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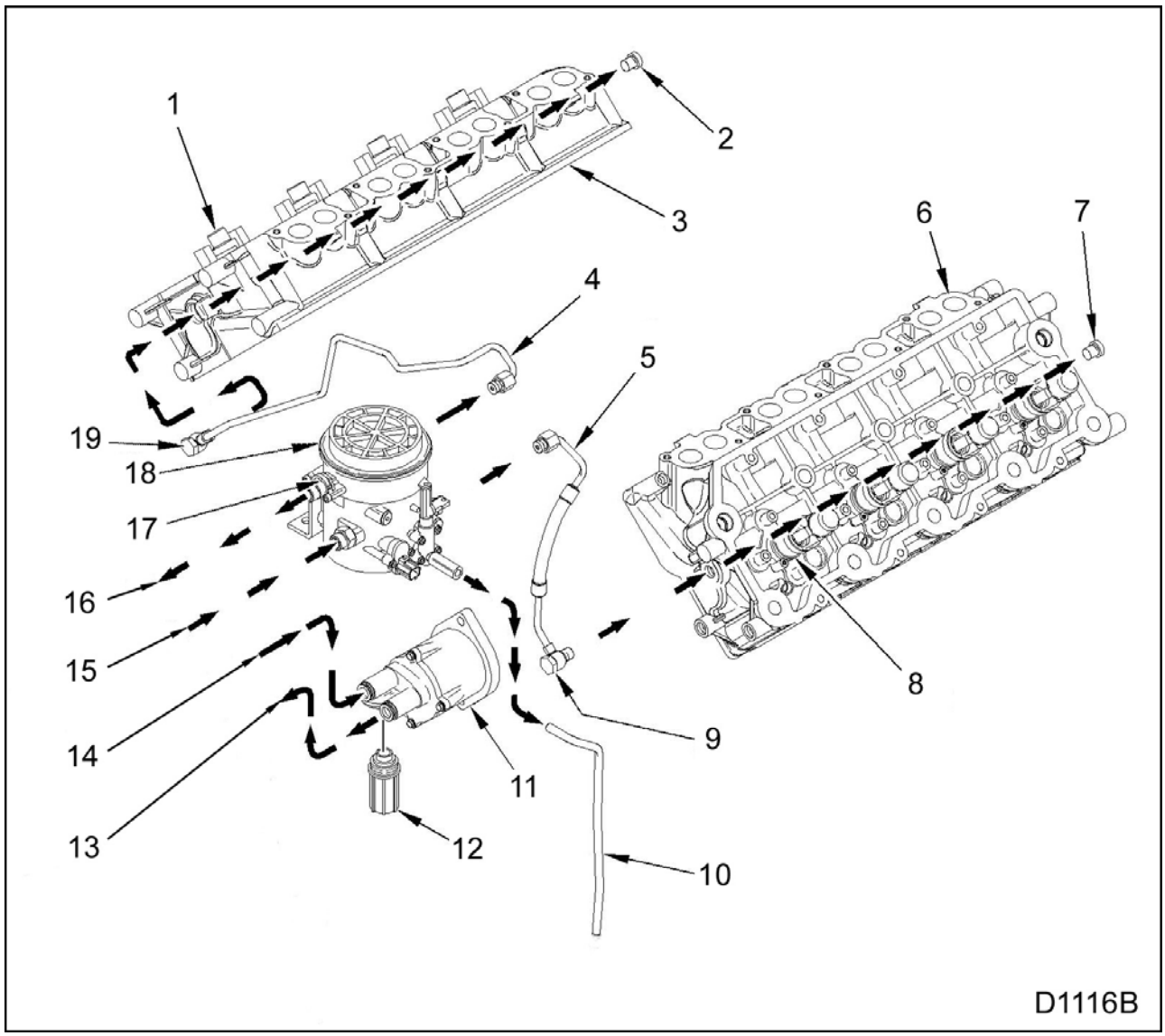

Figure 528 Fuel system components

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

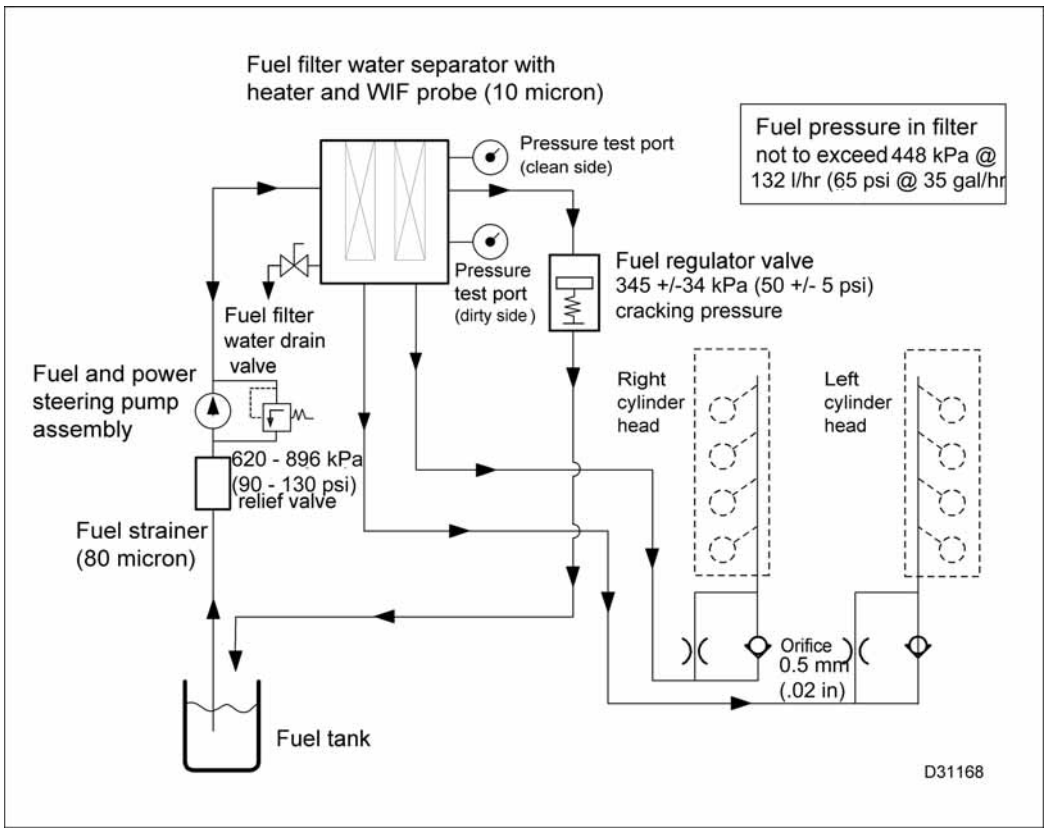

Figure 529 Fuel system schematic

Removal

Fuel Prescreen Element

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

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

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

CAUTION: Using propane or mixing propane with the recommended fuels specified in the *Engine Operation and Maintenance Manual* could cause engine damage. International Truck and Engine Corporation will not honor warranty claims against engines that have used fuels other than recommended fuels.

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.

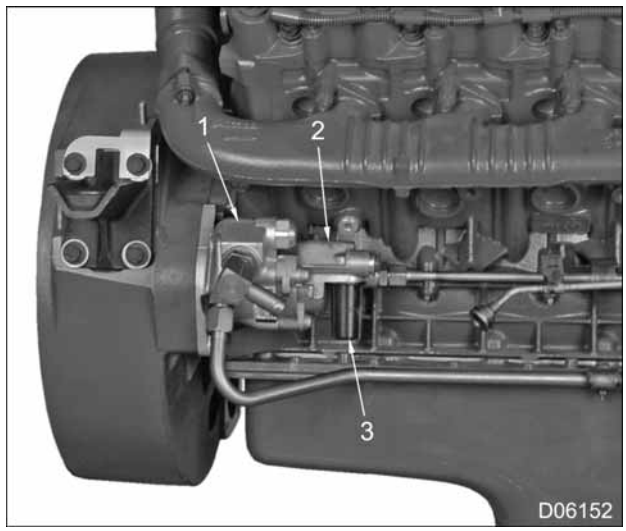

Figure 530 Removal of prescreen element

1. Power steering pump
2. Fuel pump
3. Prescreen bowl

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

Fuel Filter Element

1. Place a suitable container at end of fuel drain line to catch draining fuel.

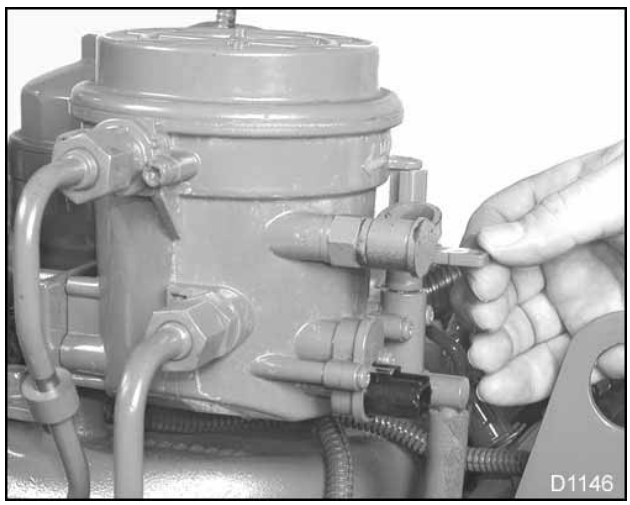

Figure 531 Fuel filter drain lever to DRAIN

2. Move fuel filter drain lever to DRAIN.
3. Remove fuel filter cap. Use an oil filter wrench if necessary.
4. Remove and discard the bevel cut gasket and clean mating surfaces.
5. Lift fuel filter element from housing.

Fuel Filter Assembly and Tubing

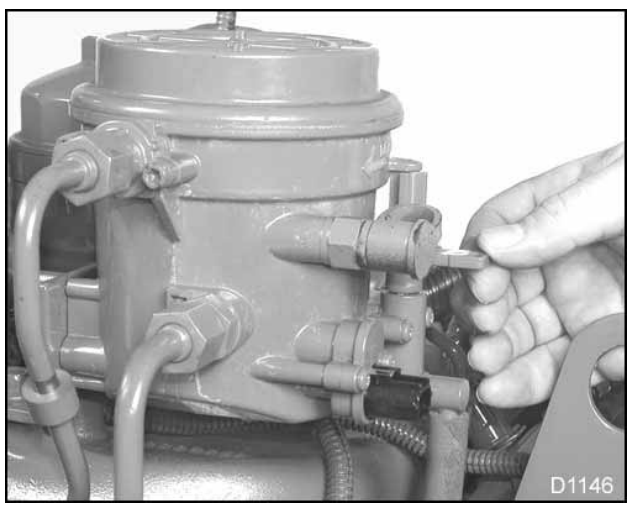

Figure 532 Fuel filter lever to DRAIN

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

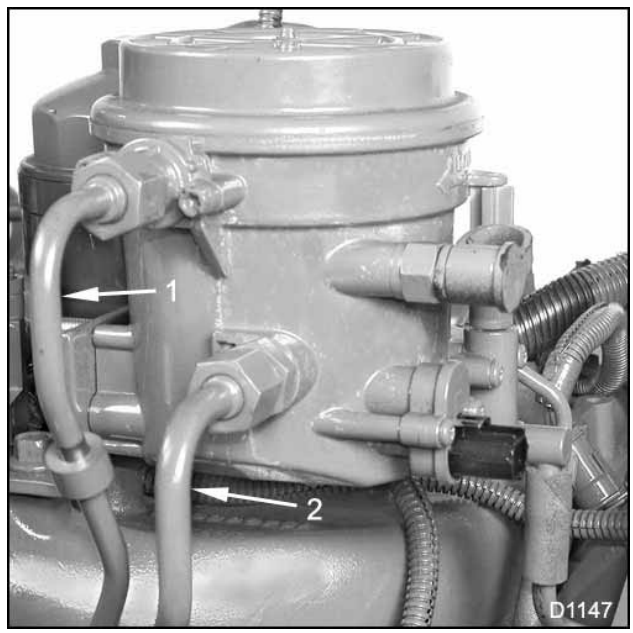

Figure 533 Fuel supply and return tubing

1. Fuel return tube
2. Fuel supply tube

3. Remove chassis fuel supply tube.
4. Remove chassis fuel return tube.
5. Remove fuel filter water drain tubing.
6. 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.
7. Remove right cylinder head fuel supply tubing.
8. Cap all openings to the fuel filter assembly.

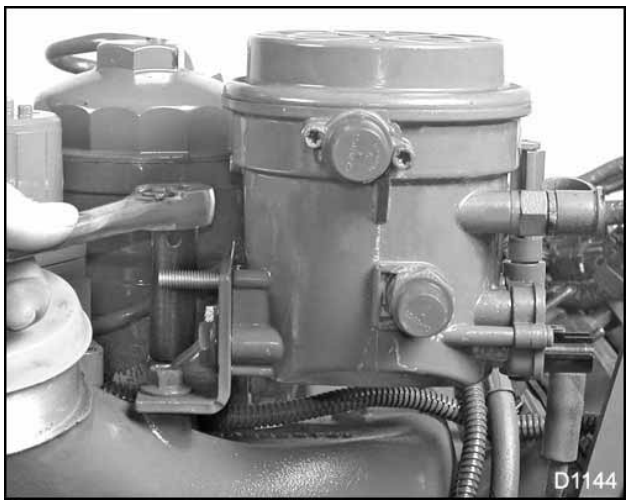

Figure 534 Removal of fuel filter support bracket

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

Fuel Injectors

NOTE: See “Cylinder Head and Valve Train” section (Removal, page 106) for removal procedures.

Inspection

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

Installation

Fuel Prescreen Element

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

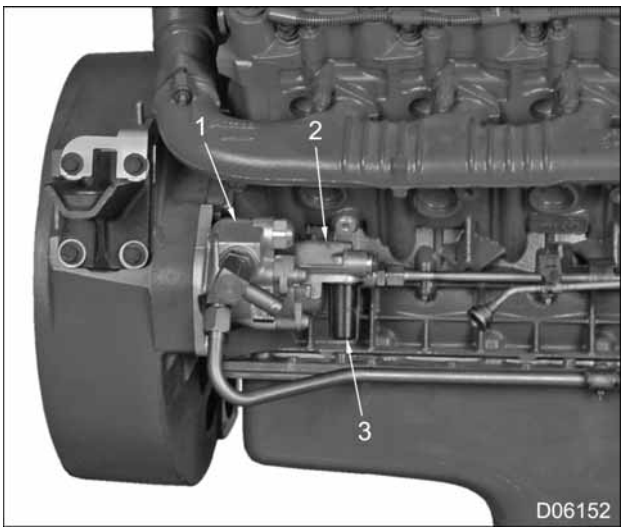

Figure 535 Installation of prescreen element and bowl

1. Power steering pump
2. Fuel pump
3. Prescreen bowl

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

Fuel Filter Assembly and Tubing

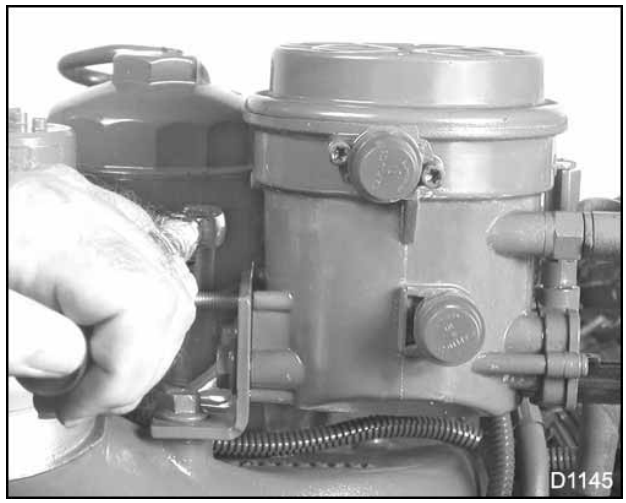

Figure 536 Fuel filter assembly

1. Install fuel filter assembly on intake manifold. Secure assembly with two M10 x 20 mounting bolts. Tighten bolts to the standard torque (Standard Torques, page 375).
2. Connect filter water drain tubing.

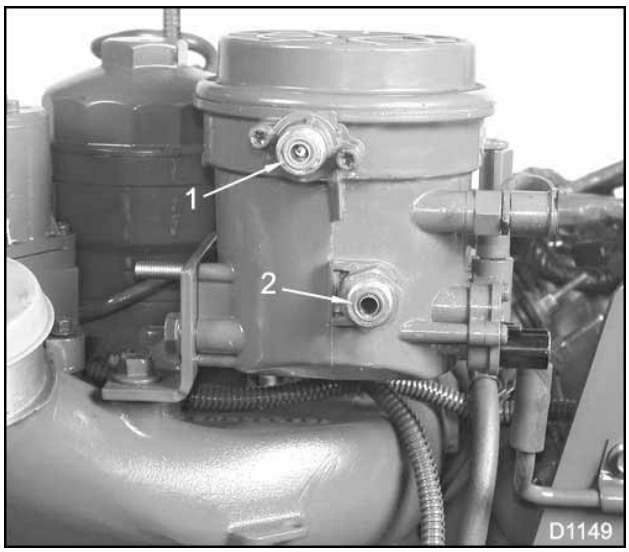

Figure 537 Fuel supply and return O-rings

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

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

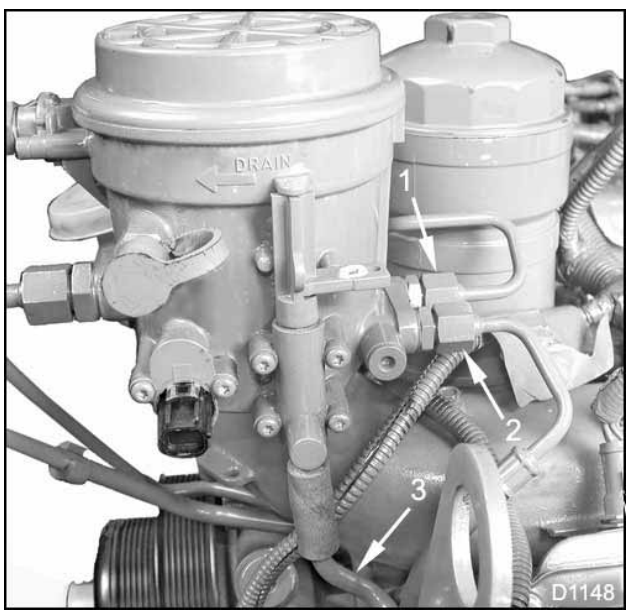

Figure 538 Filter drain and tubing for cylinder head fuel supply

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 fuel tubing to EGR cooler stud. Tighten all fittings to the special torque (Table 33).

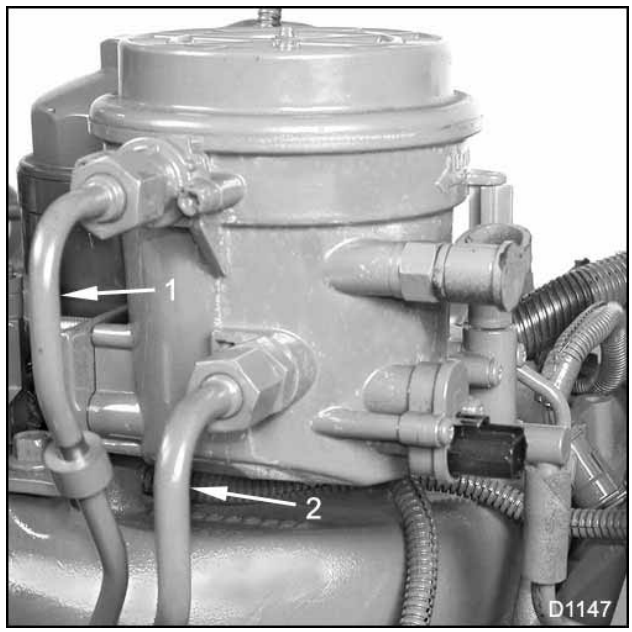

Figure 539 Connections for fuel supply and return tubing

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 33).

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 540 Removal of fuel filter cap

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 two 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 to 3 minutes to allow starter motor to cool. Repeat above procedure.
6. Repeat step 5 until engine starts and runs on its own.
   - Three to five 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.

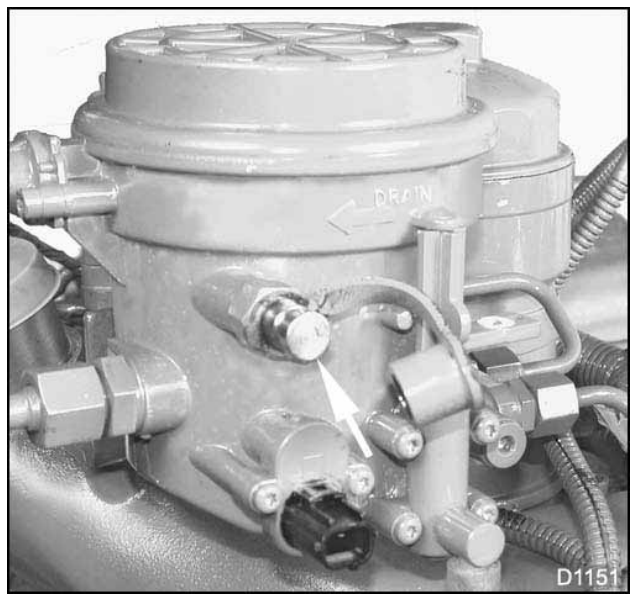

Figure 541 Unfiltered fuel pressure test port

2. Install fuel pressure test fitting in unfiltered fuel test port.
3. Attach vacuum source to fuel 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 pressure test coupler from fuel pressure test fitting.
6. Engage starter for 30 seconds and allow starter to cool for two 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 to 3 minutes to allow starter motor to cool. Repeat above procedure.

7. Repeat step 6 until engine starts and runs on its own.
   - Three to five 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 on fuel filter assembly.
2. Install new fuel filter element in 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 (Removal, page 106) for installation procedures.

Specifications

Table 32 Fuel Filter and Pressure Regulating Valve

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

Special Torque

Table 33 Fuel System Components

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)
Fuel rail plug assembly, 12 mm (back of cylinder head)	27 ± 1 N·m (20 ± 1 lbf·ft)
Power steering pump inlet elbow fitting	90 ± 10 N·m (66 ± 7 lbf·ft)
Power steering pump outlet elbow fitting	45 ± 4 N·m (33 ± 3 lbf·ft)
Power steering tube	79 ± 4 N·m (58 ± 3 lbf·ft)

Special Service Tools

Table 34 Fuel System

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

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Removal

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

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

Preliminary Checks

Flexplate (Automatic Transmission)

1. Inspect flexplate for cracks around webbing and ring gear weldments.
2. Inspect all ring gear teeth for starter pinion damage.
3. Replace flexplate if necessary.

Flywheel (Manual Transmission)

1. Inspect flywheel for cracks around webbing and bolt holes.
2. Inspect flywheel for heat checks and extensive scoring.
3. Check for ring gear damage associated with the starter pinion
4. Replace flywheel if necessary.

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.

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

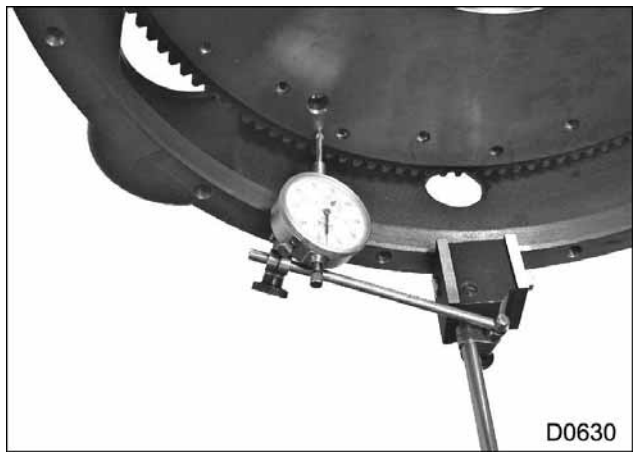

Figure 542 Flywheel surface runout

1. Attach dial indicator (Table 37) to rear cover. Place indicator tip against surface of flywheel.
2. Zero the dial indicator.
3. Rotate crankshaft slowly. (Table 35).

Rear Cover Runout

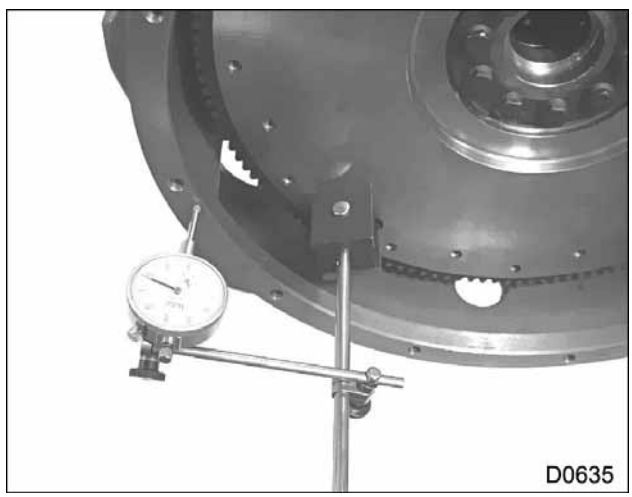

Figure 543 Rear cover runout

1. Attach dial indicator (Table 37) to surface of flywheel. Place indicator tip against rear cover.

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

2. Zero the dial indicator.

3. Measure at four points 90° apart for total face variation with (Table 35).

Backlash Test for Secondary Flange (Crankshaft Gear)

NOTE: Before doing this test, remove the power steering and fuel pump assembly. See (Secondary Flange, page 315) for procedure.

1. Attach dial indicator (Table 37) to rear cover.
2. Place indicator tip against secondary flange (crankshaft gear).
3. Lock the power steering idler gear. (For accurate measurement, the power steering idler gear must not move.)
4. Zero the dial indicator.
5. Move the secondary flange. Verify reading with the specification in (Table 35).

Backlash Test for Power Steering Idler Gear

NOTE: Before doing this test, remove the power steering and fuel pump assembly. See (Power Steering and Fuel Pump Assembly, page 316) for procedure.

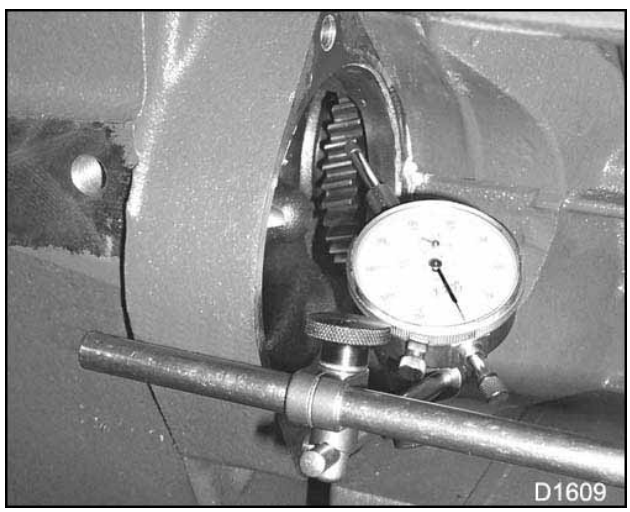

Figure 544 Idler gear backlash

1. Attach dial indicator (Table 37) to rear cover.
2. Place indicator tip against power steering idler gear.
3. Lock the power steering drive gear.

   NOTE: The power steering drive gear must be locked for an accurate measurement.
4. Zero the dial indicator.
5. Move the power steering idler gear and record the dial indicator reading. Verify reading with the specification in (Table 35).

Flexplate (Automatic Transmission)

Figure 545 Flexplate hardware

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

1. Remove and discard ten M10 x 77 flexplate mounting bolts. Do not reuse these bolts.
2. Remove the reinforcement ring, flexplate, and adapter hub.

Flywheel (Manual Transmission)

Figure 546 Flywheel guides

1. Remove and discard two M10 x 77 flywheel mounting bolts at approximately 3 o'clock and 9 o'clock. Do not reuse these bolts.
2. Install two guide pins (make locally).
3. Remove and discard remaining eight flywheel mounting bolts. Do not reuse these bolts.
4. Remove reinforcement ring.

Figure 547 Flywheel guide pins

5. Slide flywheel off guide pins and out of housing.
6. Remove guide pins from secondary flange.

Rear Main Seal and Wear Sleeve

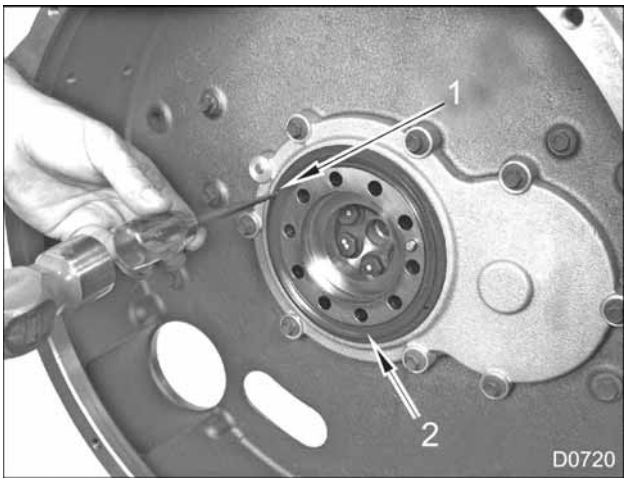

Figure 548 Starter holes

1. Starter hole
2. Rear main seal

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

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

Figure 549 Hammer screw in starter hole

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

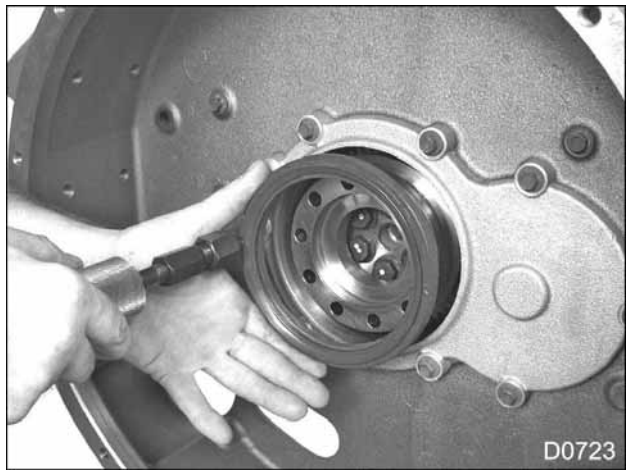

Figure 550 Rear main oil seal removal

4. Remove and discard rear main oil seal from rear oil seal carrier.

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.

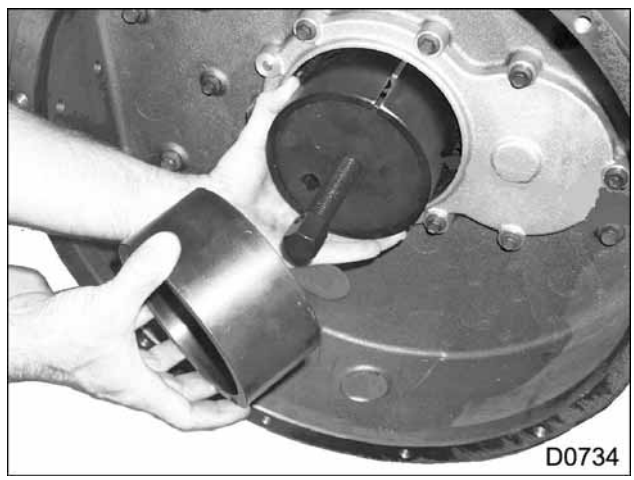

Figure 551 Wear sleeve removal tool

5. Install wear sleeve removal tool.

NOTE: Before applying force to threaded shaft, make sure the half shells of the wear sleeve removal tool are secured behind wear sleeve.

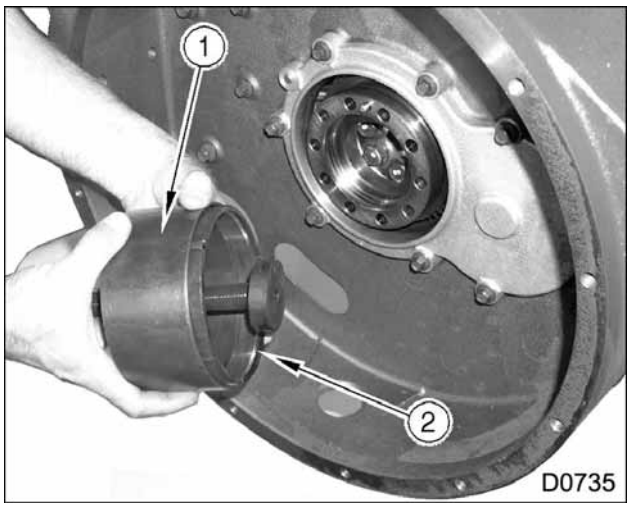

Figure 552 Wear sleeve

1. Wear sleeve removal tool
2. Wear sleeve

6. Turn the threaded shaft clockwise until the wear sleeve is free of the crankshaft flange.

Secondary Flange

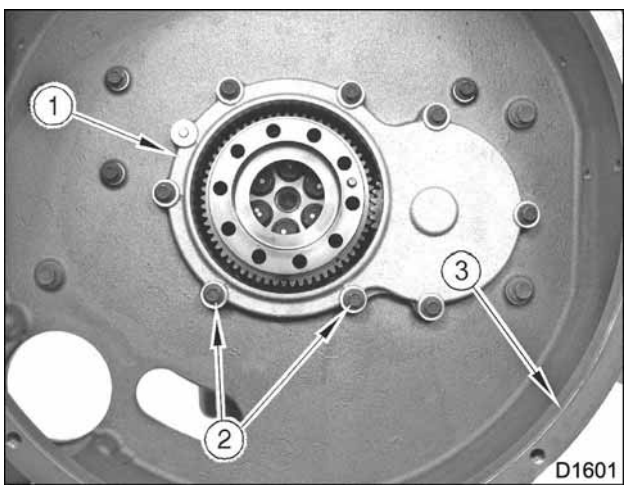

Figure 553 Rear cover and rear oil seal carrier

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

1. Remove eight M8 bolts from rear oil seal carrier .

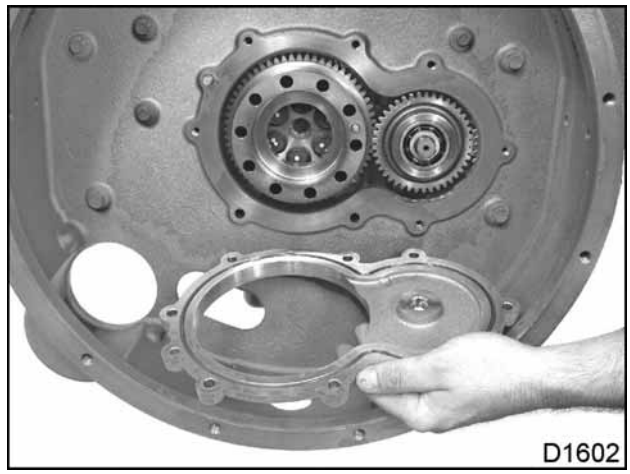

Figure 554 Rear oil seal carrier

2. Remove rear oil seal carrier and discard gasket.

NOTE: Do the backlash test for the secondary flange and power steering idler gear. See (Backlash Test for Secondary Flange (Crankshaft Gear) , page 312) before doing the following steps.

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

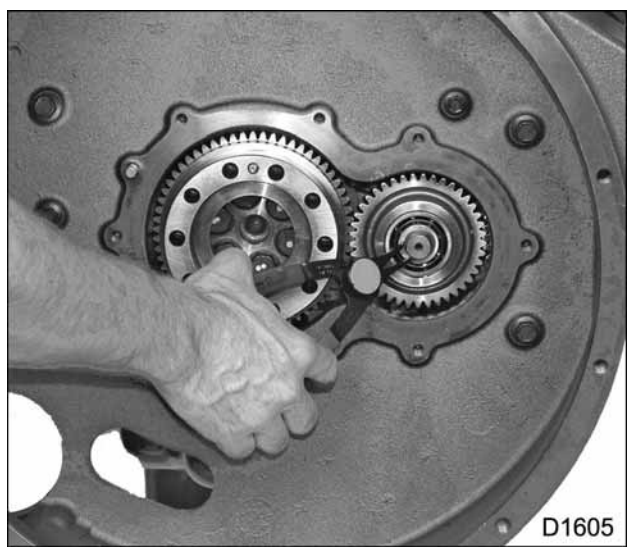

Figure 555 Snap ring on power steering idler gear

3. Remove snap ring from power steering idler gear.

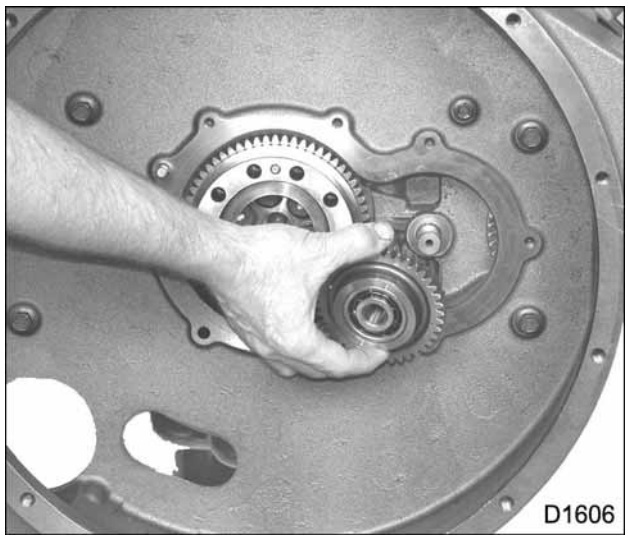

Figure 556 Power steering idler gear

4. Remove power steering idler gear.

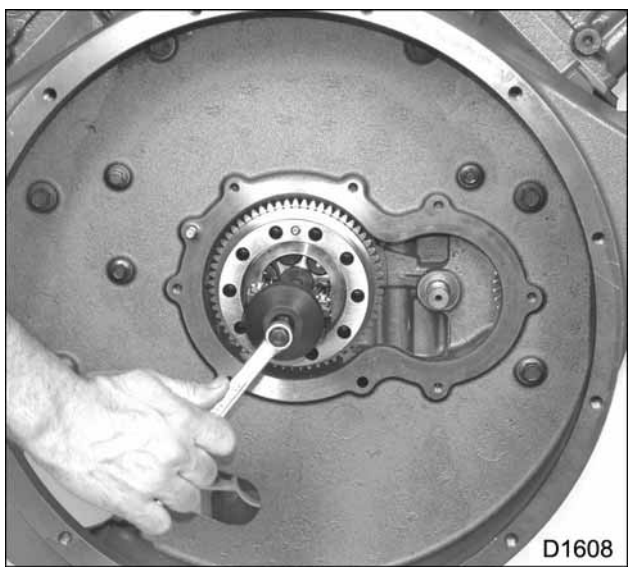

Figure 557 Secondary flange

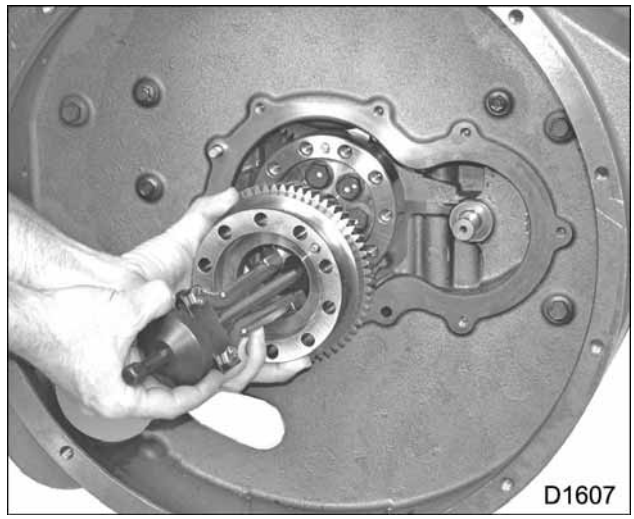

Figure 558 Gear puller

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

Power Steering and Fuel Pump Assembly

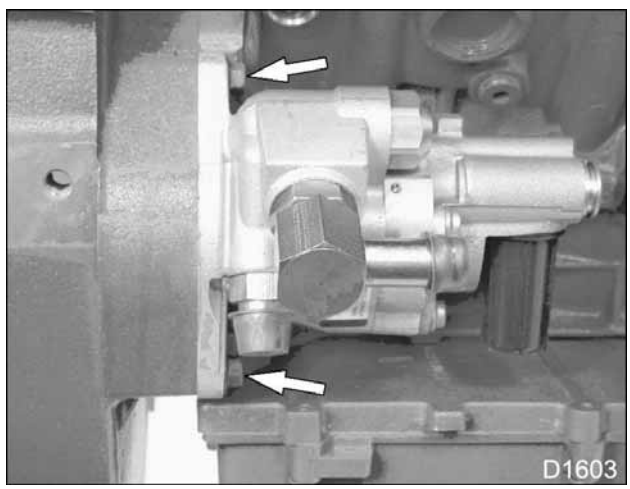

Figure 559 Mounting bolts for power steering and fuel pump assembly

1. Remove two M10 x 30 mounting bolts from power steering and fuel pump assembly.

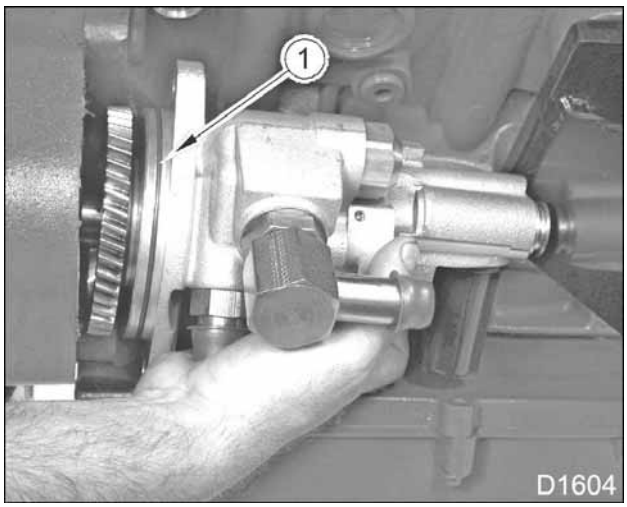

Figure 560 Power steering and fuel pump assembly

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

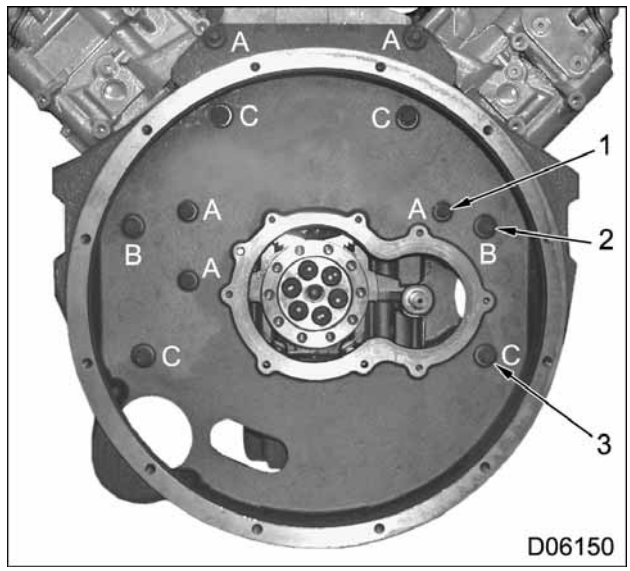

Figure 561 Rear cover mounting bolts

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 eleven mounting bolts from rear cover.
2. Use a thin gasket scraper to separate sealant between rear cover joints listed below, to avoid pulling these gaskets out when removing the rear cover assembly.
   - Upper and lower crankcase
   - Rear cover assembly
   - Crankcase
   - High-pressure oil pump cover
   - Rear cover assembly

WARNING: To prevent personal injury or death, get help when removing the rear cover.

3. Remove rear cover.

NOTE: If necessary, use a slide hammer to remove power steering idler shaft.

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, non-caustic 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

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

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

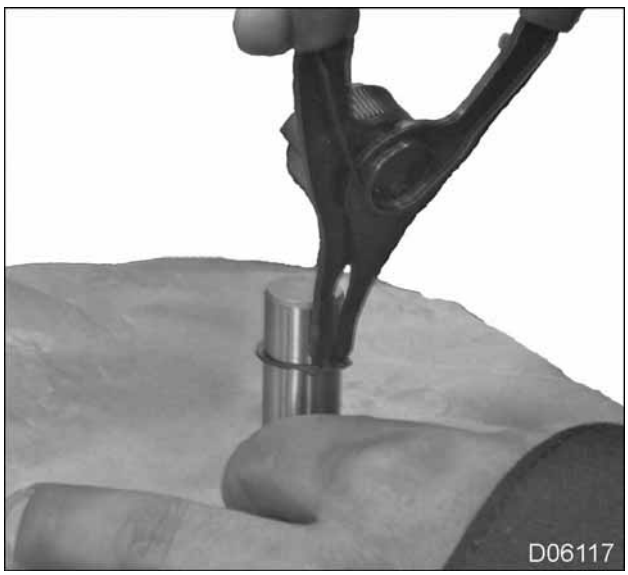

Figure 562 Retaining ring on idler shaft

2. Place a retaining ring on the end of the shaft without the threaded hole.

Figure 563 Idler shaft and retaining ring in installation tool

3. Put the threaded hole end of the idler shaft into the installation tool to set the correct height. 34.6 ± 0.15 mm (1.362 ± 0.006 in)

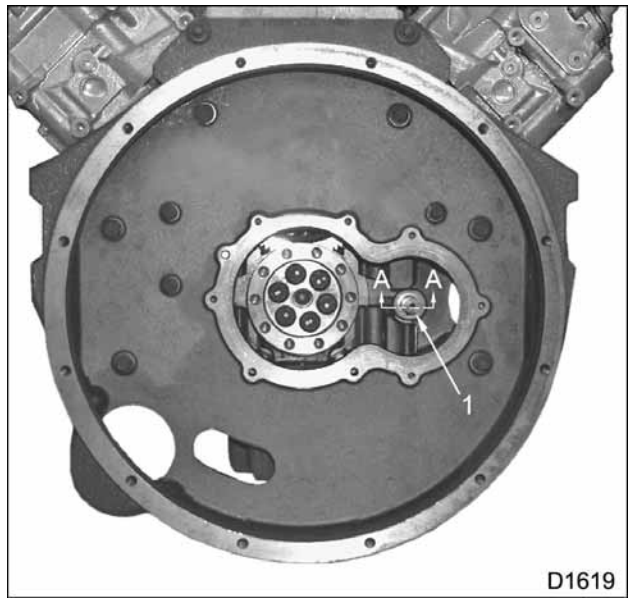

Figure 564 Power steering idler shaft in transmission side of rear cover

1. Power steering idler shaft (Section A-A)

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

Figure 565 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 correct 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.

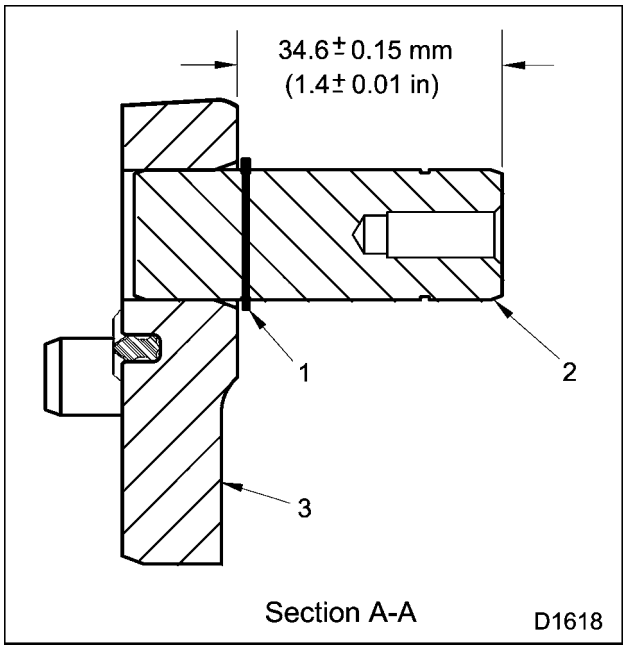

Figure 566 Power steering idler shaft installation height

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.

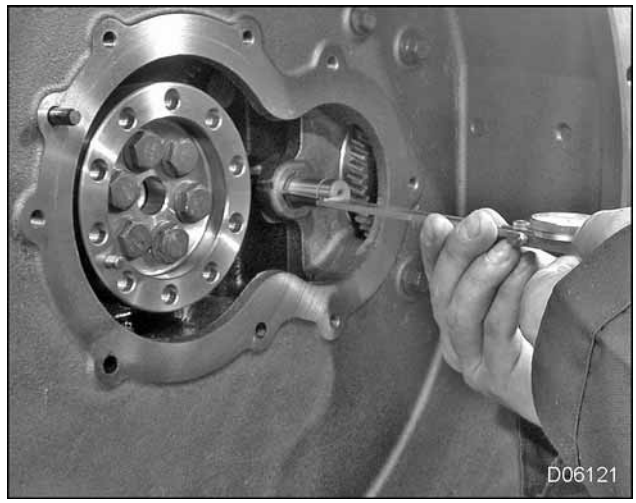

Figure 567 Idler shaft height measurement

6. Measure 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, replace dowel pins in crankcase if damaged or missing.

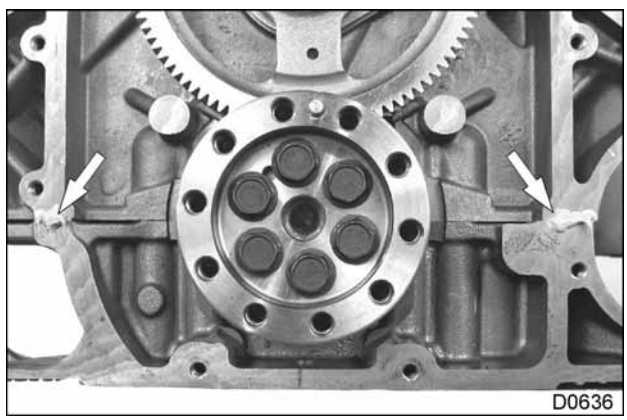

Figure 568 Application of sealant

1. Apply Liquid Gasket (RTV) (Table 37) 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.

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.

2. Make sure that the rear cover gasket is in place, before installing the rear cover.

WARNING: To prevent personal injury or death, get help when installing the rear cover.

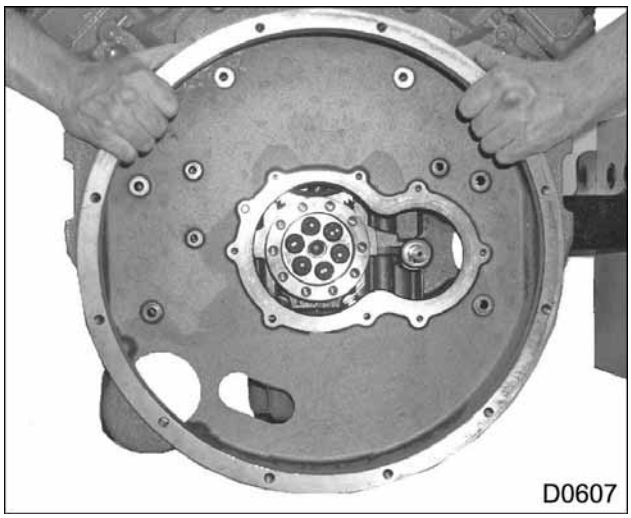

Figure 569 Rear cover

3. Install rear cover assembly with the aid of an assistant.

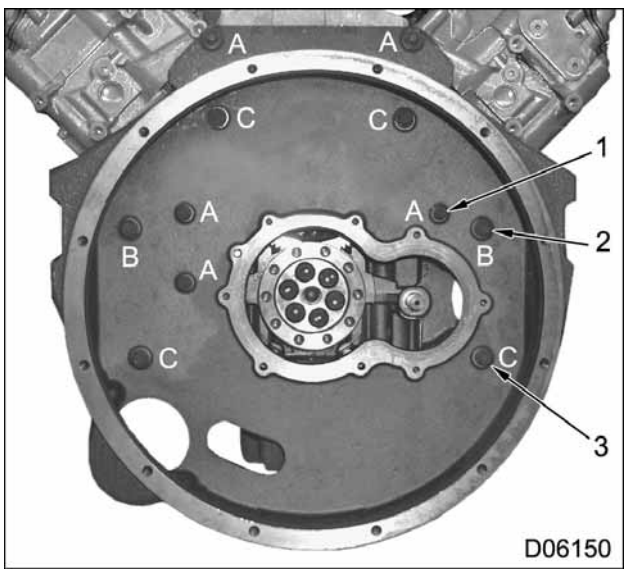

Figure 570 Rear cover mounting bolts

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

4. Install eleven rear cover mounting bolts. Tighten all bolts to the standard torque.

Secondary Flange

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

1. Install the dowel pin in the secondary flange gear.

Figure 571 Dowel pin in the secondary flange gear

2. Use a dial caliper to verify the protrusion height. Dowel pin protrusion 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 possible 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.

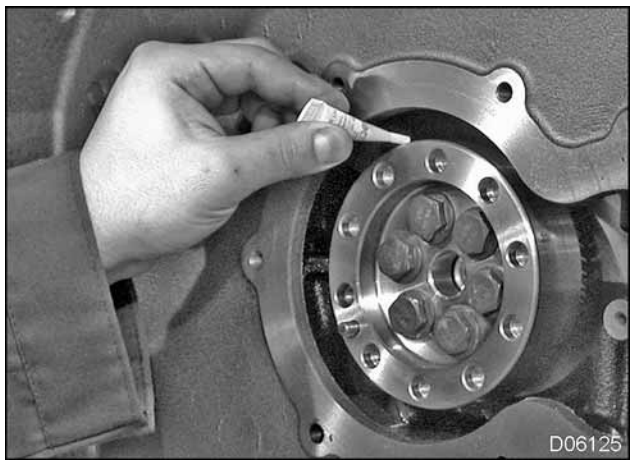

Figure 572 Application of Loctite® on the primary crankshaft flange

4. Apply Loctite® on the outside diameter of the primary crankshaft flange.

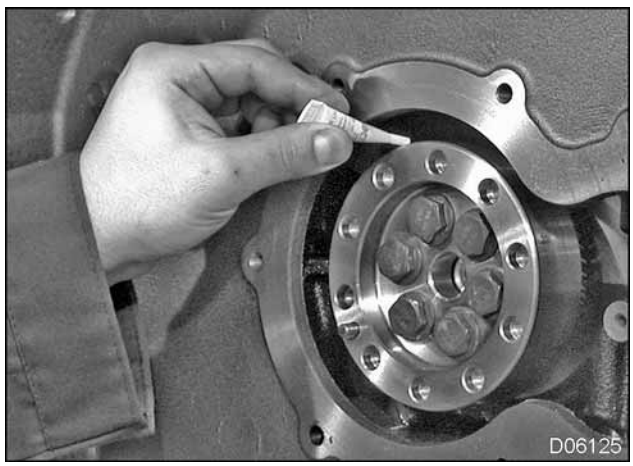

Figure 573 Application of Loctite® on the primary crankshaft flange

5. Spread the Loctite® evenly around primary crankshaft flange. Do not get any Loctite® on the face of the crankshaft flange.

CAUTION: To prevent damage to the engine, transmission, or vehicle, seat the secondary flange onto 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 574 Crankshaft secondary flange installation studs (ZTSE4720)

6. Install two Crankshaft Secondary Flange Installation Studs, evenly spaced, into the crankshaft flange.
7. Align the dowel pin hole with the crankshaft dowel pin and slide secondary flange onto the studs.

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

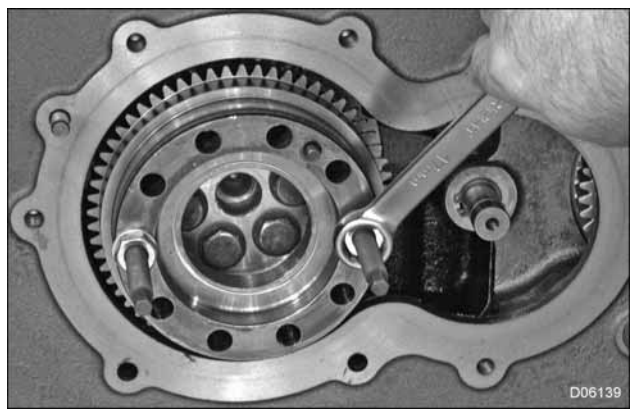

Figure 575 Secondary flange

8. Install two nuts and washers. Seat the flange by alternately tightening nuts on the studs.
9. Remove nuts, washers, and studs after flange has been seated.

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.

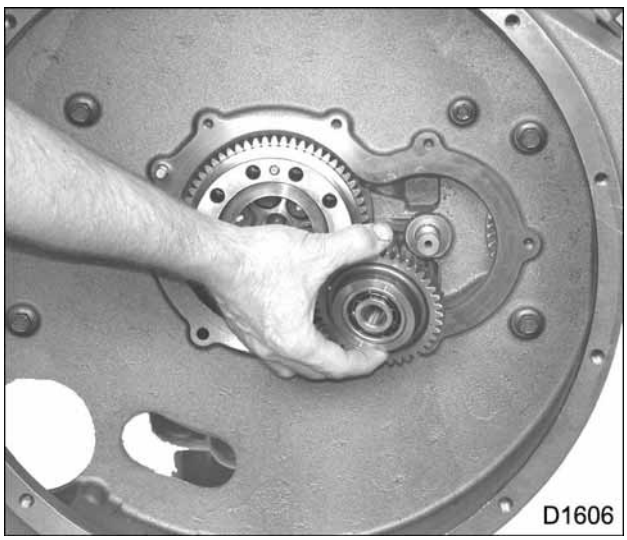

Figure 576 Power steering idler gear

10. Install power steering idler gear on shaft.

NOTE: The gear of the power steering and fuel pump assembly may have to be rotated for correct fit of the gears. Do not drive the gear onto the shaft.

11. Verify correct gear orientation and gear teeth engagement.

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

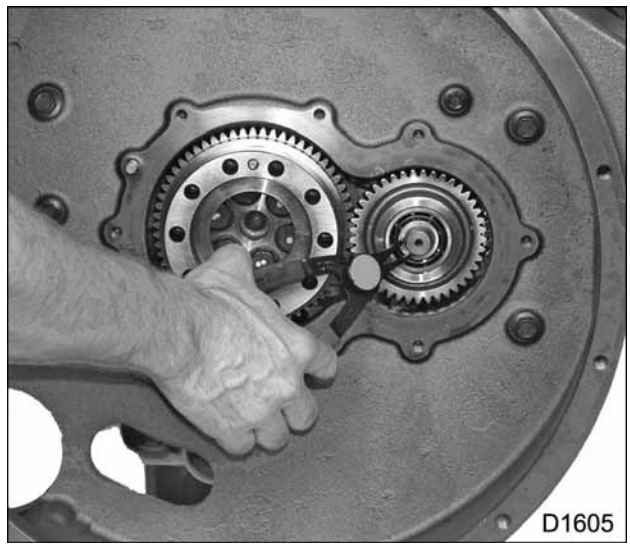

Figure 577 Power steering idler gear retaining ring on shaft

12. Install retaining ring onto the shaft for the power steering idler gear

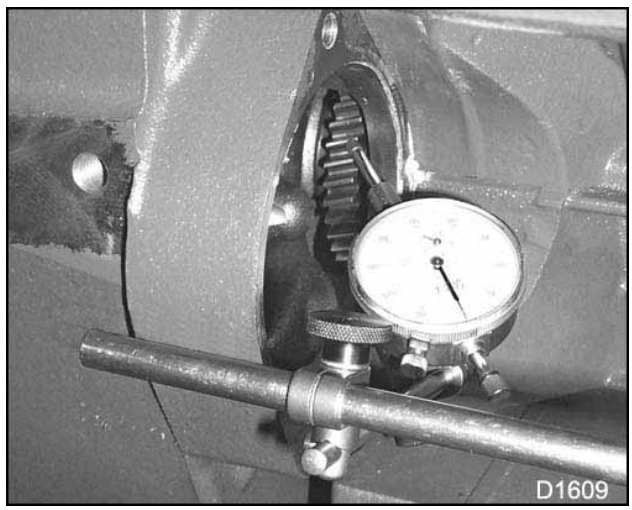

Figure 578 Idler gear backlash

13. Check the idler gear backlash. See (Figure 578).
14. Install new gasket on rear oil seal carrier.

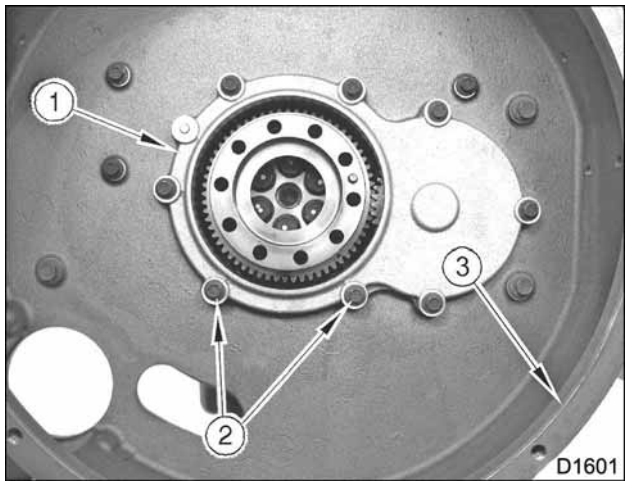

Figure 579 Rear cover and rear oil seal carrier

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

15. Install two M8 x 70 bolts in lower holes of rear oil seal carrier (Figure 579). Tighten bolts to the standard torque (Standard Torques, page 375).
16. Install six remaining x 285 bolts M8 to secure rear oil seal carrier to rear cover.(Figure 579). Tighten bolts to the standard torque (Standard Torques, page 375).

Rear Main Oil Seal and Wear Sleeve

CAUTION: To prevent engine damage, do not separate wear sleeve from oil seal; this will damage the seal and engine.

NOTE: When replacing the rear main oil 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.

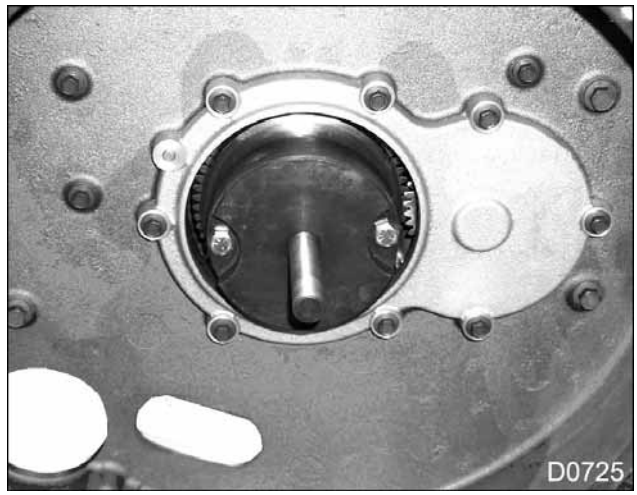

Figure 580 Rear/Wear Sleeve Installer

1. Bolt Rear/Wear Sleeve Installer (Table 37) on end of crankshaft. Make sure crankshaft alignment dowel fits in dowel recess hole in the rear/wear sleeve installer.

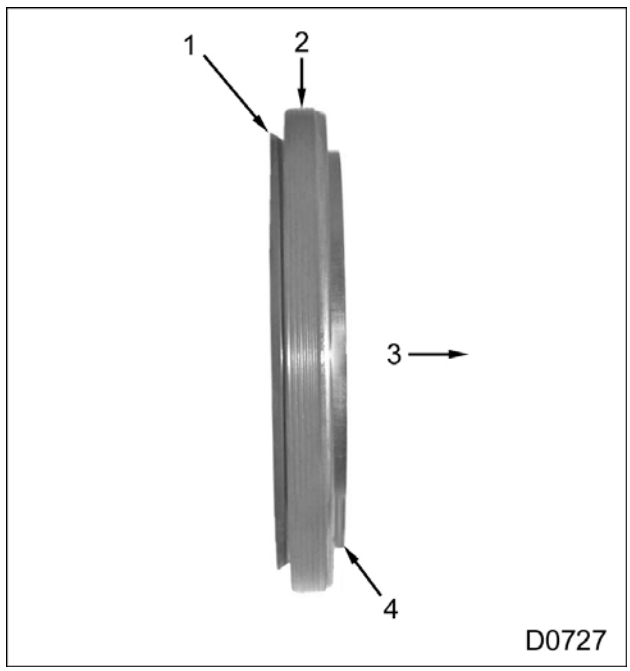

Figure 581 Orientation or rear main oil seal and wear sleeve

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

2. Position seal (Figure 581) and slide onto Rear/Wear Sleeve Installer.

NOTE: Before assembly, lubricate the outer diameter of rubber seal with a solution of dish washing soap and water (approximately 50/50 mix). Do not use other lubricants.

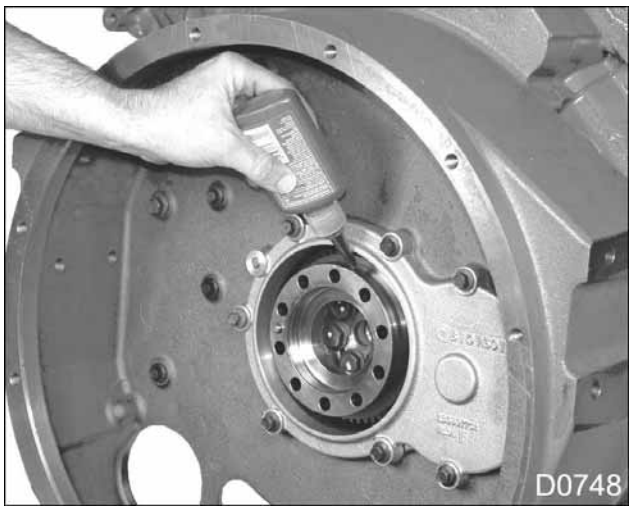

Figure 582 Sealant application to secondary crankshaft flange

3. Before installing wear sleeve and rear main seal oil, apply a 360° bead of Loctite® Hydraulic Sealant (Table 37) onto the rear edge of the secondary crankshaft flange.

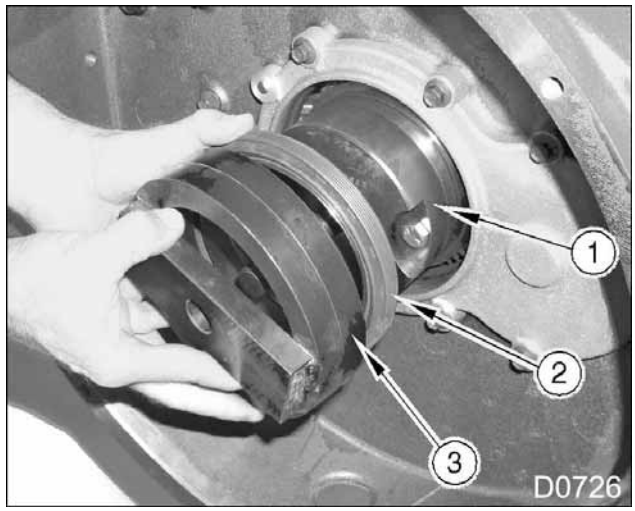

Figure 583 Rear/Wear Sleeve Installer

1. Base
2. Rear main oil seal and wear sleeve
3. Rear/wear sleeve installer

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

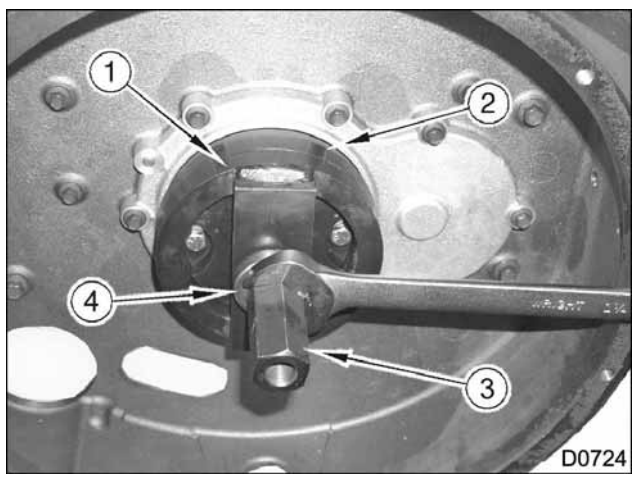

Figure 584 Rear main oil seal and wear sleeve combination on crankshaft

1. Rear/wear sleeve installer
2. Rear main oil seal
3. Drive nut
4. Thrust bearing

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

Power Steering and Fuel Pump Assembly

1. Check power steering and fuel pump assembly for cracks, leaks or other damage. Before installation, put a new O-ring on power steering and fuel pump assembly.

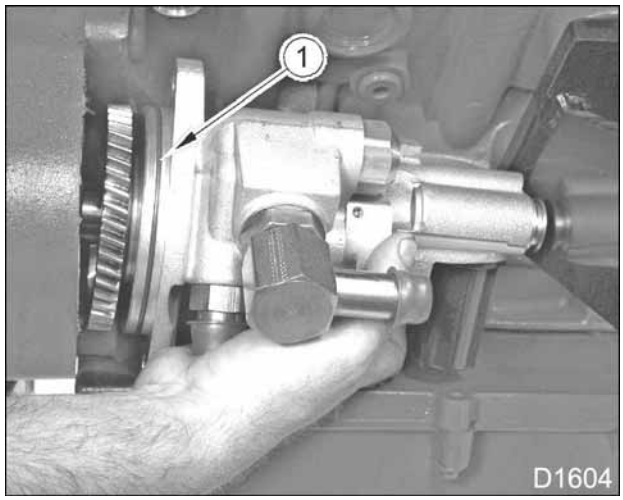

Figure 585 Power steering and fuel pump assembly

1. O-ring

2. Install power steering and fuel pump assembly in rear cover.

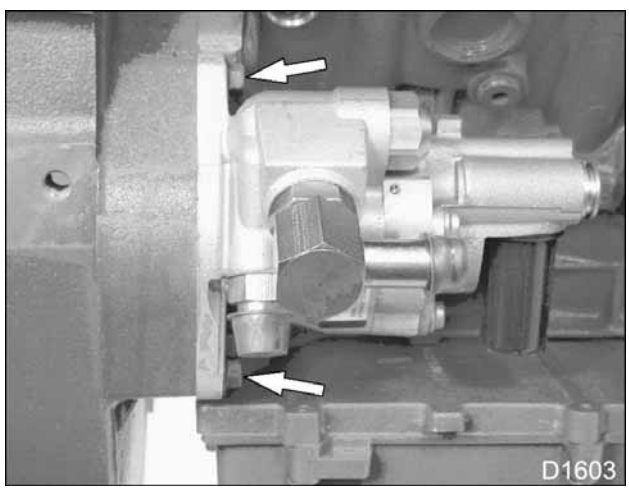

Figure 586 Mounting bolts for power steering and fuel pump assembly

3. Install two M10 x 30 mounting bolts for power steering and fuel pump assembly. Tighten bolts to the standard torque.

Flexplate

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

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

1. Position flexplate on adapter hub and align hub over the crankshaft secondary flange dowel. Make sure the XMSN-SIDE stamp is facing the transmission.

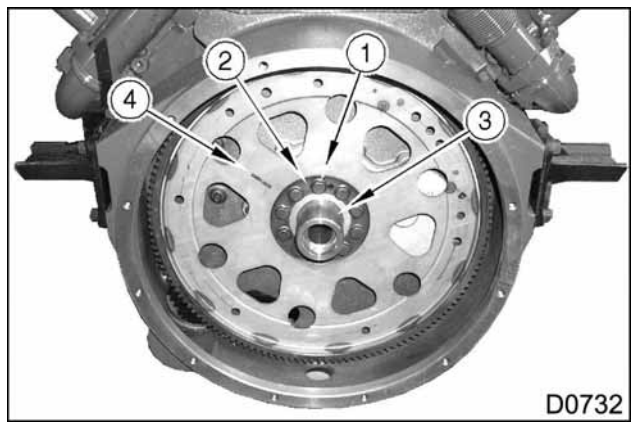

Figure 587 Flexplate

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

2. Make sure lip on outer circumference of reinforcement ring faces the transmission and align bolt holes to position reinforcement ring.
3. Install two M10 x 77 bolts for flexplate 180° apart through reinforcement ring, flexplate, and adapter hub.
4. Place flexplate assembly on crankshaft. Hand tighten two bolts to hold assembly.
5. Install eight remaining M10 x 77 mounting bolts.

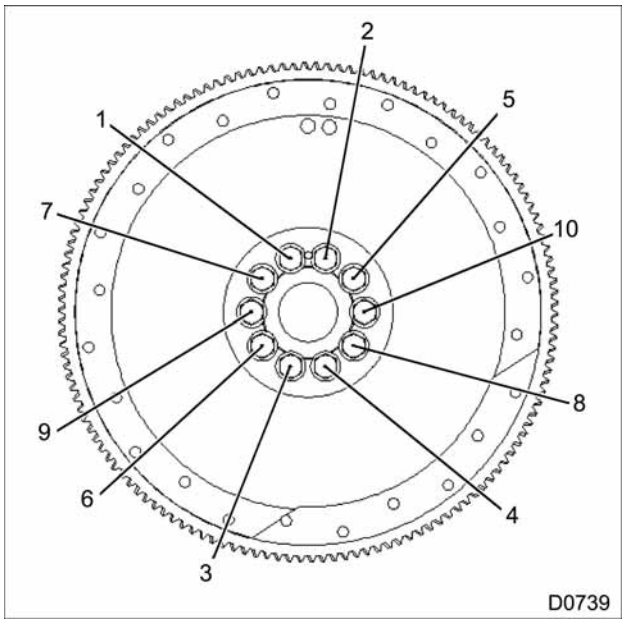

Figure 588 Torque sequence for flexplate

6. Snug all bolts in the sequence shown to 1 to 7 N·m (12 to 60 lbf·in).
7. Torque all bolts in the sequence to the special torque (Table 36).

Flywheel

Figure 589 Flywheel on guide pins

1. Install two flywheel guide pins (made locally) in crankshaft flange at approximately 3 o'clock and 9 o'clock.
2. Align dowel hole in flywheel 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 faces the transmission.

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

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

NOTE: New phosphate coated bolts do not require oil before torquing.

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

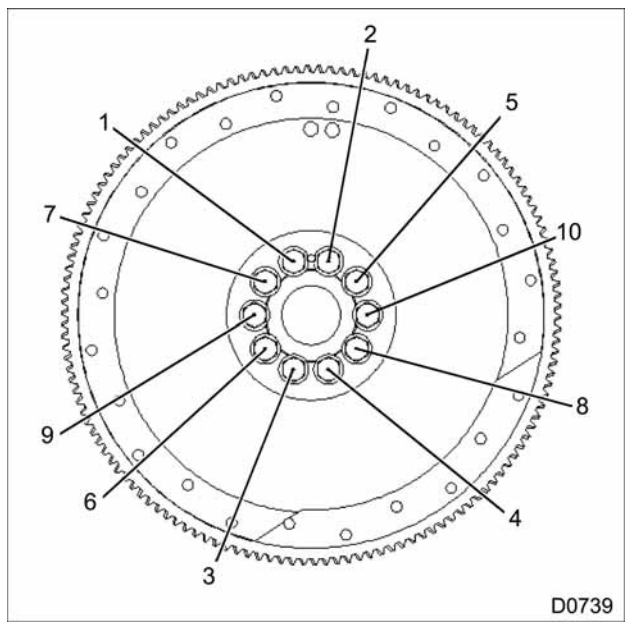

Figure 590 Torque sequence for flywheel

6. Snug bolts in the sequence to 1 to 7 N·m (12 to 60 lbf·in).
7. Torque all bolts in the sequence to the special torque (Table 36).
8. Reinstall safety guards, shields, and covers.

9. Make sure tools, cleanliness covers, loose parts, and service equipment are removed from the engine area.

Specifications

Table 35 Flywheel, Rear Cover, Power Steering and Fuel Pump

Flywheel	
Flywheel surface maximum runout (manual)	0.25 mm (0.010 in)
Flexplate ring gear T.I.R. runout (automatic)	1.27 mm (0.050 in)
Idler Gear	
Idler gear shaft height	36.4 ± 0.15 mm (1.4 ± 0.01 in)
Dowel Pin	
Dowel pin protrusion in secondary flange	8.0 ± 0.25 mm (0.315 ± 0.01 in)
Rear Cover	
Rear cover face maximum runout	0.51 mm (0.020 in)
Power Steering and Fuel Pump Drive Gear	
Backlash:	
Crankshaft to power steering and fuel pump idler gear	0.173 to 0.288 mm (0.0068 to 0.0113 in)
Power steering idler gear to power steering and fuel pump drive gear	0.173 to 0.288 mm (0.0068 to 0.0113 in)
Power Steering Pump	
Maximum operating pressure	17.5 MPa (2,538 psi)

Special Torque

Table 36 Flywheel, Flexplate and Power Steering Assembly

Flywheel mounting bolts, **new bolts only**	94 N·m (69 lbf·ft) (Figure 590)
Flexplate mounting bolts, **new bolts only**	94 N·m (69 lbf·ft) (Figure 590)
Power steering pump outlet pipe fitting	45 ± 5 N·m (33 ± 4 lbf·ft)
Power steering pump inlet pipe fitting	90 ± 10 N·m (66 ± 7 lbf·ft)

Special Service Tools

Table 37 Flywheel, Rear Cover and Power Steering and Fuel Pump

Description	Tool Number
Cap Kit (All)	ZTSE4610
Dial Indicator with Magnetic Base	Obtain locally
Liquid Gasket (RTV) (6 oz. tube)	1830858C1
Rear/Wear Sleeve Installer	ZTSE4515
Rear Wear Sleeve Removal Tool	ZTSE4518
Power Steering Idler Shaft Installation Tool	ZTSE4719
Crankshaft Secondary Flange Installation Studs	ZTSE4720
Loctite® 290 Sealant	1847432C1
Loctite® Hydraulic Sealant	Obtain locally

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.

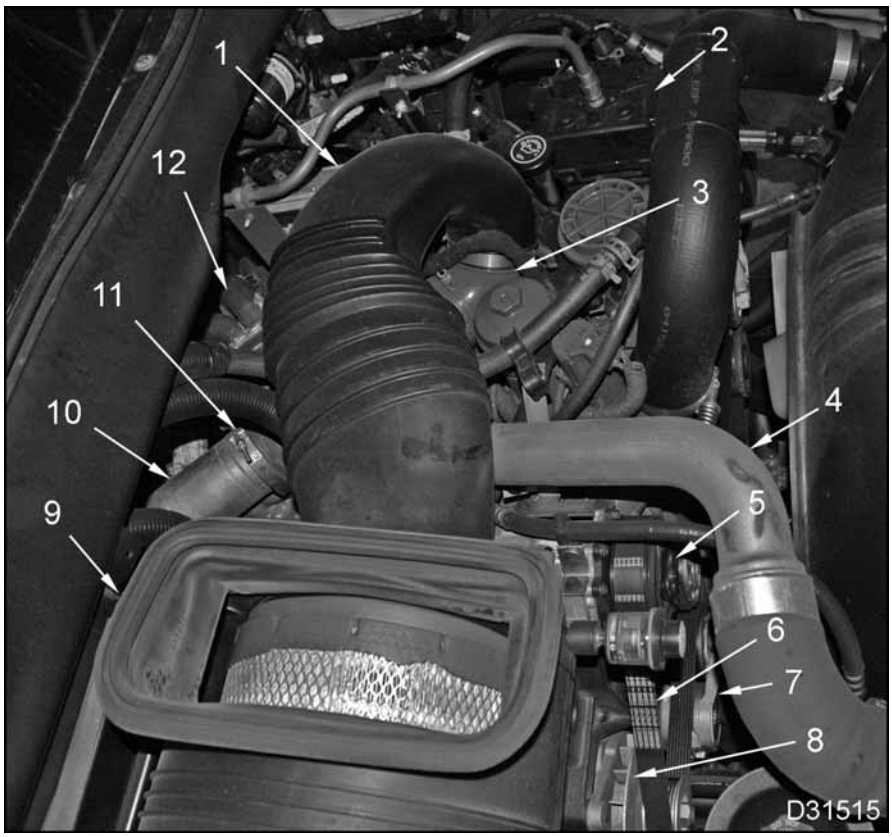

Figure 591 Parts for removal (Engine In-chassis – 4100 truck)

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, remove coolant supply line and pinch off hose. 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.

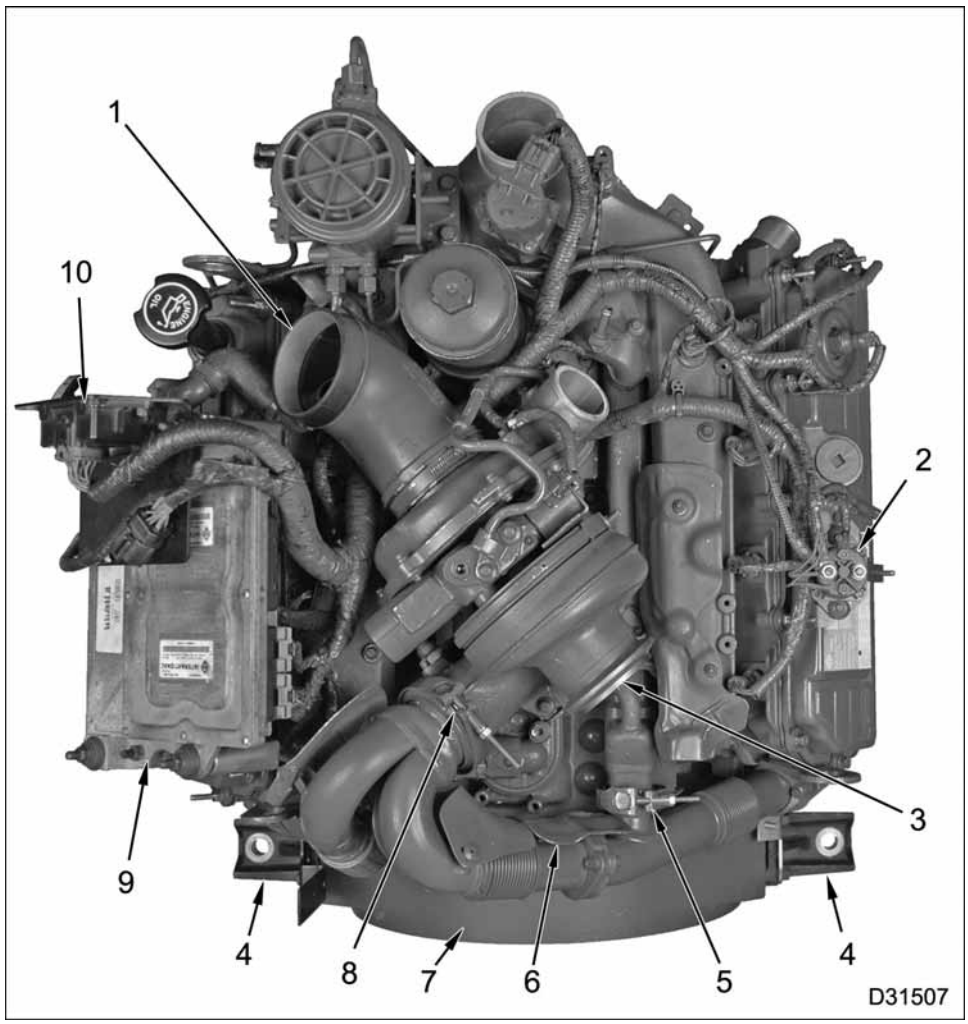

Figure 592 Parts for removal

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.

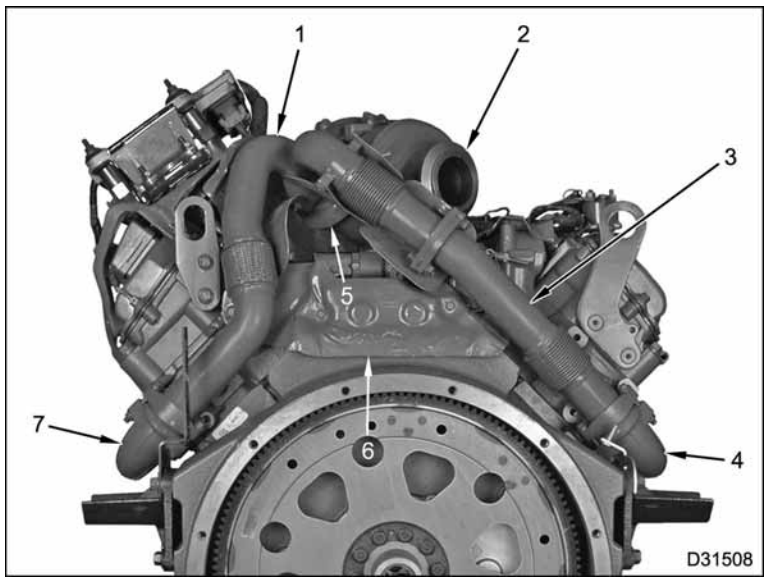

Figure 593 Air Management System parts

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 Service Manual* – “Engine Electrical” to remove the following:
    - ECM, IDM, and mounting bracket.
    - Glow plug relay and bracket
23. See *Engine Service Manual* – “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 *Engine Service Manual* – “High-pressure Oil Pump”.
25. See *Engine Service Manual* – “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 *Engine Service Manual* – “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.

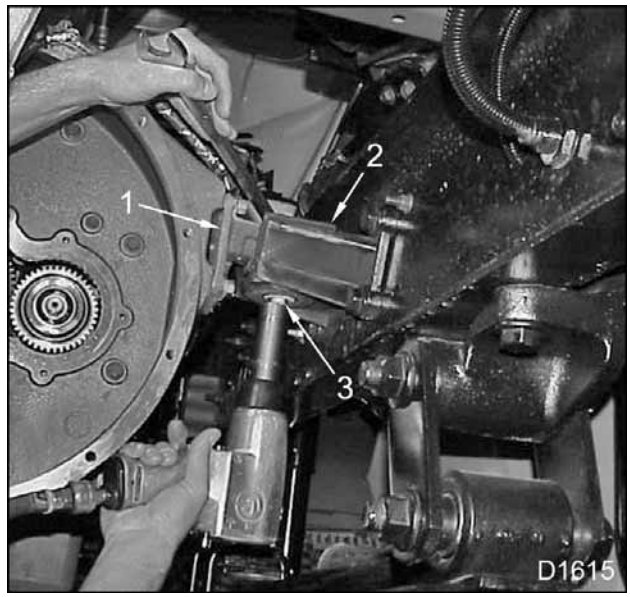

Figure 594 Removal of through bolt from rear engine mount in chassis mounting bracket

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.

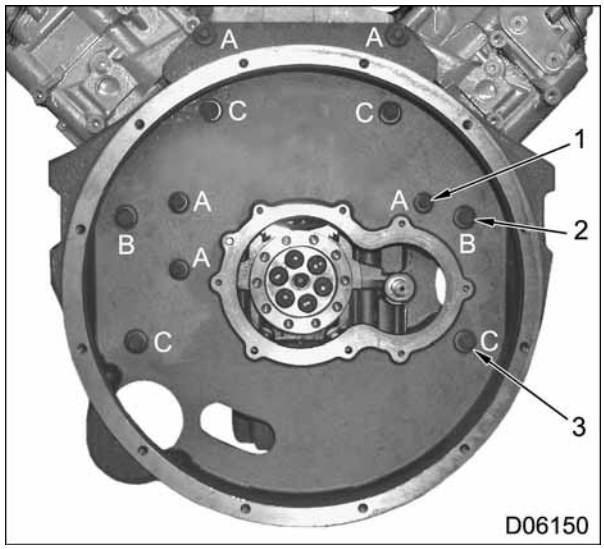

Figure 595 Rear cover mounting bolts

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.

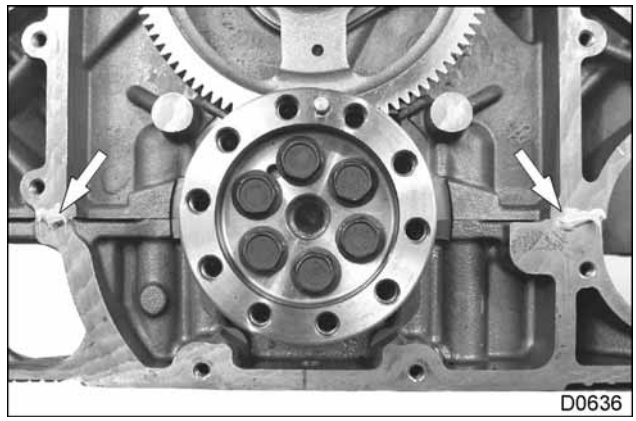

Figure 596 Sealant at upper and lower crankcase

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.

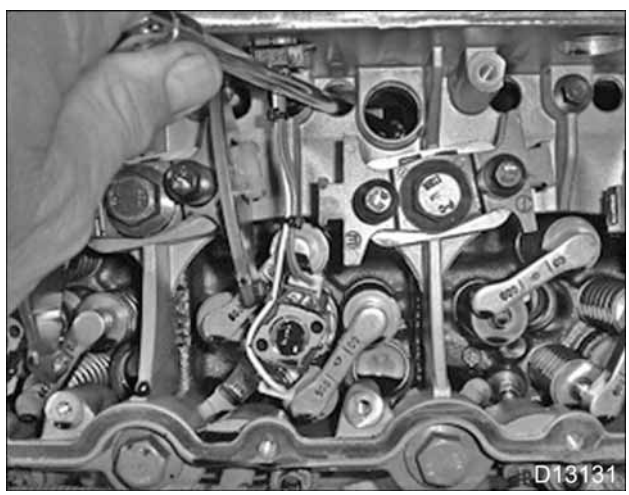

Figure 597 Extension in pushrod hole

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.

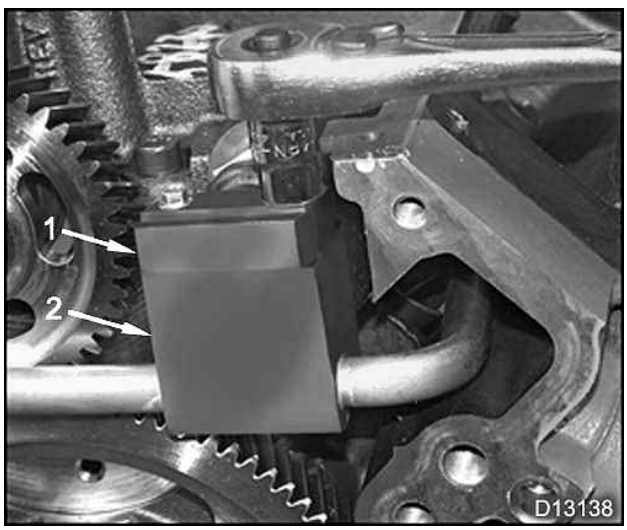

Figure 598 Removal of bolts from branch tube adaptor

1. Branch tube adaptor
2. Branch tube assembly

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

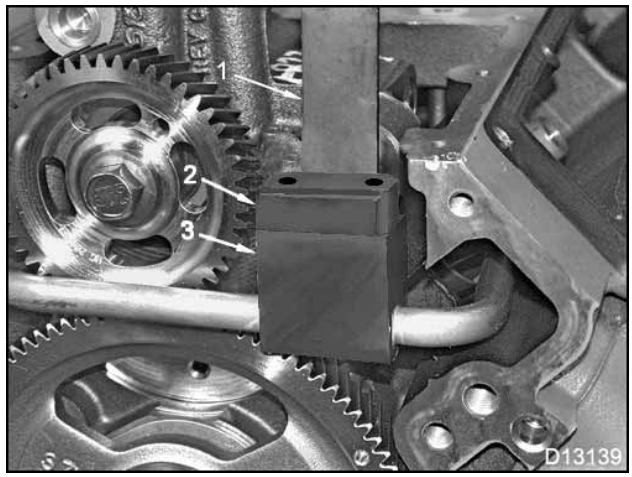

Figure 599 Removal of branch tube adapter

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 39) .

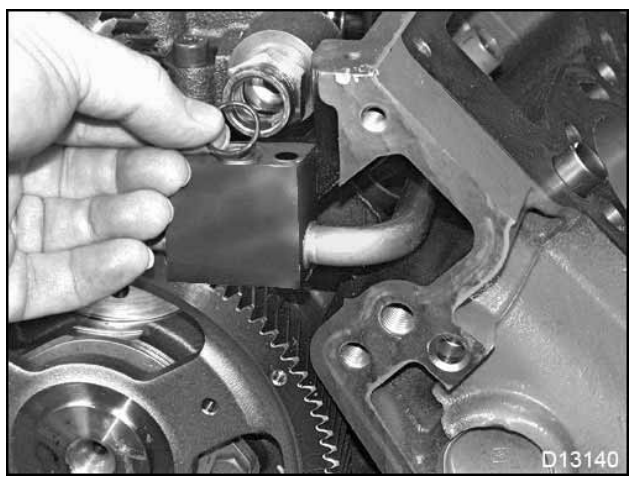

Figure 600 Removal of O-ring

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

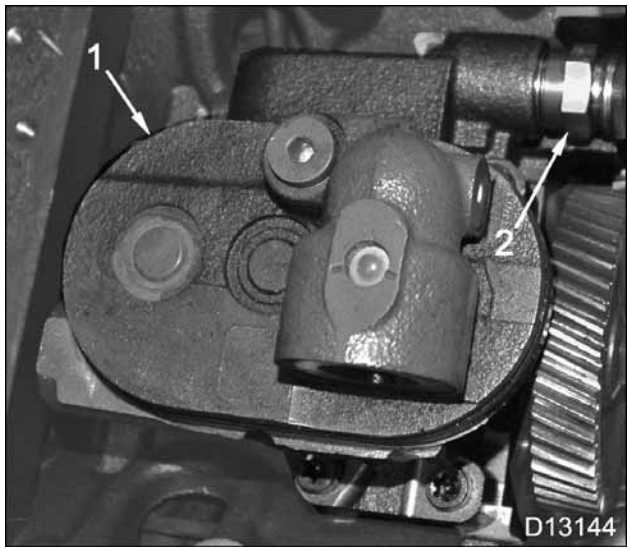

Figure 601 High-pressure oil pump assembly and STC fitting

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

53. Remove STC fitting.

54. Remove branch tube assembly.

Installation

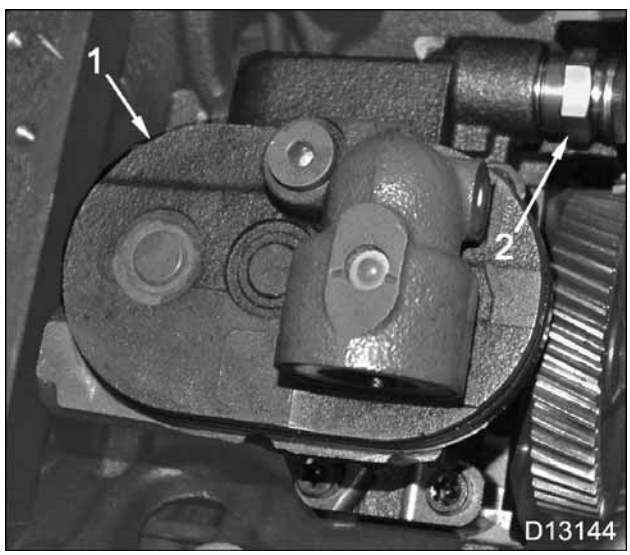

Figure 602 High-pressure oil pump assembly and STC fitting

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 68).

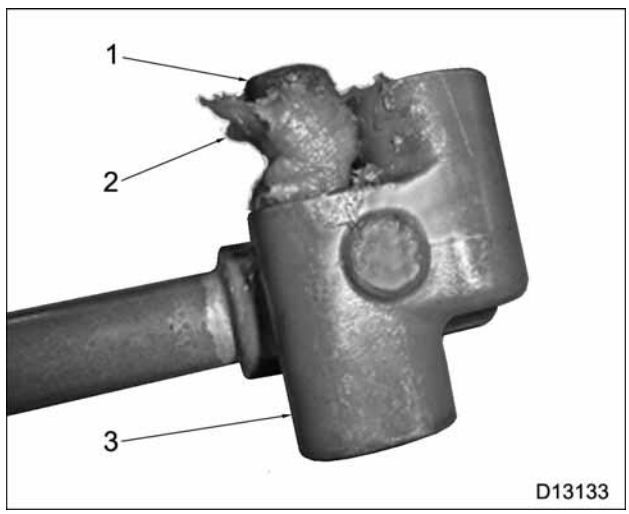

Figure 603 Mounting block on branch tube assembly

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.

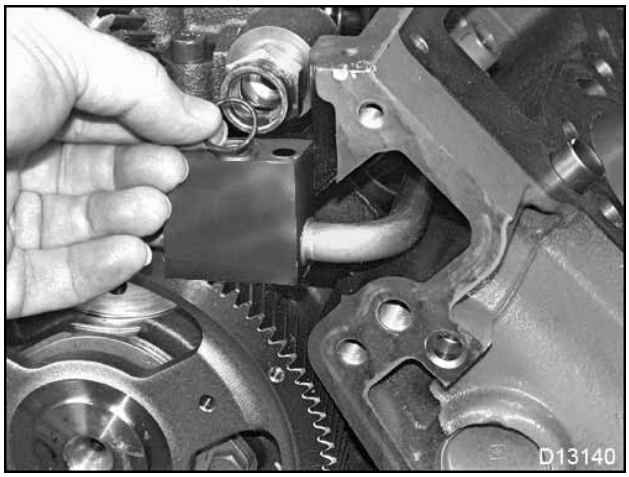

Figure 604 Installation of O-ring

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.

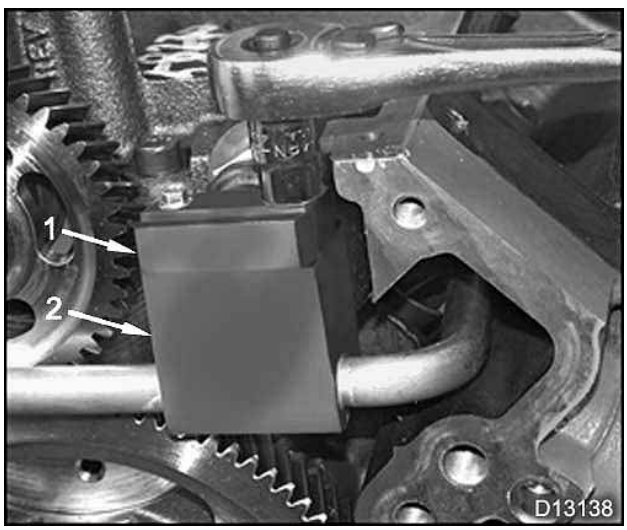

Figure 605 Installation of bolts for branch tube adapter

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.

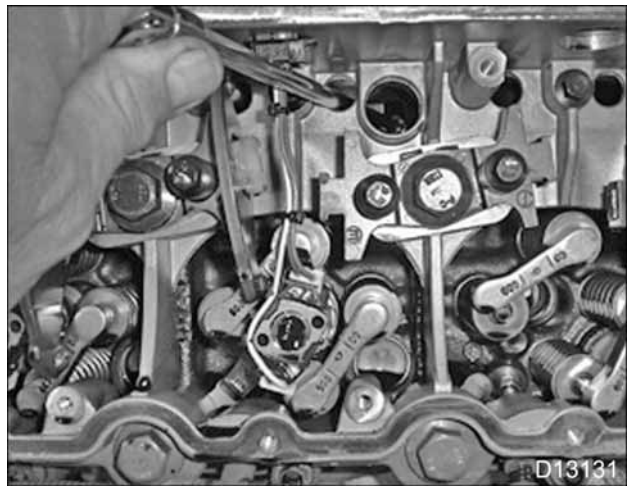

Figure 606 Extension in pushrod hole

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 68).
10. Torque both M6 x 30 mounting bolts to the special torquefor the branch tube adaptor (Table 68).
11. Install exhaust pushrod for cylinder 6.
12. Install intake and exhaust pushrods for cylinders 7 and 8.
13. See *Engine Service Manual* – “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 *Engine Service Manual* – “High-pressure Oil Pump”.

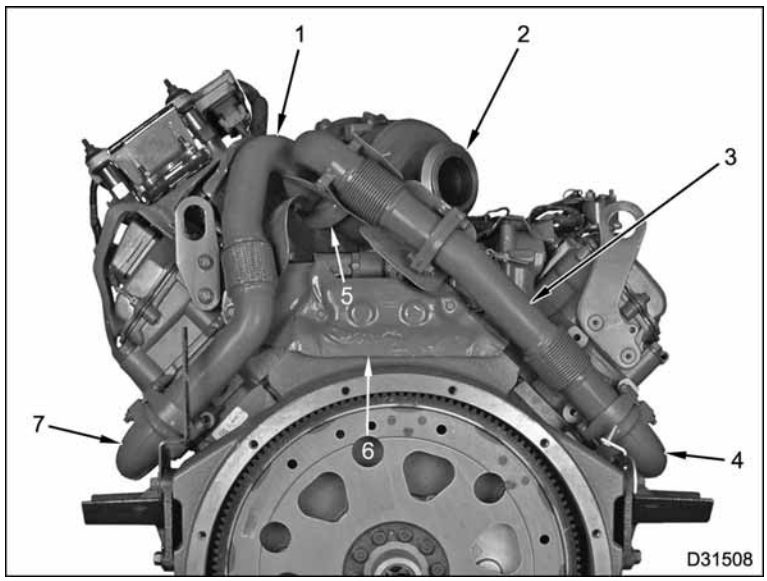

Figure 607 Air Management System parts

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 68) and one M10 x 16 heat shield bolt to the special torque (Table 68).
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 68).
19. Position V-clamp to connect right exhaust tube to EGR cooler and tighten V-clamp to to the special torque (Table 68).
20. Tighten M8 bolts securing shielded exhaust tube assembly (right exhaust tube attached) to the special torque (Table 68).
21. See *Engine Service Manual* – “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 the special torque (Table 68).

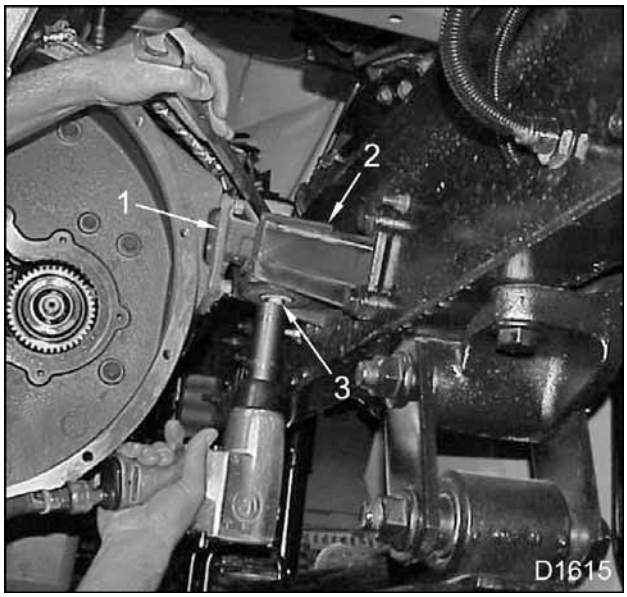

Figure 608 Installation of through bolt into rear engine mount

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 68).
26. Remove chain hoist.
27. Install starter motor assembly and tighten M10 x 40 starter bolts to the special torque (Table 68).
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.

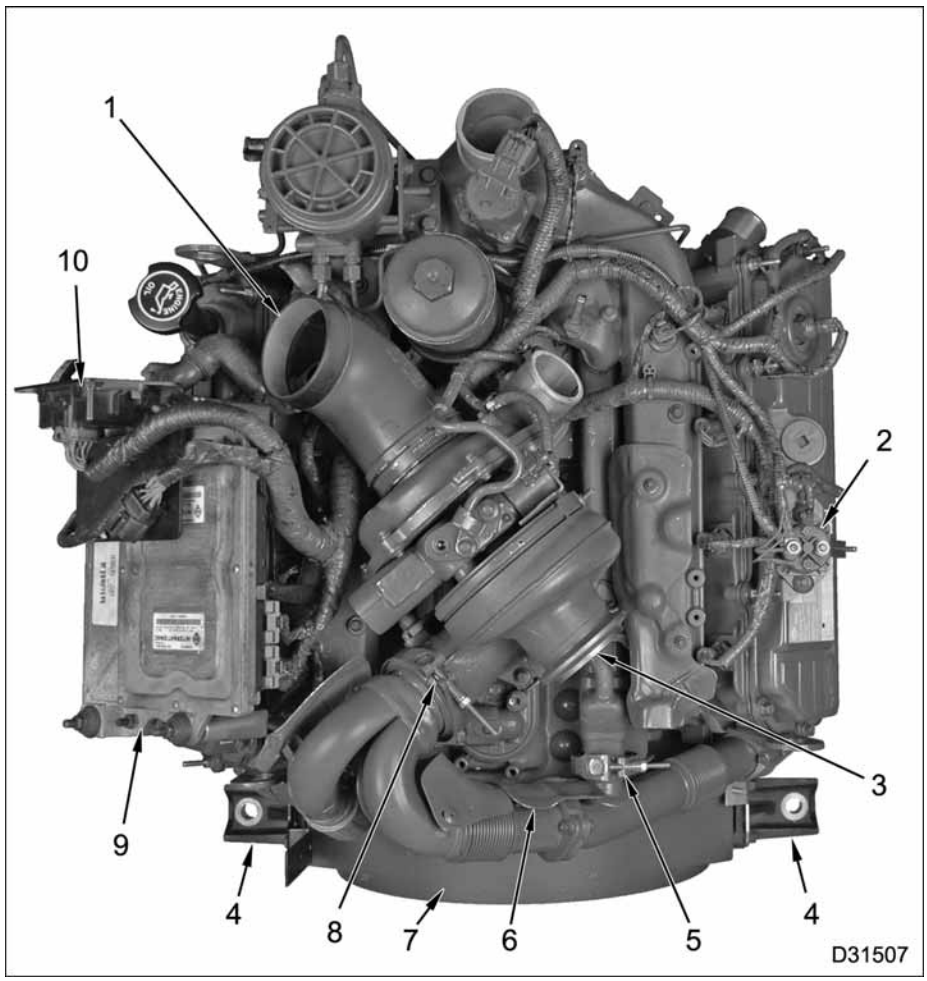

Figure 609 Parts for Installation

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 *Engine Service Manual* – “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 68).
33. See *Engine Service Manual* – “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.

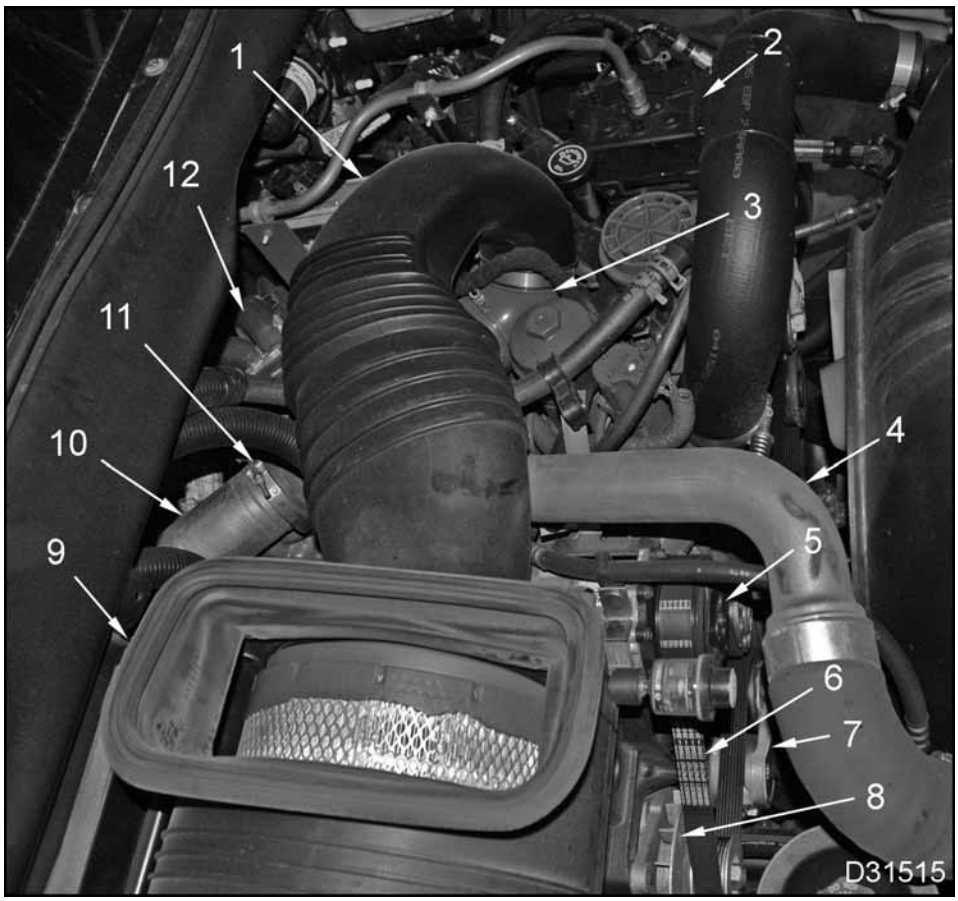

Figure 610 Parts for Installation – Engine In-chassis (4100 truck)

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 68).
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 68).
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.

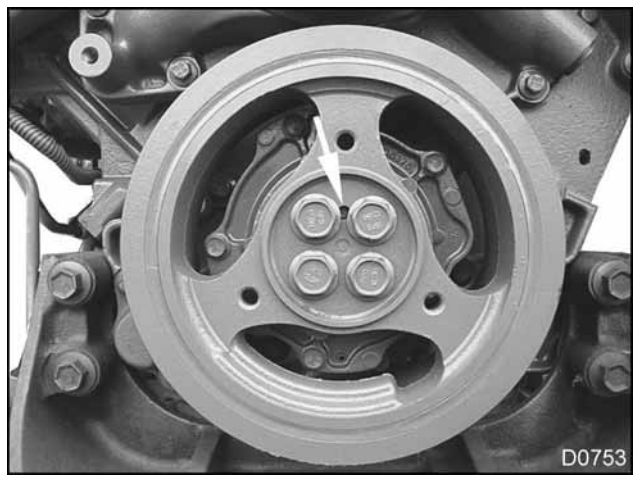

Figure 611 Dowel hole in vibration damper

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

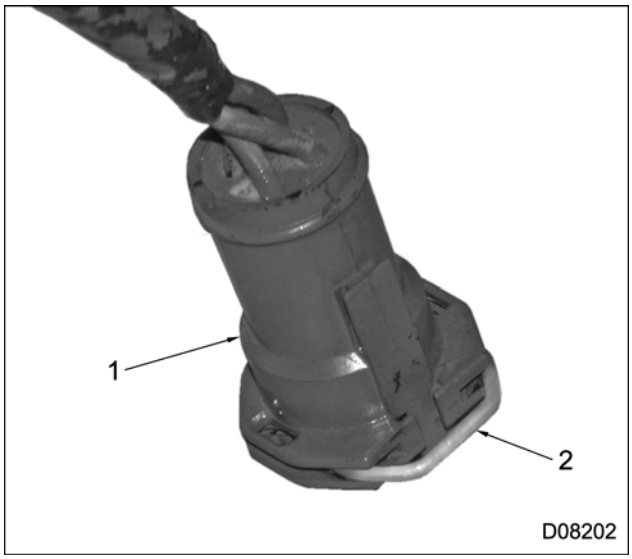

Figure 612 Engine harness connector to injector connector

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.

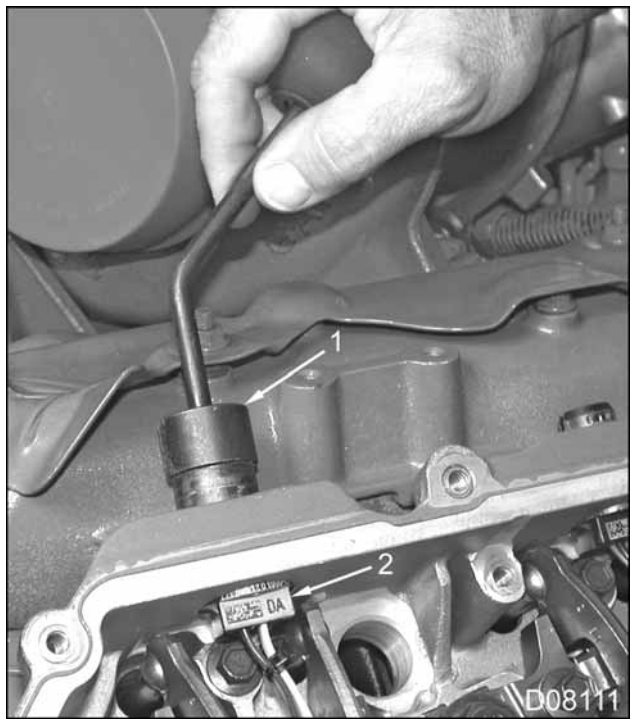

Figure 613 Injector connector removal

1. Injector Connector Release Tool
2. Fuel injector connector

5. Install the Injector Connector Release Tool (Table 40).
6. Push Injector Connector Release Tool to pop loose spring clips on the injector connector and remove connector from the rocker arm carrier.

Figure 614 Fuel Injector Hold Down Wrench

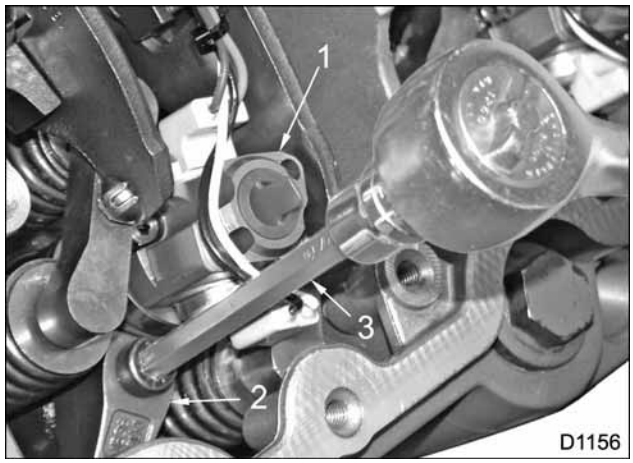

Figure 615 Removal of fuel injector hold down clamp

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 68).
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.

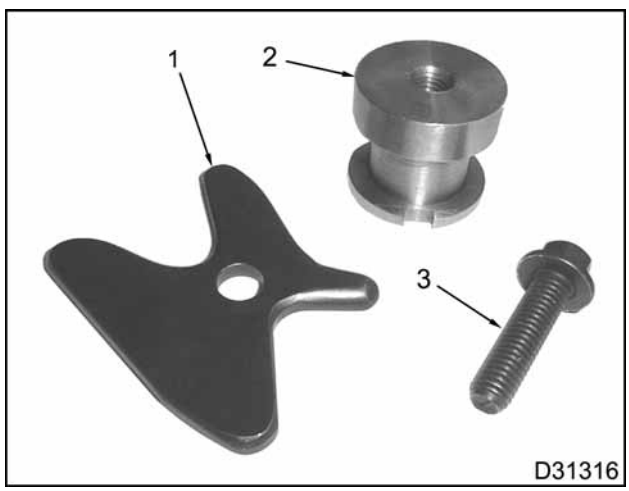

Figure 616 On-engine Valve Spring Compressor Tool

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

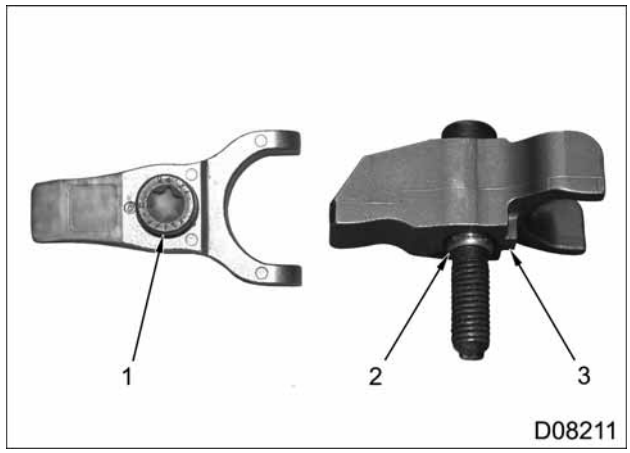

Figure 617 Fuel injector hold down clamp assembly

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

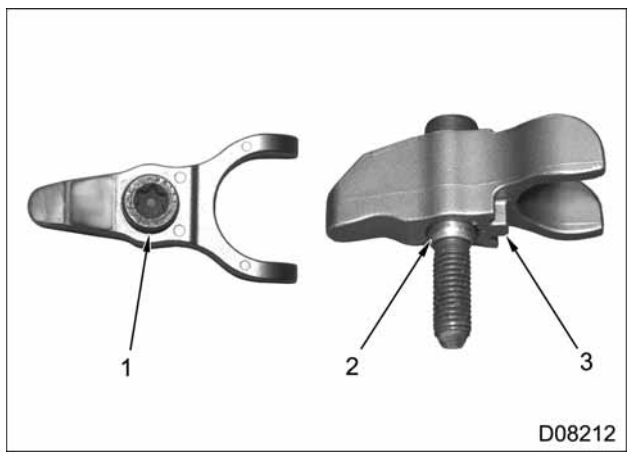

Figure 618 Fuel injector hold down clamp assembly

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

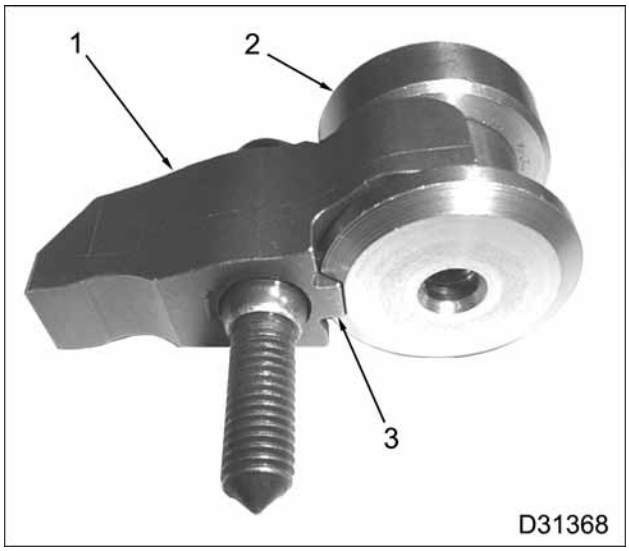

Figure 619 Hold down clamp and valve spring compressor base

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

9. Install On-engine Valve Spring Compressor Tool (Table 40).

   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.

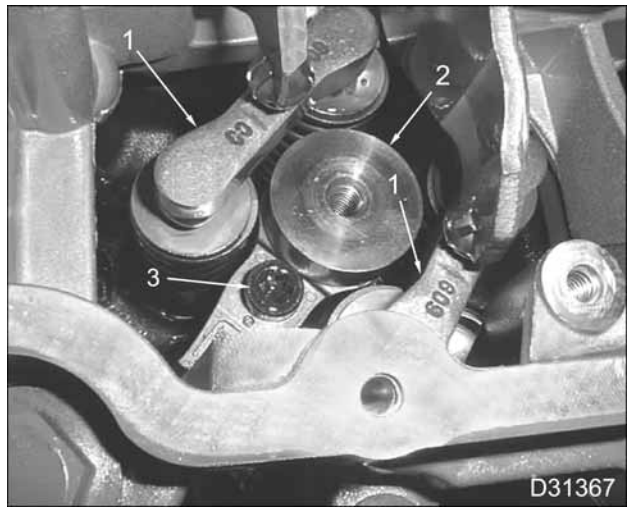

Figure 620

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.

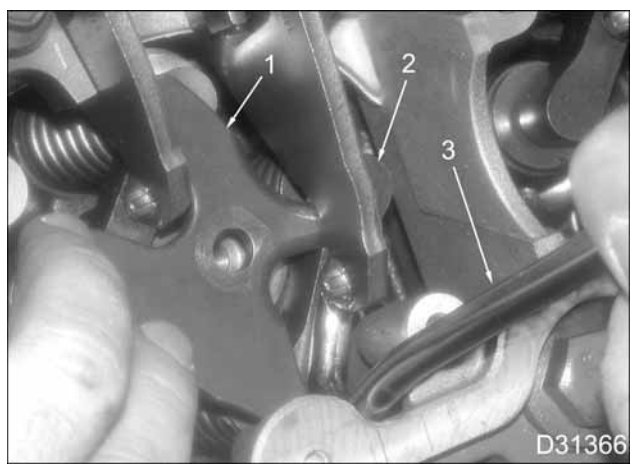

Figure 621 Clearance between rocker arm and valve bridge

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.

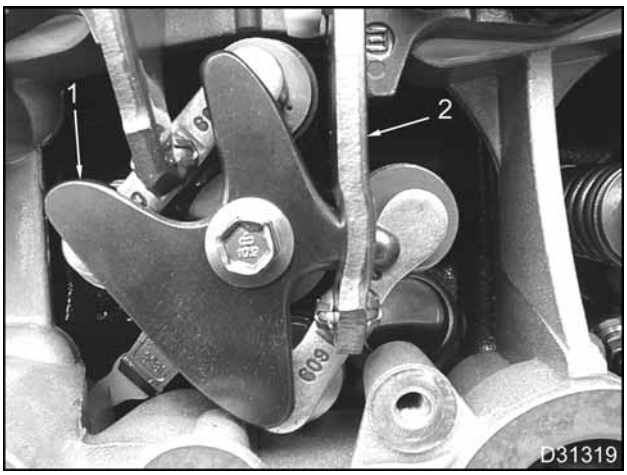

Figure 622 Valve spring compressor plate installed

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 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. .

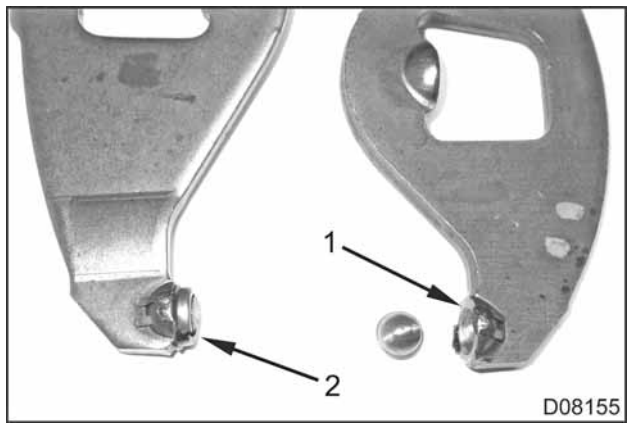

Figure 623 Damaged rocker arm pivot and retainer

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.

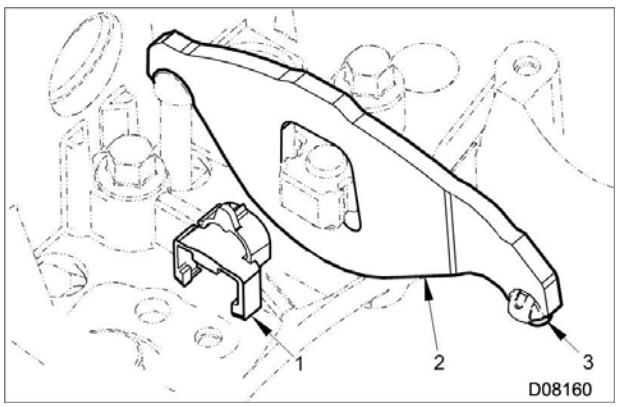

Figure 624

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.

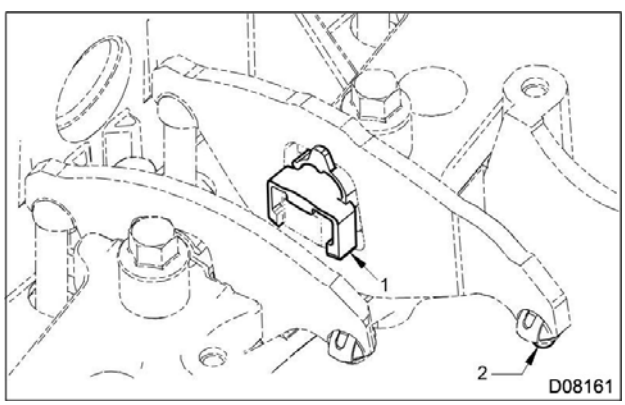

Figure 625 Retaining clip in correct position

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.

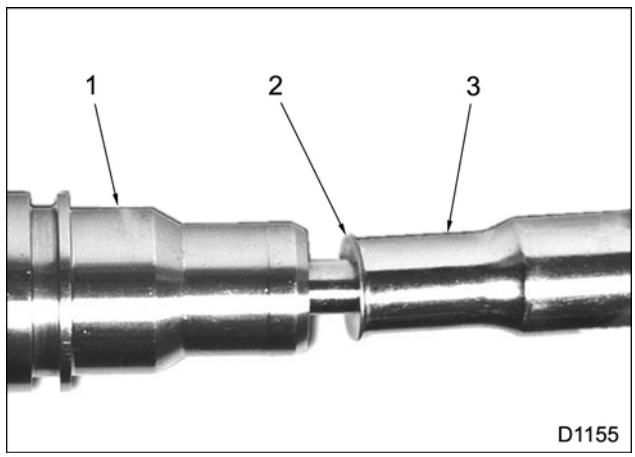

Figure 626 Seating copper gasket

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.

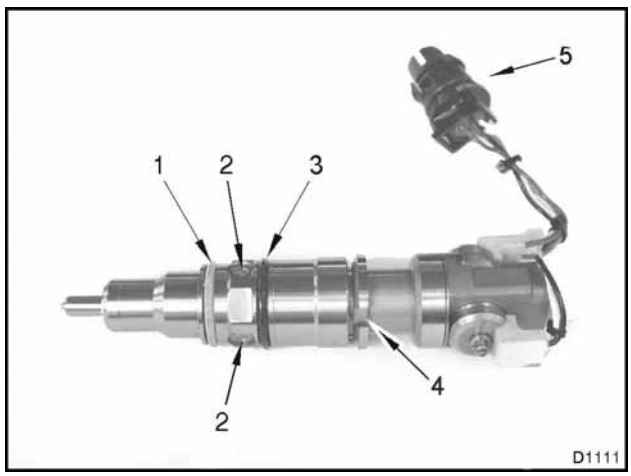

Figure 627 Fuel injector external O-rings

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 628 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 injector hold down clamp as outlined in the *Engine Service Manual*.
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 38 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 (M10 x12)	13 N·m (115 lbf·in)
Bolt for heat shield and 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 (M12 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 39 Branch Tube Assembly

Description	TOOL NUMBER
No. 10 Quick Release Tool	ZTSE4581

Table 40 Rocker Arm

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

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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 TakeOff (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 TakeOff (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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Variable Geometry Turbocharger (VGT)

Table 41 VGT Shaft

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

Manifolds and Exhaust Gas Recirculation (EGR)

Table 42 Intake and Exhaust Manifolds

Exhaust Manifold	
Maximum allowable warpage	0.08 mm (0.003 in)
Intake Manifold	
Maximum allowable clearance	**Between ports:** 0.13 mm (0.005 in) **Total:** 0.25 mm (0.010 in)
Injection Control Pressure (ICP) Sensor	
Operating pressure range	3.5 to 20.7 MPa (500 to 3,000 psi)

Cylinder Head and Valve Train

Table 43 Cylinder Head and Valve Train

Exhaust Valves	
Stem diameter	6.947 to 6.965 mm (0.2735 to 0.2742 in)
Stem to guide clearance (max. allowable before replacement)	0.140 mm (0.0055 in)
Face to stem runout (T.I.R. max.)	0.038 mm (0.0015 in)
Valve face angle	37.5°
Valve margin (minimum)	1.35 mm (0.053 in)
Valve recession in head	0.50 ± 0.18 mm (0.020 ± 0.007 in)
Intake Valves	
Stem diameter	6.947 to 6.965 mm (0.2735 to 0.2742 in)
Stem to guide clearance (max. allowable before replacement)	0.140 mm (0.0055 in)
Face to stem runout (T.I.R. max.)	0.0038 mm (0.0015 in)
Valve face angle	30.0°
Valve margin (minimum)	1.40 mm (0.055 in)
Valve recession in head	0.50 ± 0.18 mm (0.020 ± 0.007 in)

Table 43 Cylinder Head and Valve Train (cont.)

Cylinder Heads	
Valve guide inside diameter	7.003 to 7.029 mm (0.276 to 0.277 in)
Valve guide bore runout	0.05 mm (0.002 in)
Valve guide taper (maximum)	0.10 mm (0.004 in)
Valve seat width (intake)	1.80 to 2.56 mm (0.071 to 0.101 in)
Valve seat width (exhaust)	1.48 to 2.24 mm (0.058 to 0.088 in)
Valve seat angle (intake)	30.0°
Valve seat angle (exhaust)	37.5°
Valve seat runout (T.I.R. max.)	0.035 mm (0.0014 in)
Gasket surface flatness	0.05 mm (0.002 in) **per 51 mm (2 in)** 0.10 mm (0.004 in) **per total surface area**
Overall thickness of cylinder head (deck-to-deck)	95 mm (3.74 in)
Valve head recession relative to deck (surface of cylinder head)	0.32 to 0.68 mm (0.0126 to 0.0268 in)
Valve Spring:	
Free length	51.96 mm (2.045 in)
Solid height	36.1 mm (1.42 in)
Compressed*	46.3 mm @ 340 ± 17 N (1.82 in @ 76.5 ± 3.8 lbf)
Compressed*	38.3 mm @ 850 ± 43 N (1.51 in @ 191 ± 9.7 lbf)
* Spring must be compressed to a solid height, before checking test loads.	
Push Rods	
Runout (maximum)	0.25 mm (0.01 in)

Front Cover, Vibration Damper, and Gerotor Oil Pump

Table 44 Vibration Damper, Lubricating Oil Pump and Thermostat

Vibration Damper	
Face runout (maximum)	0.635 mm (0.025 in)
Rubber bulging (maximum)	1.5 mm (0.060 in)
Lubricating Oil Pump	
Type	Gerotor
Drive	Crankshaft
Location	Gerotor oil pump housing
Pressure Regulating Valve:	
Pressure, low idle (minimum @ 110°C (230°F) oil temperature)	69 kPa (10 psi)
Pressure, high idle (minimum @ 110°C (230°F) oil temperature)	276 kPa (40 psi)
Discharge pressure (2,500 rpm)	483 to 621 kPa (70 to 90 psi)
End clearance (inner and outer rotor to housing)	0.025 to 0.095 mm (0.001 to 0.004 in)
Radial clearance (between outer rotor and housing)	0.17 to 0.295 mm (0.007 to 0.012 in)
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 to 91°C (188 to 196°F)
Full-open temperature, 8 mm (0.315 in) stroke	104°C (219°F)

Connecting Rods and Pistons

Table 45 Connecting Rods and Piston Assemblies

Connecting Rods	
Connecting rod length (center to center)	176 mm (6.929 in)
Bushing bore diameter (pin end)	36.98 to 37.02 mm (1.456 to 1.457 in)
Piston pin bushing inside diameter	34.0140 to 34.0215 mm (1.3391 to 1.3394 in)
Material	I-Beam Section - Powdered
Bearing bore diameter (crankshaft end)	72.987 to 73.013 mm (2.8735 to 2.8745 in)
Bearing bore maximum out-of-round	0.013 mm (0.0005 in)

Table 45 Connecting Rods and Piston Assemblies (cont.)

Bearing bore maximum taper per 25 mm (1 in)	0.013 mm (0.0005 in)
Connecting rod bearing inside diameter	69.027 to 69.077 mm (2.7176 to 2.7196 in)
Connecting rod bearing running clearance (diameter)	0.0203 to 0.0837 mm (0.0008 to 0.0033 in)
Connecting rod side clearance	0.3 to 0.6 mm (0.012 to 0.024 in)
Weight (complete rod without bearing)	1201.5 to 1215.5 g (2.649 to 2.679 lb)
Pistons	
Material	Aluminum Alloy
Skirt diameter [1]	94.9460 to 94.9186 mm (3.737 to 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 to 21°C (66 to 70°F).	
Service Piston:	
Standard size	94.9460 to 94.9186 mm (3.737 to 3.738 in)
0.254 mm (0.010 in) oversize	95.1738 to 95.1992 mm (3.747 to 3.748 in)
0.508 mm (0.020 in) oversize	95.4278 to 95.4532 mm (3.757 to 3.758 in)
0.762 mm (0.030 in) oversize	95.6818 to 95.7072 mm (3.767 to 3.768 in)
Top compression ring groove width (measured over 2.08 mm (0.082 in) gauge pins):	
Upper limit	94.469 mm (3.7192 in)
Replacement limit	93.290 mm (3.7122 in)
Piston height above crankcase deck (protrusion)	0.9000 mm (0.0354 in)
Piston skirt clearance (1 - 8)	0.0441 to 0.0909 mm (0.0017 to 0.0036 in)
Piston Pins	
Length	65.073 to 65.327 mm (2.5619 to 2.5719 in)
Diameter	33.9975 to 34.0025 mm (1.3385 to 1.3387 in)
Pin fit at room temperature of 19 to 21°C (66 to 70°F):	
Clearance in connecting rod (piston pin bushing)	0.0115 to 0.0240 mm (0.00045 to 0.00094 in)
Clearance in piston	0.013 to 0.022 mm (0.0005 to 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 to 0.102 mm (0.0020 to 0.0040 in)

Table 45 Connecting Rods and Piston Assemblies (cont.)

Oil control	0.038 to 0.084 mm (0.0015 to 0.0033 in)
Ring gap in bore:	
Top compression	0.29 to 0.55 mm (0.011 to 0.021 in)
Intermediate compression	1.40 to 1.66 mm (0.055 to 0.065 in)
Oil control	0.24 to 0.50 mm (0.009 to 0.019 in)

Crankcase, Crankshaft and Bearings, Camshaft and Bushings

Table 46 Crankshaft and Camshaft and Bushings

Crankshaft	
Main Bearing Journal Diameter:	
Standard size	80.9873 to 81.0127 mm (3.188 to 3.150 in)
0.254 mm (0.010 in) under size	80.7333 to 80.7587 mm (3.178 to 3.140 in)
0.508 mm (0.020 in) under size	80.4793 to 80.5047 mm (3.168 to 3.130 in)
0.762 mm (0.030 in) under size	80.2253 to 80.2507 mm (3.158 to 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 to 0.086 mm (0.0008 to 0.0034 in)
Connecting Rod Journal Diameter:	
Standard size	68.99 to 69.01 mm (2.716 to 2.717 in)
0.254 mm (0.010 in) under size	68.73 to 68.75 mm (2.706 to 2.707 in)
0.508 mm (0.020 in) under size	68.48 to 68.50 mm (2.696 to 2.697 in)
0.762 mm (0.030 in) under size	68.23 to 68.25 mm (2.686 to 2.687 in)
Crankshaft end play (maximum)	0.222 mm (0.0087 in)
Camshaft	
Bearing journal diameter (all journals)	61.987 to 62.013 mm (2.440 to 2.441 in)
Bearing inside diameter	62.05 to 62.14 mm (2.443 to 2.446 in)
Journal/bushing running clearance	0.037 to 0.153 mm (0.0015 to 0.0060 in)
Camshaft end play	0.051 to 0.211 mm (0.002 to 0.008 in)
Camshaft gear backlash	0.179 to 0.315 mm (0.007 to 0.012 in)
Maximum permissible cam lobe wear	0.51 mm (0.02 in)
Camshaft thrust plate thickness	3.589 to 3.649 mm (0.1413 to 0.1436 in)

Table 46 Crankshaft and Camshaft and Bushings (cont.)

Camshaft lobe lift (maximum):	
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 47 Crankcase and Main Bearings

Crankcase	
Cylinder block top surface of crankcase (firing deck) flatness	Total: 0.10 mm (0.004 in) 150 mm x 150 mm (6 in x 6 in) area: 0.05 mm (0.02 in) 25 mm x 25 mm (1 in x 1 in) area: 0.025 mm (0.001 in)
Crankcase main bearing bore diameter	85.99 to 86.01 mm (3.3854 to 3.3862 in)
Crankcase cam bearing bore diameter	65.98 to 66.02 mm (2.597 to 2.599 in)
Valve tappet bore diameter	23.439 to 23.477 mm (0.9228 to 0.9243 in)
Valve tappet outside diameter	23.391 to 23.411 mm (0.9209 to 0.9217 in)
Cylinder bore diameter	94.999 to 95.001 mm (3.7401 to 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 48 Oil Cooler and Oil Filter

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 49 Engine Electrical

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 to +130°C (-40 to 266°F)
Injection Control Pressure (ICP) Sensor	
Operating pressure range	3.5 to 20.7 MPa (500 to 3,000 psi)
Injection Pressure Regulator (IPR) Valve	
Operating temperature range	-40 to 220°C (-40 to 428°F)
Maximum operating pressure	28 MPa (4,061 psi)

High-pressure Oil Pump

Table 50 Injection Pressure Regulator (IPR) Valve

Injection Pressure Regulator (IPR) Valve	
IPR valve cracking pressure	31 MPa (4,500 psi)
IPR valve maximum pressure	37 MPa (5,400 psi)

Fuel System

Table 51 Fuel Filter and Pressure Regulating Valve

Fuel Filter	
Type	10 micron with water separation
Normal fuel pressure (after fuel filter)	345 to 482 kPa (50 to 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 to 10.8ºC (38.5 to 51.5ºF)
Heater element deactivates	19.1 to 29.6ºC (66.5 to 83.5ºF)

Rear Cover, Flywheel, and Power Steering and Fuel Pump

Table 52 Rear Cover, Flywheel, and Power Steering and Fuel Pump

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

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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 application of standard hardware listed in the Parts Catalog for original equipment.

NOTE: Inspect parts for cleanliness and defects before assembly.

Standard Torques

Table 53 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 54 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 55 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.

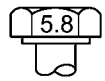
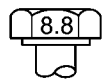
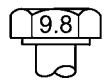
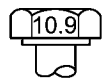
INTERNATIONAL Class	ISO R 898 I	MATERIAL	THERMAL TREATMENT	HEAD MARKING Preferred	HEAD MARKING Optional
5.8	5.8	Low or medium Carbon steel	Non required		
8.8	8.8	Medium carbon, Medium carbon Alloy steel or low Carbon boron steel	Quench and tempered		
9.8	–	Medium carbon, Medium carbon Alloy steel or low Carbon boron steel	Quench and tempered		
10.8	10.8	Medium carbon, Medium carbon Alloy steel or low Carbon boron steel	Quench and tempered		

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Figure 629 Metric fasteners – Classification and identification

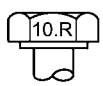
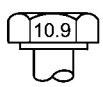
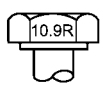
INTERNATIONAL designation	MATERIAL	THERMAL TREATMENT	HEAD MARKING Preferred	HEAD MARKING Optional
CLASS		METRIC FASTENERS		
10.R	Medium carbon, Medium carbon Alloy steel	Quench and tempered, Roll threaded after heat treatment		
10.9	Medium carbon Alloy steel	Quench and tempered		
12.9R	Medium carbon Alloy steel	Quench and tempered, Roll threaded after heat treatment		

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Figure 630 Special fasteners – Classification and identification

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 (bolt and nut), 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 correct 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 correct 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.

Torque Wrench Extension and Adapters

An extension, crowfoot or adapter may be needed with a torque wrench to torque a bolt or line fitting that is difficult to reach. Adding adapters or extensions will alter the actual clamping force at the fastener. Use the following formula to determine the torque wrench setting to achieve the known standard or special torque value.

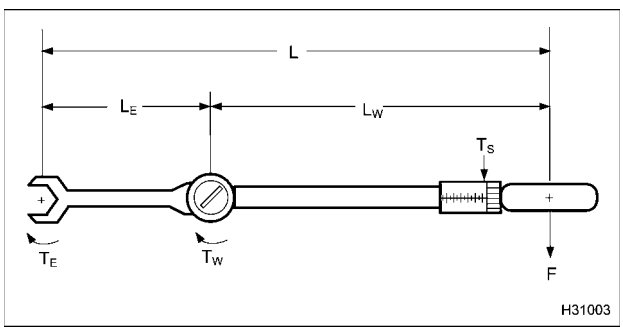

Figure 631 Torque wrench extension

- F – Force applied by technician
- L – Length through which force is applied to fastener
- L_E – Length of extension
- L_W – Length of torque wrench
- T_E – Torque applied at fastener
- T_W – Torque applied at end of torque wrench
- T_S – Torque wrench setting

$T_S = T_E (L_W / (L_W + L_E)$

Example:

A component has a known torque value of 88 N·m (65 lbf·ft) and an extension is required. What should the torque wrench setting be to compensate for the extension?

- Torque wrench = 12 inches
- Extension = 6 inches

T_S = 88 N·m (65 lbf·ft) [12 in / (12 in + 6 in]

T_S = 88 N·m (65 lbf·ft) [12 in / 18 in]

T_S = 88 N·m (65 lbf·ft) [0.666]

T_S = **58.9 N·m (43.3 lbf·ft)**

Special Torques

Mounting Engine On Stand

Table 56 Oil Pan Drain Plug

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

Variable Geometry Turbocharger (VGT)

Table 57 VGT Bolts and Clamps

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

Manifolds and Exhaust Gas Recirculation (EGR)

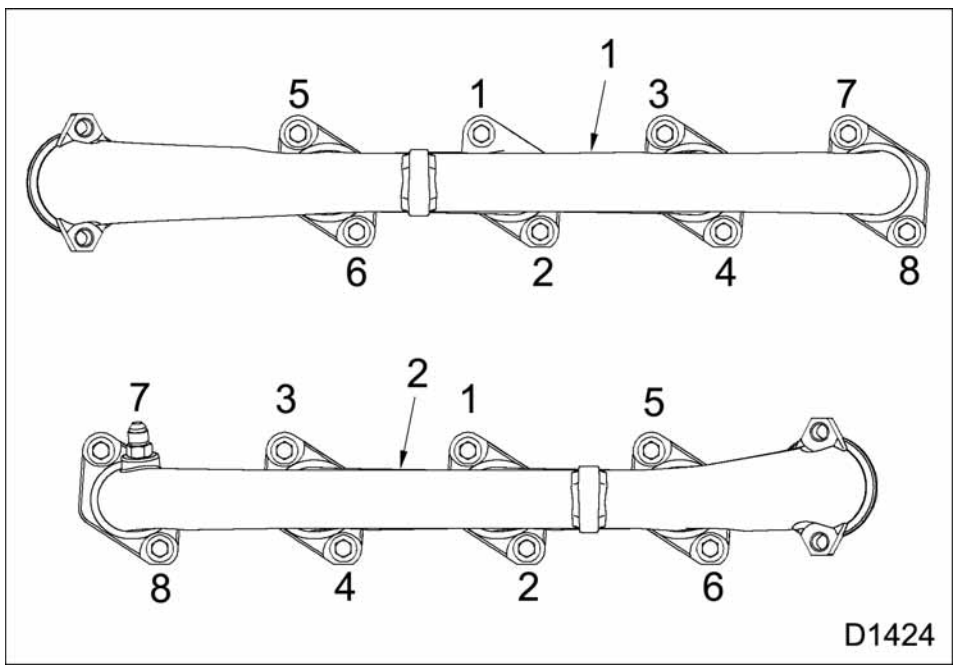

Figure 632 Tightening sequence for exhaust manifold mounting bolts

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

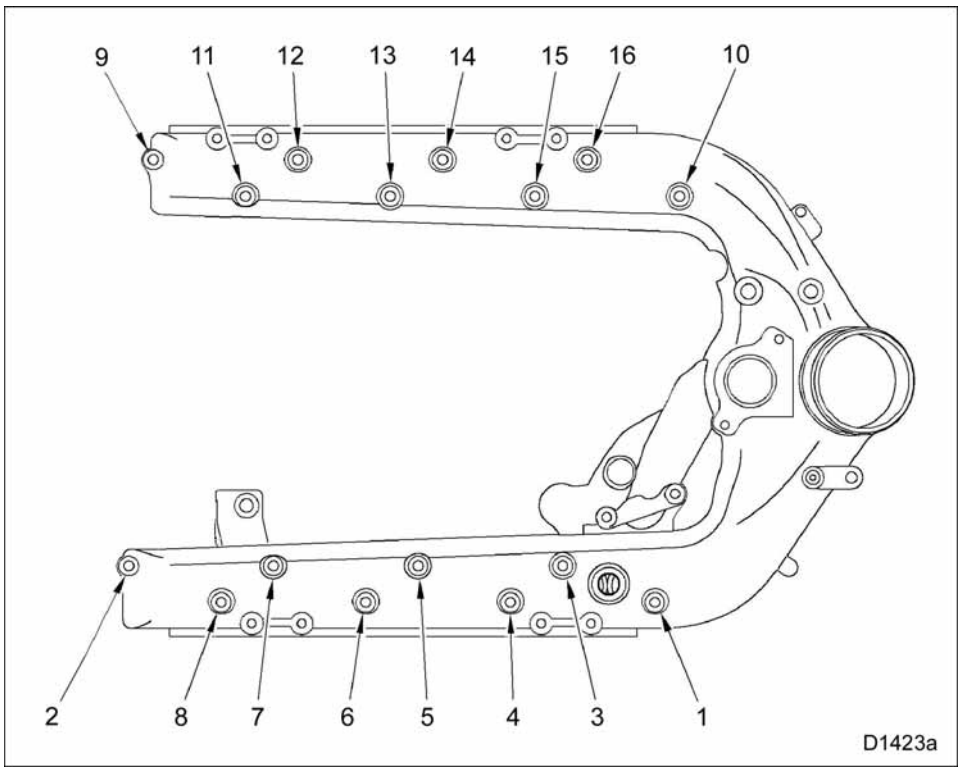

Figure 633 Tightening sequence for intake manifold mounting bolts

Table 58 Manifolds and Exhaust Gas Recirculation (EGR)

Intake manifold, M6 x 95 flange bolts	11 ± 1 N·m (96 ± 10 lbf·in) (Figure 633)
Intake heat shield, M6 nut	11 ± 3 N·m (96 ± 24 lbf·in)
Exhaust manifold flange bolts[1]	38 ± 4 N·m (28 ± 3 lbf·ft) (Figure 632)
EBP tube assembly[1]	30 ± 1 N·m (22 ± 1 lbf·ft)
EBP tube connector[1]	14 - 15 N·m (120 - 132 lbf·in)
Shielded exhaust tube to exhaust manifold (left side)[1]	27 ± 4 N·m (20 ± 3 lbf·ft)
Shielded tube exhaust to right side exhaust tube[1]	27 ± 4 N·m (20 ± 3 lbf·ft)
Exhaust tube to exhaust manifold (right side)[1]	27 ± 4 N·m (20 ± 3 lbf·ft)
VGT exhaust adapter V-clamp	12 N·m (108 lbf·in)
EGR cooler V-clamp	6 N·m (48 lbf·in)

[1] Apply anti-seize compound to bolt threads before assembly.

Cylinder Head and Valve Train

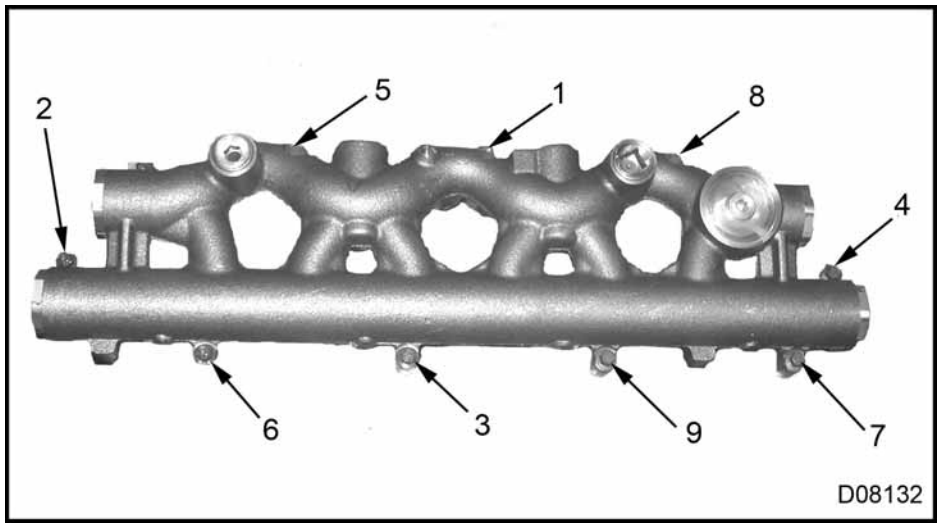

Figure 634 Torque sequence for oil rail bolts

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.

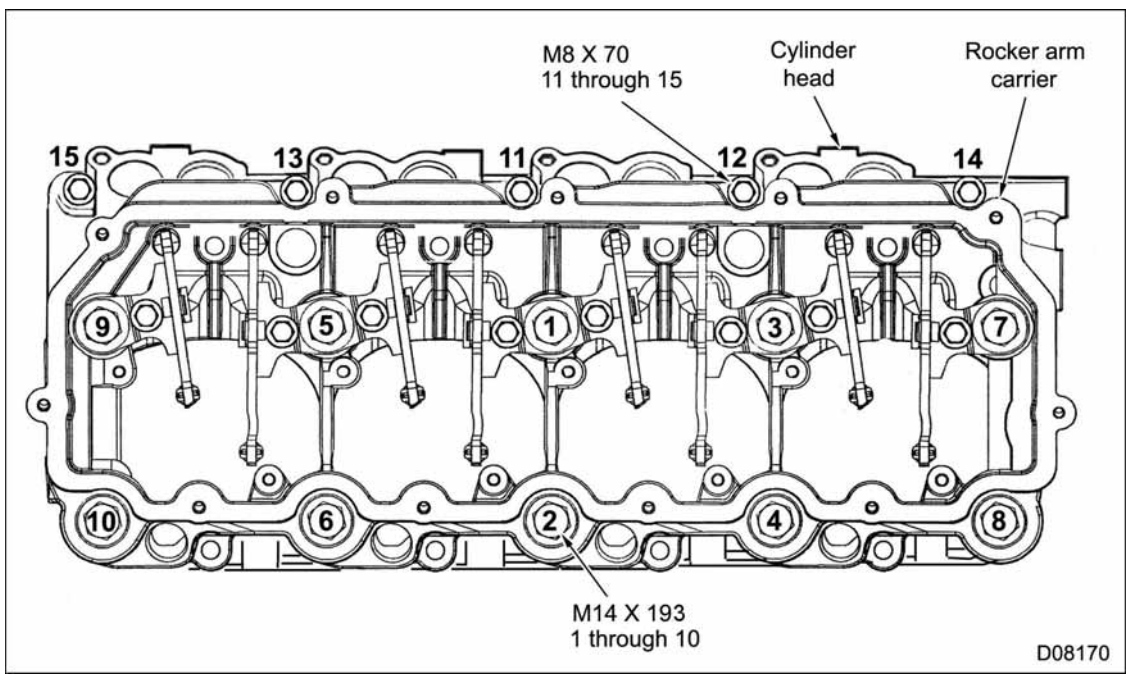

Figure 635 Tightening sequence for cylinder head mounting bolts

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 Bolts

A. Lightly lubricate all bolts and torque in the sequence numbered 1 through 10 to 88 N·m (65 lbf·ft).

B. Torque bolts 1, 3, 5, 7 and 9 in sequence to 116 N·m (85 lbf·ft).

C. Torque all bolts in sequence numbered 1 through 10, clockwise 90°.

D. Torque all bolts in sequence numbered 1 through 10, a second time clockwise 90°.

E. Torque all bolts in sequence numbered 1 through 10, a third time clockwise 90°.

F. M14 x 193 torque sequence complete.

M8 x 70 Cylinder Head Mounting Bolts

A. Install all M8 bolts and torque in the sequence numbered 11 through 15 to 24 N·m (18 lbf·ft).

B. Torque all M8 bolts in the sequence numbered 11 through 15 to 31 N·m (23 lbf·ft).

C. M8 x 70 torque sequence complete.

Table 59 Cylinder Head and Valve Train

Lifting eye, front, (M10 x 30)	41 ± N·m (30 ± 3 lbf·ft)
Lifting eye, rear, flat socket head (M10 x 35)	41 ± N·m (30 ± 3 lbf·ft)
Crankcase breather nuts	7 N·m (60 lbf·in)
Cylinder head bolt torque and sequence	(Figure 635)
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 25)	13 N·m (120 lbf·in) (Figure 634)
Crankcase-to-head tube assembly	82 N·m (60 lbf·ft)
Valve cover bolts and studs	9 +1/-2 N·m (72 ± 12 lbf·in)
Oil fill extension	14 ± 1 N·m (120 - 132 lbf·in)
Rear heat shield (M10 x 16)	49 ± 5 N·m (36 ± 4 lbf·ft)

Front Cover, Vibration Damper, and Gerotor Oil Pump

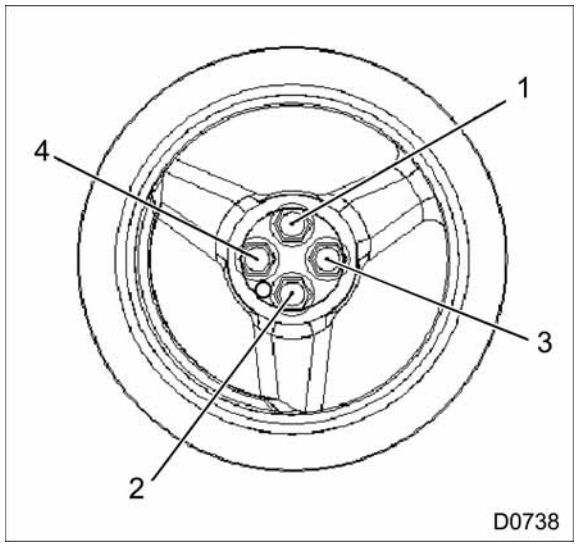

Figure 636 Torque sequence for vibration damper bolts

Table 60 Front Cover, Vibration Damper, Water Pump and Oil Pan Drain Plug

Oil pan drain plug	25 ± 5 N·m (18 ± 4 lbf·ft)
Front cover module bolts	24 N·m (18 lbf·ft)
Water pump mounting bolts	23 ± 1 N·m (17 ± 1 lbf·ft)
Vibration damper mounting bolts	New bolts only: 68 N·m (50 lbf·ft) + 90° rotation. (Figure 636)

Connecting Rods and Pistons

Table 61 Connecting Rod Assembly

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

Crankcase, Crankshaft and Bearings, Camshaft and Bushings

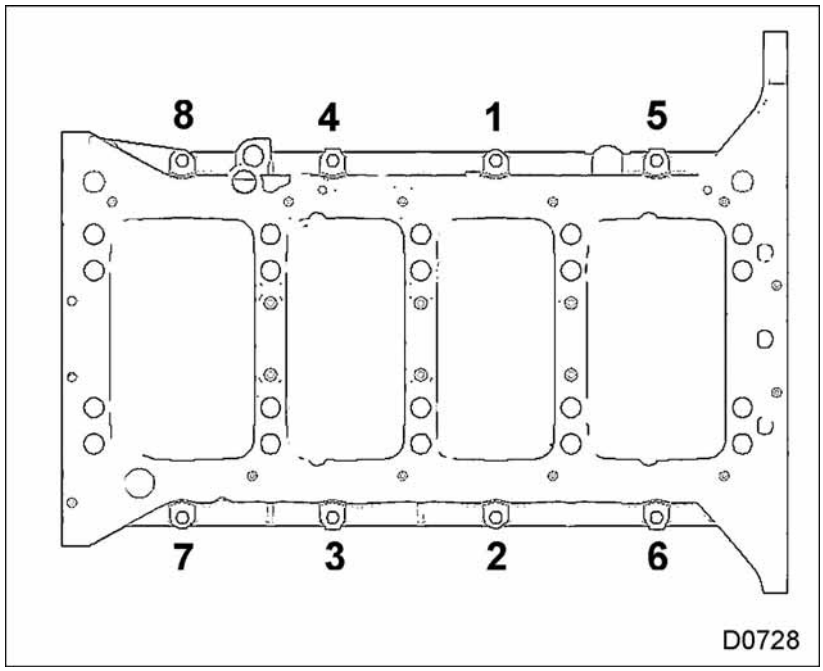

Figure 637 Torque sequence for outer lower crankcase bolts – 2004 Model Year

NOTE: For 2004 Model Year, install eight M8 x 30 bolts around outside of lower crankcase and torque in sequence to 31 N·m (23 lbf·ft).

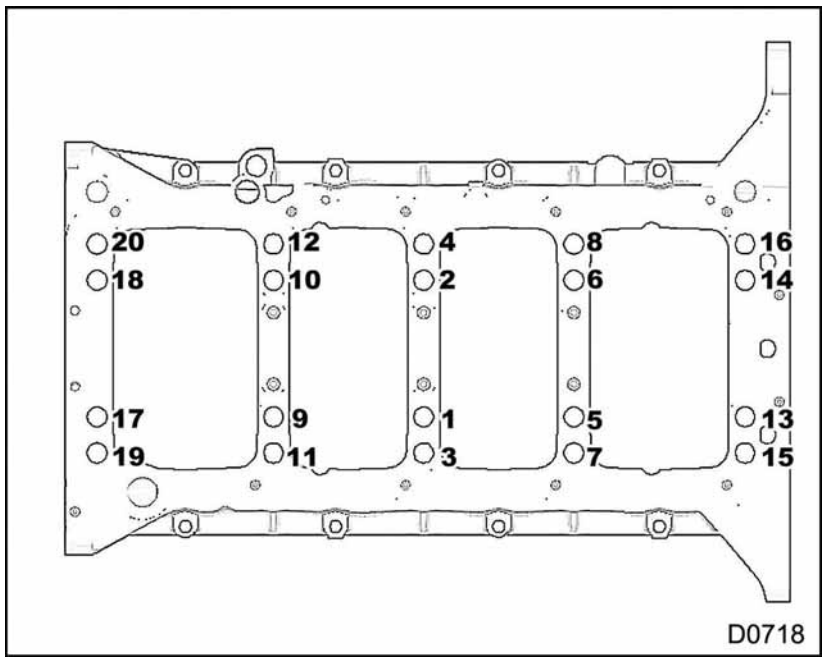

Figure 638 Tightening sequence for main bearing bolts in lower crankcase

1. Initially torque bolts to 122 N·m (90 lbf·ft).
2. Increase torque for bolts to 163 N·m (120 lbf·ft).
3. Finally, torque bolts to 231 N·m (170 lbf·ft).

Table 62 Crankcase and Heater Element

Lower crankcase main bearing cap bolts	See tightening procedure and sequence (Figure 637)
Lower crankcase outer bolts (M8 x 30), standard torque	
Coolant heater element	41 N·m (30 lbf·ft)

Oil Cooler and Oil Filter

Table 63 Oil Cooler and Oil Filter

EGR cooler coolant supply port cover (M6)	10 +1/-2 N·m (84 ± 12 lbf·in)
Oil cooler mounting bolts (M6 x 23)	10 +1/-2 N·m (84 ± 12 lbf·in)
Oil cooler cover mounting bolts (M8 x 23)	22 ± 2 N·m (17 ± 1 lbf·ft)
Oil filter housing mounting bolts (M8 x 75)	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 64 Engine Electrical

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	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 65 Oil Pump, Cover, IPR, and Heat Shields

High-pressure oil pump cover bolts	14 N·m (120 lbf·in)
Branch tube adapter bolts (M6 x 25)	14 N·m (120 lbf·in)
Injection Pressure Regulator (IPR)	50 ± 5 N·m (37 ± 4 lbf·ft)
Rear exhaust heat shield, (M6 x 12)	11 ± 3 N·m (96 ± 24 lbf·in)
Rear heat shield, (M10 x 16)	49 ± 5 N·m (36 ± 4 lbf·ft)

Fuel System

Table 66 Fuel System Components

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)
Power steering pump inlet elbow fitting	90 ± 10 N·m (66 ± 7 lbf·ft)
Power steering pump outlet elbow fitting	45 ± 4 N·m (33 ± 3 lbf·ft)
Power steering tube	79 ± 4 N·m (58 ± 3 lbf·ft)

Flywheel, Rear Cover, and Power Steering and Fuel Pump

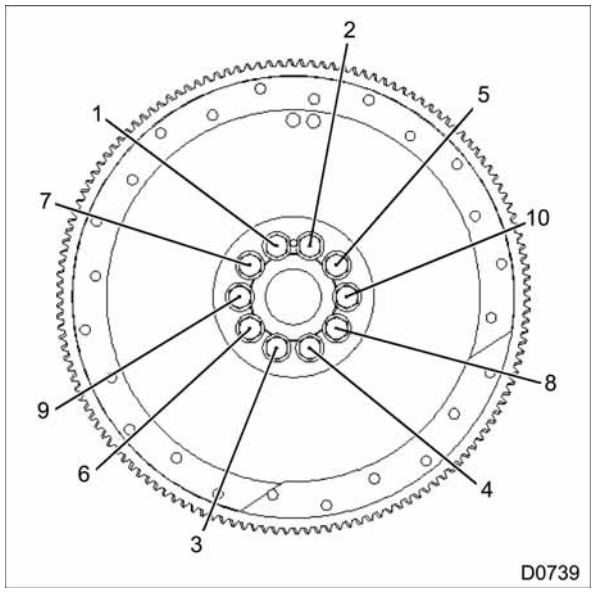

Figure 639 Torque sequence for flywheel and flexplate (typical)

Table 67 Flywheel, Flexplate and Power Steering Assembly

Flywheel mounting bolts (M10 x 77), new bolts only	94 N·m (69 lbf·ft) (Figure 639)
Flexplate mounting bolts (M10 x 77), new bolts only	94 N·m (69 lbf·ft) (Figure 639)
Power steering pump outlet pipe fitting	45 ± 5 N·m (33 ± 4 lbf·ft)
Power steering pump inlet pipe fitting	90 ± 10 N·m (66 ± 7 lbf·ft)

In-chasiss Procedures

Table 68 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 (M10 x12)	13 N·m (115 lbf·in)
Bolt for heat shield and 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 (M12 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

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

Mounting Engine on Stand

Table 69 Mounting Engine on Stand

Description	TOOL NUMBER
Engine Stand Mounting Bracket	ZTSE4507

Variable Geometry Turbocharger (VGT)

Table 70 VGT

Description	Tool Number
Cap Kit (all)	ZTSE4610
Dial Indicator with Magnetic Base	Obtain locally
Intake Guard	ZTSE4548

Manifolds and Exhaust Gas Recirculation (EGR)

Table 71 Manifolds and Exhaust Gas Recirculation (EGR)

Description	Tool Number
Anti-Seize Compound	Obtain locally
Cap Kit (all)	ZTSE4610
EGR Cooler Pressure Test Plates	ZTSE4545
EGR Valve Puller	ZTSE4669
Feeler Gauge	Obtain locally
Injector Sleeve Brush	ZTSE43041
Intake Manifold Pressure Test Plates	ZTSE4527
Intake Manifold Pressure Test Plug (Replaces EGR Valve)	ZTSE4544
Intake Port Covers (cylinder heads)	ZTSE4559
Pressure Test Adaptor (intake)	ZTSE4554
Straightedge	Obtain locally

Cylinder Head and Valve Train

Table 72 Cylinder Head and Valve Train

Description	TOOL NUMBER
Bottoming Tap (metric)	ZTSE4508
Case-to-head Removal Tool	ZTSE4694
Cylinder Head Lifting Bracket	ZTSE4535
Cylinder Head Pressure Test Plate	ZTSE4534
Dye Penetrant Kit	PT-7191
Fuel Gallery Cleaning Brush	ZTSE4541
Fuel Injector Hold Down Wrench	ZTSE4524
Fuel Injector Rack Holder	ZTSE4299B
Fuel Injector Tip Cleaning Brush	ZTSE4301
Glow Plug Sleeve Brush (nylon)	ZTSE4533
Glow Plug Sleeve Installer	ZTSE4532
Glow Plug Sleeve Remover (both the tap and the bolt and sleeve adapter)	ZTSE4531
Glow Plug Sleeve Seat Wire Brush	ZTSE4589
Injector Connector Remover	ZTSE4650
Injector Sleeve Brush	ZTSE43041
Injector Sleeve Installer	ZTSE4529
Injector Sleeve Remover (both the tap and the slide hammer adapter)	ZTSE4528
Liquid Gasket (RTV) (6 oz. tube)	1830858C1
Quick Release Tool	ZTSE4581
Quick Release Tool Kit	ZTSE4454
Slide Hammer Kit	ZTSE4398
Straightedge	Obtain locally
Valve Guide Gauge Tool	ZTSE4577
“C” Type Valve Spring Compressor	ZTSE1846
Valve Spring Tester	ZTSE2241

Front Cover, Vibration Damper, and Gerotor Oil Pump

Table 73 Front Cover, Vibration Damper, and Gerotor Oil Pump

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

Connecting Rods and Pistons

Table 74 Connecting Rods and Pistons

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

Crankcase, Crankshaft and Bearings, Camshaft and Bushings

Table 75 Crankcase, Crankshaft and Bearings, Camshaft and Bushings

Description	Tool Number
Accessory Drive Gear Puller	ZTSE4520
Camshaft Bushing Kit	ZTSE2893A
Camshaft Bushing Remover/Installer (expanding collet)	ZTSE4489
Crankshaft Timing Tool	ZTSE4519
Cylinder Bore Gauge	Obtain locally
Deglazing Hone (four inch)	ZTSE4349
Dial Indicator with Magnetic Base	Obtain locally
Freeze Plug Installer	ZTSE4509
Front Seal/Wear Sleeve Installer	ZTSE4516
Front Wear Sleeve Remover	ZTSE4517
Head Bolt Bottoming Tap	ZTSE4508
Hot Plate	Obtain locally
Liquid Gasket (RTV) (6 oz. tube)	1830858C1
Oil Gallery Cleaning Brush	ZTSE4511
Oil Gallery Plug Driver	ZTSE4512
Piston Gauge Pins (0.082 in)	ZTSE4513
Straightedge	Obtain locally
Telescoping Gauge Set	Obtain locally

Oil Cooler and Oil Filter

Table 76 Oil Cooler

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

Engine Electrical

Table 77 Engine Electrical

Description	Tool Number
Cap Kit (all)	ZTSE4610
EGR Valve Puller	ZTSE4669
Glow Plug Connector Remover/Installer	ZTSE4670

High-pressure Oil Pump

Table 78 High-pressure Oil Pump

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

Fuel System

Table 79 Fuel System

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

Flywheel, Rear Cover. and Power Steering and Fuel Pump

Table 80 Flywheel, Rear Cover, and Power Steering and Fuel Pump

Description	Tool Number
Cap Kit (all)	ZTSE4610
Liquid Gasket (RTV) (6 oz. tube)	1830858C1
Rear/Wear Sleeve Installer	ZTSE4515
Rear Wear Sleeve Removal Tool	ZTSE4518
Loctite® Hydraulic Sealant	Obtain locally

In-chasiss Procedures

Table 81 Branch Tube Assembly

Description	TOOL NUMBER
No. 10 Quick Release Tool	ZTSE4581

Table 82 Rocker Arm

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

Special Tools

Essential Tools

Figure 640 "C" Type Valve Spring Compressor ZTSE1846

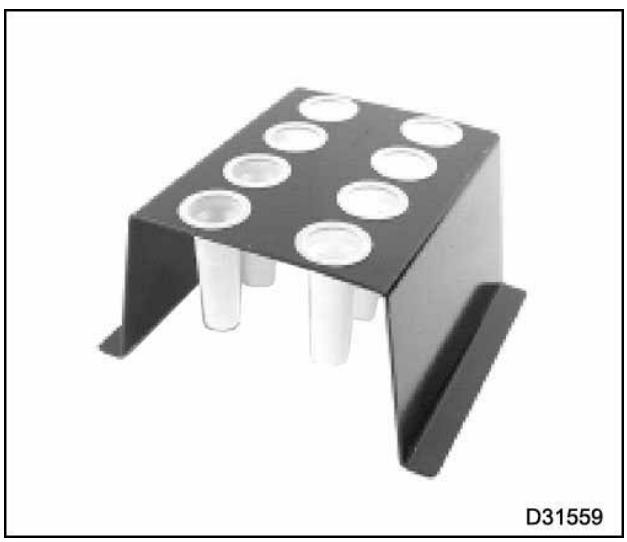

Figure 641 Fuel Injector Rack Holder ZTSE4299B

Figure 642 Slide Hammer Kit 5/8 in ZTSE4398

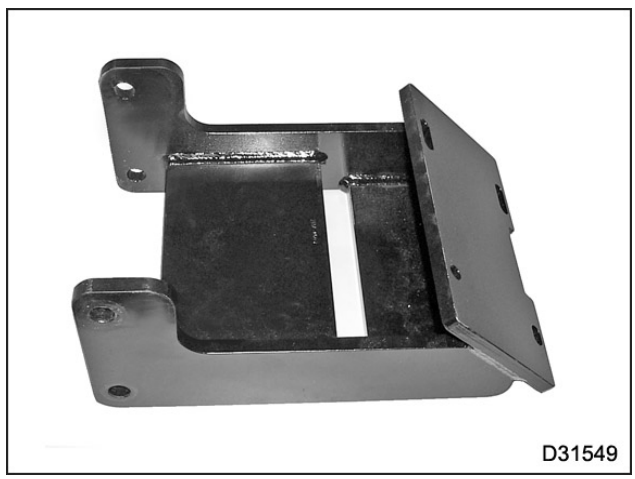

Figure 643 Engine Stand Mounting Bracket ZTSE4507

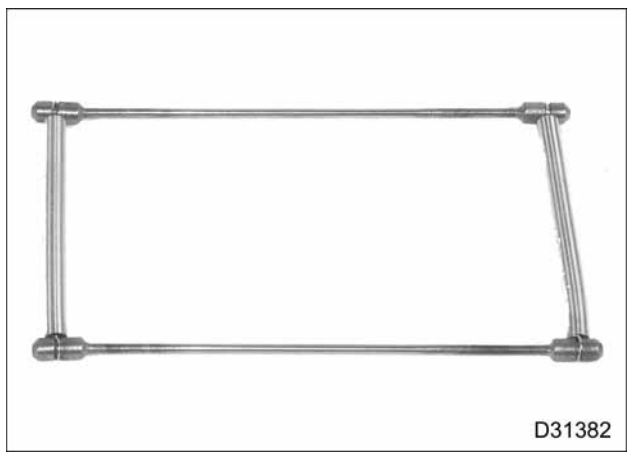

Figure 644 Piston Gauge Pins (0.082 in) ZTSE4513

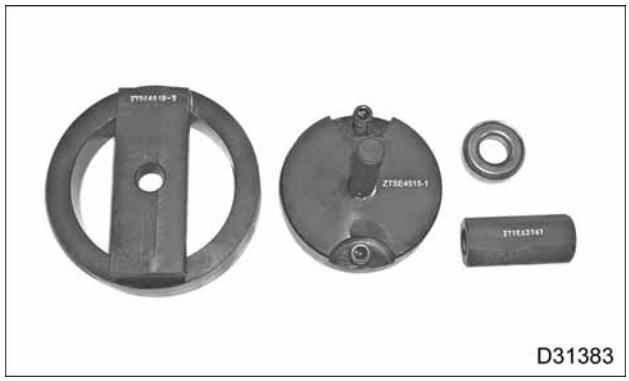

Figure 645 Crankshaft Rear Seal/Wear Sleeve Installer ZTSE4515

Figure 646 Front Seal Installer/Wear Sleeve Installer ZTSE4516

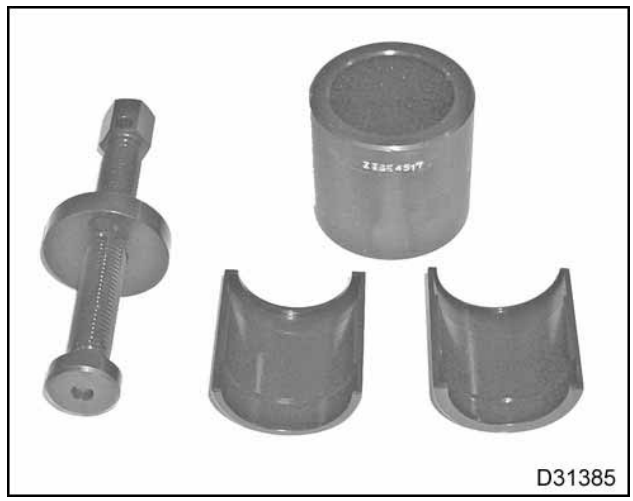

Figure 647 Front Wear Sleeve Remover ZTSE4517

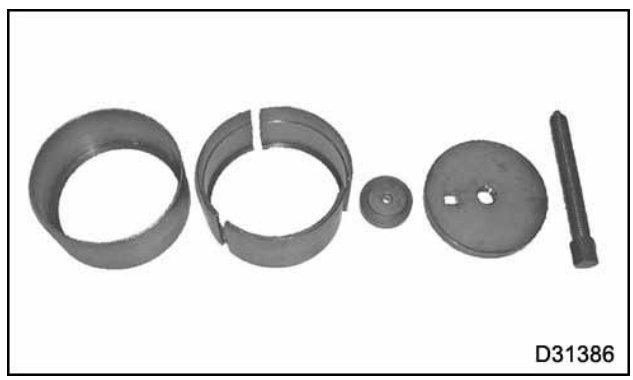

Figure 648 Crankshaft Rear Wear Sleeve Remover ZTSE4518

Figure 649 Crankshaft Timing Tool ZTSE4519

Figure 650 Fuel Injector Hold down wrench ZTSE4524

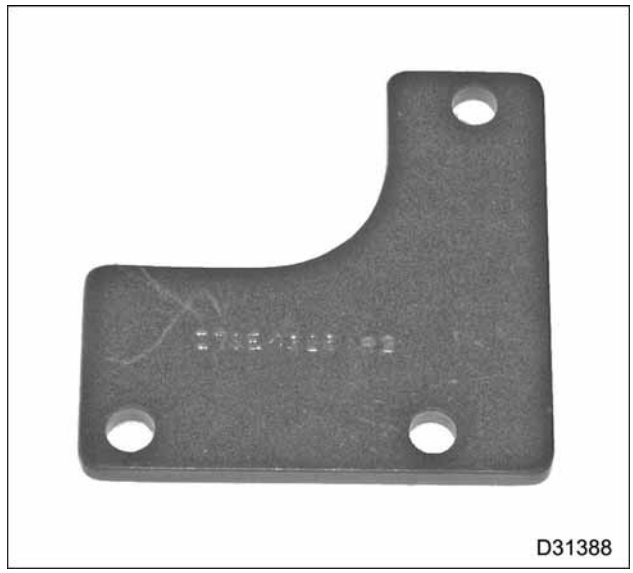

Figure 651 Oil Cooler Test Plate/Pressure Adapter ZTSE4525

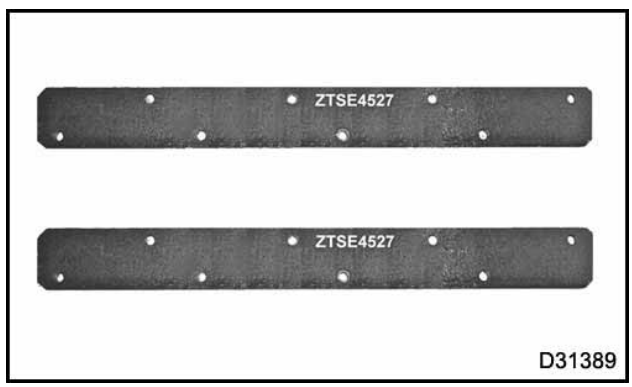

Figure 652 Intake Manifold Test Plates ZTSE4527

Figure 653 Injector Sleeve Remover ZTSE4528

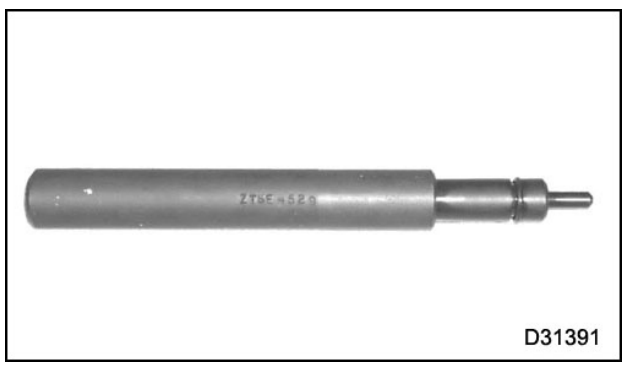

Figure 654 Injector Sleeve Installer ZTSE4529

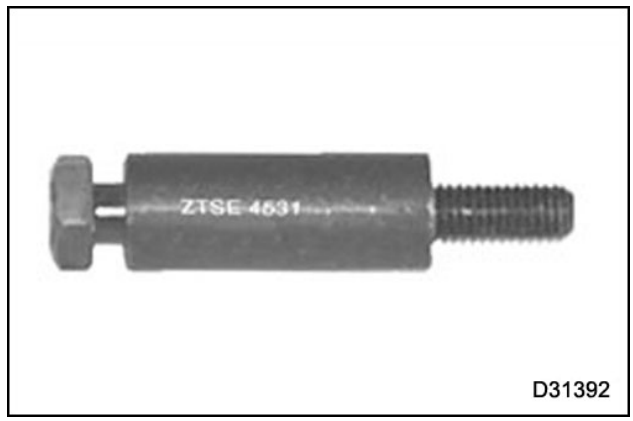

Figure 655 Glow Plug Sleeve Remover ZTSE4531

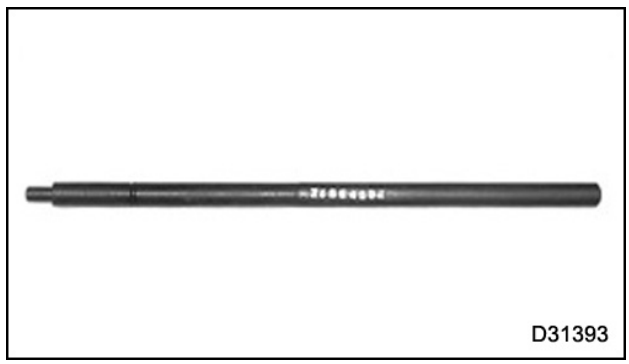

Figure 656 Glow Plug Sleeve Installer ZTSE4532

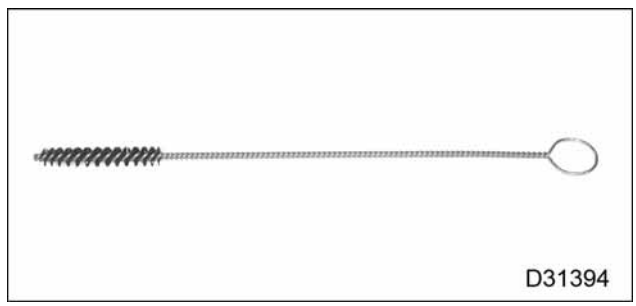

Figure 657 Glow Plug Sleeve Brush (nylon) ZTSE4533

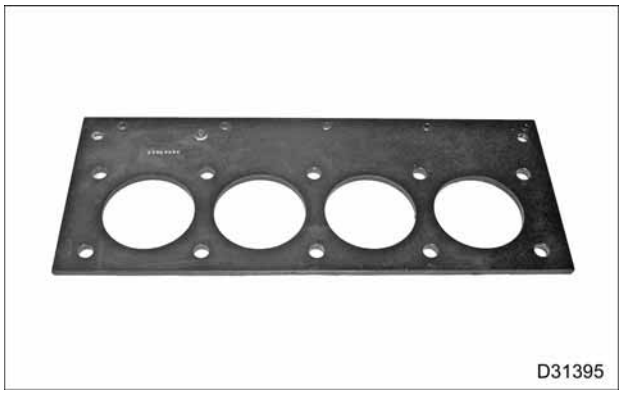

Figure 658 Cylinder Head Pressure Test Plate ZTSE4534

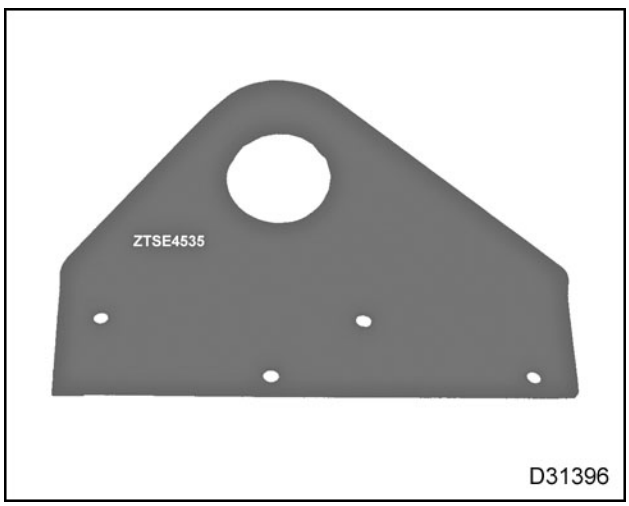

Figure 659 Cylinder Head Lifting Bracket ZTSE4535

Figure 660 Intake Manifold Pressure Test Plug (EGR Valve) ZTSE4544

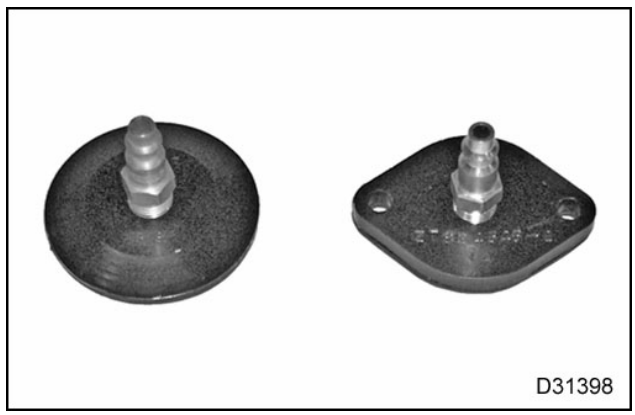

Figure 661 EGR Cooler Test Plates ZTSE4545

Figure 662 Intake Manifold Pressure Test Cap ZTSE4554

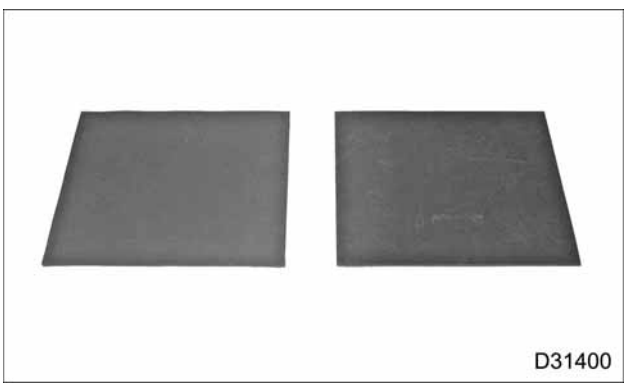

Figure 663 Oil Cooler Reservoir/High-pressure Pump Magnetic Covers ZTSE4557

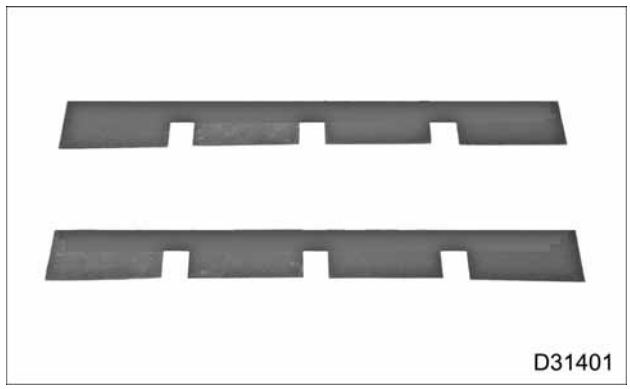

Figure 664 Magnetic Covers for Cylinder Head Intake Ports ZTSE4559

Figure 665 Quick Release Tool (No. 8 and No. 10) ZTSE4581

Figure 666 Fan Wrench (pulley bolts) ZTSE4587

Figure 667 Injector Connector Remover ZTSE4650

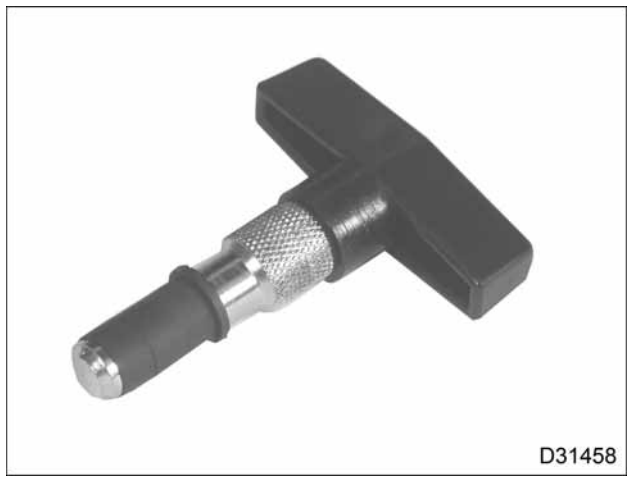

Figure 669 Crankcase-to-head Removal Tool ZTSE4694

Figure 668 EGR Valve Puller ZTSE4669

Figure 670 On-engine Valve Spring Compressor Tool ZTSE4697

Figure 671 Idler Shaft Installation Tool ZTSE4719

Figure 672 Secondary Flange Installation Tool ZTSE4720

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

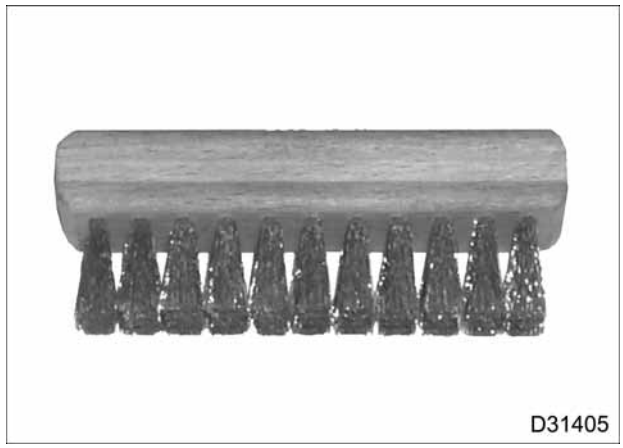

Figure 673 Injector Tip Cleaning Brush ZTSE4301

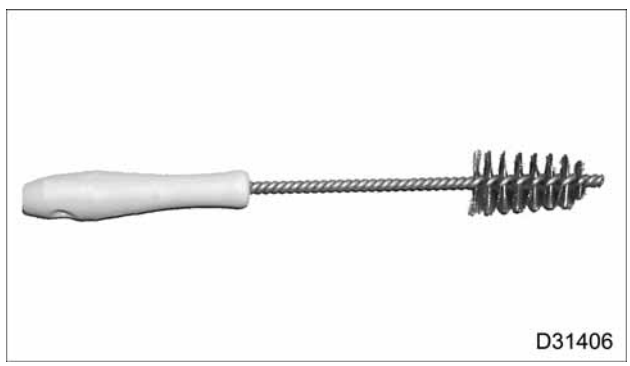

Figure 674 Injector Sleeve Brush ZTSE43041

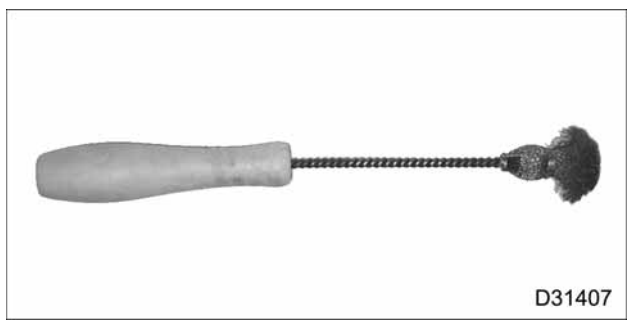

Figure 675 Injector Sleeve Flat Bottom Brush ZTSE43042

Figure 676 Fan Hub Wrench (2 inch) ZTSE43972

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