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## Cylinder Head Components

**NOTE:** Before removing cylinder heads, remove the following components:


- Fuel filter assembly and lines  
See "Fuel System."
- VGT assembly  
See "Variable Geometry Turbocharger (VGT) Assembly."
- Electronic Control Module (ECM), Injector Driver Module (IDM), and mounting bracket  
See "Engine Electrical."
- Exhaust Gas Recirculation (EGR) drive module and EGR drive module mounting bracket  
See "Engine Electrical."
- Glow plug relay and bracket  
See "Engine Electrical"
- Intake manifold  
See "Manifolds and Exhaust Gas Recirculation (EGR)"
- Flywheel and rear cover (if removing cam followers)  
See "Rear Cover, Flywheel, and Power Steering Gear Drive."
- Branch tube assembly (if removing cam followers)  
See "High-pressure Oil Pump."


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

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

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

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

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

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

## Exploded Views

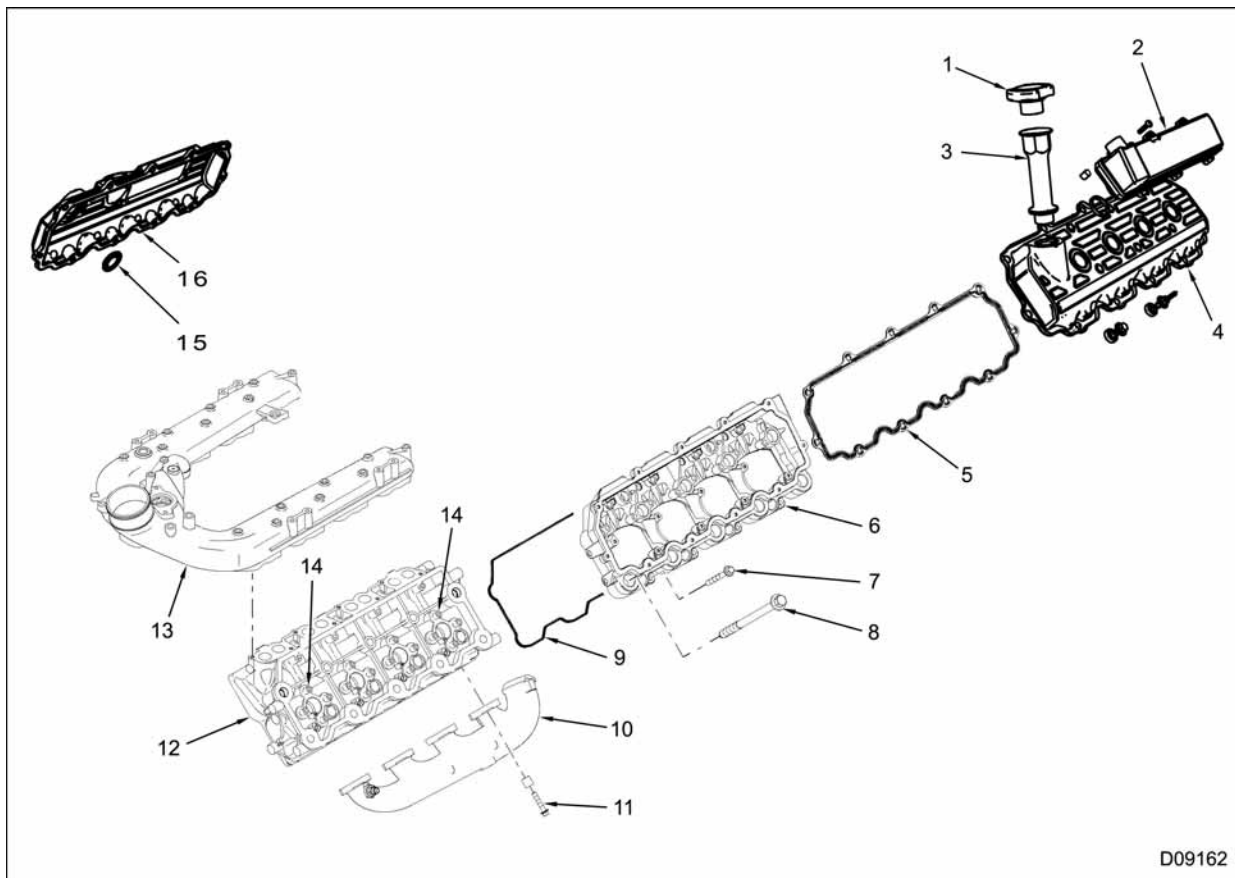
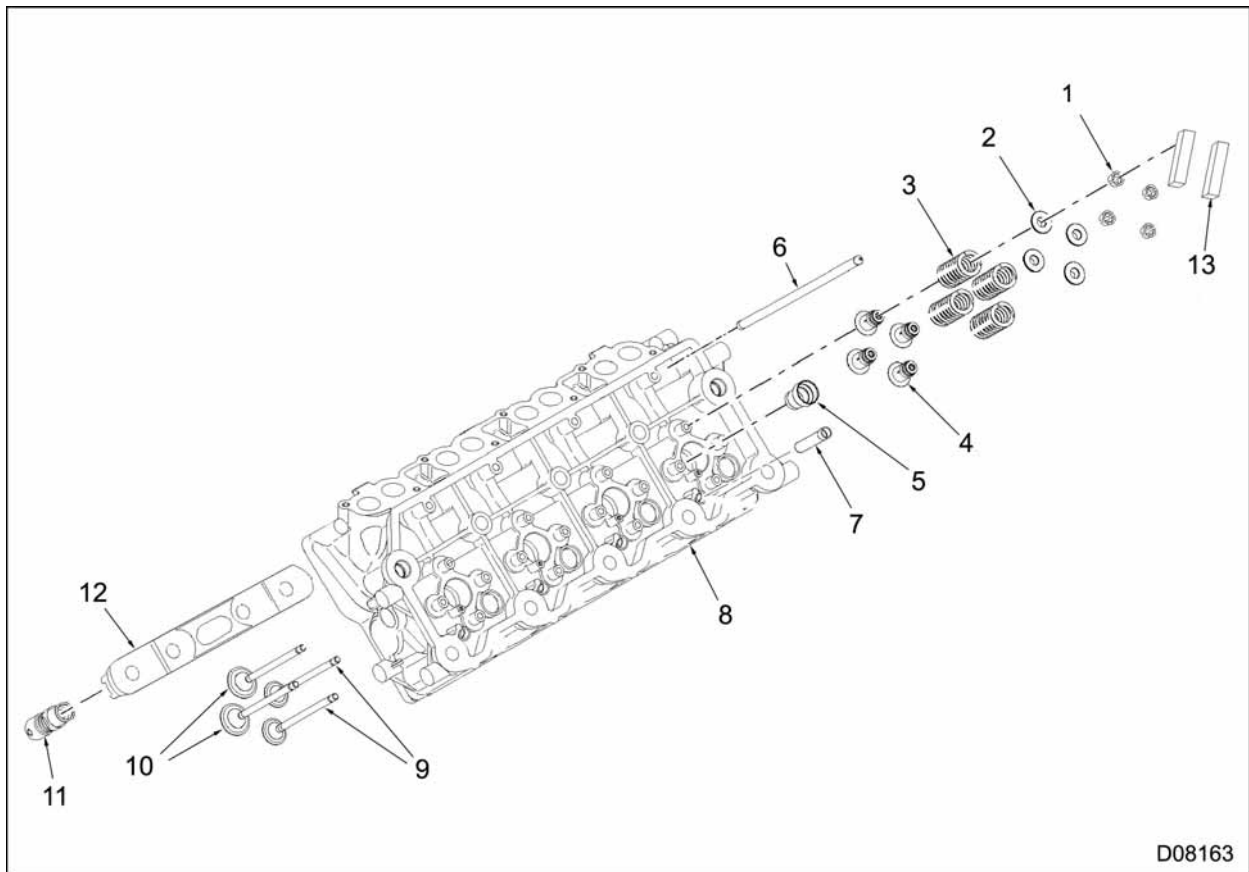


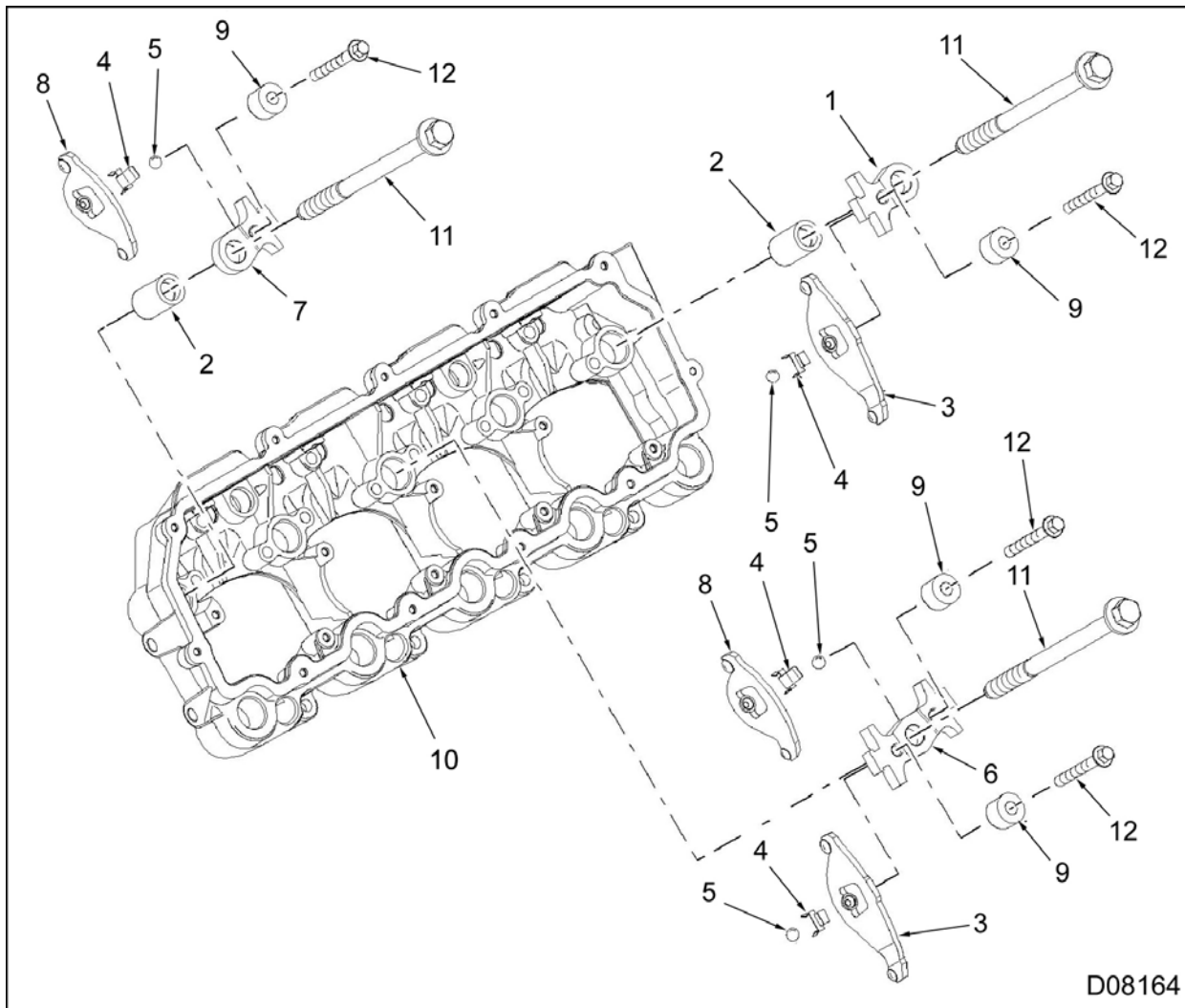
Figure 131 Cylinder head and related components (typical)

- |                            |                                     |                                     |
|----------------------------|-------------------------------------|-------------------------------------|
| 1. Oil fill cap            | 7. Rocker arm carrier mounting bolt | 13. Intake manifold                 |
| 2. Breather housing        | 8. Cylinder head bolt               | 14. Dowel                           |
| 3. Oil fill extension      | 9. Rocker arm carrier gasket        | 15. Valve cover gasket (ICP sensor) |
| 4. Valve cover (left side) | 10. Exhaust manifold (left side)    | 16. Valve cover (right side)        |
| 5. Valve cover gasket      | 11. Exhaust manifold bolts          |                                     |
| 6. Rocker arm carrier      | 12. Cylinder head (left side)       |                                     |



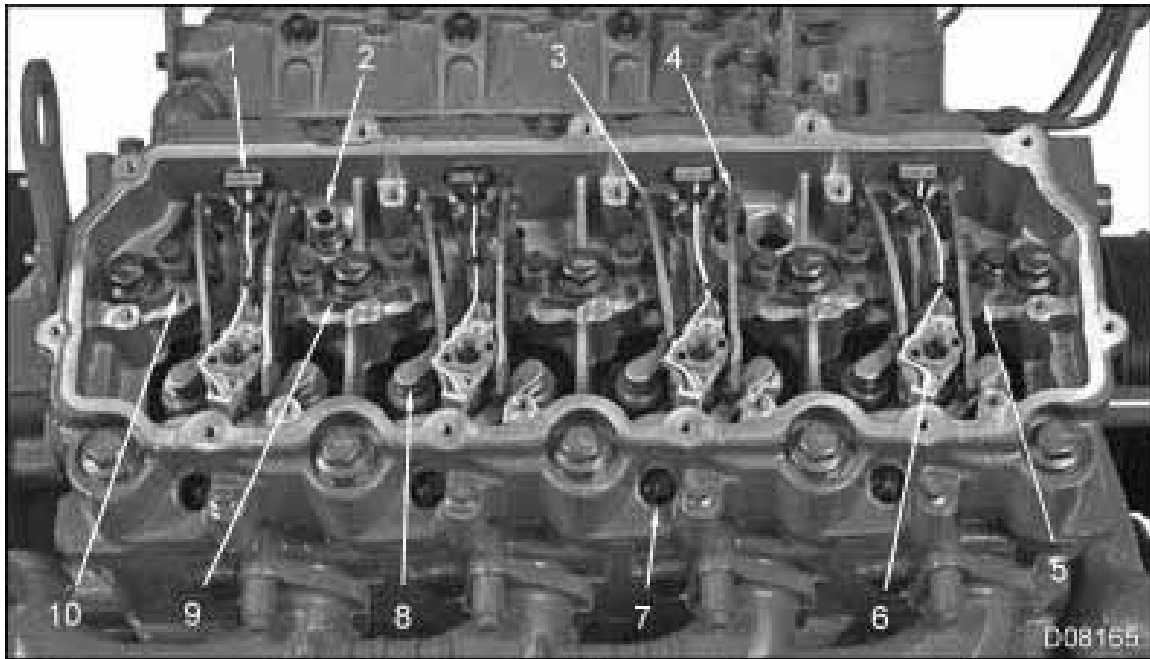
**Figure 132 Cylinder head components (typical)**

- |                               |                         |                                |
|-------------------------------|-------------------------|--------------------------------|
| 1. Valve retainer key (32)    | 6. Push rod (8)         | 11. Hydraulic cam follower (8) |
| 2. Valve spring retainer (16) | 7. Glow plug sleeve (4) | 12. Cam follower guide (2)     |
| 3. Valve spring (16)          | 8. Cylinder head        | 13. Valve bridge (8)           |
| 4. Valve stem oil seal (16)   | 9. Exhaust valve (8)    |                                |
| 5. Fuel injector sleeve (4)   | 10. Intake valve (8)    |                                |



**Figure 133 Rocker arm carrier components (typical)**

- |                                             |                                  |                        |
|---------------------------------------------|----------------------------------|------------------------|
| 1. Exhaust fulcrum plate                    | 5. Ball, 3/8 chrome (8)          | 10. Rocker arm carrier |
| 2. Dowel sleeve bushing (end fulcrums only) | 6. Dual rocker fulcrum plate (3) | 11. Head bolt          |
| 3. Exhaust rocker arm (4)                   | 7. Intake fulcrum plate          | 12. Fulcrum bolt (8)   |
| 4. Rocker arm clip                          | 8. Intake rocker arm (4)         |                        |
|                                             | 9. Fulcrum bolt spacer (8)       |                        |



**Figure 134 Rocker arm carrier and cylinder head components (typical)**

- |                                   |                          |                             |
|-----------------------------------|--------------------------|-----------------------------|
| 1. Injector harness connector (4) | 5. Exhaust fulcrum plate | 9. Fulcrum plate (dual) (3) |
| 2. Case-to-head tube assembly     | 6. Injector assembly (4) | 10. Intake fulcrum plate    |
| 3. Intake rocker arm (4)          | 7. Glow plug (4)         |                             |
| 4. Exhaust rocker arm (4)         | 8. Valve bridge (8)      |                             |

## Removal

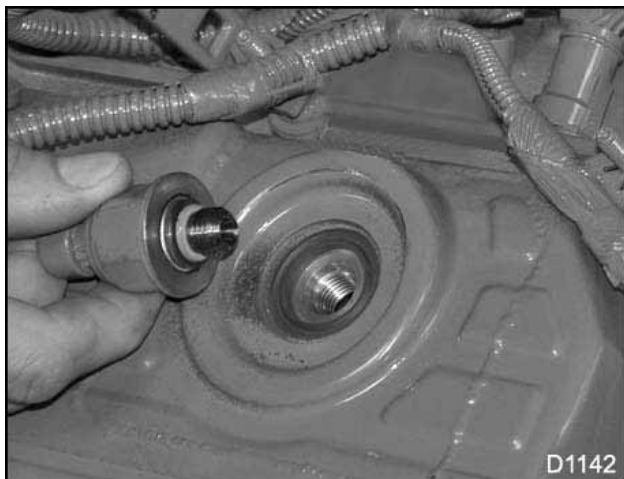
### Valve Covers, ICP Sensor, and Rear Heat Shield

#### Injection Control Pressure (ICP) Sensor (right high-pressure oil rail)



**Figure 135** Electrical connector removed from ICP sensor

1. Disconnect electrical connector from ICP sensor in the right high-pressure oil rail.



**Figure 136** ICP Sensor and O-ring

2. Remove the ICP sensor.
3. Remove O-ring from ICP sensor and discard O-ring.



**Figure 137** Valve cover seal ring for ICP sensor

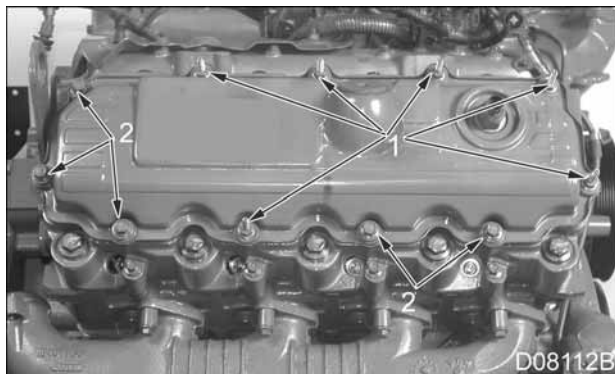
1. Valve cover seal ring for ICP sensor
2. Oil rail ICP sensor opening

**NOTE:** The ICP sensor may be removed before or after removing the right valve cover. The valve cover seal ring for the ICP sensor (under the valve cover) can be removed only after removing valve cover. If the ICP sensor is removed, for replacement or troubleshooting, the valve cover seal ring can be reused.



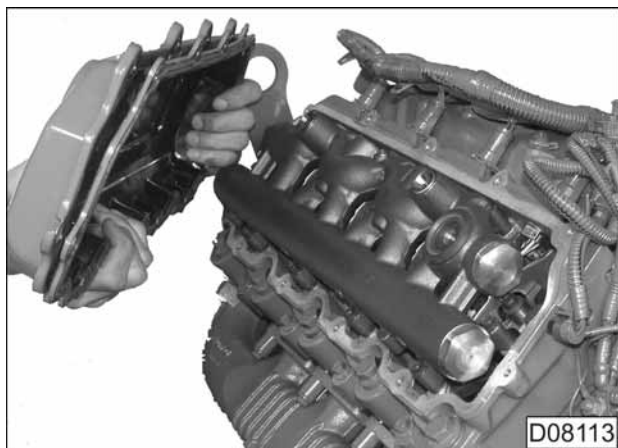
**Valve Covers**

**CAUTION:** To prevent engine damage, do not use air tools when removing and installing valve covers.

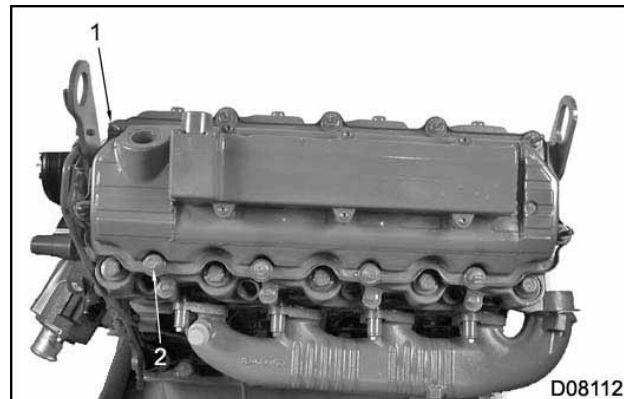
**Right Valve Cover****Figure 138 Mounting bolts and studs**

1. Stud (6)
2. Bolt (5)

1. Remove five mounting bolts and six studs.

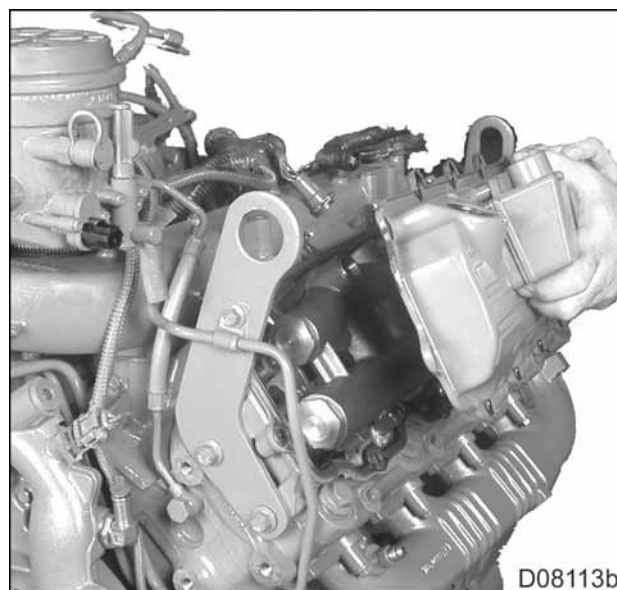
**Figure 139 Right valve cover**

2. Remove right valve cover.
3. Remove right valve cover gasket. Keep gasket for cleaning and inspection.

**Left Valve Cover****Figure 140 Mounting bolts and studs**

1. Bolt (1 )
2. Stud (10)

4. Remove one mounting bolt and 10 studs.

**Figure 141 Left valve cover with breather housing attached**

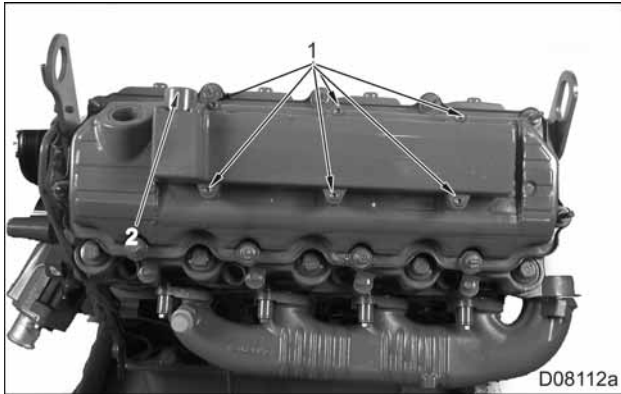
5. Remove left valve cover with breather cover attached.

**NOTE:** Unless replacing the breather housing, leave breather housing on the left valve cover.

6. Remove the left valve cover gasket. Keep gasket for cleaning and inspection.

### Breather Housing

**NOTE:** Remove the breather housing for replacement only. The breather housing may be removed with the left valve cover on or off the engine.



**Figure 142 Mounting bolts for breather housing**

1. Bolt (6)
2. Breather opening



**Figure 143 Breather housing**

7. Remove six bolts from breather housing.
8. Remove breather housing. Save housing for inspection.

9. Remove four breather opening gaskets. Keep gaskets for cleaning and inspection

### ICP Sensor (right high-pressure oil rail)

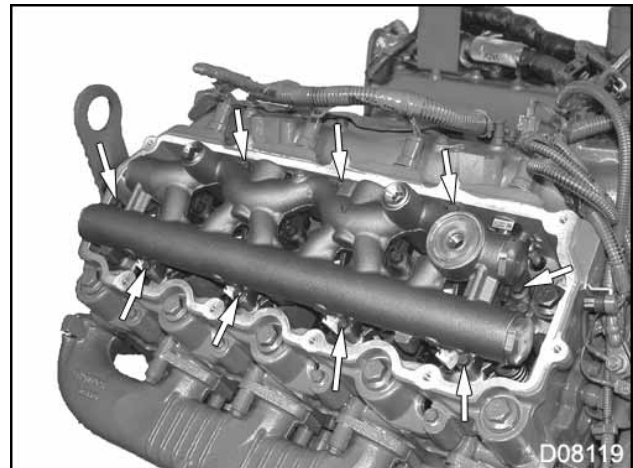


**Figure 144 Valve Cover Seal Ring for ICP Sensor**

1. Valve cover seal ring for ICP sensor
2. Oil rail ICP sensor opening

1. Remove and discard valve cover seal ring.

### High-pressure Oil Rail Assembly

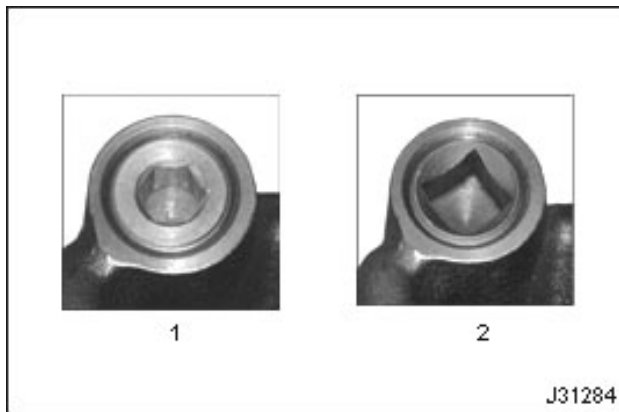


**Figure 145 Oil rail assembly bolts**

1. Loosen and remove nine M6 x 40 hex head bolts holding the oil rail assembly to the rocker arm carrier.



**Figure 146** Crankcase-to-head tube plug

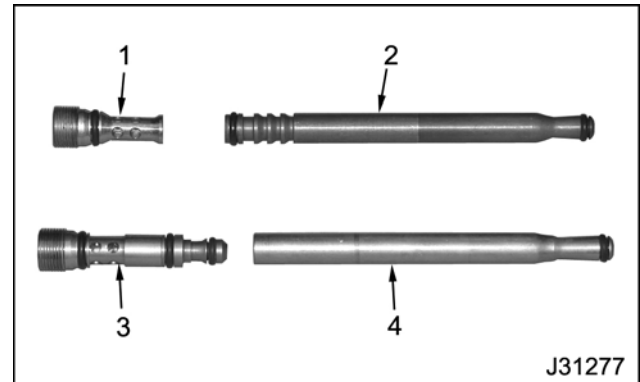


**Figure 147** Crankcase-to-head tube plugs

1. Hex socket
2. Square socket

**NOTE:** The square socket identifies the short crankcase-to-head tube plug. The hex socket identifies the longer crankcase-to-head tube plug (with check valve).

**NOTE:** The square socket short crankcase-to-head tube plug and crankcase-to-head tube assembly is not available for service.

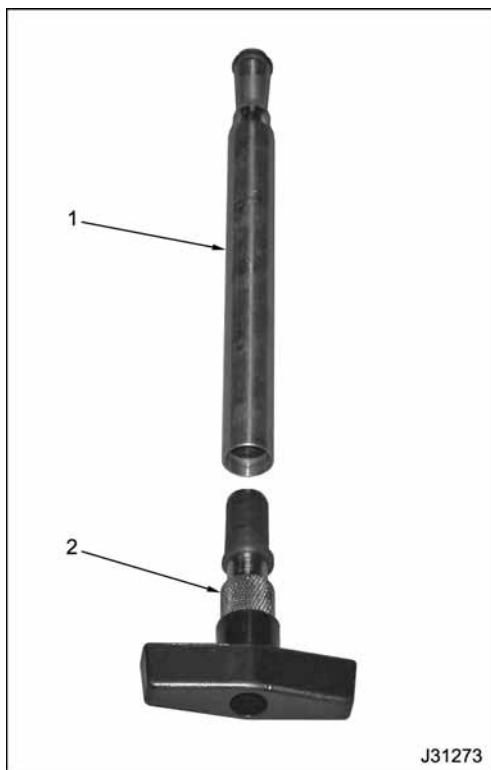


**Figure 148** Crankcase-to-head tube assemblies

1. Crankcase-to-head tube plug (short)
  2. Crankcase-to-head tube (used with item 1)
  3. Crankcase-to-head tube plug (long – with check valve)
  4. Crankcase-to-head tube (used with item 3)
2. Remove the crankcase-to-head tube assembly from right and left high-pressure oil rails.
  3. Discard crankcase-to-head tube assemblies.

**NOTE:** The crankcase-to-head tube, used with the long crankcase-to-head tube plug may remain in the crankcase.

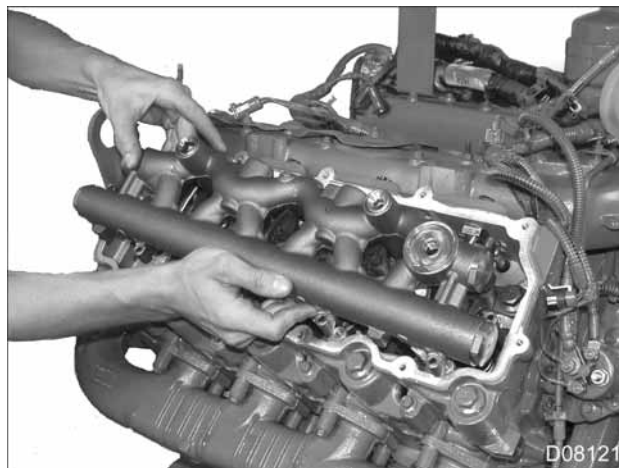
- If crankcase-to-head tube remains in the crankcase, continue with step 4.
- If both crankcase-to-head tube assemblies were removed, continue with step 6.



**Figure 149 Crankcase-to-head tube and Crankcase-to-head Removal Tool**

1. Crankcase-to-head tube
2. Crankcase-to-head Removal Tool

4. Insert the Crankcase-to-head Removal Tool (Table 12) into the crankcase-to-head tube, tighten T-handle, and pull out tube.
5. Discard crankcase-to-head tube.



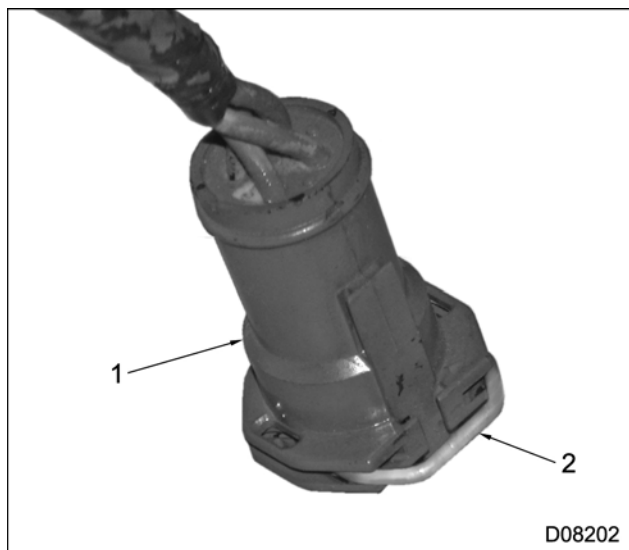
**Figure 150 Removal of oil rail assembly**

6. Lift oil rail assembly straight away from fuel injectors. Allow oil to drain back to the sump or other suitable container.

**CAUTION:** To prevent engine damage, do not remove 1-1/4 x 20 UNF oil rail end plugs or the Acoustic Wave Attenuator (AWA) bottom port fitting. Service parts are not available.

### Fuel Injectors

**NOTE:** Do not drain the fuel rail, if removing an injector from chassis.



**Figure 151 Engine Harness connector to injector connector**

1. Connector
2. Spring loaded metal clip

1. Push in the spring loaded metal clip in the engine harness connector to the fuel injector connector and remove engine harness connector.



**Figure 152 Injector connector removal**

1. Injector Connector Remover
2. Injector connector

2. Install the Injector Connector Remover (Table 12).
3. Push Injector Connector Release Tool to pop loose the spring clips on the injector connector and remove connector from rocker arm carrier.



**Figure 153 Fuel Injector Hold Down Wrench**

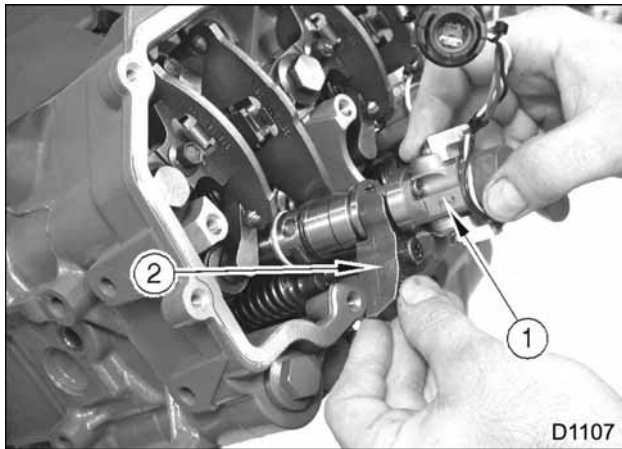


**Figure 154 Removal of fuel injector hold down clamp assembly**

1. Fuel injector assembly
2. Fuel injector hold down clamp assembly
3. Fuel Injector Hold Down Wrench

**CAUTION:** To prevent damage to fuel injector assemblies, do not use air power tools to remove or install injectors.

4. Use the Fuel Injector Hold Down Wrench (Table 12) to remove the hold down clamp assembly.



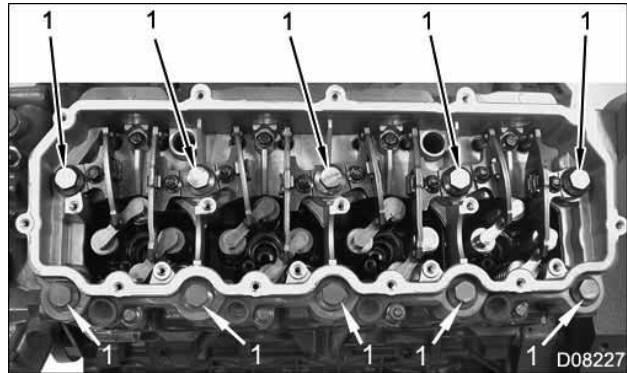
**Figure 155 Fuel Injector assembly**

1. Fuel injector assembly
2. Fuel injector hold down clamp assembly

5. Remove fuel injector from cylinder head bore by lifting injector and hold down clamp assembly straight up and out.

6. Put fuel injectors in the Fuel Injector Rack Holder (Table 12).

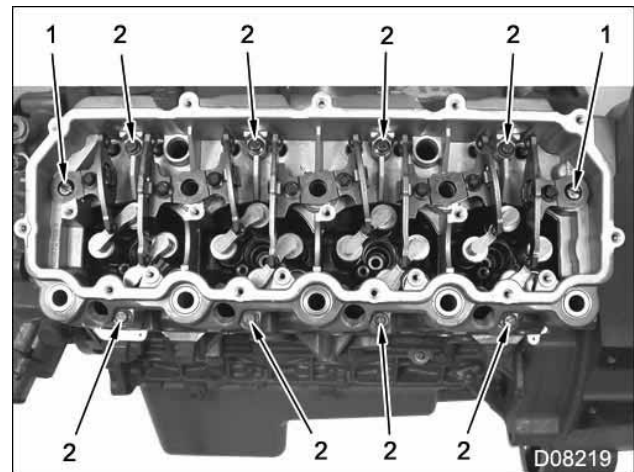
#### Rocker Arm Carrier



**Figure 156 Cylinder head bolts (typical)**

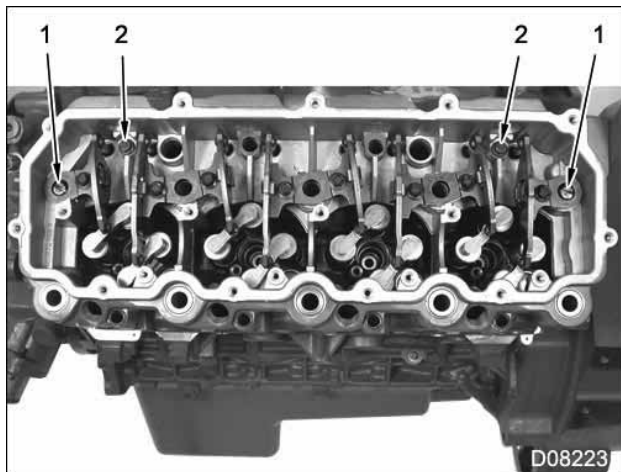
1. M14 x 193 bolts (10)

1. Using a circular pattern loosen and remove ten M14 x 193 bolts from cylinder head. Begin with the outer bolts and move inward.



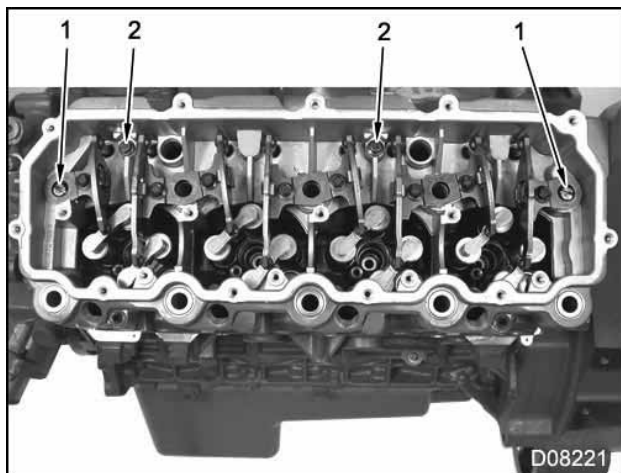
**Figure 157 2004 and 2005 Model Year (eight M8 mounting bolts for rocker arm carrier)**

1. Alignment guide (2)
2. M8 x 50 bolt (8)



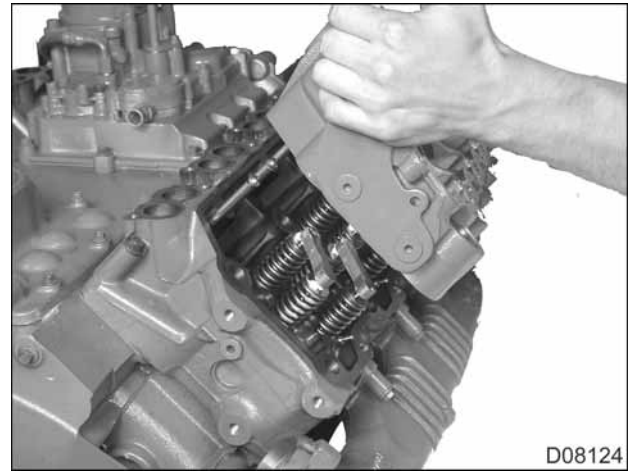
**Figure 158 2005 Model Year (two M8 mounting bolts for rocker arm carrier)**

1. Alignment guide (2)
2. M8 x 50 bolt (2)



**Figure 159 2006 Model Year (two M10 mounting bolts for rocker arm carrier)**

1. Alignment guide (2)
  2. M10 x 50 bolt (2)
2. Remove bolts from rocker arm carrier.

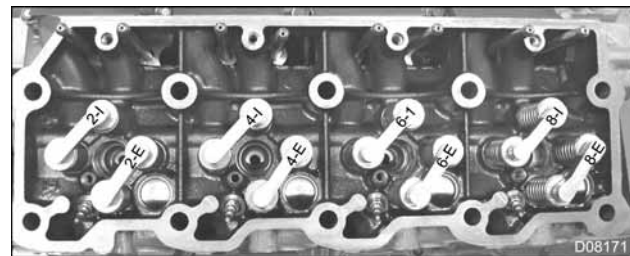


**Figure 160 Rocker arm carrier**

3. Lift rocker arm carrier assembly from cylinder head and set aside for disassembly, cleaning, inspection, and assembly.

### Valve Bridges and Pushrods

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

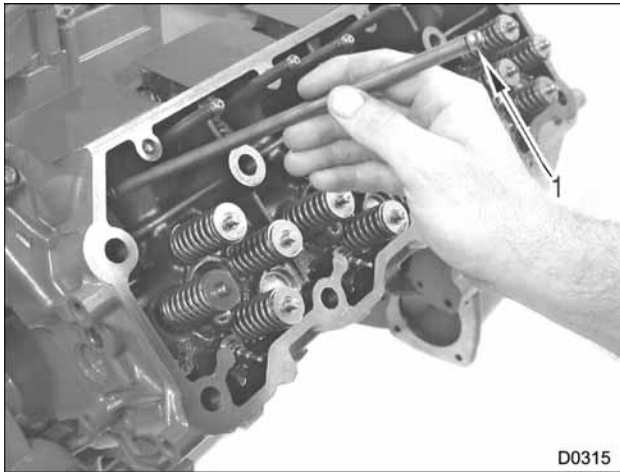


**Figure 161 Valve bridge (left cylinder head)**

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

Example: **2 - I**

- Cylinder number **2** as counted from the front of engine
- **I** = Intake, **E** = Exhaust

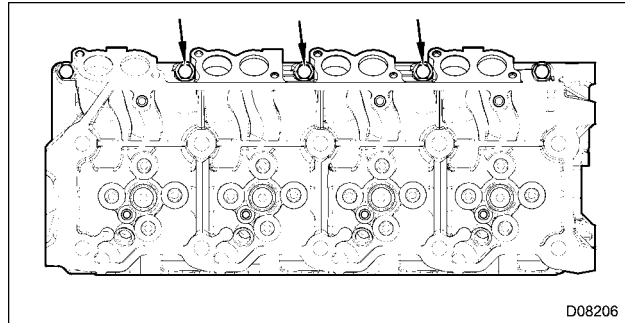
**Figure 162 Pushrods**

1. Pushrod
2. Remove and identify all pushrods; they must be installed to their original positions.

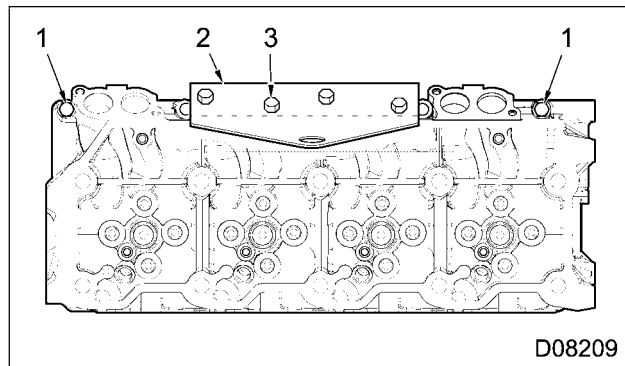
**Cylinder Heads****Figure 163 Glow plug removal**

1. Remove glow plugs.

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

**Figure 164 Removal of middle M8 x 70 bolts**

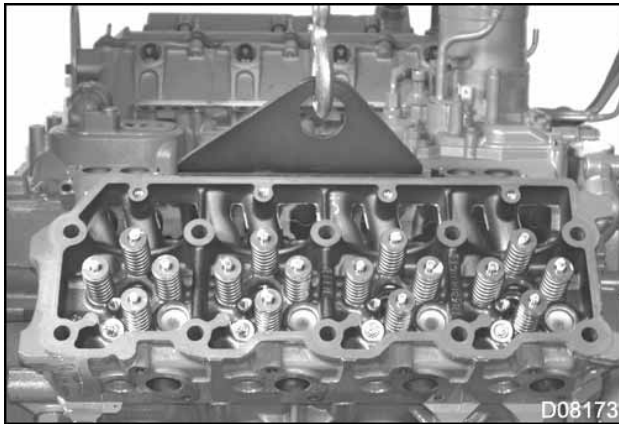
2. Remove three middle M8 x 70 bolts – cylinder head to crankcase.

**Figure 165 Cylinder head lifting bracket**

1. M8 x 70 bolt – cylinder head to crankcase
2. Cylinder head lifting bracket
3. Lifting bracket mounting bolt (4)
3. Position lifting bracket on cylinder head and install four lifting bracket mounting bolts.

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





**Figure 166** Cylinder head removal

4. Attach a lifting hoist hook or suitable lifting sling to lifting bracket.
5. Remove the two remaining M8 x 70 bolts – cylinder head to crankcase.
6. Lift cylinder head from the crankcase.

**CAUTION:** Do not damage cylinder head locating dowel sleeves.

7. Put cylinder head on suitable surface.

**CAUTION:** Do not scratch cylinder head surface.

8. Remove and discard cylinder head gasket.

### Hydraulic Cam Followers

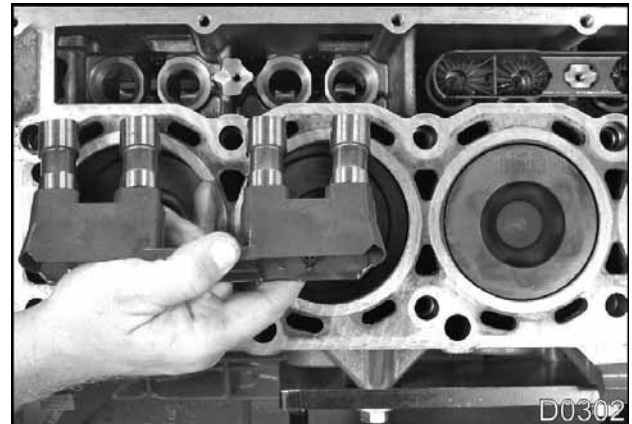
**NOTE:** If cam followers must be removed, the rear cover and the high-pressure oil pump cover must be removed to gain access to the rear engine tube assembly. See “Rear Cover, Flywheel, and Power Steering gear Drive.”

**CAUTION:** To prevent engine damage, keep cam followers and push rods in the order removed. Install cam followers and push rods to original positions.

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

1. Remove the M6 x 15 bolt with washer from each roller follower guide.

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



**Figure 167** Cam followers and roller follower guides

2. Remove cam followers and roller follower, lifting the guide straight up. A hand tool may be required.

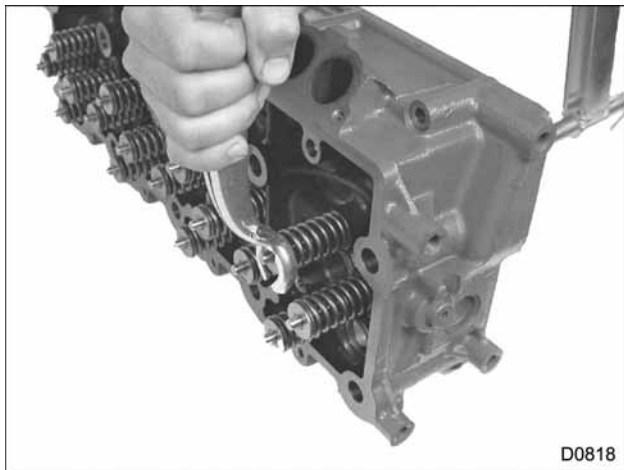


**Figure 168** Cam follower removal from roller follower guide

3. Remove cam followers from roller follower guide.

### Removing Valves from Cylinder Head

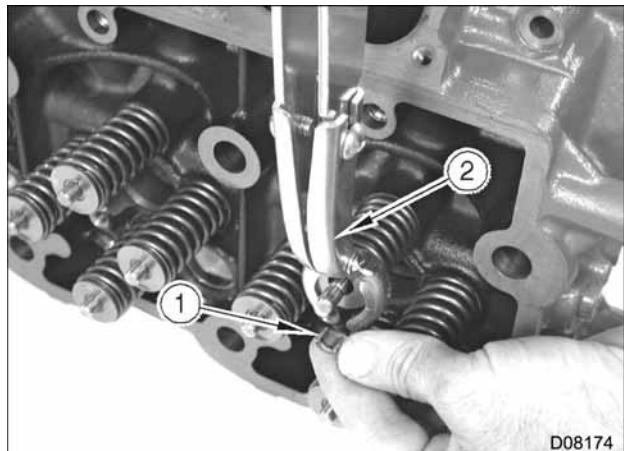
**NOTE:** Valve removal is required, if valves need replacement or seats need reconditioning. Valve seat reconditioning is not required, if the cylinder head passes the mineral spirits test. See Cleaning, Inspections, and Testing in this section.



**Figure 169 Valve spring compression**



**Figure 171 Valve spring retainer**



**Figure 170 Valve retainer key**

1. Valve retainer key
2. Valve Spring Compressor

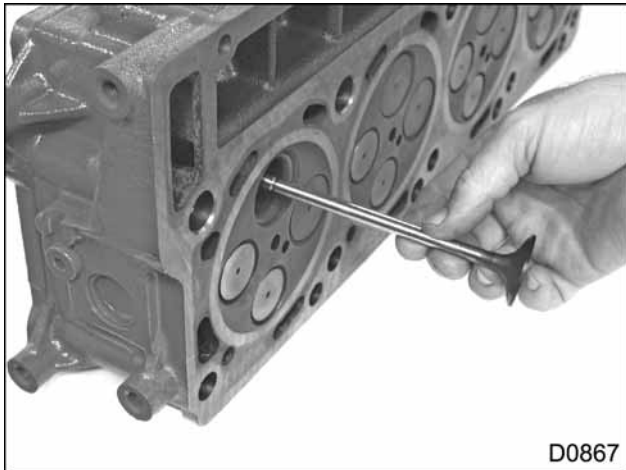
1. Use a "C" Type Valve Spring Compressor (Table 12), to compress valve springs. Remove valve retainer keys. A small magnet is useful.

2. Remove valve spring retainer.



**Figure 172 Valve spring**

3. Remove valve spring.



**Figure 173 Valve**

4. Remove valve from cylinder head.



**Figure 174 Valve stem oil seal**

5. Remove valve stem oil seal and discard. Valve stem seals are not reusable. Use pliers to remove seal from end of valve stem guide.

### Fuel Injector Sleeve Removal

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

**NOTE:** Fuel injector sleeve removal is not required unless the sleeve has been damaged. See Cleaning, Inspection and Testing in this section, to determine if sleeve replacement is required.



**Figure 175 Lubrication of Injector Sleeve Remover (Thread tap)**

**NOTE:** The fuel injector sleeve is made of stainless steel. Lubrication of the Injector Sleeve Remover is required.

1. Lubricate Injector Sleeve Remover (Table 12).



**Figure 176 Fuel injector sleeve tapped**

2. Thread Injector Sleeve Remover (thread tap) into fuel injector sleeve. Cut threads at least 3/4 inch deep to accommodate the injector sleeve remover.



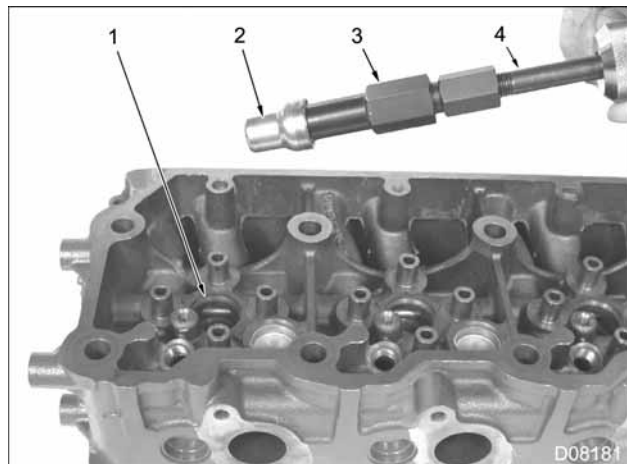
**Figure 177 Injector Sleeve Remover (Slide hammer adapter)**

3. Install Injector Sleeve Remover (slide hammer adapter) (Table 12) in the threads cut in the fuel injector sleeve and tighten.



**Figure 178 Slide hammer**

4. Thread the slide hammer (Table 12) in the injector sleeve remover.



**Figure 179 Fuel injector sleeve removal**

1. Fuel injector bore
2. Fuel injector sleeve
3. Injector Sleeve Remover
4. Slide hammer
5. Using the slide hammer, remove fuel injector sleeve.

### Glow Plug Sleeve Removal

**NOTE:** In-chassis removal of glow plug sleeves is only practical on the front two cylinders.

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

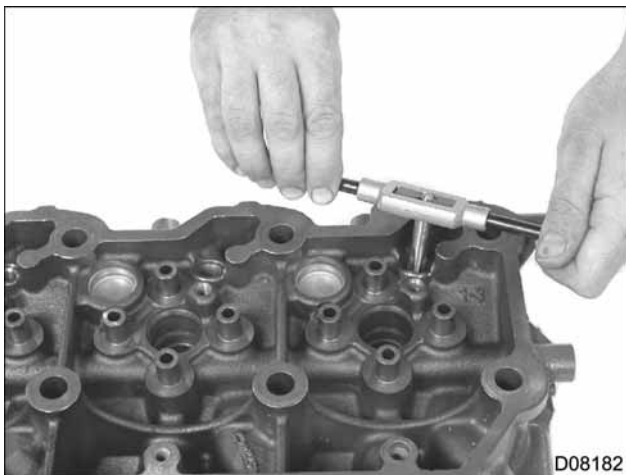
**NOTE:** Glow plug sleeve removal is not required unless sleeves are damaged. If sleeve replacement is required, see Cleaning, Inspection, and Testing in this section.



**Figure 180 Glow plug sleeve remover (Thread tap)**

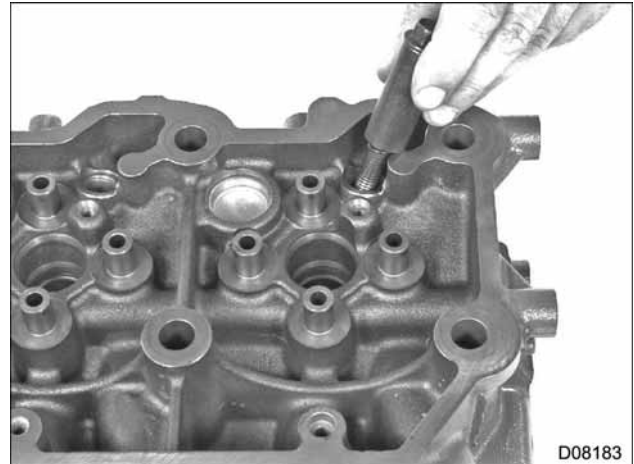
1. Lubricate Glow Plug Sleeve Remover (thread tap) (Table 12).

**NOTE:** The glow plug sleeve is made of stainless steel. Lubricate the Glow Plug Sleeve Remover (thread tap) to get the threads started – otherwise excessive force would be necessary.



**Figure 181 Glow plug sleeve tapped**

2. Cut threads in the glow plug sleeve – at least 1/2 inch deep for the Glow Plug Sleeve Remover (bolt and sleeve adapter) (Table 12).



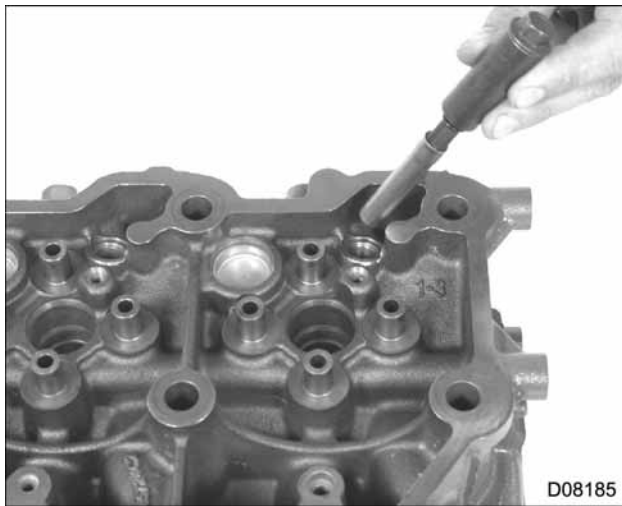
**Figure 182 Glow Plug Sleeve Remover**

3. Thread the Glow Plug Sleeve Remover into glow plug sleeve (Table 12).



**Figure 183 Removal of glow plug sleeve**

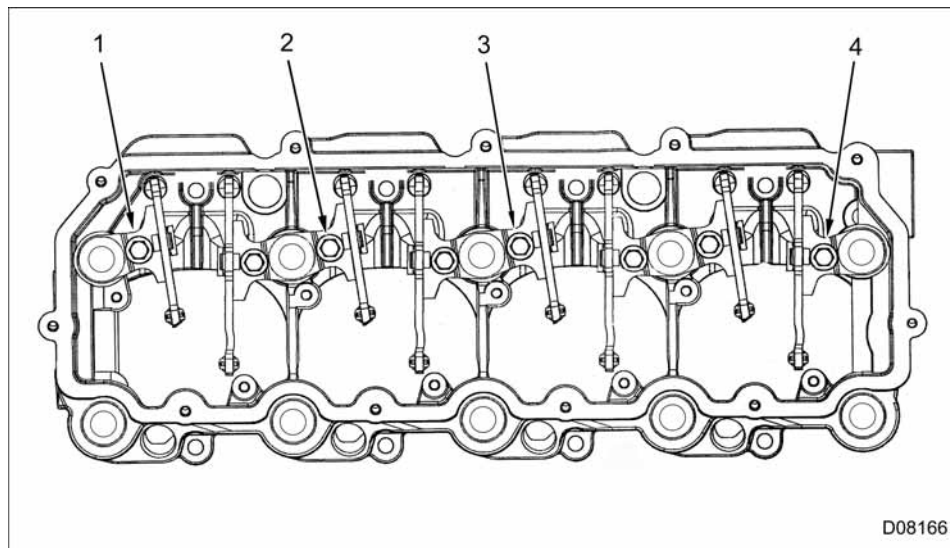
4. Use a wrench to turn the bolt of the Glow Plug Sleeve Remover until the glow plug sleeve is extracted.



**Figure 184 Glow plug sleeve**

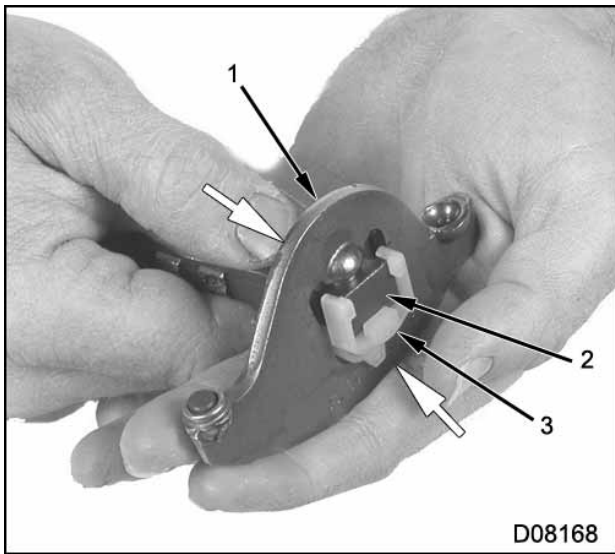
5. Remove glow plug sleeve.

#### Rocker Arm Carrier Fulcrum Removal



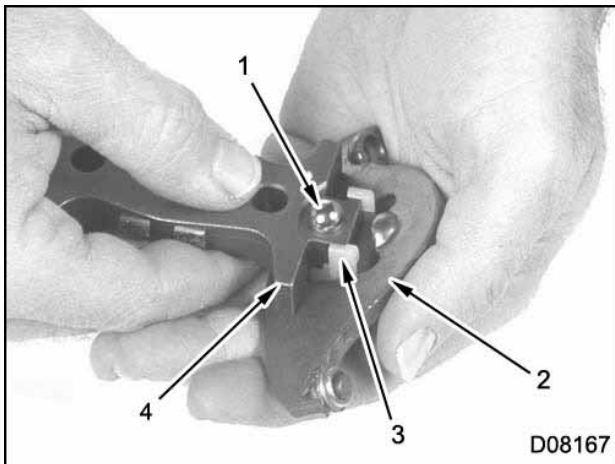
**Figure 185 Rocker arm fulcrum plates**

- |                         |                                      |                                  |                          |
|-------------------------|--------------------------------------|----------------------------------|--------------------------|
| 1. Intake fulcrum plate | 2. Mounting bolt and spacer (8 each) | 3. Dual rocker fulcrum plate (3) | 4. Exhaust fulcrum plate |
|-------------------------|--------------------------------------|----------------------------------|--------------------------|
- 
1. Remove eight M8 x 65 bolts and spacers holding rocker arm fulcrums to the rocker arm carrier.
  2. Remove – as assemblies – the intake fulcrum plate, three dual rocker fulcrum plates, and exhaust fulcrum plate from the rocker arm carrier. Do steps 3 through 6 to disassemble.



**Figure 186 Separation of rocker arm from fulcrum plate (typical)**

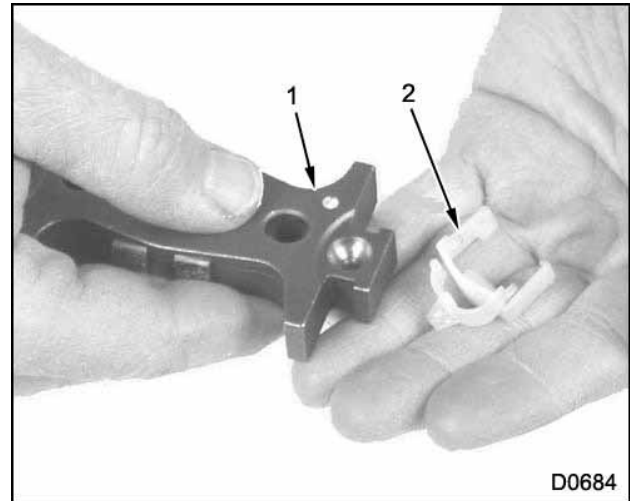
1. Rocker arm
  2. Fulcrum plate
  3. Rocker arm clip
3. Put rocker arm and fulcrum plate assembly upside down in your palm.
  4. Push up on the rocker arm with palm and forward on the fulcrum plate with thumb of opposite hand.



**Figure 187 Rocker arm separated (typical)**

1. Fulcrum plate
2. Rocker arm ball
3. Rocker arm
4. Rocker arm clip

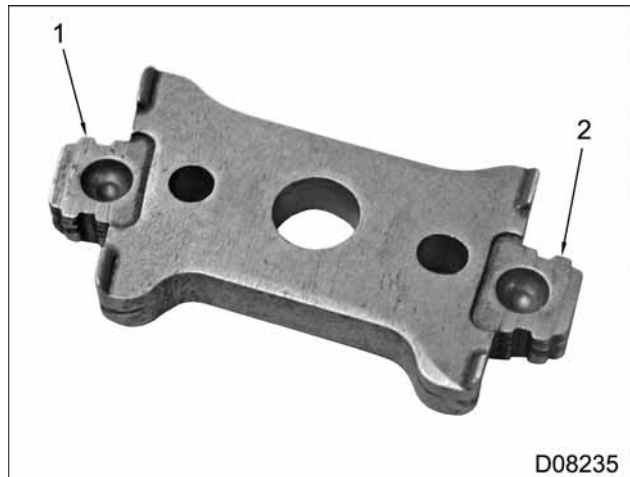
5. Remove the rocker arm and rocker arm ball.



**Figure 188 Rocker arm clip removed (typical)**

1. Fulcrum plate
2. Rocker arm clip

6. Remove and discard rocker arm clip.



**Figure 189 New rocker arm fulcrum (dual)**

1. Exhaust end
2. Intake end

**NOTE:** Earlier rocker arm fulcrums are no longer serviceable; new rocker arm fulcrums and clips are required.

## Cleaning, Inspection, and Testing

### Cylinder Head and Crankcase Components

1. With valves installed to protect seats, use a scraper and wire brush to remove deposits and gasket material from valve heads and gasket surface. Do not damage gasket surface of cylinder head.
2. Use a suitable solvent to remove dirt, grease, and deposits from removed parts.

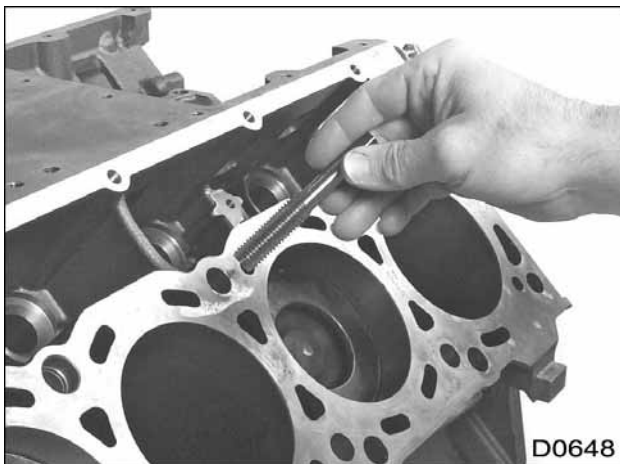
**! WARNING:** To prevent personal injury or death, wear safety glasses with side shields to protect eyes. Limit compressed air pressure to 207 kPa (30 psi).

3. Clean all bolt holes, Make sure gasket surfaces, oil return, and coolant passages are clean. After rinsing thoroughly with hot water, dry with filtered compressed air.

**CAUTION:** To prevent engine damage, new head bolts and a new cylinder head gasket must be used when installing the cylinder head. Even if one bolt was removed, a new cylinder head gasket and new bolts are required.

4. Clean all bolts (except head bolts) with a suitable solvent and dry thoroughly. New head bolts must be installed.
5. Clean crankcase threads.

**NOTE:** Dirt in threads or damaged threads may cause binding, resulting in a false torque reading.

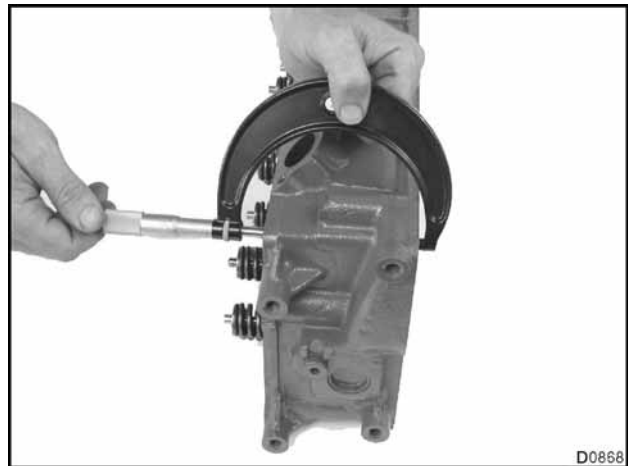


**Figure 190 Bottoming tap**

6. Use a Bottoming Tap (metric) (Table 12) to clean each tapped hole in crankcase top deck. Remove debris with filtered compressed air.
7. Thoroughly clean pushrods with a suitable solvent. Dry with filtered compressed air.

### Cylinder Head Inspection – Valves Installed

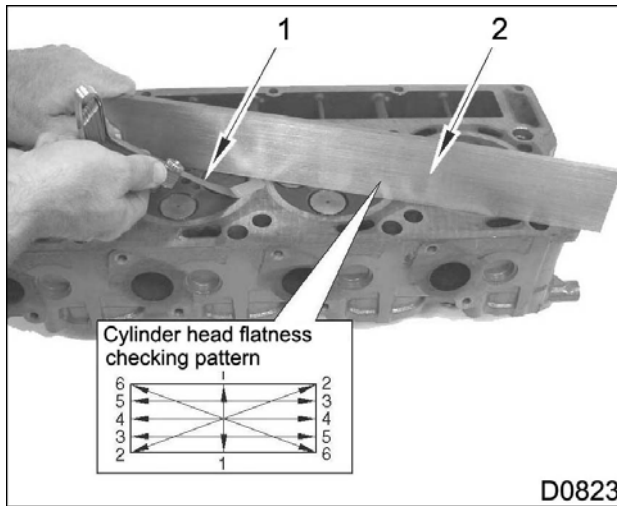
**NOTE:** Inspect cylinder head for thickness, warping, cracks, and valve leakage.



**Figure 191 Measurement of cylinder head thickness**

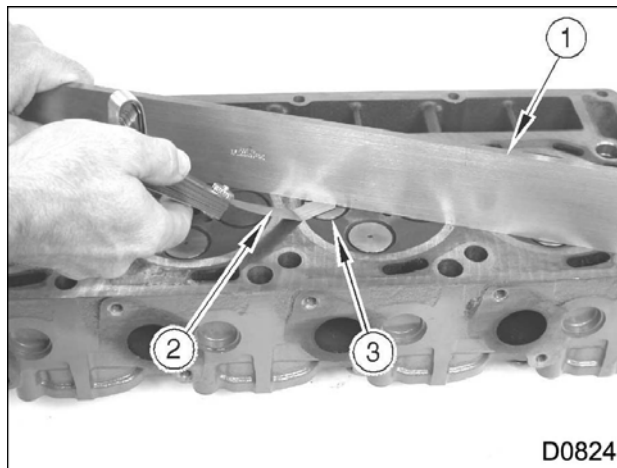
1. To determine if cylinder head has been resurfaced previously, use a 3-4 inch micrometer to measure deck thickness of cylinder head at four corner locations. If overall cylinder head thickness (deck-to-deck) specification is not met (Table 10), install new cylinder head.





**Figure 192 Check for gasket surface flatness**

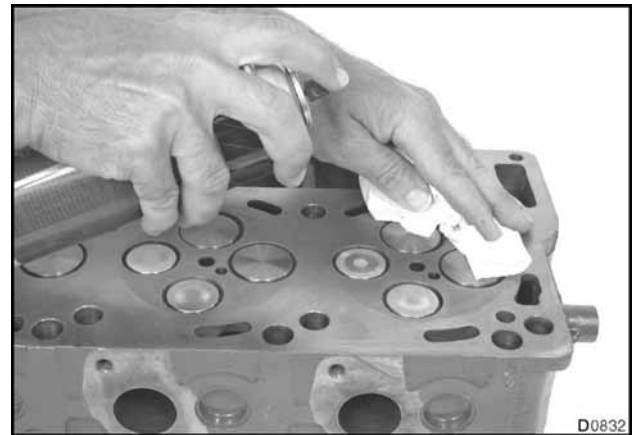
1. Feeler gauge
  2. Straightedge
2. Use a straightedge and feeler gauge to check gasket surface of cylinder head for flatness. Check for flatness horizontally, diagonally, and transversely. If not to specifications (Table 10), install new cylinder head.



**Figure 193 Checking valve recession**

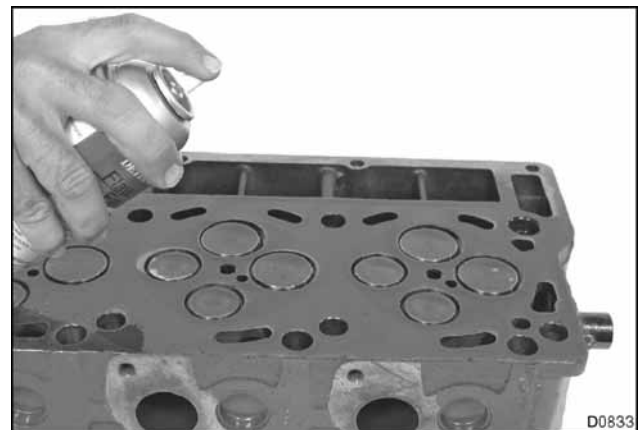
1. Straightedge
  2. Feeler gauge
  3. Valve head
3. Before removing valves, check valve head recession (relative to deck) as follows:

- a. Place a straightedge across each valve.
  - b. Place a feeler gauge between straightedge and valve head.
  - c. If out of specification (Table 10), replace valve. Do step 2 again, and if specifications are still not met, replace cylinder head.
4. Use the Dye Penetrant Kit (Table 12), to inspect for cracks in cylinder head



**Figure 194 Cleaner sprayed on cylinder head**

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

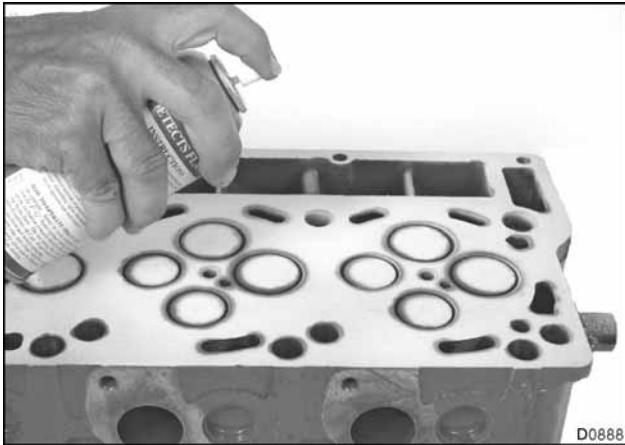


**Figure 195 Dye penetrant sprayed on cylinder head**

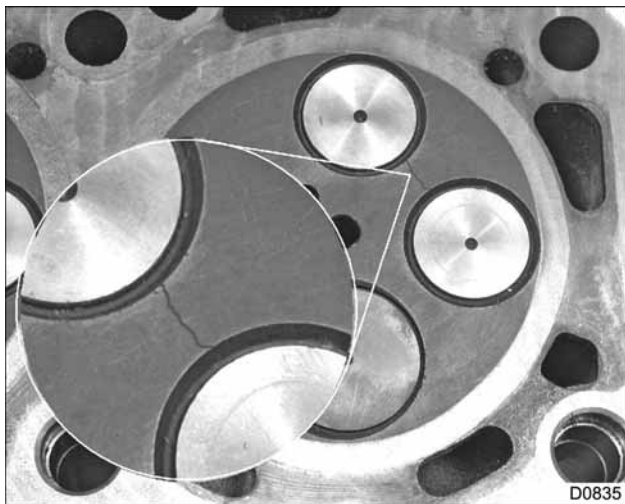
6. Spray dye penetrant on lower deck (gasket surface) of cylinder head and let dry for 5 to 15 minutes. Cracks will show up as purple lines against white developer.

7. Wipe dye off cylinder head surface.

**NOTE:** Dye will remain in cracks.



**Figure 196** Spraying developer onto cylinder head



**Figure 197** Cylinder head crack between intake and exhaust valves

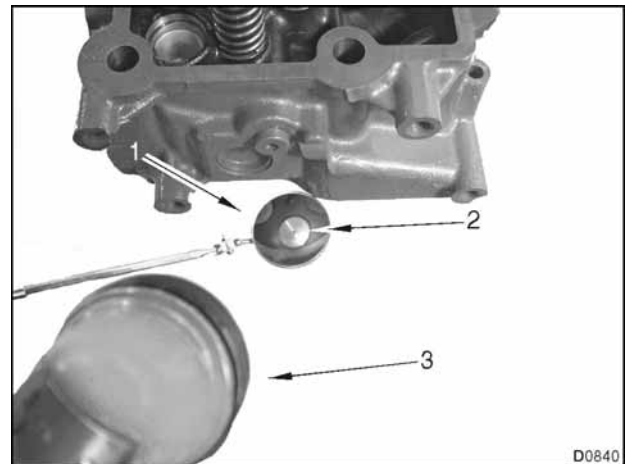
8. Spray developer on lower deck (gasket surface) of cylinder head and let dry for 5 to 15 minutes. Cracks will show up as purple lines against white developer.

**CAUTION:** To prevent engine damage, replace the cylinder head if cracked.



**Figure 198** Intake and exhaust ports sprayed with mineral spirits

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



**Figure 199** Leak inspection

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

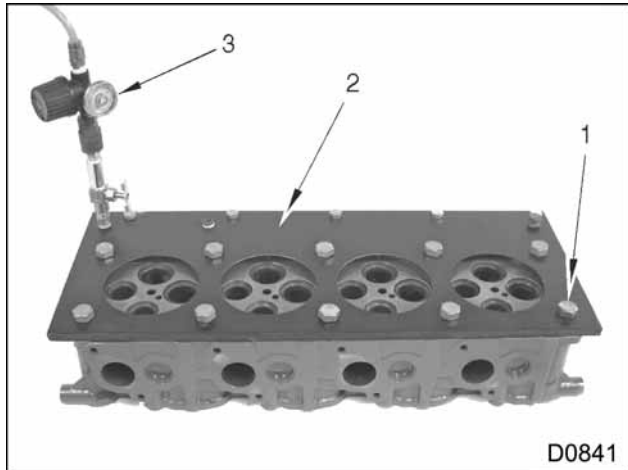
10. Wait five minutes. Use an inspection mirror to inspect valve seat area for leakage of mineral spirits.

**NOTE:** Valve seats must not leak. Valve seat reconditioning is not required, if the cylinder head passes the mineral spirits test. If valve seats leak, recondition the valves. See Removal in this section.

**Cylinder Head Inspection – Valves Removed**

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

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

**Figure 200 Cylinder head test plate**

1. Mounting bolt (15)
  2. Pressure test plate
  3. Pressure gauge and regulator
2. Fasten Cylinder Head Pressure Test Plate (Table 12) with rubber gasket attached to gasket side of cylinder head. Secure plate with ten M14 and five M8 mounting bolts.
  3. Immerse cylinder head in water. Apply air pressure and adjust to 124 to 138 kPa (18 to 20 psi) and inspect for leaks in the following places. If leaks are seen, install new cylinder head.
    - Ports
    - Upper cylinder head deck
    - Lower cylinder head deck
    - Nozzle sleeve area
    - Glow plug sleeve area

4. Install pressure test regulator and gauge assembly to cylinder head test plate (Table 12).
5. With the valves removed from the cylinder head, clean all valve guides using a nylon brush, soap and water. Blow out any residue with filtered compressed air.
6. Position an inspection light at the bottom of the valve guide bores and examine the walls for burning or cracking. Replace the cylinder head, if necessary.

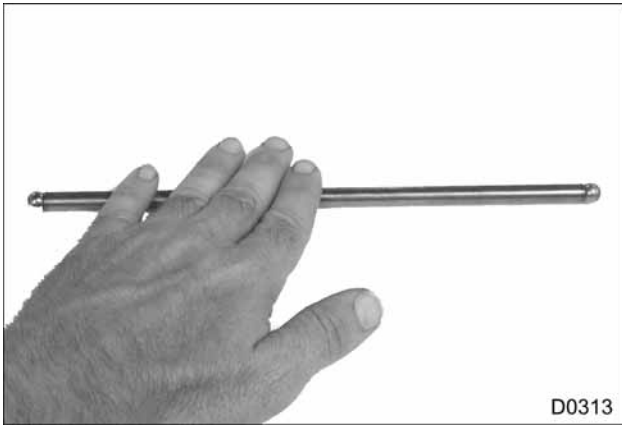
**Figure 201 Measurement of Small Hole Gauge (valve guide ID)**

7. Measure each valve guide by using a small hole gauge (Table 12) and a 0-1 inch outside micrometer.
8. Record each valve guide inner diameter so valve-to-guide running clearance may be determined.
  - If valve guide inner diameter exceeds specifications (Table 10), replace cylinder head.
9. Using the valve guide inside diameter and valve stem diameter measurements, determine valve stem-to-guide running clearance. See Specifications (Table 10). Replace valve if necessary.
10. Clean valve seat area using suitable solvent, before inspection.

11. Inspect the exhaust valve seats for burned or cracked conditions. If any of these conditions exist, replace cylinder head.

### Push Rods

1. Inspect pushrods for wear and deposits that may restrict oil flow into rocker arm assemblies. Replace pushrod if necessary.



**Figure 202 Push rod straightness**

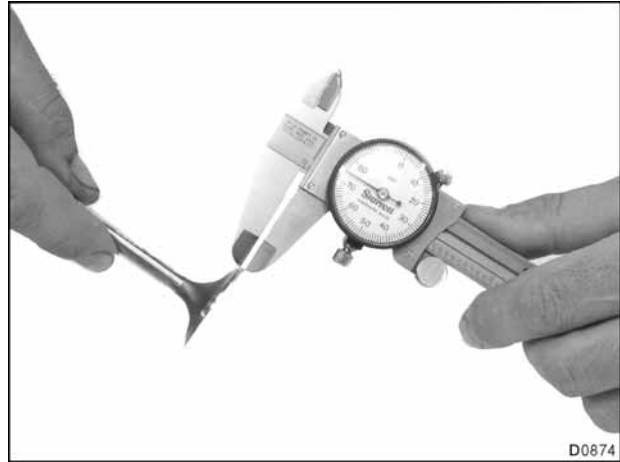
2. Roll pushrod on a flat surface to check straightness. If a pushrod is not straight, see Specifications for runout (Table 10). If specifications are exceeded, replace pushrod.

### Valves

1. Remove all carbon from valve stems and heads, using a wire brush.
2. Inspect each valve. Replace valves having burn marks, warping, scuffing, bending or valve tip spalling.
3. Measure each valve stem diameter for wear using a 0-1 inch micrometer. Measure valves at three

locations 90° apart. See Specifications (Table 10). Replace valves that exceed the specification for minimum stem diameter.

**NOTE:** The intake valve has a larger diameter head.



**Figure 203 Measurement of valve face**

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

**CAUTION:** To prevent engine damage, minimum valve face margin must be maintained across the entire valve face. An insufficient margin will not provide correct heat dissipation and lead to valve warping or breakage. Intake and exhaust valve margins are different. Replace valve, if the margin is less than specified minimum. See Specifications (Table 10).

**NOTE:** If valves and seats are serviceable, they may be refaced to specified angles (Table 10).

### Valve Springs

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



**Figure 204 Flatness check of valve spring**

3. Inspect to verify that spring ends are flat and square to prevent lateral loads on valve stem. Replace any springs if necessary.
4. Measure valve spring tension using a Valve Spring Tester (Table 12). Replace springs if necessary.



**Figure 205 Measurement of valve spring free length**

5. Measure valve spring free length. See Specifications (Table 10).



**Figure 206 Measurement of valve spring free length under load**

6. Apply correct test load to each spring and determine whether test length is achieved. See Specifications (Table 10).

#### Valve Spring Retainer Keys

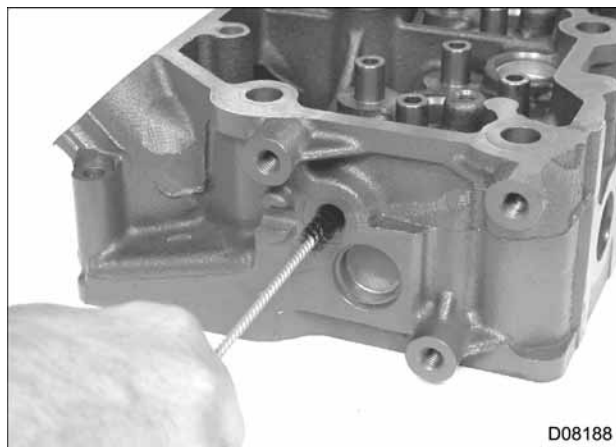
1. Clean all valve spring retainer keys with a suitable cleaning solvent.
2. Inspect inside and outside of valve spring retainer keys for wear. Replace worn valve spring keys, if necessary.

#### Fuel Injector Sleeve Bore and Gallery



**Figure 207 Injector bore**

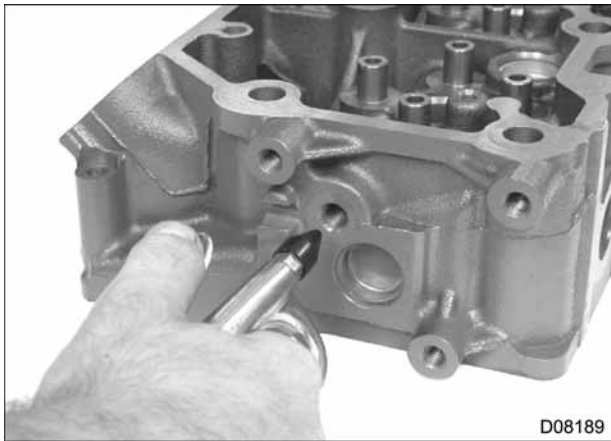
1. Insert an injector sleeve brush (Table 12) in the fuel injector bore and remove deposits and hardened sealant.
2. Remove fuel rail plug assembly (M12).



**Figure 208 Fuel gallery**

3. Clean the fuel gallery, using a Fuel Gallery Cleaning Brush (Table 12).

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



**Figure 209 Fuel gallery**

4. Use filtered compressed air to clean out debris from the fuel gallery port.
5. Install fuel rail plug assembly and tighten to the special torque (Table 11).

#### **Glow Plug Sleeve Bore**



**Figure 210 Glow plug bore**

1. Clean glow plug bore with Glow Plug Sleeve Seat Wire Brush (Table 12).

#### **Rocker Fulcrums**

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

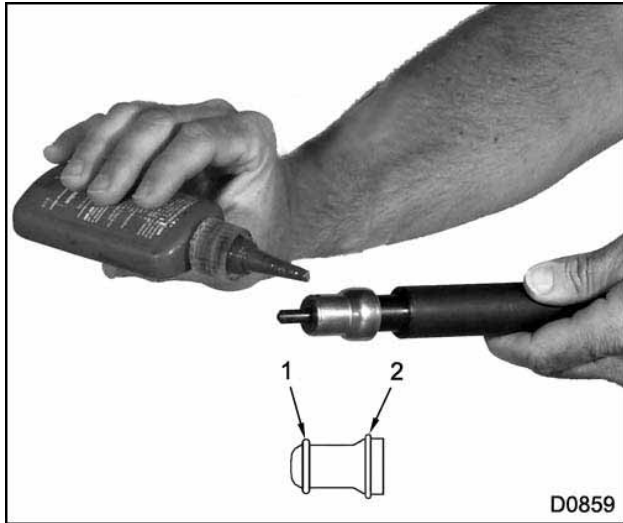
1. Clean parts with a suitable solvent. Use filtered compressed air to dry parts.
2. Inspect each rocker arm pivot foot and corresponding valve bridge for pitting or scuffing. Replace rocker arms and valve bridges, if necessary.
3. Inspect each rocker arm ball and socket for scuffing. Replace rocker arm ball and socket, if necessary.
4. Inspect rocker arm post ball socket for excessive wear. Inspect bolts for thread damage. Replace worn components, if necessary.
5. Inspect the valve cover gasket for damage or misalignment under compression. Under normal service conditions, the gasket can be reused.

## Installation

### Fuel Injector Sleeve

Do the following steps when installing a new fuel injector sleeve:

1. Verify injector bore is completely clean and dry.
2. Put fuel injector sleeve on Injector Sleeve Installer. (Table 12).



**Figure 211 Application of liquid gasket to fuel injector sleeve**

1. Wall (end)
2. Upper wall (top)
3. Apply Liquid Gasket (RTV) (Table 12) to fuel injector sleeve.
4. Carefully center the fuel injector sleeve in the injector bore.



**Figure 212 Installation of fuel injector sleeve into bore**

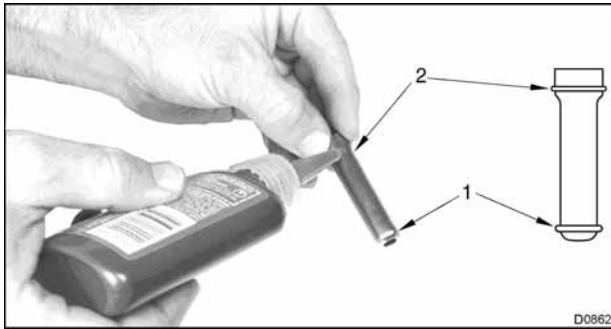
5. Use a hammer, drive Injector Sleeve Installer with fuel injector sleeve in fuel injector bore until the sleeve bottoms. If any liquid gasket gets in the inside of the injector sleeve, it must be cleaned out before it hardens.

### Glow Plug Sleeve

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

**NOTE:** Make sure the glow plug recess was cleaned out with the glow plug sleeve brush, rinsed with a suitable cleaning solution, and blown out with shop air.

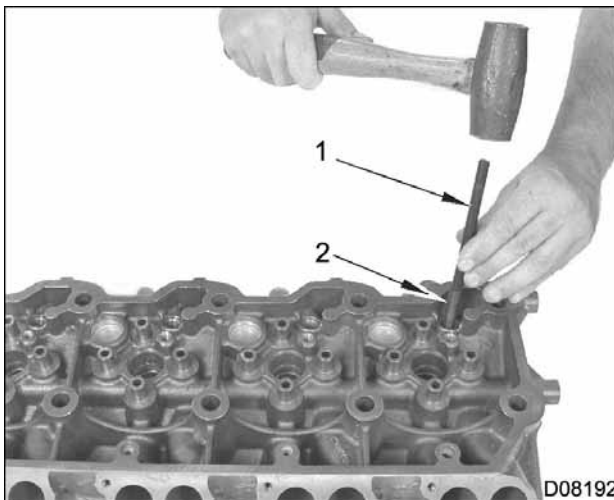




**Figure 213 Application of liquid gasket to sleeve**

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

1. Apply Liquid Gasket (RTV) (Table 12) to the wall and upper wall on the glow plug sleeve.



**Figure 214 Installation of glow plug sleeve**

1. Glow Plug Sleeve Installer
  2. Glow plug sleeve
2. Install glow plug sleeve in cylinder head with the Glow Plug Sleeve Installer (Table 12). Continue to tap the Glow Plug Sleeve Installer until the sleeve bottoms out in the recess.
  3. Clean glow plug sleeve with a Glow Plug Sleeve Brush (nylon) (Table 12) and solvent. Make sure liquid gasket is cleaned out before it hardens.

## Cylinder Head Assembly

### Install Valves

1. Clean valve faces and seats with a suitable cleaning solvent to remove all dirt or foreign material.

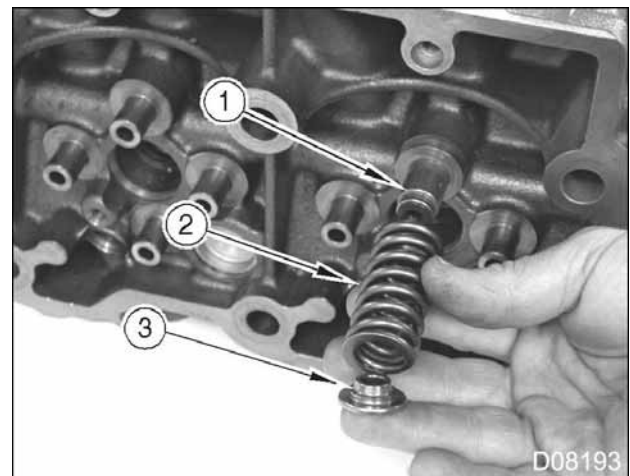
**! WARNING:** To prevent personal injury or death, wear safety glasses with side shields to protect eyes. Limit compressed air pressure to 207 kPa (30 psi).

2. Blow dry all new and used components.

**NOTE:** Guides must be clean.

3. Clean guides with valve guide brush.
4. Dry valve guides with filtered compressed air.
5. Lubricate the inside diameter of the new valve stem seal with clean engine oil and install valve seal over valve guide until it stops.

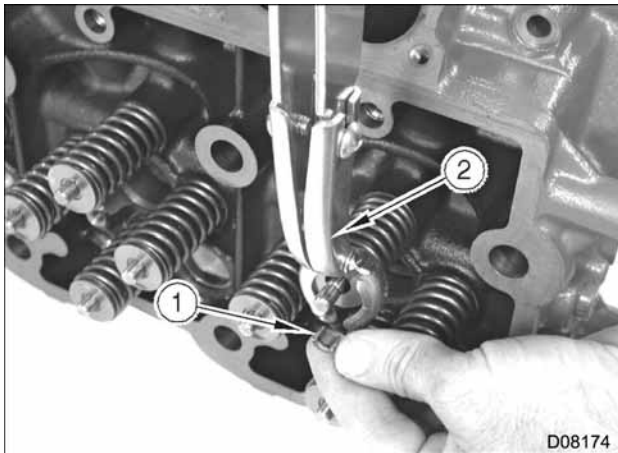
**NOTE:** Valve seal will not seat completely over valve guide by hand. Seals can be seated using a deep socket and a rubber mallet to provide a positive contact with the machined base.



**Figure 215 Installation of valve seal, spring, and retainer**

1. Valve seal
2. Valve spring
3. Valve retainer

6. Place valve spring over valve stem seal.
7. Install a valve spring retainer on top of spring.



**Figure 216** Installation of valve retainer key

1. Valve retainer key
2. Valve spring compression tool

8. Attach "C" Type Valve Spring Compressor (Table 12) and compress the valve spring. Install the retainer keys and release valve spring compression tool.

**CAUTION:** To prevent engine damage, make sure retainer keys are correctly seated in each valve stem.

9. After valve replacement, measure valve head recession relative to deck to confirm reconditioning. See Specifications (Table 10).

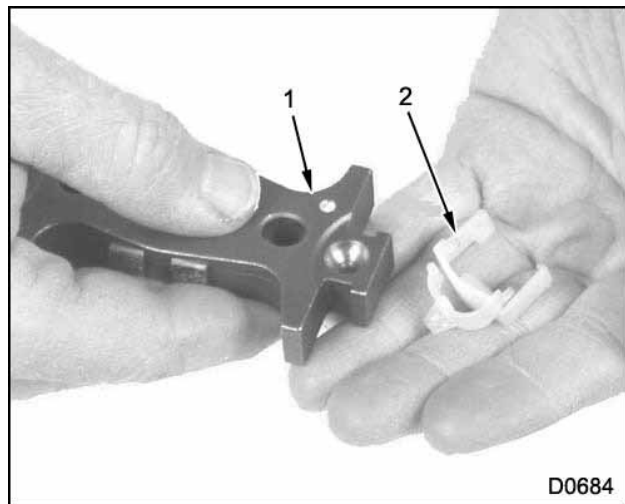
#### Rocker Arm Carrier Fulcrum Assemblies



**Figure 217** New rocker arm fulcrum (dual underside)

1. Exhaust end
2. Intake end

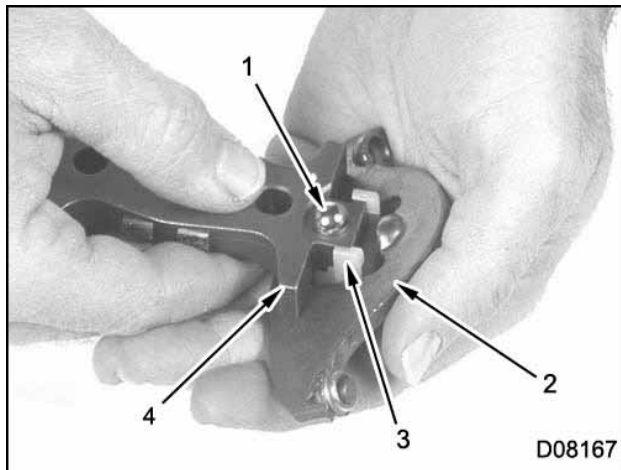
**NOTE:** Earlier rocker arm fulcrums are no longer serviceable; new rocker arm fulcrums and clips are required.



**Figure 218** Installation of new rocker arm clip (typical)

1. Fulcrum plate
2. Rocker arm clip

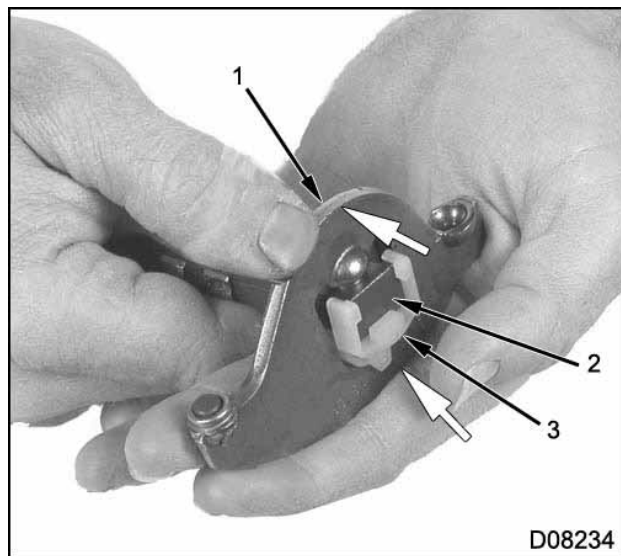
1. Install a new rocker arm clip on new fulcrum plate.



**Figure 219 Installation of rocker arm ball (typical)**

1. Rocker arm ball
2. Rocker arm
3. Rocker arm clip
4. Fulcrum plate

2. Insert rocker arm ball in detent in fulcrum plate.



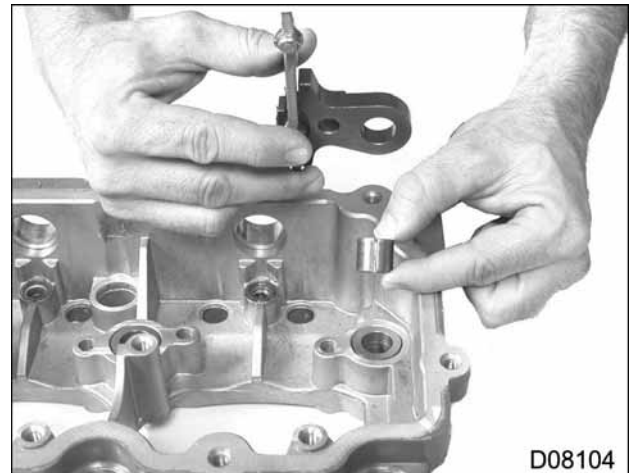
**Figure 220 Installation of rocker arm (typical)**

1. Rocker arm
2. Fulcrum plate
3. Rocker arm clip

3. Position lower part of rocker arm under rocker arm clip, push up with your palm, and use thumb back

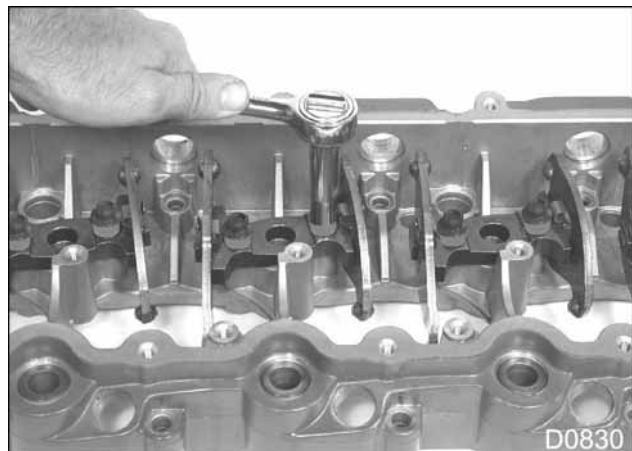
to pull upper part of rocker arm over rocker arm ball.

4. Check for freedom of movement of rocker arm on fulcrum plate.



**Figure 221 Installation of end fulcrum plate and dowel (typical)**

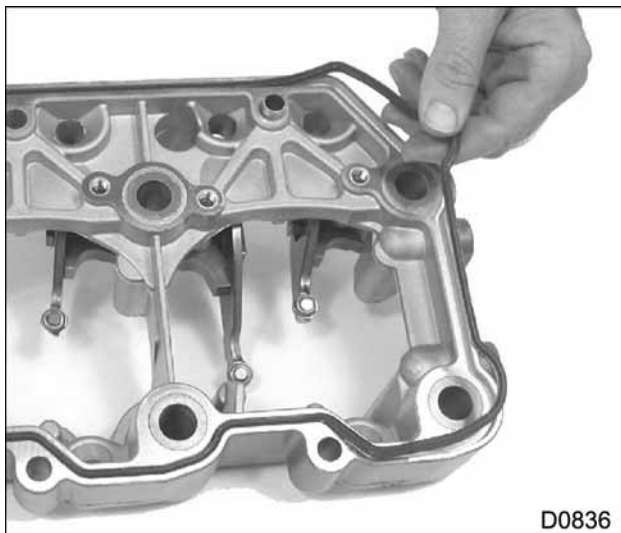
5. Assemble intake and exhaust fulcrum plates to each end of the rocker carrier assembly by setting the fulcrum on the locating dowel and orienting the stamped **E** and **I** face up. Install an M8 x 65 bolt and spacer on each fulcrum and tighten to the special torque (Table 11).



**Figure 222 Installation of dual rocker fulcrum plates**

6. Assemble the dual rocker fulcrum plates to carrier assembly by orienting the **E** and **I** up and

the casting branches toward the camshaft. Install six M8 x 65 bolts and spacers and tighten to the special torque (Table 11).



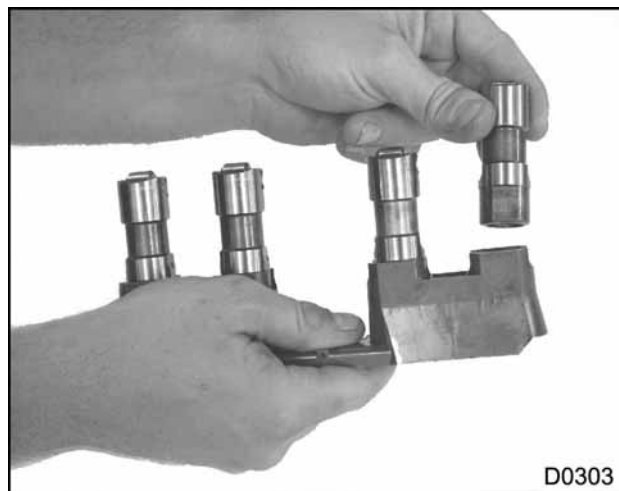
**Figure 223** Cylinder head to rocker carrier gasket

7. Replace cylinder head to rocker carrier gasket.

#### Hydraulic Cam Follower

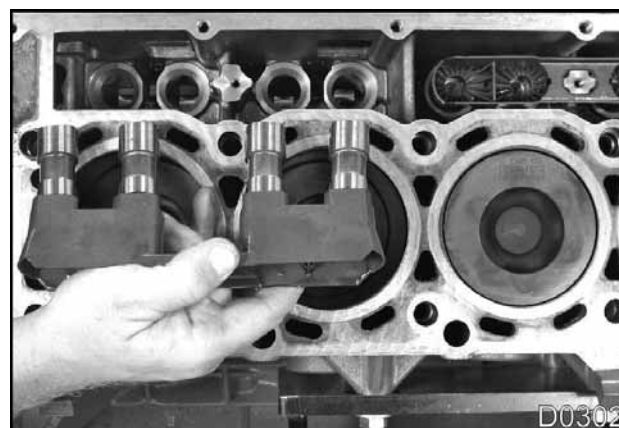
1. Clean hydraulic cam followers and roller follower guide. Use care to maintain roller follower identification and orientation.

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



**Figure 224** Installation of cam follower in guide

2. Lubricate and put each hydraulic cam follower in its respective roller follower guide.



**Figure 225** Installation of cam followers and guide

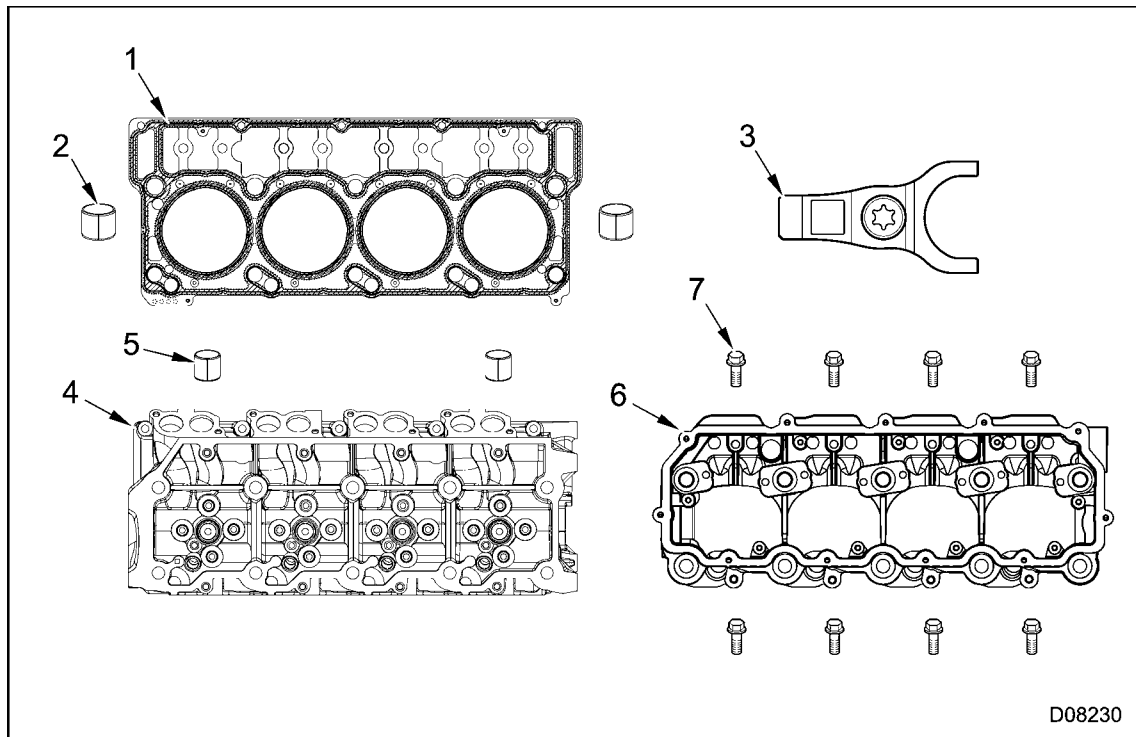
3. Lubricate cam followers with clean engine oil and install cam followers in correct bores.

**NOTE:** See "High-pressure Oil Pump" section, for procedure to mount branch tube assembly over rear cam follower guides.

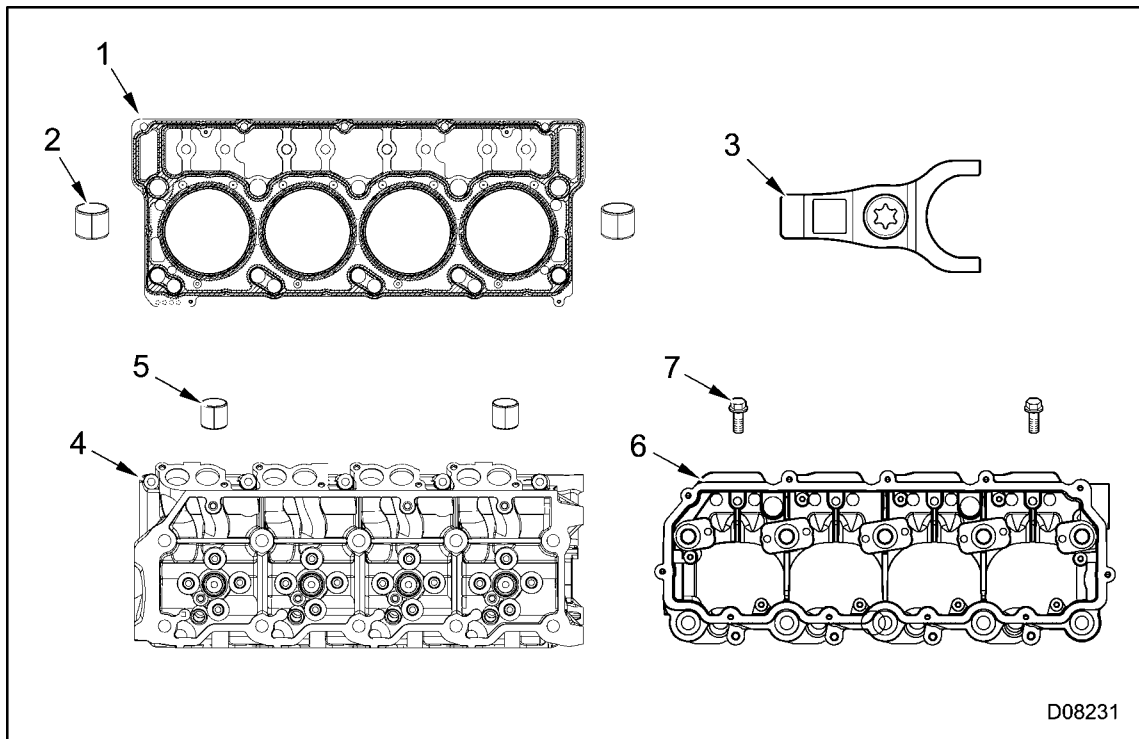
to the standard value (Standard Torques, page 375).

4. Install an M6 x 15 bolt with washer on roller follower guides (front guides only) and torque bolt

## Cylinder Head Applications

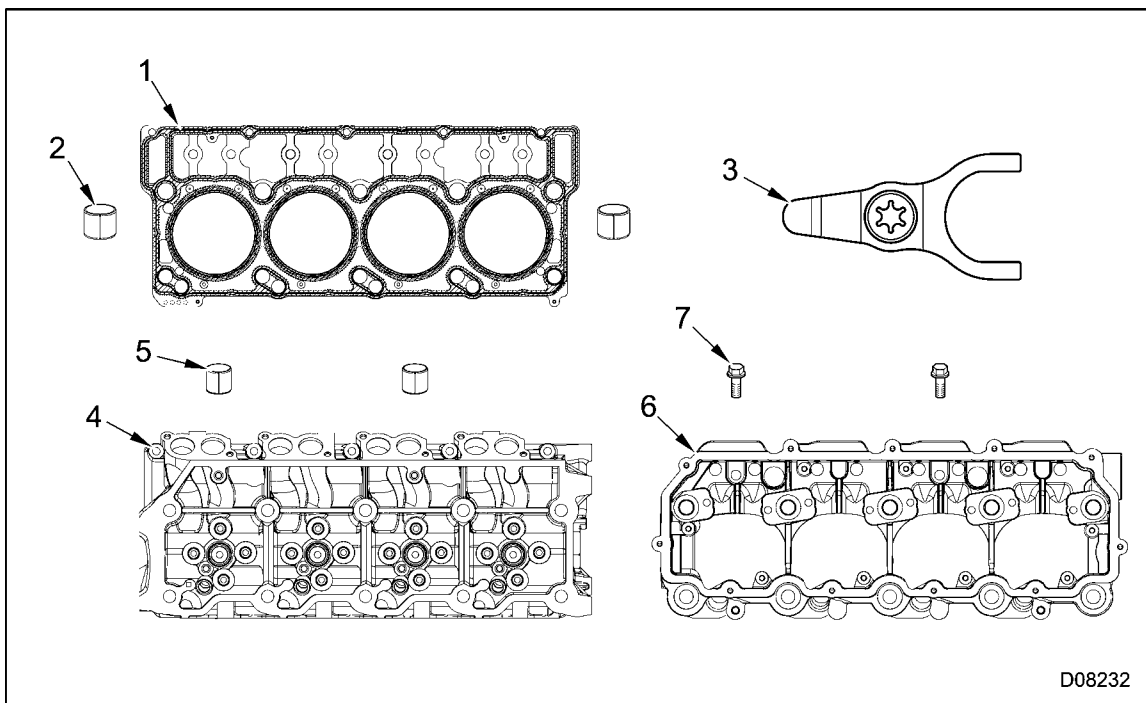
**Figure 226 2004 and 2005 Model Year (eight M8 mounting bolts for rocker arm carrier)**

- |                               |                                  |                                |
|-------------------------------|----------------------------------|--------------------------------|
| 1. Cylinder head gasket       | 3. Fuel injector hold down clamp | 5. M8 dowel sleeve bushing (2) |
| 2. 18 mm spring dowel pin (2) | (4)                              | 6. Rocker arm carrier          |
| 4. Cylinder head              | 7. M8 bolt (8)                   |                                |



**Figure 227 2005 Model Year (two M8 mounting bolts for rocker arm carrier)**

- |                               |                                  |                                 |
|-------------------------------|----------------------------------|---------------------------------|
| 1. Cylinder head gasket       | 3. Fuel injector hold down clamp | 5. M10 dowel sleeve bushing (2) |
| 2. 18 mm spring dowel pin (2) | (4)                              | 6. Rocker arm carrier           |
| 4. Cylinder head              | 7. M8 bolt (2)                   |                                 |



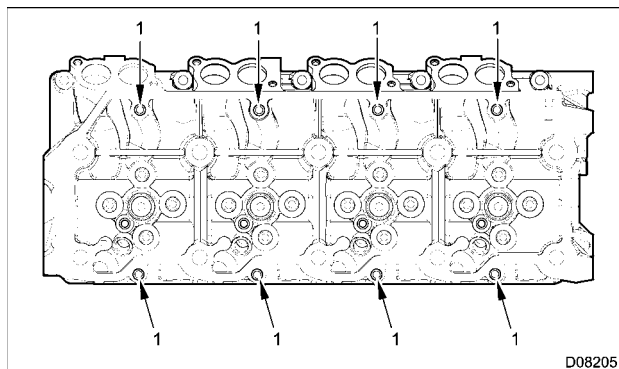
**Figure 228 2006 Model Year (two M10 mounting bolts for rocker arm carrier)**

- |                               |                                  |                                 |
|-------------------------------|----------------------------------|---------------------------------|
| 1. Cylinder head gasket       | 3. Fuel injector hold down clamp | 5. M10 dowel sleeve bushing (2) |
| 2. 20 mm spring dowel pin (2) | (4)                              | 6. Rocker arm carrier           |
| 4. Cylinder head              | 7. M10 mm bolt (2)               |                                 |

**NOTE:** 2006 Model Year parts are not interchangeable with 2004 or 2005 Model Year applications.

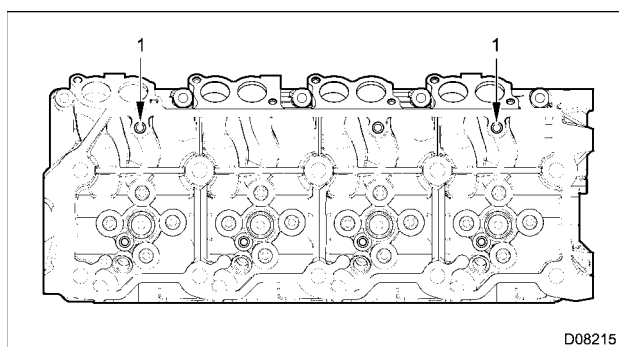


1. If not done, clean all cylinder head bolt holes with a bottoming tap (Table 12) and remove debris with filtered compressed air.



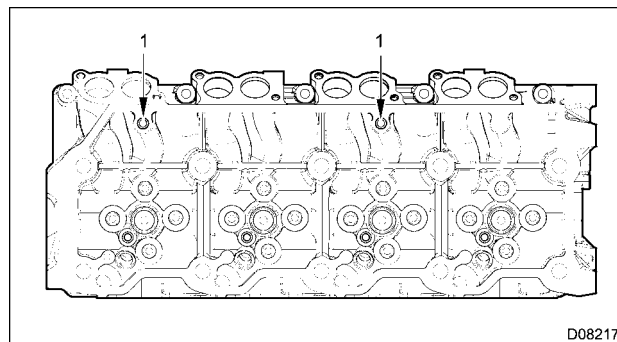
**Figure 229 2004 and 2005 Model Year cylinder head (eight tapped M8 holes)**

1. Tapped M8 bolt hole (8)



**Figure 230 2005 Model Year cylinder head (two tapped M8 holes)**

1. Tapped M8 bolt hole (2)



**Figure 231 2006 Model Year cylinder head (two tapped M10 holes)**

1. Tapped M10 bolt hole (2)



**Figure 232 Cylinder head spring dowel pin in crankcase (typical)**

1. Spring dowel pin (2)

2. Make sure two spring dowel pins are installed in crankcase.

- For 2004 and 2005 Model Year cylinder heads, use 18 mm spring dowel pins.
- For 2006 Model Year cylinder heads, use 20 mm spring dowel pins.

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

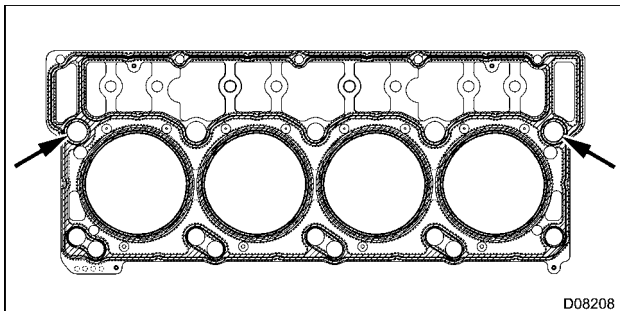
**CAUTION:** Threads in crankcase bolt holes must be clean and blown dry with filtered compressed air. Dirt or oil left in holes may cause binding or a false torque reading during assembly.

**CAUTION:** To prevent engine damage, make sure cylinder head and head gasket are clean and free of debris. A contaminated seal between the cylinder head and gasket can lead to oil, coolant, and compression leakage. Do not apply sealer to head gasket surfaces.



**Figure 233** Installation of cylinder head gasket

1. Cylinder head gasket
2. Spring dowel pins (2)



**Figure 234** Clearance holes for spring dowel pins (typical)

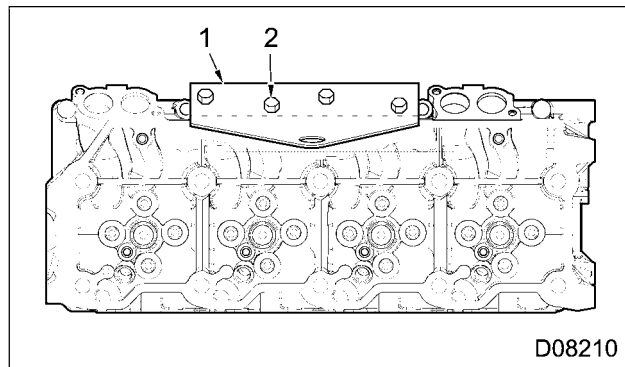
**CAUTION:** To prevent engine damage, install the correct cylinder head gasket with part number facing up. Make sure the top five bolt holes and head gasket push rod holes line up.

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

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

- For 2004 and 2005 cylinder heads, use cylinder head gasket with 18 mm with clearance holes for two spring dowel pins.
- For 2006 cylinder heads, use cylinder head gasket with 20 mm with clearance holes for two spring dowel pins.

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

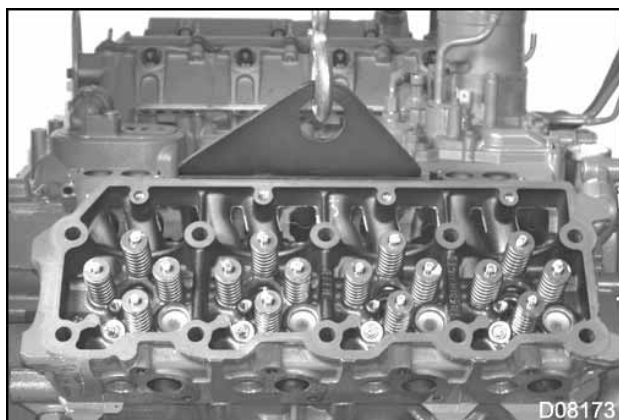


**Figure 235** Installation cylinder head lifting bracket

1. Cylinder head lifting bracket
2. Lifting bracket mounting bolt (4)

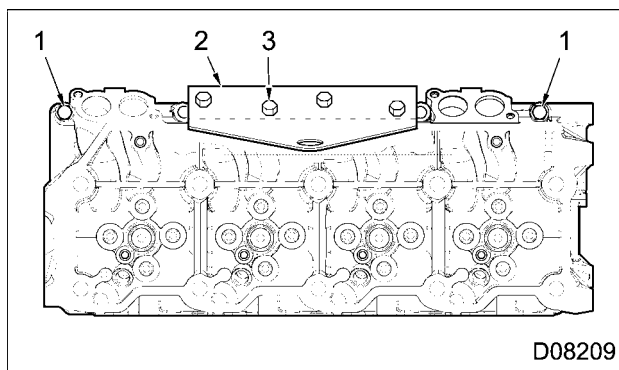
4. Install Cylinder Head Lifting Bracket (Table 12) in center of cylinder head (if removed). Tighten bracket mounting bolts.

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



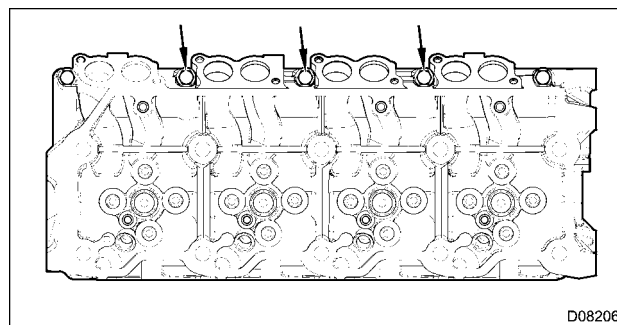
**Figure 236 Attached hoist hook**

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



**Figure 237 Installation of Cylinder head**

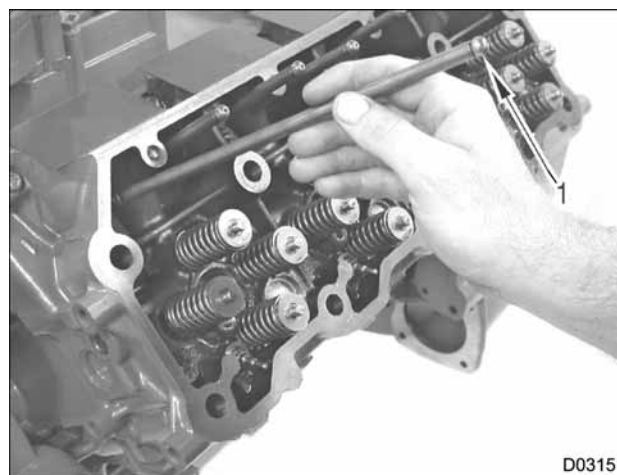
1. M8 x 70 bolt – cylinder head to crankcase (2 of 5)
  2. Cylinder head lifting bracket
  3. Lifting bracket mounting bolt (4)
6. Install two outer M8 x 70 bolts – cylinder head to crankcase. Run threads down until finger tight.
  7. Remove cylinder head lifting bracket and hoist.



**Figure 238 Installation of middle M8 x 70 bolts**

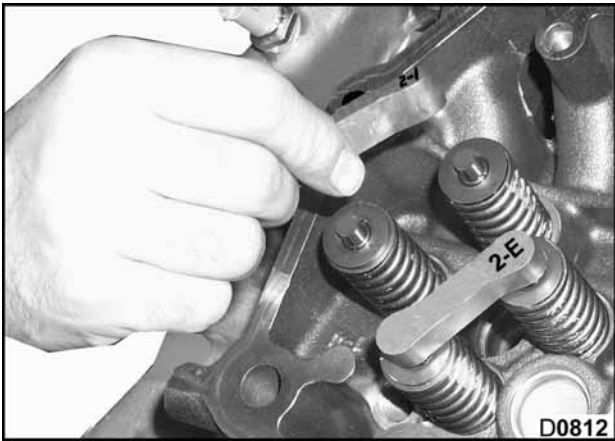
8. Install three middle M8 x 70 bolts – cylinder head to crankcase. Run threads down until finger tight.

### Valve Bridges and Push Rods



**Figure 239 Pushrod**

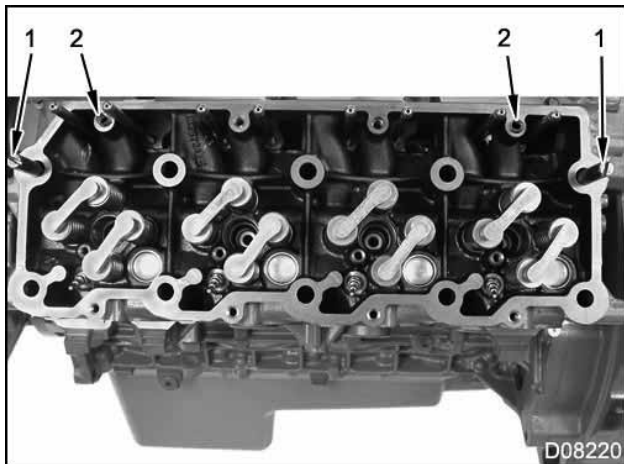
1. Pushrod
1. Apply clean engine oil to each end of pushrod and install to original locations.
  2. Coat the end of each valve stem with clean engine oil.



**Figure 240 Valve bridges**

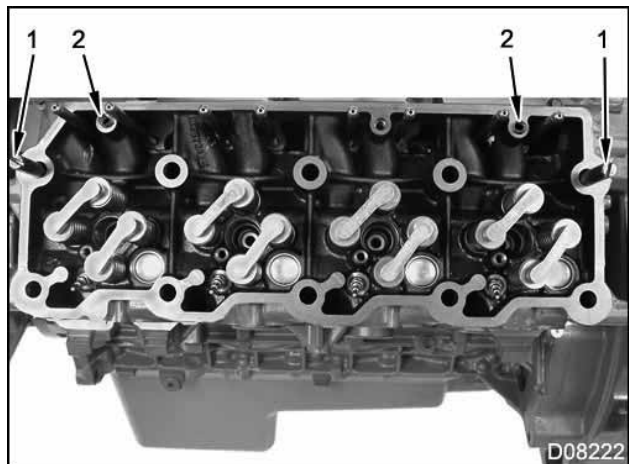
3. Place each of the previously marked valve bridges on their respective valve stems.

#### Rocker Arm Carrier



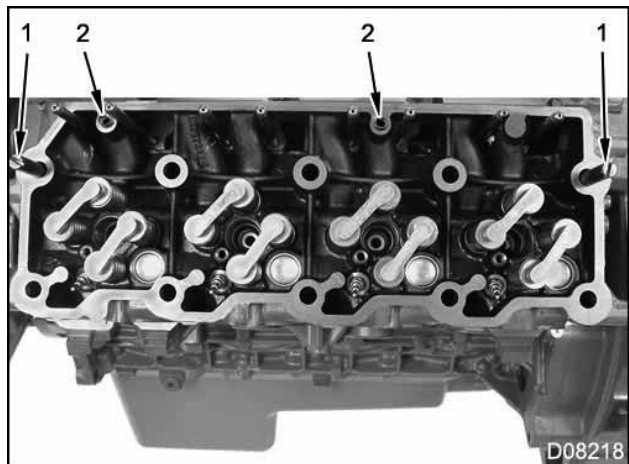
**Figure 241 Alignment guides and dowel sleeve bushing in 2004 and 2005 Model Year cylinder head (Eight tapped M8 holes)**

1. Alignment guide (2)
2. M8 dowel sleeve bushing (2)



**Figure 242 Alignment guides and dowel sleeve bushing in 2005 Model Year cylinder head (Two tapped M8 holes)**

1. Alignment guide (2)
2. M8 dowel sleeve bushing (2)



**Figure 243 Alignment guides and dowels in 2006 Model Year cylinder head (Two tapped M10 holes)**

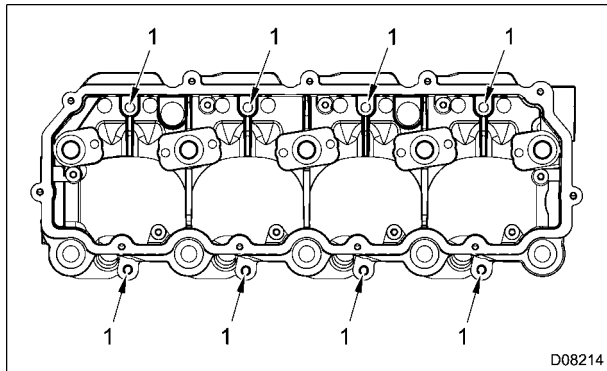
1. Alignment guide (2)
2. M10 dowel sleeve bushing (2)

1. Install dowel sleeve bushings in cylinder head.

**NOTE:** Dowel sleeve bushings may still be attached to the cylinder head side of the rocker arm carrier.

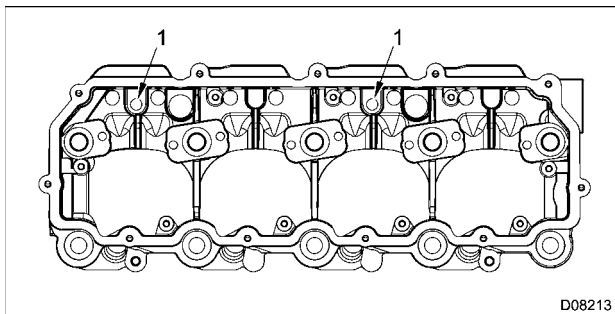
2. Install cylinder head and rocker carrier alignment guides (make locally), before installing rocker arm carrier.

3. Rotate the crankshaft until damper locating dowel hole is in the six o'clock position. This positions all pistons below TDC, so the valves do not contact the pistons when tightening the rocker arm assemblies.
4. Apply engine oil to the top center of each valve bridge.



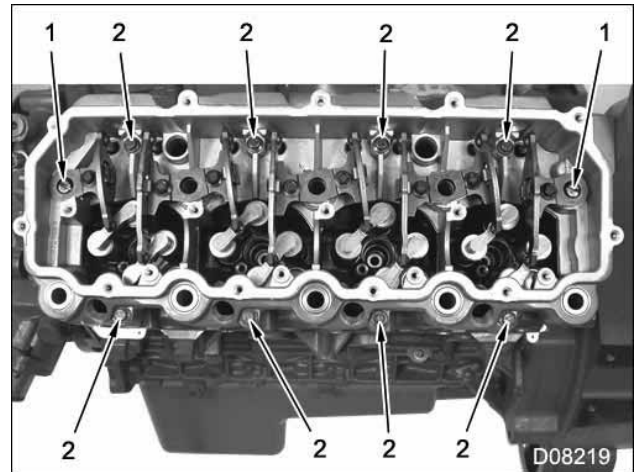
**Figure 244 2004 and 2005 Model Year rocker arm carrier (Eight M8 clearance holes)**

1. M8 clearance hole (8)



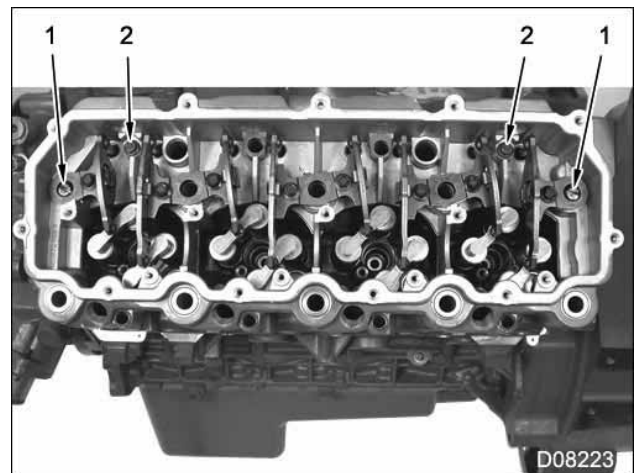
**Figure 245 2006 Model Year rocker arm carrier (Two M10 clearance holes)**

1. M10 clearance hole (2)



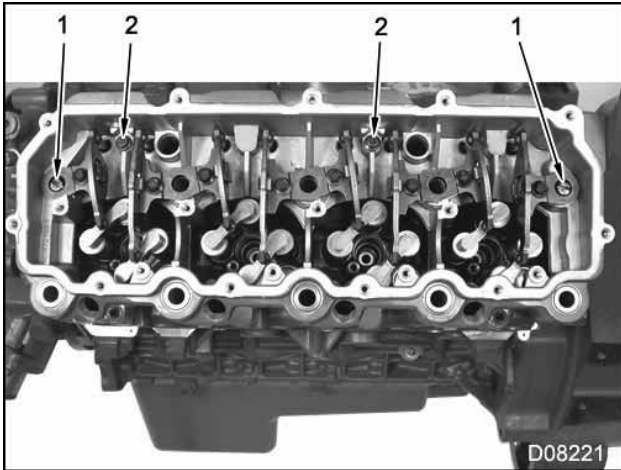
**Figure 246 Installation of 2004 and 2005 Model Year rocker arm carrier (Eight M8 mounting bolts)**

1. Alignment guides (2)
2. M8 x 50 bolt (8)



**Figure 247 Installation of 2004 and 2005 Model Year rocker arm carrier (Two M8 mounting bolts)**

1. Alignment guides (2)
2. M8 x 50 bolt (2)



**Figure 248 Installation of 2006 Model Year rocker arm carrier (Two M10 mounting bolts)**

1. Alignment guides (2)
  2. M10 x 50 bolt (2)
5. Place rocker arm carrier on guides.
  6. Install M8 bolts and tighten to the standard torque (Standard Torques, page 375).
    - Eight M8 x 50 bolts or two M8 x 50 bolts are required for 2004 and 2005 rocker arm carriers.
    - Two M10 x 50 bolts are required for 2006 rocker arm carriers.

**NOTE:** If installing eight M8 x 50 bolts, pay close attention to rocker carrier alignment dowels when tightening down rocker arm carriers. It may be necessary to tighten the top four bolts first, then the lower bolts, to ensure correct engagement of dowels.

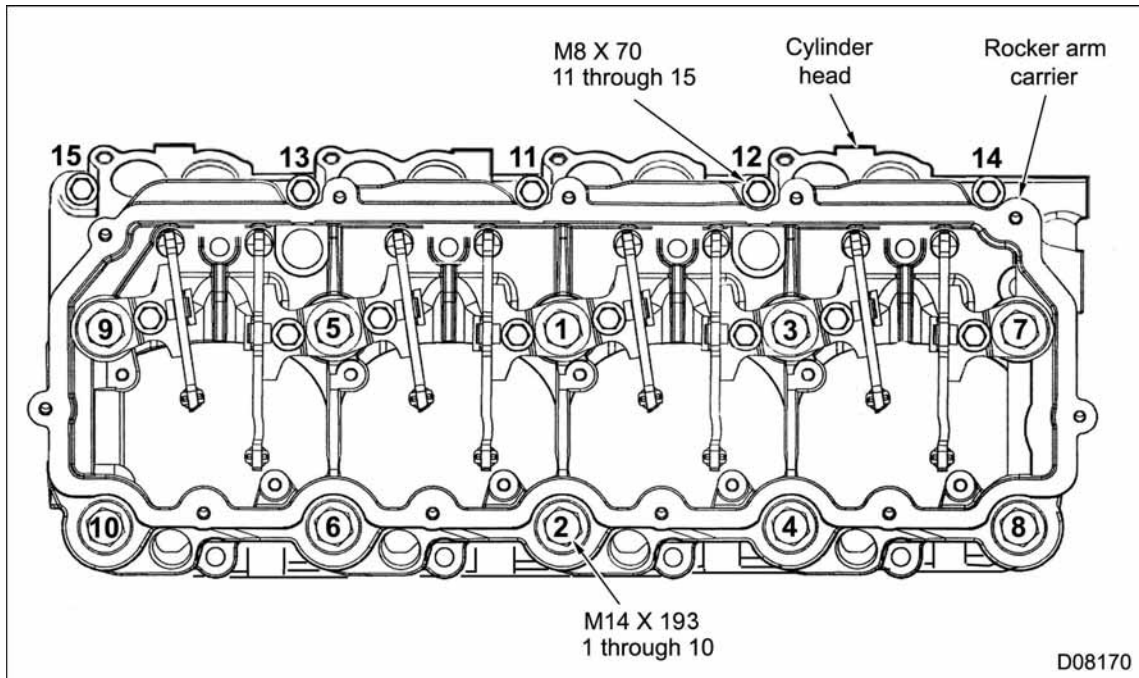
**CAUTION:** To prevent engine damage, use only permanent ink markers to identify bolt torque orientation.

**CAUTION:** To prevent engine damage, check to make sure push rod has seated in the rocker arm pocket.

**CAUTION:** To prevent engine damage, install new M14 x 193 head bolts. Lightly lubricate new bolt threads and mating surfaces of bolt flanges with clean engine oil. Too much oil will cause hydrostatic lock and give incorrect torque reading.

**CAUTION:** Do not use anti-seize, grease, or any other lubricant except engine oil. Other lubricants have an adverse effect on torque results.

7. Lightly lubricate 10 new M14 x 193 cylinder head bolts with clean engine oil.
8. Install the first eight bolts finger tight in the open positions.
9. Remove the two rocker arm carrier alignment guides and replace with the two remaining bolts finger tight.

**Tightening Sequence for Cylinder Head Bolts****M14 x 193 Bolts****Figure 249 Special torque sequence for cylinder head mounting bolts (typical)**

**NOTE:** All M14 x 193 cylinder head mounting bolts must be torqued first, before torquing M8 x 70 bolts.

1. Torque new lubricated bolts in the sequence numbered 1 through 10 to 88 N·m (65 lbf·ft).
2. Torque bolts 1, 3, 5, 7 and 9 in sequence to 116 N·m (85 lbf·ft).
3. Torque all bolts in sequence numbered 1 through 10, clockwise 90°.
4. Torque all bolts in sequence numbered 1 through 10, a second time clockwise 90°.
5. Torque all bolts in sequence numbered 1 through 10, a third time clockwise 90°.
6. M14 x 193 torque sequence complete.

**M8 x 70 Bolts**

**CAUTION:** To prevent engine damage, do not lubricate the M8 x 70 bolts. Too much oil will cause hydrostatic lock and give incorrect torque reading. Lubricants have an adverse effect on torque results.

1. See Cylinder Head Mounting Bolt Special Torque Sequence (Figure 249) for the following steps:
2. Torque M8 bolts in the sequence numbered 11 through 15 to 24 N·m (18 lbf·ft).
3. Torque all M8 bolts in the sequence numbered 11 through 15 to 31 N·m (23 lbf·ft).
4. M8 x 70 torque sequence complete.

**Fuel Injectors****Replace Copper Gasket and O-rings for Fuel Injector**

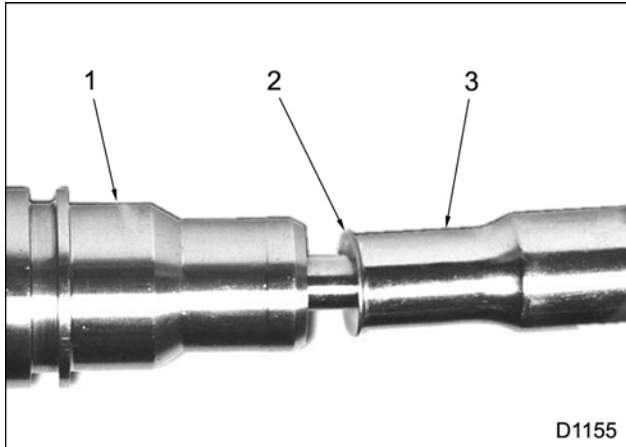
**CAUTION:** To prevent engine damage, do not use air tools when installing fuel injectors. Do not scratch injector surfaces.

**CAUTION:** To prevent engine damage, replace external O-rings and copper gasket each time a fuel injector is removed.

1. Remove the old copper gasket with a small hand tool. Wipe injector nozzle with a lint free cloth.

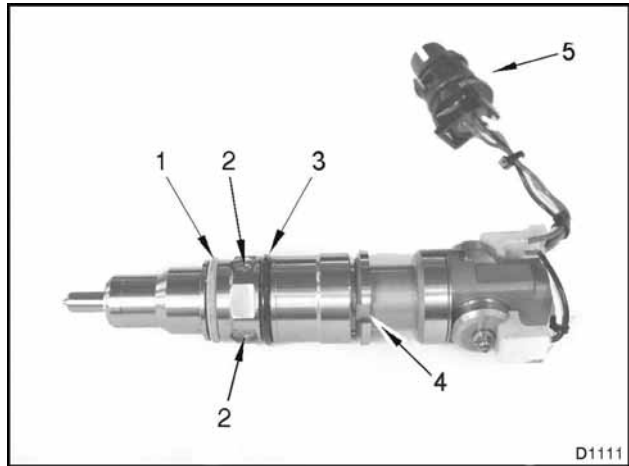
2. Install a new copper gasket injector onto injector tip.

**NOTE:** The copper gasket may be installed in either direction.



**Figure 250 Seating copper gasket**

1. Injector (nozzle end)
2. Gasket (copper)
3. Deep socket
3. To seat gasket, push on gasket with a deep socket.
4. Use a nonmetallic hand tool to remove upper and lower O-rings from fuel injector. Discard O-rings.
5. Install a new Teflon coated (white) O-ring (smaller diameter) in the lower recess just below the fuel inlet screens. Avoid contact with sharp machined surfaces.



**Figure 251 Fuel injector external O-rings**

1. O-ring, lower (white Teflon coating) (smaller diameter)
2. Fuel inlet screen (3)
3. O-ring, upper (black Teflon coating) (larger diameter)
4. Clamp alignment slot
5. O-ring, harness connector (dark blue)

6. Install a new Teflon coated (black) O-ring (larger diameter) in the recess just above the fuel inlet screens. Avoid contact with sharp machined surfaces.



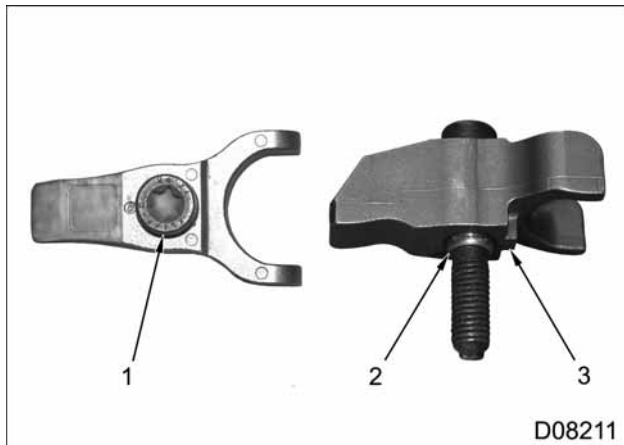
**Figure 252 Lubrication of fuel injector O-rings**

7. Lubricate upper and lower O-ring with clean engine oil.



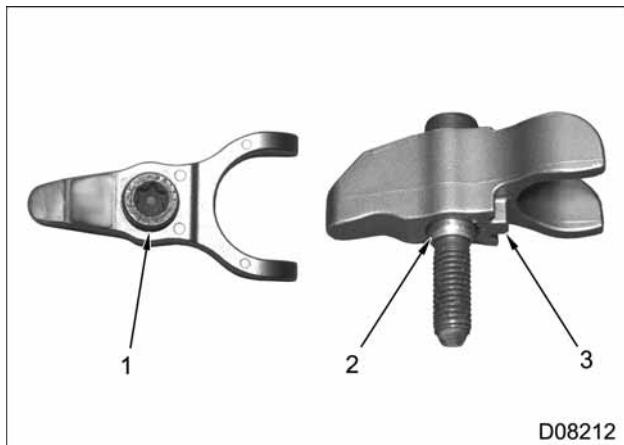
**Fuel Injector Assembly**

**CAUTION:** To prevent engine damage, verify hold down bolt retainer is in position when installing injector hold down clamp assembly.



**Figure 253 Fuel injector hold down clamp assembly (2004 and 2005 cylinder head applications)**

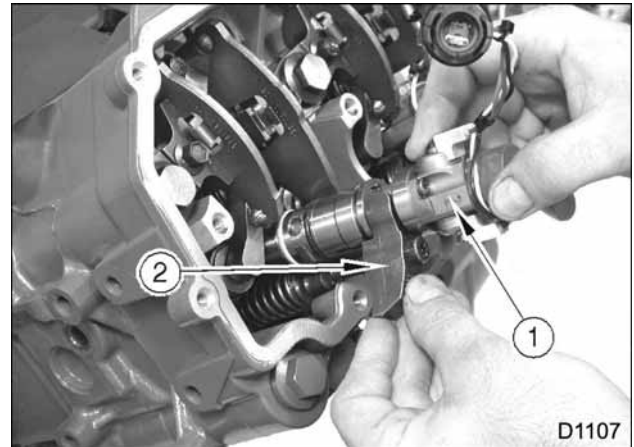
1. Bolt, M8 X 45
2. Retainer
3. Clamp alignment index



**Figure 254 Fuel injector hold down clamp assembly (2006 cylinder head application)**

1. Bolt, M8 X 45
2. Retainer
3. Clamp alignment index

1. Align injector assembly clamp alignment slot with hold down clamp alignment index. This aligns the injector correctly.



**Figure 255 Installation of injector**

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



**Figure 256 Fuel Injector Hold Down Wrench**

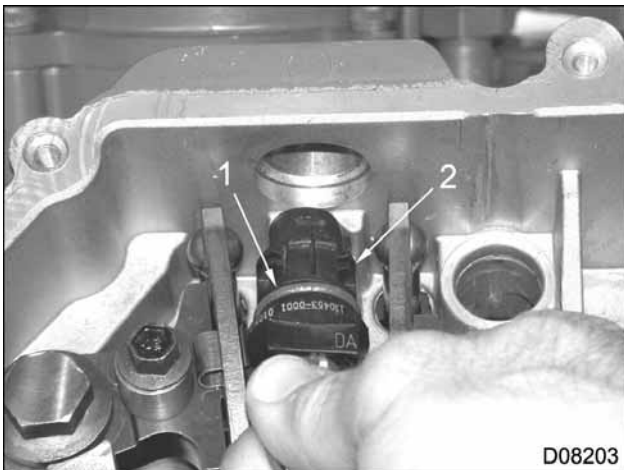


**Figure 257 Fuel Injector Hold Down Wrench installed**

1. Fuel injector assembly
2. Fuel injector hold down clamp assembly
3. Fuel Injector Hold Down Wrench

**CAUTION:** To prevent damage to fuel injector assemblies, do not use air power tools to remove or install injectors.

3. Use the Fuel Injector Hold Down Wrench (Table 12) to install the fuel injector hold down clamp assembly.
4. Tighten hold down clamp bolt to the special torque (Table 11).



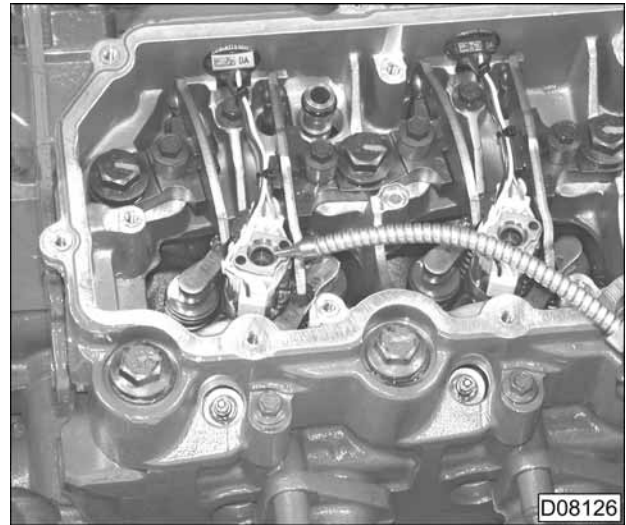
**Figure 258 Installation of injector harness connector**

1. O-ring
2. Injector harness connector

5. Replace O-ring on injector harness connector.
6. Position connector (identification marks face up) and push connector straight into mounting hole.

**CAUTION:** To prevent engine damage, be sure injector wiring is clear of moving parts.

#### High-pressure Oil Rail System

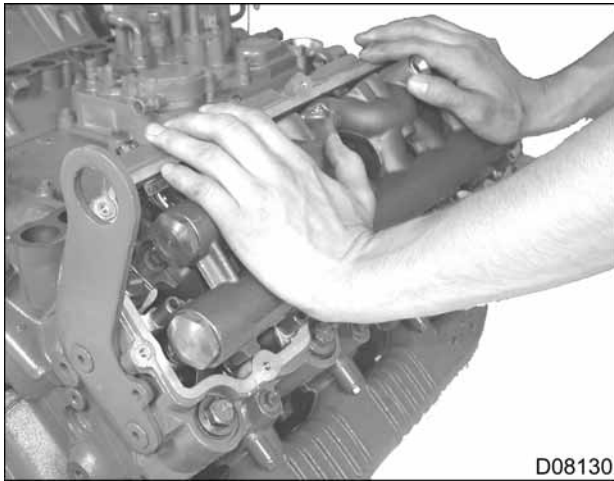


**Figure 259 Lubrication of top D-ring**

1. Lubricate the D-ring in the top of the injector cavity with clean engine oil.

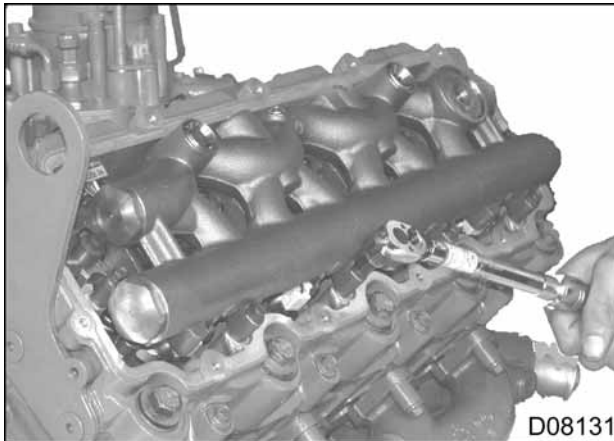


**Figure 260 Alignment of oil rail assembly to oil inlets**

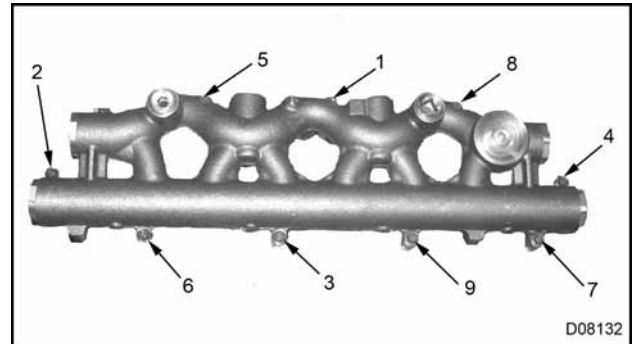


**Figure 261 Oil rail assembly**

2. Align oil rail assembly with oil inlets of each injector.
3. Tilt oil rail assembly toward engine, align oil rail assembly with case-to-head tube assembly, and push down evenly until oil rail assembly is firmly seated.
4. Hand start M6 x 25 oil rail assembly bolts 1, 2, and 3 until finger tight.

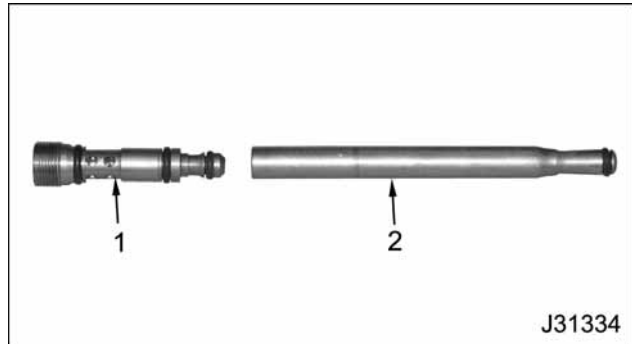


**Figure 262 Oil rail assembly**



**Figure 263 Torque sequence for oil rail bolts**

5. Finish installing the remaining bolts finger tight. Torque bolts to the special torque (Table 11) following the sequence in (Figure 263).



**Figure 264 Crankcase-to-head tube assembly**

1. Crankcase-to-head tube plug (long – with check valve)
2. Crankcase-to-head tube



**Figure 265** Crankcase-to-head tube plug (hex head)

**NOTE:** The square socket short crankcase-to-head tube plug and crankcase-to-head tube assembly is not available for service.

**CAUTION:** To prevent engine damage, install new crankcase-to-head tube plug (long – with check valve) and crankcase-to-head tube. D-rings are not replaceable.

**CAUTION:** To prevent engine damage, make sure the new crankcase-to-head tube bottoms out in the branch tube assembly. This ensures that the oil rail, case-to-head tube assembly, and fuel injectors will function correctly.

6. Lubricate D-rings on new crankcase-to-head tube assemblies with clean engine oil.
  - Crankcase-to-head tube plug (long – with check valve)
  - Crankcase-to-head tube
7. Install new crankcase-to-head assemblies through high-pressure oil rail.
8. Torque crankcase-to-head assemblies to the special torque (Table 11) (Figure 263).

### Glow Plugs



**Figure 266** Installation of glow plug

1. Install glow plugs in cylinder head.
2. Tighten glow plugs to the special torque (Table 11).

### ICP Sensor and Valve Cover Seal Ring for ICP sensor (right high-pressure oil rail)



**Figure 267** Installation of valve cover seal ring for ICP sensor

1. Valve cover seal ring for ICP sensor
2. Oil rail ICP sensor opening

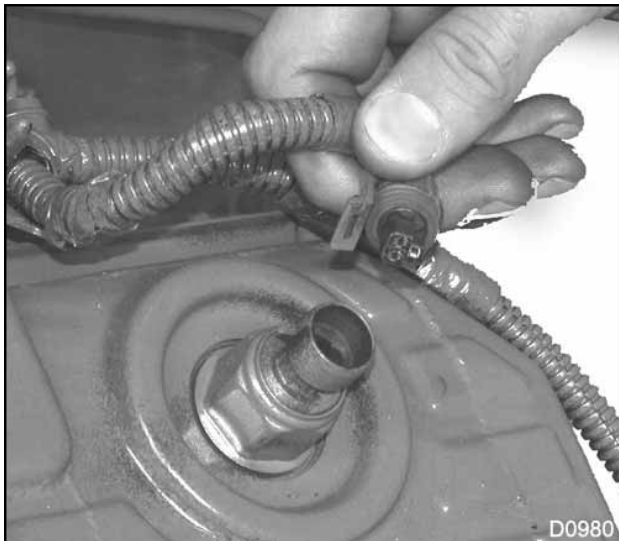
**NOTE:** If the valve cover was removed, a new valve cover seal ring is required.

1. Install valve cover seal ring for the ICP sensor and high-pressure oil rail.
2. Put new O-ring on ICP sensor.



**Figure 268 ICP Sensor and O-ring**

3. Install the ICP sensor and torque to the special torque (Table 11).



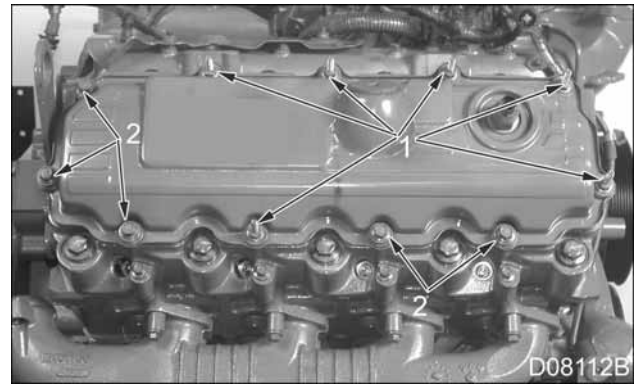
**Figure 269 ICP sensor**

4. Connect electrical connector to ICP sensor.

## Valve Covers

### Right Side Valve Cover

**CAUTION:** To prevent engine damage, do not use air powered tools, when installing valve covers.



**Figure 270 Valve cover mounting bolts and studs**

1. Stud
2. Bolt

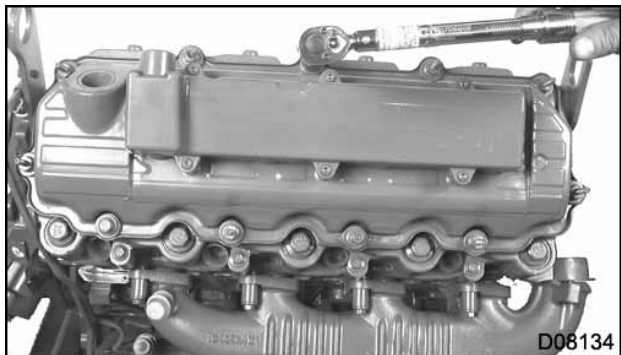
1. Install gasket.
2. Position valve cover on rocker arm carrier.
3. Install valve cover mounting bolts. Place stud bolts in correct locations to accommodate glow plug relay bracket and other harness routing hardware. Leave finger tight until bolts are started.
4. Continue installation of valve cover with remaining eight bolts. Tighten all mounting bolts to the special torque (Table 11).
5. Install the ICP sensor if not done.

**NOTE:** After the right side valve cover has been installed, the following parts can be installed. See "Engine Electrical" section for procedure.

- Glow plug relay bracket
- Tube assembly, filter to right hand cylinder head.

**Left Side Valve Cover****Figure 271 Valve cover mounting bolts and studs**

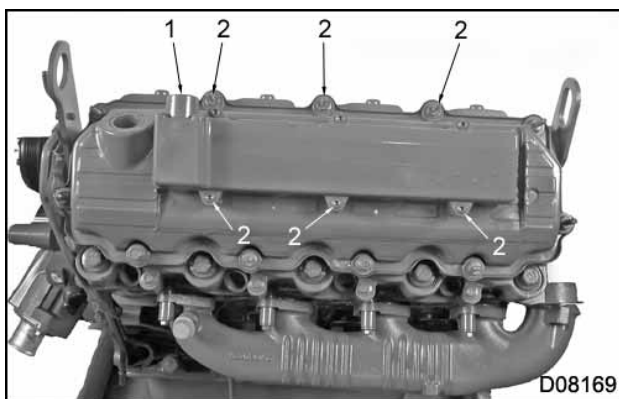
1. Bolt
2. Stud

**Figure 272 Valve cover mounting hardware**

1. Install gasket.
2. Position valve cover on rocker arm carrier.
3. Install valve cover mounting bolts. Place studs in correct locations to accommodate the ECM and

IDM bracket and other harness routing hardware. Leave finger tight until all bolts are started.

4. Tighten all bolts to the special torque (Table 11).
5. Install oil filler extension tube on valve cover.
6. If removed for any reason, install the lifting eyes on the rear of each rocker arm carrier and one on the left front carrier. Tighten bolts to the special torque (Table 11).

**Breather Housing (If removed)****Figure 273 Breather housing bolts**

1. Breather opening
2. Bolt (6)

1. Install four breather housing opening gaskets
2. Install breather housing.
3. Install six bolts finger tight.
4. Tighten all bolts to the special torque (Table 11).

---

**NOTE:** After installation of left side valve cover, install the following parts. See section identified for installation procedure:

- Breather hose assembly with pitot tube  
“ VGT Electronically Controlled Turbocharger“
  - Turbocharger air inlet duct  
“ VGT Electronically Controlled Turbocharger“
  - Tube assembly, filter to left hand cylinder head.
  - Fuel filter assembly and lines  
See “Fuel System.”
  - VGT assembly  
See “Variable Geometry Turbocharger (VGT) Assembly.”
  - Electronic Control Module (ECM), Injector Driver Module (IDM), and mounting bracket  
See “Engine Electrical.”
  - Exhaust Gas Recirculation (EGR) drive module and EGR drive module mounting bracket  
See “Engine Electrical.”
  - Glow plug relay and bracket  
See “Engine Electrical”
  - Intake manifold  
See “Manifolds and Exhaust Gas Recirculation (EGR)”
  - Flywheel and rear cover (if cam followers were removed)  
See “Rear Cover, Flywheel, and Power Steering Gear Drive.”
  - Branch tube assembly (if cam followers were removed)  
See “High-pressure Oil Pump.”
1. Reinstall all safety guards, shields, and covers.
  2. Make sure all tools, cleanliness covers, loose parts, and service equipment are removed from the engine work area.

## Specifications

**Table 10 Cylinder Head and Valve Train**

<b>Exhaust Valves</b>	
Stem diameter	6.947 to 6.965 mm (0.2735 to 0.2742 in)
Stem to guide clearance (max. allowable before replacement)	0.140 mm (0.0055 in)
Face to stem runout (T.I.R. max.)	0.038 mm (0.0015 in)
Valve face angle	37.5°
Valve margin (minimum)	1.35 mm (0.053 in)
Valve recession in head	0.50 ± 0.18 mm (0.020 ± 0.007 in)
<b>Intake Valves</b>	
Stem diameter	6.947 to 6.965 mm (0.2735 to 0.2742 in)
Stem to guide clearance (max. allowable before replacement)	0.140 mm (0.0055 in)
Face to stem runout (T.I.R. max.)	0.0038 mm (0.0015 in)
Valve face angle	30.0°
Valve margin (minimum)	1.40 mm (0.055 in)
Valve recession in head	0.50 ± 0.18 mm (0.020 ± 0.007 in)
<b>Cylinder Heads</b>	
Valve guide inside diameter	7.003 to 7.029 mm (0.276 to 0.277 in)
Valve guide bore runout	0.05 mm (0.002 in)
Valve guide taper (maximum)	0.10 mm (0.004 in)
Valve seat width (intake)	1.80 to 2.56 mm (0.071 to 0.101 in)
Valve seat width (exhaust)	1.48 to 2.24 mm (0.058 to 0.088 in)
Valve seat angle (intake)	30.0°
Valve seat angle (exhaust)	37.5°
Valve seat runout (T.I.R. max.)	0.035 mm (0.0014 in)
Gasket surface flatness	0.05 mm (0.002 in) per 51 mm (2 in)
	0.10 mm (0.004 in) per total surface area
Overall thickness of cylinder head (deck-to-deck)	95 mm (3.74 in)
Valve head recession relative to deck (surface of cylinder head)	0.32 to 0.68 mm (0.0126 to 0.0268 in)
Valve Spring:	
Free length	51.96 mm (2.045 in)
Solid height	36.1 mm (1.42 in)



**Table 10 Cylinder Head and Valve Train (cont.)**

Compressed*	46.30 mm @ 340 ± 17 N (1.82 in @ 76.5 ± 3.8 lbf)
Compressed*	38.30 mm @ 850 ± 43 N (1.51 in @ 191.1 ± 9.7 lbf)
* Spring must be compressed to a solid height before checking test loads.	
<b>Push Rods</b>	
Runout (maximum)	0.25 mm (0.01 in)

## Special Torque

**Table 11 Cylinder Head and Valve Train**

Lifting eye, front, (M10 x 30)	41 ± N·m (30 ± 3 lbf·ft)
Lifting eye, rear, flat socket head (M10 x 35)	41 ± N·m (30 ± 3 lbf·ft)
Crankcase breather nuts	7 N·m (60 lbf·in)
Fuel rail plug assembly (12 mm)	27 ± 1 N·m (20 ± 1 lbf·ft)
Fuel injector hold down clamp bolt	33 N·m (24 lbf·ft)
Rocker arm fulcrum plate (M8 x 65)	31 N·m (23 lbf·ft)
Glow plugs	19 N·m (168 lbf·in)
Injection Control Pressure (ICP) sensor	12 ± 2 N·m (108 ± 18 lbf·in)
Oil rail assembly mounting bolts (M6 x 40)	13 N·m (120 lbf·in) (Figure 273)
Crankcase-to-head tube assembly	82 N·m (60 lbf·ft)
Valve cover bolts and studs	9 +1/-2 N·m (72 ± 12 lbf·in)
Oil fill extension	14 ± 1 N·m (120 - 132 lbf·in)
Rear heat shield (M10 x 1.5 x 16)	49 ± 5 N·m (36 ± 4 lbf·ft)

## Special Service Tools

**Table 12 Cylinder Head and Valve Train**

DESCRIPTION	TOOL NUMBER
Bottoming Tap (metric)	ZTSE4508
Crankcase-to-head Removal Tool	ZTSE4694
Cylinder Head Lifting Bracket	ZTSE4535
Cylinder Head Pressure Test Plate	ZTSE4534
Dye Penetrant Kit	PT-7191
Fuel Gallery Cleaning Brush	ZTSE4541
Fuel Injector Hold Down Wrench	ZTSE4524
Fuel Injector Rack Holder	ZTSE4299B
Fuel Injector Tip Cleaning Brush	ZTSE4301
Glow Plug Sleeve Brush (nylon)	ZTSE4533
Glow Plug Sleeve Installer	ZTSE4532
Glow Plug Sleeve Remover (Both the tap and the bolt and sleeve adapter)	ZTSE4531
Glow Plug Sleeve Seat Wire Brush	ZTSE4589
Injector Connector Remover	ZTSE4650
Injector Sleeve Brush	ZTSE4304
Injector Sleeve Installer	ZTSE4529
Injector Sleeve Remover (Both the tap and the slide hammer adapter)	ZTSE4528
Liquid Gasket (RTV) (6 oz. tube)	1830858C1
Quick Release Tool	ZTSE4581
Quick Release Tool Kit	ZTSE4454
Slide Hammer Kit	ZTSE4398
Straightedge	Obtain locally
Valve Guide Gauge Tool	ZTSE4577
"C" Type Valve Spring Compressor	ZTSE1846
Valve Spring Tester	ZTSE2241

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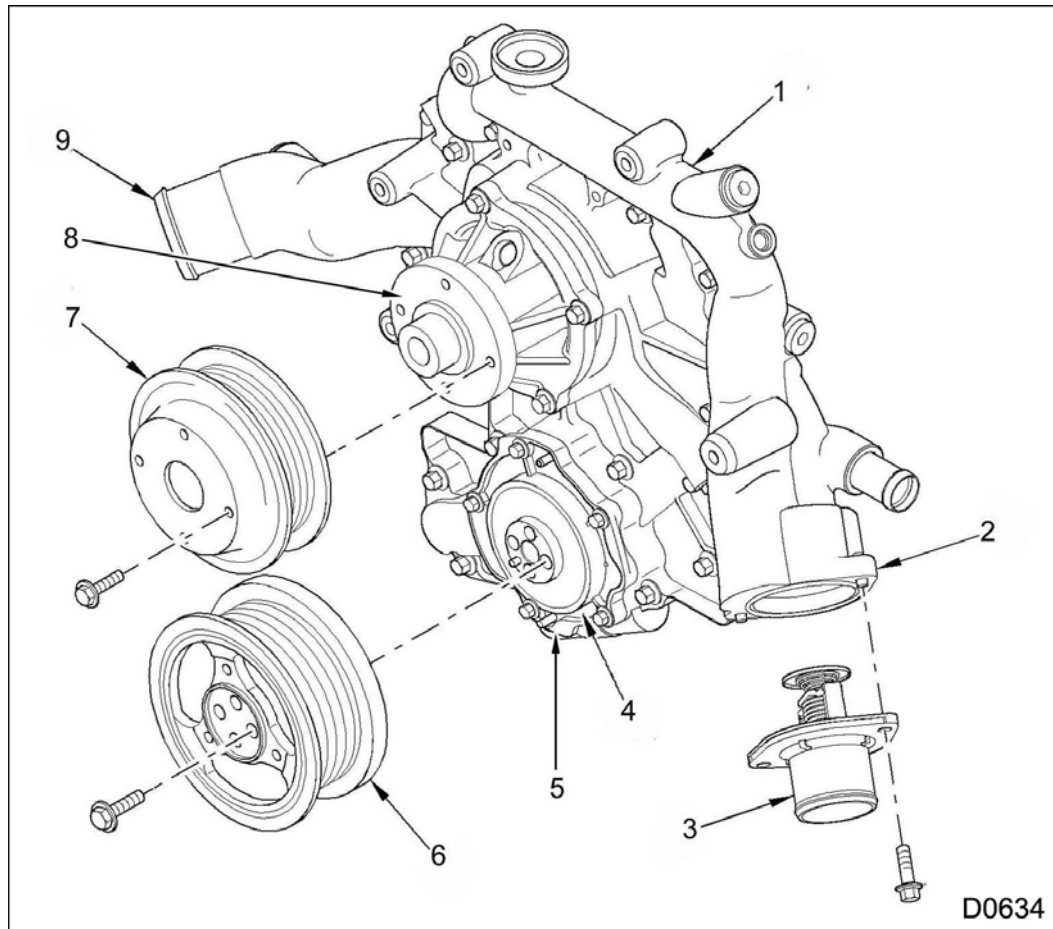
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## Description

### Front Cover Components

The front cover includes components for the cooling system, lube oil delivery, and vibration damper.



**Figure 274 Front cover components**

- |                               |                                  |                              |
|-------------------------------|----------------------------------|------------------------------|
| 1. Front cover assembly       | 4. Gerotor oil pump assembly     | 7. Pulley                    |
| 2. Front cover coolant outlet | 5. Oil pressure regulating valve | 8. Water pump assembly       |
| 3. Thermostat assembly        | 6. Vibration damper              | 9. Front cover coolant inlet |

## Removal

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

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

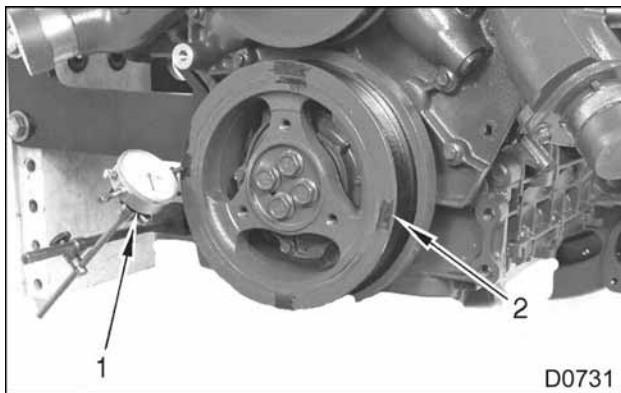
**! WARNING:** To prevent personal injury or death, make sure the engine has cooled before removing components.

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

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

### Vibration Damper

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

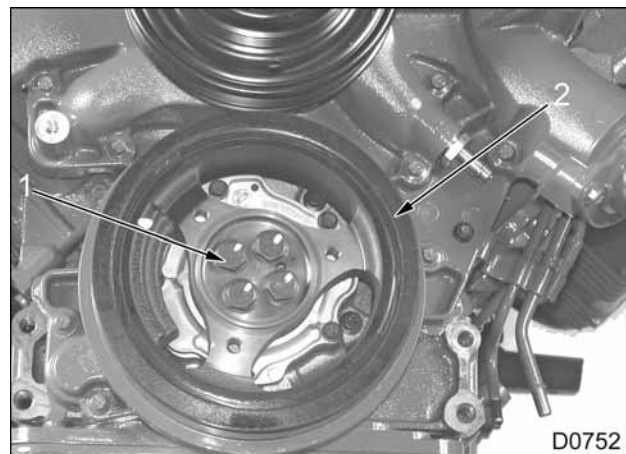


**Figure 275 Vibration damper runout**

1. Dial indicator with magnetic base
2. Paint removed, four points (90° apart)

- a. Remove paint from face of vibration damper at four points 90° apart.
  - b. Attach magnetic base dial indicator (Table 15) to front of crankcase. Position indicator point on unpainted surface.
  - c. Pry crankshaft forward and zero the dial indicator. This becomes the baseline.
- NOTE:** Pry only in one direction to eliminate possible error induced by crankshaft end play.
- d. Turn crankshaft 90°. Pry crankshaft forward and record reading.
  - e. Repeat at each unpainted surface. If run out exceeds specification (Table 13), replace vibration damper.

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



**Figure 276 Vibration damper mounting bolts**

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

### Front Oil Seal and Wear Sleeve

**NOTE:** The VT 365 is not equipped with a wear sleeve during factory production. Wear sleeves are available with an oil seal service kit.

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

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

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

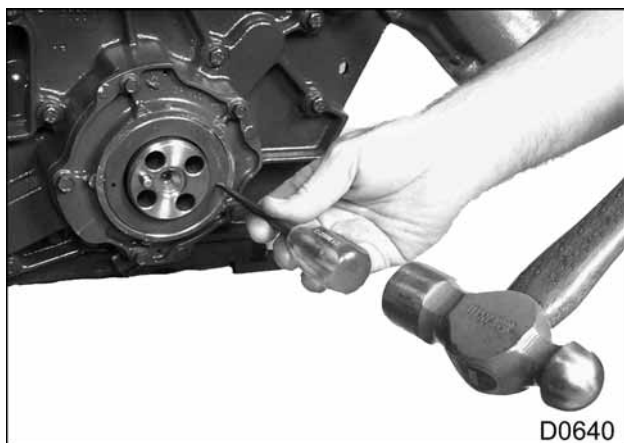


Figure 277 Holes for slide hammer

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

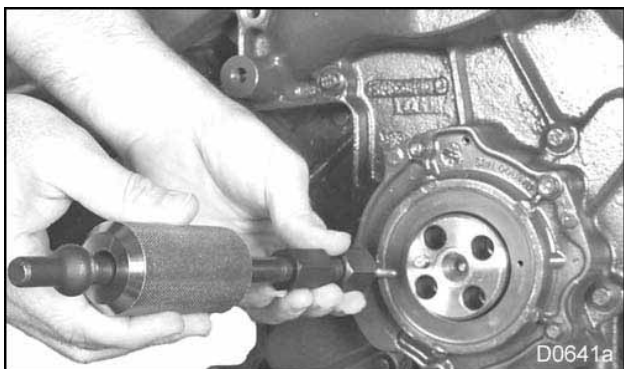


Figure 278 Slide hammer

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

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

4. Do the following steps to install the front wear sleeve remover (Table 15):

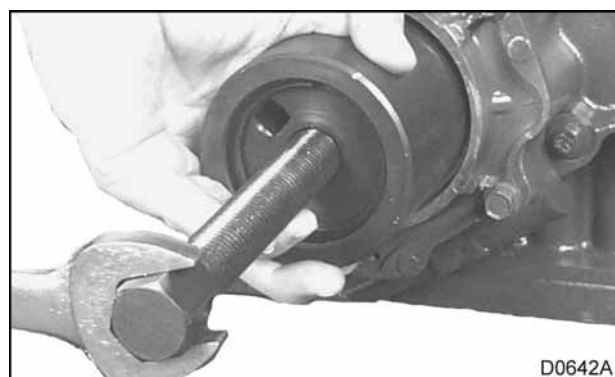


Figure 279 Removal of front wear sleeve

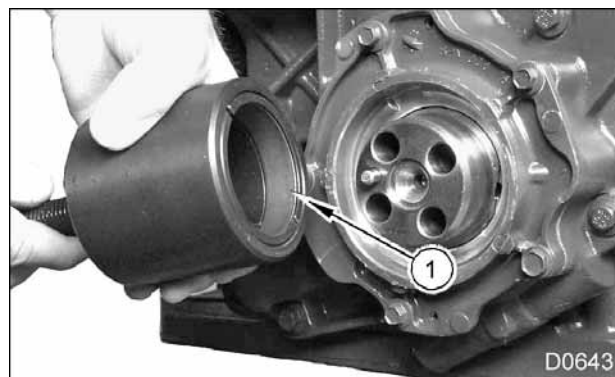
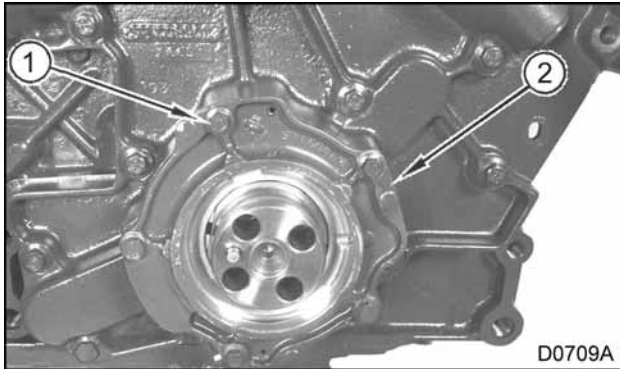


Figure 280 Front wear sleeve removed

1. Front wear sleeve
  - a. Install the tools two half shell ridges behind the front wear sleeve.
  - b. Place the threaded shaft and pulling flange inside the two shells while holding the shells together.

- c. Thread the shaft up to the crankshaft, and apply tension to the two half shells. Remove wear sleeve.

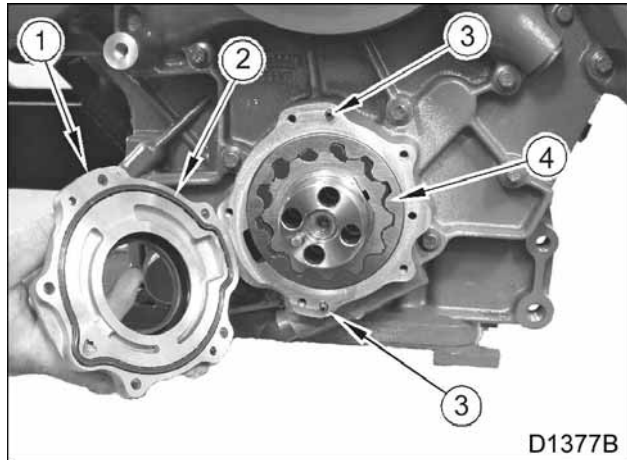
### Gerotor Oil Pump



**Figure 281 Gerotor oil pump cover**

1. Gerotor oil pump cover mounting bolts (5)
  2. Gerotor oil pump cover
1. Remove five mounting bolts from gerotor oil pump cover.
  2. Carefully remove cover to expose gerotor.
  3. Use a permanent marker to mark the front of each gerotor for correct reassembly orientation.

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



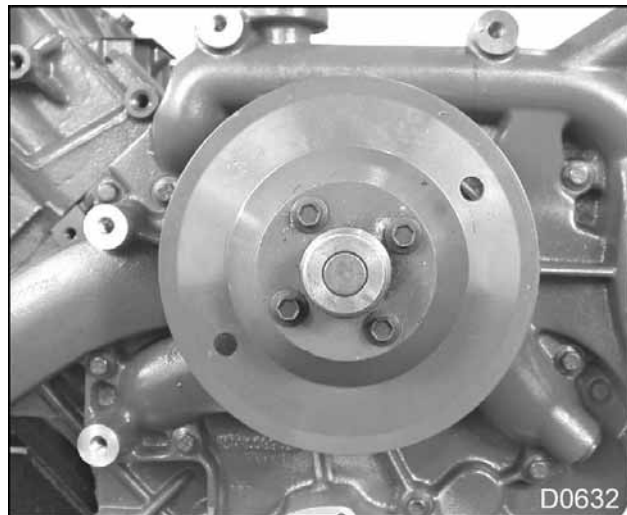
**Figure 282 Gerotor components**

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

4. Remove gerotor gear set from housing.

### Water Pump

**NOTE:** If removing the front cover, the water pump and thermostat do not need to be removed; however, the water pump pulley must be removed.

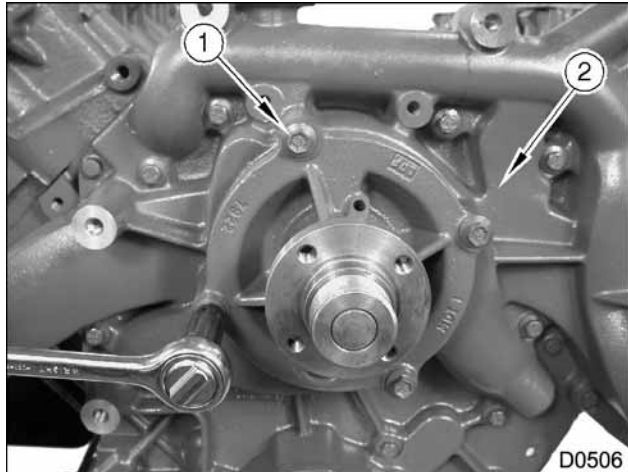


**Figure 283 Water pump pulley**

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



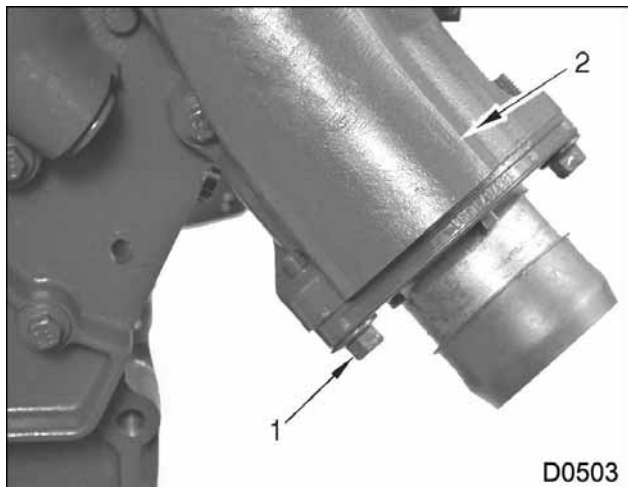
**NOTE:** If not using a air impact wrench, use a holding device to lock the water pump pulley when removing the bolts.



**Figure 284 Water pump assembly**

1. Water pump mounting bolts, M8 x 25 (4)
  2. Front cover assembly
2. Remove four M8 x 25 bolts that secure water pump assembly to front cover.
  3. Remove and discard water pump O-ring.

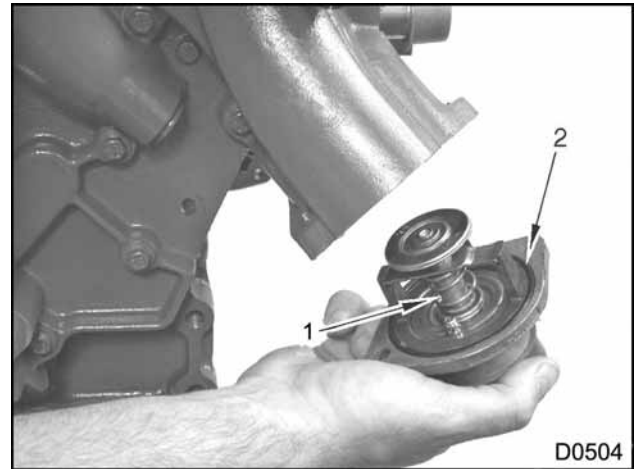
#### Thermostat



**Figure 285 Thermostat assembly mounting bolts**

1. Thermostat assembly mounting bolts, M8 x 30 (2)
2. Coolant outlet side of front cover (left side)

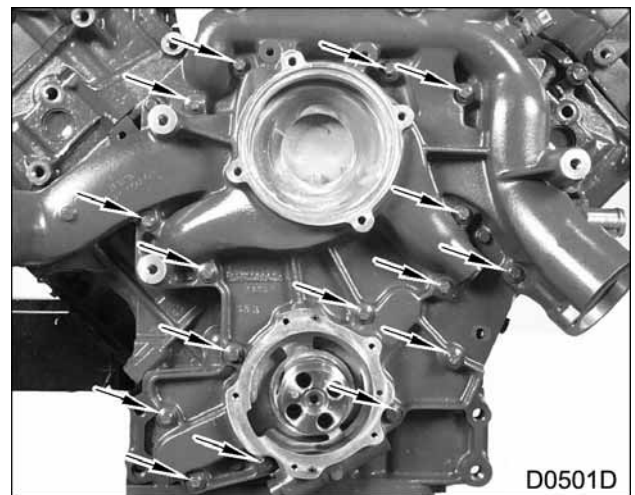
1. Remove two M8 x 30 bolts that secure thermostat assembly to left side of front cover.



**Figure 286 Thermostat assembly**

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

#### Front Cover



**Figure 287 Front cover retaining bolts**

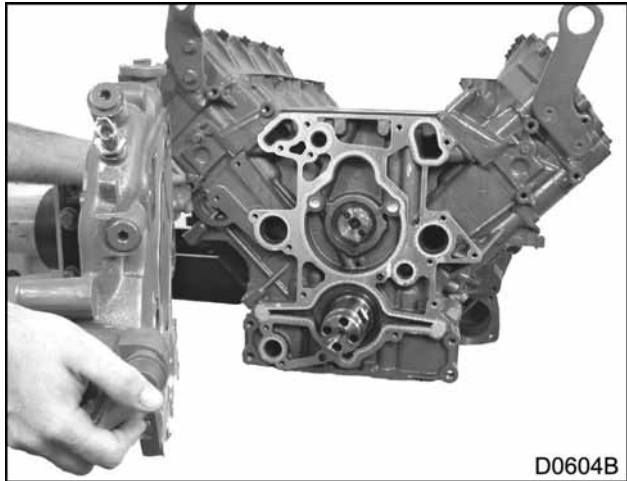
1. Remove 16 retaining bolts (M8 x 35 hex flanged, dog point) from front cover.

**CAUTION:** To prevent engine damage, when removing the front cover, cut the sealant where the upper and lower crankcase meets.



**Figure 288 Sealant between crankcase and lower crankcase joint**

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



**Figure 289 Removal of front Cover**

3. Remove front cover.
4. Remove front cover gasket.

## Cleaning, Inspection, and Testing

### Vibration Damper

**CAUTION:** To prevent engine damage, do not immerse damper in petroleum based solvents. The rubber damping element could be damaged.

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

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

2. Dry damper with filtered compressed air.
3. Inspect vibration damper rubber compound for cracks, bulging or separation. Replace vibration damper if necessary.

### Gerotor Oil Pump

1. Wash all parts thoroughly in a suitable solvent.

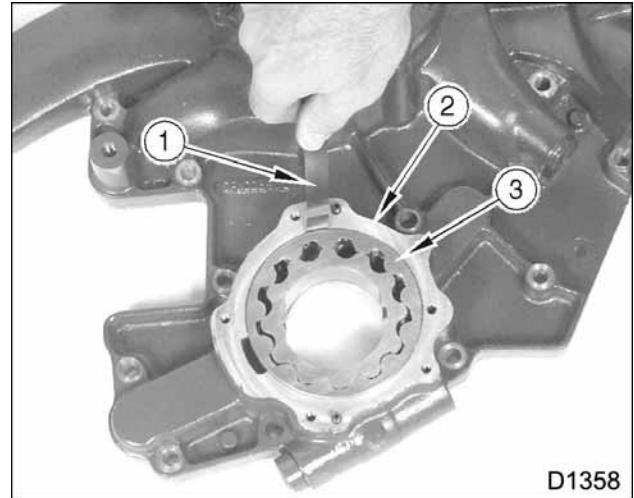
**! WARNING:** To prevent personal injury or death, wear safety glasses with side shields to protect eyes. Limit compressed air pressure to 207 kPa (30 psi).

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

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

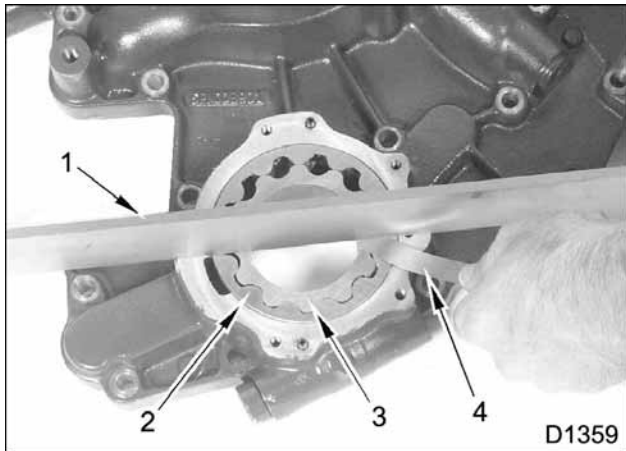
**NOTE:** If installing new gerotors, correct orientation is not necessary. If installing old gerotors, correct orientation is necessary.

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



**Figure 290 Gerotor inspection**

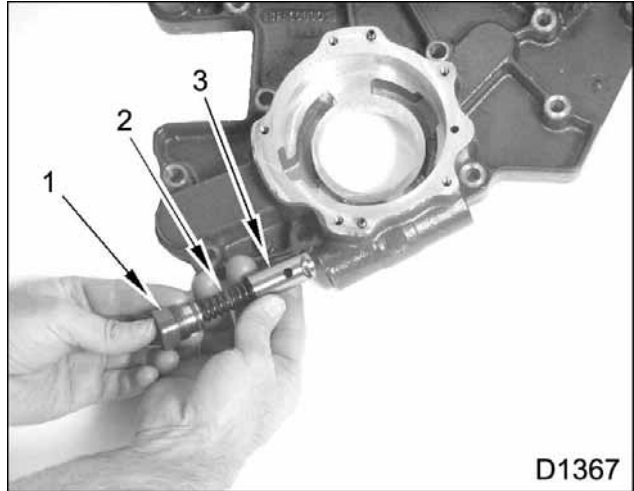
1. Feeler gauge
  2. Front cover assembly
  3. Outer gerotor
7. Use a feeler gauge to inspect for wear by checking the radial clearance between outer gerotor and oil pump housing.



**Figure 291 End clearance check for oil pump**

1. Straightedge
2. Outer gerotor
3. Inner gerotor
4. Feeler gauge

8. Check oil pump end clearance as follows:
  - a. With the gerotors in place in the front cover, put straightedge across housing.
  - b. Insert feeler gauge under straightedge at inner and outer gerotors. Compare end clearance with specifications (Table 13).
  - c. If measurements are not within specifications, replace both gerotors (as a set).
9. Use a 12 mm internal hex wrench to remove oil pressure regulator.



**Figure 292 Oil pressure regulator components**

1. End cap and O-ring
2. Oil pressure bypass spring
3. Piston poppet

10. Inspect oil pressure regulator components and bore for wear.

### Front Cover and Water Pump

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

1. Wash thoroughly in a suitable cleaning solvent.
2. Dry with filtered compressed air.
3. Inspect front cover for cracks.
4. Inspect water pump for leaks, cracks, bearing failure, and problems with bearings or shaft seal. Replace if necessary.
5. Replace front cover if cracked.

### Thermostat

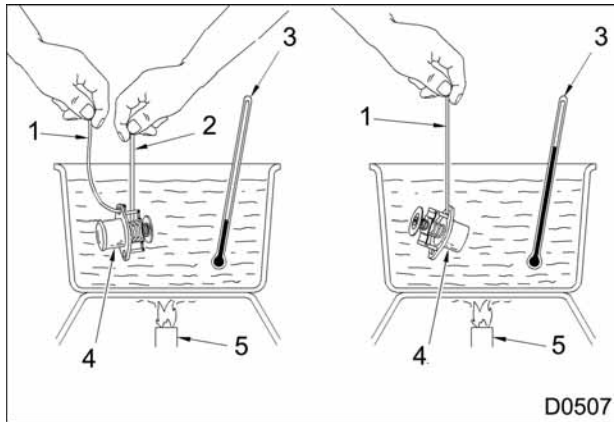
**! WARNING:** To prevent personal injury or death, wear heat resistant gloves and appropriate eye protection during thermostat operation check.

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

**NOTE:** Only genuine International® thermostats ensure correct coolant flow and positive sealing for correct engine cooling.

Check thermostat operation as follows:

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



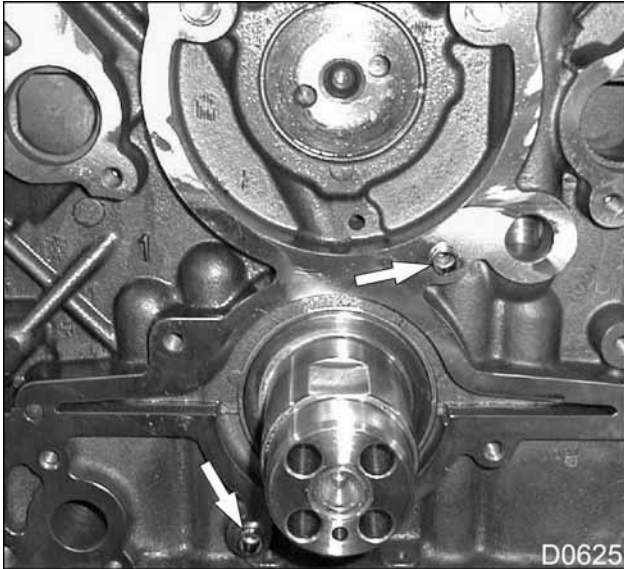
**Figure 293** Thermostat operation test

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

2. Suspend thermostat in a container so the thermostat does not touch the bottom of the container.
3. Heat the water filled container to the approximate Start-To-Open temperature of the thermostat. See specifications for temperature (Table 13).
4. Check thermometer and record the temperature as soon as the thermostat drops from the nylon ribbon. This is the Start-To-Open temperature.
5. Continue to heat the water to the Full-Open temperature of the thermostat. See Specifications (Table 13). Check movement of the thermostat sleeve.
6. While sleeve is off its seat, remove thermostat from container and inspect seat area for pitting and foreign deposits.
7. If the thermostat is damaged or operates incorrectly, replace thermostat.

## Installation

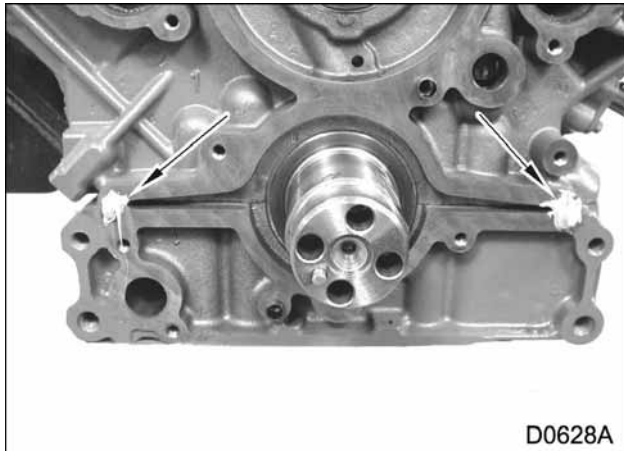
### Front Cover



**Figure 294** Front cover crankcase dowels

1. If removed, install front cover crankcase dowels.

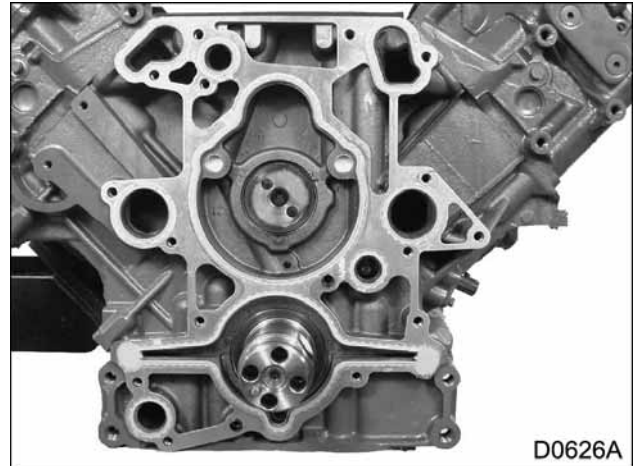
**NOTE:** Dowels may become lodged in front cover. Remove dowels and install in crankcase, if necessary.



**Figure 295** Liquid gasket applications

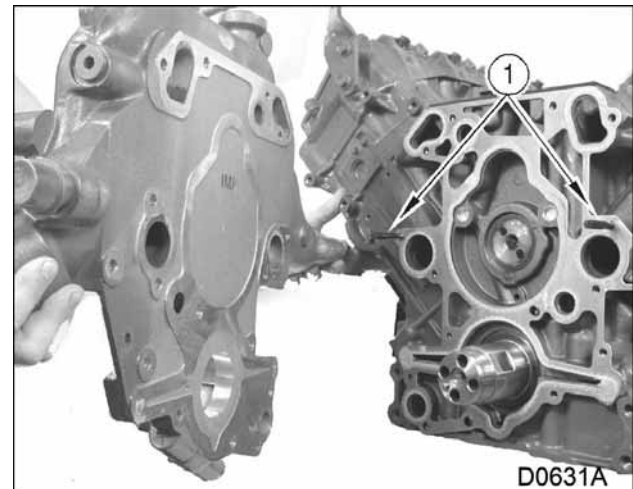
2. Apply Liquid Gasket (RTV) (Table 15) to joining surfaces of crankcase and lower crankcase.

**NOTE:** Install gasket and cover within five minutes before the liquid gasket forms a skin to ensure a leak proof joint.



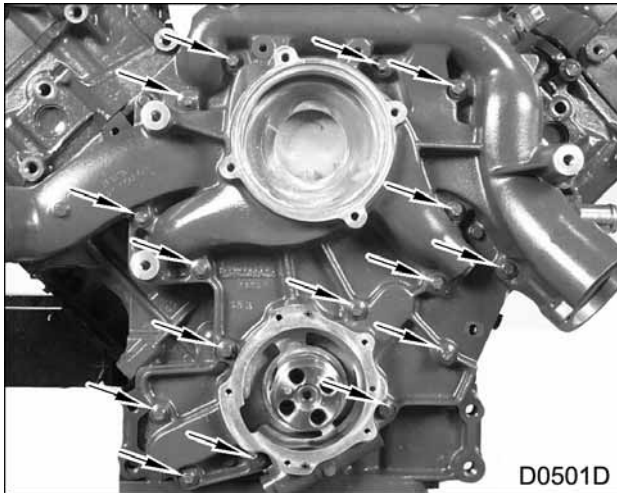
**Figure 296** Front cover gasket installed

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



**Figure 297** Front cover alignment

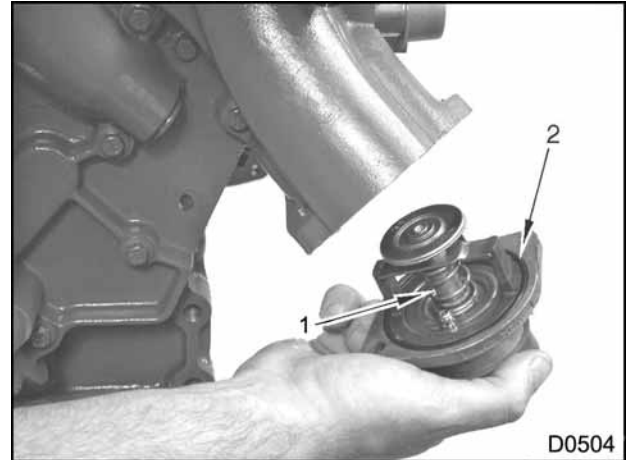
1. Alignment guides
4. Align front cover with crankcase dowels and alignment guides (made locally).



**Figure 298 Front cover module retaining bolts**

5. Fasten front cover assembly to crankcase with 16 bolts (M8 x 35 hex flanged, dog point). Tighten bolts to the special torque (Table 14).
6. If removed, install water pump on front cover with new O-ring. See (Water Pump, page 170).

### Thermostat

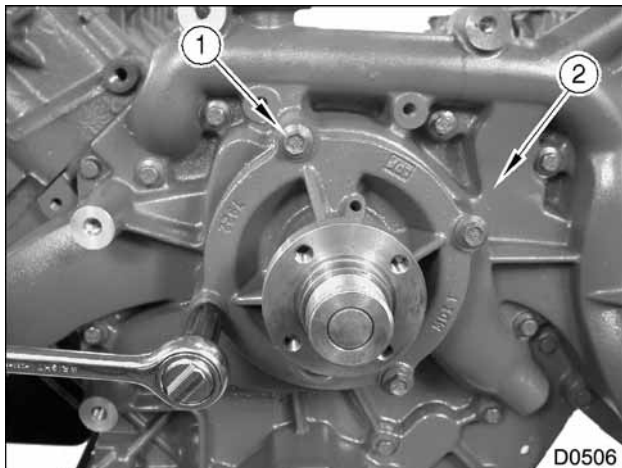


**Figure 299 Thermostat assembly**

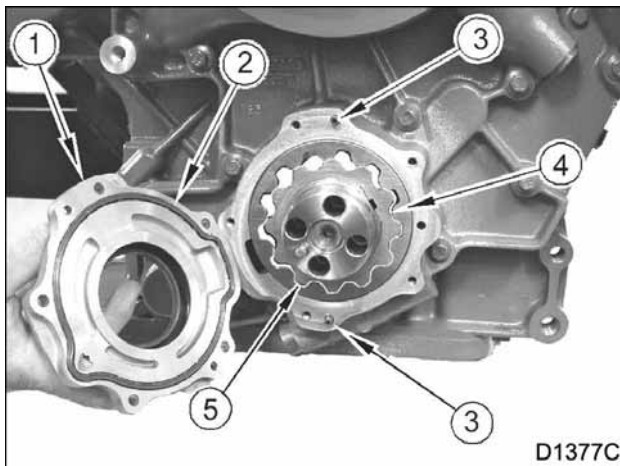
1. Thermostat
  2. Thermostat O-ring seal
1. Put new O-ring on thermostat housing and install assembly on front cover coolant outlet.
  2. Secure thermostat assembly with two M8 x 30 mounting bolts. Tighten bolts to the standard torque (Standard Torques, page 375).

**Water Pump**

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

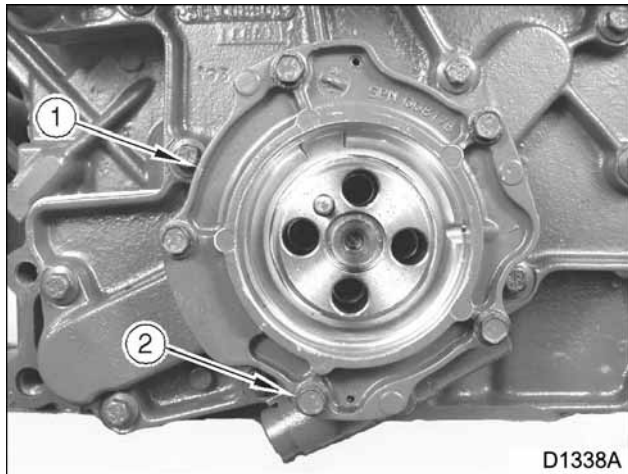
**Figure 300 Water pump**

1. Water pump mounting bolts
  2. Front cover
2. Install water pump assembly on front cover over the new O-ring and secure with four M8 x 25 mounting bolts. Tighten bolts to the special torque (Table 14).
  3. Install water pump pulley with four M8 x 12 bolts.

**Gerotor Oil Pump****Figure 301 Outer gerotor gear**

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



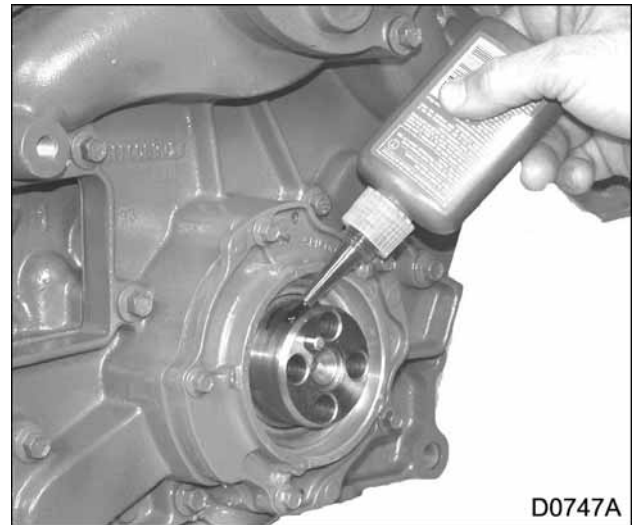


**Figure 302 Oil pump housing**

1. Oil pump cover
2. Oil pump cover retaining bolts
3. Align dowel pins and install oil pump cover on front cover.
4. Install five retaining bolts to oil pump cover and tighten to the standard torque (Standard Torques, page 375).

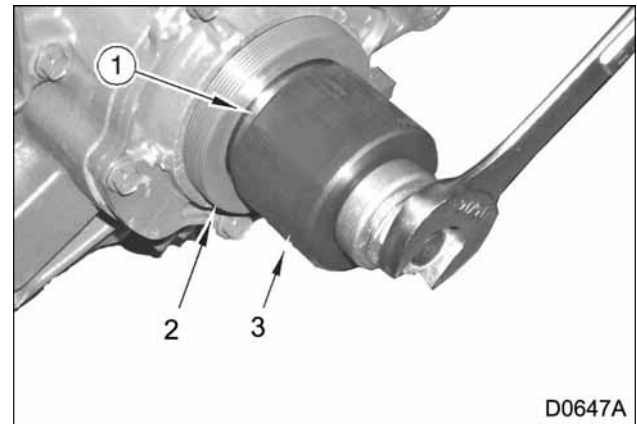
#### Front Oil Seal and Wear Sleeve

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



**Figure 303 Liquid gasket application**

1. Put a 360° bead of Loctite® Hydraulic Sealant (Table 15) on the leading edge of the crankshaft before wear sleeve installation.



**Figure 304 Front oil seal and wear sleeve**

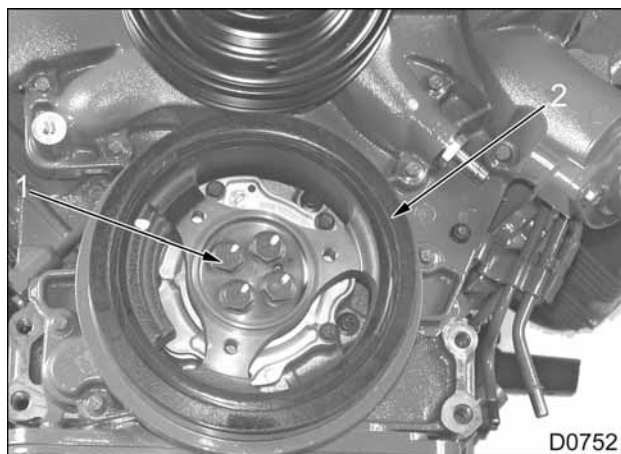
1. Wear sleeve
2. Front oil seal
3. Front Oil Seal/Wear Sleeve Installer
2. Use the Front Oil Seal/Wear Sleeve Installer (Table 15), to drive oil seal and wear sleeve assembly into the oil pump cover.

#### Vibration Damper

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

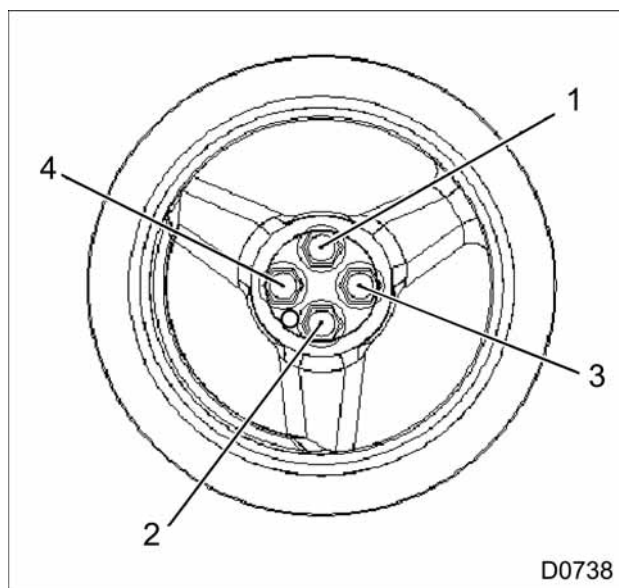
**⚠ WARNING:** To prevent personal injury or death, install four new bolts to secure the vibration damper.

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



**Figure 305 Vibration damper on crankshaft**

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



**Figure 306 Torque sequence for vibration damper bolts**

3. Vibration damper bolt torque sequence:
  - a. Tighten each bolt to the special torque (Table 14) using the above sequence.
  - b. Torque each bolt an additional 90° using the above sequence.
4. Reinstall all safety guards, shields, and covers.
5. Make sure all tools, cleanliness covers, loose parts, and service equipment are removed from the engine work area.

## Specifications

**Table 13 Vibration Damper, Lubricating Oil Pump, and Thermostat**

<b>Vibration Damper</b>	
Face runout (maximum)	0.635 mm (0.025 in)
Rubber bulging (maximum)	1.5 mm (0.060 in)
<b>Lubricating Oil Pump</b>	
Type	Gerotor
Drive	Crankshaft
Location	Gerotor oil pump housing
Pressure Regulating Valve:	
Engine oil pressure, low idle (min. @ 110°C (230°F) oil temp.)	69 kPa (10 psi)
Engine oil pressure, high idle (min. @ 110°C (230°F) oil temp.)	276 kPa (40 psi)
Oil pump discharge pressure (2,500 rpm)	483 to 621 kPa (70 to 90 psi)
End clearance (inner and outer rotor to housing)	0.025 to 0.095 mm (0.001 to 0.004 in)
Radial clearance (between outer rotor and housing)	0.15 to 0.28 mm (0.006 to 0.011 in)
<b>Thermostat</b>	
Type	Balanced pressure, wax pellet
Minimum recommended coolant operating temperature	71°C (160°F)
Start-to-open temperature, 0.381 mm (0.015 in) stroke	87 to 91°C (188 to 196°F)
Full-open temperature, 8 mm (0.315 in) stroke	104°C (219°F)

## Special Torque

**Table 14 Front Cover, Vibration Damper, Water Pump, and Oil Pan Drain Plug**

Oil pan drain plug	25 ± 5 N·m (18 ± 4 lbf·ft)
Front cover module bolts	24 N·m (18 lbf·ft)
Water pump mounting bolts	23 ± 1 N·m (17 ± 1 lbf·ft)
Vibration damper mounting bolts	<b>New bolts only:</b> 68 N·m (50 lbf·ft) + 90° rotation. (Figure 306)

**Special Service Tools****Table 15 Front Cover, Vibration Damper, and Gerotor Oil Pump**

<b>Description</b>	<b>Tool Number</b>
Dial Indicator with Magnetic Base	Obtain locally
Fan Hub Wrench (2 inch)	ZTSE43972
Fan Wrench (pulley bolts)	ZTSE4587
Front Seal/Wear Sleeve Installer	ZTSE4516
Front Wear Sleeve Remover	ZTSE4517
Liquid Gasket (RTV) (6 oz. tube)	1830858C1
Loctite® Hydraulic Sealant	Obtain locally

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## Removal

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

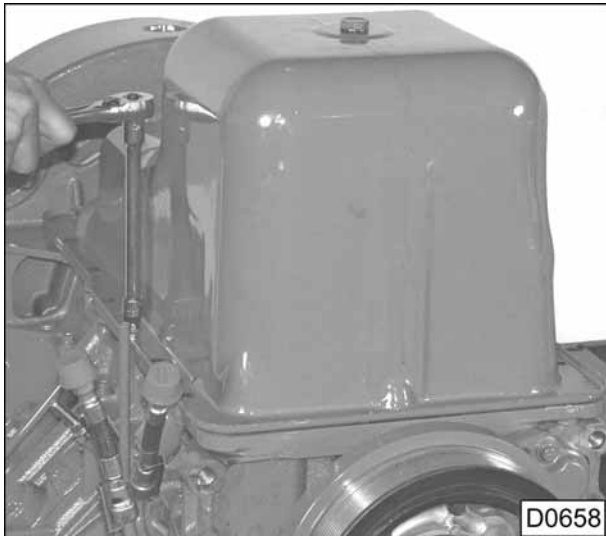
**! WARNING:** To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

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

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

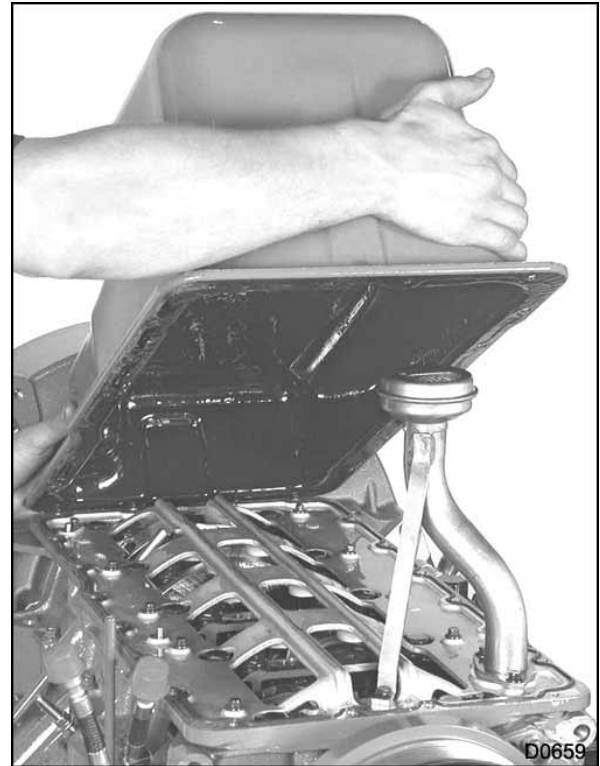
**NOTE:** Engine fluids (oil, fuel and coolant) are a threat to the environment. Recycle or dispose of engine fluids according to local regulations. Never put engine fluids in the trash, on the ground, in sewers or bodies of water.

### Lower Oil Pan



**Figure 307** Mounting bolts for lower oil pan

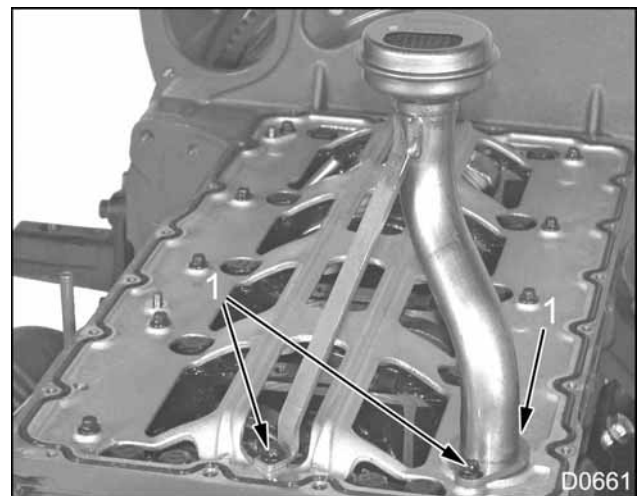
1. Remove sixteen M6 mounting bolts from lower oil pan.



**Figure 308** Lower oil pan

2. Remove lower oil pan.

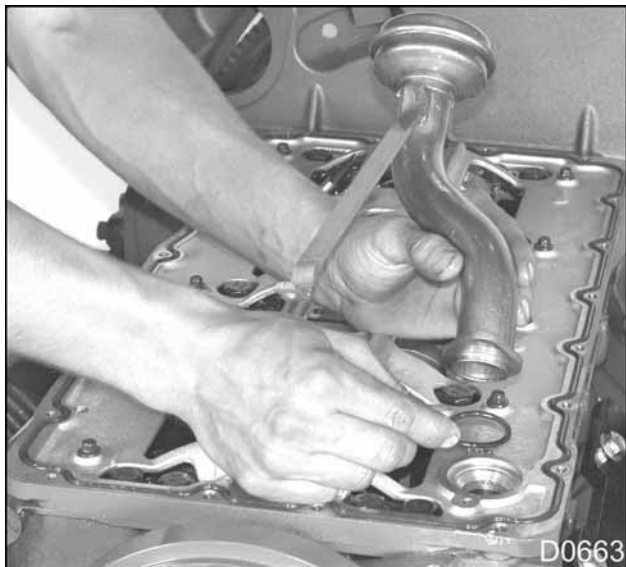
### Oil Pickup Tube



**Figure 309** Oil pickup tube

1. Oil pickup tube mounting bolts, M6 X 16 (3)

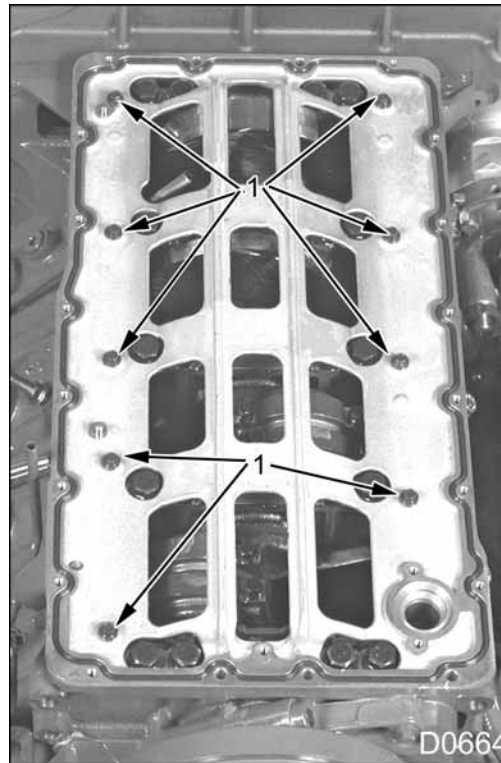
1. Remove three oil pickup tube mounting bolts and oil pickup tube.



**Figure 310 O-ring**

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

#### Upper Oil Pan



**Figure 311 Mounting bolts for upper oil pan**


1. M8 X 40 (9)

1. Remove nine mounting bolts from upper oil pan .
2. Remove upper oil pan.



## Cleaning and Inspection


### Lower Oil Pan

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

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

### Oil Pickup Tube


1. Clean tube in a suitable solvent.

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

2. Dry with filtered compressed air.
3. Inspect the oil pickup tube and bracket for cracking. Replace if necessary.

### Upper Oil Pan

1. Clean oil pan in a suitable solvent.

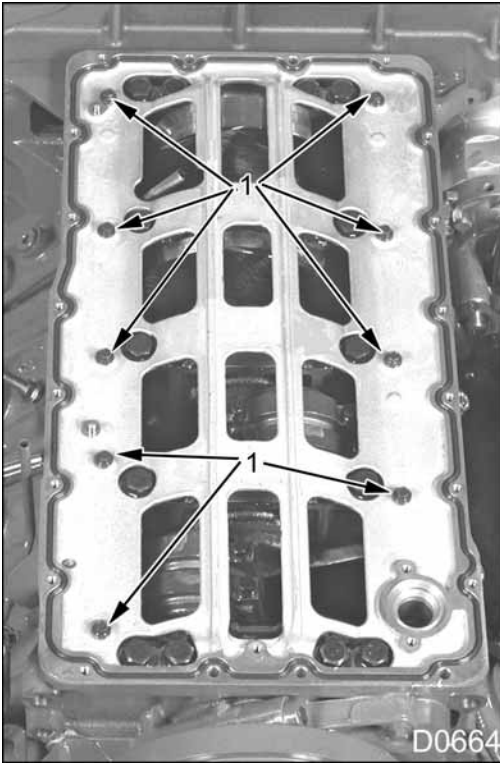
 **WARNING:** To prevent personal injury or death, wear safety glasses with side shields to protect eyes from flying debris, when using compressed air for cleaning. Limit the air pressure to 207 kPa (30 psi).

2. Dry with filtered compressed air.
3. Inspect for warping or cracking. Replace if necessary.

## Installation

### Upper Oil Pan

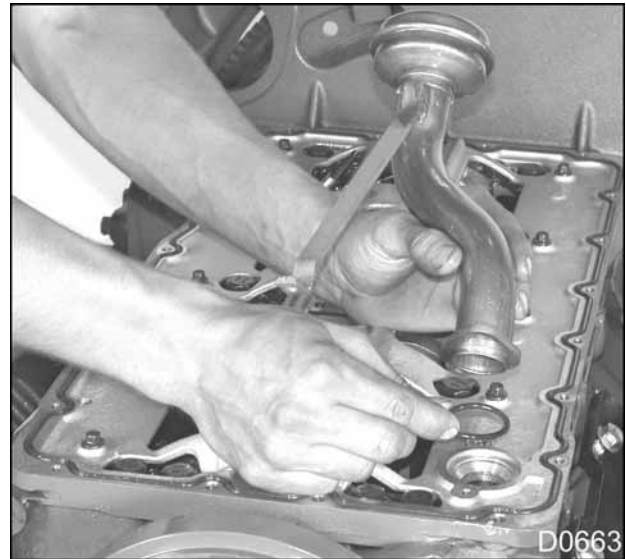
1. Install new gaskets in upper oil pan.



**Figure 312 Mounting bolts for upper oil pan**

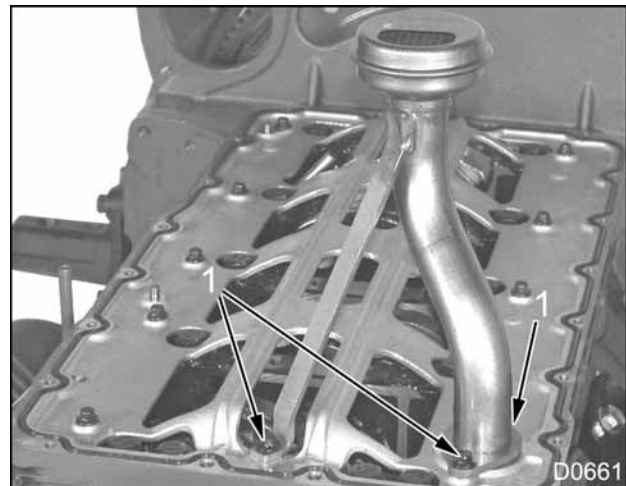
1. M8 X 40 (9)
2. Install upper oil pan and nine mounting bolts. Tighten bolts to the standard torque (Standard Torques, page 375).

### Oil Pickup Tube



**Figure 313 New O-ring**

1. Install a new O-ring on oil pickup tube. Lubricate O-ring with clean engine oil.



**Figure 314 Oil pickup tube**

1. Oil pickup tube mounting bolts, M6 X 16 (3)
2. Install oil pickup tube and three mounting bolts. Tighten bolts to the standard torque (Standard Torques, page 375).

**Lower Oil Pan**

1. Put a new gasket on upper oil pan (lower surface).



2. Place lower oil pan on upper oil pan mating surface.
3. Install 16 M6 lower oil pan mounting bolts. Tighten bolts to the standard torque (Standard Torques, page 375).
4. Reinstall all safety guards, shields, and covers.
5. Make sure all tools, cleanliness covers, loose parts, and service equipment are removed from the engine work area.

**Figure 315 Lower oil pan**




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## Removal

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

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

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

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

**CAUTION:** Replacement of the flywheel, flexplate, and vibration damper may also be necessary depending on engine serial number. Some engines have pistons with a greater mass, resulting in the need for a flywheel, flexplate and vibration damper with inertia values that compliment the additional mass. See your International® dealer for details.

**NOTE:** Engine fluids (oil, fuel and coolant) are a threat to the environment. Do not put engine fluids in the trash, pour fluids on the ground, in sewers or bodies of water.

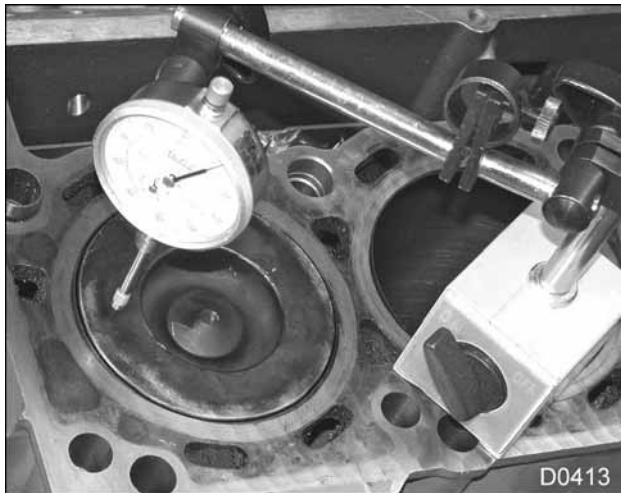
**NOTE:** Before removing pistons, rings, and connecting rods, remove the following components:

- Fuel Filter and Lines  
See “Fuel System.”
- VGT  
See “VGT Electronically Controlled Turbocharger.”
- Electronic Control Module (ECM), Injector Driver Module (IDM) and Mounting Bracket  
See “Engine Electrical.”
- Glow Plug Relay and Bracket  
See “Engine Electrical.”
- Intake Manifold  
See “Manifolds and Exhaust Gas Recirculation (EGR).”
- Cylinder Heads  
See “Cylinder Head and Valve Train.”

### Preliminary Checks

#### Piston and Connecting Rod

**NOTE:** Before removing any piston and connecting rod assemblies, piston protrusion should be evaluated. This will help identify bent or twisted connecting rods.

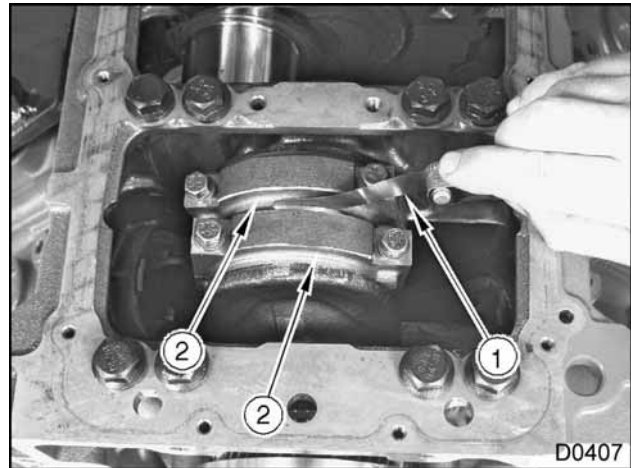


**Figure 316** Checking piston protrusion

**NOTE:** Before checking piston protrusion, make sure the crankcase deck surface is flat and level. See (Crankcase Assembly, page 213).

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

1. Check piston protrusion above crankcase as follows:
  - a. Zero dial indicator gauge (Table 18) on crankcase deck surface.
  - b. Position dial indicator tip over the piston head at 3 o'clock.
  - c. Bar the crankshaft around in the direction of normal rotation to raise the piston to its maximum outward protrusion at cylinder top dead center (TDC). Read this maximum protrusion on the dial indicator.
  - d. Record reading.
  - e. Reposition dial indicator tip on piston head at 9 o'clock.
  - f. Bar crankshaft around to raise the piston to its maximum protrusion. Read the maximum protrusion on the dial indicator.
  - g. Record reading, and then average the two readings. Replace piston and piston rod as required.



**Figure 317** Side clearance check for connecting rod

1. Feeler gauge
2. Connecting rods

2. Use a feeler gauge to check connecting rod side clearance as follows:
  - a. Pry apart a pair of connecting rods on a crankshaft rod journal. Insert largest possible feeler gauge between the connecting rods to check clearance.
  - b. Repeat for each pair of connecting rods on each crankshaft rod journal and compare with specification (Table 16).

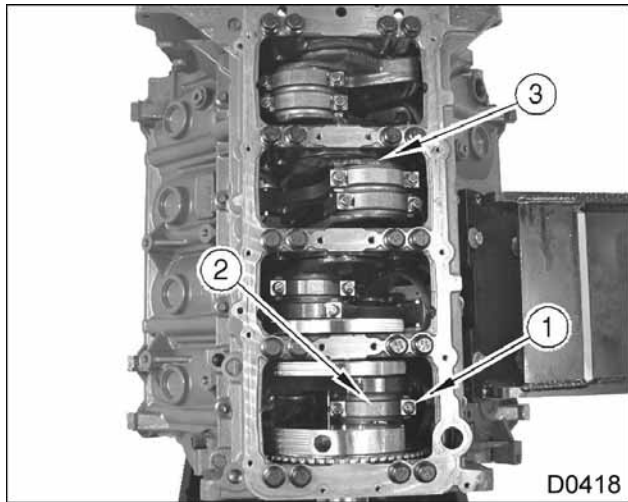
**NOTE:** Lack of clearance could indicate a damaged rod or a rod bearing out of position. Excessive clearance may require replacement of rods or crankshaft. Correct as required.

### Connecting Rod and Piston Assembly

**CAUTION:** To prevent engine damage, check for carbon ridge on top of the cylinder bore, before removing the rod and piston assemblies.

1. Scrape carbon ridge from top of cylinder bore, if necessary.



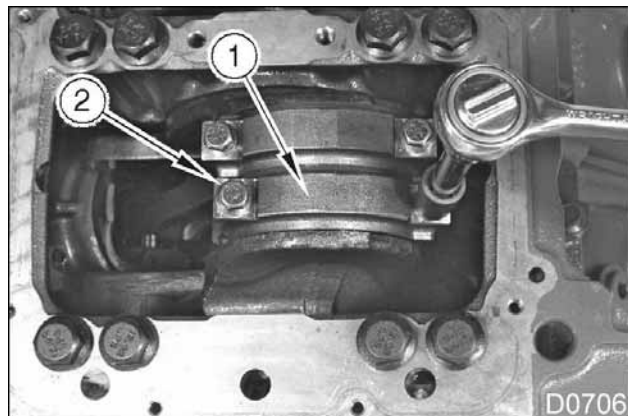


**Figure 318 Connecting rods**

1. Connecting rod bolts
2. Connecting rod cap
3. Crankshaft

2. Rotate crankshaft to position journals for removal of connecting rod assemblies. Mark connecting rod locations.

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

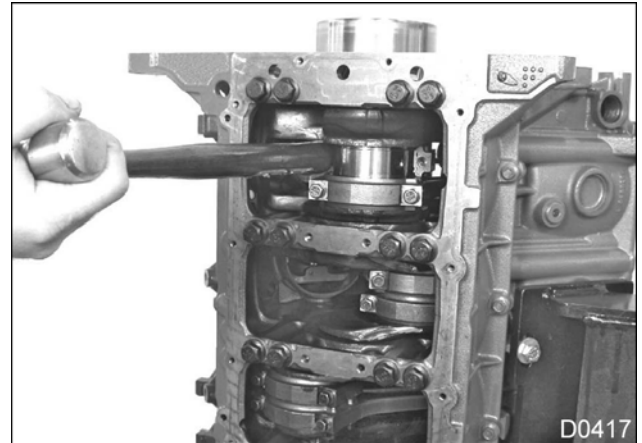


**Figure 319 Connecting rod cap bolts**

1. Connecting rod cap (8)
2. Connecting rod bolt (16)

3. Remove two connecting rod bolts and connecting rod cap.

4. Remove piston and connecting rod assemblies from crankcase as follows:



**Figure 320 Piston and connecting rod assembly**

- a. Rotate engine to a vertical position.
- b. Use a wooden or plastic handle and push piston and rod assembly from cylinder bore.
- c. Once piston rings are free of cylinder bore, remove piston and connecting rod assembly from crankcase.

**CAUTION:** To prevent engine damage, make sure each connecting rod and cap is stamped, marked, or tagged as a matched set.

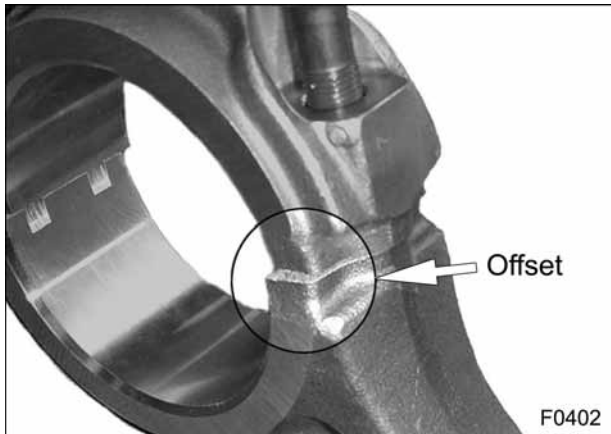
**CAUTION:** This engine uses fractured connecting rods. Do not alter or damage the fractured mating surfaces of rod and cap.



**Figure 321 Cap and rod numbers**

1. Matching numbers

5. When removed, make sure matching connecting rod and cap numbers stay together as a set. A cap from one connecting rod is not interchangeable with any other connecting rod.



**Figure 322** Offset for incorrect rod cap assembly

6. The rod cap can only be correctly installed on the connecting rod if it is oriented in the correct direction.
  - If the rod cap is reversed during assembly of the connecting rod, an obvious offset will be seen at the mating surfaces.
  - If the connecting rod assembly is installed on the crankshaft in this manner, the connecting rod must be replaced.
7. Check the crankpin fillets for damage.
  - If crankpin fillets are damaged, replace crankshaft.

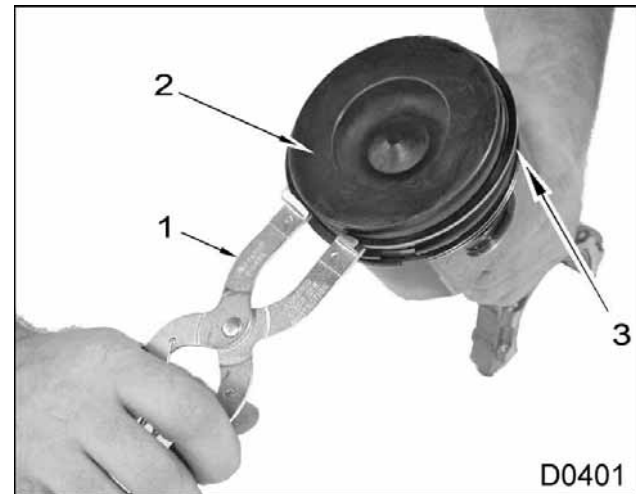
### Piston Disassembly



**WARNING:** To prevent personal injury or death, wear safety glasses when removing retaining rings.

**CAUTION:** To prevent engine damage, mark the pistons with the cylinder number from which each was removed. If pistons will be reused, reinstall in correct cylinder bore.

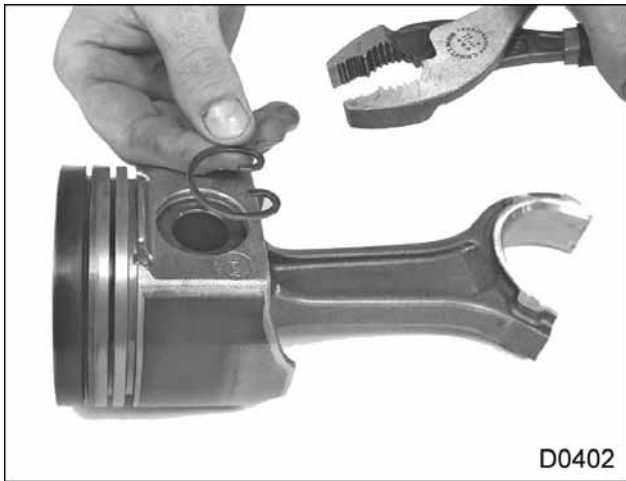
**CAUTION:** To prevent engine damage, note the engine serial number (stamped on the crankcase pad, left side rear of the crankcase) and piston part number (stamped on the piston crown). Multiple pistons are available for service applications. Do not install pistons having different part numbers.



**Figure 323** Piston ring removal

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

1. Use piston ring expansion pliers (Table 18) to remove the piston rings.
2. Remove top ring, intermediate ring, and oil control ring.



3. Use pliers to remove both piston pin retaining rings.
4. Remove piston pin from its bore by hand, and separate connecting rod from piston.

**Figure 324** Piston pin retaining ring

## Cleaning and Inspection

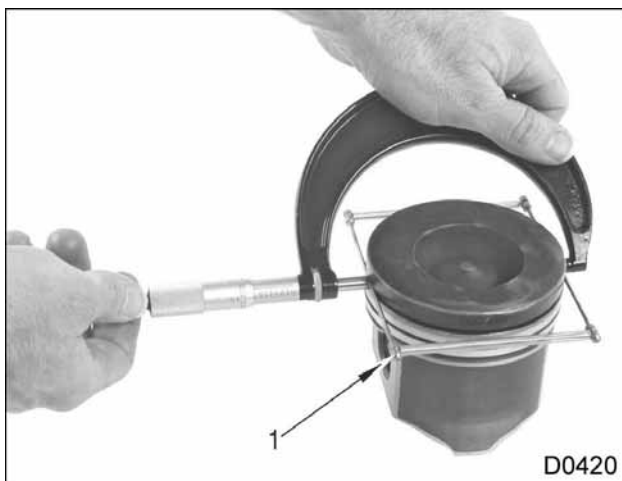
**NOTE:** Do not use a caustic solution, wire brush or bead blast material to clean aluminum pistons.

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

### Pistons

1. Inspect pistons for scuffed or scored skirts, cracked or worn ring lands, and cracked or scuffed pin bores. Replace damaged pistons.
2. Check top compression ring groove for wear.

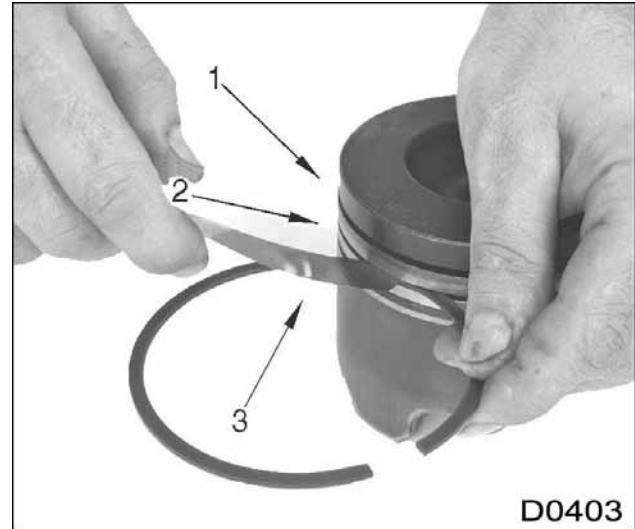
**NOTE:** Top compression ring groove is a keystone design which requires measurement over gauge pins to determine ring groove wear.



**Figure 325 Top compression ring groove**

1. Piston gauge pins (0.082 in)

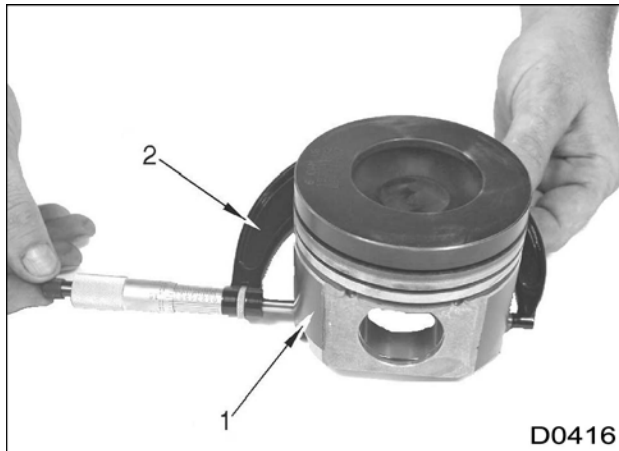
3. Install the piston gauge pins (0.082 in) (Table 18) in the top ring groove. Piston gauge pins must be parallel.
4. Use a 3 - 4 inch outside micrometer to measure diameter over piston gauge pins.
5. If measurement over the gauge pin is not within specifications (Table 16), excessive piston groove wear exists. Replace piston.



**Figure 326 Ring groove clearance check (intermediate ring shown)**

1. Compression ring groove
  2. Intermediate compression ring groove
  3. Feeler gauge
6. Check side clearance of intermediate ring groove as follows:
    - a. Place outer edge of new ring in its respective ring groove.
    - b. Roll ring entirely around piston in its respective groove. Make sure ring is able to move freely in its groove.
    - c. Use a feeler gauge to check side clearance of each ring in its respective groove (Table 16). Excessive side clearance indicates ring groove wear and requires piston replacement.
  7. Check side clearance of oil control ring groove as follows:

- a. Place outer edge of new ring in oil control ring groove.
- b. Roll ring entirely around piston in its respective groove. Make sure ring moves freely in groove.
- c. Use a feeler gauge to check side clearance of oil control ring in its respective groove. Excessive side clearance indicates ring groove wear and requires piston replacement.



**Figure 327 Piston skirt diameter**

1. Piston skirt
2. 3 - 4 inch micrometer

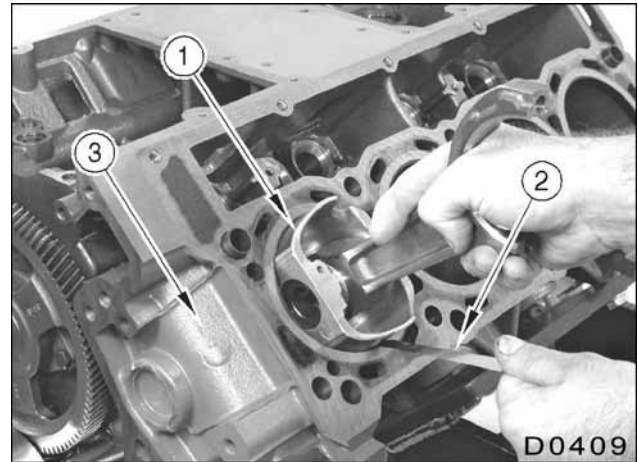
8. When considering piston replacement, check cylinder bore out-of-round specifications.
9. See Specifications in (Table 16). Cylinder boring may be required. Bore reconditioning requires oversize service pistons. Verify piston size by measuring skirt diameter under conditions indicated in Specifications (Table 16).

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

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

If cylinder bore is suitable for use without reconditioning, deglaze bore using a glaze breaker brush, then reassemble.

11. See (Cylinder Deglazing, page 215) for the correct deglazing procedure.



**Figure 328 Piston skirt clearance check in cylinder bore**

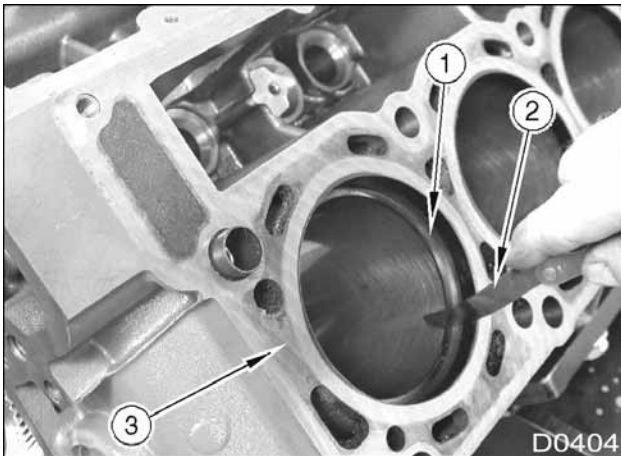
1. Piston
2. Feeler gauge
3. Crankcase

12. Check piston skirt clearance in the cylinder bore. Correct as required.

### Piston Rings

**NOTE:** Faulty rings cannot always be detected by inspection; therefore, if a piston is removed, replace piston rings.

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



**Figure 329** Piston ring end gap clearance in cylinder bore

1. Piston ring
2. Feeler gauge
3. Crankcase

- c. If gap does not meet specifications (Table 16), select another ring or recheck cylinder bore wear.

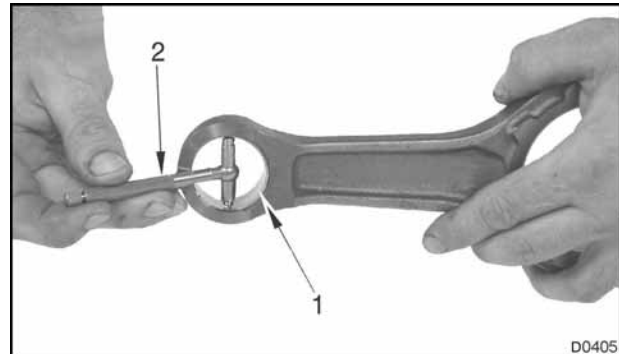
### Connecting Rods

**CAUTION:** If the rod cap is reversed when assembled to the connecting rod or a rod cap is not installed on its original matching connecting rod, the fractured mating surfaces will be useless. The entire connecting rod assembly must be replaced.

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

1. Inspect connecting rod bolts for nicks or damage. Replace as required.
2. Inspect connecting rod and cap mating surfaces and bearing bore for any indication of damage.

Bore must be smooth and free of scoring or nicks. Replace if necessary.



**Figure 330** Inside diameter of piston pin bushing

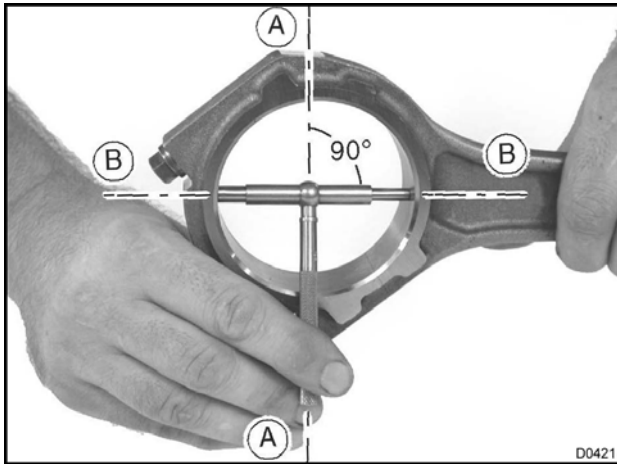
1. Piston pin bushing
2. Telescoping gauge

3. Inspect connecting rod piston pin bushing for wear as follows:
  - a. Use a telescoping gauge (Table 18) and a 1-2 inch micrometer to measure pin bore at two locations 90° apart. Record both measurements.
  - b. If inside diameter of piston pin bushing exceeds specification (Table 16), replace connecting rod.

### Connecting Rod Bore Out-of-round and Taper Check

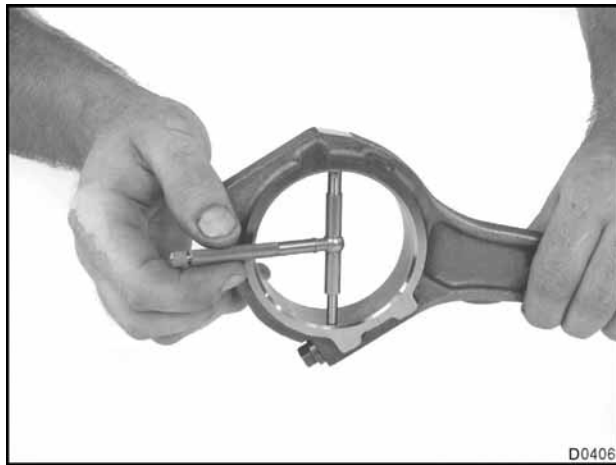
**CAUTION:** To prevent engine damage, check connecting rod bolts for binding. Bolts should thread into connecting rod freely, when lubricated with clean engine oil. If not, discard the connecting rod. Connecting rod threads cannot be retapped, if binding. Check thread condition carefully during inspection.

1. Lubricate connecting rod bolts with clean engine oil. Assemble cap to rod without bearing insert. Tighten bolts to special torque (Table 17).



**Figure 331 Measurement for out-of-round of bore of connecting rod bearing**

2. Use a telescoping gauge (Table 18), measure connecting rod at two locations, 90° apart.
3. If the difference between dimension A and B exceeds out-of-round specifications (Table 16), replace connecting rod.



**Figure 332 Measurement for bore taper of connecting rod**

4. Measure connecting rod taper as follows:
  - a. Insert a telescoping gauge (Table 18) near chamfer on either side.
  - b. Measure inner diameter of connecting rod bearing bore near chamfer on other side.

The difference between the two readings is the connecting rod bore taper. If connecting rod bore taper exceeds specification (Table 16), replace connecting rod.

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

### Connecting Rod Bearing Fit Check

**NOTE:** Bearing shells must fit tightly in the bore. When bearing shells are inserted into the connecting rod and cap, they protrude above the parting line. This protrusion is required to achieve "bearing crush."

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

When the assembly is drawn up tight, the bearing is compressed, ensuring positive contact between the backside of the bearing and the bore.

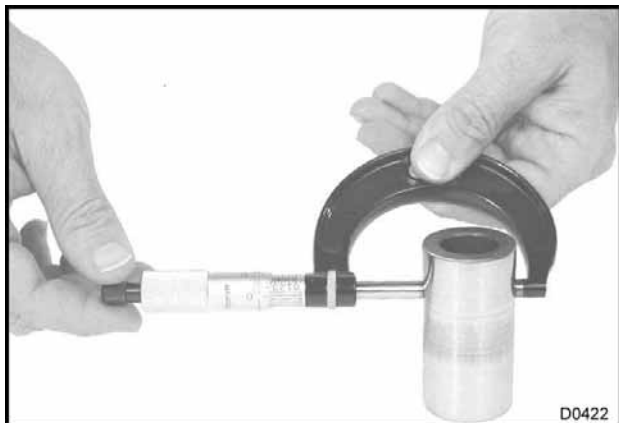
1. Lubricate connecting rod bolts with clean engine oil. Assemble cap to rod with new bearing shells installed. Tighten bolts alternately and evenly to special torque value (Table 17).
2. Use a telescoping gauge (Table 18), measure inside diameter of connecting rod bearing at two locations 90° apart. Average the two inside diameters.
3. Use a micrometer to measure each crankshaft rod journal diameter.
4. Subtract the crankshaft rod journal diameter from the respective connecting rod bearing inside diameter to obtain bearing-to-crankshaft running clearance. Repeat for each crankshaft rod journal.
5. If bearing-to-crankshaft running clearances exceed specifications because of wear on crankshaft, replace or grind crankshaft and install under-size precision type bearing shells.

**CAUTION:** To prevent engine damage, grind or replace the crankshaft only. Do not rework bearing cap or bearings; this will reduce running clearance of journal-to-bearing.

**NOTE:** Plastigage® may be used as an alternate method, to determine running clearance.

### Piston Pin Inspection

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



**Figure 333** Piston pin wear

2. Use a 1-2 inch micrometer, measure piston pin outside diameter at two locations 90° apart.
3. Measure each end of the pin and record the range of readings.
- If piston pin wear exceeds specifications (Table 16), replace piston pin.



**Figure 334** Inside diameter measurement of piston pin bore

4. Using a 1-2 inch telescoping gauge and micrometer, measure each piston pin bore inside diameter, at two locations 90° apart.
5. To check piston pin clearance, subtract outside diameter of the piston pin from the inside diameter of the piston pin bore.
  - If clearance exceeds specifications (Table 16), replace piston pin and check piston pin clearance using new piston pin.



## Installation

### Piston and Ring Assembly

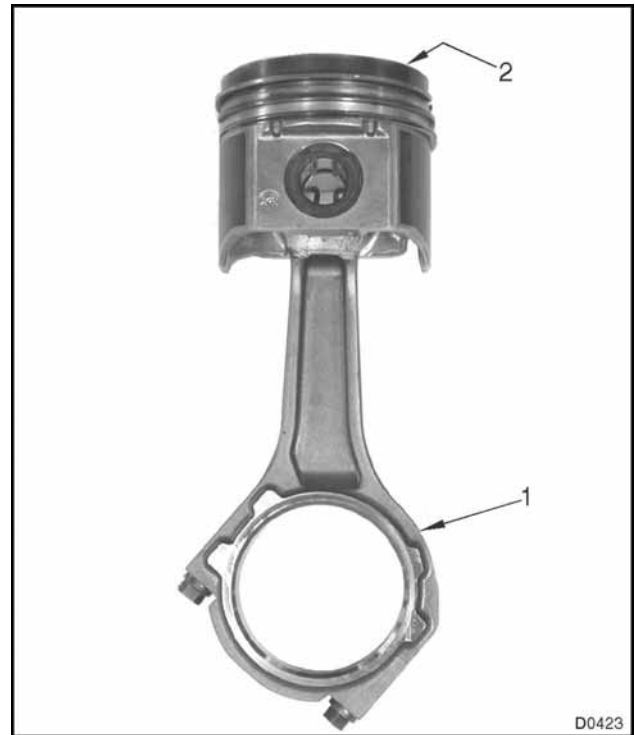
**⚠ WARNING:** To prevent personal injury or death, wear safety glasses with side shields to protect eyes.

**CAUTION:** To prevent engine damage, note the engine serial number (stamped on the crankcase pad, left side rear of the crankcase) and piston part number (stamped on the piston crown). Multiple pistons are available for service applications. Do not install pistons having different part numbers.

**CAUTION:** Some engines have pistons with a greater mass, depending on engine serial number. Inertia values of the flywheel, flexplate and vibration damper must compliment the greater mass pistons. Contact your International dealer for details.

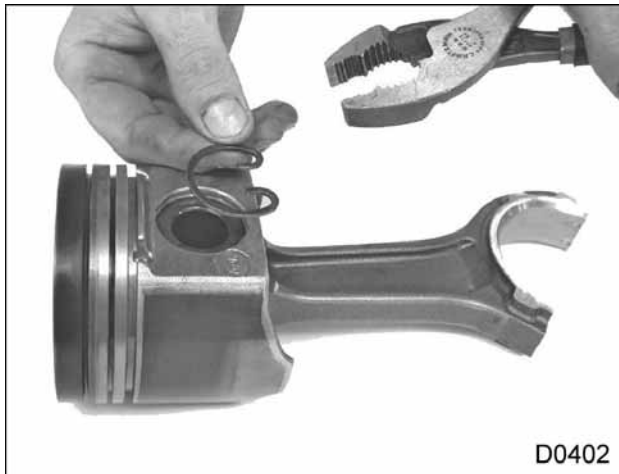
**CAUTION:** To prevent engine damage, make sure the connecting rod and piston are assembled correctly.

1. Connect piston to connecting rod as follows:



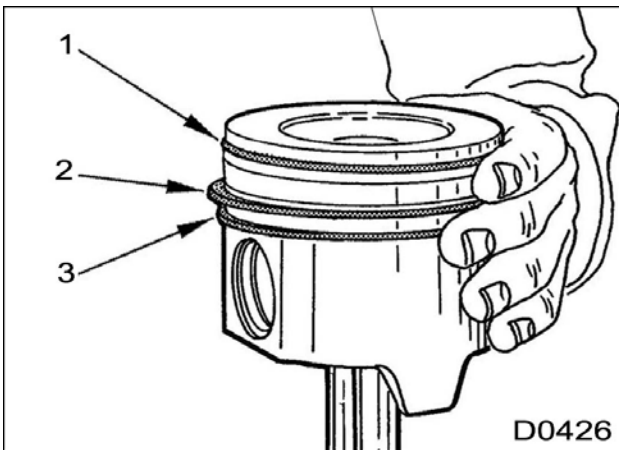
**Figure 335** Correct position of installed connecting rod

1. Longer leg of connecting rod (cam side)
2. CAM V8 stamp on cam side of piston crown
  - a. Lubricate connecting rod piston pin bore, piston pin bore, and piston pin with clean engine oil.
  - b. Orient the longer leg of the connecting rod with the side of the piston bearing the CAM V8 stamped in its crown.



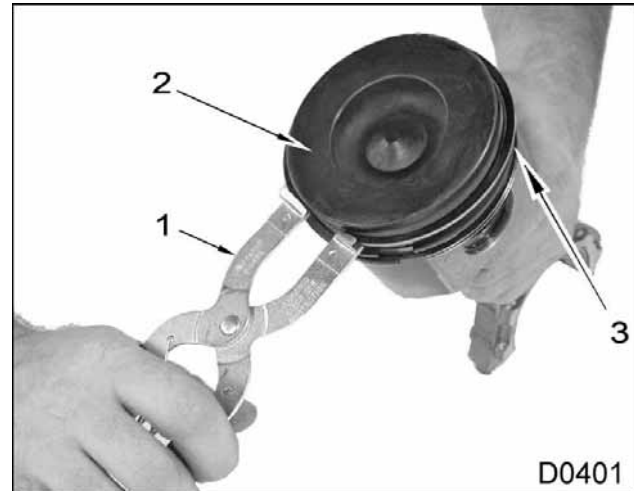
**Figure 336** Piston pin retaining ring

- c. Using pliers, install retaining ring at one end of piston pin bore.
- d. Slide piston pin through bored holes, stopping at installed retaining ring.
- e. Use pliers to install second retaining ring.
- f. Check the piston pin end clearance (Table 16).



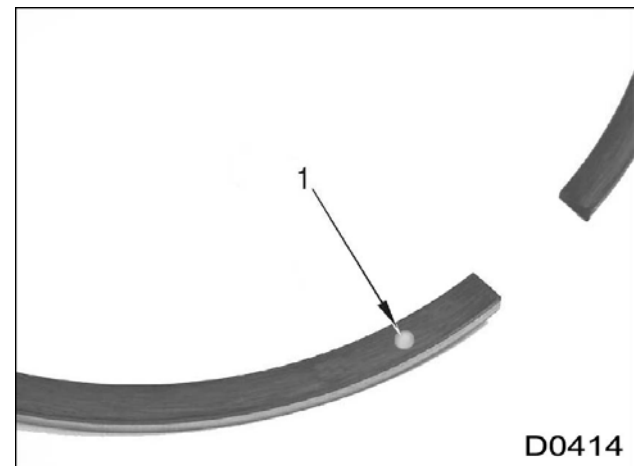
**Figure 337** Piston rings

1. Top compression ring
  2. Intermediate compression ring
  3. Oil control ring
2. Use piston ring expansion pliers (Table 18), to install piston rings.



**Figure 338** Piston rings installed

1. Piston ring expansion pliers
  2. Piston
  3. Piston ring (top compression shown)
- a. Install expansion spring component of two piece oil control ring into bottom piston groove.
  - b. Install oil scraper component of two piece oil control ring over expansion spring.



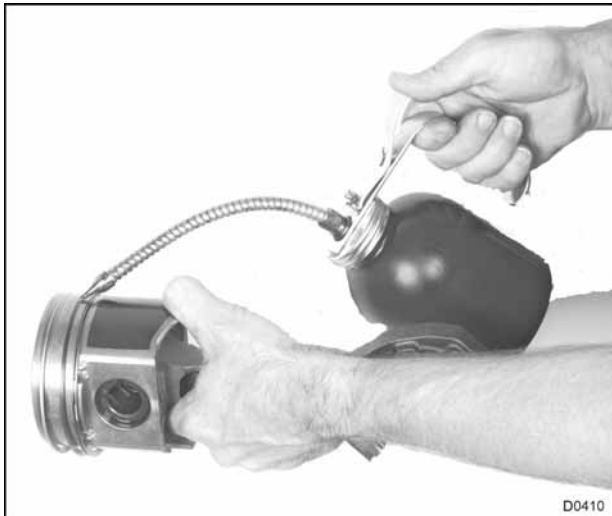
**Figure 339** Piston ring identification mark (top ring)

1. Identification mark
- c. Install intermediate ring into middle piston groove. The intermediate ring is identified by two 'OO' marks on the top surface of the

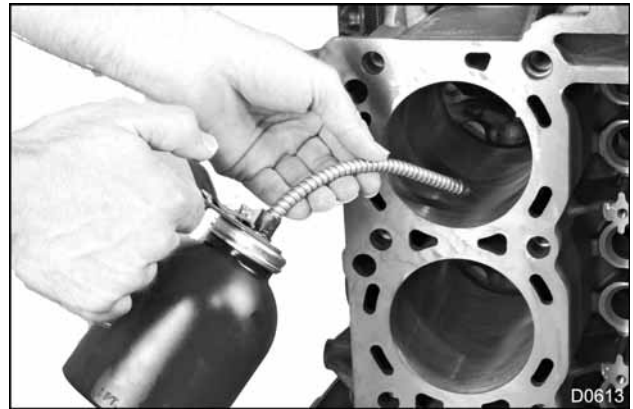
- ring. Make sure the ring is installed with the identification mark facing up.
- d. Install compression ring into top piston groove. The compression ring is identified by the 'O' mark on the top surface of the ring. Make sure the ring is installed with the identification mark facing up.
3. Install intermediate and top compression rings with their identification marks facing up (to top of piston). Space ring gaps approximately 120° apart after ring installation.

### Connecting Rod and Piston Assembly

1. Turn crankshaft so number 1 crank pin is at bottom of its stroke.



**Figure 340** Piston and piston ring lubrication



**Figure 341** Cylinder wall lubrication

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

**CAUTION:** To prevent engine damage, CAM V8 stamped on top of the piston must be oriented towards the camshaft side of the crankcase or up position.



**Figure 342** CAM V8 stamp on piston

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



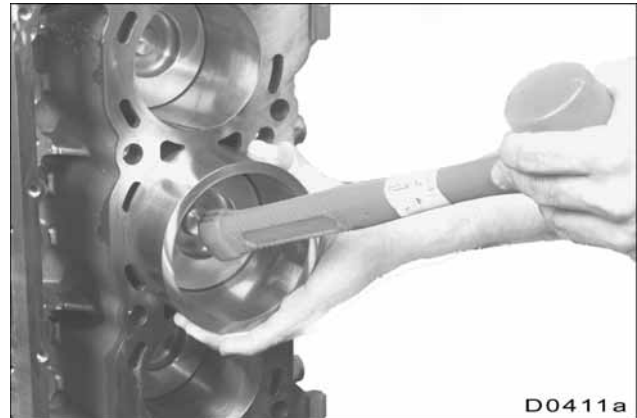
**Figure 343** Piston installed in piston cope

4. Place piston in piston cope (Table 18).
5. Install bearing shells in connecting rod and cap. Coat bearing shell in connecting rod with clean engine oil.
6. Carefully put piston and piston cope combination and connecting rod assembly in crankcase bore.

**CAUTION:** To prevent engine damage, when installing connecting rod and piston assemblies, do not damage piston cooling tubes.

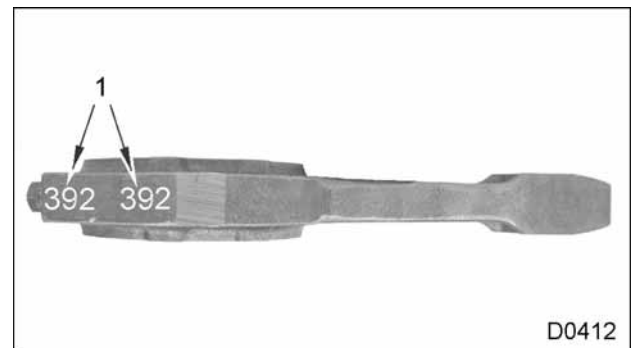
**CAUTION:** To prevent engine damage, note the engine serial number (stamped on the crankcase pad, left side rear of the crankcase) and piston part number (stamped on the piston crown). Multiple pistons are available for service applications. Do not install pistons having different part numbers.

**CAUTION:** To prevent engine damage, install pistons in the correct cylinder bore.



**Figure 344** Installation of piston in cylinder bore

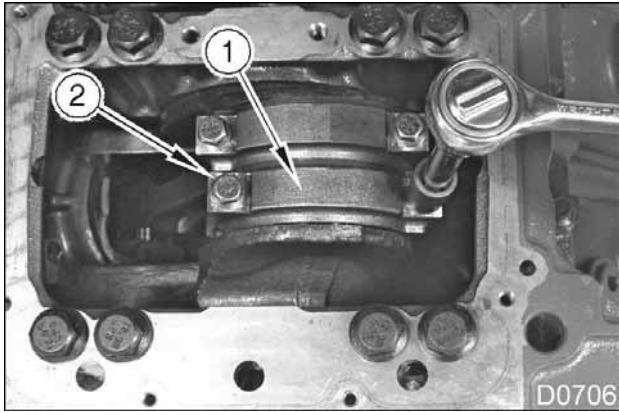
7. Once piston and connecting rod assembly have been inserted in cylinder bore, use the handle (wood or plastic) of a hammer to tap piston in crankcase bore. Guide connecting rod in place on crankshaft.
8. Apply clean engine oil to bolt hole threads for connecting rod and bearing shell in cap before installing bolts.



**Figure 345** Connecting rod and cap

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

**CAUTION:** To prevent engine damage, do not use air powered tools to install connecting rod bolts; this can seize rod bolts.



**Figure 346 Connecting rod cap**

1. Connecting rod bearing cap
2. Connecting rod bolt

10. Install and tighten connecting rod bolts evenly to initial and final torque values. See special torque (Table 17).
11. Repeat installation procedure for remaining connecting rod and piston assemblies.
12. Check connecting rod side clearance with feeler gauge. See procedure in removal section (Removal, page 185).
13. Reinstall all safety guards, shields, and covers.
14. Make sure all tools, cleanliness covers, loose parts, and service equipment are removed from the engine work area.

## Specifications

**Table 16 Connecting Rods and Pistons**

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

**Table 16 Connecting Rods and Pistons (cont.)**

Clearance in piston	0.013 to 0.022 mm (0.0005 to 0.0009 in)
End clearance	0.24 mm (0.009 in)
<b>Piston Rings</b>	
Ring diameter (standard):	95 mm (3.74 in)
Fit in groove (side clearance in bore):	
Intermediate compression	0.051 to 0.102 mm (0.0020 to 0.0040 in)
Oil control	0.038 to 0.084 mm (0.0015 to 0.0033 in)
Ring gap in bore:	
Top compression	0.29 to 0.55 mm (0.011 to 0.021 in)
Intermediate compression	1.40 to 1.66 mm (0.055 to 0.065 in)
Oil control	0.24 to 0.50 mm (0.009 to 0.019 in)

## Special Torque

**Table 17 Connecting Rod Assembly**

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

## Special Service Tools

**Table 18 Connecting Rods and Pistons**

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

