of a hammer to tap piston in crankcase bore. Guide connecting rod in place on crankshaft.

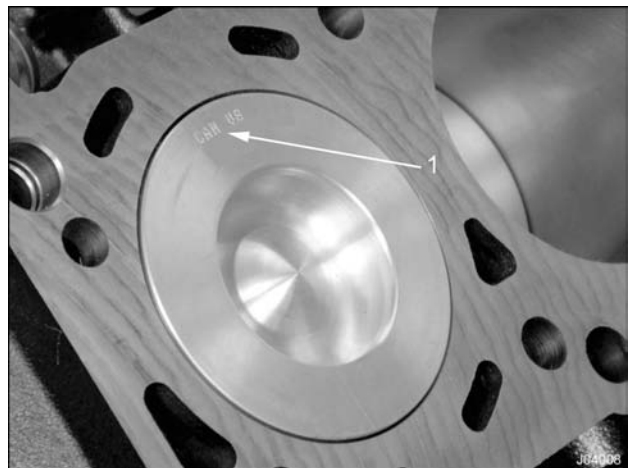


Figure 350 Proper orientation of piston installed in cylinder bore

1. Identification mark, "CAM V8"

7. Apply clean engine oil to connecting rod bolt hole threads and bearing shell in cap before installing bolts.



Figure 351 Connecting rod and cap matching identification numbers

1. Matching numbers

CAUTION: To prevent engine damage, do not alter or damage the fractured mating surfaces of the connecting rod and cap.

8. Assemble cap to connecting rod with matching identification code on same crankshaft journal from which it was removed. Be certain that the longer leg of the connecting rod and the "CAM V8" stamp on piston crown are oriented towards the camshaft.

CAUTION: To prevent engine damage, do not use air powered tools when installing connecting rod bolts. This may cause seizure of connecting rod bolts.

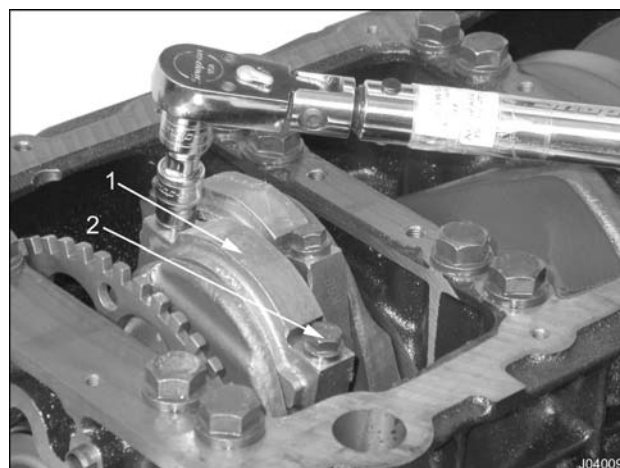


Figure 352 Torquing the connecting rod cap

1. Connecting rod bearing cap
2. Connecting rod bolt

9. Install and tighten connecting rod bolts evenly to the initial and final torque values. See Special Torque (page 213).
10. Repeat installation procedure for remaining connecting rod and piston assemblies.
11. Check connecting rod side clearance with feeler gauge. See procedure in removal section Piston and Connecting Rod Checks in this section.
12. Complete the engine rebuild and reinstall all safety guards, shields and covers after servicing the engine.
13. Make sure all tools, covers, loose parts and service equipment are removed from the engine area after all work is done.

Specifications

| Power Cylinder | |
|--|---|
| Connecting Rods | |
| Connecting rod length (center to center) | 176 mm (6.929 in) |
| Bushing bore diameter (pin end) | 36.98 to 37.02 mm (1.456 to 1.457 in) |
| Piston pin bushing inside diameter | 34.0140 to 34.0215 mm (1.3391 to 1.3394 in) |
| Bearing bore diameter (crankshaft end) | 72.987 to 73.013 mm (2.8735 to 2.8745 in) |
| Bearing bore maximum out-of-round | 0.013 mm (0.0005 in) |
| Bearing bore maximum taper per 25 mm (1 inch) | 0.013 mm (0.0005 in) |
| Connecting rod bearing inside diameter | 69.027 to 69.077 mm (2.7176 to 2.7196 in) |
| Connecting rod bearing running clearance (diameter) | 0.0203 to 0.0837 mm (0.0008 to 0.0033 in) |
| Connecting rod side clearance | 0.3 to 0.6 mm (0.012 to 0.024 in) |
| Weight (complete rod without bearing) | 1201.5 to 1215.5 g (2.649 to 2.679 lb) |
| Pistons | |
| Material | Aluminum Alloy |
| Skirt diameter ¹ | 94.9460 to 94.9186 mm (3.737 to 3.738 in) |
| ¹ Measure 14.68 mm (0.578 in) from bottom, at 90° to the piston pin. Measure only at room temperature of 19 to 21°C (66 to 70°F). | |
| Service Piston: | |
| Standard size | 94.9460 to 94.9186 mm (3.737 to 3.738 in) |
| 0.254 mm (0.010 in) oversize | 95.1738 to 95.1992 mm (3.747 to 3.748 in) |
| 0.508 mm (0.020 in) oversize | 95.4278 to 95.4532 mm (3.757 to 3.758 in) |
| 0.762 mm (0.030 in) oversize | 95.6818 to 95.7072 mm (3.767 to 3.768 in) |
| Top compression ring groove width (measured over 2.08 mm (0.082 in) gauge pins): | |
| Upper limit | 94.469 mm (3.7192 in) |
| Replacement limit | 94.290 mm (3.7122 in) |
| Piston height above crankcase deck (protrusion) | 0.900 mm (0.0354 in) |
| Piston skirt clearance (1 - 8) | 0.0441 to 0.0909 mm (0.0017 to 0.0036 in) |
| Piston Pins | |
| Length | 65.073 to 65.327 mm (2.5619 to 2.5719 in) |
| Diameter | 33.9975 to 34.0025 mm (1.3385 to 1.3387 in) |
| Pin fit at room temperature of 19 to 21°C (66 to 70°F): | |
| Clearance in connecting rod (piston pin bushing) | 0.0115 to 0.0240 mm (0.00045 to 0.00094 in) |

| | |
|---------------------|---|
| Clearance in piston | 0.013 to 0.022 mm (0.0005 to 0.0009 in) |
| End clearance | 0.24 mm (0.009 in) |

Piston Rings

| | |
|---|---|
| Ring diameter (standard): | 95 mm (3.74 in) |
| Fit in groove (side clearance in bore): | |
| Intermediate compression | 0.051 to 0.102 mm (0.0020 to 0.0040 in) |
| Oil control | 0.038 to 0.084 mm (0.0015 to 0.0033 in) |
| Ring gap in bore: | |
| Top compression | 0.29 to 0.55 mm (0.011 to 0.021 in) |
| Intermediate compression | 1.40 to 1.66 mm (0.055 to 0.065 in) |
| Oil control | 0.24 to 0.50 mm (0.009 to 0.019 in) |

Special Torque**Power Cylinder**

| | | |
|------------------------------|---------|--------------------|
| Connecting rod bearing bolts | Initial | 45 N·m (33 lbf·ft) |
| | Final | 68 N·m (50 lbf·ft) |

Special Service Tools**Power Cylinder**

| Description | Tool Number |
|-----------------------------------|----------------|
| Dial Indicator with Magnetic Base | Obtain locally |
| Feeler Gauge | Obtain locally |
| Piston Gauge Pins (0.082 in) | ZTSE4513 |
| Piston Ring Compressor (cope) | ZTSE4514 |
| Piston Ring Expansion Pliers | Obtain locally |
| Telescoping Gauge Set | Obtain locally |

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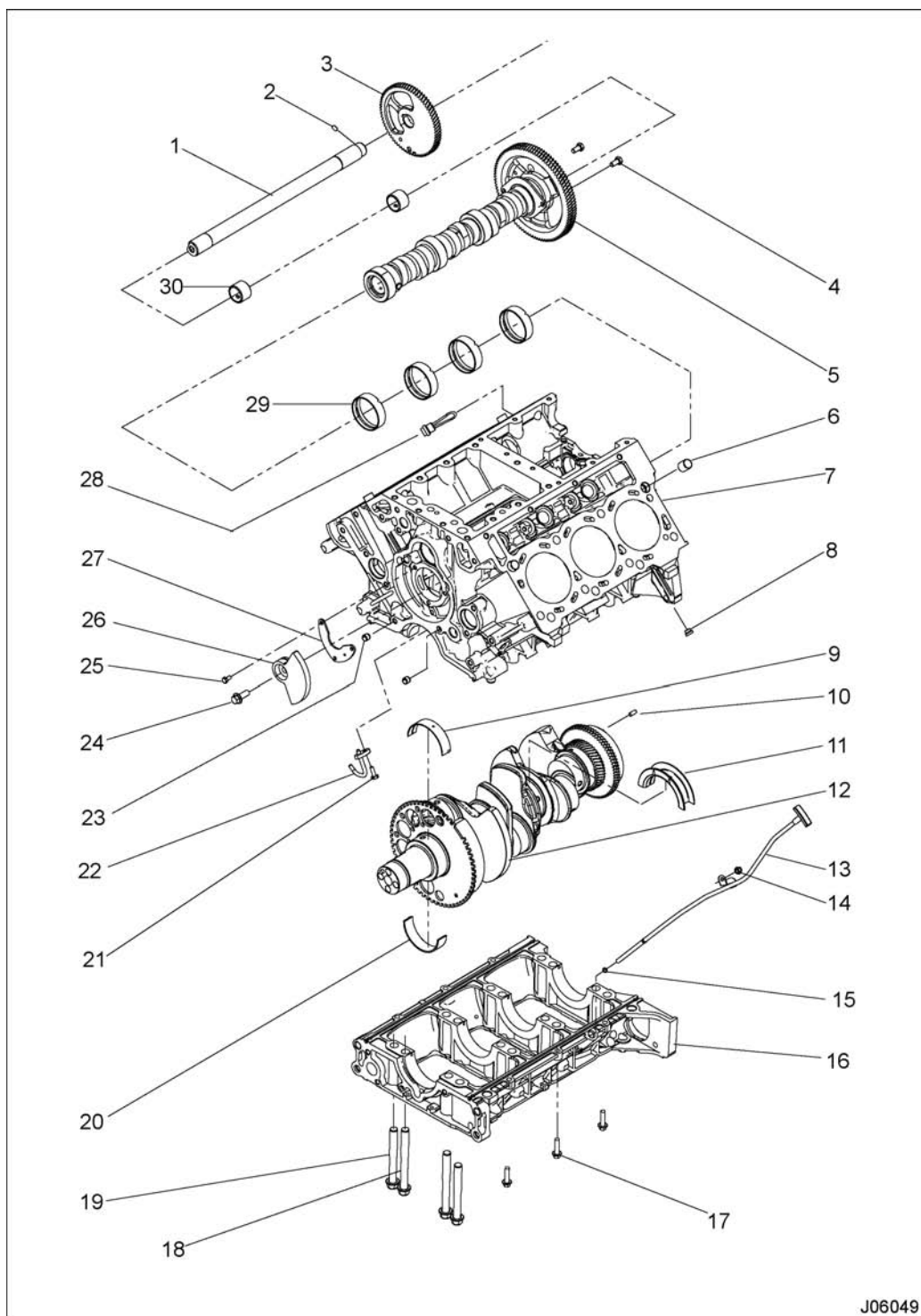


Figure 353 Exploded view of crankcase and related parts

-
- | | | |
|---|---|---|
| 1. Primary balancer shaft | 12. Crankshaft assembly | 24. Bolt, M10 x 25 |
| 2. Dowel pin | 13. Oil level gauge tube assembly | 25. Bolt, M6 x 12 (3) |
| 3. Primary balancer gear | 14. Nut, M8 | 26. Primary balancer counterweight |
| 4. Bolt, M8 x 16 (2) | 15. Dipstick tube seal | 27. Primary thrust plate |
| 5. Camshaft assembly | 16. Lower crankcase assembly | 28. Coolant heater, right side rear (optional) |
| 6. Spring dowel pin (4) | 17. Bolt, M8 x 30 (6) | 29. Camshaft bushing (4) |
| 7. Crankcase assembly | 18. Main bearing bolt, M14 x 127 (8) | 30. Primary balancer bushing (2) |
| 8. Plug, M16 (2) | 19. Main bearing bolt, M14 x 114 (8) | |
| 9. Crankshaft upper main bearing (3) | 20. Crankshaft lower main bearings (4) | |
| 10. Dowel pin | 21. Bolt, M8 x 18 (6) | |
| 11. Crankshaft upper main thrust bearing (1) | 22. Piston cooling tube (6) | |
| | 23. Dowel pin (2) | |

Removal

It will first be necessary to remove the following engine components discussed within other sections of this manual:

- Turbocharger assembly
- Intake manifold and EGR cooler
- Flywheel and rear cover
- Vibration damper and front cover
- Cylinder heads
- Upper and lower oil pan
- Piston assemblies

CAUTION: To prevent engine damage, do not remove the rear primary crankshaft flange bolts under any circumstances. If the flange is removed and reinstalled, it will result in engine vibration and premature transmission component wear.

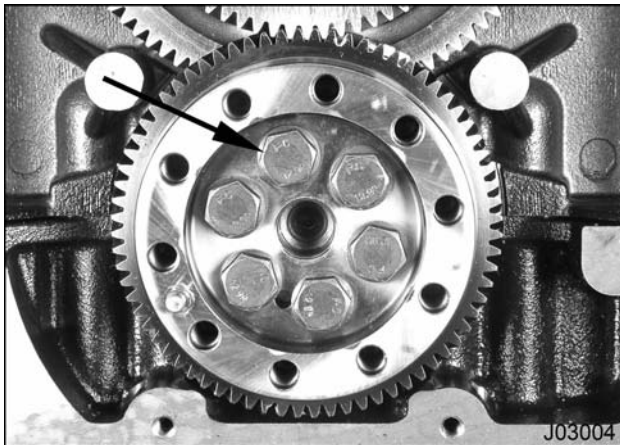


Figure 354 Rear primary crankshaft flange bolts (6)

Preliminary Checks

! WARNING: To avoid serious personal injury or possible death, make sure that the engine has cooled down sufficiently before attempting to remove any components. See "Safety Information (page 3)."

! WARNING: To avoid serious personal injury or possible death: Do not allow used engine fluids to stay on your skin. Clean your skin and nails with soap and water, or a good hand cleaner. Wash or properly throw away clothing or rags containing used engine fluids. Used engine fluids contain certain elements that may be unhealthy for skin and could even cause cancer. See "Safety Information (page 3)."

NOTE: Engine fluids, oil, fuel and coolant, can be a threat to the environment. Never dispose of engine fluids by putting them in the trash, pouring them on the ground, in the sewers, in streams or bodies of water.

NOTE: Before removing any of the components in this section, it will be necessary to determine the following backlash and end play checks:

- Crankshaft gear to camshaft gear
- Primary balancer gear to crankshaft gear
- Crankshaft end play
- Camshaft end play
- Primary balancer shaft end play

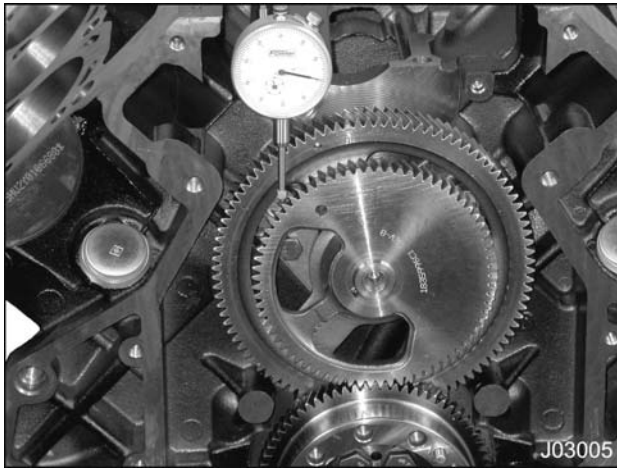


Figure 355 Primary balancer gear-to-crankshaft gear backlash

1. Check and record primary balancer gear-to-crankshaft gear backlash as follows:

NOTE: Crankshaft gear must be fixed, not allowed to rotate, only the primary balance gear should be allowed to rotate, otherwise the reading will not be valid.

- a. Mount Dial Indicator with Magnetic Base onto rear of engine. See Special Service Tools (page 250).
- b. Position dial indicator tip onto a primary balancer gear tooth and remove lash.
- c. Zero dial indicator.
- d. Rotate gear by hand and read indicator. Record backlash.
- e. If backlash exceeds specified limits, replace primary balance gear. See Specifications (page 247).

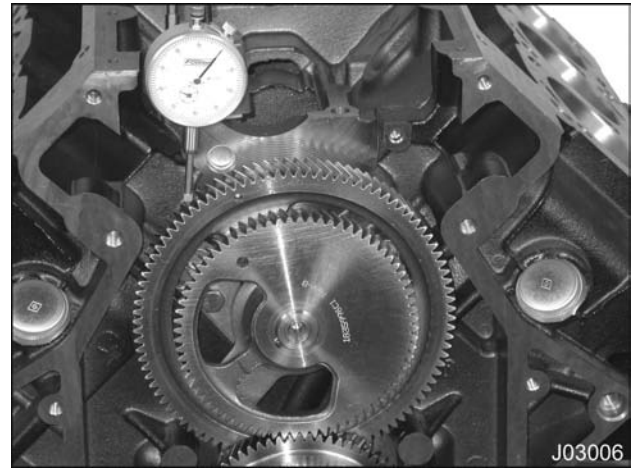


Figure 356 Camshaft-to-crankshaft gear backlash

2. Check and record camshaft gear-to-crankshaft gear backlash as follows:

NOTE: Crankshaft gear must be fixed, not allowed to rotate, only the camshaft gear should be allowed to rotate, otherwise the reading will not be valid.

- a. Mount Dial Indicator with Magnetic Base onto rear of engine. See Special Service Tools (page 250).
- b. Position dial indicator tip onto a cam gear tooth and remove lash.
- c. Zero dial indicator.
- d. Rotate gear by hand and read indicator. Record backlash.
- e. If backlash exceeds specified limits, replace camshaft gear. See Specifications (page 247).

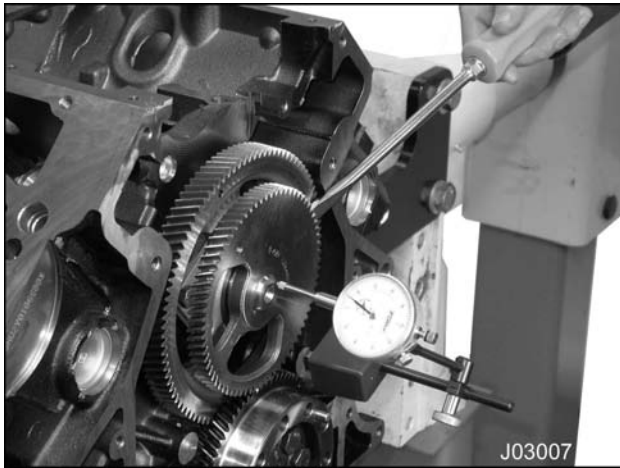


Figure 357 Checking primary balance shaft end play

3. Check and record primary balance shaft end play as follows:
 - a. Reposition dial indicator tip to balance shaft, not gear.
 - b. Push camshaft towards the front of the engine.
 - c. Zero dial indicator.
 - d. Place a small pry bar between the primary balance gear and crankcase. Lightly pry primary balance gear toward indicator. Compare dial indicator reading with specification. See Specifications (page 247).



Figure 358 Removing the balance shaft counterweight bolt

4. Remove the balance shaft counterweight bolt (M10 x 25).

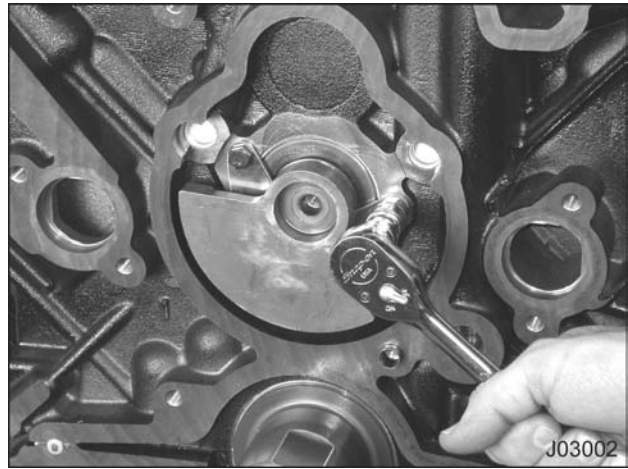


Figure 359 Removing balance shaft thrust plate bolts

5. Remove three balance shaft thrust plate bolts (M6 x 12).

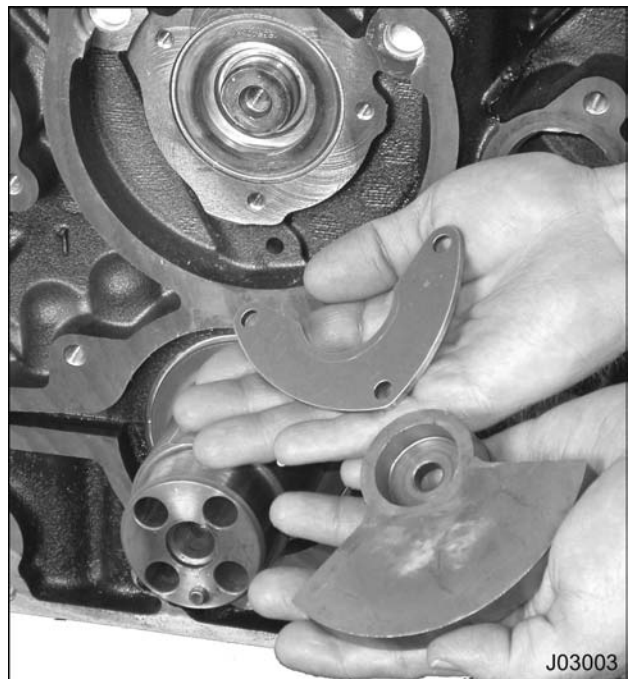


Figure 360 Balance shaft counterweight and thrust plate

6. Remove balance shaft counterweight and thrust plate.



Figure 361 Removing the balance shaft

7. Carefully remove balance shaft from the inside of the camshaft.

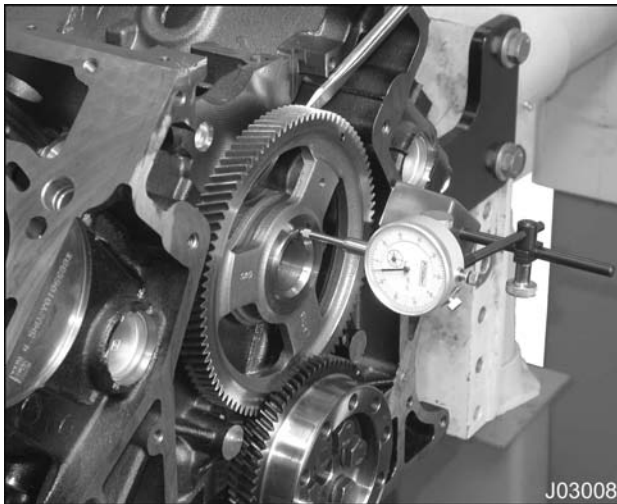


Figure 362 Checking camshaft end play

NOTE: Check end play only after the balance shaft has been removed.

8. Check and record camshaft end play as follows:
 - a. Reposition dial indicator tip onto camshaft, not gear.
 - b. Push camshaft towards the front of the engine.

- c. Zero dial indicator.
- d. Place a small pry bar or screwdriver between the camshaft gear and crankcase. Lightly pry camshaft gear towards indicator. Compare dial indicator measurement with Specifications (page 247).

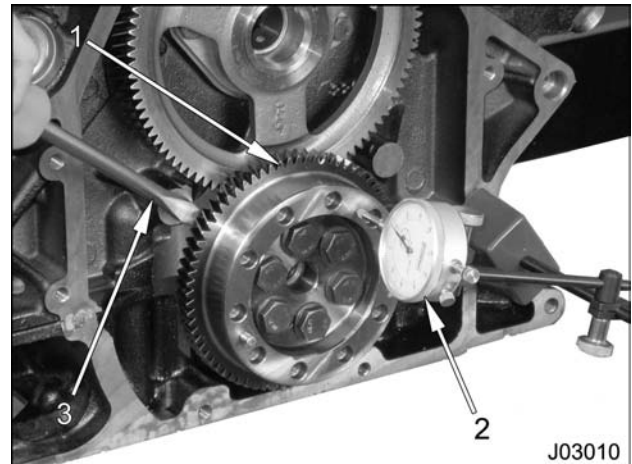


Figure 363 Checking crankshaft end play

1. Crankshaft gear
2. Dial indicator
3. Pry bar or screwdriver

9. Check crankshaft end play as follows:
 - a. Mount dial indicator on crankcase with indicator tip on the end of crankshaft flange as shown.
 - b. Pry crankshaft forward with pry bar and zero dial indicator.
 - c. Pry crankshaft back and forth while reading dial indicator. Record end play measurement.

Lower Crankcase

1. Remove oil gauge tube assembly if not done so already. Remove dipstick tube seal and discard.
2. Remove retaining bolt (M6 x 14) from Crankshaft Position (CKP) sensor located on the front of the engine, lower right.

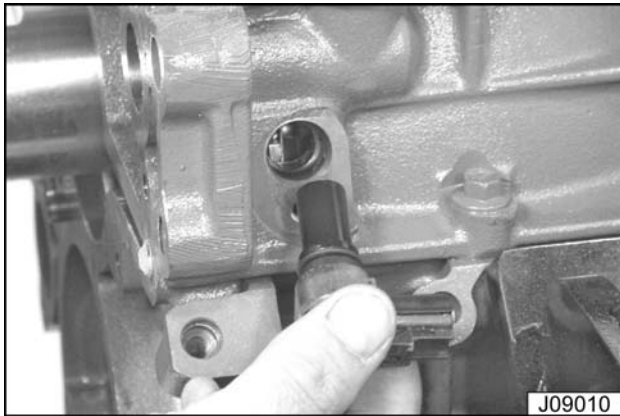


Figure 364 Removing the CKP sensor

3. Remove CKP sensor from lower crankcase. Discard the O-ring seal.



Figure 365 Removing the lower crankcase main bolts

4. Remove all lower crankcase main bearing bolts (inboard and outboard).

NOTE: There are three different bolt sizes supporting the lower crankcase:

- Eight lower crankcase main bearing bolts (M14 x 127 - inboard)
- Eight lower crankcase main bearing bolts (M14 x 114 - outboard)
- Six lower crankcase outer bolts (M8 x 30)

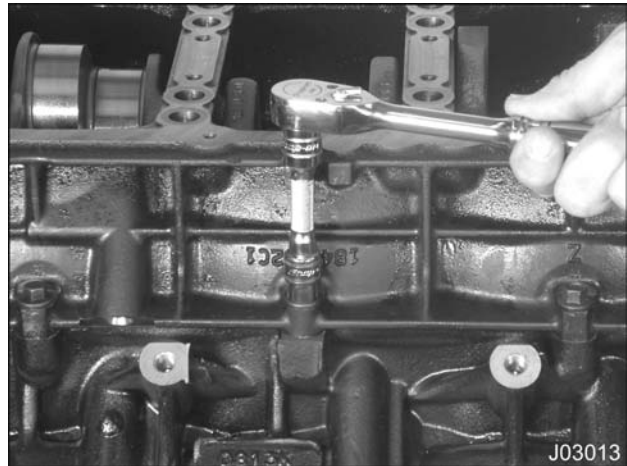


Figure 366 Removing the six lower crankcase bolts

5. Remove six lower crankcase bolts (M8 x 30).

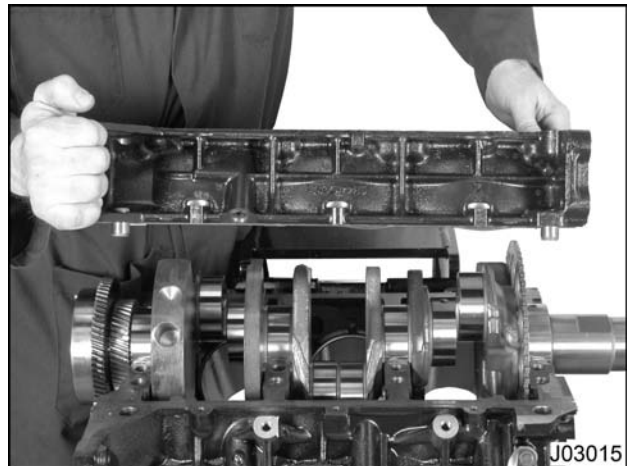


Figure 367 Removing the lower crankcase

6. Carefully lift the lower crankcase away from crankshaft. Discard the seal.
7. Remove main bearing shells from lower crankcase by pushing them out of bearing saddles. Mark each lower bearing shell with numbers 1 to 4, beginning from the front. Place them aside for inspection.

Crankshaft

! WARNING: To avoid serious personal injury or possible death, use an appropriately sized lifting sling and hoist equipped with a safety latch on hook. See "Safety Information (page 3)."

1. Install a bolt into each end of crankshaft.

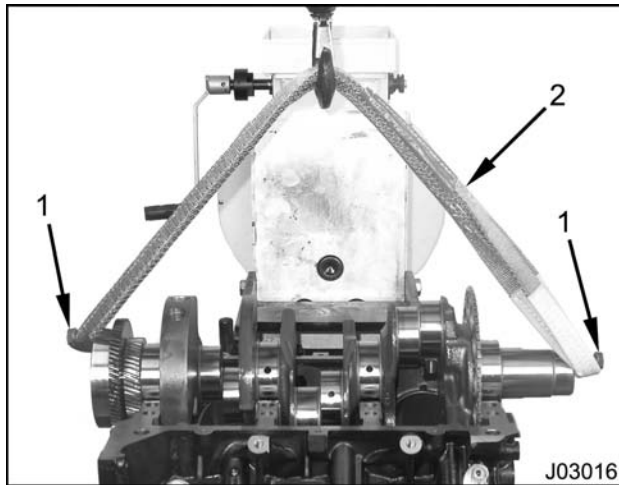


Figure 368 Removing the crankshaft from crankcase

1. Bolts threaded into crankshaft
 2. Lifting sling
2. Attach lifting sling to crankshaft over bolts installed in crankshaft. Lift crankshaft straight up and out of crankcase.

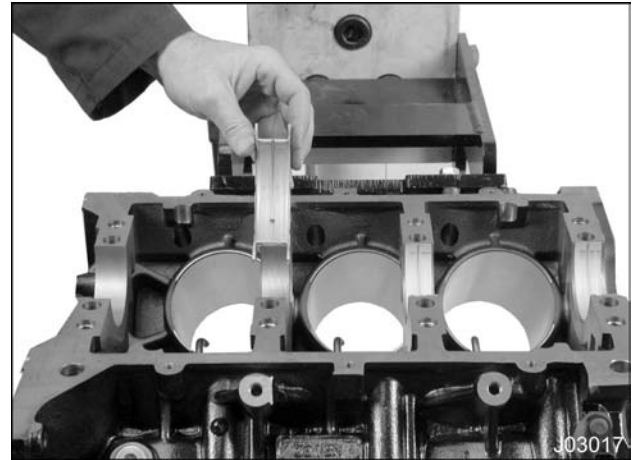


Figure 369 Removing the upper main bearings (thrust bearing shown)

3. Remove bearings from upper main bearing saddles by pushing them out. Mark upper bearings and put them with their respective lower bearings for proper inspection.

Piston Cooling Tubes

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

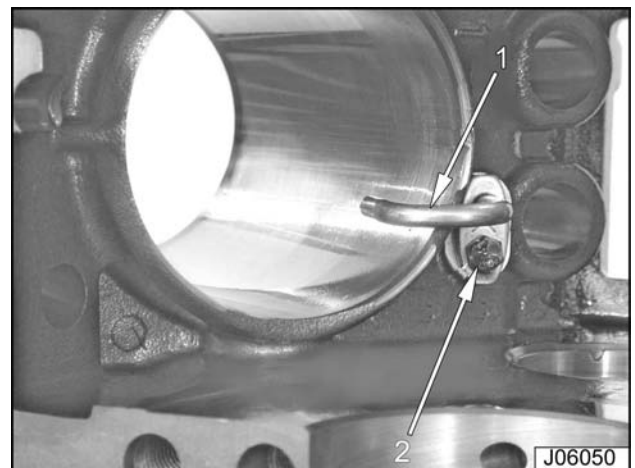


Figure 370 Piston cooling tube

1. Piston cooling tube
2. Piston cooling tube mounting bolt

Remove each piston cooling tube by removing its special patch type mounting bolt (M6 x 18). The bolts are reusable, providing you clean and inspect the bolt and add Loctite® #242 to bolt threads upon installation.

Camshaft / Primary Balancer

1. Remove the Camshaft Position (CMP) sensor retaining bolt (M6 x 14) located at front of engine, lower left.

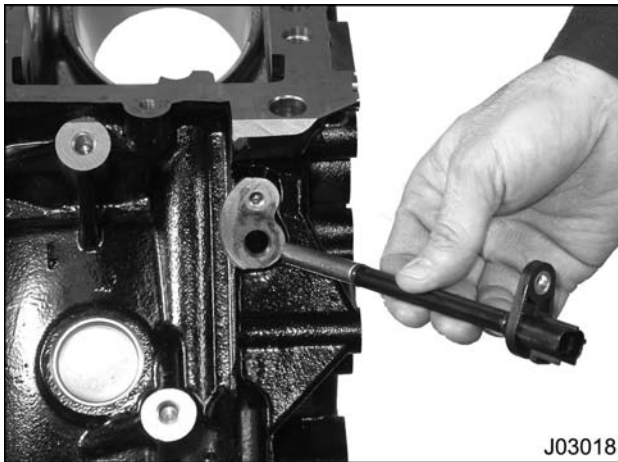


Figure 371 Removing the CMP sensor

2. Remove the CMP sensor and discard both sensor O-rings.



Figure 372 Camshaft thrust plate mounting bolts

1. Camshaft thrust plate mounting bolt (2)

3. Remove two camshaft thrust plate mounting bolts (M8 x 16).

NOTE: If the engine is mounted on a revolving stand, rotate engine so rear of engine is facing up (in vertical position). This position allows for easy removal of camshaft assembly.

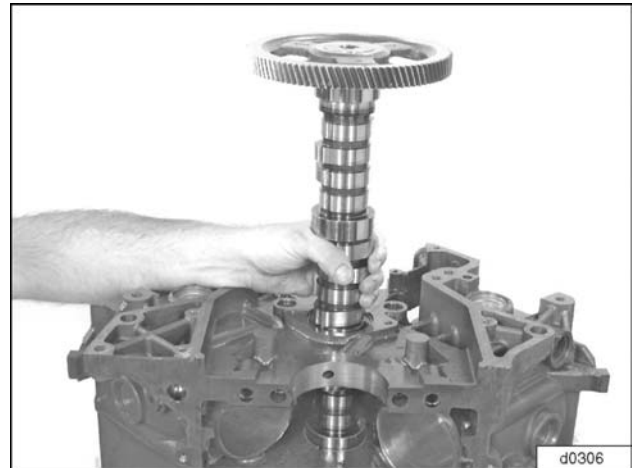


Figure 373 Removing the camshaft assembly

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

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 (Camshaft Bushings, page 234).
2. Use existing camshaft bushing kit in conjunction with Camshaft Bushing Remover / Installer (expanding collet) to remove all camshaft bushings. Install Camshaft Bushing Remover / Installer (expanding collet in collapsed state) into camshaft bushing. See Special Service Tools (page 250).

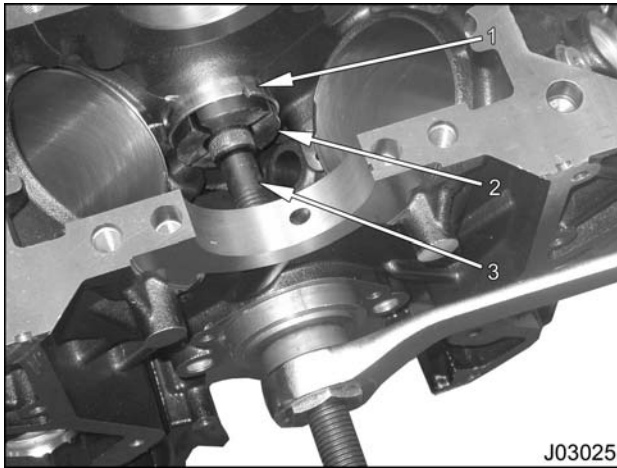


Figure 374 Removing a camshaft bushing

1. Camshaft bushing
 2. Camshaft Bushing Remover/Installer (expanding collet)
 3. Pulling screw (from camshaft bushing kit)
3. Assemble pulling screw in Camshaft Bushing Remover/Installer (expanding collet) and tighten backup nut until collet fits snug in camshaft bushing. To avoid nicks on bushings, be careful when inserting or removing threads of pulling screw.
4. Attach pulling plate, thrust bearing and drive nut on pulling screw. Tighten nut against thrust

bearing and pulling plate. Continue to thread nut on pulling screw until camshaft bushing is free from crankcase.

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

Coolant Heater

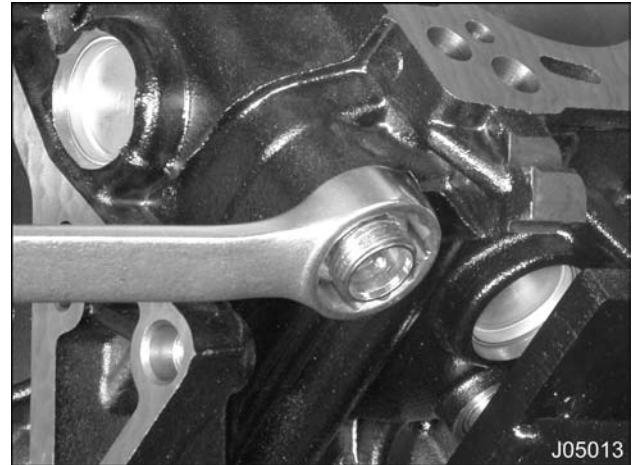


Figure 375 Removing the coolant heater

Remove coolant heater from right rear side of engine block and discard O-ring seal.

Cleaning, Inspection and Testing

Crankcase



WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using compressed air for cleaning to reduce the danger from flying debris. Limit the air pressure to 207 kPa (30 psi). See "Safety Information (page 3)."

NOTE: The best way to clean the crankcase during an engine overhaul is in a chemical bath or hot tank. This procedure removes all carbonized material and mineral deposits which collect in coolant passages. However, when a hot tank is not available, use the following procedure:

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

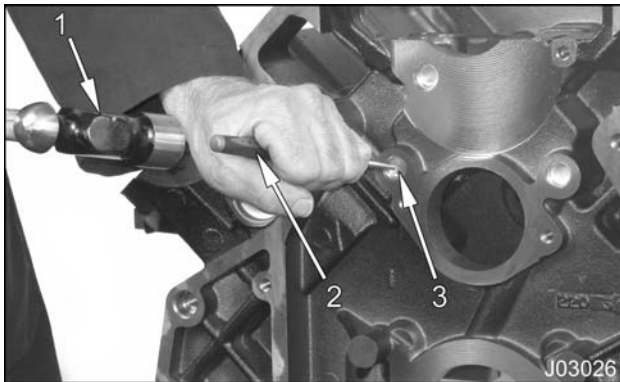


Figure 376 Removing oil gallery cup plugs

1. Hammer
 2. Punch
 3. Oil gallery cup plug (5)
1. To remove main oil gallery cup plug (16 mm) located in rear of crankcase, use a punch and hammer near the edge of the plug and strike

with hammer. Remove plug from crankcase and discard.

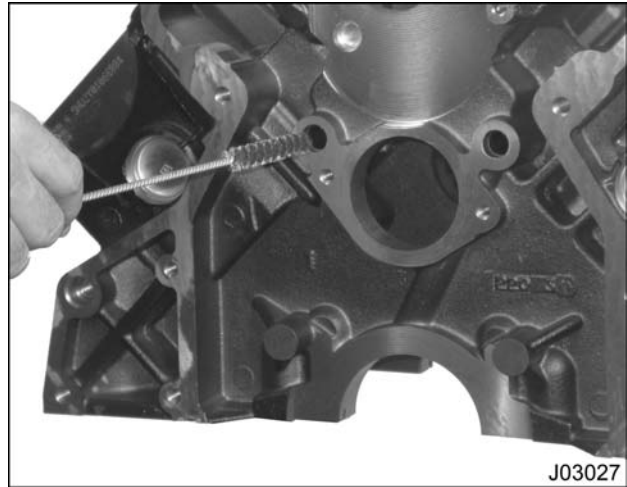


Figure 377 Cleaning the main oil gallery

2. Clean main galleries with an Oil Gallery Cleaning Brush. See Special Service Tools (page 250).
3. Spray or wipe main oil gallery cup plug bores with an appropriate cleaning solvent. The bores must be free of any oily residue for the sealant to adhere and be effective.
4. Coat edges of new oil gallery cup plugs and crankcase joints with Loctite® #620 sealant prior to installing cup plugs.
5. Use an Oil Gallery Plug Driver to install new oil gallery cup plugs. It should be flush with the crankcase surface to approximately 1.50 mm (0.060 in) below surface. See Special Service Tools (page 250).
6. Use non-metallic stiff bristle brushes and scrapers to clean gasket material from machined surfaces of crankcase.
7. Clean cylinder bore with soap, water, and a nylon stiff bristle brush.
8. Clean lower crankcase in solvent. Dry with filtered compressed air.

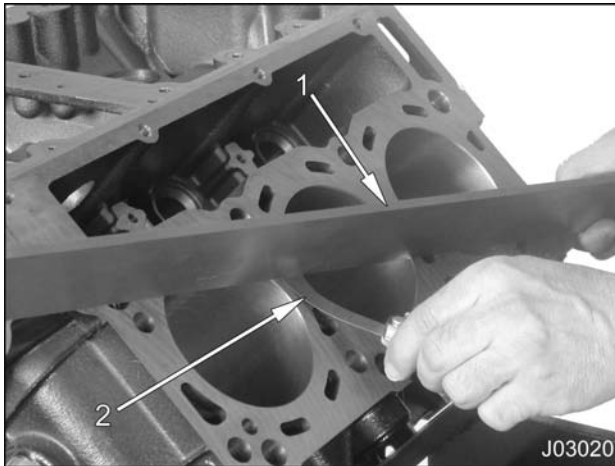


Figure 378 Checking head deck for flatness

1. Straightedge
2. Feeler gauge

9. Use a Straightedge to check the cylinder block top surface of crankcase for flatness. Insert a Feeler Gauge between the Straightedge and crankcase head surface. See Special Service Tools (page 250).
 - a. Measure the total deck surface, if any gap exceeds specifications, the crankcase must be replaced. See Specifications (page 247).
 - b. Divide the deck surface into areas of approximately 150 mm². Measure each area and if any gap exceeds specifications, the crankcase must be replaced. See Specifications (page 247).
 - c. Divide the deck surface into areas of approximately 25 mm². Measure each area and if any gap exceeds specifications, the crankcase must be replaced. See Specifications (page 247).

CAUTION: Do not resurface the crankcase. Surface defects beyond those listed above cannot be corrected.

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

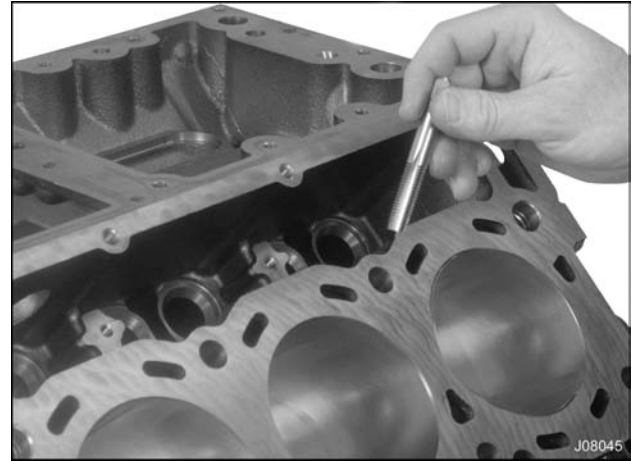


Figure 379 Cleaning head bolt holes with a bottoming tap

10. Clean all cylinder head bolt holes with the Head Bolt Bottoming Tap. Blow out chips with filtered compressed air. See Special Service Tools (page 250).
11. After cleaning, inspect crankcase for cracks, scoring, roughness or wear at cylinder bores.
12. If cylinder walls have minor surface damage, but are otherwise within out-of-round specifications, it may be possible to remove such damage by honing.

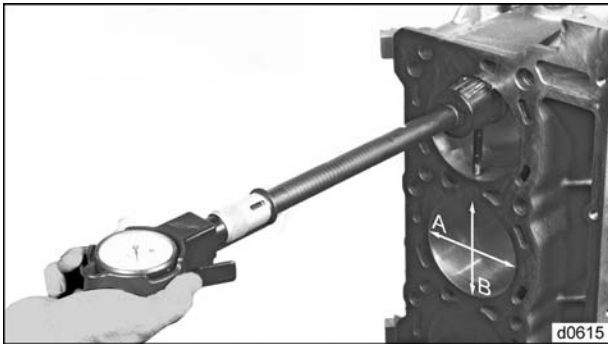


Figure 380 Checking cylinder bore for an out-of-round condition

13. Use a Cylinder Bore Gauge to check cylinder bore for out-of-round conditions. See Special Service Tools (page 250).
 - a. 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.
 - b. Measure each bore so gauge reading coincides with center line of crankshaft (dimension B). Record reading.
 - c. The difference between dimension A and dimension B is the out-of-round condition at the top of the cylinder bore.
14. Repeat the same procedure at the bottom of ring travel to check for out-of-round condition.

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 dimension.

15. If cylinder bore is within specifications, standard size pistons and rings may be used. If cylinder bore is suitable for use without reconditioning, de-glaze the cylinder bore before assembling. See Specifications (page 247).

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

16. Spray both the cylinder to be de-glazed and the de-glazing hone with penetrating fluid or

equivalent. This spray contains colloidal graphite and works well for this application.

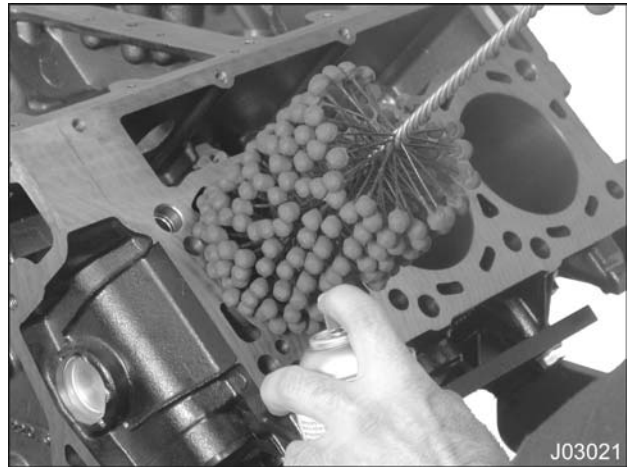


Figure 381 Preparing the de-glazing hone

17. De-glaze cylinder as follows:

- a. Attach a De-glazing Hone to a variable speed electric or air powered drill. See Special Service Tools (page 250).

! WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using compressed air for cleaning to reduce the danger from flying debris. Limit the air pressure to 207 kPa (30 psi). See "Safety Information (page 3)."

NOTE: A speed of approximately 100 to 120 rpm is required. Speed adjustment is required for the procedure to be successful.

- b. De-glaze 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 de-glazing hone from cylinder bore while brush is rotating. Wipe portion of cylinder wall and inspect cross hatch pattern.

NOTE: The cross hatch 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 as required.
 - e. Continue de-glazing cylinder bore for 10 to 15 seconds or 20 to 25 strokes.
 - f. Wipe cylinder bore clean and inspect bore for proper 45° cross hatch pattern.
18. After de-glazing, thoroughly clean cylinder bores with soft bristle brush, soap and water. Dry with filtered compressed air. Lubricate bore with clean engine oil.

Crankshaft

1. Clean and inspect the crankshaft and main bearings as follows:

! WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using compressed air for cleaning to reduce the danger from flying debris. Limit the air pressure to 207 kPa (30 psi). See "Safety Information (page 3)."

- a. Clean crankshaft with a suitable solvent and dry with compressed air.
 - b. 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.
 - c. Inspect crankshaft journals (main and connecting rod) for scratches, grooves, and scoring.
2. Inspect crankshaft bearings (main and connecting rod) for scratches, grooves, scoring, pitting, and inconsistent coloring.



Figure 382 Measuring one of the crankshafts main journals

3. Use a 3-4 inch micrometer to measure the diameter of each main journal. Measure each journal at two points 90° apart. Measure and record readings for each of the seven main journals. Difference between readings will be the main journal out-of-round value. See Specifications (page 247).



Figure 383 Measuring one of the crankshafts connecting rod journals

4. Use a 2-3 inch micrometer to measure the diameter of each connecting rod journal. Measure each journal at two points 90° apart. Measure and record readings for each connecting rod journals. Difference between readings will be the connecting rod journal out-of-round value. See Specifications (page 247).

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.



WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using compressed air for cleaning to reduce the danger from flying debris. Limit the air pressure to 207 kPa (30 psi). See "Safety Information (page 3)."

2. Use dry filtered compressed air to blow out any debris that remains from cleaning.
3. Replace any cracked or bent tubes.

Camshaft / Primary Balancer



WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using compressed air for cleaning to reduce the danger from flying debris. Limit air pressure to 207 kPa (30 psi). See "Safety Information (page 3)."

1. Wash camshaft / primary balancer assembly in cleaning solvent with a soft brush. Dry components with filtered compressed air.
2. Inspect camshaft. If any lobes are scuffed, scored or cracked, replace camshaft.

NOTE: This engine utilizes hydraulic valve tappets with roller followers. Therefore, a roller follower guide is needed to maintain proper roller to cam lobe orientation. Normal clearance between the valve tappet and guide allows for slight tracking of roller across cam lobe. This tracking of valve tappet roller is a normal characteristic as the roller accelerates and decelerates during typical engine operation. Consequently, a typical wear pattern on the cam lobes will exhibit tracks from side to side and have wide and narrow areas from the loading and unloading of the follower. The visual wear pattern (tracking) is normal and does not require camshaft replacement.

3. Beyond visual inspection, evaluate camshaft main journal and lobe condition as follows:

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



Figure 384 Measuring the camshafts main bearing journals

- a. Use a 2-3 inch micrometer to measure camshaft main bearing journals and then again at 90°. Record these measurements for later use in camshaft bushing inspection. Difference between readings will be the bearing journal out-of-round value. Compare with specifications, and if worn beyond limits replace the camshaft.

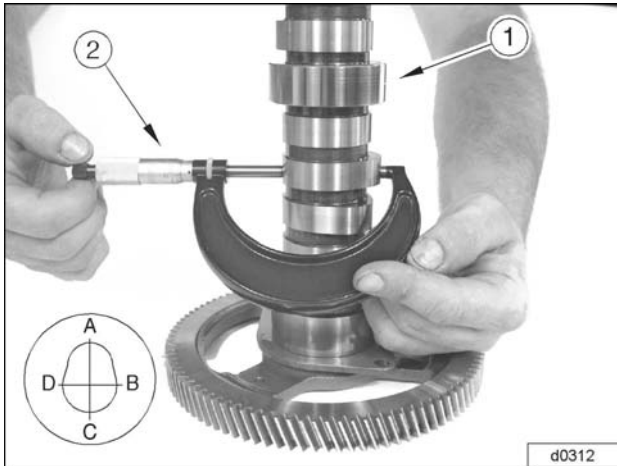


Figure 385 Measuring the camshaft intake and exhaust lobes

1. Camshaft assembly
 2. Micrometer
- b. To check camshaft intake and exhaust lobes, measure across (A to C) and across (B to D). Subtract (B to D) from (A to C). This will give cam lobe lift. Replace camshaft when cam lobe wear exceeds specifications. See Specifications (page 247).
 4. Inspect thrust plate for wear, cracks or distortion. Use a micrometer to measure thrust plate thickness. Replace thrust plate if worn or damaged. See Specifications (page 247).
 5. Inspect camshaft drive gear for worn or damaged teeth.



Figure 386 Measuring the primary balance shaft bushing inside diameter

6. Using a telescoping gauge, measure the primary balance shaft bushing inside diameter located within each end of camshaft.



Figure 387 Measuring the primary balancer shaft outside diameter

7. Measure the primary balance shaft outside diameter at each end of shaft (bushing location).
8. Subtract primary balance shaft outside diameter from primary balance shaft bushing inside diameter. This will give you the balance shaft bearing clearance. Refer to "Specifications" (page 247). Replace camshaft as necessary.

Camshaft Bushings

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

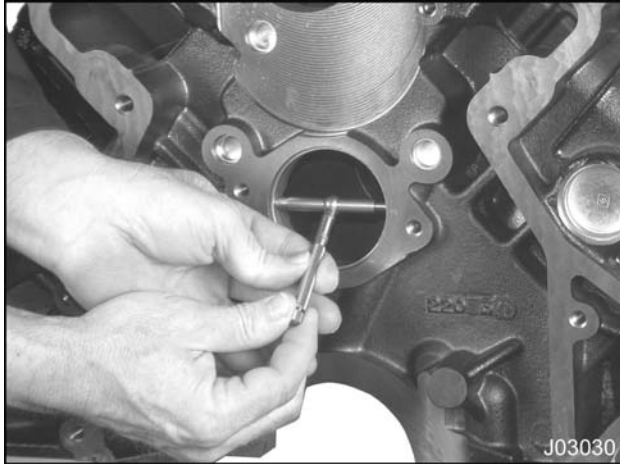


Figure 388 Measuring the camshaft bushings

1. Using a Telescoping Gauge, measure camshaft bushing inside diameter with bushings installed in crankcase. See Special Service Tools (page 250).

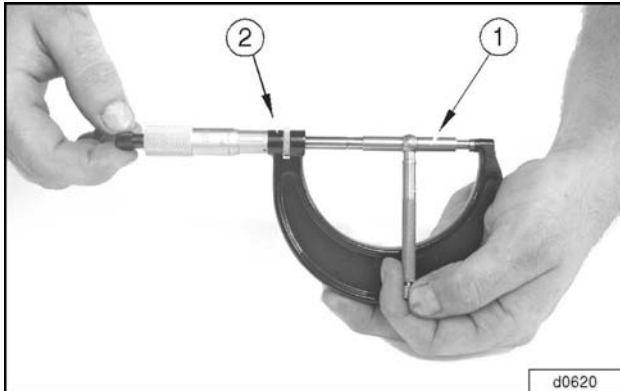


Figure 389 Measuring the camshaft bushing inner diameter

1. Telescoping gauge
2. Outside micrometer

2. Measure telescoping gauge with a 2-3 inch micrometer and record measurement.
3. To determine running clearance for each bushing / journal, subtract previous camshaft journal diameter reading from camshaft bushing inside diameter reading. See Specifications (page 247).
4. If maximum allowable running clearance is exceeded, replace camshaft bushings. See camshaft bushing removal and installation procedures within this section. Also, see Specifications (page 247).
5. Inspect each bushing bore in crankcase for burrs or debris that could potentially damage new bushings.
6. Remove burrs and clean bores thoroughly before installing new camshaft bushings.

Coolant Heater

1. Using a volt-ohm meter, inspect heater for electrical continuity.
2. Check element sealant around terminals for evidence of cracking.
3. Replace O-ring whenever heater is removed.

Installation

Camshaft Bushings

CAUTION: To prevent engine damage, use the correct Camshaft Bushing Remover / Installer (expanding collet). See Special Service Tools (page 250).

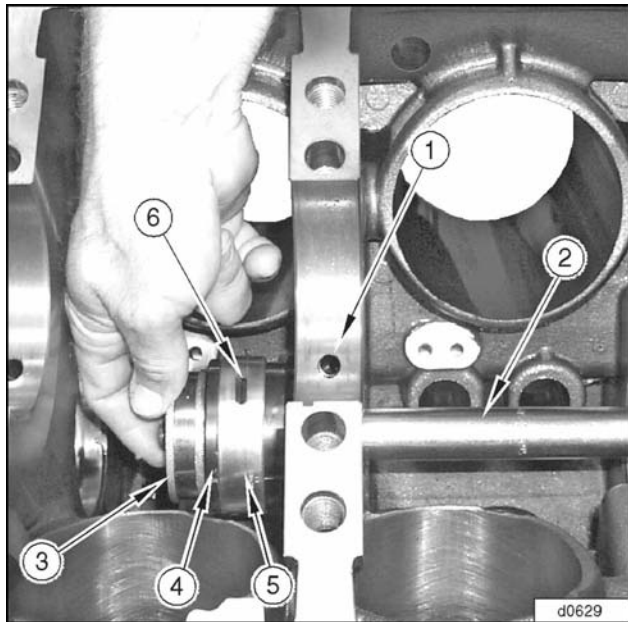


Figure 390 Installing the camshaft bushing

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
1. Slide a new bushing onto the Camshaft Bushing Remover / Installer (expanding collet). See Special Service Tools (page 250).
 2. Thread pulling screw, backup nut, and Camshaft Bushing Remover / Installer together. Tighten expanding collet by turning backup nut until bushing is held securely on the Camshaft Bushing Remover/Installer.

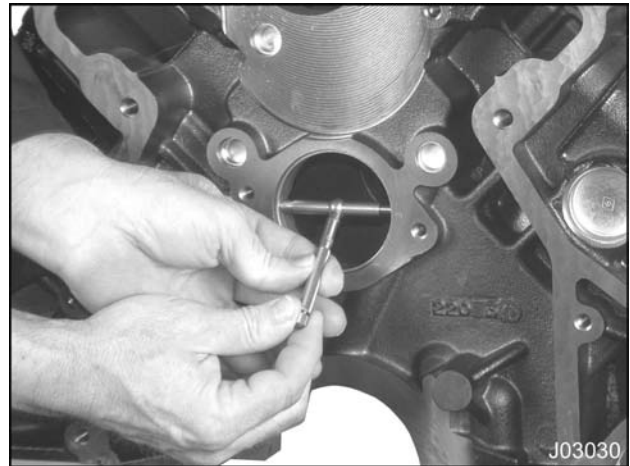


Figure 391 Measuring camshaft bushings

3. To aid in alignment of bushing and crankcase oil holes, use a marker to indicate oil hole location on backup nut of installation tool. Repeat this step for each camshaft bushing.
4. Install all camshaft bushings through rear of crankcase. Pull bushings in place at rear of crankcase by turning pulling nut on pulling screw. Remove Camshaft Bushing Remover/Installer and inspect oil hole alignment.
5. Using a Telescoping Gauge, measure the camshaft bushing inside diameter with bushings installed in crankcase. See Special Service Tools (page 250).
6. Measure telescoping gauge with a 2-3 inch micrometer and record measurement.
7. To determine running clearance for each bushing / journal, subtract previous camshaft journal diameter reading from camshaft bushing inside diameter reading. See Specifications (page 247).
8. If maximum allowable running clearance is exceeded, measure cam journal outside diameter and cam bushing inside diameter again and compare with Specifications (page 247). See camshaft bushing removal and installation procedures within this section.

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 machined within the crankcase.

9. Lubricate new camshaft bushings and crankcase bores with clean engine oil.

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.

1. Place piston cooling tubes on crankcase mounting pad.
2. When installing the piston cooling tube bolts, use either:
 - A new piston cooling tube mounting bolts (patch type)
 - Remove oil residue with a suitable solvent and apply Loctite® #242 to the threads of existing piston cooling tube bolts (patch type). See Special Service Tools (page 250).

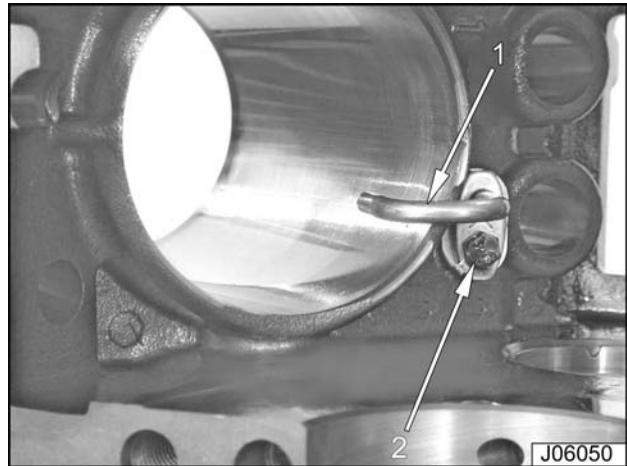


Figure 392 Piston cooling tube

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

3. Install and tighten piston cooling tube bolts (M6 x 18) to the Standard Torque (page 405).

Camshaft / Primary Balancer

1. Coat camshaft lobes and bushing journals with clean engine oil.

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

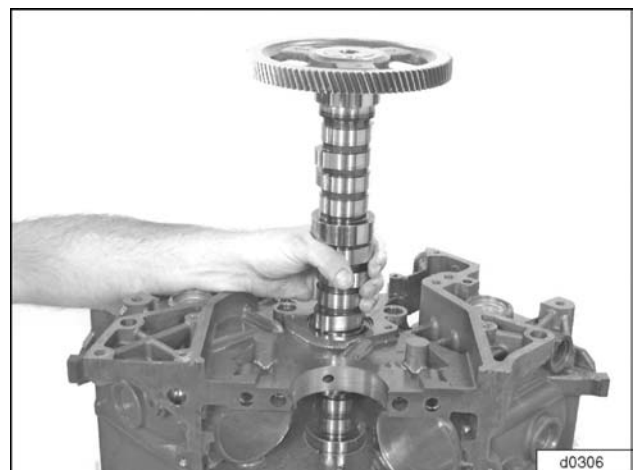


Figure 393 Installing the camshaft assembly

2. Position crankcase with rear of engine facing up on engine stand and carefully install camshaft assembly.



Figure 394 Install camshaft thrust plate mounting bolts

1. Camshaft thrust plate mounting bolts (2)
3. Install two camshaft thrust plate mounting bolts (M8 x 16). Tighten bolts to the Standard Torque (page 405).

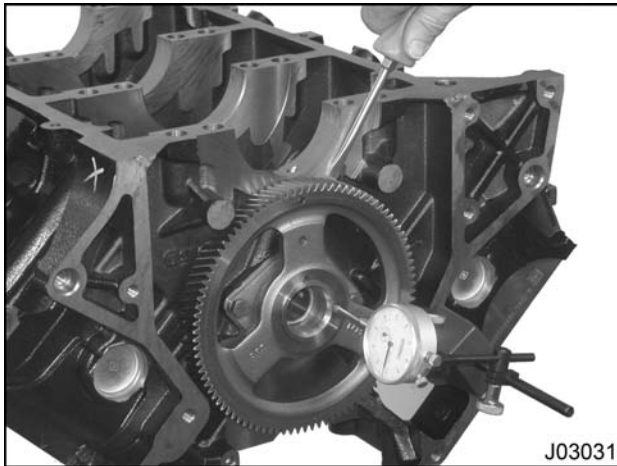


Figure 395 Measuring camshaft end play

4. Verify that camshaft end play is within specifications. See Specifications (page 247).



Figure 396 Installing the primary balance shaft

5. Coat primary balance shaft with clean engine oil and install inside camshaft.



Figure 397 Installing the balance shaft thrust plate bolts

6. Install three balance shaft thrust plate bolts (M6 x 12) and tighten to the Standard Torque (page 405).



Figure 398 Installing the balance shaft counterweight bolt

7. Install the balance shaft counterweight bolt (M10 x 25) and tighten to the Standard Torque (page 405).

Crankshaft and Timing

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

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

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

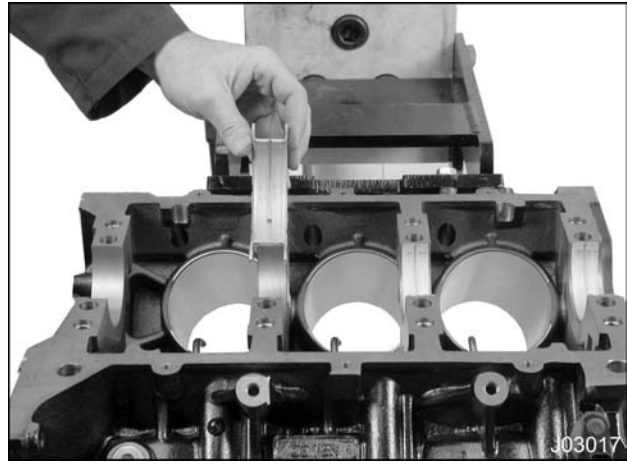


Figure 399 Install upper crankshaft main bearings (thrust bearing shown)

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

NOTE: Crankshaft thrust bearing is installed at the number 3 upper main bearing journal.

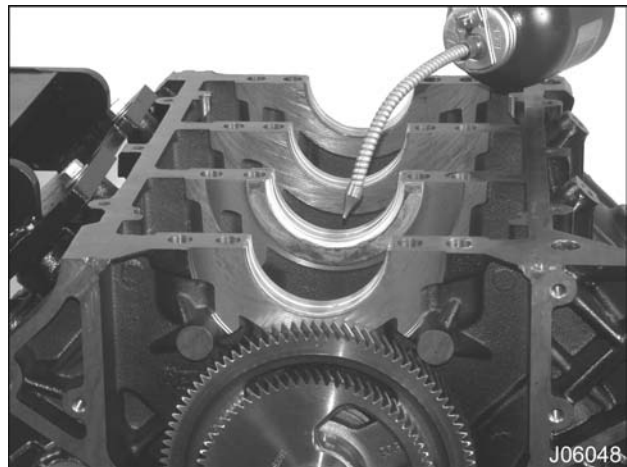


Figure 400 Lubricating the upper main bearings

4. Lubricate the upper main bearings with clean engine oil.

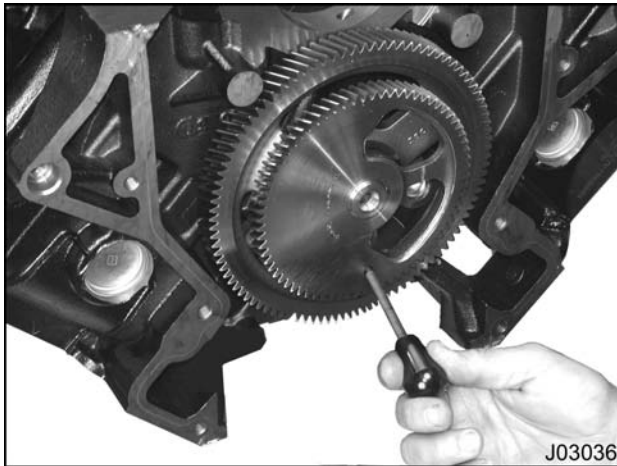


Figure 401 Installing the Crankshaft Timing Tool

5. Align index marks on both camshaft gear and primary balancer gear so that they are adjacent to each other. Install Crankshaft Timing Tool through machined holes in both balancer gear and camshaft gear as well as the machined hole in crankcase. See Special Service Tools (page 250).

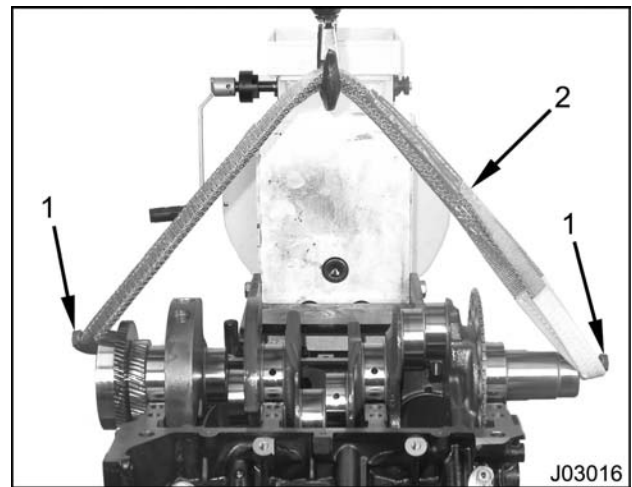


Figure 402 Installing crankshaft into crankcase

1. Bolts threaded into crankshaft
 2. Lifting sling
6. Place a bolt in each end of the crankshaft. Attach hoist and lifting sling around crankshaft bolts and carefully lower onto the four main bearings.



WARNING: To avoid serious personal injury or possible death, use an appropriately sized lifting sling and hoist equipped with a safety latch on hook. See "Safety Information (page 3)."

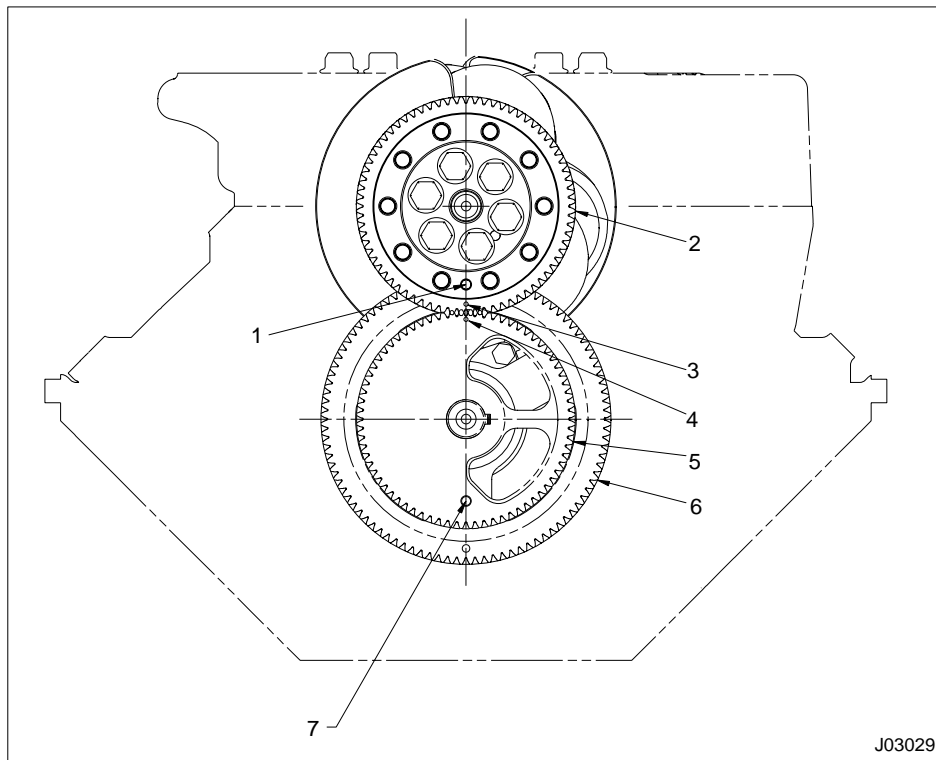


Figure 403 Crankshaft / camshaft / primary balancer timing alignment

- | | | |
|--------------------------------|--------------------------------------|--------------------------|
| 1. Flywheel alignment pin | 4. Primary balancer gear timing mark | 6. Camshaft gear |
| 2. Crankshaft gear (1 of 2) | 5. Primary balancer gear | 7. Timing tool thru hole |
| 3. Crankshaft gear timing mark | | |
7. Install crankshaft so that index mark aligns with both camshaft and primary balancer index marks.

Lower Crankcase

1. Make sure the lower crankcase sealing recesses are free of any dirt and oil.

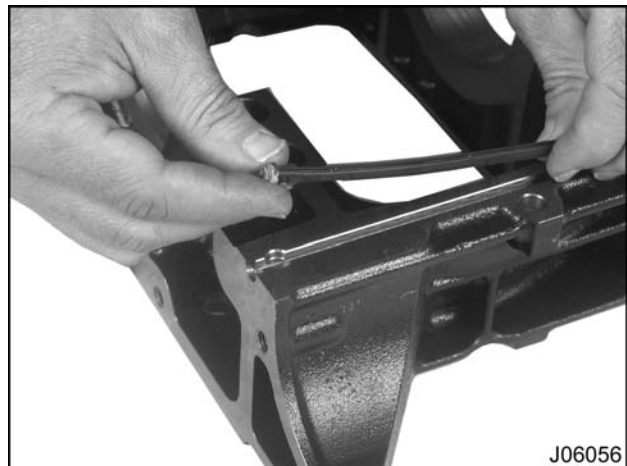


Figure 404 Installing the lower crankcase seals

2. Install two new lower crankcase seals.

NOTE: Make certain that the lower crankcase machined bearing surfaces are free of all dirt and oil.

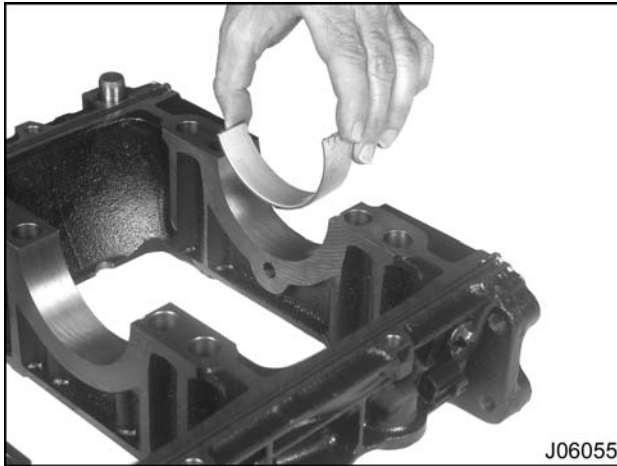


Figure 405 Installing the lower crankcase bearings

3. Install bearings into the lower crankcase, making sure bearing alignment tab is fitted into machined notch.



Figure 406 Lubricating the lower crankcase bearings

4. Apply clean engine oil to all lower bearing inserts, crankshaft journals and lower crankcase bolts.

CAUTION: To prevent engine damage, make sure that the longer main cap bolts (M14 x 127) are installed inboard and the shorter bolts (M14 x 114) are installed outboard.

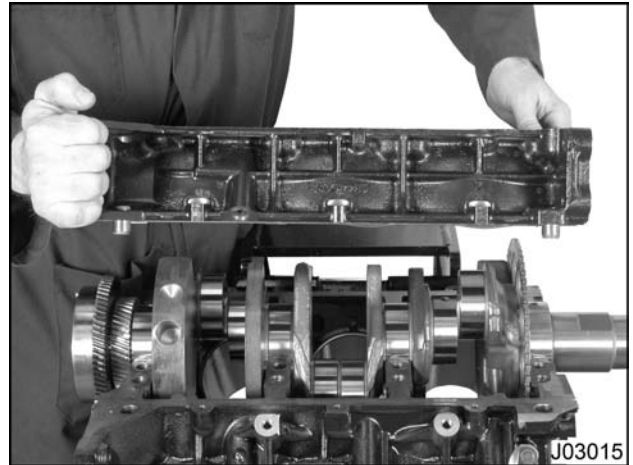


Figure 407 Installing the lower crankcase

5. Install the lower crankcase over the crankshaft being careful not to bump crankshaft and knock any bearings out.

Lower Crankcase Torque Instructions and Tightening Sequence

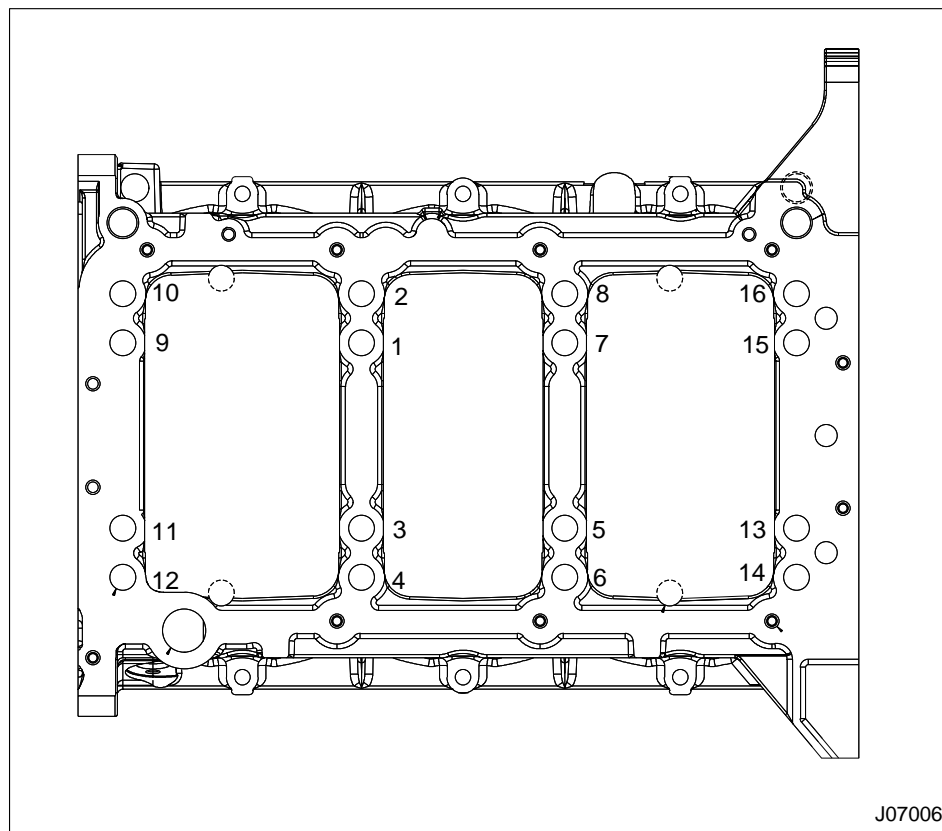


Figure 408 Lower crankcase main bearing mounting bolt tightening sequence

6. Install all 16 lower crankcase main bearing mounting bolts. Tighten main cap bolts to the special torque as follows using the sequence shown in the "Lower crankcase main bearing mounting bolt tightening sequence" (Figure 408):
 - a. Initially torque bolts to 122 N·m (90 lbf·ft) in the numerical sequence shown in "Lower crankcase main bearing mounting bolt tightening sequence" (Figure 408).
 - b. Increase torque for bolts to 163 N·m (120 lbf·ft) in the numerical sequence shown in "Lower crankcase main bearing mounting bolt tightening sequence" (Figure 408).
 - c. Increase torque for bolts to a final value of 231 N·m (170 lbf·ft) in the numerical sequence shown in "Lower crankcase main bearing mounting bolt tightening sequence" (Figure 408).

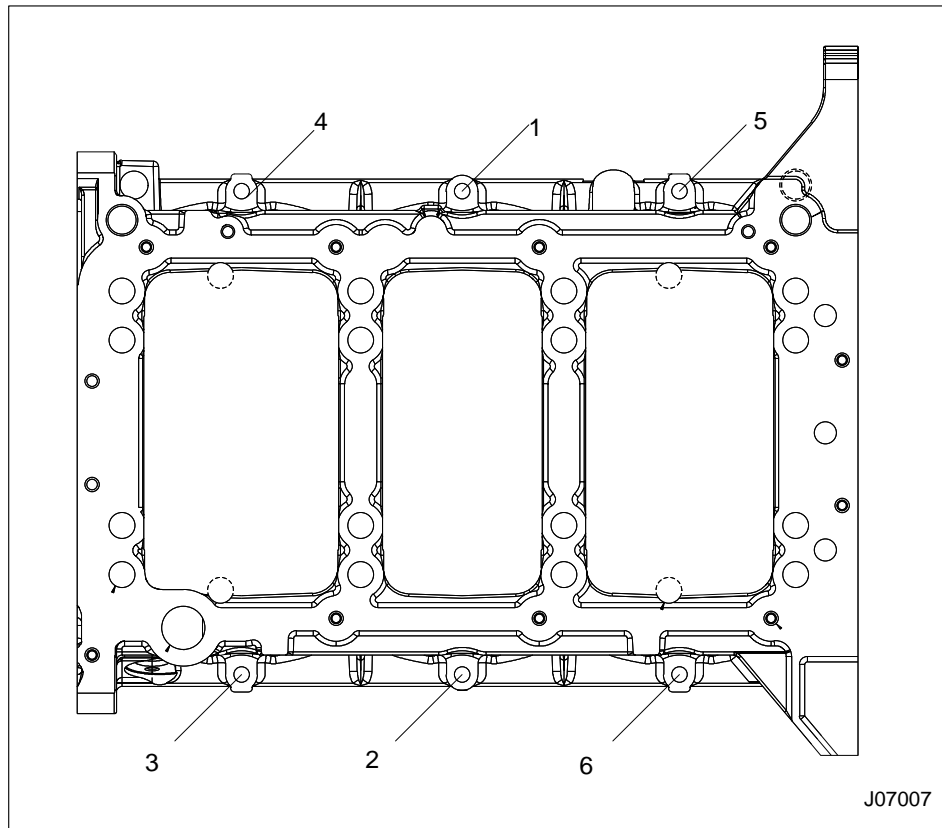


Figure 409 Lower crankcase outer bolt tightening sequence

7. Install six bolts (M8 x 30) around outside of lower crankcase. Tighten bolts to the Standard Torque (page 405) using the sequence shown in "Lower crankcase outer bolt tightening sequence" (Figure 409).

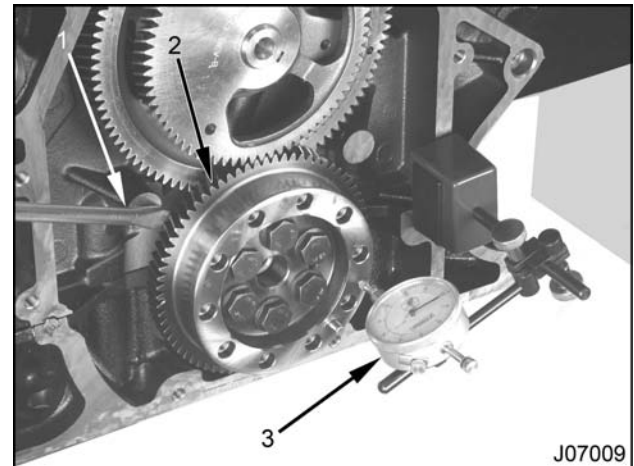


Figure 410 Measuring crankshaft end play

1. Pry bar or screwdriver
2. Crankshaft flange
3. Dial indicator

8. Check crankshaft end play as follows:

- a. Mount dial indicator on crankcase with indicator tip on the end of crankshaft flange as shown.
- b. Pry crankshaft forward with pry bar and zero dial indicator.
- c. Pry crankshaft back and forth while reading dial indicator. Record end play.

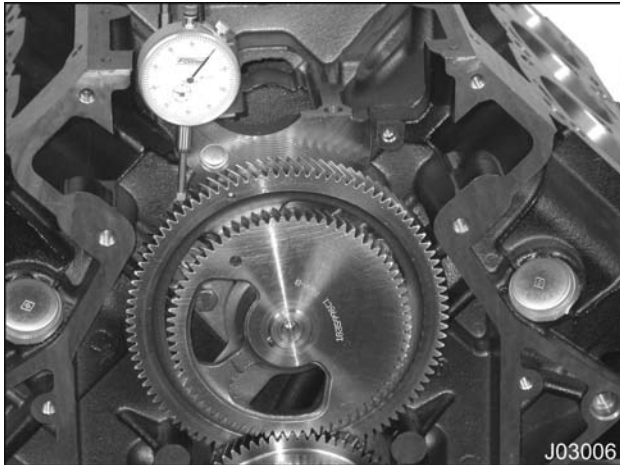


Figure 411 Checking camshaft-to-crankshaft gear backlash

9. Check and record camshaft gear-to-crankshaft gear backlash as follows:

NOTE: Crankshaft gear must be fixed, not allowed to rotate, only the camshaft gear should be allowed to rotate, otherwise the reading will be invalid.

- a. Mount Dial Indicator with Magnetic Base onto rear of engine. See Special Service Tools (page 250).
- b. Position dial indicator tip onto a gear tooth and remove any lash.
- c. Zero dial indicator index.
- d. Rotate gear by hand and read indicator. Record backlash.

- e. If backlash exceeds specified limits, replace camshaft gear. See Specifications (page 247).

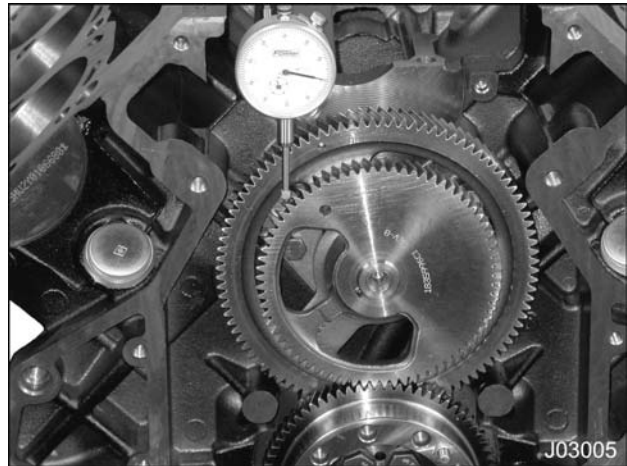


Figure 412 Checking primary balancer gear-to-crankshaft gear backlash

10. Check and record primary balancer gear-to-crankshaft gear backlash as follows:

NOTE: Crankshaft gear must be fixed, not allowed to rotate, only the primary balancer gear should be allowed to rotate, otherwise the reading will be invalid.

- a. Mount Dial Indicator with Magnetic Base onto rear of engine. See Special Service Tools (page 250).
- b. Position dial indicator tip on primary balancer gear tooth and remove lash.
- c. Zero dial indicator index.
- d. Rotate gear by hand and read indicator. Record backlash.
- e. If backlash exceeds specified limits, replace primary balancer gear. See Specifications (page 247).

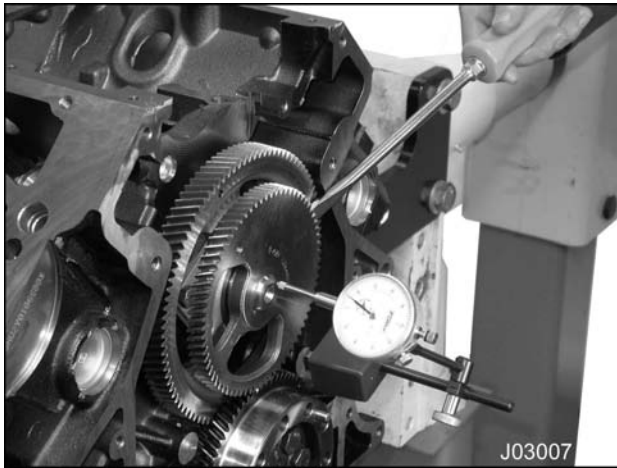


Figure 413 Measuring the primary balancer shaft end play

11. Check and record the primary balancer shaft end play as follows:
 - a. Reposition dial indicator tip to balance shaft, not gear.
 - b. Push camshaft to the front of the engine.
 - c. Zero dial indicator index.
 - d. Place a small pry bar between the primary balance gear and crankcase. Lightly pry primary balancer gear toward indicator. Compare dial indicator reading with specifications. See Specifications (page 247).
12. Slide a new dipstick tube seal onto oil level gauge assembly and install into lower crankcase, making certain that the seal is fully seated within the lower crankcase.

Crankcase Sensors and Coolant Heater

1. Place two new O-rings onto CMP sensor.

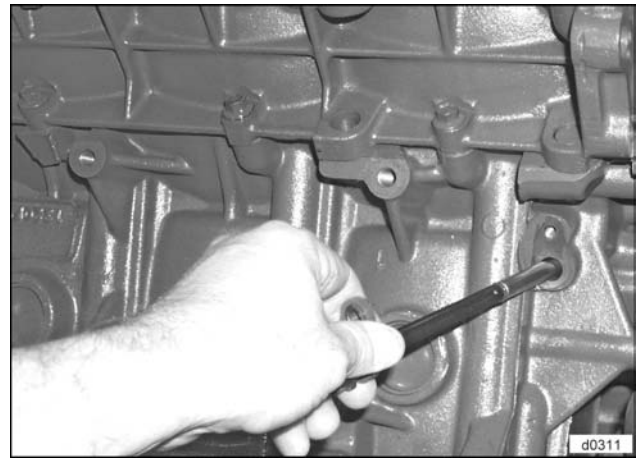


Figure 414 Installing the CMP sensor

2. Lubricate sensor O-rings with clean engine oil and install CMP sensor into crankcase.
3. Secure sensor with bolt (M6 x 16) and tighten to the Standard Torque (page 405).
4. Place a new lubricated O-ring seal onto the crankshaft position sensor.

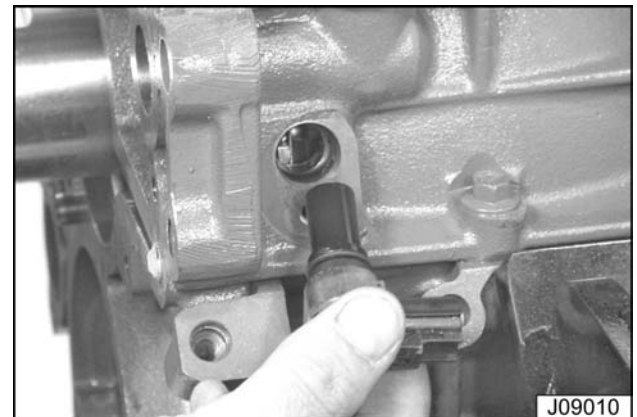


Figure 415 CKP sensor

5. Install CKP sensor into lower crankcase.
6. Install retaining bolt (M6 x 14) to CKP sensor located on the front of the engine, lower right. Tighten bolt to the Standard Torque (page 405).
7. Lubricate a new O-ring and install onto the coolant heater.

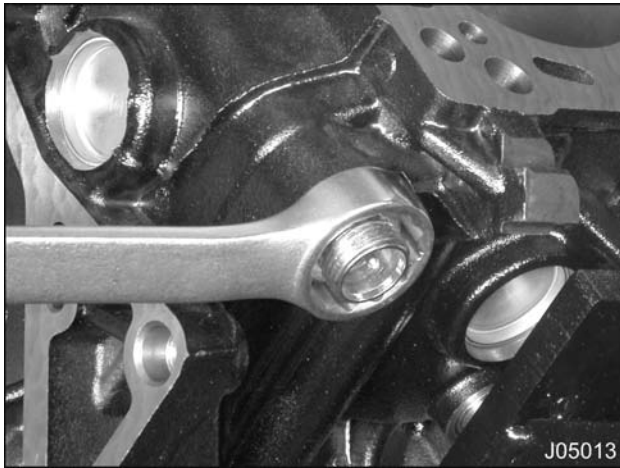


Figure 416 Installing the coolant heater

8. Install coolant heater element into crankcase and tighten to the Special Torque (page 249).
9. Remove tools, parts and equipment.
 - a. Reinstall all safety guards, shields and covers after servicing the engine.
 - b. Make sure all tools, loose parts and service equipment are removed from the engine area after all work is done.

Specifications

Crankshaft

| | |
|---|---------------------------------------|
| Crankshaft end play (maximum) | 0.222 mm (0.0087 in) |
| Crankshaft gear backlash (maximum) | 0.32 mm (0.012 in) |
| Crankshaft connecting rod out of round | 0.006 mm (0.00024 in) |
| Crankshaft main journal out of round | 0.006 mm (0.00024 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 | 0.025 to 0.076 mm (0.001 to 0.003 in) |

Main Bearing Journal Diameter

| | |
|----------------------------------|---|
| • Standard size | 80.987 to 81.012 mm (3.188 to 3.150 in) |
| • 0.254 mm (0.010 in) under size | 80.733 to 80.758 mm (3.178 to 3.140 in) |
| • 0.508 mm (0.020 in) under size | 80.479 to 80.504 mm (3.168 to 3.130 in) |
| • 0.762 mm (0.030 in) under size | 80.225 to 80.250 mm (3.158 to 3.120 in) |

Connecting Rod Journal Diameter

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

Camshaft and Bushings

| | |
|--|---|
| Camshaft bushing inside diameter | 62.05 to 62.14 mm (2.443 to 2.446 in) |
| Camshaft end play | 0.051 to 0.211 mm (0.002 to 0.008 in) |
| Camshaft gear backlash | 0.179 to 0.315 mm (0.007 to 0.012 in) |
| Camshaft lobe wear (max) | 0.51 mm (0.02 in) |
| Camshaft journal diameter (all journals) | 61.987 to 62.013 mm (2.440 to 2.441 in) |
| Camshaft thrust plate thickness | 3.589 to 3.649 mm (0.1413 to 0.1436 in) |
| Journal and bushing running clearance | 0.037 to 0.153 mm (0.0015 to 0.0060 in) |
| Primary balance shaft bearing clearance (max) | 0.123 mm (0.005 in) |
| Primary balance shaft end play | 1.77 mm (0.070 in) |
| Primary balance shaft gear backlash | 0.184 to 0.306 mm (0.007 to 0.012 in) |
| Camshaft lobe lift (maximum) | |
| • Intake | 5.820 mm (0.2291 in) |
| • Exhaust | 5.906 mm (0.2325 in) |
| Valve timing no. 1 cylinder (top of lobe) | |
| • Intake open | 16.2° BTDC |
| • Intake closed | 50.4° ABDC |
| • Exhaust open | 47.5° BBDC |
| • Exhaust closed | 14.9° ATDC |

Crankcase and Main Bearings

Crankcase

| | |
|--|--|
| Cylinder block top surface of crankcase flatness | Total deck surface: 0.10 mm (0.004 in) 150 mm ² (36 in ²) area: 0.05 mm (0.02 in) 25 mm ² (1 in ²) area: 0.025 mm (0.001 in) |
| Crankcase main bearing bore diameter | 85.99 to 86.01 mm (3.3854 to 3.3862 in) |
| Crankcase cam bearing bore diameter | 65.98 to 66.02 mm (2.597 to 2.599 in) |
| Roller follower bore diameter | 23.44 to 23.48 mm (0.923 to 0.924 in) |
| Roller follower outside diameter | 23.39 to 23.41 mm (0.921 to 0.923 in) |
| Cylinder bore diameter | 94.991 to 95.001 mm (3.740 to 3.741 in) |
| Cylinder bore maximum out-of-round | 0.008 mm (0.0003 in) |
| Cylinder stroke | 105 mm (4.13 in) |
| Coolant heater element rating | 1,000 watts, 120 volts |

Main Bearings

| | |
|-------------------------|-----------------------------|
| Material | Steel backed copper/lead |
| Number of main bearings | 4 |
| Thrust bearing location | No. 3 main upper |
| Lower crankcase | Four bolts per main journal |

Special Torque

Crankcase, Crankshaft and Camshaft

| | |
|--|--|
| Lower crankcase main bearing cap bolts | See tightening procedure and sequence (page 242) |
| Coolant heater element or plug | 41 N·m (30 lbf·ft) |
| Crankcase coolant drain plug / O-ring, M16 | 20 N·m (15 lbf·ft) |

Special Service Tools

| Crankcase, Crankshaft and Camshaft | |
|---|--------------------|
| Description | Tool Number |
| Camshaft Bushing Kit | ZTSE2893B |
| Camshaft Bushing Remover/Installer (expanding collet) | ZTSE4489 |
| Crankshaft Timing Tool | ZTSE4687 |
| Cylinder Bore Gauge | Obtain locally |
| De-glazing Hone (four-inch) | Obtain locally |
| Dial Indicator with Magnetic Base | Obtain locally |
| Feeler Gauge | Obtain locally |
| Freeze Plug Installer | ZTSE4509 |
| Front Seal/Wear Sleeve Installer | ZTSE4680 |
| Front Wear Sleeve Remover | ZTSE4517 |
| Head Bolt Bottoming Tap | ZTSE4508 |
| Loctite® #242 Threadlocker | Obtain locally |
| Loctite® #620 Compound | Obtain locally |
| Micrometer, 2-3 in | Obtain locally |
| Micrometer, 3-4 in | Obtain locally |
| Oil Gallery Cleaning Brush | ZTSE4511 |
| Oil Gallery Plug Driver | ZTSE4512 |
| Straightedge | Obtain locally |
| Telescoping Gauge Set | Obtain locally |
