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Exploded View

Cylinder Head and Related Parts

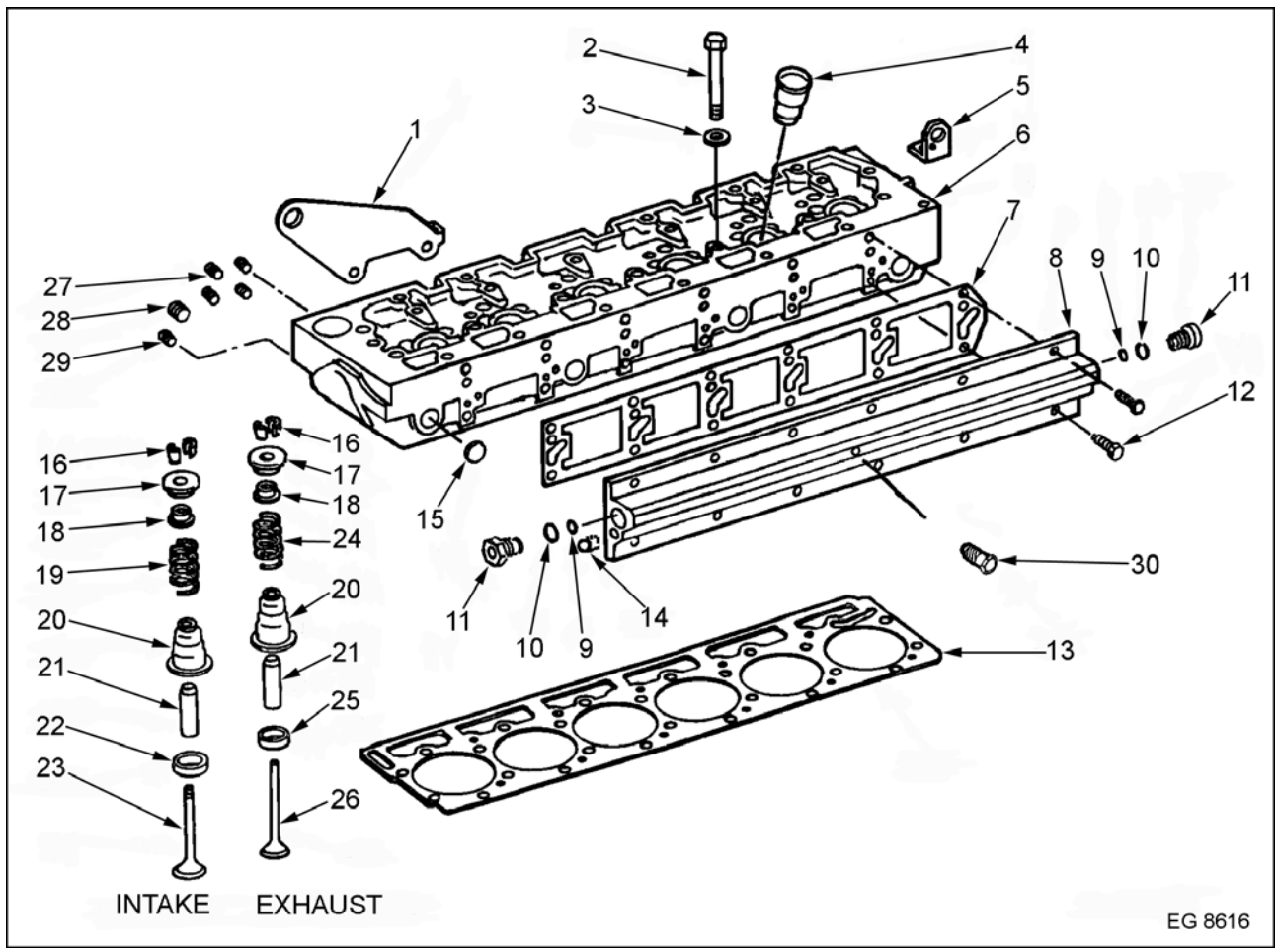

Figure 62 Cylinder head and related parts

1. Front Lifting Eye
2. Cylinder Head Short Bolt (20)
3. Cylinder Head Bolt Washer
4. Fuel Injector Sleeve
5. Rear Lifting Eye
6. Cylinder Head Assembly with Valves
7. Oil and Fuel Supply Manifold Gasket
8. High-pressure Oil and Fuel Supply Manifold
9. Manifold End and Oil Supply Plug O-ring
10. Manifold End and Oil Supply Plug Back-Up Ring
11. Manifold End Oil Supply Plug
12. Flange Bolt 40 mm (1.6 in)
13. Cylinder Head Gasket
14. Manifold End Fuel Supply Plug
15. Cup Plug - 32 mm (1-1/4 in)
16. Valve Stem Key
17. Valve Rotator
18. Valve Rotator Seal
19. Intake Valve Spring
20. Valve Stem Seal With Retainer
21. Valve Guide
22. Intake Valve Seat Insert
23. Intake Valve
24. Exhaust Valve Spring
25. Exhaust Valve Insert
26. Exhaust Valve
27. Pipe Plug - 1/2 in NPT
28. Pipe Plug - 3/4 in NPT
29. Pipe Plug - 1/8 in NPT
30. ICP Sensor

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Remove

Miscellaneous

Prior to removal of cylinder head, refer to appropriate sections of this publication and remove following items:

Turbocharger oil supply tube

Turbocharger oil drain tube

Turbocharger

Road draft tube

Exhaust manifold

ECM and mounting bracket

Main wiring harness

Valve cover and intake manifold

Fuel supply line to supply manifold from filter header

Fuel Injector Wiring Harness

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.

Once valve cover and intake manifold and gasket have been removed, identify fuel injectors and solenoid connectors. Place Cylinder Head Magnetic Intake Shield (PS94-831-1) (page 111) over intake ports of cylinder head to prevent any small loose parts, dirt or debris from falling in power cylinder.

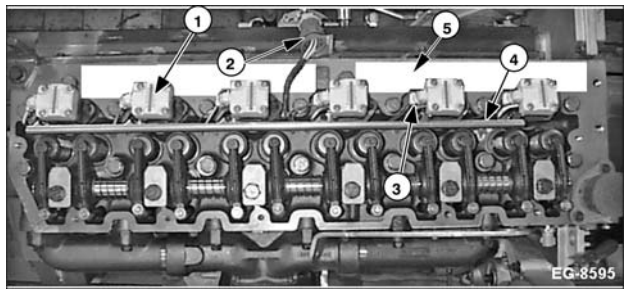

Figure 63 Fuel injector and cylinder head magnetic intake shield

1. Fuel injector
2. Main wiring harness connector
3. Fuel injector solenoid connector
4. Wiring harness channel
5. Cylinder Head Magnetic Intake Shield (PS94-831-1)

CAUTION: To avoid possible damage to the engine or vehicle, do not pull on wires.

1. Locate solenoid wire bail connector at each fuel injector. Pull back on each connector wire bail.

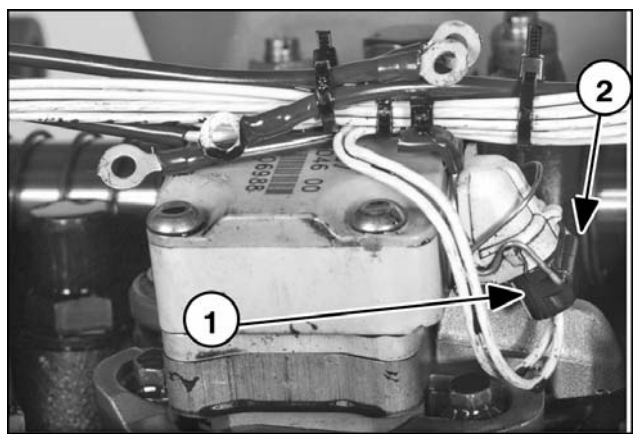

Figure 64 Solenoid connector

1. Fuel injector solenoid connector
2. Wire bail

2. Pull down on connectors to disconnect wiring harness from fuel injectors.
3. Remove wiring harness and oil deflector assembly hold down bolts.

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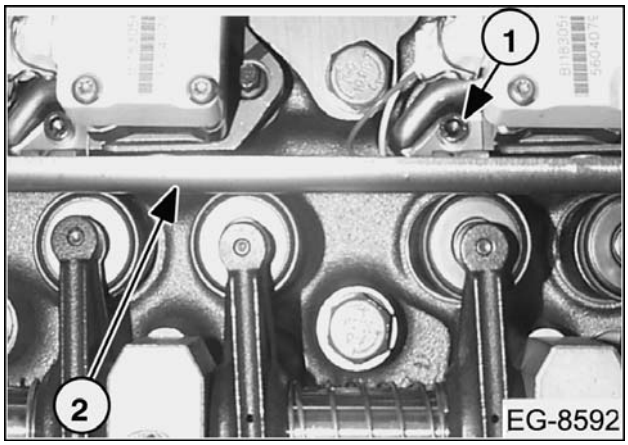

Figure 65 Remove hold down bolts

1. Hold down bolts (1 per injector)
2. Wiring harness and oil deflector assembly

4. Remove wiring harness and oil deflector assembly.

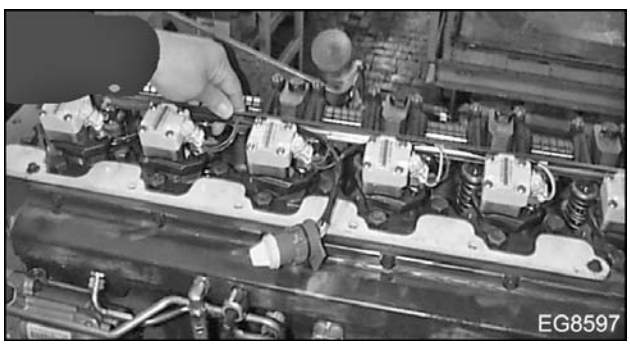

Figure 66 Remove wiring harness and oil deflector assembly

Alternate Procedure

1. Release wire bail on injector harness connector and remove connector.
2. Release top snap of fuel injector harness clip by applying a slight force in each directions indicated by arrows. Once top snap is free, release bottom snap by pushing against side of oil deflector in direction shown.
3. Slide harness clip away from fuel injector toward cam side of engine.

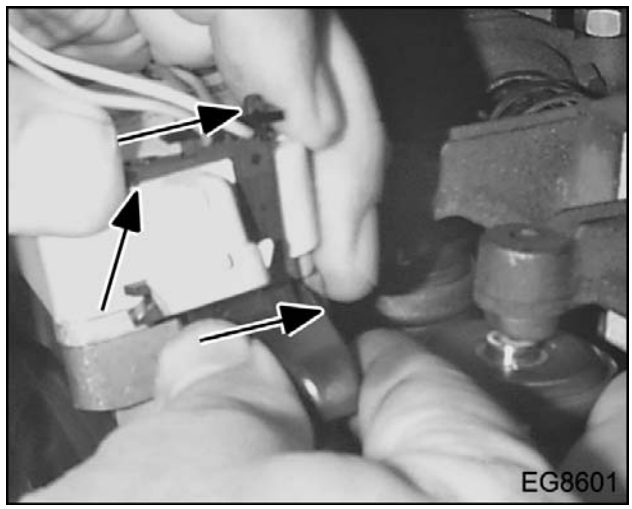

Figure 67 Remove harness clip

Drain Supply Manifold

NOTE: Supply oil rail manifold must be drained prior to removing fuel injectors to prevent leakage in cylinder bore.

1. Place rag or suitable container by supply manifold end plug. Remove supply manifold end plug. Dispose of rags and engine fluids according to local regulations.

Figure 68 Remove supply manifold end plug

2. Remove and discard O-ring and backup ring.

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NOTE: Make sure to clean old Loctite® from threads of end plug, prior to installation.

3. Clean old Loctite® from plug threads.
4. Install new O-ring and backup ring on end plug.
5. Apply Loctite® to end plug threads and install plug in supply manifold. Tighten plug to “Special Torque (page 110).”

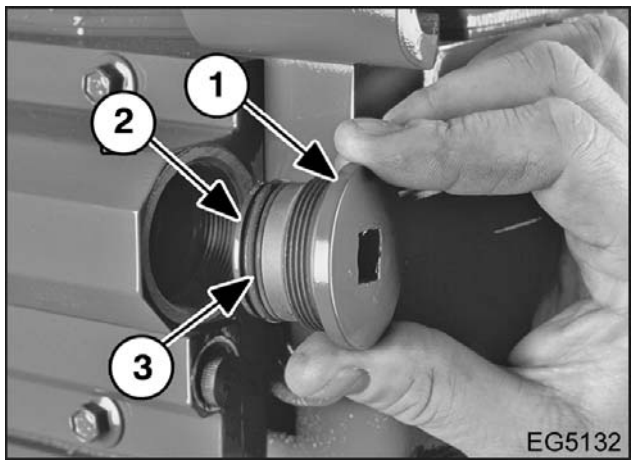

Figure 69 Install supply manifold end plug

1. End plug
2. O-ring
3. Backup ring

Supply Manifold Disconnect Points

1. Loosen nuts. Disconnect high-pressure oil supply hose from 90 degree elbow and high-pressure pump.

NOTE: Do not turn fitting connection on high-pressure pump.

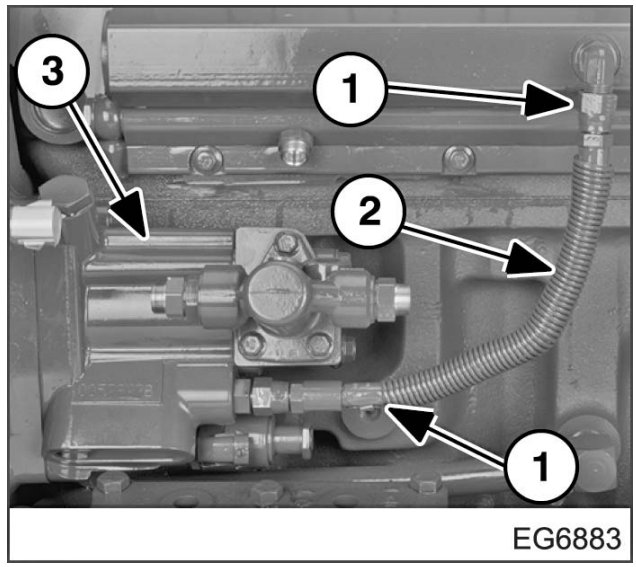

Figure 70 Supply manifold

1. Oil supply line mounting nuts
2. Oil supply line
3. High oil pressure pump

2. If not already done, disconnect fuel supply line from fuel filter header to supply manifold.

NOTE: If it is necessary to remove supply manifold, see "Supply Manifold (page 302)” in the “High-Pressure Lube Oil System” section, for the proper procedures.

3. Remove ICP sensor with O-ring from supply manifold.

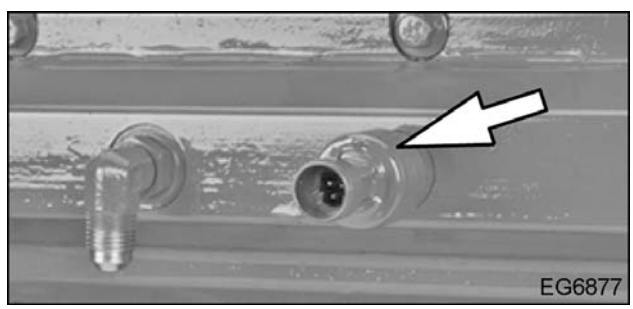

Figure 71 Remove ICP sensor

NOTE: Make sure to clean old Loctite® found on threads of sensor prior to installation.

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Fuel Injector

NOTE: Perform following steps when removing fuel injector from cylinder head.

1. Drain supply manifold oil rail.
2. Remove all fuel injector hold down bolts located in front of each fuel injector.

NOTE: Shoulder bolt at rear of each fuel injector does not require removal.

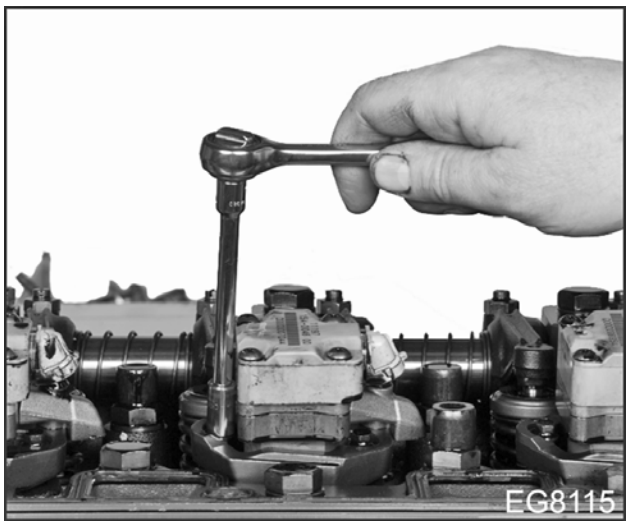

Figure 72 Remove fuel injector hold down bolts

3. Disengage fuel injector hold down clamp from shoulder bolt by sliding clamp toward rear of engine, then up and over head of shoulder bolt.

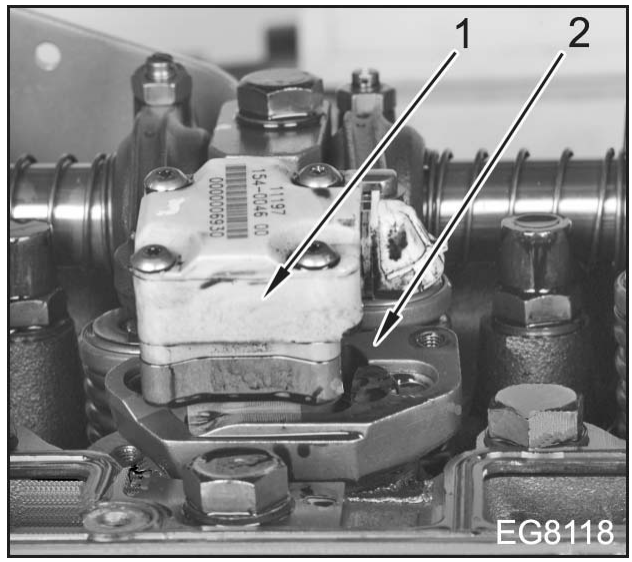

Figure 73 Fuel injector hold down clamp

1. Fuel injector
2. Hold down clamp

CAUTION: To avoid damage to fuel injector hold down bolts and engine, make sure clamps are free of shoulder bolts when prying up on clamps.

4. Insert Pry Bar (page 111) under hold down clamp and pry up.
5. Lift fuel injector straight up and out of injector bore. If required, remove six shoulder bolts.

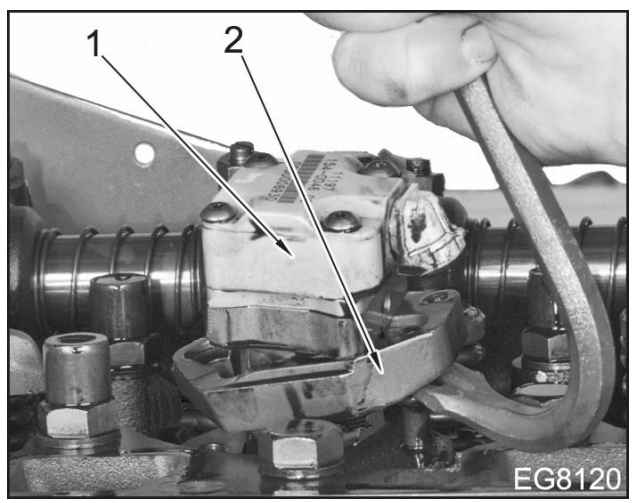

Figure 74 Remove Fuel Injector

1. Fuel Injector
2. Hold Down Clamp

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NOTE: Fuel Injector Holder Rack and Cups (ZTSE4299) (page 111), should be used to protect fuel injectors from damage while out of engine.

Valve Lever

CAUTION: To avoid possible damage to valve train and engine, sufficiently loosen adjusting screw nuts.

1. Loosen twelve valve lever adjusting screw nuts two full turns.

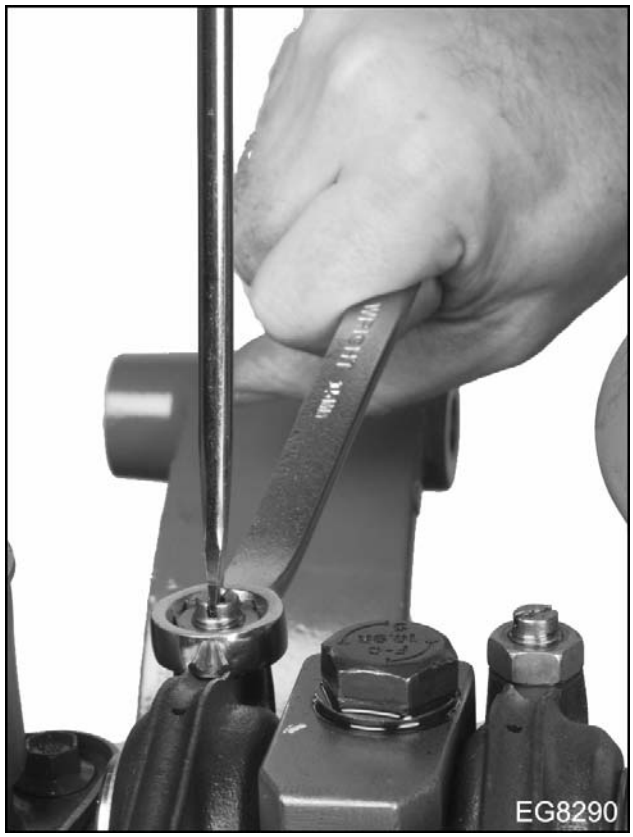

Figure 75 Loosen valve lever adjusting screw nuts

2. Remove six valve lever assembly mounting bolts (long bolts).

Figure 76 Remove valve lever assembly mounting bolts

3. Remove valve lever assembly.

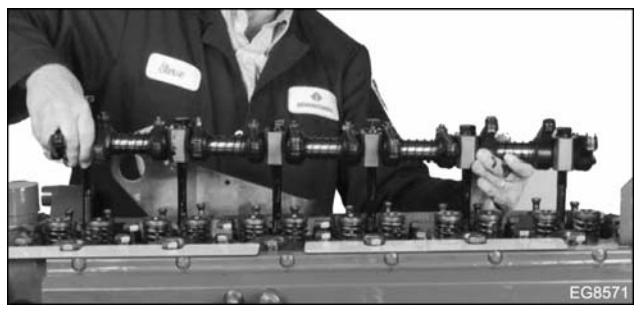

Figure 77 Remove valve lever assembly

Push Rods

NOTE: Number push rods so they can be matched to same location during installation. This helps eliminate premature wear of push rods.

Number all push rods. Remove all push rods.

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Figure 78 Remove push rods

Cylinder Head

1. Remove remaining (20) cylinder head bolts (short bolts).

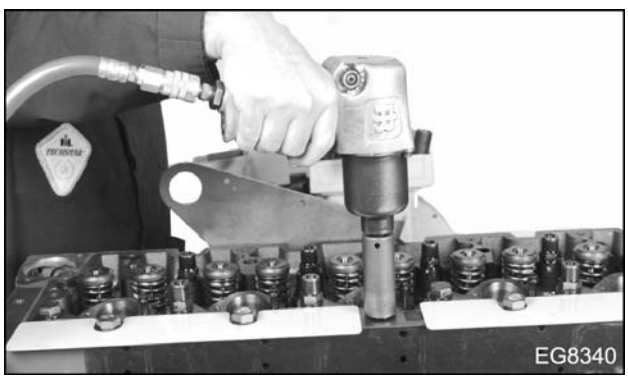

Figure 79 Remove cylinder head bolts

2. Using a small Pry Bar (page 111), carefully pry cylinder head loose from gasket, so cylinder head will lift off easily.

NOTE: Only light force should be required with pry bar to break cylinder head loose from gasket. Use wrapping on pry bar and use care to prevent marring surfaces.

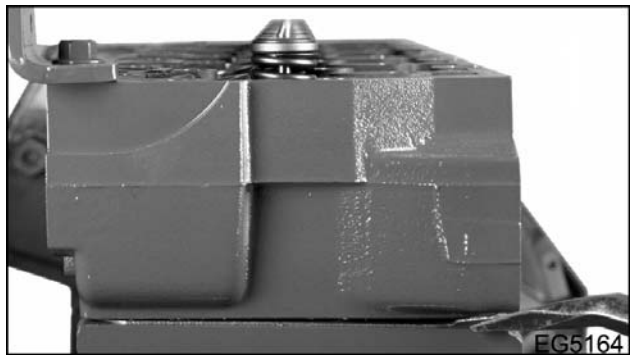

Figure 80 Pry cylinder head

⚠ WARNING: To prevent personal injury or possible death, due to heavy weight, get assistance or use appropriate lifting equipment to remove or reposition cylinder head during maintenance.

3. Lift cylinder head from crankcase using appropriate lifting equipment.

NOTE: Place cylinder head on wood blocks to protect valves and bottom deck surface.

4. Remove cylinder head gasket from crankcase.

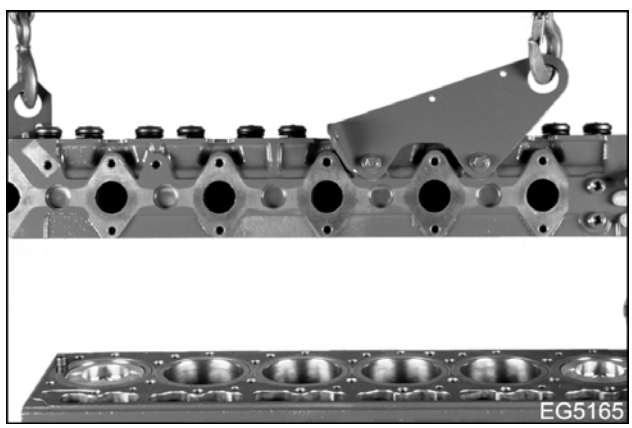

Figure 81 Remove cylinder head

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Disassemble Cylinder Head

Removing Valves from Cylinder Head

WARNING: To prevent personal injury or possible death, due to heavy weight, get assistance or use appropriate lifting equipment to remove or reposition cylinder head during maintenance.

CAUTION: To avoid damage to engine, keep intake and exhaust springs separate. Spring rates are different and must not be mixed in cylinder head.

1. Install Valve Spring Compressor (ZTSE1846) (page 111) over each valve spring to be removed, compress spring.
2. Remove valve spring locks.

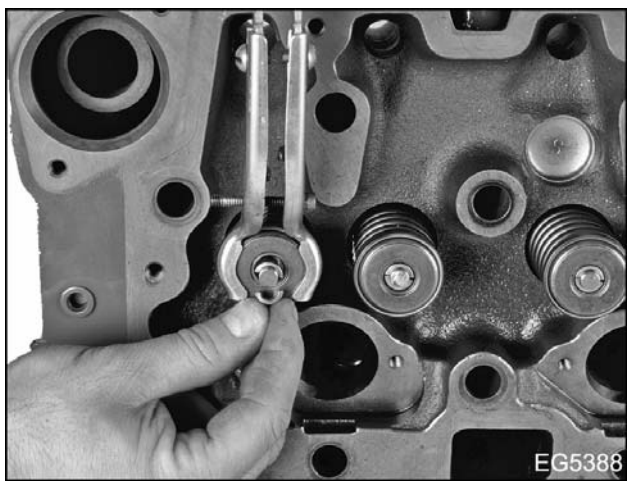

Figure 82 Remove valve spring locks

3. Slowly release spring, remove spring compressor.
4. Remove valve rotator and valve spring. Also remove valve seal, and valve. If nylon rotator seal becomes dislodged from rotator and sticks to valve stem, remove seal from valve stem. Keep intake and exhaust springs separate.

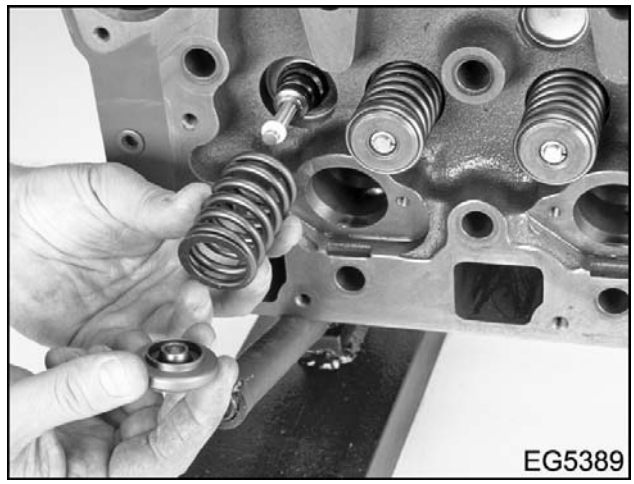

Figure 83 Remove valve components

5. Remove all other valves from cylinder head. Discard all 12 rotator seals.
6. Remove valve stem seal assemblies and valves. Discard all 12 stem seal assemblies due to damage across valve keeper grooves, from removal of valve keepers.

Remove Valve Guides

1. Place cylinder head on a hydraulic press.
2. Place Valve Guide Removal Tool (ZTSE4377) (page 111) between valve guide on valve port side of cylinder head and hydraulic press piston.

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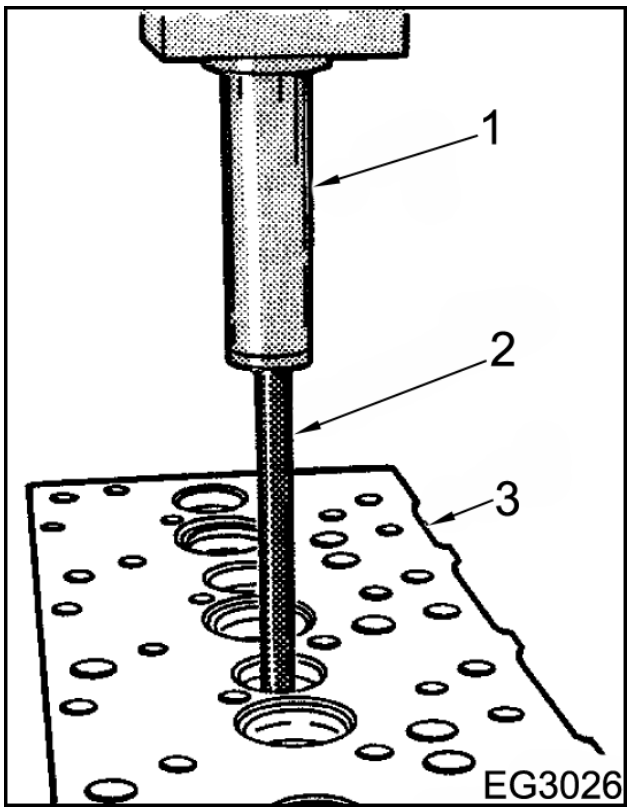

Figure 84 Remove valve guide

1. Valve Guide Removal Tool
2. Valve guide
3. Valve port side of the cylinder head

3. Press each valve guide out of cylinder head.

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Clean, Inspect, and Test

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).

NOTE: Do not use a caustic solution on engine or related components.

NOTE: Cylinder head condition must be evaluated, inspect cylinder head for warping or cracks, measure cylinder head thickness, and test valves for leakage.

Cylinder Head

Clean Cylinder Head

1. Remove lifting eyes and lifting eye mounting hardware from cylinder head.
2. Insert valve in cylinder head to protect seats.
3. Remove deposits and gasket material from gasket surface of cylinder head. Use Rotary Wire Brush or Sanding Block with Mineral Spirits (page 111).
4. Clean all block bolt holes, clean cylinder head bolt threads in block. Use appropriate brush from Cleaning Brush Set (ZTSE4320) and appropriate bottoming tap from Critical Metric Taps (ZTSE4386) (page 111).
5. Clear debris from bolt holes, oil return and water passages, using filtered compressed air.
6. Wash all bolts and washers with a suitable solvent and dry thoroughly.

NOTE: Dirt in threads or damaged threads may cause binding and result in a false torque measurement.

7. Test all head bolts, replace bolts that fail. Use Cylinder Head Bolt Gage (ZTSE4481) (page 111).
8. Remove valves from cylinder head.

Measure for Warping

Measure cylinder head gasket surface for warping. Use Bevelled Edge Straightedge (OEM1293) and Feeler Gauge (page 111), follow warp pattern shown. See “Specifications (page 108),” if measurements are not in specification cylinder head must be resurfaced or replaced. Measure cylinder head deck thickness before resurfacing, see “Measure Cylinder Head Deck Thickness” in this section. Minimum deck-to-deck dimension must be maintained during resurfacing.

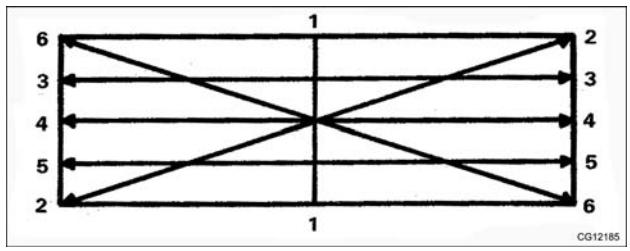

Figure 85 Warp pattern

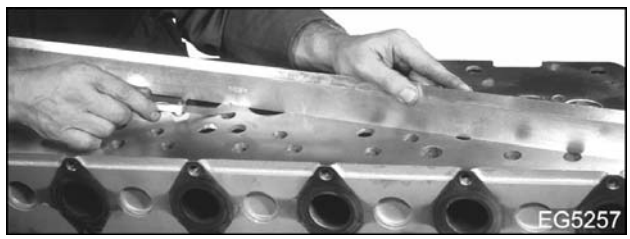

Figure 86 Measure cylinder head

Measure Cylinder Head Deck Thickness

Measure cylinder head deck thickness at six locations, four corners and two center points. Use Outside Micrometer (page 111). See cylinder head specifications in “Specifications (page 108).” If minimum deck-to-deck dimension (after rework) cannot be maintained, replace cylinder head.

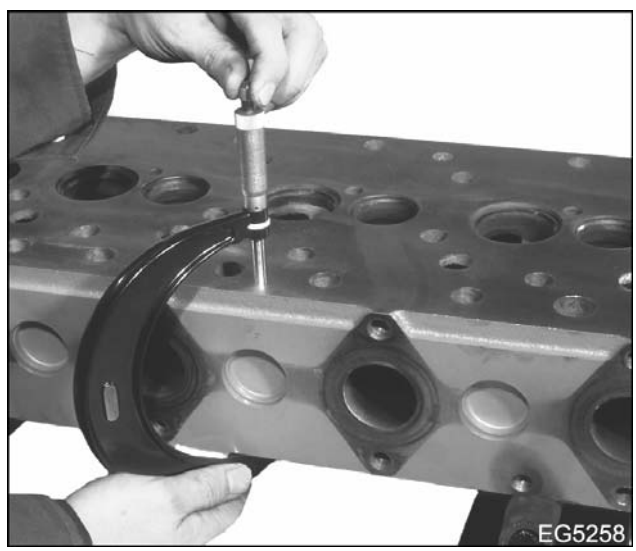

Figure 87 Measure cylinder head deck thickness

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Inspect Cylinder Head for Cracks

1. Spray cleaner on lower deck (gasket surface) of cylinder head and wipe dry. Use Defect Detector Kit (Dye Penetrant) (OEM1272) (page 111) and Clean Dry Cloth.

Figure 88 Spray cleaner

2. Spray dye penetrant on lower deck surface. Allow dye to remain on surface for one to ten minutes.

Figure 89 Spray dye penetrant

3. Lightly wipe dye penetrant off lower deck surface.

NOTE: Dye will remain in any cracks during “wipe off” step.

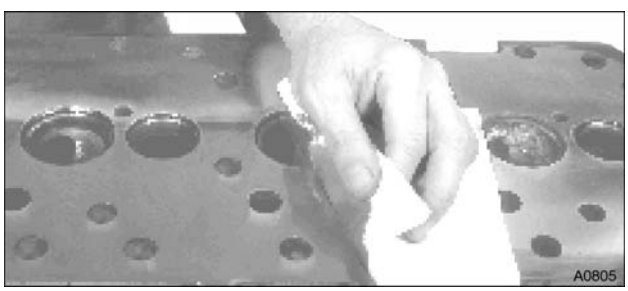

Figure 90 Wipe off dye penetrant

4. Spray developer on and let dry for five to 15 minutes. Inspect lower deck surface for cracks. Cracks will show as purple lines against white developer.

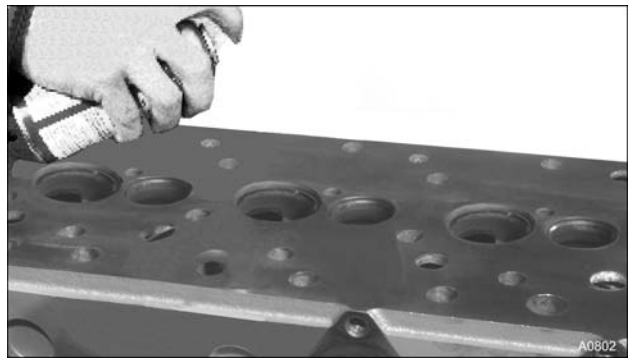

Figure 91 Spray developer

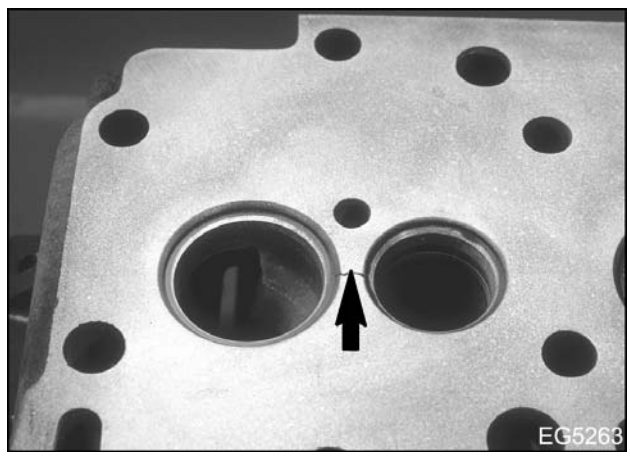

Figure 92 Crack shown

CAUTION: To avoid vehicle damage, cylinder head must be replaced, if any cracks are found.

Pressure Test Cylinder Head

Pressure test of cylinder head will reveal cracks in ports or sleeve leakage which cannot be observed using dye penetrant.

1. If removed, install fuel injector shoulder bolts in cylinder head. Tighten shoulder bolts to “Special Torque (page 110).”

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Figure 93 Torque fuel injector shoulder bolts

2. Install fuel injectors in cylinder head injector bores. See “Fuel Injector Installation” in this section.
3. Remove valves. See “Cylinder Head Reconditioning”, later in this section.
4. Install Head Pressure Test Kit (ZTSE4289A) (page 111). Attach pressure plate and gasket from the kit on cylinder head gasket surface with 24 mounting bolts and nuts also from kit.

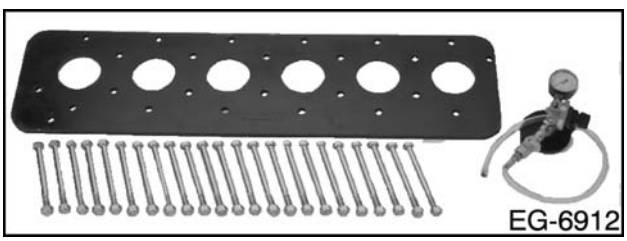

Figure 94 Head Pressure Test Kit

5. Remove thermostat. Attach Thermostat Opening Pressure Test Adapter (ZTSE4647) and Water Supply Housing Pressure Test Adapter (ZTSE4648) (page 111) to cylinder head with existing fasteners.

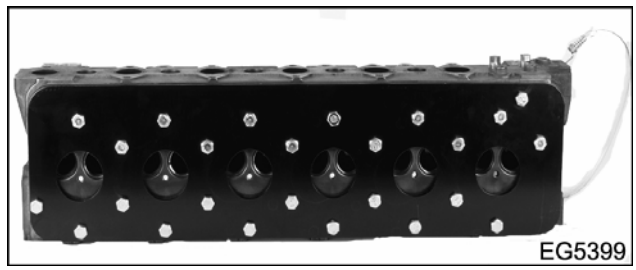

Figure 95 Fasten pressure plate to cylinder head

6. Fill cylinder head with hot water.
7. Install air regulator on the thermostat test adapter.

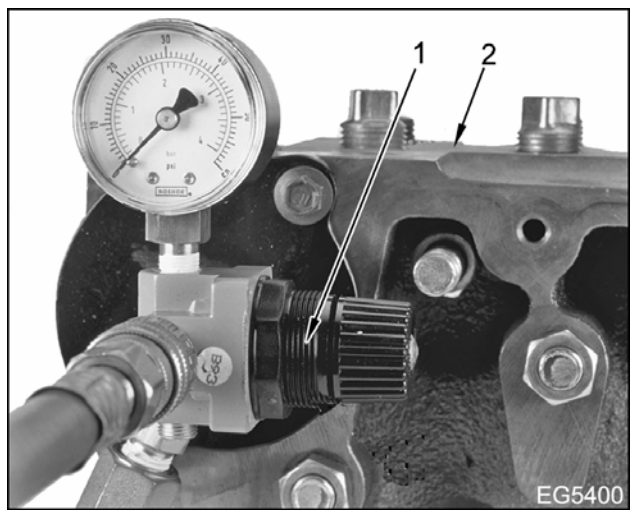

Figure 96 Install air regulator

1. Air regulator in Thermostat Opening Pressure Test Adapter (ZTSE4647)
2. Cylinder head

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8. Attach a hose fitting to the air regulator. Apply 124 to 138 kPa (18 to 20 psi) and inspect for leaks at the following locations:
   - Fuel injector nozzle sleeve area.
   - Ports
   - Upper deck
   - Lower deck

NOTE: If leakage is observed at any port or upper and lower deck, cylinder head must be replaced.

Valve Guides

Clean Valve Guides

With valves removed, clean all valve guides. Use nylon Valve Guide Brush (OEM6343) (page 111), soap and water, or other non-caustic solution.

NOTE: Do not use a caustic solution on engine or related components.

Figure 97 Clean valve guides

Inspect and Measure Valve Guides

1. Position Inspection Light under bottom of valve guide bores and examine valve guide walls for burning or cracking. Replace any guides that do not pass visual inspection. See “Remove Valve Guides” in this section.

Measure valve guides. Use appropriate size hole gage from Small Hole Gauge Set (OEM1023) and appropriate sized Outside Micrometer (page 111).

2. Measure each valve guide at 0.64 mm (0.025 in) from each end of guide and 90° from crankshaft center-line. Use valve guide measurement for valve-to-guide running clearance. If valve guide measurement exceeds “Specifications (page 108),” replace guide. See “Remove Valve Guides” in this section.

Figure 98 Measure valve guide with small hole gauge

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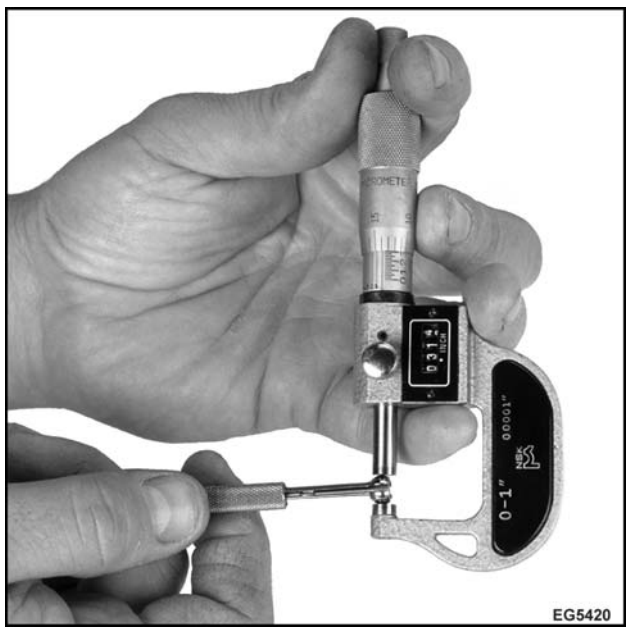

Figure 99 Measure small hole gauge

Valves

Test for Valve Leakage

1. Position cylinder head on wood blocks with gasket surface facing down.
2. Squirt Mineral Spirits in intake and exhaust ports.

Wait five minutes, use Inspection Mirror and Flashlight (page 111), inspect valve seat area for leakage of Mineral Spirits.

NOTE: There should be no leakage. Reconditioning is not required if the cylinder head passes valve leakage test. If leakage is observed, valves require reconditioning. See “Cylinder Head Reconditioning” in this section. This test does not check for condition of valve guide or valve stem-to-guide clearance.

Clean Valves

Remove all carbon from valve stems and valve heads. Use an appropriate wire brush from Cleaning Brush Set (ZTSE4320) (page 111).

Inspect and Measure Valves

1. Inspect each valve. Replacing any valve that show evidence of burn marks, warping, scuffing, bending, or valve tip spalling
2. Measure each valve stem diameter for wear. Measure valves at three locations 90° apart with 0 - 1 inch Inside Micrometer (page 111). See “Specifications (page 108),” replace any valves that exceed the minimum stem diameter.

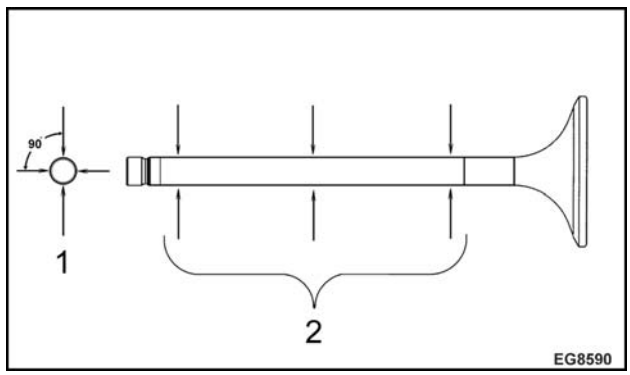

Figure 100 Measure valves

1. 90° Apart
2. Three locations on valve stem

3. Determine valve stem-to-guide interference fit dimension. Deduct valve stem diameter from valve guide dimensions. See “Specifications (page 108),” replace valves or valve guides as required.

Valve Seats

Measure Valve Seat Contact

1. Spread thin film of marker die paste (Prussian Blue™ or equivalent) on valve face.

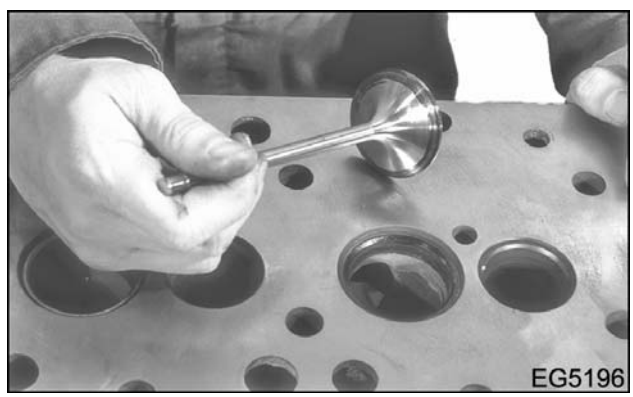

Figure 101 Apply marker die paste

2. Insert valve in respective clean valve guide.

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3. Apply pressure to center of valve head while turning valve head a quarter turn in seat to check valve face contact with valve seat.

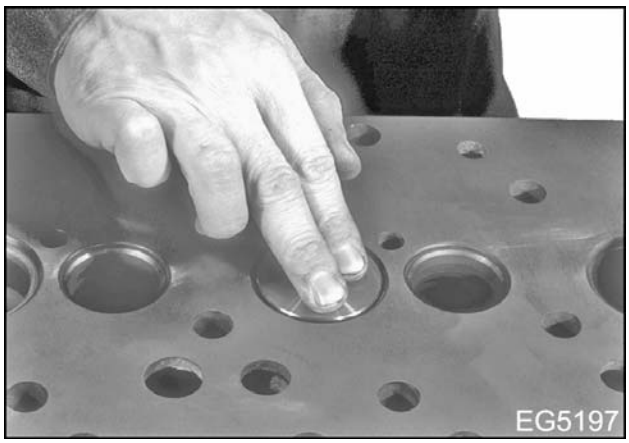

Figure 102 Apply pressure and turn valve

4. Remove valve, inspect impressions made on seat and valve face.
5. Bluing should appear around entire contact surface of valve face and valve seat to be acceptable. Check several times to prevent error. If acceptable, go to valve installation.

Measure Valve Seat Width and Recession

1. After valve seat resurfacing , measure valve seat runout and concentricity with a Dial Indicator (page 111). Measure seat width with a Dial Caliper. See “Specifications (page 108)” for seat width limits. If seat widths are excessive, they may be corrected by grinding with a 15° or smaller angle stone.

Figure 103 Measure valve seat width

2. Measure valve recession. Use Bevelled Edge Straightedge (OEM1293) and Feeler Gauge or Surface Gauge (page 111). See “Specifications (page 108)” for recession limits. If valve recession is excessive, install new valve or replace valve seat. If valve protrudes above deck, regrind valve seat.

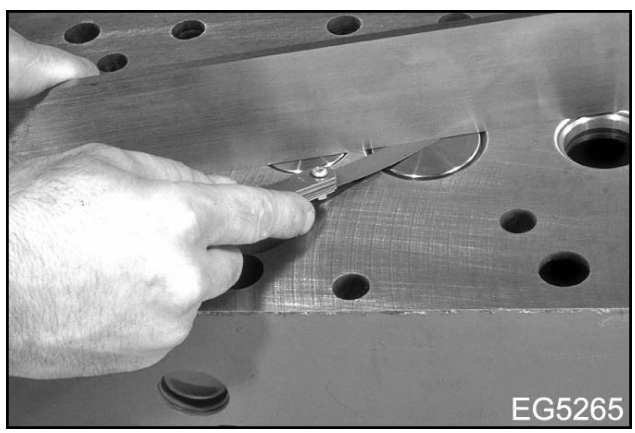

Figure 104 Measure valve recession

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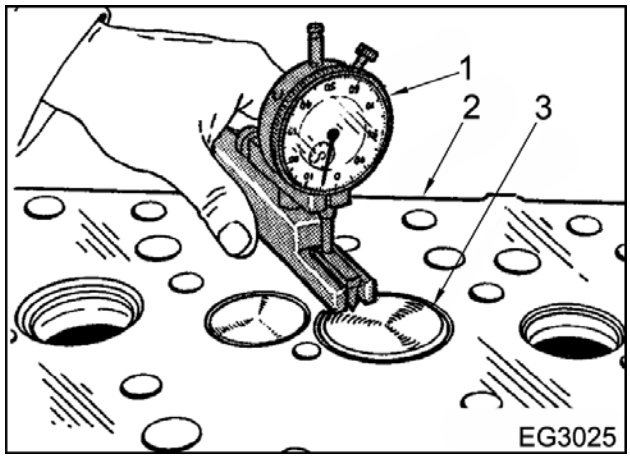

Figure 105 Measure valve recession

1. Dial indicator
2. Cylinder head
3. Valve

Valve Springs

Clean Valve Springs

Clean valve springs and seats. Use an appropriate brush, soap and water, or other non-caustic solution.

Inspect Valve Springs

1. Inspect valve springs for rust, pitting, and cracks.
2. Inspect both ends of spring at contact point between cutoff end of last coil and adjacent coil. Replace spring if cutoff end has worn a notch in adjacent coil. This condition can also be detected by compressing spring by hand and listening for a clicking sound. Clicking sound is caused by the wear notches. Replace springs that exhibit this clicking sound.

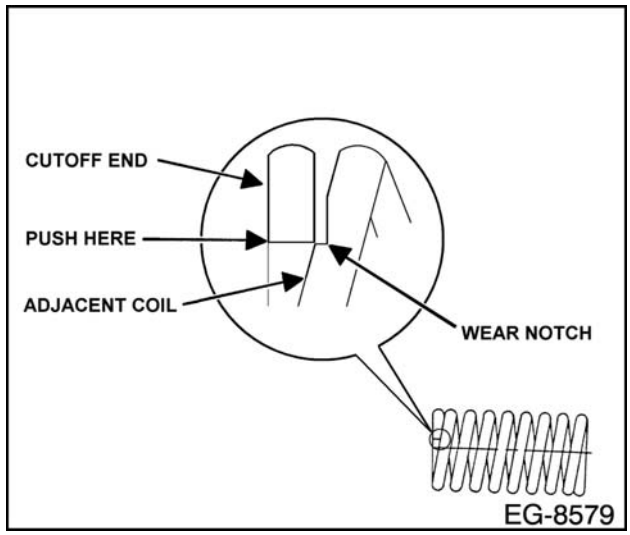

Figure 106 Inspect valve spring

3. Measure each spring length on adjacent sides. Spring ends not flat and square should be replaced. Springs ends not flat or are out of square place a side load on stem causing rapid stem guide wear.

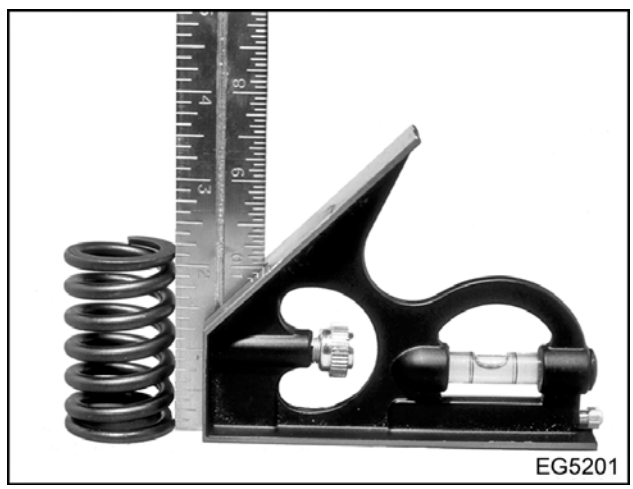

Figure 107 Measure valve springs

4. Measure valve spring tension with a Valve and Clutch Spring Tester (ZTSE2241) (page 111). Measure maximum spring length for valve closed test load. Measure minimum spring length for valve open test load. See “Specifications (page 108),” for appropriate test load for valve open spring length and valve closed spring length for

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each spring. Any spring that exceeds maximum or minimum length should be replaced.

Figure 108 Measure valve spring tension

Valve Rotators and Valve Spring Locks

Clean

Clean valve rotators and valve spring locks. Use an appropriate brush, solvent, or other non-caustic solution.

Test Rotators

CAUTION: To avoid possible damage to the engine, suitable protection must be placed between rotator and ram of Valve and Clutch Spring Tester.

NOTE: Rotator must be lubricated with clean engine oil prior to testing.

NOTE: To properly test rotator function, a valve spring load must be applied to rotator.

1. Place valve spring with rotator in Valve and Clutch Spring Tester (ZTSE2241) (page 111). Place ball bearing between rotator and ram of spring tester. Ball bearing must be large enough to prevent spring tester ram from touching any part of rotator.
2. Mark reference line on rotator.

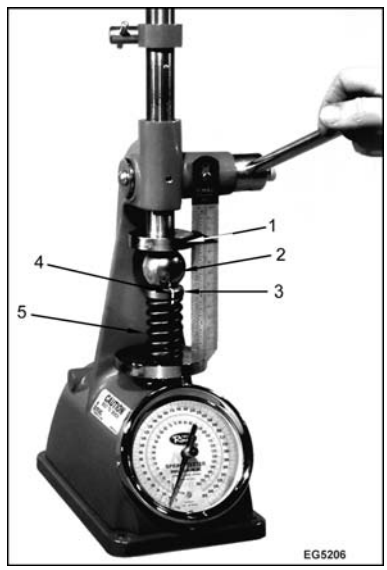

Figure 109 Test rotator

1. Indicator
2. Ball bearing
3. Rotator
4. Reference mark
5. Valve spring

3. Compress valve spring rapidly with even pressure and observe rotator as it turns.
4. Replace any rotator that does not turn.

Inspect Valve Spring Locks

Inspect inside and outside of the valve spring locks for wear. Replace any worn spring locks, as required.

Recondition

Valves

Resurface Valves

NOTE: Intake valves have larger diameter head than exhaust valves.

1. Prior to resurfacing valves, dress valve grinder cutting stone, using dressing stud attachment to grinder.

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2. Insert valve, in serviceable condition, in grinder and set to specified angle, see “Specifications (page 108).”
3. Grind valve face. Remove only minimum amount of material necessary to true up valve face.

Figure 110 Grind valve face

4. Measure valve face margin at four locations (90° apart) with Dial Caliper (page 111).

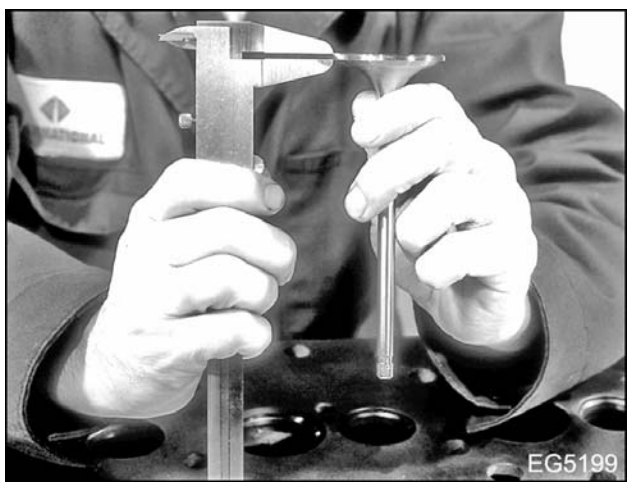

Figure 111 Measure valve face margin

CAUTION: To prevent engine damage, minimum valve face margin must be maintained across entire valve face. An insufficient margin will not provide proper heat dissipation and lead to valve warping or breakage.

NOTE: Intake and exhaust valve face margins are different. Replace valve if margin is less than specified minimum, see “Specifications (page 108).”

5. Prior to resurfacing valve stem tip, dress cutting stone using dressing stud on grinder.
6. Insert valve stem in grinder.

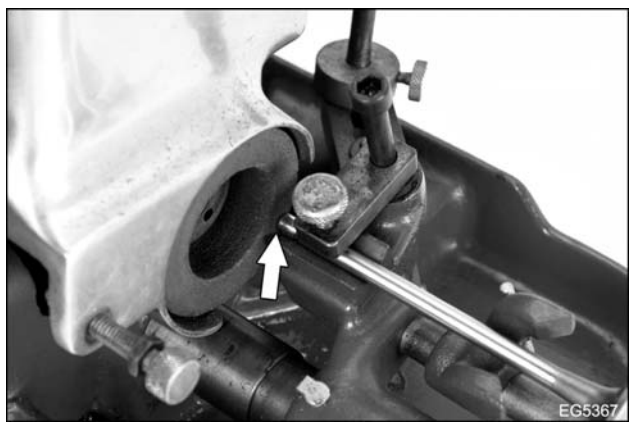

Figure 112 Insert valve stem in grinder

7. Resurface valve stem tip. Touch valve stem tip to cutting stone, remove only minimum of material.

NOTE: When resurfacing valve stem tip, leave sufficient material so valve lever (rocker arm) does not contact valve spring locks or rotators, during operation.

NOTE: Resurfacing valve stem tip provides a new wear surface for rocker arm.

8. After resurfacing valves, thoroughly clean valve and valve stem.

Valve Seat

Resurface Valve Seats

1. Lightly lubricate and insert correct size Valve Seat Installer (ZTSE4164A) (page 111) in valve guide.

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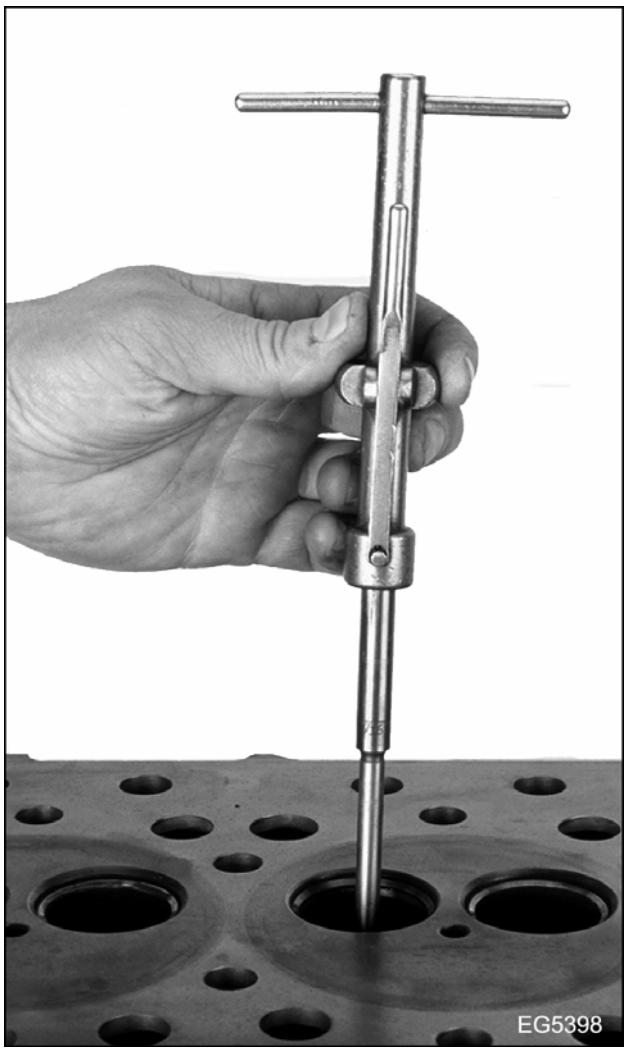

Figure 113 Insert Valve Seat Installer

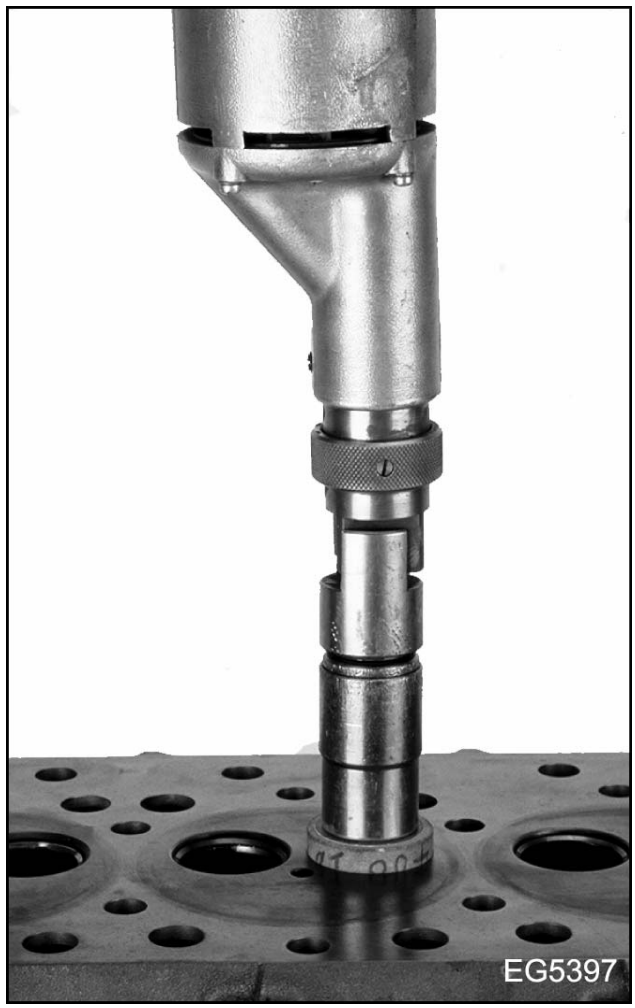

Figure 114 Grind valve seat

2. Choose correct angle grinding stone and dress stone. See “Specifications (page 108)” for valve seat angles.
3. Put grinding stone over the valve seat installer.
4. Lower grinder head over valve seat installer shank until wheel barely clears valve seat. Turn on power. Gently apply grinding wheel to valve seat. Use little pressure other than weight of the wheel. Raise wheel frequently to prevent overheating. Grind seat to a smooth even finish.
5. Clean valve guides. See “Clean Valve Guides” in this section.
6. After regrinding any seat, measure valve recession, seat width, and valve seat contact. See “Measure Valve Seat Width and Recession,” see “Specifications (page 108)” in this section.

   If new valve does not correct an excessive recession condition, valve seat must be replaced and reground, see “Replace Valve Seat,” in this section.

   If valve face protrudes above deck, valve seat will have to be reground deeper.
7. After resurfacing any valve seat, measure seat for runout and concentricity. Measure seat width. See “Measure Valve Seat Width and Recession”

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in this section. Valve seat runout, concentricity and seat width cannot be maintained in limits shown in “Specifications (page 108),” replace and resurface the valve seats.

Valve Seat Replacement

NOTE: These instructions are general in nature. Follow instructions that apply to tool.

1. Cut a groove in defective valve seat, using stone.
2. Select appropriate sized collet, part of Universal Valve Seat Extracting Kit (ZTSE1951C) (page 111). Assemble collet on valve seat removal handle.

Figure 115 Assemble collet on tool

3. Insert seat removal tool in defective valve seat. Expand collet, thread tool shaft in collet expanding collet until collet is tight inside valve seat. Insert removal tool bridge assembly between large tool handle and deck.

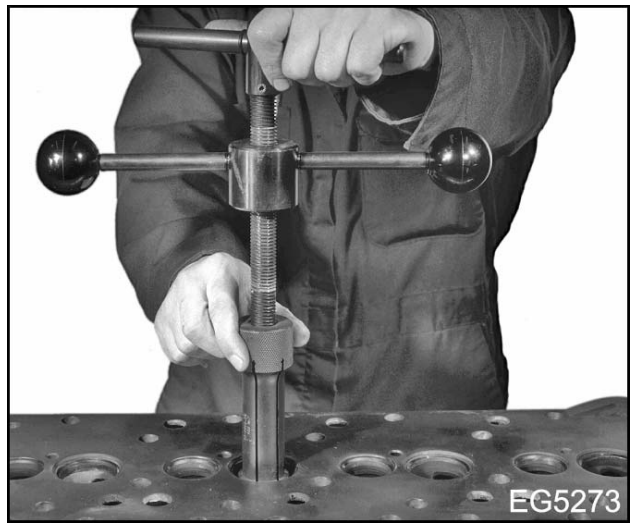

Figure 116 Insert seat removal tool

4. Turn large handle of removal tool against bridge assembly. Pull valve seat out of cylinder head.

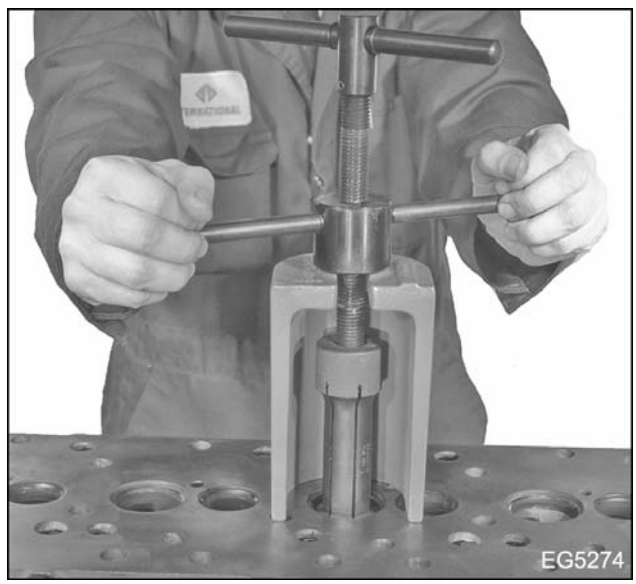

Figure 117 Remove valve seat

5. Unlock collet, loosen threaded shaft and discard valve seat.
6. Measure cylinder head valve seat counterbore diameter at 0° and 90° locations to determine average counterbore diameter.

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7. Select appropriate replacement size valve seat. See “Valve Seat Selection Chart (page 91)” in this section.

Valve Seat Selection Chart

Available Seats (Intake and Exhaust)	Valve Seat Counterbore - Intake	Valve Seat Counterbore - Exhaust
Standard	50.648 to 50.724 mm (1.9940 to 1.9970 in)	45.860 to 45.934 mm (1.8055 to 1.8085 in)
0.05 mm (0.002 in) Oversized	50.698 to 50.775 mm (1.9960 to 1.9990 in)	45.911 to 45.987 mm (1.8075 to 1.8105 in)

NOTE: Standard, 0.05 mm (0.002 in) oversized and 0.381 mm (0.015 in) oversized seats are available through service parts. If seat counterbore is damaged beyond 0.381 mm (0.002 in) oversize counterbore diameter it will be necessary to machine seat counterbore in cylinder head for 0.381 mm (0.0015 in) oversized seat. Standard and 0.05 mm (0.002 in) oversized seats do not require counterbore diameter enlargement.

8. If measured average valve seat counterbore diameter is not within ranges of “Valve Seat Selection Chart,” machine valve seat counterbore diameter to fit a 0.381 mm (0.0015 in) over sized seat insert:
   - Intake: 51.0667 ± 0.0381 mm (2.0105 ± 0.0015 in)
   - Exhaust: 46.2788 ± 0.381 mm (1.8220 ± 0.0015 in)
9. Place cylinder head deck on hydraulic press.
10. Chill replacement valve seat before installing. Place in a freezer for 30 minutes.

    NOTE: Chilling valve seat prevents peeling of metal from cylinder head counterbore during seat installation.
11. Set Valve Seat Installer (ZTSE4164A) (page 111) between hydraulic press and replacement seat. Align replacement seat in cylinder head deck to avoid cocking.
12. Press replacement seat in counterbore for affected intake or exhaust valve seat.

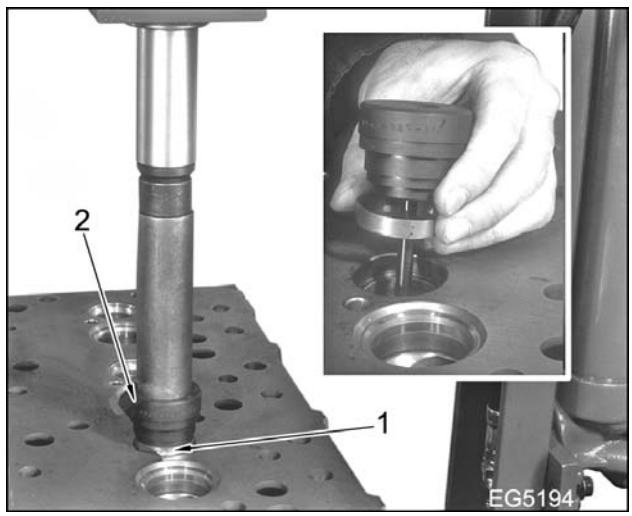

Figure 118 Install replacement valve seat

1. Valve seat
2. Valve Seat Installer

13. Surface replacement valve seat(s) to angle and width specified in “Specifications (page 108).” See “Resurface Valve Seats” in this section.

Fuel Injector Sleeve

Remove

CAUTION: To avoid possible damage to the engine, if an injector sleeve is to be removed in-chassis, place a small plug in the bottom of the injector sleeve prior to cutting threads in injector sleeve. Plug will prevent small metal chips and debris from entering combustion chamber.

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

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1. Lubricate thread tap, part of Fuel Injector Sleeve Remover (ZTSE4302A) (page 111).

   NOTE: Some fuel injector sleeves are made of stainless steel. Lubrication of thread tap is required.

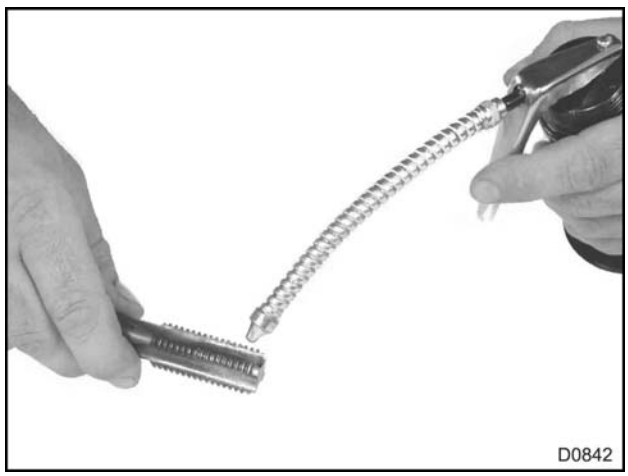

Figure 119 Lubricate thread tap

2. Insert thread tap in fuel injector sleeve.

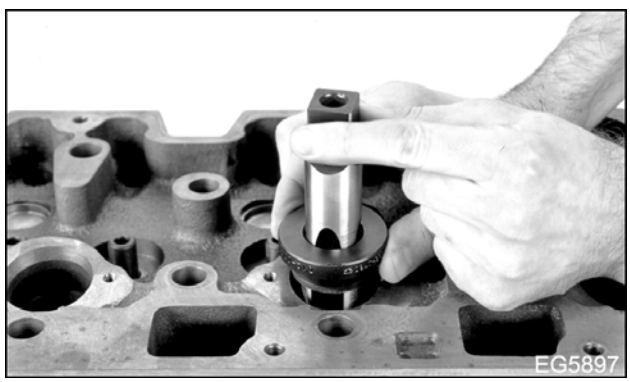

Figure 120 Insert Fuel Injector Sleeve Remover

3. Thread Fuel Injector Sleeve Remover in fuel injector sleeve. Cut threads at least ¾ inch deep to accommodate fuel injector sleeve puller. Once fuel injector sleeve has been threaded, remove thread tap from sleeve.

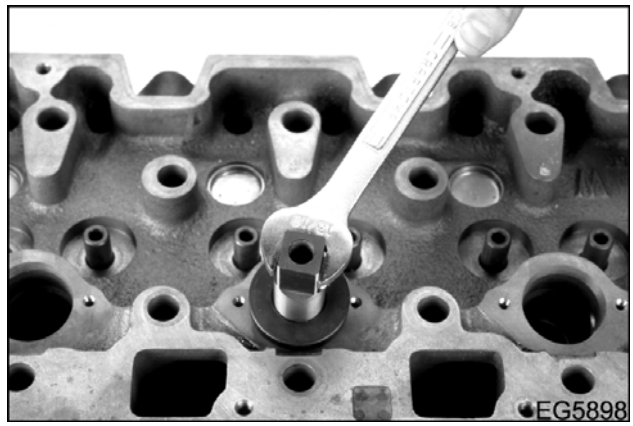

Figure 121 Thread fuel injector sleeve

4. Insert fuel injector sleeve puller, part of Fuel Injector Sleeve Remover (ZTSE4302A) (page 111), in fuel injector sleeve and tighten.

   NOTE: Ensure fuel injector sleeve puller threads sufficiently in fuel injector sleeve.

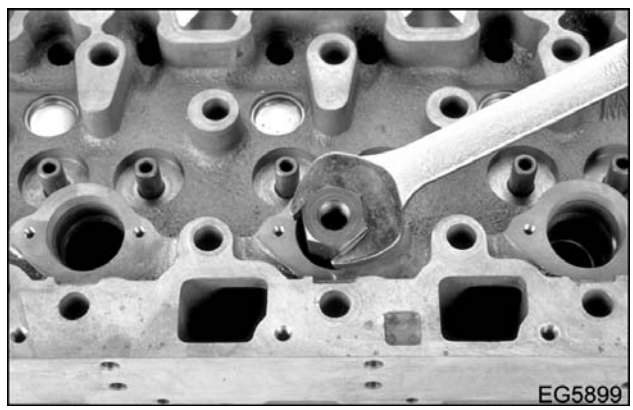

Figure 122 Insert fuel injector sleeve puller

5. Thread slide hammer, part of Slide Hammer Kit (ZTSE4398A) (page 111), in fuel injector sleeve puller.
6. Remove fuel injector sleeve from cylinder head.

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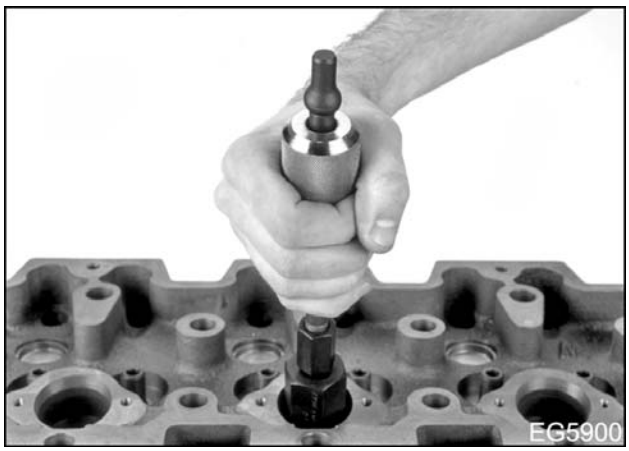

Figure 123 Remove fuel injector sleeve

Clean

1. Remove deposits and hardened sealant from fuel injector bore in cylinder head, with Tapered Wire (Sleeve Bore) Brush (ZTSE4394) (page 111).

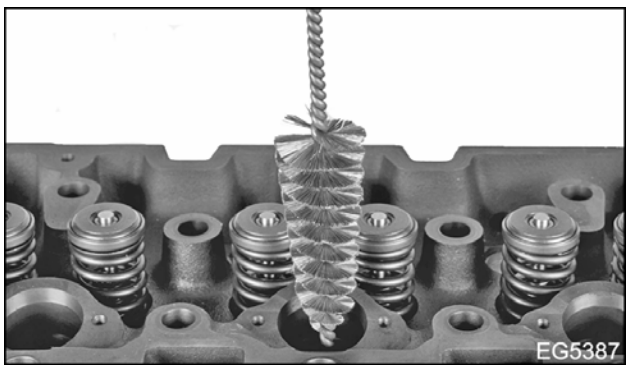

Figure 124 Clean fuel injector bore

2. Clean oil gallery. Use appropriate stiff nylon brush from Cleaning Brush Set (ZTSE4320) (page 111).
3. Blow out loose debris in all fuel and oil galleries with filtered compressed air.

Install

1. Verify fuel injector sleeve bore in cylinder head is completely clean and dry.
2. Attach replacement fuel injector sleeve to Fuel Injector Sleeve Installer (ZTSE4303) (page 111). Apply Loctite® to fuel injector sleeve points:
   a. Fuel injector sleeve wall (end of fuel injector sleeve).
   b. Fuel injector sleeve upper wall (top of fuel injector sleeve).

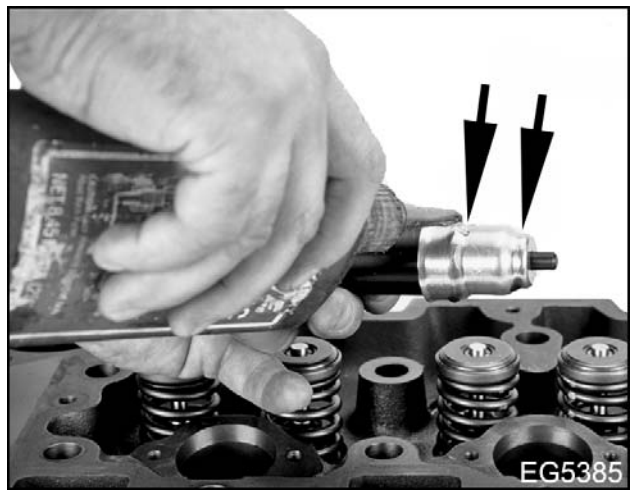

Figure 125 Apply Loctite® to fuel injector sleeve

3. Insert fuel injector sleeve with Fuel Injector Sleeve Installer in fuel injector bore in cylinder head.

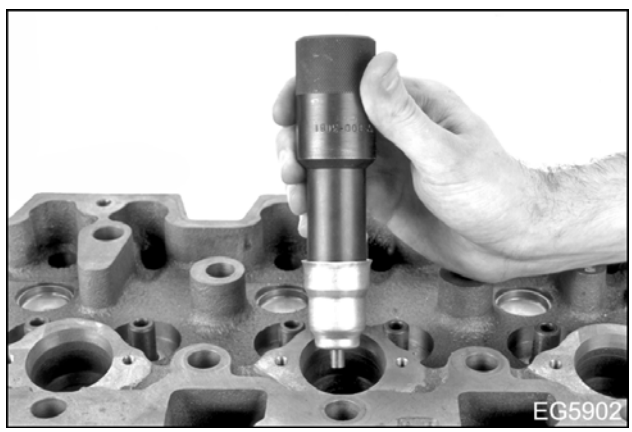

Figure 126 Insert fuel injector sleeve

4. Drive fuel injector sleeve in fuel injector bore until sleeve bottoms in the cylinder head. Use hammer on Fuel Injector Sleeve Installer. Remove Fuel Injector Sleeve Installer once fuel injector sleeve is in place.

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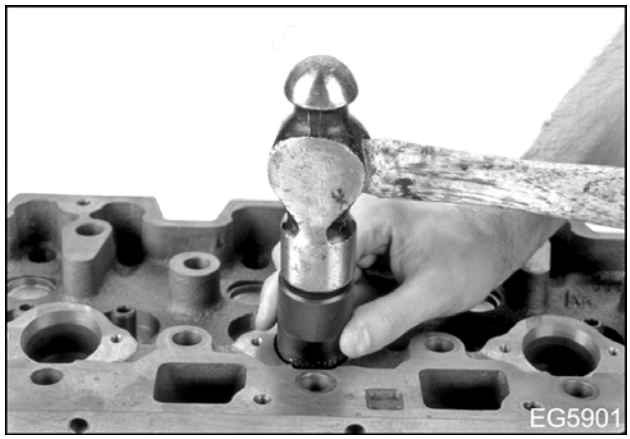

Figure 127 Install fuel injector sleeve

5. Clean fuel injector sleeve after installation, Loctite® must be cleaned out before it hardens. Use one of the Injector Sleeve Brushes (ZTSE4304) (page 111).
6. Inspect inner surface of newly installed fuel injector sleeve for nicks and scratches. If defects are found, replace fuel injector sleeve again. Look at bottom and side surfaces for installation tool to determine cause of installation defects. Replace Fuel Injector Sleeve Installer if necessary.

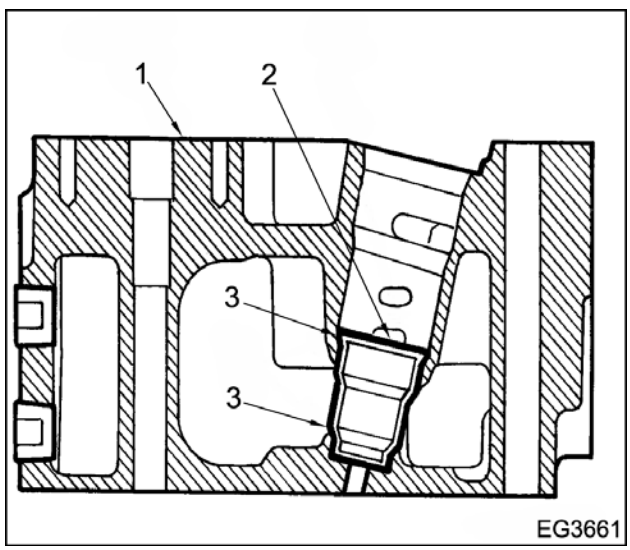

Figure 128 Cylinder head cutaway

1. Cylinder Head
2. Fuel Injector Sleeve
3. Contact Areas

Assemble

Clean Cylinder Head

1. Clean valve faces and seats with a suitable cleaning solvent to remove all dirt or foreign material. Blow dry all new and used components using filtered compressed air.
2. Thoroughly clean all valve guides, prior to valve installation. Coat a brush from Valve Guide Brush (OEM6343) (page 111) with soap and water.

   NOTE: Brush must have a slightly larger diameter than interior diameter of valve guide.
3. Insert brush in valve guide bore and clean with a turning motion to ensure removal of any deposits.
4. Dry with filtered compressed air.

   NOTE: Clean all valve guides.
5. Insert a large nylon brush in rear of oil rail gallery for cleaning.
6. Use compressed air to clean out the oil gallery.
7. Install new O-ring on end plug and install in supply manifold. Tighten to “Special Torque (page 110).”
8. Insert large nylon brush in rear of fuel rail gallery for cleaning.
9. Use compressed air to clean out fuel rail gallery.

Install Valve Guides

CAUTION: To avoid possible damage to engine, do not hammer or pound valve guides in cylinder head.

NOTE: Insert each valve guide with large 15° chamfer end down.

1. Lubricate valve guide with clean engine oil.

   NOTE: Chilling valve guide may facilitate installation.
2. Set cylinder head on hydraulic press. Set each valve guide with large 15° chamfer end down. Place Valve Guide Installer (ZTSE1943) (page 111) between valve guide and hydraulic press piston.
3. Press each valve guide in cylinder head until Valve Guide Installer bottoms against cylinder head.

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Figure 129 Install valve guide

4. Deburr valve guide, after installation with Valve Guide Deburring Tool (ZTSE4393) (page 111).

CAUTION: To avoid possible damage to engine, do not ream valve guide inside after installation. Service valve guides are provided with finished reamed condition.

5. Clean each valve guide.

Assemble Valves

1. Lubricate valve stems with clean engine oil and insert valves in valve guides.
2. Lubricate interior diameter of new valve stem seal assemblies with clean engine oil and install them over valve and valve guide as shown. Be sure seal assemblies are seated down against cylinder head spring pockets.

Figure 130 Install valve stem seal assembly

3. Install valve spring over stem seal assembly. Be sure to install proper valve spring at proper valve location. Intake has orange paint marks and exhaust have white paint marks.

   CAUTION: To avoid damage to engine, keep intake and exhaust springs separate. Spring rates are different and must not be mixed in cylinder head.

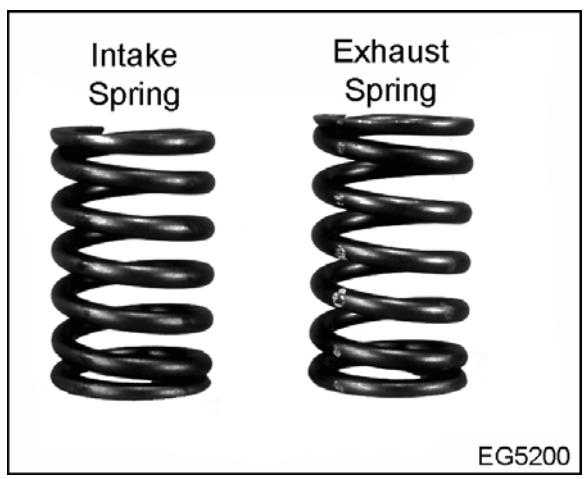

Figure 131 Intake and Exhaust Valve Spring Comparison

4. Install rotator assembly over valve spring.

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NOTE: Snap new rotator seals in bottom side (rotator cone) of valve rotators before installing rotator assembly on engine.

Figure 132 Install rotator assembly

5. Compress valve spring with Valve Spring Compressor (ZTSE1846) (page 111) and install spring locks.

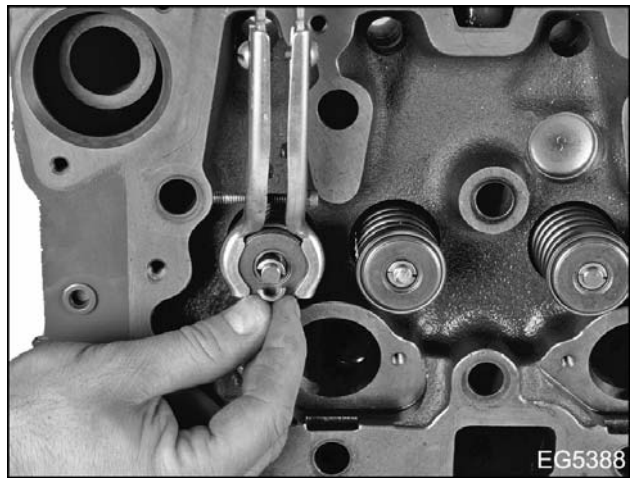

Figure 133 Install valve spring locks

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Install

Cylinder Head

WARNING: To prevent personal injury or possible death, due to heavy weight, get assistance or use appropriate lifting equipment to install the cylinder head.

1. Clean and dry cylinder head gasket surfaces.
2. Prior to cylinder head installation, check cylinder sleeve protrusion, see “Measure Cylinder Sleeve Protrusion (page 149)” in the “Power Cylinders” section of this manual.
3. Install dowel rings in crankcase top deck.

   NOTE: Dowel rings are used to locate cylinder head gasket.

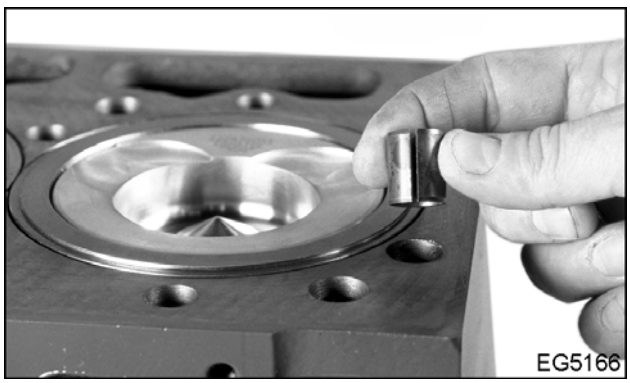

Figure 134 Install dowel rings

4. Install new cylinder head gasket over dowel rings.
5. Install lifting eye on rear of cylinder head and tighten mounting bolt. Install lifting eye on front of cylinder head, using one washer per mounting bolt. Tighten mounting bolts.
6. Carefully lower cylinder head on gasket.
7. Used cylinder head bolts (long and short) are to be tested for excessive thread stretch with Cylinder Head Bolt Gage (ZTSE4481) (page 111).

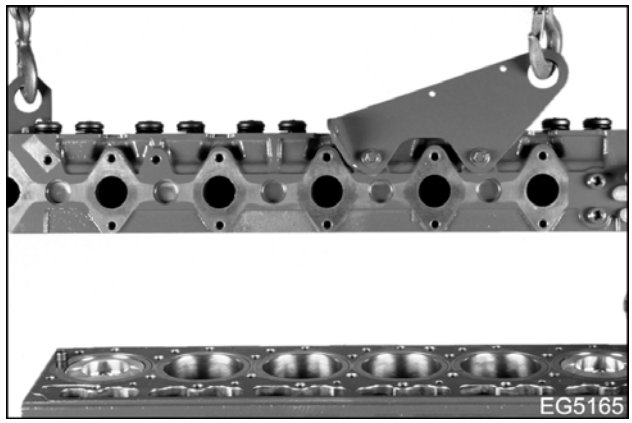

Figure 135 Install cylinder head

8. Lubricate cylinder head bolt threads, washers and under head seating area using clean engine oil.

   NOTE: Lubricate both long and short bolts.

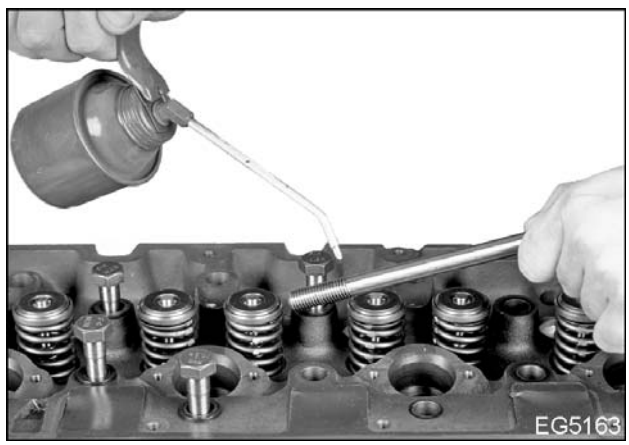

Figure 136 Lubricate cylinder head mounting bolts

9. Install (20) short cylinder head mounting bolts, the bolts should be threaded in finger-tight.

Install Push Rod

Install push rods with cup end up.

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CAUTION: To prevent possible engine damage, do not install new style valve train components in engines produced with old style valve train components. Replacement of old style valve train components requires complete replacement of all valve train components, including push rod assemblies, roller tappet assemblies, and rocker arm assemblies.

NOTE: Be sure to match push rods to proper slots as numbered during disassembly.

Figure 137 Install push rods

Valve Lever Assembly

Install

1. Insert valve lever assembly with long cylinder head bolts in their respective bolt holes.

   CAUTION: To prevent possible engine damage, do not install new style valve train components in engines produced with old style valve train components. Replacement of old style valve train components requires complete replacement of all valve train components, including push rod assemblies, roller tappet assemblies, and rocker arm assemblies.

2. Install long cylinder head bolts, the bolts should be run in finger tight (except two end bolts). Place 0.013 mm (0.005 in) Feeler Gauge between outside brackets and rocker levers to prevent binding. Finger-tighten remaining two end bolts.

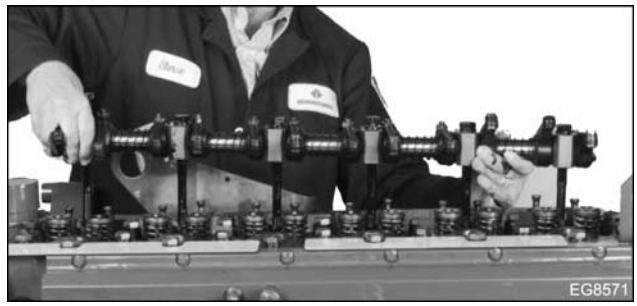

Figure 138 Install valve lever assembly

Figure 139 Tighten valve lever assembly mounting bolts

3. Tighten cylinder head bolts in four stages as specified, see “Special Torque (page 110).”

   NOTE: Check two end rocker arms for freedom of movement after tightening cylinder head bolts.

4. Remove two 0.013 mm (0.005 in) Feeler Gauges.

NOTE: All valves are adjusted by rotating the engine only twice.

5. Rotate crankshaft until piston 1 is on compression stroke and timing arrow on front cover is in line with TDC mark on vibration damper.

   NOTE: Confirm that piston 1 is on compression stroke by verifying piston 2 exhaust valve is open, valve spring is compressed.

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Alternate Method

NOTE: Confirm piston 1 is on compression stroke by removing camshaft position sensor and observing vanes on timing disk plate. When thin vane is visible through CMP sensor mounting orifice in front cover, piston 1 is on compression stroke. Continue turning engine until TDC marks are aligned in front cover and vibration damper pulley. Adjust valves that should be adjusted with piston 1 on compression stroke.

Set cold valve lash by loosening lock nut. Turning valve adjustment screw with 0.64 mm (0.025 in) Feeler Gauge inserted between rocker arm and valve stem tip. Tighten valve adjustment screw until light drag is felt.

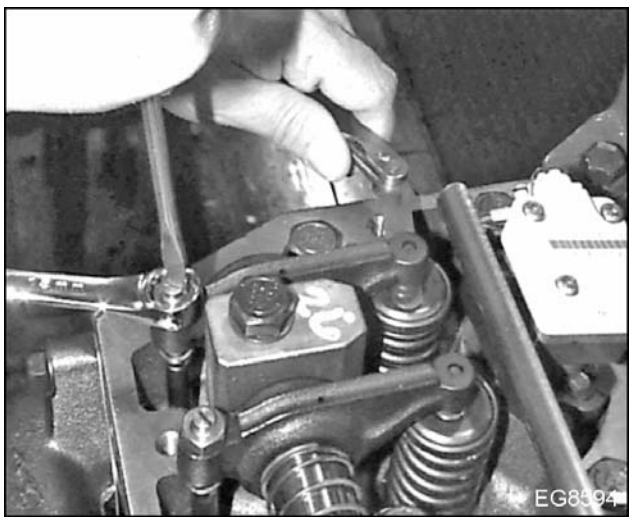

Figure 140 Set valve lash

6. Tighten lock nut once valve adjustment is set.

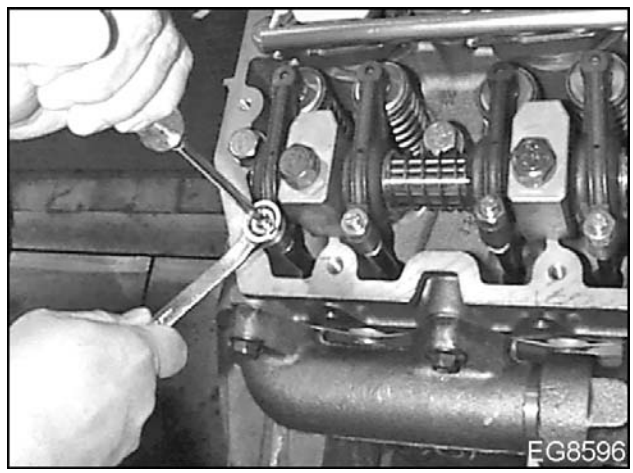

Figure 141 Tighten valve lever lock nut

7. Recheck for light drag on 0.64 mm (0.025 in) Feeler Gauge. If too tight or too loose, loosen lock nut and do steps 6 and 7 above.

Valve Lash Adjustment

Six valves are adjusted when piston 1 is at TDC (compression) and remaining six are adjusted when piston 6 is at TDC (compression).

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With	Adjust Valves											
Piston 1 at TDC (compression)	INT 1	EXH 2	INT 3			EXH 6	INT 7			EXH 10		
Piston 6 at TDC (compression)				EXH 4	INT 5			EXH 8	INT 9		INT 11	EXH 12

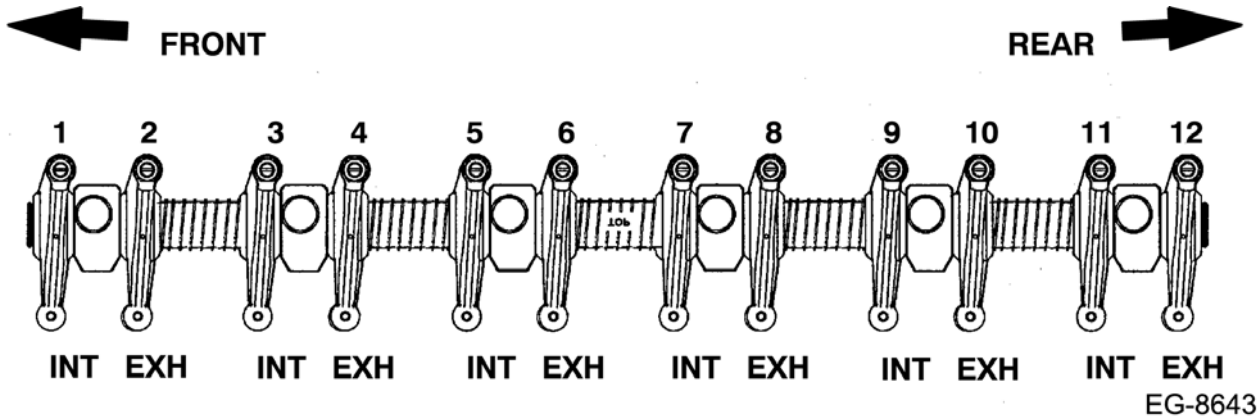

Figure 142 Valve lash adjustment valve lever positions

Fuel Injectors

Remove O-rings and Seals

NOTE: O-rings should be replaced each time a fuel injector is removed. If any fuel injector has damaged O-rings, all fuel injectors should be removed and have O-rings replaced. Care must be taken to prevent scratching seal grooves on fuel injector body while removing seals. Use non-metallic tools, such as wood or plastic.

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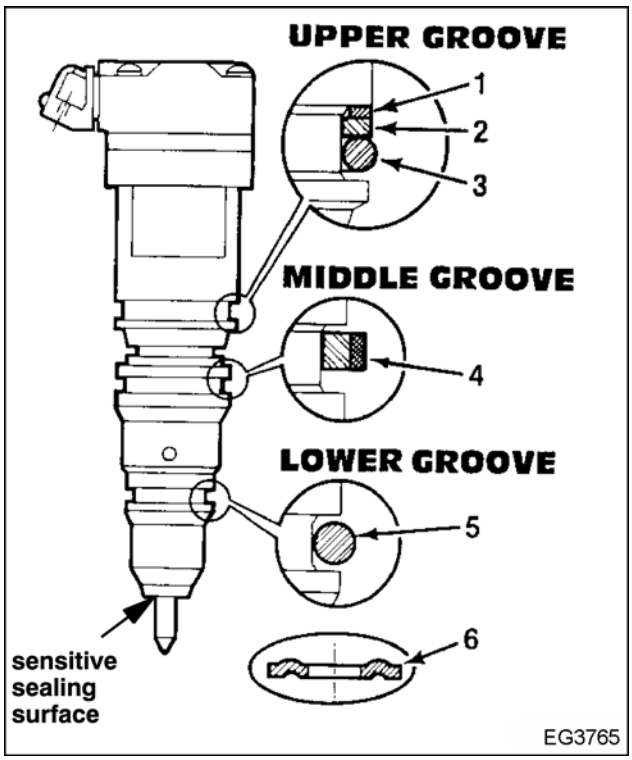

Figure 143 Fuel injector seal and ring grooves

1. Backup ring (steel)
2. Upper cushion ring (black)
3. Upper O-ring (blue)
4. Middle seal (blue and black)
5. Lower O-ring (orange)
6. Gasket (stainless steel)

1. Remove stainless steel fuel injector gasket from bottom of fuel injector.

   NOTE: Grip gasket on edge with pliers. Do not damage or scratch injector when removing stainless steel fuel injector gasket. Stainless steel is much more difficult to remove than copper.

2. Lift lower O-ring out of its groove with wooden or plastic tool. Cut seal and remove it. Discard lower O-ring.
3. Lift middle seal out of its groove with wooden or plastic tool. Cut seal and remove it. Discard middle seal.
4. Lift upper O-ring out of its groove with wooden or plastic tool. Cut seal and remove it. Discard upper O-ring.
5. Lift upper cushion ring out of its groove with wooden or plastic tool. Cut ring and remove it. Discard upper cushion ring
6. Lift one corner of backup ring from its groove, slide rest of backup ring from its groove and over tip of fuel injector. Discard backup ring.
7. Make sure fuel injector is clean and free of debris. Place fuel injector in Fuel Injector Holding Rack and Cups (ZTSE4299B) (page 111) where it will be protected from debris and damage.

Install O-rings and Seals

For proper location of seals and O-rings on fuel injector, see the following instructions.

NOTE: Injector O-rings must be lubricated with clean engine oil. When installing O-rings on injectors, be sure all O-rings and seals are located at top of O-ring grooves. This will prevent O-rings and seals from trying to roll in their respective grooves during installation procedure.

Upper Grove

1. Locate upper groove seals.
2. Lightly lubricate each of three seals with new engine oil.
3. Gently spread gap in backup ring.

   NOTE: Backup ring acts like a spring. Care must be taken when installing this part. Do not twist ring. Ring flatness is important.

4. Slide backup ring over body of fuel injector and in upper groove.

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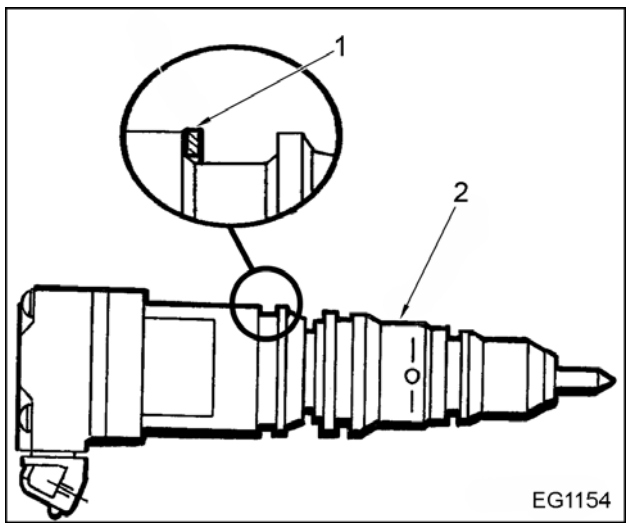

Figure 144 Install fuel injector backup ring

1. Backup ring
2. Fuel injector

5. Slide cushion ring over fuel injector body. Push cushion ring in groove. Make sure cushion ring is up against backup ring in top of groove.

   NOTE: Make sure cushion ring does not twist during installation.

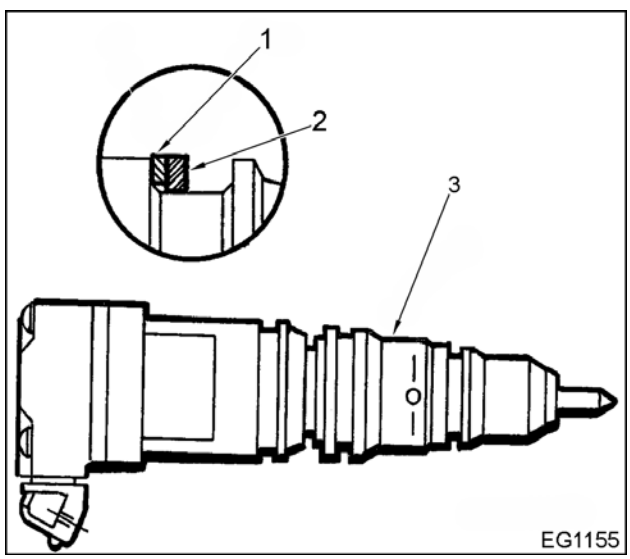

Figure 145 Install upper groove backup ring and cushion ring

1. Backup ring
2. Cushion ring
3. Fuel injector

6. Slide O-ring over fuel injector body. Push O-ring in groove. Make sure O-ring is up against cushion ring in top of groove.

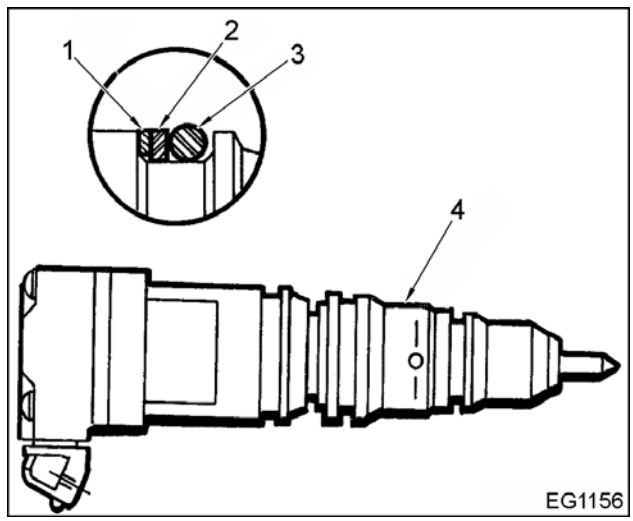

Figure 146 Install upper groove backup ring, cushion ring and O-ring

1. Backup ring
2. Cushion ring
3. O-ring seal
4. Fuel injector

Middle Groove

7. Locate middle groove seal.

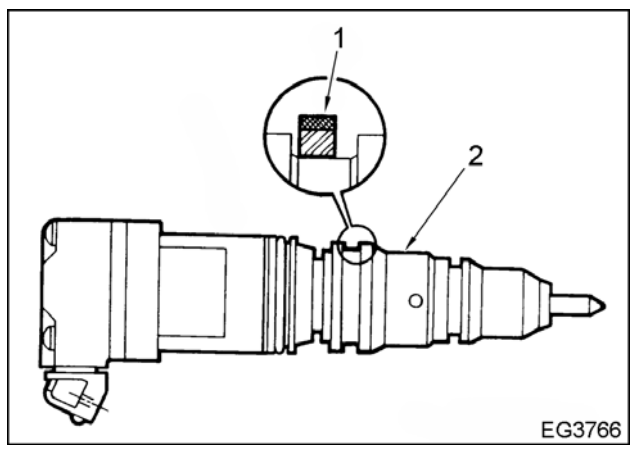

Figure 147 Install middle groove seal

1. Seal
2. Fuel injector

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8. Lightly lubricate seal with clean engine oil.
9. Slide middle seal over fuel injector and push in middle groove. Make sure middle fuel injector seal is up against top of groove.

   NOTE: Make sure middle fuel injector seal does not twist during installation.

Lower Groove

10. Locate lower groove seal.
11. Lightly lubricate seal with clean engine oil.
12. Slide lower fuel injector seal over fuel injector body and in lower groove. Make sure lower fuel injector seal is up against top of groove.

NOTE: Make sure lower fuel injector seal does not twist during installation.

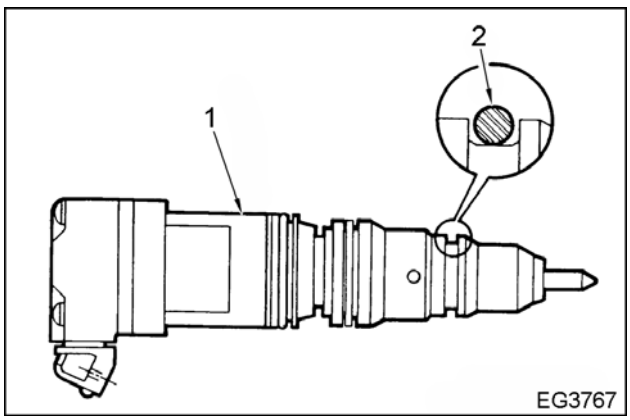

Figure 148 Install lower groove seal

1. Fuel injector
2. Seal

13. Apply light coat of grease to new stainless steel gasket and place on fuel injector.

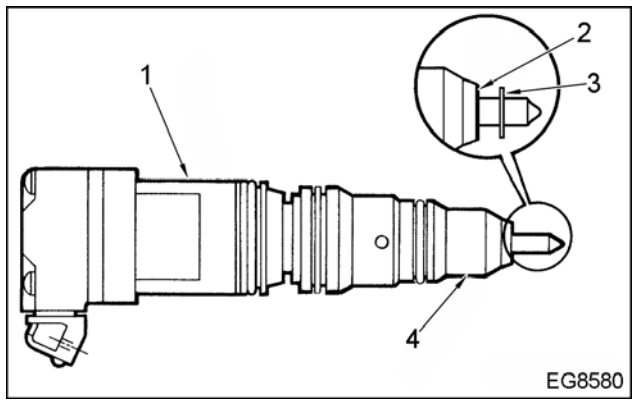

Figure 149 Install stainless steel gasket

1. Fuel injector
2. Sensitive sealing surface (no scratches or dents permitted)
3. Stainless steel gasket
4. Case nut

14. Use deep well 8 mm socket which easily fits over the nozzle tip. Lightly tap stainless steel gasket in place. Take care not to dent gasket when it bottoms on injector case nut. Be sure case nut is clean and blemish free.

Install Fuel Injector

1. If removed, install shoulder bolt and tighten to “Special Torque (page 110).”

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Figure 150 Install shoulder bolt

2. Lubricate fuel injector and insert injector assembly in bore of cylinder head.

CAUTION: To avoid possible engine damage, do not strike top of fuel injector to seat it.

NOTE: Use hand pressure, applied to top of fuel injector, until hold down clamp can be engaged under head of shoulder bolt.

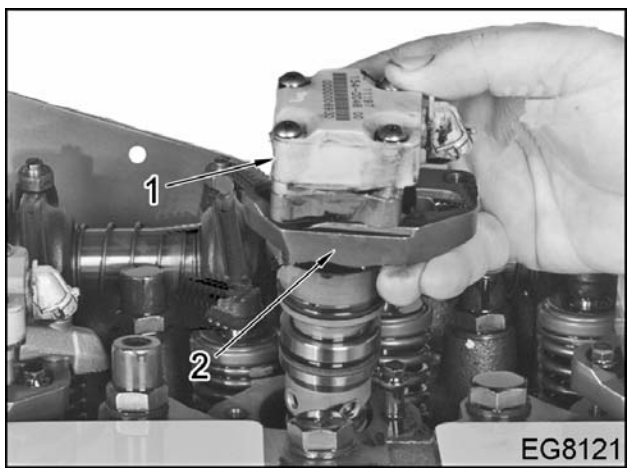

Figure 151 Install fuel injector

1. Fuel injector
2. Hold down clamp

3. Seat fuel injector in fuel injector bore with hold down clamp over shoulder bolt. Use a 16 mm (5/8 in) open end wrench on lower edge of hold down clamp to further insert fuel injector in bore of cylinder head, until seated.

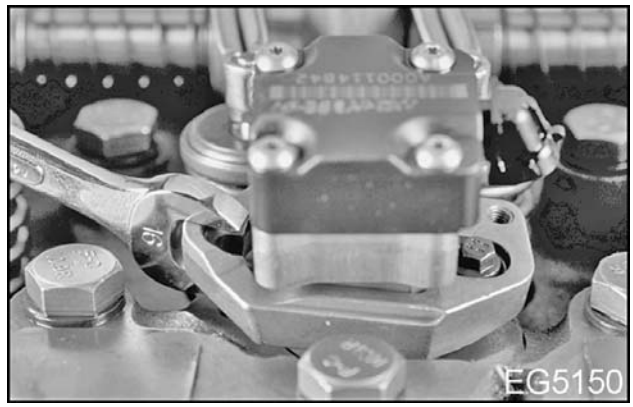

Figure 152 Secure hold down clamp

4. Install fuel injector hold down clamp mounting bolt and tighten to “Special Torque (page 110).”

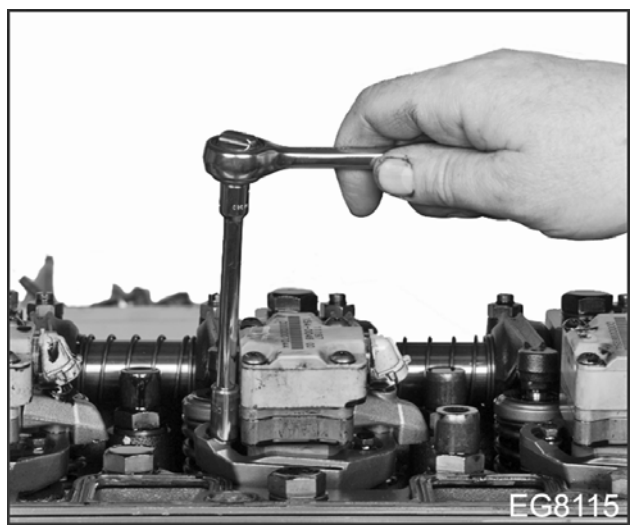

Figure 153 Tighten hold down clamp mounting bolt

CAUTION: To avoid engine damage, it is important that injector hold down clamp bolt be tightened to correct torque.

5. Install wiring harness and oil deflector assembly.

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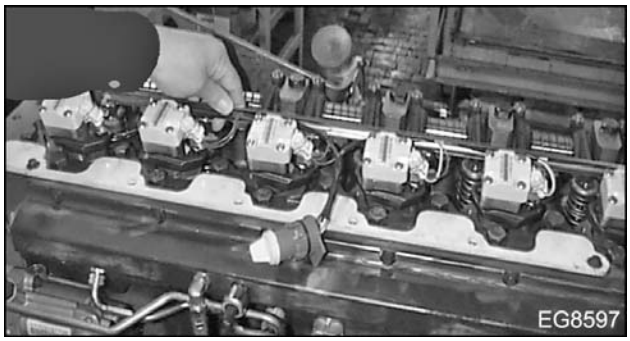

Figure 154 Install wiring channel and oil deflector assembly

6. Install wiring harness and oil deflector assembly bolts to fuel injector and tighten.

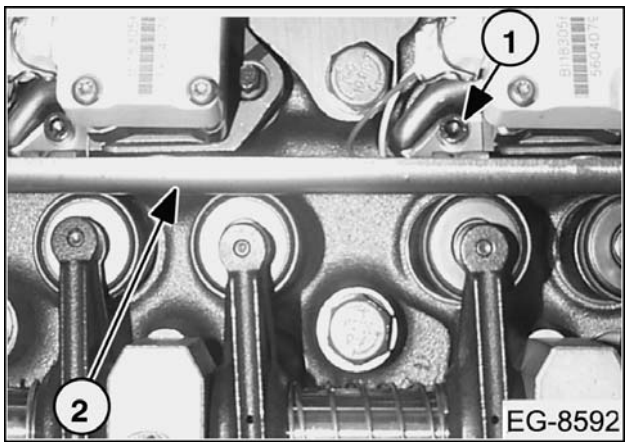

Figure 155 Fasten wiring channel and oil deflector assembly

1. Channel hold down bolt (1 per Injector)
2. Channel

7. Push wiring harness connector in fuel injector solenoid connector.
8. Lock six wiring harness connectors on fuel injector solenoid connectors using wire bails.

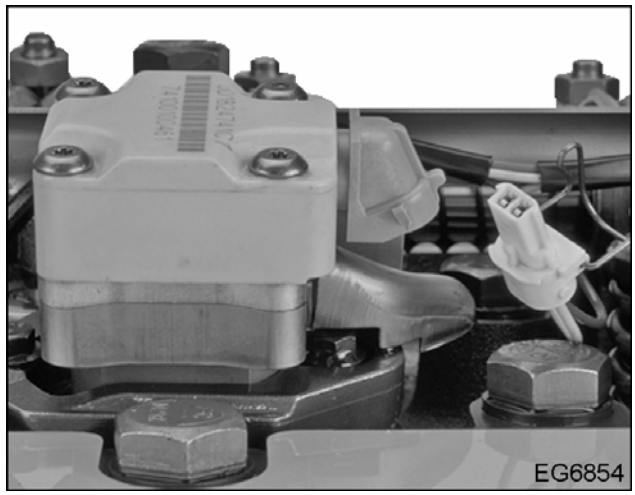

Figure 156 Install wiring harness

Alternate Method: For Wiring Harness with Plastic Oil Deflectors

1. Place wiring harness on top of injectors so pass through connector is directly over injector 3.
2. Beginning at either cylinder 1 or 6, position upper and lower harness clips inline with injector connector slots. Using both hands, apply a slight force in direction of each arrow until harness clip “snaps” in place as shown.

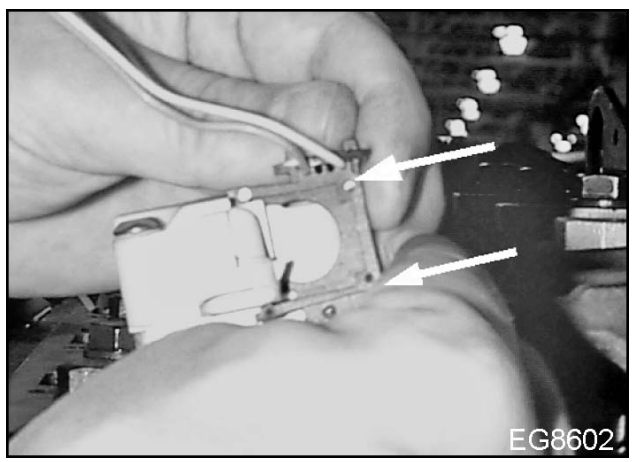

Figure 157 Snap wire bail over tab

3. Slide harness connector in each injector and snap wire bail over tab to lock harness in place.

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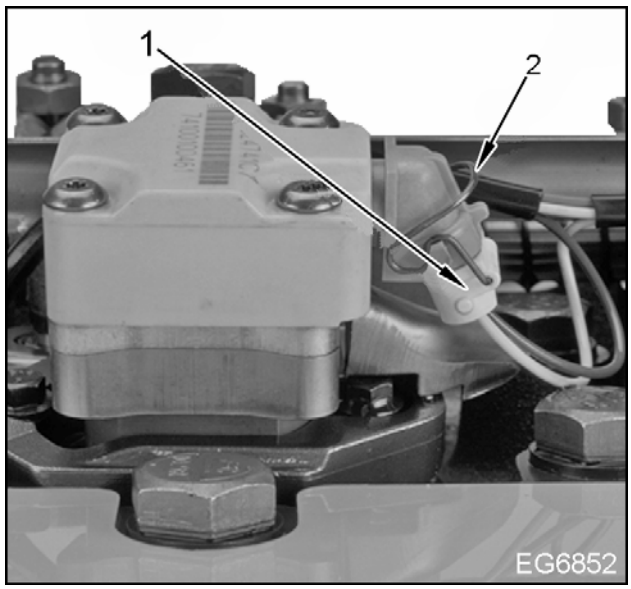

Figure 158 Lock solenoid connector

1. Fuel injector solenoid connector
2. Fuel injector solenoid connector clip

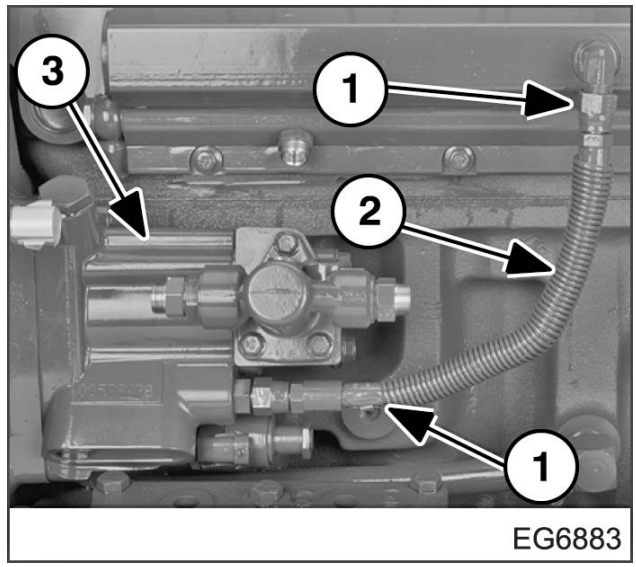

Figure 159 Install oil supply hose

1. Oil supply hose mounting nuts
2. Oil supply hose
3. High-pressure oil pump

Supply Manifold Connection Points

1. Install fuel supply line and connect it from fuel filter header to supply manifold. Tighten fittings to “Special Torque (page 110).”

CAUTION: To avoid engine damage, do not turn fitting in high-pressure oil pump.

NOTE: If it was necessary to remove supply manifold from cylinder head, see “Install - Supply Manifold (page 306)” in the “High-pressure Lube Oil System” section in this manual, for proper maintenance and installation procedures.

2. Install oil supply hose in 90 degree elbow fitting and high-pressure pump. Tighten nuts to “Special Torque (page 110).”
3. Clean all old Loctite® from threads of sensor. Apply new Loctite® #277 to threads of ICP sensor.
4. Install ICP sensor, together with O-ring, in supply manifold.

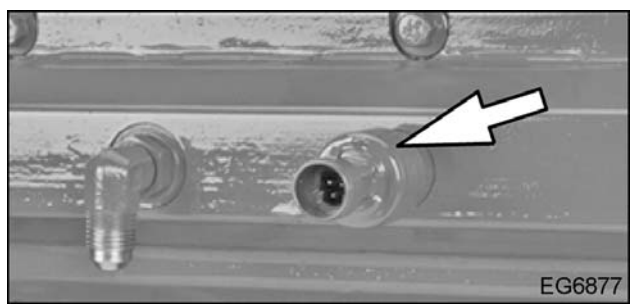

Figure 160 Install ICP sensor

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Miscellaneous

Complete installation by attaching following items. See appropriate sections for proper installation procedures:

Turbocharger oil supply tube

Turbocharger oil drain tube

Turbocharger

Road draft tube

Exhaust manifold

ECM and mounting bracket

Main wiring harness

Valve cover and intake manifold

Fuel supply line from filter header to supply manifold

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Special Information

Specifications

Exhaust Valves	
Stem Diameter	9.452 - 9.461 mm (0.37215 - 0.37250 in)
Stem to guide clearance (maximum allowable before replacement)	0.15 mm (0.006 in)
Face to stem runout (Total Indicated Runout (TIR) maximum)	0.038 mm (0.0015 in)
Valve face angle	45°
Valve face margin (minimum)	1.14 mm (0.045 in)
Valve lash	0.64 mm (0.025 in)
Intake Valves	
Stem diameter	9.452-9.461 mm (0.37215-0.37250 in)
Stem to guide clearance (maximum allowable before replacement)	0.15 mm (0.006 in)
Face to stem runout (TIR maximum)	0.038 mm (0.0015 in)
Valve face angle	30°
Valve face margin (minimum)	2.24 mm (0.088 in)
Valve Lash	0.64 mm (0.025 in)
Cylinder Head	
Valve guide length (overall)	66.294 ± .508 mm (2.61 ± 0.02 in)
Valve guide bore diameter in cylinder head for valve guide insert	15.844 - 15.880 mm (0.6238 - 0.6252 in)
Service valve guide outside diameter	15.898 - 15.918 mm (0.6259 - 0.6267 in)
Service valve guide inside diameter (after assembly)	9.50 - 9.525 mm (0.374 - 0.375 in)
Service valve guide interference fit dimension	0.018 - 0.074 mm (0.0007 - 0.0029 in)
Valve guide bore out-of-round (maximum)	0.05 mm (0.002 in)
Valve guide bore taper (maximum)	0.13 mm (0.005 in)
Valve guide height from cylinder head spring pocket (intake and exhaust)	22.05 - 22.56 mm (0.868 - 0.888 in)
Valve seat insert angle (intake)	30°
Valve seat insert angle (exhaust)	45°
Valve seat width (intake and exhaust)	1.91 - 2.16 mm (0.075 - 0.085 in)
Valve seat runout (TIR maximum)	0.05 mm (0.002 in)
Intake valve seat outside diameter:	50.787 mm (1.9995 in)
0.05 mm (0.002 in) oversize	50.838 mm (2.0015 in)
0.381 mm (0.015 in) oversize	51.168 mm (2.0145 in)

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Exhaust valve seat outside diameter:	45.999 mm (1.811 in)
0.05 mm (0.002 in) oversize	46.050 mm (1.813 in)
0.38 mm (0.015 in) oversize	46.380 mm (1.826 in)
Valve seat insert cylinder head counterbore diameter:	
Intake (standard size)	50.648 - 0.724 mm (1.9940 - 1.9970 in)
0.05 mm (0.002 in.)	50.698 - 50.775 mm (1.9960 - 1.9990 in)
0.381 mm (0.015 in)	51.067 ± 0.038 mm (2.0105 ± 0.0015 in)
Exhaust (standard size)	45.860 - 45.935 mm (1.8055 - 1.8085 in)
0.05 mm (0.002 in)	45.910 - 45.986 mm (1.8075 - 1.8105 in)
0.381 mm (0.015 in)	46.278 ± 0.038 mm (1.8220 ± 0.0015 in)
Maximum valve head recession relative to deck surface (intake and exhaust)	0.36 mm (0.014 in)
Cylinder head surface flatness	0.10 mm (0.004 in) per 229 mm (9 in)
Deck-to-deck dimension (new head)	128.27 - 128.78 mm (5.050 - 5.070 in)
Minimum deck-to-deck dimension (after rework)	128.02 mm (5.040 in)
Valve Springs (Intake)	
Number of springs per valve	1
Identification color stripe	Orange
Valve spring free length	56.623 mm (2.308 in)
Test length (valve closed)	50.292 mm (1.980 in)
Test load (valve closed)	364 - 400 N (82 - 90 lbs)
Test length (valve open)	37.5 mm (1.480 in)
Test load (valve open)	943 - 987 N (212 - 222 lbs)
Wire diameter	5.26 mm (0.207 in)
Valve Springs (Exhaust)	
Number of springs per valve	1
Identification color strip	White
Valve spring free length	64.06 mm (2.522 in)
Test length (valve closed)	50.29 mm (1.980 in)
Test load (valve closed)	611 - 651 N (137.5 - 146.5 lbs)
Test length (valve open)	38.86 mm (1.530 in)
Test load (valve open)	1129 - 1183 N (254 - 266 lbs)
Wire diameter	5.26 mm (0.207 in)

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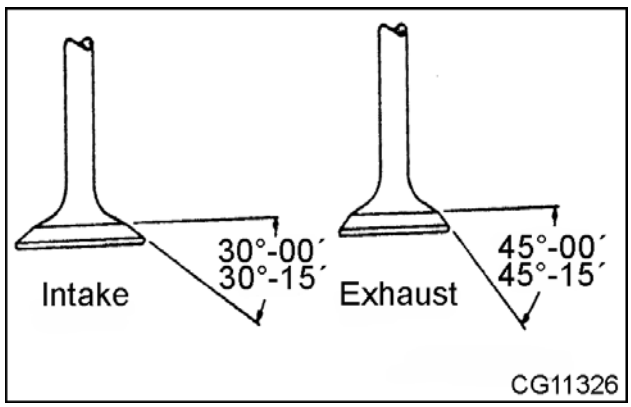

Figure 161 Valve face angles specifications

Special Torque Values

Cylinder Head Bolts	See following procedure
Fuel Injector Hold Down Clamp Mounting Bolt	13 N·m (120 lbf·in)
Fuel Injector Hold Down Clamp Shoulder Bolt	13 N·m (120 lbf·in)
Injector harness shield cap screws	6.8 N·m (60 lbf·in)
High-pressure Oil Hose Nut	26 N·m (19 lbf·ft)
Injection Control Pressure (ICP) Sensor	26 N·m (19 lbf·ft)
Engine Oil and Coolant Temperature Sensors	13.6 N·m (10 lbf·ft)
Supply Manifold Mounting Bolt	27 N·m (20 lbf·ft)
Supply Manifold End Plug	81 N·m (60 lbf·ft)
Supply Manifold Fuel Return Nut	27 N·m (20 lbf·ft)
Valve Adjusting Screw Nut	27 N·m (20 lbf·ft)

Tensioning Procedure for Torque-to-Yield Head Bolts

CAUTION: To avoid engine damage, do not use chlorinated solvents on bolts or crankcase tapped holes. Parts should be clean, dry, and free of any chemical residuals other than engine oil.

1. Position crankshaft at TDC for cylinder 1. Then rotate crankshaft 30 degrees past TDC.
2. Apply 15W40 oil to clean bolts and washers.
3. Tighten each cylinder head bolt (long and short) to 136 N·m (100 lbf·ft) in cylinder head bolt tightening sequence (Figure 162).
4. Tighten each cylinder head bolt (long and short) to 177 N·m (130 lbf·ft) in cylinder head bolt tightening sequence (Figure 162).
5. Repeat Step 4 to obtain uniformity.
6. Add paint mark on each socket and bolt head and another mark 90 degrees clockwise on the cylinder head surface.
7. Tighten each cylinder head bolt (long and short) by rotate each bolt 90 degrees (1/4 turn) in cylinder head bolt tightening sequence (Figure 162).

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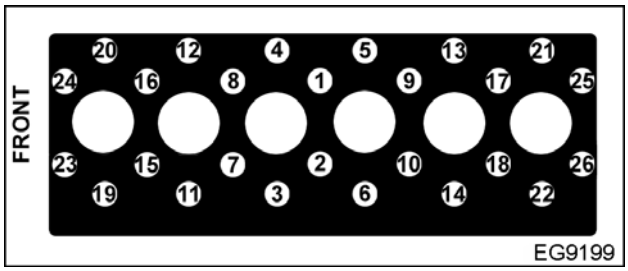

Figure 162 Cylinder head bolt tightening sequence

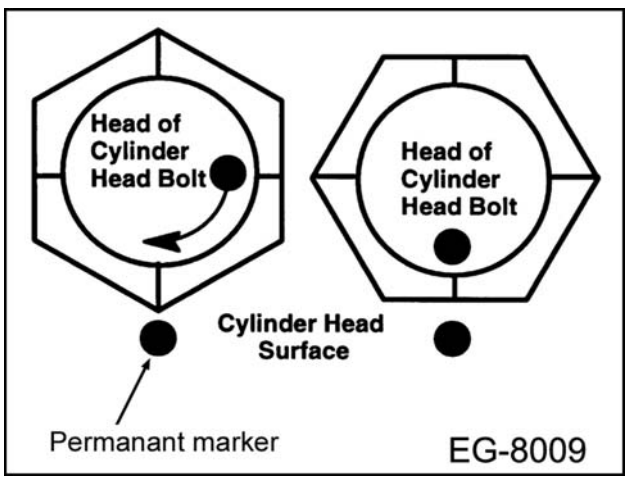

Figure 163 Cylinder head surface paint mark

Special Service Tools

Bevelled Edge Straightedge	OEM1293
Cleaning Brush Set	ZTSE4320
Critical Metric Taps	ZTSE4386
Cylinder Head Bolt Gage	ZTSE4481
Cylinder Head Magnetic Intake Shield	PS94-831-1
Defect Detector Kit (Dye Penetrant)	OEM1272
Dial Caliper	Obtain locally
Feeler Gauge (2)	Obtain locally
Flashlight	Obtain locally
Front Seal / Injector Remover	ZTSE4300
Fuel Injector Holding Rack and Cups	ZTSE4299B
Fuel Injector Sleeve Installer	ZTSE4303
Fuel Injector Sleeve Remover	ZTSE4302A

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Hammer	Obtain locally
Head Pressure Test Kit	ZTSE4289A
Injector Sleeve Brushes (2)	ZTSE4304
Inside Micrometer (0 - 1 in)	Obtain locally
Inspection Light	Obtain locally
Inspection Mirror	Obtain locally
Loctite® 262	Obtain locally
Mineral Spirits	Obtain locally
Nozzle Sleeve Seating Brush 3/4“	ZTSE4391
Outside Micrometer	Obtain locally
Pry Bar	Obtain locally
Rotary Wire Brush	Obtain locally
Sanding Block	Obtain locally
Slide Hammer Kit	ZTSE4398A
Small Hole Gauge Set	OEM1023
Tapered Wire Brush (Sleeve Bore)	ZTSE4394
Thermostat Opening Pressure Test Adapter (must be used with Head Pressure Test Kit)	ZTSE4647
Universal Valve Seat Extracting Kit	ZTSE1951C
Collet (part of Universal Valve Seat Extracting Kit ZTSE1951C)	ZTSE1951-20
Valve Guide Brush	OEM6343
Valve Guide Deburring Tool	ZTSE4393
Valve Guide Installer	ZTSE1943
Valve Guide Remover	ZTSE4377
Valve Seat Installer	ZTSE4164A
Valve Spring Compressor (“C” Type)	ZTSE1846
Valve and Clutch Spring Tester	ZTSE2241
Water Supply Housing Pressure Test Adapter (must be used with Head Pressure Test Kit)	ZTSE4648
Plastic Plug Set (6)	ZTSE43024

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Exploded View

Rocker Arm Assembly, Camshaft Assembly, Tappets, and Push Rods

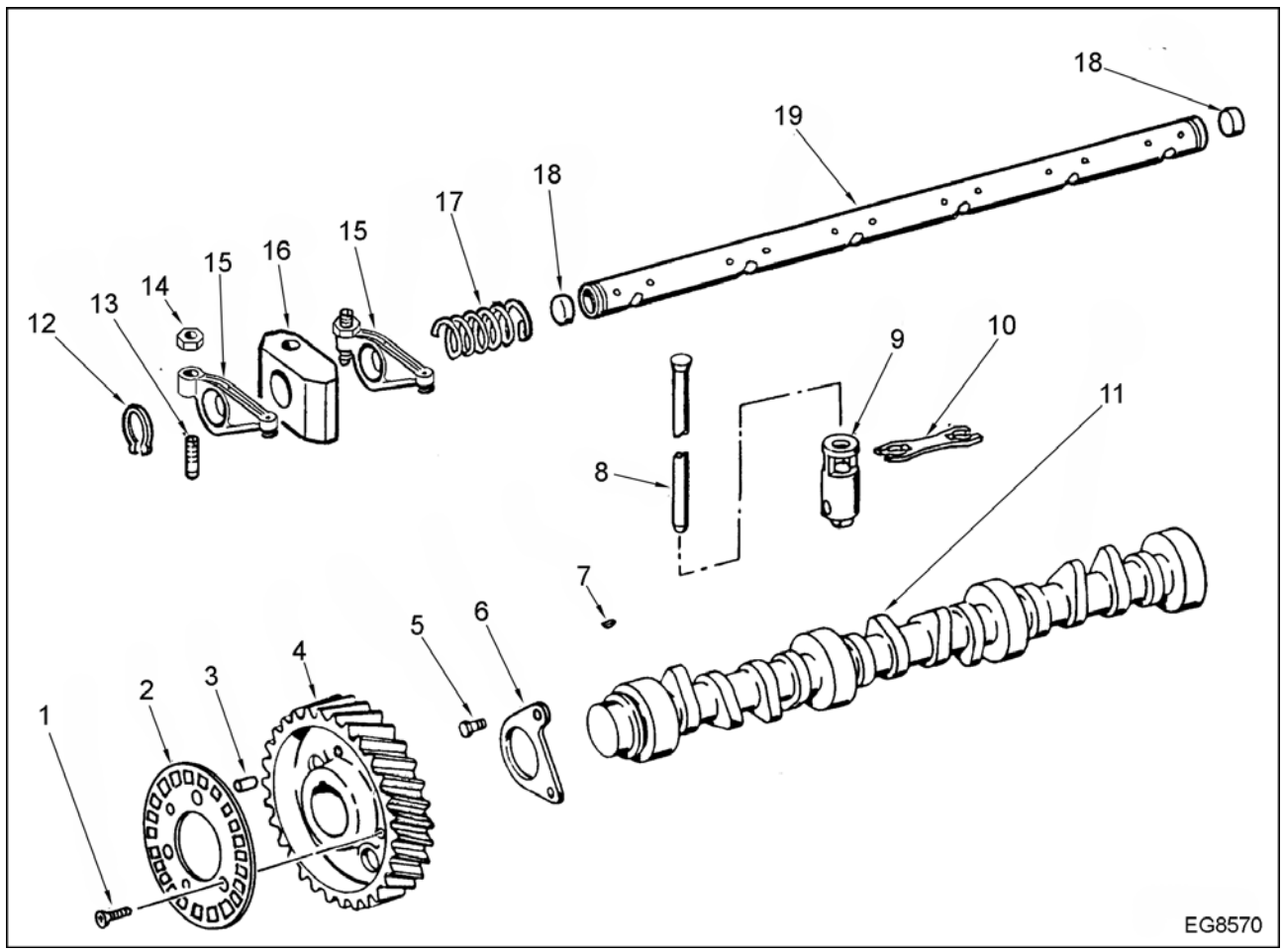

Figure 164 Exploded View Of Rocker Arm Assembly, Camshaft Assembly, Tappets, and Push Rods

1. Screw
2. Timing Sensor Disk
3. Dowel Pin
4. Camshaft Gear
5. Bolt
6. Camshaft Thrust Plate
7. Woodruff Key
8. Push Rod
9. Valve Roller Tappet
10. Roller Tappet Guide
11. Camshaft Assembly
12. Retainer Ring
13. Valve Adjusting Screw
14. Valve Adjusting Screw Nut
15. Valve Lever (Rocker Arm)
16. Rocker Shaft Bracket
17. Rocker Arm Shaft Spring
18. Rocker Arm Shaft Plug
19. Rocker Arm Shaft

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Remove

Valve Lever and Rocker Arm Assembly

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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.

WARNING: To avoid serious personal injury or possible death, make sure that the engine has cooled down sufficiently before attempting to remove any components.

1. Drain coolant to below head gasket joint.

CAUTION: To avoid possible damage to valve train and engine, sufficiently loosen adjusting screw nuts.

2. Loosen all valve lever and rocker arm adjusting screw nuts two full turns.
3. Loosen and remove six valve lever and rocker arm bracket bolts (long cylinder head bolts).
4. Lift valve lever and rocker arm assembly from cylinder head.
5. Remove six long bolts and washers from valve lever and rocker arm assembly.

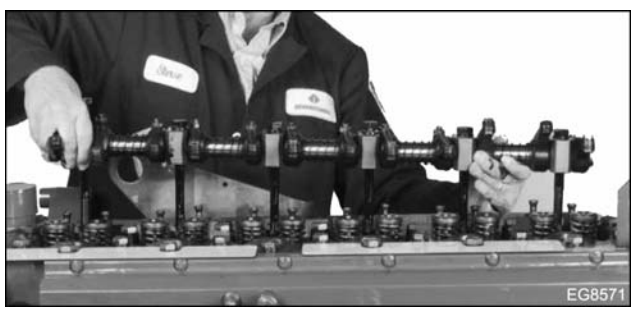

Figure 165 Remove valve lever assembly

Camshaft Gear and Camshaft

NOTE: Refer to appropriate sections for removal instructions for fuel system, cylinder head and front cover items.

Camshaft Gear Only

NOTE: Do not pry on timing disk plate.

1. Remove three timing disk plate screws from camshaft gear and discard. Remove timing disk plate.

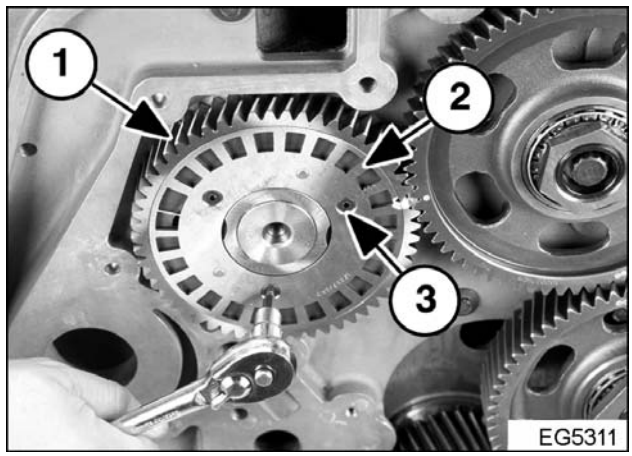

Figure 166 Remove timing disk plate

1. Camshaft gear
2. Timing disk plate
3. Timing disk plate mounting bolts

2. Install Camshaft Gear Puller (ZTSE4411) (page 132) on camshaft gear.

CAUTION: To avoid possible engine damage, do not use impact wrench. Use of an impact wrench will force camshaft to move rearward, resulting in excessive camshaft end play.

3. Turn the center shaft of gear puller to begin removing camshaft gear off camshaft. When camshaft gear has moved out approximately 13 mm (1/2 in), use pry bar or ratchet to force camshaft gear to its most forward position. Finish removing camshaft gear.

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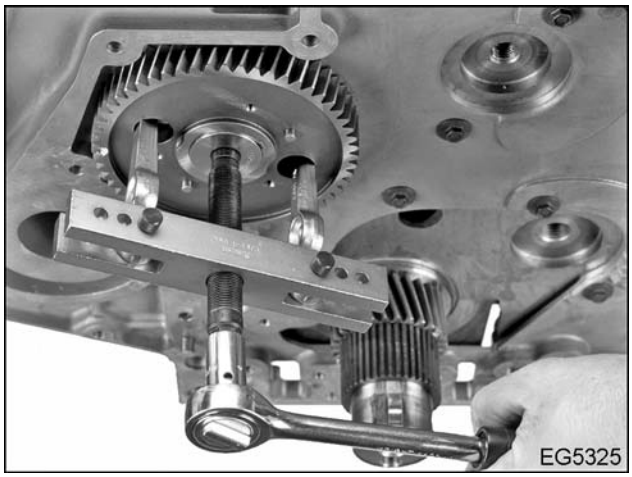

Figure 167 Remove camshaft gear

Camshaft Gear and Camshaft Assembly

Use to remove camshaft gear and camshaft as an assembly.

1. Remove roller tappets and roller tappet guides from their bores.

   NOTE: Mark the tappets as to location and orientation in the crankcase so they can be returned to their original positions and the tappet rollers will all turn in the same direction.

2. Mark location and orientation on tappets.

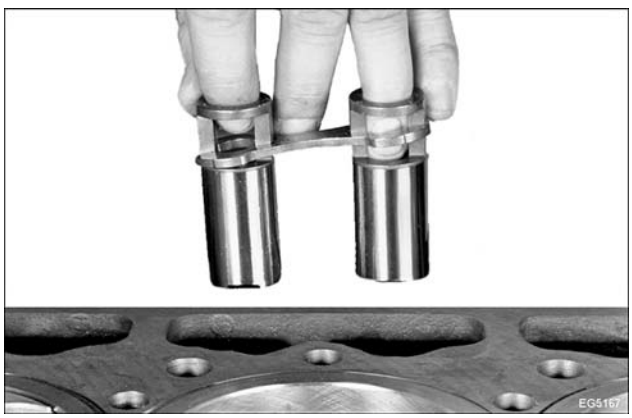

Figure 168 Remove roller tappet and guides

3. Rotate crankshaft so that timing marks on gears are aligned.

NOTE: Before removing any gear, mount a magnetic base dial indicator on engine and check gear backlash and end play. See “Measure Engine Gear Train Timing without Front Cover Removed or Engine Tear Down - Dial Indicator Method (page 225)” in the “Timing Gear Train and Front Cover” section in this manual, for the procedure.

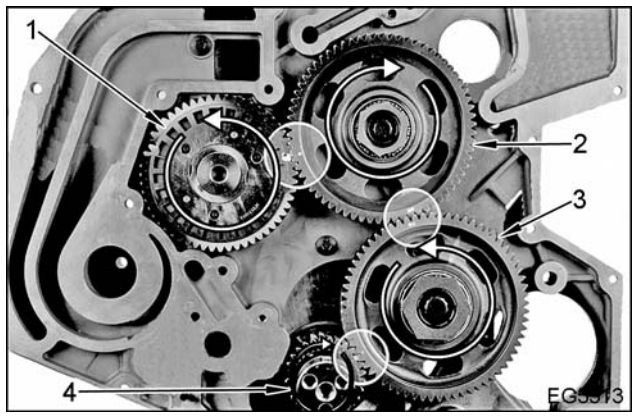

Figure 169 Gear and timing marks

1. Camshaft gear
2. Upper idler gear
3. Lower idler gear
4. Crankshaft gear

4. Remove two camshaft gear thrust plate bolts.

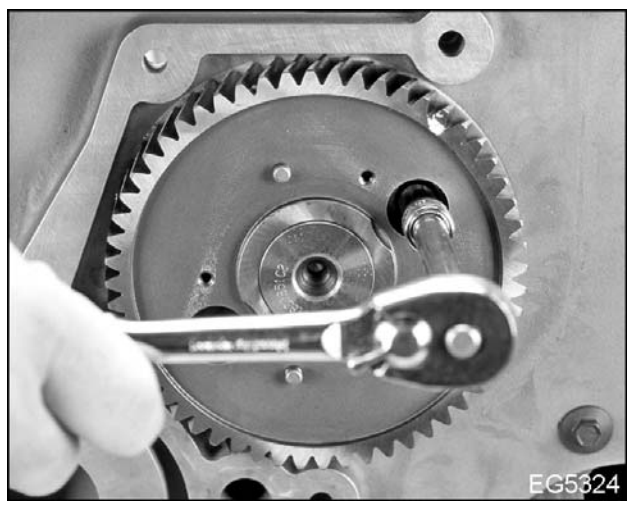

Figure 170 Remove camshaft gear thrust plate bolts

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NOTE: When engine is mounted in an engine stand, rotate engine so front of the engine is facing up. This allows for easier removal of camshaft assembly.

5. Remove camshaft from crankcase by lifting assembly straight up. This reduces risk of damaging camshaft journals and bushings.

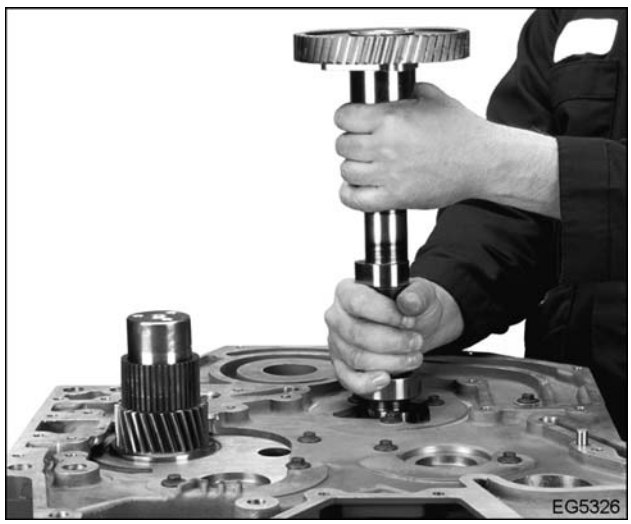

Figure 171 Remove camshaft and gear

Remove Camshaft Bushings

NOTE: When servicing camshaft bushings, crankshaft and main bearings must be removed from crankcase to avoid debris contamination.

1. Use Camshaft Bushing Service Set (ZTSE2893B) (page 132) to remove camshaft bushing.

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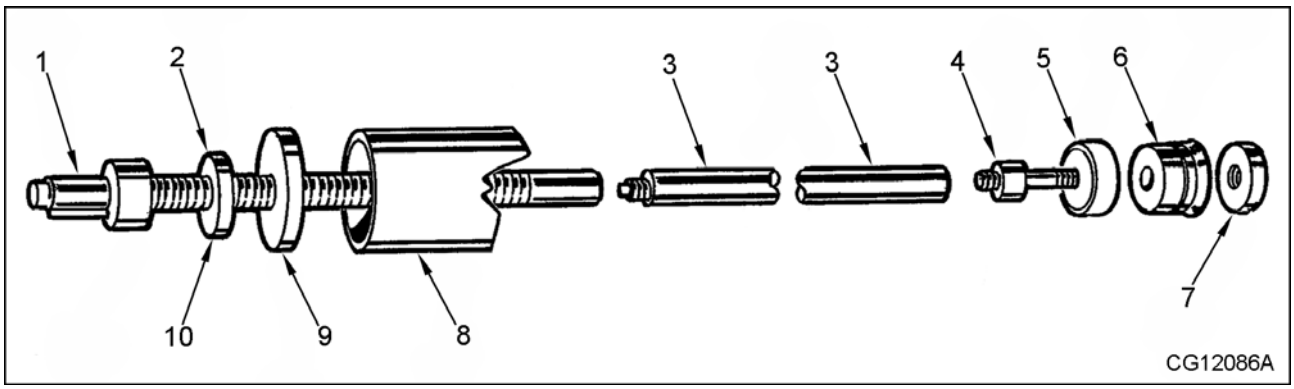

Figure 172 Camshaft Bushing Service Set (ZTSE2893B)

1. Puller screw
2. Thrust bearing
3. Puller screw extension
4. Expanding mandrel
5. Camshaft bushing (see note)
6. Expanding collet
7. Back up nut
8. Extension tube
9. Pulling plate
10. Pulling nut

NOTE: The four camshaft bushings have the same inside diameter but outside diameter and widths of each bushing are different, as is crankcase bore in which each bushing fits. See “Camshaft Bushing Chart (page 131)” for proper bushing fit. Because of different size outside diameters of bushings, remove front and rear bushings first. Then remove two intermediate bushings through front of crankcase.

2. Using camshaft bushing remover and installer tool, select proper size expanding collet and back up nut and assemble on expanding mandrel. With expanding collet collapsed, install collet assembly in camshaft bushing to be removed and tighten back up nut on expanding mandrel until collet fits camshaft housing.

3. Assemble puller screw and extension, if necessary. Install on expanding mandrel. Tighten pulling nut against thrust bearing and pulling plate to remove camshaft bushing.

   NOTE: Hold end of puller screw with a wrench to prevent it from turning when tightening the pulling nut.

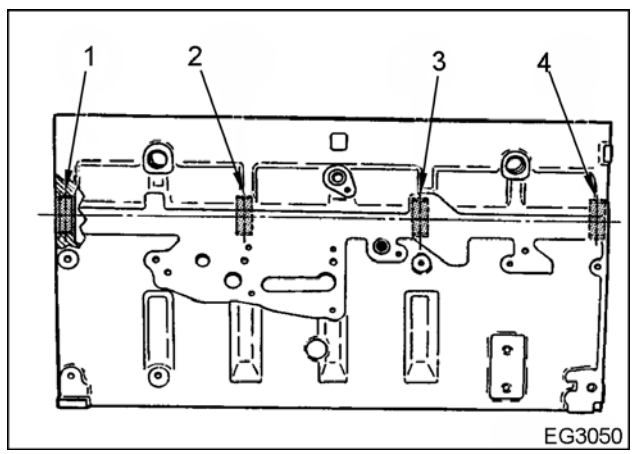

Figure 173 Camshaft bushings

1. Rear bushing
2. Rear intermediate bushing
3. Front intermediate bushing
4. Front bushing

4. Repeat this procedure for each bushing.

   NOTE: To remove rear bushing, install puller screw from rear of crankcase. All other bushings are removed by going through front of crankcase.

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Clean, Inspect, Measure, and Test

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).

NOTE: Do not use a caustic solution on engine or related components.

Valve Lever and Rocker Arm Assembly

Clean Valve Lever and Rocker Arm Assembly

1. Immerse all components in suitable solvent.
2. Use filtered compressed air to dry components.

Inspect and Measure Rocker Shaft

1. Inspect rocker shaft for scoring, pitting, or wear steps. Replace rocker shaft if any of these visual signs of wear are present.

   CAUTION: To prevent possible engine damage, replace rocker shaft with like rocker shaft. If replacing with new style rocker shaft all valve train components must be replaced. Replacement of old style valve train components requires complete replacement of all valve train components, including push rod assemblies, roller tappet assemblies, and rocker arm assemblies.

   NOTE: It is normal to see a slight polishing at lever contact area.

2. Measure rocker shaft in a non-contact area. Use an Outside Micrometer (page 132). This dimension will be used as a baseline shaft diameter.

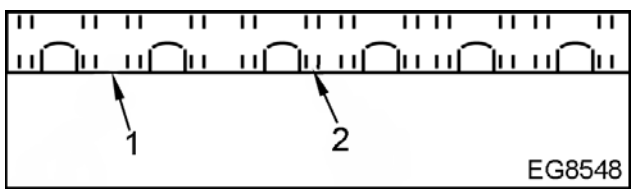

Figure 174 Non-contact and arm contact area

1. Non-contact area
2. Arm contact area

3. Measure each lever contact areas vertically.

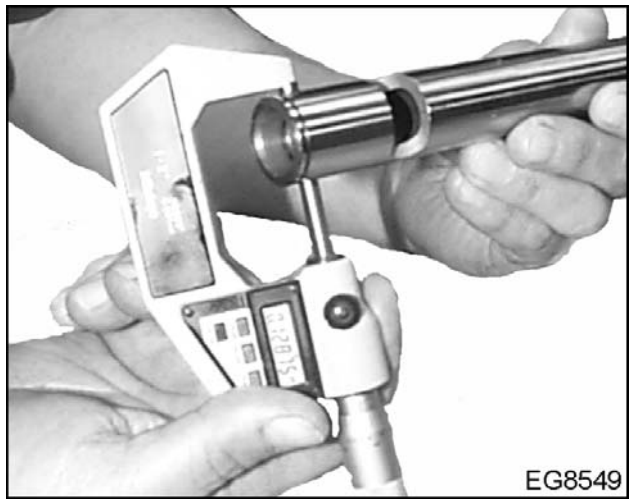

Figure 175 Measure contact and non-contact areas vertically

4. Subtract each twelve vertical measurements from baseline diameter. If difference is greater than 0.025 mm (0.001 in), replace rocker shaft.
5. Verify oil supply holes are open. Clean holes with small wire or other suitable tool if necessary.

CAUTION: To avoid possible engine failure, if replacing rocker shaft, all twelve valve levers must be replaced. Reusing rocker arms on a new shaft will not allow for an adequate break-in period and will cause premature failure of shaft and levers.

CAUTION: To prevent possible engine damage, do not install new style valve train components in engines produced with old style valve train components. Replacement of old style valve train components requires complete replacement of all valve train components, including push rod assemblies, roller tappet assemblies, and rocker arm assemblies.

NOTE: New valve levers may be installed on a used shaft.

NOTE: Cup plugs at each end of shaft are replaceable. Do not disturb cup plugs unless damaged, leaking hard part failure or contaminated oil. If replacement is required, pry damaged cup plug out and press in new cup plug.

6. Inspect cup plugs on each end of shaft for evidence of damage.
7. If cup plug(s) is damaged pry the damaged cup plug out.

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8. Clean the area around the cup plug.
9. Press in a new cup plug in the end of the shaft.

Inspect and Measure Valve Lever

1. Inspect rocker shaft for scoring, pitting, or signs of excessive wear. If valve lever bore is visibly damaged, replace valve lever.
2. Inspect lower half of valve lever. Most significant wear will occur at this location. Valve levers may be reused in their original locations if phosphate coating is worn off and the shaft is not replaced.

NOTE: Purpose of black phosphate coating on valve lever is to provide a break-in lubricant between rocker shaft and valve lever bore. It is normal to see black phosphate coatings worn off of bottom of lever arm in the shaft and bore contact area. Valve levers must be labeled and installed in their original locations to maintain proper wear pattern.

3. Measure valve lever bore diameter at two locations with Telescoping Gauge and Outside Micrometer (page 132). Measure diameter at A-B and C-D (Figure 176). If difference between diameters is greater than or equal to 0.025 mm (0.001 in), replace valve lever.

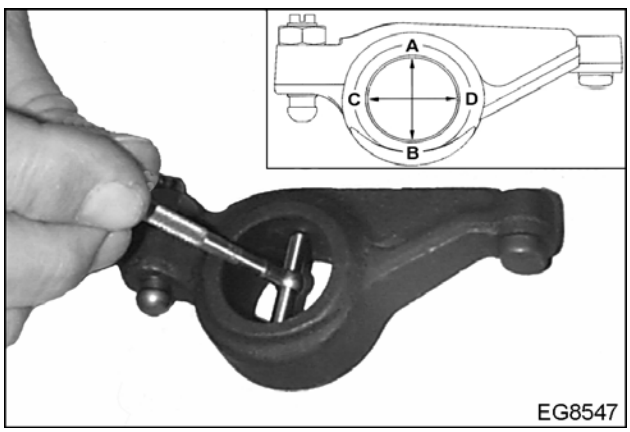

Figure 176 Measure valve lever bore

4. Inspect valve stem contact button on valve lever for scoring, pitting, or signs of excessive wear. Replace valve lever if button is worn.

CAUTION: To prevent possible engine damage, do not install new style valve train components in engines produced with old style valve train components. Replacement of old style valve train components requires complete replacement of all valve train components, including push rod assemblies, roller tappet assemblies, and rocker arm assemblies.

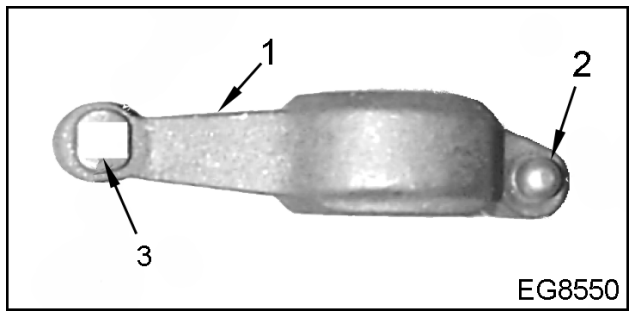

Figure 177 Inspect valve stem contact button

1. Valve lever
2. Adjusting post
3. Button

5. Inspect valve lash adjuster for signs of wear. Replace adjuster screw if excessive wear is found.
6. Inspect top oil feed hole in valve lever. Clean hole with small wire or other suitable tool if necessary.

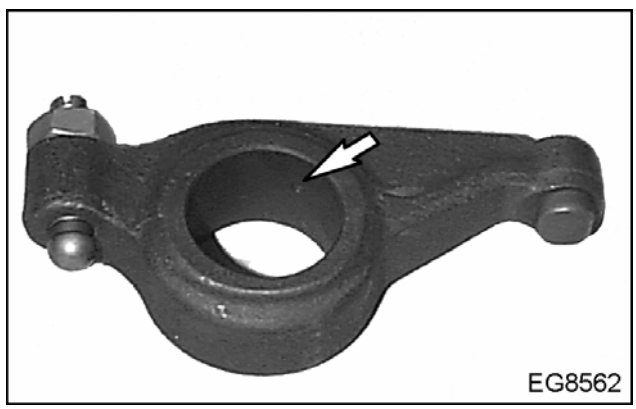

Figure 178 Inspect valve lever oil hole

Inspect and Measure Shaft Springs

1. Inspect shaft springs for rust, pitting, and cracks. Replace as required.

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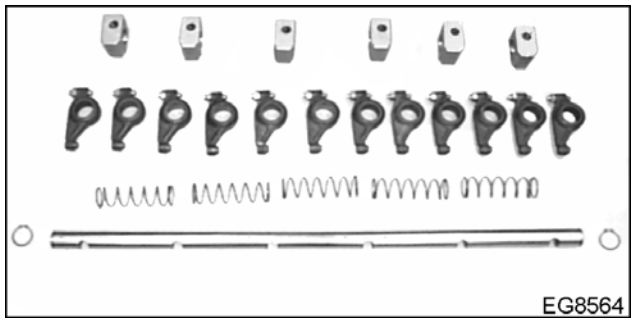

Figure 179 Inspect valve lever components

2. Measure shaft spring tension with Valve and Clutch Spring Tester (ZTSE2241) (page 132). Measure free length (no load applied). Apply correct test load and measure test length.
3. Replace any shaft springs that do not meet “Specifications (page 130).”

Figure 180 Measure shaft spring tension

Measure Camshaft Lobe Lift

NOTE: Camshaft wear can be measured without complete engine tear down, at this stage of disassembly.

NOTE: Measure camshaft lobe lift with valve lever (rocker arm) assembly removed and push rods in place.

1. Mount Dial Indicator with Magnetic Base (page 132) on cylinder head.
2. Place indicator tip on top of push rod and rotate engine until push rod is at its lowest point of travel (base circle). Zero dial indicator.

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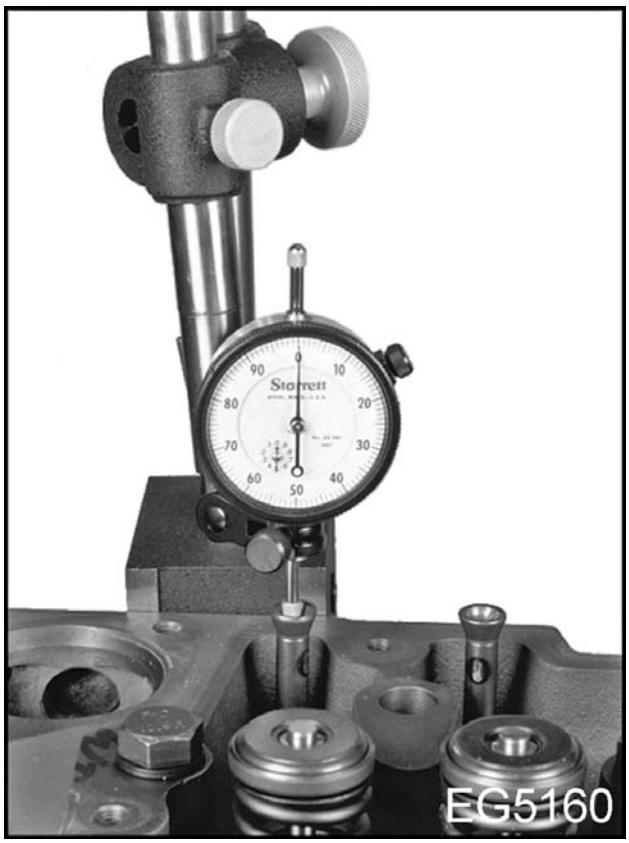

Figure 181 Mount dial indicator

3. Rotate engine, bring push rod to its highest point of travel.

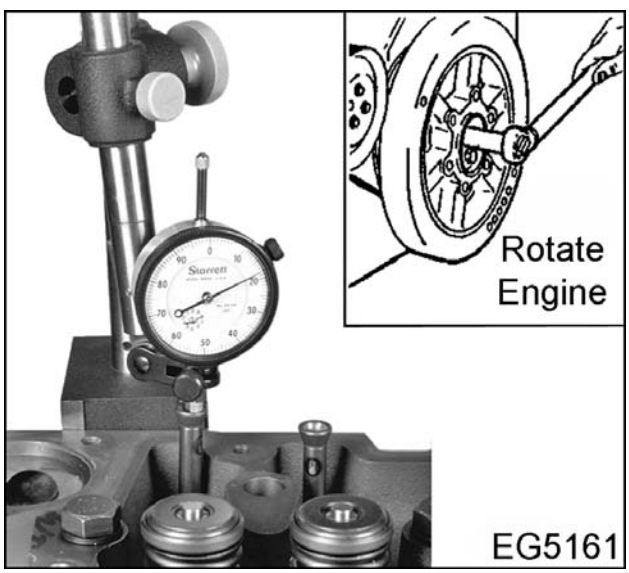

Figure 182 Camshaft lobe measurement

4. Repeat procedure for all camshaft lobes.

NOTE: Intake and exhaust valve lobe lift specifications are different.

5. See “Specifications (page 130),” if wear is greater than 0.51 mm (0.020 in), replace camshaft.

NOTE: If complete engine overhaul is scheduled, camshaft lobe wear can be determined by measuring lobes with a micrometer when camshaft is removed. See “Inspect and Measure Camshaft Gear and Camshaft” later in this section for details.

Camshaft Gear and Camshaft

Clean Camshaft Gear and Camshaft

1. Use a soft bristle brush and a suitable solvent to clean camshaft.

Inspect Camshaft Gear and Camshaft

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

Inspect and Measure Camshaft Gear and Camshaft

1. Inspect camshaft journal for wear.
2. Measure camshaft journal diameter to evaluate condition of camshaft journals lobes, with an Outside Micrometer (page 132). If any journals are worn beyond “Specifications (page 130),” replace camshaft.
3. Measure across dimensions A-D and B-C, with an Outside Micrometer (page 132). Subtract B-C from A-D This is cam lobe lift. If any cam lobe wear exceeds “Specifications (page 130),” replace camshaft.

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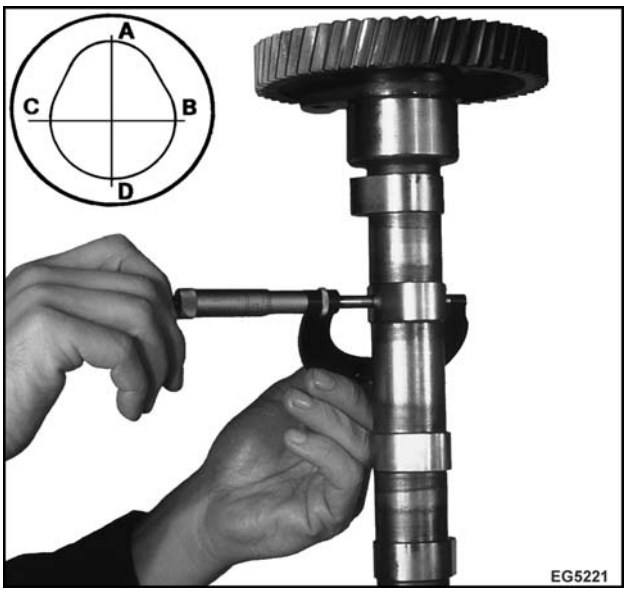

Figure 183 Measure camshaft lobe wear

4. Inspect camshaft thrust plate for wear, cracks, or distortion.
5. Measure thrust plate thickness with an Outside Micrometer (page 132). If thrust plate wear exceeds “Specifications (page 130),” or is damaged or if there is excessive camshaft end play, replace thrust plate.
6. Inspect camshaft drive gear for worn or damaged teeth. Replace as required.
7. Inspect timing disk plate. Replace as required.

Measure Camshaft End Play

1. Measure camshaft end play with a Dial Indicator with Magnetic Base (page 132). If the end play exceeds “Specifications (page 130),” camshaft has probably slipped back.

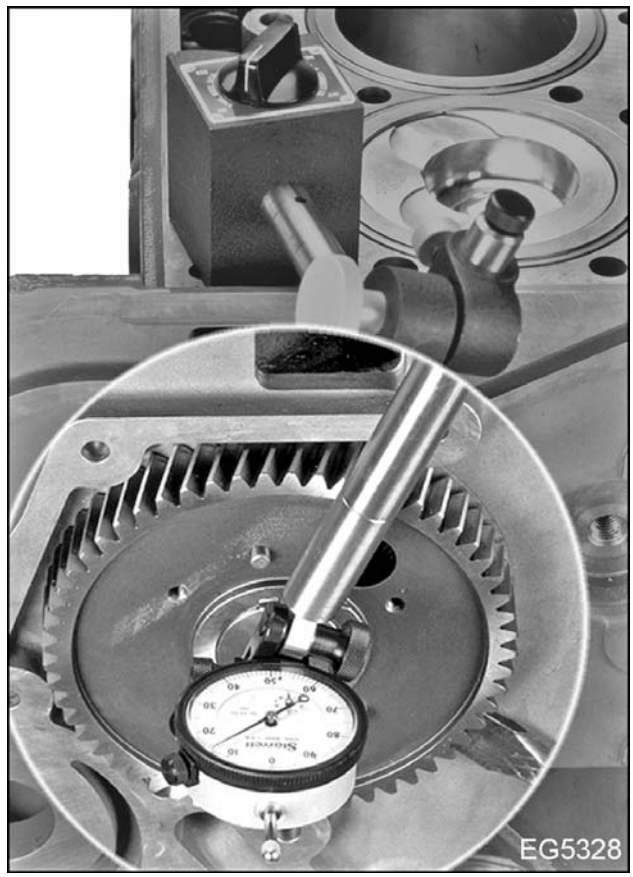

Figure 184 Measure camshaft end play

2. Remove cam gear, pull camshaft forward. Repeat step 1.

Inspect and Measure Camshaft Bushings

1. Inspect four camshaft bushings for wear and proper running clearance.
2. Measure camshaft bushing journal outside diameter at two locations, 90° apart with Outside Micrometer (page 132).
3. Measure camshaft bushing inside diameter with bushing installed in crankcase. Use Telescoping Gauge and Outside Micrometer (page 132).
4. Subtract readings obtained in Steps 2 and 3 to determine running clearance.
5. If maximum allowable running clearance in “Specifications (page 130)” is exceeded, replace camshaft bushings. See “Remove Camshaft Bushings” in this section.

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NOTE: When servicing camshaft bushings, crankshaft and main bearings must be removed from crankcase to avoid debris contamination.

Inspect and Clean Crankcase Bushing Bore

1. Inspect each bushing bore in crankcase for burrs or debris that could damage new bushings when they are installed.
2. Remove any burrs. Clean bores thoroughly before installing new camshaft bushings.

Inspect and Measure Tappets

1. Inspect all roller tappets and rollers for pitting, roughness, and free rotation of roller.
2. Measure tappet dimensionally. If “Specifications (page 130)” are exceeded replace tappet

Clean, Inspect, and Check Push Rods

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

CAUTION: To prevent possible engine damage, do not install new style valve train components in engines produced with old style valve train components. Replacement of old style valve train components requires complete replacement of all valve train components, including push rod assemblies, roller tappet assemblies, and rocker arm assemblies.

2. Inspect each rod for wear at ends. Replace as required.
3. Check all push rods for straightness by rolling on a flat surface with cup end hanging over edge of flat surface. Check push rod runout. If “Specifications (page 130)” are exceeded, replace rod. Replace any rod that is bent.

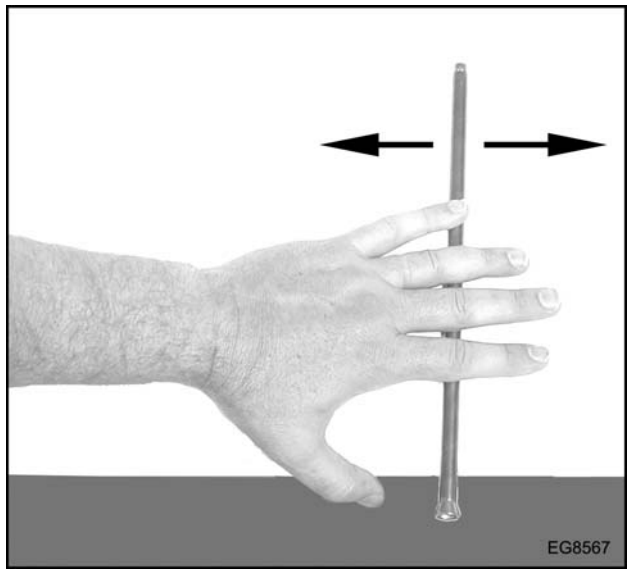

Figure 185 Check Push Rods

Disassemble

Valve Lever (Rocker Arm) Assembly

1. Place valve lever assembly on a clean flat surface.
2. Mark levers before disassembly to aid in correct location reassembly.
3. Remove valve lever retainer ring at the end of shaft with Snap Ring Tool (page 132).

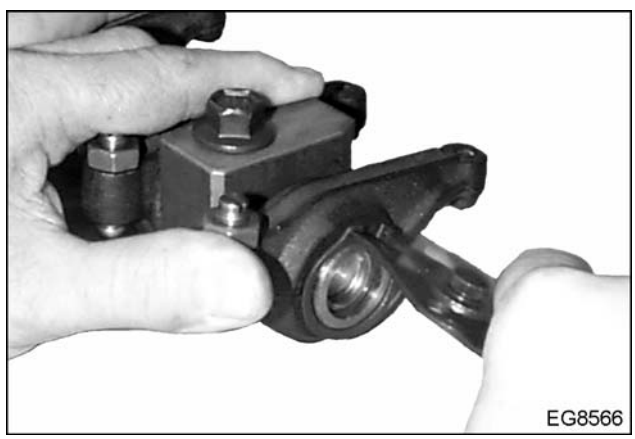

Figure 186 Remove valve lever retaining ring

4. Slide valve lever assembly components off shaft.

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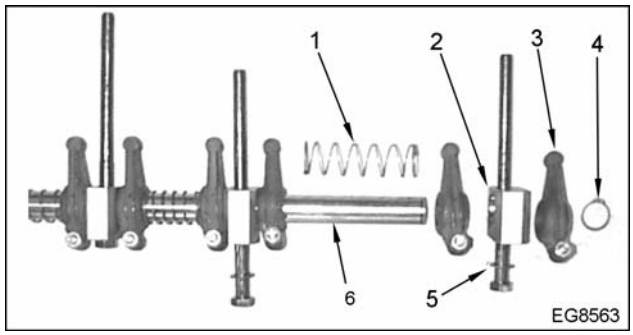

Figure 187 Valve lever assembly components

1. Spring
2. Valve lever
3. Bracket
4. Retaining ring
5. Bolt
6. Shaft

Assemble

Valve Lever (Rocker Arm) Assembly

1. Lubricate all valve lever bores with clean engine oil. Install retaining ring at one end of the shaft and assemble components.

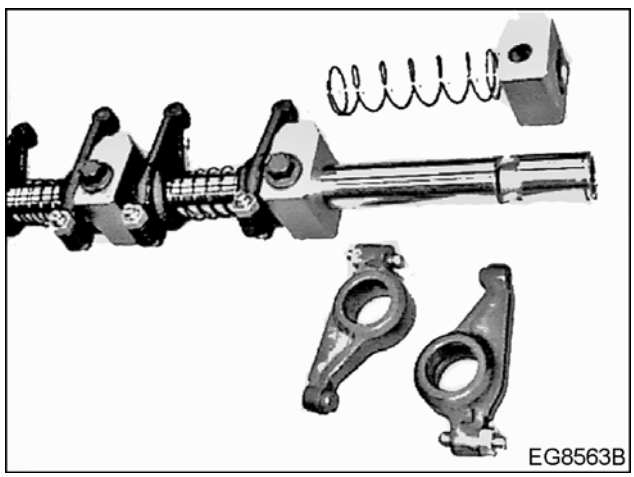

Figure 188 Assemble valve lever components

2. Arrange valve lever assembly components.

   NOTE: The word “TOP” marked on rocker shaft should face up at all times. Shaft support brackets should be assembled so part numbers face down.

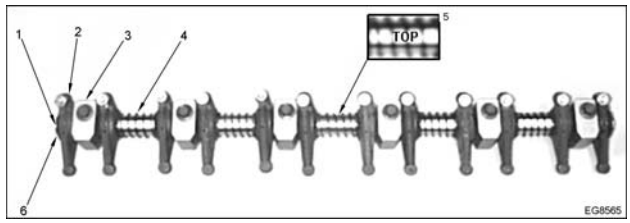

Figure 189 Valve lever assembly arrangement

1. Retaining ring (each end of shaft)
2. Valve lever (12 locations)
3. Bracket (6 locations)
4. Spring (5 locations)
5. Rocker shaft
6. Cup plug (each end of shaft)

NOTE: Brackets must line up over shaft bolt grooves. See (Figure 190) for valve lever bracket assembly correct end view position of shaft oil holes to mounting bracket.

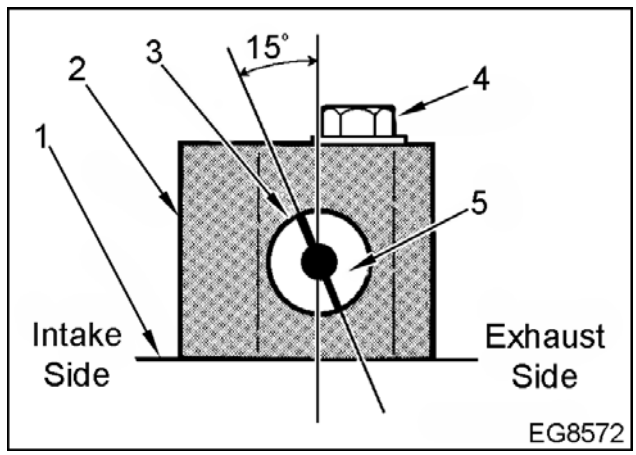

Figure 190 Correct end view orientation of valve lever bracket assembly

1. Cylinder head
2. Bracket
3. Shaft position
4. Mounting bolt
5. Shaft oil holes

3. When all components of shaft have been installed in correct order, attach retaining ring to secure components to shaft.

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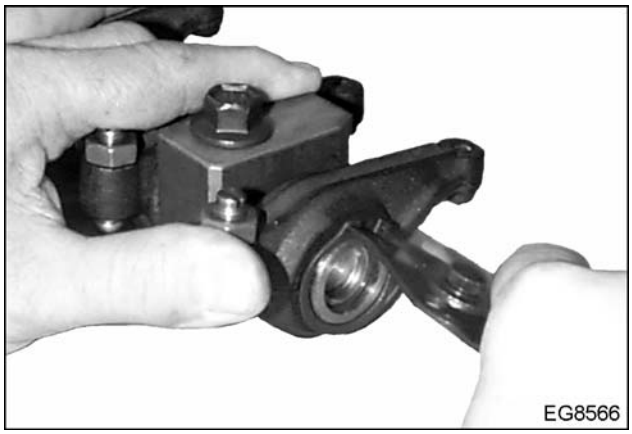

Figure 191 Install valve lever shaft retaining ring

Camshaft Assembly

1. If camshaft gear only was removed, heat camshaft gear to 149 to 177 °C (300 to 350 °F).

WARNING: To avoid serious personal injury, use heat protecting gloves to install heated camshaft gear.

NOTE: Camshaft gear should slide on camshaft with slight hand pressure. Do not force camshaft gear.

2. Remove camshaft gear assembly from heat source. Hold camshaft gear on camshaft as it cools. Camshaft gear should tighten on shaft in about 30 seconds.

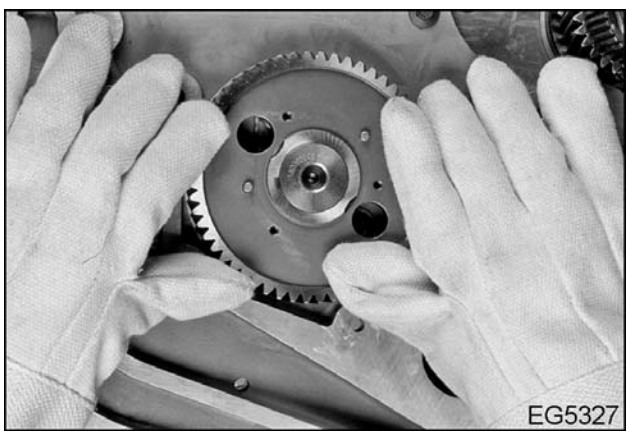

Figure 192 Install camshaft gear

Install

Assemble

Valve Lever (Rocker Arm)

1. Install valve lever assembly. Torque six mounting bolts and adjust valve lash, see “Valve Lever Assembly - Install and Valve Lash Adjustment (page 99)” in the “Cylinder Head and Valves” section of this manual, for more information.
2. Test used cylinder head bolts (long and short) for excessive thread stretching with Cylinder Head Bolt Gage (ZTSE4481) (page 132).
3. Install valve cover intake manifold and crankcase breather tube. See “Install - Valve Cover and Intake Manifold (page 66)” in the “Manifolds” section of this manual, for more information.
4. Fill coolant expansion tank with coolant. Keep expansion tank full until engine is filled and vented. Once engine is filled and vented, maintain expansion tank in operating range, see appropriate *Engine Operations and Maintenance Manual*.

NOTE: If only valve lever assembly was removed, only apply torque to yield head bolt procedure to six valve lever assembly mounting bolts. Do not torque other 20 head bolts that are already at yield.

Camshaft Bushing

1. Identify each bushing by its outside diameter (page 131).
2. Lubricate new camshaft bushings as well as crankcase bushing bore with clean engine oil.
3. Install new bushing on expanding collet and turn backup nut to tighten collet until bushing is held securely.

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Figure 193 Install bushing on collet

4. Mark oil hole location on tool backup nut to aid in alignment of bushing and crankcase oil holes.

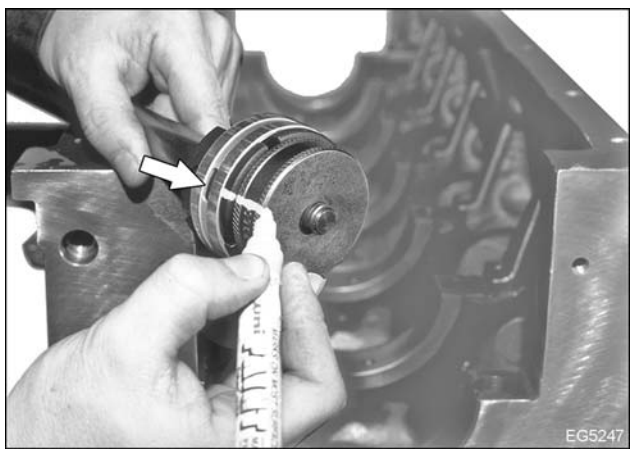

Figure 194 Mark oil hole location

NOTE: This step must be repeated for each bushing installed.

5. Install rear intermediate bushing through front of crankcase, then pull it in place at rear of crankcase by turning pulling nut on puller screw. Remove tool and inspect oil hole alignment.

   NOTE: Bushings must be installed in proper order because of different outside diameters of bushings.

6. Install front intermediate bushing next. Install through front of crankcase and pull in place from rear.

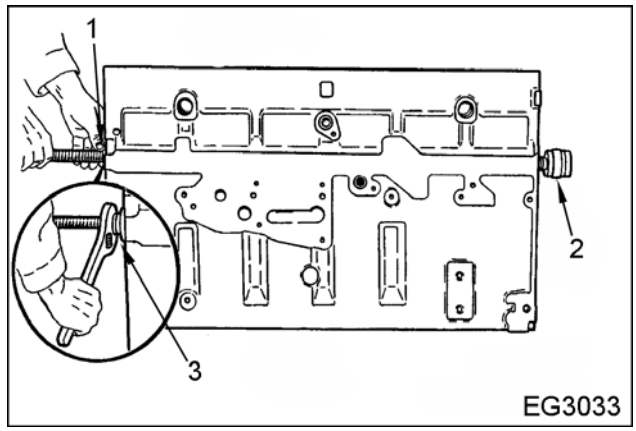

Figure 195 Install bushing

1. Align bushing with correct bore in crankcase
2. Bushing on collet
3. Assembly pulling plate, thrust bearing and pulling nut on puller screw

7. Install front camshaft bushing by pulling it in place from rear.

8. Install rear camshaft bushing by pulling it in place from front of crankcase.

   NOTE: All bushing oil holes must be in alignment with oil holes in crankcase.

Camshaft

1. Move engine to vertical position, lubricate camshaft and camshaft bushings using clean engine oil.

   CAUTION: To avoid possible engine damage, avoid damaging, nicking, or scratching camshaft bushings with cam lobes during installation of camshaft.

2. Gently slide camshaft assembly in crankcase. Be careful not to damage camshaft bushings.

3. Install two thrust plate mounting bolts and tighten to “Special Torque (page 132).”

   NOTE: Bolts securing timing disk to cam gear should be replaced every time timing disk is removed.

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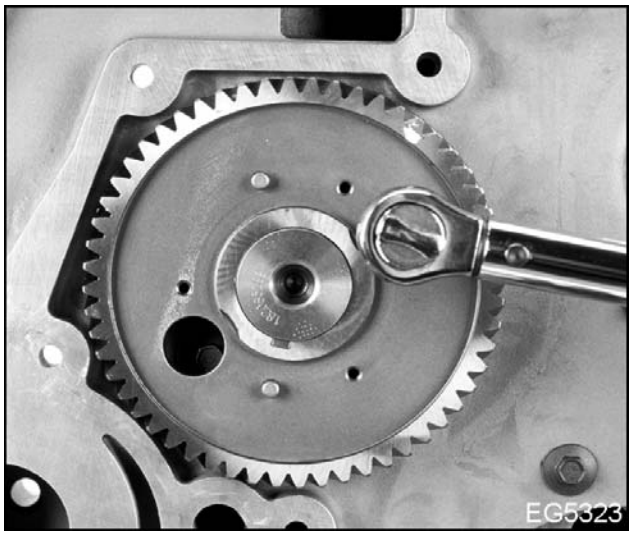

Figure 196 Install thrust plate mounting bolts

4. Install camshaft gear timing disk plate over two dowel pins with three new timing disk screws. Tighten screws to “Special Torque (page 132).”

Figure 197 Torque camshaft gear timing disk plate

5. Install idler gears, see “Install Idler Gear Assembly (page 235)” in the “Timing Gear Train and Front Cover” section of this manual, for more information.
6. Measure camshaft gear backlash and camshaft end play, see “Measure Gear Train Backlash (page 230)” in the “Timing Gear Train and Front Cover” section of this manual, for more information.

Tappets

If roller tappets are reusable, lubricate roller tappets and guides with clean engine oil. Install in their original bores. If new tappets are used, install new tappets.

CAUTION: To prevent possible engine damage, do not install new style valve train components in engines produced with old style valve train components. Replacement of old style valve train components requires complete replacement of all valve train components, including push rod assemblies, roller tappet assemblies, and rocker arm assemblies.

Figure 198 Lubricate roller tappets and guides

NOTE: Make sure reused tappet rollers are all turned in same direction as when removed.

Push Rods

Install push rods with cup end up, see “Install Push Rod (page 97)” in the “Cylinder Head and Valves” section of this manual, for more information.

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Special Information

Specifications

Camshaft	
Cam lobe lift (total):	
Intake	8.085 mm (0.31833 in)
Exhaust	7.365 mm (0.28998 in)
Maximum permissible cam lobe wear	0.51 mm (0.020 in)
Camshaft radial clearance	0.05 to 0.20 mm (0.002 to 0.008 in)
Bushing inside diameter (installed in crankcase)	58.026 to 58.115 mm (2.2845 to 2.2880 in)
Bushing journal diameter	57.948 to 57.976 mm (2.2814 to 2.2825 in)
Service bushings furnished to size	Yes
Thrust plate thickness (new)	6.96 to 7.01 mm (0.274 to 0.276 in)
Camshaft end play	0.13 to 0.33 mm (0.005 to 0.013 in)
Valve Lever and Shaft Assembly	
Valve lever shaft diameter	28.653 to 28.679 mm (1.1281 to 1.1291 in)
Valve lever clearance on shaft	0.076 to 0.127 mm (0.003 to 0.005 in)
Valve lever inside diameter (phosphate coated)	28.755 to 28.780 mm (1.1321 to 1.1331 in)
Tappets Roller	
Diameter	28.435 to 28.448 mm (1.1195 to 1.1200 in)
Length	74.24 to 75.01 mm (2.923 to 2.953 in)
Side clearance (roller to tappet body)	(0.010 to 0.026 in)
Tappet Clearance in crankcase	0.064 to 0.102 mm (0.0025 to 0.0040 in)
Push Rod	
Length	274.485 to 275.247 mm (10.8065 to 10.8365 in)[1]
Maximum runout (TIR)	0.51 mm (0.020 in)
Valve Lever Shaft Springs	
Number of springs	5
Free length	103.1 mm (4.06 in)
Test length	52.6 mm (2.07 in)
Test load	31 N·m (22 lbf·ft)
Outside diameter	33.629 mm (1.324 in)

[1] Length is measured over 7.9375 mm (0.3125 in) diameter gauge ball in cup end to theoretical end of ball.

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New Style Valve Train Components	
Valve Lever and Shaft Assembly	
Valve lever shaft diameter	28.653 to 28.679 mm (1.1281 to 1.1291 in)
Valve lever clearance on shaft	0.076 to 0.127 mm (0.003 to 0.005 in)
Valve lever inside diameter (phosphate coated)	28.755 to 28.780 mm (1.1321 to 1.1331 in)
Tappet Roller Assembly	
Diameter	27.838 to 28.042 mm (1.1195 to 1.1200 in)
Length	74.117 to 75.133 mm (2.918 to 2.958 in)
Side clearance (roller to tappet body)	(0.010 to 0.026 in)
Tappet Clearance in crankcase	0.064 to 0.102 mm (0.0025 to 0.0040 in)
Push Rod	
Length	273.736 to 274.498 mm (10.777 to 10.807 in)[1]
Maximum runout (TIR)	0.51 mm (0.020 in)

[1] Length is measured over 11.9304 mm (0.4697 in) diameter gauge ball in cup end to theoretical end of ball.

Camshaft Bushing Chart

Bushing Bore Bushing Position	Bushing Outside Diameter	Bushing Bore In Crankcase	Bushing Width
Front	63.627 to 63.665 mm (2.5050 to 2.5065 in)	63.512 to 63.550 mm (2.5005 to 2.5020 in)	25.4 mm (1.00 in)
Intermediate/Front	63.157 to 63.627 mm (2.4850 to 2.4865 in)	63.004 to 63.042 mm (2.4805 to 2.4820 in)	17.5 to 18.0 mm (0.689 to 0.709 in)
Intermediate/ Rear	62.611 to 62.649 mm (2.4650 to 2.4665 in)	62.534 to 62.611 mm (2.4605 to 2.4620 in)	17.5 to 18.0 mm (0.689 to 0.709 in)
Rear	62.103 to 62.141 mm (2.4450 to 2.4465 in)	61.988 to 62.026 mm (2.4405 to 2.4420 in)	17.8 mm (0.700 in)

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Special Torque Values

Camshaft Thrust Plate Bolt	26 N·m (19 lbf·ft)
Camshaft Gear Timing Disk Screws	7 N·m (60 lbf·in)

Special Service Tools

Camshaft Bushing Service Set	ZTSE2893B
Camshaft Gear Puller	ZTSE4411
Cylinder Head Bolt Gage	ZTSE4481
Dial Indicator with Magnetic Base	Obtain locally
Outside Micrometer	Obtain locally
Snap Ring Tool	Obtain locally
Telescoping Gauge	Obtain locally
Valve and Clutch Spring Tester	ZTSE2241

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Exploded View

Connecting Rods, Pistons, Rings, and Sleeves

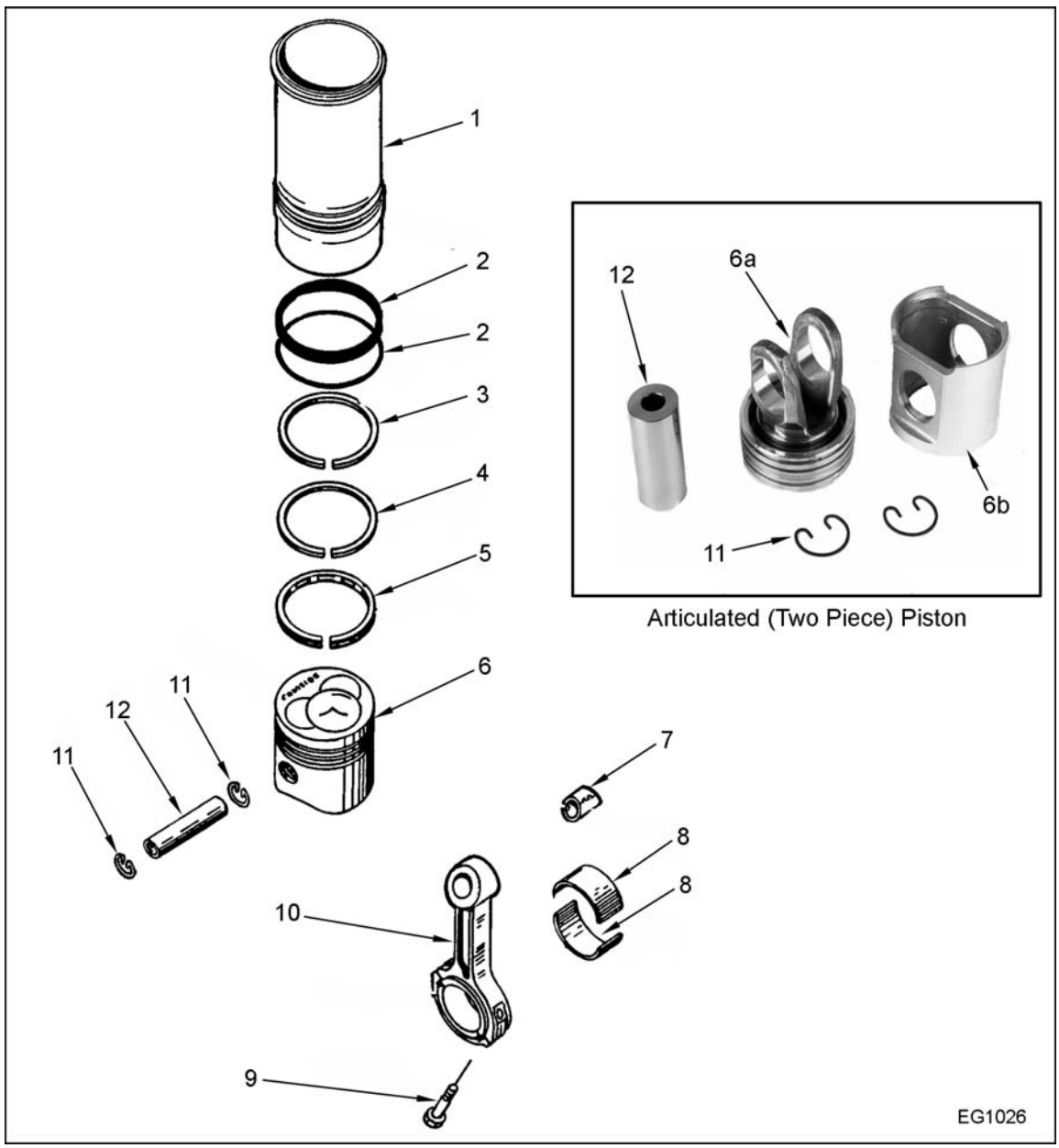

Figure 199 Connecting Rods, Pistons, Ring, and Sleeves

1. Sleeve (6)
2. Sleeve Seals
3. Piston Ring - Top Compression (6)
4. Piston Ring - Intermediate Compression (6)
5. Piston Ring - Oil Regulating (6)
6. Piston (6)
   a. Piston Crown (6)
   b. Piston Skirt (6)
7. Piston Pin Bushing (6)
8. Connecting Rod Bearing (12)
9. Bolt (12)
10. Connecting Rod And Cap (6)
11. Piston Pin Retainer (12)
12. Piston Pin (6)

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Remove

Piston and Rod Assembly

There are two types of connecting rods used on this engine for model years 2000 through 2003. The connecting rods are easily identified by the way the connecting rod caps are secured to the connecting rods.

Forged steel connecting rods are secured to the connecting rod with bolts and nuts.

Powdered metal forged steel connecting rods are secured with bolts that thread into the connecting rod (no nuts used).

The connecting rod is constructed of forged steel. It is attached to the crankshaft, one per journal. The pistons are cast aluminum alloy or steel crown with an aluminum skirt. All pistons are fitted with two compression rings and one oil ring. The piston pin is a free floating type, permitting the pin to move or float freely in the piston and connecting rod, and is held in place with pin retaining rings.

Forged Connecting Rods

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.

CAUTION: To avoid engine damage, if a carbon ridge has developed at top of cylinder sleeve, use a razor knife to scrape it off before removing piston assemblies. Care must be taken not to damage sleeve bore surface when removing carbon.

NOTE: Mark each connecting rod cap and reassemble to its respective connecting rod upon removal. Also, mark location of each connecting rod in crankcase.

1. Use razor knife to scrape carbon ridge from top of cylinder sleeve.
2. Loosen connecting rod bolts using a socket and breaker bar.

Figure 200 Remove connecting rod bolts

3. Remove bolts by hand.

NOTE: Bolts should turn out of connecting rod freely. If binding exists, check thread condition carefully.

4. Remove connecting rod cap and bearing insert.

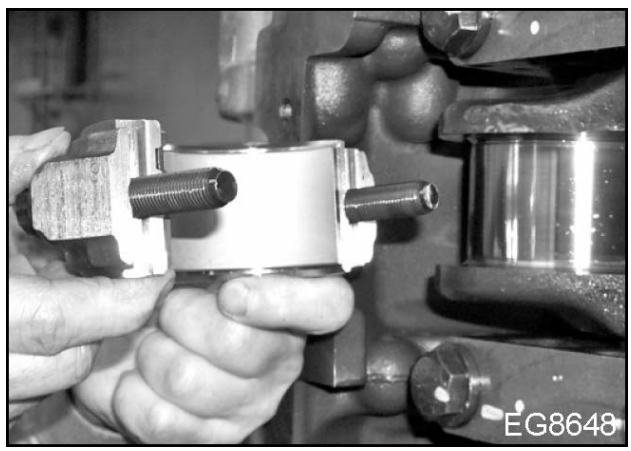

Figure 201 Remove connecting rod bearing cap

5. Rotate engine to vertical position (front end up).
6. Use hammer with plastic or wooden handle or non-marring punch to push piston out of cylinder sleeve.
7. Once piston rings are free of cylinder bore, assembly can be removed from top of crankcase.

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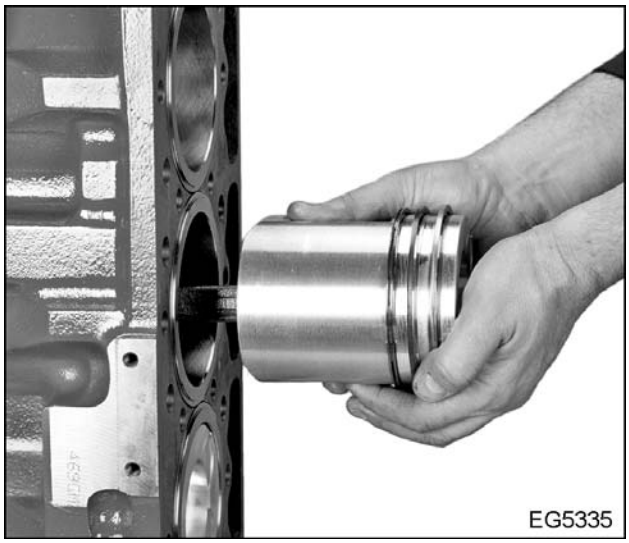

Figure 202 Remove piston and connecting rod assembly

8. Match connecting rod and piston assemblies upon removal so they can be installed in their respective cylinder bores.

Fractured Connecting Rods

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

CAUTION: To avoid engine damage, if carbon ridge has developed at top of cylinder sleeve, use a razor knife to scrape it off before removing piston assemblies. Care must be taken not to damage sleeve bore surface when removing carbon.

NOTE: For removing fractured connecting rods use the following procedures to avoid damaging mating surfaces.

1. Loosen both connecting rod bolts two turns.
2. Use brass hammer to tap on bolt heads until cap comes loose from connecting rod.

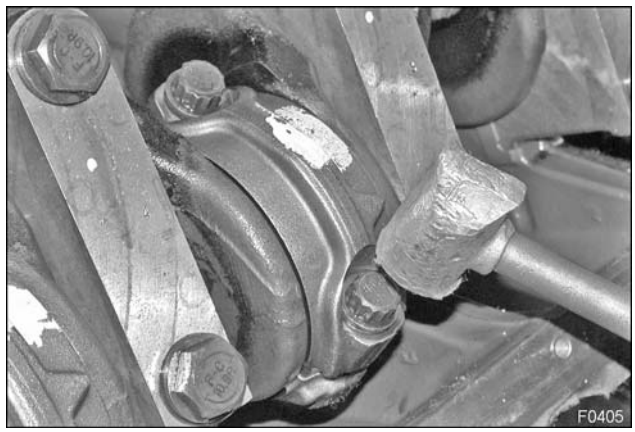

Figure 203 Remove connecting rod cap

3. Remove both bolts and cap.
4. Rotate engine to vertical position (front end up).

CAUTION: To avoid damage to the engine, do not force the piston out of the engine by pushing on the rod fracture surface.

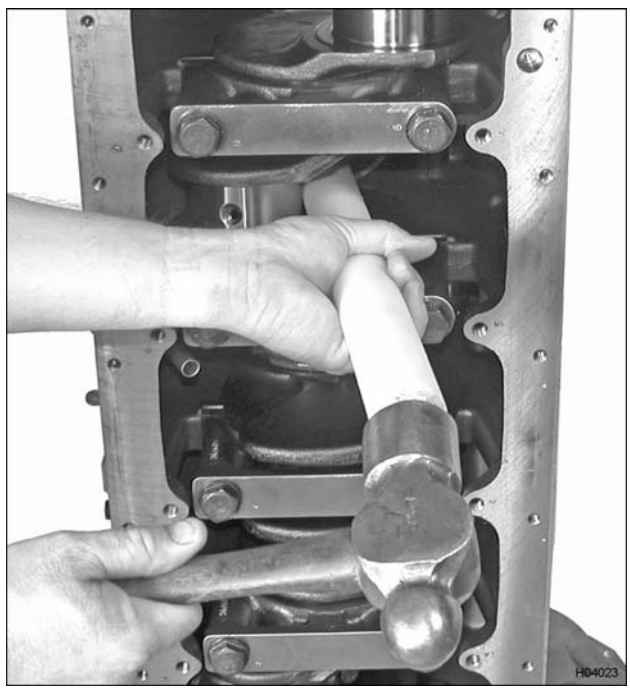

Figure 204 Push piston and connecting rod assembly

5. Do not push on rod fractured surface. Use hammer with plastic or wooden handle or

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non-marring punch to push piston out of cylinder sleeve.

6. Once piston rings are free of cylinder bore, assembly can be removed from top of crankcase.

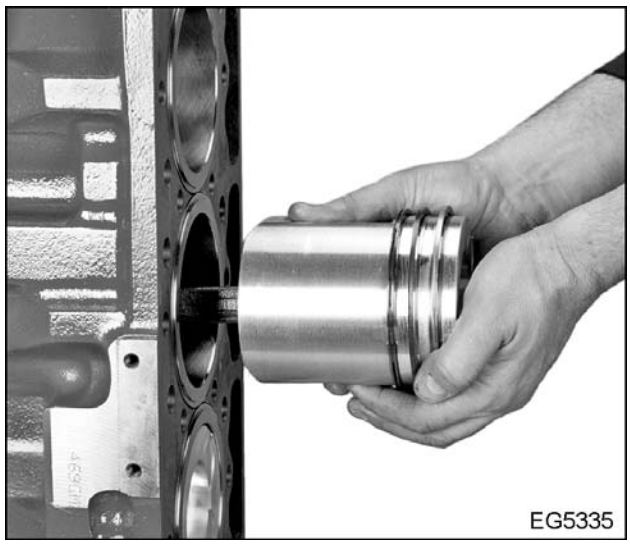

Figure 205 Remove piston and connecting rod assembly

7. Match connecting rod and piston assemblies upon removal so they can be installed in their respective cylinder bores.
8. If cap can be pulled away from connecting rod, proceed with assembly procedure in this manual.
9. If cap cannot be pulled away from connecting rod, place connecting rod on a work bench with cap extending over edge of work bench.

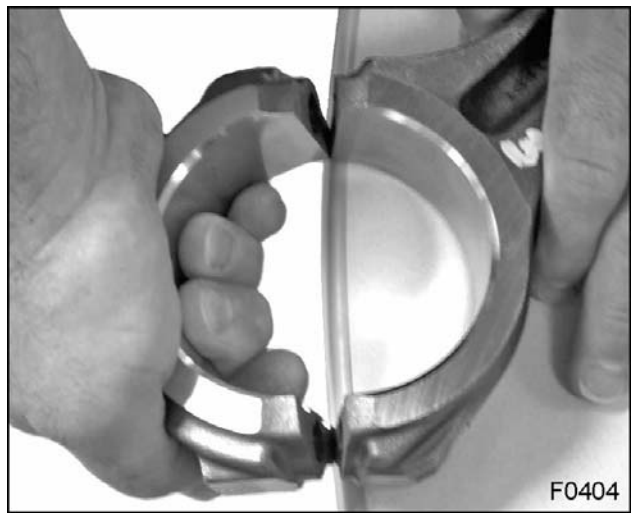

Figure 206 Split fractured connecting rod

10. Grasp connecting rod with one hand and cap outer half with other. Press down on cap to break it away from connecting rod half.

Cylinder Sleeve

NOTE: Before installing puller, bar engine over so crankshaft journal is located at bottom (low point) of its travel. This prevents possible damage to journal by puller lifting jaws during puller installation.

1. Remove cylinder sleeves with Cylinder Sleeve Puller (ZTSE2536) (page 163).

NOTE: When sleeve is removed from puller, mark sleeve with its cylinder bore number. Also mark sleeve position in engine block for purposes of inspection and assembly.

2. Position Cylinder Sleeve Puller in sleeve and spread lifting jaws so tangs grip bottom of sleeve.
3. With lifting bridge firmly on crankcase top deck, turn forcing nut to break cylinder sleeve loose from crankcase.
4. Lift sleeve and puller from crankcase.

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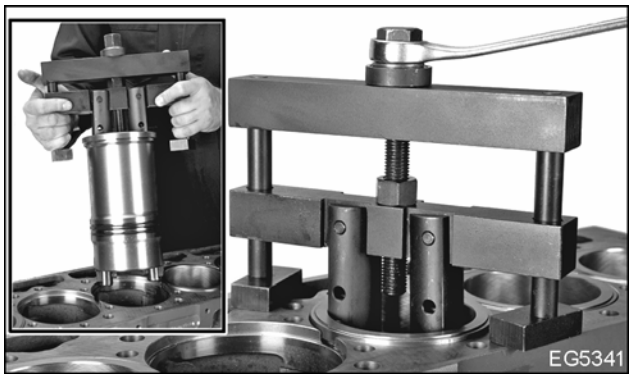

Figure 207 Remove cylinder sleeve

5. Remove and discard O-ring(s) at lower counterbore area of each cylinder sleeve.

Disassemble Connecting Rod, Piston, and Rings

1. Remove two piston pin retaining rings.

NOTE: Mark components with piston number from where they were removed, so they may be installed properly.

Figure 208 Remove piston pin retaining rings

2. Remove piston pin from its bore by hand. Separate connecting rod from piston.

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Figure 209 Remove piston pin

3. Remove piston skirt from piston crown on two-piece piston assemblies found on International® 530E diesel engines.

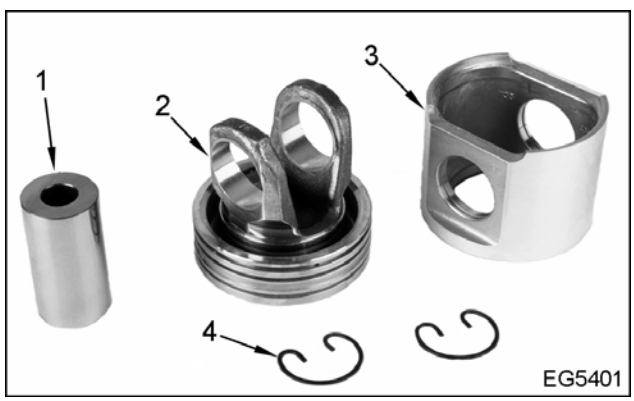

Figure 210 Two-piece piston assembly

1. Piston pin
2. Piston crown
3. Piston skirt
4. Retaining ring

4. Remove piston rings with Piston Ring Expander (ZTSE4220) (page 163). Remove top ring, intermediate ring, and oil control ring.

Figure 211 Remove piston rings

Clean, Inspect, and Test

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).

NOTE: Do not use a caustic solution on engine or related components.

Clean Connecting Rod, Piston, and Rings

1. Clean aluminum pistons using a soap and water solution. Soak and clean piston with non-metallic brush.

CAUTION: To avoid possible engine damage, never use wire brush for cleaning aluminum pistons.

2. Clean all piston ring grooves thoroughly.

NOTE: Make sure two oil drains in aluminum piston oil ring grooves are open.

3. Clean piston rings, piston pins, piston pin retainers and connecting rods components using suitable solvent.
4. Clean all rod bolt holes and threads thoroughly.
5. Clean oil hole at top of rod. Make sure it is not blocked.

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Clean Cylinder Sleeve

1. Soak cylinder sleeves in soap and water solution and clean thoroughly using non-metallic brush.
2. Dry with filtered compressed air.

Inspect Pistons

1. Inspect pistons for scuffed or scored skirts and cracked or worn lands. Replace pistons as required.
2. Check top and intermediate compression ring groove widths for wear. Install 2.921 mm (0.1150 in) gauge pins from Piston Groove Wear Measuring Tool (ZTSE3020) (page 163) in groove to be measured.

   NOTE: Gauge pins must be parallel.

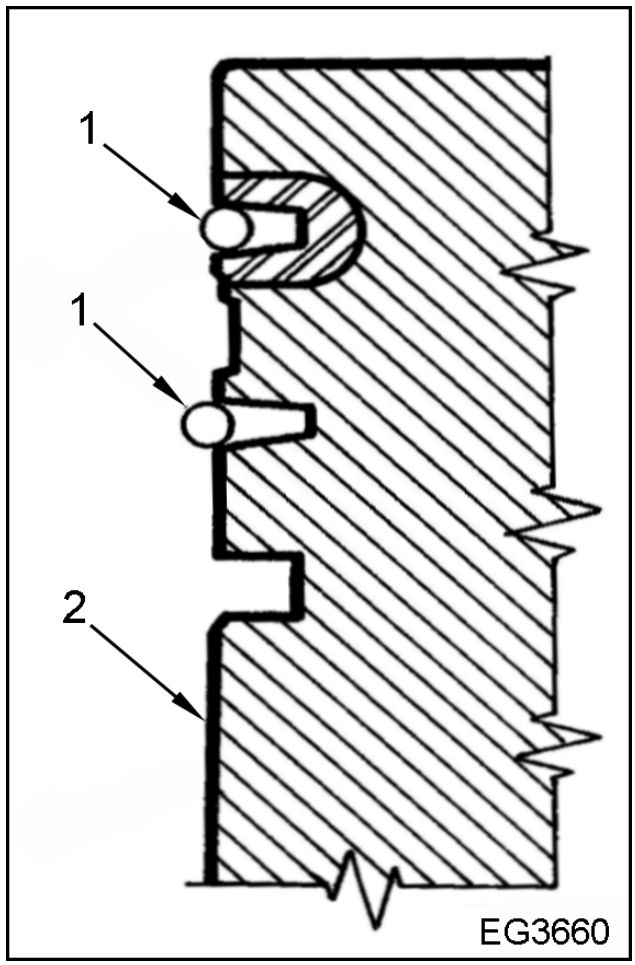

Figure 212 Setup piston ring groove measurement

1. Gauge pins - Piston Groove Wear Measuring Tool (ZTSE3020)
2. Piston

3. Measure piston ring groove diameter over gauge pins. Use an Outside Micrometer (page 163).

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Figure 213 Measure piston diameter

4. If measurement over gauge pins is not within “Specifications (page 161),” excessive piston groove wear exists and piston must be replaced with new piston.

NOTE: Rectangular ring grooves use side clearance instead of gauge pins to determine piston ring groove wear.

5. Measure rectangular oil control ring groove side clearance. Use new ring, place outer edge of ring in oil control ring groove.
6. Roll ring, in its respective groove, entirely around piston. Make sure ring is free in groove.
7. Measure oil control ring side clearance as ring is rolled around piston in groove with Feeler Gauge (page 163).

Figure 214 Measure oil control ring clearance

8. If side clearance measurement is not within “Specifications (page 161),” piston replacement is required. Excessive side clearance indicates ring groove wear.
9. Measure piston skirt diameter. With piston at room temperature, place an Outside Micrometer (page 163) 28.575 mm (1.125 in) from bottom of piston 90 degrees from pin bore.

Figure 215 Measure piston skirt diameter

10. Subtract piston skirt diameter from cylinder sleeve inside diameter. See “Measure Cylinder Sleeve” in this section. Resulting dimension is piston-to-cylinder sleeve running clearance.
11. If running clearance is not within “Specifications (page 161),” replace piston.

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Inspect Piston Rings

NOTE: Faulty rings cannot always be detected by visual inspection. Therefore, whenever a piston is removed from a cylinder, it is recommended that piston rings be replaced.

1. Inspect new rings for cleanliness.
2. Before installing rings on piston, check each ring for proper gap. Push ring down in cylinder sleeve making sure ring is square with cylinder sleeve wall.
3. Measure gap between ends of each ring with a Feeler Gauge (page 163). See “Specifications (page 161)” for ring gap. Discard any new ring that does not meet specifications.

Figure 216 Measure ring gap

Connecting Rods

Inspect Connecting Rods

1. Inspect connecting rod bolts for nicks or damage.
2. Inspect rod and cap mating surfaces for fretting. Replace as required.
3. 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.
4. Inspect connecting rod for twisting or a bent rod. Often engine component wear patterns can be identified and used to diagnose a problem. Some common examples of connecting rod wear patterns include:
   - A shiny surface on edge of piston pin bushing usually indicates that a connecting rod is bent or piston pin hole is not in proper relation to piston skirt and ring grooves.
   - Abnormal connecting rod bearing wear can be caused by either a bent connecting rod or a tapered connecting rod bore.
   - Slightly twisted connecting rods will not create an easily identifiable wear pattern but badly twisted rods will disturb action of entire piston, rings, and connecting rod assembly and may be a cause of excessive oil consumption.

   If any of these conditions exist, check connecting rods for bends or twists using a suitable alignment fixture. Follow instructions of fixture manufacturer.

CAUTION: To avoid engine damage when servicing, do not mix forged connecting rods with fractured connecting rods in the same engine. Weights of connecting rods are different and will cause engine vibration if mixed.

NOTE: If connecting rod is bent or twisted, replace entire connecting rod assembly. If connecting rods do not meet “Specification (page 161)” for connecting rod measurements, replace entire connecting rod assembly.

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Assemble Fractured Connecting Rods

CAUTION: To avoid engine damage when servicing, do not mix forged connecting rods with fractured connecting rods in the same engine. Weights of connecting rods are different and will cause engine vibration if mixed.

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

CAUTION: To avoid engine damage, if rod cap is reversed when assembled to connecting rod or a rod cap is not installed on its original matching connecting rod, fractured mating surfaces will be permanently damaged. This may cause rod cap to come loose. Entire connecting rod must be replaced.

Specification Changes for Fractured Connecting Rod Assembly

Specification	Forged Connecting Rods	Fractured Connecting Rods
Connecting Rod Assembly Weight	3.20 kg (7.05 lb)	3.40 kg (7.50 lb)
Connecting Rod Bushing Bore Diameter	48.88 mm (1.9245 in)	49.90 mm (1.9645 in)
Connecting Rod Bushing Outside Diameter	49 mm (1.9300 in)	50 mm (1.9685 in)
Connecting Rod Bushing Inside Diameter (installed)	46.37 mm (1.8258 in)	46.39 mm (1.8266 in)

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1. Keep each cap with its respective rod. Match serial numbers on side of each rod and cap.

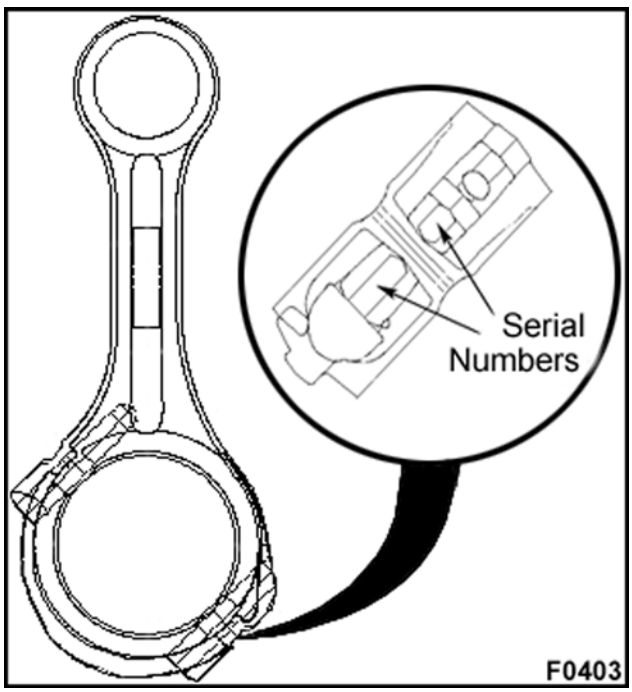

Figure 217 Match serial number

NOTE: Fractured mating surfaces of each rod and cap pair are precisely matched.

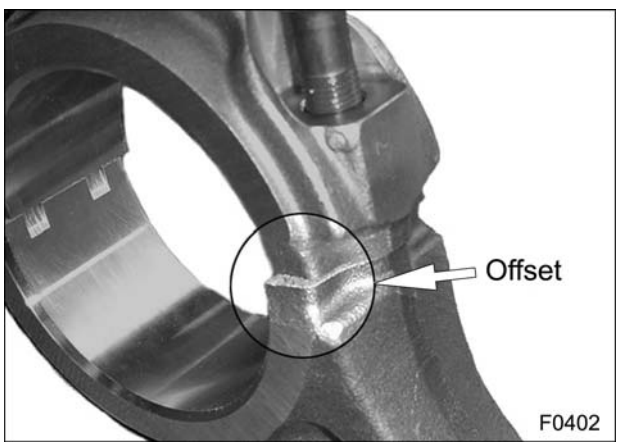

Figure 218 Incorrect rod cap assembly

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

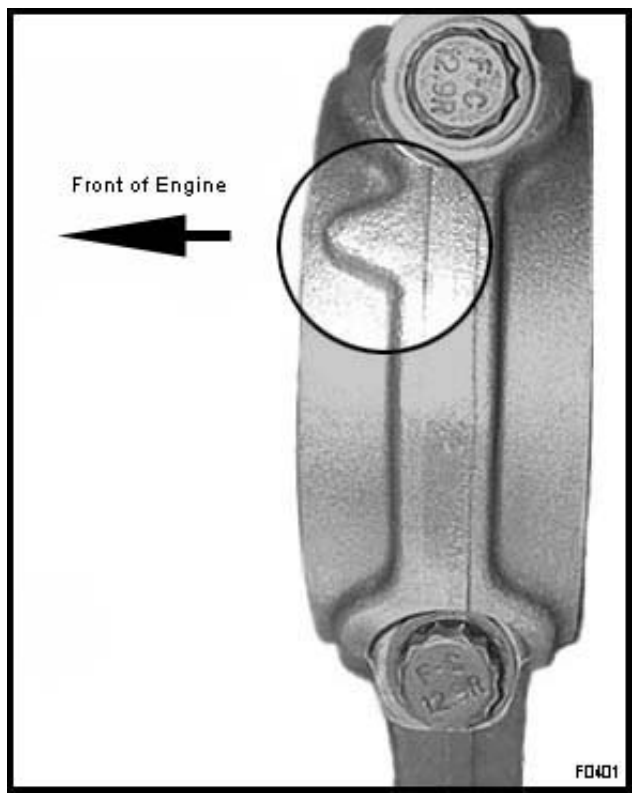

Figure 219 Correct orientation

Each rod cap has an arrow for correct orientation in engine during installation. Arrow must point toward front of engine.

Measure Connecting Rods

1. Measure connecting rod piston pin bushing at two locations 90° apart, with Telescoping Gauge Set (OEM1022) (page 163) and Outside Micrometer.

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Figure 220 Measure connecting rod piston pin bore

2. If piston pin bushing measurement exceeds “Specification (page 161),” replace entire connecting rod assembly.

Measure Connecting Rod Bore for Out-of-Round

1. Lubricate connecting rod bolts with clean engine oil and assemble cap to rod without bearing insert. Insert rod bolts fully by hand. Tighten bolts to “Special Torque (page 163).”

NOTE: When lubricated with clean engine oil, bolts must screw in rod by hand. If resistance is met, clean rod threads and retry, or try a new bolt. If a new bolt does not screw in freely, rod must be discarded. Rod threads cannot be re-tapped.

2. Measure connecting rod in three locations, with a Telescoping Gauge Set (OEM1022) and Outside Micrometer or an Inside Micrometer (page 163).

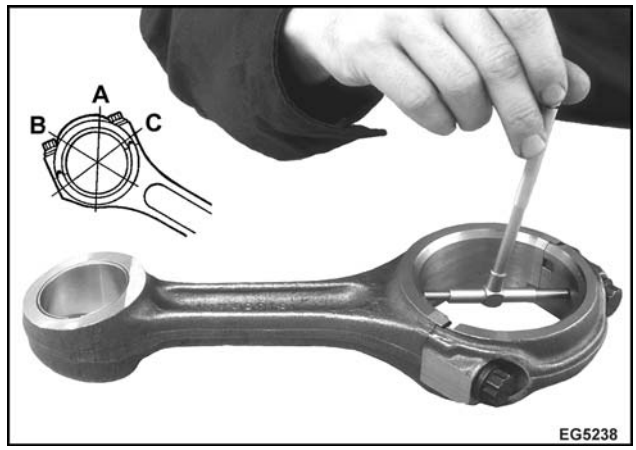

Figure 221 Measure connecting rod for out-of-round

3. If difference between point “B” and average of points “A” and “C” “([A + C] ÷ 2)” exceeds “Specifications (page 161),” entire connecting rod assembly must be replaced.

Measure Connecting Rod Bearing Bore Taper

1. Measure connecting rod bearing bore inside diameter on each side of bearing bore, with a Telescoping Gauge Set (OEM1022) and Outside Micrometer or an Inside Micrometer (page 163).

Figure 222 Measure connecting rod bearing bore taper

2. If difference between two measurements (bore taper) exceeds “Specifications (page 161),” entire connecting rod assembly must be replaced.

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Piston Pins

Inspect Piston Pins

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

Measure Piston Pin Outside Diameter

1. Measure piston pin outside diameter at two locations with Outside Micrometer (page 163).

Figure 223 Measure piston pin outside diameter

2. If piston pin wear exceeds “Specifications (page 161),” replace piston pin.

Measure Piston Pin Clearance

1. Determine piston pin clearance in rod. Subtract piston pin outside diameter measurement, see “Measure Piston Pin Outside Diameter” in this section, from piston pin bushing inside diameter measurement, see “Measure Connecting Rods” in this section.
2. If clearance exceeds “Specifications (page 161),” replace the connecting rod assembly.

Cylinder Sleeves

Inspect Cylinder Sleeves

1. Inspect inside surface of sleeve for indications of scuffing, scoring, or polishing. Replace sleeve and piston as required.
2. Inspect outer surface of sleeve for cavitation erosion. Replace as required.

Measure Cylinder Sleeve: Telescoping Gauge Method

1. Measure cylinder sleeve inside diameter at top of piston ring travel (just below carbon ridge area) with Telescoping Gauge Set (OEM1022) and Outside Micrometer (page 163).

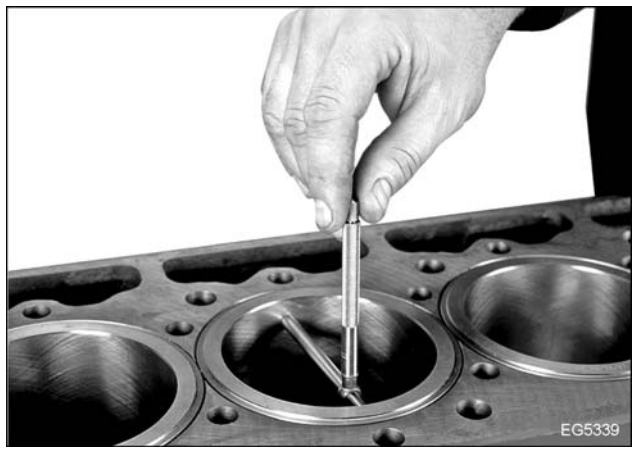

Figure 224 Measure cylinder sleeve inside diameter

2. Measure cylinder sleeve inside diameter at the bottom just below ring travel area.

Figure 225 Measure cylinder sleeve inside diameter

3. Determine cylinder sleeve wear (taper), measure difference between upper sleeve inside diameter and lower sleeve inside diameter.

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4. If cylinder sleeve wear “Specifications (page 161)” are exceeded, replace sleeve.

Measure Cylinder Sleeve: Cylinder Bore Gauge Method

1. Measure cylinder sleeve inside diameter at top of piston ring travel, just below carbon ridge area with Cylinder Bore Gauge (OEM1032) (page 163).

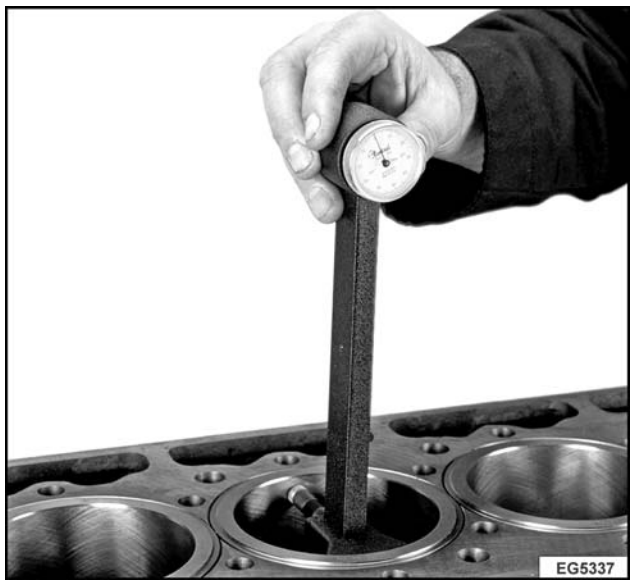

Figure 226 Measure cylinder sleeve upper diameter

2. Measure cylinder sleeve inside diameter at bottom of piston ring travel, just below ring travel area.

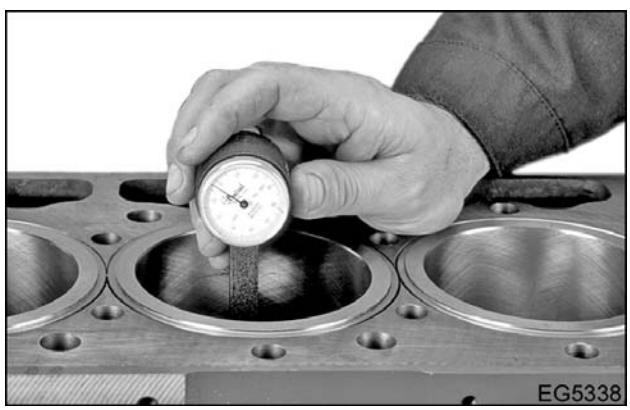

Figure 227 Measure cylinder sleeve lower diameter

3. Determine cylinder sleeve wear (taper), measure difference between upper sleeve inside diameter and lower sleeve inside diameter.
4. If cylinder sleeve wear “Specifications (page 161)” are exceeded, replace sleeve.

Measure Cylinder Sleeve: Feeler Gauge Method

1. Measure cylinder sleeve inside diameter at top of piston ring travel, just below carbon ridge area. Install compression (top) ring squarely above top of ring travel. Measure ring end gap with a Feeler Gauge.

NOTE: Use piston to be sure ring is seated squarely in bore.

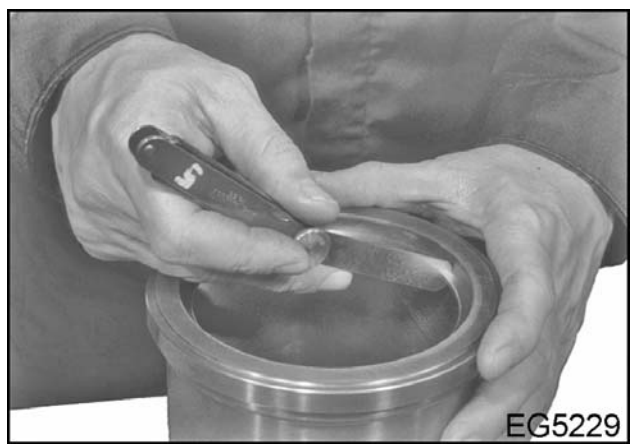

Figure 228 Measure ring gap

2. Measure cylinder sleeve inside diameter at bottom of piston ring travel, just below ring travel area. Install same piston ring squarely below top ring travel turnaround area and measure ring end gap.
3. Determine cylinder sleeve wear (taper), measure difference between upper sleeve inside diameter and lower sleeve inside diameter. Every 0.07 mm (0.003 in) increase in ring gap equals a 0.025 mm (0.001 in) increase in bore size.
4. If cylinder sleeve wear “Specifications (page 161)” are exceeded, replace sleeve.

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Measure Cylinder Sleeve Counterbore: Cylinder Liner Height Gauge Method

1. Mount Cylinder Liner Height Gauge (page 163) on crankcase deck. Zero dial indicator on crankcase deck.

Figure 229 Measure cylinder sleeve counterbore depth

2. Move indicator to counterbore ledge and measure depth. Perform counterbore depth measurement at four points equal distance around counterbore.
3. If maximum variation between four measurement points for counterbore depth exceeds “Specifications (page 161),” resurface counterbore.

Measure Cylinder Sleeve Counterbore: Depth Micrometer Method

1. Measure cylinder sleeve counterbore depth at four points around sleeve with a Depth Micrometer (page 163).

Figure 230 Measure cylinder sleeve counterbore depth

2. If maximum variation between four measurement points for counterbore depth exceeds “Specifications (page 161),” resurface counterbore.

Measure Cylinder Sleeve Protrusion

1. Thoroughly clean cylinder sleeve and counterbore area of crankcase.
2. Install cylinder sleeve in cylinder bore without O-rings. Install Cylinder Liner Holding Adapters (ZTSE25151) (page 163) with grade 8 bolts and hardened washers. Tighten all three bolts in two steps as follows:
   a. Torque bolts to 55 N·m (40 lbf·ft).
   b. Torque bolts to 110 N·m (80 lbf·ft).

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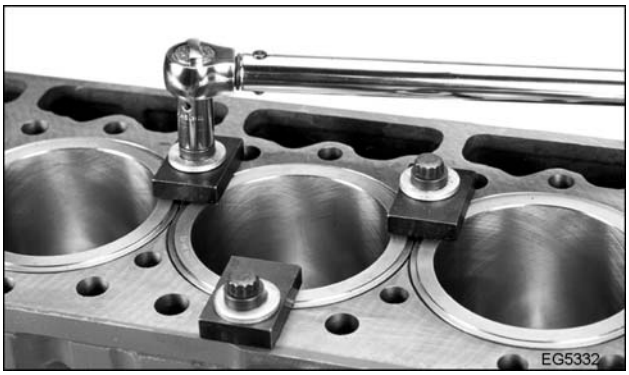

Figure 231 Torque Cylinder Liner Holding Adapters

3. Place dial indicator tip of Surface Gauge (page 163) on cylinder sleeve flange. Zero indicator and move block until indicator tip slides off flange to crankcase deck.

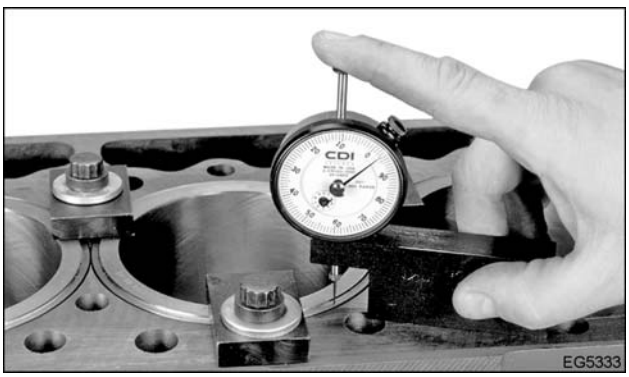

Figure 232 Measure cylinder sleeve protrusion

4. Take measurements at three points around sleeve.
5. Use average measurement to determine which shim(s), if any, is needed to bring cylinder sleeve protrusion within “Specifications (page 161).” See “Adjust Cylinder Sleeve Protrusion” in this section for more information.

Bearing Fit

About Bearing Crush and Spread

Bearing shells must fit tightly in bore. When bearing shells are inserted in connecting rod and cap, they protrude above paring line. This protrusion is required to achieve “Bearing Crush.”

Bearing shells are designed with “Spread.” That is, width across open ends are slightly larger than diameter of connecting rod bore in which they are assembled. This condition is designed in bearing shell. By inserting crankshaft, it pushes the bearing downward in the bore thus forcing the bearing ends inward.

Some “Snap” may be lost in normal use but bearing replacement is not required because of a nominal loss of “Snap.”

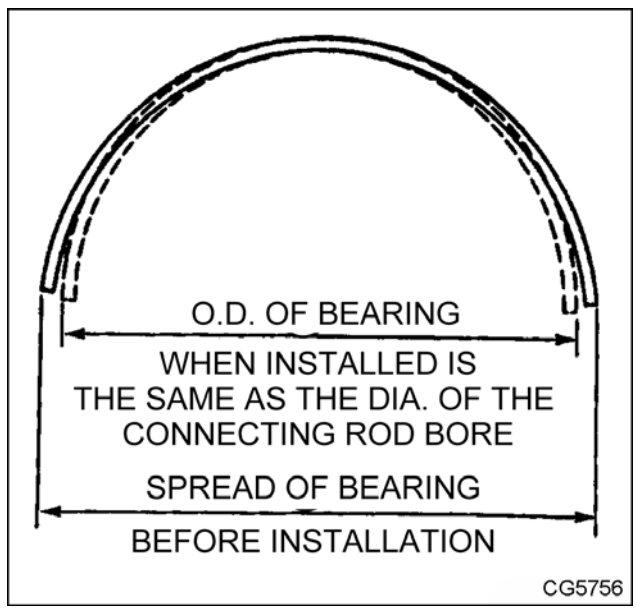

Figure 233 Bearing fit

1. Outside Diameter of Bearing (same as the diameter of the connecting rod bore when installed)
2. Spread of Bearing (before installation)

If bearing-to-crankshaft running clearances exceed specifications because of wear on the crankshaft, replace or regrind crankshaft and install under size precision-type bearing shells. See “Install Crankshaft and Main Bearings (page 195)” in the “Vibration Damper, Crankshaft, Main Bearings, Flywheel, and Crankcase” section in this manual, for procedure.

NOTE: Do not attempt to reduce journal-to-bearing running clearances by reworking bearing cap, bearings, or both. Regrind or replace crankshaft only.

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Measure Connecting Rod Bearing Crush

CAUTION: To avoid engine damage when servicing, do not mix forged connecting rods with fractured connecting rods in the same engine. Weights of connecting rods are different and will cause engine vibration if mixed.

CAUTION: To avoid engine damage, reworking bearing cap or bearing will destroy engineered fit of bearing shells in their bores.

1. Tighten connecting rod bolts alternately and evenly to “Special Torque (page 163).”

NOTE: When assembly is drawn up tight, bearing is compressed, ensuring positive contact between bearing back and bore.

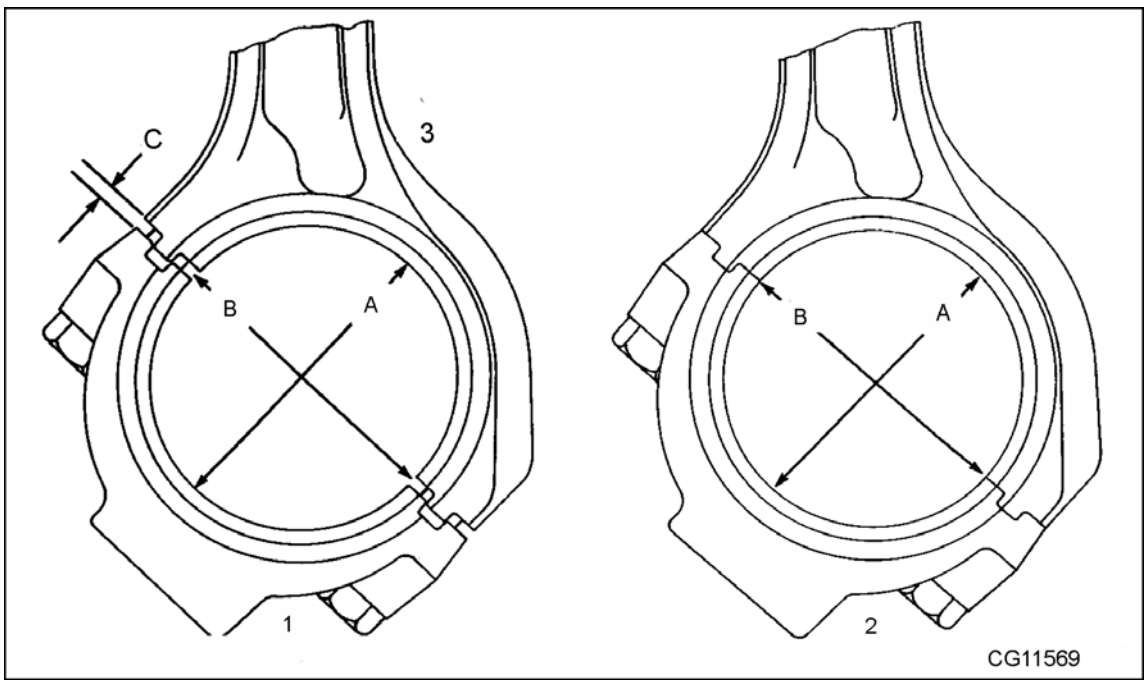

Figure 234 Measure bearing crush

1. Diameter (A) at right angles to parting lines is greater than diameter (B).
2. With bearing cap drawn up tight, diameters (A) and (B) are equal.
3. Difference between diameters (A) and (B) is Bearing Crush (C).

Measure Connecting Rod Bearing Running Clearance

1. With bearing cap removed, wipe oil from face of bearing insert and exposed portion of crankshaft journal.
2. Place a piece of Plastigage® across full width of bearing about 6 mm (1/4 in) off center.
3. Install bearing cap. Tighten bolts evenly and alternately to “Special Torque (page 163).”

NOTE: Do not turn crankshaft during running clearance check.

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4. Remove connecting rod bearing cap. The Plastigage® will be found adhering to either bearing shell or crankshaft. Do not remove Plastigage®. Use Plastigage® scale to measure widest point of flattened plastic material. The number in graduated marks on scale indicates clearance in thousandths of an inch or millimeters.

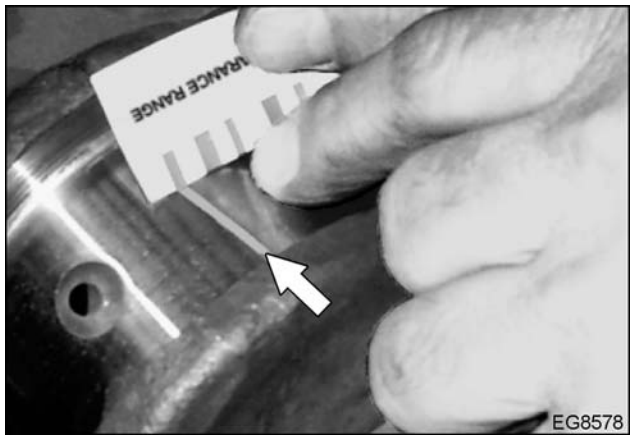

Figure 235 Measure flattened plastic material

5. Completely remove test material (crushed Plastigage® material) and repeat test for each connecting rod bearing.
6. If bearing-to-crankshaft running clearances exceed “Specifications (page 161),” replace or regrind crankshaft and install under size precision-type bearing shells. See “Install Crankshaft and Main Bearings (page 195)” in the “Vibration Damper, Crankshaft, Main Bearings, Flywheel, and Crankcase” section in this manual, for procedure.

NOTE: Bearing cap torque is very important. Repeat running clearance check procedure before condemning crankshaft.

NOTE: With precision bearings used, no problem should be encountered. If proper clearance is not achieved, a problem with connecting rod, bearing set, or crankshaft may exist which requires regrinding and use of under size bearings.

7. Measure side clearance between connecting rod and crankshaft journal with Feeler Gauge (page 163).

Figure 236 Measure connecting rod side clearance

Measure Connecting Rod Side Clearance

Lack of connecting rod side clearance could indicate a damaged rod or a rod bearing out of position. Excessive connecting rod side clearance may require replacement of the rods or crankshaft.

1. Place tip of Dial Indicator on connecting rod cap.
2. Pry connecting rod cap toward rear of the engine and zero dial indicator.
3. Pry connecting rod cap toward front of engine. Read Dial Indicator.
4. Connecting rod side clearance must be in “Specification (page 161).” Repeat this procedure for all connecting rods.

NOTE: Connecting rod side clearance must be checked to be sure that specified clearance exists.

Recondition Cylinder Sleeve

Recondition Cylinder Sleeve Counterbore

Check crankcase counterbore depth with Cylinder Liner Height Gauge (ZTSE2515A) or Depth Micrometer (page 163).

Preparation

1. Prepare Counterbore Tool (ZTSE2514) (page 163) with appropriate Counter Bore Cutting Head.

NOTE: The counterbore tool is a low profile tool which can be used in-chassis.

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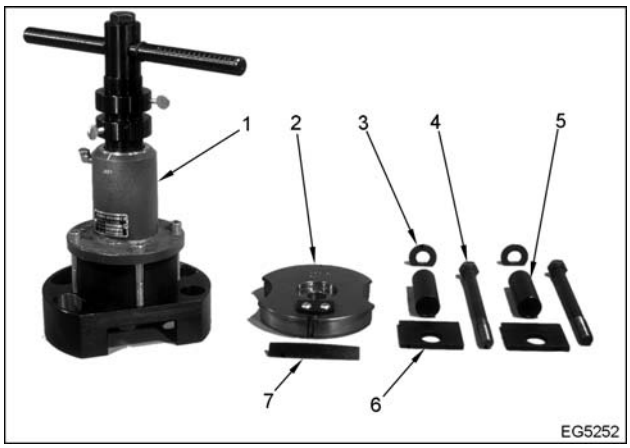

Figure 237 Counterbore Tool

1. Counterbore Tool
2. Counter Bore Cutting Head
3. Washers (2)
4. Mounting bolts (2)
5. Spacer (2)
6. Locking plate (7)
7. Feeler Gauge

2. Preset Counter Bore Cutting Head by placing a 0.20 to 0.25 mm (0.008 to 0.010 in) Feeler Gauge (page 163) on outside of cutter head. Push cutting head out until it touches Feeler Gauge. Lock cutting head in place by tightening locking plate.

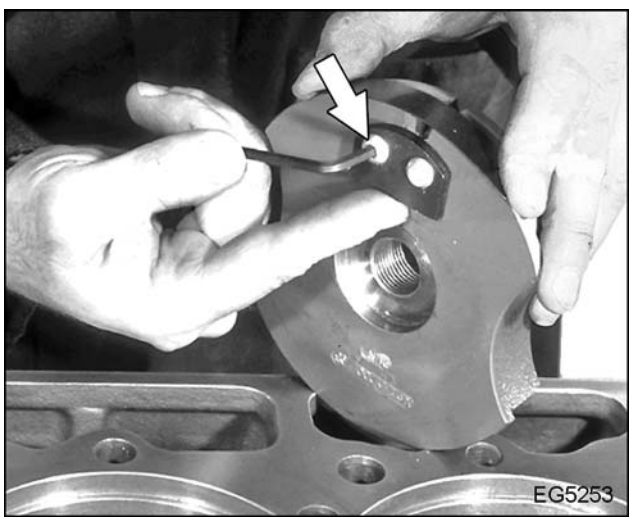

Figure 238 Lock cutting head

3. Install cutter head on Counterbore Tool.

4. Raise cutter head, pull plunger and lifting handle. Attach Counterbore Tool to crankcase. Tighten mounting bolts finger tight. Torque mounting bolts to 45 N·m (33 lbf·ft).

Figure 239 Position Counterbore Tool

1. Turn knuckles
2. Locking screws
3. Mounting bolts (2)
4. Spacers (2)
5. Washers (2)
6. Locking plates (2)

5. Lower cutting head, loosening locking screws on turn knuckles. Pull plunger up to desired height. Tighten turn knuckle in opposite direction and lock in place with locking screws.
6. Set depth of cut, see “Resurface, Setting Depth with Graduated Marks on Tool” or “Resurface, Setting Depth with Feeler Gauge” in this section.

Resurface, Setting Depth with Graduated Marks on Tool

1. Loosen locking screw.
2. Rotate adjusting nut counterclockwise until nut contacts driver unit housing.
3. Back off adjusting nut by amount of cut desired.

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NOTE: Each graduated marking equals 0.025 mm (0.001 in). If 0.050 mm (0.002 in) material will be removed, you must back off adjusting nut two marks.

Never attempt to remove more than 0.050 mm (0.002 in) material at any one time.

4. Tighten adjusting nut lock screw.

Resurface, Setting Depth with Feeler Gauge

1. Loosen locking screw.
2. Insert appropriate size Feeler Gauge 0.05 mm (0.002 in.) (page 163) maximum between upper and lower turn knuckle. Rotate upper turn knuckle until feeler gauge is just held in place.

Figure 240 Set Counterbore Tool

3. Tighten locking screw and remove feeler gauge.

Cut Cylinder Sleeve Counterbore

CAUTION: To avoid possible engine damage and damage to tool, do not rotate Counterbore Tool counterclockwise when cutting tool is in contact with cylinder sleeve counterbore.

1. Rotating Counterbore Tool handle smoothly clockwise, cutting cylinder sleeve counterbore. Continue until tool handle turns freely and is bottomed out between adjusting nut and top of tool housing.

Figure 241 Cut cylinder sleeve counterbore

2. Once counterbore has been resurfaced, remove Counterbore Tool.
3. Clean counterbore, measure counterbore depth. See “Measure Cylinder Sleeve Counterbore” in this section.

Adjust Cylinder Sleeve Protrusion

1. Remove Cylinder Liner Holding Adapters and cylinder sleeve.
2. Clean crankcase top deck and cylinder sleeve counterbore.

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3. Install shim(s) as required to bring protrusion above crankcase deck within “Specifications (page 161).”

Shim Packaging

Shim Size - mm	Shim size - in
0.01	0.0004
0.05	0.002
0.25	0.010
0.51	0.020
0.81	0.032

4. Follow cylinder sleeve installation instructions. See “Install Cylinder Sleeves” later in this section.

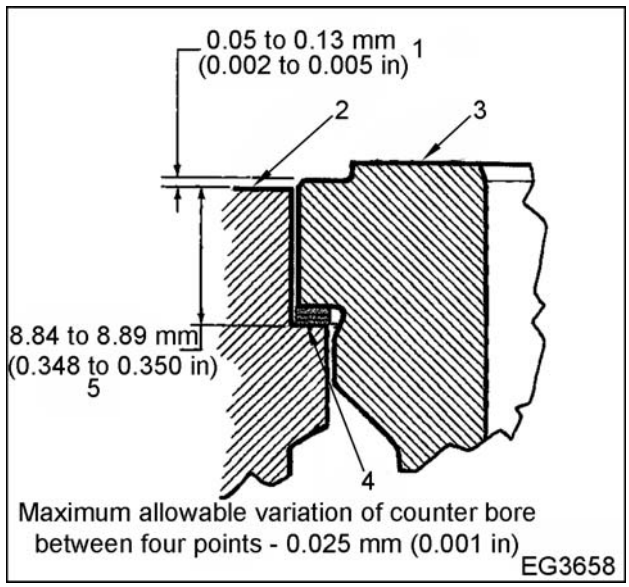

Figure 242 Install shims

1. Sleeve protrusion
2. Crankcase top surface
3. Sleeve
4. Shim to suit
5. Maximum allowable counter bore - 10.49 mm (0.413 in)

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Install

Install Cylinder Sleeve

1. Lubricate cylinder sleeve O-ring(s) with clean engine oil. Install O-ring(s) in cylinder sleeve groove (do not allow O-ring(s) to twist).

Figure 243 Lubricate cylinder sleeve and rings

2. Install proper shim(s) in crankcase counterbore (as required). See “Adjust Cylinder Sleeve Protrusion (page 154)” in this section.
3. Make sure O-rings are properly aligned in each groove.
4. Apply clean engine oil to lower crankcase counterbore.

Figure 244 Lubricate cylinder sleeve bore

5. Carefully install cylinder sleeve. If reusing sleeve, rotate sleeve 90° from original position. Reused sleeve must be installed in original bore.

Figure 245 Install cylinder sleeve

6. After installation, measure cylinder sleeve protrusion. See “Measure Cylinder Sleeve Protrusion (page 149)” in this section.
7. Measure cylinder sleeve bore dimensions and sleeve wear (taper). See “Inspect and Measure Cylinder Sleeves (page 147)” in this section. If sleeve does not meet “Specifications (page 161),” check first for improperly aligned O-rings.

Assemble Pistons and Rings

Assemble Two-Piece Pistons

1. Assemble piston skirt on piston crown.

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Figure 246 Assemble two-piece piston (parts are upside down for assembling)

Install Piston Rings

1. Install piston rings on piston, with a Piston Ring Expander (ZTSE4220) (page 163).
2. Install piston rings in following order:
   a. Oil control ring

      NOTE: Oil ring does not have identification marks. There is no top or bottom. It may be installed in either direction.

   b. Second compression ring. Identification marks must face up. Rings have permanently marked “O” on top side. Stagger rings 120 degrees apart.

   c. Top compression ring. Identification marks must face up. Rings have permanently marked “O” on top side. Stagger the rings 120 degrees apart.

Figure 247 Install piston rings

Assemble Piston and Connecting Rod

1. Lubricate connecting rod piston pin bushing with clean engine oil.
2. Install retaining ring at one end of piston pin bore.

CAUTION: To avoid engine damage when servicing, do not mix forged connecting rods with fractured connecting rods in the same engine. Weights of connecting rods are different and will cause engine vibration if mixed.

3. Insert connecting rod in piston, align bored holes of rod and piston. Short side of split on crank end of rod must be facing side of piston marked with piston part number.

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Figure 248 Insert piston pin

4. Align pin bores and insert piston pin.
5. Install second retaining ring.

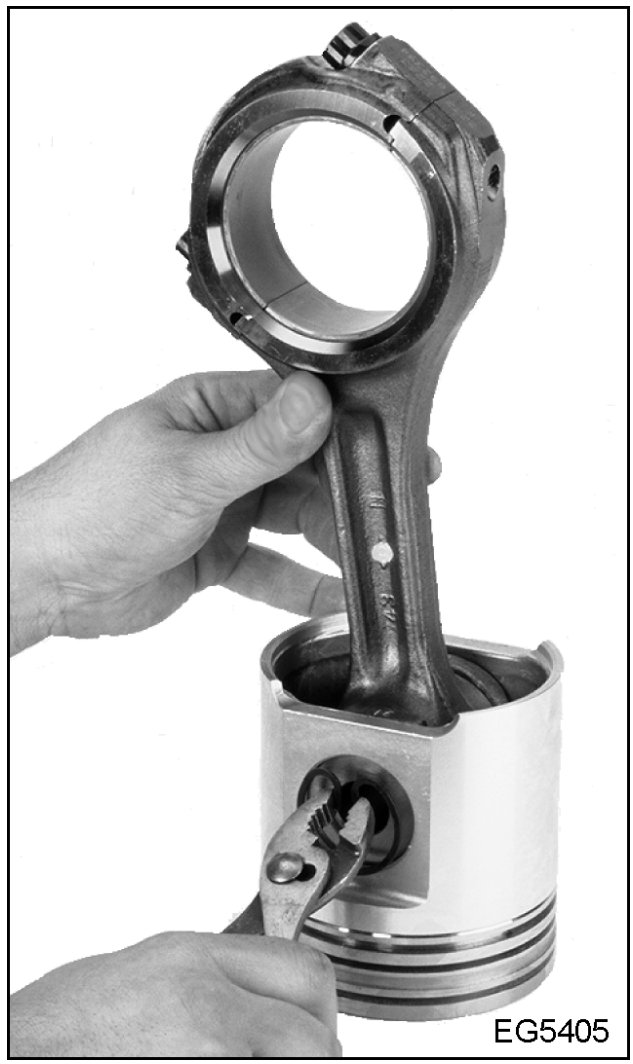

Figure 249 Install piston pin retaining ring

NOTE: Connecting rod and cap matching numbers must be opposite cam side of piston.

Install Piston and Connecting Rod Assembly

1. Start with cylinder 1 piston and rod assembly. Procedure for installing cylinder 2 through 6 piston and rod assemblies are identical.
2. Turn crankshaft three times. Position cylinder 1 and 6 rod journals at Bottom Dead Center (BDC).
3. Lubricate cylinder sleeve inner surface with clean engine oil.
4. Lubricate piston rings on piston and connecting rod assembly 1 with clean engine oil and stagger ring gaps 120° apart.

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5. Install Piston Ring Compressor (page 163) over the piston rings on piston and connecting rod assembly 1.

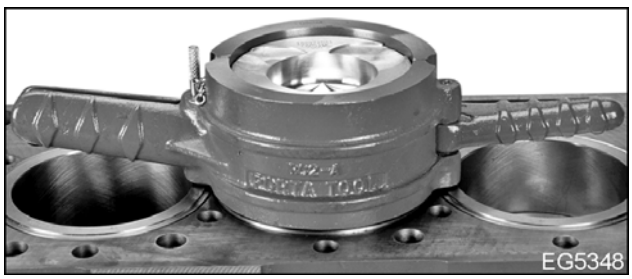

Figure 250 Install Piston Ring Compressor

6. Insert piston and connecting rod assembly 1 in cylinder sleeve. Use wooden or plastic handle or tool. Numbers on connecting rod must face away from camshaft while markings on top of piston face toward the camshaft side of the engine.
7. Guide connecting rod in place on crankshaft.

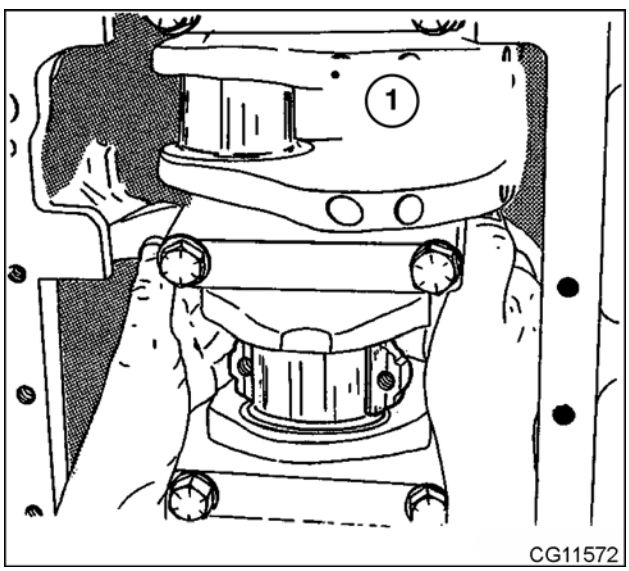

Figure 251 Guide connecting rod

8. Repeat this procedure for piston and rod assemblies 6, 2, 5, 3, and 4 until all piston and rod assemblies are installed.

Install Connecting Rod Bearing Insert and Cap

NOTE: See “Bearing Fit (page 150)” in this section for connecting rod bearing cap running and side clearance procedures.

1. Lubricate connecting rod bearing inserts.
2. Install connecting rod cap, match and align numbers on cap and rod.

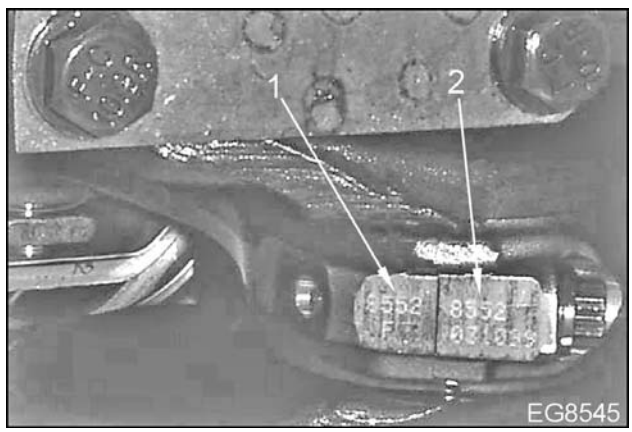

Figure 252 Match and align numbers on connecting rod and cap

1. Numbers on connecting rod
2. Numbers on connecting rod cap

3. Install connecting rod bearing cap mounting bolts finger-tight. Torque connecting rod bearing cap mounting bolts to “Special Torque (page 163).”

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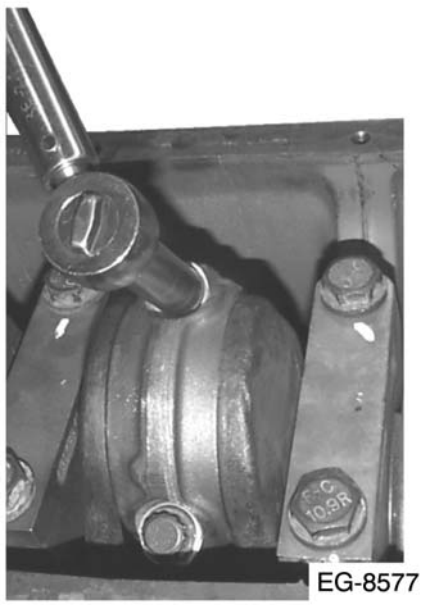

Figure 253 Torque connecting rod bearing cap

Miscellaneous

Refer to appropriate section of this publication for installation procedures for following:

Turbocharge oil supply line

Turbocharger oil drain line

Turbocharger

Oil filter

Oil cooler

Exhaust manifold

ECM and mounting bracket, if equipped

Wiring harness

Valve cover and intake manifold

Rocker arm assembly

Cylinder head

Front engine mounting bar

Vibration damper

Oil pan pickup tube

Oil pan

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Special Information

Specifications

Connecting Rods	
Center-to-center distance between connecting rod bearing bore and piston pin bushing	219.5 to 219.4 mm (8.64 to 8.63 in)
Bushing bore diameter (pin end) (forged connecting rods)	48.91 to 48.86 mm (1.926 to 1.924 in)
Maximum bushing bore diameter (pin end) (fractured connecting rods)	49.90 mm (1.965 in)
Maximum connecting rod bushing outside diameter (forged connecting rods)	49.00 mm (1.930 in)
Maximum connecting rod bushing outside diameter (fractured connecting rods)	50.00 mm (1.969 in)
Piston pin bushing inside diameter (installed) (forged connecting rods)	46.38 to 46.37 mm (1.826 to 1.825 in)
Piston pin bushing inside diameter (installed) (fractured connecting rods)	46.39 mm (1.827 in)
Bearing bore diameter (crankshaft end)	85.16 to 85.13 mm (3.353 to 3.352 in)
Maximum out-of-round	0.051 mm (0.002 in)
Maximum taper per inch	0.13 mm (0.005 in)
Connecting rod bearing inside diameter (installed)	80.12 to 80.07 mm (3.154 to 3.152 in)
NOTE: Do not use service bolts from forged connecting rods with fractured connecting rods.	
Bearing running clearance	0.127 to 0.046 mm (0.0050 to 0.0018 in)
Maximum permissible bearing running clearance (before reconditioning)	0.18 mm (0.007 in)
Connecting rod side clearance on crankshaft	0.30 to 0.42 mm (0.012 to 0.17 in)
Connecting rod alignment twist	0.51 mm (0.020 in)
Bend	0.38 mm (0.015 in)
Pistons	
Running clearance between piston and cylinder sleeve	Steel 2-piece: 0.05 to 0.10 mm (0.002 to 0.004 in) Aluminum: 0.07 to 0.13 mm (0.003 to 0.005 in)
Aluminum Piston	
Measure 90° from pin bore at Skirt Diameter, 28.575 mm (1.125 in) from bottom of piston.	116.472 to 116.497 mm (4.5855 to 4.5865 in)
Steel Piston	
Measured 90° from pin bore at Skirt Diameter, 39.4 mm (1.55 in) from bottom of piston.	116.497 to 116.523 mm (4.5865 to 4.5875 in)
Number of rings per piston	3

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Piston Ring Groove Widths:	
Top Compression Ring Measure over 2.92 mm (0.115 in) gauge pins	114.33 to 114.58 mm (4.501 to 4.511 in)
Intermediate Compression Ring - Keystone All Aluminum 466E above 215 bhp, and 530E pistons measured over 2.92 mm (0.115 in) gauge pins	116.84 to 116.92 mm (4.600 to 4.603 in)
Rectangular Groove Width 466E at 215 bhp and below and 530E at 300 bhp and above.	3.028 to 3.048 mm (0.1192 to 0.1200 in)
Side clearance: Oil control ring	0.05 to 0.10 mm (0.002 to 0.004 in)
Piston Rings - Compression	
Number of rings per piston	2
Type (face and finish): Top Ring	Full Keystone (barrel faced) - Plasma Coated
Intermediate Ring: For 466E engines rated at 215 bhp and below	Rectangular (Negative Twist) - Phosphate Coated
For engines rated above 215 bhp	Full Keystone (taper face)
Intermediate Ring: All 530E engines with aluminum pistons	Full Keystone (taper face)
All engines with steel pistons	Rectangular (negative twist) - Phosphate coated
Ring Gap With New Sleeve	
Top ring	0.40 to 0.66 mm (0.016 to 0.026 in)
Intermediate ring	1.65 to 1.91 mm (0.065 to 0.075 in)
Piston Rings - Oil Control	
Number of oil control rings per piston	1
Type (face and finish)	One piece slotted - Chrome
Ring gap	0.30 to 0.56 mm (0.012 to 0.022 in)
Piston Pins	
Outside diameter	46.352 to 46.357 mm (1.8249 to 1.8251 in)
Length	96.57 to 96.82 mm (3.802 to 3.812 in)
Clearance in rod	0.015 to 0.028 mm (0.0006 to 0.0011 in)
Maximum permissible clearance in rod, before replacing	0.08 mm (0.003 in)
Clearance in piston	0.0165 to 0.0292 mm (0.00065 to 0.00115 in)
Maximum permissible clearance in piston before replacing	0.064 mm (0.00258 in)
Cylinder Sleeves	

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Inside Diameter (new)	116.57 to 116.60 mm (4.589 to 4.590 in)
Maximum permissible diameter sleeve wear at top of ring travel before replacement (sleeve taper)	0.10 mm (0.004 in)
Counterbore dimension in crankcase	8.84 to 8.89 mm (0.348 to 0.350 in)
Maximum allowable variation of counterbore depth (between four points)	0.025 mm (0.001 in)
Maximum cylinder sleeve counterbore allowable depth (used with shim kit)	10.49 mm (0.413 in)
Flange thickness	8.97 to 8.94 mm (0.0353 to 0.0352 in)
Protrusion above crankcase	0.13 to 0.05 mm (0.005 to 0.002 in)

Special Torque Values

Connecting Rod Cap Mounting Bolts	163 N·m (120 lbf·ft)

Special Service Tools

Counterbore Tool	ZTSE2514
Counter Bore Cutting Head	ZTSE25144A
Cylinder Bore Gauge	OEM1032
Cylinder Liner Height Gauge	ZTSE2515A
Cylinder Liner Holding Adapters	ZTSE25151
Cylinder Sleeve Puller	ZTSE2536
Depth Micrometer	Obtain locally
Dial Indicator with Magnetic Base	Obtain locally
Feeler Gauge	Obtain locally
Inside Micrometer	Obtain locally
Outside Micrometer	Obtain locally
Piston Groove Wear Measuring Tool	ZTSE3020
Piston Ring Compressor	Obtain locally
Piston Ring Expander	ZTSE4220
Telescoping Gauge Set	OEM1022

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