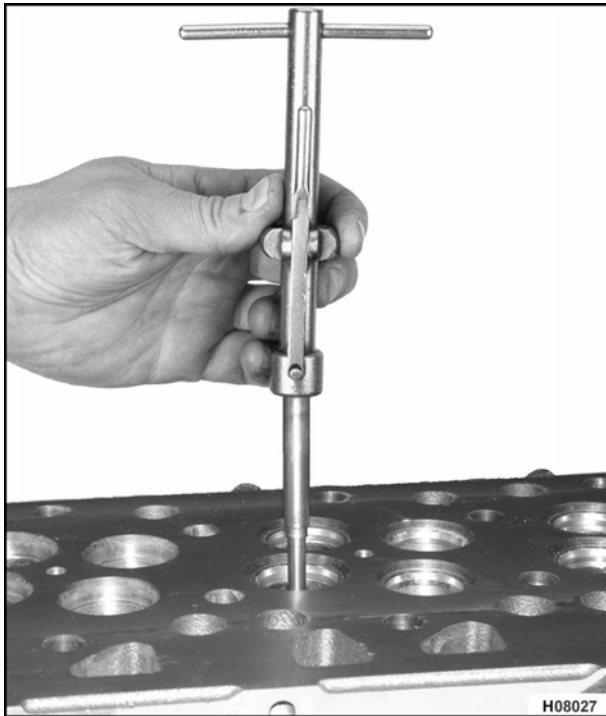
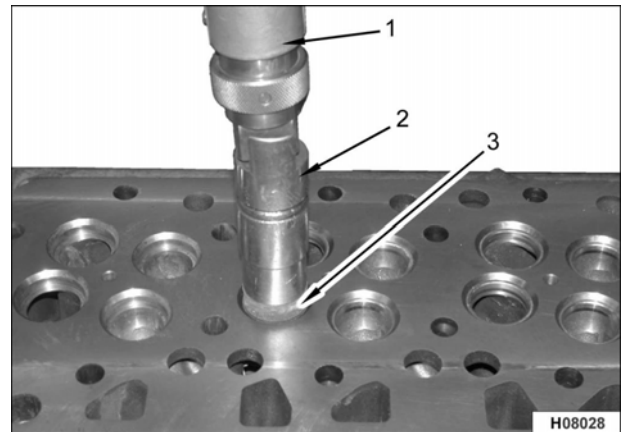
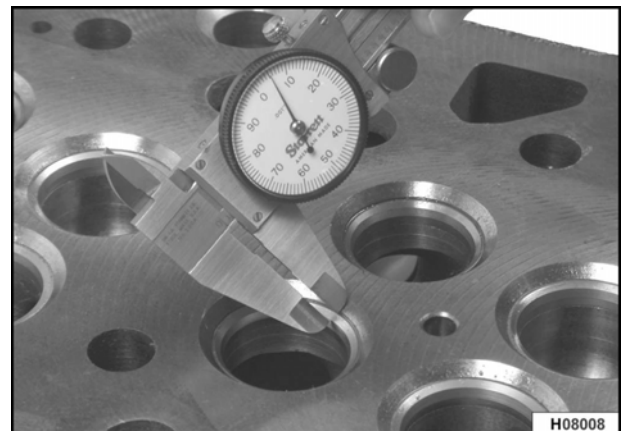


Resurfacing Valve Seats**Figure 151 Installing valve guide pilot**

1. Lightly lubricate the correct size of grinding pilot. Install the pilot into the valve guide.
2. Choose the correct angle grinding stone and dress the stone. See "Specifications" for the correct valve seat angle.
3. Install the grinding stone over the pilot.

**Figure 152 Grinding the valve seat**

1. Motor and drive
 2. Holder
 3. Grindstone
4. Turn on the power and gently apply the weight of the grinding motor to the grindstone. Raise the grinding stone frequently to prevent overheating. Grind the valve seat to a smooth even finish, paying attention to achieving an acceptable uniform width (Table 16).

**Figure 153 Checking valve seat width**

5. Use a caliper to check the valve seat width. If the valve seat width exceeds specifications, the valve seat may be corrected by grinding with a 15 degree or smaller angle stone.

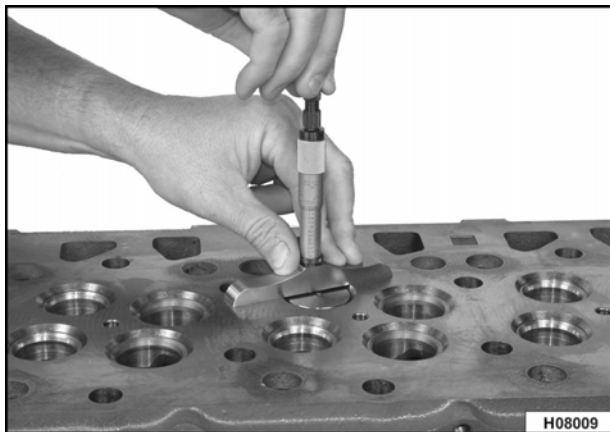


Figure 154 Checking valve recession

6. Install valve in guide. Use a depth micrometer to check valve recession. If valve recession is excessive, install a new valve or replace valve seat as necessary. If the valve protrudes above the surface of the cylinder head, regrind the valve seat. After grinding the valve seat, check valve seat width again. Also check the valve face-to-valve seat contact (See Checking Valve Face-to-Valve Seat Contact, page 118).
7. Use an appropriate dial indicator to check the valve seat runout. If runout exceeds specifications, replace valve seat.

Replacing Valve Seats

Removal

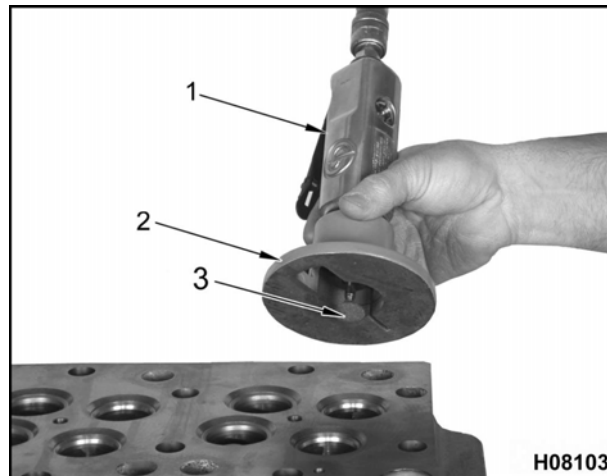


Figure 155 Grinding group tool

1. Air motor
2. Grinding base
3. Grinding wheel

1. Use grinding group tool (Table 18) to cut a groove in the valve seat insert.

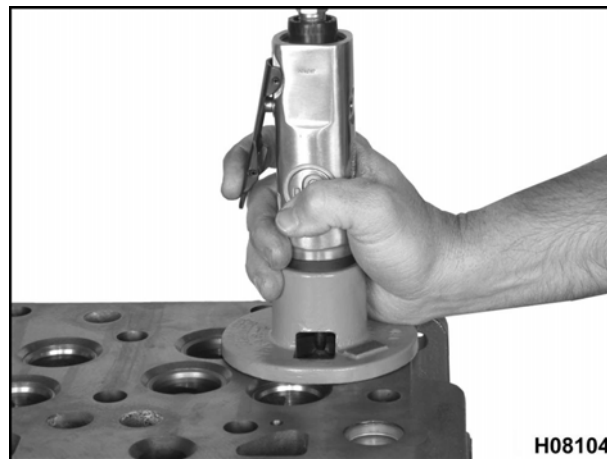


Figure 156 Grinding groove in valve seat

2. Position the appropriate size extractor in the valve seat.

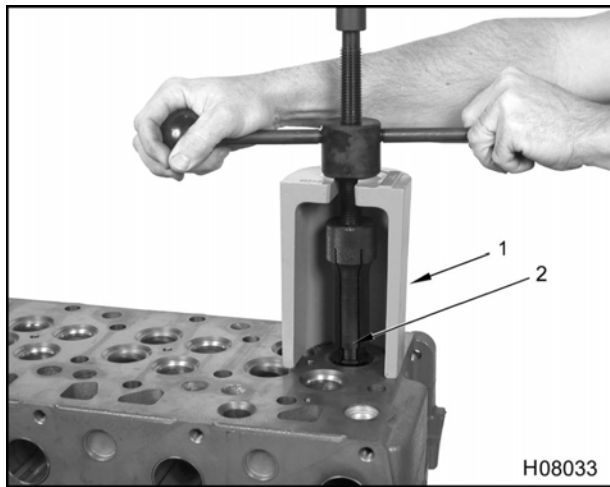


Figure 157 Removing the valve seat insert

1. Lifting bridge
 2. Valve seat remover (collet)
3. Expand collet by threading the shaft into the valve seat remover until it is tight inside the valve seat. Turn T-handle on shaft to pull the valve seat insert from cylinder head.

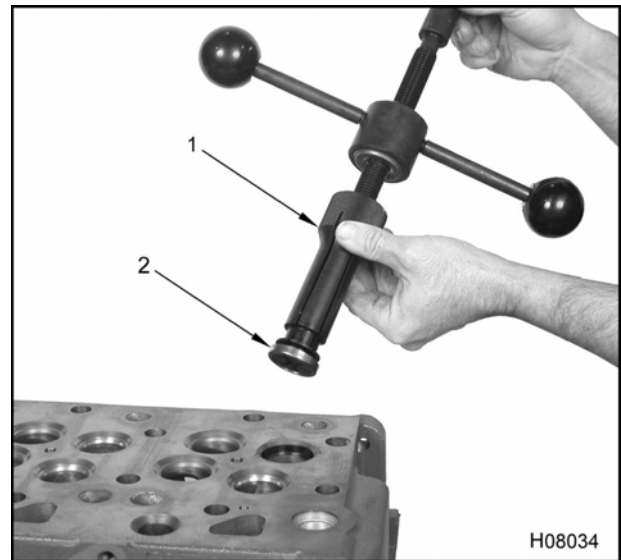


Figure 158 Valve seat insert removed

1. Collet
 2. Valve seat insert
4. Unlock the collet by loosening the threaded shaft. Discard valve seat insert.

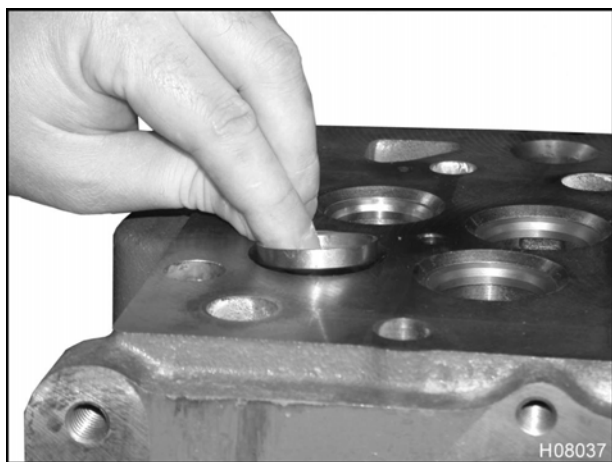
Installation

1. Use a micrometer to measure the diameter of the valve seat insert counterbore at two locations, 90° apart. Average the two measurements to determine the appropriate size valve seat insert to install.

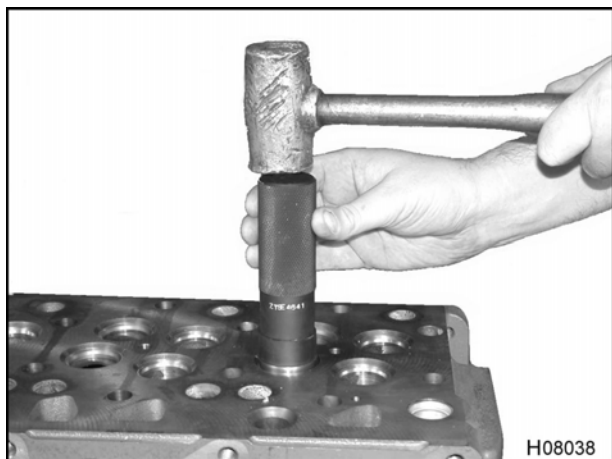
Table 13 Valve Seat Insert Selection Chart

Available inserts (int. and exh.)	Ave. dia. of intake counterbore	Ave. dia. of exhaust counterbore
Standard	40.119 - 40.170 mm (1.5795 - 1.5815 in)	37.478 - 37.529 mm (1.4755 - 1.4775 in)
Oversize - 0.05 mm (0.002 in)	40.170 - 40.221 mm (1.5815 - 1.5835 in)	37.529 - 37.579 mm (1.4775 - 1.4795 in)

- Chill the valve seat insert in a freezer for 30 minutes. This will prevent the outer layer of metal from being shaved off during installation.

**Figure 159 Placing chilled valve seat into head**

- Align insert over counterbore to avoid misalignment.

**Figure 160 Driving valve seat into place**

- Using a hammer and valve seat installation tool drive the valve seat into place until it is fully

seated, see Cylinder head and valve special service tools (Table 18).

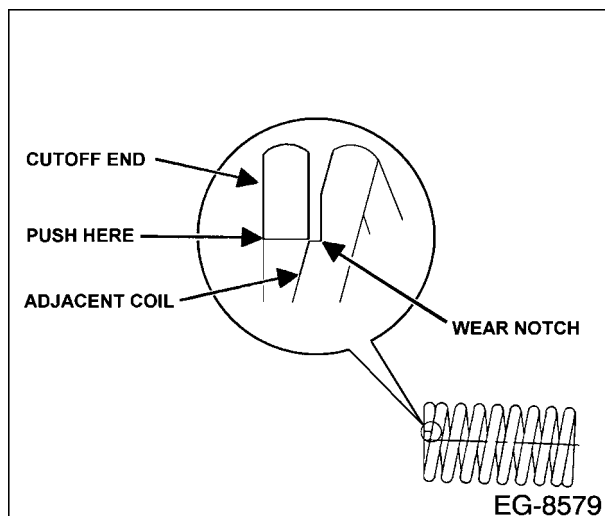
- Grind new valve seats to the specified angles and widths, see Cylinder Head Specifications (Table 16) in this section.

Inspecting Valve Springs

- Clean all of the valve springs in a suitable solvent.

CAUTION: To avoid engine damage, do not wire brush or grind valve springs. Disruption of surface may result in fatigue cracks and spring failure.

- Check the valve springs for rust, cracks, and pitting. Replace any damaged valve springs.

**Figure 161 Valve spring inspection**

- Check both ends of each valve spring at the contact point between the cutoff end of the last coil and the adjacent coil. If the cutoff end has

worn a notch in the adjacent coil, replace the spring.

NOTE: These wear notches can also be detected by compressing the spring and listening for a clicking sound.

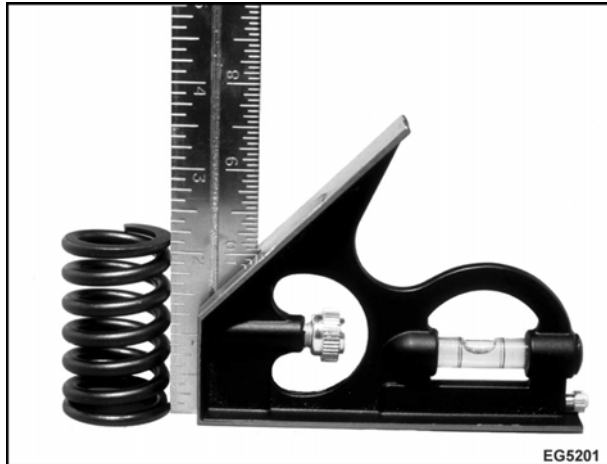


Figure 162 Checking perpendicularity and flatness of valve spring

NOTE: Valve springs that are not perpendicular to a flat surface place an unequal lateral load on the valve stem during operation, causing premature valve guide wear.

4. Use a square to check flatness and perpendicularity of spring ends. If the end of any valve spring is not flat and square, replace spring.

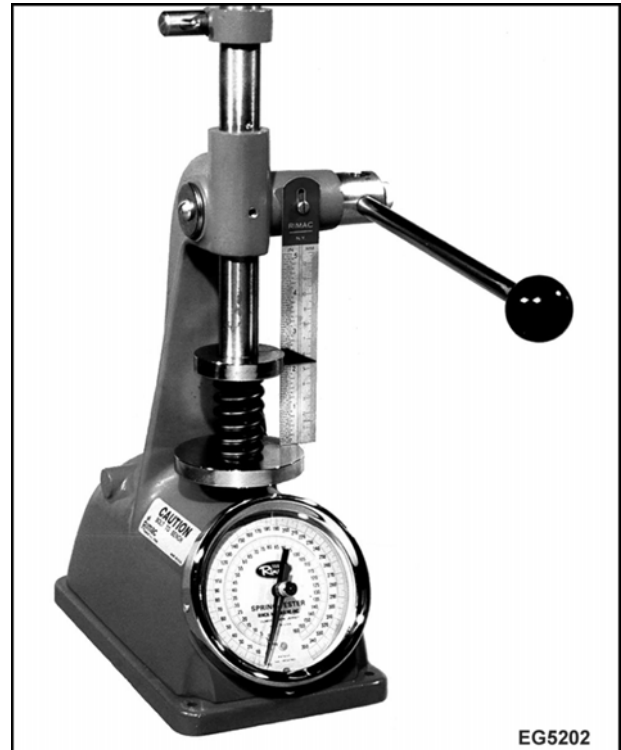


Figure 163 Measuring valve spring tension

5. Use a spring tester to measure the valve spring tension. Measure the maximum and minimum lengths of the spring at the appropriate test loads (valve closed and valve open). Replace any valve spring that does not meet valve spring specifications (Table 15).

Inspecting Valve Rotators

1. Clean all valve rotators in a suitable solvent.

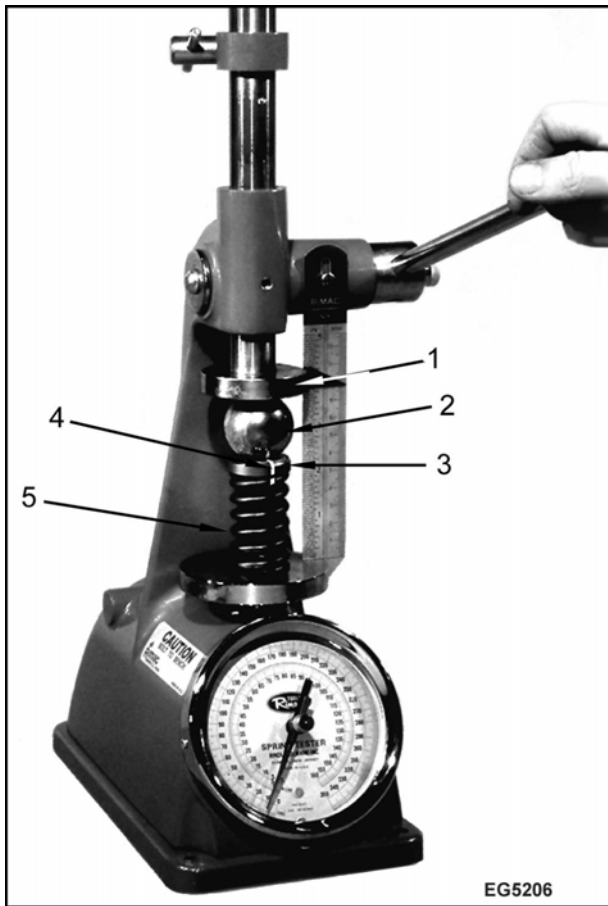


Figure 164 Checking valve rotator

1. Ram
 2. Steel ball bearing
 3. Paint reference line
 4. Valve rotator
 5. Spring
2. Lubricate the valve rotator with clean engine oil. Place the valve spring and rotator in spring tester.
 3. Place a ball bearing between the valve rotator and the ram of the spring tester. The ball bearing must be large enough to prevent the ram from touching any part of the rotator.
 4. Paint a reference line on the valve rotator and spring.
 5. Compress the valve spring rapidly with even pressure and observe the valve rotator as it turns. Replace any valve rotator that does not turn.

Inspecting Valve Spring Retainer Keys

1. Clean all valve spring retainer keys with a suitable solvent.
2. Check the inside and outside of the valve spring retainer keys for wear. Replace any worn retainer keys.

Replacing Fuel Injector Sleeves

Removal

NOTE: If the fuel injector sleeve is being removed while the engine is in-chassis, place a cup plug in the bore before removal to prevent debris from entering the cylinder bore.

1. Insert the fuel injector sleeve removal tool into the fuel injector bore.
2. Turn the removal tool to cut threads into the fuel injector sleeve. Remove the tool from the bore.
3. Install the fuel injector sleeve puller tool into the bore and tighten. Make sure that the puller tool is threaded all the way into the fuel injector sleeve.
4. Install a slide hammer onto the puller tool. Remove the fuel injector sleeve from the bore.

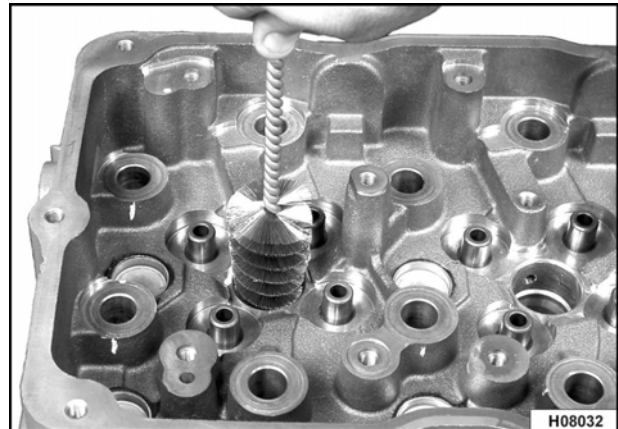


Figure 165 Cleaning fuel injector bore

5. Use a stiff wire brush to clean deposits and hardened sealant from the fuel injector bore.
6. Insert a small stiff nylon brush tool into oil gallery for cleaning.
7. Use compressed air page 3 to clean out all fuel and oil galleries of debris.

Installation

1. Inspect installation tool for a bent pilot shaft or any nicks where sleeve will seat

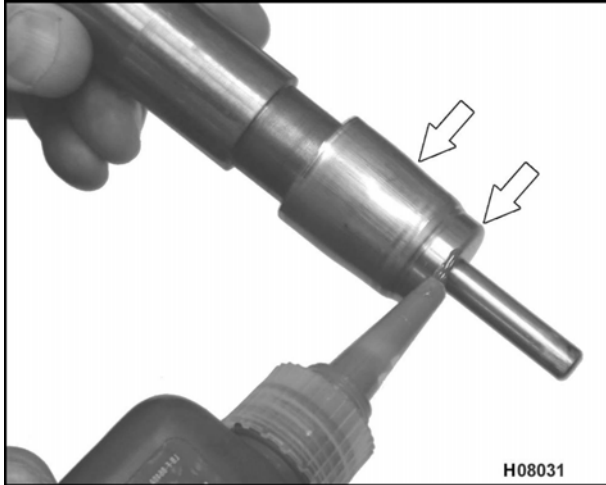


Figure 166 Applying Loctite™620 sealant to fuel injector sleeve

2. Place a new fuel injector sleeve on the end of the installation tool, see cylinder head and valve special service tools (Table 18).

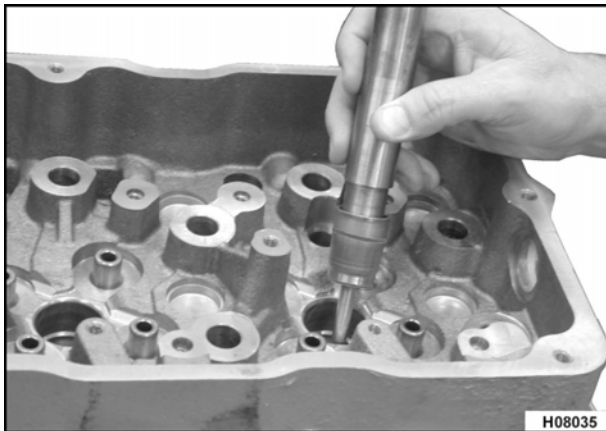


Figure 167 Installing fuel injector sleeve into bore

3. Apply Loctite® 620 around the outside diameter at the bottom of the sleeve and around the beginning of the taper at the middle of the sleeve.



Figure 168 Installing fuel injector sleeve

4. Install the sleeve and installation tool into the fuel injector bore.
5. Use a hammer to drive the fuel injector sleeve into the bore. Remove the installation tool when the sleeve is seated.
6. Use a soft nylon brush to clean the fuel injector sleeve after installation.
7. Inspect the inside surfaces of the installed fuel injector sleeve. If nicks and scratches are evident, replace the sleeve again. Make sure that the installation tool is not causing such damage. Use a different installation tool, if necessary.

Installing Valves**Cleaning**

1. Clean the valve faces and seats with a suitable cleaning solvent. Dry all components using filtered compressed air page 3.
2. To clean valve guides, coat a brush with soap and water. Insert the brush into each valve guide bore and rotate in one direction with an up and down motion. Dry the valve guide bores using filtered compressed air page 3.
3. Insert a large nylon brush in the rear of the fuel rail gallery to loosen any dirt and deposits. Blow out any debris using filtered compressed air page 3.

Assembly

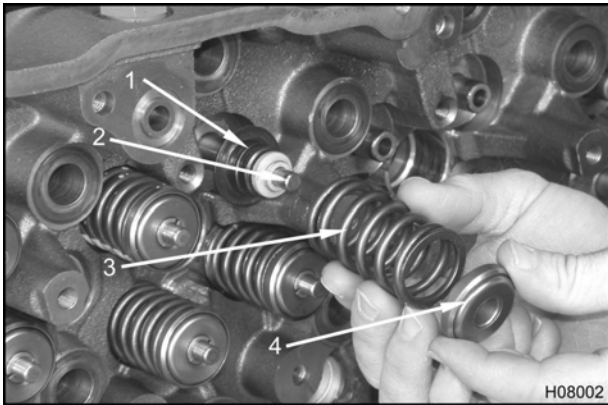


Figure 169 Installing valve stem seal, spring, and valve rotator

1. Valve rotator
 2. Valve spring
 3. Valve stem
 4. Valve stem seal
1. Lubricate the valve stems with clean engine oil and insert into the valve guides.
 2. Lubricate the inside diameter of the new valve stem seals with clean engine oil. Install the seals over the valve stems and valve guides. Make sure that the seals are completely seated against the cylinder head spring pockets.
 3. Install the valve springs over the valve stem seals.
 4. Then install the valve rotators on top of the valve springs.



WARNING: To avoid serious personal injury or possible death, wear safety glasses before using the valve spring compressor.

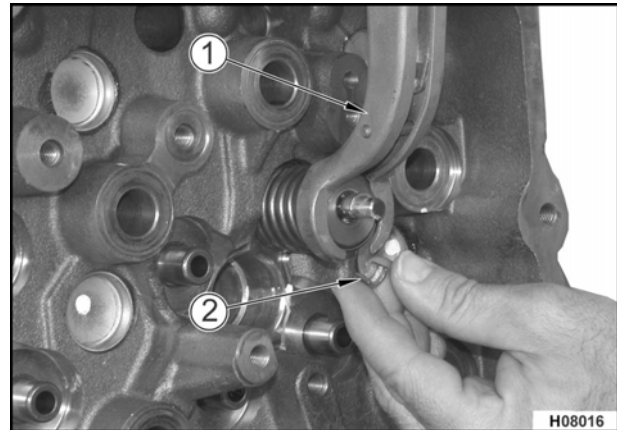


Figure 170 Installing valve spring retainer keys

1. Valve spring compressor tool
 2. Valve spring retainer key
5. Install a valve spring compressor tool over the valve, see cylinder head and valve special service tools (Table 18). Compress the valve spring.
 6. Install the valve spring retainer keys.

Installation

Installing the Cylinder Head

NOTE: Before cylinder head installation, check cylinder sleeve protrusion (See Checking Cylinder Sleeve Protrusion, page 206).

1. Install two lifting eyes with four bolts (M12 x 25) onto cylinder head. Tighten bolts to the standard torque value (See General Torque Guidelines, page 409).
2. Clean and dry the cylinder head gasket surface. Also use the correct size tap to clean head bolt holes in the crankcase.

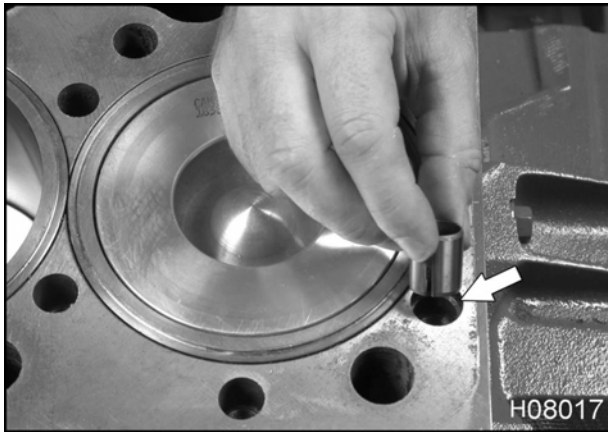


Figure 171 Installing alignment dowels

3. Install or verify that alignment dowels are in the top of the crankcase.

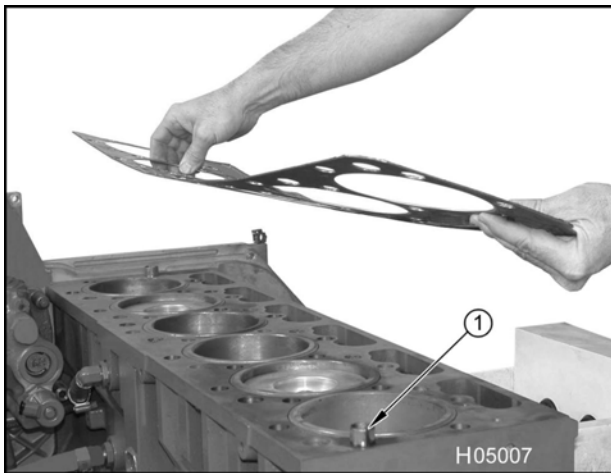


Figure 172 Installing cylinder head gasket

1. Alignment dowels
4. Install a new cylinder head gasket over the alignment dowels.

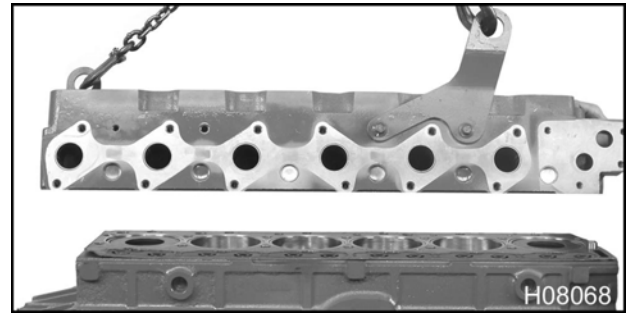


Figure 173 Lowering cylinder head onto crankcase

5. Attach an appropriate hoist and lifting hooks to the lifting eyes page 3. Carefully lower the cylinder head onto the crankcase.

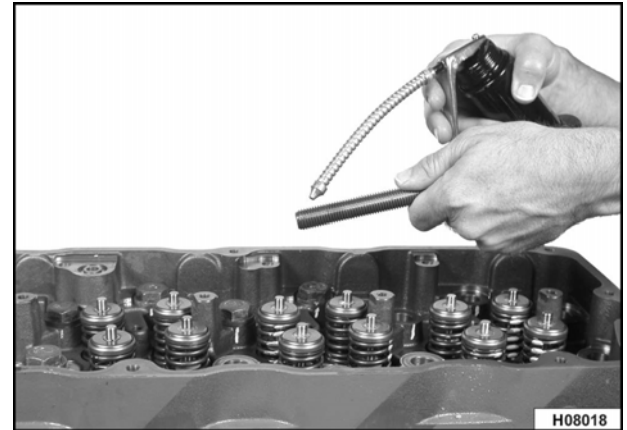


Figure 174 Lubricating cylinder head mounting bolts

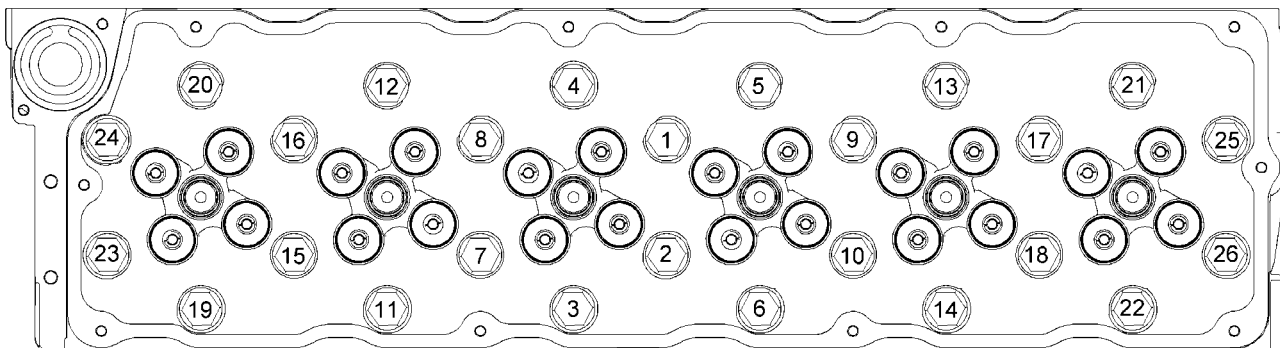
CAUTION: To avoid engine damage, verify that the cylinder head bolts have been checked for signs of excessive stretch. Bolts that do not thread into the head bolt thread gauge (Table 18) freely must be replaced. If bolts are reused that do not pass this test, the bolts may break during the tightening procedure.

NOTE: Do not use chlorinated solvents on cylinder head bolts. Parts should be clean, dry, and free of any chemical residue other than engine oil.

6. Lightly lubricate threads and bolt flange of all 26 cylinder head bolts with clean engine oil.
7. Install all of the cylinder head mounting bolts finger tight only.
8. Torque all cylinder head bolts per the following procedure and in the specified sequence.

Torque-to-Yield Head Bolts

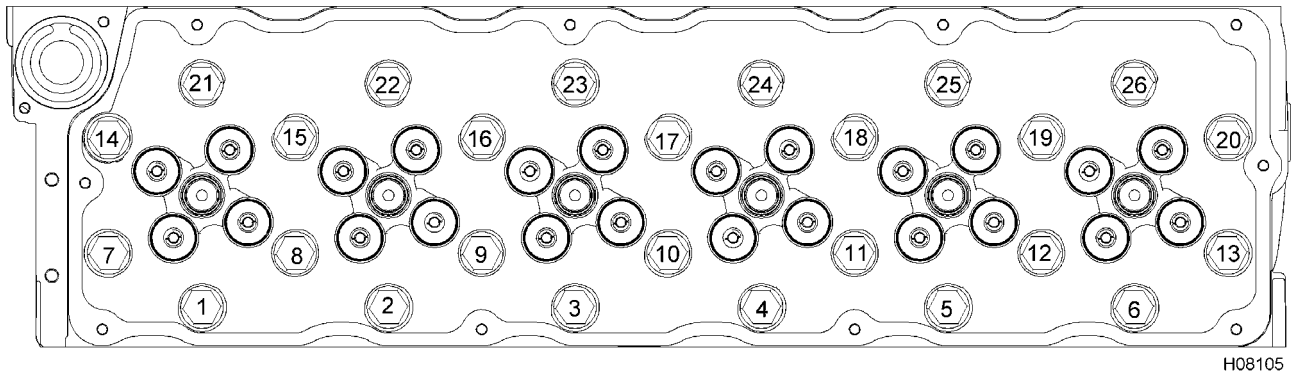
Tightening Procedure for Torque-to-Yield Head Bolts



H08040

Figure 175 Cylinder head torque sequence A

1. Position the crankshaft at TDC for the No. 1 cylinder. Then rotate the crankshaft 30 degrees past TDC.
2. Torque each cylinder head bolt to 150 N·m (110 lbf·ft) in the special tightening sequence A (Figure 175).
3. Torque each cylinder head bolt to 204 N·m (150 lbf·ft) in the special tightening sequence A (Figure 175).



H08105

Figure 176 Cylinder head torque sequence B

4. Torque each cylinder head bolt again to 204 N·m (150 lbf·ft) in the special tightening sequence B (Figure 176).

NOTE: It is necessary to torque the cylinder head twice at 204 N·m (150 lbf·ft) in order to obtain uniformity.

5. Using a permanent marker, make a mark on each bolt head. Make another mark 90° counter-clockwise on the bolt, and another mark on the socket corresponding to the bolt mark. Align mark on each socket and bolt head with other mark 90° clockwise on the bolt head.
6. Rotate each bolt 90 degrees (1/4 turn).

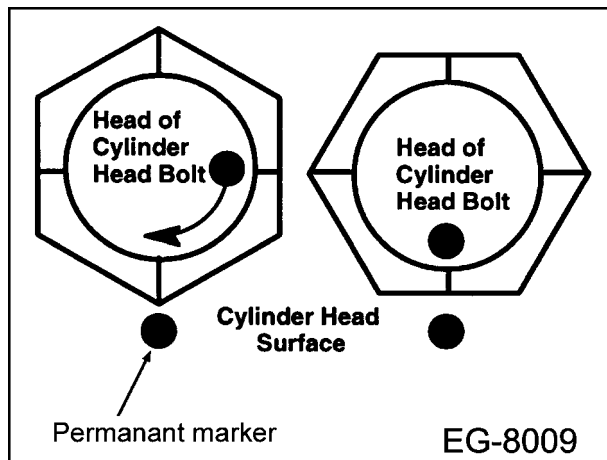
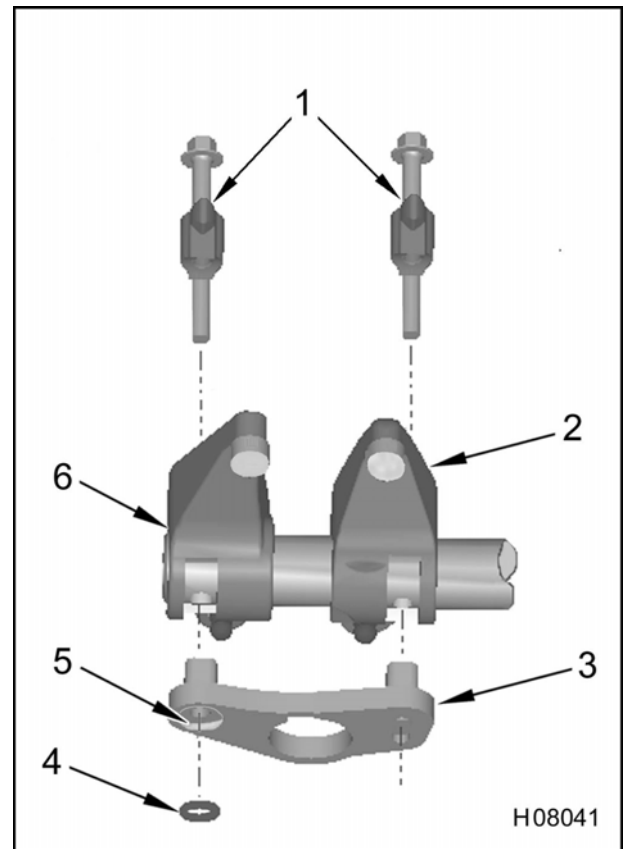


Figure 177 Torque-to-yield sequence

NOTE: See "Fuel System" section for fuel injector installation procedure (See Fuel Injectors, page 321).

Installing Rocker Arms



H08041

Figure 178 Rocker arm configuration

1. Clamp bolt assembly
2. Exhaust rocker arm
3. Rocker arm shaft support
4. Lower support washer
5. Machined recessed
6. Intake rocker arm

1. Slide each of the 12 rocker arms onto the rocker shaft in the order they were removed (rocker arms should have been marked for this occasion).

NOTE: Ensure that the rocker arm shaft has the big "T" stamped facing up (Figure 179).

2. Place a bolt and clamp assembly through each rocker arm shaft support and align shaft with bolt hole in cylinder head (Figure 178).
3. Install plastic washer (assembly aid) onto each intake rocker arm retaining bolt.

Installing the Rocker Arm Assembly

1. Place valve bridges across each set of valves. These should be marked if removed. The recessed holes set over the valve stems.

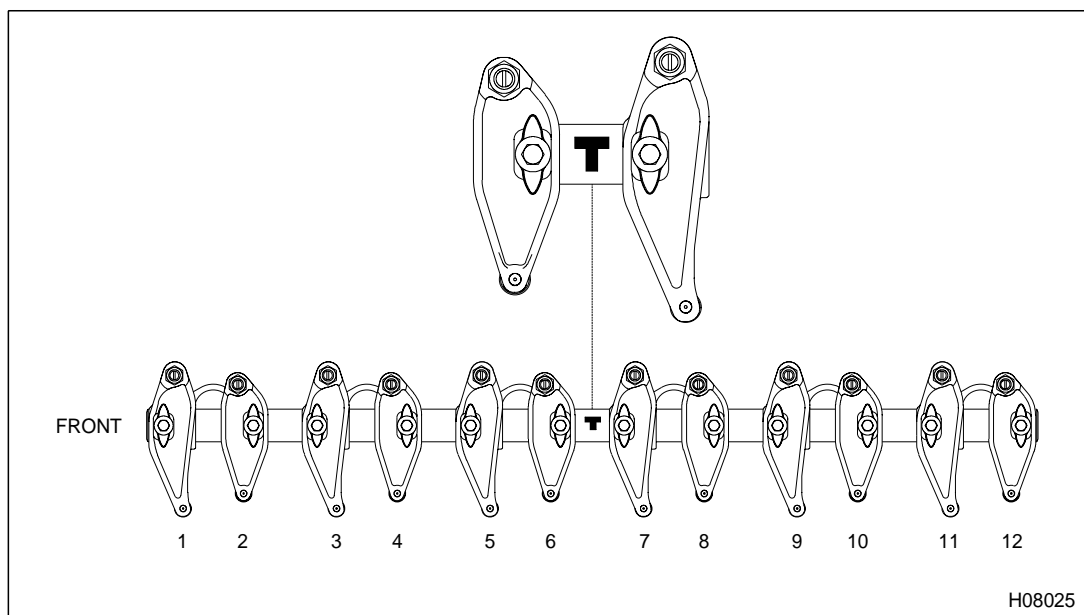


Figure 179 Rocker arm orientation

2. Align rocker arm assembly with bolts over mounting holes and thread hand tight.

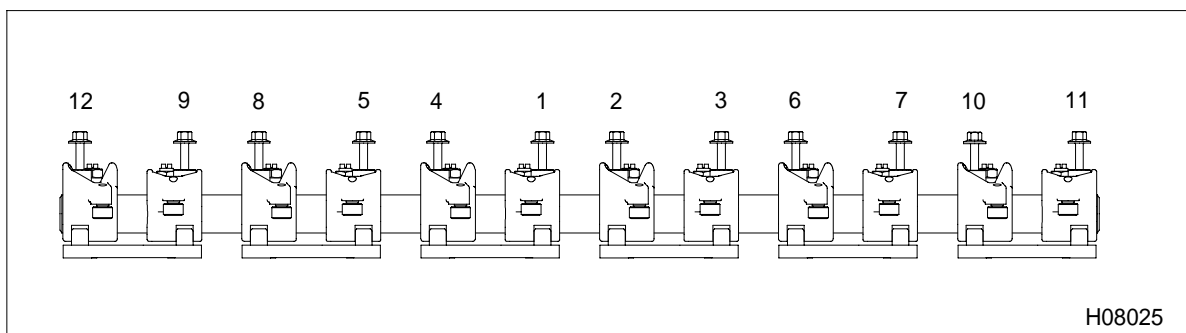


Figure 180 Rocker arm torque sequence

3. Torque bolts in two passes in the sequence illustrated above and to the specified value.
 - a. Torque rocker arm clamp assembly bolts to 27 N·m (20 lbf·ft) for the first pass.
 - b. Torque rocker arm clamp assembly bolts to 37 N·m (27 lbf·ft) for the final pass.

Valve Lash for Intake and Exhaust Valves

During the procedure to adjust valve lash, the crankshaft is rotated two times:

- Six adjustments are made when piston 1 is at Top Dead Center (TDC) compression.
- Six adjustments are made when piston 6 is at Top Dead Center (TDC) compression.

If the engine is equipped with the Diamond Logic™ engine brake, corresponding brake actuator lash (See Adjusting Valve Lash, page 132) can be adjusted before and after rotating the crankshaft the second time.

Adjusting Valve Lash

1. Remove valve cover, (See Valve Cover, page 104).
2. Turn crankshaft in the direction of engine rotation to remove gear lash from gear train and align the timing mark on the damper pulley with the TDC mark on the front cover.
3. Confirm that piston 1 is at TDC compression by turning both push rods by hand to verify that the valves are closed.
 - If push rods are loose and turn easily, piston 1 is at TDC compression and valves are closed. If piston 1 is at TDC, see (Figure 181) and do steps 4, 5, and 6.
 - If push rods will not turn easily, piston 6 is at TDC compression. Confirm that valves are closed by making sure that push rods for cylinder 6 are loose and turn easily. If piston 6 is at TDC, see (Figure 182) and do steps 4, 5, and 6.

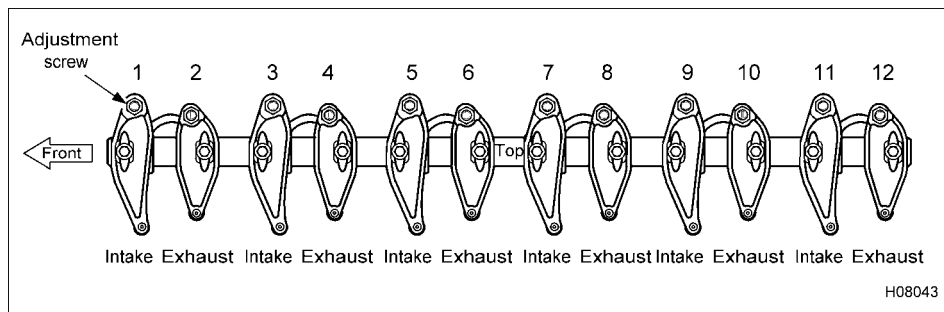
Valve and brake lash adjustments (Inches) with piston 1 at TDC compression											
Cylinder 1		Cylinder 2		Cylinder 3		Cylinder 4		Cylinder 5		Cylinder 6	
Intake 1	Exhaust 2	Intake 3	Exhaust 4	Intake 5	Exhaust 6	Intake 7	Exhaust 8	Intake 9	Exhaust 10	Intake 11	Exhaust 12
0.019	0.019	0.019			0.019	0.019			0.019		
Brake				Brake				Brake			
0.019				0.019				0.019			

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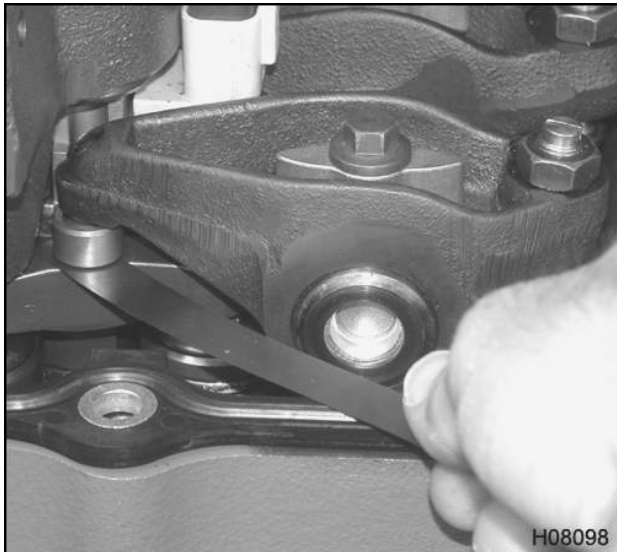
Figure 181 Valve and brake lash adjustments with piston 1 at TDC compression

Valve and brake lash adjustments (Inches) with piston 6 at TDC compression											
Cylinder 1		Cylinder 2		Cylinder 3		Cylinder 4		Cylinder 5		Cylinder 6	
Intake 1	Exhaust 2	Intake 3	Exhaust 4	Intake 5	Exhaust 6	Intake 7	Exhaust 8	Intake 9	Exhaust 10	Intake 11	Exhaust 12
			0.019	0.019			0.019	0.019		0.019	0.019
		Brake				Brake				Brake	
		0.019				0.019				0.019	

H08045

Figure 182 Valve and brake lash adjustments with piston 6 at TDC compression

H08043

Figure 183 Valve lash adjustment

H08098

Figure 184 Feeler gauge between the pivot foot and valve bridge

4. Check cold valve lash with a (0.019 in) feeler gauge between the pivot foot and valve bridge. If adjustment is required, loosen the locknut and turn the valve adjustment screw until a light drag is felt.

5. Once valve adjustment is set, tighten the locknut. See Cylinder head special torques (Table 17) and remove the feeler gauge. Recheck for light drag on feeler gauge. If drag is too tight or loose, repeat steps 4 and 5.

If engine is equipped with the Diamond Logic™ engine brake, corresponding brake actuator lash can be adjusted before rotating the crankshaft (See Engine Brake Actuator Lash, page 369).

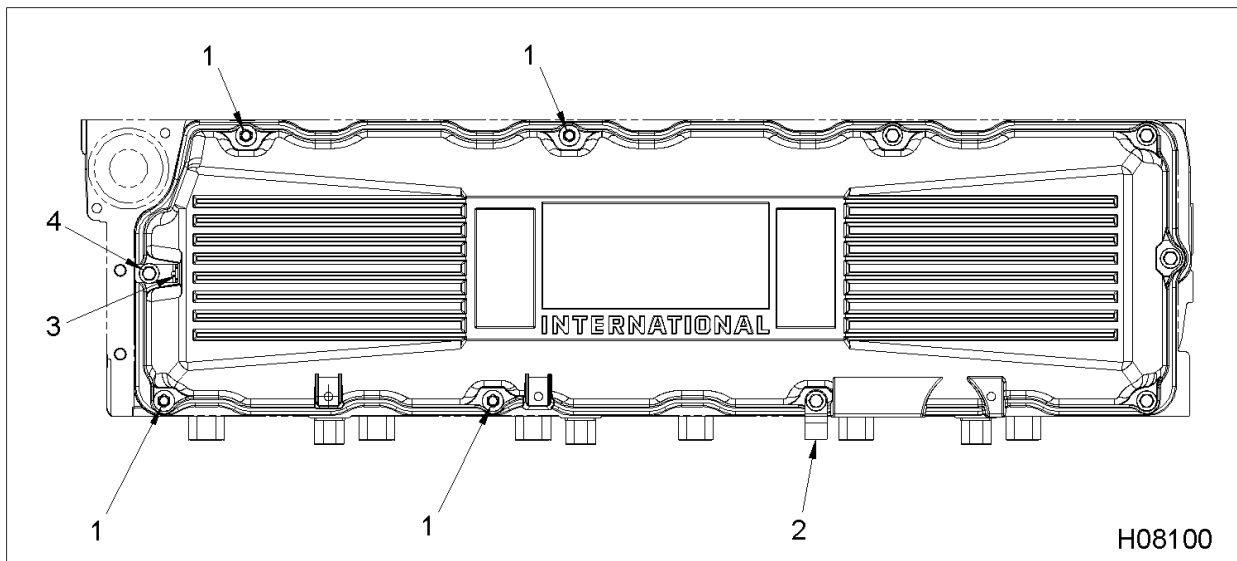
6. Turn crankshaft 360° in the direction of engine rotation to remove gear lash from gear train and

realign the timing mark on the damper pulley with the TDC mark on the front cover.

- If first adjustments were with piston 1 at TDC compression, cylinder 6 should be at TDC compression. Confirm that valves are closed by making sure that push rods for cylinder 6 are loose and turn easily. If piston 6 is at TDC compression, see (Figure 182) and do steps 4 and 5.
- If first adjustments were with Piston 6 at TDC compression, cylinder 1 should be at TDC compression. Confirm that valves are closed by making sure that push rods for cylinder 1 are loose and turn easily. If piston 1 is at TDC compression, see (Figure 181) and do steps 4 and 5.

Valve Cover

1. Install valve cover gasket.
2. Connect all electrical and injector connectors to the valve cover gasket, if disconnected.
3. Install valve cover onto cylinder head.

**Figure 185 Valve cover assembly detail**

- | | | |
|----------------------------------|---|----------------------|
| 1. Bolt / stud, M8 x 80 / 19 (4) | 3. Valve cover harness mounting bracket | 4. Bolt, M8 x 80 (6) |
| 2. Extension bracket | | |
-
4. Install four valve cover bolt / studs (M8 x 80 / 19) finger tight.
 5. Install six valve cover bolts (M8 x 80) finger tight.
 6. Tighten all bolts and studs to the standard torque value (See General Torque Guidelines, page 409).
 7. Add any necessary brackets to the appropriate studs.
 8. Connect crankcase ventilation piping (See Crankcase Ventilation System, page 248).
 9. Add coolant (if cylinder head was removed in chassis).

SPECIFICATIONS

Table 14 Valve Specifications

Camshaft lobe lift	Intake: 6.68 mm (0.263 in) Exhaust: 6.91 mm (0.272 in)
Valve face angle	Intake: 59.75- 60.00° Exhaust: 44.75-45.00°
Valve face margin (min.)	Intake: 1.32 mm (0.052 in) Exhaust: 1.16 mm (0.046 in)
Valve face-to-valve stem runout (max.)	0.038 mm (0.0015 in)
Valve lash (cold), intake and exhaust	0.48 mm (0.019 in)
Valve stem diameter (new condition)	Intake: 7.928 ± 0.0089 mm (0.3121 ± 0.00035 in) Exhaust: 7.908 ± 0.0089 mm (0.3113 ± 0.00035 in)
Valve stem-to-valve guide clearance (max.)	Intake: 0.10 mm (0.004 in) Exhaust: 0.11 mm (0.005 in)

Table 15 Valve Spring Specifications

Intake and Exhaust Valve Springs	
Free length	52.35 mm (2.061 in)
Solid height (max.)	27.43 mm (1.080 in)
Test load	Valve closed: 410 N (92 lbs) Valve open: 764 N (172 lbs)
Test length	Valve closed: 40.01 mm (1.575 in) Valve open: 29.34 mm (1.155 in)

Table 16 Cylinder Head Specifications

Cylinder head gasket surface flatness	0.10 mm (0.004 in.) per 229 mm (9.0 in)
Cylinder head thickness	New: 160.48 mm (6.318 in) Minimum: 159.97 mm (6.298 in)
Exhaust	1.40 ± 0.13 mm (0.055 ± .005 in)
Exhaust valve seat insert counterbore diameter	Standard: 37.503 ± 0.003 mm (1.477 ± 0.001 in) Oversize: 0.05 mm (0.002 in) 37.55 ± 0.03 mm (1.478 ± 0.001 in)
Exhaust valve seat outside diameter	Standard: 37.56 mm (1.479 in) Oversize: 0.05 mm (0.002 in) 37.61 mm (1.481 in)
Intake	1.02 ± 0.13 mm (0.040 ± 0.005 in)
Intake valve seat insert counterbore diameter	Standard: 33.50 ± 0.03 mm (1.319 ± 0.001 in) Oversize: 0.05 mm (0.002 in) 35.55 ± 0.03 mm (1.321 ± 0.001 in)
Intake valve seat outside diameter	Standard: 40.20 mm (1.583 in) Oversize: 0.05 mm (0.002 in) 40.25 mm (1.585 in)
Valve guide bore diameter	14.308 ± 0.017 mm (0.5633 ± 0.0007 in)
Valve guide bore out-of-round (max.)	0.005 mm (0.0002 in)
Valve guide bore taper (max.)	0.013 mm (0.0005 in)
Valve guide height from cylinder head spring pocket (intake)	16.53 ± 0.13 mm (0.651 ± 0.005 in)
Valve guide insert inside diameter (installed)	7.98 - 8.00 mm (0.314 - 0.315 in)
Valve guide insert interference fit dimension	0.043 mm (0.0017 in)
Valve guide insert outside diameter	14.351 ± 0.010 mm (0.5650 ± 0.0004 in)
Valve guide length (overall)	65.71 mm (2.587 in)
Valve recession	Intake: 1.02 mm (0.040 in) Exhaust: 1.40 mm (0.055 in)
Valve seat angles	Intake: 59.75 - 60° Exhaust: 44.75 - 45°
Valve seat runout (max.)	0.05 mm (0.002 in)
Valve seat width	1.91 - 2.16 mm (0.075 - 0.085 in)

Special Torque**Table 17 Cylinder Head and Valve Train Special Torques**

BCP sensor	20-30 N·m (15-22 lbf·ft)
Cylinder head mounting bolts torque and sequence	(See Tightening Procedure for Torque-to-Yield Head Bolts, page 128)
Fuel injector mounting bolt	41 N·m (30 lbf·ft)
High-pressure oil hose fitting	46 N·m (34 lbf·ft)
ICP sensor	20-30 N·m (15-22 lbf·ft)
Rocker arm bolts torque and sequence	(See Installing Rocker Arms, page 129)
Valve adjustment locknut	27 N·m (20 lbf·ft)

SPECIAL SERVICE TOOLS**Table 18 Cylinder Head Special Service Tools**

Cylinder head test plate	ZTSE4289A
Dye penetrant kit	Obtain locally
Head bolt thread gauge	ZTSE4667
Injector sleeve brush set (set of 2)	ZTSE4304
Injector sleeve installer	ZTSE4642
Injector sleeve remover	ZTSE4643
Pressure regulator	Obtain locally
Slide hammer puller set	ZTSE1879
Small hole gauge set	Obtain locally
Straightedge	Obtain locally
Thermostat opening pressure adapter	ZTSE4647
Valve guide deburring tool	ZTSE4393
Valve guide installer	ZTSE1943
Valve guide remover	ZTSE4377
Valve seat extractor kit (universal)	ZTSE1951C
Valve seat grinder	ZTSE1631A
Valve seat grinding stones 45° (exhaust)	Obtain locally
Valve seat grinding stones 60° (intake)	Obtain locally
Valve seat installer	ZTSE4641
Valve seat remover (collet)	ZTSE4640
Valve spring compressor	ZTSE1846
Valve spring compressor jaws	ZTSE4652
Water supply housing pressure adapter	ZTSE4648

