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Description

INJECTION OIL SYSTEM FLOW

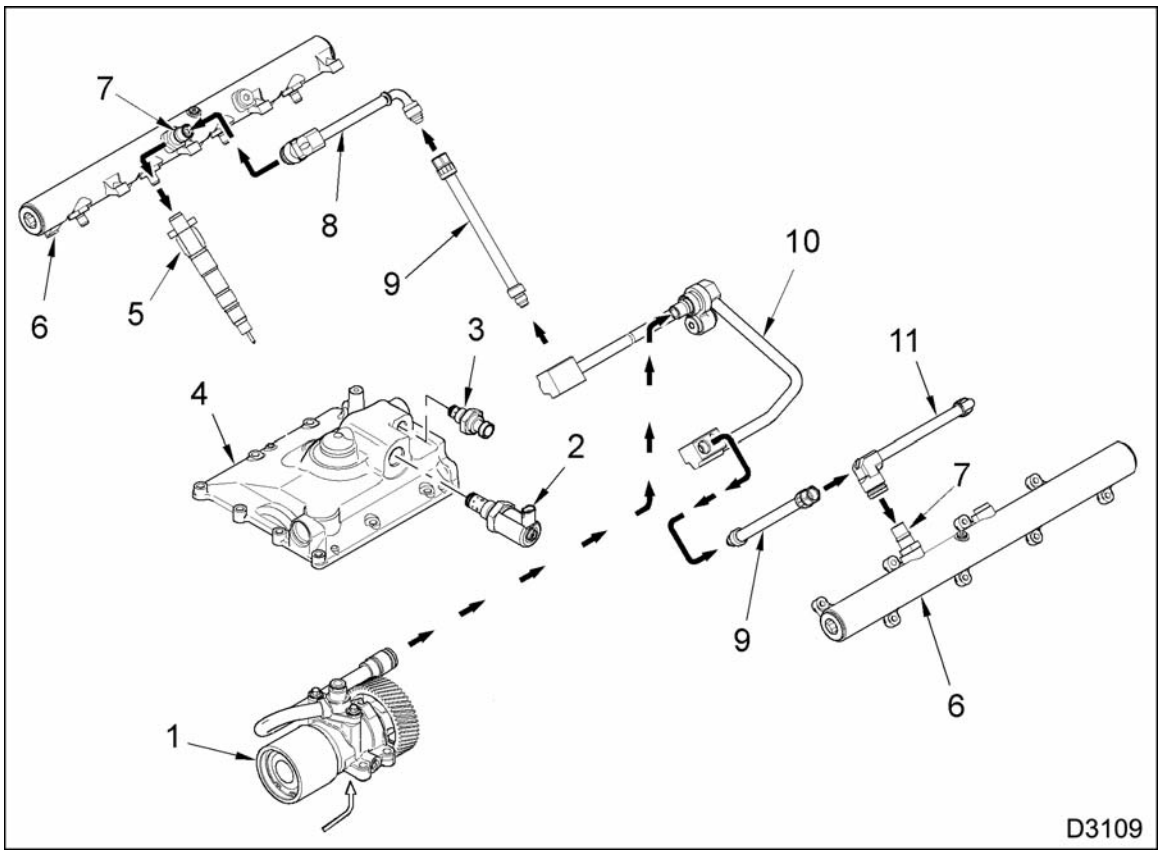

Figure 422 High-pressure oil system

1. Hydraulic oil pump assembly (high-pressure), with discharge tube
2. IPR valve
3. ICP sensor
4. Hydraulic pump cover
5. Fuel injector assembly (8)
6. Oil rail assembly (2)
7. Oil rail check valve fitting assembly
8. Oil hose assembly (right side)
9. Crankcase to head tube assembly (2)
10. Rear engine tube assembly (branch)
11. Oil hose assembly (left side)

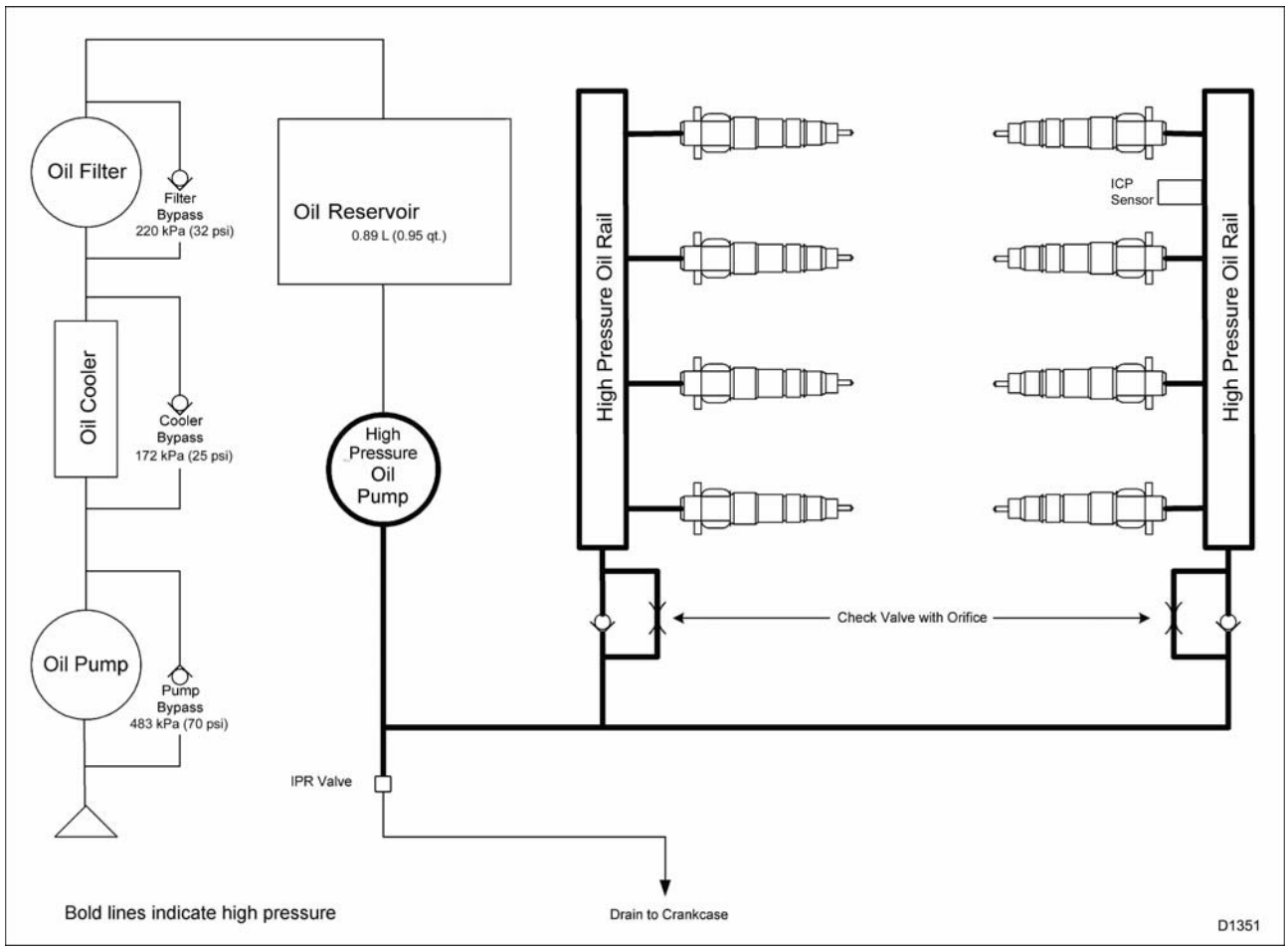

Figure 423 High-pressure flow

The bold arrow lines indicate flow at higher pressures.
See Specifications for range of pressure (Table 30).

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.

NOTE: Before removing high-pressure oil system components, remove the following:

- 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."

- Glow plug relay and bracket

  See "Engine Electrical."

- Exhaust Manifolds and the EGR cooler V-clamp.

  See "Manifolds and Exhaust Gas Recirculation (EGR)."

- Rear cover

  See "Rear Cover, Flywheel, and Power Steering Gear Drive."

Hydraulic Pump Cover

NOTE: The Injection Control Pressure (ICP) sensor or Injection Pressure Regulator (IPR) valve can be removed before or after removing the hydraulic pump cover, if required.

If you are removing the hydraulic pump cover, it is not necessary to remove the ICP sensor or IPR valve at this time.

1. Loosen three rear exhaust heat shield mounting bolts and remove heat shield.

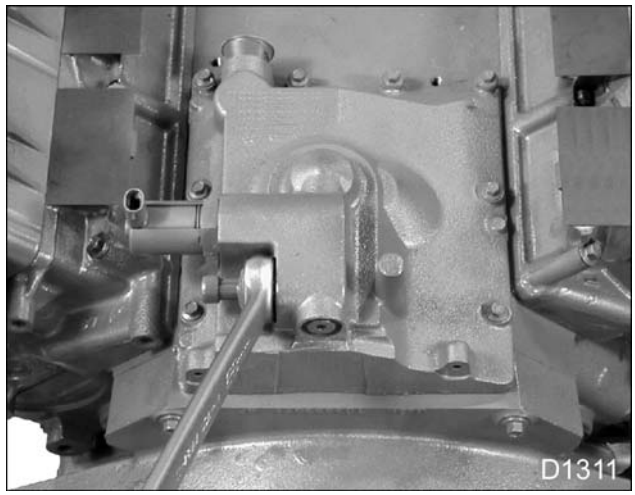

Figure 424 Removing ICP sensor

2. If requiring service, remove ICP sensor from hydraulic pump cover.

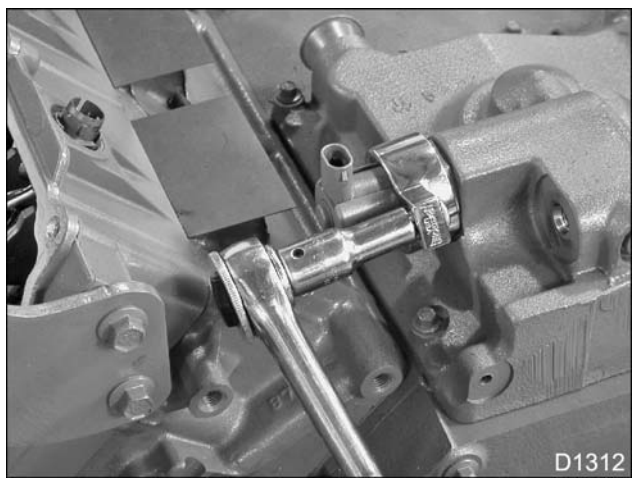

Figure 425 Removing IPR valve

3. If requiring service, remove IPR valve from hydraulic pump cover.

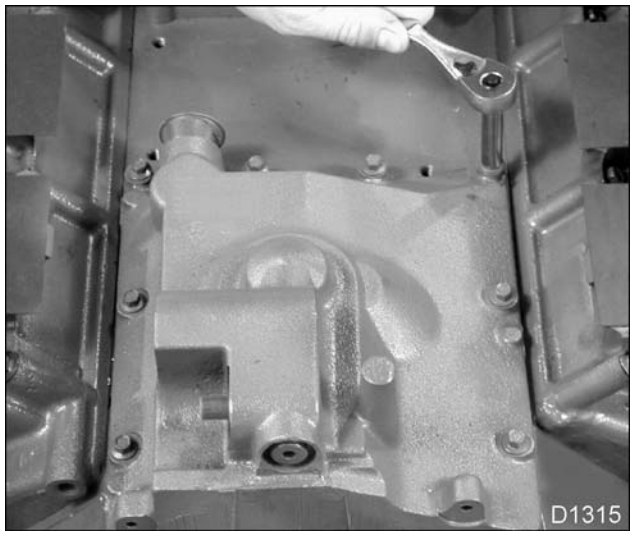

Figure 426 Removing the hydraulic pump cover

4. Remove eight cover bolts from hydraulic pump cover.

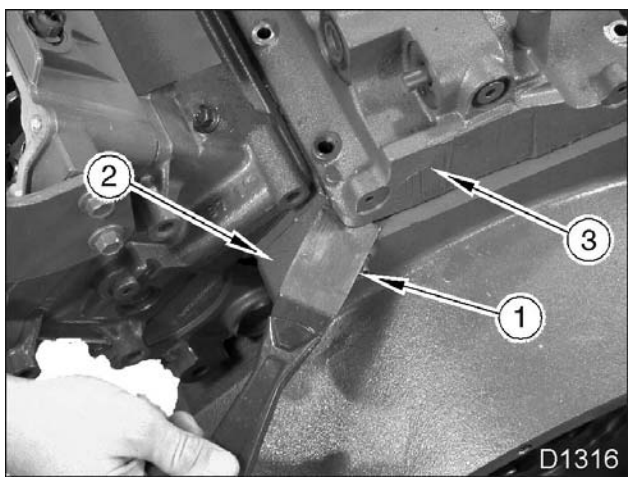

Figure 427 Separating hydraulic pump cover from rear cover

1. Gasket scraper
2. Rear cover
3. Hydraulic pump cover

5. Use a thin gasket scraper to separate sealant between crankcase/rear cover seam and hydraulic pump cover. Do this on both sides at the rear of the pump cover.

CAUTION: To prevent engine damage, do not pry hydraulic pump cover off of pump; damage to pump could occur.

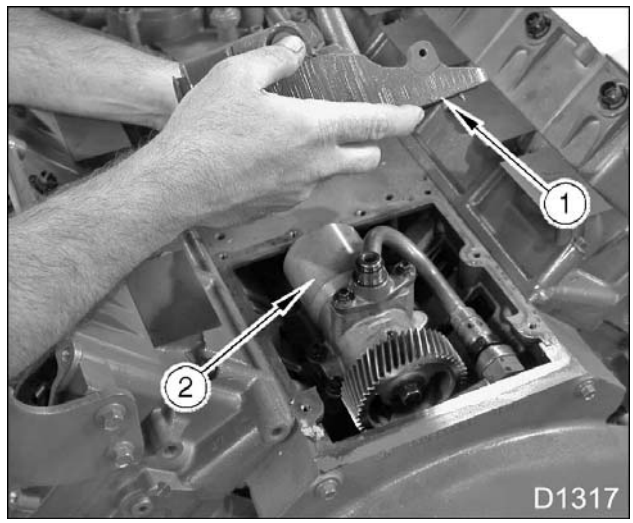

Figure 428 Removing hydraulic pump cover

1. Hydraulic pump cover
2. Hydraulic pump assembly

6. Only after breaking sealant, lift hydraulic pump cover straight up and off hydraulic pump assembly.

Hydraulic Pump Assembly

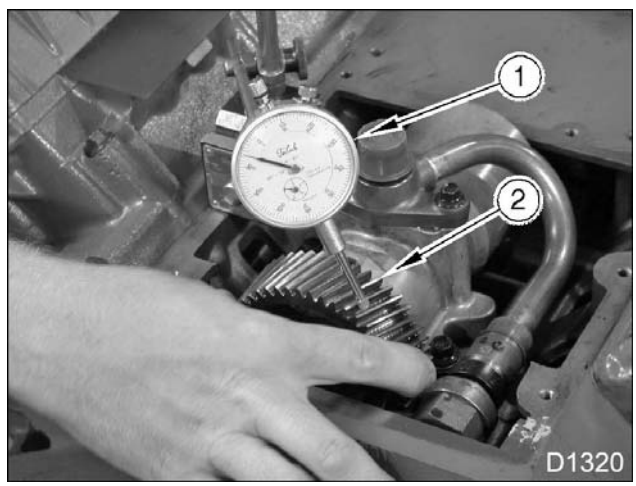

Figure 429 Determining gear backlash

1. Dial Indicator with Magnetic Base
2. Hydraulic oil pump drive gear

1. Determine gear backlash of hydraulic oil pump as follows:
   a. Mount Dial Indicator with Magnetic Base (Table 32).
   b. Place measuring tip of dial indicator on tooth of pump gear.
   c. Turn pump gear by hand until it stops. Zero the dial indicator.
   d. Turn pump gear in opposite direction and record dial indicator reading.
2. Remove D-ring from the top of the high-pressure discharge tube and discard.

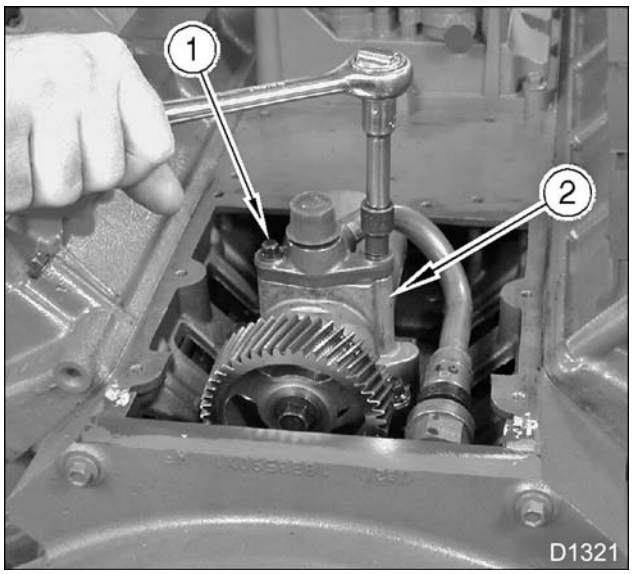

Figure 430 Removing bolts from high-pressure discharge tube

1. High-pressure oil discharge tube mounting bolts
2. Hydraulic oil pump assembly

3. Remove two mounting bolts from high-pressure discharge tube.

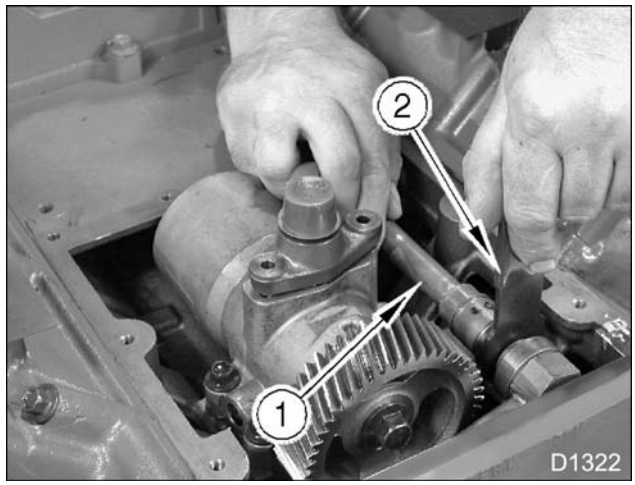

Figure 431 Removing high-pressure discharge tube

1. High-pressure discharge tube
2. #10 Quick Release Tool

4. Use a #10 Quick Release Tool (Table 32) to disconnect fitting from high-pressure discharge tube.

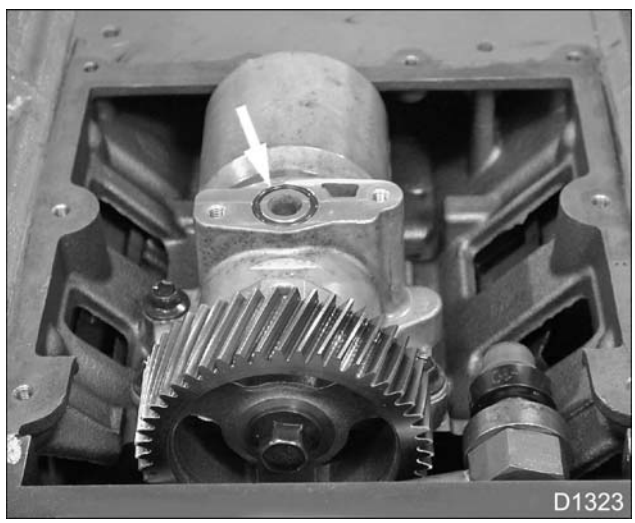

Figure 432 High-pressure discharge tube O-ring

5. Remove high-pressure discharge tube and discard O-ring.

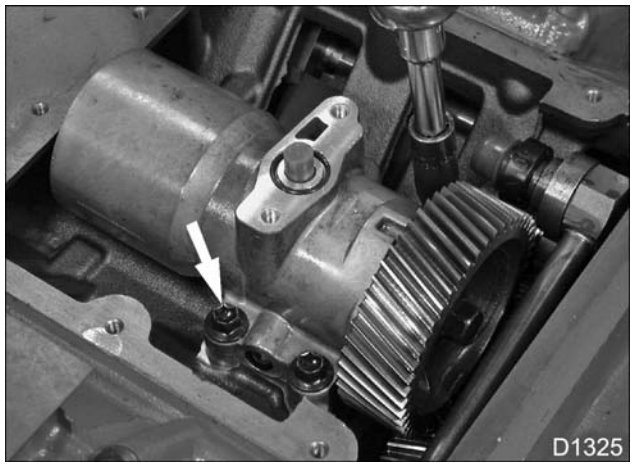

Figure 433 Mounting bolts for hydraulic oil pump

6. Remove three bolts that secure the hydraulic oil pump to crankcase. Lift pump out of the crankcase. Remove and discard O-ring.

NOTE: To remove the rear engine tube assembly, the rear cover and cylinder heads must be removed. See “Rear Cover, Flywheel, Power Steering Gear Drive and Cylinder Head and Valve Train” sections.

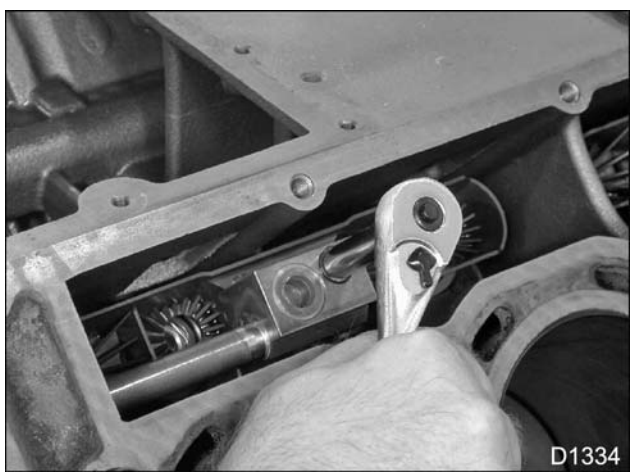

Figure 434 Mounting bolts for rear engine tube assembly (right side)

7. Remove mounting bolts (one on each side) from rear engine tube assembly.

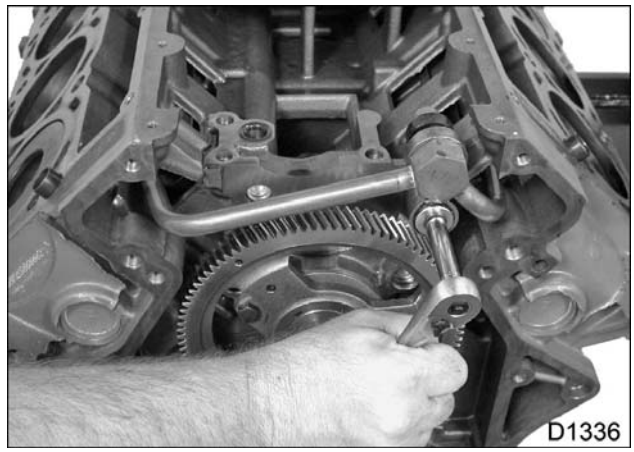

Figure 435 Mounting bolt for rear engine tube assembly

8. Remove rear mounting bolt from rear engine tube assembly.

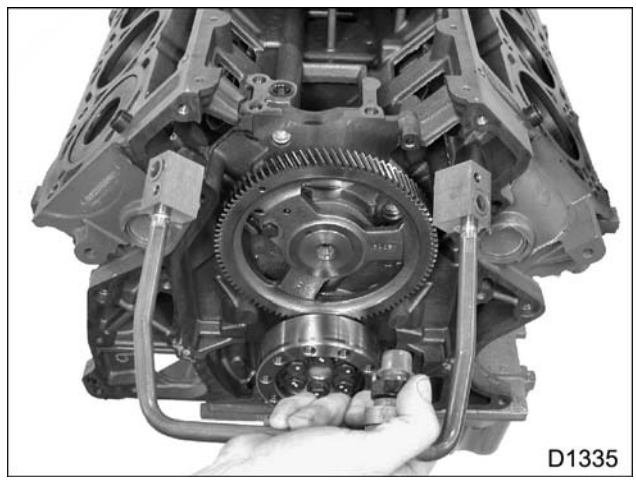

Figure 436 Rear engine tube assembly

9. Remove rear engine tube assembly.

Inspection

NOTE: The hydraulic oil pump and drive gear are serviced as a unit.

1. Inspect rear engine discharge tube assembly visually for evidence of misalignment and condition of brazed or welded joints.
2. Inspect grommet on rear engine tube assembly. If grommet is distorted in any way, discharge tube assembly may be misaligned. Replace if necessary.

Installation

Hydraulic Pump Assembly

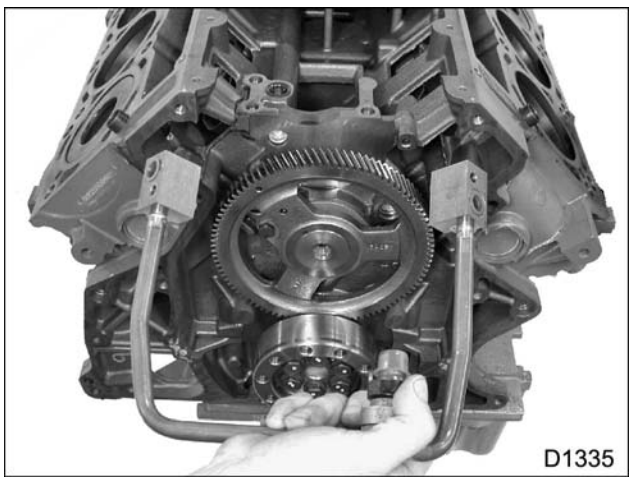

Figure 437 Rear engine tube assembly

1. Install the rear engine tube assembly.

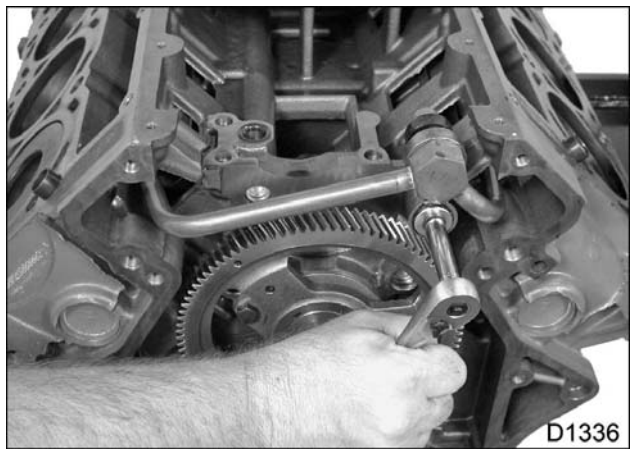

Figure 438 Rear engine tube assembly mounting bolt

2. Install rear mounting bolt into tube assembly. Hand tighten only at this point.

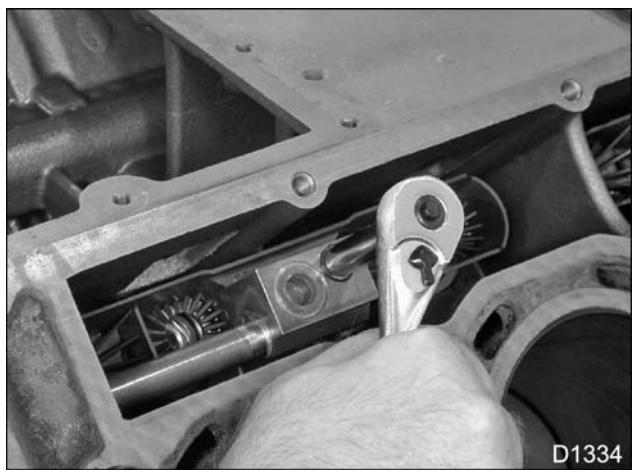

Figure 439 Mounting bolt for rear engine tube assembly (right side)

3. Install a M6 x 45 mounting bolt through the right side of the rear engine tube assembly, which mounts over the right rear roller follower guide. Hand tighten only at this point.
4. Install a M6 x 45 mounting bolt through the left side of the rear engine tube assembly, which mounts over the left rear roller follower guide (similar to the right side). Tighten all three tube assembly mounting bolts to the standard torque (General Torque Guidelines, page333).

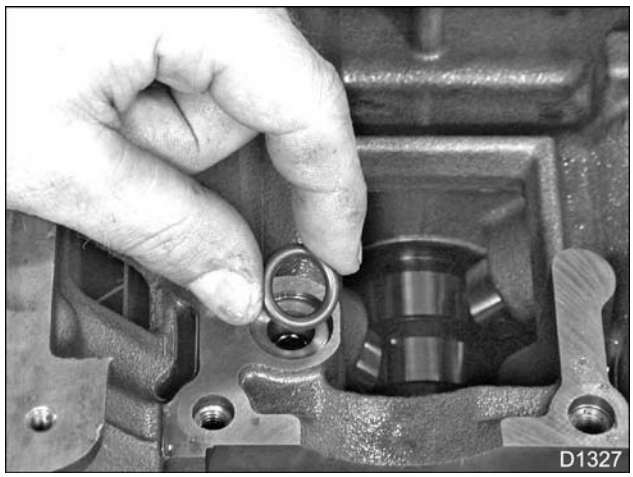

Figure 440 Hydraulic oil pump inlet O-ring

5. Place a new O-ring onto the hydraulic oil pump inlet recess.

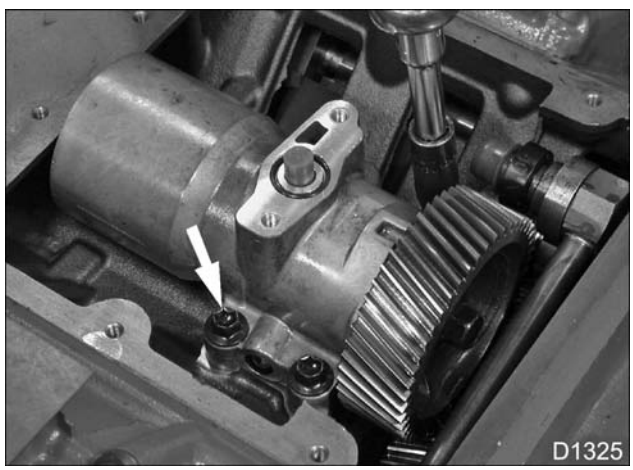

Figure 441 Hydraulic oil pump

6. Install three M8 x 35 bolts to secure the hydraulic oil pump to the crankcase. Tighten bolts to the standard torque (General Torque Guidelines, page 333).

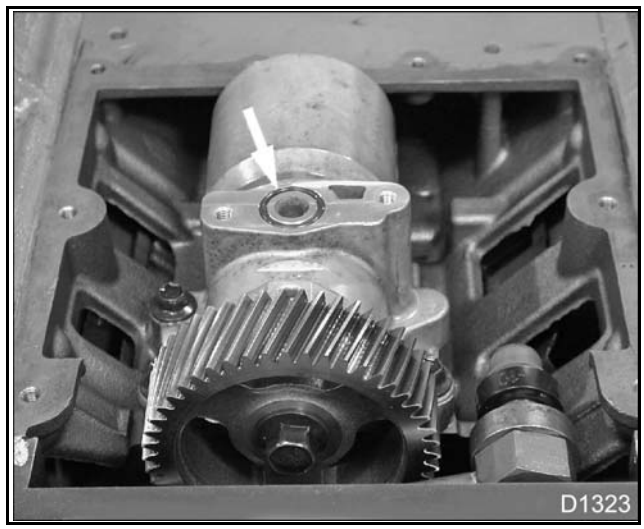

Figure 442 Hydraulic oil pump discharge port O-ring

7. Install new O-ring around the hydraulic oil pump discharge port.

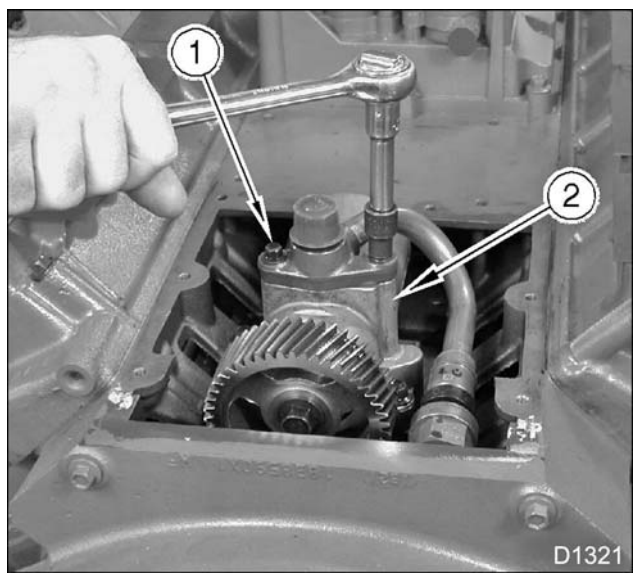

Figure 443 Installing high-pressure oil discharge tube

1. High-pressure discharge tube bolts
2. Hydraulic oil pump

8. Install the high-pressure oil discharge tube assembly and two mounting bolts (M6 x 25). Make sure that it snaps into place. Tighten bolts to the special torque (Table 31).

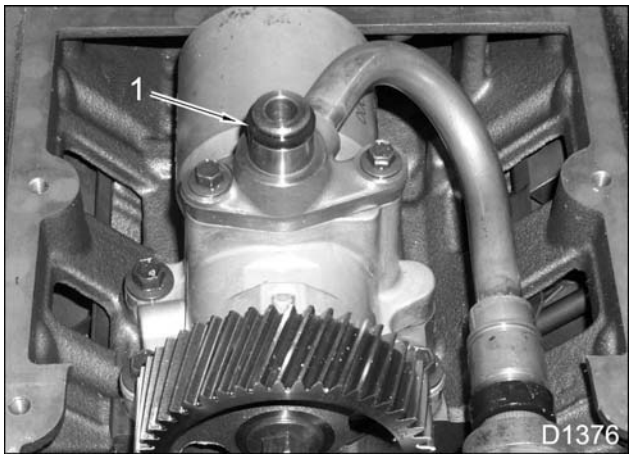

Figure 444 High-pressure discharge tube D-ring seal

1. High-pressure discharge tube D-ring seal

9. Place a new D-ring seal on top of the high-pressure discharge tube.
10. Check gear backlash of hydraulic oil pump gear.

Hydraulic Pump Cover

1. Place a new gasket into the hydraulic pump cover.
2. Clean any old sealant residue.

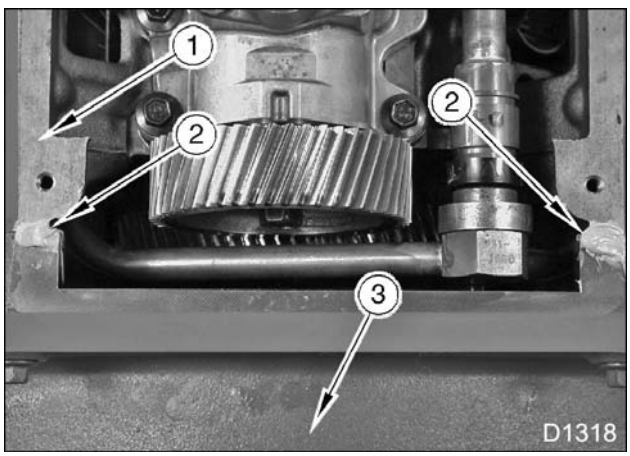

Figure 445 Sealant at rear cover and crankcase

1. Crankcase assembly
2. Liquid gasket
3. Rear cover assembly

3. Apply Liquid gasket (RTV) (Table 32) at two locations where rear cover and crankcase meet.
4. Lubricate D-ring seal on high-pressure discharge tube with clean engine oil.
5. Install the hydraulic pump cover by pressing evenly until discharge tube is seated within cover. Install eight M6 x 25 mounting bolts and tighten bolts to the special torque (Table 31).

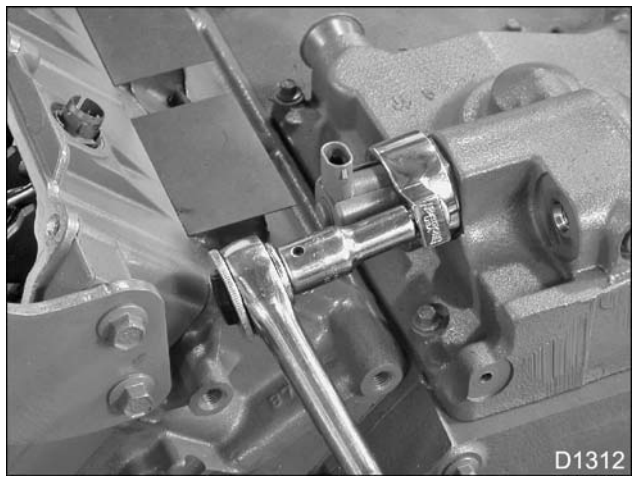

Figure 446 IPR valve

6. If removed, install IPR valve and tighten to the special torque (Table 31).

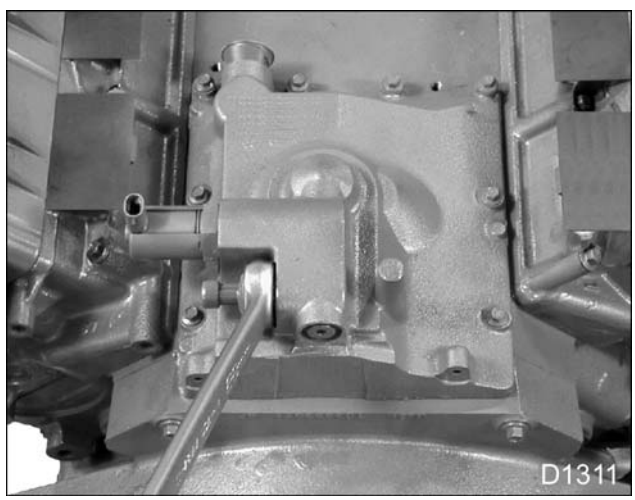

Figure 447 ICP sensor

7. If removed, install ICP sensor and tighten to the special torque (Table 31).

8. Install the three rear exhaust heat shield mounting bolts and tighten to the special torque (Table 31).

Specifications

Table 30

Hydraulic Oil Pump	
Gear backlash	0.179 - 0.315 mm (0.007 - 0.0124 in)
Injection Control Pressure Regulator	
Operating pressure range	3.5 - 20.7 MPa (500 - 3,000 psi)

Special Torque

Table 31

Hydraulic pump cover bolts	11 N·m (96 lbf·in)
Hydraulic oil pump drive gear bolt	129 ± 3 N·m (95 ± 2 lbf·ft)
HP discharge tube assembly bolts (M6 x 1.0 x 25)	11 N·m (96 lbf·in)
Injection Control Pressure (ICP) sensor	12 ± 2 N·m (108 ± 18 lbf·in)
Injection Pressure Regulator (IPR)	50 ± 5 N·m (37 ± 4 lbf·ft)
Rear heat shield, (M6 x 1.0 x 12)	11 ± 3 N·m (96 ± 24 lbf·in)
Rear heat shield, (M10 x 1.5 x 16)	49 ± 5 N·m (36 ± 4 lbf·ft)

Special Service Tools

Table 32

Tool Number	Description
ZTSE4557	Magnetic Cover
ZTSE4564	IPR Valve Removal Tool
ZTSE4581	Quick Release Tool
ZTSE4610	Cap Kit (All)
Obtain locally	Dial Indicator with Magnetic Base
1830858C1	Liquid gasket (RTV) (6 oz. tube)

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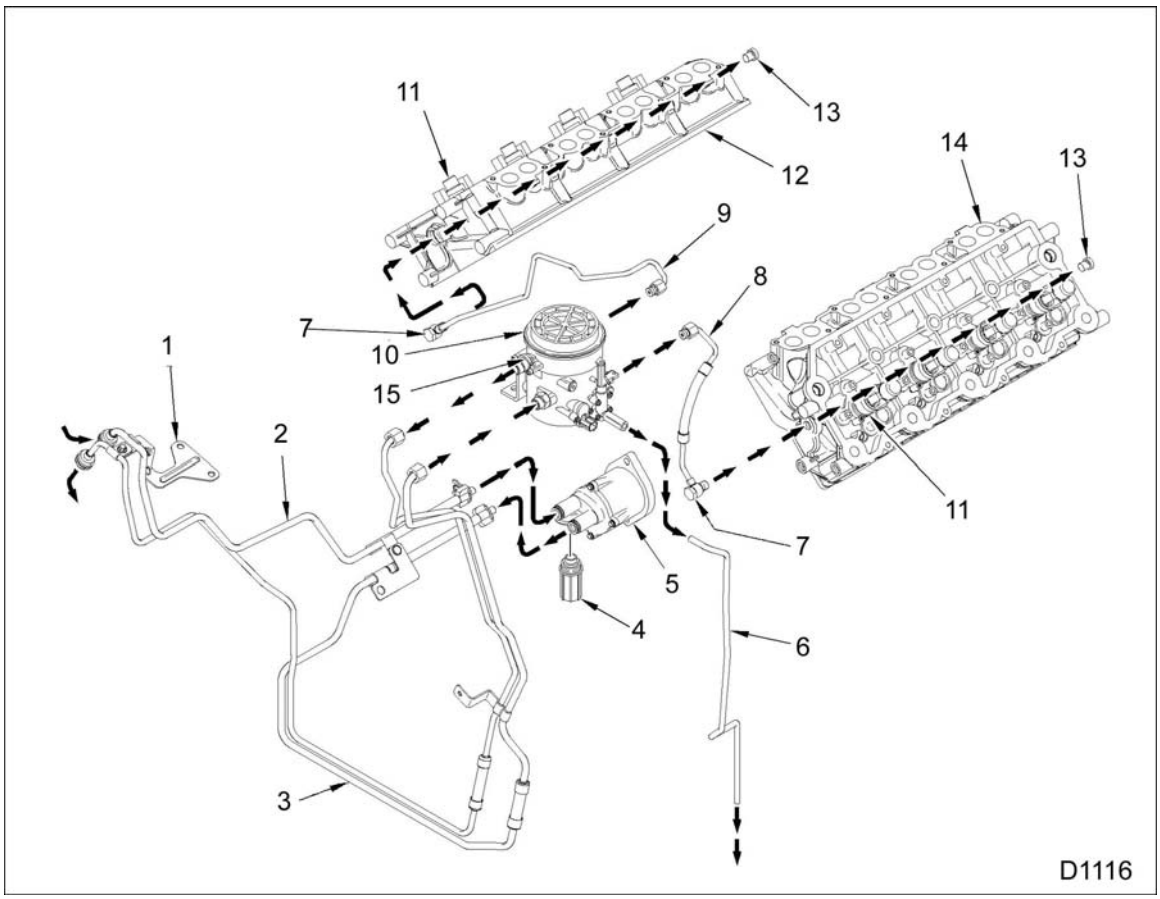

Figure 448 Fuel system components

1. Fuel tube mounting bracket
2. Fuel supply tube from tank
3. Fuel supply and return tube assembly
4. Filter strainer assembly
5. Fuel and power steering pump assembly (gear driven)
6. Fuel filter water drain tube assembly
7. 12 mm banjo bolt w/ check valves (2)
8. Fuel supply line, left cylinder head
9. Fuel supply line, right cylinder head
10. Fuel filter housing assembly
11. Fuel injector assembly (8)
12. Cylinder head, right side
13. Fuel rail plug assembly, (2)
14. Cylinder head, left side
15. Fuel filter regulator valve assembly

Fuel System Schematic

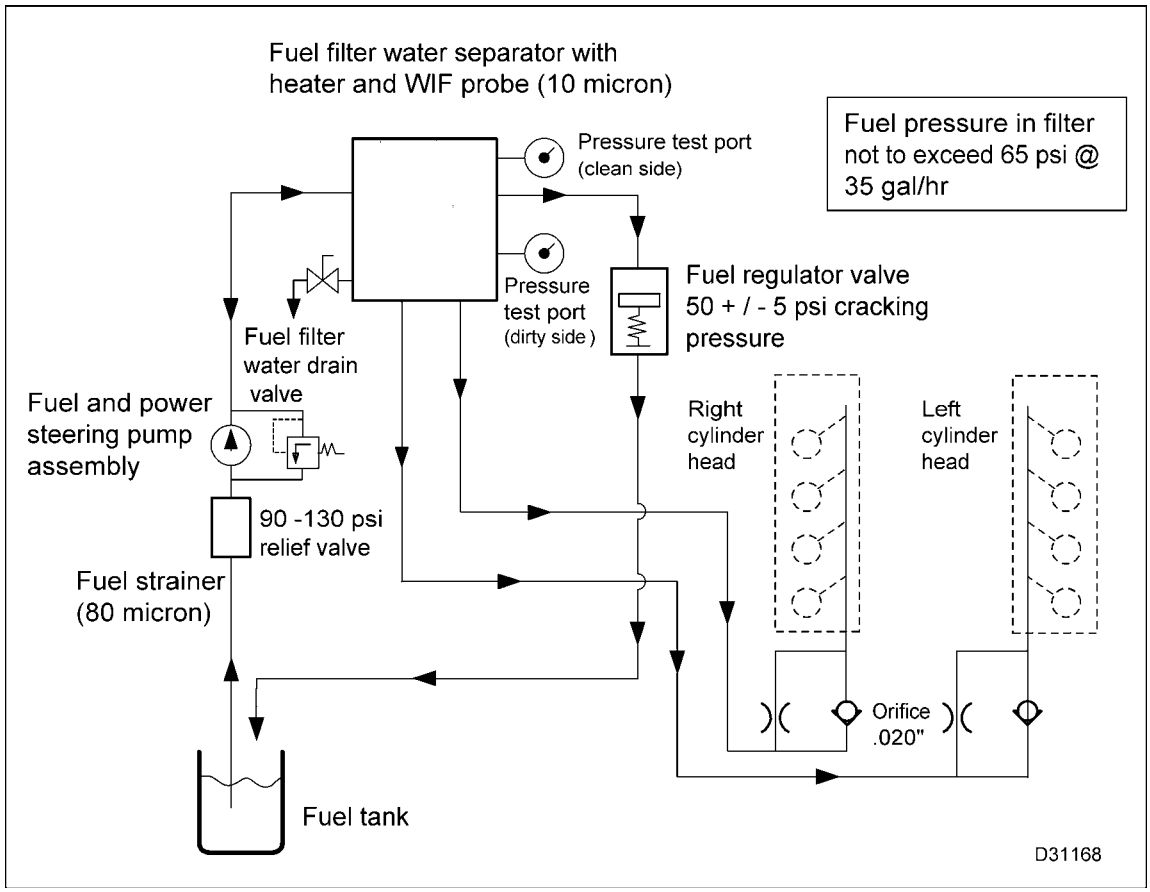

Figure 449 Fuel system schematic

Removal

Fuel Prescreen Element

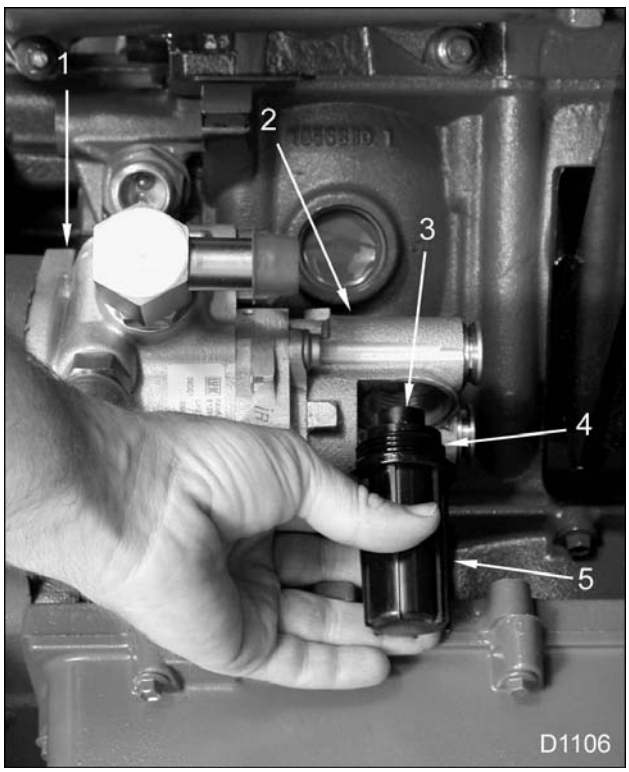

Figure 450 Removing prescreen element

1. Power steering pump
2. Fuel pump
3. Prescreen element
4. O-ring
5. Prescreen bowl

1. Use a 30 mm box end wrench to remove the prescreen bowl from the fuel pump assembly.
2. Clean prescreen element after inspection or replace if necessary.

Fuel Filter Element

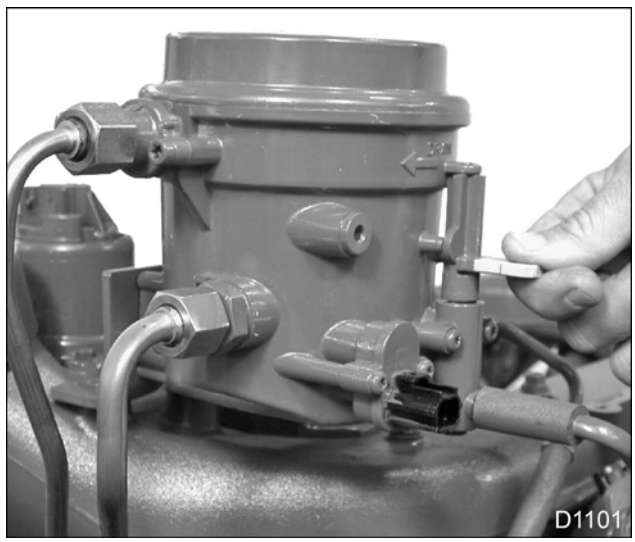

Figure 451 Fuel filter drain lever to DRAIN

1. Place a suitable container at end of fuel drain line to catch draining fuel. Move fuel filter drain lever to DRAIN.
2. Remove fuel filter element and cap assembly as follows:
   a. Remove fuel filter cap. Use an oil filter wrench if necessary.
   b. Remove and discard the bevel cut gasket and carefully clean mating surfaces.
   c. Lift fuel filter element out of housing.

Fuel Filter Assembly and Tubing

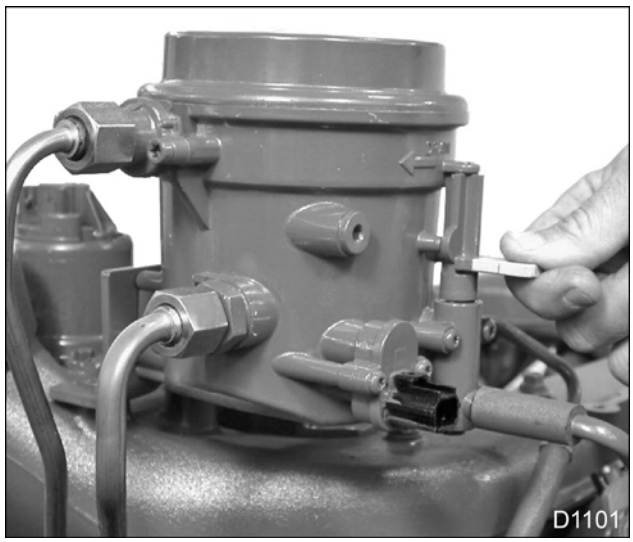

Figure 452 Fuel filter drain lever to DRAIN

1. Place a suitable container at end of fuel drain line to catch draining fuel. Move fuel filter drain lever to DRAIN. Close DRAIN lever when filter is empty.

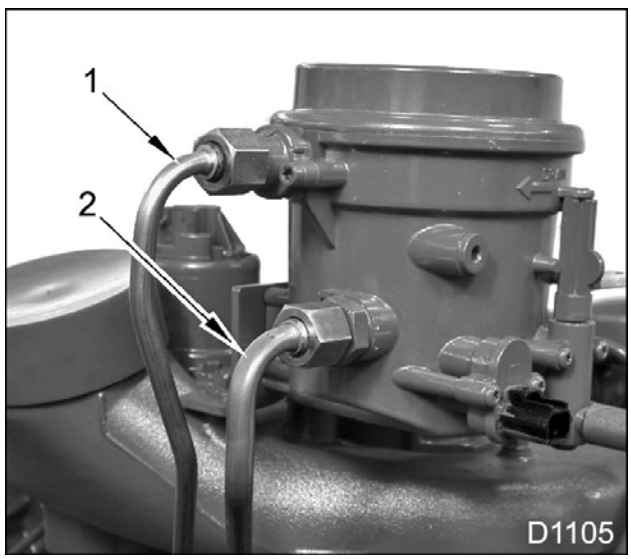

Figure 453 Fuel supply and return tubing

1. Fuel return tube
2. Fuel supply tube

2. Remove all tube connections attached to fuel filter assembly as follows:
   a. Remove chassis fuel supply tube.
   b. Remove chassis fuel return tube.
   c. Remove fuel filter water drain tubing (Figure 454).
   d. Remove left cylinder head fuel supply tubing from fuel filter assembly.

      NOTE: To remove the right cylinder head fuel supply tubing, it may be necessary to remove the oil filter cap assembly from the oil filter housing. This allows counterclockwise movement of the tube to be removed from the intake manifold.

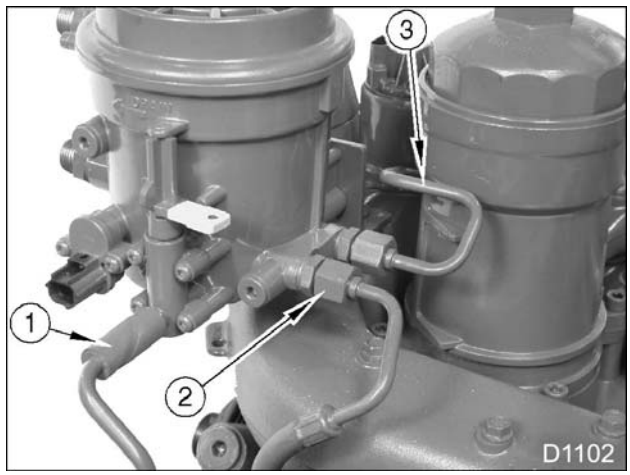

Figure 454 Fuel filter tubing, drain, and cylinder head supply

1. Water drain tube assembly
2. Filter to left cylinder head tube assembly
3. Filter to right cylinder head tube assembly

   e. Remove right cylinder head fuel supply tubing.
   f. Cap all openings to the fuel filter assembly.

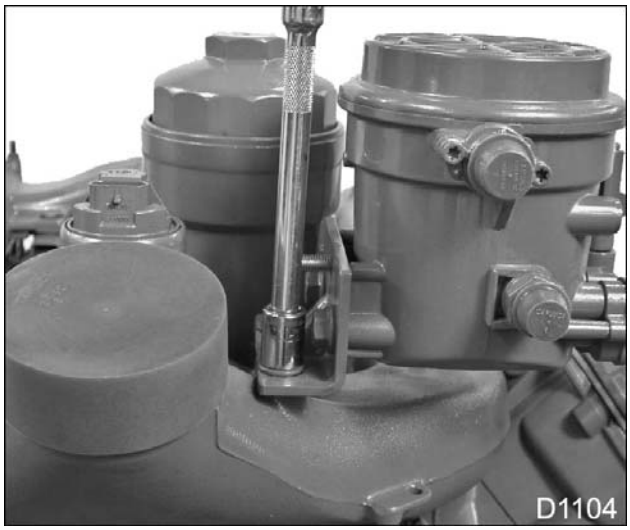

Figure 455 Removing fuel filter support bracket

3. Remove two M10 x 20 bolts that secure fuel filter support bracket to intake manifold.
4. Remove fuel filter assembly.

Fuel Injectors

NOTE: See “Cylinder Head and Valve Train” for fuel injector removal and installation.

Inspection

1. Inspect fuel lines for damage. Replace fuel lines if necessary.

Installation

Fuel Prescreen Element

1. Place a cleaned prescreen element into the bowl or obtain a new precleaner assembly.

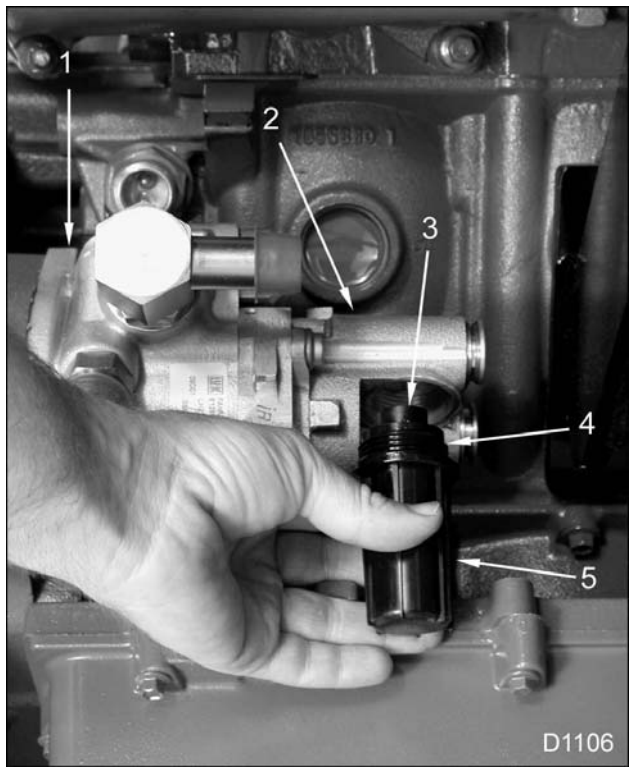

Figure 456 Installing the prescreen element and bowl

1. Power steering pump
2. Fuel pump
3. Prescreen element
4. O-ring
5. Prescreen bowl

2. Apply a coating of diesel fuel to a new strainer O-ring and prescreen bowl. Thread onto fuel transfer pump until hand tight and snug O-ring with and 30 mm box end wrench.

Fuel Filter Assembly and Tubing

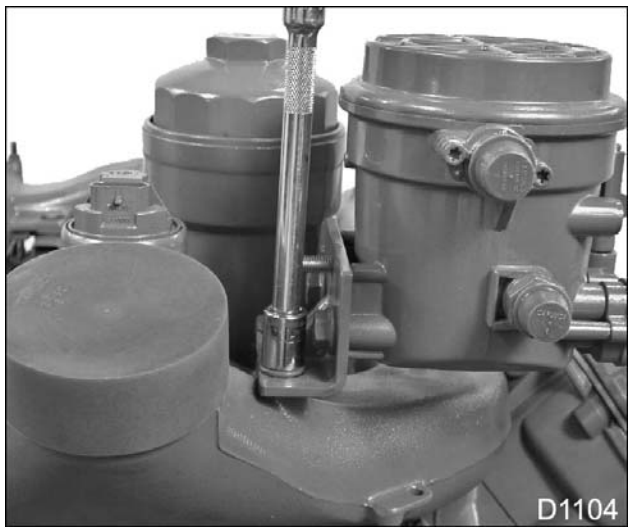

Figure 457 Installing fuel filter assembly

1. Install fuel filter assembly onto intake manifold. Secure assembly with two M10 x 20 mounting bolts. Tighten bolts to the standard torque (General Torque Guidelines, page333).
2. Connect filter water drain tubing.

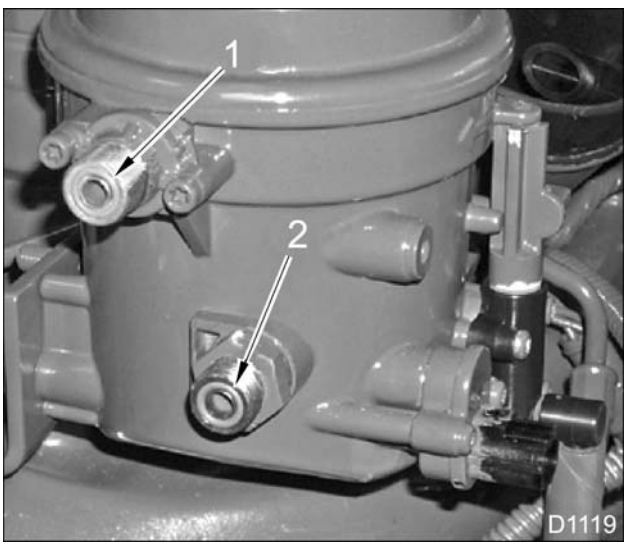

Figure 458 Fuel supply and return O-rings

1. Fuel return O-ring
2. Fuel supply O-ring

3. Replace all O-rings at fuel return and supply fittings. Replace all banjo fitting copper washers at cylinder heads.

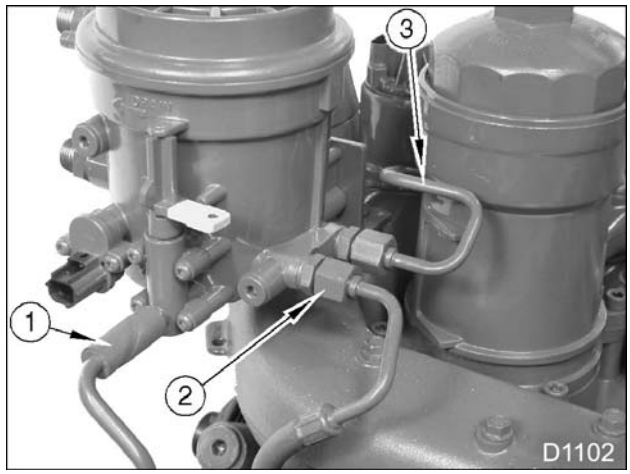

Figure 459 Filter drain and cylinder head fuel supply tubing

1. Water drain tube assembly
2. Filter to left cylinder head tube assembly
3. Filter to right cylinder head tube assembly

4. Connect fuel tubing fittings to fuel filter assembly and leave hand tight. Connect banjo fitting ends to the left and right cylinder heads. Anchor right side fuel tubing to EGR cooler stud. Tighten all fittings to the special torque (Table 34).

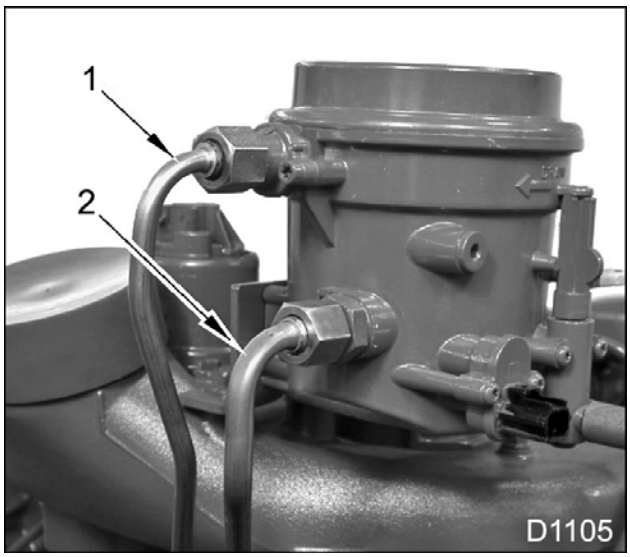

Figure 460 Connecting fuel supply and return tubing

1. Fuel return tube assembly
2. Fuel supply tube assembly

5. Connect chassis fuel supply and return tube assembly to fuel filter assembly and tighten fittings to the special torque (Table 34).

NOTE: Fuel filter drain lever must be closed.

Priming the Fuel System

Priming without Vacuum Source

NOTE: If the fuel system will not prime during diagnosis, the engine will exhibit white to black smoke and pulsating fuel pressure. See Combustion Leaks to Fuel in Section 4 of *Engine Diagnostics Manual* EGES-240.

If the engine is out of fuel, do the following steps:

1. Add fuel to tank. If equipped with dual tanks, add fuel to passenger side tank. Check fuel level in operator side tank to verify transfer pump is operating correctly.

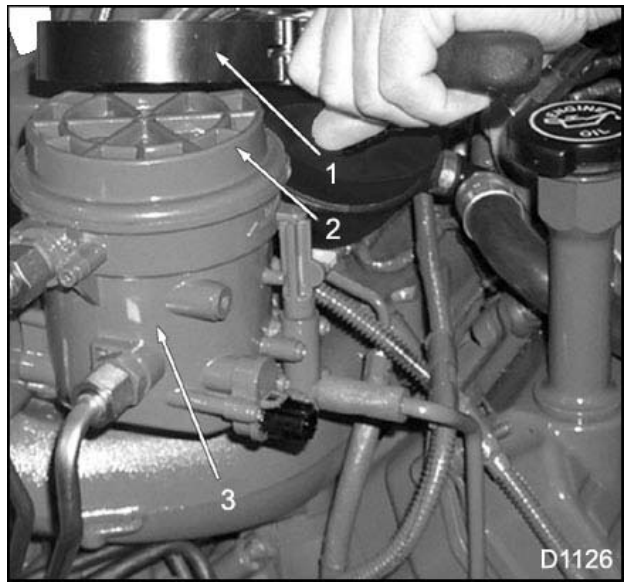

Figure 461 Removing fuel filter cap

1. Band wrench
2. Fuel filter cap
3. Fuel filter assembly

2. Remove fuel filter cap using a band wrench. Leave filter in housing.
3. Fill fuel filter housing with diesel fuel up to the filter cap threads.
4. Replace fuel filter cap and tighten.
5. Engage starter for 30 seconds and allow starter to cool for 2 minutes.

   NOTE: Return ignition key to RUN only between starts to decrease load on batteries. This will prevent glow plugs from recycling.

   CAUTION: To prevent damage to the starter, if engine fails to start within 30 seconds, release ignition switch and wait 2–3 minutes to allow starter motor to cool. Repeat above procedure.
6. Repeat step 5 until engine starts and runs on its own.

   - 3 to 5 cranking periods will be required to start vehicle. Additional cranking periods may be required if fuel filter is not primed.

NOTE: Engines in bus applications require more cranking time, since the rear tank is farther from the engine.

Priming with Vacuum Source

NOTE: If the fuel system will not prime during diagnosis, the engine will exhibit white to black smoke and pulsating fuel pressure. See Combustion Leaks to Fuel in Section 4 of *Engine Diagnostics Manual* EGES-240.

1. Add fuel to tank. If equipped with dual tanks, add fuel to passenger side tank. Check fuel level in operator side tank to verify transfer pump is operating correctly.

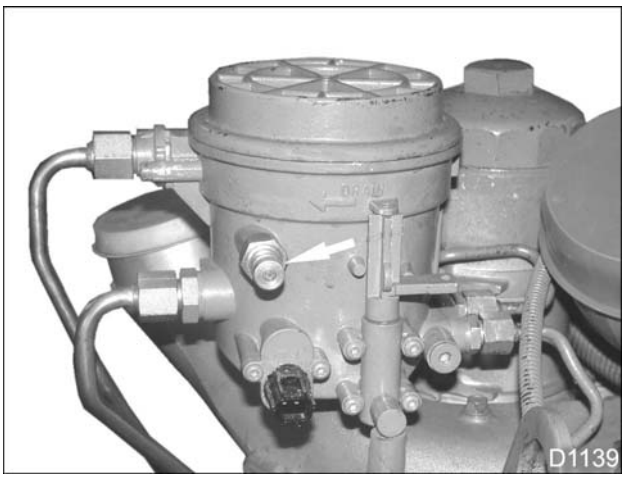

Figure 462 Unfiltered fuel pressure test port

2. Install fuel pressure test fitting in unfiltered fuel test port.
3. Attach vacuum source to fuel/oil pressure test coupling and connect to fuel pressure test fitting.
4. Draw fuel from tank using vacuum source until level in fuel filter housing reaches fitting.
5. Disconnect vacuum source and fuel/oil pressure test coupler from fuel pressure test fitting.
6. Engage starter for 30 seconds and allow starter to cool for 2 minutes.

   NOTE: Return ignition key to RUN only between starts to decrease load on batteries. This will prevent glow plugs from recycling.

   CAUTION: To avoid damage to the starter, if engine fails to start within 30 seconds, release ignition switch and wait 2–3 minutes to allow starter motor to cool. Repeat above procedure.
7. Repeat step 5 until engine starts and runs on its own.
   - 2 to 4 cranking periods will be required to start vehicle. Additional cranking periods may be required if fuel filter is not primed.
8. After engine has been started and is running smoothly, stop engine and remove fuel pressure test fitting and reinstall plug in filter housing.

Fuel Filter Element

NOTE: If the fuel system has been completely drained, prime the fuel system to aid starting. Fill the filter housing with clean diesel fuel up to the filter cap threads, before installing the cap. Priming is not necessary, if only the filter housing was drained for regular filter replacement.

1. Apply coating of diesel fuel to new bevel gasket and install onto fuel filter assembly.
2. Install new fuel filter element into fuel filter housing and tighten cap onto fuel filter assembly.

CAUTION: To prevent engine damage, tighten fuel cap on fuel filter assembly. The engine will not run, if the fuel filter element is not installed. The fuel filter element is required to open the valve in the center stand pipe, allowing fuel to flow into the filter.

3. Move fuel filter drain lever to close.

Fuel Injectors

NOTE: See the “Cylinder Head and Valve Train” section for installation procedures.

Specifications

Table 33

Fuel Filter	
Type	10 micron with water separation
Normal fuel pressure (after fuel filter)	345 - 482 kPa (50 - 70 psi)
Fuel Pressure Regulating Valve	
Valve opening pressure	351 ± 31 kPa (51 ± 5 psi)
Heater element activates	3.6 - 10.8 ºC (38.5 - 51.5 ºF)
Heater element deactivates	19.1 - 29.6 ºC (66.5 - 83.5 ºF)

Special Torque

Table 34

Fuel supply tube assembly at filter	41 ± 4 N·m (30 ± 3 lbf·ft)
Fuel return tube assembly at filter	25 ± 2 N·m (19 ± 2 lbf·ft)
Left and right cylinder head supply tubing at filter	25 ± 2 N·m (18 ± 2 lbf·ft)
Banjo bolt, 12 mm	38 ± 4 N·m (28 ± 3 lbf·ft)
Plug assembly, 12 mm (back of cylinder head)	27 ± 1 N·m (20 ± 1 lbf·ft)

Special Service Tools

Table 35

Tool Number	Description
ZTSE4541	Fuel Gallery Cleaning Brush
ZTSE4610	Cap Kit (All)

Table of Contents

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.

Flexplate

Inspect flexplate for evidence of cracking around webbing and ring gear weldments.

Inspect all ring gear teeth for evidence of starter pinion damage. Replace flexplate if necessary.

Flywheel and Rear Cover

Inspect for cracking around webbing and bolt holes. Inspect flywheel for cracks, heat checks, and extensive scoring. These conditions would make it unfit for further service. Replace as required.

Checking Flywheel Surface Runout

CAUTION: To prevent engine damage, check runout of flywheel surface to ensure correct alignment of engine to transmission. Failure to ensure correct bore concentricity and face runout may reduce life of clutch or transmission.

1. Check for ring gear damage associated with the starter pinion.

NOTE: Keep the crankshaft end play at zero in the same direction for all measurements.

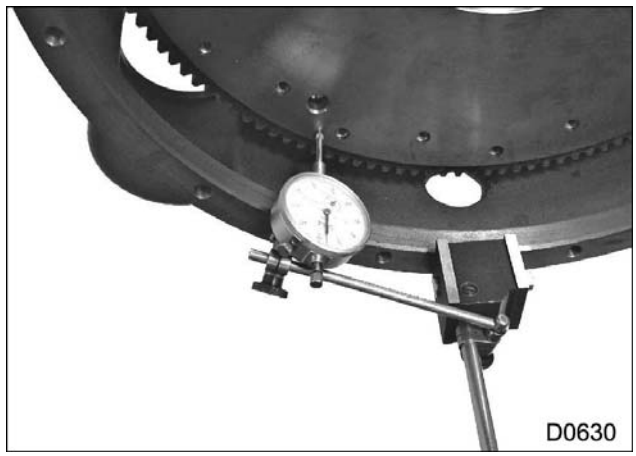

Figure 463 Flywheel surface runout

2. Check flywheel surface runout as follows:
   a. Attach Dial Indicator with Magnetic Base (Table 38) to rear cover. Place indicator tip against surface of flywheel.
   b. Zero the dial indicator.
   c. Rotate crankshaft slowly. Record total indicator variation (Table 36).

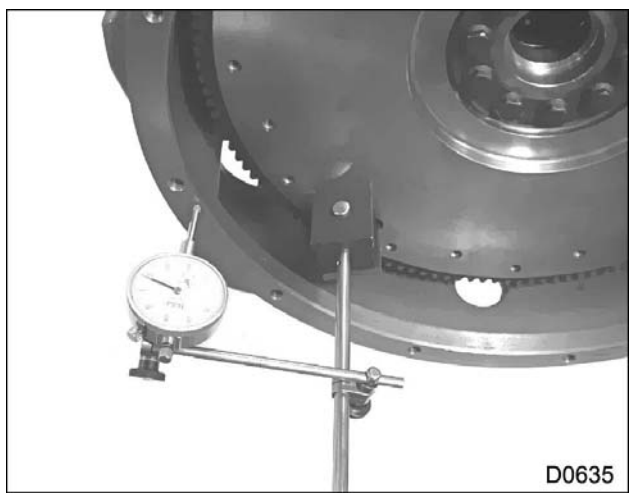

Figure 464 Rear cover runout

3. Check rear cover face runout as follows:

   NOTE: Keep the crankshaft end play at zero in the same direction for all measurements.

a. Attach Dial Indicator with Magnetic Base (Table 38) to surface of flywheel. Place indicator tip against rear cover.

b. Zero the dial indicator.

c. Measure at four points 90° apart for total face variation (Table 36).

Secondary Flange and Power Steering Idler Gear

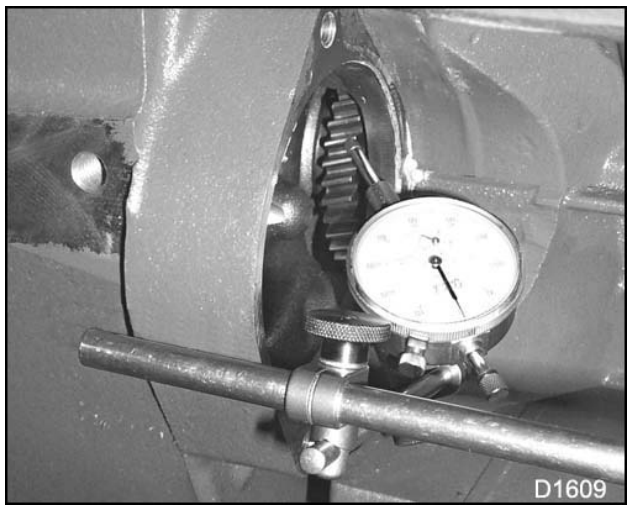

Figure 465 Idler gear backlash

Check backlash between power steering idler gear and secondary flange. (Power Steering and Fuel Pump Assembly, page274) for removal instructions.

Flexplate (Automatic Transmission)

Figure 466 Flexplate hardware

1. Flexplate bolts (10)
2. Reinforcement ring
3. Flexplate adapter hub
4. Transmission side stamp (XMSN-SIDE)

Remove ten M10 x 77 mounting bolts, reinforcement ring, flexplate and the adapter hub. Discard the ten mounting bolts as they are not reusable.

Flywheel (Manual Transmission)

Figure 467 Flywheel guides

1. Remove two M10 x 77 flywheel mounting bolts at approximately the 3 o'clock and 9 o'clock positions. Install two guide pins (make locally).
2. Remove remaining eight flywheel mounting bolts and reinforcement ring. Discard all ten mounting bolts as they are not reusable.

Figure 468 Flywheel guide pins

3. Slide flywheel out of housing and off guide pins. With flywheel removed, guide pins can be removed from secondary flange.

Rear Main Seal and Wear Sleeve

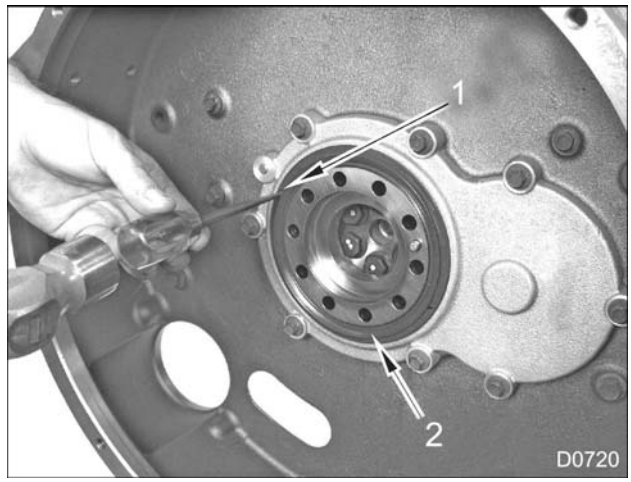

Figure 469 Starter holes

1. Starter hole
2. Rear main seal

1. Use an awl or 1/8 inch drill bit to make two small starter holes 180° apart into rear main seal.

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

Figure 470 Hammer screw in starter hole

2. Thread slide hammer screw into one of the starter holes. To remove seal evenly, slide hammer on one side, then alternate to other side.

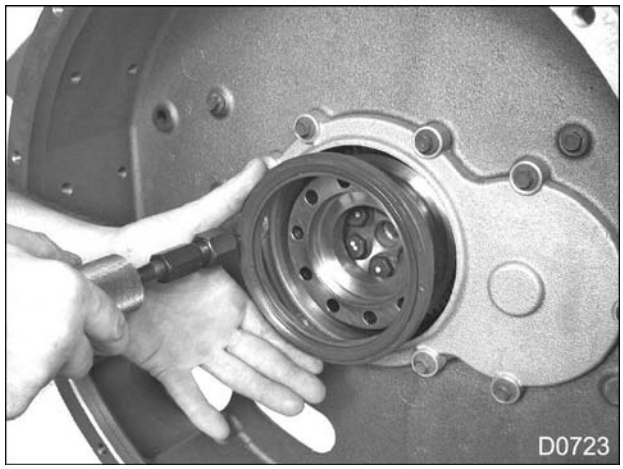

Figure 471 Rear main oil seal removal

3. Remove rear oil seal from rear oil seal carrier. Discard oil seal.

NOTE: When replacing the rear main seal, note that production engines will not have a wear sleeve. Wear sleeves are only available as a service item included with the replacement rear main oil seal.

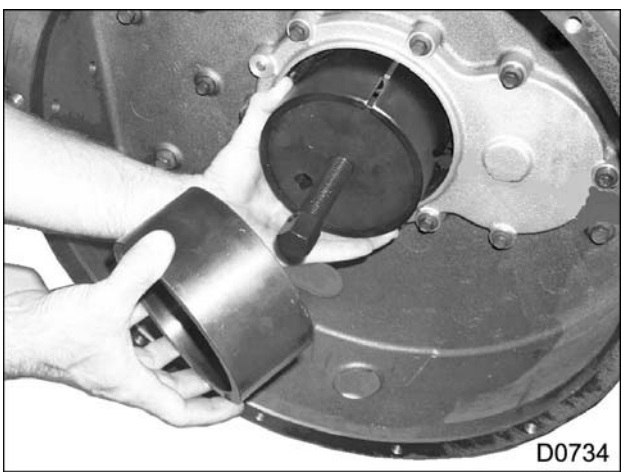

Figure 472 Rear Wear Sleeve Removal Tool

4. Install Rear Wear Sleeve Removal Tool (Table 38). Make sure remover tool half shells are securely in place behind wear sleeve prior to applying any force to threaded shaft.

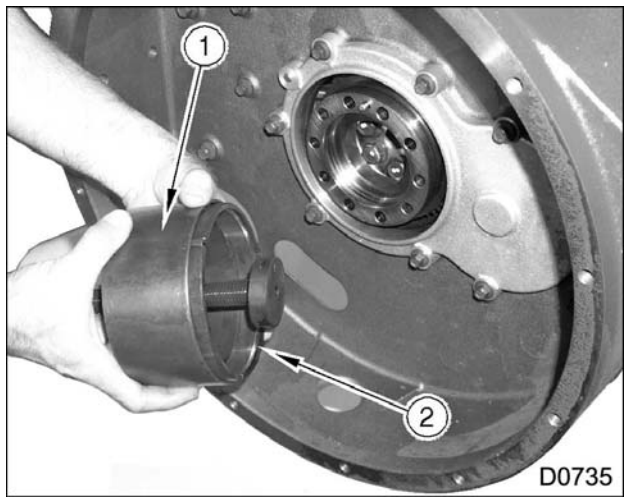

Figure 473 Wear sleeve

1. Wear sleeve removal tool
2. Wear sleeve

5. Turn the threaded shaft clockwise until the wear sleeve is free from the crankshaft flange.

Secondary Flange

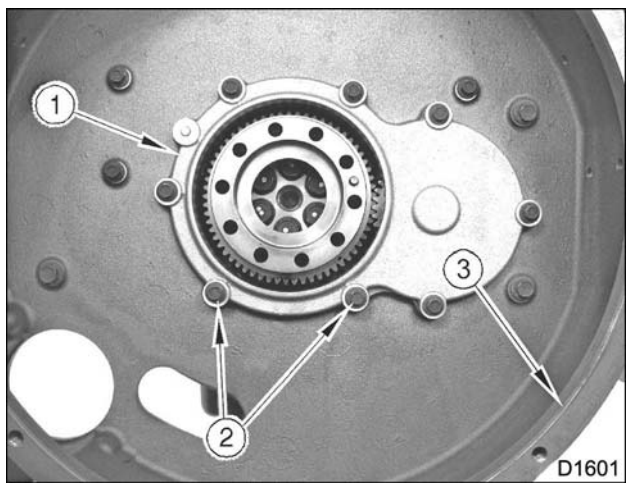

Figure 474 Rear cover and rear oil seal carrier

1. Rear oil seal carrier
2. Long bolts
3. Rear cover

1. Remove eight M8 bolts that secure the rear oil seal carrier to rear cover.

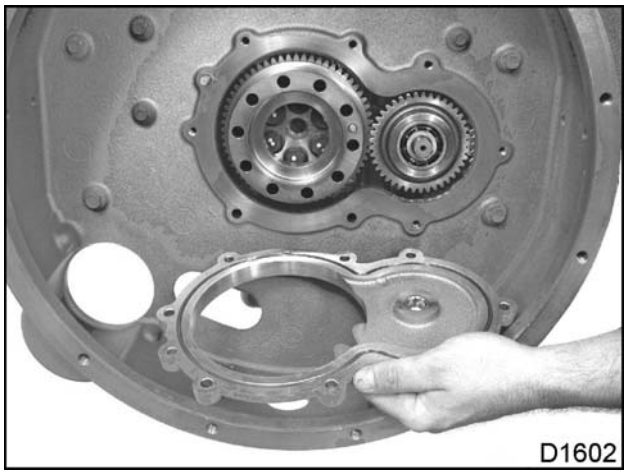

Figure 475 Rear oil seal carrier

2. Remove rear oil seal carrier and discard gasket.

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

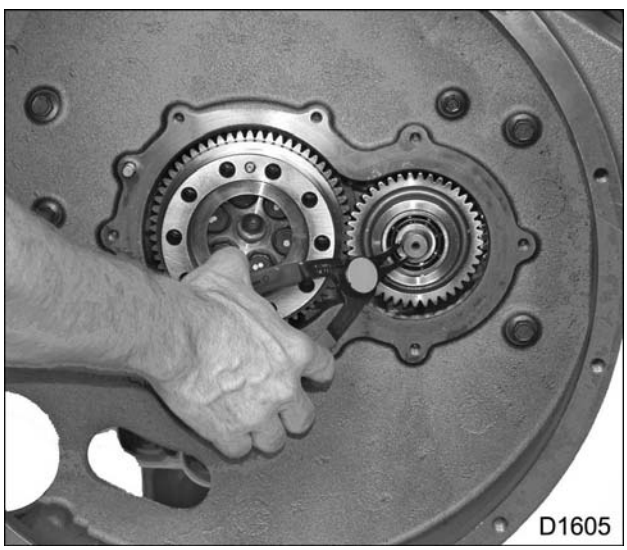

Figure 476 Snap ring on power steering idler gear

3. Remove snap ring from power steering idler gear.

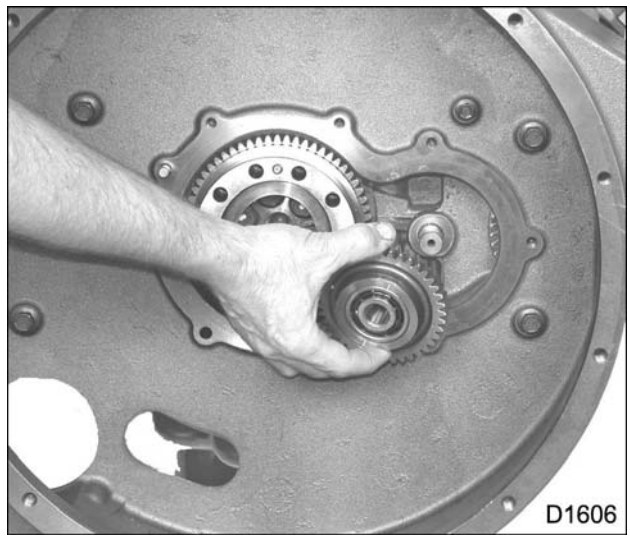

Figure 477 Power steering idler gear

4. Remove power steering idler gear.

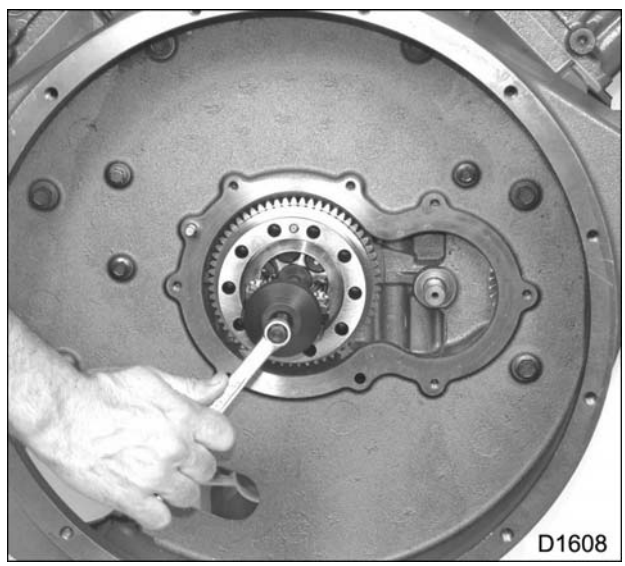

Figure 478 Secondary flange

5. Use a gear puller to remove the secondary flange.

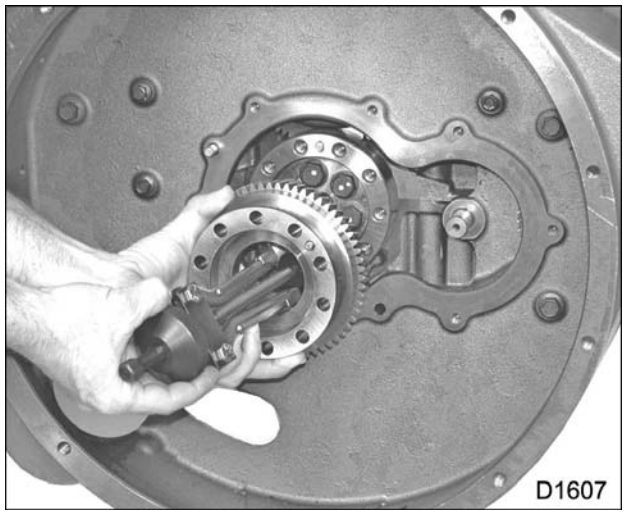

Figure 479 Gear puller

Power Steering and Fuel Pump Assembly

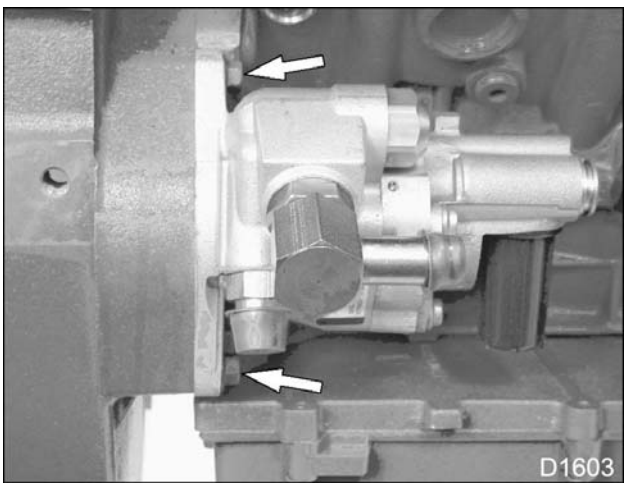

Figure 480 Mounting bolts for power steering and fuel pump assembly

1. Remove two M10 x 30 mounting bolts that secure power steering and fuel pump assembly to rear cover.

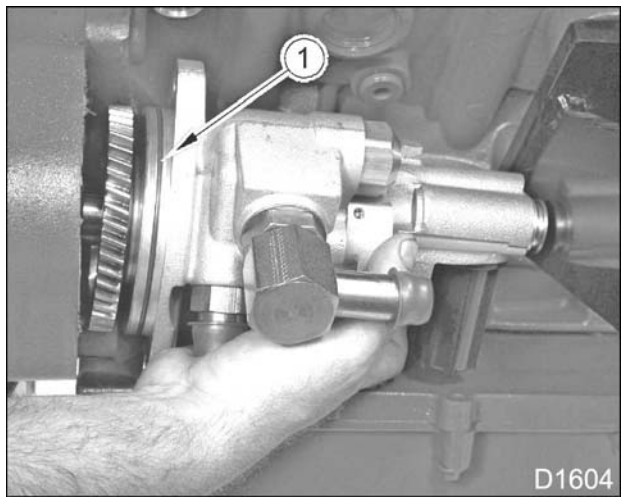

Figure 481 Power steering and fuel pump assembly

1. O-ring

2. Remove power steering and fuel pump assembly from rear cover and discard O-ring.

NOTE: The power steering and fuel pump assembly is serviced only as a single unit.

Rear Cover and Power Steering Idler Shaft

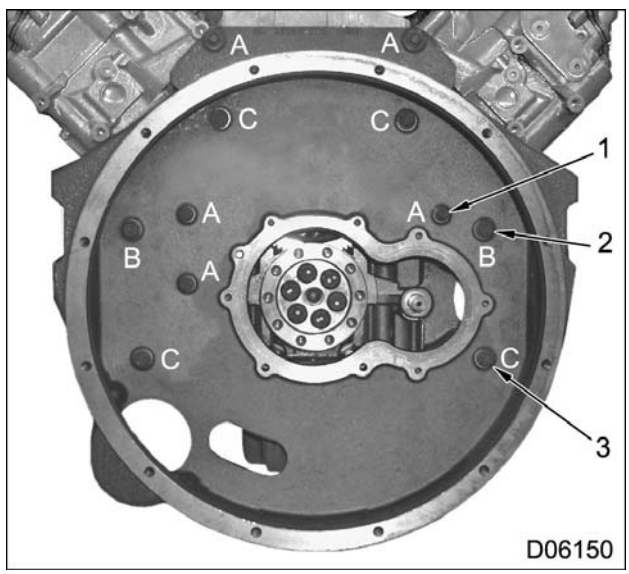

Figure 482 Rear cover mounting bolts

1. Bolts marked A, (M10 x 55) (5)
2. Bolts marked B, (M10 x 70) (2)
3. Bolts marked C, (M10 x 60) (4)

1. Remove bolts from rear cover.

WARNING: To prevent personal injury or possible death, use a suitable lifting device or get help when removing the rear cover.

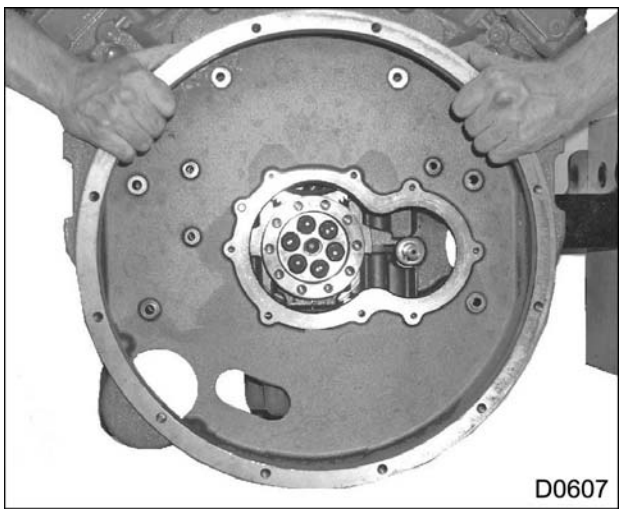

Figure 483 Rear cover assembly

2. Remove rear cover assembly with the aid of an assistant.

   NOTE: If the hydraulic pump cover is in place, make sure the hydraulic pump cover gasket does not pull out when removing the rear cover. Also avoid pulling out the gasket between the upper and lower crankcase.

NOTE: If required, the power steering idler shaft can be removed using a slide hammer.

Cleaning

All Components

1. Clean foreign material from gasket surfaces of crankcase and rear cover. Use a scraper or wire brush to remove sealant from gasket surfaces.
2. Gasket surfaces must oil free for good adhesion of liquid gasket during assembly. Use a commercially available, noncaustic brake cleaner to clean gasket surfaces of crankcase and rear cover.
3. Remove sealant under the hydraulic oil pump cover while it is still in place.

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).

4. Wash rear oil seal carrier, flywheel, flexplate, and rear cover. Dry all with filtered compressed air.
5. Wash secondary flange, power steering idler gear, and shaft with a stiff brush and suitable solvent. Dry all with filtered compressed air.

Installation

Rear Cover and Power Steering Idler Shaft

1. If removed, install the power steering idler shaft into the rear cover by making sure the idler shaft bore is clean.

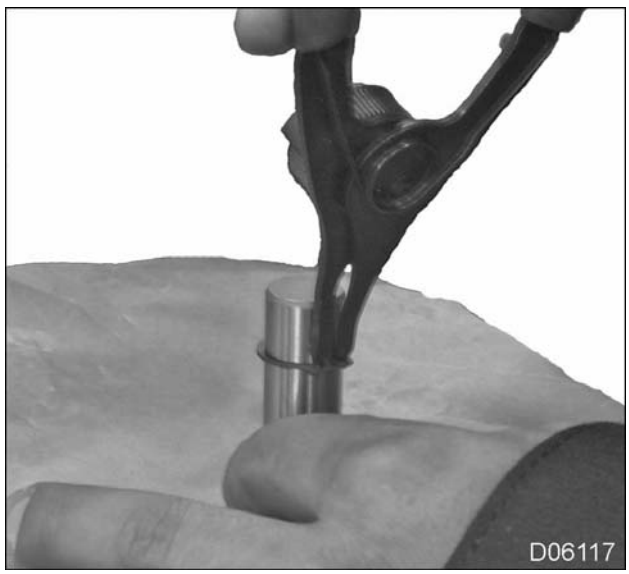

Figure 484 Install retaining ring on the idler shaft

2. Place a retaining ring on the end of the shaft that does not have the threaded hole.

Figure 485 Idler shaft and retaining ring in the Power Steering Idler Shaft Installation Tool

3. Place the idler shaft in the Power Steering Idler Shaft Installation Tool (Table 38). Place the end with the threaded hole in the tool first. This tool is designed to install the idler shaft in the rear cover at the proper height.

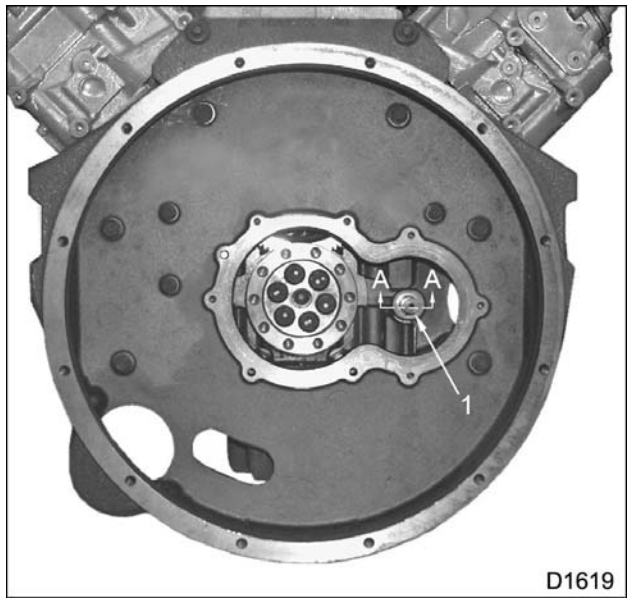

Figure 486 Power steering idler shaft in transmission side of rear cover

1. Power steering idler shaft

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

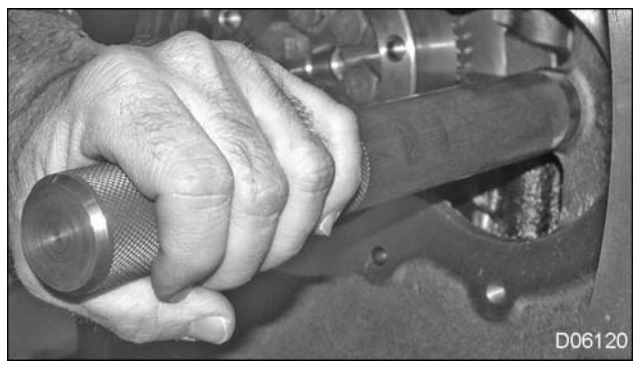

Figure 487 Idler shaft in the rear cover assembly

CAUTION: To prevent engine damage, do not allow the retaining ring to contact the rear cover. Contact may distort the retaining ring, adversely affecting its performance as a gear thrust surface.

4. Align the idler shaft in the rear cover at the proper location. Using the installation tool, drive the idler shaft in the idler shaft bore in the transmission side of the rear cover, until the installation tool bottoms out.

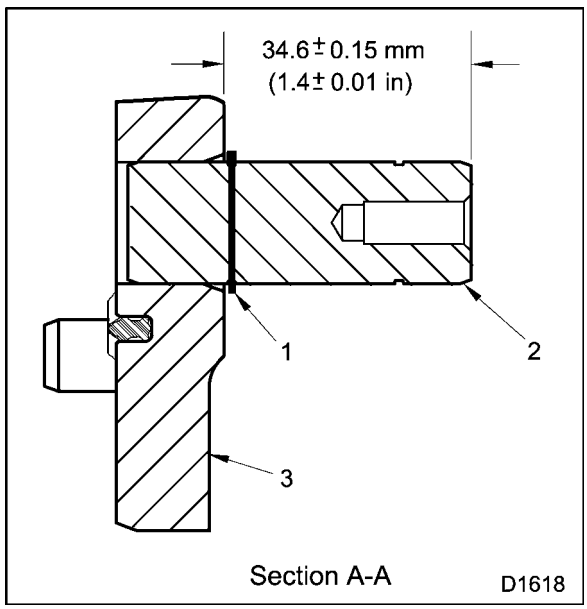

Figure 488 Installation height of power steering idler shaft

1. Retaining ring
2. Power steering idler shaft
3. Rear cover assembly

5. If installation tool is not available, use brass drift to install the idler shaft in the rear cover to the correct height.

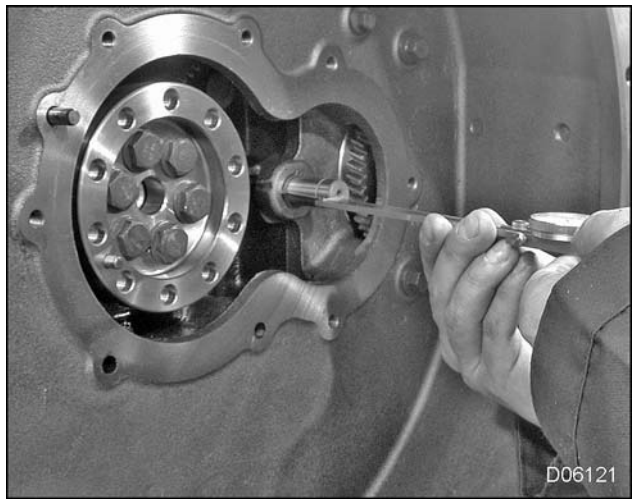

Figure 489 Verify idler shaft height

6. Verify idler shaft height, using a dial caliper. Idler shaft height should be 34.6 ± 0.15 mm (1.362 ± 0.006 in).

CAUTION: To prevent engine damage, install new dowel pins in crankcase if pins are damaged or missing.

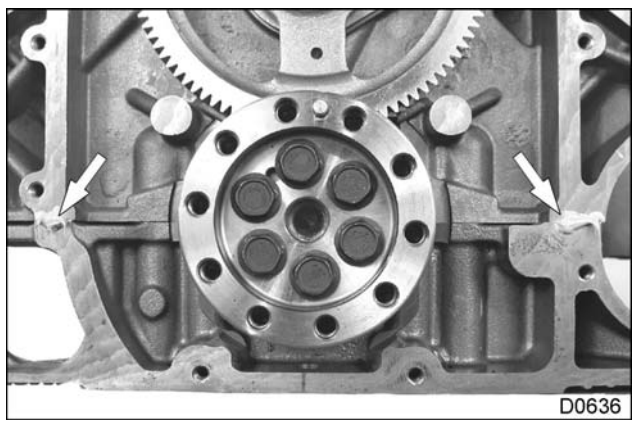

Figure 490 Application of Sealant

7. Apply Liquid Gasket (RTV) (Table 38) at the ends, where the crankcase and the lower crankcase meet. Apply liquid gasket to the hydraulic oil pump cover joint, if the cover was not removed.

⚠ WARNING: To prevent personal injury or death, use a suitable lifting device or get help to install the rear cover.

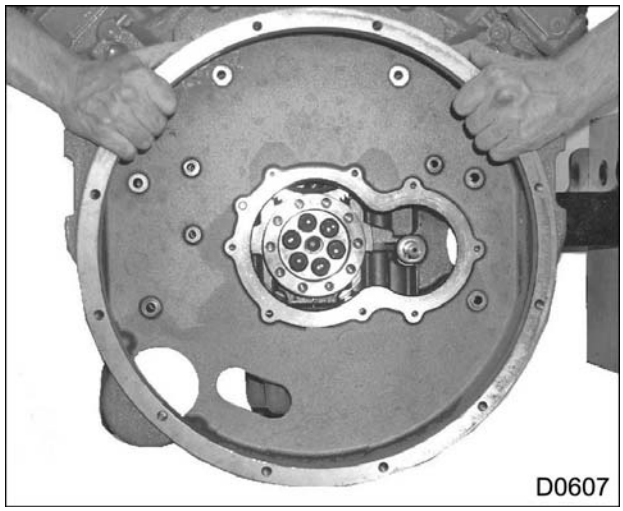

Figure 491 Rear cover assembly

8. Install rear cover assembly.

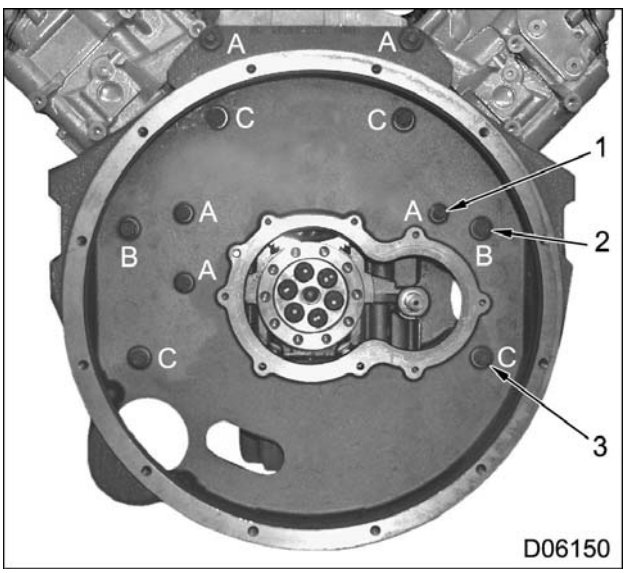

Figure 492 Rear cover mounting bolts

1. Bolts marked A, (M10 x 55) (5)
2. Bolts marked B, (M10 x 70) (2)
3. Bolts marked C, (M10 x 60) (4)

9. Install eleven mounting bolts into the rear cover. See illustration for size and location. Tighten all bolts to the standard torque (General Torque Guidelines, page333).

Secondary Flange

CAUTION: To prevent damage to the engine, transmission or truck, correct dowel pin protrusion is critical when aligning the flywheel or flexplate and the reinforcement ring.

Figure 493 Dowel pin in the secondary flange gear

1. Install the dowel pin in the secondary flange gear.
2. Verify the protrusion height using a dial caliper. Dowel pin protrusion height should be 8.0 ± 0.25 mm (0.315 ± 0.01 in).
3. Clean the inside surfaces and the inner face surface of the secondary flange gear.

CAUTION: To prevent damage to the engine or truck, do not apply sealant on the face of the primary flange or the inner mounting surface of the secondary flange.

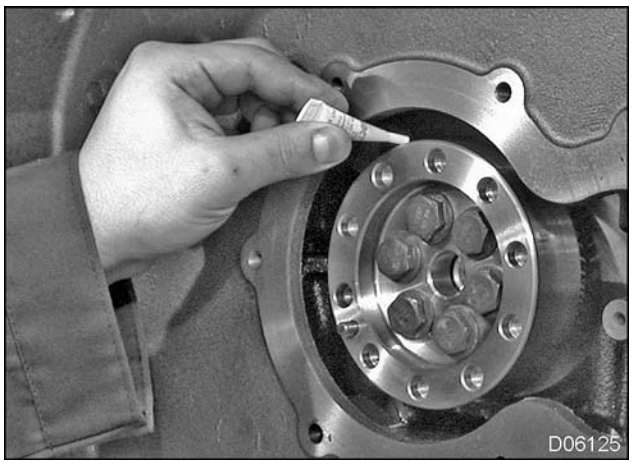

Figure 494 Application of Loctite® on primary crankshaft flange

4. Put Loctite® (Table 38) on the outside diameter of the primary crankshaft flange.

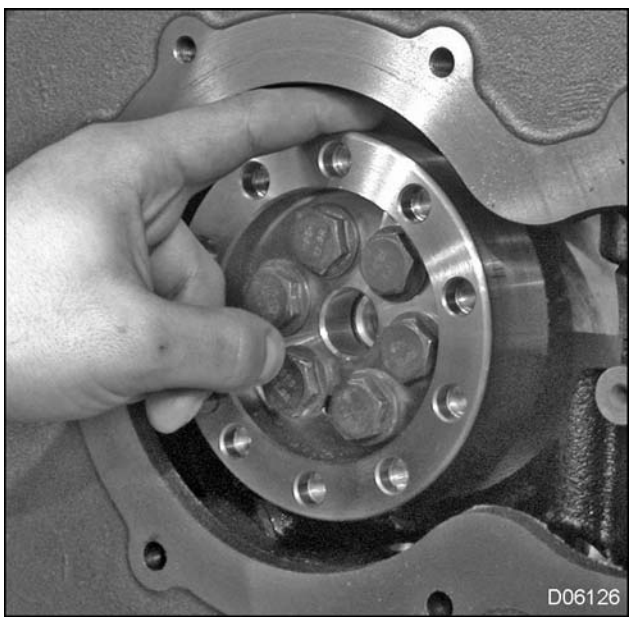

Figure 495 Loctite® coverage around primary crankshaft flange

5. Spread the Loctite® (Table 38) around flange to ensure complete coverage. Do not get Loctite® on face of crankshaft flange.

CAUTION: To prevent damage to the engine, transmission, or vehicle, seat the secondary flange onto the crankshaft in one step. When two surfaces are mated (air is removed) Loctite® sets up within 5 minutes. Installation after Loctite® has set will break the seal between the crankshaft flange and the secondary flange and cause leakage.

Figure 496 Crankshaft Secondary Flange Installation Studs

6. Install two Crankshaft Secondary Flange Installation Studs (Table 38) in the crankshaft flange evenly spaced on the crankshaft flange.

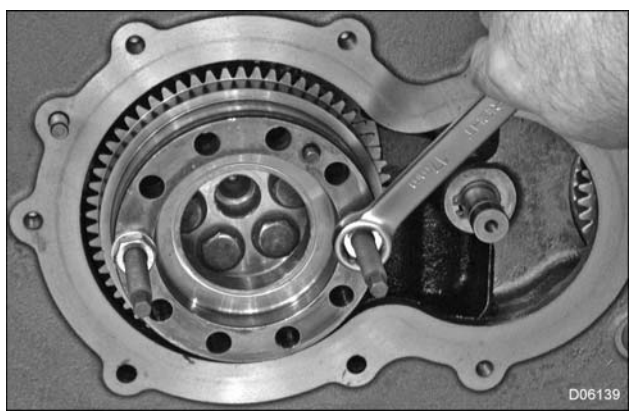

Figure 497 Secondary flange

7. Put the secondary flange on the studs, aligning the dowel pin hole with the crankshaft dowel pin. Install two nuts and washers. Pull the flange in place by tightening alternating nuts on the studs. Remove nuts, washers, and studs after flange has been seated.

   NOTE: You have 5 minutes to fully draw the secondary flange on the crankshaft flange.

CAUTION: To prevent possible engine or vehicle damage, do not drive the idler gear onto the shaft: this could damage the gear and gear teeth. For correct fit, rotate the gear for the power steering and fuel pump assembly .

CAUTION: To prevent possible engine or vehicle damage, ensure the circular witness groove is facing you. Installing the gear in backwards will cause abnormal wear and damage to the gear.

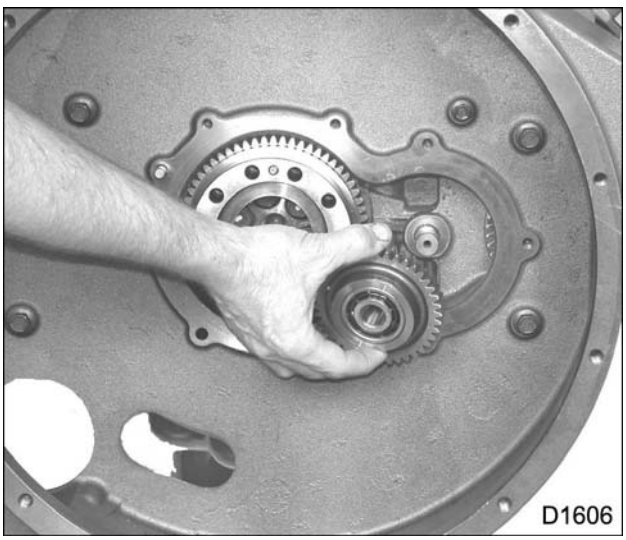

Figure 498 Power steering idler gear

8. Install power steering idler gear onto shaft. The gear of the power steering and fuel pump assembly may have to be rotated for proper fit of the gears. Do not drive the gear on the shaft.
9. Verify correct orientation or the gears, and the gears teeth are properly engaged.

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

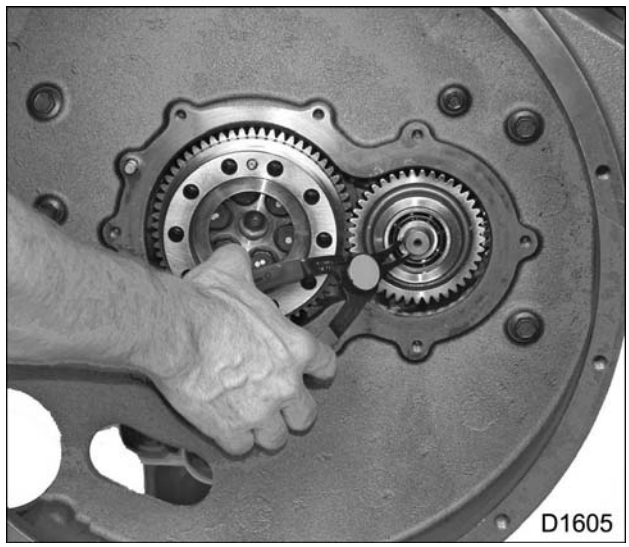

Figure 499 Power steering idler gear retaining ring on shaft

10. Install the power steering idler gear retaining ring on the idler shaft.
11. Check the gear backlash .
12. Place a new gasket onto the rear oil seal carrier.

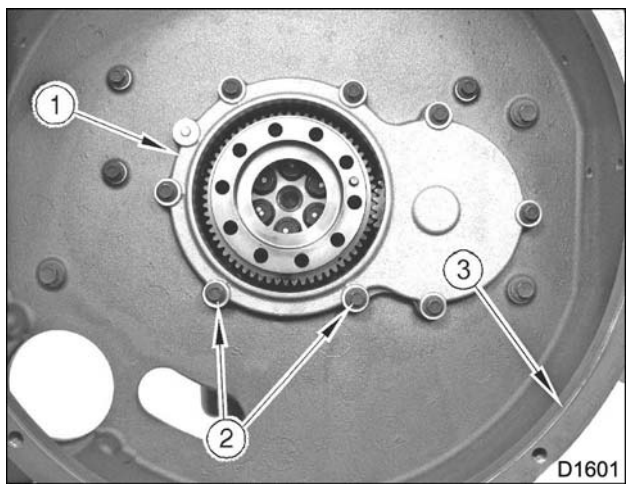

Figure 500 Rear cover and rear oil seal carrier

1. Rear oil seal carrier
2. Longer bolts (M8 x 70)
3. Rear cover

13. Install two M8 x 70 bolts in lower holes . Install six remaining bolts (M8 x 25) to secure rear oil seal carrier to rear cover. Tighten all bolts to

the standard torque (General Torque Guidelines, page 333).

Rear Main Seal and Wear Sleeve

NOTE: When replacing the rear main seal, note that production engines will not have a wear sleeve. Wear sleeves are only available as a service item included with the replacement rear main oil seal.

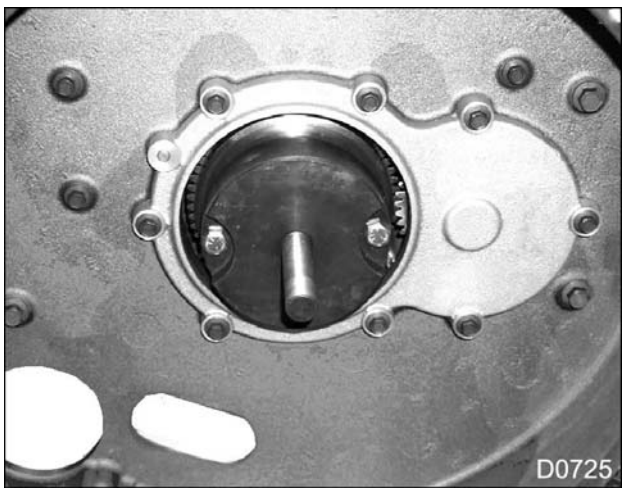

Figure 501 Rear/Wear Sleeve Installer

1. Bolt Rear / Wear Sleeve Installer tool (Table 38) onto end of crankshaft. Make sure crankshaft alignment dowel fits in dowel recess hole in the installation tool.

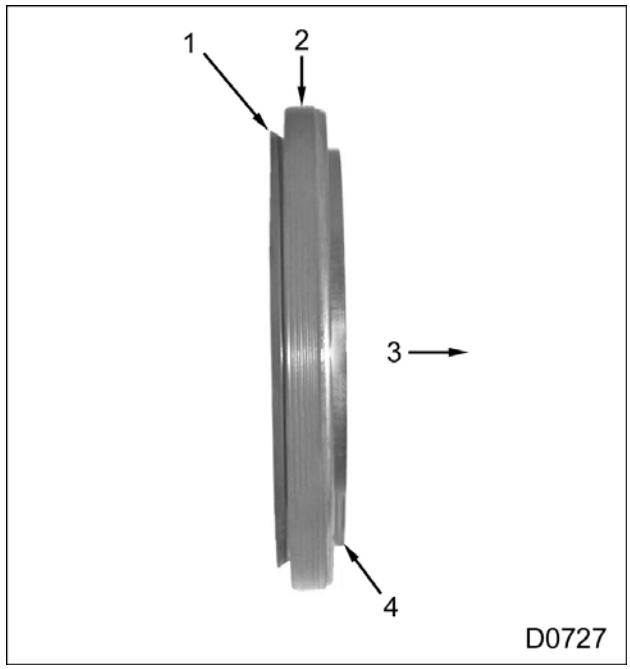

Figure 502 Orientation or rear main oil seal and wear sleeve

1. Dust seal lip
2. Rear main oil seal
3. Crankshaft side (forward)
4. Wear sleeve (internal bevel)

NOTE: Lubricate the outer diameter of rear main oil seal with an approximate 50/50 solution of dish washing soap and water prior to assembly. Do not use any other type of lubricant.

2. Orient seal as shown in the following graphic and slide onto installation tool.

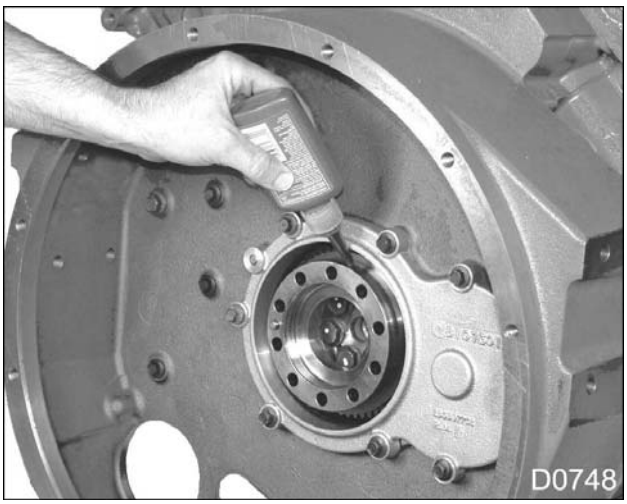

Figure 503 Sealant application to secondary crankshaft flange

3. Place a 360° bead of Loctite® (Table 38) hydraulic sealant onto the rear edge of the secondary crankshaft flange prior to wear sleeve / oil seal installation.

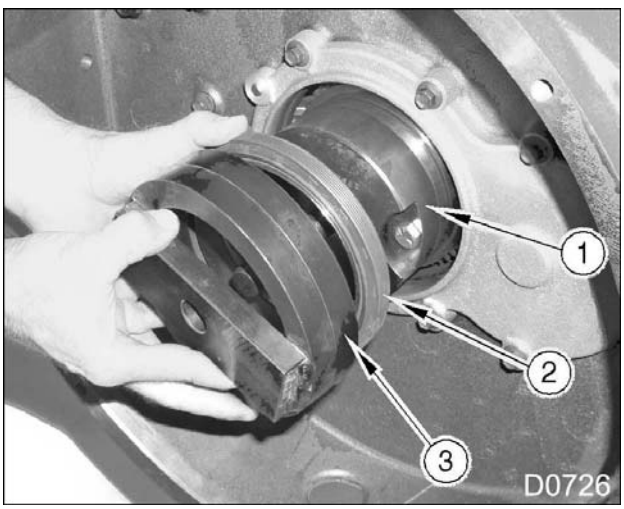

Figure 504 Rear/Wear Sleeve Installer

1. Base
2. Rear main oil seal and wear sleeve
3. Rear / Wear Sleeve Installer

4. Position rear main oil seal / wear sleeve combination onto the rear main oil seal / wear sleeve installer.

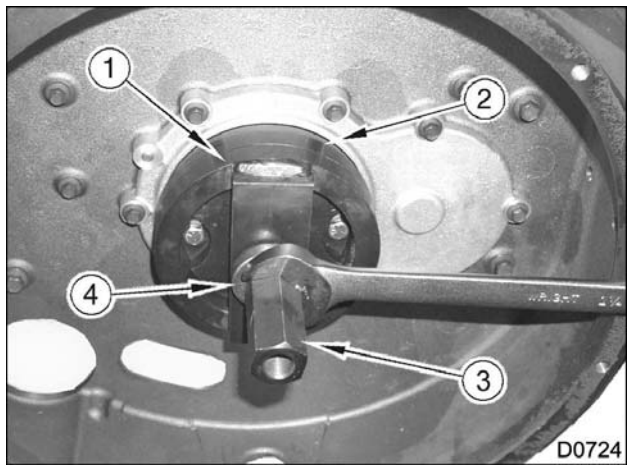

Figure 505 Rear main oil seal and wear sleeve combination on crankshaft

1. Rear / Wear Sleeve Installer
2. Rear main oil seal
3. Drive nut
4. Thrust bearing

5. Place thrust bearing and drive nut onto threaded shaft. Tighten nut until rear main oil seal bottoms out in rear oil seal carrier.

Power Steering and Fuel Pump Assembly

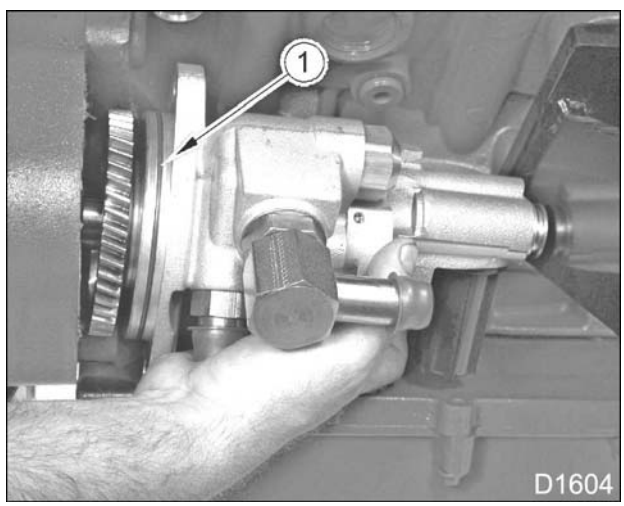

Figure 506 Power steering and fuel pump assembly

1. O-ring

1. Check pump assembly for cracks, leaks or other signs of damage. Place a new O-ring on power steering and fuel pump assembly prior to installation.
2. Install power steering and fuel pump assembly, with new O-ring, to rear cover.

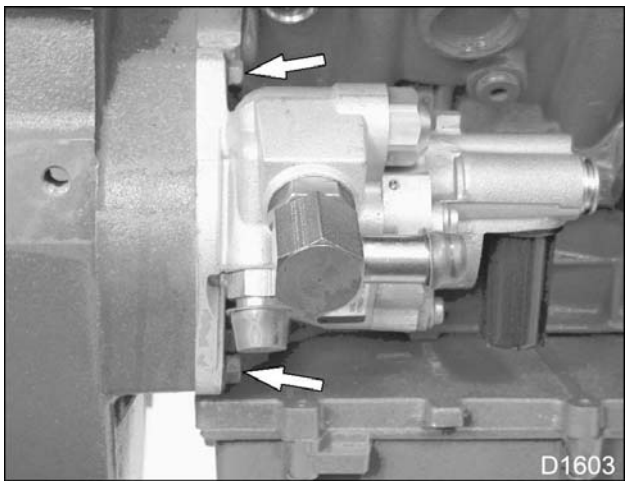

Figure 507 Mounting bolts for power steering and fuel pump assembly

3. Install two M10 x 1.5 x 30 mounting bolts for power steering and fuel pump assembly. Tighten bolts to the standard torque (General Torque Guidelines, page 333).

Flexplate

CAUTION: To prevent engine damage, use new bolts to install flexplate.

CAUTION: To prevent engine damage, do not use anitseize, grease, or lubricants on flexplate bolts. Each has an adverse effect on torque results.

Figure 508 Flexplate

1. Flexplate bolts, M10 x 77 (10)
2. Reinforcement ring
3. Flexplate adapter hub
4. Transmission side stamp (XMSN-SIDE)

1. Position the flexplate onto adapter hub and align hub over the crankshaft secondary flange dowel. Make sure the XMSN-SIDE stamp is facing toward the transmission.
2. Install reinforcement ring and align all bolt holes. Make sure lip on outer circumference of ring is facing towards the transmission.
3. Put two M10 x 77 bolts 180° apart through reinforcement ring, flexplate, and adapter hub.
4. Place entire flexplate assembly onto crankshaft. Hand tighten two bolts to hold assembly in place.
5. Install eight remaining M10 x 77 flexplate mounting bolts.
6. Snug all bolts in the sequence shown to 1 - 7 N·m (12 - 60 lbf·in).
7. Torque all bolts to the special torque (Table 37) and in the sequence shown .

Flywheel

Figure 509 Flywheel on guide pins

1. Install two flywheel guide pins (make locally) into crankshaft flange at approximately 3 o'clock and 9 o'clock positions.
2. Align flywheel dowel hole with crankshaft secondary flange dowel and slide flywheel onto guide pins.
3. Align reinforcement ring with dowel and slide over guide pins. Make sure lip on outer circumference of ring is facing towards the transmission.

CAUTION: To prevent engine damage, use new bolts to install flywheel.

CAUTION: To prevent engine damage, do not use antiseize, grease, or lubricants on flywheel bolts. Each has an adverse effect on torque results.

4. Install two M10 x 77 flywheel mounting bolts to secure flywheel to crankshaft. Remove both guide pins.
5. Install eight remaining M10 x 77 flywheel mounting bolts.

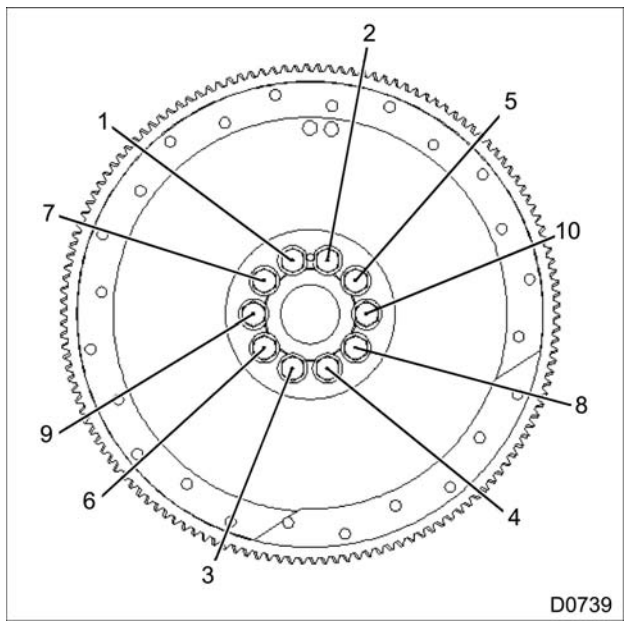

Figure 510 Torque sequence for flexplate

6. Snug all bolts in the sequence to 1 - 7 N·m (12 - 60 lbf·in).
7. Torque all bolts to the special torque (Table 37) and in the sequence shown below.

Specifications

Table 36

Flywheel	
Flywheel surface maximum runout (manual)	0.25 mm (0.010 in)
Flexplate ring gear TIR runout (automatic)	1.27 mm (0.050 in)
Rear Cover	
Rear cover face maximum runout	0.51 mm (0.020 in)
Power Steering / Fuel Pump Drive Gear	
Backlash:	
Crankshaft to idler gear	0.173 - 0.288 mm (0.0068 - 0.0113 in)
Idler gear to pump drive gear	0.173 - 0.288 mm (0.0068 - 0.0113 in)
Power Steering Pump	
Maximum operating pressure	17.5 MPa (2,538 psi)

Special Torque

Table 37

Flywheel mounting bolts, new bolts only	94 N·m (69 lbf·ft)
Flexplate mounting bolts, new bolts only	94 N·m (69 lbf·ft)

Special Service Tools

Table 38

Tool Number	Description
Obtain locally	Dial Indicator with Magnetic Base
ZTSE4515	Rear / Wear Sleeve Installer
ZTSE4518	Rear Wear Sleeve Removal Tool
ZTSE4719	Power Steering Idler Shaft Installation Tool
ZTSE4720	Crankshaft Secondary Flange Installation Studs
1830858C1	Liquid Gasket (RTV) (6 oz. tube)
1847432C1	Loctite® 290 Sealant

Table of Contents

Branch Tube Assembly

Removal

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.

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

1. Disconnect negative battery cable and Electronic Control Module (ECM) ground.
2. Drain air tanks, if equipped.
3. Remove inside engine cover from truck, if equipped. See *Truck Service Manual*.
4. Remove the right inner fender well, if required.

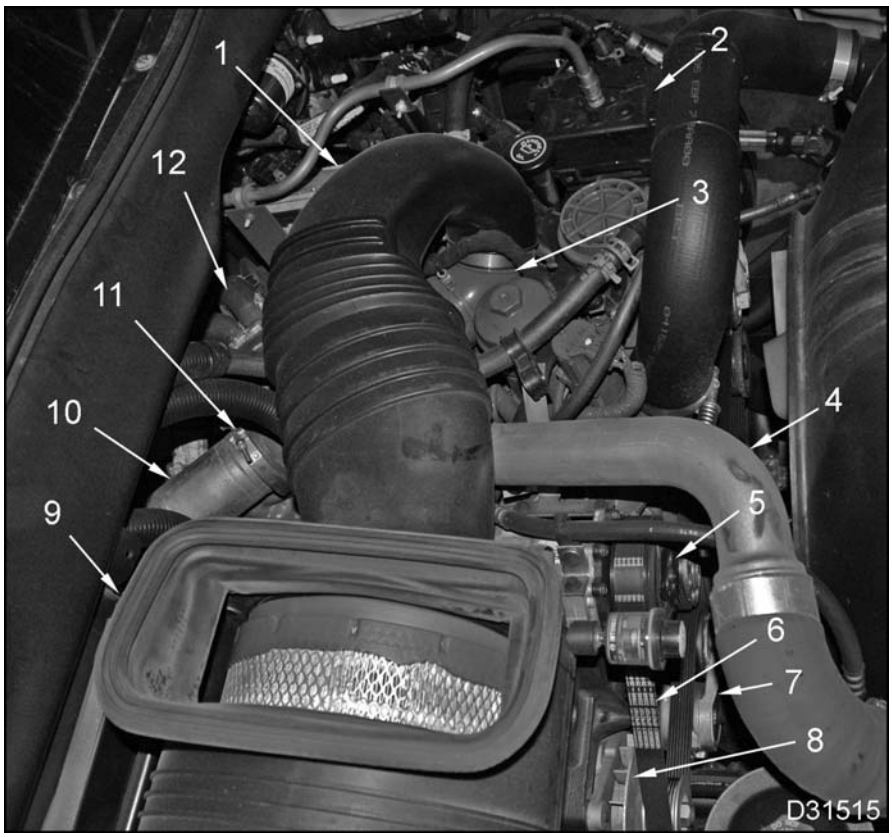

Figure 511 Parts for removal (Engine In-chassis – 4100 truck)

1. Air intake duct
2. Air compressor
3. Turbocharger air inlet duct
4. Charge Air Cooler (CAC) pipe
5. Air conditioning compressor
6. Serpentine drive belt
7. Belt tensioner
8. Alternator assembly
9. Air filter housing
10. Exhaust down pipe
11. Turbocharger exhaust clamp
12. Shielded tube exhaust assembly

5. Remove air intake duct, air filter housing, and mounting bracket.
6. Loosen CAC pipe clamps and remove CAC pipe.
7. Rotate belt tensioner clockwise to release belt tension and remove serpentine drive belts.
8. Remove alternator wiring and remove alternator assembly.

WARNING: To prevent personal injury or death, do not open pressurized air conditioning lines.

9. If truck is equipped with air conditioning, remove air conditioning compressor bolts from mounting bracket, but do not remove or disconnect pressurized air conditioning lines. Move compressor out of the way and secure with a strap.
10. Remove mounting bracket for alternator and air conditioning compressor.
11. If truck is equipped with an air compressor, pinch off hose and remove coolant supply line. Remove two of three M10 air compressor mounting bracket bolts. Loosen third bolt and pivot or reposition air compressor out of the way.
12. If required to remove valve covers; remove oil dipstick, washer bottle, and bracket.
13. Loosen turbocharger exhaust clamp and remove exhaust down pipe from turbocharger exhaust flange.

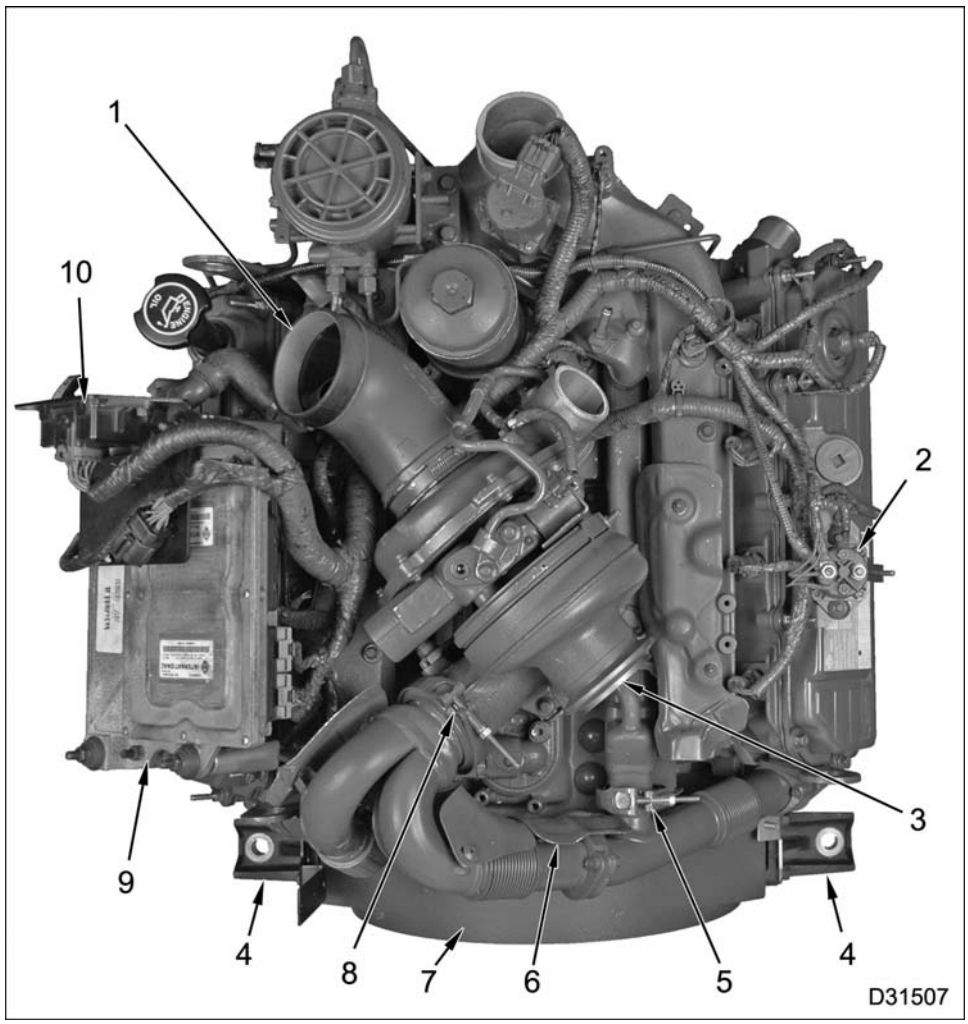

Figure 512 Parts for removal

1. Turbocharger air inlet duct
2. Glow plug relay
3. Turbocharger exhaust flange
4. Rear engine mounting bracket (2)
5. V-clamp (Right exhaust tube to EGR cooler)
6. Pump gasket heat shield
7. Rear cover
8. V-clamp (Shielded tube exhaust assembly to turbocharger)
9. Electronic Control Module (ECM) / Injector Drive Module (IDM)
10. EGR Drive Module

14. Loosen V-clamp connecting shielded tube exhaust assembly to turbocharger.
15. Loosen V-clamp connecting right exhaust tube to EGR cooler.

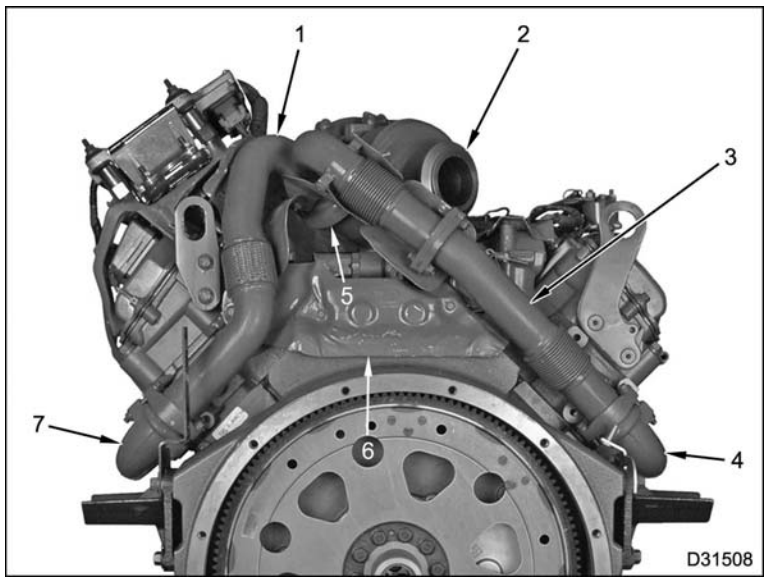

Figure 513 Air Management System parts

1. Shielded tube exhaust assembly
2. Turbocharger exhaust flange
3. Exhaust tube assembly, right
4. Exhaust manifold, right
5. V-clamp (Shielded tube exhaust assembly to turbocharger)
6. Pump gasket heat shield
7. Exhaust manifold, left

16. Remove two M8 bolts and nuts connecting shielded tube exhaust assembly to left exhaust manifold.
17. Remove two M8 bolts and nuts connecting right exhaust tube to right exhaust manifold.
18. Leaving right exhaust tube attached, remove shielded tube exhaust assembly.
19. Remove three bolts from pump gasket heat shield and remove heat shield.
20. Unplug the EGR drive module and remove module and mounting bracket.
21. Unplug ECM and IDM electrical connectors.
22. See “Engine Electrical” to remove the following:
    - ECM, IDM, and mounting bracket.
    - Glow plug relay and bracket
23. See “Electronically Controlled Variable Geometry Turbocharger (VGT)” to remove the following:
    - Turbocharger air inlet duct
    - VGT assembly
24. Remove the high-pressure oil pump cover. See “High-pressure Oil Pump”.
25. See “Cylinder Head and Valve Train” to remove the following:
    - Valve covers
    - High-pressure oil rails
    - Case-to-head tube assemblies
    - Fuel injectors for cylinders 6, 7, and 8.
    - Rocker arm assemblies (intake and exhaust) for cylinders 7 and 8.
    - Rocker arm assembly (exhaust) for cylinder 6.

WARNING: To prevent personal injury or death, use a suitable lifting device to support and lower transmission assembly.

26. Remove transmission assembly.
27. Remove clutch assembly, if equipped with a manual transmission.
28. See “Rear Cover, Flywheel, and Power Steering Gear Drive” to remove the following:

- Flywheel or flex-plate
- Oil seal carrier
- Power steering idler gear
- Crankshaft secondary flange

29. Remove two M10 x 30 bolts from power steering and fuel pump assembly, and support the power steering and fuel pump assembly.
30. Disconnect starter motor assembly wiring, remove M10 bolts from starter motor, and remove starter motor assembly.

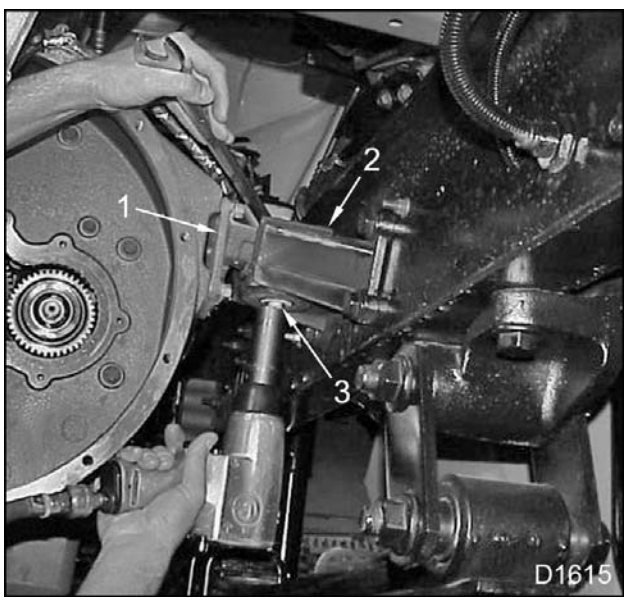

Figure 514 Removal of through bolt from rear engine mount in chassis mounting bracket

1. Rear engine mounting bracket
2. Chassis mounting bracket
3. Through bolt

WARNING: To prevent personal injury or death, use a chain hoist rated for the weight of the engine, follow manufacturer’s installation and safety instructions, and attach safety latch lifting hooks to lifting eyes on the engine.

31. Attach a hoist to support the engine.
32. Remove two M16 through bolts and nuts from rear engine mounts.
33. Raise engine with a hoist and support engine with a jack.
34. Remove eight M12 bolts from rear engine mounting brackets, and remove brackets from rear cover.
35. Remove wiring retaining clips from rear cover assembly, if installed.

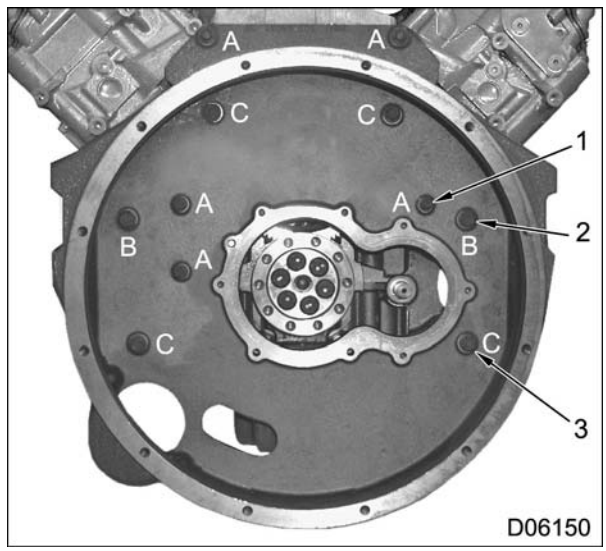

Figure 515 Rear cover mounting bolts

1. Bolts marked A, (M10 x 55) (5)
2. Bolts marked B, (M10 x 70) (2)
3. Bolts marked C, (M10 x 60) (4)

36. Remove rear cover mounting bolts marked A and C in figure.

WARNING: To prevent personal injury or death, use a suitable lifting device or get help to lower rear cover.

37. Loosen rear cover mounting bolts marked B, but do not remove.

CAUTION: To prevent engine damage when removing the rear cover, avoid pulling out gasket between the upper and lower crankcase.

38. Use a thin gasket scraper to separate sealant between the upper and lower crankcase and the rear cover assembly.
39. Remove rear cover mounting bolts marked B and remove rear cover.

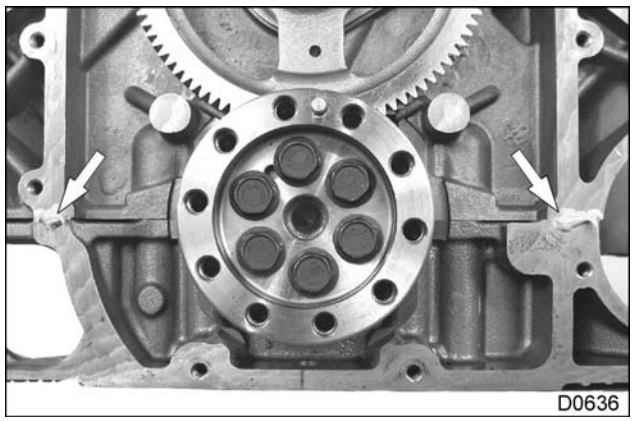

Figure 516 Sealant at upper and lower crankcase

CAUTION: To prevent engine damage, cut sealant at upper and lower crankcase.

40. Remove remaining sealant from upper crankcase, lower crankcase and rear cover, using a sharp gasket scraper or putty knife.
41. Remove intake and exhaust pushrods from cylinders 7 and 8.
42. Remove exhaust pushrod from cylinder 6.
43. Attach a No. 27 torx bit to a 1/4 x 10 inch extension.

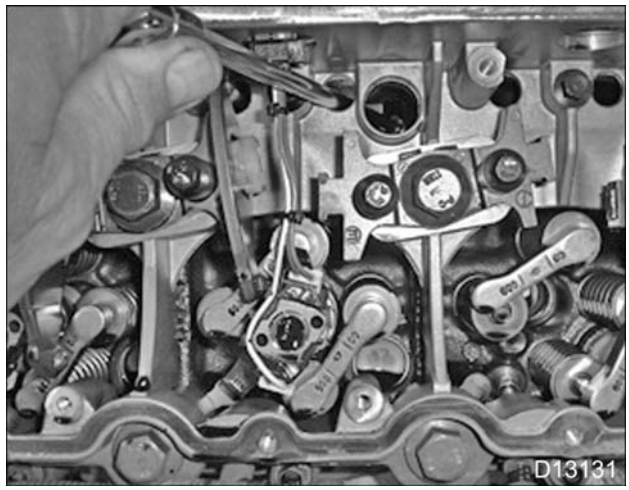

Figure 517 Extension in pushrod hole

44. Look through back of crankcase and insert extension through exhaust pushrod hole for cylinder 6 and push torx bit into M6 x 40 torx bolt in block of branch tube assembly.

CAUTION: To prevent engine damage, do not drop mounting bolts into crankcase.

45. Carefully loosen torx bolt to allow removal.
46. Remove extension from pushrod hole.
47. Look through back of crankcase and use a magnet to carefully remove torx bolt in one of three ways:
    - Magnet inserted through pushrod hole
    - Magnet inserted through hole for crankcase-to-head tube
    - Magnet inserted through back of crankcase
48. Insert extension through exhaust pushrod hole for cylinder 7 and push torx bit into M6 x 40 torx bolt in block of branch tube assembly.
49. Repeat steps 45 through 47.

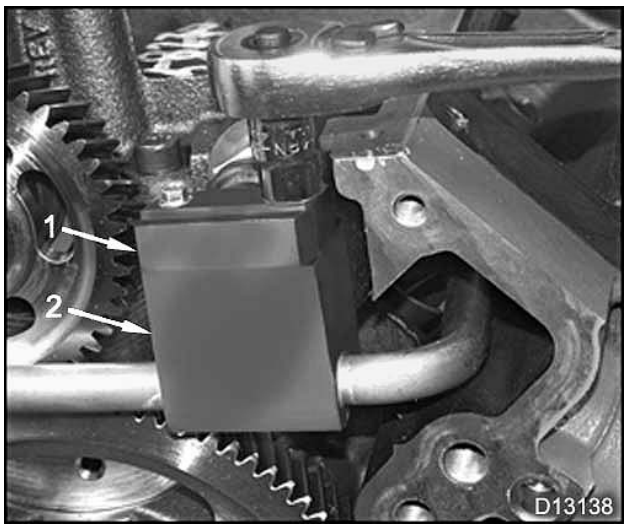

Figure 518 Removal of bolts from branch tube adaptor

1. Branch tube adaptor
2. Branch tube assembly

50. Remove two M6 x 30 bolts connecting branch tube adapter to branch tube assembly.

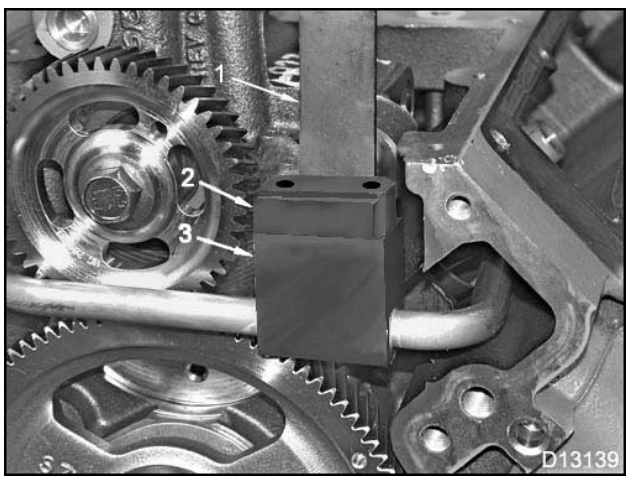

Figure 519 Removal of branch tube adapter

1. No.10 quick release tool
2. Branch tube adapter
3. Branch tube assembly

51. Remove branch tube adapter, using a No.10 Quick Release Tool (Table 40) .

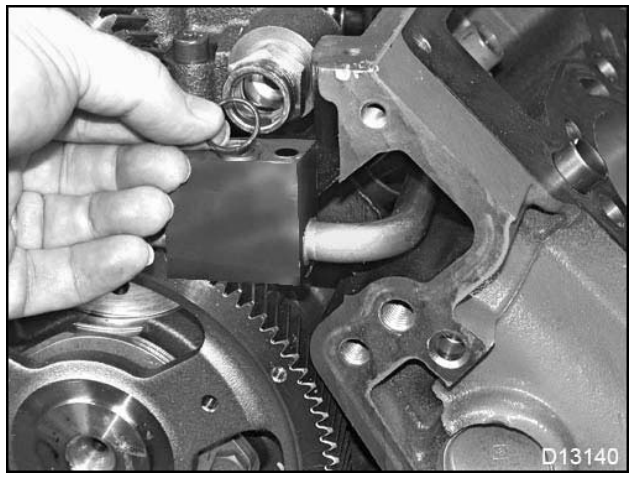

Figure 520 Removal of O-ring

52. Remove O-ring from recess in branch tube assembly.

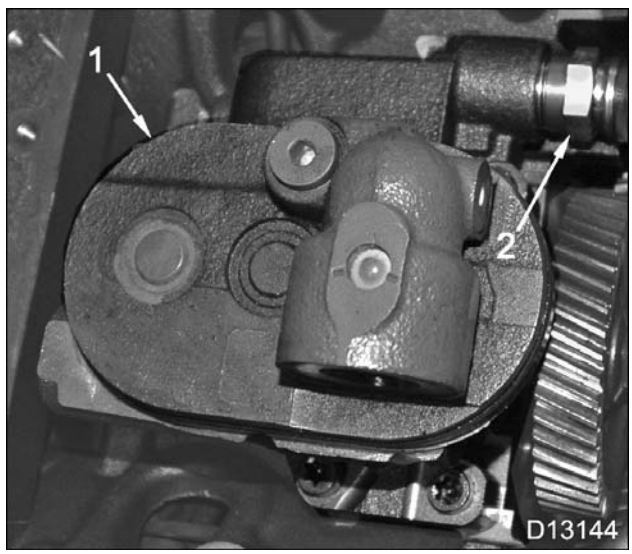

Figure 521 High-pressure oil pump assembly and STC fitting

1. High-pressure oil pump assembly
2. Snap To Connection (STC) fitting

53. Remove STC fitting.

54. Remove branch tube assembly.

Installation

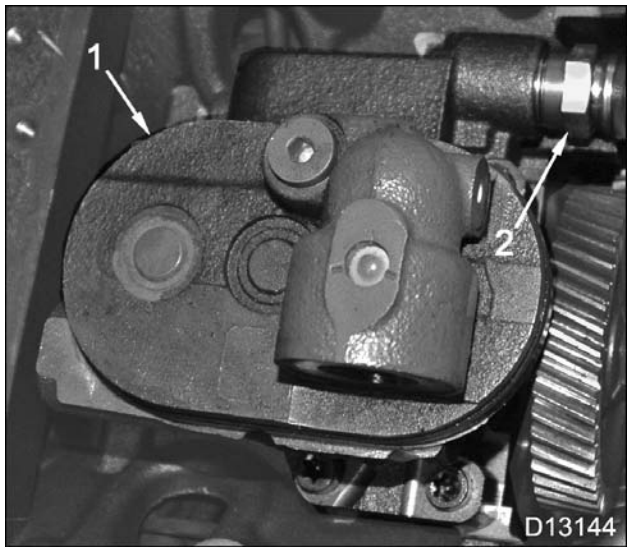

Figure 522 High-pressure oil pump assembly and STC fitting

1. High-pressure oil pump assembly
2. STC fitting

CAUTION: To prevent engine damage, a new STC fitting must be installed.

1. Install a new STC fitting for the high-pressure oil pump.

CAUTION: To prevent engine damage, do not over tighten the STC fitting; if over tightened, the STC fitting will fail.

2. Tighten new STC fitting to the special torque (Table 39).

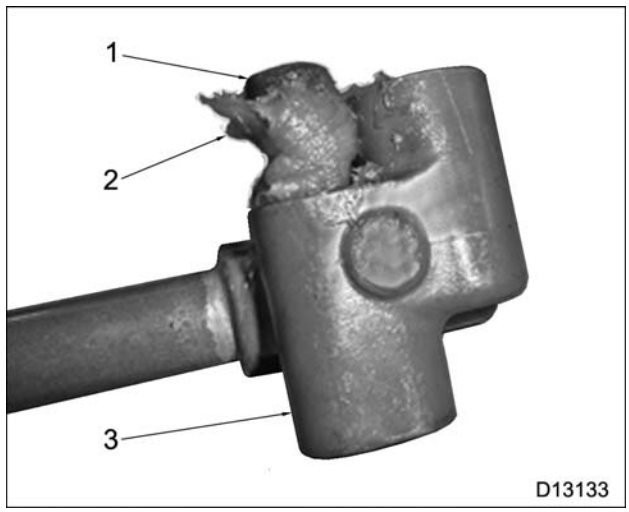

Figure 523 Mounting block on branch tube assembly

1. M6 x 40 torx bolt
2. Grease
3. Mounting block

CAUTION: To prevent engine damage, a new branch tube assembly must be installed.

3. Grease each M6 x 40 torx bolt and insert into mounting blocks of new branch tube assembly.

CAUTION: To prevent engine damage, do not drop mounting bolts into crankcase.

4. Position new branch tube assembly for mounting in crankcase.

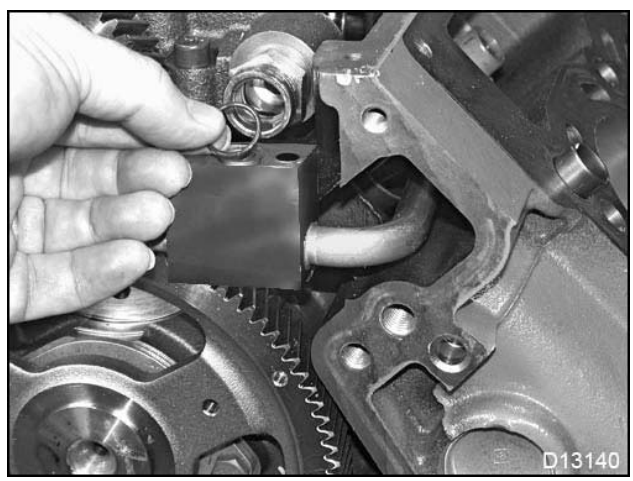

Figure 524 Installation of O-ring

CAUTION: To prevent engine damage, a new O-ring must be installed.

5. Install new O-ring in the recess of the branch tube assembly.

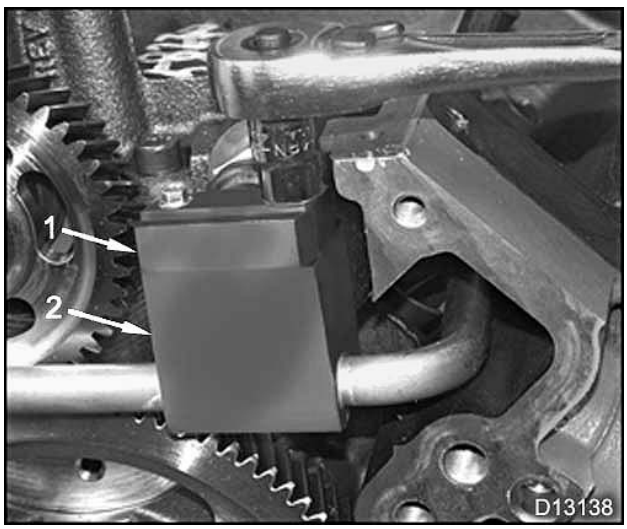

Figure 525 Installation of bolts for branch tube adapter

1. Branch tube adaptor
2. Branch tube assembly

6. Install and loosely tighten two M6 x 30 mounting bolts to connect new branch tube adapter to branch tube assembly.

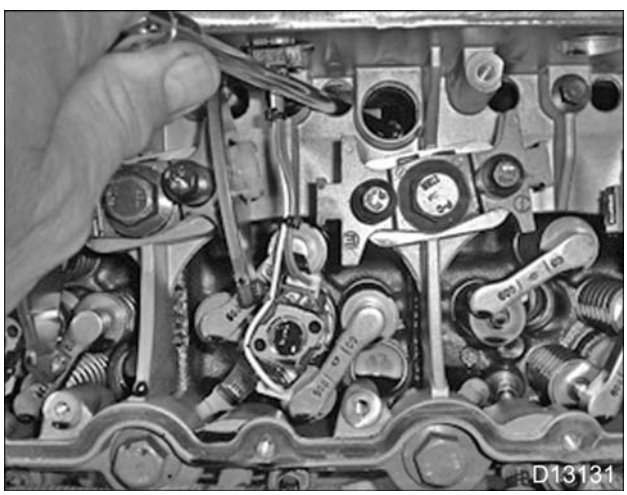

Figure 526 Extension in pushrod hole

7. Look through back of crankcase, insert extension – with No. 27 torx bit attached – through exhaust pushrod hole for cylinder 6, and install and loosely tighten M6 x 40 torx bolt.
8. Look through back of crankcase, insert extension – with No. 27 torx bit attached – through exhaust pushrod hole for cylinder 7, and install and loosely tighten M6 x 40 torx bolt.
9. Tighten both M6 x 40 torx bolts to the special torque (Table 39).
10. Torque both M6 x 30 mounting bolts to the special torque for the branch tube adaptor (Table 39).
11. Install exhaust pushrod for cylinder 6.
12. Install intake and exhaust pushrods for cylinders 7 and 8.
13. See “Cylinder Head and Valve Train” to install the following:
    - Fuel injectors for cylinders 6, 7, and 8.
    - Case-to-head tube assemblies
    - High-pressure oil rails
    - Rocker arm assembly (exhaust) for cylinder 6.
    - Rocker arm assemblies (intake and exhaust) for cylinders 7 and 8.
    - Valve covers
14. Install high-pressure oil pump cover. See “High-pressure Oil Pump”.

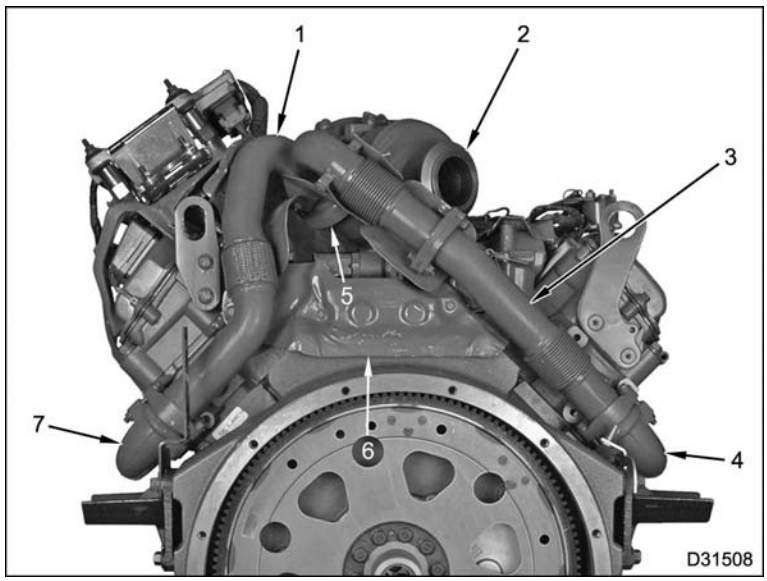

Figure 527 Air Management System parts

1. Shielded tube exhaust assembly
2. Turbocharger exhaust flange
3. Exhaust tube assembly, right
4. Exhaust manifold, right
5. V-clamp (Shielded tube exhaust assembly to turbocharger)
6. Pump gasket heat shield
7. Exhaust manifold, left

15. Position pump gasket heat shield and install three bolts finger tight.
16. Tighten two M6 x 12 heat shield bolts to the special torque (Table 39) and one M10 x 16 heat shield bolt to the special torque (Table 39).
17. Position shielded exhaust tube assembly on engine with right exhaust tube and EGR cooler gasket attached. Install four M8 exhaust bolts and nuts finger tight to secure assembly to exhaust manifolds.
18. Position V-clamp to connect shielded tube exhaust assembly to turbocharger and tighten V-clamp to the special torque (Table 39).
19. Position V-clamp to connect right exhaust tube to EGR cooler and tighten V-clamp to the special torque (Table 39).
20. Tighten M8 bolts securing shielded exhaust tube assembly (right exhaust tube attached) to the special torque (Table 39).
21. See “Rear Cover, Flywheel, and Power Steering Gear Drive” for installation of the following:
    - Rear cover assembly
    - Crankshaft secondary flange
    - Power steering idler gear
    - Rear oil seal carrier
    - Power steering and fuel pump assembly
    - Flex-plate or flywheel
22. Reinstall wiring clips on rear cover, if necessary.
23. Install rear engine mounting brackets on the rear cover assembly and tighten eight M12 x 40 bolts to the special torque (Table 39).

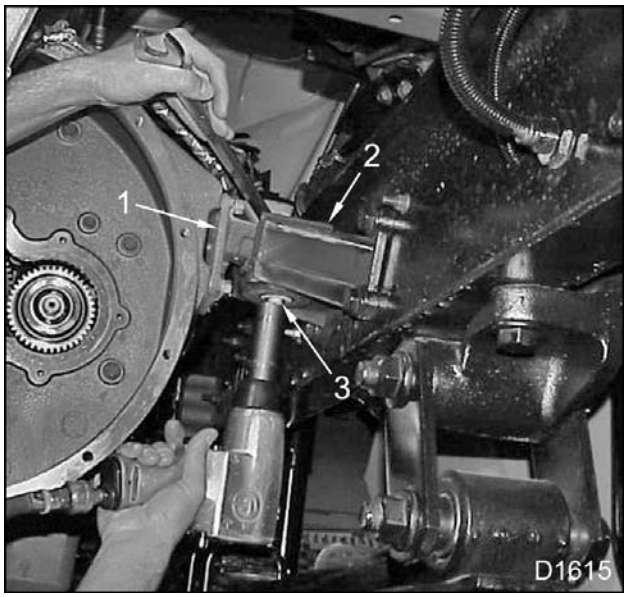

Figure 528 Installation of through bolt into rear engine mount

1. Rear engine mounting bracket
2. Chassis mounting bracket
3. Through bolt

WARNING: To prevent personal injury or death, make sure the lifting hoist and hooks are secure – before lowering the engine.

24. Lower engine to set rear engine mounting brackets in chassis mounting brackets.
25. Install two M16 through bolts and nuts to secure rear engine mounts to chassis mounting brackets. Tighten nuts to the special torque (Table 39).
26. Remove chain hoist.
27. Install starter motor assembly and tighten M10 x 40 starter bolts to the special torque (Table 39).
28. Reconnect starter wiring.
29. Install clutch and pressure plate, if equipped with a manual transmission.

WARNING: To prevent personal injury or death, use a suitable lifting device to support and raise transmission assembly.

30. Install transmission assembly.

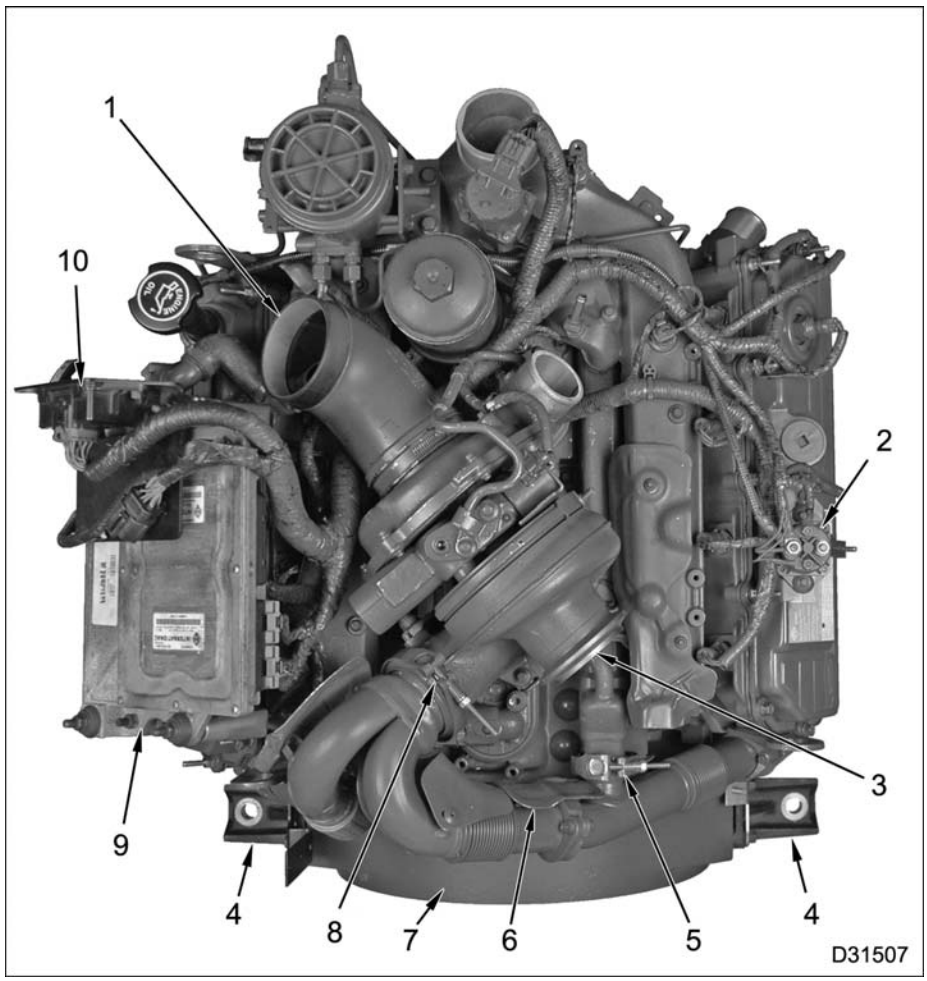

Figure 529 Parts for Installation

1. Turbocharger air inlet duct
2. Glow plug relay
3. Turbocharger exhaust flange
4. Rear engine mounting bracket (2)
5. V-clamp (Right exhaust tube to EGR cooler)
6. Pump gasket heat shield
7. Rear cover
8. V-clamp (Shielded tube exhaust assembly to turbocharger)
9. Electronic Control Module (ECM) / Injector Drive Module (IDM)
10. EGR Drive Module

31. See “Electronically Controlled Variable Geometry Turbocharger (VGT)” to install the following:
    - VGT assembly
    - Turbocharger air inlet duct
32. Install exhaust down pipe onto turbocharger exhaust flange and tighten exhaust clamp to the special torque (Table 39).
33. See “Engine Electrical” to install the following:
    - Glow plug relay and bracket
    - Electronic Control Module (ECM), Injector Driver Module (IDM), and mounting bracket.
34. Plug in ECM and IDM electrical connectors.
35. Install EGR drive module with mounting bracket and plug in electrical connector.

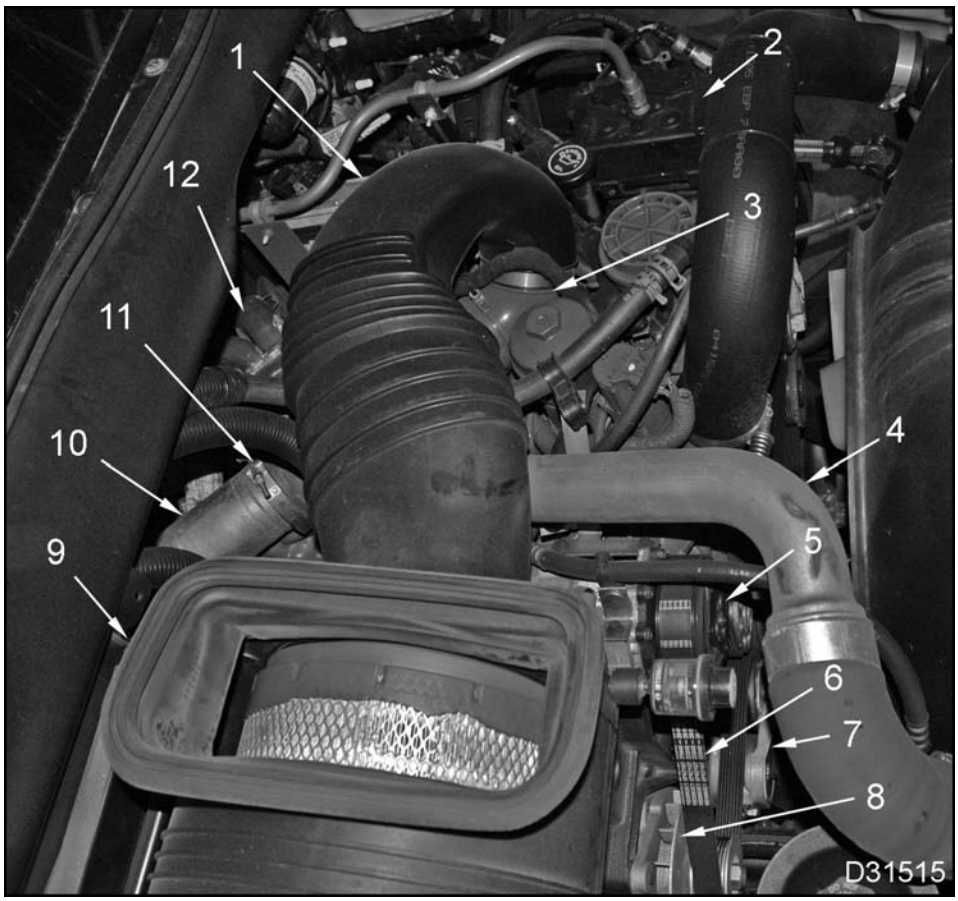

Figure 530 Parts for Installation – Engine In-chassis (4100 truck)

1. Air intake duct
2. Air compressor
3. Turbocharger air inlet duct
4. Charge Air Cooler (CAC) pipe
5. Air conditioning compressor
6. Serpentine drive belt
7. Belt tensioner
8. Alternator assembly
9. Air filter housing
10. Exhaust down pipe
11. Turbocharger exhaust clamp
12. Shielded tube exhaust assembly

36. Install oil dipstick, washer bottle, and bracket, if removed.
37. Install alternator and air conditioning compressor mounting bracket and tighten M10 bolts to the special torque (Table 39).
38. Install alternator and reconnect alternator wiring.
39. If removed, install air conditioning compressor.
40. If removed, install air compressor and mounting bracket. Tighten three M10 x 100 air compressor mounting bracket bolts to the special torque (Table 39).
41. Reconnect air compressor lines and hoses.
42. Install serpentine drive belts.
43. Install CAC pipe and tighten clamps.
44. Install air intake duct, air filter housing, and mounting bracket.
45. Install right inner fender well, if removed.
46. Install inside engine cover in truck, if equipped. See *Truck Service Manual*.
47. Reconnect Electronic Control Module (ECM) ground and negative battery cable.

Rocker Arm

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.

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

NOTE: Before doing the rocker arm removal procedure below, remove the following components:

- Turbocharger inlet air ducting

  See "Electronically Controlled Variable Geometry Turbocharger (VGT)"

- Valve covers

  See "Cylinder Head And Valve Train"

- High-pressure oil rails

  See "Cylinder Head And Valve Train"

CAUTION: To prevent engine damage, insert clean shop towels (see TSI-02-12-16) or piece of rubber hose into oil drain holes in rocker arm carrier before removing fuel injectors. This will ensure that the following parts or pieces of these parts will not fall into the oil supply:

- 3/8" rocker arm pivot balls
- Rocker arm pivots and pivot retainers

NOTE: Account for all parts or pieces, before removing shop towels or rubber hoses after rocker arms have been replaced.

1. Find dowel hole in vibration damper between two of the four bolt heads.

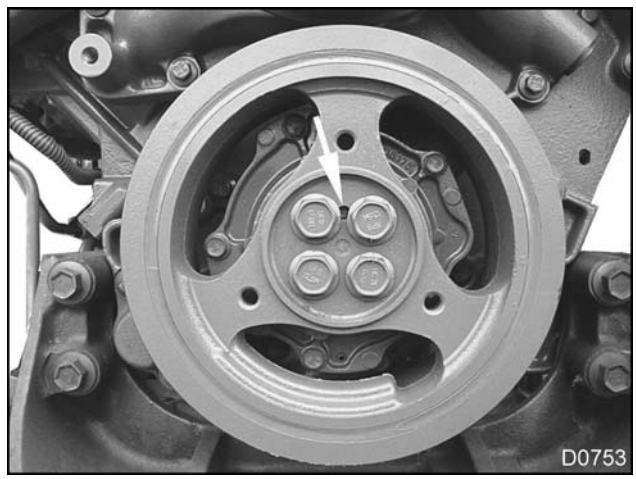

Figure 531 Dowel hole in vibration damper

2. Rotate crankshaft to position dowel hole at 12:00.
3. Wiggle both rocker arms for cylinder 1.
   - If rocker arms feel free of valve train loading, the valves are completely closed. Rocker arms can be serviced for cylinders 1, 2, 7, and 8.

     Do steps 4 through 16

   - If rocker arms do not feel free, rotate crankshaft (360°) to put crankshaft in the correct position. Rocker arms can be serviced for cylinders 1, 2, 7, and 8.

     Do steps 4 through 16

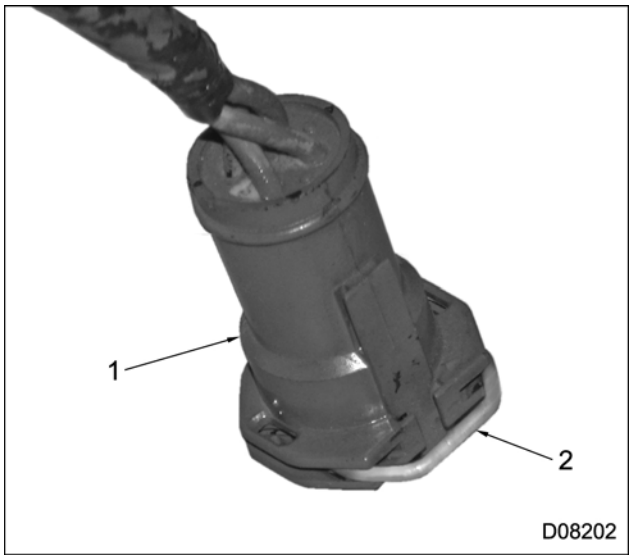

Figure 532 Engine harness connector to injector connector

1. Engine harness connector
2. Spring loaded metal clip

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

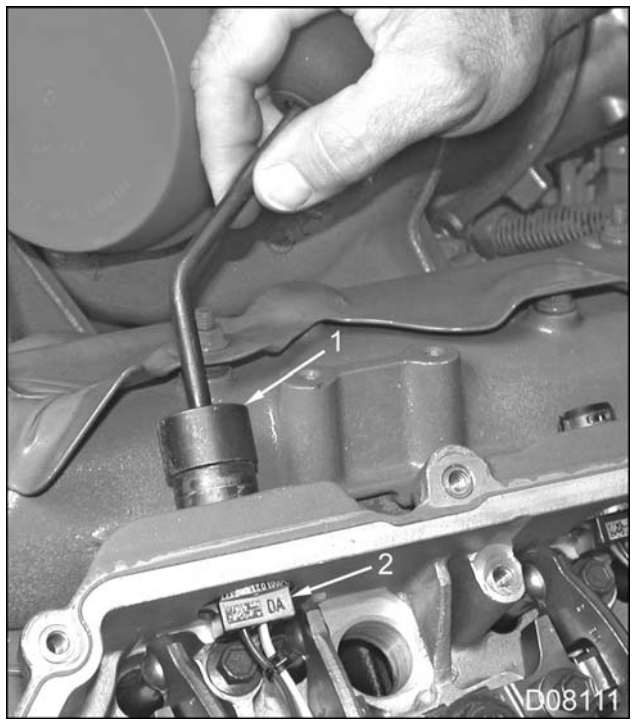

Figure 533 Injector connector removal

1. Injector Connector Release Tool
2. Fuel injector connector

5. Install the Injector Connector Release Tool (Table 41).
6. Push Injector Connector Release Tool to pop loose spring clips on the injector connector and remove connector from the rocker arm carrier.

Figure 534 Fuel Injector Hold Down Wrench

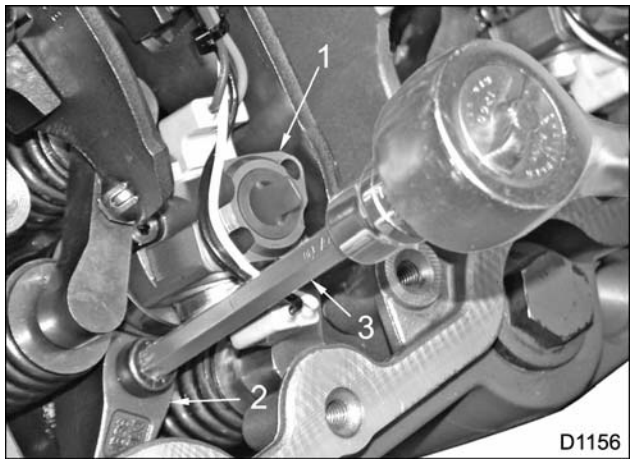

Figure 535 Removal of fuel injector hold down clamp

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

7. Remove the fuel injector hold down clamp assembly, using the Fuel Injector Hold Down Wrench (Table 41).
8. Remove injector and place into injector cup.

CAUTION: To prevent engine damage, insert a clean paper towel inside injector sleeve to keep foreign material out.

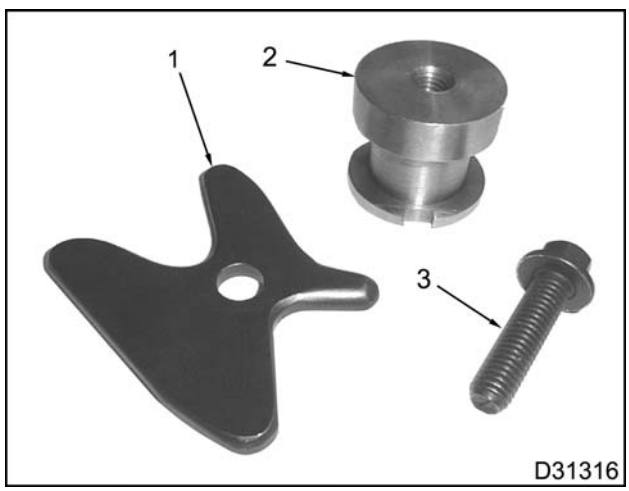

Figure 536 On-engine Valve Spring Compressor Tool

1. Valve spring compressor plate
2. Valve spring compressor base
3. Valve spring compressor bolt

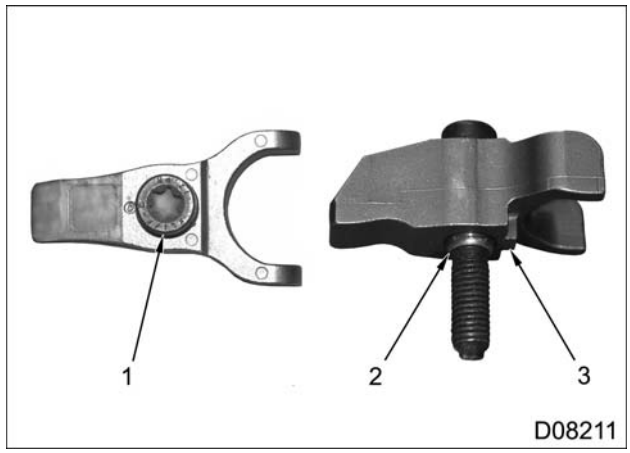

Figure 537 Old fuel injector hold down clamp assembly

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

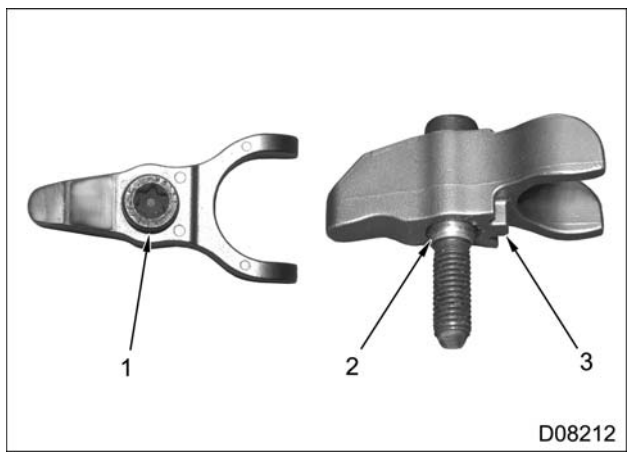

Figure 538 New fuel injector hold down clamp assembly

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

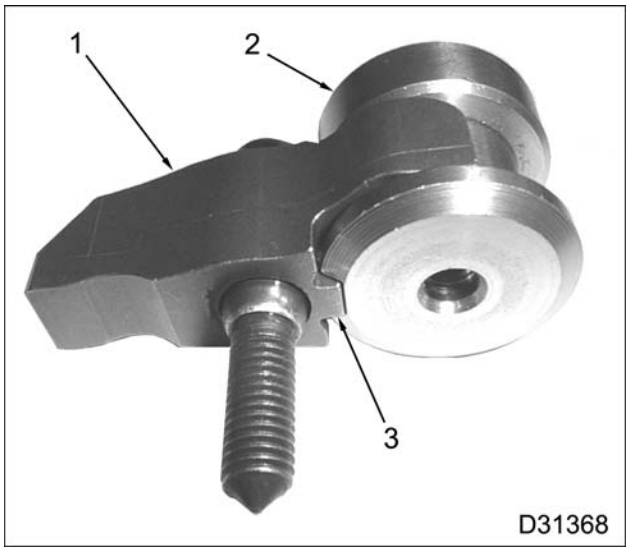

Figure 539 Hold down clamp and valve spring compressor base

1. Injector hold down clamp
2. Valve spring compressor base
3. Clamp alignment index

9. Install On-engine Valve Spring Compressor Tool (Table 41).

   Insert valve spring compressor base into a new injector hold down clamp. Make sure the notch in the valve spring compressor base aligns with the alignment index tab on hold down clamp.

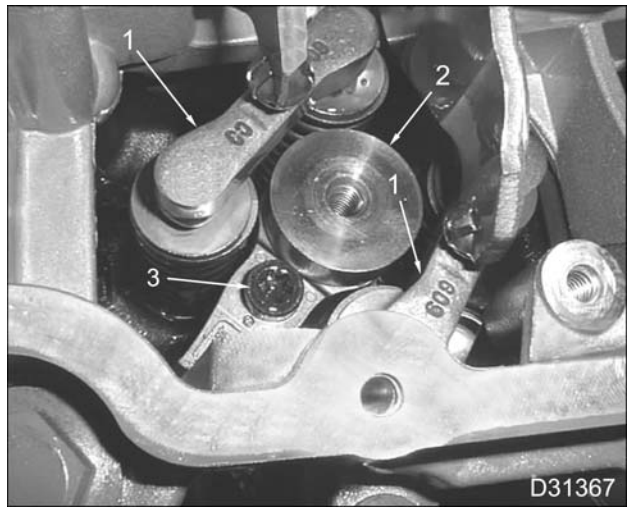

Figure 540

1. Valve bridge
2. Valve spring compressor base and hold down clamp
3. Hold down bolt

10. Install new hold down clamp and valve spring compressor base between valve bridges.

    NOTE: While centering base between the two valve bridges, lightly tighten hold down bolt, but do not torque.

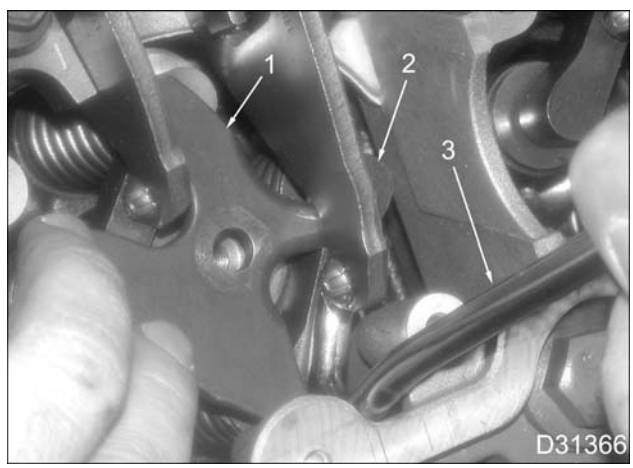

Figure 541 Clearance between rocker arm and valve bridge

1. Valve spring compressor plate
2. Valve bridge
3. Small pry bar

11. Install valve spring compressor plate onto top of valve bridge, inserting small point of plate between the exhaust rocker and valve bridge.

    NOTE: If exhaust rocker is severely worn, insert a small pry bar between the exhaust rocker arm and valve bridge. Compress the valve bridge down to raise the rocker for enough clearance to rotate the small point of the compressor plate between the two components.

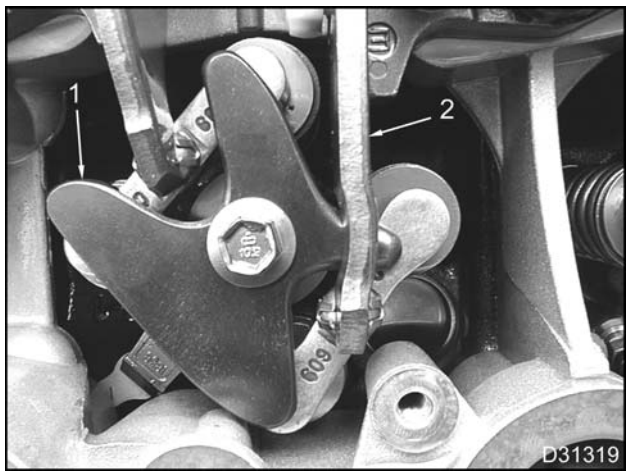

Figure 542 Valve spring compressor plate installed

1. Valve spring compressor plate
2. Exhaust rocker arm

12. Once compressor plate is in position, install valve spring compressor bolt through plate and into valve spring compressor base.
13. Using a hand wrench, tighten bolt to compress valve springs until plate contacts top of valve spring compressor base.

CAUTION: To prevent engine damage, do not use power tools.

14. Disengage rocker arm from push rod, while rotating rocker arm and compressing rocker arm clip simultaneously.
15. Remove rocker arm and retaining clip.

CAUTION: To prevent engine damage, account for two 3/8” rocker arm pivot balls. If balls fall onto cylinder head, retrieve balls with a magnet.

CAUTION: To prevent engine damage, account for each rocker arm pivot and pivot retainer. Failure to account for broken pieces requires removal of oil pan to retrieve.

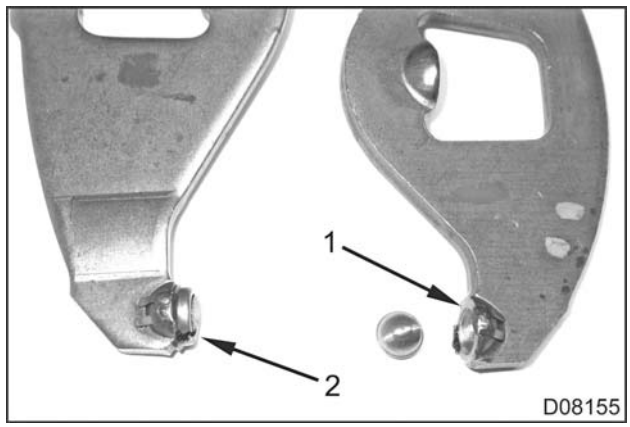

Figure 543 Damaged rocker arm pivot and retainer

1. Retainer partially missing (unaccounted for)
2. Retainer cracked (intact and accounted for)

16. With rocker arms removed, back out valve spring compressor bolt and remove valve spring compressor plate to access valve bridges.

Cleaning and Inspection

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

1. Following valve bridge replacement, place a dab of wheel bearing grease onto new rocker arm socket to hold new 3/8” ball in place, compress valves, and install new rocker arms.

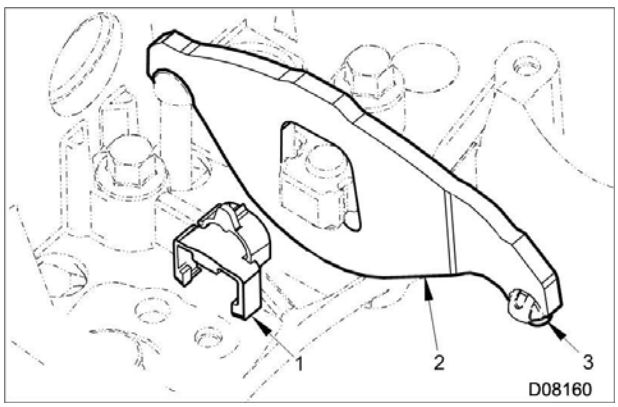

Figure 544

1. Rocker arm retaining clip
2. Fulcrum plate
3. 3/8” ball

2. Position 3/8” ball and rocker arm underneath fulcrum and rotate rocker arm into place, making sure push rod is seated within rocker arm.

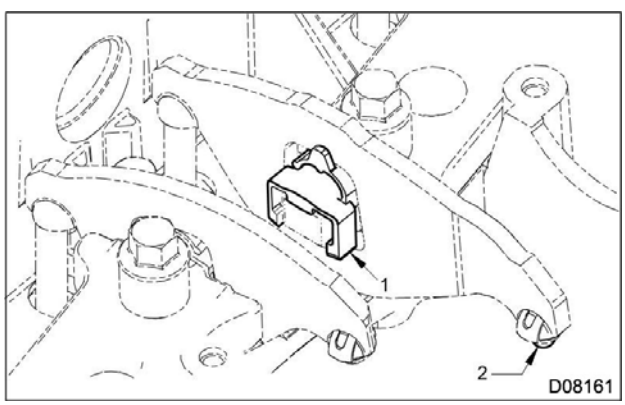

Figure 545 Retaining clip in correct position

1. Rocker arm retaining clip
2. Fulcrum plate

3. Install new plastic rocker arm retaining clip by positioning top of clip to top of rocker arm opening and rotating clip snapping into position around fulcrum plate.
4. Remove valve spring compressor bolt. Make sure the rocker arm and 3/8” ball are in place.

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.

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

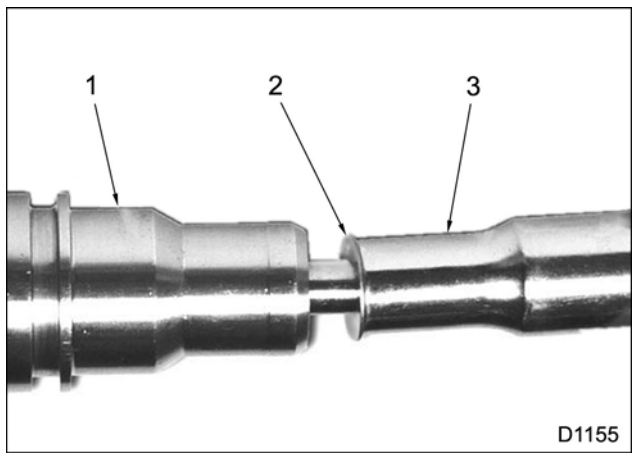

Figure 546 Seating copper gasket

1. Injector (nozzle end)
2. Gasket (copper)
3. Deep socket

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

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

7. To seat gasket, push on gasket with a deep socket.
8. Use a nonmetallic hand tool to remove upper and lower O-rings from fuel injector. Discard O-rings.

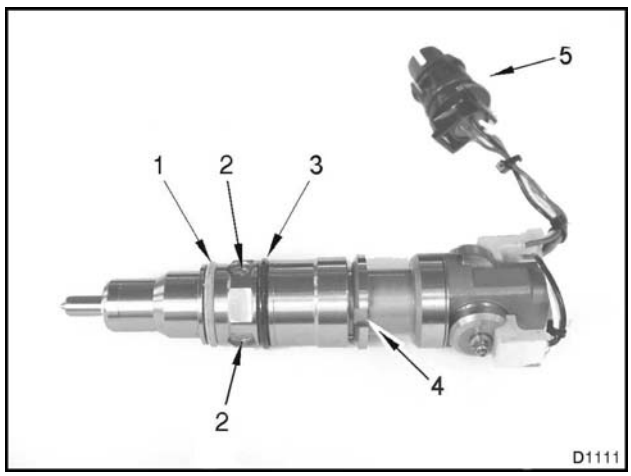

Figure 547 Fuel injector external O-rings

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)

9. Use a nonmetallic hand tool to remove upper and lower O-rings from fuel injector. Discard O-rings.
10. Install a new Teflon coated (white) O-ring (smaller diameter) in the lower recess just below the fuel screens. Avoid contact with sharp machined surfaces.
11. 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 548 Lubrication of fuel injector O-rings

12. Lubricate upper and lower O-rings with clean engine oil.
13. Remove paper towels from injector bores and install injectors and injector hold down clamps. See “Cylinder Head And Valve Train”.
14. Check for small broken particles (using a magnet), before removing shop towels or rubber hose from oil drain holes.
15. Install the following components:
    - Crankcase-to-head tube assembly

      See “Cylinder Head And Valve Train”
    - High-pressure oil rail

      See “Cylinder Head And Valve Train”
    - Valve covers

      See “Cylinder Head And Valve Train”
    - Turbocharger inlet air ducting

      See “Electronically Controlled Variable Geometry Turbocharger (VGT)”

Special Torque

Table 39 Branch Tube Assembly

Bolts for branch tube mounting blocks	13 N·m (115 lbf·in)
Bolts for branch tube adapter	13 N·m (115 lbf·in)
STC fitting	53 ± 4 N·m (39 ± 3 lbf·ft)
Bolts for heat shield (M8 x12)	13 N·m (115 lbf·in)
Bolt for heat shield (M10 x 16)	62 N·m (45 lbf·ft)
V-clamp for shielded exhaust tube	12 N·m (106 lbf·in)
Bolts for right exhaust tube (shielded exhaust tube connected) to right exhaust manifold (M8)	27 ± 4 N·m (20 ± 3 lbf·ft))
Bolts for rear engine mounts (M12 x 40)	107 N·m (79 lbf·ft)
Nut for bolt through rear engine mounts and chassis mounts (M16)	294 – 325 N·m (216 – 239 lbf·ft)
Bolts for starter motor (M10 x 40)	47 –58 N·m (35–43 lbf·ft)
Turbocharger exhaust clamp for turbocharger down pipe	25 – 10 N·m (4 – 6 lbf·ft)
Bolts for alternator and air conditioning compressor bracket (M10)	72 N·m (53 lbf·ft)
Bolts for air compressor bracket (M10 x 100)	72 N·m (53 lbf·ft)

Special Service Tools

Table 40 Branch Tube Assembly

Description	TOOL NUMBER
No. 10 Quick Release Tool	ZTSE4581

Table 41 Rocker Arm

Description	TOOL NUMBER
Injector Connector Release Tool	ZTSE4650
Fuel Injector Hold Down Wrench	ZTSE4524
On-engine Valve Spring Compressor Tool	ZTSE4697

Table of Contents

Terminology

Accessory work – The work per cycle required to drive engine accessories (normally, only those essential to engine operation).

Actuator – A device that performs work in response to an input signal.

Aeration – The entrainment of air or combustion gas in coolant, lubricant, or fuel.

Aftercooler (Charge Air Cooler) – A heat exchanger mounted in the charge air path between the turbocharger and engine intake manifold. The aftercooler reduces the charge air temperature by transferring heat from the charge air to a cooling medium (usually air).

Ambient temperature – The environmental air temperature in which a unit is operating. In general, the temperature is measured in the shade (no solar radiation) and represents the air temperature for other engine cooling performance measurement purposes. Air entering the radiator may or may not be the same ambient due to possible heating from other sources or recirculation. (SAE J1004 SEP81)

Ampere (amp) – The standard unit for measuring the strength of an electrical current. The flow rate of a charge in a conductor or conducting medium of one coulomb per second. (SAE J1213 NOV82)

Analog – A continuously variable voltage.

Analog to digital converter (A/D) – A circuit in the ECM processing section that converts an analog signal (DC or AC) to a usable digital signal for the microprocessor.

American Trucking Association (ATA) Datalink – A serial datalink specified by the American Trucking Association and the SAE.

Boost pressure – 1. The pressure of the charge air leaving the turbocharger.

2. Inlet manifold pressure that is greater than atmospheric pressure. Obtained by turbocharging.

Bottom Dead Center (BDC) – The lowest position of the piston during the stroke.

Brake Horsepower (bhp) – The power output from an engine, not the indicated horsepower. The power output of an engine, sometimes-called flywheel horsepower is less than the indicated horsepower by the amount of friction horsepower consumed in the engine.

Brake Horsepower (bhp) net – Net brake horsepower is measured with all engine components. The power of an engine when configured as a fully equipped engine. (SAE J1349 JUN90)

Calibration – The data values used by the strategy to solve equations and make decisions. Calibration values are stored in ROM and put into the processor during programming to allow the engine to operate within certain parameters.

Catalyst – A substance that produces a chemical reaction without undergoing a chemical change itself.

Catalytic converter – An antipollution device in the exhaust system that contains a catalyst for chemically converting some pollutants in the exhaust gases (carbon monoxide, unburned hydrocarbons, and oxides of nitrogen) into harmless compounds.

Cavitation – A dynamic condition in a fluid system that forms gas-filled bubbles (cavities) in the fluid.

Cetane number – 1. The auto-ignition quality of diesel fuel.

2. A rating applied to diesel fuel similar to octane rating for gasoline.

3. A measure of how readily diesel fuel starts to burn (autoignites) at high compression temperature.

Diesel fuel with a high cetane number autoignites shortly after injection into the combustion chamber. Therefore, it has a short ignition delay time. Diesel fuel with a low cetane number resists autoignition. Therefore, it has a longer ignition delay time.

Charge air – Dense, pressurized, heated air discharged from the turbocharger.

Charge Air Cooler (CAC) – See **Aftercooler**.

Closed crankcase – A crankcase ventilation that recycles crankcase gases through a breather, then back to the clean air intake.

Closed loop operation – A system that uses a sensor to provide feedback to the ECM. The ECM uses the sensor to continuously monitor variables and adjust to match engine requirements.

Cloud point – The point when wax crystals occur in fuel, making fuel cloudy or hazy. Usually below -12 °C (10 °F).

Cold cranking ampere rating (battery rating) – The sustained constant current (in amperes) needed to produce a minimum terminal voltage under a load of 7.2 volts per battery after 30 seconds.

Continuous Monitor Test – An ECM function that continuously monitors the inputs and outputs to ensure that readings are within set limits.

Coolant – A fluid used to transport heat from one point to another.

Coolant level switch – A switch sensor used to indicate low coolant level.

Crankcase – The housing that encloses the crankshaft, connecting rods, and allied parts.

Crankcase breather – A vent for the crankcase to release excess interior air pressure.

Crankcase pressure – The force of air inside the crankcase against the crankcase housing.

Current – The flow of electrons passing through a conductor. Measured in amperes.

Damper – A device that reduces the amplitude of torsional vibration. (SAE J1479 JAN85)

Deaeration – The removal or purging of gases (air or combustion gas) entrained in coolant or lubricating oil.

Deaeration tank – A separate tank in the cooling system used for one or more of the following functions:

- Deaeration
- Coolant reservoir (fluid expansion and afterboil)
- Coolant retention
- Filling
- Fluid level indication (visible)

Diagnostic Trouble Code (DTC) – Formerly called a Fault Code or Flash Code. A DTC is a three digit numeric code used for troubleshooting.

Digital Multimeter (DMM) – An electronic meter that uses a digital display to indicate a measured value. Preferred for use on microprocessor systems because it has a very high internal impedance and will not load down the circuit being measured.

Disable – A computer decision that deactivates a system and prevents operation of the system.

Displacement – The stroke of the piston multiplied by the area of the cylinder bore multiplied by the number of cylinders in the engine.

Driver (high side) – A transistor within an electronic module that controls the power to an actuator circuit.

Driver (low side) – A transistor within an electronic module that controls the ground to an actuator circuit.

Duty cycle – A control signal that has a controlled on/off time measurement from 0 to 100%. Normally used to control solenoids.

Engine lamp – An instrument panel lamp that comes on when DTCs are set. DTCs can be read as flash codes (red and amber instrument panel lamps).

Engine OFF tests – Tests that are done with the ignition switch ON and the engine OFF.

Engine rating – Engine rating includes **Rated hp** and **Rated rpm**.

Engine RUNNING tests – Tests done with the engine running.

Exhaust brake – A brake device using engine exhaust back pressure as a retarding medium.

Exhaust manifold – Exhaust gases flow through the exhaust manifold to the turbocharger exhaust inlet and are directed to the EGR cooler.

Fault detection/management – An alternate control strategy that reduces adverse effects that can be caused by a system failure. If a sensor fails, the ECM substitutes a good sensor signal or assumed sensor value in its place. A lit amber instrument panel lamp signals that the vehicle needs service.

Filter restriction – A blockage, usually from contaminants, that prevents the flow of fluid through a filter.

Flash code – See **Diagnostic Trouble Code (DTC)**.

Fuel inlet restriction – A blockage, usually from contaminants, that prevents the flow of fluid through the fuel inlet line.

Fuel pressure – The force that the fuel exerts on the fuel system as it is pumped through the fuel system.

Fuel strainer – A pre-filter in the fuel system that keeps larger contaminants from entering the fuel system.

Fully equipped engine – A fully equipped engine is an engine equipped with only those accessories necessary to perform its intended service. A fully equipped engine does not include components that are used to power auxiliary systems. If these components are integral with the engine or for any reason are included on the test engine, the power absorbed may be determined and added to the net brake power. (SAE J1995 JUN90)

Fusible link (fuse link) – A fusible link is a special section of low tension cable designed to open the circuit when subjected to an extreme current overload. (SAE J1156 APR86)

Gradeability – The maximum percent grade which the vehicle can transverse for a specified time at a specified speed. The gradeability limit is the grade upon which the vehicle can just move forward. (SAE J227a)

Gross Combined Weight Rating (GCWR) – Maximum combined weight of towing vehicle (including passengers and cargo) and the trailer. The GCWR indicates the maximum loaded weight that the vehicle is allowed to tow.

Gross brake horsepower – The power of a complete basic engine, with air cleaner, without fan, and alternator and air compressor not charging.

Hall effect – The development of a transverse electric potential gradient in a current-carrying conductor or semiconductor when a magnetic field is applied.

Hall effect sensor – Generates a digital on/off signal that indicates speed and timing.

High speed digital inputs – Inputs to the ECM from a sensor that generates varying frequencies (engine speed and vehicle speed sensors).

Horsepower (hp) – Horsepower is the unit of work done in a given period of time, equal to 33,000 pounds multiplied by one foot per minute. **1hp = 33,000 lb x 1 ft /1 min**.

Hydrocarbons – Unburned or partially burned fuel molecules.

Idle speed –

- Low idle is minimum rpm at no load.
- High idle is maximum rpm at no load.

Intake manifold – A collection of tubes through which the fuel-air mixture flows from the fuel injector to the intake valves of the cylinders.

International NGV Tool Utilized for Next Generation Electronics (INTUNE) – The diagnostics software for chassis related components and systems.

Low speed digital inputs – Switched sensor inputs that generate an on/off (high/low) signal to the ECM. The input to the ECM from the sensor could be from a high input source switch (usually 5 or 12 volts) or from a grounding switch that grounds the signal from a current limiting resistor in the ECM that creates a low signal (0 volts).

Lubricity – Lubricity is the ability of a substance to reduce friction between solid surfaces in relative motion under loaded conditions.

Lug (engine) – A condition when the engine is operating at or below maximum torque speed.

Manometer – A double-leg liquid-column gauge, or a single inclined gauge, used to measure the difference between two fluid pressures. Typically, a manometer records in inches of water.

MasterDiagnostics® (MD) – The diagnostics software for engine related components and systems.

Microprocessor – An integrated circuit in a microcomputer that controls information flow.

Nitrogen Oxides (NO_x) – Nitrogen oxides form by a reaction between nitrogen and oxygen at high temperatures and pressures in the combustion chamber.

Normally closed – Refers to a switch that remains closed when no control force is acting on it.

Normally open – Refers to a switch that remains open when no control force is acting on it.

Ohm (Ω) – The unit of resistance. One ohm is the value of resistance through which a potential of one volt will maintain a current of one ampere. (SAE J1213 NOV82)

On demand test – A self test that the technician initiates using the EST and is run from a program in the processor.

Output Circuit Check (OCC) – An On demand test done during an Engine OFF self test to check the continuity of selected actuators.

Output State Test (OST) – An On demand test that forces the processor to activate actuators (High or Low) for additional diagnostics.

pH – A measure of the acidity or alkalinity of a solution.

Particulate matter – Particulate matter includes mostly burned particles of fuel and engine oil.

Piezometer – An instrument for measuring fluid pressure.

Positive On Shaft Excluder (POSE) – A Positive On Shaft Excluder is a separate piece from the rest of the front or rear seal used to keep out dust / debris.

Power – Power is a measure of the rate at which work is done. Compare with **Torque**.

Power Take Off (PTO) – Accessory output, usually from the transmission, used to power a hydraulic pump for a special auxiliary feature (garbage packing, lift equipment, etc).

Pulse Width Modulation (PWM) – The time that an actuator, such as an injector, remains energized.

Random Access Memory (RAM) – Computer memory that stores information. Information can be written to and read from RAM. Input information (current engine speed or temperature) can be stored in RAM to be compared to values stored in Read Only Memory (ROM). All memory in RAM is lost when the ignition switch is turned off.

Rated gross horsepower – Engine gross horsepower at rated speed as declared by the manufacturer. (SAE J1995 JUN90)

Rated horsepower – Maximum brake horsepower output of an engine as certified by the engine manufacturer. The power of an engine when configured as a basic engine. (SAE J1995 JUN90)

Rated net horsepower – Engine net horsepower at rated speed as declared by the manufacturer. (SAE J1349 JUN90)

Rated speed – The speed, as determined by the manufacturer, at which the engine is rated. (SAE J1995 JUN90)

Rated torque – Maximum torque produced by an engine as certified by the manufacturer.

Ratiometric Voltage – In a Micro Strain Gauge (MSG) sensor pressure to be measured exerts force on a pressure vessel that stretches and compresses to change resistance of strain gauges bonded to the surface of the pressure vessel. Internal sensor electronics convert the changes in resistance to a ratiometric voltage output.

Read Only Memory (ROM) – Computer memory that stores permanent information for calibration tables and operating strategies. Permanently stored information in ROM cannot be changed or lost by turning the engine off or when ECM power is interrupted.

Reference voltage (V_{REF}) – A 5 volt reference supplied by the ECM to operate the engine sensors.

Reserve capacity – Time in minutes that a fully charged battery can be discharged to 10.5 volts at 25 amperes.

Signal ground – The common ground wire to the ECM for the sensors.

Speed Control Command Switches (SCCS) – A set of switches used for cruise control, Power Take Off (PTO), and remote hand throttle system.

Steady state condition – An engine operating at a constant speed and load and at stabilized temperatures and pressures. (SAE J215 JAN80)

Strategy – A plan or set of operating instructions that the microprocessor follows for a desired goal. Strategy is the computer program itself, including all equations and decision making logic. Strategy is always stored in ROM and cannot be changed during calibration.

Stroke – Stroke is the movement of the piston from Top Dead Center (TDC) to Bottom Dead Center (BDC).

Substrate – Material that supports the washcoating or catalytic materials.

Sulfur dioxide (SO_2) – Sulfur dioxide is caused by oxidation of sulfur contained in fuel.

System restriction (air) – The static pressure differential that occurs at a given air flow from air entrance through air exit in a system. Usually measured in inches (millimeters) of water. (SAE J1004 SEP81)

Tachometer output signal – Engine speed signal for remote tachometers.

Thermistor – A semiconductor device. A sensing element that changes resistance as the temperature changes.

Thrust load – A thrust load pushes or reacts through a bearing in a direction parallel to the shaft.

Top Dead Center (TDC) – The uppermost position of the piston during the stroke.

Torque – A force having a twisting or turning effect. For a single force, the cross product of a vector from some reference point to the point of application of the force within the force itself. Also known as moment of force or rotation moment. Torque is a measure of the ability of an engine to do work.

Truck Computer Analysis of Performance and Economy (TCAPE) – Truck Computer Analysis of Performance and Economy is a computer program that simulates the performance and fuel economy of trucks.

Turbocharger – A turbine driven compressor mounted to the exhaust manifold. The turbocharger increases the pressure, temperature and density of intake air to charge air.

Variable capacitance sensor – A variable capacitance sensor is measures pressure. The pressure forces a ceramic material closer to a thin metal disc in the sensor, changing the capacitance of the sensor.

Vehicle Electronic System Programming System – The computer system used to program electronically controlled vehicles.

Vehicle Retarder Enable/Engage – Output from the ECM to a vehicle retarder.

Vehicle Speed Sensor (VSS) – Normally a magnetic pickup sensor mounted in the tailshaft housing of the transmission, used to indicate ground speed.

Viscosity – The internal resistance to the flow of any fluid.

Viscous fan – A fan drive that is activated when a thermostat, sensing high air temperature, forces fluid through a special coupling. The fluid activates the fan.

Volt (v) – A unit of electromotive force that will move a current of one ampere through a resistance of one Ohm.

Voltage – Electrical potential expressed in volts.

Voltage drop – Reduction in applied voltage from the current flowing through a circuit or portion of the circuit current multiplied by resistance.

Voltage ignition – Voltage supplied by the ignition switch when the key is ON.

Washcoat – A layer of alumina applied to the substrate in a monolith-type converter.

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Electronic Variable Response Turbocharger

Table 42

Max. turbine shaft axial end play	0.091 mm (0.0036 in)
Max. turbine shaft radial shaft movement (play)	0.5 mm (0.02 in)

Manifolds and Exhaust Gas Recirculation (EGR)

Table 43

Exhaust Manifold	
Maximum allowable clearance (cold)	0.0762 mm (0.003 in)
Intake Manifold	
Maximum allowable warpage	Between ports: 0.13 mm (0.005 in) Total: 0.25 mm (0.010 in)

Cylinder Head and Valve Train

Table 44 Cylinder Head and Valve Train

Exhaust Valves	
Stem diameter	6.947 - 6.965 mm (0.2735 - 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 (min.)	1.35 mm (0.053 in)
Valve recession in head	0.50 ± 0.18 mm (0.020 ± 0.007 in)
Intake Valves	
Stem diameter	6.947 - 6.965 mm (0.2735 - 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 (min.)	1.40 mm (0.055 in)
Valve recession in head	0.50 ± 0.18 mm (0.020 ± 0.007 in)
Cylinder Heads	
Valve guide inside diameter	7.003 - 7.029 mm (0.276 - 0.277 in)
Valve guide bore runout	0.05 mm (0.002 in)

Table 44 Cylinder Head and Valve Train (cont.)

Valve guide taper (max.)	0.10 mm (0.004 in)
Valve seat width (int.)	1.80 - 2.56 mm (0.071 - 0.101 in)
Valve seat width (exh.)	1.48 - 2.24 mm (0.058 - 0.088 in)
Valve seat angle (int.)	30.0°
Valve seat angle (exh.)	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 - 0.68 mm (0.0126 - 0.0268 in)
Valve Spring:	
Free length	51.96 mm (2.045 in)
Solid height	36.1 mm (1.42 in)
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.	
Push Rods	
Runout (max.)	0.25 mm (0.01 in)

Front Cover, Vibration Damper, and Gerotor Oil Pump

Table 45

Vibration Damper	
Face runout (max.)	0.635 mm (0.025 in)
Rubber bulging (max.)	1.5 mm (0.060 in)
Lubricating Oil Pump	
Type	Gerotor
Drive	Crankshaft
Location	Gerotor oil pump housing
Pressure Regulating Valve:	
Pressure, low idle (min @ 110 °C (230 °F) oil temp.)	69 kPa (10 psi)
Pressure, high idle (min @ 110 °C (230 °F) oil temp.)	276 kPa (40 psi)
Discharge pressure (2,500 rpm)	483 - 621 kPa (70 - 90 psi)
End clearance (inner and outer rotor to housing)	0.02 - 0.08 mm (0.001 - 0.003 in)
Radial clearance (between outer rotor and housing)	0.15 - 0.28 mm (0.006 - 0.011in)
Thermostat	
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 - 91 °C (188 - 196 °F)
Full-open temperature, 8 mm (0.315 in) stroke	104 °C (219 °F)

Connecting Rods and Pistons

Table 46

Connecting Rods	
Connecting rod length (center to center)	176 mm (6.929 in)
Bushing bore diameter (pin end)	36.98 - 37.02 mm (1.456 - 1.457 in)
Piston pin bushing inside diameter	34.0140 - 34.0215 mm (1.3391 - 1.3394 in)
Material	I-Beam Section - Powdered
Bearing bore diameter (crankshaft end)	72.987 - 73.013 mm (2.8735 - 2.8745 in)
Bearing bore maximum out-of-round	0.013 mm (0.0005 in)
Bearing bore maximum taper per 25 mm (1 in)	0.013 mm (0.0005 in)
Connecting rod bearing inside diameter	69.027 - 69.077 mm (2.7176 - 2.7196 in)
Connecting rod bearing running clearance (diameter)	0.0203 - 0.0837 mm (0.0008 - 0.0033 in)
Connecting rod side clearance	0.3 - 0.6 mm (0.012 - 0.024 in)
Weight (complete rod without bearing)	1201.5 - 1215.5 g (2.649 - 2.679 lb)
Pistons	
Material	Aluminum Alloy
Skirt diameter [1]	94.9460 - 94.9186 mm (3.737 - 3.738 in)
[1] Measure 14.68 mm (0.578 in) from bottom, at 90° to the piston pin. Measure only at room temperature of 19 - 21 °C (66 - 70 °F).	
Service Piston:	
Standard size	94.9460 - 94.9186 mm (3.737 - 3.738 in)
0.254 mm (0.010 in) oversize	95.1738 - 95.1992 mm (3.747 - 3.748 in)
0.508 mm (0.020 in) oversize	95.4278 - 95.4532 mm (3.757 - 3.758 in)
0.762 mm (0.030 in) oversize	95.6818 - 95.7072 mm (3.767 - 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	93.290 mm (3.7122 in)
Piston height above crankcase deck (protrusion)	0.900 mm (0.0354 in)
Piston skirt clearance (1 - 8)	0.0441 - 0.0909 mm (0.0017 - 0.0036 in)
Piston Pins	
Length	65.073 - 65.327 mm (2.5619 - 2.5719 in)
Diameter	33.9975 - 34.0025 mm (1.3385 - 1.3387 in)
Pin fit at room temperature of 19 - 21 °C (66 - 70 °F):	

Clearance in connecting rod (piston pin bushing)	0.0115 - 0.0240 mm (0.00045 - 0.00094 in)
Clearance in piston	0.013 - 0.022 mm (0.0005 - 0.0009 in)
End clearance	0.24 mm (0.009 in)
Piston Rings	
Ring diameter (standard):	95 mm (3.74 in)
Fit in groove (side clearance in bore):	
Top compression	0.165 mm (0.0065 in)
Intermediate compression	0.051 - 0.102 mm (0.0020 - 0.0040 in)
Oil control	0.038 - 0.084 mm (0.0015 - 0.0033 in)
Ring gap in bore:	
Top compression	0.29 - 0.55 mm (0.011 - 0.021 in)
Intermediate compression	1.40 - 1.66 mm (0.055 - 0.065 in)
Oil control	0.24 - 0.50 mm (0.009 - 0.019 in)

Crankcase, Crankshaft / Bearings, Camshaft / Bushings

Table 47

Crankshaft	
Main Bearing Journal Diameter:	
Standard size	80.9873 - 81.0127 mm (3.188 - 3.150 in)
0.254 mm (0.010 in) undersize	80.7333 - 80.7587 mm (3.178 - 3.140 in)
0.508 mm (0.020 in) undersize	80.4793 - 80.5047 mm (3.168 - 3.130 in)
0.762 mm (0.030 in) undersize	80.2253 - 80.2507 mm (3.158 - 3.120 in)
Main bearing thrust face maximum runout	0.051 mm (0.002 in)
Oil seal journal maximum runout	0.025 mm (0.001 in)
Vibration damper mounting area maximum runout	0.05 mm (0.002 in)
Flywheel mounting surface maximum runout	0.05 mm (0.002 in)
Main bearing to crankshaft running clearance	0.020 - 0.086 mm (0.0008 - 0.0034 in)
Connecting Rod Journal Diameter:	
Standard size	68.99 - 69.01 mm (2.716 - 2.717 in)
0.254 mm (0.010 in) undersize	68.73 - 68.75 mm (2.706 - 2.707 in)
0.508 mm (0.020 in) undersize	68.48 - 68.50 mm (2.696 - 2.697 in)
0.762 mm (0.030 in) undersize	68.23 - 68.25 mm (2.686 - 2.687 in)
Crankshaft end play (max.)	0.222 mm (0.0087 in)
Camshaft	
Bearing journal diameter (all journals)	61.987 - 62.013 mm (2.440 - 2.441 in)
Bearing inside diameter	62.05 - 62.14 mm (2.443 - 2.446 in)
Journal/bushing running clearance	0.037 - 0.153 mm (0.0015 - 0.0060 in)
Camshaft end play	0.051 - 0.211 mm (0.002 - 0.008 in)
Camshaft gear backlash	0.179 - 0.315 mm (0.007 - 0.012 in)
Maximum permissible cam lobe wear	0.51 mm (0.02 in)
Camshaft thrust plate thickness	3.589 - 3.649 mm (0.1413 - 0.1436 in)
Camshaft lobe lift (max.):	
Intake	5.744 mm (0.2261 in)
Exhaust	5.832 mm (0.2296 in)
Valve timing no. 1 cylinder (top of lobe):	
Intake open	7.22° BTDC
Intake closed	34.66° ABDC

Exhaust open	45.12° BBDC
Exhaust closed	6.24° ATDC

Table 48

Crankcase	
Crankcase deck flatness	**Per 51 mm (2 in):** 0.025 mm (0.001 in) **Total:** 0.10 mm (0.004 in)
Crankcase main bearing bore diameter	85.99 - 86.01 mm (3.3854 - 3.3862 in)
Crankcase cam bearing bore diameter	65.98 - 66.02 mm (2.597 - 2.599 in)
Valve tappet bore diameter	23.439 - 23.477 mm (0.9228 - 0.9243 in)
Valve tappet outside diameter	23.391 - 23.411 mm (0.9209 - 0.9217 in)
Cylinder bore diameter	94.999 - 95.001 mm (3.7401 - 3.7402 in)
Cylinder bore maximum out-of-round	0.05 mm (0.002 in)
Cylinder stroke	105 mm (4.13 in)
Rear oil seal face runout (T.I.R. maximum)	0.38 mm (0.015 in)
Front oil seal face runout (T.I.R. maximum)	0.25 mm (0.010 in)
Main Bearings:	
Type	Precision replaceable
Material	Steel backed copper/lead
Number of main bearings	5
Thrust applied at	No. 4 main upper
Lower crankcase	Four bolts per main journal
Coolant heater element rating	1,000 watts, 120 volts

Oil Cooler and Oil Filter

Table 49

Oil Cooler	
Type	Full-flow, fin bundle
Location	Engine valley (forward)
Oil Filter	
Type	Cartridge, full flow - disposable
Location	Front, oil cooler mounted
Filter bypass location	Oil filter return tube assembly
Oil filter bypass opening pressure	220 ± 41 kPa (32 ± 6 psi)

Engine Electrical

Table 50

Glow Plugs	
Location	Cylinder Head
Quantity	8
Camshaft Position (CMP) Sensor	
Location	Crankcase (left side)
Crankshaft Position (CKP) Sensor	
Location	Crankcase (right side)
Operating actuator speed	15 to 2,000 rpm
Operating temperature	-40 °C to +130 °C (-40 °F to 266 °F)
Injection Pressure Regulator (IPR) Valve	
Operating temperature range	-40 °C to 125 °C (-40 °F to 257 °F)
Maximum operating pressure	20.7 MPa (3,000 psi)

High Pressure Oil Pump

Table 51

Hydraulic Oil Pump	
Gear backlash	0.179 - 0.315 mm (0.007 - 0.0124 in)
Injection Control Pressure Regulator	
Operating pressure range	3.5 - 20.7 MPa (500 - 3,000 psi)
IPR valve cracking pressure	31 MPa (4,500 psi)
IPR valve maximum pressure	37 MPa (5,400 psi)

Fuel System

Table 52

Fuel Filter	
Type	10 micron with water separation
Normal fuel pressure (after fuel filter)	345 - 482 kPa (50 - 70 psi)
Fuel pressure in filter not to exceed	448 kPa @ 132 L/h (65 psi @ 35 gal/h)
Fuel Pressure Regulating Valve	
Valve opening pressure	351 ± 31 kPa (51 ± 4.5 psi)
Heater element activates	3.6 - 10.8 ºC (38.5 - 51.5 ºF)
Heater element deactivates	19.1 - 29.6 ºC (66.5 - 83.5 ºF)

Flywheel, Rear Cover, and Power Steering and Fuel Pump

Table 53

Flywheel	
Flywheel surface maximum runout (manual)	0.25 mm (0.010 in)
Flexplate ring gear TIR runout (automatic)	1.27 mm (0.050 in)
Rear Cover	
Rear cover face maximum runout	0.51 mm (0.020 in)
Power Steering / Fuel Pump Drive Gear	
Backlash:	
Crankshaft to idler gear	0.173 - 0.288 mm (0.0068 - 0.0113 in)
Idler gear to pump drive gear	0.173 - 0.288 mm (0.0068 - 0.0113 in)
Power Steering Pump	
Maximum operating pressure	17.5 MPa (2,538 psi)

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General Torque Guidelines

CAUTION: To prevent engine damage, do not substitute fasteners. Original equipment standard hardware is defined as Class 10.9 metric or Grade 8 standard coarse thread bolts and nuts and hardened flat washers (Rockwell “C" 38-45), all phosphate coated.

The standard torque charts provide the tightening torque for general purpose applications using original equipment standard hardware as listed in the Parts Catalog for the application involved.

Table 54 Standard Torques – Pipe Thread

Thread Size	Torque[1]
1/8 in NPT	11 N·m (90 lbf·in)
1/4 in NPT	14 N·m (120 lbf·in)
3/8 in NPT	20 N·m (180 lbf·in)
1/2 in NPT	34 N·m (25 lbf·ft)
3/4 in NPT	41 N·m (30 lbf·ft)

[1] Tolerances are ±10% of nominal value.

Table 55 Standard Torques — Class 10.9 Metric Bolts and Studs

Thread Diameter	Thread Pitch (mm/thread)	Torque[1]
6 mm	1	13 N·m (115 lbf·in)
8 mm	1.25	31 N·m (23 lbf·ft)
10 mm	1.5	62 N·m (45 lbf·ft)
12 mm	1.75	107 N·m (79 lbf·ft)
14 mm	2	172 N·m (127 lbf·ft)
15 mm	2	216 N·m (159 lbf·ft)
16 mm	2	266 N·m (196 lbf·ft)
18 mm	2.5	368 N·m (272 lbf·ft)
20 mm	2.5	520 N·m (384 lbf·ft)

[1] Tolerances are ±10% of nominal value.

Table 56 Standard Torques — Class 12.9 Metric Bolts and Studs

Thread Diameter	Thread Pitch (mm/thread)	Torque[1]
6 mm	1	15 N·m (132 lbf·in)
8 mm	1.25	36 N·m (27 lbf·ft)
10 mm	1.5	72 N·m (53 lbf·ft)
12 mm	1.75	126 N·m (93 lbf·ft)
14 mm	2	201 N·m (148 lbf·ft)
15 mm	2	252 N·m (186 lbf·ft)
16 mm	2	311 N·m (230 lbf·ft)
18 mm	2.5	430 N·m (317 lbf·ft)
20 mm	2.5	608 N·m (448 lbf·ft)

[1] Tolerances are ±10% of nominal value.

DESIGNATION		MATERIAL TYPE	THERMAL TREATMENT	HEAD MARKING	
INTERNATIONAL CLASS	ISO R 898 I			PREFFERED	OPTIONAL
5.8	5.8	LOW OR MEDIUM CARBON STEEL	NON REQUIRED		
8.8	8.8	MEDIUM CARBON OR MEDIUM CARBON ALLOY STEEL OR LOW CARBON BORON STEEL	QUENCH AND TEMPERED		
9.8	--				
10.9	10.9				

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Figure 549 Classification and Identification – Metric Fasteners

INTERNATIONAL DESIGNATION	TYPE OF MATERIAL	THERMAL TREATMENT	HEAD MARKING	
CLASS	METRIC FASTENERS		PREFERRED	OPTIONAL
10.9R	MEDIUM CARBON, MEDIUM CARBON ALLOY STEEL	QUENCH AND TEMPERED, ROLL THREADED AFTER HEAT TREATMENT		
12.9	MEDIUM CARBON ALLOY STEEL	QUENCH AND TEMPERED		
12.9R		QUENCH AND TEMPERED ROLL THREADED AFTER HEAT TREATMENT		

d31210

Figure 550 Classification and Identification – Special Use Fasteners

Many conditions affect torque and the results of torque applications. The major purpose in tightening a fastener to a specified torque is to obtain tension in the fastener (i.e., bolt, nut, etc.), which in turn develops a clamping load which exceeds any possible loading imposed on parts due to engine rpm or vibration.

New phosphate coated fasteners do not require oil lubrication during assembly and torque application. Reused fasteners (even if originally phosphate coated) do require oil lubrication to the threads and under head area for proper torque application.

Threads that are dry, excessively rough, battered or filled with dirt require considerable effort just to rotate. Then when the clamping load is developed or the bolt tension is applied, the torque reading mounts rapidly (due to thread friction) to the specified torque value. However, the desired bolt tension and maximum clamping effect is not achieved. This condition can lead to failure of the fastener to maintain component integrity. The proper bolt tension and clamping effect can never be attained if the fastener is dry. The fastener threads must have a film of clean lubricant (engine oil) to be considered lubricated.

Special Torque

Mounting Engine On Stand

Table 57

Oil pan drain plug	25 ± 5 N·m (18 ± 4 lbf·ft)

Electronic Variable Response Turbocharger

Table 58

Air inlet duct hose clamp	4 - 5 N·m (36 - 48 lbf·in)
Turbocharger to mounting bracket bolts	31 ± 4 N·m (23 ± 3 lbf·ft)
Turbocharger exhaust adapter V-clamp	12 N·m (108 lbf·in)

Manifolds and Exhaust Gas Recirculation (EGR)

Table 59

Intake manifold, M6 x 95 flange bolts	11 ± 1 N·m (96 ± 10 lbf·in) (Figure 552)
Intake heat shield, M6 nut	11 ± 3 N·m (96 ± 24 lbf·in)
Exhaust manifold flange bolts*	38 ± 4 N·m (28 ± 3 lbf·ft) (Figure 551)
EBP tube assembly*	30 ± 1 N·m (22 ± 1 lbf·ft)
EBP sensor tube fitting*	14 - 15 N·m (120 - 132 lbf·in)
Shielded exhaust tube to exhaust manifold (left side)*	27 ± 4 N·m (20 ± 3 lbf·ft)
Shielded tube exhaust to right side exhaust tube*	27 ± 4 N·m (20 ± 3 lbf·ft)
Exhaust tube to exhaust manifold (right side)*	27 ± 4 N·m (20 ± 3 lbf·ft)
Turbocharger exhaust adapter V-clamp	12 N·m (108 lbf·in)
EGR cooler V-band clamp	6 N·m (48 lbf·in)

*Apply antiseize compound to bolt threads before assembly.

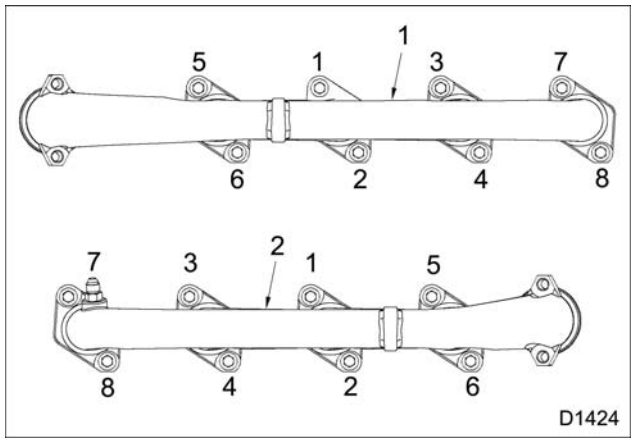

Figure 551 Tightening sequence for exhaust manifold mounting bolts

1. Right side exhaust manifold
2. Left side exhaust manifold

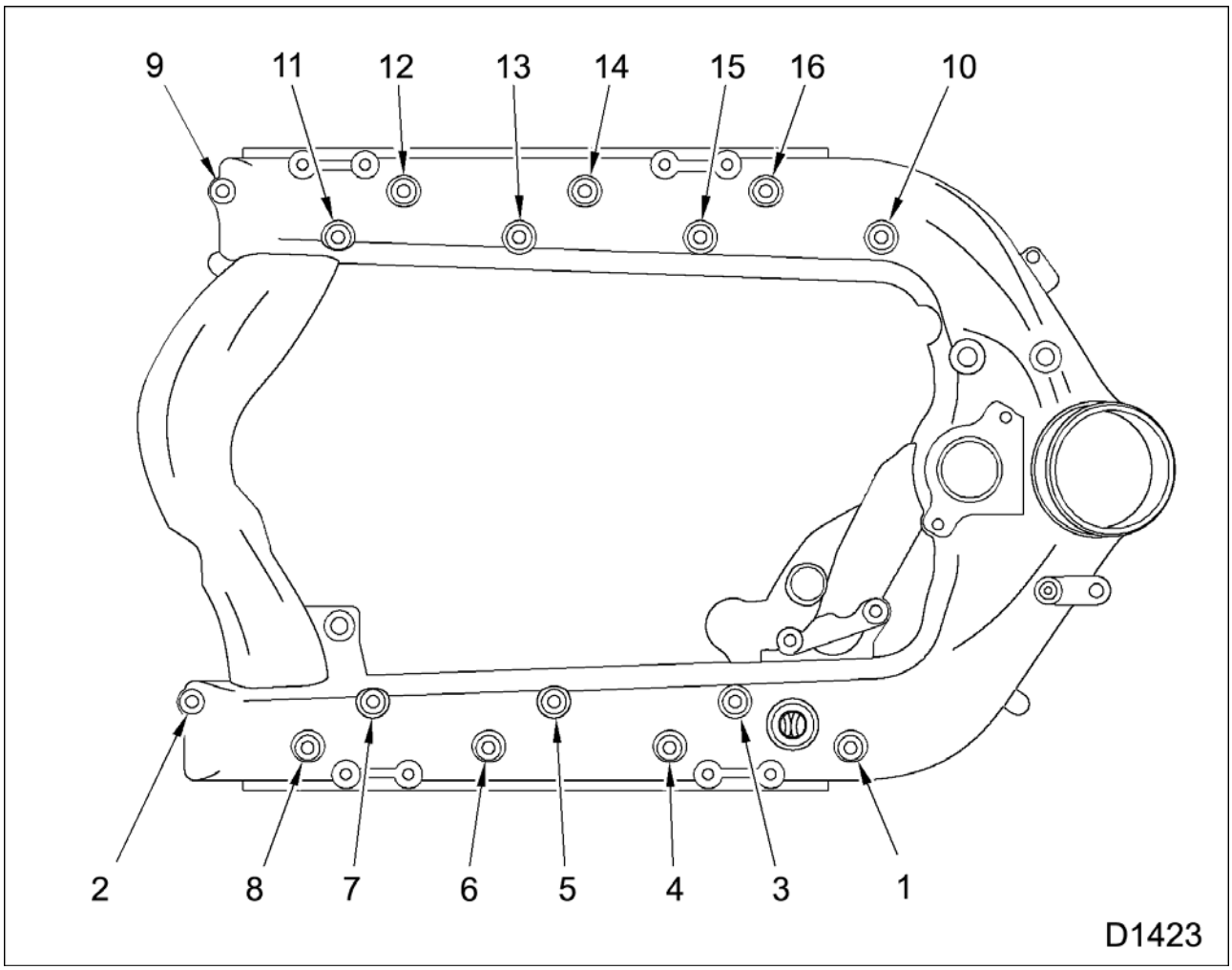

Figure 552 Tightening sequence for intake manifold mounting bolts

Cylinder Head and Valve Train

Table 60

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)
Cylinder head bolt torque and sequence	(Cylinder Head Torque Instructions and Tightening Sequence, page 125)
Fuel injector hold down 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 1 x 25)	13 N·m (120 lbf·in) (Figure 553)
Crankcase to head tube assembly (M14 x 1.5)	45 N·m (33 lbf·ft)
Oil rail check valve fitting (M14 x 1.5)	34 N·m (25 lbf·ft)
Plug assembly w/o-ring (oil supply) (M14 x 1.5)	45 N·m (33 lbf·ft)
Oil rail vent plugs (bleed port) (M8 x 1)	10 N·m (90 lbf·in)
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)
Fuel rail plug (M12)	36 ± 1 N·m (27 ± 1 lbf·ft)
Rear heat shield (M10 x 1.5 x 16)	49 ± 5 N·m (36 ± 4 lbf·ft)

Oil Rail Torque Sequence

1. Press rail down until seated. Thread remaining bolts finger tight.
2. Torque bolts to the special torque in the sequence below.

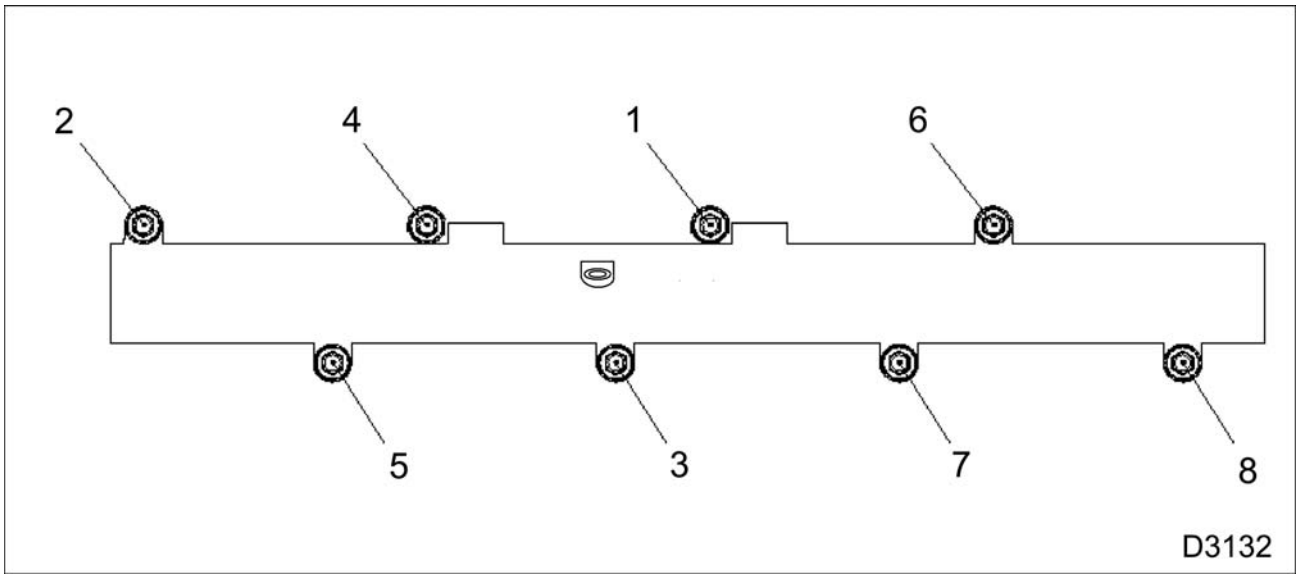

Figure 553 Torque sequence for oil rail bolts

Torque Sequence for Oil Rail Bolts

A. Press rail down until seated. Thread remaining bolts finger tight.

B. Torque bolts to the special torque in the sequence above.

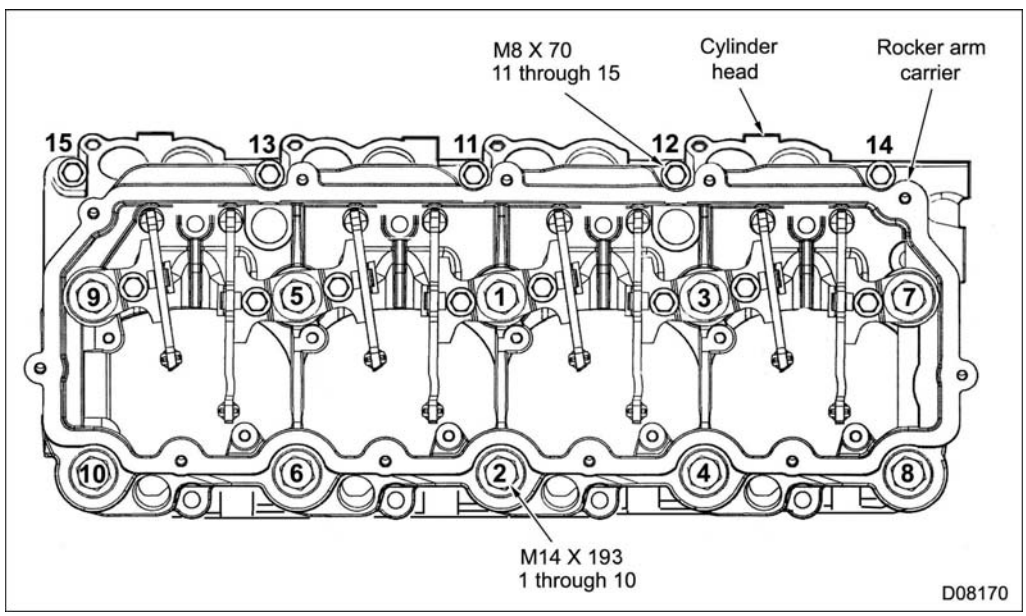

Figure 554 Tightening sequence for cylinder head mounting bolts

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

M14 x 193 Cylinder Head Mounting Bolt Tightening Sequence

1. Lightly lubricate all bolts and torque 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 Cylinder Head Mounting Bolt Tightening Sequence

1. Install all M8 bolts and torque in the sequence numbered 11 through 15 to 24 N·m (18 lbf·ft).
2. Torque all M8 bolts in the sequence numbered 11 through 15 to 31 N·m (23 lbf·ft).
3. M8 x 70 torque sequence complete.

Front Cover, Vibration Damper, and Gerotor Oil Pump

Table 61

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	New bolts only: 68 N·m (50 lbf·ft) + 90° rotation. (Figure 555)

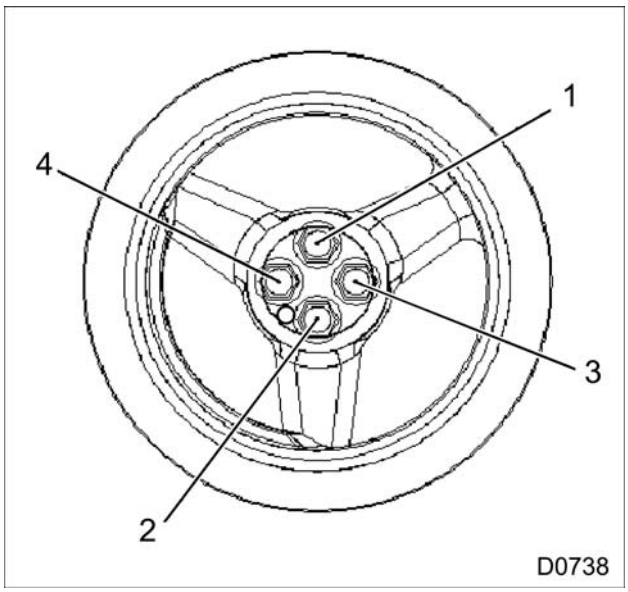

Figure 555 Vibration damper torque sequence

Connecting Rods and Pistons

Table 62

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

Crankcase, Crankshaft/Bearings, Camshaft/Bushings

Table 63

Lower crankcase main bearing cap bolts	See tightening procedure and sequence (Figure 556)
Lower crankcase outer bolts (M8 x 30), standard torque	(Figure 557)
Coolant heater element	41 N·m (30 lbf·ft)

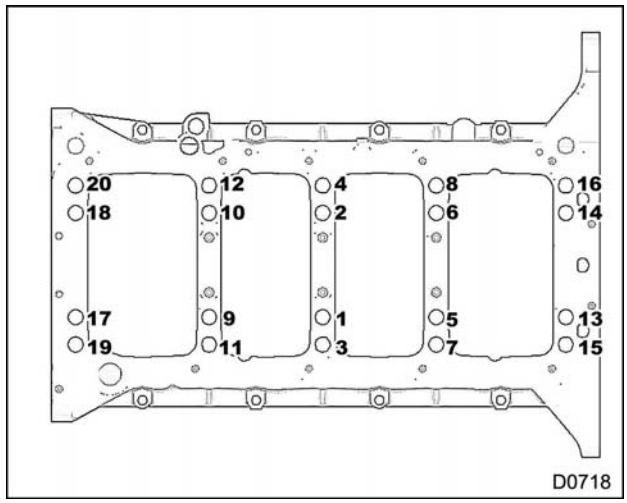

Figure 556 Tightening sequence for lower crankcase main bearing bolts

Lower Crankcase Main Bearing Bolt Tightening Procedure

1. Torque bolts to 122 N·m (90 lbf·ft) in the numbered sequence shown in the illustration.
2. Torque bolts again to 163 N·m (120 lbf·ft) in the numbered sequence shown in the illustration.
3. Torque bolts finally to 231 N·m (170 lbf·ft) in the numbered sequence shown in the illustration.

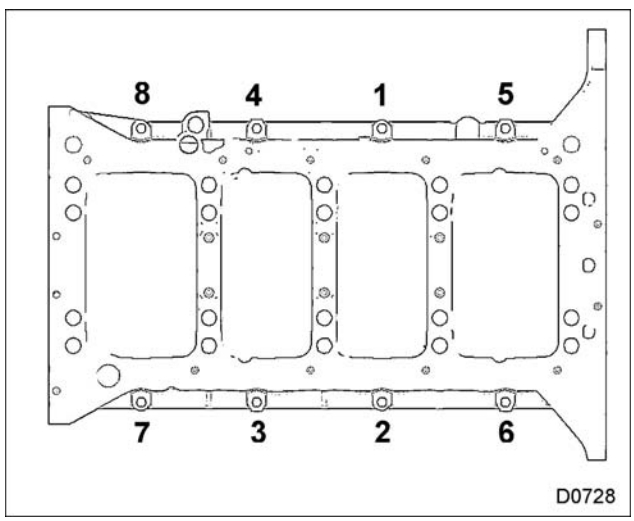

Figure 557 Tightening sequence for lower crankcase outer bolts (standard torque)

Oil Cooler and Oil Filter

Table 64

EGR cooler coolant supply port cover (M6 x 25)	10 N·m (85 lbf·in)
Oil filter base bolts (M8 x 23)	23 N·m (17 lbf·ft)
Oil filter base bolts (M6 x 25)	10 N·m (85 lbf·in)
Lock screw (M5 x 18)	6.8 N·m (60 lbf·in)
Oil cooler mounting bolts (M8 x 30)	10 N·m (85 lbf·in)
Oil cooler mounting bolts (M8 x 85)	22 ± 2 N·m (17 ± 1 lbf·ft)
Oil filter return tube bolt	New base plate: 6 N·m (50 lbf·in) Reinstallation: 3 N·m (23 lbf·in)
Oil filter cap	25 N·m (18 lbf·ft)

Engine Electrical

Table 65

Exhaust Back Pressure (EBP) sensor	12 + 2/-3 N·m (108 ± 12 lbf·in)
Engine Coolant Temperature sensor (ECT)	12 ± 2 N·m (108 ± 12 lbf·in)
Engine Oil Temperature sensor (EOT)	12 ± 2 N·m (108 ± 12 lbf·in)
Engine Oil Pressure sensor (EOP)	12 ± 2 N·m (108 ± 12 lbf·in)
Glow plug relay nuts	19 N·m (168 lbf·in)
Injection Control Pressure (ICP) sensor	12 ± 2 N·m (108 ± 18 lbf·in)
Injection Pressure Regulator (IPR)	50 ± 5 N·m (37 ± 4 lbf·ft)
Manifold Absolute Pressure (MAP) sensor	12 ± 2 N·m (108 ± 12 lbf·in)
Manifold Air Temperature (MAT) sensor	18 + 2/-3 N·m (156 ± 24 lbf·in)

High-pressure Oil Pump

Table 66

Hydraulic pump cover bolts	11 N·m (96 lbf·in)
Hydraulic oil pump drive gear bolt	129 ± 3 N·m (95 ± 2 lbf·ft)
HP discharge tube assembly bolts (M6 x 1.0 x 25)	11 N·m (96 lbf·in)
Injection Control Pressure (ICP) sensor	12 ± 2 N·m (108 ± 18 lbf·in)
Injection Pressure Regulator (IPR)	50 ± 5 N·m (37 ± 4 lbf·ft)
Rear heat shield, (M6 x 1.0 x 12)	11 ± 3 N·m (96 ± 24 lbf·in)
Rear heat shield, (M10 x 1.5 x 16)	49 ± 5 N·m (36 ± 4 lbf·ft)

Fuel System

Table 67

Fuel supply tube assembly at filter	41 ± 4 N·m (30 ± 3 lbf·ft)
Fuel return tube assembly at filter	25 ± 2 N·m (19 ± 2 lbf·ft)
Left and right cylinder head supply tubing at filter	25 ± 2 N·m (18 ± 2 lbf·ft)
Banjo bolt, 12 mm	38 ± 4 N·m (28 ± 3 lbf·ft)
Plug assembly, 12 mm (back of cylinder head)	27 ± 1 N·m (20 ± 1 lbf·ft)

Flywheel, Rear Cover, and Power Steering and Fuel Pump

Table 68

Flywheel mounting bolts, new bolts only	94 N·m (69 lbf·ft) (Figure 558)
Flexplate mounting bolts, new bolts only	94 N·m (69 lbf·ft) (Figure 558)

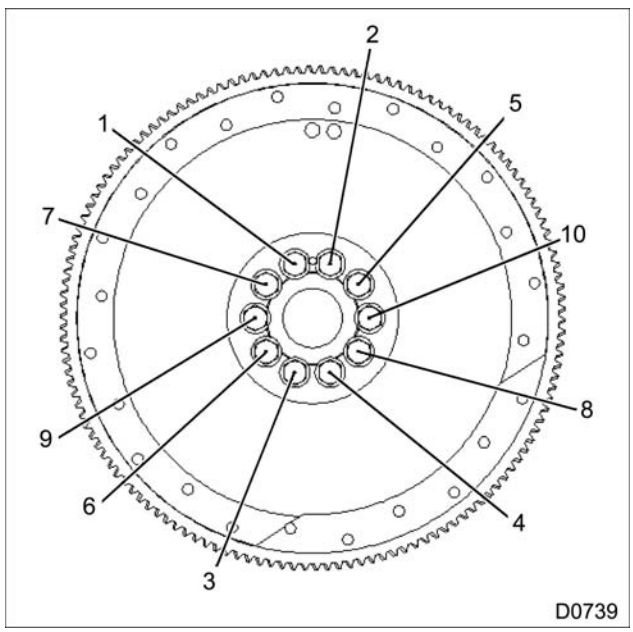

Figure 558 Typical Flywheel / Flexplate Torque Sequence

In-chassis Procedures

Table 69 Branch Tube Assembly

Bolts for branch tube mounting blocks	13 N·m (115 lbf·in)
Bolts for branch tube adapter	13 N·m (115 lbf·in)
STC fitting	53 ± 4 N·m (39 ± 3 lbf·ft)
Bolts for heat shield (M8 x12)	13 N·m (115 lbf·in)
Bolt for heat shield (M10 x 16)	62 N·m (45 lbf·ft)
V-clamp for shielded exhaust tube	12 N·m (106 lbf·in)
Bolts for right exhaust tube (shielded exhaust tube connected) to right exhaust manifold (M8)	27 ± 4 N·m (20 ± 3 lbf·ft))
Bolts for rear engine mounts (M12 x 40)	107 N·m (79 lbf·ft)
Nut for bolt through rear engine mounts and chassis mounts (M16)	294 – 325 N·m (216 – 239 lbf·ft)
Bolts for starter motor (M10 x 40)	47 –58 N·m (35–43 lbf·ft)
Turbocharger exhaust clamp for turbocharger down pipe	25 – 10 N·m (4 – 6 lbf·ft)
Bolts for alternator and air conditioning compressor bracket (M10)	72 N·m (53 lbf·ft)
Bolts for air compressor bracket (M10 x 100)	72 N·m (53 lbf·ft)

Table of Contents

Special tools for the VT 365 engine can be ordered from the **SPX Corporation, 1- 800- 520-2584**.

Mounting Engine on Stand

Table 70

Tool Number	Description
ZTSE4507	Engine Stand Mounting Bracket

Electronic Variable Response Turbocharger

Table 71

Tool Number	Description
ZTSE4548	Intake Guard
ZTSE4581	Quick Release Tool
	Dial Indicator with Magnetic Base
ZTSE4610	Cap Kit (All)

Manifolds and Exhaust Gas Recirculation (EGR)

Table 72

Tool Number	Description
ZTSE4527	Intake Manifold Pressure Test Plates
ZTSE4543	EGR Valve Puller
ZTSE4544	Intake Manifold Pressure Test Plug (EGR Valve)
ZTSE4545	EGR Cooler Pressure Test Plates
ZTSE4554	Pressure Test Adaptor (intake)
ZTSE4559	Intake Port Covers (cylinder heads)
ZTSE4610	Cap Kit (All)
	Straightedge

Cylinder Head and Valve Train

Table 73

TOOL NUMBER	DESCRIPTION
ZTSE2241	Valve Spring Tester
ZTSE4299	Fuel Injector Rack Holder
ZTSE4398	Slide Hammer Kit
ZTSE4454	Quick Release Tool Kit
ZTSE4508	Bottoming tap (metric)
ZTSE4301	Fuel Injector Tip Cleaning Brush
ZTSE4523	Fuel Injector Holder Plastic Cups
ZTSE4524	Fuel Injector Hold Down Wrench
ZTSE4528	Injector Sleeve Remover
ZTSE4529	Injector Sleeve Installer
ZTSE43041	Injector Sleeve Brush
ZTSE4531	Glow Plug Sleeve Remover
ZTSE4532	Glow Plug Sleeve Installer
ZTSE4533	Glow Plug Sleeve Brush (nylon)
ZTSE4534	Cylinder Head Pressure Test Plate
ZTSE4535	Cylinder Head Lifting Bracket
ZTSE4539	Valve Spring Compressor
ZTSE4541	Fuel Gallery Cleaning Brush
ZTSE4577	Valve Guide Gauge Tool
ZTSE4581	Quick Release Tool
ZTSE4589	Glow Plug Sleeve Seat Wire Brush
Pt-7194	Dye Penetrant Kit
Obtain locally	Straightedge
Liquid Gasket (RTV) (6 oz. tube	1830858C1

Front Cover, Vibration Damper, and Gerotor Oil Pump

Table 74

Tool Number	Description
Obtain locally	Dial Indicator with Magnetic Base
ZTSE4517	Front Wear Sleeve Remover
ZTSE4516	Front Seal / Wear Sleeve Installer
ZTSE4587	Fan Wrench (pulley bolts)
ZTSE43972	Fan Hub Wrench (2 inch)
1830858C1	Liquid gasket (RTV) (6 oz. tube)
Obtain locally	Straightedge

Connecting Rods and Pistons

Table 75

Tool Number	Description
ZTSE4220	Piston Ring Expansion Pliers
ZTSE4513	Piston Gauge Pins (0.082 in)
ZTSE4514	Piston Ring Compressor (Cope)
	Dial Indicator with Magnetic Base
	Telescoping Gauge Set

Crankcase, Crankshaft/Bearings, Camshaft/Bushings

Table 76

Tool Number	Description
ZTSE2893A	Camshaft Bushing Kit.
ZTSE4349	Deglazing Hone (4 inch)
ZTSE4489	Camshaft Bushing Remover / Installer (expanding collet)
ZTSE4508	Head Bolt Bottoming Tap
ZTSE4511	Oil Gallery Cleaning Brush
ZTSE4512	Oil Gallery Plug Driver
ZTSE4519	Crankshaft Timing Tool
ZTSE4520	Accessory Drive Gear Puller
Obtain locally	Straightedge
Obtain locally	Dial Indicator with Magnetic Base
Obtain locally	Telescoping Gauge Set
Obtain locally	Cylinder Bore Gauge
Obtain locally	Loctite® #242
Liquid Gasket (RTV) (6 oz. tube)	1830858C1

Oil Cooler and Oil Filter

Table 77

Tool Number	Description
ZTSE4525	Oil Cooler Pressure Test Plate
ZTSE4557	Magnetic Cover

Engine Electrical

Table 78

Tool Number	Description
ZTSE4610	Cap Kit (All)

High-Pressure Oil Pump

Table 79

Tool Number	Description
ZTSE4557	Magnetic Cover
ZTSE4564	IPR Valve Removal Tool
ZTSE4581	Quick Release Tool
ZTSE4610	Cap Kit (All)
	Dial Indicator with Magnetic Base
1830858C1	Liquid gasket (RTV) (6 oz. tube)

Fuel System

Table 80

Tool Number	Description
ZTSE4541	Fuel Gallery Cleaning Brush
ZTSE4610	Cap Kit (All)

Flywheel, Rear Cover and Power Steering/Fuel Pump

Table 81

Tool Number	Description
ZTSE4515	Rear / Wear Sleeve Installer
ZTSE4518	Rear Wear Sleeve Removal Tool
ZTSE4719	Power Steering Idler Shaft Installation Tool
ZTSE4720	Crankshaft Secondary Flange Installation Studs
1830858C1	Liquid gasket (RTV) (6 oz. tube)
1847432C1	Loctite® 290 Sealant

In-chasiss Procedures

Table 82 Branch Tube Assembly

Description	TOOL NUMBER
No. 10 Quick Release Tool	ZTSE4581

Table 83 Rocker Arm

Description	TOOL NUMBER
Injector Connector Release Tool	ZTSE4650
Fuel Injector Hold Down Wrench	ZTSE4524
On-engine Valve Spring Compressor Tool	ZTSE4697

Photos of Essential Tools

Figure 559 “C” Type Valve Spring Compressor ZTSE1846

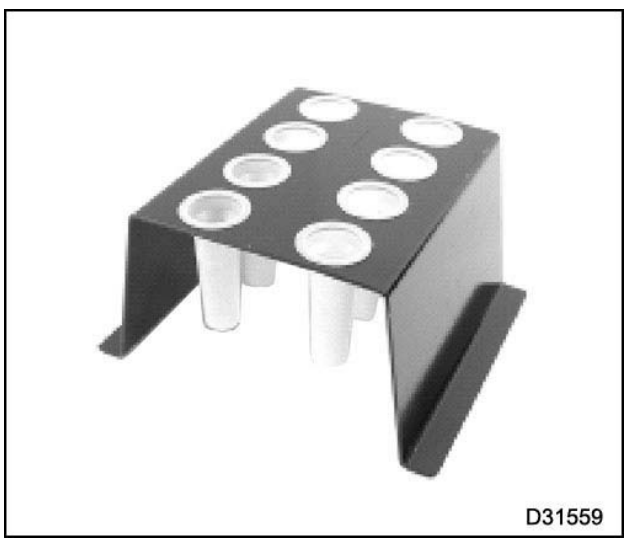

Figure 560 Fuel Injector Rack Holder ZTSE4299B

Figure 561 Side Hammer Kit 5/8 in ZTSE4398

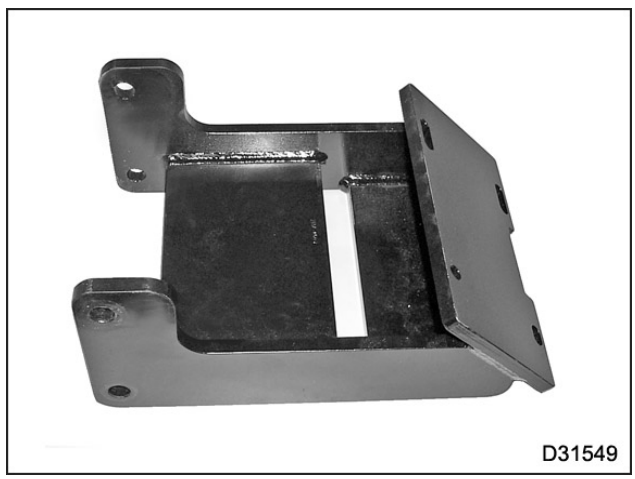

Figure 562 Engine Stand Mounting Bracket ZTSE4507

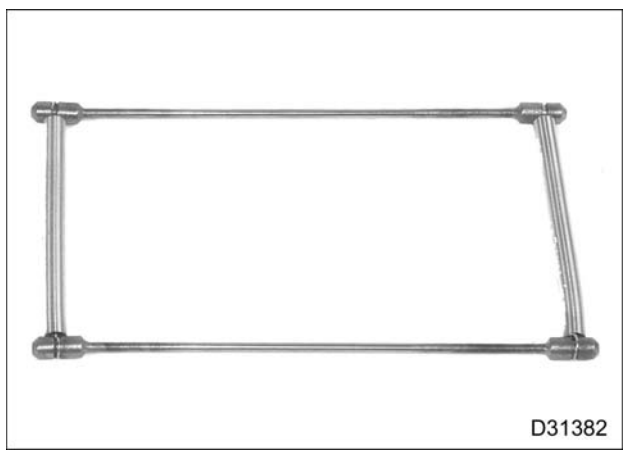

Figure 563 Piston Gauge Pins (0.082 in.) ZTSE4513

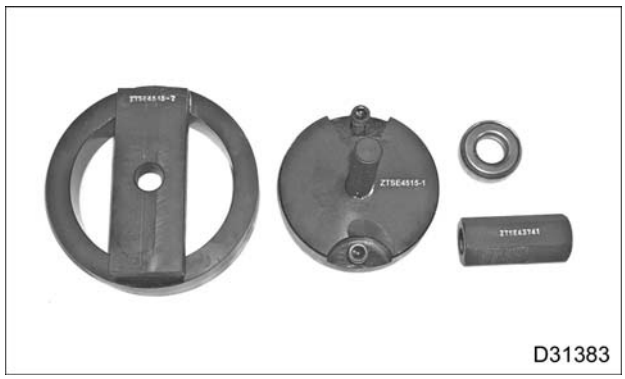

Figure 564 Crankshaft Rear Seal / Wear Sleeve Installer ZTSE4515

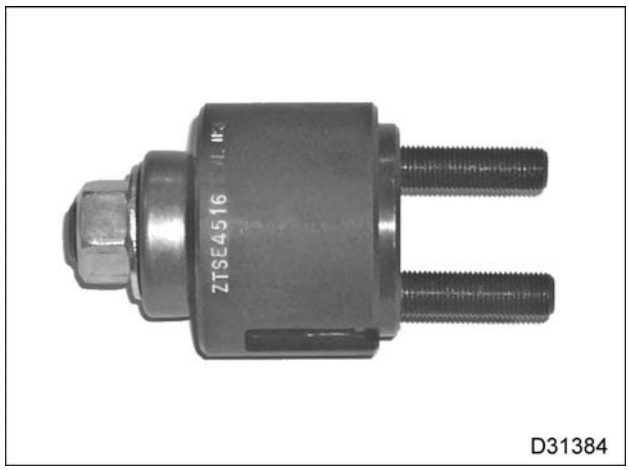

Figure 565 Front Seal Installer / Wear Sleeve Installer ZTSE4516

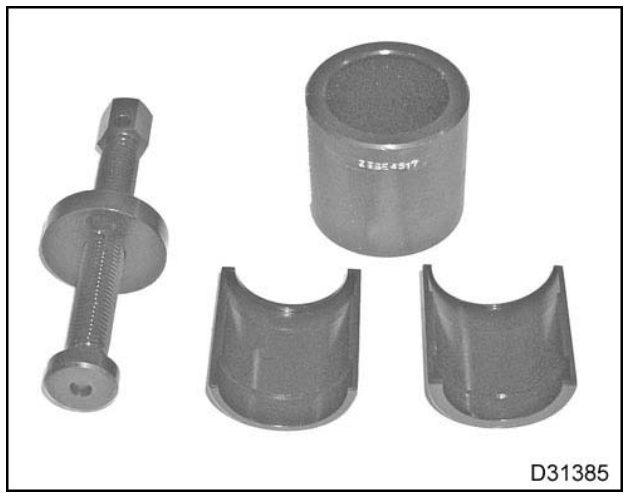

Figure 566 Front Wear Sleeve Remover ZTSE4517

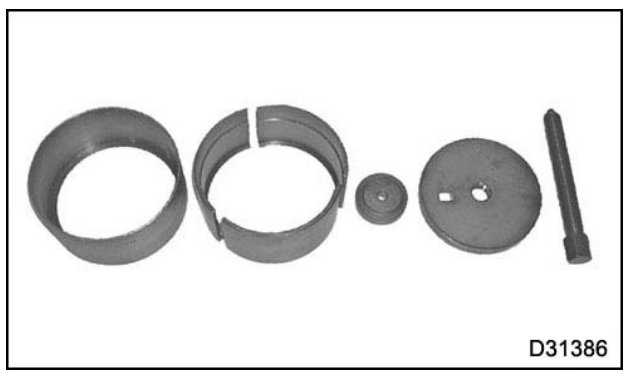

Figure 567 Crankshaft Rear Wear Sleeve Remover ZTSE4518

Figure 568 Crankshaft Timing Tool ZTSE4519

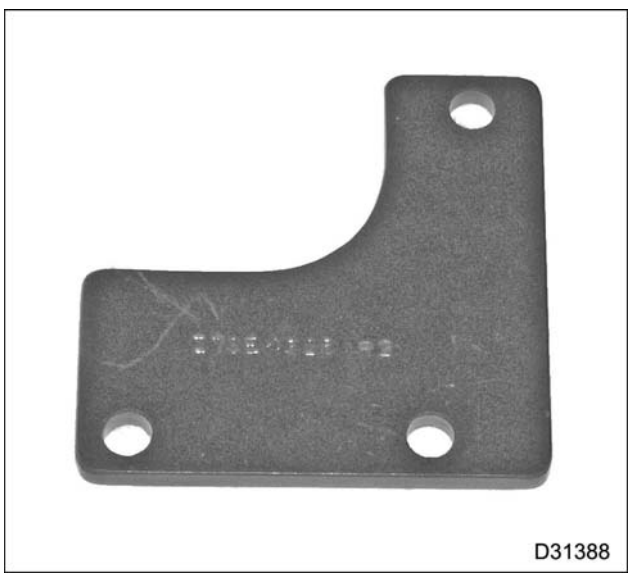

Figure 569 Oil Cooler Test Plate / Pressure Adapter ZTSE4525

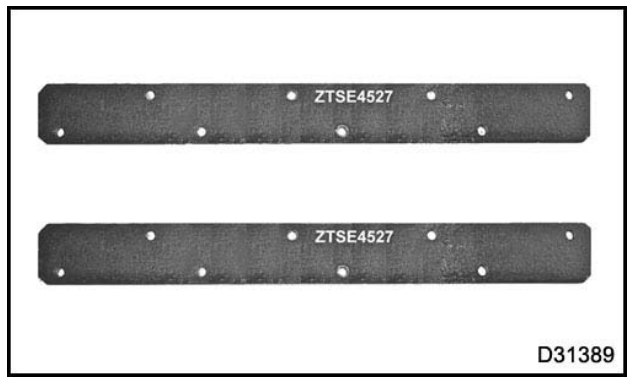

Figure 570 Intake Manifold Test Plates ZTSE4527

Figure 571 Injector Sleeve Remover ZTSE4528

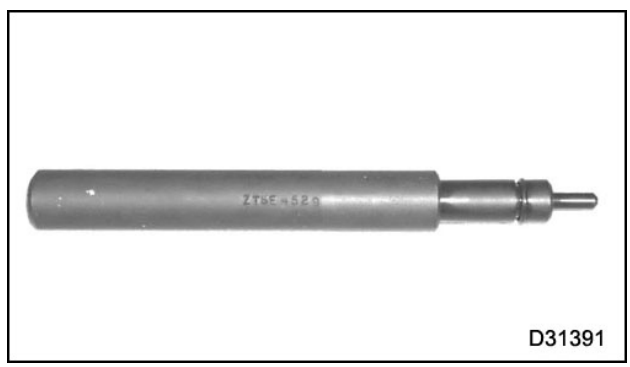

Figure 572 Injector Sleeve Installer ZTSE4529

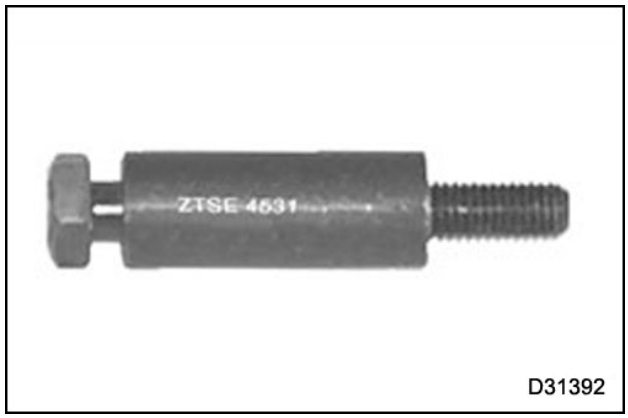

Figure 573 Glow Plug Sleeve Remover ZTSE4531

Figure 574 Glow Plug Sleeve Installer ZTSE4532

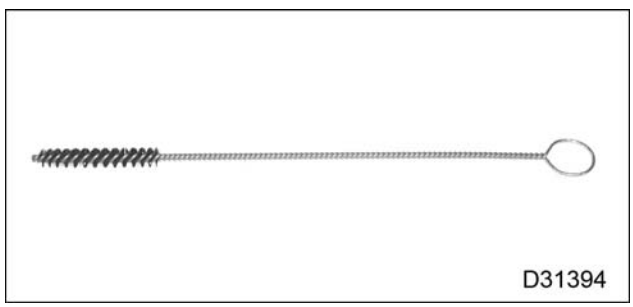

Figure 575 Glow Plug Sleeve Brush (nylon) ZTSE4533

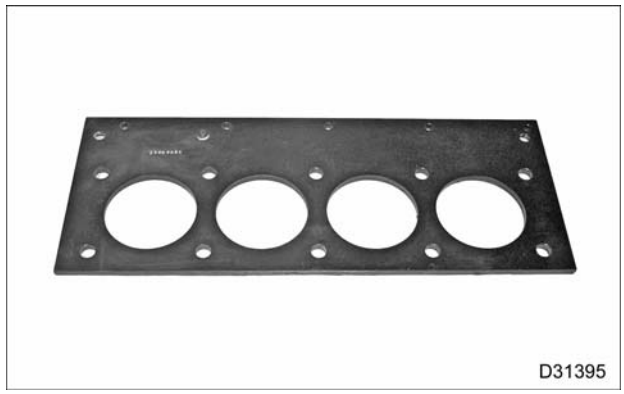

Figure 576 Cylinder Head Pressure Test Plate ZTSE4534

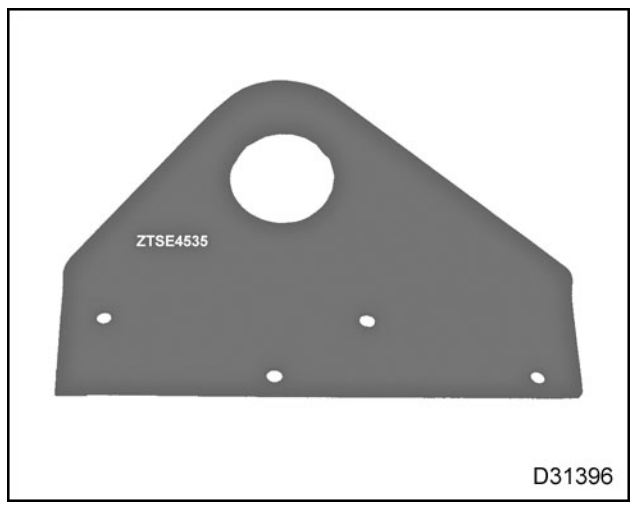

Figure 577 Cylinder Head Lifting Bracket ZTSE4535

Figure 578 EGR Valve Puller ZTSE4543

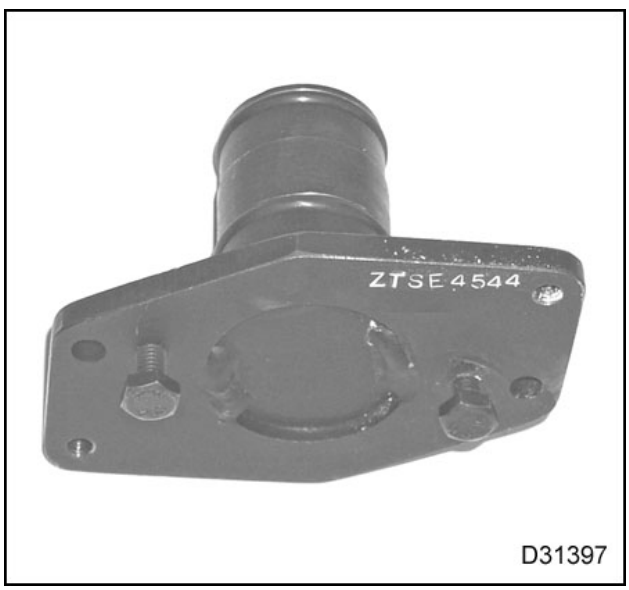

Figure 579 Intake Manifold Pressure Test Plug (EGR Valve) ZTSE4544

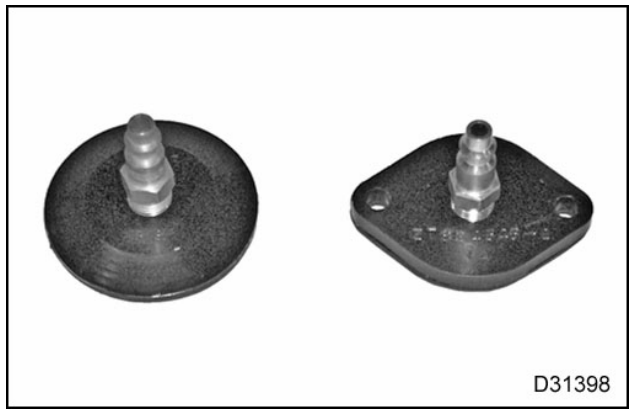

Figure 580 EGR Cooler Test Plates ZTSE4545

Figure 581 Intake Manifold Pressure Test Cap ZTSE4554

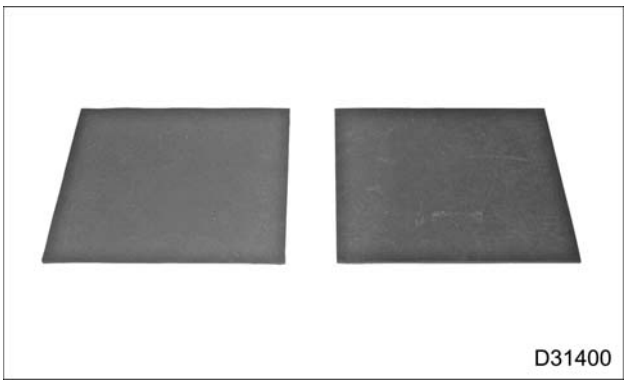

Figure 582 Oil Cooler Reservoir / High Pressure Pump Magnetic Covers ZTSE4557

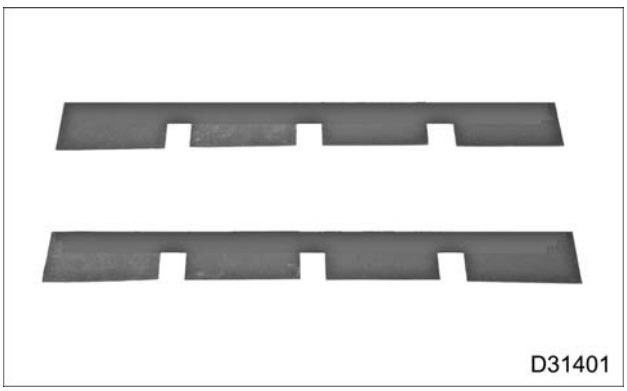

Figure 583 Magnetic Covers for Cylinder Head Intake Ports ZTSE4559

Figure 584 Quick Release Tool (#8 and #10) ZTSE4581

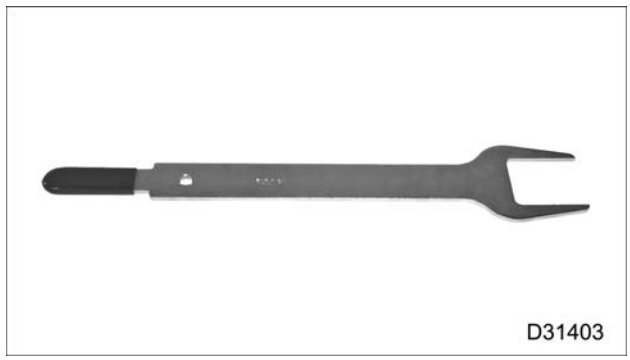

Figure 585 Fan Wrench (pulley bolts) ZTSE4587

Photos of Essential Tools from T 444E Essential Tool Kit ZTSE4350

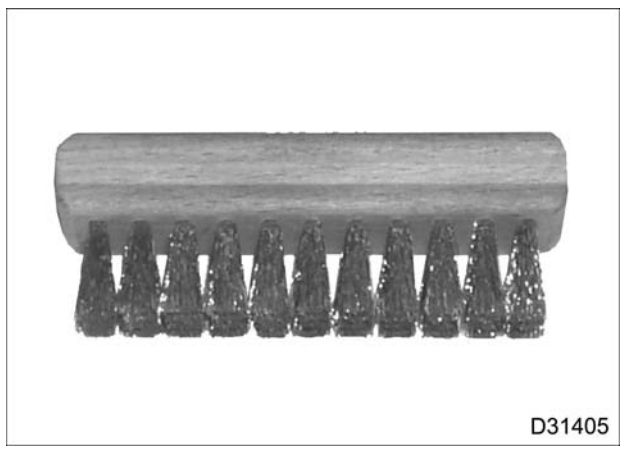

Figure 586 Injector Tip Cleaning Brush ZTSE4301

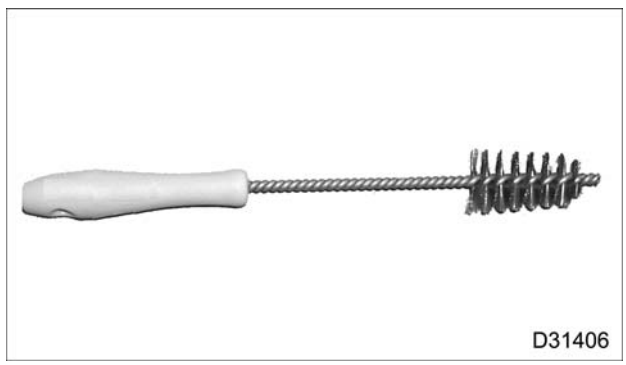

Figure 587 Injector Bore Cleaning Brush, ZTSE43041

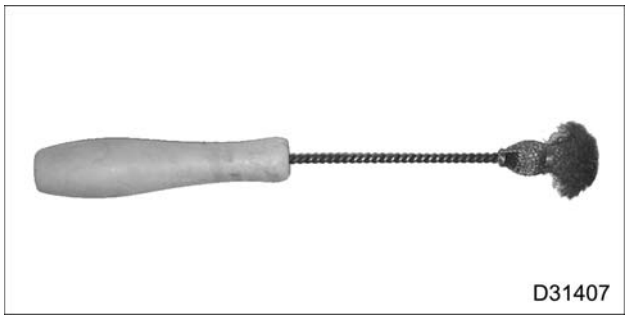

Figure 588 Injector Sleeve Flat Bottom Brush ZTSE43042

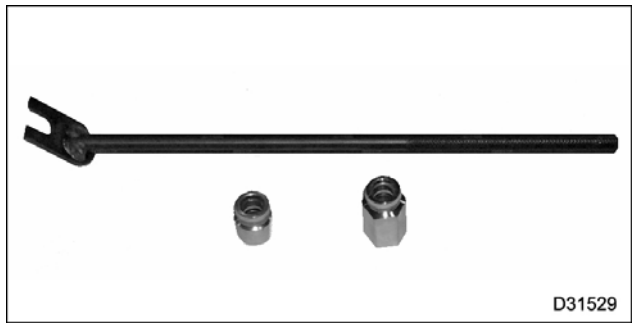

Figure 590 Quick Release Tool Kit ZTSE4454

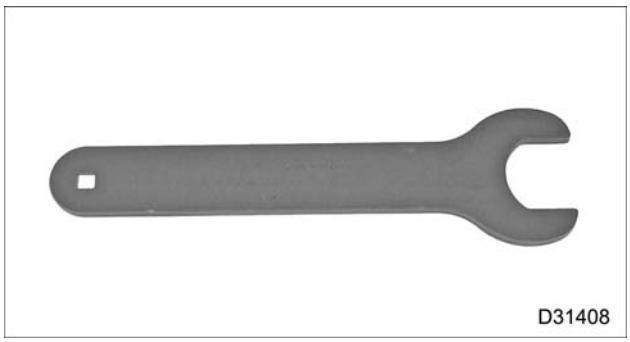

Figure 589 Fan Hub Wrench (2 inch) ZTSE43972

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