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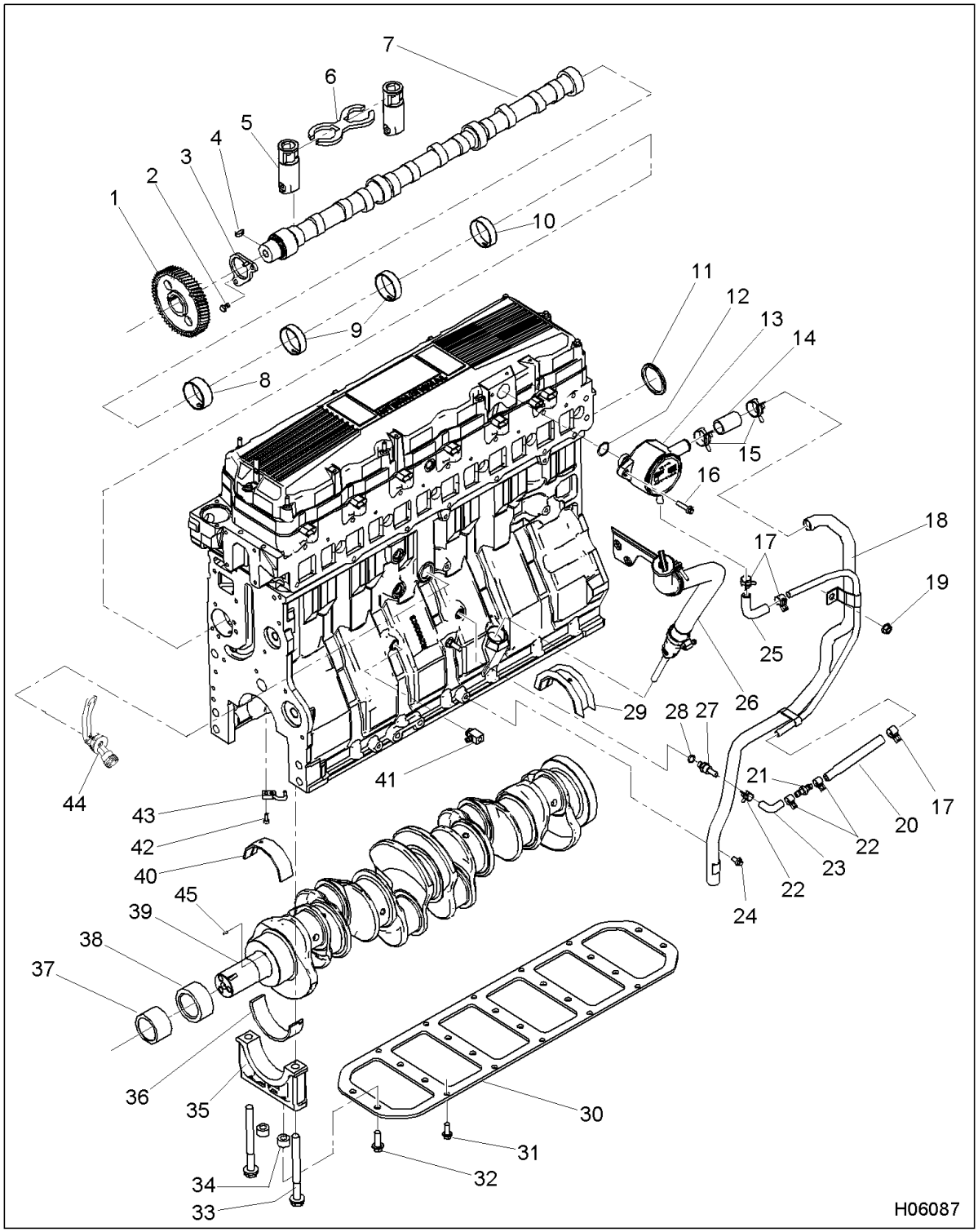

Figure 322 Crankcase, Crankshaft, and Camshaft

1. Camshaft gear assembly
2. Bolt, M8 x 20 (2)
3. Camshaft thrust plate
4. Key, ¼ x ¾
5. Roller tappet assembly (12)
6. Roller tappet guide (6)
7. Camshaft
8. Front camshaft bearing
9. Intermediate camshaft bearings (2)
10. Rear camshaft bearing
11. Camshaft seal ring, rear
12. O-ring, #214
13. Breather assembly
14. Hose, 1 in. I.D.
15. Clamp, 1 in. diameter (2)
16. Bolt, M8 x 35 (2)
17. Clamp, ½ in. diameter (3)
18. Vent and drain tube assembly
19. Nut, M10
20. Reducer hose
21. Check valve
22. Clamp (3)
23. Rubber elbow
24. Bolt, M8 x 16
25. Drain hose elbow
26. Oil level gauge assembly (Figure 324)
27. Fitting assembly, M12
28. O-ring seal
29. Main bearing, upper (#7 thrust)
30. Crankcase ladder (DT 570 >300 bhp)
31. Bolt, M10 x 25 (10)
32. Bolt, M12 x 35 (14)
33. Bearing cap bolt, M15 x 162 (14)
34. Spacer (14)
35. Main bearing cap (7)
36. Main bearing, lower (7)
37. Oil pump drive (spline)
38. Crankshaft gear
39. Crankshaft
40. Main bearing, upper (6)
41. Tee assembly, M12
42. Bolt, piston cooling tube (6)
43. Piston cooling tube assembly (6) (see “Power Cylinders”)
44. Block heater assembly (option)
45. Slotted pin, 5/32 x 5/16

Removal

Crankcase Ventilation System

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, read all safety instructions in the "Safety Information" section of this manual.

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, make sure the transmission is in neutral, parking brake is set, and wheels are blocked before doing diagnostic or service procedures on engine or vehicle.

To remove the crankcase ventilation system as an assembled unit, perform the following steps, refer to the following illustration:

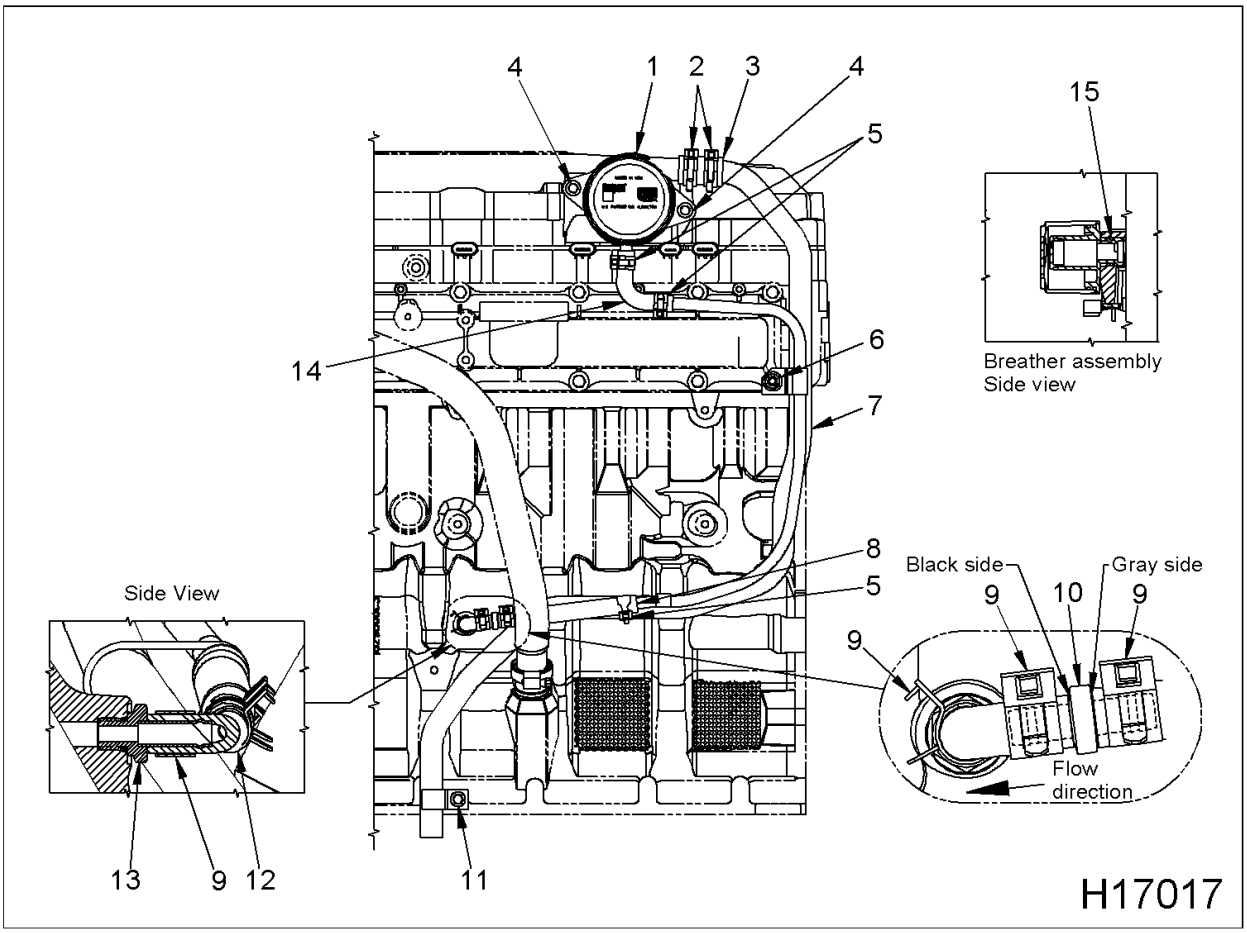

Figure 323 Crankcase ventilation

1. Breather assembly
2. Clamp, 25.4 mm (1 in) diameter (2)
3. Hose, 25.4 mm (1 in) I.D.
4. Bolt, M8 x 35 (2)
5. Clamp, ½ in. diameter (3)
6. Nut, M10
7. Vent and drain tube assembly
8. Reducer hose
9. Clamp (3)
10. Check valve
11. Bolt, M8 x 16
12. Rubber elbow
13. Fitting assembly, M12
14. Drain hose elbow
15. O-ring, #214

NOTE: Have an oil pan handy before disconnecting the oil drain hose. It is possible for a column of oil to be maintained above the check valve, as the check valve does require a certain amount of pressure to allow passage of oil back to the crankcase.

1. Move clamp (½ in) out of way and remove reducer hose from vent and drain tube assembly. Allow tube and reducer hose to drain. Reconnect reducer hose and clamp.
2. Remove clamp and rubber elbow on the crankcase side of the check valve. Leave fitting assembly in crankcase unless evidence of leaking is occurring from fitting O-ring.
3. Remove the bolt (M8 x 16) securing the vent and drain tube assembly to the crankcase, located at the end of the vent tube.
4. Remove two bolts (M8 x 35) securing the breather assembly to the valve cover.
5. Remove the nut (M10) securing the vent and drain tube to the intake manifold.

6. Carefully pull breather assembly out of valve cover.
7. Remove breather and tubing assembly and place in solvent wash tank.

Oil Level Gauge

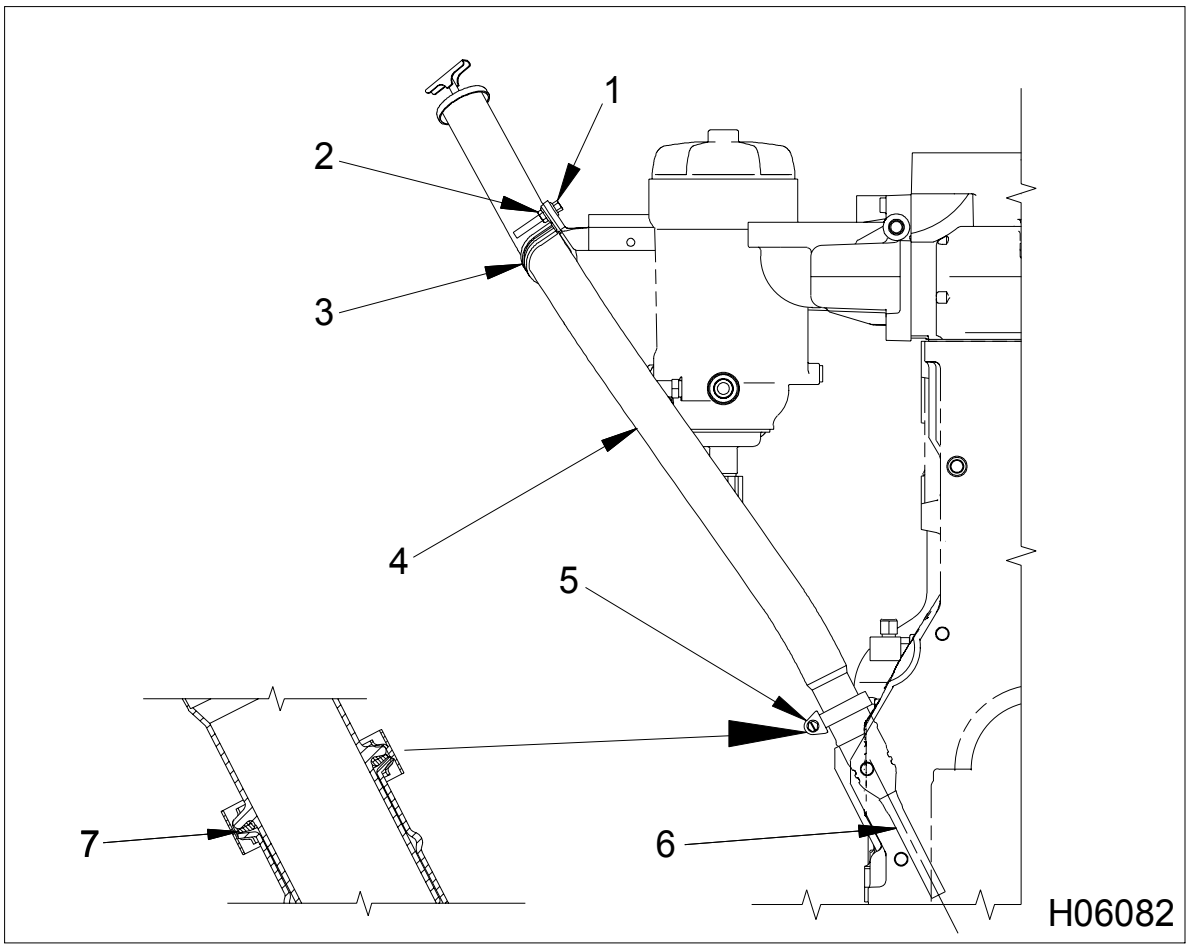

Figure 324 Oil level gauge assembly

1. Bolt, M6 x 40
2. Nut, M6
3. Cushioned clamp
4. Oil filler tube
5. Tube clamp
6. Oil level gauge tube
7. Oil dipstick tube seal

1. Remove the oil filler tube bolt (M6 x 40) and nut (M6) at the fuel filter bracket.
2. Remove the tube clamp at the crankcase and discard oil dipstick tube seal.
3. If necessary, remove oil level gauge tube from crankcase by using a brass drift and hammer

Crankcase Ladder (570 series only) > 300 bhp

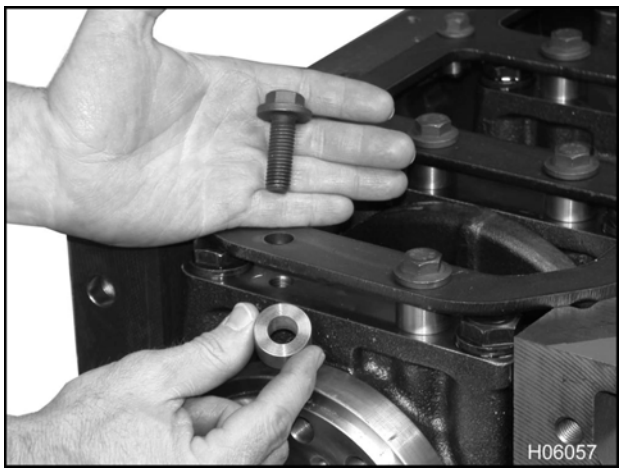

Figure 325 Crankcase ladder hardware

NOTE: Refer to the following for information regarding the removal or installation of these related components:

- Oil pan (See Removing the Oil Pan, page 184)
- Oil suction tube (See Removing the Oil Suction Tube, page 186)

1. Remove 14 crankcase ladder bolts (M12 x 35) and spacers.
2. Remove 10 crankcase ladder bolts (M10 x 25).

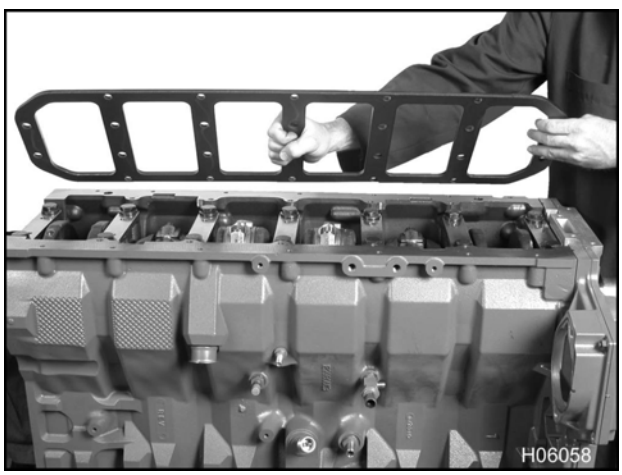

Figure 326 Removing the crankcase ladder

3. Remove the crankcase ladder.

Crankshaft Disassembly

NOTE: Before removing the crankshaft, it may be necessary to remove the piston assemblies (See Removing Piston and Connecting Rod Assembly, page 195).

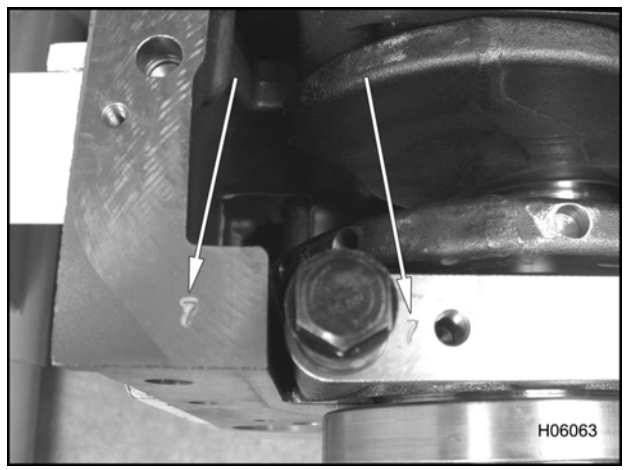

Figure 327 Main bearing cap identification stamps

1. Verify that the main bearing caps and crankcase are numbered. You may have to degrease accordingly to gain access to the stamped numbers.
2. Loosen all the main bearing bolts (M15 x 162).

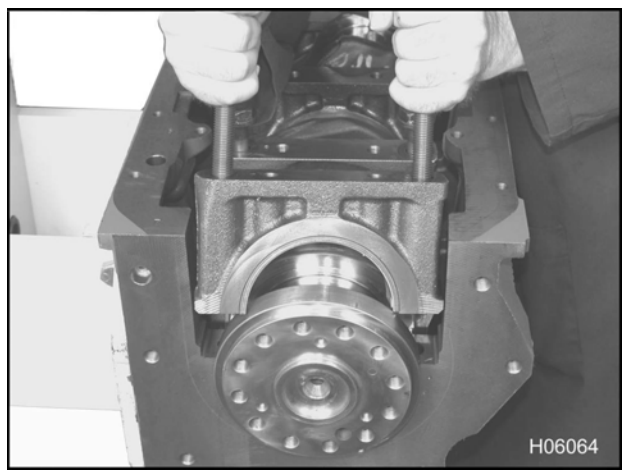

Figure 328 Removing the main bearings

3. Lift up both bolts until about half the threads are exposed. Use both bolts to rock main bearing cap free from crankcase.
4. Discard all of the removed main bearing bolts. These are not reusable due to the permanent stretch they received from “torque-to-yield”.

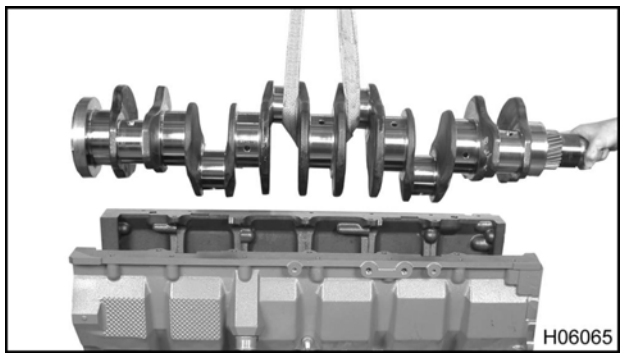

Figure 329 Removing the crankshaft assembly

5. Place an appropriately sized sling around the middle of the crankshaft and attach it to a hoist or crane. Lift crankshaft out of crankcase and place on workbench.
6. Visually inspect the crankshaft gears for chipping or wear. Replace as required.
7. Place a chisel between the gear teeth and strike the chisel with a hammer to split the gear.

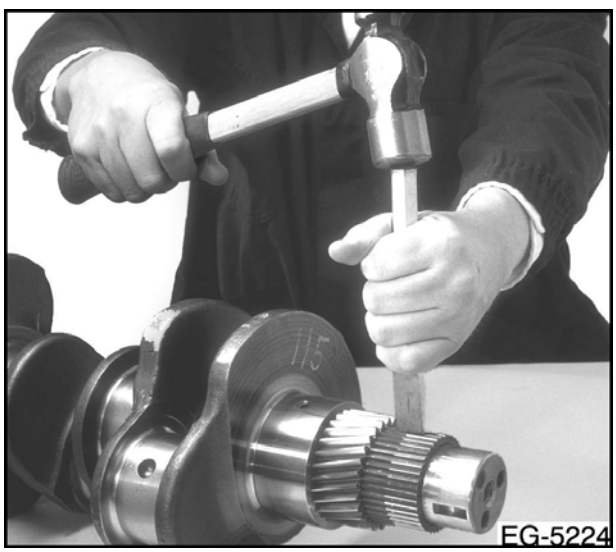

Figure 330 Removing oil pump drive spline

8. Remove the oil pump drive first to access the crankshaft gear.
9. Be careful not to damage the crankshaft during gear removal.

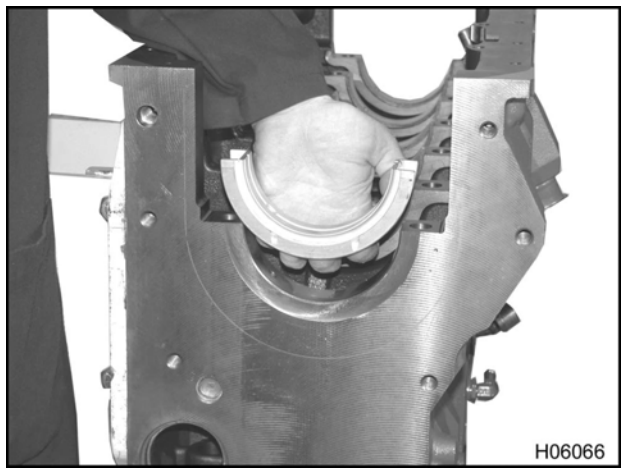

Figure 331 Removing the number seven upper thrust bearing

10. Remove upper main bearing shells by pushing them out of main bearing saddle with your thumbs. Mark the upper shells with bearing number and orientation. Set aside each upper bearing shell with the lower shells until a proper inspection can be done.

Valve Lifters

1. Using a hooked shaped tool or piece of stiff wire, reach into crankcase to catch the center of the lifter guide.

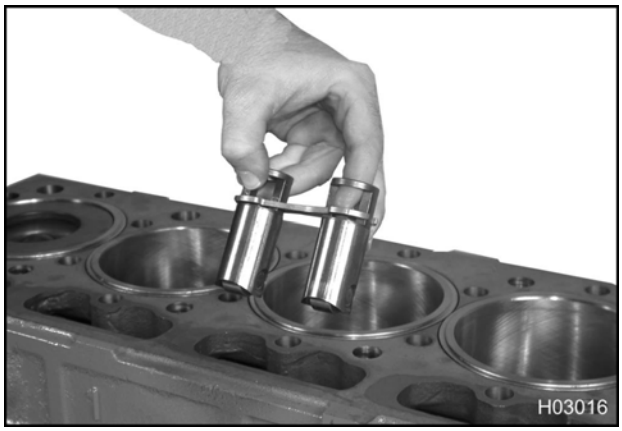

Figure 332 Removing valve lifters

2. Remove each set of valve lifters and guides.
3. Mark orientation of valve lifter and guide in the event these components will be placed back into service.

Cam Gear from Camshaft

NOTE: If removing the whole camshaft assembly, skip to next procedure.

1. Install gear puller making sure claws are positively engaged with cam gear and the threaded shaft is aligned with camshaft.

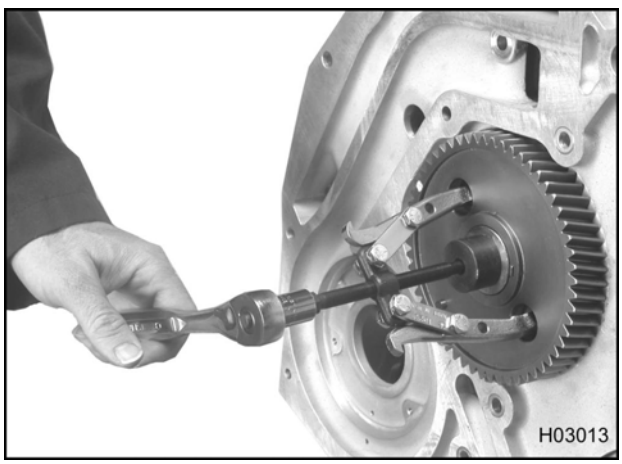

Figure 333 Removing camshaft gear

2. Using a socket or wrench apply force to tool until gear is just about off. Use both hands to remove cam gear and tool.

Camshaft Disassembly

NOTE: Use this procedure to remove the cam gear and camshaft as a unit.

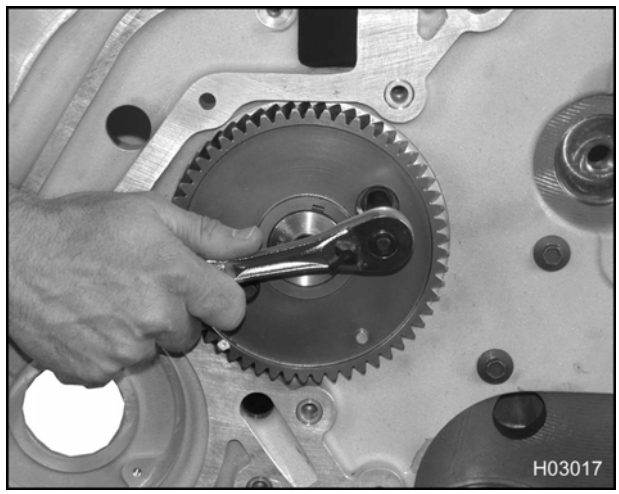

Figure 334 Removing camshaft thrust plate bolts

1. Remove the two camshaft thrust plate bolts (M8 x 20).

Figure 335 Removing the camshaft assembly

2. Carefully remove the camshaft assembly from the crankcase.

Camshaft Bushings

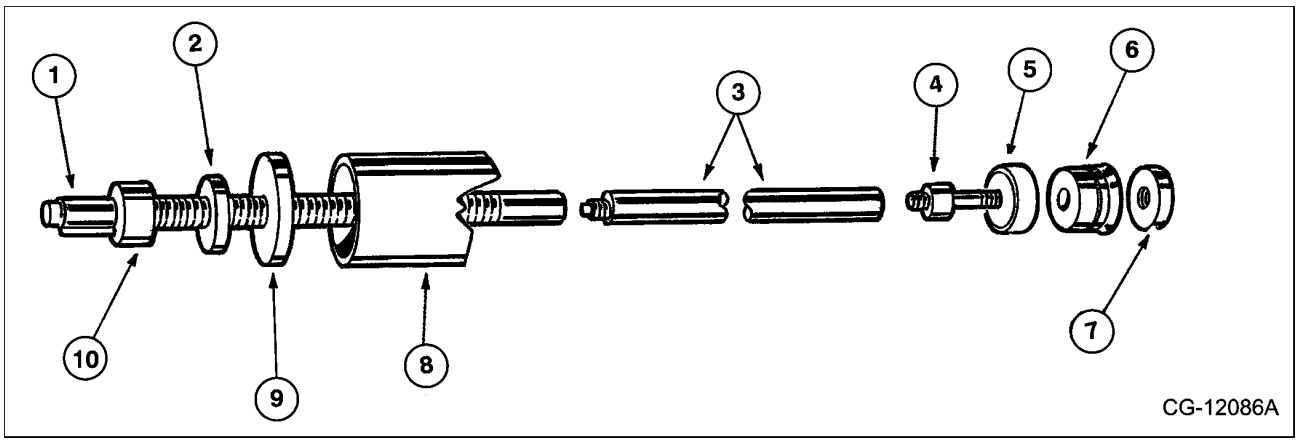

Figure 336 Camshaft bushing service set components

1. Puller screw
2. Thrust bearing
3. Extension tube
4. Puller screw extension
5. Camshaft bushing
6. Backup nut
7. Expanding collet
8. Expanding mandrel
9. Pulling plate
10. Pulling nut

NOTE: Although the inside diameter of each camshaft bushing is the same, the outside diameters and widths are different depending on bushing location. The bushing diameters have changed from previous designs and this determines how bushings are removed and installed.

Table 35

Bushing Location	Outside Diameter (nominal)	Width (nominal)
Front	65.5 mm (2.50 in)	25.4 mm (1.00 in)
Rear	65.5 mm (2.50 in)	17.8 mm (0.70 in)
Intermediate	63.0 mm (2.48 in)	17.8 mm (0.70 in)

Remove the front and rear bushings (1) first. The rear bushing and camshaft seal ring **must** be removed from the rear of the crankcase. It is recommended that the intermediate bushings be removed according to the following illustration.

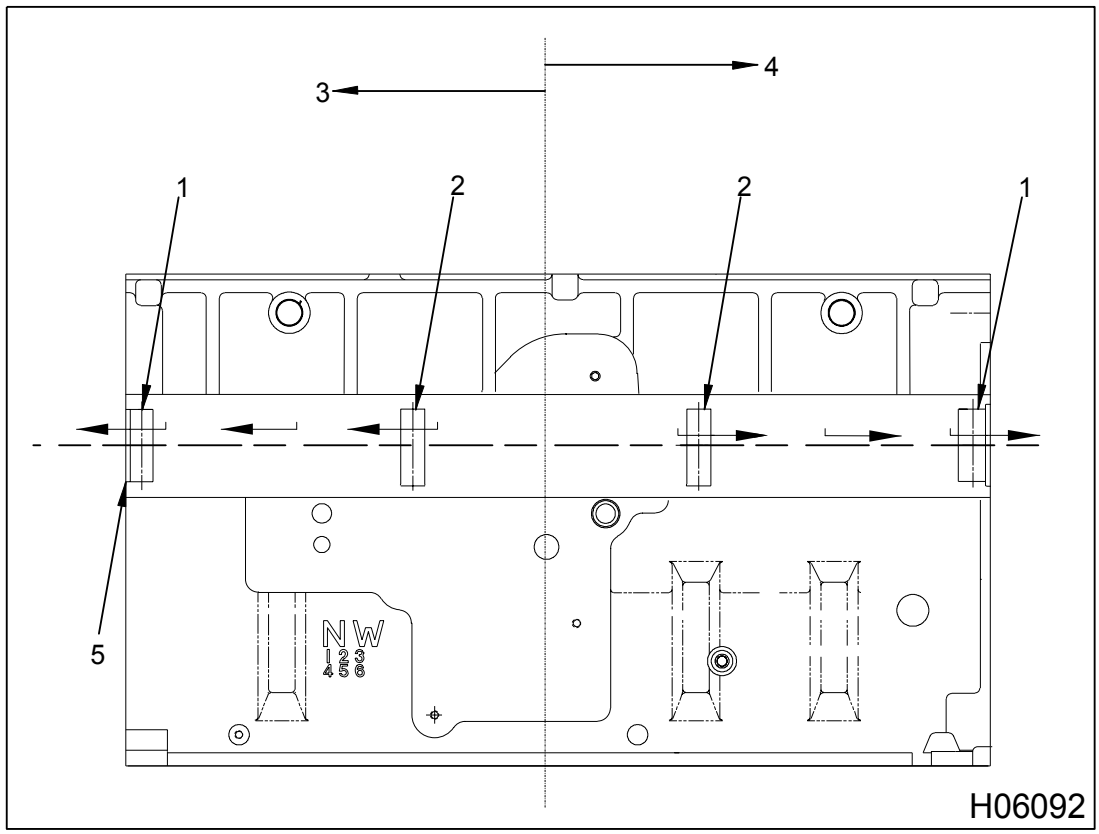

Figure 337 Pulling direction for individual camshaft bushing removal

1. Front and rear bushings
2. Intermediate bushings
3. Rear half of engine
4. Front half of engine
5. Camshaft seal ring

1. Assemble the correct expanding collet size and backup nut onto the expanding mandrel.
2. With the collet collapsed, install the collet assembly into the camshaft bushing. Tighten the backup nut onto the expanding mandrel until the collet fits the camshaft housing.
3. Assemble the puller screw and extension, if necessary. Install the puller screw onto the expanding mandrel.
4. Hold the end of the puller screw with a wrench to keep it from turning. Tighten the pulling nut against the thrust bearing and the pulling plate until the camshaft bushing is removed.

Coolant Heater (if equipped)

1. Make sure coolant has been drained out of the engine or at least drained to a level below the coolant heater, if simply servicing the heater.
2. Loosen 5/32 in hex socket head cap screw sufficient to remove the coolant heater from the crankcase.
3. Clean out coolant heater cavity at crankcase.

Cleaning and Inspection

Cleaning the Crankcase

CAUTION: To avoid engine damage, the oil cooler must be replaced if there was a bearing failure. Debris from a bearing failure cannot be removed from the oil cooler.

NOTE: The best way to clean the crankcase during engine overhaul is in a chemical bath or hot tank. This removes all carbonaceous material and mineral deposits that collect in the cooling passages. If the hot tank is not available, use the following cleaning procedure.

1. Clean all old gasket material from the surfaces of the crankcase, if any.

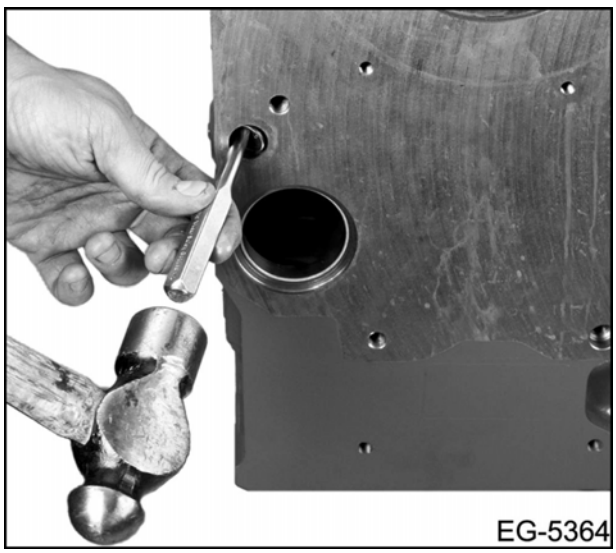

Figure 338 Removing crankcase plugs

2. Remove the main oil gallery cup plug, located at the rear of the crankcase by using a hammer and chisel. Knockout main oil gallery cup plug.
3. With the plugs removed from the crankcase, clean the crankcase as follows:
   a. Use a nylon brush (Table 40) with soap and water to clean oil galleries.
   b. Clean cross drillings using a nylon brush (Table 40) with soap and water.
   c. Use filtered compressed air page 3 to blow out oil galleries and cross drillings.
   d. Clean all threaded holes with an appropriately sized tap (Table 40).
4. Install a new main oil gallery cup plug as follows:
   a. Clean the mating surfaces of the plug and crankcase.
   b. Apply Loctite® 262 to the outside edge of the cup plug.
   c. Use an arbor to drive the cup plug in. The arbor must be approximately 6 mm (¼ in) smaller in diameter than the plug that is being installed.
   d. Recess the cup plug 3.2 mm (⅛).
5. Install new plugs in the rear of the crankcase.
6. Inspect the piston cooling tubes for damage and blockage as follows:
   a. Inspect both ends of the tube. Verify that the flanged end next to the bearing saddle is intact and the orifice end protruding from the crankcase is not broken. Replace any tubes that are damaged.
   b. Hold tube under running water in a sink. Water should stream out of tube end. If not, blockage will have to be physically removed by compressed air page 3 or piston oil tube must be replaced.

Crankcase Ventilation

1. Place breather and tubing assembly (Figure 323) into a solvent parts cleaner and disassemble.
2. Thoroughly clean all hoses, clamps, tubing, check valve and breather assembly. Run solvent through each end of the check valve to confirm directional flow.
3. Blow dry with filtered compressed air page 3.
4. Inspect all rubber hoses for cracking or deformation. Replace components as necessary.

Crankshaft and Main Bearings

Perform the following steps:

1. Clean the bearing inserts and caps thoroughly in solvent and dry with filtered compressed air page 3. **Do not scrape gum or varnish deposits from bearing shells**.
2. Clean all the internal oil passages of the crankshaft using a stiff nylon brush (Table 40). Loosen all dirt, sludge and deposits which may have accumulated. Flush the oil passages with a suitable non-caustic solvent.
3. Blow passages dry with filtered compressed air page 3.
4. Inspect the crankshaft journals (main and rod) for scratches, grooves and scoring. Use dye penetrant methods to check for cracks.
5. Inspect all bearing inserts. Replace bearings that are scored, chipped or worn.

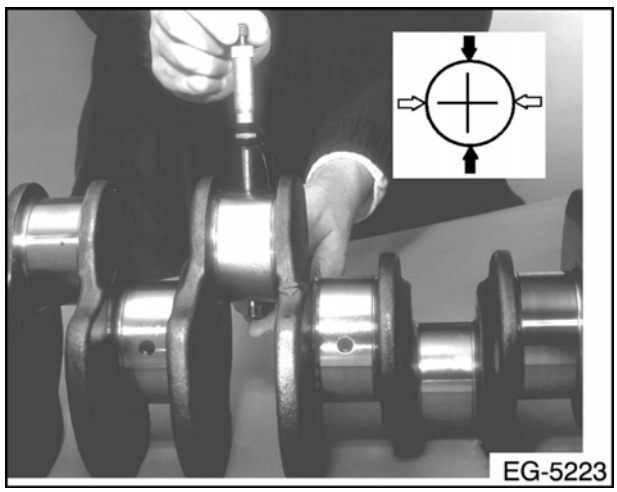

Figure 339 Inspecting the crankshaft journals

6. Measure the diameter of each journal using a micrometer. Measure each journal at two points, right angles to each other. Move the micrometer over the entire width of the journal.

NOTE: If journals exceed maximum out-of-round specification, crankshaft must be reground or replaced. The crankshaft can be ground to the following undersizes:

- 0.25 mm (0.010 in)
- 0.51 mm (0.020 in)
- 0.76 mm (0.030 in)

Checking Camshaft Assembly

1. Use a soft bristle brush and a suitable solvent to clean the camshaft and cam gear.
2. Inspect the cam gear for worn and damaged teeth. Replace the gear assembly, if necessary.
3. Inspect the camshaft for scuffed, scored and cracked lobes. Replace the camshaft if necessary.
4. Inspect the camshaft thrust plate for wear, cracks, and distortion. Use an outside micrometer to measure the thickness of the thrust plate. If the thrust plate is too worn or damaged, replace the thrust plate.

Checking Camshaft Lobes and Journals

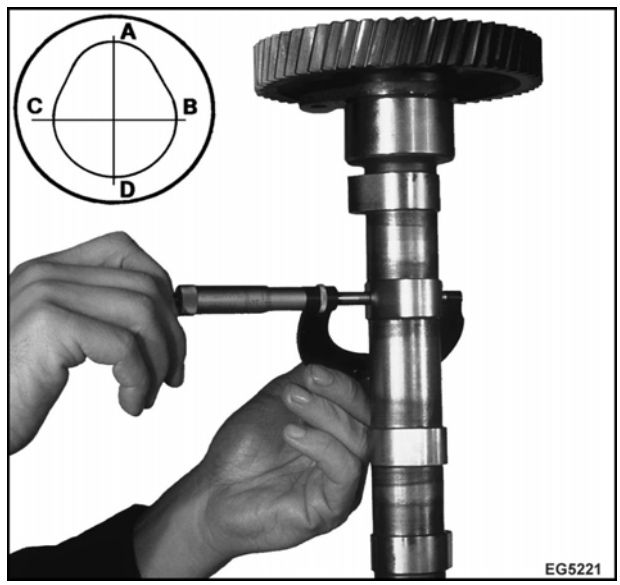

Figure 340 Checking camshaft lobes and journals for wear

1. Use an outside micrometer to measure across each camshaft lobe from A-D and B-C. Subtract measurement B-C from measurement A-D. This is the cam lobe lift.

   If any measurement exceeds the specification, replace the camshaft.
2. Use an outside micrometer to measure the diameter of each camshaft journal.

If any measurement exceed specifications (Table 38), replace the camshaft.

Installation

Coolant Heater (if equipped)

1. If servicing a leaky coolant heater, replace O-ring on heater assembly.
2. Place non-petroleum base lubricant around O-ring area and install into crankcase. Orient electrical connector so that it is facing downward (6 o'clock position).
3. Tighten the 5/32 in hex socket head cap screw to the special torque value (Table 39).
4. Replenish coolant level if only servicing coolant heater.

Camshaft Bushings

1. Identify each camshaft bushing according to its outside diameter.

Table 36

Bushing Location	Outside Diameter (nominal)	Width (nominal)
Front	65.5 mm (2.50 in)	25.4 mm (1.00 in)
Rear	65.5 mm (2.50 in)	17.8 mm (0.70 in)
Intermediate	63.0 mm (2.48 in)	17.8 mm (0.70 in)

2. Lubricate each new camshaft bushing and crankcase bushing bore with clean engine oil.

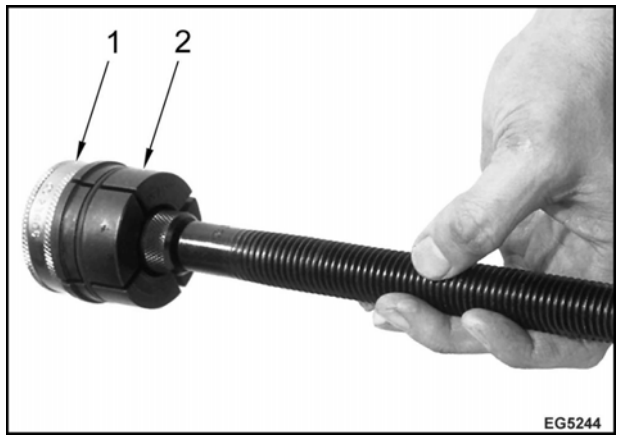

Figure 341 Camshaft bushing installation tool

1. Adjusting nut
2. Expanding collet

3. Install new camshaft bushing onto the expanding collet. Tighten collet by turning adjusting nut until the bushing is held securely in place.

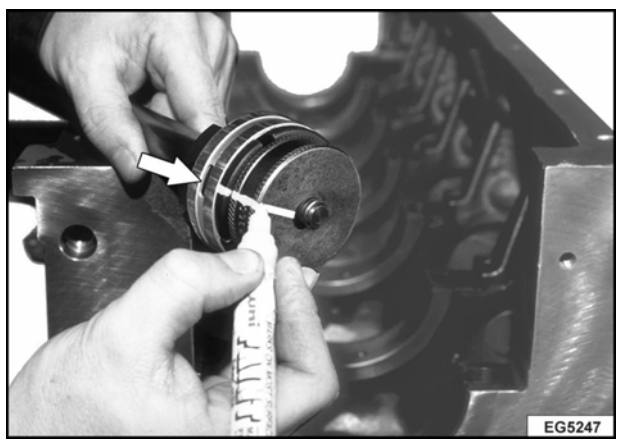

Figure 342 Marking oil hole location on bushing

4. Mark the bushing oil hole location on the backup nut of the installation tool to help align the oil hole in the bushing with the oil hole in the crankcase. Repeat this step for each bushing.

CAUTION: To avoid engine damage, camshaft bushings must be installed in the proper order due to differing outside diameters. Both intermediate cam bushings have an outer diameter that is slightly smaller than bushings used in the front and rear positions.

Cam bushing oil holes must align with oil holes in cylinder block.

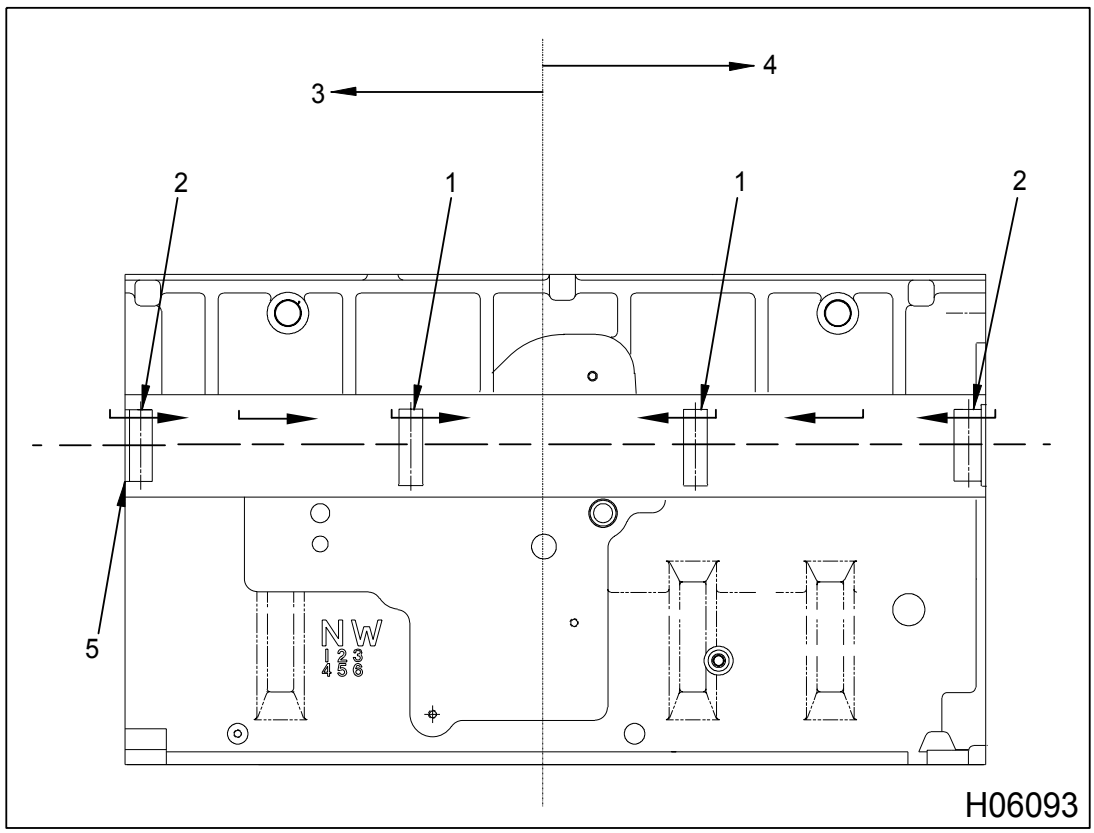

Figure 343 Pulling direction for individual camshaft bushing installation

1. Intermediate bushings
2. Front and rear bushings
3. Rear half of engine
4. Front half of engine
5. Camshaft seal ring

5. Install the rear intermediate bushing through the rear of the crankcase. Pull the bushing into place from the front of the crankcase by turning the pulling nut on the puller screw. Remove the installation tool and inspect the oil hole alignment.
6. Install the front intermediate bushing through the front of the crankcase. Pull the bushing into place from the rear of the crankcase by turning the pulling nut on the puller screw. Remove the installation tool and inspect oil hole alignment.

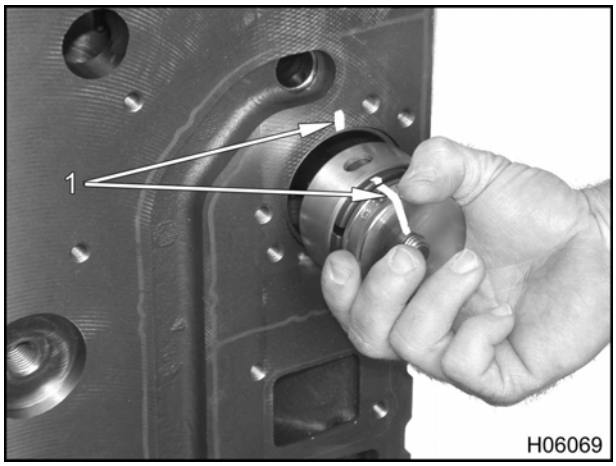

Figure 344 Installing the front thrust bushing

1. Paint marks to indicate oil hole alignment

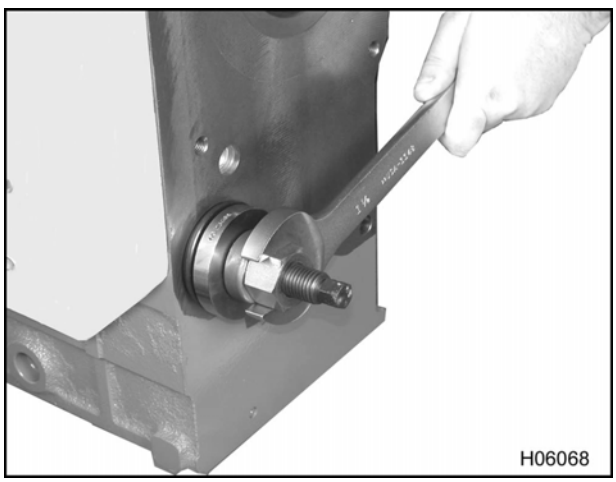

Figure 345 Pulling in the front bushing

7. Install the front bushing through the front of the crankcase. Pull the bushing into place from the rear of the crankcase by turning the pulling nut on the puller screw. Remove the installation tool and inspect the oil hole alignment.
8. Install the rear bushing through the rear of the crankcase. Pull the bushing into place from the front of the crankcase by turning the pulling nut on the puller screw. Remove the installation tool and inspect the oil hole alignment.

Camshaft Assembly

NOTE: Use this procedure to install the cam gear and camshaft as a unit.

Figure 346 Installing camshaft assembly

1. Rotate crankcase to a vertical position.
2. Lubricate all camshaft journals and bushings with clean engine oil.
3. Install the camshaft assembly in the crankcase.

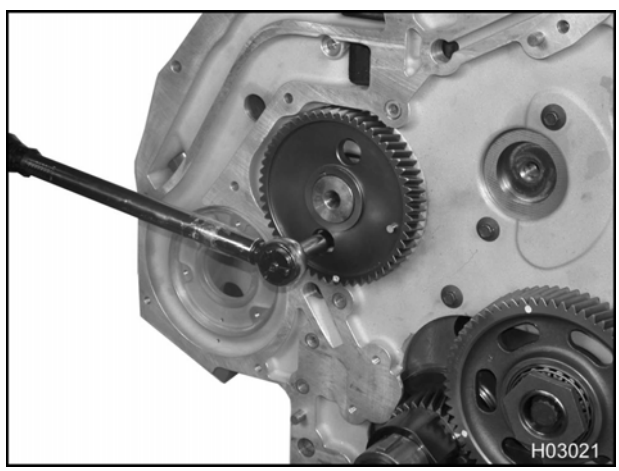

Figure 347 Torquing camshaft thrust plate bolts

4. Install the two camshaft thrust plate bolts (M8 x 20). Tighten the bolts to the special torque value (Table 39).

Cam Gear on Camshaft

WARNING: To avoid serious personal injury or possible death, wear heat resistant gloves when handling heated components.

Figure 348 Heating the camshaft gear

1. If the camshaft gear was removed from the camshaft, heat the cam gear on a hot plate (Table 40) or other controlled heat source to 149-177°C (300-350°F).

CAUTION: To avoid engine damage, heating the cam gear beyond 177°C (350°F) will cause gear to turn blue and adversely effect its wear resistance. Do not use any gear that has turned blue from overheating.

2. Pull camshaft assembly forward prior to sliding heated gear onto camshaft.

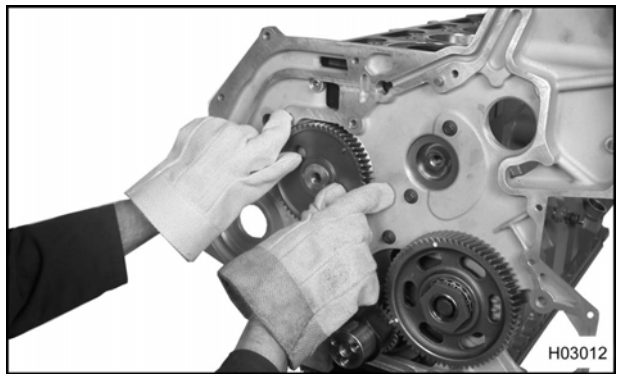

Figure 349 Installing cam gear on camshaft

3. Use heat resistant gloves to install the heated cam gear onto the camshaft. The cam gear should slide onto the camshaft with only slight hand pressure. Hold the cam gear (while thoroughly seated) until it cools onto the camshaft (approximately 30 seconds).

NOTE: Heated gear should easily slide onto camshaft. Do not tap into place to avoid camshaft end play issues. If gear does not slide easily, reheat gear and try again.

Checking Camshaft End Play

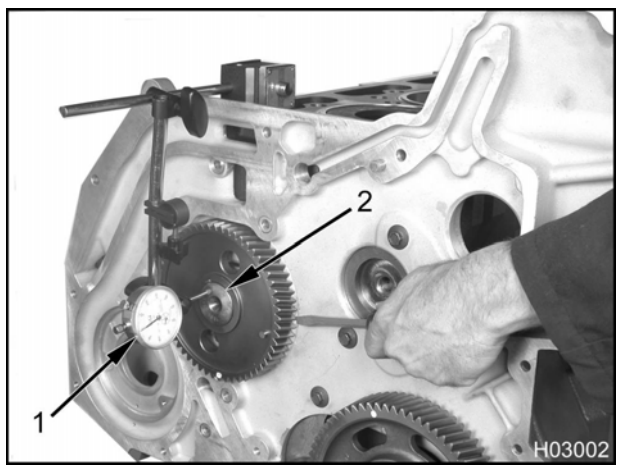

Figure 350 Checking camshaft end play

1. Dial indicator set
2. Camshaft

1. Mount a dial indicator on the front cover or crankcase, depending on mounting options.

2. Place the tip of the dial indicator on the end of the camshaft and zero the dial indicator.
3. Use a screwdriver to pry the camshaft gear back and forth. Record the reading on the dial indicator.

   If the end play exceeds the specification, remove the cam gear and pull the camshaft forward. Repeat the procedure.

Crankshaft Assembly

1. Rotate the engine so the main bearing saddles are facing up. Clean the bearing saddles with a lint-free cloth. The supports must be free of oil. Do not lubricate the back side of the bearing inserts.

⚠ WARNING: To avoid serious personal injury or possible death, wear heat resistant gloves when handling heated components.

2. With gears removed, heat the crankshaft gear and oil pump drive spline, using a hot plate (Table 40), to 188-202°C (370-395°F).
3. Position the slotted locating pin (5/32 x 5/16) onto the crankshaft.

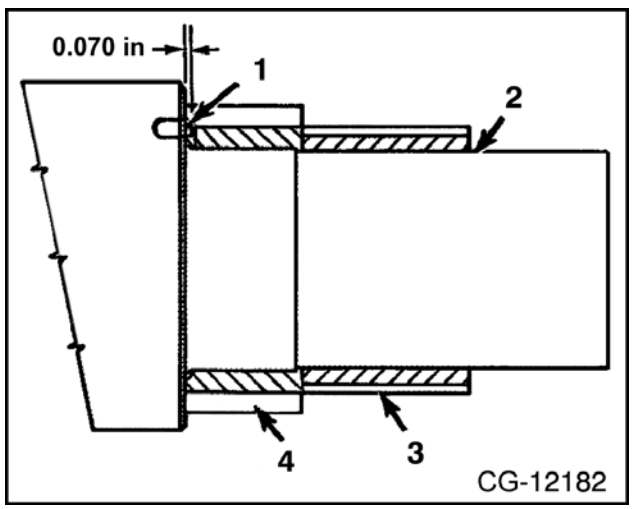

Figure 351 Installing crankshaft gear

1. Slotted pin, 5/32 x 5/16
2. Crankshaft
3. Oil pump drive spline
4. Crankshaft gear

4. Using gloves specifically designed for extremely hot objects, install heated crankshaft gear first, aligning the slotted pin with hole in crankshaft gear. Press the gear into place holding against crankshaft shoulder.
5. Slide the hot oil pump drive (splined) up against the crankshaft gear (no orientation required).
6. Hold oil pump drive and crankshaft gear in place until cool enough to sufficiently hold onto crankshaft.

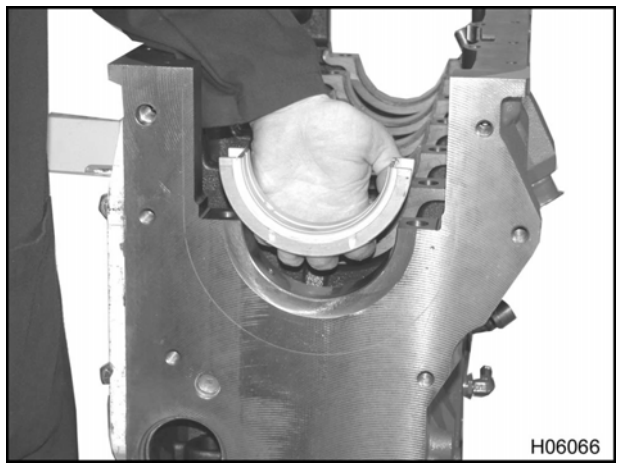

Figure 352 Installing the number seven thrust bearing

7. Install the thrust bearing into the number seven upper bearing saddle. Make sure the locking tangs on the bearings are snapped into the crankcase.
8. Install the remaining six upper bearing inserts into the saddles. Make sure the locking tangs on the bearings are snapped into the crankcase.
9. Apply Prussian Blue® to the crankshaft main bearing journals.

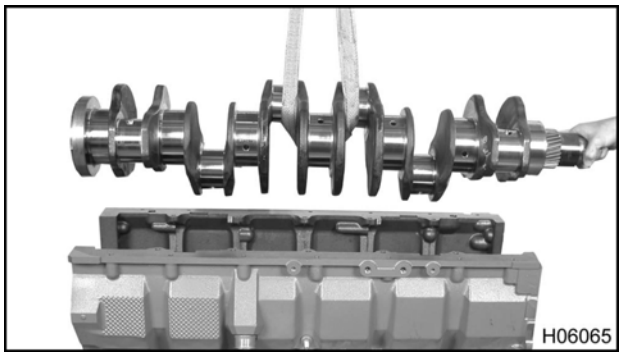

Figure 353 Installing the crankshaft assembly

10. Using an appropriate lifting sling, carefully lower the crankshaft onto the main bearing inserts in the crankcase.

NOTE: Do not install the main bearing caps and lower bearing inserts at this time.

11. Rotate the crankshaft 180 degrees (½ turn).
12. Carefully remove the crankshaft and inspect the upper bearing inserts for an even transfer of bluing agent from the journals to the bearings.

NOTE: If voids appear in the bluing transfer, crankcase integrity is considered questionable.

13. If the crankcase is not damaged and is free of distortion and burrs around upper bearing insert seats, then clean all Prussian Blue™ from the bearings and crankshaft journals.

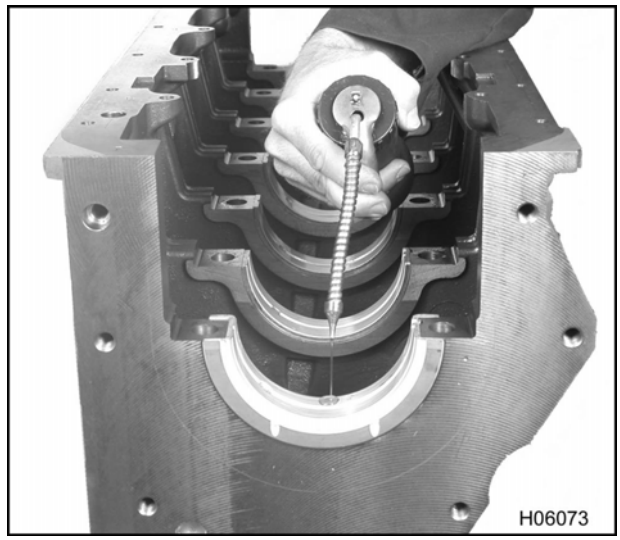

Figure 354 Lubricating the upper main bearing inserts

14. Lubricate the upper main bearing inserts with clean engine oil.

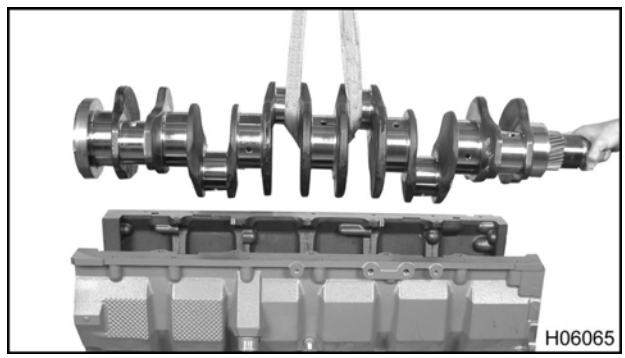

Figure 355 Installing the crankshaft assembly

15. Using an appropriate lifting sling, carefully lower the crankshaft onto the main bearings.

Bearing Fitting Procedure

1. Install a new bearing insert into the bearing cap, as required. The bearing surface of the bearing caps must be free of oil. Do not lubricate the backside of the bearing inserts. Make sure the locking tangs on the bearing inserts are snapped into the bearing cap notch.

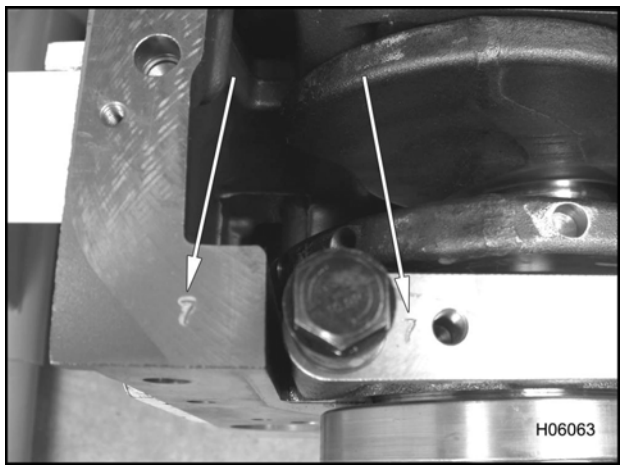

Figure 356 Main bearing cap identification stamps

2. Align each main bearing cap with its identification stamp.
3. Check bearing clearance as follows:
   a. Clean the bearing surface and the exposed half of the crankshaft journal. Make sure these surfaces are free of oil.
   b. Install the lower inserts and bearing caps. Oil the threads of new main bearing bolts with clean engine oil.
   c. Torque bolts in the following steps in a circular pattern.

      NOTE: This two step torque procedure to 177 N·m (130 lbf·ft), simply checks bearing fit and will not permanently stretch the new main bearing bolts. Do not follow the torque-to-yield procedure until final assembly.

      1. Tighten each main bearing bolt to 136 N·m (100 lbf·ft) using the recommended torque sequence (Figure 359).
      2. Tighten each main bearing bolt to 177 N·m (130 lbf·ft) using the recommended torque sequence (Figure 359).

   d. Remove one bearing cap and insert at a time. Leave the remaining caps tight while checking the fit of the bearing with the cap removed.
   e. Wipe oil from all contact surfaces of the exposed journal, bearing insert and cap that is removed.
   f. Place a piece of Plastigage® across the full width of the bearing surface on the crankshaft journal (or bearing insert) approximately 6 mm (¼ in) off center. Install the bearing cap and tighten the cap bolt to 177 N·m (130 lbf·ft).

      NOTE: Do not turn the crankshaft.

      NOTE: In chassis service only: When bearing oil clearance is checked, the crankshaft will have to be supported and held against the upper main bearing halves to get a correct Plastigage® reading. Use a jack at the crankshaft counterweight nearest to each main bearing being checked to apply local support. Failure to support the crankshaft will result in inaccurate readings.

   g. Remove the bearing cap and insert.
   h. Do not disturb the Plastigage®. Use the scale on the Plastigage® envelope to measure the widest point of the flattened Plastigage®. This reading indicates the bearing clearance in thousandths of an inch or millimeters.

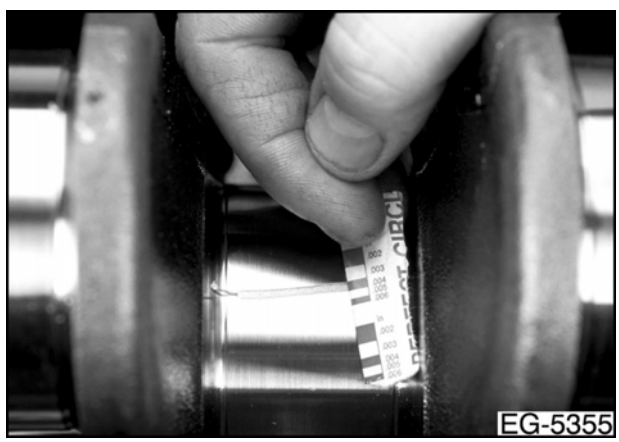

Figure 357 Measuring Plastigage®

i. If the bearing clearance is not within specifications, the crankshaft must be replaced or reground and undersize bearings installed.

Main Bearings and Caps

CAUTION: To avoid engine damage, use new main bearing cap bolts whenever the bearing caps are serviced.

NOTE: The thrust bearing located at number 7 is found only in the upper half. All seven lower bearings share the same part number.

1. Clean the Plastigage® from main bearing and or crankshaft journal surfaces.
2. Coat all bearing surface journals with clean engine oil.
3. Apply clean engine oil to main bearing bolts (threads and under head).
4. Place the No. 1 through No. 7 main bearing caps with the lower bearing inserts installed.

NOTE: Make sure the main bearings are installed with the arrow pointing to the cam side and numbered from the front of the engine to the rear.

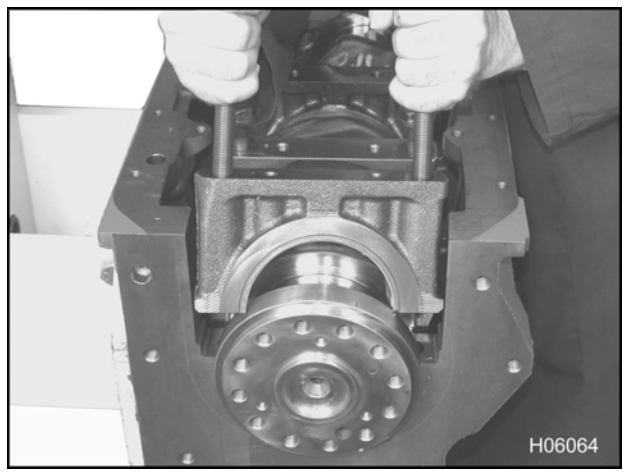

Figure 358 Installing the main bearing caps

5. Align and seat each of the main bearing caps.

Tensioning Procedure for Torque-to-Yield Bearing Bolts

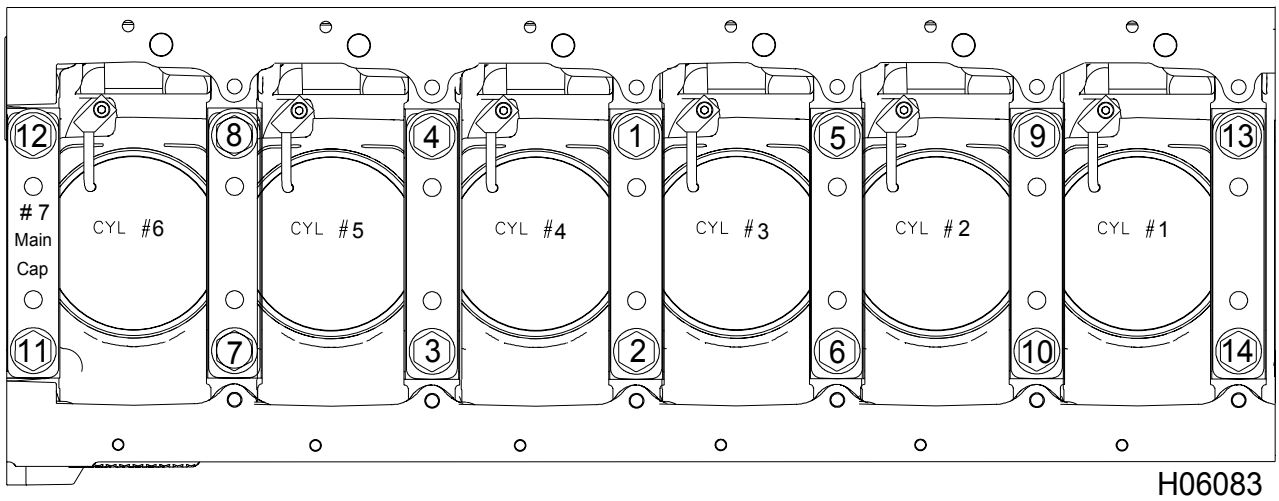

Figure 359 Recommended main bearing bolt torque sequence

1. Torque the new main bearing cap bolts No. 1 through No. 7.
   a. Tighten each main bearing bolt to 136 N·m (100 lbf·ft) using the recommended torque sequence.

      Check crankshaft end play using a dial indicator as follows:

      1. Mount the dial indicator onto crankcase with indicator tip on crankcase flange face.
      2. Lightly pry the crankshaft forward and zero indicator.
      3. Pry crankshaft rearward and record dial indicator reading. Repeat to ensure an accurate reading.
      4. If end play exceeds specifications, replace thrust bearing and recheck crankshaft end play. If end play is less than specified, loosen the thrust bearing cap, reposition, torque and check end play again.

   b. Tighten each main bearing bolt to 177 N·m (130 lbf·ft) using the recommended torque sequence.

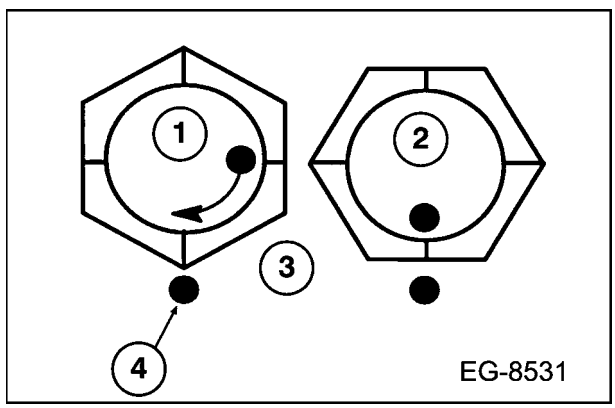

Figure 360 Crankshaft main bearing bolt

1. Head of bolt with mark, position 1
2. Head of bolt with mark, position 2 (bolt stretches)
3. Main cap surface
4. Mark (permanent marker)

   c. Use a permanent marker to add a mark on each bolt head and another mark 90° clockwise on the main cap. Also mark the socket to match the bolt marking.

   d. Rotate each crankshaft main bearing bolt (Figure 360) 90 degrees (¼ turn).

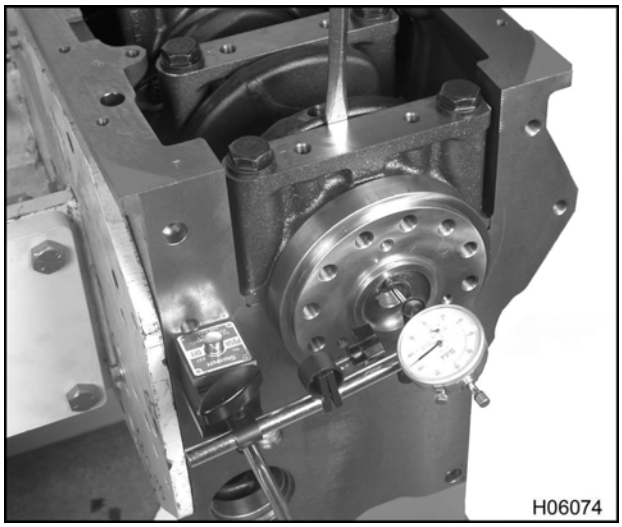

Figure 361 Checking crankshaft end play

2. Check crankshaft end play using a dial indicator as follows:
   a. Mount the dial indicator onto crankcase with indicator tip on crankcase flange face.
   b. Lightly pry the crankshaft forward and zero indicator.
   c. Then pry crankshaft rearward and record dial indicator reading. Repeat to ensure an accurate reading.
   d. If end play exceeds specifications, replace thrust bearing and recheck crankshaft end play. If end play is less than specified, loosen main bearing caps, reposition, torque and check end play again.

Crankcase Ladder (570 series only) > 300 bhp

NOTE: The crankcase ladder is symmetrical in design, therefore it doesn't matter which way it is installed.

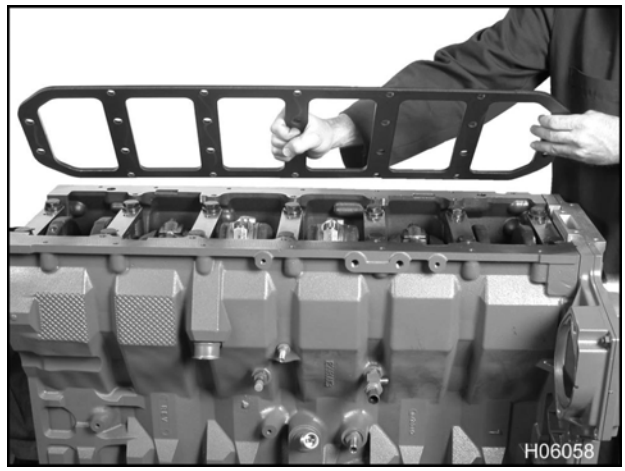

Figure 362 Installing the crankcase ladder

1. Install crankcase ladder onto crankcase.

Figure 363 Crankcase ladder hardware

2. Install 14 crankcase ladder spacers and bolts (M12 x 35) to the 14 inboard bolt holes finger tight.
3. Install 10 crankcase ladder bolts (M10 x 25) to the 10 outboard bolt holes finger tight.

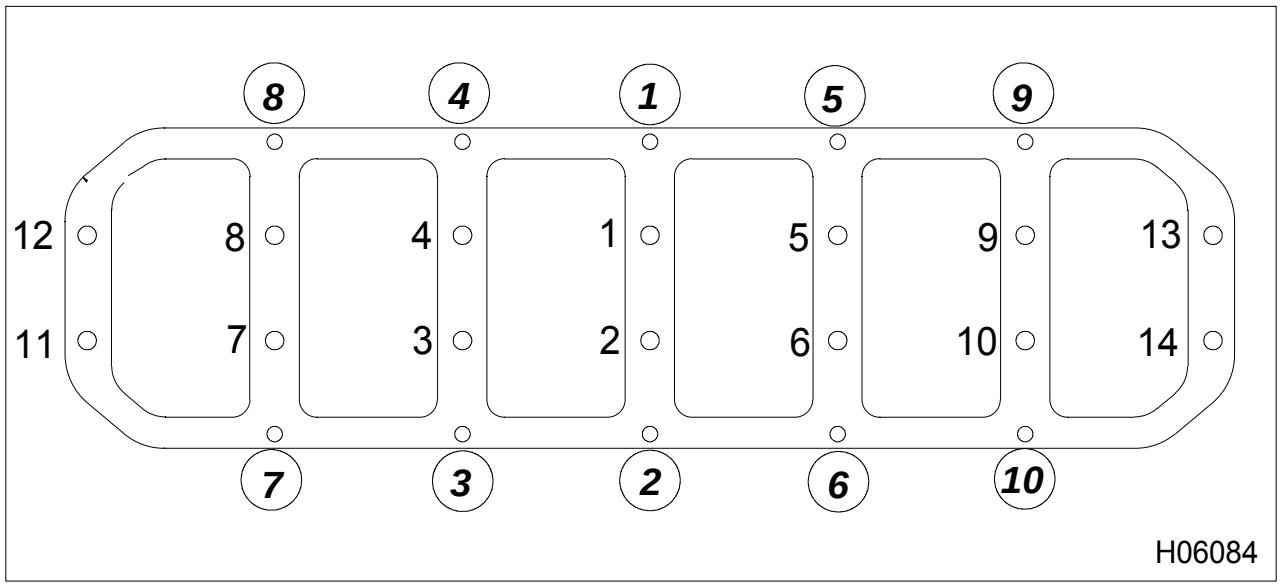

Figure 364 Recommended crankcase ladder torque sequence

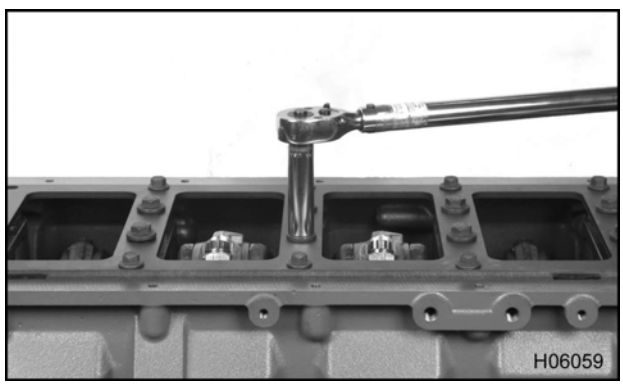

Figure 365 Torquing the crankcase ladder bolts

4. Using the recommended crankcase ladder torque sequence, tighten the inboard bolts (M12 x 35) to the special torque value (Table 39).
5. Using the recommended crankcase ladder torque sequence, tighten the outboard bolts (M10 x 25) to the special torque value (Table 39). These bolts are indicated by the circled numbers in the above illustration.

Valve Lifters

NOTE: Piston assemblies should have been installed by now. See “Power Cylinders” in this manual for more information regarding the installation of piston and connecting rod assemblies.

1. Lubricate each set of lifters with clean engine oil before installation.
2. Assemble each set of valve lifters and guides in the same orientation as removed (if reusing lifters). New lifter and guides can be installed in either direction.

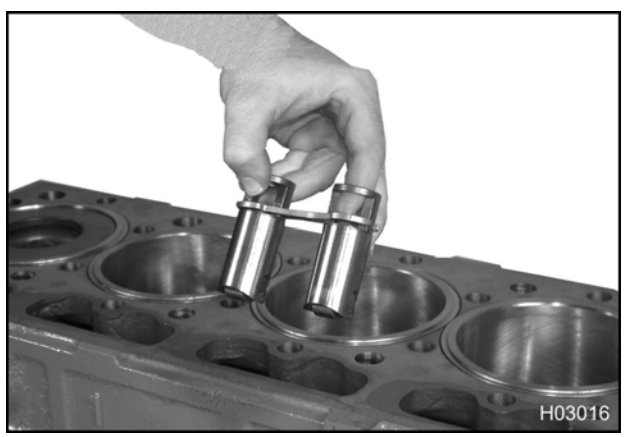

Figure 366 Installing valve lifters

3. Place two fingers into valve lifter (if they fit) or place a piece of stiff wire onto each lifter and lower lifter set into crankcase.

NOTE: Do not rotate engine stand after roller lifters have been installed.

Oil Level Gauge

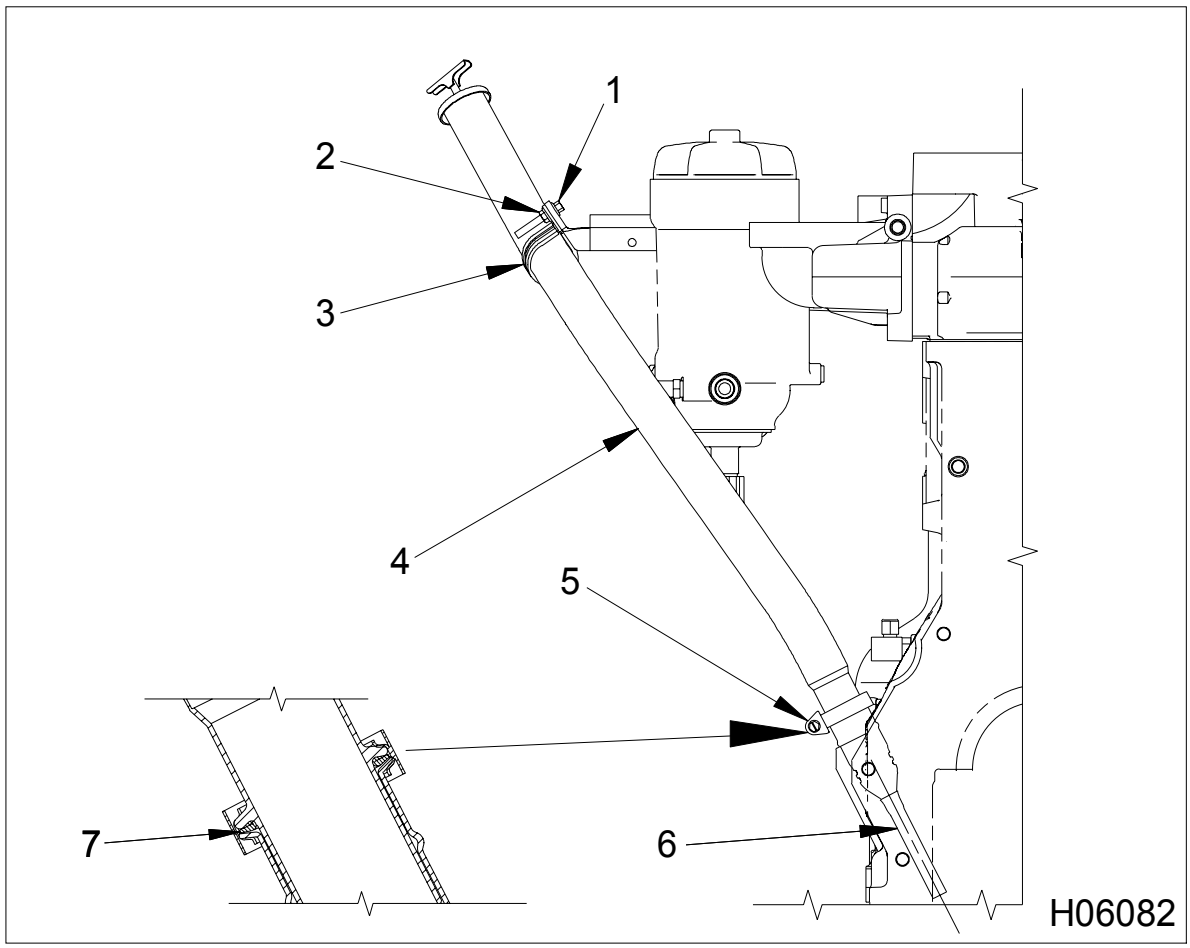

Figure 367 Oil level gauge assembly

1. Bolt, M6 x 40
2. Nut, M6
3. Cushioned clamp
4. Oil filler tube
5. Tube clamp
6. Oil level gauge tube
7. Oil dipstick tube seal

1. If removed earlier, install the oil level gauge tube by first applying Loctite® #277 around entire circumference of tube and casting. Drive tube into crankcase until bead of tube is seated in chamfer of crankcase boss.
2. Install a new oil dipstick tube seal between oil filler tube and crankcase oil tube flange.
3. Install the tube clamp at the crankcase.
4. Install the oil filler tube bolt (M6 x 40) and nut (M6) at the fuel filter bracket.

Crankcase Ventilation System

1. If fitting assembly (M12) was leaking at the crankcase, replace O-ring. Tighten fitting to the standard torque value (See General Torque Guidelines, page 409).

> **CAUTION: To avoid engine damage, do not use any type of impact tools to seat the (M8 x 35) bolts. Using impact tools will cause thread damage.**

2. Install a new O-ring onto breather assembly and push into valve cover grommet.

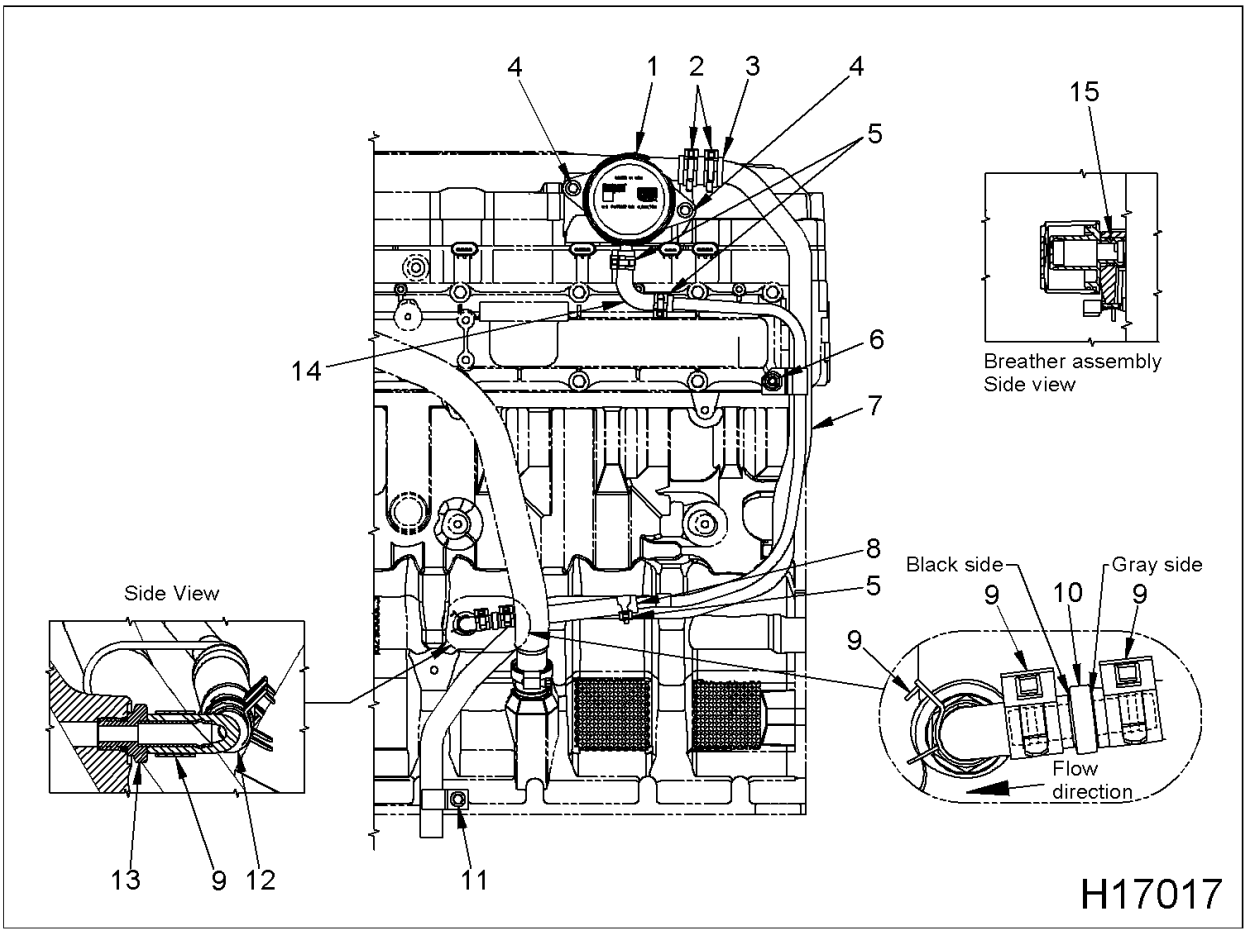

Figure 368 Crankcase ventilation

1. Breather assembly
2. Clamp, (1 in) diameter (2)
3. Hose, (1 in) I.D.
4. Bolt, M8 x 35 (2)
5. Clamp, ½ in. diameter (3)
6. Nut, M10
7. Vent and drain tube assembly
8. Reducer hose
9. Clamp (3)
10. Check valve
11. Bolt, M8 x 16
12. Rubber elbow
13. Fitting assembly, M12
14. Drain hose elbow
15. O-ring, #214

3. Position drain hose elbow and one inch hose onto breather assembly. Secure with clamps, see illustration.
4. Place appropriate hose clamps onto vent and drain tube assembly. Position vent and drain tube assembly into breather assembly hoses.
5. Align vent and drain tubing assembly bracket with intake manifold stud. Thread nut (M10) onto stud finger tight.
6. Attach bottom of vent tubing to crankcase and secure with bolt (M8 x 16).
7. Combine rubber elbow, clamps, check valve, and reducer hose, making sure check valve is oriented correctly. Connect to drain side of tubing and clamp.
8. Tighten all hardware to the standard torque value (See General Torque Guidelines, page 409) and move clamps into their sealing positions.

SPECIFICATIONS

Table 37 Crankshaft Specifications

Type	Steel forged, induction hardened, grindable
Main bearing journal diameter:	
0.254 mm (0.010 in) undersized	107.70 ± 0.0152 mm (4.240 ± 0.0006 in)
0.508 mm (0.020 in) undersized	107.44 ± 0.0152 mm (4.230 ± 0.0006 in)
0.762 mm (0.030 in) undersized	107.19 ± 0.0152 mm (4.220 ± 0.0006 in)
Damper mounting area runout (maximum)	0.03 mm (0.001 in)
Flywheel mounting surface runout (maximum)	0.05 mm (0.002 in)
Main bearing journal maximum out-of-round	0.05 mm (0.002 in)
Main bearing journal taper (maximum per inch)	0.071 mm (0.0028 in)
Main bearing thrust face runout (TIR maximum)	0.03 mm (0.001 in)
Main bearing width (except rear thrust)	34.19 ± 0.13 mm (1.346 ± 0.005 in)
Number of main bearings	7
Rear oil seal journal runout (maximum)	0.08 mm (0.003 in)
Standard size	107.95 ± 0.015 mm (4.250 ± 0.0006 in)
Thrust taken by	No. 7 rear upper main bearing
Thrust Bearing Journal Length:	
0.76 mm (0.030 in) undersized	34.404 ± 0.025 mm (1.3545 ± 0.0010 in)
0.0254 mm (0.010 in) undersized	79.7 ± 0.0152 mm (3.1400 ± 0.0006 in)
0.508 mm (0.020 in) undersized	79.5 ± 0.0152 mm (3.1300 ± 0.0006 in)
0.762 mm (0.030 in) undersized	79.2 ± 0.0152 mm (3.1200 ± 0.0006 in)
Center line of main bearing bore to head deck	368.3 ± 0.05 mm (14.50 ± 0.002 in)
Connecting rod bearing to crankshaft running clearance	0.030 - 0.107 mm (0.0012 - 0.0042 in)
Connecting rod bearing width	40.01 mm (1.575 in)
Connecting rod journal diameter standard size	80.0 ± 0.0152 mm (3.1500 ± 0.0006 in)
Connecting rod journal maximum out-of-round	0.0064 mm (0.00025 in)
Connecting rod journal taper (maximum per inch)	0.0069 mm (0.00027 in)
Crankcase deck flatness	0.08 mm (0.003 in)
Crankshaft end play	0.15-0.31 mm (0.006 - 0.012 in)
Crankshaft end play maximum wear limit	0.51 mm (0.020 in)
Crankshaft flange outside diameter	155.58 mm (6.125 in)
Crankshaft gear backlash	0.08-0.41 mm (0.003 - 0.016 in)
Crankcase main bearing bore diameter	97.80 ± 0.01 mm (3.849 ± 0.001 in)
Main bearing to crankshaft running clearance	0.046 - 0.127 mm (0.0018 - 0.0050 in)

Table 37 Crankshaft Specifications (cont.)

Rod to crankshaft side clearance	0.30 ± 0.11 mm (0.012 ± 0.005 in)
Standard size to 0.51 mm (0.020 in) undersized	34.404 ± 0.03 mm (1.3545 ± 0.010 in)

Table 38 Crankcase Specifications

Cap attachment	2 bolts per cap
Coolant heater rating	1250 W, 120 V
Counterbore dimension in crankcase	8.865 ± 0.025 at 132 mm (0.349 ± 0.001 at 5.189 in)
Cylinder sleeve counterbore maximum allowable depth	9.25 mm (0.364 in)
Main bearing type	Precision replaceable
Material	Steel-backed copper, lead, tin
Maximum allowable variation of counterbore depth (between four points)	0.025 mm (0.001 in)
Piston cooling tube dia. (spray hole) DT 466	1.91 - 2.06 mm (0.075 - 0.081 in)
Piston cooling tube dia. (spray hole) DT 570, HT 570	2.26 - 2.41 mm (0.089 - 0.095 in)
Roller tappet outside diameter	28.435 - 28.448 mm (1.1195 -1.1200 in)
Sleeve protrusion above crankcase	0.05 - 0.13 mm (0.002 - 0.005 in)
Tappet bore diameter	28.51 - 28.55 mm (1.123 - 1.124 in)
Thrust taken by	No. 7 rear upper main bearing
Camshaft	
Bushing I.D. (installed)	58.03-58.12 mm (2.285-2.288 in)
Cam lobe lift, exhaust	6.91 mm (0.272 in)
Cam lobe lift, intake	6.68 mm (0.263 in)
Camshaft end play	0.18-0.33 mm (0.007-0.013 in)
Camshaft journal diameter	57.95-58.98 mm (2.282-2.283 in)
Camshaft radial clearance	0.05- 0.17 mm (0.002-0.007 in)
Maximum permissible cam lobe wear	0.25 mm (0.010 in)
Service bushings furnished to size	Yes
Thrust plate thickness (new)	6.96 - 7.01 mm (0.274 - 0.276 in)
Camshaft Bushing Bore Diameter in Crankcase	
Front	65.51 - 63.55 mm (2.501 - 2.502 in)
Intermediate front	63.01 - 63.04 mm (2.481 - 2.482 in)
Intermediate rear	63.01 - 63.04 mm (2.481 - 2.482 in)
Rear	65.51 - 63.55 mm (2.501 - 2.502 in)

Special Torque

Table 39 Crankcase, Crankshaft and Camshaft Special Torques

Camshaft thrust plate bolts	26 N·m (19 lbf·ft)
Crankcase ladder, M12 x 35	122 N·m (90 lbf·ft)
Coolant heater bolt	2-3 N·m (20-25 lbf·in)
Crankcase ladder, M10 x 25	63 N·m (46 lbf·ft)
Crankshaft main bearing cap bolt torque and sequence	(See Tensioning Procedure for Torque-to-Yield Bearing Bolts, page 244)

SPECIAL SERVICE TOOLS

Table 40 Crankcase, Crankshaft and Camshaft Special Service Tools

Cam gear puller	ZTSE4411
Camshaft bushing puller	ZTSE2893B
Hot plate	Obtain locally
Nylon brush	ZTSE4389
Tap, cylinder head bolt holes	ZTSE4671
Tap set	ZTSE4386
Stiff nylon brush	ZTSE4392